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Analytic Cross Sections for Collisions of H, H_2, He and Li Atoms and Ions with Atoms and Molecules. I

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Analytic expressions fitted to Barnett's recommended data are given for the cross sections of the following reactions: (1) electron capture by H, H^+, H_2^+, He^+, and He^{2+} colliding with atoms, molecules, and ions and (2) electron capture into excited states by H^+, He^+, and He^{2+} colliding with atoms and molecules. The latter category includes cross sections for photon emission due to electron capture. The expressions use the semiempirical functional forms proposed by Green and McNeal and some modified forms to make it possible not only to interpolate but also to extrapolate the recommended data.

Keywords: Electron Capture, H, H_2, He, Li

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H, H_2, HeおよびLi原子・イオンと原子・分子の衝突断面積の解析的表式 I

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Barnettの推奨データ〔ＯＲＮＬ－６０８６／Ｖ１(1990)〕に対する解析的表式を電子捕獲および励起状態への電子捕獲の反応断面積について与えた。後者には電子捕獲に伴う光放出断面積も含まれている。解析的表式として，推奨データの内外挿ができるようにGreen and McNeal〔J. Geophys. Res. 76, 133 (1971)〕の経験式を変形したものを採用した。

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1 Introduction

For diagnostics and modeling of plasmas in thermonuclear-fusion research, data on cross sections for inelastic collisions between atoms, molecules and ions, especially of the lightest elements, are important. Barnett [1] has published recommended data on such cross sections for the elements of hydrogen, helium and lithium. To facilitate interpolation, Barnett has also given least-squares Chebyshev polynomial fits to the recommended cross- sections as a function of projectile energy. The polynomial fits, however, cannot be used for extrapolation, because they often show physically unreasonable behavior just outside the energy range of the data used. This inconvenience can be removed by using analytic expressions that approximate low-energy and high-energy asymptotic trends.

Green and McNeal [2] proposed semi-empirical expressions for inelastic collision cross-sections of hydrogen atoms and ions with gaseous atoms and molecules. By using the same functional form as the Green-McNeal expressions and some modified forms, Nakai *et al.* [3] have published a number of analytic cross-sections for charge transfer of hydrogen atoms and ions colliding with gaseous atoms and molecules. Analytic cross-sections useful for thermonuclear-fusion research and other purposes are also available for the following reactions: charge transfer of hydrogen atoms and ions colliding with metal vapors [4], single-electron capture of hydrogen ions leading to specified excited states of hydrogen [5], charge transfer of helium atoms and ions colliding with gaseous atoms and molecules [6], single-electron capture by multiply charged ions colliding with H, H_2 and He [7], and ionization of H, H_2 and He by multiply-charged ions [8]. References from [3] to [8] are the products of the joint research program of data compilation sponsored by Japan Atomic Energy Research Institute. Presently a project of formulating analytic expressions fitted to Barnett's recommended data is in progress, and part of the result is given in this report.

1.1 Formulation

One of the basic functional forms of the present analytic expressions is the one used by Green and McNeal to express the cross sections for electron capture by H^+. We write it in the form:

$$\sigma = \sigma_0 a_1 (E/E_{\mathrm{R}})^{a_2} / [1 + (E/a_3)^{a_2+a_4} + (E/a_5)^{a_2+a_6}], \tag{1}$$

where σ is the cross section, σ_0 is a convenient cross-section unit (here 10^{-16} cm^2), E is the projectile energy, E_{R} is a convenient energy unit (we use the Rydberg energy multiplied by the ratio of the projectile mass to the electron mass; 25 keV for H and H^+, 50 keV for $H_2{}^+$, and 99.27 keV for He^+ and He^{2+}), and a_i (i=1, 2, ..., 6) are adjustable parameters. When the above expression is used down to the energy close to

the threshold energy E_t of the reaction, E should be replaced by $E-E_t$. Equation (1) includes the approximate theoretical expressions derived by Rapp and Francis [9] for low- and intermediate-energy regions. At high energies it shows the form given by Bohr's semiclassical argument or by the Born approximation. In finding optimum values for a_i in Eq. (1), it is necessary to use nonlinear least-squares fit, in contrast to linear least-squares fit for the Chebyshev polynomial. The form of Eq. (1), however, allows us to guess good starting values for a_i rather easily from the plot of the cross section *vs* energy in logarithmic scales.

When two peaks or a peak and a shoulder appear in the dependence of the cross section on energy, we use a superposition of plural terms, each having the form of the right-hand side of Eq. (1). The superposition is used also when a fit with a single term do not give a satisfactory result in spite of the absence of clear evidence for plural peaks. A similar but more sophisticated superposition was used by Rudd *et al.* [10] to express their own experimental data on the electron-capture cross-section for H^+ colliding with gases. To achieve a better fit to some cross-section curves, additional terms have been included in the numerator or the denominator of Eq. (1). The functional form used and the values of adjustable parameters determined for each cross section are given in the main tables of this report.

Table 1. Examples of accuracy of the recommended data and deviations of the fits. The symbol δ_{rms} represents the rms deviation, δ_{max} the maximum deviation, and n the number of adjustable parameters.

Reaction	Accuracy (%)	Chebyshev fit δ_{rms} (%)	Chebyshev fit δ_{max} (%)	Present expression δ_{rms} (%)	Present expression δ_{max} (%)	n
$H+H\rightarrow H^-+H^+$	20–50	1.0	2.0	2.4	4.4	4
$H+He\rightarrow H^-+He^+$	30	1.8	2.9	3.3	6.0	8
$H^++H\rightarrow H+H^+$	10–20	4.5	13.5	1.6	4.9	10
$H^++He\rightarrow H^-+He^{2+}$	40–100	10	21	5.0	15	8
$H_2{}^++H\rightarrow H_2+H^+$	30	0.1	0.2	0.8	1.7	4
$He^++He\rightarrow He+He^+$	20	2.4	9.2	1.5	3.3	10
$He^{2+}+Li\rightarrow He+Li^{2+}$	30	3.1	8.4	0.8	1.4	8

1.2 Discussion

The Chebyshev fits given by Barnett [1] mostly use nine adjustable parameters (eighth-degree polynomial). On the other hand, the number of adjustable parameters used in the present expressions is less than this for most of the reactions. For small number of

reactions, however, numbers of parameters from ten to fifteen were used. The accuracy of the recommended data, the root-mean-square (rms) and maximum deviations of the Chebyshev fit and those of the present expression are compared in Table 1 for representative reactions. The deviation of the present expression is sometimes larger than that of the Chebyshev fit, but is almost always much smaller than the uncertainty of the recommended data.

The possible error of the present expressions when they are used for the extrapolation of the recommended data is difficult to estimate, because it strongly depends on the unknown behavior of the cross section in the energy ranges outside the available data. We can however obtain a rough estimation by comparing a special expression, fitted only to a central part of the known curve, with the rest of the recommended data. Such an estimation is described in the following. We have fitted Eq. (1) to part of the recommended data for the reaction $H^+ + He \rightarrow H^- + He^{2+}$, in the energy range from 4 to 100 keV. The expression obtained represents the recommended data in this energy range within a deviation of 2.9%. When we use this expression down to 0.47 keV (the energy lower by a factor of about 10 than the low-energy end of the data used), the maximum deviation is 9.5%. The low-energy extrapolation of this cross section represents a rather favorable case, because the cross section decreases rather slowly with an almost constant gradient on a logarithmic plot. On the other hand, the extrapolation up to 1000 keV (the energy higher by a factor 10 than the high-energy end of the data used) shows the maximum deviation of 62%. This represents a rather unfavorable case, because the cross section decreases rapidly in the energy range above 100 keV by changing the gradient on a logarithmic plot.

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2 List of Analytic Expressions

In Tables the analytic expression used for each reaction is denoted as Equation m-n, where m represents the principal number assigned to a group of expressions that use the same basic function or a set of basic functions, and n represents the subnumber equal to the total number of adjustable parameters in the expression.
When a value of $E_{\rm th}$ is given for a reaction in Tables, E in the expression should be replaced by $E_1 = E - E_{\rm th}$.

The meaning of symbols are as follows:

σ	Cross section of process
σ_0	Unit of cross section, 10^{-16} cm^2
E	Projectile energy (in keV/amu)
$E_{\rm R}$	Rydberg energy multiplied by the ratio of the atomic mass of projectile species to the electron mass (25.0 keV for the projectiles of H and H^+, 50.0 keV for the projectile of $H_2{}^+$, 99.27 keV for the projectiles of He^+ and He^{2+})
$E_{\rm th}$	Threshold energy of process (in keV)
a_i $(i = 1, 2, \ldots)$	Adjustable parameters

$m = 3$

$n = 3$ $\sigma = f(E)$
$n = 5$ $\sigma = f(E) + a_4 f(E/a_5)$
$n = 7$ $\sigma = f(E) + a_4 f(E/a_5) + a_6 f(E/a_7)$,

where

$$f(x) = \sigma_0 a_1 (x/E_{\rm R})^{a_2} / [1 + (x/a_3)^{2a_2}].$$

$m = 4$

$n = 4$ $\sigma = f(E)$
$n = 6$ $\sigma = f(E) + a_5 f(E/a_6)$
$n = 8$ $\sigma = f(E) + a_5 f(E/a_6) + a_7 f(E/a_8)$,

where

$$f(x) = \sigma_0 a_1 (x/E_{\rm R})^{a_2} / [1 + (x/a_3)^{a_2+a_4}].$$

$m = 5$

$n = 10 \quad \sigma = f(E, a_2) + a_6 f(E/a_7, a_5) + a_9 f(E/a_{10}, a_8),$

where

$$f(x) = \sigma_0 a_1 (x/E_{\mathrm{R}})^{\alpha} / [1 + (x/a_3)^{\alpha + a_4}].$$

$m = 6$

$n = 6 \quad \sigma = f(E)$

$n = 8 \quad \sigma = f(E) + a_7 f(E/a_8)$

$n = 10 \quad \sigma = f(E) + a_7 f(E/a_8) + a_9 f(E/a_{10})$

$n = 12 \quad \sigma = f(E) + a_7 f(E/a_8) + a_9 f(E/a_{10}) + a_{11} f(E/a_{12}),$

where

$$f(x) = \sigma_0 a_1 (x/E_{\mathrm{R}})^{a_2} / [1 + (x/a_3)^{a_2 + a_4} + (x/a_5)^{a_2 + a_6}]$$

$$g(x) = \sigma_0 a_1 (x/E_{\mathrm{R}})^{a_2} / [1 + (x/a_5)^{a_2 + a_6}].$$

$m = 9$

$n = 10 \quad \sigma = f(E) + a_5 f(E/a_6) + a_7 g(E/a_8),$

where

$$f(x) = \sigma_0 a_1 (x/E_{\mathrm{R}})^{a_2} / [1 + (x/a_3)^{a_2 + a_4}]$$

$$g(x) = \sigma_0 a_1 (x/E_{\mathrm{R}})^{a_2} / [1 + (x/a_9)^{a_2 + a_{10}} + (x/a_3)^{a_2 + a_4}].$$

$m = 10$

$n = 10 \quad \sigma = f(E)$

$n = 12 \quad \sigma = f(E) + a_{11} f(E/a_{12}),$

where

$$f(x) = \sigma_0 a_1 (x/E_{\mathrm{R}})^{a_2} / [1 + (x/a_3)^{a_2 + a_4} + (x/a_5)^{a_2 + a_6} + (x/a_7)^{a_2 + a_8} + (x/a_9)^{a_2 + a_{10}}].$$

$m = 11$

$$
\begin{aligned}
n=10 \quad & \sigma = f(E, a_2, a_4) + a_7 f(E/a_8, a_9, a_{10}) \\
n=11 \quad & \sigma = f(E, a_2, a_4) + a_7 f(E/a_8, a_2, a_4) + a_9 f(E/a_{10}, a_{11}, a_4) \\
n=12 \quad & \sigma = f(E, a_2, a_4) + a_7 f(E/a_8, a_2, a_4) + a_9 f(E/a_{10}, a_{11}, a_{12}) \\
n=13 \quad & \sigma = f(E, a_2, a_4) + a_7 f(E/a_8, a_2, a_4) + a_9 f(E/a_{10}, a_2, a_4) \\
& \quad + a_{11} f(E/a_{12}, a_{13}, a_4) \\
n=14 \quad & \sigma = f(E, a_2, a_4) + a_7 f(E/a_8, a_2, a_4) + a_9 f(E/a_{10}, a_{11}, a_4) \\
& \quad + a_{12} f(E/a_{13}, a_{14}, a_4),
\end{aligned}
$$

where

$$f(x, \alpha, \beta) = \sigma_0 a_1 (x/E_{\mathrm{R}})^{\alpha} / [1 + (x/a_3)^{\alpha+\beta} + (x/a_5)^{\alpha+a_6}].$$

$m = 12$

$$n=12 \quad \sigma = f(E) + a_7 g(E/a_8) + a_9 g(E/a_{10}) + a_{11} g(E/a_{12}),$$

where

$$f(x) = \sigma_0 a_1 (x/E_{\mathrm{R}})^{2a_2} / [1 + (x/a_3)^{2a_2+a_4} + (x/a_5)^{2a_2+a_6}]$$

$$g(x) = \sigma_0 a_1 (x/E_{\mathrm{R}})^{a_2} / [1 + (x/a_3)^{2a_2}].$$

$m = 13$

$$
\begin{aligned}
n=11 \quad & \sigma = f(E, a_2, a_4) + a_5 f(E/a_6, a_2, a_7) + a_8 f(E/a_9, a_{10}, a_{11}) \\
n=12 \quad & \sigma = f(E, a_2, a_4) + a_5 f(E/a_6, a_2, a_7) + a_8 f(E/a_9, a_2, a_7) \\
& \quad + a_{10} f(E/a_{11}, a_{12}, a_{12}),
\end{aligned}
$$

where

$$f(x, \alpha, \beta) = \sigma_0 a_1 (x/E_{\mathrm{R}})^{\alpha} / [1 + (x/a_3)^{\alpha+\beta}].$$

$m = 14$

$$
\begin{aligned}
n=8 \quad & \sigma = f(E, a_2) + a_4 f(E/a_5, a_6) + a_7 f(E/a_8, a_6) \\
n=10 \quad & \sigma = f(E, a_2) + a_4 g(E/a_5, a_6, a_7) + a_8 g(E/a_9, a_6, a_{10}),
\end{aligned}
$$

where

$$f(x, \alpha) = \sigma_0 a_1 (x/E_{\mathrm{R}})^{\alpha} / [1 + (x/a_3)^{2\alpha}]$$

$$g(x, \alpha, \beta) = \sigma_0 a_1 (x/E_{\mathrm{R}})^{\alpha} / [1 + (x/a_3)^{\alpha+\beta}].$$

$m = 15$

$n = 15 \quad \sigma = f(E) + a_7[g(E, a_8, a_{10}) + h(E/a_{11}) + a_{13}g(E/a_{14}, a_{15}, 2a_{15})],$

where

$$f(x) = \begin{cases} 0 & \text{for } x \leq 1 \text{ keV} \\ \sigma_0 a_1 (x/E_{\mathrm{R}})^{a_2}/[1 + (x/a_3)^{a_2+a_4} + (x/a_5)^{a_2+a_6}] & \text{for } x > 1 \text{ keV} \end{cases}$$

$$g(x, \alpha, \beta) = \sigma_0 a_1 (x/E_{\mathrm{R}})^{\alpha}/[1 + (x/a_9)^{\alpha+\beta}]$$

$$h(x) = \begin{cases} \sigma_0 a_1 (x/E_{\mathrm{R}})^{a_8}/[1 + (x/a_9)^{a_8+a_{12}}] & \text{for } x < 10 \text{ keV} \\ 0 & \text{for } x \geq 10 \text{ keV}. \end{cases}$$

$m = 16$

$n = 10 \quad \sigma = f(E, a_2) + a_4 f(E/a_5, a_2) + a_6 f(E/a_7, a_8) + a_9 f(E/a_{10}, a_8),$

where

$$f(x, \alpha) = \sigma_0 a_1 (x/E_{\mathrm{R}})^{\alpha}/[1 + (x/a_3)^{2\alpha}].$$

$m = 17$

$n = 15 \quad \sigma = f(E) + a_6 g(E/a_7) + a_9 h(E/a_{10}, a_{12}) + a_{13} h(E/a_{14}, a_{15}),$

where

$$f(x) = \sigma_0 a_1 (x/E_{\mathrm{R}})^{a_2}/[1 + (x/a_3)^{a_2+a_4} + (x/a_5)^{2a_2}]$$

$$g(x) = \sigma_0 a_1 (x/E_{\mathrm{R}})^{a_2}/[1 + (x/a_5)^{a_2+a_8}]$$

$$h(x, \alpha) = \begin{cases} \sigma_0 a_1 (x/E_{\mathrm{R}})^{a_{11}}/[1 + (x/a_5)^{a_{11}+\alpha}] & \text{for } x \leq 5 \text{ keV} \\ 0 & \text{for } x > 5 \text{ keV}. \end{cases}$$

$m = 18$

$n = 8 \quad \sigma = f(E) + a_7 g(E/a_8, a_2)$

$n = 9 \quad \sigma = f(E) + a_7 g(E/a_8, a_9)$

$n = 14 \quad \sigma = f(E) + a_7 h(E/a_8, a_9, a_{10}) + a_{11} h(E/a_{12}, a_{13}, a_{14}),$

where

$$f(x) = \sigma_0 a_1 (x/E_{\mathrm{R}})^{a_2}/[1 + (x/a_3)^{a_2+a_4} + (x/a_5)^{a_2+a_6}]$$

$$g(x, \alpha) = \sigma_0 a_1 (x/E_{\mathrm{R}})^{\alpha}/[1 + (x/a_5)^{\alpha+a_6}]$$

$$h(x, \alpha, \beta) = \sigma_0 a_1 (x/E_{\mathrm{R}})^{\alpha}/[1 + (x/a_3)^{\alpha+\beta}].$$

3 Explanation of Tables

The followings are given for each process:

Range of recommended data	Energy range in which Barnett's recommended data are available
Accuracy	Accuracy of recommended data
Analytic exparession	Functional form of analytic expression, values of constants, values of adjustable parameters, and rms and maximum deviations of analytic expression from recommended data

List of Tables of Parameters for Electron Capture Collisions

Electron Capture by Neutral H

$H + H \rightarrow H^- + H^+$
$H + H_2 \rightarrow H^- + H_2{}^+$
$H + He \rightarrow H^- + He^+$
$H + Li \rightarrow H^- + Li^+$
$H + H^- \rightarrow H^- + H$

Electron Capture by H^+

$H^+ + H \rightarrow H + H^+$
$H^+ + H_2 \rightarrow H$
$H^+ + H_2 \rightarrow H^- + 2H^+$
$H^+ + He \rightarrow H + He^+$
$H^+ + He \rightarrow H^- + He^{2+}$
$H^+ + Li \rightarrow H + Li^+$
$H^+ + H^- \rightarrow H^- + H^+$
$H^+ + H^- \rightarrow 2H$
$H^+ + He^+ \rightarrow [(H + He^{2+}) + (H^+ + He^{2+} + e^-)]$
$H^+ + He^+ \rightarrow H + He^{2+}$

Electron Capture by $H_2{}^+$

$H_2{}^+ + H \rightarrow H_2 + H^+$
$H_2{}^+ + H_2 \rightarrow H_2 + H_2{}^+$
$H_2{}^+ + He \rightarrow H_2 + He^+$
$H_2{}^+(\nu) + H_2 \rightarrow H_2$

Electron Capture by He^+

$He^+ + H \rightarrow He + H^+$
$He^+ + H^- \rightarrow He + H$
$He^+ + H_2 \rightarrow He$
$He^+ + He \rightarrow He + He^+$
$He^+ + Li \rightarrow He + Li^+$
$He^+ + He^+ \rightarrow He + He^{2+}$

Electron Capture by He^{2+}

$He^{2+} + He^+ \rightarrow He^+ + He^{2+}$ (Partial and Total)
$He^{2+} + H^- \rightarrow He^+ + H$
$He^{2+} + H \rightarrow He^+ + H^+$
$He^{2+} + H_2 \rightarrow He^+$
$He^{2+} + H_2 \rightarrow He$
$He^{2+} + He \rightarrow He^+ + He^+$
$He^{2+} + He \rightarrow He + He^{2+}$
$He^{2+} + Li \rightarrow He^+ + Li^+$
$He^{2+} + Li \rightarrow He + Li^{2+}$

List of Tables of Parameters for Electron Capture into Excited States

Electron Capture by H^+

$H^+ + H \rightarrow H(2s) + H^+$
$H^+ + H \rightarrow H(2p) + H^+$
$H^+ + H_2 \rightarrow H(2s)$
$H^+ + H_2 \rightarrow H(2p)$
$H^+ + H_2 \rightarrow H(\text{Lyman-}\alpha\text{ Total})$
$H^+ + H_2 \rightarrow H(\text{Balmer-}\alpha)$
$H^+ + H_2 \rightarrow H(\text{Balmer-}\beta)$
$H^+ + H_2 \rightarrow H(3s)$
$H^+ + H_2 \rightarrow H(3p)$
$H^+ + H_2 \rightarrow H(3d)$
$H^+ + He \rightarrow H(2s) + He^+$
$H^+ + He \rightarrow H(2p) + He^+$
$H^+ + He \rightarrow H(\text{Balmer-}\alpha) + He^+$
$H^+ + He \rightarrow H(3s) + He^+$
$H^+ + He \rightarrow H(3p) + He^+$
$H^+ + He \rightarrow H(3d) + He^+$
$H^+ + Li \rightarrow H(2s) + Li^+$

$H^+ + Li \rightarrow H(2p) + Li^+$
$H^+ + Li \rightarrow H(3s) + Li^+$
$H^+ + Li \rightarrow H(3p) + Li^+$
$H^+ + Li \rightarrow H(3d) + Li^+$

Electron Capture by He^+

$He^+ + H_2 \rightarrow He(2^1S+2^3S)$
$He^+ + H_2 \rightarrow He(2^1P)$
$He^+ + H_2 \rightarrow He(3^1P)$
$He^+ + H_2 \rightarrow He(447.1\ nm)$
$He^+ + H_2 \rightarrow He(587.6\ nm)$
$He^+ + H_2 \rightarrow He(667.8\ nm)$
$He^+ + He \rightarrow He(2^1S+2^3S)$
$He^+ + He \rightarrow He(2^1P) + He^+$
$He^+ + He \rightarrow He(3^1S) + He^+$
$He^+ + He \rightarrow He(3^1P) + He^+$
$He^+ + He \rightarrow He(3^1D) + He^+$
$He^+ + He \rightarrow He(3^3S) + He^+$
$He^+ + He \rightarrow He(3^3P) + He^+$
$He^+ + He \rightarrow He(3^3D) + He^+$
$He^+ + He \rightarrow He(4^1S) + He^+$
$He^+ + He \rightarrow He(4^1P) + He^+$
$He^+ + He \rightarrow He(4^1D) + He^+$
$He^+ + He \rightarrow He(4^3S) + He^+$
$He^+ + He \rightarrow He(4^3P) + He^+$
$He^+ + He \rightarrow He(4^3D) + He^+$
$He^+ + Li \rightarrow He(53.7\ nm) + Li^+$
$He^+ + Li \rightarrow He(58.4\ nm) + Li^+$

Electron Capture by He^{2+}

$He^{2+} + H \rightarrow He^+(2s) + H^+$
$He^{2+} + H \rightarrow He^+(2p) + H^+$
$He^{2+} + H \rightarrow He^+(\text{Lyman-}\alpha) + H^+$
$He^{2+} + H \rightarrow He^+(\text{Lyman-}\beta) + H^+$
$He^{2+} + H \rightarrow He^+(\text{Lyman-}\gamma) + H^+$
$He^{2+} + H \rightarrow He^+(\text{Balmer-}\alpha) + H^+$
$He^{2+} + H \rightarrow He^+(3p) + H^+$
$He^{2+} + H \rightarrow He^+(3s+3d) + H^+$
$He^{2+} + H \rightarrow He^+(4p) + H^+$
$He^{2+} + H_2 \rightarrow He^+(2s)$

$He^{2+} + H_2 \rightarrow He^{+}(2p)$
$He^{2+} + H_2 \rightarrow He^{+}(\text{Lyman-}\alpha)$
$He^{2+} + H_2 \rightarrow He^{+}(\text{Lyman-}\beta)$
$He^{2+} + H_2 \rightarrow He^{+}(\text{Lyman-}\gamma)$
$He^{2+} + H_2 \rightarrow He^{+}(\text{Balmer-}\alpha)$
$He^{2+} + H_2 \rightarrow He^{+}(3p)$
$He^{2+} + H_2 \rightarrow He^{+}(3s+3d)$
$He^{2+} + H_2 \rightarrow He^{+}(4p)$
$He^{2+} + He \rightarrow He^{+}(2s) + He^{+}$
$He^{2+} + Li \rightarrow He^{+}(2p) + Li^{+}$
$He^{2+} + Li \rightarrow He^{+}(3p) + Li^{+}$
$He^{2+} + Li \rightarrow He^{+}(4p) + Li^{+}$
$He^{2+} + Li \rightarrow He^{+}(3s+3d) + Li^{+}$
$He^{2+} + Li \rightarrow He^{+}(4s+4d) + Li^{+}$
$He^{2+} + Li \rightarrow He^{+}(\text{Lyman-}\alpha) + Li^{+}$
$He^{2+} + Li \rightarrow He^{+}(\text{Lyman-}\beta) + Li^{+}$
$He^{2+} + Li \rightarrow He^{+}(\text{Lyman-}\gamma) + Li^{+}$
$He^{2+} + Li \rightarrow He^{+}(\text{Balmer-}\alpha) + Li^{+}$
$He^{2+} + Li \rightarrow He^{+}(\text{Balmer-}\beta) + Li^{+}$
$He^{2+} + Li \rightarrow He^{+}(\text{Balmer-}\gamma) + Li^{+}$
$He^{2+} + Li \rightarrow He^{+}(\text{Balmer-}\delta) + Li^{+}$

Tables of Parameters for Electron Capture Collisions

Electron Capture by Neutral H

$$H + H \rightarrow H^- + H^+$$

Range of recommended data: 2.0 keV/amu $\leq E \leq$ 73 keV/amu.
Accuracy: 50% for $E \leq$ 8 keV/amu; 20% for $E >$ 8 keV/amu.
Analytic expression: Equation 4-4, E_R = 25.0 keV.
Values of a_i (i = 1, 2, 3, 4) are as follows.

a_1	a_2	a_3	a_4
3.939E−01	1.283E+00	2.092E+01	2.507E+00

The expression represents the recommended data with an rms deviation of 2.4%.
The maximum deviation is 4.4% at 31 keV/amu.
See Graph 1.

$$H + H_2 \rightarrow H^- + H_2{}^+$$

Range of recommended data: 4.0×10^{-2} keV/amu $\leq E \leq 4.6\times10^{2}$ keV/amu.
Accuracy: 25%.
Analytic expression: Equation 6-12, E_R = 25.0 keV.
Values of a_i (i = 1, 2, ..., 12) are as follows.

a_1	a_2	a_3	a_4	a_5	a_6
6.206E−01	2.070E+00	1.538E+01	1.125E+00	4.666E+01	4.899E+00

a_7	a_8	a_9	a_{10}	a_{11}	a_{12}
1.555E+00	3.510E−01	2.478E−01	8.277E−03	5.078E−02	1.600E−03

The value of a_{12} was assumed.
The expression represents the recommended data withan rms deviation of 5.2%.
The maximum deviation is 11% at 1.0×10^{2} keV/amu.
See Graph 2.

$H + He \rightarrow H^- + He^+$

Range of recommended data: 0.77 keV/amu $\leq E \leq 7.6\times10^2$ keV/amu.
Accuracy: 30%.
Analytic expression: Equation 6-8, $E_R = 25.0$ keV.
Values of a_i ($i = 1, 2, \ldots, 8$) are as follows.

a_1	a_2	a_3	a_4
3.491E−02	1.426E+00	4.698E+01	2.409E+00

a_5	a_6	a_7	a_8
1.241E+02	5.603E+00	1.122E+00	3.453E−01

The expression represents the recommended data with an rms deviation of 3.3%.
The maximum deviation is 6.0% at 10 keV/amu.
See Graph 3.

$H + Li \rightarrow H^- + Li^+$

Range of recommended data: 30 keV/amu $\leq E \leq 1.0\times10^2$ keV/amu.
Accuracy: 30%.
Analytic expression: Equation 3-5, $E_R = 25.0$ keV.
Values of a_i ($i = 1, 2, \ldots, 5$) are as follows.

a_1	a_2	a_3	a_4	a_5
4.476E−04	2.344E+00	8.058E+01	1.104E+04	1.000E−02

The value of a_5 was selected among trial values.
The expression represents the recommended data with an rms deviation of 2.9%.
The maximum deviation is 5.1% at 40 keV/amu.
See Graph 4.

$H + H^- \rightarrow H^- + H$

Range of recommended data: 2.0×10^{-3} keV/amu $\leq E \leq 7.1$ keV/amu.
Accuracy: 30%.
Analytic expression: Equation 6-8, $E_R = 25.0$ keV.
Values of a_i ($i = 1, 2, \ldots, 8$) are as follows.

a_1	a_2	a_3	a_4
5.964E+01	4.784E−03	5.204E−01	8.708E−01

a_5	a_6	a_7	a_8
1.538E+00	2.508E+00	1.566E+00	2.627E−02

The expression represents the recommended data with an rms deviation of 0.49%.
The maximum deviation is 1.1% at 0.4 keV/amu.
See Graph 5.

Electron Capture by H^+

$$H^+ + H \rightarrow H + H^+$$

Range of recommended data: 1.2×10^{-4} keV/amu $\leq E \leq 6.3\times10^{2}$ keV/amu.
Accuracy: 10% for $E < 1 \times 10^{-2}$ keV/amu; 15% for 1×10^{-2} keV/amu $\leq E \leq 1$ keV/amu; 5% for 1 keV/amu $< E < 1\times10^{2}$ keV/amu; 20% for 1×10^{2} keV/amu $\leq E \leq 6.3\times10^{2}$ keV/amu.
Analytic expression: Equation 11-10, $E_R = 25.0$ keV.
Values of a_i ($i = 1, 2, \ldots, 10$) are as follows.

a_1	a_2	a_3	a_4	a_5
4.880E+00	−1.090E−01	3.410E+01	3.368E+00	7.351E+01

a_6	a_7	a_8	a_9	a_{10}
5.876E+00	2.287E+00	1.358E−01	−1.028E−01	1.051E+00

The expression represents the recommended data with an rms deviation of 1.6%.
The maximum deviation is 4.9% at 70 keV/amu.
See Graph 6.

$$H^+ + H_2 \rightarrow H$$

Range of recommended data: 2.6×10^{-3} keV/amu $\leq E \leq 4.0\times10^{3}$ keV/amu.
Accuracy: Unknown for $E < 1\times10^{-1}$ keV/amu; 10% for $E > 1\times10^{-1}$ keV/amu.
Analytic expression: Equation 11-13, $E_R = 25.0$ keV, $E_{th} = 1.84\times10^{-3}$ keV.
Values of a_i ($i = 1, 2, \ldots, 13$) are as follows.

a_1	a_2	a_3	a_4	a_5
1.873E+01	9.782E-01	1.675E+01	1.868E+00	4.934E+01

a_6	a_7	a_8	a_9	a_{10}
5.282E+00	1.009E+00	2.598E−01	4.645E−08	3.302E+01

a_{11}	a_{12}	a_{13}
1.006E−01	1.501E−04	1.478E+00

The expression represents the recommended data with an rms deviation of 8.1%.
The maximum deviation is 17% at 7.0×10^2 keV/amu.
See Graph 7.

$$\mathbf{H^+ + H_2 \rightarrow H^- + 2H^+}$$

Range of recommended data: 0.20 keV/amu $\leq E \leq 1.0\times10^3$ keV/amu.
Accuracy: 25% for $E\leq1\times10$ keV/amu; 15% for 1×10 keV/amu<E<1×10^2 keV/amu; 40% for $E \geq 1\times10^2$ keV/amu.
Analytic expression: Equation 6-10, $E_R = 25.0$ keV.
Values of a_i ($i = 1, 2, \ldots, 10$) are as follows.

a_1	a_2	a_3	a_4	a_5
1.692E−01	1.633E+00	2.420E+01	3.751E+00	4.557E+01

a_6	a_7	a_8	a_9	a_{10}
8.647E+00	6.697E−04	1.154E−02	4.599E−04	2.543E+00

The expression represents the recommended data with an rms deviation of 2.9%.
The maximum deviation is 7.8% at 7.0×10^2 keV/amu.
See Graph 8.

$$\mathbf{H^+ + He \rightarrow H + He^+}$$

Range of recommended data: 9.9×10^{-2} keV/amu $\leq E \leq 1.1\times10^4$ keV/amu.
Accuracy: 40% for $E \leq 5$ keV/amu; 20% for $E > 5$ keV/amu.
Analytic expression: Equation 10-12, $E_R = 25.0$ keV, $E_{th} = 1.84\times10_{-3}$.
Values of a_i ($i = 1, 2, \ldots, 12$) are as follows.

a_1	a_2	a_3	a_4	a_5	a_6
5.568E+03	4.302E+00	1.707E+00	−1.654E+00	6.045E+00	9.806E−01

a_7	a_8	a_9	a_{10}	a_{11}	a_{12}
1.447E+01	3.538E+00	3.2866E+01	5.6243E+00	1.068E−04	5.165E−02

The expression represents the recommended data with an rms deviation of 4.7%.
The maximum deviation is 12% at 1.1×10^4 keV/amu.
See Graph 9.

$H^+ + He \rightarrow H^- + He^{2+}$

Range of recommended data: 0.47 keV/amu $\leq E \leq 1.0\times10^3$ keV/amu.
Accuracy: Factor 2 or more for $E \leq 1\times10$ keV/amu; 40% for $E > 1\times10$ keV/amu.
Analytic expression: Equation 6-8, $E_R = 25.0$ keV.
Values of a_i ($i = 1, 2, \ldots, 8$) are as follows.

a_1	a_2	a_3	a_4
5.425E−03	1.945E+00	3.693E+01	4.847E+00

a_5	a_6	a_7	a_8
6.277E+01	8.544E+00	2.858E−01	1.665E+00

The expression represents the recommended data with an rms deviation of 5.0%.
The maximum deviation is 15% at 7.0×10^2 keV/amu.
See Graph 10.

$H^+ + Li \rightarrow H + Li^+$

Range of recommended data: 0.25 keV/amu $\leq E \leq 5.6\times10^2$ keV/amu.
Accuracy: 30%.
Analytic expression: Equation 6-8, $E_R = 25.0$ keV.
Values of a_i ($i = 1, 2, \ldots, 8$) are as follows.

a_1	a_2	a_3	a_4
2.184E+03	1.541E+00	3.088E+00	1.005E+00

a_5	a_6	a_7	a_8
6.858E+00	4.029E+00	3.980E−03	1.697E+01

The expression represents the recommended data with an rms deviation of 3.0%.
The maximum deviation is 5.8% at 50 keV/amu.
See Graph 11.

$H^+ + H^- \rightarrow H^- + H^+$

Range of recommended data: 5.9×10^{-2} keV/amu $\leq E \leq 1.1$ keV/amu.
Accuracy: 30%.
Analytic expression: Equation 12-12, $E_R = 25.0$ keV.
Values of a_i ($i = 1, 2, \ldots, 12$) are as follows.

a_1	a_2	a_3	a_4	a_5	a_6
7.846E+37	9.087E+00	2.001E−01	−1.868E+00	2.316E−01	1.538E+00

a_7	a_8	a_9	a_{10}	a_{11}	a_{12}
1.916E−19	7.875E−01	2.419E−19	5.055E−01	3.111E−19	3.113E−01

The expression represents the recommended data with an rms deviation of 3.5%.
The maximum deviation is 6.6% at 8.9 $\times 10^{-2}$ keV/amu.
See Graph 12.

$$\mathbf{H^+ + H^- \rightarrow 2H}$$

Range of recommended data: 2.0×10^{-4} keV/amu $\leq E \leq$ 4.8 keV/amu.
Accuracy: 20% for $E > 2\times10^{-2}$ keV/amu; factor 2 for $E \leq 2\times10^{-2}$ keV/amu.
Analytic expression: Equation 4-6, $E_R = 25.0$ keV.
Values of a_i ($i = 1, 2, \ldots, 6$) are as follows.

a_1	a_2	a_3	a_4	a_5	a_6
9.356E+02	4.351E−01	1.319E+00	9.500E−01	2.491E+01	4.253E−05

The expression represents the recommended data with an rms deviation of 2.9%.
The maximum deviation is 6.1% at 1.0×10^{-2} keV/amu.
See Graph 13.

$$\mathbf{H^+ + He^+ \rightarrow [(H + He^{2+}) + (H^+ + He^{2+} + e^-)]}$$

Range of recommended data: 3.3 keV/amu $\leq E \leq 5.2\times10^2$ keV/amu.
Accuracy: 20%.
Analytic expression: Equation 6-8, $E_R = 25.0$ keV.
Values of a_i ($i = 1, 2, \ldots, 8$) are as follows.

a_1	a_2	a_3	a_4
4.124E−01	4.101E+00	2.215E+01	−3.209E−01

a_5	a_6	a_7	a_8
3.640E+01	1.355E+00	4.888E−03	1.454E−01

The expression represents the recommended data with an rms deviation of 3.1%.
The maximum deviation is 5.7% at 7.0 keV/amu.
See Graph 14.

$$H^+ + He^+ \rightarrow H + He^{2+}$$

Range of recommended data: 1.8 keV/amu $\leq E \leq 2.4\times10^2$ keV/amu.
Accuracy: Factor 2 for $E \leq 10$ keV/amu;
25% for 10 keV/amu $< E \leq 2.4\times10^2$ keV/amu.
Analytic expression: Equation 6-8, $E_R = 25.0$ keV.
Values of a_i ($i = 1, 2, \ldots, 8$) are as follows.

a_1	a_2	a_3	a_4
2.411E+03	1.0319E+01	4.773E+00	−3.058E+00

a_5	a_6	a_7	a_8
1.260E+01	1.632E+00	2.316E+00	5.305E−01

The expression represents the recommended data with an rms deviation of 3.3%.
The maximum deviation is 6.6% at 10 keV/amu.
See Graph 15.

Electron Capture by H_2^+

$$H_2^+ + H \rightarrow H_2 + H^+$$

Range of recommended data: 5.0×10^{-2} keV/amu $\leq E \leq 5.0$ keV/amu.
Accuracy: 30%.
Analytic expression: Equation 4-4, $E_R = 50.0$ keV.
Values of a_i ($i = 1, 2, 3, 4$) are as follows.

a_1	a_2	a_3	a_4
1.906E+01	1.252E−01	5.121E+00	1.439E+00

The expression represents the recommended data with an rms deviation of 0.81%.
The maximum deviation is 1.7% at 3.5 keV/amu.
See Graph 16.

$$H_2^+ + H_2 \rightarrow H_2 + H_2^+$$

Range of recommended data: 2.0×10^{-3} keV/amu $\leq E \leq 1.0\times10^2$ keV/amu.
Accuracy: 30% for $E \leq 1$ keV/amu; 20% for $E > 1$ keV/amu.
Analytic expression: Equation 11-9, $E_R = 50.0$ keV.
Values of a_i ($i = 1, 2, \ldots, 9$) are as follows.

a_1	a_2	a_3	a_4	a_5
1.009E+01	1.374E−01	8.152E+00	9.787E−01	2.340E+01

a_6	a_7	a_8	a_9
3.369E+00	3.441E−01	3.344E−03	−2.379E−01

The expression represents the recommended data with an rms deviation of 2.8%.
The maximum deviation is 6.0% at 80 keV/amu.
See Graph 17.

$$\mathbf{H_2{}^+ + He \rightarrow H_2 + He^+}$$

Range of recommended data: 1.2 keV/amu $\leq E \leq$ 24 keV/amu.
Accuracy: Unknown.
Analytic expression: Equation 3-7, $E_R = 50.0$ keV.
Values of a_i ($i = 1, 2, \ldots, 7$) are as follows.

a_1	a_2	a_3	a_4
1.066E+00	2.369E+00	2.189E+01	1.500E−01

a_5	a_6	a_7
1.910E−01	1.842E−01	6.632E−02

The expression represents the recommended data with an rms deviation of 1.9%.
The maximum deviation is 3.8% at 8.0 keV/amu.
See Graph 18.

$$\mathbf{H_2{}^+(\nu) + H_2 \rightarrow H_2}$$

$\nu = 0$ *Range of recommended data:* 4.0×10^{-3} keV/amu $\leq E \leq$ 0.50 keV/amu.
Accuracy: Unknown.
Analytic expression: Equation 6-8, $E_R = 50.0$ keV.
Values of a_i ($i = 1, 2, \ldots, 8$) are as follows.

a_1	a_2	a_3	a_4
3.443E+03	5.7636E−01	3.139E−03	3.6504E−01

a_5	a_6	a_7	a_8
6.3656E−02	3.9691E+00	1.081E+00	1.2375E+02

The expression represents the recommended data with an rms deviation of 0.39%.
The maximum deviation is 0.64% at 9.0×10^{-2} keV/amu.
See Graph 19.

$\nu = 1$ *Range of recommended data:* 4.0×10^{-3} keV/amu $\leq E \leq$ 0.50 keV/amu.
Accuracy: Unknown.
Analytic expression: Equation 3-5, $E_R = 50.0$ keV.
Values of a_i ($i = 1, 2, \ldots, 5$) are as follows.

a_1	a_2	a_3	a_4	a_5
7.815E+00	2.426E−01	2.118E+03	1.225E+00	4.000E−07

The value of a_5 was selected among trial values.
The expression represents the recommended data with an rms deviation of 1.1%.
The maximum deviation is 2.3% at 0.20 keV/amu.
See Graph 20.

$\nu = 2$ *Range of recommended data:* 4.0×10^{-3} keV/amu $\leq E \leq$ 0.50 keV/amu.
Accuracy: Unknown.
Analytic expression: Equation 3-5, $E_R = 50.0$ keV.
Values of a_i($i = 1, 2, \ldots, 5$) are as follows.

a_1	a_2	a_3	a_4	a_5
1.789E+02	3.966E−01	6.393E−02	3.629E+01	2.500E−06

The value of a_5 was selected among trial values.
The expression represents the recommended data with an rms deviation of 0.61%.
The maximum deviation is 1.1% at 0.20 keV/amu.
See Graph 21.

$\nu = 3$ *Range of recommended data:* 4.0×10^{-3} keV/amu $\leq E \leq$ 0.50 keV/amu.
Accuracy: Unknown.
Analytic expression: Equation 6-8, $E_R = 50.0$ keV.
Values of a_i ($i = 1, 2, \ldots, 8$) are as follows.

a_1	a_2	a_3	a_4
3.4475E+12	2.5577E+00	1.749E−03	1.5146E−01

a_5	a_6	a_7	a_8
1.2947E−02	2.9658E+00	6.123E−01	5.631E+01

The expression represents the recommended data with an rms deviation of 0.33%.
The maximum deviation is 0.60% at 0.20 keV/amu.
See Graph 22.

Electron Capture by He^+

$He^+ + H \rightarrow He + H^+$

Range of recommended data: 0.25 keV/amu $\leq E \leq 7.0\times10^2$ keV/amu.
Accuracy: Unknown for $E \leq 0.6$ keV/amu; 30% for $E > 0.6$ keV/amu.
Analytic expression: Equation 6-10, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 10$) are as follows.

a_1	a_2	a_3	a_4	a_5
2.114E+00	1.002E+00	4.911E+01	3.330E+00	1.844E+02

a_6	a_7	a_8	a_9	a_{10}
8.849E+00	4.065E+00	3.949E−01	4.103E−01	2.361E−02

The expression represents the recommended data with an rms deviation of 5.0%.
The maximum deviation is 14% at 1.0×10^2 keV/amu.
See Graph 23.

$He^+ + H^- \rightarrow He + H$

Range of recommended data: 4.2×10^{-2} keV/amu $\leq E \leq 7.7$ keV/amu.
Accuracy: 20%.
Analytic expression: Equation 6-8, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 8$) are as follows.

a_1	a_2	a_3	a_4
6.788E+10	2.664E+00	4.435E−01	2.562E+00

a_5	a_6	a_7	a_8
5.607E−02	7.878E−02	2.812E+05	1.000E−04

The value of a_8 was selected among trial values.
The expression represents the recommended data with an rms deviation of 1.1%.
The maximum deviation is 2.9% at 5.0×10^{-2} keV/amu.
See Graph 24.

$He^+ + H_2 \rightarrow He$

Range of recommended data: 2.4×10^{-6} keV/amu $\leq E \leq 7.0\times10^{2}$ keV/amu.
Accuracy: Unknown for $E \leq 2$ keV/amu; 20% for $E > 2$ keV/amu.
Analytic expression: Equation 11-14, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 14$) are as follows.

a_1	a_2	a_3	a_4	a_5
1.260E+02	1.292E+00	7.245E+00	6.593E−01	3.125E+01

a_6	a_7	a_8	a_9	a_{10}
4.949E+00	1.701E−01	2.676E+00	5.749E−02	4.234E−04

a_{11}	a_{12}	a_{13}	a_{14}
2.889E+00	2.868E−05	1.914E−05	−2.607E−01

The expression represents the recommended data with an rms deviation of 6.9%.
The maximum deviation is 16% at 4.0×10^{-2} keV/amu.
See Graph 25.
Note: Reinig *et al.* [At. Plasma-Wall Int. Data for Fusion, **2**, 95 (1992)] argue that the Barnett's recommended data for this reaction is in a severe disagreement with the experimental data on the dominant process of dissociative charge transfer, $He^+ + H_2 \rightarrow He + H + H^+$.

$He^+ + He \rightarrow He + He^+$

Range of recommended data: 4.0×10^{-5} keV/amu $\leq E \leq 5.3\times10^{2}$ keV/amu.
Accuracy: 20%.
Analytic expression: Equation 6-10, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 10$) are as follows.

a_1	a_2	a_3	a_4	a_5
3.580E+00	−1.228E−01	1.536E+01	1.276E+00	5.199E+01

a_6	a_7	a_8	a_9	a_{10}
4.954E+00	1.421E−01	2.902E+00	5.920E−01	3.612E−02

The expression represents the recommended data with an rms deviation of 1.5%.
The maximum deviation is 3.3% at 4.0×10^{-2} keV/amu.
See Graph 26.

$He^+ + Li \rightarrow He + Li^+$

Range of recommended data: 6.4×10^{-2} keV/amu $\leq E \leq 1.0\times10^{2}$ keV/amu.
Accuracy: 30%.
Analytic expression: Equation 11-12, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 12$) are as follows.

a_1	a_2	a_3	a_4	a_5	a_6
6.630E+03	1.176E+00	2.689E+00	1.192E+00	9.768E+00	6.329E+00

a_7	a_8	a_9	a_{10}	a_{11}	a_{12}
7.257E−03	1.406E+01	3.196E+00	1.055E−01	1.572E+00	6.340E−01

The expression represents the recommended data with an rms deviation of 3.0%.
The maximum deviation is 6.3% at 7.0 keV/amu.
See Graph 27.

$He^+ + He^+ \rightarrow He + He^{2+}$

Range of recommended data: 3.75 keV/amu $\leq E \leq$ 57.5 keV/amu.
Accuracy: 20%.
Analytic expression: Equation 4-4, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, 3, 4$) are as follows.

a_1	a_2	a_3	a_4
4.952E−01	1.694E+00	8.284E+01	9.754E−01

The expression represents the recommended data with an rms deviation of 1.7%.
The maximum deviation is 2.6% at 30 keV/amu.
See Graph 28.

Electron Capture by He^{2+}

$He^{2+} + He^+ \rightarrow He^+ + He^{2+}$ (Partial and Total)

Partial *Note:* In the experiment a problem arises from the mutual repulsion between the reaction products. The repulsion results in scattering with some of the ions not reaching the detector which has a finite acceptance angle. Such results are termed partial cross-sections.
Range of recommended data: 7.0×10^{-3} keV/amu $\leq E \leq$ 16 keV/amu.
Accuracy: Unknown.

Analytic expression: Equation 10-12, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 12$) are as follows.

a_1	a_2	a_3	a_4	a_5	a_6
2.870E+30	8.0855E+00	1.999E−02	−9.110E−01	2.181E−02	1.721E−01

a_7	a_8	a_9	a_{10}	a_{11}	a_{12}
8.927E−02	2.1218E+00	4.620E+00	1.1708E+01	1.164E−01	2.728E−01

The expression represents the recommended data with an rms deviation of 0.72%.
The maximum deviation is 1.7% at 4.0×10^{-2} keV/amu.
See Graph 29.

Total *Range of recommended data:* 8.5×10^{-3} keV/amu $\leq E \leq 3.0\times10^{2}$ keV/amu.
Accuracy: Unknown.
Analytic expression: Equation 10-10, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 12$) are as follows.

a_1	a_2	a_3	a_4	a_5	a_6
4.421E+11	2.681E+00	1.102E−02	1.487E−01	1.422E−02	−7.560E−01

a_7	a_8	a_9	a_{10}	a_{11}	a_{12}
1.650E−01	1.695E+00	6.719E+00	6.226E+00	5.071E−02	1.5E−01

The expression represents the recommended data with an rms deviation of 1.1%.
The maximum deviation is 2.6% at 1.5×10^{2} keV/amu.
See Graph 30.

$$\mathbf{He^{2+} + H^{-} \rightarrow He^{+} + H}$$

Range of recommended data: 4.7×10^{-4} keV/amu $\leq E \leq 3.0$ keV/amu.
Accuracy: 40%.
Analytic expression: Equation 6-8, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 8$) are as follows.

a_1	a_2	a_3	a_4
5.896E+17	2.877E+00	6.554E−04	1.026E−01

a_5	a_6	a_7	a_8
1.082E−02	1.343E+00	5.948E+01	1.000E−05

The value of a_8 was selected among trial values.
The expression represents the recommended data with an rms deviation of 0.77%.
The maximum deviation is 1.5% at 8.0×10^{-3} keV/amu.
See Graph 31.

$$\mathbf{He^{2+} + H \rightarrow He^{+} + H^{+}}$$

Range of recommended data: 7.0×10^{-2} keV/amu $\leq E \leq 5.0\times10^{2}$ keV/amu.
Accuracy: Unknown for $E \leq 6\times10^{-1}$ keV/amu; 20% for $E > 6\times10^{-1}$ keV/amu.
Analytic expression: Equation 6-10, $E_R = 99.27$ keV, $E_R = 99.27$ keV. The parameter E_{th} was used as an additional adjustable parameter.
Values of a_i ($i = 1, 2, \ldots, 10$) are as follows.

a_1	a_2	a_3	a_4	a_5
4.093E+04	2.162E+00	2.474E+00	7.809E−01	5.881E+00

a_6	a_7	a_8	a_9	a_{10}
4.137E+00	1.382E+00	4.251E+00	6.037E−02	9.330E+00

The expression represents the recommended data with an rms deviation of 4.6%.
The maximum deviation is 9.4% at 0.50 keV/amu.
See Graph 32.

$$\mathbf{He^{2+} + H_2 \rightarrow He^{+}}$$

Range of recommended data: 0.14 keV/amu $\leq E \leq 1.0\times10^{3}$ keV/amu.
Accuracy: 20%.
Analytic expression: Equation 11-12, $E_R = 99.27$ keV.
, $E_{th} = 2.99\times10^{-2}$ keV, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 11$) are as follows.

a_1	a_2	a_3	a_4	a_5	a_6
5.427E+01	7.987E−01	2.736E+01	1.740E+00	6.346E+01	4.925E+00

a_7	a_8	a_9	a_{10}	a_{11}
1.045E−02	3.048E+00	2.921E−01	9.872E−03	2.089E+00

The expression represents the recommended data with an rms deviation of 1.5%.
The maximum deviation is 3.5% at 2.0 keV/amu.
See Graph 33.

$He^{2+} + H_2 \rightarrow He$

Range of recommended data: 0.30 keV/amu $\leq E \leq 3.7\times10^2$ keV/amu.
Accuracy: Unknown for $E\leq2.5$ keV/amu; 40% for 2.5 keV/amu$<E<1\times10^2$ keV/amu; 50% for $E>1\times10^2$ keV/amu.
Analytic expression: Equation 11-12, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 12$) are as follows.

a_1	a_2	a_3	a_4	a_5	a_6
2.831E+00	9.915E−01	3.324E+01	2.908E+00	7.172E+01	6.601E+00

a_7	a_8	a_9	a_{10}	a_{11}	a_{12}
1.580E−01	4.361E−01	1.129E+01	1.285E−02	2.960E+00	1.144E+00

The expression represents the recommended data with an rms deviation of 1.1%.
The maximum deviation is 2.5% at 4.0 keV/amu.
See Graph 34.

$He^{2+} + He \rightarrow He^{+} + He^{+}$

Range of recommended data: 2.4×10^{-7} keV/amu $\leq E \leq 2.0\times10^3$ keV/amu.
Accuracy: Unknown for $E \leq 0.25$ keV/amu; 20% for $E > 0.25$ keV/amu.
Accuracy: 20%.
Analytic expression: Equation 11-11, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 11$) are as follows.

a_1	a_2	a_3	a_4	a_5	a_6
2.113E+01	1.139E+00	3.445E+01	1.514E+00	1.047E+02	4.563E+00

a_7	a_8	a_9	a_{10}	a_{11}
3.638E−02	7.568E−02	1.981E−06	1.687E−04	−5.079E−01

The expression represents the recommended data with an rms deviation of 4.7%.
The maximum deviation is 9.8% at 4.0×10^{-3} keV/amu.
See Graph 35.

$He^{2+} + He \rightarrow He + He^{2+}$

Range of recommended data: 7.0×10^{-3} keV/amu $\leq E \leq 4.0\times10^{2}$ keV/amu.
Accuracy: 20%.
Analytic expression: Equation 6-6, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 6$) are as follows.

a_1	a_2	a_3	a_4	a_5	a_6
1.543E+00	−1.164E−01	2.020E+01	9.647E−01	6.088E+01	4.736E+00

The expression represents the recommended data with an rms deviation of 3.5%.
The maximum deviation is 11% at 2.0×10^{2} keV/amu.
See Graph 36.

$He^{2+} + Li \rightarrow He^{+} + Li^{+}$

Range of recommended data: 0.10 keV/amu $\leq E \leq 5.9\times10^{2}$ keV/amu.
Accuracy: 30% for $E \leq 2\times10^{2}$ keV/amu; 40% for $E \geq 2\times10^{2}$ keV/amu.
Analytic expression: Equation 6-8, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 8$) are as follows.

a_1	a_2	a_3	a_4
3.634E+04	9.529E−01	4.052E−01	2.301E−01

a_5	a_6	a_7	a_8
6.010E+00	3.707E+00	1.040E−02	1.253E+01

The expression represents the recommended data with an rms deviation of 4.0%.
The maximum deviation is 11% at 1.5×10^{2} keV/amu.
See Graph 37.

$He^{2+} + Li \rightarrow He + Li^{2+}$

Range of recommended data: 6.1 keV/amu $\leq E \leq 5.0\times10^{2}$ keV/amu.
Accuracy: 30%.
Analytic expression: Equation 6-8, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 8$) are as follows.

a_1	a_2	a_3	a_4
3.354E+02	2.930E+00	1.277E+01	1.287E+00

a_5	a_6	a_7	a_8
7.154E+01	8.359E+00	5.866E−04	1.000E+01

The value of a_8 was assumed.
The expression represents the recommended data with an rms deviation of 5.1%.
The maximum deviation is 13% at 3.0×10^2 keV/amu.
See Graph 38.

Tables of Parameters for Electron Capture into Excited States

Electron Capture by H^+

$H^+ + H \rightarrow H(2s) + H^+$

Range of recommended data: 2.0 keV/amu $\leq E \leq 2.0\times10^2$ keV/amu.
Accuracy: Factor 2 for $E \leq 3$ keV/amu; 30% for 3 keV/amu $\leq E < 1\times10^2$ keV/amu; 50% for $E \geq 1\times10^2$ keV/amu.
Analytic expression: Equation 6-6, $E_R = 25.0$ keV.
Values of a_i ($i = 1, 2, \ldots, 6$) are as follows.

a_1	a_2	a_3	a_4	a_5	a_6
1.352E+00	1.808E+00	1.887E+01	1.076E−02	2.5143E+01	3.0316E+00

The expression represents the recommended data with an rms deviation of 2.5%.
The maximum deviation is 4.9% at 60 keV/amu.
See Graph 39.

$H^+ + H \rightarrow H(2p) + H^+$

Range of recommended data: 0.60 keV/amu $\leq E \leq 2.4\times10^2$ keV/amu.
Accuracy: 40% for $E \leq 2.0$ keV/amu; 25% for 2.0 keV/amu $\leq E < 3.0\times10$ keV/amu; unknown for $E > 3.0\times10$ keV/amu.
Analytic expression: Equation 6-10, $E_R = 25.0$ keV.
Values of a_i ($i = 1, 2, \ldots, 10$) are as follows.

a_1	a_2	a_3	a_4	a_5
2.236E+01	2.889E+00	6.354E+00	5.679E−01	1.301E+01

a_6	a_7	a_8	a_9	a_{10}
3.217E+00	5.906E−03	8.981E+00	1.142E+00	1.902E−01

The expression represents the recommended data with an rms deviation of 1.9%.
The maximum deviation is 4.8% at 1.5 keV/amu.
See Graph 40.

$H^+ + H_2 \rightarrow H(2s)$

Range of recommended data: 2.0 keV/amu $\leq E \leq 2.0\times10^2$ keV/amu.
Accuracy: 50%.
Analytic expression: Equation 6-8, $E_R = 25.0$ keV.
Values of a_i ($i = 1, 2, \ldots, 8$) are as follows.

a_1	a_2	a_3	a_4
5.140E−01	1.389E+00	2.677E+01	1.585E+00

a_5	a_6	a_7	a_8
5.474E+01	4.387E+00	4.418E−02	1.111E−01

The expression represents the recommended data with an rms deviation of 0.82%.
The maximum deviation is 1.5% at 10 keV/amu.
See Graph 41.

$H^+ + H_2 \rightarrow H(2p)$

Range of recommended data: 4.0 keV/amu $\leq E \leq 1.5\times10^2$ keV/amu.
Accuracy: 50%.
Analytic expression: Equation 4-8, $E_R = 25.0$ keV.
Values of a_i ($i = 1, 2, \ldots, 8$) are as follows.

a_1	a_2	a_3	a_4
3.089E−01	3.327E−01	2.2885E+01	3.840E+00

a_5	a_6	a_7	a_8
4.249E−02	7.928E+00	2.203E−01	2.475E+00

The expression represents the recommended data with an rms deviation of 0.24%.
The maximum deviation is 0.49% at 10 keV/amu.
See Graph 42.

$H^+ + H_2 \rightarrow H(\text{Lyman-}\alpha\ \text{Total})$

Range of recommended data: 8.2×10^{-2} keV/amu $\leq E \leq 1.4\times10^2$ keV/amu.
Accuracy: 40%.
Analytic expression: Equation 6-8, $E_R = 25.0$ keV.
Values of a_i ($i = 1, 2, \ldots, 8$) are as follows.

a_1	a_2	a_3	a_4
4.069E+02	3.380E+00	1.887E+00	−1.687E+00

a_5	a_6	a_7	a_8
4.822E+00	7.950E−01	3.717E−01	1.169E−01

The expression represents the recommended data with an rms deviation of 2.5%.
The maximum deviation is 4.2% at 14 keV/amu.
See Graph 43.

$$\mathbf{H^+ + H_2 \longrightarrow H(Balmer\text{-}\alpha)}$$

Range of recommended data: 0.50 keV/amu $\leq E \leq 4.0\times10^2$ keV/amu.
Accuracy: > Factor 2.
Analytic expression: Equation 6-10, $E_R = 25.0$ keV.
Values of a_i ($i = 1, 2, \ldots, 10$) are as follows.

a_1	a_2	a_3	a_4	a_5
4.383E+00	3.441E+00	6.918E+00	−2.778E−01	2.508E+01

a_6	a_7	a_8	a_9	a_{10}
4.747E+00	1.026E−01	2.144E+00	3.223E−01	1.203E−01

The expression represents the recommended data with an rms deviation of 1.8%.
The maximum deviation is 4.6% at 30 keV/amu.
See Graph 44.

$$\mathbf{H^+ + H_2 \longrightarrow H(Balmer\text{-}\beta)}$$

Range of recommended data: 0.50 keV/amu $\leq E \leq 1.5\times10^2$ keV/amu.
Accuracy: Unknown.
Analytic expression: Equation 6-6, $E_R = 25.0$ keV.
Values of a_i ($i = 1, 2, \ldots, 6$) are as follows.

a_1	a_2	a_3	a_4	a_5	a_6
1.638E+01	2.653E+00	1.016E+00	−1.968E−01	6.679E+00	2.553E+00

The expression represents the recommended data with an rms deviation of 3.1%.
The maximum deviation is 5.1% at 0.70 keV/amu.
See Graph 45.

$H^+ + H_2 \rightarrow H(3s)$

Range of recommended data: 1.0 keV/amu $\leq E \leq 3.0\times10^2$ keV/amu.
Accuracy: Factor 2.
Analytic expression: Equation 6-8, $E_R = 25.0$ keV.
Values of a_i ($i = 1, 2, \ldots, 8$) are as follows.

a_1	a_2	a_3	a_4
6.588E−02	1.176E+00	4.409E+01	2.645E+00

a_5	a_6	a_7	a_8
7.489E+01	4.990E+00	3.268E−02	4.308E−02

The expression represents the recommended data with an rms deviation of 3.6%.
The maximum deviation is 6.7% at 4.0 keV/amu.
See Graph 46.

$H^+ + H_2 \rightarrow H(3p)$

Range of recommended data: 2.2 keV/amu $\leq E \leq 3.4\times10^2$ keV/amu.
Accuracy: Factor 2.
Analytic expression: Equation 6-6, $E_R = 25.0$ keV.
Values of a_i ($i = 1, 2, \ldots, 6$) are as follows.

a_1	a_2	a_3	a_4	a_5	a_6
6.607E+04	6.199E+00	2.397E+00	−2.969E−01	4.486E+00	2.248E+00

The expression represents the recommended data with an rms deviation of 5.5%.
The maximum deviation is 8.8% at 32 keV/amu.
See Graph 47.

$H^+ + H_2 \rightarrow H(3d)$

Range of recommended data: 1.4 keV/amu $\leq E \leq 3.0\times10^2$ keV/amu.
Accuracy: Factor 2.
Analytic expression: Equation 6-8, $E_R = 25.0$ keV.
Values of a_i ($i = 1, 2, \ldots, 8$) are as follows.

a_1	a_2	a_3	a_4
3.940E−02	7.769E−01	1.555E+01	1.987E+00

a_5	a_6	a_7	a_8
4.523E+01	6.270E+00	2.970E−03	1.185E+01

The expression represents the recommended data with an rms deviation of 3.4%.
The maximum deviation is 6.0% at 30 keV/amu.
See Graph 48.

$$\mathbf{H^+ + He \rightarrow H(2s) + He^+}$$

Range of recommended data: 2.8 keV/amu $\leq E \leq 2.0\times10^2$ keV/amu.
Accuracy: 50%.
Analytic expression: Equation 6-8, $E_R = 25.0$ keV.
Values of a_i ($i = 1, 2, \ldots, 8$) are as follows.

a_1	a_2	a_3	a_4
4.240E−02	2.965E+00	3.820E+01	1.061E+00

a_5	a_6	a_7	a_8
6.775E+01	4.694E+00	9.376E−02	2.326E−01

The expression represents the recommended data with an rms deviation of 1.2%.
The maximum deviation is 2.6% at 30 keV/amu.
See Graph 49.

$$\mathbf{H^+ + He \rightarrow H(2p) + He^+}$$

Range of recommended data: 0.70 keV/amu $\leq E \leq 3.0\times10^2$ keV/amu.
Accuracy: 30%.
Analytic expression: Equation 6-8, $E_R = 25.0$ keV.
Values of a_i ($i = 1, 2, \ldots, 8$) are as follows.

a_1	a_2	a_3	a_4
2.723E−01	2.321E+00	1.222E+01	5.430E−01

a_5	a_6	a_7	a_8
2.879E+01	3.524E+00	1.152E−01	2.932E−01

The expression represents the recommended data with an rms deviation of 3.3%.
The maximum deviation is 6.8% at 1.0×10^2 keV/amu.
See Graph 50.

$H^+ + He \rightarrow H(\text{Balmer-}\alpha) + He^+$

Range of recommended data: 1.3 keV/amu $\leq E \leq 3.0\times10^2$ keV/amu.
Accuracy: 40%.
Analytic expression: Equation 6-6, $E_R = 25.0$ keV.
Values of a_i ($i = 1, 2, \ldots, 6$) are as follows.

a_1	a_2	a_3	a_4	a_5	a_6
2.965E−02	2.082E+00	3.330E+01	9.724E−01	6.177E+01	3.850E+00

The expression represents the recommended data with an rms deviation of 3.6%.
The maximum deviation is 6.0% at 20 keV/amu.
See Graph 51.

$H^+ + He \rightarrow H(3s) + He^+$

Range of recommended data: 1.2 keV/amu $\leq E \leq 1.3\times10^3$ keV/amu.
Accuracy: Unknown.
Analytic expression: Equation 6-12, $E_R = 25.0$ keV.
Values of a_i ($i = 1, 2, \ldots, 12$) are as follows.

a_1	a_2	a_3	a_4	a_5	a_6
1.107E−02	2.087E+00	4.197E+01	1.605E+00	9.742E+01	5.420E+00

a_7	a_8	a_9	a_{10}	a_{11}	a_{12}
5.266E−03	3.367E+00	7.257E−02	1.359E−01	4.518E−02	3.357E−02

The expression represents the recommended data with an rms deviation of 1.9%.
The maximum deviation is 4.0% at 10 keV/amu.
See Graph 52.

$H^+ + He \rightarrow H(3p) + He^+$

Range of recommended data: 1.7 keV/amu $\leq E \leq 1.2\times10^3$ keV/amu.
Accuracy: Unknown.
Analytic expression: Equation 6-6, $E_R = 25.0$ keV.
Values of a_i ($i = 1, 2, \ldots, 6$) are as follows.

a_1	a_2	a_3	a_4	a_5	a_6
1.026E−02	7.646E−01	5.748E+01	2.735E+00	1.077E+02	5.519E+00

The expression represents the recommended data with an rms deviation of 2.4%.
The maximum deviation is 4.4% at 7.0×10^2 keV/amu.
See Graph 53.

$H^+ + He \rightarrow H(3d) + He^+$

Range of recommended data: 3.0 keV/amu $\leq E \leq 3.2\times10^2$ keV/amu.
Accuracy: Unknown.
Analytic expression: Equation 6-6, $E_R = 25.0$ keV.
Values of a_i ($i = 1, 2, \ldots, 6$) are as follows.

a_1	a_2	a_3	a_4	a_5	a_6
3.662E−03	5.174E−01	1.803E+01	1.360E+00	5.590E+01	4.600E+00

The expression represents the recommended data with an rms deviation of 4.2%.
The maximum deviation is 7.7% at 1.0×10^2 keV/amu.
See Graph 54.

$H^+ + Li \rightarrow H(2s) + Li^+$

Range of recommended data: 0.96 keV/amu $\leq E \leq 1.3\times10^2$ keV/amu.
Accuracy: 60% for $E < 20$ keV/amu; unknown for $E \geq 20$ keV/amu.
Analytic expression: Equation 6-6, $E_R = 25.0$ keV.
Values of a_i ($i = 1, 2, \ldots, 6$) are as follows.

a_1	a_2	a_3	a_4	a_5	a_6
1.489E+03	1.481E+00	4.728E+00	3.241E+00	2.621E+00	8.836E−01

The expression represents the recommended data with an rms deviation of 1.6%.
The maximum deviation is 4.1% at 14 keV/amu.
See Graph 55.

$H^+ + Li \rightarrow H(2p) + Li^+$

Range of recommended data: 0.98 keV/amu $\leq E \leq 1.1\times10^2$ keV/amu.
Accuracy: 60% for $E < 2\times10$ keV/amu; unknown for $E \geq 2\times10$ keV/amu.
Analytic expression: Equation 6-10, $E_R = 25.0$ keV.
Values of a_i ($i = 1, 2, \ldots, 10$) are as follows.

a_1	a_2	a_3	a_4	a_5
3.222E+02	9.544E−01	4.138E+00	1.310E+00	7.546E+00

a_6	a_7	a_8	a_9	a_{10}
5.604E+00	4.696E−06	1.025E+01	2.592E−02	2.380E+00

The expression represents the recommended data with an rms deviation of 2.4%.
The maximum deviation is 5.0% at 9.7 keV/amu.
See Graph 56.

$H^+ + Li \rightarrow H(3s) + Li^+$

Range of recommended data: 1.3 keV/amu $\leq E \leq 1.3\times10^2$ keV/amu.
Accuracy: 60% for $E < 2\times10$ keV/amu; unknown for $E \geq 2\times10$ keV/amu.
Analytic expression: Equation 6-12, $E_R = 25.0$ keV.
Values of a_i ($i = 1, 2, \ldots, 12$) are as follows.

a_1	a_2	a_3	a_4	a_5 a_6	
8.330E+04	6.812E+00	6.236E+00	7.182E−01	8.174E+00	4.264E+00

a_7	a_8	a_9	a_{10}	a_{11}	a_{12}
3.113E−04	8.941E+00	2.617E−01	4.776E−01	2.330E−01	2.033E−01

The expression represents the recommended data with an rms deviation of 2.5%.
The maximum deviation is 7.1% at 60 keV/amu.
See Graph 57.

$H^+ + Li \rightarrow H(3p) + Li^+$

Range of recommended data: 0.98 keV/amu $\leq E \leq 1.3\times10^2$ keV/amu.
Accuracy: 60% for $E < 20$ keV/amu; unknown for $E \geq 20$ keV/amu.
Analytic expression: Equation 6-10, $E_R = 25.0$ keV.
Values of a_i ($i = 1, 2, \ldots, 10$) are as follows.

a_1	a_2	a_3	a_4	a_5
4.529E+03	3.471E+00	3.535E+00	4.068E−01	6.853E+00

a_6	a_7	a_8	a_9	a_{10}
4.117E+00	5.115E−05	1.139E+01	3.780E−01	2.240E−01

The expression represents the recommended data with an rms deviation of 2.8%.
The maximum deviation is 5.1% at 30 keV/amu.
See Graph 58.

$H^+ + Li \rightarrow H(3d) + Li^+$

Range of recommended data: 3.1 keV/amu $\leq E \leq 1.5\times10^2$ keV/amu.
Accuracy: 60% for $E < 20$ keV/amu; unknown for $E \geq 20$ keV/amu.
Analytic expression: Equation 6-8, $E_R = 25.0$ keV.
Values of a_i ($i = 1, 2, \ldots, 8$) are as follows.

a_1	a_2	a_3	a_4
3.551E+00	7.423E−01	9.695E+00	3.357E+00

a_5	a_6	a_7	a_8
1.387E+01	4.428E+00	1.017E−03	5.025E+00

The expression represents the recommended data with an rms deviation of 3.3%.
The maximum deviation is 5.8% at 1.3×10^2 keV/amu.
See Graph 59.

Electron Capture by He^+

$He^+ + H_2 \rightarrow He(2^1S+2^3S)$

Range of recommended data: 2.5 keV/amu $\leq E \leq$ 64 keV/amu.
Accuracy: 40%.
Analytic expression: Equation 4-6, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 6$) are as follows.

a_1	a_2	a_3	a_4	a_5	a_6
3.519E+01	1.979E+00	1.873E+01	1.354E+00	2.163E−01	3.324E−01

The expression represents the recommended data with an rms deviation of 1.4%.
The maximum deviation is 2.3% at 64 keV/amu.
See Graph 60.

$He^+ + H_2 \rightarrow He(2^1P)$

Range of recommended data: 1.3 keV/amu $\leq E \leq$ 8.8 keV/amu.
Accuracy: 60%.
Analytic expression: Equation 4-6, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 6$) are as follows.

a_1	a_2	a_3	a_4	a_5	a_6
4.125E+02	2.155E+00	4.043E+00	4.751E−01	1.007E+00	2.095E−01

The expression represents the recommended data with an rms deviation of 0.93%.
The maximum deviation is 1.8% at 1.5 keV/amu.
See Graph 61.

$He^+ + H_2 \rightarrow He(3^1P)$

Range of recommended data: 1.3 keV/amu $\leq E \leq$ 8.8 keV/amu.
Accuracy: 60%.
Analytic expression: Equation 4-6, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 6$) are as follows.

a_1	a_2	a_3	a_4	a_5	a_6
1.390E+04	5.509E+00	8.808E+00	8.414E−01	1.406E+00	1.864E−01

The expression represents the recommended data with an rms deviation of 1.7%.
The maximum deviation is 2.9% at 3.5 keV/amu.
See Graph 62.

$He^+ + H_2 \rightarrow He(447.1\ nm)$

Range of recommended data: 2.0×10^{-2} keV/amu $\leq E \leq$ 10 keV/amu.
Accuracy: 40%.
Analytic expression: Equation 6-10, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 10$) are as follows.

a_1	a_2	a_3	a_4	a_5
3.974E+32	1.1762E+01	9.020E−02	−2.143E+00	1.043E−01

a_6	a_7	a_8	a_9	a_{10}
4.562E−01	3.711E−02	2.265E−01	5.303E−01	4.605E+01

The expression represents the recommended data with an rms deviation of 3.9%.
The maximum deviation is 9.5% at 10 keV/amu.
See Graph 63.

$He^+ + H_2 \rightarrow He(587.6\ nm)$

Range of recommended data: 1.7×10^{-2} keV/amu $\leq E \leq$ 7.8 keV/amu.
Accuracy: 40%.
Analytic expression: Equation 5-10, $E_R = 99.27$ keV, $E_{th} = 1.541\times10^{-2}$ keV. The parameter E_{th} was used as an additional adjustable parameter.
Values of a_i ($i = 1, 2, \ldots, 10$) are as follows.

a_1	a_2	a_3	a_4	a_5
1.577E+09	3.915E+00	1.561E−01	5.480E−01	2.245E+00

a_6	a_7	a_8	a_9	a_{10}
6.052E−08	4.754E−02	8.058E−01	2.137E−09	1.210E+02

The expression represents the recommended data with an rms deviation of 1.8%.
The maximum deviation is 4.6% at 0.52 keV/amu.
See Graph 64.

$He^+ + H_2 \rightarrow He(667.8\ nm)$

Range of recommended data: 3.7×10^{-2} keV/amu $\leq E \leq$ 0.2 keV/amu.
Accuracy: 40%.
Analytic expression: Equation 4-6, E_R = 99.27 keV, E_{th} = 2.73×10^{-2} keV. The parameter E_{th} was used as an additional adjustable parameter. Values of a_i (i = 1, 2, ..., 6) are as follows.

a_1	a_2	a_3	a_4	a_5	a_6
7.137E+03	2.280E+00	3.563E+00	6.175E+00	5.247E−04	3.689E−02

The expression represents the recommended data with an rms deviation of 5.6%.
The maximum deviation is 11% at 5×10^{-2} keV/amu.
See Graph 65.

$He^+ + He \rightarrow He(2^1S+2^3S)$

Range of recommended data: 1.0×10^{-2} keV/amu $\leq E \leq$ 50 keV/amu.
Accuracy: 40%.
Analytic expression: Equation 9-10, E_R = 99.27 keV.
Values of a_i (i = 1, 2, ..., 10) are as follows.

a_1	a_2	a_3	a_4	a_5
2.882E+02	2.669E+00	7.976E+00	5.086E−01	8.964E−02

a_6	a_7	a_8	a_9	a_{10}
7.173E−03	1.322E+00	9.322E−03	7.156E−01	−8.167E−01

The expression represents the recommended data with an rms deviation of 4.2%.
The maximum deviation is 7.3% at 10 keV/amu.
See Graph 66.

$He^+ + He \rightarrow He(2^1P) + He^+$

Range of recommended data: 1.3 keV/amu $\leq E \leq 2.5\times10^2$ keV/amu.
Accuracy: Unknown.
Accuracy: 60% for $E < 20$ keV/amu; unknown for $E \geq 20$ keV/amu.
Analytic expression: Equation 6-6, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 6$) are as follows.

a_1	a_2	a_3	a_4	a_5	a_6
2.197E−02	5.141E−02	4.594E+00	6.850E−01	7.259E+01	4.716E+00

The expression represents the recommended data with an rms deviation of 0.95%.
The maximum deviation is 1.6% at 70 keV/amu.
See Graph 67.

$He^+ + He \rightarrow He(3^1S) + He^+$

Range of recommended data: 2.5 keV/amu $\leq E \leq 40$ keV/amu.
Accuracy: 40%.
Analytic expression: Equation 6-8, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 8$) are as follows.

a_1	a_2	a_3	a_4
7.698E+00	3.147E+00	1.454E+01	−6.133E−01

a_5	a_6	a_7	a_8
1.781E+01	4.821E−01	1.819E+00	1.200E−04

The value of a_8 was selected among trial values. The expression represents the recommended data with an rms deviation of 1.4%.
The maximum deviation is 2.9% at 10 keV/amu.
See Graph 68.

$He^+ + He \rightarrow He(3^1P) + He^+$

Range of recommended data: 0.75 keV/amu $\leq E \leq 38$ keV/amu.
Accuracy: 40%.
Analytic expression: Equation 5-10, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 10$) are as follows.

a_1	a_2	a_3	a_4	a_5
7.252E−01	2.124E+00	2.138E+01	1.782E+00	3.588E+00

a_6	a_7	a_8	a_9	a_{10}
4.575E+00	1.094E−01	3.588E+00	1.364E+00	3.276E−02

The expression represents the recommended data with an rms deviation of 3.4%.
The maximum deviation is 6.7% at 3.5 keV/amu.
See Graph 69.

$$\mathbf{He^+ + He \rightarrow He(3^1D) + He^+}$$

Range of recommended data: 2.0 keV/amu $\leq E \leq$ 37 keV/amu.
Accuracy: 40%.
Analytic expression: Equation 6-8, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 8$) are as follows.

a_1	a_2	a_3	a_4
3.687E+02	3.145E+00	3.922E+00	5.666E−01

a_5	a_6	a_7	a_8
1.112E+01	4.280E+00	1.822E+00	6.175E−02

The expression represents the recommended data with an rms deviation of 1.2%.
The maximum deviation is 2.0% at 30 keV/amu.
See Graph 70.

$$\mathbf{He^+ + He \rightarrow He(3^3S) + He^+}$$

Range of recommended data: 5.0 keV/amu $\leq E \leq$ 30 keV/amu.
Accuracy: 40%.
Analytic expression: Equation 3-5, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 5$) are as follows.

a_1	a_2	a_3	a_4	a_5
5.028E−01	1.963E+00	3.462E+01	1.032E−01	1.214E−01

The expression represents the recommended data with an rms deviation of 1.0%.
The maximum deviation is 2.1% at 20 keV/amu.
See Graph 71.

$He^+ + He \rightarrow He(3^3P) + He^+$

Range of recommended data: 0.25 keV/amu $\leq E \leq$ 37 keV/amu.
Accuracy: 40%.
Analytic expression: Equation 14-8, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 8$) are as follows.

a_1	a_2	a_3	a_4
3.147E−02	5.187E−01	8.052E+01	4.819E−01

a_5	a_6	a_7	a_8
2.318E−02	3.458E+00	8.820E−02	2.820E−03

The expression represents the recommended data with an rms deviation of 2.6%.
The maximum deviation is 5.8% at 4.0 keV/amu.
See Graph 72.

$He^+ + He \rightarrow He(3^3D) + He^+$

Range of recommended data: 0.25 keV/amu $\leq E \leq$ 38 keV/amu.
Accuracy: 40%.
Analytic expression: Equation 13-12, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 12$) are as follows.

a_1	a_2	a_3	a_4	a_5	a_6
2.375E+03	4.762E+00	8.071E+00	1.566E+00	7.700E−01	4.588E−01

a_7	a_8	a_9	a_{10}	a_{11}	a_{12}
3.436E+00	1.048E+00	1.692E−01	1.134E−04	2.722E−02	9.186E−01

The expression represents the recommended data with an rms deviation of 2.8%.
The maximum deviation is 5.6% at 2.8 keV/amu.
See Graph 73.

$He^+ + He \rightarrow He(4^1S) + He^+$

Range of recommended data: 0.62 keV/amu $\leq E \leq$ 38 keV/amu.
Accuracy: 40%.
Analytic expression: Equation 13-11, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 11$) are as follows.

a_1	a_2	a_3	a_4	a_5	a_6
8.814E−02	2.097E+00	2.380E+01	1.252E+00	5.527E−02	4.150E−02

a_7	a_8	a_9	a_{10}	a_{11}
3.137E+00	2.232E+02	7.975E−02	7.523E+00	6.031E−01

The expression represents the recommended data with an rms deviation of 3.1%.
The maximum deviation is 9.3% at 12 keV/amu.
See Graph 74.

$$\mathbf{He^+ + He \rightarrow He(4^1P) + He^+}$$

Range of recommended data: 1.0 keV/amu $\leq E \leq$ 39 keV/amu.
Accuracy: 40%.
Analytic expression: Equation 14-10, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 10$) are as follows.

a_1	a_2	a_3	a_4	a_5
2.008E−01	1.820E+00	2.102E+01	6.877E−02	2.077E−01

a_6	a_7	a_8	a_9	a_{10}
1.298E+00	4.857E+00	2.877E−02	5.104E−02	1.620E+01

The expression represents the recommended data with an rms deviation of 2.0%.
The maximum deviation is 5.6% at 16 keV/amu.
See Graph 75.

$$\mathbf{He^+ + He \rightarrow He(4^1D) + He^+}$$

Range of recommended data: 0.25 keV/amu $\leq E \leq$ 38 keV/amu.
Accuracy: 40%.
Analytic expression: Equation 15-15, $E_R = 99.27$ keV. The function $f(x)$ have to be computed in double precision arithmetic in Fortran.
Values of a_i ($i = 1, 2, \ldots, 15$) are as follows.

a_1	a_2	a_3	a_4	a_5
1.840E+14	1.2372E+01	3.964E+00	−1.213E+00	6.289E+00

a_6	a_7	a_8	a_9	a_{10}
3.604E+00	1.001E−09	5.259E+00	2.717E+00	1.605E+01

a_{11}	a_{12}	a_{13}	a_{14}	a_{15}
3.261E−01	6.563E−01	3.563E−05	1.387E−01	2.260E+00

The expression represents the recommended data with an rms deviation of 3.1%.
The maximum deviation is 7.4% at 30 keV/amu.
See Graph 76.

$$\mathbf{He^+ + He \rightarrow He(4^3S) + He^+}$$

Range of recommended data: 0.37 keV/amu $\leq E \leq$ 37 keV/amu.
Accuracy: 40%.
Analytic expression: Equation 16-10, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 10$) are as follows.

a_1	a_2	a_3	a_4	a_5
1.045E−01	1.864E+00	3.836E+01	6.403E−02	6.800E−02

a_6	a_7	a_8	a_9	a_{10}
6.858E−01	2.029E−02	5.395E+00	1.192E+00	9.097E−03

The expression represents the recommended data with an rms deviation of 4.1%.
The maximum deviation is 11% at 15 keV/amu.
See Graph 77.

$$\mathbf{He^+ + He \rightarrow He(4^3P) + He^+}$$

Range of recommended data: 0.37 keV/amu $\leq E \leq$ 37 keV/amu.
Accuracy: 40%.
Analytic expression: Equation 17-15, $E_R = 99.27$ keV. The functions $f(x)$ and $g(x, \alpha)$ have to be computed in double precision arithmetic in Fortran.
Values of a_i ($i = 1, 2, \ldots, 15$) are as follows.

a_1	a_2	a_3	a_4	a_5
7.093E+01	2.626E+00	6.405E−01	−8.793E−01	1.5E+01

a_6	a_7	a_8	a_9	a_{10}
2.214E−03	2.096E−01	6.248E+00	2.513E+19	3.946E−02

a_{11}	a_{12}	a_{13}	a_{14}	a_{15}
3.0E+01	3.973E+00	4.650E+19	8.594E−03	1.488E+00

The value of a_{11} was assumed.
The expression represents the recommended data with an rms deviation of 4.2%.
The maximum deviation is 15% at 0.57 keV/amu.
See Graph 78.

$$\mathbf{He^+ + He \rightarrow He(4^3D) + He^+}$$

Range of recommended data: 0.25 keV/amu $\leq E \leq$ 38 keV/amu.
Accuracy: 40%.
Analytic expression: Equation 18-14, E_R = 99.27 keV.
Values of a_i (i = 1, 2, ..., 14) are as follows.

a_1	a_2	a_3	a_4	a_5
1.436E+00	2.237E+00	8.701E+00	1.442E+00	3.012E+01

a_6	a_7	a_8	a_9	a_{10}
1.202E+01	9.641E+01	1.344E−01	4.208E+00	2.136E+00

a_{11}	a_{12}	a_{13}	a_{14}
1.146E+00	4.038E−02	2.234E+00	2.661E+00

The expression represents the recommended data with an rms deviation of 2.2%.
The maximum deviation is 4.3% at 30 keV/amu.
See Graph 79.

$$\mathbf{He^+ + Li \rightarrow He(53.7\ nm) + Li^+}$$

Range of recommended data: 0.50 keV/amu $\leq E \leq$ 5.0 keV/amu.
Accuracy: Unknown.
Analytic expression: Equation 3-5, E_R = 99.27 keV.
Values of a_i (i = 1, 2, ..., 5) are as follows.

a_1	a_2	a_3	a_4	a_5
2.741E+03	2.593E+00	4.621E+00	1.228E−01	2.811E−01

The expression represents the recommended data with an rms deviation of 2.0%.
The maximum deviation is 3.2% at 1.0 keV/amu.
See Graph 80.

$He^+ + Li \rightarrow He(58.4\ nm) + Li^+$

Range of recommended data: 0.50 keV/amu $\leq E \leq$ 5.0 keV/amu.
Accuracy: Unknown.
Analytic expression: Equation 3-5, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 5$) are as follows.

a_1	a_2	a_3	a_4	a_5
1.984E+03	1.747E+00	4.998E+00	3.685E−01	1.714E−01

The expression represents the recommended data with an rms deviation of 3.4%.
The maximum deviation is 6.5% at 2.5 keV/amu.
See Graph 81.

Electron Capture by He^{2+}

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

Range of recommended data: 2.3×10^{-2} keV/amu $\leq E \leq 2.5\times10^3$ keV/amu.
Accuracy: 40% for 1.5 keV/amu $< E < 1.22\times10^2$ keV/amu; else unknown.
Analytic expression: Equation 10-10, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 10$) are as follows.

a_1	a_2	a_3	a_4	a_5
2.614E+11	5.060E+00	3.130E−01	−1.804E+00	6.559E−01

a_6	a_7	a_8	a_9	a_{10}
1.428E−01	3.189E+00	3.341E+00	8.290E+00	5.349E+00

The expression represents the recommended data with an rms deviation of 5.0%.
The maximum deviation is 10% at 4.0×10^{-2} keV/amu.
See Graph 82.

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

Range of recommended data: 0.30 keV/amu $\leq E \leq 5.7\times10^2$ keV/amu.
Accuracy: 20% for 1.0×10^{-3} keV/amu $< E <$ 10 keV/amu.
Analytic expression: Equation 18-8, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 8$) are as follows.

a_1	a_2	a_3	a_4
6.469E+03	1.747E+00	2.830E+00	1.918E−01

a_5	a_6	a_7	a_8
1.243E+01	3.428E+00	7.780E−06	4.570E+01

The expression represents the recommended data with an rms deviation of 3.3%.
The maximum deviation is 11% at 80 keV/amu.
See Graph 83.

$$\mathbf{He^{2+} + H \rightarrow He^{+}(Lyman\text{-}\alpha) + H^{+}}$$

Range of recommended data: 1.2 keV/amu $\leq E \leq$ 10 keV/amu.
Accuracy: 30%.
Analytic expression: Equation 3-5, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 5$) are as follows.

a_1	a_2	a_3	a_4	a_5
8.082E+01	1.183E+00	2.660E+01	7.611E−01	2.000E−01

The value of a_5 was selected among trial values.
The expression represents the recommended data with an rms deviation of 1.4%.
The maximum deviation is 3.6% at 1.5 keV/amu.
See Graph 84.

$$\mathbf{He^{2+} + H \rightarrow He^{+}(Lyman\text{-}\beta) + H^{+}}$$

Range of recommended data: 1.6 keV/amu $\leq E \leq$ 10 keV/amu.
Accuracy: 30%.
Analytic expression: Equation 4-6, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 6$) are as follows.

a_1	a_2	a_3	a_4	a_5	a_6
1.100E+05	3.426E+00	2.325E+00	2.292E−01	1.726E+00	6.044E+00

The expression represents the recommended data with an rms deviation of 0.61%.
The maximum deviation is 1.6% at 2.9 keV/amu.
See Graph 85.

$$\mathbf{He^{2+} + H \rightarrow He^{+}(Lyman\text{-}\gamma) + H^{+}}$$

Range of recommended data: 4.8 keV/amu $\leq E \leq$ 10 keV/amu.
Accuracy: 30%.

Analytic expression: Equation 3-5, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 5$) are as follows.

a_1	a_2	a_3	a_4	a_5
7.981E+00	2.183E+00	4.696E+02	1.101E−04	1.000E−02

The value of a_5 was assumed.
The expression represents the recommended data with an rms deviation of 0.46%.
The maximum deviation is 0.66% at 5.0 keV/amu.
See Graph 86.

$$He^{2+} + H \rightarrow He^{+}(\text{Balmer-}\alpha) + H^{+}$$

Range of recommended data: 2.8 keV/amu $\leq E \leq$ 10 keV/amu.
Accuracy: 30%.
Analytic expression: Equation 4-6, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 6$) are as follows.

a_1	a_2	a_3	a_4	a_5	a_6
4.261E+02	2.489E+00	8.493E+00	1.241E+00	2.829E−01	2.763E−01

The expression represents the recommended data with an rms deviation of 0.32%.
The maximum deviation is 0.75% at 6.5 keV/amu.
See Graph 87.

$$He^{2+} + H \rightarrow He^{+}(3p) + H^{+}$$

Range of recommended data: 1.6 keV/amu $\leq E \leq$ 10 keV/amu.
Accuracy: 30%.
Analytic expression: Equation 6-6, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 6$) are as follows.

a_1	a_2	a_3	a_4	a_5	a_6
3.202E+09	5.8005E+00	1.7337E+00	−4.663E−01	3.190E+00	1.106E+00

The expression represents the recommended data with an rms deviation of 0.44%.
The maximum deviation is 1.0% at 2.5 keV/amu.
See Graph 88.

$$He^{2+} + H \rightarrow He^{+}(3s{+}3d) + H^{+}$$

Range of recommended data: 2.5 keV/amu $\leq E \leq$ 10 keV/amu.
Accuracy: 30%.
Analytic expression: Equation 3-5, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 5$) are as follows.

a_1	a_2	a_3	a_4	a_5
8.002E+01	1.9184E+00	9.960E+00	2.487E−01	1.991E−01

The expression represents the recommended data with an rms deviation of 0.20%.
The maximum deviation is 0.33% at 4.5 keV/amu.
See Graph 89.

$$He^{2+} + H \rightarrow He^{+}(4p) + H^{+}$$

Range of recommended data: 5.0 keV/amu $\leq E \leq$ 10 keV/amu.
Accuracy: 30%.
Analytic expression: Equation 3-5, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 5$) are as follows.

a_1	a_2	a_3	a_4	a_5
7.039E+00	2.118E+00	5.041E+02	1.117E−04	1.000E−02

The value of a_5 was selected among trial values.
The expression represents the recommended data with an rms deviation of 0.61%.
The maximum deviation is 1.2% at 9.0 keV/amu.
See Graph 90.

$$He^{2+} + H_2 \rightarrow He^{+}(2s)$$

Range of recommended data: 2.0 keV/amu $\leq E \leq$ 15 keV/amu.
Accuracy: 60%.
Analytic expression: Equation 4-6, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 6$) are as follows.

a_1	a_2	a_3	a_4	a_5	a_6
6.172E+02	2.542E+00	1.206E+01	2.101E+00	1.067E−01	3.365E−01

The expression represents the recommended data with an rms deviation of 1.9%.
The maximum deviation is 3.0% at 10 keV/amu.
See Graph 91.

$He^{2+} + H_2 \rightarrow He^{+}(2p)$

Range of recommended data: 1.2 keV/amu $\leq E \leq$ 10 keV/amu.
Accuracy: 30%.
Analytic expression: Equation 3-5, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 5$) are as follows.

a_1	a_2	a_3	a_4	a_5
4.755E+02	1.682E+00	1.263E+01	2.783E−02	9.032E−02

The expression represents the recommended data with an rms deviation of 2.4%.
The maximum deviation is 4.4% at 5.0 keV/amu.
See Graph 92.

$He^{2+} + H_2 \rightarrow He^{+}(\text{Lyman-}\alpha)$

Range of recommended data: 1.3 keV/amu $\leq E \leq$ 10 keV/amu.
Accuracy: 30%.
Analytic expression: Equation 3-5, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 5$) are as follows.

a_1	a_2	a_3	a_4	a_5
3.810E+02	1.596E+00	1.559E+01	1.190E−02	6.000E−02

The value of a_5 was assumed.
The expression represents the recommended data with an rms deviation of 1.8%.
The maximum deviation is 2.6% at 5.0 keV/amu.
See Graph 93.

$He^{2+} + H_2 \rightarrow He^{+}(\text{Lyman-}\beta)$

Range of recommended data: 1.7 keV/amu $\leq E \leq$ 10 keV/amu.
Accuracy: 30%.
Analytic expression: Equation 3-5, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 5$) are as follows.

a_1	a_2	a_3	a_4	a_5
3.659E+01	1.998E+00	9.115E+00	4.775E−02	2.286E−01

The expression represents the recommended data with an rms deviation of 0.65%.
The maximum deviation is 1.1% at 5.7 keV/amu.
See Graph 94.

$He^{2+} + H_2 \rightarrow He^{+}$(Lyman-$\gamma$)

Range of recommended data: 5.0 keV/amu $\leq E \leq$ 10 keV/amu.
Accuracy: 30%.
Analytic expression: Equation 3-3, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 3$) are as follows.

a_1	a_2	a_3
3.068E+02	3.702E+00	9.991E+00

The expression represents the recommended data with an rms deviation of 3.3%.
The maximum deviation is 6.1% at 6.5 keV/amu.
See Graph 95.

$He^{2+} + H_2 \rightarrow He^{+}$(Balmer-$\alpha$)

Range of recommended data: 2.5 keV/amu $\leq E \leq$ 10 keV/amu.
Accuracy: 30%.
Analytic expression: Equation 3-5, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 5$) are as follows.

a_1	a_2	a_3	a_4	a_5
5.732E+01	2.042E+00	1.214E+01	8.591E−02	2.334E−01

The expression represents the recommended data with an rms deviation of 0.99%.
The maximum deviation is 1.8% at 2.9 keV/amu.
See Graph 96.

$He^{2+} + H_2 \rightarrow He^{+}$(3p)

Range of recommended data: 2.5 keV/amu $\leq E \leq$ 10 keV/amu.
Accuracy: 30%.
Analytic expression: Equation 3-5, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 5$) are as follows.

a_1	a_2	a_3	a_4	a_5
1.787E+01	1.628E+00	1.584E+01	7.560E−02	8.000E−02

The value of a_5 was assumed.
The expression represents the recommended data with an rms deviation of 2.8%.
The maximum deviation is 7.1% at 3.0 keV/amu.
See Graph 97.

$He^{2+} + H_2 \rightarrow He^{+}(3s+3d)$

Range of recommended data: 1.9 keV/amu $\leq E \leq$ 10 keV/amu.
Accuracy: 30%.
Analytic expression: Equation 4-6, E_R = 99.27 keV.
Values of a_i (i = 1, 2, ..., 6) are as follows.

a_1	a_2	a_3	a_4	a_5	a_6
3.295E+01	2.008E+00	1.010E+01	3.719E+00	1.153E−01	4.290E−01

The expression represents the recommended data with an rms deviation of 2.2%.
The maximum deviation is 4.9% at 2.3 keV/amu.
See Graph 98.

$He^{2+} + H_2 \rightarrow He^{+}(4p)$

Range of recommended data: 5.0 keV/amu $\leq E \leq$ 10 keV/amu.
Accuracy: 30%.
Analytic expression: Equation 4-6, E_R = 99.27 keV.
Values of a_i (i = 1, 2, ..., 6) are as follows.

a_1	a_2	a_3	a_4	a_5	a_6
1.871E+05	6.065E+00	8.421E+00	1.416E+00	9.224E−02	5.214E−01

The expression represents the recommended data with an rms deviation of 0.88%.
The maximum deviation is 1.6% at 8.5 keV/amu.
See Graph 99.

$He^{2+} + He \rightarrow He^{+}(2s) + He^{+}$

Range of recommended data: 2.0 keV/amu $\leq E \leq 4.7\times10^2$ keV/amu.
Accuracy: 50% for E < 20 keV/amu; unknown for $E \geq$ 20 keV/amu.
Analytic expression: Equation 6-10, E_R = 99.27 keV.
Values of a_i (i = 1, 2, ..., 10) are as follows.

a_1	a_2	a_3	a_4	a_5
3.552E+01	2.254E+00	1.710E+01	5.422E−01	3.595E+01

a_6	a_7	a_8	a_9	a_{10}
3.271E+00	1.456E−03	1.020E+01	5.708E−02	7.923E−02

The expression represents the recommended data with an rms deviation of 2.3%.
The maximum deviation is 5.3% at 4.0×10^2 keV/amu.
See Graph 100.

$He^{2+} + Li \rightarrow He^{+}(2p) + Li^{+}$

Range of recommended data: 11 keV/amu $\leq E \leq$ 38 keV/amu.
Accuracy: Unknown but believed that data are accurate to within 60%.
Analytic expression: Equation 4-4, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 4$) are as follows.

a_1	a_2	a_3	a_4
3.780E−01	−1.039E+00	3.969E+01	8.071E+00

The expression represents the recommended data with an rms deviation of 0.46%.
The maximum deviation is 0.74% at 15 keV/amu.
See Graph 101.

$He^{2+} + Li \rightarrow He^{+}(3p) + Li^{+}$

Range of recommended data: 0.56 keV/amu $\leq E \leq$ 30 keV/amu.
Accuracy: Unknown but believed that data are accurate to within 60%.
Analytic expression: Equation 6-6, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 6$) are as follows.

a_1	a_2	a_3	a_4	a_5	a_6
9.775E+00	−3.112E−01	9.756E+00	3.463E+00	2.074E+01	1.058E+01

The expression represents the recommended data with an rms deviation of 1.1%.
The maximum deviation is 1.7% at 20 keV/amu.
See Graph 102.

$He^{2+} + Li \rightarrow He^{+}(4p) + Li^{+}$

Range of recommended data: 1.3 keV/amu $\leq E \leq$ 38 keV/amu.
Accuracy: Unknown but believed that data are accurate to within 60%.
Analytic expression: Equation 6-8, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 8$) are as follows.

a_1	a_2	a_3	a_4
7.026E+02	1.511E+00	8.370E+00	1.348E+00

a_5	a_6	a_7	a_8
1.346E+01	5.216E+00	2.986E−01	2.392E−01

The value of a_2 was not adjusted but assumed.
The expression represents the recommended data with an rms deviation of 1.4%.
The maximum deviation is 2.7% at 20 keV/amu.
See Graph 103.

$$\mathbf{He^{2+} + Li \rightarrow He^{+}(3s{+}3d) + Li^{+}}$$

Range of recommended data: 3.8 keV/amu $\leq E \leq$ 38 keV/amu.
Accuracy: Unknown but believed that data are accurate to within 60%.
Analytic expression: Equation 4-4, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 4$) are as follows.

a_1	a_2	a_3	a_4
1.039E+01	−5.491E−01	1.265E+01	4.457E+00

The expression represents the recommended data with an rms deviation of 5.2%.
The maximum deviation is 10% at 30 keV/amu.
See Graph 104.

$$\mathbf{He^{2+} + Li \rightarrow He^{+}(4s{+}4d) + Li^{+}}$$

Range of recommended data: 3.8 keV/amu $\leq E \leq$ 37 keV/amu.
Accuracy: Unknown but believed that data are accurate to within 60%.
Analytic expression: Equation 3-7, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 7$) are as follows.

a_1	a_2	a_3	a_4
1.864E+04	2.812E+00	8.799E+00	9.703E−01

a_5	a_6	a_7
5.586E−01	1.085E−01	1.866E+00

The expression represents the recommended data with an rms deviation of 0.73%.
The maximum deviation is 1.1% at 6.0 keV/amu.
See Graph 105.

$$\mathbf{He^{2+} + Li \rightarrow He^{+}(Lyman\text{-}\alpha) + Li^{+}}$$

Range of recommended data: 8.1×10^{-4} keV/amu $\leq E \leq$ 38 keV/amu.
Accuracy: Unknown.

Analytic expression: Equation 6-10, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 10$) are as follows.

a_1	a_2	a_3	a_4	a_5
2.007E+14	4.6584E+00	2.121E−01	−1.690E−03	9.670E−01

a_6	a_7	a_8	a_9	a_{10}
2.9335E+00	1.240E−01	1.144E−02	6.399E−02	9.042E−04

The expression represents the recommended data with an rms deviation of 1.0%.
The maximum deviation is 2.0% at 5.0 keV/amu.
See Graph 106.

$$\mathrm{He}^{2+} + \mathrm{Li} \rightarrow \mathrm{He}^{+}(\text{Lyman-}\beta) + \mathrm{Li}^{+}$$

Range of recommended data: 8.3×10^{-4} keV/amu $\leq E \leq$ 38 keV/amu.
Accuracy: Unknown.
Analytic expression: Equation 6-10, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 10$) are as follows.

a_1	a_2	a_3	a_4	a_5
1.185E+03	9.876E−01	4.245E+00	1.444E+00	1.099E+01

a_6	a_7	a_8	a_9	a_{10}
5.084E+00	1.599E+00	1.052E−01	3.001E−01	8.579E−04

The expression represents the recommended data with an rms deviation of 2.1%.
The maximum deviation is 5.4% at 15 keV/amu.
See Graph 107.

$$\mathrm{He}^{2+} + \mathrm{Li} \rightarrow \mathrm{He}^{+}(\text{Lyman-}\gamma) + \mathrm{Li}^{+}$$

Range of recommended data: 1.3 keV/amu $\leq E \leq$ 35 keV/amu.
Accuracy: Unknown.
Analytic expression: Equation 6-8, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 8$) are as follows.

a_1	a_2	a_3	a_4
2.541E+02	1.266E+00	9.947E+00	1.754E+00

a_5	a_6	a_7	a_8
1.467E+01	5.291E+00	2.952E−01	2.591E−01

The value of a_2 was not adjusted but assumed.
The expression represents the recommended data with an rms deviation of 1.1%.
The maximum deviation is 2.0% at 15 keV/amu.
See Graph 108.

$$\mathbf{He^{2+} + Li \rightarrow He^{+}(Balmer\text{-}\alpha) + Li^{+}}$$

Range of recommended data: 3.9 keV/amu $\leq E \leq$ 37 keV/amu.
Accuracy: Unknown.
Analytic expression: Equation 4-8, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 8$) are as follows.

a_1	a_2	a_3	a_4
8.512E+01	9.864E−01	1.625E+01	4.633E+00

a_5	a_6	a_7	a_8
5.610E+00	5.441E−01	6.302E+00	2.705E−01

The expression represents the recommended data with an rms deviation of 2.8%.
The maximum deviation is 6.7% at 30 keV/amu.
See Graph 109.

$$\mathbf{He^{2+} + Li \rightarrow He^{+}(Balmer\text{-}\beta) + Li^{+}}$$

Range of recommended data: 3.8 keV/amu $\leq E \leq$ 38 keV/amu.
Accuracy: 60%.
Analytic expression: Equation 3-5, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 5$) are as follows.

a_1	a_2	a_3	a_4	a_5
3.932E+04	2.5958E+00	4.893E+00	9.472E−01	1.976E+00

The expression represents the recommended data with an rms deviation of 1.3%.
The maximum deviation is 2.5% at 20 keV/amu.
See Graph 110.

$He^{2+} + Li \rightarrow He^{+}(\text{Balmer-}\gamma) + Li^{+}$

Range of recommended data: 5.0 keV/amu $\leq E \leq$ 38 keV/amu.
Accuracy: 60%.
Analytic expression: Equation 6-8, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 8$) are as follows.

a_1	a_2	a_3	a_4
4.999E+04	3.258E+00	6.426E+00	1.399E+00

a_5	a_6	a_7	a_8
1.402E+01	9.529E+00	1.456E−01	2.609E+00

The expression represents the recommended data with an rms deviation of 0.95%.
The maximum deviation is 1.8% at 6.0 keV/amu.
See Graph 111.

$He^{2+} + Li \rightarrow He^{+}(\text{Balmer-}\delta) + Li^{+}$

Range of recommended data: 5.0 keV/amu $\leq E \leq$ 38 keV/amu.
Accuracy: 60%.
Analytic expression: Equation 4-6, $E_R = 99.27$ keV.
Values of a_i ($i = 1, 2, \ldots, 6$) are as follows.

a_1	a_2	a_3	a_4	a_5	a_6
1.773E+00	1.710E−01	1.971E+01	7.900E+00	1.509E−01	2.233E+00

The expression represents the recommended data with an rms deviation of 1.4%.
The maximum deviation is 2.7% at 15 keV/amu.
See Graph 112.

4 Explanation of Graphs

Graphs. Cross section vs Energy

Ordinate	Cross section (in cm^2)
Abscissa	Projectile energy (in eV/amu)

The curve represents the analytic expression, and points, recommended data given by Barnett [1]. The curve is shown, when possible, over the range of projectile energy from $E_{min}/10$ to $10E_{max}$, where E_{min} and E_{max} are the minimum and the maximum energy of the recommended data.

List of Graphs of Cross Sections for Electron Capture Collisions

Electron Capture by Neutral H

$H + H \rightarrow H^- + H^+$
$H + H_2 \rightarrow H^- + H_2{}^+$
$H + He \rightarrow H^- + He^+$
$H + Li \rightarrow H^- + Li^+$
$H + H^- \rightarrow H^- + H$

Electron Capture by H^+

$H^+ + H \rightarrow H + H^+$
$H^+ + H_2 \rightarrow H$
$H^+ + H_2 \rightarrow H^- + 2H^+$
$H^+ + He \rightarrow H + He^+$
$H^+ + He \rightarrow H^- + He^{2+}$
$H^+ + Li \rightarrow H + Li^+$
$H^+ + H^- \rightarrow H^- + H^+$
$H^+ + H^- \rightarrow 2H$
$H^+ + He^+ \rightarrow [(H + He^{2+}) + (H^+ + He^{2+} + e^-)]$
$H^+ + He^+ \rightarrow H + He^{2+}$

Electron Capture by $H_2{}^+$

$H_2{}^+ + H \rightarrow H_2 + H^+$
$H_2{}^+ + H_2 \rightarrow H_2 + H_2{}^+$
$H_2{}^+ + He \rightarrow H_2 + He^+$
$H_2{}^+(\nu) + H_2 \rightarrow H_2$

Electron Capture by He^+

$He^+ + H \rightarrow He + H^+$
$He^+ + H^- \rightarrow He + H$
$He^+ + H_2 \rightarrow He$
$He^+ + He \rightarrow He + He^+$
$He^+ + Li \rightarrow He + Li^+$
$He^+ + He^+ \rightarrow He + He^{2+}$

Electron Capture by He^{2+}

$He^{2+} + He^+ \rightarrow He^+ + He^{2+}$ (Partial and Total)
$He^{2+} + H^- \rightarrow He^+ + H$
$He^{2+} + H \rightarrow He^+ + H^+$
$He^{2+} + H_2 \rightarrow He^+$
$He^{2+} + H_2 \rightarrow He$
$He^{2+} + He \rightarrow He^+ + He^+$
$He^{2+} + He \rightarrow He + He^{2+}$
$He^{2+} + Li \rightarrow He^+ + Li^+$
$He^{2+} + Li \rightarrow He + Li^{2+}$

List of Graphs of Cross Sections for Electron Capture into Excited States

Electron Capture by H^+

$H^+ + H \rightarrow H(2s) + H^+$
$H^+ + H \rightarrow H(2p) + H^+$
$H^+ + H_2 \rightarrow H(2s)$
$H^+ + H_2 \rightarrow H(2p)$
$H^+ + H_2 \rightarrow H(\text{Lyman-}\alpha\text{ Total})$
$H^+ + H_2 \rightarrow H(\text{Balmer-}\alpha)$
$H^+ + H_2 \rightarrow H(\text{Balmer-}\beta)$
$H^+ + H_2 \rightarrow H(3s)$
$H^+ + H_2 \rightarrow H(3p)$
$H^+ + H_2 \rightarrow H(3d)$
$H^+ + He \rightarrow H(2s) + He^+$
$H^+ + He \rightarrow H(2p) + He^+$
$H^+ + He \rightarrow H(\text{Balmer-}\alpha) + He^+$
$H^+ + He \rightarrow H(3s) + He^+$
$H^+ + He \rightarrow H(3p) + He^+$
$H^+ + He \rightarrow H(3d) + He^+$
$H^+ + Li \rightarrow H(2s) + Li^+$

$H^+ + Li \rightarrow H(2p) + Li^+$
$H^+ + Li \rightarrow H(3s) + Li^+$
$H^+ + Li \rightarrow H(3p) + Li^+$
$H^+ + Li \rightarrow H(3d) + Li^+$

Electron Capture by He^+

$He^+ + H_2 \rightarrow He(2^1S+2^3S)$
$He^+ + H_2 \rightarrow He(2^1P)$
$He^+ + H_2 \rightarrow He(3^1P)$
$He^+ + H_2 \rightarrow He(447.1\ nm)$
$He^+ + H_2 \rightarrow He(587.6\ nm)$
$He^+ + H_2 \rightarrow He(667.8\ nm)$
$He^+ + He \rightarrow He(2^1S+2^3S)$
$He^+ + He \rightarrow He(2^1P) + He^+$
$He^+ + He \rightarrow He(3^1S) + He^+$
$He^+ + He \rightarrow He(3^1P) + He^+$
$He^+ + He \rightarrow He(3^1D) + He^+$
$He^+ + He \rightarrow He(3^3S) + He^+$
$He^+ + He \rightarrow He(3^3P) + He^+$
$He^+ + He \rightarrow He(3^3D) + He^+$
$He^+ + He \rightarrow He(4^1S) + He^+$
$He^+ + He \rightarrow He(4^1P) + He^+$
$He^+ + He \rightarrow He(4^1D) + He^+$
$He^+ + He \rightarrow He(4^3S) + He^+$
$He^+ + He \rightarrow He(4^3P) + He^+$
$He^+ + He \rightarrow He(4^3D) + He^+$
$He^+ + Li \rightarrow He(53.7\ nm) + Li^+$
$He^+ + Li \rightarrow He(58.4\ nm) + Li^+$

Electron Capture by He^{2+}

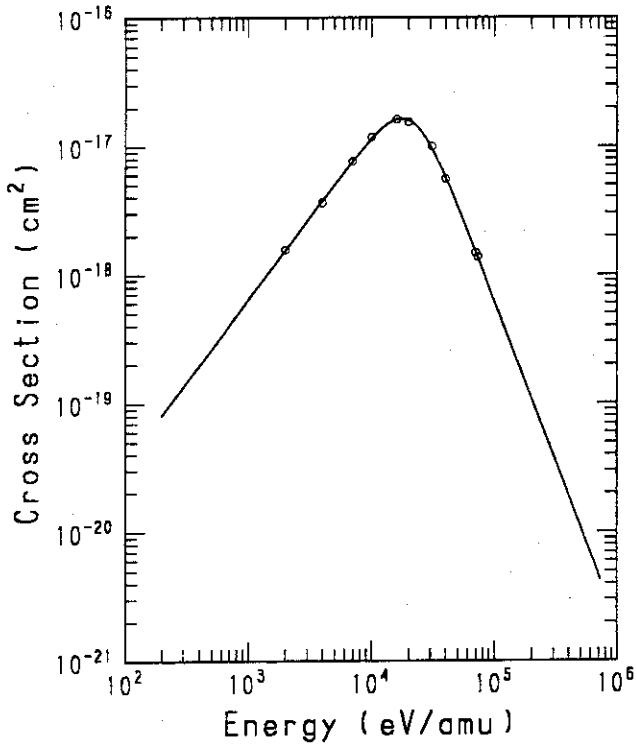
$He^{2+} + H \rightarrow He^+(2s) + H^+$
$He^{2+} + H \rightarrow He^+(2p) + H^+$
$He^{2+} + H \rightarrow He^+(\text{Lyman-}\alpha) + H^+$
$He^{2+} + H \rightarrow He^+(\text{Lyman-}\beta) + H^+$
$He^{2+} + H \rightarrow He^+(\text{Lyman-}\gamma) + H^+$
$He^{2+} + H \rightarrow He^+(\text{Balmer-}\alpha) + H^+$
$He^{2+} + H \rightarrow He^+(3p) + H^+$
$He^{2+} + H \rightarrow He^+(3s+3d) + H^+$
$He^{2+} + H \rightarrow He^+(4p) + H^+$
$He^{2+} + H_2 \rightarrow He^+(2s)$

$He^{2+} + H_2 \rightarrow He^{+}(2p)$
$He^{2+} + H_2 \rightarrow He^{+}(\text{Lyman-}\alpha)$
$He^{2+} + H_2 \rightarrow He^{+}(\text{Lyman-}\beta)$
$He^{2+} + H_2 \rightarrow He^{+}(\text{Lyman-}\gamma)$
$He^{2+} + H_2 \rightarrow He^{+}(\text{Balmer-}\alpha)$
$He^{2+} + H_2 \rightarrow He^{+}(3p)$
$He^{2+} + H_2 \rightarrow He^{+}(3s+3d)$
$He^{2+} + H_2 \rightarrow He^{+}(4p)$
$He^{2+} + He \rightarrow He^{+}(2s) + He^{+}$
$He^{2+} + Li \rightarrow He^{+}(2p) + Li^{+}$
$He^{2+} + Li \rightarrow He^{+}(3p) + Li^{+}$
$He^{2+} + Li \rightarrow He^{+}(4p) + Li^{+}$
$He^{2+} + Li \rightarrow He^{+}(3s+3d) + Li^{+}$
$He^{2+} + Li \rightarrow He^{+}(4s+4d) + Li^{+}$
$He^{2+} + Li \rightarrow He^{+}(\text{Lyman-}\alpha) + Li^{+}$
$He^{2+} + Li \rightarrow He^{+}(\text{Lyman-}\beta) + Li^{+}$
$He^{2+} + Li \rightarrow He^{+}(\text{Lyman-}\gamma) + Li^{+}$
$He^{2+} + Li \rightarrow He^{+}(\text{Balmer-}\alpha) + Li^{+}$
$He^{2+} + Li \rightarrow He^{+}(\text{Balmer-}\beta) + Li^{+}$
$He^{2+} + Li \rightarrow He^{+}(\text{Balmer-}\gamma) + Li^{+}$
$He^{2+} + Li \rightarrow He^{+}(\text{Balmer-}\delta) + Li^{+}$

Graphs of Cross Sections for Electron Capture Collisions

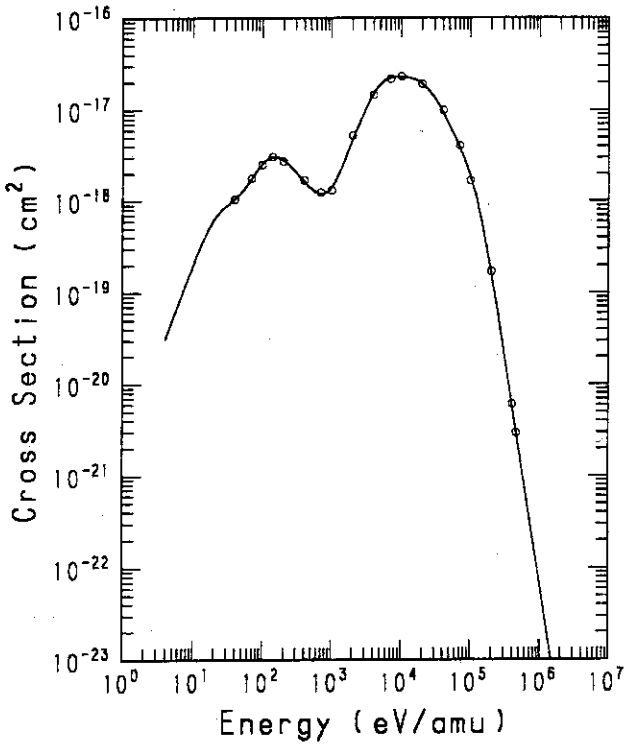
GRAPH 1

$H + H \rightarrow H^- + H^+$



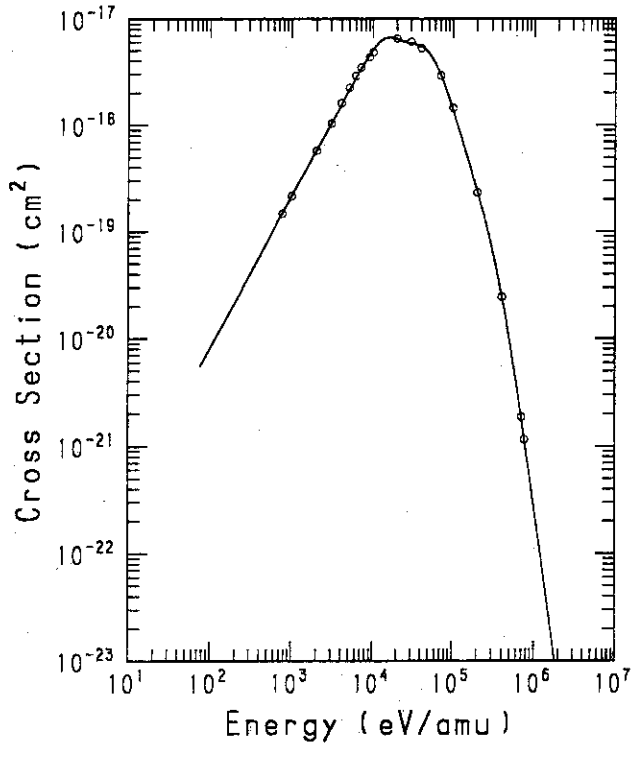
GRAPH 2

$H + H_2 \rightarrow H^- + H_2^+$



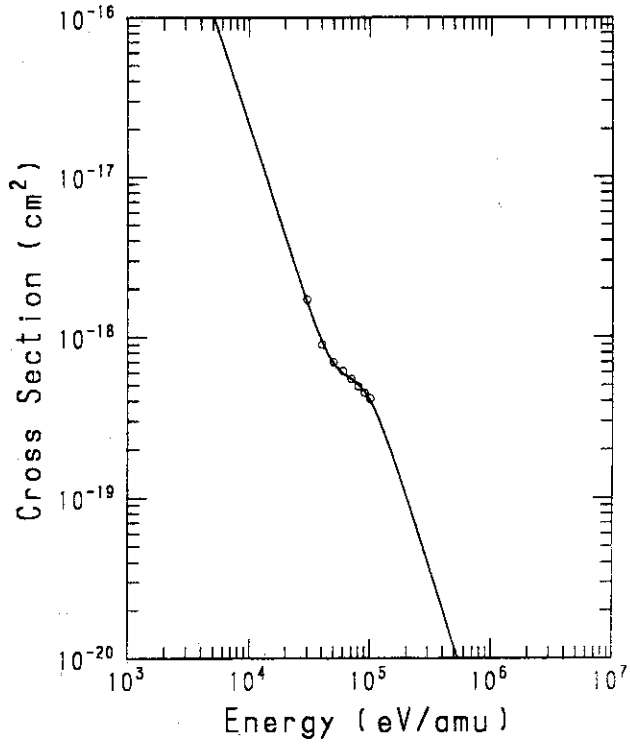
GRAPH 3

$H + He \rightarrow H^- + He^+$



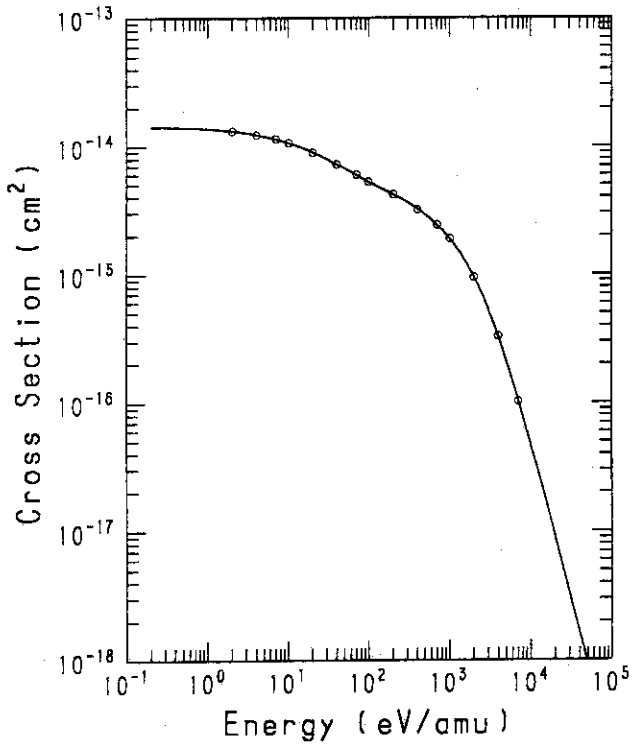
GRAPH 4

$H + Li \rightarrow H^- + Li^+$



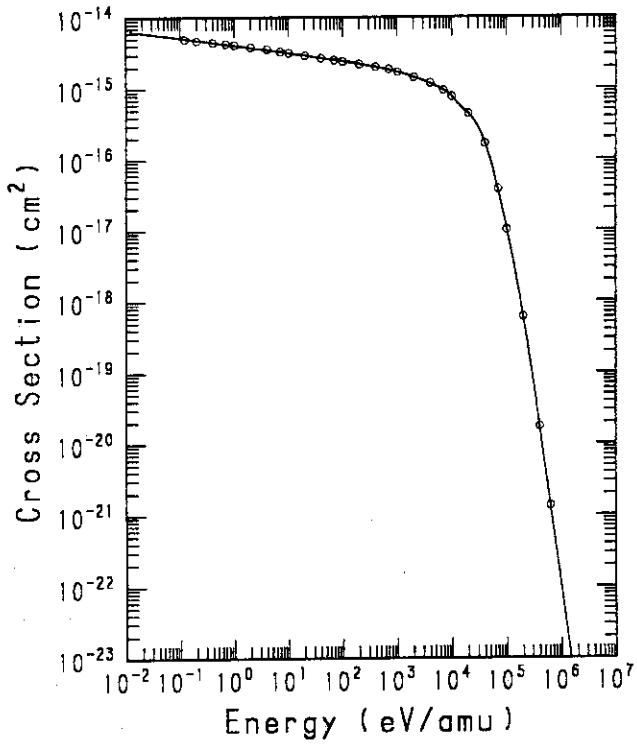
GRAPH 5

$H + H^- \rightarrow H^- + H$



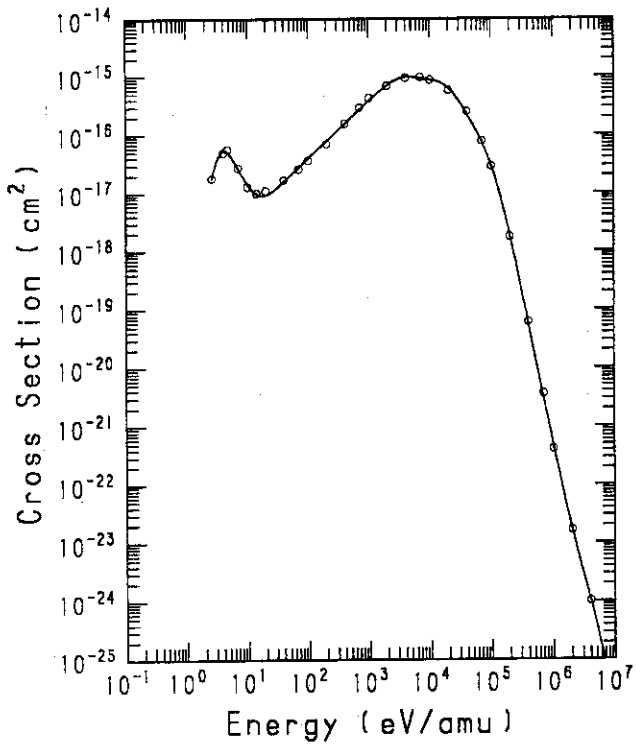
GRAPH 6

$H^+ + H \rightarrow H + H^+$



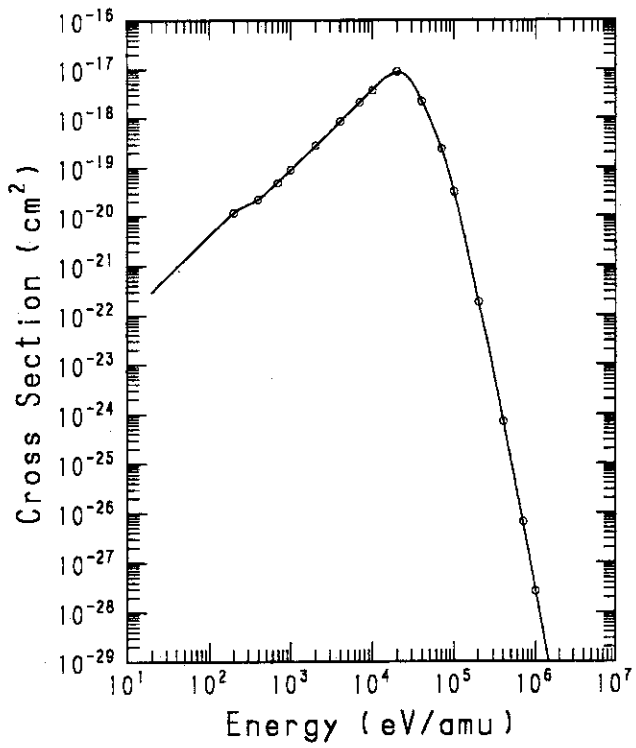
GRAPH 7

$H^+ + H_2 \rightarrow H$



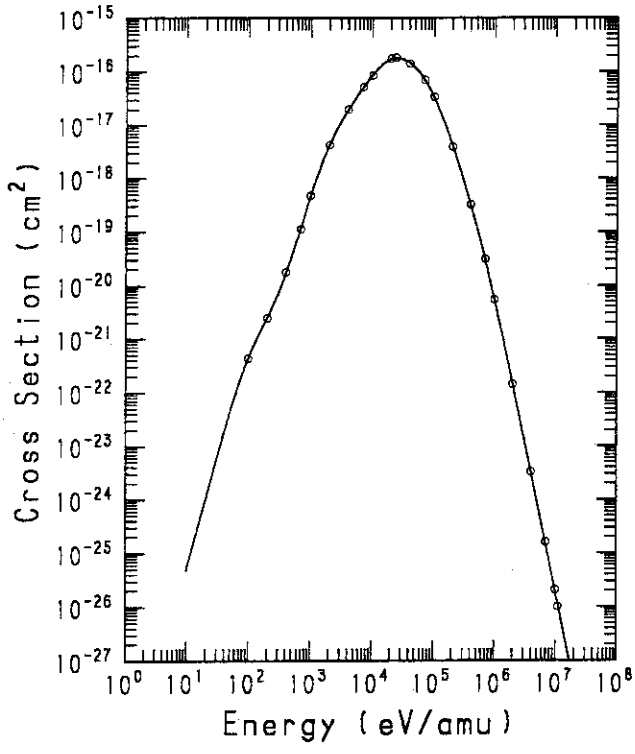
GRAPH 8

$H^+ + H_2 \rightarrow H^- + 2H^+$



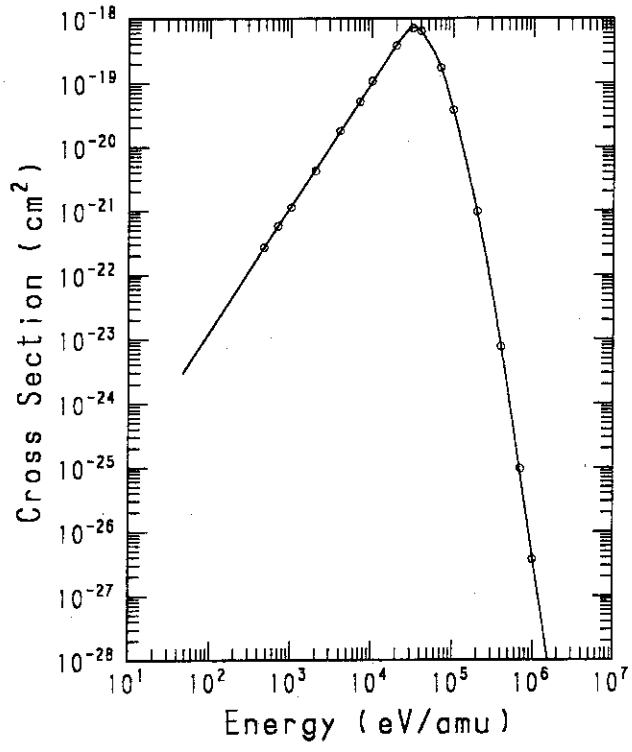
GRAPH 9

$H^+ + He \rightarrow H + He^+$



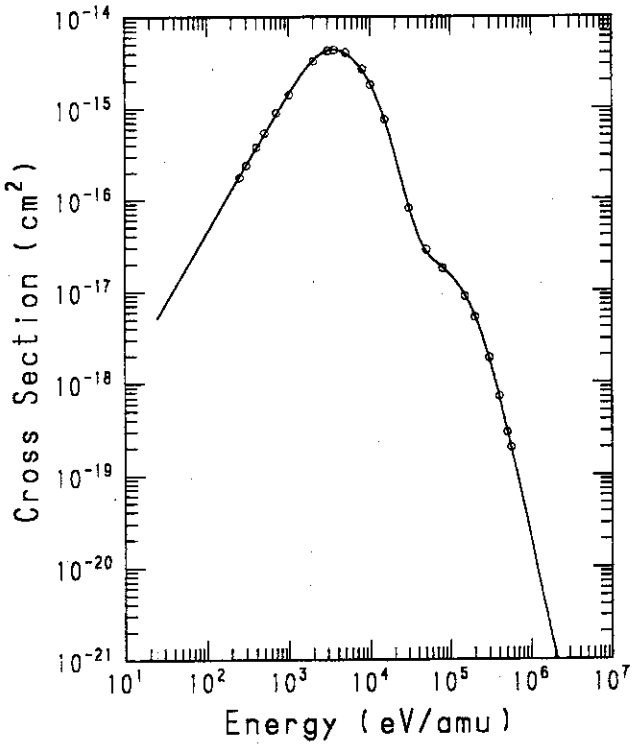
GRAPH 10

$H^+ + He \rightarrow H^- + He^{2+}$



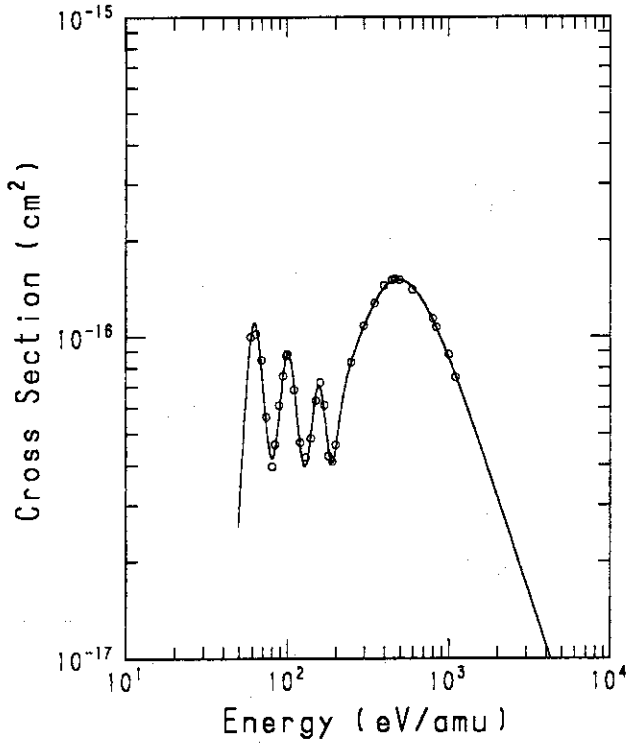
GRAPH 11

$H^+ + Li \rightarrow H + Li^+$



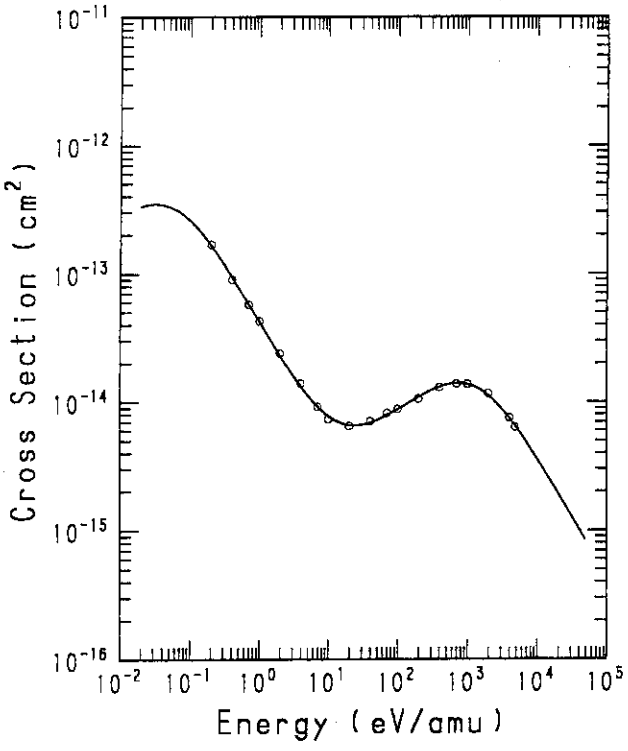
GRAPH 12

$H^+ + H^- \rightarrow H^- + H^+$



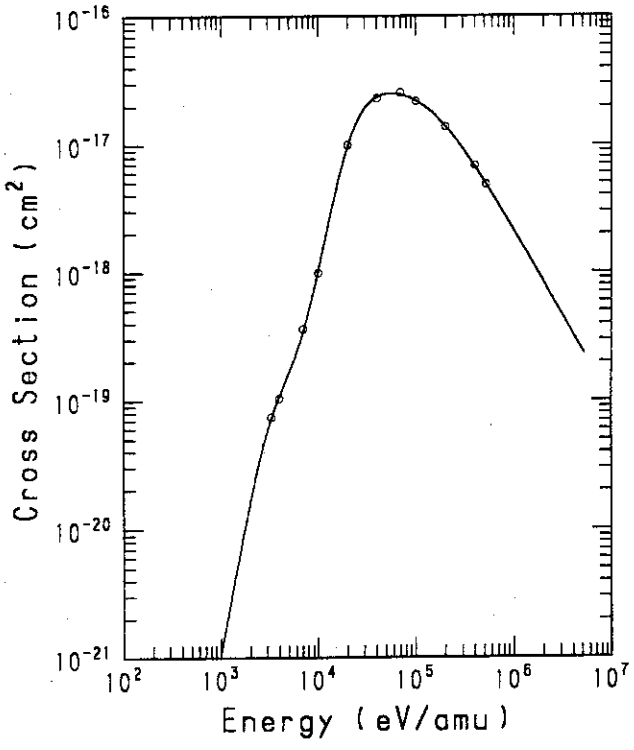
GRAPH 13

$H^+ + H^- \rightarrow 2H$



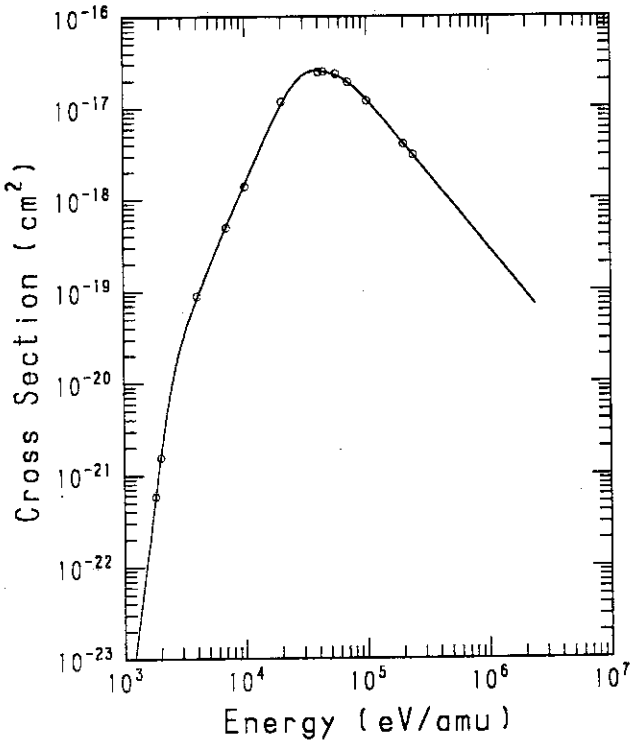
GRAPH 14

$H^+ + He^+ \rightarrow (H+He^{2+}) + (H^++He^{2+}+e)$



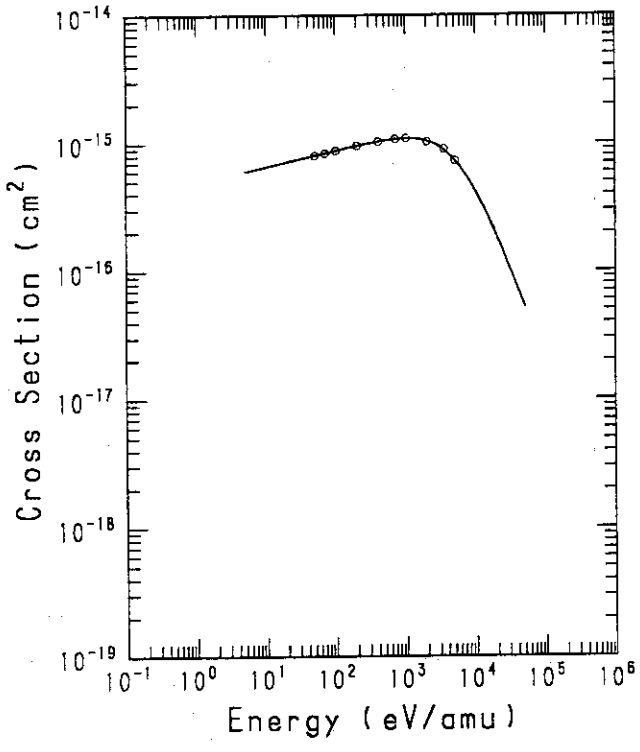
GRAPH 15

$H^+ + He^+ \rightarrow H + He^{2+}$



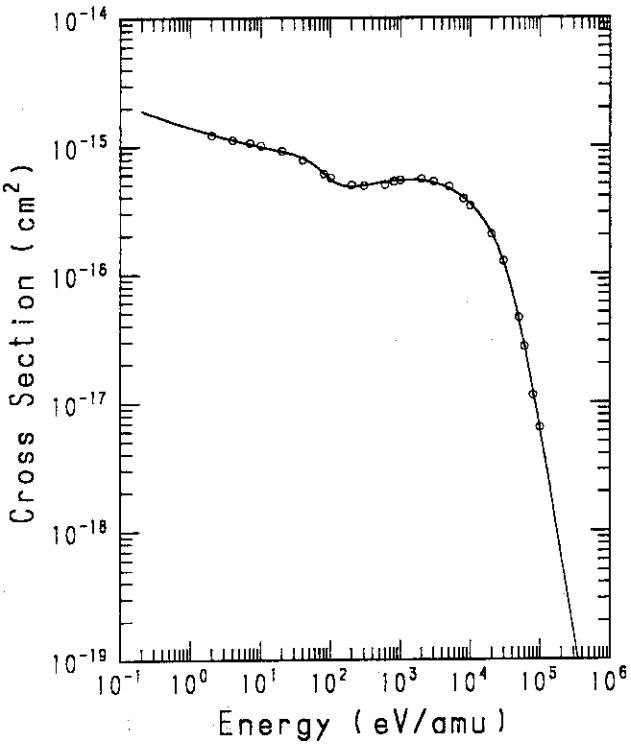
GRAPH 16

$H_2^+ + H \rightarrow H_2 + H^+$



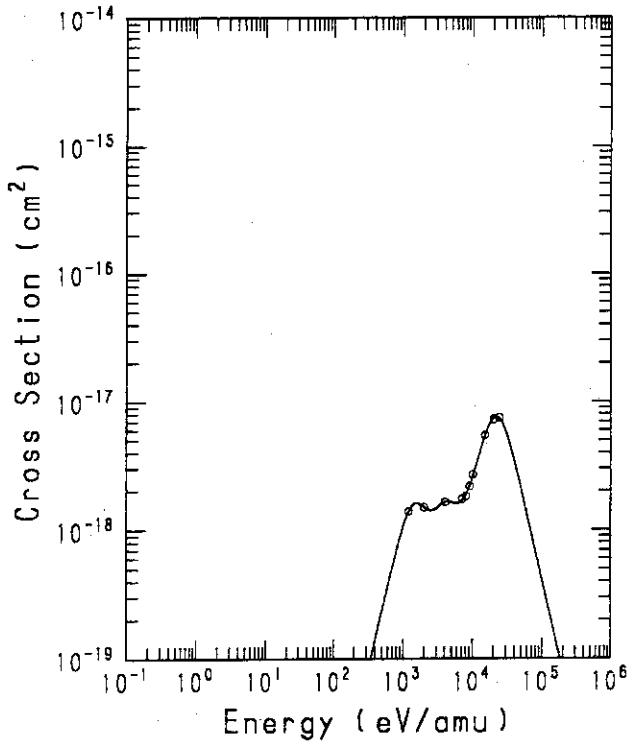
GRAPH 17

$H_2^+ + H_2 \rightarrow H_2 + H_2^+$



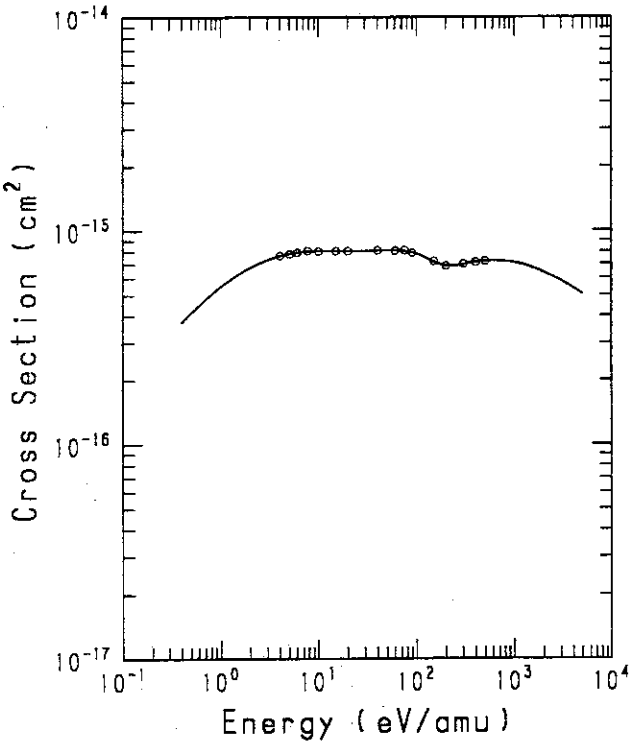
GRAPH 18

$H_2^+ + He \rightarrow H_2 + He^+$



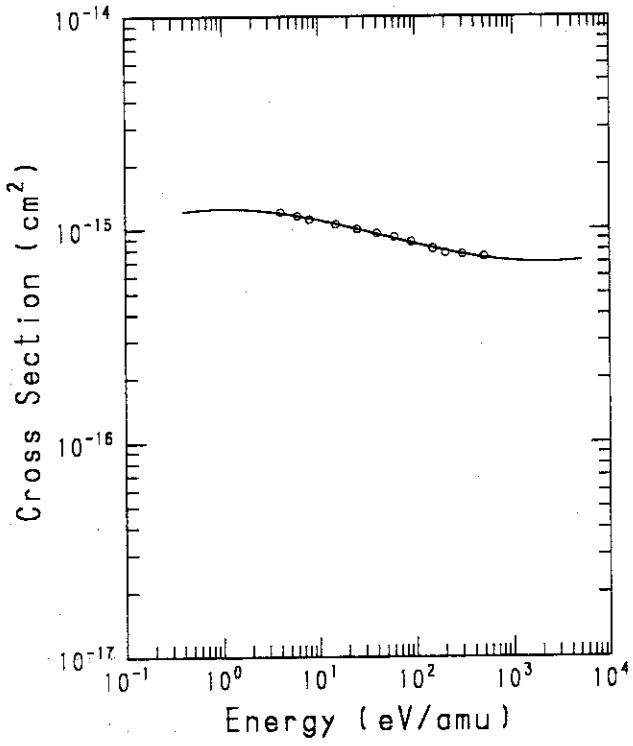
GRAPH 19

$H_2^+(v=0) + H_2 \rightarrow H_2$



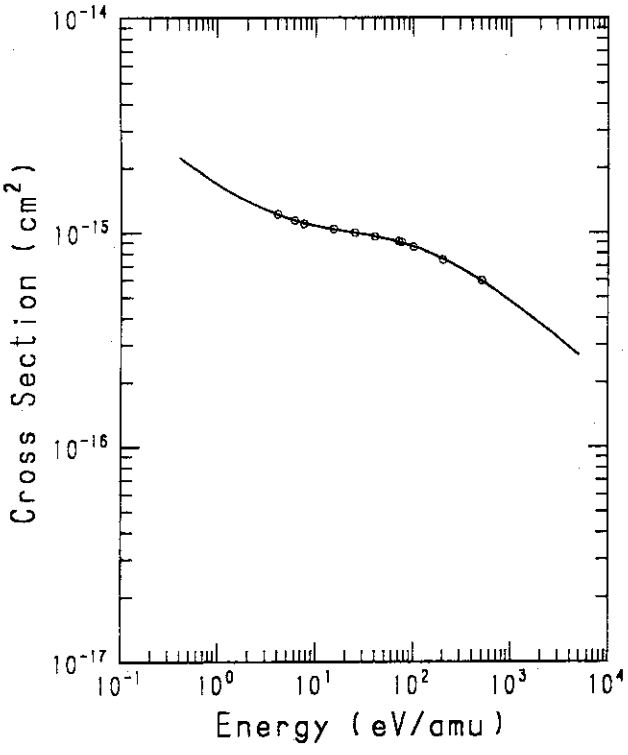
GRAPH 20

$H_2^+(v=1) + H_2 \rightarrow H_2$



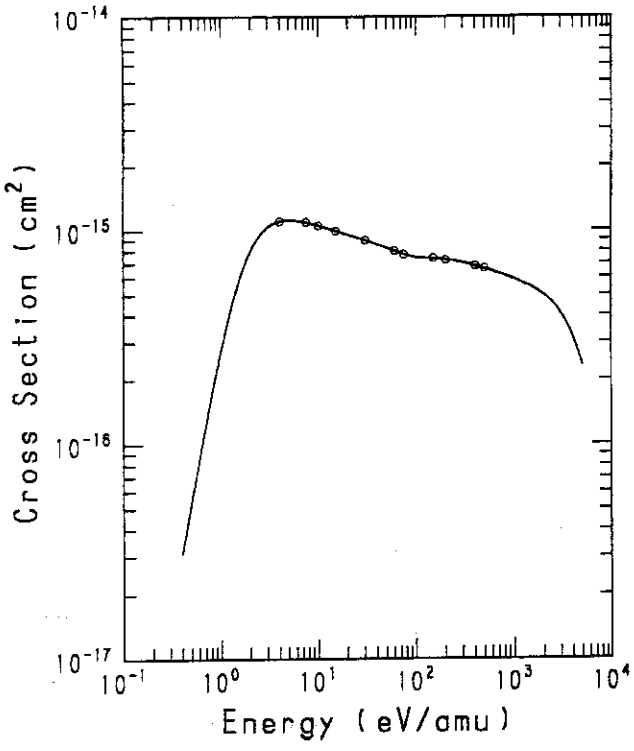
GRAPH 21

$H_2^+(v=2) + H_2 \rightarrow H_2$



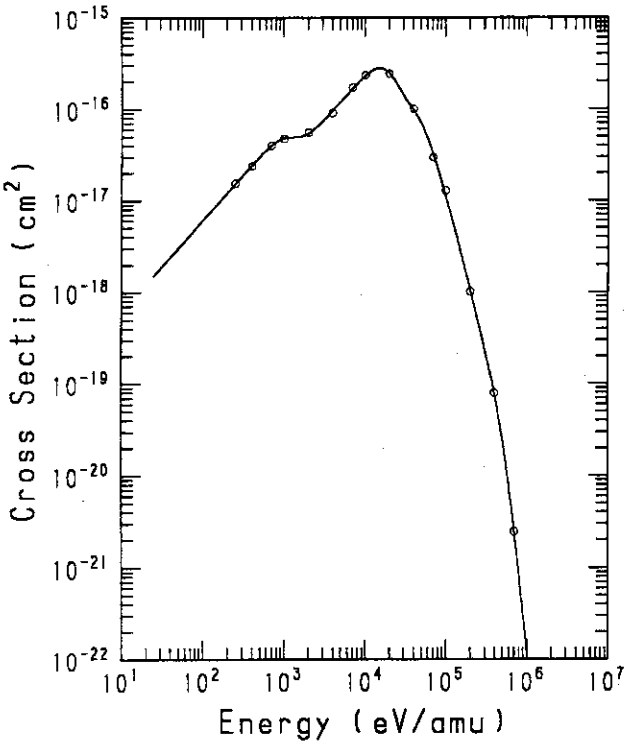
GRAPH 22

$H_2^+(v=3) + H_2 \rightarrow H_2$



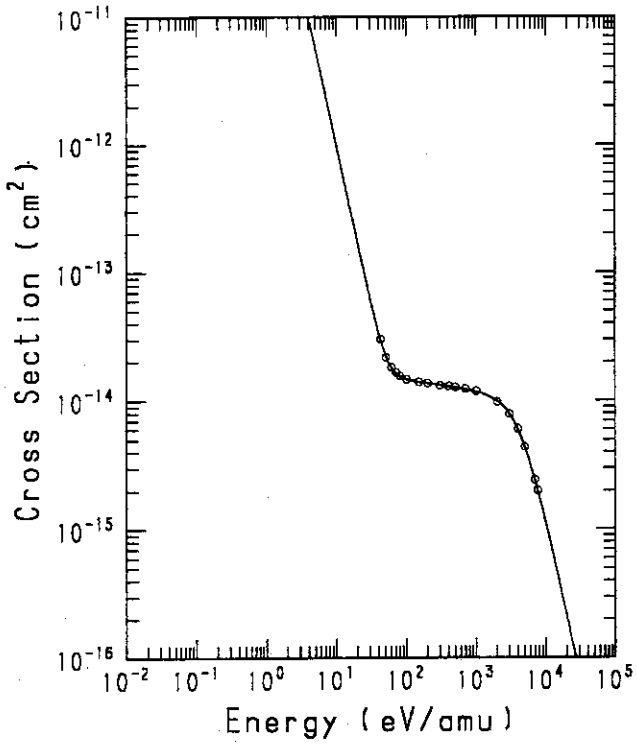
GRAPH 23

$He^+ + H \rightarrow He + H^+$



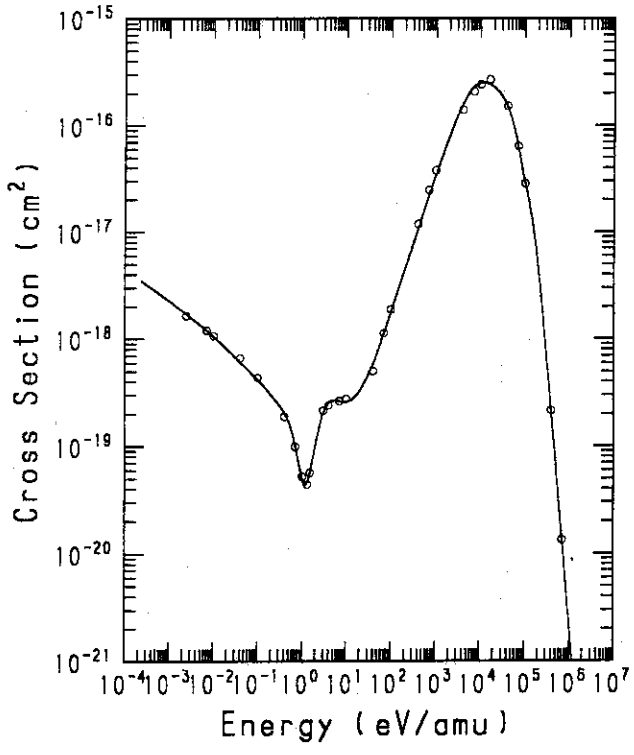
GRAPH 24

$He^+ + H^- \rightarrow He + H$



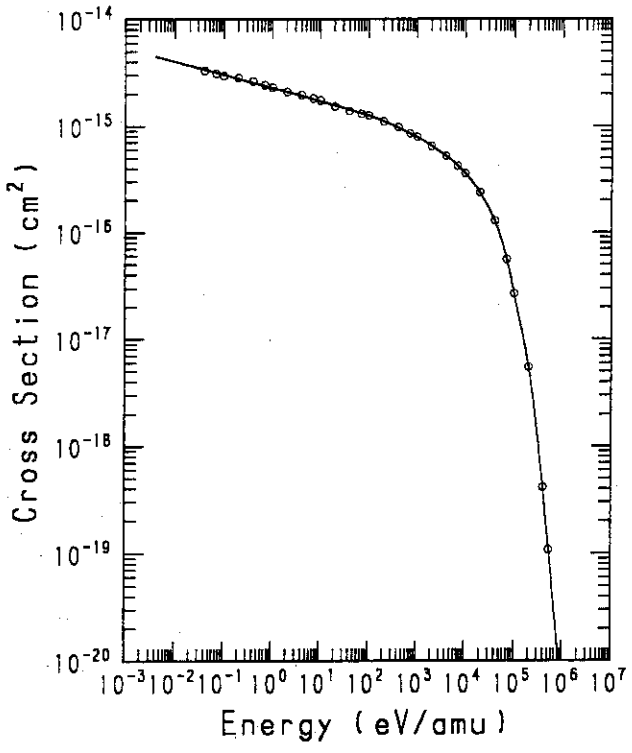
GRAPH 25

$He^+ + H_2 \rightarrow He$



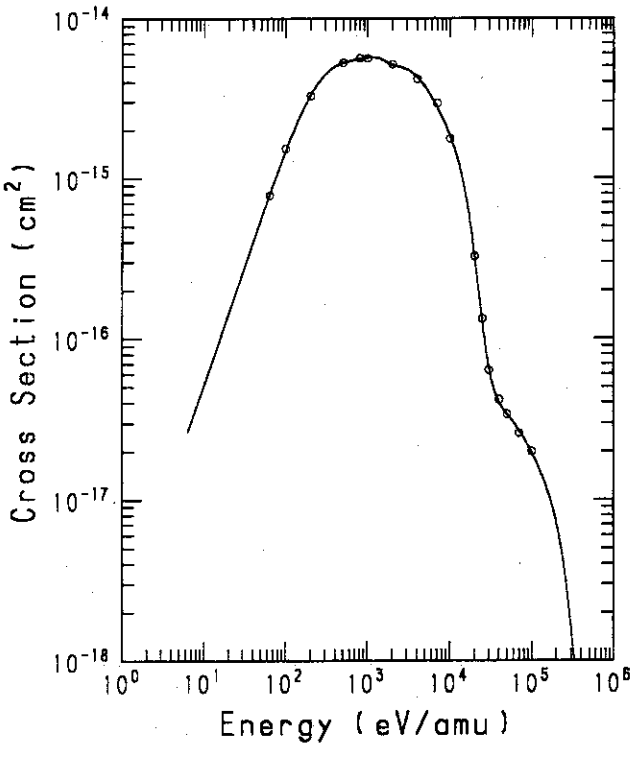
GRAPH 26

$He^+ + He \rightarrow He + He^+$



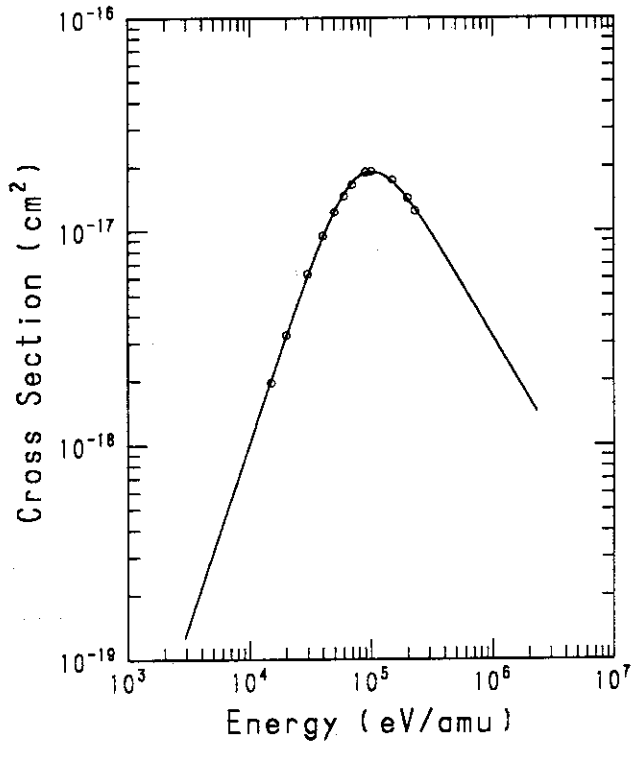
GRAPH 27

$He^+ + Li \rightarrow He + Li^+$



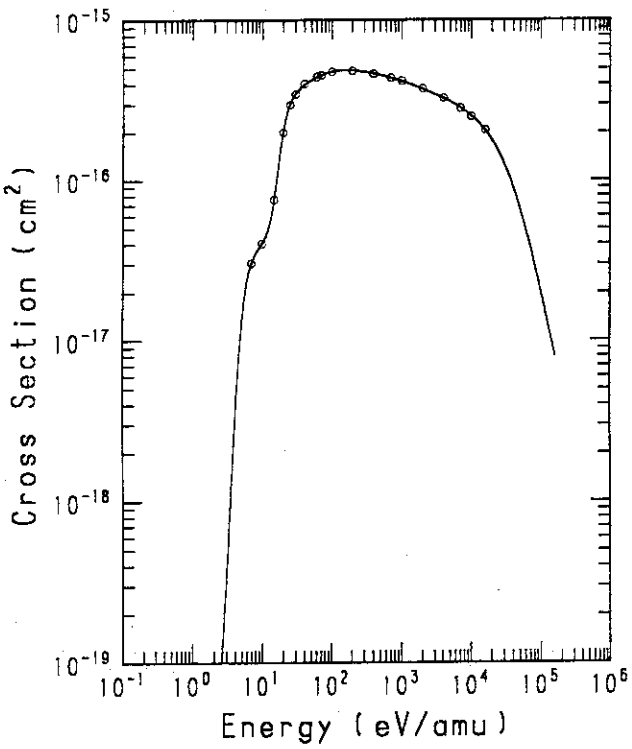
GRAPH 28

$He^+ + He^+ \rightarrow He + He^{2+}$



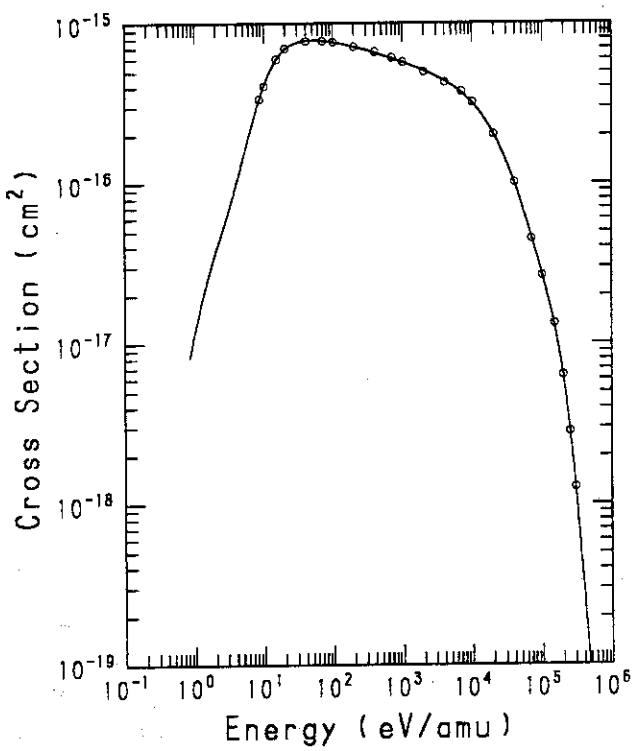
GRAPH 29

$He^{2+} + He^{+} \rightarrow He^{+} + He^{2+}$ (Partial)



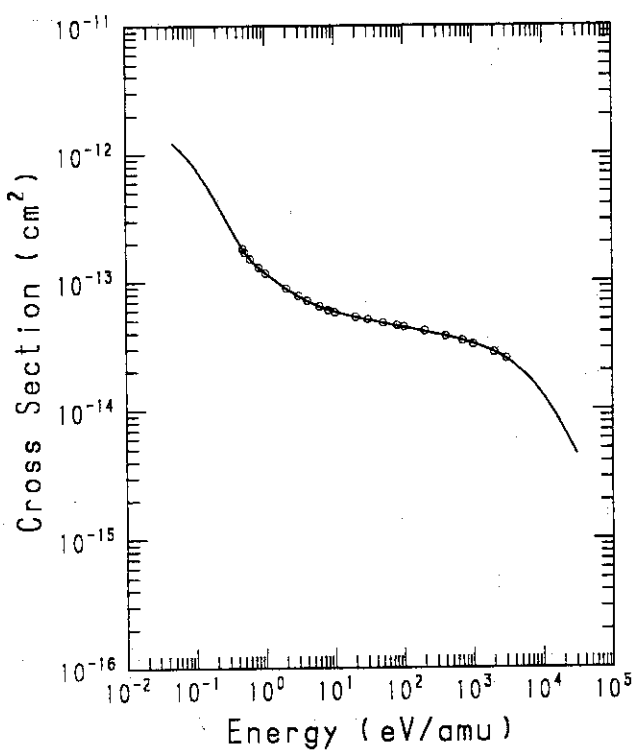
GRAPH 30

$He^{2+} + He^{+} \rightarrow He^{+} + He^{2+}$ (Total)



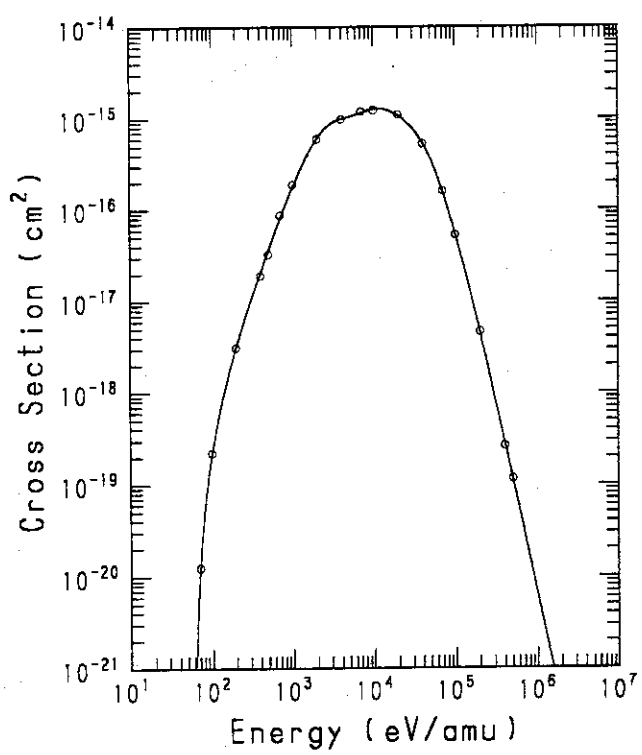
GRAPH 31

$He^{2+} + H^{-} \rightarrow He^{+} + H$



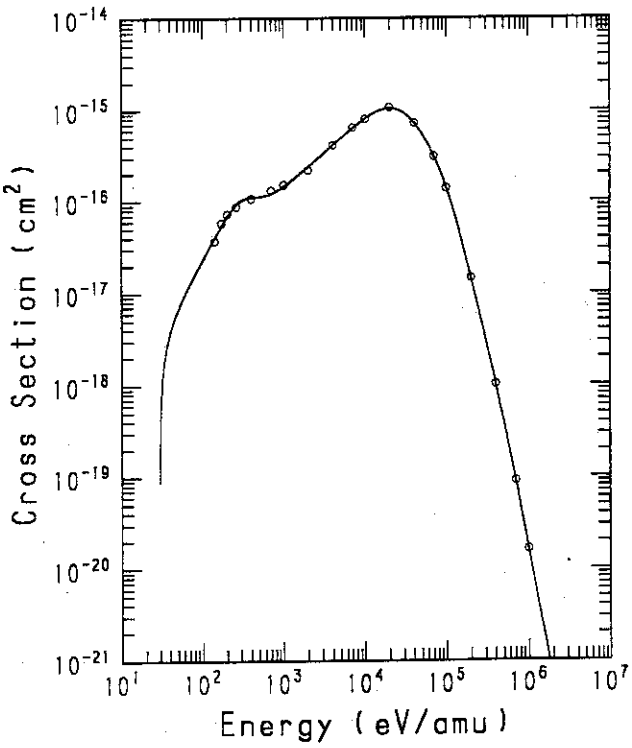
GRAPH 32

$He^{2+} + H \rightarrow He^{+} + H^{+}$



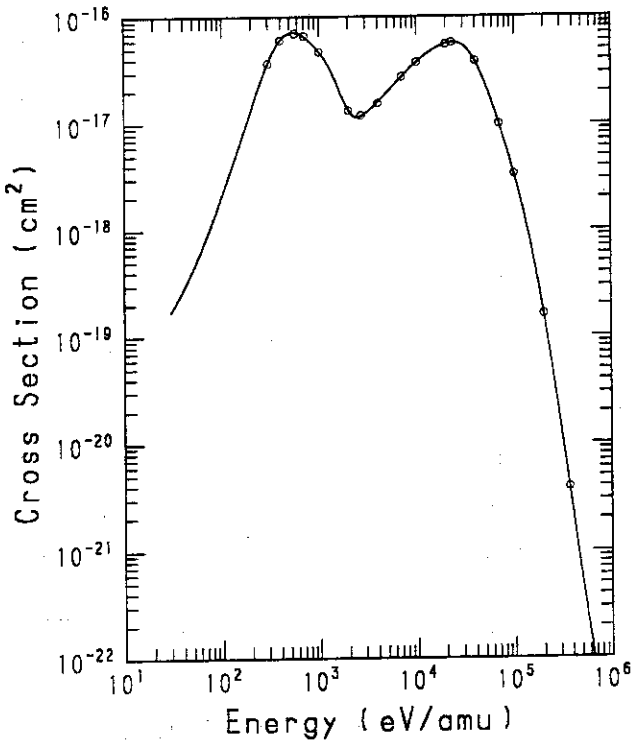
GRAPH 33

$He^{2+} + H_2 \rightarrow He^{+}$



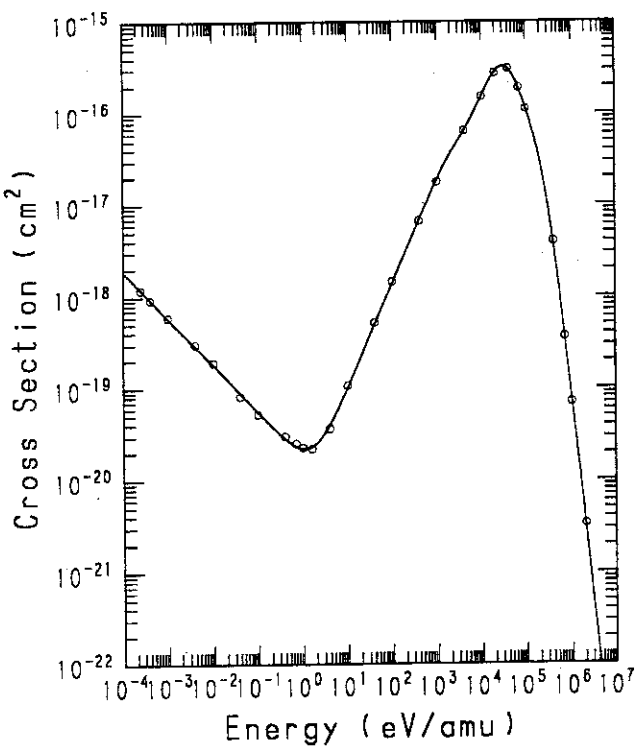
GRAPH 34

$He^{2+} + H_2 \rightarrow He$



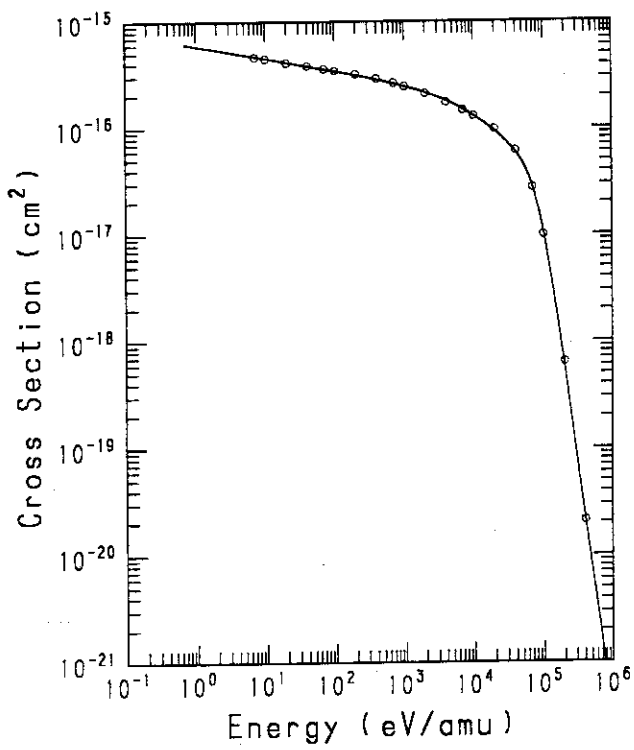
GRAPH 35

$He^{2+} + He \rightarrow He^{+} + He^{+}$



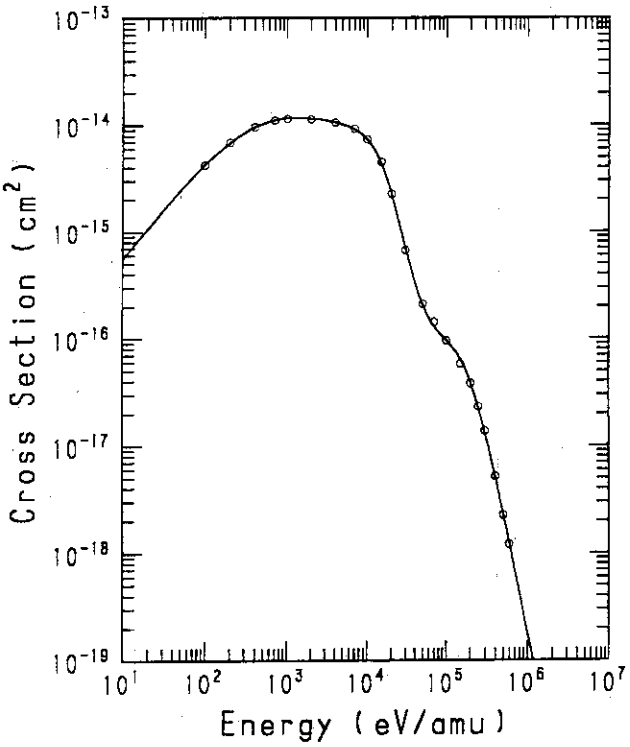
GRAPH 36

$He^{2+} + He \rightarrow He + He^{2+}$



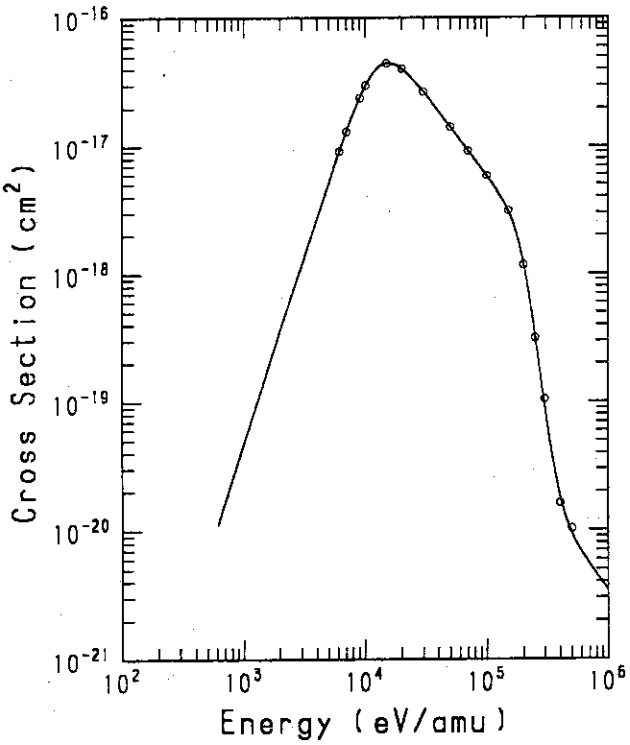
GRAPH 37

$He^{2+} + Li \rightarrow He^{+} + Li^{+}$



GRAPH 38

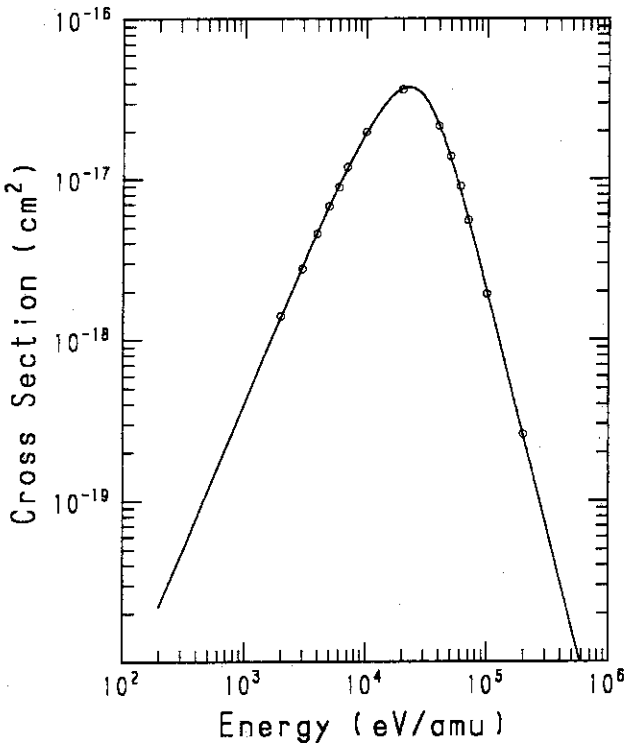
$He^{2+} + Li \rightarrow He + Li^{2+}$



Graphs of Cross Sections for Electron Capture into Excited States

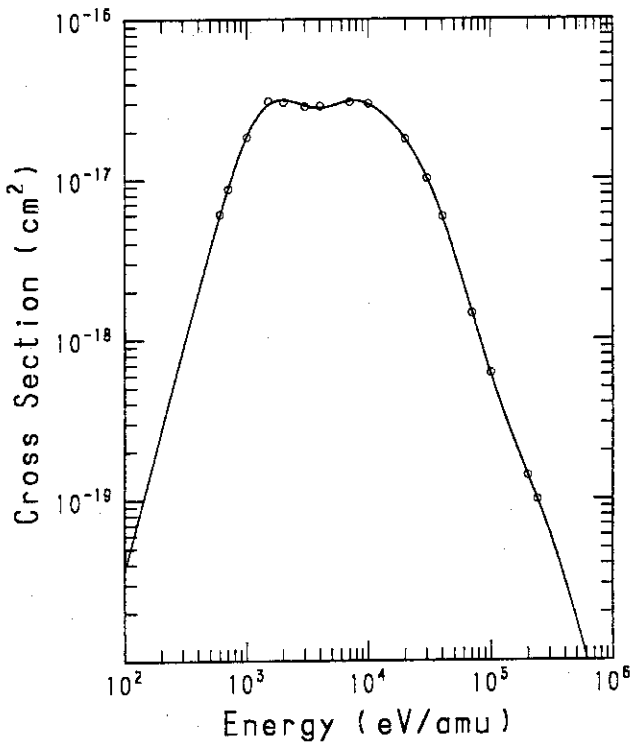
GRAPH 39

$H^+ + H \rightarrow H(2s) + H^+$



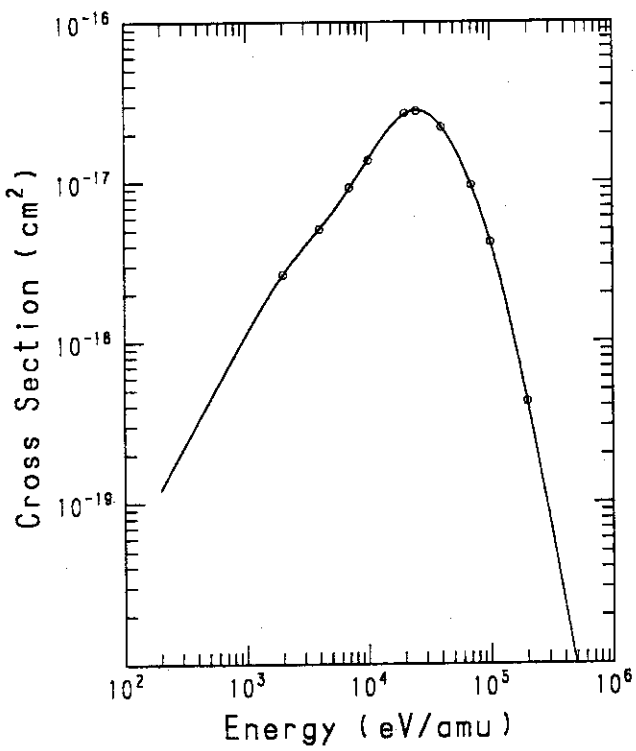
GRAPH 40

$H^+ + H \rightarrow H(2p) + H^+$



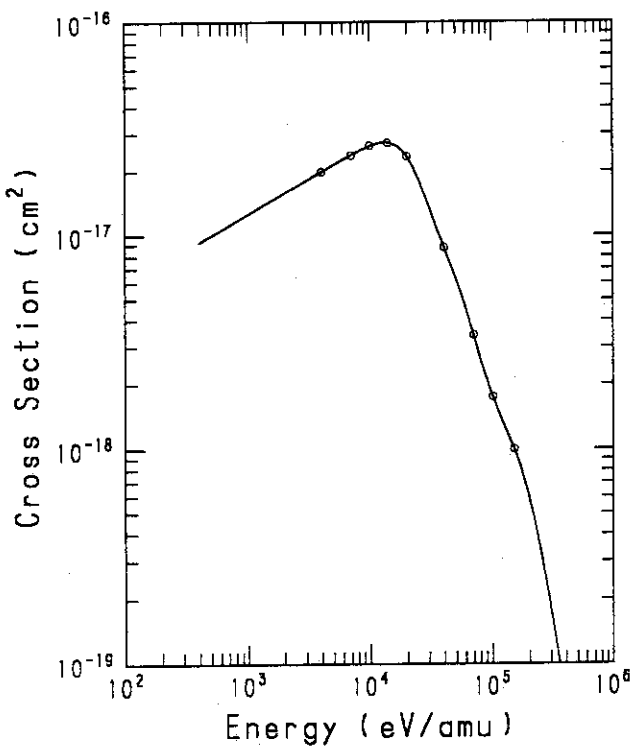
GRAPH 41

$H^+ + H_2 \rightarrow H(2s)$



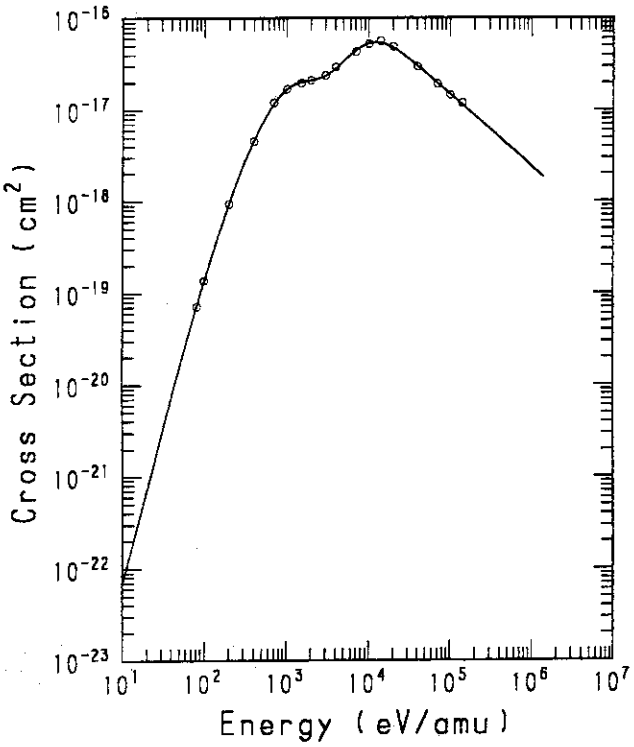
GRAPH 42

$H^+ + H_2 \rightarrow H(2p)$



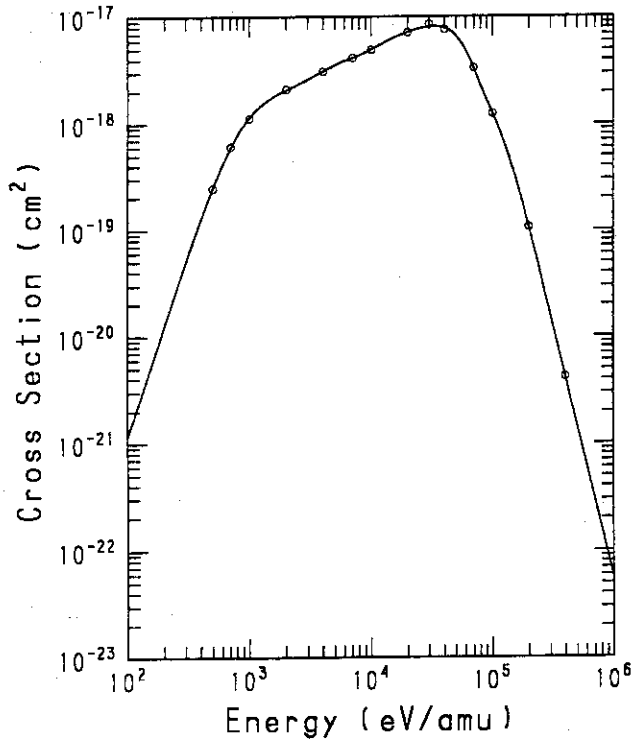
GRAPH 43

$H^+ + H_2 \rightarrow H(Ly\alpha)Total$



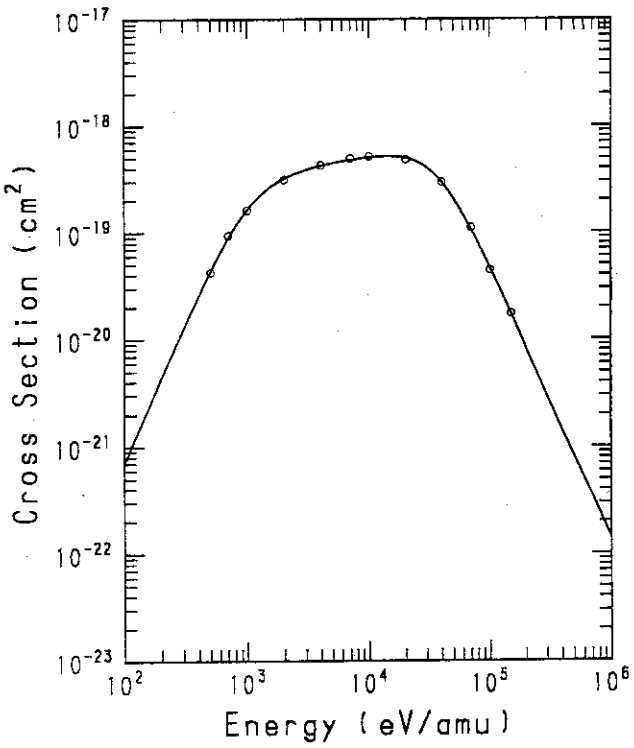
GRAPH 44

$H^+ + H_2 \rightarrow H(H\alpha)$



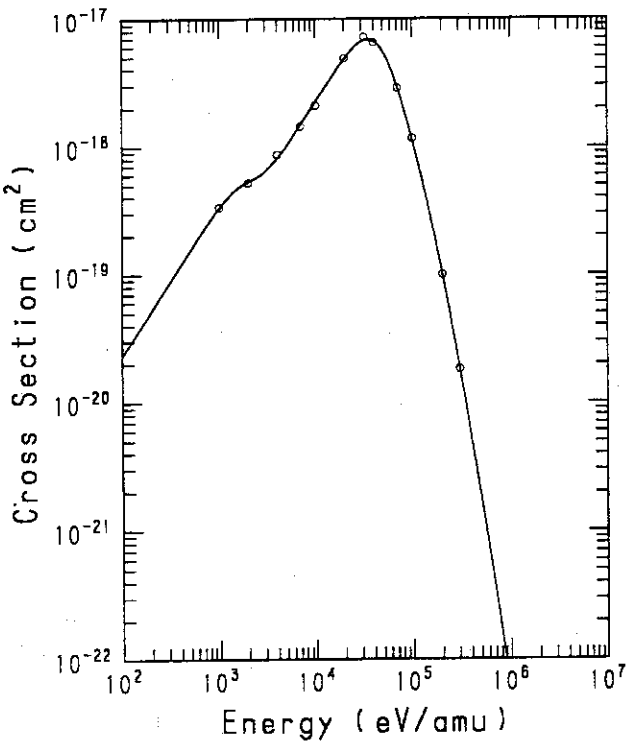
GRAPH 45

$H^+ + H_2 \rightarrow H(H\beta)$



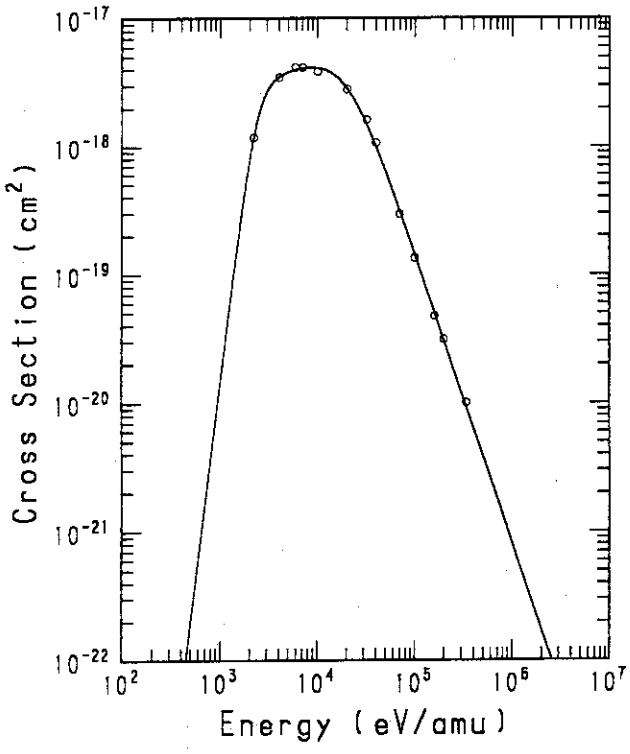
GRAPH 46

$H^+ + H_2 \rightarrow H(3s)$



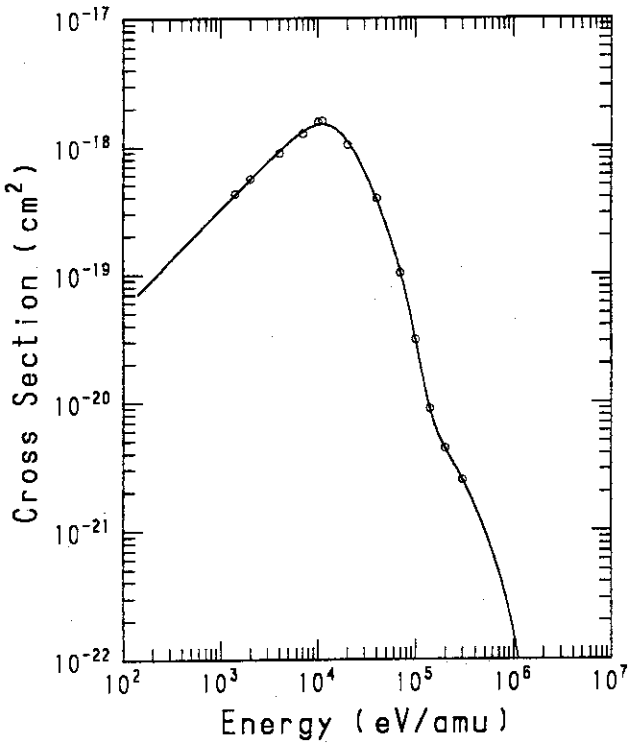
GRAPH 47

$H^+ + H_2 \rightarrow H(3p)$



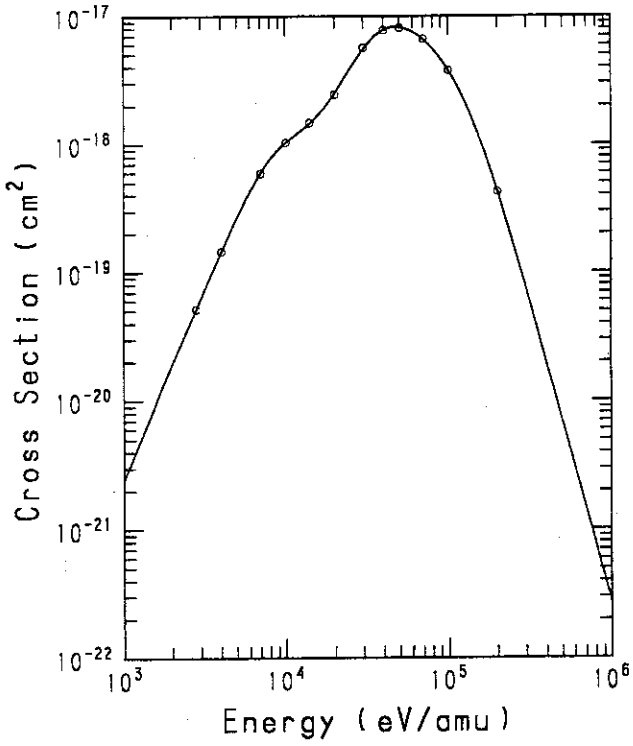
GRAPH 48

$H^+ + H_2 \rightarrow H(3d)$



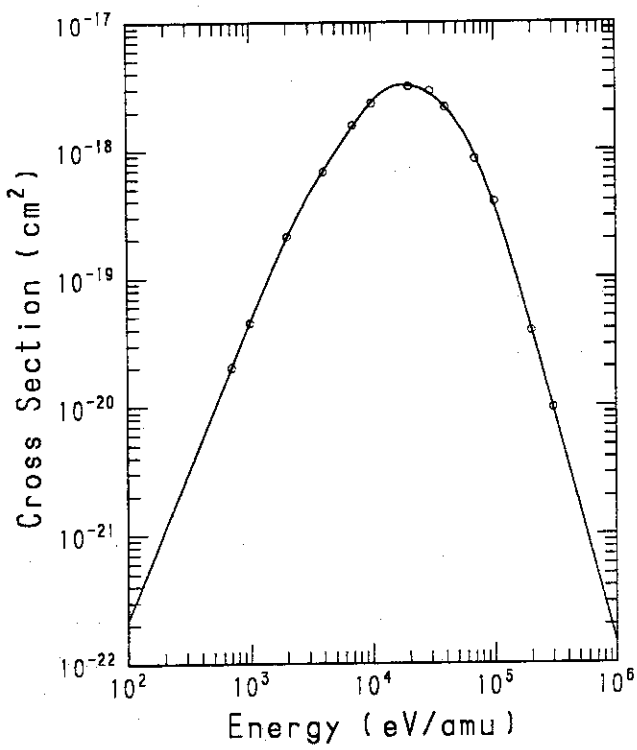
GRAPH 49

$H^+ + He \rightarrow H(2s) + He^+$



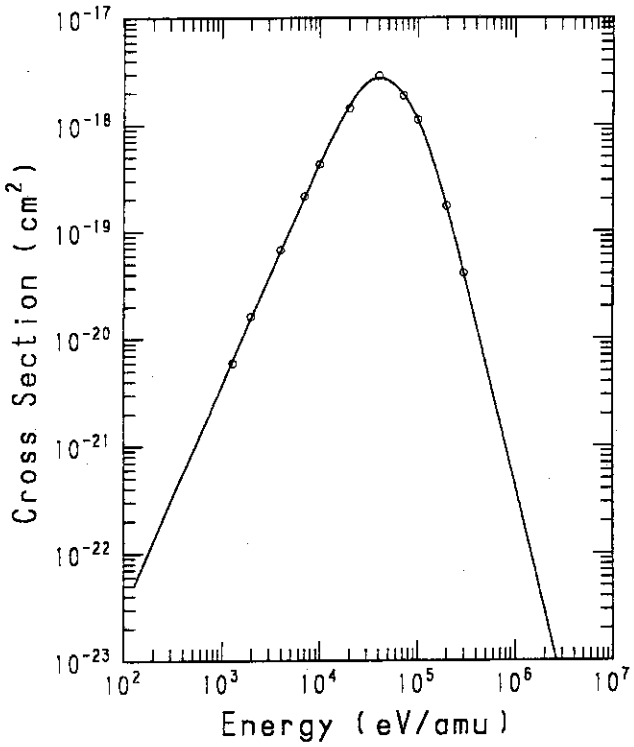
GRAPH 50

$H^+ + He \rightarrow H(2p) + He^+$



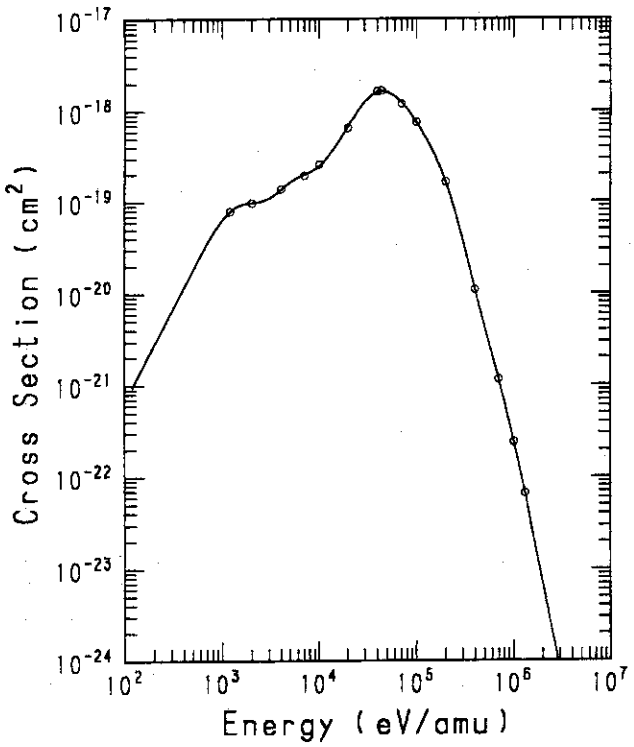
GRAPH 51

$H^+ + He \rightarrow H(H\alpha) + He^+$



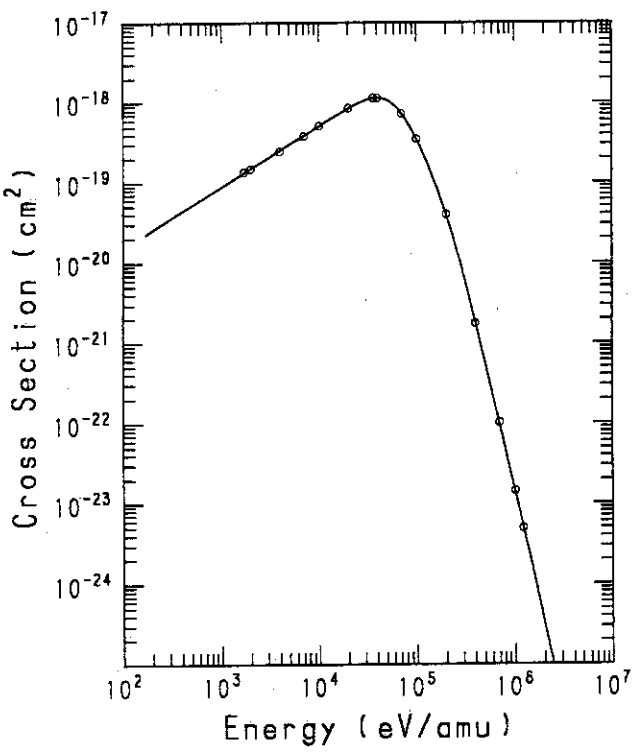
GRAPH 52

$H^+ + He \rightarrow H(3s) + He^+$



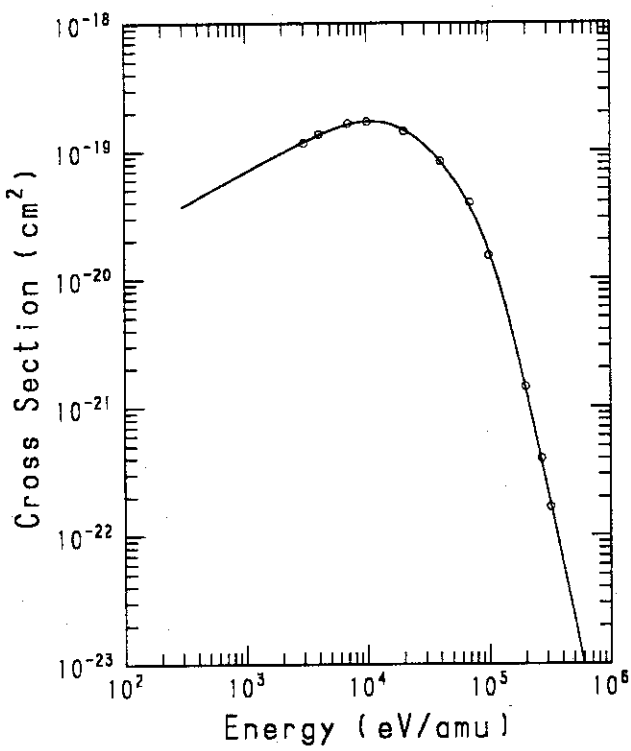
GRAPH 53

$H^+ + He \rightarrow H(3p) + He^+$



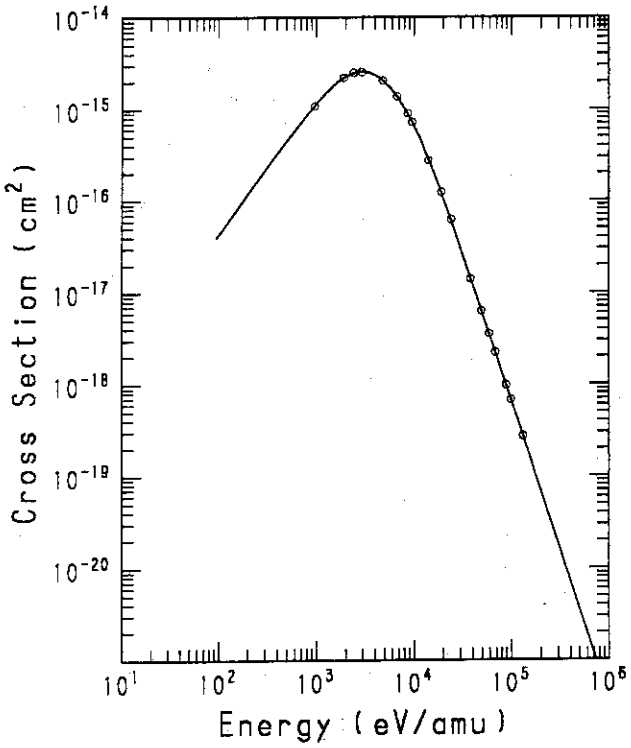
GRAPH 54

$H^+ + He \rightarrow H(3d) + He^+$



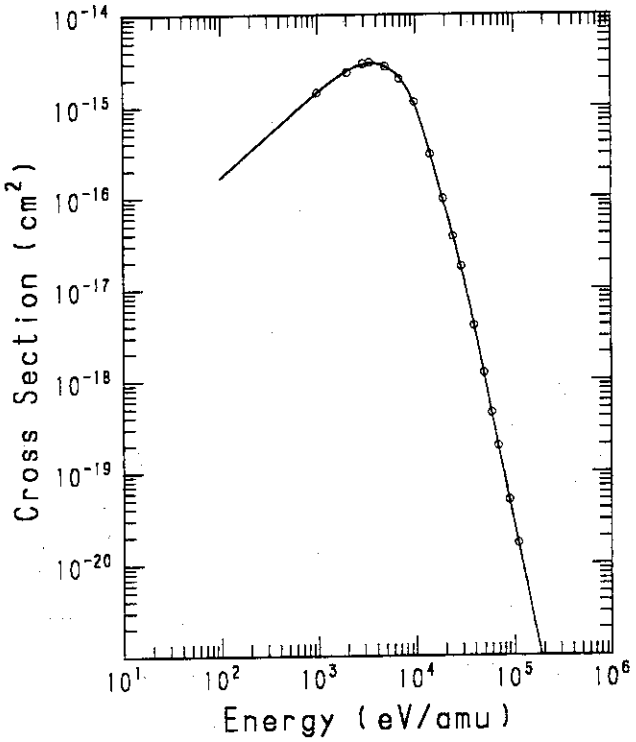
GRAPH 55

$H^+ + Li \rightarrow H(2s) + Li^+$



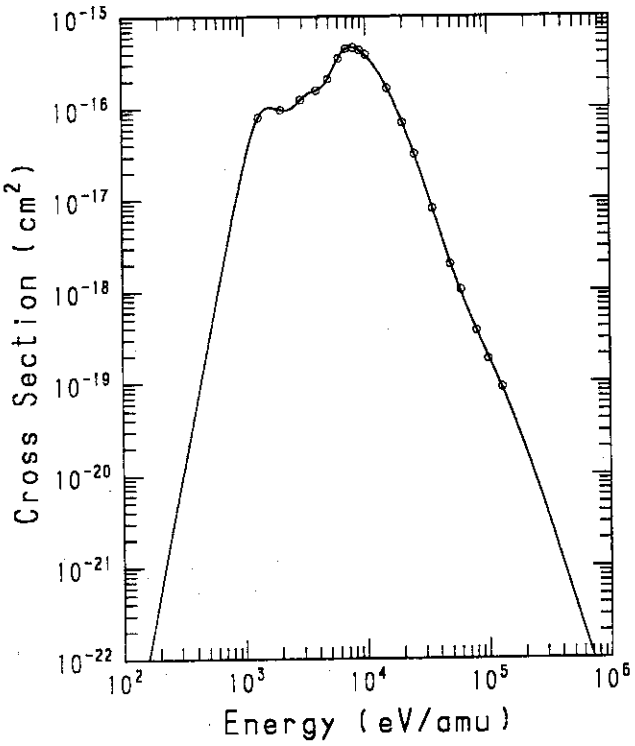
GRAPH 56

$H^+ + Li \rightarrow H(2p) + Li^+$



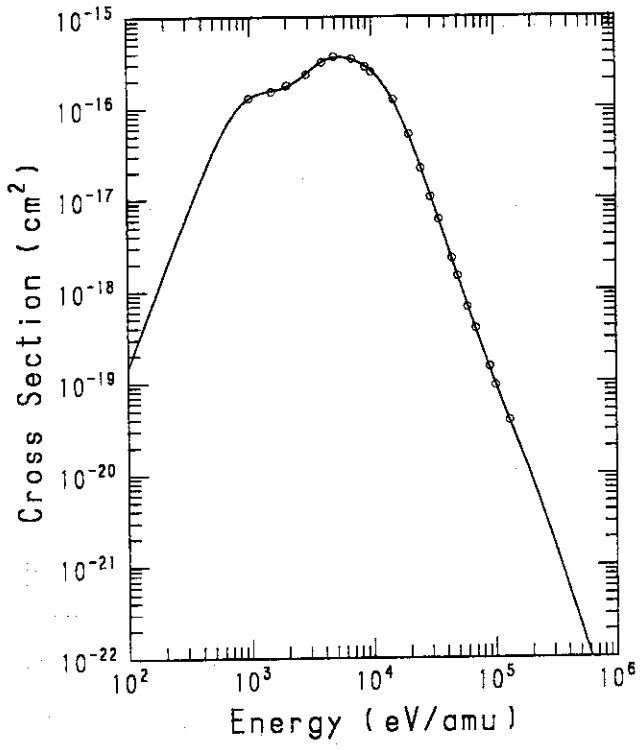
GRAPH 57

$H^+ + Li \rightarrow H(3s) + Li^+$



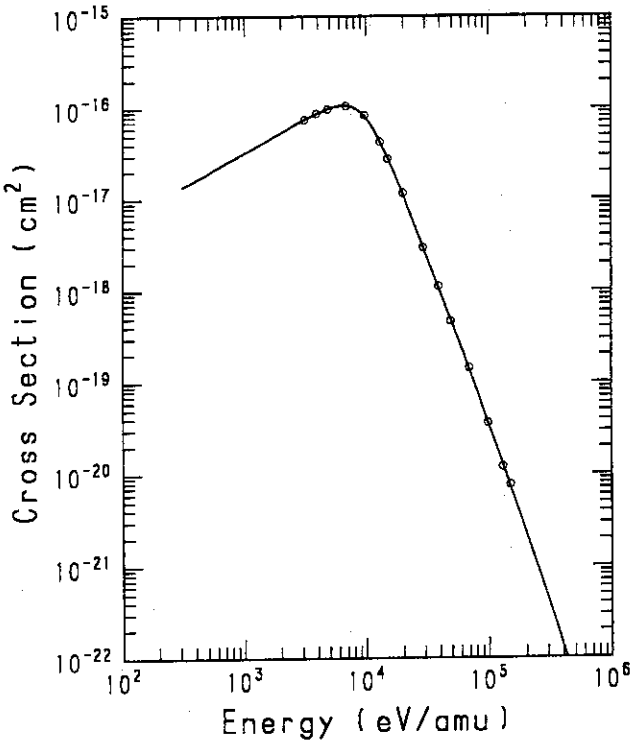
GRAPH 58

$H^+ + Li \rightarrow H(3p) + Li^+$



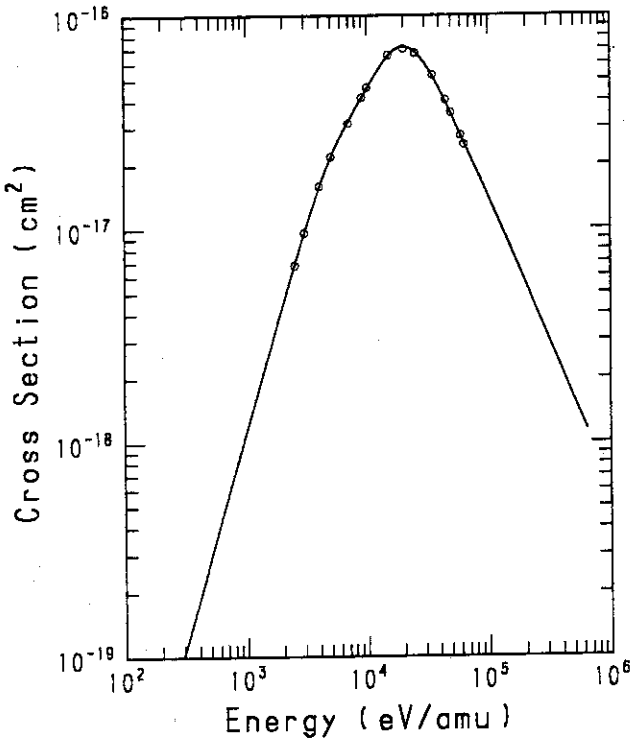
GRAPH 59

$H^+ + Li \rightarrow H(3d) + Li^+$



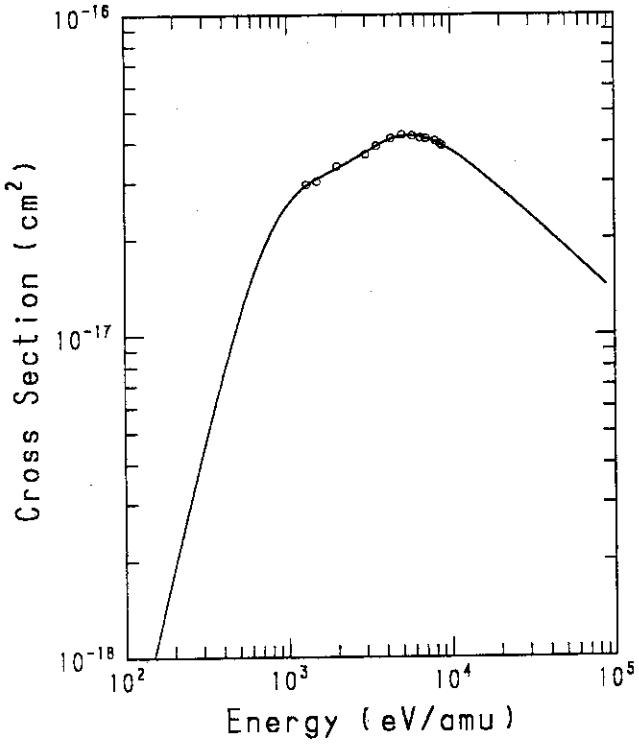
GRAPH 60

$He^+ + H_2 \rightarrow He(2^1S + 2^3S)$



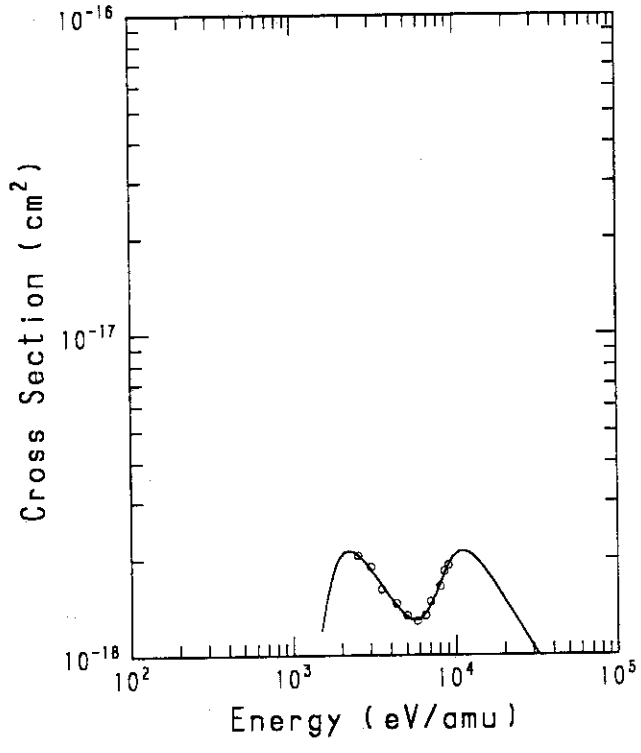
GRAPH 61

$He^+ + H_2 \rightarrow He(2^1P)$



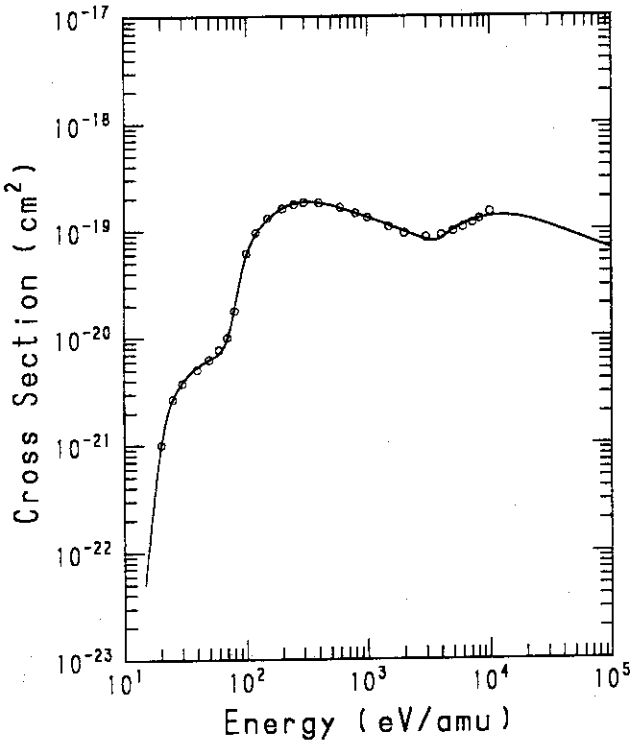
GRAPH 62

$He^+ + H_2 \rightarrow He(3^1P)$



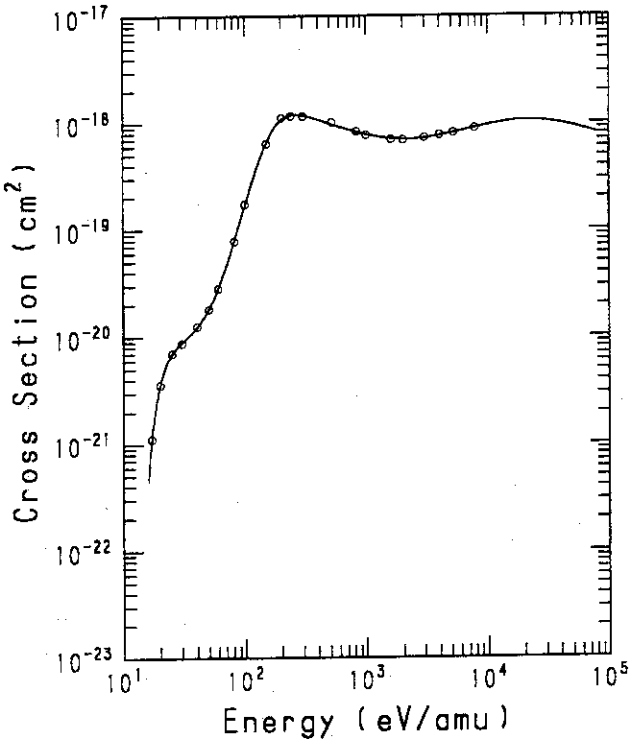
GRAPH 63

$He^+ + H_2 \rightarrow He(447.1nm)$



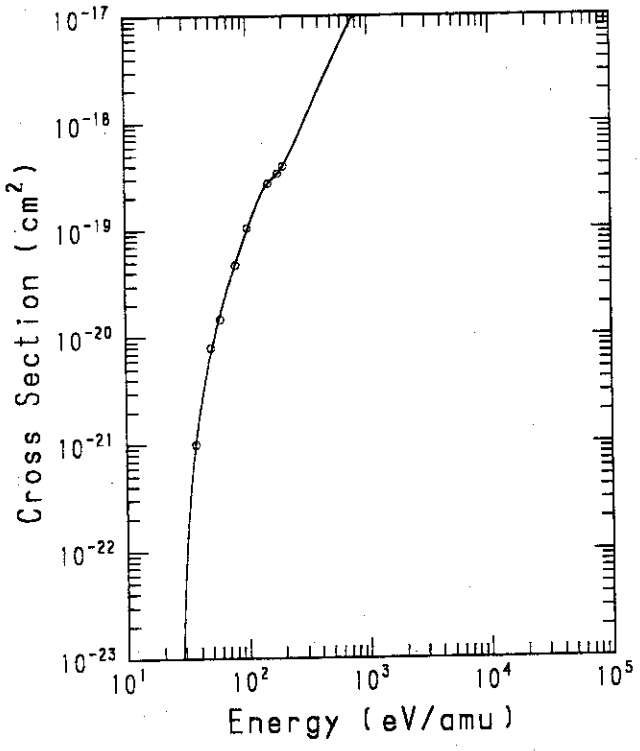
GRAPH 64

$He^+ + H_2 \rightarrow He(587.6nm)$



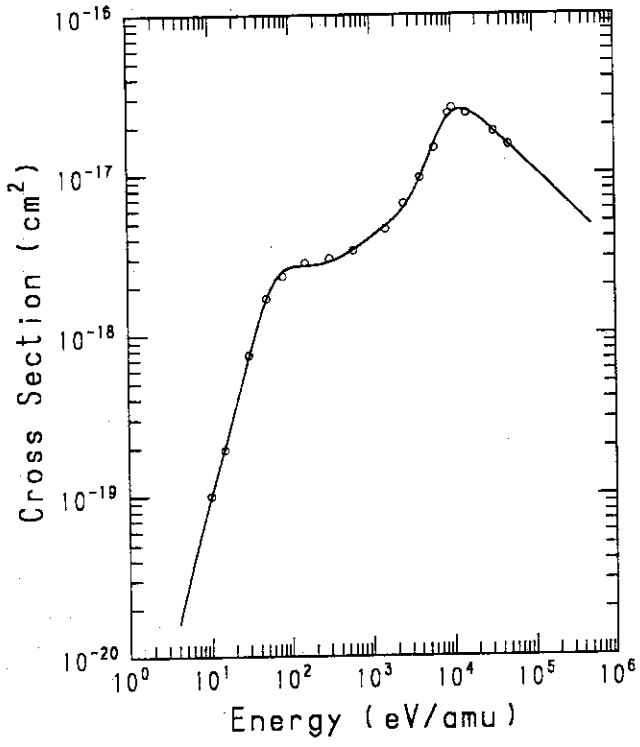
GRAPH 65

$He^+ + H_2 \rightarrow He(667.8nm)$



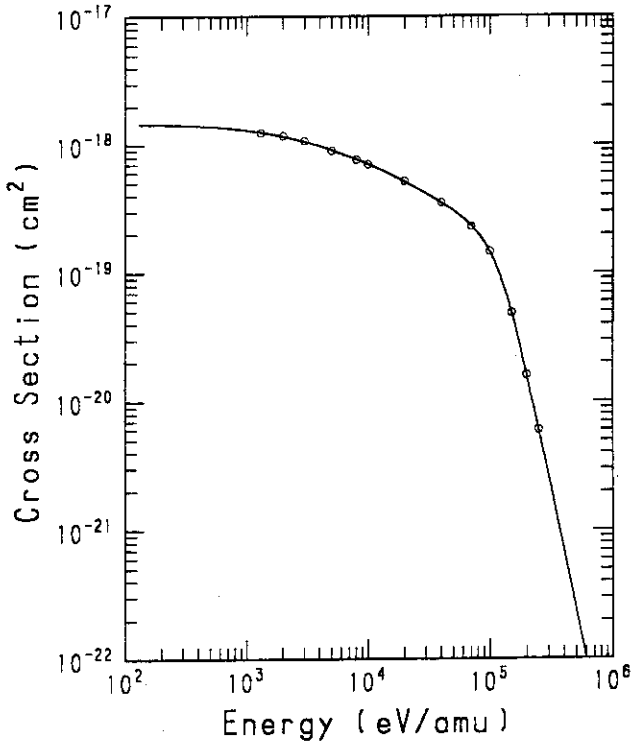
GRAPH 66

$He^+ + He \rightarrow He(2^1S + 2^3S)$



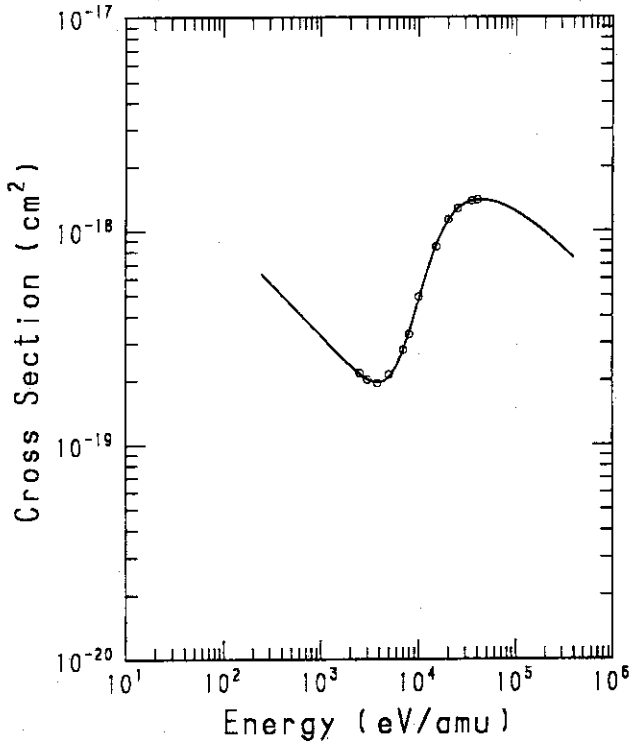
GRAPH 67

$He^+ + He \rightarrow He(2^1P) + He^+$



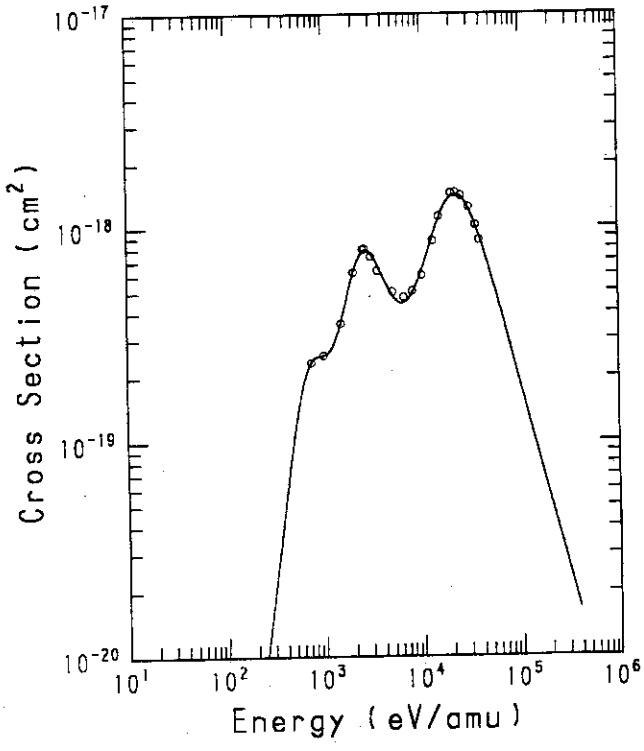
GRAPH 68

$He^+ + He \rightarrow He(3^1S) + He^+$



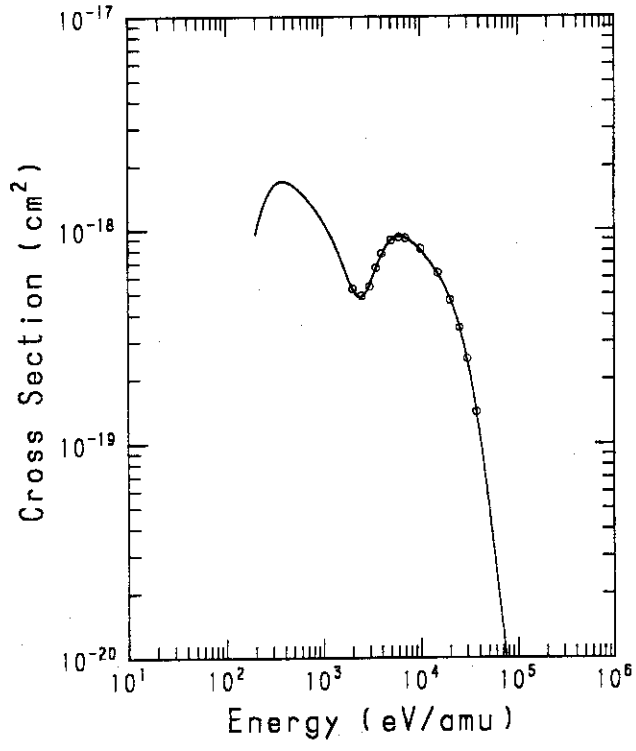
GRAPH 69

$He^+ + He \rightarrow He(3^1P) + He^+$



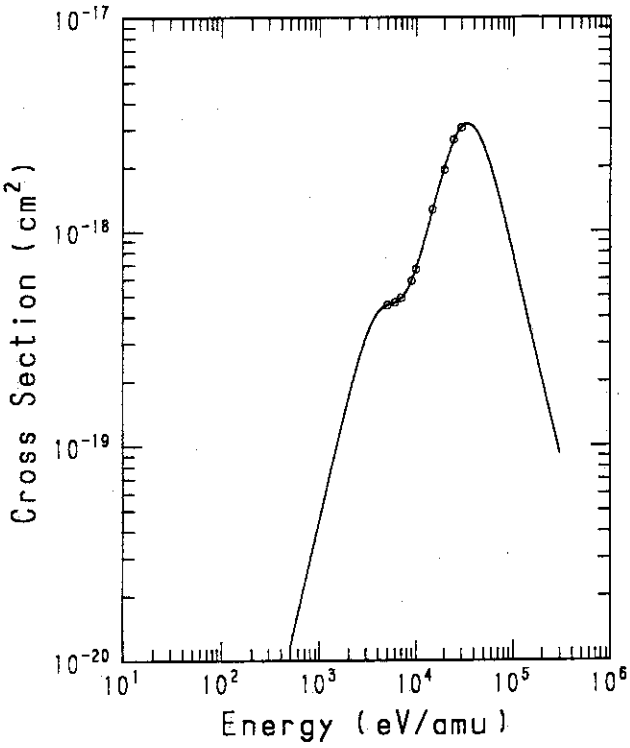
GRAPH 70

$He^+ + He \rightarrow He(3^1D) + He^+$



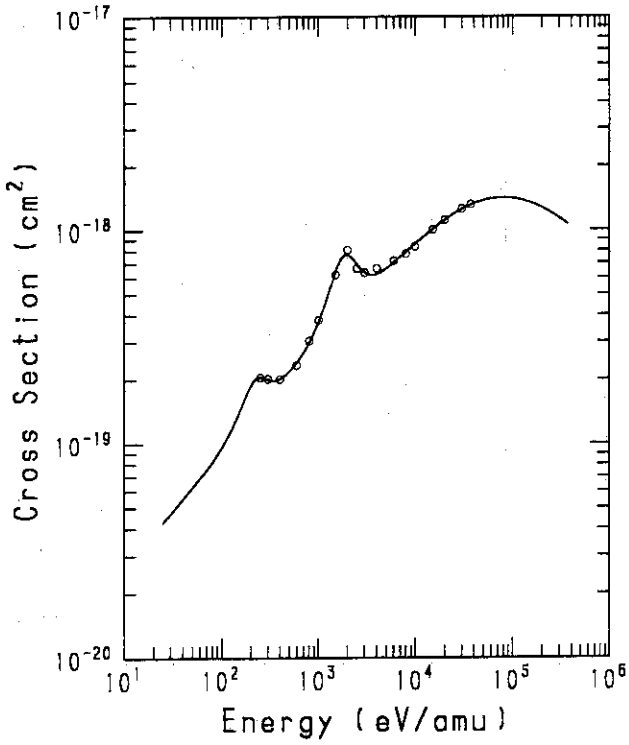
GRAPH 71

$He^+ + He \rightarrow He(3^3S) + He^+$



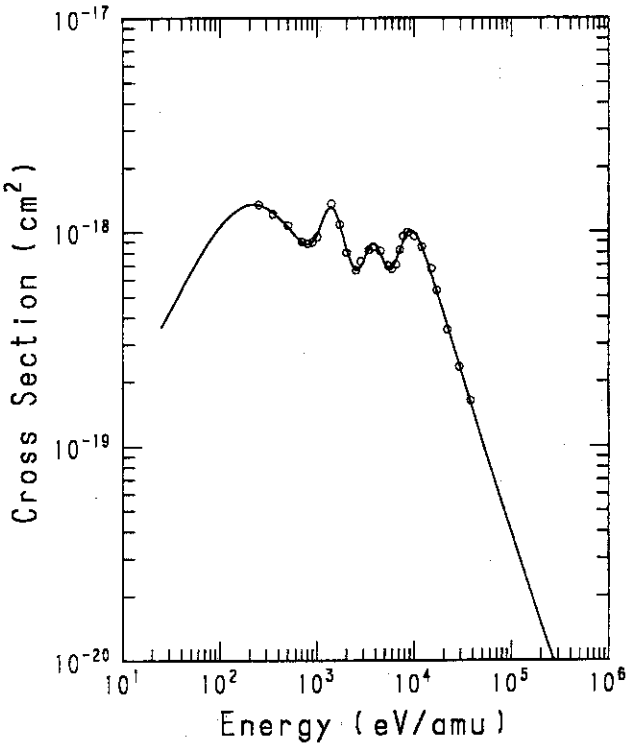
GRAPH 72

$He^+ + He \rightarrow He(3^3P) + He^+$



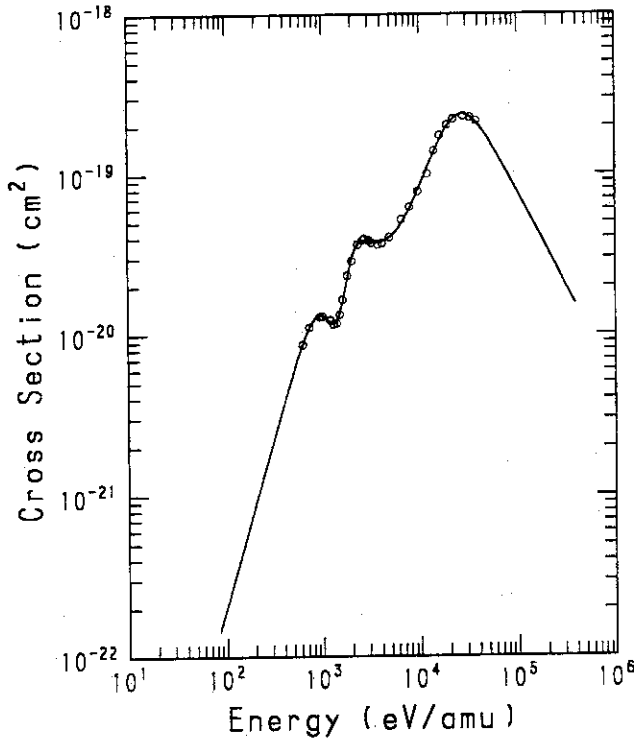
GRAPH 73

$He^+ + He \rightarrow He(3^3D) + He^+$



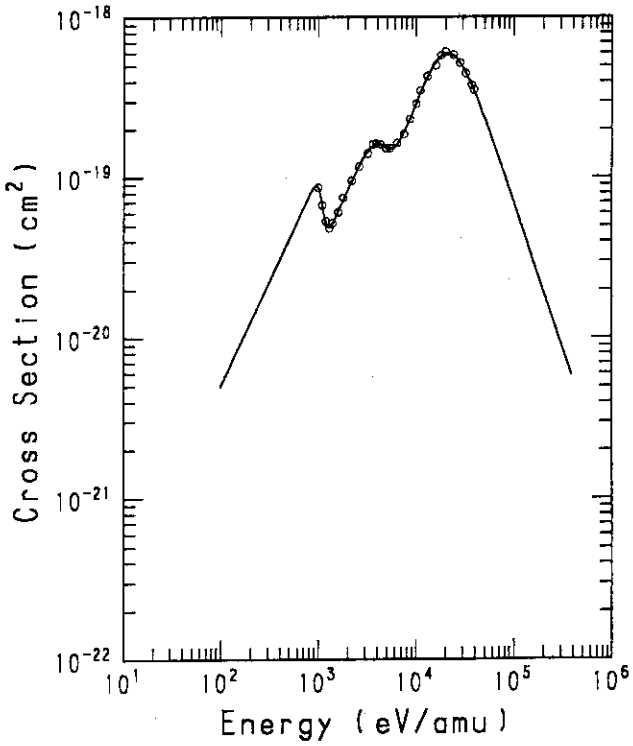
GRAPH 74

$He^+ + He \rightarrow He(4^1S) + He^+$



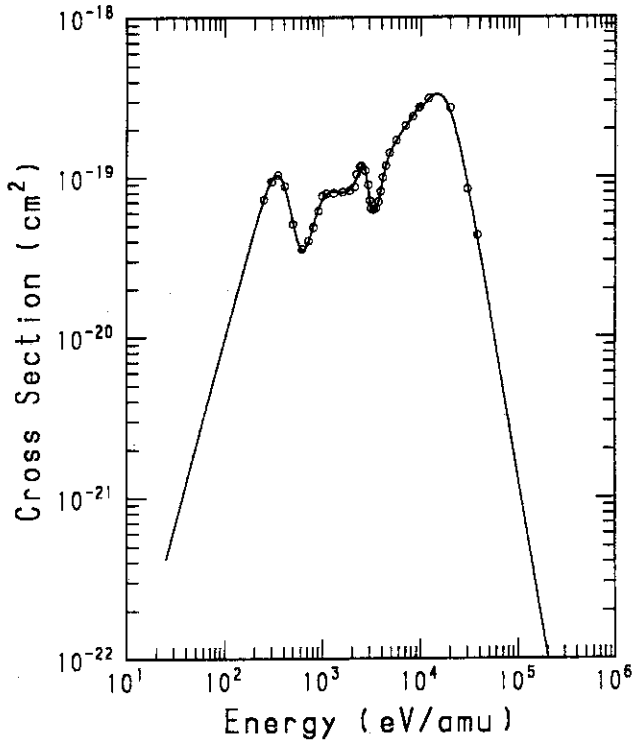
GRAPH 75

$He^+ + He \rightarrow He(4^1P) + He^+$



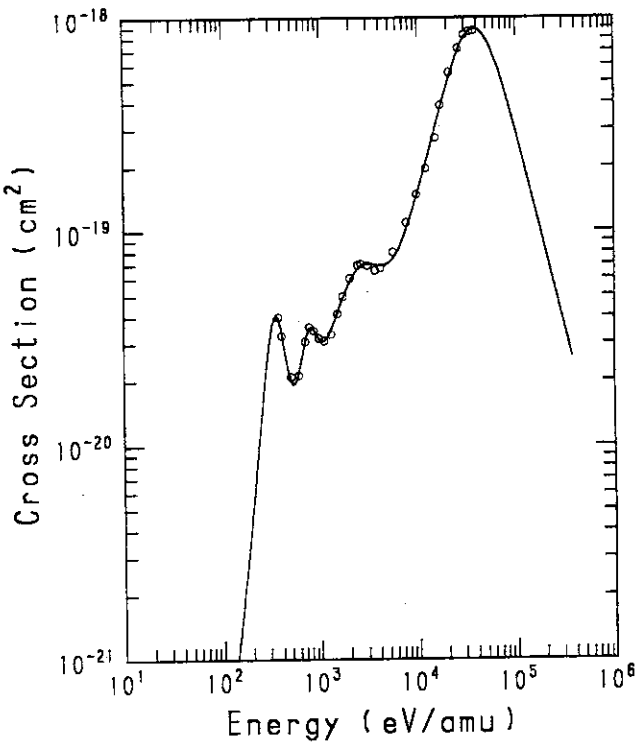
GRAPH 76

$He^+ + He \rightarrow He(4^1D) + He^+$



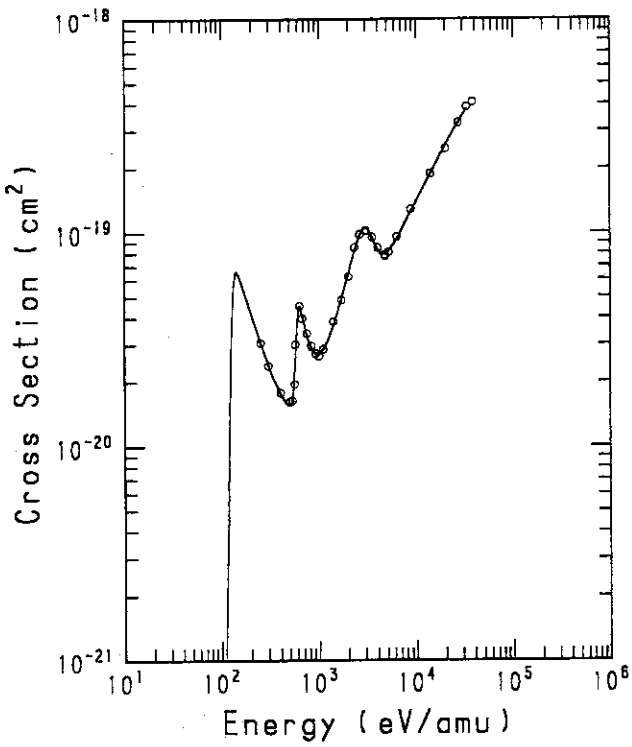
GRAPH 77

$He^+ + He \rightarrow He(4^3S) + He^+$



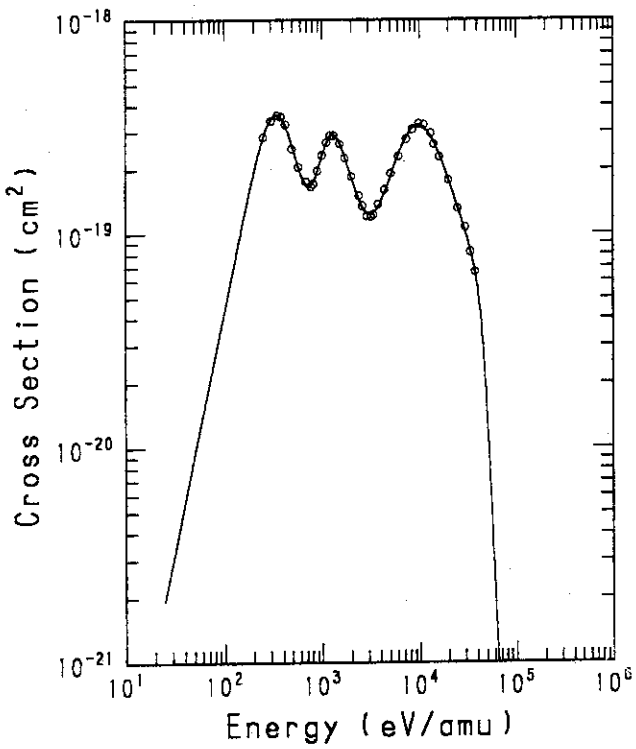
GRAPH 78

$He^+ + He \rightarrow He(4^3P) + He^+$



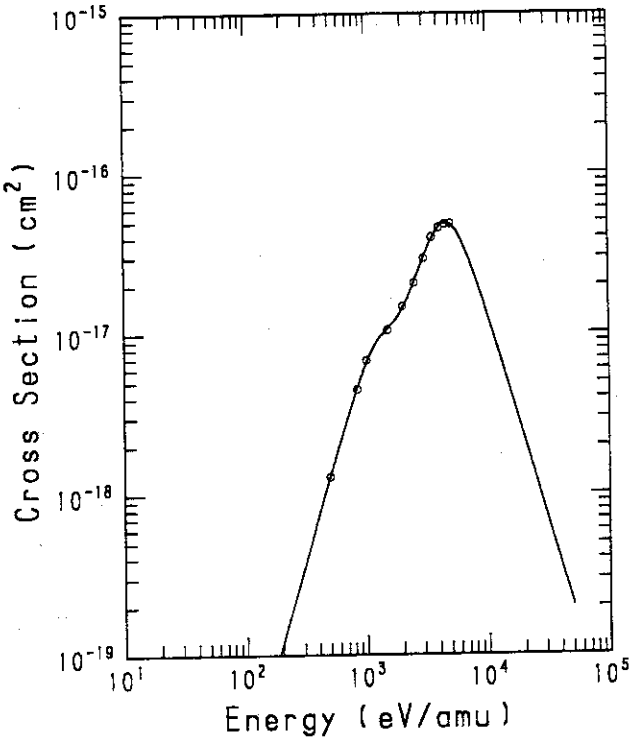
GRAPH 79

$He^+ + He \rightarrow He(4^3D) + He^+$



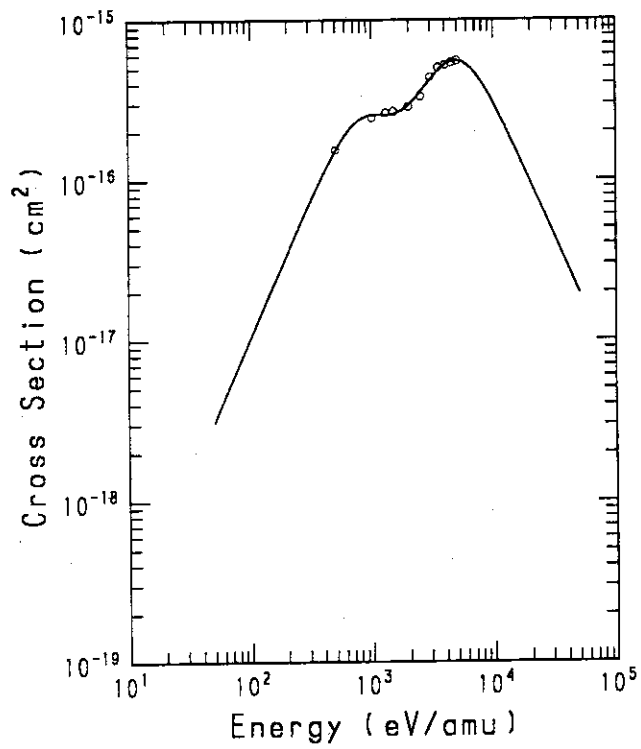
GRAPH 80

$He^+ + Li \rightarrow He(53.7nm) + Li^+$



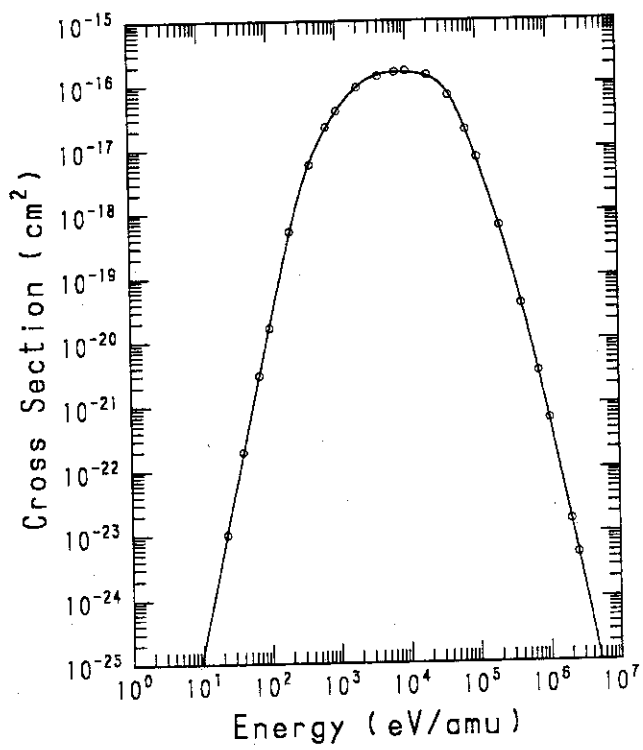
GRAPH 81

$He^+ + Li \rightarrow He(58.4nm) + Li^+$



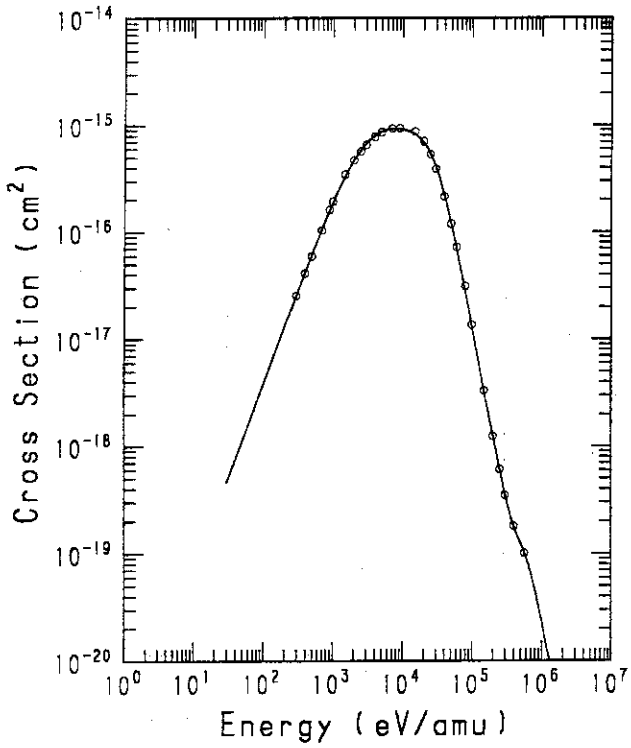
GRAPH 82

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



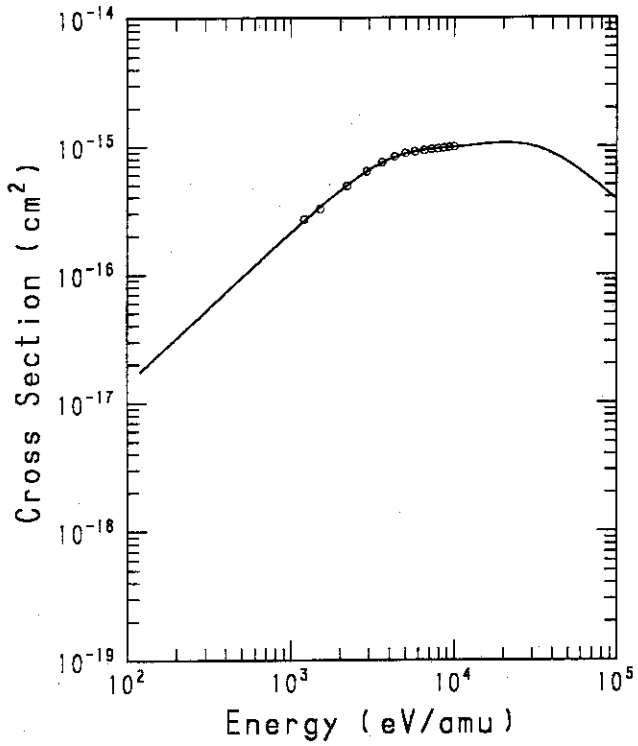
GRAPH 83

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



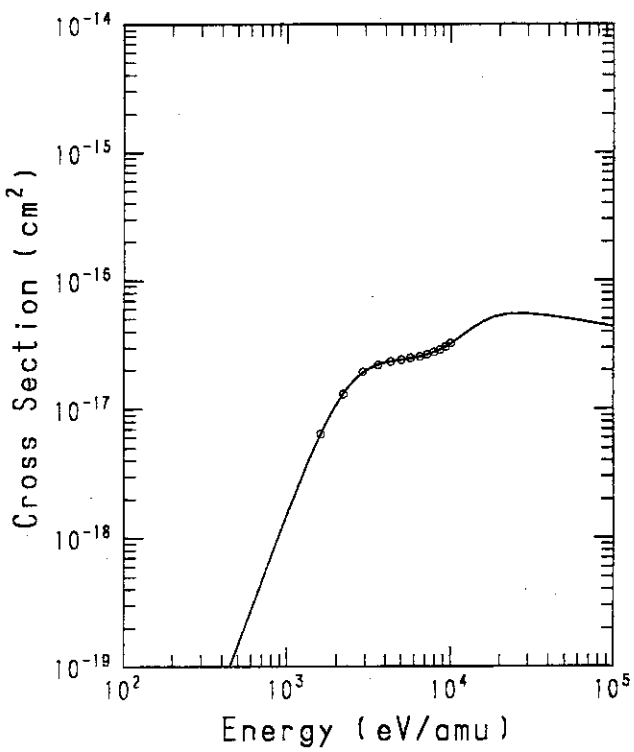
GRAPH 84

$He^{2+} + H \rightarrow He^{+}(Ly\alpha) + H^{+}$



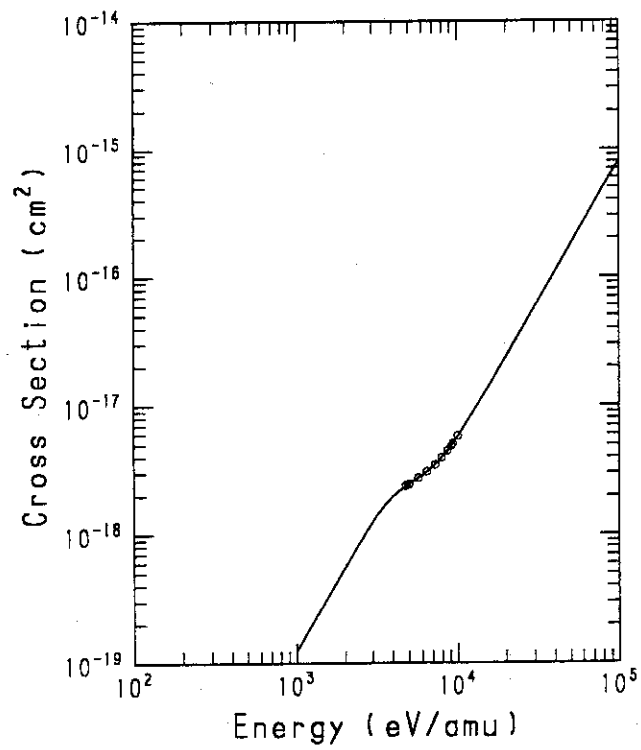
GRAPH 85

$He^{2+} + H \rightarrow He^{+}(Ly\beta) + H^{+}$



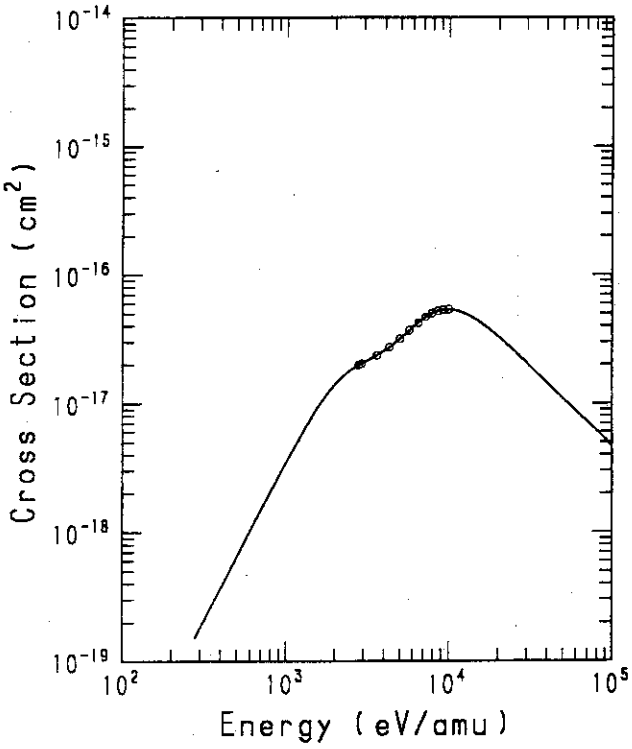
GRAPH 86

$He^{2+} + H \rightarrow He^{+}(Ly\gamma) + H^{+}$



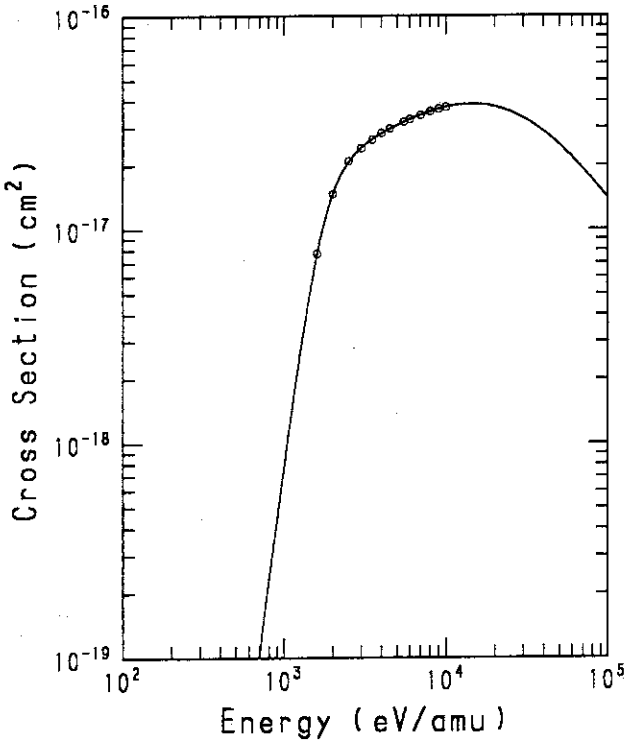
GRAPH 87

$He^{2+} + H \rightarrow He^{+}(H\alpha) + H^{+}$



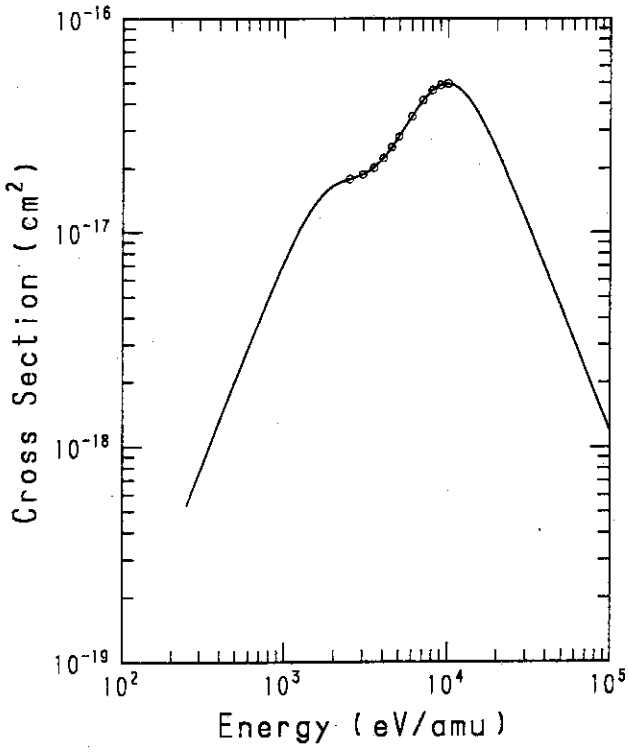
GRAPH 88

$He^{2+} + H \rightarrow He^{+}(3p) + H^{+}$



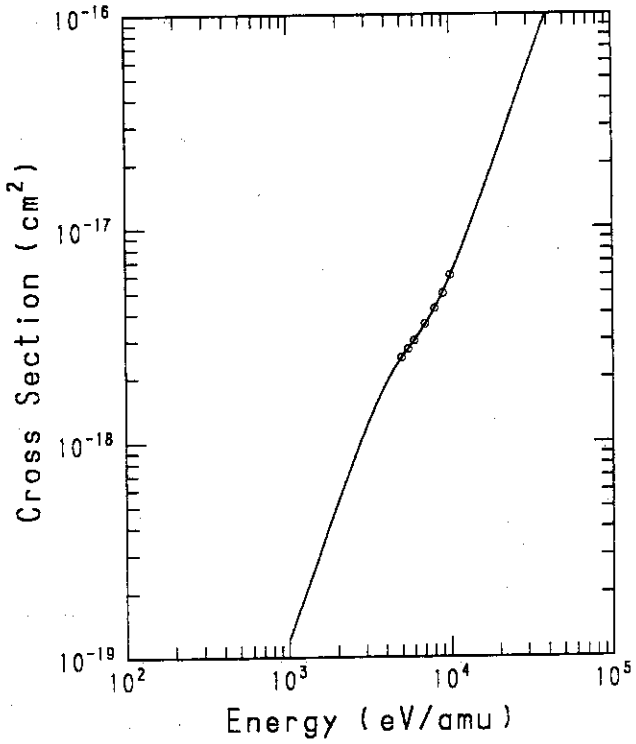
GRAPH 89

$He^{2+} + H \rightarrow He^{+}(3s+3d) + H^{+}$



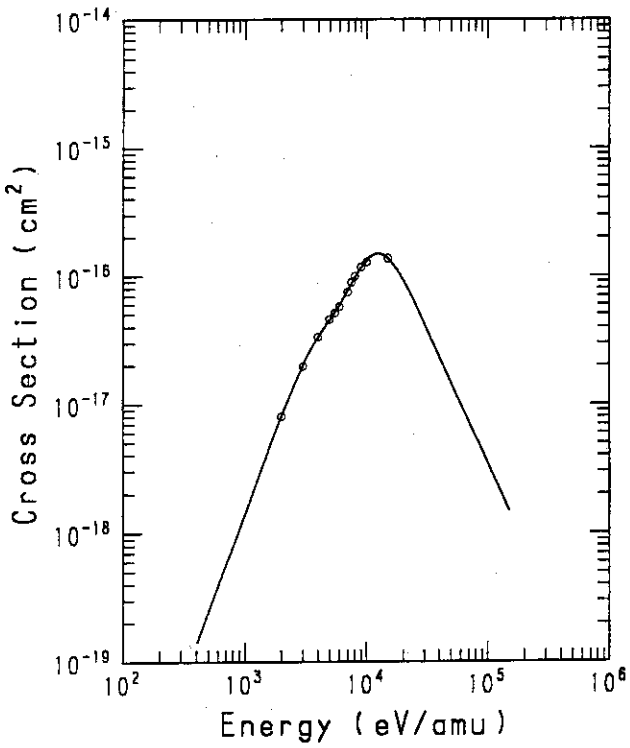
GRAPH 90

$He^{2+} + H \rightarrow He^{+}(4p) + H^{+}$



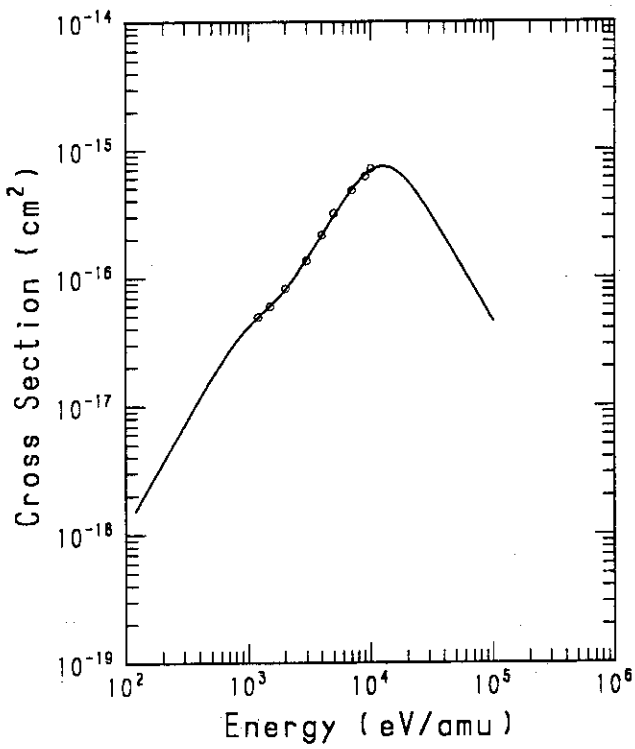
GRAPH 91

$He^{2+} + H_2 \rightarrow He^{+}(2s)$



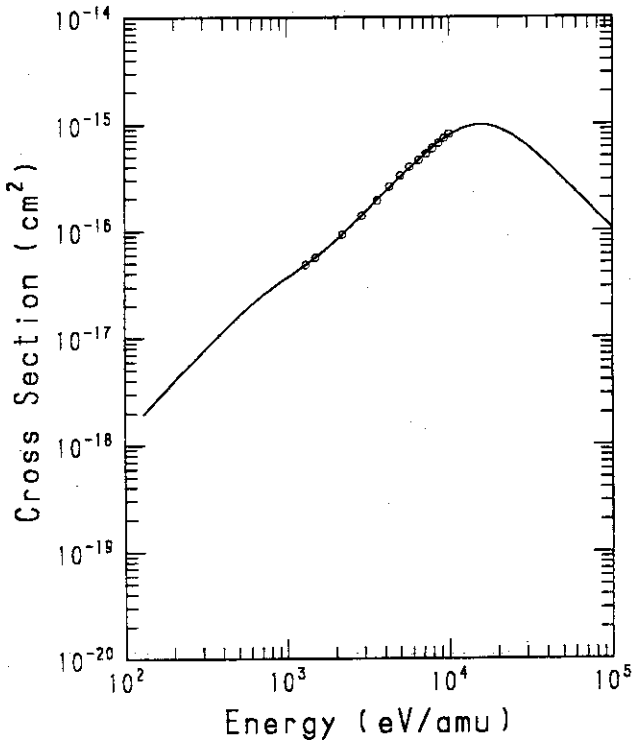
GRAPH 92

$He^{2+} + H_2 \rightarrow He^{+}(2p)$



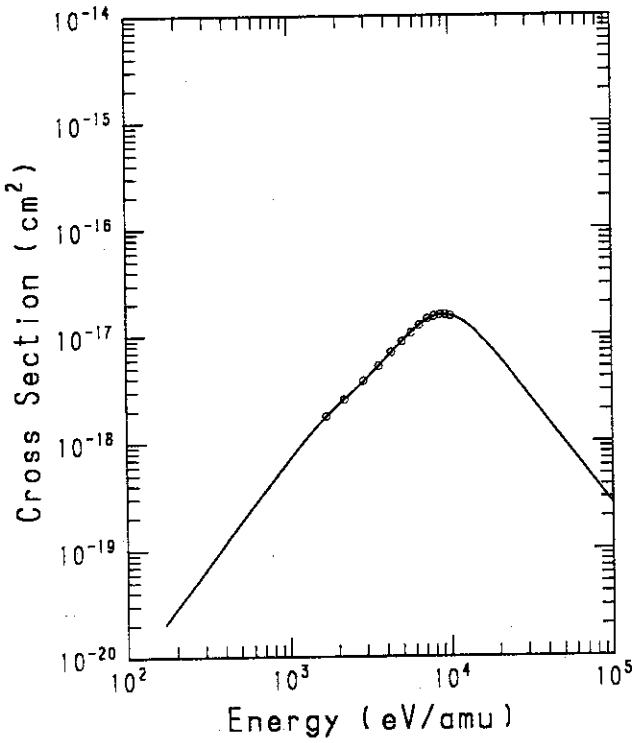
GRAPH 93

$He^{2+} + H_2 \rightarrow He^{+}(Ly\alpha)$



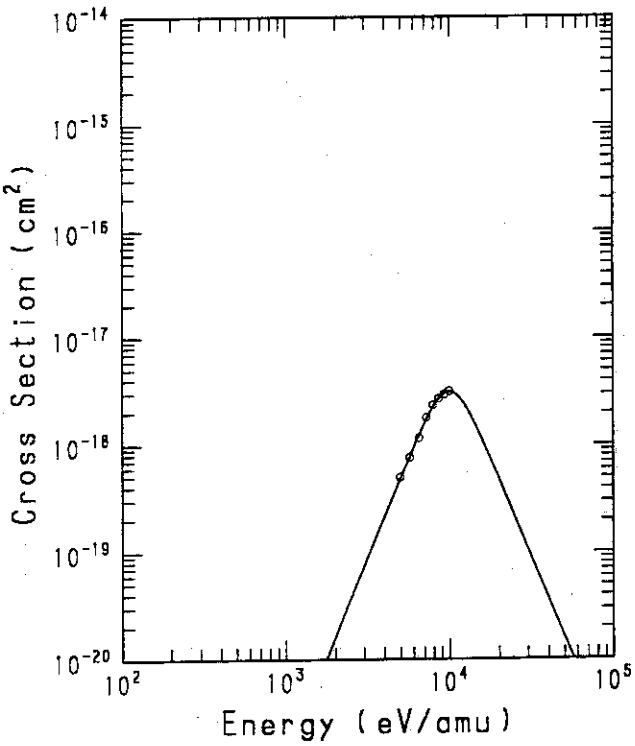
GRAPH 94

$He^{2+} + H_2 \rightarrow He^{+}(Ly\beta)$



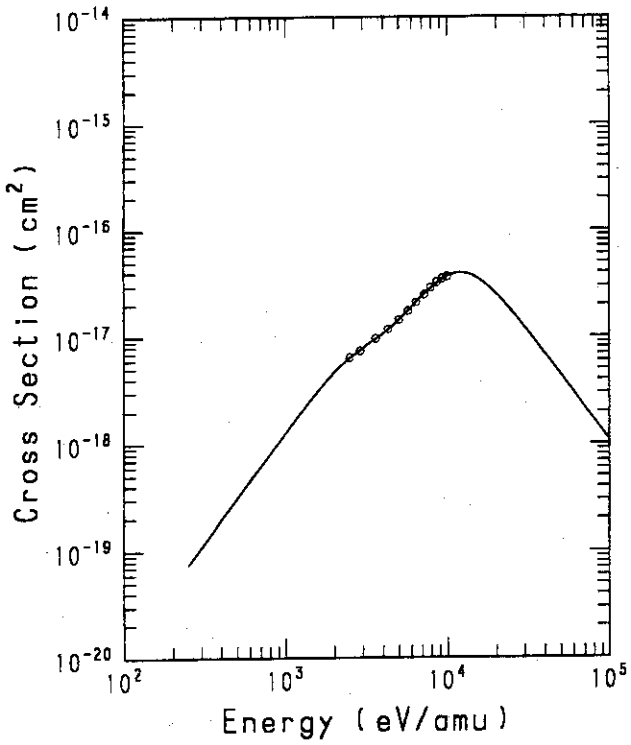
GRAPH 95

$He^{2+} + H_2 \rightarrow He^{+}(Ly\gamma)$



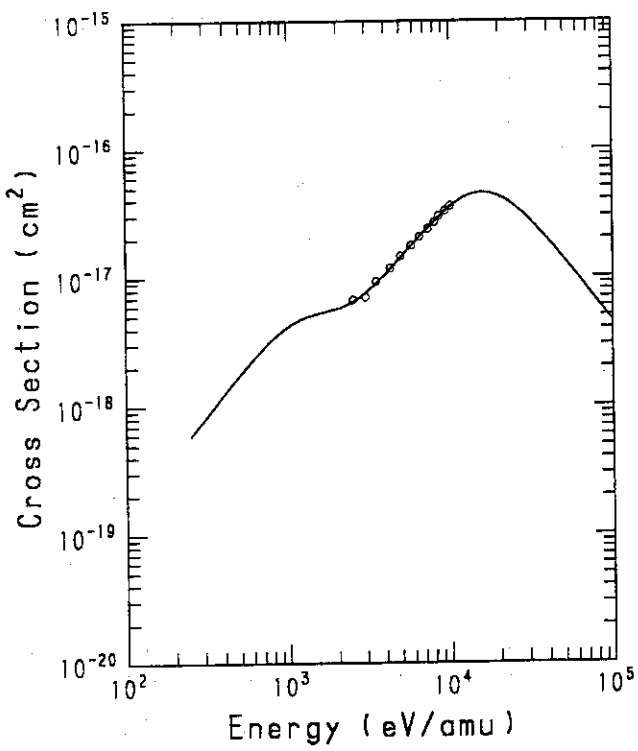
GRAPH 96

$He^{2+} + H_2 \rightarrow He^{+}(H\alpha)$



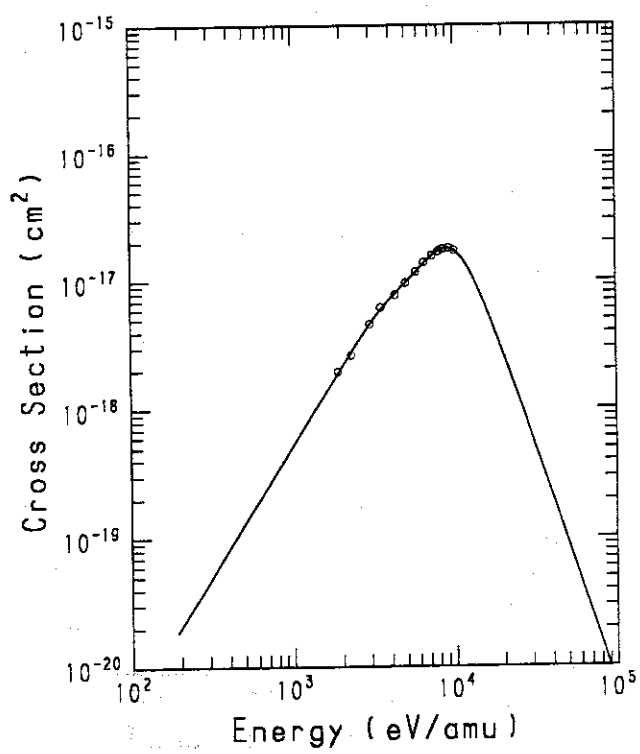
GRAPH 97

$He^{2+} + H_2 \rightarrow He^{+}(3p)$



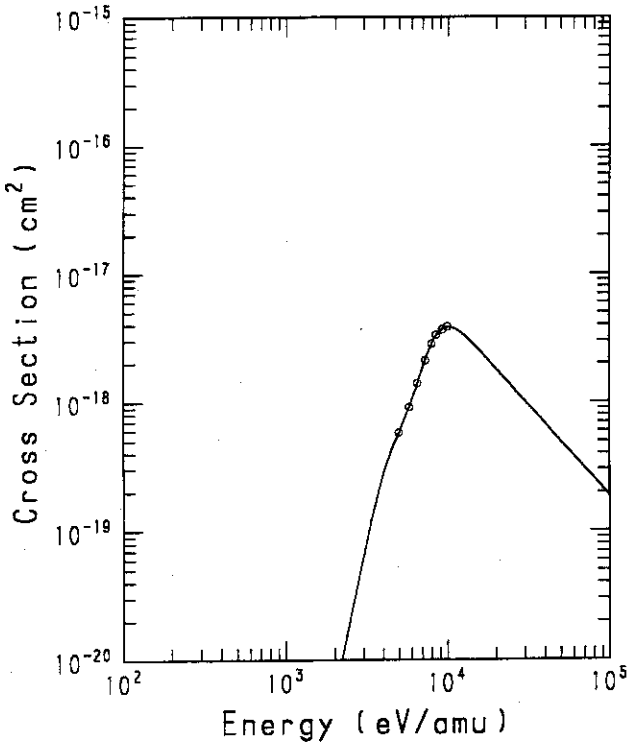
GRAPH 98

$He^{2+} + H_2 \rightarrow He^{+}(3s+3d)$



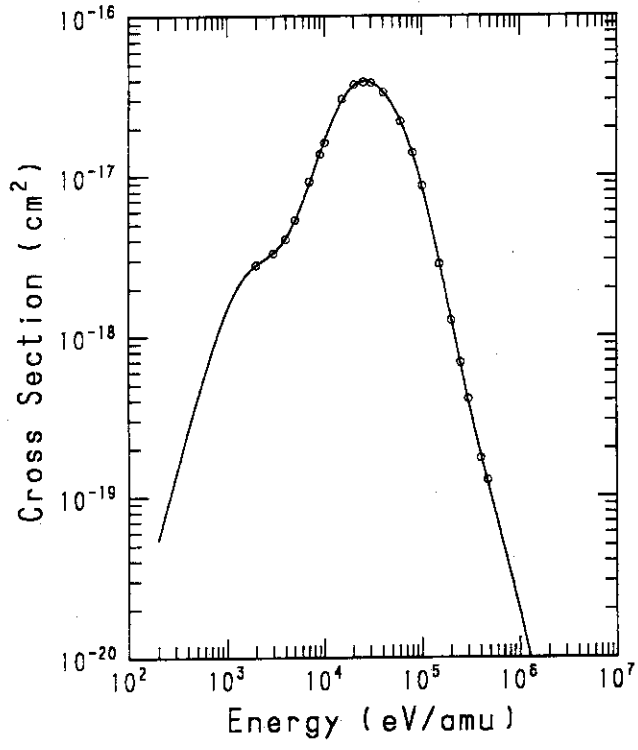
GRAPH 99

$He^{2+} + H_2 \rightarrow He^{+}(4p)$



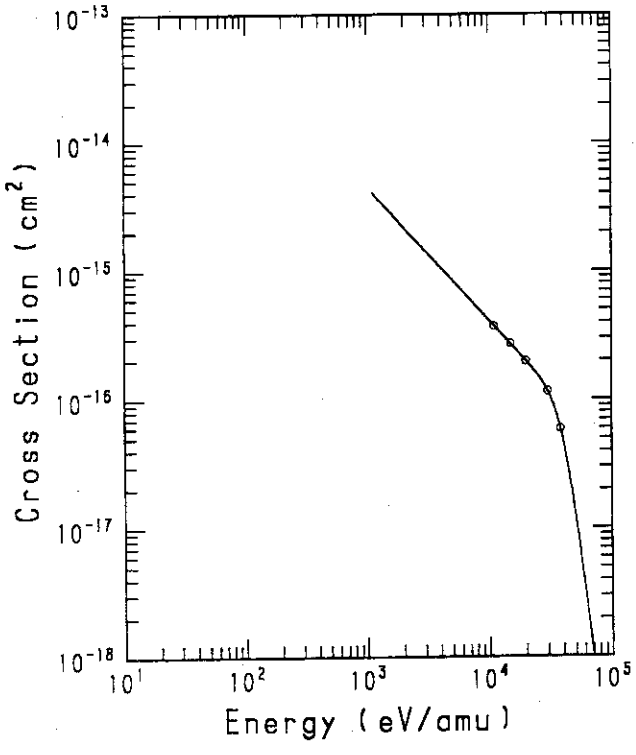
GRAPH 100

$He^{2+} + He \rightarrow He^{+}(2s) + He^{+}$



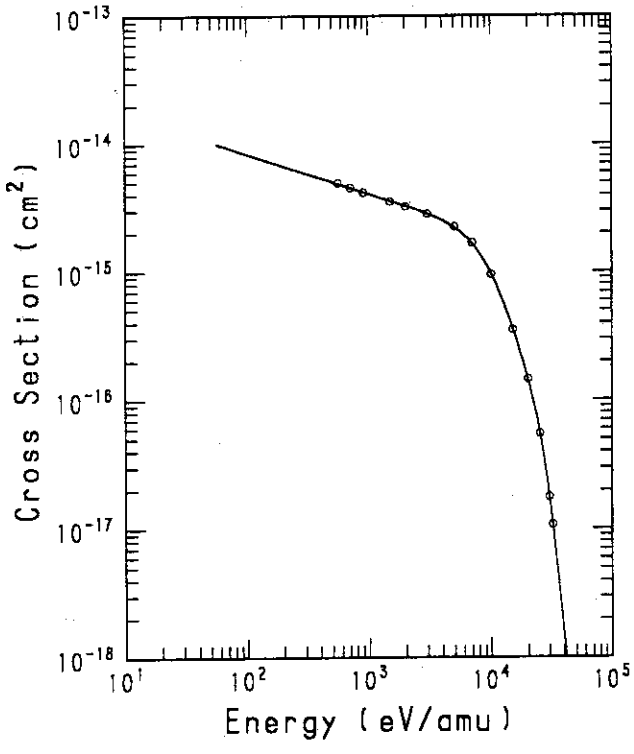
GRAPH 101

$He^{2+} + Li \rightarrow He^{+}(2p) + Li^{+}$



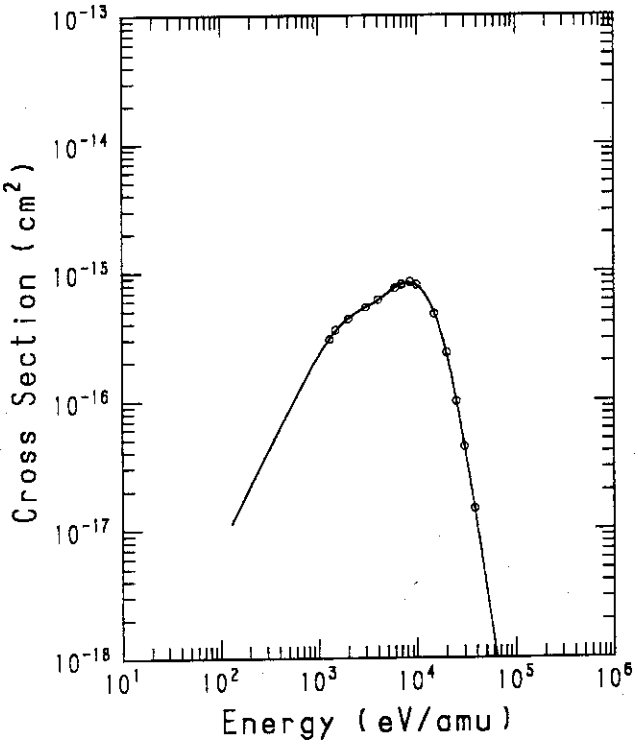
GRAPH 102

$He^{2+} + Li \rightarrow He^{+}(3p) + Li^{+}$



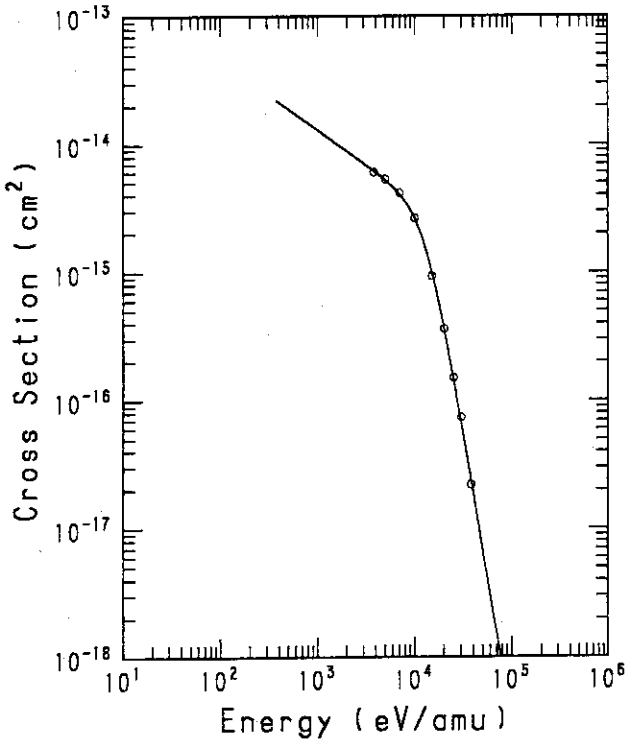
GRAPH 103

$He^{2+} + Li \rightarrow He^{+}(4p) + Li^{+}$



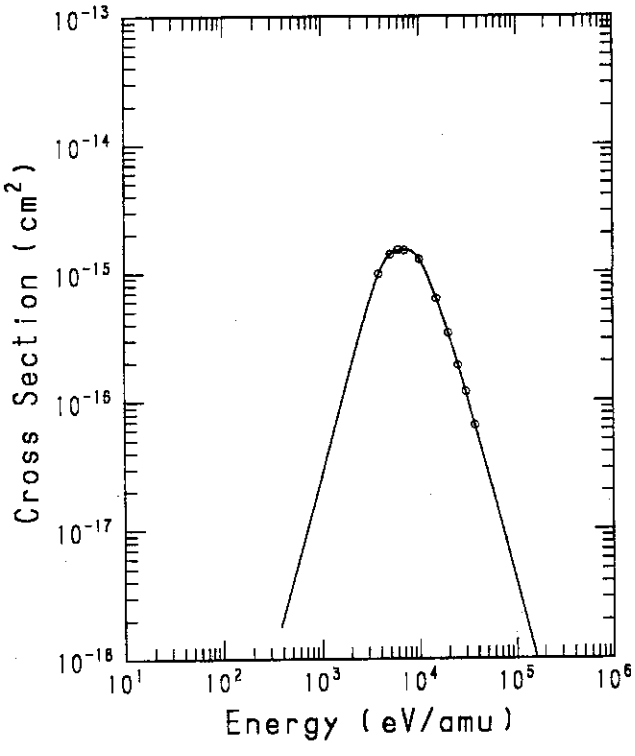
GRAPH 104

$He^{2+} + Li \rightarrow He^{+}(3s+3d) + Li^{+}$



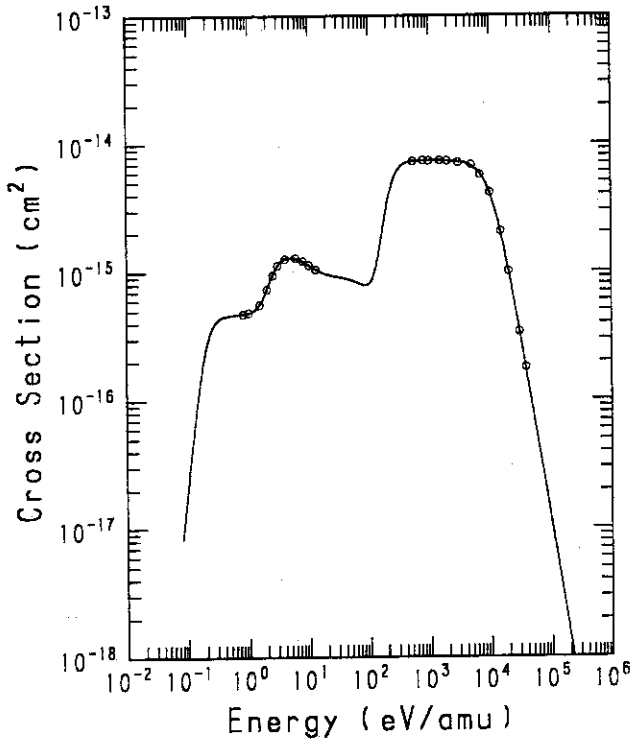
GRAPH 105

$He^{2+} + Li \rightarrow He^{+}(4s+4d) + Li^{+}$



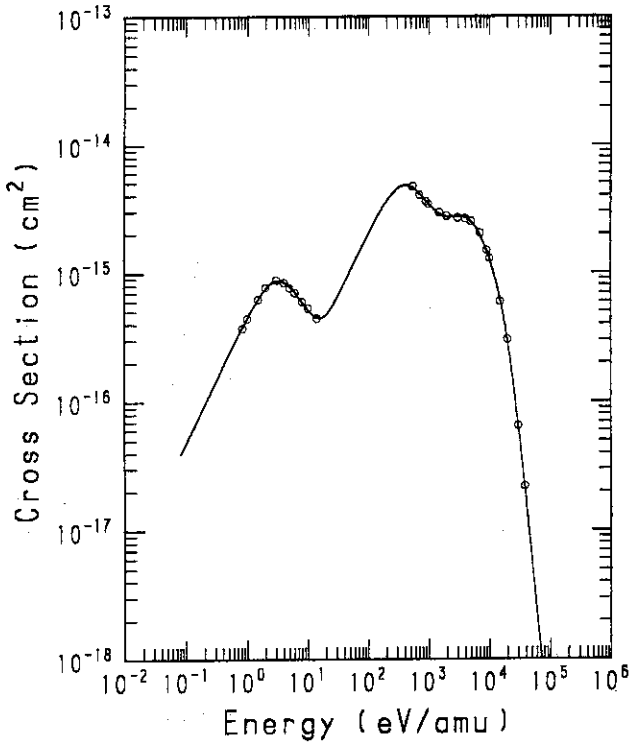
GRAPH 106

$He^{2+} + Li \rightarrow He^{+}(Ly\alpha) + Li^{+}$



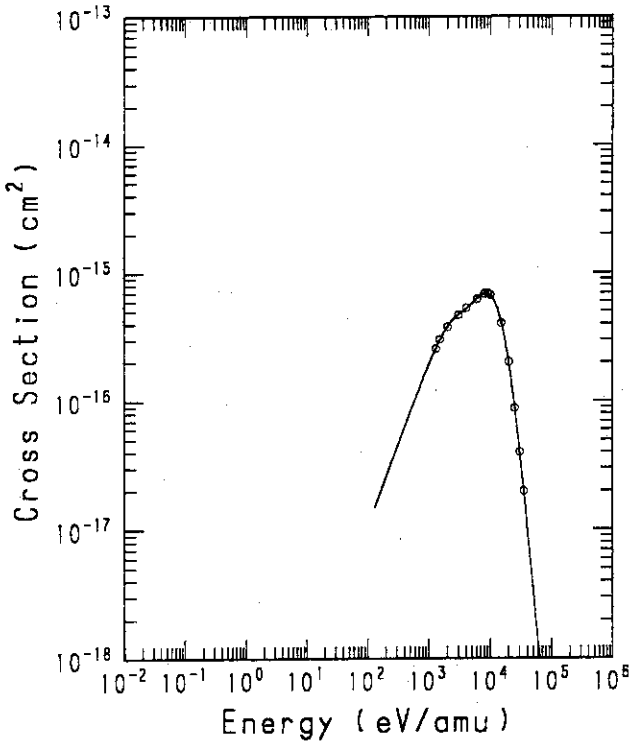
GRAPH 107

$He^{2+} + Li \rightarrow He^{+}(Ly\beta) + Li^{+}$



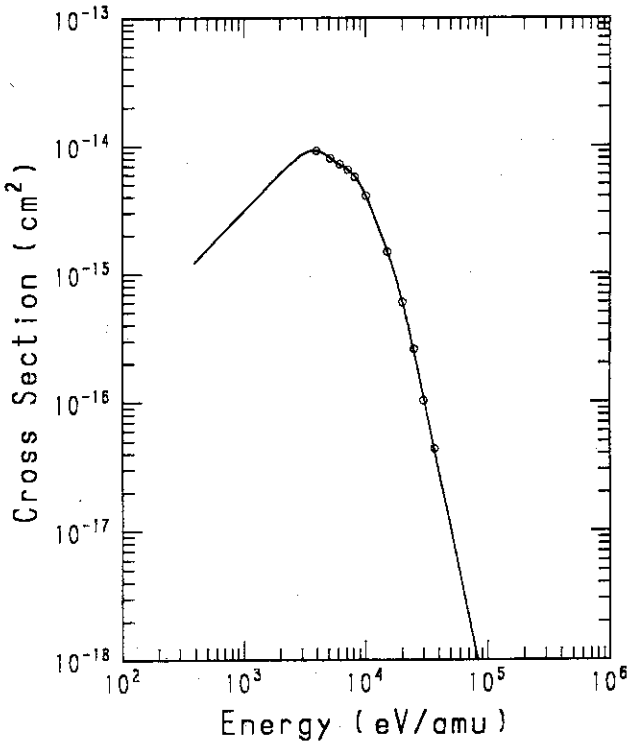
GRAPH 108

$He^{2+} + Li \rightarrow He^{+}(Ly\gamma) + Li^{+}$



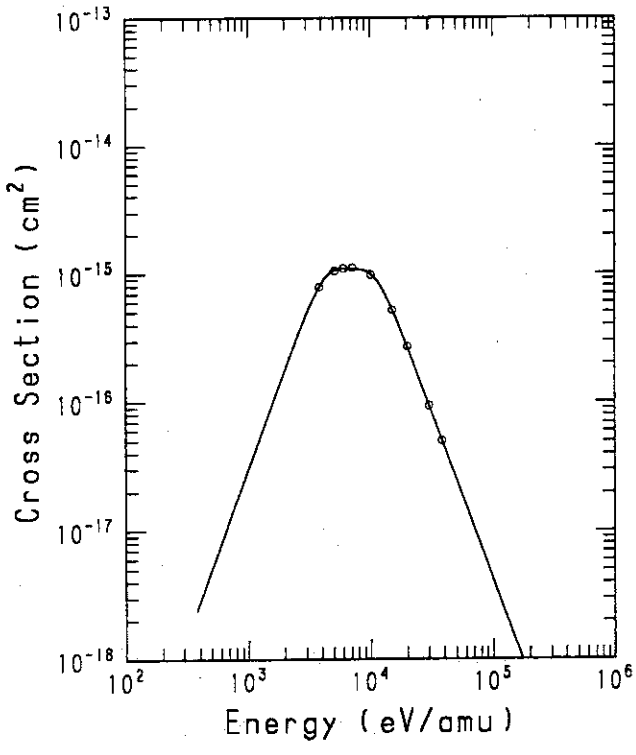
GRAPH 109

$He^{2+} + Li \rightarrow He^{+}(H\alpha) + Li^{+}$



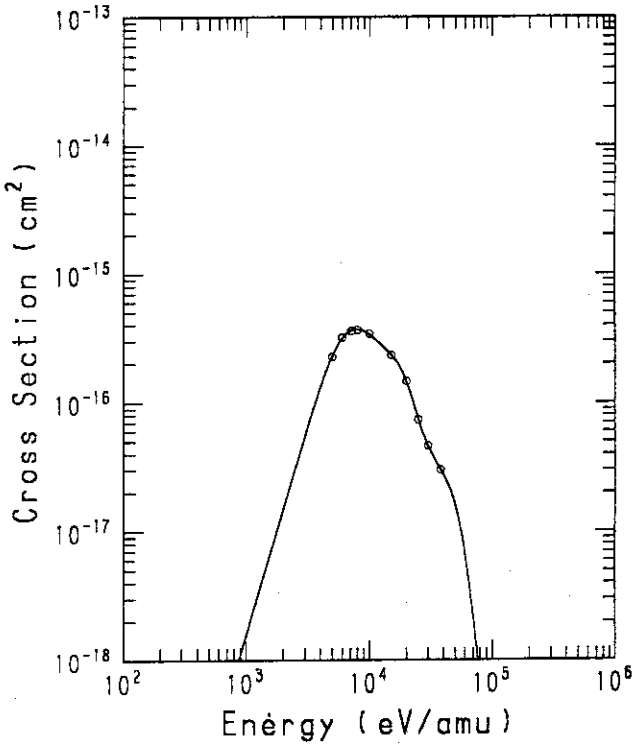
GRAPH 110

$He^{2+} + Li \rightarrow He^{+}(H\beta) + Li^{+}$



GRAPH 111

$He^{2+} + Li \rightarrow He^{+}(H\gamma) + Li^{+}$



GRAPH 112

$He^{2+} + Li \rightarrow He^{+}(H\delta) + Li^{+}$