The data file HYDHEL:
Atomic and Molecular Data for EIRENE
based upon: Janev, Langer, Evans, Post, "Elementary Processes in Hydrogen-Helium Plasmas", Springer 1987

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Version: January 13, 2020

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v

4 H.8 : Fits for $\langle \sigma \cdot v \cdot E_p \rangle (T_b) \, [cm^3/s \cdot eV]$ **206**

I Errata, list of modifications as compared to the original 1987 book [1]

A first set of corrections, errata, modifications was published by Reiter et al, in [2]. Most of them are also contained in the following, more comprehensive list.

- Reaction 2.2.5

  The cross-section and rate coefficients for this reaction are about a factor 3 too low. This error has been introduced between the draft version and the final printed version of the book in 1987. Here we have corrected this error, i.e., the fit coefficients from the (un-published) draft version of the book are given here, whereas the erroneous fit coefficients from the printed version of the book are retained in the database AMJUEL, (reaction 2.2.5o), for reference purposes.

- Reaction 3.1.8

  The cross-section H.1, 3.1.8 has been improved by adding the low energy extrapolation coefficients.

  The fit H.3, 3.1.8 has been replaced with a better one, such that it becomes more consistent with the cross-section H.1 3.1.8. This leads to significantly improved energy balance in case of tracklength estimators for the CX energy loss.

  The original fits from the 1987 book have been kept in file amjuel.tex, under H.3, 3.1.8org

  In Aug. 2017 the cross section fit was further improved. It had a tiny remaining discontinuity at E=0.1 eV, which is now removed.

- Feb 2013

  Some reaction and species formulas in section headers slightly changed to permit automated CR model construction (species and reaction type identification) for HYDKIN online tool

- Mar 2013

  Added: H.1 (cross-sections): *Eth* (threshold energy), used for online plots and Maxwellian rate integration

  Added: H.1 (cross-sections) *Mcross* (Mass as used in energy scale. Electron mass (kg), or heavy particle mass, (AMU).)

- Reaction 2.1.3

  cross-section and reaction rate of electron-impact process 2.1.3 (Chibisov) are both a factor 10 too small. Also Chibisov analytic formula for cross-section given in 1987 book: factor 10 too small. Not yet corrected here in fits. (Can be done by a modification of coefficients a_0 and b_0) The corresponding proton-impact data (3.1.3) seem to be correct.

- Reaction 2.2.13

  The cross-section and rate coefficient plotted on page 61 of the 1987 version of the book are both by a factor 10 too large. The fitting coefficients for cross-section and rate coefficient appear to be correct, however.

- Reaction 3.1.7

  The BEA cross-section formula given in text give cross-section results that are by a factor 4 too small, due to a corresponding error in numerical factors given (page 126)

- Reaction 7.3.1

  Both the cross-section and rate coefficient for this reaction are incorrect, by several orders of magnitude. Do not use these data !

- Reaction 2.1.8

  In the original book a closed form expression is given for the radiative recombination rate coefficients for protons into the *nl* states of H atom. Added in Jan. 2014: H.2 rate coefficient polynomial fitting of these rate coefficients, for recombination into $1s, 2s$ and $2p$ states, to allow automated processing with same format as for other cross-sections and rate coefficients in this data-base

- June 2015: H.2 for Reaction 3.1.8

  A single parameter fit: H.2 3.1.8 is added, vs. proton temperature only and for "stationary" H(1s). It has been derived algebraically from the H.3 fit, evaluated at E=0.1 eV, and this procedure was verified by independent Maxwellian averaging of the asymptotically correct cross-section fit H.1 3.1.8, (vs. E) The mass used on the temperature scale is the proton mass.

- July 2015-I

  Some state notations, in particular for He excited states in section headers slightly changed to permit automated CR model construction (species and reaction type identification) for HYDKIN online tool. Notation also now consistent with AMJUEL He CR model data.

- July 2015-II, 2.2.14

  Reaction 2.2.14: In AMJUEL the reaction fits for H.1 and H.2 are reduced to be linear in log-log scale and hence $\ln \sigma(E) = a_0 + a_1 \ln(T)$ and $\ln \langle \sigma v \rangle(T) = b_0 + b_1 \ln(T)$, respectively, because higher non- zero coefficients in original book [1] seem to be spurious for this reaction. In this simpler (AMJUEL) form for the rate coefficient H.2 the corresponding H.8 fit is exact: $\ln \langle \sigma v E_{elec} \rangle(T) = h_0 + h_1 \ln(T)$ with $h_0 = b_0 + \ln(3/2 + b_1)$ and $h_1 = b_1 + 1$, see H.8 2.2.14 in AMJUEL. An independently computed H.8 fit using a table from the full H.2 rate fit is still retained in the present HYDHEL file here, (formerly at AMJUEL H.8), for backward compatibility

- Sept. 2015: state notation for process 2.3.4b: final state notation was wrong. Now corrected

- Jan 16: asymptotically better cross-sections for some processes. Reaction H.1: 3.3.2, 3.3.6a, 3.3.6b, 6.2.1, 6.3.1 fitted to a wider energy range, asymptotically correct at high collision energies. The corresponding new cross-sections are labeled: 3.3.2n, 3.3.6an 3.3.6bn, 6.2.1n and 6.3.1n

- H.8 2.2.14 added here, consistent with H.2 2.2.14 dissociative. recomb. A better representation is given in AMJUEL. from the linearity on a log-log scale exact consistency can

be achieved, and is stored there, and is also the hard-coded EIRENE default for process 2.2.14

- Feb 16 added for various cross-sections: ELABMAX and high energy end extrapolation: H.1: 3.1.1, 3.1.2, 3.1.6, 3.1.8, 3.1.9, 3.1.11b, 3.2.1b, 3.2.4a, 3.2.5, 3.2.6, 3.3.1, 3.3.6a, 3.3.6b, 4.2.1, 4.3.1, 4.3.3, 4.4.1, 5.2.3, 6.1.6, and 7.2.2

- May 2016: H.2 3.2.3 added: H.2 for 3.2.3. same as earlier done (June 15) for 3.1.8: thermal rate coefficient, evaluated at Eb =0.1 eV ≈ 0.0 eV Ebmin of H.3 fit for 3.2.3 is about 0.1 eV.

- May 2016 H.2 2.2.10 and 2.2.12:

  Process 2.2.12, starting from bound state H_2^+, is not contained in two step process 2.2.10, which starts from H_2, because in 2.2.10 the transition from H_2 to $H + H^+$ proceeds either via the repulsive part of the H_2^+ ground state, or by direct transition from H_2 to the first excited H_2^+ B state, without an intermediate bound H_2^+ state.

II to be done

- 2.1.8 and 2.3.13 missing fits for H.2 rate coeffs. (for stationary (E0=0.0) beam)

- H.2 rad rec coeff:

  In original monograph only closed form analytic expressions are given for H+ and He+ rad rec. rate coefficients. (and nothing for the cross-sections). 2.1.8, 2.1.8a and 2.1.8b fits for H.2 rad rec rate coefficients had already been added earlier (see list of changes/errata in previous section). The same is needed still for 2.3.13 (helium rad. rec), in particular since the closed form expression from the book is hard wired as default recombination rate in EIRENE code for He^+.

  Perhaps the closed form expression allows a direct (analytical) translation into polynomial fit? It seems to be the case indeed from the new 2.1.8 fits that only two coefficients may be needed. No: two different slopes Te**s at low Te and at high Te. Cannot be accomodated by a single fit which is linear in log-log scale.

- H.8 rates for recombination processes

  for the closed form expressions for 2.1.8 and 2.3.13 these rates can be given also in closed form (and are coded in the EIRENE default A&M model routines). It might be desirable to add them also as H.8 into the database. Same for 2.2.14 (diss. rec of H2+). This latter is already here in HYDHEL (update from July 2015), and EIRENE default was 0.88*Te times rate 2.2.14. So the H.8 2.2.14 was approximately, but not exactly, the previous EIRENE default. The H.8 fit can not be derived from the H.2 fit exactly. H.8 follows from H.2 directly, if only the b0 and b1 coefficients in the H.2 fit are non-zero, see: AMJUEL.tex For 2.2.14: Change EIRENE default (H.2 and H.8) to that 2 parameter fit from AMJUEL for H.8, Done.

  In Sept. 18 a fit for recombination: H.8 2.1.8 has been added, using only the first 2 coefficients b0 and b1 from the corresponding H.2 fit. (In an attempt to mimik the closed form analytical default model in EIRENE): However: in case of process 2.1.8 this turns

out to be unsatisfactory. Apparently the higher coefficients in H.2, although small, matter, to provide the T**-3/2 decay of the rate at high Te (rather than the near T**-1/2 decay at low Te.

- process 2.2.15 is linear in log log scale.

  Check coefficients, make H.8, set spurious coeffs. to zero

- H.2 5.3.1 and 6.3.1 to be added, at Eb=0.1

  m_lab=4, but m_reduced=2 for these processes

- Maxrate: sigma * v_lab

  started to implement the maximum of product sigma * v_lab, for heavy particle process cross-sections: Done for 7.2.2

- corrections from 1992 PSI paper (Reiter, Bogen, Samm, [2])

  various KER values....

This next string is searched by EIRENE in subroutine SLREAC to initialize search for a particular set of fit coefficients.

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

1 H.1 FITS FOR σ

Reaction 2.1.1 $e + H(1s) \rightarrow e + H(2p)$

```
a0 -4.991816994666e+02    a1  6.320402753550e+02    a2 -3.652213752597e+02
a3  1.165699645892e+02    a4 -2.250557133404e+01    a5  2.695101794905e+00
a6 -1.958839549072e-01    a7  7.917154881015e-03    a8 -1.365267533573e-04
   Emin  1.08e+01   s(Emin)  1.00e-19   smax  7.50e-17   Error  2.36e-01
   Eth 10.2
   Mcross 9.1093826E-31


   aBorn,1= 1.68301e-16  nBorn,1= 8.44454e-01

   Emin  1.08e+01    s(Emin)  1.00e-19    Error  5.16e-01


   aBorn,2= 2.08151e-16  nBorn,2= 9.18070e-01

   Emin  1.08e+01    s(Emin)  1.00e-19    Error  3.95e-01
```

Reaction 2.1.2 $e + H(1s) \rightarrow e + H(2s)$

```
a0 -1.773223143614e+03    a1  2.868021256119e+03    a2 -2.019174875577e+03
a3  7.913558639288e+02    a4 -1.890880793711e+02    a5  2.824418882926e+01
a6 -2.579116350676e+00    a7  1.318146425812e-01    a8 -2.890652428531e-03
   Emin  1.08e+01   s(Emin)  1.00e-19   smax  1.91e-17   Error  3.00e-01
   Eth 10.2
   Mcross 9.1093826E-31
```

Reaction 2.1.3 $e + H(2s) \rightarrow e + H(2p)$

```
a0 -3.015144307129e+01    a1 -8.929446571004e-01    a2 -5.730368414517e-03
a3  4.111473087803e-04    a4 -3.370055284368e-05    a5  2.817934394179e-06
a6 -1.944521853229e-07    a7  8.570956054828e-09    a8 -1.688382595819e-10
    Emin  1.00e-01   s(Emin)  6.06e-13   smax  6.06e-13   Error  1.75e-10
    Eth 1.934e-5
    Mcross 9.1093826E-31
```

A more extensive analytic formula is given in the text.

Reaction 2.1.4 $e + H(n) \rightarrow e + H(m)(m > n, m \neq 2)$

An analytic formula is given in the text.

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

```
a0 -7.778213049931e+02    a1  9.540190857268e+02    a2 -5.227766973807e+02
a3  1.592701052833e+02    a4 -2.952557198074e+01    a5  3.413024145539e+00
a6 -2.405520814365e-01    a7  9.465181268476e-03    a8 -1.594325350979e-04
    Emin  1.43e+01   s(Emin)  1.00e-19   smax  7.15e-17   Error  1.11e-01
     Eth 13.6
     Mcross 9.1093826E-31


    aBorn,1= 1.53753e-16  nBorn,1= 8.61942e-01

    Emin  1.43e+01    s(Emin)  1.00e-19    Error  8.84e-01


    aBorn,2= 2.34616e-16  nBorn,2= 1.02119e+00

    Emin  1.43e+01    s(Emin)  1.00e-19    Error  5.01e-01
```

Reaction 2.1.6 $e + H(2s) \rightarrow e + H^+ + e$

```
a0 -1.323829114032e+02    a1  1.651239202115e+02    a2 -1.140121644712e+02
a3  4.230980472378e+01    a4 -9.296147227462e+00    a5  1.243911606504e+00
a6 -9.947722917370e-02    a7  4.367280737208e-03    a8 -8.092922245217e-05
    Emin  3.58e+00   s(Emin)  1.00e-19    smax  8.30e-16   Error  2.93e-01
     Eth 3.4
     Mcross 9.1093826E-31


    aBorn,1= 1.87046e-15  nBorn,1= 8.93875e-01

    Emin  3.58e+00    s(Emin)  1.00e-19    Error  7.51e-01



    aBorn,2= 2.57396e-15  nBorn,2= 1.01823e+00

    Emin  3.58e+00    s(Emin)  1.00e-19    Error  7.62e-01
```

Reaction 2.1.7 $e + H(n = 3) \rightarrow e + H^+ + e$

```
a0 -5.210905240460e+01    a1  4.541756148570e+01    a2 -3.994563990284e+01
a3  1.774554892576e+01    a4 -4.490170942194e+00    a5  6.717581547587e-01
a6 -5.875054514668e-02    a7  2.774373803025e-03    a8 -5.460792035331e-05
   Emin  1.55e+00   s(Emin)  1.00e-19   smax  5.76e-15   Error  5.89e-01
   Eth  1.5111
   Mcross 9.1093826E-31

   A more extensive analytic formula for all n > 2 is given in the text.
```

Reaction 2.2.1a $e + H_2(v = 0) \rightarrow e + H_2(v = 1)$

```
a0 -4.063959689566e+01    a1  1.636189705461e+01    a2 -3.342841685940e+01
a3  3.479549344686e+01    a4 -2.082704506646e+01    a5  7.301916128338e+00
a6 -1.477679988432e+00    a7  1.596127782326e-01    a8 -7.118499383243e-03
    Emin  8.95e-01   s(Emin)  1.00e-19   smax  4.79e-17   Error  3.82e-02
    Eth  0.5
    Mcross 9.1093826E-31
```

Reaction 2.2.1b $e + H_2(v = 0) \rightarrow e + H_2(v = 2)$

```
a0 -4.401593275820e+01     a1 -5.428337849062e+00     a2  2.781894563620e+01
a3 -3.059898206514e+01     a4  1.618430684710e+01     a5 -4.799622608369e+00
a6  8.162961901622e-01     a7 -7.445555845412e-02     a8  2.825425451852e-03
   Emin  1.38e+00   s(Emin)  1.00e-19   smax  8.61e-18   Error  7.10e-04
   Eth  1.0
   Emax 3.0E+02
   Mcross 9.1093826E-31

   Not valid for E < 1.1 or E > 300 eV.
```

Reaction 2.2.2 $e + H_2(X^1\Sigma_g^+) \to e + H_2(B^1\Sigma_u^+ 2p\sigma)$

```
a0 -4.293519441750e+02    a1  5.112210939087e+02    a2 -2.848127939455e+02
a3  8.831033879636e+01    a4 -1.665959177505e+01    a5  1.957960915869e+00
a6 -1.401282416514e-01    a7  5.591134833381e-03    a8 -9.537010324465e-05
    Emin  1.25e+01   s(Emin)  1.00e-19   smax  2.94e-17   Error  1.04e-01
    Eth  11.37
    Mcross 9.1093826E-31


    aBorn,1= 1.10665e-17  nBorn,1= 8.08245e-01

    Emin  1.38e+00    s(Emin)  1.00e-19    Error  1.52e+00


    aBorn,2= 4.71632e-17  nBorn,2= 1.37760e+00

    Emin  1.38e+00    s(Emin)  1.00e-19    Error  1.86e+00
```

Reaction 2.2.3 $e + H_2(X^1\Sigma_g^+) \rightarrow e + H_2(C^1\Pi_u 2p\pi)$

```
a0 -8.194268487911e+02     a1  9.870509999996e+02     a2 -5.309554319119e+02
a3  1.591702330888e+02     a4 -2.912103674573e+01     a5  3.332102780153e+00
a6 -2.330596118299e-01     a7  9.119178195801e-03     a8 -1.529895022672e-04
    Emin  1.58e+01   s(Emin)  1.00e-19   smax  3.80e-17   Error  1.18e-01
     Eth  11.7
     Mcross 9.1093826E-31


    aBorn,1= 6.74162e-17  nBorn,1= 8.01562e-01

    Emin  1.58e+01     s(Emin)  1.00e-19     Error  4.64e-01


    aBorn,2= 1.15646e-16  nBorn,2= 1.00587e+00

    Emin  1.58e+01     s(Emin)  1.00e-19     Error  1.15e+00
```

Reaction 2.2.4 $e + H_2(X^1\Sigma_g^+) \rightarrow e + H_2(E, F^1\Sigma_g^+)$

```
a0 -1.285300373043e+03    a1  1.791037396609e+03    a2 -1.109180722424e+03
a3  3.858482892334e+02    a4 -8.239751178005e+01    a5  1.105885445011e+01
a6 -9.113361334764e-01    a7  4.218997111854e-02    a8 -8.407951365268e-04
    Emin  1.65e+01   s(Emin)  1.00e-19   smax  4.77e-18   Error  2.51e-02
    Eth  12.2
    Mcross 9.1093826E-31
```

Reaction 2.2.5 $e + H_2(X^1\Sigma_g^+) \rightarrow e + H_2(b^3\Sigma_u^+, a^3\Sigma_g^+, c^3\Pi_u) \rightarrow e + H(1s) + H(1s)$

```
a0 -1.019870329452e+05    a1  2.252601430192e+05    a2 -2.158143676206e+05
a3  1.171042848075e+05    a4 -3.936494849617e+04    a5  8.395340835067e+03
a6 -1.109486871647e+03    a7  8.308421522823e+01    a8 -2.699781210407e+00
   Emin  1.08e+01   s(Emin)  1.00e-19   smax  8.84e-17   Error  5.39e-01
   Eth  8.5
   Mcross 9.1093826E-31
```

Reaction 2.2.6 $e + H_2(X^1\Sigma_g^+) \rightarrow e + H_2(1s\sigma_g, nl\lambda|^1\Lambda) \rightarrow e + H(1s) + H(2s)$

```
a0 -1.157041752123e+03     a1  1.501936271844e+03     a2 -8.611938700508e+02
a3  2.754926257351e+02     a4 -5.380465012731e+01     a5  6.573972423327e+00
a6 -4.912318139657e-01     a7  2.054926773000e-02     a8 -3.689035889972e-04
    Emin  1.65e+01   s(Emin)  1.00e-19   smax  1.64e-17   Error  1.12e-01
     Eth  14.9
      Mcross 9.1093826E-31

    aBorn,1= 3.90596e-17  nBorn,1= 9.29053e-01

    Emin  1.65e+01    s(Emin)  1.00e-19    Error  3.41e-01



    aBorn,2= 4.72962e-17  nBorn,2= 1.00759e+00

    Emin  1.65e+01    s(Emin)  1.00e-19    Error  2.72e-01
```

Reaction 2.2.7 $e + H_2(X^1\Sigma_g^+) \rightarrow e + H_2(2p\sigma_u, nl\lambda|Q_2^1\Pi_u) \rightarrow e + H(2p) + H(2s)$

```
a0 -2.057786420733e+04     a1  2.950256031919e+04     a2 -1.831052572622e+04
a3  6.414232477826e+03     a4 -1.387462186158e+03     a5  1.898300554210e+02
a6 -1.604843781908e+01     a7  7.667894395976e-01     a8 -1.585946768503e-02
    Emin  2.88e+01   s(Emin)  1.00e-19   smax  3.19e-18   Error  1.73e-02
     Eth  23.0
     Mcross 9.1093826E-31


    aBorn,1= 1.14191e-17  nBorn,1= 1.29810e+00

    Emin  2.88e+01    s(Emin)  1.00e-19    Error  9.63e-02


    aBorn,2= 1.05756e-17  nBorn,2= 1.25115e+00

    Emin  2.88e+01    s(Emin)  1.00e-19    Error  7.37e-02
```

Reaction 2.2.8 $e + H_2(X^1\Sigma_g^+) \rightarrow e + H_2(2p\sigma_u; n = 3) \rightarrow e + H(1s) + H(n = 3)$

```
a0 -3.287645365957e+03    a1  5.014406168806e+03    a2 -3.348881857725e+03
a3  1.262084567851e+03    a4 -2.934110683163e+02    a5  4.308239201745e+01
a6 -3.902409019508e+00    a7  1.994401403354e-01    a8 -4.405117731369e-03
   Emin  1.90e+01   s(Emin)  1.00e-19   smax  1.79e-18   Error  5.54e-03
    Eth  19.0
    Mcross 9.1093826E-31


   aBorn,1= 4.23517e-18  nBorn,1= 9.45107e-01

   Emin  1.90e+01    s(Emin)  1.00e-19    Error  1.02e-01



   aBorn,2= 6.12160e-18  nBorn,2= 1.10089e+00

   Emin  1.90e+01    s(Emin)  1.00e-19    Error  1.17e-01
```

Reaction 2.2.9 $e + H_2(X^1\Sigma_g^+) \rightarrow e + H_2^+(v) + e$

```
a0 -1.387609624141e+03    a1  1.699141305899e+03    a2 -9.108411850551e+02
a3  2.719534700245e+02    a4 -4.949789923430e+01    a5  5.628121884179e+00
a6 -3.908551117391e-01    a7  1.517692897197e-02    a8 -2.526183660091e-04
    Emin  1.87e+01   s(Emin)  1.00e-19   smax  1.11e-16   Error  1.94e-01
     Eth  15.4
     Mcross 9.1093826E-31


    aBorn,2= 3.58910e-16  nBorn,2= 1.01326e+00

    Emin  1.87e+01    s(Emin)  1.00e-19    Error  7.46e-01
```

Reaction 2.2.10 $e + H_2(X^1\Sigma_g^+) \rightarrow e + [H_2^+(\Sigma_g, \Sigma_u) + e] \rightarrow e + H^+ + H(1s) + e$

```
a0 -3.833822745947e+03     a1  5.694871055047e+03     a2 -3.683040395270e+03
a3  1.338526896657e+03     a4 -2.988408134179e+02     a5  4.197687137005e+01
a6 -3.624797562843e+00     a7  1.760638946986e-01     a8 -3.685905968490e-03
    Emin  2.11e+01   s(Emin)  1.00e-19   smax  5.75e-18   Error  2.17e-02


    Eth  18.0
    Mcross 9.1093826E-31
```

Reaction 2.2.11 $e + H_2^+(v) \to e + H^+ + H^+ + e, (v = 0 \ldots 9)$

```
a0 -7.175166253949e+02    a1  8.527284836302e+02    a2 -4.615650223553e+02
a3  1.402626692658e+02    a4 -2.611719315325e+01    a5  3.047273508837e+00
a6 -2.175218173132e-01    a7  8.689141623830e-03    a8 -1.488365280435e-04
    Emin  1.79e+01   s(Emin)  1.00e-19   smax  1.74e-17   Error  2.37e-02
    Eth  14.7
    Mcross 9.1093826E-31
```

Reaction 2.2.12 $e + H_2^+(v) \rightarrow e + H_2^+(2p\sigma_u) \rightarrow e + H^+ + H(1s), (v = 0 \dots 9)$

```
a0 -8.734971153234e+01     a1  1.018145800541e+02     a2 -7.763161913681e+01
a3  3.095286370113e+01     a4 -7.178129093553e+00     a5  1.001376002948e+00
a6 -8.276605899370e-02     a7  3.731813613454e-03     a8 -7.068946002778e-05
    Emin  2.70e+00   s(Emin)  1.00e-19   smax  1.01e-15   Error  6.04e-01
    Eth   2.4
    Mcross 9.1093826E-31
```

Reaction 2.2.13 $e + H_2^+(v) \rightarrow e + H_2^+(2p\pi_u) \rightarrow e + H^+ + H(n = 2), (v = 0 \ldots 9)$

```
a0 -1.261570316476e+03    a1  1.600546555479e+03    a2 -8.875792683132e+02
a3  2.730297710707e+02    a4 -5.103300875879e+01    a5  5.943996543464e+00
a6 -4.220104525394e-01    a7  1.672668012176e-02    a8 -2.838410215959e-04
   Emin  1.44e+01   s(Emin)   1.00e-19   smax 5.06e-17   Error 4.05e-02
    Eth   14.0
    Mcross 9.1093826E-31

   aBorn,1= 1.35488e-16  nBorn,1= 1.04143e+00

   Emin  1.44e+01   s(Emin)   1.00e-19  Error 4.20e-01



   aBorn,2= 1.38216e-16  nBorn,1= 1.04143e+00

   Emin  1.44e+01   s(Emin)   1.00e-19  Error 4.20e-01
```

Reaction 2.2.14 $e + H_2^+(v) \rightarrow H(1s) + H(n), (v = 0\ldots9, n \geq 2)$

```
a0 -3.479249259777e+01    a1 -1.103564847459e+00    a2 -1.817595501089e-13
a3  1.913718292296e-13    a4 -8.296778314084e-15    a5 -3.945007662626e-14
a6  1.480375530361e-14    a7 -2.096231848232e-15    a8  1.067937159826e-16
   Emin  1.00e-01   s(Emin)  9.85e-15    smax  9.85e-15   Error  1.74e-25
   Eth  0.0
   Mcross 9.1093826E-31
```

Reaction 2.2.15 $e + H_3^+ \rightarrow H + H + H$ **or** $\rightarrow H_2(v > 5) + H(n = 2)$

```
a0 -3.497403537065e+01     a1 -9.050073352581e-01     a2 -6.875577121635e-13
a3  1.212286779103e-13     a4  1.320680420105e-13     a5 -6.368710212825e-14
a6  1.136465595184e-14     a7 -9.184755712215e-16     a8  2.814743077081e-17
   Emin  1.00e-01   s(Emin)  5.20e-15   smax  5.20e-15   Error  1.12e-24
   Eth  0.0
   Mcross 9.1093826E-31
```

Reaction 2.2.16 $e + H_3^+ \rightarrow e + H^+ + 2H$

```
a0 -1.180802127731e+03    a1  1.469242595864e+03    a2 -8.010903182743e+02
a3  2.427879961198e+02    a4 -4.477455604823e+01    a5  5.150533546464e+00
a6 -3.613881605497e-01    a7  1.416168832727e-02    a8 -2.376509206426e-04
    Emin  1.65e+01   s(Emin)  1.00e-19   smax  7.36e-16   Error  5.22e-01
     Eth  14.0
     Mcross 9.1093826E-31


    aBorn,1= 1.38785e-15  nBorn,1= 7.41773e-01

    Emin  1.65e+01    s(Emin)  1.00e-19    Error  9.17e-01



    aBorn,2= 1.75195e-15  nBorn,2= 8.18483e-01

    Emin  1.65e+01    s(Emin)  1.00e-19    Error  9.58e-01
```

Reaction 2.2.17 $e + H_2(v \geq 4) \rightarrow (H_2^-) \rightarrow H^- + H$

```
a0 -3.533068072400e+01    a1 -1.305146001161e+00    a2 -5.402400752335e-01
a3 -1.929128735755e-01    a4 -3.998229471894e-01    a5 -2.442412657121e-01
a6  7.577527589687e-03    a7  4.268454076562e-02    a8  9.029646852927e-03
     Emin  1.00e-01   s(Emin)  8.94e-16   smax  1.03e-15   Error  6.40e-04


 Eth  0.1
 Emax 5.0E+00
 Mcross 9.1093826E-31


        Not valid for E > 5 eV.
```

Reaction 2.3.1a $e + He(1s^2 1S) \rightarrow e + He(1s^1 2p^1 1P)$

```
a0 -1.035570462579e+03    a1  1.215931704603e+03    a2 -6.359454827397e+02
a3  1.861198276080e+02    a4 -3.333317507125e+01    a5  3.741542708002e+00
a6 -2.572201220135e-01    a7  9.910988972511e-03    a8 -1.640390854438e-04
    Emin  2.18e+01   s(Emin)  1.00e-19   smax  9.79e-18   Error  3.00e-02
     Eth  21.217
     Mcross 9.1093826E-31


    aBorn,1= 1.92235e-17  nBorn,1= 7.83233e-01

    Emin  2.18e+01    s(Emin)  1.00e-19    Error  1.78e-01



    aBorn,2= 2.57557e-17  nBorn,2= 8.83509e-01

    Emin  2.18e+01    s(Emin)  1.00e-19    Error  1.03e-01
```

A more extensive analytic formula for transition to (1snl|1P) is given

Reaction 2.3.1b $e + He(1s^2 1S) \rightarrow e + He(1s^1 3p^1 1P)$

```
a0 -2.634840114580e+03    a1  3.509384108909e+03    a2 -2.045577442205e+03
a3  6.707125167844e+02    a4 -1.352829871406e+02    a5  1.719155337173e+01
a6 -1.344786986986e+00    a7  5.923822227197e-02    a8 -1.125813888453e-03
    Emin  2.50e+01    s(Emin)  1.00e-19    smax  2.35e-18    Error  1.62e-02
     Eth  23.086
     Mcross 9.1093826E-31


    aBorn,1= 4.99196e-18  nBorn,1= 8.11369e-01

    Emin  2.50e+01     s(Emin)  1.00e-19     Error  1.08e-01



    aBorn,2= 6.56234e-18  nBorn,2= 9.07863e-01

    Emin  2.50e+01     s(Emin)  1.00e-19     Error  9.15e-02

        A more extensive analytic formula for transition to (1snl|1P) is given
```

Reaction 2.3.2 $e + He(1s^2 1S) \rightarrow e + He(1s^1 2s^1 1S)$

```
a0 -1.340229681600e+04    a1  2.117221297932e+04    a2 -1.450345815377e+04
a3  5.610930330567e+03    a4 -1.341090060181e+03    a5  2.028369172741e+02
a6 -1.896426422663e+01    a7  1.002440728214e+00    a8 -2.294532805220e-02
    Emin  2.17e+01   s(Emin)  1.00e-19   smax  2.72e-18   Error  1.23e-01
     Eth  20.614
     Mcross 9.1093826E-31


    aBorn,1= 1.16605e-17  nBorn,1= 1.52195e+00

    Emin  2.17e+01    s(Emin)  1.00e-19    Error  2.30e-01


    aBorn,2= 1.01757e-17  nBorn,2= 1.42944e+00

    Emin  2.17e+01    s(Emin)  1.00e-19    Error  1.68e-01

    An analytic formula for s for transition to this and
    other nl|1L states is given in the text.
```

Reaction 2.3.3a $e + He(1s^2 1S) \rightarrow e + He(1s^1 2s^1 3S)$

```
a0 -5.203190079746e+07     a1  1.114126390950e+08     a2 -1.041333130230e+08
a3  5.549110256155e+07     a4 -1.843990770358e+07     a5  3.912927216807e+06
a6 -5.177965474575e+05     a7  3.906790796143e+04     a8 -1.286793467718e+03
    Emin  2.17e+01   s(Emin)  1.00e-19   smax  3.08e-18   Error  3.46e-01
     Eth  19.818
     Mcross 9.1093826E-31


    This fit is not recommended.




    aBorn,1= 2.57061e-17  nBorn,1= 4.07784e+00
```

```
                    17
```

```
    Emin  2.17e+01    s(Emin)  1.00e-19    Error  6.90e-01



    aBorn,2= 4.23197e-17  nBorn,2= 5.18074e+00

    Emin  2.17e+01    s(Emin)  1.00e-19    Error  1.32e+00

    An analytic formula for s for transition to this and other nl|3L states is g
```

Reaction 2.3.3b $e + He(1s^2 1S) \rightarrow e + He(1s^1 2p^1 3P)$

```
a0 -4.793169045161e+06    a1  9.882446793715e+06    a2 -8.888886013658e+06
a3  4.555681859005e+06    a4 -1.455138589620e+06    a5  2.966235458426e+05
a6 -3.768463275632e+04    a7  2.728166188657e+03    a8 -8.616903005294e+01
   Emin  2.17e+01   s(Emin)  1.00e-19   smax  2.89e-18   Error  1.70e-01
    Eth  20.936
    Mcross 9.1093826E-31


   aBorn,1= 1.87693e-17  nBorn,1= 2.84919e+00

   Emin  2.17e+01    s(Emin)  1.00e-19    Error  6.02e-01



   aBorn,2= 2.73848e-17  nBorn,2= 3.37724e+00

   Emin  2.17e+01    s(Emin)  1.00e-19    Error  6.43e-01

   An analytic formula for s for transition to this and other nl|3L states is g
```

Reaction 2.3.3c $e + He(1s^2 1S) \rightarrow e + He(1s^1 3s^1 3S)$

```
a0 -4.788014731830e+08     a1  1.022518413821e+09     a2 -9.540217735841e+08
a3  5.079285422983e+08     a4 -1.687812725605e+08     a5  3.584473999432e+07
a6 -4.751258664024e+06     a7  3.593838762943e+05     a8 -1.187665518764e+04
   Emin  2.50e+01   s(Emin)  1.00e-19   smax  8.49e-19   Error  9.16e-02
    Eth  22.717
    Mcross 9.1093826E-31


   This fit is not recommended.



   aBorn,1= 6.73891e-18  nBorn,1= 3.38203e+00

   Emin  2.50e+01    s(Emin)  1.00e-19    Error  2.57e-01



   aBorn,2= 8.73337e-18  nBorn,2= 3.82261e+00

   Emin  2.50e+01    s(Emin)  1.00e-19    Error  3.10e-01

   An analytic formula for s for transition to this and other (nl|3L) states is
```

Reaction 2.3.3d $e + He(1s^2 1S) \rightarrow e + He(1s^1 3p^1 3P)$

```
a0 -3.936065650971e+07     a1  8.116028811410e+07     a2 -7.306391247418e+07
a3  3.750824079156e+07     a4 -1.200982299576e+07     a5  2.456048818627e+06
a6 -3.132802195794e+05     a7  2.278831373521e+04     a8 -7.237641204949e+02
    Emin  2.50e+01   s(Emin)  1.00e-19   smax  1.62e-18   Error  1.85e-01
     Eth  23.006
     Mcross 9.1093826E-31


    This fit is not recommended.



    aBorn,1= 1.32373e-17  nBorn,1= 3.41922e+00

    Emin  2.50e+01    s(Emin)  1.00e-19    Error  3.91e-01



    aBorn,2= 1.67554e-17  nBorn,2= 3.81681e+00

    Emin  2.50e+01    s(Emin)  1.00e-19    Error  4.46e-01

An analytic formula for s for transition to this and other nl|3L states is g
```

Reaction 2.3.4a $e + He(1s^1 2s^1 3S) \rightarrow e + He(1s^1 2s^1 1S)$

```
a0 -3.767284614946e+01    a1  1.242374777500e+01    a2 -1.733730671197e+01
a3  1.065193441154e+01    a4 -3.545021903004e+00    a5  6.760042577381e-01
a6 -7.381907066438e-02    a7  4.291139737209e-03    a8 -1.029193004464e-04
    Emin  8.96e-01   s(Emin)  1.00e-19   smax  6.14e-16   Error  4.84e-01
     Eth 0.796
     Mcross 9.1093826E-31


    aBorn,1= 2.18988e-15  nBorn,1= 1.34842e+00

    Emin  8.96e-01    s(Emin)  1.00e-19    Error  1.14e+00


    aBorn,2= 2.23252e-15  nBorn,2= 1.36293e+00

    Emin  8.96e-01    s(Emin)  1.00e-19    Error  1.23e+00

    An analytic formula for s is given in the text.
```

Reaction 2.3.4b $e + He(1s^1 2s^1 3S) \rightarrow e + He(1s^1 2p^1 1P)$

```
a0 -5.319933965992e+01     a1  4.744554023140e+01     a2 -4.844985223676e+01
a3  2.500468700294e+01     a4 -7.374551620285e+00     a5  1.290076459738e+00
a6 -1.322635763531e-01     a7  7.335813534997e-03     a8 -1.698321860588e-04
    Emin  1.56e+00   s(Emin)  1.00e-19    smax  3.07e-16   Error  4.17e-01
     Eth  1.399
     Mcross 9.1093826E-31

    aBorn,1= 1.10118e-15  nBorn,1= 1.35219e+00

    Emin  1.56e+00    s(Emin)  1.00e-19    Error  9.62e-01



    aBorn,2= 1.11692e-15  nBorn,2= 1.36330e+00

    Emin  1.56e+00    s(Emin)  1.00e-19    Error  1.02e+00

    An analytic formula for s is given in the text.
```

Reaction 2.3.4c $e + He(1s^1 2s^1 1S) \rightarrow e + He(1s^1 2p^1 3P)$

```
a0 -3.317860766309e+01     a1 -5.306038723803e-01     a2 -2.695255954243e+00
a3  2.632267872941e+00     a4 -1.099156687924e+00     a5  2.377305480208e-01
a6 -2.790496421908e-02     a7  1.688187005669e-03     a8 -4.125774276276e-05
   Emin  3.90e-01   s(Emin)  1.00e-19   smax  2.41e-15   Error  6.04e-01
    Eth  0.349
    Mcross 9.1093826E-31

   aBorn,1= 8.65146e-15  nBorn,1= 1.35184e+00

   Emin  3.90e-01    s(Emin)  1.00e-19    Error  1.57e+00


   aBorn,2= 8.78111e-15  nBorn,2= 1.36352e+00

   Emin  3.90e-01    s(Emin)  1.00e-19    Error  1.67e+00

   An analytic formula for s is given in the text.
```

Reaction 2.3.4d $e + He(1s^1 2p^1 3P) \rightarrow e + He(1s^1 2p^1 1P)$

```
a0 -3.550958147337e+01    a1 -2.148096190520e+00    a2  3.301727694779e-01
a3  1.489817873888e+00    a4 -1.281057689191e+00    a5  4.334863480750e-01
a6 -7.269238026113e-02    a7  6.015845378859e-03    a8 -1.962092219181e-04
    Emin  2.62e-01   s(Emin)  1.00e-19    smax  4.39e-16   Error  2.60e-01
     Eth  0.254
     Mcross  9.1093826E-31

    aBorn,1= 1.62992e-15  nBorn,1= 1.37522e+00

    Emin  2.62e-01    s(Emin)  1.00e-19    Error  1.37e+00



    aBorn,2= 1.59075e-15  nBorn,2= 1.36145e+00

    Emin  2.62e-01    s(Emin)  1.00e-19    Error  1.29e+00

    An analytic formula for s is given in the text.
```

Reaction 2.3.5a $e + He(1s^1 2s^1 1S) \rightarrow e + He(1s^1 2p^1 1P)$

```
a0 -3.325138159927e+01    a1  6.965673711167e+00    a2 -9.102522690164e+00
a3  5.178880611636e+00    a4 -1.570251042131e+00    a5  2.686249148763e-01
a6 -2.602715945748e-02    a7  1.332101581144e-03    a8 -2.797505613652e-05
    Emin  6.77e-01    s(Emin)  1.00e-19    smax  1.44e-14    Error  7.36e-01
     Eth  0.602
     Mcross 9.1093826E-31

    aBorn,2= 4.26417e-14  nBorn,2= 8.79209e-01

    Emin  6.87e-01    s(Emin)  1.00e-19    Error  1.56e+00

    An analytic formula for s is given in the text.
```

Reaction 2.3.5b $e + He(1s^12s^13S) \rightarrow e + He(1s^12p^13P)$

```
a0 -4.190861763587e+01    a1  2.589117787777e+01    a2 -2.543442341964e+01
a3  1.224262304780e+01    a4 -3.287256784979e+00    a5  5.142698379467e-01
a6 -4.655881399807e-02    a7  2.259789810984e-03    a8 -4.548031395449e-05
    Emin  1.15e+00   s(Emin)  1.00e-19   smax  7.52e-15   Error  5.53e-01
     Eth  1.145
     Mcross 9.1093826E-31

    An analytic formula for s is given in the text.
```

Reaction 2.3.6a $e + He(1s^1 2s^1 1S) \rightarrow e + He(1s^1 3p^1 1P)$

```
a0 -7.945340796384e+01    a1  7.952123040074e+01    a2 -5.901873964305e+01
a3  2.336041841867e+01    a4 -5.418217641105e+00    a5  7.574234290606e-01
a6 -6.273863245111e-02    a7  2.833779484304e-03    a8 -5.374700574749e-05
    Emin  2.72e+00   s(Emin)  1.00e-19    smax  2.68e-16    Error  2.62e-01
     Eth  2.472
     Mcross 9.1093826E-31
```

An analytic formula for s for transition to this and other np|1P states is g

Reaction 2.3.6b $e + He(1s^1 2s^1 3S) \rightarrow e + He(1s^1 3p^1 3P)$

```
a0 -8.720058224600e+01    a1  8.669127167337e+01    a2 -6.125632963824e+01
a3  2.323452528088e+01    a4 -5.206449941296e+00    a5  7.082705099324e-01
a6 -5.741257577852e-02    a7  2.548456501150e-03    a8 -4.765136776607e-05
   Emin  3.14e+00   s(Emin)  1.00e-19   smax  7.66e-17   Error  1.61e-01
    Eth  3.188
    Mcross 9.1093826E-31

   aBorn,2= 1.95245e-16  nBorn,2= 8.39781e-01

   Emin  3.14e+00    s(Emin)  1.00e-19    Error  5.55e-01

   An analytic formula for s for transition to this and other np|3P states is g
```

Reaction 2.3.7a $e + He(1s^1 2p^1 1P) \rightarrow e + He(1s^1 3d^1 1D)$

```
a0 -6.380148486246e+01    a1  6.207791717177e+01    a2 -5.009739526736e+01
a3  2.108909461860e+01    a4 -5.130498771379e+00    a5  7.448846309387e-01
a6 -6.362451646494e-02    a7  2.947637642636e-03    a8 -5.710909679690e-05
    Emin  2.05e+00   s(Emin)  1.00e-19   smax  2.73e-15   Error  6.02e-01
     Eth  1.856
     Mcross 9.1093826E-31

    aBorn,2= 7.85272e-15   nBorn,2= 8.59826e-01

    Emin  2.05e+00    s(Emin)  1.00e-19    Error  1.21e+00

    An analytic formula for s is given in the text.
```

Reaction 2.3.7b $e + He(1s^12p^13P) \rightarrow e + He(1s^13d^13D)$

```
a0 -7.355382422374e+01    a1  7.757733939986e+01    a2 -6.021028662561e+01
a3  2.456897613696e+01    a4 -5.830267812736e+00    a5  8.299661528547e-01
a6 -6.978241370066e-02    a7  3.191768833116e-03    a8 -6.118911403921e-05
    Emin  2.35e+00   s(Emin)  1.00e-19   smax  2.01e-15   Error  5.79e-01
     Eth  2.109
     Mcross 9.1093826E-31

    aBorn,2= 5.69936e-15  nBorn,2= 8.78100e-01

    Emin  2.35e+00    s(Emin)  1.00e-19    Error  1.12e+00

    An analytic formula for s is given in the text.
```

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

```
a0 -1.864515653677e+03    a1  2.200039160012e+03    a2 -1.13502043008e+03
a3  3.275368136458e+02    a4 -5.782773248653e+01    a5  6.398861014578e+00
a6 -4.337092983841e-01    a7  1.647885719077e-02    a8 -2.690038700620e-04
   Emin  2.50e+01   s(Emin)  1.00e-19   smax  3.75e-17   Error  5.25e-02
    Eth  24.588
     Mcross 9.1093826E-31

    aBorn,2= 2.66551e-15  nBorn,2= 1.02404e+00

    Emin  5.45e+00    s(Emin)  1.00e-19    Error  8.86e-01
```

Reaction 2.3.10a $e + He(1s^1 2s^1 1S) \rightarrow e + He^+(1s) + e$

```
a0 -1.588165958608e+02    a1  2.025096794972e+02    a2 -1.359677027927e+02
a3  4.931464639049e+01    a4 -1.062291122924e+01    a5  1.397102480527e+00
a6 -1.100503977820e-01    a7  4.767747225791e-03    a8 -8.732475392853e-05
    Emin  4.11e+00   s(Emin)  1.00e-19   smax  8.05e-16   Error  4.12e-01
     Eth 3.973
     Mcross 9.1093826E-31

    aBorn,1= 1.76528e-15  nBorn,1= 8.45023e-01

    Emin  4.11e+00    s(Emin)  1.00e-19    Error  8.55e-01



    aBorn,2= 2.22317e-15  nBorn,2= 9.31407e-01

    Emin  4.11e+00    s(Emin)  1.00e-19    Error  6.68e-01

    An analytic formula for s is given in the text.
```

Reaction 2.3.10b $e + He(1s^1 2p^1 1P) \rightarrow e + He^+(1s) + e$

```
a0 -1.307379836148e+02    a1  1.632174408167e+02    a2 -1.129614525216e+02
a3  4.199589716864e+01    a4 -9.233643615441e+00    a5  1.235205673096e+00
a6 -9.868890735893e-02    a7  4.326993699443e-03    a8 -8.006280122436e-05
   Emin  3.58e+00   s(Emin)  1.00e-19   smax  1.14e-15   Error  3.47e-01
    Eth  3.371
    Mcross 9.1093826E-31

   aBorn,1= 2.44771e-15  nBorn,1= 8.44077e-01

   Emin  3.58e+00    s(Emin)  1.00e-19    Error  1.02e+00



   aBorn,2= 3.10641e-15  nBorn,2= 9.33260e-01

   Emin  3.58e+00    s(Emin)  1.00e-19    Error  8.13e-01

   An analytic formula for s is given in the text.
```

Reaction 2.3.10c $e + He(1s^12s^13S) \rightarrow e + He^+(1s) + e$

```
a0 -2.339247199323e+02    a1  3.108263537901e+02    a2 -2.004035199806e+02
a3  7.013664348852e+01     a4 -1.464607997646e+01    a5  1.875537708304e+00
a6 -1.443996329241e-01     a7  6.134194672052e-03    a8 -1.104612714554e-04
    Emin  5.45e+00   s(Emin)  1.00e-19   smax  9.37e-16   Error  5.07e-01
     Eth  4.769
     Mcross 9.1093826E-31

    aBorn,1= 2.44417e-15  nBorn,1= 9.85122e-01

    Emin  5.45e+00    s(Emin)  1.00e-19    Error  8.95e-01



    aBorn,2= 2.66551e-15  nBorn,2= 1.02404e+00

    Emin  5.45e+00    s(Emin)  1.00e-19    Error  8.86e-01

    An analytic formula for s is given in the text.
```

Reaction 2.3.10d $e + He(1s^1 2p^1 3P) \rightarrow e + He^+(1s) + e$

```
a0 -1.514909720389e+02    a1  1.917899987253e+02    a2 -1.291695579859e+02
a3  4.694225725512e+01    a4 -1.012623462168e+01    a5  1.333169086771e+00
a6 -1.050969063989e-01    a7  4.555911465700e-03    a8 -8.348482513741e-05
   Emin  4.14e+00   s(Emin)  1.00e-19   smax  9.85e-16   Error  4.18e-01
    Eth  3.625
    Mcross 9.1093826E-31

   aBorn,1= 2.09009e-15  nBorn,1= 8.39105e-01

   Emin  4.14e+00    s(Emin)  1.00e-19    Error  1.16e+00



   aBorn,2= 2.72108e-15  nBorn,2= 9.37659e-01

   Emin  4.14e+00    s(Emin)  1.00e-19    Error  9.35e-01

   An analytic formula for s is given in the text.
```

Reaction 2.3.12 $e + He(1s^1nl^1\{2S+1\}L) \rightarrow e + He^+(nl) + e$

```
a0 -2.149046249050e+04    a1  2.587653680045e+04    a2 -1.349616963351e+04
a3  3.975822003764e+03    a4 -7.236994991416e+02    a5  8.336945178595e+01
a6 -5.937449760897e+00    a7  2.390910599514e-01    a8 -4.169354418025e-03
    Emin  5.71e+01   s(Emin)  1.00e-19   smax  1.10e-17   Error  1.27e-01
     Eth 54.4
     Mcross 9.1093826E-31

    aBorn,1= 4.41503e-17  nBorn,1= 1.48779e+00

    Emin  5.71e+01    s(Emin)  1.00e-19    Error  3.50e-01



    aBorn,2= 4.20803e-17  nBorn,2= 1.45655e+00

    Emin  5.71e+01    s(Emin)  1.00e-19    Error  2.98e-01

    An analytic formula for s is given in the text.
```

Reaction 2.3.13 $e + He^+(1s) \rightarrow He(1s^1 nl^1 \{2S+1\}L) + hv$
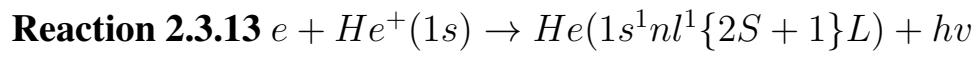
See text for analytic formulas.

Reaction 2.3.14 $e + He^+(1s) \rightarrow e + He^+(2p)$

```
a0 -4.215091396506e+03    a1  4.764415543278e+03    a2 -2.333572119719e+03
a3  6.411861251368e+02    a4 -1.081470970453e+02    a5  1.147267078966e+01
a6 -7.480739782521e-01    a7  2.743315170494e-02    a8 -4.335336435784e-04
    Emin  4.32e+01   s(Emin)  1.00e-19   smax  1.70e-17   Error  1.66e-01
     Eth  40.8
     Mcross 9.1093826E-31

    aBorn,1= 4.51430e-17  nBorn,1= 9.28386e-01

    Emin  4.32e+01    s(Emin)  1.00e-19    Error  1.96e-01



    aBorn,2= 4.19403e-17  nBorn,2= 8.97086e-01

    Emin  4.32e+01    s(Emin)  1.00e-19    Error  2.07e-01

    An analytic formula for s is given in the text.
```

Reaction 2.3.15 $e + He^+(1s) \rightarrow e + He^+(2s)$

```
a0 -4.363513156598e+04    a1  6.029422825525e+04    a2 -3.615014929003e+04
a3  1.227349742282e+04    a4 -2.581215777982e+03    a5  3.443868798585e+02
a6 -2.847203555533e+01    a7  1.333878006451e+00    a8 -2.711798666500e-02
    Emin  4.33e+01   s(Emin)  1.00e-19   smax  3.29e-18   Error  1.27e-01
     Eth 40.8
     Mcross 9.1093826E-31

    aBorn,1= 1.55600e-17  nBorn,1= 1.68750e+00

    Emin  4.33e+01    s(Emin)  1.00e-19    Error  3.88e-01



    aBorn,2= 1.31202e-17  nBorn,2= 1.55578e+00

    Emin  4.33e+01    s(Emin)  1.00e-19    Error  2.24e-01

    An analytic formula for s is given in the text.
```

Reaction 2.3.19 $e + He^+(1s) \rightarrow e + He^{++} + e$

```
a0 -6.397975729831e+03     a1  7.234572604639e+03     a2 -3.553226640490e+03
a3  9.838309068727e+02     a4 -1.679762955979e+02     a5  1.811299630401e+01
a6 -1.205027911620e+00     a7  4.524170259779e-02     a8 -7.342485039293e-04
    Emin  5.74e+01    s(Emin)  1.00e-19    smax  4.84e-18    Error  6.16e-02
     Eth  54.4
     Mcross 9.1093826E-31

    aBorn,1= 1.11824e-17  nBorn,1= 8.89614e-01
    Emin  5.74e+01     s(Emin)  1.00e-19     Error  1.88e-01

    aBorn,2= 1.35777e-17  nBorn,2= 9.66349e-01
    Emin  5.74e+01     s(Emin)  1.00e-19     Error  1.70e-01
```

Reaction 3.1.1 $p + H(1s) \rightarrow p + H(2p)$

```
   a0  1.498711267601e+03     a1 -1.883748471843e+03     a2  9.798674598591e+02
   a3 -2.840533664327e+02     a4  5.025004769585e+01     a5 -5.555355513127e+00
   a6  3.748565821577e-01     a7 -1.412032135035e-02     a8  2.274926861613e-04
  ar0 -1.196915681000E+02    ar1  1.572533096000E+01    ar2 -7.444839514000E-01
ELABMAX=  1.20000E+05 eV
      Emin  5.01e+01    s(Emin)  1.00e-19    smax  3.09e-17    Error  2.54e-03
      Eth  10.2
      Mcross 1.0E+00
      Not valid for E < 30 eV.
```

Reaction 3.1.2 $p + H(1s) \rightarrow p + H(2s)$

```
   a0  2.829875237564e+03    a1 -6.116917512897e+03    a2  3.922809899060e+03
   a3 -1.246183868116e+03    a4  2.285990672320e+02    a5 -2.546914306461e+01
   a6  1.706611319064e+00    a7 -6.339871351017e-02    a8  1.005024483671e-03
  ar0 -8.703695946000E+01   ar1  9.315160999000E+00   ar2 -4.461712204000E-01
ELABMAX=  8.00000E+04 eV
     Emin  6.00e+02   s(Emin)  1.00e-19   smax  9.15e-18   Error  1.95e-03
     Eth  10.2
     Mcross 1.0E+00
     Not valid for E < 400 eV.
```

Reaction 3.1.3 $p + H(2s) \rightarrow p + H(2p)$

```
a0 -7.074596259394e+01    a1  1.053200029604e+02    a2 -9.022427163873e+01
a3  3.938090329805e+01    a4 -9.804841353212e+00    a5  1.447083362703e+00
a6 -1.251503545319e-01    a7  5.855600339770e-03    a8 -1.143715732966e-04
    Emin  1.76e+00   s(Emin)  1.00e-19   smax  3.61e-11   Error  2.20e+00
    Eth    0.0
    Mcross 1.0E+00
    This fit is not recommended.  Use the analytic formula for s given in the
    text (Chibisov,1969).
```

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

```
   a0 -3.476414561951e+06     a1  2.961782930805e+06     a2 -1.100587541308e+06
   a3  2.329850579421e+05     a4 -3.073181275800e+04     a5  2.586508086362e+03
   a6 -1.356488358412e+02     a7  4.053120293214e+00     a8 -5.282803274226e-02
  al0 -7.104410581000E+01    al1  5.699173611000E+00    al2 -2.002816430000E-01
  ar0 -4.489505659000E+01    ar1  1.926156466000E+00    ar2 -1.091588336000E-01
ELABMIN=  2.00000E+03 eV
ELABMAX=  2.25000E+04 eV
      Emin  1.52e+03   s(Emin)  1.00e-19   smax  1.53e-16   Error  1.16e-02
      Eth   13.6
      Mcross 1.0E+00
      An analytic formula for s is given in the text.
```

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

```
   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 -3.294589600000E+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
```

Reaction 3.1.9 $p + H(1s) \rightarrow H(2p) + p$

```
   a0 -2.197571949935e+01    a1 -4.742502251260e+01    a2  3.628013140596e+01
   a3 -1.423003075866e+01    a4  3.273090240144e+00    a5 -4.557928912260e-01
   a6  3.773588347458e-02    a7 -1.707904867106e-03    a8  3.251203344615e-05
  ar0 -5.861021344000E+01   ar1  5.229876071000E+00   ar2 -3.222657437000E-01
ELABMAX=  6.50000E+04 eV
      Emin  1.90e+01   s(Emin)  1.00e-19   smax  2.97e-17   Error  3.29e-03
      Eth  10.2
      Mcross 1.0E+00
      Not valid for E < 10 eV.
```

Reaction 3.1.10 $p + H(1s) \rightarrow H(2s) + p$

```
a0 -1.327325087764e+04    a1  1.317576614520e+04    a2 -5.683932157858e+03
a3  1.386309780149e+03    a4 -2.089794561307e+02    a5  1.992976245274e+01
a6 -1.173800576157e+00    a7  3.902422810767e-02    a8 -5.606240339932e-04
   Emin  2.62e+02   s(Emin)  1.00e-19   smax  3.20e-17   Error  1.03e-03
   Eth  10.2
   Mcross 1.0E+00
```

Reaction 3.1.11a $p + H(n = 2) \rightarrow H(n = 2) + p$

```
a0 -3.160064085208e+01    a1 -1.063971267559e-01    a2  1.758632420708e-02
a3 -1.343032128288e-02    a4 -2.158483440621e-03    a5  2.016888852861e-03
a6 -3.768535435172e-04    a7  2.790447577960e-05    a8 -7.334007645451e-07
    Emin  1.00e-01   s(Emin)  2.50e-14   smax  2.50e-14   Error  9.57e-04
    Eth   0.0
    Mcross 1.0E+00
```

Reaction 3.1.11b $p + H(n=3) \rightarrow H(n=3) + p$

```
   a0 -3.007479360386e+01    a1 -1.033159234538e-01    a2 -5.813424077828e-03
   a3  3.520834872493e-03    a4 -1.498488713106e-04    a5 -4.614034275366e-04
   a6  1.226477420816e-04    a7 -1.180475816996e-05    a8  3.892872672032e-07
  ar0 -3.732339082000E+01   ar1  1.751199692000E+00   ar2 -1.246752946000E-01
ELABMAX=  2.00000E+04 eV
      Emin  1.00e-01   s(Emin)  1.07e-13   smax  1.07e-13   Error  2.04e-04
      Eth  0.0
      Mcross 1.0E+00
```

Reaction 3.2.1a $p + H_2(j = 0) \rightarrow p + H_2(j')(j' \geq 2)$

```
a0 -3.351219959966e+01    a1 -1.635225977493e-01    a2 -6.547019337483e-02
a3 -2.075062265158e-03    a4 -4.874756961659e-03    a5 -4.660550753949e-03
a6  2.817993595595e-04    a7  2.508118915628e-04    a8 -2.791892312099e-05
   Emin  1.00e-01   s(Emin)  3.23e-15   smax  3.23e-15   Error  8.28e-04
   Eth  0.05
   Mcross 1.0E+00
```

Reaction 3.2.1b $p + H_2(j = 1) \rightarrow p + H_2(j')(j' \geq 3)$

```
  a0 -3.393406708822e+01    a1 -1.040291133860e-01    a2 -2.235808125213e-02
  a3 -3.320456299848e-02    a4 -2.081525199080e-02    a5  1.897906681845e-03
  a6  1.657385114123e-03    a7 -3.410682026726e-04    a8  1.868694684385e-05
 ar0 -3.098471597000E+01   ar1 -1.645306432000E+00   ar2 -1.849934446000E-02
ELABMAX=  1.00000E+02 eV
      Emin  1.00e-01   s(Emin)  2.19e-15   smax  2.19e-15   Error  4.08e-04
      Eth  0.05
      Emax 2.0E+03
      Mcross 1.0E+00
      Not valid for E > 2000 eV.
```

Reaction 3.2.2 $p + H_2(v = 0) \rightarrow p + H_2(v > 0)$

```
a0 -4.048908822949e+01    a1  3.404344799771e+00    a2 -1.787578523150e+00
a3  1.394845302080e+00    a4 -5.775848321190e-01    a5  1.183902638008e-01
a6 -1.276577600153e-02    a7  6.983034334039e-04    a8 -1.531189559106e-05
    Emin  6.02e-01   s(Emin)  1.00e-19   smax  1.24e-15   Error  2.22e-02
    Eth  0.5
    Mcross 1.0E+00
```

Reaction 3.2.3 $p + H_2 \rightarrow H(1s) + H_2^+$

```
a0 -8.965985910240e+01    a1  1.057326823133e+02    a2 -8.364373343149e+01
a3  3.396650519934e+01    a4 -7.931279499027e+00    a5  1.110667708159e+00
a6 -9.213077375317e-02    a7  4.170940125995e-03    a8 -7.937779949951e-05
   Emin  2.72e+00   s(Emin)  1.00e-19   smax  1.03e-15   Error  2.46e-01
   Eth  1.83
   Mcross 1.0E+00
```

Reaction 3.2.4a $p + D_2 \rightarrow D^+ + HD(\textbf{or } H + D)$

```
    a0 -3.514598267631e+01    a1 -1.638772651981e+00    a2 -3.145916075331e-01
    a3  2.614991388325e-01    a4  2.453621020680e-03    a5 -2.572795334322e-02
    a6  5.870493979209e-03    a7 -5.239437578054e-04    a8  1.696795511874e-05
   ar0 -3.711342385000E+01   ar1 -4.917503936000E-01   ar2 -2.634191267000E-02
ELABMAX=  5.00000E+03 eV
      Emin  1.00e-01   s(Emin)  2.47e-15   smax  2.47e-15   Error  3.74e-02
      Eth  0.04
      Mcross 1.0E+00
```

Reaction 3.2.4b $p + D_2 \rightarrow D + HD^+$

```
a0 -3.793844403725e+03     a1  1.562579182141e+04     a2 -2.785112864175e+04
a3  2.778553560654e+04     a4 -1.698201826254e+04     a5  6.517141981195e+03
a6 -1.535237801461e+03     a7  2.031763319972e+02     a8 -1.157681794201e+01
    Emin  2.72e+00   s(Emin)  1.00e-19   smax  2.33e-17   Error  3.79e-01
    Eth  1.87
    Mcross 1.0E+00
```

Reaction 3.2.5 $p + H_2 \rightarrow p + H_2^+(v \leq 9) + e$

```
   a0  1.681920096116e+01    a1 -8.751084517093e+01    a2  5.024534132103e+01
   a3 -1.560982391827e+01    a4  2.931478842554e+00    a5 -3.421137108600e-01
   a6  2.429148918124e-02    a7 -9.612735627840e-04    a8  1.625014598463e-05
  ar0 -8.067212059000E+01   ar1  8.148943513000E+00   ar2 -3.720218589000E-01
ELABMAX=  1.00000E+05 eV
      Emin  4.36e+01   s(Emin)  1.00e-19   smax  1.19e-16   Error  2.51e-04
      Eth  15.41
      Mcross 1.0E+00

      Not valid for E < 30 eV.
```

Reaction 3.2.6 $p + H_2^+(v) \rightarrow p + H(1s) + H^+$

```
    a0 -5.100296089295e+01    a1 -7.618139241529e+00    a2  9.925169617893e+00
    a3 -4.105615029225e+00    a4  9.552023306824e-01    a5 -1.333440043499e-01
    a6  1.095282998853e-02    a7 -4.868705304669e-04    a8  9.034188174517e-06
   ar0 -3.914276949000E+01   ar1  1.668753218000E+00   ar2 -1.266187689000E-01
ELABMAX=  2.00000E+04 eV
      Emin  1.90e+01   s(Emin)  1.00e-19   smax  1.79e-15   Error  9.54e-04
      Eth  6.0
      Mcross 1.0E+00

      Not valid for E < 10 eV.
```

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

```
   a0 -4.883734637847e+01     a1 -7.864577316892e+00     a2  1.051518602966e+01
   a3 -4.731600895321e+00     a4  1.169830752883e+00     a5 -1.750344914778e-01
   a6  1.574934435872e-02     a7 -7.784849464356e-04     a8  1.611953487366e-05
  ar0 -6.990672456000E+01    ar1  7.540193740000E+00    ar2 -4.130236463000E-01
ELABMAX=  8.00000E+04 eV
      Emin  1.73e+01   s(Emin)  1.00e-19   smax  1.79e-16   Error  8.53e-04
      Eth  11.2
      Mcross 1.0E+00

      Not valid for E < 10 eV.
```

Reaction 3.3.2 $p + He \rightarrow p + He^+(1s) + e$

```
a0  4.624871765081e+03    a1 -4.745692532499e+03    a2  2.081508647511e+03
a3 -5.150987820537e+02    a4  7.872087768079e+01    a5 -7.611766573851e+00
a6  4.549589444268e-01    a7 -1.537511000653e-02    a8  2.250170199350e-04
   Emin 2.00e+02   s(Emin)  1.00e-19   smax  7.90e-17   Error 1.58e-04
   Eth  24.58
   Mcross 1.0E+00
```

Reaction 3.3.2n $p + He \rightarrow p + He^+(1s) + e$

revised version 2016, new fit. Better asymptotics

```
a0  4.195044321889E+02    a1 -3.711223698781E+02    a2  1.209086460598E+02
a3 -2.057942831375E+01    a4  1.924450806836E+00    a5 -8.969801627503E-02
a6  8.987363020501E-04    a7  7.919962773841E-05    a8 -2.232174653859E-06
   Eth  24.58
```

Reaction 3.3.3 $p + He(1s^2 1S) \rightarrow p + He(1s^1 2p^1 1P)$

```
a0 -1.817859864600e+03     a1  1.862928035048e+03     a2 -8.556804144556e+02
a3  2.228609435255e+02     a4 -3.580573984427e+01     a5  3.624830875484e+00
a6 -2.255912682713e-01     a7  7.890547281314e-03     a8 -1.188134235646e-04
   Emin  1.38e+02   s(Emin)  1.00e-19    smax  7.73e-17    Error  1.91e-05
   Eth  19.819
   Mcross 1.0E+00
```

A more extensive analytic formula is given in the text.

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

```
   a0 -4.488921384477e+01    a1  4.960932531533e+00    a2 -3.262576803403e-01
   a3 -2.936130156727e-01    a4  9.830719566023e-02    a5 -1.436613419090e-02
   a6  1.109137228313e-03    a7 -4.365781757124e-05    a8  6.819428318304e-07
  ar0 -1.490705981000E+02   ar1  2.580229694000E+01   ar2 -1.245093082000E+00
ELABMAX=  1.00000E+08 eV
      Emin  1.26e+00   s(Emin)  1.00e-19   smax  2.13e-15   Error  6.71e-04
      Eth  0.57
      Mcross 1.0E+00
```

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

revised version 2016, better asymptotics

```
   a0 -4.538332073827E+01    a1  7.170783239771E+00    a2 -3.297134523000E+00
   a3  1.487270508093E+00    a4 -4.585715075309E-01    a5  8.239364319341E-02
   a6 -8.248906041886E-03    a7  4.255246239358E-04    a8 -8.812571753203E-06
      Eth  0.57
```

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

```
   a0 -4.848650583528e+01      a1 -3.932691714215e+00      a2  7.523124596576e+00
   a3 -3.127572865354e+00      a4  6.776405973062e-01      a5 -8.713461726775e-02
   a6  6.707424051145e-03      a7 -2.863198766538e-04      a8  5.218187112892e-06
  ar0 -3.785059671000E+01     ar1  9.686976447000E-01     ar2 -5.936675659000E-02
ELABMAX=  1.00000E+05 eV
      Emin  6.06e+00    s(Emin)  1.00e-19    smax  1.85e-15    Error  7.93e-04
      Eth  1.369
      Mcross 1.0E+00

      Not valid for E < 5.
```

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

revised version, better asymptotics

```
   a0 -8.074074443551E+01      a1  5.555156807550E+01      a2 -3.738101128542E+01
   a3  1.501104472390E+01      a4 -3.618982367308E+00      a5  5.256859236453E-01
   a6 -4.485164096934E-02      a7  2.062076755012E-03      a8 -3.933113737905E-05
Eth  1.369
```

Reaction 3.3.7a $p + He(1s^1 2p^1 1P) \rightarrow H(2p) + He^+(1s)$

```
a0 -3.761174237974e+01    a1  3.151158037643e+00    a2 -9.333114666012e-01
a3  2.699732305042e-01    a4 -7.727620729277e-02    a5  1.499779990623e-02
a6 -1.669176505953e-03    a7  9.612733086019e-05    a8 -2.222038029912e-06
   Emin  3.02e-01   s(Emin)  1.00e-19   smax  1.07e-14   Error  6.71e-03
   Eth  0.0
   Mcross 1.0E+00
```

Reaction 3.3.7b $p + He(1s^1 2p^1 3P) \rightarrow H(2p) + He^+(1s)$

```
a0 -3.567086579938e+01    a1  2.166873578000e+00    a2 -8.322452040300e-01
a3  3.967778327802e-01    a4 -1.418439656872e-01    a5  2.883195206911e-02
a6 -3.206621198950e-03    a7  1.828199967957e-04    a8 -4.182687867891e-06
   Emin  2.61e-01   s(Emin)  1.00e-19   smax  1.32e-14   Error  7.49e-02
   Eth  0.225
   Mcross 1.0E+00
```

Reaction 4.2.1 $H_2^+(v) + H(1s) \rightarrow H_2^+(2p\sigma_u) + H(1s) \rightarrow H^+ + H + H(1s), (v = 0\ldots 9)$

```
   a0  1.885518121144e+04     a1 -1.730109845144e+04     a2  6.789143089426e+03
   a3 -1.495308617111e+03     a4  2.025858786888e+02     a5 -1.731165351422e+01
   a6  9.120053117120e-01     a7 -2.709481429950e-02     a8  3.476220959653e-04
  ar0 -1.032118444000E+03    ar1  1.641681892000E+02    ar2 -6.789412670000E+00
ELABMAX=  1.00000E+06 eV
      Emin  3.96e+02   s(Emin)  1.00e-19   smax  1.99e-16   Error  2.02e-03
      Eth  6.0
      Mcross 2.0E+00

      Not valid for E < 300 eV.
```

Reaction 4.3.1 $H_2^+ + H_2 \rightarrow H_2 + H_2^+$

```
   a0 -3.427958758517e+01     a1 -7.121484125189e-02     a2  4.690466187943e-02
   a3 -8.033946660540e-03     a4 -2.265090924593e-03     a5 -2.102414848737e-04
   a6  1.948869487515e-04     a7 -2.208124950005e-05     a8  7.262446915488e-07
  ar0 -7.463331048000E+01    ar1  8.629058909000E+00    ar2 -4.691006442000E-01
ELABMAX=  1.00000E+05 eV
      Emin  1.00e-01   s(Emin)  2.10e-15    smax  2.10e-15    Error  3.91e-04
      Eth  0.
      Mcross 2.0E+00
```

Reaction 4.3.2 $H_2^+ + H_2 \rightarrow H_2^+ + H_2^+ + e$

```
a0 -2.383489439121e+02    a1  2.384368432909e+02    a2 -1.263102889116e+02
a3  3.746454397894e+01    a4 -6.767700946931e+00    a5  7.629123486032e-01
a6 -5.246096809457e-02    a7  2.014116839267e-03    a8 -3.310073123768e-05
   Emin  3.67e+01   s(Emin)  1.00e-19    smax  3.30e-16   Error 1.11e-04
   Eth  15.4
   Mcross 2.0E+00
```

Reaction 4.3.3 $H_2^+ + H_2 \rightarrow H_3^+ + H$

```
    a0 -3.422188283057e+01    a1 -7.733921420462e-01    a2 -4.625452844356e-01
    a3 -2.307540053739e-01    a4  3.188925541844e-02    a5  3.622033742962e-02
    a6 -5.093822617734e-03    a7 -2.420060478318e-03    a8  4.634259500837e-04
   ar0 -3.242526389000E+01   ar1 -2.753789651000E+00   ar2 -9.217068775000E-02
ELABMAX=  3.00000E+01 eV
      Emin  1.00e-01   s(Emin)  4.26e-15   smax  4.26e-15   Error  2.99e-04
      Eth  0.0
      Emax 4.0E+01
      Mcross 2.0E+00
      Not valid for E > 40 eV.
```

Reaction 4.4.1 $H_2^+ + He \rightarrow H_2^+ + He^+(1s) + e$

```
    a0 -1.279183240553e+02     a1  7.851907373534e+01     a2 -3.133748457688e+01
    a3  6.817786375262e+00     a4 -8.395843945734e-01     a5  5.456579807937e-02
    a6 -1.161799515932e-03     a7 -5.185457132932e-05     a8  2.416658401748e-06
   ar0 -4.780235129000E+01    ar1  2.462576818000E+00    ar2 -1.322702144000E-01
ELABMAX=  1.00000E+05 eV
      Emin  4.52e+01    s(Emin)  1.00e-19    smax  1.30e-16    Error  1.34e-04
      Eth  24.58
      Mcross 2.0E+00
```

Reaction 5.2.1 $He^+(1s) + H_2 \rightarrow He^+(1s) + H_2^+ + e$

```
a0 -2.325294713788e+02    a1  2.137835372191e+02    a2 -1.060826620181e+02
a3  3.048034248334e+01    a4 -5.472938698614e+00    a5  6.242016892196e-01
a6 -4.400795546393e-02    a7  1.751040972949e-03    a8 -3.008006324086e-05
   Emin  1.90e+01   s(Emin)  1.00e-19   smax  5.51e-17   Error  3.94e-03
   Eth  15.4
   Mcross 4.0E+00
```

Reaction 5.2.2 $He^+(1s) + H_2 \rightarrow He(1s^2 1S) + H_2^+$

```
a0 -1.108066480195e+04    a1  1.008755280085e+04    a2 -4.018540037373e+03
a3  9.114656395741e+02    a4 -1.288151812962e+02    a5  1.162404023738e+01
a6 -6.543944103705e-01    a7  2.101966590407e-02    a8 -2.949737399468e-04
   Emin  5.84e+02   s(Emin)  1.00e-19   smax  1.39e-16   Error  1.86e-04
   Eth   0.0
   Mcross 4.0E+00
```

Reaction 5.2.3 $He^+(1s) + H_2 \rightarrow He(1s^2 1S) + H^+ + H$

```
    a0 -4.311350879235e+01     a1  5.515944942674e-02     a2 -5.606069194725e-01
    a3  1.291230751283e-01     a4  1.533686418592e-01     a5 -6.125769782521e-02
    a6  8.886802346189e-03     a7 -5.806431060224e-04     a8  1.440125514216e-05
   ar0 -5.560154242000E+01    ar1  5.037170638000E+00    ar2 -3.585460009000E-01
ELABMAX=  2.00000E+04 eV
      Emin  2.33e-01    s(Emin)  1.00e-19    smax  1.33e-16    Error  2.66e-02
      Eth  0.0
      Mcross 4.0E+00

      Not valid for E < 0.3 eV.
```

Reaction 5.3.1 $He^+(1s) + He \rightarrow He + He^+(1s)$

```
a0 -3.369296194290e+01    a1 -8.324653178943e-02    a2  6.660151719388e-03
a3 -3.592504363592e-03    a4 -1.745382918016e-04    a5  1.497204460315e-04
a6 -2.152122621503e-05    a7  1.473684503283e-06    a8 -4.401831552698e-08
    Emin  1.00e-01   s(Emin)  3.00e-15   smax  3.00e-15   Error  5.63e-05
    Eth  0.0
    Mcross 4.0E+00
```

Reaction 5.3.2 $He^+ + He \rightarrow He^+ + He^+ + e$

```
a0 -1.126408326504e+03    a1  1.221414787395e+03    a2 -5.910936989464e+02
a3  1.609170847736e+02    a4 -2.693537704047e+01    a5  2.837798810047e+00
a6 -1.837630539164e-01    a7  6.688462818228e-03    a8 -1.048046510736e-04
   Emin  2.88e+01   s(Emin)  1.00e-19   smax  6.12e-17   Error  1.13e-02
   Eth  24.58
   Mcross 4.0E+00
```

Reaction 6.1.1 $He^{++} + H(1s) \rightarrow He^{++} + H(2p)$

```
a0 -3.935171502778e+03    a1  3.121350934839e+03    a2 -1.090958722369e+03
a3  2.154761368634e+02    a4 -2.615076564408e+01    a5  1.988438495730e+00
a6 -9.217310084360e-02    a7  2.372722474405e-03    a8 -2.585687269696e-05
    Emin  7.18e+02   s(Emin)  1.00e-19   smax  1.03e-16   Error  1.19e-05
    Eth  10.275
    Mcross 4.0E+00
```

A more extensive analytic formula for all n >= 2 is given in the text.

Reaction 6.1.3 $He^{++} + H(1s) \rightarrow He^{++} + H^+ + e$

```
a0 -4.108092972648e+05    a1  3.538162825295e+05    a2 -1.328131904744e+05
a3  2.837637619784e+04    a4 -3.774364805704e+03    a5  3.200454272008e+02
a6 -1.689565219222e+01    a7  5.077317110574e-01    a8 -6.650084296041e-03
   Emin  1.34e+03   s(Emin)  1.00e-19   smax  1.60e-16   Error 9.63e-04
   Eth  13.6
   Mcross 4.0E+00
```

Reaction 6.1.4 $He^{++} + H(n) \rightarrow He^{++} + H^+ + e(n \geq 2)$

An analytic formula for the cross-section for all n is given in the text.

Reaction 6.1.5 $He^{++} + H(2s) \rightarrow He^{++} + H(2p)$

```
An analytic formula for cross-section is given in the text.
Neutral particle at rest, charged particle energy E_lab(eV)

cross_cm = $6.336e-10/E_{lab}*log(0.5515*E_{lab})$
```

Reaction 6.1.6 $He^{++} + H \rightarrow He^+(n=2) + H^+$

```
  a0 -4.315145081040e+01    a1  1.153902751649e+00    a2 -1.770607674796e-03
  a3 -4.249237424243e-02    a4  2.552430939448e-02    a5 -6.612097121922e-03
  a6  8.587538946329e-04    a7 -5.501612272760e-05    a8  1.373936349802e-06
 ar0 -4.052049207000E+01   ar1  1.753255540000E+00   ar2 -1.110727227000E-01
ELABMAX=  1.00000E+05 eV
      Emin  6.00e-01   s(Emin)  1.00e-19   smax  1.36e-15   Error  2.92e-04
      Eth  0
      Mcross 4.0E+00
```

Reaction 6.1.7 $He^{++} + H(n) \rightarrow He^+(n') + H^+$

```
An analytic formula for s is given in the text.
Neutral particle at rest, charged particle energy E_{lab}(eV)

Transition: n --> n',   with n'=2n, n=2,4,6,....; E_th=0

        v = 3.1623e-3*sqrt(E_lab)
cross_cm = 4.69e-16*n**4/(1.+0.8*(n*v)**0.4+2.6*n*v)

Transition: n --> n',   with n'=2n-1, n=2,4,6,....; E_th=...

cross(2 --> 3) =  0.75* cross(2 --> 4)
cross(3 --> 5) =  0.80* cross(3 --> 6)
cross(4 --> 7) =  0.85* cross(4 --> 8)
```

Reaction 6.2.1 $He^{++} + H_2 \rightarrow He^{++} + H_2^+(v) + e$

```
a0 -3.888955469991e+01     a1 -9.866429655660e+00     a2  5.655068418984e+00
a3 -1.577966214613e+00     a4  2.645599512156e-01     a5 -2.758466438253e-02
a6  1.761704594534e-03     a7 -6.345561877676e-05     a8  9.903373373326e-07
   Emin  3.31e+01   s(Emin)  1.00e-19   smax  3.87e-16   Error  6.85e-05
   Eth  15.4
   Mcross 4.0E+00

   Not valid for E < 30 eV.
```

Reaction 6.2.1n $He^{++} + H_2 \rightarrow He^{++} + H_2^+(v) + e$

revised version, better asymptotics

```
a0 -1.348256538024E+02     a1  9.118284774788E+01     a2 -3.835314779831E+01
a3  8.719939323071E+00     a4 -1.142249374234E+00     a5  8.618810448200E-02
a6 -3.470340641765E-03     a7  5.759492568234E-05     a8 -9.734400000000E-24
   Eth  15.4
```

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Reaction 6.3.1 $He^{++} + He \rightarrow He + He^{++}$

```
a0 -3.459818117569e+01    a1 -8.748942423786e-02    a2 -2.445604128495e-02
a3  2.392295193337e-03    a4  9.876388162277e-04    a5 -2.282012750308e-04
a6  3.598361283629e-06    a7  1.940270105613e-06    a8 -1.105794797036e-07
   Emin  1.00e-01   s(Emin)  1.03e-15   smax  1.03e-15   Error  1.74e-04
   Eth  0
   Mcross 4.0E+00
```

Reaction 6.3.2 $He^{++} + He \rightarrow He^{++} + He^{+}(1s) + e$

```
a0  1.416740796235e+06    a1 -1.119008170939e+06    a2  3.857965046775e+05
a3 -7.583813526516e+04    a4  9.297450568358e+03    a5 -7.279675981729e+02
a6  3.555154263032e+01    a7 -9.901755546104e-01    a8  1.204251833183e-02
   Emin  4.75e+03   s(Emin)  1.00e-19   smax  2.50e-17   Error 3.33e-05
   Eth  24.588
   Mcross 4.0E+00
```

Reaction 6.3.2n $He^{++} + He \rightarrow He^{++} + He^{+}(1s) + e$

revised version, better asymptotics

```
a0 -1.055124995647E+04    a1  7.814313871085E+03    a2  -2.525546560126E+03
a3  4.623987021985E+02    a4 -5.238841605982E+01    a5   3.757793036669E+00
a6 -1.665366765547E-01    a7  4.167057779117E-03    a8  -4.505951553161E-05
   Eth  24.588
```

Reaction 7.1.1 $e + H^- \rightarrow e + H(1s) + e$

```
a0 -3.934913643088e+01    a1  7.492484197616e+00    a2 -6.138735352362e+00
a3  3.326569253609e+00    a4 -1.040328294213e+00    a5  1.834296974839e-01
a6 -1.814008493227e-02    a7  9.403286251360e-04    a8 -1.989848289161e-05
    Emin  9.06e-01   s(Emin)  1.00e-19   smax  3.75e-15   Error  2.64e-01
    Eth   0.75
    Mcross 9.1093826E-31
```

Reaction 7.1.2 $e + H^- \rightarrow e + H^+ + 2e$

```
a0 -7.448448227127e+02    a1  8.696721447863e+02    a2 -4.584681915725e+02
a3  1.353555608991e+02    a4 -2.446848674683e+01    a5  2.771980281770e+00
a6 -1.922085761453e-01    a7  7.462384021984e-03    a8 -1.243029551161e-04
    Emin  1.66e+01   s(Emin)  1.00e-19   smax  5.06e-17   Error  3.39e-02
    Eth   14.35
    Mcross 9.1093826E-31
```

Reaction 7.2.1 $p + H^- \rightarrow p + H + e$

```
a0 -1.050889816750e+04    a1  1.054502629910e+04    a2 -4.618343915803e+03
a3  1.147184656009e+03    a4 -1.766806773292e+02    a5  1.727351520643e+01
a6 -1.046726308683e+00    a7  3.593652631660e-02    a8 -5.350831095528e-04
    Emin  2.25e+02   s(Emin)  1.00e-19   smax  4.76e-15   Error  1.18e-03
    Eth   0.75
    Mcross 1.0E+00
```

Reaction 7.2.2 $p + H^- \rightarrow H(n = 2) + H(1s)$

```
  a0 -3.498808881328e+01    a1  2.152450508307e-01    a2 -2.356286641829e-02
  a3  5.494715530438e-02    a4  5.379328883390e-03    a5 -6.055070213687e-03
  a6  9.991683287907e-04    a7 -6.636255640130e-05    a8  1.612283845094e-06
 ar0 -2.918073629000e+01   ar1 -1.327281071000e-01   ar2 -4.679898982000e-02
ELABMAX=  2.00000E+04 eV
      Emin  1.00e-01   s(Emin)  3.30e-16   smax  1.38e-14   Error  2.29e-03
      Eth  0.
      Mcross 1.0E+00
      Maxrate (sigma * vlab) = 2.730823e-13 at Elab= 7.479523e+02
```

Reaction 7.2.3 $p + H^- \rightarrow H(n=3) + H(1s)$

```
a0 -3.114793359560e+01    a1 -7.730205271965e-01    a2  5.492043775127e-02
a3 -2.733249841523e-03    a4 -1.228312883866e-03    a5  4.350498278844e-04
a6 -6.216595007254e-05    a7  4.120468065072e-06    a8 -1.039784996359e-07
   Emin  1.00e-01   s(Emin)  2.25e-13   smax  2.25e-13   Error  5.93e-05
   Eth  0.
   Mcross 1.0E+00
```

Reaction 7.3.1 $H^- + H(1s) \rightarrow H(1s) + H^-(1s)$

```
a0 -3.896158248196e+01    a1 -2.677306137623e-03    a2 -6.353177906590e-03
a3 -7.238847698066e-03    a4  1.297916639224e-03    a5  5.654591683916e-04
a6 -2.351925503212e-04    a7  2.913484058046e-05    a8 -1.229505901932e-06
   Emin  1.00e-01   s(Emin)  1.23e-17    smax  1.23e-17    Error  4.04e-04
   Eth  0.
   Mcross 1.0E+00
```

Reaction 7.3.2a $H^- + H \rightarrow H_2^-(\Sigma_g) \rightarrow H + H + e$

```
a0 -3.617990822381e+01    a1  1.166151722958e+00    a2 -1.419286024586e-01
a3 -1.111959587916e-02    a4 -1.725059947629e-03    a5  1.590403561378e-03
a6 -2.531961443012e-04    a7  1.669782349801e-05    a8 -4.097257966950e-07
   Emin  1.00e-01   s(Emin)  6.09e-18   smax  1.54e-15   Error  3.23e-04
   Eth  0.
   Mcross 1.0E+00
```

Reaction 7.3.2b $H^- + H \rightarrow H_2^-\left(\Sigma_u\right) \rightarrow H_2 + e$

```
a0 -3.441529065653e+01    a1 -3.393482086017e-01    a2  5.665917047817e-02
a3 -9.051504593339e-03    a4  7.660604175354e-04    a5 -4.271264623381e-05
a6 -1.572737493346e-07    a7  2.576076771707e-07    a8 -1.200719193800e-08
   Emin  1.00e-01   s(Emin)  3.84e-15   smax  3.84e-15   Error  9.90e-05
   Eth  0.
   Mcross 1.0E+00
```

2 H.2 POLYNOMIAL FITS FOR $< \sigma v >$ FOR FIXED E

Reaction 2.1.1 $e + H(1s) \rightarrow e + H(2p)$

```
b0 -2.814949375869e+01    b1  1.009828023274e+01    b2 -4.771961915818e+00
b3  1.467805963618e+00    b4 -2.979799374553e-01    b5  3.861631407174e-02
b6 -3.051685780771e-03    b7  1.335472720988e-04    b8 -2.476088392502e-06
 Tmin 1.26e+00   <sv>(Tmin) 4.78e-12   <sv>max 3.18e-08   Error 1.51e-05
```

Reaction 2.1.2 $e + H(1s) \rightarrow e + H(2s)$

```
b0 -2.833259375256e+01    b1  9.587356325603e+00    b2 -4.833579851041e+00
b3  1.415863373520e+00    b4 -2.537887918825e-01    b5  2.800713977946e-02
b6 -1.871408172571e-03    b7  6.986668318407e-05    b8 -1.123758504195e-06
 Tmin 1.26e+00    <sv>(Tmin) 3.54e-12    <sv>max 3.22e-09    Error 3.33e-06
```

Reaction 2.1.3 $e + H(2s) \rightarrow e + H(2p)$

```
b0 -1.219616012805e+01    b1 -3.859057071006e-01    b2 -6.509976401685e-03
b3  4.981099209058e-04    b4 -4.184102479407e-05    b5  3.054358926267e-06
b6 -1.328567638366e-07    b7  8.974535105058e-10    b8  1.010269574757e-10
 Tmin 1.00e-01   <sv>(Tmin) 1.18e-05   <sv>max 1.18e-05   Error 2.16e-11
```

Reaction 2.1.4a $e + H(n = 1) \rightarrow e + H(n = 3)$

```
b0 -3.113714569232e+01    b1  1.170494035550e+01    b2 -5.598117886823e+00
b3  1.668467661343e+00    b4 -3.186788446245e-01    b5  3.851704802605e-02
b6 -2.845199866183e-03    b7  1.171512424827e-04    b8 -2.059295818495e-06
 Tmin 1.58e+00    <sv>(Tmin) 2.32e-12    <sv>max 6.09e-09    Error 3.54e-06
```

Reaction 2.1.4b $e + H(n=2) \rightarrow e + H(n=3)$

```
b0 -1.515830911091e+01    b1  1.923956400537e+00    b2 -9.275338417712e-01
b3  3.370367299915e-01    b4 -8.758162223598e-02    b5  1.409066167839e-02
b6 -1.325225954526e-03    b7  6.672025878086e-05    b8 -1.387615199713e-06
 Tmin 1.58e-01   <sv>(Tmin) 9.92e-12   <sv>max 2.00e-06   Error 4.99e-05
```

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

```
b0 -3.271396786375e+01    b1  1.353655609057e+01    b2 -5.739328757388e+00
b3  1.563154982022e+00    b4 -2.877056004391e-01    b5  3.482559773737e-02
b6 -2.631976175590e-03    b7  1.119543953861e-04    b8 -2.039149852002e-06
 Tmin 2.00e+00    <sv>(Tmin) 7.22e-12    <sv>max 3.11e-08    Error 1.71e-05
```

Reaction 2.1.6 $e + H(2s) \rightarrow e + H^+ + e$

```
b0 -1.973476726029e+01    b1  3.992702671457e+00    b2 -1.773436308973e+00
b3  5.331949621358e-01    b4 -1.181042453190e-01    b5  1.763136575032e-02
b6 -1.616005335321e-03    b7  8.093908992682e-05    b8 -1.686664454913e-06
 Tmin 3.98e-01   <sv>(Tmin) 8.87e-12   <sv>max 1.71e-07   Error 7.10e-05
```

Reaction 2.1.7 $e + H(n = 3) \rightarrow e + H^+ + e$

```
b0 -1.566968719411e+01    b1  1.719661170920e+00    b2 -8.365041963678e-01
b3  2.642794957304e-01    b4 -6.527754894629e-02    b5  1.066883130107e-02
b6 -1.041488149422e-03    b7  5.457216484634e-05    b8 -1.177539827071e-06
 Tmin 1.26e-01   <sv>(Tmin) 2.00e-12   <sv>max 6.80e-07   Error 9.85e-05
```

A more extensive analytic formula for all n > 2 is given in the text.

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

general formula: see original text. Here: added fit to rate for recomb into 1s ground state

```
b0 -2.95894689000e+01     b1 -0.529779950000e+00     b2 -0.005968130000e+00
b3 -0.00033543090e+00     b4 -0.003004446800e+00     b5 -0.000470231100e+00
b6  0.00025139600e+00     b7 -2.776281210000e-05     b8  9.833670340000e-07
 Tmin 1.00e-01    Tmax=1.00e+04
```

Reaction 2.1.8a $e + H^+ \rightarrow H(2s) + hv$

general formula: see original text. Here: added fit to rate for recomb into 2s excited state

```
b0 -3.14497513000e+01     b1 -0.525649298000e+00     b2 -0.011206549700e+00
b3 -0.00823278120e+00     b4 -0.002464058500e+00     b5  0.000284729200e+00
b6  5.62007081000e-05     b7 -9.251862920000e-06     b8  3.544559600000e-07
 Tmin 1.00e-01    Tmax=1.00e+04
```

Reaction 2.1.8b $e + H^+ \rightarrow H(2p) + hv$

general formula: see original text. Here: added fit to rate for recomb into 2p excited state

```
b0 -3.06473715000e+01     b1 -0.653170766000e+00     b2 -0.068667509300e+00
b3 -0.01770596520e+00     b4  0.000560929000e+00     b5  0.001091531300e+00
b6 -0.00020918050e+00     b7  1.546343080000e-05     b8 -4.228481280000e-07
 Tmin 1.00e-01    Tmax=1.00e+04
```

Reaction 2.2.1a $e + H_2(v = 0) \rightarrow e + H_2(v = 1)$

```
b0 -2.017212494454e+01    b1  9.563952280637e-01    b2 -6.931474225637e-01
b3  1.673671529631e-01    b4 -3.228762898855e-02    b5  5.838603222226e-03
b6 -8.580542691302e-04    b7  7.456311623168e-05    b8 -2.666978300757e-06
 Tmin 1.58e-01   <sv>(Tmin) 5.83e-12   <sv>max 2.60e-09   Error 2.55e-06
```

Reaction 2.2.1b $e + H_2(v = 0) \rightarrow e + H_2(v = 2)$

```
b0 -2.265507686305e+01    b1  2.239943592222e+00    b2 -1.099426577160e+00
b3  2.339027647223e-01    b4 -2.528511103871e-02    b5  6.851302489620e-04
b6  1.253426182224e-04    b7 -1.253475051672e-05    b8  3.545892878015e-07
 Tmin 3.98e-01    <sv>(Tmin) 5.93e-12    <sv>max 7.07e-10    Error 2.74e-07
```

Reaction 2.2.2 $e + H_2(X^1\Sigma_g^+) \rightarrow e + H_2(B^1\Sigma_u^+ 2p\sigma)$

```
b0 -3.081902926338e+01    b1  1.038866780735e+01    b2 -4.259768348687e+00
b3  1.181228673120e+00    b4 -2.277513907465e-01    b5  2.900576728856e-02
b6 -2.287591474628e-03    b7  1.004346442778e-04    b8 -1.869930069131e-06
 Tmin 2.00e+00    <sv>(Tmin) 9.88e-12    <sv>max 1.47e-08    Error 9.52e-06
```

Reaction 2.2.3 $e + H_2(X^1\Sigma_g^+) \to e + H_2(C^1\Pi_u 2p\pi)$

```
b0 -3.348199796300e+01    b1  1.371702271009e+01    b2 -5.922607900694e+00
b3  1.709719148860e+00    b4 -3.505232830275e-01    b5  4.834376067841e-02
b6 -4.131406425550e-03    b7  1.948388368131e-04    b8 -3.854278715563e-06
 Tmin 2.00e+00    <sv>(Tmin) 3.59e-12    <sv>max 1.39e-08    Error 8.14e-05
```

Reaction 2.2.4 $e + H_2(X^1\Sigma_g^+) \rightarrow e + H_2(E, F^1\Sigma_g^+)$

```
b0 -3.646589741675e+01    b1  1.430361969329e+01    b2 -6.074430521073e+00
b3  1.677305768580e+00    b4 -3.128705597349e-01    b5  3.805424730473e-02
b6 -2.860085821803e-03    b7  1.199641410078e-04    b8 -2.142231851104e-06
 Tmin 3.16e+00    <sv>(Tmin) 5.27e-12    <sv>max 2.23e-09    Error 2.11e-06
```

Reaction 2.2.5 $e + H_2(X^1\Sigma_g^+) \rightarrow e + H_2(b^3\Sigma_u^+, a^3\Sigma_g^+, c^3\Pi_u) \rightarrow e + H(1s) + H(1s)$

```
b0 -2.787217511174e+01    b1  1.052252660075e+01    b2 -4.973212347860e+00
b3  1.451198183114e+00    b4 -3.062790554644e-01    b5  4.433379509258e-02
b6 -4.096344172875e-03    b7  2.159670289222e-04    b8 -4.928545325189e-06
 Tmin 1.26e+00    <sv>(Tmin) 6.91e-12    <sv>max 9.81e-09    Error 5.94e-07
```

Reaction 2.2.6 $e + H_2(X^1\Sigma_g^+) \rightarrow e + H_2(1s\sigma_g, nl\lambda|^1\Lambda) \rightarrow e + H(1s) + H(2s)$

```
b0 -3.454175591367e+01    b1  1.412655911280e+01    b2 -6.004466156761e+00
b3  1.589476697488e+00    b4 -2.775796909649e-01    b5  3.152736888124e-02
b6 -2.229578042005e-03    b7  8.890114963166e-05    b8 -1.523912962346e-06
 Tmin 2.51e+00    <sv>(Tmin) 7.88e-12    <sv>max 6.92e-09    Error 2.74e-06
```

Reaction 2.2.7 $e + H_2(X^1\Sigma_g^+) \rightarrow e + H_2(2p\sigma_u, nl\lambda|Q_2^1\Pi_u) \rightarrow e + H(2p) + H(2s)$

```
b0 -4.794288960529e+01    b1  2.629649351119e+01    b2 -1.151117702256e+01
b3  2.991954880790e+00    b4 -4.949305181578e-01    b5  5.236320848415e-02
b6 -3.433774290547e-03    b7  1.272097387363e-04    b8 -2.036079507592e-06
 Tmin 5.01e+00    <sv>(Tmin) 6.48e-12    <sv>max 1.31e-09    Error 3.76e-07
```

Reaction 2.2.8 $e + H_2(X^1\Sigma_g^+) \rightarrow e + H_2(2p\sigma_u; n = 3) \rightarrow e + H(1s) + H(n = 3)$

```
b0 -3.884976142596e+01    b1  1.520368281111e+01    b2 -6.078494762845e+00
b3  1.535455119900e+00    b4 -2.628667482712e-01    b5  2.994456451213e-02
b6 -2.156175515382e-03    b7  8.826547202670e-05    b8 -1.558890013181e-06
 Tmin 3.98e+00    <sv>(Tmin) 4.09e-12    <sv>max 7.73e-10    Error 6.05e-06
```

Reaction 2.2.9 $e + H_2(X^1\Sigma_g^+) \rightarrow e + H_2^+(v) + e$

```
b0 -3.568640293666e+01    b1  1.733468989961e+01    b2 -7.767469363538e+00
b3  2.211579405415e+00    b4 -4.169840174384e-01    b5  5.088289820867e-02
b6 -3.832737518325e-03    b7  1.612863120371e-04    b8 -2.893391904431e-06
 Tmin 2.00e+00    <sv>(Tmin) 2.34e-12    <sv>max 5.18e-08    Error 6.45e-06
```

Reaction 2.2.10 $e + H_2(X^1\Sigma_g^+) \rightarrow e + [H_2^+(\Sigma_g, \Sigma_u) + e] \rightarrow e + H^+ + H(1s) + e$

```
b0 -3.834597006782e+01    b1  1.426322356722e+01    b2 -5.826468569506e+00
b3  1.727940947913e+00    b4 -3.598120866343e-01    b5  4.822199350494e-02
b6 -3.909402993006e-03    b7  1.738776657690e-04    b8 -3.252844486351e-06
 Tmin 3.98e+00    <sv>(Tmin) 3.74e-12    <sv>max 2.89e-09    Error 4.61e-05
```

Reaction 2.2.11 $e + H_2^+(v) \to e + H^+ + H^+ + e, (v = 0 \ldots 9)$

```
b0 -3.746192301092e+01    b1  1.559355031108e+01    b2 -6.693238367093e+00
b3  1.981700292134e+00    b4 -4.044820889297e-01    b5  5.352391623039e-02
b6 -4.317451841436e-03    b7  1.918499873454e-04    b8 -3.591779705419e-06
 Tmin 3.16e+00    <sv>(Tmin) 5.23e-12    <sv>max 9.06e-09    Error 2.26e-05
```

Reaction 2.2.12 $e + H_2^+(v) \rightarrow e + H_2^+(2p\sigma_u) \rightarrow e + H^+ + H(1s), (v = 0 \ldots 9)$

```
b0 -1.781416067709e+01    b1  2.277799785711e+00    b2 -1.266868411626e+00
b3  4.296170447419e-01    b4 -9.609908013189e-02    b5  1.387958040699e-02
b6 -1.231349039470e-03    b7  6.042383126281e-05    b8 -1.247521040900e-06
 Tmin 2.00e-01   <sv>(Tmin) 1.23e-12   <sv>max 1.15e-07   Error 8.64e-05
```

Reaction 2.2.13 $e + H_2^+(v) \rightarrow e + H_2^+(2p\pi_u) \rightarrow e + H^+ + H(n = 2), (v = 0 \ldots 9)$

```
b0 -3.408905929046e+01    b1  1.573560727511e+01    b2 -6.992177456733e+00
b3  1.852216261706e+00    b4 -3.130312806531e-01    b5  3.383704123189e-02
b6 -2.265770525273e-03    b7  8.565603779673e-05    b8 -1.398131377085e-06
 Tmin 2.00e+00    <sv>(Tmin) 5.03e-12    <sv>max 1.77e-08    Error 2.05e-06
```

Reaction 2.2.14 $e + H_2^+(v) \rightarrow H(1s) + H(n)(v = 0\ldots9, n \geq 2)$

```
b0 -1.670435653561e+01    b1 -6.035644995682e-01    b2 -1.942745783445e-08
b3 -2.005952284492e-07    b4  2.962996104431e-08    b5  2.134293274971e-08
b6 -6.353973401838e-09    b7  6.152557460831e-10    b8 -2.025361858319e-11
 Tmin 1.00e-01   <sv>(Tmin) 2.23e-07   <sv>max 2.23e-07   Error 3.30e-13
```

Reaction 2.2.15 $e + H_3^+ \rightarrow H + H + H$ **or** $\rightarrow H_2(v > 5) + H(n = 2)$

```
b0 -1.700270758355e+01    b1 -4.050073042947e-01    b2  1.018733477232e-08
b3 -1.695586285687e-08    b4  1.564311217508e-10    b5  1.979725412288e-09
b6 -4.395545994733e-10    b7  3.584926377078e-11    b8 -1.024189019465e-12
 Tmin 1.00e-01   <sv>(Tmin) 1.05e-07   <sv>max 1.05e-07   Error 3.27e-15
```

Reaction 2.2.16 $e + H_3^+ \rightarrow e + H^+ + 2H$

```
b0 -3.078408636631e+01    b1  1.509421488513e+01    b2 -7.349167207324e+00
b3  2.320966107642e+00    b4 -4.818077551719e-01    b5  6.389229162737e-02
b6 -5.161880953089e-03    b7  2.303985092606e-04    b8 -4.344846146197e-06
 Tmin 1.26e+00   <sv>(Tmin) 9.46e-13   <sv>max 4.18e-07   Error 6.20e-05
```

Reaction 2.2.17 $e + H_2(v \geq 4) \rightarrow (H_2^-) \rightarrow H^- + H$

```
b0 -1.774398466232e+01    b1 -6.207038732492e-01    b2 -2.811412695673e-01
b3  2.540958044519e-02    b4  6.643467825225e-03    b5 -8.877629159412e-04
b6 -3.705776394283e-04    b7  9.313511559362e-05    b8 -5.995758360037e-06
 Tmin 1.00e-01   <sv>(Tmin) 1.58e-08   <sv>max 2.70e-08   Error 4.67e-07
```

Reaction 2.3.1a $e + He(1s^2 1S) \rightarrow e + He(1s^1 2p^1 1P)$

```
b0 -4.076450793433e+01    b1  1.847216050626e+01    b2 -7.553534847500e+00
b3  1.936036716566e+00    b4 -3.278509524847e-01    b5  3.627243238755e-02
b6 -2.509995616613e-03    b7  9.829302307697e-05    b8 -1.659516418994e-06
 Tmin 3.98e+00    <sv>(Tmin) 7.72e-12    <sv>max 6.23e-09    Error 1.17e-06
```

Reaction 2.3.1b $e + He(1s^2 1S) \rightarrow e + He(1s^1 3p^1 1P)$

```
b0 -4.439802014466e+01    b1  2.170928173941e+01    b2 -9.582182742745e+00
b3  2.631183876455e+00    b4 -4.687644097236e-01    b5  5.361959275824e-02
b6 -3.786601021417e-03    b7  1.500190728471e-04    b8 -2.548241584846e-06
 Tmin 5.01e+00   <sv>(Tmin) 5.50e-12   <sv>max 1.55e-09   Error 1.10e-06
```

Reaction 2.3.2 $e + He(1s^2 1S) \rightarrow e + He(1s^1 2s^1 1S)$

```
b0 -3.944902284550e+01    b1  1.801440475215e+01    b2 -7.941287139217e+00
b3  2.108879073816e+00    b4 -3.656365579422e-01    b5  4.130418209599e-02
b6 -2.921666597766e-03    b7  1.171506777488e-04    b8 -2.027094391374e-06
 Tmin 3.16e+00    <sv>(Tmin) 2.84e-12    <sv>max 7.92e-10    Error 4.16e-06
```

Reaction 2.3.3a $e + He(1s^2 1S) \rightarrow e + He(1s^1 2s^1 3S)$

```
b0 -3.907389635096e+01    b1  1.922614839789e+01    b2 -9.704341826798e+00
b3  3.077375531860e+00    b4 -6.879793654863e-01    b5  1.062748336765e-01
b6 -1.074378374967e-02    b7  6.372192184143e-04    b8 -1.676476511183e-05
 Tmin 3.16e+00    <sv>(Tmin) 4.52e-12    <sv>max 2.53e-10    Error 8.14e-10
```

Reaction 2.3.3b $e + He(1s^2 1S) \rightarrow e + He(1s^1 2p^1 3P)$

```
b0 -4.126478834982e+01    b1  2.115462440402e+01    b2 -1.037798544679e+01
b3  3.223448557463e+00    b4 -7.047523358686e-01    b5  1.058143518376e-01
b6 -1.030712489010e-02    b7  5.837301581720e-04    b8 -1.454656422289e-05
 Tmin 3.98e+00    <sv>(Tmin) 8.87e-12    <sv>max 3.32e-10    Error 8.73e-10
```

Reaction 2.3.3c $e + He(1s^2 1S) \rightarrow e + He(1s^1 3s^1 3S)$

```
b0 -4.403421631102e+01    b1  2.245729554242e+01    b2 -1.077239790242e+01
b3  3.245104419002e+00    b4 -6.897865199057e-01    b5  1.022237988347e-01
b6 -1.003860681229e-02    b7  5.860847901785e-04    b8 -1.537517028977e-05
 Tmin 5.01e+00    <sv>(Tmin) 5.43e-12    <sv>max 9.25e-11    Error 7.14e-10
```

Reaction 2.3.3d $e + He(1s^2 1S) \rightarrow e + He(1s^1 3p^1 3P)$

```
b0 -4.364496383346e+01    b1  2.269089069271e+01    b2 -1.084808588246e+01
b3  3.247690604813e+00    b4 -6.828905628843e-01    b5  9.957070020879e-02
b6 -9.564409022565e-03    b7  5.429268148822e-04    b8 -1.376622041888e-05
 Tmin 5.01e+00    <sv>(Tmin) 9.95e-12    <sv>max 1.79e-10    Error 6.08e-10
```

Reaction 2.3.4a $e + He(1s^12s^13S) \rightarrow e + He(1s^12s^11S)$

```
b0 -1.744584533214e+01    b1  7.146118553487e-01    b2 -4.873579904205e-01
b3  1.481188090592e-01    b4 -3.507761998312e-02    b5  5.690374429946e-03
b6 -5.623763509155e-04    b7  3.001973812574e-05    b8 -6.601806234046e-07
 Tmin 1.00e-01   <sv>(Tmin) 1.46e-11   <sv>max 3.80e-08   Error 5.08e-05
```

Reaction 2.3.4b $e + He(1s^1 2s^1 3S) \rightarrow e + He(1s^1 2p^1 1P)$

```
b0 -1.844735966200e+01    b1  1.427274973351e+00    b2 -8.091153742158e-01
b3  2.487008240878e-01    b4 -5.643723514177e-02    b5  8.601493865150e-03
b6 -8.023972821093e-04    b7  4.085320629082e-05    b8 -8.650886326975e-07
 Tmin 1.58e-01   <sv>(Tmin) 3.93e-12   <sv>max 2.52e-08   Error 4.76e-05
```

Reaction 2.3.4c $e + He(1s^1 2s^1 1S) \rightarrow e + He(1s^1 2p^1 3P)$

```
b0 -1.615322214290e+01    b1  1.433777584524e-01    b2 -2.487826648613e-01
b3  7.026918912149e-02    b4 -1.553687005936e-02    b5  2.421396865761e-03
b6 -2.348531854752e-04    b7  1.243991031364e-05    b8 -2.729353858047e-07
 Tmin 1.00e-01   <sv>(Tmin) 4.15e-09   <sv>max 9.87e-08   Error 8.49e-06
```

Reaction 2.3.4d $e + He(1s^1 2p^1 3P) \rightarrow e + He(1s^1 2p^1 1P)$

```
b0 -1.799224192385e+01    b1  5.839648278021e-03    b2 -1.939973920965e-01
b3  5.349246643243e-02    b4 -1.150308510199e-02    b5  1.759192625459e-03
b6 -1.689530419550e-04    b7  8.909865872231e-06    b8 -1.951982101314e-07
 Tmin 1.00e-01   <sv>(Tmin) 1.76e-09   <sv>max 1.53e-08   Error 4.25e-06
```

Reaction 2.3.5a $e + He(1s^1 2s^1 1S) \rightarrow e + He(1s^1 2p^1 1P)$

```
b0 -1.421481564800e+01    b1  9.816324588875e-01    b2 -3.700239299608e-01
b3  9.320731611434e-02    b4 -2.517642644099e-02    b5  4.899403741414e-03
b6 -5.506956047085e-04    b7  3.192647759391e-05    b8 -7.407861678228e-07
 Tmin 1.00e-01   <sv>(Tmin) 1.01e-09   <sv>max 1.78e-06   Error 7.22e-05
```

Reaction 2.3.5b $e + He(1s^12s^13S) \rightarrow e + He(1s^12p^13P)$

```
b0 -1.524234054303e+01    b1  1.457459036199e+00    b2 -6.089961105515e-01
b3  1.908341260995e-01    b4 -4.902955652013e-02    b5  8.357212748265e-03
b6 -8.436990703093e-04    b7  4.535984449474e-05    b8 -9.983744250475e-07
 Tmin 1.00e-01    <sv>(Tmin) 3.98e-12    <sv>max 1.15e-06    Error 1.38e-04
```

Reaction 2.3.6a $e + He(1s^1 2s^1 1S) \rightarrow e + He(1s^1 3p^1 1P)$

```
b0 -2.012491737344e+01    b1  2.975868118455e+00    b2 -1.241263834768e+00
b3  4.133514681102e-01    b4 -1.015874512196e-01    b5  1.570108000623e-02
b6 -1.424919814936e-03    b7  6.934961916285e-05    b8 -1.396714673826e-06
 Tmin 3.16e-01   <sv>(Tmin) 4.88e-12   <sv>max 7.94e-08   Error 9.99e-06
```

Reaction 2.3.6b $e + He(1s^12s^13S) \rightarrow e + He(1s^13p^13P)$

```
b0 -2.168967273514e+01    b1  3.469927386366e+00    b2 -1.500284971036e+00
b3  4.514495446931e-01    b4 -9.830380729357e-02    b5  1.412098625701e-02
b6 -1.235528152366e-03    b7  5.912904162725e-05    b8 -1.182410155429e-06
 Tmin 3.98e-01   <sv>(Tmin) 2.79e-12   <sv>max 1.86e-08   Error 2.22e-05
```

Reaction 2.3.7a $e + He(1s^1 2p^1 1P) \rightarrow e + He(1s^1 3d^1 1D)$

```
b0 -1.685934192513e+01    b1  2.084943159821e+00    b2 -8.554198255397e-01
b3  2.987507152419e-01    b4 -8.260619461169e-02    b5  1.427561766421e-02
b6 -1.419997912094e-03    b7  7.446342219961e-05    b8 -1.594736923452e-06
 Tmin 1.58e-01    <sv>(Tmin) 2.29e-12    <sv>max 6.12e-07    Error 6.74e-05
```

Reaction 2.3.7b $e + He(1s^12s^13P) \rightarrow e + He(1s^13d^13D)$

```
b0 -1.733661165939e+01    b1  2.317215831044e+00    b2 -9.924882089292e-01
b3  3.415918344358e-01    b4 -9.030135166591e-02    b5  1.508647305121e-02
b6 -1.468232978539e-03    b7  7.588691677324e-05    b8 -1.608841144485e-06
 Tmin 2.00e-01    <sv>(Tmin) 5.66e-12    <sv>max 4.46e-07    Error 6.51e-05
```

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

```
b0 -4.409864886561e+01    b1  2.391596563469e+01    b2 -1.075323019821e+01
b3  3.058038757198e+00    b4 -5.685118909884e-01    b5  6.795391233790e-02
b6 -5.009056101857e-03    b7  2.067236157507e-04    b8 -3.649161410833e-06
 Tmin 3.16e+00    <sv>(Tmin) 1.83e-12    <sv>max 2.46e-08    Error 1.06e-05
```

Reaction 2.3.10a $e + He(1s^12s^11S) \rightarrow e + He^+(1s) + e$

```
b0 -2.043240580802e+01    b1  4.673025479860e+00    b2 -2.068053911581e+00
b3  6.103799741884e-01    b4 -1.268205164080e-01    b5  1.740804412692e-02
b6 -1.474132011694e-03    b7  6.914279610834e-05    b8 -1.368015031384e-06
 Tmin 3.98e-01   <sv>(Tmin) 1.72e-12   <sv>max 2.04e-07   Error 3.70e-05
```

Reaction 2.3.10b $e + He(1s^1 2p^1 1P) \rightarrow e + He^+(1s) + e$

```
b0 -1.946719737710e+01    b1  4.039554859050e+00    b2 -1.792264505398e+00
b3  5.357588980704e-01    b4 -1.142854169815e-01    b5  1.614022386298e-02
b6 -1.401937207088e-03    b7  6.717110442234e-05    b8 -1.352531071210e-06
 Tmin 3.16e-01    <sv>(Tmin) 1.07e-12    <sv>max 2.61e-07    Error 4.96e-05
```

Reaction 2.3.10c $e + He(1s^12s^13S) \rightarrow e + He^+(1s) + e$

```
b0 -2.061635956597e+01    b1  5.212998266179e+00    b2 -2.421560769610e+00
b3  7.237890101587e-01    b4 -1.480837244899e-01    b5  1.981796970055e-02
b6 -1.635383361916e-03    b7  7.495465496705e-05    b8 -1.454005255301e-06
 Tmin 5.01e-01   <sv>(Tmin) 7.17e-12   <sv>max 2.12e-07   Error 2.71e-05
```

Reaction 2.3.10d $e + He(1s^1 2p^1 3P) \rightarrow e + He^+(1s) + e$

```
b0 -1.988624861383e+01    b1  4.310402355871e+00    b2 -1.896654131474e+00
b3  5.547033134672e-01    b4 -1.146241097190e-01    b5  1.568822815337e-02
b6 -1.326558850059e-03    b7  6.217750779265e-05    b8 -1.229838359991e-06
 Tmin 3.98e-01   <sv>(Tmin) 5.08e-12   <sv>max 2.34e-07   Error 3.01e-05
```

Reaction 2.3.12 $e + He(1s^1nl^1\{2S+1\}L) \rightarrow e + He^+(nl) + e$

```
b0 -6.896861656133e+01    b1  4.483212792736e+01    b2 -1.838301143477e+01
b3  4.508647323762e+00    b4 -7.148481765711e-01    b5  7.375319623123e-02
b6 -4.780158615887e-03    b7  1.766513036839e-04    b8 -2.837371604097e-06
 Tmin 7.94e+00    <sv>(Tmin) 7.62e-12    <sv>max 5.15e-09    Error 1.12e-06
```

Reaction 2.3.13 $e + He^+(1s) \rightarrow He(1s^1nl^1\{2S+1\}L) + h\nu$
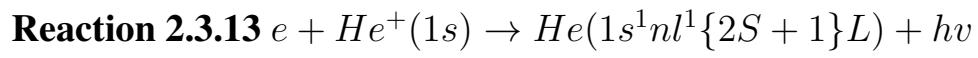
See text for analytic formulas.

Reaction 2.3.14 $e + He^+(1s) \rightarrow e + He^+(2p)$

```
b0 -5.731132225657e+01    b1  3.618757468205e+01    b2 -1.568012557533e+01
b3  4.060438624043e+00    b4 -6.700744538238e-01    b5  7.100638013026e-02
b6 -4.682434354620e-03    b7  1.749898327054e-04    b8 -2.831521166310e-06
 Tmin 5.01e+00    <sv>(Tmin) 2.96e-12    <sv>max 1.37e-08    Error 1.24e-06
```

Reaction 2.3.15 $e + He^+(1s) \rightarrow e + He^+(2s)$

```
b0 -5.754975783112e+01    b1  3.459060731107e+01    b2 -1.462527320845e+01
b3  3.680688204381e+00    b4 -5.969493660071e-01    b5  6.279719136636e-02
b6 -4.138222038101e-03    b7  1.551309719300e-04    b8 -2.522897333444e-06
 Tmin 6.31e+00    <sv>(Tmin) 4.41e-12    <sv>max 1.23e-09    Error 1.19e-06
```

Reaction 2.3.19 $e + He^+(1s) \rightarrow e + He^{++} + e$

```
b0 -6.871040990212e+01    b1  4.393347632635e+01    b2 -1.848066993568e+01
b3  4.701626486759e+00    b4 -7.692466334492e-01    b5  8.113042097303e-02
b6 -5.324020628287e-03    b7  1.975705312221e-04    b8 -3.165581065665e-06
 Tmin 7.94e+00   <sv>(Tmin) 2.62e-12   <sv>max 4.01e-09   Error 1.04e-06
```

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

added by DR: single parameter Maxwellian rate coeff., vs. T_p, for neutral target at rest, obtained from corresponding 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 asymptotics.

```
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
```

Reaction 3.2.3 $p + H_2(v = 0) \rightarrow H(1s) + H_2^+$

Note: Ground state H2 only.
added by DR: single parameter Maxwellian rate coeff., vs. T_p, for neutral target at rest, obtained from corresponding 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 asymptotics.

```
b0 -2.440996809955E+01     b1  2.552627389749E+00     b2 -2.608194219039E+00
b3  1.347571390219E+00     b4 -3.646182244708E-01     b5  5.938400660590E-02,
b6 -5.795480327782E-03     b7  3.075899232458E-04     b8 -6.769294455276E-06,
```

Reaction 7.1.1 $e + H^- \rightarrow e + H(1s) + e$

```
b0 -1.801849334273e+01    b1  2.360852208681e+00    b2 -2.827443061704e-01
b3  1.623316639567e-02    b4 -3.365012031363e-02    b5  1.178329782711e-02
b6 -1.656194699504e-03    b7  1.068275202678e-04    b8 -2.631285809207e-06
 Tmin 1.26e-01   <sv>(Tmin) 7.72e-12   <sv>max 9.73e-07   Error 3.51e-03
```

Reaction 7.1.2 $e + H^- \rightarrow e + H^+ + 2e$

```
b0 -3.637051952368e+01     b1  1.586803736621e+01     b2 -6.478287148158e+00
b3  1.735140500106e+00     b4 -3.233529702765e-01     b5  4.020531565638e-02
b6 -3.114827827749e-03     b7  1.347768741748e-04     b8 -2.478586915713e-06
 Tmin 2.51e+00   <sv>(Tmin) 4.61e-12   <sv>max 2.15e-08   Error 3.47e-06
```

3 H.3 DOUBLE POLYNOMIAL FITS FOR $< \sigma v >$

Reaction 3.1.1 $p + H(1s) \rightarrow p + H(2p)$

E Index T Index	0	1	2
0	-6.261494333673e+01	1.976921673516e+01	-4.770700042332e+00
1	2.417692686638e+01	-1.641857278453e+01	5.395012240434e+00
2	-4.051480211975e+00	4.191026443943e+00	-2.252096048936e+00
3	-1.318153914548e+00	1.189223903948e-01	4.211072262111e-01
4	7.528061358848e-01	-2.607978652180e-01	-2.386725153241e-02
5	-1.498666287447e-01	5.494605745283e-02	-3.642074979445e-03
6	1.512983951035e-02	-5.414151972843e-03	6.902343394169e-04
7	-7.735934229437e-04	2.658505260322e-04	-4.272194199546e-05
8	1.590699544686e-05	-5.245923671227e-06	9.478841315945e-07

E Index T Index	3	4	5
0	1.033248569152e+00	-2.868779139503e-01	6.404381294137e-02
1	-1.414868849757e+00	3.184423304843e-01	-4.982800665252e-02
2	7.292508717933e-01	-1.433443925906e-01	1.696153624540e-02
3	-1.843635318950e-01	3.265971640208e-02	-2.763613623053e-03
4	2.201347577554e-02	-3.551163806974e-03	2.007525885427e-04
5	-5.612540938735e-04	4.481699611261e-05	2.535074888925e-06
6	-1.334876998570e-04	2.919499398918e-05	-1.991423479045e-06
7	1.298404615938e-05	-2.701941401993e-06	1.791270932567e-07
8	-3.581309543014e-07	7.633070244335e-08	-5.593302645030e-09

E Index T Index	6	7	8
0	-8.140654835343e-03	5.192124519721e-04	-1.297112781664e-05
1	4.662131405403e-03	-2.320827027679e-04	4.724538772162e-06
2	-1.171374695689e-03	4.320048440550e-05	-6.523542632649e-07
3	9.516447719628e-05	4.017247431177e-07	-7.031689068197e-08
4	2.320428113156e-06	-6.344720465694e-07	1.688277259644e-08
5	8.398201633252e-08	-4.021594027671e-08	1.420992975620e-09
6	-1.026348613432e-07	1.519024137139e-08	-3.851106645960e-10
7	5.539305326395e-09	-8.915090538633e-10	1.877667458640e-11
8	-8.712370707504e-12	1.172349575278e-11	-1.236556517200e-13

Error 4.08e-03 (D)

Reaction 3.1.2 $p + H(1s) \rightarrow p + H(2s)$

```
   E Index          0                     1                     2
T Index
   0       -3.303672309056e+01   5.435398491796e-02  -4.479069874895e-01
   1        8.129573868895e-02  -1.573070446304e-01  -2.343645075304e-01
   2       -1.367357596276e+00   1.264162602757e-01   9.132454530131e-02
   3        2.430769064611e-01  -4.277967668065e-03   4.379389784137e-02
   4        1.762729645847e-01  -1.171278439692e-02  -2.284640793483e-02
   5       -6.257579731175e-02   3.045403958595e-03   4.069924950563e-03
   6        8.093824710704e-03  -3.259338404156e-04  -3.654555742323e-04
   7       -4.766590709264e-04   1.630335031310e-05   1.697015649467e-05
   8        1.073880975629e-05  -3.135178689449e-07  -3.290603109143e-07

   E Index          3                     4                     5
T Index
   0       -6.207816515028e-02   4.982680171938e-02   2.631060067396e-03
   1        4.641882710210e-02   7.584683292302e-03  -1.878798454594e-03
   2       -2.504726147521e-02   3.623287819690e-03  -5.425414507567e-04
   3       -3.802802560195e-03  -4.458407685510e-03   1.053772036026e-03
   4        4.085275116537e-03   6.304577672385e-04  -2.393639075300e-04
   5       -8.856894051785e-04   6.116944101767e-05   8.195766073173e-06
   6        8.857371143951e-05  -1.967353079496e-05   2.374701722762e-06
   7       -4.353073546873e-06   1.500381004201e-06  -2.478107830550e-07
   8        8.576165925108e-08  -3.781894053698e-08   6.945366389669e-09

   E Index          6                     7                     8
T Index
   0       -2.180659228486e-03   2.245818225902e-04  -7.072385408498e-06
   1        2.999568075912e-05   1.180308123781e-05  -5.753191579259e-07
   2        7.217756265772e-05  -5.369814852090e-06   1.555461051039e-07
   3       -8.298313802105e-05   1.948415887525e-06   1.941860942555e-08
   4        2.472786370494e-05  -1.023360259850e-06   1.277393659635e-08
   5       -2.180680441264e-06   1.728454123757e-07  -4.691407260680e-09
   6       -3.745411947057e-08  -1.145030836069e-08   5.454860678474e-10
   7        1.282096306376e-08   2.790689700798e-10  -2.878902181247e-11
   8       -4.240491240271e-10  -1.382267062457e-12   6.143782726250e-13

   Error  4.49e-03 (D)
```

Reaction 3.1.3 $p + H(2s) \rightarrow p + H(2p)$

```
   E Index          0                  1                  2
 T Index
    0      -9.990724901145e+00  5.351348305631e-01  4.939529241653e-02
    1       6.537727443011e-01 -5.280296904194e-01  6.425969893761e-02
    2      -1.241140027113e-01  2.060077489360e-01 -7.862588561762e-02
    3       7.149154773117e-03 -4.485819636159e-02  2.658545734784e-02
    4      -5.339018890395e-03  6.460674060103e-03 -3.577827264905e-03
    5       1.800856199793e-03 -6.601657449132e-04  8.937792817252e-05
    6      -2.467032039166e-04  4.579703537623e-05  2.480990637873e-05
    7       1.545051869941e-05 -1.863242109937e-06 -2.397125514853e-06
    8      -3.690040224068e-07  3.246974149460e-08  6.587817957450e-08

   E Index          3                  4                  5
 T Index
    0      -5.106541840021e-02 -1.828656123929e-03  3.278050583806e-03
    1       3.146872034794e-02 -7.747008551462e-03 -2.009436212555e-05
    2      -1.590857166173e-03  6.697068316092e-03 -1.587286144423e-03
    3      -2.091225617309e-03 -1.807442248515e-03  5.583369851577e-04
    4       6.191341147148e-04  1.098333544712e-04 -5.443789910797e-05
    5      -1.018025884107e-04  3.338304419913e-05 -3.089670487553e-06
    6       1.151440883472e-05 -6.871587246464e-06  8.975741200024e-07
    7      -7.605187577154e-07  4.906237903385e-07 -5.574178438230e-08
    8       2.067476350932e-08 -1.254526895853e-08  1.104305607237e-09

   E Index          6                  7                  8
 T Index
    0      -5.540100092190e-04  3.801593003417e-05 -9.608738344988e-07
    1       1.517188390097e-04 -1.513420504861e-05  4.584486596613e-07
    2       1.684564123048e-04 -8.692146674273e-06  1.773890443608e-07
    3      -6.883882904255e-05  4.004504488417e-06 -9.090763486841e-08
    4       7.663155026086e-06 -4.749223957327e-07  1.111022258304e-08
    5      -7.483785818283e-08  2.292140559850e-08 -8.177571335015e-10
    6      -1.732595885303e-08 -3.335002305887e-09  1.547780692175e-10
    7      -1.171822397960e-09  4.663773505803e-10 -1.825227169097e-11
    8       1.095408126793e-10 -1.896445830085e-11  6.805323199305e-13

   Error  1.02e-03 (C)
```

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

```
   E Index          0                      1                      2
 T Index
    0      -1.617454916209e+02   1.767238902030e+01  -4.334843983767e+01
    1       1.021458246570e+02  -7.102574692619e+01   3.855259623260e+01
    2      -5.712267930902e+01   4.246688953154e+01  -1.316883030631e+01
    3       2.140540272484e+01  -1.128638171243e+01   2.145592145856e+00
    4      -4.767517412803e+00   1.661679851896e+00  -1.467281287038e-01
    5       6.293295208376e-01  -1.476754423056e-01  -2.915256218527e-03
    6      -4.858173640838e-02   8.175790218529e-03   1.092542891192e-03
    7       2.031177914273e-03  -2.732531913524e-04  -6.205102802216e-05
    8      -3.557982934756e-05   4.398387454014e-06   1.158798945435e-06

   E Index          3                      4                      5
 T Index
    0       2.464254915383e+01  -5.439093405254e+00   5.959975304236e-01
    1      -1.283426276878e+01   2.357085001656e+00  -2.391382925527e-01
    2       2.369698902002e+00  -2.961732508220e-01   2.789277301925e-02
    3      -1.506665823159e-01  -9.917174972226e-04   8.562387824450e-05
    4      -8.144926683660e-03   1.935894665907e-03  -1.340759667335e-04
    5       2.231505500086e-03  -1.679264493005e-05  -5.927455645560e-06
    6      -2.210941355372e-04   5.532386419162e-08   5.820264508685e-07
    7       1.310924337643e-05  -1.121430499351e-06   7.694068657107e-08
    8      -3.431837053957e-07   5.960280736984e-08  -4.972708712807e-09

   E Index          6                      7                      8
 T Index
    0      -3.361958123977e-02   8.706597041685e-04  -6.359765062372e-06
    1       1.289667246580e-02  -3.140899683782e-04   1.742836004704e-06
    2      -1.858739201548e-03   7.343984485463e-05  -1.235536456998e-06
    3       9.235982885753e-05  -8.601564864429e-06   2.257852760280e-07
    4       9.875232214392e-06  -6.467790579320e-07   1.608335682237e-08
    5      -1.680823118052e-06   1.734797315767e-07  -3.855914336143e-09
    6       3.019916624608e-08   2.523651535182e-09  -3.556222618473e-10
    7       6.889325889968e-09  -1.719633613108e-09   7.627265694554e-11
    8      -3.171970185702e-10   7.332933714195e-11  -2.960493966948e-12

   Error  2.51e-03 (C)
```

Reaction 3.1.8 $p + H(1s) \to H(1s) + p$

original fit from Springer book replaced by this one, which has better consistency with cross-section, hence: better energy conservation

```
        E-Index:      0                      1                      2
T-Index:
      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

        E-Index:      3                      4                      5
T-Index:
      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

        E-Index:      6                      7                      8
T-Index:
      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 %
```

Reaction 3.1.9 $p + H(1s) \rightarrow H(2p) + p$

```
   E Index         0                      1                      2
 T Index
    0      -7.537230406957e+01   4.362515351094e+01  -1.318797741915e+01
    1       5.056939990348e+01  -4.322632990301e+01   1.243803991192e+01
    2      -2.304556023867e+01   1.808673367993e+01  -5.041889107660e+00
    3       5.946693576057e+00  -4.192991836651e+00   1.150647211570e+00
    4      -9.025227545139e-01   5.941171802341e-01  -1.616667927236e-01
    5       8.062506740891e-02  -5.340479630862e-02   1.424698941315e-02
    6      -3.996458180607e-03   3.028277898563e-03  -7.611581001083e-04
    7       9.092787501258e-05  -1.009830499229e-04   2.216348373380e-05
    8      -4.227552753922e-07   1.538300832396e-06  -2.615703495579e-07

   E Index         3                      4                      5
 T Index
    0       3.884832686395e-01   6.956399122965e-01  -1.768051294154e-01
    1      -6.391999122917e-01  -4.102677587957e-01   1.022299957977e-01
    2       4.302521809170e-01   6.674825725277e-02  -1.905495347022e-02
    3      -1.437283377093e-01   4.745169406603e-03   8.000515536149e-04
    4       2.533878850824e-02  -2.550521752939e-03   1.202073413278e-04
    5      -2.271818162002e-03   2.517099528196e-04  -1.115096374756e-05
    6       7.750647375638e-05  -3.466368199953e-06   1.352159519053e-07
    7       1.503739282859e-06  -7.169612925965e-07  -3.978675907993e-09
    8      -1.204847091978e-07   2.957975348352e-08   7.777167529587e-10

   E Index         6                      7                      8
 T Index
    0       1.957698184804e-02  -1.056851602712e-03   2.265661905063e-05
    1      -1.064957247532e-02   5.395365812293e-04  -1.089046627301e-05
    2       1.819440410123e-03  -8.006107003062e-05   1.352840661769e-06
    3      -9.926992183313e-05   4.294899850373e-06  -6.488121891471e-08
    4       6.513242953616e-06  -1.107878363495e-06   3.840860903452e-08
    5      -1.478504972220e-06   2.121938496244e-07  -7.452662892489e-09
    6       1.959691983490e-08  -4.994907944039e-09   2.384601530335e-10
    7       1.365715388161e-08  -1.203216169780e-09   3.140684652583e-11
    8      -6.927312822621e-10   6.265289730204e-11  -1.756983474278e-12

   Error  2.14e-03 (C)
```

Reaction 3.1.10 $p + H(1s) \rightarrow H(2s) + p$

```
  E Index          0                    1                    2
T Index
   0      -9.454040572046e+01   3.575745803548e+01  -1.510443829941e+01
   1       6.768817040733e+01  -5.227279271076e+01   1.701370184857e+01
   2      -3.843706771660e+01   2.980450196644e+01  -8.131009677919e+00
   3       1.385221298623e+01  -9.039653668981e+00   2.086424489113e+00
   4      -3.117564250516e+00   1.631432036287e+00  -3.080742439399e-01
   5       4.327242290244e-01  -1.819412845040e-01   2.620862225175e-02
   6      -3.575580797373e-02   1.236067989017e-02  -1.200955067032e-03
   7       1.606326046639e-03  -4.707337881721e-04   2.380595128998e-05
   8      -3.014539201968e-05   7.726558074630e-06  -5.572946409399e-08

  E Index          3                    4                    5
T Index
   0       4.295083359171e+00  -5.229601897556e-01  -7.946315775931e-03
   1      -3.003110377892e+00   3.010370634031e-01  -1.508174268564e-02
   2       9.231651795395e-01  -3.487948145308e-02   1.651938581961e-03
   3      -1.650992173822e-01  -7.573668823425e-03   1.643120830451e-03
   4       1.839941901217e-02   1.873700049273e-03  -3.898508080526e-04
   5      -1.170843781709e-03  -7.837602630428e-05   1.901716727239e-05
   6       2.536771557591e-05  -8.991629432058e-06   1.917169241407e-06
   7       1.205300240917e-06   8.541173405977e-07  -2.062752779297e-07
   8      -5.817548248007e-08  -1.874443584825e-08   4.932865323528e-09

  E Index          6                    7                    8
T Index
   0       7.914390432835e-03  -6.838905496435e-04   1.882232072017e-05
   1       5.550437127230e-05   2.964326783525e-05  -9.736741374779e-07
   2      -6.142591967279e-04   6.119831154619e-05  -1.838162822528e-06
   3      -7.419534566620e-06  -7.945476516010e-06   3.130407892340e-07
   4       2.719285839940e-05  -8.813515513714e-07   1.079647425709e-08
   5      -2.516543465515e-06   1.865515247748e-07  -5.301524876773e-09
   6      -7.319251234821e-08  -5.372098865883e-09   3.196679636762e-10
   7       1.560273243360e-08  -3.793947135803e-10  -2.054614693679e-12
   8      -4.284893236218e-10   1.548062509417e-11  -1.558508528883e-13

  Error  2.70e-03 (C)
```

Reaction 3.1.11a $p + H(n=2) \rightarrow H(n=2) + p$

```
 E Index          0                    1                    2
T Index
   0       -1.719825327366e+01   1.884984890020e-01   6.897051389182e-02
   1        2.142580064300e-01  -9.872388055616e-02  -3.940258746400e-03
   2        5.168472844325e-02   6.212920647036e-03  -9.888896994201e-03
   3       -1.048694623894e-02   6.029698215976e-03   1.504715422531e-03
   4       -1.391648927155e-03  -9.288450680283e-04   5.238686379254e-04
   5        1.062236858414e-03  -1.207901919277e-04  -1.467630362018e-04
   6       -1.941489579494e-04   3.746697774137e-05   1.105904477472e-05
   7        1.443503540040e-05  -3.003621079325e-06  -1.018783959628e-07
   8       -3.830825345601e-07   8.083955156001e-08  -1.150674668496e-08

 E Index          3                    4                    5
T Index
   0       -1.572342769599e-02  -3.026782383076e-03   2.133841357975e-03
   1        7.386092651403e-03  -2.707096061380e-04  -3.315460371996e-04
   2       -1.514031260298e-04   7.422527656251e-04  -9.788494576192e-05
   3       -1.084990452398e-03  -2.534332965992e-05   6.638160972083e-05
   4        1.397189710440e-04  -6.198909026340e-05   4.565982508704e-07
   5        2.978558026688e-05   1.074474230594e-05  -2.854550682552e-06
   6       -7.191352563366e-06  -2.116398505416e-07   3.026311807218e-07
   7        5.019583257618e-07  -5.860162734729e-08  -4.086656000107e-09
   8       -1.160924102260e-08   3.001361914394e-09  -3.647228557972e-10

 E Index          6                    7                    8
T Index
   0       -3.794323219371e-04   2.766697866894e-05  -7.245291602834e-07
   1        6.222275341197e-05  -4.353916183620e-06   1.095768172868e-07
   2       -1.538008374846e-06   8.506156759757e-07  -3.579248331944e-08
   3       -1.070825967335e-05   6.727768972585e-07  -1.517922643230e-08
   4        1.624804729003e-06  -1.835711031271e-07   6.039716625198e-09
   5        1.266431527284e-07   1.074561840233e-08  -7.130630889442e-10
   6       -2.451278913609e-08  -4.162807697535e-10   6.485611244670e-11
   7        4.087633684476e-11   1.064004947231e-10  -5.907545942925e-12
   8        5.848501246633e-11  -6.316916199588e-12   2.360870657000e-13

   Error  5.81e-04 (B)
```

Reaction 3.1.11b $p + H(n = 3) \rightarrow H(n = 3) + p$

```
  E Index          0                    1                    2
T Index
   0       -1.564176694793e+01  1.700998335355e-01  4.947885926277e-02
   1        2.232010663420e-01 -1.049739713449e-01 -2.908751470450e-03
   2        5.316235880113e-02  7.036341129098e-03 -1.117747362624e-02
   3       -4.935673795010e-03  6.200377256109e-03  1.303552526033e-03
   4       -1.741592426003e-03 -1.023534361944e-03  6.993209254704e-04
   5        4.843336390075e-04 -1.026575078128e-04 -1.690721678970e-04
   6       -4.393060568249e-05  3.646643689823e-05  1.129769317091e-05
   7        1.066531598161e-06 -3.043044894680e-06  2.706113202831e-09
   8        2.083548419270e-08  8.441512078238e-08 -1.618789305180e-08


  E Index          3                    4                    5
T Index
   0        3.480696525110e-03 -2.016588092927e-03 -2.304544529246e-04
   1        7.235971573222e-03 -4.237602215706e-04 -2.525856005478e-04
   2       -2.219063125013e-04  8.910349218491e-04 -1.240905152629e-04
   3       -1.007225809037e-03 -5.690437985817e-06  5.076337989874e-05
   4        1.326302857329e-04 -8.434009637807e-05  6.519707374655e-06
   5        2.567668892391e-05  1.430883419261e-05 -3.208617580385e-06
   6       -6.607411884531e-06 -3.382705306787e-07  2.749197577537e-07
   7        4.871162221333e-07 -6.897801542295e-08 -1.416282255917e-09
   8       -1.204005789548e-08  3.636288208820e-09 -4.076090686778e-10


  E Index          6                    7                    8
T Index
   0        1.218034746095e-04 -1.302517417161e-05  4.404350923087e-07
   1        4.862602710052e-05 -3.343139362692e-06  8.182936615708e-08
   2       -2.780251764272e-07  8.939610410070e-07 -3.949474200870e-08
   3       -7.792361018067e-06  4.473546907095e-07 -8.802476545107e-09
   4        9.878685208347e-07 -1.545621666271e-07  5.588732113261e-09
   5        9.561811139849e-08  1.702219787538e-08 -9.641507489238e-10
   6       -1.646787390856e-08 -1.115049016888e-09  8.683886799640e-11
   7        4.716863630756e-11  8.023274024363e-11 -4.773160877761e-12
   8        3.777088131426e-11 -3.347579230007e-12  1.292746807996e-13


   Error  1.54e-04 (A)
```

Reaction 3.2.1a $p + H_2(j = 0) \rightarrow p + H_2(j'), (j' \geq 2)$

```
   E Index            0                    1                    2
 T Index
    0       -1.931976581025e+01 -1.131727838595e-02  5.564692006285e-02
    1        1.780878236605e-01 -1.304342119382e-01 -2.977647895678e-02
    2       -2.541254437243e-02  2.555760073023e-02 -1.343274859600e-02
    3       -4.673484115780e-02  7.858332235684e-03  3.183062244762e-03
    4       -1.146770335720e-03 -1.657368695811e-03  7.282634108198e-04
    5        2.889570096820e-03 -5.065872411962e-05 -1.009959155222e-04
    6       -5.181754952484e-04  1.639669433305e-05 -2.569913821108e-05
    7        3.889651963743e-05  3.837821202667e-07  4.649279483411e-06
    8       -1.107229000254e-06 -7.670491474577e-08 -1.956375986525e-07

   E Index            3                    4                    5
 T Index
    0        4.612780090544e-02 -2.004969108653e-02 -5.405622666261e-03
    1        2.598050022977e-02  1.347793245045e-03 -2.528774951362e-03
    2       -2.445543192015e-03  2.818570059181e-03 -4.999237741132e-05
    3       -3.596822533950e-03  2.532346636968e-04  4.009000053692e-04
    4        2.613056855048e-04 -2.483817325793e-04  1.398464524064e-07
    5        1.042472672998e-04  2.267800856786e-06 -1.589742168453e-05
    6       -8.619281945578e-06  7.897307131770e-06  8.582336209267e-07
    7       -7.536640398566e-07 -9.405159896274e-07  1.327216559054e-07
    8        6.639899136555e-08  3.236749066622e-08 -9.607318326503e-09

   E Index            6                    7                    8
 T Index
    0        2.191546075602e-03 -2.320194246052e-04  8.008357976190e-06
    1        4.600974334650e-04 -3.107626515638e-05  6.945270043940e-07
    2       -1.748459008343e-04  2.776052578344e-05 -1.206654268341e-06
    3       -9.738076845118e-05  7.572697075882e-06 -1.827758690708e-07
    4        1.815503467330e-05 -2.855321802747e-06  1.239043759009e-07
    5        1.897116878857e-06  9.701076200284e-08 -1.311379859022e-08
    6       -4.399860357799e-07  2.641401745588e-08  9.621252004735e-11
    7        1.171108373785e-08 -1.727778312454e-09  2.797736054220e-11
    8        5.928009302898e-10 -5.140400246008e-13 -1.647139266864e-13

   Error  2.98e-03 (D)
```

Reaction 3.2.1b $p + H_2(j = 1) \rightarrow p + H_2(j'), (j' \geq 3)$

```
  E Index           0                    1                    2
T Index
   0       -1.973243992807e+01  1.247414117614e-01   9.226482332314e-02
   1        1.829696809063e-01 -1.297428942606e-01  -4.048210910881e-02
   2       -3.965576412456e-02  3.618197482242e-02  -9.421328372950e-03
   3       -4.313466950038e-02 -2.291104293914e-03   6.559525504445e-03
   4        9.636266519704e-04 -2.918601086415e-03  -4.932567471708e-04
   5        2.253096845378e-03  1.405510037846e-03  -2.369615891213e-04
   6       -4.356551994020e-04 -2.600932648209e-04   5.724350136902e-05
   7        3.282766964094e-05  2.127068115091e-05  -4.867932845087e-06
   8       -9.076785125326e-07 -6.411159887874e-07   1.475347595640e-07

  E Index           3                    4                    5
T Index
   0       -3.714490319222e-02 -1.356114029701e-02   4.100083713039e-03
   1        2.971894544949e-02  1.876669259108e-03  -3.322968917828e-03
   2       -1.981651027277e-03  1.569164989146e-03  -3.053099313902e-04
   3       -1.090766391534e-03 -4.420842120460e-04   3.568181091302e-04
   4        5.013178555056e-04 -3.266081392759e-05  -3.038322725843e-05
   5       -2.533635465343e-04  4.489607178747e-05  -1.262675526559e-06
   6        5.665115351398e-05 -1.000727087071e-05  -4.278214878688e-07
   7       -5.233684321566e-06  9.078582661039e-07   1.038286804798e-07
   8        1.702995300347e-07 -2.952394683317e-08  -4.770640084428e-09

  E Index           6                    7                    8
T Index
   0       -3.666387513519e-04  1.083946601986e-05   1.351070637014e-08
   1        6.903747113211e-04 -5.754069299179e-05   1.739402046218e-06
   2        1.988204507361e-05  3.731257202030e-07  -6.182586349800e-08
   3       -8.469119247598e-05  8.182865454249e-06  -2.786434350401e-07
   4        8.613590729944e-06 -8.986091403746e-07   3.310895101467e-08
   5        6.220415471942e-07 -1.315998111932e-07   6.286616924397e-09
   6        2.197126754622e-08  1.839451977445e-08  -1.214916175628e-09
   7       -2.062547364677e-08  1.216554321342e-10   5.337970791360e-11
   8        1.119243083769e-09 -5.101049613696e-11  -1.189621855444e-13

  Error  2.05e-03 (C)
```

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Reaction 3.2.2 $p + H_2(v = 0) \rightarrow p + H_2(v > 0)$

E Index	0	1	2
T Index			
0	-2.329087453007e+01	5.834682857859e-01	3.016206818784e-01
1	2.119794074231e+00	-4.707130034299e-01	-1.627052975735e-01
2	4.378420793629e-02	7.098659965089e-02	-1.538726713612e-03
3	-1.212485645824e-01	1.716068200911e-02	1.234418739201e-02
4	-6.784743989202e-05	-3.554071145865e-03	-1.963491271592e-03
5	6.091207437528e-03	-5.334937961855e-04	2.680505429999e-06
6	-1.035395322074e-03	1.771858360014e-04	2.137128521413e-05
7	6.956622116761e-05	-1.519815181883e-05	-1.689036732606e-06
8	-1.714843775518e-06	4.355820063409e-07	4.019682578322e-08

E Index	3	4	5
T Index			
0	2.566603966328e-02	-2.256516571421e-02	-5.628180168021e-04
1	2.772025396684e-02	1.100571275815e-02	-3.271820121481e-03
2	-8.406926164519e-03	-1.645206696492e-03	1.346715958215e-03
3	-3.779824694550e-03	9.007565031801e-04	-2.318342461147e-04
4	1.849557056204e-03	-4.387553829325e-04	4.379338463619e-05
5	-3.000343967886e-04	8.809999443469e-05	-8.221671799210e-06
6	2.287377536516e-05	-8.300877832833e-06	8.352812135871e-07
7	-7.931460846045e-07	3.626282328864e-07	-3.748271128306e-08
8	8.837549978855e-09	-5.713862092713e-09	5.406617870326e-10

E Index	6	7	8
T Index			
0	7.740619846564e-04	-8.045484752448e-05	2.526516293312e-06
1	3.282645173821e-04	-1.405235013910e-05	2.050808638586e-07
2	-2.333687223953e-04	1.660986465802e-05	-4.315116954882e-07
3	3.388077149363e-05	-2.302170766555e-06	5.814386667558e-08
4	-1.679616585635e-06	-5.915996895685e-09	1.292933101414e-09
5	2.043346638977e-07	3.266439560921e-09	3.038024520814e-11
6	-3.882583129136e-08	2.553655884029e-09	-1.293452258893e-10
7	2.558173370326e-09	-2.723495529714e-10	1.327159233871e-11
8	-4.963660570583e-11	7.622204418800e-12	-3.884869166334e-13

Error 3.04e-03 (D)

Error is improved to 8.94e-04 (B) if only values of <sv> for T > 1 eV are considered.

Reaction 3.2.3 $p + H_2 \rightarrow H(1s) + H_2^+$

```
   E Index          0                    1                    2
T Index
   0        -2.393090018673e+01  6.248759475696e-01  4.860672617319e-02
   1         1.497880823202e+00 -1.321184618254e+00  1.610180305377e-01
   2        -1.108848312589e+00  1.026939763848e+00 -2.764437632008e-01
   3         2.723796545755e-01 -3.349189897157e-01  1.525831234833e-01
   4         2.721877464232e-02  4.328258310611e-02 -4.172607648071e-02
   5        -1.779177173774e-02  4.465034873018e-04  6.494173133750e-03
   6         2.547195398346e-03 -6.602886969983e-04 -5.936946344163e-04
   7        -1.581068390892e-04  6.000753124589e-05  2.989789198510e-05
   8         3.720016363224e-06 -1.724843689004e-06 -6.403267693113e-07

   E Index          3                    4                    5
T Index
   0        -1.200688114292e-01  8.087736504737e-03  9.460417081363e-03
   1         1.165310493854e-01 -3.963918450387e-02  4.451468403951e-03
   2        -3.948109106588e-02  3.853676685634e-02 -9.097709483121e-03
   3        -9.592981926094e-03 -1.131614493158e-02  3.519316476081e-03
   4         1.001163900824e-02  3.016020168360e-04 -4.649867654705e-04
   5        -2.726517864643e-03  3.947434451322e-04 -3.560364682888e-06
   6         3.516907384191e-04 -7.253981468239e-05  6.007588925145e-06
   7        -2.210901325776e-05  5.074761954649e-06 -4.890225279817e-07
   8         5.443461456508e-07 -1.285040546716e-07  1.225908917355e-08

   E Index          6                    7                    8
T Index
   0        -2.128651089328e-03  1.685181886244e-04 -4.665309226730e-06
   1        -1.304738719348e-04 -8.714697396102e-06  4.796574269551e-07
   2         1.042066219239e-03 -5.955686719189e-05  1.358749516236e-06
   3        -4.463914380371e-04  2.672110767494e-05 -6.218012239798e-07
   4         7.356430658399e-05 -4.797055206851e-06  1.159195338618e-07
   5        -4.585211534749e-06  4.292978331848e-07 -1.209703556619e-08
   6        -1.866842996766e-08 -2.383240469589e-08  9.353713300206e-10
   7         1.067090708836e-08  1.188959741308e-09 -5.741789281748e-11
   8        -1.967393094286e-10 -3.854014407618e-11  1.748544462760e-12

   Error  7.17e-03 (D)

   Error is improved to 2.24e-03 (C) if only values of <sv> for T > 1 eV are
   considered.
```

Reaction 3.2.4a $p + D_2 \rightarrow D^+ + HD, (\mathbf{or} H + D)$

```
E Index            0                    1                    2
T Index
  0       -2.111896543160e+01 -1.025538356060e-01 -1.465668919808e-01
  1       -6.219092009914e-01  6.936787446352e-02  9.499279319950e-02
  2       -1.215025308696e-01  8.780031887817e-03 -4.821837782776e-03
  3        6.815442586718e-02 -1.525104088494e-02 -7.956267907252e-03
  4        2.752449038333e-03  1.225019378208e-03  1.085462645581e-03
  5       -5.750611656794e-03  1.232968333824e-03  3.447823950790e-04
  6        1.125377790650e-03 -3.422288971501e-04 -1.018650054891e-04
  7       -8.919363340228e-05  3.365851906238e-05  9.449139307317e-06
  8        2.601744783012e-06 -1.162845386047e-06 -3.033572820292e-07


E Index            3                    4                    5
T Index
  0       -1.856546171568e-02  1.365853496631e-02 -3.826961311141e-04
  1       -1.160097875790e-03 -9.106571030308e-03  1.473315037711e-03
  2        4.849238242696e-03  7.525239416510e-04 -7.495029297215e-04
  3        1.124986687656e-03  5.331715821535e-04 -1.190706225054e-04
  4       -6.853757310073e-04 -1.075209684417e-04  9.573379729918e-05
  5       -5.896278139458e-05  3.476245629170e-06 -5.875969746146e-06
  6        4.848804836962e-05 -7.966497740323e-08 -2.512498875224e-06
  7       -6.135496085718e-06  9.456855386541e-08  3.985794665381e-07
  8        2.408475811630e-07 -6.748305167707e-09 -1.666573853398e-08


E Index            6                    7                    8
T Index
  0       -3.727957061966e-04  4.748991519766e-05 -1.698399806385e-06
  1       -1.495473343687e-05 -9.835840608225e-06  4.860991365689e-07
  2        1.403289748223e-04 -1.067949058111e-05  2.955867761367e-07
  3        5.146965646887e-06  3.731108583161e-07 -2.546014093405e-08
  4       -1.739495667153e-05  1.302457212236e-06 -3.566296705821e-08
  5        1.552565062442e-06 -1.430402446135e-07  4.485383482007e-09
  6        4.667259306147e-07 -3.425538256234e-08  9.189075599465e-10
  7       -8.312637284424e-08  6.615368641527e-09 -1.889019472636e-10
  8        3.654557715832e-09 -2.995367307547e-10  8.734664246336e-12


  Error  7.28e-03 (D)
```

Error is improved to 6.67e-04 (B) if only values of <sv> for T > 1 eV are considered.

Reaction 3.2.4b $p + D_2 \rightarrow D + HD^+$

```
  E Index           0                    1                    2
T Index
   0       -2.529005922309e+01   3.371688551898e-01   4.693918630510e-02
   1        1.881570344354e+00  -5.113434583372e-01  -5.273216405018e-02
   2       -8.814004836556e-01   2.968842541690e-01   3.441039128935e-02
   3        1.691850902103e-01  -8.619057072559e-02  -5.980460778885e-02
   4       -6.652054410222e-02   1.093768968050e-02   5.059893495850e-02
   5        2.240305503202e-02   2.436569548502e-04  -1.818236207409e-02
   6       -3.819487238341e-03  -2.196174841406e-04   3.110816934408e-03
   7        3.069356789436e-04   2.140188150215e-05  -2.512796010299e-04
   8       -9.328627869191e-06  -6.680477536797e-07   7.694384931049e-06


  E Index           3                    4                    5
T Index
   0        1.384303400933e-02   2.197297492088e-02  -5.238094233772e-03
   1       -5.260928525467e-02  -1.183131187811e-02   1.230475793211e-02
   2        1.331208476230e-02  -6.086729631519e-03  -3.440498761785e-03
   3        2.992464843607e-02   6.494689656712e-03  -5.095348269685e-03
   4       -2.273638325874e-02  -4.060667412372e-03   4.212401093393e-03
   5        6.836786141131e-03   1.468739824255e-03  -1.329242365115e-03
   6       -1.028059797546e-03  -2.651119233481e-04   2.067742478703e-04
   7        7.612976218275e-05   2.242650259038e-05  -1.567120609980e-05
   8       -2.199089655518e-06  -7.103958561240e-07   4.597541185577e-07


  E Index           6                    7                    8
T Index
   0       -2.589041456721e-03   5.971878512503e-04  -2.960695486568e-05
   1        2.243312170048e-04  -5.598084624364e-04   4.754533831647e-05
   2        8.268141028700e-04   3.941921240841e-05  -1.101845343079e-05
   3        9.066019513957e-04  -6.629895278703e-05   2.061740481891e-06
   4       -9.043842324620e-04   7.471396669600e-05  -1.946743502969e-06
   5        2.869803101647e-04  -2.489904593762e-05   7.165571176206e-07
   6       -4.325324514439e-05   3.772514035078e-06  -1.135486249420e-07
   7        3.158371725991e-06  -2.722540885633e-07   8.321982058577e-09
   8       -8.960027960892e-08   7.591855363103e-09  -2.323959696375e-10


  Error  1.18e-04 (A)


  <sv> < 1.0e-11 for E > 100 eV for the entire T range considered here.  The
  fit gives unphysical values for E > 100 eV in this range and should not be
  used there.
```

Reaction 3.2.5 $p + H_2 \rightarrow p + H_2^+(v) + e, (v \leq 9)$

```
   E Index          0                     1                     2
 T Index
    0       -5.367225610927e+01   8.561616047237e+00   1.816558609991e+00
    1        1.788157706832e+01  -6.286008716933e+00  -1.245074165012e+00
    2       -4.732013902744e+00   1.828154334899e+00   2.297272982398e-01
    3        5.202644682964e-01  -2.797342414213e-01   3.359419100500e-02
    4        3.521809500536e-02   3.001478994199e-02  -2.022030104793e-02
    5       -1.648514003195e-02  -3.511706068001e-03   3.466696529491e-03
    6        1.922206340707e-03   3.867557051749e-04  -2.971236668059e-04
    7       -1.035405866079e-04  -2.470578459133e-05   1.298468816782e-05
    8        2.203112678635e-06   6.255426859518e-07  -2.312060025019e-07

   E Index          3                     4                     5
 T Index
    0       -1.522333614377e+00   3.759529679375e-01  -4.786079082066e-02
    1        1.069094789286e+00  -2.542196973682e-01   3.177817178124e-02
    2       -2.574312651499e-01   6.235010781304e-02  -7.498165815343e-03
    3        1.396148560079e-02  -5.455674772716e-03   7.627828208046e-04
    4        4.167002536339e-03  -2.961138095159e-04  -1.989496685088e-05
    5       -7.713464611496e-04   9.296859682627e-05  -4.390690629457e-06
    6        4.630325714231e-05  -6.209296988115e-06   7.802446823898e-07
    7       -5.951650262538e-07   1.040160519423e-07  -6.013540281517e-08
    8       -2.277567397969e-08   2.205724295105e-09   1.764776882153e-09

   E Index          6                     7                     8
 T Index
    0        3.386576601010e-03  -1.260406274176e-04   1.909653870707e-06
    1       -2.284002706788e-03   9.015781280225e-05  -1.528190392357e-06
    2        4.874507232153e-04  -1.603249117471e-05   2.009004806425e-07
    3       -4.735379021213e-05   9.681751756528e-07   9.137775800355e-09
    4        5.017190961057e-06  -3.312351285579e-07   7.657715805259e-09
    5       -5.449234862617e-07   8.306829849916e-08  -3.008901804950e-09
    6       -9.036886465169e-09  -6.038768586675e-09   3.127724512237e-10
    7        5.701208151560e-09  -2.749357161379e-12  -1.065774817217e-11
    8       -2.564871978479e-10   9.360384058829e-12   2.125011883790e-14

   Error  7.60e-05 (A)
```

Reaction 3.2.6 $p + H_2^+(v) \rightarrow p + H(1s) + H^+$

```
  E Index           0                     1                     2
T Index
    0     -3.503949588630e+01   3.596223868947e-03   5.850451146780e-01
    1      3.056567004229e+00   3.101537521281e-01  -3.802213472822e-01
    2      6.995656851497e-01  -1.714310765924e-01   4.075164360191e-02
    3     -2.282773440449e-01   2.456336476294e-02   2.462515616912e-02
    4      2.032409655024e-02   4.693764706073e-03  -8.013907630788e-03
    5      7.333965699110e-04  -2.072064243724e-03   9.248040165878e-04
    6     -3.031298255102e-04   2.853271682462e-04  -4.190818382811e-05
    7      2.353662179363e-05  -1.783778591788e-05   1.188782788257e-07
    8     -6.209682283669e-07   4.280148575920e-07   2.898023610900e-08

  E Index           3                     4                     5
T Index
    0      9.474524219612e-02  -3.938575923140e-02   4.666084706751e-03
    1     -4.164890965970e-02   3.732884150575e-02  -5.553031214904e-03
    2      6.345887908944e-04  -7.388540130210e-03   2.215252505302e-03
    3     -1.163184524936e-03  -8.552780029379e-04  -6.842088086239e-05
    4      9.714618199968e-04   3.399582328819e-04  -7.945188972850e-05
    5     -1.686569365114e-04  -1.260646704530e-05   9.272036136361e-06
    6      9.494328352046e-06  -3.548328747232e-06   3.006199198249e-07
    7      3.338996422125e-08   3.705771699362e-07  -8.431446572047e-08
    8     -1.257918518905e-08  -1.036436256550e-08   3.078907880655e-09

  E Index           6                     7                     8
T Index
    0     -3.236705187942e-04   1.538536999072e-05  -3.695652391342e-07
    1      2.646628484405e-04   3.287941538949e-06  -4.204509688663e-07
    2     -2.704279067013e-04   1.508871496609e-05  -3.179547222229e-07
    3      4.711638356898e-05  -4.822026376406e-06   1.518903664812e-07
    4      4.045609876795e-06   1.545451740861e-07  -1.283734364199e-08
    5     -1.248629759318e-06   6.544957875539e-08  -1.110642504800e-09
    6      3.221166999732e-08  -5.258665703836e-09   1.800452602126e-10
    7      5.927769241279e-09  -5.999414332265e-11  -4.977523706425e-12
    8     -2.953243500461e-10   1.037093087158e-11  -6.464182493927e-14

  Error  4.86e-04 (B)
```

Reaction 3.3.1 $p + He \rightarrow H + He^+$

```
   E Index          0                      1                      2
T Index
   0        -3.353816664129e+01  -4.586784908436e-01   1.594898247008e-01
   1         1.781370892516e+00   6.891694453609e-01  -1.611575823430e-01
   2         6.707672251154e-01  -3.169866636164e-01   7.765165360131e-02
   3        -7.477930071091e-02   3.350898800561e-02  -3.392131794663e-02
   4        -8.381713330773e-02   1.622059625803e-02   1.247636271907e-02
   5         2.694989933554e-02  -5.889292565221e-03  -2.789567626468e-03
   6        -3.290961646690e-03   8.008575628447e-04   3.401335910688e-04
   7         1.824292103062e-04  -5.051648761026e-05  -2.091692923886e-05
   8        -3.841146748130e-06   1.228049521583e-06   5.084397192524e-07


   E Index          3                      4                      5
T Index
   0         1.993834571954e-01  -2.908726266195e-02  -4.587782047584e-03
   1        -1.491282657121e-01   4.812768747296e-02  -3.997981241748e-03
   2         2.652950675220e-02  -2.159277544971e-02   5.139425409123e-03
   3         8.474034802338e-03   2.748759961113e-03  -1.420567682255e-03
   4        -5.507438871028e-03   5.154609993383e-04   1.065291472218e-04
   5         1.293406768681e-03  -2.021983674764e-04   1.031174122595e-05
   6        -1.563868173318e-04   2.528045360094e-05  -1.979594316338e-06
   7         9.545486229202e-06  -1.444453762830e-06   9.506598262937e-08
   8        -2.317334470853e-07   3.187947009859e-08  -1.162138178659e-09


   E Index          6                      7                      8
T Index
   0         1.233562953962e-03  -8.959520538477e-05   2.153885795280e-06
   1        -1.453386884233e-04   3.438904204074e-05  -1.235017420599e-06
   2        -5.776151273370e-04   3.150136684703e-05  -6.720649580897e-07
   3         2.214493222620e-04  -1.503183655470e-05   3.810469912151e-07
   4        -2.770978822291e-05   2.235082592688e-06  -6.269566270205e-08
   5         8.328481121158e-07  -1.256070804240e-07   4.314925565866e-09
   6         5.230582879539e-08   2.635177963503e-09  -1.574479246009e-10
   7        -8.519235005422e-10  -2.264396092848e-10   9.108750391681e-12
   8        -1.347103798052e-10   1.468879806508e-11  -4.188673847162e-13

   Error  1.58e-03 (C)
```

Reaction 3.3.2 $p + He \rightarrow p + He^+ + e$

```
   E Index              0                      1                      2
T Index
      0          -3.513975817234e+01    -5.242917555404e-01    -3.826194904402e-01
      1          -5.385780070980e-01     7.943799641890e-02     1.983252146365e-01
      2           9.035205217957e-01     1.231698104678e-01    -4.512064453109e-02
      3           6.154592887522e-02    -4.082389668808e-02     8.492939132060e-03
      4          -8.683888520960e-02     1.363524072485e-03    -6.877816557895e-04
      5           1.850283102315e-02     1.065556461944e-03    -1.981157465961e-04
      6          -1.829730723913e-03    -1.792886431140e-04     5.180204798722e-05
      7           8.903233974874e-05     1.133222476812e-05    -4.281190983076e-06
      8          -1.723417501407e-06    -2.598637070808e-07     1.212392744890e-07


   E Index              3                      4                      5
T Index
      0           1.749071804038e-01     3.379968769905e-02    -1.684873318946e-02
      1          -2.966737668036e-02    -2.195230807923e-02     7.987671929803e-03
      2          -2.632395045040e-02     9.106381567773e-03    -1.220083366385e-03
      3           4.950008931722e-03    -2.125790233999e-03     2.856685316297e-04
      4           1.539732094359e-03     1.989843795364e-05    -8.201311837293e-05
      5          -5.591852085968e-04     8.588977130038e-05     6.771413834410e-06
      6           6.660694317589e-05    -1.557623357777e-05     6.328328243704e-07
      7          -3.537756092409e-06     1.101685345092e-06    -1.130645655532e-07
      8           7.093957802151e-08    -2.828418079985e-08     4.145168773820e-09


   E Index              6                      7                      8
T Index
      0           2.235958862320e-03    -1.282599958804e-04     2.760095475019e-06
      1          -1.078408322383e-03     6.664182706070e-05    -1.576989885173e-06
      2           1.013506718990e-04    -5.755496123590e-06     1.585191024717e-07
      3          -1.436171240398e-05     5.512329277872e-08     1.055695620784e-08
      4           1.095726116510e-05    -4.861620705084e-07     5.080813644487e-09
      5          -1.907336915250e-06     1.057876163056e-07    -1.372842995387e-09
      6           7.169146469455e-08    -4.866671700650e-09     1.446148171715e-11
      7           5.780678333429e-09    -2.912824978296e-10     1.171657019875e-11
      8          -3.562927197437e-10     2.049378727457e-11    -5.867221352941e-13


   Error 1.18e-04
```

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

```
 E Index           0                   1                   2
T Index
    0      -2.545206891667e+01  4.087721421944e-01  1.586491378549e-01
    1       2.913542861083e+00 -4.603441740870e-01 -1.538179897348e-01
    2      -2.751712354111e-01  1.679980585979e-01  4.131633234926e-02
    3      -2.633545354224e-02 -1.567302034710e-02 -4.520967162781e-04
    4       8.622940210562e-03 -3.336538128570e-03 -8.260874599039e-04
    5      -2.300706825690e-04  8.171653956449e-04 -4.965497872141e-05
    6      -1.125479569857e-04 -5.470534020950e-05  3.466402080937e-05
    7       1.223862287149e-05  4.510736761276e-07 -3.432193506153e-06
    8      -3.807538916669e-07  4.917383484449e-08  1.058745036988e-07


 E Index           3                   4                   5
T Index
    0       5.058971318815e-02 -3.791312599700e-03 -3.833049897763e-03
    1       5.222489871516e-03  1.003438746972e-02 -1.168850382452e-03
    2      -1.641664176824e-02 -4.107214837202e-03  1.967371773324e-03
    3       3.430116367838e-03  2.838382928506e-04 -4.209650788467e-04
    4      -9.020143604576e-05  1.347016172889e-04 -4.958012853527e-06
    5       1.188821428901e-05 -3.313627492240e-05  8.279160796936e-06
    6      -1.041943673755e-05  3.202234108937e-06 -5.675677716610e-07
    7       1.271716123512e-06 -1.476246727512e-07 -1.066910658350e-08
    8      -4.477991722400e-08  2.709447373704e-09  1.358296626830e-09


 E Index           6                   7                   8
T Index
    0       7.950734542136e-04 -5.885681325041e-05  1.541378919766e-06
    1      -5.579601385349e-05  1.353899796842e-05 -5.122850004231e-07
    2      -2.673125550197e-04  1.566853623054e-05 -3.415999363201e-07
    3       7.898192930901e-05 -5.854327119904e-06  1.562313674827e-07
    4      -4.094959727394e-06  5.353989855247e-07 -1.913396611346e-08
    5      -6.413236333283e-07  4.848646930188e-09  8.121470593220e-10
    6       3.608129963110e-08  5.274666256825e-10 -8.954629500955e-11
    7       4.563092914087e-09 -4.419337156204e-10  1.449959132985e-11
    8      -2.914831320408e-10  2.266195254549e-11 -6.387372749942e-13


  Error  2.14e-04 (A)
```

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

```
 E Index          0                  1                  2
T Index
   0      -3.122938685456e+01  4.028257956860e-01  2.334348862506e-01
   1       4.307517366770e+00 -1.334773437980e-01 -2.727882564258e-01
   2      -2.361736602090e-02 -1.432708434183e-01  1.201423191752e-01
   3      -2.081939800843e-01  9.945616177435e-02 -2.709414076376e-02
   4       4.838048334741e-02 -2.358233412220e-02  4.734052652172e-03
   5      -4.823009462310e-03  2.401135023266e-03 -8.658412840062e-04
   6       1.881322513534e-04 -6.847646462892e-05  1.174757836154e-04
   7       1.638221308510e-06 -4.485862371494e-06 -8.367996886287e-06
   8      -2.228643990360e-07  2.485885176817e-07  2.302713313337e-07

 E Index          3                  4                  5
T Index
   0       9.957171612712e-02 -1.023449426184e-02 -4.496822279877e-03
   1      -6.164153370524e-02  3.370797060231e-02 -3.319571865630e-03
   2       1.135420376951e-02 -1.984294955107e-02  4.774462913892e-03
   3       6.080332812779e-04  3.775623225478e-03 -1.322011971814e-03
   4      -1.366781281246e-03  1.119535101746e-04  8.050305381600e-05
   5       4.843193058320e-04 -1.376705233410e-04  1.437228606346e-05
   6      -7.634853296888e-05  1.971646855797e-05 -2.212285070187e-06
   7       5.557461570216e-06 -1.186541505079e-06  9.199979549866e-08
   8      -1.522032174656e-07  2.678514729721e-08 -6.757808737035e-10

 E Index          6                  7                  8
T Index
   0       9.241247688814e-04 -6.358490712348e-05  1.525433983093e-06
   1      -8.936775061168e-05  2.722213770738e-05 -1.020668178963e-06
   2      -5.033398600438e-04  2.498282187124e-05 -4.741136942425e-07
   3       1.886421813109e-04 -1.237062202523e-05  3.083020170351e-07
   4      -2.071452083937e-05  1.798870106702e-06 -5.365052965492e-08
   5       8.302103147893e-08 -9.892824420452e-08  4.289062541986e-09
   6       7.058025912797e-08  4.738735970150e-09 -2.878639826635e-10
   7       1.761485514114e-09 -6.097061454789e-10  2.321326366521e-11
   8      -2.771866976517e-10  2.928170189987e-11 -8.892938915985e-13

 Error  3.14e-04 (B)
```

Reaction 3.3.7a $p + He(1s^1 2p^1 1P) \rightarrow H(2p) + He^+(1s)$

```
  E Index           0                    1                    2
T Index
   0      -2.096277724233e+01  2.908363629618e-01  1.344210657325e-01
   1       1.838253461492e+00 -3.440722063330e-01 -1.075733974740e-01
   2      -1.504683700198e-01  1.391168674341e-01  1.407833937250e-02
   3      -1.988914332352e-02 -1.827777489629e-02  6.303582937881e-03
   4       5.224868789594e-03 -1.503338958950e-03 -1.588632341093e-03
   5       7.903708169506e-05  6.281421973346e-04 -5.706206467996e-06
   6      -1.088955465421e-04 -5.979073448137e-05  3.124053598819e-05
   7       1.035977420345e-05  2.110596750983e-06 -3.069558569915e-06
   8      -3.067244916001e-07 -1.576601346659e-08  9.145348279705e-08


  E Index           3                    4                    5
T Index
   0       2.643049515080e-02 -5.367852119278e-03 -1.337347909674e-03
   1       1.130230128759e-02  6.583514261893e-03 -1.227749129234e-03
   2      -1.376123125770e-02 -8.644040120194e-04  1.013028508387e-03
   3       2.150624640205e-03 -4.951984366580e-04 -1.010346550533e-04
   4       2.568647734327e-04  1.217005674709e-04 -2.937286287021e-05
   5      -7.591611145466e-05 -1.357219951533e-06  4.933729396290e-06
   6       3.384790316520e-06 -1.821787693981e-06  5.718370339432e-08
   7       2.181939775695e-07  1.762529764553e-07 -4.223388769976e-08
   8      -1.459318779306e-08 -5.010568584481e-09  1.790351359196e-09


  E Index           6                    7                    8
T Index
   0       3.643627994364e-04 -2.927921977642e-05  8.016074291976e-07
   1       4.333172602701e-05  3.531045210401e-06 -2.066151687336e-07
   2      -1.589309518095e-04  1.005180995389e-05 -2.313721814532e-07
   3       3.299776657730e-05 -2.892265994707e-06  8.406596588342e-08
   4       1.370261783588e-06  9.004843536308e-08 -6.389625540292e-09
   5      -7.078827921616e-07  3.342727890413e-08 -3.633168197949e-10
   6       1.974622062662e-08 -1.472504522071e-09  1.736212449338e-11
   7       4.174185414825e-09 -2.207503317650e-10  5.469661760878e-12
   8      -2.233522764425e-10  1.319988966081e-11 -3.154892040215e-13


  Error  1.32e-04 (A)
```

Reaction 3.3.7b $p + He(1s^1 2p^1 3P) \rightarrow H(2p) + He^+(1s)$

```
 E Index            0                      1                      2
T Index
   0      -1.990230529818e+01   2.522093890961e-01   1.239244757420e-01
   1       1.500741968514e+00  -2.951590494714e-01  -9.430103505170e-02
   2      -1.124864006941e-01   1.201976126897e-01   7.788712358907e-03
   3      -1.795417514240e-02  -1.603483373300e-02   7.712444722040e-03
   4       5.194941686189e-03  -1.383721748856e-03  -1.777603361970e-03
   5      -2.042833130770e-04   6.021103147616e-04   2.064037010474e-05
   6      -5.295363277471e-05  -6.246797487185e-05   2.744322340445e-05
   7       6.198420111343e-06   2.646123676389e-06  -2.758240361873e-06
   8      -1.960046743830e-07  -3.649994467826e-08   8.182448832297e-08


 E Index            3                      4                      5
T Index
   0       1.742021976180e-02  -5.521806381035e-03  -4.054669219838e-04
   1       1.218926273762e-02   5.820172532684e-03  -1.295775597112e-03
   2      -1.191866922435e-02  -1.362329499044e-04   7.107218103516e-04
   3       1.549234171092e-03  -6.809505756955e-04   9.404549508879e-07
   4       3.665320868067e-04   1.165229196925e-04  -3.679801125361e-05
   5      -1.010994386303e-04   7.956025749673e-06   3.831718379904e-06
   6       7.717708517072e-06  -3.365265395665e-06   2.479212041233e-07
   7      -1.385756782677e-07   2.808607980980e-07  -5.087249153750e-08
   8      -3.853798064799e-09  -7.625575723278e-09   1.871480566627e-09


 E Index            6                      7                      8
T Index
   0       1.843910580845e-04  -1.594987619980e-05   4.473710134751e-07
   1       7.954619252281e-05   7.572338624031e-08  -1.024950580103e-07
   2      -1.181843011735e-04   7.615476962452e-06  -1.763379176652e-07
   3       1.702222446329e-05  -1.814838357759e-06   5.703526185010e-08
   4       3.068724996897e-06  -5.005474959780e-08  -2.339128601417e-09
   5      -7.153412104701e-07   4.200555361511e-08  -7.453854004436e-10
   6       1.745775447721e-08  -2.506978553877e-09   6.748855851556e-11
   7       3.524103509748e-09  -9.220739545880e-11   5.381508915908e-13
   8      -1.806607060530e-10   7.993276670629e-12  -1.381625354747e-13

 Error  1.18e-04 (A)
```

Reaction 4.2.1 $H_2^+(v) + H(1s) \rightarrow H_2^+(2p\sigma_u) + H(1s) \rightarrow H^+ + H + H(1s), (v = 0 \ldots 9)$

```
    E Index            0                        1                        2
  T Index
     0      -3.332967494942e+02   1.433058540744e+02  -2.947284166509e+01
     1       2.408101998902e+02  -1.362501559544e+02   2.801041076177e+01
     2      -8.996254988743e+01   5.285412858800e+01  -1.040643658208e+01
     3       2.113931204200e+01  -1.101441118819e+01   1.881216179150e+00
     4      -3.311192105349e+00   1.359065776894e+00  -1.560567106434e-01
     5       3.429437857518e-01  -1.029838658966e-01   1.219202707337e-03
     6      -2.241037042190e-02   4.809469933342e-03   7.390343876677e-04
     7       8.329672118744e-04  -1.335338145990e-04  -4.892703647590e-05
     8      -1.338140072499e-05   1.818158167900e-06   9.766334115013e-07


    E Index            3                        4                        5
  T Index
     0       4.969309555880e+00  -8.148122128593e-01   9.323059658335e-02
     1      -2.474427836778e+00   1.543035928035e-01  -3.251763597742e-02
     2       5.085589872685e-01   6.361992438909e-02  -2.591606323191e-03
     3      -5.077119677970e-02  -1.852297452693e-02   1.600942164119e-03
     4      -2.033265136901e-03   9.718962378108e-04   8.040301331558e-06
     5       1.601047711063e-03   6.336414922385e-05  -3.788387994691e-05
     6      -2.320531548991e-04   2.588021875832e-06   3.001128191660e-06
     7       1.473207837914e-05  -1.282873408948e-06   9.991541256156e-09
     8      -3.535181371877e-07   5.620757041266e-08  -5.034820677719e-09


    E Index            6                        7                        8
  T Index
     0      -5.854170815799e-03   1.656707831222e-04  -1.178234924866e-06
     1       5.085816021807e-03  -3.411499000615e-04   8.295196911491e-06
     2      -1.089685945002e-03   1.132751576739e-04  -3.266248682724e-06
     3       3.805592017920e-05  -8.847884634595e-06   2.721236736970e-07
     4       7.171822512541e-07  -7.530004219739e-07   3.651109616529e-08
     5       1.786513937009e-06   9.799503679830e-08  -6.480643645772e-09
     6      -2.271952317871e-07   1.029652468585e-09   2.338178917351e-10
     7       4.685569702988e-09  -2.668266102694e-10   4.756847923643e-12
     8       2.048241675655e-10   1.327375467275e-12  -2.566621089266e-13


    Error  1.64e-02 (D)
```

Reaction 4.3.1 $H_2^+ + H_2 \rightarrow H_2 + H_2^+$

```
 E Index          0                   1                   2
T Index
   0      -2.013143517466e+01  1.875197914224e-01  6.865479604288e-02
   1       2.643458086299e-01 -1.177247941077e-01 -6.758032286178e-03
   2       7.295645990688e-02  6.053418575149e-03 -1.068656224307e-02
   3      -1.022454343675e-02  7.350954380641e-03  6.814213275702e-04
   4      -4.801198168030e-03 -1.111612877392e-03  8.373319888351e-04
   5       1.141613586234e-03 -1.371389288760e-04 -1.733761953296e-04
   6      -3.388853048483e-05  4.426148343648e-05  9.992317920676e-06
   7      -6.418225985394e-06 -3.652063962019e-06  1.351312819077e-07
   8       3.555592819527e-07  1.012701361110e-07 -1.993091213299e-08

 E Index          3                   4                   5
T Index
   0       6.246595384100e-03 -5.017891372102e-03 -3.907644829287e-04
   1       8.585003721992e-03 -3.261863407467e-04 -3.322528542186e-04
   2      -9.371235639464e-04  9.735708783528e-04 -9.933049259228e-05
   3      -8.156435157073e-04  2.903991825737e-05  3.223596225946e-05
   4       1.392977576749e-04 -9.316910697276e-05  8.814981236658e-06
   5       1.602610140599e-05  1.464235749797e-05 -2.944711701791e-06
   6      -5.333970870280e-06 -2.999105886511e-07  2.275612517364e-07
   7       4.285396408056e-07 -7.184302986068e-08 -3.265552364687e-10
   8      -1.131561847140e-08  3.678869095972e-09 -3.639982258214e-10

 E Index          6                   7                   8
T Index
   0       2.786239030986e-04 -2.942576591004e-05  9.352275354690e-07
   1       6.015471216449e-05 -4.039435357369e-06  9.730479674748e-08
   2      -6.786246802840e-06  1.438327767305e-06 -5.530742535057e-08
   3      -5.199055182831e-06  2.852443990256e-07 -4.825480212106e-09
   4       6.675626166047e-07 -1.325441927019e-07  5.012529587757e-09
   5       6.365231650682e-08  1.872976659964e-08 -1.014883015867e-09
   6      -1.173422836715e-08 -1.364602870139e-09  9.566404348683e-11
   7       1.585228996542e-10  6.431866226702e-11 -4.507074278992e-12
   8       2.056662091085e-11 -1.804254277469e-12  9.042973335167e-14

 Error  2.58e-04 (A)
```

Reaction 4.3.2 $H_2^+ + H_2 \rightarrow H_2^+ + H_2^+ + e$

```
   E Index          0                      1                      2
T Index
     0       -3.361709356815e+01  2.069962590009e+00 -9.010533538327e-01
     1        2.233317520475e+00 -2.726590828625e+00  1.643915864856e+00
     2       -7.287181470383e-01  1.661423051779e+00 -1.025272729232e+00
     3        4.891752418641e-01 -5.973230637071e-01  3.079590537141e-01
     4       -1.587248070170e-01  1.357406226261e-01 -4.995160576771e-02
     5        2.786295111792e-02 -1.954886177187e-02  4.482229513351e-03
     6       -2.710661372128e-03  1.714035434070e-03 -2.108888570649e-04
     7        1.370951998574e-04 -8.287462331299e-05  4.245802696647e-06
     8       -2.813882491422e-06  1.685813575983e-06 -1.243788238044e-08

   E Index          3                      4                      5
T Index
     0        4.757423977733e-01 -1.173499542871e-01  1.574858380323e-02
     1       -5.767723646300e-01  1.225177255213e-01 -1.583053141876e-02
     2        3.012750644438e-01 -5.027357052159e-02  5.155737495648e-03
     3       -7.997349646419e-02  1.082475428239e-02 -7.031584157104e-04
     4        1.041402498039e-02 -1.202077056853e-03  4.396765142500e-05
     5       -4.121930331601e-04  2.634686881556e-05 -1.954016523336e-06
     6       -4.475697526351e-05  9.018648895762e-06  4.809988527180e-08
     7        5.227237760667e-06 -9.414336727644e-07  1.246197373405e-08
     8       -1.530261560799e-07  2.877226549741e-08 -8.668284019609e-10

   E Index          6                      7                      8
T Index
     0       -1.166206787765e-03  4.383027530849e-05 -6.348470910454e-07
     1        1.209069864044e-03 -4.994507398820e-05  8.566470175705e-07
     2       -3.336823259195e-04  1.297196226977e-05 -2.351485202412e-07
     3        1.145932327551e-05  8.141233815222e-07 -2.868358002582e-08
     4        5.587705467605e-06 -6.600350475588e-07  2.019835260065e-08
     5       -3.033359082874e-07  6.422702166049e-08 -2.757788924867e-09
     6       -6.552590854175e-08  1.043541445947e-09  1.156250997817e-10
     7        6.735598908536e-09 -3.714404901163e-10  1.840510894514e-12
     8       -1.644678010990e-10  1.198441513399e-11 -1.614965817473e-13

   Error 1.62e-04
```

Reaction 4.3.3 $H_2^+ + H_2 \rightarrow H_3^+ + H$

```
E Index           0                   1                   2
T Index
   0      -2.094582001426e+01 -2.903671854391e-01 -1.484602213957e-01
   1      -3.908059227757e-01  5.612290953081e-02  7.311639731340e-02
   2      -1.406586222305e-01  3.034165415227e-02 -1.768280719269e-02
   3      -2.329090939587e-02 -3.655835575292e-03 -8.362574927676e-04
   4       4.478632359998e-03 -2.378407903866e-03  1.315628515286e-03
   5       1.028607802560e-03  4.205001381642e-04 -1.125270518181e-04
   6      -3.155447765047e-04  1.597095151191e-05 -2.355907533211e-05
   7       2.828211032630e-05 -6.662911839399e-06  3.842898711627e-06
   8      -8.646163087099e-07  3.261593568923e-07 -1.473565567371e-07

E Index           3                   4                   5
T Index
   0      -7.788282133984e-02 -2.716693083523e-02  2.888660862916e-03
   1       5.829061271518e-02  7.552808963242e-03 -9.437914641041e-03
   2      -5.709689089835e-03  7.796493173156e-03  2.150949138545e-03
   3      -4.779241336163e-03 -1.812406227884e-03  7.881163019295e-04
   4       8.267929702836e-04 -4.230180219524e-04 -2.567042908792e-04
   5       1.289639680255e-04  1.253485982824e-04  8.799819972454e-06
   6      -3.554580445806e-05 -6.132110996274e-06  2.803562696685e-06
   7       2.286178560056e-06 -4.109569999864e-07 -2.529649414563e-07
   8      -3.749876424917e-08  2.926978739503e-08  5.144928119898e-09

E Index           6                   7                   8
T Index
   0       1.962991371294e-03 -2.537688817604e-04  3.167927580722e-06
   1      -9.682436127328e-04  6.252187020332e-04 -4.847265436175e-05
   2      -5.832002101739e-04 -9.096057686629e-05  1.497380403845e-05
   3       1.857587010565e-04 -5.555787804993e-05  2.979712834131e-06
   4       2.408905813848e-05  1.512607065092e-05 -1.688827943562e-06
   5      -1.011644205055e-05 -1.202093866229e-06  2.611308007476e-07
   6       8.619910002153e-07  1.741997695030e-08 -1.925603640419e-08
   7      -2.042542214746e-08  1.432103401478e-09  7.102441362723e-10
   8      -9.824207587793e-11 -3.870509135647e-11 -1.074647099491e-11
```

 Error 1.90e-04 (A)

 <sv> < 1.0e-11 for E > 50 eV for the entire T range considered here. The
 fit gives unphysical values for E > 50 eV in this range and should not be
 used there.

Reaction 4.4.1 $H_2^+ + He \rightarrow H_2^+ + He^+ + e$

```
  E Index          0                      1                      2
T Index
   0       -4.309726141841e+01   6.475006995833e+00  -1.883249802835e-01
   1        1.281172385125e+01  -7.243378485529e+00   5.043373334075e-01
   2       -5.890999853236e+00   3.579212080875e+00  -4.030617651034e-01
   3        1.885032038426e+00  -1.033881853032e+00   1.536625297945e-01
   4       -3.859849765629e-01   1.929288495908e-01  -3.246664649774e-02
   5        5.040064801144e-02  -2.379010323165e-02   4.018297415320e-03
   6       -4.013079090991e-03   1.869730413126e-03  -2.907360932536e-04
   7        1.755528395798e-04  -8.421826651094e-05   1.143340331457e-05
   8       -3.214596451062e-06   1.641069021089e-06  -1.897006152308e-07

  E Index          3                      4                      5
T Index
   0       -6.707987015268e-01   2.639446649402e-01  -4.723560827520e-02
   1        5.831511375074e-01  -2.063394187655e-01   3.239770290912e-02
   2       -1.771129376316e-01   6.192783929198e-02  -8.167418547801e-03
   3        1.742222425989e-02  -8.070784446837e-03   9.406258713749e-04
   4        1.606419041683e-03   1.581892175211e-04  -3.508868395189e-05
   5       -4.700427633330e-04   7.455005712397e-05  -5.328157796217e-06
   6        3.265369551305e-05  -8.049211111537e-06   1.040817302013e-06
   7       -4.917056270388e-07   2.951503045367e-07  -7.703466212797e-08
   8       -1.671870630370e-08  -2.615761487320e-09   2.128865104658e-09

  E Index          6                      7                      8
T Index
   0        4.533392612738e-03  -2.256809803213e-04   4.569435145102e-06
   1       -2.763842540794e-03   1.247895466478e-04  -2.344043545995e-06
   2        5.254335475410e-04  -1.537799120839e-05   1.331837837243e-07
   3       -3.856233447220e-05  -4.156140436365e-07   5.034959925043e-08
   4        3.791183556963e-06  -2.366231626960e-07   5.992973459021e-09
   5       -5.795596041141e-07   9.708186393302e-08  -3.488558225848e-09
   6        4.399518745143e-10  -7.685681194865e-09   3.468947174405e-10
   7        5.520600090967e-09   1.762439907887e-11  -9.396171756462e-12
   8       -2.654154152549e-10   1.103963564691e-11  -8.957193708196e-14

  Error  8.31e-05 (A)
```

Reaction 5.2.1 $He^+ + H_2 \rightarrow He^+ + H^+ + e$

```
  E Index          0                   1                   2
T Index
   0      -3.713019551543e+01  4.513880809792e+00  4.465734536727e-01
   1       7.312992983242e+00 -4.230698925401e+00  3.363491931239e-01
   2      -1.404602569517e+00  1.574352939860e+00 -4.712948306828e-01
   3       8.465714459741e-02 -2.805696953923e-01  1.811965461049e-01
   4       3.001601051201e-02  1.978938422099e-02 -3.599941390452e-02
   5      -9.026893259159e-03  9.283132403167e-04  4.476205535455e-03
   6       1.077346431372e-03 -2.592422590385e-04 -3.727829206896e-04
   7      -6.008751203326e-05  1.667265275798e-05  1.918105806793e-05
   8       1.276481720290e-06 -3.728072837540e-07 -4.453576012678e-07


  E Index          3                   4                   5
T Index
   0      -2.439394070482e-01  4.439220456707e-03  7.345794340485e-03
   1       2.216628364304e-01 -5.119093601500e-02  1.943198225007e-03
   2      -8.374208591879e-03  2.953035366897e-02 -6.222917082325e-03
   3      -3.500869288503e-02 -2.890323734594e-03  2.024599123408e-03
   4       1.278467857143e-02 -1.232540236931e-03 -1.666275826514e-04
   5      -2.115580254273e-03  3.444824743426e-04 -1.323145031233e-05
   6       1.909506623157e-04 -3.388660283649e-05  2.315290984180e-06
   7      -9.201901683360e-06  1.408112739218e-06 -6.069498647130e-08
   8       1.865212152535e-07 -1.872002189577e-08 -1.479591373403e-09


  E Index          6                   7                   8
T Index
   0      -1.199883122444e-03  7.929882485919e-05 -1.987990204346e-06
   1       4.465865599601e-04 -5.004811416214e-05  1.512094392826e-06
   2       5.950227580914e-04 -2.787837758738e-05  5.190549973795e-07
   3      -2.984004616508e-04  1.902451334721e-05 -4.579503385483e-07
   4       4.481020441245e-05 -3.425924289459e-06  9.026683813135e-08
   5      -2.146946788021e-06  2.383193769092e-07 -6.906305571460e-09
   6       6.088037548996e-09 -7.326969450051e-09  2.239693051242e-10
   7      -4.353244789583e-09  4.457527394302e-10 -9.398012612903e-12
   8       3.962791753244e-10 -2.513406814921e-11  5.068098237861e-13


  Error  8.03e-04 (B)
```

Reaction 5.2.2 $He^+ + H_2 \rightarrow He + H^+$

```
  E Index          0                     1                     2
T Index
    0       -3.617851314340e+01   8.245563741195e-01   1.415890461293e-01
    1        6.564887398262e-01  -3.337749950700e-01  -1.008073891739e-03
    2        9.531332794256e-02  -1.931877094955e-02  -2.177569825223e-02
    3       -1.790261298028e-02   2.362156898359e-02   2.481269859100e-03
    4        7.873069533268e-03   2.305021543232e-05   1.062397303161e-03
    5        1.625577954098e-03  -1.341341170672e-03  -2.453799729668e-04
    6       -6.243925896235e-04   2.389932224800e-04   1.310149299938e-05
    7        5.723897329155e-05  -1.662664310436e-05   4.255519558344e-07
    8       -1.690364064992e-06   4.200646087287e-07  -3.882714153340e-08


  E Index          3                     4                     5
T Index
    0       -5.245109545409e-02   2.574263879790e-03   5.081113179086e-03
    1        2.353864809890e-02  -8.611685556552e-04  -1.235953005371e-03
    2        6.296784545643e-03   8.056466799286e-04  -4.422528088809e-04
    3       -3.194145659097e-03   5.097167452777e-05   1.492942136767e-04
    4       -2.226509858382e-04  -7.132717180757e-05   1.590997815012e-05
    5        2.171893645658e-04  -1.504822330128e-06  -7.627038293158e-06
    6       -3.205058255713e-05   3.153131057610e-06   5.374886487540e-07
    7        1.892187997659e-06  -3.671662723350e-07   1.240410469109e-08
    8       -3.981815711162e-08   1.257613148417e-08  -1.559147916406e-09


  E Index          6                     7                     8
T Index
    0       -1.105146703191e-03   8.466844977067e-05  -2.264180150260e-06
    1        2.385360257195e-04  -1.708395525986e-05   4.375864733045e-07
    2        5.451070303994e-05  -2.660983244927e-06   4.244385976642e-08
    3       -2.350969502990e-05   1.328072187288e-06  -2.480965060631e-08
    4       -5.247303578452e-08  -1.381151133836e-07   6.646376709202e-09
    5        7.408427546841e-07  -8.825036538220e-10  -1.353868832823e-09
    6       -6.764350122786e-08  -8.407299219054e-10   1.978309478483e-10
    7       -5.125341539638e-10   2.770888875227e-10  -1.654942575020e-11
    8        1.599391141086e-10  -1.434870919386e-11   5.493012109985e-13


  Error  6.06e-04 (B)
```

Reaction 5.2.3 $He^+ + H_2 \rightarrow He + H^+ + H$

```
 E Index           0                      1                      2
T Index
   0       -3.569345457680e+01   5.467675953787e+00  -1.525452874272e+00
   1        6.602257860447e+00  -5.860473216356e+00   2.567792367148e+00
   2       -1.802030727618e+00   2.776708580765e+00  -1.456435131755e+00
   3        5.980682857428e-01  -7.669462419521e-01   3.877769522782e-01
   4       -1.515033763091e-01   1.355123344697e-01  -5.328079168644e-02
   5        2.273923829034e-02  -1.552431054752e-02   3.680122521552e-03
   6       -1.950876085219e-03   1.107193551999e-03  -9.861964956657e-05
   7        8.879641773477e-05  -4.427419374545e-05  -8.643444105803e-07
   8       -1.662550081283e-06   7.525447749722e-07   5.761680732896e-08


 E Index           3                      4                      5
T Index
   0        7.645781657996e-01  -2.285145605072e-01   3.561471492616e-02
   1       -7.921692885504e-01   1.791134818786e-01  -2.709395158440e-02
   2        3.727025613660e-01  -5.373124189344e-02   4.827265290690e-03
   3       -9.180531536723e-02   9.188213414014e-03   8.930961476819e-05
   4        1.152256687649e-02  -1.182322907825e-03  -1.868126294929e-05
   5       -5.961207420320e-04   1.152911876232e-04  -1.321659022007e-05
   6       -7.612968632797e-06  -6.066035684733e-06   1.527361008857e-06
   7        1.816255353042e-06   4.628107113547e-08  -1.127225337804e-08
   8       -4.462116763253e-08   5.201413577832e-09  -2.441066078656e-09


 E Index           6                      7                      8
T Index
   0       -3.040755662326e-03   1.357901348722e-04  -2.481641682718e-06
   1        2.495321136581e-03  -1.249516606345e-04   2.598469347617e-06
   2       -3.006881501965e-04   1.324810154101e-05  -3.023835422188e-07
   3       -9.701225760383e-05   7.510874054331e-06  -1.880555391455e-07
   4        1.703238064971e-05  -1.506318180829e-06   4.324855274434e-08
   5        1.049002267297e-07   7.987013573220e-08  -3.751370813720e-09
   6       -4.649027875076e-08  -8.266614643058e-09   4.561224301361e-10
   7       -9.674327862739e-09   1.432037876831e-09  -5.371138414560e-11
   8        6.786765390955e-10  -6.724210849363e-11   2.191944328954e-12


 Error  3.75e-04 (B)
```

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Reaction 5.3.1 $He^+ + He \rightarrow He + He^+$

```
  E Index         0                    1                    2
T Index
   0       -1.992795874184e+01   1.866121633782e-01   5.632774905403e-02
   1        2.342319832717e-01  -1.085479286023e-01  -5.796164637185e-03
   2        5.150488618567e-02   5.502643799842e-03  -1.070448355458e-02
   3       -4.457831664145e-03   6.751016280248e-03   1.348104812381e-03
   4       -1.543592188979e-03  -9.368501420643e-04   6.678034019800e-04
   5        3.127935819690e-04  -1.564547327374e-04  -1.638591652038e-04
   6       -1.478649318411e-05   4.454044051200e-05   1.091423551219e-05
   7       -4.796924334410e-07  -3.559977035839e-06   1.429006251276e-08
   8        3.623344342191e-08   9.673665606073e-08  -1.626046817162e-08

  E Index         3                    4                    5
T Index
   0       -1.523524839309e-03  -2.153750537851e-03   3.308881419986e-04
   1        7.964340512260e-03  -2.259674261582e-04  -3.444207072047e-04
   2       -2.811049856343e-04   8.802921038196e-04  -1.198248793959e-04
   3       -1.009960297392e-03  -2.397230757181e-05   5.675989835329e-05
   4        1.271484361215e-04  -7.802314691135e-05   5.096915155186e-06
   5        2.743635453507e-05   1.364264736037e-05  -3.146182664420e-06
   6       -6.757942983709e-06  -3.524476702306e-07   2.858958575343e-07
   7        4.890540879010e-07  -6.293604516614e-08  -2.702231414235e-09
   8       -1.188613673713e-08   3.383446775161e-09  -3.684509743141e-10

  E Index         6                    7                    8
T Index
   0       -1.293912998397e-05  -4.067520041201e-07   2.451185017055e-08
   1        6.164032099379e-05  -4.156975252360e-06   1.009896955766e-07
   2       -7.766013174537e-07   9.213287306897e-07  -4.014244306169e-08
   3       -8.581799112319e-06   4.932159877322e-07  -9.746139175914e-09
   4        1.122093772403e-06  -1.600545758983e-07   5.662679103625e-09
   5        9.721160837100e-08   1.677569938034e-08  -9.661966135256e-10
   6       -1.739320039203e-08  -1.179041806243e-09   9.352212060009e-11
   7        5.123073994873e-11   9.702183602739e-11  -5.755013542991e-12
   8        3.976640871840e-11  -4.096335085504e-12   1.667878217006e-13

  Error  2.36e-05 (A)
```

Reaction 5.3.2 $He^+ + He \rightarrow He^+ + He^+ + e$

```
   E Index          0                    1                    2
T Index
    0       -6.749257304678e+01   3.080627051012e+01  -1.145813141153e+01
    1        4.329467261355e+01  -4.031602483159e+01   1.707905481142e+01
    2       -2.016026525056e+01   2.231984392732e+01  -1.017738982563e+01
    3        5.878320131150e+00  -6.882901423348e+00   3.201825080229e+00
    4       -1.137799010228e+00   1.302313958330e+00  -5.884044412402e-01
    5        1.450552810169e-01  -1.555507288279e-01   6.537275456166e-02
    6       -1.155793628115e-02   1.147650951410e-02  -4.329368714852e-03
    7        5.167930765975e-04  -4.781324647004e-04   1.576230053609e-04
    8       -9.839244996808e-06   8.600494351291e-06  -2.434988045802e-06

   E Index          3                    4                    5
T Index
    0        3.388015690088e+00  -7.536552992052e-01   1.094516886818e-01
    1       -4.478579850964e+00   8.066021028840e-01  -9.979059856890e-02
    2        2.509824455963e+00  -3.656980663805e-01   3.191586604783e-02
    3       -7.552669555755e-01   9.255840851869e-02  -4.641142473768e-03
    4        1.311191744239e-01  -1.402143172466e-02   3.427843990627e-04
    5       -1.323051154888e-02   1.229786796421e-03  -2.028911469770e-05
    6        7.369414642692e-04  -5.269558335123e-05   1.766303852396e-06
    7       -1.928032791874e-05   3.603057782872e-07  -1.010518517671e-07
    8        1.339321812560e-07   3.028039050683e-08   1.838236320858e-09

   E Index          6                    7                    8
T Index
    0       -9.463880450938e-03   4.398620168160e-04  -8.450244877636e-06
    1        7.955955791002e-03  -3.617178669983e-04   7.048366766523e-06
    2       -1.586656930186e-03   3.830211108983e-05  -2.609071874454e-07
    3       -1.294999476918e-04   2.388282840962e-05  -7.277202967312e-07
    4        6.774806939936e-05  -6.211048957431e-06   1.613570924718e-07
    5       -4.743973580278e-06   3.064327230164e-07  -4.853224348333e-09
    6       -3.419422565839e-07   4.593362543917e-08  -1.743858127735e-09
    7        5.170772455352e-08  -5.600340502767e-09   1.859063429189e-10
    8       -1.602801532247e-09   1.701252086315e-10  -5.520060744854e-12

   Error  1.35e-03 (C)
```

Reaction 6.1.1 $He^{++} + H(1s) \rightarrow He^{++} + H(2p)$

```
   E Index            0                      1                      2
T Index
   0       -3.128291192763e+01 -3.861939808947e-01 -2.544645152942e+00
   1       -6.826991894490e-01 -8.408347453138e-01  2.629943082927e-01
   2       -1.441334316248e+00  1.422092876991e-01  2.002181867767e-01
   3        3.169981863524e-01  1.363426173469e-01 -3.622433372588e-02
   4        1.440567980361e-01 -5.023547473715e-02 -2.472425668256e-03
   5       -5.309434904043e-02  6.625411757408e-03  1.347168808606e-03
   6        6.713712881021e-03 -3.657613813881e-04 -1.801819884810e-04
   7       -3.836344721605e-04  4.833466842639e-06  1.173107765224e-05
   8        8.388799849538e-06  1.548286845930e-07 -3.101524382401e-07

   E Index            3                      4                      5
T Index
   0        4.669451368190e-01  2.917550661840e-01 -1.053780859061e-01
   1        9.881934763967e-02 -5.354197329704e-02  9.617629874772e-03
   2       -2.373167102469e-02 -1.943544641502e-02  6.728262805201e-03
   3       -2.125279295018e-02  8.196892532228e-03 -1.126751334420e-03
   4        5.090021728980e-03 -1.140089320112e-03  6.794493424970e-05
   5       -8.841712146365e-05  1.628036645708e-05 -8.948432185115e-06
   6       -6.309125180824e-05  1.390057420949e-05  5.519228022295e-07
   7        5.917408932712e-06 -1.490516597840e-06  5.820616731175e-08
   8       -1.596933841423e-07  4.769562622033e-08 -4.561904992676e-09

   E Index            6                      7                      8
T Index
   0        1.364529328613e-02 -8.022046090155e-04  1.802849723372e-05
   1       -8.611117374892e-04  3.908664672328e-05 -7.212446215523e-07
   2       -9.041409091166e-04  5.666864142514e-05 -1.373057978697e-06
   3        7.645412457648e-05 -2.667684868645e-06  4.124172622729e-08
   4        7.368858127714e-06 -1.106305479253e-06  3.817455135007e-08
   5        5.678884593513e-07  4.642154492296e-08 -3.598042180209e-09
   6       -1.911269421448e-07  6.044313534001e-09  1.456318833459e-10
   7        3.639779928913e-09  6.910541467229e-11 -2.002452819345e-11
   8        3.328417422480e-10 -2.908652620490e-11  1.180447220494e-12

   Error  9.47e-04 (B)
```

A more extensive analytic formula for all $n >= 2$ is given in the text.

Reaction 6.1.3 $He^{++} + H(1s) \rightarrow He^{++} + H^+ + e$

```
   E Index          0                     1                     2
T Index
       0     -3.213525339461e+01   4.048855987534e-01 -1.459217274977e+00
       1      8.616833916021e-01  -6.950245301215e-01 -5.645946950077e-01
       2     -1.516319957636e+00  -3.812512076134e-01  1.893299195739e-01
       3      1.006874043269e-01   2.037666264960e-01  2.977523227454e-02
       4      1.821009470616e-01  -1.888567920879e-03 -1.257914490683e-02
       5     -5.204900520164e-02  -1.011975370629e-02  1.459518537491e-03
       6      6.024060604719e-03   1.811281409653e-03 -1.071747691134e-04
       7     -3.279965879464e-04  -1.255314364414e-04  6.740808642651e-06
       8      6.955537637694e-06   3.158339223563e-06 -2.201431842876e-07


   E Index          3                     4                     5
T Index
       0      1.832446087964e-01   1.820448886287e-01 -5.894612068336e-02
       1      1.997861354267e-01   2.296013792400e-02 -1.598128574471e-02
       2      2.287526434742e-02  -2.230595108739e-02  5.497523259018e-03
       3     -3.596233294198e-02   4.420728440672e-03  3.823858799635e-04
       4      3.554216072576e-03  -5.852198392288e-04 -1.045811648109e-05
       5      8.588876790382e-04   2.884916307632e-06 -3.389979591571e-05
       6     -1.914502607375e-04   1.361700778479e-05  3.642721103256e-06
       7      1.338794701145e-05  -1.635502392200e-06 -3.684855814169e-08
       8     -3.236734300402e-07   5.702927636593e-08 -4.938860692978e-09


   E Index          6                     7                     8
T Index
       0      7.308767351095e-03  -4.181939938771e-04  9.207950478799e-06
       1      2.380832450865e-03  -1.504225027785e-04  3.547002873170e-06
       2     -6.993554812224e-04   4.516232482147e-05 -1.154715783315e-06
       3     -1.099529103897e-04   7.543892418062e-06 -1.708252421708e-07
       4      1.672568631267e-05  -1.836430836869e-06  6.080236805727e-08
       5      2.793668955085e-06   3.838407710178e-08 -6.689521714938e-09
       6     -3.804617509593e-07  -2.464497412799e-09  8.281161472560e-10
       7      5.704885906583e-10   1.543017124482e-09 -8.445486242553e-11
       8      7.699246994125e-10  -8.580250216262e-11  3.189523199623e-12


   Error 1.32e-03
```

Reaction 6.1.6 $He^{++} + H \rightarrow He^{+}(n=2) + H^{+}$

```
 E Index          0                    1                    2
T Index
   0       -2.684068918587e+01  1.077159851869e+00  1.611434095003e-01
   1        5.117541237230e-01 -3.292088112707e-01  4.193651221864e-02
   2        1.598500363509e-01 -3.812957840397e-02 -2.103399170458e-02
   3        1.228188346785e-02  1.765620781249e-02 -4.556545487291e-03
   4       -4.554467900719e-03  9.457132816015e-04  1.645608151050e-03
   5       -2.778583050511e-04 -7.305848198936e-04  4.612991944463e-05
   6        1.538644839183e-04  8.140980182115e-05 -4.793549304493e-05
   7       -1.499611384855e-05 -3.278119258256e-06  4.727047352918e-06
   8        4.697369923421e-07  3.332532647980e-08 -1.433575769997e-07

 E Index          3                    4                    5
T Index
   0       -1.941671951055e-02 -3.364587603920e-03  1.137572625288e-03
   1        1.365931518647e-02 -3.060504283824e-03 -2.183962062545e-04
   2        5.585565653003e-03  7.325879113415e-04 -3.247877168930e-04
   3       -1.963806169076e-03  5.344561040129e-04  1.955747622998e-05
   4       -2.070478545640e-04 -1.384142733303e-04  3.281664341316e-05
   5        9.376080341880e-05 -4.104939830509e-06 -4.823335474719e-06
   6       -6.580665188724e-06  3.695002531601e-06 -2.170325944322e-07
   7       -8.828451438638e-08 -3.495383517796e-07  6.589695469087e-08
   8        1.452542457751e-08  1.021940844352e-08 -2.746221662026e-09

 E Index          6                    7                    8
T Index
   0       -1.030059621084e-04  1.662587903156e-06  9.868838320179e-08
   1        1.038012581189e-04 -9.397899971402e-06  2.755750977475e-07
   2        3.172192984549e-05 -9.448677346635e-07 -3.817181255094e-09
   3       -1.514747820761e-05  1.426520725713e-06 -4.189371841853e-08
   4       -1.906464376446e-06 -4.474317916254e-08  4.942196257155e-09
   5        7.911914689813e-07 -4.216279314031e-08  6.314000693621e-10
   6       -3.184743031465e-08  3.644605422841e-09 -9.468908601909e-11
   7       -4.423644969643e-09  9.850791365204e-11  1.012931336353e-13
   8        2.722901729050e-10 -1.217986052601e-11  2.087076950595e-13

   Error  3.45e-04 (B)
```

Reaction 6.2.1 $He^{++} + H_2 \rightarrow He^{++} + H_2^+(v) + e$

```
  E Index          0                      1                      2
T Index
   0       -3.740458528875e+01   4.819839382288e+00  -1.368722314416e+00
   1        3.697794623317e+00  -4.260575420078e+00   2.274586443382e+00
   2       -1.952883135699e-01   1.519624000877e+00  -1.186623344815e+00
   3        4.006262224030e-02  -2.914307027385e-01   2.640808145769e-01
   4       -4.786632316714e-02   3.732741697654e-02  -2.125640108014e-02
   5        1.435334952996e-02  -4.126872601223e-03  -1.316704448334e-03
   6       -1.857371914077e-03   3.915654055393e-04   3.686192037472e-04
   7        1.126777142893e-04  -2.328456641412e-05  -2.488855854519e-05
   8       -2.637987783791e-06   5.796033701332e-07   5.770496917262e-07


  E Index          3                      4                      5
T Index
   0        5.415964848279e-01  -1.558092591583e-01   2.673033645460e-02
   1       -7.477112914979e-01   1.630231019898e-01  -2.322732220110e-02
   2        3.996652574630e-01  -7.388600606929e-02   8.214102149542e-03
   3       -9.703573952883e-02   1.783463570481e-02  -1.705433511392e-03
   4        8.833454031367e-03  -2.009464031032e-03   2.249935053360e-04
   5        5.248086049074e-04  -8.919967388651e-06  -1.246262891020e-05
   6       -1.737291298205e-04   2.577341999196e-05  -9.482137841850e-07
   7        1.300558673415e-05  -2.344702491575e-06   1.629428614542e-07
   8       -3.314156416545e-07   6.741539632029e-08  -5.955349313768e-09


  E Index          6                      7                      8
T Index
   0       -2.578884501918e-03   1.294681717674e-04  -2.635783475569e-06
   1        2.040440748140e-03  -9.909710584927e-05   2.022083060567e-06
   2       -5.623626152450e-04   2.244646297525e-05  -4.065894891850e-07
   3        7.664104809530e-05  -8.191992528308e-07  -2.753294486929e-08
   4       -9.861657413217e-06  -9.995859937832e-08   1.424254131071e-08
   5        1.395191641953e-06  -3.685926734937e-08  -5.729382287379e-10
   6       -9.379121901004e-08   7.777171419994e-09  -1.213248180319e-10
   7       -2.275396327537e-10  -4.097026715756e-10   1.086349587424e-11
   8        1.692734428835e-10   4.442825612279e-12  -2.196742224277e-13


  Error  1.95e-04 (A)
```

Reaction 6.3.1 $He^{++} + He \rightarrow He + He^{++}$

```
 E Index          0                  1                  2
T Index
   0       -2.087067966395e+01   1.770710917672e-01   5.286663352724e-02
   1        2.094653607929e-01  -1.035630036136e-01  -1.587484833047e-03
   2        4.515569927112e-02   7.753021609986e-03  -1.172352137681e-02
   3       -2.156818929353e-03   5.844613611271e-03   1.584520908151e-03
   4       -1.034417290024e-03  -9.988691720266e-04   6.430330809960e-04
   5        6.711410038952e-05  -9.039725081170e-05  -1.686928979307e-04
   6        1.634228365980e-05   3.360212044374e-05   1.244878523706e-05
   7       -2.018162243333e-06  -2.811596499823e-06  -1.289872750639e-07
   8        5.700761275390e-08   7.785762968811e-08  -1.168383579394e-08

 E Index          3                  4                  5
T Index
   0       -4.108533645663e-03  -1.682325393036e-03   6.311322867200e-04
   1        6.980778548791e-03  -4.701965411677e-04  -2.345754812673e-04
   2        7.248911771056e-05   8.809460604163e-04  -1.426429587991e-04
   3       -1.074296069145e-03  -1.654629083347e-05   5.761893046505e-05
   4        1.311854988163e-04  -7.851442095351e-05   5.422244523002e-06
   5        2.782958218572e-05   1.353549005040e-05  -3.148005712744e-06
   6       -6.878943315863e-06  -3.391029687238e-07   2.812067777116e-07
   7        5.026743092262e-07  -6.291522264312e-08  -2.775917122056e-09
   8       -1.243441979051e-08   3.348779288410e-09  -3.430378749002e-10

 E Index          6                  7                  8
T Index
   0       -1.034343472222e-04   8.284373934314e-06  -2.585107151364e-07
   1        4.656851963845e-05  -3.237799181386e-06   7.973037168095e-08
   2        3.719681370598e-06   5.772787018529e-07  -3.063528285547e-08
   3       -8.884055251880e-06   5.210682232168e-07  -1.062878498510e-08
   4        1.051027365170e-06  -1.540544793432e-07   5.483293214541e-09
   5        1.019425830844e-07   1.607622514801e-08  -9.352273349479e-10
   6       -1.692119208451e-08  -1.156062045162e-09   9.051243592979e-11
   7        8.794108865463e-11   8.904209111206e-11  -5.320379447337e-12
   8        3.429943174964e-11  -3.505937279725e-12   1.434656878037e-13

 Error  1.09e-04 (A)
```

Reaction 6.3.2 $He^{++} + He \rightarrow He^{++} + He^{+} + e$

```
   E Index          0                    1                    2
 T Index
      0      -3.357512088469e+01   2.481002270207e-01  -2.844754225626e-01
      1       2.132558452382e-01  -2.898782569957e-02  -8.859152207456e-02
      2      -7.629285367047e-01  -1.246031034296e-02   4.339076002927e-02
      3       5.899289086465e-02   3.450829479956e-03   1.171516743657e-02
      4       9.617944830667e-02   8.115543683934e-04  -8.351029524143e-03
      5      -2.754369102041e-02  -5.252894338980e-04   1.845370884466e-03
      6       3.193662877844e-03   9.140552891498e-05  -2.084303350442e-04
      7      -1.743435861477e-04  -6.732493173329e-06   1.209578227317e-05
      8       3.702563187159e-06   1.817766164959e-07  -2.844186742354e-07

   E Index          3                    4                    5
 T Index
      0      -5.040226778288e-02   3.354002274183e-02  -1.866620628241e-03
      1       1.729393805563e-02   4.254520286926e-03  -1.601440080094e-03
      2      -3.393002840651e-03   1.091192986540e-03  -4.407674396150e-04
      3      -1.741588094600e-03  -1.275836278696e-03   3.728086620067e-04
      4       1.074669748613e-03   1.010631022949e-04  -4.311397774907e-05
      5      -2.123309981019e-04   2.130784765152e-05  -3.112264677191e-06
      6       1.979855424701e-05  -3.124685666404e-06   7.997641396203e-07
      7      -8.939845877979e-07   9.995018170226e-08  -4.204213158284e-08
      8       1.584012353330e-08   7.506298931854e-10   5.227401148548e-10

   E Index          6                    7                    8
 T Index
      0      -4.168527021261e-04   5.230828266632e-05  -1.675138710355e-06
      1       1.850932900121e-04  -9.312584153371e-06   1.726529087665e-07
      2       5.983672818341e-05  -3.329152402921e-06   6.553879080128e-08
      3      -3.777955894029e-05   1.581526045462e-06  -2.076968820260e-08
      4       5.700910741004e-06  -3.693703626455e-07   9.504432686918e-09
      5      -1.055200072961e-07   4.925799326252e-08  -2.289228094874e-09
      6      -4.220795463450e-08  -3.412218769390e-09   2.463341794395e-10
      7       3.190991837665e-09   1.145196210456e-10  -1.210616102483e-11
      8      -5.846914988817e-11  -1.673892090785e-12   2.258466544149e-13

   Error 8.04e-05
```

Reaction 7.2.1 $p + H^- \rightarrow p + H + e$

```
   E Index          0                    1                    2
 T Index
    0       -5.820131282154e+01  -4.418295075826e-01   1.273789037973e+00
    1        7.921427713311e+00   4.771816683717e-01  -3.122978202046e-02
    2        2.729868361636e+00  -1.003942758610e+00  -1.263868632256e-01
    3       -1.702566612373e+00   5.785696129573e-01  -4.732954195668e-03
    4        3.973780588321e-01  -1.478528997647e-01   1.158502169314e-02
    5       -4.870825299595e-02   1.969477666027e-02  -2.123634522072e-03
    6        3.236718833237e-03  -1.407103305708e-03   1.493109405401e-04
    7       -1.084755026674e-04   4.998674210260e-05  -3.376656915211e-06
    8        1.396208954849e-06  -6.620153170835e-07  -2.627392847530e-08

   E Index          3                    4                    5
 T Index
    0        1.527207940425e+00  -7.536424630223e-01   1.439466388013e-01
    1       -7.888775801865e-01   3.288138016027e-01  -5.784931758231e-02
    2        1.435920376766e-01  -3.733709098912e-02   5.120254991289e-03
    3       -1.244717631219e-02  -8.125405039157e-04   5.304019788343e-04
    4        1.217335613258e-03   1.744838040179e-05  -6.302890522722e-05
    5       -1.652073669891e-04   7.132512952865e-05  -7.166374800128e-06
    6        9.210684173413e-06  -6.258784083367e-06   9.976414798586e-07
    7        1.518653946410e-07  -5.285593274691e-09  -1.618019219414e-08
    8       -1.935457835554e-08   1.017637467796e-08  -9.682272656474e-10

   E Index          6                    7                    8
 T Index
    0       -1.390229840299e-02   6.747109860492e-04  -1.308869018310e-05
    1        5.240004832333e-03  -2.411772118083e-04   4.478567757510e-06
    2       -4.068737543562e-04   1.774870848760e-05  -3.291488867455e-07
    3       -5.311181815494e-05   1.788414701774e-06  -8.455601658664e-09
    4        8.167685239892e-06  -4.004411200193e-07   6.703922705847e-09
    5       -2.654278454630e-08   4.575052609148e-08  -1.985275499541e-09
    6       -3.804512852913e-08  -3.484409058380e-09   2.245422239581e-10
    7        1.247165282825e-09   1.121719496535e-10  -9.065883281241e-12
    8        1.821912346903e-11  -3.038200599319e-13   7.144344819156e-14

   Error  5.01e-04 (B)
```

Reaction 7.2.2 $p + H^- \rightarrow H(n=2) + H(1s)$

```
   E Index            0                    1                    2
T Index
   0       -2.009840732855e+01  2.945311019841e-01  6.747596918807e-02
   1        5.206452202262e-01 -1.774365164859e-01 -1.065938217336e-02
   2        1.523257622741e-01  9.772247255291e-03 -1.671909485907e-02
   3        2.453955732425e-02  1.021908459294e-02  2.438519414977e-03
   4       -6.480928896115e-03 -1.242525298942e-03  1.015757625636e-03
   5       -1.975172853627e-03 -2.672450143654e-04 -2.328706013052e-04
   6        5.435998708470e-04  6.631970392344e-05  9.462039923651e-06
   7       -4.472026617583e-05 -4.970789806324e-06  8.120583670855e-07
   8        1.251083879369e-06  1.282034444684e-07 -5.184939728768e-08

   E Index            3                    4                    5
T Index
   0        5.281180712235e-02  1.853075990865e-03 -5.214983547816e-03
   1        8.534567745269e-03 -2.015642900438e-04 -1.875060648516e-04
   2       -2.499942893968e-03  1.198848516168e-03  5.837864405510e-05
   3       -2.108370566003e-03 -8.621652320901e-05  1.290879800077e-04
   4        2.995184004525e-04 -1.140789673124e-04 -3.180399692215e-06
   5        7.043847826279e-05  2.122349981883e-05 -5.763532119771e-06
   6       -1.718398943085e-05 -4.277037568906e-07  6.826848999792e-07
   7        1.233759362312e-06 -1.215395288499e-07 -1.469076279075e-08
   8       -2.971450478059e-08  6.283704324845e-09 -5.567626168906e-10

   E Index            6                    7                    8
T Index
   0        9.106146930077e-04 -6.179659482888e-05  1.518671797497e-06
   1        2.166774591691e-05 -7.154959806623e-07  3.341578770132e-10
   2       -4.532942700372e-05  4.566989804119e-06 -1.425164722921e-07
   3       -1.884472793311e-05  1.063634324920e-06 -2.098030063540e-08
   4        3.691852062324e-06 -3.822422186488e-07  1.207671501711e-08
   5        2.097347343793e-07  2.744685327018e-08 -1.629591430987e-09
   6       -4.961730812520e-08 -1.574040495320e-09  1.647011369051e-10
   7        3.375069155440e-10  2.528285218582e-10 -1.407865804427e-11
   8        1.064408722092e-10 -1.331534803275e-11  5.209521592110e-13

   Error  9.91e-04 (B)
```

Reaction 7.2.3 $p + H^- \rightarrow H(n=3) + H(1s)$

```
  E Index            0                    1                    2
T Index
    0       -1.708169812006e+01  -1.310597645979e-01  -2.016054239030e-02
    1       -1.098675942533e-01   8.969312492472e-02  -1.001934703492e-02
    2       -2.424453483379e-02  -7.668315551548e-03   1.118173178217e-02
    3        8.542779858410e-03  -5.728980402850e-03  -1.374395114022e-03
    4        7.546932951352e-04   1.282616012621e-03  -5.242666757105e-04
    5       -4.460619874465e-04  -6.407045514906e-06   1.627184981581e-04
    6        5.689498536274e-05  -2.131881433227e-05  -1.769191253093e-05
    7       -3.155262052836e-06   2.122673795556e-06   8.581432797541e-07
    8        6.668405706096e-08  -6.364778304060e-08  -1.541736278733e-08


  E Index            3                    4                    5
T Index
    0        8.964903471778e-03   6.442616660302e-04  -4.660365148908e-04
    1       -5.890144705724e-03   1.384217913807e-03   1.779238684618e-05
    2       -1.257344700418e-03  -6.729866629037e-04   2.054778233488e-04
    3        1.029305874211e-03  -5.123704753586e-05  -4.411992401625e-05
    4       -1.091263631596e-04   5.650953446193e-05  -4.197841783909e-06
    5       -2.000801209847e-05  -7.808493438675e-06   1.772154859168e-06
    6        5.122279431664e-06   1.659419345620e-07  -1.384458129532e-07
    7       -3.925060139873e-07   3.050794133610e-08   1.377776084081e-09
    8        1.041255114173e-08  -1.512980436877e-09   1.332411705243e-10


  E Index            6                    7                    8
T Index
    0        6.370816676015e-05  -3.782683702643e-06   8.609188888839e-08
    1       -3.013382774299e-05   2.954660809114e-06  -8.931384100116e-08
    2       -2.315115305809e-05   1.190025285551e-06  -2.326585429997e-08
    3        9.037770228405e-06  -6.768442086761e-07   1.812120616012e-08
    4       -5.411932096608e-07   8.415741816738e-08  -2.978331246224e-09
    5       -9.596489328029e-08  -2.035464169710e-09   2.147130564694e-10
    6        1.037345875045e-08   1.399052051710e-11  -1.531475772097e-11
    7       -1.232733782717e-11  -2.816042650663e-11   1.402510343416e-12
    8       -1.732775970924e-11   1.621564942355e-12  -5.400526340307e-14


  Error  1.23e-05 (A)
```

Reaction 7.3.1 $H^- + H(1s) \rightarrow H(1s) + H^-(1s)$

```
   E Index          0                    1                    2
 T Index
    0       -2.446549884269e+01  2.282921659881e-01  6.932259053475e-02
    1        2.634131317967e-01 -1.250144616925e-01 -6.564104931024e-03
    2        5.739515657001e-02  1.401243736042e-02 -1.370769740386e-02
    3       -3.083480423288e-03  5.762622642079e-03  1.641868158109e-03
    4       -2.155324535935e-03 -1.741051127171e-03  8.917026172582e-04
    5        7.685873715096e-05  1.906770746936e-04 -1.497853929999e-04
    6        8.087530514888e-05 -1.359658266200e-05 -9.370283912465e-06
    7       -1.201616211995e-05  9.404454583406e-07  2.798537842077e-06
    8        4.838440948297e-07 -3.591774662931e-08 -1.280487901835e-07


   E Index          3                    4                    5
 T Index
    0       -1.460337641019e-02 -1.148284334186e-03  1.888298450789e-03
    1        1.034238130425e-02 -1.160529409915e-04 -6.554701103747e-04
    2       -1.631710543681e-03  1.504466063314e-03 -1.492959802239e-04
    3       -1.158102233053e-03 -1.500016779601e-04  1.333539925260e-04
    4        3.323370760750e-04 -1.435851350450e-04  8.827631680416e-08
    5       -3.852538752998e-05  3.638688148903e-05 -5.971816791477e-06
    6        5.240710288295e-06 -2.673369866914e-06  5.756054051438e-07
    7       -6.106253322733e-07  3.599735795836e-09  9.761611536846e-09
    8        2.617375100182e-08  4.349591668816e-09 -1.894102703596e-09


   E Index          6                    7                    8
 T Index
    0       -5.048413591687e-04  5.442003557424e-05 -2.119938012240e-06
    1        1.312358086468e-04 -1.025406435973e-05  2.930874591340e-07
    2       -1.535700264182e-05  3.028402252514e-06 -1.223371130502e-07
    3       -2.335914959456e-05  1.720243174222e-06 -4.737046201928e-08
    4        4.695207254022e-06 -5.743305788389e-07  2.072162215301e-08
    5        1.312086122421e-07  3.381300299186e-08 -1.846446053198e-09
    6       -4.928206213204e-08  1.359692653300e-09  7.095887472625e-12
    7       -9.446355577370e-10  1.324857300193e-11  1.212840280599e-12
    8        2.250181340057e-10 -1.085735441577e-11  1.640670966131e-13

   Error  2.16e-03 (C)
```

203

Reaction 7.3.2a $H^- + H \rightarrow H_2^-(\Sigma_g) \rightarrow H + H + e$

```
E Index            0                    1                    2
T Index
   0       -2.060381621916e+01   5.309100960058e-01   1.392829074695e-01
   1        7.588123099350e-01  -3.576940273729e-01  -1.987510302857e-02
   2        6.731769657604e-02   4.484233894719e-02  -2.733782810986e-02
   3       -2.921355392156e-02   1.482283181415e-02   5.906948645836e-03
   4       -8.146699299025e-04  -3.643845685721e-03   9.773942210504e-04
   5        1.155948959822e-03  -2.087103325148e-05  -3.907609724337e-04
   6       -1.581407518895e-04   6.895932849865e-05   4.008820591876e-05
   7        8.836837813921e-06  -6.605304596227e-06  -1.507273917480e-06
   8       -1.822275438433e-07   1.936335851996e-07   1.172227886690e-08


E Index            3                    4                    5
T Index
   0       -2.102641710803e-02  -6.781349963009e-03   2.016215809719e-03
   1        2.668242766164e-02  -3.261461848245e-04  -1.366958646410e-03
   2       -1.554648294430e-03   2.123755455543e-03  -2.773916489042e-04
   3       -2.598822894319e-03  -1.875799348857e-04   1.758361880894e-04
   4        4.600843838170e-04  -1.448878357902e-04  -1.060700155439e-06
   5        2.315526538554e-05   3.237966723085e-05  -5.841079752828e-06
   6       -1.092581698940e-05  -2.012024682441e-06   6.606514619140e-07
   7        8.757818250078e-07  -1.331205306048e-08  -1.679915115556e-08
   8       -2.240888951133e-08   3.415505655444e-09  -3.436228509229e-10


E Index            6                    7                    8
T Index
   0       -2.021191702941e-04   8.841314274130e-06  -1.379541011203e-07
   1        2.452687401131e-04  -1.698794209121e-05   4.269734144618e-07
   2        9.627819846149e-07   1.668014583065e-06  -7.372505366253e-08
   3       -2.636740402205e-05   1.616979349290e-06  -3.621463869178e-08
   4        3.717760767389e-06  -3.932211297595e-07   1.249308982925e-08
   5        1.129239553545e-07   3.349164498023e-08  -1.726363311444e-09
   6       -3.323645378786e-08  -2.310130864690e-09   1.678089205296e-10
   7        7.727272538571e-11   2.259701266295e-10  -1.191390422294e-11
   8        8.001148282982e-11  -9.879026759786e-12   3.844676704391e-13


Error  7.20e-05 (A
```

Reaction 7.3.2b $H^- + H \rightarrow H_2^-(\Sigma_g) \rightarrow H_2 + e$

```
E Index          0                    1                    2
T Index
   0      -2.010720050130e+01   9.270256057913e-02   4.064624494679e-02
   1       1.269636887793e-01  -4.008719210304e-02  -1.212200218053e-02
   2       3.912641450862e-02  -4.922699464361e-03  -2.358617965735e-03
   3       2.444823703314e-03   3.862828408110e-03   6.245030315710e-05
   4      -1.375395363511e-03   9.136383818175e-05   3.424787531975e-04
   5       7.705307936032e-06  -2.452524870403e-04  -4.618148515540e-05
   6       2.808922151936e-05   4.232400689568e-05  -2.685853929702e-06
   7      -2.890778521667e-06  -2.902579165065e-06   7.058422006406e-07
   8       8.872270416775e-08   7.252699730279e-08  -2.925937563766e-08


E Index          3                    4                    5
T Index
   0       4.009352818185e-03  -1.538314339134e-03   6.474680671630e-06
   1       4.382832251342e-03   5.808750658711e-04  -3.518386094650e-04
   2      -9.020736846330e-04   3.801661661405e-04   1.342533092878e-05
   3      -3.877053574415e-04  -3.173212632597e-05   2.768229470146e-05
   4       3.970724372076e-05  -4.033536057563e-05   2.837106654166e-06
   5       2.083693473819e-05   7.210478132956e-06  -2.015504293252e-06
   6      -4.253675760089e-06  -4.555400231697e-08   1.858779383984e-07
   7       2.828822067547e-07  -5.462822668312e-08  -6.645063119276e-10
   8      -6.263750441883e-09   2.637137895225e-09  -3.152813312676e-10


E Index          6                    7                    8
T Index
   0       2.652929923557e-05  -2.559456729654e-06   7.459443536792e-08
   1       4.949650860383e-05  -2.957539611478e-06   6.557962278545e-08
   2      -1.447007766306e-05   1.557308263715e-06  -5.100926653114e-08
   3      -3.314905595837e-06   1.239094303050e-07  -3.472887336273e-10
   4       6.818837404440e-07  -9.934681425484e-08   3.579429434382e-09
   5       6.344059934988e-08   1.253846512396e-08  -7.317167395513e-10
   6      -1.179832220191e-08  -9.932172729863e-10   7.663678877930e-11
   7      -5.638246638305e-11   8.392102689376e-11  -4.907260382466e-12
   8       3.426087000167e-11  -3.525203792329e-12   1.448748836700e-13


Error  2.06e-05 (A)
```

4 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 kinetic energy of the impacting electron or ion in eV, or the radiation energy loss per reaction, etc. In the present section (newly added to this database by DR) the energy weighted rate is a function of temperature [eV] of the impacting electron or ion.

The general expression for this type of incident particle energy weighted rate, vs. temperature of the first particle A involved in the collision process and in which the second particle B is at rest, reads:

$\langle \sigma v_A E_A \rangle (T_A) = kT_A \cdot \langle \sigma v_A \rangle \cdot \left(3/2 + \frac{d\ln\langle\sigma v_A\rangle}{d\ln(kT_A)} \right)$

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

general formula for rate: see original text. Here: fit to rate for recomb into 1s ground state.
Then: take only the first 2 coeffs and derive the corresponding electron energy rate.
Do not use: This is a poor approximation at higher Te, as it only captures the low Te behaviour
(b1 approx -0.5, h1 approx 0.5).

```
h0 -2.96197012800e+01    h1  0.470220050000e+00    h2  0.000000000000e+00
h3  0000000000000e+00    h4  0.000000000000e+00    h5  0.000000000000e+00
h6  0.00000000000e+00    h7  0.000000000000e+00    h8  0.000000000000e+00
```

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 fit should result in
$\langle \sigma v_e E_{elec} \rangle (T_e) \approx 0.89 \, kT_e \, \langle \sigma v_e \rangle$,
i.e. low energy electrons are preferred in this reaction, rather than the average electrons with
$3/2 \, kT_e$

```
h0 -1.682072926000e+01    h1  3.964351525300e-01    h2 -2.501012514300e-11
h3  1.066503238000e-11    h4  2.724261514100e-12    h5 -2.120710160500e-12
h6  4.248055273200e-13    h7 -3.653955751100e-14    h8  1.187177640600e-15
```

References

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[2] D. Reiter, P. Bogen, U. Samm, Journal Nuclear Materials, Vol 196-198, 1992, 1059-1064