The data file AMJUEL_DR: Additional Atomic and Molecular Data for EIRENE

Since 2019 this particular version, taken from the SOLPS-ITER code repository (https://www.iter.org/), is updated and maintained by Detlev-Reiter-Consulting, Düren, under various consultancy contracts with 3rd parties, as well as under the auspices of the ITER ISFN fellowship network.

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Contents

I Introduction

Additional atomic data fits, read by EIRENE

I.1 Record New (from March 2019):

- March 20
  Fit H.4 2.2.9g added and also Te range of fit H.4 2.2.9 extended. 2.2.9g includes Greenland's (Te dep) vibr. distribution in ground state. 2.2.9 is from H2(v=0) initial state only. The difference is too small to be relevant, This update was just for consistency with other rates implicitly involving Greenland's vibr. distr. such as 2.2.5g and 3.2.3g

- Dec 20:
  ratios H.12 2.2b,c: continue = const above temperature P1MAX=500 eV. The fits H.12 2.0b,c are corrupt above 1000eV, but these ratios are about constant above a few 100 eV (for each selected density), which is also the default eirene extrapolation. Tbd: check 2.2a. as well as other density ratios.

- Oct. 21:
  H.0, H.2 Trubnikov potential parameters added, for EIRENE Trace Ion Module. unfinished. Was started in late 2018 (until March 19) to sync. the eirene neutral and trace ion reaction data treatment.

  H.2 3.2.3 renamed to H.2 3.2.3g, because Greenland's vibr. distribution is included. H.3 3.2.3 renamed to H.3 3.2.3g, because Greenland's vibr. distribution is included. Kept here with both names (via an alias) for old input files only. A corresponding "thermal" H.2 3.2.3 (without "g") has been added in hydhel.tex, without that vibr. distribution, i.e. just from the vibr. ground state data.

- Jan. 22:
  fitting range limits d2min, d2max, t1max added to some H.10, H.11 reactions.

- Oct. 22
  For consistency with other H.10 rates: N and O ionising component electron cooling rates added. The old rates H.10 2.7A0 and 2.8A0 have apparently been the ADAS PLT rates, i.e., the associated radiative cooling rates only. These are now labeled: 2.7A0r and 2.8A0r, resp., in section H.10, while the new full electron cooling rates are now stored under the same names 2.7A0 and 2.8A0 as previously were the old (radiation only) fits.

- Nov. 22
  Reaction 3.2.3i (MAI channel of H2+ condensed CX on H2) low Te asympt. behaviour corrected. The old fit was valid only down to 0.3 eV. The new one stays plausible down to 0.02 eV (EIRENE default Te cut off), now the same as it was the case already for the corresponding MAR and MAD channels 3.2.3r and 3.2.3d, resp.

- Nov. 22
  Replacing ADAS 93 Carbon ionisation, recombination, and radiation/electron cooling rates, with newer ADAS data (ADAS 96, but apparently re-compiled 1999).

I.e., H.4 2.6A0 and 2.3.6A0 fits, as well as H.10 2.6A0 and 2.3.6A0 fits are redone. Also added: H.10 2.6A0r: radiation loss only, whereas 2.6A0 is the (total) electron cooling rate. The older ADAS 93 previously used for the fits had a narrower validity range in density, and a shifted validity range in temperature.

I.2 Record Old (until March 2019):

- update 6.12/94
  Boron ionization rates H.2, 2.5B0, 2.5B1
  Boron rec. rates H.4, 2.3.5B0, 2.3.5B1

- update 6.4/95
  elast. data revised, from: elrep.dat

- update 25.4/95
  H.9, 3.1.8 improved

- update 12. 1/96
  Ar ionization rates H.2, 2.18B0, 2.18B1
  Ar rec. rates H.4, 2.3.18B0, 2.3.18B1
  Ar el.cool H.8, 2.18B0, 2.18B1, H.11,2.18B0
  Be el.cool H.8, 2.4B0, 2.4B1, H.11,2.4B0
  B el.cool H.8, 2.5B0, 2.5B1, H.11,2.5B0

- update 12. 2/96
  N ionization rate H.2, 2.7B0

- update 7. 3/96
  He+ ionization rate H.4, 2.2C
  He++ recomb. rate H.4, 2.3.2C

- update 17. 8/96
  elast.rate H.3, 0.3T revised

- update 3. 9/96
  new: negative ions: H^- contributions to Lyman and Balmer series
  added: ratios H.12 7.2a, 7.2b 2.0b, 2.0c
  added: ratios H.11 7.0 2.0a

  Note regarding the role of vibrationally excited molecules:

  if H2(v) is present, then in addition to the existing processes one may have:

  H2(v) + e $\rightarrow$ H + H^-, and the H^- may provide a photon (e.g., H-alpha) after mutual neutralisation with protons, or

H2(v) + p → H_2^+ + H , and the H_2^+ may provide a photon (e.g., H-alpha) after dissociative recombination into an excited state of the H atom.

Hence a suggested extended procedure in the EIRENE hydrogen line emission routines (e.g. Ba_alpha):

There have been already 4 channels contributing to H-light emissions:

- 1.) proportional to H - density PDENA(..)
- 2.) proportional to H^+ - density DIIN(..)
- 3.) proportional to H_2 - density PDENM(..)
- 4.) proportional to H_2^+ - density PDENI(..)

....
now: we add one further channel:
....

- 5.) proportional to H^- - density PDENI(..)

For example the CR population coefficient H(n=3)/H^- is stored in AMJUEL, H.12, 7.2a This ratio must be multiplied by the H^- density and by the Einstein coefficient 4.41e7 (as in the other channels) to obtain an emissivity. Since we may not always have computed the H^- density, we multiply instead by the H_2 density (PDENM) and by the CR-equilibrium ratio H^-/H_2 . This latter ratio is stored in AMJUEL H.11, 7.0

To account for the additional new channel producing H_2^+ (ion conversion) it is suggested to only replace the H_2^+ density (PDENI) in the line emission routines now by H_2 (PDENM) and by the CR equilibrium ratio: H_2^+/H_2. That CR equilibrium ratio is stored in H.12, 2.0c. This equilibrium ratio includes the above mentioned additional process leading to H_2^+ production. If instead the H_2^+ density PDENI IN EIRENE is computed only from electron impact collisions, not yet including additionally ion impact (ion conversion) collisions, then the CR equilibrium density ratio H.12, 2.0b must be retained in the line emission routines as multiplicative factor for the H_2 density, for consistency.

- update 6. 9/96
  H- CX multistep recombination, low proton energy, H.4 7.2.3a
  H- CX multistep ionization, low proton energy, H.4 7.2.3b

- update 26.2/97
  Corona H-ionization rate from SOLXY: out, because: wrong, and never used anyway (i.e. H.8 2.1.5G out).

- update 18.3/97
  H.4 2.1.5FU, H.4 2.1.8FU (Fujimoto rates) (0.1-1e3 eV)
  H.2 3.2.3 (only slow molecules, E0=0.37 eV as proxy for E0=0, and no plasma flow)
  H.2 2.2.17

- update 28.7/97
  H.3 3.2.3 = HYDHEL H.3 3.2.3 (vs. Ebeam and Ti) + plus slow vibr. ex. molecules must be modified to account for Ebeam of vibr. excited molecules (scale cross-section). DONE: see below: 11.05.04
  H.4 2.2.5g, as 2.2.5 but Greenland's vibr. distribution of H2 molecules

- update 8.8/97
  H.2 2.10B0, 2.10B1
  H.8 2.10B0, 2.10B1
  H.11 2.10B0

- update 18.8/97
  H.3 0.1D 0.2D, 0.3D 0.4D

- update 8.9/97
  H.1 3.1.8R (Riviere) revised (better extrapolation to low energy)
  H.1 3.1.8ST new (Schultz total cx cross-section)
  H.1 3.1.8SD new (Schultz momentum transfer cross-section)
  H.1 3.1.8 (Janev total cx cross-section, also: 3.1.8J)
  H.1 3.1.8J2 new (Janev total cx cross-section *2 = mom trans. x-section)
  H.1 3.1.8ST2 new (Schultz total cx cross-section *2 = mom trans. x-section)
  note: 3.1.8SD $\approx$ 2 * 3.1.8ST within line thickness

- update 23.9/97
  H.2 2.6B0 strahl carbon data ionization
  H.4 2.3.6B0 strahl carbon data recombination
  H.4 2.6A0 ADAS 93 carbon ionization
  H.4 2.3.6A0 ADAS 93 carbon recombination
  H.10 2.6A0 ADAS 93 carbon line radiation plus 11.3 per ionization
  (=electron cooling rate)
  H.10 2.3.6A0 ADAS 93 carbon line radiation due to recombination
  (=electron cooling rate + 11.3 per ionisation)
  H.12 2.6A0 ADAS 93 carbon line radiation per ionization
  H.12 2.3.6A0 ADAS 93 carbon line radiation per recombination

- update 22.4/98
  H.2 3.1.6FJ Freeman and Jones ion impact ionization, Ebeam=0.

- update 10.10/98
  red. pop. coeff revised (n=2, n=3) and new ones (n=4, n=5) now all based on Sawada/Fujimoto's modifications to Johnson/Hinnov
  H.12 2.1.5 a,b,c,d reduced pop. coeff, coupling to H ground state
  H.12 2.1.8 a,b,c,d reduced pop. coeff, coupling to H+
  H.12 2.2.5 a,b,c,d reduced pop. coeff, coupling to H2
  H.12 2.2.14 a,b,c,d reduced pop. coeff, coupling to H2+
  H.12 7.2 a,b,c,d reduced pop. coeff, coupling to H-

- update 20.1/99
  H.12 2.2.5e Fulcher emissivity (cm^3/s), coupling to H2, relative d state population amongst N=3 triplet: 2/9

- update 17.2/99
  H.12 2.2.5g revised (because of low Te extrapolation)
  new format for plots for H.4, h2, h2fuji, h2fuji-vibr
  done for 2.2.5, 2.2.5g, 2.2.9, 2.2.11

- update 10.4/99
  Fujimoto He-col.rad model revised.
  Form.II ionization rate H.4 2.3.9a, done
  elec. cooling rate H.10 2.3.9a, done
  $\delta_E/ionis$ H.12 2.3.9a, done
  Form.I ionization rates revised.
  K1→ K10=K1-K12-K13
  K2→ K20=K2-K21-K23
  K3→ K30=K3-K31-K32
  H.4 2.3.9b, 2.3.9c 2.3.9d redone
  (only 2.3.9b,K10, differs from earlier version)
  H.4 2.3.9e, 2.3.9f 2.3.9g redone
  (only 2.3.9f,K20, differs from earlier version)
  H.4 2.3.9h, 2.3.9i 2.3.9j redone
  (only 2.3.9j,K30, differs from earlier version)

- update 2.7/99
  Johnson Hinnov ionization and recombination revised.
  all rates are now available for Ly-transparent (as in older versions) and (new) for Ly-opaque conditions. The labels for the opaque data have an additional "o". E.g.: H.4 2.1.5 (for transparent data for effective ionization) and (new): H.4 2.1.5o (same process, but Lyman-opaque conditions). Same for: H.4 2.1.8 and (new) H.4 2.1.8o

- update 2.7/99
  During this update, an error in the Johnson Hinnov code was detected. It affects the rate H.10 2.1.8, at $T_e > 10eV$. The slope of the effective electron cooling rate above this T_e was too steep. H.10 2.1.8 (and, correspondingly: H.12 2.1.8) have been corrected.

- update 23.11/99
  H.1, 3.1.6, Freeman and Jones ion impact ionization cross-section, for beam penetration runs.
  Figure H.12 2.2.5b corrected (was wrong figure).

- update 3.2/00
  new: ratio of population coeff. p(6)/p(1)
  H.12 7.2e added
  H.12 2.2.14e added

H.12 2.2.5e added. Former 2.2.5e (Fulcher emissivity) is now: 2.2.5fl
H.12 2.1.5e added. Former 2.1.5e (del-e) is now: 2.1.5de
H.12 2.1.8e added. Former 2.1.8e (del-e) is now: 2.1.8de

- update 23.5/00
  H.12 2.2.5fl revised: labeling of n=2 triplet levels in Sawada's code corrected.

- update 06.8/00
  H.2 2.26B0 and H.2 2.26B1 added (ionization rates for Iron).

- update 26.12/00
  H.1 (elastics: p + noble gases).

- update 21.01/01
  error detected in H.1, 0.3D, 0.3V and 0.4D, 0.4V, fit coefficients
  for extrapolation wrong (different expression). Corrected.
  H.3 (elastics: p + noble gases).
  Figures included/redone for all elastics H.1 0.1 – 0.8,
  and same for H.3, $I_{0,0}$ and $I_{1,0}$

- update 16.03/01
  H.10 and H.12 added for 2.3.13a (He.rec.elec.cooling rates)
  Figures added, helraecr and helraecc

- update 1.10/01
  H.12 2.2.5fu added (to replace 2.2.5fl)

- update 1.11/01
  H.12 2.2a, 2.2b, 2.2c 2.3.2a, 2.3.2b, 2.3.2c added
  Helium population coefficients, for states no. 6,7 and 10

- update 8.11/01
  H.12 2.2c → 2.2d ,2.3.2c → 2.3.2d
  newly included: 2.2c, 2.2e, 2.3.2c, 2.3.2e Helium population coefficients, for states no. 8 and 16

- update 23.01/02
  H.0 Potentials for elastic collision processes included
  fit-flag 01 (repulsive) and fit-flag 02 (Morse) introduced.

- update 13.03/04
  3.1.8L: Langevin approximation for CX , for testing of internal consistency
  H.1: 3.1.8L done
  H.2: 3.1.8L done (in July 2015)
  H.3: 3.1.8L done
  H.8: 3.1.8L done (in Sept.2016
  H.9: 3.1.8L done
  H.3: 3.1.8org: original fit from Janev's Springer 1987 book
  (only for reference purpose. don't use!)

- update 11.05/04
  H.11 2.0a, 2.0b redone, correct $E_{H2} = 0.1$ eV
  H.11 7.0c renamed to H.11 7.0a
  H.12 2.0a, 2.0b and 2.0c fits and plots new, $E_{H2} = 0.1$ eV
  H.4 2.2.5r, 2.2.5d, 2.2.5i fits and plots, MAR, MAD and MAI rate coeff.
  H.3 3.2.3 new (aka 3.2.3g), E_{H2} consistent for all H2(v)
  H.2 3.2.3 (aka 3.2.3g) and 2.2.17 redone, $E_{H2} = 0.1$, rather 0.37

- update 18.04/05
  H.12 2.1.5 added: H^+ in Col-Rad. equil. with H_{ground} atoms
  H.12 2.1.8 added: H_{ground} in Col-Rad. equil. with H^+ ions

- update 14.02/06
  Strahl (ADAS89) data completed for Iron
  H.8 2.26B0, 2.26B1, H.11 2.26B0

- update 14.07/06
  H.4 7.2.3a 7.2.3b redone
  Col rad $p + H- \rightarrow H + H$ and $\rightarrow H + p$, for $E_{H^-} = 0.1$ eV
  MAR,MAD,MAI rates via H2+, for condensed H2+, renamed from 2.2.5r,d,i to 3.2.3r,d,i

- update 14.01/07 H.10, 2.1.8-t: for comparison with ADAS PRB
  remove $d(ln\langle sigv\rangle)/d(lnT)$ corrections in free-bound transition
  then: good agreement with ADAS PRB found (tested for JET divertor case)
  hence: this correction seemed to be missing in ADAS
  Also added: H.12 2.1.8de-t, (DE per event) and figures
  Old H.12 2.1.5t and 2.1.8t renamed into 2.1.5tot and 2.1.8tot, resp. Sept. 18: The intermediate "test fits" H.10 2.1.8-t, H.12 2-1-8de-t from 2007 removed now.

- update 07.08/07 2.1.5 H.4 and H.10 Johnson-Hinnov renamed to 2.1.5JH
  New "default" is Sawada-Fujimoto: old H.4 2.1.5FU now: H.4 2.1.5
  and H.10 2.1.5 (FU) is newly added.
  to be done: H.12 2.1.5de (JH to be replaced by FU: H.12 2.1.5de)
  H.4 2.1.8 already renamed to H.4 2.1.8JH, and new default is FU: H.4 2.1.8
  to be done: H.10 2.1.8 H.12 2.1.8de (JH to be replaced by FU)

- update 17.08/07 H.0 0.100 to H.0 0.103: defaults for
  Fokker-Planck collisions between charged particles,
  ee, ei, ie, and ii collisions. Fit-Flag: 03

- update Nov. 07: introduce subsections for H.1, to order reactions according to electron impact, proton impact, He+ impact, etc..

- update Oct. 09: fit H.3: 2.1.5, for electron impact of H beam (Eb $>$ 700 eV, across cold edge (Te $<$ 1000 eV)

- update Oct. 09: fit H.3: 2.3.9, for electron impact of He beam across cold edge

- update Jan. 2010:
  some text added regarding ADAS CR rates ...A0, in H.4, H.10 and H.12

- update Mar. 2011:
  fit H.3: 3.2.3 (aka 3.2.3g) corrected. Was completely off. Figure was ok, i.e. bug in fit program. Newly fitted using odrpack95.

- remove blanks from parenthesis (e.g. H2(a bc) → H2(abc), for online plots under www.eirene.de)

- update Dec. 08 2011:
  O ionisation, O+ recombination: ADAS 96, H.4 and H.10 fits added 2.8A0 and 2.3.8A0, resp. N.b.: H.10 rates are the rad loss rates (PLT, PRB) only, not including the ionisation energy cost, see: update from oct. 2022

- update Dec. 09 2011:
  N ionisation, N+ recombination: ADAS 96, H.4 and H.10 fits added 2.7A0 and 2.3.7A0, resp. N.b.: H.10 rates are the rad loss rates (PLT, PRB) only, not including the ionisation energy cost, see: update from oct. 2022

- update July 12:
  H.2: 3.2.3old (aka 3.2.3g.old)re-introduced, for backward compatibility, i.e. $E_{H_2} =$ 0.37 eV, (as around year 2000) whereas now (since 2004) in H.2: 3.2.3 (aka 3.2.3g) this energy is 0.1 eV.

- update August 12: new figures for H4: 2.2.12 and 2.2.14 (the red HYDHEL curves had been missing. Both these fits have problems below 0.1 eV. to be done.
  Reaction H.2 2.2.5 renamed to 2.2.5org (this is the old, incorrect fit from the 87 Springer book), not to be used anyway.

- update Aug. 12:
  added H.12: 2.2.15a,..2.2.15e red. pop. coeff H(2)...,H(6) with respect to H3+, based on production of H*(n=2) via Janev, HYDHEL H.2: 2.2.15

- update Sept.13: N,N2,N2+ corona model.
  1.) added H.8 and H.11 for N+e ionisation, constant electron energy loss = ionisation potential
  2.) revised H.8 and H.11 for Ar and C ionisation, (constant electron energy loss=ionisation potential, to derive electron cooling fits H.8 and H.11 from those for rate coefficients H.2
  3.) new H.2 rate coeff. added for N2 and N2+:
  H.2 2.7.5, 2.7.9, 2.7.10, 2.7.11, 2.7.12, 2.7.15 (and 2.7.14 added Jan 2016)
  checked: e+N ionisation. Cross-sections from Bell and Brooks are identical. Checked: rate coefficients H.2 2.7, 2.7B0 are identical too. (hence: rate coeffs. should also be identical to open ADAS). further checks: H.4 e + N vs. H.2 e + N?? Is the ADAS corona limit correct?, see plot for H.4 rate coeff., label of red curve incorrect on this plot

- Jan 14:
  some reaction headers edited, in H.12 (for automatic online processing)

- Jan 15:
  electron energy loss rates for H_2 added: H.10 2.2.H2c (total electron cooling) and H.10 2.2.H2r (radiation energy loss rate only). Both in eV cm^3/s. Currently these two rates are related to processes 2.2.5 (DE) plus 2.2.9 (I), but not yet including dissociative excitation and ionization channels 2.2.10

- April 15:
  HYDHEL cross-section for 3.1.8 (cx) added here too (same as in hydhel.tex file) This can be used for low and high E0 limit extrapolation. to be done: make H.2 rate to be used for low E0 limit extrapolation...Nov. 17 done now !

- April 15:
  Some header texts changed, e.g *ratio* → *Ratio* in H.12 headers

- June 15:
  state notations changed for H, H2, He, to remove further blanks from parenthesis, and now also to distinguish meta-stable-resolved effective rates from single meta-stable-QSS rates. The former have an additional ";r" in their state notation. Also paragraph headers for Trubnikov potentials (H.0) changed.

- July 15:
  started to add H.2 rates from fits of H.3 rates for Ebeam → 0 Done for 0.1, 0.2 and 0.3 elastic reactions. The low Ebeam value was found by comparing H.3 rate fits with independent integration of H.1 cross-sections at low E. Strictly: the H.3 fits should automatically become identical to the H.2 fits for low Ebeam, or EIRENE should automatically use these H.2 fits below a critical Ebeam.

  Similarly: H.4, such that H.2 is the correct corona limit at low densities. And also similarly: low T limit (for H.2, H.3 and H.4) should automatically turn into H.1 cross-section(E) times sqrt(E)...., or at least: threshold behaviour $1/T^2 \times \exp(-\Delta E/T)$??

- Oct 15:
  Further H.2 rates added for heavy particle collisions. These H.2 rates should be scalable to the corresponding Omega integrals for continuum descriptions consistent with the kinetic formulations based on H.3 rates. done: 0.4, 0.5, 0.6, 0.7, 0.8, both: T (total) and D (diffusion) rates.

- Oct 15:
  started to add T1MIN, T1MAX, N2MIN, N2MAX, E2MIN, E2MAX, P2MIN, P2MAX parameters for extrapolation beyond fit range. Currently all H.4 rates should have N2MIN=1.e8, and be extrapolated with these values taken also for all lower electron densities (Corona limit). In this case $ln^i(\tilde{ne}) = 0.0,\ i = 1, 2, \ldots, 8$, fit must reduce to H.2 format. I.e., these 9 H.2 coefficients can directly be obtained as subset of the 81 H.4 coefficients.

- Jan.16:
  N2+ diss.rec added: rate: H.2 2.7.14, is linear on log-log scale, and hence corresponding H.1 and H.8 data follow analytically.

- May 16:
  H.2 2.2.17s, H.4 2.2.17r and H.4 2.2.17d: effective, H- condensed, DIS, MAR, MAD rate coefficients for H2, via H2-.

- June 16:
  H.4 2.1.5 and H.10 2.1.5 CR electron impact ionisation: fit range extended from 1e3 to 2e4 eV, new fits and figures

- Jan. 17:
  H.11 4.0a added. Ratio of production rate constant for H3+ to destruction rate coefficient (vs.(Te)). From this ratio, by multiplying it with nH2+/ne, one finds the nH3+/nH2 ratio, when H2+ and H3+ are in equilibrium with H2.

- Jun. 17:
  H.4 2.1.8, H.10 2.1.8 and H.12 2.1.8de redone, fit range extended from 0.1 –1e3, to 0.1..2e4, to avoid spurious recombination rates in hot core plasmas.

- Aug. 17:
  H.1 3.1.8 and 3.1.8J2 left asympt. (al0) corrected. Slope was correct, but a small jump at E=0.1 eV. H.1 3.1.8ST and 3.1.8ST2 left asympt. added. Was missing.

- Nov. 17:
  H.1 3.1.8 right asympt. added (taken from hydhel). Also H.2 3.1.8 added, (taken from hydhel)

- Mar. 18:
  H.12 2.2.5fu, redone. Also: 2.2.5we and 2.2.5ly added (upper Werner and Lyman band states pop. coef.)

- May 18:
  0.13 p,d,t and 0.14 p,d.t added. H.1 and H.3 Elastic cross-sections and rate coeff. (Krstic, Schultz), taken here for vel. dep. relaxation approximation (scattering angle=pi)

- May 18:
  H.2 3.1 added: ionisation of W, used a few years ago in a PET paper (Mekkaoui et al.) on study of plasma fluctuations on impurity penetration and CX sputtering.

I.3 to be done:

- Check text in H.12, 2.2.5fl: is Aik already multiplied into this ratio fit, i.e. is this fit a “Fulcher emission rate” (1/s), or is this factor still to be multiplied?

- Further H.2 rate fits available for heavy particle reactions, e.g. 0.5,..., 3.1.6,....still to be implemented

- Check Behringer (Strahl) database for Li ionisation and recomb...

- 2.2.14: H.2 fit made strictly linear on log-log scale, for H.1, H.2 and H.8. Then use H.2 coefficients to derive, exactly, the corresponding H.1 and H.8 coefficients. Done for H.8, 2.2.14, To be done for H.1 for this process, and also for other (probably mostly recombination) processes, e.g. 2.1.8, 2.2.15, 2.3.13, 2.7.14.... H.8 2.7.14: done

- Aug. 17: 3.1.8 H.2, H.3 and H.9 rate coefficients must be redone, due to Aug. 17 correction of left asymptotic part in cross-section. Will perhaps further improve the track-length estimator energy balance. So far we have no 3.1.8S (Schultz) rate coeff. of any kind.
- Jan. 22: H.10 rates from ADAS tables: missing d2min,d2max validity range. Check original tables from which these fits have been made.
- Aug. 22: lots of not documented stuff between 2017 and 2022: where did it go?

Additional atomic data fits, read by EIRENE
Format as HYDHEL DATEN [2] or METHANE DATEN [1]. See description in HYDHEL.pdf

II Numerical Fits to σ and $\langle\sigma v\rangle$

(See again: [2], only slightly generalized version here:)

We derived numerical fits for σ and $\langle\sigma v\rangle$ so that these processes can be evaluated easily in numerical codes and in other instances that demand simple and/or repeated evaluations. Since σ and $\langle\sigma v\rangle$ vary over many orders of magnitude, we made polynomial fits for $\ln\sigma$ in terms of $\ln E$ and for $\ln\langle\sigma v\rangle$ in terms of $\ln T$:

$$\ln\sigma = \sum_{n=0}^{N} a_n(\ln E)^n,$$

$$\ln\langle\sigma v\rangle = \sum_{n=0}^{N} b_n(\ln T)^n,$$

For the electron reactions, or any process in which the projectile particle is assumed to be almost at rest relative to the Maxwellian background, $\langle\sigma v\rangle$ is essentially independent of E within the range of energies considered here.
A more useful fit for the heavy-particle reactions is a double polynomial fit in both E and T:

$$\ln\langle\sigma v\rangle = \sum_{n=0}^{N}\sum_{m=0}^{M} \alpha_{n,m}(\ln E)^m(\ln T)^n.$$

Such a fit requires a large number of coefficients in order to be accurate, but can be used for arbitrary E and T.
Analogously, a fit for the density and temperature dependent reaction rate coefficients is a double polynomial fit in both n and T:

$$\ln\langle\sigma v\rangle = \sum_{n=0}^{N}\sum_{m=0}^{M} \alpha_{n,m}(\ln\tilde{n})^m(\ln T)^n.$$

Most fits in the present database with density and temperature dependence have been set up for density range $1e8 - 1e16$ cm^{-3}, but with the density parameter $\tilde{n}$ being a scaled density: $\tilde{n} = n/10^8$, n in cm^{-3}. As a result, at $n = 10^8, \ln(\tilde{n}) = 0$ the 2-parametric fit collapses to a one parametric fit vs. temperature only:

$$\ln\langle\sigma v\rangle(T, n \leq 10^8) = \sum_{n=0}^{N} \alpha_{n,0}(\ln T)^n$$

which can be taken as Corona (density independent) limit, for proper low density parameter asymptotic behaviour.

Further asymptotically correct forms of these fits (at other boundaries of the parameters E, n, T, are described below in subsections II.3.1, II.3.2, etc.. for the various types of data.

II.1 Example of Use of Fits

As an example (taken from [2]) of the use of the tables of fits for cross-sections and reaction rate coefficients consider the calculation of $\langle\sigma v\rangle$ for reaction 2.1.5, $e+H(ls) \rightarrow e+H^{+}+e$. We compute

$$\ln\langle\sigma v\rangle = \sum_{n=0}^{8} b_n (\ln T)^n$$

below for T = 10 eV using the coefficients for reaction 2.1.5 in Sect. 8.2 in [2]. In the calculation below, only six digits need to be kept for these to be nearly perfect fits (see Sect. 8.2) and the coefficients have been truncated at six digits.

$$\begin{aligned}
\ln\langle\sigma v\rangle \quad = \quad & -3.27139e+01 \qquad\qquad\quad + 1.35365e+01(2.30259) \\
& -5.73932e+00(2.30259)^2 + 1.56315e+00(2.30259)^3 \\
& -2.87705e-01(2.30259)^4 + 3.48255e-02(2.30259)^5 \\
& -2.63197e-03(2.30259)^6 + 1.11954e-04(2.30259)^7 \\
& -2.03914e-06(2.30259)^8
\end{aligned}$$

$$\ln\langle\sigma v\rangle = -19.07995.$$

Thus,

$$\langle\sigma v\rangle = 5.17228e-09\ cm^3/s.$$

II.2 SLREAC.f: Fortran module for reading Data from AMJUEL

Single parameter fits are identified by the character string

```
'p0' in case of H.0  (interaction potential, or differential cross-section)
'a0' in case of H.1  (cross-section)
'b0' in case of H.2  (rate coefficient vs. T-target, E0=0.)
'e0' in case of H.5  (momentum-weighted rate coeff. vs. T-target, E0=0.)
'h0' in case of H.8  (energy-weighted rate coefficient vs. T-target, E0=0.)
'k0' in case of H.11
```

Format: E20.12
Double parameter fits are identified by the character string 'Index'
Data are transferred from a data file into the EIRENE code by calls to subroutine SLREAC, listed below.

```
C
      SUBROUTINE SLREAC (IR,FILNAM,H123,REAC,CRC)
c
C  input
C    FILNAM: read a&m data from file filnam, e.g. AMJUEL, HYDHEL, METHAN, CONST
c    IR    : store data on EIRENE array CREAC(...,...,IR)
c    H123  : identifyer for data type in filnam, e.g. H.1, H.2, H.3, ...
c    REAC  : number of reaction in filnam, e.g. 2.2.5
c    CRC   : type of process, e.g. EI, CX, OT, etc
C  internal
C    ISW   <-- H123
C    IO    derived from ISW, initial value of 2nd index in CREAC
C  output
c    ISWR  : EIRENE flag for type of process  (1,2,...7)
c    CREAC : EIRENE storage array for a&m data CREAC(9,0:9,IR)
c    MODCLF: see below
c    DELPOT: ionization potential (for H.10 data),
c            currently handled in input.f. not nice!
c    IFTFLG: EIRENE flag for type of fitting expression ("fit-flag=...")
C            DEFAULTS: =2 FOR POTENTIAL (GEN. MORSE)
C                      =0 FOR ALL OTHERS (POLYNOMIAL, DOUBLE POLYNOMIAL)
c
C  READ A&M DATA FROM THE FILES INTO EIRENE ARRAY CREAC
C
C
C  OUTPUT (IN COMMON COMXS):
C    READ DATA FROM "FILNAM" INTO ARRAY "CREAC"
C    DEFINE PARAMETER MODCLF(IR) (5 DIGITS NMLKJ)
C    FIRST DECIMAL  J           =1  POTENTIAL AVAILABLE
C                                   (ON CREAC(..,-1,IR))
C                   J           =0  ELSE
C    SECOND DECIMAL K           =1  CROSS-SECTION AVAILABLE
C                                   (ON CREAC(..,0,IR))
C                   K           =0  ELSE
C    THIRD  DECIMAL L           =1  <SIGMA V> FOR ONE
C                                   PARAMETER E (E.G.
C                                   PROJECTILE ENERGY OR ELECTRON
C                                   DENSITY) AVAILABLE
C                                   (ON CREAC(..,1,IR))
C                               =2  <SIGMA V> FOR
C                                   9 PROJECTILE ENERGIES AVAILABLE
C                                   (ON CREAC(..,J,IR),J=1,9)
C                               =3  <SIGMA V> FOR
C                                   9 ELECTRON DENSITIES  AVAILABLE
C                                   (ON CREAC(..,J,IR),J=1,9)
C                   L           =0  ELSE
C    FOURTH DECIMAL M               DATA FOR MOMENTUM EXCHANGE
C                                   TO BE WRITTEN
C    FIFTH  DECIMAL N           =1  DELTA E FOR ONE PARAMETER E (E.G.
C                                   PROJECTILE ENERGY OR ELECTRON
```

```
C                                    DENSITY) AVAILABLE
C                                    (ON CREAC(..,1,IR))
C                                =2  DELTA E FOR
C                                    9 PROJECTILE ENERGIES AVAILABLE
C                                    (ON CREAC(..,J,IR),J=1,9)
C                                =3  DELTA E FOR
C                                    9 ELECTRON DENSITIES  AVAILABLE
C                                    (ON CREAC(..,J,IR),J=1,9)
C                    N           =0  ELSE
C
      USE PRECISION
      USE PARMMOD
      USE COMPRT
      USE COMXS
      USE PHOTON

C  current version: see EIRENE on FZJ GIT repository, under:

C  Eirene/file-handling/slreac.f

      END
```

II.3 Types of data, general prescriptions

The present compilation contains data fits for atomic/molecular processes in a format which can be utilized e.g. in EIRENE code runs. Fits are stored here for interaction potentials (H.0), total cross-sections (H.1), rate coefficients (H.2, H.3 and H.4) and momentum- (H.5, H.6 and H.7) and energy-weighted (H.8, H.9, H.10) rate coefficients, respectively, as well as some supplementary data fits (H.11 and H.12), often reduced population coefficients, and meant mainly for post-processing and other purposes.

II.3.0 H.0: interaction potentials

The classical elastic collision kinetics is determined by the interaction potential $V(r)$. In EIRENE for given (random sampling) impact parameter b and relative collision energy E_r (in eV) the deflection angle χ in the center of mass system is computed and the test particle velocity is then changed accordingly in the laboratory system. There are various options for potential functions $V(r)$. The potential is always in eV, and the distance r (and also b in EIRENE) are in (atomic) units of the Bohr radius $a_0 = 0.529\times10^{-8}$ cm. The parameter FIT-FLAG determines which particular fit expression is used for the potential. The potential $V(r)$ can be specified then by up to 9 fit coefficients $p_0, \ldots, p_8$, see Section 0.

FIT-FLAG=

=1 purely repulsive potential: to be written

=2 Morse like potential:

$$V(r) = \epsilon\left[e^{2g(1-\rho)} - 2e^{g(1-\rho)}\right]$$

with

$$\rho := r/r_m \quad ; \quad g := \begin{cases} g_1 & \text{for } \rho < 1 \\ g_1 g_2 & \text{for } \rho \geq 1 \end{cases} \tag{1}$$

with the parameters:
$p_0 = \epsilon$ (eV)
$p_1 = g_1$
$p_2 = g_2$
$p_3 = r_m$ (in units of a_0), the minimum of $V(r) : V(r_m) = -\epsilon$
Derived Parameters are:
$p_4 = r_0 = r_m\left(1 - \frac{\ln 2}{g_1}\right)$, the root of $V(r) : V(r_0) = 0$
$p_5 = r_w = r_m\left(1 + \frac{\ln 2}{g_1 g_2}\right)$, the point of inflection of $V(r)$
p_6 not in use
$p_7 = V(r_w) = -\frac{3\epsilon}{4}$
p_8 not in use

II.3.1 H.1: cross-section vs. energy

Fits for $\sigma(E_{lab,1})$ $[cm^2]$
Collision cross are functions of relative velocity, but, due to historic reasons in the EIRENE databases, which initially had been built on data of ref. [2], the laboratory energy of one of the colliding particles (usually the charged particle) is used, with the second collision

partner (usually the neutral particle) being at rest. I.e., $\sigma = \sigma(E_{lab,1})$. To convert to center of mass energies, or to other isotopes of the same atom, one uses $E_{lab,1} = m_1/2\ v_1^2$ and $E_{CM} = \mu/2\ v_{rel}^2$ with $\mu = m_1 m_2/(m_1+m_2)$ being the reduced mass and $v_{rel} = |v_1 - v_2|$ the relative collision velocity.
Cross-sections for elastic collision processes (classical orbits) are given in this paragraph. We distinguish between total, diffusion and viscosity cross-sections, by capital letters T, D and V attached to a cross-section label.
These are defined as (written here as function of relative collision velocity v_{rel}):
A): the **"total scattering cross-section"**

$$\sigma^t(v_{rel}) = \int_0^\pi d\theta \frac{\partial\sigma(\theta, v_{rel})}{\partial\theta} \sin(\theta) \tag{2}$$

where θ is the scattering angle in the center of mass frame and $d\sigma/d\theta$ is the differential scattering cross-section, which, in an EIRENE application is internally derived classically from the interaction potentials specified under H.0, with proper cut-offs at small scattering angles.
B): the **"diffusion cross-section"**

$$\sigma^d(v_{rel}) = \int_0^\pi d\theta \frac{\partial\sigma(\theta, v_{rel})}{\partial\theta} (1 - \cos(\theta)) \sin(\theta) \tag{3}$$

in which scattering events are weighted with their momentum transfer efficiency $(1 - \cos(\theta))$
C) the **"viscosity cross-section"**

$$\sigma^v(v_{rel}) = \int_0^\pi d\theta \frac{\partial\sigma(\theta, v_{rel})}{\partial\theta} (1 - \cos^2(\theta)) \sin(\theta) \tag{4}$$

arising in continuum descriptions of gas and plasma transport, e.g. the Chapman-Enskog expansion.

Special cases, Langevin cross-section In some special cases the cross-section fits in polynomial form become exact, both for cross-sections and for their associated (weighted) rate coefficients. This is the case for cross-sections of the form

$$\sigma(v) = c_r v^r \ [cm^2] \tag{5}$$

with c_r a positive constant and parameter $r > -4$. An important special case is $r = -1$, the Langevin cross-section. The corresponding (H.2) Maxwellian rate coefficient is

$$\langle\sigma(v) \cdot v\rangle(T) = \sqrt{\frac{2T}{m}}^{(r+1)} c_r \frac{2}{\sqrt{\pi}} \Gamma(\frac{r}{2} + 2) \ [cm^3/s] \tag{6}$$

For the Langevin cross-section, $r = -1$, this reduces simply to a constant rate coefficient:

$$\langle\sigma(v) \cdot v\rangle(T_p) = c_r \ [cm^3/s] \tag{7}$$

independent of T or T/m. Note that in this case also the (H.3) Beam-Maxwellian rates (see paragraph II.3.3 below) collapse to the same constant.

Cross-sections in this present database are fitted vs. "laboratory" collision energy E, rather than vs. " laboratory" collision velocity v, with $v = \mathrm{cvela}\sqrt{E(eV)/m(amu)}$. The reference velocity *cvela* in the EIRENE code is cvela = $1.38912e6$ $[cm/s]$ and m is the mass of the first (usually the charged) particle, assuming the second (usually the neutral) particle to be at rest. Hence the mass m must not be confused with the reduced mass μ for the center of mass collision velocity. A resulting fit (linear on log-log scale) for $\ln(\sigma(E)) = a_0 + a_1 \ln(E)$ then is: to be written...

II.3.2 H.2: rate coefficients vs. temperature (zero beam energy)

Fits for $\langle\sigma(v) \cdot v\rangle(T_p)$ $[cm^3/s]$
Maxwellian rate coefficients are taken for neutral particle energy $E_0 = 0.0$ eV and for stationary background (plasma): i.e., drift velocity $\mathbf{V}_p = \mathbf{0}$ vs. temperature T_p (electron or ion temp., resp.) of the Maxwellian $f_{maxw}(v_p, T_p)$. I.e. :
$\langle\sigma v\rangle(T_p) = \int d^3v_p \ \sigma(v_p) \cdot v_p \cdot f_{maxw}(\mathbf{v}_p, T_p)$
The rate coefficients can be scaled to different isotopes and to finite neutral particle temperatures T_0 by evaluating the fits at an effective temperature T_{eff} given by

$$T_{eff} = \frac{m_p}{m_1} T_1 + \frac{m_p}{m_2} T_2 \tag{8}$$

Here m_p is the mass of the background particle (typically ions or electrons)) as used in calculating the rate coefficients, m_1 and m_2 are the masses of the two isotopes in the particular collision process considered, and T_1 and T_2 are their two temperatures.
For electron impact collisions on heavy (neutral) particles (mass $m_1 = m_0$), i.e. with $m_2 = m_p = m_e$ we have: $m_e \ll m_1$, and hence typically $T_{eff} \approx T_e = T_2$, so the re-scaling to an effective temperature is only required for heavy particle (here: ion impact) collisions.

II.3.3 H.3: rate coefficient vs. temperature and energy

Beam-Maxwellian rate coefficients. These coefficients are generalisations of the H.2 (isotropic) stationary Maxwellian rate coefficients and account for either a finite velocity (energy E_0) of the test particle (or beam) or for a fluid drift $\mathbf{V_p}$ in the Maxwellian background, or both.
Beam-Maxwellian rate coefficients with drifting Maxwellians $f_{maxw}(T_p, V_p)$ of the background particles "p", with temperature T_p of the Maxwellian and with $|\mathbf{V_p}| = V_p$ can be evaluated in the rest frame of the background "p", i.e. with the beam energy parameter re-defined as

$$\widetilde{E}_0 = m_0/2|\mathbf{V_0} - \mathbf{V_p}|^2 \tag{9}$$

These rate coefficients are therefore fits with two independent parameters, and averaging is over an isotropic (stationary) Maxwellian:
Fits are for $\langle\sigma \cdot v_{rel}\rangle(E_0, T_p)$ $[cm^3/s]$
The fit expression is a double polynomial of order 8 in each of the independent variables E_0 and T_p. The fitted expression is $\ln\langle\sigma \cdot v_{rel}\rangle(\ln E_0, \ln T_p)$. Note that the role of the beam particle is now reversed as compared to that of cross-section data, the energy parameter is now the energy of the mono-energetic (neutral) particle beam (with mass m_0), which is traveling in a host medium of (charged) particles "p", mass m_p, with stationary Maxwellian distribution and temperature T_p.

II.3.4 H.4: rate coefficient vs. temperature and density

Fits for $\langle \sigma \cdot v_{rel} \rangle (n_p, T_p)$ $[cm^3/s]$
Same expression of fit as for Beam-Maxwellian rate coefficients, but with beam energy E_0 (eV) replaced by density n_p. I.e. these rates are given for a fixed energy of the "beam-particle", typically $E_0 = 0.0$ eV, but a density dependence arises due to multiple (ladder-like) processes involved in one "effective step".
For historic reasons and to preserve backward compatibility, the density n_p in this fit must be given in units of 10^8 cm^{-3}, i.e., with density given in cm^{-3} and the numerical value then divided by 10^8, or density given in m^{-3} and then divided by $100^3 \times 10^8 = 10^{14}$.

Asymptotical behaviour, density parameter Unless otherwise stated the valid range of the scaled density $\ln(\tilde{n}) = \ln(n/10^8)$ ranges from $\ln(\tilde{n}) = \ln(1.0) = 0.0$ (at $n = 10^8\, cm^{-3}$) to $\ln(\tilde{n}) = \ln(10^8) = 8\ln(10) \approx 18.421$ (at $n = 10^{16}\, cm^{-3}$).
Further rescaling the fit expression to a density parameter $\ln(\hat{n}) = 1/b \ln(n/10^8)$ with $b = 8\ln(10)$ brings the validity range $[10^8, 10^{16}]$ of the density parameter n $[cm^{-3}]$ to the interval $[0, 1]$ for the scaled density parameter $\ln(\hat{n})$. At these boundaries for the scaled density parameter the collisional radiative rate coefficients become density independent (Corona and LTE conditions, respectively). The fit expression (see II)

$$\ln\langle \sigma v \rangle = \sum_{n=0}^{N} \sum_{m=0}^{M} \alpha_{n,m} (\ln \tilde{n})^m (\ln T)^n$$

then becomes

$$\ln\langle \sigma v \rangle = \sum_{n=0}^{N} \sum_{m=0}^{M} \hat{\alpha}_{n,m} (\ln \hat{n})^m (\ln T)^n$$

with $\hat{\alpha}_{n,m} = b^m \alpha_{n,m}$. At the validity boundaries $\ln(\hat{n}) = 0$ and $\ln(\hat{n}) = 1$ this expression collapses to the correct limiting single parameter fits for the temperature dependence:

$$\ln\langle \sigma v \rangle = \sum_{n=0}^{N} \hat{\alpha}_{n,0} (\ln T)^n$$

at $n \leq 10^8\, cm^{-3}$) and

$$\ln\langle \sigma v \rangle = \sum_{n=0}^{N} \hat{\beta}_n (\ln T)^n$$

at $n \geq 10^{16}\, cm^{-3}$) with $\hat{\beta}_n = \sum_{m=0}^{M} \hat{\alpha}_{n,m}$
The range between the density independent Corona and LTE limits, taken here to be $[10^8, 10^{16}]$, is representative for most relevant applications of EIRENE, but strictly is also temperature dependent. The range should be made wider (on both boundaries) at lower temperatures (below a few eV) and shrinks (at both boundaries) at higher temperatures. Therefore the density parameter $\hat{n}$ in the fit might better be made temperature dependent, e.g. as $\hat{n} = b\ln(an)/ln(T)$, analogous as for the energy parameter in H.3 fits, see II.3.3.

Asymptotical behaviour, temperature parameter to be written

II.3.5 H.5: momentum-weighted rates vs. temperature

currently not in use. Probably for electron-neutral friction vs. T_e, Omega integrals, etc..

II.3.6 H.6: momentum-weighted rates vs. temperature and energy

This section contains reaction rates for track-length estimators for momentum sources (EIRENE, options IESTM=2). The momentum exchange in a collision of a test particle, subscript 0 and another (e.g. plasma) particle, subscript p, is:

$$\Delta \mathbf{P}_0 = m_0 \cdot (\mathbf{v}_0 - \mathbf{v}_0') = \mu(1-\cos(\theta))\,(\mathbf{v}_0 - \mathbf{v}_p) \tag{10}$$

with $\mathbf{v}_0', \mu, \theta$ being the post collision test particle velocity, the reduced mass and the scattering angle in the center of mass frame, respectively. The second equality follows from momentum conservation and the additional assumption that no internal energy is transferred during the collision (i.e., elastic, or resonant ($v_0' = v_p, v_p' = v_0$) charge exchange). Also here: $m_0 = m_0'$ and $m_p = m_p'$. Generalizations to un-symmetric resonant charge exchange are discussed below.

Stationary Maxwellian background The rate coefficient of momentum transfer from a single test particle, with velocity $\mathbf{v_0}$ and energy E_0 to the thermal (stationary) plasma background (temperature T_p) is

$$\begin{aligned} \mathbf{sm}_0 = \langle \sigma \cdot v_{rel} \cdot \Delta \mathbf{P}_0 \rangle (E_0, T_p) &= \langle \sigma \cdot v_{rel} \cdot (\mathbf{v}_0 - \mathbf{v}_0') \cdot m_0 \rangle (E_0, T_p) \qquad (11)\\ &= \mathbf{e}_0 \; \mu \sqrt{\frac{2T_p}{m_p}} \cdot \left[I_{1)}^{(1)}(E_0, T_p) - \frac{1}{2} \sqrt{\frac{m_0 \cdot T_p}{m_p \cdot E_0}} I_{0)}^{(1)}(E_0, T_p) \right] \end{aligned}$$

where $\langle \cdots \rangle$ denotes averaging over the stationary Maxwellian distribution for ion velocities (plasma background) $f_{maxw}(v_p, T_p)$;
$\mathbf{e}_0 = \mathbf{v}_0 / v_0$ the speed unit vector in the direction of the test particle flight. Due to symmetry (isotropy) of the background velocity distribution and averaging over this distribution, momentum can be transferred to/from test particles (and hence also to/from bulk (plasma) particles) only in the direction of test particle flight.
$\sigma(v_{rel})$ and v_{rel} are the collision cross-section and the relative velocity of colliding particles $v_{rel} = |\mathbf{v}_0 - \mathbf{v}_p|$, respectively;
T_p and E_0 is the plasma temperature and the test particle (beam) energy, respectively;
m_p and m_0 is the mass of the plasma particle and the test particle, respectively;
$\mu = (m_p \cdot m_0)/(m_p + m_0)$ is the reduced mass;
$\mathbf{v}_0$ and $\mathbf{v}_0'$ is the velocity of the test particle before and after collision, respectively;
$I^{(l,n)}(E_0, T_p)$ is the generalized Beam-Maxwellian collision integral introduced in [6]. $l = 0$ stands for using the total collision cross-section $\sigma^t(v_{rel}) = \int d\theta \sin(\theta)\; d\sigma(v_{rel}, \theta)/d\theta$, here $d\sigma/d\theta$ denotes the differential scattering cross-section and θ is the scattering angle. The superscript $l = 1, 2...$ stands for momentum transfer, viscosity, ... cross-sections, respectively,

$$\sigma^l(v_{rel}) = \int d\theta \sin(\theta)\; d\sigma(v_{rel}, \theta)/d\theta \cdot [1 - cos^l(\theta)], l = 1, 2, ... \tag{12}$$

After averaging the momentum exchange rate coefficient once again, this time over the test particle velocity distribution $f_0(\mathbf{v}_0)$, the resulting momentum transfer rate becomes a vector in the direction of $\mathbf{V}_0 = \int d^3 v_0 \mathbf{v}_0 f_0(\mathbf{v}_0)$, i.e. in the direction of the mean test particle (flow) speed:

$$\mathbf{Sm}_0(f_0, T_p) = \langle \langle \sigma \cdot v_{rel} \cdot \Delta \mathbf{P}_0 \rangle \rangle (f_0, T_p) \tag{13}$$

and we see that this rate vanishes for isotropic distributions f_0, simply already because of $\mathbf{V_0} = 0$.

drifting Maxwellian background We now turn to momentum exchange rates between the test particle community, subscript 0 and a background (plasma), subscript p.
As discussed already for general Beam-Maxwellian rate coefficients, paragraph H.3, in a first step we transform to the rest frame of the plasma:

$$\mathbf{V}_p = \int d^3 v_p \mathbf{v}_p f(\mathbf{v}_p); \quad \tilde{\mathbf{v}}_0 = \mathbf{v}_0 - \mathbf{V}_p; \quad \widetilde{E}_0 = \frac{m_0}{2}\tilde{v}_0^2; \quad \widetilde{\mathbf{V}}_0 = \mathbf{V}_0 - \mathbf{V}_p \tag{14}$$

where $\tilde{\mathbf{v}}_0$ is the test particle velocity in the rest frame of the plasma and $\widetilde{E}_0$ is the corresponding energy, Eq. (9). Momentum transfer from an individual test particle to a drifting Maxwellian plasma background is then in the direction $\tilde{\mathbf{e}}_0 = \tilde{\mathbf{v}}_0/\widetilde{v_0}$
The vector $\widetilde{\mathbf{V}}_0$ is the average (macroscopic) test particle flow velocity in the rest frame of the plasma; The total rate of momentum transfer from the entire test particle community "0" to the (drifting Maxwellian) background community "p" is a vector in this direction $\widetilde{\mathbf{E}}_0 = \widetilde{\mathbf{V}}_0/\widetilde{V}_0$.
From here on: to be re-written, below: old text from Vlad....
Parallel momentum transfer rate (momentum *loss* for the background (plasma)):

$$\mathbf{Sm}^i_{mu_\parallel} = \mathbf{b}\,(\tilde{\mathbf{e}}_{mom}\cdot\mathbf{b})\,\langle\sigma\cdot v_r\cdot p\rangle\left(\widetilde{E}_0, T_p\right)$$

Where
$\mathbf{V}_t^L$ and $\mathbf{V}_{dr}$ is the test particle velocity in laboratory frame and the plasma drift velocity, respectively;

$\mathbf{b}$ is the magnetic field unit vector.
The final rate is in laboratory frame.
The programming realization can be found in EIRENE in `volume-processes/fpatha.f`, `fpathm.f` and `couple_Tria_new/uptcop.f`
The rates in the present database have been calculated for hydrogen atoms ($m_0 = 1$ amu) in a hydrogen ion background ($m_p = 1$ amu). The mass rescaling is the following. If $\sigma = \sigma(V_r)$ then $I^{(l,n)} = F\left(\frac{E}{m_t}, \frac{T}{m_p}\right)$ and

$$\langle\sigma\cdot v_r\cdot p\rangle\,(E,T) = \frac{m_r^n}{m_r^o}\,\langle\sigma\cdot v_r\cdot p\rangle\,(\frac{m_t^o}{m_t^n}E, \frac{m_p^o}{m_p^n}T)$$

This kind of rescaling is applied for charge exchange, see `volume-processes/xstcx.f`. If $\sigma = \sigma(E_r)$ then $I^{l,n} = \frac{1}{\sqrt{m_r}}F\left(\frac{m_r}{m_p}T, \frac{m_r}{m_t}E\right)$ and

$$\langle\sigma\cdot v_r\cdot p\rangle = \langle\sigma\cdot v_r\cdot p\rangle\left(\frac{m_r^n\cdot m_p^o}{m_r^o\cdot m_p^n}T, \frac{m_r^n\cdot m_t^o}{m_r^o\cdot m_t^n}E\right)$$

This rescaling is used for elastic collisions according to [23], see `volume-processes/xstel.f`. Here superscript "o" means the masses for those the fitting was calculated, and "n" means real masses.

The rate 0.3 (elastic $p + H_2$ collisions) from this set was successfully compared with the same sources, calculated by collisional estimator. The same test for the resonant CX rates 3.1.8 *was not yet successful*

II.3.7 H.7: momentum-weighted rates vs. temperature and density

II.3.8 H.8: energy-weighted rates vs. temperature

Under label H.8 energy-weighted rate coefficients are stored, vs. temperature (eV) of the Maxwellian electron or heavy particle distributions. (E.g., unless otherwise stated, these rates are taken for test particles at rest: $E_0 \approx 0.0\ eV$). The general relation between the energy-weighted rate coefficients H.8 and the "ordinary" rate coefficients H.2 is (integration by parts):

$$H.8[eV cm^3/s] = T \times H.2 \times \left[3/2 + \frac{d\ln(H.2)}{d\ln T}\right] \tag{15}$$

with rate coefficient H.2 in cm^3/s and H.8 in $eV cm^3/s$ and temperature T in eV. If the H.2 rate coefficients are fitted as:

$$\ln(H.2) = \sum_{i=0}^{8} b_i \ln^i(T) \tag{16}$$

then

$$\frac{d\ln(H.2)}{d\ln T} = \sum_{i=0}^{7} b_{i+1}(i+1)\ln^i(T) = b_1 + 2b_2\ln(T) + 3b_3\ln^2(T) + ... \tag{17}$$

and hence, for the H.8 coefficient, in the same fit format as for the H.2 coefficient:

$$\ln(H.8) = \ln(T) + \ln(H.2) + \ln(3/2 + b_1 + 2b_2\ln(T) + 3b_3\ln^2(T) + ...) \tag{18}$$

If a H.2 rate coefficient is linear on a log-log scale, as e.g. often the case for recombination processes, then $b_2 = b_3 = ... = b_8 = 0$, and hence, for the fit coefficients of the corresponding H.8 rate coefficient:
$h_0 = b_0 + \ln[3/2 + b_1], h_1 = b_1 + 1, h_2 = h_3 = ... = h_8 = 0$
An explicit numerical example is detailed under H.8 2.2.14 (dissociative recombination of $H_2^+(v)$ molecular ions) or H.8 2.7.14 (dissociative recombination of N_2^+ molecular ions).

II.3.9 H.9: energy-weighted rates vs. temperature and energy

II.3.10 H.10: energy-weighted rates vs. temperature and density

Fits for $\langle\sigma \cdot v \cdot E\rangle(n_e, T)\ [cm^3/s \cdot eV]$
The units of T and n in the fits are the same as for H.4 and H.7 rates. E is the total energy loss for the electron or ion gas per collision event, in eV units. These rates, therefore, if multiplied by the electron charge 1.6022 10^{-19}, are electron- or ion energy loss rates in Watt/cm^3. Unless otherwise noted these are total energy loss rate coefficients associated with the particular process or set of processes. If such a process is an "effective process", implicitly including fast transitions between excited states of particles which are considered to be in a certain (collision radiative) equilibrium, then these total effective rates

include also line- (bound-bound) and continuum (free-bound) radiation losses, kinetic energy of products (e.g. in case of dissociation processes) and internal (potential) energy differences between pre- and post-collision particles, but **not** bremsstrahlung (free-free) losses.

If the potential energy difference in a particular collision process is negative, as, e.g., in recombination processes or in electron impact de-excitation of meta-stables to a lower level, then this total energy loss rate may become negative, for some values of the parameters, and remain positive for others. I.e., the coefficients may change sign within the parameter range covered by the fit. The fits in this database are, however, often given for the logarithm of the rate coefficient. In such cases we have subtracted the (negative) potential energy contribution from these coefficients before fitting.

More generally, the fitted coefficients, therefore, read:

$\langle \sigma \cdot v \cdot E \rangle_{fit} = \langle \sigma \cdot v \cdot E \rangle - \Delta E_{subtr.} \langle \sigma \cdot v \rangle$

with $\Delta E_{subtr.}$ specified for each particular rate coefficient below, together with the fitting coefficients.

By default we have chosen $\Delta E_{subtr.} = 0.0$ in this expression for all processes in which the potential energy (reaction enthalpy) is enhanced ("sub-elastic" processes, such as ionization, excitation).

For the opposite case (recombination, collisional de-excitation, i.e., "super-elastic" processes, we have chosen $\Delta E_{subtr.} = \Delta E_{pot}$

One can show with some boring algebra on the matrices which arise in collision radiative models that with this particular choice of the subtracted energy loss rate for collision radiative electron cooling rates the remaining fitted expression $\langle \sigma \cdot v \cdot E \rangle_{fit}$ turns out to be exactly the radiation energy loss rate associated with a particular process or set of processes.

In other words: the total effective electron cooling rate is the sum of the effective radiation energy loss rate plus the effective potential energy loss rate, however, with the latter rate being simply given as

$\langle \sigma \cdot v \cdot \Delta E_{pot} \rangle_{effective} = \Delta E_{pot} \cdot \langle \sigma \cdot v \rangle_{effective}$

In this expression $\langle \sigma \cdot v \rangle_{effective}$ is just the effective rate coefficient for the process under consideration, i.e. the coefficient for the same process as given in section H.4.

Note: Electron cooling rate coefficients (as well as radiation rate coefficients) are physically related to a particular species, not necessarily to a particular process.

E.g. electron cooling and radiation rates for H_2 molecules correspond to electron collisions on H_2 and are therefore not related to either dissociative excitation, dissociative ionization or ionization of that molecule individually, but only to the (weighted) sum of these three channels.

Similarly, electron cooling rates associated with a Helium atom, if meta-stables He atoms are retained explicitly in the transport equations, are related to a weighted sum of excitation, de-excitation and ionization processes from a particular meta-stable state, but not to these individual processes.

II.3.11 H.11: other data, e.g. reduced population coefficients

single parameter fit for any other data, e.g. to be used in special user supplied programs, i.e. not generally understood by EIRENE, but can be used in problem specific "..USR" routines of EIRENE, e.g. for post processing. The data fitted in H.11 are, therefore, typically not rate-coefficients, but often (not always) ratios between two single parameter rate coefficients. This comprises data derived from CR models, such as reduced population coefficients, or QSS equilibrium density ratios. Typically the density ratios A/B are distinguished by the formation process of species B, from species A:

$$n_A\langle\sigma v; A \to B\rangle(T) = n_B\langle\sigma v; B_{loss}\rangle(T) \to n_B/n_A = \frac{\langle\sigma v; A \to B\rangle(T)}{\langle\sigma v; B_{loss}\rangle(T)} \tag{19}$$

Also reduced population coefficients are such density ratios, however the production of upper level B may result from various multi-step processes, all starting from ("coupled to") A.

II.3.12 H.12: other data, e.g. reduced population coefficients

double parameter fit for any other data, e.g. to be used in special user supplied programs, i.e. not generally understood by EIRENE, but can be used in problem specific "..USR" routines of EIRENE, e.g. for post processing. The data fitted in H.12 are, therefore, typically not rate-coefficients, but often (not always) ratios between two rate coefficients, see (19). The double parameter fit data in the present paragraph result if at least one of the two involved rate coefficients have a density dependence in addition to the temperature dependence.
Exceptions exist, where a hard-wired reading of data from this section is coded into EIRENE: these are the reduced population coefficients for hydrogenic plasmas, i.e. 2.1.5a,....2.1.5e, 2.2.5a, 2.2.5e, etc... are currently automatically read in EIRENE postprocessing routines in code section "output", routines: Ba_alpha, Ly_alpha, Ba_beta, Ba_gamma, Ba_gamma,..

II.4 End of preface

This next string is searched by EIRENE in subroutine SLREAC to initialize search for a particular set of fit coefficients. From here on, a character string **'H.n'**, with n an integer, must only appear in the section title, but not in the text. Likewise: identifiers p0, a0, b0, ...,h0, k0 are used in SLREAC and must not appear in the text elsewhere, from here on.

```
.............................................
.                                           .
.       ##BEGIN DATA HERE##                 .
.                                           .
.............................................
```

0 H.0 : Fits for Potentials

0.1 Reaction 0.1T $p + H(1s) \rightarrow p + H(1s)$ potential, binary elastic

This potential is not yet implemented here. It is still explicitly programmed in EIRENE, elastics.f. It is the first repulsive H_2^+ potential.

```
fit-flag 01
p0  0.000000000000D+00  p1  0.000000000000D+00  p2  0.000000000000D+00
p3  0.000000000000D+00  p4  0.000000000000D+00  p5  0.000000000000D+00
p6  0.000000000000D+00  p7  0.000000000000D+00  p8  0.000000000000D+00
```

0.2 Reaction 0.2T $p+He(1s^2 1S) \rightarrow p+He(1s^2 1S)$ potential, binary elastic

Morse potential, see [9]

```
fit-flag 02
p0  2.000000000000D+00  p1  2.200000000000D+00  p2  0.850000000000D+00
p3  1.455600000000D+00  p4  0.996990000000D+00  p5  1.995150000000D+00
p6  0.000000000000D+00  p7 -1.500000000000D+00  p8  0.000000000000D+00
```

0.3 Reaction 0.3T $p + H_2 \rightarrow p + H_2$ potential, binary elastic

Morse potential, see [9]

```
fit-flag 02
p0  2.700000000000D+00  p1  3.000000000000D+00  p2  1.000000000000D+00
p3  2.835500000000D+00  p4  2.180380000000D+00  p5  3.490687000000D+00
p6  0.000000000000D+00  p7 -2.025000000000D+00  p8  0.000000000000D+00
```

0.4 Reaction 0.4T $He^{+} + He \rightarrow He^{+} + He$ potential, binary elastic

Morse potential, see [9]

```
fit-flag 02
p0  2.550000000000D+00  p1  2.350000000000D+00  p2  0.900000000000D+00
p3  1.984200000000D+00  p4  1.399080000000D+00  p5  2.634500000000D+00
p6  0.000000000000D+00  p7 -1.912500000000D+00  p8  0.000000000000D+00
```

0.5 Reaction 0.5T $p + Ne \to p + Ne$ potential, binary elastic

Morse potential, see [10]

```
fit-flag 02
p0  2.280000000000D+00  p1  2.680000000000D+00  p2  0.850000000000D+00
p3  1.870900000000D+00  p4  1.387000000000D+00  p5  2.440200000000D+00
p6  0.000000000000D+00  p7 -1.710000000000D+00  p8  0.000000000000D+00
```

0.6 Reaction 0.6T $p + Ar \rightarrow p + Ar$ potential, binary elastic

Morse potential, see [10]

```
fit-flag 02
p0  4.040000000000D+00  p1  2.500000000000D+00  p2  0.860000000000D+00
p3  2.475600000000D+00  p4  1.789200000000D+00  p5  3.273700000000D+00
p6  0.000000000000D+00  p7 -3.030000000000D+00  p8  0.000000000000D+00
```

0.7 Reaction 0.7T $p + Kr \rightarrow p + Kr$ potential, binary elastic

Morse potential, see [10]

```
fit-flag 02
p0  4.450000000000D+00  p1  2.500000000000D+00  p2  0.800000000000D+00
p3  2.777900000000D+00  p4  2.007700000000D+00  p5  3.740600000000D+00
p6  0.000000000000D+00  p7 -3.337500000000D+00  p8  0.000000000000D+00
```

0.8 Reaction 0.8T $p + Xe \to p + Xe$ potential, binary elastic

```
fit-flag 02
p0  6.750000000000D+00  p1  3.800000000000D+00  p2  1.080000000000D+00
p3  3.288200000000D+00  p4  2.688400000000D+00  p5  3.843600000000D+00
p6  0.000000000000D+00  p7 -5.062500000000D+00  p8  0.000000000000D+00
```

0.9 Reaction 0.13p $p + Be \to p + Be$ potential

Default: scattering by angle PI in CM system (strong collision)

```
fit-flag 1
p0  -1.000000000000D+00  p1 -1.000000000000D+00  p2 -1.000000000000D+00
p3  -1.000000000000D+00  p4 -1.000000000000D+00  p5 -1.000000000000D+00
p6  -1.000000000000D+00  p7 -1.000000000000D+00  p8 -1.000000000000D+00
```

0.10 Reaction 0.14p $p + C \to p + C$ potential

Default: scattering by angle PI in CM system (strong collision)

```
fit-flag 1
p0  -1.000000000000D+00  p1 -1.000000000000D+00  p2 -1.000000000000D+00
p3  -1.000000000000D+00  p4 -1.000000000000D+00  p5 -1.000000000000D+00
p6  -1.000000000000D+00  p7 -1.000000000000D+00  p8 -1.000000000000D+00
```

0.11 Coulomb collisions (not ready)

0.11.1 Reaction 0.100 $e + e_b \rightarrow e + e_b$ Trubnikov potential

bulk-electrons on test-electron, Fokker-Planck elastic
Data for Trubnikov Potentials for Fokker-Planck collision operator, bulk-electrons on test-electrons.
currently: none

```
fit-flag 03
p0  0.000000000000D+00  p1  0.000000000000D+00  p2  0.000000000000D+00
p3  0.000000000000D+00  p4  0.000000000000D+00  p5  0.000000000000D+00
p6  0.000000000000D+00  p7  0.000000000000D+00  p8  0.000000000000D+00
```

0.12 Reaction 0.101 $i + e_b \rightarrow i + e_b$ Trubnikov potential

bulk-electrons + test-ions, Fokker-Planck elastic
Data for Trubnikov Potentials for Fokker-Planck collision operator, bulk-electrons on test-ions.
currently: none

```
fit-flag 03
p0  0.100000000000D+00  p1  0.000000000000D+00  p2  0.000000000000D+00
p3  0.000000000000D+00  p4  0.000000000000D+00  p5  0.000000000000D+00
p6  0.000000000000D+00  p7  0.000000000000D+00  p8  0.000000000000D+00
```

0.13 Reaction 0.101e $i + e_b \rightarrow i + e_b$ Trubnikov potential

bulk-electrons + test-ions, Fokker-Planck elastic
Data for Trubnikov Potentials for Fokker-Planck collision operator, bulk-electrons on test-ions. effective diffusion coefficient
currently: none

```
fit-flag 03
p0  0.010000000000D+00  p1  1.000000000000D+00  p2  0.000000000000D+00
p3  0.000000000000D+00  p4  0.000000000000D+00  p5  0.000000000000D+00
p6  0.000000000000D+00  p7  0.000000000000D+00  p8  0.000000000000D+00
```

0.14 Reaction 0.102 $e + i_b \rightarrow e + i_b$ Trubnikov potential

bulk-ions on test-electron, Fokker-Planck elastic
Data for Trubnikov Potentials for Fokker-Planck collision operator, bulk-ions on test-electrons.
currently: none

```
fit-flag 03
p0  0.000000000000D+00  p1  0.000000000000D+00  p2  0.000000000000D+00
p3  0.000000000000D+00  p4  0.000000000000D+00  p5  0.000000000000D+00
p6  0.000000000000D+00  p7  0.000000000000D+00  p8  0.000000000000D+00
```

0.15 Reaction 0.103 $i + i_b \rightarrow i + i_b$ Trubnikov potential

bulk-ions + test-ions, Fokker-Planck elastic
Data for Trubnikov Potentials for Fokker-Planck collision operator, bulk-ions on test-ions.
currently: none

```
fit-flag 03
p0  0.100000000000D+00  p1  0.000000000000D+00  p2  0.000000000000D+00
p3  0.000000000000D+00  p4  0.000000000000D+00  p5  0.000000000000D+00
p6  0.000000000000D+00  p7  0.000000000000D+00  p8  0.000000000000D+00
```

0.16 Reaction 0.103e $i + i_b \rightarrow i + i_b$ Trubnikov potential

bulk-ions + test-ions, Fokker-Planck elastic
Data for Trubnikov Potentials for Fokker-Planck collision operator, bulk-ions on test-ions.
currently: none

```
fit-flag 03
p0  0.010000000000D+00  p1  1.000000000000D+00  p2  0.000000000000D+00
p3  0.000000000000D+00  p4  0.000000000000D+00  p5  0.000000000000D+00
p6  0.000000000000D+00  p7  0.000000000000D+00  p8  0.000000000000D+00
```

0.17 Reaction 0.104 $i + i_b \rightarrow i + i_b$ Trubnikov potential

dummy reaction used to invoke FPKCOL

```
fit-flag 04
p0  0.100000000000D+00  p1  0.000000000000D+00  p2  0.000000000000D+00
p3  0.000000000000D+00  p4  0.000000000000D+00  p5  0.000000000000D+00
p6  0.000000000000D+00  p7  0.000000000000D+00  p8  0.000000000000D+00
```

1 H.1 : Fits for $\sigma(E_{lab})$

1.1 electron impact processes

1.1.1 Reaction 2.2.5org $e + H_2(X_g^+ S) \rightarrow ... \rightarrow e + H(1s) + H(1s)$

Fit as given in monograph [2], repeated here only for reference purposes. EIRENE uses in its minimal (default) database the corresponding fit as given in the unpublished preprint for [2]. This latter fit seems to be more plausible and has been put into the file HYDHEL. It is therefore recommended to read these fit coefficients from the database HYDHEL, and not from here (AMJUEL).

$$e + H_2(X_g^+ S) \rightarrow e + H(b^3\Sigma_u^+, a^3\Sigma_g^+, c^3\Pi_u) \rightarrow e + H(1s) + H(1s)$$

```
a0 -2.297914361380e+05    a1  5.303988579693e+05    a2 -5.316636672593e+05
a3  3.022690779470e+05    a4 -1.066224144320e+05    a5  2.389841369114e+04
a6 -3.324526406357e+03    a7  2.624761592546e+02    a8 -9.006246604428e+00
    Eth 8.5
    Emin  1.08e+01   s(Emin)  1.00e-19   smax  2.92e-17   Error  5.62e-01
```

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1.1.2 Reaction 2.2.14 $e + H_2^+(v) \rightarrow H(1s) + H(n), (v = 0 \ldots 9, n \geq 2)$

EIRENE uses in its default database the corresponding fit from [2], but with all fit coefficients except the first two being set to zero, i.e. a linear fit on a log-log scale.
This latter fit seems to be more plausible. It is therefore recommended to read these fit coefficients from the present database AMJUEL, and not from HYDHEL.

```
a0 -3.479249259777e+01    a1 -1.103564847459e+00    a2  0.000000000000e+00
a3  0.000000000000e+00    a4  0.000000000000e+00    a5  0.000000000000e+00
a6  0.000000000000e+00    a7  0.000000000000e+00    a8  0.000000000000e+00
    Emin  1.00e-01   s(Emin)  9.85e-15   smax  9.85e-15   Error  1.74e-25
    Eth  0.0
    Mcross 9.1093826E-31
```

1.2 proton impact collisions

Elastic collisions between neutral and charged particles, Bachmann/Reiter ([9]) cross-sections as function of E_{lab},
$E_{lab} = (m_{lab}/2) \cdot v^2$
m_{lab} is the ion mass throughout. "T" stands for "total" cross-section (obtained with cut-off at impact parameter such that diffusion and viscosity cross-sections remain accurate. "D" stands for "diffusion" cross-section, and "V" for "viscosity" cross-section.

1.2.1 Reaction 0.1T $p + H(1s) \rightarrow p + H(1s)$ total cross section

```
   a0  0.000000000000D+00  a1  0.000000000000D+00  a2  0.000000000000D+00
   a3  0.000000000000D+00  a4  0.000000000000D+00  a5  0.000000000000D+00
   a6  0.000000000000D+00  a7  0.000000000000D+00  a8  0.000000000000D+00
  al0 -3.253031352541D+01 al1 -2.559032645641D-01 al2 -1.449996483552D-02
  ar0 -3.262937357400D+01 ar1 -8.719626183599D-02 ar2 -7.346647926269D-02
ELABMIN=   1.82060E 00 eV
ELABMAX=   1.82060E 00 eV
       Eth  0.0
```

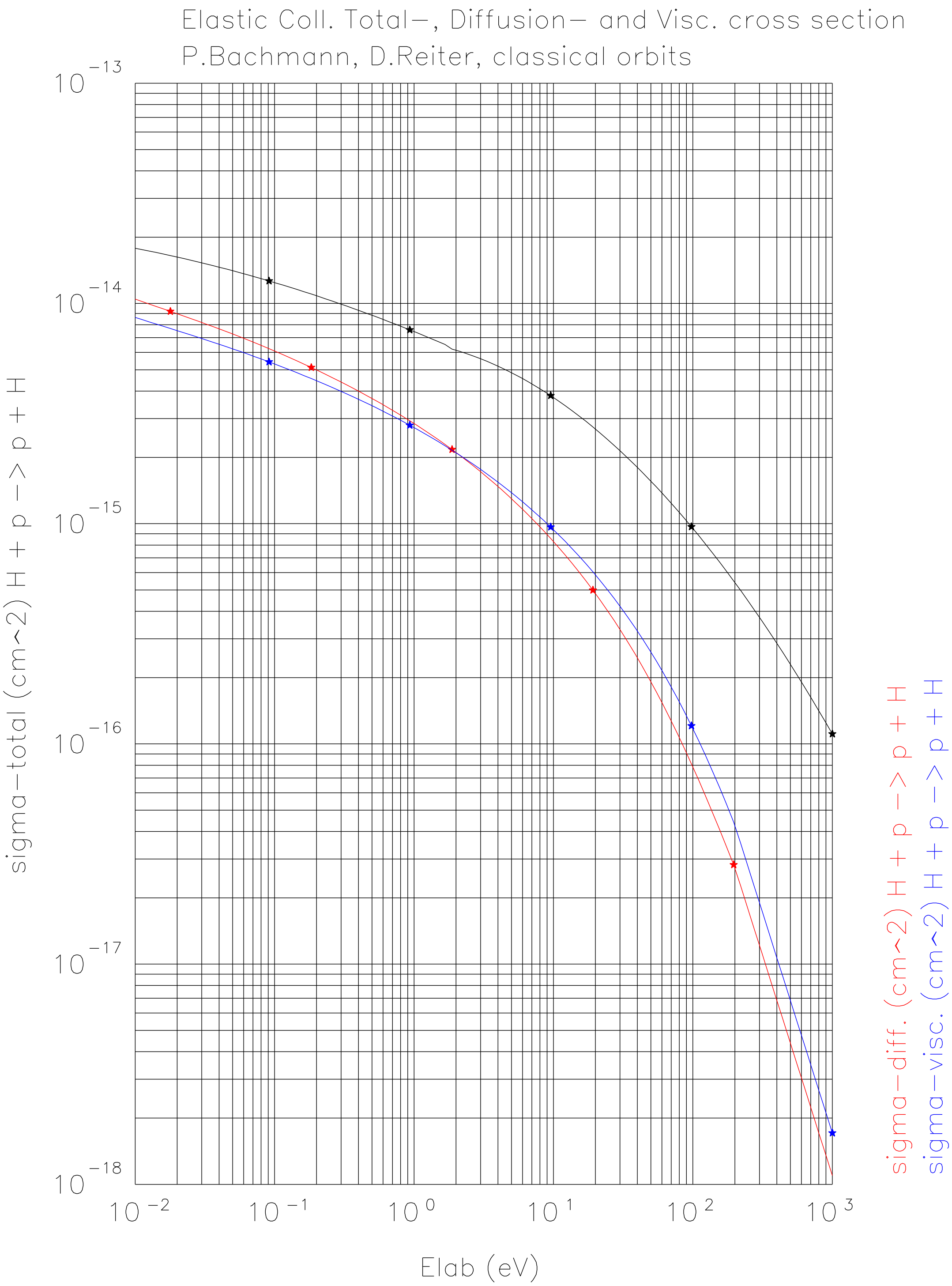
1.2.2 Reaction 0.1D $p + H(1s) \rightarrow p + H(1s)$ diff. cross section

```
   a0 -3.349115100108D+01  a1 -4.047040620920D-01  a2 -4.340959073105D-02
   a3 -5.224890973622D-03  a4 -1.019115858754D-04  a5 -3.314157761518D-06
   a6 -4.336259011986D-05  a7 -1.781020734395D-06  a8  1.220393550627D-06
  al0 -3.320677627738D+01 al1 -2.205942040112D-01 al2  0.000000000000D+00
  ar0 -2.753878563969D+01 ar1 -2.000000000000D+00 ar2  0.000000000000D+00
ELABMIN=  0.02000E 00 eV
ELABMAX=  2.00000E 02 eV
       Eth  0.0
```

1.2.3 Reaction 0.1V $p + H(1s) \rightarrow p + H(1s)$ visc. cross-section

```
   a0 -3.353420922048D+01  a1 -3.522409780724D-01  a2 -3.587214262651D-02
   a3 -4.282561006823D-03  a4 -3.230618998917D-04  a5 -4.343173698940D-05
   a6 -1.753965583282D-05  a7 -4.580920664987D-07  a8  3.738689325195D-07
  al0 -3.330015157525D+01 al1 -1.992625366488D-01 al2  0.000000000000D+00
  ar0 -2.709329427260D+01 ar1 -2.000000000000D+00 ar2  0.000000000000D+00
ELABMIN=  0.02000E 00 eV
ELABMAX=  2.00000E 02 eV
       Eth  0.0
```

Note: This elastic reaction should only be used, if the resonant charge exchange differential cross-section (and hence: diffusion cross-section) is reduced accordingly. The sum: elastic plus charge exchange transport ("diffusion"-) cross-section should be twice the charge exchange total cross-section. The assumption of an exchange of identity (scattering angle π in the center of mass system) at charge exchange produces that factor 2. Hence the need for a revised (smaller) charge exchange scattering angle, if the elastic collision contribution is explicitly added in.


Elastic Coll. Total–, Diffusion– and Visc. cross section
P.Bachmann, D.Reiter, classical orbits
sigma–total (cm^2) H + p –> p + H
sigma–diff. (cm^2) H + p –> p + H
sigma–visc. (cm^2) H + p –> p + H
Elab (eV)
10^-13
10^-14
10^-15
10^-16
10^-17
10^-18
10^-2
10^-1
10^0
10^1
10^2
10^3

1.2.4 Reaction 0.2T $p + He(1s^2 1S) \rightarrow p + He(1s^2 1S)$ total cross-section

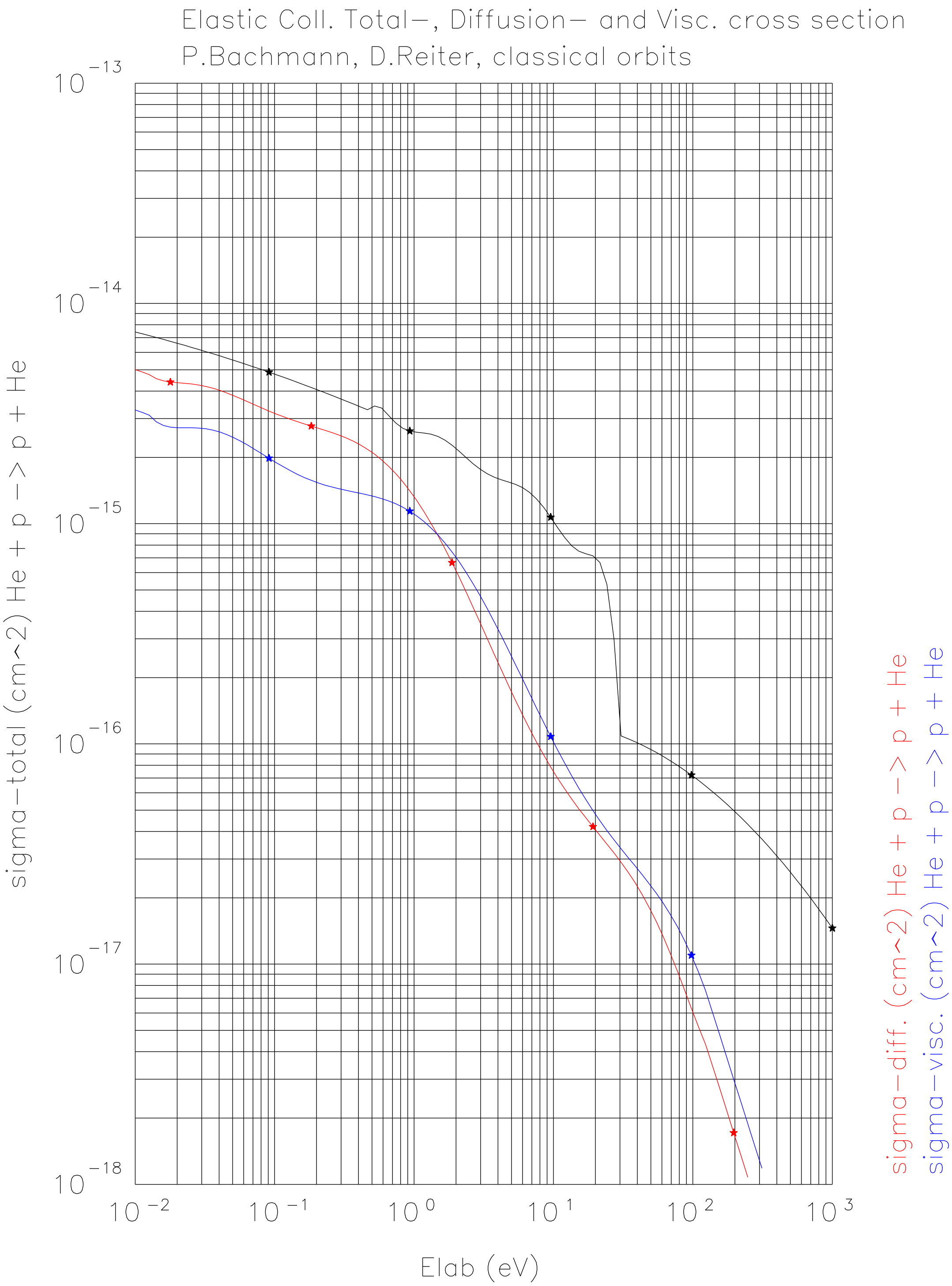
```
   a0 -3.357907136508D+01  a1 -9.811659406594D-02   a2  3.798308269292D-01
   a3 -1.259671949006D+00  a4 -4.473947519984D-02   a5  1.565182597363D+00
   a6 -1.203733922915D+00  a7  3.525830383820D-01   a8 -3.668922671043D-02
  al0 -3.355838377904D+01 al1 -2.845473342853D-01  al2 -1.351427675077D-02
  ar0 -3.706830076698D+01 ar1  4.204258692619D-01  ar2 -9.648359210100D-02
ELABMIN=  0.50810E 00 eV
ELABMAX=  2.94431E 01 eV
       Eth  0.0
```

1.2.5 Reaction 0.2D $p + He(1s^2 1S) \rightarrow p + He(1s^2 1S)$ diff. cross section

```
   a0 -3.425585328953D+01   a1 -8.999762959781D-01  a2 -3.434858124811D-01
   a3  1.549750110754D-02   a4  3.963555202866D-02  a5  3.343570605088D-04
   a6 -2.207534449376D-03   a7 -3.378852519380D-05  a8  4.224511209820D-05
  al0 -3.390101844960D+01  al1 -2.111706771112D-01 al2  0.000000000000D+00
  ar0 -3.034765152080D+01  ar1 -2.000000000000D+00 ar2  0.000000000000D+00
ELABMIN=  0.01250E 00 eV
ELABMAX=  1.25000E 02 eV
       Eth  0.0
```

1.2.6 Reaction 0.2V $p + He(1s^2 1S) \rightarrow p + He(1s^2 1S)$ visc. cross section

```
  a0 -3.443725345071D+01   a1 -4.337427858507D-01  a2 -2.896488696126D-01
  a3 -6.451669335555D-02   a4  2.950009865269D-02  a5  5.752283385868D-03
  a6 -1.589840628629D-03   a7 -1.502468439244D-04  a8  3.151161681447D-05
 al0 -3.432276031579D+01  al1 -2.111706771112D-01 al2  0.000000000000D+00
 ar0 -2.978907423990D+01  ar1 -2.000000000000D+00 ar2  0.000000000000D+00
ELABMIN=  0.01250e 00 eV
ELABMAX=  1.25000e 02 eV
       Eth  0.0
```



Elastic Coll. Total−, Diffusion− and Visc. cross section
P.Bachmann, D.Reiter, classical orbits
sigma−total (cm^2) He + p −> p + He
sigma−diff. (cm^2) He + p −> p + He
sigma−visc. (cm^2) He + p −> p + He
Elab (eV)

1.2.7 Reaction 0.3T $p + H_2 \to p + H_2$ total cross-section

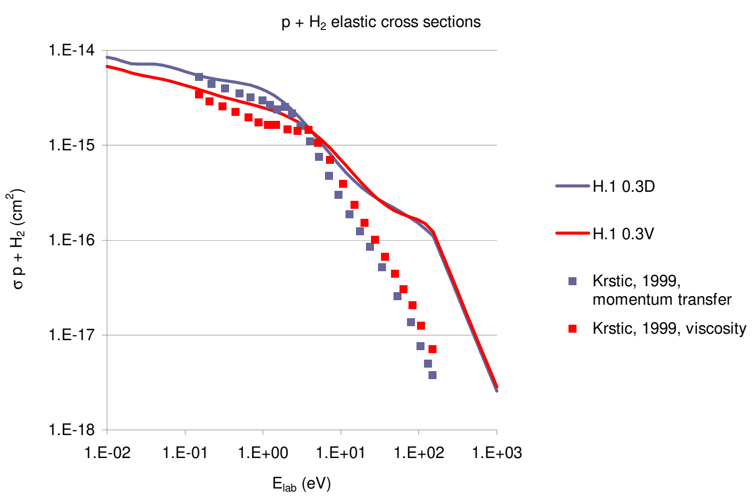
```
   a0 -3.452141819446D+01  a1  1.092015526305D+01  a2 -2.732690257819D+01
   a3  3.466297654768D+01  a4 -2.524607958646D+01  a5  1.092376446349D+01
   a6 -2.770065796605D+00  a7  3.796353200921D-01  a8 -2.168988142310D-02
  al0 -3.275286840950D+01 al1 -2.351764912137D-01 al2 -1.045602118569D-02
  ar0 -3.537275807146D+01 ar1  2.144573517210D-01 ar2 -4.643079956637D-02
ELABMIN=  1.55980E 00 eV
ELABMAX=  6.18164E 01 eV
       Eth  0.0
```

1.2.8 Reaction 0.3D $p + H_2 \to p + H_2$ diff. cross-section

```
   a0 -3.318680874597D+01  a1 -3.580417289312D-01  a2 -2.274382376951D-01
   a3 -5.005702120342D-02  a4  2.369248748869D-02  a5  5.013459267775D-03
   a6 -1.357018742589D-03  a7 -1.393776090855D-04  a8  3.029808591929D-05
  al0 -3.319348529474D+01 al1 -1.726918000000D-01 al2  0.000000000000D+00
  ar0 -2.668769803274D+01 ar1 -2.000000000000D+00 ar2  0.000000000000D+00
ELABMIN=  0.01500E 00 eV
ELABMAX=  1.50000E 02 eV
       Eth  0.0
```

1.2.9 Reaction 0.3V $p + H_2 \to p + H_2$ visc. cross-section

```
   a0 -3.362402037774D+01  a1 -2.337285826242D-01  a2 -5.404526201247D-02
   a3 -4.473235272373D-02  a4 -4.691524784882D-03  a5  3.121568334037D-03
   a6  4.229065229431D-04  a7 -6.739555319843D-05  a8 -7.756198335533D-06
  al0 -3.342235494450D+01 al1 -1.726917299089D-01 al2  0.000000000000D+00
  ar0 -2.658939177532D+01 ar1 -2.000000000000D+00 ar2  0.000000000000D+00
ELABMIN=  0.01500E 00 eV
ELABMAX=  1.50000E 02 eV
       Eth  0.0
```



Comparison of the classical cross-sections given here with quantal calculations by Krstic et al., J. Phys. B, **32**, 2415 (1999), the latter converted from center of mass energy to (proton) laboratory energy.

1.2.10 Reaction 0.5T $p + Ne \rightarrow p + Ne$ total cross section

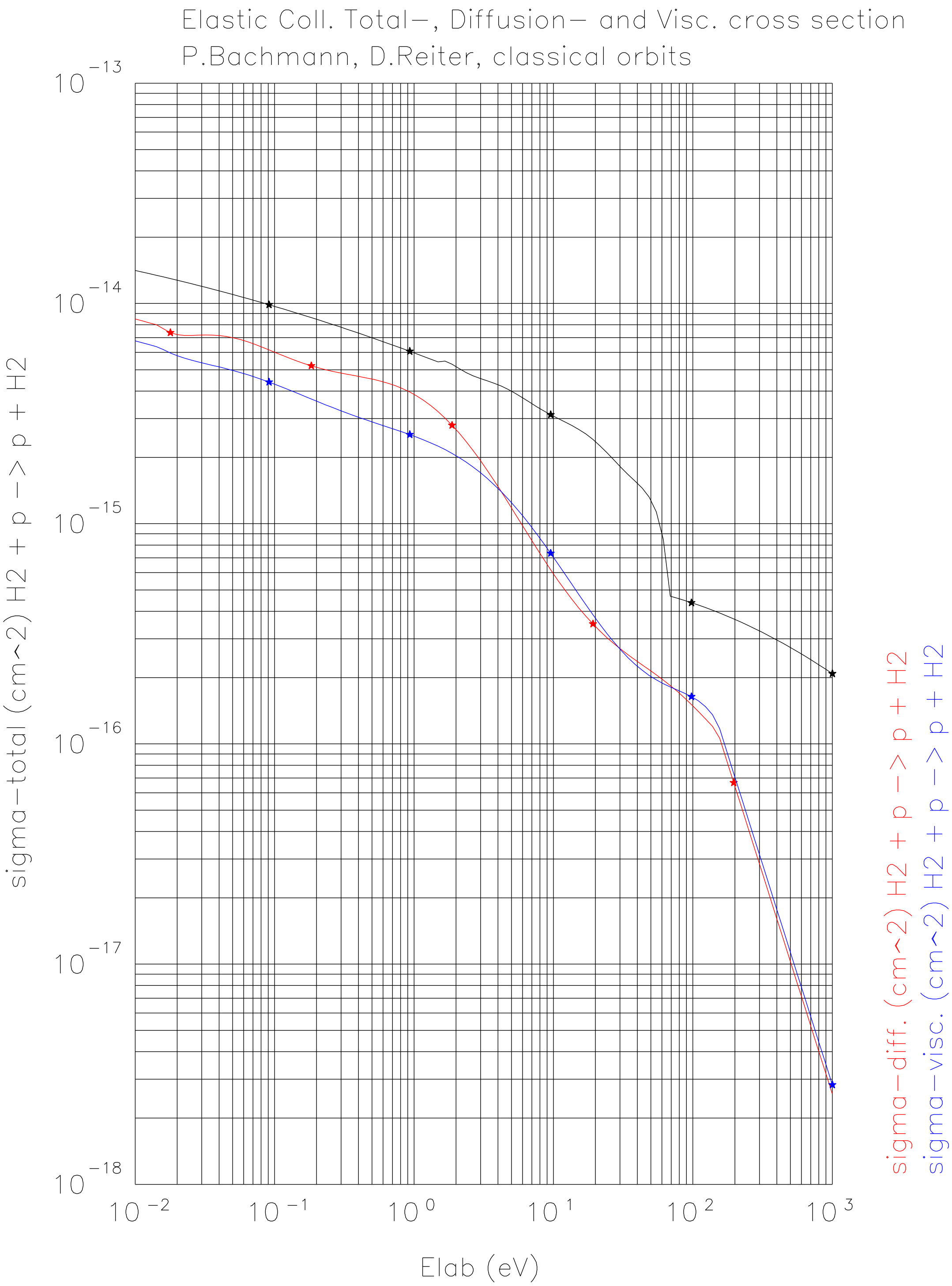
```
   a0 -3.333282545037D+01    a1 -2.591757686627D-01    a2  5.905962318567D-02
   a3 -2.001826855775D-01    a4 -5.669049674832D-02    a5  3.137174515541D-01
   a6 -2.299821550060D-01    a7  6.688038706682D-02    a8 -6.994996779393D-03
  al0 -3.334100609281D+01   al1 -2.660471531811D-01   al2 -1.171591760471D-02
  ar0 -3.771378768853D+01   ar1  9.099449063061D-01   ar2 -1.337354731926D-01
ELABMIN=  0.62790E 00 eV
ELABMAX=  3.19973E 01 eV
       Eth  0.0
```

1.2.11 Reaction 0.5D $p + Ne \rightarrow p + Ne$ diff. cross section

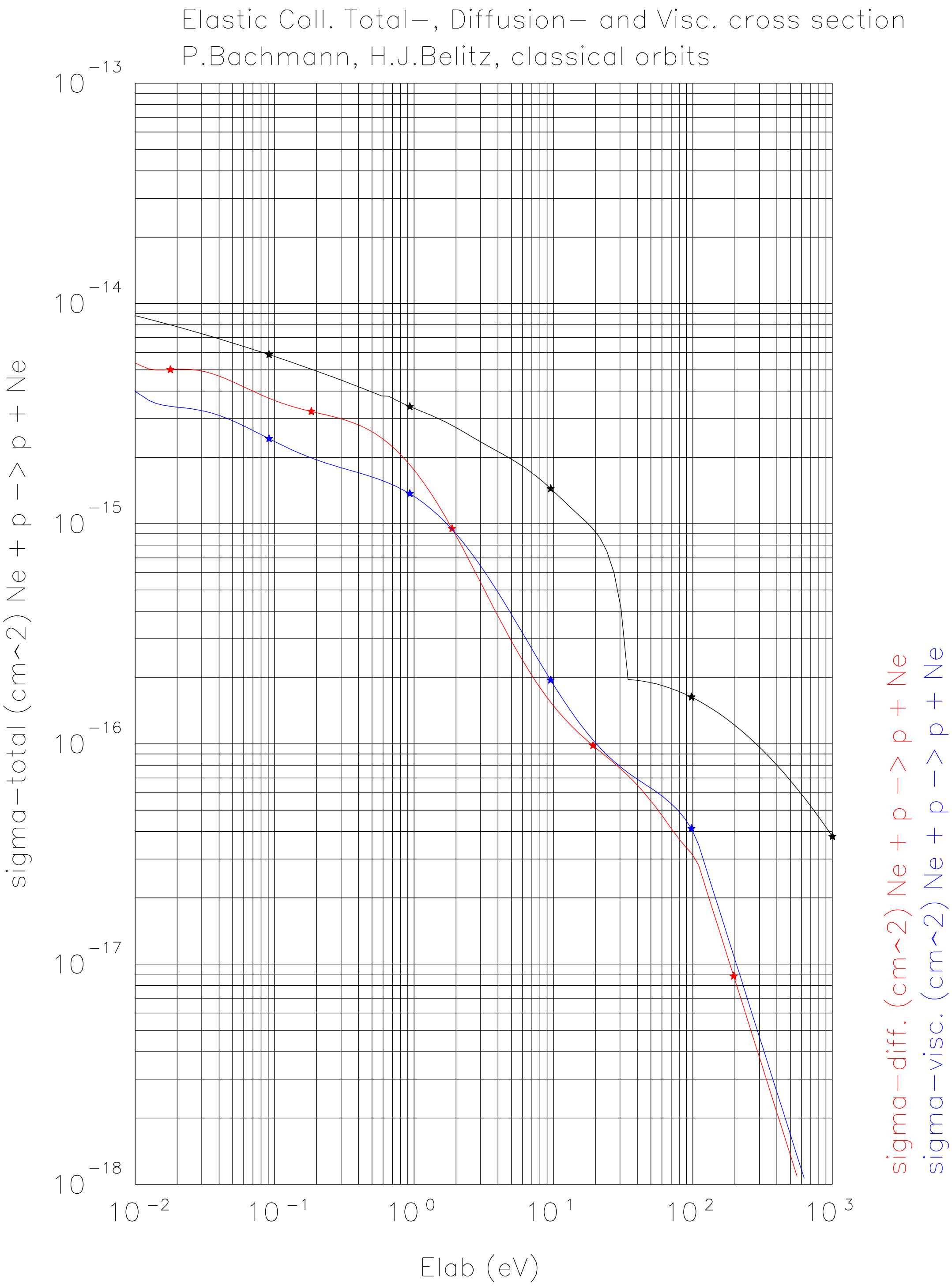
```
   a0 -3.397612223333D+01    a1 -7.944741087630D-01    a2 -3.200443973964D-01
   a3  2.143674395544D-02    a4  4.021546316704D-02    a5 -4.263678799110D-04
   a6 -2.276386458638D-03    a7 -3.001154820480D-06    a8  4.436110664443D-05
  al0 -3.344006570082D+01   al1 -1.264736732177D-01   al2  0.000000000000D+00
  ar0 -2.871071324009D+01   ar1 -2.000000000000D+00   ar2  0.000000000000D+00
ELABMIN=  0.01050E 00 eV
ELABMAX=  1.05000E 02 eV
       Eth  0.0
```

1.2.12 Reaction 0.5V $p + Ne \rightarrow p + Ne$ visc. cross section

```
   a0 -3.425296680643D+01    a1 -4.079254123231D-01    a2 -2.051623201200D-01
   a3 -4.669640022898D-02    a4  1.746802660208D-02    a5  4.241270429401D-03
   a6 -7.397954249705D-04    a7 -1.059957777533D-04    a8  1.168831982170D-05
  al0 -3.373988599214D+01   al1 -1.264736732177D-01   al2  0.000000000000D+00
  ar0 -2.849668424775D+01   ar1 -2.000000000000D+00   ar2  0.000000000000D+00
ELABMIN=  0.01050e 00 eV
ELABMAX=  1.05000e 02 eV
       Eth  0.0
```



Elastic Coll. Total–, Diffusion– and Visc. cross section
P.Bachmann, D.Reiter, classical orbits
sigma–total (cm^2) H2 + p –> p + H2
sigma–diff. (cm^2) H2 + p –> p + H2
sigma–visc. (cm^2) H2 + p –> p + H2
Elab (eV)
10^-13
10^-14
10^-15
10^-16
10^-17
10^-18
10^-2
10^-1
10^0
10^1
10^2
10^3



Elastic Coll. Total–, Diffusion– and Visc. cross section
P.Bachmann, H.J.Belitz, classical orbits
10^-13
10^-14
10^-15
10^-16
10^-17
10^-18
10^-2
10^-1
10^0
10^1
10^2
10^3
Elab (eV)
sigma–total (cm^2) Ne + p –> p + Ne
sigma–diff. (cm^2) Ne + p –> p + Ne
sigma–visc. (cm^2) Ne + p –> p + Ne

1.2.13 Reaction 0.6T $p + Ar \rightarrow p + Ar$ total cross section

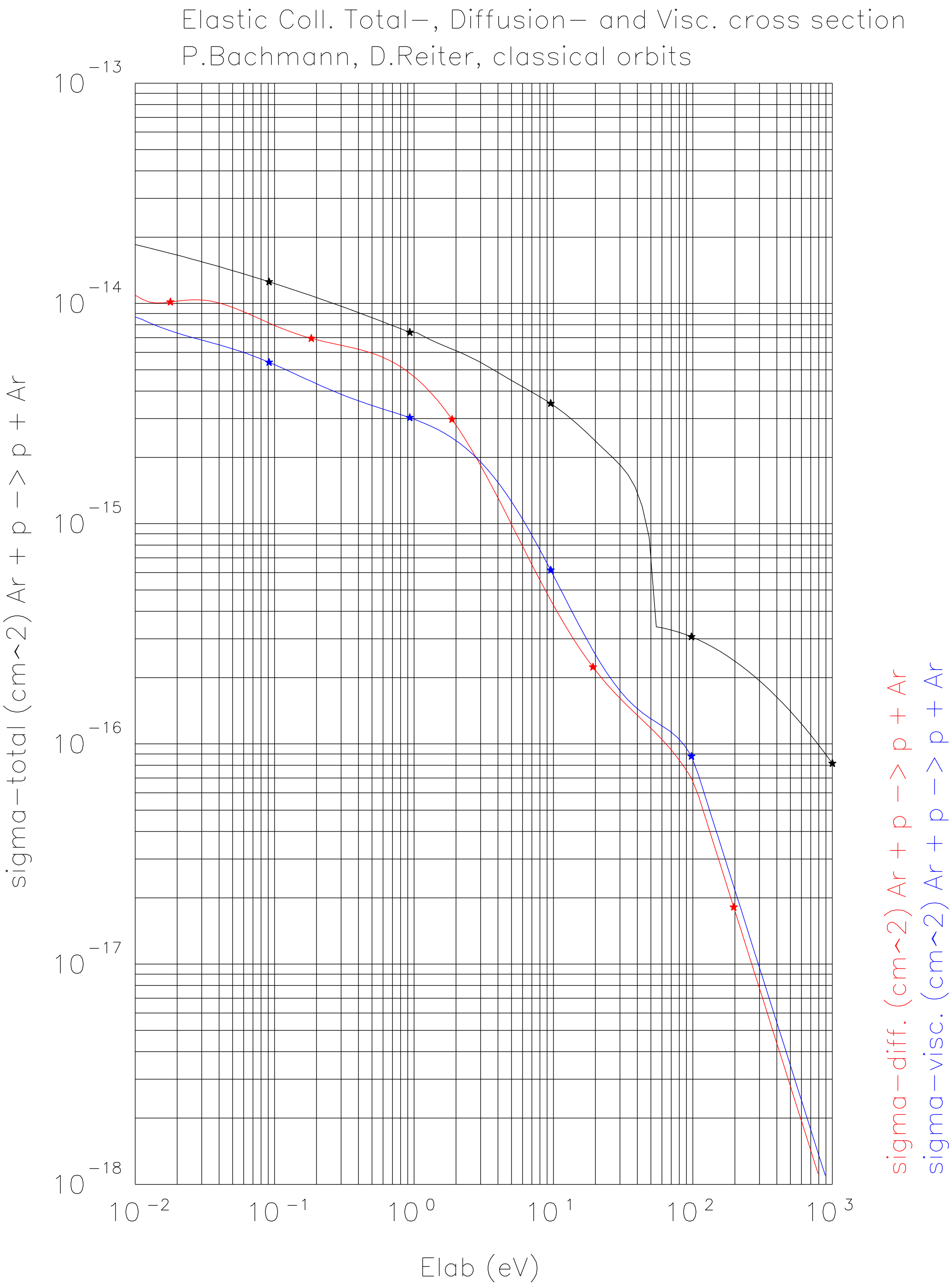
```
   a0 -3.252771558768D+01    a1 -2.994313973955D-01    a2 -3.235294539387D-01
   a3  1.292660022245D+00    a4 -1.875728041457D+00    a5  1.314385161305D+00
   a6 -4.834707764434D-01    a7  8.976263360824D-02    a8 -6.639912411263D-03
  al0 -3.255656992304D+01   al1 -2.557987010452D-01   al2 -1.142012674223D-02
  ar0 -3.733310020910D+01   ar1  9.621654379319D-01   ar2 -1.332505124850D-01
ELABMIN=  1.00563E 00 eV
ELABMAX=  5.43280E 01 eV
       Eth  0.0
```

1.2.14 Reaction 0.6D $p + Ar \rightarrow p + Ar$ diff. cross section

```
   a0 -3.300046179597D+01    a1 -5.241652502840D-01    a2 -2.862188345952D-01
   a3 -3.808042387800D-02    a4  2.731692136471D-02    a5  3.732186449899D-03
   a6 -1.323867831716D-03    a7 -9.428149507977D-05    a8  2.340068227020D-05
  al0 -3.200195937779D+01   al1  3.219272946637D-02   al2  0.000000000000D+00
  ar0 -2.798873683611D+01   ar1 -2.000000000000D+00   ar2  0.000000000000D+00
ELABMIN=  0.01025E 00 eV
ELABMAX=  1.02500E 02 eV
       Eth  0.0
```

1.2.15 Reaction 0.6V $p + Ar \rightarrow p + Ar$ visc. cross section

```
   a0 -3.344659528005D+01    a1 -2.316327281065D-01    a2 -7.902810934692D-02
   a3 -7.081702521173D-02    a4 -8.163451484200D-03    a5  5.173767719011D-03
   a6  8.930487483240D-04    a7 -1.149225205768D-04    a8 -2.179416064042D-05
  al0 -3.222949872234D+01   al1  3.219272946637D-02   al2  0.000000000000D+00
  ar0 -2.777200494194D+01   ar1 -2.000000000000D+00   ar2  0.000000000000D+00
ELABMIN=  0.01025e 00 eV
ELABMAX=  1.02500e 02 eV
       Eth  0.0
```



Elastic Coll. Total–, Diffusion– and Visc. cross section
P.Bachmann, D.Reiter, classical orbits
sigma–total (cm^2) Ar + p –> p + Ar
sigma–diff. (cm^2) Ar + p –> p + Ar
sigma–visc. (cm^2) Ar + p –> p + Ar
Elab (eV)

1.2.16 Reaction 0.7T $p + Kr \rightarrow p + Kr$ total cross section

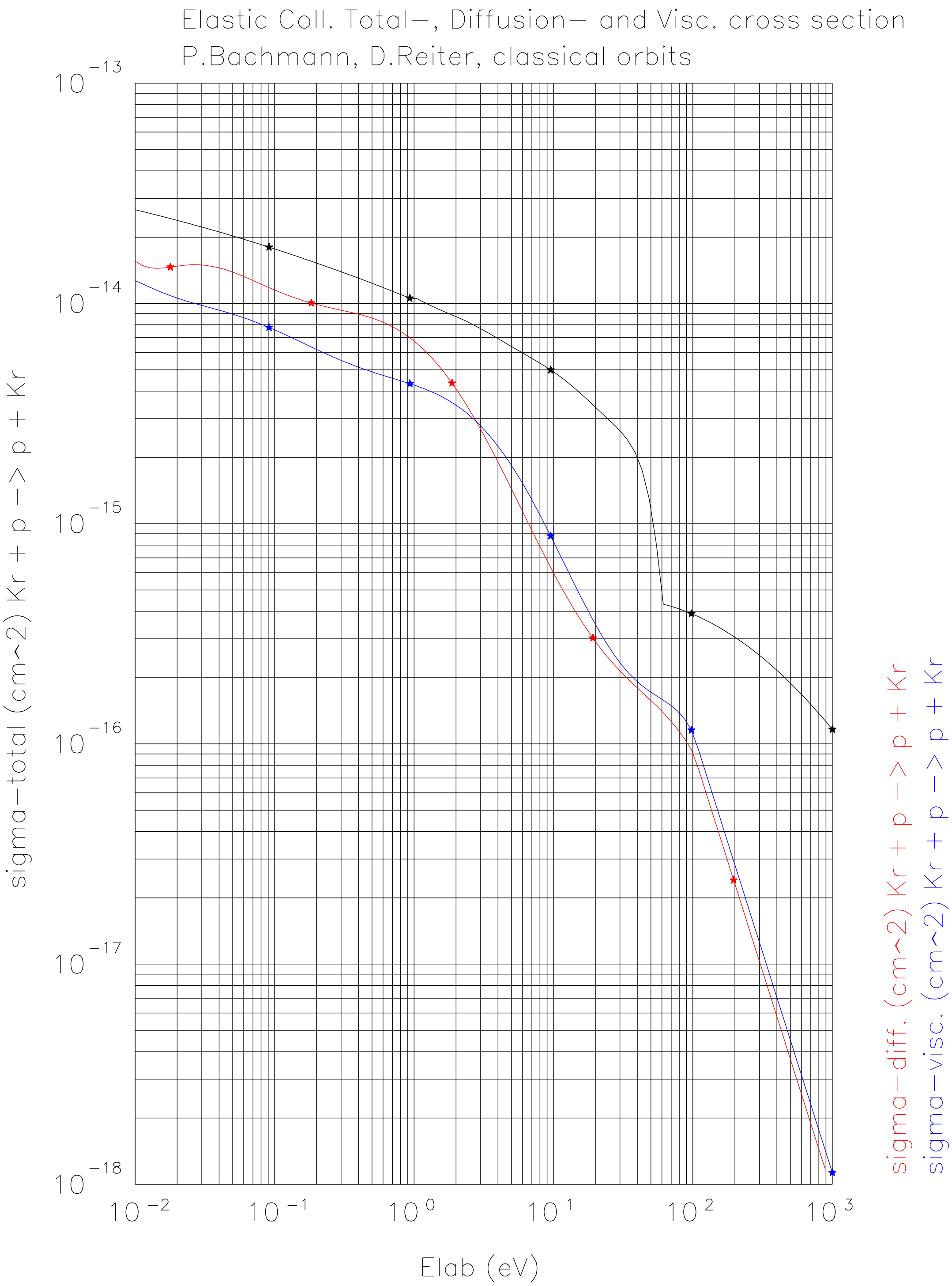
```
   a0 -3.217099198301D+01    a1 -2.966377676688D-01    a2 -2.616163755904D-01
   a3  1.046180820426D+00    a4 -1.532374878331D+00    a5  1.080443653930D+00
   a6 -3.994323904320D-01    a7  7.448807486523D-02    a8 -5.532560545765D-03
  al0 -3.219832641289D+01   al1 -2.577194242716D-01   al2 -1.156457632593D-02
  ar0 -3.656299611480D+01   ar1  7.386503642992D-01   ar2 -1.095842303625D-01
ELABMIN=  0.99496E 00 eV
ELABMAX=  5.69606E 01 eV
       Eth  0.0
```

1.2.17 Reaction 0.7D $p + Kr \rightarrow p + Kr$ diff. cross section

```
   a0 -3.262831875045D+01    a1 -5.132763454362D-01    a2 -2.834710685102D-01
   a3 -4.303577717283D-02    a4  2.549874332091D-02    a5  4.067614437201D-03
   a6 -1.176633809631D-03    a7 -1.008012190920D-04    a8  1.995735768760D-05
  al0 -3.206995069647D+01   al1 -5.998480905376D-02   al2  0.000000000000D+00
  ar0 -2.770706826427D+01   ar1 -2.000000000000D+00   ar2  0.000000000000D+00
ELABMIN=  0.01011E 00 eV
ELABMAX=  1.01114E 02 eV
       Eth  0.0
```

1.2.18 Reaction 0.7V $p + Kr \rightarrow p + Kr$ visc. cross section

```
   a0 -3.308937458718D+01    a1 -2.158553767021D-01    a2 -6.932630020130D-02
   a3 -7.534625980338D-02    a4 -1.066481934150D-02    a5  5.423170191562D-03
   a6  1.055574923129D-03    a7 -1.193974259452D-04    a8 -2.508108481903D-05
  al0 -3.227537561040D+01   al1 -5.998480905376D-02   al2  0.000000000000D+00
  ar0 -2.750803302740D+01   ar1 -2.000000000000D+00   ar2  0.000000000000D+00
ELABMIN=  0.01011e 00 eV
ELABMAX=  1.01114e 02 eV
       Eth  0.0
```



Elastic Coll. Total–, Diffusion– and Visc. cross section
P.Bachmann, D.Reiter, classical orbits
sigma–total (cm^2) Kr + p –> p + Kr
sigma–diff. (cm^2) Kr + p –> p + Kr
sigma–visc. (cm^2) Kr + p –> p + Kr
Elab (eV)

1.2.19 Reaction 0.8T $p + Xe \rightarrow p + Xe$ total cross section

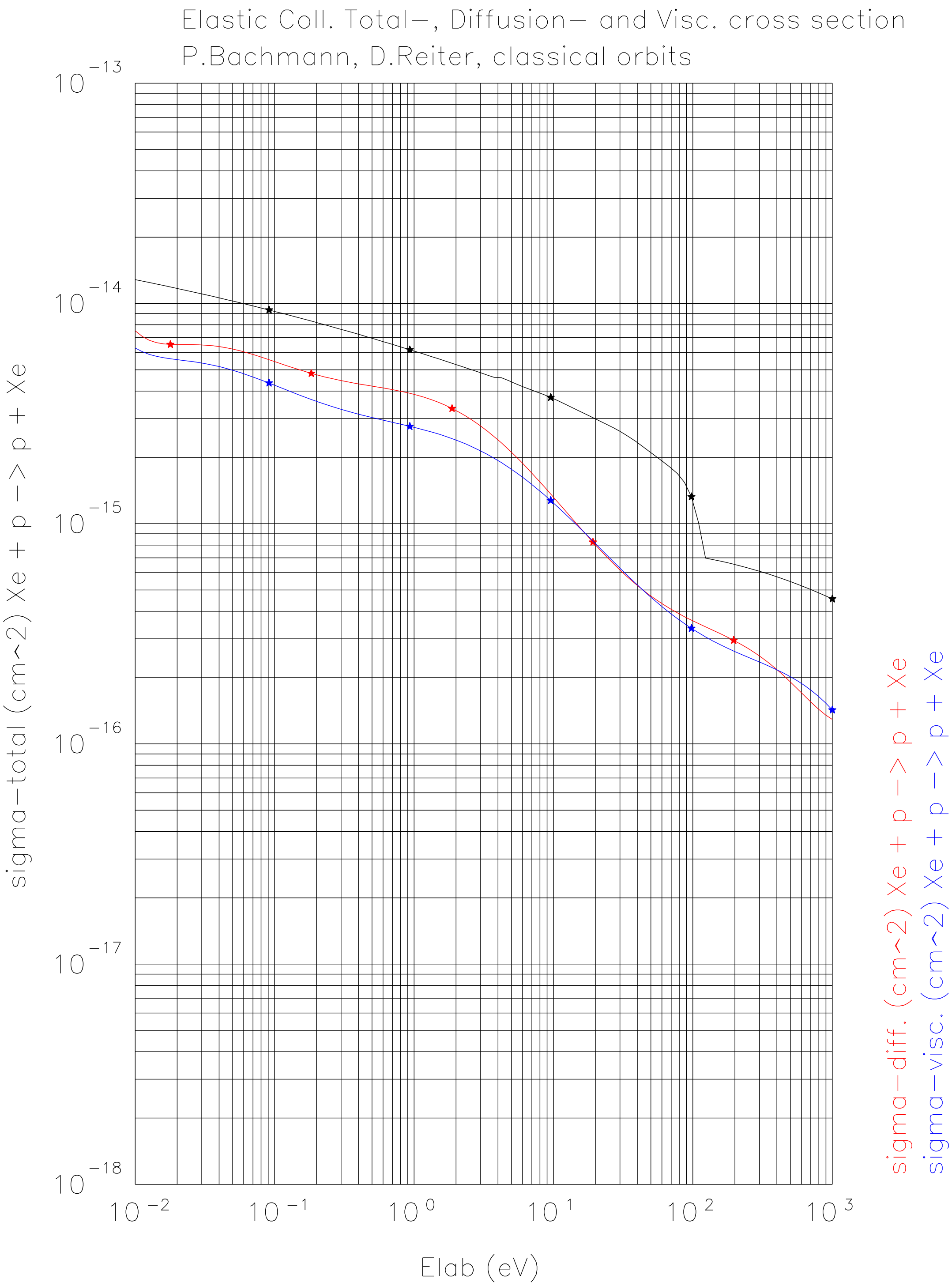
```
   a0 -8.022745305889D+01    a1  1.563497534909D+02    a2 -2.198787103607D+02
   a3  1.720041600893D+02    a4 -8.202458014402D+01    a5  2.443504314279D+01
   a6 -4.445085155020D+00    a7  4.519723658716D-01    a8 -1.969077046350D-02
  al0 -3.273372765185D+01   al1 -1.978370734932D-01   al2 -7.780729379878D-03
  ar0 -3.529762555521D+01   ar1  2.820997908369D-01   ar2 -4.141441372472D-02
ELABMIN=  4.11282E 00 eV
ELABMAX=  1.22993E 02 eV
       Eth  0.0
```

1.2.20 Reaction 0.8D $p + Xe \rightarrow p + Xe$ diff. cross section

```
   a0 -3.318665017785D+01    a1 -1.652711162673D-01    a2 -8.820446797035D-02
   a3 -4.031476436668D-02    a4  4.816376369566D-03    a5  2.865304171410D-03
   a6 -2.624353623005D-04    a7 -6.271242694944D-05    a8  6.709771809639D-06
  al0 -3.367397269144D+01   al1 -2.502739321615D-01   al2  0.000000000000D+00
  ar0 -2.275819247054D+01   ar1 -2.000000000000D+00   ar2  0.000000000000D+00
ELABMIN=  0.01008E 00 eV
ELABMAX=  1.00760E 03 eV
       Eth  0.0
```

1.2.21 Reaction 0.8V $p + Xe \rightarrow p + Xe$ visc. cross section

```
   a0 -3.353160943338D+01    a1 -1.556474053592D-01    a2 -3.165283483361D-02
   a3 -2.954761000116D-02    a4 -1.020213798216D-04    a5  1.787583845145D-03
   a6 -4.672186377936D-05    a7 -3.577368889534D-05    a8  2.586881672353D-06
  al0 -3.326401521314D+01   al1 -1.220855990887D-01   al2  0.000000000000D+00
  ar0 -2.266117187300D+01   ar1 -2.000000000000D+00   ar2  0.000000000000D+00
ELABMIN=  0.01008e 00 eV
ELABMAX=  1.00760e 03 eV
       Eth  0.0
```



Elastic Coll. Total−, Diffusion− and Visc. cross section
P.Bachmann, D.Reiter, classical orbits
sigma−total (cm^2) Xe + p −> p + Xe
sigma−diff. (cm^2) Xe + p −> p + Xe
sigma−visc. (cm^2) Xe + p −> p + Xe
Elab (eV)

1.3 Reaction 0.13p $p + Be \rightarrow p + Be$

Relaxation model, take: half of the momentum transfer cross-section section
[P. Krstic, D. Schultz, PP, vol. 16 (2009), p. 053503]

```
   a0    -3.432911046254e+01  a1    -2.981766563063e-01  a2    -2.747140212160e-03
   a3    -9.888209801767e-02  a4     1.277819275721e-02  a5     5.604365199896e-03
   a6    -1.798975676281e-03  a7     1.873165090959e-04  a8    -6.739311119307e-06
ELABMIN=1.000000e-01 eV
ELABMAX=1.000000e+04 eV
       Eth  0.0
MAXERR=9.420281e+00 %
MIDERR=3.699055e+00 %
```

1.4 Reaction 0.13d $d + Be \rightarrow d + Be$

Relaxation model, take: half of the momentum transfer cross-section section
[P. Krstic, D. Schultz, PP, vol. 16 (2009), p. 053503]

```
   a0    -3.429847239061e+01  a1    -2.970572100641e-01  a2     2.225098488848e-02
   a3    -1.038644613722e-01  a4     1.090206315848e-02  a5     6.452930419639e-03
   a6    -1.922155122744e-03  a7     1.949450215711e-04  a8    -6.904617523867e-06
ELABMIN=1.000000e-01 eV
ELABMAX=1.000000e+04 eV
       Eth  0.0
MAXERR=9.480029e+00 %
MIDERR=3.721394e+00 %
```

1.5 Reaction 0.13t $t + Be \rightarrow t + Be$

Relaxation model, take: half of the momentum transfer cross-section section
[P. Krstic, D. Schultz, PP, vol. 16 (2009), p. 053503]

```
   a0    -3.496365351820e+01  a1    -3.001445356961e-01  a2     4.591434817499e-02
   a3    -1.076154031752e-01  a4     8.896989671817e-03  a5     7.236320863176e-03
   a6    -2.026608049532e-03  a7     2.007699253304e-04  a8    -7.009352516893e-06
ELABMIN=1.000000e-01 eV
ELABMAX=1.000000e+04 eV
       Eth  0.0
MAXERR=9.649480e+00 %
MIDERR=3.664496e+00 %
```

1.6 Reaction 0.14p $p + C \to p + C$

Relaxation model, take: half of the momentum transfer cross-section section
[P. Krstic, D. Schultz, PP, vol. 13 (2006), p. 053501]

```
   a0    -3.469669448083e+01  a1    -6.465336127803e-01  a2    -2.507493283133e-01
   a3     5.150725759535e-02  a4     2.606050422216e-02  a5    -1.200069052688e-02
   a6     1.870487465021e-03  a7    -1.320377335268e-04  a8     3.583861884216e-06
ELABMIN=1.000000e-01 eV
ELABMAX=1.000000e+04 eV
       Eth  0.0
MAXERR=1.359190e+01 %
MIDERR=3.567110e+00 %
```

1.7 Reaction 0.14d $d + C \to d + C$

Relaxation model, take: half of the momentum transfer cross-section section
[P. Krstic, D. Schultz, PP, vol. 13 (2006), p. 053501]

```
   a0    -3.467431708479e+01  a1    -6.039120001583e-01  a2    -2.291079734779e-01
   a3     3.028388597223e-02  a4     2.684378189799e-02  a5    -9.913519764240e-03
   a6     1.329864451784e-03  a7    -7.980666826518e-05  a8     1.784639219274e-06
ELABMIN=1.000000e-01 eV
ELABMAX=1.000000e+04 eV
       Eth  0.0
MAXERR=1.766724e+01 %
MIDERR=4.238927e+00 %
```

1.8 Reaction 0.14t $t + C \to t + C$

Relaxation model, take: half of the momentum transfer cross-section section
[P. Krstic, D. Schultz, PP, vol. 13 (2006), p. 053501]

```
   a0    -3.534658901399e+01  a1    -5.578781967387e-01  a2    -2.132235368452e-01
   a3     1.089144735337e-02  a4     2.797214775907e-02  a5    -8.126362752782e-03
   a6     8.523433043919e-04  a7    -3.327701820563e-05  a8     1.778193853599e-07
ELABMIN=1.000000e-01 eV
ELABMAX=1.000000e+04 eV
       Eth  0.0
MAXERR=2.049295e+01 %
MIDERR=4.869674e+00 %
```

1.8.1 Reaction 3.1.6FJ $p + H \rightarrow ... \rightarrow p + e + p$

Freeman and Jones coefficients, transformed from the keV to eV energy scale, E is the proton energy, [21].

```
a0 -5.607099441961D+02  a1  2.905103863403D+02  a2 -6.871403140568D+01
a3  8.714435377189D+00  a4 -6.169007495812D-01  a5  2.294651604603D-02
a6 -3.495444000000D-04  a7  0.000000000000D+00  a8  0.000000000000D+00
     Eth  0.0
```

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1.8.2 Reaction 3.1.8org $p + H(1s) \rightarrow H(1s) + p$

original Janev-Langer fit as in 1987 Springer book, i.e. without asympt. energy correction.

```
   a0 -3.274123792568e+01    a1 -8.916456579806e-02    a2 -3.016990732025e-02
   a3  9.205482406462e-03    a4  2.400266568315e-03    a5 -1.927122311323e-03
   a6  3.654750340106e-04    a7 -2.788866460622e-05    a8  7.422296363524e-07
       Emin  1.00e-01   s(Emin)  7.00e-15   smax  7.00e-15   Error  2.25e-03
       Eth  0.0
       Mcross 1.0E+00
```

1.8.3 Reaction 3.1.8 $p + H(1s) \rightarrow H(1s) + p$

same as HYDHEL cx total cross-section. Improved from original Janev-Langer fit at low energies by asymptotic fit.: al0 + al1* ln(E) al0 changed in Aug.17., ar0,.... added in Nov. 17

```
   a0 -3.274123792568e+01    a1 -8.916456579806e-02    a2 -3.016990732025e-02
   a3  9.205482406462e-03    a4  2.400266568315e-03    a5 -1.927122311323e-03
   a6  3.654750340106e-04    a7 -2.788866460622e-05    a8  7.422296363524e-07
  al0 -3.294589355000e+01   al1 -1.713112000000e-01   al2  0.000000000000e+00
  ar0 -5.787734011000E+01   ar1  7.671416829000E+00   ar2 -5.208376804000E-01
ELABMIN=   0.10000E 00 eV
ELABMAX=   5.00000E 05 eV
       Emin  1.00e-01   s(Emin)  7.00e-15   smax  7.00e-15   Error  2.25e-03
       Eth  0.0
       Mcross 1.0E+00
```

1.8.4 Reaction 3.1.8J2 $p + H(1s) \rightarrow H(1s) + p$

Janev cross-section for momentum exchange (= cx total cross-sections times 2), obtained by increasing absolute coefficients a_0 and al_0 by adding ln(2)

```
   a0 -3.204809074000e+01    a1 -8.916456579806e-02    a2 -3.016990732025e-02
   a3  9.205482406462e-03    a4  2.400266568315e-03    a5 -1.927122311323e-03
   a6  3.654750340106e-04    a7 -2.788866460622e-05    a8  7.422296363524e-07
  al0 -3.225274637000e+01   al1 -1.713112000000e-01   al2  0.000000000000e+00
ELABMIN=   0.10000E 00 eV
       Eth  0.0
```

1.8.5 Reaction 3.1.8R $p + H(1s) \rightarrow H(1s) + p$

Riviere cross-section formula for charge exchange ([3]), fitted into "Janev-Langer (polynomial) format" [2]

```
  a0 -3.260293402651D+01  a1 -1.302091929244D-01  a2 -3.264584699247D-03
  a3 -2.837612246121D-03  a4  2.259716141071D-04  a5  3.105542152111D-04
  a6 -9.613308889191D-05  a7  1.043010252591D-05  a8 -3.944350620003D-07
  Max. rel. Error:    .7501 %
  Mean rel. Error:    .2304 %
       Eth  0.0
```

1.8.6 Reaction 3.1.8ST $p + H(1s) \rightarrow H(1s) + p$

D.Schultz total cross-section for charge exchange fitted into "Janev format", left asympt. added.

```
   a0 -3.296040048723D+01    a1 -9.877533792693D-02    a2  2.622855374688D-03
   a3 -3.210858385884D-03    a4 -2.175078820057D-04    a5  2.394562232339D-05
   a6  1.665865000000D-05    a7  0.000000000000D+00    a8  0.000000000000D+00
  al0 -3.307949733000D+01   al1 -1.713112000000D-01   al2  0.000000000000e+00
  ar0 -3.291743242047D+01   ar1 -1.358551000000D-01   ar2  0.000000000000D+00
ELABMIN=  0.10000E 00 eV
ELABMAX=  2.00000E 01 eV
       Eth  0.0
```

1.8.7 Reaction 3.1.8ST2 $p + H(1s) \rightarrow H(1s) + p$

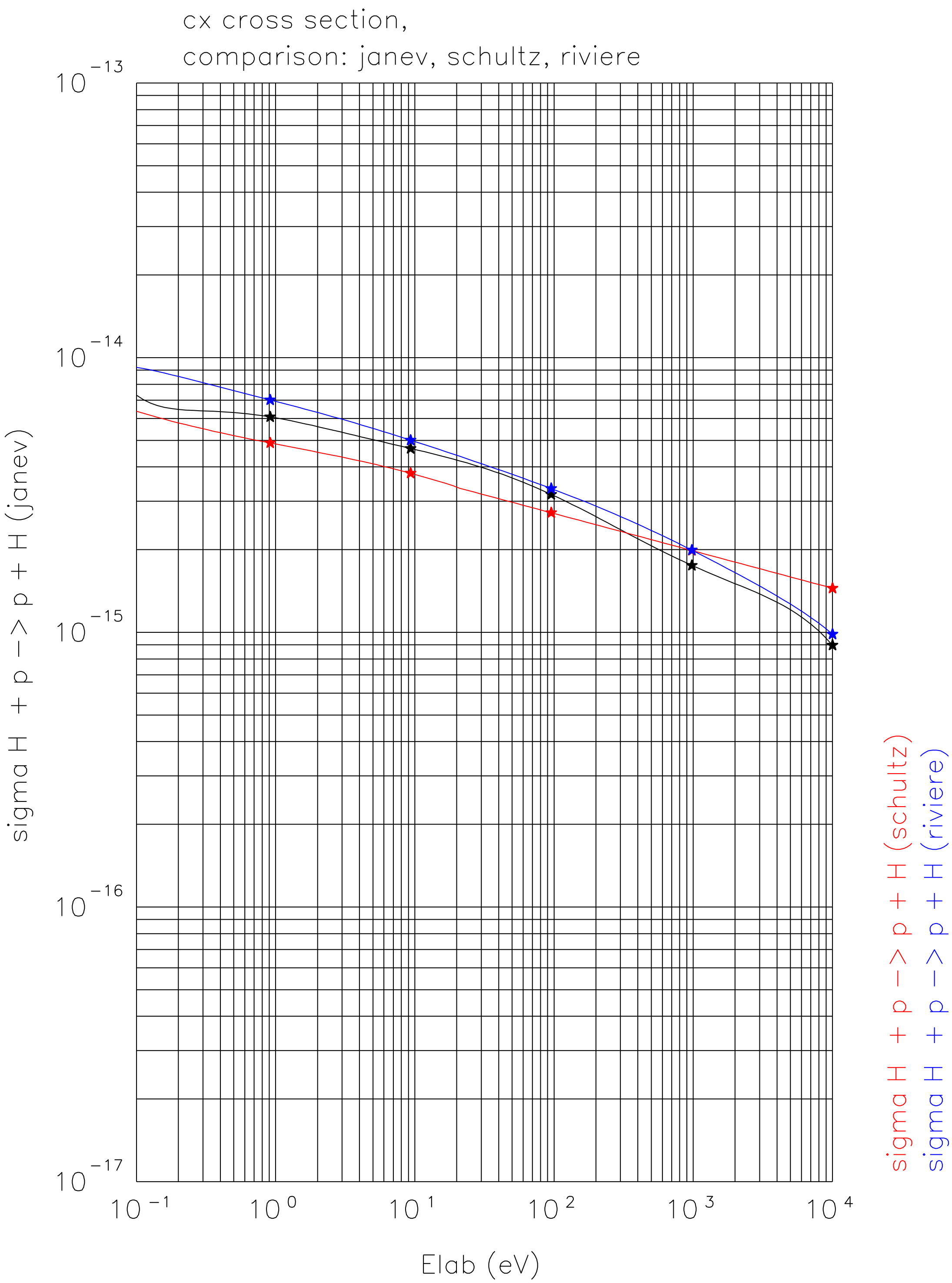
D.Schultz total cross-section for charge exchange *2 increase absolute coefficients a_0 and ar_0 by adding ln(2)

```
   a0 -3.226725330000D+01    a1 -9.877533792693D-02    a2  2.622855374688D-03
   a3 -3.210858385884D-03    a4 -2.175078820057D-04    a5  2.394562232339D-05
   a6  1.665865000000D-05    a7  0.000000000000D+00    a8  0.000000000000D+00
  al0 -3.238635015000D+01   al1 -1.713112000000D-01   al2  0.000000000000e+00
  ar0 -3.222428522000D+01   ar1 -1.358551000000D-01   ar2  0.000000000000D+00
ELABMAX=  2.00000E 01 eV
       Eth  0.0
```

1.8.8 Reaction 3.1.8SD $p + H(1s) \rightarrow H(1s) + p$

D.Schultz "diffusion" cross-section for momentum exchange (elastic plus cx) fitted into "Janev format". Should be close to ST2, total cx cross-section times 2.

```
   a0 -3.225844350904D+01    a1 -1.220948860470D-01    a2  7.214005848073D-03
   a3  5.997760021277D-04    a4 -1.060316696581D-03    a5 -7.487092727391D-05
   a6  3.824773000000D-05    a7  0.000000000000D+00    a8  0.000000000000D+00
  ar0 -3.221533966214D+01   ar1 -1.386002000000D-01   ar2  0.000000000000D+00
ELABMAX=  2.00000E 01 eV
       Eth  0.0
```


cx cross section,
comparison: janev, schultz, riviere
sigma H + p -> p + H (janev)
sigma H + p -> p + H (schultz)
sigma H + p -> p + H (riviere)
Elab (eV)
10^{-13}
10^{-14}
10^{-15}
10^{-16}
10^{-17}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}

1.8.9 Reaction 3.1.8L $p + H(1s) \rightarrow H(1s) + p$

For testing purposes: Langevin cross-section: $\sigma(v) = A0 \times v^{-1}$, or, for hydrogen mass: $\sigma(E) = A \times E^{-1/2}$ such that the rate coefficient, $\langle \sigma \times v_{rel} \rangle = const = A0 = 2.0\ 10^{-8}$ cm^3/s
(Note: $\pi a_0^2 v_0 = 1.92310^{-8}$, the reference rate coefficient with a_0: Bohr radius and $v_0 = e^2/\hbar$: unit velocity in atomic units) Here: $A = A0/1.3891e06$, when v is in cm/s and E in eV, a hydrogen energy.

```
a0 -3.187171457000e+01    a1 -0.500000000000e-00    a2  0.000000000000e-00
a3  0.000000000000e+00    a4  0.000000000000e+00    a5  0.000000000000e+00
a6  0.000000000000e+00    a7  0.000000000000e+00    a8  0.000000000000e+00
    Eth  0.0
```

1.9 He^+ impact processes

1.9.1 Reaction 0.4T $He^+(1s) + He(1s^2 1S) \rightarrow He^+(1s) + He(1s^2 1S)$ total cross-section

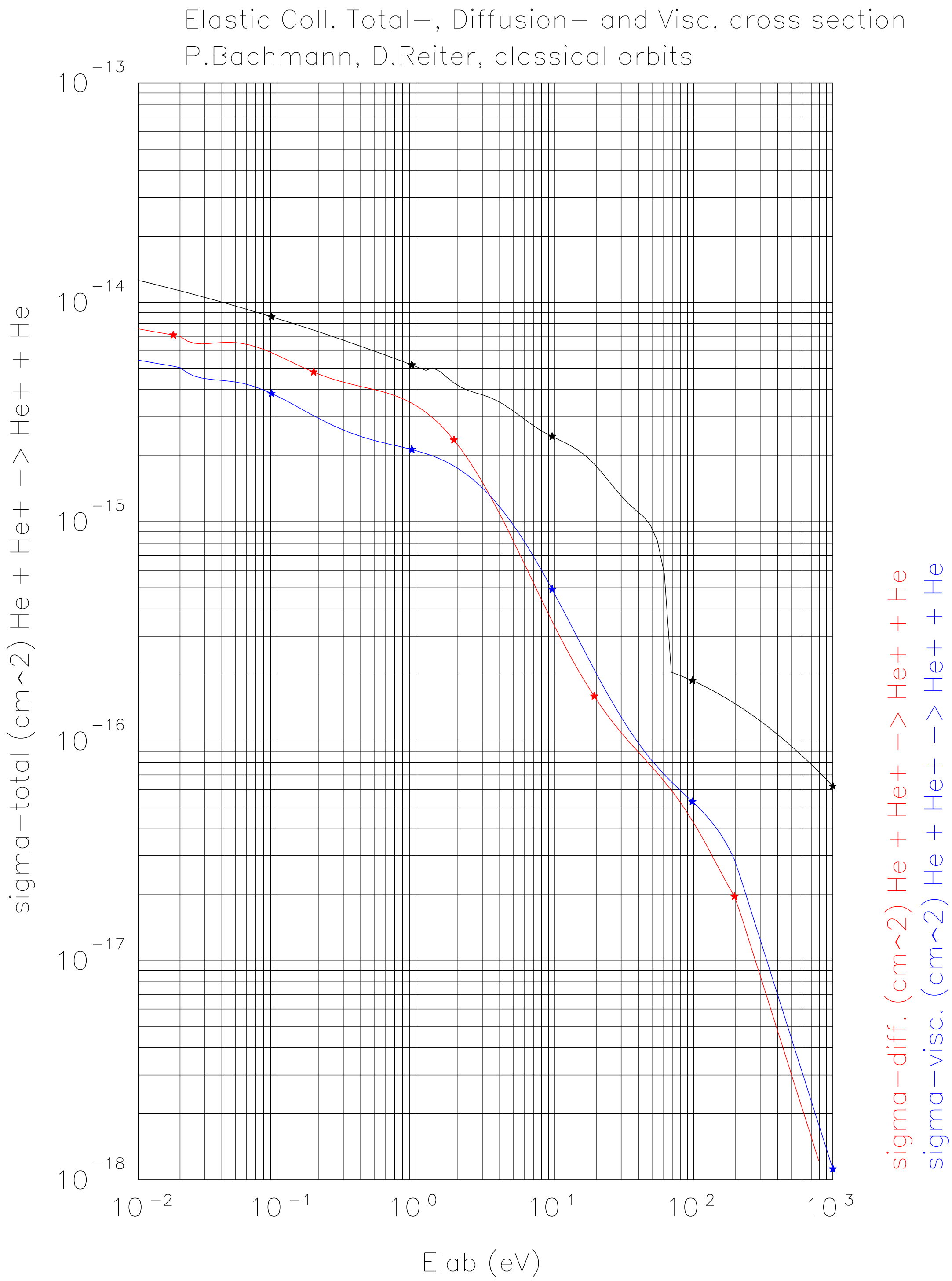
```
   a0 -3.336949020454D+01  a1  4.374909804779D+00  a2 -1.517973301721D+01
   a3  2.345459194687D+01  a4 -1.969436659467D+01  a5  9.472303986781D+00
   a6 -2.604153028956D+00  a7  3.801132783280D-01  a8 -2.282922057203D-02
  al0 -3.291071330248D+01 al1 -2.416669402887D-01 al2 -9.821377921757D-03
  ar0 -3.664691925424D+01 ar1  4.752719886448D-01 ar2 -8.280792916138D-02
ELABMIN=  1.21220E 00 eV
ELABMAX=  6.46090E 01 eV
       Eth  0.0
```

1.9.2 Reaction 0.4D $He^+(1s) + He(1s^2 1S) \rightarrow He^+(1s) + He(1s^2 1S)$ diff. cross-section

```
   a0 -3.332091557452D+01  a1 -3.823354679977D-01  a2 -2.666453887008D-01
   a3 -8.177418933677D-02  a4  2.593188019755D-02  a5  8.320863897668D-03
   a6 -1.649825718076D-03  a7 -2.491587647454D-04  a8  4.351897658362D-05
  al0 -3.302935901459D+01 al1 -1.115060000000D-01 al2  0.000000000000D+00
  ar0 -2.789589583796D+01 ar1 -2.000000000000D+00 ar2  0.000000000000D+00
ELABMIN=  0.02000E 00 eV
ELABMAX=  2.00000E 02 eV
       Eth  0.0
```

1.9.3 Reaction 0.4V $He^+(1s) + He(1s^2 1S) \rightarrow He^+(1s) + He(1s^2 1S)$ visc. cross-section

```
   a0 -3.379346231200D+01  a1 -1.740525006979D-01  a2 -8.091712353563D-02
   a3 -8.223847315134D-02  a4 -1.443276051210D-03  a5  6.530393601967D-03
   a6 -5.593294441844D-05  a7 -1.742244159818D-04  a8  1.068285383642D-05
  al0 -3.335648222384D+01 al1 -1.115060177785D-01 al2  0.000000000000D+00
  ar0 -2.751718958486D+01 ar1 -2.000000000000D+00 ar2  0.000000000000D+00
ELABMIN=  0.02000E 00 eV
ELABMAX=  2.00000E 02 eV
       Eth  0.0
```



Elastic Coll. Total−, Diffusion− and Visc. cross section
P.Bachmann, D.Reiter, classical orbits
sigma−total (cm^2) He + He+ −> He+ + He
sigma−diff. (cm^2) He + He+ −> He+ + He
sigma−visc. (cm^2) He + He+ −> He+ + He
Elab (eV)

2 H.2 : Fits for $\langle\sigma v\rangle(T)$

Some (single parameter) Maxwellian rate coefficients, obtained algebraically from corresponding Beam-Maxwellian fits, at the limit of low ($\approx$ zero) beam energies. The suitable low beam energy limit of these 2-parameter fits was identified by independent integration of cross-sections which have proper low energy extrapolation.

2.1 Reaction 0.1T $p + H(1s) \rightarrow p + H(1s)$ total rate coef.

Maxwellian rate coefficient vs. T_p, with $H(1s)$ at rest, obtained by taking the corresponding Beam-Maxw. rate coefficient at Eb=0.08 eV and verification by independent integration of cross-section

```
b0 -1.833882000000E+01  b1  2.368705000000E-01  b2 -1.469575000000E-02
b3 -1.139850000000E-02  b4  6.379644000000E-04  b5  3.162724000000E-04
b6 -6.681994000000E-05  b7  3.812123000000E-06  b8  8.652321000000E-09
```

2.2 Reaction 0.1D $p + H(1s) \rightarrow p + H(1s)$ diff. rate coef.

Maxwellian rate coefficient vs. T_p, with $H(1s)$ at rest, obtained by taking the corresponding Beam-Maxw. rate coefficient at Eb=0.08 eV and verification by independent integration of cross-section

```
b0 -1.937499000000E+01  b1  1.064443000000E-01  b2 -5.831768000000E-02
b3 -2.768932000000E-02  b4  1.018222000000E-02  b5  1.253253000000E-03
b6 -1.245254000000E-03  b7  2.110022000000E-04  b8 -1.121733000000E-05
```

2.3 Reaction 0.2T $p + He(1s^2 1S) \rightarrow p + He(1s^2 1S)$ total rate coef.

Maxwellian rate coefficient vs. T_p, with $He(1s^2 1S)$ at rest, obtained by taking the corresponding Beam-Maxw. rate coefficient at Eb=0.2 eV and verification by independent integration of cross-section

```
b0 -1.940685000000E+01  b1  1.706015000000E-01  b2  5.518956000000E-03
b3 -1.073297000000E-02  b4 -1.744782000000E-02  b5  1.271241000000E-03
b6  1.541255000000E-03  b7 -3.211063000000E-04  b8  1.805115000000E-05
```

2.4 Reaction 0.2D $p + He(1s^2 1S) \rightarrow p + He(1s^2 1S)$ diff. rate coef.

Maxwellian rate coefficient vs. T_p, with $He(1s^2 1S)$ at rest, obtained by taking the corresponding Beam-Maxw. rate coefficient at Eb=0.2 eV and verification by independent integration of cross-section

```
b0 -2.030007000000E+01  b1 -3.092379000000E-01  b2 -1.701258000000E-01
b3  1.495117000000E-02  b4  1.340661000000E-02  b5 -1.869797000000E-03
b6 -6.819520000000E-04  b7  1.622554000000E-04  b8 -9.363090000000E-06
```

2.5 Reaction 0.3T $p + H_2 \rightarrow p + H_2$ total rate coef.

Maxwellian rate coefficient vs. T_p, with H_2 at rest, obtained by taking the corresponding Beam-Maxw. rate coefficient at Eb=0.06 eV and verification by independent integration of cross-section

```
b0 -1.857812000000E+01  b1  2.411708000000E-01  b2  1.046088000000E-02
b3 -1.203649000000E-02  b4 -3.679626000000E-03  b5  2.895358000000E-04
b6  1.354441000000E-04  b7 -2.712317000000E-06  b8 -1.356528000000E-06
```

2.6 Reaction 0.3D $p + H_2 \rightarrow p + H_2$ diff. rate coef.

Maxwellian rate coefficient vs. T_p, with H_2 at rest, obtained by taking the corresponding Beam-Maxw. rate coefficient at Eb=0.1 eV and verification by independent integration of cross-section

```
b0 -1.914667000000E+01  b1  7.511853000000E-03  b2 -1.408236000000E-01
b3 -7.208816000000E-03  b4  1.464363000000E-02  b5  5.237593000000E-05
b6 -9.787576000000E-04  b7  1.491343000000E-04  b8 -6.478446000000E-06
```

2.7 Reaction 0.4T $He^+(1s) + He(1s^2 1S) \rightarrow He^+(1s) + He(1s^2 1S)$ total rate coef.

Maxwellian rate coefficient vs. T_{He^+}, with He at rest, obtained by taking the corresponding Beam-Maxw. rate coefficient at Eb=0.2 eV and verification by independent integration of cross-section

```
b0 -1.938952000000E+01  b1  1.284344000000E-01  b2  2.749434000000E-02
b3  1.321028000000E-02  b4 -1.215805000000E-02  b5 -1.771858000000E-03
b6  1.250552000000E-03  b7 -1.586374000000E-04  b8  6.000872000000E-06
```

2.8 Reaction 0.4D $He^+(1s) + He(1s^2 1S) \rightarrow He^+(1s) + He(1s^2 1S)$ diff. rate coef.

Maxwellian rate coefficient vs. T_{He^+}, with He at rest, obtained by taking the corresponding Beam-Maxw. rate coefficient at Eb=0.2 eV and verification by independent integration of cross-section

```
b0 -2.002066000000E+01  b1 -8.176109000000E-02  b2 -1.436536000000E-01
b3 -1.526248000000E-02  b4  1.239665000000E-02  b5  3.669366000000E-04
b6 -7.044353000000E-04  b7  9.121888000000E-05  b8 -3.350873000000E-06
```

2.9 Reaction 0.5T $p + Ne \rightarrow p + Ne$ total rate coef.

Maxwellian rate coefficient vs. T_p, with Ne at rest, obtained by taking the corresponding Beam-Maxw. rate coefficient at Eb=0.2 eV and verification by independent integration of cross-section

```
b0 -1.919918000000E+01  b1  2.302126000000E-01  b2 -6.513570000000E-03
b3 -2.016719000000E-02  b4 -1.221527000000E-02  b5  2.242603000000E-03
b6  9.298891000000E-04  b7 -2.398546000000E-04  b8  1.462516000000E-05
```

2.10 Reaction 0.5D $p + Ne \rightarrow p + Ne$ diff. rate coef.

Maxwellian rate coefficient vs. T_p, with Ne at rest, obtained by taking the corresponding Beam-Maxw. rate coefficient at Eb=0.1 eV and verification by independent integration of cross-section

```
b0 -2.002715000000E+01  b1 -2.621343000000E-01  b2 -1.469315000000E-01
b3  2.687596000000E-02  b4  1.266229000000E-02  b5 -2.448273000000E-03
b6 -6.258496000000E-04  b7  1.654175000000E-04  b8 -9.716880000000E-06
```

2.11 Reaction 0.6T $p + Ar \rightarrow p + Ar$ total rate coef.

Maxwellian rate coefficient vs. T_p, with Ar at rest, obtained by taking the corresponding Beam-Maxw. rate coefficient at Eb=0.05 eV and verification by independent integration of cross-section

```
b0 -1.840169000000E+01  b1  2.394376000000E-01  b2 -2.360132000000E-02
b3  6.595325000000E-03  b4 -8.347203000000E-03  b5 -1.735906000000E-03
b6  1.204285000000E-03  b7 -1.658480000000E-04  b8  6.963785000000E-06
```

2.12 Reaction 0.6D $p + Ar \rightarrow p + Ar$ diff. rate coef.

Maxwellian rate coefficient vs. T_p, with Ar at rest, obtained by taking the corresponding Beam-Maxw. rate coefficient at Eb=0.07 eV and verification by independent integration of cross-section

```
b0 -1.906021000000E+01  b1 -4.674038000000E-02  b2 -1.962414000000E-01
b3 -7.174255000000E-03  b4  2.020135000000E-02  b5 -8.507943000000E-04
b6 -1.210751000000E-03  b7  2.196434000000E-04  b8 -1.117489000000E-05
```

2.13 Reaction 0.7T $p + Kr \rightarrow p + Kr$ total rate coef.

Maxwellian rate coefficient vs. T_p, with Ar at rest, obtained by taking the corresponding Beam-Maxw. rate coefficient at Eb=0.05 eV and verification by independent integration of cross-section

```
b0 -1.803236000000E+01  b1  1.992221000000E-01  b2 -3.227483000000E-03
b3  1.395545000000E-02  b4 -1.344849000000E-02  b5 -1.615546000000E-03
b6  1.484410000000E-03  b7 -2.152296000000E-04  b8  9.514869000000E-06
```

2.14 Reaction 0.7D $p + Kr \rightarrow p + Kr$ diff. rate coef.

Maxwellian rate coefficient vs. T_p, with Kr at rest, obtained by taking the corresponding Beam-Maxw. rate coefficient at Eb=0.1 eV and verification by independent integration of cross-section

```
b0 -1.865129000000E+01  b1 -1.062916000000E-01  b2 -1.827846000000E-01
b3 -2.368024000000E-03  b4  1.711988000000E-02  b5 -6.251324000000E-04
b6 -1.097944000000E-03  b7  1.970191000000E-04  b8 -9.968727000000E-06
```

2.15 Reaction 0.8T $p + Xe \rightarrow p + Xe$ total rate coef.

Maxwellian rate coefficient vs. T_p, with Xe at rest, obtained by taking the corresponding Beam-Maxw. rate coefficient at Eb=0.2 eV and verification by independent integration of cross-section

```
b0 -1.850781000000E+01  b1  2.709525000000E-01  b2  4.983184000000E-03
b3 -5.736578000000E-03  b4  1.424879000000E-03  b5 -6.005354000000E-04
b6 -2.027911000000E-04  b7  8.186987000000E-05  b8 -6.300191000000E-06
```

2.16 Reaction 0.8D $p + Xe \rightarrow p + Xe$ diff. rate coef.

Maxwellian rate coefficient vs. T_p, with Xe at rest, obtained by taking the corresponding Beam-Maxw. rate coefficient at Eb=0.1 eV and verification by independent integration of cross-section

```
b0 -1.903991000000E+01  b1  2.089862000000E-01  b2 -7.784350000000E-02
b3 -1.756400000000E-02  b4  5.522983000000E-03  b5  9.448506000000E-04
b6 -2.428668000000E-04  b7 -5.632953000000E-08  b8  1.296757000000E-06
```

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Data from Freeman and Jones [21], are labeled "FJ", and are kept for comparison with old cases.
Note: FJ Maxwellian rate coefficients are taken at neutral particle energy = 0.0 eV (i.e.: neutral atom at rest) vs. temperature (electron or ion temp., resp.) of the Maxwellian f_{maxw}. I.e. :
$\langle\sigma v\rangle = \int d^3 v_p \; \sigma(v_p) \cdot v_p \cdot f_{maxw}(v_p)$
The FJ ion impact rates can be scaled to different isotopes and to finite neutral particle temperatures T_n by evaluating the fits at an effective temperature T_{eff} given by
$T_{eff} = \frac{M}{M_1} T_1 + \frac{M}{M_2} T_2$
Here M is the mass of the ion as used in the Freeman/Jones rate coefficients, $M = 1$ (AMU) for hydrogen ion targets. M_1 and M_2 are the masses (AMU) of the two isotopes in the particular collision process considered, and T_1 and T_2 are the two temperatures.

2.17 Reaction 2.1.5FJ $e + H(1s) \rightarrow e + H^+ + e$

```
b0 -0.317385000000e+02  b1  0.114381800000e+02  b2 -0.383399800000e+01
b3  0.704669200000e+00  b4 -0.743148620000e-01  b5  0.415374900000e-02
b6 -0.948696700000e-04  b7  0.000000000000e-00  b8  0.000000000000e+00
```

2.18 Reaction 3.1.6FJ $p + H(1s) \rightarrow p + p + e$

```
b0 -0.149086100000e+03  b1  0.759257500000e+02  b2 -0.220928100000e+02
b3  0.390970900000e+01  b4 -0.440216800000e+00  b5  0.320904700000e-01
b6 -0.149340900000e-02  b7  0.409415100000e-04  b8 -0.506977700000e-06
```

2.19 Reaction 3.1.8 $p + H(1s) \rightarrow H(1s) + p$

added by DR for convenience: single parameter Maxwellian rate coeff., vs. T_p, for neutral target at rest, obtained from corresponding HYDHEL fit for Beam-Maxwellian rate coeff. evaluated at $E_b = 0.1$ eV and then verified by independent integration of cross-section with proper low energy asymptotic.

```
b0 -1.850280000000E+01    b1  3.708409000000E-01    b2  7.949876000000E-03
b3 -6.143769000000E-04    b4 -4.698969000000E-04    b5 -4.096807000000E-04
b6  1.440382000000E-04    b7 -1.514243000000E-05    b8  5.122435000000E-07
```

2.20 Reaction 3.1.8FJ $p + H(1s) \rightarrow H(1s) + p$

```
b0 -0.184175600000e+02  b1  0.528295000000e+00  b2 -0.220047700000e+00
b3  0.975019200000e-01  b4 -0.174918300000e-01  b5  0.495429800000e-03
b6  0.217491000000e-03  b7 -0.253020600000e-04  b8  0.823075100000e-06
```

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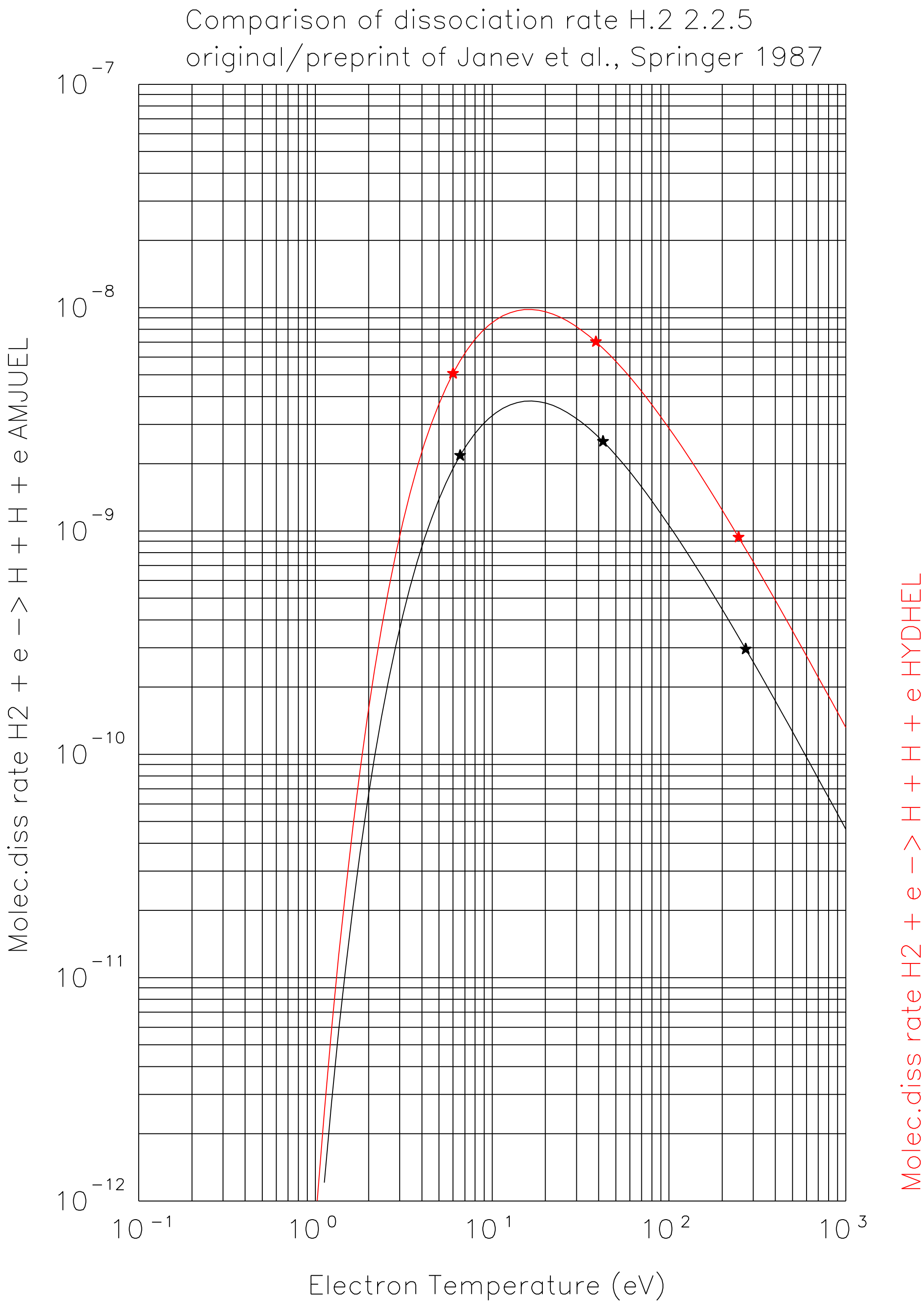
2.21 Reaction 2.2.5org $e + H_2(X_g^+S) \to ... \to e + H(1s) + H(1s)$

Old fit as given in [2], probably based on incorrect cross-section data.
EIRENE uses, as default, the fit as given in preprint for [2], unless otherwise specified, for this dissociation process. This latter fit seems to be more plausible. Therefore, the (presumably more correct) preprint data are stored in file HYDHEL, whereas the original data from ref.[2] are given here in AMJUEL, for reference purposes only.

$$e + H_2(X_g^+S) \to e + H(b^3\Sigma_u^+, a^3\Sigma_g^+, c^3\Pi_u) \to e + H(1s) + H(1s)$$

```
b0 -2.858072836568e+01    b1  1.038543976082e+01    b2 -5.383825026583e+00
b3  1.950636494405e+00    b4 -5.393666392407e-01    b5  1.006916814453e-01
b6 -1.160758573972e-02    b7  7.411623859122e-04    b8 -2.001369618807e-05
 Tmin 1.26e+00   <sv>(Tmin) 3.25e-12   <sv>max 3.82e-09   Error 1.07e-06
```



Comparison of dissociation rate H.2 2.2.5
original/preprint of Janev et al., Springer 1987
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
Electron Temperature (eV)
Molec.diss rate H2 + e -> H + H + e AMJUEL
Molec.diss rate H2 + e -> H + H + e HYDHEL

2.22 Reaction 2.2.14 $e + H_2^+(v) \rightarrow H(1s) + H(n) (v = 0 \ldots 9, n \geq 2)$

Fit as given in [2] but with all higher coefficients b2,b3,...b8 set to zero, for this dissociative recombination process. This latter fit seems to be more plausible. Therefore, the (presumably more correct) data are stored here, whereas the original data from ref.[2] are still given in HYDHEL, for reference purposes only.

```
b0 -1.670435653561e+01    b1 -6.035644995682e-01    b2  0.000000000000e+00
b3  0.000000000000e+00    b4  0.000000000000e+00    b5  0.000000000000e+00
b6  0.000000000000e+00    b7  0.000000000000e+00    b8  0.000000000000e+00
 Tmin 1.00e-01   <sv>(Tmin) 2.23e-07   <sv>max 2.23e-07   Error 3.30e-13
```

2.23 Reaction 2.2.17 $e + H_2 \rightarrow e + H_2(v) \rightarrow H + H^-$

Effective dissociative attachment rate.
$\langle \sigma v \rangle_{eff} = \langle \sigma v \rangle_{H_2(v=0)} + \sum_{v=1}^{14} \langle \sigma v \rangle_{H_2(v)} \cdot pH_2(v)$
Vibrational distribution $pH_2(v; T_e)$ (vs. T_e) taken into account. Only coupling to $H_2(v)$ electronic ground state. No population of $H_2(v)$ from electronically excited H_2^*, no radiative transitions between vibrational levels. Assume: incident H_2 particle with 0.1 eV (for the rate taken to be for H_2 at rest) and $T_p = T_e$, hence: density independent vibrational distribution and effective rate, as well as neutral molecule energy independent rate.
Competing processes: see ion conversion, below, and contribution to dissociation via vibrational states, i.e., enhanced transition into repulsive triplet ^3b.... state.

```
b0 -2.278396332892D+01  b1  8.634828071751D-01  b2 -1.686619409809D+00
b3  4.392288378207D-01  b4 -4.393128035945D-01  b5  2.640299048385D-01
b6 -6.748601049114D-02  b7  7.753368735736D-03  b8 -3.328288267126D-04

Max. rel. Error:  11.6159 %
Mean rel. Error:   5.8452 %
```

2.24 Reaction 2.2.17s $e + H_2 \rightarrow H + H + e$ (Diss via H^-, cold H_2)

Effective (intermediate H^- condensed) dissociation rate coefficient, via $H_2^- --> H + H^-$ channel and $e + H^- --> H + 2e$.
Vibrational distribution $pH_2(v; T_e)$ (vs. T_e) taken into account. Only coupling to $H_2(v)$ electronic ground state. No population of $H_2(v)$ from electronically excited H_2^*, no radiative transitions between vibrational levels. Assume: incident H_2 particle with 0.1 eV (for the rate taken to be for H_2 at rest) and $T_p = T_e$, hence: density independent vibrational distribution and effective rate, as well as neutral molecule energy independent rate.
Competing processes: see H^- MAR, H^- MAD, below.

```
b0 -2.412637388641D+01  b1  2.933435541120D+00  b2 -3.070089133892D+00
b3  5.421534021185D-01  b4 -1.096901334427D-01  b5  5.895406094562D-02
b6 -1.454957631310D-02  b7  1.472799599671D-03  b8 -5.199158850052D-05

Max. rel. Error:   0.220E+02 %
Mean rel. Error:   0.113E+02 %
```

2.25 Reaction 3.1.8L $p + H(1s) \rightarrow H(1s) + p$

Langevin rate coefficient, constant at 2e-8

```
b0 -1.772753356000D+01  b1  0.000000000000D+00  b2  0.000000000000D+00
b3  0.000000000000D+00  b4  0.000000000000D+00  b5  0.000000000000D+00
b6  0.000000000000D+00  b7  0.000000000000D+00  b8  0.000000000000D+00
```

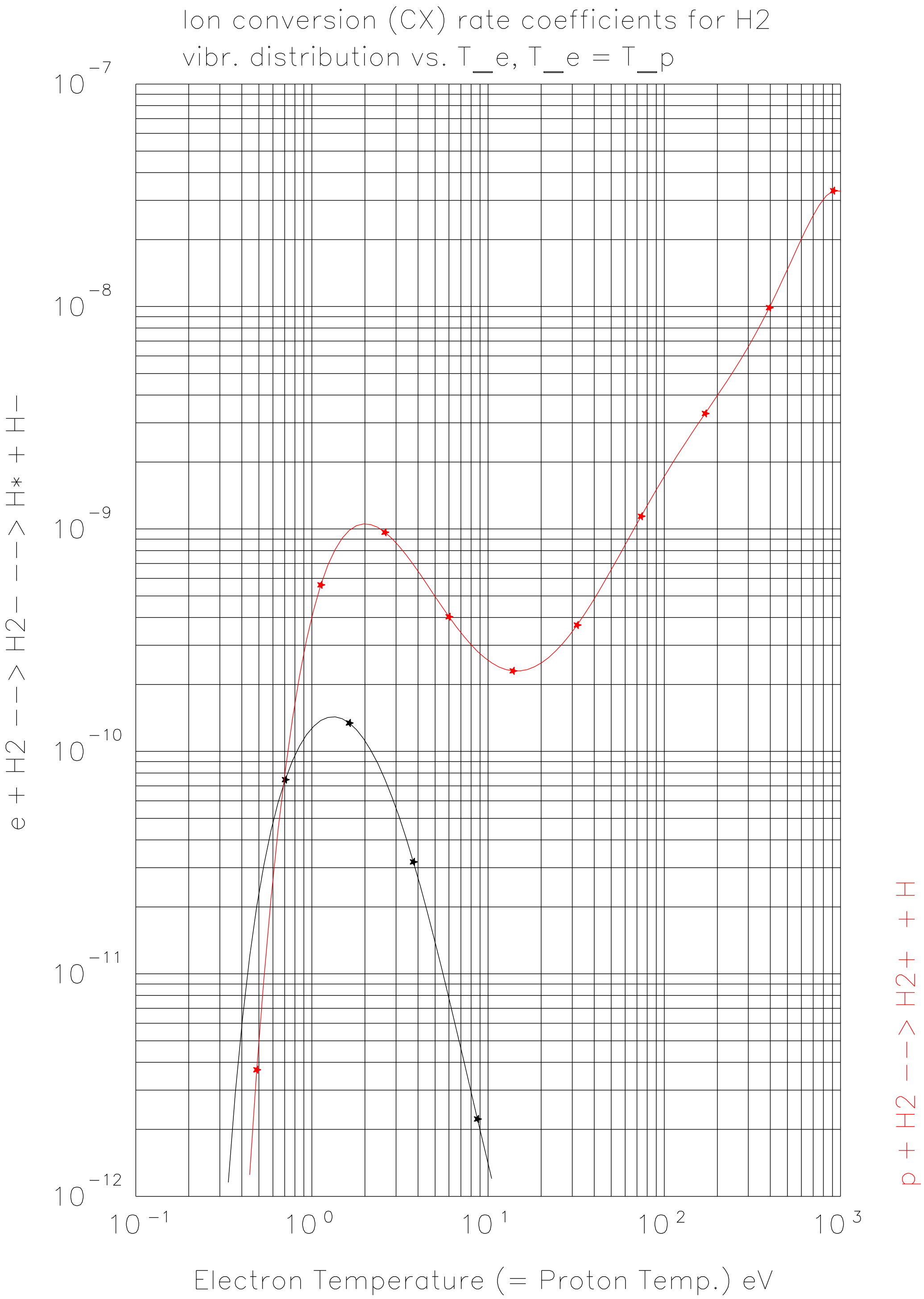
2.26 Reaction 3.2.3g $p + H_2 \rightarrow H + H_2^+$

3.2.3 is renamed now to 3.2.3g, because it implicitly contains Greenland's vibr. distribution (and hence: $T_e = T_p$).
Effective ion conversion rate (charge exchange on H_2)
$\langle \sigma v \rangle_{eff} = \langle \sigma v \rangle_{H_2(v=0)} + \sum_{v=1}^{14} \langle \sigma v \rangle_{H_2(v)} \cdot pH_2(v)$
Same "Greenland" vibrational distribution $pH_2(v; T_e)$ (as function of T_e) as for other rates with implicit "Greenland" vibrational distribution. Therefore: single parameter fit vs. T_e, since vibrational distribution does not depend upon density, E_0 is fixed (at 0.1 eV) and $T_p = T_e = T$.

```
b0 -2.163099643422D+01  b1  3.206843053514D+00  b2 -3.369939911269D+00
b3  1.290238400703D+00  b4 -3.988189754178D-01  b5  1.462287796966D-01
b6 -3.524154596754D-02  b7  4.146324082808D-03  b8 -1.846022446828D-04

Max. rel. Error:  10.2031 %
Mean rel. Error:   6.3799 %
```

Competing process at low T: see above: dissociative electron attachment, process 2-2-17


Ion conversion (CX) rate coefficients for H2
vibr. distribution vs. T_e, T_e = T_p
e + H2 --> H2- --> H* + H-
p + H2 --> H2+ + H
Electron Temperature (= Proton Temp.) eV
10^-7
10^-8
10^-9
10^-10
10^-11
10^-12
10^-1
10^0
10^1
10^2
10^3

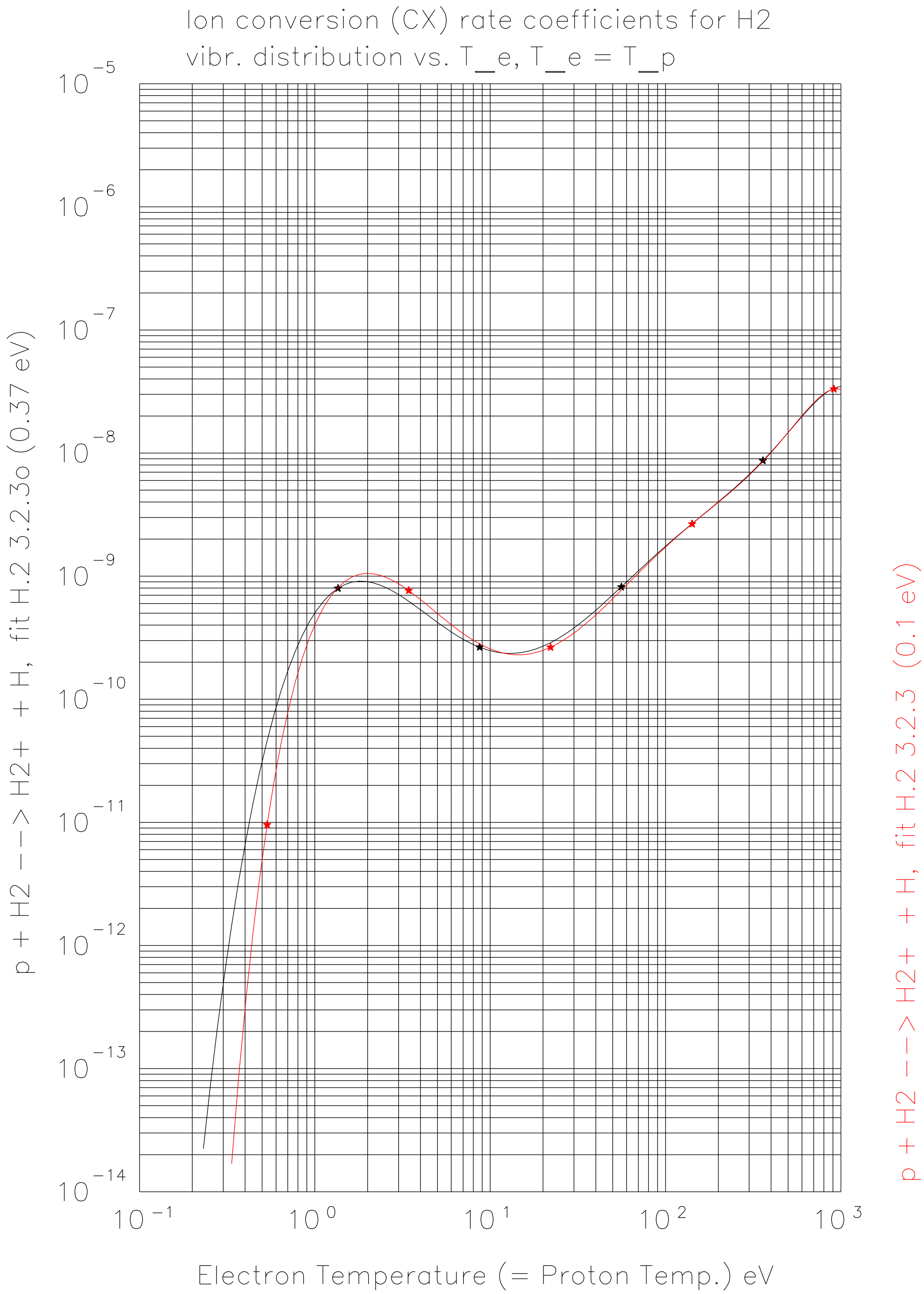
2.27 Reaction 3.2.3g.old $p + H_2 \rightarrow H + H_2^+$

Effective ion conversion rate (charge exchange on H_2 (old version before 2004)
$< \sigma v >_{eff} = < \sigma v >_{H_2(v=0)} + \sum_{v=1}^{14} < \sigma v >_{H_2(v)} \cdot pH_2(v)$
Same vibrational distribution $pH_2(v; T_e)$ (as function of T_e) as above. Therefore: single parameter fit vs. T_e, since vibrational distribution does not depend upon density, E_0 is fixed (0.37 eV) and $T_p = T_e = T$.

```
b0 -2.141025782776D+01  b1  2.159799627973D+00  b2 -2.275674008102D+00
b3  5.413573872835D-01  b4 -6.391621888218D-03  b5  1.566655266221D-02
b6 -1.068539042185D-02  b7  1.770824218105D-03  b8 -9.267718112477D-05

Max. rel. Error:  10.9657 %
Mean rel. Error:   6.2957 %
```

In principle the same as 3-2-3g, above, previous reaction, but here evaluated with old default H_2 energy: E = 0.37 eV, rather than the current choice of E =0.1 eV (as proxy for E = 0.0 eV). Old data are kept here only for backward compatibility. (The old rate coefficient was mostly used in ITER applications and in SOLPS4.x in general). Strictly this rate coefficient should be evaluated for stationary H_2 (energy=0.0) to permit correct mass scaling in the Maxwellian averages.
Competing process at low T: see above: dissociative electron attachment, process 2-2-17



Ion conversion (CX) rate coefficients for H2
vibr. distribution vs. T_e, T_e = T_p
p + H2 --> H2+ + H, fit H.2 3.2.3o (0.37 eV)
p + H2 --> H2+ + H, fit H.2 3.2.3 (0.1 eV)
Electron Temperature (= Proton Temp.) eV

Next few reactions: rate coefficients, vs. Te, for a number of N_2, N_2^+ corona dissociation and ionisation channels

2.28 Reaction 2.7.5 $e + N_2 \to e + N + N$

Dissociation from ground state N_2, cross-section from [11], $\Delta E_{el} = 9.7527$ eV, KER: 0.95 eV (spectra with two peaks, at 0.8 and 1.1 eV resp.)

```
b0 -3.093625000000E+01    b1  1.094180000000E+01    b2 -2.878686000000E+00
b3 -2.524814000000E-01    b4  3.966283000000E-01    b5 -1.209670000000E-01
b6  1.849840000000E-02    b7 -1.461561000000E-03    b8  4.746380000000E-05
```

2.29 Reaction 2.7.9 $e + N_2 \to e + N_2^+ + e$

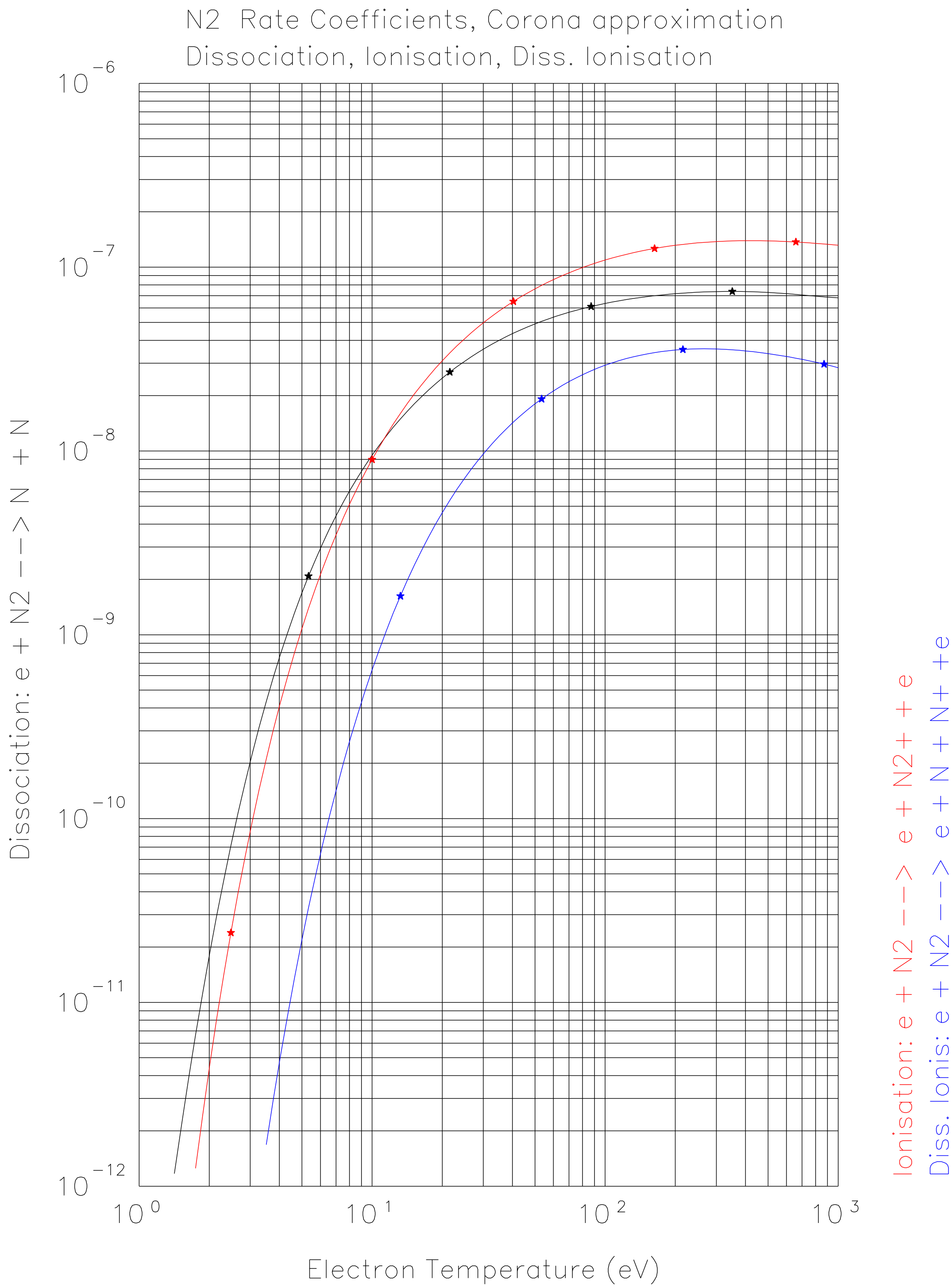
ionisation cross-section: total: [13], I, DI separate [14] (branching ratio R(E)) Here: ionisation to N_2^+
$\Delta E_{el} = 15.581$ eV KER=0.

```
b0 -3.455402000000E+01    b1  1.633449000000E+01    b2 -7.480952000000E+00
b3  2.334744000000E+00    b4 -5.161607000000E-01    b5  7.902320000000E-02
b6 -7.919992000000E-03    b7  4.635395000000E-04    b8 -1.191714000000E-05
```

2.30 Reaction 2.7.10 $e + N_2 \to e + N + N^+ + e$

ionisation cross-section: total: [13], I, DI separate [14] (branching ratio R(E)) Here: dissociative ionisation to $N + N^+$
$\Delta E_{el} = 24.34$ eV, KER: 8 eV (estimated, not clearly specified in paper)

```
b0 -4.583945000000E+01    b1  2.487449000000E+01    b2 -1.169168000000E+01
b3  4.066783000000E+00    b4 -1.070205000000E+00    b5  1.985772000000E-01
b6 -2.383370000000E-02    b7  1.636738000000E-03    b8 -4.849195000000E-05
```


N2 Rate Coefficients, Corona approximation
Dissociation, Ionisation, Diss. Ionisation
Dissociation: e + N2 --> N + N
Ionisation: e + N2 --> e + N2+ + e
Diss. Ionis: e + N2 --> e + N + N+ +e
Electron Temperature (eV)
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{0}
10^{1}
10^{2}
10^{3}

2.31 Reaction 2.7.11 $e + N_2^+ \rightarrow e + 2N^+ + e$

Dissociative ionisation, cross-section: [12] ΔE_{el} = 31.2 eV, KER: max: 11.8 eV

```
b0 -5.137074000000E+01    b1  3.135383000000E+01    b2 -1.560923000000E+01
b3  5.444979000000E+00    b4 -1.354319000000E+00    b5  2.264527000000E-01
b6 -2.359782000000E-02    b7  1.362664000000E-03    b8 -3.285464000000E-05
```

2.32 Reaction 2.7.12 $e + N_2^+ \rightarrow e + N + N^+$

Dissociative excitation, cross-section: [12] ΔE_{el} = 8.4 eV, KER: max. of 6.4 eV at 120 eV, KER nearly = 0 near threshold (i.e. pre-dissociation via various channels).

```
b0 -2.695366000000E+01    b1  8.978136000000E+00    b2 -4.296075000000E+00
b3  1.392124000000E+00    b4 -3.247302000000E-01    b5  5.222337000000E-02
b6 -5.327033000000E-03    b7  3.023081000000E-04    b8 -7.105405000000E-06
```

2.33 Reaction 2.7.14 $e + N_2^+ \rightarrow N + N$

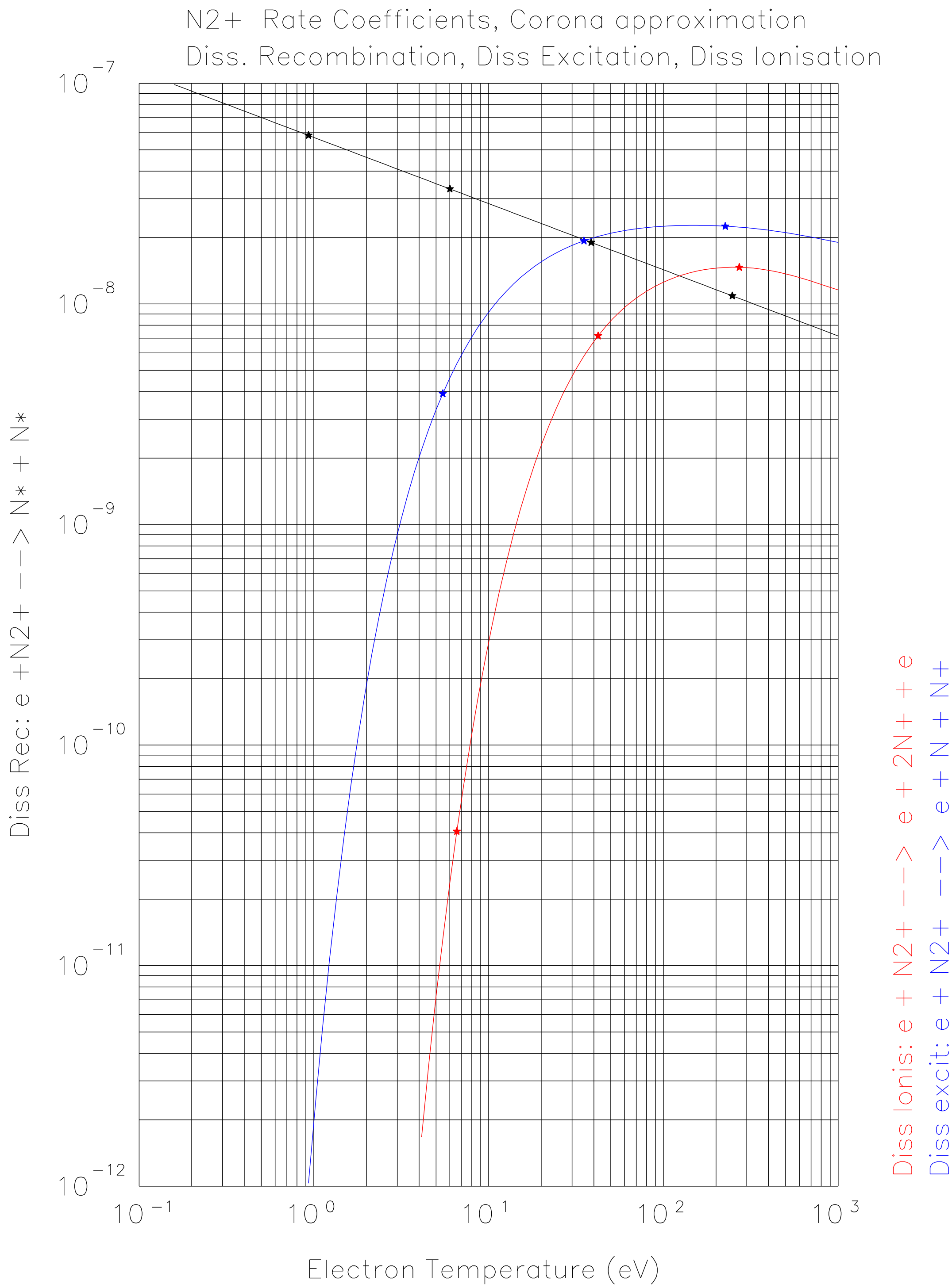
Dissociative recombination, cross-section: [16] ΔE_{el} can be taken from electron energy-weighted rate coefficient. KER: 1.06 - 5.824 eV at zero electron impact energy, depending on vibrational state of N_2^+ and electronic state of products. Suggestion: KER = 3.5 eV

```
b0 -1.668240000000E+01    b1 -0.300000000000E+00    b2  0.000000000000E+00
b3  0.000000000000E+00    b4  0.000000000000E+00    b5  0.000000000000E+00
b6  0.000000000000E+00    b7  0.000000000000E+00    b8  0.000000000000E+00
Eth=0.0
```

2.34 Reaction 2.7.15 $e + N_2^+ \rightarrow e + N_2^{++} + e$

Single ionisation of N_2^+, cross-section: [12]
ΔE_{el} = 27.12 eV, KER=0.

```
b0 -4.675067000000E+01    b1  2.768681000000E+01    b2 -1.260874000000E+01
b3  3.402022000000E+00    b4 -5.302686000000E-01    b5  3.823736000000E-02
b6  6.310561000000E-04    b7 -2.798009000000E-04    b8  1.272992000000E-05
```



N2+ Rate Coefficients, Corona approximation
Diss. Recombination, Diss Excitation, Diss Ionisation
10^-7
10^-8
10^-9
10^-10
10^-11
10^-12
10^-1
10^0
10^1
10^2
10^3
Electron Temperature (eV)
Diss Rec: e +N2+ --> N* + N*
Diss Ionis: e + N2+ --> e + 2N+ + e
Diss excit: e + N2+ --> e + N + N+

2.35 Reaction 2.2FJ $e + He(1s^2 1S) \rightarrow e + He^+(1s) + e$

Freeman and Jones rate coefficient for electron impact ionization of helium atoms [21] .

```
b0 -0.445091700000e+02    b1  0.244298800000e+02    b2 -0.102571400000e+02
b3  0.247093100000e+01    b4 -0.342636620000e+00    b5  0.250510000000e-01
b6 -0.743867500000e-03    b7  0.000000000000e-00    b8  0.000000000000e+00
```

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Data from impurity transport code "STRAHL" (K. Behringer) [19]
All reaction data with label ..aB0 or ..aB1 are taken from that reference. "a" is the nuclear charge number. aB0: ionisation of neutral atom. aB1: ionisation of singly charged ion.

2.36 Reaction 2.2B0 $e + He(1s^2 1S) \rightarrow e + He^+(1s) + e$

Ionization Rate for neutral Helium Atoms, STRAHL code.

```
b0 -4.445750823378D+01    b1  2.505856927901D+01    b2 -1.196552488672D+01
b3  3.715887422949D+00    b4 -7.729722462758D-01    b5  1.055704673374D-01
b6 -9.047513943647D-03    b7  4.403714187787D-04    b8 -9.276447001487D-06
```

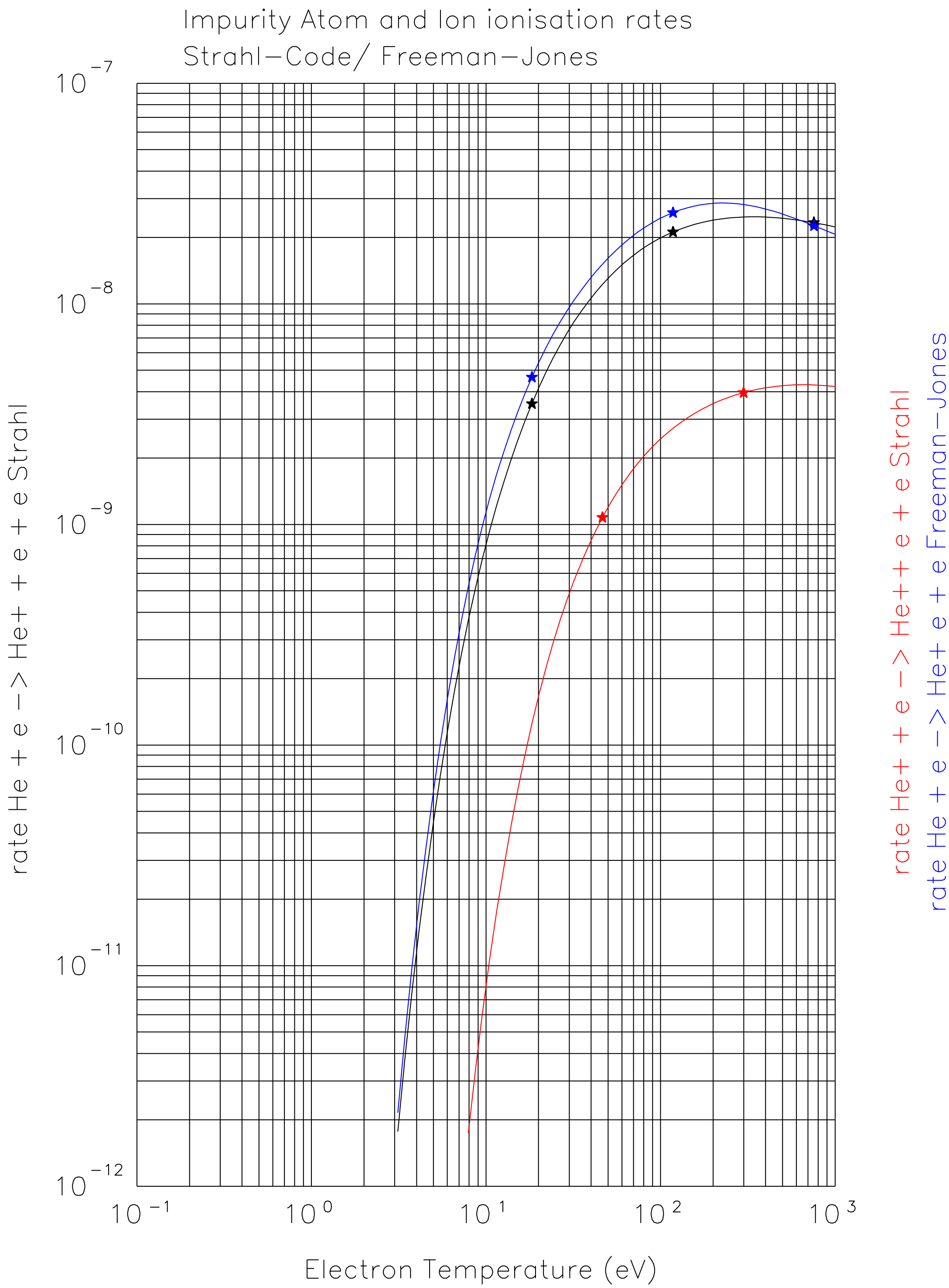
```
Max. rel. Error:   0.4138 %
Mean rel. Error:   0.1636 %
```

2.37 Reaction 2.2B1 $e + He^+(1s) \rightarrow e + He^{++} + e$

Ionization Rate for single charged Helium Ions, STRAHL code

```
b0 -7.559669902889D+01    b1  5.464529470916D+01    b2 -2.644507121426D+01
b3  8.159073714053D+00    b4 -1.694080618046D+00    b5  2.348225872648D-01
b6 -2.073277438991D-02    b7  1.049056816265D-03    b8 -2.305310731172D-05
```

```
Max. rel. Error:   0.9472 %
Mean rel. Error:   0.5457 %
```



Impurity Atom and Ion ionisation rates
Strahl–Code/ Freeman–Jones
rate He + e –> He+ + e + e Strahl
rate He+ + e –> He++ e + e Strahl
rate He + e –> He+ e + e Freeman–Jones
Electron Temperature (eV)

Ionization Rates for neutral Beryllium Atoms

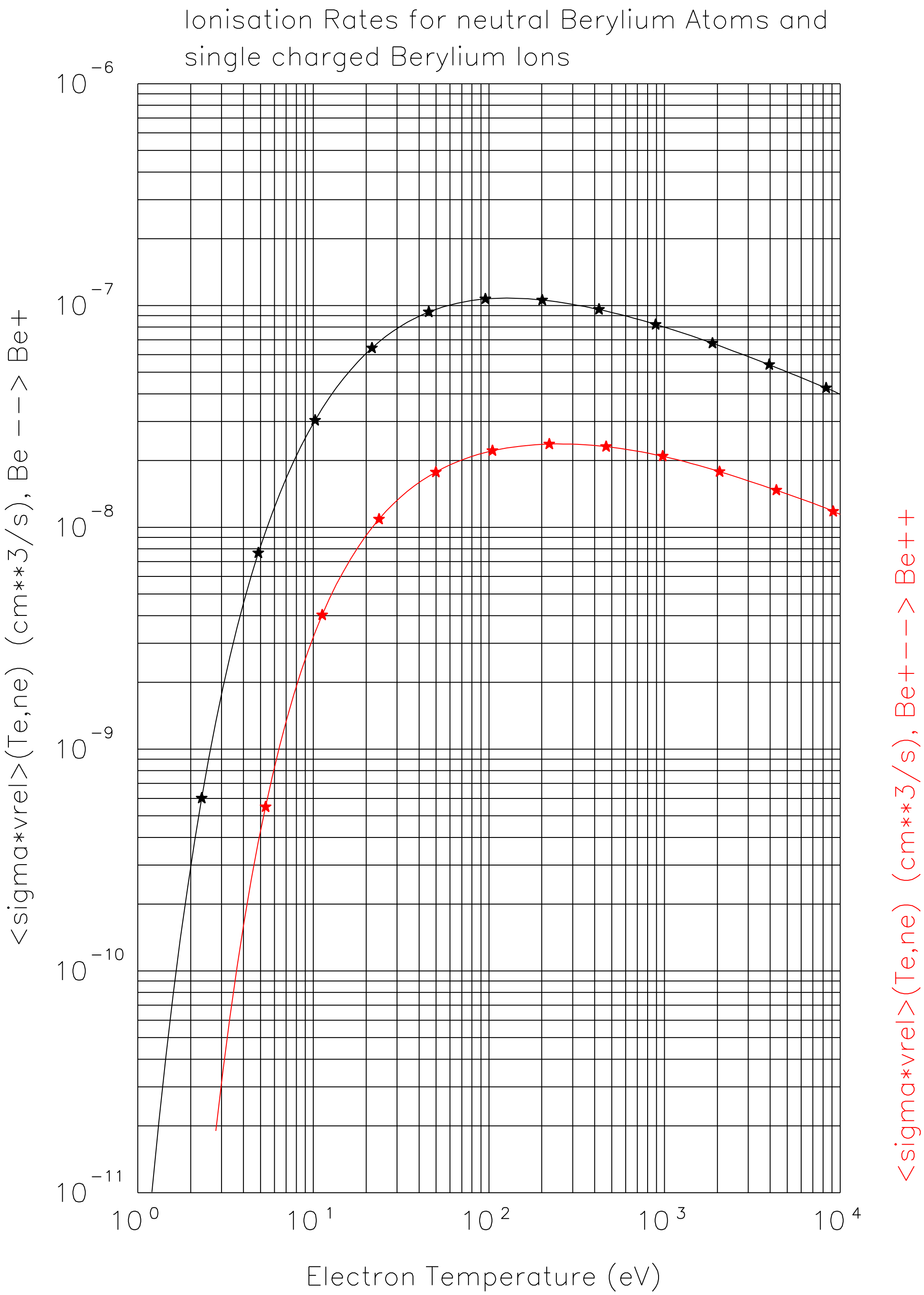
2.38 Reaction 2.4B0 $e + Be \rightarrow e + Be^{+} + e$

```
b0 -2.701191641765D+01    b1  9.882275334399D+00    b2 -4.581384174259D+00
b3  1.463446005529D+00    b4 -3.282155444497D-01    b5  4.895458945839D-02
b6 -4.558103660501D-03    b7  2.382205094374D-04    b8 -5.319547065990D-06

Max. rel. Error:    .1411 %
Mean rel. Error:    .0582 %
```

Ionization Rates for single charged Beryllium Ions

2.39 Reaction 2.4B1 $e + Be^{+} \rightarrow e + Be^{++} + e$

```
b0 -3.677989427190D+01    b1  1.855869089956D+01    b2 -8.843053626300D+00
b3  2.708167857179D+00    b4 -5.651333671979D-01    b5  7.947570447499D-02
b6 -7.160867067297D-03    b7  3.705422825861D-04    b8 -8.322700230771D-06

Max. rel. Error:    .3962 %
Mean rel. Error:    .2225 %
```



Ionisation Rates for neutral Berylium Atoms and single charged Berylium Ions
10^-6
10^-7
10^-8
10^-9
10^-10
10^-11
10^0
10^1
10^2
10^3
10^4
Electron Temperature (eV)
<sigma*vrel>(Te,ne) (cm**3/s), Be --> Be+
<sigma*vrel>(Te,ne) (cm**3/s), Be+--> Be++

2.40 Reaction 2.5B0 $e + B \rightarrow e + B^{+} + e$

Ionization Rates for neutral Boron Atoms

b0	-2.652112807432D+01	b1	8.818502481012D+00	b2	-3.832208851779D+00
b3	1.206778920817D+00	b4	-2.766330884306D-01	b5	4.255759023412D-02
b6	-4.078840883672D-03	b7	2.185455019432D-04	b8	-4.985646766233D-06

2.41 Reaction 2.5B1 $e + B^{+} \rightarrow e + B^{++} + e$

Ionization Rates for single charged Boron Ions

b0	-4.420568125967D+01	b1	2.558429301929D+01	b2	-1.226766585830D+01
b3	3.790617724445D+00	b4	-7.898969090461D-01	b5	1.094004163863D-01
b6	-9.602179535698D-03	b7	4.812751663763D-04	b8	-1.045722639512D-05

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2.42 Reaction 2.6B0 $e + C \to e + C^+ + e$

Ionization rate for neutral Carbon Atoms, STRAHL code
$\langle sigma * vrel \rangle (Te)(cm * *3/s), C - - > C^+$

```
b0 -2.955122753053D+01  b1  1.180604026361D+01  b2 -5.438799573749D+00
b3  1.750648117869D+00  b4 -3.946542606866D-01  b5  5.887749368990D-02
b6 -5.469027807326D-03  b7  2.850693136991D-04  b8 -6.354758903485D-06

Max. rel. Error:    .3712 %
Mean rel. Error:    .1458 %
```

2.43 Reaction 2.6B1 $e + C^+ \to e + C^{++} + e$

Ionization rate for singly charged Carbon Ions (STRAHL code)

```
b0 -4.406752926798D+01  b1  2.464907506907D+01  b2 -1.157330396759D+01
b3  3.619195611010D+00  b4 -7.853469883899D-01  b5  1.149856668829D-01
b6 -1.070995852675D-02  b7  5.681198605329D-04  b8 -1.299242985961D-05

Max. rel. Error:    .9478 %
Mean rel. Error:    .4820 %
```

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2.44 Reaction 2.7B0 $e + N \rightarrow e + N^+ + e$

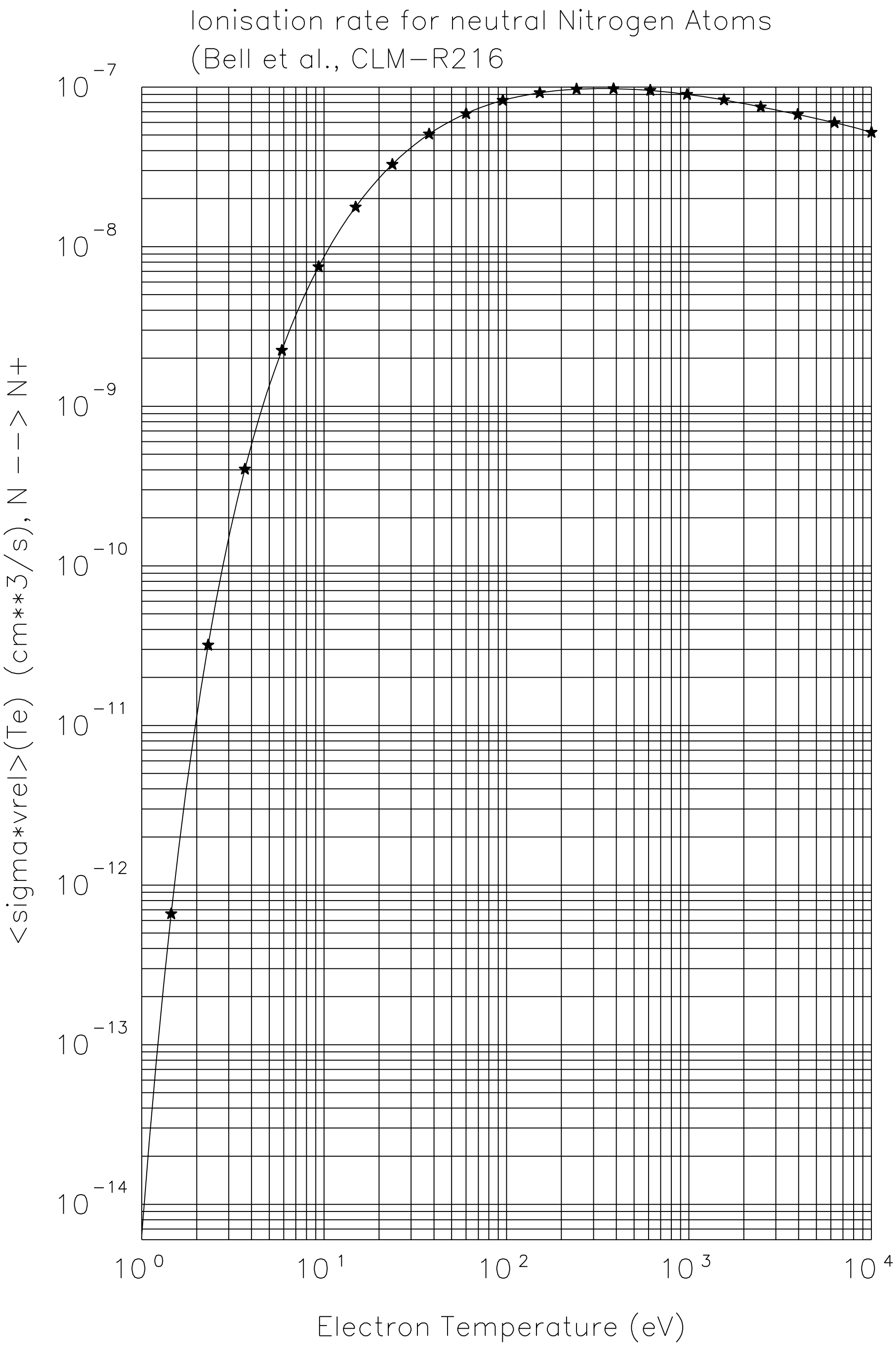
Ionization rate coefficient for neutral Nitrogen Atoms, STRAHL code (Bell et al., CLM-R216) [8]
$\langle sigma * vrel\rangle(Te)(cm * *3/s), N - - > N^+$

```
b0 -3.267927139870D+01  b1  1.487745850177D+01  b2 -7.393982038208D+00
b3  2.552657836634D+00  b4 -6.031414732283D-01  b5  9.299608313666D-02
b6 -8.862541230616D-03  b7  4.718778196780D-04  b8 -1.071093371002D-05
```

2.45 Reaction 2.7 $e + N \rightarrow e + N^+ + e$

cross-section data from Brook, [15] for $e+N- > N^+ +2e$, same cross-section data source was used for the Bell rate coefficient in the STRAHL code data. (Checked, Oct.2013: original Bell report and Brook cross-sections are identical)
$\Delta E_{el} = 14.5$

```
b0   -3.218851E+01   b1   1.430745E+01  b2  -6.932106E+00
b3    2.271990E+00   b4  -4.951687E-01  b5   6.792600E-02
b6   -5.419575E-03   b7   2.123706E-04  b8  -2.405294E-06
```



Ionisation rate for neutral Nitrogen Atoms
(Bell et al., CLM−R216
<sigma*vrel>(Te) (cm**3/s), N −−> N+
Electron Temperature (eV)

2.46 Reaction 2.8B0 $e + O \rightarrow e + O^+ + e$

Ionization rate for neutral Oxygen Atoms
$\langle sigma * vrel \rangle (Te)(cm * *3/s), O - - > O^+$

```
b0 -3.193820900000D+01  b1  3.246161040000D+01  b2 -3.545538700000D+01
b3  2.559678950000D+01  b4 -1.215735520000D+01  b5  3.673666600000D+00
b6 -6.763574930000D-01  b7  6.905007430000D-02  b8 -2.994628570000D-03
```

2.47 Reaction 2.8B1 $e + O^+ \rightarrow e + O^{++} + e$

Ionization rate for singly charged Oxygen Ions

```
b0 -5.489947730000D+01 b1  8.1057031200000D+01 b2 -8.7719154800000D+01
b3  6.043339780000D+01 b4 -2.7530283600000D+01 b5  8.1635002700000D+00
b6 -1.505562720000D+00 b7  1.5615477900000D-01 b8 -6.9385679400000D-03
```

2.48 Reaction 2.10B0 $e + Ne \rightarrow e + Ne^+ + e$

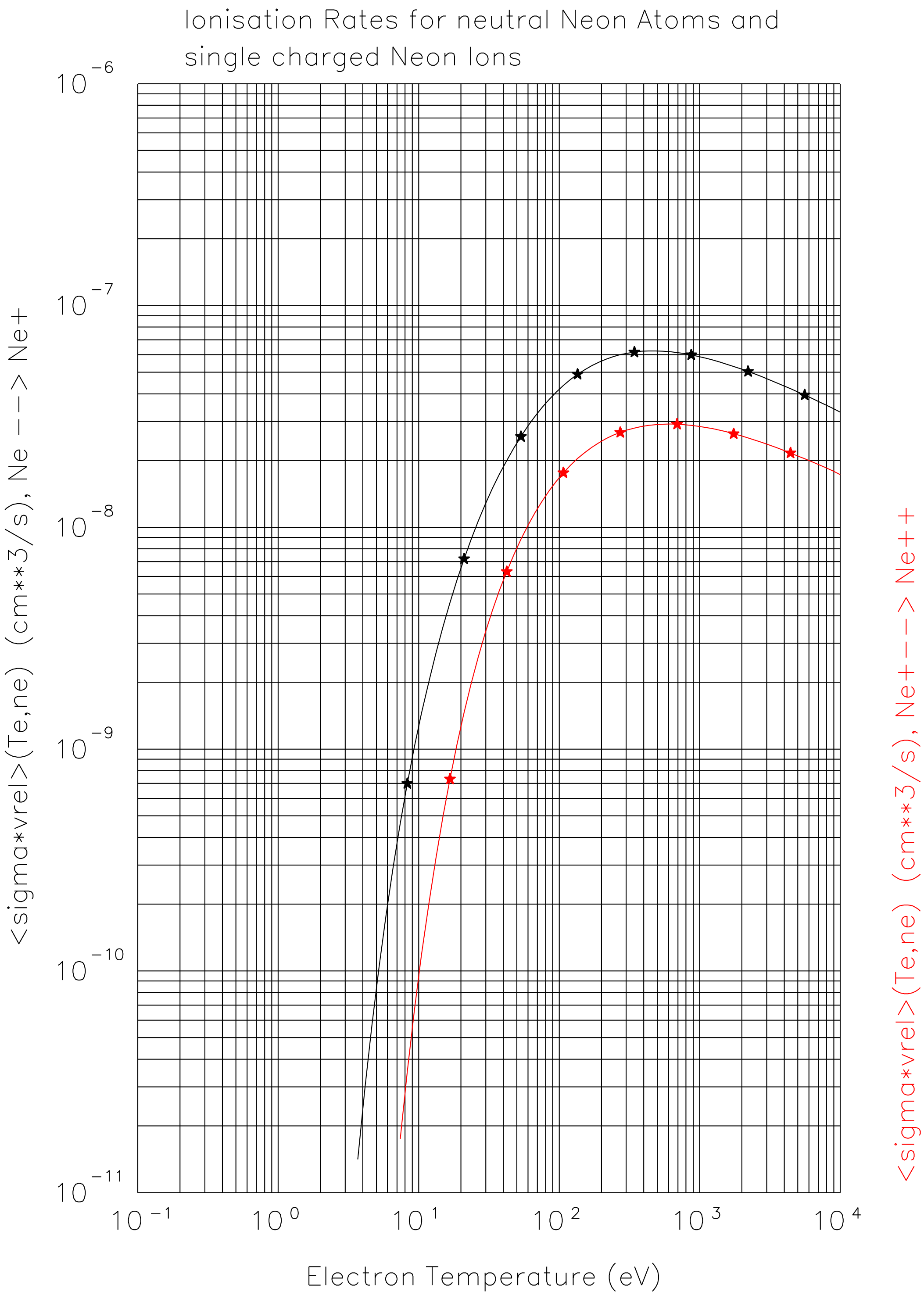
Ionization Rate for neutral Neon Atoms

```
b0 -4.164979646286D+01  b1  2.217184105146D+01  b2 -1.042613793789D+01
b3  3.175650981066D+00  b4 -6.293446783142D-01  b5  7.941711930007D-02
b6 -6.140370720421D-03  b7  2.651559926489D-04  b8 -4.900429196295D-06

Max. rel. Error:    .0200 %
Mean rel. Error:    .0103 %
```

2.49 Reaction 2.10B1 $e + Ne^+ \rightarrow e + Ne^{++} + e$

Ionization Rate for single charged Neon Ions

```
b0 -6.100121276752D+01  b1  4.015006828838D+01  b2 -1.879440280294D+01
b3  5.630907545903D+00  b4 -1.119573454119D+00  b5  1.458082247661D-01
b6 -1.192136518944D-02  b7  5.544020624369D-04  b8 -1.117943418062D-05

Max. rel. Error:    .1916 %
Mean rel. Error:    .0814 %
```



Ionisation Rates for neutral Neon Atoms and
single charged Neon Ions
<sigma*vrel>(Te,ne) (cm**3/s), Ne --> Ne+
<sigma*vrel>(Te,ne) (cm**3/s), Ne+--> Ne++
Electron Temperature (eV)
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}

2.50 Reaction 2.18B0 $e + Ar \rightarrow e + Ar^{+} + e$

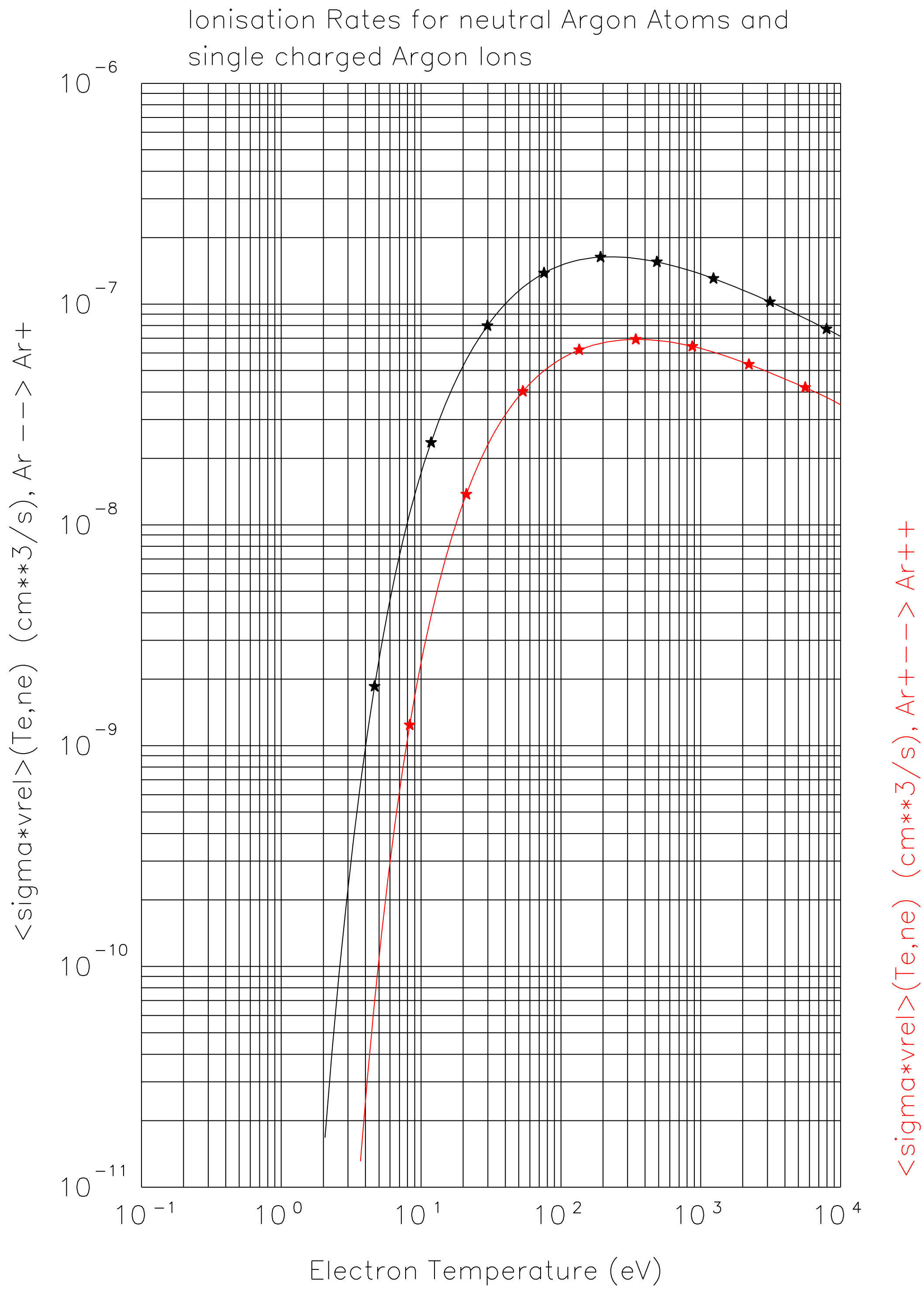
Ionization Rate for neutral Argon Atoms

```
b0 -3.330347417325D+01  b1  1.627861918393D+01  b2 -7.765170847889D+00
b3  2.446384994382D+00  b4 -5.186581624286D-01  b5  7.184868450814D-02
b6 -6.200405891186D-03  b7  3.018464732517D-04  b8 -6.325074170944D-06

Max. rel. Error:    .1093 %
Mean rel. Error:    .0503 %
```

2.51 Reaction 2.18B1 $e + Ar^{+} \rightarrow e + Ar^{++} + e$

Ionization Rate for single charged Argon Ions

```
b0 -4.577132769437D+01  b1  2.796761945871D+01  b2 -1.347073209993D+01
b3  4.188634468306D+00  b4 -8.778893409977D-01  b5  1.220883796618D-01
b6 -1.073976899816D-02  b7  5.386460788345D-04  b8 -1.169793339733D-05

Max. rel. Error:    .3659 %
Mean rel. Error:    .2214 %
```


Ionisation Rates for neutral Argon Atoms and
single charged Argon Ions
<sigma*vrel>(Te,ne) (cm**3/s), Ar --> Ar+
<sigma*vrel>(Te,ne) (cm**3/s), Ar+ --> Ar++
Electron Temperature (eV)

2.52 Reaction 2.26B0 $e + Fe \rightarrow e + Fe^{+} + e$

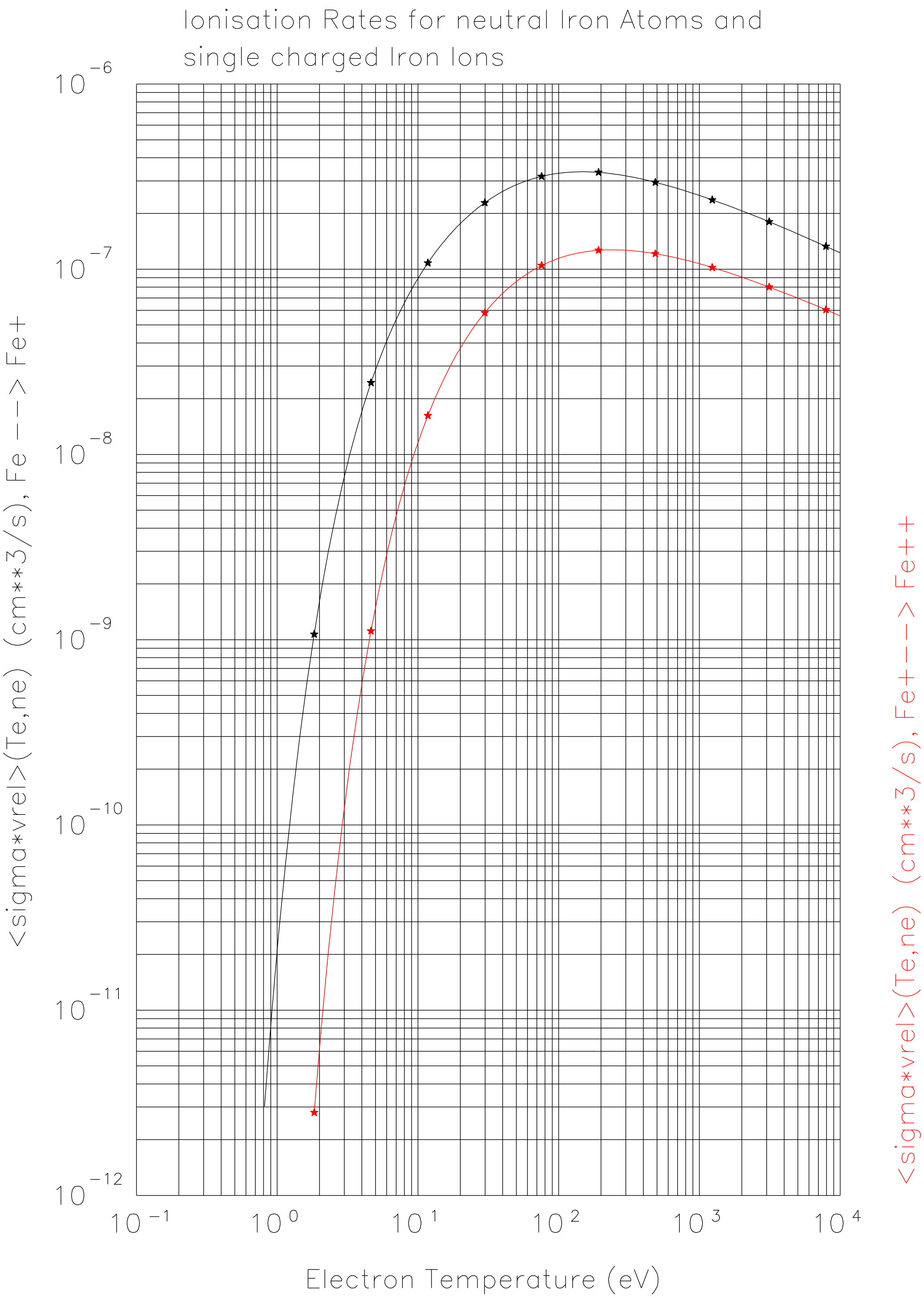
Ionization Rate for neutral Iron Atoms

```
b0 -2.457959373433D+01  b1  8.433391049230D+00  b2 -3.846892092374D+00
b3  1.185976759143D+00  b4 -2.459329335625D-01  b5  3.266162856106D-02
b6 -2.642594731066D-03  b7  1.182305727446D-04  b8 -2.237621366618D-06

Max. rel. Error:    .0907 %
Mean rel. Error:    .0450 %
```

2.53 Reaction 2.26B1 $e + Fe^{+} \rightarrow e + Fe^{++} + e$

Ionization Rate for single charged Iron Ions

```
b0 -3.437574762141D+01  b1  1.685181764677D+01  b2 -7.911217139035D+00
b3  2.442620345655D+00  b4 -5.072788444089D-01  b5  6.899131935535D-02
b6 -5.866292819569D-03  b7  2.825378750379D-04  b8 -5.881378739141D-06

Max. rel. Error:    .2106 %
Mean rel. Error:    .1105 %
```



Ionisation Rates for neutral Iron Atoms and
single charged Iron Ions
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}
Electron Temperature (eV)
<sigma*vrel>(Te,ne) (cm**3/s), Fe --> Fe+
<sigma*vrel>(Te,ne) (cm**3/s), Fe+ --> Fe++

2.54 Reaction 0.100 $e + e_b \rightarrow e + e_b$ Trubnikov potential

bulk-electrons on test-electron, Fokker-Planck elastic
Data for Trubnikov Potentials for Fokker-Planck collision operator, bulk-electrons on test-electrons.
currently: none

```
fit-flag 03
b0 -1.000000000000D+30  b1  0.000000000000D+00  b2  0.000000000000D+00
b3  0.000000000000D+00  b4  0.000000000000D+00  b5  0.000000000000D+00
b6  0.000000000000D+00  b7  0.000000000000D+00  b8  0.000000000000D+00
```

2.55 Reaction 0.101 $i + e_b \rightarrow i + e_b$ Trubnikov potential

bulk-electrons + test-ions, Fokker-Planck elastic
Data for Trubnikov Potentials for Fokker-Planck collision operator, bulk-electrons on test-ions.
currently: none

```
fit-flag 03
b0 -1.000000000000D+30  b1  0.000000000000D+00  b2  0.000000000000D+00
b3  0.000000000000D+00  b4  0.000000000000D+00  b5  0.000000000000D+00
b6  0.000000000000D+00  b7  0.000000000000D+00  b8  0.000000000000D+00
```

2.56 Reaction 0.101e $i + e_b \rightarrow i + e_b$ Trubnikov potential

bulk-electrons + test-ions, Fokker-Planck elastic
Data for Trubnikov Potentials for Fokker-Planck collision operator, bulk-electrons on test-ions.
currently: none

```
fit-flag 03
b0 -1.000000000000D+30  b1  0.000000000000D+00  b2  0.000000000000D+00
b3  0.000000000000D+00  b4  0.000000000000D+00  b5  0.000000000000D+00
b6  0.000000000000D+00  b7  0.000000000000D+00  b8  0.000000000000D+00
```

2.57 Reaction 0.102 $e + i_b \rightarrow e + i_b$ Trubnikov potential

bulk-ions on test-electron, Fokker-Planck elastic
Data for Trubnikov Potentials for Fokker-Planck collision operator, bulk-ions on test-electrons.
currently: none

```
fit-flag 03
b0 -1.000000000000D+30  b1  0.000000000000D+00  b2  0.000000000000D+00
b3  0.000000000000D+00  b4  0.000000000000D+00  b5  0.000000000000D+00
b6  0.000000000000D+00  b7  0.000000000000D+00  b8  0.000000000000D+00
```

2.58 Reaction 0.103 $i + i_b \rightarrow i + i_b$ Trubnikov potential

bulk-ions + test-ions, Fokker-Planck elastic
Data for Trubnikov Potentials for Fokker-Planck collision operator, bulk-ions on test-ions.
currently: none

```
fit-flag 03
b0 -1.000000000000D+30  b1  0.000000000000D+00  b2  0.000000000000D+00
b3  0.000000000000D+00  b4  0.000000000000D+00  b5  0.000000000000D+00
b6  0.000000000000D+00  b7  0.000000000000D+00  b8  0.000000000000D+00
```

2.59 Reaction 0.103e $i + i_b \rightarrow i + i_b$ Trubnikov potential

bulk-ions + test-ions, Fokker-Planck elastic
Data for Trubnikov Potentials for Fokker-Planck collision operator, bulk-ions on test-ions.
currently: none

```
fit-flag 03
b0 -1.000000000000D+30  b1  0.000000000000D+00  b2  0.000000000000D+00
b3  0.000000000000D+00  b4  0.000000000000D+00  b5  0.000000000000D+00
b6  0.000000000000D+00  b7  0.000000000000D+00  b8  0.000000000000D+00
```

2.60 Reaction 0.104 $i + i_b \rightarrow i + i_b$ Trubnikov potential

dummy reaction used to invoke FPKCOL

```
fit-flag 04
b0 -1.000000000000D+30  b1  0.000000000000D+00  b2  0.000000000000D+00
b3  0.000000000000D+00  b4  0.000000000000D+00  b5  0.000000000000D+00
b6  0.000000000000D+00  b7  0.000000000000D+00  b8  0.000000000000D+00
```

2.61 Reaction 3.1 $W + e \rightarrow W^+ + 2e$

tungsten coef. rate

```
b0 -23.79630000000D+00  b1  8.522300000000D+00  b2 -4.027100000000D+00
b3  1.339000000000D+00  b4 -0.339800000000D+00  b5  0.063800000000D+00
b6 -0.008200000000D+00  b7  0.000600000000D+00  b8  0.000000000000D+00
```

3 H.3 : Fits for $\langle \sigma v \rangle (E,T)$

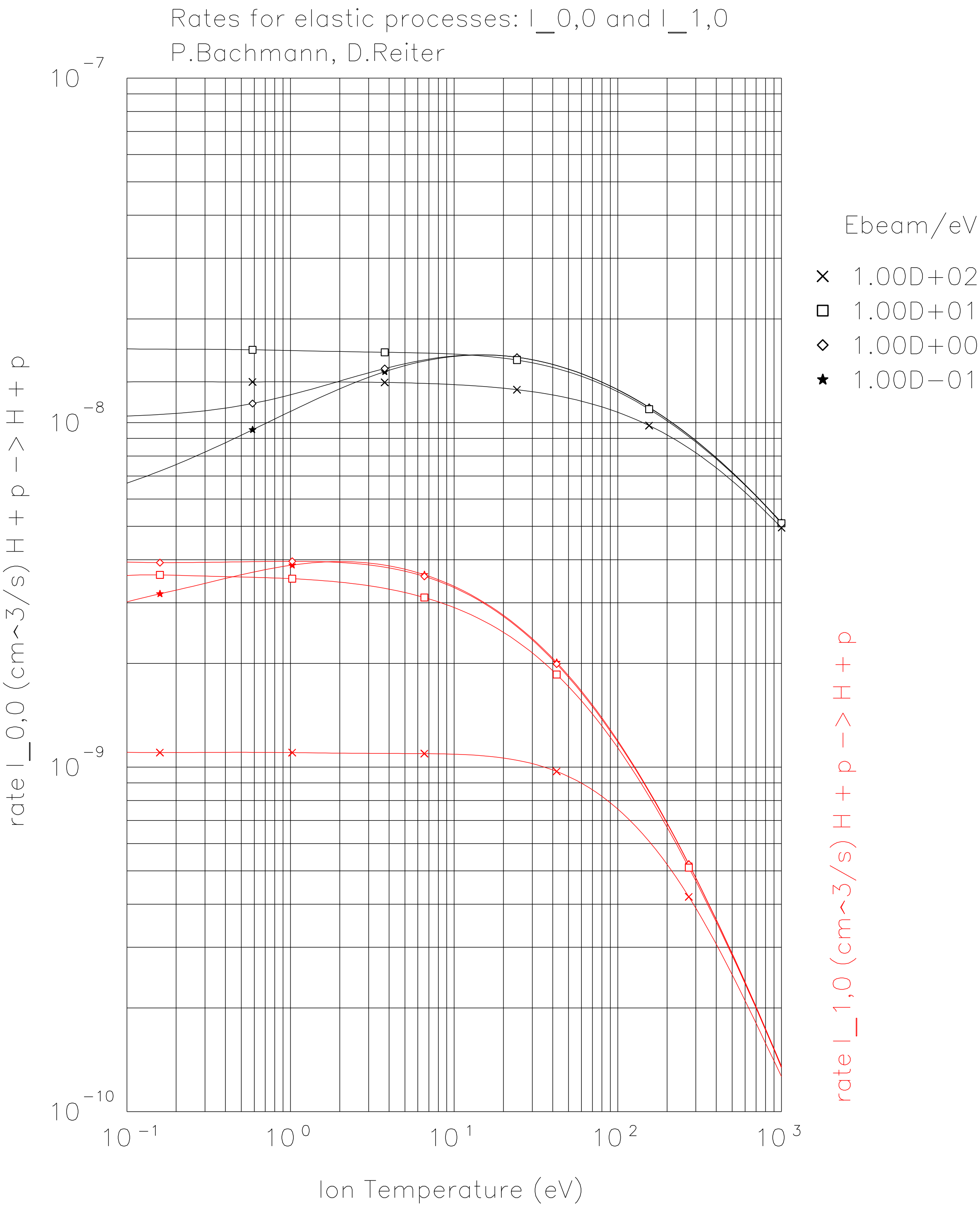
3.1 Reaction 0.1T $p + H(1s) \rightarrow p + H(1s)$, elastic, $I_{0,0}$

T-Index \ E-Index:	0	1	2
0	-1.823472394862D+01	1.043929094352D-01	3.385021298310D-02
1	1.218869427323D-01	-8.071776515805D-02	-6.163024588310D-03
2	2.183144859635D-02	6.947238019788D-03	-1.029753867911D-02
3	-8.144414285471D-03	7.950619428888D-03	1.480212482573D-03
4	-2.414158185489D-03	-1.610515523206D-03	1.147576632073D-03
5	4.042335482230D-04	-3.333068266837D-04	-2.109287055048D-04
6	6.684610364551D-05	1.395481729149D-04	-3.872093410396D-05
7	-1.814826813629D-05	-1.589238118662D-05	1.137141330233D-05
8	1.049993252610D-06	6.124957529757D-07	-6.966443729323D-07

T-Index \ E-Index:	3	4	5
0	-2.048059867515D-03	-4.577324303045D-03	5.174052650323D-05
1	8.404776509987D-03	5.448141329729D-04	-6.017991251450D-04
2	-1.660137737426D-03	1.687354957150D-03	1.123876140912D-05
3	-1.907814505083D-03	2.558232467687D-05	1.587671168547D-04
4	5.801892116713D-04	-2.945348864215D-04	-2.556467005779D-05
5	8.053144974289D-05	2.875034864587D-05	-9.746625582656D-06
6	-5.043290334814D-05	1.493675458929D-05	3.216371174204D-06
7	6.798870422148D-06	-3.269371275613D-06	-3.202325463122D-07
8	-3.006730549005D-07	1.854263211106D-07	1.033863743276D-08

T-Index \ E-Index:	6	7	8
0	2.673201510283D-04	-4.451268371503D-05	2.199498285047D-06
1	3.536937592691D-05	9.054714466075D-06	-8.596768109209D-07
2	-1.224423097417D-04	2.126181472934D-05	-1.100195177512D-06
3	-2.858120151811D-05	1.112919746718D-06	4.374805864224D-08
4	2.747846551451D-05	-4.380086290415D-06	2.202510674285D-07
5	-6.360748557750D-07	3.783870577323D-07	-2.732689440408D-08
6	-1.738436960565D-06	2.363371059212D-07	-1.072861195261D-08
7	3.156490387804D-07	-5.006550452098D-08	2.526895478569D-09
8	-1.655735806555D-08	2.801053970232D-09	-1.467609659450D-10

Max. rel. Error: 0.5284 %
Mean rel. Error: 0.0853 %


Rates for elastic processes: I_0,0 and I_1,0
P.Bachmann, D.Reiter
rate I_0,0 (cm^3/s) H + p -> H + p
rate I_1,0 (cm^3/s) H + p -> H + p
Ion Temperature (eV)
Ebeam/eV
1.00D+02
1.00D+01
1.00D+00
1.00D−01

3.2 Reaction 0.1D $p + H(1s) \rightarrow p + H(1s)$, elastic, $I_{1,0}$

T-Index \ E-Index	0	1	2
0	-1.934778779385D+01	2.193162842747D-02	-5.787610534513D-04
1	8.400121290584D-04	-5.025758478606D-02	9.405606314808D-03
2	-1.072570686950D-02	1.258217951174D-02	-7.629292880371D-03
3	-7.329656452946D-03	1.017355462044D-02	-2.212101744320D-03
4	-1.548110966373D-03	-4.141816249813D-03	1.623377903131D-03
5	8.780715214347D-05	-5.483013774324D-04	1.371503461028D-04
6	6.351915617491D-05	4.711920962053D-04	-1.702351291260D-04
7	-1.071915622348D-05	-7.653900655552D-05	2.828377077442D-05
8	5.468789447600D-07	3.989227802803D-06	-1.457895095025D-06

T-Index \ E-Index	3	4	5
0	-9.555854995025D-03	-3.071069026823D-03	5.668304238739D-04
1	1.213464571187D-02	-3.615417883123D-03	-8.289738887452D-04
2	-3.222678509228D-03	2.181349883244D-03	1.491076548317D-04
3	-4.530314087059D-03	1.707627243838D-03	3.285319171515D-04
4	1.894095127078D-03	-8.173359548467D-04	-1.268607651578D-04
5	2.806873100807D-04	-1.147859100868D-04	-2.036026302326D-05
6	-2.386998803904D-04	9.947217842552D-05	1.676927171418D-05
7	3.936468195914D-05	-1.609704117822D-05	-2.801579443731D-06
8	-2.077060263537D-06	8.298532548793D-07	1.504259503231D-07

T-Index \ E-Index	6	7	8
0	1.023499873278D-04	-4.375997865613D-05	3.554762032992D-06
1	4.794896057762D-04	-7.011568552117D-05	3.413857855011D-06
2	-2.352460376261D-04	4.210499686989D-05	-2.314387560956D-06
3	-2.365796504952D-04	3.759133611684D-05	-1.934588738006D-06
4	1.083092577128D-04	-1.817871861306D-05	9.758474990215D-07
5	1.584828965214D-05	-2.554030249359D-06	1.314431146313D-07
6	-1.358046593907D-05	2.254690862488D-06	-1.202340694084D-07
7	2.216781743757D-06	-3.678764178035D-07	1.970465840287D-08
8	-1.154459633382D-07	1.906633038081D-08	-1.021379321893D-09

Max. rel. Error: 2.5240
Mean rel. Error: 0.4077

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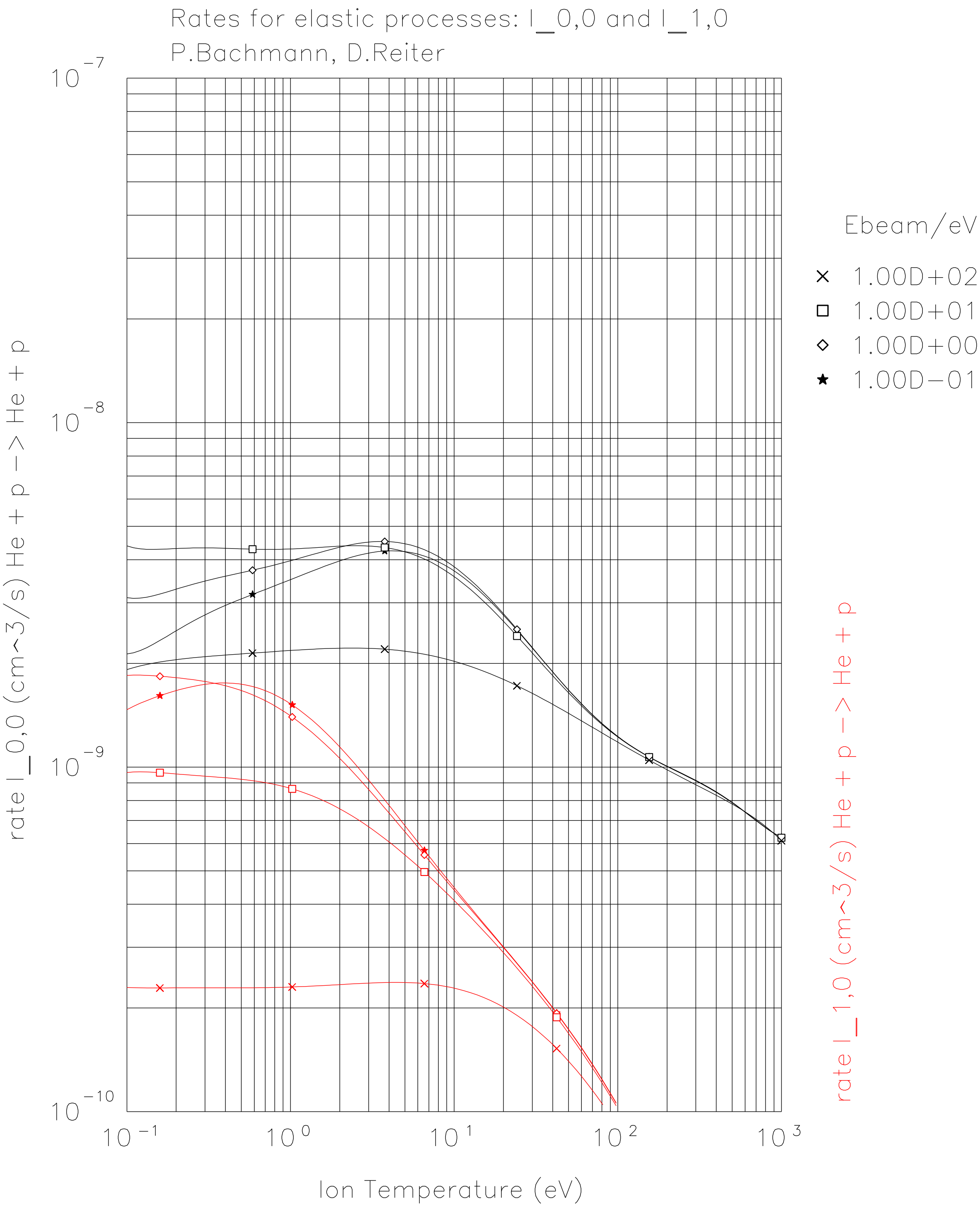
3.3 Reaction 0.2T $p + He(1s^2 1S) \rightarrow p + He(1s^2 1S)$, elastic, $I_{0,0}$

T-Index \ E-Index	0	1	2
0	-1.934393021918D+01	6.563446707236D-02	-1.132533853318D-01
1	1.301350106064D-01	-4.071555273225D-02	2.016906859537D-02
2	1.828664127573D-02	1.460635793653D-02	6.745665311224D-03
3	-1.572566883649D-02	-3.953675178715D-03	1.747850519967D-03
4	-1.651243630315D-02	-2.847284094044D-04	-1.016420463987D-03
5	1.536731193440D-03	5.204625005620D-04	-1.110404741405D-04
6	1.407936221176D-03	-1.273303544933D-04	7.874267771795D-05
7	-3.024575206489D-04	1.258652128299D-05	-9.943699290077D-06
8	1.717075379788D-05	-4.489657191575D-07	3.942435517534D-07

T-Index \ E-Index	3	4	5
0	-2.108203840264D-02	5.126981927132D-02	-3.332060792240D-03
1	4.145056754712D-03	-1.207683748654D-02	9.777916409735D-04
2	-2.343836845279D-03	-2.643817205066D-03	4.122233549648D-04
3	1.316616725294D-03	-3.328603688720D-04	-1.025202074732D-04
4	2.115185323595D-04	3.305924890461D-04	-4.422649148500D-05
5	-2.096646478748D-04	4.907753719257D-05	1.750257851569D-05
6	3.694523090258D-05	-3.137559296212D-05	-2.054573401396D-06
7	-2.076330117601D-06	3.934064976552D-06	7.117080375326D-08
8	5.837947019108D-09	-1.543181228289D-07	1.142825149606D-09

T-Index \ E-Index	6	7	8
0	-5.396242466413D-03	1.236276138019D-03	-7.628885182442D-05
1	1.273531852240D-03	-3.057392495993D-04	1.949879233267D-05
2	2.238463116916D-04	-5.822708605029D-05	3.713522343609D-06
3	3.644852940119D-05	-2.948705115200D-06	2.772902778994D-08
4	-2.296832307757D-05	5.703124977270D-06	-3.560603032570D-07
5	-7.404629231556D-06	8.730873892378D-07	-3.238131969596D-08
6	3.004305767140D-06	-4.823864866020D-07	2.370653749977D-08
7	-3.116821151336D-07	4.985170981511D-08	-2.366645009836D-09
8	9.670471248063D-09	-1.366953072466D-09	5.308492125136D-11

Max. rel. Error: 43.0372 %
Mean rel. Error: 3.6615 %



Rates for elastic processes: I_0,0 and I_1,0
P.Bachmann, D.Reiter
Ebeam/eV
1.00D+02
1.00D+01
1.00D+00
1.00D−01
rate I_0,0 (cm^3/s) He + p −> He + p
rate I_1,0 (cm^3/s) He + p −> He + p
Ion Temperature (eV)

3.4 Reaction 0.2D $p + He(1s^2 1S) \rightarrow p + He(1s^2 1S)$, elastic, $I_{1,0}$

T-Index \ E-Index	0	1	2
0	-2.038078616420D+01	-4.993496998398D-02	2.460551521383D-02
1	-3.301657139332D-01	-3.084287321372D-02	1.554461839749D-02
2	-1.250516030333D-01	3.495799299565D-02	-1.424614705786D-02
3	6.328424290736D-03	-3.821208294684D-03	-1.623627120526D-03
4	1.127524699096D-02	-2.410962290755D-03	1.757598241612D-03
5	-1.287708708939D-03	4.847023005705D-04	9.455808977270D-05
6	-6.368309748535D-04	4.413818051866D-05	-1.552922023412D-04
7	1.421859797928D-04	-1.659744792044D-05	2.551798508100D-05
8	-8.055939868827D-06	1.038460845033D-06	-1.289836231544D-06

T-Index \ E-Index	3	4	5
0	-1.517017165274D-02	-2.397648448576D-02	3.029365163804D-03
1	3.040700264374D-02	-2.593835985009D-03	-3.146176415388D-03
2	-9.657174093701D-03	7.433666067399D-03	4.191585645845D-04
3	-2.321909525809D-03	7.614727149051D-04	2.681001889717D-04
4	1.188908537635D-03	-1.115315269461D-03	-4.859218322237D-05
5	3.089582619996D-05	7.699187722499D-06	-8.863762072239D-06
6	-6.629197652130D-05	8.154996921696D-05	1.796356820001D-06
7	9.800954064911D-06	-1.473582389149D-05	6.040382986474D-08
8	-4.465334549154D-07	7.821310450330D-07	-1.548297648690D-08

T-Index \ E-Index	6	7	8
0	2.120043324652D-03	-5.206063712236D-04	3.229462400161D-05
1	6.652125688558D-04	-2.834612166641D-05	-1.127219264426D-06
2	-8.556829101842D-04	1.582340533265D-04	-8.789744795492D-06
3	-1.226460004470D-04	1.517380199975D-05	-6.070841562603D-07
4	1.341954089088D-04	-2.572769659598D-05	1.459166812937D-06
5	-8.619326544178D-07	6.166331772717D-07	-5.093661426041D-08
6	-9.360612397745D-06	1.830066731050D-06	-1.043424396036D-07
7	1.676084936402D-06	-3.453407619810D-07	2.029350887316D-08
8	-8.843599781403D-08	1.879251002731D-08	-1.123059892608D-09

Max. rel. Error: 4.5211
Mean rel. Error: 1.0118

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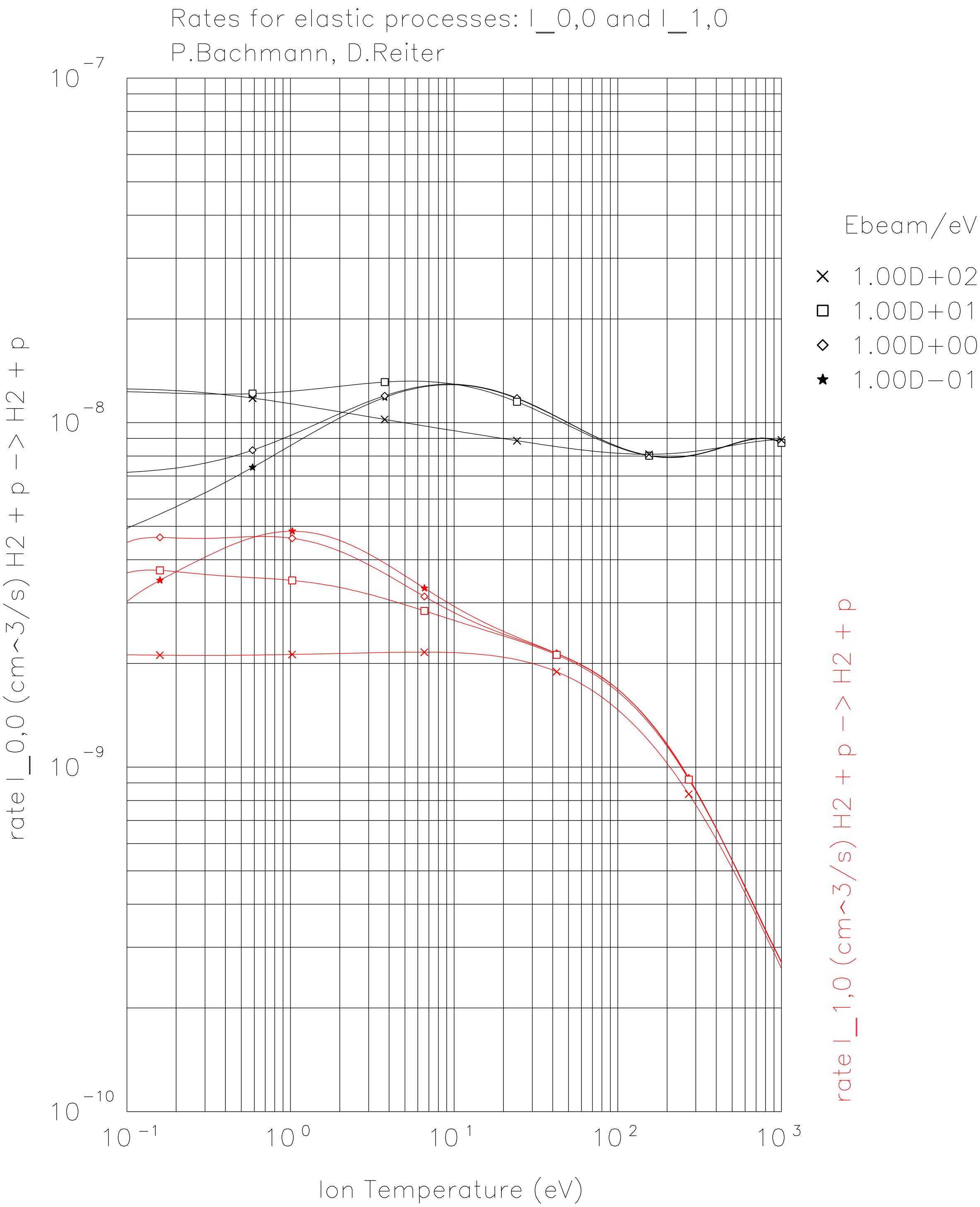
3.5 Reaction 0.3T $p + H_2 \rightarrow p + H_2$, elastic, $I_{0,0}$

T-Index \ E-Index	0	1	2
0	-1.850658754996D+01	7.211082264457D-02	2.881570478725D-02
1	2.020169165482D-01	-6.382135800278D-02	-1.628749501583D-02
2	2.598024510290D-02	1.330939790463D-02	-3.589374170071D-03
3	-1.678447543630D-02	1.969680248144D-03	2.420309504140D-03
4	-3.805013471382D-03	-8.538366688716D-04	1.219958125509D-04
5	5.832875302941D-04	1.404105142335D-05	-1.373999872185D-04
6	1.183272287480D-04	1.754003746153D-05	4.575214200943D-06
7	-9.013768167130D-06	-1.593144865711D-06	2.703806954321D-06
8	-7.237839929582D-07	1.856207389335D-08	-2.288152742189D-07

T-Index \ E-Index	3	4	5
0	2.824670772476D-03	-1.925459417470D-03	-3.785321033027D-04
1	3.609681973946D-03	2.430555593258D-03	-5.689585982541D-04
2	-2.973717962634D-03	-2.983530508154D-05	4.140245564780D-04
3	1.164630658778D-04	-3.334041165620D-04	-1.688850581453D-05
4	2.448727242148D-04	3.615934391216D-06	-2.949112340307D-05
5	-3.662763983152D-05	2.253519645066D-05	4.135548971992D-06
6	-4.332949346678D-06	-1.278290014948D-06	5.039287664347D-07
7	1.185717497396D-06	-5.094274460491D-07	-1.239318519727D-07
8	-6.264732541905D-08	4.920894679796D-08	5.881467421248D-09

T-Index \ E-Index	6	7	8
0	1.364568368798D-04	1.549425706176D-05	-6.618501118923D-06
1	-1.393818486289D-04	6.326271239195D-05	-6.695217940204D-06
2	-9.885614172244D-06	-3.254217622645D-05	4.703412615895D-06
3	1.899933955654D-05	-1.395858712371D-06	6.819987383210D-08
4	1.515103150938D-06	1.989212957512D-06	-3.032181942708D-07
5	-1.527239138118D-06	-2.816863864732D-08	1.345210099656D-08
6	3.182007050723D-08	-4.398423525407D-08	6.503053760354D-09
7	3.952472363950D-08	8.350979668461D-10	-3.926411713518D-10
8	-3.379572792986D-09	3.141592395102D-10	-2.459493010474D-11

Max. rel. Error: 3.4420 %
Mean rel. Error: 1.2045 %
Ti: 0.01---1000, EB: 0.1---100



Rates for elastic processes: I_0,0 and I_1,0
P.Bachmann, D.Reiter
rate I_0,0 (cm^3/s) H2 + p -> H2 + p
rate I_1,0 (cm^3/s) H2 + p -> H2 + p
Ion Temperature (eV)
Ebeam/eV
1.00D+02
1.00D+01
1.00D+00
1.00D-01

3.6 Reaction 0.3D $p + H_2 \rightarrow p + H_2$, elastic, $I_{1,0}$

T-Index \ E-Index	0	1	2
0	-1.919275366997D+01	-1.865238346305D-02	4.682617815803D-02
1	-5.947780482087D-02	-5.971382726967D-02	5.854568958623D-03
2	-9.004077564531D-02	3.225709371997D-02	-6.402554946956D-03
3	-1.870459871354D-02	-1.438038218134D-03	2.190778358004D-03
4	1.491376597764D-02	-1.614133948666D-03	-1.009422051586D-03
5	9.563126960467D-04	3.707880488168D-04	-7.731975035804D-05
6	-1.330077285945D-03	-5.353962725785D-05	1.351235395106D-04
7	2.020583687196D-04	6.849923024482D-06	-2.550615695507D-05
8	-9.277851726161D-06	-4.082429350941D-07	1.441579661485D-06

T-Index \ E-Index	3	4	5
0	-8.932266130300D-03	-2.903882752834D-02	3.477806471368D-03
1	1.637194804434D-02	-3.291459604645D-04	-1.492225099738D-03
2	-1.308998760658D-03	2.367849536658D-03	-2.633913429665D-04
3	-2.828299306442D-04	-4.686890203582D-07	4.818941917867D-05
4	-5.326505552258D-04	1.673303613736D-04	6.564947466483D-05
5	2.493241008729D-05	-2.434562819338D-05	-5.585591947606D-06
6	6.595946297185D-05	-2.509630806820D-05	-5.474903148493D-06
7	-1.420945572125D-05	6.290869308799D-06	1.207885423899D-06
8	8.431661832790D-07	-4.002257378192D-07	-7.135379893415D-08

T-Index \ E-Index	6	7	8
0	2.790218940150D-03	-6.908438427090D-04	4.338681573230D-05
1	1.443370523034D-04	2.409850106077D-05	-2.849926680503D-06
2	-1.712112384677D-04	4.233619961041D-05	-2.665571098691D-06
3	-1.902274102571D-05	2.446426035585D-06	-9.693955463859D-08
4	-2.847616427622D-05	3.578927723952D-06	-1.517016799547D-07
5	4.669438326556D-06	-7.601170248698D-07	3.823110747713D-08
6	3.257943960303D-06	-4.775908920414D-07	2.342435491722D-08
7	-8.361574596535D-07	1.290522448864D-07	-6.505820743915D-09
8	5.318078186713D-08	-8.385721089159D-09	4.277930018700D-10

Max. rel. Error: 5.2866
Mean rel. Error: 1.2591

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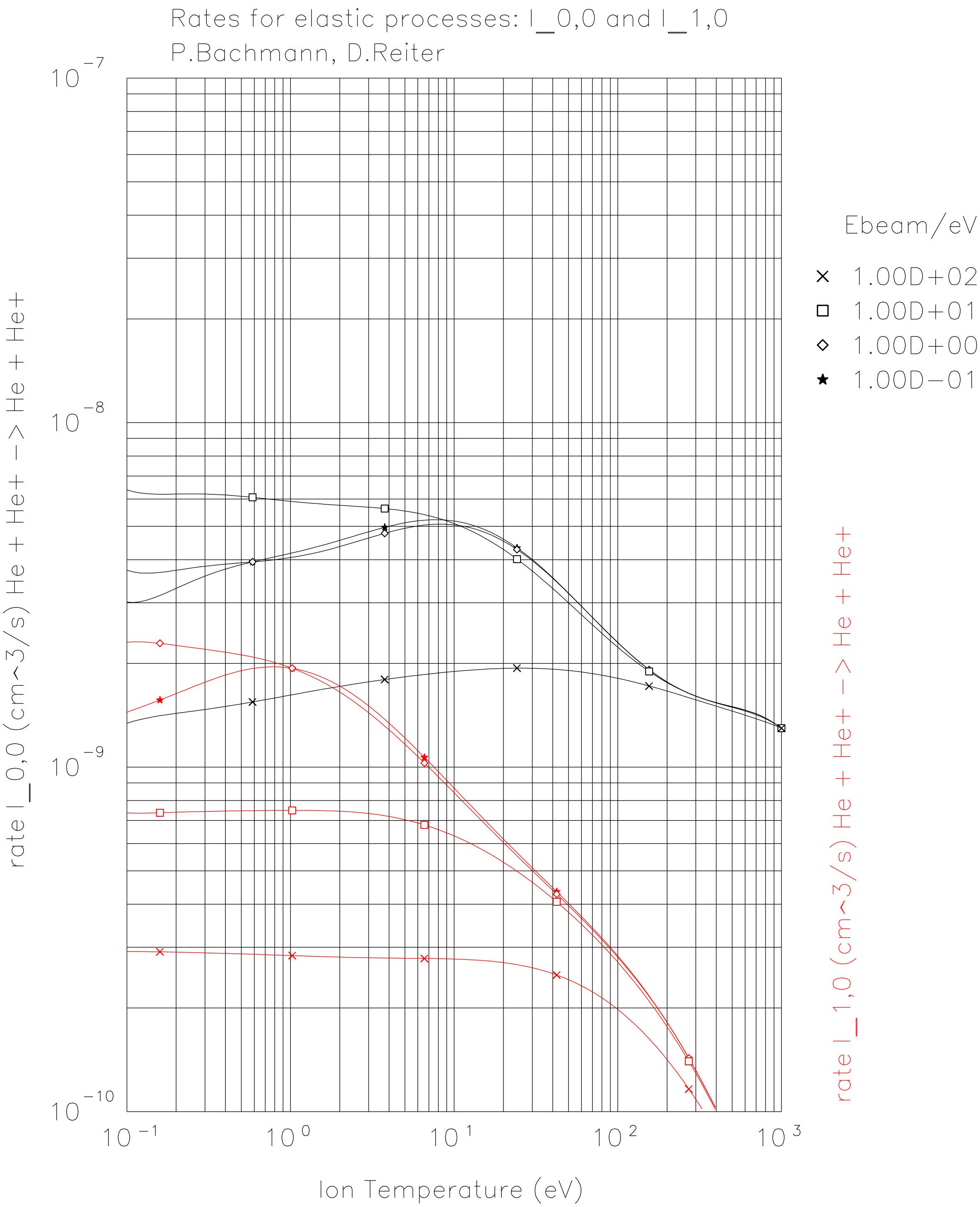
3.7 Reaction 0.4T $He^{+}(1s) + He(1s^2 1S) \rightarrow He^{+}(1s) + He(1s^2 1S)$, elastic, $I_{0,0}$

T-Index \ E-Index	0	1	2
0	-1.932287393135D+01	-6.254173654177D-02	7.946623543420D-02
1	7.420452433663D-02	-1.124812231885D-02	-2.699799758379D-02
2	4.578246117879D-02	5.807748349427D-03	-6.767337797049D-03
3	9.376519610500D-03	3.743869063612D-03	1.935668442071D-03
4	-1.232363387636D-02	-1.100675144650D-03	3.439916049619D-04
5	-1.307054294818D-03	-8.910211076373D-05	-1.851109052007D-04
6	1.118562583548D-03	5.617956521495D-05	4.722943119535D-05
7	-1.434031268233D-04	-6.365356860650D-06	-7.103013883339D-06
8	5.358989072610D-06	2.334269507353D-07	4.090109024266D-07

T-Index \ E-Index	3	4	5
0	8.838505558116D-02	-2.793201134092D-02	-9.954061526499D-03
1	-1.884565424365D-02	1.123857510199D-02	1.596841699378D-03
2	-2.495042935023D-03	1.439511185350D-04	2.861967025267D-04
3	-2.047050990056D-03	-1.947991019023D-04	2.018359028340D-04
4	7.434976678383D-04	-4.730384293613D-05	-6.250784297096D-05
5	1.117168152610D-04	3.115251093953D-05	-1.325389437604D-05
6	-5.881739628460D-05	-1.308533305864D-05	6.051250040246D-06
7	6.666955388827D-06	2.380955160803D-06	-7.094040977952D-07
8	-2.367498282831D-07	-1.427503775556D-07	2.786934787376D-08

T-Index \ E-Index	6	7	8
0	3.764403463819D-03	-3.408466490224D-04	6.412518246520D-06
1	-1.389644457539D-03	2.161107270253D-04	-1.049187773127D-05
2	-4.171591875990D-06	-1.196874977368D-05	1.094079145119D-06
3	-1.598805546650D-05	-2.311078550298D-06	2.483893468689D-07
4	1.280702702425D-05	-7.877322455546D-07	9.482501133602D-09
5	-2.131389375108D-07	3.650222503579D-07	-2.688165319879D-08
6	1.603031094261D-07	-1.683294115673D-07	1.140269704662D-08
7	-1.056486811884D-07	3.540020523528D-08	-2.124298972987D-09
8	9.141132772747D-09	-2.324505150923D-09	1.328831955405D-10

Max. rel. Error: 45.6817
Mean rel. Error: 5.1917


Rates for elastic processes: I_0,0 and I_1,0
P.Bachmann, D.Reiter
Ebeam/eV
1.00D+02
1.00D+01
1.00D+00
1.00D−01
rate I_0,0 (cm^3/s) He + He+ −> He + He+
rate I_1,0 (cm^3/s) He + He+ −> He + He+
Ion Temperature (eV)
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}

3.8 Reaction 0.4D $He^{+}(1s) + He(1s^2 1S) \rightarrow He^{+}(1s) + He(1s^2 1S)$, elastic, $I_{1,0}$

T-Index \ E-Index	0	1	2
0	-2.005856706409D+01	-2.416298567134D-02	-1.290643907647D-01
1	-1.723033466633D-01	-2.876974997211D-02	6.358697996829D-02
2	-8.480540790141D-02	2.121102722373D-02	1.060648053441D-03
3	-1.583772608067D-02	2.831738365425D-04	3.604228124024D-04
4	7.141918601934D-03	-2.712847139884D-03	-1.390046088713D-03
5	1.050415524504D-03	3.514199969505D-04	-1.430457735837D-04
6	-5.609743409859D-04	1.114910501595D-04	1.776137463792D-04
7	5.528775780351D-05	-2.849479698839D-05	-2.957402039735D-05
8	-1.298487796038D-06	1.744141312203D-06	1.511018855995D-06

T-Index \ E-Index	3	4	5
0	-7.609374902789D-02	2.051842775759D-02	6.700343984959D-03
1	1.484173774740D-02	-1.259800535085D-02	-3.314345389346D-04
2	7.437796246116D-03	-1.933320600619D-03	-8.197110013265D-04
3	5.722003993817D-04	1.577284882295D-04	-1.165904265498D-04
4	-7.836120750894D-04	5.279763008829D-04	7.329216329788D-05
5	-8.871424676206D-05	1.610771935311D-06	9.934442032629D-06
6	6.401396318081D-05	-5.184619145829D-05	-4.985193070868D-06
7	-7.539210289621D-06	9.524059409052D-06	4.297672500003D-07
8	2.529392826633D-07	-5.084304524420D-07	-5.932611004947D-09

T-Index \ E-Index	6	7	8
0	-2.466827019035D-03	2.195450363238D-04	-4.275624910534D-06
1	9.943338501590D-04	-1.676144873446D-04	8.508217370560D-06
2	3.610884437671D-04	-4.659019201525D-05	2.019277552554D-06
3	1.134360853468D-05	9.293505569914D-07	-1.249357290876D-07
4	-6.844730630933D-05	1.119496625366D-05	-5.759041144367D-07
5	-1.298801064099D-06	-4.988842872544D-08	9.924160039487D-09
6	6.074150104979D-06	-1.029965177536D-06	5.399132209393D-08
7	-1.048375199655D-06	1.905679254148D-07	-1.033208843896D-08
8	5.357991449124D-08	-1.021819231976D-08	5.659599344410D-10

Max. rel. Error: 4.6006
Mean rel. Error: 1.4030

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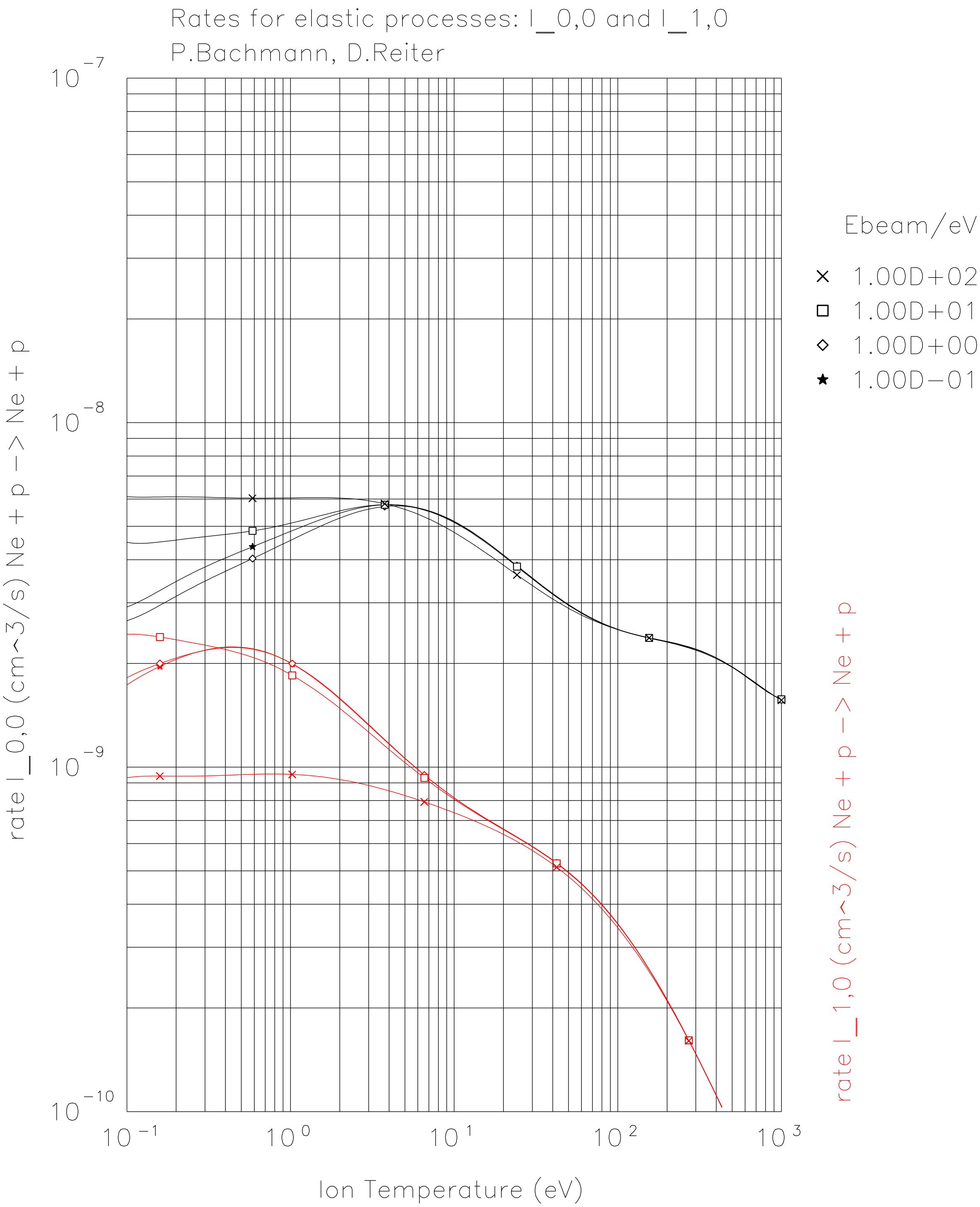
3.9 Reaction 0.5T $p + Ne \rightarrow p + Ne$, elastic, $I_{0,0}$

T-Index \ E-Index	0	1	2
0	-1.920759314942D+01	-5.203892840321D-02	6.256738740832D-02
1	2.301174650324D-01	4.598103585536D-02	-4.529061500977D-02
2	-2.844809537536D-03	-2.458775402853D-03	5.193663554519D-03
3	-2.057818892403D-02	-7.174444135106D-03	1.007438682679D-03
4	-1.247725873726D-02	1.478687710859D-03	3.953183188726D-04
5	2.157436023407D-03	3.355091844482D-04	-8.112880498847D-05
6	9.992078785249D-04	-1.437802559650D-04	-5.015798225079D-05
7	-2.519290342081D-04	1.679868230149D-05	1.313639535025D-05
8	1.528819949488D-05	-6.582462835809D-07	-8.420538426381D-07

T-Index \ E-Index	3	4	5
0	3.570384214557D-02	-2.599370622275D-02	-1.307788828471D-03
1	-3.361904573721D-02	1.857018937894D-02	1.960502872244D-03
2	4.605054021354D-03	-1.471661007966D-03	-3.978819729213D-04
3	3.298168445875D-03	-9.406952560414D-04	-2.831787775281D-04
4	-7.251750861538D-04	-7.779131291367D-05	8.979474917231D-05
5	-1.832873740518D-04	7.101665930610D-05	1.518922775711D-05
6	7.431587797692D-05	4.751928717840D-06	-9.288005671637D-06
7	-8.355288839969D-06	-3.287000259239D-06	1.308988935499D-06
8	3.123866169547D-07	2.487732705021D-07	-6.106353269941D-08

T-Index \ E-Index	6	7	8
0	3.079721700396D-03	-5.958055457558D-04	3.413526344209D-05
1	-2.294912090837D-03	4.037290717482D-04	-2.198722138819D-05
2	1.769972448752D-04	-2.083969105626D-05	8.333041368586D-07
3	1.507107647921D-04	-2.125246166296D-05	9.847199659415D-07
4	-7.898054427499D-07	-3.134863355412D-06	2.737318021218D-07
5	-1.088302678431D-05	1.723721432651D-06	-8.713592846203D-08
6	7.411456169336D-07	1.836531987751D-07	-2.021065290807D-08
7	2.067606837134D-07	-9.097454398809D-08	6.730401523292D-09
8	-2.086750507882D-08	6.592902645608D-09	-4.544772018004D-10



Rates for elastic processes: I_0,0 and I_1,0
P.Bachmann, D.Reiter
Ebeam/eV
1.00D+02
1.00D+01
1.00D+00
1.00D−01
rate I_0,0 (cm^3/s) Ne + p −> Ne + p
rate I_1,0 (cm^3/s) Ne + p −> Ne + p
Ion Temperature (eV)

3.10 Reaction 0.5D $p + Ne \rightarrow p + Ne$, elastic, $I_{1,0}$

T-Index \ E-Index:	0	1	2
0	-2.002574827025D+01	-9.486205506769D-03	-1.916286734818D-02
1	-2.537906409600D-01	1.220589506641D-02	-4.405411696435D-03
2	-1.492855002501D-01	2.319954090051D-04	1.263929021478D-02
3	2.277262949762D-02	-4.830188456031D-03	-2.750452234840D-03
4	1.454565132881D-02	1.634829233387D-03	-7.315594083272D-04
5	-2.459106378105D-03	3.600089747182D-05	2.671541616531D-04
6	-7.404449444601D-04	-9.641735194704D-05	-7.552824895881D-06
7	1.859174611798D-04	1.571912622960D-05	-4.091377459615D-06
8	-1.080632769187D-05	-7.917702265677D-07	3.295235267228D-07

T-Index \ E-Index:	3	4	5
0	3.064150950343D-04	5.770565072378D-03	-1.288012249760D-03
1	-9.350961151995D-03	2.046783521289D-03	1.263699863822D-03
2	5.587555734861D-03	-3.892475694794D-03	-2.567575758703D-04
3	3.929098223217D-04	4.312366386482D-04	-1.038820514086D-04
4	-7.648388450741D-04	3.694752429370D-04	4.454311674256D-05
5	9.309623048752D-05	-7.252696686113D-05	-1.552983373470D-06
6	2.291515177534D-05	-9.054806193408D-06	-1.496738021147D-06
7	-5.643860949550D-06	3.070565006104D-06	2.494317965158D-07
8	3.263260078468D-07	-1.924412405804D-07	-1.206274348614D-08

T-Index \ E-Index:	6	7	8
0	-6.056764332700D-04	1.841533150445D-04	-1.268081106690D-05
1	-3.065943896812D-04	6.450450819580D-06	1.427066945930D-06
2	4.415539725039D-04	-8.037605353389D-05	4.426529308029D-06
3	-2.150818421027D-05	8.166836349571D-06	-6.038520579569D-07
4	-5.066174985198D-05	9.122002151237D-06	-5.057086230537D-07
5	7.660825723624D-06	-1.561716894668D-06	9.411992094619D-08
6	1.670809775312D-06	-3.122277677479D-07	1.755858285560D-08
7	-4.493868279400D-07	8.907923424961D-08	-5.237533360927D-09
8	2.688180498679D-08	-5.445051092452D-09	3.250534258748D-10

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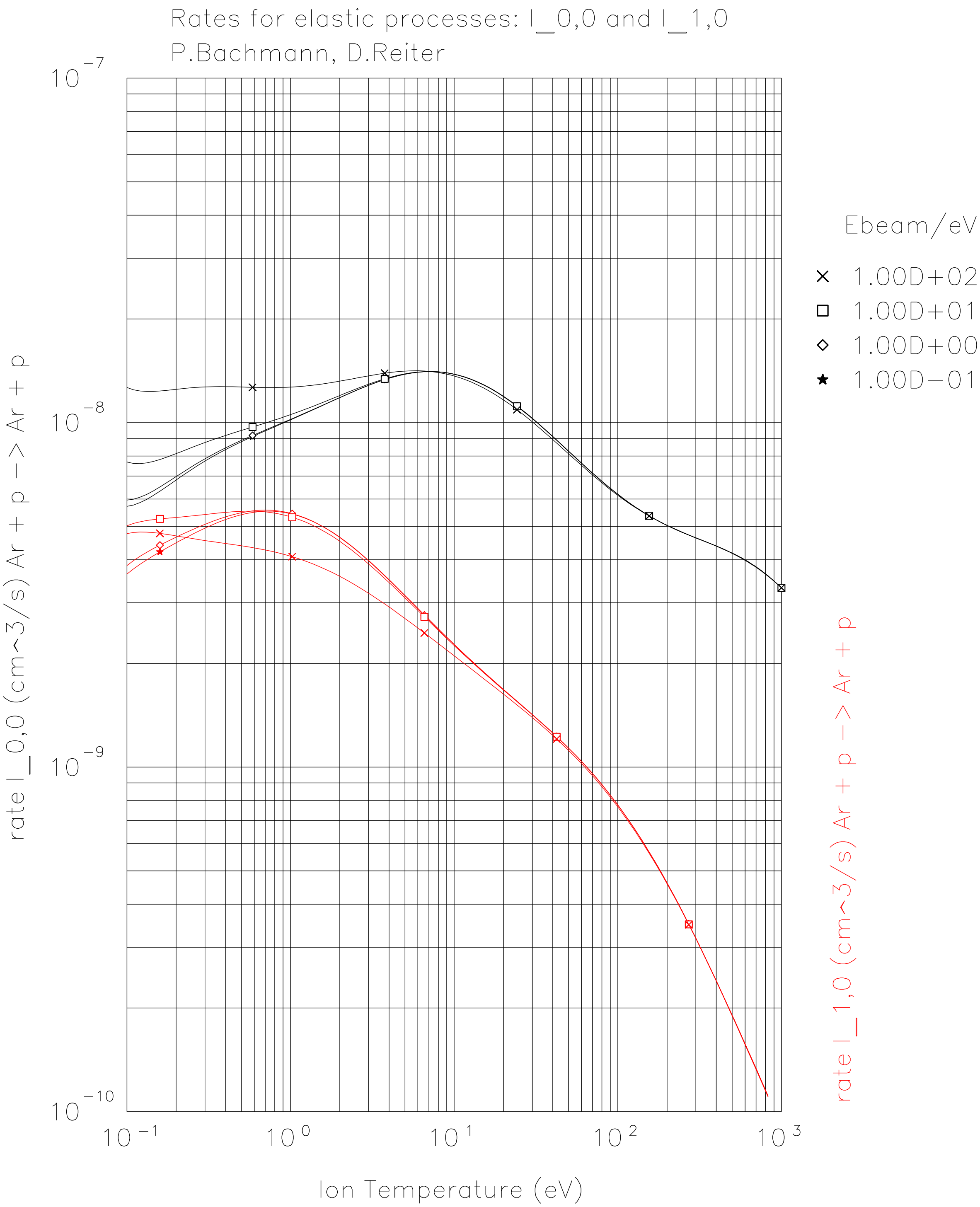
3.11 Reaction 0.6T $p + Ar \rightarrow p + Ar$, elastic, $I_{0,0}$

T-Index \ E-Index:	0	1	2
0	-1.839897580907D+01	4.030184662143D-03	1.802460470789D-03
1	2.037060320748D-01	-5.396105402336D-03	-7.769954287934D-04
2	1.248391636263D-02	2.603532176725D-03	-3.227588765414D-04
3	7.219811509122D-03	-4.061565358391D-04	-3.750257185540D-04
4	-1.470827813902D-02	2.065674500382D-05	3.333229773836D-04
5	-8.480842849852D-04	-4.796563627170D-05	-5.309221423582D-05
6	1.475843994216D-03	2.151994248608D-05	-7.098388544357D-06
7	-2.369733723824D-04	-3.291364962627D-06	2.359507987294D-06
8	1.134634185229D-05	1.702489707640D-07	-1.506817496256D-07

T-Index \ E-Index:	3	4	5
0	3.294800134968D-04	1.465250143471D-04	8.663294112725D-05
1	-6.037520883955D-05	-7.833105742017D-04	-7.893554189454D-05
2	2.800210419328D-04	7.133616427016D-04	-7.316301877565D-05
3	-3.944497369254D-04	1.428880614656D-07	6.395999790794D-05
4	1.035484083951D-04	-1.259450451777D-04	-6.254483715556D-06
5	2.614410225361D-05	2.546750118822D-05	-5.673820883686D-06
6	-1.539637991363D-05	2.130859838243D-06	1.919659151259D-06
7	2.333187328954D-06	-9.290655798117D-07	-2.320465866922D-07
8	-1.174046627783D-07	6.235484198986D-08	1.001839767228D-08

T-Index \ E-Index:	6	7	8
0	6.685225434320D-07	-4.106232974060D-06	2.723608800669D-07
1	7.183376311050D-05	-7.472067446331D-06	1.322655803936D-07
2	-7.138077909744D-05	1.620936024346D-05	-9.673898950970D-07
3	-1.770621609979D-06	-2.727090501391D-06	2.643852072903D-07
4	1.305037799181D-05	-2.175685933563D-06	1.088658237035D-07
5	-2.138483570591D-06	6.604985427235D-07	-4.569211762479D-08
6	-4.041031701627D-07	-3.355268537350D-09	2.937036162249D-09
7	1.213582669967D-07	-1.417846453379D-08	4.992956309007D-10
8	-7.672622548871D-09	1.110090107209D-09	-5.119220753399D-11



Rates for elastic processes: I_0,0 and I_1,0
P.Bachmann, D.Reiter
Ebeam/eV
1.00D+02
1.00D+01
1.00D+00
1.00D−01
rate I_0,0 (cm^3/s) Ar + p −> Ar + p
rate I_1,0 (cm^3/s) Ar + p −> Ar + p
Ion Temperature (eV)
10⁻⁷
10⁻⁸
10⁻⁹
10⁻¹⁰
10⁻¹
10⁰
10¹
10²
10³

3.12 Reaction 0.6D $p + Ar \rightarrow p + Ar$, elastic, $I_{1,0}$

T-Index \ E-Index	0	1	2
0	-1.902636300376D+01	3.001140234133D-03	-5.268608243610D-03
1	-1.190527528568D-01	-9.553336489669D-03	8.838025019236D-03
2	-1.730087103659D-01	4.587817497859D-03	-1.385574331019D-03
3	-1.555030094420D-04	-6.909759775226D-05	-2.299454149526D-03
4	1.652235885356D-02	-2.381913347984D-04	8.373956786709D-04
5	-8.324171609940D-04	-2.293808078785D-05	5.460206572452D-05
6	-1.029303844386D-03	2.488294466911D-05	-6.512005353386D-05
7	1.906300286920D-04	-3.895517435876D-06	1.038339787073D-05
8	-9.787840807784D-06	1.909716194883D-07	-5.237600871611D-07

T-Index \ E-Index	3	4	5
0	-3.745428185818D-03	1.799497927500D-03	3.198330217071D-04
1	3.207879804088D-03	-4.594149568994D-03	3.457996925194D-06
2	7.517190218616D-04	1.585823173330D-03	-2.165980750364D-04
3	-1.236341581941D-03	6.255302087543D-04	7.892735992329D-05
4	2.230976227599D-04	-3.347480301314D-04	5.331115058296D-06
5	7.233602681294D-05	-4.639425388458D-06	-6.590740254953D-06
6	-3.100626413849D-05	2.210113950523D-05	1.029508831544D-06
7	3.988838107824D-06	-3.769212293593D-06	-4.076159591930D-08
8	-1.769431052019D-07	1.950084020747D-07	-1.116568059624D-09

T-Index \ E-Index	6	7	8
0	-2.403744917992D-04	2.279983724758D-05	-1.931788624409D-08
1	4.912047383164D-04	-9.410833593792D-05	5.088836276642D-06
2	-1.484255933008D-04	3.868365832252D-05	-2.534300688720D-06
3	-6.764773601651D-05	1.041550065999D-05	-5.033712296102D-07
4	3.231656107374D-05	-6.733195279376D-06	4.029898146395D-07
5	9.314900214037D-07	5.580215548355D-08	-1.063413052225D-08
6	-2.175492032074D-06	4.036437533899D-07	-2.288971303250D-08
7	3.569143181296D-07	-7.087085127829D-08	4.174797773877D-09
8	-1.803893978156D-08	3.691585310844D-09	-2.208748178924D-10

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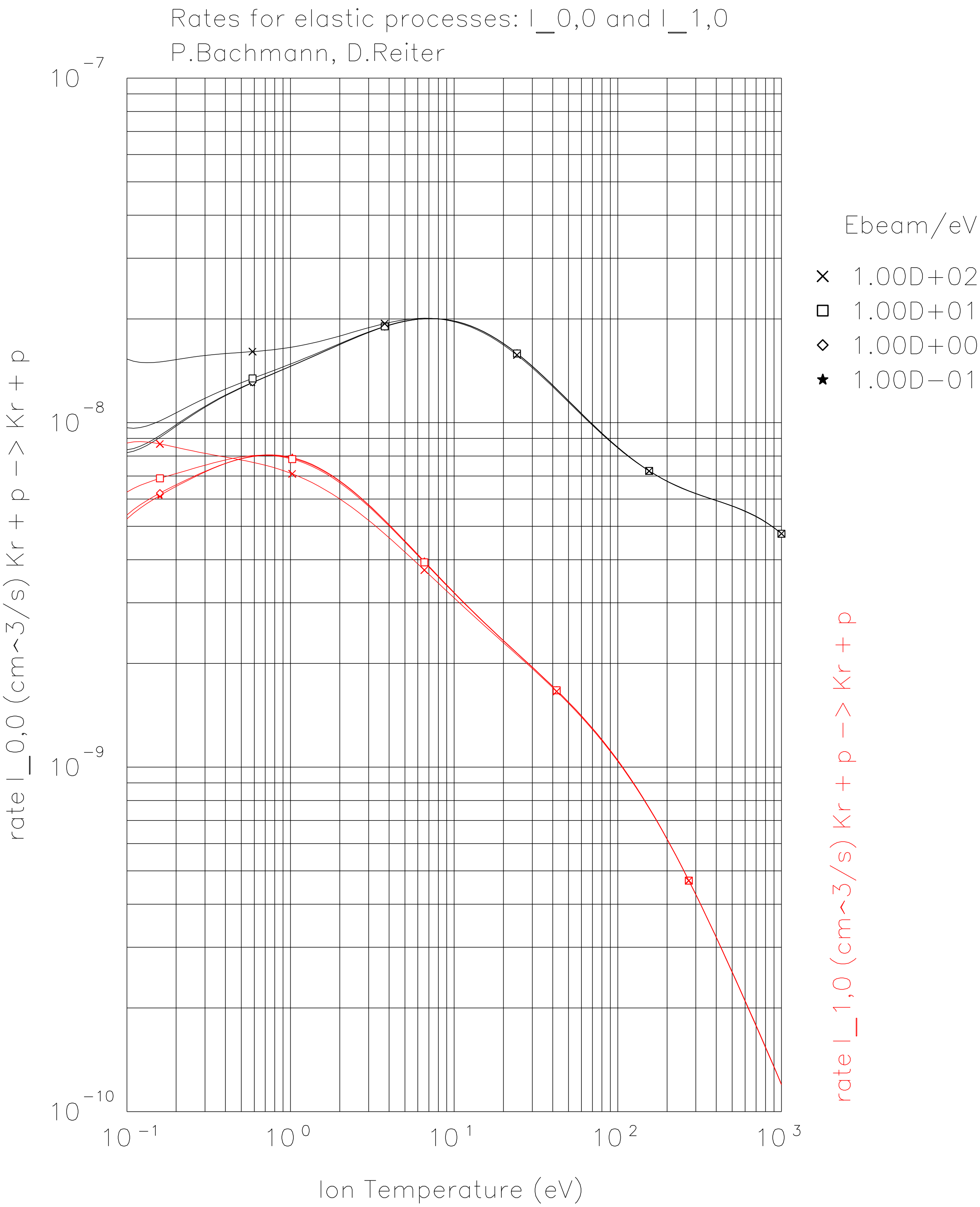
3.13 Reaction 0.7T $p + Kr \rightarrow p + Kr$, elastic, $I_{0,0}$

T-Index \ E-Index	0	1	2
0	-1.804373557904D+01	1.559321831821D-03	1.404133353439D-03
1	2.031777449493D-01	-2.592160804293D-03	-1.467585847319D-03
2	9.686882765703D-03	1.516696535508D-03	3.516527725030D-05
3	8.643169704852D-03	-2.293872602067D-04	2.022613761542D-04
4	-1.424299843875D-02	-3.467610803097D-05	2.405799623813D-05
5	-1.048137401376D-03	-1.163533423390D-05	-4.664386608096D-05
6	1.430609919337D-03	1.091497123198D-05	1.254896476704D-05
7	-2.194259131788D-04	-1.955482471322D-06	-1.369663518077D-06
8	1.009389168927D-05	1.086879702977D-07	5.472917240108D-08

T-Index \ E-Index	3	4	5
0	3.120877691343D-04	-1.817512879035D-04	4.117059852657D-05
1	1.242877797139D-04	9.112376503933D-05	-1.233416285351D-04
2	-1.573876413696D-04	2.563895433480D-04	4.138546015912D-05
3	-1.420956386480D-04	-1.528253798614D-04	2.912014736234D-05
4	9.590594342402D-05	5.645092477734D-07	-1.535634290988D-05
5	-6.142656580682D-06	1.596912487433D-05	1.203913423509D-07
6	-5.141525041188D-06	-4.044272726929D-06	9.881486025146D-07
7	1.084914594786D-06	3.915011722907D-07	-1.811507168253D-07
8	-6.255863642133D-08	-1.333876245529D-08	9.821435035614D-09

T-Index \ E-Index	6	7	8
0	2.839905184310D-05	-6.378458873924D-06	3.184713992614D-07
1	-1.279935281113D-05	8.614723298861D-06	-6.786954072347D-07
2	-2.600699325895D-05	2.200678327510D-06	-2.925585047627D-09
3	1.312098730964D-05	-3.454115928930D-06	2.098391843619D-07
4	9.219516369433D-07	4.847045590986D-07	-4.845129241580D-08
5	-1.422113360703D-06	2.351780708953D-07	-1.060289207166D-08
6	2.602916257409D-07	-8.197279350456D-08	5.265588912826D-09
7	-1.502708544211D-08	9.287156417397D-09	-6.890608304608D-10
8	4.565464331790D-11	-3.636906385821D-10	3.037183480051D-11


Rates for elastic processes: I_0,0 and I_1,0
P.Bachmann, D.Reiter
Ebeam/eV
1.00D+02
1.00D+01
1.00D+00
1.00D−01
rate I_0,0 (cm^3/s) Kr + p −> Kr + p
rate I_1,0 (cm^3/s) Kr + p −> Kr + p
Ion Temperature (eV)

3.14 Reaction 0.7D $p + Kr \rightarrow p + Kr$, elastic, $I_{1,0}$

T-Index \ E-Index:	0	1	2
0	-1.865545505448D+01	-2.224653891670D-03	3.512510248126D-03
1	-1.067068862517D-01	-2.372607771064D-03	-2.528011293662D-03
2	-1.793062289927D-01	3.411244442908D-03	-5.757528343672D-04
3	-3.949316377716D-03	-9.122323825167D-04	7.332721562736D-04
4	1.720673370392D-02	-8.376797069854D-05	-5.923952768477D-05
5	-5.292205338392D-04	5.171588105599D-05	-6.998516881937D-05
6	-1.123585474018D-03	-1.123489868132D-06	2.209356688942D-05
7	1.995670109878D-04	-1.062124014473D-06	-2.542259189383D-06
8	-1.005942932112D-05	8.744976036870D-08	1.047152545942D-07

T-Index \ E-Index:	3	4	5
0	5.208166935036D-04	-1.718161556721D-03	1.592709184582D-04
1	4.342669746539D-04	6.205372491923D-04	-2.512144246616D-04
2	-6.548561119095D-04	7.557892819154D-04	8.655880993873D-05
3	-1.170727706000D-06	-4.588074844111D-04	3.617188469585D-05
4	1.148785626919D-04	2.681963226773D-05	-2.204300778275D-05
5	-1.734332538201D-05	3.427749154446D-05	3.700519676902D-07
6	-4.518652819335D-06	-9.660892785904D-06	1.410244055501D-06
7	1.243519343884D-06	1.011493440280D-06	-2.646219750940D-07
8	-7.777508674647D-08	-3.800858381217D-08	1.452395343502D-08

T-Index \ E-Index:	6	7	8
0	1.760192998914D-04	-4.823181012443D-05	3.283695269304D-06
1	-5.953843658876D-05	2.746473855990D-05	-2.212169538346D-06
2	-8.109653911492D-05	1.104868697474D-05	-4.181441820322D-07
3	4.537025011410D-05	-1.035893652496D-05	6.333257556842D-07
4	-1.525645889670D-06	1.261725358435D-06	-1.056714078118D-07
5	-3.440639370908D-06	6.338548661992D-07	-3.391092703214D-08
6	8.551857146979D-07	-2.188109556451D-07	1.399325047660D-08
7	-7.894576610417D-08	2.545593595077D-08	-1.763312508912D-09
8	2.520441766028D-09	-1.046876612281D-09	7.719196237445D-11

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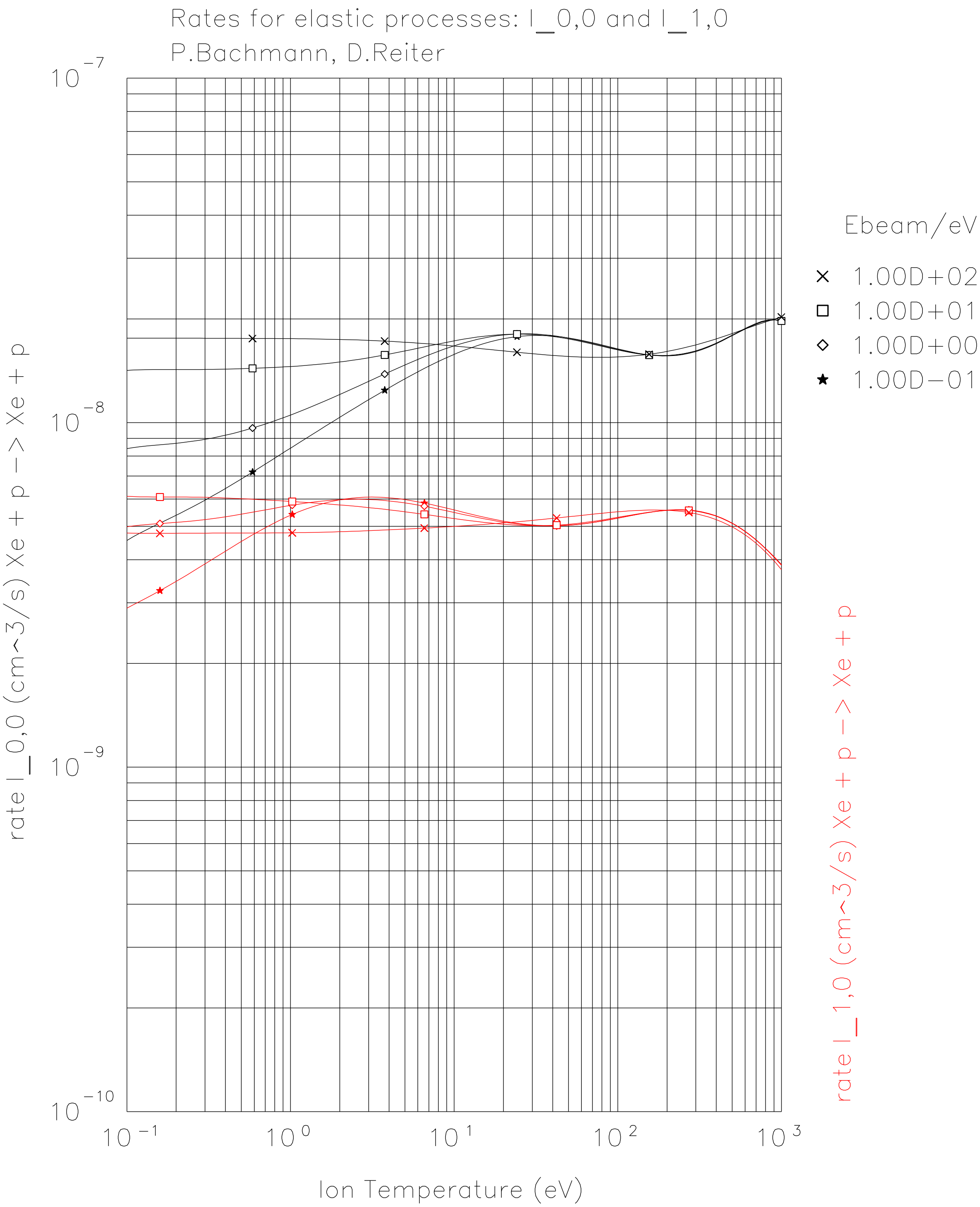
3.15 Reaction 0.8T $p + Xe \rightarrow p + Xe$, elastic, $I_{0,0}$

T-Index \ E-Index	0	1	2
0	-1.837022175444D+01	1.966234873272D-01	-8.045525227882D-02
1	1.805905055691D-01	-9.802945396045D-02	3.544388629813D-03
2	3.047012359914D-02	6.128643067258D-03	-4.012918398972D-03
3	-6.923416688779D-03	5.221800119943D-03	4.204812055154D-03
4	-3.195025138086D-04	-1.316526854062D-03	6.034285640091D-04
5	-1.935784557781D-04	-7.420136378842D-05	-4.344482793235D-04
6	-1.933096968862D-04	9.094117569189D-05	5.180202859895D-06
7	7.175836632929D-05	-1.543061104752D-05	1.174663734921D-05
8	-5.568595272341D-06	8.358080592792D-07	-9.761323315864D-07

T-Index \ E-Index	3	4	5
0	-4.848631362553D-02	4.750879899677D-02	5.610953213302D-04
1	1.612499614172D-02	-5.523987597225D-03	-9.460219395869D-04
2	6.794095254509D-04	-9.895305035946D-04	-2.861258121115D-05
3	-1.150110473980D-03	-7.631572145165D-04	1.776787179903D-04
4	3.981780177076D-04	-1.483284811460D-04	-3.107860031349D-05
5	6.891189917320D-06	1.027084520227D-04	-1.030852624977D-05
6	-3.951029440916D-05	7.160419132800D-06	4.694154796307D-06
7	8.033492283600D-06	-4.946108320253D-06	-6.642328462598D-07
8	-4.761690151100D-07	3.755070632999D-07	3.283487948208D-08

T-Index \ E-Index	6	7	8
0	-5.413232395756D-03	1.094586062581D-03	-6.392041039556D-05
1	7.755701996850D-04	-1.315661918085D-04	7.128051226064D-06
2	1.645431285623D-04	-3.499826315853D-05	2.119997135712D-06
3	3.410974410072D-05	-1.133727004658D-05	7.517805454064D-07
4	1.782649548441D-05	-2.411600549323D-06	1.058674617194D-07
5	-7.065840257206D-06	1.628340574934D-06	-9.783727086764D-08
6	-1.830471247020D-06	2.273687191682D-07	-9.553571528267D-09
7	6.407304183785D-07	-1.061766307764D-07	5.519134501912D-09
8	-4.447805281256D-08	7.735214914952D-09	-4.130970468715D-10


Rates for elastic processes: I_0,0 and I_1,0
P.Bachmann, D.Reiter
Ebeam/eV
1.00D+02
1.00D+01
1.00D+00
1.00D−01
rate I_0,0 (cm^3/s) Xe + p −> Xe + p
rate I_1,0 (cm^3/s) Xe + p −> Xe + p
Ion Temperature (eV)
10^−7
10^−8
10^−9
10^−10
10^−1
10^0
10^1
10^2
10^3

3.16 Reaction 0.8D $p + Xe \rightarrow p + Xe$, elastic, $I_{1,0}$

T-Index \ E-Index	0	1	2
0	-1.897424529930D+01	6.759221376448D-02	2.831656966128D-02
1	7.880568783648D-02	-1.013433977091D-01	-4.803501715713D-04
2	-2.211004195406D-02	2.780616010153D-02	-9.803026089070D-03
3	-1.881720757004D-02	7.288240524563D-03	3.622352023952D-03
4	1.881626843867D-03	-3.506478495212D-03	1.038874766045D-04
5	1.555723381321D-03	-6.488785021639D-05	-3.629668747278D-04
6	-2.155563511636D-04	1.904734853680D-04	9.263791323244D-05
7	-1.309212493163D-05	-2.940905387089D-05	-9.735247959278D-06
8	2.085088015611D-06	1.405276321600D-06	3.784816393936D-07

T-Index \ E-Index	3	4	5
0	-1.132739367386D-02	-1.136836207882D-02	1.644151842499D-03
1	1.616595589060D-02	-6.630385050040D-04	-1.261647418326D-03
2	-3.466486887128D-03	2.154814681750D-03	6.929992653084D-05
3	-1.469864494259D-03	-3.263588910597D-04	1.619007714736D-04
4	5.655409965690D-04	-6.761053529597D-05	-3.542760579601D-05
5	7.812054156187D-06	5.307617978533D-05	-6.584683292245D-06
6	-2.696200061727D-05	-1.593650897407D-05	3.272732707082D-06
7	4.097153412890D-06	2.165559988365D-06	-4.226732919171D-07
8	-1.941951920917D-07	-1.068579438469D-07	1.856975994299D-08

T-Index \ E-Index	6	7	8
0	9.347764278165D-04	-2.260015561966D-04	1.349778327834D-05
1	2.184449544252D-04	-4.870473229076D-06	-6.585679719393D-07
2	-1.768547787859D-04	3.062903702294D-05	-1.606726635371D-06
3	-5.383734875328D-06	-3.242779246901D-06	2.887563512048D-07
4	8.898390092703D-06	-5.828977975784D-07	2.514867221936D-09
5	-2.668417682123D-06	6.656669113253D-07	-4.118906229906D-08
6	9.467025678674D-07	-2.778964165257D-07	1.810797219300D-08
7	-1.603923367792D-07	4.412968572947D-08	-2.823552915243D-09
8	9.066091691589D-09	-2.353837415803D-09	1.478176477260D-10

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3.17 Reaction 2.1.5 $e + H \rightarrow 2e + H^+$,

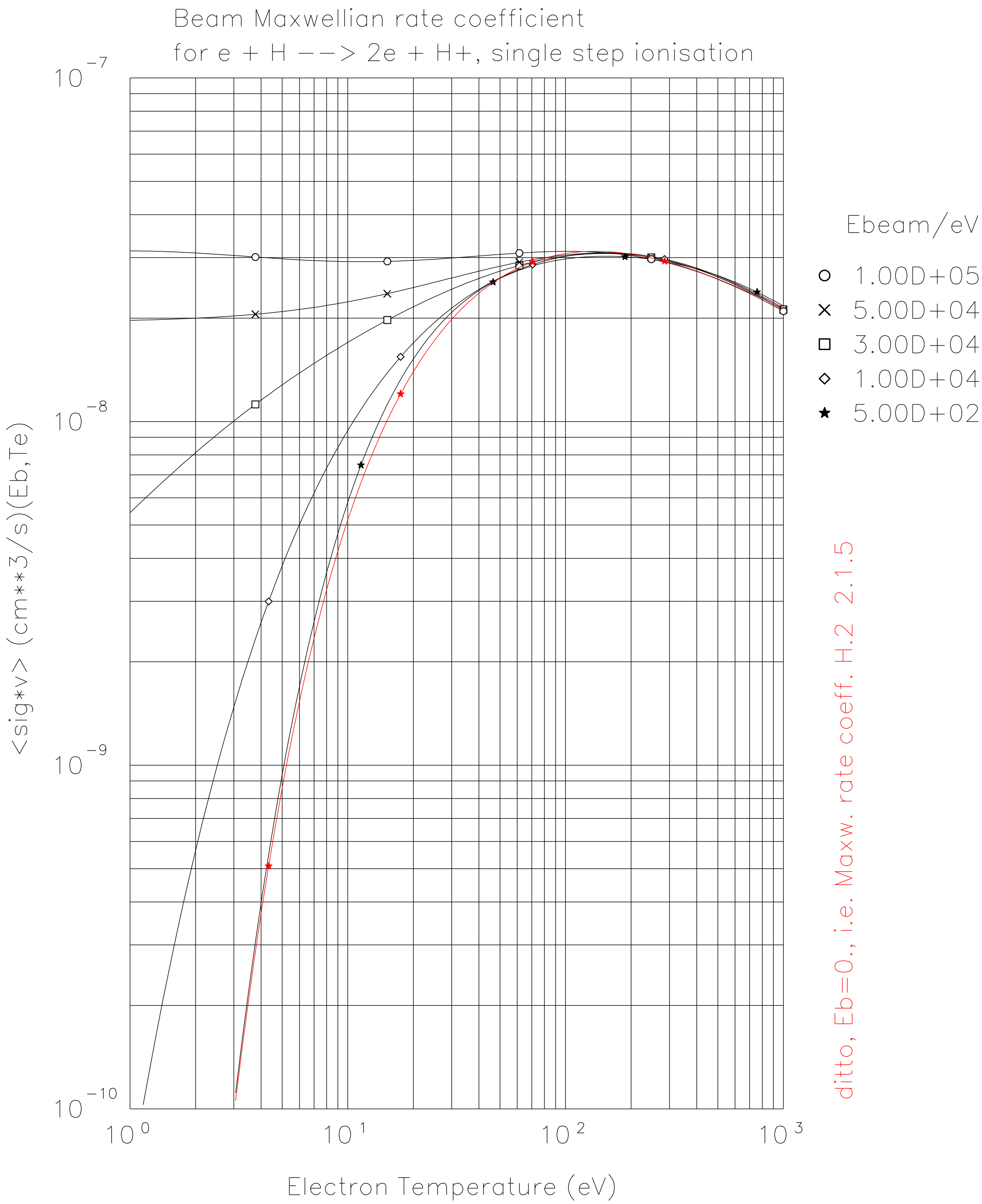
Valid for $700 < E_H < 1.0\ E5$ and $T_e < 1000$ eV. Needed for beam penetration across cold electron (edge) plasma.

T-Index \ E-Index	0	1	2
0	-3.250886702080D+02	2.690772962219D+02	-9.333762356936D+01
1	-6.667333547390D+01	7.233538183560D+01	-2.570910666822D+01
2	-4.983434468076D+01	2.412479733168D+01	-3.884870450118D+00
3	2.670550884979D+00	-1.723167957478D+00	5.587782905216D-01
4	6.674948903612D-01	-4.124756061678D-01	1.712842277416D-02
5	6.808976023219D-02	2.688754230792D-03	6.611670857544D-03
6	-1.438915473788D-02	-1.901194630463D-04	7.298416521085D-05
7	1.098989211142D-03	2.219783796362D-05	-3.960365474618D-05
8	-6.711866174955D-05	2.280924070357D-05	-4.884031598541D-06

T-Index \ E-Index	3	4	5
0	1.424150846209D+01	-4.467268971241D-01	-1.584732741666D-01
1	4.380976345270D+00	-3.009427651758D-01	-8.501949526254D-03
2	-3.398932408165D-02	4.907514406262D-02	2.703730871097D-05
3	-3.351001372815D-02	-6.702807790436D-03	7.244114949870D-04
4	5.697717251645D-03	-2.395062750188D-04	-2.620114677424D-06
5	-1.699139379366D-03	5.177635368277D-05	6.870966611037D-06
6	2.324432128978D-05	5.858353012396D-06	-1.366593951118D-06
7	5.355353697737D-06	-6.855890659797D-07	9.381430540897D-08
8	7.838237578617D-07	-9.827043958796D-08	9.095791108734D-09

T-Index \ E-Index	6	7	8
0	2.361460417677D-02	-1.345770476010D-03	2.864129137742D-05
1	2.358018185463D-03	-1.102091465927D-04	1.382211119292D-06
2	-5.608636378890D-04	3.536474507865D-05	-5.535259754631D-07
3	-8.650970561566D-06	6.995157343181D-08	-5.266956839472D-08
4	-3.717702510307D-06	2.369570100312D-07	5.319224060533D-10
5	1.019488700190D-07	-4.942023555843D-08	1.311808222738D-09
6	8.201753350995D-08	-2.693263792508D-09	8.430296741463D-11
7	-1.145196074924D-08	9.355510173137D-10	-3.109161125504D-11
8	-3.977195669572D-10	-6.688281017183D-12	7.995091233984D-13

Max. rel. Error: 22.9827 %
Mean rel. Error: 1.3423 %


Beam Maxwellian rate coefficient
for e + H --> 2e + H+, single step ionisation
<sig*v> (cm**3/s)(Eb,Te)
Electron Temperature (eV)
Ebeam/eV
1.00D+05
5.00D+04
3.00D+04
1.00D+04
5.00D+02
ditto, Eb=0., i.e. Maxw. rate coeff. H.2 2.1.5

3.18 Reaction 2.3.9 $e + He(1s^2 1S) \rightarrow 2e + He^+(1s)$,

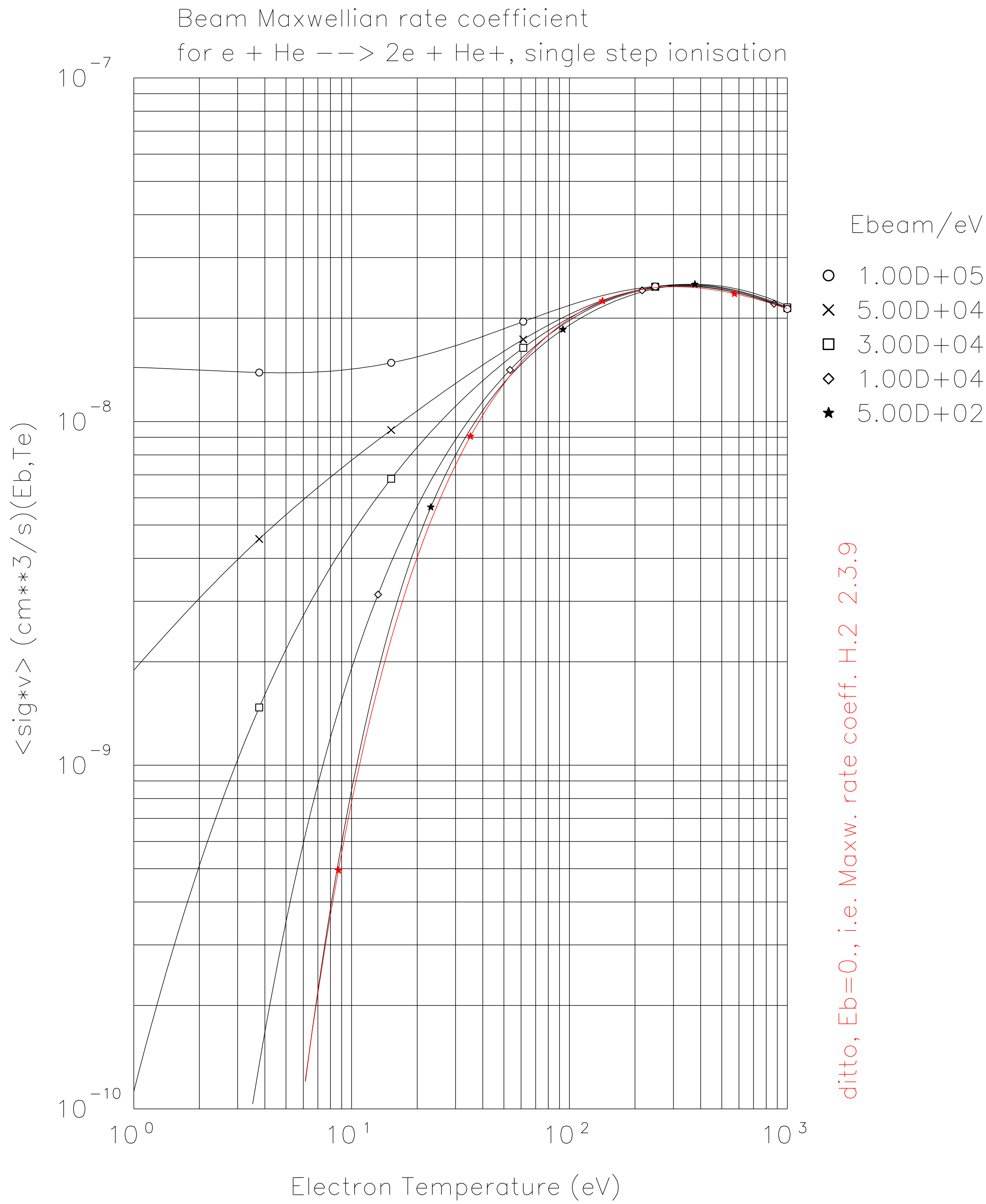
Valid for $700 < E_{He} < 1.0\ E5$ and $T_e < 1000$ eV. Needed for beam penetration across cold electron (edge) plasma.

T-Index \ E-Index:	0	1	2
0	1.310034245752D+03	-8.508771372056D+02	2.066760366749D+02
1	-2.508353150675D+02	1.015419189021D+02	-1.581037633890D+01
2	9.417451507809D+01	-1.778751771269D+01	-2.824530306780D+00
3	-3.009050226462D+01	6.654788597405D+00	2.915588715563D-01
4	4.385660180646D+00	-1.117837142443D+00	-1.511745757585D-02
5	-4.443019677779D-02	4.662788141049D-02	-5.658517658565D-04
6	-5.383557897871D-02	3.946435769665D-03	1.039284516303D-03
7	5.931731041041D-03	-7.716369089119D-04	-2.018331102194D-05
8	-1.677718659922D-04	1.297692472884D-05	1.627194163577D-06

T-Index \ E-Index:	3	4	5
0	-2.021517461823D+01	-6.037177234072D-01	3.448434382624D-01
1	2.160874670018D+00	-3.181962238105D-01	3.285332322121D-02
2	6.741447605303D-01	-3.148060740119D-02	7.078822091135D-04
3	-8.288011998601D-02	-1.758799128561D-03	-1.384555059849D-04
4	1.167648389744D-02	-1.409170634544D-04	9.546658161713D-05
5	-6.515681704203D-04	-4.715250869462D-05	9.071842143868D-06
6	-1.534799377103D-05	-1.066216257020D-05	-4.208681902142D-07
7	-1.528843582156D-05	2.822659922448D-06	1.096321036847D-07
8	1.009911437330D-06	-2.105689698877D-07	4.570730739908D-09

T-Index \ E-Index:	6	7	8
0	-3.436317750271D-02	1.530379719746D-03	-2.666449302822D-05
1	-2.281896275305D-03	1.104943101710D-04	-2.667926304328D-06
2	-1.624346097258D-05	-1.339087397064D-05	8.519546024053D-07
3	5.890695384015D-05	1.457482299662D-06	-2.463663989543D-07
4	-1.459401479449D-05	-8.971022779692D-08	3.962468074256D-08
5	3.123976730622D-08	-1.013694223158D-08	-7.468250327850D-10
6	2.419036579858D-09	1.458105491288D-08	-7.464201861260D-10
7	-2.457770000492D-08	-9.361060954216D-11	5.503065552145D-11
8	8.004030822610D-10	-1.580695841260D-11	-1.314359641034D-12

Max. rel. Error: 7.5847 %
Mean rel. Error: 0.8667 %


Beam Maxwellian rate coefficient
for e + He --> 2e + He+, single step ionisation
<sig*v> (cm**3/s)(Eb,Te)
Electron Temperature (eV)
Ebeam/eV
1.00D+05
5.00D+04
3.00D+04
1.00D+04
5.00D+02
ditto, Eb=0., i.e. Maxw. rate coeff. H.2 2.3.9

3.19 Reaction 3.1.8 $p + H(1s) \rightarrow H(1s) + p$

Charge exchange between protons and hydrogen atoms. Cross-section: 3.1.8, improved fit. (Identically in: HYDHEL.tex)
$\langle sigma * vrel \rangle$(Ti,Ebeam) (cm**3/s)

T-Index \ E-Index:	0	1	2
0	-1.831670498376D+01	1.650239332070D-01	5.025740610454D-02
1	2.143624996483D-01	-1.067658289373D-01	-5.304993033743D-03
2	5.139117192662D-02	9.536923957409D-03	-1.306075129405D-02
3	-9.896180369559D-04	6.315097684976D-03	2.655464630308D-03
4	-2.495327546080D-03	-1.265503371044D-03	7.569269700468D-04
5	-2.417046684097D-05	-6.945512319613D-05	-2.956984088728D-04
6	1.177406072793D-04	3.698501620365D-05	3.424317896619D-05
7	-1.483036457978D-05	-3.348172574417D-06	-1.527018819072D-06
8	5.351909441226D-07	9.728230870242D-08	1.676354786072D-08

T-Index \ E-Index:	3	4	5
0	5.288358515136D-03	-2.437122342843D-03	-4.461891214720D-04
1	8.289383645942D-03	-9.698773663345D-05	-4.470180279338D-04
2	-1.033166370333D-03	1.280464204775D-03	-8.453294908907D-05
3	-1.365781346175D-03	-1.859939123743D-04	1.237942304972D-04
4	2.756946036257D-04	-1.107375149384D-04	-7.217379426085D-06
5	2.318277483195D-05	3.704494397140D-05	-6.066558692480D-06
6	-9.815693511794D-06	-4.285719813022D-06	1.169257650609D-06
7	8.362050692462D-07	2.058392726953D-07	-7.463594884928D-08
8	-2.237567830699D-08	-3.081685803820D-09	1.450862501121D-09

T-Index \ E-Index:	6	7	8
0	1.731631548110D-04	-1.588434781959D-05	4.482291414386D-07
1	7.944326905066D-05	-5.303688417551D-06	1.235167254501D-07
2	-3.040874906105D-05	4.747888095498D-06	-1.923953750574D-07
3	-1.588253432932D-05	6.603560345800D-07	-1.970606344918D-09
4	5.769971321188D-06	-6.717311113584D-07	2.440961351104D-08
5	-4.951573401626D-07	1.437520597154D-07	-6.998724470004D-09
6	-4.968953461875D-10	-1.618948982477D-08	9.440094842562D-10
7	5.924370389093D-10	1.078208689229D-09	-6.619767848464D-11
8	4.434231893204D-11	-3.324377862622D-11	1.935019679501D-12

Max. rel. Error: 1.1026 %
Mean rel. Error: 0.3105 %

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3.20 Reaction 0.13p $p + Be \to p + Be$, elastic

Integral 0.5*I(1,0) for cross-sections from [P. Krstic, D. Schultz, PP, vol. 16 (2009), p. 053503]

T-Index \ E-Index	0	1	2
0	-2.014045187283e+01	-2.345625000690e-02	3.305320330967e-03
1	1.633235466137e-02	9.980449030332e-03	-7.067639616596e-03
2	-3.302490936436e-02	-6.598307698802e-03	-1.473079734140e-04
3	-2.690595407156e-02	5.590562085972e-03	1.477424631936e-03
4	2.553977796175e-03	-1.198166632910e-03	-1.524065320318e-04
5	1.172235136758e-03	-1.627408163499e-04	-1.042267671149e-04
6	-3.266982332705e-04	8.416159467290e-05	2.904236972264e-05
7	3.149289760802e-05	-9.814022851618e-06	-2.783408339643e-06
8	-1.076486147594e-06	3.734238744568e-07	9.357156799975e-08

T-Index \ E-Index	3	4	5
0	1.622640980311e-02	-2.885998551391e-03	-1.852231865164e-03
1	-8.621417251817e-03	1.995454066090e-03	7.882913154204e-04
2	3.438592757542e-04	1.915119499255e-04	3.167930363372e-05
3	-6.421972752548e-04	-1.406068934136e-04	6.824350317931e-05
4	3.247948234786e-04	-4.440977842360e-05	-3.426686939963e-05
5	1.259107326962e-05	1.754218150033e-05	-2.903525712509e-06
6	-2.000702118557e-05	-1.316461187594e-06	2.530910339762e-06
7	2.750657732561e-06	-4.943105315783e-08	-3.306763428407e-07
8	-1.137313391413e-07	6.118327388870e-09	1.336258126385e-08

T-Index \ E-Index	6	7	8
0	5.421800944799e-04	-5.322004264036e-05	1.832505454673e-06
1	-2.997846142138e-04	3.377208808135e-05	-1.279370584937e-06
2	-2.736718480233e-05	3.730502557681e-06	-1.525714105067e-07
3	-2.323654071260e-06	-1.001562341663e-06	7.501383504538e-08
4	1.110870800408e-05	-1.161197671721e-06	4.065284401394e-08
5	-8.530135081745e-07	2.096419478952e-07	-1.142479721401e-08
6	-4.412259984447e-07	2.047224411741e-08	1.657880705324e-10
7	7.676685086250e-08	-5.969845881133e-09	1.375019627044e-10
8	-3.463828351937e-09	3.040257273837e-10	-8.604737523486e-12

E2MIN=1.000000e-01 eV
E2MAX=1.000000e+04 eV
T1MIN=1.000000e-01 eV
T1MAX=1.000000e+04 eV
MAXERR=5.469149e+00 %
MIDERR=7.773394e-01 %

3.21 Reaction 0.13d $d + Be \rightarrow d + Be$, elastic

Integral 0.5*I(1,0) for the cross-section from [P. Krstic, D. Schultz, PP, vol. 16 (2009), p. 053503]

T-Index \ E-Index	0	1	2
0	-2.044307298348e+01	-1.435241859928e-03	1.536041365683e-02
1	2.282279489380e-02	-1.083413843840e-02	-1.474843156363e-02
2	-3.170234700651e-02	-8.490883393848e-03	2.079688557536e-03
3	-2.416047263489e-02	9.432119244308e-03	2.845241397793e-04
4	1.612944406737e-03	-1.129269279296e-03	1.052724354051e-04
5	1.205969880650e-03	-5.902894606367e-04	-6.217142758003e-05
6	-3.042059744854e-04	1.796859651710e-04	8.003975381593e-06
7	2.824343373145e-05	-1.807466354009e-05	-3.081218221035e-07
8	-9.440508892226e-07	6.302872079617e-07	-1.339799374312e-09

T-Index \ E-Index	3	4	5
0	5.278833185608e-03	-4.469538509276e-03	-6.491235580500e-04
1	8.841283319500e-04	1.826216287017e-03	-2.939210322706e-04
2	7.657158765681e-04	-1.946476894373e-05	1.867693028736e-05
3	-2.207552889630e-03	3.239632365588e-04	2.103141514803e-04
4	2.762713059735e-04	-9.265776869906e-05	-2.429517900194e-05
5	2.007011160713e-04	-2.487759075076e-05	-2.147229167781e-05
6	-6.121399958981e-05	1.092764172317e-05	6.327259228592e-06
7	6.243585391457e-06	-1.262789392490e-06	-6.350894325811e-07
8	-2.197691313245e-07	4.791605625816e-08	2.208688569691e-08

T-Index \ E-Index	6	7	8
0	3.450099986899e-04	-3.955146569842e-05	1.483280922015e-06
1	-2.313493476983e-05	7.116368703341e-06	-3.656772740674e-07
2	-2.058020487807e-05	3.396561608698e-06	-1.601568020599e-07
3	-6.822453223473e-05	7.105361952178e-06	-2.495941974516e-07
4	1.283283500423e-05	-1.653037734175e-06	6.795382247769e-08
5	6.650188435941e-06	-6.799250049849e-07	2.350487416086e-08
6	-2.280587373535e-06	2.549634635361e-07	-9.522348114958e-09
7	2.442175006227e-07	-2.824182688477e-08	1.083669713484e-09
8	-8.866460450561e-09	1.047525061112e-09	-4.087338886486e-11

E2MIN=1.000000e-01 eV
E2MAX=1.000000e+04 eV
T1MIN=1.000000e-01 eV
T1MAX=1.000000e+04 eV
MAXERR=6.574404e+00 %
MIDERR=8.464843e-01 %

3.22 Reaction 0.13t $t + Be \rightarrow t + Be$, elastic

Integral 0.5*I(1,0) for the cross-section from [P. Krstic, D. Schultz, PP, vol. 16 (2009), p. 053503]

T-Index \ E-Index	0	1	2
0	-2.129504307011e+01	1.773225057252e-02	1.880909643601e-02
1	2.546933381457e-02	-2.324877220081e-02	-1.682441670552e-02
2	-2.981010432291e-02	-9.794461284777e-03	3.725523265517e-03
3	-2.203655582429e-02	9.891081092090e-03	-7.870974350538e-04
4	9.964028273375e-04	-6.435065292429e-04	2.019639487327e-04
5	1.172605871159e-03	-7.189019182284e-04	1.838780642892e-05
6	-2.758762887050e-04	1.835500405043e-04	-1.518921596258e-05
7	2.485043659547e-05	-1.689818645796e-05	2.005438908327e-06
8	-8.151836846467e-07	5.511097601102e-07	-8.189837190188e-08

T-Index \ E-Index	3	4	5
0	-5.132900735360e-03	-4.421925566607e-03	3.914099368416e-04
1	6.590793034811e-03	1.268075388723e-03	-8.863334795471e-04
2	1.288530049780e-03	-2.754660024957e-04	-3.072806984273e-05
3	-2.235933725670e-03	5.344193391390e-04	2.000597752829e-04
4	3.631519990032e-05	-7.422560675901e-05	2.446011993064e-06
5	2.349882452429e-04	-4.838038543847e-05	-2.356761071496e-05
6	-5.519654333492e-05	1.507441074875e-05	5.230990882083e-06
7	4.849741630919e-06	-1.539910716377e-06	-4.401471679875e-07
8	-1.511215532691e-07	5.397860122684e-08	1.312783790155e-08

T-Index \ E-Index	6	7	8
0	9.754804763614e-05	-1.653532824608e-05	7.049898523652e-07
1	1.579820086189e-04	-1.220944882003e-05	3.527637498767e-07
2	5.755383129853e-06	2.384782937003e-07	-3.938740456374e-08
3	-8.253882854736e-05	9.685611260827e-06	-3.750354024418e-07
4	5.655895591655e-06	-9.924327352819e-07	4.744625742485e-08
5	9.018349071660e-06	-1.037798443713e-06	3.976147439343e-08
6	-2.385966333490e-06	2.959527372233e-07	-1.195770882126e-08
7	2.250364369523e-07	-2.909177070852e-08	1.208277625427e-09
8	-7.428846811499e-09	9.919713207429e-10	-4.206437314661e-11

E2MIN=1.000000e-01 eV
E2MAX=1.000000e+04 eV
T1MIN=1.000000e-01 eV
T1MAX=1.000000e+04 eV
MAXERR=6.852958e+00 %
MIDERR=9.227778e-01 %

3.23 Reaction 0.14p $p + C \rightarrow p + C$, elastic

Integral 0.5*I(1,0) the cross-section from [P. Krstic, D. Schultz, PP, vol. 13 (2006), p. 053501]

T-Index \ E-Index	0	1	2
0	-2.070325937875e+01	-1.606842198142e-02	8.714205649382e-03
1	-1.649258379129e-01	-1.370586397944e-02	-8.610928985264e-03
2	-8.228323037947e-02	1.042893658701e-02	2.920352519091e-03
3	1.291744053436e-02	-4.056102000351e-05	-4.279330275042e-04
4	4.972022465187e-03	-1.142479600302e-03	-1.823021533207e-05
5	-1.658137593639e-03	3.005724020801e-04	2.552407020562e-05
6	1.313758641539e-04	-3.251665906188e-05	-5.645220513458e-06
7	5.599391312349e-07	1.536984797877e-06	5.394244202523e-07
8	-2.939698517936e-07	-2.321423842233e-08	-1.912639278713e-08

T-Index \ E-Index	3	4	5
0	4.463808489764e-03	-5.048490029821e-03	-5.485971584014e-04
1	5.941389343177e-03	1.591030489357e-03	-6.724348380444e-04
2	-2.167804845149e-03	2.090440852555e-04	2.551690026771e-04
3	-7.729931321856e-04	9.617898796550e-06	7.887372433086e-05
4	3.057086385239e-04	-5.118348604852e-05	-3.010408438357e-05
5	8.168255647779e-06	7.542836997958e-06	-2.112912729057e-06
6	-1.289999822011e-05	5.408322650236e-07	1.620261227354e-06
7	1.614389314707e-06	-1.609136480749e-07	-1.933340387247e-07
8	-6.208603824932e-08	7.883780259005e-09	7.301712180137e-09

T-Index \ E-Index	6	7	8
0	4.753915903398e-04	-6.407354904082e-05	2.631638764433e-06
1	4.244975247061e-05	3.663120971952e-06	-3.285624239340e-07
2	-8.069104998325e-05	8.696126832052e-06	-3.209550762837e-07
3	-1.424206928869e-05	7.815274543195e-07	-7.191976670581e-09
4	1.013975911159e-05	-1.079636710772e-06	3.886976338792e-08
5	-2.792752786643e-07	9.100460959963e-08	-5.111179984264e-09
6	-3.490894641470e-07	2.449855146898e-08	-4.889613885858e-10
7	5.016256863184e-08	-4.331776839658e-09	1.234776996758e-10
8	-2.052868727602e-09	1.896731767020e-10	-5.862153355385e-12

E2MIN=1.000000e-01 eV
E2MAX=1.000000e+04 eV
T1MIN=1.000000e-01 eV
T1MAX=1.000000e+04 eV
MAXERR=4.502810e+00 %
MIDERR=6.356092e-01 %

3.24 Reaction 0.14d $d + C \rightarrow d + C$, elastic

Integral 0.5*I(1,0) the cross-section from [P. Krstic, D. Schultz, PP, vol. 13 (2006), p. 053501]

T-Index \ E-Index:	0	1	2
0	-2.101813469909e+01	6.489171371708e-03	4.901025644886e-03
1	-1.516889520308e-01	-2.470762179054e-02	-1.463167664648e-03
2	-7.453976358810e-02	1.017233018332e-02	1.214375528209e-03
3	7.618704589773e-03	-9.301827218280e-05	-9.984709341439e-04
4	4.787096833727e-03	-7.691694929083e-04	2.180371997435e-04
5	-1.061371660357e-03	1.971538044810e-04	1.333591660518e-05
6	-2.611197691070e-06	-2.228824297723e-05	-9.942256019663e-06
7	1.244816787057e-05	1.224609831860e-06	1.170723630532e-06
8	-6.769910487661e-07	-2.666403772875e-08	-4.404252434081e-08

T-Index \ E-Index:	3	4	5
0	-1.455339394665e-02	-3.081622015142e-03	1.402095087223e-03
1	1.350947310121e-02	-4.798802447621e-04	-1.349325857828e-03
2	-6.950748629568e-04	2.872915794277e-04	4.662582695229e-05
3	-1.214397303373e-03	2.233321486915e-04	1.275394051016e-04
4	7.599744499071e-05	-6.336940059363e-05	-2.985716810841e-06
5	9.546689677128e-05	-9.724010172447e-06	-1.185798104005e-05
6	-2.358526693542e-05	4.777607503632e-06	2.759385297831e-06
7	2.131249678191e-06	-5.428934065172e-07	-2.441680332756e-07
8	-6.877886538867e-08	2.018352694021e-08	7.786080358510e-09

T-Index \ E-Index:	6	7	8
0	-6.630931867974e-05	-1.282323960899e-05	9.612329327013e-07
1	3.203078193087e-04	-2.808404180189e-05	8.728428841695e-07
2	-3.437225083080e-05	4.758395513068e-06	-2.029214764132e-07
3	-4.113910109706e-05	4.190543564938e-06	-1.444698458017e-07
4	4.739036860771e-06	-6.721181446886e-07	2.826795931179e-08
5	3.315817743830e-06	-3.169812151056e-07	1.038065294736e-08
6	-9.498884071161e-07	1.013104127800e-07	-3.620554915035e-09
7	9.310944420933e-08	-1.038636437355e-08	3.832761193363e-10
8	-3.193093520991e-09	3.667768696803e-10	-1.381157363749e-11

E2MIN=1.000000e-01 eV
E2MAX=1.000000e+04 eV
T1MIN=1.000000e-01 eV
T1MAX=1.000000e+04 eV

MAXERR=4.812259e+00 %
MIDERR=6.856970e-01 %

3.25 Reaction 0.14t $t + C \rightarrow t + C$, elastic

Integral 0.5*I(1,0) the cross-section from [P. Krstic, D. Schultz, PP, vol. 13 (2006), p. 053501]

T-Index \ E-Index:	0	1	2
0	-2.188182287316e+01	1.454179492997e-02	-2.384032349700e-03
1	-1.354699933152e-01	-2.467760316153e-02	4.334653134039e-03
2	-7.060750858774e-02	9.399641668674e-03	8.481034134188e-04
3	2.864022450514e-03	-5.997943672361e-04	-1.380612802836e-03
4	4.981251211249e-03	-5.556527566954e-04	2.241298739717e-04
5	-6.269621444826e-04	1.920636450763e-04	4.700039868950e-05
6	-1.106351233133e-04	-2.866120650169e-05	-1.720762234455e-05
7	2.242128826376e-05	2.112462685008e-06	1.768524963647e-06
8	-1.005706263641e-06	-6.234864792351e-08	-6.175770363502e-08

T-Index \ E-Index:	3	4	5
0	-2.397323674331e-02	-1.240783245409e-03	2.302905154607e-03
1	1.387587499142e-02	-1.507728991767e-03	-1.294765807979e-03
2	4.651760567797e-04	1.680622109107e-04	-9.233250740936e-05
3	-9.635680205527e-04	3.061725227014e-04	9.789384481491e-05
4	-8.260913884022e-05	-4.654027458768e-05	1.346465972623e-05
5	9.503215133225e-05	-2.034050613835e-05	-1.108666689667e-05
6	-1.687203771025e-05	6.428514127795e-06	1.879502286805e-06
7	1.223944073583e-06	-6.489118024901e-07	-1.325772816947e-07
8	-3.237088551006e-08	2.257395302166e-08	3.416404221018e-09

T-Index \ E-Index:	6	7	8
0	-3.707252919630e-04	1.872349911606e-05	-1.381007109570e-07
1	3.668635462607e-04	-3.575440980571e-05	1.214465065926e-06
2	7.098045828556e-06	5.013656731141e-07	-5.200474146650e-08
3	-4.091586513333e-05	4.654803151256e-06	-1.739935848177e-07
4	6.912225143953e-08	-2.203785010051e-07	1.320720305232e-08
5	3.905694982934e-06	-4.228074741734e-07	1.534216866201e-08
6	-8.828000916527e-07	1.061224417073e-07	-4.120856941484e-09
7	7.736267322509e-08	-9.874970633391e-09	3.973883678734e-10
8	-2.453765580729e-09	3.278998627368e-10	-1.354402027084e-11

E2MIN=1.000000e-01 eV
E2MAX=1.000000e+04 eV
T1MIN=1.000000e-01 eV
T1MAX=1.000000e+04 eV
MAXERR=4.267937e+00 %
MIDERR=6.880224e-01 %

3.26 Reaction 3.1.8org $p + H(1s) \rightarrow H(1s) + p$

original fit from Janev's springer book 1987 in HYDHEL.tex. Now there is the improved fit (see above), leading to better energy balance with tracklength estimators and the energy-weighted rate (below)

T Index \ E Index	0	1	2
0	-1.829079581680e+01	1.640252721210e-01	3.364564509137e-02
1	2.169137615703e-01	-1.106722014459e-01	-1.382158680424e-03
2	4.307131243894e-02	8.948693624917e-03	-1.209480567154e-02
3	-5.754895093075e-04	6.062141761233e-03	1.075907881928e-03
4	-1.552077120204e-03	-1.210431587568e-03	8.297212635856e-04
5	-1.876800283030e-04	-4.052878751584e-05	-1.907025662962e-04
6	1.125490270962e-04	2.875900435895e-05	1.338839628570e-05
7	-1.238982763007e-05	-2.616998139678e-06	-1.171762874107e-07
8	4.163596197181e-07	7.558092849125e-08	-1.328404104165e-08

T Index \ E Index	3	4	5
0	9.530225559189e-03	-8.519413589968e-04	-1.247583860943e-03
1	7.348786286628e-03	-6.343059502294e-04	-1.919569450380e-04
2	-3.675019470470e-04	1.039643390686e-03	-1.553840717902e-04
3	-8.119301728339e-04	8.911036876068e-06	3.175388949811e-05
4	1.361661816974e-04	-1.008928628425e-04	1.080693990468e-05
5	1.141663041636e-05	1.775681984457e-05	-3.149286923815e-06
6	-4.340802793033e-06	-7.003521917385e-07	2.318308730487e-07
7	3.517971869029e-07	-4.928692832866e-08	1.756388998863e-10
8	-9.170850253981e-09	3.208853883734e-09	-3.952740758950e-10

T Index \ E Index	6	7	8
0	3.014307545716e-04	-2.499323170044e-05	6.932627237765e-07
1	4.075019351738e-05	-2.850044983009e-06	6.966822400446e-08
2	2.670827249272e-06	7.695300597935e-07	-3.783302281524e-08
3	-4.515123641755e-06	2.187439283954e-07	-2.911233951880e-09
4	5.106059413591e-07	-1.299275586093e-07	5.117133050290e-09
5	3.105491554749e-08	2.274394089017e-08	-1.130988250912e-09
6	-6.030983538280e-09	-1.755944926274e-09	1.005189187279e-10
7	-1.446756795654e-10	7.143183138281e-11	-3.989884105603e-12
8	2.739558475782e-11	-1.693040208927e-12	6.388219930167e-14

Error 8.88e-04 (B)

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3.27 Reaction 3.1.8L $p + H(1s) \rightarrow H(1s) + p$

Langevin approximation: sigma v = const = 2e-8

T-Index \ E-Index:	0	1	2
0	-1.772753356000D+01	0.000000000000D+00	0.000000000000D+00
1	0.000000000000D+00	0.000000000000D+00	0.000000000000D+00
2	0.000000000000D+00	0.000000000000D+00	0.000000000000D+00
3	0.000000000000D+00	0.000000000000D+00	0.000000000000D+00
4	0.000000000000D+00	0.000000000000D+00	0.000000000000D+00
5	0.000000000000D+00	0.000000000000D+00	0.000000000000D+00
6	0.000000000000D+00	0.000000000000D+00	0.000000000000D+00
7	0.000000000000D+00	0.000000000000D+00	0.000000000000D+00
8	0.000000000000D+00	0.000000000000D+00	0.000000000000D+00

T-Index \ E-Index:	3	4	5
0	0.000000000000D+00	0.000000000000D+00	0.000000000000D+00
1	0.000000000000D+00	0.000000000000D+00	0.000000000000D+00
2	0.000000000000D+00	0.000000000000D+00	0.000000000000D+00
3	0.000000000000D+00	0.000000000000D+00	0.000000000000D+00
4	0.000000000000D+00	0.000000000000D+00	0.000000000000D+00
5	0.000000000000D+00	0.000000000000D+00	0.000000000000D+00
6	0.000000000000D+00	0.000000000000D+00	0.000000000000D+00
7	0.000000000000D+00	0.000000000000D+00	0.000000000000D+00
8	0.000000000000D+00	0.000000000000D+00	0.000000000000D+00

T-Index \ E-Index:	6	7	8
0	0.000000000000D+00	0.000000000000D+00	0.000000000000D+00
1	0.000000000000D+00	0.000000000000D+00	0.000000000000D+00
2	0.000000000000D+00	0.000000000000D+00	0.000000000000D+00
3	0.000000000000D+00	0.000000000000D+00	0.000000000000D+00
4	0.000000000000D+00	0.000000000000D+00	0.000000000000D+00
5	0.000000000000D+00	0.000000000000D+00	0.000000000000D+00
6	0.000000000000D+00	0.000000000000D+00	0.000000000000D+00
7	0.000000000000D+00	0.000000000000D+00	0.000000000000D+00
8	0.000000000000D+00	0.000000000000D+00	0.000000000000D+00

Max. rel. Error: 0.0000 %
Mean rel. Error: 0.0000 %

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3.28 Reaction 3.2.3g $p + H_2(v) \rightarrow H + H_2^+$

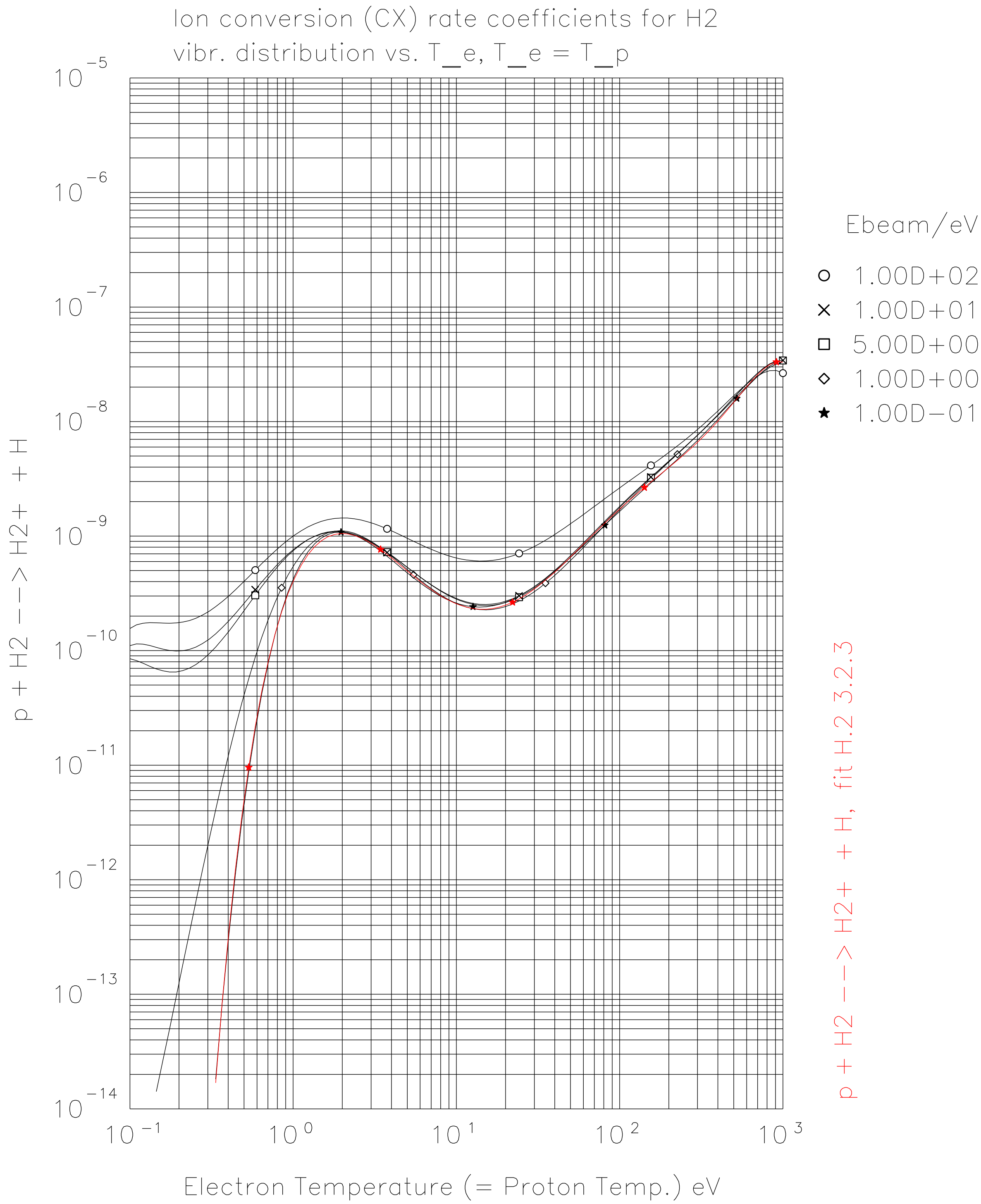
3.2.3 is renamed now to 3.2.3g, because it implicitly contains Greenland's vibr. distribution. Effective ion conversion (Charge exchange on H_2) as function of T_p (from Janev,[2]). Greenland's vibrational distribution $pH_2(v;T_e)$ is density independent, assume: $T_e = T_p = T$, hence: function of $E_{beam} = E_{H2}$ and T

E-Index: T-Index:	0	1	2
0	-2.133104980000E+01	2.961905900000E-01	-2.876892150000E-02
1	2.308461720000E+00	-1.064800460000E+00	2.310120950000E-01
2	-2.026151710000E+00	1.142806740000E+00	-2.621943460000E-01
3	1.648000330000E-01	-4.675786500000E-01	1.242261910000E-01
4	1.651993580000E-01	5.766584690000E-02	-3.659922760000E-02
5	-2.598458070000E-02	1.349144350000E-02	8.871659800000E-03
6	-4.330453510000E-03	-5.246404340000E-03	-1.636107180000E-03
7	1.187405610000E-03	6.281964210000E-04	1.740000360000E-04
8	-6.897815380000E-05	-2.667160440000E-05	-7.528040300000E-06

E-Index: T-Index:	3	4	5
0	-3.323271590000E-02	7.234558340000E-03	2.940230100000E-04
1	6.809382980000E-02	-4.241210420000E-02	8.271152020000E-03
2	-6.877694430000E-02	4.012716970000E-02	-6.143307540000E-03
3	1.774294860000E-02	-1.157658350000E-02	1.311061300000E-03
4	7.083346120000E-03	3.403537010000E-04	-2.752152790000E-04
5	-5.231162040000E-03	3.324241650000E-04	1.985585660000E-04
6	1.242023150000E-03	-4.524774630000E-05	-6.369415730000E-05
7	-1.337853740000E-04	6.784609160000E-07	8.284840740000E-06
8	5.516687380000E-06	1.140207820000E-07	-3.837975410000E-07

E-Index: T-Index:	6	7	8
0	-8.005031610000E-05	0.000000000000E+00	0.000000000000E+00
1	-6.275988100000E-04	0.000000000000E+00	0.000000000000E+00
2	3.233852920000E-04	0.000000000000E+00	0.000000000000E+00
3	-1.125957730000E-05	0.000000000000E+00	0.000000000000E+00
4	2.225165850000E-05	0.000000000000E+00	0.000000000000E+00
5	-2.813630850000E-05	0.000000000000E+00	0.000000000000E+00
6	8.679231940000E-06	0.000000000000E+00	0.000000000000E+00
7	-1.075372230000E-06	0.000000000000E+00	0.000000000000E+00
8	4.793672020000E-08	0.000000000000E+00	0.000000000000E+00

Max. rel. Error: 16.7 %
Mean rel. Error: 5.09 %



Ion conversion (CX) rate coefficients for H2
vibr. distribution vs. T_e, T_e = T_p
p + H2 --> H2+ + H
Ebeam/eV
1.00D+02
1.00D+01
5.00D+00
1.00D+00
1.00D-01
p + H2 --> H2+ + H, fit H.2 3.2.3
Electron Temperature (= Proton Temp.) eV

3.29 Reaction 3.3.1 $p + He(1s^2 1S) \rightarrow H + He^+(1s)$

T-Index \ E-Index:	0	1	2
0	-3.777393171216D+01	1.034570822224D+00	5.500659259212D-01
1	9.354555314272D+00	-1.691165109278D+00	-7.450052207738D-01
2	-4.235897398162D+00	1.383244831625D+00	3.396734449323D-01
3	1.350058534401D+00	-6.640009322644D-01	-2.562301717488D-02
4	-2.418149537330D-01	1.946040141373D-01	-2.712202677247D-02
5	1.747617790690D-02	-3.507141422752D-02	9.840686949146D-03
6	7.868843917720D-04	3.782419535260D-03	-1.470034129542D-03
7	-1.857520833749D-04	-2.234371833506D-04	1.049668682077D-04
8	7.419442223475D-06	5.549545840266D-06	-2.941631374324D-06

T-Index \ E-Index:	3	4	5
0	4.271707093128D-02	-5.858821491798D-02	1.392666257426D-02
1	1.174092828553D-02	1.114511012703D-01	-2.954831571871D-02
2	-6.307600501935D-02	-6.111443567710D-02	2.198175535806D-02
3	3.966559773589D-02	9.770353095467D-03	-6.712723502770D-03
4	-1.172231175354D-02	2.197390583445D-03	6.399497506338D-04
5	1.999302843269D-03	-1.106397155875D-03	9.894710667600D-05
6	-2.070618270598D-04	1.765303992000D-04	-2.889915777541D-05
7	1.226009237337D-05	-1.292057629192D-05	2.493401272590D-06
8	-3.182522175779D-07	3.665898328329D-07	-7.535980089596D-08

T-Index \ E-Index:	6	7	8
0	-1.826013734833D-03	1.338360116582D-04	-4.094793119826D-06
1	3.221947627445D-03	-1.596959700477D-04	2.851937035822D-06
2	-2.959465078436D-03	1.811254083073D-04	-4.188871522474D-06
3	1.199132836096D-03	-9.257540264113D-05	2.685063664954D-06
4	-2.155848545229D-04	2.170199383545D-05	-7.480430374938D-07
5	1.197406032871D-05	-2.356790229752D-06	1.014622773664D-07
6	1.233468768851D-06	8.575083472581D-08	-6.548641344013D-09
7	-1.868672214120D-07	3.144081097677D-09	1.518680425956D-10
8	6.598419439525D-09	-2.255951200310D-10	7.165455179223D-13

Max. rel. Error: 28.3918 %
Mean rel. Error: 1.3778 %

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3.30 Reaction 3.3.6a $p + He^*(1s^1 2s^1 1S) \rightarrow H^*(2s) + He^+(1s)$

T-Index \ E-Index	0	1	2
0	-2.547454346557D+01	4.128640321938D-01	1.681364689904D-01
1	2.925159193919D+00	-4.482539906582D-01	-1.510618145526D-01
2	-2.632374609849D-01	1.498243646661D-01	4.224863000625D-02
3	-3.665347937696D-02	-4.030592366279D-03	-6.024374907107D-03
4	1.186624566602D-02	-7.264454630020D-03	1.759741131185D-03
5	-7.743098120973D-04	1.549566023754D-03	-5.251712659531D-04
6	-6.048032854477D-05	-1.303138256507D-04	7.489465754264D-05
7	9.567845819569D-06	4.491545385436D-06	-4.865196018372D-06
8	-3.240997611305D-07	-3.791720988961D-08	1.182380927243D-07

T-Index \ E-Index	3	4	5
0	4.770799895182D-02	-4.589820198321D-03	-3.381658191835D-03
1	5.782833798276D-04	1.062966905109D-02	-1.000814684417D-03
2	-1.379424993966D-02	-4.799947755285D-03	2.003286792299D-03
3	3.861551147569D-03	8.428413708310D-04	-6.216316421045D-04
4	-5.418286557573D-04	-2.942217454245D-05	7.238789629847D-05
5	1.074828795860D-04	-1.693095034492D-05	-1.682620078098D-06
6	-1.905146446763D-05	3.627851762042D-06	-3.555921820186D-07
7	1.601618148499D-06	-3.021602782205D-07	3.224220197809D-08
8	-4.832611082122D-08	9.163386368269D-09	-8.754524349299D-10

T-Index \ E-Index	6	7	8
0	7.216467750187D-04	-5.367354341527D-05	1.404882131093D-06
1	-1.026211922836D-04	1.753943422756D-05	-6.292768990258D-07
2	-2.604060260416D-04	1.473506727808D-05	-3.094165446584D-07
3	1.074723588583D-04	-7.721788090796D-06	2.030369344275D-07
4	-1.611312475612D-05	1.369478220738D-06	-4.100428990113D-08
5	1.009293380060D-06	-1.149043918048D-07	4.074816429488D-09
6	-1.512787587046D-08	5.066369422287D-09	-2.328387385602D-10
7	-7.878569805292D-10	-1.445940103849D-10	8.580766309466D-12
8	2.044140116707D-11	3.044550460011D-12	-1.768485828956D-13

Max. rel. Error: 7.6526 %
Mean rel. Error: 1.0667 %

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3.31 Reaction 3.3.6b $p + He^*(1s^1 2s^1 3S) \rightarrow H^*(2s) + He^+(1s)$

T-Index \ E-Index	0	1	2
0	-3.143965131590D+01	6.213651065042D-01	1.902530458816D-01
1	5.052041699363D+00	-7.148284765635D-01	-1.237588528705D-01
2	-1.123510624616D+00	5.432613921547D-01	8.782764771787D-02
3	5.348600593230D-01	-2.975038694390D-01	-7.480657433556D-02
4	-2.135986381612D-01	1.005463096676D-01	3.217845093386D-02
5	4.690491969254D-02	-1.984365278750D-02	-6.930272101671D-03
6	-5.582187291915D-03	2.224271972399D-03	7.806801953220D-04
7	3.414974814001D-04	-1.311003795110D-04	-4.398645721299D-05
8	-8.438843692321D-06	3.153343412371D-06	9.747101004706D-07

T-Index \ E-Index	3	4	5
0	6.905094039815D-02	2.031144550828D-03	-5.216959360609D-03
1	-3.733697369694D-02	-4.284814988611D-04	8.393728104870D-03
2	-6.508591153825D-02	1.088127433701D-02	-1.741996511515D-03
3	6.989130699630D-02	-1.052805212797D-02	-1.083666162584D-03
4	-2.714253969913D-02	4.258559341854D-03	4.082988867720D-04
5	5.298275385423D-03	-9.198385408429D-04	-1.481408240559D-05
6	-5.526051789225D-04	1.111995316138D-04	-9.733079909866D-06
7	2.923449260993D-05	-7.085139465779D-06	1.368541840554D-06
8	-6.120199563565D-07	1.849580238681D-07	-5.378697856092D-08

T-Index \ E-Index	6	7	8
0	6.870508923626D-04	-2.653292731940D-05	1.208474130385D-08
1	-1.989364522591D-03	1.753792411592D-04	-5.477952397515D-06
2	3.431473662601D-04	-3.592640513827D-05	1.335701974095D-06
3	4.316290417315D-04	-4.061169944387D-05	1.281804690424D-06
4	-1.790232068370D-04	1.771568491253D-05	-5.843104467181D-07
5	2.117076885890D-05	-2.256441586648D-06	7.622251547211D-08
6	2.956849458181D-07	6.754190895102D-09	-4.412084334419D-10
7	-2.054349022277D-07	1.712307554998D-08	-5.567694760593D-10
8	9.859620416969D-09	-8.710088226618D-10	2.871802269066D-11

Max. rel. Error: 34.6091 %
Mean rel. Error: 1.4428 %

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4 H.4 : Fits for $\langle\sigma v\rangle(n_e, T)$

4.1 Reaction 2.1.5JH $H + e \rightarrow H^+ + 2e$

Effective hydrogenic ionization rate. Data: L.C.Johnson Report: Mahn, Welge, IPP, [4]

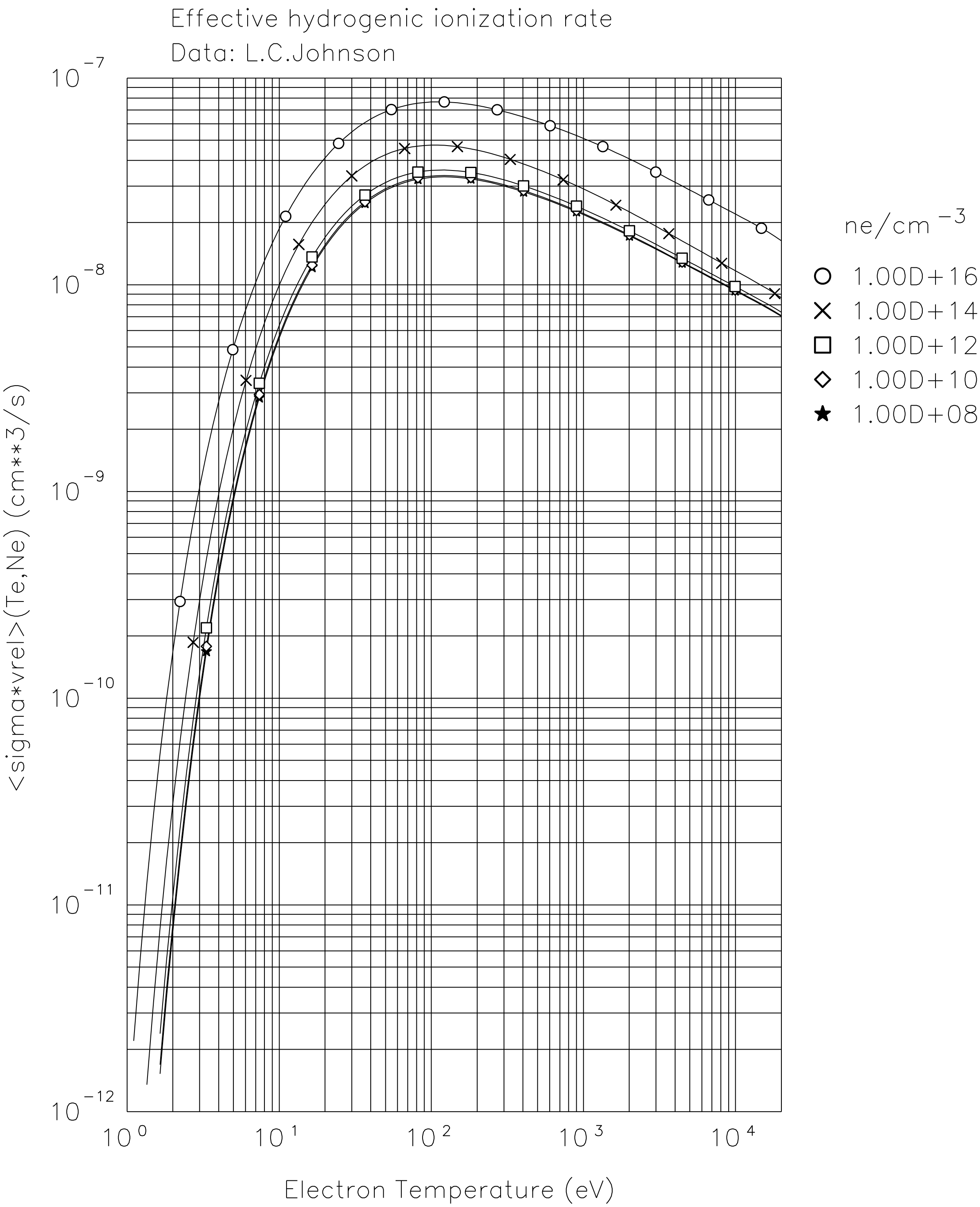
T-Index \ E-Index	0	1	2
0	-3.292647100524D+01	1.293481375348D-02	5.517562508468D-03
1	1.423977672396D+01	-1.173143955186D-02	1.063440108279D-03
2	-6.519438729039D+00	-7.189825749516D-03	9.247377414923D-04
3	2.009996151806D+00	1.275979740638D-02	-4.693479616874D-03
4	-4.289594424073D-01	-5.340866322754D-03	2.324582357388D-03
5	6.047834607038D-02	9.624900593359D-04	-4.182981184259D-04
6	-5.304737965836D-03	-7.854872454067D-05	2.735823803201D-05
7	2.606946949696D-04	2.317442253442D-06	5.148890779990D-08
8	-5.467903073834D-06	6.077380038450D-09	-4.712893073569D-08

T-Index \ E-Index	3	4	5
0	-7.853816321645D-04	1.436128501544D-04	-3.883750282085D-07
1	-1.600053527730D-03	1.136554639958D-05	5.177662275946D-05
2	2.037026745547D-03	-3.668717204076D-04	5.368630315837D-06
3	-2.389224140310D-05	1.358069915666D-04	-1.454897555460D-05
4	-3.217228075879D-04	6.660581406632D-06	2.396531874534D-06
5	7.957230182146D-05	-7.447042563915D-06	1.849155263575D-07
6	-5.915348564130D-06	8.666302868477D-07	-6.115514821045D-08
7	-7.144182523188D-09	-2.540194754187D-08	4.097857835689D-09
8	1.086858755070D-08	-3.448417246175D-10	-8.714183216468D-11

T-Index \ E-Index	6	7	8
0	-1.489774355194D-06	1.416361431167D-07	-3.890932078762D-09
1	-7.947999902838D-06	4.508505683240D-07	-8.952614093357D-09
2	3.713958914062D-06	-3.125764373429D-07	7.451213220623D-09
3	4.212031496989D-08	5.506044670830D-08	-1.852677638893D-09
4	-1.785208321244D-07	6.095649574151D-10	1.470204228549D-10
5	1.618233640838D-08	-8.182928298434D-10	4.835789623340D-12
6	1.075473174260D-09	4.118000674849D-11	-1.089323091222D-12
7	-2.048657335774D-10	3.027916374251D-12	1.155854020410D-14
8	8.023660696154D-12	-2.396518500447D-13	2.173645280354D-15

N2MIN = 1.00000D 08 1/CM3
N2MAX = 1.00000D 16 1/CM3

Max. rel. Error: .8487 %
Mean rel. Error: .2419 %


Effective hydrogenic ionization rate
Data: L.C.Johnson
<sigma*vrel>(Te,Ne) (cm**3/s)
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

4.2 Reaction 2.1.5o $H + e \rightarrow H^{+} + 2e$, Ly-opaque

Effective hydrogenic ionization rate. Data: L.C.Johnson, Ly-opaque Report: Mahn, Welge, IPP, [4]

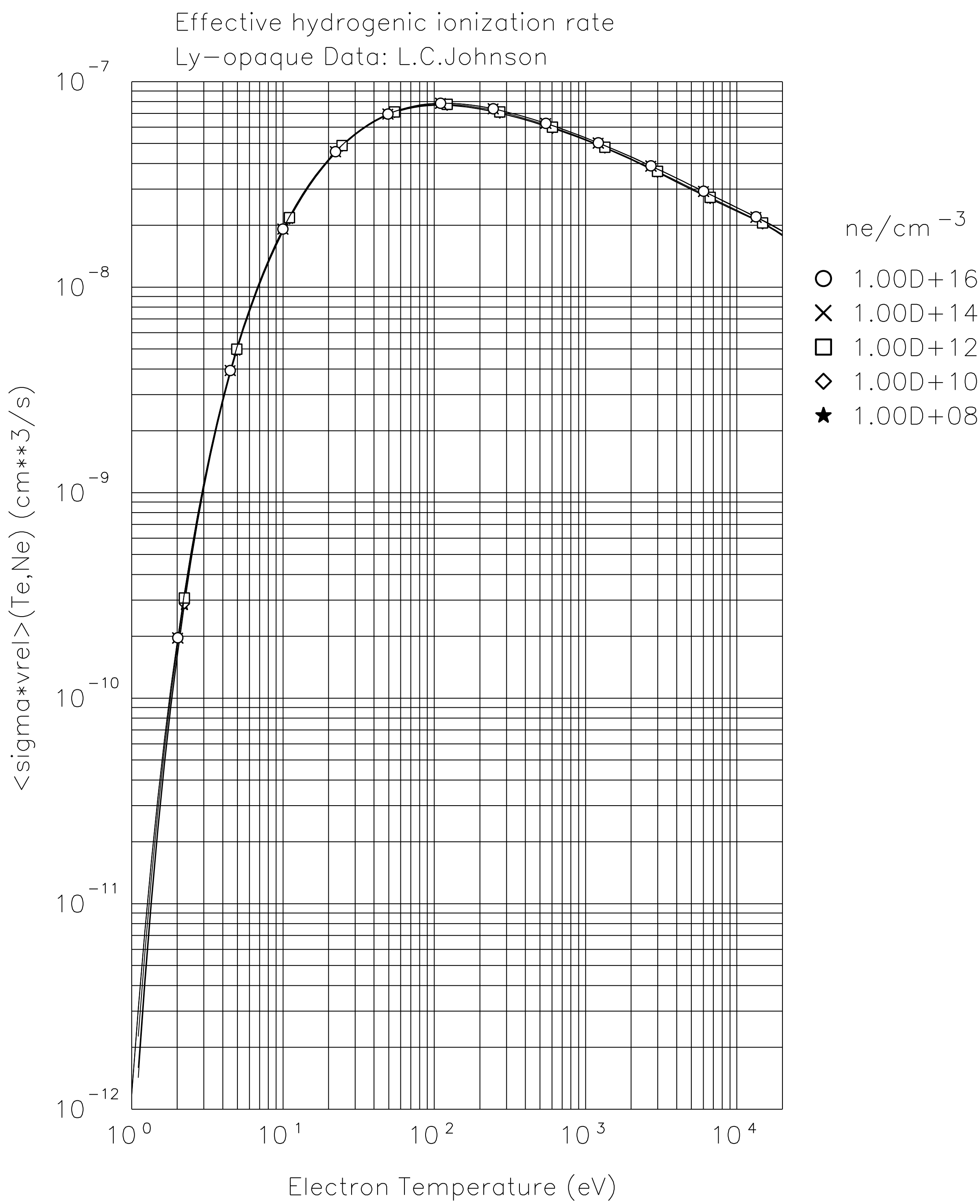
T-Index \ E-Index	0	1	2
0	-2.842625123610D+01	3.816926440645D-02	-2.093090374769D-02
1	1.212167851020D+01	-8.864661558973D-02	2.578404580790D-02
2	-6.815821411657D+00	1.136458676986D-01	-3.209328253150D-02
3	2.625844925126D+00	-7.176672848153D-02	2.221528694064D-02
4	-6.666700835468D-01	2.362874407172D-02	-7.539637780701D-03
5	1.063576010855D-01	-4.303004854934D-03	1.340877575599D-03
6	-1.019791186281D-02	4.388098086177D-04	-1.289968813905D-04
7	5.357498344762D-04	-2.353712235761D-05	6.392439908462D-06
8	-1.183601163067D-05	5.183054638931D-07	-1.286865471654D-07

T-Index \ E-Index	3	4	5
0	1.173278205549D-02	-3.195307082806D-03	4.891090254225D-04
1	-1.125027025423D-02	3.132061119992D-03	-5.478419611750D-04
2	7.428129132200D-03	-1.359196323415D-03	2.455552537690D-04
3	-3.813499462891D-03	3.488231091499D-04	-5.136595197719D-05
4	1.139599698461D-03	-5.231484976569D-05	3.851106631395D-06
5	-1.830544200085D-04	3.418266263749D-06	2.695420674804D-07
6	1.595087521180D-05	-5.244682697928D-08	-4.069155577999D-08
7	-7.334538727835D-07	7.314879444968D-09	-1.321258886395D-09
8	1.468328421917D-08	-8.136369296580D-10	2.036456697308D-10

T-Index \ E-Index	6	7	8
0	-3.972967626237D-05	1.591035727928D-06	-2.476205052687D-08
1	4.881508340119D-05	-2.055128753437D-06	3.275823973472D-08
2	-2.356276122712D-05	1.024674585628D-06	-1.635599873170D-08
3	5.236557713321D-06	-2.300633304095D-07	3.500516071428D-09
4	-4.712865883416D-07	2.015344675266D-08	-2.228472576727D-10
5	-1.533579453796D-09	2.312045651251D-10	-2.651886075183D-11
6	6.001489992879D-10	-5.139558636314D-11	3.525452470540D-12
7	3.249620872276D-10	-1.169248684183D-11	1.979747513777D-14
8	-2.321096956876D-11	9.053581287584D-13	-1.015243451999D-14

```
N2MIN =   1.00000D 08 1/CM3
N2MAX =   1.00000D 16 1/CM3

  Max. rel. Error:   1.6436 %
  Mean rel. Error:    .4360 %
```


Effective hydrogenic ionization rate
Ly−opaque Data: L.C.Johnson
10^-7
10^-8
10^-9
10^-10
10^-11
10^-12
<sigma*vrel>(Te,Ne) (cm**3/s)
10^0
10^1
10^2
10^3
10^4
Electron Temperature (eV)
ne/cm^-3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

4.3 Reaction 2.1.5 $H + e \rightarrow H^+ + 2e$

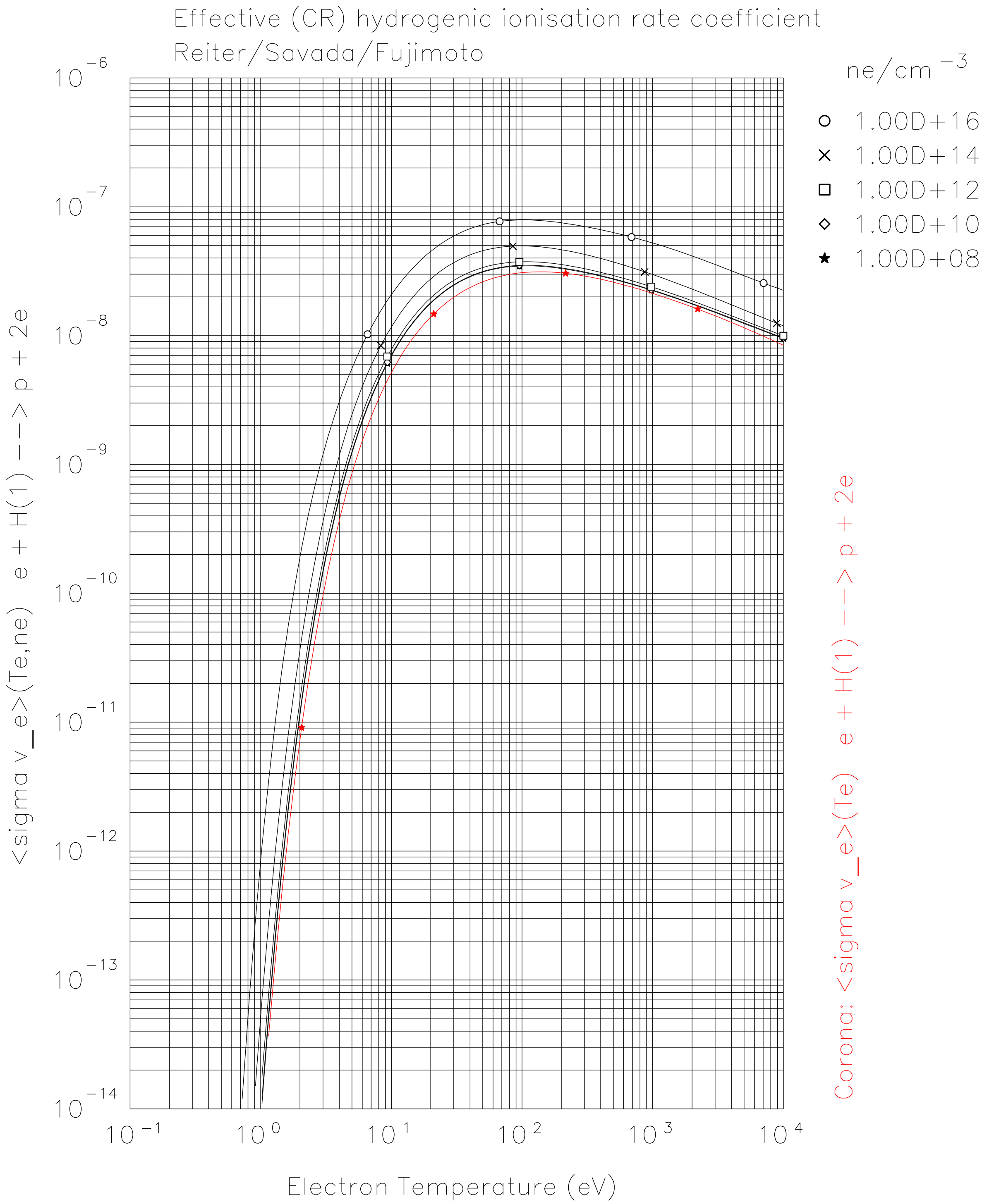
Effective hydrogenic ionization rate Data: K. Sawada/T. Fujimoto (redone: 2016, extend Te range of fit validity from 0.1 – 1e3 to 0.1 – 2e4 eV) [7]

```
      E-Index:     0                    1                    2
  T-Index:
        0    -3.248025330340D+01   -5.440669186583D-02    9.048888225109D-02
        1     1.425332391510D+01   -3.594347160760D-02   -2.014729121556D-02
        2    -6.632235026785D+00    9.255558353174D-02   -5.580210154625D-03
        3     2.059544135448D+00   -7.562462086943D-02    1.519595967433D-02
        4    -4.425370331410D-01    2.882634019199D-02   -7.285771485050D-03
        5     6.309381861496D-02   -5.788686535780D-03    1.507382955250D-03
        6    -5.620091829261D-03    6.329105568040D-04   -1.527777697951D-04
        7     2.812016578355D-04   -3.564132950345D-05    7.222726811078D-06
        8    -6.011143453374D-06    8.089651265488D-07   -1.186212683668D-07

      E-Index:     3                    4                    5
  T-Index:
        0    -4.054078993576D-02    8.976513750477D-03   -1.060334011186D-03
        1     1.039773615730D-02   -1.771792153042D-03    1.237467264294D-04
        2    -5.902218748238D-03    1.295609806553D-03   -1.056721622588D-04
        3     5.803498098354D-04   -3.527285012725D-04    3.201533740322D-05
        4     4.643389885987D-04    1.145700685235D-06    8.493662724988D-07
        5    -1.201550548662D-04    6.574487543511D-06   -9.678782818849D-07
        6     8.270124691336D-06    3.224101773605D-08    4.377402649057D-08
        7     1.433018694347D-07   -1.097431215601D-07    7.789031791949D-09
        8    -2.381080756307D-08    6.271173694534D-09   -5.483010244930D-10

      E-Index:     6                    7                    8
  T-Index:
        0     6.846238436472D-05   -2.242955329604D-06    2.890437688072D-08
        1    -3.130184159149D-06   -3.051994601527D-08    1.888148175469D-09
        2     4.646310029498D-06   -1.479612391848D-07    2.852251258320D-09
        3    -1.835196889733D-06    9.474014343303D-08   -2.342505583774D-09
        4    -1.001032516512D-08   -1.476839184318D-08    6.047700368169D-10
        5     5.176265845225D-08    1.291551676860D-09   -9.685157340473D-11
        6    -2.622921686955D-09   -2.259663431436D-10    1.161438990709D-11
        7    -4.197728680251D-10    3.032260338723D-11   -8.911076930014D-13
        8     3.064611702159D-11   -1.355903284487D-12    2.935080031599D-14
T1MIN =   0.10000D 00 EV
T1MAX =   2.00000D 04 EV
N2MIN =   1.00000D 08 1/CM3
N2MAX =   1.00000D 16 1/CM3

  Max. rel. Error:   1.98 %
  Mean rel. Error:   0.479 %
```



Effective (CR) hydrogenic ionisation rate coefficient
Reiter/Savada/Fujimoto
ne/cm^-3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08
<sigma v_e>(Te,ne) e + H(1) --> p + 2e
Corona: <sigma v_e>(Te) e + H(1) --> p + 2e
Electron Temperature (eV)
10^-6
10^-7
10^-8
10^-9
10^-10
10^-11
10^-12
10^-13
10^-14
10^-1
10^0
10^1
10^2
10^3
10^4

4.4 Reaction 2.1.8JH $H^+ + e \rightarrow H(1s)$

Effective hydrogenic recombination rate Data: L.C.Johnson, radiative + three-body contribution, Report: Mahn, Welge, IPP, [4]

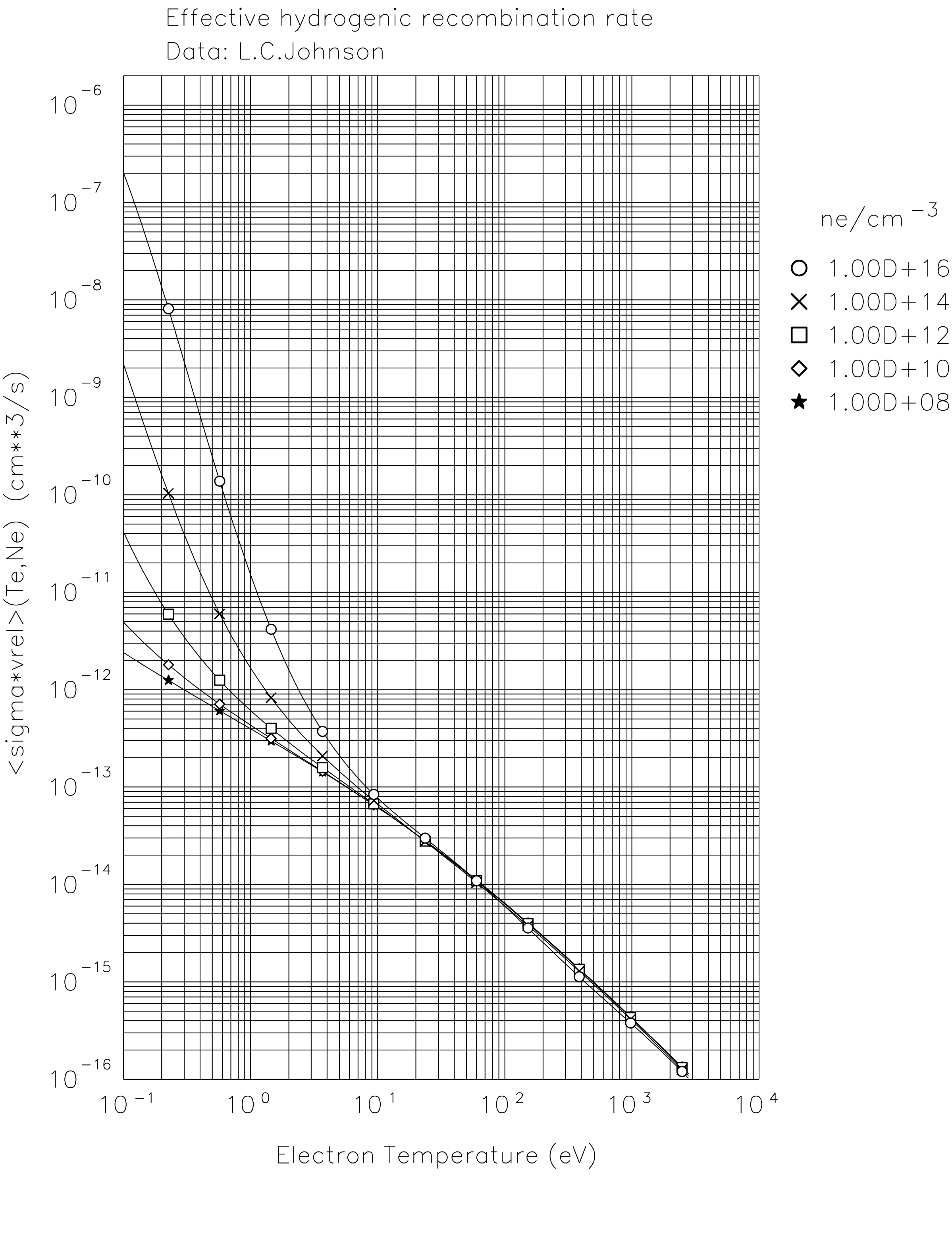
T-Index \ E-Index:	0	1	2
0	-2.855728479302D+01	3.488563234375D-02	-2.799644392058D-02
1	-7.664042607917D-01	-3.583233366133D-03	-7.452514292790D-03
2	-4.930424003280D-03	-3.620245352252D-03	6.958711963182D-03
3	-5.386830982777D-03	-9.532840484460D-04	4.631753807534D-04
4	-1.626039237665D-04	1.888048628708D-04	1.288577690147D-04
5	6.080907650243D-06	-1.014890683861D-05	-1.145028889459D-04
6	2.101102051942D-05	2.245676563601D-05	-2.245624273814D-06
7	-2.770717597683D-06	-4.695982369246D-06	3.250878872873D-06
8	1.038235939800D-07	2.523166611507D-07	-2.145390398476D-07

T-Index \ E-Index:	3	4	5
0	1.209545317879D-02	-2.436630799820D-03	2.837893719800D-04
1	2.709299760454D-03	-7.745129766167D-04	1.142444698207D-04
2	-2.139257298118D-03	4.603883706734D-04	-5.991636837395D-05
3	-5.371179699661D-04	1.543350502150D-04	-2.257565836876D-05
4	-1.634580516353D-05	-9.601036952725D-06	3.425262385387D-06
5	5.942193980802D-05	-1.211851723717D-05	1.118965496365D-06
6	-2.944873763540D-06	1.002105099354D-06	-1.291320799814D-07
7	-9.387290785993D-07	1.392391630459D-07	-1.139093288575D-08
8	7.381435237585D-08	-1.299713684966D-08	1.265189576423D-09

T-Index \ E-Index:	6	7	8
0	-1.886511169084D-05	6.752155602894D-07	-1.005893858779D-08
1	-9.382783518064D-06	3.902800099653D-07	-6.387411585521D-09
2	4.729262545726D-06	-1.993485395689D-07	3.352589865190D-09
3	1.730782954588D-06	-6.618240780594D-08	1.013364275013D-09
4	-4.077019941998D-07	2.042041097083D-08	-3.707977721109D-10
5	-4.275321573501D-08	3.708616111085D-10	7.068450112690D-12
6	7.786155463269D-09	-2.441127783437D-10	3.773208484020D-12
7	5.178505597480D-10	-9.452402157390D-12	-4.672724022059D-14
8	-6.854203970018D-11	1.836615031798D-12	-1.640492364811D-14

```
N2MIN =   1.00000D 08 1/CM3
N2MAX =   1.00000D 16 1/CM3

  Max. rel. Error:   6.8962 %
  Mean rel. Error:    .5559 %
```



Effective hydrogenic recombination rate
Data: L.C.Johnson
<sigma*vrel>(Te,Ne) (cm**3/s)
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

4.5 Reaction 2.1.8o $H^+ + e \rightarrow H(1s)$ Ly-opaque

Effective hydrogenic recombination rate Data: L.C.Johnson, radiative + three-body contribution all Lyman lines opaque, i.e. no radiative transition to ground state. Report: Mahn, Welge, IPP, [4]

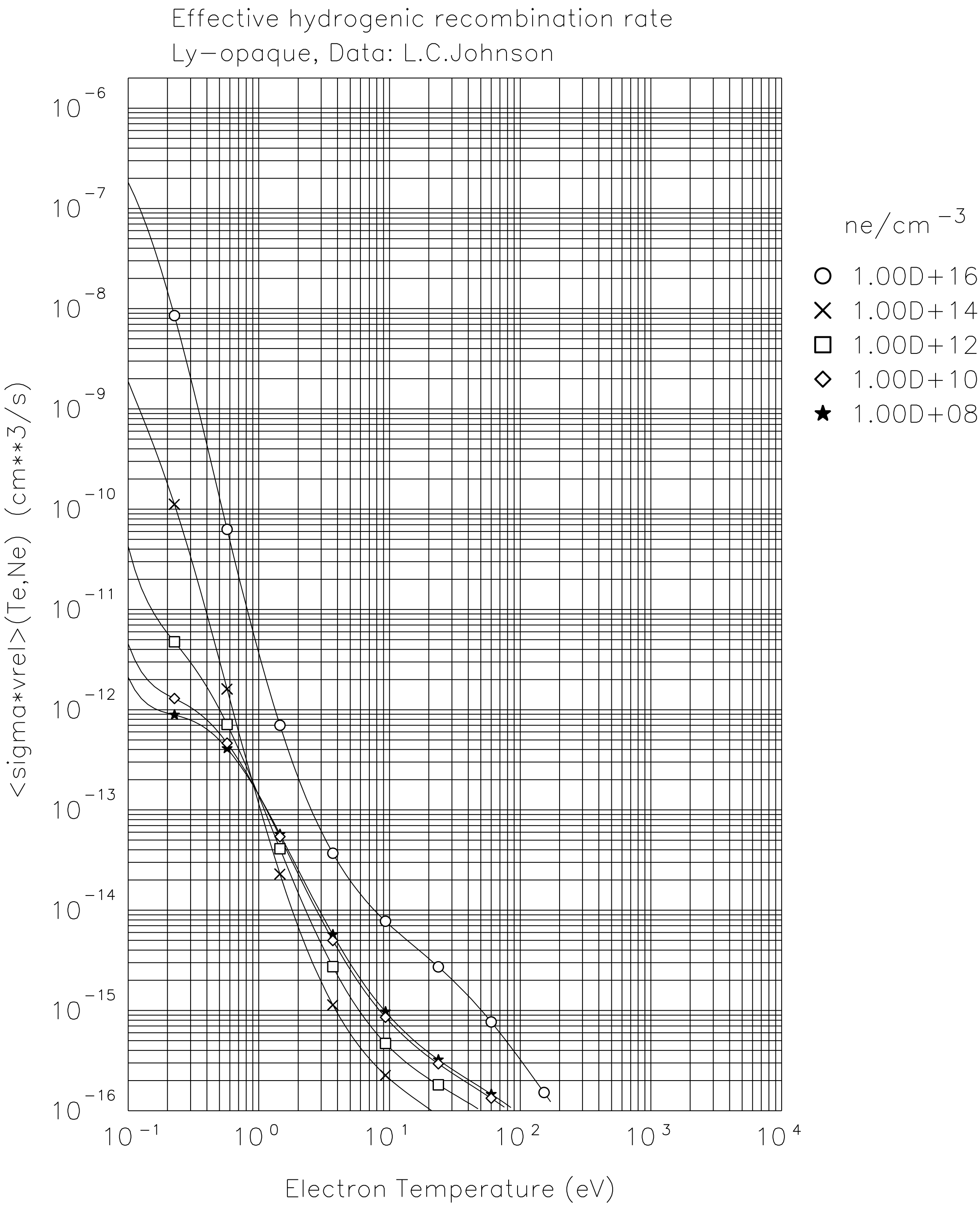
T-Index \ E-Index:	0	1	2
0	-2.959696621207D+01	-2.370057688281D-01	2.485234780243D-01
1	-2.261509350573D+00	-3.916834765592D-01	4.175284638738D-01
2	-4.674937331875D-01	-5.569001933269D-03	1.424684098594D-02
3	2.507869795516D-01	2.497608379269D-02	-3.407068292654D-02
4	2.069706780864D-02	-6.227904899439D-03	7.567752788769D-03
5	-2.504106136665D-02	5.231970346733D-03	-4.961906824405D-03
6	4.740060719354D-03	-1.583429487117D-03	1.485117205295D-03
7	-3.716199599046D-04	1.790096302797D-04	-1.687816759412D-04
8	1.078074419507D-05	-6.889626133438D-06	6.523611088216D-06

T-Index \ E-Index:	3	4	5
0	-9.938245216461D-02	1.980881578608D-02	-2.122222479009D-03
1	-1.818480115491D-01	3.961587768727D-02	-4.770502751429D-03
2	-7.573368055249D-03	2.345252431484D-03	-3.903412960562D-04
3	1.848151065349D-02	-4.874151697039D-03	6.859699832287D-04
4	-3.519012590703D-03	7.900468003264D-04	-9.404610318098D-05
5	1.530766046402D-03	-1.980846746944D-04	7.679462128899D-06
6	-4.566472727887D-04	6.072295908223D-05	-2.912042904116D-06
7	5.315093984335D-05	-7.528931894689D-06	4.568686753692D-07
8	-2.087698447004D-06	3.070917297414D-07	-2.078805542480D-08

T-Index \ E-Index:	6	7	8
0	1.218203616198D-04	-3.464708585003D-06	3.763195232065D-08
1	3.183363649173D-04	-1.099361683574D-05	1.532076900830D-07
2	3.495619343912D-05	-1.549589929805D-06	2.649470795327D-08
3	-5.207997134901D-05	2.003342466410D-06	-3.056485646618D-08
4	5.971364301743D-06	-1.910514915873D-07	2.423960414424D-09
5	5.127742944183D-07	-5.042762997588D-08	1.117985320964D-09
6	-6.966012349475D-08	1.046266371637D-08	-2.448127591728D-10
7	-4.197741084618D-09	-6.390754230254D-10	1.836925499320D-11
8	4.554850332229D-10	1.165730429588D-11	-4.891755053806D-13

```
N2MIN =   1.00000D 08 1/CM3
N2MAX =   1.00000D 16 1/CM3

  Max. rel. Error:  21.7976 %
  Mean rel. Error:   8.2471 %
```


Effective hydrogenic recombination rate
Ly−opaque, Data: L.C.Johnson
<sigma*vrel>(Te,Ne) (cm**3/s)
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

4.6 Reaction 2.1.8 $H^{+} + e \rightarrow H(1s)$

Effective hydrogenic recombination rate Data: K. Sawada, T.Fujimoto, radiative + three-body contribution, [7] June17: Fit range extended from 0.1 – 1e3 to 0.1 – 2e4

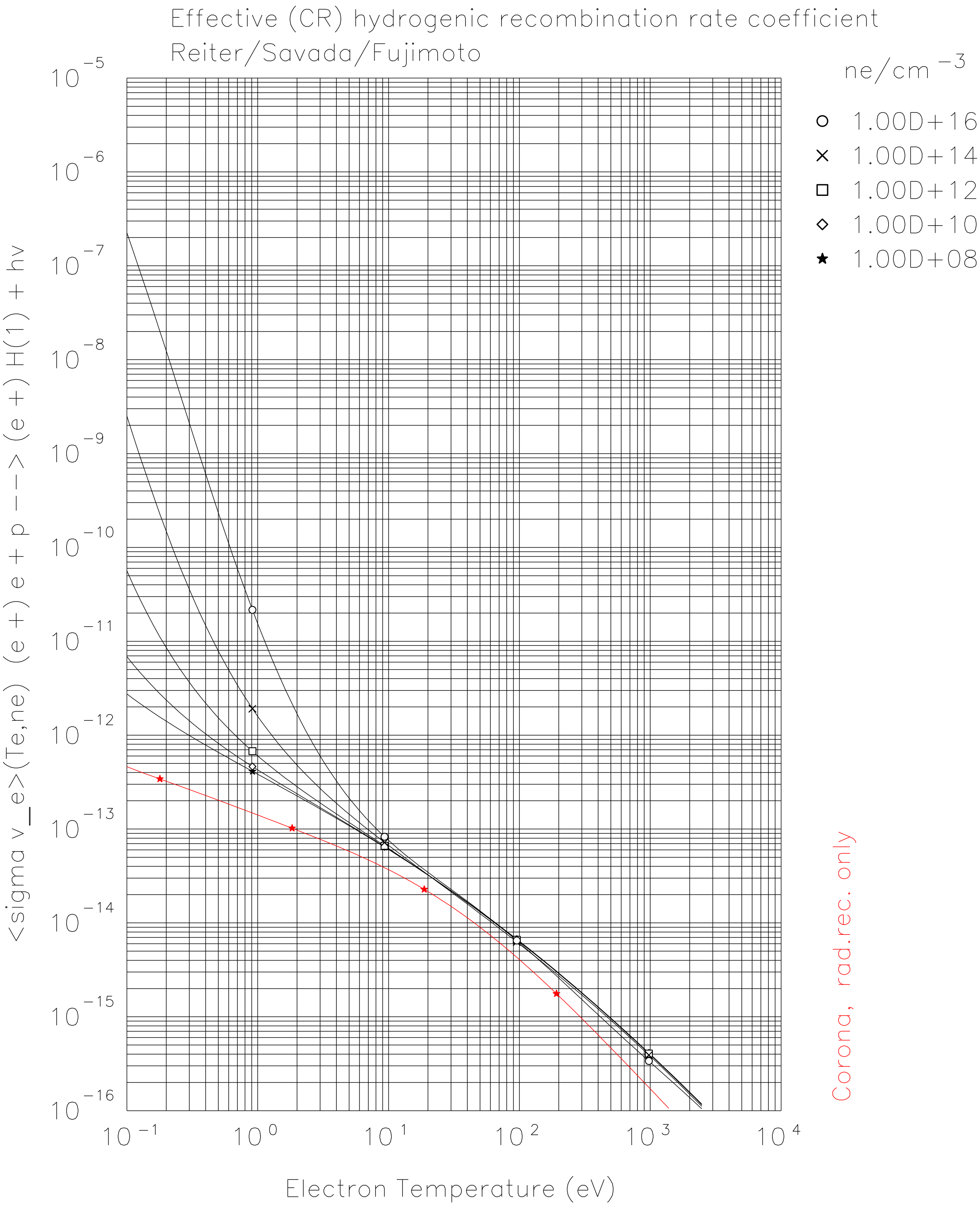
T-Index \ E-Index:	0	1	2
0	-2.858858570847D+01	2.068671746773D-02	-7.868331504755D-03
1	-7.676413320499D-01	1.278006032590D-02	-1.870326896978D-02
2	2.823851790251D-03	-1.907812518731D-03	1.121251125171D-02
3	-1.062884273731D-02	-1.010719783828D-02	4.208412930611D-03
4	1.582701550903D-03	2.794099401979D-03	-2.024796037098D-03
5	-1.938012790522D-04	2.148453735781D-04	3.393285358049D-05
6	6.041794354114D-06	-1.421502819671D-04	6.143879076080D-05
7	1.742316850715D-06	1.595051038326D-05	-7.858419208668D-06
8	-1.384927774988D-07	-5.664673433879D-07	2.886857762387D-07

T-Index \ E-Index:	3	4	5
0	3.843362133859D-03	-7.411492158905D-04	9.273687892997D-05
1	3.828555048890D-03	-3.627770385335D-04	4.401007253801D-07
2	-3.711328186517D-03	6.617485083301D-04	-6.860774445002D-05
3	-1.005744410540D-03	1.013652422369D-04	-2.044691594727D-06
4	6.250304936976D-04	-9.224891301052D-05	7.546853961575D-06
5	-3.746423753955D-05	7.509176112468D-06	-8.688365258514D-07
6	-1.232549226121D-05	1.394562183496D-06	-6.434833988001D-08
7	1.774935420144D-06	-2.187584251561D-07	1.327090702659D-08
8	-6.591743182569D-08	8.008790343319D-09	-4.805837071646D-10

T-Index \ E-Index:	6	7	8
0	-7.063529824805D-06	3.026539277057D-07	-5.373940838104D-09
1	1.932701779173D-06	-1.176872895577D-07	2.215851843121D-09
2	4.508046989099D-06	-1.723423509284D-07	2.805361431741D-09
3	-4.431181498017D-07	3.457903389784D-08	-7.374639775683D-10
4	-3.682709551169D-07	1.035928615391D-08	-1.325312585168D-10
5	7.144767938783D-08	-3.367897014044D-09	6.250111099227D-11
6	-2.746804724917D-09	3.564291012995D-10	-8.551708197610D-12
7	-1.386720240985D-10	-1.946206688519D-11	5.745422385081D-13
8	6.459706573699D-12	5.510729582791D-13	-1.680871303639D-14

```
T1MIN =   0.10000D 00 EV
T1MAX =   2.00000D 04 EV
N2MIN =   1.00000D 08 1/CM3
N2MAX =   1.00000D 16 1/CM3

  Max. rel. Error:   0.931E+01 %
  Mean rel. Error:   0.745E+00 %
```



Effective (CR) hydrogenic recombination rate coefficient
Reiter/Savada/Fujimoto
ne/cm $^{-3}$
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08
<sigma v_e>(Te,ne) (e+) e + p --> (e+) H(1) + hv
Corona, rad.rec. only
Electron Temperature (eV)

4.7 Reaction 2.1.8a $H^+ + e \rightarrow H(1s) + hv$

Effective hydrogenic recombination rate coefficient, cm^3/s
Data: L.C.Johnson, radiative contribution only Report: Mahn, Welge, IPP, [4]

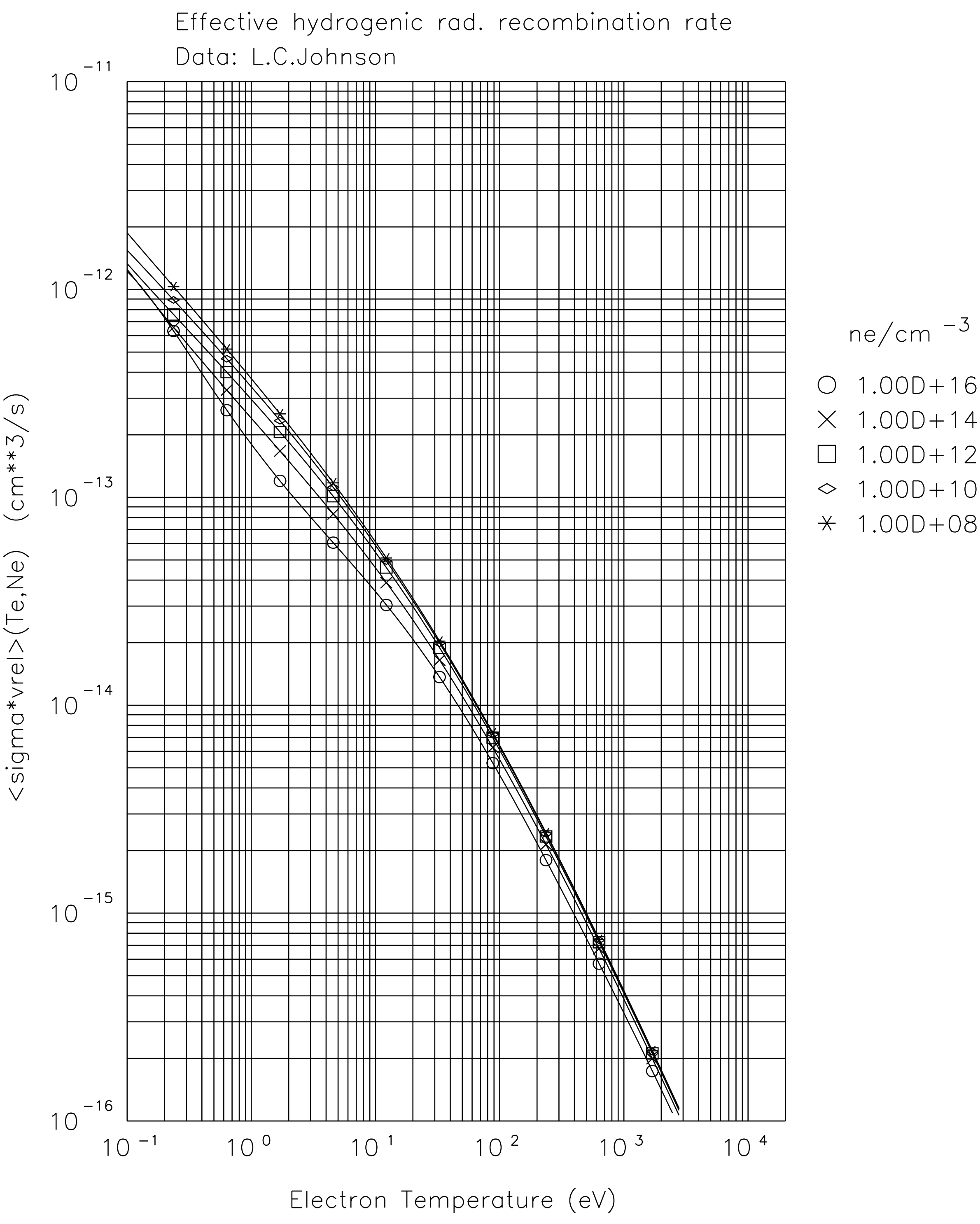
T-Index \ E-Index:	0	1	2
0	-2.861779556590D+01	-1.786166918005D-02	6.391553337864D-04
1	-7.251997071478D-01	3.210966054964D-03	4.550251497787D-03
2	-1.735023322687D-02	-3.112517426840D-03	1.077863345492D-03
3	-3.557752804131D-03	1.558966107388D-03	-1.037331531958D-03
4	-2.777882255016D-04	-9.329932857673D-05	1.096331766957D-04
5	2.060295404466D-05	-1.283711654633D-04	7.312311894769D-05
6	1.593238392469D-05	3.705503401064D-05	-2.407235857913D-05
7	-2.116580756634D-06	-3.854172456142D-06	2.662392026941D-06
8	7.665990100168D-08	1.400789118322D-07	-1.008951470934D-07

T-Index \ E-Index:	3	4	5
0	-4.509415260040D-04	7.095459017274D-05	-5.660309928918D-06
1	-1.882306456891D-03	3.983133042462D-04	-4.851835293564D-05
2	-2.616958968739D-04	5.459332810644D-05	-8.635308675130D-06
3	2.817237174744D-04	-4.407815167942D-05	4.646017350681D-06
4	-4.567488387292D-05	8.495787235165D-06	-7.261076273040D-07
5	-1.064805149480D-05	-1.498776433806D-07	1.199087596048D-07
6	4.915213917257D-06	-3.346609397503D-07	-4.912753691671D-09
7	-6.120846201882D-07	5.663728215333D-08	-1.474221162308D-09
8	2.495214914834D-08	-2.678484130657D-09	1.170138331019D-10

T-Index \ E-Index:	6	7	8
0	1.160186631232D-07	7.564986067995D-09	-2.969815025786D-10
1	3.404834497087D-06	-1.280839994482D-07	1.982839967575D-09
2	8.383106368091D-07	-4.133352004945D-08	7.872491728981D-10
3	-3.365654551356D-07	1.428350791171D-08	-2.522153346435D-10
4	2.326992940046D-08	2.208089550616D-10	-1.989979386039D-11
5	-5.668079133507D-09	-1.018554043516D-10	7.766578964142D-12
6	1.302393677822D-09	-3.169013613822D-11	-1.783762758524D-13
7	-7.373095178045D-11	4.314457229158D-12	-4.791677504810D-14
8	-1.588254701759D-13	-1.226345218681D-13	2.329402447113D-15

N2MIN = 1.00000D 08 1/CM3
N2MAX = 1.00000D 16 1/CM3

Max. rel. Error: 2.5215 %
Mean rel. Error: 0.1955 %



Effective hydrogenic rad. recombination rate
Data: L.C.Johnson
ne/cm -3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08
<sigma*vrel>(Te,Ne) (cm**3/s)
Electron Temperature (eV)

4.8 Reaction 2.1.8b $H^+ + e + e \rightarrow H(1s) + e$

Effective hydrogenic recombination rate coefficient, cm^3/s, i.e. one of the two electron density factors is already included.
Data: L.C.Johnson, three-body contribution only Report: Mahn, Welge, IPP, [4]

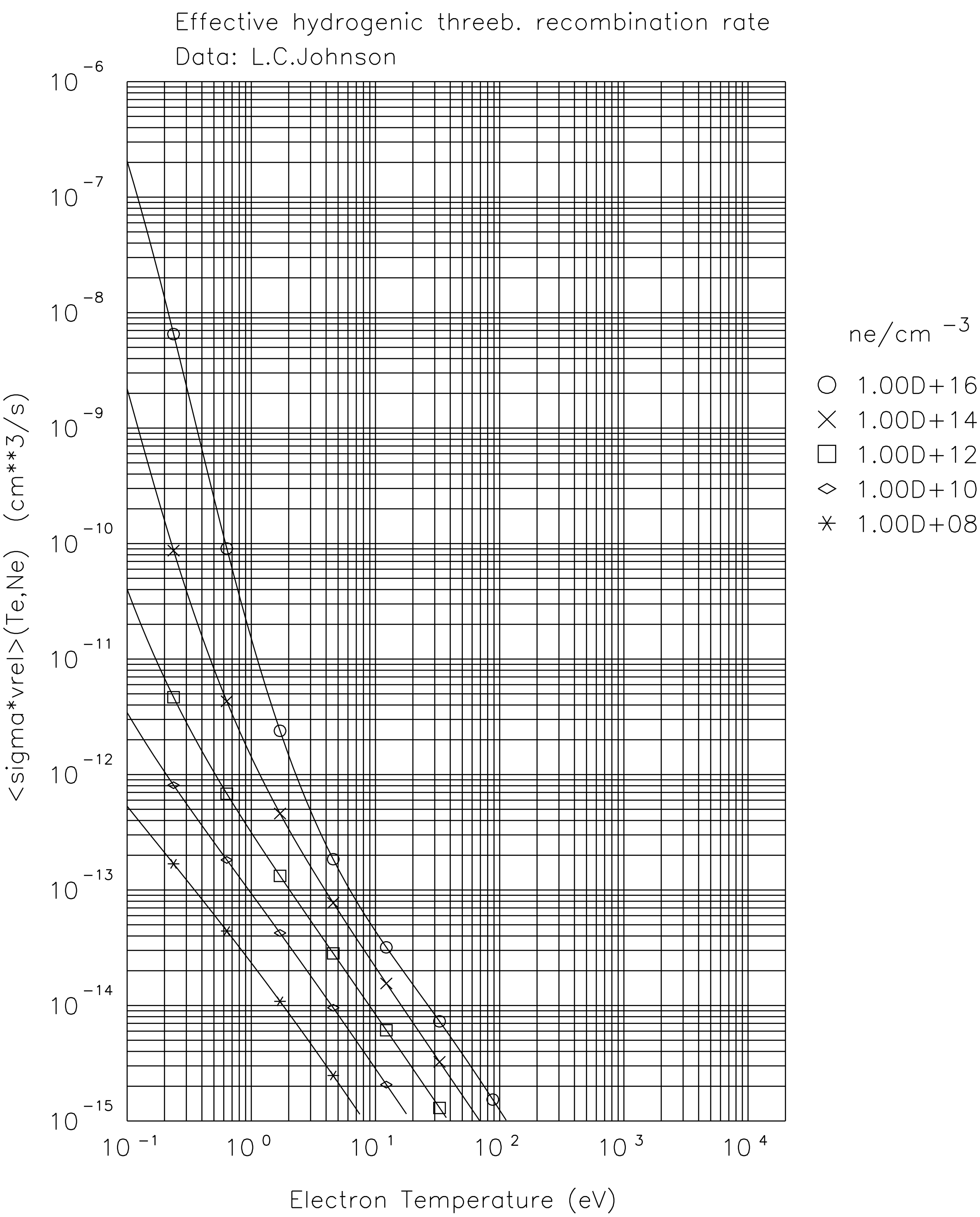
T-Index \ E-Index:	0	1	2
0	-3.138669506796D+01	2.558074094965D-01	7.547564538159D-02
1	-1.417925704352D+00	-1.066708008069D-01	8.912699543671D-02
2	-3.966595205668D-02	1.064506076088D-01	-9.185507688379D-02
3	-2.739310162323D-03	1.071195586887D-02	-1.158499493255D-02
4	1.342474842019D-03	-1.404239147230D-02	1.282799910712D-02
5	-3.784959334108D-05	2.130406018949D-03	-1.795433974878D-03
6	-2.481473746256D-05	-2.906534460063D-05	4.381082887635D-07
7	3.022022778586D-06	-1.227016198396D-05	1.250237920569D-05
8	-1.059584647842D-07	5.895982135096D-07	-5.420516699864D-07

T-Index \ E-Index:	3	4	5
0	-3.195165302392D-02	5.993840007093D-03	-6.049665420516D-04
1	-3.076861794558D-02	5.170778601878D-03	-4.681886539105D-04
2	3.233942643372D-02	-5.730070151158D-03	5.639470554955D-04
3	4.028223463613D-03	-6.775275129877D-04	5.927342203251D-05
4	-4.343906483582D-03	7.330672175437D-04	-6.737562862785D-05
5	5.739582951694D-04	-9.301568592793D-05	8.339289670874D-06
6	4.646781534504D-06	-9.443082582766D-07	4.567269449835D-08
7	-4.231117608526D-06	6.309570737001D-07	-4.235798707450D-08
8	1.668808712577D-07	-2.180052385585D-08	1.047870711900D-09

T-Index \ E-Index:	6	7	8
0	3.390872601321D-05	-9.817548467947D-07	1.135964925849D-08
1	2.260490762610D-05	-5.312960958760D-07	4.417913806532D-09
2	-3.105931750375D-05	8.954284624235D-07	-1.053605286933D-08
3	-2.695731962799D-06	5.604944938198D-08	-3.081951853519D-10
4	3.406464134420D-06	-8.840559993869D-08	9.088416616843D-10
5	-4.195355464733D-07	1.130977058144D-08	-1.314879735454D-10
6	3.574490849965D-09	-4.342693823216D-10	1.186584611296D-11
7	7.775072659869D-10	4.164660123508D-11	-1.575223043337D-12
8	2.251635634963D-11	-3.743444984134D-12	9.336979510479D-14

```
N2MIN =   1.00000D 08 1/CM3
N2MAX =   1.00000D 16 1/CM3

 Max. rel. Error:   6.0738 %
 Mean rel. Error:   0.8731 %
```



Effective hydrogenic threeb. recombination rate
Data: L.C.Johnson
<sigma*vrel>(Te,Ne) (cm**3/s)
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

4.9 Reaction 2.2.5 $e + H_2 \rightarrow e + H + H$

H2 multi-step model
Data: K. Sawada/Fujimoto ,[7]
coupling to reservoir of $H(1), H_2, H_2^+, H^+$ ("transported" species)
H_2 is in vibrational ground state $v = 0$, and the electronic levels in the molecules as discussed in [7] are taken into account.

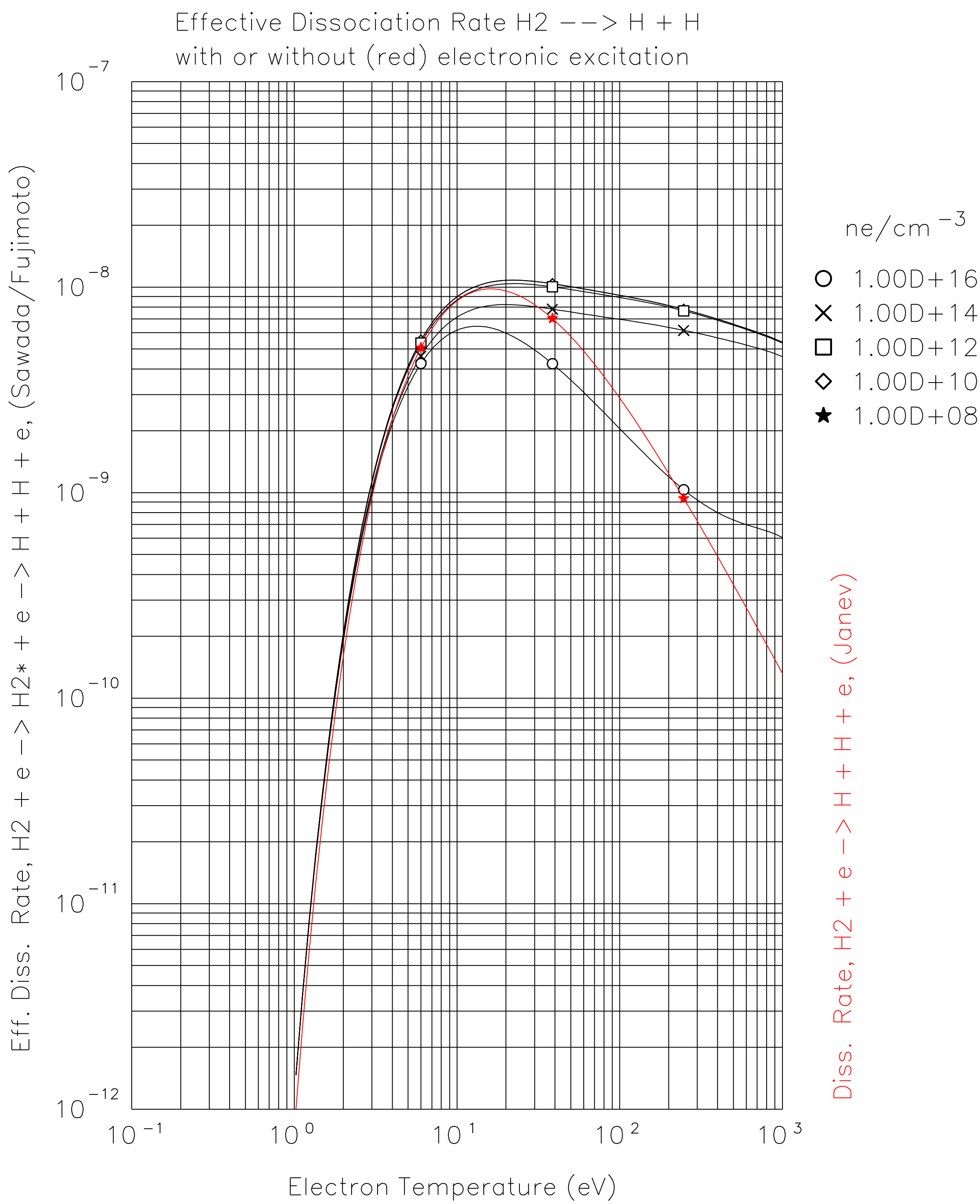
T-Index \ E-Index:	0	1	2
0	-2.748251723699D+01	5.245554722385D-04	-2.978103958861D-04
1	1.032713102402D+01	-4.288853521030D-04	-4.899568733097D-04
2	-5.042872981718D+00	2.836621770958D-03	-3.043912367565D-03
3	1.608638174175D+00	-1.261120000328D-03	1.887422712154D-03
4	-4.314430346833D-01	-8.545622758573D-04	7.288308305238D-04
5	9.436567726730D-02	3.330555462733D-04	-3.941114594575D-04
6	-1.384992697339D-02	5.154637596963D-06	2.704571960637D-05
7	1.132016190295D-03	-1.288164830284D-05	7.769128981290D-06
8	-3.842014088368D-05	1.171737695451D-06	-9.017007769431D-07

T-Index \ E-Index:	3	4	5
0	-2.360275829176D-07	2.352410977770D-05	-4.997866180134D-06
1	4.986004995584D-04	-1.488915435909D-04	2.064670043755D-05
2	1.292894496252D-03	-2.905449411133D-04	3.788502709678D-05
3	-9.327238099803D-04	2.128634474527D-04	-2.509788157193D-05
4	-2.484715070595D-04	4.842155320136D-05	-6.186008058267D-06
5	1.711527657525D-04	-3.637820737985D-05	4.163286478680D-06
6	-2.084393307530D-05	5.401855723043D-06	-6.247464789742D-07
7	-1.221455182210D-06	-3.231445161484D-09	9.993216378891D-09
8	2.476534052706D-07	-3.367686347533D-08	2.869160964443D-09

T-Index \ E-Index:	6	7	8
0	4.276219304407D-07	-1.656742885479D-08	2.414039859152D-10
1	-1.483657661440D-06	5.231689914639D-08	-7.056262049968D-10
2	-2.892758625724D-06	1.174418148176D-07	-1.927933996765D-09
3	1.553010173585D-06	-4.703323705313D-08	5.371568383284D-10
4	5.102144895277D-07	-2.321199392340D-08	4.255457918971D-10
5	-2.597547413556D-07	8.256194712004D-09	-1.040875802194D-10
6	3.214084295485D-08	-5.485492350310D-10	-2.766340477990D-12
7	1.346287938920D-10	-7.497501425175D-11	2.502198014796D-12
8	-1.931319268617D-10	9.102276313210D-12	-1.872646131609D-13

```
N2MIN =   1.00000D 08 1/CM3
N2MAX =   1.00000D 16 1/CM3

 Max. rel. Error:   1.7118 %
 Mean rel. Error:   0.4517 %
```


Effective Dissociation Rate H2 --> H + H
with or without (red) electronic excitation
Eff. Diss. Rate, H2 + e -> H2* + e -> H + H + e, (Sawada/Fujimoto)
Diss. Rate, H2 + e -> H + H + e, (Janev)
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

4.10 Reaction 2.2.5g $e + H_2 \rightarrow e + H + H$

H2 multi-step model, data: Sawada/Fujimoto/Greenland. $H(1), H_2, H_2^+, H^+$ transported (slow species). The $H_2(v)$ are in vibrational equilibrium (depends only upon T_e), and the electronic levels in the molecules as discussed in [7] are taken into account. CX losses from vibr. distribution are computed assuming $T_e = T_i$, $n_e = n_p$, and an energy of H_2-Beam = 0.1 eV.

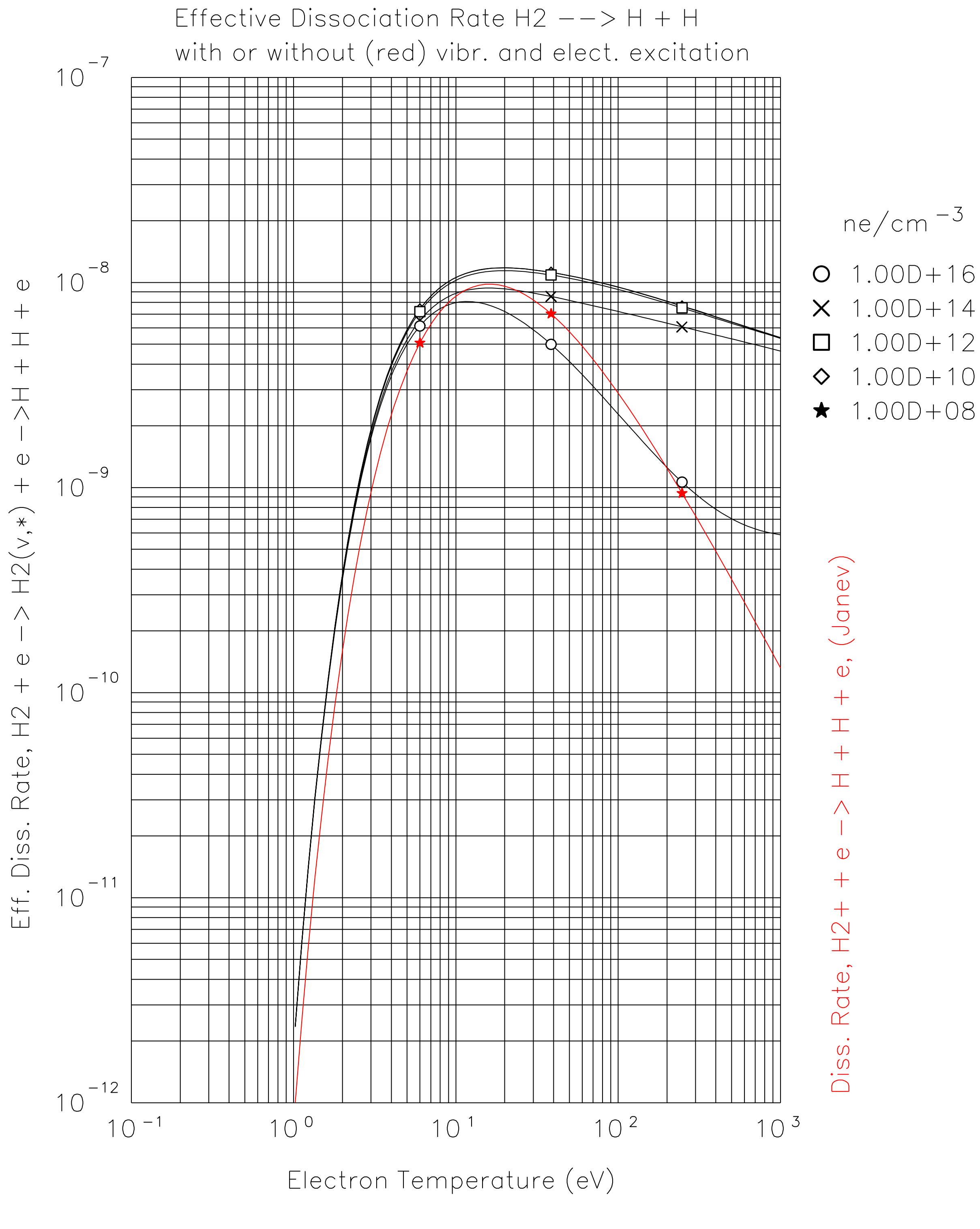
T-Index \ E-Index	0	1	2
0	-2.702372540584D+01	-3.152103191633D-03	5.990692171729D-03
1	1.081756417479D+01	-1.487216964825D-02	1.417396532101D-02
2	-5.368872027676D+00	5.419787589654D-03	-1.747268613395D-02
3	1.340684229143D+00	1.058157580038D-02	-3.446019122786D-03
4	-1.561644923145D-01	-3.847438570333D-03	3.571477356851D-03
5	-1.444731533894D-04	-3.194532513126D-04	-2.987368098475D-04
6	2.117693926546D-03	2.679309814780D-04	-1.037559373832D-04
7	-2.143738340207D-04	-3.539232757385D-05	1.909399233821D-05
8	6.979740947331D-06	1.462031952352D-06	-8.858634506391D-07

T-Index \ E-Index	3	4	5
0	-3.151252835426D-03	7.457309144890D-04	-9.238664007853D-05
1	-4.689911797083D-03	7.180338663163D-04	-5.502798587526D-05
2	9.532963297450D-03	-2.196705622859D-03	2.611447288152D-04
3	-7.032769815599D-04	4.427959286553D-04	-7.370484189164D-05
4	-1.103305795473D-03	1.476712517858D-04	-8.461162952132D-06
5	2.092094838648D-04	-4.339352509941D-05	4.009328699469D-06
6	7.297053580368D-06	1.454171585421D-06	-2.251616910293D-07
7	-3.819368125069D-06	3.754063159414D-07	-2.441872829462D-08
8	2.099830142707D-07	-2.606862169776D-08	2.039813579349D-09

T-Index \ E-Index	6	7	8
0	6.222557542845D-06	-2.160024578659D-07	3.028755759836D-09
1	1.983066081752D-06	-2.207639762507D-08	-2.116339335271D-10
2	-1.695536960581D-05	5.737375510694D-07	-7.940900078995D-09
3	5.746786010618D-06	-2.182085196303D-07	3.264045809897D-09
4	9.757111870171D-08	8.130014050833D-09	-2.234996157750D-10
5	-1.762651912129D-07	3.357860444624D-09	-1.857322587267D-11
6	9.191700327811D-09	-2.052366968228D-11	-3.567738654108D-12
7	1.437490161488D-09	-6.172308568891D-11	1.104905484620D-12
8	-1.113483084607D-10	3.859777100010D-12	-5.909099891913D-14

```
T1MIN =   0.10000D 00 EV
T1MAX =   1.00000D 03 EV
N2MIN =   1.00000D 08 1/CM3
N2MAX =   1.00000D 16 1/CM3

  Max. rel. Error:  11.6439 %
  Mean rel. Error:   2.6169 %
```


Effective Dissociation Rate H2 --> H + H
with or without (red) vibr. and elect. excitation
Eff. Diss. Rate, H2 + e -> H2(v,*) + e ->H + H + e
Diss. Rate, H2+ + e -> H + H + e, (Janev)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08
Electron Temperature (eV)
10 −7
10 −8
10 −9
10 −10
10 −11
10 −12
10 −1
10 0
10 1
10 2
10 3

4.11 Reaction 2.2.9 $e + H_2 \rightarrow 2e + H_2^+$

effective CR ionization rate, only from $v = 0$, vibrational ground state, Sawada-Fujimoto CR model, 2022: new fit, with wider Te range.

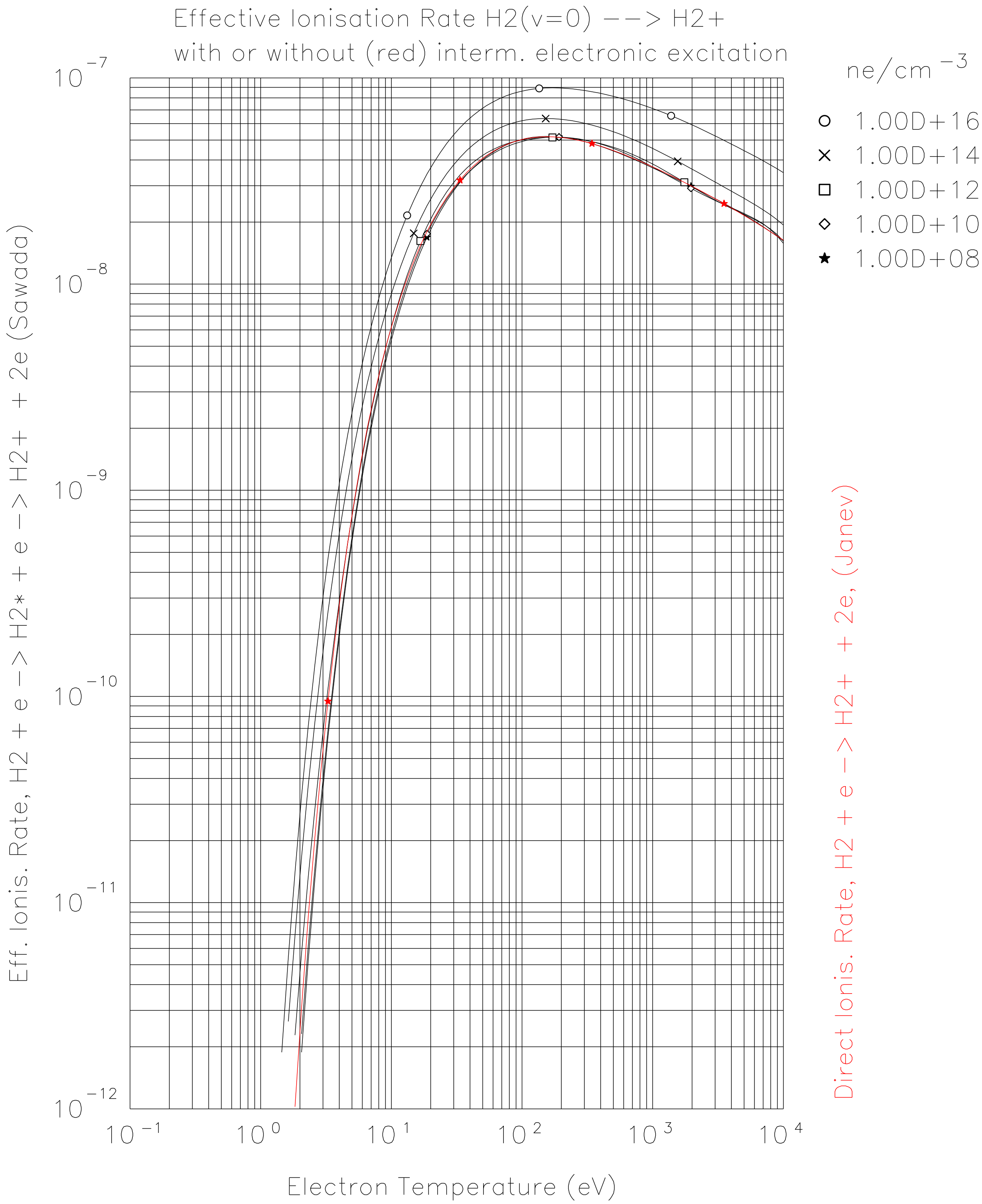
T-Index \ E-Index	0	1	2
0	-3.592236857853D+01	7.588483385936D-02	2.535474843325D-02
1	1.626726383397D+01	-8.404492944487D-02	-1.421174642841D-01
2	-6.362920375170D+00	-1.315258055169D-01	1.878685202713D-01
3	1.479278171454D+00	2.130215176332D-01	-1.491006868222D-01
4	-2.086974490197D-01	-9.320485842872D-02	5.282873945879D-02
5	1.589853265399D-02	1.715621508423D-02	-7.806212788386D-03
6	-3.763682603705D-04	-1.297026248461D-03	2.620089287801D-04
7	-2.407346768556D-05	1.523419297360D-05	3.813770677095D-05
8	1.261638023541D-06	1.646876007347D-06	-2.614554813347D-06

T-Index \ E-Index	3	4	5
0	-7.879944316854D-03	1.926947743183D-03	-1.182535914681D-04
1	6.541352964596D-02	-1.523394642974D-02	1.813412339869D-03
2	-5.439034353614D-02	7.467862942483D-03	-5.776243113392D-04
3	3.477587449149D-02	-2.605792741376D-03	-4.149275624611D-05
4	-1.231513472407D-02	8.630660535337D-04	2.661391169210D-05
5	1.910636707371D-03	-1.409241505974D-04	-2.310134017102D-06
6	-7.468644482138D-05	3.613580195483D-06	2.835872227933D-07
7	-8.616410645273D-06	1.129943262132D-06	-5.833639190048D-08
8	6.351942122828D-07	-7.512685568360D-08	3.501169476579D-09

T-Index \ E-Index	6	7	8
0	-4.401918055202D-06	5.920205216987D-07	-1.367370686834D-08
1	-1.132611574429D-04	3.564818647332D-06	-4.482392846850D-08
2	2.575990024621D-05	-6.109678848651D-07	5.798738622401D-09
3	1.500117690451D-05	-7.188689775602D-07	1.126791065389D-08
4	-5.958230464514D-06	2.598672639011D-07	-3.742067299155D-09
5	6.477466850430D-07	-2.324675686606D-08	2.266162425808D-10
6	-6.038534834392D-09	-1.496412976670D-09	5.203406469838D-11
7	-2.476499598978D-09	3.302539513585D-10	-8.012922613581D-12
8	9.089258219104D-11	-1.338587612270D-11	3.155160367434D-13

```
T1MIN =   0.10000D 00 EV
T1MAX =   1.00000D 04 EV
N2MIN =   1.00000D 08 1/CM3
N2MAX =   1.00000D 16 1/CM3

  Max. rel. Error:   0.510E+01 %
  Mean rel. Error:   0.140E+01 %
```



Effective Ionisation Rate H2(v=0) --> H2+
with or without (red) interm. electronic excitation
ne/cm -3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08
Eff. Ionis. Rate, H2 + e -> H2* + e -> H2+ + 2e (Sawada)
Direct Ionis. Rate, H2 + e -> H2+ + 2e, (Janev)
Electron Temperature (eV)

4.12 Reaction 2.2.9g $e + H_2(v) \rightarrow 2e + H_2^+$

effective H2 ionization rate, with Greenland's vibrational distribution in ground state, and Janev/Reiter scaling [18] of ionisation cross sections from vibrational states.

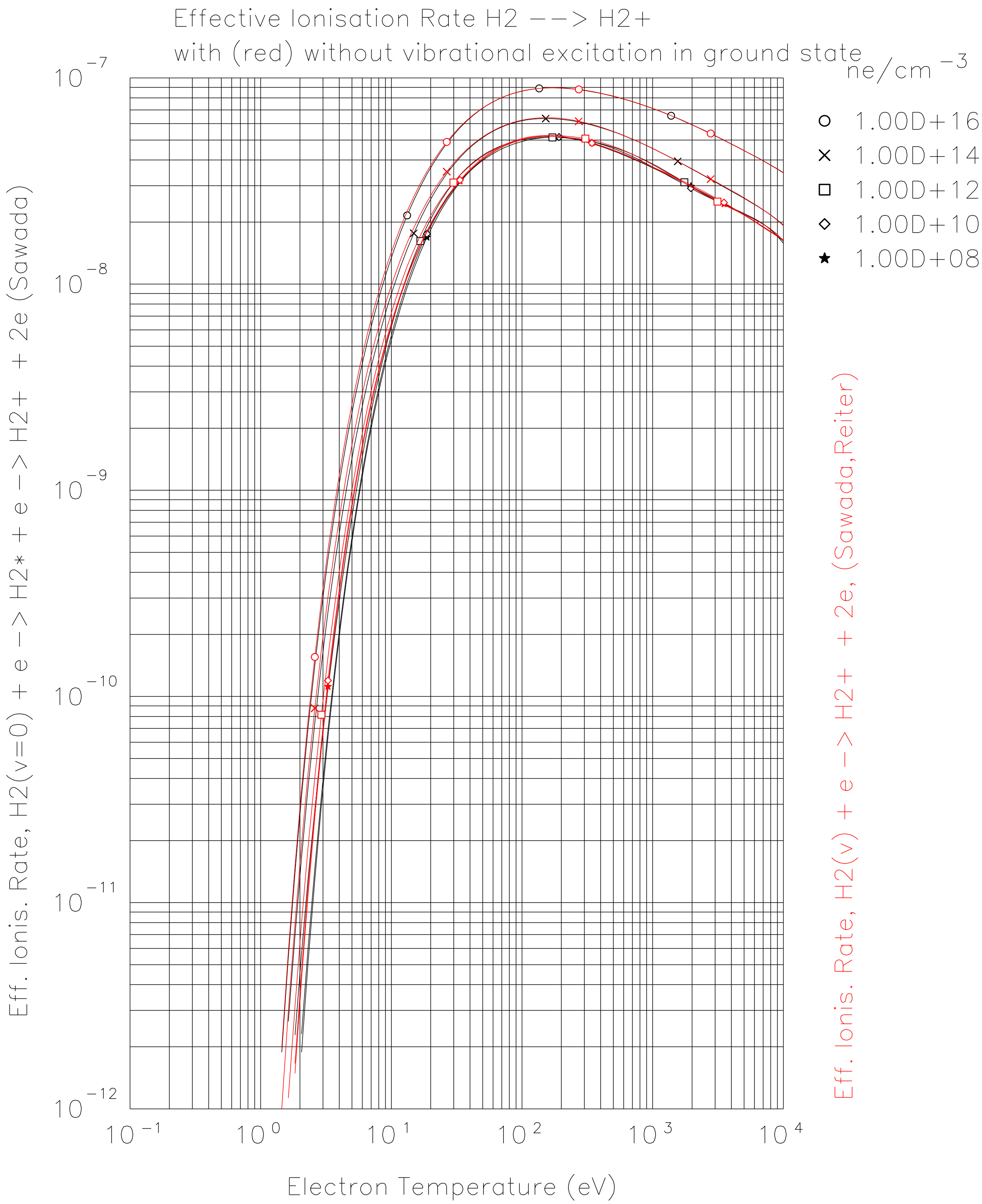
T-Index \ E-Index	0	1	2
0	-3.482395131930D+01	-9.081453174790D-02	1.123386725743D-01
1	1.615241430950D+01	-3.478039974697D-02	-9.090359886209D-02
2	-6.990857037353D+00	3.113610733366D-01	-7.345126427513D-02
3	1.902593074900D+00	-2.953107005555D-01	7.690046745718D-02
4	-3.406696127590D-01	1.310126135142D-01	-2.982850102237D-02
5	3.947146726166D-02	-3.149544561351D-02	6.242479664869D-03
6	-2.851707592241D-03	4.169603905670D-03	-7.148191827662D-04
7	1.179246477119D-04	-2.846857336975D-04	4.068968306051D-05
8	-2.166270504626D-06	7.814780479722D-06	-8.606819638940D-07

T-Index \ E-Index	3	4	5
0	-4.001034213136D-02	7.284506504256D-03	-5.946088693634D-04
1	5.188751204891D-02	-1.354848343652D-02	1.650718967014D-03
2	2.588410789884D-03	2.938995819769D-03	-6.078722815238D-04
3	-9.177751798153D-03	4.058265985369D-04	7.424555321833D-05
4	2.425686291567D-03	-2.057287369018D-04	9.490287400767D-06
5	-1.488381460029D-04	5.981072606708D-06	-3.551768998710D-06
6	-3.742531313780D-05	7.657247101042D-06	6.290116557953D-08
7	6.869294984747D-06	-1.285621323676D-06	5.549155691196D-08
8	-3.260679014349D-07	6.171939737475D-08	-3.961768240505D-09

T-Index \ E-Index	6	7	8
0	1.940783625677D-05	-4.236706611614D-08	-6.651791542302D-09
1	-1.014229889636D-04	3.073163339207D-06	-3.661761766017D-08
2	5.057452455898D-05	-1.950726249785D-06	2.883329278528D-08
3	-1.258128746046D-05	6.852294183262D-07	-1.273678573730D-08
4	1.154972739661D-06	-1.235090485408D-07	2.997083874888D-09
5	1.358046278978D-07	7.646079458368D-09	-3.425560628958D-10
6	-2.556355171781D-08	1.731973672568D-10	1.924792718762D-11
7	-2.766754063511D-10	2.654501140771D-12	-9.096387425722D-13
8	1.227483507349D-10	-2.676524607095D-12	4.586864171705D-14

```
N2MIN =   1.00000D 08 1/CM3
N2MAX =   1.00000D 16 1/CM3
T1MIN =   0.10000D 00 EV
T1MAX =   1.00000D 04 EV

  Max. rel. Error:   0.543E+01 %
  Mean rel. Error:   0.132E+01 %
```



Effective Ionisation Rate H2 --> H2+
with (red) without vibrational excitation in ground state
ne/cm -3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08
Eff. Ionis. Rate, H2(v=0) + e -> H2* + e -> H2+ + 2e (Sawada)
Eff. Ionis. Rate, H2(v) + e -> H2+ + 2e, (Sawada,Reiter)
Electron Temperature (eV)

4.13 Reaction 2.2.10 $e + H_2 \rightarrow 2e + H + H^+$

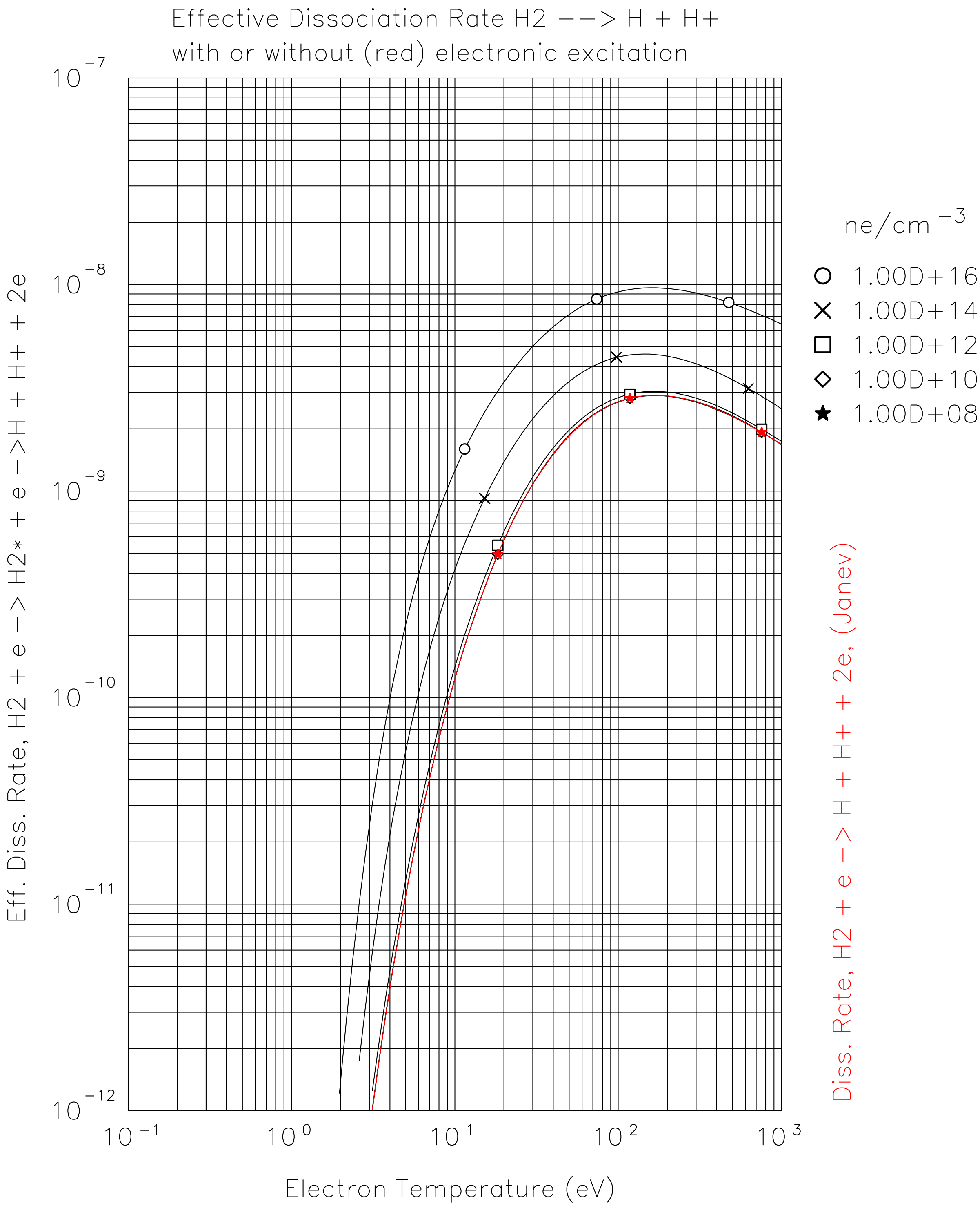
T-Index \ E-Index	0	1	2
0	-3.793749300315D+01	-3.333162972531D-01	1.849601203843D-01
1	1.280249398154D+01	1.028969438485D+00	-3.271855492638D-01
2	-3.778148553140D+00	-1.415561059533D+00	2.928509524911D-01
3	2.499987501522D-01	1.032922656537D+00	-1.580288004759D-01
4	2.480574522949D-01	-4.372934216955D-01	6.448433196301D-02
5	-9.960628182831D-02	1.092652428162D-01	-1.782307798975D-02
6	1.709129400742D-02	-1.574889001363D-02	2.865310743302D-03
7	-1.435304503973D-03	1.203823111704D-03	-2.350465388313D-04
8	4.808639828229D-05	-3.761591649539D-05	7.490531472388D-06

T-Index \ E-Index	3	4	5
0	-8.803945197107D-02	2.205180180735D-02	-2.852568161901D-03
1	1.305597441611D-01	-3.408439821910D-02	4.591924060066D-03
2	-7.425165688158D-02	2.028424685287D-02	-3.042376564749D-03
3	9.934702707539D-03	-2.450845732158D-03	5.716646876513D-04
4	1.229222932630D-03	-9.281410519553D-04	5.946235618034D-05
5	1.192181214757D-04	2.310636556641D-04	-2.492990725967D-05
6	-1.700396064727D-04	-1.502644504654D-06	3.297869416435D-07
7	2.507288189894D-05	-3.077975735212D-06	3.748299687254D-07
8	-1.077314971617D-06	1.950247963978D-07	-2.569729600929D-08

T-Index \ E-Index	6	7	8
0	1.942314738448D-04	-6.597388255594D-06	8.798544848606D-08
1	-3.167471002157D-04	1.070920193931D-05	-1.408139742113D-07
2	2.279124955373D-04	-8.197224564797D-06	1.130682076163D-07
3	-5.339115778704D-05	2.135848413694D-06	-3.072223247387D-08
4	-8.758032156912D-08	-7.270955072707D-08	1.100087131523D-09
5	1.217600444191D-06	-3.624263301602D-08	6.139167092128D-10
6	6.572135289627D-10	4.269190108005D-10	-3.666090917669D-11
7	-2.613600078122D-08	8.263175463927D-10	-8.509179497022D-12
8	1.804377780165D-09	-6.031847199601D-11	7.416020205748D-13

T1MIN =   0.05000D 00 EV
T1MAX =   1.00000D 03 EV
N2MIN =   1.00000D 08 1/CM3
N2MAX =   1.00000D 16 1/CM3

Max. rel. Error: 1.2041 %
Mean rel. Error: .4804 %



Effective Dissociation Rate H2 --> H + H+
with or without (red) electronic excitation
Eff. Diss. Rate, H2 + e -> H2* + e ->H + H+ + 2e
Diss. Rate, H2 + e -> H + H+ + 2e, (Janev)
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

4.14 Reaction 2.2.11 $e + H_2^+ \rightarrow 2e + H^+ + H^+$

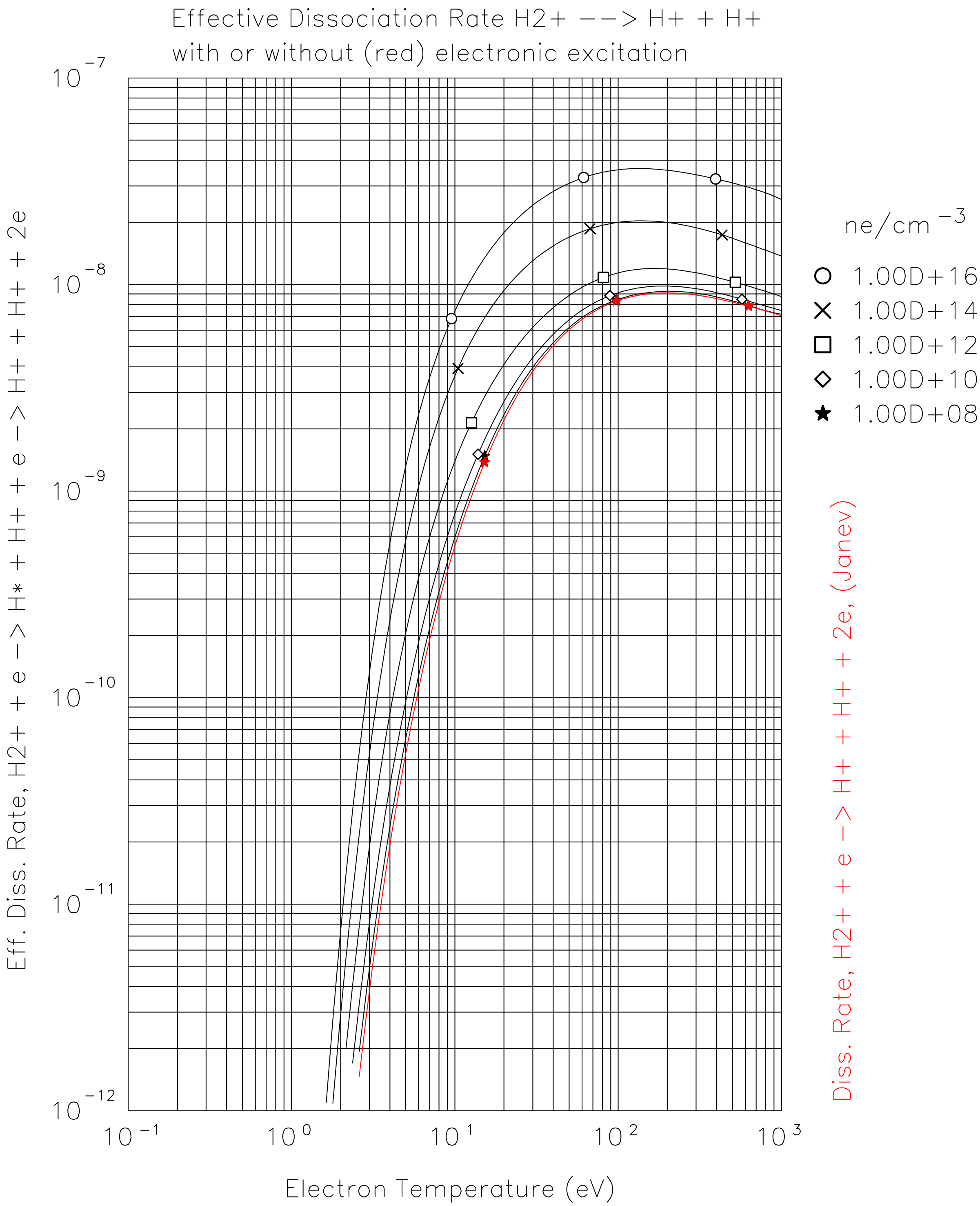
T-Index \ E-Index	0	1	2
0	-3.708803769397D+01	9.784233987341D-02	-7.200361272130D-03
1	1.561780529774D+01	-1.673256230592D-02	2.743322772895D-02
2	-6.874406034117D+00	-7.782929961315D-03	-6.888773684846D-03
3	2.010540060675D+00	-3.226785148562D-03	-6.181192193854D-03
4	-3.614768906120D-01	3.710098881765D-03	2.045814599796D-03
5	2.956861321735D-02	-5.524443504504D-04	-2.457951062112D-05
6	9.662490252868D-04	-1.548556801431D-04	1.417215042439D-05
7	-3.543571865464D-04	4.662969089421D-05	-1.471117766355D-05
8	1.827109843671D-05	-3.179895716088D-06	1.432429412413D-06

T-Index \ E-Index	3	4	5
0	6.496843022778D-03	-1.420590818760D-03	1.703620321164D-04
1	-1.026956102747D-02	1.999561527383D-03	-2.043607814503D-04
2	2.306107197863D-03	-4.029222834436D-04	3.932152471491D-05
3	2.388146990238D-03	-5.018901320009D-04	5.520233512352D-05
4	-8.523935993991D-04	1.751295192861D-04	-1.944203941844D-05
5	3.433179945503D-05	-1.450208898992D-06	-2.447566480782D-07
6	-6.444863591678D-06	-1.566028729499D-06	4.152486680818D-07
7	5.235585096328D-06	-5.779667826854D-07	2.139729421817D-08
8	-5.141065080107D-07	7.734387173369D-08	-6.163336831045D-09

T-Index \ E-Index	6	7	8
0	-1.160738946400D-05	4.148222302162D-07	-6.007853385325D-09
1	1.084177127603D-05	-2.671800995803D-07	2.093182411476D-09
2	-2.094907364150D-06	5.682907060010D-08	-6.320752545610D-10
3	-3.080798536641D-06	7.864770315002D-08	-6.357395371638D-10
4	1.138888354831D-06	-3.256303793266D-08	3.501794038444D-10
5	1.375679100044D-08	4.863880510459D-10	-3.004374374556D-11
6	-2.855068942744D-08	6.081804811000D-10	9.512865901179D-13
7	-3.656048425230D-10	3.759866326965D-11	-1.486151370215D-12
8	3.128313515842D-10	-1.061842444216D-11	1.771099769640D-13

T1MIN = 0.02 EV
N2MIN = 1.00000D 08 1/CM3
N2MAX = 1.00000D 16 1/CM3

Max. rel. Error: 1.0209 %
Mean rel. Error: 0.3164 %



Effective Dissociation Rate H2+ --> H+ + H+
with or without (red) electronic excitation
Eff. Diss. Rate, H2+ + e -> H* + H+ + e -> H+ + H+ + 2e
Diss. Rate, H2+ + e -> H+ + H+ + 2e, (Janev)
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

4.15 Reaction 2.2.12 $e + H_2^+ \rightarrow e + H + H^+$

Effective dissociative excitation of H_2^+ to H and H^+, including the component $e + H_2^+ \rightarrow H + H^* \rightarrow H + H^+$ from dissociative recombination of H_2^+ with excited products.

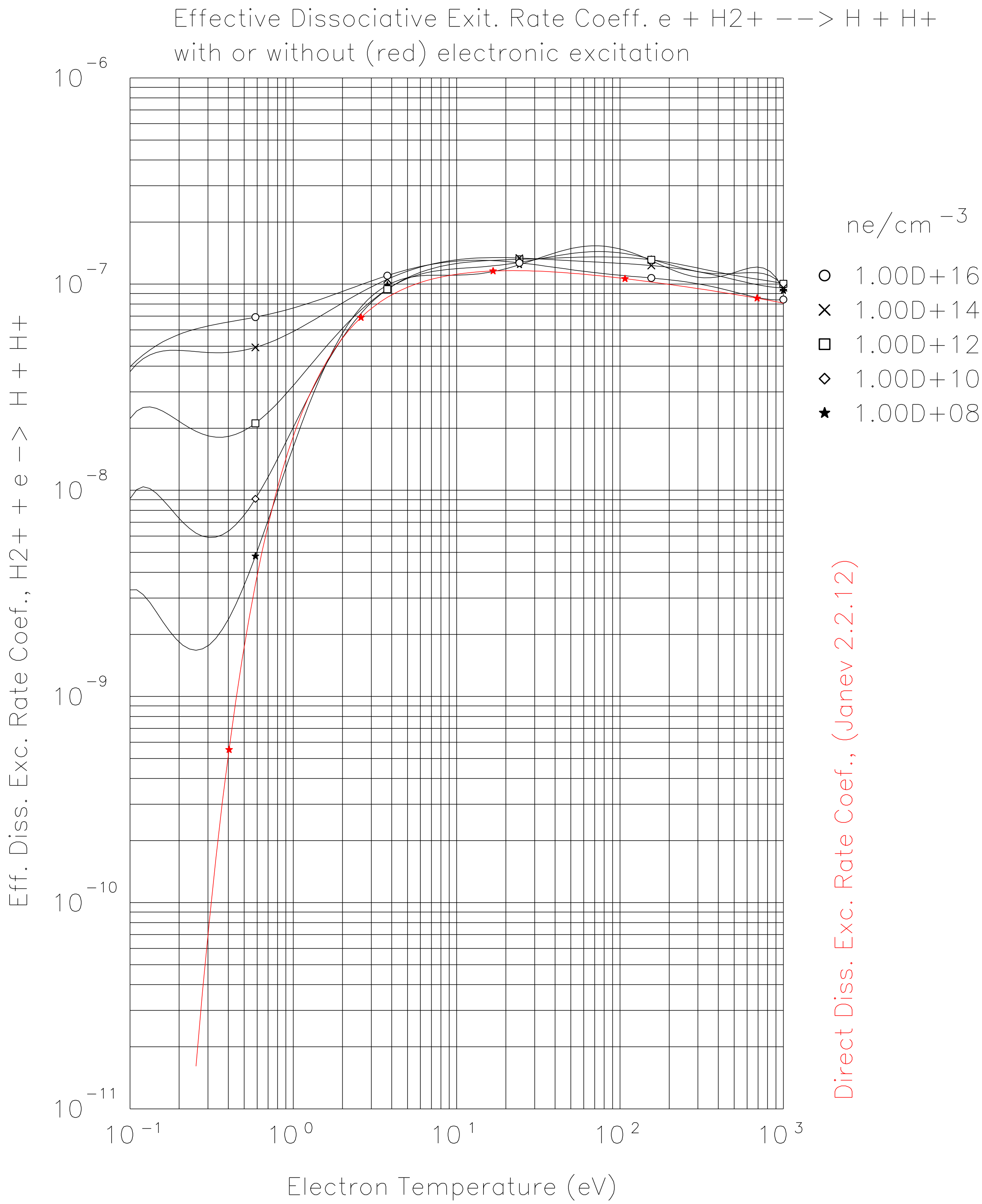
T-Index \ E-Index	0	1	2
0	-1.793443274600D+01	-4.932783688604D-02	1.039088280849D-01
1	2.236108757681D+00	-2.545406018621D-02	-1.160421006835D-01
2	-3.620018994703D-01	6.721527680150D-02	1.564387124002D-02
3	-4.353922258965D-01	-3.051033606589D-02	3.512861172521D-02
4	1.580381801957D-01	2.493654957203D-03	-1.601970998119D-02
5	1.697880687685D-02	2.106675963900D-03	4.521983358170D-04
6	-1.521914651109D-02	-7.527862162788D-04	9.095551479381D-04
7	2.406276368070D-03	9.971361856278D-05	-1.760978402353D-04
8	-1.219469579955D-04	-4.785505675232D-06	9.858840337511D-06

T-Index \ E-Index	3	4	5
0	-4.375935166008D-02	9.196691651936D-03	-1.043378648769D-03
1	4.407846563362D-02	-8.192521304984D-03	8.200277386433D-04
2	-4.939045440424D-03	4.263195867947D-04	1.034216805418D-05
3	-1.179504564265D-02	2.091772760029D-03	-1.991100044575D-04
4	5.346709597939D-03	-8.711870134835D-04	7.542066727545D-05
5	-3.017151690655D-04	6.209239389357D-05	-7.598119096817D-06
6	-2.372576223034D-04	3.018561480848D-05	-1.365255868731D-06
7	4.877659148871D-05	-6.477358351729D-06	3.541106430252D-07
8	-2.779210878533D-06	3.720379996058D-07	-2.110289928486D-08

T-Index \ E-Index	6	7	8
0	6.600342421838D-05	-2.198466460165D-06	3.004145701249D-08
1	-4.508284363534D-05	1.282824614809D-06	-1.474719350236D-08
2	-3.975028601900D-06	2.322116289258D-07	-4.381217154470D-09
3	1.018080238045D-05	-2.597941866088D-07	2.524118386011D-09
4	-3.410778344979D-06	7.120460603822D-08	-4.412295474522D-10
5	5.523273241689D-07	-2.130508249251D-08	3.319099650589D-10
6	-4.604769733903D-08	5.867910270430D-09	-1.357779142836D-10
7	1.309772899670D-09	-8.072907334230D-10	2.074669430611D-11
8	3.753875073646D-11	4.024906665497D-11	-1.075990572574D-12

```
T1MIN =   0.02         EV
N2MIN =   1.00000D 08 1/CM3
N2MAX =   1.00000D 16 1/CM3

 Max. rel. Error:  15.8263 %
 Mean rel. Error:   3.9031 %
```



Effective Dissociative Exit. Rate Coeff. e + H2+ --> H + H+
with or without (red) electronic excitation
Eff. Diss. Exc. Rate Coef., H2+ + e -> H + H+
Direct Diss. Exc. Rate Coef., (Janev 2.2.12)
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

4.16 Reaction 2.2.14 $e + H_2^+ \rightarrow H + H$

Effective dissociative recombination of H_2^+ to H and H, subtracting the ionising component $e{+}H_2^+ \rightarrow H{+}H^* \rightarrow H{+}H^+$ from dissociative recombination of H_2^+ with excited products.

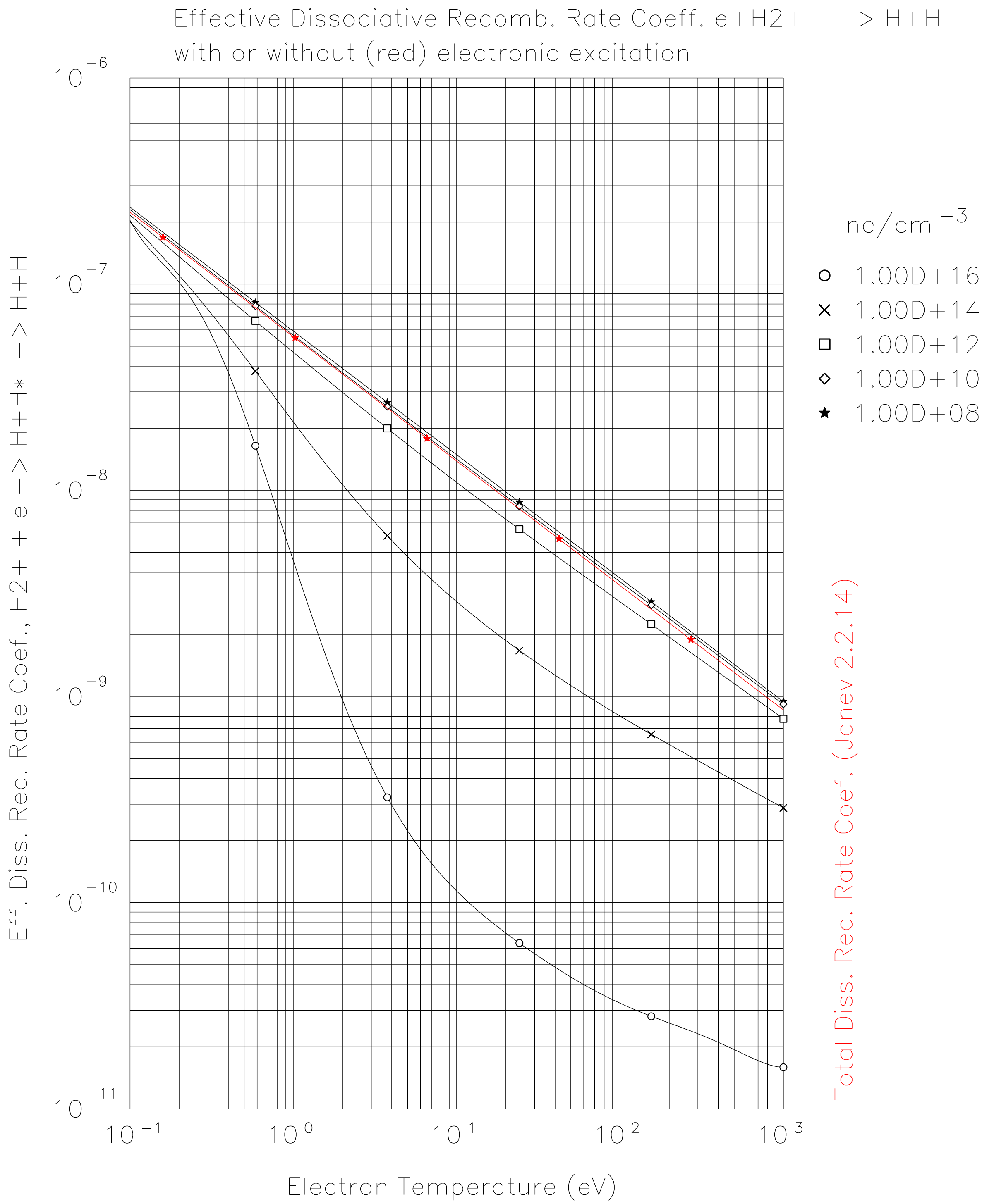
T-Index \ E-Index:	0	1	2
0	-1.664335253647D+01	8.953780953631D-02	-1.056411030518D-01
1	-6.005444031657D-01	4.063933992726D-02	-4.753947846841D-02
2	4.494812032769D-04	7.884508616595D-05	3.688007562485D-04
3	1.632894866655D-04	3.108116177617D-04	-3.521552580917D-04
4	-7.234142549752D-05	-1.316311320262D-03	1.643509328764D-03
5	-1.504085050039D-05	1.315865970237D-04	-1.025653773999D-04
6	1.113923667684D-05	2.711411525392D-05	-8.495922363727D-05
7	-1.843926162250D-06	-1.663674537499D-06	1.308069926896D-05
8	9.864173150662D-08	-2.212261708468D-07	-4.431749501051D-07

T-Index \ E-Index:	3	4	5
0	4.477000808690D-02	-9.729945434357D-03	1.174456882002D-03
1	2.188304031377D-02	-5.201085606791D-03	6.866340394051D-04
2	-4.659255785539D-04	1.907115980400D-04	-3.434324710145D-05
3	-2.233169775063D-04	1.869415236037D-04	-4.329991211511D-05
4	-6.412764282779D-04	1.048891053765D-04	-7.018555173322D-06
5	5.310324781249D-05	-1.831888048039D-05	3.423755373077D-06
6	4.026487801017D-05	-6.289324474240D-06	1.911447036702D-07
7	-7.324021449032D-06	1.431739868187D-06	-1.085644779665D-07
8	3.270530731011D-07	-7.282085521177D-08	6.578253567957D-09

T-Index \ E-Index:	6	7	8
0	-7.987743820637D-05	2.842957892768D-06	-4.104508608435D-08
1	-5.059940013116D-05	1.930213882205D-06	-2.963966822809D-08
2	3.067651560323D-06	-1.325689465590D-07	2.212493073620D-09
3	4.465256901322D-06	-2.136296167564D-07	3.873085368404D-09
4	4.776213235854D-08	1.380537343974D-08	-4.199397846492D-10
5	-3.303384352061D-07	1.551627097700D-08	-2.809391819541D-10
6	3.638198230235D-08	-3.235540606394D-09	7.605442050634D-11
7	1.143164983367D-09	2.151595003971D-10	-7.052562220005D-12
8	-1.925258267827D-10	-4.217474167519D-12	2.364754029318D-13

N2MIN = 1.00000D 08 1/CM3
N2MAX = 1.00000D 16 1/CM3

Max. rel. Error: 3.3331 %
Mean rel. Error: 0.3010 %



Effective Dissociative Recomb. Rate Coeff. e+H2+ --> H+H
with or without (red) electronic excitation
Eff. Diss. Rec. Rate Coef., H2+ + e -> H+H* -> H+H
Electron Temperature (eV)
ne/cm -3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08
Total Diss. Rec. Rate Coef. (Janev 2.2.14)
10 -6
10 -7
10 -8
10 -9
10 -10
10 -11
10 -1
10 0
10 1
10 2
10 3

4.17 Reaction 2.3.9a $e + He(1s^2 1S) \rightarrow e + He^+(1s) + e$

Helium multi-step model, here ionization, Eth=24.56 eV
Fujimoto Formulation II, meta-stable unresolved, (only ground level transported, no meta-stables kept explicit), [22]

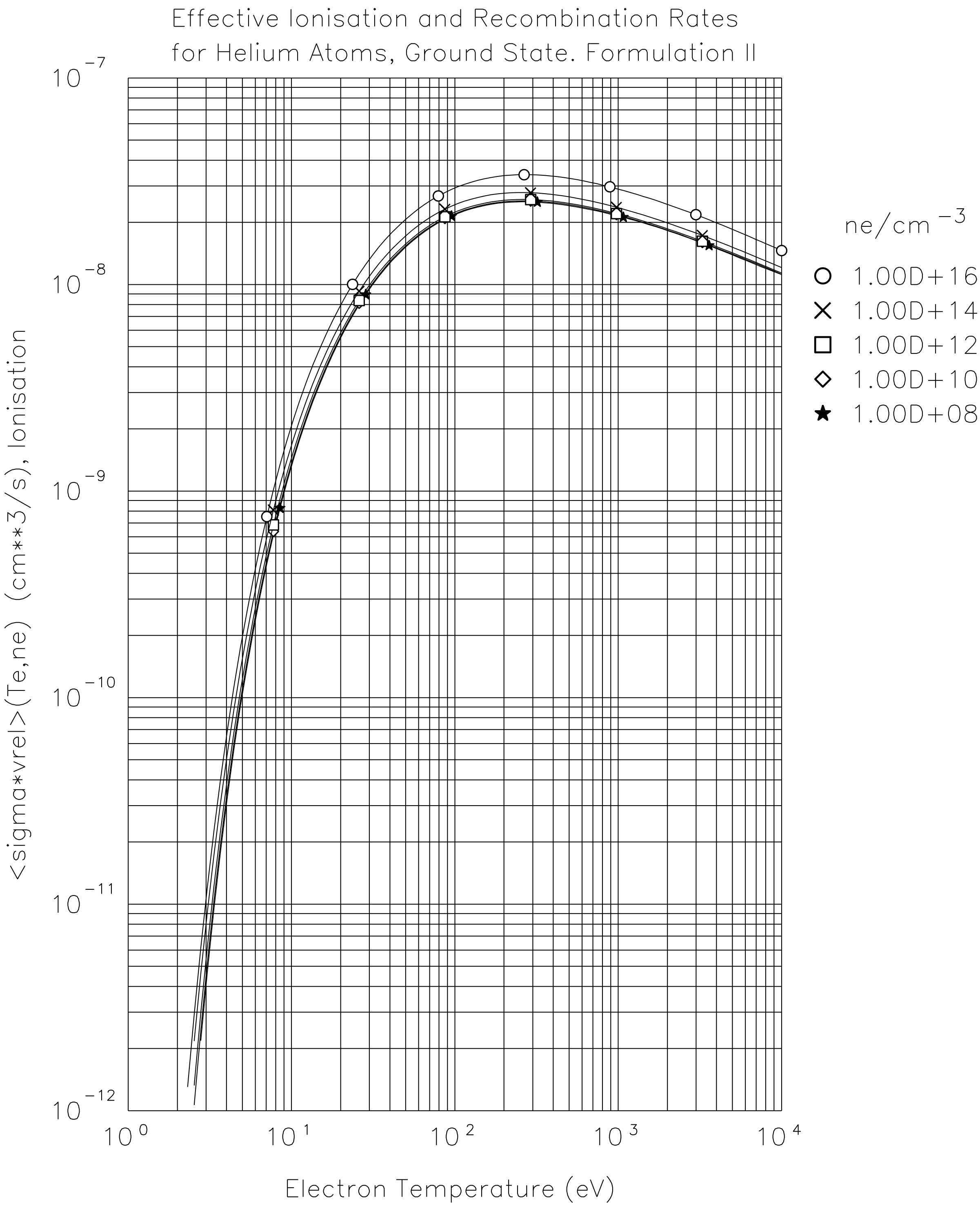
T-Index \ E-Index	0	1	2
0	-4.227118452798D+01	1.294554451998D-01	-8.433979538052D-02
1	2.411668100975D+01	-8.121999208281D-02	4.052570160482D-02
2	-1.203181133667D+01	-3.998282970932D-03	-2.819919193060D-03
3	3.829444688521D+00	2.546414073266D-02	2.654490306111D-03
4	-7.945839257175D-01	-1.493597874850D-02	-1.018320076497D-03
5	1.054334178555D-01	4.338821244147D-03	-1.483560478208D-04
6	-8.578643565653D-03	-6.689202603525D-04	9.084162487421D-05
7	3.886232727181D-04	5.180805123476D-05	-1.125453787291D-05
8	-7.487575233223D-06	-1.582977433740D-06	4.413792107083D-07

T-Index \ E-Index	3	4	5
0	4.910721979375D-02	-1.454047282438D-02	2.178105605879D-03
1	-2.367924962508D-02	8.488392041366D-03	-1.452752408581D-03
2	-1.904887727240D-03	-2.390948585334D-04	1.844484422285D-04
3	1.087493205419D-03	-4.469192206896D-04	3.715538155590D-05
4	2.821927325759D-04	3.269264854581D-05	-5.937518354028D-06
5	-6.901574689672D-05	6.350490312899D-06	-4.414167358057D-07
6	-4.184111347149D-06	1.153919327151D-07	3.797435455934D-08
7	1.536214841434D-06	-1.632601398517D-07	8.948177075796D-09
8	-7.832095176637D-08	9.586974774950D-09	-6.739076170810D-10

T-Index \ E-Index	6	7	8
0	-1.657512355348D-04	6.161429564793D-06	-8.910615590909D-08
1	1.170902182939D-04	-4.410479245308D-06	6.297315949647D-08
2	-1.972728027860D-05	7.779440219801D-07	-1.033814145233D-08
3	-1.595144154431D-06	6.311039124056D-08	-1.485989166680D-09
4	4.714656637197D-07	-2.433462923993D-08	5.307423532159D-10
5	1.266603603049D-08	8.049435558339D-10	-3.807796193572D-11
6	-4.123383037275D-09	1.095960078746D-10	-5.109801608123D-14
7	-1.853674996294D-10	1.342166707999D-14	1.184569645146D-14
8	2.565598443992D-11	-4.994625098807D-13	4.124048804450D-15

```
N2MIN =   1.00000D 08 1/CM3
N2MAX =   1.00000D 16 1/CM3

  Max. rel. Error:   1.4966 %
  Mean rel. Error:    .1241 %
```


Effective Ionisation and Recombination Rates
for Helium Atoms, Ground State. Formulation II
<sigma*vrel>(Te,ne) (cm**3/s), Ionisation
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

4.18 Reaction 2.3.9b $e + He(1s^2 1S; r) \rightarrow e + He^+(1s) + e$

Eth=24.588 eV Fujimoto Formulation I (meta-stable resolved, i.e., ground level and 2 meta-stable levels transported) [22]

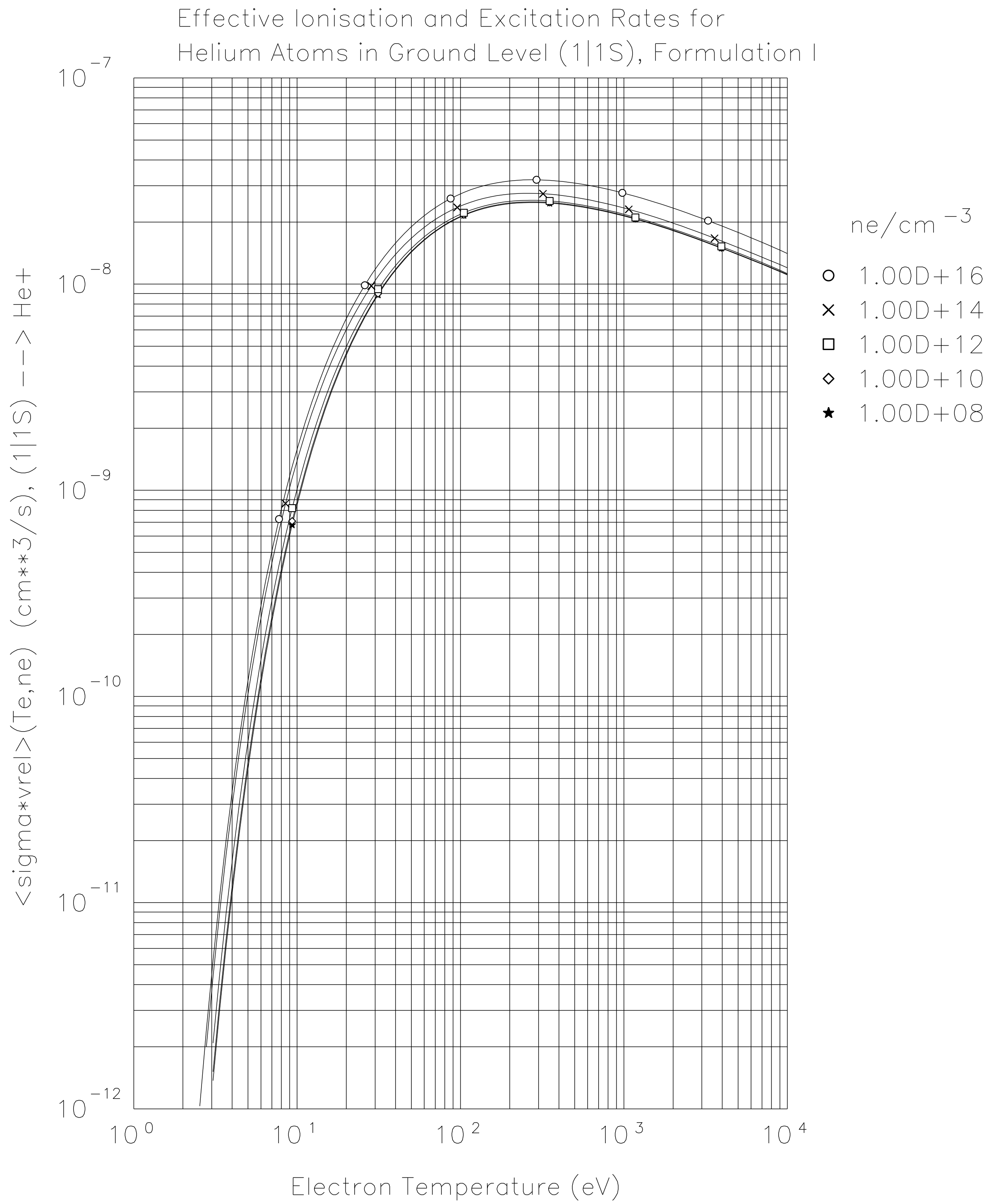
T-Index \ E-Index	0	1	2
0	-4.465926038712D+01	2.779089377769D-01	-1.924882766567D-01
1	2.525835077281D+01	-3.615923725584D-01	1.317375998510D-01
2	-1.209203690110D+01	2.546508612886D-01	-4.865271188617D-02
3	3.800524426932D+00	-1.050334429568D-01	1.534747997056D-02
4	-8.039502806290D-01	2.383460807262D-02	-2.453115299067D-03
5	1.113782505171D-01	-2.736570987242D-03	-1.204111477713D-04
6	-9.620115283603D-03	1.170152671250D-04	8.499825475516D-05
7	4.684217843660D-04	2.993567258600D-06	-9.064004864288D-06
8	-9.803749599678D-06	-2.872558504737D-07	3.052211397578D-07

T-Index \ E-Index	3	4	5
0	8.206249637969D-02	-1.857913019533D-02	2.303280474362D-03
1	-3.756327901158D-02	7.553859741475D-03	-9.078039556264D-04
2	3.019270415903D-03	6.079717185636D-05	-1.971883028916D-05
3	-1.216174535037D-04	-1.789202918039D-04	2.652901470795D-05
4	1.469571845580D-04	-3.672662632973D-05	3.283809863879D-06
5	1.895504949459D-05	9.915856648703D-06	-1.080542155973D-06
6	-1.228789754131D-05	-2.775942493726D-07	3.600949456643D-08
7	1.331783826572D-06	-3.482200586084D-08	3.023300632995D-09
8	-4.228344440471D-08	1.047078160211D-09	-7.325236965794D-11

T-Index \ E-Index	6	7	8
0	-1.557492713615D-04	5.412603196390D-06	-7.592974771773D-08
1	6.285196169828D-05	-2.363737361863D-06	3.748123629849D-08
2	-1.284093049142D-06	2.768704515392D-07	-9.149600770688D-09
3	-7.430360191467D-07	-7.771887920734D-08	3.535086119528D-09
4	-3.318791946233D-07	3.208524419469D-08	-1.011210049359D-09
5	5.266320143919D-08	-3.383189536291D-09	1.132832454025D-10
6	3.748617077019D-09	-1.897621201127D-10	-6.405513953940D-13
7	-7.781196082881D-10	4.279614523560D-11	-6.119815491934D-13
8	2.391497281895D-11	-1.495486439356D-12	2.587685854804D-14

```
N2MIN =   1.00000D 08 1/CM3
N2MAX =   1.00000D 16 1/CM3

  Max. rel. Error:   1.3886 %
  Mean rel. Error:    .1520 %
```



Effective Ionisation and Excitation Rates for
Helium Atoms in Ground Level (1|1S), Formulation I
<sigma*vrel>(Te,ne) (cm**3/s), (1|1S) --> He+
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

4.19 Reaction 2.3.9c $e + He(1s^2 1S; r) \rightarrow e + He(1s^1 2s^1 1S; r)$

Eth=20.614

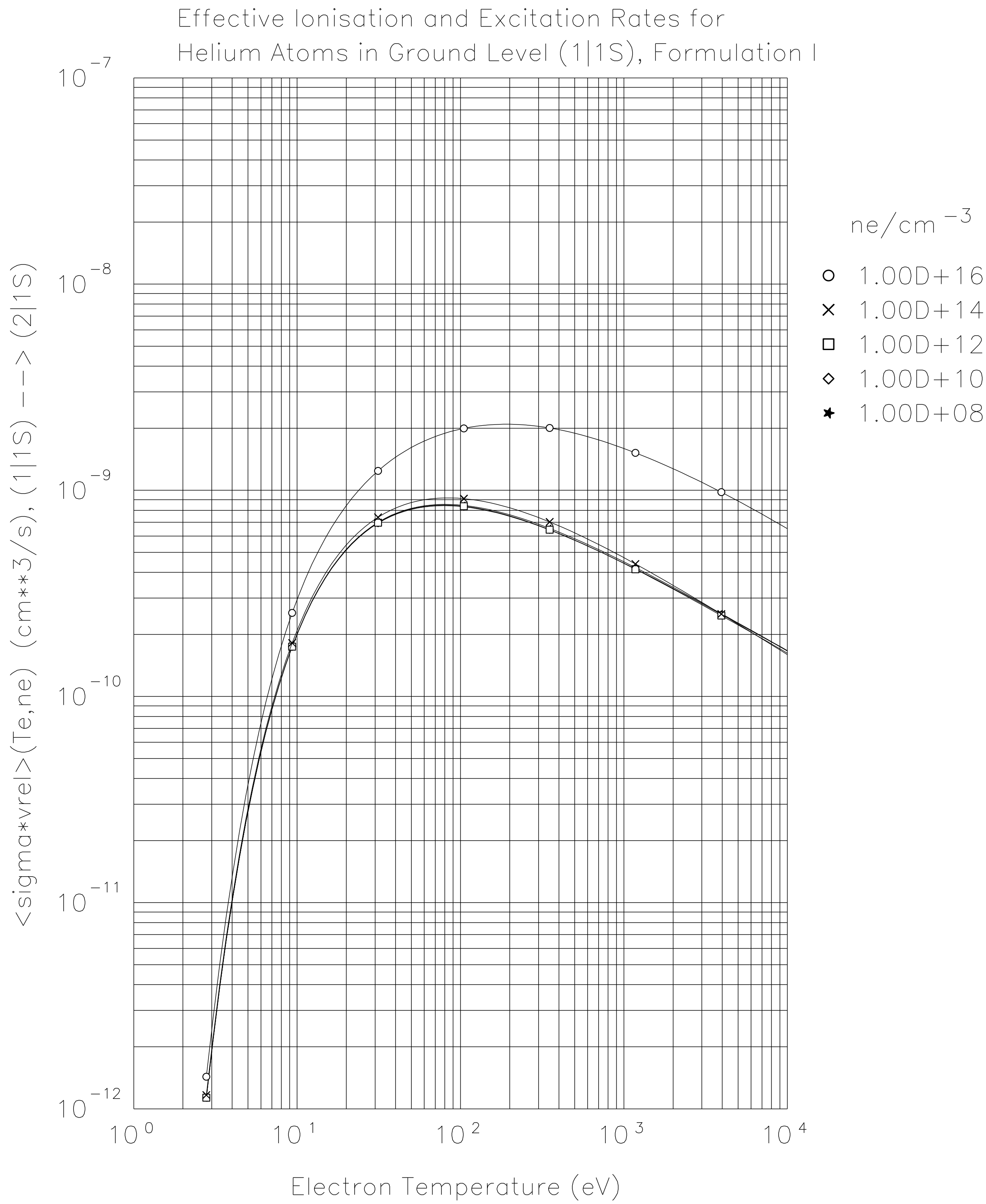
T-Index \ E-Index	0	1	2
0	-4.046178452435D+01	2.793780023801D-02	-2.636827236275D-02
1	2.021782349890D+01	-8.168151009006D-02	6.137459348454D-02
2	-9.976409627529D+00	7.203017486249D-02	-4.594744469839D-02
3	3.121941621264D+00	-3.252368776384D-02	1.838136188172D-02
4	-6.605740116932D-01	7.971710032974D-03	-3.491501531484D-03
5	9.314429433629D-02	-1.237053221067D-03	3.539330238278D-04
6	-8.331619915042D-03	1.280998359531D-04	-2.164671094364D-05
7	4.255343291630D-04	-7.951439218420D-06	7.965320643996D-07
8	-9.415940442146D-06	2.158374132954D-07	-1.212346927674D-08

T-Index \ E-Index	3	4	5
0	9.966974050192D-03	-1.925058189572D-03	2.074618402408D-04
1	-1.789108699037D-02	2.499301042347D-03	-1.708164459820D-04
2	1.099110619333D-02	-1.123236352791D-03	2.768319881512D-05
3	-4.067150951400D-03	4.169742301105D-04	-1.424941738587D-05
4	5.821208934666D-04	-4.623802427724D-05	8.865908638099D-07
5	-1.693003577039D-05	-2.195524273463D-06	2.451445678475D-07
6	-3.496132235049D-06	7.607387051093D-07	-2.643851478727D-08
7	4.015715517122D-07	-6.690887808842D-08	2.045934897132D-09
8	-1.496923652893D-08	2.594682285097D-09	-1.399655571965D-10

T-Index \ E-Index	6	7	8
0	-1.262053793968D-05	4.055587151672D-07	-5.348263576276D-09
1	4.628208806209D-06	2.791547274449D-08	-2.554662311089D-09
2	3.397787872961D-06	-2.546734368181D-07	5.048596843802D-09
3	-7.637600844108D-07	7.190678272390D-08	-1.515996656096D-09
4	1.543470779365D-07	-1.154851629261D-08	2.413115266566D-10
5	-1.466182203352D-08	7.285294206745D-10	-1.706462195600D-11
6	-1.132975723190D-09	6.492076232833D-11	-3.972506213491D-13
7	1.178546445834D-10	-6.482775463755D-12	5.122149685044D-14
8	2.346036357946D-12	-3.268745663823D-14	1.995604762061D-15

N2MIN = 1.00000D 08 1/CM3
N2MAX = 1.00000D 16 1/CM3

Max. rel. Error: 1.9207 %
Mean rel. Error: .5914 %


Effective Ionisation and Excitation Rates for
Helium Atoms in Ground Level (1|1S), Formulation I
<sigma*vrel>(Te,ne) (cm**3/s), (1|1S) --> (2|1S)
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

4.20 Reaction 2.3.9d $e + He(1s^2 1S; r) \rightarrow e + He(1s^1 2s^1 3S; r)$

Eth=19.818 eV

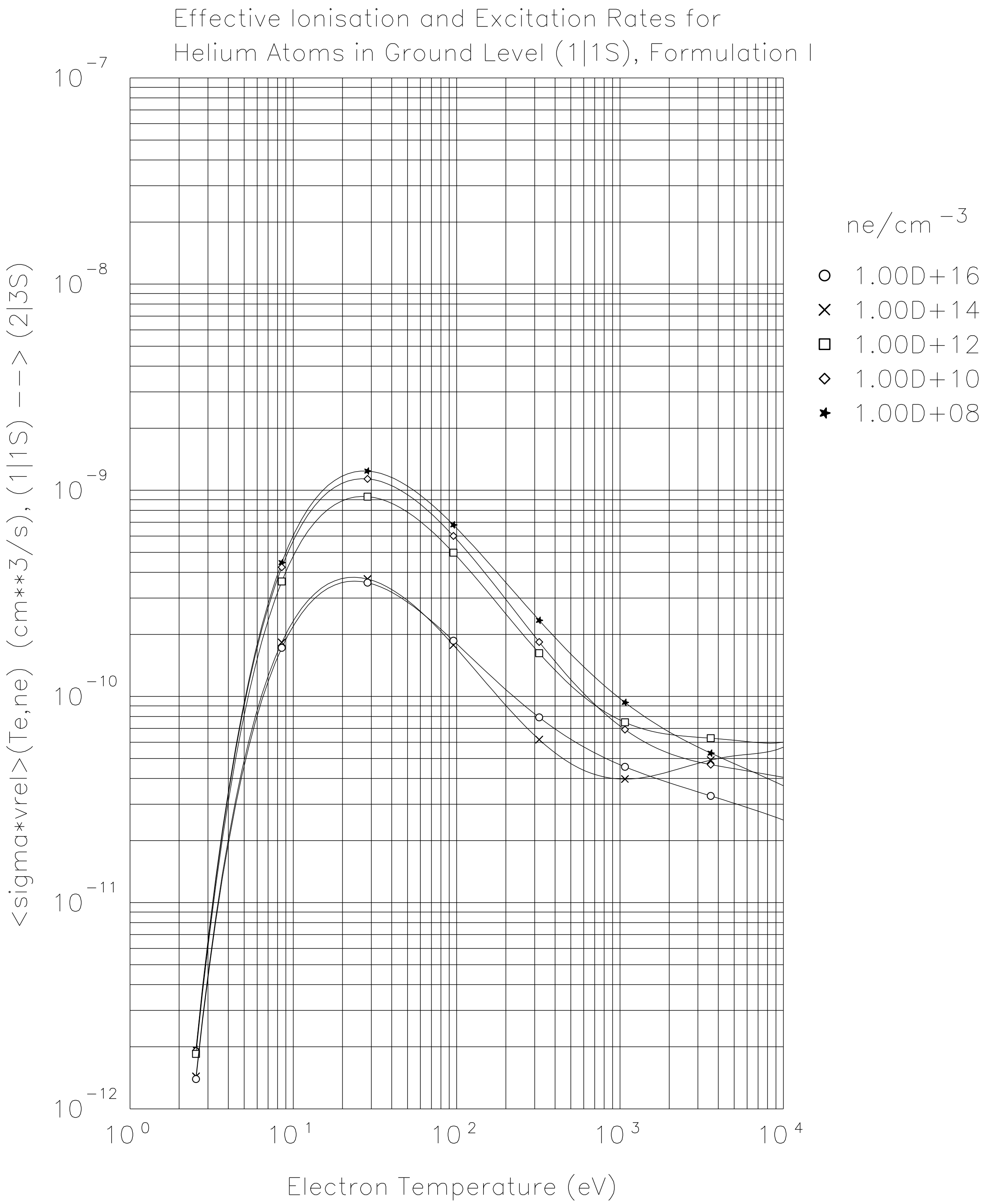
T-Index \ E-Index	0	1	2
0	-3.886266644950D+01	7.019809942099D-04	-4.884086339705D-03
1	1.929521258283D+01	-2.357936604103D-02	-1.328300789738D-02
2	-9.046404053855D+00	8.666192442035D-02	5.474654335859D-02
3	2.673018107253D+00	-1.398928491802D-01	3.218710988103D-03
4	-5.548107653535D-01	7.465434423573D-02	-1.179392922571D-02
5	7.774830542594D-02	-1.905817901709D-02	3.638331146570D-03
6	-6.848256427157D-03	2.528446995280D-03	-4.700217870527D-04
7	3.400854043835D-04	-1.673888466652D-04	2.614365787435D-05
8	-7.262673007156D-06	4.357192276102D-06	-4.506225745622D-07

T-Index \ E-Index	3	4	5
0	4.394808572685D-03	-1.302054032826D-03	1.826711561551D-04
1	1.082410659623D-03	8.797507874605D-04	-1.904140538432D-04
2	-2.932730590755D-02	5.819861355501D-03	-6.211677015176D-04
3	7.586337950327D-03	-1.674705131468D-03	1.745859315455D-04
4	2.158501813724D-04	7.916139470987D-05	-6.470261758484D-06
5	-2.830357834958D-04	2.090178740450D-05	-2.905940657585D-06
6	2.610671874389D-05	-7.317822457225D-07	2.937506973332D-07
7	9.223198907867D-07	-4.349863908454D-07	1.893279869199D-08
8	-1.418436717966D-07	3.344143189525D-08	-2.438361820942D-09

T-Index \ E-Index	6	7	8
0	-1.338147384862D-05	4.944420378156D-07	-7.274738213340D-09
1	1.572144633422D-05	-5.949713883471D-07	8.661413444821D-09
2	3.751189894835D-05	-1.205285676422D-06	1.596181856159D-08
3	-1.072392282940D-05	3.817775426074D-07	-5.941731934892D-09
4	5.703111011170D-07	-4.610054978455D-08	1.257685434225D-09
5	1.376224572390D-07	3.158742833521D-09	-2.256374221221D-10
6	-2.123916588197D-08	-1.342964777517D-10	2.534904955517D-11
7	2.438015393047D-11	2.825944427401D-11	-1.724540860429D-12
8	8.609576897508D-11	-2.649053786615D-12	6.205443362599D-14

N2MIN = 1.00000D 08 1/CM3
N2MAX = 1.00000D 16 1/CM3

Max. rel. Error: 4.7040 %
Mean rel. Error: 1.6362 %



Effective Ionisation and Excitation Rates for
Helium Atoms in Ground Level (1|1S), Formulation I
<sigma*vrel>(Te,ne) (cm**3/s), (1|1S) --> (2|3S)
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

4.21 Reaction 2.3.9e $e + He(1s^1 2s^1 1S; r) \rightarrow e + He(1s^2 1S; r)$

Exotherm by -20.614 eV

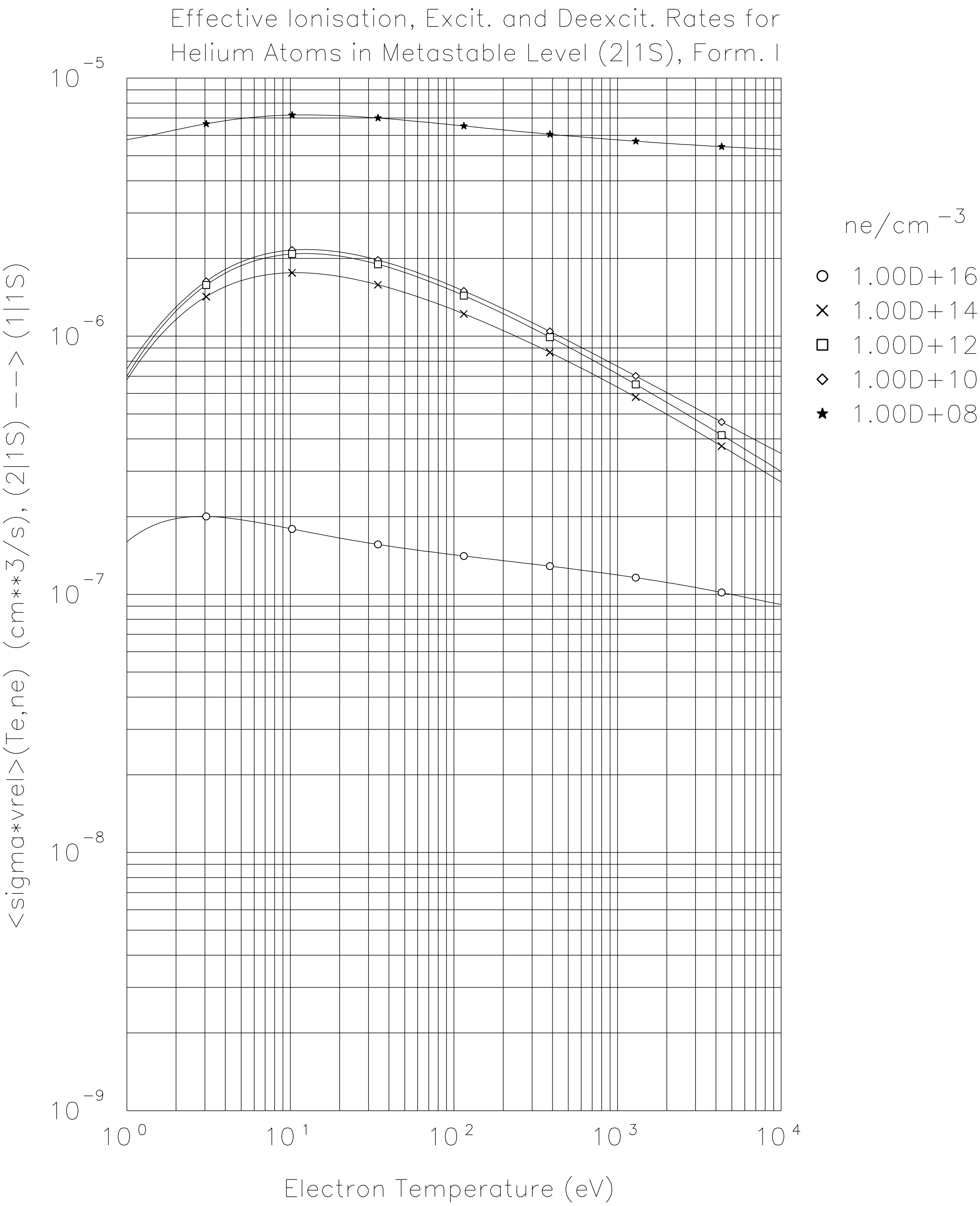
T-Index \ E-Index:	0	1	2
0	-1.206284357030D+01	-9.395741200722D-01	8.941559006967D-02
1	1.001413279976D-01	1.092169776728D-01	1.368198258579D-01
2	7.586400083695D-02	-3.795422777009D-03	-4.592861987024D-02
3	-6.305941229397D-02	-1.344397679189D-02	5.918300497317D-03
4	1.769150254942D-02	3.790811280315D-03	-6.656861914400D-06
5	-2.649142451670D-03	-4.390182739385D-04	-1.378634631707D-04
6	2.286216360493D-04	1.421107391865D-05	2.727632307001D-05
7	-1.081890897336D-05	1.614465895521D-06	-2.798379357036D-06
8	2.194368384994D-07	-1.169587182544D-07	1.178226546132D-07

T-Index \ E-Index:	3	4	5
0	2.236104074143D-02	-6.491279005972D-03	6.949727832958D-04
1	-5.565930009734D-02	1.010402473629D-02	-1.046827564504D-03
2	1.258334121198D-02	-1.876085557457D-03	1.902110155531D-04
3	6.956902121898D-04	-2.605824960044D-04	1.950702712776D-05
4	-5.678513919575D-04	9.916918467853D-05	-5.461700671234D-06
5	9.155083108892D-05	-9.582108792123D-06	-4.823548954286D-08
6	-8.973643720110D-06	5.015822067600D-07	4.733355630355D-08
7	7.315416774742D-07	-6.070951170683D-08	2.496749755159D-09
8	-3.205208905129D-08	4.211868482308D-09	-4.146419126420D-10

T-Index \ E-Index:	6	7	8
0	-3.798849551595D-05	1.060426073614D-06	-1.221792772705D-08
1	6.343654833533D-05	-2.081812227589D-06	2.840825118625D-08
2	-1.235336841503D-05	4.391737031475D-07	-6.361146384328D-09
3	-2.609090338780D-07	-2.035332888490D-08	5.697468968308D-10
4	9.584672975523D-09	7.522667390232D-09	-1.643595153340D-10
5	4.899977333096D-08	-2.232347489472D-09	2.900728952005D-11
6	-4.956007021108D-09	1.036072591263D-10	5.476491421305D-13
7	-2.464346448050D-10	1.983186245349D-11	-4.977113923684D-13
8	3.334367936705D-11	-1.585718526609D-12	2.983699805655D-14

N2MIN = 1.00000D 08 1/CM3
N2MAX = 1.00000D 16 1/CM3

Max. rel. Error: 1.4647 %
Mean rel. Error: .6179 %


Effective Ionisation, Excit. and Deexcit. Rates for
Helium Atoms in Metastable Level (2|1S), Form. I
<sigma*vrel>(Te,ne) (cm**3/s), (2|1S) --> (1|1S)
Electron Temperature (eV)
ne/cm -3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

4.22 Reaction 2.3.9f $e + He(1s^1 2s^1 1S; r) \rightarrow e + He^+(1s) + e$

Eth=24.588-20.614 eV= 3.974 eV

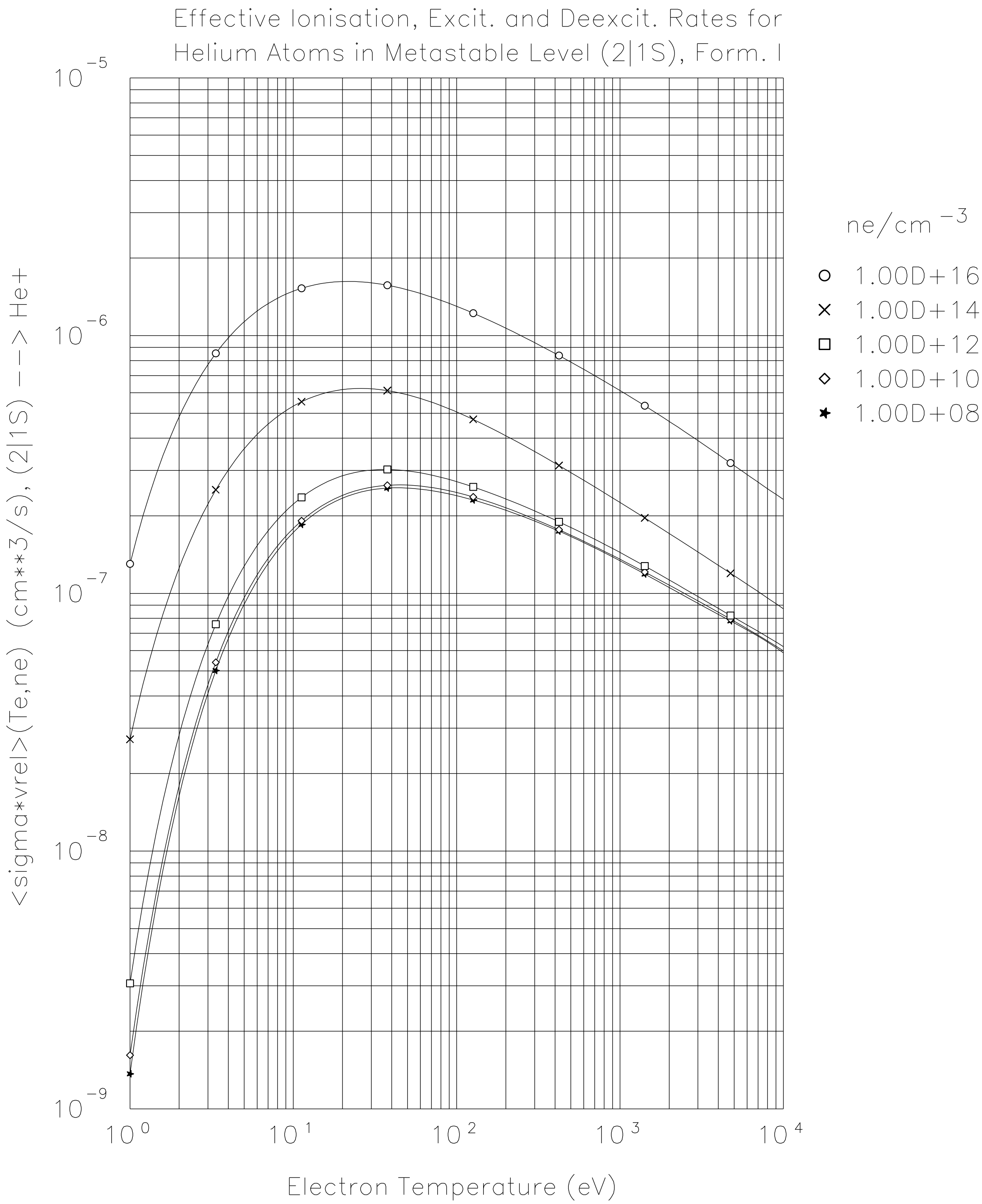
T-Index \ E-Index	0	1	2
0	-2.041118707850D+01	2.064277904192D-01	-2.301314111088D-01
1	4.734415747558D+00	-2.552828703588D-01	2.342297501453D-01
2	-2.031119990372D+00	1.324170464675D-01	-4.709002494788D-02
3	6.371388191840D-01	-6.485323499659D-02	-1.318105876403D-02
4	-1.606102572000D-01	3.031094673577D-02	4.353315277834D-03
5	2.869498856933D-02	-8.594657926314D-03	1.245406154419D-04
6	-3.217835269221D-03	1.298813772998D-03	-1.446399013109D-04
7	1.992406567281D-04	-9.756034343132D-05	1.558038205391D-05
8	-5.162497860818D-06	2.873135417997D-06	-5.121082856413D-07

T-Index \ E-Index	3	4	5
0	1.064846554112D-01	-2.384946202844D-02	2.875360842310D-03
1	-1.009365349705D-01	2.154424500834D-02	-2.450397986314D-03
2	1.965251665219D-02	-4.861043898033D-03	5.741139338224D-04
3	6.274439358726D-03	-5.336599826346D-04	6.766527255195D-06
4	-2.730895337646D-03	2.879856399739D-04	-8.539443051056D-06
5	3.376848227155D-04	-2.761034449494D-05	-1.226863119476D-06
6	-1.429851963639D-05	8.564331543394D-07	2.266756951926D-07
7	1.313034465605D-07	-1.155540500016D-07	8.907397769803D-09
8	-9.429070218568D-09	1.043211307579D-08	-1.547549446017D-09

T-Index \ E-Index	6	7	8
0	-1.875978041743D-04	6.245347035980D-06	-8.331988072406D-08
1	1.492018825102D-04	-4.569691982094D-06	5.506673096644D-08
2	-3.190474508863D-05	7.544465168586D-07	-4.738153009264D-09
3	-4.524848313611D-07	1.101272889478D-07	-3.647448463620D-09
4	1.327453253122D-07	-2.364732558216D-08	8.985219510628D-10
5	1.509448581903D-07	-1.051090322975D-09	-1.035749496501D-10
6	-1.493652619657D-08	-1.728825755255D-10	1.851526257919D-11
7	-1.266737591814D-09	1.032899830898D-10	-2.632477381331D-12
8	1.383817472027D-10	-6.759540208869D-12	1.300020937903D-13

N2MIN = 1.00000D 08 1/CM3
N2MAX = 1.00000D 16 1/CM3

Max. rel. Error: 3.1668 %
Mean rel. Error: .5043 %



Effective Ionisation, Excit. and Deexcit. Rates for
Helium Atoms in Metastable Level (2|1S), Form. I
<sigma*vrel>(Te,ne) (cm**3/s), (2|1S) --> He+
Electron Temperature (eV)
ne/cm -3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

4.23 Reaction 2.3.9g $e + He(1s^1 2s^1 1S; r) \rightarrow e + He(1s^1 2s^1 3S; r)$

Exothermic by -20.614 + 19.818 eV = -0.796 eV

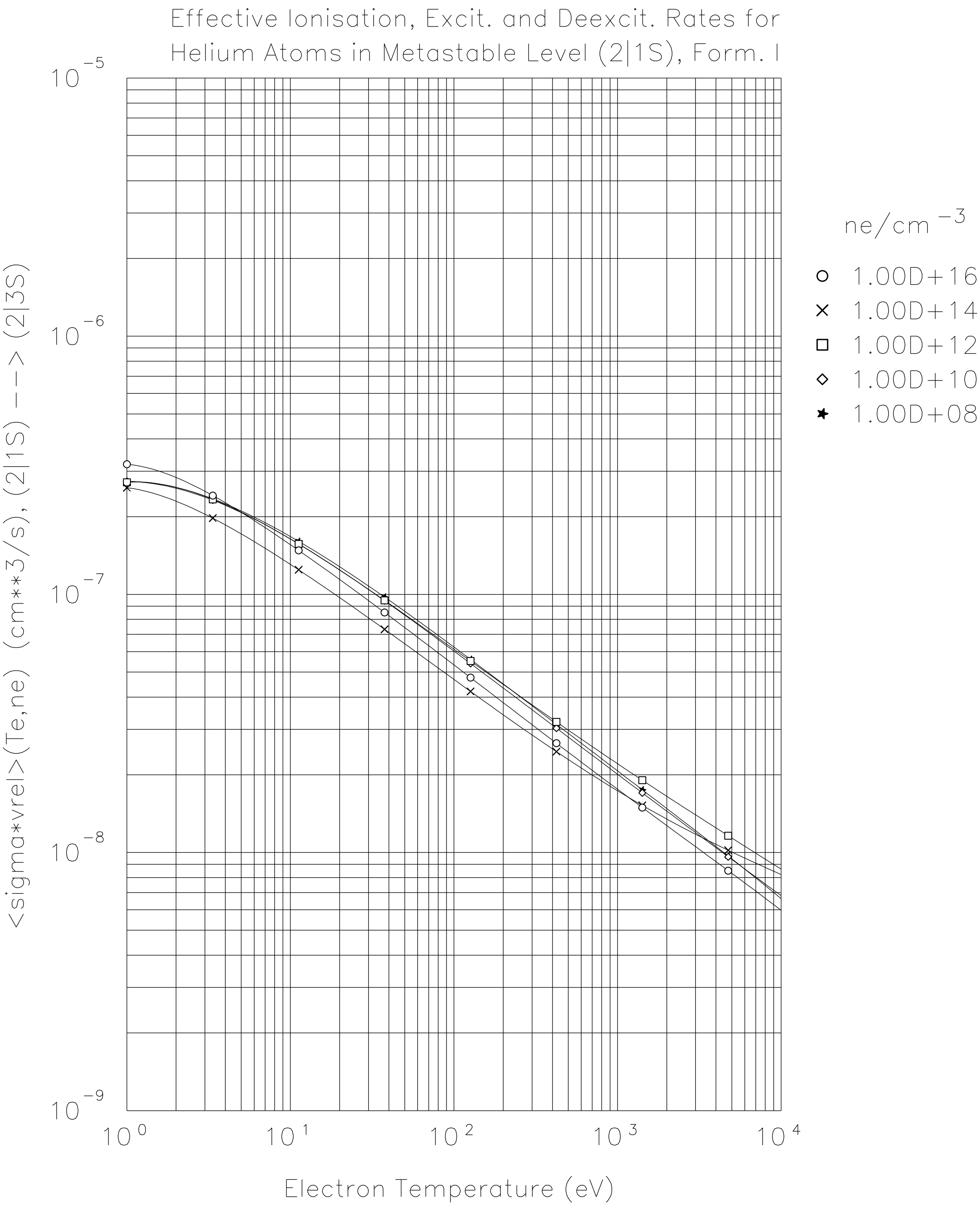
T-Index \ E-Index:	0	1	2
0	-1.511346543847D+01	-8.315548974761D-03	1.043755302803D-03
1	2.080755731664D-02	-1.438655344675D-02	3.050387143129D-02
2	-1.559881223335D-01	-4.819070749165D-03	5.469768725333D-03
3	3.593311746308D-02	-3.264350393911D-03	-2.797070666582D-03
4	-7.539069188132D-03	2.816838207584D-03	1.209358979731D-04
5	1.249554266705D-03	-6.865425821712D-04	4.394712468238D-05
6	-1.346691563985D-04	7.711126608572D-05	-3.761880439834D-06
7	8.141009386823D-06	-4.262318558331D-06	-5.160666241730D-08
8	-2.101701177702D-07	1.010890135509D-07	3.792122360486D-09

T-Index \ E-Index:	3	4	5
0	2.642487583410D-03	-1.141726366943D-03	1.946543332558D-04
1	-1.854158470475D-02	4.594389089735D-03	-5.599959861484D-04
2	2.070413057149D-04	-3.457506453968D-04	4.738780926722D-05
3	8.235312574359D-04	-9.572690868675D-05	8.428282893341D-06
4	-1.330419686348D-04	1.899203210608D-05	-1.396220087820D-06
5	1.494981666075D-05	-3.053826052126D-06	2.132092797921D-07
6	-2.368299001887D-06	4.919560666227D-07	-3.450359185228D-08
7	2.216347288940D-07	-4.134834676754D-08	2.800553268281D-09
8	-5.585637013718D-09	9.462594289102D-10	-4.980912274284D-11

T-Index \ E-Index:	6	7	8
0	-1.635057730275D-05	6.698344020218D-07	-1.065235099548D-08
1	3.560438313422D-05	-1.132594240133D-06	1.422148875942D-08
2	-2.442018698579D-06	4.281026474337D-08	5.902980719683D-11
3	-6.289242286208D-07	2.809710863001D-08	-4.986421098936D-10
4	5.944783491030D-08	-1.403317455776D-09	1.466091168551D-11
5	-2.812985305069D-09	-2.643823395694D-10	7.873039688058D-12
6	3.288755762988D-10	5.309244160943D-11	-1.497810114810D-12
7	-2.188207542114D-11	-4.594641184965D-12	1.274835520030D-13
8	-1.490478001851D-12	2.101409635615D-13	-4.858731679885D-15

N2MIN = 1.00000D 08 1/CM3
N2MAX = 1.00000D 16 1/CM3

Max. rel. Error: 3.2971 %
Mean rel. Error: .9554 %



Effective Ionisation, Excit. and Deexcit. Rates for
Helium Atoms in Metastable Level (2|1S), Form. I
<sigma*vrel>(Te,ne) (cm**3/s), (2|1S) --> (2|3S)
10^-5
10^-6
10^-7
10^-8
10^-9
10^0
10^1
10^2
10^3
10^4
Electron Temperature (eV)
ne/cm^-3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

4.24 Reaction 2.3.9h $e + He(1s^1 2s^1 3S; r) \rightarrow e + He(1s^2 1S; r)$

Exothermic by = -19.818 eV

E-Index: 0, 1, 2

T-Index	0	1	2
0	-1.830459498604D+01	1.680944192322D-01	-1.907710632311D-01
1	1.261631206881D+00	-3.697196539108D-01	3.033207775574D-01
2	-6.559878055182D-01	3.061935618408D-01	-1.782153223733D-01
3	1.697614445868D-01	-1.342126595676D-01	5.676221077284D-02
4	-3.176415719557D-02	3.126025766778D-02	-1.011584147746D-02
5	3.950262828345D-03	-3.455627026606D-03	6.079929754617D-04
6	-2.881881569143D-04	1.125950976085D-04	5.069359855193D-05
7	1.022634571062D-05	7.797965660632D-06	-7.903959237155D-06
8	-1.046204166475D-07	-5.060676841045D-07	2.672428957821D-07

E-Index: 3, 4, 5

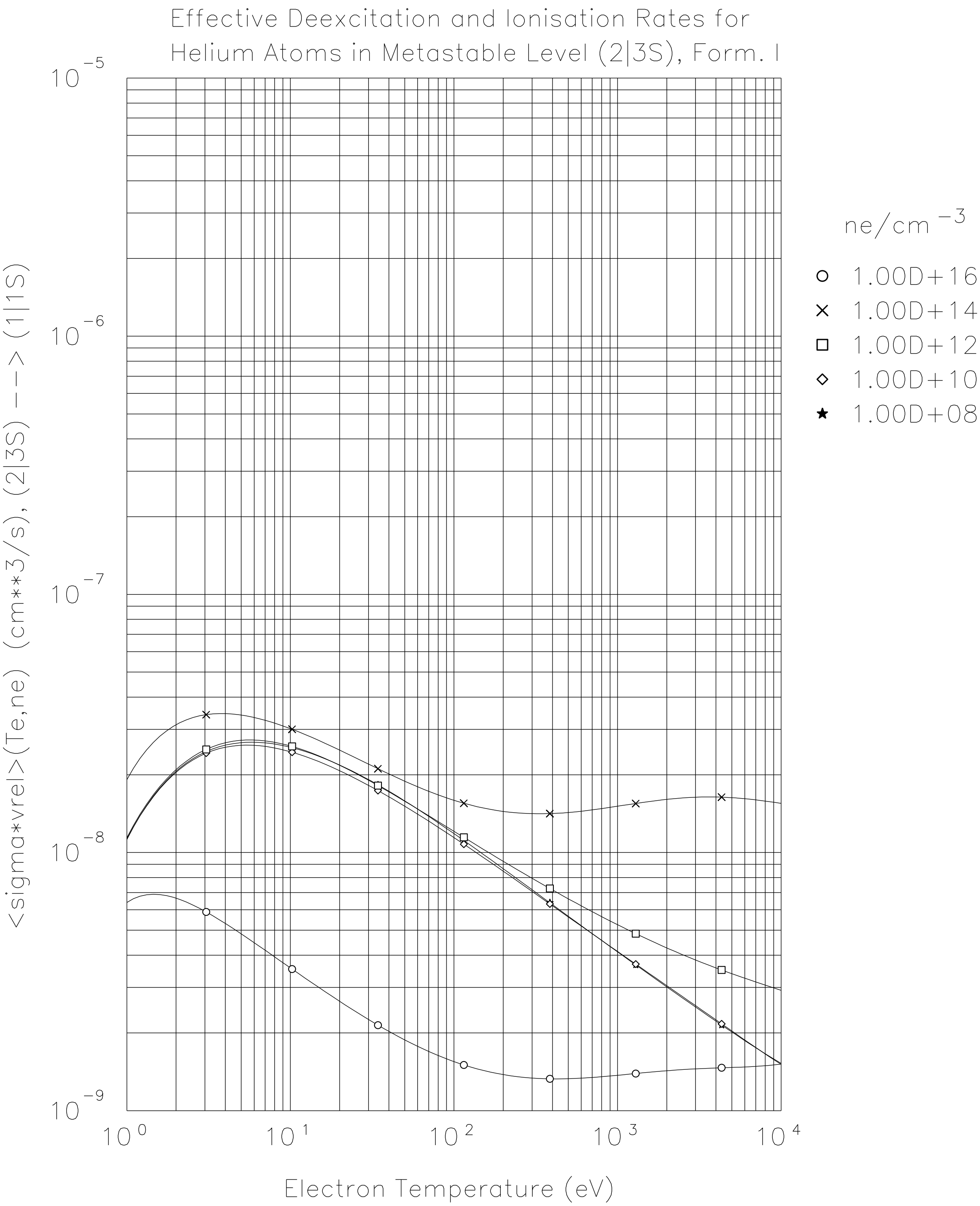
T-Index	3	4	5
0	7.870000493965D-02	-1.578049324901D-02	1.693793556658D-03
1	-1.021849055299D-01	1.773149558150D-02	-1.726009071069D-03
2	4.310244321027D-02	-5.236106415441D-03	3.417399063180D-04
3	-8.861603178392D-03	3.398799078845D-04	4.431709264967D-05
4	1.152839986316D-03	9.136542557803D-06	-9.999842824089D-06
5	-1.259483668399D-05	-8.845662317330D-06	8.897275861513D-07
6	-1.194283431812D-05	8.912124314893D-07	-4.132333818961D-08
7	7.631517909210D-07	5.811563274232D-08	-6.834989323422D-09
8	-3.354009675567D-09	-6.847471248575D-09	6.066678972621D-10

E-Index: 6, 7, 8

T-Index	6	7	8
0	-9.871776235813D-05	2.943212020081D-06	-3.527779579573D-08
1	9.567692855718D-05	-2.834877407571D-06	3.493434187484D-08
2	-1.237776471579D-05	2.515470587336D-07	-2.566899239887D-09
3	-4.572811804993D-06	1.335801462225D-07	-8.926601447859D-10
4	3.785048727116D-07	1.570413745481D-08	-7.805586685406D-10
5	3.807398587262D-08	-7.209735737750D-09	2.098640072212D-10
6	-2.405215414685D-09	4.468725637555D-10	-1.423750029854D-11
7	-9.649173073383D-12	1.030982426102D-11	-1.042452128502D-13
8	-2.881700207187D-12	-1.158584840686D-12	2.909357590574D-14

N2MIN = 1.00000D 08 1/CM3
N2MAX = 1.00000D 16 1/CM3

Max. rel. Error: 6.5233 %
Mean rel. Error: 1.8951 %


Effective Deexcitation and Ionisation Rates for
Helium Atoms in Metastable Level (2|3S), Form. I
<sigma*vrel>(Te,ne) (cm**3/s), (2|3S) --> (1|1S)
10^-5
10^-6
10^-7
10^-8
10^-9
10^0
10^1
10^2
10^3
10^4
Electron Temperature (eV)
ne/cm^-3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

4.25 Reaction 2.3.9i $e + He(1s^1 2s^1 3S; r) \rightarrow e + He(1s^1 2s^1 1S; r)$

Eth = 20.614 - 19.818 eV = 0.796 eV

T-Index \ E-Index	0	1	2
0	-1.745844276703D+01	8.157573269596D-02	-8.846137669182D-02
1	7.481807449876D-01	-8.855888981396D-02	6.895575898405D-02
2	-4.821059764779D-01	4.679324654447D-02	-3.297751569188D-02
3	1.178180871789D-01	-6.059351136561D-03	6.707641671282D-03
4	-1.832266433398D-02	-3.019133239406D-03	-4.072864365252D-06
5	1.619689578381D-03	1.226840796832D-03	-1.633059618549D-04
6	-5.423530837755D-05	-1.774072691416D-04	1.112445681671D-05
7	-1.967026987940D-06	1.153537885107D-05	9.730921470847D-07
8	1.471829150856D-07	-2.811554762172D-07	-8.690862477419D-08

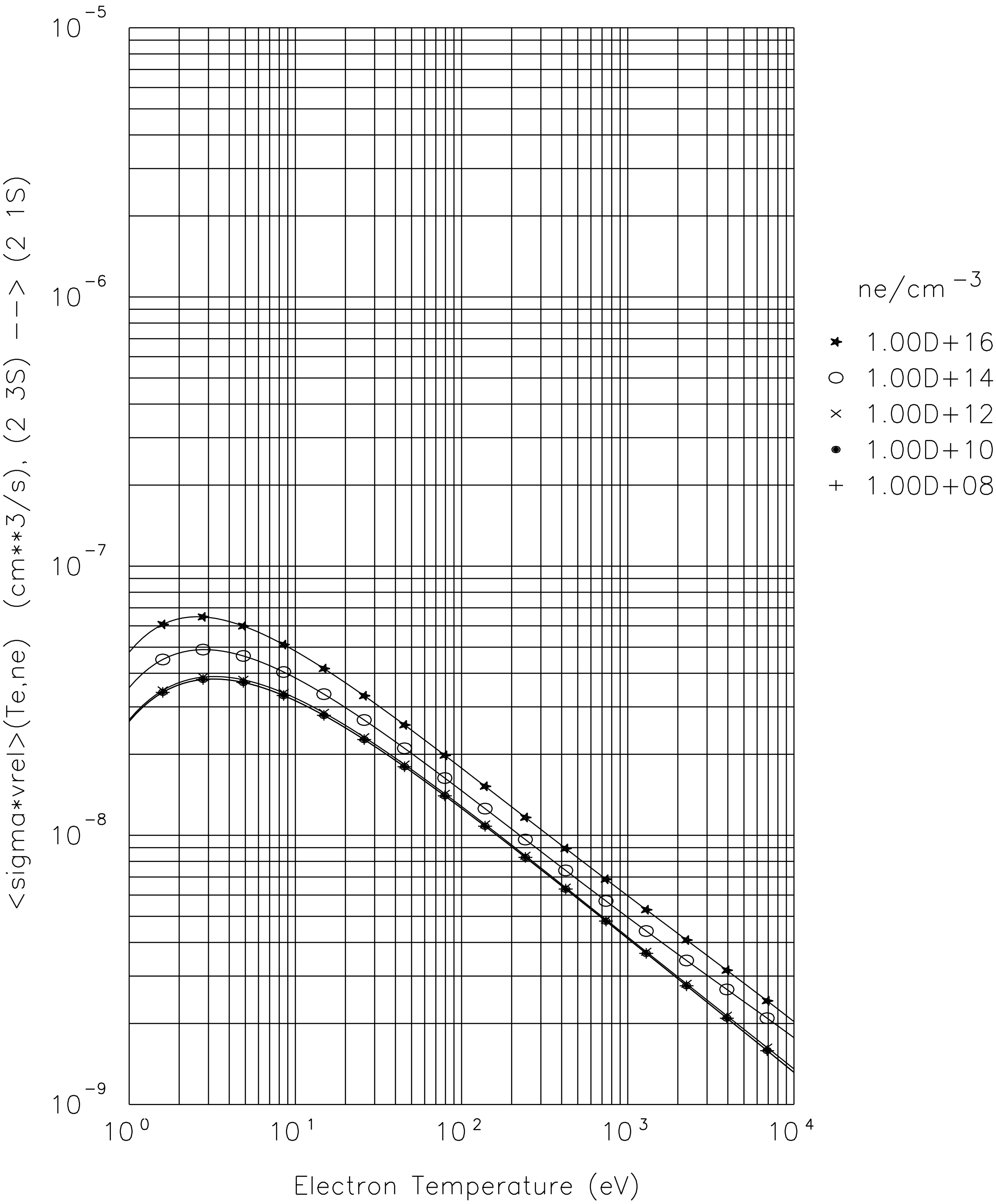
T-Index \ E-Index	3	4	5
0	3.729534986051D-02	-7.748150218997D-03	8.681073774233D-04
1	-2.009477611517D-02	2.695260975948D-03	-1.670023006117D-04
2	7.266340675294D-03	-5.231546959702D-04	-1.405113747904D-05
3	-1.185084843308D-03	-7.521294935444D-06	1.345383423264D-05
4	-3.463344438708D-06	2.717377734542D-05	-3.273238480292D-06
5	5.881112042281D-06	-3.089656478315D-06	4.514505533598D-07
6	6.093509408469D-06	-8.020661101230D-07	1.087961936931D-08
7	-1.135225653662D-06	1.679703656220D-07	-7.767824389490D-09
8	5.404365621466D-08	-8.134516470380D-09	4.439057728063D-10

T-Index \ E-Index	6	7	8
0	-5.326368279955D-05	1.687247391834D-06	-2.160318603760D-08
1	3.273035637060D-06	9.077935253350D-08	-3.430880317364D-09
2	3.581367863934D-06	-1.600203938605D-07	2.265889575361D-09
3	-7.627838979440D-07	1.599025715771D-09	4.761644881308D-10
4	1.521655610951D-08	1.078364608775D-08	-3.386106465918D-10
5	-8.083755569905D-09	-1.161692326935D-09	4.153576692338D-11
6	2.280605076008D-09	-9.703614416875D-11	8.269006530832D-13
7	-1.272866644000D-10	1.985460981397D-11	-4.226560743702D-13
8	1.412497774809D-13	-8.003922930542D-13	1.975681079140D-14

N2MIN = 1.00000D 08 1/CM3
N2MAX = 1.00000D 16 1/CM3

Max. rel. Error: 1.8916 %
Mean rel. Error: .4888 %

Effective Deexcitation and Ionisation Rates
for Helium Atoms in Metastable Level (2 3S)



4.26 Reaction 2.3.9j $e + He(1s^1 2s^1 3S; r) \rightarrow e + He^+(1s) + e$

Eth = 24.588 - 19.818 eV = 4.770 eV

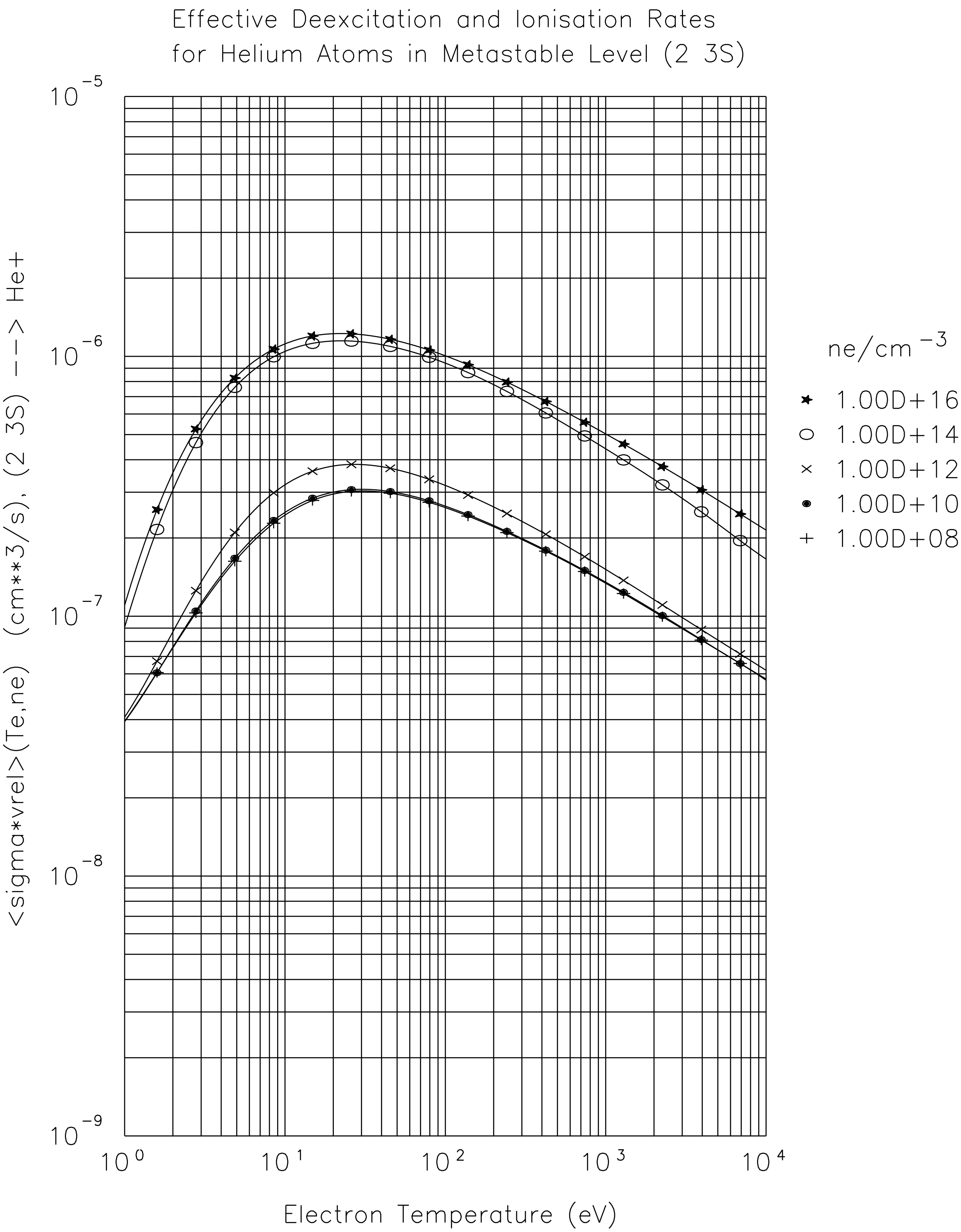
T-Index \ E-Index	0	1	2
0	-2.055363233340D+01	4.495119087580D-01	-5.238622256836D-01
1	5.210334391329D+00	-2.968974679742D-01	2.779506719390D-01
2	-2.250469356935D+00	7.010500442526D-02	-1.213577735853D-01
3	5.852050404826D-01	8.921407862649D-02	4.101964952741D-03
4	-9.522800090383D-02	-6.623026789339D-02	1.426598675675D-02
5	8.361746435674D-03	1.876265413172D-02	-4.938987966830D-03
6	-2.082000823695D-04	-2.653612987499D-03	7.235705862418D-04
7	-1.971223241071D-05	1.866108873151D-04	-5.008080286294D-05
8	1.129438144977D-06	-5.204161575593D-06	1.341100873190D-06

T-Index \ E-Index	3	4	5
0	2.389768266075D-01	-5.282830816524D-02	6.225525677663D-03
1	-9.544309562602D-02	1.574089888139D-02	-1.373029882004D-03
2	3.981143589359D-02	-5.552464406897D-03	4.010663176656D-04
3	-6.610103528390D-03	9.857909449549D-04	-6.826906017552D-05
4	-7.969610821575D-04	-1.713086806983D-05	3.192882264529D-06
5	4.727105277550D-04	-1.892061941621D-05	5.709120517813D-07
6	-6.875356963100D-05	2.067400657772D-06	-4.852278760689D-08
7	4.145701518111D-06	-3.688167910326D-09	-5.119123986569D-09
8	-8.570742834160D-08	-5.179756344998D-09	4.745066997076D-10

T-Index \ E-Index	6	7	8
0	-3.959446131986D-04	1.281892887943D-05	-1.658021134736D-07
1	6.228002425783D-05	-1.303442479359D-06	8.322300537481D-09
2	-1.588204879114D-05	3.456291200468D-07	-3.614686328664D-09
3	3.402964809821D-06	-1.409141853759D-07	2.865103804351D-09
4	-3.264060374187D-07	2.446519428773D-08	-6.273758803879D-10
5	-3.265134644505D-08	8.398689087309D-10	1.744587191452D-12
6	1.231197186211D-08	-8.532974556790D-10	1.733410572003D-11
7	-1.110937956560D-09	9.978997213312D-11	-2.217674451730D-12
8	3.268128548473D-11	-3.678837719391D-12	8.560132404451D-14

N2MIN = 1.00000D 08 1/CM3
N2MAX = 1.00000D 16 1/CM3

Max. rel. Error: 7.0831 %
Mean rel. Error: 2.2103 %


Effective Deexcitation and Ionisation Rates
for Helium Atoms in Metastable Level (2 3S)
<sigma*vrel>(Te,ne) (cm**3/s), (2 3S) --> He+
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

4.27 Reaction 2.3.13a $e + He^{+}(1s) \rightarrow He(1s^2 1S)$

Helium multi-step model, here recombination: radiative + threebody + dielectronic Fujimoto Formulation II (only ground level transported, no metastables kept explicit), [22]

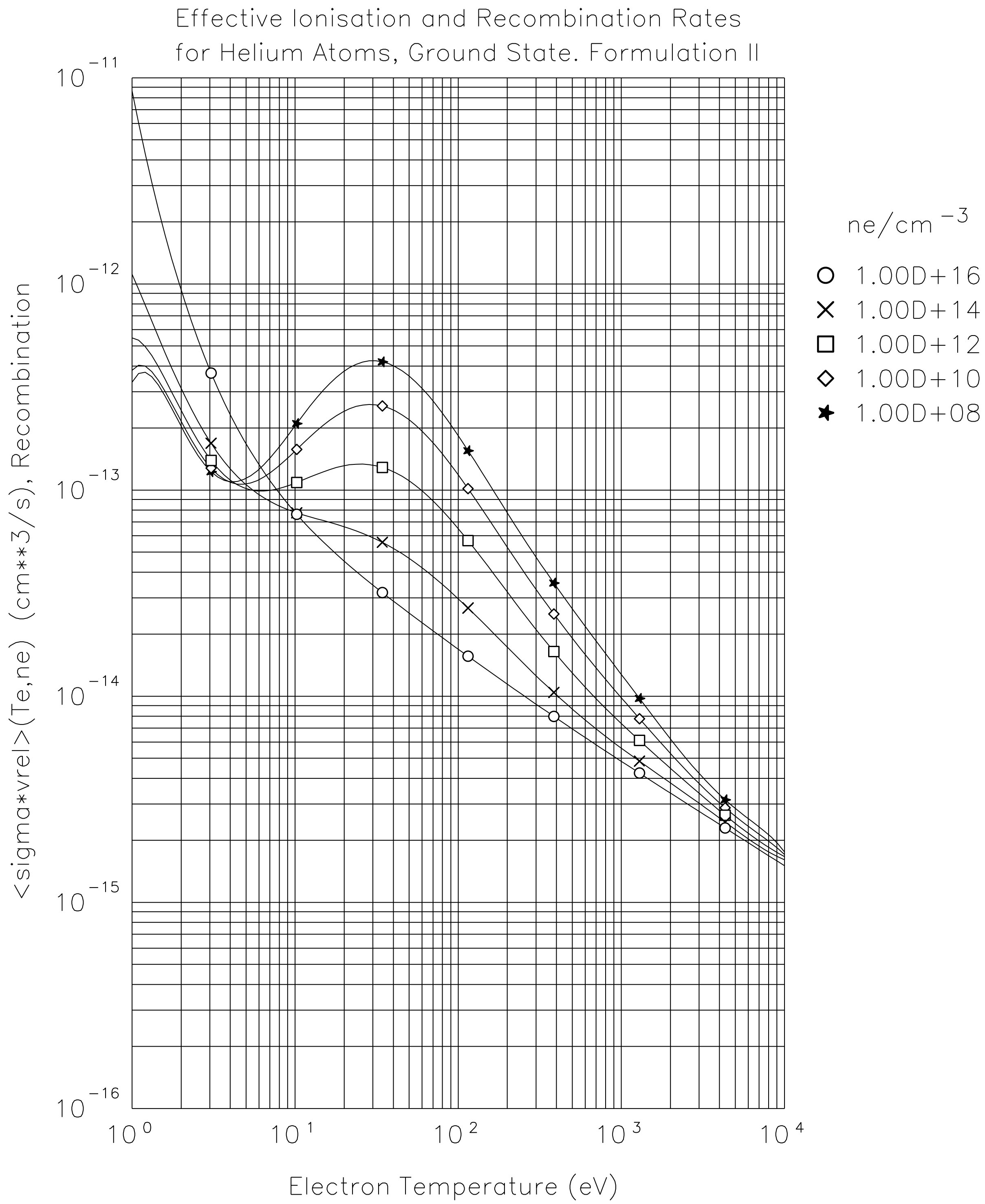
T-Index \ E-Index	0	1	2
0	-2.872754373123D+01	-6.171082987797D-03	2.414548639597D-02
1	1.564233603544D+00	-3.972220721457D-02	-4.466712599181D-02
2	-6.182140631482D+00	1.626641668186D-01	3.366589582541D-02
3	5.459428677778D+00	-1.700323494998D-01	-1.540106384088D-02
4	-2.128115924661D+00	7.233939709414D-02	5.819196258503D-03
5	4.373730373037D-01	-1.574917019835D-02	-1.456253436544D-03
6	-4.972257208732D-02	1.866175274689D-03	2.047337498511D-04
7	2.967287371427D-03	-1.147811325052D-04	-1.460813593905D-05
8	-7.271204747116D-05	2.874049670122D-06	4.124421172202D-07

T-Index \ E-Index	3	4	5
0	-7.188662067622D-03	9.481268604767D-04	-1.958887458637D-05
1	1.247359158796D-02	-1.660591942878D-03	6.019181402025D-05
2	-7.413737965595D-03	1.220189896183D-03	-9.505295724750D-05
3	9.524545793262D-04	-8.734341535385D-05	-2.796027477899D-06
4	-7.655935845761D-05	-1.837949067050D-05	4.725789832980D-06
5	4.772491845078D-05	-1.827059132463D-06	-6.941163292710D-08
6	-1.004438052808D-05	7.590734865850D-07	-6.771179147667D-08
7	7.422385993164D-07	-3.281946488134D-08	2.164459880579D-09
8	-1.689203971933D-08	-9.071172814458D-10	1.844295219334D-10

T-Index \ E-Index	6	7	8
0	-5.507786383328D-06	4.358288686930D-07	-9.503272091010D-09
1	3.800156798817D-06	-3.377807793756D-07	6.828447501225D-09
2	4.459492214068D-06	-1.552772441333D-07	2.866586118879D-09
3	4.561981097438D-07	4.940311502014D-09	-6.525725010760D-10
4	-3.997782411860D-07	1.036731541123D-08	-3.373845712183D-11
5	2.716740135949D-08	-1.143121626264D-09	1.295139027087D-11
6	1.218720257518D-09	6.787024479540D-11	-2.432253541918D-12
7	1.113868237282D-10	-1.513922678655D-11	3.951084520871D-13
8	-2.055023511556D-11	1.101902611511D-12	-2.206082129473D-14

```
N2MIN =   1.00000D 08 1/CM3
N2MAX =   1.00000D 16 1/CM3

  Max. rel. Error:  16.4494 %
  Mean rel. Error:   3.2360 %
```



Effective Ionisation and Recombination Rates
for Helium Atoms, Ground State. Formulation II
<sigma*vrel>(Te,ne) (cm**3/s), Recombination
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

4.28 Reaction 2.3.13b $e + He^{+}(1s) \rightarrow He(1s^2 1S; r)$

Helium multi-step model, here recombination: radiative + threebody + dielectronic Fujimoto Formulation I (ground level and 2 meta-stable levels transported), effective recombination into ground state $(1|1S)$

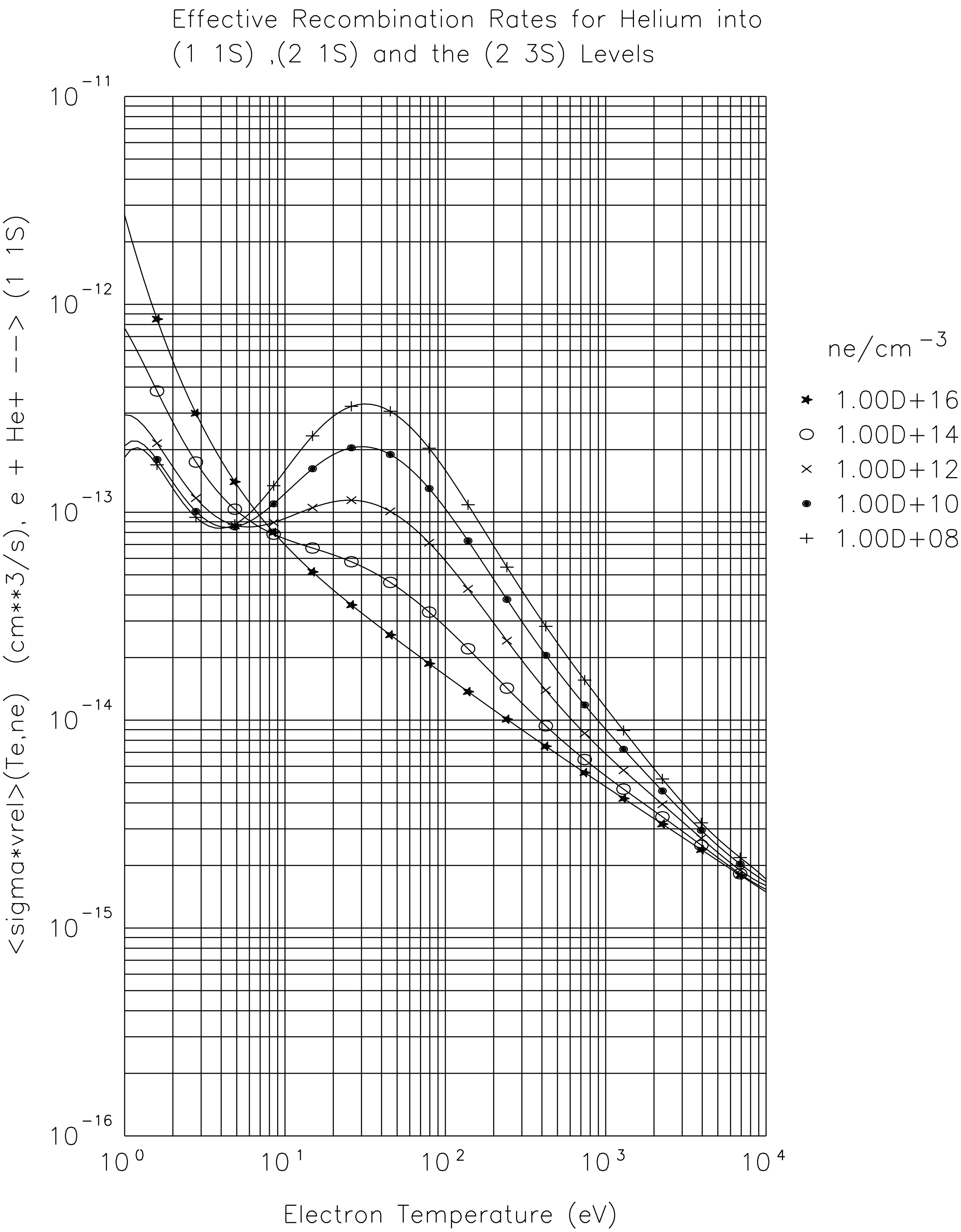
T-Index \ E-Index	0	1	2
0	-2.932450239883D+01	-1.725214936087D-02	4.209507397331D-02
1	1.368459463821D+00	-7.548584212824D-02	-3.321889449021D-02
2	-5.057940093488D+00	2.531332526084D-01	-1.925988688740D-02
3	4.437755591817D+00	-2.369773678428D-01	2.411850401784D-02
4	-1.704236205062D+00	9.630485149239D-02	-6.971157814419D-03
5	3.430644471030D-01	-2.061167258227D-02	7.487855629993D-04
6	-3.809452269361D-02	2.434745940239D-03	-1.722706965522D-06
7	2.218026788496D-03	-1.502211895379D-04	-5.165559630643D-06
8	-5.301589276464D-05	3.780661493099D-06	2.647213620732D-07

T-Index \ E-Index	3	4	5
0	-1.843883199649D-02	4.330069861940D-03	-5.571398183907D-04
1	2.246769961570D-02	-6.920109284335D-03	1.034704067336D-03
2	-1.562041938975D-03	2.844891620769D-03	-5.840417169956D-04
3	-6.245247150004D-03	1.707788608782D-04	8.828047075521D-05
4	2.150122229030D-03	-1.997306644340D-04	2.987453868437D-06
5	-2.352870835454D-04	2.321396939441D-05	-1.669051074965D-06
6	-1.929788529702D-06	1.001774243168D-06	7.435769683477D-08
7	1.999043007214D-06	-3.211502011021D-07	8.114609805127D-09
8	-9.897241177277D-08	1.504658532546D-08	-5.883462440247D-10

T-Index \ E-Index	6	7	8
0	4.006413547865D-05	-1.488766590351D-06	2.211904689519D-08
1	-8.066726007499D-05	3.137222500010D-06	-4.796687278784D-08
2	5.166332348737D-05	-2.133727041895D-06	3.362146796114D-08
3	-1.099721749926D-05	5.014979395019D-07	-8.105197770220D-09
4	4.904814231191D-07	-2.358575243153D-08	2.498171028400D-10
5	1.745034668357D-07	-1.128396994326D-08	2.586295673609D-10
6	-3.342032519922D-08	2.451263340785D-09	-5.477602284810D-11
7	2.414625764231D-09	-2.022906627308D-10	4.590099192405D-12
8	-6.465233005227D-11	6.181507714121D-12	-1.430061439345D-13

N2MIN = 1.00000D 08 1/CM3
N2MAX = 1.00000D 16 1/CM3

Max. rel. Error: 15.0191 %
Mean rel. Error: 3.1731 %



Effective Recombination Rates for Helium into
(1 1S) ,(2 1S) and the (2 3S) Levels
10^{-11}
10^{-12}
10^{-13}
10^{-14}
10^{-15}
10^{-16}
<sigma*vrel>(Te,ne) (cm**3/s), e + He+ --> (1 1S)
10^0
10^1
10^2
10^3
10^4
Electron Temperature (eV)
ne/cm $^{-3}$
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

4.29 Reaction 2.3.13c $e + He^+(1s) \rightarrow He(1s^1 2s^1 1S; r) + hv$

[22]. Here: effective recombination into meta-stable level $(2|1S)$.

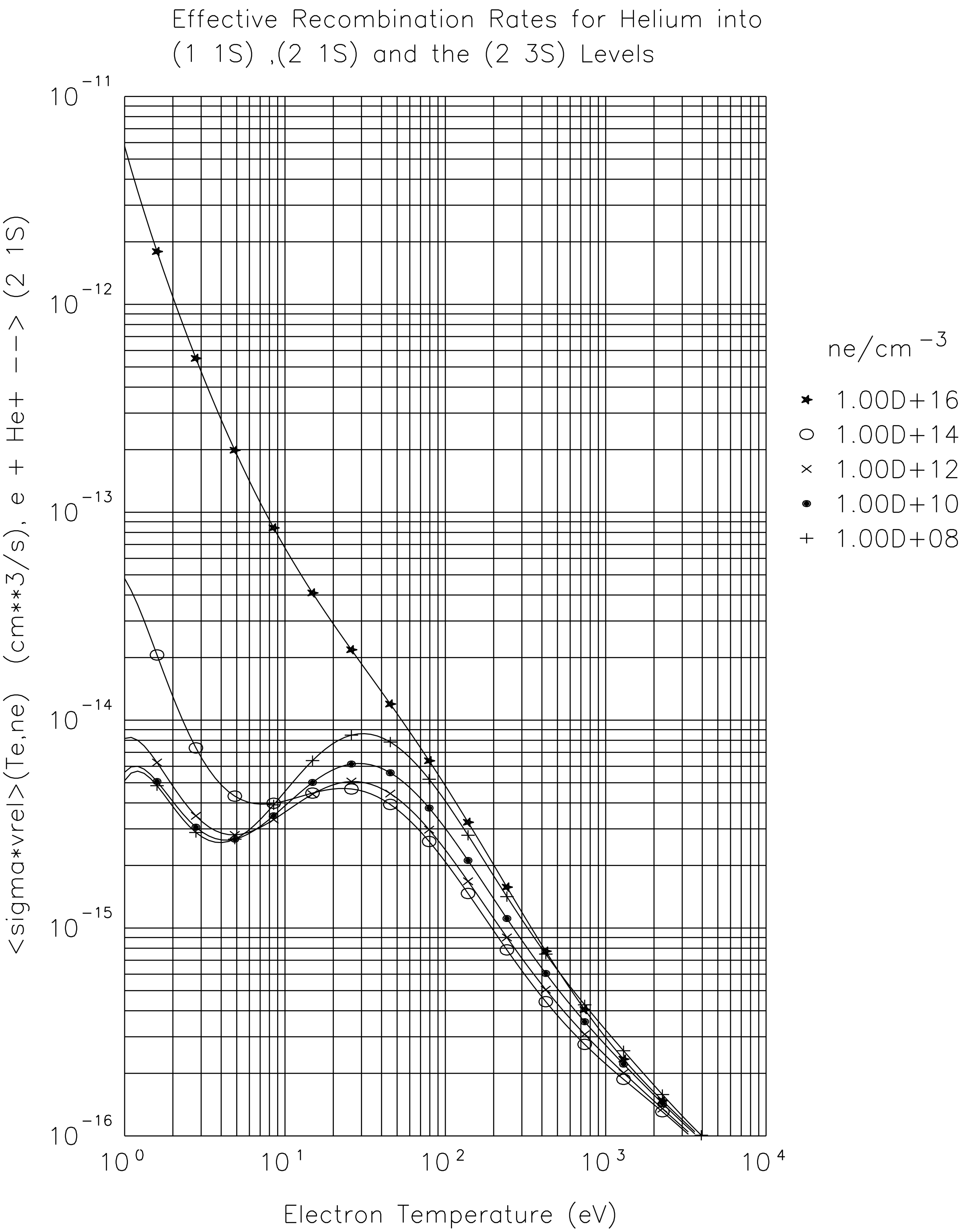
T-Index \ E-Index	0	1	2
0	-3.290594969157D+01	5.936377204270D-01	-5.786568026984D-01
1	1.289118555318D+00	-7.322821510173D-01	5.216313908016D-01
2	-4.581116130605D+00	4.359234826400D-01	-1.879684009591D-01
3	3.975023080430D+00	-1.135607337249D-01	-2.093787195291D-02
4	-1.511744296191D+00	9.273954721890D-03	3.091151170807D-02
5	3.006694544045D-01	-7.098672020828D-04	-6.524345786670D-03
6	-3.291282273842D-02	4.674323034046D-04	3.252758528411D-04
7	1.885862263038D-03	-7.894912660673D-05	3.023350709086D-05
8	-4.430501809351D-05	3.801909601518D-06	-2.522313594898D-06

T-Index \ E-Index	3	4	5
0	2.219812747147D-01	-4.301992587218D-02	4.645717376756D-03
1	-1.469524854136D-01	1.758178948996D-02	-6.553480315101D-04
2	4.156489474989D-02	-1.653580474529D-03	-5.740235177360D-04
3	4.449510483711D-03	-7.099391762833D-04	1.140482945563D-04
4	-6.447934562370D-03	5.521339815402D-04	-1.215385049113D-05
5	1.190208632381D-03	-8.535844740287D-05	1.100343069640D-06
6	7.662178711899D-06	-1.003394753061D-05	9.133676744341D-07
7	-1.693836511335D-05	2.998300023499D-06	-2.134268520285D-07
8	1.008933043477D-06	-1.637662372864D-07	1.194860574397D-08

T-Index \ E-Index	6	7	8
0	-2.827549938027D-04	9.098967864743D-06	-1.204212130817D-07
1	-3.911503234413D-05	3.838699392781D-06	-8.432388008514D-08
2	8.252435318894D-05	-4.174329959264D-06	7.461274593602D-08
3	-1.015903498277D-05	4.067368927608D-07	-5.956193776494D-09
4	-1.743597814483D-06	1.504881645494D-07	-3.516856295239D-09
5	3.283228084253D-07	-2.777357769656D-08	6.855090395029D-10
6	-3.246510016651D-08	1.021166636920D-09	-2.826061022812D-11
7	5.448904749550D-09	1.026064555133D-11	-1.372295711583D-12
8	-3.572199625876D-10	1.353028569150D-12	7.810473188768D-14

N2MIN = 1.00000D 08 1/CM3
N2MAX = 1.00000D 16 1/CM3

Max. rel. Error: 12.8697 %
Mean rel. Error: 4.3370 %



Effective Recombination Rates for Helium into
(1 1S) ,(2 1S) and the (2 3S) Levels
<sigma*vrel>(Te,ne) (cm**3/s), e + He+ --> (2 1S)
Electron Temperature (eV)
ne/cm^{-3}
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

4.30 Reaction 2.3.13d $e + He^{+}(1s) \rightarrow He(1s^{1}2s^{1}3S; r) + hv$

[22]. Here: effective recombination into meta-stable level $(2|3S)$.

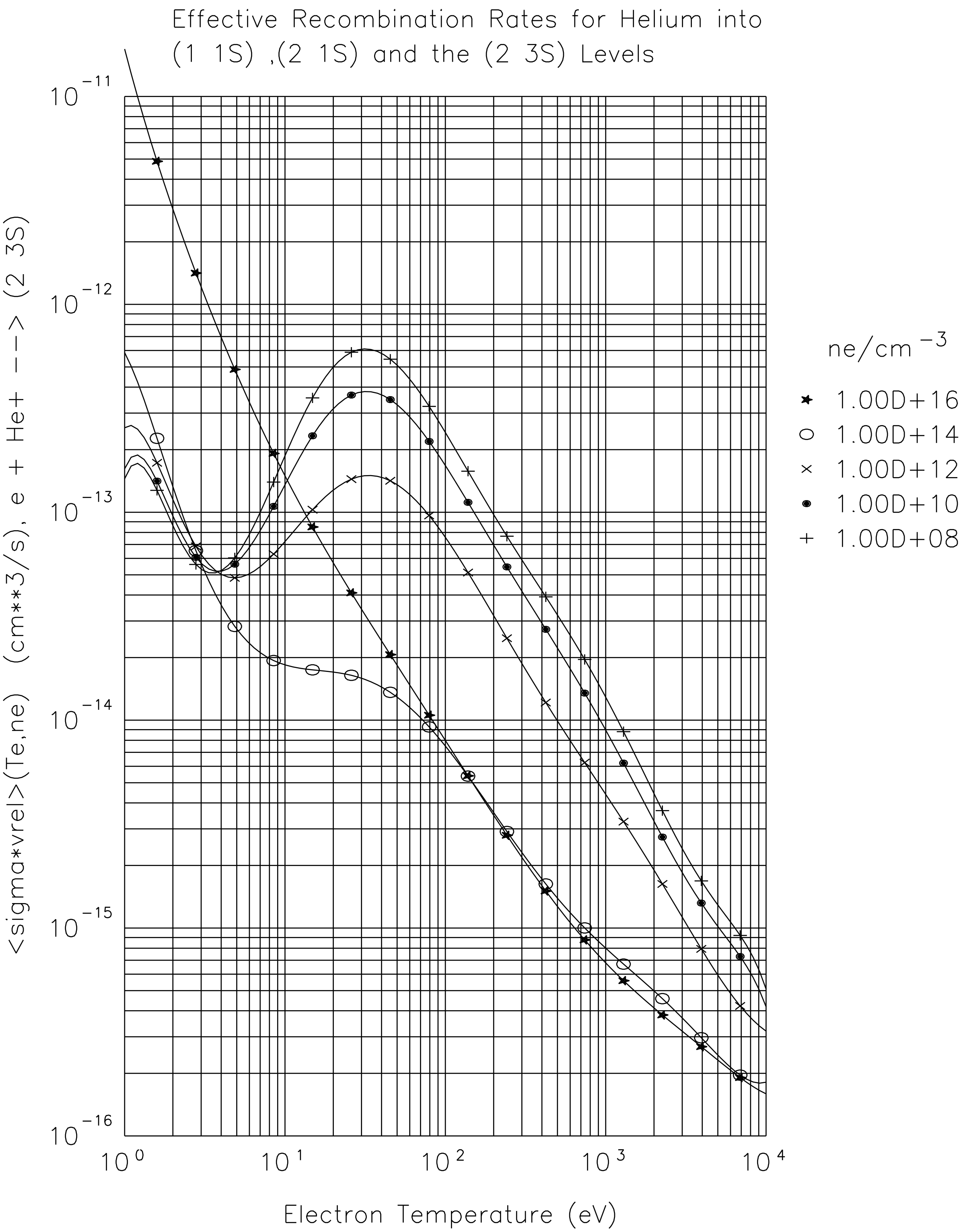
T-Index \ E-Index	0	1	2
0	-2.956247006586D+01	4.857379877013D-01	-4.698385090723D-01
1	2.226655583858D+00	-5.008925977592D-01	4.409072277517D-01
2	-8.386271074322D+00	-6.680555751755D-02	1.358293373473D-01
3	7.802551872732D+00	1.513454163302D-01	-2.382523353494D-01
4	-3.176066118073D+00	-2.915513853670D-02	8.389442053277D-02
5	6.790403187679D-01	-8.583336134054D-03	-8.339355078342D-03
6	-8.005018693268D-02	3.501616009283D-03	-8.108811483383D-04
7	4.936833057738D-03	-4.038202701566D-04	1.917972012272D-04
8	-1.245931475232D-04	1.550754095349D-05	-8.944775549284D-06

T-Index \ E-Index	3	4	5
0	1.816491812551D-01	-3.584007722558D-02	4.008582628581D-03
1	-1.490076771833D-01	2.428208422290D-02	-2.197248681202D-03
2	-4.192264845130D-02	6.681287810863D-03	-3.474715517406D-04
3	7.034251548002D-02	-9.653541471324D-03	3.950052472624D-04
4	-2.594911934917D-02	3.785834072023D-03	-1.721024156646D-04
5	3.100772841149D-03	-5.641898835295D-04	3.146400786804D-05
6	1.226453809803D-04	9.772361084934D-06	-1.220791337288D-06
7	-4.737671071626D-05	4.334084847132D-06	-1.862385782715D-07
8	2.364380548912D-06	-2.583267263336D-07	1.313403535033D-08

T-Index \ E-Index	6	7	8
0	-2.562289391561D-04	8.707904177549D-06	-1.215806872260D-07
1	1.109906018249D-04	-2.900632901582D-06	3.027934182965D-08
2	-1.076950834118D-05	1.529234802310D-06	-3.663757563702D-08
3	2.408158683211D-05	-2.450750101163D-06	5.482201735529D-08
4	-8.229247133546D-06	9.351454862581D-07	-2.147970339341D-08
5	1.022459855218D-06	-1.480508733520D-07	3.599099499020D-09
6	-8.112983260770D-08	1.090170350156D-08	-2.777349026055D-10
7	6.415033848685D-09	-3.093185955060D-10	7.625408371264D-12
8	-2.624838999683D-10	-6.850467836445D-13	5.598594440202D-14

```
N2MIN =   1.00000D 08 1/CM3
N2MAX =   1.00000D 16 1/CM3

  Max. rel. Error:  21.5948 %
  Mean rel. Error:   5.8841 %
```



Effective Recombination Rates for Helium into
(1 1S) ,(2 1S) and the (2 3S) Levels
<sigma*vrel>(Te,ne) (cm**3/s), e + He+ --> (2 3S)
Electron Temperature (eV)
ne/cm -3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

4.31 Reaction 2.2C $e + He^{+}(1s) \rightarrow He^{++} + e + e$

Ionization Rates for singly charged helium ions
COLRAD (McWhirter), hydrogen-like approximation [24]
$\langle sigma * vrel\rangle(Te, ne)$(cm**3/s)

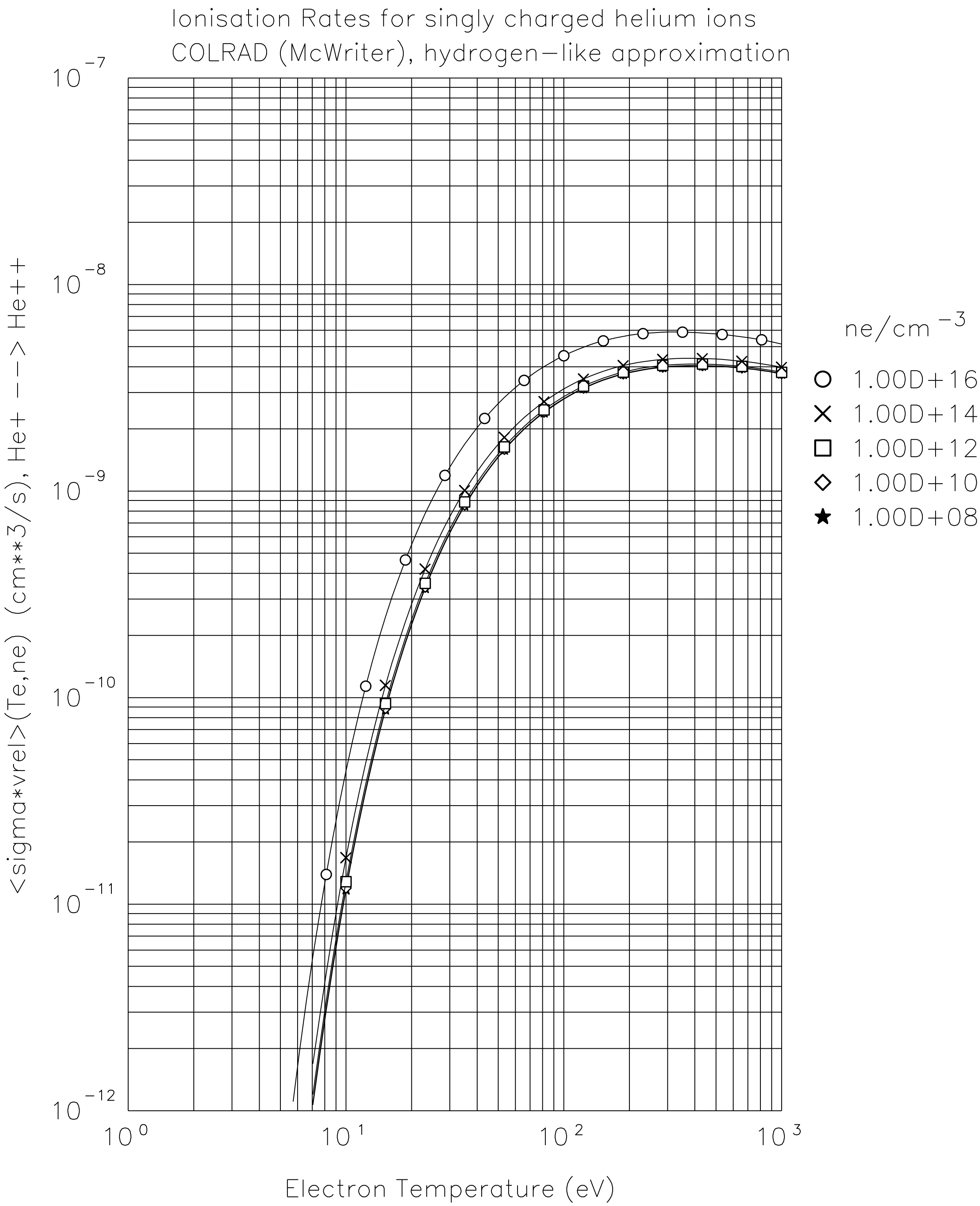
T-Index \ E-Index:	0	1	2
0	-7.504895618885D+01	2.201465463709D-02	-5.069769253639D-03
1	5.475513292431D+01	-5.417589714886D-02	3.775044165759D-02
2	-2.693028880068D+01	3.774947998557D-02	-2.411882491817D-02
3	8.660359434783D+00	-1.764877195580D-02	7.243690204418D-03
4	-1.955813859940D+00	8.202168146805D-03	-3.070056924124D-03
5	3.098090672677D-01	-2.771730559069D-03	1.297834186151D-03
6	-3.271260113212D-02	5.325112160328D-04	-2.929485587655D-04
7	2.050483088051D-03	-5.190809564237D-05	3.145856505861D-05
8	-5.719259025474D-05	2.004313708534D-06	-1.292078319547D-06

T-Index \ E-Index:	3	4	5
0	3.915543748345D-03	-1.031132793821D-03	1.654691798718D-04
1	-1.633041262280D-02	3.459931210677D-03	-4.194602018842D-04
2	8.989971506710D-03	-1.829622573856D-03	2.164276869595D-04
3	-1.273168299077D-03	1.763624435402D-04	-2.479535228702D-05
4	9.752207930721D-05	6.251121832296D-05	-6.640018325938D-06
5	-1.296242864408D-04	-8.805176355814D-06	1.717983972172D-06
6	4.563001069981D-05	-1.836358658149D-06	-6.237635823497D-08
7	-5.886932297134D-06	4.277584502763D-07	-1.234530993035D-08
8	2.657229485598D-07	-2.298984920724D-08	9.125550698905D-10

T-Index \ E-Index:	6	7	8
0	-1.471360785546D-05	6.823504501535D-07	-1.247427417560D-08
1	2.861803302953D-05	-1.036298188456D-06	1.553321018673D-08
2	-1.391926980686D-05	4.512942119697D-07	-5.904011561947D-09
3	1.882628114227D-06	-6.323064673756D-08	8.275404429978D-10
4	1.952370344224D-07	1.751264412799D-09	-1.622640470420D-10
5	-5.793682625805D-08	-1.220451186228D-09	7.819729115572D-11
6	1.020925549512D-09	4.417455780936D-10	-1.689115024159D-11
7	4.669160272059D-10	-4.606556580267D-11	1.506577519668D-12
8	-2.598750073326D-11	1.464529452448D-12	-4.669913022501D-14

```
N2MIN =   1.00000D 08 1/CM3
N2MAX =   1.00000D 16 1/CM3

  Max. rel. Error:    .3141 %
  Mean rel. Error:    .1103 %
```



Ionisation Rates for singly charged helium ions
COLRAD (McWriter), hydrogen–like approximation
<sigma*vrel>(Te,ne) (cm**3/s), He+ --> He++
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

4.32 Reaction 2.6A0old $e + C \rightarrow C^{+} + 2e$

Ionization Rates for neutral carbon atoms, ADAS 93
$\langle sigma * vrel \rangle (Te, ne)$(cm**3/s)

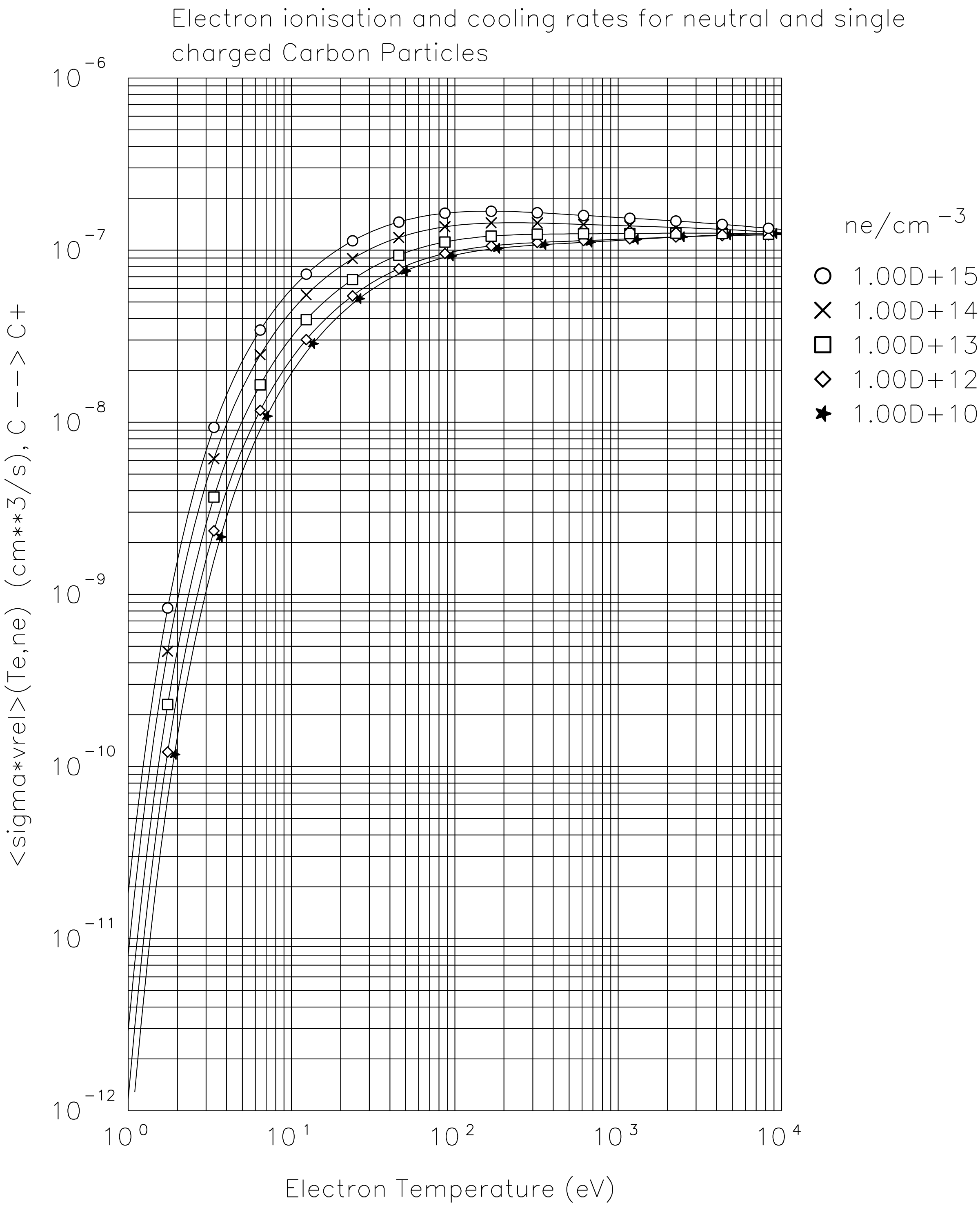
T-Index \ E-Index	0	1	2
0	-2.971457639565D+01	1.107810794514D+00	-4.929092425558D-01
1	1.499806652944D+01	-2.549991583370D+00	9.026830825116D-01
2	-7.145949073329D+00	6.664487958895D-01	-1.727631701810D-01
3	2.340511256186D+00	-1.160562412201D-01	1.411445363827D-02
4	-5.249343322780D-01	2.135356892092D-02	-1.638667443530D-03
5	7.562193210612D-02	-2.918522374196D-03	1.286365870759D-04
6	-6.679478578836D-03	3.000723261637D-04	-1.608459495742D-05
7	3.270945618657D-04	-1.883054084198D-05	1.732029469888D-06
8	-6.675613055770D-06	4.142784144247D-07	-3.486309036661D-08

T-Index \ E-Index	3	4	5
0	1.300116911300D-01	-2.066054730760D-02	2.042310400958D-03
1	-1.879920996407D-01	2.431269610957D-02	-2.004879563783D-03
2	2.797274709016D-02	-2.903521270254D-03	1.995997150157D-04
3	-5.971983093427D-04	-7.377767439216D-05	1.267367125997D-05
4	6.910190376581D-05	-5.464445143303D-06	5.674562003155D-07
5	-7.001250033151D-07	7.855848854211D-07	-8.856533728232D-08
6	4.049976855256D-07	-2.088187353775D-08	-6.089302275674D-09
7	-1.675345958159D-07	1.579162356473D-08	-6.994965968869D-10
8	2.814990023664D-09	-2.947061589979D-10	2.418389203250D-11

T-Index \ E-Index	6	7	8
0	-1.198777580517D-04	3.797623457774D-06	-5.001748956830D-08
1	1.013724485054D-04	-2.844335907618D-06	3.386548334244D-08
2	-8.259361032307D-06	1.731145419218D-07	-1.270740802103D-09
3	-1.039751082795D-06	4.599752398553D-08	-7.953804201299D-10
4	1.653887367244D-08	-3.425776625948D-09	8.586728657030D-11
5	-4.099151298763D-09	5.982763605144D-10	-1.370643938638D-11
6	1.485858394226D-09	-8.987472676089D-11	1.616606601615D-12
7	-1.867411789486D-11	2.235327393834D-12	-3.862181485750D-14
8	-1.188451034508D-12	4.216699821614D-14	-9.477595087316D-16

```
T1MIN =   1.00000D 00 EV
T1MAX =   5.00000D 04 EV
N2MIN =   1.00000D 10 1/CM3
N2MAX =   1.00000D 15 1/CM3

  Max. rel. Error:   1.2246 %
  Mean rel. Error:    .2748 %
```



Electron ionisation and cooling rates for neutral and single
charged Carbon Particles
<sigma*vrel>(Te,ne) (cm**3/s), C --> C+
Electron Temperature (eV)
ne/cm −3
1.00D+15
1.00D+14
1.00D+13
1.00D+12
1.00D+10

4.33 Reaction 2.6A0 $e + C \rightarrow C^+ + 2e$

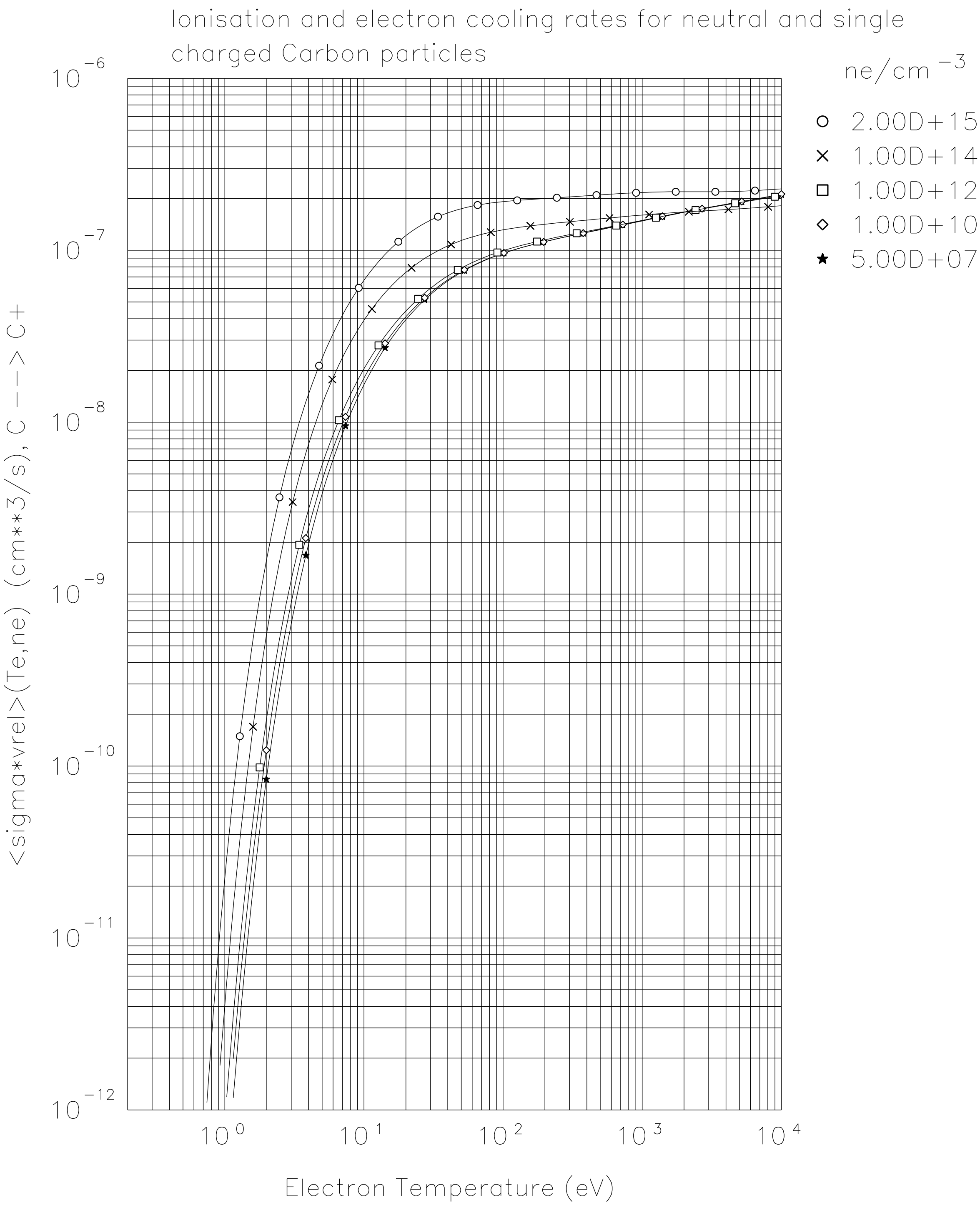
Ionization Rates for neutral carbon atoms, ADAS 96 (SCD file created 1999), wider ne range, valid down to Te
$\langle sigma * vrel \rangle (Te, ne)$(cm**3/s)

T-Index \ E-Index:	0	1	2
0	-2.890504943234D+01	9.382839308120D-02	2.146808798456D-02
1	1.128485221871D+01	-5.850481452497D-02	2.374566494759D-02
2	-5.283388592745D+00	6.329297280568D-03	-4.302638519171D-02
3	1.689125680998D+00	6.808882801275D-03	2.502867263820D-02
4	-3.714940077956D-01	-3.481037248289D-03	-7.268774147421D-03
5	5.363195671451D-02	7.835377415214D-04	1.207900142438D-03
6	-4.766905571057D-03	-9.598529131309D-05	-1.210126896293D-04
7	2.345920029717D-04	6.175011485777D-06	6.977119694001D-06
8	-4.872178662005D-06	-1.628130866861D-07	-1.790817980766D-07

T-Index \ E-Index:	3	4	5
0	-2.339754225821D-02	9.200846573095D-03	-1.599349146121D-03
1	1.931530108075D-03	-3.071331917173D-03	6.114583335214D-04
2	9.287508601615D-03	-5.127151471163D-04	-3.433146946945D-05
3	-6.178662143043D-03	6.351219035494D-04	-3.691080660263D-05
4	1.658483232062D-03	-1.322063957569D-04	3.930837141541D-06
5	-2.374617290052D-04	7.430007372665D-06	1.203511359877D-06
6	2.204871338469D-05	-9.261361677301D-08	-1.720094674893D-07
7	-1.413574574644D-06	5.974559368526D-08	-1.021257540576D-09
8	4.551518866341D-08	-5.024236657462D-09	6.046297479837D-10

T-Index \ E-Index:	6	7	8
0	1.372347450635D-04	-5.686843038956D-06	9.103688643261D-08
1	-5.240748877572D-05	2.088709914551D-06	-3.180763933757D-08
2	5.408272819845D-06	-2.358727101110D-07	3.623621457130D-09
3	1.327643406022D-06	-2.444856842874D-08	6.043768384445D-11
4	1.152400985903D-08	-3.548578028426D-09	7.792109116104D-11
5	-1.003883166088D-07	2.397274969888D-09	-7.946985931213D-12
6	8.106904295618D-09	1.071971005151D-10	-9.102843406962D-12
7	6.994299194286D-10	-6.638887280272D-11	1.708046514034D-12
8	-6.818402877894D-11	3.914737351814D-12	-8.253571086476D-14

T1MIN = 0.20000D 00 EV
T1MAX = 1.50000D 04 EV
N2MIN = 5.00000D 07 1/CM3
N2MAX = 2.00000D 15 1/CM3
Max. rel. Error: 0.259E+01 %
Mean rel. Error: 0.700E+00 %



Ionisation and electron cooling rates for neutral and single charged Carbon particles
ne/cm −3
2.00D+15
1.00D+14
1.00D+12
1.00D+10
5.00D+07
<sigma*vrel>(Te,ne) (cm**3/s), C --> C+
10 −6
10 −7
10 −8
10 −9
10 −10
10 −11
10 −12
10 0
10 1
10 2
10 3
10 4
Electron Temperature (eV)

4.34 Reaction 2.7A0 $e + N \rightarrow N^{+} + 2e$

Ionization Rates for neutral nitrogen, ADAS 96
$\langle sigma * vrel \rangle (Te, ne)$(cm**3/s)

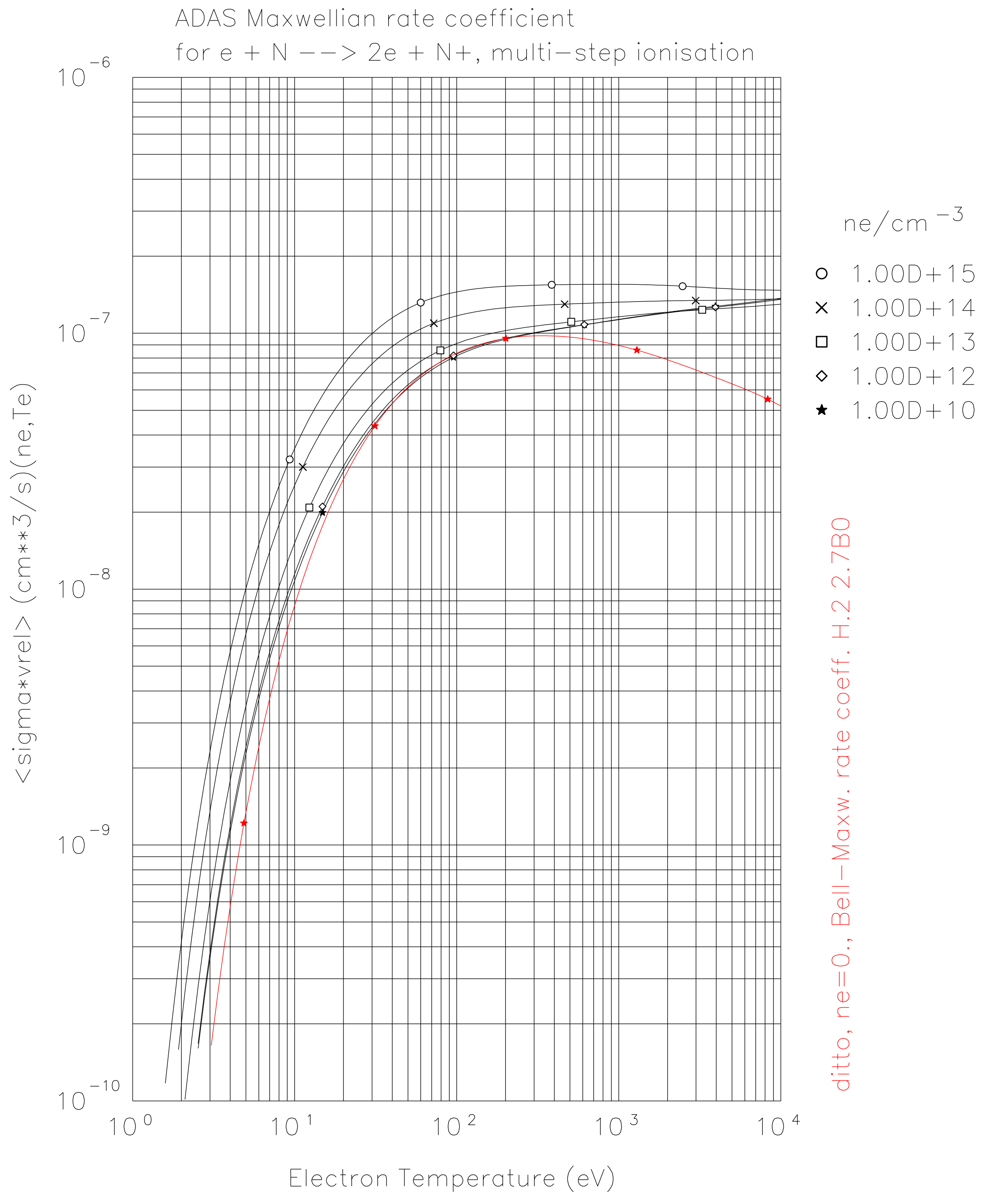
T-Index \ E-Index:	0	1	2
0	-3.125599079514D+01	8.881344790721D-02	3.875689690924D-02
1	1.501972942719D+01	-2.245019983323D-01	-1.170266566017D-01
2	-8.563505396323D+00	2.563611550679D-01	5.993043917730D-02
3	3.259172785778D+00	-1.459562059574D-01	-3.629785517504D-03
4	-8.028485847461D-01	4.560133800137D-02	-3.579706539679D-03
5	1.239955993583D-01	-8.202838629323D-03	9.221893790607D-04
6	-1.152891908930D-02	8.472922768697D-04	-8.914562423314D-05
7	5.889464965188D-04	-4.669795084986D-05	3.515034526935D-06
8	-1.269186213968D-05	1.064343317380D-06	-3.611292369142D-08

T-Index \ E-Index:	3	4	5
0	-7.367355926910D-03	-8.933351435213D-04	1.937451469905D-04
1	4.426863655734D-02	-4.430861799571D-03	3.253064203736D-05
2	-3.020399271227D-02	3.927234491519D-03	-1.959177270882D-04
3	6.189975576309D-03	-7.279341465385D-04	2.546794744614D-05
4	-2.466055005611D-04	-1.287111351337D-05	7.621210137952D-06
5	-3.039643456169D-05	9.491026278127D-06	-1.535906103316D-06
6	-2.900624448150D-06	3.745360666294D-07	3.692979682516D-08
7	8.586152612035D-07	-1.356120392220D-07	4.747296972249D-09
8	-3.812958439511D-08	5.487542777793D-09	-1.437006614531D-10

T-Index \ E-Index:	6	7	8
0	-4.302425039372D-06	-4.449062046116D-07	1.641092601069D-08
1	1.829955290678D-05	-1.088030063258D-06	2.060046531889D-08
2	1.624638825366D-06	2.150911835291D-07	-6.785152839285D-09
3	-1.935192712324D-07	-2.396214128585D-10	1.822600582381D-10
4	-2.751092797923D-07	-9.878792756722D-09	3.880864455805D-10
5	3.342842434144D-08	3.080573580529D-09	-1.004120274888D-10
6	5.903820424145D-10	-3.124143842671D-10	8.467756187765D-12
7	3.173842995092D-11	-2.659413955852D-12	4.729814633051D-14
8	-1.577918732137D-11	1.171782749066D-12	-2.466359817399D-14

T1MIN = 0.20000D 00 1/CM3
T1MAX = 1.50000D 04 1/CM3
N2MIN = 5.00000D 07 1/CM3
N2MAX = 2.00000D 15 1/CM3

Max. rel. Error: 2.9930 %
Mean rel. Error: 0.7199 %



ADAS Maxwellian rate coefficient
for e + N --> 2e + N+, multi-step ionisation
<sigma*vrel> (cm**3/s)(ne,Te)
Electron Temperature (eV)
ne/cm -3
1.00D+15
1.00D+14
1.00D+13
1.00D+12
1.00D+10
ditto, ne=0., Bell-Maxw. rate coeff. H.2 2.7B0

4.35 Reaction 2.8A0 $e + O \rightarrow O^{+} + 2e$

Ionization Rates for neutral oxygen, ADAS 96
$\langle sigma * vrel \rangle (Te, ne)$(cm**3/s)

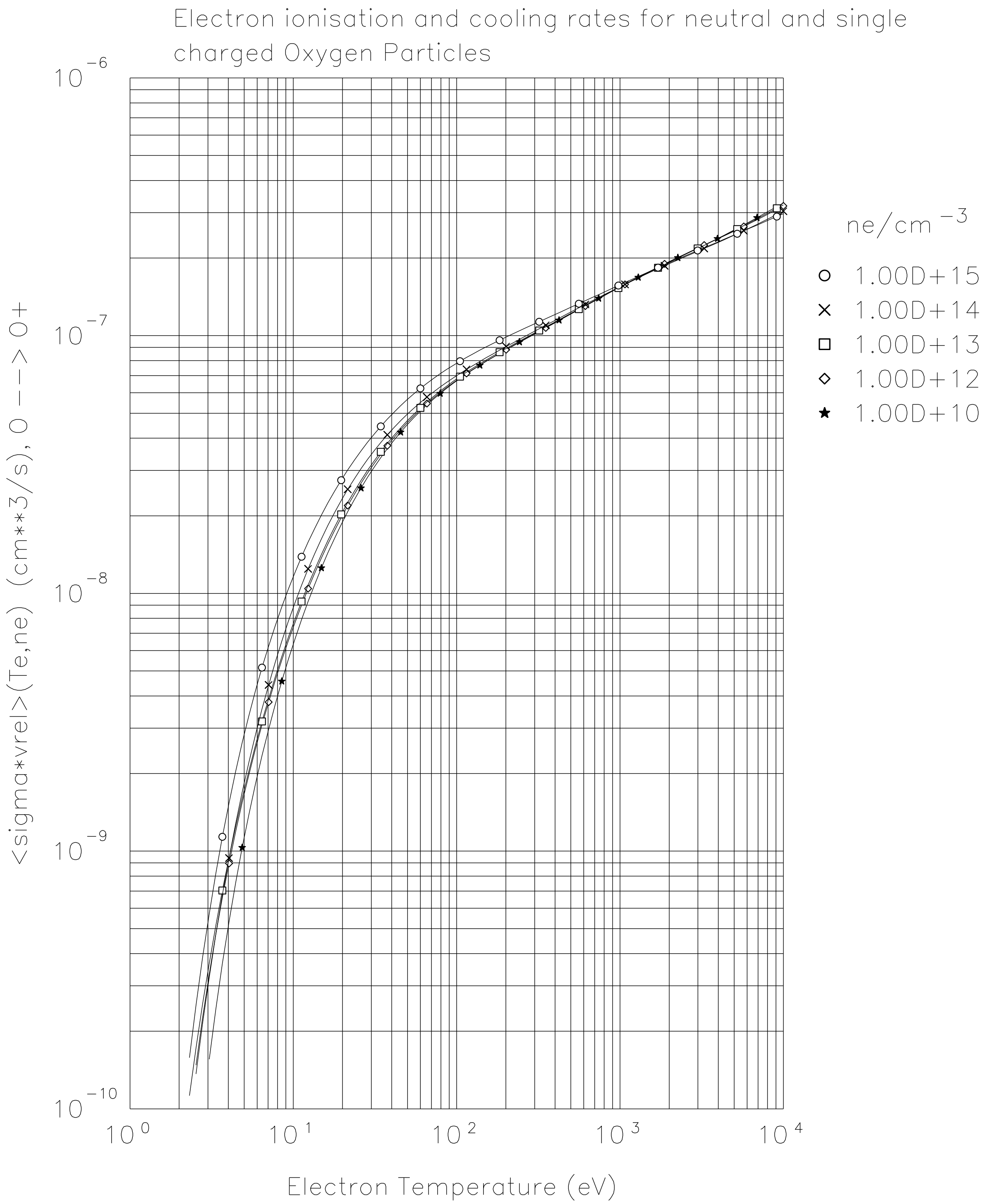
T-Index \ E-Index	0	1	2
0	-3.328362393733D+01	-4.484395495461D-01	6.167722720177D-01
1	1.655302385400D+01	9.070420476255D-01	-7.492202987359D-01
2	-9.246899232716D+00	-6.861308571709D-01	3.853130674026D-01
3	3.468152479829D+00	2.653279717129D-01	-9.503130449306D-02
4	-8.532829072212D-01	-5.834222497364D-02	9.030518658158D-03
5	1.333834015615D-01	7.496194087446D-03	4.753498599348D-04
6	-1.265465442757D-02	-5.453745857810D-04	-1.638438870269D-04
7	6.624459298778D-04	2.000567259474D-05	1.131325208597D-05
8	-1.465832842295D-05	-2.619665824220D-07	-2.369684156977D-07

T-Index \ E-Index	3	4	5
0	-2.589961397492D-01	4.118976653137D-02	-1.959950990473D-03
1	2.638779663615D-01	-3.490775262239D-02	5.793136771074D-04
2	-1.247067819410D-01	1.680118594677D-02	-5.089127052875D-04
3	2.929033903989D-02	-4.430118646918D-03	2.507450743683D-04
4	-2.550710866039D-03	4.693149835285D-04	-3.225531357806D-05
5	-1.298585181626D-04	-1.260782059434D-06	-6.674084144123D-07
6	3.005970684014D-05	-2.808693744681D-07	3.437325607970D-08
7	-5.378571580338D-07	-4.142319433039D-07	5.148458125516D-08
8	-5.436002215866D-08	2.927695957962D-08	-3.654799869508D-09

T-Index \ E-Index	6	7	8
0	-9.739946501376D-05	1.139459064885D-05	-2.689494629827D-07
1	2.088106459889D-04	-1.507734725052D-05	3.066201565961D-07
2	-5.644498060513D-05	4.238399098405D-06	-7.745613330596D-08
3	-3.986851509525D-06	7.226554994339D-08	-6.046272342238D-09
4	1.782158795226D-06	-1.325057610801D-07	4.204627741204D-09
5	2.320632028445D-08	9.646974765235D-09	-4.535319182284D-10
6	-1.080831526075D-08	1.525797006183D-10	1.266728082419D-11
7	-2.138597283955D-09	3.312940600087D-11	-2.535541525696D-13
8	1.982722701483D-10	-4.851782342710D-12	4.242787336605D-14

```
T1MIN =   0.20000D 00 1/CM3
T1MAX =   1.50000D 04 1/CM3
N2MIN =   5.00000D 07 1/CM3
N2MAX =   2.00000D 15 1/CM3

  Max. rel. Error:   8.8515 %
  Mean rel. Error:   0.9745 %
```


Electron ionisation and cooling rates for neutral and single
charged Oxygen Particles
<sigma*vrel>(Te,ne) (cm**3/s), O --> O+
Electron Temperature (eV)
ne/cm −3
1.00D+15
1.00D+14
1.00D+13
1.00D+12
1.00D+10

4.36 Reaction 2.3.2B0 $e + He^{+}(1s) \rightarrow He(1s^{2}1S) + hv$

Data from impurity transport code "STRAHL", [19]
Recombination Rates for single charged Helium Ions (w/o three-body)

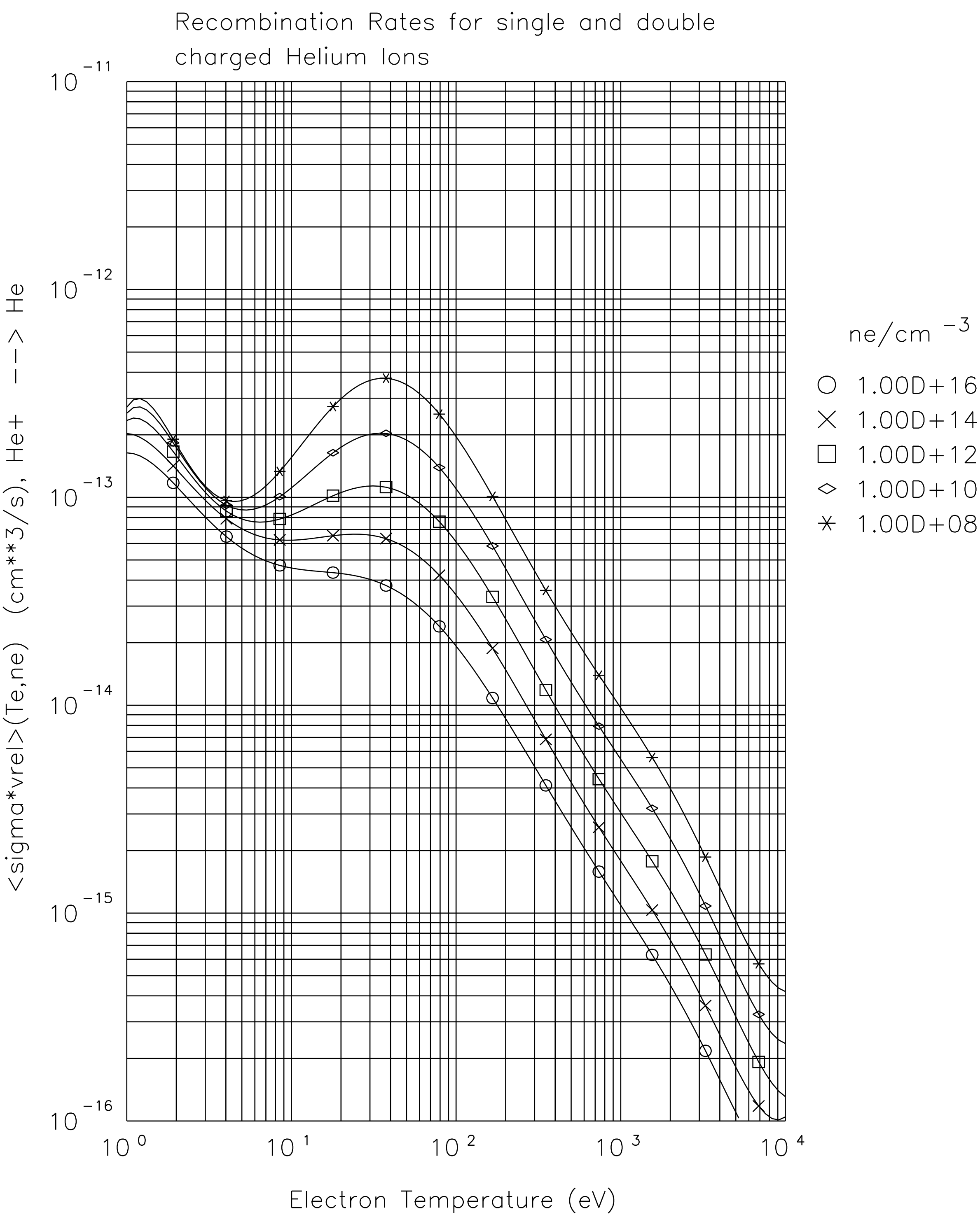
T-Index \ E-Index:	0	1	2
0	-2.898866818182D+01	-3.068735204957D-02	7.818231657785D-02
1	1.816504622984D+00	-1.996644882484D-01	-2.022934910684D-01
2	-5.957620306977D+00	5.564226839342D-01	2.720939045109D-01
3	4.883356392367D+00	-5.504736532364D-01	-1.589729887673D-01
4	-1.785690784875D+00	2.554161096465D-01	4.391044966362D-02
5	3.443976158874D-01	-6.304562647473D-02	-6.048646045521D-03
6	-3.666670180913D-02	8.499875301084D-03	4.080124220783D-04
7	2.042474095540D-03	-5.896220272289D-04	-1.226466093436D-05
8	-4.653873125342D-05	1.644314326566D-05	1.520073468241D-07

T-Index \ E-Index:	3	4	5
0	-4.360289476744D-02	1.088616122909D-02	-1.442780146671D-03
1	1.057079914763D-01	-2.358570776702D-02	2.968485844589D-03
2	-1.235076579967D-01	2.248324096678D-02	-2.497067848696D-03
3	6.635551763548D-02	-9.269476706908D-03	8.089219419856D-04
4	-1.831174182029D-02	1.752848228102D-03	-7.418643102963D-05
5	2.905705534546D-03	-1.678595996471D-04	-7.790745301776D-06
6	-2.926914092439D-04	1.437277876918D-05	1.085106848461D-06
7	1.894207582471D-05	-1.612501983994D-06	6.632343028157D-08
8	-5.989406850464D-07	8.425772893569D-08	-8.367921447451D-09

T-Index \ E-Index:	6	7	8
0	1.043554466513D-04	-3.878190225512D-06	5.783675088058D-08
1	-2.149050424333D-04	8.207356509792D-06	-1.268150915732D-07
2	1.779838048026D-04	-7.127873717134D-06	1.175164928521D-07
3	-5.675497459272D-05	2.589770454486D-06	-4.902088171680D-08
4	5.561292499931D-06	-4.363201173962D-07	1.122814678532D-08
5	2.465992165628D-07	5.016603759447D-08	-1.901239672341D-09
6	-4.188299784450D-09	-8.149167953030D-09	2.753349347791D-10
7	-1.167337552792D-08	1.023904862606D-09	-2.578964505694D-11
8	8.321169431770D-10	-4.756050161152D-11	9.973991458967D-13

```
N2MIN =   1.00000D 08 1/CM3
N2MAX =   1.00000D 16 1/CM3

  Max. rel. Error:  16.6458 %
  Mean rel. Error:   6.0389 %
```



Recombination Rates for single and double
charged Helium Ions
10^{-11}
10^{-12}
10^{-13}
10^{-14}
10^{-15}
10^{-16}
<sigma*vrel>(Te,ne) (cm**3/s), He+ --> He
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}
Electron Temperature (eV)
ne/cm $^{-3}$
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

4.37 Reaction 2.3.2B1 $e + He^{++} \rightarrow He^{+}(1s) + hv$

Data from impurity transport code "STRAHL", [19]
Recombination Rates for double charged Helium Ions (w/o three-body)

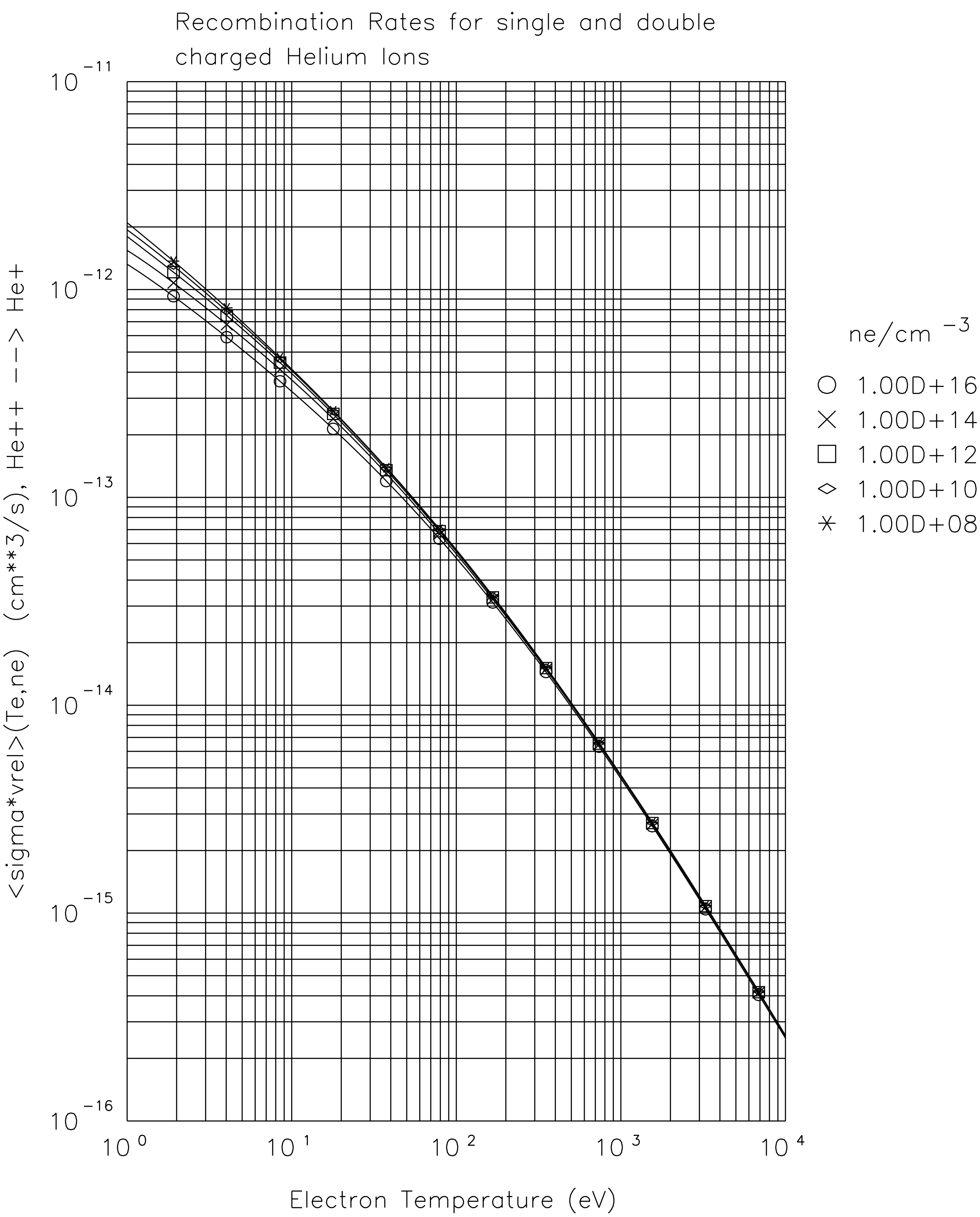
T-Index \ E-Index:	0	1	2
0	-2.689730745452D+01	-4.189774474235D-02	3.907009691550D-02
1	-6.433874222932D-01	3.299308672728D-02	-2.112564779272D-02
2	-1.779312827872D-02	-2.784310132407D-02	3.756334628555D-03
3	-2.941208629331D-03	2.348797955174D-02	-3.603044725903D-03
4	-1.097079440712D-04	-1.041386945451D-02	2.110484002085D-03
5	3.627190561298D-05	2.454594288891D-03	-5.469934610104D-04
6	-2.051498433274D-06	-3.182066464328D-04	7.445181597104D-05
7	9.049897913059D-08	2.153132862082D-05	-5.311099451965D-06
8	-2.589196837551D-09	-5.949628493511D-07	1.570204824882D-07

T-Index \ E-Index:	3	4	5
0	-1.856976066463D-02	4.225395376848D-03	-5.189796861077D-04
1	9.361575704851D-03	-2.096884296496D-03	2.460978351345D-04
2	-1.500786464745D-05	-5.281337256827D-05	1.822688274176D-05
3	-1.199741248527D-04	7.729105625058D-05	-1.292571216711D-05
4	-1.215394704492D-04	8.835563507260D-07	2.346139078670D-07
5	3.717841775232D-05	-4.659128130528D-07	2.336659134693D-08
6	-4.784046635653D-06	-1.879150864927D-07	3.484666707655D-08
7	3.629533941682D-07	1.916572317480D-08	-4.026763260489D-09
8	-1.317789208085D-08	-1.808855222707D-10	9.539953463992D-11

T-Index \ E-Index:	6	7	8
0	3.509533525807D-05	-1.228955181999D-06	1.739986570439D-08
1	-1.534423152274D-05	4.789360346264D-07	-5.852399019136D-09
2	-2.723344400799D-06	1.665540778802D-07	-3.521640501579D-09
3	1.408094932910D-06	-7.805738049487D-08	1.598423694616D-09
4	-8.824848629130D-08	8.227207653809D-09	-2.131061531618D-10
5	2.250976512907D-10	-4.235527036624D-10	1.550066068535D-11
6	-2.041471088674D-09	8.365367756013D-11	-1.652661621540D-12
7	2.600592567487D-10	-9.155241214856D-12	1.419133004850D-13
8	-6.933726687326D-12	2.503906957552D-13	-3.798372386466D-15

N2MIN = 1.00000D 08 1/CM3
N2MAX = 1.00000D 16 1/CM3

Max. rel. Error: 4.5211 %
Mean rel. Error: 0.3321 %



Recombination Rates for single and double
charged Helium Ions
<sigma*vrel>(Te,ne) (cm**3/s), He++ --> He+
Electron Temperature (eV)
ne/cm -3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

4.38 Reaction 2.3.2C $e + He^{++} \rightarrow He^{+}(1s) + hv$

McWhirter's COLRAD (Hydrogen-like-ion) code: [24]

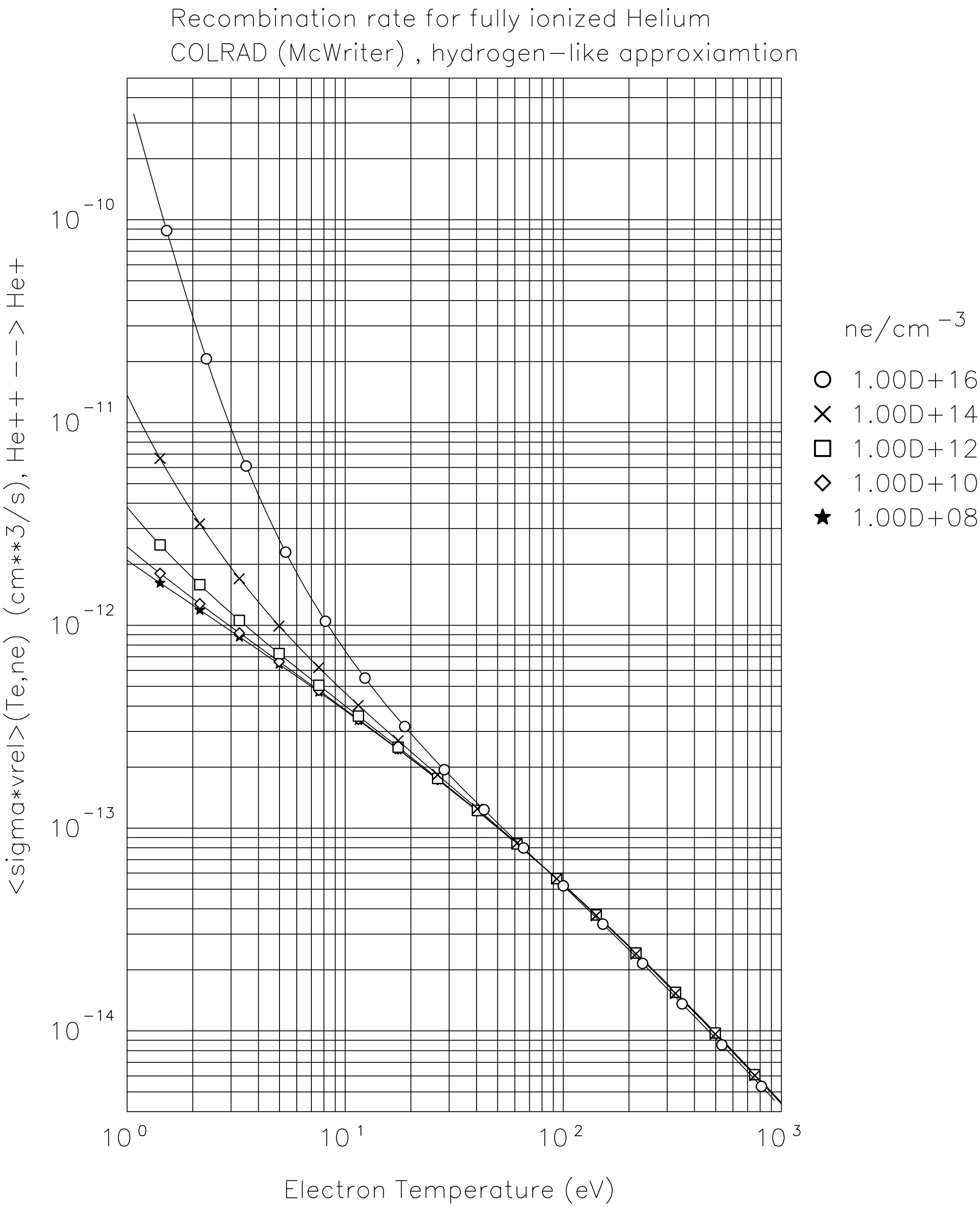
T-Index \ E-Index:	0	1	2
0	-2.689214714131D+01	3.841692092650D-02	-2.151460046121D-02
1	-7.416684284021D-01	-5.199553857553D-02	3.438416388654D-02
2	1.549811628148D-02	1.921849237497D-02	-8.089751449111D-03
3	-5.022643137206D-03	1.540629050827D-03	-7.848453879802D-03
4	-2.966821161678D-03	-1.893539924742D-03	4.846354316088D-03
5	1.716018223894D-03	6.468052386412D-06	-9.304158014361D-04
6	-4.229257398810D-04	1.430545146021D-04	2.720980715002D-05
7	4.855298100008D-05	-2.713103018793D-05	1.061403221125D-05
8	-2.091379921301D-06	1.529918299298D-06	-8.819776625245D-07

T-Index \ E-Index:	3	4	5
0	1.113251929355D-02	-2.612008568492D-03	3.555115960397D-04
1	-1.649709408021D-02	3.745035825507D-03	-4.770050113400D-04
2	5.051466915107D-03	-1.400888615025D-03	1.945119633833D-04
3	2.248785870746D-03	-1.593097934071D-04	-1.072827330359D-05
4	-1.751184149675D-03	2.311213551980D-04	-1.261592043312D-05
5	3.966217825812D-04	-5.599522857044D-05	3.206357069410D-06
6	-2.835692554212D-05	3.986381335434D-06	-1.237526859045D-07
7	-1.563313372280D-06	2.625959470738D-07	-3.940819818057D-08
8	2.172325347358D-07	-3.473325519567D-08	3.579469680317D-09

T-Index \ E-Index:	6	7	8
0	-2.731753894771D-05	1.106668461341D-06	-1.811175295207D-08
1	3.368532716741D-05	-1.237223053047D-06	1.842374272400D-08
2	-1.349677736259D-05	4.458107763508D-07	-5.616195641425D-09
3	1.549801888675D-06	-4.466672928817D-08	1.764795248975D-10
4	2.970110443204D-07	-7.035453496351D-09	1.847001891274D-10
5	-7.282619416548D-08	9.859256161271D-10	-1.965913679526D-11
6	-6.579575377692D-09	3.713367646234D-10	-4.389109805641D-12
7	2.919813070386D-09	-9.345142710166D-11	1.091816211559D-12
8	-2.087578972278D-10	6.033495076188D-12	-6.834858440297D-14

```
N2MIN =   1.00000D 08 1/CM3
N2MAX =   1.00000D 16 1/CM3

  Max. rel. Error:    .2915 %
  Mean rel. Error:    .0363 %
```


Recombination rate for fully ionized Helium
COLRAD (McWriter) , hydrogen−like approxiamtion
<sigma*vrel>(Te,ne) (cm**3/s), He++ −−> He+
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

Data from impurity transport code "STRAHL", [19]
Recombination Rates for single charged Be Ions (w/o three-body)

4.39 Reaction 2.3.4B0 $e + Be^{+} \rightarrow Be + hv$

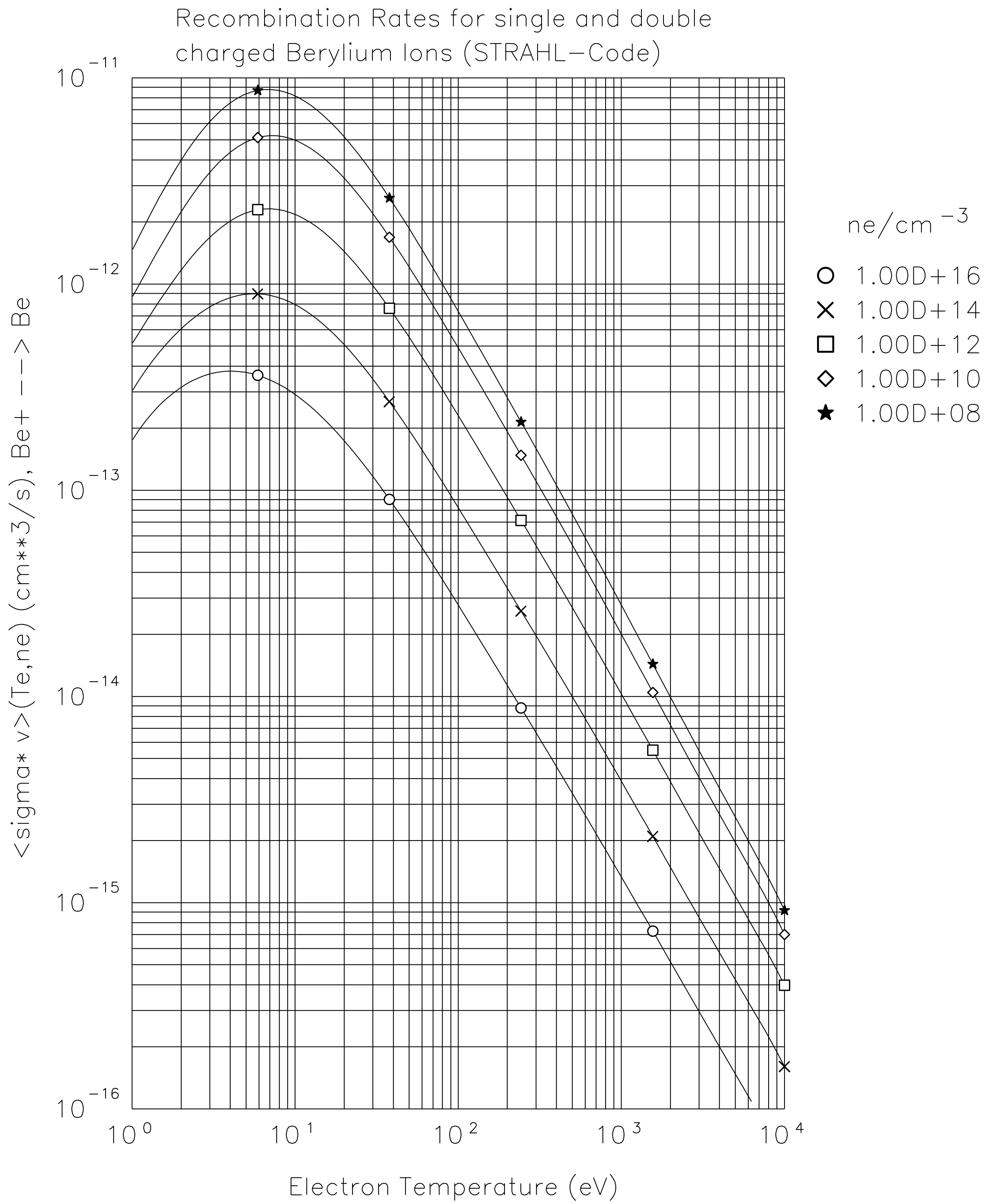
T-Index \ E-Index	0	1	2
0	-2.725929462038D+01	-1.296055365219D-01	2.245292514899D-02
1	1.598632576296D+00	1.302182159333D-04	-2.924508048254D-02
2	-7.069733638623D-02	1.301621002137D-02	1.388489192201D-02
3	-2.067343201215D-01	1.279607652398D-02	-8.226493898105D-03
4	2.796219393914D-02	-1.144848913448D-02	3.649484551890D-03
5	5.780534740910D-03	3.235328959441D-03	-7.482336928187D-04
6	-1.791370907134D-03	-4.230924884959D-04	5.874787455135D-05
7	1.653534958925D-04	2.595221480786D-05	-2.868950341068D-08
8	-5.311684839816D-06	-5.924897096316D-07	-1.331690294260D-07

T-Index \ E-Index	3	4	5
0	-1.244235177506D-02	3.352082223981D-03	-4.750321394261D-04
1	1.419746473600D-02	-4.100011934711D-03	6.269202287880D-04
2	-4.288663227065D-03	1.247934273073D-03	-2.322360688726D-04
3	2.497646037590D-04	4.417198058647D-05	1.716710307904D-05
4	2.490565857171D-05	-6.848577114910D-05	3.867029384089D-06
5	-2.697562238180D-05	1.387239687374D-05	-4.925211191787D-07
6	1.287864123306D-05	-2.354269427799D-06	3.073587970762D-08
7	-1.972411742335D-06	2.825061118192D-07	-7.702743784611D-09
8	9.449990775297D-08	-1.322880879849D-08	5.884617340207D-10

T-Index \ E-Index	6	7	8
0	3.617661866105D-05	-1.399725603339D-06	2.156930157877D-08
1	-5.003180914560D-05	1.985020029777D-06	-3.097413546292D-08
2	2.077646031907D-05	-8.667756318377D-07	1.374149193674D-08
3	-2.600090567970D-06	1.170403862720D-07	-1.712303962785D-09
4	-4.054013167812D-08	3.807690920711D-09	-2.098135936009D-10
5	-7.568193559820D-09	-9.343144402500D-10	6.008228504862D-11
6	6.869621840242D-09	-1.575414388099D-10	-3.255005891524D-12
7	-5.010735365600D-10	2.217617931435D-11	-5.017068152436D-14
8	2.010217590918D-12	-5.523345073293D-13	4.450782184771D-15

N2MIN = 1.00000D 08 1/CM3
N2MAX = 1.00000D 16 1/CM3

Max. rel. Error: 6.2699 %
Mean rel. Error: 1.0385 %


Recombination Rates for single and double
charged Berylium Ions (STRAHL−Code)
10 −11
10 −12
10 −13
10 −14
10 −15
10 −16
<sigma* v>(Te,ne) (cm**3/s), Be+ −−> Be
10 0
10 1
10 2
10 3
10 4
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

Data from impurity transport code "STRAHL", [19]
Recombination Rates for doubly charged Be Ions (w/o three-body)

4.40 Reaction 2.3.4B1 $e + Be^{++} \rightarrow Be^{+} + hv$

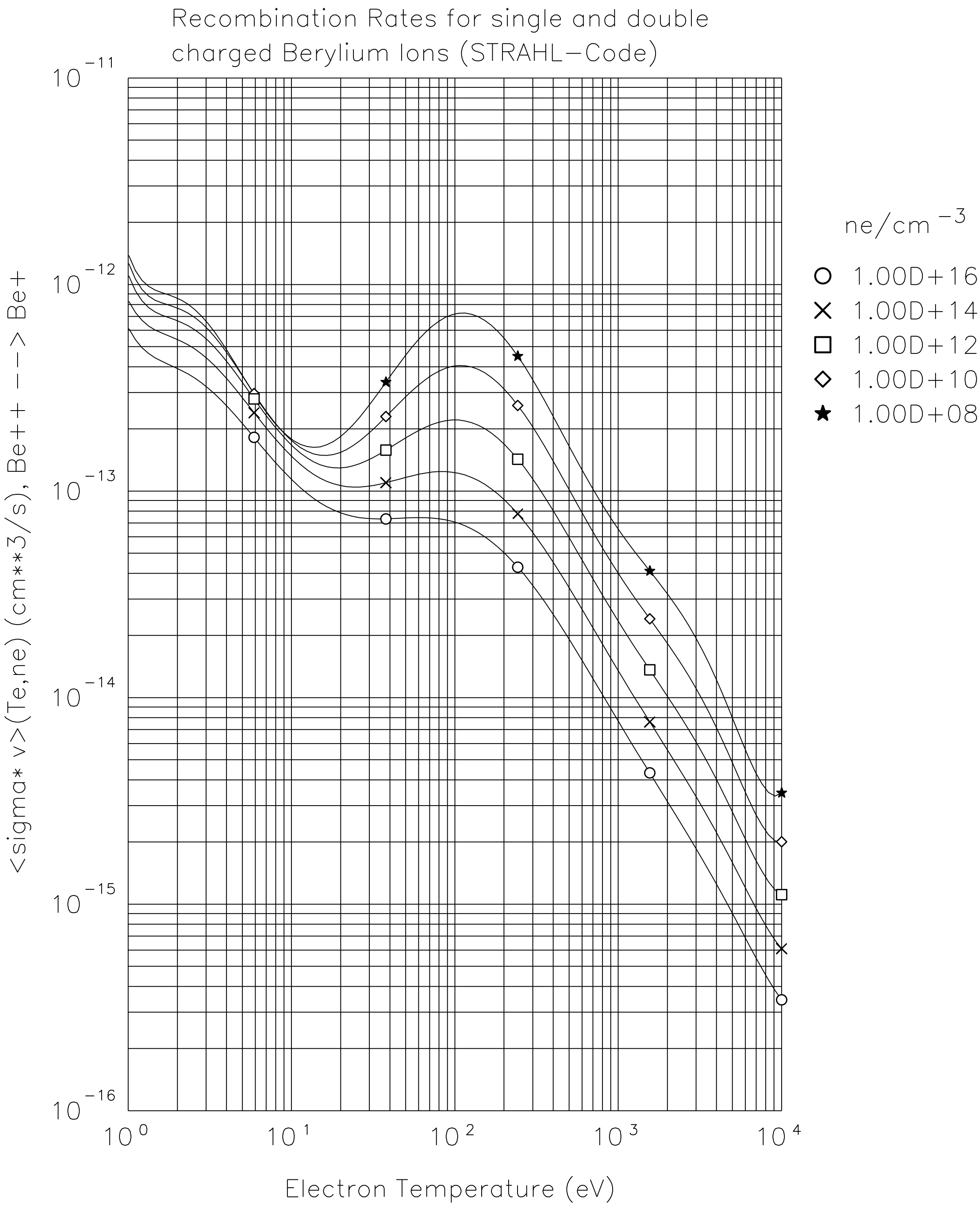
T-Index \ E-Index	0	1	2
0	-2.728409454363D+01	-1.241811114602D-01	1.328174994693D-01
1	-2.299481340923D+00	1.889049385273D-01	-2.096802695556D-01
2	4.885685671195D+00	-2.008764876827D-01	1.648701897617D-01
3	-5.251357791035D+00	1.631486837681D-01	-7.503508975743D-02
4	2.543387065980D+00	-7.665832661210D-02	1.818184962498D-02
5	-6.269100539052D-01	1.928103605570D-02	-2.110079141475D-03
6	8.249496717063D-02	-2.610043486921D-03	7.049607917706D-05
7	-5.541301207997D-03	1.802133911336D-04	5.702189021974D-06
8	1.496309096538D-04	-4.989437255700D-06	-3.793346968439D-07

T-Index \ E-Index	3	4	5
0	-5.910214948004D-02	1.285989947336D-02	-1.526818134096D-03
1	7.862010247287D-02	-1.449011071235D-02	1.461947439599D-03
2	-5.176172885669D-02	7.317236286761D-03	-5.006068297333D-04
3	2.174133611107D-02	-2.589246910885D-03	1.224743194508D-04
4	-5.098247822369D-03	5.664018911361D-04	-2.623256825779D-05
5	5.566735359374D-04	-5.584858194143D-05	3.211048838419D-06
6	-1.070413228691D-05	-3.231789926435D-07	-9.263670040464D-08
7	-2.513802136711D-06	4.313606598236D-07	-1.345931063116D-08
8	1.390196607821D-07	-2.084300790388D-08	8.301747763811D-10

T-Index \ E-Index	6	7	8
0	1.005202819403D-04	-3.444000702166D-06	4.788161890026D-08
1	-8.097933215082D-05	2.286740613012D-06	-2.544219441065D-08
2	1.209066466730D-05	2.327109476167D-07	-1.143146298073D-08
3	1.794422803392D-06	-3.537707361735D-07	8.456876614023D-09
4	-2.156876176312D-07	6.001245421502D-08	-1.405872631137D-09
5	-1.162693902875D-07	2.839971828955D-09	-4.787146737233D-11
6	2.652307178112D-08	-1.756949577531D-09	3.793381075708D-11
7	-2.115315858957D-09	1.781987654521D-10	-3.982036996716D-12
8	6.140791320298D-11	-5.995928373217D-12	1.365597034534D-13

N2MIN = 1.00000D 08 1/CM3
N2MAX = 1.00000D 16 1/CM3

Max. rel. Error: 19.0670 %
Mean rel. Error: 6.8000 %


Recombination Rates for single and double
charged Berylium Ions (STRAHL−Code)
<sigma* v>(Te,ne) (cm**3/s), Be++ −−> Be+
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

Data from impurity transport code "STRAHL", [19]
Recombination Rates for singly charged B Ions (w/o three-body)

4.41 Reaction 2.3.5B0 $e + B^{+} \rightarrow B + hv$

T-Index \ E-Index	0	1	2
0	-2.918956305904D+01	3.267550103394D-02	-4.823066950210D-02
1	8.901372275414D-01	-3.397383703545D-01	1.289852726858D-01
2	3.343506939285D+00	2.282515642460D-01	-9.103783258930D-02
3	-3.008679922076D+00	-5.388342232412D-02	2.167553199906D-02
4	1.112964165086D+00	1.260534666317D-03	-7.052258987157D-04
5	-2.245854583458D-01	1.232228819204D-03	-1.977243930068D-04
6	2.569483673112D-02	-1.483676372126D-04	-3.653164425984D-05
7	-1.563882824177D-03	2.300571590825D-06	1.068539912027D-05
8	3.933351235932D-05	2.450506888590D-07	-5.790374711265D-07

T-Index \ E-Index	3	4	5
0	1.084235624678D-02	4.281860869234D-05	-3.006985941012D-04
1	-3.793909504492D-02	4.214381437312D-03	5.910871725608D-06
2	2.943514986182D-02	-4.396644202855D-03	2.457154873853D-04
3	-7.736046881343D-03	1.441634147933D-03	-1.205002465319D-04
4	3.041197053727D-04	-1.227481836109D-04	1.626382262962D-05
5	1.177319584913D-04	-1.388326649605D-05	3.987367591191D-07
6	-2.705344470187D-06	1.266769783662D-06	-1.190611163202D-07
7	-2.136704633704D-06	2.158430175622D-07	-1.198466851774D-08
8	1.462074438369D-07	-1.888327232304D-08	1.358886807026D-09

T-Index \ E-Index	6	7	8
0	3.913363201372D-05	-1.987487775013D-06	3.630009838447D-08
1	-3.407335594737D-05	2.302780682573D-06	-4.724118588530D-08
2	3.689509356594D-06	-8.271291751691D-07	2.110278755964D-08
3	3.252526057299D-06	7.531658549775D-08	-3.753147142803D-09
4	-7.584147771365D-07	5.617754775370D-09	2.618328829288D-10
5	1.169505739833D-09	4.403213913778D-10	-2.082516311551D-11
6	6.928958657672D-09	-2.614080202244D-10	3.949718599255D-12
7	2.061339771948D-10	7.658743006289D-12	-2.294692069099D-13
8	-5.021219740097D-11	7.599476609801D-13	-1.699102278262D-15

N2MIN = 1.00000D 08 1/CM3
N2MAX = 1.00000D 16 1/CM3

Max. rel. Error: 15.7065 %
Mean rel. Error: 2.2281 %

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Data from impurity transport code "STRAHL", [19]
Recombination Rates for doubly charged B Ions (w/o three-body)

4.42 Reaction 2.3.5B1 $e + B^{++} \rightarrow B^{+} + hv$

T-Index \ E-Index	0	1	2
0	-2.696271008275D+01	-7.423987167527D-02	3.571997357107D-02
1	2.025499561046D+00	-2.017543096490D-01	3.889732429633D-02
2	-4.525788140577D-01	1.968460159120D-01	-6.412952427778D-02
3	-3.570127232580D-01	-7.677034125200D-02	2.458200773053D-02
4	2.176453653579D-01	1.757254624302D-02	-4.002911937506D-03
5	-5.551419899407D-02	-2.867264920419D-03	3.695449702619D-04
6	7.441747604883D-03	3.370916489954D-04	-3.534397855198D-05
7	-5.097962423085D-04	-2.392639746135D-05	3.307875064213D-06
8	1.405770163082D-05	7.241258048176D-07	-1.324815003798D-07

T-Index \ E-Index	3	4	5
0	-1.957405255310D-02	4.910268684892D-03	-6.464476031989D-04
1	-5.508972762098D-03	-4.103038628528D-04	1.902830434350D-04
2	1.585484361226D-02	-2.177399186175D-03	1.563169407076D-04
3	-4.639868259732D-03	6.167716090045D-04	-4.549330605404D-05
4	4.476991372525D-05	2.476330393040D-05	-4.315071827987D-06
5	1.274740751517D-04	-2.134889461534D-05	1.854544233927D-06
6	-1.479662046092D-05	1.581279654885D-06	-5.641458092706D-08
7	3.704493921569D-07	4.734791626350D-08	-1.455285738785D-08
8	1.013413641304D-08	-5.639914715196D-09	8.778548005120D-10

T-Index \ E-Index	6	7	8
0	4.608213097181D-05	-1.682328343662D-06	2.462552849920D-08
1	-1.936931659635D-05	8.242354232962D-07	-1.278778364027D-08
2	-5.717563499079D-06	1.159226451051D-07	-1.577559627995D-09
3	1.710077304240D-06	-4.608894528959D-08	1.034076249492D-09
4	4.279304514899D-07	-1.372870923770D-08	1.655700973007D-11
5	-1.249051804766D-07	3.972618831455D-09	-2.392056598119D-11
6	3.662805039340D-09	-1.410127247126D-10	-5.284190509036D-13
7	8.814048276934D-10	-2.379651723043D-11	3.923946846891D-13
8	-5.221503829879D-11	1.455883950215D-12	-1.921453513095D-14

N2MIN = 1.00000D 08 1/CM3
N2MAX = 1.00000D 16 1/CM3

Max. rel. Error: 7.5135 %
Mean rel. Error: 2.0952 %

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Data from impurity transport code "STRAHL", [19]
Recombination Rates for singly charged C Ions (w/o three-body)

4.43 Reaction 2.3.6B0 $e + C^{+} \rightarrow C + hv$

T-Index \ E-Index	0	1	2
0	-2.923411311232D+01	1.678337974062D-01	-1.269890700218D-01
1	-1.749378923698D+00	-5.867508813696D-01	3.397276446168D-01
2	6.127446343098D+00	3.513770163224D-01	-3.131110083174D-01
3	-4.441560794072D+00	-3.036137429391D-02	1.289084037863D-01
4	1.527841448611D+00	-3.932152302666D-02	-2.579185039826D-02
5	-2.957532224524D-01	1.516783137012D-02	2.555395039340D-03
6	3.288049698838D-02	-2.329750940307D-03	-1.325353309286D-04
7	-1.958690224903D-03	1.660871088628D-04	6.019220191601D-06
8	4.844127251791D-05	-4.535654544518D-06	-2.688488538169D-07

T-Index \ E-Index	3	4	5
0	2.720437652981D-02	-1.111631011430D-03	-3.480216080173D-04
1	-6.886574322654D-02	3.439645295541D-03	5.751243071725D-04
2	6.328287422211D-02	-4.081409017151D-03	-2.359905542867D-04
3	-2.671202258246D-02	2.108719776241D-03	-7.726681822181D-06
4	5.571312305715D-03	-4.818176068215D-04	1.334742280902D-05
5	-6.449949817748D-04	5.958291545901D-05	-1.609837915859D-06
6	5.723823810059D-05	-6.760386887666D-06	1.723115899471D-07
7	-4.762486550175D-06	7.317966975006D-07	-3.186790226580D-08
8	2.051810131854D-07	-3.486630219212D-08	2.049817590722D-09

T-Index \ E-Index	6	7	8
0	5.022696584875D-05	-2.548461445798D-06	4.576047167523D-08
1	-8.585218474052D-05	4.198580036578D-06	-7.219262965042D-08
2	4.464512662440D-05	-2.122412913024D-06	3.430797320366D-08
3	-6.790151469405D-06	2.960526415072D-07	-3.591611206495D-09
4	-8.898179366602D-08	2.113053977058D-08	-8.335017960966D-10
5	1.948025779931D-08	-3.879062320437D-09	1.297193866948D-10
6	1.158556735339D-08	-6.938508364472D-10	1.200809450653D-11
7	-9.678693700555D-10	1.166071387136D-10	-2.726800105081D-12
8	-8.574281546240D-13	-4.129172667888D-12	1.141324130890D-13

N2MIN = 1.00000D 08 1/CM3
N2MAX = 1.00000D 16 1/CM3

Max. rel. Error: 20.1006 %
Mean rel. Error: 2.5839 %

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4.44 Reaction 2.3.6A0 $e + C^{+} \rightarrow C + hv$

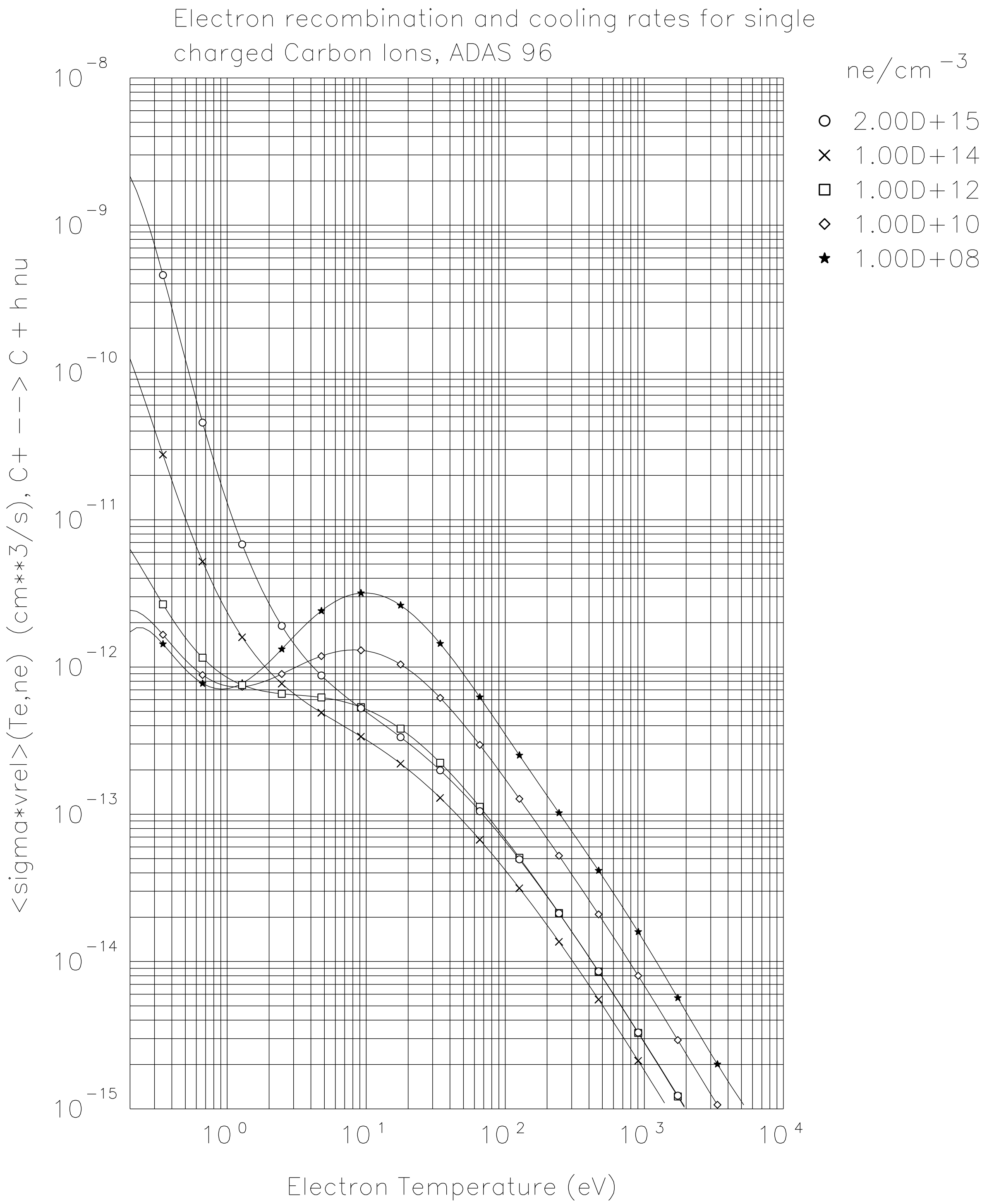
Recombination Rates for single charged Carbon Ions, ADAS 96, ACD rate, from 1999

T-Index \ E-Index	0	1	2
0	-2.796992538381D+01	6.819988039287D-03	3.842257610864D-02
1	1.471288791723D-01	-6.003209478730D-02	1.802911650863D-02
2	8.103931593515D-01	-3.504731380245D-02	-1.474290508525D-02
3	-1.623026496643D-01	1.274235445026D-02	2.060790563244D-03
4	-1.302169466770D-01	5.386695283253D-03	1.374456844694D-03
5	5.599274717311D-02	-3.085338510613D-03	-6.711535775454D-04
6	-8.929381749016D-03	5.539912095799D-04	1.230412514990D-04
7	6.550309402473D-04	-4.393065970093D-05	-1.036405910354D-05
8	-1.847457580217D-05	1.312856950673D-06	3.322982165259D-07

T-Index \ E-Index	3	4	5
0	-3.235896717762D-02	1.058873776305D-02	-1.710302443470D-03
1	-1.432167451365D-02	3.991884915376D-03	-5.752159798480D-04
2	6.579990576789D-03	-1.711173254046D-03	2.471461141394D-04
3	-1.076244103261D-03	2.333787946767D-04	-2.765733583071D-05
4	7.009089449357D-05	-4.787665210412D-05	4.816602111031D-06
5	4.864774756898D-05	8.008233456428D-06	-1.456885739549D-06
6	-1.813541577007D-05	5.543949043609D-07	9.444280069593D-08
7	2.196906769877D-06	-2.169818778260D-07	1.039102846927D-08
8	-8.856499450725D-08	1.195743943528D-08	-9.279005105188D-10

T-Index \ E-Index	6	7	8
0	1.452483800866D-04	-6.183333912008D-06	1.041103899070D-07
1	4.642474333442D-05	-2.012796753335D-06	3.611687769688D-08
2	-1.883650960415D-05	7.208627253974D-07	-1.098881493964D-08
3	1.432158848272D-06	-1.356564602721D-08	-6.484565786223D-10
4	-1.188047699234D-07	-8.137941011234D-09	3.668739870069D-10
5	1.043503386039D-07	-3.533424648528D-09	4.435771058377D-11
6	-1.483929180968D-08	8.541721518049D-10	-1.763336737449D-11
7	2.924832871584D-10	-5.157701888881D-11	1.429627587009D-12
8	2.710612984187D-11	5.535730249483D-13	-3.333237604857D-14

```
T1MIN =   0.20000D 00 1/CM3
T1MAX =   1.50000D 04 1/CM3
N2MIN =   5.00000D 07 1/CM3
N2MAX =   2.00000D 15 1/CM3
  Max. rel. Error:   0.195E+02 %
  Mean rel. Error:   0.429E+01 %
```


Electron recombination and cooling rates for single
charged Carbon Ions, ADAS 96
ne/cm −3
2.00D+15
1.00D+14
1.00D+12
1.00D+10
1.00D+08
<sigma*vrel>(Te,ne) (cm**3/s), C+ --> C + h nu
Electron Temperature (eV)
10 −8
10 −9
10 −10
10 −11
10 −12
10 −13
10 −14
10 −15
10 0
10 1
10 2
10 3
10 4

4.45 Reaction 2.3.6A0old $e + C^{+} \rightarrow C + hv$

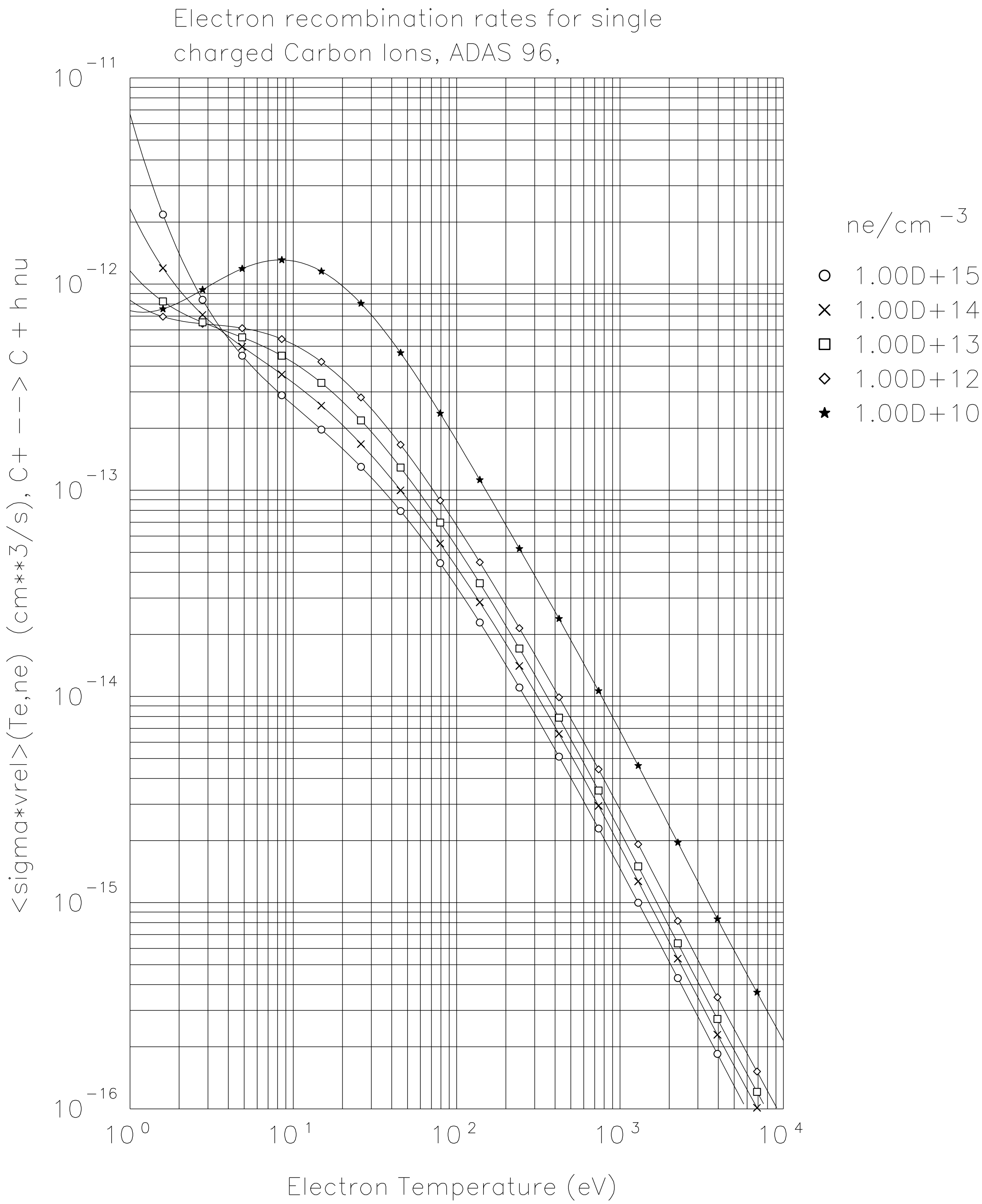
Recombination Rates for single charged Carbon Ions, ADAS 93, smaller valid density range than in Behringer (STRAHL) rate, 1e9 –4e15, i.e. also wrong low ne (Corona) limit.

```
      E-Index:     0                    1                    2
  T-Index:
      0    -2.386015899408D+01   -3.910955838564D+00    1.552770970883D+00
      1    -5.659678700923D+00    3.273571762123D+00   -1.226359264263D+00
      2     5.390501265589D+00   -2.355302777087D-01   -5.195368951742D-02
      3    -3.714328835667D+00    3.628845439540D-01   -2.200031489025D-02
      4     1.135859606525D+00   -1.186644208284D-01    5.551341663448D-03
      5    -1.869372950502D-01    1.628631987628D-02    6.410015500816D-04
      6     1.780826701298D-02   -1.478766722313D-03   -8.533991517766D-05
      7    -9.287327719634D-04    9.071133960815D-05   -1.095758224111D-06
      8     2.035725216911D-05   -2.414914230400D-06    1.597295024608D-07

      E-Index:     3                    4                    5
  T-Index:
      0    -3.450187675134D-01    4.712272970491D-02   -4.042671286872D-03
      1     2.600531850861D-01   -3.341908339155D-02    2.682578223051D-03
      2     1.011059953763D-02   -1.169563926566D-03    6.667572788661D-05
      3     3.526377986446D-03   -3.427847110389D-04    1.835504781865D-05
      4    -8.838264136732D-04    8.565268990423D-05   -1.066175819677D-06
      5    -8.593821289931D-05    5.272524686958D-06   -1.224520162331D-06
      6     2.660975471746D-06    1.089822895916D-06   -2.890683271478D-09
      7     1.203297067573D-06   -2.099731716273D-07    6.174132427111D-09
      8    -4.421659538874D-08    4.310876850464D-09    2.079113580150D-10

      E-Index:     6                    7                    8
  T-Index:
      0     2.122032361962D-04   -6.207489360202D-06    7.739602341370D-08
      1    -1.336715470333D-04    3.811224434825D-06   -4.747119054140D-08
      2     1.856735987460D-06   -3.458187396125D-07    9.391749990270D-09
      3    -2.365613863260D-06    2.014784469522D-07   -5.309278460907D-09
      4     2.407496723541D-07   -4.228290011762D-08    1.385165315494D-09
      5     3.962428233835D-08    4.764982812388D-09   -2.132127641260D-10
      6    -8.202254054789D-10   -4.541903480422D-10    2.006990579325D-11
      7     2.277931530317D-10    3.545967143036D-12   -6.419790552377D-13
      8    -4.192645662630D-11    1.557121980135D-12   -1.271691932014D-14
N2MIN =   1.00000D 10 1/CM3
N2MAX =   4.00000D 15 1/CM3

  Max. rel. Error:   7.2475 %
  Mean rel. Error:   1.9064 %
```



Electron recombination rates for single
charged Carbon Ions, ADAS 96,
10^-11
10^-12
10^-13
10^-14
10^-15
10^-16
<sigma*vrel>(Te,ne) (cm**3/s), C+ --> C + h nu
10^0
10^1
10^2
10^3
10^4
Electron Temperature (eV)
ne/cm^-3
1.00D+15
1.00D+14
1.00D+13
1.00D+12
1.00D+10

4.46 Reaction 2.3.7A0 $e + N^{+} \rightarrow N + hv$

Recombination Rates for single charged Nitrogen Ions, ADAS 96 smaller valid density range than in Behringer (STRAHL) rate: 1e8 –4e15

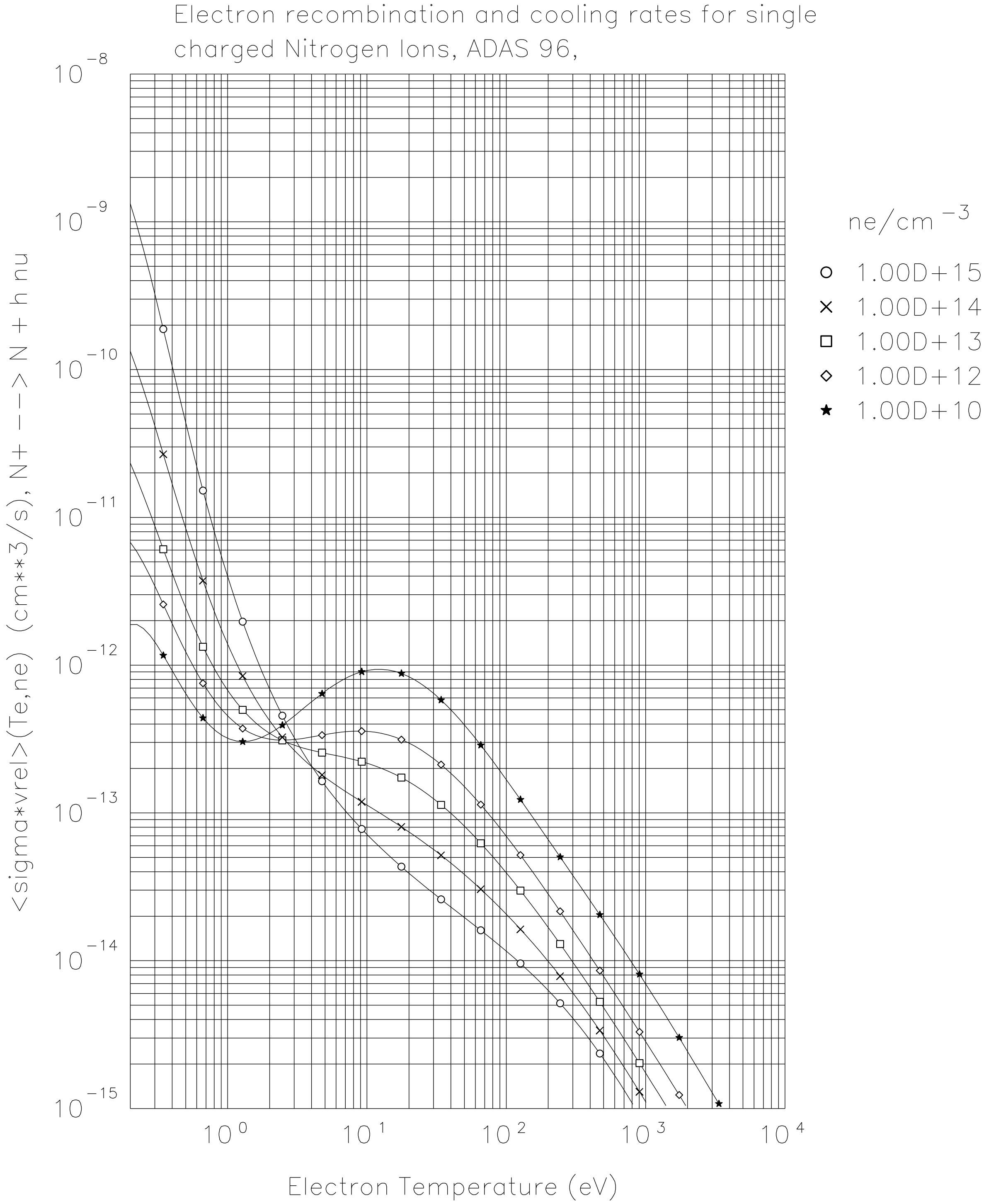
T-Index \ E-Index	0	1	2
0	-2.890979447961D+01	3.404781058304D-02	3.109171343385D-02
1	-1.174542935934D-01	-6.300786378143D-02	1.285451136251D-02
2	1.062396631545D+00	-4.594988800022D-02	-2.144355651778D-02
3	-1.281784857503D-01	1.750663794712D-02	-4.218563857410D-04
4	-1.778575430266D-01	7.578877787156D-03	3.404271527997D-03
5	6.798785783958D-02	-4.597105849322D-03	-4.739820114489D-04
6	-1.028526325632D-02	8.617482106535D-04	-6.225202836732D-05
7	7.268082281380D-04	-7.084122217378D-05	1.512785518009D-05
8	-1.988053691842D-05	2.183474002160D-06	-7.348547415367D-07

T-Index \ E-Index	3	4	5
0	-2.959597171711D-02	9.972437524383D-03	-1.611047280109D-03
1	-3.284720599538D-03	-3.277710167038D-04	1.453494237233D-04
2	1.590875283251D-02	-4.416788978628D-03	6.137394728855D-04
3	-4.267873772733D-03	1.898156366712D-03	-3.376326628079D-04
4	-9.522209957584D-04	9.592101950028D-06	2.643190197805D-05
5	2.795617403751D-04	-5.664874714649D-05	5.086981091994D-06
6	1.044379154837D-05	1.194568825982D-07	-2.192339608178D-07
7	-5.854382133761D-06	1.051704842577D-06	-9.578564349722D-08
8	3.249656113647D-07	-6.545647058295D-08	6.814062555229D-09

T-Index \ E-Index	6	7	8
0	1.362263347704D-04	-5.786235879715D-06	9.750444797037D-08
1	-1.452433975975D-05	5.648617057221D-07	-7.117648875509D-09
2	-4.553987913630D-05	1.730678240365D-06	-2.652544738754D-08
3	2.933958065856D-05	-1.240562994480D-06	2.045493282478D-08
4	-3.634440120548D-06	1.885575439239D-07	-3.485971868424D-09
5	-1.949862893743D-07	2.024442443875D-09	2.630734008273D-11
6	2.521164443225D-08	-1.296752613661D-09	2.627656129565D-11
7	4.358665026882D-09	-7.347981360072D-11	-2.477653636206D-13
8	-3.772451802902D-10	1.008260868721D-11	-9.316575573714D-14

```
T1MIN =   0.20000D 00 1/CM3
T1MAX =   1.50000D 04 1/CM3
N2MIN =   5.00000D 07 1/CM3
N2MAX =   2.00000D 15 1/CM3

  Max. rel. Error:  21.5715 %
  Mean rel. Error:   6.5304 %
```



Electron recombination and cooling rates for single charged Nitrogen Ions, ADAS 96,
<sigma*vrel>(Te,ne) (cm**3/s), N+ --> N + h nu
Electron Temperature (eV)
ne/cm −3
1.00D+15
1.00D+14
1.00D+13
1.00D+12
1.00D+10

4.47 Reaction 2.3.8A0 $e + O^{+} \rightarrow O + hv$

Recombination Rates for single charged Oxygen Ions, ADAS 96 smaller valid density range than in Behringer (STRAHL) rate

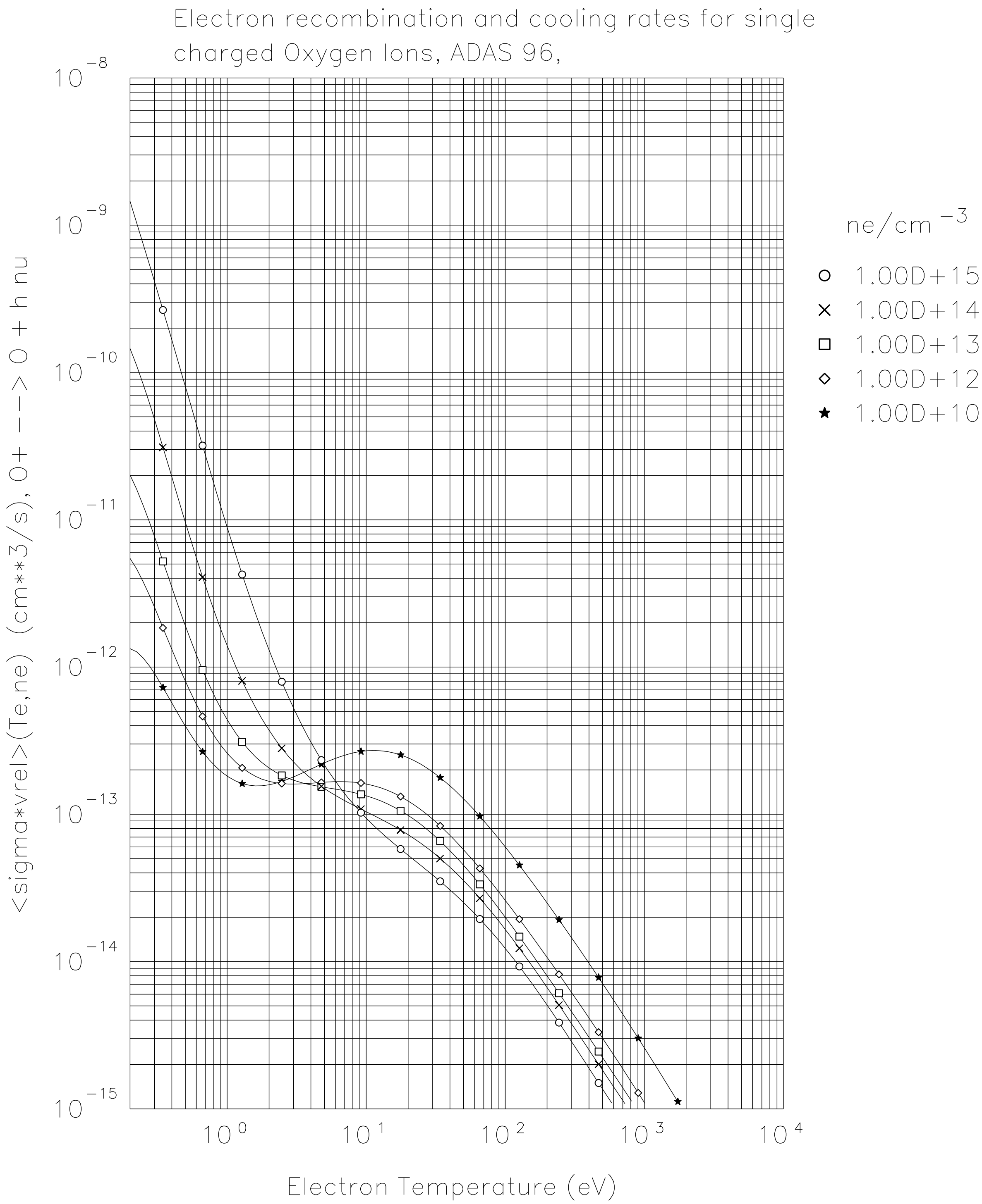
T-Index \ E-Index	0	1	2
0	-2.950202333277D+01	3.417421048652D-02	5.550176406244D-04
1	-3.905878105714D-01	-3.366885804101D-02	5.611644267242D-03
2	8.142161905922D-01	-2.619980609301D-02	1.119917102498D-02
3	-6.314301870760D-02	-6.677833838048D-04	-4.595557614154D-03
4	-1.300209551942D-01	7.344464113626D-03	1.010388603060D-03
5	4.543327490228D-02	-2.431608679889D-03	-1.605807371797D-04
6	-6.551209458023D-03	3.385675498043D-04	1.776299449335D-05
7	4.487444713804D-04	-2.208733089758D-05	-1.188982868102D-06
8	-1.202054123175D-05	5.549447564031D-07	3.573244244320D-08

T-Index \ E-Index	3	4	5
0	-4.878404722759D-03	2.496704857025D-03	-4.801811432048D-04
1	-6.846315928181D-03	1.781404680449D-03	-2.299350278961D-04
2	-7.650465593431D-03	2.291477501261D-03	-3.428663325456D-04
3	3.319766657887D-03	-8.305632223570D-04	9.687240430638D-05
4	-7.429595897823D-04	1.597082088291D-04	-1.586721570563D-05
5	9.174847318131D-05	-1.791485541629D-05	2.557912304553D-06
6	-3.656971171905D-06	4.415203015131D-07	-2.729885842433D-07
7	-2.390420213573D-07	8.850471294306D-08	1.320290015666D-08
8	1.760145190417D-08	-5.311149778654D-09	-1.932208107521D-10

T-Index \ E-Index	6	7	8
0	4.414828976029D-05	-1.913653761986D-06	3.169334833101D-08
1	1.629563730611D-05	-6.508094947057D-07	1.168016914799D-08
2	2.801630724815D-05	-1.195893028045D-06	2.066069583201D-08
3	-5.817227023091D-06	1.815236921961D-07	-2.440874713720D-09
4	6.876080976925D-07	-7.143508700482D-09	-1.579410946829D-10
5	-2.191883763675D-07	9.084875748335D-09	-1.438945391695D-10
6	4.429673221310D-08	-2.592667144327D-09	5.218677785470D-11
7	-3.785422204476D-09	2.552603164217D-10	-5.520425235115D-12
8	1.170863046694D-10	-8.639504027193D-12	1.945039811844D-13

```
T1MIN =   0.20000D 00 1/CM3
T1MAX =   1.50000D 04 1/CM3
N2MIN =   5.00000D 07 1/CM3
N2MAX =   2.00000D 15 1/CM3
```

```
Max. rel. Error:  17.6166 %
Mean rel. Error:   5.7730 %
```


Electron recombination and cooling rates for single
charged Oxygen Ions, ADAS 96,
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
10^{-14}
10^{-15}
<sigma*vrel>(Te,ne) (cm**3/s), O+ --> O + h nu
10^0
10^1
10^2
10^3
10^4
Electron Temperature (eV)
ne/cm $^{-3}$
1.00D+15
1.00D+14
1.00D+13
1.00D+12
1.00D+10

4.48 Reaction 2.3.10B0 $e + Ne^{+} \rightarrow Ne + hv$

Data from impurity transport code "STRAHL", [19]
Recombination Rates for singly charged Ne Ions (w/o threebody)

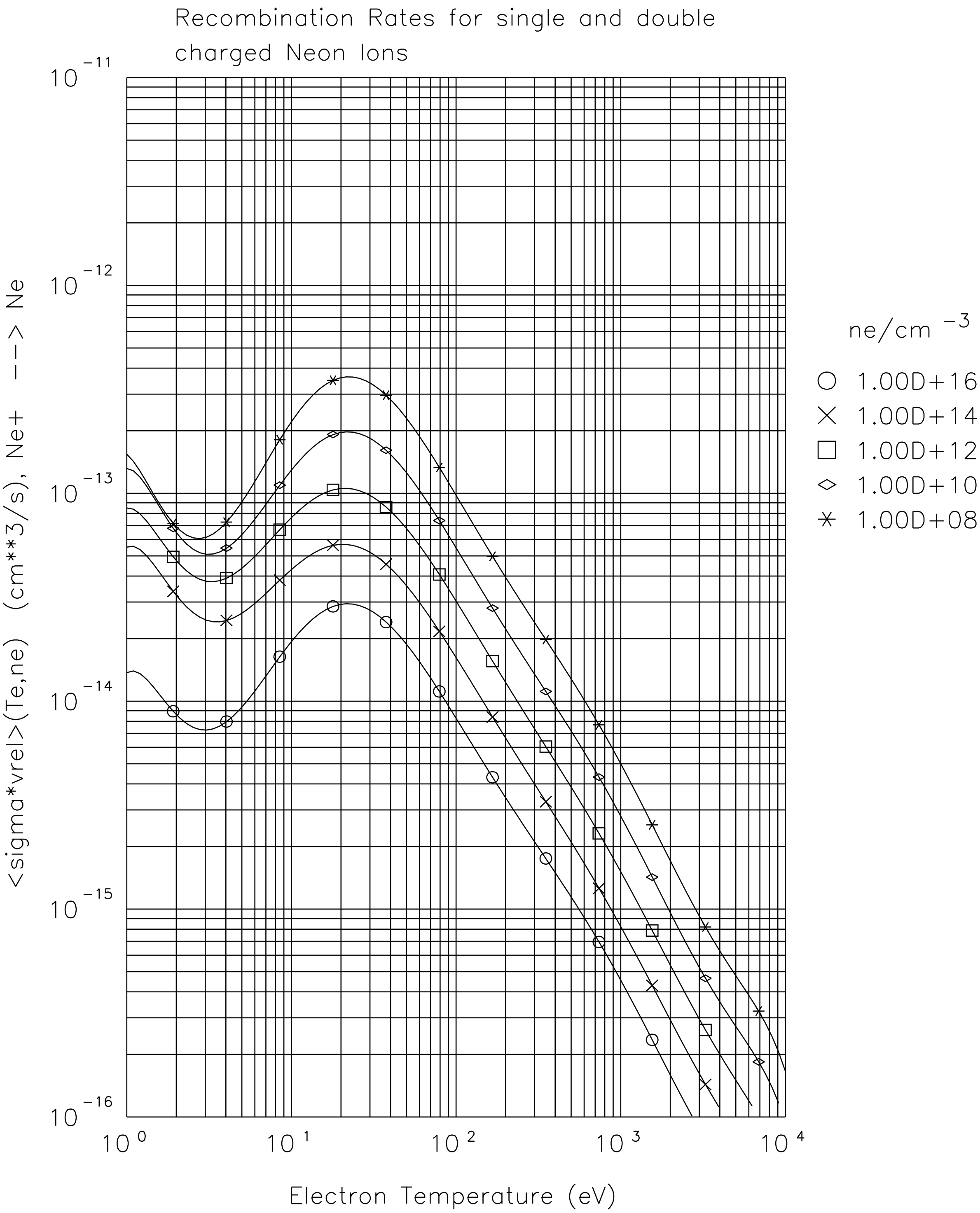
T-Index \ E-Index	0	1	2
0	-2.950007003885D+01	3.491651842120D-01	-4.526729152358D-01
1	-6.520457077063D-01	7.213904325098D-02	3.658011914091D-01
2	-2.555722669669D+00	-7.475436856707D-01	9.738719342931D-02
3	3.661205101651D+00	5.765147468133D-01	-1.604649380940D-01
4	-1.748125063014D+00	-2.102066448685D-01	6.321986952859D-02
5	4.075296845781D-01	4.352555184156D-02	-1.311266215655D-02
6	-5.084544478774D-02	-5.232558963021D-03	1.582205007651D-03
7	3.267745768343D-03	3.392758114186D-04	-1.046424800738D-04
8	-8.515144644683D-05	-9.147101439320D-06	2.913148029419D-06

T-Index \ E-Index	3	4	5
0	1.822526019576D-01	-3.440093707612D-02	3.365607055965D-03
1	-1.925738935529D-01	4.196008186724D-02	-4.824821656521D-03
2	2.722985240177D-02	-9.973812872134D-03	1.461560737391D-03
3	1.878485303345D-02	-1.385285413951D-03	9.295164050536D-06
4	-7.774293016035D-03	7.843935223543D-04	-5.991856389796D-05
5	1.332124081154D-03	-1.033638922199D-04	8.612183709508D-06
6	-1.337988184391D-04	5.636490415762D-06	-4.121413995158D-07
7	8.230405845512D-06	-1.571454512161D-07	3.845854426768D-09
8	-2.383823550795D-07	4.365491330109D-09	2.073873285125D-12

T-Index \ E-Index	6	7	8
0	-1.720328845594D-04	4.174907414363D-06	-3.433683135382D-08
1	3.088521584980D-04	-1.043623699368D-05	1.452433604004D-07
2	-1.188366580476D-04	5.102874363441D-06	-8.840074619382D-08
3	1.172576233056D-05	-9.701778130960D-07	2.315053595109D-08
4	1.480911313552D-06	7.311631221035D-08	-3.231110770367D-09
5	-3.779888128247D-07	1.120723303371D-09	2.214485537742D-10
6	2.901125564163D-08	-7.405559613471D-10	1.446032893388D-12
7	-1.213848594721D-09	7.298790343151D-11	-1.305351788753D-12
8	3.400354319444D-11	-2.737297017901D-12	6.063188511756D-14

N2MIN = 1.00000D 08 1/CM3
N2MAX = 1.00000D 16 1/CM3

Max. rel. Error: 54.9736 %
Mean rel. Error: 6.6709 %



Recombination Rates for single and double
charged Neon Ions
<sigma*vrel>(Te,ne) (cm**3/s), Ne+ --> Ne
Electron Temperature (eV)
ne/cm -3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

Data from impurity transport code "STRAHL", [19]
Recombination Rates for doubly charged Ne Ions (w/o three-body)

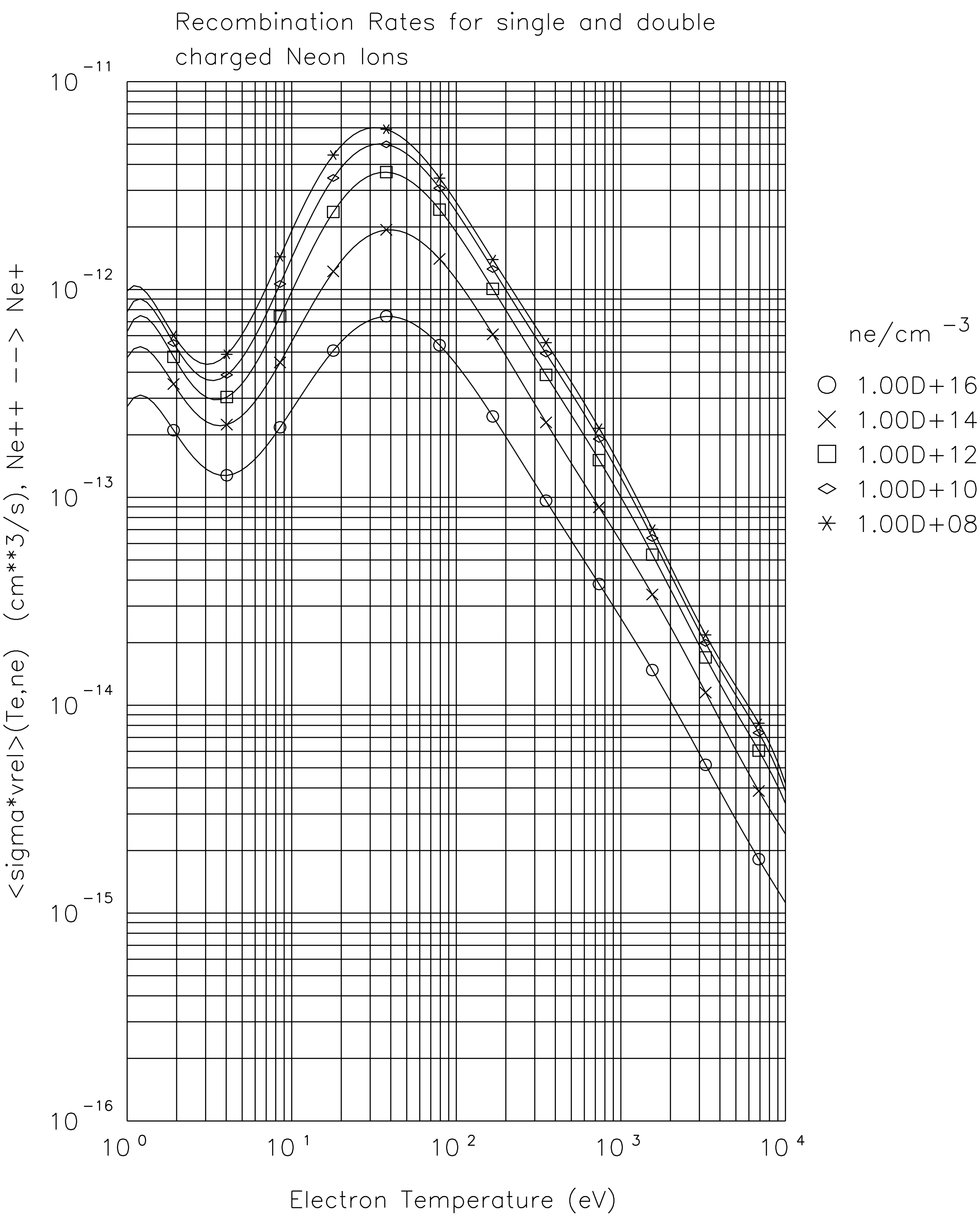
4.49 Reaction 2.3.10B1 $e + Ne^{++} \rightarrow Ne^{+} + hv$

```
        E-Index:     0                      1                      2
 T-Index:
        0    -2.764720323935D+01   -1.955655877647D-01    1.671527355799D-01
        1     1.118894063339D+00    3.129124651555D-01   -1.009059388068D-01
        2    -5.807229758743D+00   -4.303560193277D-01    5.147902079014D-02
        3     5.906119436289D+00    2.908074868726D-01   -3.504756895839D-02
        4    -2.486369699756D+00   -1.066677872724D-01    1.675054599333D-02
        5     5.400218712330D-01    2.285969690928D-02   -4.685542119686D-03
        6    -6.423019855816D-02   -2.860087284730D-03    7.328508385727D-04
        7     3.984332639562D-03    1.927287799126D-04   -5.887153870896D-05
        8    -1.009911047233D-04   -5.380432470580D-06    1.881736675497D-06

        E-Index:     3                      4                      5
 T-Index:
        0    -7.260114126178D-02    1.583009936797D-02   -1.898589530133D-03
        1     3.746533708965D-02   -8.655894421673D-03    1.099661830628D-03
        2    -6.718805346046D-03    1.999612428280D-03   -3.290996365052D-04
        3    -4.526057371154D-04   -1.450332583776D-05    6.267094921401D-05
        4     4.734615609031D-04   -1.872293739068D-04    1.215375414502D-06
        5    -1.215606626036D-05    5.132159918071D-05   -2.379109789101D-06
        6    -2.422737859678D-05   -4.568253290882D-06    2.259728294625D-07
        7     3.940458387139D-06    2.917180971670D-08    6.379283743551D-09
        8    -1.800023588704D-07    9.209746135240D-09   -1.047238386420D-09

        E-Index:     6                      7                      8
 T-Index:
        0     1.268000506338D-04   -4.414136321690D-06    6.233135264975D-08
        1    -7.507106502001D-05    2.542756842488D-06   -3.303898330923D-08
        2     2.397963779263D-05   -6.716878731698D-07    3.568810796685D-09
        3    -6.220521674696D-06    1.257734260178D-07    2.204442932049D-09
        4     9.599983583142D-07   -1.352244273881D-08   -1.106786869688D-09
        5    -1.008039023067D-07    1.880168166012D-09    2.080209442599D-10
        6     1.781190939483D-08   -6.447382343471D-10   -1.518762965124D-11
        7    -2.457175556170D-09    9.557839810920D-11    1.286224146698D-14
        8     1.179856275948D-10   -4.471022550637D-12    3.079250396313D-14
N2MIN =   1.00000D 08 1/CM3
N2MAX =   1.00000D 16 1/CM3

 Max. rel. Error:  21.1204 %
 Mean rel. Error:   6.0132 %
```



Recombination Rates for single and double
charged Neon Ions
<sigma*vrel>(Te,ne) (cm**3/s), Ne++ --> Ne+
10 −11
10 −12
10 −13
10 −14
10 −15
10 −16
10 0
10 1
10 2
10 3
10 4
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

Data from impurity transport code “STRAHL”, [19]
Recombination Rates for singly charged Ar Ions (w/o three-body)

4.50 Reaction 2.3.18B0 $e + Ar^{+} \rightarrow Ar + hv$

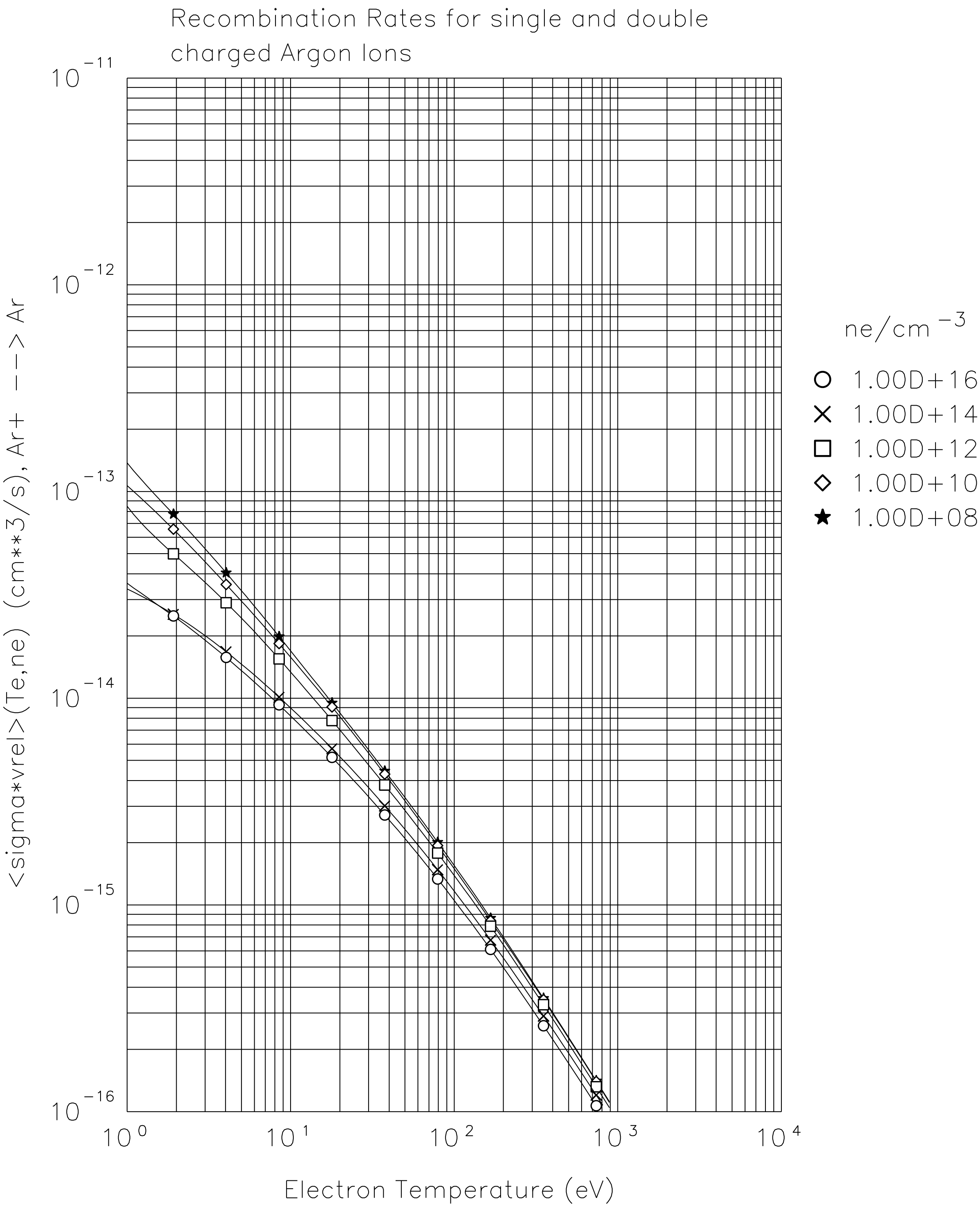
T-Index \ E-Index	0	1	2
0	-2.961523714505D+01	-3.466294797008D-01	3.739734228058D-01
1	-9.700717663678D-01	3.174213911999D-01	-2.690300717347D-01
2	2.733587493672D-01	-3.157221881515D-01	6.974859201463D-02
3	-2.623209601735D-01	2.934758215827D-01	-5.501202052884D-02
4	1.121844963088D-01	-1.406901237239D-01	3.460910634739D-02
5	-2.608050847276D-02	3.514232816083D-02	-9.818421888710D-03
6	3.353322712511D-03	-4.716045851013D-03	1.375466865468D-03
7	-2.241669321389D-04	3.232299270856D-04	-9.397908348434D-05
8	6.083901388792D-06	-8.888872233070D-06	2.502839044441D-06

T-Index \ E-Index	3	4	5
0	-1.677610771210D-01	3.629620906444D-02	-4.200257817954D-03
1	1.288420244186D-01	-3.161715324237D-02	4.057456599586D-03
2	-1.580414272181D-02	5.471732050209D-03	-8.980424488739D-04
3	-9.482732378151D-04	4.606867303099D-04	7.340402374160D-06
4	-1.908249918710D-03	-8.498577198828D-05	9.702094170437D-06
5	8.582053824339D-04	-2.071529296492D-05	-1.272108567719D-07
6	-1.258112651082D-04	1.949277321810D-06	2.643262514781D-07
7	7.448923978325D-06	2.740906796410D-07	-7.103042442755D-08
8	-1.383359038597D-07	-2.541568324398D-08	4.131280999373D-09

T-Index \ E-Index	6	7	8
0	2.648330614117D-04	-8.569045126425D-06	1.113597041124D-07
1	-2.773372679142D-04	9.588925395704D-06	-1.320334721938D-07
2	6.859512197435D-05	-2.469218146406D-06	3.413301196731D-08
3	-3.175389000213D-06	1.354114675747D-07	-1.709524073729D-09
4	-1.895926857712D-07	-4.275832820919D-09	1.814552488433D-10
5	-7.124015966833D-08	7.365306362028D-09	-1.907511087995D-10
6	-3.822283871117D-09	-9.046050010004D-10	3.169432383695D-11
7	3.382667208777D-09	-1.902820234583D-11	-1.500255342391D-12
8	-2.249462681920D-10	4.358044610945D-12	-5.630369486130D-16

N2MIN = 1.00000D 08 1/CM3
N2MAX = 1.00000D 16 1/CM3

Max. rel. Error: 21.9156 %
Mean rel. Error: 2.3347 %



Recombination Rates for single and double charged Argon Ions
10^{-11}
10^{-12}
10^{-13}
10^{-14}
10^{-15}
10^{-16}
<sigma*vrel>(Te,ne) (cm**3/s), Ar+ --> Ar
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}
Electron Temperature (eV)
ne/cm^{-3}
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

Data from impurity transport code “STRAHL”, [19]
Recombination Rates for doubly charged Ar Ions (w/o three-body)

4.51 Reaction 2.3.18B1 $e + Ar^{++} \rightarrow Ar^{+} + hv$

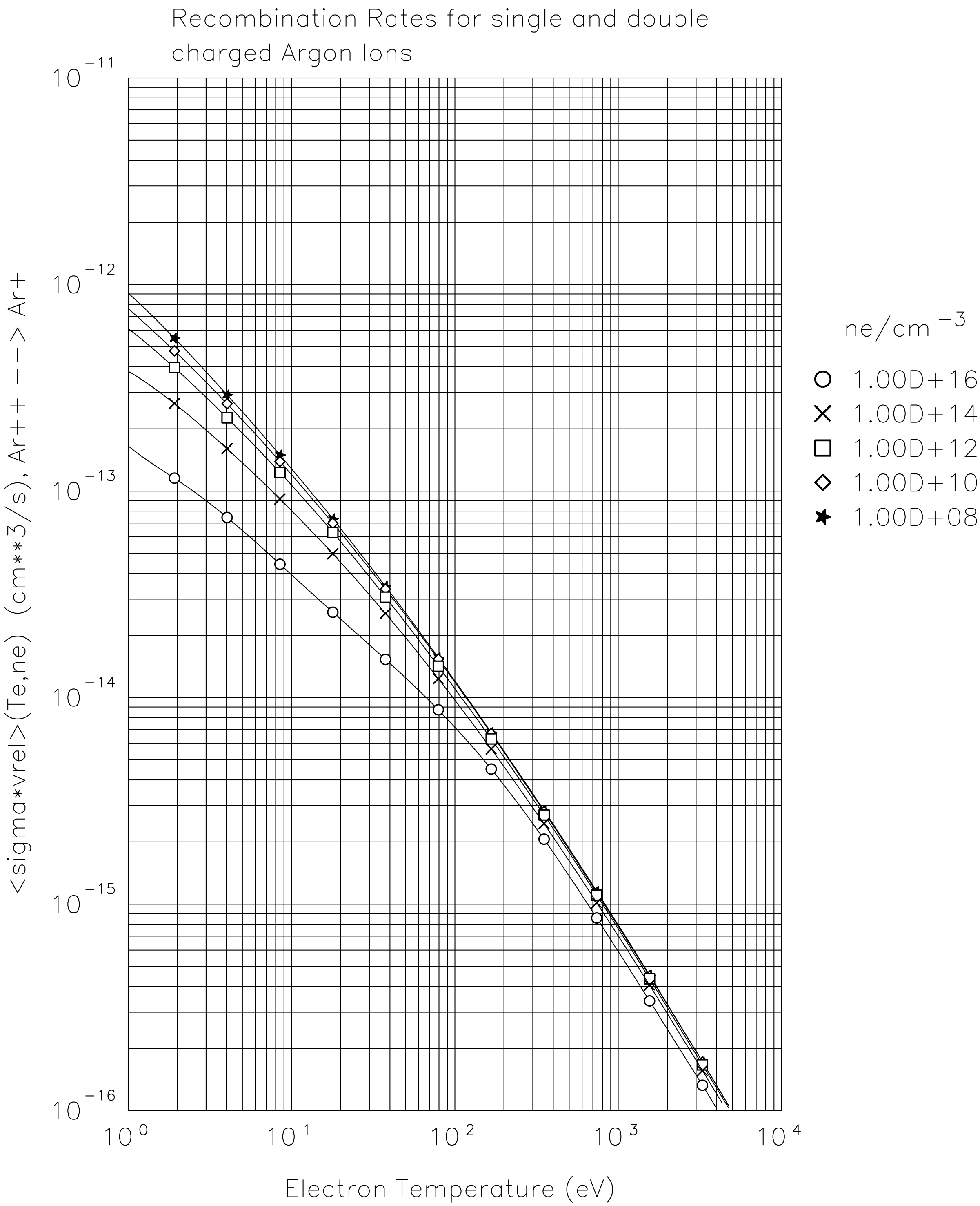
T-Index \ E-Index	0	1	2
0	-2.772725546092D+01	-1.964508067762D-01	2.324627102422D-01
1	-6.978601807006D-01	-3.079561336369D-02	-2.145381507914D-02
2	-1.450309406042D-01	1.046307484649D-01	-4.369629888000D-02
3	7.260838315993D-02	-3.466094766036D-02	-7.255991015237D-04
4	-2.582804347800D-02	1.815351628023D-03	6.871280269968D-03
5	5.160665923838D-03	1.395970098141D-03	-2.114054789289D-03
6	-5.799496412067D-04	-3.699751917053D-04	3.252016165358D-04
7	3.420248521929D-05	3.736066138991D-05	-2.707472572922D-05
8	-8.205975768535D-07	-1.373593769853D-06	9.391881125204D-07

T-Index \ E-Index	3	4	5
0	-1.121363406353D-01	2.586067808011D-02	-3.210690057370D-03
1	1.781324636009D-02	-4.150064170275D-03	4.491490678296D-04
2	1.565988829654D-02	-4.208889079256D-03	6.472110597204D-04
3	-1.979769358644D-04	6.722846983901D-04	-1.476650287912D-04
4	-1.629081885435D-03	7.839217315971D-05	5.746848866889D-06
5	3.607110982734D-04	-3.524282842463D-06	-1.878125337156D-06
6	-4.180965183796D-05	-2.409133311107D-06	5.593232200934D-07
7	3.500759466355D-06	1.374491446170D-07	-3.705743160513D-08
8	-1.463187124936D-07	4.107894379819D-09	1.824159518664D-10

T-Index \ E-Index	6	7	8
0	2.193249820474D-04	-7.757566204730D-06	1.108985082330D-07
1	-2.393877794814D-05	5.679271788812D-07	-3.900827694763D-09
2	-5.394011848597D-05	2.272796732271D-06	-3.777889093261D-08
3	1.363319474233D-05	-5.936164719619D-07	9.957385133643D-09
4	-6.009177241892D-07	1.485983255077D-08	-3.099011150065D-11
5	1.007709629207D-08	8.232051597397D-09	-2.668448723973D-10
6	-1.251252096167D-08	-1.153506022137D-09	4.325526291510D-11
7	5.438054847774D-10	1.039015370714D-10	-3.543703207540D-12
8	4.191847861623D-11	-5.007688195721D-12	1.309659229521D-13

N2MIN = 1.00000D 08 1/CM3
N2MAX = 1.00000D 16 1/CM3

Max. rel. Error: 25.0141 %
Mean rel. Error: 1.9704 %


Recombination Rates for single and double charged Argon Ions
<sigma*vrel>(Te,ne) (cm**3/s), Ar++ --> Ar+
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

4.52 Reaction 3.2.3r $p + H_2(+e) \rightarrow H + H + H$ (MAR via H_2^+, cold H_2)

H_2 multi-step model, "intermediate H_2^+ condensed" MAR rate coefficient cm^3/s. Data: Sawada/Fujimoto [7]. $H_2(v=0)$ transported, H_2^+ in QSS with H_2, $E_{H_2} = 0.1$ eV
$H_2(v \geq 1)$ is also in QSS with $H_2(v=0)$. Vibrational distribution $pH_2(v;T_e)$ as fct. of T_e $(= T_p)$ only (assuming $n_e = n_p$, so density cancels here).
The MAR rate coefficient is a fct. of n_e and $T(T_e = T_p)$, and must be multiplied with density n_p to turn it into a collision rate $1/s$, and then with $n_{H_2(v=0)}$ to turn it into a volumetric reaction rate $(cm^{-3}s^{-1})$. This is consistent with underlying $pH_2(v;T_e)$ only for $n_e = n_p$.

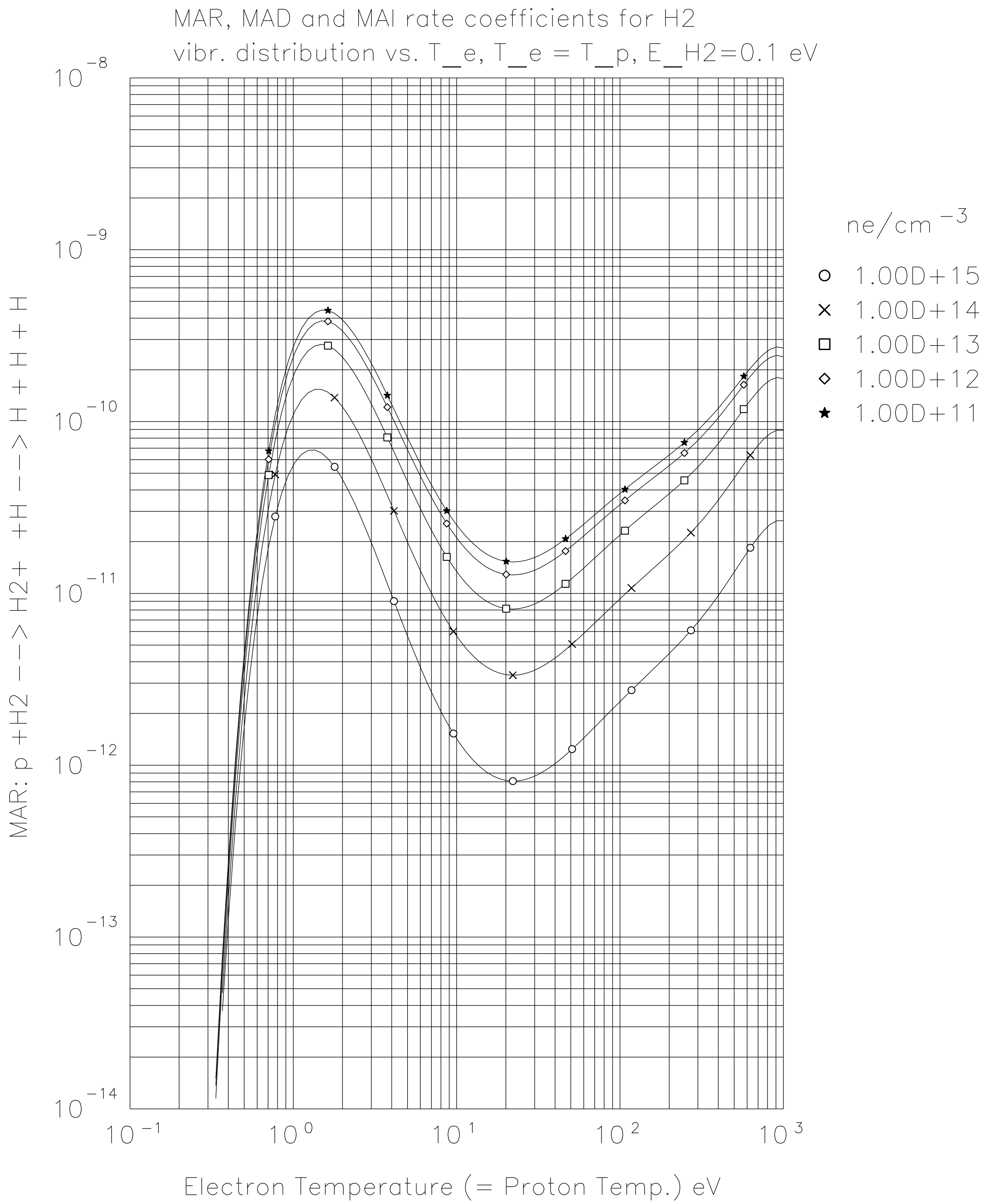
T-Index \ E-Index	0	1	2
0	-2.191302446846D+01	2.201979359177D-02	-5.084127804366D-02
1	2.515287131029D+00	-1.951782673829D-03	1.210559594877D-02
2	-3.739165027129D+00	-5.039990032868D-03	5.156475880767D-02
3	1.460287495804D+00	-1.902427777619D-02	-2.653691460740D-03
4	-3.613420054183D-01	-9.136720216773D-03	-4.776315047524D-03
5	1.022097226981D-01	1.430112787487D-02	-2.068159413388D-03
6	-2.326509820253D-02	-4.698557490053D-03	1.350601458627D-03
7	2.755718181169D-03	6.183157753063D-04	-2.180157674348D-04
8	-1.245440617856D-04	-2.916396705941D-05	1.131212737957D-05

T-Index \ E-Index	3	4	5
0	2.725675449247D-02	-6.821140812496D-03	8.984277627487D-04
1	-1.056465122608D-02	3.268414282907D-03	-4.770499814477D-04
2	-3.005896796044D-02	7.117618884301D-03	-8.640595844451D-04
3	8.718387627078D-03	-3.083275129564D-03	4.690013186619D-04
4	2.274299170449D-03	-8.429380778242D-05	-5.166724308864D-05
5	-8.581335425960D-04	2.018790326947D-04	-9.377832906111D-06
6	9.091464941954D-06	-3.214048434350D-05	2.476622604418D-06
7	1.640987010283D-05	1.594693278851D-06	-1.857150815035D-07
8	-1.227368784843D-06	-6.059729362682D-09	4.830770876395D-09

T-Index \ E-Index	6	7	8
0	-6.471300739878D-05	2.392339469853D-06	-3.542871296534D-08
1	3.555893312434D-05	-1.316695158693D-06	1.915346495446D-08
2	5.696582068003D-05	-1.943708118398D-06	2.693231032650D-08
3	-3.587259258804D-05	1.355091397789D-06	-2.009854793386D-08
4	7.313297805130D-06	-3.673160516940D-07	6.439394992510D-09
5	-6.689618689827D-07	6.721794871158D-08	-1.490826423672D-09
6	4.829313987833D-08	-1.004736504929D-08	2.534364634180D-10
7	-4.842242342991D-09	9.541230138142D-10	-2.466137348591D-11
8	2.201416000842D-10	-3.685384915056D-11	9.608086847565D-13

```
T1MIN =   0.02         EV
N2MIN =   1.00000D 08 1/CM3
N2MAX =   1.00000D 16 1/CM3
```

```
Max. rel. Error:  12.2399 %
Mean rel. Error:   5.5197 %
```


MAR, MAD and MAI rate coefficients for H2
vibr. distribution vs. T_e, T_e = T_p, E_H2=0.1 eV
MAR: p +H2 --> H2+ +H --> H + H + H
Electron Temperature (= Proton Temp.) eV
ne/cm −3
1.00D+15
1.00D+14
1.00D+13
1.00D+12
1.00D+11

4.53 Reaction 3.2.3d $p + H_2(+e) \rightarrow p + H + H(+e)$ (MAD via H_2^+, cold H_2)

H_2 multi-step model, "intermediate H_2^+ condensed" MAD rate coefficient cm^3/s, same conditions as for effective MAR rate coefficient: $n_e = n_p$ to remove n_e and n_p dependence in $pH_2(v; T_e)$, $T_e = T_p$ to remove T_p dependence in $pH_2(v; T_e)$, $E_{H_2} = 0.1$ eV.

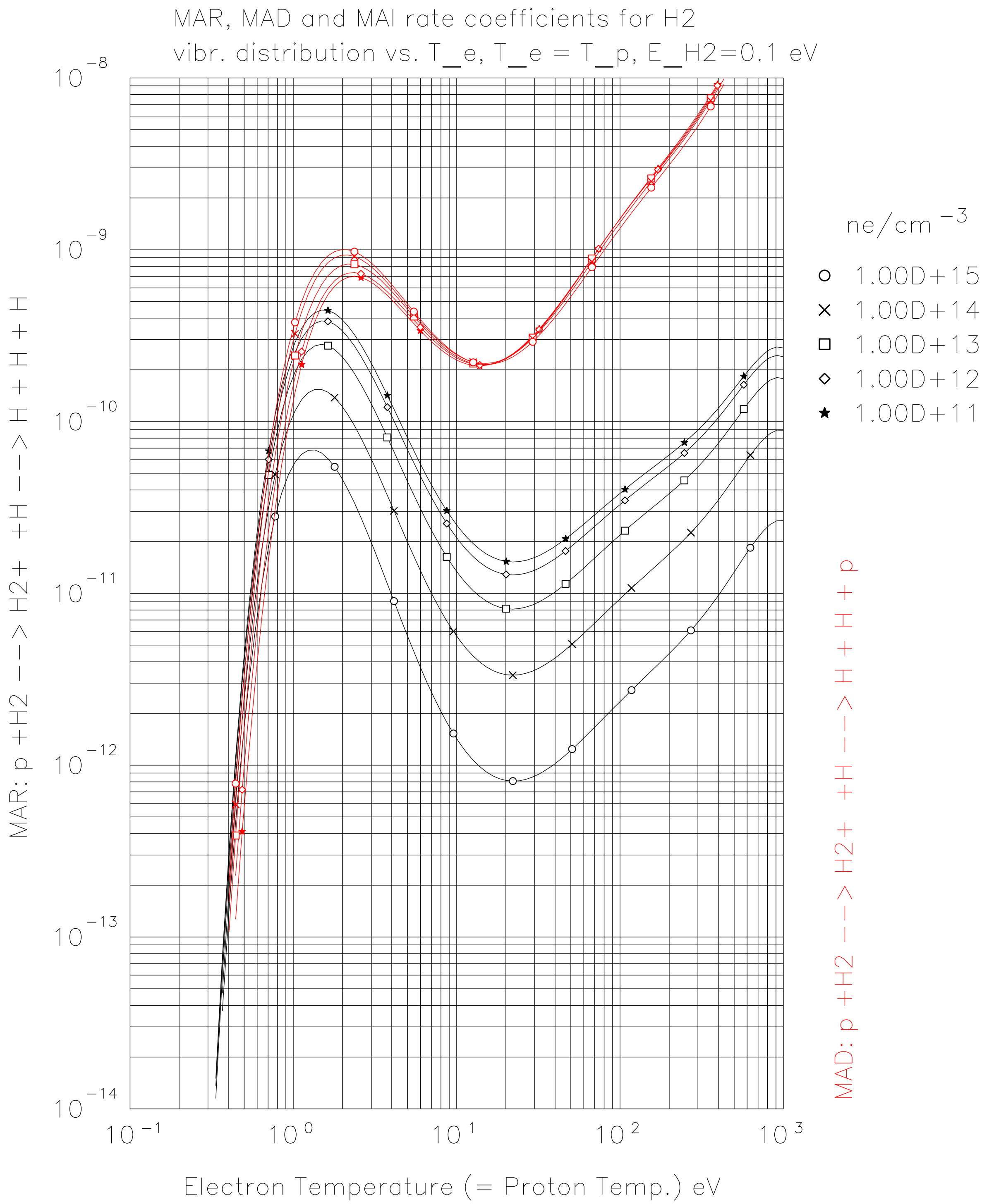
T-Index \ E-Index	0	1	2
0	-2.305748927979D+01	5.724038174456D-02	-5.615862094751D-02
1	5.292904264798D+00	-1.292700263854D-01	3.199290063730D-02
2	-4.589002200888D+00	1.035141485454D-01	4.245746723064D-02
3	1.282553627472D+00	8.228634639144D-03	-6.982329836971D-02
4	-5.768335357015D-02	-4.231280575573D-02	4.520570788253D-02
5	-1.762738366359D-02	1.754153736792D-02	-1.333930685945D-02
6	-6.220461405830D-04	-2.841940983105D-03	1.674562107704D-03
7	6.413295998688D-04	1.777701087291D-04	-5.286124278229D-05
8	-4.623793560750D-05	-2.110102637934D-06	-2.826184196637D-06

T-Index \ E-Index	3	4	5
0	2.580537345185D-02	-5.187638531338D-03	5.591824235916D-04
1	-1.411097510416D-03	-1.861670137347D-03	3.728807776936D-04
2	-2.833978655627D-02	6.680453562388D-03	-7.508030455334D-04
3	2.197499638706D-02	-2.786872754376D-03	1.536533061795D-04
4	-9.850360398006D-03	5.824809680428D-04	2.282005339391D-05
5	2.328857648314D-03	-4.906664256889D-05	-9.488057748931D-06
6	-1.644016839248D-04	-2.447100861104D-05	2.465487188700D-06
7	-1.933715475610D-05	7.307909083302D-06	-5.218713324203D-07
8	2.372770563877D-06	-5.341529037052D-07	3.931259348181D-08

T-Index \ E-Index	6	7	8
0	-3.282931512925D-05	9.814853142975D-07	-1.164322982242D-08
1	-3.011576633244D-05	1.138828160076D-06	-1.667604512176D-08
2	4.303656667760D-05	-1.201510983254D-06	1.269878029776D-08
3	-1.336438693130D-06	-1.902010802533D-07	5.308752951539D-09
4	-3.734435698157D-06	1.331754413945D-07	-1.412895213605D-09
5	1.096115694138D-07	3.997691612605D-08	-1.319357291444D-09
6	1.527860379159D-07	-2.055626589064D-08	5.202352548656D-10
7	-1.441930896339D-08	2.541011510181D-09	-6.500006263746D-11
8	-7.928979184194D-11	-9.515229004763D-11	2.697745453159D-12

```
T1MIN =   0.02         EV
N2MIN =   1.00000D 08 1/CM3
N2MAX =   1.00000D 16 1/CM3

  Max. rel. Error:  11.3558 %
  Mean rel. Error:   5.3396 %
```



MAR, MAD and MAI rate coefficients for H2
vibr. distribution vs. T_e, T_e = T_p, E_H2=0.1 eV
ne/cm −3
1.00D+15
1.00D+14
1.00D+13
1.00D+12
1.00D+11
MAR: p +H2 −−> H2+ +H −−> H + H + H
MAD: p +H2 −−> H2+ +H −−> H + H + p
Electron Temperature (= Proton Temp.) eV

4.54 Reaction 3.2.3i $p + H_2(+e) \to p + p + H + e(+e)$ (MAI via H_2^+, cold H_2)

H_2 multi-step model, "intermediate H_2^+ condensed" MAI rate coefficient cm^3/s, Data: Sawada/Fujimoto ,[7]
same conditions as for effective MAR rate coefficient: $n_e = n_p$ to remove n_e and n_p dependence in $pH_2(v;T_e)$, $T_e = T_p$ to remove T_p dependence in $pH_2(v;T_e)$, $E_{H_2} = 0.1$ eV.

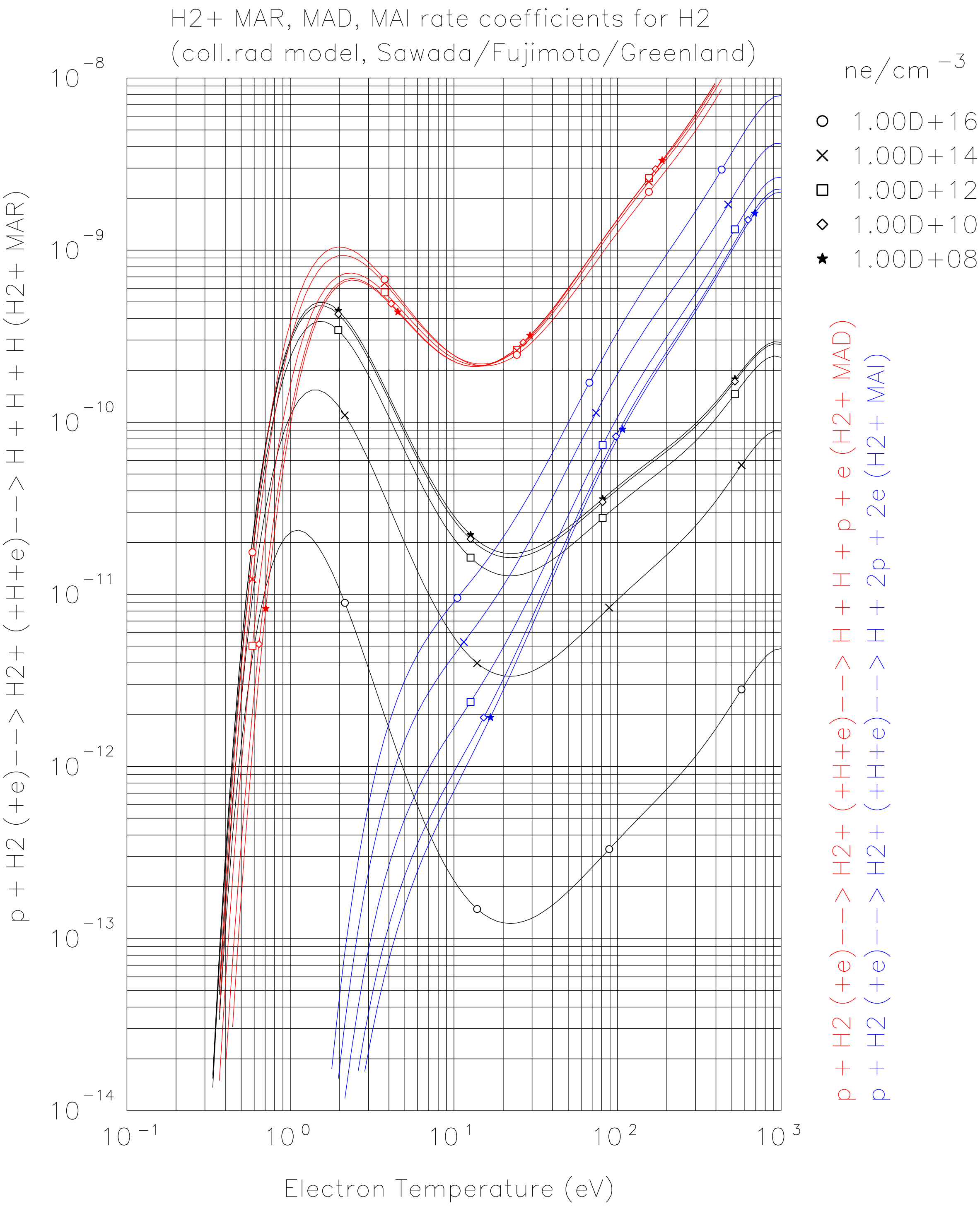
T-Index \ E-Index	0	1	2
0	-4.303487632383D+01	1.354912617518D-01	-4.208031387359D-02
1	1.865187030911D+01	4.794828738240D-02	-4.480081774222D-02
2	-1.031235964977D+01	-1.293354222605D-01	1.111154290344D-01
3	3.307974304211D+00	5.334601182629D-02	-5.767730834082D-02
4	-7.018008768823D-01	-6.609316223687D-03	1.756236589281D-02
5	1.407770965813D-01	-2.476809489378D-03	-3.079572104348D-03
6	-2.573389525387D-02	1.234571807098D-03	7.355554979654D-05
7	2.832176875576D-03	-1.984090837382D-04	5.092261127132D-05
8	-1.253682008794D-04	1.098686058571D-05	-4.581179858782D-06

T-Index \ E-Index	3	4	5
0	2.121453226850D-02	-4.560368123712D-03	5.385964928692D-04
1	2.151498888543D-02	-4.953503286261D-03	6.290139256418D-04
2	-4.723608675734D-02	1.025690317657D-02	-1.233716973622D-03
3	2.115356837268D-02	-3.950036110284D-03	4.004367285444D-04
4	-6.266465667016D-03	9.162100987544D-04	-4.707060975656D-05
5	1.550470987573D-03	-2.373302363288D-04	8.130584197231D-06
6	-2.090727055692D-04	4.180440850182D-05	-2.076576093883D-06
7	7.621054760107D-06	-2.912890793462D-06	1.796774800723D-07
8	3.872446367147D-07	2.676741053904D-08	-1.461819460351D-09

T-Index \ E-Index	6	7	8
0	-3.564625006225D-05	1.231884531233D-06	-1.725245514910D-08
1	-4.489890782277D-05	1.683519980411D-06	-2.570209718732D-08
2	8.303545850850D-05	-2.918512642744D-06	4.158237444788D-08
3	-2.185332948759D-05	5.877868751551D-07	-5.831534154631D-09
4	-1.420209458730D-06	2.138103587950D-07	-5.331437955361D-09
5	1.098217281234D-06	-9.940126421166D-08	2.270470549773D-09
6	-1.416098822509D-07	1.596596015502D-08	-3.851440558976D-10
7	1.034664599902D-08	-1.316442587155D-09	3.289242583740D-11
8	-5.505971394192D-10	5.078945037524D-11	-1.213224548584D-12

```
T1MIN =   0.02          EV
N2MIN =   1.00000D 08 1/CM3
N2MAX =   1.00000D 16 1/CM3

  Max. rel. Error:   0.114E+02 %
  Mean rel. Error:   0.574E+01 %
```


H2+ MAR, MAD, MAI rate coefficients for H2
(coll.rad model, Sawada/Fujimoto/Greenland)
ne/cm -3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08
p + H2 (+e)--> H2+ (+H+e)--> H + H + H (H2+ MAR)
p + H2 (+e)--> H2+ (+H+e)--> H + H + p + e (H2+ MAD)
p + H2 (+e)--> H2+ (+H+e)--> H + 2p + 2e (H2+ MAI)
Electron Temperature (eV)

4.55 Reaction 7.2.3a $p + H^- \rightarrow H + H$ (for cold H^-)

CX multistep recombination rate for H^- ions, [7]
Rate p + $H^- \rightarrow H + H^*$ followed by $H^* \rightarrow H(1)$
$\langle \sigma * v_{rel} \rangle (T_e, n_e)(cm^3/s)$
Assume low energy of projectile, $E(H^-) = 0.1$ eV, $T_e = T_i$. Intermediate H^* production based on HYDHEL 7.2.2, 7.2.3.

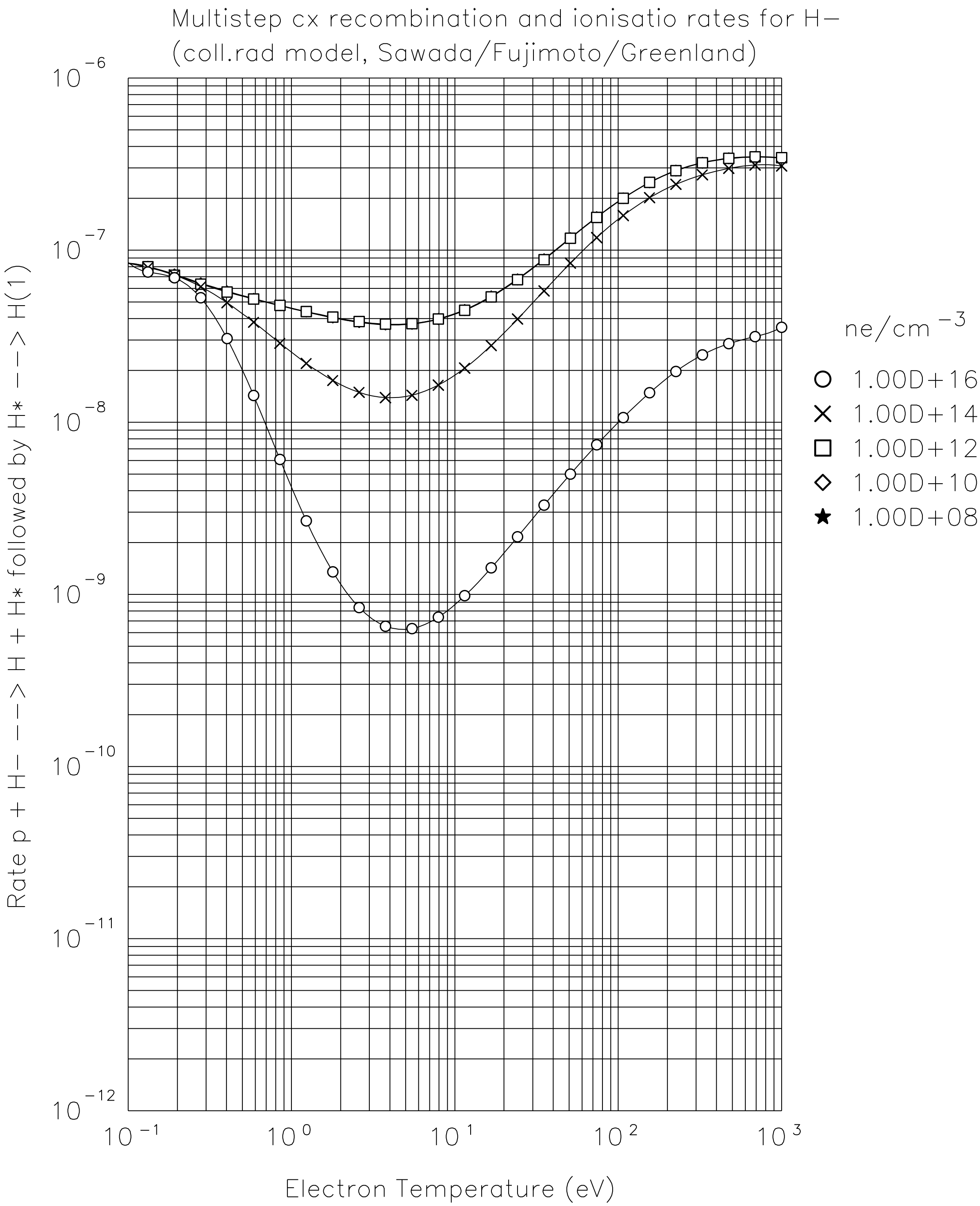
T-Index \ E-Index	0	1	2
0	-1.690146932812D+01	7.569370314490D-02	-1.118661556236D-01
1	-2.301580195362D-01	2.981364856606D-03	-1.296888142995D-02
2	2.124304411230D-02	-4.585972147659D-02	7.447057284991D-02
3	7.720995917466D-03	3.504507942086D-03	1.734371731330D-04
4	1.331695301990D-02	-9.042026807455D-04	-4.764566765886D-03
5	3.536238349067D-04	-8.011930719727D-04	1.101704458636D-03
6	-1.446558546363D-03	1.152532160685D-03	-8.305881275354D-04
7	2.479021261394D-04	-2.773890711262D-04	2.167753172783D-04
8	-1.248597948333D-05	1.903633250451D-05	-1.590752591530D-05

T-Index \ E-Index	3	4	5
0	5.784649204408D-02	-1.430206446825D-02	1.883300059210D-03
1	9.188878355062D-03	-2.795985155376D-03	4.355473614802D-04
2	-3.922380885092D-02	9.609624588460D-03	-1.240136716983D-03
3	-1.347164354237D-03	5.423527604759D-04	-9.468953600274D-05
4	3.858570576628D-03	-1.128426542832D-03	1.607204158523D-04
5	-5.449050513405D-04	1.255763496307D-04	-1.495920840346D-05
6	2.084267816803D-04	-1.903417990674D-05	-2.796205484739D-07
7	-6.195779421732D-05	7.927649861583D-06	-4.211576616550D-07
8	4.992428048704D-06	-7.522431288906D-07	5.827438308119D-08

T-Index \ E-Index	6	7	8
0	-1.346209157175D-04	4.900081433053D-06	-7.105742130265D-08
1	-3.579321024690D-05	1.457520878645D-06	-2.319369078632D-08
2	8.671653962517D-05	-3.101461653370D-06	4.442783018453D-08
3	8.309512179236D-06	-3.552667688177D-07	5.887954953357D-09
4	-1.197915401674D-05	4.484319353024D-07	-6.656156226037D-09
5	9.441566217674D-07	-2.989807912656D-08	3.717785721362D-10
6	1.584268580014D-07	-9.504026475042D-09	1.811886563961D-10
7	2.531413590874D-10	7.572949322455D-10	-1.937737123063D-11
8	-2.220813567852D-09	3.174650814148D-11	6.296020826533D-14

```
T1MIN =   0.02         EV
N2MIN =   1.00000D 08 1/CM3
N2MAX =   1.00000D 16 1/CM3

  Max. rel. Error:   4.1781 %
  Mean rel. Error:    .9694 %
```



Multistep cx recombination and ionisatio rates for H−
(coll.rad model, Sawada/Fujimoto/Greenland)
Rate p + H− −−> H + H* followed by H* −−> H(1)
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

4.56 Reaction 7.2.3b $p + H^- \rightarrow H + H^+ + 2e$ (for cold H^-)

CX multistep ionization rate for H^- ions, [7]
Rate p + $H^- \rightarrow H + H^*$ followed by $H^* \rightarrow H^+ + e$
$\langle \sigma * v_{rel} \rangle (T_e, n_e)(cm^3/s)$
Assume low energy of projectile, $E(H^-) = 0.1$ eV, $T_e = T_i$. Intermediate H^* production based on HYHDEL 7.2.2, 7.2.3 (not included: process 7.2.1 of proton impact electron detachment).

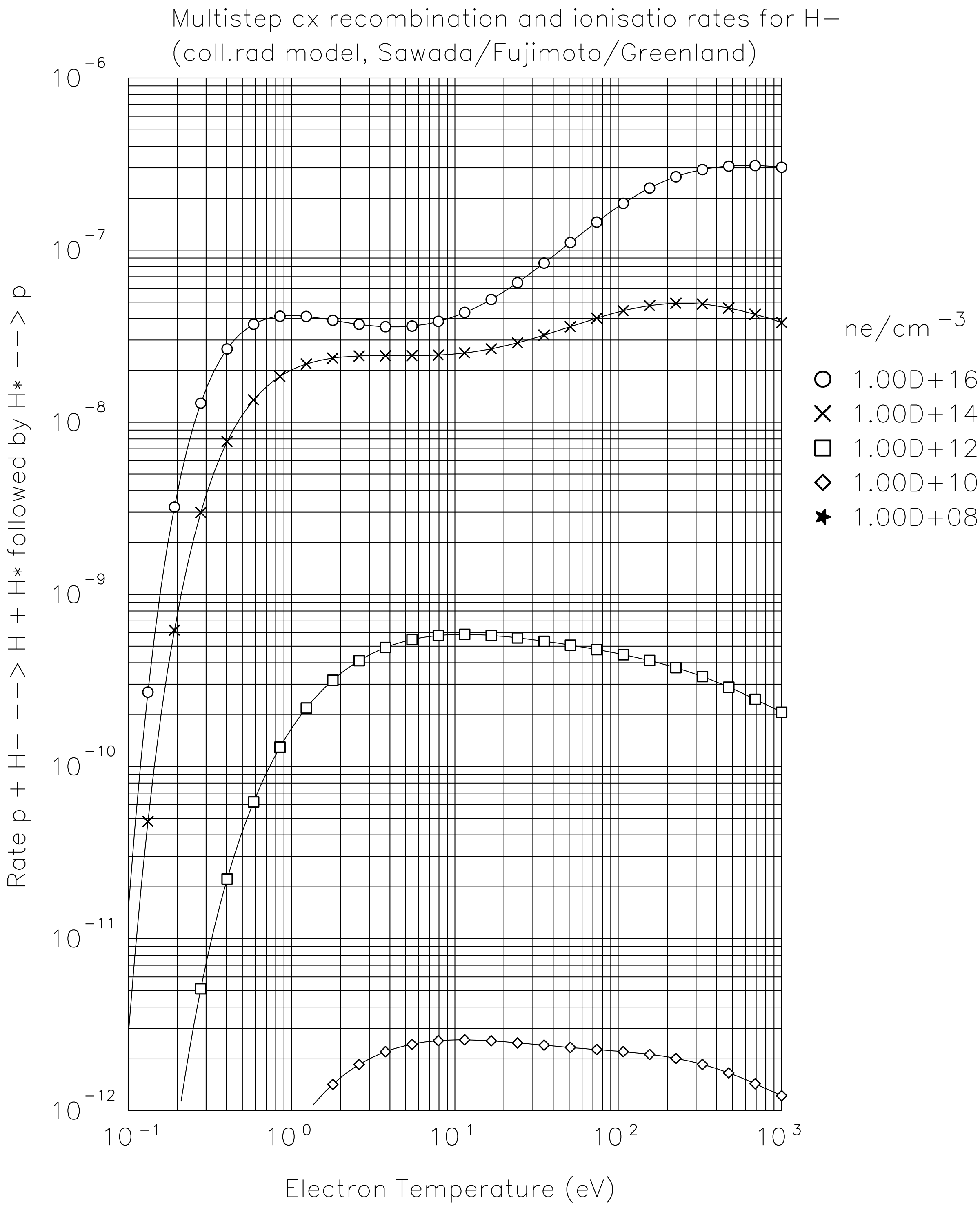
T-Index \ E-Index:	0	1	2
0	-3.274642366537D+01	1.055347808907D+00	-8.644168315786D-02
1	1.594755262357D+00	-1.134505488332D-01	1.193838572515D-01
2	-7.947374319647D-01	5.372231672557D-02	-1.798104638021D-02
3	2.774560684070D-01	-3.731637924945D-02	1.249720348407D-02
4	-9.340115304254D-02	7.824080188667D-03	-7.880149239516D-05
5	2.404236598616D-02	8.348790303724D-04	-1.947217396578D-03
6	-3.635353640159D-03	-4.379659530212D-04	4.542431412762D-04
7	2.758341263855D-04	4.578696899777D-05	-3.345082277318D-05
8	-7.995248003067D-06	-1.405530335553D-06	4.938572628097D-07

T-Index \ E-Index:	3	4	5
0	5.770739917980D-02	-1.651543971724D-02	2.426926977738D-03
1	-4.779741494751D-02	9.036602994533D-03	-8.828786882875D-04
2	-2.492326178844D-04	1.070003818666D-03	-1.975024076418D-04
3	-2.377802775838D-03	3.185245795525D-04	-3.766701342971D-05
4	2.730699348365D-04	-1.613682461379D-04	2.956305967893D-05
5	4.228772072344D-04	-3.061264744513D-05	-4.412707867464D-07
6	-8.943967815733D-05	7.191065760263D-06	-2.516431736865D-07
7	3.040805346315D-06	4.037034921179D-07	-7.745783067338D-08
8	2.407555731254D-07	-8.580821961541D-08	1.001281190560D-08

T-Index \ E-Index:	6	7	8
0	-1.852128922021D-04	6.948553416066D-06	-1.014917161032D-07
1	4.408052942176D-05	-1.018626285421D-06	7.671244985570D-09
2	1.598210863669D-05	-6.159714930603D-07	9.185228515472D-09
3	3.135633075387D-06	-1.383905482846D-07	2.380265714001D-09
4	-2.493019966708D-06	1.000180106519D-07	-1.546520999798D-09
5	1.760055762971D-07	-8.605767550690D-09	1.338507166605D-10
6	5.049361112014D-09	-2.841033281170D-10	9.491816236733D-12
7	4.107873810473D-09	-5.899534309929D-11	-6.502135074988D-13
8	-5.295286447696D-10	1.196080372249D-11	-7.019149004762D-14

T1MIN = 0.02 EV
N2MIN = 1.00000D 08 1/CM3
N2MAX = 1.00000D 16 1/CM3

Max. rel. Error: 4.7342 %
Mean rel. Error: 1.9827 %



Multistep cx recombination and ionisatio rates for H−
(coll.rad model, Sawada/Fujimoto/Greenland)
Rate p + H− ––> H + H* followed by H* ––> p
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

4.57 Reaction 2.2.17r $e + H_2(+p) \rightarrow H + H + H$ (MAR via H^-, cold H_2)

H_2 multi-step model, "intermediate H$^-$ condensed" MAR rate coefficient cm^3/s. Data: Sawada/Fujimoto/Greenland [7] $H_2(v=0)$ transported, $H-$ in QSS with H_2, $E_{H_2} = 0.1$ eV
$H_2(v \geq 1)$ is also in QSS with $H_2(v=0)$. Vibrational distribution $pH_2(v;T_e)$ as fct. of T_e only (assuming $n_e = n_p$, so density dependence cancels in $pH_2(v;T_e)$).
The MAR rate coefficient is a fct. of n_e and $T(T_e = T_p)$, and must be multiplied with density n_e to turn it into a collision rate $1/s$, and then with $n_{H_2(v=0)}$ to turn it into a volumetric reaction rate ($cm^{-3}s^{-1}$).

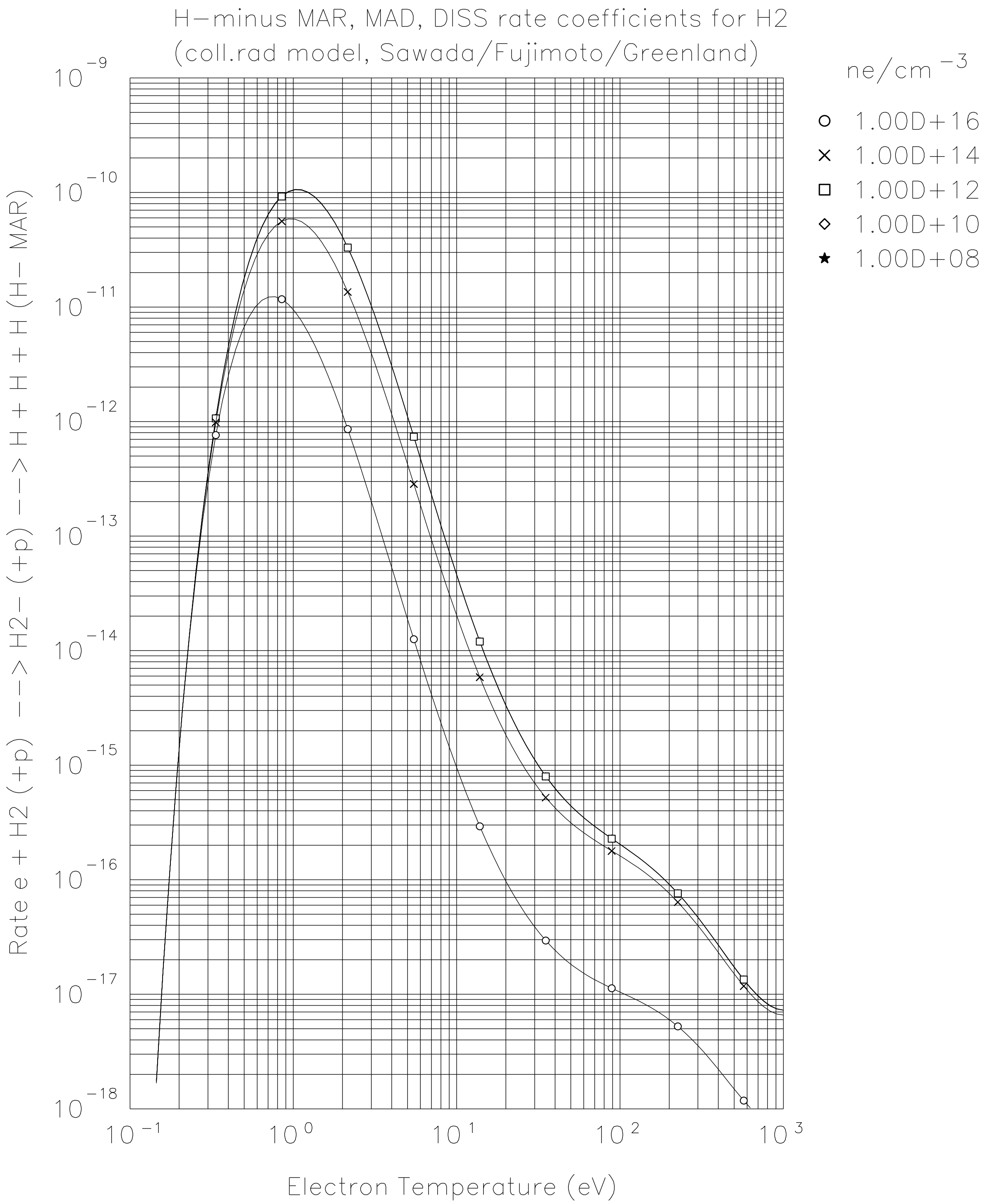
T-Index \ E-Index	0	1	2
0	-2.297800283146D+01	6.534592113445D-02	-9.544034335177D-02
1	3.255752862650D-01	-4.609955130788D-02	5.098906708830D-02
2	-2.786114306651D+00	-1.546214758321D-02	2.847577356774D-02
3	5.451071688762D-01	1.247241020831D-02	-1.353760272178D-02
4	-6.286158855226D-02	-4.389219885290D-03	3.206993381146D-03
5	4.602307315406D-02	-3.365073093686D-04	4.783138611752D-04
6	-1.377583511277D-02	6.740788490537D-04	-6.551863726515D-04
7	1.527262955311D-03	-1.450720501257D-04	1.431871130747D-04
8	-5.704031483864D-05	9.223227686785D-06	-9.308552409010D-06

T-Index \ E-Index	3	4	5
0	4.970735210679D-02	-1.243141252556D-02	1.655580726220D-03
1	-1.954797928578D-02	3.399801537594D-03	-2.849051225621D-04
2	-1.678956104784D-02	4.504025971793D-03	-6.240461921076D-04
3	5.119377169125D-03	-8.773390579671D-04	7.144457352822D-05
4	-5.136674287472D-04	-7.768096468037D-05	3.000125315688D-05
5	-2.297027336534D-04	4.978316796624D-05	-5.355797001723D-06
6	2.206810315147D-04	-3.303528206775D-05	2.195396861484D-06
7	-4.980757484889D-05	8.014816441375D-06	-6.397577372929D-07
8	3.352896292336D-06	-5.723489499349D-07	5.088071892707D-08

T-Index \ E-Index	6	7	8
0	-1.194692428627D-04	4.379565825329D-06	-6.383725114244D-08
1	1.051829766407D-05	-9.154397761809D-08	-2.152692619811D-09
2	4.608932334537D-05	-1.718655992974D-06	2.542645887393D-08
3	-2.388410284649D-06	2.655768446028D-09	1.025732328009D-09
4	-3.192832412396D-06	1.454747252965D-07	-2.454086710166D-09
5	2.865878646518D-07	-6.904361734587D-09	5.002886041869D-11
6	-3.785101515696D-08	-2.050241512510D-09	7.102693831116D-11
7	2.367506961773D-08	-2.530033040264D-10	-3.372527364917D-12
8	-2.359337617271D-09	5.134816267193D-11	-3.545642487622D-13

N2MIN = 1.00000D 08 1/CM3
N2MAX = 1.00000D 16 1/CM3

```
Max. rel. Error:   0.234E+02 %
Mean rel. Error:   0.116E+02 %
```



H−minus MAR, MAD, DISS rate coefficients for H2
(coll.rad model, Sawada/Fujimoto/Greenland)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08
Rate e + H2 (+p) −−> H2− (+p) −−> H + H + H (H− MAR)
Electron Temperature (eV)
10 −9
10 −10
10 −11
10 −12
10 −13
10 −14
10 −15
10 −16
10 −17
10 −18
10 −1
10 0
10 1
10 2
10 3

4.58 Reaction 2.2.17d $e + H_2(+p) \rightarrow p + H + H$ (MAD via H^-, cold H_2)

H_2 multi-step model, "intermediate H$^-$ condensed" MAD rate coefficient cm^3/s, same conditions as for effective MAR rate coefficient: $n_e = n_p, T_e = T_p$ to remove n_p, T_p dependence in second step, $E_{H_2} = 0.1$ eV.

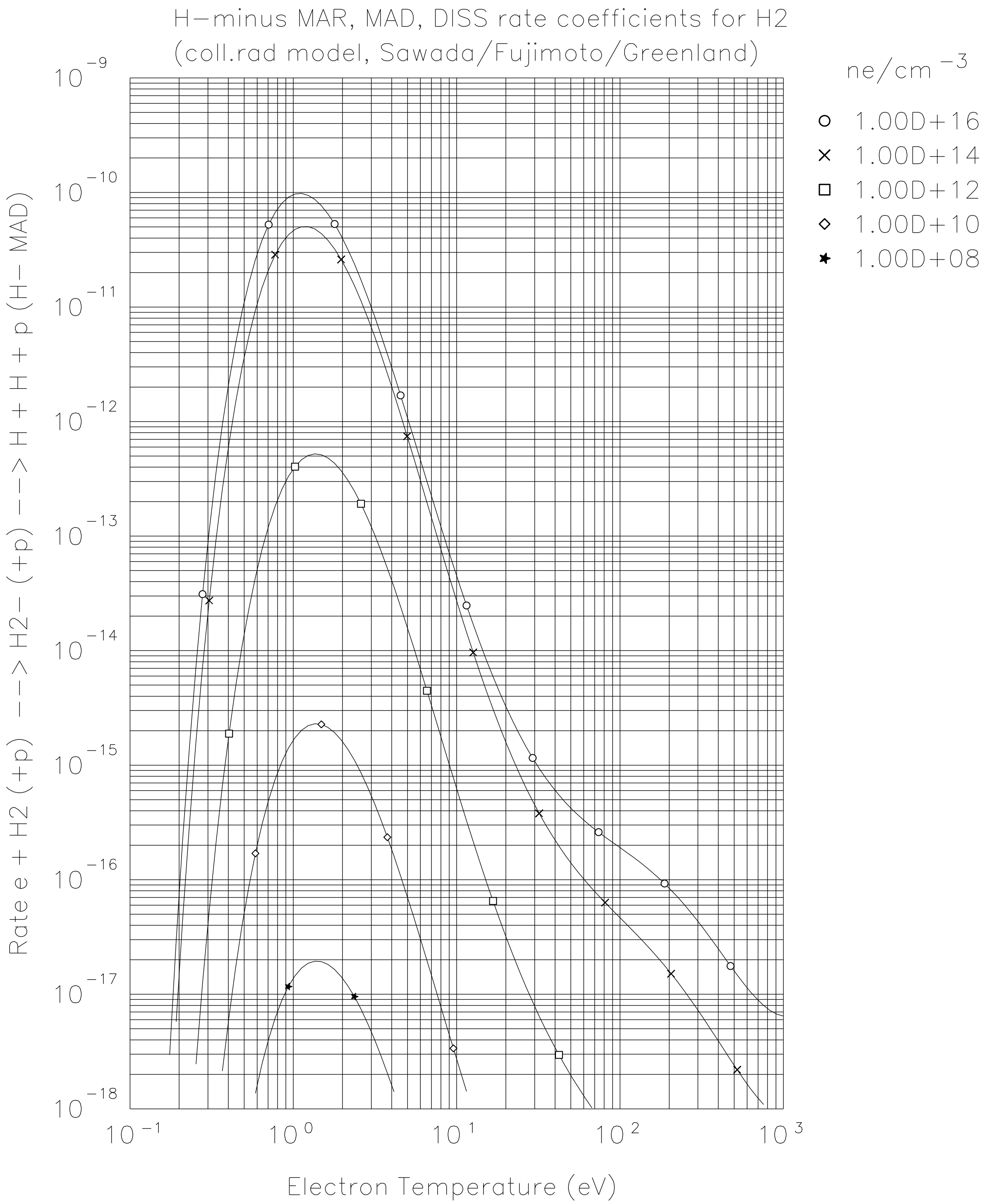
T-Index \ E-Index	0	1	2
0	-3.882083547683D+01	1.095791921388D+00	-1.230711293981D-01
1	2.151709312342D+00	-4.168827415549D-02	4.892315481992D-02
2	-3.595143998663D+00	-2.412908863509D-02	3.295635167166D-02
3	7.775259996676D-01	-6.068712552241D-03	3.634654300394D-03
4	-1.395293276372D-01	4.544589777558D-03	-4.066643547905D-03
5	6.013775491272D-02	-1.839703814205D-04	3.051477843336D-04
6	-1.461016120534D-02	-6.880568170969D-05	-5.434943913724D-05
7	1.482124097593D-03	-1.816234384924D-06	2.631936396542D-05
8	-5.220871340356D-05	9.259820722261D-07	-2.405390251053D-06

T-Index \ E-Index	3	4	5
0	7.156191553995D-02	-1.924429230749D-02	2.729436304739D-03
1	-2.163365368372D-02	4.090487899919D-03	-3.583331242137D-04
2	-1.528766675405D-02	3.561575456573D-03	-4.454863057078D-04
3	-1.214281149023D-03	2.441534541113D-04	-3.652079252543D-05
4	1.744404381785D-03	-3.908220370889D-04	5.014932056722D-05
5	-2.160937153726D-04	5.731455836804D-05	-7.513434462406D-06
6	5.747785604281D-05	-1.494808974427D-05	1.694028119666D-06
7	-1.618482069160D-05	3.709442120281D-06	-4.001502419799D-07
8	1.271263892578D-06	-2.787472368647D-07	2.994682318717D-08

T-Index \ E-Index	6	7	8
0	-2.041720297851D-04	7.573899339820D-06	-1.099140704569D-07
1	1.252069523769D-05	-1.374650112152D-08	-5.466351407287D-09
2	3.063903823423D-05	-1.087318819599D-06	1.550671864150D-08
3	3.268697767939D-06	-1.457925944423D-07	2.490300520343D-09
4	-3.621341085954D-06	1.350800086799D-07	-2.014614269650D-09
5	5.230899431395D-07	-1.841979478877D-08	2.572500353175D-10
6	-9.509188594474D-08	2.540647702443D-09	-2.460554994619D-11
7	2.191691514991D-08	-5.803874517021D-10	5.695004783405D-12
8	-1.671204190850D-09	4.617233523173D-11	-4.914469012752D-13

N2MIN = 1.00000D 08 1/CM3
N2MAX = 1.00000D 16 1/CM3

Max. rel. Error: 0.250E+02 %
Mean rel. Error: 0.108E+02 %



H−minus MAR, MAD, DISS rate coefficients for H2
(coll.rad model, Sawada/Fujimoto/Greenland)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08
Rate e + H2 (+p) −−> H2− (+p) −−> H + H + p (H− MAD)
Electron Temperature (eV)

5 H.5 : Fits for $\langle \sigma \cdot v \cdot momentum \rangle (T)$

to be written

6 H.6 : Fits for $\langle \sigma \cdot v \cdot momentum \rangle (E, T)$

to be written

7 H.7 : Fits for $\langle \sigma \cdot v \cdot momentum \rangle (n_e, T)$

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8 H.8 : Fits for $\langle \sigma \cdot v \cdot E_p \rangle (T_b)$ $[cm^3/s \cdot eV]$

E_p is a relevant energy related to the process, e.g. it may be the impacting electron or ion in eV, or the radiation energy loss per reaction, etc. In the present section the energy-weighted rate is a function of temperature [eV] of the impacting electron or ion

8.1 Reaction 2.2.14 $e + H_2^+(v) \rightarrow H(1s) + H^*(n)(v = 0 - 9, n \geq 2)$

The energy weighting in this rate coefficient is done with the kinetic energy of impacting electron. The general expression for this type of incident particle energy-weighted rate, in which the second particle is at rest, reads:
$\langle \sigma v_e E_{elec} \rangle (T_e) = kT_e \cdot \langle \sigma v_e \rangle \cdot \left(3/2 + \frac{d \ln \langle \sigma v_e \rangle}{d \ln (kT_e)}\right)$
The fit for the particular process in this paragraph should result in
$\langle \sigma v_e E_{elec} \rangle (T_e) \approx 0.896\ kT_e\ \langle \sigma v_e \rangle$,
i.e. low energy electrons are preferred in this reaction, over the average electrons with $3/2\ kT_e$

```
h0 -1.681368547011e+01    h1  3.964355004318e-01    h2  0.000000000000e+00
h3  0.000000000000e+00    h4  0.000000000000e+00    h5  0.000000000000e+00
h6  0.000000000000e+00    h7  0.000000000000e+00    h8  0.000000000000e+00
```

8.2 Reaction 2.7.14 $e + N_2^+ \rightarrow N + N^*(n)$

The energy weighting in this rate coefficient is done with the kinetic energy of impacting electron. The same procedure is applied as for H_2^+ dissociative recombination, see above in this section.

```
h0 -1.650010000000e+01    h1  0.700000000000e+00    h2  0.000000000000e+00
h3  0.000000000000e+00    h4  0.000000000000e+00    h5  0.000000000000e+00
h6  0.000000000000e+00    h7  0.000000000000e+00    h8  0.000000000000e+00
```

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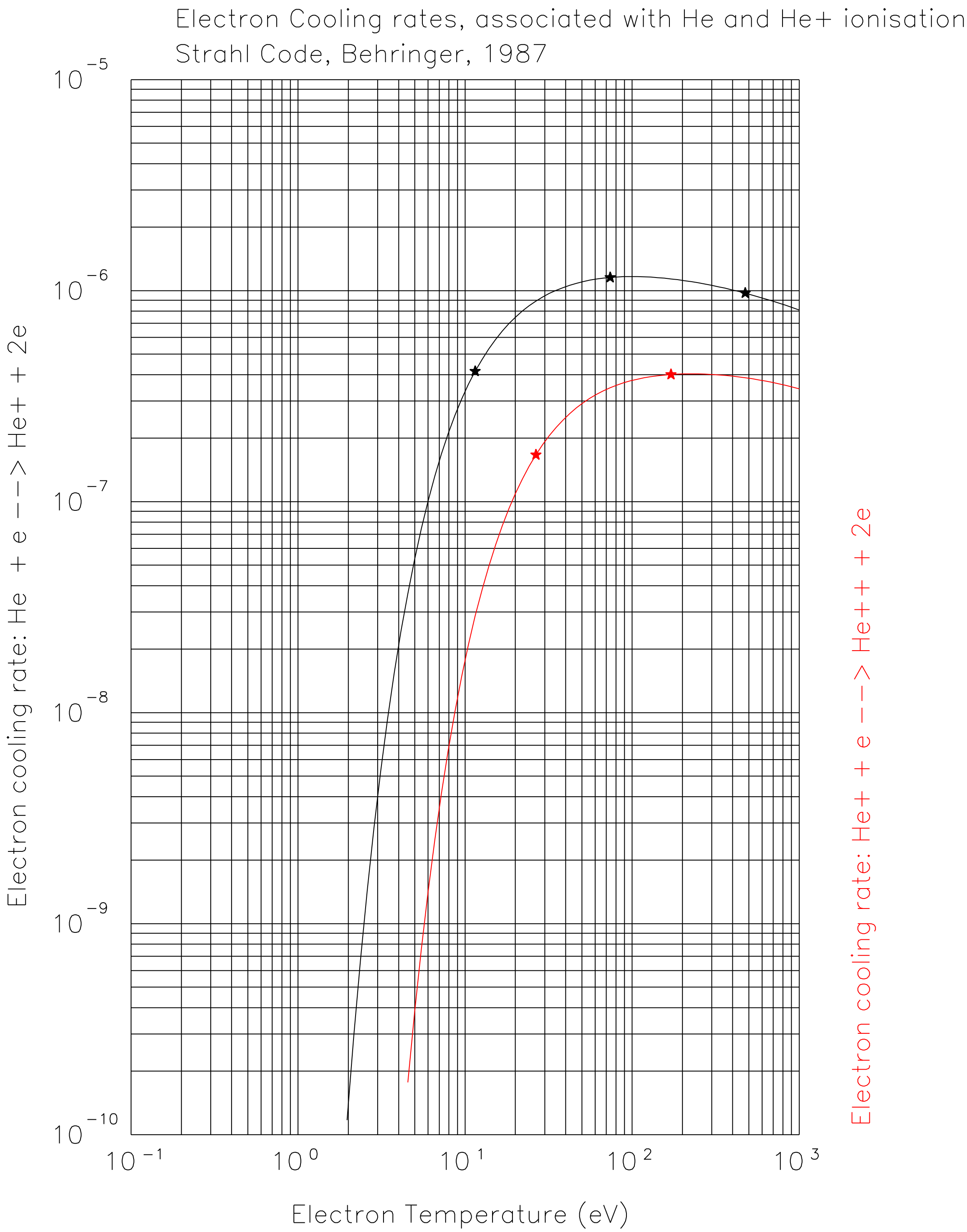
8.3 Reaction 2.2B0 $e + He(1s^2 1S) \rightarrow e + He^+(1s) + e$ 11/94 update

```
h0 -3.294427070846D+01  h1  2.058485983359D+01    h2 -1.018663912043D+01
h3  3.072113276309D+00  h4 -6.121540418115D-01    h5  8.135920959426D-02
h6 -6.956871247682D-03  h7  3.454933903445D-04    h8 -7.541153102380D-06
```

8.4 Reaction 2.2B1 $e + He^+(1s) \rightarrow e + He^{++} + e$ 11/94 update

```
h0 -5.355348236978D+01    h1  4.009715623653D+01    h2 -1.981585158765D+01
h3  6.148719835529D+00    h4 -1.288397616745D+00    h5  1.817351838759D-01
h6 -1.642324160178D-02    h7  8.519919601377D-04    h8 -1.917188865674D-05
```


Electron Cooling rates, associated with He and He+ ionisation
Strahl Code, Behringer, 1987
Electron cooling rate: He + e ––> He+ + 2e
Electron cooling rate: He+ + e ––> He++ + 2e
Electron Temperature (eV)
10^-5
10^-6
10^-7
10^-8
10^-9
10^-10
10^-1
10^0
10^1
10^2
10^3

8.5 Reaction 2.4B0 $e + Be \rightarrow e + Be^{+} + e$ 1/96 update

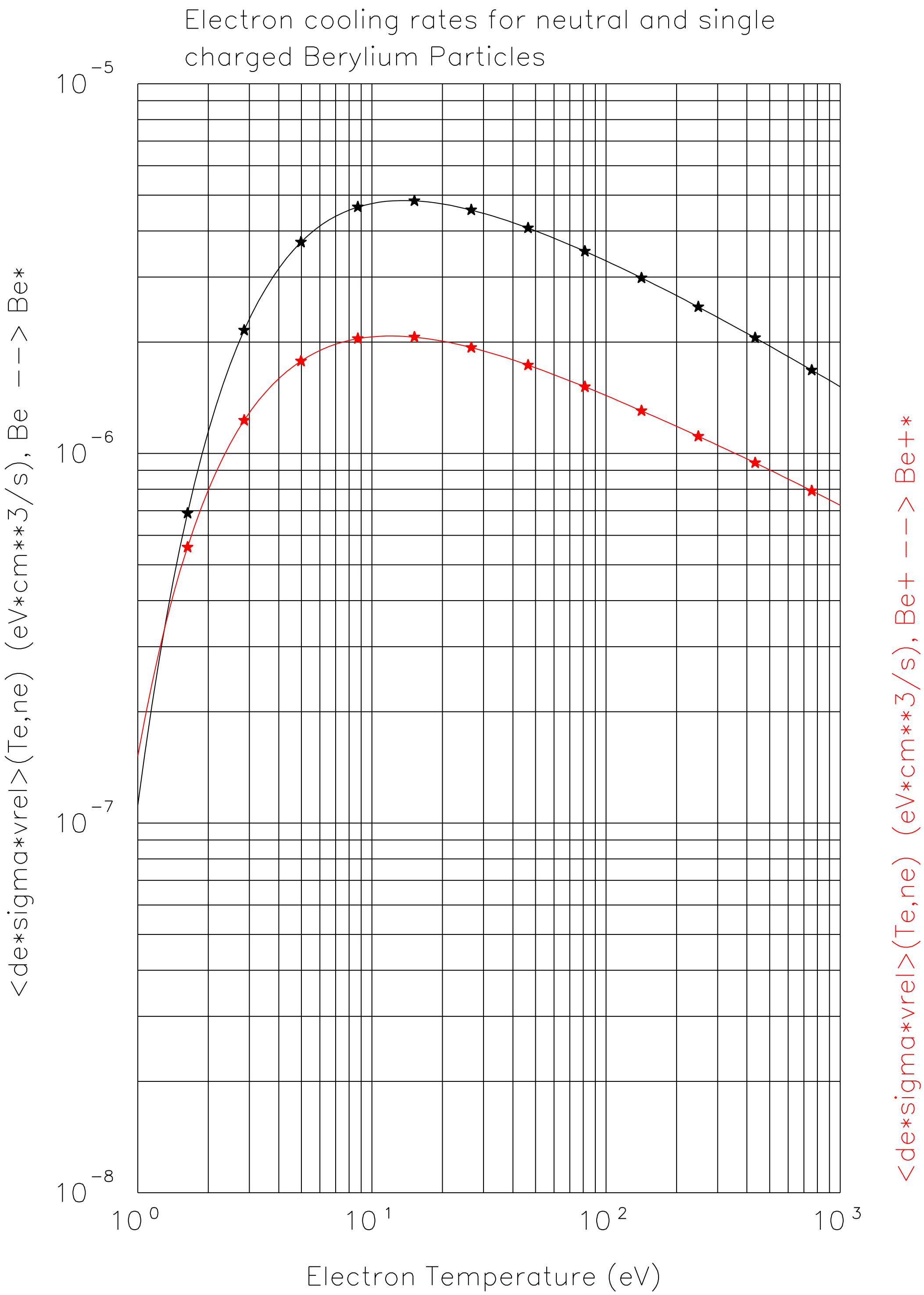
Electron cooling rates for neutral Beryllium Atoms
$\langle de * sigma * vrel \rangle (T_e)(eV * cm * *3/s), Be \rightarrow Be^{*}$

```
h0 -1.600797819812D+01  h1  4.801721310374D+00  h2 -2.546377115756D+00
h3  7.688590079004D-01  h4 -1.502880642117D-01  h5  1.910668947476D-02
h6 -1.528566911077D-03  h7  6.997210970692D-05  h8 -1.398145303385D-06

Max. rel. Error:    .1477 %
Mean rel. Error:    .0376 %
```

8.6 Reaction 2.4B1 $e + Be^{+} \rightarrow e + Be^{++} + e$ 1/96 update

Electron cooling rates for single charged Beryllium Ions
$\langle de * sigma * vrel \rangle (T_e)(eV * cm * *3/s), Be^{+} \rightarrow Be^{+*}$

```
h0 -1.570117098474D+01  h1  3.492073280813D+00  h2 -1.988895527002D+00
h3  6.770887182178D-01  h4 -1.567537912034D-01  h5  2.416405226747D-02
h6 -2.343329470312D-03  h7  1.280666147623D-04  h8 -2.989849097428D-06

Max. rel. Error:    .1400 %
Mean rel. Error:    .0783 %
```


Electron cooling rates for neutral and single
charged Berylium Particles
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{0}
10^{1}
10^{2}
10^{3}
Electron Temperature (eV)
<de*sigma*vrel>(Te,ne) (eV*cm**3/s), Be --> Be*
<de*sigma*vrel>(Te,ne) (eV*cm**3/s), Be+ --> Be+*

8.7 Reaction 2.5B0 $e + B \rightarrow e + B^{+} + e$ 1/96 update

Electron cooling rates for neutral Boron Particles
$\langle de * sigma * vrel \rangle (T_e)(eV * cm * *3/s), B \rightarrow B^{*}$

```
h0 -1.854307390504D+01    h1  6.477147013729D+00    h2 -3.012265953316D+00
h3  7.443204571714D-01    h4 -9.875163519457D-02    h5  4.879302715434D-03
h6  3.317004129594D-04    h7 -5.135297123379D-05    h8  1.774782835741D-06
```

8.8 Reaction 2.5B1 $e + B^{+} \rightarrow e + B^{++} + e$ 1/96 update

Electron cooling rates for single charged Boron Particles
$\langle de * sigma * vrel \rangle (T_e)(eV * cm * *3/s), B^{+} \rightarrow B^{+*}$

```
h0 -2.025375436381D+01    h1  8.540697000676D+00    h2 -4.378249188138D+00
h3  1.324025185106D+00    h4 -2.627439468179D-01    h5  3.472998074572D-02
h6 -2.959016392102D-03    h7  1.467662520364D-04    h8 -3.204537616409D-06
```

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8.9 Reaction 2.6B0 $e + C \rightarrow e + C^{+} + e$ 1/98 update

Electron cooling rates for neutral Carbon Particles. Here: use $\Delta E_e = I_p = const = 11.30$ constant multiplier to corresp. ionisation fit.
$\langle de * sigma * vrel \rangle (T_e)(eV * cm * *3/s), C \rightarrow C^{*}$

```
h0 -2.712642477000D+01  h1  1.180604026361D+01  h2 -5.438799573749D+00
h3  1.750648117869D+00  h4 -3.946542606866D-01  h5  5.887749368990D-02
h6 -5.469027807326D-03  h7  2.850693136991D-04  h8 -6.354758903485D-06
```

8.10 Reaction 2.6B1 $e + C^{+} \rightarrow e + C^{++} + e$ 1/98 update

Electron cooling rates for single charged Carbon Particles
$\langle de * sigma * vrel \rangle (T_e)(eV * cm * *3/s), C^{+} \rightarrow C^{+*}$

```
h0 -2.182881258910D+01  h1  8.721441032283D+00  h2 -3.874718527697D+00
h3  9.883761525498D-01  h4 -1.611584081736D-01  h5  1.774337558846D-02
h6 -1.355435656870D-03  h7  6.703143691651D-05  h8 -1.588682523808D-06

Max. rel. Error:   1.0056 %
Mean rel. Error:    .3730 %
```

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8.11 Reaction 2.7B0 $e + N \rightarrow e + N^{+} + e$

Electron cooling rates for neutral Nitrogen atoms due to ionisation. here: use $\Delta E_e = I_p = const = 14.535$
$\langle de * sigma * vrel \rangle (T_e)(eV * cm * *3/s), N \rightarrow N^{*}$

```
h0 -3.000278067000D+01  h1  1.487745850177D+01  h2 -7.393982038208D+00
h3  2.552657836634D+00  h4 -6.031414732283D-01  h5  9.299608313666D-02
h6 -8.862541230616D-03  h7  4.718778196780D-04  h8 -1.071093371002D-05
```

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8.12 Reaction 2.10B0 $e + Ne \rightarrow e + Ne^{+} + e$ 1/96 update

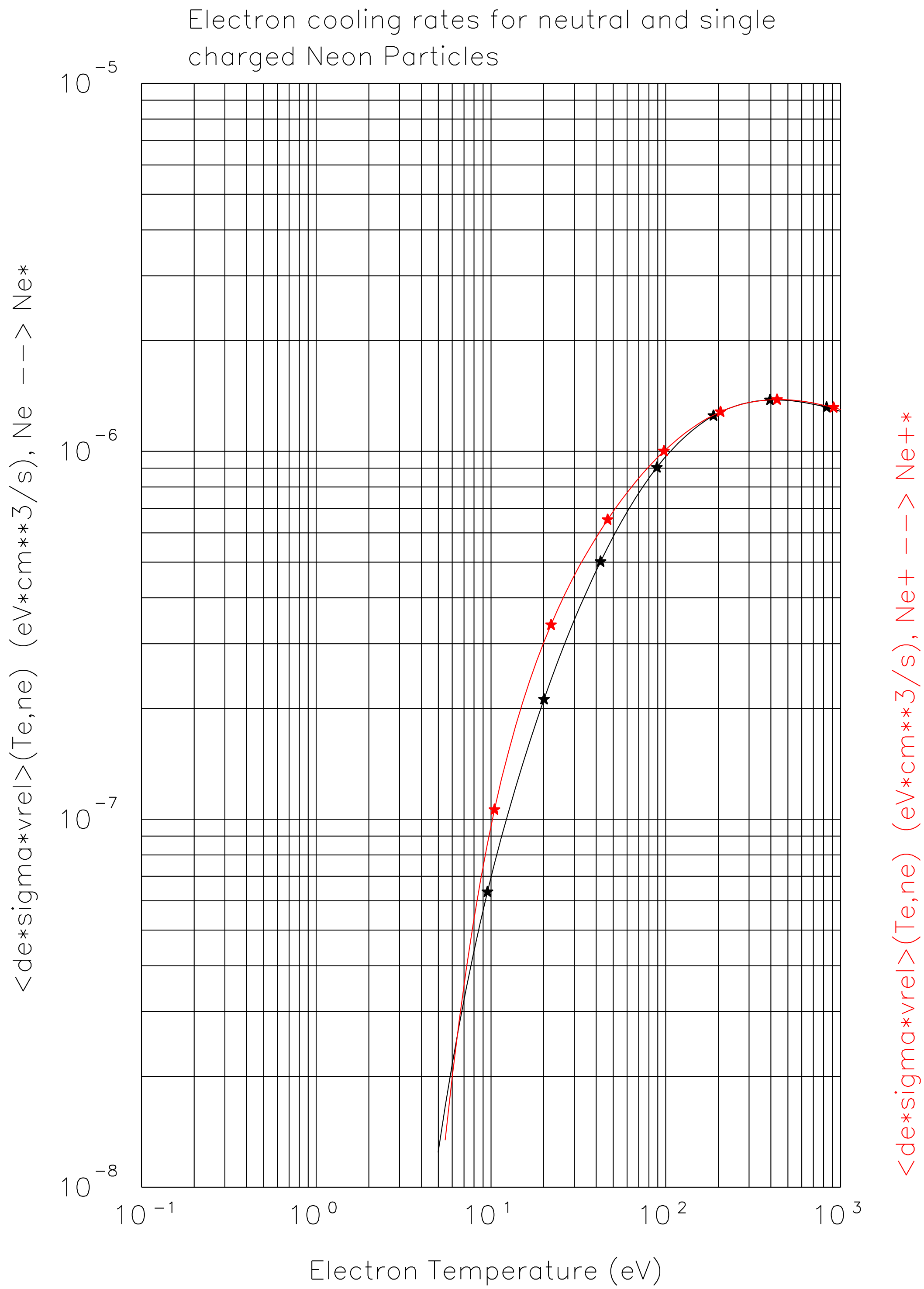
Electron cooling rates for neutral and single charged Neon Particles $\langle de{*}sigma{*}vrel\rangle(T_e)(eV* cm**3/s), Ne \rightarrow Ne^{*}$

```
h0 -3.296011717683D+01  h1  2.090175238087D+01  h2 -1.260497269687D+01
h3  4.703674520432D+00  h4 -1.084256841690D+00  h5  1.545011409578D-01
h6 -1.329678439752D-02  h7  6.349448203560D-04  h8 -1.293944291911D-05

Max. rel. Error:    .0768 %
Mean rel. Error:    .0448 %
```

8.13 Reaction 2.10B1 $e + Ne^{+} \rightarrow e + Ne^{++} + e$ 1/96 update

Electron cooling rates for neutral and single charged Neon Particles $\langle de * sigma * v - rel\rangle(T_e)(eV * cm * *3/s), Ne^{+} \rightarrow Ne^{+*}$

```
h0 -4.016425730032D+01  h1  2.721204153637D+01  h2 -1.284168864085D+01
h3  3.355303591105D+00  h4 -4.850926860273D-01  h5  3.324128846263D-02
h6 -7.385513932230D-05  h7 -1.193933246957D-04  h8  4.774152004995D-06

Max. rel. Error:    .3700 %
Mean rel. Error:    .2182 %
```


Electron cooling rates for neutral and single
charged Neon Particles
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
Electron Temperature (eV)
<de*sigma*vrel>(Te,ne) (eV*cm**3/s), Ne --> Ne*
<de*sigma*vrel>(Te,ne) (eV*cm**3/s), Ne+ --> Ne+*

8.14 Reaction 2.18B0 $e + Ar \rightarrow e + Ar^{+} + e$ 1/96 update

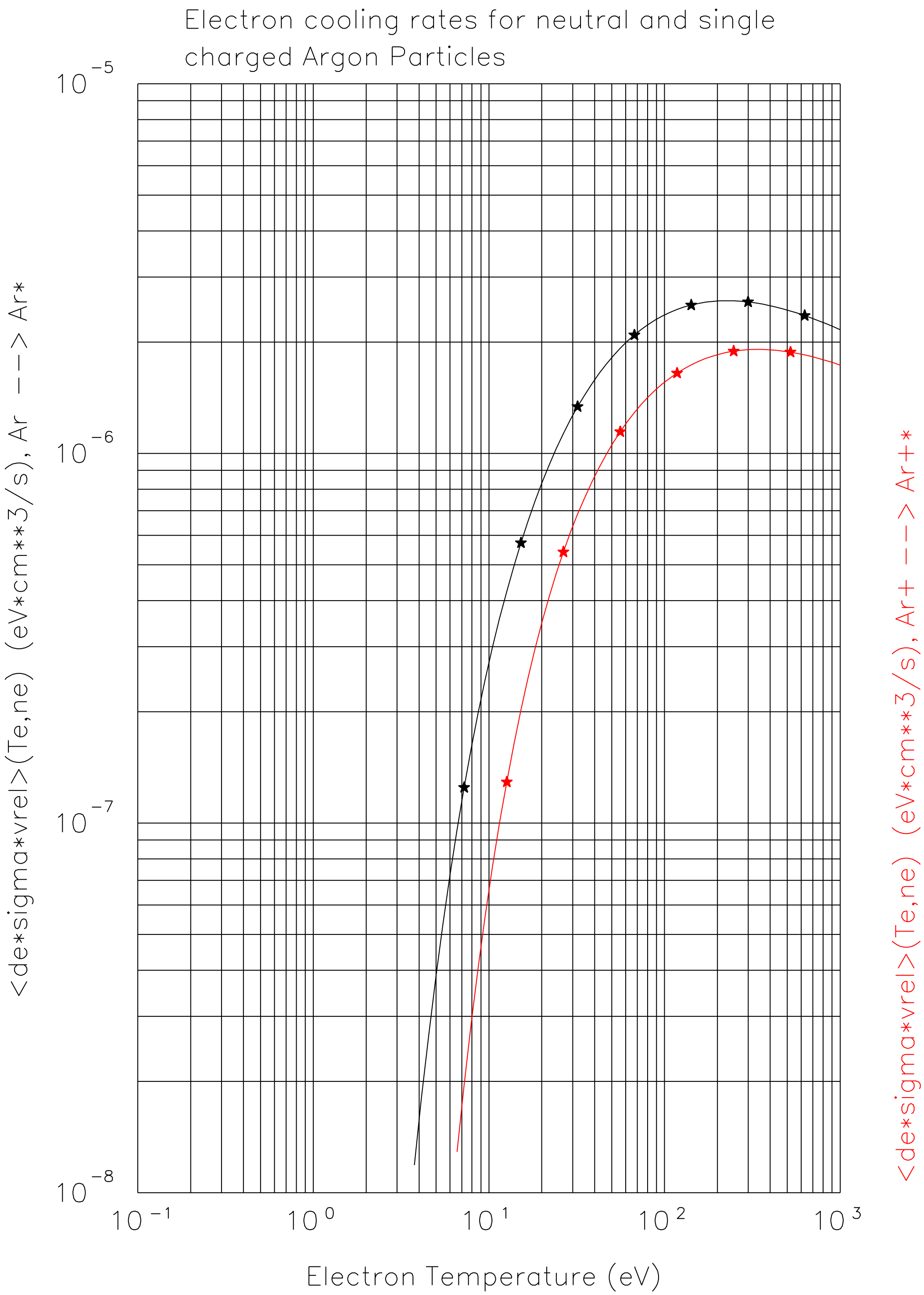
Electron cooling rates for neutral and single charged Argon Particles here: use $\Delta E_e = I_p = const = 15.7596$, constant multiplier to corresp. ionisation fit.
$\langle de * sigma * vrel\rangle(T_e)(eV * cm * *3/s), Ar \rightarrow Ar^{*}$

```
h0 -3.054602443000D+01  h1  1.627861918393D+01  h2 -7.765170847889D+00
h3  2.446384994382D+00  h4 -5.186581624286D-01  h5  7.184868450814D-02
h6 -6.200405891186D-03  h7  3.018464732517D-04  h8 -6.325074170944D-06
```

8.15 Reaction 2.18B1 $e + Ar^{+} \rightarrow e + Ar^{++} + e$ 1/96 update

Electron cooling rates for neutral and single charged Argon Particles $\langle de * sigma * vrel\rangle(T_e)(eV * cm * *3/s), Ar^{+} \rightarrow Ar^{+*}$

```
h0 -4.165898540334D+01  h1  2.608109647112D+01  h2 -1.166949407607D+01
h3  3.280473403465D+00  h4 -6.113171083108D-01  h5  7.504889391247D-02
h6 -5.828589448772D-03  h7  2.593634229260D-04  h8 -5.035811848208D-06

Max. rel. Error:    .0697 %
Mean rel. Error:    .0288 %
```


Electron cooling rates for neutral and single
charged Argon Particles
10^-5
10^-6
10^-7
10^-8
10^-1
10^0
10^1
10^2
10^3
Electron Temperature (eV)
<de*sigma*vrel>(Te,ne) (eV*cm**3/s), Ar --> Ar*
<de*sigma*vrel>(Te,ne) (eV*cm**3/s), Ar+ --> Ar+*

8.16 Reaction 2.26B0 $e + Fe \rightarrow e + Fe^{+} + e$ 2/06 update

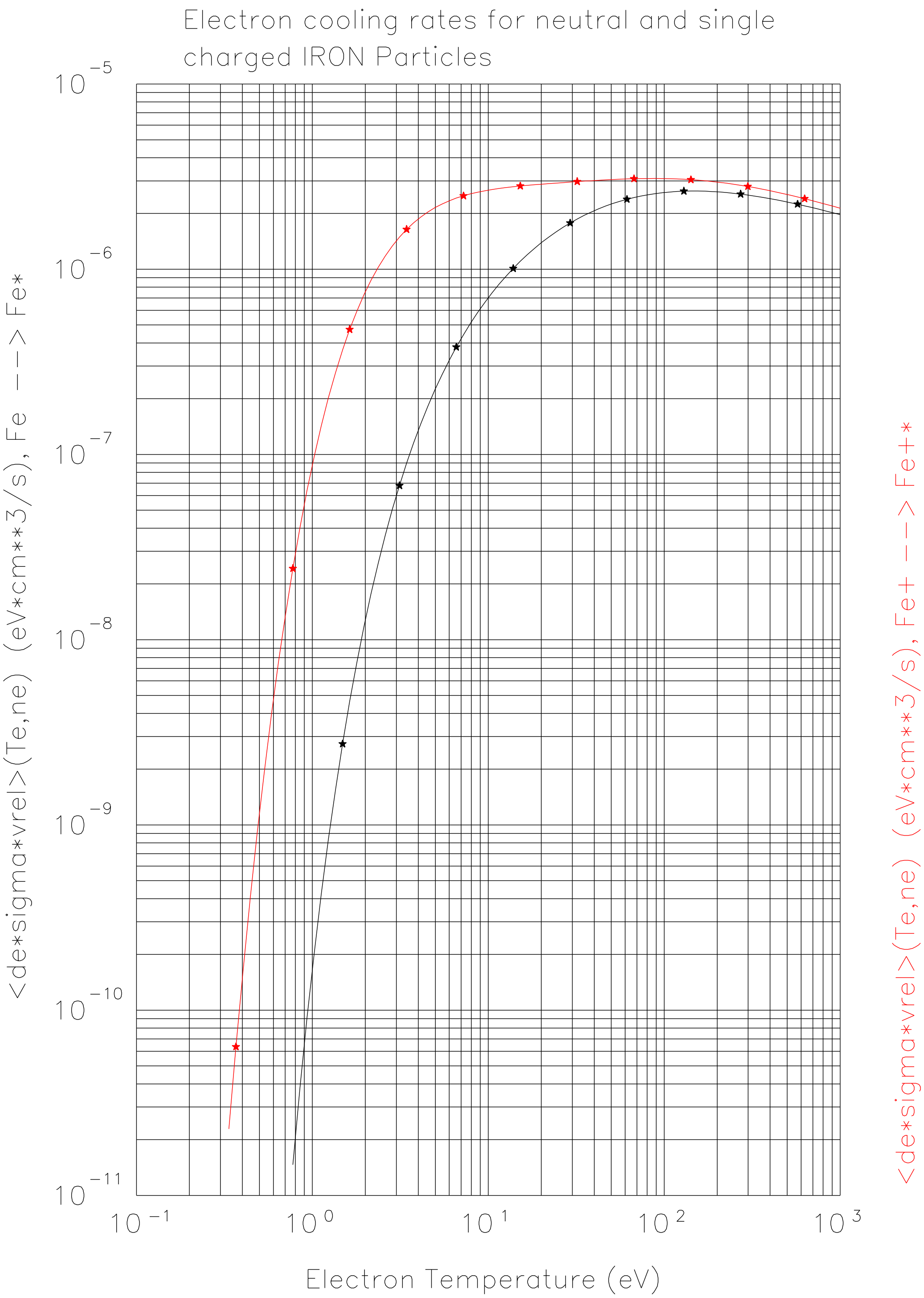
Electron cooling rates for neutral and single charged Iron Particles $\langle de{*}sigma{*}vrel\rangle(T_e)(eV * cm * *3/s), Fe \rightarrow Fe^{*}$

```
h0 -2.251653573541D+01  h1  8.433391246873D+00  h2 -3.846892917152D+00
h3  1.185977478850D+00  h4 -2.459331954696D-01  h5  3.266167601116D-02
h6 -2.642599090120D-03  h7  1.182307520821D-04  h8 -2.237623328108D-06

Max. rel. Error:    .0906 %
Mean rel. Error:    .0450 %
```

8.17 Reaction 2.26B1 $e + Fe^{+} \rightarrow e + Fe^{++} + e$ 2/06 update

Electron cooling rates for neutral and single charged Iron Particles $\langle de{*}sigma{*}vrel\rangle(T_e)(eV * cm * *3/s), Fe^{+} \rightarrow Fe^{+*}$

```
h0 -1.624809050332D+01  h1  4.421997781459D+00  h2 -2.249312140674D+00
h3  5.326087246569D-01  h4 -3.768433369019D-02  h5 -8.032685540054D-03
h6  1.913339126234D-03  h7 -1.516002249042D-04  h8  4.332622078891D-06

Max. rel. Error:    .4042 %
Mean rel. Error:    .2088 %
```



Electron cooling rates for neutral and single
charged IRON Particles
10^-5
10^-6
10^-7
10^-8
10^-9
10^-10
10^-11
10^-1
10^0
10^1
10^2
10^3
Electron Temperature (eV)
<de*sigma*vrel>(Te,ne) (eV*cm**3/s), Fe --> Fe*
<de*sigma*vrel>(Te,ne) (eV*cm**3/s), Fe+ --> Fe+*

8.18 Reaction 3.1.8L $p + H(1s) \rightarrow H(1s) + p$

Langevin CX rate, for testing only.
E_p is the kinetic energy of the impacting ion in eV. The energy-weighted rate for the Langevin approximation is 3/2 kT * 2e-8

```
       E-Index:     0                     1                     2
 T-Index:
  h0 -1.732206846000D+01  h1  1.000000000000D+00  h2  0.000000000000D+00
  h3  0.000000000000D+00  h4  0.000000000000D+00  h5  0.000000000000D+00
  h6  0.000000000000D+00  h7  0.000000000000D+00  h8  0.000000000000D+00
```

9 H.9 :Fits for $\langle\sigma \cdot v \cdot E_p\rangle(E_0, T_p)$ $[cm^3/s \cdot eV]$

9.1 Reaction 3.1.8 $p + H(1s) \rightarrow H(1s) + p$

E_p is the kinetic energy of the impacting ion in eV. The energy-weighted rate coefficient is a function of ion temperature T_p [eV] and of the impacting neutral particle kinetic energy E_0 [eV]

T-Index \ E-Index:	0	1	2
0	-1.777579549728D+01	1.009523650881D-01	4.654228527844D-02
1	1.275231758810D+00	-9.644906009036D-02	-2.211669235384D-02
2	4.530160377165D-02	2.342045574729D-02	-9.203651373424D-03
3	-5.955369019980D-03	3.554165401021D-03	5.687922583665D-03
4	-1.979653552345D-03	-2.139061718958D-03	-5.015782273336D-05
5	1.387089441785D-04	2.267300682383D-04	-4.035280214497D-04
6	9.252160306969D-05	1.040699979357D-05	8.704096952722D-05
7	-1.432658980502D-05	-2.945710692553D-06	-7.300036168036D-06
8	5.659366058900D-07	1.274167039318D-07	2.222526255554D-07

T-Index \ E-Index:	3	4	5
0	1.086931313538D-02	-2.594201995447D-03	-7.731266223508D-04
1	8.467481122042D-03	1.412559491188D-03	-7.442507107710D-04
2	-4.737882712502D-03	1.276905220752D-03	2.370696675146D-04
3	-1.107407133685D-03	-5.709773444309D-04	1.803637598216D-04
4	6.785109655871D-04	-6.025307354437D-05	-5.642411701218D-05
5	-5.545614797192D-05	6.129382543768D-05	-3.599116584649D-06
6	-9.853811706993D-06	-1.141186867496D-05	2.733706713304D-06
7	1.708575489575D-06	8.872884700942D-07	-3.140831827282D-07
8	-6.988406373694D-08	-2.556421038443D-08	1.135791478659D-08

T-Index \ E-Index:	6	7	8
0	2.413613977749D-04	-2.132300538605D-05	6.057223635716D-07
1	9.518302025258D-05	-4.753012706978D-06	7.069997192010D-08
2	-1.000952289205D-04	1.059536089242D-05	-3.696859736968D-07
3	-1.512070888533D-05	5.360958997427D-08	2.773215541900D-08
4	1.500712819446D-05	-1.393253051164D-06	4.521246252095D-08
5	-1.937812763003D-06	3.059696948703D-07	-1.282436081613D-08
6	-9.308661633534D-08	-1.924954958807D-08	1.274653104848D-09
7	2.993136285588D-08	-4.094687301095D-10	-4.251053762140D-11
8	-1.386563064570D-09	5.641978567123D-11	-1.151564989100D-13

Max. rel. Error: 1.2514 %
Mean rel. Error: 0.2865 %

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9.2 Reaction 3.1.8L $p + H(1s) \rightarrow H(1s) + p$

E_p is the kinetic energy of the impacting ion in eV. The energy-weighted rate for the Langevin approximation is 3/2 kT * 2e-8

T-Index \ E-Index:	0	1	2
0	-1.732206846000D+01	0.000000000000D+00	0.000000000000D+00
1	1.000000000000D+00	0.000000000000D+00	0.000000000000D+00
2	0.000000000000D+00	0.000000000000D+00	0.000000000000D+00
3	0.000000000000D+00	0.000000000000D+00	0.000000000000D+00
4	0.000000000000D+00	0.000000000000D+00	0.000000000000D+00
5	0.000000000000D+00	0.000000000000D+00	0.000000000000D+00
6	0.000000000000D+00	0.000000000000D+00	0.000000000000D+00
7	0.000000000000D+00	0.000000000000D+00	0.000000000000D+00
8	0.000000000000D+00	0.000000000000D+00	0.000000000000D+00

T-Index \ E-Index:	3	4	5
0	0.000000000000D+00	0.000000000000D+00	0.000000000000D+00
1	0.000000000000D+00	0.000000000000D+00	0.000000000000D+00
2	0.000000000000D+00	0.000000000000D+00	0.000000000000D+00
3	0.000000000000D+00	0.000000000000D+00	0.000000000000D+00
4	0.000000000000D+00	0.000000000000D+00	0.000000000000D+00
5	0.000000000000D+00	0.000000000000D+00	0.000000000000D+00
6	0.000000000000D+00	0.000000000000D+00	0.000000000000D+00
7	0.000000000000D+00	0.000000000000D+00	0.000000000000D+00
8	0.000000000000D+00	0.000000000000D+00	0.000000000000D+00

T-Index \ E-Index:	6	7	8
0	0.000000000000D+00	0.000000000000D+00	0.000000000000D+00
1	0.000000000000D+00	0.000000000000D+00	0.000000000000D+00
2	0.000000000000D+00	0.000000000000D+00	0.000000000000D+00
3	0.000000000000D+00	0.000000000000D+00	0.000000000000D+00
4	0.000000000000D+00	0.000000000000D+00	0.000000000000D+00
5	0.000000000000D+00	0.000000000000D+00	0.000000000000D+00
6	0.000000000000D+00	0.000000000000D+00	0.000000000000D+00
7	0.000000000000D+00	0.000000000000D+00	0.000000000000D+00
8	0.000000000000D+00	0.000000000000D+00	0.000000000000D+00

Max. rel. Error: 0.0000 %
Mean rel. Error: 0.0000 %

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9.3 Reaction 3.3.1 $p + He(1s^2 1S) \rightarrow H + He^+(1s)$

Proton energy-weighted charge exchange rate coefficient, protons with ground state Helium He, $E_{th} \approx 11.2$ eV. Corresponding un-weighted rate coefficient is given also here in an earlier section and in HYHEL with same sub-section number.

T-Index \ E-Index:	0	1	2
0	-3.445873460852D+01	8.326134682590D-01	1.933054122941D-01
1	7.061207340144D+00	-1.313817435577D+00	-2.022008463051D-02
2	-1.736559910607D+00	9.850170907730D-01	-2.150416408177D-01
3	2.831856629788D-01	-4.245131595514D-01	1.739383391445D-01
4	2.241285385641D-02	1.103647192643D-01	-6.088038032579D-02
5	-2.212724523621D-02	-1.746079083640D-02	1.145240838422D-02
6	4.425243772505D-03	1.637736454226D-03	-1.204202849751D-03
7	-3.781548873891D-04	-8.345178061307D-05	6.671405376586D-05
8	1.193024795969D-05	1.774873395657D-06	-1.517888839586D-06

T-Index \ E-Index:	3	4	5
0	6.873661138878D-02	-2.530594845507D-02	3.637744786711D-03
1	-1.061062949296D-01	4.412103967546D-02	-3.685824519445D-03
2	6.376880737273D-02	-1.785764179094D-02	1.574503264024D-03
3	-2.171235372363D-02	-3.103258502378D-04	-7.908060831688D-05
4	5.072440380901D-03	1.643836342594D-03	-1.585285238384D-04
5	-8.662593688148D-04	-3.914961081124D-04	5.595248036912D-05
6	1.004763175634D-04	3.863654089420D-05	-8.367160814608D-06
7	-6.737998131918D-06	-1.587918693338D-06	6.003371579626D-07
8	1.916686027968D-07	1.615498260138D-08	-1.693306893859D-08

T-Index \ E-Index:	6	7	8
0	-4.698314268303D-04	4.502855041540D-05	-1.724119064743D-06
1	-4.081552915490D-04	7.523889576611D-05	-3.020854867113D-06
2	1.755019472132D-04	-3.622077917093D-05	1.578825987882D-06
3	8.820311155289D-05	-1.096383895966D-05	4.077966484815D-07
4	-4.325767085415D-05	7.303630284565D-06	-3.055052941782D-07
5	3.995980258215D-06	-1.053387214627D-06	4.789068581038D-08
6	4.989305627062D-07	4.799823908148D-09	-9.771077724410D-10
7	-1.009348152873D-07	8.912440158402D-09	-3.117095091366D-10
8	4.438767986041D-09	-4.806081198001D-10	1.835893653264D-11

Max. rel. Error: 13.4603 %
Mean rel. Error: 0.9308 %

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9.4 Reaction 3.3.6a $p + He^*(1s^1 2s^1 1S) \rightarrow H^*(2s) + He^+(1s)$

Proton energy-weighted charge exchange rate coefficient, protons with first meta-stable He*, $E_{th} \approx 0.57$ eV. Corresponding (un-weighted) rate coefficient is given here in an earlier section and in HYHEL with same sub-section number.

T-Index \ E-Index	0	1	2
0	-2.397668404788D+01	3.159485036283D-01	1.251349908668D-01
1	3.791127359443D+00	-3.761884787063D-01	-1.201611289430D-01
2	-3.031005464839D-01	1.547966958268D-01	3.418807730147D-02
3	-2.042285843152D-02	-1.849518757027D-02	-2.705500175969D-03
4	9.317257534521D-03	-3.497722978839D-03	5.266899471936D-04
5	-4.841929631711D-04	1.244615194159D-03	-3.264196261141D-04
6	-9.483126811734D-05	-1.399032118750D-04	6.356897513547D-05
7	1.241207591818D-05	6.987980280667D-06	-4.975196671014D-06
8	-4.191666003951D-07	-1.299861951387D-07	1.392550743313D-07

T-Index \ E-Index	3	4	5
0	3.856067365269D-02	-2.026573130919D-03	-2.759136201694D-03
1	-6.229570032866D-03	7.539673693629D-03	3.228125296776D-05
2	-1.117399758747D-02	-3.402440317662D-03	1.301470355832D-03
3	4.346233632875D-03	2.577875598472D-04	-4.359935280851D-04
4	-6.346015739054D-04	1.053315422043D-04	3.920000120015D-05
5	6.551645356748D-05	-2.376485094163D-05	1.685178990397D-06
6	-8.200597026708D-06	1.844480677683D-06	-3.712741557353D-07
7	7.170567793961D-07	-5.326280408650D-08	9.229946485903D-09
8	-2.381772742595D-08	2.014368954375D-10	2.686050437848D-10

T-Index \ E-Index	6	7	8
0	5.281724050161D-04	-3.697200097287D-05	9.237548925974D-07
1	-2.159762940362D-04	2.275443392926D-05	-7.099802232376D-07
2	-1.482835634810D-04	6.952989686416D-06	-1.085642522433D-07
3	7.949763771555D-05	-5.715813906994D-06	1.481611026493D-07
4	-1.214272931648D-05	1.128632380175D-06	-3.510270530142D-08
5	5.986765602098D-07	-9.526271005415D-08	3.781185514127D-09
6	4.147212027299D-09	4.109065328207D-09	-2.316799675035D-10
7	-6.505709803163D-11	-1.612579446392D-10	9.811627985408D-12
8	-4.990895417628D-11	5.743415083193D-12	-2.467665429406D-13

Max. rel. Error: 6.2499 %
Mean rel. Error: 0.8870 %

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9.5 Reaction 3.3.6b $p + He^*(1s^1 2s^1 3S) \rightarrow H^*(2s) + He^+(1s)$

Proton energy-weighted charge exchange rate coefficient, protons with second meta-stable He*, $E_{th} \approx 1.37$ eV. Corresponding (un-weighted) rate coefficient is given here in an earlier section and in HYHEL with same sub-section number.

T-Index \ E-Index	0	1	2
0	-2.956696212252D+01	5.281567610030D-01	1.525645856454D-01
1	5.608996254071D+00	-5.554651091960D-01	-8.310107491980D-02
2	-5.586148730643D-01	2.869596240969D-01	2.693533782880D-02
3	8.445222522903D-02	-9.885450333344D-02	-2.375836603441D-02
4	-4.080969150629D-02	2.380017857884D-02	1.216452673035D-02
5	1.109225928721D-02	-3.788861207335D-03	-2.898997798061D-03
6	-1.454903843517D-03	3.686204124267D-04	3.488800425650D-04
7	9.246654975855D-05	-1.956645015230D-05	-2.070012209875D-05
8	-2.304179941047D-06	4.310780137920D-07	4.810780135493D-07

T-Index \ E-Index	3	4	5
0	5.501159994270D-02	5.231877282834D-03	-5.104807314720D-03
1	-3.503708291156D-02	-6.194296661419D-03	8.545246673022D-03
2	-2.619680827152D-02	9.409111065614D-03	-3.292720454900D-03
3	3.066491792837D-02	-6.421108100188D-03	1.185509375312D-04
4	-1.125547411729D-02	2.175569508209D-03	9.073341073380D-05
5	2.024041838757D-03	-4.121003738472D-04	7.128259787760D-06
6	-1.907412735028D-04	4.489456337277D-05	-6.215149457584D-06
7	8.849836285624D-06	-2.639451182160D-06	7.576420403373D-07
8	-1.534752844870D-07	6.492509343847D-08	-2.852852143477D-08

T-Index \ E-Index	6	7	8
0	6.537231707620D-04	-2.747946210980D-05	1.809150198692D-07
1	-1.763283177626D-03	1.440173210330D-04	-4.252159818280D-06
2	6.322499969920D-04	-5.569656379195D-05	1.811409365339D-06
3	9.910404393999D-05	-1.096951926860D-05	3.556184138250D-07
4	-7.195067291013D-05	7.772807797383D-06	-2.677198674596D-07
5	8.134485110505D-06	-1.024492516657D-06	3.813168247354D-08
6	4.630863375819D-07	-1.150736736272D-08	-2.200040624310D-10
7	-1.265796349526D-07	9.977170726720D-09	-2.923241327427D-10
8	5.638328877632D-09	-4.845499350959D-10	1.514129155630D-11

Max. rel. Error: 6.1811 %
Mean rel. Error: 0.6136 %

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10 H.10 :Fits for $\langle \sigma \cdot v \cdot E_p \rangle (n_p, T_p)$ $[cm^3/s \cdot eV]$

E_p is either the kinetic energy (or the energy loss per event) of the impacting electron or ion, in eV, or the energy loss (energy cost), associated with a process or set of processes. In the latter case these energy-weighted rate coefficients are obtained from collision-radiative modeling.

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10.1 Reaction 2.1.5JH $e + H \rightarrow H^+ + 2e$

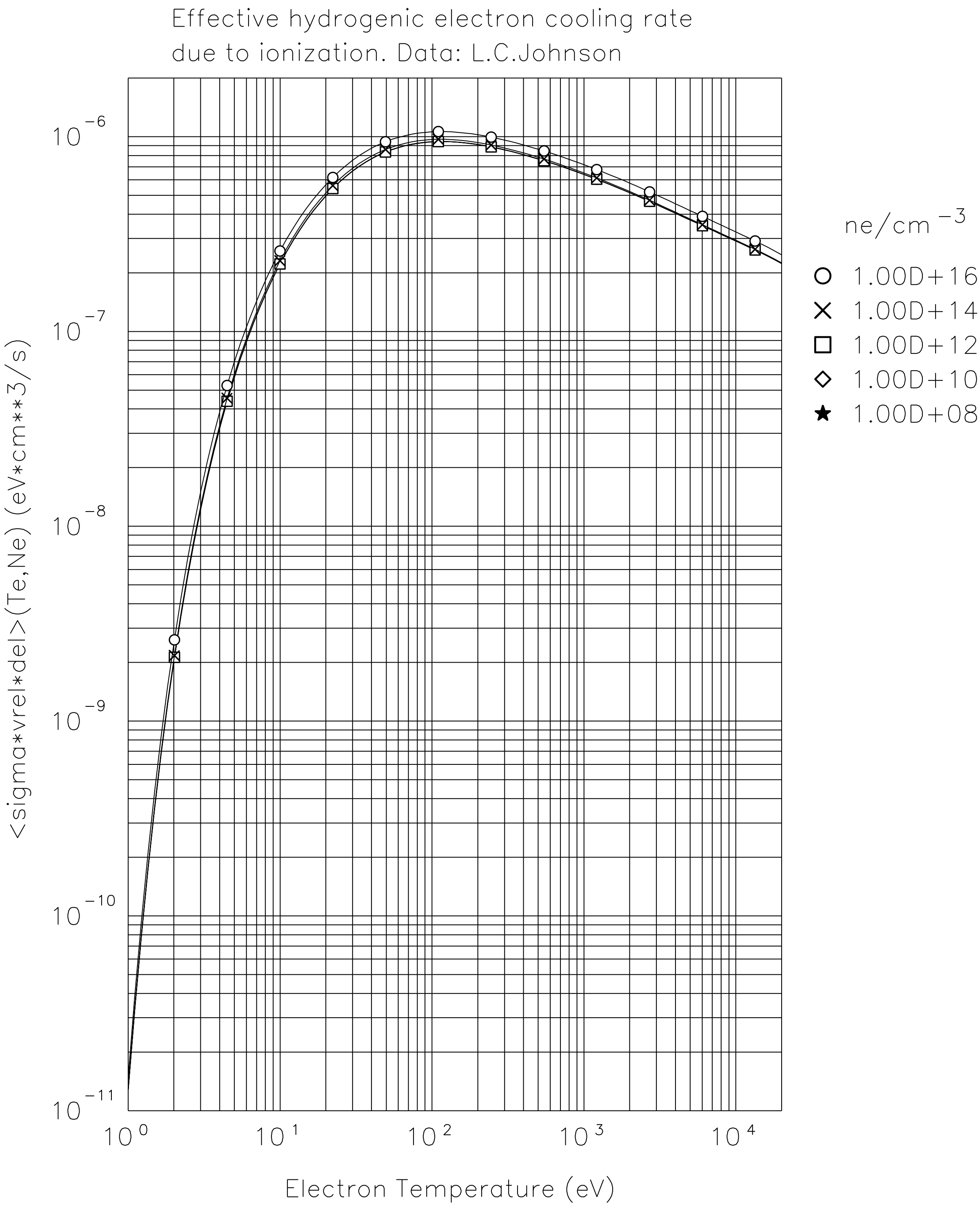
Electron energy loss weighted rate coefficient. Total: radiation plus potential energy cost.
Data: Johnson, [4]

T-Index \ E-Index:	0	1	2
0	-2.508124023824D+01	1.734108135759D-02	-1.891777149512D-02
1	9.961634412423D+00	-1.573307884566D-02	1.843734255418D-02
2	-4.776180166264D+00	2.970917601727D-04	-3.807758859655D-03
3	1.630713043514D+00	3.457819922651D-03	-1.182846239993D-03
4	-3.862246458538D-01	-1.354707016609D-03	5.758335877954D-04
5	5.908348117252D-02	2.467671779140D-04	-9.707776439937D-05
6	-5.502149035570D-03	-2.550039601080D-05	9.186912710069D-06
7	2.825693139758D-04	1.479374192570D-06	-5.357992990165D-07
8	-6.126373636033D-06	-3.768914931663D-08	1.516539648383D-08

T-Index \ E-Index:	3	4	5
0	7.823415079914D-03	-1.631549805821D-03	1.886435723148D-04
1	-7.526506973636D-03	1.445482212534D-03	-1.430089553311D-04
2	2.108820285359D-03	-4.156648351099D-04	3.407098816806D-05
3	-1.066332982000D-05	2.942499095980D-05	-8.976235585729D-07
4	-6.053903755468D-05	-4.227285712967D-07	-2.352473868493D-09
5	7.784473195273D-06	7.205874145075D-07	-9.883252326876D-08
6	-5.442048934307D-07	-8.990161485463D-08	8.933475010389D-09
7	4.797758886682D-08	-1.637030558354D-09	5.735798106880D-10
8	-2.404105327023D-09	3.753206693445D-10	-6.002003170733D-11

T-Index \ E-Index:	6	7	8
0	-1.224700235983D-05	4.170427242828D-07	-5.775556894342D-09
1	7.221376553657D-06	-1.633748217561D-07	1.028215793306D-09
2	-8.300185166679D-07	-2.671730459566D-08	1.140062425575D-09
3	-3.006283377398D-07	2.400198464058D-08	-4.901297252541D-10
4	4.544140153285D-08	-2.854579885273D-09	3.868612101415D-11
5	2.577124843878D-09	-1.007675407273D-10	6.215200297376D-12
6	-1.937960153333D-10	1.664413123118D-11	-9.521242149750D-13
7	-6.978042599136D-11	1.836020981290D-12	1.884922171479D-14
8	5.011156979547D-12	-1.641995819473D-13	1.257296690473D-15

```
N2MIN =   1.00000D 08 1/CM3
N2MAX =   1.00000D 16 1/CM3
  Max. rel. Error:    .4678 %
  Mean rel. Error:    .2498 %
```


Effective hydrogenic electron cooling rate
due to ionization. Data: L.C.Johnson
<sigma*vrel*del>(Te,Ne) (eV*cm**3/s)
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

10.2 Reaction 2.1.5 $e + H \rightarrow H^+ + 2e$

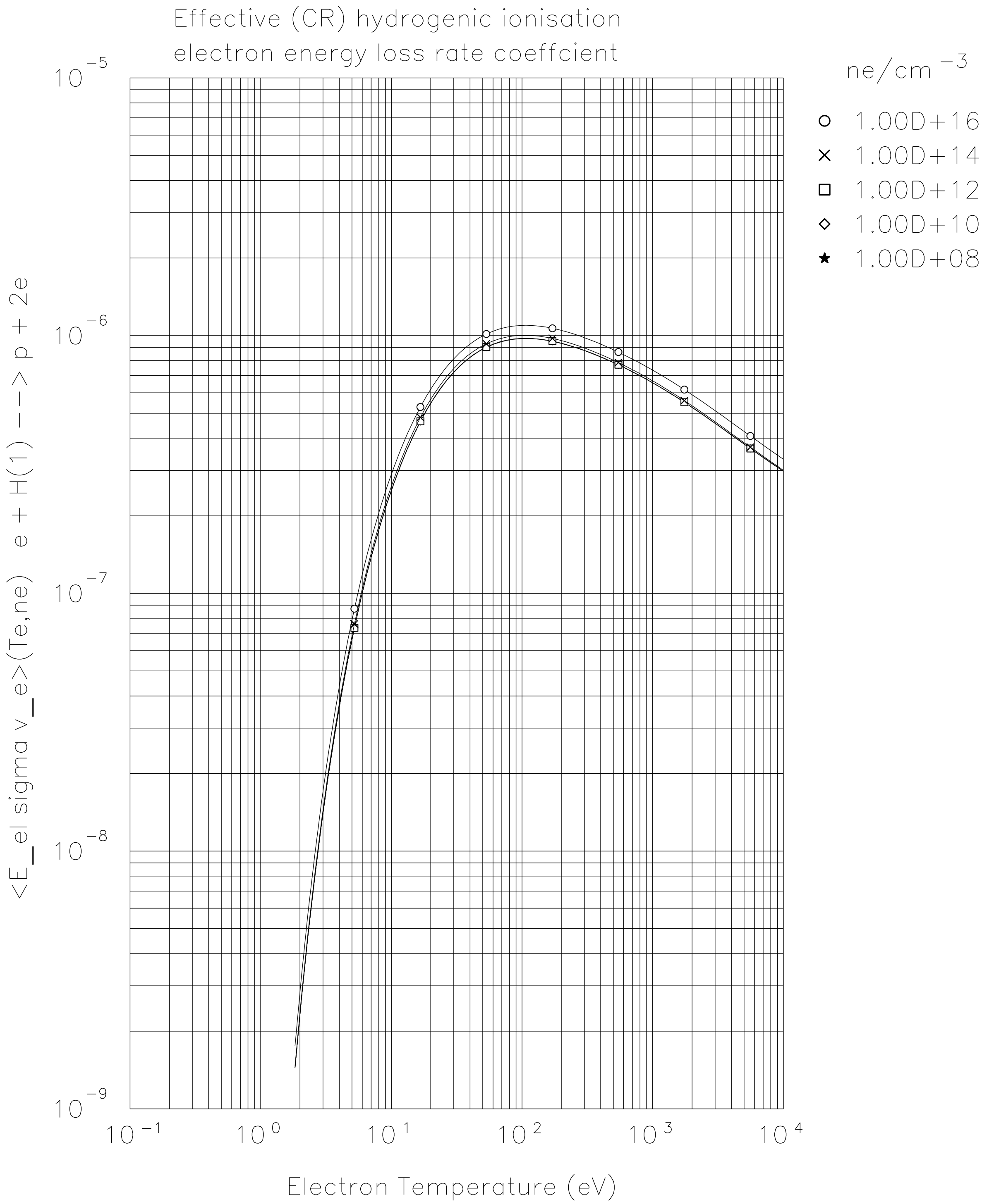
Electron energy loss weighted rate coefficient. Data: Sawada/Fujimoto, [7] (redone May 2016: extend Te range of fit validity from 0.1 – 1e3 now to 0.1 – 2e4 eV)

T-Index \ E-Index:	0	1	2
0	-2.497580168306D+01	1.081653961822D-03	-7.358936044605D-04
1	1.004448839974D+01	-3.189474633369D-03	2.510128351932D-03
2	-4.867952931298D+00	-5.852267850690D-03	2.867458651322D-03
3	1.689422238067D+00	7.744372210287D-03	-3.087364236497D-03
4	-4.103532320100D-01	-3.622291213236D-03	1.327415215304D-03
5	6.469718387357D-02	8.268567898126D-04	-2.830939623802D-04
6	-6.215861314764D-03	-9.836595524255D-05	3.017296919092D-05
7	3.289809895460D-04	5.845697922558D-06	-1.479323780613D-06
8	-7.335808238917D-06	-1.367574486885D-07	2.423236476442D-08

T-Index \ E-Index:	3	4	5
0	4.122398646951D-04	-1.408153300988D-04	2.469730836220D-05
1	-7.707040988954D-04	1.031309578578D-04	-3.716939423005D-06
2	-8.328668093987D-04	2.056134355492D-04	-3.301570807523D-05
3	4.707676288420D-04	-5.508611815406D-05	7.305867762241D-06
4	-1.424078519508D-04	3.307339563081D-06	5.256679519499D-09
5	2.411848024960D-05	5.707984861100D-07	-1.016945693300D-07
6	-1.474253805845D-06	-2.397868837417D-07	1.518743025531D-08
7	-4.633029022577D-08	3.337390374041D-08	-1.770252084837D-09
8	5.733871119707D-09	-1.512777532459D-09	8.733801272834D-11

T-Index \ E-Index:	6	7	8
0	-2.212823709798D-06	9.648139704737D-08	-1.611904413846D-09
1	-4.249704742353D-07	4.164960852522D-08	-9.893423877739D-10
2	2.831739755462D-06	-1.164969298033D-07	1.785440278790D-09
3	-6.000115718138D-07	2.045211951761D-08	-1.790312871690D-10
4	7.597020291557D-10	1.799505288362D-09	-9.280890205774D-11
5	3.517154874443D-09	-4.453195673947D-10	2.002478264932D-11
6	4.149084521319D-10	-6.803200444549D-12	-1.151855939531D-12
7	-5.289806153651D-11	3.864394776250D-12	-8.694978774411D-15
8	7.196798841269D-13	-1.441033650378D-13	1.734769090475D-15

```
T1MIN =   0.10000D 00 EV
T1MAX =   2.00000D 04 EV
N2MIN =   1.00000D 08 1/CM3
N2MAX =   1.00000D 16 1/CM3
  Max. rel. Error:   0.922E+00 %
  Mean rel. Error:   0.471E+00 %
```



Effective (CR) hydrogenic ionisation
electron energy loss rate coeffcient
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08
<E_el sigma v_e>(Te,ne)   e + H(1) −−> p + 2e
10 −5
10 −6
10 −7
10 −8
10 −9
10 −1
10 0
10 1
10 2
10 3
10 4
Electron Temperature (eV)

10.3 Reaction 2.1.5o $e + H \rightarrow H^+ + 2e$ Ly-opaque

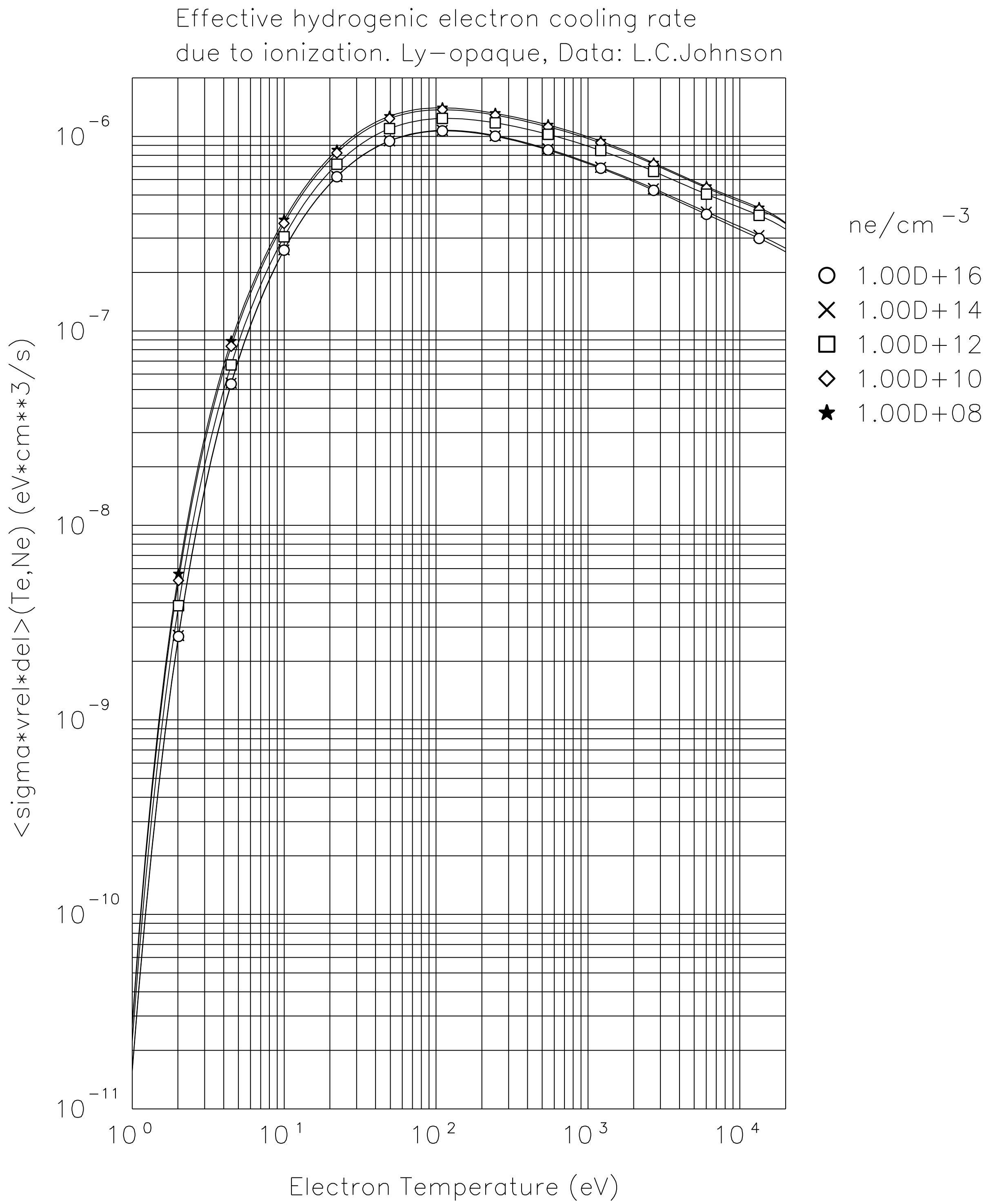
Ditto, all Lyman lines (and continuum) opaque

T-Index \ E-Index:	0	1	2
0	-2.431395592098D+01	-2.395941007384D-01	2.591565194903D-01
1	1.113429718187D+01	1.849722545279D-01	-2.423728103974D-01
2	-6.654446687338D+00	2.195366491981D-02	6.179888393756D-02
3	2.747075059275D+00	-6.901300857989D-02	1.006521130909D-02
4	-7.372137934626D-01	2.943069908340D-02	-7.829953302392D-03
5	1.227074461193D-01	-6.057176837025D-03	1.694081601397D-03
6	-1.216484938923D-02	6.701189895777D-04	-1.793079853259D-04
7	6.566484532457D-04	-3.779995638455D-05	8.950721046575D-06
8	-1.483802107723D-05	8.441118380444D-07	-1.530047985372D-07

T-Index \ E-Index:	3	4	5
0	-1.087825788137D-01	2.304158174814D-02	-2.708007727528D-03
1	9.801393644159D-02	-1.946235514182D-02	2.079309382971D-03
2	-2.979923286006D-02	5.913142010781D-03	-5.549143094821D-04
3	1.702193123225D-03	-6.298136767386D-04	4.093195127037D-05
4	6.752425702279D-04	2.856788083851D-05	-7.732295592583D-07
5	-1.621646872661D-04	-2.526799196487D-06	2.543500809367D-07
6	1.506237912301D-05	4.384573257407D-07	-1.137888186554D-08
7	-4.568263582843D-07	-5.697388918232D-08	-1.072747527249D-09
8	-6.560997301392D-09	3.141908302488D-09	3.111434993423D-12

T-Index \ E-Index:	6	7	8
0	1.777247119352D-04	-6.080187141189D-06	8.438023009891D-08
1	-1.231134698172D-04	3.827948966411D-06	-4.895455818239D-08
2	2.684044174965D-05	-6.633266274667D-07	6.895128780616D-09
3	-4.598542858756D-09	-5.542757391998D-08	9.032937294372D-10
4	-3.124180764582D-07	1.188861911457D-08	1.649196327692D-11
5	1.826904076362D-08	4.273639168838D-10	-5.875558984747D-11
6	-4.163110915594D-09	3.345977887826D-11	5.495071058936D-12
7	6.106046869680D-10	-2.063138694762D-11	-9.709542597057D-16
8	-2.241669215814D-11	9.998773490453D-13	-9.539526341658D-15

```
N2MIN =   1.00000D 08 1/CM3
N2MAX =   1.00000D 16 1/CM3
  Max. rel. Error:   2.4939 %
  Mean rel. Error:    .6828 %
```

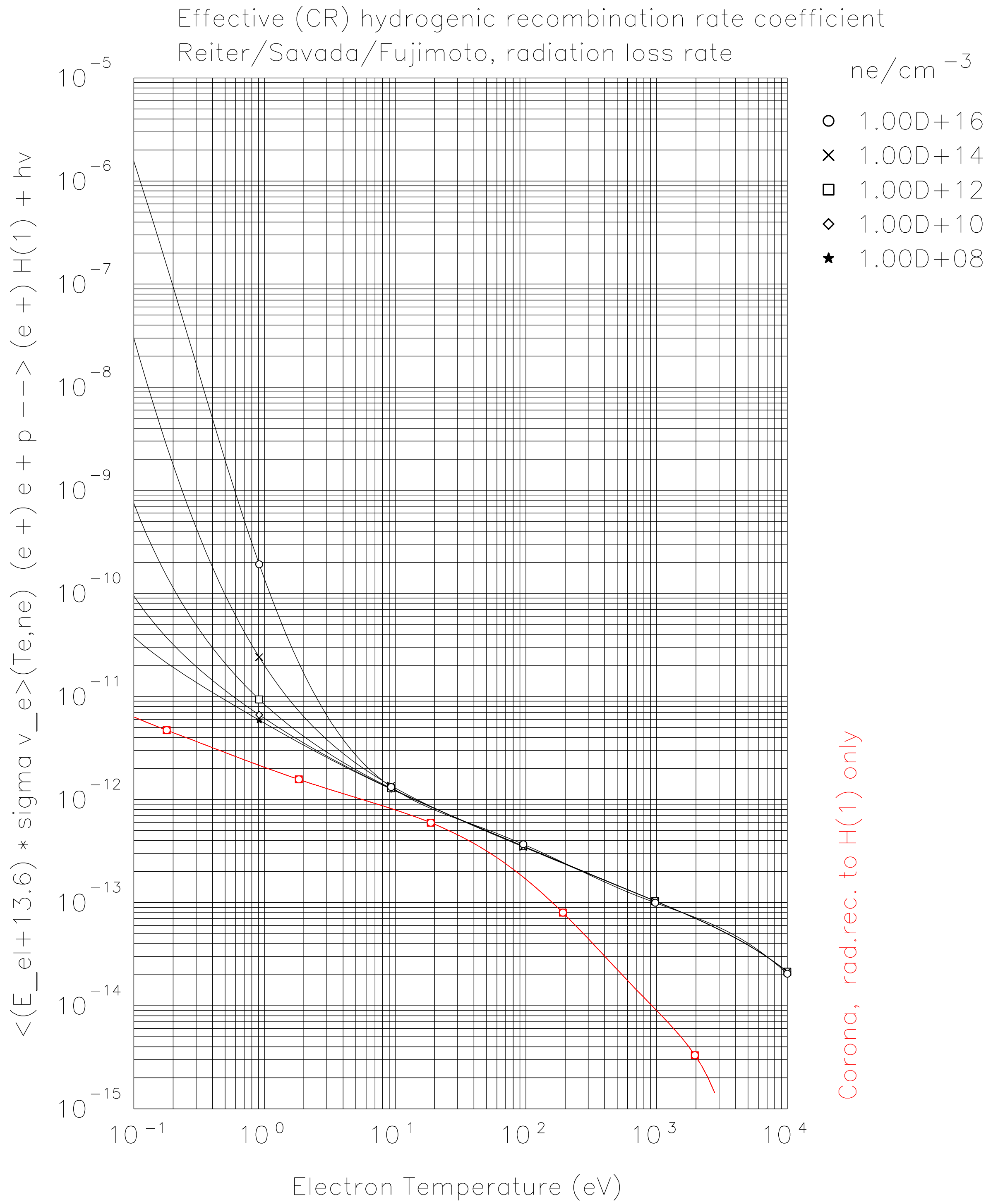


Effective hydrogenic electron cooling rate
due to ionization. Ly−opaque, Data: L.C.Johnson
<sigma*vrel*del>(Te,Ne) (eV*cm**3/s)
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}
Electron Temperature (eV)
ne/cm $^{-3}$
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

10.4 Reaction 2.1.8 $H^+ + e \rightarrow H(1s)$

effective electron cooling rate due to rad.+three-b. recombination potential energy term 13.6*(eff-rec.rate) still needs to be subtracted (may render the loss negative, i.e., turn it into a gain) Hence: the quantity given here happens to be the radiation loss. June17: Fit range extended from 0.1–1e3 to 0.1–2e4

```
       E-Index:     0                     1                     2
  T-Index:
       0    -2.592450349909D+01    1.222097271874D-02    4.278499401907D-05
       1    -7.290670236493D-01   -1.540323930666D-02   -3.406093779190D-03
       2     2.363925869096D-02    1.164453346305D-02   -5.845209334594D-03
       3     3.645333930947D-03   -1.005820792983D-03    6.956352274249D-04
       4     1.594184648757D-03   -1.582238007548D-05    4.073695619272D-04
       5    -1.216668033378D-03   -3.503070140126D-04    1.043500296633D-04
       6     2.376115895241D-04    1.172709777146D-04   -6.695182045674D-05
       7    -1.930977636766D-05   -1.318401491304D-05    8.848025453481D-06
       8     5.599257775146D-07    4.977823319311D-07   -3.615013823092D-07

       E-Index:     3                     4                     5
  T-Index:
       0     1.943967743593D-03   -7.123474602102D-04    1.303523395892D-04
       1     1.532243431817D-03   -4.658423772784D-04    5.972448753445D-05
       2     2.854145868307D-03   -5.077485291132D-04    4.211106637742D-05
       3    -9.305056373739D-04    2.584896294384D-04   -3.294643898894D-05
       4    -9.379169243859D-05    1.490890502214D-06    2.245292872209D-06
       5     9.536162767321D-06   -6.908681884097D-06    8.232019008169D-07
       6     1.188184006210D-05   -4.381514364966D-07   -6.936267173079D-08
       7    -2.072370711390D-06    2.055919993599D-07   -7.489632654212D-09
       8     9.466989306497D-08   -1.146485227699D-08    6.772338917155D-10

       E-Index:     6                     7                     8
  T-Index:
       0    -1.186560752561D-05    5.334455630031D-07   -9.349857887253D-09
       1    -4.070843294052D-06    1.378709880644D-07   -1.818079729166D-09
       2    -1.251436618314D-06   -1.626555745259D-08    1.073458810743D-09
       3     2.112924018518D-06   -6.544682842175D-08    7.810293075700D-10
       4    -3.150901014513D-07    1.631965635818D-08   -2.984093025695D-10
       5    -2.905331051259D-08   -3.169038517749D-10    2.442765766167D-11
       6     6.592249255001D-09   -1.778887958831D-10    1.160762106747D-12
       7    -7.073797030749D-11    1.047087505147D-11   -1.877446271350D-13
       8    -1.776496344763D-11    7.199195061382D-14    3.929300283002D-15
T1MIN =   0.10000D 00 EV
T1MAX =   2.00000D 04 EV
N2MIN =   1.00000D 08 1/CM3
N2MAX =   1.00000D 16 1/CM3

  Max. rel. Error:   0.930E+01 %
  Mean rel. Error:   0.127E+01 %
```



Effective (CR) hydrogenic recombination rate coefficient
Reiter/Savada/Fujimoto, radiation loss rate
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08
<(E_el+13.6) * sigma v_e>(Te,ne) (e+) e + p −−> (e+) H(1) + hv
Electron Temperature (eV)
Corona, rad.rec. to H(1) only

10.5 Reaction 2.1.8o $H^+ + e \rightarrow H(1s)$ Ly-opaque

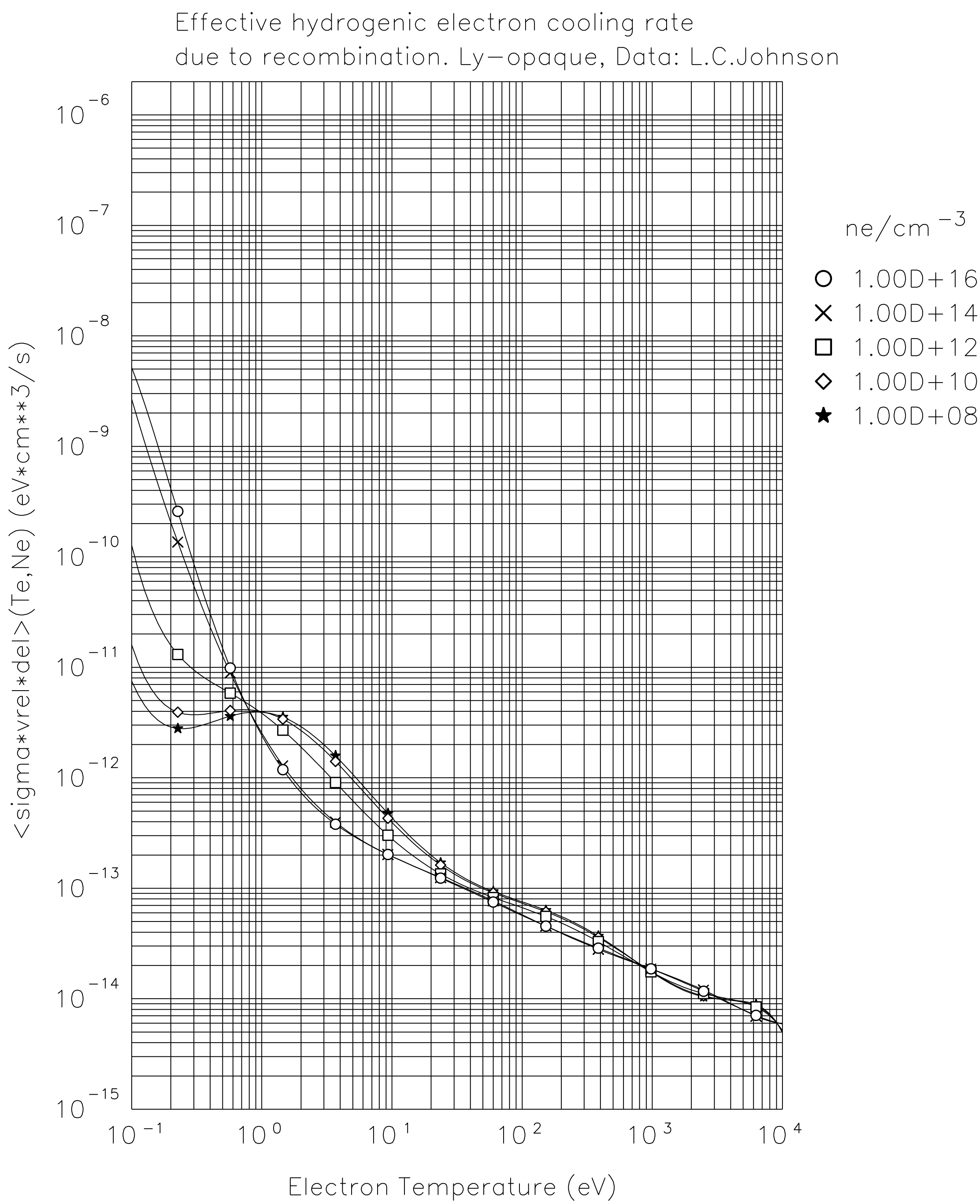
effective electron cooling rate due to rad.+three-b. recombination potential energy term 13.6*(eff-rec.rate) still needs to be subtracted (may render the loss negative, i.e., turn it into a gain) Hence: the quantity given here happens to be the radiation loss.

T-Index \ E-Index	0	1	2
0	-2.626461971500D+01	-1.141522828006D-01	1.076393602102D-01
1	-8.898849653304D-02	-3.942292858703D-01	4.197250110873D-01
2	-4.795279065913D-01	-1.335489318623D-01	1.698162748512D-01
3	-6.457641001473D-02	4.613800494941D-02	-6.378456442460D-02
4	6.800392305050D-02	2.637589098726D-02	-2.927766641228D-02
5	-7.780596827160D-03	-1.696354616404D-03	4.101919602398D-03
6	-9.252420142124D-04	-2.153234057341D-03	1.724087525894D-03
7	2.115742192807D-04	3.847511359996D-04	-3.531396348434D-04
8	-9.909336050813D-06	-1.829769520002D-05	1.745121101762D-05

T-Index \ E-Index	3	4	5
0	-3.951176865624D-02	7.434448907130D-03	-7.651735363726D-04
1	-1.819873891755D-01	3.954265794034D-02	-4.746673604459D-03
2	-7.777618558640D-02	1.791770402443D-02	-2.265419802670D-03
3	3.368756666920D-02	-8.588159967647D-03	1.161221464744D-03
4	1.215210455092D-02	-2.536449841814D-03	2.949052179931D-04
5	-2.853313172787D-03	8.331295381374D-04	-1.219354343653D-04
6	-3.889280715498D-04	1.445906496031D-05	5.400239087927D-06
7	1.117507761644D-04	-1.626382515941D-05	1.138105849294D-06
8	-5.935692251130D-06	9.750922276399D-07	-8.514634639125D-08

T-Index \ E-Index	6	7	8
0	4.256550578560D-05	-1.183957210565D-06	1.267430439071D-08
1	3.160257175597D-04	-1.090132407225D-05	1.518762884136D-07
2	1.597834560300D-04	-5.867107114568D-06	8.703048627852D-08
3	-8.476482397035D-05	3.148378986370D-06	-4.661383263216D-08
4	-1.945865547958D-05	6.794359168371D-07	-9.714166652574D-09
5	9.388539733773D-06	-3.625759741848D-07	5.530677587059D-09
6	-7.463824586159D-07	3.657036916983D-08	-6.329837178101D-10
7	-3.277550512167D-08	-2.762994890889D-11	1.306756395427D-11
8	4.007910080852D-09	-9.447800370353D-11	8.488148236190D-13

N2MIN = 1.00000D 08 1/CM3
N2MAX = 1.00000D 16 1/CM3
Max. rel. Error: 26.2822 %
Mean rel. Error: 8.6945 %



Effective hydrogenic electron cooling rate
due to recombination. Ly−opaque, Data: L.C.Johnson
<sigma*vrel*del>(Te,Ne) (eV*cm**3/s)
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

10.6 Reaction 2.2.h2c $H_2 + e \rightarrow ....$

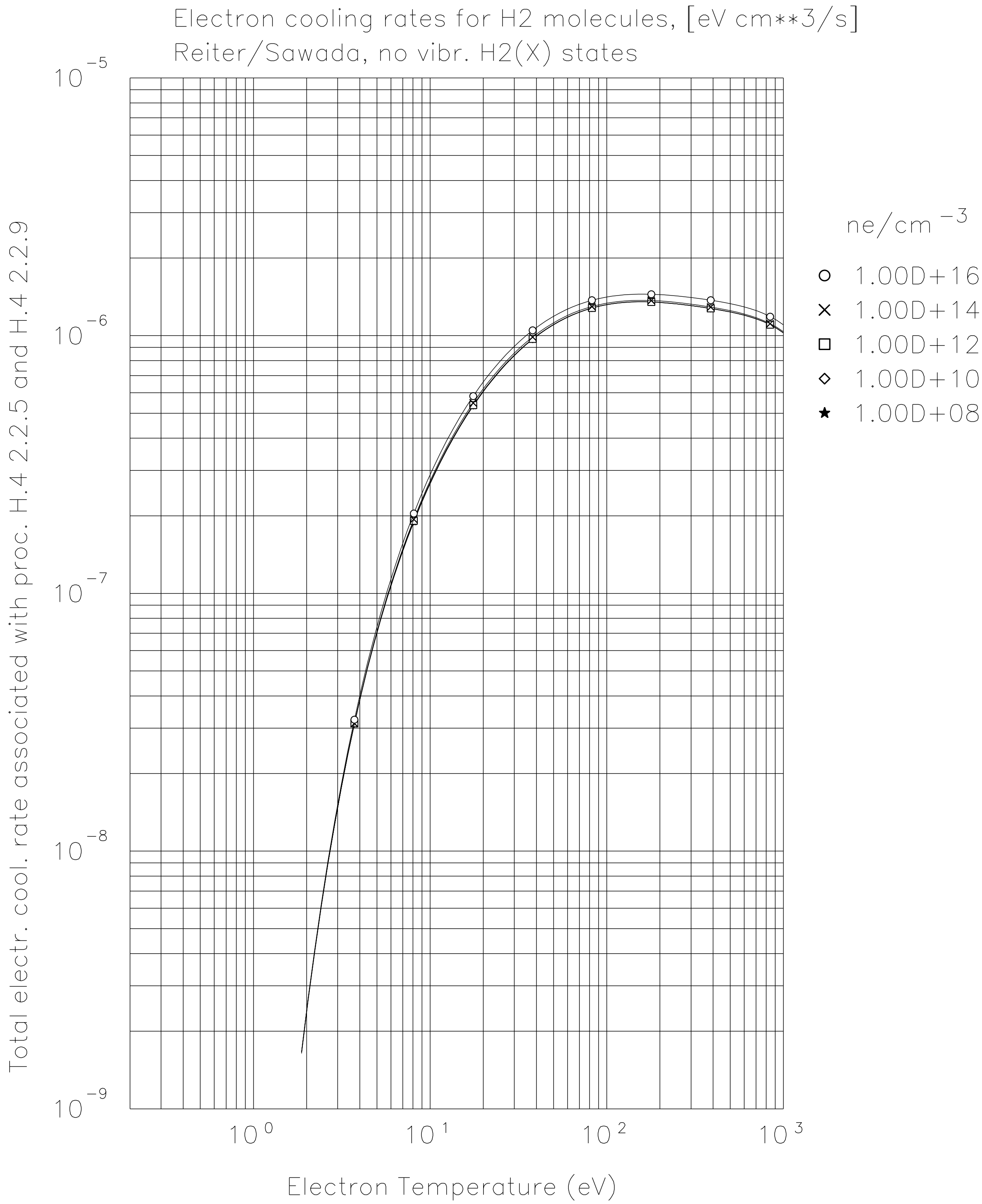
effective electron cooling rate due to destruction of H2 molecules by processes 2.2.5 or 2.2.9, i.e. by dissociation or ionisation. $\Delta E_d = 9.94$, $\Delta E_i = 15.386$

T-Index \ E-Index	0	1	2
0	-2.511426358838D+01	-1.502968736502D-03	2.270301997818D-03
1	1.039650366780D+01	1.940526565095D-03	-2.039057105217D-03
2	-5.056418866002D+00	4.267610495700D-04	-1.570825376355D-03
3	1.698357023335D+00	-1.100217175513D-03	1.346702996596D-03
4	-3.946794266607D-01	8.530611978697D-04	-5.956794001881D-04
5	6.332951863565D-02	-3.363804010733D-04	1.935332922569D-04
6	-7.076439854566D-03	6.801240259521D-05	-3.813794805193D-05
7	5.117651399462D-04	-6.744466929271D-06	3.834955698487D-06
8	-1.768573967186D-05	2.610531177384D-07	-1.508866204608D-07

T-Index \ E-Index	3	4	5
0	-1.160949145671D-03	2.711890444924D-04	-3.316751545455D-05
1	8.471089743180D-04	-1.668780150866D-04	1.846170371568D-05
2	1.011062331716D-03	-2.493635375898D-04	3.107778205672D-05
3	-6.015963727342D-04	1.254388145616D-04	-1.431788137516D-05
4	1.440206127855D-04	-1.821423270769D-05	1.364766339804D-06
5	-3.053105755056D-05	1.434719315650D-06	1.264447977870D-07
6	6.171515920637D-06	-4.045829346605D-07	-5.237650672670D-09
7	-7.117247208887D-07	7.283932745297D-08	-3.875678618801D-09
8	3.137300758374D-08	-3.990100914364D-09	3.015422105813D-10

T-Index \ E-Index	6	7	8
0	2.179799509766D-06	-7.292508854487D-08	9.764136720820D-10
1	-1.200391601516D-06	4.255709533045D-08	-6.263044644580D-10
2	-2.068798871142D-06	7.024008304152D-08	-9.571647703521D-10
3	9.254739688370D-07	-3.161858685796D-08	4.410801074405D-10
4	-7.044718093836D-08	2.445238251993D-09	-3.975970296405D-11
5	-1.650023620224D-08	6.035147397334D-10	-6.735406816093D-12
6	2.105913693789D-09	-9.389056833568D-11	1.197541371030D-12
7	6.547129244936D-11	1.340983691609D-12	-3.151269189538D-14
8	-1.176278308629D-11	2.089055860523D-13	-1.505656589693D-15

N2MIN = 1.00000D 08 1/CM3
N2MAX = 1.00000D 16 1/CM3
Max. rel. Error: 3.4722 %
Mean rel. Error: 1.4166 %



Electron cooling rates for H2 molecules, [eV cm**3/s]
Reiter/Sawada, no vibr. H2(X) states
Total electr. cool. rate associated with proc. H.4 2.2.5 and H.4 2.2.9
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

10.7 Reaction 2.2.h2r $H_2 + e \rightarrow ....$

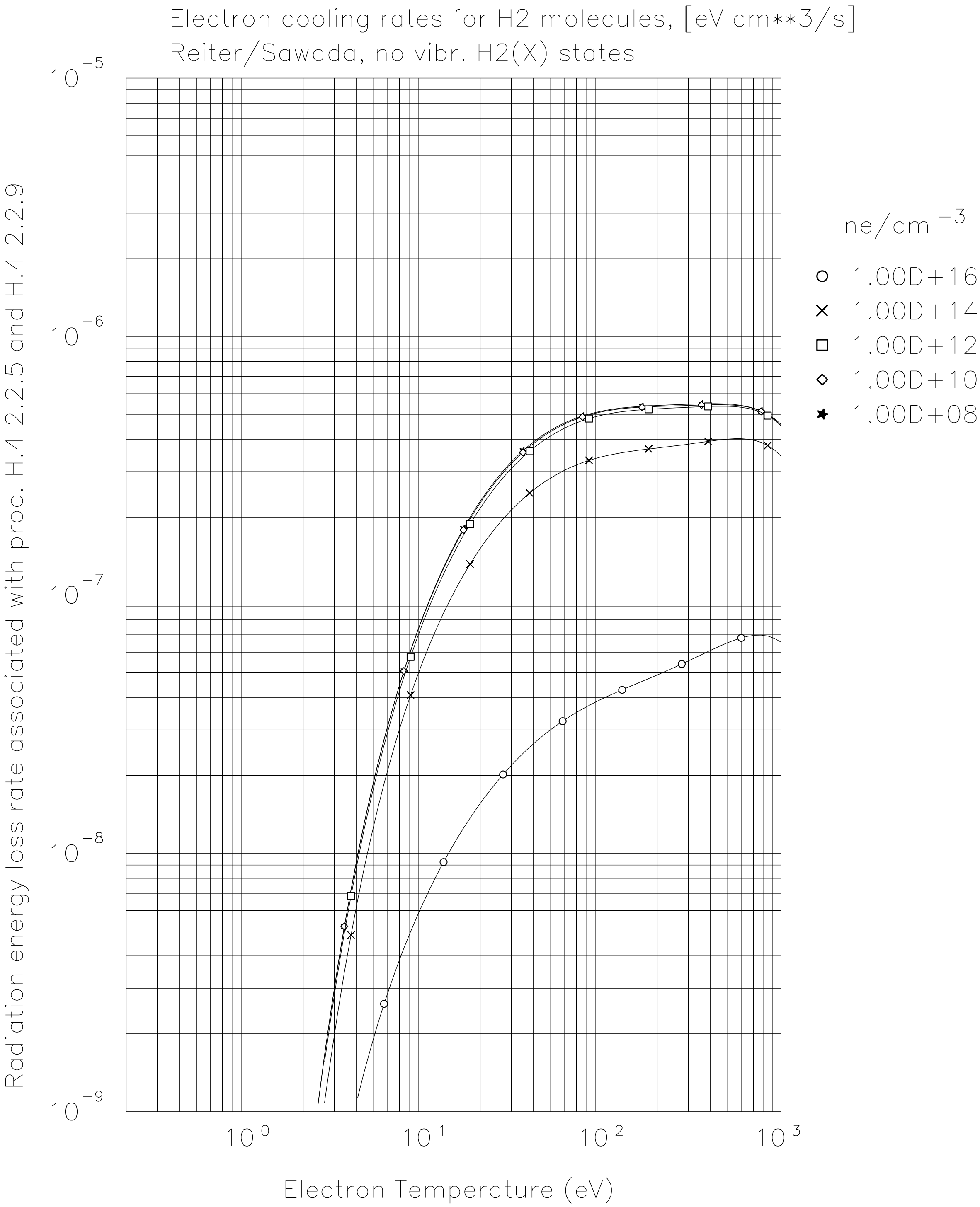
effective electron radiation energy loss rate due to destruction of H2 molecules by processes 2.2.5 or 2.2.9, i.e. by dissociation or ionisation

E-Index:	0	1	2
T-Index:			
0	-2.801822188516D+01	-2.680763935218D-02	4.076970248467D-02
1	1.226559489761D+01	-1.963731382190D-01	1.282479989566D-01
2	-5.867759617478D+00	8.536319354128D-02	-3.568022393739D-02
3	1.891664482986D+00	1.471792937991D-01	-9.271446717483D-02
4	-4.033980053975D-01	-1.394921763886D-01	7.381914918665D-02
5	5.439662377414D-02	4.818384180161D-02	-2.188105491841D-02
6	-4.642268879563D-03	-8.093950922937D-03	2.987412465436D-03
7	2.626009837514D-04	6.623097639192D-04	-1.742669318441D-04
8	-8.606720377928D-06	-2.105277432641D-05	2.632539922731D-06

E-Index:	3	4	5
T-Index:			
0	-2.299699721311D-02	5.853248550552D-03	-7.648533513094D-04
1	-3.150018219862D-02	3.847305623421D-03	-2.332949388707D-04
2	4.210762118334D-03	-7.901166941528D-05	-2.122748674317D-05
3	2.257794051374D-02	-2.486055370273D-03	1.021925655299D-04
4	-1.526303663894D-02	1.475511672936D-03	-5.499022366195D-05
5	3.689194332467D-03	-2.674426267836D-04	4.688389683681D-06
6	-3.073444697161D-04	-7.067430960799D-06	3.032281232409D-06
7	-7.581041097732D-06	6.310703738513D-06	-7.164508757577D-07
8	1.619250275583D-06	-4.490216679338D-07	4.418606553487D-08

E-Index:	6	7	8
T-Index:			
0	5.258892572564D-05	-1.807126279032D-06	2.441424496287D-08
1	5.066091926016D-06	9.700999841682D-08	-4.515881112268D-09
2	2.343578854939D-06	-1.149634211274D-07	2.218794688735D-09
3	2.171207268498D-06	-2.959885648343D-07	6.448680553698D-09
4	-1.169850372738D-06	1.491856181978D-07	-3.172311462398D-09
5	4.636734103570D-07	-2.759830094699D-08	4.590631115748D-10
6	-1.829914413027D-07	3.868936732678D-09	-1.492736071699D-11
7	3.248465119283D-08	-5.180769016510D-10	-6.701126858615D-13
8	-1.932812965191D-09	3.208399835617D-11	-1.703503159464D-14

N2MIN = 1.00000D 08 1/CM3
N2MAX = 1.00000D 16 1/CM3
Max. rel. Error: 9.7237 %
Mean rel. Error: 2.8617 %



Electron cooling rates for H2 molecules, [eV cm**3/s]
Reiter/Sawada, no vibr. H2(X) states
Radiation energy loss rate associated with proc. H.4 2.2.5 and H.4 2.2.9
Electron Temperature (eV)
ne/cm -3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

10.8 Reaction 2.3.9a $e + He(1s^2 1S) \rightarrow He^+(1s) + 2e$

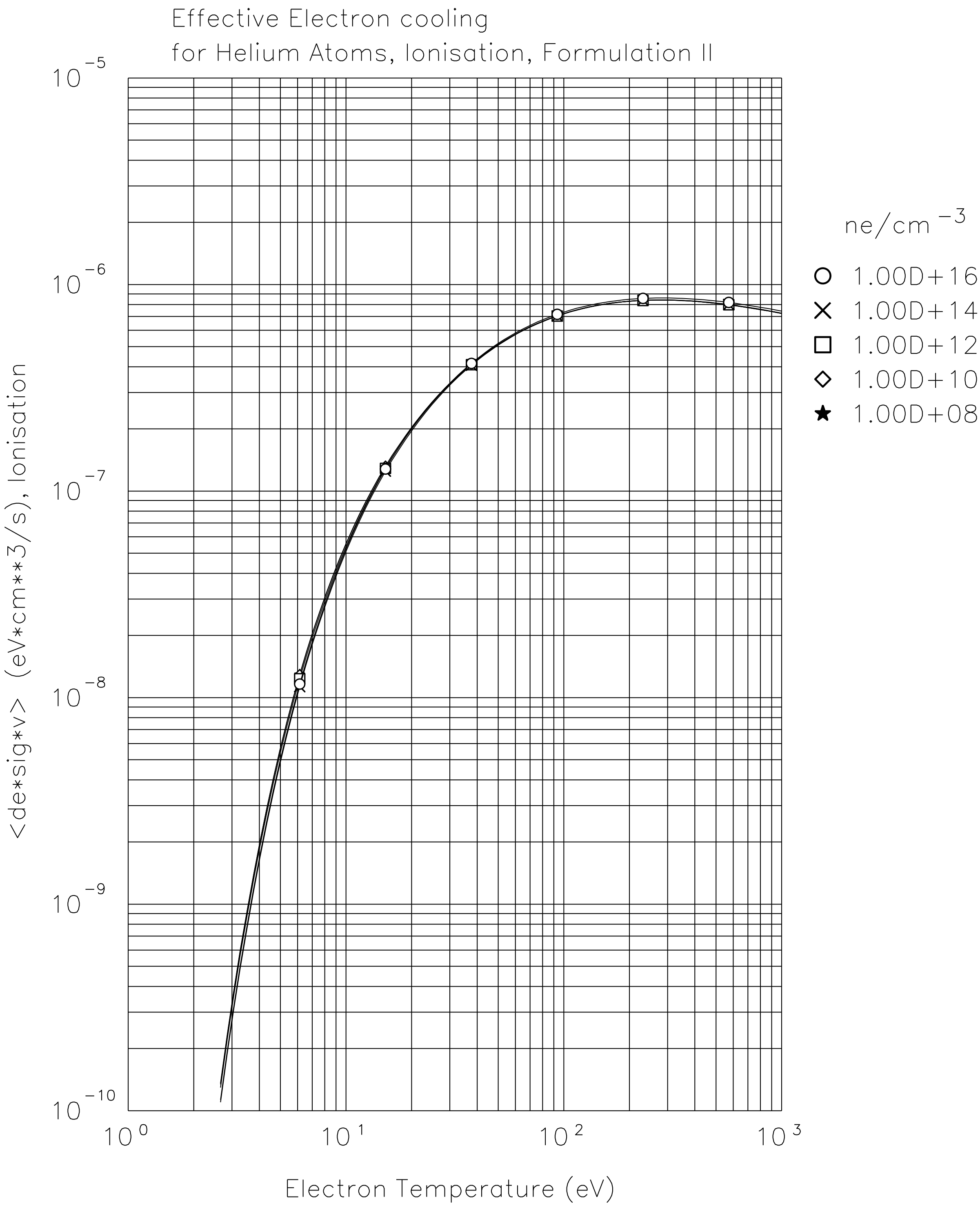
Eth=24.588 eV effective electron cooling rate due to ionization of Helium atoms. Fujimoto Formulation II (only ground level transported, no meta-stables kept explicit), [22].

T-Index \ E-Index	0	1	2
0	-3.535258393674D+01	-3.428249311738D-02	6.378071832382D-02
1	1.981855871044D+01	4.854482688892D-02	-5.088928946831D-02
2	-9.334355651224D+00	-4.524206463148D-02	2.103002869692D-02
3	2.800314250410D+00	2.474350787980D-02	-6.012991773715D-03
4	-5.489088598705D-01	-7.339538872774D-03	7.783071302508D-04
5	6.902095610357D-02	1.234159378604D-03	2.989745411104D-05
6	-5.342940069130D-03	-1.223169549107D-04	-1.500790305823D-05
7	2.313175089975D-04	6.966436907981D-06	8.944962909810D-07
8	-4.279800193256D-06	-1.815466669910D-07	-2.282174576618D-09

T-Index \ E-Index	3	4	5
0	-2.849818870377D-02	6.041903480645D-03	-6.864532165560D-04
1	1.732110218818D-02	-2.781419068092D-03	2.244804771683D-04
2	-4.463941003028D-03	2.900917070658D-04	2.482449118881D-05
3	8.918009845745D-04	-2.616249899141D-05	-6.885545577757D-06
4	-4.483274558979D-05	1.900991581685D-06	-9.747171692727D-07
5	-3.040906203340D-05	2.951386149372D-06	7.592185107575D-08
6	5.253922160283D-06	-4.468905893926D-07	7.483496971361D-09
7	-1.712024596447D-07	-9.782015167261D-09	2.499416349949D-09
8	-6.972920569943D-09	2.607191494540D-09	-2.870919514967D-10

T-Index \ E-Index	6	7	8
0	4.251155616815D-05	-1.351759350582D-06	1.728801977101D-08
1	-8.875290574348D-06	1.399429819761D-07	-1.389778740510D-10
2	-4.278064413224D-06	2.040570181783D-07	-3.324224092217D-09
3	7.013616309712D-07	-2.570063437935D-08	3.573487194914D-10
4	1.349829568374D-07	-5.815812094637D-09	6.686532777575D-11
5	-1.805060230413D-08	3.156859219121D-10	1.071168697340D-11
6	-9.777558713428D-10	1.770619394125D-10	-6.050995244427D-12
7	4.731973382221D-11	-1.845161957843D-11	6.011070143230D-13
8	8.059675146168D-12	3.704316808942D-13	-1.713225271579D-14

```
N2MIN =   1.00000D 08 1/CM3
N2MAX =   1.00000D 16 1/CM3
  Max. rel. Error:   1.8148 %
  Mean rel. Error:    .1839 %
```



Effective Electron cooling
for Helium Atoms, Ionisation, Formulation II
<de*sig*v> (eV*cm**3/s), Ionisation
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

10.9 Reaction 2.3.13a $e + He^{+}(1s) \rightarrow He(1s^2 1S)$

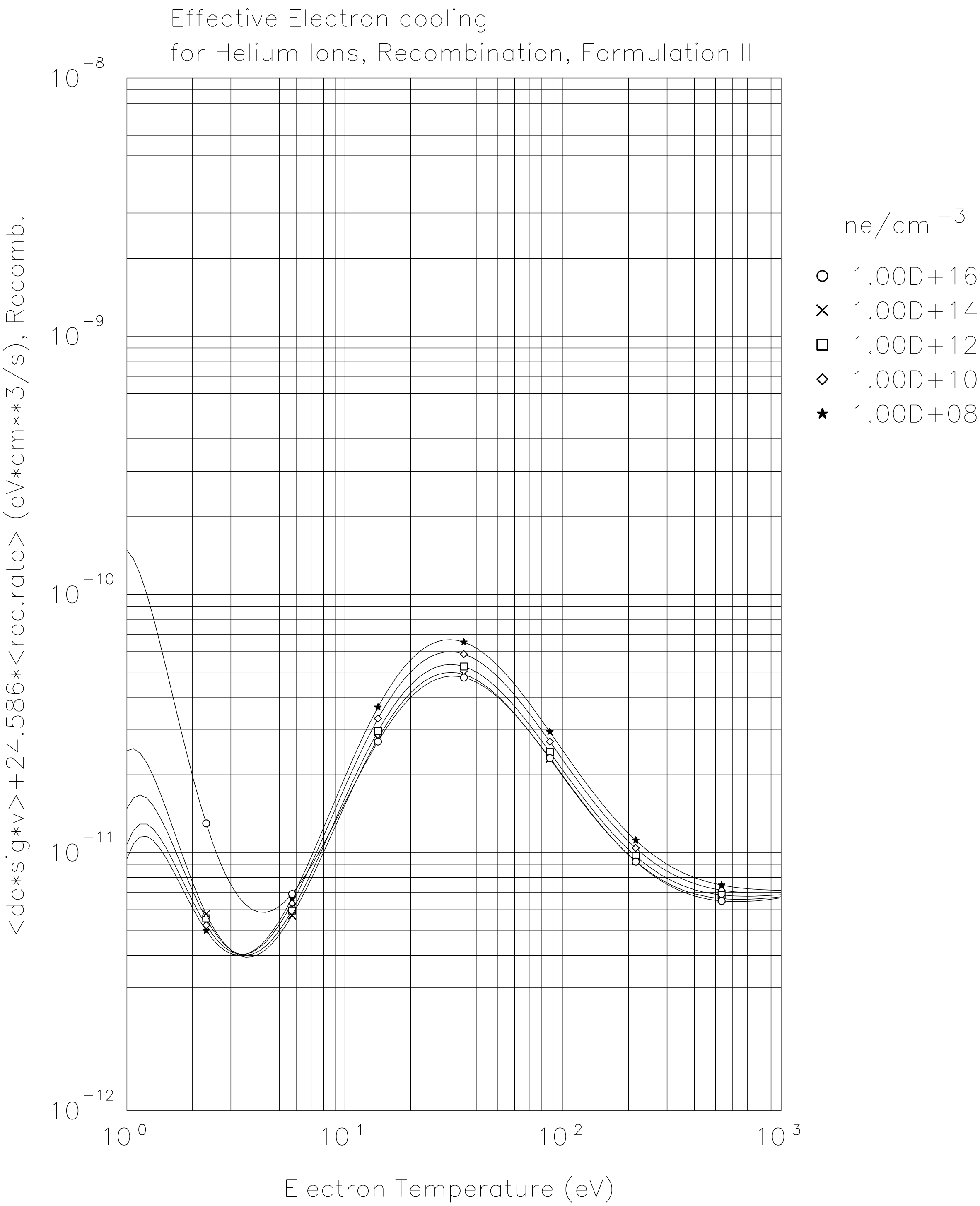
Helium multi-step model, here recombination: radiative + three-body + dielectronic Fujimoto Formulation II (only ground level transported, no meta-stables kept explicit), [22]. The quantity given here happens to be the radiation loss. The loss of potential energy still needs to be subtracted to make this a total electron energy loss (or gain) rate.

T-Index \ E-Index	0	1	2
0	-2.538377692766D+01	-4.826880987619D-02	6.796575967310D-02
1	2.472758419513D+00	1.668058989207D-01	-1.265192781981D-01
2	-8.864417999957D+00	-1.882326730037D-01	1.194028674310D-01
3	8.394970578944D+00	8.397993216045D-02	-5.796972813740D-02
4	-3.465864794112D+00	-1.572684180220D-02	1.398192327776D-02
5	7.479071085372D-01	5.997666028811D-04	-1.614053457119D-03
6	-8.863575102304D-02	1.901540166344D-04	6.941090299375D-05
7	5.484926807853D-03	-2.510359436743D-05	1.123735445147D-06
8	-1.388441945179D-04	9.141995596700D-07	-1.168915890330D-07

T-Index \ E-Index	3	4	5
0	-2.401710021390D-02	4.130156138736D-03	-3.494803122018D-04
1	2.938171777028D-02	-2.216525055070D-03	-1.261523686946D-04
2	-2.382836629119D-02	1.134820469638D-03	1.782113978272D-04
3	1.158600348753D-02	-7.504743150582D-04	-2.602911694939D-05
4	-2.700181027443D-03	1.902304157269D-04	-1.534387905925D-06
5	2.620866439317D-04	-1.103039382799D-05	-4.215447554819D-07
6	-3.042043168371D-06	-1.677907209787D-06	2.153652742395D-07
7	-9.198494797723D-07	2.058851315121D-07	-1.866416375894D-08
8	3.485370731777D-08	-5.086412415216D-09	3.674153797642D-10

T-Index \ E-Index	6	7	8
0	1.345025100540D-05	-1.323917127568D-07	-2.551716207606D-09
1	2.701401918133D-05	-1.370446267883D-06	2.313673787201D-08
2	-2.305554399898D-05	9.430294093180D-07	-1.305188423829D-08
3	4.568209602293D-06	-1.458110560501D-07	9.826599911934D-10
4	-1.032060079260D-07	-1.355858638619D-08	5.917279771473D-10
5	-9.926133276192D-09	4.148813674084D-09	-1.207867670158D-10
6	-6.354480058307D-09	-1.223103792568D-10	5.543057946730D-12
7	7.564835556537D-10	-1.622993472948D-11	2.428986170198D-13
8	-1.621809988343D-11	6.737654534264D-13	-1.678705755876D-14

```
N2MIN =   1.00000D 08 1/CM3
N2MAX =   1.00000D 16 1/CM3
  Max. rel. Error:  22.6665 %
  Mean rel. Error:   8.4662 %
```


Effective Electron cooling
for Helium Ions, Recombination, Formulation II
<de*sig*v>+24.586*<rec.rate> (eV*cm**3/s), Recomb.
Electron Temperature (eV)
ne/cm^-3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

10.10 Reaction 2.6A0r $e + C \rightarrow C^+ + 2e$

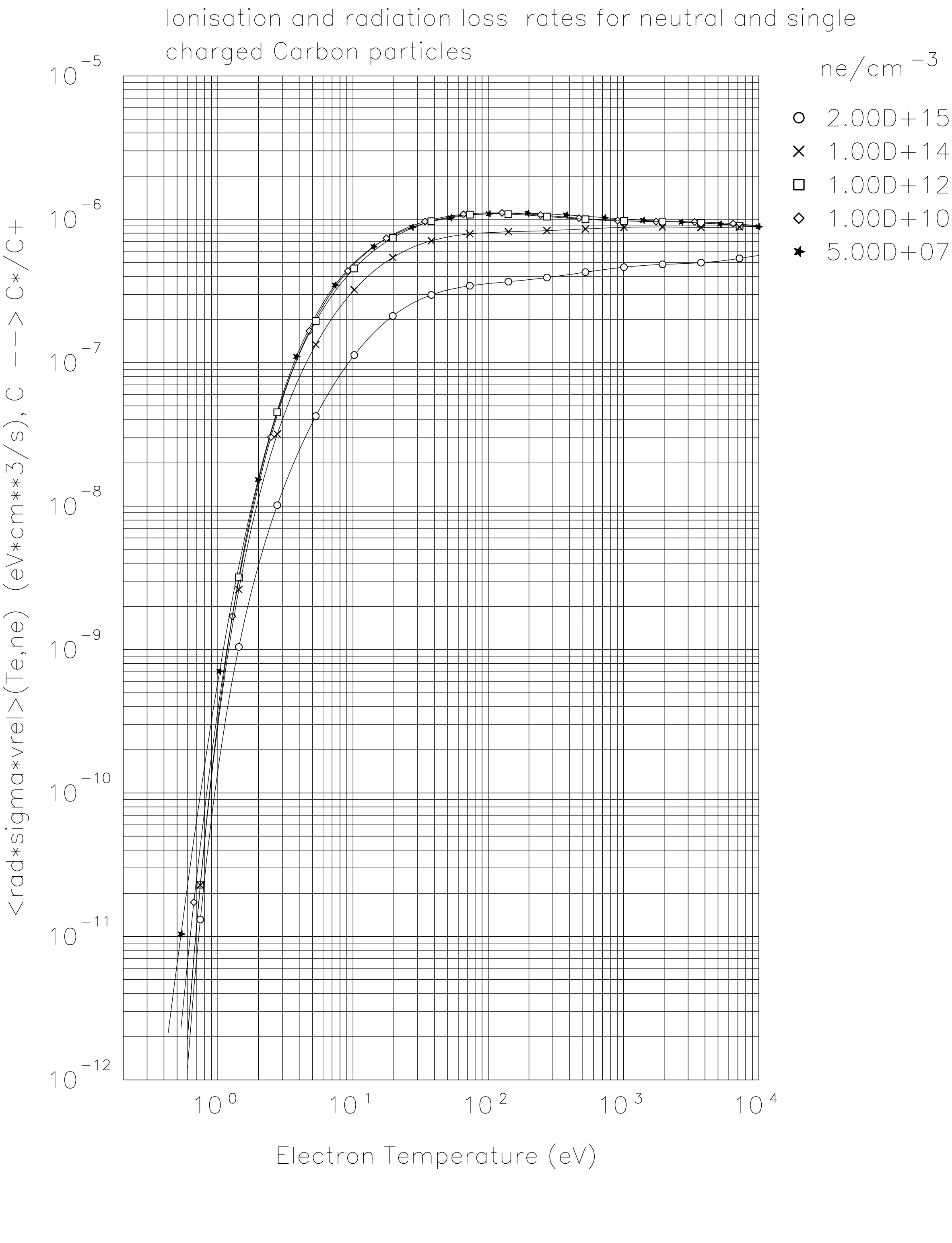
radiation rate due to ionization of C atoms [eV * cm**3/s] ADAS 96, i.e., PLT rate only

T-Index \ E-Index	0	1	2
0	-2.134320594564D+01	-5.946603516310D-02	8.447557526366D-02
1	5.747871027304D+00	1.742910759701D-01	6.358855662184D-02
2	-1.446292343924D+00	-1.934880440813D-01	-6.137783135780D-02
3	-2.975197342585D-02	1.012407305789D-01	-9.718853445116D-03
4	1.064347292200D-01	-2.743226249142D-02	9.525798537604D-03
5	-2.837533619480D-02	3.973936070899D-03	-1.153950153613D-03
6	3.653851093532D-03	-2.952184312930D-04	-8.475825853417D-05
7	-2.385788202088D-04	9.230939672709D-06	2.196401178503D-05
8	6.295597901357D-06	-3.739019584385D-08	-9.970598553763D-07

T-Index \ E-Index	3	4	5
0	-5.406978466857D-02	1.281083229789D-02	-1.524632271001D-03
1	-6.767588642303D-02	2.421647016699D-02	-3.892494482542D-03
2	7.147500084854D-02	-2.467911698429D-02	3.787372907637D-03
3	-8.551103015011D-03	4.588623493575D-03	-7.759605546668D-04
4	-3.105314942145D-03	3.910363804964D-04	-2.637644628597D-05
5	5.644866007299D-04	-1.302260794666D-04	1.650834989207D-05
6	2.723119788519D-05	-2.201121528129D-06	-2.002446340934D-08
7	-9.668998805059D-06	1.832226214738D-06	-2.011877719908D-07
8	4.625120996597D-07	-9.396591971771D-08	1.083943504650D-08

T-Index \ E-Index	6	7	8
0	9.919783469232D-05	-3.390120579583D-06	4.764279569959D-08
1	3.134352436854D-04	-1.243436505673D-05	1.939633867405D-07
2	-2.932314717191D-04	1.127988849900D-05	-1.719568432115D-07
3	6.241719224490D-05	-2.485841557640D-06	3.970461264397D-08
4	3.479453033340D-07	6.665382024825D-08	-2.684446507228D-09
5	-9.127757073511D-07	1.147772765576D-08	3.450452278757D-10
6	-2.813390939437D-08	4.263395349024D-09	-1.405639406896D-10
7	1.602576612200D-08	-8.181888314759D-10	1.772730263189D-11
8	-8.075206325455D-10	3.593473277824D-11	-6.892418982501D-13

```
T1MIN =   0.20000D 00 EV
T1MAX =   1.50000D 04 EV
N2MIN =   5.00000D 07 1/CM3
N2MAX =   2.00000D 15 1/CM3
  Max. rel. Error:   0.100E+02 %
  Mean rel. Error:   0.200E+01 %
```


Ionisation and radiation loss rates for neutral and single
charged Carbon particles
ne/cm -3
2.00D+15
1.00D+14
1.00D+12
1.00D+10
5.00D+07
<rad*sigma*vrel>(Te,ne) (eV*cm**3/s), C --> C*/C+
Electron Temperature (eV)
10 -5
10 -6
10 -7
10 -8
10 -9
10 -10
10 -11
10 -12
10 0
10 1
10 2
10 3
10 4

10.11 Reaction 2.6A0 $e + C \to C^+ + 2e$

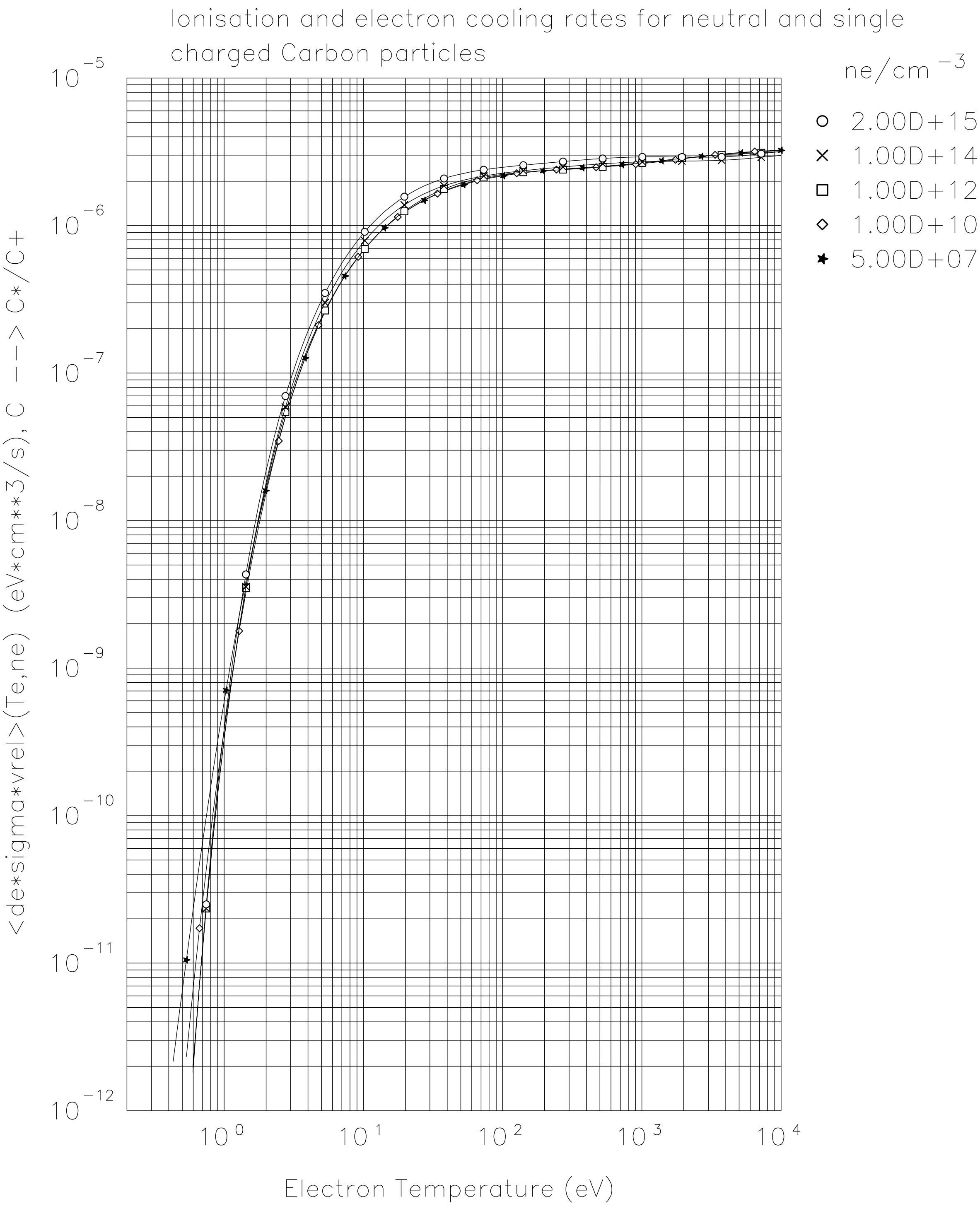
electron cooling rate due to ionization of C atoms [eV * cm**3/s] ADAS 96, (PLT+11.26*SCD),i.e. here: total: radiation plus ionization energy cost

T-Index \ E-Index	0	1	2
0	-2.133396354757D+01	-6.357933428520D-02	7.322019686722D-02
1	5.822564248781D+00	1.900589591492D-01	-1.173296354859D-02
2	-1.385591876980D+00	-1.745922613183D-01	-5.320275675268D-02
3	-4.127224605147D-02	8.506483730371D-02	2.715047887674D-02
4	9.941818676021D-02	-2.646688423407D-02	-2.673052161748D-03
5	-2.452879124126D-02	5.352445004232D-03	-1.037523367690D-03
6	2.920062208976D-03	-6.599824357731D-04	3.054771240112D-04
7	-1.759851331966D-04	4.411914421547D-05	-3.006574526514D-05
8	4.288683943581D-06	-1.213013574298D-06	1.040500072319D-06

T-Index \ E-Index	3	4	5
0	-4.148727336030D-02	8.356238119585D-03	-7.805494120571D-04
1	-2.283569745159D-02	1.314907632784D-02	-2.471854754993D-03
2	5.212625576114D-02	-1.651794415812D-02	2.306652993801D-03
3	-2.215980844602D-02	5.621973436724D-03	-5.868183610849D-04
4	3.534997445498D-03	-7.559059861065D-04	3.800914071967D-05
5	-1.388263330394D-05	1.211567645890D-05	4.656822141389D-06
6	-6.790919543670D-05	8.674399690016D-06	-7.925427874444D-07
7	8.205833940094D-06	-1.034434041031D-06	4.377458056752D-08
8	-3.097346801697D-07	3.923484117825D-08	-1.109477551162D-09

T-Index \ E-Index	6	7	8
0	3.525995267161D-05	-6.650996620302D-07	2.237812821762D-09
1	2.130552549473D-04	-8.713194594575D-06	1.374270681464D-07
2	-1.599213713942D-04	5.427282847247D-06	-7.206916114716D-08
3	2.672425227705D-05	-4.248106963210D-07	-8.546664878654D-10
4	1.961254191502D-06	-2.029252485567D-07	4.072209304284D-09
5	-6.814829622373D-07	2.448728935791D-08	-1.196546597529D-10
6	9.278125208435D-09	3.303486773069D-09	-1.340586957136D-10
7	5.270465869665D-09	-6.326146542912D-10	1.792640337529D-11
8	-2.626431071254D-10	2.571423816620D-11	-6.727258777135D-13

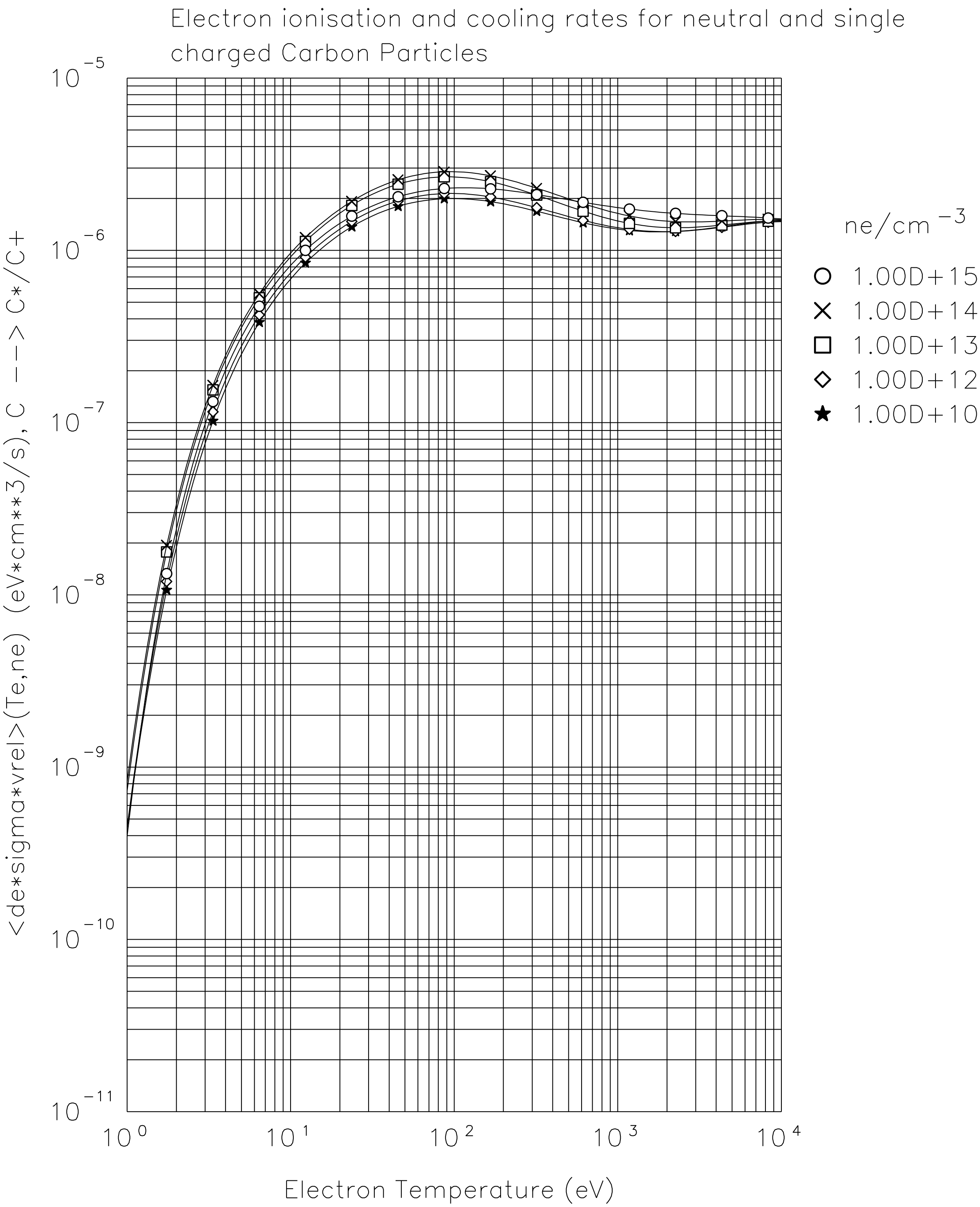
```
T1MIN =   0.20000D 00 EV
T1MAX =   1.50000D 04 EV
N2MIN =   5.00000D 07 1/CM3
N2MAX =   2.00000D 15 1/CM3
  Max. rel. Error:   0.896E+01 %
  Mean rel. Error:   0.156E+01 %
```


Ionisation and electron cooling rates for neutral and single charged Carbon particles
ne/cm −3
2.00D+15
1.00D+14
1.00D+12
1.00D+10
5.00D+07
<de*sigma*vrel>(Te,ne) (eV*cm**3/s), C --> C*/C+
Electron Temperature (eV)
10 −5
10 −6
10 −7
10 −8
10 −9
10 −10
10 −11
10 −12
10 0
10 1
10 2
10 3
10 4

10.12 Reaction 2.6A0old $e + C \rightarrow C^{+} + 2e$

electron cooling rate due to ionization of C atoms [eV * cm**3/s] ADAS 93, i.e. here: total: radiation plus ionization energy cost

```
       E-Index:     0                     1                     2
  T-Index:
       0   -1.541340319198D+01   -4.635323668693D+00    1.424306255525D+00
       1    6.871565603800D+00    3.062312115608D-02    1.785653882692D-02
       2   -2.581732757825D+00   -1.272125958091D-01    3.493561583728D-02
       3    4.800945236897D-01    9.573076930006D-02   -2.511071760242D-02
       4   -3.221877058224D-02   -1.391798645331D-02    2.175585061019D-03
       5   -8.242753615795D-03    1.145594247121D-03    3.885428995621D-05
       6    2.099340312561D-03   -1.276880024615D-04   -4.884605861642D-06
       7   -1.795437092836D-04    1.389068259360D-05   -1.113237444693D-06
       8    5.520442022231D-06   -6.375114106630D-07    9.859364572176D-08

       E-Index:     3                     4                     5
  T-Index:
       0   -2.158652670331D-01    1.412329738807D-02    1.168676999154D-04
       1   -1.094056812899D-02    3.136700005660D-03   -3.963442307288D-04
       2   -5.370773139210D-03    2.974489768572D-04   -1.432652388384D-05
       3    3.687719429910D-03   -2.848608239928D-04    1.690331087319D-05
       4   -1.746771988767D-04   -3.294582308635D-06    8.485083720382D-07
       5   -1.528532398519D-05    1.555056417236D-06   -5.074853324543D-08
       6    6.205604777862D-08    1.558979315126D-07   -1.140737345155D-08
       7    1.652357272442D-07   -1.003365245229D-08   -1.633709577156D-09
       8   -1.163642679910D-08    2.003281042296D-10    1.350639090685D-10

       E-Index:     6                     7                     8
  T-Index:
       0   -6.658345040546D-05    3.254244791032D-06   -5.053767538668D-08
       1    2.266757015103D-05   -5.406980202349D-07    3.681457471642D-09
       2    1.906448581780D-06   -9.658075171996D-08    7.628999658428D-10
       3   -6.509994237871D-07   -1.483571537540D-08    1.479901251703D-09
       4   -1.063260940363D-07    1.336948585246D-08   -5.357328879289D-10
       5    2.810998774881D-09   -8.868420910603D-10    4.953950208308D-11
       6    9.322775355772D-10   -5.119114288255D-11   -2.546806508137D-13
       7    1.240247466159D-10    1.352672081064D-12   -1.036766300560D-13
       8   -1.122860695875D-11    2.002505887771D-13    1.458669917591D-15
T1MIN =   1.00000D 00 EV
T1MAX =   5.00000D 04 EV
N2MIN =   1.00000D 10 1/CM3
N2MAX =   1.00000D 15 1/CM3
  Max. rel. Error:   9.7643 %
  Mean rel. Error:   3.1877 %
```



Electron ionisation and cooling rates for neutral and single charged Carbon Particles
<de*sigma*vrel>(Te,ne) (eV*cm**3/s), C --> C*/C+
Electron Temperature (eV)
ne/cm −3
1.00D+15
1.00D+14
1.00D+13
1.00D+12
1.00D+10

10.13 Reaction 2.7A0 $e + N \rightarrow N^{+} + 2e$

electron cooling rate due to ionization of N atoms [eV * cm**3/s] ADAS 96, PLT + dE * SRC, dE=14.5341

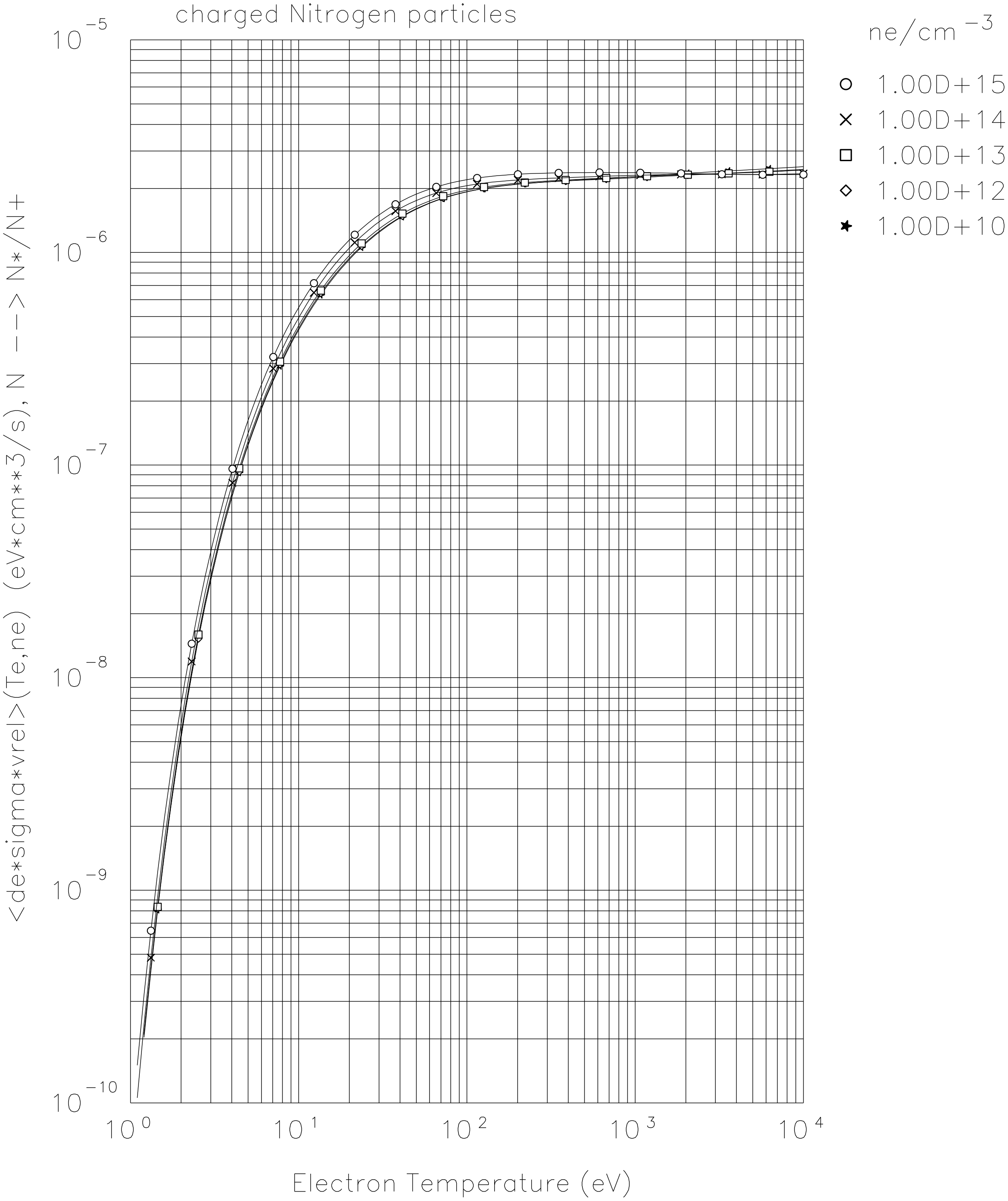
T-Index	E-Index: 0	1	2
0	-2.252513097778D+01	-6.938525895110D-01	7.360368747256D-02
1	5.490652571906D+00	1.862687530920D+00	-1.271514001937D-01
2	-1.505415457619D-01	-2.018680044626D+00	1.445926892160D-01
3	-9.081900426408D-01	1.132838716303D+00	-9.747043468654D-02
4	4.068069723462D-01	-3.608075086233D-01	3.653093538389D-02
5	-8.638825383198D-02	6.750688719666D-02	-7.720051882275D-03
6	1.002679915935D-02	-7.333387921410D-03	9.161251630723D-04
7	-6.095338448270D-04	4.274790767253D-04	-5.693430257954D-05
8	1.517571414107D-05	-1.033080781937D-05	1.441576543166D-06

T-Index	E-Index: 3	4	5
0	7.790350765676D-03	-1.220520407695D-03	-8.562329955638D-05
1	-3.708260573043D-02	4.390135671422D-03	2.020637755048D-04
2	3.362930611438D-02	-3.459233397206D-03	-2.741064498762D-04
3	-1.367691446959D-02	1.566187074413D-03	9.953611472149D-05
4	2.857315903877D-03	-4.181124408592D-04	-1.502950182478D-05
5	-3.004150467461D-04	6.228650058258D-05	1.552015773983D-06
6	1.192396934000D-05	-4.791555906044D-06	-2.304496895978D-07
7	2.739583605029D-07	1.553976916638D-07	2.549621568751D-08
8	-2.525594364749D-08	-7.057611372888D-10	-1.039226808101D-09

T-Index	E-Index: 6	7	8
0	1.991789252481D-05	-1.061029835476D-06	1.858432994983D-08
1	-4.869752209884D-05	2.330274827818D-06	-3.482609627536D-08
2	4.579272949943D-05	-1.809398260022D-06	1.970910200136D-08
3	-1.529768639271D-05	4.127745992187D-07	9.759489620558D-10
4	2.220077385515D-06	9.312580189453D-09	-2.948115439545D-09
5	-1.775119032724D-07	-1.401260087400D-08	7.693409169207D-10
6	1.839043737482D-08	1.572175939438D-09	-8.308060663377D-11
7	-2.064519462010D-09	-4.186789790815D-11	3.839596540797D-12
8	9.033073726027D-11	-1.013943666893D-12	-5.350676044166D-14

```
T1MIN =   0.20000D 00 EV
T1MAX =   1.50000D 04 EV
N2MIN =   5.00000D 07 1/CM3
N2MAX =   2.00000D 15 1/CM3
  Max. rel. Error:   5.63E+00 %
  Mean rel. Error:   0.728E+00 %
```

Electron ionisation and cooling rates for neutral and single charged Nitrogen particles



10.14 Reaction 2.7A0r $e + N \rightarrow N^+ + 2e$

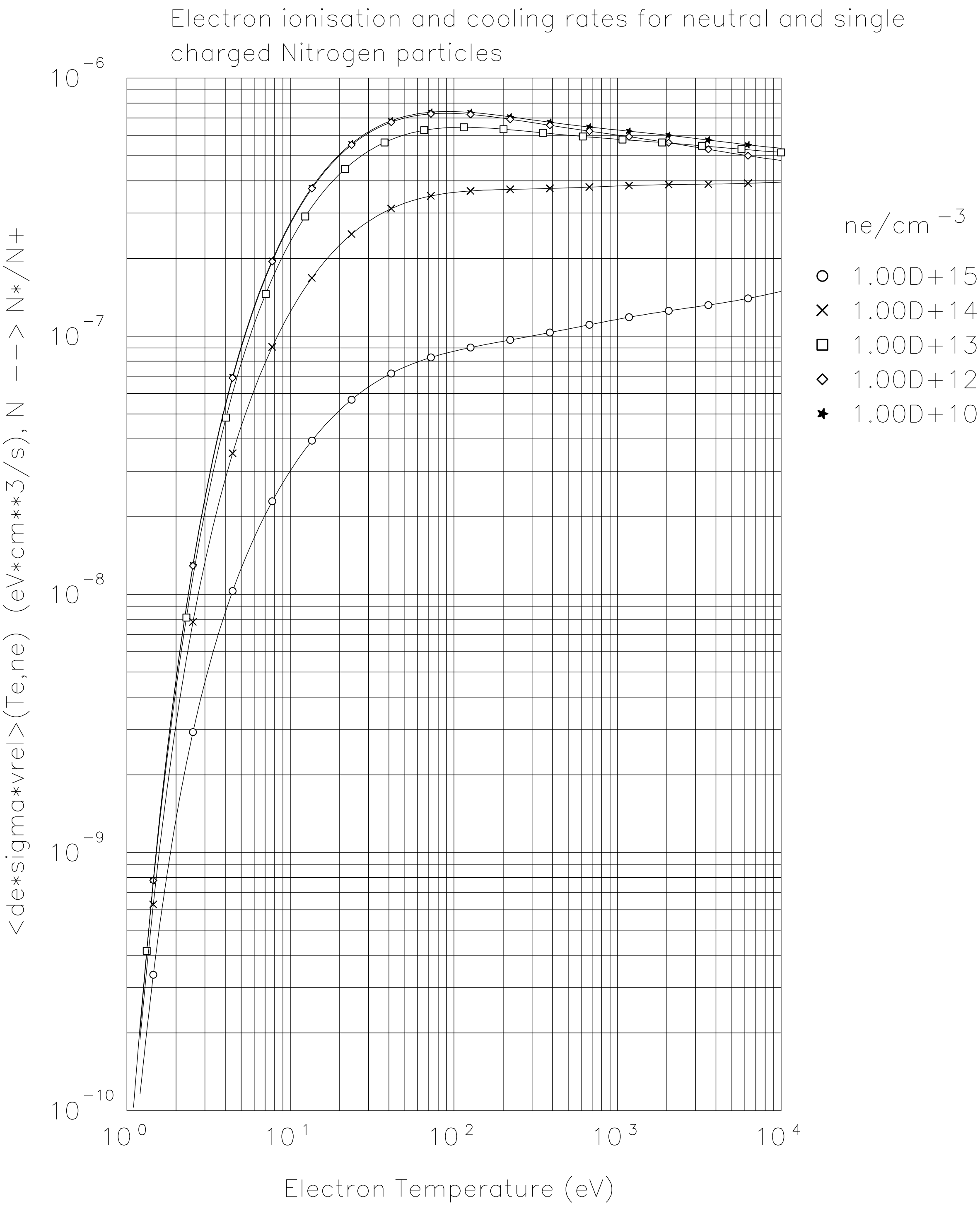
electron cooling rate due to ionization of N atoms [eV * cm**3/s] ADAS 96, here: only radiation loss, ADAS "PLT" file. One must add: 14.53 eV per ionisation to turn ADAS radiation rate into electron cooling rate.

T-Index \ E-Index	0	1	2
0	-2.253812547614D+01	-6.608569288276D-01	1.150452384879D-01
1	5.432527437912D+00	1.539439865129D+00	-1.576693820511D-01
2	-2.952608997109D-01	-1.412585437109D+00	4.638775789522D-02
3	-8.226013960740D-01	6.717054943053D-01	2.187384074057D-02
4	3.729388695172D-01	-1.832836584927D-01	-1.722342009795D-02
5	-7.841898395520D-02	2.976002632760D-02	4.564235143138D-03
6	8.985696288257D-03	-2.839310501238D-03	-6.044432608775D-04
7	-5.395985855412D-04	1.468399332248D-04	4.023312734034D-05
8	1.328834197911D-05	-3.174449965134D-06	-1.072687574774D-06

T-Index \ E-Index	3	4	5
0	-1.065634043574D-02	9.532285913431D-04	-1.346476910993D-04
1	5.813528015171D-03	-1.646122278862D-03	3.939136003165D-04
2	1.251511770456D-02	1.934102369820D-04	-2.591298980417D-04
3	-1.391948893870D-02	6.061371309834D-04	4.715854993637D-05
4	5.665942301636D-03	-2.864541076848D-04	-2.009919110756D-06
5	-1.191674192800D-03	5.671367249642D-05	1.560417026937D-07
6	1.394992142385D-04	-6.170732864889D-06	-5.745521323400D-08
7	-8.635747882439D-06	3.695648390668D-07	5.028838822894D-09
8	2.207714212398D-07	-9.661992346983D-09	-1.002410123923D-10

T-Index \ E-Index	6	7	8
0	1.499025275503D-05	-8.381690183270D-07	1.754250184956D-08
1	-4.099253727990D-05	2.056031618879D-06	-4.072262920583D-08
2	2.795198852134D-05	-1.439391948855D-06	3.065144075600D-08
3	-5.768287114529D-06	3.294456589515D-07	-8.730420469452D-09
4	3.415790996484D-07	-2.777746715732D-08	1.367779235643D-09
5	1.791473635965D-09	7.602227311451D-10	-1.668997333521D-10
6	9.035743229573D-10	-4.011075190405D-11	1.670019578529D-11
7	-1.822072807905D-10	6.518277639583D-12	-1.040108515933D-12
8	4.463372771101D-12	-1.949905209490D-13	2.634684643675D-14

T1MIN = 0.20000D 00 EV
T1MAX = 1.50000D 04 EV
N2MIN = 5.00000D 07 1/CM3
N2MAX = 2.00000D 15 1/CM3
Max. rel. Error: 5.8662 %
Mean rel. Error: 1.3550 %



Electron ionisation and cooling rates for neutral and single charged Nitrogen particles
<de*sigma*vrel>(Te,ne) (eV*cm**3/s), N --> N*/N+
Electron Temperature (eV)
ne/cm −3
1.00D+15
1.00D+14
1.00D+13
1.00D+12
1.00D+10

10.15 Reaction 2.8A0 $e + O \rightarrow O^{+} + 2e$

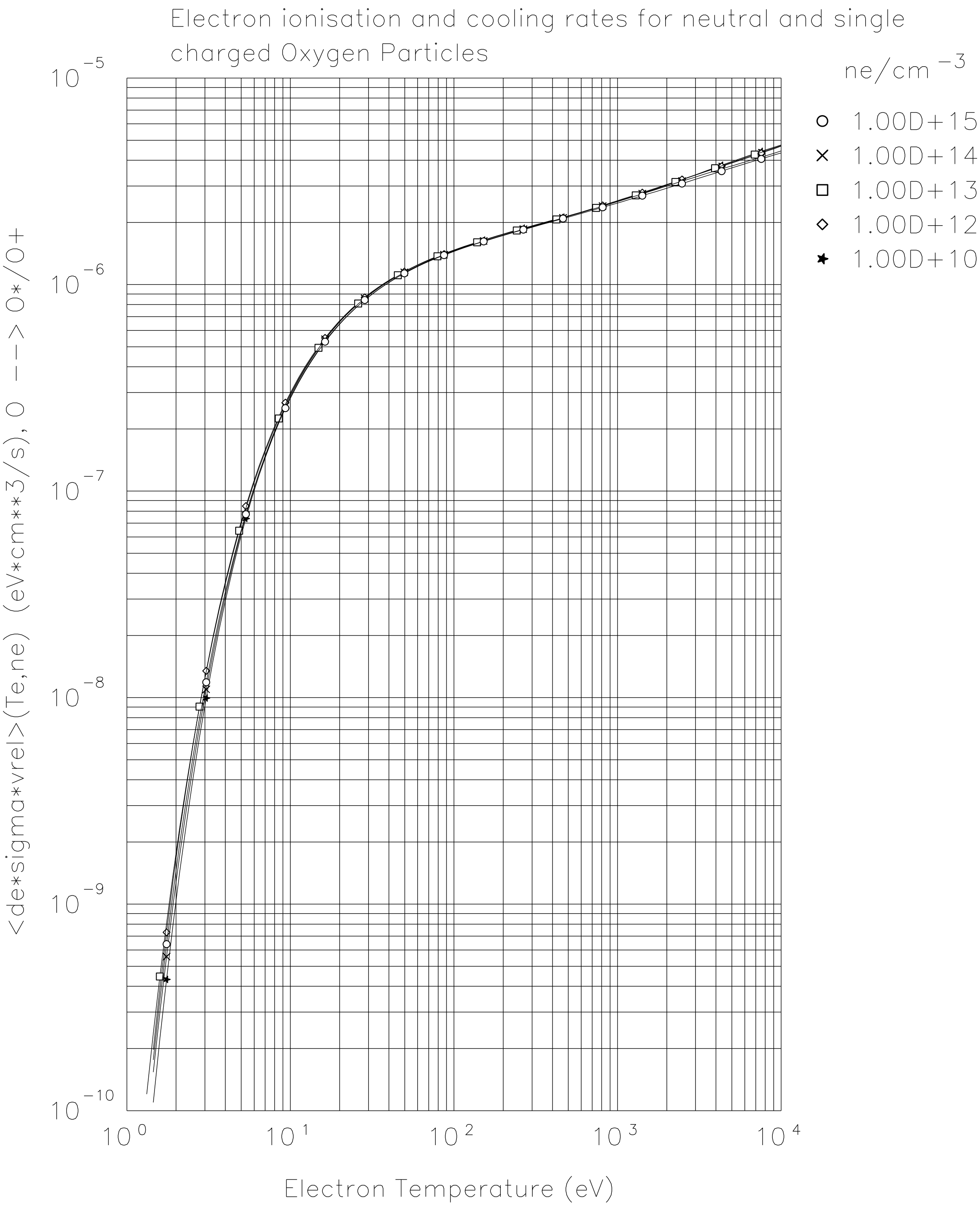
electron cooling rate due to ionization of O atoms [eV * cm**3/s] ADAS 96, PLT + 13.62 SCD

T-Index	E-Index: 0	1	2
0	-2.466138341969D+01	-8.116786196024D-01	2.156098826096D-01
1	6.294065613373D+00	1.917653675870D+00	-5.126040455489D-01
2	4.169947620973D-01	-1.762272010936D+00	4.946754888194D-01
3	-1.440821095346D+00	8.348952646637D-01	-2.315185825999D-01
4	5.793856506637D-01	-2.254745053995D-01	5.770621380639D-02
5	-1.152585175726D-01	3.591634468522D-02	-7.906197030141D-03
6	1.270352271875D-02	-3.327034036230D-03	5.749935870122D-04
7	-7.402495436662D-04	1.651879651465D-04	-1.907021606554D-05
8	1.780053898010D-05	-3.387119327934D-06	1.618345525908D-07

T-Index	E-Index: 3	4	5
0	-1.551623604131D-02	-1.035328327703D-02	2.942777879853D-03
1	5.415595131601D-02	1.226795295130D-02	-3.849935243694D-03
2	-7.985211650371D-02	5.748074680812D-04	1.272681449806D-03
3	4.286952781626D-02	-2.665900453388D-03	-1.214864213289D-04
4	-1.070010255570D-02	7.198609421959D-04	6.516970568169D-06
5	1.352605021497D-03	-6.620192814455D-05	-3.657688381337D-06
6	-8.412494926860D-05	1.061990976552D-06	5.570636828925D-07
7	2.093122097794D-06	8.762294262323D-08	-1.399830328643D-08
8	-4.854934999850D-09	-1.329206593116D-10	-8.809765813180D-10

T-Index	E-Index: 6	7	8
0	-3.080298061324D-04	1.437189742453D-05	-2.507423177221D-07
1	3.843177456353D-04	-1.678461366568D-05	2.731173341260D-07
2	-1.356433138071D-04	5.357153507040D-06	-7.215666632437D-08
3	1.670075321919D-05	-2.917167266543D-07	-6.340520240578D-09
4	-5.920359721220D-07	-1.442194804790D-07	6.194752166291D-09
5	1.505297788299D-08	3.612860525491D-08	-1.336874885628D-09
6	1.202458568069D-08	-4.914839753825D-09	1.632417540012D-10
7	-3.549414908473D-09	4.233445855041D-10	-1.181080686334D-11
8	2.133708107663D-10	-1.585146599884D-11	3.777218666320D-13

```
T1MIN =   0.20000D 00 EV
T1MAX =   1.50000D 04 EV
N2MIN =   5.00000D 07 1/CM3
N2MAX =   2.00000D 15 1/CM3
  Max. rel. Error:   0.780E+01 %
  Mean rel. Error:   0.108E+01 %
```



Electron ionisation and cooling rates for neutral and single
charged Oxygen Particles
ne/cm −3
1.00D+15
1.00D+14
1.00D+13
1.00D+12
1.00D+10
<de*sigma*vrel>(Te,ne) (eV*cm**3/s), O --> O*/O+
10 −5
10 −6
10 −7
10 −8
10 −9
10 −10
10 0
10 1
10 2
10 3
10 4
Electron Temperature (eV)

10.16 Reaction 2.8A0r $e + O \rightarrow O^+ + 2e$

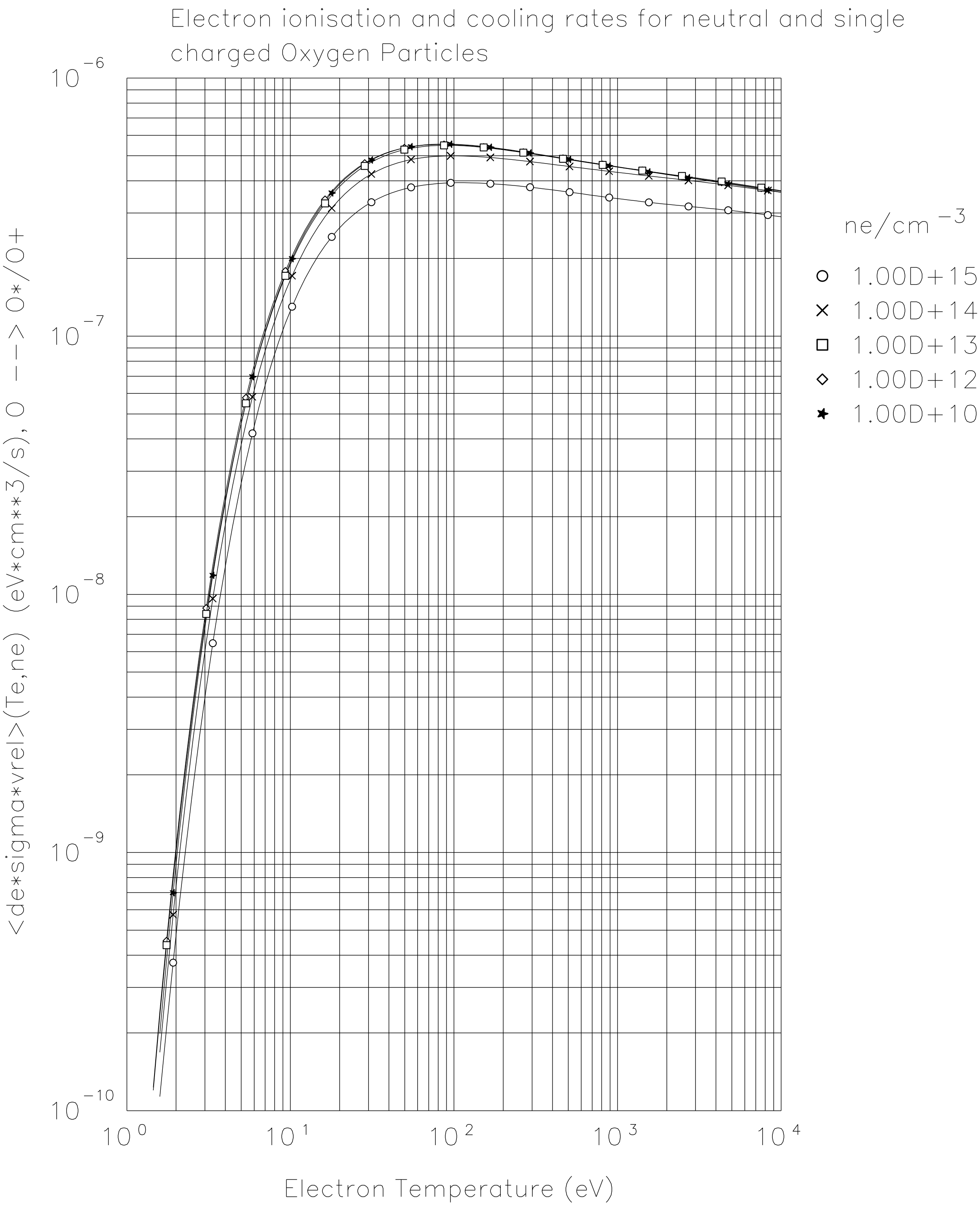
electron cooling rate due to ionization of O atoms [eV * cm**3/s] ADAS 96, here: only radiation loss, ADAS "PLT" file. One must add: 13.62 eV per ionisation to turn ADAS radiation rate into electron cooling rate.

T-Index \ E-Index	0	1	2
0	-2.445741605915D+01	-7.558170805452D-01	6.462171267483D-02
1	5.492606381344D+00	1.669520214597D+00	-1.021865903908D-01
2	9.943826013037D-01	-1.499918897355D+00	6.087399488466D-02
3	-1.654552652454D+00	7.182604764825D-01	-1.614322696382D-02
4	6.113756777865D-01	-2.013060379640D-01	1.632283021337D-03
5	-1.156778163561D-01	3.398915754215D-02	8.787006821195D-05
6	1.226872019465D-02	-3.396064383950D-03	-3.540766244850D-05
7	-6.927024005103D-04	1.846756585347D-04	3.021508483124D-06
8	1.622250023780D-05	-4.207838369666D-06	-8.903799103489D-08

T-Index \ E-Index	3	4	5
0	1.750162767171D-02	-7.322414636615D-03	1.347646519764D-03
1	-2.873370694294D-02	8.462882768193D-03	-1.412980882660D-03
2	1.848835552799D-02	-2.365388843634D-03	2.826588118171D-04
3	-8.427594128571D-03	1.652841141310D-04	5.183935809798D-05
4	2.680245268321D-03	-2.704851290479D-05	-2.072676809016D-05
5	-5.202897127637D-04	1.692837429290D-05	1.540185566308D-06
6	5.734498698465D-05	-3.001759890924D-06	7.192469818350D-08
7	-3.294622184638D-06	2.062548801876D-07	-1.157818482174D-08
8	7.669410612531D-08	-4.861603869267D-09	2.925221400690D-10

T-Index \ E-Index	6	7	8
0	-1.286672269176D-04	6.000293275220D-06	-1.078783359137D-07
1	1.379642813223D-04	-6.752421303830D-06	1.268943574449D-07
2	-3.651758284440D-05	2.307784252948D-06	-5.079380257776D-08
3	1.044710535961D-06	-3.994468803276D-07	1.234290357456D-08
4	3.081389976655D-07	8.140394138239D-08	-2.815585650608D-09
5	1.040513862277D-07	-1.905054927605D-08	5.310423435817D-10
6	-2.833458966155D-08	2.502214203633D-09	-5.916747741154D-11
7	2.098501461403D-09	-1.497495555462D-10	3.217115168440D-12
8	-4.734353103748D-11	3.144698339762D-12	-6.342196909047D-14

```
T1MIN =   0.20000D 00 EV
T1MAX =   1.50000D 04 EV
N2MIN =   5.00000D 07 1/CM3
N2MAX =   2.00000D 15 1/CM3
  Max. rel. Error:   3.7053 %
  Mean rel. Error:   0.5707 %
```



Electron ionisation and cooling rates for neutral and single charged Oxygen Particles
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
<de*sigma*vrel>(Te,ne) (eV*cm**3/s), O --> O*/O+
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}
Electron Temperature (eV)
ne/cm $^{-3}$
1.00D+15
1.00D+14
1.00D+13
1.00D+12
1.00D+10

10.17 Reaction 2.3.6A0 $C^+ + e \to C$

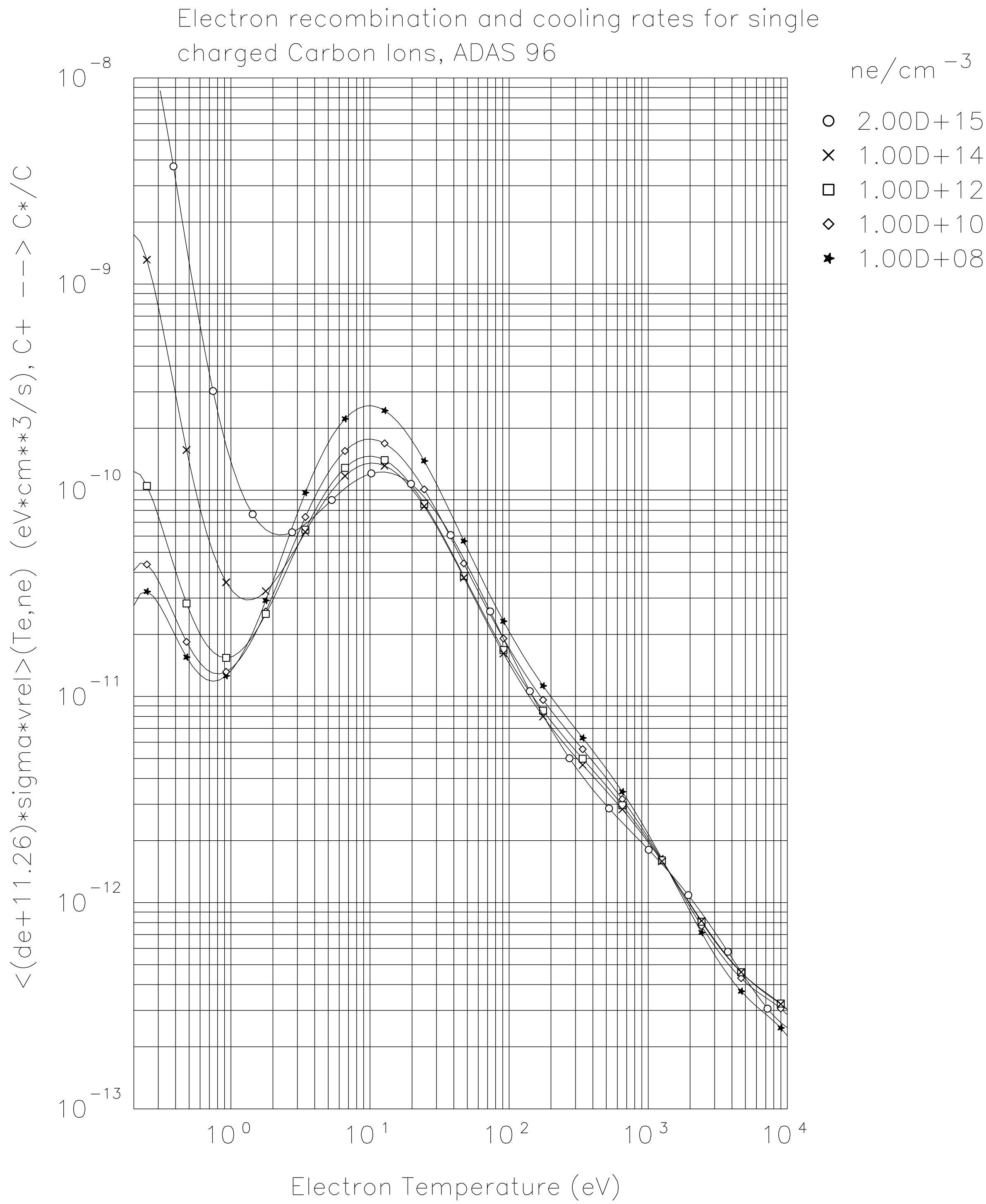
electron cooling rate due to recombination of C^+ ions [eV * cm**3/s], ADAS 96 (PRB rate, from 1999)
One must subtract: 11.26 eV per recombination to turn ADAS radiation rate into electron cooling (or heating) rate. Hence: the quantity "PRB" given here happens to be the radiation loss only. Note: these ADAS "PRB" rates include Bremsstrahlung.

T-Index \ E-Index	0	1	2
0	-2.504262998859D+01	1.226223310838D-02	1.577309269873D-02
1	7.879631634304D-01	-3.496332932469D-02	2.696503185718D-02
2	1.249367284771D+00	-1.671828393374D-02	-2.573355578426D-03
3	-3.482800276496D-01	1.290624872585D-02	-1.507534586829D-02
4	-1.947465794224D-01	-9.347273511999D-04	7.819274438376D-03
5	9.779360451639D-02	-8.018137927550D-04	-1.831352503495D-03
6	-1.672079431288D-02	2.139822162048D-04	2.413632311458D-04
7	1.285008100178D-03	-2.040719200566D-05	-1.732961831214D-05
8	-3.752281932750D-05	6.884845974155D-07	5.204736440092D-07

T-Index \ E-Index	3	4	5
0	-1.810826827041D-02	6.558564014409D-03	-1.114728775958D-03
1	-2.029599188878D-02	5.164836592191D-03	-6.496946434707D-04
2	3.169945750553D-03	-1.098191382614D-03	1.994163094053D-04
3	7.959528619719D-03	-1.812096513307D-03	2.094174982054D-04
4	-3.608120181276D-03	7.360014670114D-04	-7.963785819720D-05
5	7.188159989315D-04	-1.142345292372D-04	8.470313225808D-06
6	-8.584031885837D-05	1.003195961250D-05	-1.203570250061D-07
7	6.153152421261D-06	-6.219283277548D-07	-1.954383755090D-08
8	-1.961528482689D-07	2.129785929015D-08	4.159909038372D-10

T-Index \ E-Index	6	7	8
0	9.800649072784D-05	-4.291355270156D-06	7.411624450327D-08
1	4.387844304114D-05	-1.557167168613D-06	2.299640288445D-08
2	-1.901724531513D-05	9.143408919215D-07	-1.746723185929D-08
3	-1.304049149203D-05	4.195241979356D-07	-5.446867333889D-09
4	4.887626003198D-06	-1.680563744805D-07	2.583618629051D-09
5	-2.880211294935D-07	5.008023721315D-09	-8.619745491461D-11
6	-5.415840440468D-08	3.367012138032D-09	-5.529743733256D-11
7	7.015334454925D-09	-3.964024102294D-10	6.798738030639D-12
8	-2.154853963173D-10	1.281840300991D-11	-2.296423778649D-13

```
T1MIN =   0.20000D 00 1/CM3
T1MAX =   1.50000D 04 1/CM3
N2MIN =   5.00000D 07 1/CM3
N2MAX =   2.00000D 15 1/CM3
  Max. rel. Error:   0.296E+02 %
  Mean rel. Error:   0.100E+02 %
```


Electron recombination and cooling rates for single
charged Carbon Ions, ADAS 96
ne/cm -3
2.00D+15
1.00D+14
1.00D+12
1.00D+10
1.00D+08
<(de+11.26)*sigma*vrel>(Te,ne) (eV*cm**3/s), C+ --> C*/C
Electron Temperature (eV)
10 -8
10 -9
10 -10
10 -11
10 -12
10 -13
10 0
10 1
10 2
10 3
10 4

10.18 Reaction 2.3.7A0 $N^+ + e \rightarrow N$

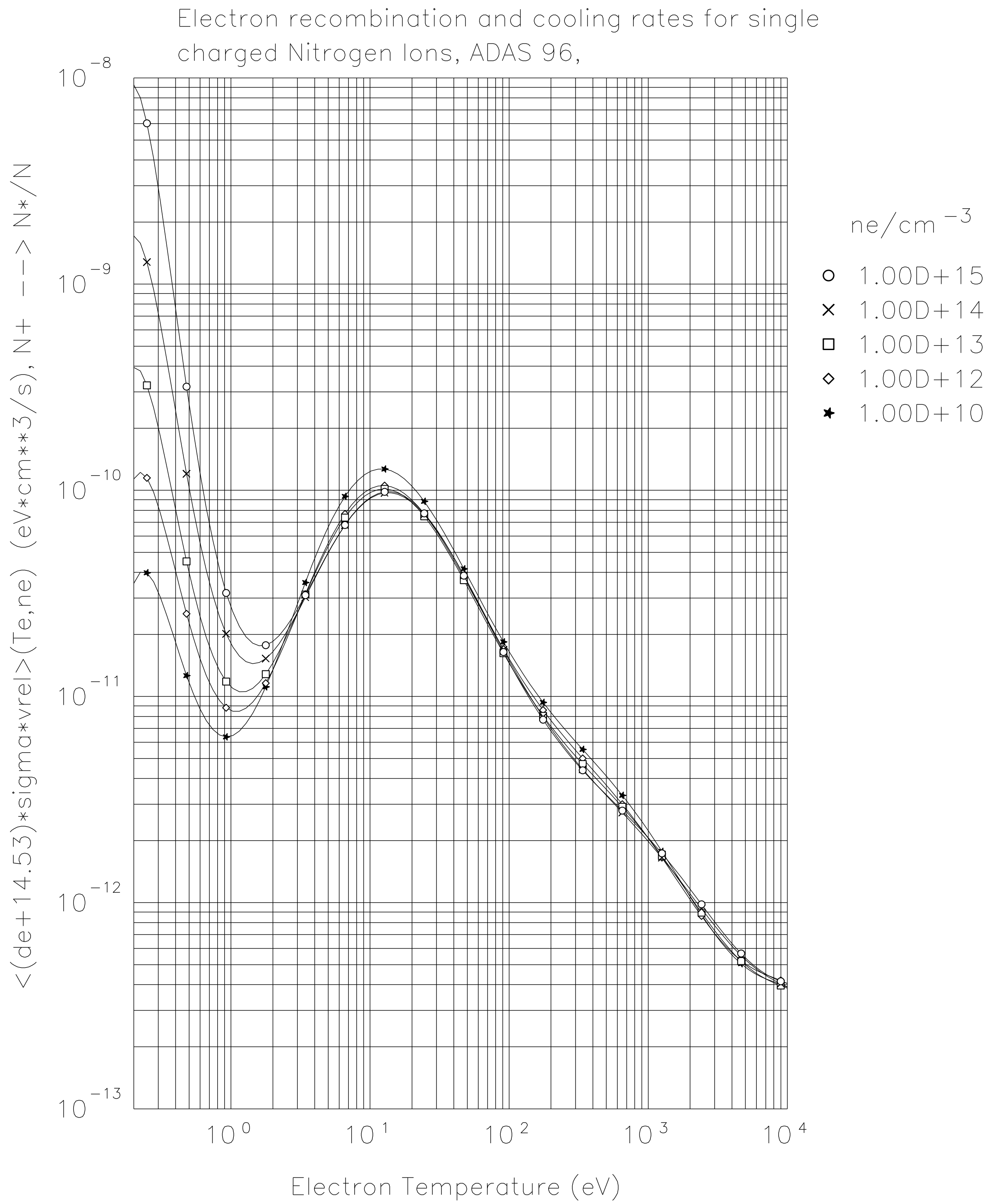
electron cooling rate due to recombination of N^+ ions [eV * cm**3/s], ADAS 96
One must subtract: 14.53 eV per recombination to turn ADAS radiation rate into electron cooling (or heating) rate. Hence: the quantity "PRB" given here happens to be the radiation loss only. Note: these ADAS "PRB" rates include Bremsstrahlung.

T-Index \ E-Index:	0	1	2
0	-2.586820731518D+01	-3.773123878982D-04	7.482871509909D-02
1	4.400357172984D-01	-5.955879689023D-02	-6.069655421640D-02
2	1.523969394400D+00	3.425371495869D-02	-8.101981223987D-02
3	-3.077040183629D-01	5.713803828212D-03	4.307965640960D-02
4	-2.499858560511D-01	-1.181574525071D-02	3.378336563136D-03
5	1.122891964175D-01	4.206198954046D-03	-4.429675538662D-03
6	-1.845412035984D-02	-6.674583671370D-04	8.097511152946D-04
7	1.383369072901D-03	5.032061800809D-05	-5.815584065023D-05
8	-3.962101000292D-05	-1.468219566959D-06	1.461427252466D-06

T-Index \ E-Index:	3	4	5
0	-4.804133327132D-02	1.306447013294D-02	-1.812654742590D-03
1	5.106007492864D-02	-1.546284626871D-02	2.268830444441D-03
2	4.279413046901D-02	-1.024270007475D-02	1.316026883921D-03
3	-3.115909800990D-02	8.767085102681D-03	-1.239304971154D-03
4	2.713999948320D-03	-1.295602004725D-03	2.196982388776D-04
5	1.151215043288D-03	-1.200389519219D-04	3.592098287396D-06
6	-2.493973858283D-04	3.804621927607D-05	-3.384244902180D-06
7	1.658217707026D-05	-2.328052761042D-06	1.932298218606D-07
8	-3.196107515802D-07	2.507602295919D-08	-5.676151311100D-11

T-Index \ E-Index:	6	7	8
0	1.354629644171D-04	-5.174213693006D-06	7.914218642264D-08
1	-1.751819021358D-04	6.833826024190D-06	-1.061582477502D-07
2	-9.341518771019D-05	3.450572575050D-06	-5.173974255663D-08
3	9.351800226170D-05	-3.596490667485D-06	5.541585525207D-08
4	-1.805778311706D-05	7.263438826071D-07	-1.148112128372D-08
5	2.332387839470D-07	-1.879365909923D-08	3.676966892592D-10
6	1.870011605909D-07	-6.064415580300D-09	8.687600130338D-11
7	-1.049655308155D-08	3.552860851546D-10	-5.454408362195D-12
8	-8.202530145299D-11	3.479987632860D-12	-4.036153078945D-14

Max. rel. Error: 32.2303 %
Mean rel. Error: 12.2391 %



Electron recombination and cooling rates for single
charged Nitrogen Ions, ADAS 96,
<(de+14.53)*sigma*vrel>(Te,ne) (eV*cm**3/s), N+ --> N*/N
Electron Temperature (eV)
ne/cm -3
1.00D+15
1.00D+14
1.00D+13
1.00D+12
1.00D+10

10.19 Reaction 2.3.8A0 $O^+ + e \rightarrow O$

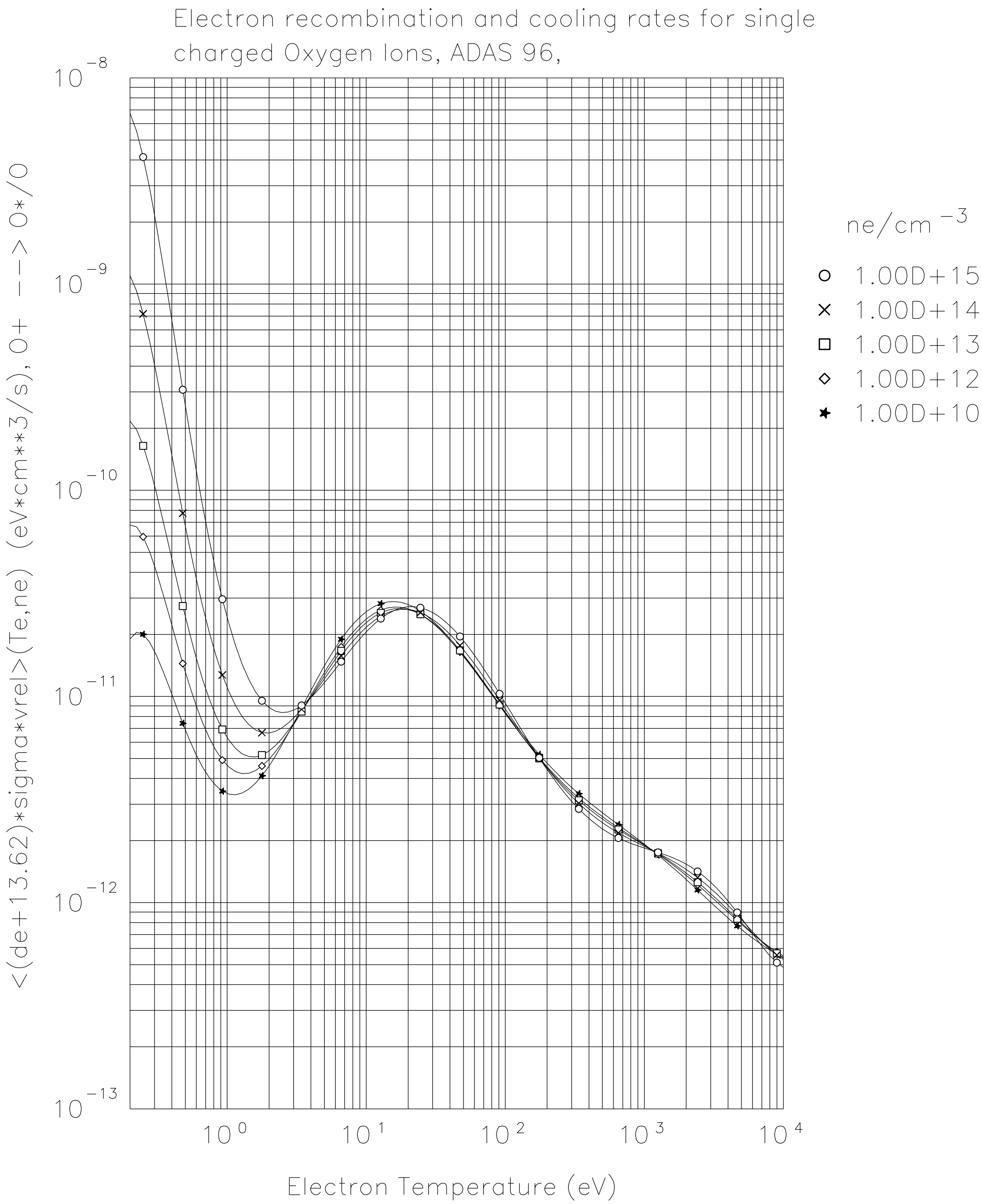
electron cooling rate due to recombination of O^+ ions [eV * cm**3/s], ADAS 96
One must subtract: 13.62 eV per recombination to turn ADAS radiation rate into electron cooling (or heating) rate. Hence: the quantity "PRB" given here happens to be the radiation loss only. Note: these ADAS "PRB" rates include Bremsstrahlung.

T-Index \ E-Index:	0	1	2
0	-2.653313950168D+01	2.216925829689D-02	5.476125200862D-03
1	-6.354270172271D-02	-2.970370946175D-02	-2.924232567362D-03
2	1.136262534246D+00	-1.638321618233D-02	4.543680765812D-03
3	-1.281599573767D-01	3.819386824901D-03	3.005270657055D-04
4	-1.909197964757D-01	5.701759939452D-03	-1.426212735570D-03
5	7.244841497960D-02	-2.697317691499D-03	5.384553818515D-04
6	-1.085354529891D-02	4.751006113548D-04	-9.079081560679D-05
7	7.572289001622D-04	-3.780469918978D-05	7.402729380985D-06
8	-2.041631801536D-05	1.138361613897D-06	-2.361510545802D-07

T-Index \ E-Index:	3	4	5
0	-4.314967559213D-03	1.308676572081D-03	-1.736787698498D-04
1	1.081523218557D-03	-3.561991531376D-04	4.308167373509D-05
2	8.372086622214D-04	-3.337360481944D-04	3.545299576488D-05
3	-4.893123129767D-04	7.578633030575D-05	2.917876532730D-06
4	-3.128536602414D-05	7.234833821022D-05	-1.233696295835D-05
5	3.583912600700D-05	-2.670990378994D-05	2.932629504712D-06
6	-2.993913602201D-06	2.724569084701D-06	-9.569324831913D-08
7	-2.244802134509D-07	-2.933697608069D-08	-2.654846978216D-08
8	2.401245642186D-08	-5.331361909937D-09	1.859310874804D-09

T-Index \ E-Index:	6	7	8
0	1.143937144703D-05	-3.426119753220D-07	3.343988039951D-09
1	-2.436289695706D-06	4.547126890253D-08	2.943681279832D-10
2	-9.130986620243D-07	-5.056377574243D-08	2.244312734391D-09
3	-1.421649431925D-06	1.060528794829D-07	-2.467404974614D-09
4	9.066971436761D-07	-3.076963252506D-08	3.790588865731D-10
5	-7.287895559905D-08	-4.525321022016D-09	1.980047129074D-10
6	-2.908578180313D-08	2.796398755095D-09	-7.153988149004D-11
7	5.437629784614D-09	-3.630282613909D-10	8.162616568071D-12
8	-2.565417747456D-10	1.497599750014D-11	-3.151739443995D-13

Max. rel. Error: 29.6584 %
Mean rel. Error: 9.6090 %



Electron recombination and cooling rates for single
charged Oxygen Ions, ADAS 96,
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
<(de+13.62)*sigma*vrel>(Te,ne) (eV*cm**3/s), O+ --> O*/O
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}
Electron Temperature (eV)
ne/cm $^{-3}$
1.00D+15
1.00D+14
1.00D+13
1.00D+12
1.00D+10

11 H.11: Other single polynomial fits

11.1 Reaction 2.2B0 $He + e \rightarrow He^*,\ <de> (T_e)\ [eV],$

Electron cooling for neutral and single charged Helium Particles, divided by corresponding collision rates, i.e. the fit here is for the mean electron energy cost per collision [eV]

```
k0  1.151324376008D+01  k1 -4.473761205167D+00  k2  1.778986582799D+00
k3 -6.438551868755D-01  k4  1.608511765799D-01  k5 -2.421866396738D-02
k6  2.091573687632D-03  k7 -9.493936758931D-05  k8  1.736942898336D-06
```

11.2 Reaction 2.4B0 $Be + e \rightarrow Be^*,\ <de> (T_e)\ [eV],$

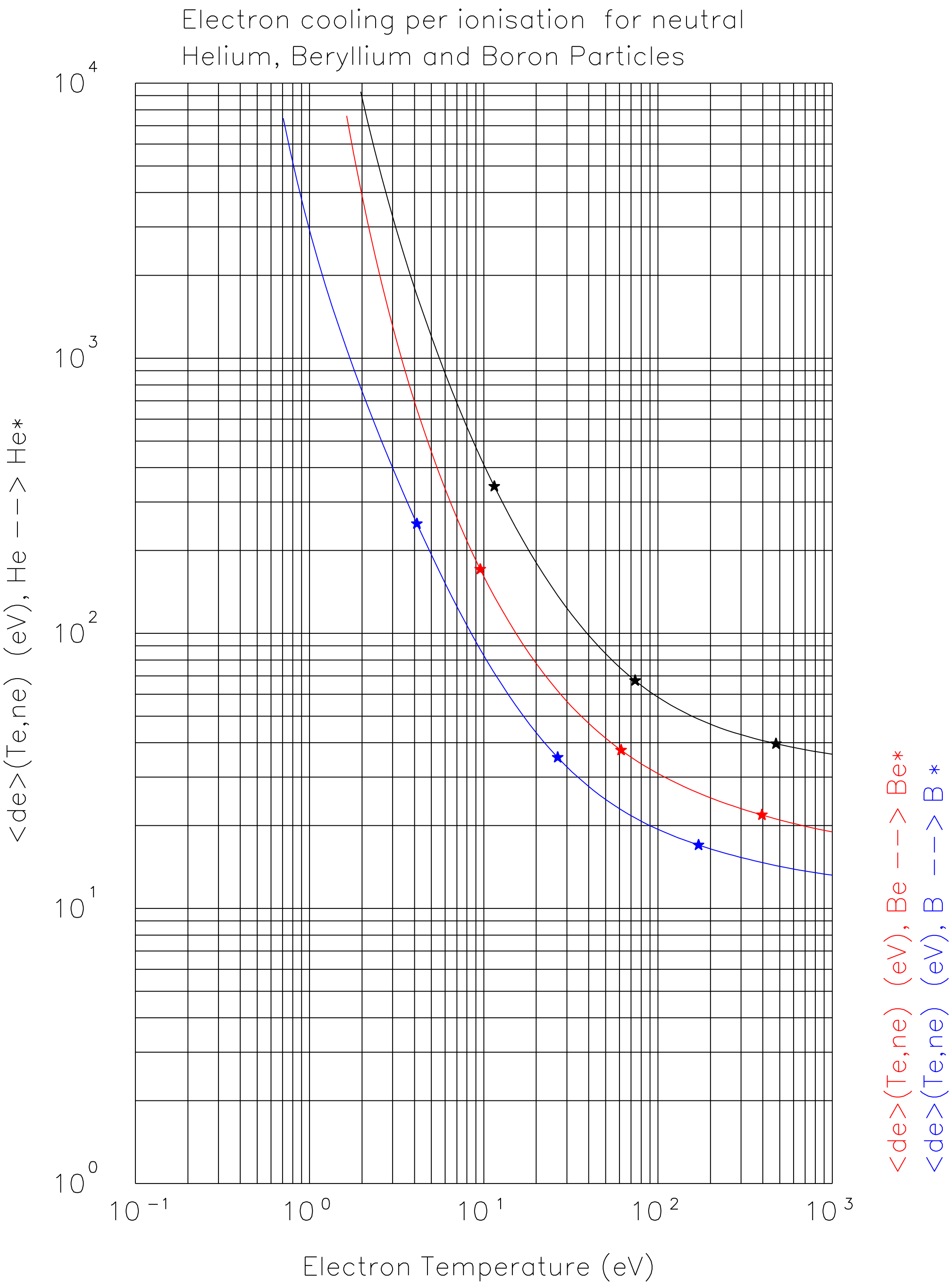
Electron cooling rates for neutral and single charged Beryllium Particles, divided by corresponding collision rates, i.e. the fit here is for the mean electron energy cost per collision [eV]

```
k0  1.100391045815D+01  k1 -5.081216135395D+00  k2  2.036662223616D+00
k3 -6.960133333130D-01  k4  1.785218452743D-01  k5 -2.998205644075D-02
k6  3.046320376267D-03  k7 -1.693432568467D-04  k8  3.950464677598D-06
```

11.3 Reaction 2.5B0 $B + e \rightarrow B^*,\ <de> (T_e)\ [eV]$

Electron cooling rates for neutral and single charged Boron Particles, divided by corresponding collision rates, i.e. the fit here is for the mean electron energy cost per collision [eV]

```
k0  7.978054620918D+00    k1 -2.341359084919D+00    k2  8.199491879599D-01
k3 -4.624629728853D-01    k4  1.778831014506D-01    k5 -3.767862190039D-02
k6  4.410579417779D-03    k7 -2.699007579966D-04    k8  6.760485583089D-06
```


Electron cooling per ionisation for neutral
Helium, Beryllium and Boron Particles
<de>(Te,ne) (eV), He ––> He*
<de>(Te,ne) (eV), Be ––> Be*
<de>(Te,ne) (eV), B ––> B *
Electron Temperature (eV)
10^4
10^3
10^2
10^1
10^0
10^-1
10^0
10^1
10^2
10^3

11.4 Reaction 2.6B0 $C + e \rightarrow C^*,\ <de>(T_e)\ [eV]$

Electron cooling rates for neutral and single charged Carbon Particles, divided by corresponding collision rates, i.e. the fit here is for the mean electron energy cost per collision [eV]. Currently: constant, = ionisation potential of Carbon = 11.30 eV

```
k0  2.424802725729D+00  k1  0.000000000000D+00  k2  0.000000000000D+00
k3  0.000000000000D+00  k4  0.000000000000D+00  k5  0.000000000000D+00
k6  0.000000000000D+00  k7  0.000000000000D+00  k8  0.000000000000D+00

Max. rel. Error:    .0000 %
Mean rel. Error:    .0000 %
```

11.5 Reaction 2.7B0 $N + e \rightarrow N^*,\ <de>(T_e)\ [eV]$

Electron cooling rates for neutral Nitrogen particles, divided by corresponding collision rates, i.e. the fit here is for the mean electron energy cost per collision [eV]. Currently: constant, = ionisation potential of Nitrogen = 14.534 eV

```
k0  2.676490732000D+00  k1  0.000000000000D+00  k2  0.000000000000D+00
k3  0.000000000000D+00  k4  0.000000000000D+00  k5  0.000000000000D+00
k6  0.000000000000D+00  k7  0.000000000000D+00  k8  0.000000000000D+00

Max. rel. Error:    .0000 %
Mean rel. Error:    .0000 %
```

11.6 Reaction 2.10B0 $Ne + e \rightarrow Ne^*,\ <de>(T_e)\ [eV]$

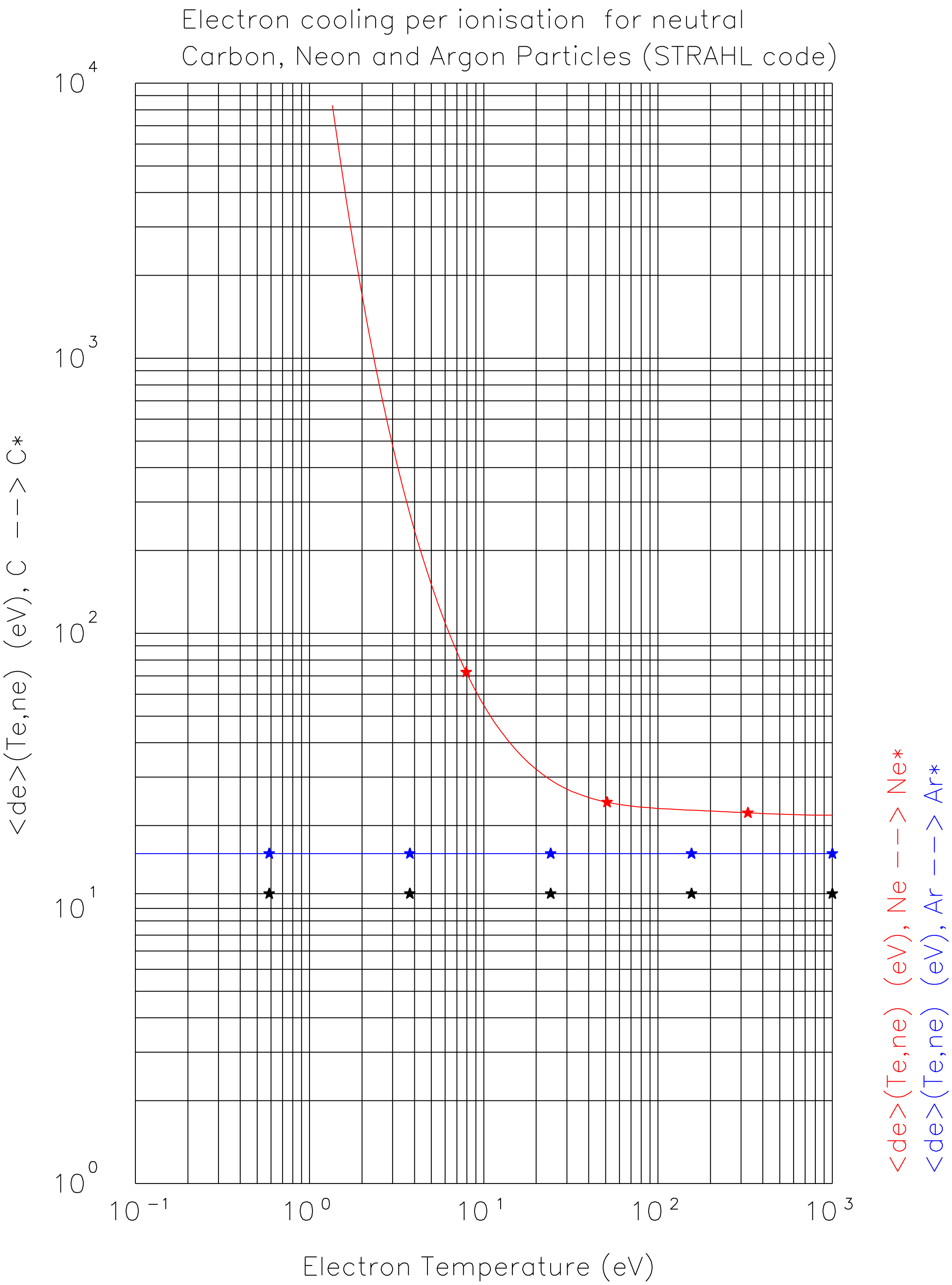
Electron cooling rates for neutral and single charged Neon Particles, divided by corresponding collision rates, i.e. the fit here is for the mean electron energy cost per collision [eV]

```
k0  1.059049152999D+01  k1 -5.769454465431D+00  k2  2.125621468764D+00
k3 -6.517811286454D-01  k4  1.883422085531D-01  k5 -3.905034526242D-02
k6  4.823070375814D-03  k7 -3.148120306333D-04  k8  8.365625760942D-06

Max. rel. Error:    .9028 %
Mean rel. Error:    .5524 %
```

11.7 Reaction 2.18B0 $Ar + e \rightarrow Ar^*,\ <de>(T_e)\ [eV]$

Electron cooling rates for neutral and single charged Argon Particles, divided by corresponding collision rates, i.e. the fit here is for the mean electron energy cost per collision [eV] here use constant ionisation potential $DeltaE_e = I_p = 15.7596$ eV.

```
k0  2.757449703000D+00  k1  0.000000000000D+00  k2  0.000000000000D+00
k3  0.000000000000D+00  k4  0.000000000000D+00  k5  0.000000000000D+00
k6  0.000000000000D+00  k7  0.000000000000D+00  k8  0.000000000000D+00

Max. rel. Error:     .0000 %
Mean rel. Error:     .0000 %
```



Electron cooling per ionisation for neutral
Carbon, Neon and Argon Particles (STRAHL code)
10^4
10^3
10^2
10^1
10^0
10^-1
10^0
10^1
10^2
10^3
Electron Temperature (eV)
<de>(Te,ne) (eV), C --> C*
<de>(Te,ne) (eV), Ne --> Ne*
<de>(Te,ne) (eV), Ar --> Ar*

11.8 Reaction 2.0b $p + H_2(v = 0) \rightarrow H_2^+ + ...$, Ratio H_2^+/H_2

gain of H_2^+: production by CX (ion conversion, proton impact) on cold (0.1 eV) $H_2(0)$, vibr. ground state only. Only dependence on one temperature T_p.
loss of H_2^+: coll. rad. model for H_2, H_2^+, Sawada, Fujimoto, [7], electron impact dissociative recombination, excitation and ionization. Total loss: electron density independent.

Note: the contribution 2.0a to this ratio from electron impact processes leading to H_2^+ is electron density dependent, because the effective electron impact ionisation is density dependent. This contribution to the ratio is given in the next chapter under the "double-polynomial fits".

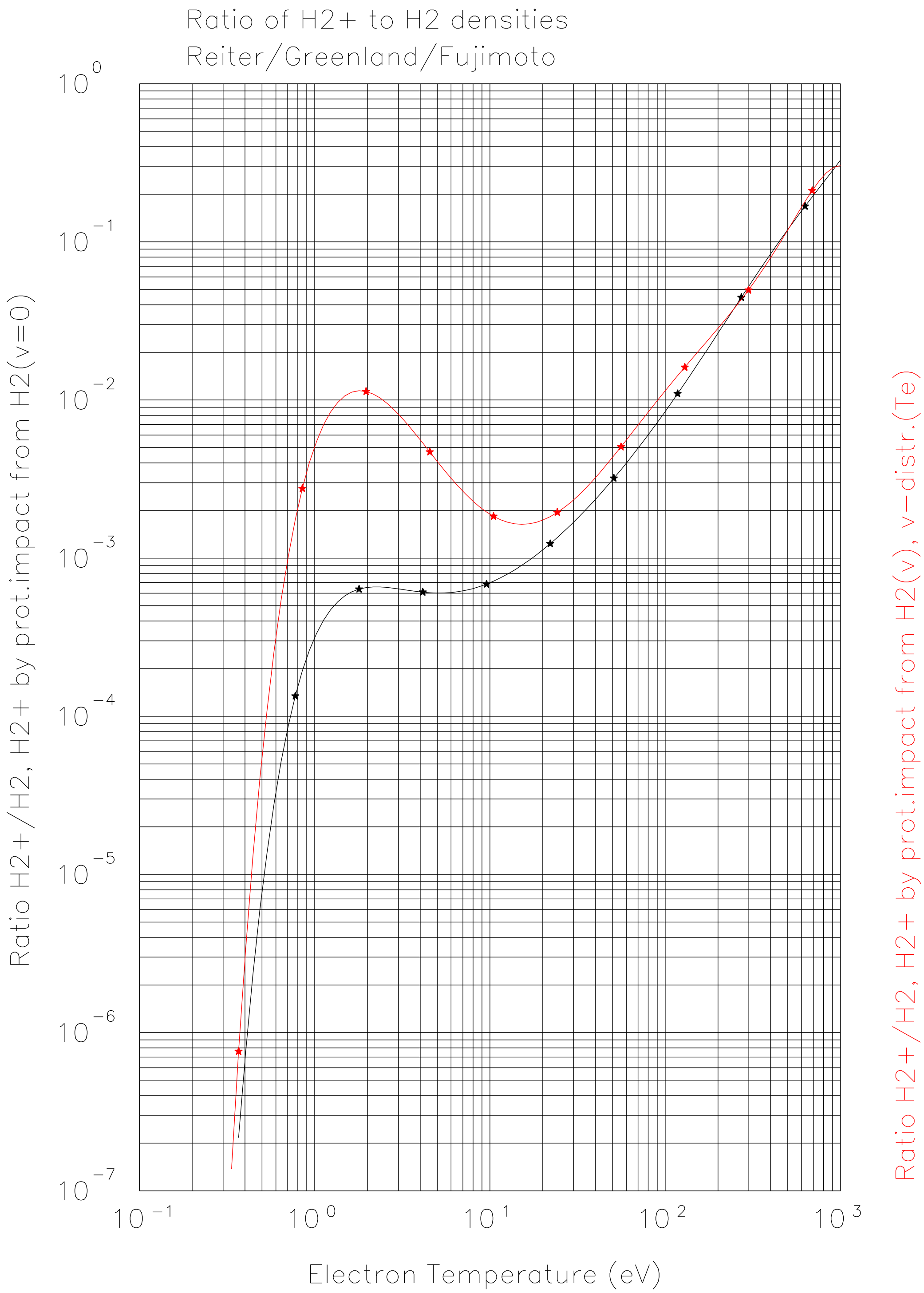
```
k0 -8.061954078771D+00  k1  2.475896585902D+00  k2 -2.933737852849D+00
k3  1.492083638260D+00  k4 -3.461597813263D-01  k5  3.266006392880D-02
k6  1.357009637322D-03  k7 -5.021441756376D-04  k8  2.737802193621D-05

Max. rel. Error:   1.3369 %
Mean rel. Error:    .8127 %
```

11.9 Reaction 2.0c $p + H_2(v) \rightarrow H_2^+ + ...$, Ratio H_2^+/H_2

gain of H_2^+: coll. model for vibr. excitation, Greenland, Reiter, [17]), and then: H_2^+ production by CX (ion conversion, proton impact) on these $H_2(v)$. The density dependence on vibrational distribution $pH_2(v; T_e)$ of $H_2(v)$ vanishes for $n_e = n_p$. Only dependence on one temperature for $T_e = T_p$.
loss of H_2^+: coll. rad. model for H_2, H_2^+, Sawada, Fujimoto, [7], electron impact dissociative recombination, excitation and ionization. Total loss: electron density independent.

Assumptions:
$E_{H2} = 0.1$ eV, $T_p = T_e$, vibrational distribution $pH_2(v; T_e)$ in electr. ground state of H_2 with no coupling to B,C states, hence: also gain rate of H_2^+ due to this process is independent of n_e. B,C coupling to vibr. states is non-linear in density and would hence make this ratio density dependent.

```
k0 -5.281428900665D+00  k1  3.115995571855D+00  k2 -3.690629726865D+00
k3  1.448918180601D+00  k4 -3.928689243481D-01  k5  1.236809448625D-01
k6 -2.877121006548D-02  k7  3.391113110854D-03  k8 -1.521565312043D-04

Max. rel. Error:   9.3977 %
Mean rel. Error:   5.6685 %
```



Ratio of H2+ to H2 densities
Reiter/Greenland/Fujimoto
Ratio H2+/H2, H2+ by prot.impact from H2(v=0)
Ratio H2+/H2, H2+ by prot.impact from H2(v), v−distr.(Te)
Electron Temperature (eV)
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}

11.10 Reaction 4.0a $H_2 + H_2^+ \rightarrow H_3^+ + H$, Ratio H_3^+/H_2

Fit for ln(RATIO), defined such that $n_{H_3^+}/n_{H_2}$ = RATIO $\times n_{H_2^+}/n_e$

Ratio of densities: $n_{H_3^+}/n_{H_2}$ = Ratio of production rate constant to destruction rate coefficient $\times n_{H_2^+}/n_e$.

Production of H_3^+ from $H_2(v)$: rate constant obtained from HYDHEL rate coefficient for $H_2^+ + H_2(v) \rightarrow H_3^+ + H$ evaluated at $T_{H_2} = T_{H_2^+} = 0.1$ eV, $\approx 1.160947956e - 9$.

Destruction of H_3^+: diss. recombination (DR) from HYDHEL, 2.2.15, vs. T_e. Used here: algebraic expression from original rate constant and fit of ln(DR rate coef.) for this ln(RATIO).

```
k0 -3.571300000000e+00    k1  4.050073042947e-01    k2 -1.018733477232e-08
k3  1.695586285687e-08    k4 -1.564311217508e-10    k5 -1.979725412288e-09
k6  4.395545994733e-10    k7 -3.584926377078e-11    k8  1.024189019465e-12
```

11.11 Reaction 7.0a $e + H_2(v) \rightarrow H^- + H$, Ratio H^-/H_2 from DA

Ratio of densities: n_{H^-}/n_{H_2}.
vibr. distribution $pH_2(v; T_e)$ of $H_2(v)$: coll. model for vibr. excitation, Greenland, Reiter, [17]

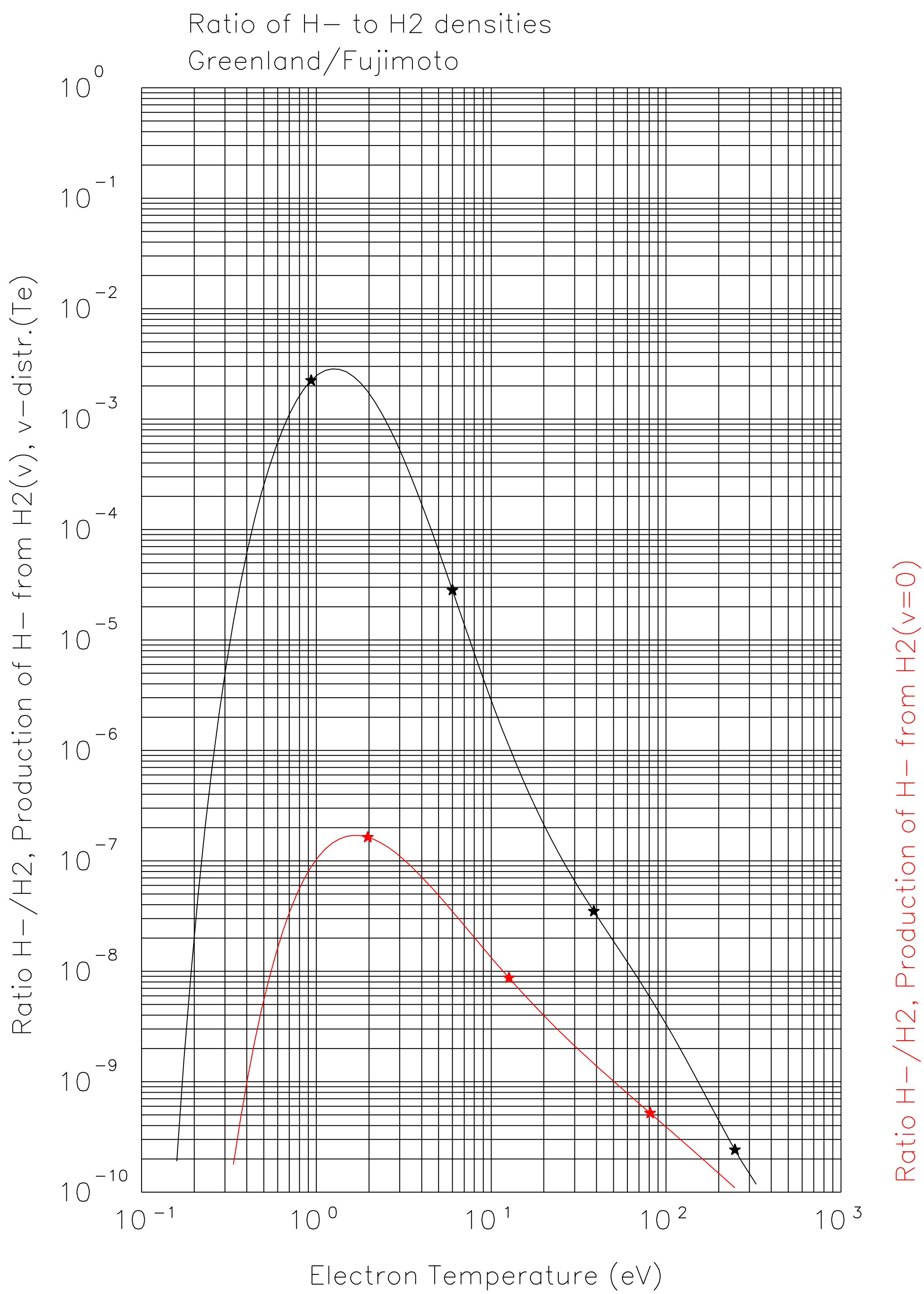
Vibrational distribution $H_2(v)$ evaluated at $E_{H_2} = 0.1eV$, $T_p = T_e$ and $n_p = n_e$.
Production of H^- from $H_2(v)$: Dissociative attachment on $H_2(v) : e + H_2(v) \rightarrow H^- + H$
Destruction of H^-: electron detachment, proton MN, with $E_{H^-} = 0.1$ and $T_p = T_e$ and $n_p = n_e$.

```
k0 -6.001820741967D+00  k1  1.247273997745D+00  k2 -2.753387653632D+00
k3  2.274419556537D-01  k4  1.148400271668D-02  k5  8.614331916062D-02
k6 -3.482537437480D-02  k7  4.822974299102D-03  k8 -2.291190247346D-04

Max. rel. Error:  23.4821 %
Mean rel. Error:  10.7677 %
```

11.12 Reaction 7.0b $e + H_2(0) \rightarrow H^- + H$, Ratio H^-/H_2 from DA

same as 7.0a, but DA (diss. attachment) only from vibr. ground state
Ratio of densities: n_{H^-}/n_{H_2}
Production of H^- from $H_2(v = 0)$: Dissociative attachment on $H_2(v = 0) : e + H_2(0) \rightarrow H^- + H$
Destruction of H^-: electron detachment, proton MN, with $E_{H^-} = 0.1$ and $T_p = T_e$ and $n_p = n_e$.

```
k0 -1.608434690479D+01  k1  2.105039374877D+00  k2 -2.553803267076D+00
k3  7.038135447597D-01  k4 -6.586584264400D-02  k5 -2.548302462129D-03
k6  2.922944743984D-04  k7  8.800611380131D-05  k8 -7.939105674896D-06

Max. rel. Error:   3.3989 %
Mean rel. Error:   1.0220 %
```


Ratio of H− to H2 densities
Greenland/Fujimoto
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
Electron Temperature (eV)
Ratio H−/H2, Production of H− from H2(v), v−distr.(Te)
Ratio H−/H2, Production of H− from H2(v=0)

12 H.12: Other double polynomial fits

12.1 Reaction 2.1.5 $H + e \leftrightarrow H^+ + 2e$, Ratio $H^+/H(1)$

This ratio provides the collisional radiative equilibrium ion density, for a given ground state atom density. In CR equilibrium this ratio is a function of T_e and n_e.
From $0 = n_1 \times \langle s_{ion} \rangle - n^+ \times \langle \alpha_{rec} \rangle$.
Assumed: $n^+ = n_e$

T-Index \ E-Index	0	1	2
0	-3.885296435411D+00	-5.697204983970D-02	7.332383617797D-02
1	1.505487187018D+01	4.633572829771D-04	-1.702732444633D-03
2	-6.749191912028D+00	1.050145613783D-03	-3.148776304951D-03
3	2.212221660002D+00	4.854461323593D-03	-2.452783916892D-03
4	-5.257981277508D-01	-3.179654723425D-03	1.767567981601D-03
5	8.824411449640D-02	9.193475524397D-04	-4.299802583958D-04
6	-9.799369577387D-03	-1.679454700153D-04	7.381643118061D-05
7	6.413937652029D-04	1.902440743752D-05	-9.875692439849D-06
8	-1.861114574375D-05	-9.394367819466D-07	5.893327001637D-07

T-Index \ E-Index	3	4	5
0	-3.505183129037D-02	8.175768579910D-03	-1.025860190568D-03
1	1.882868187070D-03	-6.728098565933D-04	1.133241004935D-04
2	1.594704172137D-03	-3.246647453262D-04	3.184754694533D-05
3	4.064257852894D-04	-2.059459670150D-05	-2.358171220598D-06
4	-3.839001285389D-04	4.783673711689D-05	-3.378269018931D-06
5	6.248027250326D-05	-4.077787495573D-06	1.124935475483D-07
6	-7.865967145477D-06	-4.674862715791D-08	4.744742742259D-08
7	1.734207080274D-06	-1.760833256154D-07	1.551629723045D-08
8	-1.457328885095D-07	2.193301182972D-08	-2.248254389232D-09

T-Index \ E-Index	6	7	8
0	7.041006112962D-05	-2.467291455100D-06	3.436102553376D-08
1	-9.735191629933D-06	4.053170686858D-07	-6.463282471161D-09
2	-1.387656614654D-06	1.600623293301D-08	2.722493472041D-10
3	3.488698891258D-07	-1.422059161908D-08	1.698254518458D-10
4	9.511636577030D-08	6.913540712148D-10	-5.483090178167D-11
5	1.140116701448D-08	-1.211498169926D-09	3.020216342872D-11
6	-4.127705769609D-09	2.185243304602D-10	-4.848384547542D-12
7	-9.432683181108D-10	2.682232500047D-11	-2.216051536502D-13
8	1.398963108397D-10	-4.493865381320D-12	5.590467018306D-14

```
P2MIN =   1.00000D 08 1/CM3
P2MAX =   1.00000D 16 1/CM3
  Max. rel. Error:    .9684 %
  Mean rel. Error:    .4161 %
```

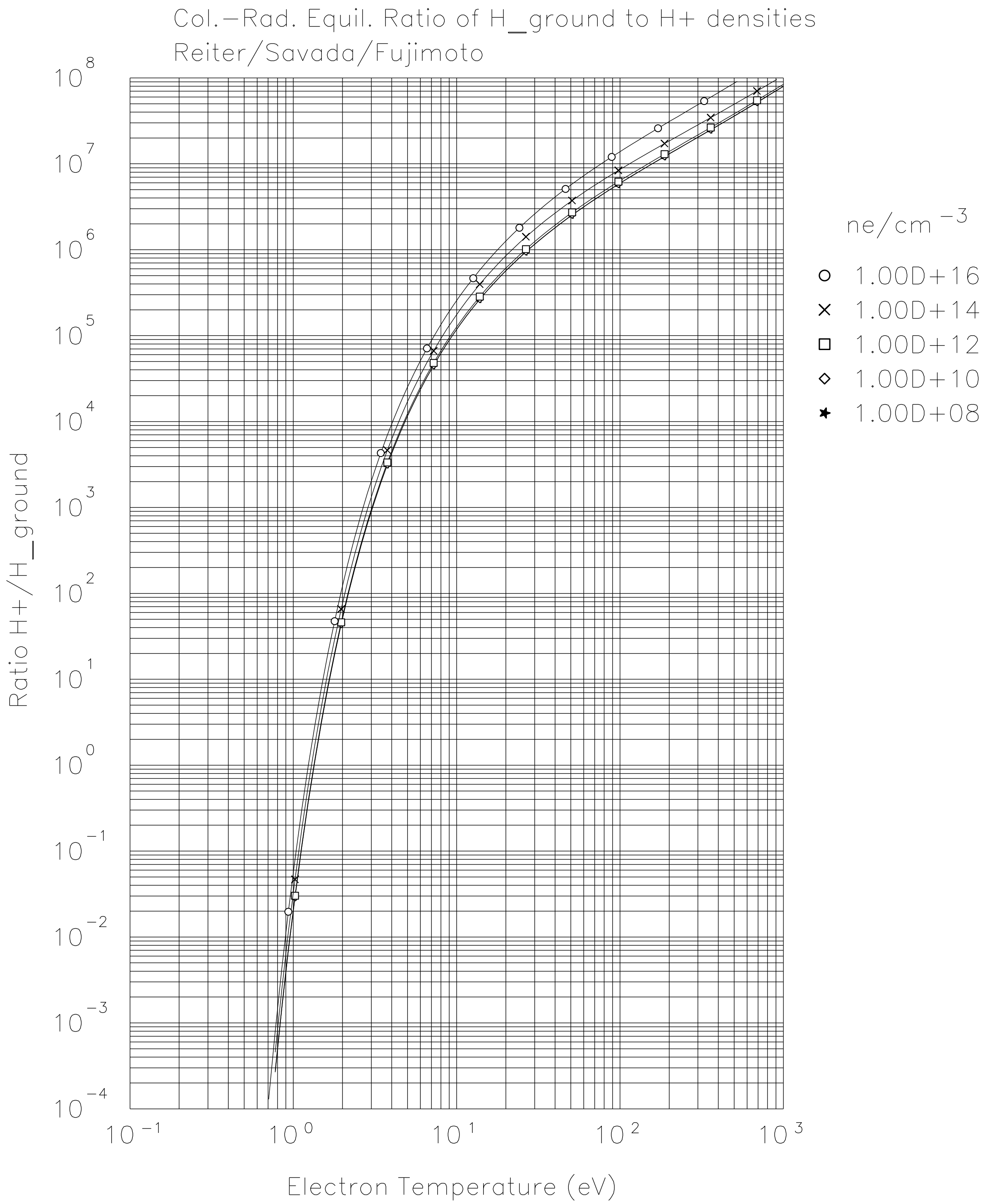
12.2 Reaction 2.1.5a $H + e \rightarrow H^+ + 2e$, Ratio $H(3)/H(1)$

T-Index \ E-Index	0	1	2
0	-3.082877684472D+01	9.740982428834D-01	2.693447564427D-02
1	1.187030265272D+01	1.968338090648D-02	-2.495504765088D-02
2	-5.889482037865D+00	-8.737684945730D-03	9.951688266911D-03
3	2.017399399792D+00	-1.014609925009D-02	1.040081859210D-02
4	-5.303360302839D-01	3.297808176838D-03	-2.712205422397D-03
5	1.080451047951D-01	9.673290806118D-04	-1.096708705743D-03
6	-1.555010466762D-02	-5.167168286670D-04	4.637911190482D-04
7	1.327158680898D-03	7.389473703435D-05	-5.797555862425D-05
8	-4.872105203992D-05	-3.537584073064D-06	2.453443334473D-06

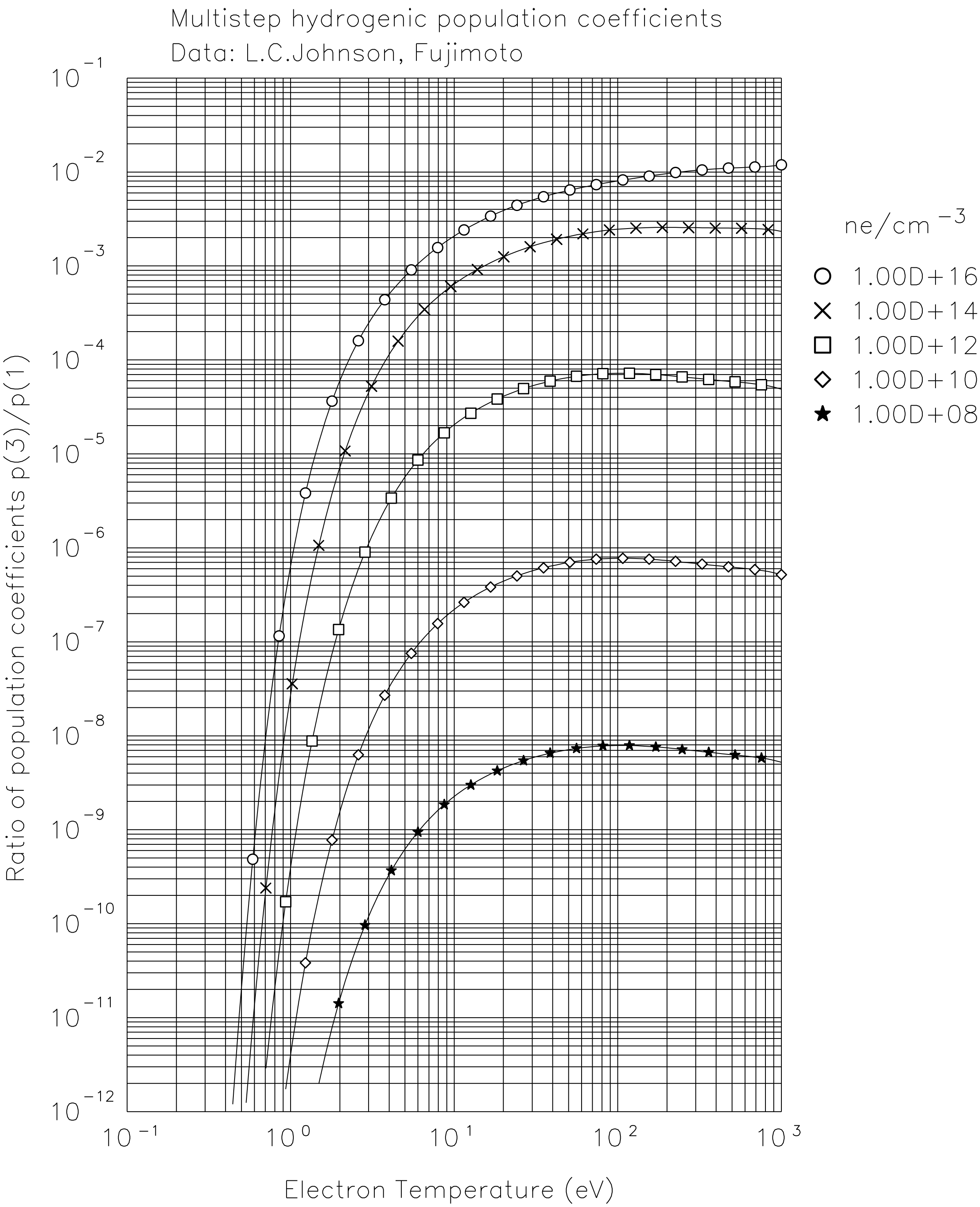
T-Index \ E-Index	3	4	5
0	-9.004934091051D-03	1.222843687947D-03	-5.210804049741D-05
1	1.123130855030D-02	-2.651909936461D-03	3.534709147248D-04
2	-5.241271640755D-03	1.372483328336D-03	-1.917275090304D-04
3	-3.478025606446D-03	5.572774095384D-04	-4.848784231802D-05
4	8.454526208306D-04	-1.362168127545D-04	1.306146151315D-05
5	3.872258199271D-04	-6.353971343367D-05	5.417022322731D-06
6	-1.380893374707D-04	1.849429028886D-05	-1.166761555949D-06
7	1.440341699187D-05	-1.290902554237D-06	-4.889963932464D-09
8	-4.745956710582D-07	5.546604517157D-09	7.579547673173D-09

T-Index \ E-Index	6	7	8
0	-2.739765256223D-06	2.927097984040D-07	-6.646459819509D-09
1	-2.632450715422D-05	9.987762315441D-07	-1.501421276021D-08
2	1.441627470961D-05	-5.481720522735D-07	8.264009775214D-09
3	2.416915703008D-06	-6.658457254421D-08	8.215818515744D-10
4	-7.772290534634D-07	2.655224800515D-08	-3.968977724198D-10
5	-2.470245979511D-07	5.722044899754D-09	-5.443566855045D-11
6	2.955124264492D-08	3.184408123607D-11	-8.216232831023D-12
7	7.390396686250D-09	-4.052521721349D-10	6.720841155202D-12
8	-8.635578634097D-10	3.738695038824D-11	-5.757075610089D-13

P2MIN = 1.00000D 08 1/CM3
P2MAX = 1.00000D 16 1/CM3
Max. rel. Error: 3.7804 %
Mean rel. Error: 1.3368 %



Col.–Rad. Equil. Ratio of H_ground to H+ densities
Reiter/Savada/Fujimoto
Ratio H+/H_ground
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08



Multistep hydrogenic population coefficients
Data: L.C.Johnson, Fujimoto
Ratio of population coefficients p(3)/p(1)
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

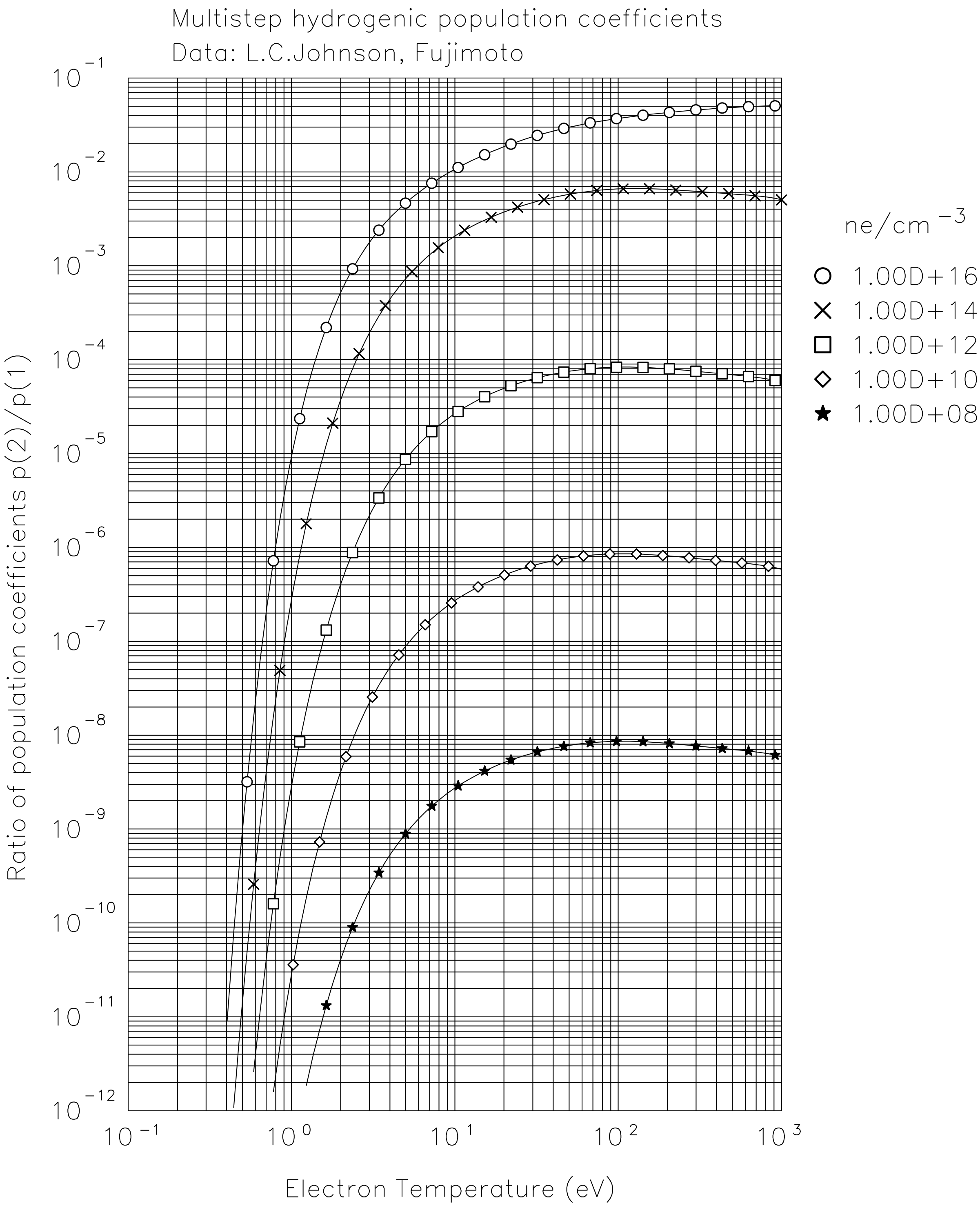
12.3 Reaction 2.1.5b $H + e \rightarrow H^+ + 2e$, Ratio $H(2)/H(1)$

T-Index \ E-Index:	0	1	2
0	-2.888782240542D+01	9.694042304562D-01	4.613129045722D-02
1	9.909537514500D+00	-4.163537878599D-02	2.444011013342D-02
2	-4.942743781185D+00	1.230545313063D-02	-1.289174377763D-02
3	1.715668267417D+00	3.034149311755D-02	-1.837812030403D-02
4	-4.508004155190D-01	-1.136449435241D-02	7.857406065923D-03
5	9.042516000563D-02	-2.874540451423D-03	1.787805444265D-03
6	-1.280973933282D-02	1.947546784046D-03	-1.325209820376D-03
7	1.084341450206D-03	-3.175349945580D-04	2.227323600480D-04
8	-3.974359134401D-05	1.688199339120D-05	-1.209472946500D-05

T-Index \ E-Index:	3	4	5
0	-2.216757216719D-02	5.067711671376D-03	-6.212032986616D-04
1	-5.092551836572D-03	4.080645015829D-04	-5.739581031596D-06
2	4.174980751883D-03	-5.559754475561D-04	2.207616832672D-05
3	3.719122644080D-03	-2.039974521144D-04	-2.170634046629D-05
4	-1.818309410916D-03	1.348196284756D-04	7.621772971297D-06
5	-4.049163510078D-04	3.839701084642D-05	-1.182790529172D-06
6	3.200749637228D-04	-3.075854301471D-05	4.485031199179D-07
7	-5.559573928329D-05	5.656373947352D-06	-1.236115053324D-07
8	3.100021285561D-06	-3.323560174565D-07	9.896407186442D-09

T-Index \ E-Index:	6	7	8
0	4.172445968364D-05	-1.439572350231D-06	1.978486731178D-08
1	-6.441112682031D-07	1.766524953307D-08	4.500335193180D-11
2	1.604359947467D-06	-1.668549821257D-07	3.956288361818D-09
3	3.319046346231D-06	-1.530562339677D-07	2.467744887550D-09
4	-1.742105663717D-06	9.539025646066D-08	-1.764749848063D-09
5	-3.224230256996D-08	2.293257666191D-09	-2.626033062059D-11
6	1.187820950781D-07	-7.725204735890D-09	1.455730327605D-10
7	-1.829679294498D-08	1.312011360384D-09	-2.576831583186D-11
8	8.003219743811D-10	-6.578827971726D-11	1.343525928267D-12

P2MIN = 1.00000D 08 1/CM3
P2MAX = 1.00000D 16 1/CM3
Max. rel. Error: 5.0202 %
Mean rel. Error: .9593 %



Multistep hydrogenic population coefficients
Data: L.C.Johnson, Fujimoto
Ratio of population coefficients p(2)/p(1)
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

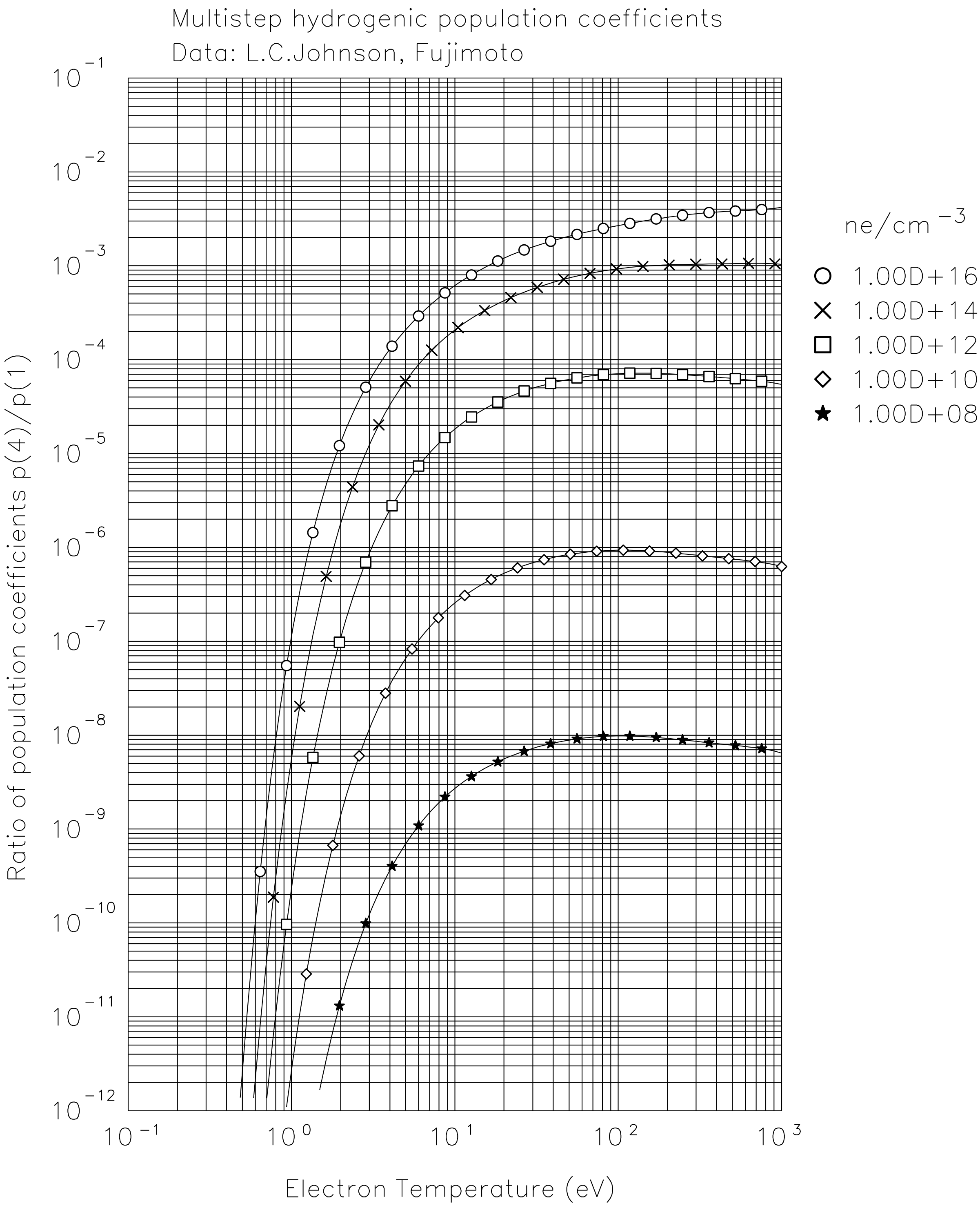
12.4 Reaction 2.1.5c $H + e \rightarrow H^{+} + 2e$, Ratio $H(4)/H(1)$

T-Index \ E-Index	0	1	2
0	-3.121459339796D+01	8.335828009713D-01	2.325042085123D-01
1	1.250950592132D+01	9.112878380113D-03	-5.491646502669D-02
2	-6.229984587067D+00	-1.938627422961D-02	1.621303063286D-02
3	2.142105600364D+00	3.084489232048D-02	-3.147946146487D-03
4	-5.615155300856D-01	-5.885518785970D-03	-1.131771898094D-03
5	1.127449459065D-01	-6.211271050025D-03	3.856805502108D-03
6	-1.590343046823D-02	2.950230045038D-03	-1.748272049931D-03
7	1.333705010633D-03	-4.583201098446D-04	2.858630200307D-04
8	-4.836027605927D-05	2.417569815070D-05	-1.585276481393D-05

T-Index \ E-Index	3	4	5
0	-1.096388203376D-01	2.434624647621D-02	-2.848412091044D-03
1	2.972045500915D-02	-6.752777629102D-03	7.907482466413D-04
2	-6.819605362801D-03	1.639046907231D-03	-2.316409264833D-04
3	-4.981563534979D-03	1.797076203455D-03	-2.547644660956D-04
4	2.277414510956D-03	-7.295707497520D-04	1.047093315160D-04
5	-9.720154554360D-04	1.201895430371D-04	-7.956678504065D-06
6	3.838584264558D-04	-3.212460389716D-05	-8.181068284295D-08
7	-6.739012881651D-05	6.684315041032D-06	-1.703080933280D-07
8	4.013119711268D-06	-4.619672863742D-07	2.215787076654D-08

T-Index \ E-Index	6	7	8
0	1.789669578362D-04	-5.712451213773D-06	7.267386885023D-08
1	-5.078726612521D-05	1.694110618282D-06	-2.296731891384D-08
2	1.859544292047D-05	-7.663932535000D-07	1.248233937322D-08
3	1.790413918002D-05	-6.225635876900D-07	8.589352663796D-09
4	-7.734966472367D-06	2.868598630187D-07	-4.235795995646D-09
5	2.942004754571D-07	-6.030861909870D-09	5.715848860621D-11
6	1.721805311242D-07	-9.730371684031D-09	1.730299677672D-10
7	-1.655594650506D-08	1.235894145239D-09	-2.408500349383D-11
8	2.731478375019D-11	-3.750344543532D-11	9.061707694269D-13

P2MIN = 1.00000D 08 1/CM3
P2MAX = 1.00000D 16 1/CM3
Max. rel. Error: 3.6808 %
Mean rel. Error: 1.2901 %


Multistep hydrogenic population coefficients
Data: L.C.Johnson, Fujimoto
Ratio of population coefficients p(4)/p(1)
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

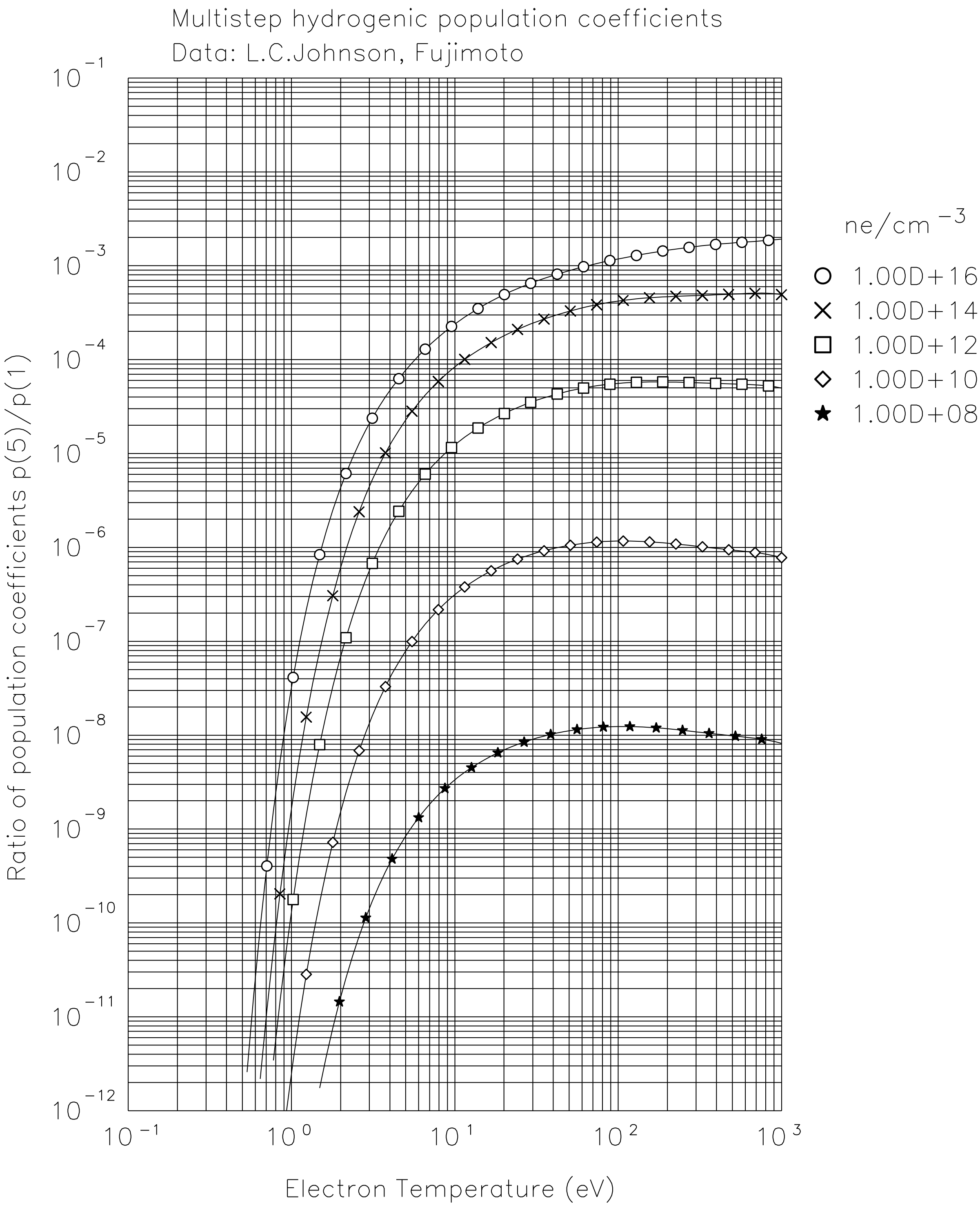
12.5 Reaction 2.1.5d $H + e \rightarrow H^+ + 2e$, Ratio $H(5)/H(1)$

T-Index \ E-Index	0	1	2
0	-3.126718125624D+01	9.282945460974D-01	1.070213380676D-01
1	1.281374709913D+01	3.573873112144D-02	-4.872701879146D-02
2	-6.380408105491D+00	-1.144110981890D-03	-4.680598150266D-05
3	2.191577061685D+00	-5.161589020256D-03	6.439656957369D-03
4	-5.751755938054D-01	1.676622419964D-03	-1.568501026478D-03
5	1.157406495600D-01	1.486290009897D-04	-1.404765081110D-04
6	-1.631671197369D-02	-2.016003370833D-04	1.639222741263D-04
7	1.362647208936D-03	3.901702147732D-05	-3.141140575728D-05
8	-4.908854946631D-05	-2.325049769834D-06	1.888930116590D-06

T-Index \ E-Index	3	4	5
0	-5.984835557747D-02	1.574482420977D-02	-2.152803383431D-03
1	2.122340688681D-02	-4.335261058803D-03	4.511000731668D-04
2	4.899399906199D-04	-1.730051136321D-04	2.045111743029D-05
3	-2.595193985854D-03	5.083896758770D-04	-5.001475048416D-05
4	5.235042780927D-04	-8.901350181088D-05	8.437562876296D-06
5	1.953433357615D-05	3.171136646292D-06	-1.281135706652D-06
6	-3.782479181914D-05	2.829273502486D-06	1.645529677700D-07
7	7.810730453019D-06	-7.640509497691D-07	9.357372398314D-09
8	-4.970298877362D-07	5.607762235203D-08	-2.232480288100D-09

T-Index \ E-Index	6	7	8
0	1.533450613139D-04	-5.416190220272D-06	7.503092506245D-08
1	-2.514757812007D-05	7.098607959133D-07	-7.948198678409D-09
2	-4.780097207035D-07	-3.664829135622D-08	1.435704784493D-09
3	2.378856833473D-06	-4.662729327187D-08	1.885707833825D-10
4	-4.722754735716D-07	1.525662957088D-08	-2.277373255316D-10
5	1.539182389681D-07	-7.795475709363D-09	1.408203935795D-10
6	-3.844013350899D-08	2.070018927471D-09	-3.568996816514D-11
7	3.398945819263D-09	-2.120439941817D-10	3.643140818164D-12
8	-6.095037813579D-11	6.718495301125D-12	-1.229967242093D-13

```
P2MIN =   1.00000D 08 1/CM3
P2MAX =   1.00000D 16 1/CM3
  Max. rel. Error:   2.8664 %
  Mean rel. Error:   1.0041 %
```



Multistep hydrogenic population coefficients
Data: L.C.Johnson, Fujimoto
Ratio of population coefficients p(5)/p(1)
Electron Temperature (eV)
10^-1
10^-2
10^-3
10^-4
10^-5
10^-6
10^-7
10^-8
10^-9
10^-10
10^-11
10^-12
10^-1
10^0
10^1
10^2
10^3
ne/cm^-3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

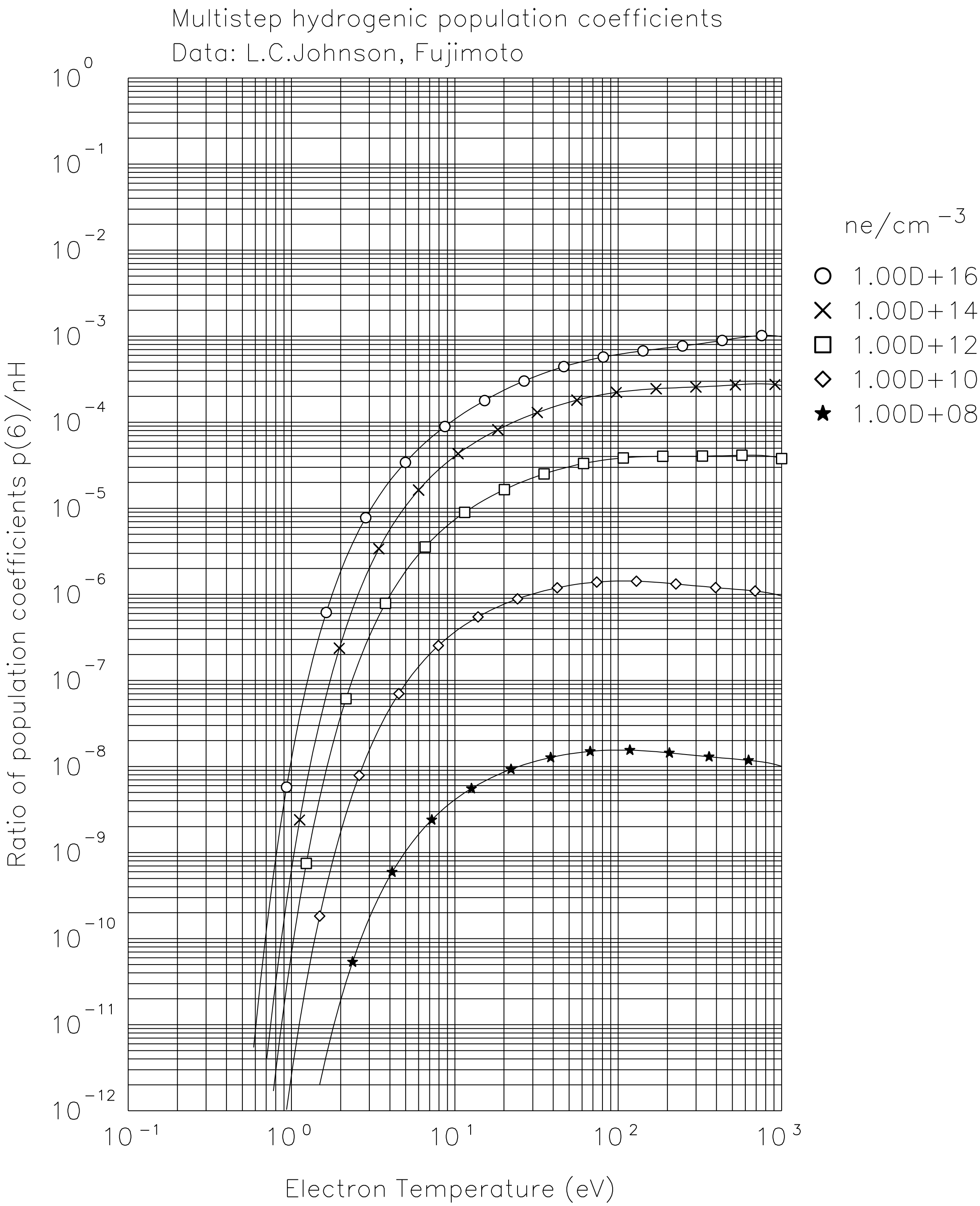
12.6 Reaction 2.1.5e $H + e \rightarrow H^+ + 2e$, Ratio $H(6)/H(1)$

T-Index \ E-Index	0	1	2
0	-3.118788806329D+01	1.051705868661D+00	-6.954764617920D-02
1	1.300365034969D+01	5.806024278787D-02	-7.054107872877D-02
2	-6.464611656902D+00	-3.350148712230D-02	3.809632279775D-02
3	2.198690942590D+00	-1.651116960139D-02	1.248202030331D-02
4	-5.762198964354D-01	8.782966049217D-03	-7.253814512300D-03
5	1.190459835777D-01	7.937734220940D-04	-3.032198147605D-04
6	-1.758172528529D-02	-8.425168421647D-04	4.935184501531D-04
7	1.540671110406D-03	1.322737632505D-04	-7.161027491097D-05
8	-5.782468318198D-05	-6.483373521666D-06	3.088146690349D-06

T-Index \ E-Index	3	4	5
0	2.612329534702D-02	-3.911384137475D-03	1.474794675693D-04
1	3.209814487839D-02	-7.336538391803D-03	8.838327301328D-04
2	-1.663574690203D-02	3.667522832624D-03	-4.409479869479D-04
3	-3.600008781362D-03	5.273464947078D-04	-4.137511227236D-05
4	2.434417487959D-03	-4.385057360151D-04	4.589037396076D-05
5	-6.693627833492D-05	4.755833322780D-05	-8.654363224389D-06
6	-8.020637279277D-05	-2.254322145665D-06	1.858918078917D-06
7	9.120131097155D-06	1.138969748088D-06	-3.791832116704D-07
8	-1.704370060355D-07	-1.258928004543D-07	2.744344149529D-08

T-Index \ E-Index	6	7	8
0	9.191757017392D-06	-7.898231632650D-07	1.514512376570D-08
1	-5.779085565904D-05	1.935287412436D-06	-2.603161887414D-08
2	2.975048782418D-05	-1.054940416948D-06	1.523660684271D-08
3	1.553774051571D-06	-1.704433673171D-08	-2.016881015852D-10
4	-2.785668187173D-06	9.065547432614D-08	-1.223436753078D-09
5	7.303664535216D-07	-2.952279140710D-08	4.597194098628D-10
6	-1.970736415814D-07	8.619751903229D-09	-1.383868509607D-10
7	3.596045684588D-08	-1.495930494169D-09	2.332244458469D-11
8	-2.357827363714D-09	9.371149524100D-11	-1.424213663602D-12

P2MIN = 1.00000D 08 1/CM3
P2MAX = 1.00000D 16 1/CM3
Max. rel. Error: 5.6136 %
Mean rel. Error: 1.7770 %


Multistep hydrogenic population coefficients
Data: L.C.Johnson, Fujimoto
Ratio of population coefficients p(6)/nH
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

12.7 Reaction 2.1.5tot $H + e \rightarrow H^+ + 2e$, Ratio $H(tot)/H(1)$

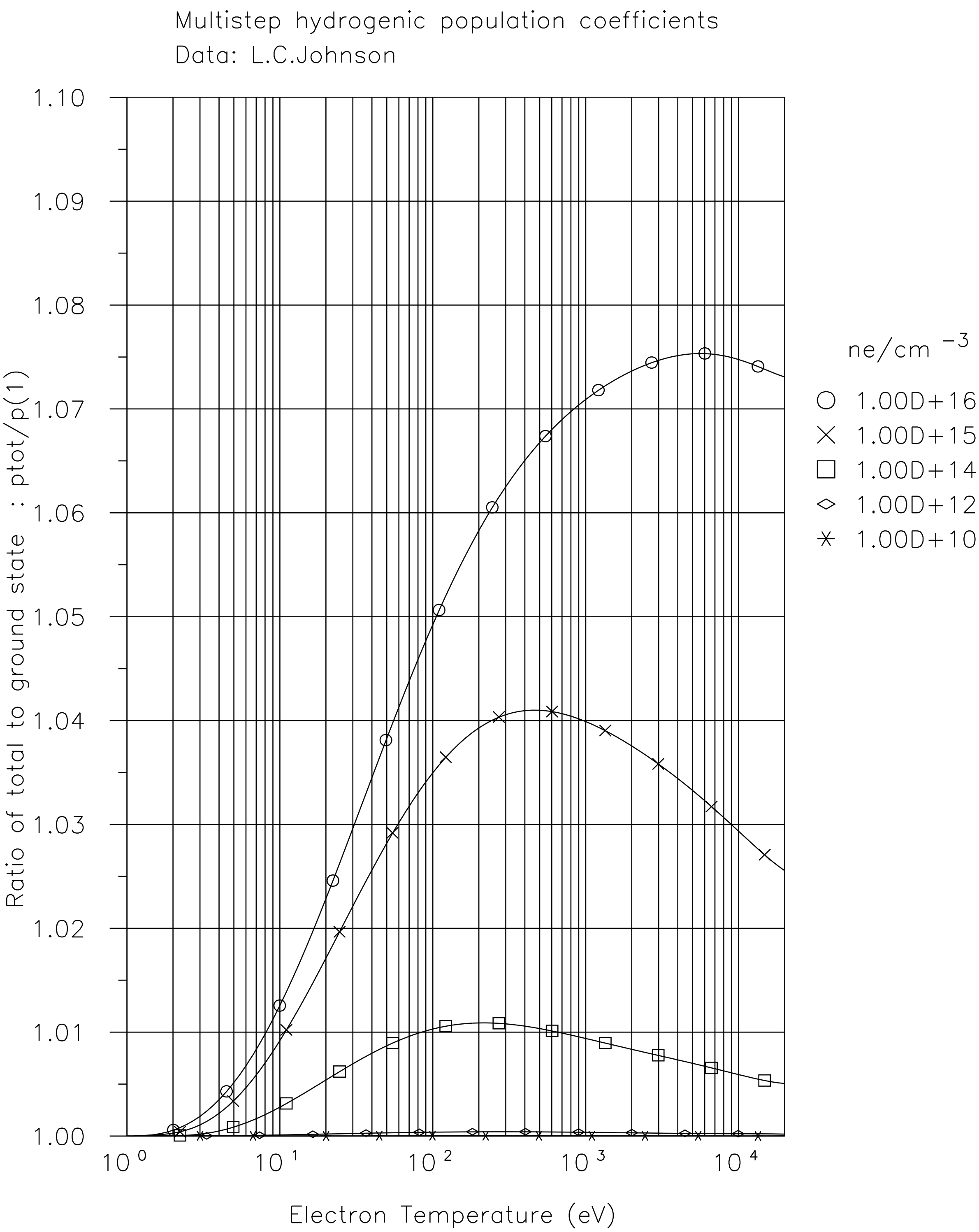
total density (ground plus all excited states) in CR equilibrium with ground state

T-Index \ E-Index	0	1	2
0	9.999989080920D-01	6.569869814870D-04	-6.526259178085D-04
1	-6.684079057216D-06	-1.624733380895D-03	1.517116722391D-03
2	2.553992642225D-05	9.833706477844D-04	-8.771533719662D-04
3	-2.462557791473D-05	-2.342847322381D-04	2.116654525863D-04
4	1.062360801108D-05	2.225391064535D-05	-2.995563308037D-05
5	-2.399855499712D-06	2.478808045973D-06	1.242643822457D-06
6	2.951154702233D-07	-7.469982004941D-07	1.518536644908D-07
7	-1.871893412626D-08	5.751651874704D-08	-1.380451507029D-08
8	4.796659338151D-10	-1.452959768161D-09	2.101916949778D-10

T-Index \ E-Index	3	4	5
0	2.446820545529D-04	-4.633538453818D-05	4.889372584120D-06
1	-5.196975095555D-04	8.835186629866D-05	-8.286820244724D-06
2	2.694565448733D-04	-3.889200026191D-05	2.928290705068D-06
3	-5.533211626824D-05	5.123221852559D-06	-1.729804749149D-08
4	8.273895035263D-06	-6.797808694765D-07	-1.060219799928D-08
5	-5.874504858843D-07	4.859497595281D-08	1.114394044002D-09
6	7.883226202848D-09	-1.005021139591D-09	-2.177196303683D-10
7	-9.799681363679D-10	4.054138156358D-10	-2.970144566810D-11
8	1.213701692902D-10	-3.377976381012D-11	3.362497319640D-12

T-Index \ E-Index	6	7	8
0	-2.917482144379D-07	9.209996969945D-09	-1.195587997940D-10
1	4.378814547750D-07	-1.223407550017D-08	1.405657502664D-10
2	-1.169351655337D-07	2.258524229896D-09	-1.460715455401D-11
3	-2.426972326758D-08	1.404805094637D-09	-2.540724522759D-11
4	3.476416204584D-09	-1.330157773056D-10	1.424915474012D-12
5	-8.129340876771D-11	-1.183776577049D-11	5.125710307402D-13
6	5.313468965034D-12	1.675867714679D-12	-6.770309443179D-14
7	1.619425683239D-12	-1.268121213878D-13	3.934356277466D-15
8	-1.798937732279D-13	6.521970562366D-15	-1.251030581090D-16

P2MIN = 1.00000D 08 1/CM3
P2MAX = 1.00000D 16 1/CM3



Multistep hydrogenic population coefficients
Data: L.C.Johnson
1.10
1.09
1.08
1.07
1.06
1.05
1.04
1.03
1.02
1.01
1.00
10 0
10 1
10 2
10 3
10 4
Electron Temperature (eV)
Ratio of total to ground state : ptot/p(1)
ne/cm -3
1.00D+16
1.00D+15
1.00D+14
1.00D+12
1.00D+10

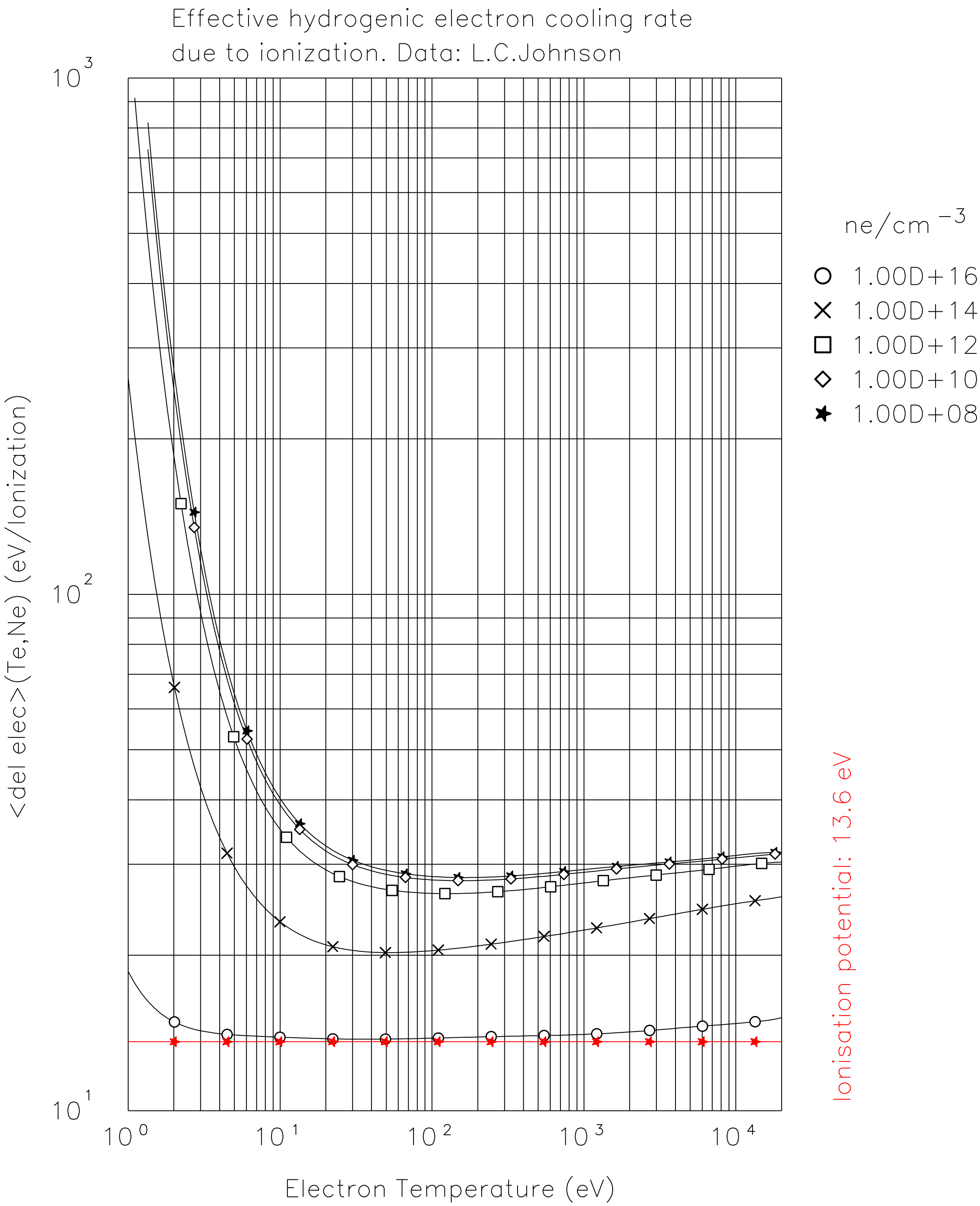
12.8 Reaction 2.1.5de $H + e \rightarrow H^+ + 2e$, $< de >$ $[eV]$

T-Index \ E-Index	0	1	2
0	7.845107077886D+00	-4.158388629994D-02	2.060681712432D-02
1	-4.270502285463D+00	9.505957771815D-02	-7.673602080150D-02
2	1.726068286328D+00	-4.522519386379D-02	5.154287556942D-02
3	-3.652415321353D-01	-5.349008403944D-03	-1.089345117269D-02
4	3.713344797329D-02	9.550154852851D-03	-1.137782108759D-03
5	-1.816044037023D-04	-2.867587202499D-03	8.354453807701D-04
6	-3.430690631609D-04	3.909898872586D-04	-1.337503951808D-04
7	3.098356603724D-05	-2.559885625243D-05	9.077886701887D-06
8	-8.899184097510D-07	6.519466167972D-07	-2.268251226270D-07

T-Index \ E-Index	3	4	5
0	-8.052322446345D-03	1.361616907232D-03	-1.426513742220D-04
1	2.563880114503D-02	-3.821401798942D-03	2.937551907788D-04
2	-1.720715317463D-02	2.290689977061D-03	-1.253606753443D-04
3	4.775945182204D-03	-6.467228312794D-04	2.975489992699D-05
4	-3.721823938539D-04	7.419831565375D-05	-3.809552723616D-06
5	-8.073915024648D-05	3.196729352202D-06	-4.577796946576D-08
6	1.863239051629D-05	-1.462457758789D-06	6.102229658187D-08
7	-1.331114942698D-06	1.094119960469D-07	-4.763060764998D-09
8	3.160102832021D-08	-2.366622776376D-09	9.028757163018D-11

T-Index \ E-Index	6	7	8
0	9.199187026673D-06	-3.626126425744D-07	6.526649455096D-09
1	-1.081310544107D-05	1.291895685695D-07	1.068484717217D-09
2	-1.280245967862D-08	2.592986543781D-07	-7.113378488276D-09
3	8.057527653614D-07	-1.189385405932D-07	2.982171776258D-09
4	-9.060932716087D-08	1.580536007694D-08	-4.320760123314D-10
5	-5.069290362681D-10	-2.785729865499D-10	1.593762976817D-11
6	2.554338381631D-10	-9.890935002552D-11	1.770328452101D-12
7	-9.336950682103D-12	8.093464288205D-12	-1.767574119215D-13
8	1.044083905543D-12	-2.066392792622D-13	4.436324698144D-15

P2MIN = 1.00000D 08 1/CM3
P2MAX = 1.00000D 16 1/CM3
Max. rel. Error: .4629 %
Mean rel. Error: .0970 %

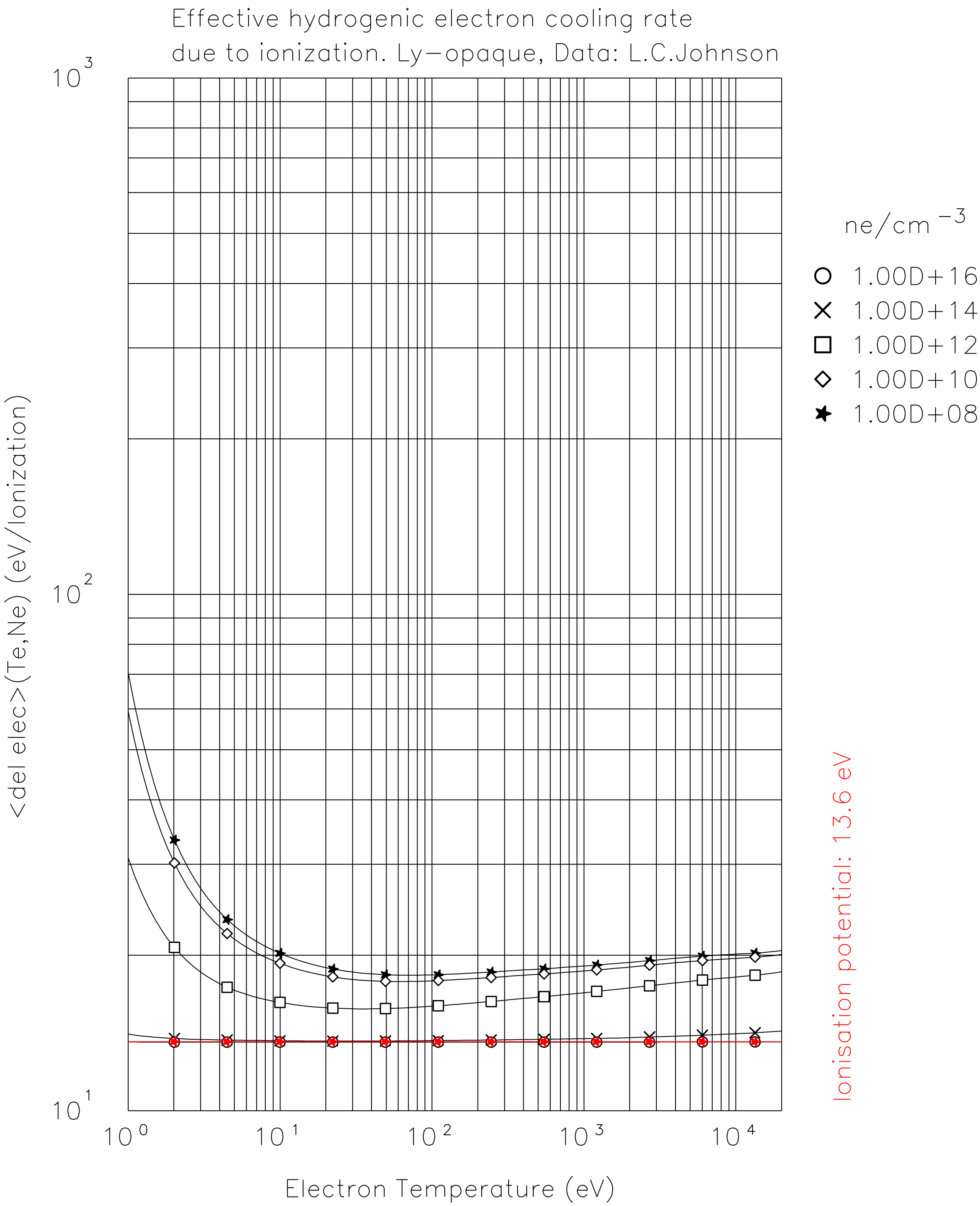


Effective hydrogenic electron cooling rate
due to ionization. Data: L.C.Johnson
<del elec>(Te,Ne) (eV/Ionization)
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08
Ionisation potential: 13.6 eV

12.9 Reaction 2.1.5o $H + e \rightarrow H^+ + 2e$, $< de >$ $[eV]$ Ly-opaque

Lyman opaque

```
      E-Index:     0                    1                    2
  T-Index:
      0     4.257426092590D+00   -2.648139307081D-01    2.747475375517D-01
      1    -1.580642905913D+00    1.856918325247D-01   -1.887867610999D-01
      2     9.487720032428D-01   -4.334108248024D-02    4.027363438413D-02
      3    -3.653667544231D-01    1.938361132039D-03   -1.064922255960D-03
      4     9.142288235830D-02    6.321600657670D-04   -1.359591518986D-04
      5    -1.446402551044D-02   -2.277509541327D-04   -1.939963902602D-05
      6     1.384901599216D-03    4.074186530390D-05    1.262940841492D-06
      7    -7.297260412218D-05   -3.278960026730D-06    5.700992619392D-08
      8     1.620578859074D-06    9.263823594567D-08    1.592211120194D-09

      E-Index:     3                    4                    5
  T-Index:
      0    -1.211356030412D-01    2.685695232533D-02   -3.317777605290D-03
      1     8.363647099141D-02   -1.868059156820D-02    2.327504355627D-03
      2    -1.875679395058D-02    4.434521459505D-03   -5.945647526149D-04
      3     7.959030639825D-04   -2.528345636722D-04    5.007272230577D-05
      4     5.074526064710D-06   -3.035134696595D-06   -2.203465100709D-06
      5     2.365267620753D-05   -2.398473162099D-06    3.489675236875D-07
      6    -3.631085495565D-06    4.137564902109D-07   -2.971694422141D-08
      7     2.493062937307D-07   -3.179509396878D-08    1.585728061318D-09
      8    -9.298947595442D-09    1.468230792208D-09   -9.887260958280D-11

      E-Index:     6                    7                    8
  T-Index:
      0     2.278436663051D-04   -8.091967627921D-06    1.156866070535D-07
      1    -1.605612738266D-04    5.703707563566D-06   -8.131849775947D-08
      2     4.346897926519D-05   -1.605515516330D-06    2.346223121561D-08
      3    -4.662162321782D-06    1.981562216998D-07   -3.155996422050D-09
      4     3.653404338885D-07   -1.942106127435D-08    3.499018522662D-10
      5    -3.942216779052D-08    2.001379932680D-09   -3.673145766979D-11
      6     1.954467664699D-09   -8.738736712781D-11    1.665200022479D-12
      7    -2.359672833575D-11   -4.475930371767D-13    7.240045137258D-15
      8     2.798900106658D-12   -1.040603787711D-14   -5.219184133080D-16
P2MIN =   1.00000D 08 1/CM3
P2MAX =   1.00000D 16 1/CM3
  Max. rel. Error:    .4321 %
  Mean rel. Error:    .0858 %
```



Effective hydrogenic electron cooling rate
due to ionization. Ly−opaque, Data: L.C.Johnson
<del elec>(Te,Ne) (eV/Ionization)
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08
Ionisation potential: 13.6 eV

12.10 Reaction 2.1.8 $H^+ + e \leftrightarrow H(1s)$, Ratio $H(1)/H^+$

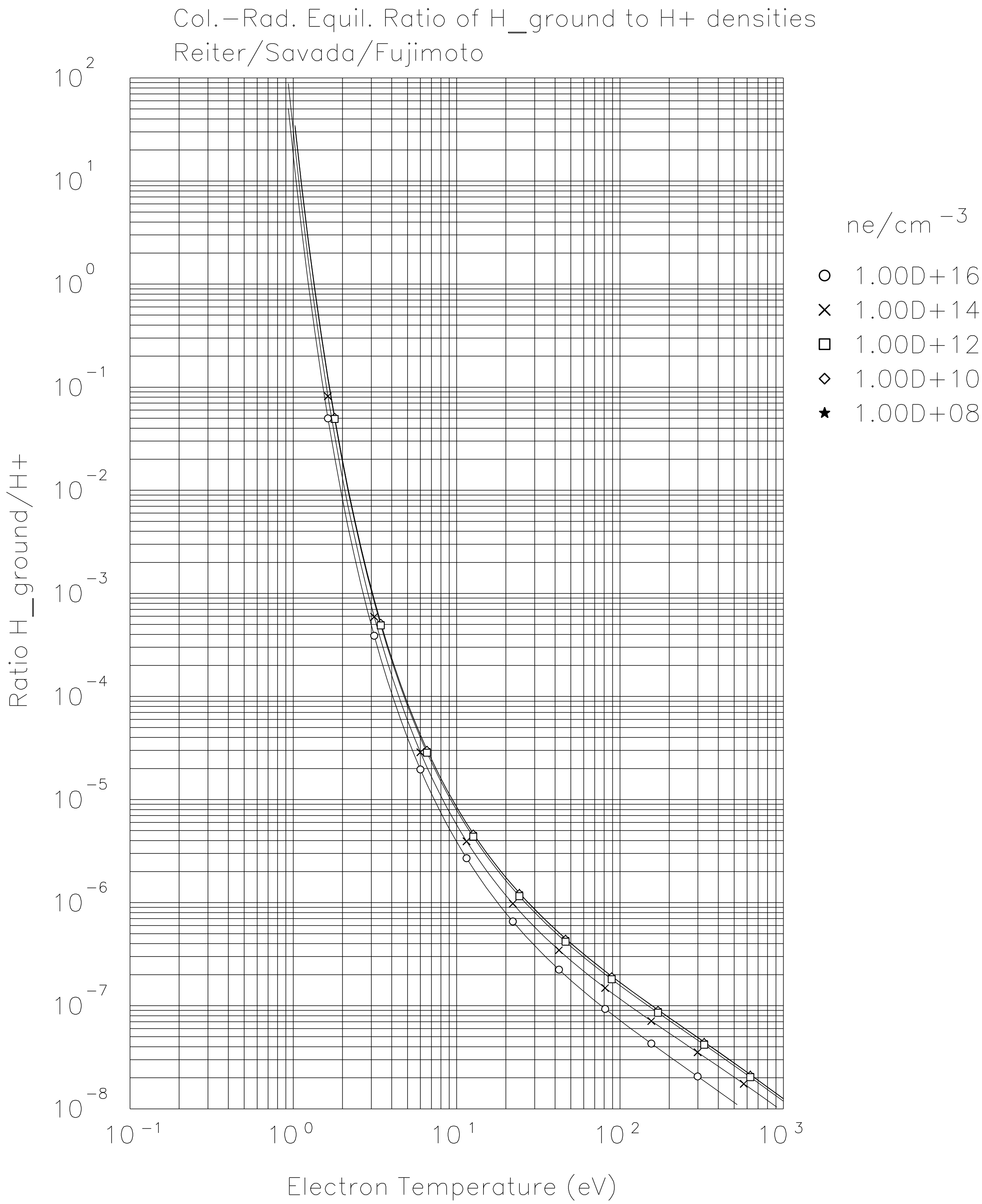
This ratio provides the collisional radiative equilibrium ground state atom density, for a given ion density.
From $0 = n_1 \times \langle s_{ion} \rangle - n^+ \times \langle \alpha_{rec} \rangle$.
Assumed: $n^+ = n_e$. This is the inverse ratio of the ratio H^+/H given above.

T-Index \ E-Index:	0	1	2
0	3.884817920291D+00	5.748230037228D-02	-7.354743589465D-02
1	-1.505405435407D+01	-2.069666264052D-03	2.740273217181D-03
2	6.752413643513D+00	-2.852568692095D-03	2.645950103684D-03
3	-2.218947925718D+00	3.880371810496D-04	2.448954939235D-03
4	5.306456586404D-01	-1.106924750936D-03	-1.425570179604D-03
5	-8.996474445862D-02	8.001173589203D-04	1.442342394885D-04
6	1.012370581895D-02	-1.970308892236D-04	1.763054900761D-05
7	-6.725100993525D-04	2.003187510884D-05	-2.805603265326D-06
8	1.980680600260D-05	-7.148042140142D-07	5.062324995954D-08

T-Index \ E-Index:	3	4	5
0	3.514369843739D-02	-8.200095897737D-03	1.029247980732D-03
1	-2.232044284757D-03	7.372183809405D-04	-1.199006377953D-04
2	-1.418041310973D-03	3.361254031169D-04	-3.854655884633D-05
3	-6.306614528176D-04	2.629206773651D-05	6.811979362899D-06
4	5.100161790571D-04	-6.541482923176D-05	3.819981137349D-06
5	-6.628089424783D-05	7.250593421266D-06	-4.680128307062D-07
6	-2.918830286653D-06	1.005848267335D-06	-7.444889071158D-08
7	5.969286375471D-07	-1.181102409670D-07	3.398470038793D-09
8	3.373896520254D-09	-1.875159711383D-09	7.447934965772D-10

T-Index \ E-Index:	6	7	8
0	-7.065616546499D-05	2.476181590024D-06	-3.448732313124D-08
1	1.010186897559D-05	-4.156554445603D-07	6.576866918837D-09
2	2.077865905425D-06	-4.493493845615D-08	1.680184085191D-10
3	-8.395863513859D-07	3.306347645323D-08	-4.092185917718D-10
4	-9.078967708851D-08	7.126270754412D-10	-1.502691682691D-11
5	2.975843593936D-08	-1.562087549982D-09	3.533269604119D-11
6	-2.195532523309D-09	3.847295886912D-10	-1.006718276842D-11
7	8.756896081564D-10	-7.247037436751D-11	1.603229219763D-12
8	-9.983397630247D-11	5.334255622655D-12	-1.003858224247D-13

```
P2MIN =   1.00000D 08 1/CM3
P2MAX =   1.00000D 16 1/CM3
  Max. rel. Error:    .9699 %
  Mean rel. Error:    .4163 %
```


Col.−Rad. Equil. Ratio of H_ground to H+ densities
Reiter/Savada/Fujimoto
Ratio H_ground/H+
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

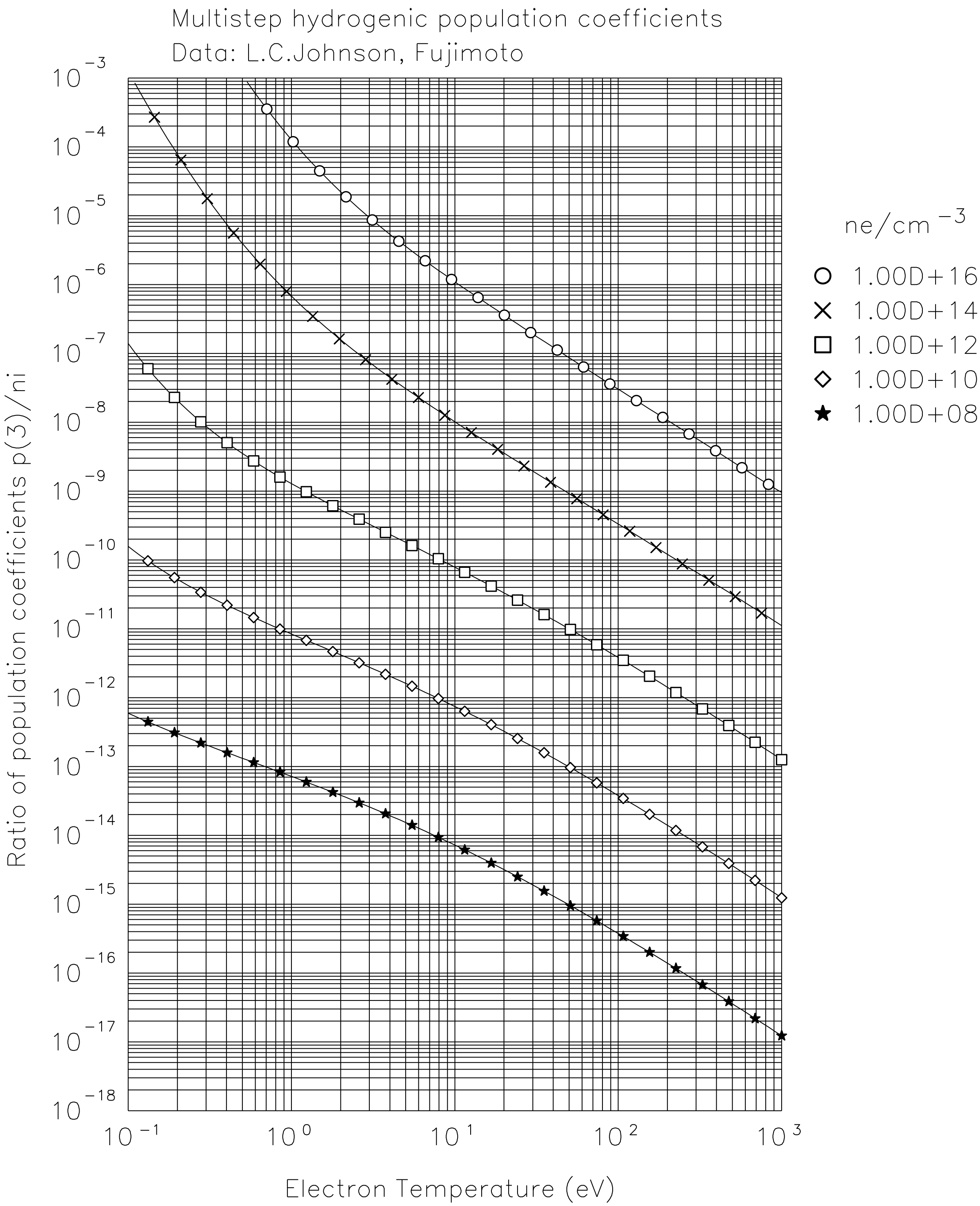
12.11 Reaction 2.1.8a $H^+ + e \rightarrow H(1s)$, Ratio $H(3)/H^+$

T-Index \ E-Index	0	1	2
0	-3.026567737773D+01	1.152583719426D+00	-1.626038509544D-01
1	-8.879460687468D-01	-5.351933360860D-02	4.426984905627D-02
2	-2.779342631813D-02	6.030457249067D-03	1.515441331512D-03
3	-1.196375890811D-02	-2.871588085187D-03	2.404285503458D-04
4	1.822980963695D-03	-1.575168978328D-06	8.405772103417D-04
5	-2.196477309909D-04	5.066260303625D-04	-5.971643097799D-04
6	3.323843511157D-05	-1.520492801515D-04	1.281232614617D-04
7	-1.697007294106D-06	1.825841763069D-05	-1.220563921933D-05
8	-5.916439943353D-08	-8.242186020597D-07	4.677827163183D-07

T-Index \ E-Index	3	4	5
0	7.198684018769D-02	-1.490875604355D-02	1.619553420918D-03
1	-1.852578901204D-02	3.331452439870D-03	-2.948572788751D-04
2	-9.056841023031D-04	3.563549006757D-04	-5.590965690725D-05
3	-8.226476286514D-05	2.960920971970D-05	-8.086208258569D-06
4	-3.464740688021D-04	5.922304252082D-05	-4.850028146748D-06
5	2.105198711062D-04	-3.609362517850D-05	3.423756972171D-06
6	-3.517980076344D-05	4.427958188863D-06	-2.493221748446D-07
7	2.198069639127D-06	-6.705985847102D-09	-4.128988875743D-08
8	-4.300266775823D-08	-1.512563397687D-08	4.068624995447D-09

T-Index \ E-Index	6	7	8
0	-9.269115359815D-05	2.618073045777D-06	-2.835709536455D-08
1	1.169406889954D-05	-1.253572620552D-07	-1.886947676134D-09
2	4.196575697004D-06	-1.482582457939D-07	1.946426380509D-09
3	9.143236603084D-07	-4.362855429636D-08	7.452885416070D-10
4	2.164045324446D-07	-6.474547723428D-09	1.156823417385D-10
5	-1.851415491252D-07	5.487390918519D-09	-7.088510716926D-11
6	4.694709505540D-10	5.338069108949D-10	-1.542307935794D-11
7	5.373013388538D-09	-2.844239825756D-10	5.516973870161D-12
8	-4.168331974260D-10	2.004403028395D-11	-3.695127505869D-13

P2MIN = 1.00000D 08 1/CM3
P2MAX = 1.00000D 16 1/CM3
Max. rel. Error: 4.5193 %
Mean rel. Error: .9402 %



Multistep hydrogenic population coefficients
Data: L.C.Johnson, Fujimoto
Ratio of population coefficients p(3)/ni
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08
10 −3
10 −4
10 −5
10 −6
10 −7
10 −8
10 −9
10 −10
10 −11
10 −12
10 −13
10 −14
10 −15
10 −16
10 −17
10 −18
10 −1
10 0
10 1
10 2
10 3

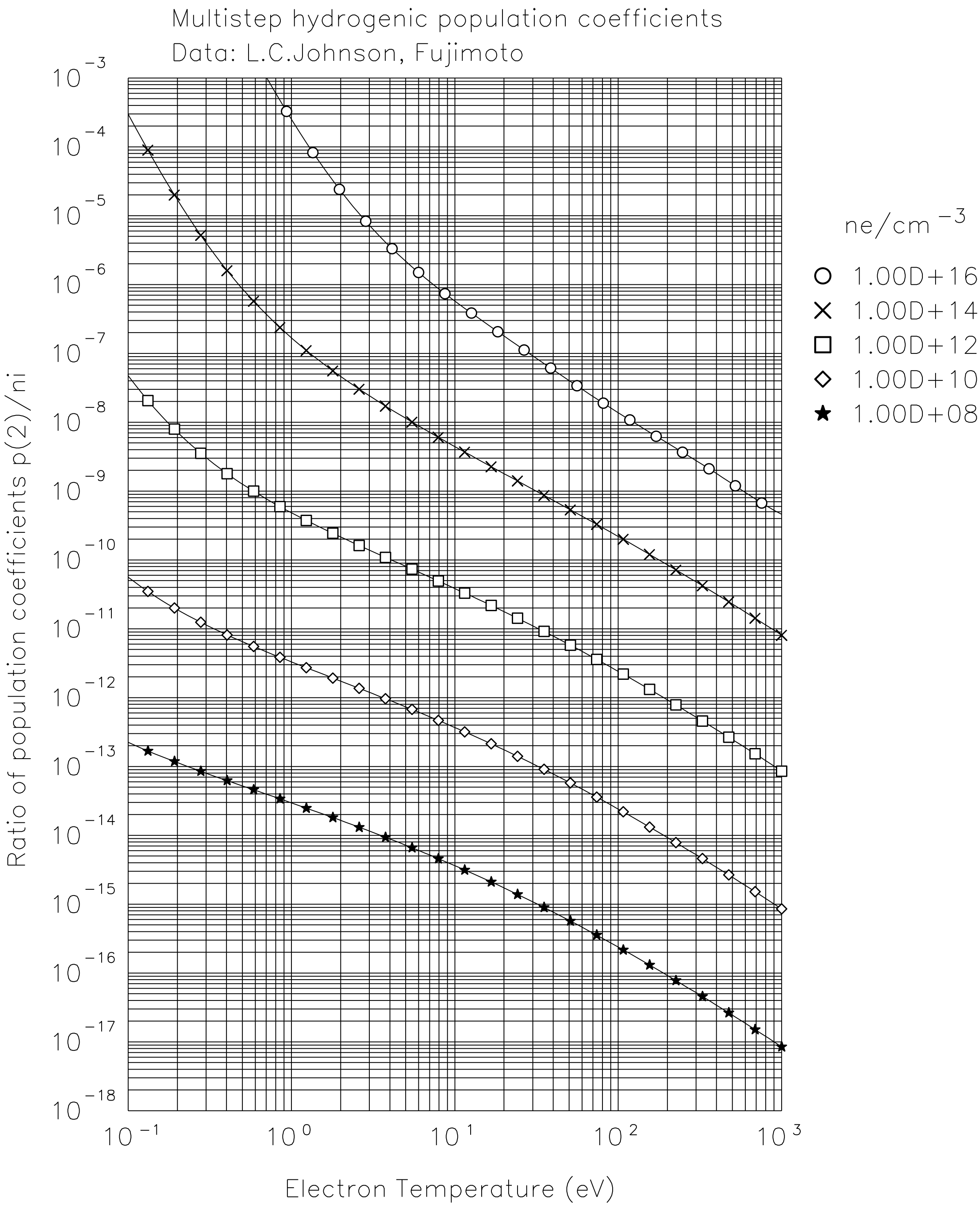
12.12 Reaction 2.1.8b $H^+ + e \rightarrow H(1s)$, Ratio $H(2)/H^+$

T-Index \ E-Index	0	1	2
0	-3.115038577088D+01	9.264747680865D-01	1.116069825638D-01
1	-8.266322399304D-01	-5.055344435832D-03	-5.172879304080D-03
2	-1.958933034940D-02	1.996587961213D-02	-1.406505755991D-02
3	-1.098097104386D-02	-8.026613963832D-03	2.384792377395D-03
4	2.240953060530D-03	6.216308441596D-04	4.708126181720D-04
5	-4.287502766451D-04	1.030957503524D-03	-8.066658779253D-04
6	2.695143837765D-05	-3.813692505803D-04	2.807631048773D-04
7	4.431006229058D-06	4.875879498318D-05	-3.657593211279D-05
8	-4.836943342929D-07	-2.119652719791D-06	1.615837004793D-06

T-Index \ E-Index	3	4	5
0	-4.999361806664D-02	1.110692800547D-02	-1.318266873039D-03
1	-2.471719625656D-04	2.512113939106D-04	-4.782708408420D-05
2	6.003957672996D-03	-1.118685805994D-03	1.071846833065D-04
3	2.913902175387D-04	-3.137930614752D-04	6.113629942161D-05
4	-3.710502524841D-04	1.004704612837D-04	-1.265344424602D-05
5	1.874529789965D-04	-9.988538268116D-06	-1.920784234786D-06
6	-6.603768771619D-05	4.665491245671D-06	3.297381117360D-07
7	9.282643997639D-06	-9.265752285496D-07	1.709073955313D-08
8	-4.302365964264D-07	5.056403909495D-08	-2.595051961188D-09

T-Index \ E-Index	6	7	8
0	8.540286307962D-05	-2.815699854432D-06	3.675943603675D-08
1	3.802889409563D-06	-1.453090712874D-07	2.181183016555D-09
2	-5.066273468359D-06	9.656495668618D-08	-2.071395871695D-10
3	-5.318038556138D-06	2.186221742805D-07	-3.426977855059D-09
4	7.996838066338D-07	-2.418791195391D-08	2.661640394733D-10
5	3.024841319851D-07	-1.543862403318D-08	2.709969256279D-10
6	-6.616004144573D-08	3.369760494944D-09	-5.636580218277D-11
7	3.122103721669D-09	-1.967871537035D-10	3.230724672289D-12
8	3.213236793835D-11	1.140062879563D-12	-1.343611820864D-14

P2MIN = 1.00000D 08 1/CM3
P2MAX = 1.00000D 16 1/CM3
Max. rel. Error: 3.9289 %
Mean rel. Error: .5704 %



Multistep hydrogenic population coefficients
Data: L.C.Johnson, Fujimoto
Ratio of population coefficients p(2)/ni
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

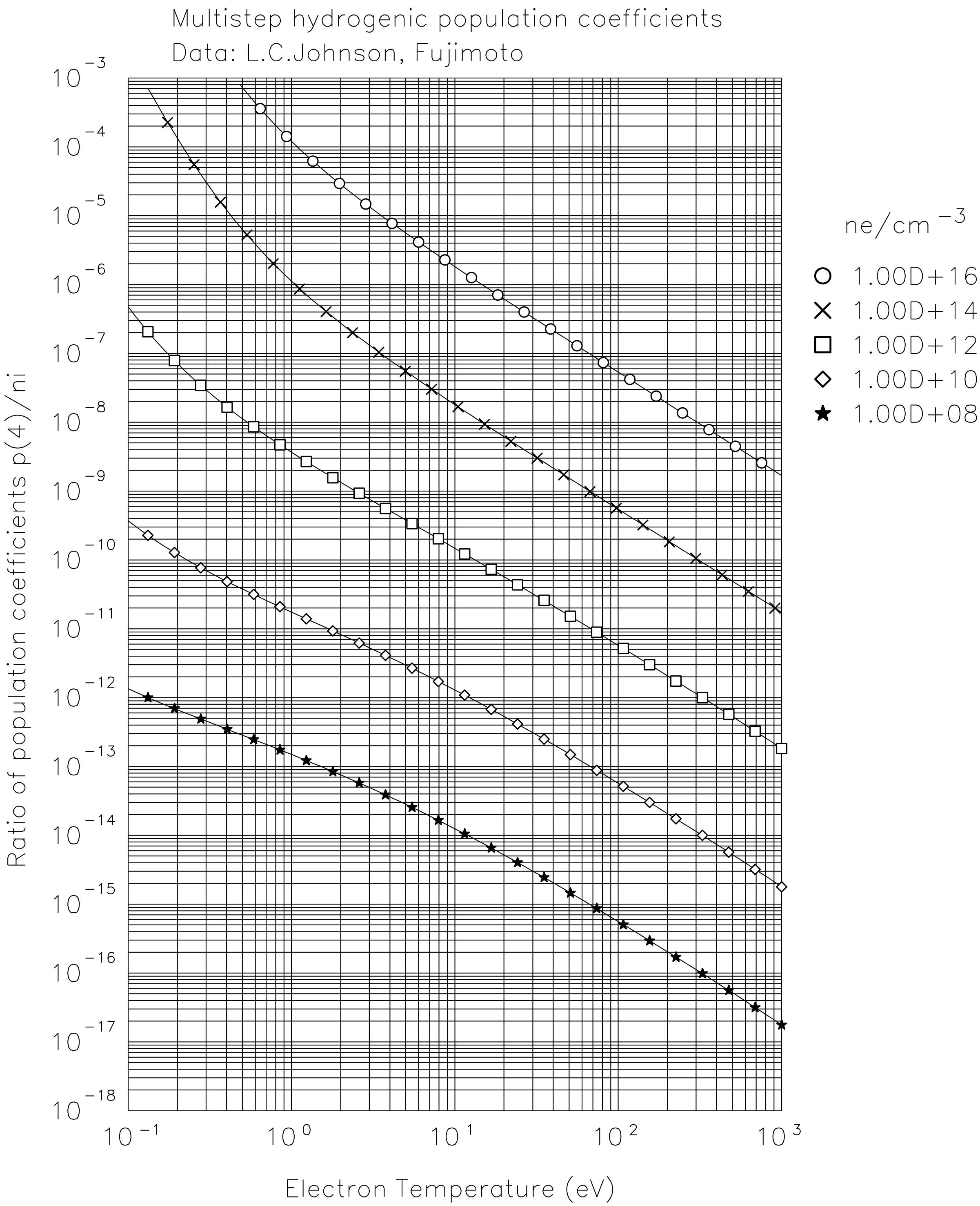
12.13 Reaction 2.1.8c $H^+ + e \rightarrow H(1s)$, Ratio $H(4)/H^+$

T-Index \ E-Index	0	1	2
0	-2.953191910521D+01	9.871472575458D-01	8.335595020148D-03
1	-9.556069945203D-01	-3.479296508982D-02	3.951762140637D-02
2	-3.712742175485D-02	3.782567517335D-02	-3.658223474024D-02
3	-9.582306874061D-03	-1.030473600466D-02	8.044191938471D-03
4	1.337505622469D-03	3.261828837170D-04	5.825308847532D-04
5	-2.564587290898D-04	1.167215404726D-04	-2.625484568114D-04
6	1.083049171042D-04	2.603250284906D-05	-2.172994325710D-05
7	-1.652237169896D-05	-8.358946327039D-06	9.583200142966D-06
8	7.926514417410D-07	5.226431312203D-07	-6.190692135710D-07

T-Index \ E-Index	3	4	5
0	1.287791418429D-02	-6.337729479020D-03	1.170329931626D-03
1	-2.556830678726D-02	7.040128215489D-03	-9.992314993605D-04
2	1.632735440252D-02	-3.401365727621D-03	3.765651076870D-04
3	-3.131290915260D-03	5.532459754610D-04	-4.812308414974D-05
4	-3.168083167077D-04	7.594919813871D-05	-9.295628844487D-06
5	1.297679885878D-04	-2.681169439239D-05	2.486736935154D-06
6	2.967532719536D-06	-1.552348470032D-07	9.914557379237D-08
7	-3.107547721696D-06	5.261339241776D-07	-6.078003254539D-08
8	2.129711932150D-07	-3.682886859964D-08	3.943673329206D-09

T-Index \ E-Index	6	7	8
0	-1.003471065764D-04	4.052095946656D-06	-6.254934022483D-08
1	7.419247879214D-05	-2.738645028702D-06	3.973261293345D-08
2	-2.252802392381D-05	6.849333710573D-07	-8.279262117799D-09
3	1.952561489849D-06	-2.606240633525D-08	-1.668491146428D-10
4	6.041299678217D-07	-1.989967163130D-08	2.616873567872D-10
5	-9.162513063487D-08	2.197291562634D-10	3.883962188438D-11
6	-1.959030711680D-08	1.270158481004D-09	-2.671947435341D-11
7	4.857708161457D-09	-2.162490178679D-10	3.822243417577D-12
8	-2.753763204013D-10	1.095025653423D-11	-1.798235585379D-13

P2MIN = 1.00000D 08 1/CM3
P2MAX = 1.00000D 16 1/CM3
Max. rel. Error: 3.8778 %
Mean rel. Error: .7384 %


Multistep hydrogenic population coefficients
Data: L.C.Johnson, Fujimoto
Ratio of population coefficients p(4)/ni
Electron Temperature (eV)
ne/cm $^{-3}$
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

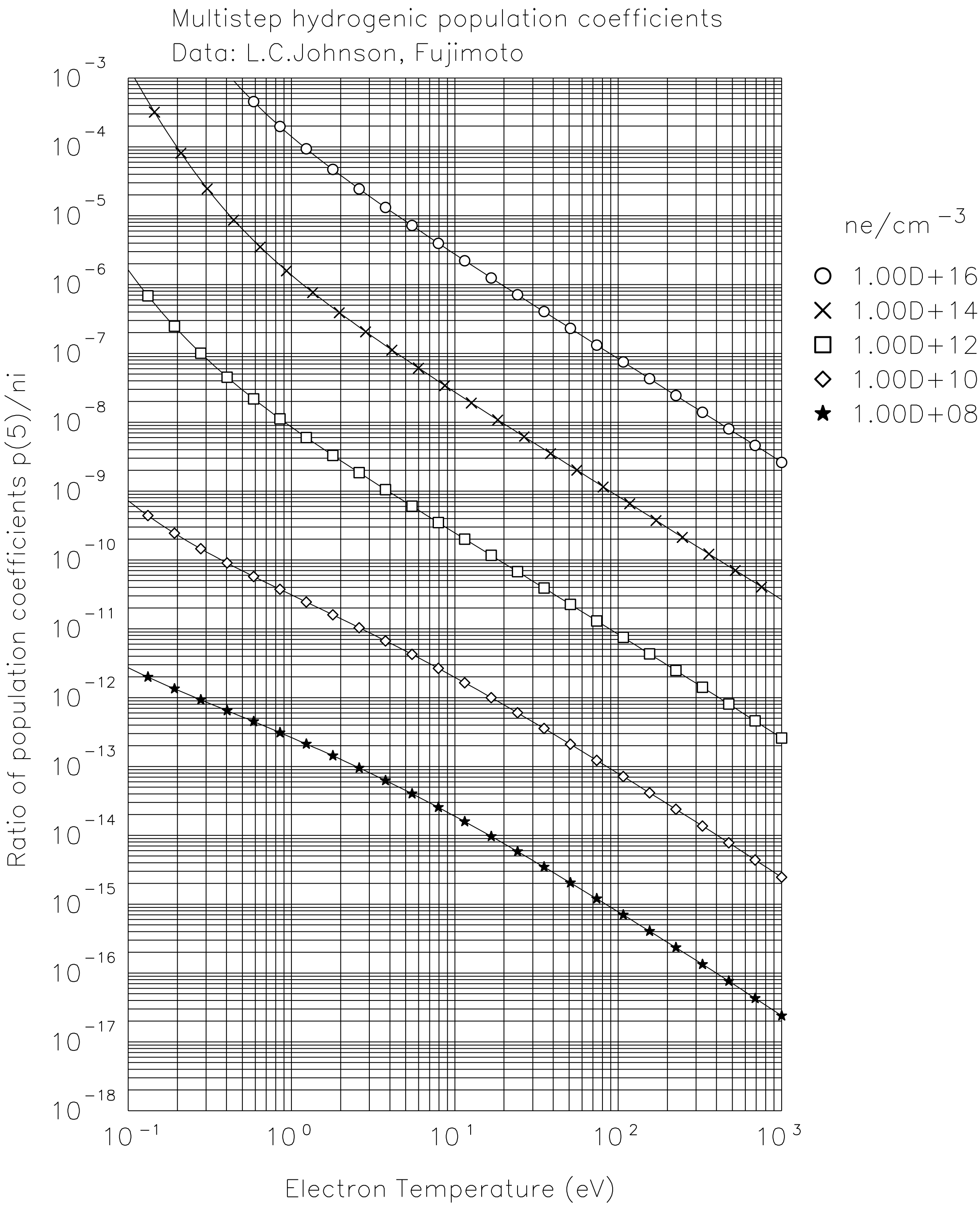
12.14 Reaction 2.1.8d $H^+ + e \rightarrow H(1s)$, Ratio $H(5)/H^+$

T-Index \ E-Index:	0	1	2
0	-2.896620907578D+01	8.263162726911D-01	2.453412310701D-01
1	-1.020472386996D+00	6.774681712067D-02	-9.359887389995D-02
2	-3.909076727301D-02	9.233229043428D-03	-6.811898776723D-03
3	-8.108346091837D-03	-1.114009915066D-02	7.784902980212D-03
4	1.019109955231D-03	2.143186124447D-03	-7.445628503896D-04
5	-3.832012105835D-04	7.665209835422D-04	-6.615105657343D-04
6	2.074862770456D-04	-4.323660314654D-04	3.084220743425D-04
7	-3.467034971602D-05	7.046871983203D-05	-5.074193286238D-05
8	1.826483263765D-06	-3.843166437506D-06	2.864841439776D-06

T-Index \ E-Index:	3	4	5
0	-1.095918159657D-01	2.352340764192D-02	-2.606799746665D-03
1	3.777179622766D-02	-7.435824927042D-03	7.370730125395D-04
2	5.541316826680D-03	-1.652672599440D-03	2.451627952732D-04
3	-3.103060845765D-03	6.334549501483D-04	-7.027215944854D-05
4	-4.194692950067D-06	5.637881977255D-05	-1.207354069047D-05
5	2.344290799663D-04	-4.452581583360D-05	4.741482394533D-06
6	-8.589872787033D-05	1.127548136764D-05	-6.664466414066D-07
7	1.398275288859D-05	-1.748270612401D-06	8.910652633496D-08
8	-8.177688767346D-07	1.076944846317D-07	-6.310685093478D-09

T-Index \ E-Index:	6	7	8
0	1.550006217168D-04	-4.720230271207D-06	5.795820807765D-08
1	-3.773216809044D-05	9.378701533392D-07	-8.638031636714D-09
2	-1.885289195306D-05	7.183528697382D-07	-1.073414499710D-08
3	4.215222394060D-06	-1.276305499861D-07	1.520731912855D-09
4	1.096969913038D-06	-4.657703480617D-08	7.564520027104D-10
5	-2.779296405890D-07	8.321497480007D-09	-9.899754662843D-11
6	6.572553261299D-09	8.982707823537D-10	-2.633081356088D-11
7	6.037786936012D-10	-2.111950717307D-10	5.235642212608D-12
8	6.366831945852D-11	8.080764312523D-12	-2.351015375046D-13

```
P2MIN =   1.00000D 08 1/CM3
P2MAX =   1.00000D 16 1/CM3
  Max. rel. Error:   5.3024 %
  Mean rel. Error:    .9480 %
```



Multistep hydrogenic population coefficients
Data: L.C.Johnson, Fujimoto
Ratio of population coefficients p(5)/ni
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

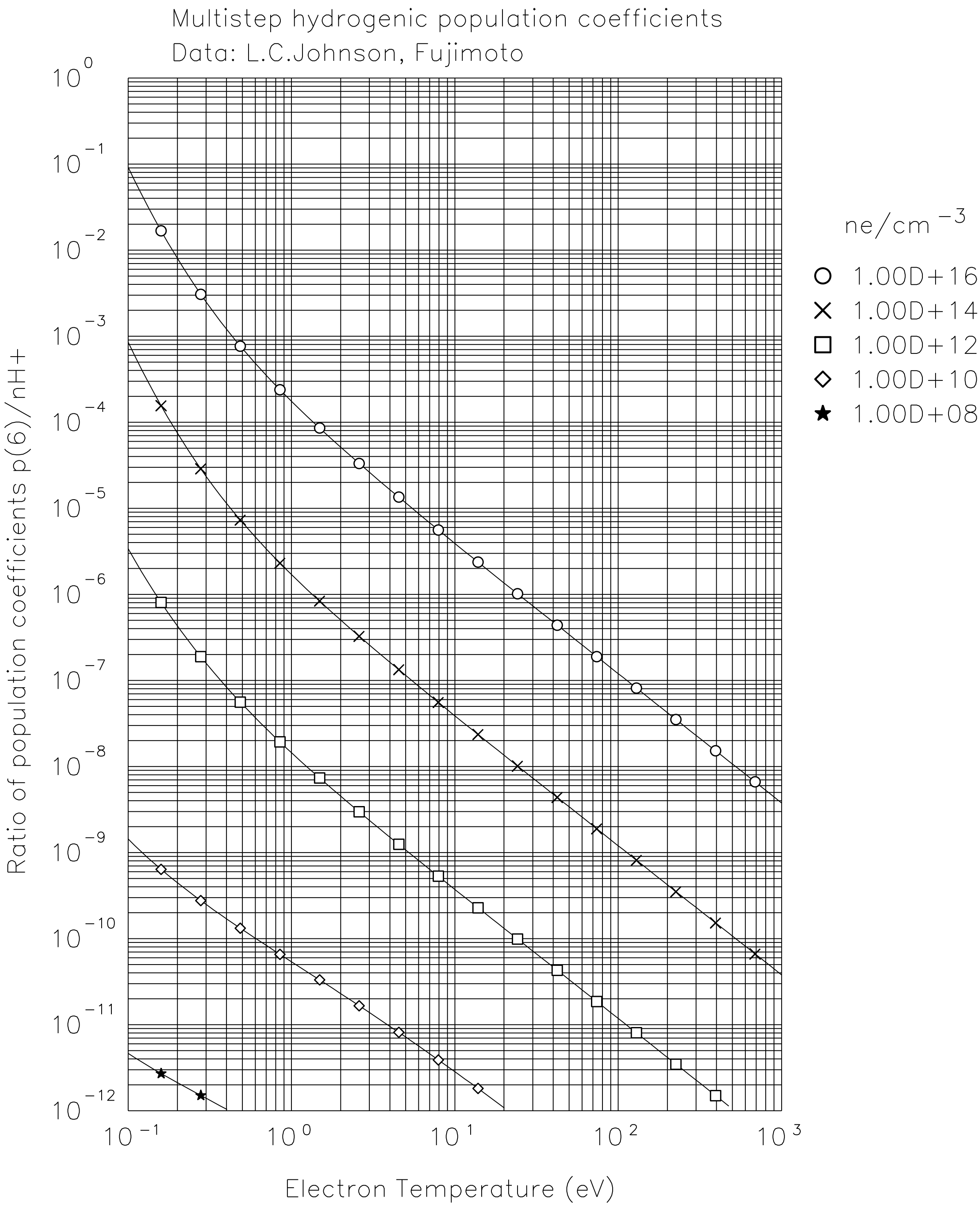
12.15 Reaction 2.1.8e $H^+ + e \rightarrow H(1s)$, Ratio $H(6)/H^+$

T-Index \ E-Index	0	1	2
0	-2.853134339900D+01	1.025762058140D+00	4.820359378086D-02
1	-1.057384296999D+00	-1.367338116022D-02	-3.351784927664D-02
2	-4.357129898325D-02	-7.394478242994D-03	2.206668060201D-02
3	-1.022068439636D-02	8.205900215515D-03	-9.593969669623D-03
4	2.240869860862D-03	-2.398078272359D-03	2.119411722051D-03
5	-2.845620700011D-04	1.159424639874D-04	-6.688436690039D-05
6	1.056461895367D-04	6.774788436258D-05	-6.199652445552D-05
7	-1.924352018053D-05	-1.263343934006D-05	1.111364886603D-05
8	1.083397517395D-06	6.663341827792D-07	-5.889621084106D-07

T-Index \ E-Index	3	4	5
0	-3.882358720615D-02	1.237087286269D-02	-1.764105210919D-03
1	2.391618457883D-02	-7.152556397423D-03	9.907047976258D-04
2	-1.040668635206D-02	2.383766498799D-03	-2.822620365202D-04
3	3.186917464795D-03	-4.976528642770D-04	3.877389269379D-05
4	-5.566686572310D-04	5.664600566222D-05	-5.658026509008D-07
5	2.276886525280D-06	2.992207488831D-06	-6.105459843829D-07
6	1.913273349345D-05	-2.523727510933D-06	1.167652225992D-07
7	-3.255526057721D-06	4.051238507748D-07	-1.532222680198D-08
8	1.737855470748D-07	-2.223530055553D-08	9.525747219138D-10

T-Index \ E-Index	6	7	8
0	1.262454385864D-04	-4.469205240312D-06	6.250167666694D-08
1	-6.978776837879D-05	2.446946729997D-06	-3.400752053390D-08
2	1.791903200774D-05	-5.823791297469D-07	7.631403828079D-09
3	-1.446134439476D-06	1.918944143993D-08	6.658988931422D-11
4	-2.818155986041D-07	1.813752401935D-08	-3.433445792332D-10
5	5.203793299428D-08	-2.092865649431D-09	3.247676557005D-11
6	2.465131736062D-09	-3.635425072620D-10	8.132197656808D-12
7	-8.118597627154D-10	7.842131310409D-11	-1.656179057643D-12
8	3.184540505918D-11	-3.747826185419D-12	8.214908508402D-14

P2MIN = 1.00000D 08 1/CM3
P2MAX = 1.00000D 16 1/CM3
Max. rel. Error: 2.9379 %
Mean rel. Error: .6634 %



Multistep hydrogenic population coefficients
Data: L.C.Johnson, Fujimoto
Ratio of population coefficients p(6)/nH+
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

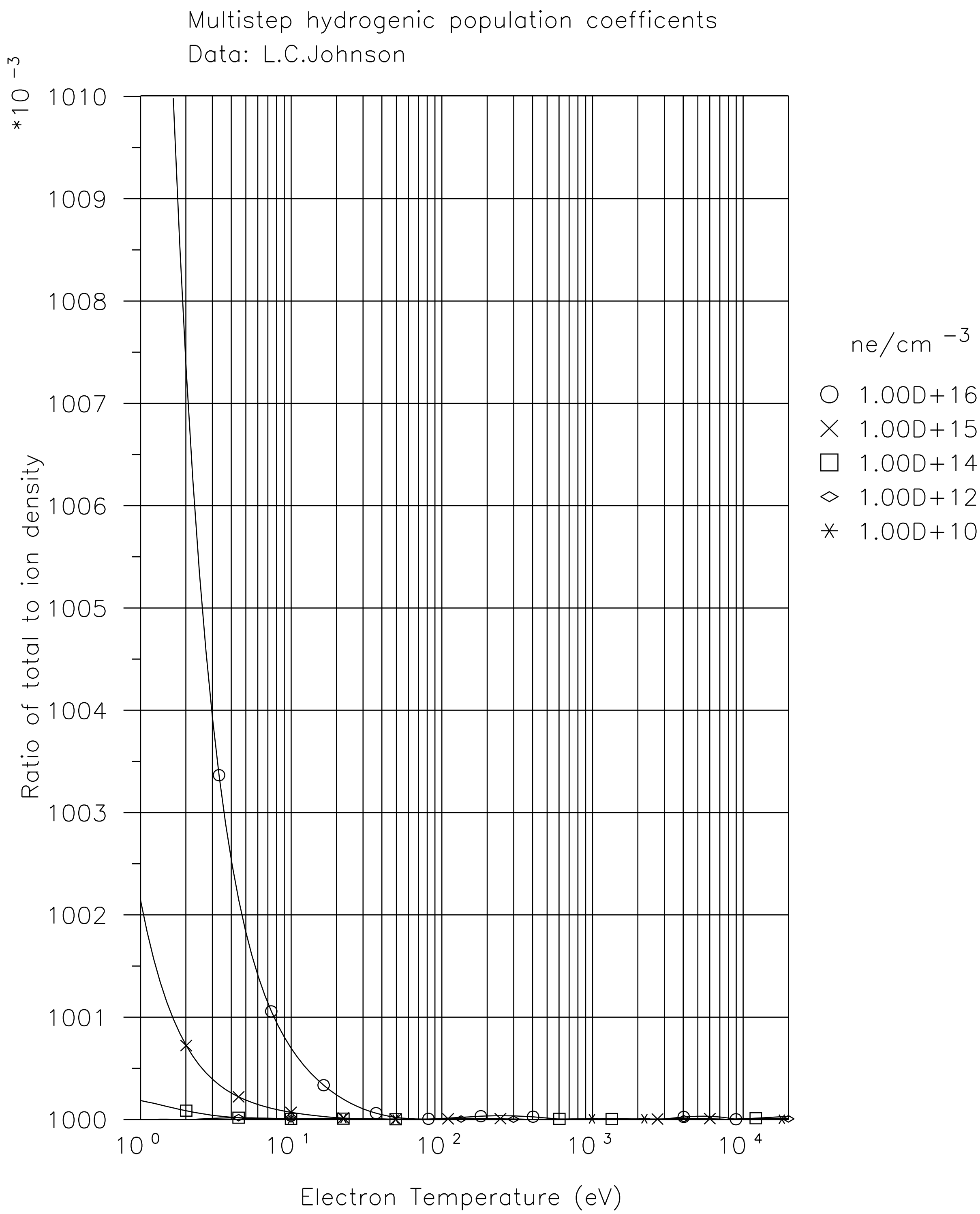
12.16 Reaction 2.1.8tot $H^+ + e \rightarrow H(1s)$, Ratio $H(tot)/H^+$

T-Index \ E-Index:	0	1	2
0	-2.235624329253D+01	9.763145521833D-01	1.918330680061D-02
1	-1.439934055420D+00	-2.519401923047D-02	3.585508737762D-03
2	1.060215606120D-03	-1.118872464044D-03	1.720136583820D-03
3	2.244412354881D-03	-6.704475990451D-04	-6.699472886502D-04
4	5.982736693346D-05	1.208170153071D-06	1.246488800870D-04
5	-8.466861405156D-05	3.561208397089D-05	-1.494745309621D-05
6	1.175099184836D-05	-4.822515840160D-06	7.839022932286D-07
7	-7.023031296681D-07	2.948938110645D-07	-5.225388371277D-08
8	1.609249642095D-08	-8.845142466159D-09	3.899049823853D-09

T-Index \ E-Index:	3	4	5
0	-4.691259242713D-03	6.288351029702D-04	-5.107818695069D-05
1	-3.606855133841D-04	2.098139498792D-05	4.491184999788D-07
2	-5.631447161500D-04	1.107941690049D-04	-1.324767192387D-05
3	3.084892726230D-04	-6.392879662268D-05	7.279340567526D-06
4	-4.311535218313D-05	7.637892784584D-06	-7.417970337062D-07
5	6.008386349890D-07	3.291652198945D-07	-7.214543918759D-08
6	3.310641902198D-07	-9.636153557710D-08	1.224666378778D-08
7	-4.418889088947D-09	-5.755172852233D-10	2.933776480728D-10
8	-1.417759796908D-09	4.224902609944D-10	-6.257737712706D-11

T-Index \ E-Index:	6	7	8
0	2.511251181976D-06	-6.877740736899D-08	8.022672312302D-10
1	-1.748905208728D-07	1.096079038665D-08	-2.309525766240D-10
2	9.284121363830D-07	-3.520965065456D-08	5.652221180618D-10
3	-4.730061277373D-07	1.650428248605D-08	-2.440356698087D-10
4	4.087003980074D-08	-1.104737352197D-09	9.985107172732D-12
5	6.581760780626D-09	-3.342177330708D-10	7.477370951765D-12
6	-9.009824883694D-10	4.485057352449D-11	-1.092334989093D-12
7	-2.513282999634D-11	7.402108547860D-14	3.356083702441D-14
8	4.562227755580D-12	-1.394585520243D-13	9.622937037320D-16

P2MIN = 1.00000D 08 1/CM3
P2MAX = 1.00000D 16 1/CM3
Max. rel. Error: 3.0878 %
Mean rel. Error: 0.2211 %



Multistep hydrogenic population coefficents
Data: L.C.Johnson
*10 -3
1010
1009
1008
1007
1006
1005
1004
1003
1002
1001
1000
Ratio of total to ion density
10 0
10 1
10 2
10 3
10 4
Electron Temperature (eV)
ne/cm -3
1.00D+16
1.00D+15
1.00D+14
1.00D+12
1.00D+10

12.17 Reaction 2.1.8de $H^+ + e \rightarrow H(1s)$, $< de > +13.6$ $[eV]$

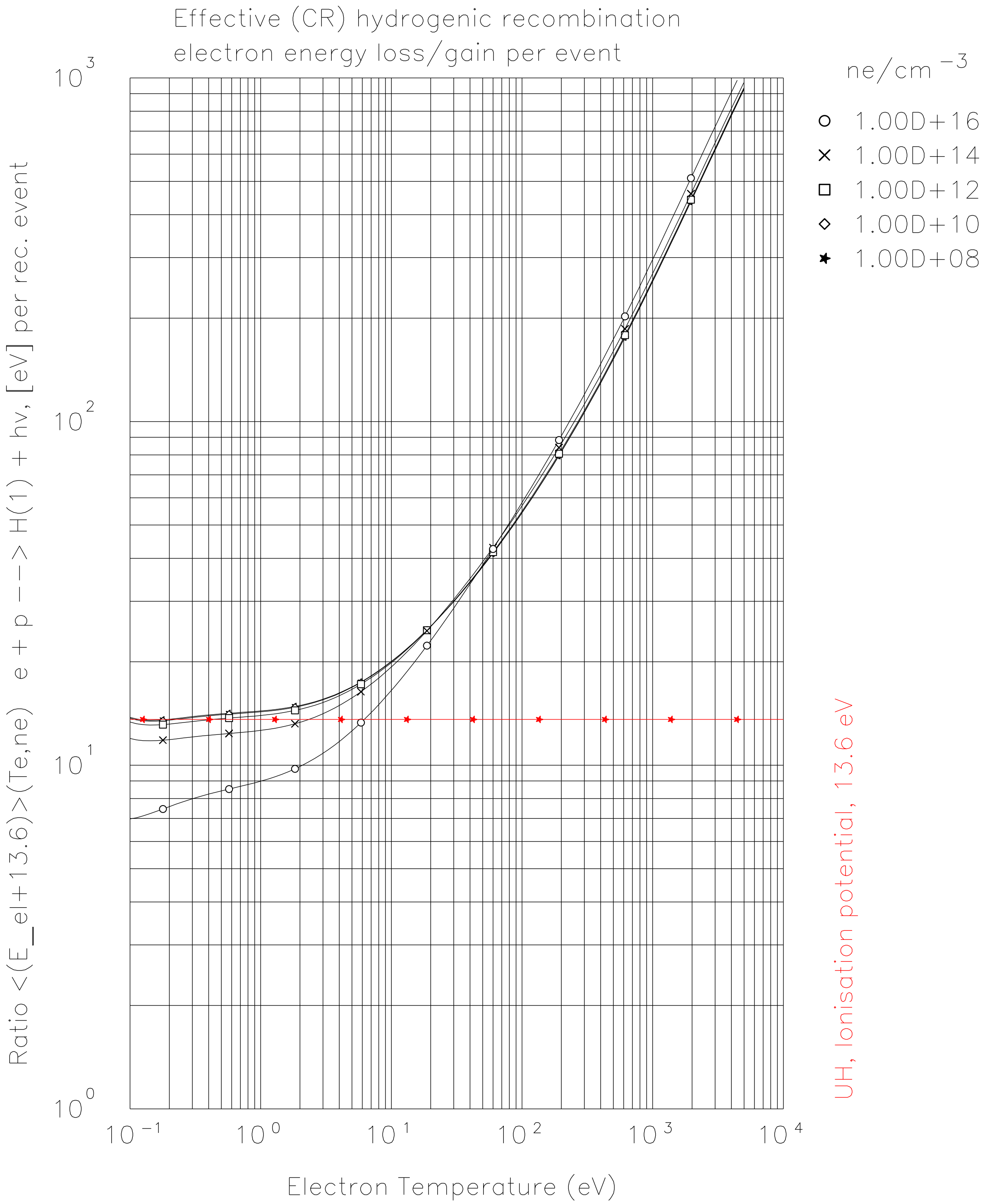
electron energy loss (radiative) due to one effective recombination. 13.6 eV (ionization potential) has to be subtracted, which may render the total electron loss negative, i.e., make it a gain. June17: Fit range extended from 0.1–1e3 to 0.1–2e4

T-Index \ E-Index	0	1	2
0	2.665899500132D+00	6.909524133474D-03	-1.016251787345D-02
1	3.234097857001D-02	-1.342936828253D-03	2.649709301973D-03
2	1.839736371673D-02	-4.543287906774D-04	4.049474254061D-04
3	1.721979500535D-02	-2.420941858648D-04	1.070964671190D-04
4	-1.634188788045D-06	1.272188632742D-04	-9.608788872527D-05
5	-1.354019822678D-03	5.547796579740D-06	1.885659127034D-06
6	3.103952150736D-04	-7.717377610260D-06	4.450028524311D-06
7	-2.813815821385D-05	1.049652451777D-06	-6.757200946909D-07
8	9.248132243469D-07	-4.314339279524D-08	2.916075421796D-08

T-Index \ E-Index	3	4	5
0	4.785952485138D-03	-1.111528620197D-03	1.389338869715D-04
1	-1.417016315380D-03	3.507678014757D-04	-4.569145026078D-05
2	-9.053523602330D-05	1.610290448013D-06	2.067872533338D-06
3	-9.886490927616D-06	-1.137795705868D-06	2.009074194306D-07
4	2.503871421337D-05	-2.776557044750D-06	8.202377087937D-08
5	-1.899847063838D-06	3.608820989932D-07	-1.820175080726D-08
6	-8.590535929797D-07	6.494073446907D-08	-1.005495853368D-09
7	1.536224332903D-07	-1.526291610537D-08	5.443143280155D-10
8	-7.087510165394D-09	7.772501731042D-10	-3.490536063716D-11

T-Index \ E-Index	6	7	8
0	-9.560728735427D-06	3.390700499449D-07	-4.846257262550D-09
1	3.245267105321D-06	-1.188371670550D-07	1.758631015908D-09
2	-2.955908411210D-07	1.631510169903D-08	-3.250767238535D-10
3	-5.336134881504D-09	-2.995961467613D-10	1.244053679153D-11
4	8.526944203010D-09	-7.591463931965D-10	1.735202334766D-11
5	-1.160792778179D-09	1.375444359851D-10	-3.427633513798D-12
6	-7.157425528109D-11	1.695155282725D-12	2.341575042551D-14
7	1.259157231611D-11	-1.469505460319D-12	3.084731172193D-14
8	-1.453313559078D-13	6.474896531735D-14	-1.572212991946D-15

P2MIN = 1.00000D 08 1/CM3
P2MAX = 1.00000D 16 1/CM3
Max. rel. Error: 0.331E+01 %
Mean rel. Error: 0.927E+00 %


Effective (CR) hydrogenic recombination
electron energy loss/gain per event
ne/cm -3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08
Ratio <(E_el+13.6)>(Te,ne) e + p --> H(1) + hv, [eV] per rec. event
UH, Ionisation potential, 13.6 eV
Electron Temperature (eV)

12.18 Reaction 2.1.8o $H^+ + e \rightarrow H(1s)$, $< de > +13.6\ [eV]$ Ly-opaque

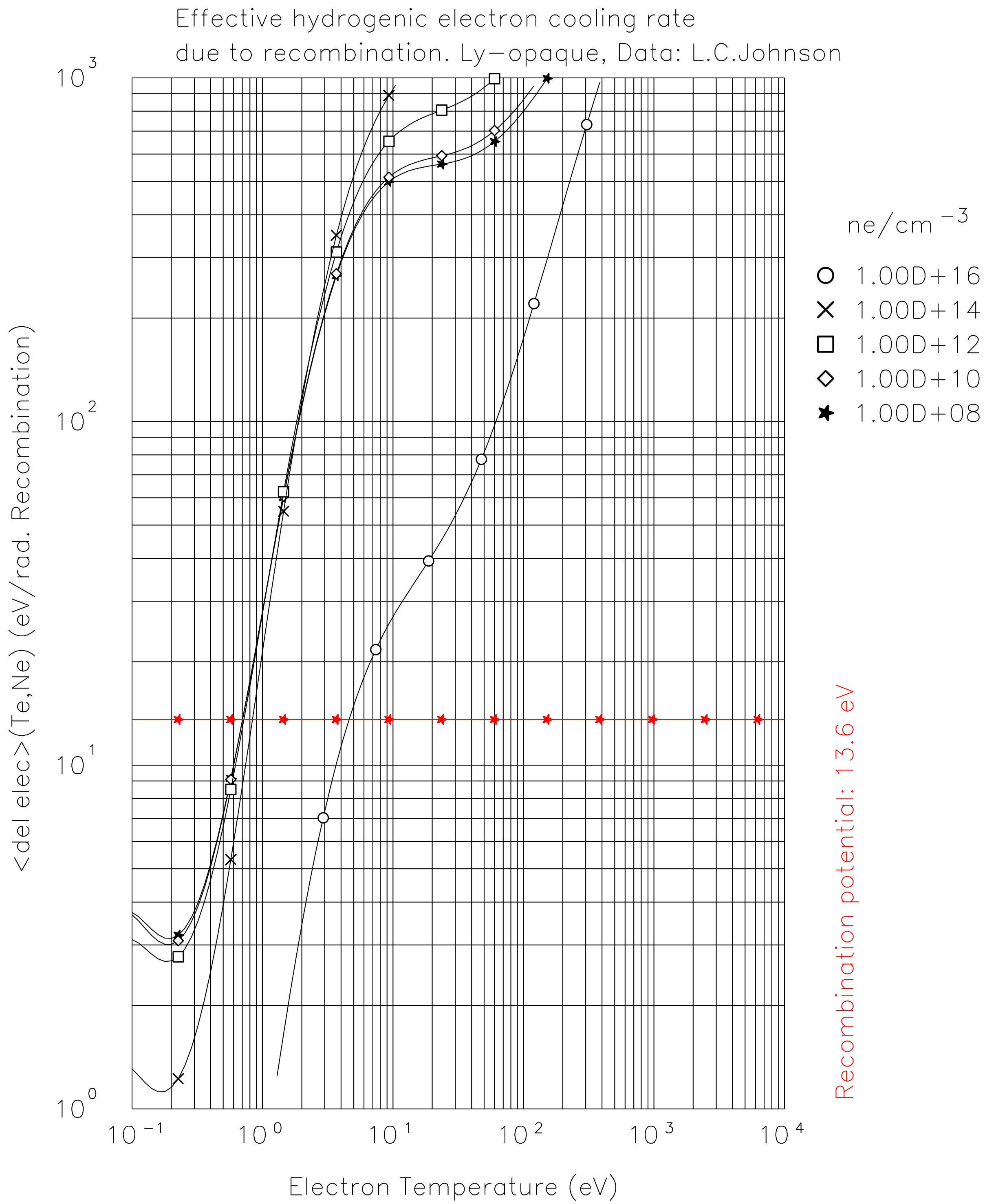
electron energy loss (radiative) due to one effective recombination event. 13.6 eV (ionization potential) has to be subtracted, which may render the total electron loss negative, i.e., make it a gain.

T-Index \ E-Index:	0	1	2
0	3.332760890904D+00	2.276467542533D-02	-3.375104085272D-02
1	2.095607992432D+00	2.149640996135D-01	-2.163109435324D-01
2	-7.718235594111D-03	5.342318925152D-02	-3.826264614382D-02
3	-2.796028848568D-01	-5.076194843679D-02	4.211090303923D-02
4	4.114054656028D-02	1.167368824693D-03	-2.634010977122D-03
5	1.379031566337D-02	4.766103150116D-03	-3.140405264654D-03
6	-4.442827387044D-03	-1.168245938217D-03	8.103728635753D-04
7	4.466408723499D-04	1.067947114632D-04	-7.426869611152D-05
8	-1.550852684757D-05	-3.448224819513D-06	2.365214591310D-06

T-Index \ E-Index:	3	4	5
0	1.533294583406D-02	-2.993999791570D-03	2.625217527284D-04
1	8.513801946679D-02	-1.708115211759D-02	1.908032465874D-03
2	9.848556553690D-03	-1.198540836499D-03	7.289210776603D-05
3	-1.343364231895D-02	2.197734625605D-03	-2.020807399429D-04
4	1.540828008778D-03	-3.888233553638D-04	5.009886243915D-05
5	6.669070177773D-04	-4.301617499659D-05	-3.131696299090D-06
6	-1.953437642437D-04	1.957310765780D-05	-4.682020227901D-07
7	1.819420479360D-05	-1.913117253436D-06	6.213331827001D-08
8	-5.704392451980D-07	5.826373961407D-08	-1.634950425947D-09

T-Index \ E-Index:	6	7	8
0	-7.802660138687D-06	-1.578343346285D-07	8.885318650802D-09
1	-1.191827223971D-04	3.886108418638D-06	-5.149798003444D-08
2	-1.886829891317D-06	-4.065327740691D-09	7.815045054601D-10
3	1.049475835680D-05	-2.854931151940D-07	3.138820449657D-09
4	-3.454361952343D-06	1.217245343098D-07	-1.725312803637D-09
5	5.905901174405D-07	-3.001019530996D-08	5.223614921536D-10
6	-5.627862273723D-08	4.147493653191D-09	-8.140380486253D-11
7	3.646425627446D-09	-3.215059278414D-10	6.559359042393D-12
8	-1.392555515521D-10	1.101965822929D-11	-2.192243607759D-13

P2MIN = 1.00000D 08 1/CM3
P2MAX = 1.00000D 16 1/CM3
Max. rel. Error: 17.4151 %
Mean rel. Error: 7.1827 %


Effective hydrogenic electron cooling rate
due to recombination. Ly−opaque, Data: L.C.Johnson
<del elec>(Te,Ne) (eV/rad. Recombination)
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08
Recombination potential: 13.6 eV

12.19 Reaction 2.2a $e + He \rightarrow He^*$ Ratio $He(6)/He(1)$

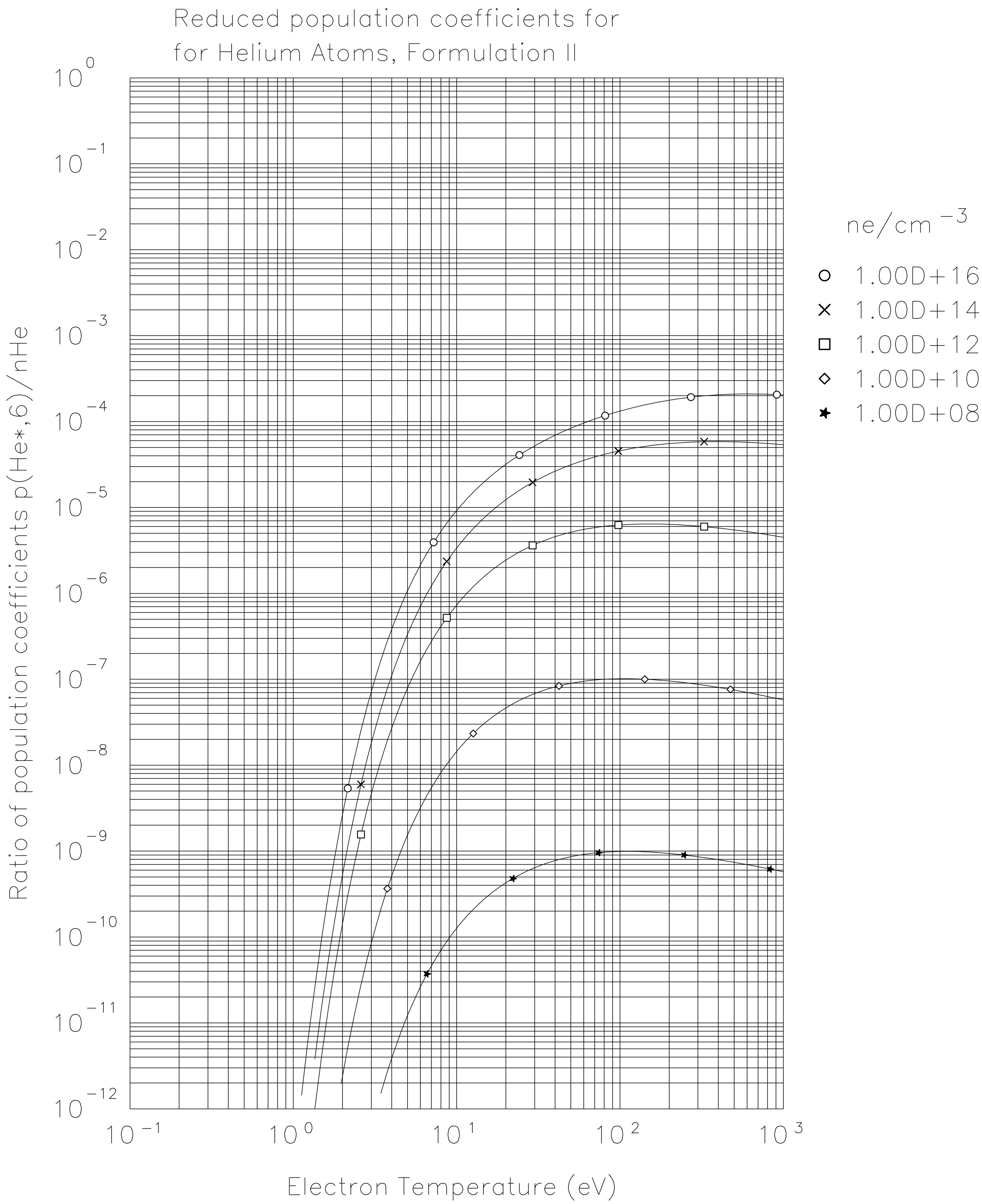
3^1S state reduced population coefficients, formulation II, Coupling to groundstate, [22].
For 728 nm line: $\rightarrow 2^1P$, A(6,4)=1.810629e7, dE=1.7023 eV

T-Index \ E-Index	0	1	2
0	-4.311315252344D+01	1.068788324945D+00	4.607816591604D-01
1	2.227727400968D+01	2.533246784559D-02	-4.171642913247D-01
2	-1.092526995496D+01	-3.147570844629D-02	1.875310957896D-01
3	3.455212456083D+00	-1.389486107084D-02	-4.063899942293D-02
4	-7.374015718678D-01	2.242933213868D-02	-2.420756303296D-03
5	1.038623596715D-01	-8.572063066145D-03	3.324173037175D-03
6	-9.192956530427D-03	1.455904553910D-03	-6.673595425546D-04
7	4.616742167799D-04	-1.160328883781D-04	5.534829062629D-05
8	-1.001260661416D-05	3.542757576830D-06	-1.685458944344D-06

T-Index \ E-Index	3	4	5
0	-2.288516993884D-01	4.934442752394D-02	-5.604584821093D-03
1	1.615799989993D-01	-2.658923546753D-02	2.208439837134D-03
2	-6.250400889583D-02	7.917685175679D-03	-4.072650465024D-04
3	1.516486061778D-02	-1.624326286753D-03	3.323367272941D-05
4	-1.576970797070D-03	2.296103941475D-04	-2.793441980969D-06
5	-2.351628215299D-04	-3.805995868992D-06	-3.856178638492D-07
6	7.622121272510D-05	-2.414972618793D-06	3.145956146766D-08
7	-6.623209681071D-06	1.396329196910D-07	1.644463329342D-08
8	1.880631768107D-07	2.036496093646D-09	-1.449219917820D-09

T-Index \ E-Index	6	7	8
0	3.438226618132D-04	-1.077128821245D-05	1.352276198706D-07
1	-9.431672141577D-05	1.862180588113D-06	-1.132114188246D-08
2	4.546258048294D-06	2.365213157088D-07	-4.976268161753D-09
3	2.722186667141D-06	-9.017760018097D-08	-4.904178184171D-10
4	-4.152461824776D-07	-6.241223808031D-09	8.068574923944D-10
5	6.209519268505D-08	1.441911748739D-09	-1.316978098635D-10
6	-3.356847387494D-09	-3.697594587912D-11	7.240088197508D-12
7	-9.792067155585D-10	2.164943531687D-11	-2.800778214544D-13
8	8.944524915556D-11	-2.169200058693D-12	1.817590942107D-14

```
P2MIN =   1.00000D 08 1/CM3
P2MAX =   1.00000D 16 1/CM3
  Max. rel. Error:   4.7466 %
  Mean rel. Error:   1.8012 %
```


Reduced population coefficients for
for Helium Atoms, Formulation II
Ratio of population coefficients p(He*,6)/nHe
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

12.20 Reaction 2.2b $e + He \rightarrow He^*$ Ratio $He(7)/He(1)$

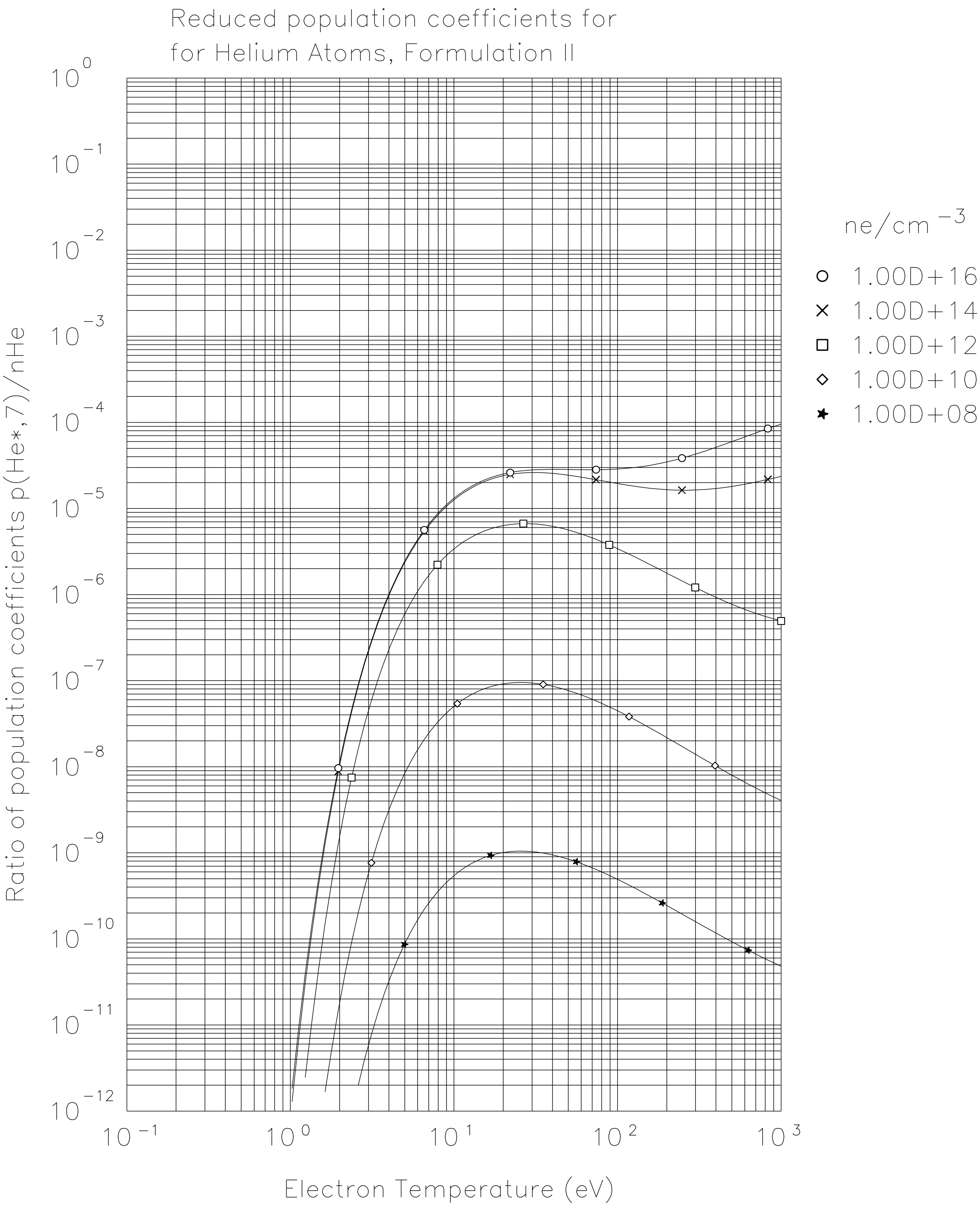
3^3S state, reduced population coefficients, formulation II, Coupling to groundstate, [22].
For 706 nm line: $\rightarrow 2^3P$, A(7,5)=2.76441e7, dE =1.75437 eV

T-Index \ E-Index	0	1	2
0	-4.007960997971D+01	9.034446644096D-01	1.165111771540D-01
1	2.144863586125D+01	1.947485468069D-01	-1.301067140494D-01
2	-1.062424949389D+01	-2.036865355513D-01	1.502619709740D-01
3	3.274440069862D+00	6.002917850635D-02	-4.500559725551D-02
4	-6.910270587692D-01	-5.778030255527D-03	6.133919377226D-03
5	9.696455049644D-02	-3.615838261304D-04	-5.591761507584D-04
6	-8.558419026409D-03	1.372863071237D-04	3.079519906206D-05
7	4.299591264600D-04	-1.352177886718D-05	1.363347413015D-06
8	-9.396794815079D-06	5.081568411364D-07	-1.918622684719D-07

T-Index \ E-Index	3	4	5
0	-2.597504506357D-02	1.439511190742D-04	5.735113536484D-04
1	-1.134174339750D-03	8.934529257747D-03	-1.672264590109D-03
2	-2.435598894352D-02	2.959994394968D-04	2.087336754163D-04
3	5.473014417323D-03	9.912931702266D-05	-3.121815866488D-05
4	-1.569913055752D-04	-1.068830646003D-04	5.591339866244D-06
5	3.468442843104D-05	-7.773486473364D-06	2.269135973852D-06
6	-1.109174473451D-05	3.766577588319D-06	-4.517137662136D-07
7	1.823956910222D-07	-1.482530106434D-07	6.084462068041D-09
8	4.597529153937D-08	-7.085546973595D-09	1.411547564036D-09

T-Index \ E-Index	6	7	8
0	-7.136082319245D-05	3.362863636423D-06	-5.629721496083D-08
1	1.290346463406D-04	-4.579314176342D-06	6.164974848265D-08
2	-1.619346650396D-05	3.859684910385D-07	-1.226364851070D-09
3	-4.970042343218D-07	1.575739269032D-07	-4.434371121129D-09
4	4.546393179958D-07	-4.580471294432D-08	1.080771415075D-09
5	-1.879528911353D-07	6.906966394218D-09	-1.112570278287D-10
6	1.591625909374D-08	3.622976767180D-11	-6.002477025919D-12
7	1.509097136492D-09	-1.196127739728D-10	2.320887234439D-12
8	-1.631586971717D-10	7.893728865910D-12	-1.311109499334D-13

```
P2MIN =   1.00000D 08 1/CM3
P2MAX =   1.00000D 16 1/CM3
  Max. rel. Error:   5.3070 %
  Mean rel. Error:   1.9605 %
```



Reduced population coefficients for
for Helium Atoms, Formulation II
Ratio of population coefficients p(He*,7)/nHe
Electron Temperature (eV)
ne/cm $^{-3}$
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

12.21 Reaction 2.2c $e + He \rightarrow He^*$ Ratio $He(8)/He(1)$

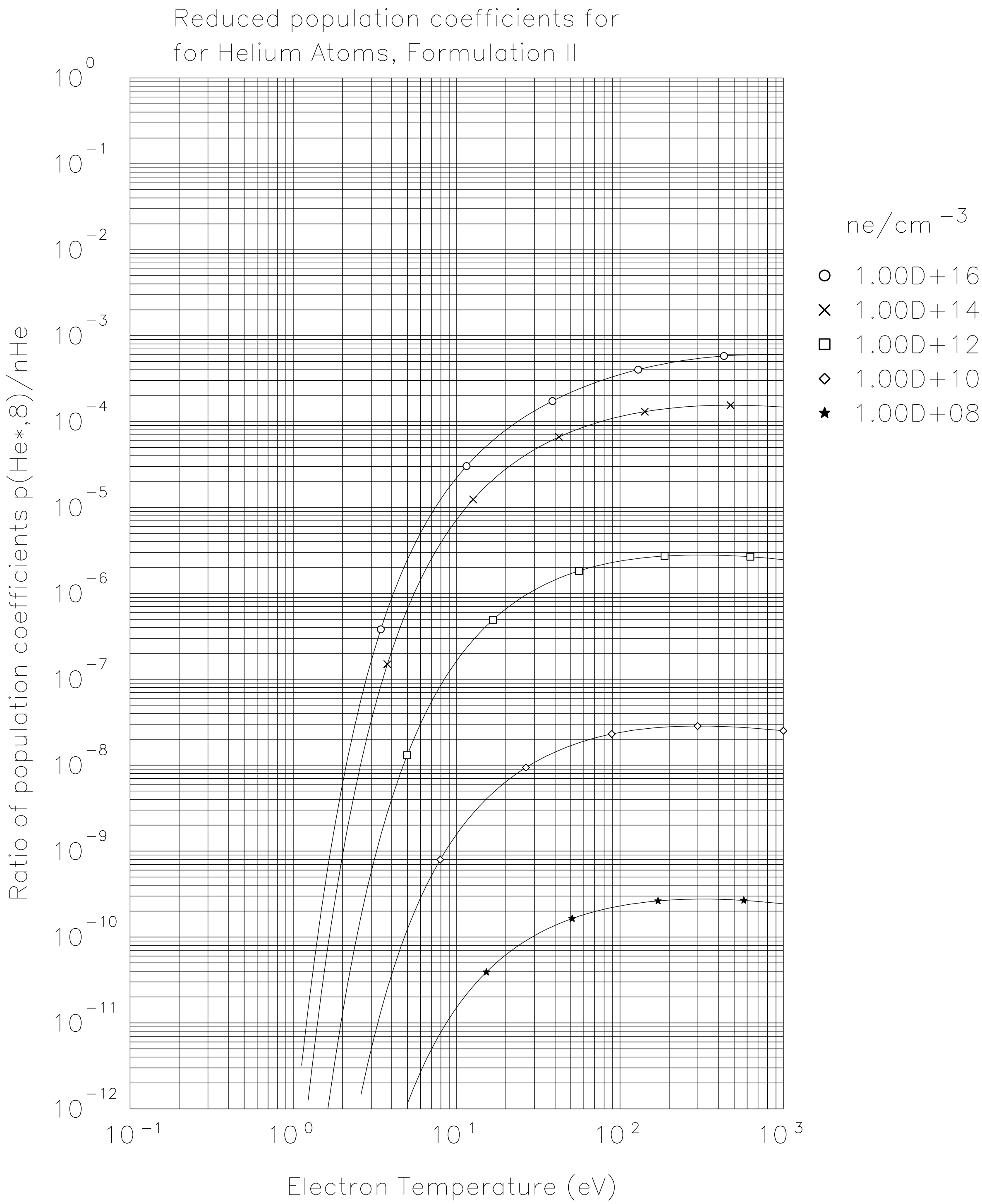
3^1P state, reduced population coefficients, formulation II, Coupling to groundstate, [22]. For 501 nm line: $\rightarrow 2^1S$, A(8,2)=1.35143E7, dE = 2.47126 eV

T-Index \ E-Index	0	1	2
0	-4.653397136053D+01	1.061565404274D+00	1.538213466570D-01
1	2.341040126523D+01	-2.338924405778D-01	-1.620037152343D-01
2	-1.139498311209D+01	3.614149800761D-01	1.852266870603D-02
3	3.614773239756D+00	-2.470591133234D-01	1.639517537700D-02
4	-7.802147409864D-01	9.652798837959D-02	-1.139696161330D-02
5	1.129731936040D-01	-2.211800736270D-02	3.415302206693D-03
6	-1.046003037564D-02	2.894859026350D-03	-5.216830627677D-04
7	5.566146923182D-04	-1.990551598260D-04	3.914361279505D-05
8	-1.287797826551D-05	5.559558313857D-06	-1.141508901494D-06

T-Index \ E-Index	3	4	5
0	-4.960776358631D-02	3.721007453372D-03	4.129592286060D-04
1	7.079138649586D-02	-1.107648995898D-02	7.955218807596D-04
2	-2.002227448100D-02	2.516435028232D-03	-8.077169032818D-05
3	4.996213760875D-03	-6.235419082909D-04	5.622895177211D-06
4	-8.188564258666D-04	1.489938947126D-04	-1.639651945413D-06
5	5.788680997946D-06	-1.848630429871D-05	-2.817393417179D-07
6	1.476821784698D-05	1.555280785423D-06	2.630583281095D-08
7	-1.461225058243D-06	-1.566386546423D-07	1.078484737480D-08
8	3.755714180141D-08	8.635247245624D-09	-9.744421400623D-10

T-Index \ E-Index	6	7	8
0	-7.595441650236D-05	3.938916077091D-06	-6.904203416831D-08
1	-2.492979564442D-05	1.479965187751D-07	5.129381943121D-09
2	-3.279337614319D-06	2.317424648906D-07	-3.212001663062D-09
3	1.149833159917D-06	-1.744164295894D-09	-1.271403337443D-09
4	-1.099736125961D-07	-1.622513539030D-08	7.323542946653D-10
5	6.181107684745D-08	1.189086401587D-09	-1.030873863310D-10
6	-8.335949262711D-09	5.417107113342D-11	6.544932959532D-12
7	-2.073967263488D-10	1.158671282787D-11	-4.346356593657D-13
8	4.965186141757D-11	-1.582356159149D-12	2.463828951285D-14

P2MIN = 1.00000D 08 1/CM3
P2MAX = 1.00000D 16 1/CM3
Max. rel. Error: 4.4334 %
Mean rel. Error: 1.0452 %



Reduced population coefficients for
for Helium Atoms, Formulation II
Ratio of population coefficients p(He*,8)/nHe
Electron Temperature (eV)
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
ne/cm $^{-3}$
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

12.22 Reaction 2.2d $e + He \rightarrow He^*$ Ratio $He(10)/He(1)$

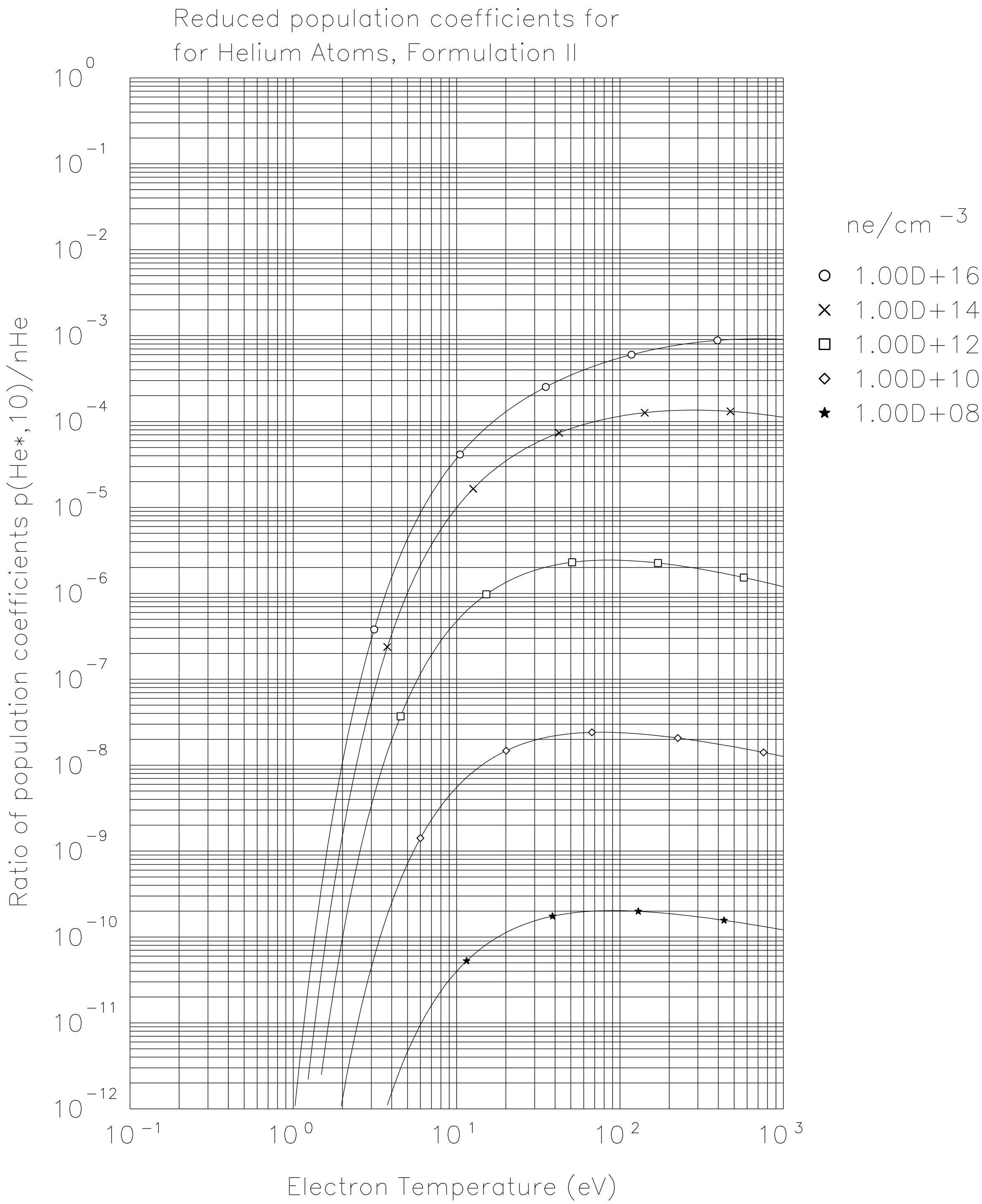
3^1D state, reduced population coefficients, formulation II, Coupling to groundstate, [22].
For 667 nm line: $\rightarrow 2^1P$, A(10,4)=6.27547e7, dE = 1.8561 eV

T-Index \ E-Index	0	1	2
0	-4.387462178720D+01	1.297729348975D+00	2.171426368859D-01
1	2.231897245990D+01	-7.254021696102D-02	-2.818676964157D-01
2	-1.103840904811D+01	8.933431516828D-03	1.084333935229D-01
3	3.439678364969D+00	8.110861039861D-03	-1.419780536561D-02
4	-7.194379330234D-01	-7.617376918719D-03	-7.804052035737D-04
5	9.977541313333D-02	2.492457513616D-03	4.151471795535D-04
6	-8.744899237837D-03	-3.818311009548D-04	-5.656979814142D-05
7	4.364458313084D-04	2.772577703683D-05	4.646402252581D-06
8	-9.420938125153D-06	-7.681794402039D-07	-1.810036079763D-07

T-Index \ E-Index	3	4	5
0	-1.227267686184D-01	2.684569500768D-02	-3.084104019669D-03
1	1.283426585873D-01	-2.558157078407D-02	2.736593361910D-03
2	-4.640225933795D-02	8.670127027232D-03	-8.320926095332D-04
3	6.159942757994D-03	-1.210673774922D-03	1.034347467373D-04
4	2.605016526459D-04	3.287984864674D-05	-4.952370009630D-06
5	-1.787934297272D-04	7.093030346467D-06	1.042617033617D-06
6	2.864168088776D-05	-1.737189312029D-06	-1.314488727944D-07
7	-2.630470520737D-06	2.699291231064D-07	-6.034998122757D-09
8	1.046366140500D-07	-1.472124741829D-08	9.766999701447D-10

T-Index \ E-Index	6	7	8
0	1.927330419368D-04	-6.192457335223D-06	8.013020564099D-08
1	-1.625900542113D-04	5.035250553353D-06	-6.326313962119D-08
2	4.258487531484D-05	-1.078934966891D-06	1.012644792468D-08
3	-3.461954139324D-06	-8.569915050105D-09	2.035476745628D-09
4	-6.887941807259D-08	2.782454606073D-08	-8.823571239501D-10
5	-7.282533905038D-08	-7.826443302463D-10	9.734519877427D-11
6	1.515466306533D-08	-2.609983592228D-10	-5.766562927060D-12
7	-2.777752615430D-10	-1.005417881311D-12	5.711155616810D-13
8	-4.089947705610D-11	1.537624472911D-12	-3.487131096914D-14

```
P2MIN =   1.00000D 08 1/CM3
P2MAX =   1.00000D 16 1/CM3
  Max. rel. Error:   4.2913 %
  Mean rel. Error:   1.0561 %
```


Reduced population coefficients for
for Helium Atoms, Formulation II
Ratio of population coefficients p(He*,10)/nHe
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

12.23 Reaction 2.2e $e + He \rightarrow He^*$ Ratio $He(16)/He(1)$

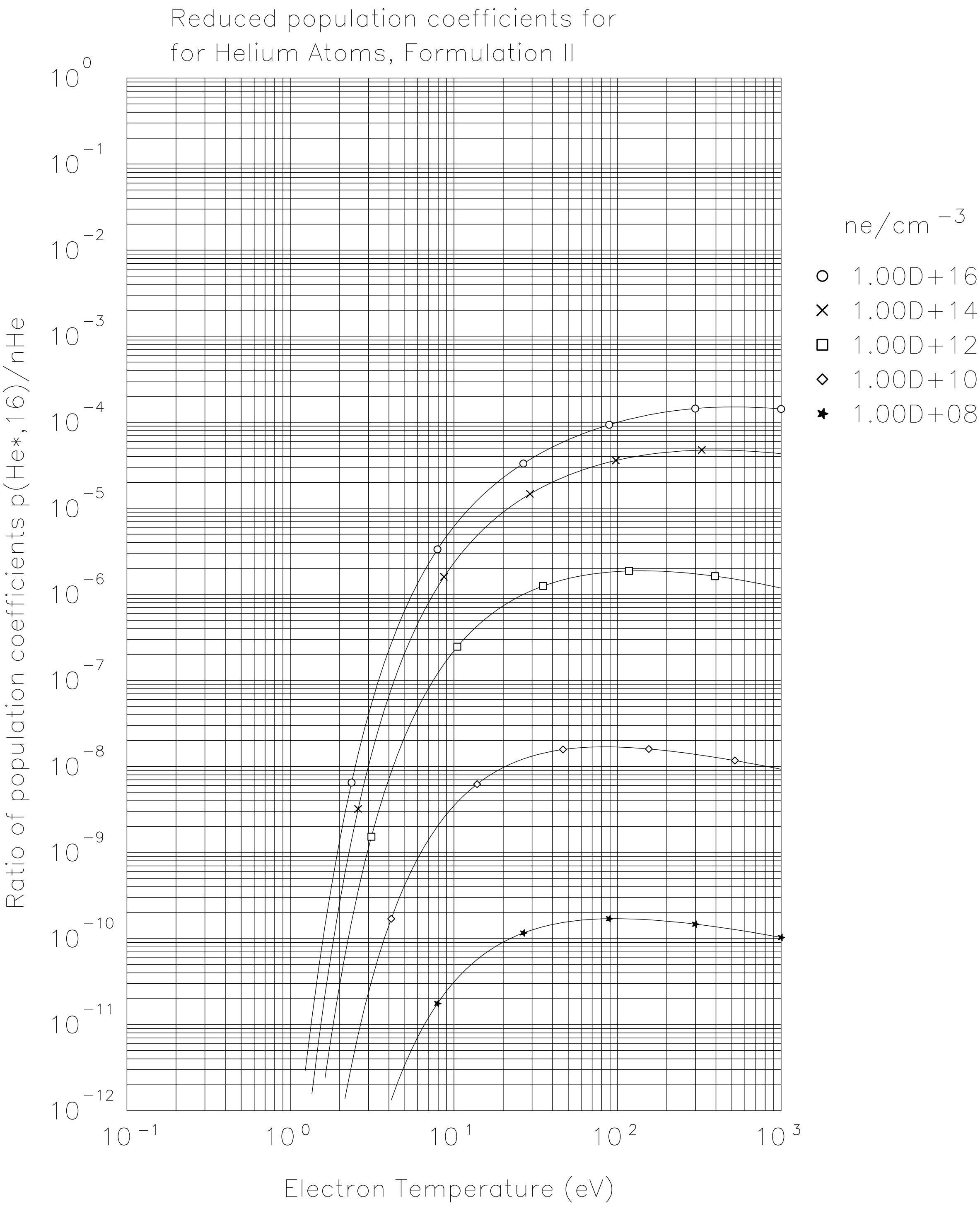
4^1D state, reduced population coefficients, formulation II, Coupling to groundstate, [22] .
For 492 nm line: $\rightarrow 2^1P$, A(16,4)=1.95062E7, dE = 2.5183 eV

T-Index \ E-Index:	0	1	2
0	-4.471883009004D+01	1.379902734939D+00	-1.588304426869D-02
1	2.301803742916D+01	-4.112391837175D-01	4.020010647943D-02
2	-1.142290678089D+01	2.325073124471D-01	-2.363867774084D-02
3	3.584520289665D+00	-9.292301814148D-02	1.399795303239D-02
4	-7.588759927163D-01	2.769660867165D-02	-5.996411152428D-03
5	1.071981413506D-01	-5.846876265058D-03	1.730779175387D-03
6	-9.623807639587D-03	7.555908490695D-04	-2.665737696024D-04
7	4.938446976776D-04	-5.141246970493D-05	1.928578993317D-05
8	-1.097930969158D-05	1.395884806885D-06	-5.127774120276D-07

T-Index \ E-Index:	3	4	5
0	1.102005327143D-03	-2.776453047428D-03	5.951669267394D-04
1	-7.083881196314D-03	3.184653460498D-03	-5.939046552980D-04
2	2.183867697930D-04	-5.291800815389D-04	1.705675041358D-04
3	1.229903491947D-04	-5.697630240547D-05	-2.236164784844D-05
4	4.993998679121D-05	7.400566057679D-05	-3.844211220285D-06
5	-1.193787781320D-04	-6.321252008286D-06	5.997152437237D-07
6	2.840484021461D-05	-8.190964593875D-07	3.074212731682D-08
7	-2.172661190110D-06	5.852557117498D-08	9.693636966803D-10
8	4.622655761109D-08	2.165754381744D-09	-5.193903473398D-10

T-Index \ E-Index:	6	7	8
0	-5.438344417754D-05	2.323368482605D-06	-3.790056253508D-08
1	4.958874975704D-05	-1.935263751082D-06	2.888456240999D-08
2	-1.624226089828D-05	6.305375766051D-07	-8.706585722074D-09
3	2.531455667103D-06	-7.702409620971D-08	4.463396284857D-10
4	5.210309715124D-08	-6.836232292167D-09	2.958879358471D-10
5	-1.506763120215D-08	1.252708957129D-09	-4.685561440635D-11
6	-3.582721370055D-09	8.034963393881D-11	9.950344146148D-13
7	7.970509295800D-12	-1.219308703370D-12	-3.005051437224D-14
8	3.149843951988D-11	-9.361514367135D-13	1.191949633363D-14

P2MIN = 1.00000D 08 1/CM3
P2MAX = 1.00000D 16 1/CM3
Max. rel. Error: 3.6319 %
Mean rel. Error: 1.2457 %



Reduced population coefficients for
for Helium Atoms, Formulation II
Ratio of population coefficients p(He*,16)/nHe
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08
10 0
10 −1
10 −2
10 −3
10 −4
10 −5
10 −6
10 −7
10 −8
10 −9
10 −10
10 −11
10 −12
10 −1
10 0
10 1
10 2
10 3

12.24 Reaction 2.3.2a $e + He^{+} \rightarrow He^{*}$ Ratio $He(6)/He^{+}$

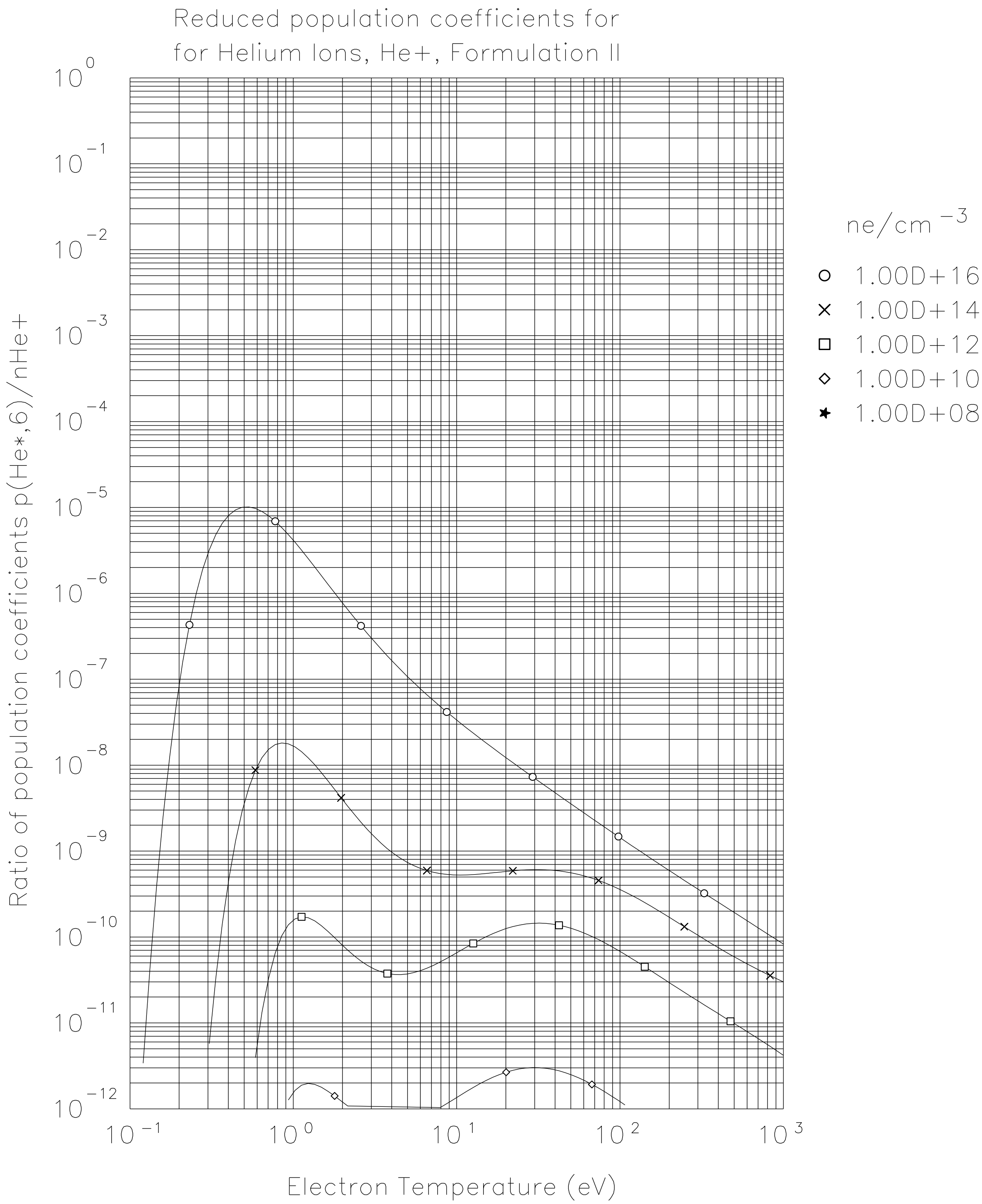
3^1S state reduced population coefficients, formulation II, Coupling to He^{+}, [22].
For 728 nm line: $\rightarrow 2^1P$, A(6,4)=1.810629e7, dE=1.7023 eV

T-Index \ E-Index:	0	1	2
0	-3.216150314541D+01	1.017126728848D+00	2.503192212525D-01
1	2.472997234218D+00	-6.604244815764D-01	4.447853197254D-01
2	-7.273641530992D+00	6.512267559345D-01	-3.697133484751D-01
3	6.312899128558D+00	-3.221127513661D-01	1.407336611903D-01
4	-2.475271968793D+00	9.628490082958D-02	-3.860831119148D-02
5	5.141511842314D-01	-1.679217364205D-02	6.622911077550D-03
6	-5.911906094824D-02	1.521368851222D-03	-4.758101424176D-04
7	3.565096703678D-03	-5.540747253127D-05	-4.988643158537D-06
8	-8.814835329708D-05	1.000054107875D-07	1.442316009145D-06

T-Index \ E-Index:	3	4	5
0	-1.573779795630D-01	4.193259536500D-02	-5.714327145825D-03
1	-1.373512721569D-01	2.642773580772D-02	-3.333243832771D-03
2	8.180617352023D-02	-1.194178092608D-02	1.504343740838D-03
3	-1.575910145395D-02	-4.261270008957D-04	1.160434934873D-04
4	4.321891266732D-03	1.535428208875D-04	-5.462458572233D-05
5	-1.141504489899D-03	1.088062290891D-04	-6.933905317108D-06
6	9.243986342244D-05	-1.491809640805D-05	1.546659340673D-06
7	4.349712967453D-06	-5.545082995129D-07	3.861187877207D-08
8	-5.722874156419D-07	9.632513971858D-08	-9.509739163118D-09

T-Index \ E-Index:	6	7	8
0	4.136519317417D-04	-1.509799360230D-05	2.184621419674D-07
1	2.515045346534D-04	-1.007775905926D-05	1.635743918463D-07
2	-1.333316361152D-04	6.445989555292D-06	-1.234698479875D-07
3	2.714541315649D-06	-8.940705316636D-07	2.952675110887D-08
4	2.756655915997D-06	6.165051309359D-08	-5.082966020137D-09
5	3.178875894924D-07	-2.390667896507D-08	8.828419978172D-10
6	-7.331886684615D-08	2.614867580638D-09	-7.330106832639D-11
7	-4.023931989434D-09	1.812490590825D-10	-1.428342946112D-12
8	6.381564120008D-10	-2.352182090998D-11	3.197916618777D-13

```
P2MIN =   1.00000D 08 1/CM3
P2MAX =   1.00000D 16 1/CM3
  Max. rel. Error:  23.9646 %
  Mean rel. Error:   6.2722 %
```



Reduced population coefficients for
for Helium Ions, He+, Formulation II
Ratio of population coefficients p(He*,6)/nHe+
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

12.25 Reaction 2.3.2b $e + He^{+} \rightarrow He^{*}$ Ratio $He(7)/He^{+}$

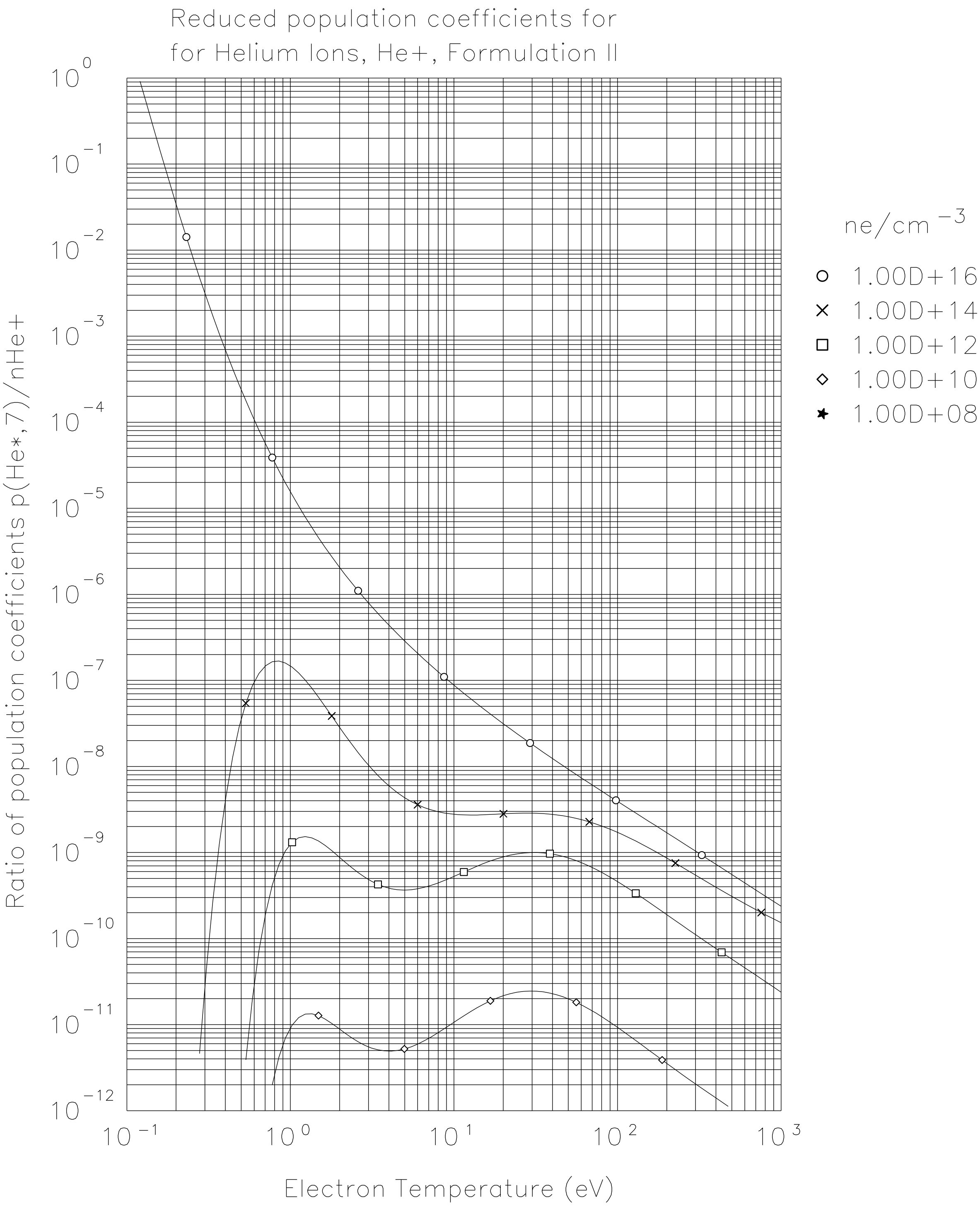
3^3S state, reduced population coefficients, formulation II, Coupling to He$^+$, [22].
For 706 nm line: $\rightarrow 2^3P$, A(7,5)=2.76441e7, dE =1.75437 eV

T-Index \ E-Index:	0	1	2
0	-3.021804030158D+01	1.130848334651D+00	-1.073740464502D-01
1	3.523368969674D+00	-5.478378025513D-01	6.458417120865D-01
2	-8.974598355857D+00	3.778216418622D-01	-5.081928217917D-01
3	7.635897546212D+00	-9.147403628179D-02	1.662078021034D-01
4	-3.000303742731D+00	-9.002194876928D-03	-1.863105119205D-02
5	6.285699508085D-01	9.416908796340D-03	-3.038866915586D-03
6	-7.304205616620D-02	-1.989766581715D-03	1.144474905838D-03
7	4.453488758391D-03	1.821308292697D-04	-1.240908829743D-04
8	-1.113155471497D-04	-6.266781207601D-06	4.673905317880D-06

T-Index \ E-Index:	3	4	5
0	4.970170535549D-02	-1.165239967844D-02	1.510313083106D-03
1	-2.735061111112D-01	5.462012224337D-02	-5.869531956065D-03
2	2.064807405621D-01	-3.532912576039D-02	3.081608767454D-03
3	-7.412844397846D-02	1.064378821100D-02	-5.813109620435D-04
4	1.464638881441D-02	-1.982598876641D-03	5.279445200867D-05
5	-1.322561156054D-03	2.390586823075D-04	-8.306640146040D-06
6	-3.560089264490D-05	-1.201538636649D-05	1.411823544331D-06
7	1.602474940002D-05	-6.171115568805D-07	-8.146917989801D-08
8	-8.353650874253D-07	6.599657419719D-08	2.416556483484D-10

T-Index \ E-Index:	6	7	8
0	-1.081306838597D-04	3.980420063002D-06	-5.865611960494D-08
1	3.455835282567D-04	-1.051504918041D-05	1.297001161406D-07
2	-1.414786677129D-04	3.275747814089D-06	-3.119868249308D-08
3	1.147245647095D-06	8.409794703428D-07	-1.823740755654D-08
4	6.867272943685D-06	-4.730788976909D-07	8.026049328029D-09
5	-7.306589669632D-07	5.266691013685D-08	-8.117214675526D-10
6	-6.030271577709D-08	1.815641913753D-09	-4.671055888097D-11
7	1.133396885188D-08	-5.820505536000D-10	1.163064737956D-11
8	-3.847614776613D-10	2.391347375446D-11	-4.850942377843D-13

```
P2MIN =   1.00000D 08 1/CM3
P2MAX =   1.00000D 16 1/CM3
  Max. rel. Error:  23.6466 %
  Mean rel. Error:   6.3388 %
```


Reduced population coefficients for
for Helium Ions, He+, Formulation II
Ratio of population coefficients p(He*,7)/nHe+
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08
10 0
10 −1
10 −2
10 −3
10 −4
10 −5
10 −6
10 −7
10 −8
10 −9
10 −10
10 −11
10 −12
10 −1
10 0
10 1
10 2
10 3

12.26 Reaction 2.3.2c $e + He^{+} \rightarrow He^{*}$ Ratio $He(8)/He^{+}$

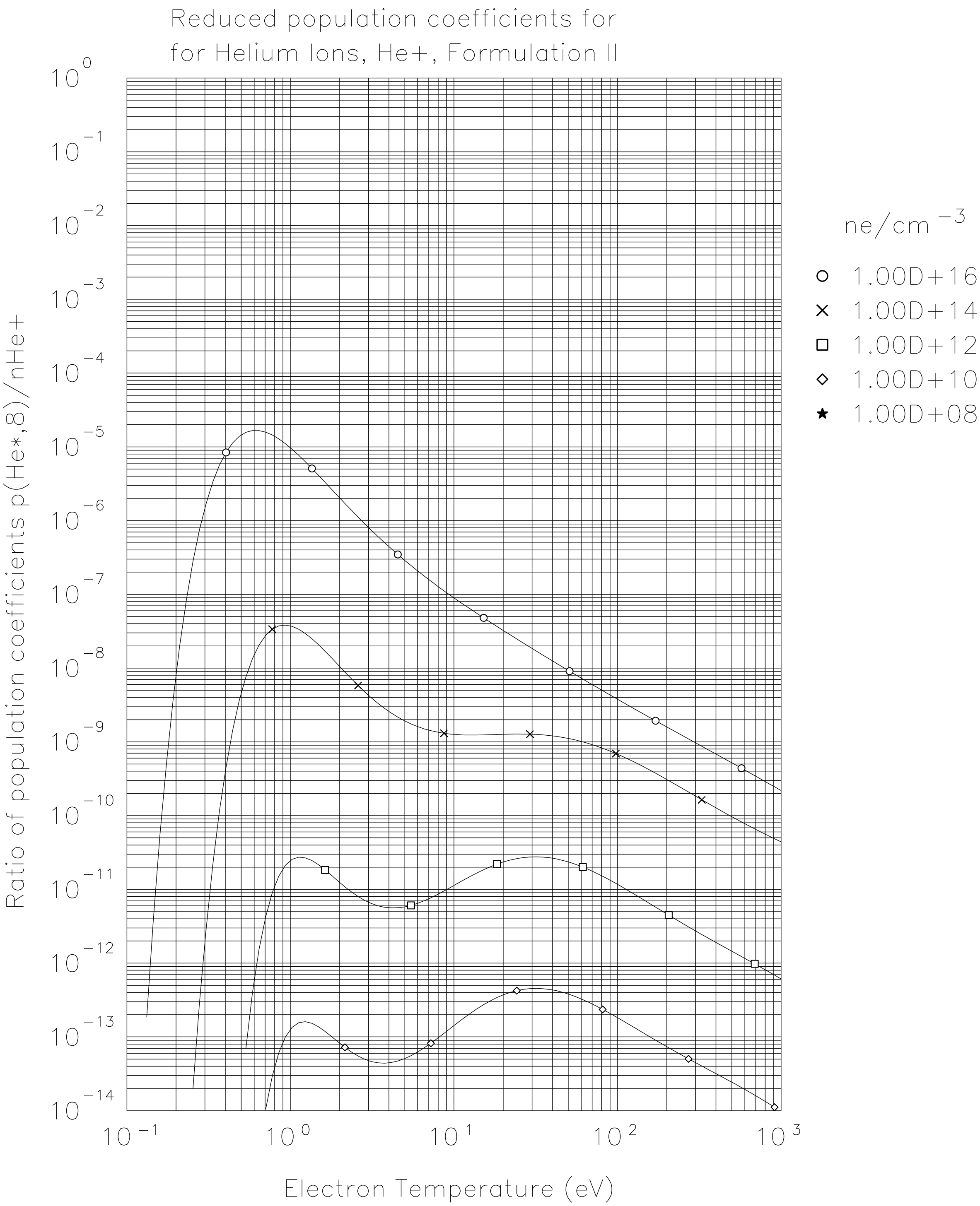
3^1P state, reduced population coefficients, formulation II, Coupling to He^+, [22].
For 501 nm line: $\rightarrow 2^1S$, A(8,2)=1.35143E7 dE = 2.47126 eV

T-Index \ E-Index	0	1	2
0	-3.445572948968D+01	1.137519254060D+00	-1.204158609891D-01
1	2.775136339237D+00	-4.487673567858D-01	4.037515904078D-01
2	-9.482806590562D+00	5.618314205781D-01	-3.914168608519D-01
3	8.753415720243D+00	-3.569019076961D-01	1.753910146247D-01
4	-3.577960912550D+00	1.343719586718D-01	-5.423186626416D-02
5	7.706325166736D-01	-2.952144452037D-02	1.111018961085D-02
6	-9.158735526626D-02	3.628637458935D-03	-1.291959720425D-03
7	5.693572104634D-03	-2.288531778507D-04	7.302736513118D-05
8	-1.447822452674D-04	5.723900429738D-06	-1.455648868887D-06

T-Index \ E-Index	3	4	5
0	5.518321955152D-02	-1.275404675701D-02	1.567946643590D-03
1	-1.505032740194D-01	3.105545096940D-02	-3.891527004898D-03
2	1.175987658408D-01	-2.021206967023D-02	2.440969566947D-03
3	-3.667084372893D-02	2.854422446911D-03	-1.660305334064D-04
4	9.559862125182D-03	-9.162545378146D-05	-8.032611295151D-05
5	-2.147001210922D-03	7.977007897719D-05	8.625984135551D-06
6	2.735972256964D-04	-1.938645862420D-05	6.853343303742D-07
7	-1.532878284339D-05	1.233959442253D-06	-9.081746795921D-08
8	2.445107599088D-07	-1.001706708366D-08	1.073020722799D-09

T-Index \ E-Index	6	7	8
0	-1.004500270631D-04	3.178038428972D-06	-3.936121532969D-08
1	2.854040739913D-04	-1.113667661675D-05	1.772401326973D-07
2	-1.919209138406D-04	8.352922848971D-06	-1.483995437185D-07
3	1.763502677889D-05	-1.312005258433D-06	3.373289875724D-08
4	5.629040165925D-06	-5.258717216470D-08	-3.151242886886D-09
5	-7.699661573237D-07	7.542813546822D-09	5.034382828487D-10
6	-3.749930108264D-08	3.406483389911D-09	-1.104413275874D-10
7	7.612336214085D-09	-4.287524304739D-10	9.944501803630D-12
8	-1.818784682827D-10	1.208359092107D-11	-2.808344024957D-13

P2MIN = 1.00000D 08 1/CM3
P2MAX = 1.00000D 16 1/CM3
Max. rel. Error: 25.0250 %
Mean rel. Error: 6.9230 %



Reduced population coefficients for
for Helium Ions, He+, Formulation II
Ratio of population coefficients p(He*,8)/nHe+
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

12.27 Reaction 2.3.2d $e + He^+ \rightarrow He^*$ Ratio $He(10)/He^+$

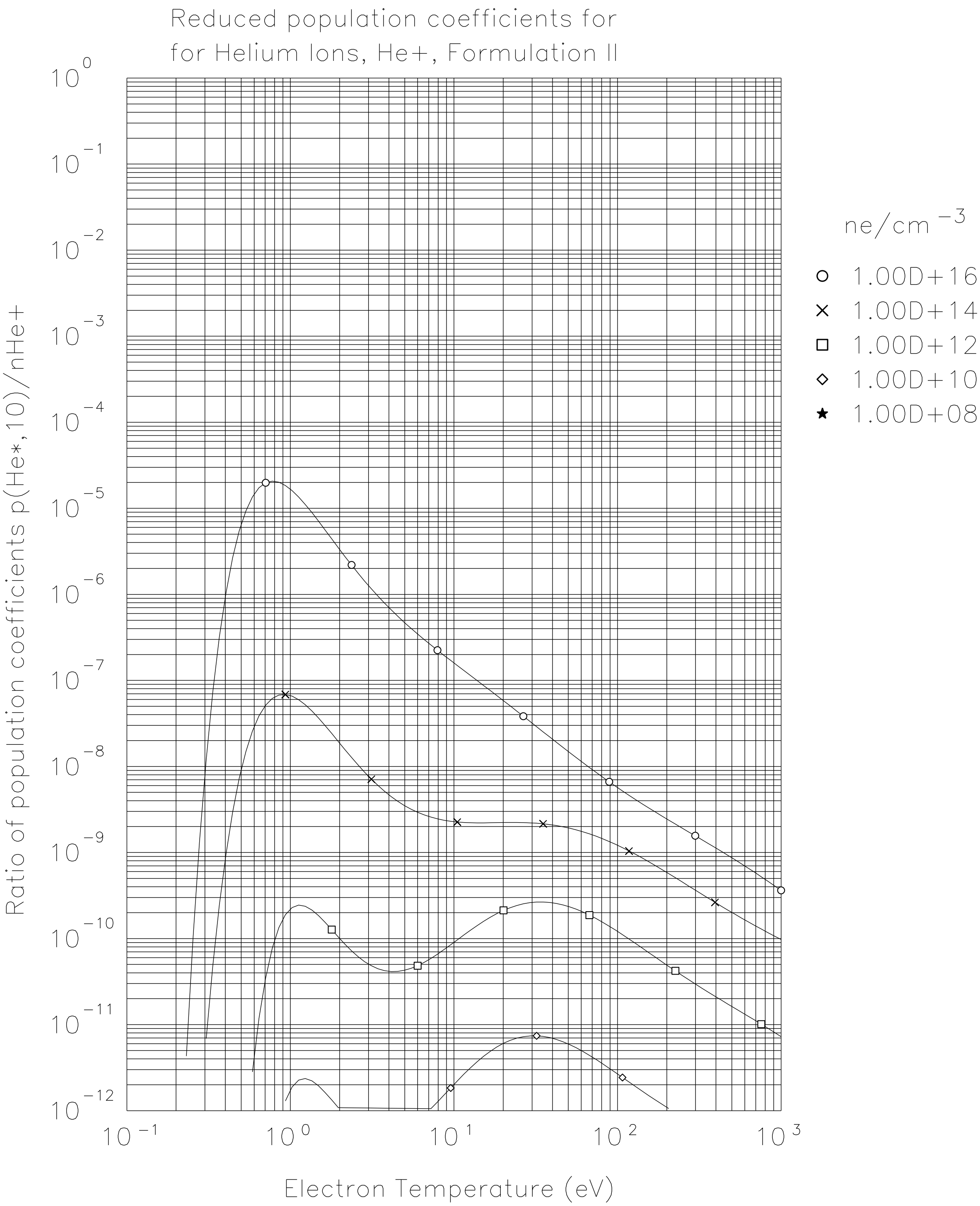
3^1D state, reduced population coefficients, formulation II, Coupling to He$^+$, [22].
For 667 nm line: $\rightarrow 2^1P$, A(10,4)=6.27547e7, dE = 1.8561 eV

T-Index \ E-Index	0	1	2
0	-3.192508131204D+01	7.730604480077D-01	3.913705333191D-01
1	2.828623875238D+00	3.043166975331D-01	-5.394294436435D-01
2	-1.094286352161D+01	4.449752413106D-01	5.999182478623D-02
3	1.052099366893D+01	-7.603297466416D-01	3.020794746641D-01
4	-4.404840999690D+00	3.789883977105D-01	-1.864822739530D-01
5	9.659859829733D-01	-8.886124374969D-02	4.574019828906D-02
6	-1.164625241195D-01	1.078353226216D-02	-5.432191040269D-03
7	7.324584132923D-03	-6.529437247704D-04	3.049402440492D-04
8	-1.880391228394D-04	1.553160134143D-05	-6.266500198751D-06

T-Index \ E-Index	3	4	5
0	-1.895103722167D-01	4.458135648534D-02	-5.670836879252D-03
1	3.196979542189D-01	-7.857255265840D-02	9.520006805526D-03
2	-2.102789422795D-01	6.659906282329D-02	-8.539428018247D-03
3	1.669978165448D-02	-2.112215942331D-02	3.118385995004D-03
4	2.327397267002D-02	1.834729531187D-03	-4.527735068892D-04
5	-7.557858145939D-03	1.796130918335D-04	2.396527075095D-05
6	8.888503829029D-04	-2.025043121277D-05	-2.255417061932D-06
7	-3.985563239078D-05	-2.090429714735D-06	4.928756876729D-07
8	3.268393543240D-07	2.036815496667D-07	-2.933925056569D-08

T-Index \ E-Index	6	7	8
0	3.963745460112D-04	-1.424905218920D-05	2.052965619067D-07
1	-6.049392469505D-04	1.923558499837D-05	-2.397863109992D-07
2	5.302906384868D-04	-1.548203816799D-05	1.630918993190D-07
3	-1.871228014319D-04	4.525444542407D-06	-2.484052167901D-08
4	2.215031871253D-05	-3.969555753912D-09	-1.502410481834D-08
5	5.050715387567D-07	-1.944403098333D-07	6.132124950693D-09
6	-1.681357574652D-07	2.937982495017D-08	-8.509572249650D-10
7	-8.155554263527D-09	-1.366419067606D-09	4.898820258533D-11
8	1.198416940460D-09	5.339525486382D-12	-9.014052780522D-13

```
P2MIN =   1.00000D 08 1/CM3
P2MAX =   1.00000D 16 1/CM3
  Max. rel. Error:  28.7561 %
  Mean rel. Error:   8.5118 %
```


Reduced population coefficients for
for Helium Ions, He+, Formulation II
Ratio of population coefficients p(He*,10)/nHe+
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08
10⁰
10⁻¹
10⁻²
10⁻³
10⁻⁴
10⁻⁵
10⁻⁶
10⁻⁷
10⁻⁸
10⁻⁹
10⁻¹⁰
10⁻¹¹
10⁻¹²
10⁻¹
10⁰
10¹
10²
10³

12.28 Reaction 2.3.2e $e + He^+ \rightarrow He^*$ Ratio $He(16)/He^+$

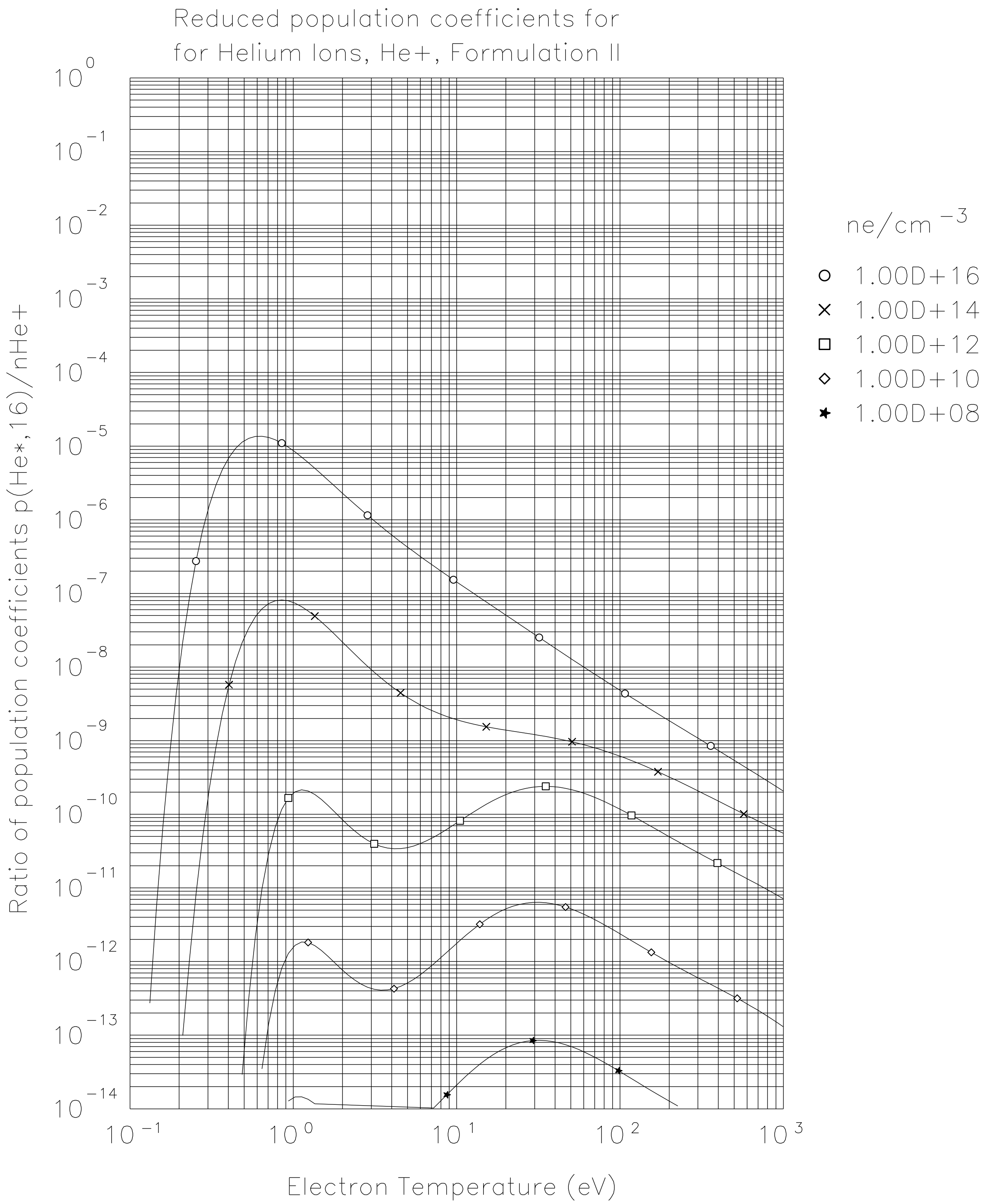
4^1D state, reduced population coefficients, formulation II, Coupling to He^+, [22].
For 492 nm line: $\rightarrow 2^1P$, A(16,4)=1.95062E7, dE = 2.5183 eV

T-Index \ E-Index:	0	1	2
0	-3.188482573905D+01	8.610245311120D-01	-7.871637904226D-02
1	9.933879030912D-01	2.266459651326D+00	-9.472857315400D-01
2	-7.486546162203D+00	-3.150308486050D+00	1.212822565689D+00
3	7.834652212756D+00	1.901758352641D+00	-6.605089155304D-01
4	-3.347990149324D+00	-6.248586863904D-01	2.007495980841D-01
5	7.366886873864D-01	1.190475683473D-01	-3.602551009154D-02
6	-8.864057763980D-02	-1.309846016686D-02	3.760565403015D-03
7	5.555256683180D-03	7.711297791954D-04	-2.099326142463D-04
8	-1.421052566331D-04	-1.878580877217D-05	4.822799528233D-06

T-Index \ E-Index:	3	4	5
0	1.007691814520D-01	-3.094881651282D-02	4.360394656253D-03
1	1.590010861827D-01	-1.031249533204D-02	-2.061971584679D-04
2	-2.039503541069D-01	1.940627970159D-02	-1.269842997337D-03
3	9.150327990878D-02	-6.639386857171D-03	3.547850561263D-04
4	-2.342313204830D-02	1.172376176842D-03	-2.311168366669D-05
5	3.768569485892D-03	-1.588304810091D-04	-2.066241218916D-07
6	-3.706654458246D-04	1.841194915725D-05	-4.050823848900D-07
7	1.996960560623D-05	-1.358423173826D-06	7.836592920988D-08
8	-4.433571946131D-07	4.149590065641D-08	-3.556757547808D-09

T-Index \ E-Index:	6	7	8
0	-3.145292638212D-04	1.131115258763D-05	-1.610863865001D-07
1	6.454814129154D-05	-3.308023119594D-06	5.784207966726D-08
2	6.690737638410D-05	-2.294961757856D-06	3.201017904975D-08
3	-2.521266112731D-05	1.253726502750D-06	-2.225943158869D-08
4	3.096507943757D-06	-2.590646481613D-07	5.452184158491D-09
5	-2.280634231739D-07	3.149850598031D-08	-6.947518389720D-10
6	3.729749615530D-08	-2.770965878183D-09	4.800254654826D-11
7	-4.762215328192D-09	1.745304400761D-10	-1.658813624438D-12
8	2.026923384162D-10	-5.318966772198D-12	2.100743151512D-14

```
P2MIN =   1.00000D 08 1/CM3
P2MAX =   1.00000D 16 1/CM3
  Max. rel. Error:  37.7911 %
  Mean rel. Error:   6.9227 %
```


Reduced population coefficients for
for Helium Ions, He+, Formulation II
Ratio of population coefficients p(He*,16)/nHe+
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

12.29 Reaction 2.3.9a $He(1s^2 1S) + e \rightarrow He^+(1s) + 2e \quad < de > \quad [eV]$

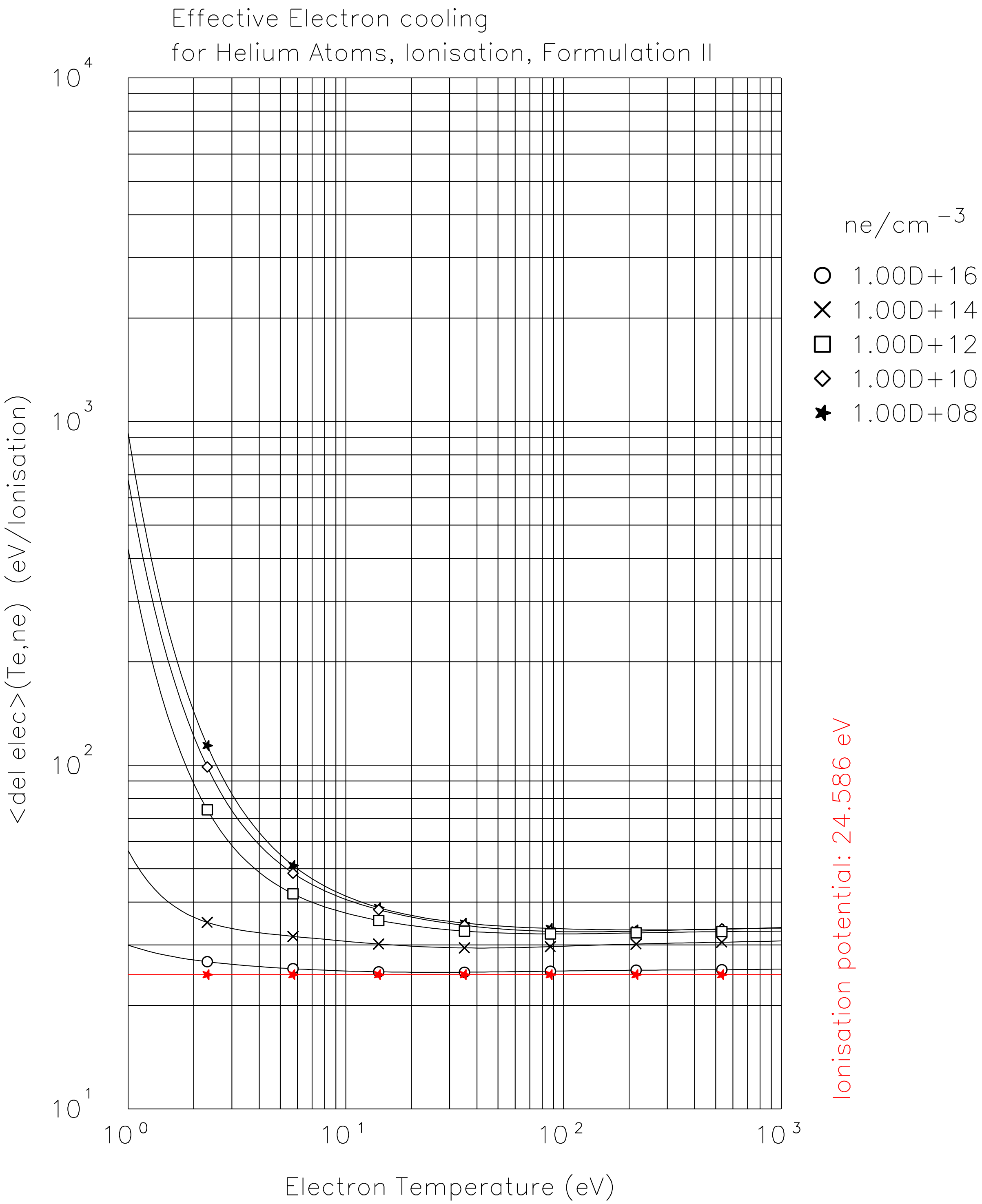
electron energy loss (radiative plus potential) due to one effective ionization.

T-Index \ E-Index	0	1	2
0	6.833598031940D+00	-2.581591750171D-01	3.002724552043D-01
1	-3.963803034848D+00	1.083742817806D-01	-2.185819272140D-01
2	2.340984418775D+00	7.960301860904D-02	-2.380541593246D-02
3	-8.720605342433D-01	-2.187065734893D-02	4.335409780587D-02
4	2.151914370389D-01	-2.025747886335D-02	-6.222418098960D-03
5	-3.480057305671D-02	1.039843241545D-02	-1.466657569917D-03
6	3.519085971631D-03	-1.896269271396D-03	4.723390036919D-04
7	-2.005331697724D-04	1.550021181454D-04	-4.460430898110D-05
8	4.890032176597D-06	-4.783948237900D-06	1.434239402361D-06

T-Index \ E-Index	3	4	5
0	-1.562968002089D-01	3.804132257792D-02	-4.819950771068D-03
1	1.380891687214D-01	-3.493851885048D-02	4.336864850281D-03
2	-2.233168326792D-02	8.567898287243D-03	-1.135198845537D-03
3	-9.017359555794D-03	4.146449794934D-04	2.229593440360D-05
4	2.872369142740D-03	-3.563116903860D-04	2.183046296448D-05
5	-1.004362351325D-04	2.650562392977D-05	-1.006835018389D-06
6	-4.170965146914D-05	1.520955505512D-06	-1.199396957406D-07
7	4.727045263171D-06	-1.341691381461D-07	-9.067558155258D-09
8	-1.408579120961D-07	-2.631952383725D-09	1.504095408373D-09

T-Index \ E-Index	6	7	8
0	3.251351974739D-04	-1.108119967409D-05	1.502088801630D-07
1	-2.788751037407D-04	8.919934156922D-06	-1.121476666732D-07
2	6.881062206346D-05	-1.901589536293D-06	1.850790588779D-08
3	-1.237210702996D-06	-5.350049703101D-08	2.614670721314D-09
4	-8.649474896814D-07	2.477033243810D-08	-3.749285231265D-10
5	-7.916173274377D-08	7.346267688694D-09	-1.619067607087D-10
6	2.102619442307D-08	-1.402551865343D-09	3.013612509314D-11
7	2.537560484891D-10	3.296713149429D-11	-1.211004021082D-12
8	-1.050110011758D-10	2.672317014529D-12	-1.734344850181D-14

P2MIN = 1.00000D 08 1/CM3
P2MAX = 1.00000D 16 1/CM3
Max. rel. Error: 4.8670 %
Mean rel. Error: .4586 %


Effective Electron cooling
for Helium Atoms, Ionisation, Formulation II
<del elec>(Te,ne) (eV/Ionisation)
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08
Ionisation potential: 24.586 eV

12.30 Reaction 2.3.13a $e + He^{+}(1s) \rightarrow He(1s^{2}1S) + hv \quad < de > +24.58\ [eV]$

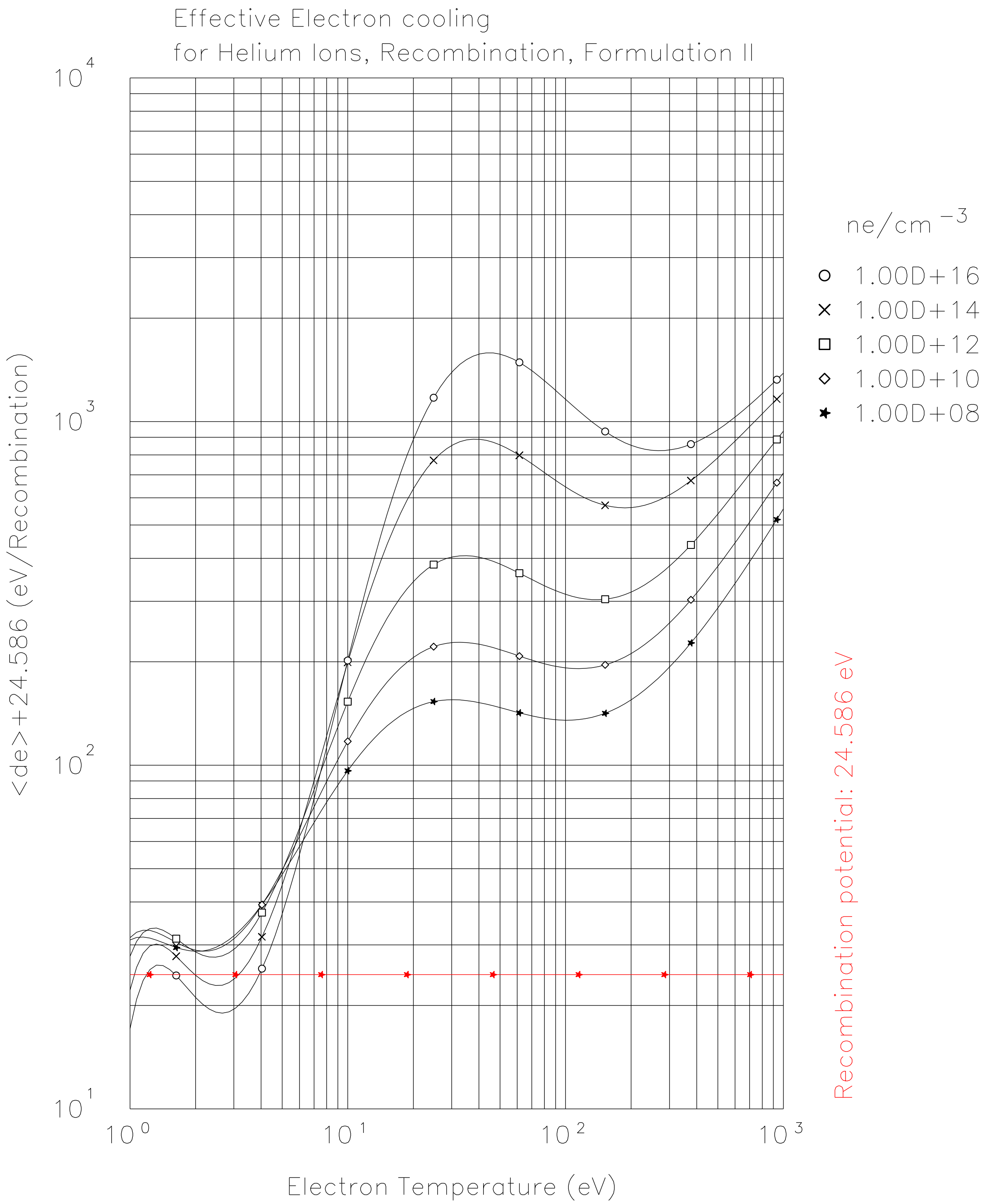
electron energy loss (radiative plus potential) due to one effective recombination. 24.586 eV (ionization potential) has to be subtracted, which may render the total electron loss negative, i.e., make it a gain.

T-Index \ E-Index	0	1	2
0	3.433913136981D+00	-4.838690601594D-03	-3.012005651151D-03
1	3.571941963713D-01	1.366702629693D-01	4.305394970015D-03
2	-1.878217847962D+00	-2.687159886881D-01	3.681576112685D-02
3	2.424802386624D+00	1.668555927113D-01	-1.489289566691D-02
4	-1.167489860199D+00	-3.968312198499D-02	-5.806242392586D-03
5	2.785216165202D-01	2.794413323851D-03	3.748295131357D-03
6	-3.549870765089D-02	3.061971808105D-04	-6.964994225616D-04
7	2.325006625009D-03	-5.536285155093D-05	5.514149047897D-05
8	-6.167011906326D-05	2.237779310326D-06	-1.602672918010D-06

T-Index \ E-Index	3	4	5
0	4.897530083159D-03	-1.501012076471D-03	1.946127138348D-04
1	-2.542692753033D-02	8.618718418466D-03	-1.155324896611D-03
2	4.404690243381D-03	-4.417465105562D-03	6.541649981092D-04
3	5.027112091534D-03	2.212796313573D-04	-6.372305615527D-05
4	-1.157260624154D-03	9.661422893980D-05	-7.830966474304D-06
5	-7.990778489925D-05	-5.166337856831D-06	5.389604603452D-07
6	3.596656976635D-05	1.433564986542D-07	1.512821193564D-08
7	-2.512892127544D-06	-2.280106015151D-07	1.957605446858D-08
8	3.299538986852D-08	1.871390766422D-08	-1.821480547627D-09

T-Index \ E-Index	6	7	8
0	-1.279526998241D-05	4.198553031308D-07	-5.453125267641D-09
1	7.588474563611D-05	-2.435602148969D-06	3.048074124737D-08
2	-4.062514764122D-05	1.126080643711D-06	-1.084879079455D-08
3	1.646788579650D-06	1.017675408347D-07	-3.909525540561D-09
4	1.221818458812D-06	-7.525537630546D-08	1.491574341448D-09
5	-5.819508932994D-08	1.849145077320D-09	-1.280524821596D-12
6	-1.800399945032D-08	1.587416635024D-09	-3.976884843047D-11
7	1.171329251871D-09	-1.635594061798D-10	4.324427772952D-12
8	1.868229185881D-11	4.166329792374D-12	-1.347143462455D-13

```
P2MIN =   1.00000D 08 1/CM3
P2MAX =   1.00000D 16 1/CM3
  Max. rel. Error:  22.5154 %
  Mean rel. Error:   7.8340 %
```



Effective Electron cooling
for Helium Ions, Recombination, Formulation II
<de>+24.586 (eV/Recombination)
Electron Temperature (eV)
ne/cm $^{-3}$
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08
Recombination potential: 24.586 eV

12.31 Reaction 2.6A0 $C + e \rightarrow C^+ + 2e \quad < de > [eV]$

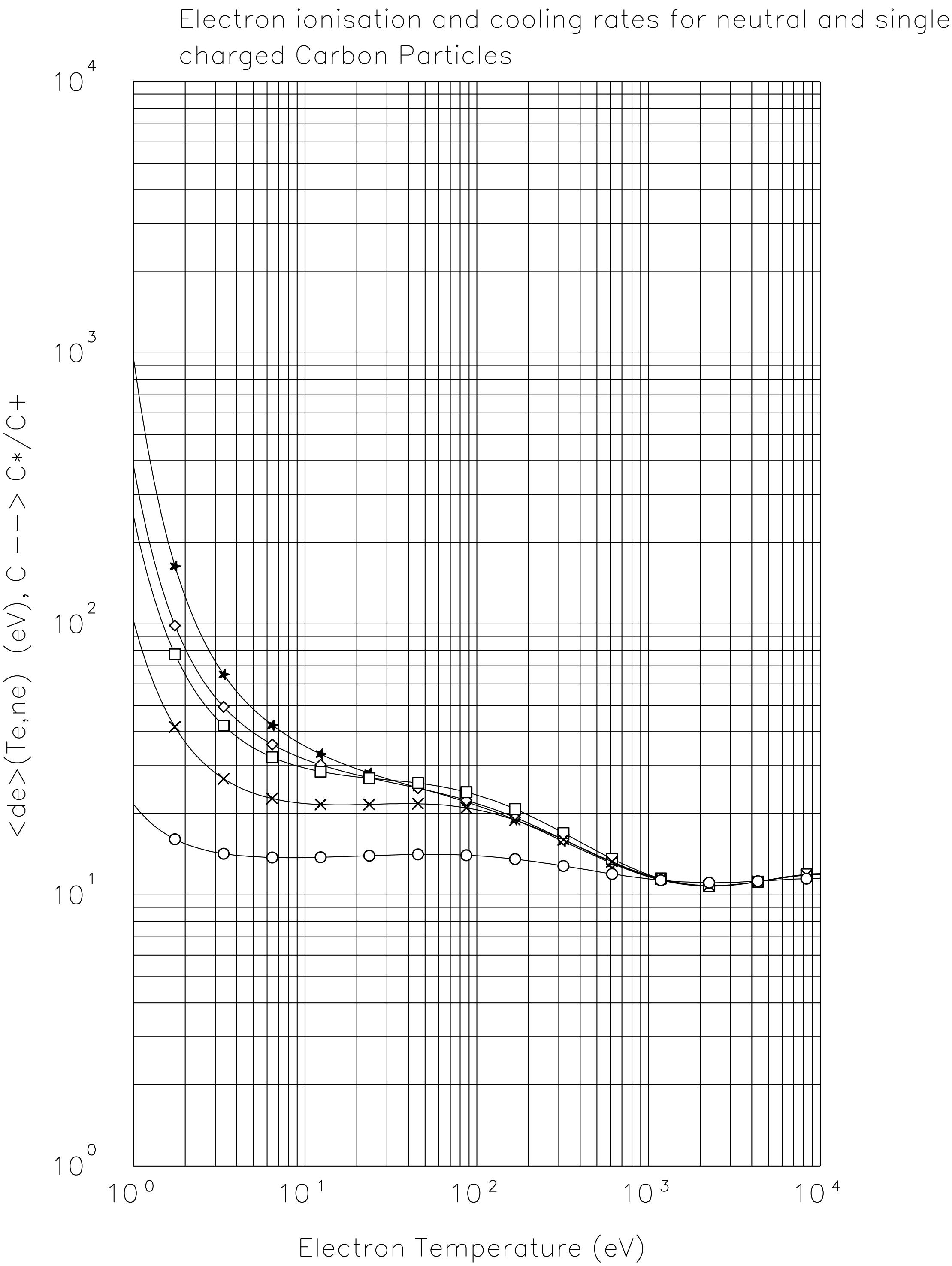
ADAS 93: electron energy loss (radiative+potential) due to one effective ionization.

T-Index \ E-Index	0	1	2
0	9.498032398433D+00	-1.819265937462D+00	5.796344005492D-01
1	-2.316370818977D+00	-1.912413251967D+00	5.639266856065D-01
2	2.320704120275D+00	7.593550209141D-01	-2.384731751044D-01
3	-1.423469978730D+00	-3.888330744867D-02	1.868782289925D-02
4	4.441710451586D-01	-1.408402765701D-02	4.609271425672D-04
5	-8.198134345687D-02	3.816981348123D-03	-1.201041388569D-04
6	9.025343419623D-03	-5.956250281350D-04	3.460685141518D-05
7	-5.421408064934D-04	5.242557410997D-05	-5.660290060134D-06
8	1.358691589766D-05	-1.845719396806D-06	2.798854323430D-07

T-Index \ E-Index	3	4	5
0	-9.876225428908D-02	7.923470670427D-03	-1.889758400029D-04
1	-7.502544061825D-02	4.301133626753D-03	1.263821297128D-04
2	3.513874434013D-02	-2.722831770062D-03	5.261936992701D-05
3	-2.516467231041D-03	1.815314237493D-04	-3.776094914794D-07
4	-5.595871698878D-05	1.172374862061D-05	-1.427876732685D-06
5	-9.049612725058D-06	-2.823320281538D-07	1.856100050999D-07
6	8.873065193751D-07	-1.786247323757D-07	6.579947427433D-09
7	2.934330556330D-07	5.202583801575D-09	-2.631835360203D-09
8	-2.439978518785D-08	7.004344333195D-10	1.000272415897D-10

T-Index \ E-Index	6	7	8
0	-1.022904037358D-05	5.840788152953D-07	-6.375736799139D-09
1	-3.427310072061D-05	1.885339856267D-06	-3.505352276047D-08
2	6.880039401864D-06	-4.536973415974D-07	7.687829752307D-09
3	-3.936336799962D-07	-1.180564243948D-08	1.277731900255D-09
4	-4.740152838620D-08	1.512393664320D-08	-5.903109943091D-10
5	-1.544365666000D-09	-1.278608019932D-09	6.083549010546D-11
6	2.900458497992D-11	4.157695298962D-12	-1.518435981756D-12
7	1.539892599330D-10	-6.042934507312D-13	-4.298624172985D-14
8	-9.023325396014D-12	1.668395598922D-13	7.457156257137D-16

```
T1MIN =   1.00000D 00 EV
T1MAX =   5.00000D 04 EV
N2MIN =   1.00000D 10 1/CM3
N2MAX =   1.00000D 15 1/CM3
  Max. rel. Error:  10.0848 %
  Mean rel. Error:   3.3383 %
```


Electron ionisation and cooling rates for neutral and single
charged Carbon Particles
<de>(Te,ne) (eV), C ––> C*/C+
Electron Temperature (eV)
10^4
10^3
10^2
10^1
10^0
10^0
10^1
10^2
10^3
10^4

12.32 Reaction 2.3.6A0 $C^{+} + e \rightarrow C \quad < de > +11.3 \; [eV]$

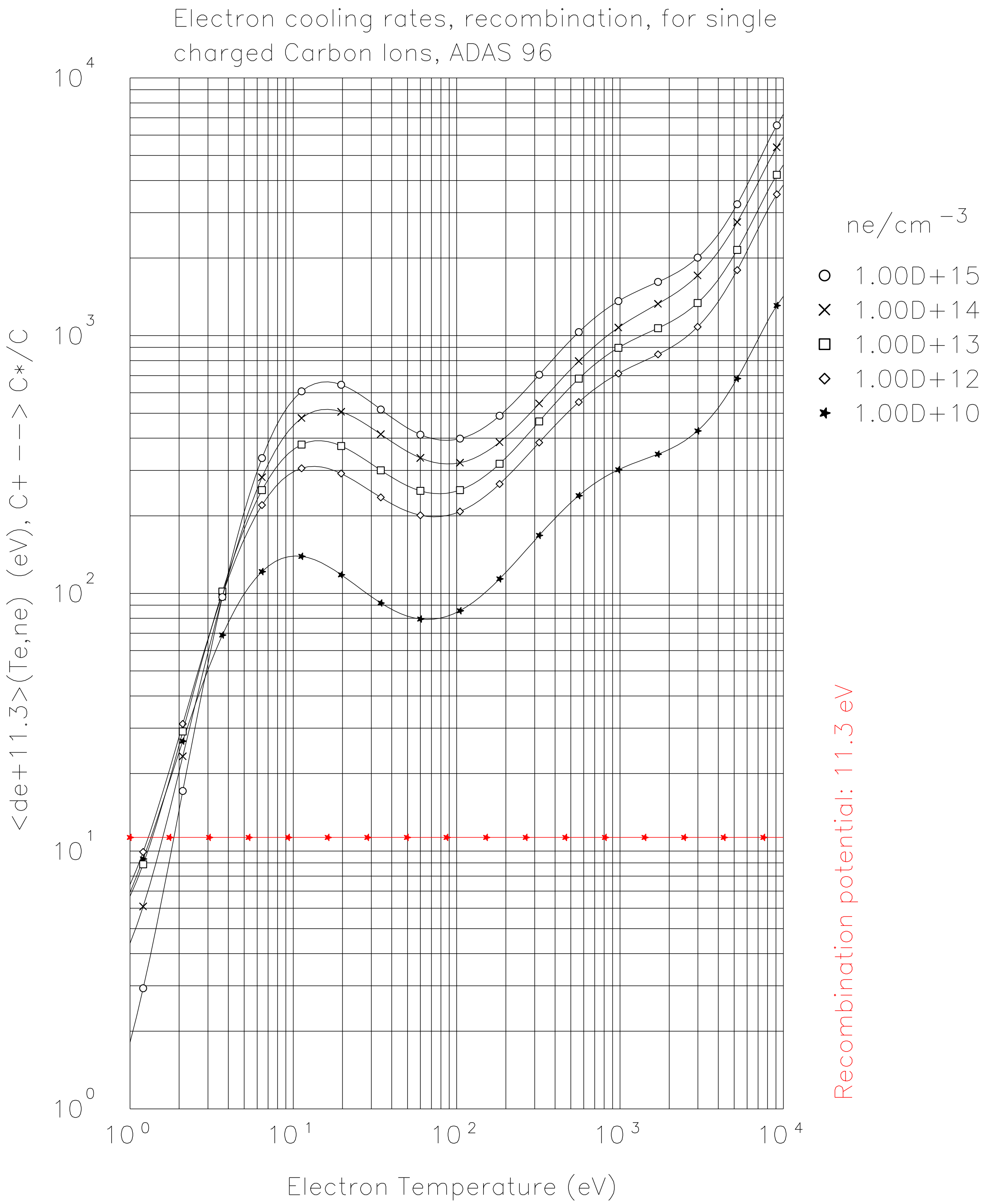
electron energy loss (radiative) due to one effective recombination. For the total electron energy loss, 11.3 eV (potential) have to be subtracted, which may render the loss negative, i.e., make it a gain.

T-Index \ E-Index	0	1	2
0	6.453628189480D+00	-3.411959121202D+00	1.027601643412D+00
1	5.566257359499D+00	-2.827487978046D+00	1.323581114195D+00
2	7.023144782419D-02	-8.719987617388D-01	2.676321249963D-01
3	-1.612434026349D-01	1.081834795086D-01	-7.116653339183D-02
4	6.539562167664D-02	4.139385617180D-02	2.769162614331D-03
5	-2.206442445551D-02	-7.840262448517D-03	-9.995675347671D-04
6	2.871920422343D-03	8.502276174927D-04	1.251507934880D-04
7	-1.549156846628D-04	-6.373587175654D-05	-3.129721638855D-06
8	3.278924523113D-06	1.670923171850D-06	8.554676549572D-08

T-Index \ E-Index	3	4	5
0	-1.501284760092D-01	9.016194688684D-03	2.238571380263D-04
1	-3.322262917492D-01	4.865809696737D-02	-4.343709230425D-03
2	-2.643011608926D-02	5.658846165674D-04	1.413672739471D-04
3	7.688215878015D-03	-5.493080299892D-04	3.497209232351D-05
4	5.691532547205D-04	-1.149074252290D-04	4.807423173738D-06
5	5.044633066348D-05	4.715897395507D-06	-9.154583868877D-08
6	-1.234952236991D-05	-9.240109636586D-08	4.248634746180D-08
7	3.335538428637D-07	2.604300994523D-08	-3.070635332640D-09
8	-3.205409357745D-08	4.814828405950D-09	-5.332849014591D-10

T-Index \ E-Index	6	7	8
0	-5.983556406852D-05	2.938264102004D-06	-4.865346084259D-08
1	2.324145347640D-04	-6.832076246100D-06	8.466507036184D-08
2	-1.468227303594D-05	5.744169024370D-07	-8.237111069147D-09
3	-2.064808887243D-06	7.798853036278D-08	-1.206248775248D-09
4	2.193418042952D-07	-1.995457258897D-08	3.575861953373D-10
5	-4.818418728971D-08	2.776256710020D-09	-3.694099060448D-11
6	-2.045420857293D-10	-3.406586578331D-11	-7.204537382726D-13
7	1.097056113387D-11	2.734596577436D-12	2.335553372556D-14
8	3.762885118005D-11	-1.334245563205D-12	1.722914980319D-14

Max. rel. Error: 9.9451 %
Mean rel. Error: 4.6015 %



Electron cooling rates, recombination, for single charged Carbon Ions, ADAS 96
<de+11.3>(Te,ne) (eV), C+ --> C*/C
Electron Temperature (eV)
ne/cm −3
1.00D+15
1.00D+14
1.00D+13
1.00D+12
1.00D+10
Recombination potential: 11.3 eV

12.33 Reaction 2.2.5a $H_2 + e \rightarrow ... + H(3)$, Ratio $H(3)/H_2$

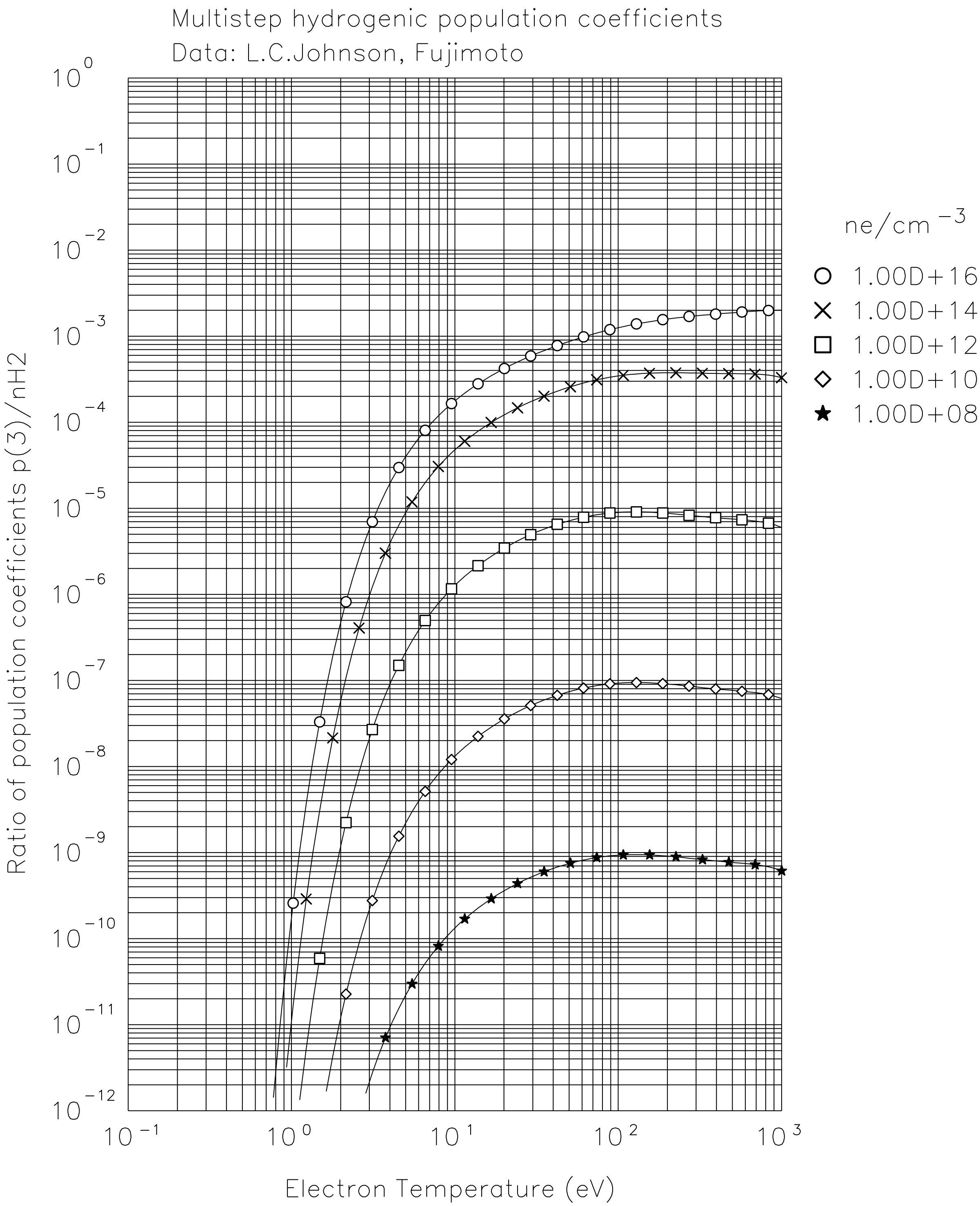
Multi-step hydrogenic population coefficients Data: K. Sawada, T.Fujimoto [7] Ratio of population coefficients: p(3)/nH2

T-Index \ E-Index	0	1	2
0	-3.843232308973D+01	9.866136797620D-01	-7.630767164474D-04
1	1.763737135501D+01	-7.268396239737D-02	1.044914850159D-01
2	-9.102596461463D+00	6.283138055344D-02	-7.375751509571D-02
3	3.044087169667D+00	-4.582914429668D-02	4.001305352976D-02
4	-6.799512263137D-01	2.529525369912D-02	-1.619747297605D-02
5	1.021208740284D-01	-9.089155747301D-03	4.651977381511D-03
6	-1.027903716284D-02	1.911308645888D-03	-8.844096702821D-04
7	6.460492607832D-04	-2.089424506198D-04	9.480996308587D-05
8	-1.923319726365D-05	9.093882674319D-06	-4.196010732530D-06

T-Index \ E-Index	3	4	5
0	8.463761770878D-03	-3.668738045523D-03	6.470552634326D-04
1	-5.045692652261D-02	1.145016084229D-02	-1.370891627120D-03
2	2.874156352094D-02	-5.093075324948D-03	4.483604397328D-04
3	-1.247549414985D-02	1.733717971265D-03	-1.065732952139D-04
4	3.883454673035D-03	-4.379243673277D-04	2.751938724811D-05
5	-7.719439518973D-04	4.105848834550D-05	-9.791293810522D-07
6	1.045477116614D-04	4.536233386087D-06	-1.259893630895D-06
7	-9.553834264468D-06	-1.115019494878D-06	2.363713809533D-07
8	4.237208860211D-07	5.589085089129D-08	-1.252796449945D-08

T-Index \ E-Index	6	7	8
0	-5.551234542034D-05	2.284493199758D-06	-3.621267376539D-08
1	8.882007338293D-05	-2.941321182498D-06	3.890740158619D-08
2	-1.885697574083D-05	2.852269978935D-07	8.496957677236D-10
3	1.618515118726D-06	9.254848831070D-08	-2.858249742968D-09
4	-1.329060444185D-06	5.670350444090D-08	-1.228700843631D-09
5	2.901690837726D-07	-2.818973160122D-08	7.385401732551D-10
6	2.538253614744D-08	3.282804098763D-09	-1.212274570019D-10
7	-1.107068687207D-08	-5.725981536387D-12	7.272031033863D-12
8	7.329111895115D-10	-1.221514806869D-11	-8.661756397302D-14

```
P2MIN =   1.00000D 08 1/CM3
P2MAX =   1.00000D 16 1/CM3
 Max. rel. Error:   3.0327 %
 Mean rel. Error:   1.0280 %
```



Multistep hydrogenic population coefficients
Data: L.C.Johnson, Fujimoto
Ratio of population coefficients p(3)/nH2
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

12.34 Reaction 2.2.5b $H_2 + e \rightarrow ... + H(2)$, Ratio $H(2)/H_2$

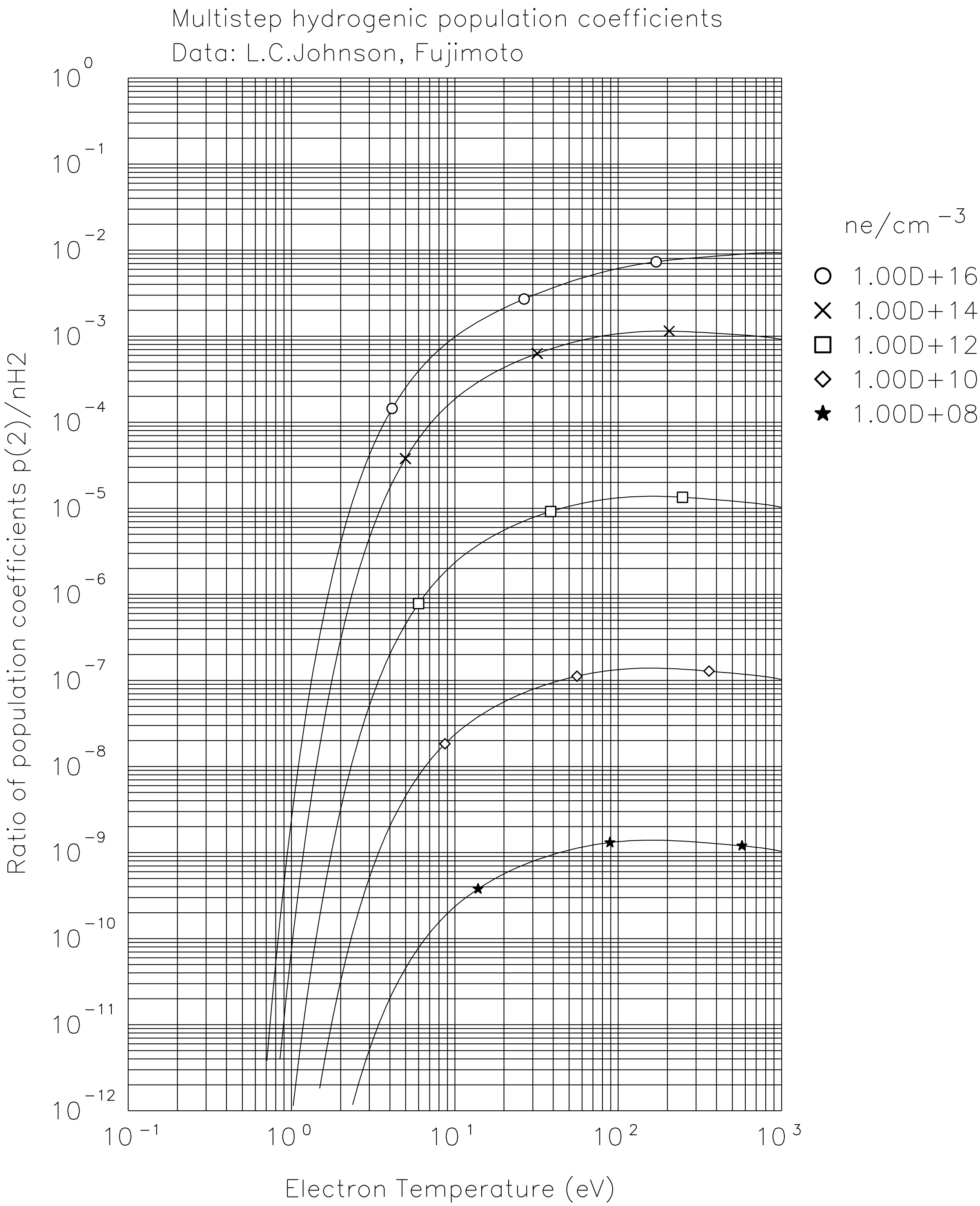
Ratio of population coefficients: p(2)/nH2
Multi-step hydrogenic population coefficients Data: K. Sawada, T.Fujimoto [7]

T-Index \ E-Index	0	1	2
0	-3.709244791220D+01	9.687241476053D-01	3.742262659150D-02
1	1.669985823625D+01	-1.746089790847D-02	2.153832458702D-02
2	-8.309237048353D+00	3.381127410703D-02	-3.556201387754D-02
3	2.657739315672D+00	-8.512812279243D-03	1.196655088860D-02
4	-6.132396646504D-01	-2.552858621025D-03	1.194454859764D-04
5	1.101743243476D-01	1.097984176326D-03	-4.977907148307D-04
6	-1.475653262109D-02	-4.324624980123D-05	-1.194492163554D-07
7	1.224129849314D-03	-1.978420677869D-05	1.695927041869D-05
8	-4.446691780917D-05	1.813978843455D-06	-1.455738811700D-06

T-Index \ E-Index	3	4	5
0	-1.651081799644D-02	3.565764257714D-03	-4.174591391487D-04
1	-1.090577226038D-02	2.794096310833D-03	-3.908538558075D-04
2	1.407590381030D-02	-2.699474372936D-03	2.742035615058D-04
3	-5.055672344660D-03	9.440106236031D-04	-8.615580226180D-05
4	3.664276773773D-04	-1.108403409912D-04	1.373091515639D-05
5	1.084866241578D-04	-9.612225065207D-06	-3.739409418091D-07
6	-5.135563052511D-06	1.895456383045D-06	-1.588469158937D-07
7	-3.814928055218D-06	2.731245678489D-07	1.634952517283D-09
8	3.749880009743D-07	-3.989523167029D-08	1.603033939474D-09

T-Index \ E-Index	6	7	8
0	2.688883877617D-05	-8.884834785320D-07	1.159228215260D-08
1	2.999154465824D-05	-1.175608698972D-06	1.820253115424D-08
2	-1.469100393011D-05	3.734482260499D-07	-3.177600597413D-09
3	3.725098060685D-06	-5.918174922608D-08	-6.433645161998D-11
4	-9.325142355108D-07	3.763485456338D-08	-7.145755570016D-10
5	1.704997971383D-07	-1.376296741989D-08	3.514893200953D-10
6	-1.145517528846D-08	1.898641500278D-09	-5.838483361781D-11
7	1.312392622432D-10	-1.035003695410D-10	4.030531144035D-12
8	-2.253655572832D-11	2.072693141970D-12	-9.944952208106D-14

```
P2MIN =   1.00000D 08 1/CM3
P2MAX =   1.00000D 16 1/CM3
 Max. rel. Error:   1.9631 %
 Mean rel. Error:   0.6656 %
```


Multistep hydrogenic population coefficients
Data: L.C.Johnson, Fujimoto
Ratio of population coefficients p(2)/nH2
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

12.35 Reaction 2.2.5c $H_2 + e \rightarrow ... + H(4)$, Ratio $H(4)/H_2$

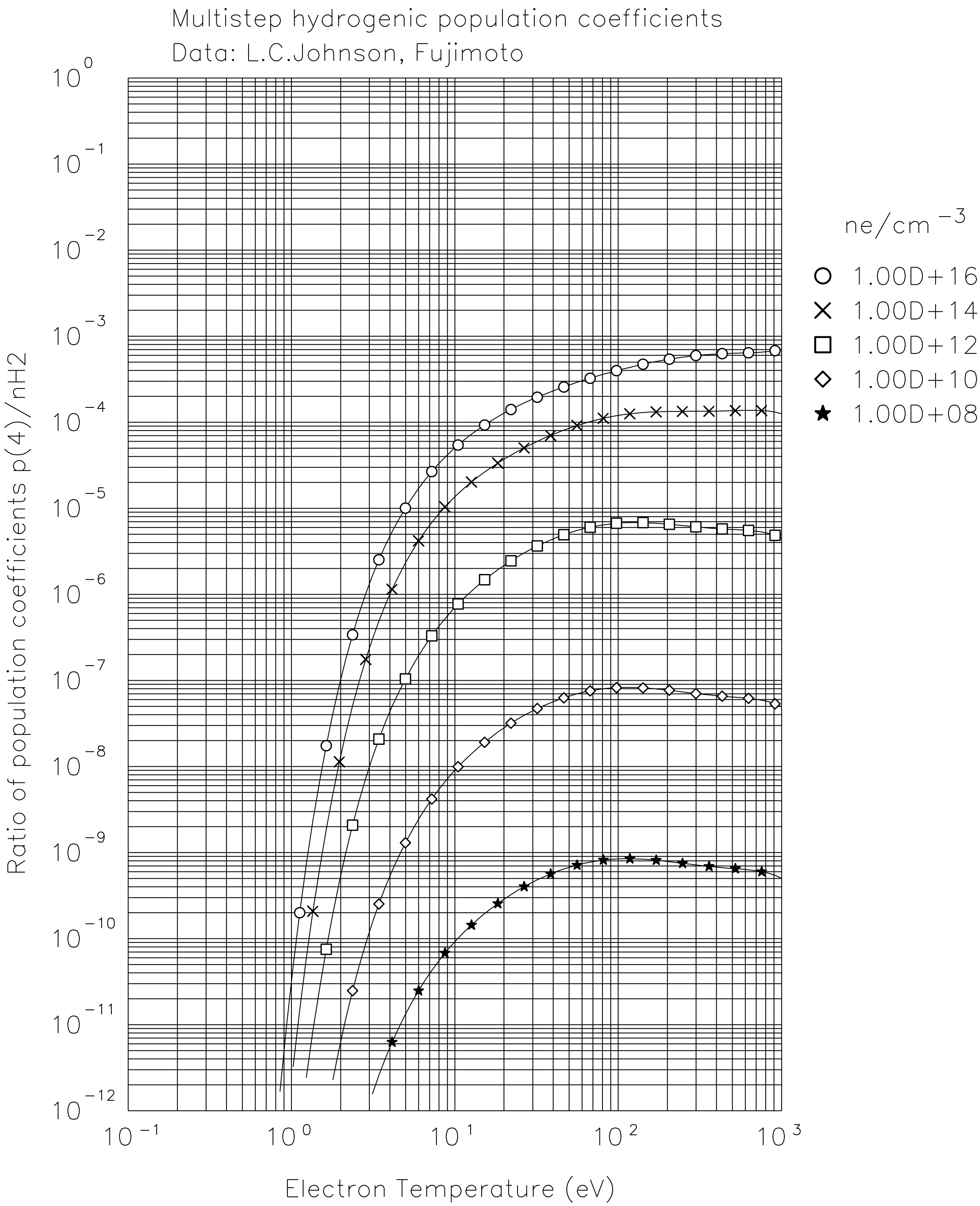
Ratio of population coefficients: p(4)/nH2
Multi-step hydrogenic population coefficients Data: K. Sawada, T.Fujimoto [7]

T-Index \ E-Index	0	1	2
0	-3.912344526943D+01	9.262202059006D-01	9.389410302438D-02
1	1.756197573185D+01	-4.343762540494D-02	6.126434071800D-02
2	-8.886628104138D+00	2.119621111180D-02	-2.656188467734D-02
3	3.057910637954D+00	-1.535881342701D-03	2.932875657740D-03
4	-7.835206514361D-01	-1.389945765942D-03	1.255399530700D-03
5	1.580308696978D-01	1.928352522209D-04	-3.543899525036D-04
6	-2.353640097896D-02	4.031200319945D-05	2.846252498973D-05
7	2.128743508257D-03	-8.795964786784D-06	-1.512497781432D-06
8	-8.285077032772D-05	4.111725894460D-07	1.270837350725D-07

T-Index \ E-Index	3	4	5
0	-4.264954883585D-02	9.104064233267D-03	-9.991876289465D-04
1	-3.242966270346D-02	8.357146835162D-03	-1.147734080465D-03
2	1.227590202063D-02	-2.719431170815D-03	3.144838167343D-04
3	-1.186497869383D-03	1.497138310345D-04	3.644078028099D-06
4	-5.552975953317D-04	1.352074320357D-04	-1.821378482602D-05
5	1.750515375163D-04	-3.621530587129D-05	3.319095280981D-06
6	-2.248136922616D-05	4.496488473333D-06	-2.595976205911D-07
7	2.265470434041D-06	-4.927085512215D-07	3.240824081247D-08
8	-1.404975048998D-07	3.246838389464D-08	-2.985897409147D-09

T-Index \ E-Index	6	7	8
0	5.646131117170D-05	-1.541734784320D-06	1.563548973536D-08
1	8.491836730798D-05	-3.177470024031D-06	4.698887012882D-08
2	-1.909003815732D-05	5.644098554224D-07	-6.240476308631D-09
3	-2.108751238830D-06	1.449614494660D-07	-3.025489423066D-09
4	1.329682209766D-06	-4.835654939859D-08	6.736536866134D-10
5	-1.024702456679D-07	-1.838064127165D-09	1.096804376213D-10
6	-1.383903232721D-08	1.811451752221D-09	-4.443051906110D-11
7	8.783996080897D-10	-1.570045781133D-10	3.895723973541D-12
8	9.149043474391D-11	1.200102594315D-12	-7.103779862531D-14

```
P2MIN =   1.00000D 08 1/CM3
P2MAX =   1.00000D 16 1/CM3
  Max. rel. Error:   5.8311 %
  Mean rel. Error:   2.4005 %
```



Multistep hydrogenic population coefficients
Data: L.C.Johnson, Fujimoto
Ratio of population coefficients p(4)/nH2
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

12.36 Reaction 2.2.5d $H_2 + e \rightarrow ... + H(5)$, Ratio $H(5)/H_2$

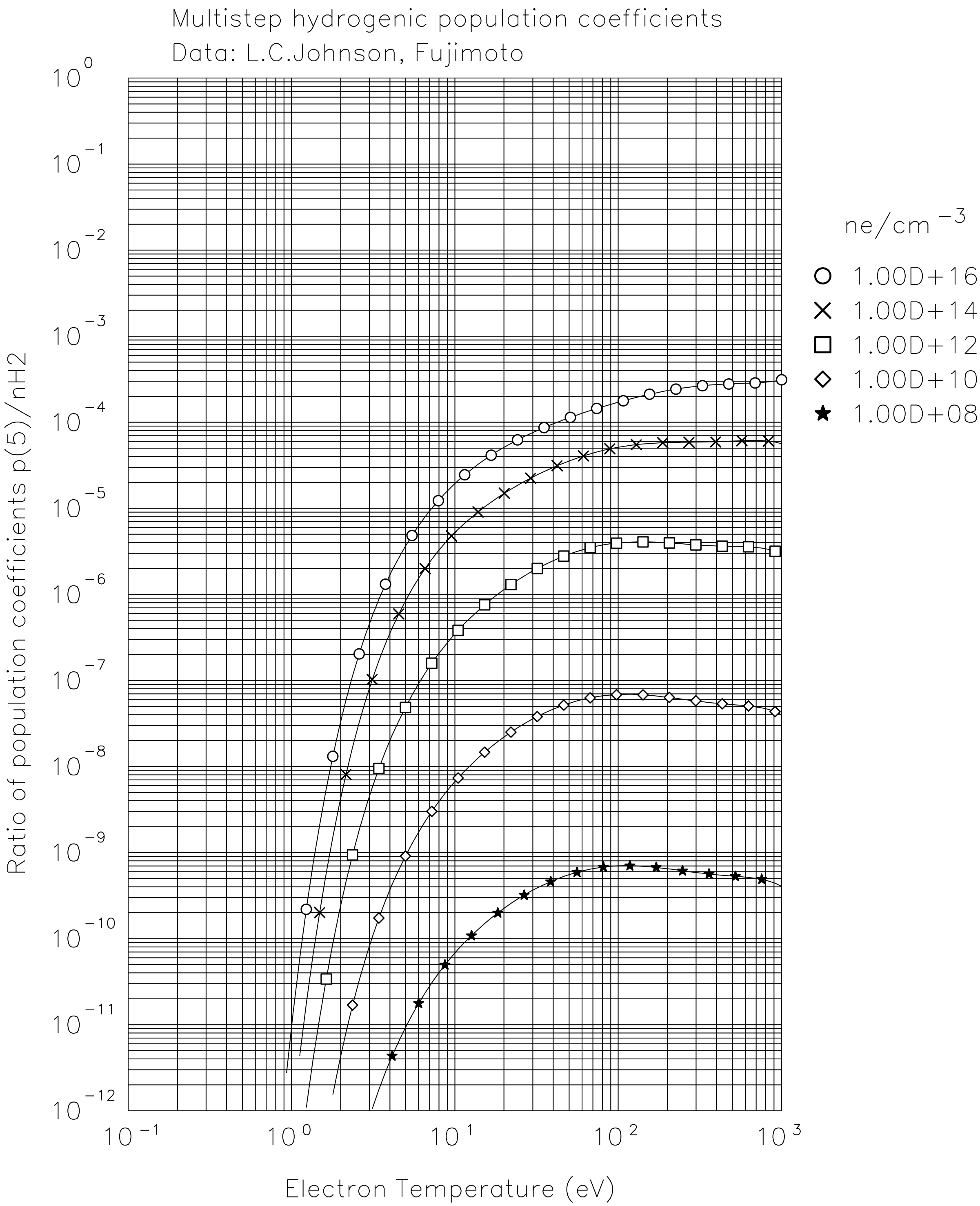
Ratio of population coefficients: p(5)/nH2
Multi-step hydrogenic population coefficients Data: K. Sawada, T.Fujimoto [7]

T-Index \ E-Index:	0	1	2
0	-3.951411187905D+01	9.845720830236D-01	2.965188823982D-02
1	1.754222947805D+01	8.247738158426D-03	-1.272102756074D-02
2	-8.876801014058D+00	4.901299958077D-03	-5.280618932755D-03
3	3.072154572289D+00	-1.530726569770D-03	2.607605517865D-03
4	-7.853999520176D-01	-2.345612983161D-03	2.701173976139D-03
5	1.567509317981D-01	8.814896942982D-04	-1.049815583642D-03
6	-2.318325485784D-02	-7.993944555387D-05	7.600898233240D-05
7	2.098355270569D-03	-3.387024520670D-06	9.244162752622D-06
8	-8.207983816964D-05	5.528578997147D-07	-1.019716004446D-06

T-Index \ E-Index:	3	4	5
0	-1.988697872409D-02	5.937630704750D-03	-8.791623431456D-04
1	5.501038151489D-03	-8.566607598092D-04	2.183252927157D-05
2	2.314980071502D-03	-5.478894140036D-04	7.109825032007D-05
3	-1.396561346251D-03	3.325686900420D-04	-3.809967071864D-05
4	-1.125294104660D-03	2.296369788655D-04	-2.539533631356D-05
5	4.447398821903D-04	-9.021186699180D-05	9.582338741375D-06
6	-2.411443826400D-05	2.990412729672D-06	-5.900509921306D-08
7	-5.982892783306D-06	1.671607281419D-06	-2.370199152045D-07
8	5.706608511575D-07	-1.455207707019D-07	1.922725997681D-08

T-Index \ E-Index:	6	7	8
0	6.453161013676D-05	-2.282669216724D-06	3.113968814246D-08
1	5.326208461631D-06	-4.221360253600D-07	8.838098533169D-09
2	-4.628672509606D-06	1.314409444715D-07	-1.108256720247D-09
3	1.973863091768D-06	-3.710162944512D-08	2.441617394808D-11
4	1.549890921198D-06	-4.822256530984D-08	5.795655841101D-10
5	-5.224195972980D-07	1.313051592940D-08	-1.087986680607D-10
6	-2.099205652655D-08	1.716078063896D-09	-3.742956025175D-11
7	1.822822435371D-08	-7.148600246211D-10	1.095760653021D-11
8	-1.375709745925D-09	5.028096539680D-11	-7.253832666784D-13

```
P2MIN =   1.00000D 08 1/CM3
P2MAX =   1.00000D 16 1/CM3
  Max. rel. Error:   5.8770 %
  Mean rel. Error:   2.4838 %
```



Multistep hydrogenic population coefficients
Data: L.C.Johnson, Fujimoto
Ratio of population coefficients p(5)/nH2
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

12.37 Reaction 2.2.5e $H_2 + e \rightarrow ... + H(6)$, Ratio $H(6)/H_2$

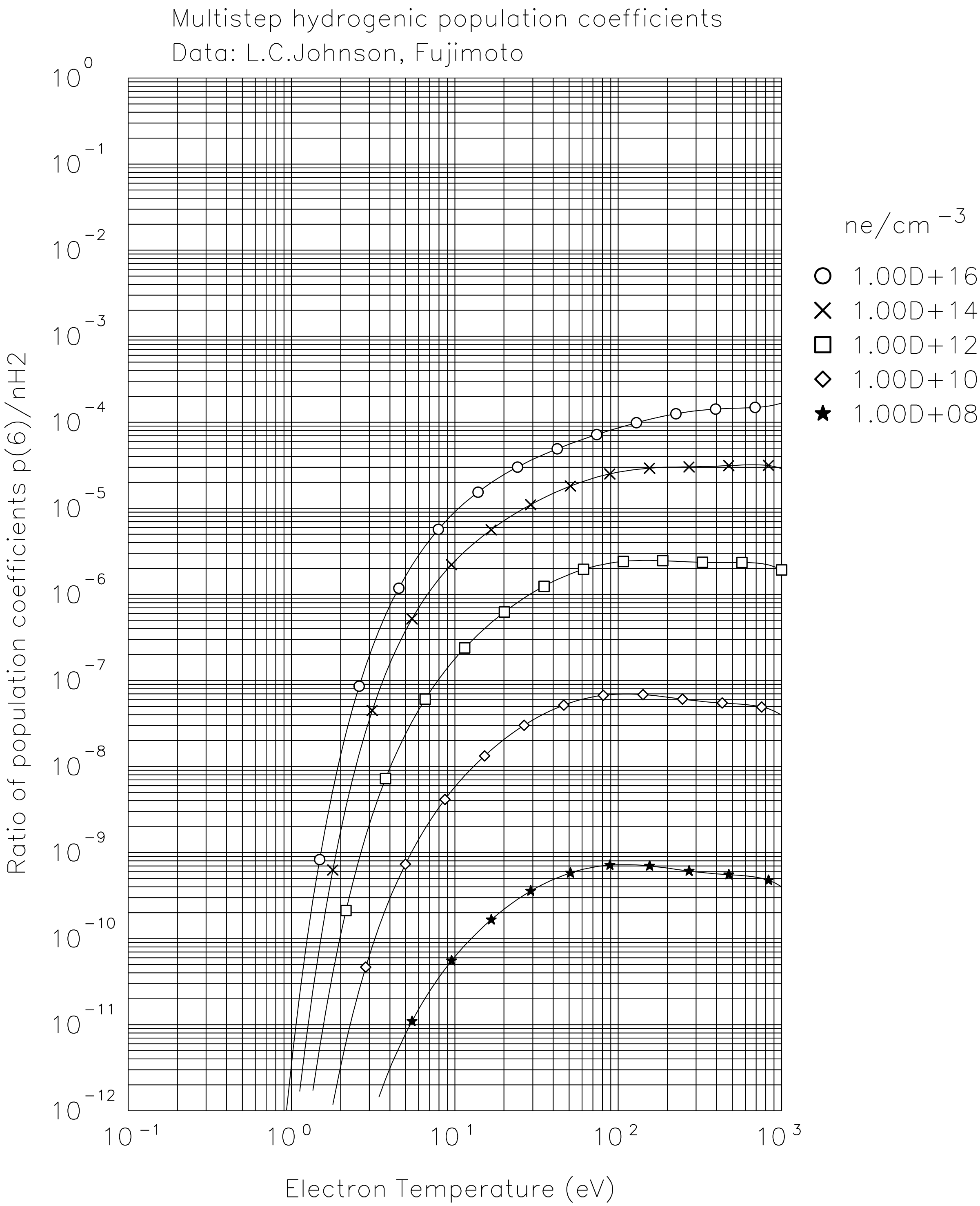
Ratio of population coefficients: p(6)/nH2
Multi-step hydrogenic population coefficients Data: K. Sawada, T.Fujimoto [7]

T-Index \ E-Index	0	1	2
0	-3.976375830432D+01	1.080938475473D+00	-1.041552669840D-01
1	1.755396272137D+01	1.997928889454D-02	-1.798710059345D-02
2	-8.859630135249D+00	-2.504982400656D-02	2.543100868921D-02
3	3.076066110143D+00	-7.835891215709D-03	3.545212479895D-03
4	-7.843523260590D-01	5.646209832689D-03	-3.561003903809D-03
5	1.561553501837D-01	7.187156275750D-04	-5.963069173321D-04
6	-2.332414342207D-02	-7.250674775397D-04	5.042502000331D-04
7	2.152674655984D-03	1.218456761872D-04	-8.096427977714D-05
8	-8.602048471984D-05	-6.415059271451D-06	4.107777281787D-06

T-Index \ E-Index	3	4	5
0	4.597090039926D-02	-9.342295727179D-03	9.308478102486D-04
1	7.525111338364D-03	-1.729122256079D-03	1.982524112989D-04
2	-1.066061134667D-02	2.308937441320D-03	-2.749941500007D-04
3	-3.509536109581D-05	-2.051879002933D-04	4.063170393346D-05
4	8.140229792921D-04	-8.180427544392D-05	3.613298743897D-06
5	1.757400200541D-04	-2.144818777523D-05	7.661627732789D-07
6	-1.279018270105D-04	1.377362109836D-05	-4.685940627108D-07
7	1.925404378767D-05	-1.822283216087D-06	2.708967643411D-08
8	-9.154258157002D-07	7.217533878534D-08	1.433836277468D-09

T-Index \ E-Index	6	7	8
0	-4.990551313939D-05	1.412124656401D-06	-1.686977249955D-08
1	-1.100090823914D-05	2.783571526155D-07	-2.545786068789D-09
2	1.844047875979D-05	-6.611108809876D-07	9.857959406283D-09
3	-3.580865956702D-06	1.526795464151D-07	-2.489702863615D-09
4	-5.514937069176D-08	1.282783100756D-09	-7.929654586724D-11
5	7.413860626664D-08	-7.230260739451D-09	1.670076436316D-10
6	-2.752310640534D-08	2.519485275718D-09	-5.096968024103D-11
7	6.897900227166D-09	-4.409727389145D-10	7.792707281870D-12
8	-5.340626613072D-10	2.786970513377D-11	-4.532087311135D-13

P2MIN = 1.00000D 08 1/CM3
P2MAX = 1.00000D 16 1/CM3
Max. rel. Error: 7.8110 %
Mean rel. Error: 3.3876 %

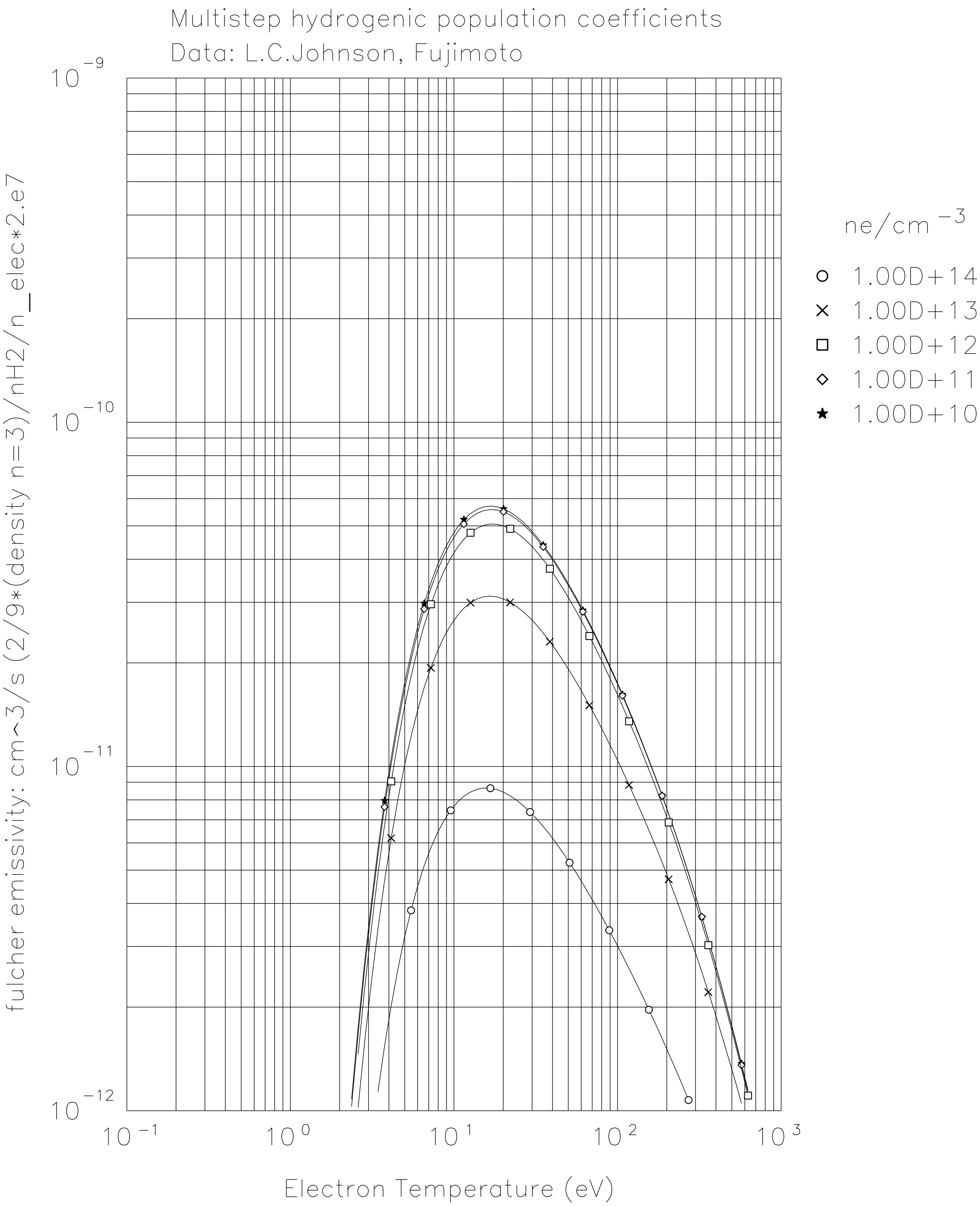


Multistep hydrogenic population coefficients
Data: L.C.Johnson, Fujimoto
Ratio of population coefficients p(6)/nH2
Electron Temperature (eV)
ne/cm $^{-3}$
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

12.38 Reaction 2.2.5fl $H_2 + e \rightarrow ... + H_2(N = 3, Triplet)$

Normalized emissivity: $H2(N = 3, Triplet)/H_2/n_e * 2/9 * 2E7$
Fulcher emissivity, cm^3/s. relative 2/9: statistical weight of upper d (Pi) triplet state amongst all N=3 triplet states. 2E7: approx. Fulcher Aik coeff for $N = 3 : d \rightarrow N = 2 : a$ transition in triplet system.
Multi-step hydrogenic molecule population coefficients Data: K.Sawada, T.Fujimoto [7]

```
        E-Index:      0                     1                     2
  T-Index:
        0   -3.504557850421D+01    9.344698340987D-02   -1.262393982454D-01
        1    1.265185253675D+01    3.464589180343D-01   -1.897206206043D-01
        2   -5.915984508527D+00   -4.770835779343D-01    2.383409770393D-01
        3    1.567639302331D+00    3.390100280427D-01   -1.091189901772D-01
        4   -2.590628281288D-01   -1.393257670314D-01    3.068867791726D-02
        5    2.135659024123D-02    3.392916031088D-02   -5.998734336944D-03
        6    2.067218294860D-04   -4.798473917584D-03    7.772903414015D-04
        7   -1.751915106668D-04    3.619887562438D-04   -5.646895975370D-05
        8    9.203730354946D-06   -1.119572886551D-05    1.591317926643D-06

        E-Index:      3                     4                     5
  T-Index:
        0    5.877352224633D-02   -1.302261116596D-02    1.540680462958D-03
        1    5.862703454732D-02   -1.095188520145D-02    1.183240573644D-03
        2   -6.570429435087D-02    1.114775452853D-02   -1.070181983249D-03
        3    1.814682024195D-02   -2.295511323493D-03    1.728358529303D-04
        4   -1.552484350393D-03    1.648565252382D-05   -2.120282511290D-06
        5   -1.441720545043D-04    3.491712665534D-05    3.814455169266D-06
        6    5.391904676009D-05   -6.544745167097D-06   -9.545517784441D-07
        7   -7.783493080968D-06    1.329842208929D-06   -2.466307689654D-08
        8    4.941214511748D-07   -1.119035840584D-07    1.039673602122D-08

        E-Index:      6                     7                     8
  T-Index:
        0   -1.002500011070D-04    3.343404484895D-06   -4.450494173734D-08
        1   -7.027920699731D-05    2.111151704919D-06   -2.487468982378D-08
        2    5.325609368599D-05   -1.188266988002D-06    7.422508082261D-09
        3   -3.839135008823D-06   -1.858093262988D-07    7.490073429227D-09
        4   -7.719566036043D-07    9.893554038792D-08   -2.773366208727D-09
        5   -4.033028965823D-07    4.648379959066D-09    2.007004276332D-10
        6    1.065338439445D-07   -2.602264223322D-09   -2.414058704987D-12
        7   -9.313819595092D-10   -9.979867907432D-11    5.230579069087D-12
        8   -7.005564197388D-10    3.183343414621D-11   -6.155115004501D-13
P2MIN =   1.00000D 08 1/CM3
P2MAX =   1.00000D 16 1/CM3
  Max. rel. Error:   2.1244 %
  Mean rel. Error:    .5558 %
```


Multistep hydrogenic population coefficients
Data: L.C.Johnson, Fujimoto
fulcher emissivity: cm^-3/s (2/9*(density n=3)/nH2/n_elec*2.e7
Electron Temperature (eV)
ne/cm -3
1.00D+14
1.00D+13
1.00D+12
1.00D+11
1.00D+10

12.39 Reaction 2.2.5fu $H_2 + e \rightarrow ... + H_2(N = 3, Triplet, d - state)$

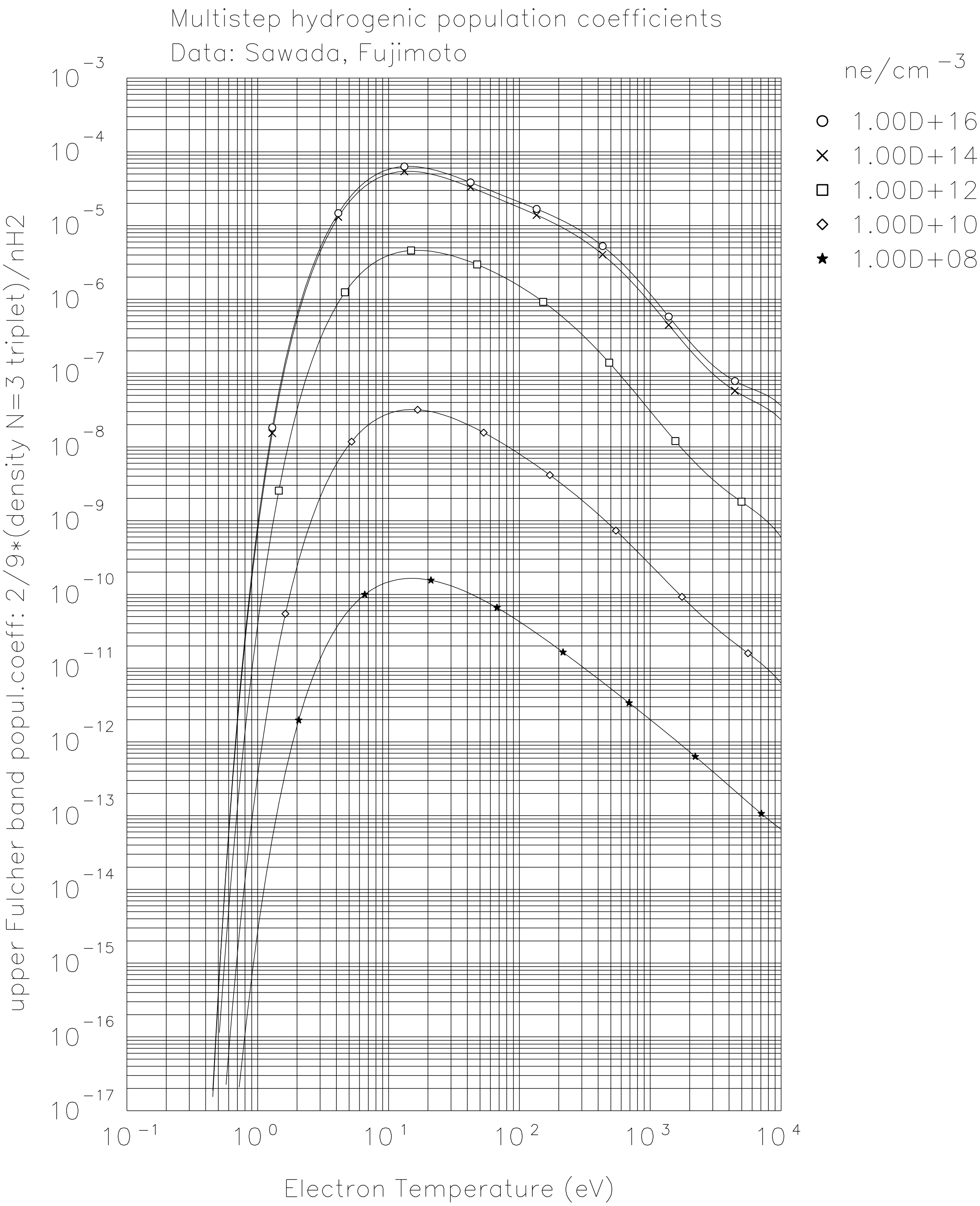
redone March 18, fit range 0.1 to 1e4 eV.
Ratio $H_2(N = 3, Triplet)/H_2 * 2/9$, 2/9 stat. weight to reduce N=3 state to d-state upper Fulcher population coefficient. Triplet d-state, $A_{Fulch} \approx$ 2.43E7 (priv. com. D.W.) for radiative d-triplet to a-triplet transitions.
Multi-step hydrogenic molecule population coefficients Data: K.Sawada, T.Fujimoto [7]

T-Index \ E-Index:	0	1	2
0	-3.354489060165D+01	1.468103242439D+00	-4.646307499703D-01
1	1.277739086685D+01	3.336987615778D-01	-2.662110674962D-01
2	-6.100361344044D+00	-1.199272310765D+00	7.903343009701D-01
3	1.668734740401D+00	7.492770342809D-01	-3.449602217244D-01
4	-2.995198269449D-01	-2.252050456671D-01	5.136460634062D-02
5	3.362068612317D-02	4.204168766681D-02	-2.887256470209D-03
6	-2.119643421070D-03	-5.136593278645D-03	3.021224427790D-04
7	5.764101894151D-05	3.665248081377D-04	-5.591909814617D-05
8	-7.556159315810D-08	-1.116271612850D-05	3.029453078051D-06

T-Index \ E-Index:	3	4	5
0	1.917594272036D-01	-3.914204712405D-02	4.405136273290D-03
1	8.977043337317D-02	-1.465813195424D-02	1.295941582003D-03
2	-2.277339349300D-01	3.517830118856D-02	-3.086638209564D-03
3	7.427634680932D-02	-9.056373914556D-03	6.168596878350D-04
4	-8.289600947012D-04	-9.842202184975D-04	1.569147488627D-04
5	-1.991926819207D-03	4.475984672915D-04	-4.330338627262D-05
6	1.465996491981D-04	-1.802283714021D-05	-6.406153919161D-09
7	1.108868720206D-05	-3.651785291583D-06	5.709622791954D-07
8	-1.032756417661D-06	2.547765262252D-07	-3.281099947589D-08

T-Index \ E-Index:	6	7	8
0	-2.784827610173D-04	9.205781819517D-06	-1.234563971007D-07
1	-6.294510247871D-05	1.558832548058D-06	-1.505796810383D-08
2	1.508616892274D-04	-3.741483445376D-06	3.548369121880D-08
3	-1.858979358827D-05	-1.756205740430D-08	8.600099983333D-09
4	-1.263963013577D-05	5.424603147976D-07	-9.427049641092D-09
5	2.594991460544D-06	-9.710865279198D-08	1.635299658521D-09
6	5.807832346907D-08	-1.194710140642D-09	-2.074052769889D-11
7	-4.002665073483D-08	1.260114477597D-09	-1.421785470367D-11
8	2.142746257616D-09	-6.776734606365D-11	8.207577984364D-13

```
P2MIN =   1.00000D 08 1/CM3
P2MAX =   1.00000D 16 1/CM3
  Max. rel. Error:   0.145E+02 %
  Mean rel. Error:   0.381E+01 %
```


Multistep hydrogenic population coefficients
Data: Sawada, Fujimoto
ne/cm $^{-3}$
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08
upper Fulcher band popul.coeff: 2/9*(density N=3 triplet)/nH2
Electron Temperature (eV)

12.40 Reaction 2.2.5we $H_2 + e \rightarrow ... + H_2(N = 2, Singlet\ C)$

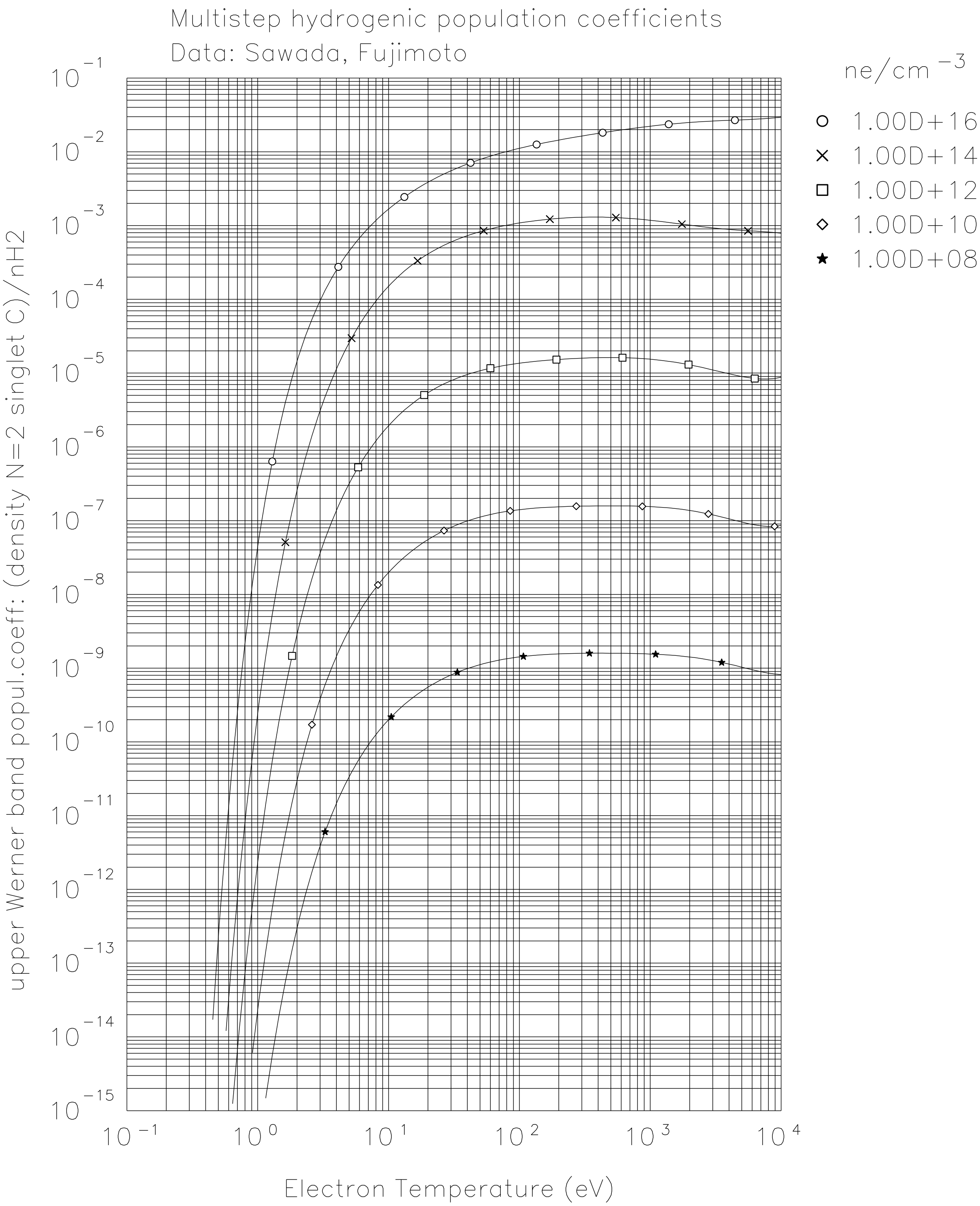
Ratio $H_2(N = 2, Singlet\ C - state)/H_2$
upper Werner band population coefficient. Singlet C-state, $A_{Werner} \approx$ 1.04E9 (priv. com. D.W.)
Multi-step hydrogenic molecule population coefficients Data: K.Sawada, T.Fujimoto [7]

T-Index \ E-Index:	0	1	2
0	-3.593649328832D+01	8.308979586264D-01	1.868771272352D-01
1	1.358996226939D+01	1.144733915906D-01	-7.166182521067D-02
2	-5.734471422048D+00	-2.150843448759D-02	-3.824097076465D-02
3	1.467418653563D+00	-2.501578958293D-03	2.923616954773D-02
4	-2.188119913056D-01	1.995231637494D-03	-6.640370721872D-03
5	1.406297652325D-02	-6.783126412988D-04	7.510665534693D-04
6	5.561129014609D-04	1.351258986187D-04	-5.745270250733D-05
7	-1.327036442082D-04	-1.315685619246D-05	3.749140942633D-06
8	5.386791451187D-06	4.829742920546D-07	-1.381191058408D-07

T-Index \ E-Index:	3	4	5
0	-8.319521746811D-02	1.822290028150D-02	-2.139848284025D-03
1	3.561940208530D-02	-8.730170894414D-03	1.111181710062D-03
2	8.090632884354D-03	-3.760749351686D-04	-8.428342936127D-05
3	-7.006055255923D-03	9.723873035654D-04	-6.790200414082D-05
4	9.388209633191D-04	-1.188419004204D-04	8.205572285784D-06
5	4.252484681099D-05	-1.045078968002D-05	1.071348879998D-06
6	-1.359995374888D-05	1.767498689737D-06	-1.033888505778D-07
7	4.214609548524D-07	4.105679338979D-08	-1.391632590311D-08
8	1.760472357584D-08	-8.302282439471D-09	1.229878733295D-09

T-Index \ E-Index:	6	7	8
0	1.363166907638D-04	-4.410389531348D-06	5.649304185589D-08
1	-7.568165245508D-05	2.610898259323D-06	-3.590058481557D-08
2	1.332628938065D-05	-7.119317923666D-07	1.326801124893D-08
3	1.270541815502D-06	6.913679414367D-08	-2.456304218566D-09
4	-4.661860601440D-08	-1.560880825875D-08	4.036797301220D-10
5	-8.639208387211D-08	3.008291257423D-09	-2.251160398320D-11
6	2.681223177046D-09	1.999325699443D-10	-1.047788129925D-11
7	1.395885069414D-09	-8.052768706091D-11	1.889487362615D-12
8	-9.665361477916D-11	4.462593169355D-12	-8.850565688461D-14

```
P2MIN =   1.00000D 08 1/CM3
P2MAX =   1.00000D 16 1/CM3
  Max. rel. Error:   0.115E+02 %
  Mean rel. Error:   0.299E+01 %
```



Multistep hydrogenic population coefficients
Data: Sawada, Fujimoto
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08
upper Werner band popul.coeff: (density N=2 singlet C)/nH2
Electron Temperature (eV)

12.41 Reaction 2.2.5ly $H_2 + e \rightarrow ... + H_2(N = 2, Singlet\ B)$

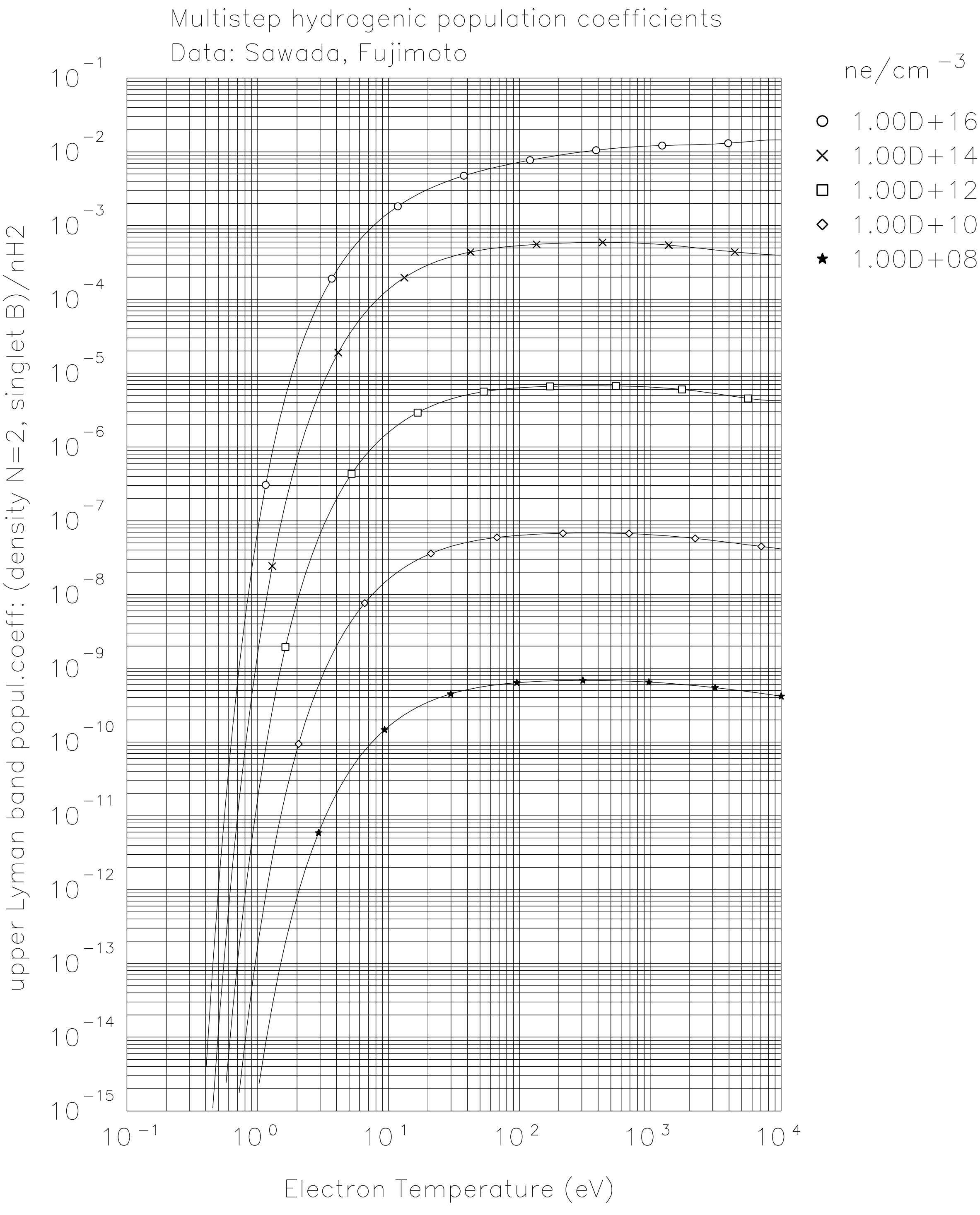
Ratio $H_2(N = 2, Singlet\ B - state)/H_2$
upper Lyman band population coefficient. Singlet B-state, A_{Lyman} ≈0.84E9 (priv. com. D.W.)
Multi-step hydrogenic molecule population coefficients Data: K.Sawada, T.Fujimoto [7]

T-Index \ E-Index:	0	1	2
0	-3.397850573163D+01	1.006056939133D+00	-1.202042794510D-02
1	1.196167467450D+01	1.019392480038D-01	-3.246741602640D-02
2	-5.552980751071D+00	-2.182674613256D-01	1.310622385883D-01
3	1.710517188280D+00	1.056574565611D-01	-7.126216596227D-02
4	-3.699083854427D-01	-8.996140369756D-03	8.169425385102D-03
5	5.450770431960D-02	-5.497328775049D-03	3.109194223938D-03
6	-5.114378920377D-03	1.574026731653D-03	-9.964122308190D-04
7	2.718181436155D-04	-1.570909362877D-04	1.033573137707D-04
8	-6.182952661054D-06	5.533588242821D-06	-3.725344805031D-06

T-Index \ E-Index:	3	4	5
0	4.355523162462D-03	-6.382190527349D-04	3.974915237112D-05
1	3.508265857386D-04	1.382009361884D-03	-2.488403752281D-04
2	-3.383652044906D-02	4.052689315875D-03	-2.098203509930D-04
3	2.137531087390D-02	-2.874452928505D-03	1.560319164372D-04
4	-3.936780405633D-03	6.865779069553D-04	-4.267656587715D-05
5	-3.226247705626D-04	-2.485199148367D-05	4.187303245886D-06
6	1.949593539968D-04	-1.432573062806D-05	2.716870257549D-07
7	-2.279031922723D-05	2.122592718556D-06	-7.778350690825D-08
8	8.693803378144D-07	-8.875683289762D-08	3.853513064998D-09

T-Index \ E-Index:	6	7	8
0	-4.817941325124D-07	-4.818422950101D-08	1.400297189617D-09
1	1.880067470651D-05	-6.625349071032D-07	8.813516831326D-09
2	1.142439741442D-06	2.743493930710D-07	-7.006934630012D-09
3	4.392236473310D-07	-3.371829185419D-07	8.645219519537D-09
4	-3.428952578243D-07	1.270631026599D-07	-3.377504202843D-09
5	2.905622963853D-08	-1.867759838623D-08	5.575839817605D-10
6	-7.981727857836D-10	9.983567417040D-10	-3.988647877134D-11
7	3.870317660182D-10	8.064843019666D-12	7.746226928676D-13
8	-3.436981127862D-11	-1.627459347813D-12	2.106967385582D-14

```
P2MIN =   1.00000D 08 1/CM3
P2MAX =   1.00000D 16 1/CM3
  Max. rel. Error:   0.922E+01 %
  Mean rel. Error:   0.210E+01 %
```


Multistep hydrogenic population coefficients
Data: Sawada, Fujimoto
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08
upper Lyman band popul.coeff: (density N=2, singlet B)/nH2
Electron Temperature (eV)
10 −1
10 0
10 1
10 2
10 3
10 4
10 −2
10 −3
10 −4
10 −5
10 −6
10 −7
10 −8
10 −9
10 −10
10 −11
10 −12
10 −13
10 −14
10 −15

12.42 Reaction 2.2.14a $H_2^+ + e \rightarrow ... + H(3)$, Ratio $H(3)/H_2^+$

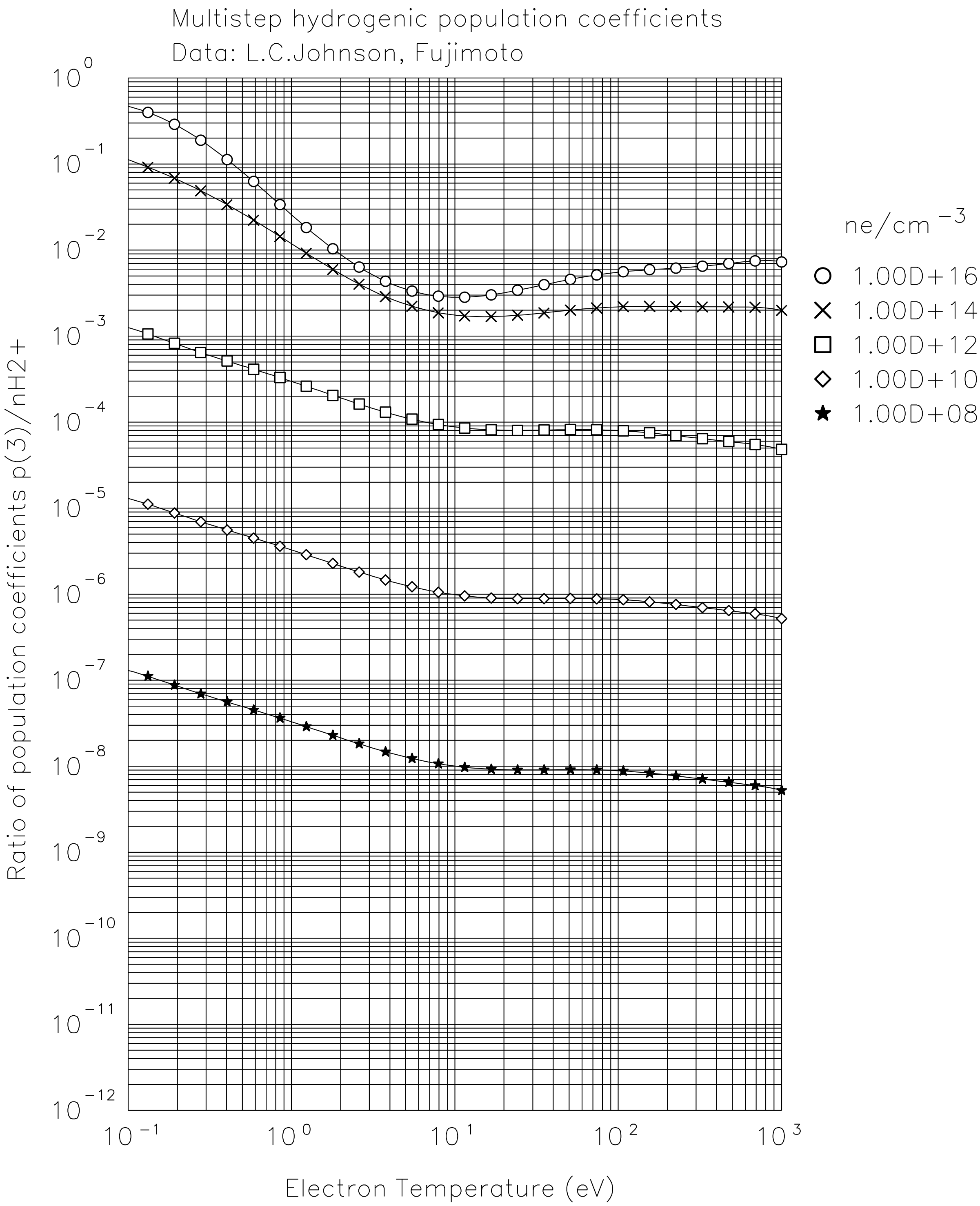
Multi-step hydrogenic population coefficients Data: K. Sawada, T.Fujimoto [7]
Ratio of population coefficients: p(3)/nH2+

T-Index \ E-Index	0	1	2
0	-1.722688127458D+01	1.153283206758D+00	-1.683858517653D-01
1	-6.130457183836D-01	1.914093897035D-01	-2.119334228080D-01
2	-3.288796872020D-02	-2.400733485492D-02	2.404651735462D-02
3	1.011296840186D-02	-1.550958978732D-02	1.584315646622D-02
4	1.661600971350D-02	4.557160690820D-03	-3.973908011295D-03
5	-1.332921799914D-03	1.037539779315D-05	6.731975412111D-05
6	-1.279967875089D-03	-2.589228947175D-04	1.486622411070D-04
7	2.677167178361D-04	5.420325237257D-05	-3.368818743134D-05
8	-1.506445178315D-05	-3.499465420549D-06	2.352582612122D-06

T-Index \ E-Index	3	4	5
0	6.918918524329D-02	-1.429478386078D-02	1.613571468557D-03
1	9.109177794808D-02	-2.007505252911D-02	2.472425643895D-03
2	-9.020252068955D-03	1.671217936164D-03	-1.647723170945D-04
3	-6.589011823707D-03	1.468052024984D-03	-1.881996632423D-04
4	1.324545590207D-03	-2.271138929258D-04	2.197082919209D-05
5	-2.225087720532D-05	-3.948031909877D-06	2.183242092156D-06
6	-2.359201102735D-05	5.994534813816D-07	8.163420117561D-08
7	5.871647174879D-06	-7.017526293806D-08	-7.321361270638D-08
8	-4.869333174029D-07	2.666937131278D-08	2.907495025800D-09

T-Index \ E-Index	6	7	8
0	-9.996182392999D-05	3.143558308195D-06	-3.894902873796D-08
1	-1.710731264281D-04	6.171658058460D-06	-8.994609018799D-08
2	8.489265493722D-06	-2.013488013000D-07	1.438802569384D-09
3	1.372284113113D-05	-5.221176658885D-07	7.993094218338D-09
4	-1.193452426271D-06	3.308071890623D-08	-3.519685687680D-10
5	-2.896287982222D-07	1.562000946898D-08	-3.009928452053D-10
6	1.559281307950D-09	-6.451643409471D-10	1.995316529751D-11
7	7.478573101616D-09	-2.883419180345D-10	3.944931881913D-12
8	-4.438182202186D-10	2.053419620687D-11	-3.291110119780D-13

```
P2MIN =   1.00000D 08 1/CM3
P2MAX =   1.00000D 16 1/CM3
 Max. rel. Error:   3.5492 %
 Mean rel. Error:   1.1008 %
```


Multistep hydrogenic population coefficients
Data: L.C.Johnson, Fujimoto
Ratio of population coefficients p(3)/nH2+
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

12.43 Reaction 2.2.14b $H_2^+ + e \rightarrow ... + H(2)$, Ratio $H(2)/H_2^+$

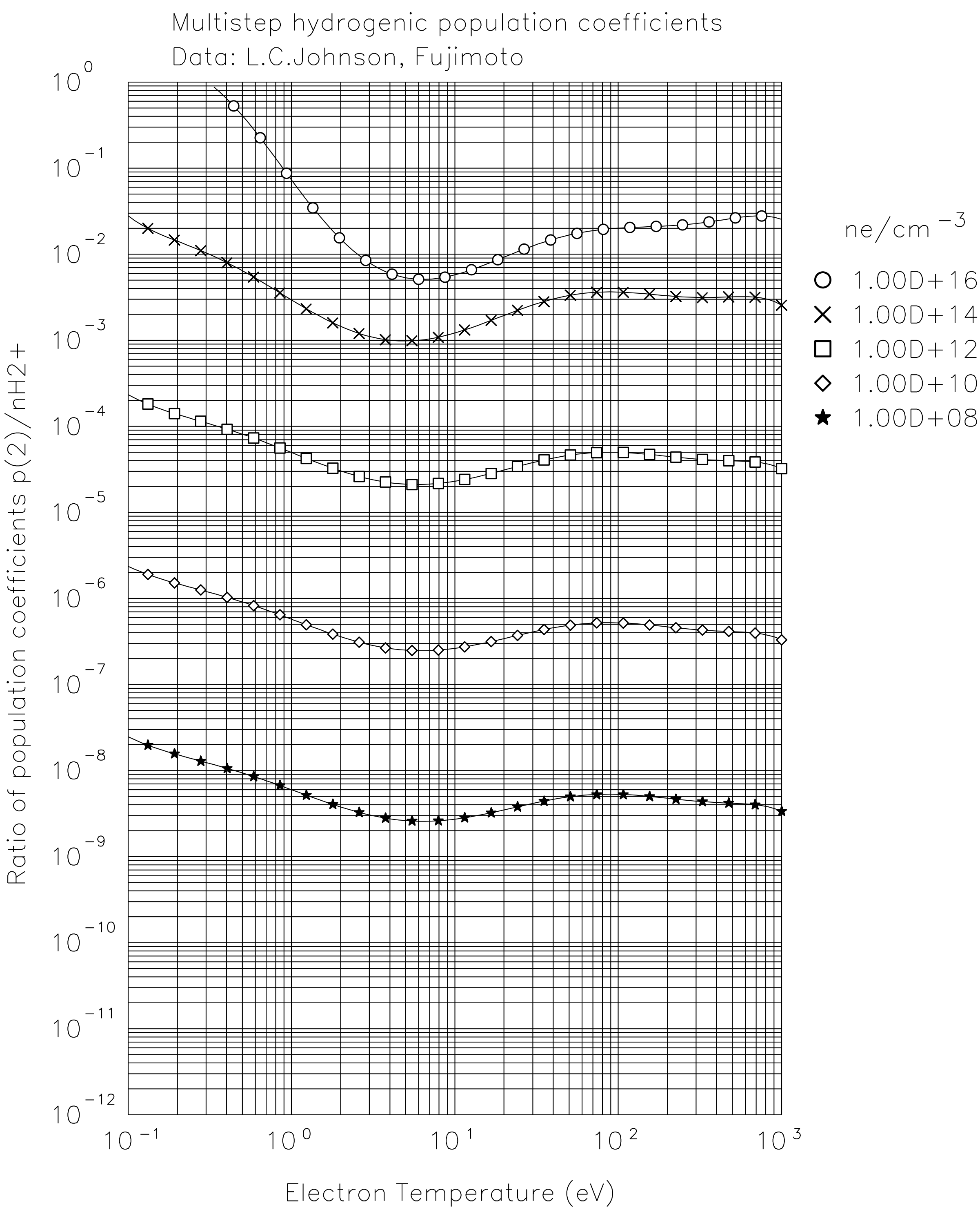
Multi-step hydrogenic population coefficients Data: K. Sawada, T.Fujimoto [7]
Ratio of population coefficients: p(2)/nH2+

T-Index \ E-Index	0	1	2
0	-1.893340627587D+01	9.384468043754D-01	6.845844295054D-02
1	-6.928605971087D-01	-8.026687490301D-02	9.467107255600D-02
2	-2.281426599901D-02	2.469204550924D-02	-2.484665906437D-02
3	7.477602038370D-02	2.032608947899D-02	-2.519725182225D-02
4	1.800864421577D-02	-6.090658281624D-03	7.017163446504D-03
5	-7.998916722808D-03	-9.279887714293D-05	2.698897287206D-04
6	-3.810034520682D-04	-2.106056251267D-05	-1.953567231400D-05
7	2.854892030780D-04	4.128701336617D-05	-4.250413339334D-05
8	-2.071857549683D-05	-4.001420432076D-06	4.379705502021D-06

T-Index \ E-Index	3	4	5
0	-3.000866490557D-02	6.301221120024D-03	-7.121426054946D-04
1	-4.166524495938D-02	8.977392904028D-03	-1.051153710461D-03
2	9.033528728860D-03	-1.517598590401D-03	1.263880354474D-04
3	1.162950470259D-02	-2.606098938264D-03	3.140565339454D-04
4	-3.000019054211D-03	6.218383225871D-04	-6.912762960613D-05
5	-2.042942399126D-04	6.121533276155D-05	-8.909019790621D-06
6	3.395544918660D-05	-1.198646949905D-05	1.803522408198D-06
7	1.505473503739D-05	-2.586687292054D-06	2.484264221846D-07
8	-1.726884062383D-06	3.360010725821D-07	-3.628922644305D-08

T-Index \ E-Index	6	7	8
0	4.370331341973D-05	-1.366214208274D-06	1.690062454965D-08
1	6.808364131429D-05	-2.298331729242D-06	3.151517460256D-08
2	-4.822206870495D-06	5.000680158777D-08	8.129482308185D-10
3	-2.070880988429D-05	7.034167608369D-07	-9.610489042355D-09
4	4.193160605355D-06	-1.303566995266D-07	1.616380399841D-09
5	6.656671628061D-07	-2.464877011413D-08	3.582951420528D-10
6	-1.317043941884D-07	4.601629603901D-09	-6.103803830641D-11
7	-1.416917248903D-08	4.608792938645D-10	-6.675661118338D-12
8	2.234037377054D-09	-7.375120969117D-11	1.017886320572D-12

P2MIN = 1.00000D 08 1/CM3
P2MAX = 1.00000D 16 1/CM3
Max. rel. Error: 10.9817 %
Mean rel. Error: 4.1166 %



Multistep hydrogenic population coefficients
Data: L.C.Johnson, Fujimoto
Ratio of population coefficients p(2)/nH2+
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

12.44 Reaction 2.2.14c $H_2^+ + e \rightarrow ... + H(4)$, Ratio $H(4)/H_2^+$

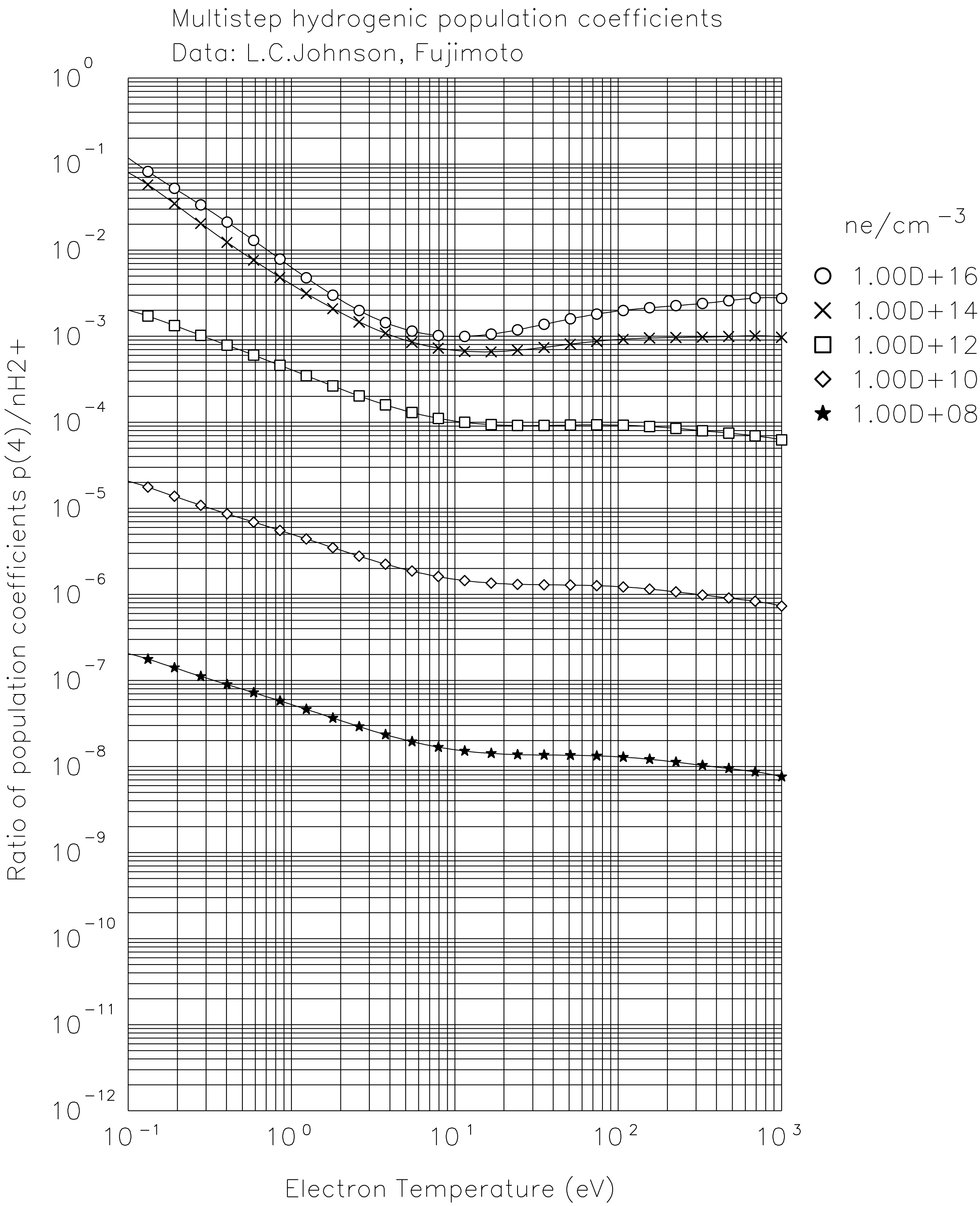
Multi-step hydrogenic population coefficients Data: K. Sawada, T.Fujimoto [7]
Ratio of population coefficients: p(4)/nH2+

T-Index \ E-Index	0	1	2
0	-1.676331978580D+01	9.080085441987D-01	1.147906180602D-01
1	-6.109051309024D-01	-8.294588654086D-03	1.632432484919D-02
2	-2.909737666296D-02	5.624264669551D-03	-1.197286367681D-02
3	7.623264778786D-03	-9.078213947581D-04	5.223194421632D-03
4	1.521423403054D-02	1.676511919497D-03	-2.501873457928D-03
5	-9.030920815279D-04	-1.632212690782D-03	1.351745824791D-03
6	-1.243913874997D-03	5.018902795712D-04	-3.645436069304D-04
7	2.498705414219D-04	-6.291439776017D-05	4.327516333116D-05
8	-1.382134054195D-05	2.822461526917D-06	-1.872083205062D-06

T-Index \ E-Index	3	4	5
0	-5.270106237531D-02	1.127860512722D-02	-1.245143403573D-03
1	-1.096202696457D-02	3.286907157227D-03	-4.917565920190D-04
2	7.584360997821D-03	-2.062094702685D-03	2.791821975336D-04
3	-3.449375282404D-03	8.838838532938D-04	-1.095438324110D-04
4	1.102143471476D-03	-2.160129746705D-04	2.129894386269D-05
5	-3.962453758917D-04	5.313919176171D-05	-3.533864379468D-06
6	9.622258500169D-05	-1.184926396450D-05	7.911742891778D-07
7	-1.107791453066D-05	1.379188891744D-06	-1.041402141388D-07
8	4.704345845794D-07	-5.961078067778D-08	4.961931789364D-09

T-Index \ E-Index	6	7	8
0	7.175810811923D-05	-2.069167769109D-06	2.363328371263D-08
1	3.752753236914D-05	-1.408607567442D-06	2.070687771858D-08
2	-1.963835974805D-05	6.884652898708D-07	-9.525997813634D-09
3	7.004585234319D-06	-2.213148187150D-07	2.720461054725D-09
4	-1.080619499451D-06	2.598412251320D-08	-2.157639142592D-10
5	1.153292411062D-07	-1.686998701330D-09	9.600285735482D-12
6	-3.457481362906D-08	1.132144357690D-09	-1.987071178818D-11
7	5.897518730021D-09	-2.354087236528D-10	4.278831126984D-12
8	-3.227509261038D-10	1.380778939747D-11	-2.522987941747D-13

```
P2MIN =   1.00000D 08 1/CM3
P2MAX =   1.00000D 16 1/CM3
  Max. rel. Error:   3.2596 %
  Mean rel. Error:   1.2619 %
```



Multistep hydrogenic population coefficients
Data: L.C.Johnson, Fujimoto
Ratio of population coefficients p(4)/nH2+
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

12.45 Reaction 2.2.14d $H_2^+ + e \rightarrow ... + H(5)$, Ratio $H(5)/H_2^+$

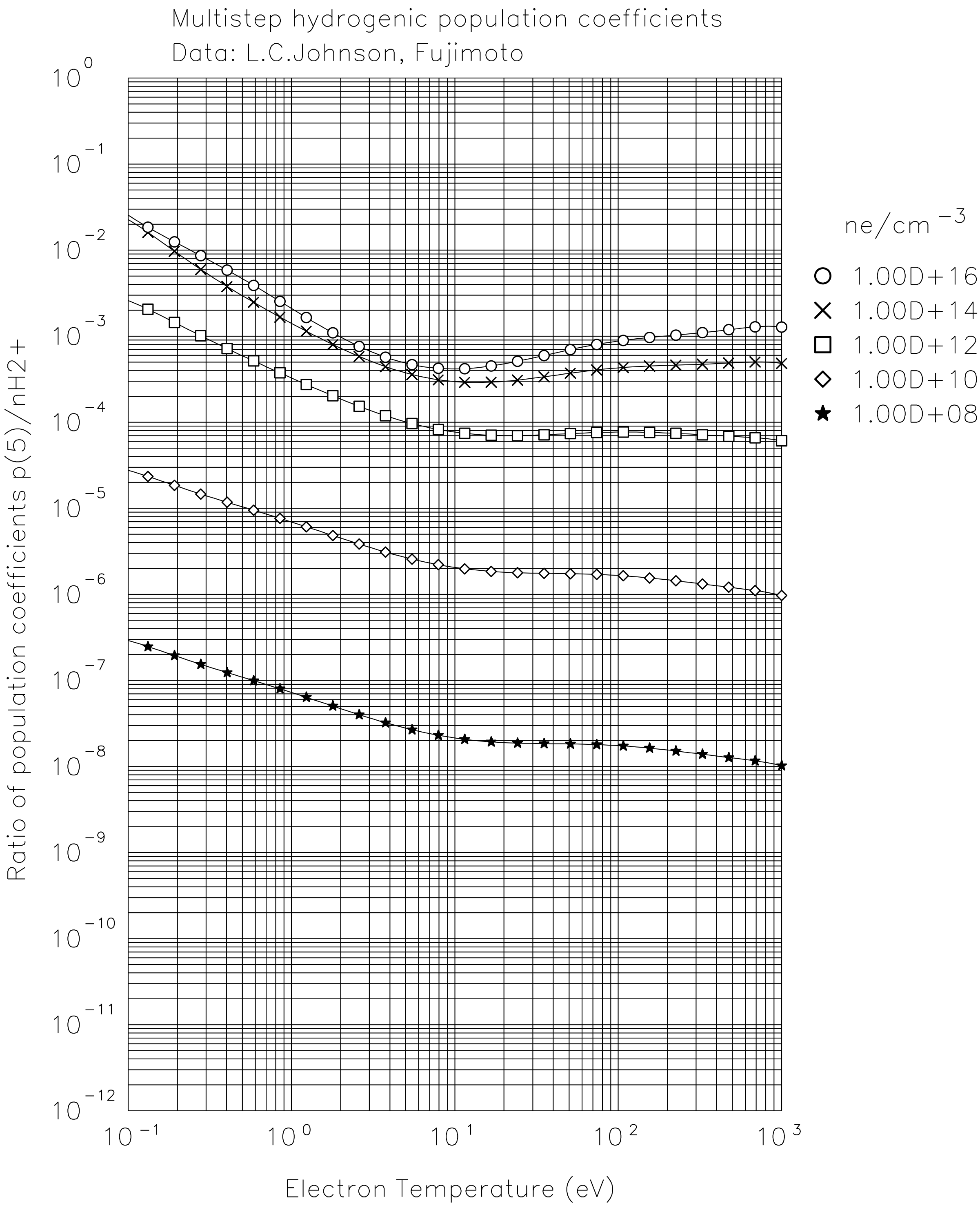
Multi-step hydrogenic population coefficients Data: K. Sawada, T.Fujimoto [7]
Ratio of population coefficients: p(5)/nH2+

T-Index \ E-Index	0	1	2
0	-1.644185145736D+01	1.012436644382D+00	6.786438608987D-03
1	-6.098791364927D-01	5.430488667435D-02	-7.847894120730D-02
2	-2.950068702716D-02	-3.373771077709D-02	3.289895028745D-02
3	6.754065058068D-03	7.451626213157D-03	-3.969682127389D-03
4	1.537038416857D-02	4.118426250990D-03	-4.555083248726D-03
5	-9.947711516605D-04	-1.833979398896D-03	1.801381990375D-03
6	-1.192700661337D-03	3.791226761015D-05	-3.145634625643D-05
7	2.404465554223D-04	5.021181230894D-05	-5.066197038660D-05
8	-1.326828264262D-05	-4.564492434807D-06	4.606059092522D-06

T-Index \ E-Index	3	4	5
0	-1.636359203529D-02	6.460968901937D-03	-1.074723144885D-03
1	3.737579519968D-02	-8.178265373295D-03	9.193848105982D-04
2	-1.134088065312D-02	1.754362025677D-03	-1.242294410730D-04
3	1.576874933190D-04	2.391978264795D-04	-5.252636585235D-05
4	1.826529292073D-03	-3.545645854345D-04	3.657837147066D-05
5	-6.662982315176D-04	1.215614803183D-04	-1.209604459175D-05
6	1.450525549912D-05	-3.710641046768D-06	5.511118540490D-07
7	1.829155353709D-05	-3.170388065293D-06	2.866743369560D-07
8	-1.697317371127D-06	3.048871380215D-07	-2.932146588732D-08

T-Index \ E-Index	6	7	8
0	8.419235123864D-05	-3.153526630862D-06	4.581163952178D-08
1	-5.560014479351D-05	1.725272054044D-06	-2.159304879239D-08
2	3.243207880260D-06	3.071703458548D-08	-2.031512439383D-09
3	4.543948082974D-06	-1.784049810861D-07	2.642282279507D-09
4	-2.037354098418D-06	5.743682572167D-08	-6.369815462623D-10
5	6.745084225490D-07	-1.997093162477D-08	2.459303044047D-10
6	-4.734113162030D-08	2.110906778108D-09	-3.702822546028D-11
7	-1.322386162924D-08	2.686441115973D-10	-1.341741119398D-12
8	1.518492393831D-09	-3.921390964093D-11	3.853896510803D-13

P2MIN = 1.00000D 08 1/CM3
P2MAX = 1.00000D 16 1/CM3
Max. rel. Error: 3.3950 %
Mean rel. Error: 1.2048 %


Multistep hydrogenic population coefficients
Data: L.C.Johnson, Fujimoto
Ratio of population coefficients p(5)/nH2+
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

12.46 Reaction 2.2.14e $H_2^+ + e \rightarrow ... + H(6)$, Ratio $H(6)/H_2^+$

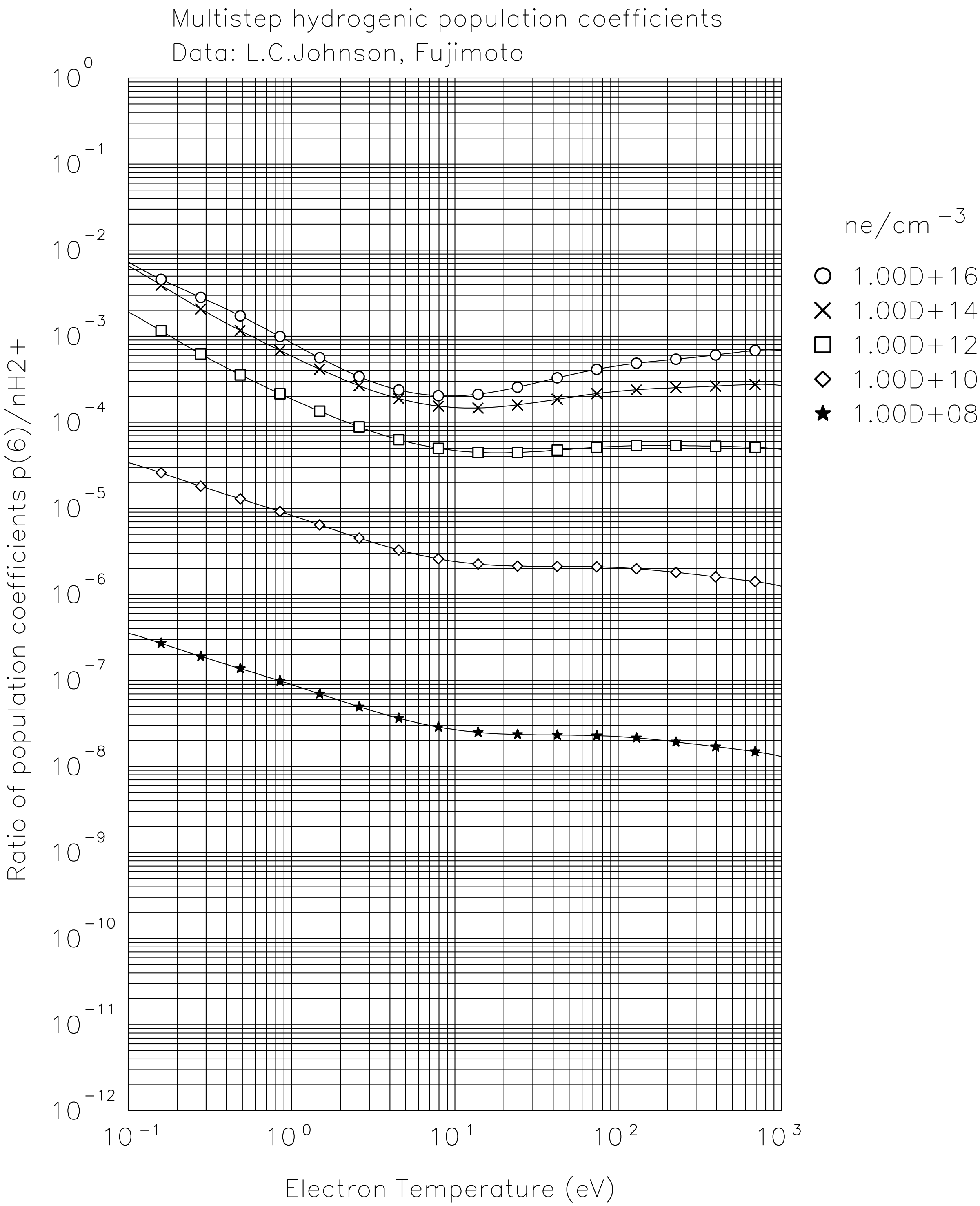
Multi-step hydrogenic population coefficients Data: K. Sawada, T.Fujimoto [7]
Ratio of population coefficients: p(6)/nH2+

E-Index:	0	1	2
T-Index:			
0	-1.622999065239D+01	1.114789960848D+00	-1.520045539695D-01
1	-6.128088795544D-01	4.799590905456D-02	-6.226002600050D-02
2	-2.843662556626D-02	-2.981491981788D-02	3.771158615252D-02
3	9.040540246117D-03	-5.376296672908D-03	2.724387350634D-03
4	1.488157339780D-02	4.117070101509D-03	-3.845342947354D-03
5	-1.100892809269D-03	6.973802180775D-05	2.700981820011D-04
6	-1.154443469425D-03	-2.746343562656D-04	1.329065248252D-04
7	2.372720363390D-04	4.450995037612D-05	-2.399096395388D-05
8	-1.321939690927D-05	-2.168171198227D-06	1.138090912890D-06

E-Index:	3	4	5
T-Index:			
0	6.454947459361D-02	-1.251452482400D-02	1.176116823129D-03
1	3.120222040133D-02	-7.656737664171D-03	9.697768241674D-04
2	-1.714743824449D-02	3.730164832607D-03	-4.245864266326D-04
3	-7.284121072944D-04	1.754857033177D-04	-2.833588922766D-05
4	1.501531035131D-03	-3.095442801682D-04	3.552383842276D-05
5	-1.870097557763D-04	4.709088535767D-05	-5.863892714562D-06
6	-1.824639804367D-05	-6.062961769823D-07	4.017509350696D-07
7	4.371493229928D-06	-2.114447008583D-07	-3.261214899093D-08
8	-1.889513057698D-07	3.153827435466D-09	2.672896065823D-09

E-Index:	6	7	8
T-Index:			
0	-5.801776455917D-05	1.436236089573D-06	-1.386191157402D-08
1	-6.554993759673D-05	2.252572465958D-06	-3.097271363753D-08
2	2.617269803427D-05	-8.313443339779D-07	1.069290183120D-08
3	2.404364824295D-06	-9.739423966586D-08	1.496981935094D-09
4	-2.266688480662D-06	7.510316070422D-08	-1.007253682698D-09
5	3.929720894592D-07	-1.368756170273D-08	1.948330325484D-10
6	-4.284044640046D-08	1.967059565426D-09	-3.388443373389D-11
7	5.152899170025D-09	-2.667100015865D-10	4.835046441176D-12
8	-3.370174839133D-10	1.633061281105D-11	-2.854661230035D-13

P2MIN = 1.00000D 08 1/CM3
P2MAX = 1.00000D 16 1/CM3
Max. rel. Error: 3.0278 %
Mean rel. Error: 1.1252 %



Multistep hydrogenic population coefficients
Data: L.C.Johnson, Fujimoto
Ratio of population coefficients p(6)/nH2+
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

12.47 Reaction 2.2.15a $H_3^+ + e \rightarrow ... + H(3)$, Ratio $H(3)/H_3^+$

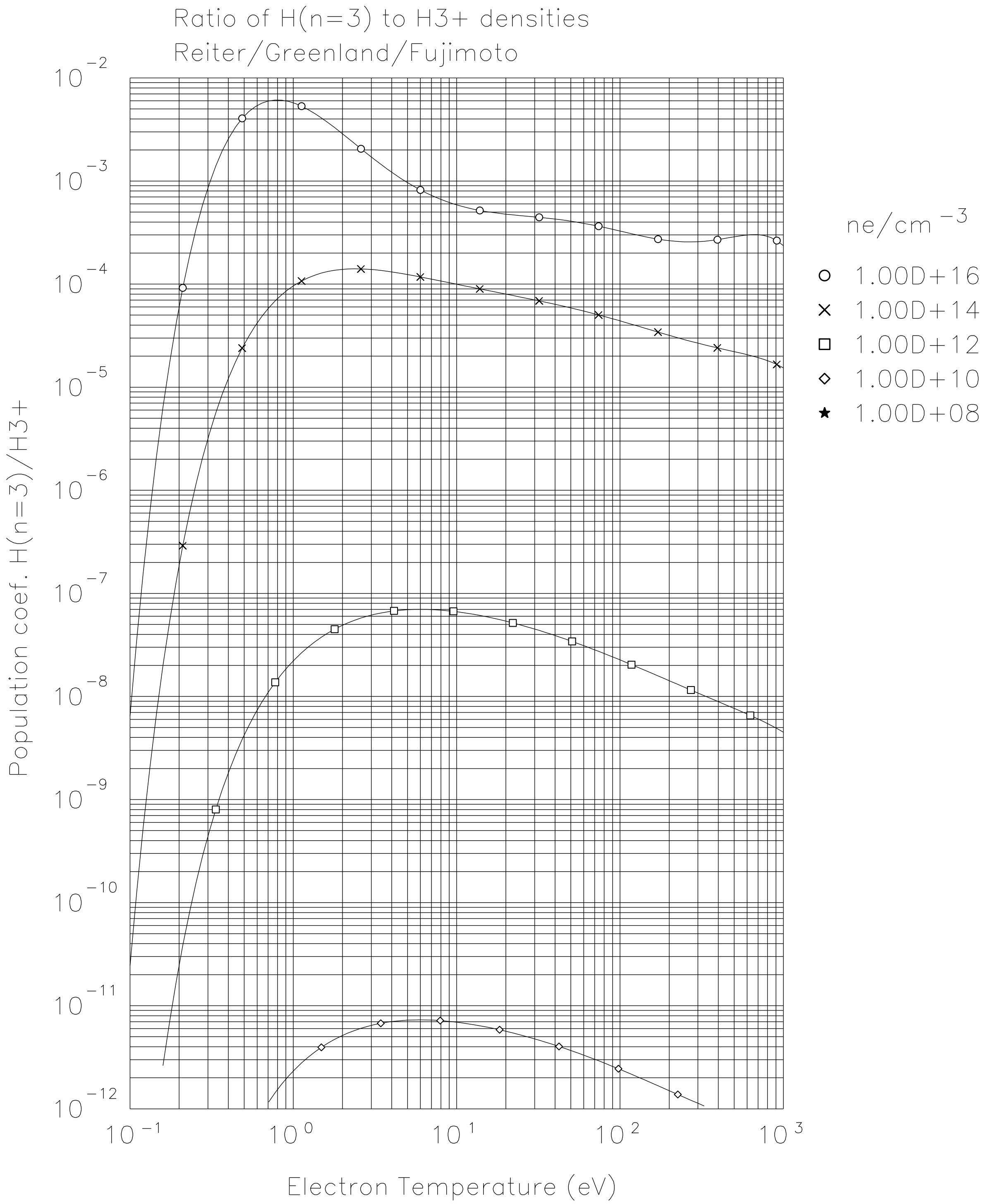
Multi-step hydrogenic population coefficients Data: K. Sawada, T.Fujimoto, [7] and R. Janev et al., 1987
Production of initial $H(n = 2)$ from H_3^+ via $1/3.5 \times \langle Hydhel\ 2.2.15\rangle$, then CR redistribution in H leading to $n = 3$ population
Ratio of population coefficients: p(3)/nH3+

T-Index \ E-Index:	0	1	2
0	-3.601119233903D+01	2.194488055582D+00	-2.490229101640D-01
1	1.652206692785D+00	-1.271092194312D-01	1.058603034484D-01
2	-8.700785019712D-01	-2.161600166796D-02	6.271502055705D-02
3	2.662217617059D-01	4.349904766090D-02	-3.964570429934D-02
4	-7.742301294851D-02	-1.588421393163D-02	6.518330779752D-03
5	1.931368710773D-02	-8.106962079405D-04	1.708355185624D-03
6	-3.409295405632D-03	1.740482076055D-03	-1.205558081593D-03
7	3.453367238152D-04	-3.495754916386D-04	2.280918882182D-04
8	-1.456129857393D-05	2.117574196146D-05	-1.399865611289D-05

T-Index \ E-Index:	3	4	5
0	1.132911350765D-01	-2.495101533471D-02	2.958065372132D-03
1	-3.391043609190D-02	5.252542828036D-03	-4.133003716081D-04
2	-3.563092105078D-02	8.658671254321D-03	-1.084373448947D-03
3	1.425402485426D-02	-2.606626099566D-03	2.640179631726D-04
4	2.942975651757D-05	-3.820356368930D-04	7.370218634646D-05
5	-9.096498355642D-04	2.144809623279D-04	-2.630207934234D-05
6	3.241732853912D-04	-4.279559204346D-05	2.895227184007D-06
7	-5.583861278880D-05	6.224370200950D-06	-2.797277959239D-07
8	3.502116490766D-06	-4.075936276354D-07	2.091741957019D-08

T-Index \ E-Index:	6	7	8
0	-1.921033371324D-04	6.398969176227D-06	-8.555066878081D-08
1	1.550419246049D-05	-2.077147754254D-07	-6.217681464656D-10
2	7.328429963825D-05	-2.541071707141D-06	3.547229620058D-08
3	-1.498023460658D-05	4.469952296008D-07	-5.466006320221D-09
4	-6.089548777788D-06	2.375890801408D-07	-3.584223895612D-09
5	1.746057261430D-06	-5.958058472873D-08	8.192333835651D-10
6	-9.061691336736D-08	6.391542243791D-10	1.652477882971D-11
7	-2.150518066178D-09	5.692555261125D-10	-1.288476392288D-11
8	-1.494056033386D-10	-2.437016814580D-11	6.330132340750D-13

P2MIN = 1.00000D 08 1/CM3
P2MAX = 1.00000D 16 1/CM3
Max. rel. Error: 14.3433 %
Mean rel. Error: 2.2859 %



Ratio of H(n=3) to H3+ densities
Reiter/Greenland/Fujimoto
Population coef. H(n=3)/H3+
Electron Temperature (eV)
ne/cm -3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

12.48 Reaction 2.2.15b $H_3^+ + e \rightarrow ... + H(2)$, Ratio $H(2)/H_3^+$

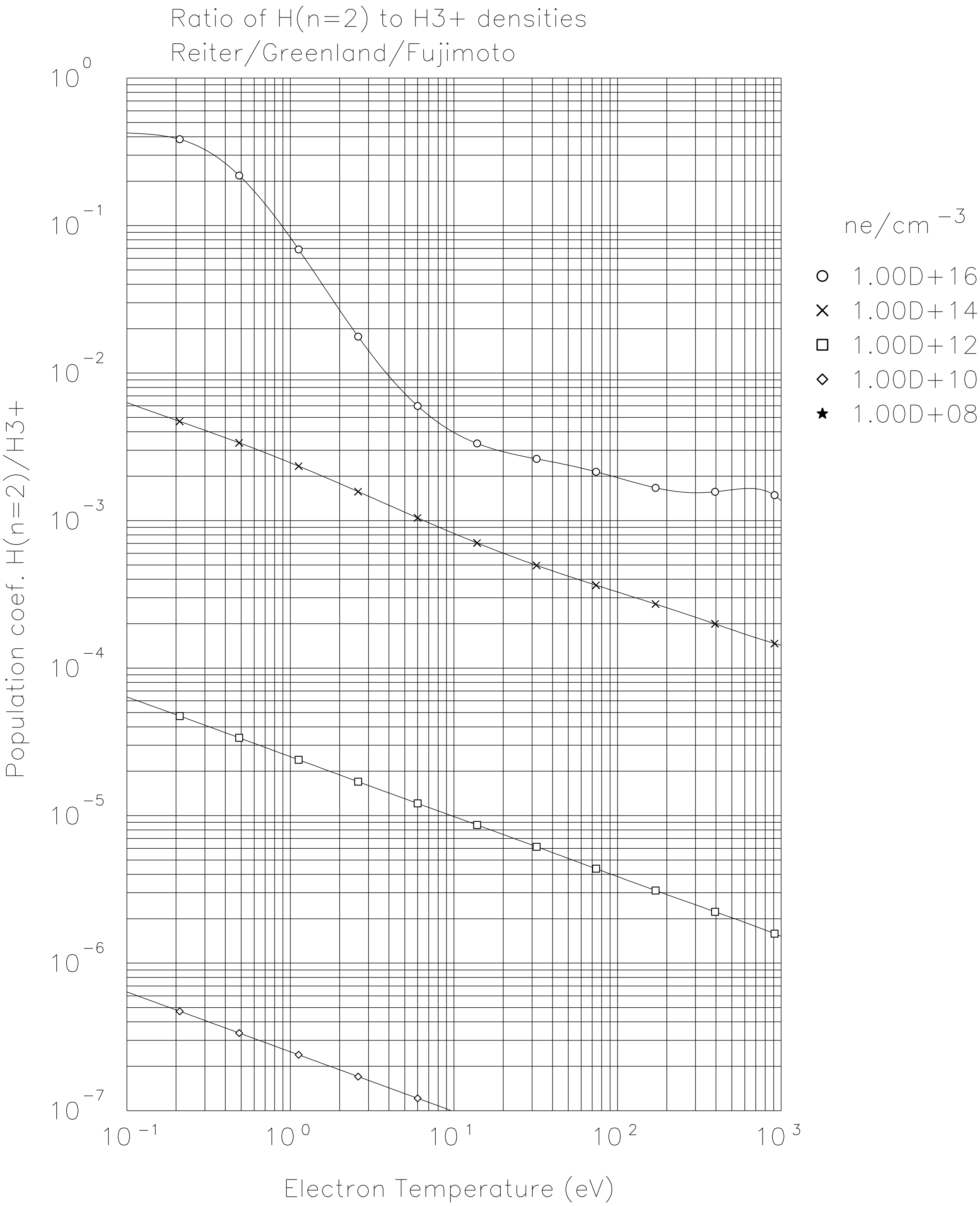
Multi-step hydrogenic population coefficients Data: K. Sawada, T.Fujimoto, [7] and R. Janev et al 1987
Production of initial $H(n = 2)$ from H_3^+ via $1/3.5 \times \langle Hydhel\ 2.2.15 \rangle$, then CR redistribution in H
Ratio of population coefficients: p(2)/nH3+

T-Index \ E-Index	0	1	2
0	-1.980337179098D+01	9.999289774464D-01	3.393626221267D-03
1	-4.071476496934D-01	2.924762633195D-02	-2.851786085227D-02
2	5.495688975883D-04	-1.023099678564D-02	1.171745245738D-02
3	7.151298543821D-04	-1.106236848753D-02	1.167194822465D-02
4	-1.082581109495D-04	2.080154145037D-03	-2.381045517182D-03
5	-5.784697350796D-05	8.818867850337D-04	-9.290488913510D-04
6	7.828814939830D-06	-1.410356074545D-04	1.579270228374D-04
7	1.289405712476D-06	-1.803694888454D-05	1.839342236091D-05
8	-1.757435874999D-07	2.740075492523D-06	-2.922976584923D-06

T-Index \ E-Index	3	4	5
0	-2.831872924647D-03	8.844257796365D-04	-1.335820142114D-04
1	9.798033707980D-03	-1.513369733986D-03	1.052372400307D-04
2	-5.063164235821D-03	1.105581200627D-03	-1.355736418332D-04
3	-4.519763859219D-03	8.509755038057D-04	-8.608757693484D-05
4	1.016230997894D-03	-2.163134055907D-04	2.552512545027D-05
5	3.594734574380D-04	-6.760036792740D-05	6.820693101367D-06
6	-6.562061294501D-05	1.349897286883D-05	-1.527216042839D-06
7	-6.838474731524D-06	1.216126202961D-06	-1.128282531105D-07
8	1.149792069313D-06	-2.210992439606D-07	2.299563923333D-08

T-Index \ E-Index	6	7	8
0	1.039688098878D-05	-3.967254803956D-07	5.751612166377D-09
1	-2.022407714950D-06	-9.533644334113D-08	3.425386624889D-09
2	9.500661752185D-06	-3.550036000270D-07	5.446553318204D-09
3	4.757811195092D-06	-1.348973665777D-07	1.542565685557D-09
4	-1.703589672933D-06	6.030500436147D-08	-8.781256295629D-10
5	-3.748567528049D-07	1.051005276609D-08	-1.176476798245D-10
6	9.704016493388D-08	-3.256173927393D-09	4.497431785523D-11
7	5.418531608876D-09	-1.198313236434D-10	8.246578075788D-13
8	-1.317209482279D-09	3.905293970215D-11	-4.696677196057D-13

```
P2MIN =   1.00000D 08 1/CM3
P2MAX =   1.00000D 16 1/CM3
  Max. rel. Error:  10.2841 %
  Mean rel. Error:   0.8237 %
```


Ratio of H(n=2) to H3+ densities
Reiter/Greenland/Fujimoto
Population coef. H(n=2)/H3+
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

12.49 Reaction 2.2.15c $H_3^+ + e \rightarrow ... + H(4)$, Ratio $H(4)/H_3^+$

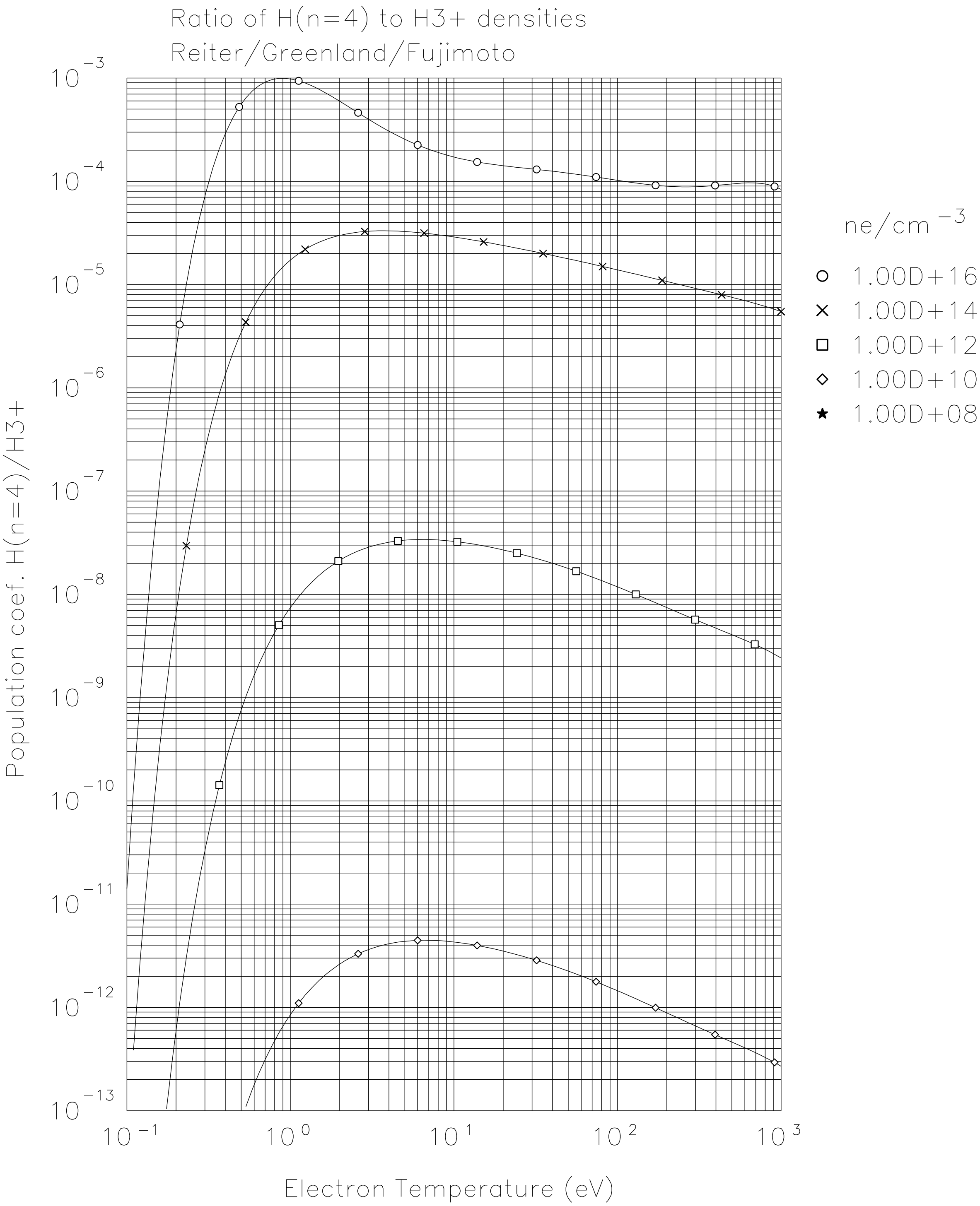
Multi-step hydrogenic population coefficients Data: K. Sawada, T.Fujimoto, [7] and R. Janev et al 1987
Production of initial $H(n = 2)$ from H_3^+ via $1/3.5 \times \langle Hydhel\ 2.2.15\rangle$, then CR redistribution in H
Ratio of population coefficients: p(4)/nH3+

T-Index \ E-Index	0	1	2
0	-3.699168687840D+01	2.001554576899D+00	2.962673017164D-03
1	2.327818682219D+00	-6.477623277677D-03	1.302747597894D-02
2	-1.222503946813D+00	1.123694153535D-02	-1.836859736247D-02
3	3.759451408212D-01	-6.964877949667D-03	8.967141291539D-03
4	-1.057717328620D-01	1.811746894110D-03	-1.588506334985D-03
5	2.564558082290D-02	-1.557448494435D-04	-1.318163984811D-04
6	-4.362034354566D-03	1.336313932390D-05	5.677385912381D-05
7	4.213673231999D-04	-5.353070791744D-06	-1.630395162429D-06
8	-1.690754255016D-05	5.204418811823D-07	-2.764507346651D-07

T-Index \ E-Index	3	4	5
0	-3.049473442883D-03	8.934957580265D-04	-1.187680147766D-04
1	-7.302167340628D-03	1.743088872108D-03	-2.033314551240D-04
2	7.937475042441D-03	-1.495920915105D-03	1.335789358832D-04
3	-3.759736445513D-03	7.328783639342D-04	-7.467260815755D-05
4	7.588920331506D-04	-1.913322099599D-04	2.691316713419D-05
5	6.936970796563D-05	-9.160519294976D-06	-1.145889879420D-07
6	-4.339223919979D-05	1.175796204569D-05	-1.577537099191D-06
7	4.425066124877D-06	-1.614546001621D-06	2.599419206670D-07
8	-9.831082955550D-08	6.376842626606D-08	-1.222812849688D-08

T-Index \ E-Index	6	7	8
0	7.833656739024D-06	-2.831734234040D-07	4.376125518706D-09
1	1.154895519966D-05	-3.074042636582D-07	2.967824771774D-09
2	-5.103130444119D-06	3.555541061620D-08	1.457153306360D-09
3	4.119385753462D-06	-1.159886623812D-07	1.308198318452D-09
4	-2.112133421406D-06	8.508133152131D-08	-1.360850938372D-09
5	1.014287149029D-07	-6.777611535609D-09	1.373041841284D-10
6	1.137461746810D-07	-4.208250772675D-09	6.264373124745D-11
7	-2.137126396561D-08	8.696995094294D-10	-1.384296355974D-11
8	1.098305710577D-09	-4.703325555132D-11	7.717446791356D-13

P2MIN = 1.00000D 08 1/CM3
P2MAX = 1.00000D 16 1/CM3
Max. rel. Error: 9.0711 %
Mean rel. Error: 1.5148 %



Ratio of H(n=4) to H3+ densities
Reiter/Greenland/Fujimoto
Population coef. H(n=4)/H3+
Electron Temperature (eV)
ne/cm -3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

12.50 Reaction 2.2.15d $H_3^+ + e \rightarrow ... + H(5)$, Ratio $H(5)/H_3^+$

Multi-step hydrogenic population coefficients Data: K. Sawada, T.Fujimoto, [7] and Janev et al. 1987

Production of initial $H(n=2)$ from H_3^+ via $1/3.5 \times \langle Hydhel\ 2.2.15 \rangle$, then CR redistribution in H

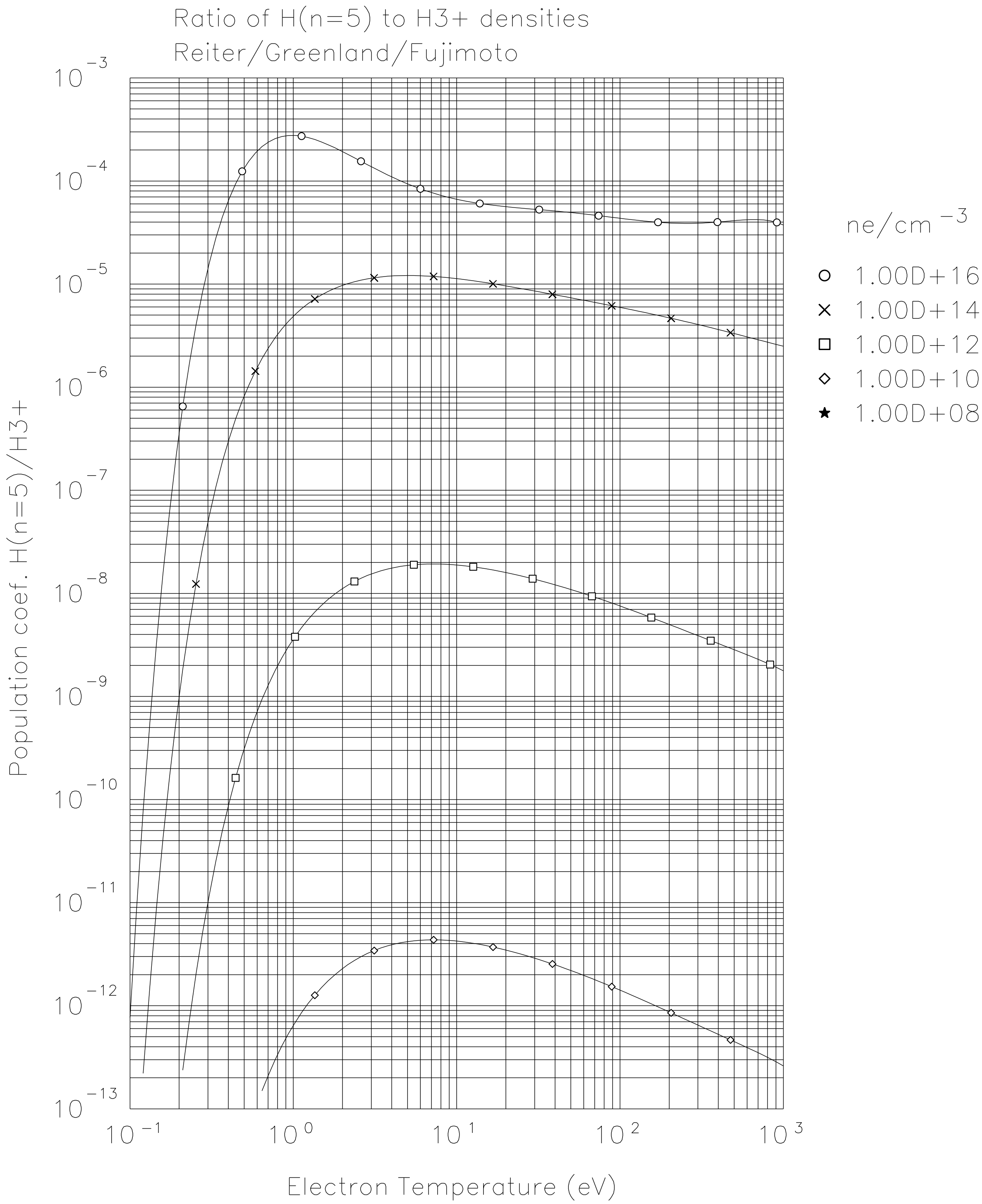
Ratio of population coefficients: p(5)/nH3+

T-Index \ E-Index	0	1	2
0	-3.726636544624D+01	2.133976447955D+00	-1.437643407818D-01
1	2.607984145369D+00	3.736342257132D-02	-5.206732236717D-02
2	-1.372459802644D+00	-1.168450793414D-02	1.039452553074D-02
3	4.381136968184D-01	-1.599858338454D-03	5.567058463253D-03
4	-1.232102950459D-01	7.200465026127D-04	-1.555111093198D-03
5	2.788050336665D-02	-7.778193777532D-04	5.986504728580D-04
6	-4.325272890946D-03	4.366753618704D-04	-3.489782061433D-04
7	3.870202141408D-04	-8.396034178185D-05	7.283739797379D-05
8	-1.472534680030D-05	5.195720673557D-06	-4.730954375662D-06

T-Index \ E-Index	3	4	5
0	5.266218557769D-02	-8.735567392297D-03	6.919538677059D-04
1	2.575215280557D-02	-6.008209560283D-03	7.323649110173D-04
2	-3.335259288099D-03	5.070348402932D-04	-4.437286309383D-05
3	-3.908320707976D-03	1.078790219266D-03	-1.445807390811D-04
4	1.013385566510D-03	-2.751391890149D-04	3.756629725211D-05
5	-1.609098607097D-04	2.001630094507D-05	-1.302966127214D-06
6	9.381316606795D-05	-1.092384086404D-05	4.836506460925D-07
7	-2.247960619374D-05	3.327027913749D-06	-2.544047801913D-07
8	1.570234172126D-06	-2.565871792243D-07	2.263302154308D-08

T-Index \ E-Index	6	7	8
0	-2.537313706204D-05	2.755002502292D-07	3.064689208500D-09
1	-4.894113742491D-05	1.689063212815D-06	-2.350820776172D-08
2	2.940248173139D-06	-1.320244963238D-07	2.543920290364D-09
3	1.004638359166D-05	-3.485706886049D-07	4.792765609299D-09
4	-2.744526032933D-06	1.021810292434D-07	-1.520931726158D-09
5	5.431702781882D-08	-1.711017659423D-09	2.880788636234D-11
6	6.484042961226D-09	-1.162802787754D-09	2.568800325791D-11
7	9.642946338642D-09	-1.417047906131D-10	-7.123549343893D-14
8	-1.083303425027D-09	2.604279537307D-11	-2.404346400046D-13

```
P2MIN =   1.00000D 08 1/CM3
P2MAX =   1.00000D 16 1/CM3
  Max. rel. Error:   8.0720 %
  Mean rel. Error:   1.8795 %
```


Ratio of H(n=5) to H3+ densities
Reiter/Greenland/Fujimoto
Population coef. H(n=5)/H3+
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

12.51 Reaction 2.2.15e $H_3^+ + e \rightarrow ... + H(6)$, Ratio $H(6)/H_3^+$

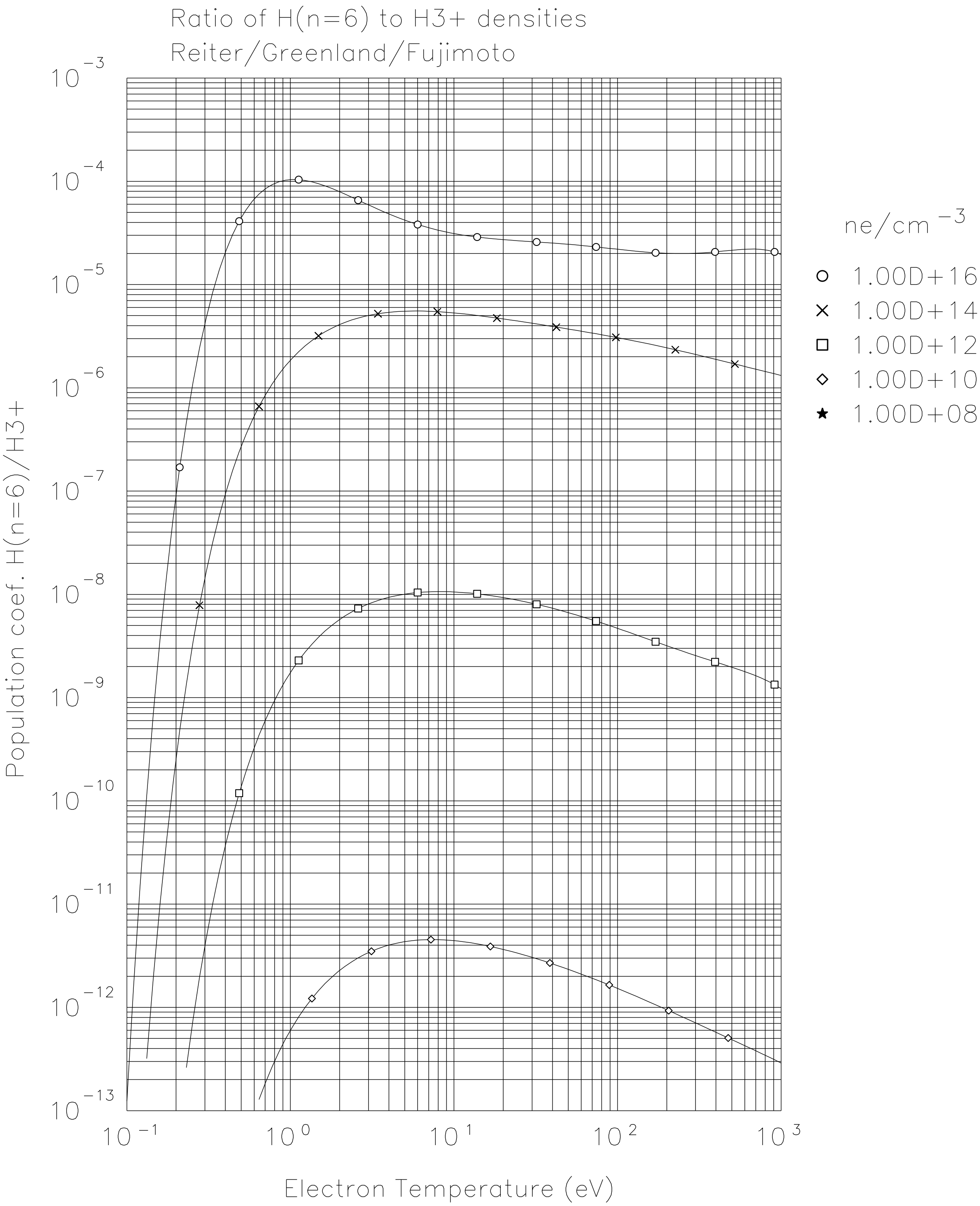
Multi-step hydrogenic population coefficients Data: K. Sawada, T.Fujimoto, [7] and R. Janev et al, 1987
Production of initial $H(n=2)$ from H_3^+ via $1/3.5 \times \langle Hydhel\ 2.2.15 \rangle$, then CR redistribution in H
Ratio of population coefficients: p(6)/nH3+

T-Index \ E-Index:	0	1	2
0	-3.731306702718D+01	2.226799613424D+00	-2.713541077245D-01
1	2.721916003669D+00	2.752077117728D-01	-2.817824763132D-01
2	-1.445171758730D+00	-3.455207346437D-02	2.128468170611D-02
3	4.869784512858D-01	-1.117099787519D-01	1.101949732661D-01
4	-1.366199370764D-01	1.963591329586D-02	-1.452797917604D-02
5	2.789289520108D-02	8.956074919162D-03	-9.295896282076D-03
6	-3.785560599727D-03	-2.449188168800D-03	1.956661410764D-03
7	3.086189807154D-04	1.287091624921D-04	-1.507685975982D-05
8	-1.139982513894D-05	3.981631091951D-06	-1.109641079725D-05

T-Index \ E-Index:	3	4	5
0	1.160222068193D-01	-2.351441393066D-02	2.434601322965D-03
1	1.173245156970D-01	-2.491839320070D-02	2.905055223332D-03
2	-5.633298373088D-03	7.917813609696D-04	-6.244317946507D-05
3	-4.412365175467D-02	8.991092209700D-03	-1.015055902253D-03
4	4.769180959321D-03	-8.470242324439D-04	8.762486764680D-05
5	3.796552815269D-03	-7.759741376950D-04	8.718058637354D-05
6	-6.790907264022D-04	1.241005294221D-04	-1.291557445220D-05
7	-1.814513841588D-05	6.730818401122D-06	-9.728795555375D-07
8	5.957908324528D-06	-1.396807603409D-06	1.699967143140D-07

T-Index \ E-Index:	6	7	8
0	-1.345468571268D-04	3.762918405002D-06	-4.176542071199D-08
1	-1.885547024432D-04	6.375389426295D-06	-8.745135270264D-08
2	3.292884698321D-06	-1.190866363308D-07	2.060340214319D-09
3	6.410030327458D-05	-2.116865424138D-06	2.846524837720D-08
4	-5.282031902152D-06	1.714977601939D-07	-2.311882826237D-09
5	-5.462320288173D-06	1.789108252698D-07	-2.387626221779D-09
6	7.684830295858D-07	-2.431186166102D-08	3.170509451364D-10
7	7.002458436648D-08	-2.501985930755D-09	3.541620765501D-11
8	-1.121847222632D-08	3.812117569450D-10	-5.230180135049D-12

P2MIN = 1.00000D 08 1/CM3
P2MAX = 1.00000D 16 1/CM3
Max. rel. Error: 7.7841 %
Mean rel. Error: 2.1550 %



Ratio of H(n=6) to H3+ densities
Reiter/Greenland/Fujimoto
Population coef. H(n=6)/H3+
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

12.52 Reaction 7.2a $H^- + p \rightarrow ... + H(3)$, Ratio $H(3)/H^-$, cold H^-

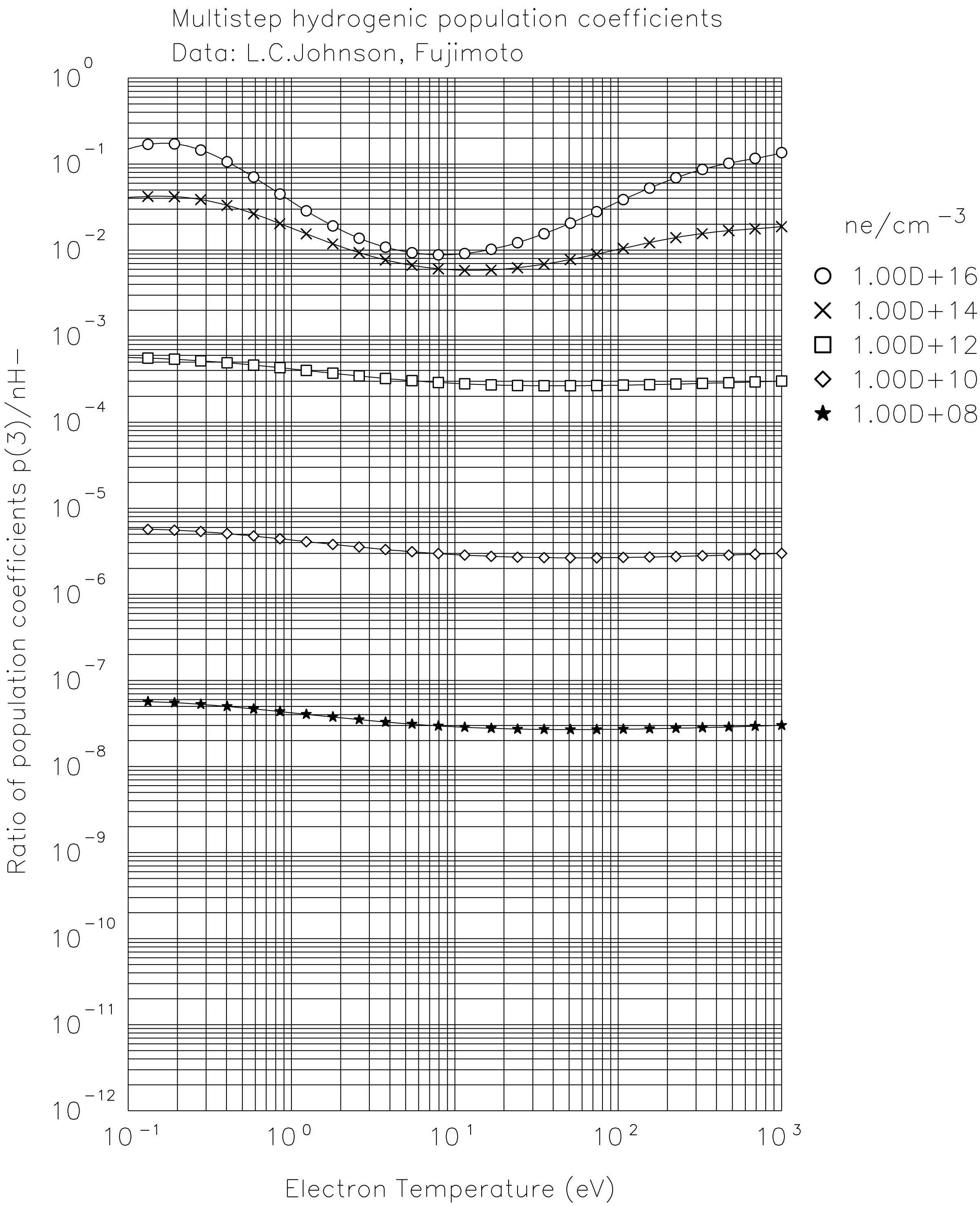
Multi-step hydrogenic population coefficients Data: K. Sawada, T.Fujimoto, [7] and Janev et al, 1987, and P.T. Greenland
Production of initial $H(n=2), H(n=3)$ from H^- via $\langle Hydhel\ 7.2.2\rangle + \langle Hydhel\ 7.2.3\rangle$, then CR redistribution in H
Ratio of population coefficients: p(3)/nH-

T-Index \ E-Index	0	1	2
0	-1.698348739110D+01	1.121505448583D+00	-1.562056461483D-01
1	-1.986622381979D-01	-2.318217689253D-02	1.896031486639D-02
2	-3.050975728615D-03	-3.329699545201D-02	3.779763018328D-02
3	1.002499912290D-02	1.045462457960D-02	-9.650053061780D-03
4	-6.398953884751D-04	1.441395323793D-03	-1.689635207883D-03
5	-7.711075007663D-05	-1.265328413655D-03	1.172945655383D-03
6	-2.049983387516D-05	2.044766998421D-04	-1.600026196636D-04
7	6.408878869927D-06	-7.052533095200D-06	1.334460994662D-07
8	-3.926518102708D-07	-4.161804947648D-07	7.965715911231D-07

T-Index \ E-Index	3	4	5
0	7.384423345663D-02	-1.696804365272D-02	2.090058776152D-03
1	-3.664162784606D-03	-4.356306374247D-04	2.146755452836D-04
2	-1.612181968354D-02	3.403282708663D-03	-3.903169292552D-04
3	3.237264411283D-03	-4.804144315515D-04	2.972541984716D-05
4	7.163905079239D-04	-1.561640485896D-04	1.914209762341D-05
5	-4.120367467656D-04	7.008894220942D-05	-6.189441302916D-06
6	5.033444502959D-05	-7.181438176276D-06	4.108056332733D-07
7	1.170985498327D-06	-4.690125988575D-07	8.503464517525D-08
8	-3.594245312260D-07	7.814690334520D-08	-9.611375720209D-09

T-Index \ E-Index	6	7	8
0	-1.399195453462D-04	4.756587306459D-06	-6.422505400847D-08
1	-2.514789071754D-05	1.212290889597D-06	-2.106280292156D-08
2	2.457727782342D-05	-7.941349227263D-07	1.025519706079D-08
3	-1.694973729097D-07	-5.142251421864D-08	1.423052870937D-09
4	-1.305410385352D-06	4.544728618553D-08	-6.246887421462D-10
5	2.736219149295D-07	-4.974014655394D-09	1.101207197277D-11
6	1.974698869452D-09	-1.016713293612D-09	2.621621803143D-11
7	-7.763141441637D-09	3.392374094524D-10	-5.632384756330D-12
8	6.750917451519D-10	-2.475979110847D-11	3.641741567554D-13

```
P2MIN =   1.00000D 08 1/CM3
P2MAX =   1.00000D 16 1/CM3
  Max. rel. Error:   3.9821 %
  Mean rel. Error:   1.1463 %
```



Multistep hydrogenic population coefficients
Data: L.C.Johnson, Fujimoto
Ratio of population coefficients p(3)/nH−
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

12.53 Reaction 7.2b $H^- + p \rightarrow ... + H(2)$, Ratio $H(2)/H^-$, cold H^-

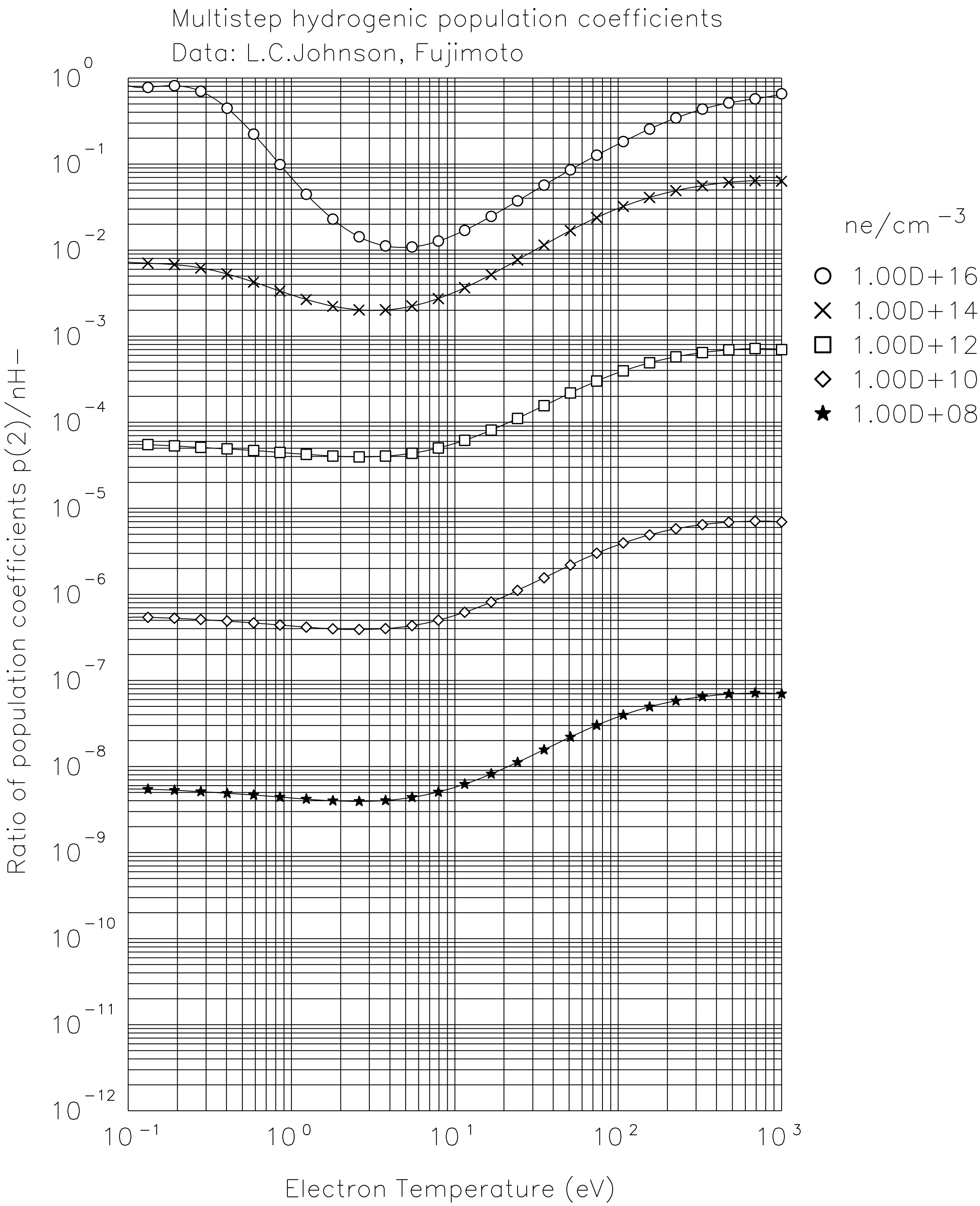
Multi-step hydrogenic population coefficients Data: K. Sawada, T.Fujimoto, [7] and R. Janev et al, 1987, and P.T. Greenland
Production of initial $H(n=2), H(n=3)$ from H^- via $\langle Hydhel\ 7.2.2\rangle + \langle Hydhel\ 7.2.3\rangle$, then CR redistribution in H
Ratio of population coefficients: p(2)/nH-

T-Index \ E-Index:	0	1	2
0	-1.926343612010D+01	9.700693610120D-01	3.086732967457D-02
1	-1.496546124174D-01	-1.162600124695D-02	2.092625890254D-02
2	1.400659517460D-02	-1.908809713587D-03	4.474825228504D-03
3	3.712727041944D-02	-3.993957797149D-03	-4.541915418960D-04
4	1.113294261028D-02	1.611302161934D-03	-5.800693212819D-04
5	-2.330535554138D-03	9.558196184261D-04	-6.770389256165D-04
6	-7.776821303119D-04	-4.777860585666D-04	3.191698603955D-04
7	1.906239407094D-04	6.855600321265D-05	-4.406502657234D-05
8	-1.086976945156D-05	-3.231539920350D-06	1.960565560845D-06

T-Index \ E-Index:	3	4	5
0	-1.026100449251D-02	1.333365556163D-03	-4.164574430779D-05
1	-1.057668991857D-02	2.292243771977D-03	-2.438392602831D-04
2	-3.880343783906D-03	1.355446874959D-03	-2.254517664957D-04
3	1.729089007572D-03	-5.825182714335D-04	8.058493209277D-05
4	3.161122491789D-05	-4.291165076538D-06	3.882643863521D-06
5	1.355992925800D-04	-1.875746974531D-06	-2.072988238143D-06
6	-7.101794671976D-05	5.892592961569D-06	-1.070175076067D-07
7	9.542955450383D-06	-7.940664442729D-07	2.114115776211D-08
8	-3.805705631298D-07	2.128669195423D-08	9.157761577608D-10

T-Index \ E-Index:	6	7	8
0	-4.925686587468D-06	4.112831538264D-07	-8.777239592815D-09
1	1.320368718562D-05	-3.516108767654D-07	3.593691259527D-09
2	1.896658591425D-05	-7.769484207076D-07	1.231580177702D-08
3	-5.398656503144D-06	1.737911735033D-07	-2.130553272068D-09
4	-6.162993739156D-07	3.529468645256D-08	-6.926859162458D-10
5	2.283983783682D-07	-9.387255029589D-09	1.353162447593D-10
6	-5.193261748972D-09	-8.326872653843D-12	8.362383797066D-12
7	-2.705240932212D-10	5.067994995276D-11	-2.001347795107D-12
8	-1.122561005445D-10	1.928570020702D-12	3.288397756094D-14

```
P2MIN =   1.00000D 08 1/CM3
P2MAX =   1.00000D 16 1/CM3
  Max. rel. Error:   4.1304 %
  Mean rel. Error:    .7570 %
```


Multistep hydrogenic population coefficients
Data: L.C.Johnson, Fujimoto
Ratio of population coefficients p(2)/nH−
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

12.54 Reaction 7.2c $H^- + p \rightarrow ... + H(4)$, Ratio $H(4)/H^-$, cold H^-

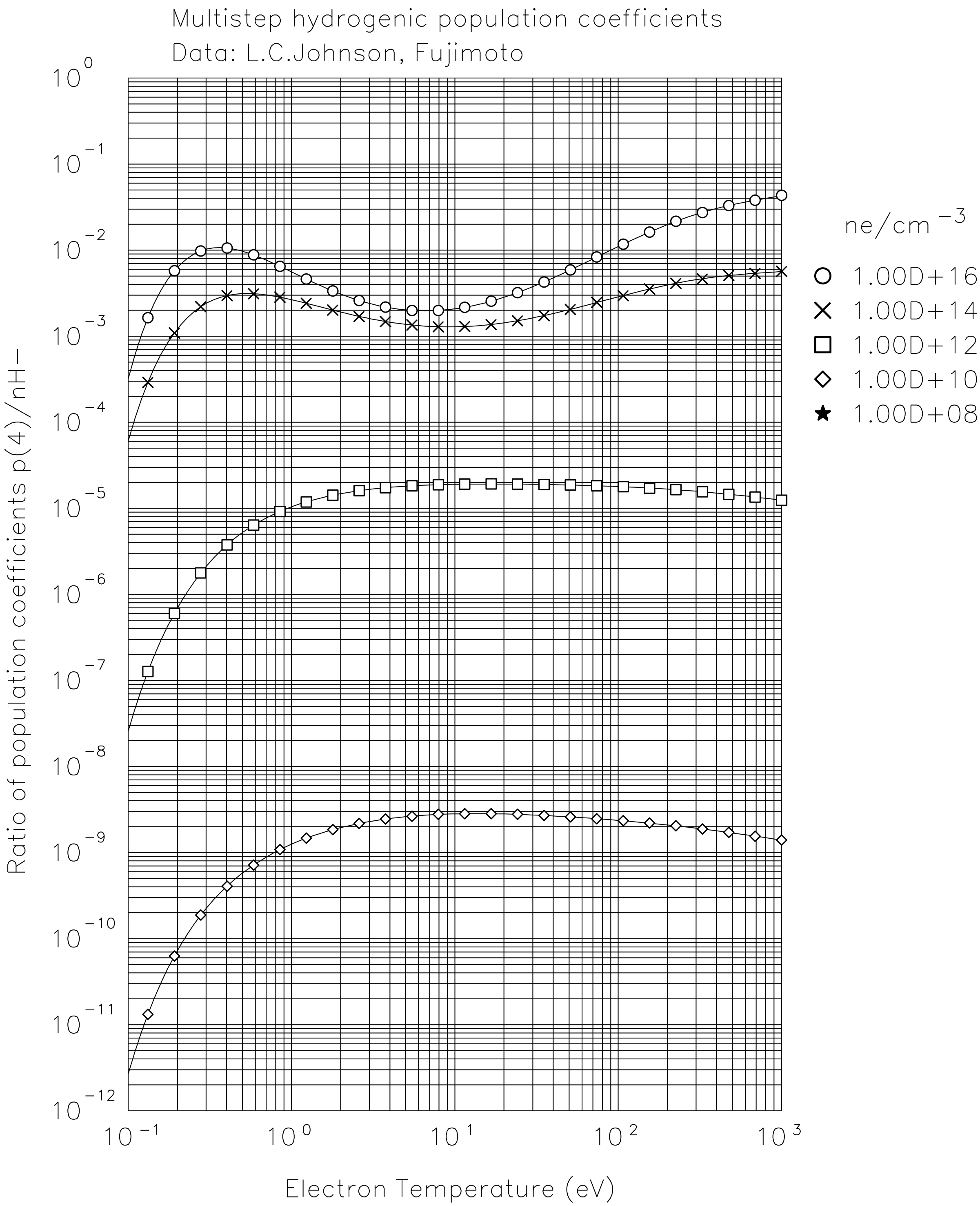
Multi-step hydrogenic population coefficients Data: K. Sawada, T.Fujimoto, [7] and R. Janev et al, 1987, and P.T. Greenland
Production of initial $H(n = 2), H(n = 3)$ from H^- via $\langle Hydhel\ 7.2.2\rangle + \langle Hydhel\ 7.2.3\rangle$, then CR redistribution in H
Ratio of population coefficients: p(4)/nH-

T-Index \ E-Index:	0	1	2
0	-2.969108713736D+01	1.931658904309D+00	7.005369877806D-02
1	8.583491624134D-01	-8.544233834909D-02	9.904671957939D-02
2	-3.327946567475D-01	1.355262241947D-02	-1.899077114113D-02
3	8.772623007048D-02	-4.247217004031D-03	6.314342474404D-03
4	-2.582394435391D-02	1.090757038295D-03	-1.202894310870D-03
5	6.746292673873D-03	-3.228772733572D-04	1.070577412178D-04
6	-1.132324670043D-03	6.889983086344D-05	-6.086331074514D-07
7	1.006838799981D-04	-5.193593477524D-06	-2.845251555754D-06
8	-3.599766107118D-06	3.508499294249D-08	3.027924280383D-07

T-Index \ E-Index:	3	4	5
0	-2.422134716752D-02	3.199185442634D-03	-6.987784095340D-05
1	-4.450036905348D-02	9.670609772772D-03	-1.101676052891D-03
2	8.393372221366D-03	-1.661524835400D-03	1.641367406906D-04
3	-2.639744634139D-03	5.083813172965D-04	-5.282312671120D-05
4	3.818974330343D-04	-6.097846279683D-05	6.274556790674D-06
5	9.032592725060D-06	-6.659380541156D-06	8.007827323926D-07
6	-7.241191756806D-06	1.656854215049D-06	-1.498873287066D-07
7	1.401115633607D-06	-2.121062436653D-07	1.534383868464D-08
8	-1.101496052033D-07	1.593127950555D-08	-1.277557055555D-09

T-Index \ E-Index:	6	7	8
0	-1.803884638427D-05	1.309228115068D-06	-2.572694262914D-08
1	6.597236559178D-05	-1.961355019834D-06	2.274461149865D-08
2	-8.182135682187D-06	1.912043686849D-07	-1.561456368451D-09
3	3.184968943859D-06	-1.061178779633D-07	1.506697376442D-09
4	-4.432073749742D-07	1.802283140716D-08	-2.998106690730D-10
5	-3.770998670281D-08	7.419022111792D-10	-5.644157060356D-12
6	7.339285822808D-09	-2.538540703677D-10	5.059927143765D-12
7	-7.934859405533D-10	3.738687857068D-11	-8.858974656396D-13
8	7.567293625031D-11	-3.326379990558D-12	6.790144662322D-14

P2MIN = 1.00000D 08 1/CM3
P2MAX = 1.00000D 16 1/CM3
Max. rel. Error: 4.0429 %
Mean rel. Error: 1.7450 %


Multistep hydrogenic population coefficients
Data: L.C.Johnson, Fujimoto
Ratio of population coefficients p(4)/nH−
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

12.55 Reaction 7.2d $H^- + p \rightarrow ... + H(5)$, Ratio $H(5)/H^-$, cold H^-

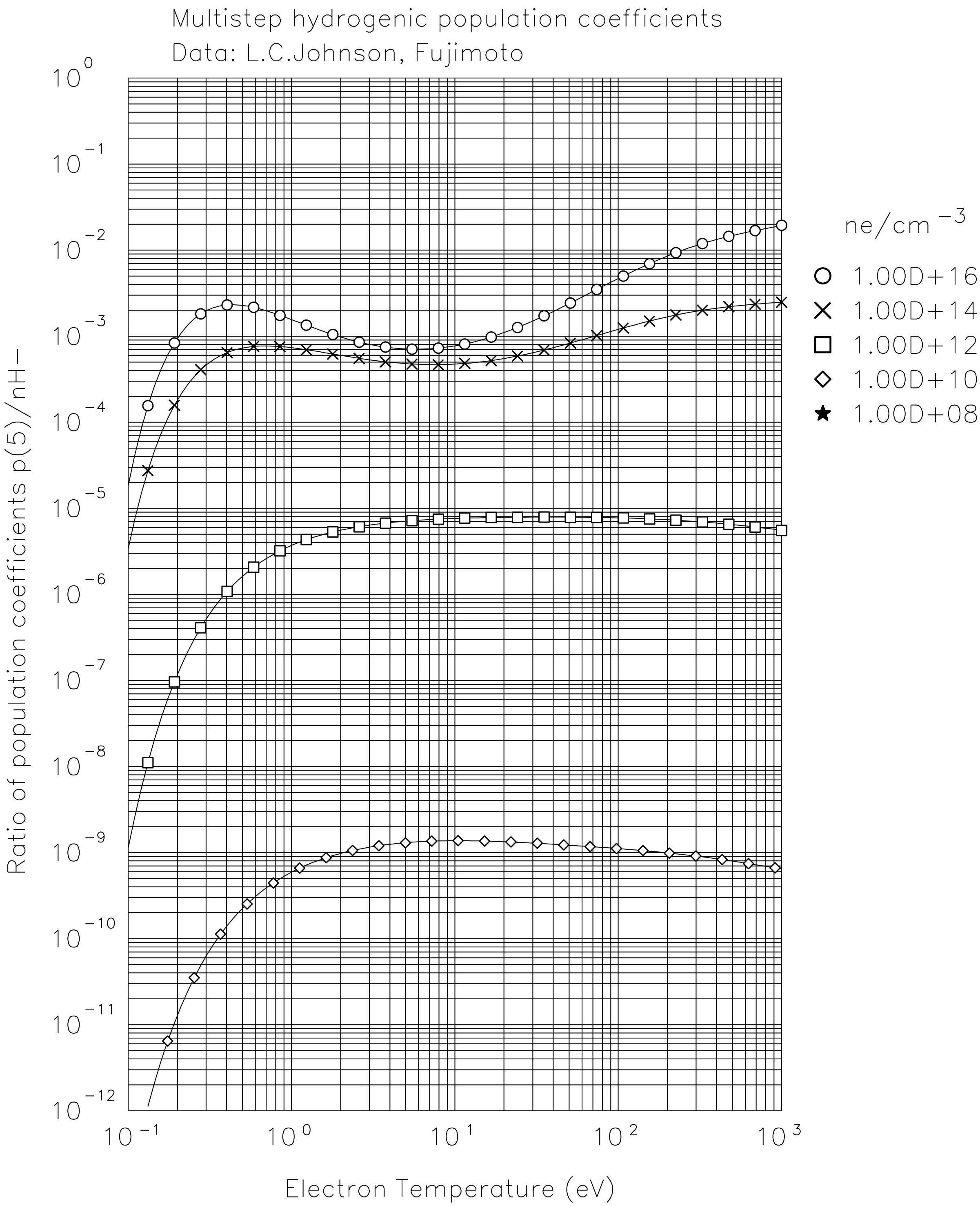
Multi-step hydrogenic population coefficients Data: K. Sawada, T.Fujimoto, [7] and R. Janev et al, 1987, and P.T. Greenland
Production of initial $H(n=2), H(n=3)$ from H^- via $\langle Hydhel\ 7.2.2\rangle + \langle Hydhel\ 7.2.3\rangle$, then CR redistribution in H
Ratio of population coefficients: p(5)/nH-

T-Index \ E-Index:	0	1	2
0	-3.043880324651D+01	2.037032074318D+00	-5.086322906145D-02
1	1.011406665313D+00	-6.365628088545D-02	7.087018763490D-02
2	-4.732792128048D-01	-1.434223357911D-02	1.444177153118D-02
3	1.440745315416D-01	3.264873576448D-03	1.234505116701D-04
4	-4.082830889986D-02	1.991190906181D-03	-2.756435764540D-03
5	9.541548408277D-03	-9.069208554478D-04	6.996980010317D-04
6	-1.454117847671D-03	1.551884580262D-04	-5.857488300427D-05
7	1.198928707328D-04	-1.400228251698D-05	6.473439676219D-07
8	-4.030214875087D-06	6.097512779644D-07	4.415255128121D-08

T-Index \ E-Index:	3	4	5
0	2.509733144867D-02	-6.315994199856D-03	8.827794491945D-04
1	-2.975345239990D-02	5.983399626204D-03	-6.277759777604D-04
2	-5.166305865235D-03	9.106705396634D-04	-8.761725049017D-05
3	-1.123250849126D-03	4.288583660416D-04	-6.890481712127D-05
4	1.147789672027D-03	-2.316365246467D-04	2.543759697649D-05
5	-1.993228761853D-04	2.517330858438D-05	-1.247794740929D-06
6	9.762118554856D-06	-3.741044970390D-07	-9.913305397062D-08
7	2.196741015054D-07	6.182578609139D-08	-2.188081446861D-08
8	-1.180565156491D-09	-1.449312603808D-08	3.350274299704D-09

T-Index \ E-Index:	6	7	8
0	-6.942768316956D-05	2.730469037199D-06	-4.155159141638D-08
1	3.369864501513D-05	-8.510546585606D-07	7.531215060388D-09
2	4.914337425208D-06	-1.501058689051D-07	1.891596830989D-09
3	5.529304847315D-06	-2.178898125651D-07	3.358437789658D-09
4	-1.555058635679D-06	4.945103866119D-08	-6.348990139489D-10
5	-1.032098974250D-08	3.032884418381D-09	-7.544164802502D-11
6	1.356968032839D-08	-6.737882205239D-10	1.229312195398D-11
7	2.266731611803D-09	-9.840633948791D-11	1.532952032542D-12
8	-3.079193750552D-10	1.282055029730D-11	-2.003506603284D-13

```
P2MIN =   1.00000D 08 1/CM3
P2MAX =   1.00000D 16 1/CM3
  Max. rel. Error:   3.6382 %
  Mean rel. Error:   1.4968 %
```



Multistep hydrogenic population coefficients
Data: L.C.Johnson, Fujimoto
Ratio of population coefficients p(5)/nH−
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

12.56 Reaction 7.2e $H^- + p \rightarrow ... + H(6)$, Ratio $H(6)/H^-$, cold H^-

Multi-step hydrogenic population coefficients Data: K. Sawada, T.Fujimoto, [7] and R. Janev et al, 1987, and P.T. Greenland
Production of initial $H(n=2), H(n=3)$ from H^- via $\langle Hydhel\ 7.2.2\rangle + \langle Hydhel\ 7.2.3\rangle$, then CR redistribution in H
Ratio of population coefficients: p(6)/nH-

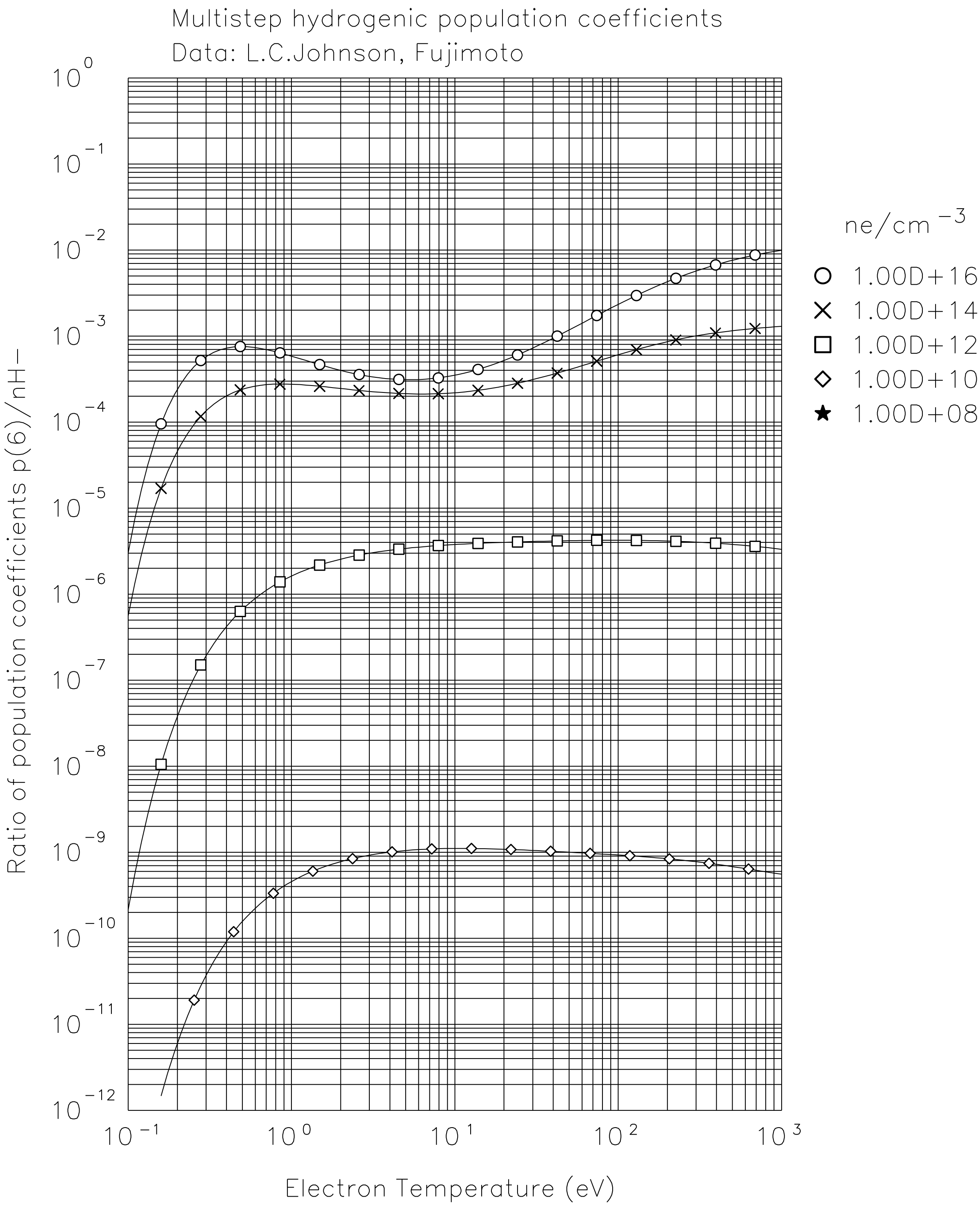
T-Index \ E-Index:	0	1	2
0	-3.067097488487D+01	2.133892956222D+00	-1.858785381782D-01
1	1.107995704752D+00	-7.267316900367D-02	8.619894154229D-02
2	-5.345011110243D-01	-3.782902464706D-02	3.756478330674D-02
3	1.764954640174D-01	-1.032649676351D-02	6.464524722712D-03
4	-5.202491523226D-02	9.880352020439D-03	-7.493150468782D-03
5	1.098049582592D-02	6.531384081385D-04	-4.330923663414D-04
6	-1.298474536154D-03	-1.099967577090D-03	7.673435067944D-04
7	6.641085066002D-05	1.987746890586D-04	-1.359755033628D-04
8	-6.055672527870D-07	-1.099732061179D-05	7.398032652292D-06

T-Index \ E-Index:	3	4	5
0	9.184112431405D-02	-2.187443850319D-02	2.732957962088D-03
1	-3.580517565764D-02	6.746409669729D-03	-6.444562044629D-04
2	-1.526915092790D-02	3.195158804825D-03	-3.642351248993D-04
3	-1.591669787688D-03	2.306297194231D-04	-2.527875779410D-05
4	2.344024954832D-03	-3.904912867153D-04	3.759207667760D-05
5	8.191445720958D-05	3.579949470965D-07	-1.520984760597D-06
6	-2.001600190074D-04	2.348421586345D-05	-1.161204797043D-06
7	3.467501043759D-05	-3.909320595026D-06	1.690954968052D-07
8	-1.839785030150D-06	1.966330012309D-07	-6.837510677821D-09

T-Index \ E-Index:	6	7	8
0	-1.868296143542D-04	6.535291194065D-06	-9.119318650851D-08
1	3.052346096314D-05	-6.246714758968D-07	3.118274317587D-09
2	2.310260448654D-05	-7.637664587365D-07	1.022317615231D-08
3	1.917516778339D-06	-7.990930597360D-08	1.329300639507D-09
4	-2.089962077496D-06	6.184502696051D-08	-7.491029220022D-10
5	1.631598610791D-07	-6.823070866810D-09	1.018157208247D-10
6	1.519122575792D-09	1.768275307240D-09	-4.254302334326D-11
7	2.544277095276D-09	-4.245685956755D-10	9.325245214987D-12
8	-3.147128047635D-10	2.969365004153D-11	-6.059328354768D-13

P2MIN = 1.00000D 08 1/CM3
P2MAX = 1.00000D 16 1/CM3
Max. rel. Error: 4.5793 %

```
Mean rel. Error:   1.9756 %
```



Multistep hydrogenic population coefficients
Data: L.C.Johnson, Fujimoto
Ratio of population coefficients p(6)/nH−
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

12.57 Reaction 2.0a $e + H_2 \rightarrow H_2^+ + ...$, Ratio H_2^+/H_2

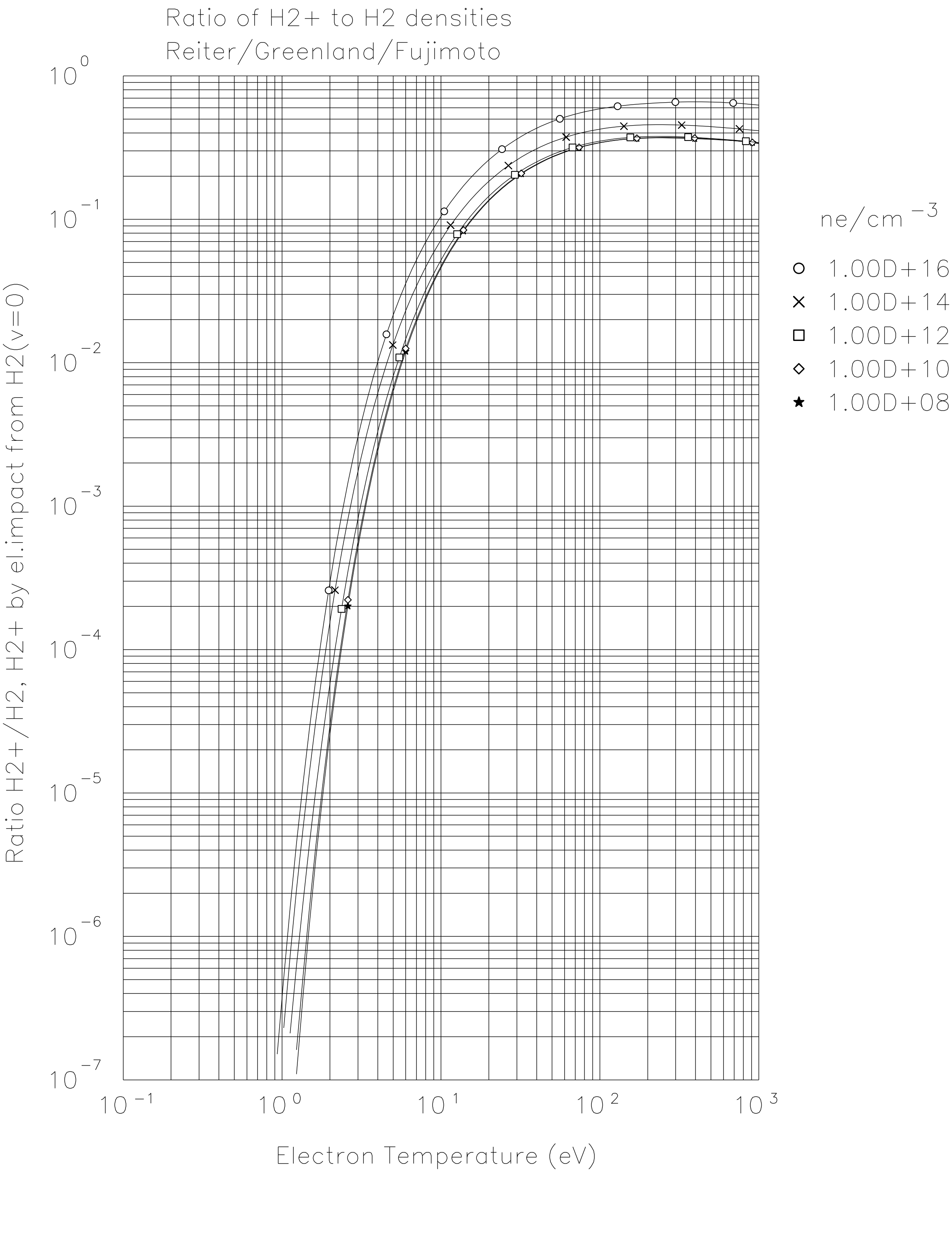
Multi-step hydrogenic density ratios Data: K. Sawada, T.Fujimoto, [7] and Janev et al, 1987, and P.T. Greenland
alias: 2.0ei (still missing: 2.0eig: with Greenland's vibr. distr.) CR equilibrium ratio H2+ to H2 density (coll.rad model, Sawada/Fujimoto/Greenland) here: H2+ gain from electron impact on $H_2(v = 0)$ only
only contribution from EI on H2 and H2* to production rate of H_2^+

T-Index \ E-Index:	0	1	2
0	-1.929803964240D+01	2.097006502950D-01	-1.100904809661D-01
1	1.727612905933D+01	-4.662670859833D-01	8.567341672326D-02
2	-8.438025952533D+00	6.115179297110D-01	-1.153478632323D-01
3	2.883389908864D+00	-4.286361930144D-01	6.596018559458D-02
4	-7.403401021470D-01	1.809442086665D-01	-1.864042138902D-02
5	1.387371448471D-01	-4.879175895909D-02	4.430141421894D-03
6	-1.746217632264D-02	8.151856339270D-03	-1.015594807894D-03
7	1.287561948974D-03	-7.544209459715D-04	1.374937928555D-04
8	-4.136061327089D-05	2.914443517923D-05	-7.106408217685D-06

T-Index \ E-Index:	3	4	5
0	4.477781641551D-02	-9.060826089295D-03	1.170547725039D-03
1	-6.827368520293D-03	-3.618060467670D-03	6.852659500488D-04
2	1.993457166448D-02	1.643837202714D-04	-3.516424328964D-04
3	-1.341784022457D-02	1.582201264314D-03	-7.056994955968D-05
4	1.875666968084D-03	-2.978688155916D-04	2.721069163086D-05
5	1.476743155802D-04	-3.955049388000D-05	2.382368688632D-06
6	6.205132641268D-06	7.210178682186D-06	-6.812476857444D-07
7	-1.222677896703D-05	8.247029259344D-07	-5.043186962921D-08
8	1.041267499432D-06	-1.158374992604D-07	9.052478729563D-09

T-Index \ E-Index:	6	7	8
0	-8.893455666588D-05	3.479454987799D-06	-5.361512296401D-08
1	-4.473404420068D-05	1.209602016239D-06	-1.069974187479D-08
2	3.207886028645D-05	-1.101305933603D-06	1.299192188737D-08
3	4.431489645883D-07	2.326874797653D-08	1.068518137706D-10
4	-1.428413713222D-06	4.845148645034D-08	-8.048035605554D-10
5	-5.790867265229D-08	-6.986008432331D-10	4.535659079263D-11
6	3.277446170025D-08	-8.583517963518D-10	9.700723935742D-12
7	2.025920058300D-09	-3.655728430701D-11	8.337869178540D-14
8	-4.280094258996D-10	1.063115935764D-11	-1.030790224273D-13

```
P2MIN =   1.00000D 08 1/CM3
P2MAX =   1.00000D 16 1/CM3
  Max. rel. Error:   1.8077 %
  Mean rel. Error:    .3852 %
```



Ratio of H2+ to H2 densities
Reiter/Greenland/Fujimoto
Ratio H2+/H2, H2+ by el.impact from H2(v=0)
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

12.58 Reaction 2.0b $e + H_2(v = 0) \rightarrow H_2^+ + ...$, Ratio H_2^+/H_2

alias 2.0tot, only v=0 state Multi-step hydrogenic density ratios Data: K. Sawada, T.Fujimoto, [7] and R. Janev et al, 1987, and P.T. Greenland
CR equilibrium ratio H_2^+ to H_2 density (coll.rad model, Sawada/Fujimoto/Greenland) contribution from both: EI on H_2 and H_2^* plus from CX on cold $H_2(v = 0)$, ($E_{H_2}(v = 0) = 0.1$ eV) and assuming $n_e = n_p, T_e = T_p$
Should always be larger than the corresponding H11, 2.0cx pure p process, ratio for contrib. from CX alone. Slightly violated due to fitting inaccuracies near 1-2 eV

T-Index \ E-Index	0	1	2
0	-8.073335051460D+00	6.423193640255D-03	-8.948271203923D-03
1	1.653303173229D+00	-2.467726829997D-02	2.781981866915D-03
2	-2.823571725913D+00	4.179798625064D-02	-3.843754761904D-02
3	3.990452244578D+00	3.234966368980D-02	1.652438305320D-02
4	-1.928017324234D+00	-5.924941119276D-02	2.747810096639D-03
5	4.270719810226D-01	3.111963342548D-02	-5.375451827926D-03
6	-4.448144242484D-02	-7.757664930424D-03	2.077957627729D-03
7	1.689930248766D-03	9.331136287171D-04	-3.275780863917D-04
8	1.023775315217D-05	-4.333393780782D-05	1.830671388026D-05

T-Index \ E-Index	3	4	5
0	4.582288903630D-03	-1.133062383784D-03	1.472017794904D-04
1	2.885192609023D-03	-9.313120366375D-04	1.193603851194D-04
2	1.457779901878D-02	-2.689882985994D-03	2.781888663389D-04
3	-1.096201612859D-02	1.873511746692D-03	-1.169697988538D-04
4	5.081237207186D-03	-1.022266662048D-03	5.028620238286D-05
5	-1.087834901368D-03	3.309186604685D-04	-2.068184308171D-05
6	-4.372642244363D-05	-3.372497244723D-05	2.250956728263D-06
7	4.092745909295D-05	-2.274671467977D-06	2.463960054850D-07
8	-3.393709830706D-06	3.905523509303D-07	-3.774892100311D-08

T-Index \ E-Index	6	7	8
0	-1.037336914709D-05	3.752297970376D-07	-5.454015313711D-09
1	-7.537317404876D-06	2.293533267915D-07	-2.631009817091D-09
2	-1.566116716437D-05	4.383284185329D-07	-4.647720359472D-09
3	3.575003652413D-07	2.295739667060D-07	-6.354279184897D-09
4	1.852056305253D-06	-2.235055431776D-07	5.044313531628D-09
5	-1.431641793698D-07	4.978742338393D-08	-1.196745758163D-09
6	4.433372743456D-08	-7.031624330495D-09	1.525402495797D-10
7	-2.449746761192D-08	1.051457900024D-09	-1.574612982461D-11
8	2.386870809793D-09	-7.721695858310D-11	9.552566353384D-13

```
P1MAX =  4.000000e+02 eV
P2MIN =    1.00000D 08 1/CM3
P2MAX =    1.00000D 16 1/CM3
  Max. rel. Error:  20.6614 %
  Mean rel. Error:   8.5812 %
```

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12.59 Reaction 2.0c $e + H_2(v) \rightarrow H_2^+ + ...$, Ratio H_2^+/H_2

alias 2.0totg Multi-step hydrogenic density ratios Data: K. Sawada, T.Fujimoto, [7] and R. Janev et al, 1987, and P.T. Greenland
CR equilibrium ratio H2+ to H2 density (coll.rad model, Sawada/Fujimoto/Greenland) for vibrational population $pH_2(v;T_e)$ contribution from CX on cold H2(v) ($E_{H_2}(v) = 0.1$ eV) and EI on H2 and H2*
Should always be larger than the corresponding H11, 2.0cxg pure p process, ratio for contrib. from CX alone. Slightly violated due to fitting inaccuracies near 1-2 eV

T-Index \ E-Index:	0	1	2
0	-5.179118614571D+00	1.286086917362D-02	-1.247224025136D-02
1	2.724390078109D+00	2.834163745797D-02	-3.864050364482D-02
2	-4.386686018740D+00	-2.926061072808D-02	2.894878695435D-02
3	2.264569877939D+00	1.815438259403D-02	-1.085596419844D-02
4	7.274238145138D-02	-8.711469240181D-03	1.228482582919D-03
5	-3.332379782334D-01	3.737790746246D-03	-2.689540529741D-04
6	9.526327139861D-02	-1.046333532366D-03	2.549358736065D-04
7	-1.096455316607D-02	1.457992401832D-04	-5.912048929304D-05
8	4.636081955869D-04	-7.621573981592D-06	3.973565261183D-06

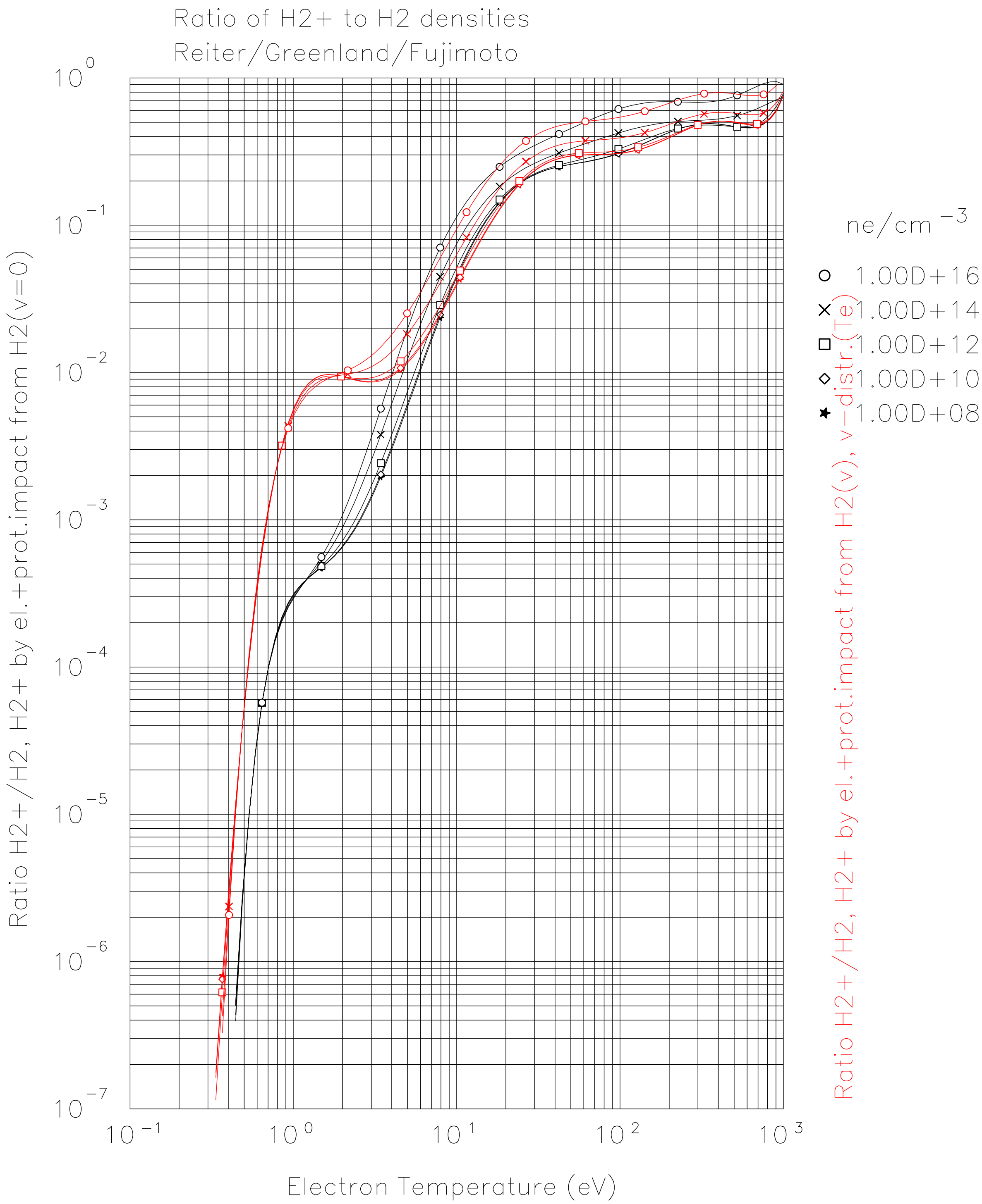
T-Index \ E-Index:	3	4	5
0	4.533679343348D-03	-8.361635510932D-04	8.553044625491D-05
1	1.706652099436D-02	-3.663038423578D-03	4.202564138138D-04
2	-9.446648200804D-03	1.518996106179D-03	-1.265997327758D-04
3	3.413100865417D-03	-5.414461499166D-04	5.583904028460D-05
4	-2.783712092681D-04	4.118527168273D-05	-1.416596336268D-05
5	-7.626065770945D-05	3.568228589947D-05	-1.406315371249D-06
6	-3.059560467433D-05	-3.460893323989D-06	4.064186524949D-07
7	1.303239138604D-05	-1.086383020673D-06	6.161003040376D-08
8	-1.046764002685D-06	1.291713097220D-07	-9.932517910526D-09

T-Index \ E-Index:	6	7	8
0	-4.999715093023D-06	1.571098567732D-07	-2.060813085997D-09
1	-2.662584829521D-05	8.795062121815D-07	-1.182222955604D-08
2	5.854399926391D-06	-1.486122653306D-07	1.689012430939D-09
3	-3.494312204501D-06	1.176151828469D-07	-1.631239647294D-09
4	1.434270108351D-06	-5.449461807998D-08	6.856555143001D-10
5	-3.197342970575D-08	-4.539301068809D-10	9.975543797298D-11
6	-3.342848157445D-08	2.469622408760D-09	-6.675572336239D-11
7	2.239916154599D-10	-2.455363614572D-10	7.954115052237D-12
8	3.412487324650D-10	1.748563436447D-12	-2.514652180013D-13

P1MAX = 4.000000e+02 eV

Max. rel. Error: 18.5554 %

```
Mean rel. Error:   8.9531 %
```



Ratio of H2+ to H2 densities
Reiter/Greenland/Fujimoto
Ratio H2+/H2, H2+ by el.+prot.impact from H2(v=0)
Ratio H2+/H2, H2+ by el.+prot.impact from H2(v), v−distr.(Te)
Electron Temperature (eV)
ne/cm −3
1.00D+16
1.00D+14
1.00D+12
1.00D+10
1.00D+08

13 Appendix

References

[1] A.B.Ehrhardt, W.D.Langer, PPPL 2477 (1987)

[2] R.K. Janev, B. Langer et al. Springer Series on Atoms+Plasmas, Vol 4, 1987

[3] A.C.Riviere, Nucl.Fus. 11 (1971), p363

[4] C.Mahn, V.Welge, IPP 2/239, June 1978

[5] Reiter, D., Eckstein, W., Giesen, G., Belitz, H.J., Database for recycling and penetration of neutral helium atoms in the boundary of a fusion plasma, Jül-2605 (1991)

[6] Reiter, D. in "Atomic and Plasma Material Interaction Processes", eds. R.K. Janev, H.W. Drawin, Elsevier Science Publishers 1993

[7] Sawada,K., Fujimoto,T., J. Appl. Phys.78 (5), (1995) ,p2913

[8] Bell et al.,"Atomic and molecular data for fusion, part I: recommended cross-sections and rates for electron ionization of light atoms and ions" report CLM-R 216, UKAEA Culham, 1982

[9] Bachmann, P., Reiter, D., Contrib. Plas. Phys. 35, (1995), 1, pp45

[10] P. Bachmann, H.J. Belitz, Database for Elastic Collisions of Protons with Noble Gas Atoms, Max-Planck-Institut fuer Plasmaphysik Report IPP 8/5, June 1995

[11] P.C. Cosby, "Electron-impact dissociation of nitrogen", J. Chem. Phys 98 (1993) 9544

[12] E.M. Bahati, J.J. Jureta, D.S. Belic, H. Cherkani-Hassani, M.O. Abdellahi and P. Defrance, "Electron impact dissociation and ionization of N2+", J. Phys. B: At. Mol. Opt. Phys. 34 (2001) 2963

[13] D. Rapp and P. Englander-Golden, "Total cross-sections for ionization and attachment in gases by electron impact. I. Positive ionization", J. Chem. Phys 43 (1965) 1464

[14] D. Rapp, P. Englander-Golden and D.D. Briglia, "Cross-sections for dissociative ionization of molecules by electron impact", J. Chem Phys. 42 (1965) 4081

[15] E. Brook, M.F.A. Harrison and A.C.H. Smith, J. Phys. B: : At. Mol. Opt. Phys. 11 (1978) 3115

[16] J.R. Petersen, A. Le Padellec, H. Danared et al., J. Chem. Phys. 108 (5), (1998), p1978

[17] Greenland, T., Reiter, D., "The Role of Molecular Hydrogen in Plasma Recombination", Report, JUEL-3258 (1996), FZ-Jülich

[18] Janev, R., Reiter, D., Samm, U., "Collision Processes in Low-Temperature Hydrogen Plasmas", Report, JUEL-4105 (1996), FZ-Jülich, Dezember 2003 ISSN 0944-2952

[19] Behringer, K., “Description of the Impurity Transport Code “STRAHL” ”. Report JET-R (1987) 08 and Report JET-R (1989) 03, JET Joint Undertaking, Abingdon Oxon OX 14 3EA

[20] Schultz, D. in “Atomic and Molecular Processes in Fusion Edge Plasmas”, ed.: Janev, R.K., Plenum Press, New York, 1995

[21] Freeman, R., Jones, E., (1974), CLMR-137, Culham Laboratory report, Abingdon, England

[22] T. Fujimoto, J. Quant. Spectrosc. Radiat. Transfer, 21 (1979) 439 and: M. Goto, J. Quant. Spectrosc. Radiat. Transfer, 76 (2003) 331

[23] Kristic P. S., Schultz D. R., Physical Review A, 60 (1999), p2118

[24] R.W.P. McWhirter, A.G. Hearn, Proc. Phys. Soc. 82 (1963), p641