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ANALYTIC CROSS SECTIONS FOR ELECTRON COLLISIONS WITH HYDROCARBONS: CH_4, C_2H_6, C_2H_4, C_2H_2, C_3H_8, AND C_3H_6

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Cross sections for 138 processes in collisions of electrons with hydrocarbons, based on available literature sources, are critically compiled. The literature has been surveyed up to September 2000. A short comment is given for each measurement. The recommended data sets are presented in separate graphs for each process. Analytic fits to the recommended cross sections are also presented.

Data files associated with this article may be found on IDEAL at http://www.idealibrary.com/links/doi/10.1006/adnd.2001.0878/dat.

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CONTENTS

INTRODUCTION

Cross section data for collision processes involving electron impact of hydrocarbons (CH_4, C_2H_6, C_2H_4, C_2H_2, C_3H_8, and C_3H_6) are necessary for understanding and modeling diverter plasmas (e.g., Janev [1]), where such molecules are produced through proton-induced chemical sputtering of graphite tiles used for the first walls of present-day and future tokamak fusion devices. Moreover, these data are also needed to elucidate the mechanisms of astrophysical phenomena (e.g., Perry et al. [2]) and to control plasma processing employed in industry (e.g., Morgan [3]).

For these processes, Tawara et al. [4] have previously surveyed the literature through 1990 and made a comprehensive compilation of cross section data. Since then, quite a large number of works have produced relevant cross section data. Taking these new data into account, the previous compilation has been updated and the results are presented here.

With the help of IAEA publications [5] and other bibliographies the literature was surveyed through September 2000. The recommended data in the previous compilation [4] have been replaced by the new ones only when more reliable data are available. Otherwise, the previous conclusion is adopted. The previous recommended data are indicated as Tawara et al. (1992) [4] in the present graphs. In such cases, the discussions in the previous paper should be consulted for the quality of the data shown, and the references for those

data are not repeated here. As in the previous compilation, only experimental data are considered here.

In cases where only a single set of measured cross sections is available, it is adopted as the recommended data, unless it is deemed unreliable. When a disagreement exists among different data sets, a renormalization of the data is made in some cases to the most reliable one to obtain the recommended data set for an energy range as wide as possible.

In order to facilitate practical use of the data, an analytic formula fitted by the method of least squares is given for each set of cross section data recommended in the present paper. The values of threshold energy have been taken from tables of standard thermodynamic properties of chemical substances for molar enthalpy of formation and of ionization energies of gas-phase molecules [6].

Data Sources

Methane (CH_4)

For methane, Kanik et al. [7] reviewed cross section data and determined the recommended values as of 1992 for total scattering, elastic, vibrational, and total ionization cross sections.

Since 1990 (see Graph 1), the total cross section has been measured by Zecca et al. [8], Kanik et al. [9], and García and Mareno [10] using a beam attenuation method. The agreement among these cross sections is, in general, good within a few percent, but the result of Zecca et al. [8] seems to decrease too fast with increasing energy above 1 keV. In this range we have adopted the results of García and Mareno [10].

The elastic scattering cross section is available from Boesten and Tanaka [11], Bundschu et al. [12], and Iga et al. [13] (Graph 2). All those results are in good agreement with the previous recommended data [4] within 20%. The result of Boesten and Tanaka [11] shows the highest maximum of the resonance at 7.5 eV, but seems to be too small at 100 eV. Above 100 eV, the recommended data of Kanik et al. [7] are used here. The momentum transfer cross section was obtained from the beam experiments mentioned above [11–13] and, at low energies below 2 eV, from a swarm method used by Schmidt [14] (Graph 3). We see a pronounced Ramsauer minimum at about 0.3 eV, which is deeper than that in the previous compilation [4].

Cross sections for the vibrational excitation of the $(v_1 + v_3)$ and $(v_2 + v_4)$ unresolved normal modes were reported by Tanaka et al. [15], Schmidt [14], Shyn [16], and Bundschu et al. [12]. Graphs 4 and 5 show these data together with the values recommended in the previous paper [4]. The cross section data scatter so widely that no recommended values can be determined.

No recent data are available for the electron attachment cross section and the previous recommendation is adopted (Graph 6).

For total ionization, cross sections were measured by Djurić et al. [17], Nishimura and Tawara [18], Vallance et al. [19], and Tian and Vidal [20]. The agreement among these measurements is generally good, except for the result of Vallance et al. [19], which shows a rapid fall-off of the cross section at energies above 100 eV. Nishimura and Tawara [18] measured total ionization cross section systematically for the hydrocarbon molecules. In the present paper, the use of their cross section is recommended as far as available (Graph 7). A calculation by Hwang et al. [21] based on the binary-encounter Bethe model is also shown for comparison. Straub et al. [22] measured partial cross sections for the production of CH_x^+ ($x = 0$–4) and H_x^+ ($x = 1$–2) (Graphs 8–14) for the electron energies from threshold to 1000 eV. The experimental uncertainty of their cross sections is estimated to be as small as ±3.5%. We have adopted their results here. Another recent measurement of the partial ionization cross sections, the result of which agrees well with those of Straub et al. [22] within 5%, was done by Tian and Vidal [20].

The total dissociation cross section determined by Winters [23] was recommended in the previous compilation [4] (Graph 15). The cross section for the production of CH_3 radical due to the neutral dissociation and dissociative ionization was given by Motlagh and Moore [24] (Graph 16), who derived the absolute values with the help of information on the total dissociation cross section of Winters [23] and the dissociative ionization cross sections by Straub et al. [22]. The cross section for the H($2s$) production was first measured along with the Lyman-α emission cross section by Vroom and de Heer [25]. We found that the latter cross section values are too high compared with a recent measurement of Motohashi et al. [26]. Therefore, the result for the former cross section is also considered to be too high and has been reduced by the factor obtained from the comparison of the latter cross section (Graph 17).

Motohashi et al. [26] also measured the cross sections for the emission from the various fragments produced at the dissociation (Graphs 18–25, 27, 28): the Lyman series of H with $n = 2$–4, the Balmer series of H with $n = 3$–6, CH($A\ ^2\Delta \rightarrow X\ ^2\Pi$) at 420–440 nm, C($2p3s \rightarrow 2p^2$) at 165.7 nm, and C($2s2p^3 \rightarrow 2s^22p^2$) at 156.1 nm. The cross section value of 7.3×10^{-18} cm^2 for the Lyman-α emission upon the electron impact dissociation of H_2 at 100 eV was employed for the intensity calibration. The uncertainties of the resulting cross sections are estimated to be ±20% for the Lyman-α emission, ±12% for the Balmer-α emission, ±20% for the CH band emission, and ±50% for the C-line

emission. We have adopted these results. Motohashi et al. [26] did not measure the emission of $C(2p3s \rightarrow 2p^2)$ at 193.1 nm (Graph 26).

While not directly involving the collision of electrons with the neutral methane molecule (CH_4), related cross sections for processes involving CH_x^+ ($x = 1$–4) and CD_x ($x = 1$–3) are shown in Graphs 29–41.

No recent measurements are available for the total dissociative recombination cross sections for the CH_x^+ ($x = 1$–4) ions (Graphs 29–32).

Absolute cross sections for the total ionization and the dissociative ionization of the deuterated methane molecule CD_4 and the radicals CD_x ($x = 1$–3) (Graphs 33–41) were measured by Tarnovsky et al. [27] in the energy range from threshold to 200 eV, using a fast-neutral beam technique. The uncertainties are estimated to be ±15% for the ionization cross sections of the parent molecules and ±18% for the dissociative ionization cross sections. Their results agree well with the previous recommended data [4]. A comparison of the cross sections for the total ionization and dissociative ionization of CD_4 with the corresponding data of CH_4 indicates no isotope effects. It should be noted that the cross section for the production of CD_2^+ due to dissociative ionization of CD_4 in the energy range above 70 eV is somewhat larger than that in the case of CH_4. However, this difference is due not to isotope effect, but to a better collection of energetic fragment ions in the CD_4 experiment. In conclusion, the CH_4 results can be used for CD_4 in the energy range above 30 eV, where the presence of vibrationally excited molecules in the neutralized CD_4 beam does not affect the cross section.

The total ionization cross sections of the radicals CD_x ($x = 1$–3) are also compared with the calculations, based on the binary-encounter Bethe model, by Hwang et al. [21] for the radicals CH_x ($x = 2$–3) and by Kim [28] for the CH radical.

Ethane (C_2H_6)

The total scattering cross section was determined by Nishimura and Tawara [29] and Kimura et al. [30] in the energy range 1–400 eV (Graph 42). These two sets of cross sections agree with each other and with the earlier measurements in Ref. [4] within the respective uncertainties.

The cross section for elastic scattering was newly measured by Merz and Linder [31] in the energy range 0.3–10 eV with an estimated uncertainty of ±25% (Graph 43). In the energy range 1–2 eV, the present total cross section seems too small compared with the elastic one. However, considering the uncertainty of the latter, there is no inconsistency between the two cross sections. Shishikura et al. [32] analyzed a swarm experiment and derived the momentum transfer cross section in the range 0.1–100 eV. Merz and Linder [31] also derived the momentum transfer cross section with the phase shift determined from their elastic cross section measured and using the modified effective range theory. They estimated the value at zero energy to be 3.2×10^{-15} cm^2. The two sets of momentum transfer cross sections (Graph 44) are in fairly good agreement with each other at energies around 0.1 eV, but the result of Shishikura et al. [32] seems to be too high at the lower energies. In the lower energy range, only the result of Merz and Linder [31] has been adopted.

As stated in the case of CH_4, the total ionization cross section measured by Nishimura and Tawara [18] (Graph 45) is plotted along with the calculation by Hwang et al. [21] based on the binary-encounter Bethe model. The partial ionization cross sections for the production of $C_2H_x^+$ ($x = 0$–6), CH_x^+ ($x = 0$–3), and H_x^+ ($x = 1$–3) were determined by Tian and Vidal [33] (Graphs 46–59). The uncertainties are estimated to be ±10%. These data sets are more reliable than those of Grill et al. [34], because all the ionic fragments are believed to be collected properly.

No recent data are available for the cross sections for the total dissociation (Graph 60), $H(2s)$ production (Graph 61), and photon emission (Graph 62–66). The previous recommended values [4] are reproduced here. It should be noted that the cross sections for $H(2s)$ production and the Lyman-α emission are renormalized as in the case of CH_4 (Graph 61).

Ethylene (C_2H_4)

The total scattering cross section in the previous compilation [4] is in good agreement with that of Nishimura and Tawara [29] (Graph 67).

No recent measurements are available for momentum transfer cross section (Graph 68).

As stated in the case of CH_4, total ionization cross section measured by Nishimura and Tawara [18] is recommended here (Graph 69). Tian and Vidal [35] obtained the dissociative ionization cross sections for the production of $C_2H_x^+$ ($x = 0$–4), CH_x^+ ($x = 0$–3), and H_x^+ ($x = 1$–2) in the energy range from threshold to 600 eV (Graphs 70–80). Their experimental uncertainty is estimated to be ±10%. We have adopted these results. The sum of the partial cross sections is consistent with the present recommended values of total ionization cross section.

No recent measurements are available for the cross sections for $H(2s)$ production (Graph 81) and photon emission (Graphs 82–87). It should be noted that the cross section values of the $H(2s)$ production and Lyman-α emission are renormalized as in the case of CH_4 (Graph 81).

Acetylene (C_2H_2)

The total cross section was provided by Kimura et al. [30] in the energy range 1–400 eV and by Xing et al. [36] in the range 400–2600 eV, both using a beam attenuation technique (Graph 88). The uncertainties of the two experiments are estimated to be ±3% and ±5%, respectively. We have adopted these results.

A measurement of the elastic scattering cross section was made by Khakoo et al. [37] in the energy range 3–100 eV with an estimated uncertainty of about 20% (Graph 89). A relative flow method was employed for normalization. Their result is consistent with the difference between the total scattering cross section and the total ionization one presented here.

No recent measurements are available for momentum transfer cross section (Graph 90).

Cross sections for the dissociative ionization to form $C_2H_x^+$ ($x = 0$–2), CH_x^+ ($x = 0$–1), and H^+ were determined by Tian and Vidal [20] (Graphs 92–97). The corresponding data obtained by Zheng and Srivastava [38] are too low, probably because of incomplete collection of energetic fragment ions. Since there is no reliable direct measurement of total ionization cross section, the sum of the partial cross sections of Tian and Vidal [20] is recommended here as the total ionization cross section (Graph 91). The results are plotted along with a calculation by Kim et al. [28] based on the binary-encounter Bethe model.

No recent measurements are available for photon emission cross sections (Graphs 98–105).

Propane (C_3H_8)

The total scattering cross section has been taken from Kimura et al. [30] (Graph 106), which is in good agreement with the earlier works shown in the previous compilation [4].

The elastic scattering (Graph 107) and momentum transfer (Graph 108) cross sections were measured by Boesten et al. [39] in the energy range 1.5–100 eV.

The cross section for total ionization was reported by Djurić et al. [17], Grill et al. [40], and Nishimura and Tawara [18] (Graph 109). As in the case of CH_4, we have adopted the result of Nishimura and Tawara [18], which is shown in comparison with a calculation by Hwang et al. [21] based on the binary-encounter Bethe model.

Absolute partial ionization cross sections were determined by Grill et al. [40] for the production of $C_3H_x^+$ ($x = 0$–8), $C_2H_x^+$ ($x = 0$–5), CH_x^+ ($x = 0$–3), and $C_3H_x^{2+}$ ($x = 2$–5) in the energy range from threshold to 950 eV. They used the total ionization cross section at 100 eV of Djurić et al. [17], which is by about 18% smaller than that of Nishimura and Tawara [18], to normalize their relative cross sections. In the present paper, therefore, the partial cross sections of Grill et al. [40] are multiplied by 1.18 and plotted as recommended values (Graphs 110–132). The uncertainties are estimated to be ±15% for the dominant ions and ±20% for minor ones.

No measurements are available for photon emission except for Balmer-β emission (Graph 133).

Propene and Cyclopropane (C_3H_6)

The total scattering (Graphs 134 and 137) and total ionization (Graphs 135 and 138) cross sections were measured by Nishimura and Tawara [18, 29].

No measurements are available for photon emission except for Balmer-β emission (Graph 136).

Analytic Expressions

The functional forms of the analytic expressions used for the cross sections except for ionization are those derived semiempirically by Green and McNeal [41] with such modifications as adopted in our previous work [42, 43]. For the ionization cross section, use is made, in most cases, of the function with an asymptotic form of $\ln E/E$ (E being the incident electron energy), as proposed by Lotz [44], and with a near-threshold form used in the previous work [43] [see Eq. (14) below]. First we introduce three different functions in the form

$$f_1(x; c_1, c_2) = \sigma_0 c_1 (x/E_R)^{c_2} \quad \text{(i)}$$

$$f_2(x; c_1, c_2, c_3, c_4) = f_1(x; c_1, c_2) \Big/ \left[1 + (x/c_3)^{c_2+c_4}\right] \quad \text{(ii)}$$

$$f_3(x; c_1, c_2, c_3, c_4, c_5, c_6 = f_1(x; c_1, c_2) \Big/ \left[1 + (x/c_3)^{c_2+c_4} + (x/c_5)^{c_2+c_6}\right] \quad \text{(iii)}$$

with $\sigma_0 = 1 \times 10^{-16}$ cm^2 and $E_R = 1.361 \times 10^{-2}$ keV (Rydberg constant). The symbols x and c_i ($i = 1, 2, \ldots, 6$) in Eqs. (i)–(iii) denote dummy parameters. The cross sections recommended in the present paper are expressed by one of the following forms involving the combination of the above functions,

$$\sigma = f_1(E_1; a_1, a_2) \quad (1)$$

$$\sigma = f_2(E_1; a_1, a_2, a_3, a_4) \quad (2)$$

$$\sigma = f_1(E_1; a_1, a_2) + f_2(E_1; a_3, a_4, a_5, a_6) \quad (3)$$

$$\sigma = f_2(E_1; a_1, a_2, a_3, a_4) + a_5 f_2(E_1/a_6; a_1, a_2, a_3, a_4) \quad (4)$$

$$\sigma = f_2(E_1; a_1, a_2, a_3, a_4) + f_2(E_1; a_5, a_6, a_7, a_4) \quad (5)$$

$$\sigma = f_2(E_1; a_1, a_2, a_3, a_4) + f_2(E_1; a_5, a_6, a_7, a_8) \quad (6)$$

$$\sigma = f_2(E_1; a_1, a_2, a_3, a_4) + f_2(E_1; a_5, a_6, a_7, a_4) + f_2(E_1; a_8, a_9, a_{10}, a_4) \quad (7)$$

$$\sigma = f_2(E_1; a_1, a_2, a_3, a_4) + f_2(E_1; a_5, a_6, a_7, a_8) + f_2(E_1; a_9, a_{10}, a_{11}, a_{12}) \quad (8)$$

$$\sigma = f_3(E_1; a_1, a_2, a_3, a_4, a_5, a_6) \quad (9)$$

$$\sigma = f_1(E_1; a_1, a_2) + f_3(E_1; a_3, a_4, a_5, a_6, a_7, a_8) \quad (10)$$

$$\sigma = f_3(E_1; a_1, a_2, a_3, a_4, a_5, a_6) + a_7 f_3(E_1/a_8; a_1, a_2, a_3, a_4, a_5, a_6) \quad (11)$$

$$\sigma = f_2(E_1; a_1, a_2, a_3, a_4) + f_3(E_1; a_5, a_6, a_7, a_8, a_9, a_4) \quad (12)$$

$$\sigma = f_2(E_1; a_1, a_2, a_3, a_4) + f_3(E_1; a_5, a_6, a_7, a_8, a_9, a_{10}) + f_2(E_1; a_{11}, a_{12}, a_{13}, a_{10}) \quad (13)$$

$$\sigma = \sigma_0 a_1[\ln(E/E_{\text{th}}) + a_2]/[E_{\text{th}} E(1 + (a_3/E_1)^{a_4})], \quad (14)$$

where $E_1 = E - E_{\text{th}}$ with E the incident electron energy in keV and E_{th} the threshold energy of reaction in keV. Depending on the formula chosen from Eqs. (1)–(14) above, the value of E_1 or E_1/a_i ($i = 6$ or 8) is substituted for x, and a_1, a_2, etc. are substituted for c_i. The tables (read across two facing pages) give the values of the fitting parameters ($a_1, a_2, \ldots$), which have been determined by least-squares fits to the recommended data with some additional constraints to guarantee reasonable behavior outside the energy range of the available data. The present expressions allow one not only to interpolate but also to extrapolate the data to some extent. This is in contrast to polynomial fits, which frequently show physically unreasonable behavior just outside the energy range of the available data.

The resulting analytic expressions are shown in the graphs together with the recommended data. Normally the present forms fit the data quite well. To show the agreement quantitatively, the root-mean-square and the maximum deviations of the expressions from the data are also given in the tables.

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EXPLANATION OF TABLES

TABLE I. **Energy Ranges of Data, Fitting Errors, and Parameters of the Analytic Expressions for Methane (CH_4)**

TABLE II. **Energy Ranges of Data, Fitting Errors, and Parameters of the Analytic Expressions for Ethane (C_2H_6)**

TABLE III. **Energy Ranges of Data, Fitting Errors, and Parameters of the Analytic Expressions for Ethylene (C_2H_4)**

TABLE IV. **Energy Ranges of Data, Fitting Errors, and Parameters of the Analytic Expressions for Acetylene (C_2H_2)**

TABLE V. **Energy Ranges of Data, Fitting Errors, and Parameters of the Analytic Expressions for Propane (C_3H_8)**

TABLE VI. **Energy Ranges of Data, Fitting Errors, and Parameters of the Analytic Expressions for Propene and Cyclopropane (C_3H_6)**

No.	Number label identifying a particular reaction process in the same sequence as in the Graphs.
Process	The relevant reaction process.
E_{min}	Minimum energy (in keV) of experimental data.
E_{max}	Maximum energy (in keV) of experimental data.
δ_{rms}	Root-mean-square relative deviation (in %) of the analytic expression from the data.
δ_{max}	Maximum relative deviation (in %) of the analytic expression from the data.
$E_{\delta max}$	Energy (in keV) at which the relative deviation takes on the value δ_{max}.
Eq.	The identifying number of the equation to be used for deriving the recommended cross sections.
n	Number of applicable fit parameters.
E_{th}	Threshold energy of the reaction (in keV).
a_j $(j = 1, 2, \ldots, 12)$	Fit parameters.
	The notation $1.23 - 1$ means 1.23×10^{-1}.

EXPLANATION OF GRAPHS

GRAPHS. Cross Section vs Electron Energy

Graphs are numbered in order of the entries in Tables I through VI.

Ordinate	Cross section in cm^2.
Abscissa	Electron energy in eV in the center-of-mass system.
Solid line	Recommended data from the analytic formula of the present work.
Symbols	Experimental data from sources as explained in the legends.

TABLE I. Energy Ranges of Data, Fitting Errors, and Parameters of the Analytic Expressions for Methane (CH_4)

See page 154 for Explanation of Tables

No.	Process	E_{min}	E_{max}	δ_{rms}	δ_{max}	$E_{\delta_{max}}$
1	Total Scattering	8.00−5	5.00	4.8	1.1+1	3.00−3
2	Elastic Scattering	2.00−4	1.00	9.9	3.4+1	1.00−1
3	Momentum transfer	1.00−6	5.00−1	1.4+1	3.6+1	7.00−4
4	Vibrational Excitation ($v_2 + v_4$)					
5	Vibrational Excitation ($v_1 + v_3$)					
6	Attachment	8.00−3	1.30−2	1.3	2.7	9.50−3
7	Total Ionization	1.50−2	3.00	3.3	1.2+1	3.00
8	CH_4^+ Production	1.50−2	1.00	2.0	6.9	1.75−2
9	CH_3^+ Production	1.50−2	1.00	3.1	1.0+1	1.75−2
10	CH_2^+ Production	1.75−2	1.00	9.1	2.8+1	2.25−2
11	CH^+ Production	2.50−2	1.00	5.9	2.1+1	3.00−2
12	C^+ Production	3.00−2	1.00	3.3	6.9	4.00−2
13	H_2^+ Production	2.50−2	1.00	1.8+1	8.3+1	2.50−2
14	H^+ Production	2.50−2	1.00	1.6	4.1	4.50−2
15	Total Dissociation	1.10−2	5.00−1	5.1	1.4+1	1.20−2
16	CH_3 Production	1.01−2	5.03−1	2.7	8.6	2.38−2
17	H(2s) Production	1.00−1	6.00	2.5	6.3	3.00
18	Ly-α Emission	2.06−2	9.86−1	1.1+1	2.4+1	2.37−2
19	Ly-β Emission	2.03−2	9.88−1	5.0	1.5+1	2.17−2
20	Ly-γ Emission	2.15−2	9.94−1	5.9	1.8+1	2.23−2
21	H-α Emission	2.16−2	6.00	4.7	1.1+1	2.66−2
22	H-β Emission	2.07−2	6.00	6.5	2.5+1	2.13−2
23	H-γ Emission	1.88−2	6.00	1.0+1	3.2+1	1.99−2
24	H-δ Emission	2.02−2	6.00	9.3	2.5+1	2.02−2
25	CH($A\,^2\Delta - X\,^2\Pi$) Emission at 420–440 nm	1.46−2	5.00	7.0	1.6+1	2.50−2
26	C($2p3s\,^1P^o - 2p^2\,^1D$) Emission at 193.1 nm	2.75−2	4.00−1	3.0	8.4	4.50−2

TABLE I. Energy Ranges of Data, Fitting Errors, and Parameters of the Analytic Expressions for Methane (CH_4)

See page 154 for Explanation of Tables

No.	Eq.	n	E_{th}	a_1 a_7	a_2 a_8	a_3 a_9	a_4 a_{10}	a_5 a_{11}	a_6 a_{12}
1	10	8	0.0	3.330−2 1.660−2	−9.850−1 1.090	2.330+2	1.849	5.450−3	4.580−1
2	3	6	0.0	2.930−2	−1.030	3.280+2	2.190	5.400−3	7.920−1
3	6	8	0.0	3.300 6.670−3	−2.060−1 1.318	6.020−5	2.620	1.360+2	1.789
4									
5									
6	9	6	7.750−3	2.857+1	3.065	3.669−4	−4.317−1	2.090−3	7.759
7	14	4	1.300−2	3.539−3	3.600−2	3.730−2	9.060−1		
8	9	6	1.299−2	4.886	1.627	7.420−3	−4.500−2	3.300−2	1.040
9	9	6	1.424−2	2.350	1.435	1.130−2	7.400−2	5.500−2	1.200
10	9	6	1.520−2	1.210−1	1.868	3.440−2	3.000−1	5.520−2	1.000
11	9	6	2.414−2	1.038−1	1.161	4.000−2	6.700−1	1.400−1	1.600
12	9	6	2.820−2	6.400−2	1.430	1.330−2	−3.300−1	4.240−2	1.181
13	9	6	2.023−2	4.900−3	3.610	2.570−2	−3.900−2	4.400−2	1.290
14	9	6	1.800−2	4.949−2	2.855	3.180−2	−3.300−1	5.130−2	1.155
15	4	6	4.510−3	4.590	3.590	1.321−2	3.450−1	6.200−1	3.700
16	9	6	4.510−3	1.385+2	5.790	5.880−3	−6.070−1	9.280−3	6.150−1
17	9	6	1.470−2	3.430−1	9.700	6.100−3	−1.900	1.164−2	9.989−1
18	9	6	1.470−2	8.540−3	2.820	2.720−2	−1.900−1	5.950−2	1.600
19	9	6	1.660−2	5.210−2	4.650	5.910−3	−1.237	1.660−2	1.100
20	9	6	1.730−2	2.240−2	4.210	5.800−3	−1.120	1.780−2	1.158
21	9	6	1.660−2	1.330−2	2.410	1.040−2	−1.190	3.350−2	1.040
22	9	6	1.730−2	1.550−2	3.540	6.400−3	−1.060	1.900−2	1.052
23	9	6	1.760−2	1.330−3	1.980	2.300−2	−4.000−1	4.080−2	1.084
23	9	6	1.770−2	4.050−4	2.310	2.490−2	−3.200−1	4.060−2	1.106
25	11	8	1.220−2	1.070 3.270	1.600+1 2.770−1	8.400−3	−1.191	1.184−2	9.090−1
26	11	8	2.350−2	1.080−2 1.745	4.350 4.990	8.080−3	−2.300−1	1.370−2	1.810

TABLE I. Energy Ranges of Data, Fitting Errors, and Parameters of the Analytic Expressions for Methane (CH_4)

See page 154 for Explanation of Tables

No.	Process	E_{min}	E_{max}	δ_{rms}	δ_{max}	$E_{\delta_{max}}$
27	C($2p3s\ ^3P^o - 2p^2\ ^3P$) Emission at 165.7 nm	2.43−2	9.80−1	1.8+1	6.0+1	2.43−2
28	C($2s2p^3\ ^3D^o - 2s^22p^2\ ^3P$) Emission at 156.1 nm	2.62−2	1.00	2.1+1	7.3+1	2.62−2
29	Dissociative Recombination/CH_4^+	2.00−5	1.00−3	0.4	0.6	5.00−4
30	Dissociative Recombination/CH_3^+	2.00−5	2.00−3	1.4+1	2.1+1	1.00−4
31	Dissociative Recombination/CH_2^+	2.00−5	2.00−3	6.3	9.5	1.00−4
32	Dissociative Recombination/CH^+	2.00−5	2.00−3	1.3+1	2.1+1	1.00−3
33	Total Ionization/CD_3	1.10−2	2.00−1	4.3	8.6	1.60−2
34	CD_3^+ Production/CD_3	1.10−2	2.00−1	3.0	7.8	2.00−2
35	CD_2^+ Production/CD_3	1.60−2	2.00−1	2.4	4.9	1.90−2
36	Total Ionization/CD_2	1.10−2	2.00−1	3.8	8.7	3.00−2
37	CD_2^+ Production/CD_2	1.10−2	2.00−1	1.9	4.5	1.20−2
38	CD^+ Production/CD_2	1.60−2	2.00−1	3.9	1.4+1	1.70−2
39	Total Ionization/CD	1.20−2	2.00−1	6.1	1.4+1	1.50−2
40	CD^+ Production/CD	1.20−2	2.00−1	3.7	9.4	1.50−2
41	C^+ Production/CD	1.70−2	2.00−1	6.4	1.8+1	1.90−2

TABLE I. Energy Ranges of Data, Fitting Errors, and Parameters of the Analytic Expressions for Methane (CH_4)

See page 154 for Explanation of Tables

No.	Eq.	n	E_{th}	a_1 a_7	a_2 a_8	a_3 a_9	a_4 a_{10}	a_5 a_{11}	a_6 a_{12}
27	11	8	1.570−2	6.880−4 1.220	6.550 3.160	1.720−2	2.100−1	2.500−2	1.800
28	11	8	2.500−2	3.360−3 1.820	2.200 5.850	1.160−2	9.500−1	1.870−2	9.500−1
29	2	4	0.0	1.941	−9.260−1	2.830−4	1.994		
30	2	4	0.0	1.820	−1.000	1.600−4	1.520		
31	1	2	0.0	9.440−1	−1.007				
32	1	2	0.0	7.530−1	−9.420−1				
33	14	4	9.840−3	1.811−3	0.0	4.620−2	1.015		
34	9	6	9.840−3	9.250+1	3.010	1.810−3	−9.180−1	5.900−3	4.480−1
35	9	6	1.530−2	4.040	1.773	5.490−3	−1.620−1	4.380−2	1.990
36	14	4	1.040−2	2.036−3	4.500−3	7.810−2	8.210−1		
37	9	6	1.040−2	3.770	1.670	8.140−3	−3.630−1	1.940−2	5.500−1
38	9	6	1.490−2	7.190−1	1.458	1.640−2	1.430−1	7.700−2	1.280
39	14	4	1.060−2	1.221−3	0.0	2.810−2	1.077		
40	9	6	1.060−2	1.610	4.200−1	6.400−3	−2.180	6.700−2	6.400−1
41	9	6	1.470−2	6.180−1	1.500−4	1.770−2	−1.760	2.600−1	9.300−1

TABLE II. Energy Ranges of Data, Fitting Errors, and Parameters of the Analytic Expressions for Ethane (C_2H_6)

See page 154 for Explanation of Tables

No.	Process	E_{min}	E_{max}	δ_{rms}	δ_{max}	$E_{\delta_{max}}$
42	Total Scattering	1.00−3	4.00−1	3.9	1.7+1	1.00−3
43	Elastic Scattering	5.00−5	1.00−1	2.6	7.7	9.95−3
44	Momentum Transfer	1.58−6	9.75−1	9.7	2.7+1	2.01−4
45	Total Ionization	2.50−2	6.00−1	1.7	5.2	3.00−2
46	$C_2H_6^+$ Production	1.75−2	6.00−1	3.5	1.0+1	2.00−2
47	$C_2H_5^+$ Production	1.75−2	6.00−1	3.8	1.2+1	2.00−2
48	$C_2H_4^+$ Production	1.75−2	6.00−1	4.0	1.4+1	2.00−2
49	$C_2H_3^+$ Production	1.75−2	6.00−1	4.0	1.4+1	2.00−2
50	$C_2H_2^+$ Production	1.75−2	6.00−1	4.8	1.6+1	2.00−2
51	C_2H^+ Production	3.50−2	6.00−1	1.2	3.0	2.25−1
52	C_2^+ Production	4.50−2	6.00−1	2.2	6.2	3.50−1
53	CH_3^+ Production	1.75−2	6.00−1	5.2	1.5+1	3.50−2
54	CH_2^+ Production	3.00−2	6.00−1	3.1	7.8	3.50−2
55	CH^+ Production	4.00−2	6.00−1	2.9	6.4	1.75−1
56	C^+ Production	4.50−2	6.00−1	3.6	8.8	5.50−1
57	H_3^+ Production	3.50−2	6.00−1	4.8	1.3+1	6.00−2
58	H_2^+ Production	2.50−2	6.00−1	2.2	6.0	4.50−2
59	H^+ Production	2.50−2	6.00−1	2.3	7.2	3.50−2
60	Total Dissociation	1.50−2	6.00−1	1.5	2.5	3.00−2
61	H(2s) Production	5.00−2	6.00	1.4	2.6	2.00−1
62	Ly-α Emission	5.00−2	6.00	3.0	7.3	2.00−1
63	H-α Emission	5.00−2	6.00	3.8	6.2	8.00−1
64	H-β Emission	5.00−2	6.00	1.2	2.3	2.00−1
65	H-γ Emission	5.00−2	6.00	4.3	6.9	2.00−1
66	H-δ Emission	5.00−2	6.00	3.2	5.5	2.00−1

TABLE II. Energy Ranges of Data, Fitting Errors, and Parameters of the Analytic Expressions for Ethane (C_2H_6)

See page 154 for Explanation of Tables

No.	Eq.	n	E_{th}	a_1 a_7	a_2 a_8	a_3 a_9	a_4 a_{10}	a_5 a_{11}	a_6 a_{12}
42	7	10	0.0	1.370+5	2.980	4.960−4	7.640−1	2.660−3	2.250
				5.930−3	1.070+1	2.950−1	8.600−2		
43	8	12	0.0	4.050−1	−5.800−1	4.700−5	1.790	1.060+3	1.390
				7.300−4	6.000−1	1.950+2	2.060	7.010−3	8.040−1
44	8	12	0.0	1.650−1	−5.770−1	4.690−5	5.000	3.190+2	1.180
				1.040−3	1.010	3.890+2	2.710	5.090−3	1.140
45	14	4	1.150−2	5.350−3	0.0	4.520−2	1.030		
46	9	6	1.150−2	1.010	3.050	1.281−2	−5.400−2	2.840−2	9.200−1
47	9	6	1.280−2	8.290−1	2.500	1.270−2	3.570−2	3.950−2	1.110
48	9	6	1.270−2	2.960	2.390	1.420−2	7.130−2	4.120−2	1.080
49	9	6	1.540−2	6.290−1	1.265	3.060−2	4.490−1	1.900−1	1.700
50	2	4	1.530−2	3.238−1	1.161	4.640−2	7.100−1		
51	9	6	2.880−2	1.560−1	2.070	1.120−2	−4.700−1	3.150−2	1.131
52	9	6	3.400−2	4.090−2	5.200	9.700−3	−9.520−1	2.140−2	1.250
53	2	4	1.400−2	8.170−2	1.116	8.390−2	9.450−1		
54	2	4	2.580−2	6.290−2	1.043	6.560−2	9.380−1		
55	9	6	3.000−2	5.240−2	3.620	1.130−2	−7.000−1	2.780−2	1.347
56	9	6	3.200−2	1.051−2	7.220	1.327−2	−9.570−1	2.230−2	1.203
57	2	4	3.320−2	1.712−2	1.092	5.540−2	8.420−1		
58	9	6	1.800−2	9.720−3	2.336	4.860−2	−1.750−1	6.220−2	1.140
59	9	6	2.050−2	3.420	4.330	3.450−3	−1.479	1.520−2	1.004
60	9	6	3.900−3	4.900	4.120	1.360−2	−6.700−1	2.150−2	5.940−1
61	2	4	1.440−2	3.530−3	9.240−1	6.640−2	9.944−1		
62	2	4	1.440−2	2.550−2	9.000−1	6.810−2	9.980−1		
63	2	4	1.630−2	8.350−3	1.110	6.390−2	1.000		
64	2	4	1.700−2	3.260−3	8.390−1	7.180−2	1.037		
65	2	4	2.730−2	1.860−3	7.300−1	6.780−2	1.039		
66	2	4	2.740−2	1.035−3	7.760−1	6.240−2	1.030		

TABLE III. Energy Ranges of Data, Fitting Errors, and Parameters of the Analytic Expressions for Ethylene (C_2H_4)

See page 154 for Explanation of Tables

No.	Process	E_{min}	E_{max}	δ_{rms}	δ_{max}	$E_{\delta_{max}}$
67	Total Scattering	1.00−3	4.00−1	1.6	3.	2.00−2
68	Momentum Transfer	1.03−5	1.00	5.9	1.1+1	2.64−2
69	Total Ionization	1.10−2	1.20+1	6.7	2.6+1	1.10−2
70	$C_2H_4^+$ Production	1.75−2	6.00−1	1.2	2.4	8.00−2
71	$C_2H_3^+$ Production	1.75−2	6.00−1	2.5	6.9	2.00−2
72	$C_2H_2^+$ Production	1.75−2	6.00−1	1.9	4.4	3.00−2
73	C_2H^+ Production	2.00−2	6.00−1	8.9	2.6+1	3.00−2
74	C_2^+ Production	3.00−2	6.00−1	3.6	1.0+1	6.00−1
75	CH_3^+ Production	2.50−2	6.00−1	9.9	2.3+1	3.00−1
76	CH_2^+ Production	2.50−2	6.00−1	2.7	6.3	4.50−1
77	CH^+ Production	2.50−2	6.00−1	7.7	2.5+1	2.50−2
78	C^+ Production	3.00−2	6.00−1	9.0	3.1+1	4.00−2
79	H_2^+ Production	3.00−2	6.00−1	6.2	1.5+1	3.00−2
80	H^+ Production	3.00−2	6.00−1	2.2	4.5	4.00−2
81	H(2s) Production	5.00−2	6.00	2.9	4.5	2.00−1
82	Ly-α Emission	5.00−2	6.00	3.6	5.4	8.00−2
83	H-α Emission	5.00−2	6.00	3.7	7.5	1.00
84	H-β Emission	5.00−2	6.00	4.0	6.4	6.00
85	H-γ Emission	5.00−2	6.00	3.2	4.8	1.00
86	H-δ Emission	5.00−2	6.00	1.5	2.7	2.00
87	$CH(A\,^2\Delta - X\,^2\Pi)$ Emission at 420–440 nm	5.00−2	6.00	1.0	2.2	2.00−1

TABLE III. Energy Ranges of Data, Fitting Errors, and Parameters of the Analytic Expressions for Ethylene (C_2H_4)

See page 154 for Explanation of Tables

No.	Eq.	n	E_{th}	a_1	a_2	a_3	a_4	a_5	a_6	
				a_7	a_8	a_9	a_{10}	a_{11}	a_{12}	a_{13}
67	6	8	0.0	1.257+2	1.020	2.270−3	6.600	1.036+2	1.087	
				6.860−3	5.260−1					
68	13	13	0.0	1.420−1	−5.920−1	6.140−5	9.400	4.090+11	5.180	
				1.103−4	−5.510−1	2.750−4	1.494	1.890+1	6.730−1	2.050−2
69	14	4	1.050−2	3.500−3	3.900−1	5.640−2	1.265			
70	9	6	1.050−2	4.760	3.950	1.017−2	−2.830−1	1.860−2	8.340−1	
71	9	6	1.320−2	1.510	2.350	1.220−2	−8.900−2	3.830−2	1.110	
72	9	6	1.320−2	9.690−1	2.004	1.650−2	6.600−2	5.500−2	1.260	
73	2	4	1.830−2	1.049−1	1.037	6.150−2	9.290−1			
74	9	6	1.950−2	2.680−2	4.080	1.440−2	−8.200−1	2.920−2	1.157	
75	2	4	1.700−2	7.770−3	8.650−1	6.030−2	7.700−1			
76	2	4	1.790−2	1.034−1	1.101	6.510−2	8.470−1			
77	2	4	1.780−2	3.100−2	1.241	7.820−2	1.094			
78	2	4	2.560−2	2.510−2	9.360−1	1.070−1	1.197			
79	2	4	1.720−2	5.950−3	1.567	6.660−2	9.590−1			
80	2	4	1.820−2	7.610−2	1.541	7.330−2	9.500−1			
81	2	4	1.480−2	2.000−3	1.030	5.880−2	9.780−1			
82	2	4	1.480−2	3.070−2	9.000−1	6.220−2	9.850−1			
83	2	4	1.670−2	1.290−2	9.900−1	6.320−2	1.034			
84	2	4	1.740−2	3.580−3	8.100−1	7.240−2	1.048			
85	2	4	1.820−2	1.670−3	8.600−1	6.360−2	1.026			
86	2	4	1.780−2	7.750−4	9.850−1	6.380−2	1.025			
87	2	4	1.010−2	6.240−3	1.017	6.270−2	8.699−1			

TABLE IV. Energy Ranges of Data, Fitting Errors, and Parameters of the Analytic Expressions for Acetylene (C_2H_2)

See page 154 for Explanation of Tables

No.	Process	E_{min}	E_{max}	δ_{rms}	δ_{max}	$E_{\delta_{max}}$
88	Total Scattering	1.00−3	2.60	4.4	1.0+1	5.50−3
89	Elastic Scattering	5.00−3	1.00−1	4.9	7.2	1.00−1
90	Momentum Transfer	1.00−5	9.79−1	5.2	1.1+1	4.85−5
91	Total Ionization	1.75−2	6.00−1	3.4	1.1+1	2.50−2
92	$C_2H_2^+$ Production	1.75−2	6.00−1	1.2	3.6	2.50−2
93	C_2H^+ Production	2.00−2	6.00−1	1.2	2.5	1.25−1
94	C_2^+ Production	2.50−2	6.00−1	1.4	3.7	3.50−2
95	CH^+ Production	2.50−2	6.00−1	1.5	3.0	1.25−1
96	C^+ Production	3.00−2	6.00−1	2.2	5.0	3.50−2
97	H^+ Production	2.50−2	6.00−1	4.4	8.8	5.00−2
98	Ly-α Emission	2.25−2	4.00−1	2.3	6.6	2.75−2
99	Ly-β Emission	2.75−2	4.00−1	1.5	3.0	3.00−2
100	H-β Emission	2.49−2	1.53−1	1.3	2.9	1.01−1
101	$CH(A\,^2\Delta - X\,^2\Pi)$ Emission at 420–440 nm	2.21−2	2.23−1	4.6	8.7	4.80−2
102	$C_2(d\,^3\Pi_g - a\,^3\Pi_u; \delta v = 0)$ Emission	2.18−2	2.23−1	0.6	1.3	1.57−1
103	$C_2(d\,^3\Pi_g - a\,^3\Pi_u; \delta v = 1)$ Emission	3.48−2	2.20−1	0.5	0.8	6.18−2
104	$C_2(d\,^3\Pi_g - a\,^3\Pi_u; \delta v = -1)$ Emission	2.21−2	2.23−1	0.8	1.6	3.48−2
105	$C(2p3s\,^3P^o - 2p^2\,^3P)$ Emission at 165.7 nm	2.00−2	1.00	1.1+1	4.1+1	2.00−2

TABLE IV. Energy Ranges of Data, Fitting Errors, and Parameters of the Analytic Expressions for Acetylene (C_2H_2)

See page 154 for Explanation of Tables

No.	Eq.	n	E_{th}	a_1 a_7	a_2 a_8	a_3 a_9	a_4 a_{10}	a_5 a_{11}	a_6 a_{12}
88	6	8	0.0	1.000+7 3.300−1	6.400 1.080	1.772−3	5.800−1	1.400+1	−1.370−1
89	2	4	0.0	3.291+2	2.000	4.732−3	8.030−1		
90	7	10	0.0	3.610 7.000−4	−1.080−1 3.270+4	1.042−1 3.750	1.637 2.149−3	2.380+2	6.860−1
91	14	4	1.140−2	4.260−3	0.0	4.240−2	1.129		
92	9	6	1.140−2	9.550	2.590	8.810−3	−1.970−1	2.370−2	9.130−1
93	9	6	1.650−2	1.560	2.144	9.790−3	−1.540−1	2.900−2	9.800−1
94	9	6	1.950−2	3.396−1	2.830	1.097−2	−4.050−1	2.370−2	9.550−1
95	9	6	2.060−2	1.010	3.690	6.910−3	−1.030	1.740−2	8.760−1
96	9	6	2.370−2	7.230−2	1.620	4.300−2	−1.900−1	6.300−2	1.100
97	2	4	1.850−2	6.480−2	1.665	6.500−2	8.380−1		
98	9	6	1.510−2	6.130−3	3.670	1.880−2	−1.230	3.370−2	9.480−1
99	9	6	1.700−2	1.257−3	4.930	1.499−2	−1.216	2.970−2	1.246
100	9	6	1.760−2	3.080−2	6.110	7.250−3	−1.473	1.600−2	9.500−1
101	2	4	1.290−2	5.760−3	7.240−1	2.280−1	1.500		
102	9	6	8.660−3	3.546−3	1.510	2.940−2	1.880−1	5.000−1	1.000
103	9	6	8.460−3	2.614−3	1.240	4.410−2	3.690−1	5.000−1	1.000
104	9	6	8.870−3	2.242−3	1.256	4.330−2	3.980−1	5.000−1	1.000
105	5	7	1.660−2	1.670−3 6.810−2	8.900	1.473−2	9.470−1	5.140−4	2.218

TABLE V. Energy Ranges of Data, Fitting Errors, and Parameters of the Analytic Expressions for Propane (C_3H_8)

See page 154 for Explanation of Tables

No.	Process	E_{min}	E_{max}	δ_{rms}	δ_{max}	$E_{\delta_{max}}$
106	Total Scattering	8.00−4	6.00−1	2.7	6.7	5.50−3
107	Elastic Scattering	2.00−3	1.00−1	2.0	4.0	7.50−3
108	Momentum Transfer	9.79−6	1.00−1	1.0+1	2.1+1	2.00−3
109	Total Ionization	1.20−2	1.20+1	2.7	8.9	1.50−2
110	$C_3H_8^+$ Production	1.32−2	9.52−1	4.0	1.5+1	1.69−2
111	$C_3H_7^+$ Production	1.38−2	9.53−1	1.1+1	5.3+1	1.38−2
112	$C_3H_6^+$ Production	1.38−2	9.51−1	1.8	4.3	1.63−2
113	$C_3H_5^+$ Production	1.76−2	9.54−1	4.8	1.6+1	2.63−2
114	$C_3H_4^+$ Production	2.26−2	9.52−1	1.9	4.5	6.40−2
115	$C_3H_3^+$ Production	2.26−2	9.54−1	2.8	9.5	2.51−2
116	$C_3H_2^+$ Production	2.73−2	9.50−1	3.0	1.4+1	3.36−2
117	C_3H^+ Production	2.78−2	9.51−1	2.1	5.1	4.94−2
118	C_3^+ Production	3.92−2	9.49−1	3.9	8.4	5.56−2
119	$C_2H_5^+$ Production	1.43−2	9.51−1	5.9	2.8+1	1.56−2
120	$C_2H_4^+$ Production	1.37−2	9.53−1	7.2	3.6+1	1.37−2
121	$C_2H_3^+$ Production	1.56−2	9.50−1	1.8	6.8	1.81−2
122	$C_2H_2^+$ Production	1.55−2	9.51−1	6.0	2.1+1	2.58−2
123	C_2H^+ Production	3.09−2	9.52−1	1.0+1	4.4+1	3.09−2
124	C_2^+ Production	5.05−2	9.55−1	7.5	2.6+1	8.55−1
125	CH_3^+ Production	2.38−2	9.54−1	3.5	1.4+1	3.00−2
126	CH_2^+ Production	2.69−2	9.54−1	8.2	2.4+1	3.32−2
127	CH^+ Production	2.32−2	9.49−1	6.8	2.2+1	2.01−1
128	C^+ Production	3.77−2	9.49−1	1.3+1	3.8+1	3.91−2
129	$C_3H_5^{2+}$ Production	3.32−2	9.48−1	6.7	2.6+1	4.51−2
130	$C_3H_4^{2+}$ Production	3.65−2	9.54−1	8.8	2.0+1	1.42−1
131	$C_3H_3^{2+}$ Production	4.03−2	9.53−1	7.1	3.1+1	5.32−2
132	$C_3H_2^{2+}$ Production	4.00−2	9.52−1	7.9	3.4+1	4.78−2
133	H-β Emission	5.43−2	5.28−1	3.5	6.9	5.28−1

TABLE V. Energy Ranges of Data, Fitting Errors, and Parameters of the Analytic Expressions for Propane (C_3H_8)

See page 154 for Explanation of Tables

No.	Eq.	n	E_{th}	a_1	a_2	a_3	a_4	a_5	a_6
				a_7	a_8	a_9	a_{10}	a_{11}	a_{12}
106	12	9	0.0	4.090+1	3.300−1	5.900−3	1.077	2.410+3	4.270
				5.150−3	7.600−2	1.030−2			
107	6	8	0.0	3.550+2	9.100−1	9.400−4	5.100−1	1.640+3	3.750
				5.400−3	7.700−1				
108	6	8	0.0	1.210−2	−1.120	6.700−5	6.000	5.140+1	5.350−1
				1.020−2	1.250				
109	14	4	1.100−2	7.863−3	1.510−1	6.090−2	1.034		
110	9	6	1.095−2	2.020	2.280	7.560−3	−2.800−1	1.960−2	7.110−1
111	9	6	1.160−2	3.080	2.760	6.100−3	−2.900−1	1.710−2	8.100−1
112	9	6	1.100−2	1.995−1	1.823	1.239−2	−4.900−2	4.220−2	1.040
113	9	6	1.480−2	3.240−1	1.349	2.180−2	3.120−1	1.530−1	1.620
114	9	6	1.274−2	5.360−2	2.090	2.110−2	1.600−1	5.500−2	1.100
115	9	6	1.450−2	6.430−1	4.150	1.402−2	−6.600−1	2.090−2	7.330−1
116	9	6	1.780−2	2.738−2	5.500	2.003−2	−9.370−1	3.034−2	1.038
117	9	6	2.180−2	3.050−2	3.326	2.360−2	−7.010−1	4.200−2	1.133
118	9	6	3.280−2	3.160−2	5.030	1.040−2	−1.126	2.320−2	1.157
119	9	6	1.190−2	7.050	2.140	7.200−3	−2.800−1	2.350−2	8.600−1
120	9	6	1.140−2	3.190	1.990	8.000−3	−1.400−1	2.840−2	9.200−1
121	9	6	1.450−2	1.239	1.082	3.130−2	4.100−1	1.520−1	1.430
122	2	4	1.410−2	1.478−1	1.718	4.590−2	7.060−1		
123	2	4	3.040−2	2.418−2	1.075	8.490−2	1.111		
124	9	6	4.050−2	1.863−3	1.870	6.250−2	6.900−1	2.190−1	3.740
125	9	6	1.400−2	5.460−2	4.410	2.298−2	−3.900−1	3.440−2	1.043
126	9	6	2.370−2	4.770	5.900	5.320−3	−1.229	1.170−2	9.430−1
127	9	6	1.890−2	8.470−3	1.781	6.070−2	4.600−1	1.110−1	1.760
128	9	6	3.490−2	6.000−3	1.380	7.400−2	4.300−1	1.480−1	2.160
129	2	4	3.240−2	3.061−4	1.163	5.480−2	8.260−1		
130	9	6	3.140−2	3.890+1	1.350+1	6.330−3	−1.600	9.210−3	8.640−1
131	9	6	3.540−2	2.970−3	2.860	2.760−2	−8.700−2	4.960−2	1.250
132	9	6	3.460−2	5.140−3	2.240	3.720−2	2.300−1	7.200−2	1.330
133	2	4	1.850−2	1.740−3	8.100−1	1.130−1	1.210		

TABLE VI. Energy Ranges of Data, Fitting Errors, and Parameters of the Analytic Expressions for Propene and Cyclopropane (C_3H_6)

See page 154 for Explanation of Tables

No.	Process	E_{min}	E_{max}	δ_{rms}	δ_{max}	$E_{\delta_{max}}$
134	Total Scattering/propene	4.00−3	5.00−1	1.4	3.6	4.50−1
135	Total Ionization/propene	1.00−2	3.00	1.2+1	5.9+1	1.00−2
136	H-β Emission/propene	5.34−2	5.20−1	2.5	4.9	5.20−1
137	Total Scattering/cyclopropane	3.96−3	4.93−1	1.8	3.9	8.92−2
138	Total Ionization/cyclopropane	1.00−2	3.00	1.4+1	7.8+1	1.00−2

TABLE VI. Energy Ranges of Data, Fitting Errors, and Parameters of the Analytic Expressions for Propene and Cyclopropane (C_3H_6)

See page 154 for Explanation of Tables

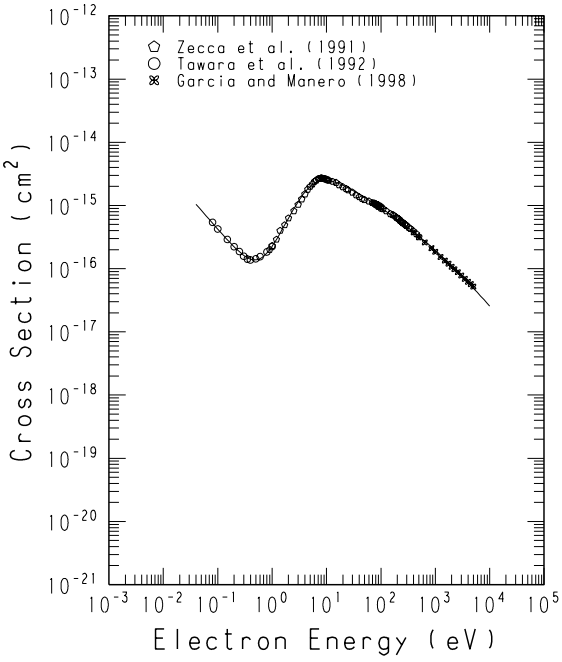
No.	Eq.	n	E_{th}	a_1 a_7	a_2 a_8	a_3 a_9	a_4 a_{10}	a_5 a_{11}	a_6 a_{12}
134	9	6	0.0	1.388+3	2.650	3.970−3	2.150−1	1.370−2	1.274
135	14	4	9.730−3	5.790−3	3.500−1	7.680−2	1.130		
136	2	4	1.900−2	1.690−3	1.010	8.230−2	1.161		
137	9	6	0.0	5.976+2	2.300	4.380−3	3.390−1	1.940−2	1.475
138	14	4	9.860−3	5.610−3	2.100−1	6.430−2	1.210		

GRAPHS. Cross Section vs Electron Energy

See page 155 for Explanation of Graphs

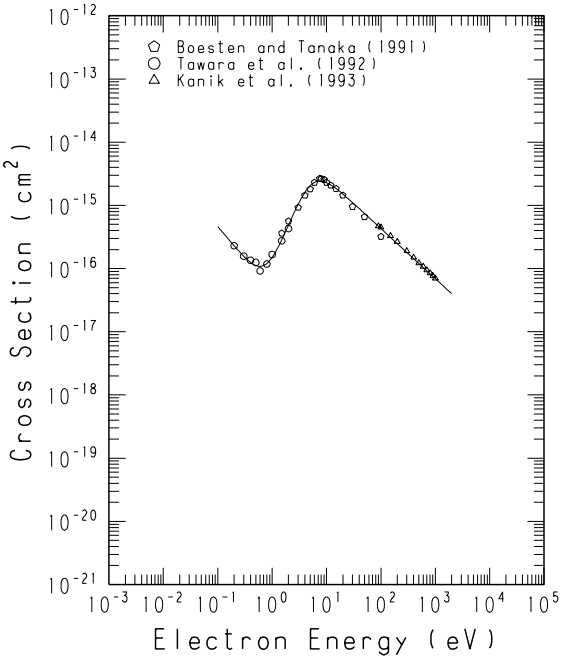
GRAPH 1

Total Scattering/CH_4



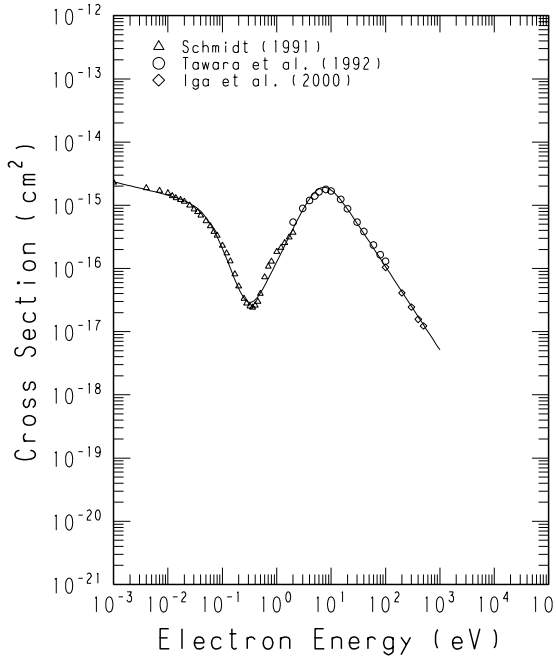
GRAPH 2

Elastic Scattering/CH_4



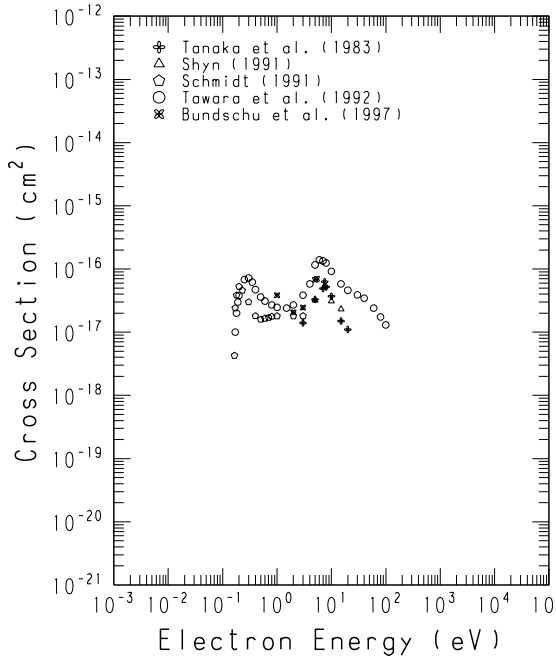
GRAPH 3

Momentum Transfer/CH_4



GRAPH 4

Vibrational Excitation (v_2 + v_4)/CH_4

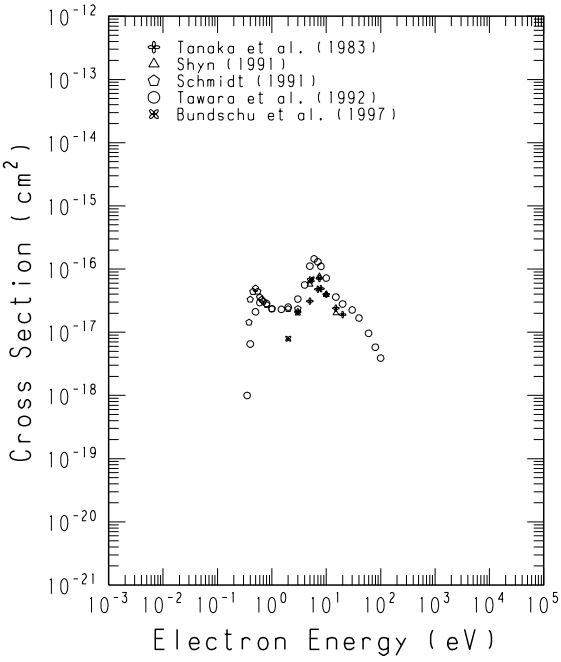


GRAPHS. Cross Section vs Electron Energy

See page 155 for Explanation of Graphs

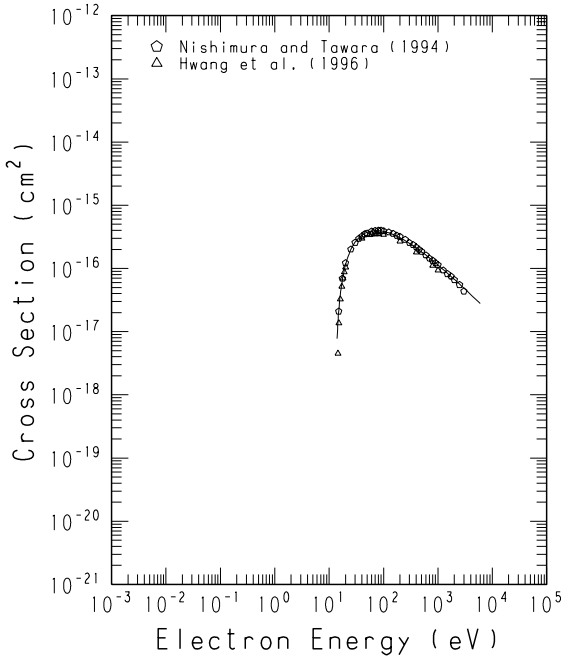
GRAPH 5

Vibrational Excitation (v_1 + v_3)/CH_4



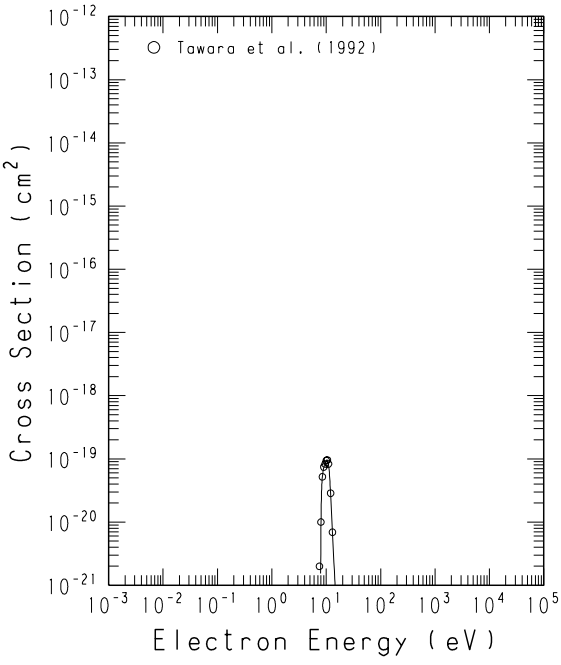
GRAPH 7

Total Ionization/CH_4



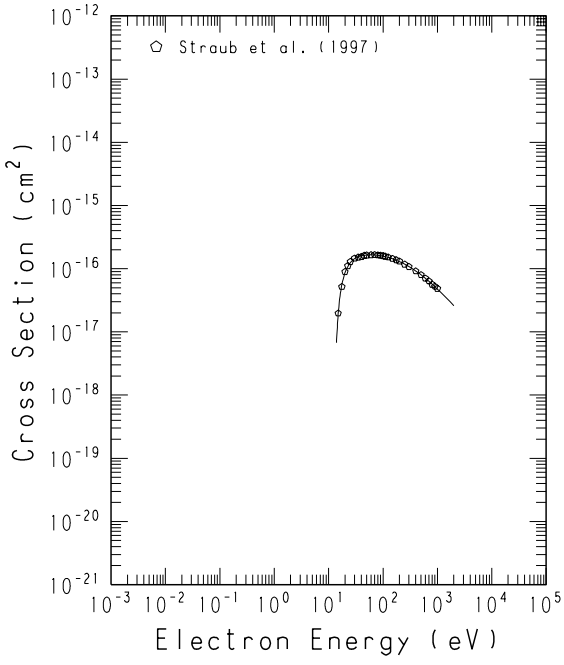
GRAPH 6

Attachment/CH_4



GRAPH 8

CH_4^+ Production/CH_4

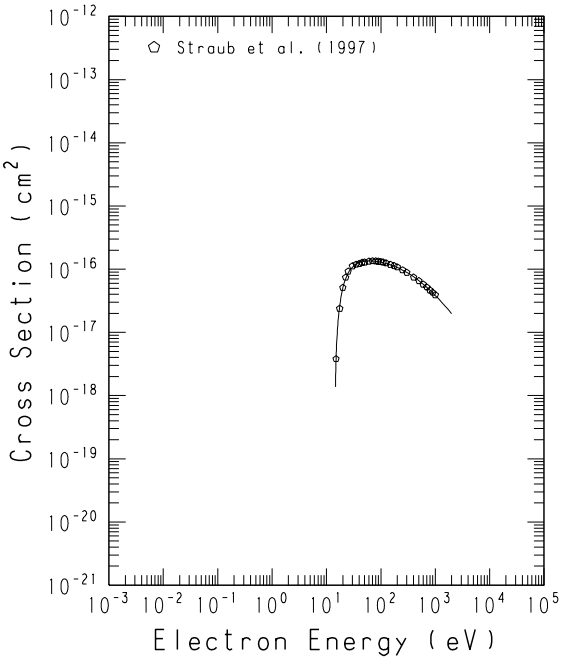


GRAPHS. Cross Section vs Electron Energy

See page 155 for Explanation of Graphs

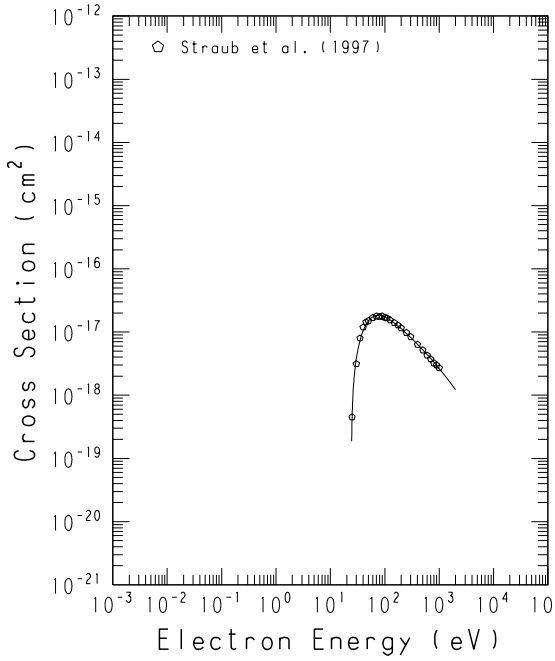
GRAPH 9

CH_3^+ Production/CH_4



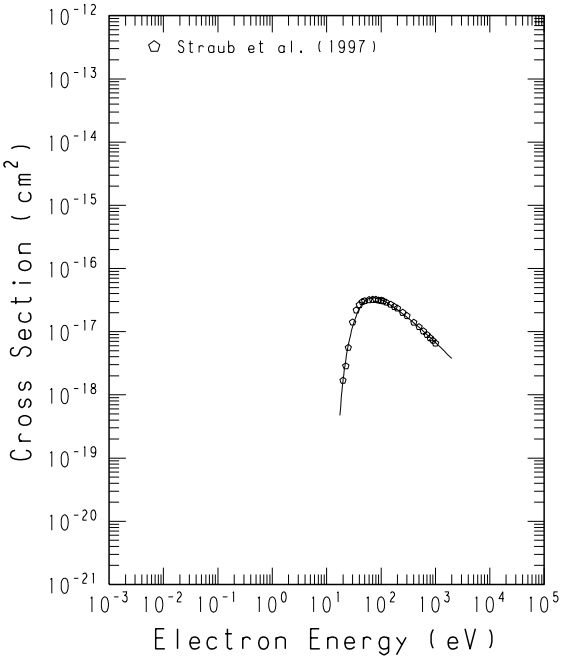
GRAPH 11

CH^+ Production/CH_4



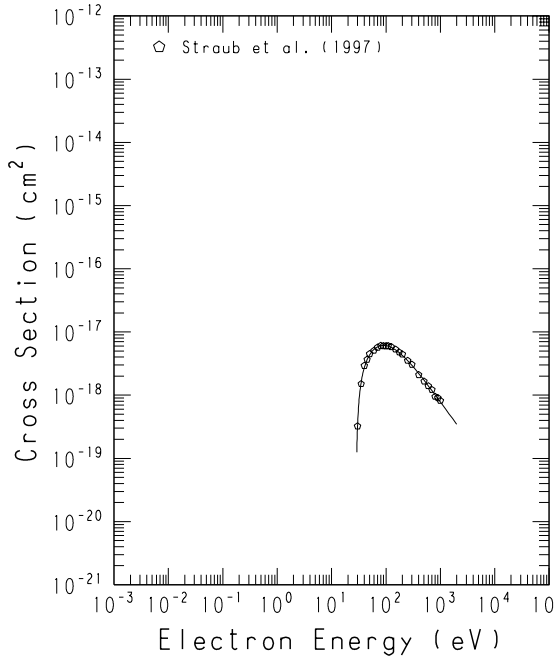
GRAPH 10

CH_2^+ Production/CH_4



GRAPH 12

C^+ Production/CH_4

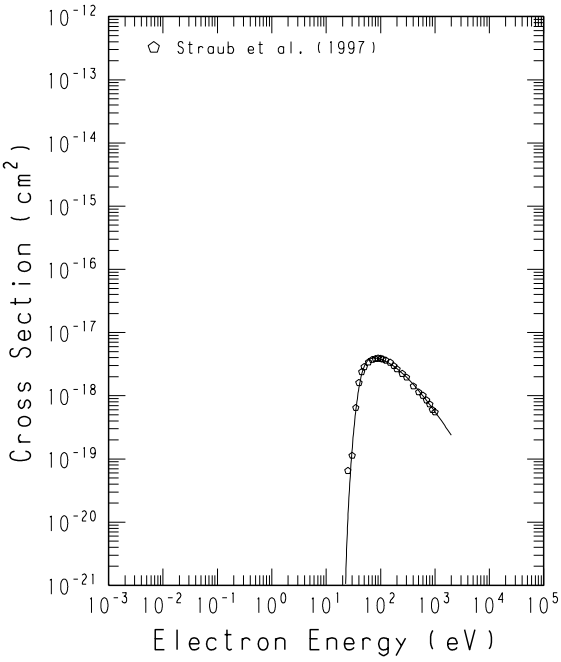


GRAPHS. Cross Section vs Electron Energy

See page 155 for Explanation of Graphs

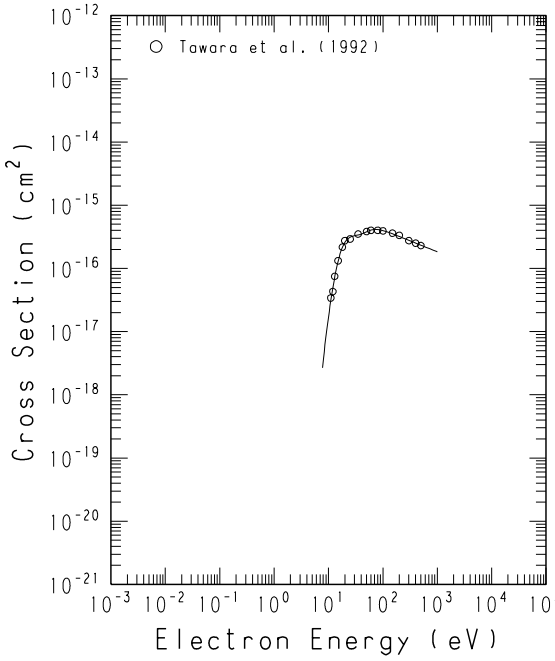
GRAPH 13

H_2^+ Production/CH_4



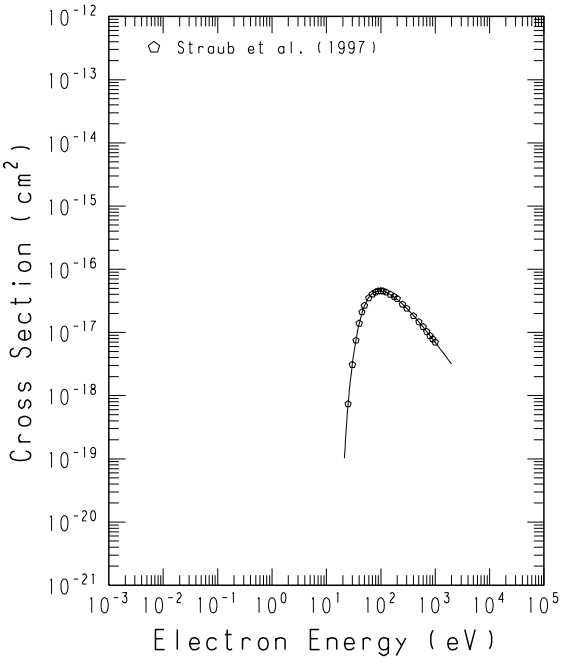
GRAPH 15

Total Dissociation/CH_4



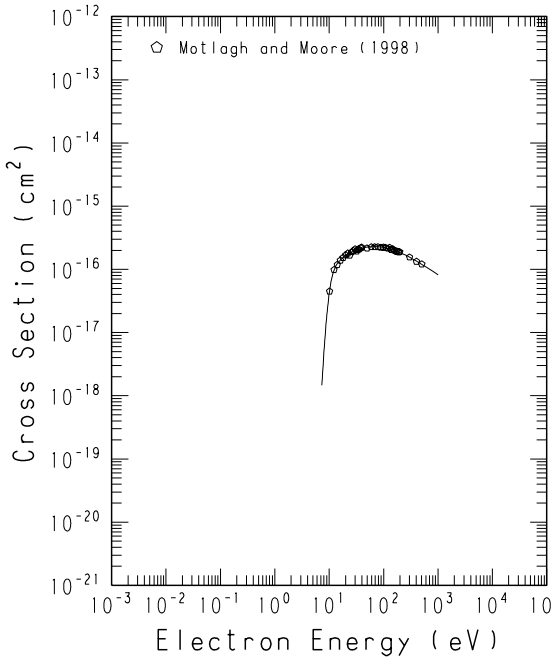
GRAPH 14

H^+ Production/CH_4



GRAPH 16

CH_3 Production/CH_4

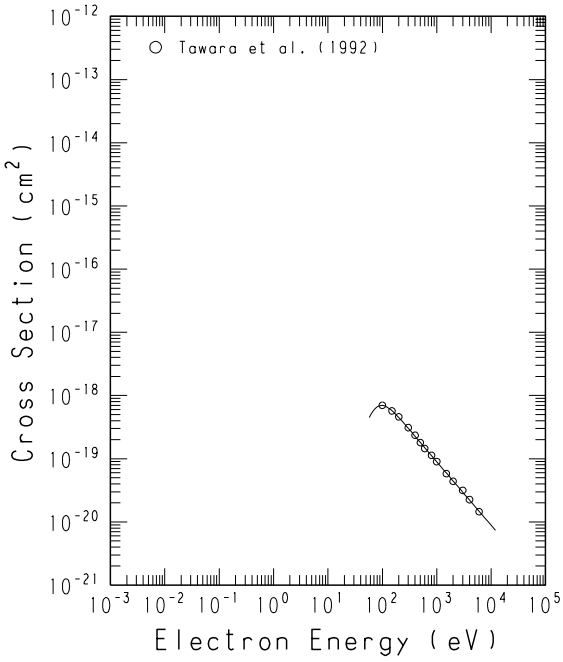


GRAPHS. Cross Section vs Electron Energy

See page 155 for Explanation of Graphs

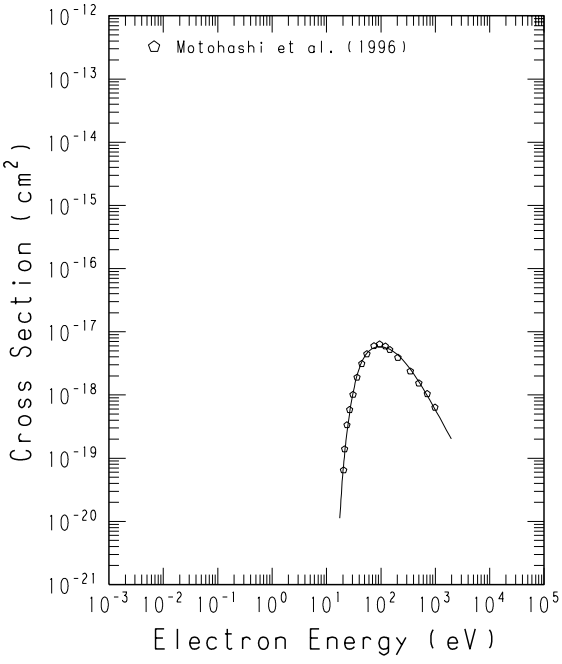
GRAPH 17

H(2s) Production/CH_4



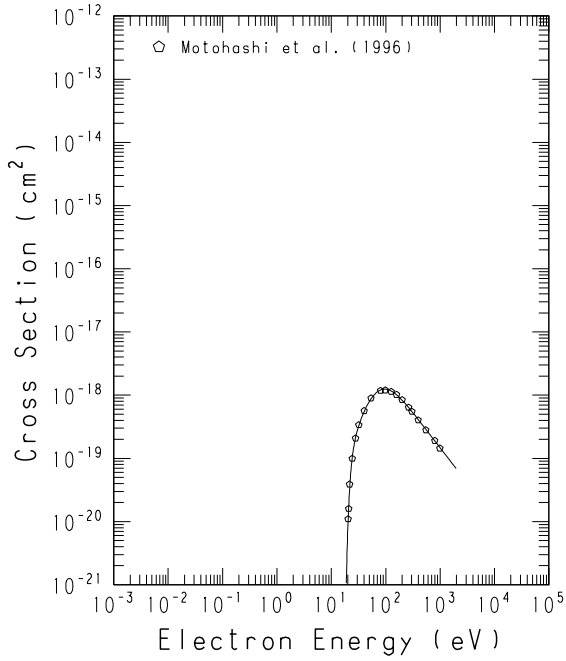
GRAPH 18

Lyα Emission/CH_4



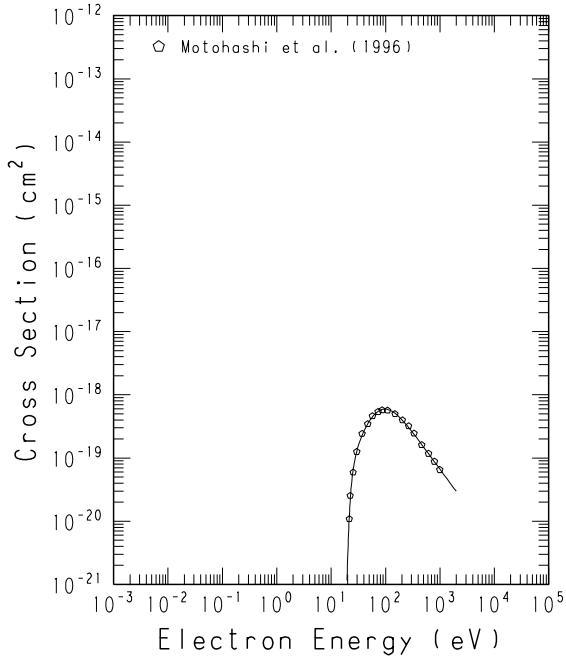
GRAPH 19

Lyβ Emission/CH_4



GRAPH 20

Lyγ Emission/CH_4

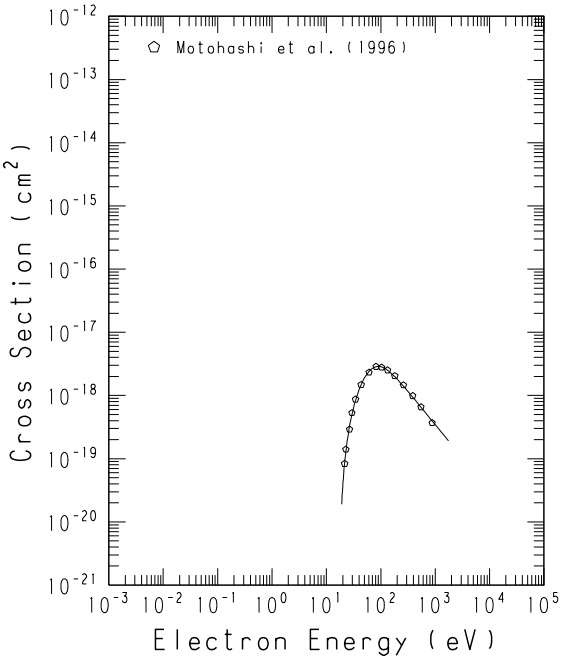


GRAPHS. Cross Section vs Electron Energy

See page 155 for Explanation of Graphs

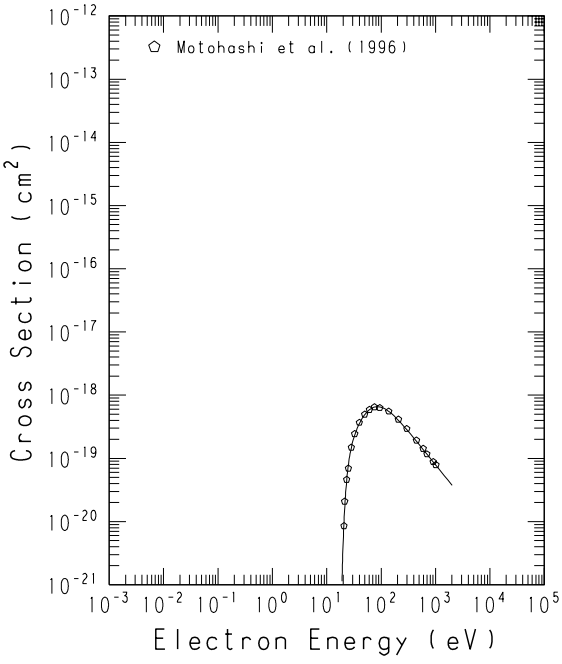
GRAPH 21

Hα Emission/CH_4



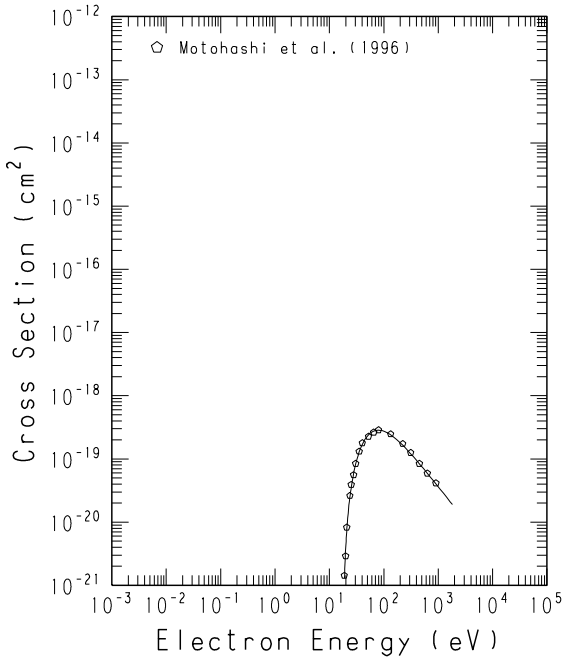
GRAPH 22

Hβ Emission/CH_4



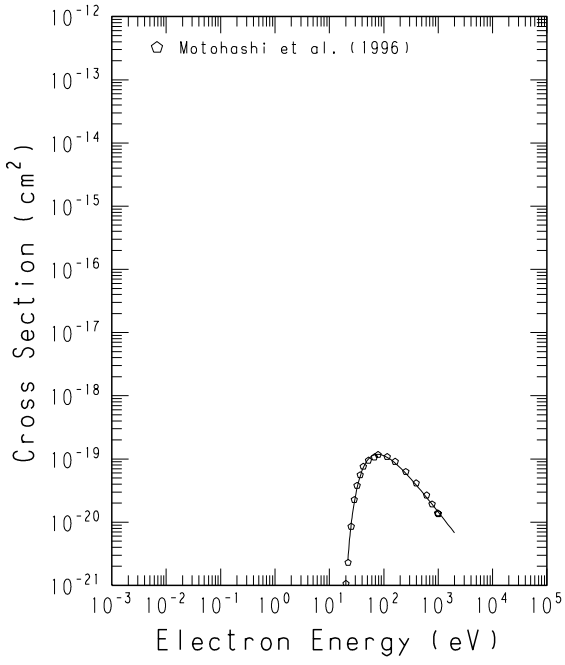
GRAPH 23

Hγ Emission/CH_4



GRAPH 24

Hδ Emission/CH_4



GRAPHS. Cross Section vs Electron Energy

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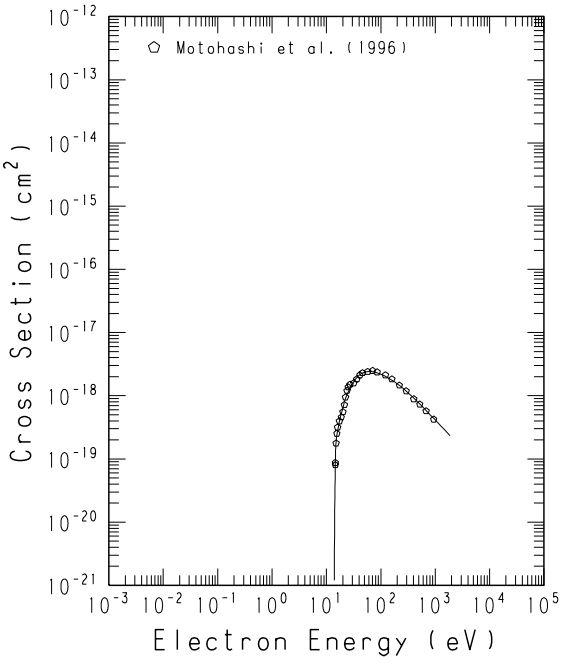
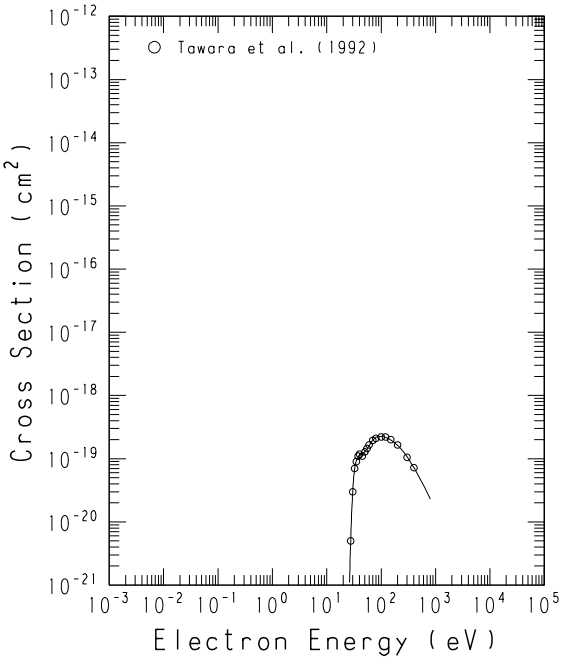
GRAPH 25

CH(420-440nm) Emission/CH_4



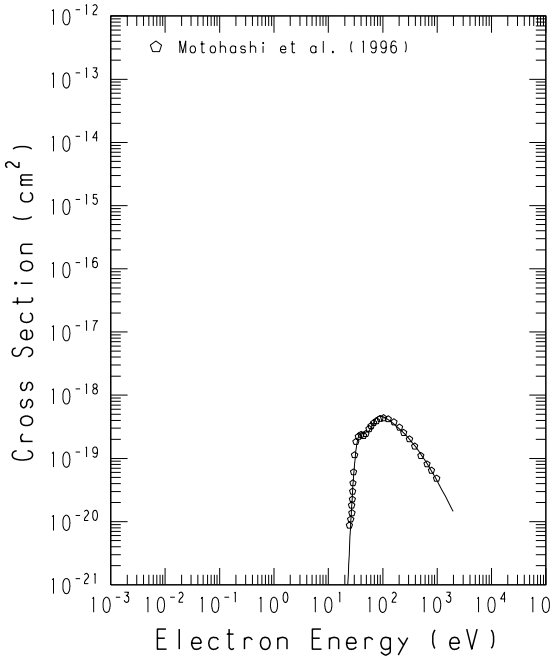
GRAPH 26

C(193.1nm) Emission/CH_4



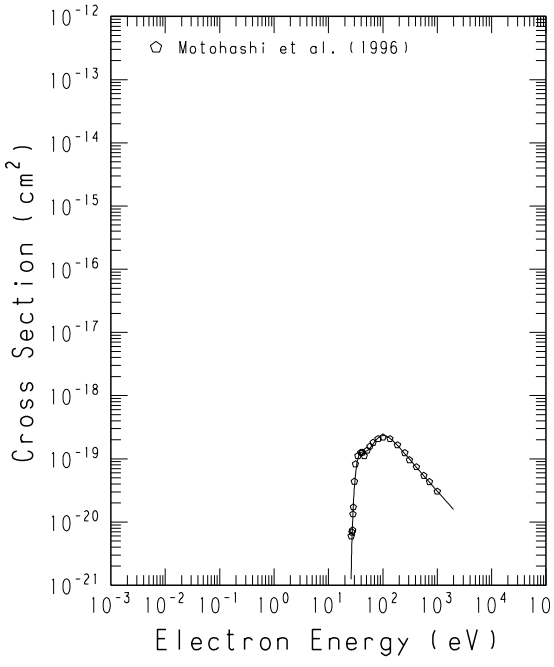
GRAPH 27

C(165.7nm) Emission/CH_4



GRAPH 28

C(156.1nm) Emission/CH_4



GRAPHS. Cross Section vs Electron Energy

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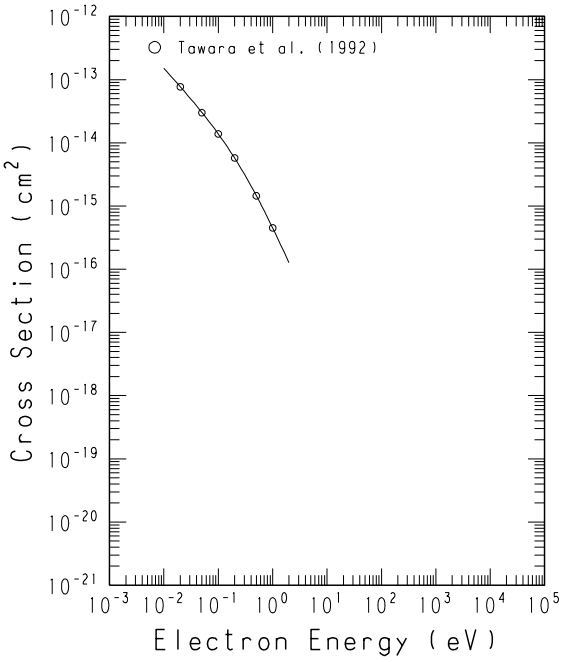
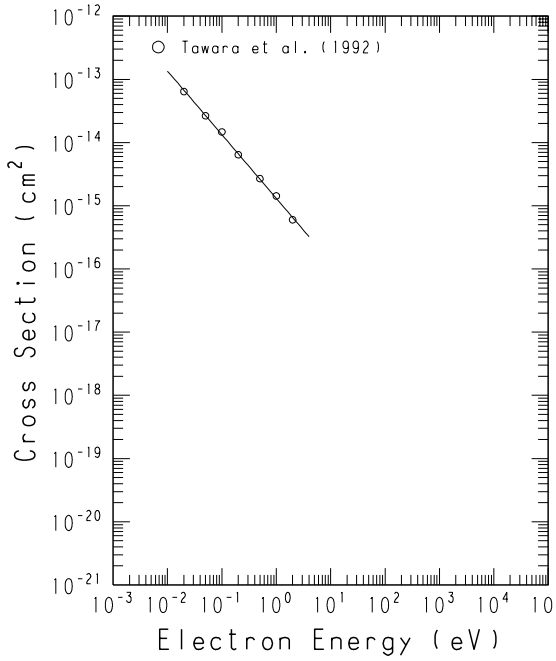
GRAPH 29

CH_4^+ - Dissociative Recombination



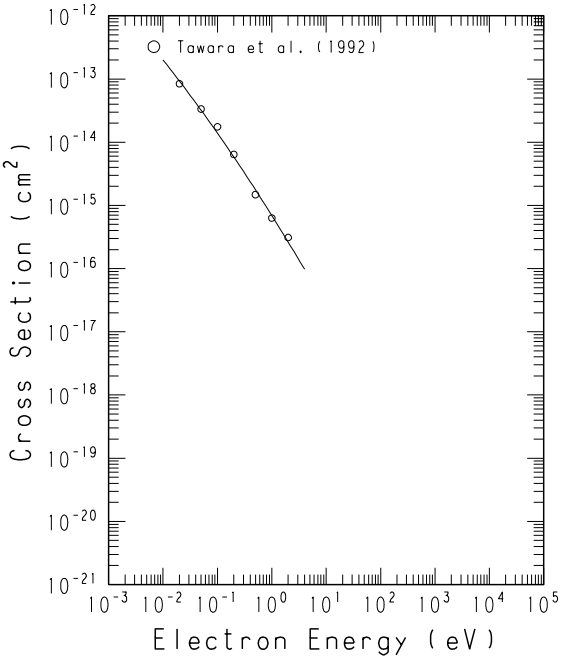
GRAPH 31

CH_2^+ - Dissociative Recombination



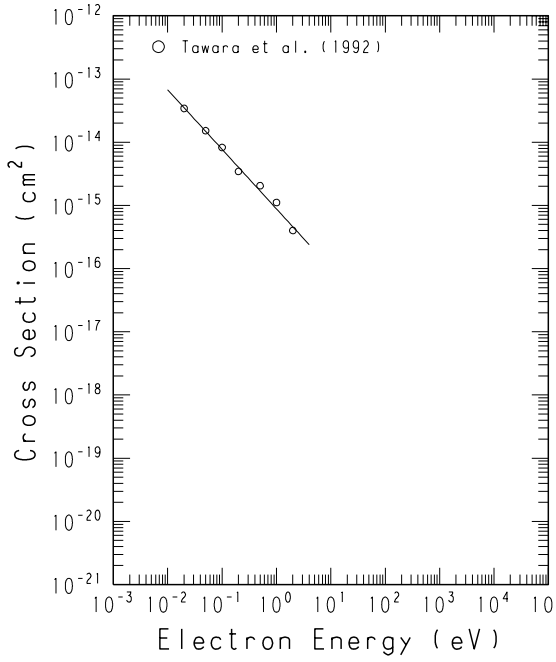
GRAPH 30

CH_3^+ - Dissociative Recombination



GRAPH 32

CH^+ - Dissociative Recombination



GRAPHS. Cross Section vs Electron Energy

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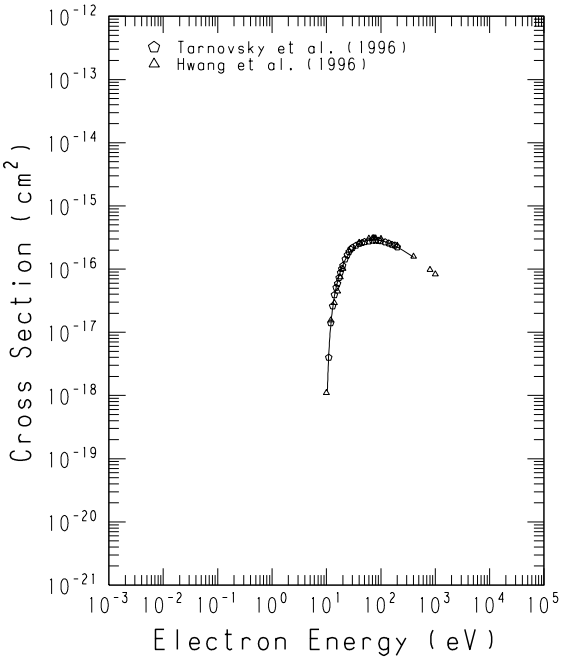
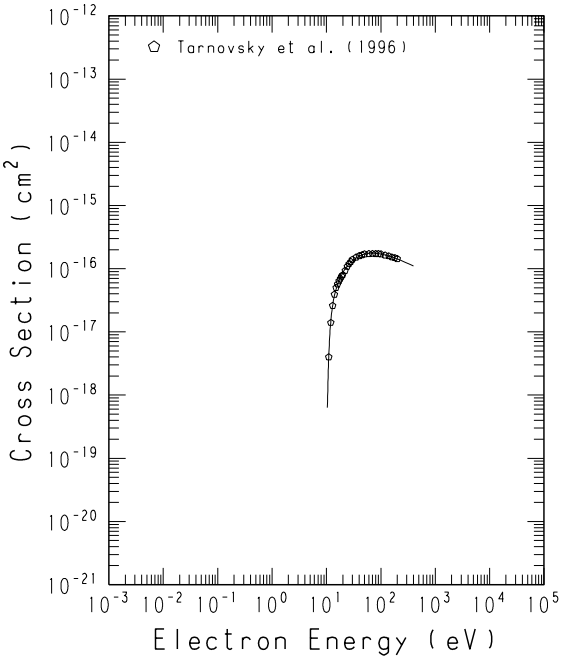
GRAPH 33

Total Ionization/CD_3



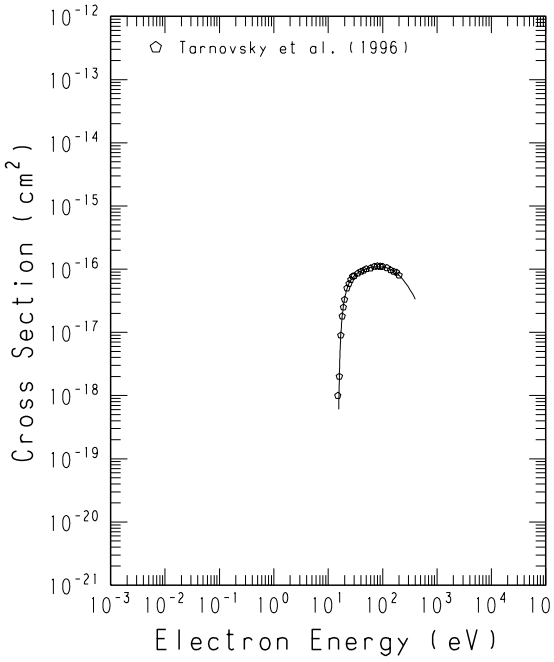
GRAPH 34

CD_3^+ Production/CD_3



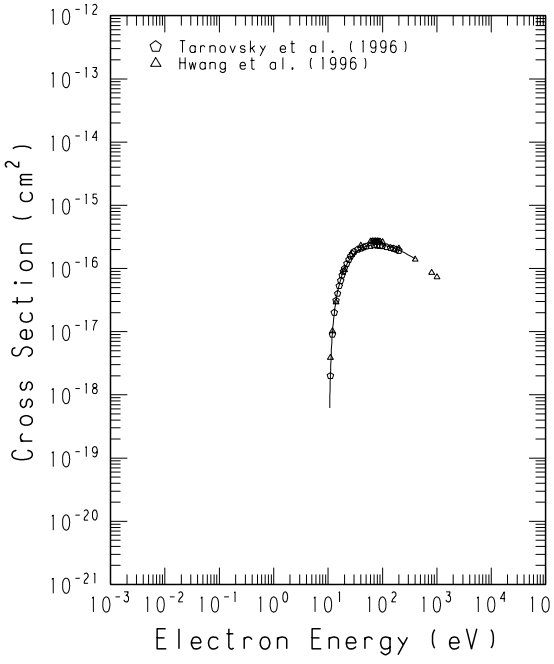
GRAPH 35

CD_2^+ Production/CD_3



GRAPH 36

Total Ionization/CD_2



GRAPHS. Cross Section vs Electron Energy

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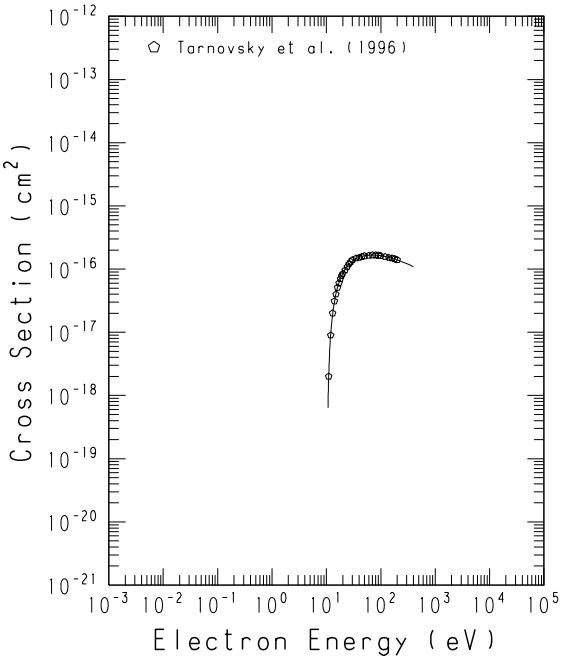
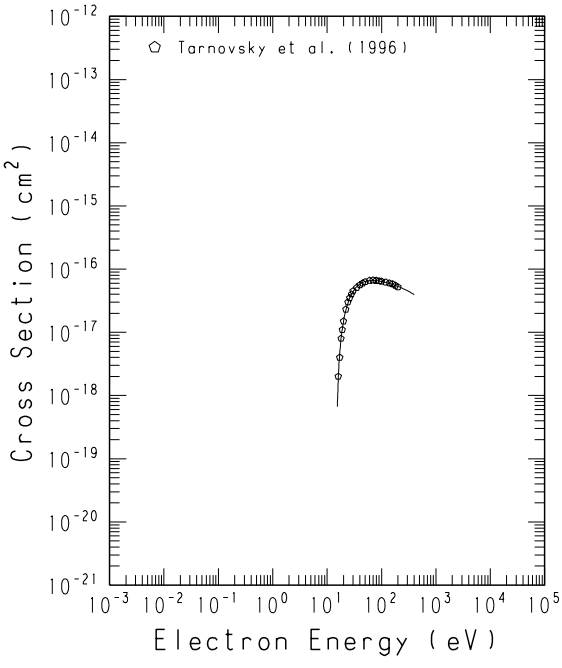
GRAPH 37

CD_2^+ Production/CD_2



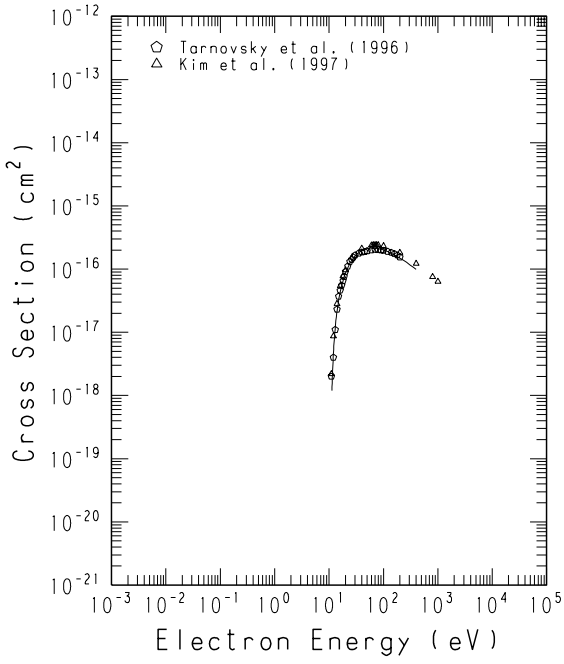
GRAPH 38

CD^+ Production/CD_2



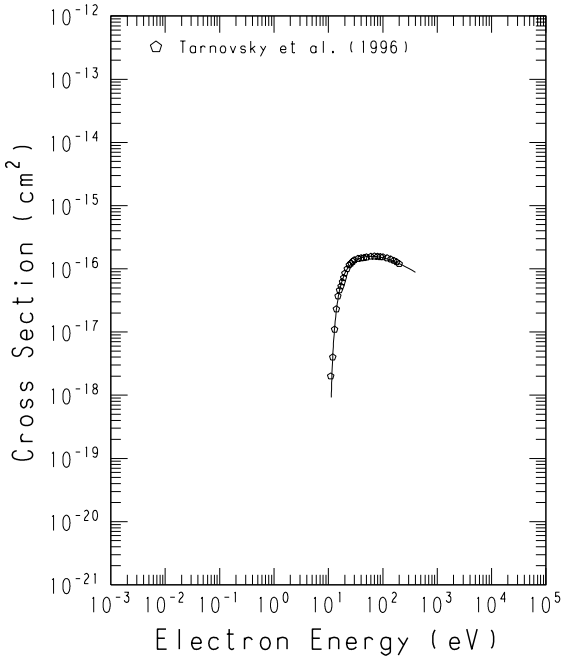
GRAPH 39

Total Ionization/CD



GRAPH 40

CD^+ Production/CD



GRAPHS. Cross Section vs Electron Energy

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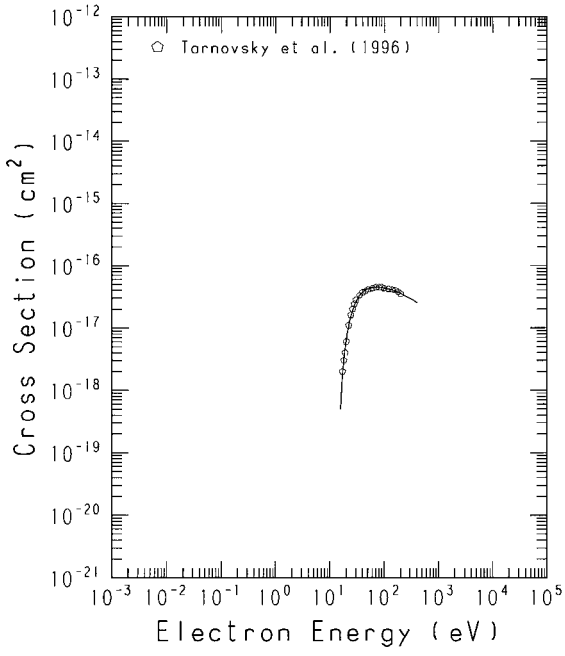
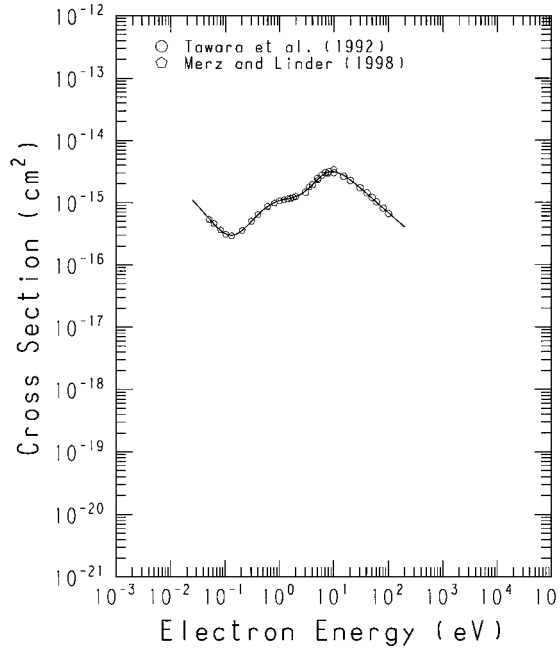
GRAPH 41

C^+ Production/CD



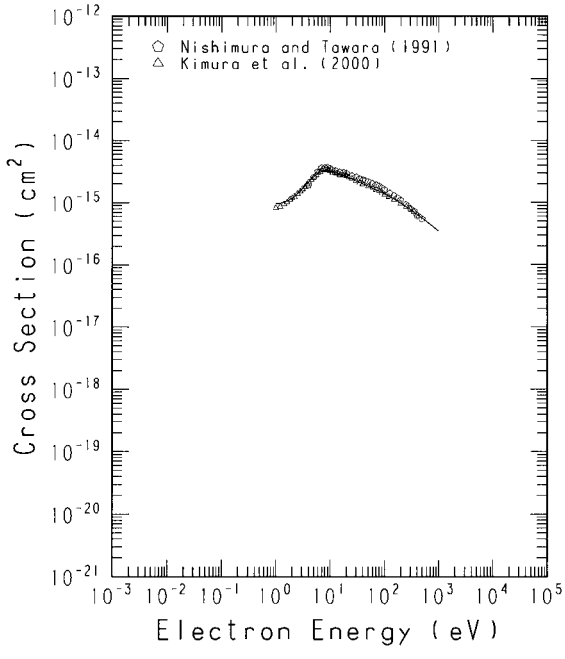
GRAPH 43

Elastic Scattering/C_2H_6



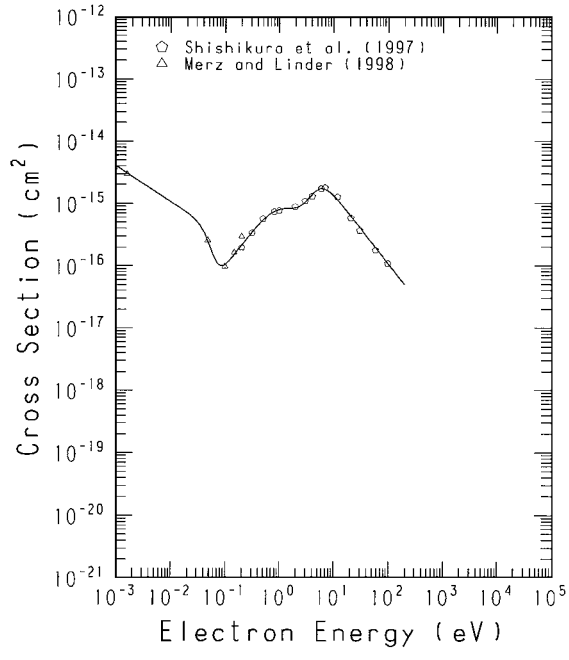
GRAPH 42

Total Scattering/C_2H_6



GRAPH 44

Momentum Transfer/C_2H_6



GRAPHS. Cross Section vs Electron Energy

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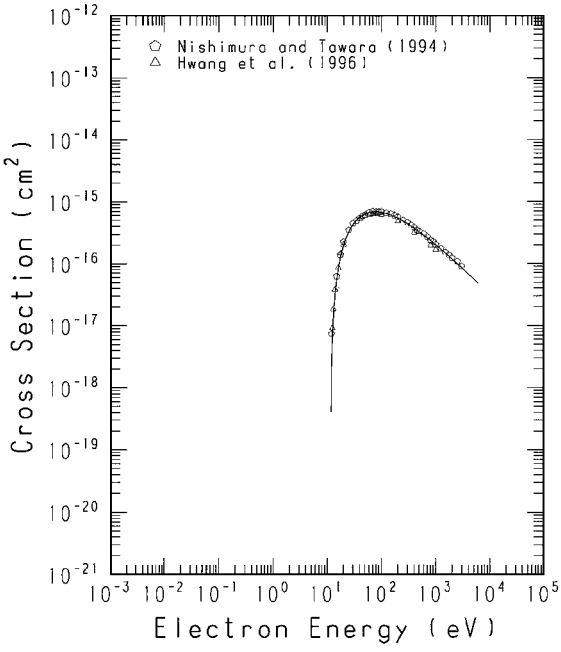
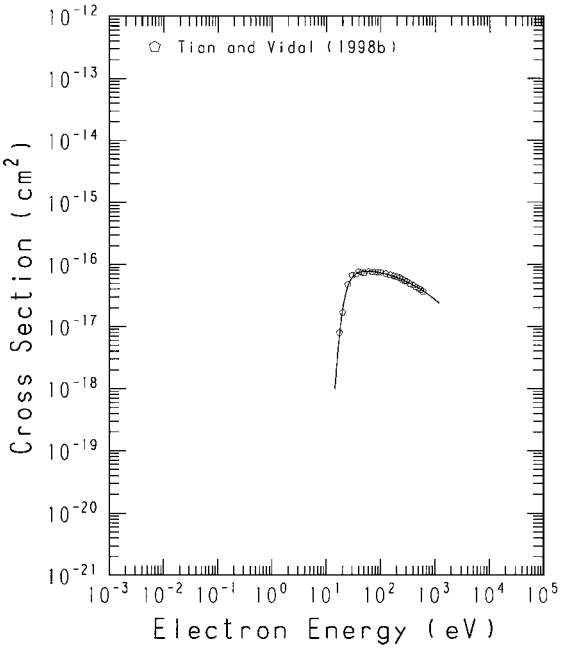
GRAPH 45

Total Ionization/C_2H_6



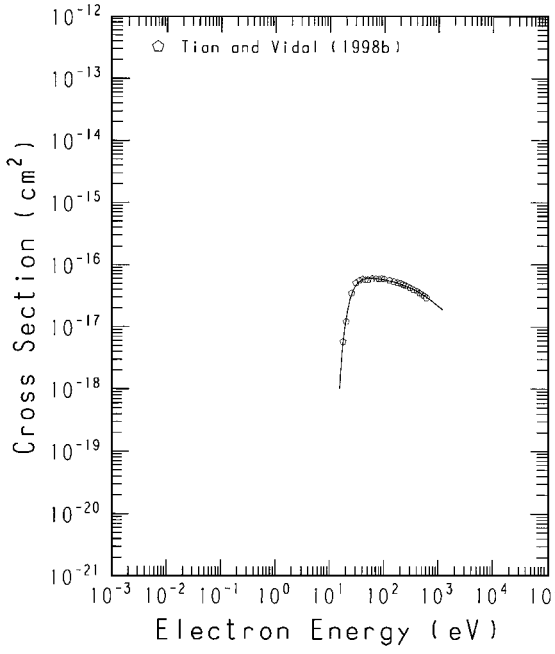
GRAPH 46

$C_2H_6^+$ Production/C_2H_6



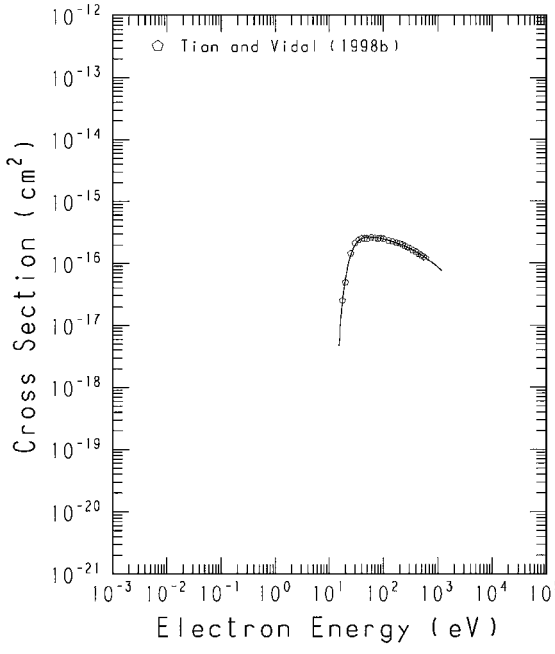
GRAPH 47

$C_2H_5^+$ Production/C_2H_6



GRAPH 48

$C_2H_4^+$ Production/C_2H_6



GRAPHS. Cross Section vs Electron Energy

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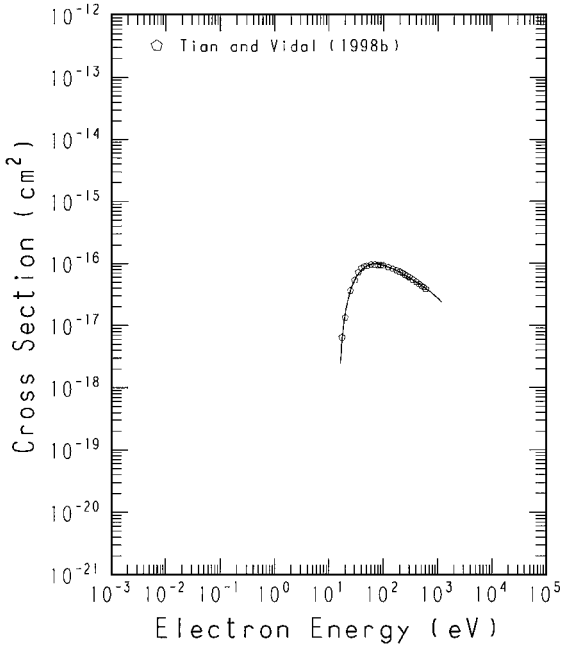
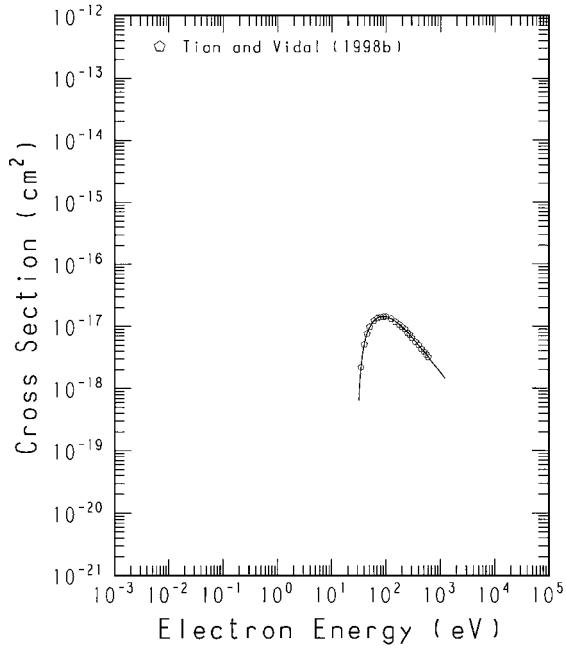
GRAPH 49

$C_2H_3^+$ Production/C_2H_6



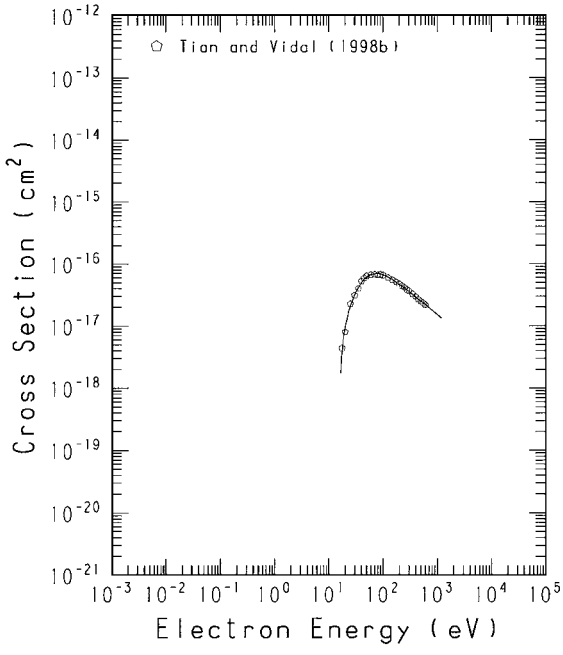
GRAPH 51

C_2H^+ Production/C_2H_6



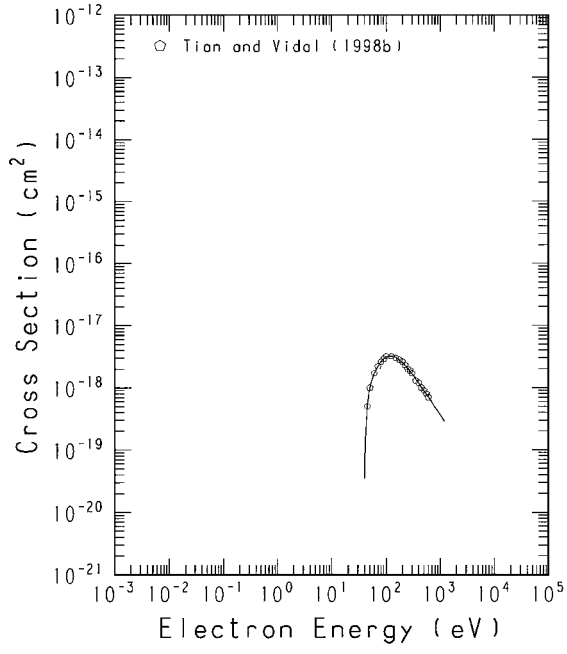
GRAPH 50

$C_2H_2^+$ Production/C_2H_6



GRAPH 52

C_2^+ Production/C_2H_6



GRAPHS. Cross Section vs Electron Energy

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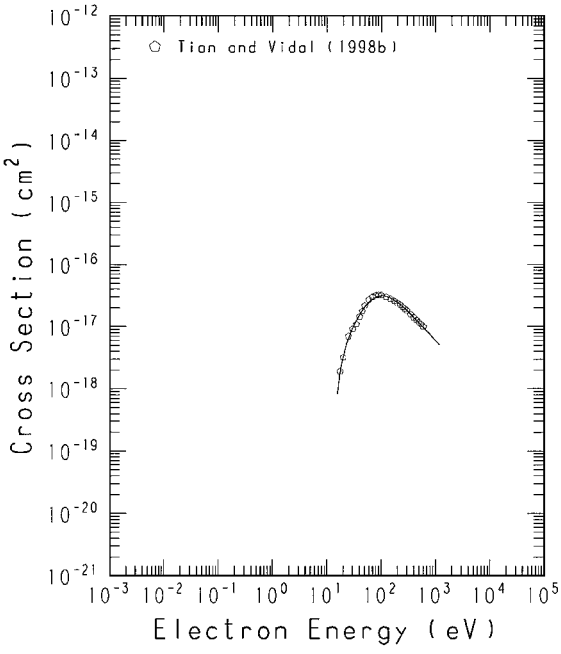
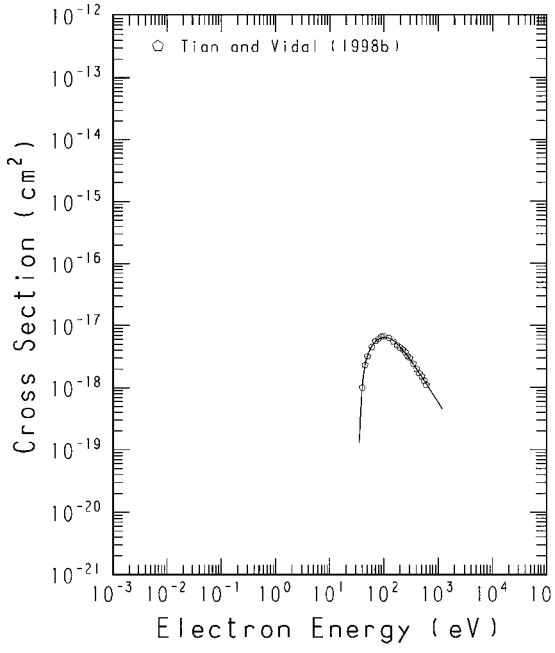
GRAPH 53

CH_3^+ Production/C_2H_6



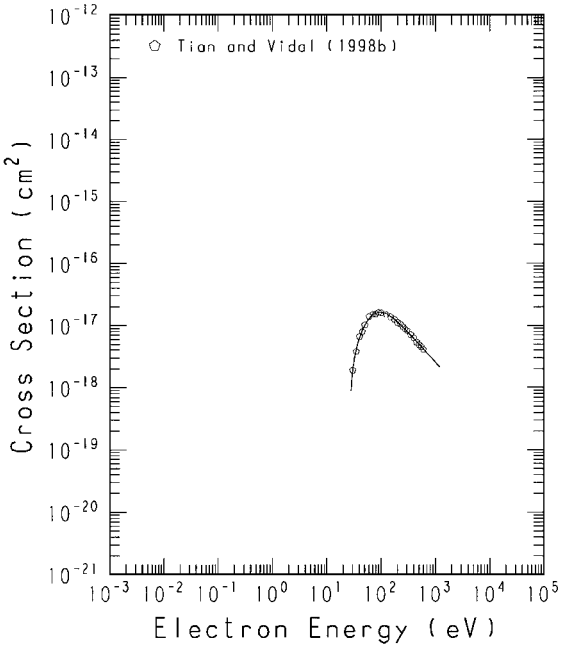
GRAPH 55

CH^+ Production/C_2H_6



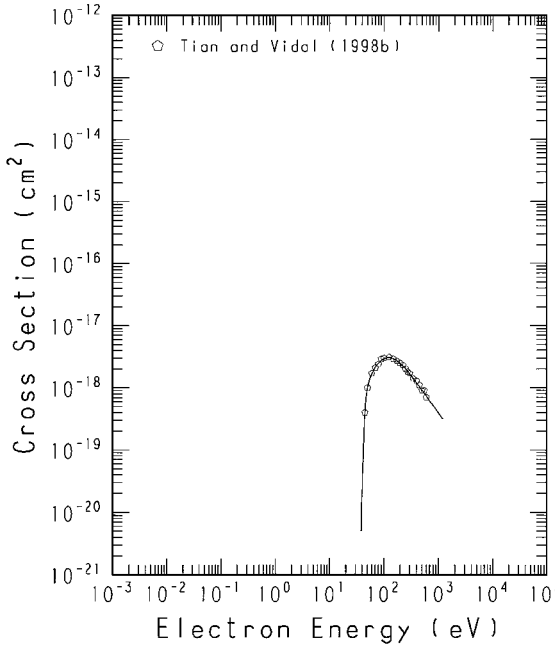
GRAPH 54

CH_2^+ Production/C_2H_6



GRAPH 56

C^+ Production/C_2H_6



GRAPHS. Cross Section vs Electron Energy

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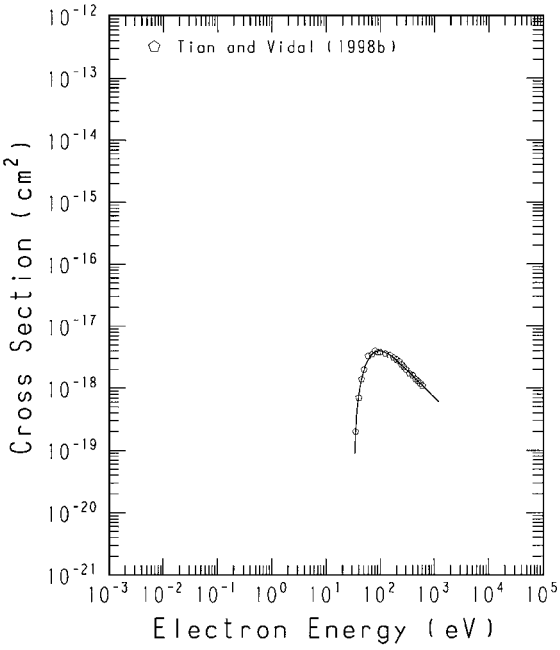
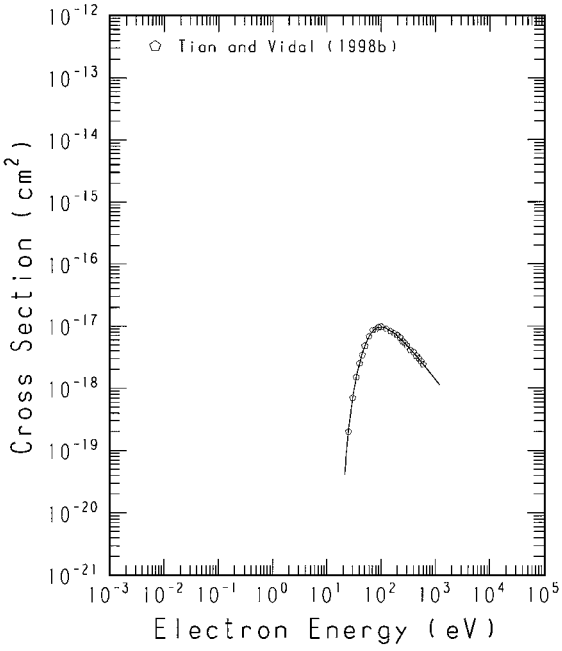
GRAPH 57

H_3^+ Production/C_2H_6



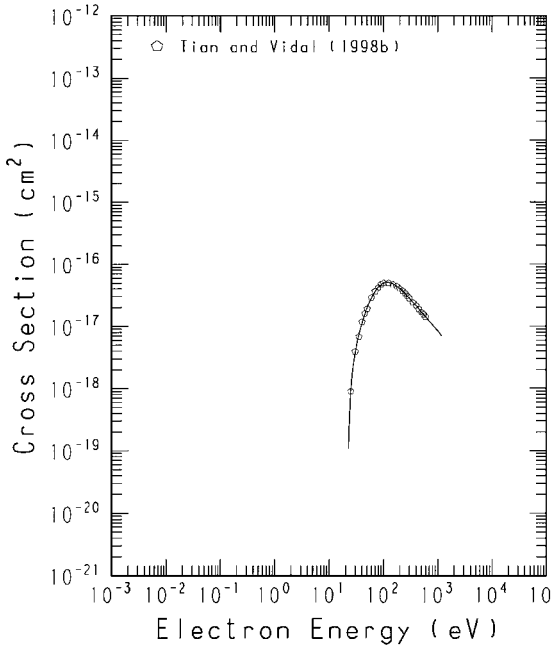
GRAPH 58

H_2^+ Production/C_2H_6



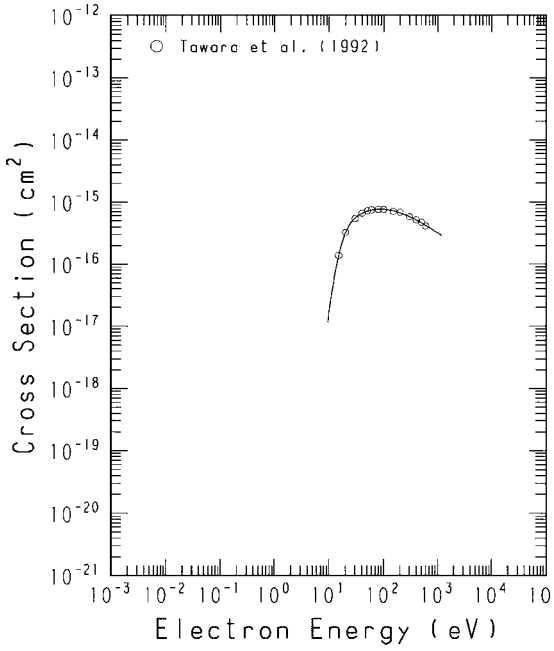
GRAPH 59

H^+ Production/C_2H_6



GRAPH 60

Total Dissociation/C_2H_6



GRAPHS. Cross Section vs Electron Energy

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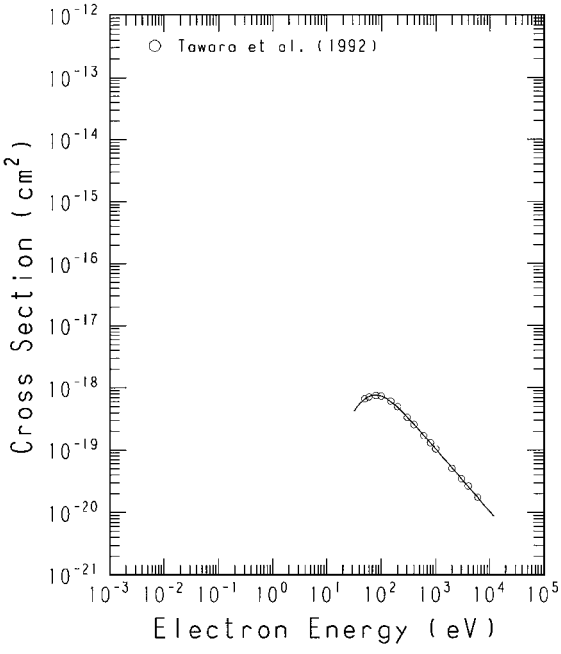
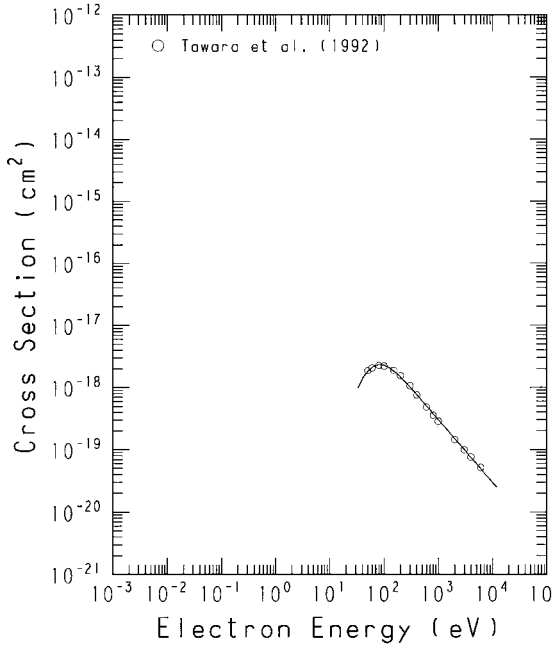
GRAPH 61

H(2s) Production/C_2H_6



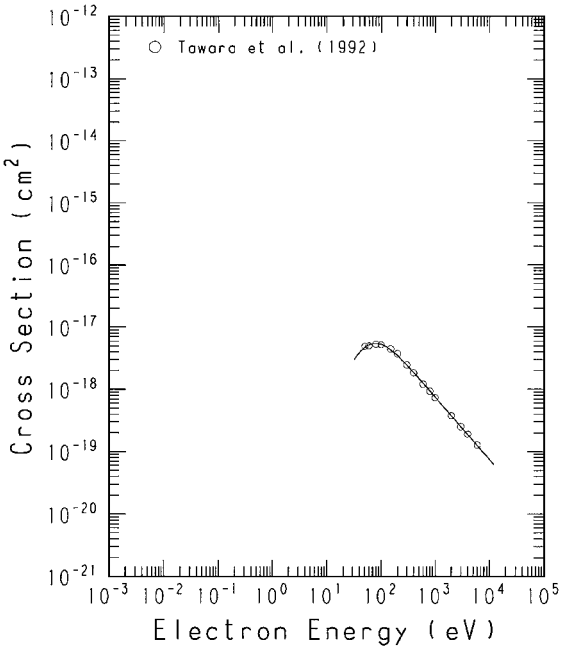
GRAPH 63

H-α Emission/C_2H_6



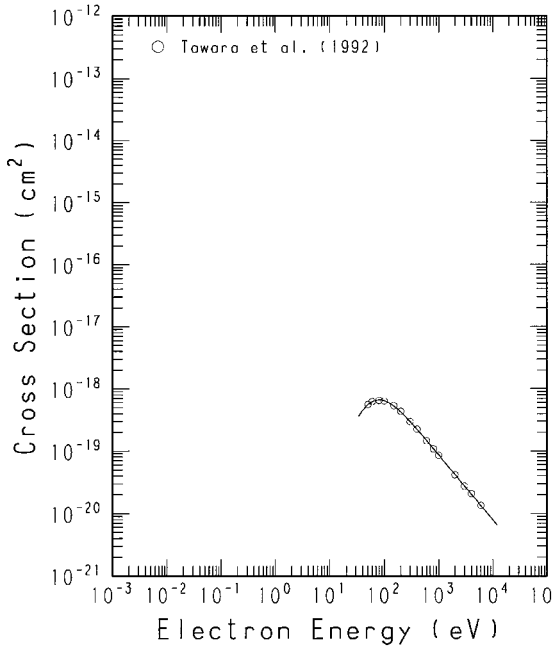
GRAPH 62

Ly-α Emission/C_2H_6



GRAPH 64

H-β Emission/C_2H_6



GRAPHS. Cross Section vs Electron Energy

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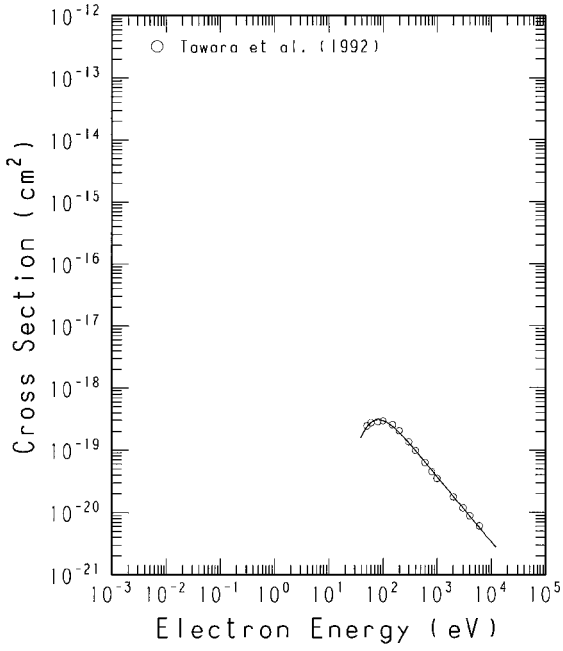
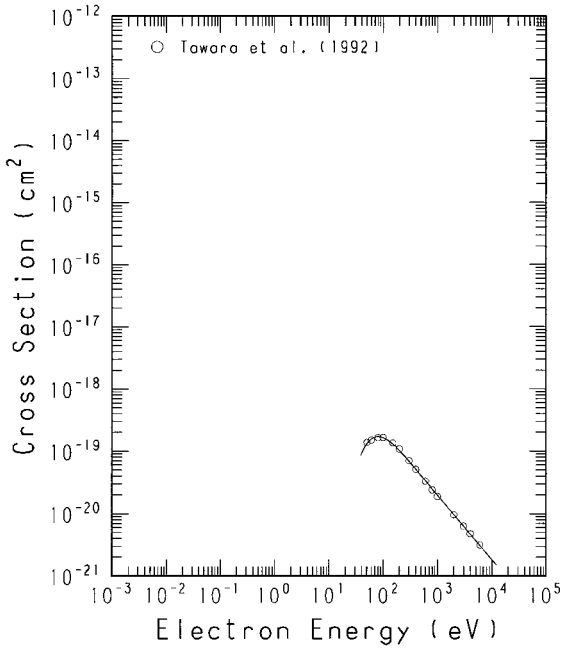
GRAPH 65

H-γ Emission/C_2H_6



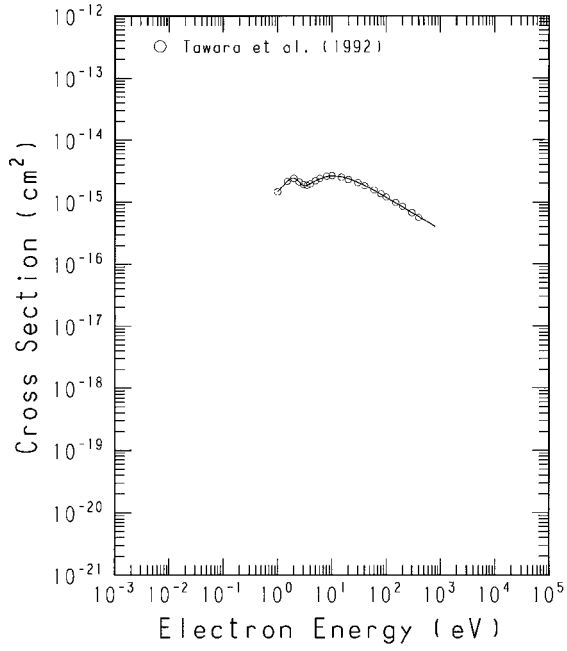
GRAPH 66

H-δ Emission/C_2H_6



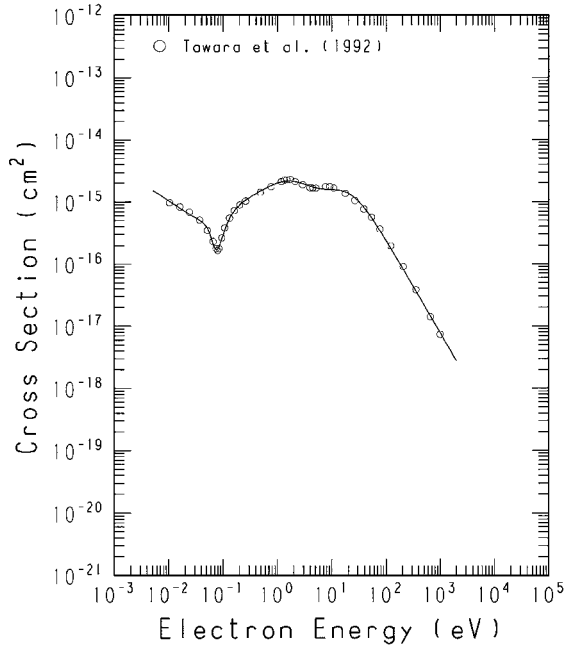
GRAPH 67

Total Scattering/C_2H_4



GRAPH 68

Momentum Transfer/C_2H_4



GRAPHS. Cross Section vs Electron Energy

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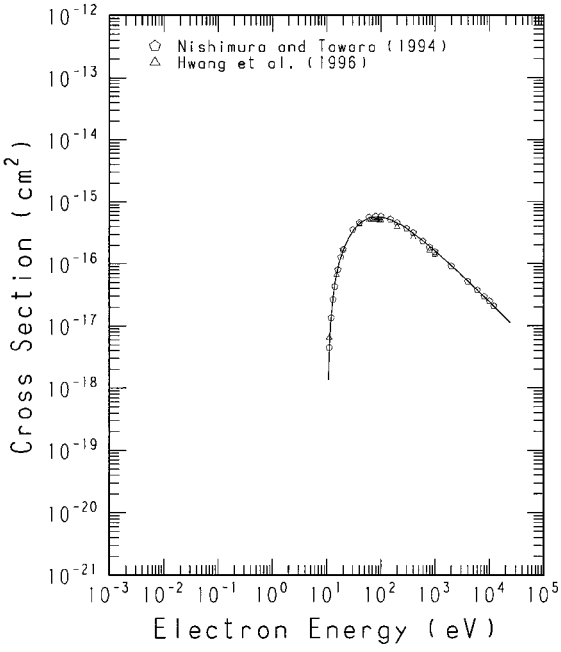
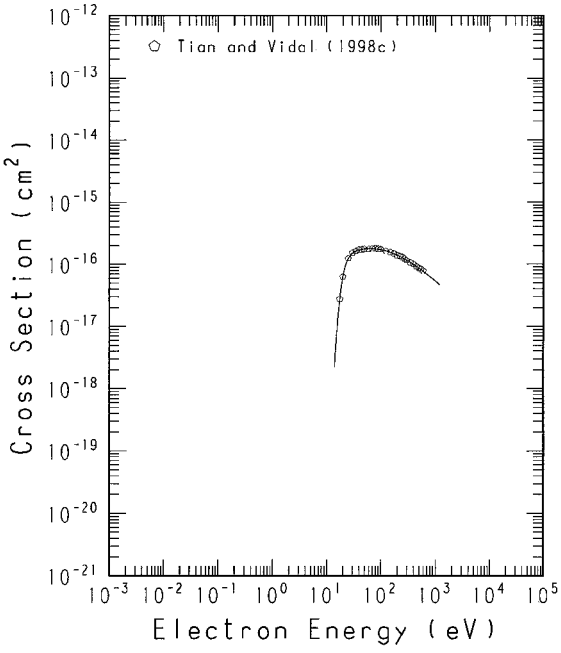
GRAPH 69

Total Ionization/C_2H_4



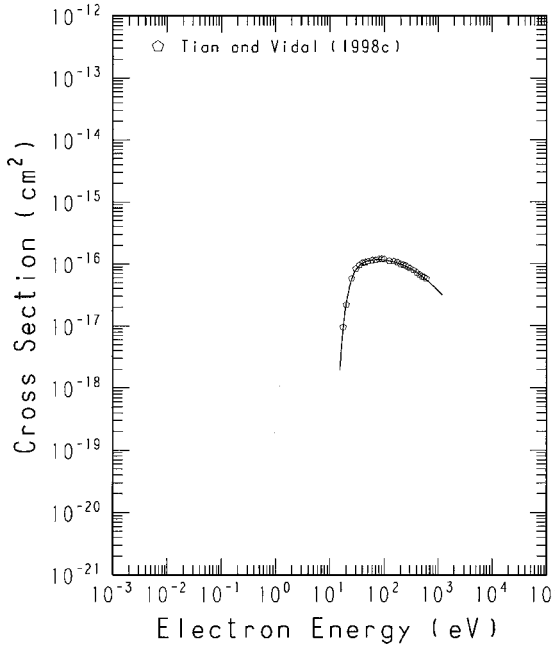
GRAPH 70

$C_2H_4^+$ Production/C_2H_4



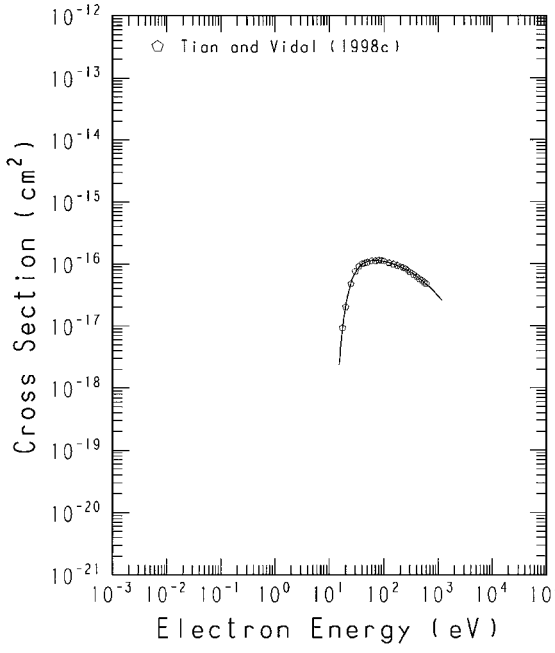
GRAPH 71

$C_2H_3^+$ Production/C_2H_4



GRAPH 72

$C_2H_2^+$ Production/C_2H_4

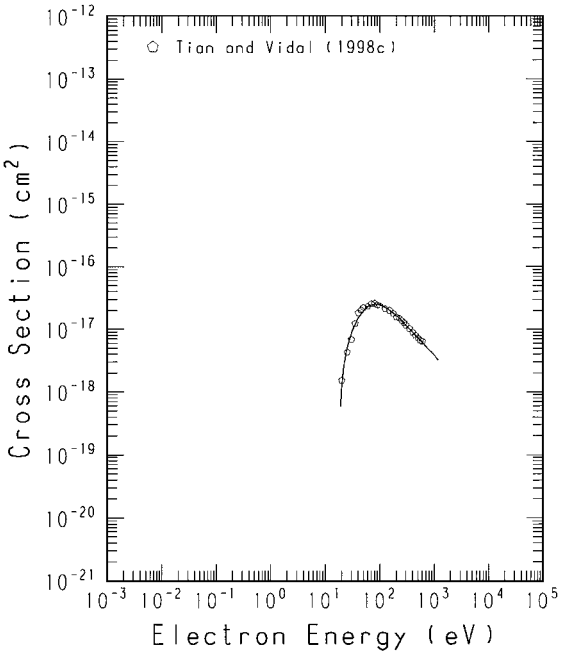


GRAPHS. Cross Section vs Electron Energy

See page 155 for Explanation of Graphs

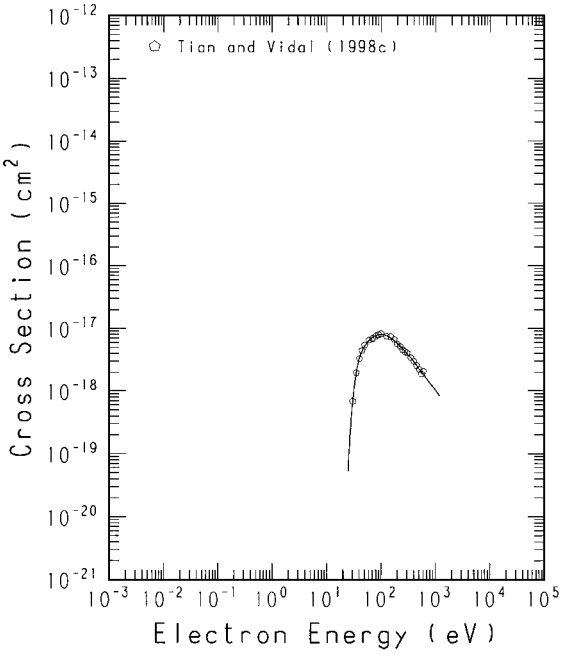
GRAPH 73

C_2H^+ Production/C_2H_4



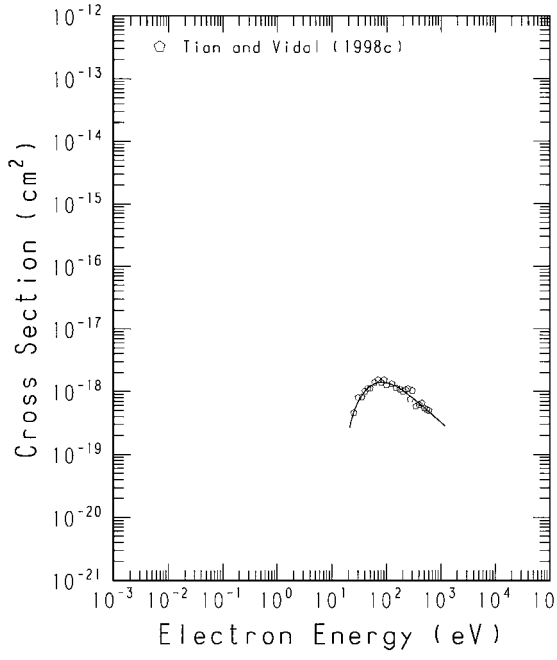
GRAPH 74

C_2^+ Production/C_2H_4



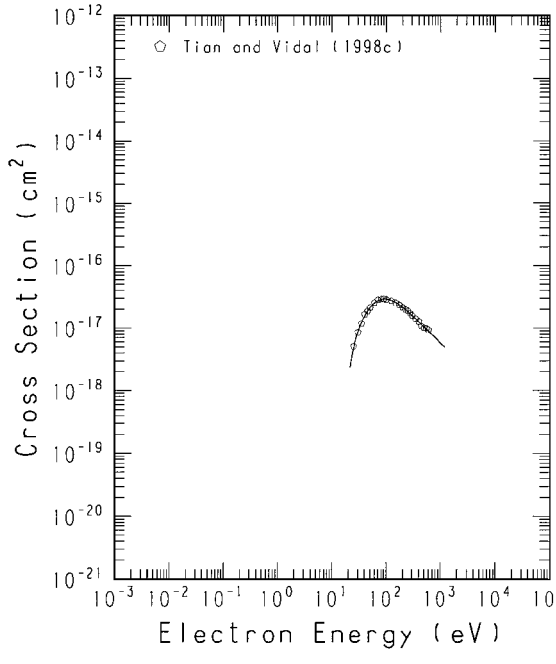
GRAPH 75

CH_3^+ Production/C_2H_4



GRAPH 76

CH_2^+ Production/C_2H_4



GRAPHS. Cross Section vs Electron Energy

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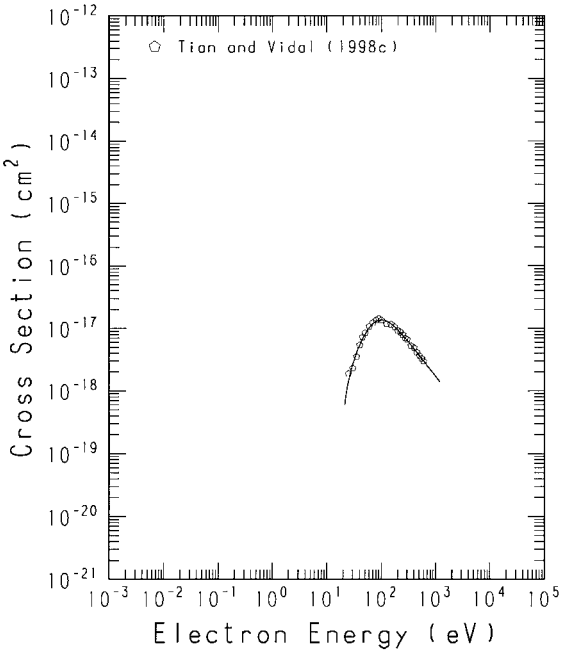
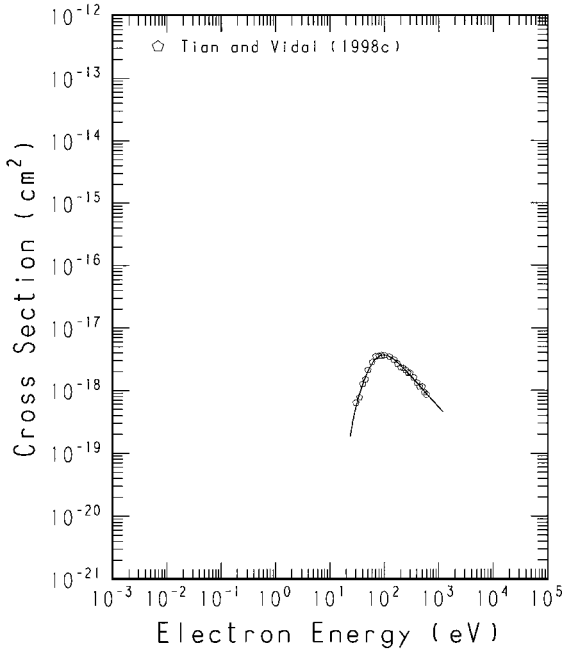
GRAPH 77

CH^+ Production/C_2H_4



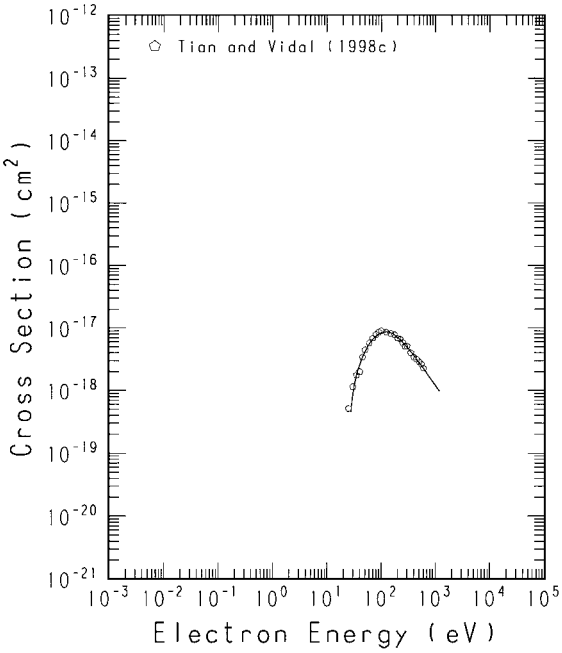
GRAPH 79

H_2^+ Production/C_2H_4



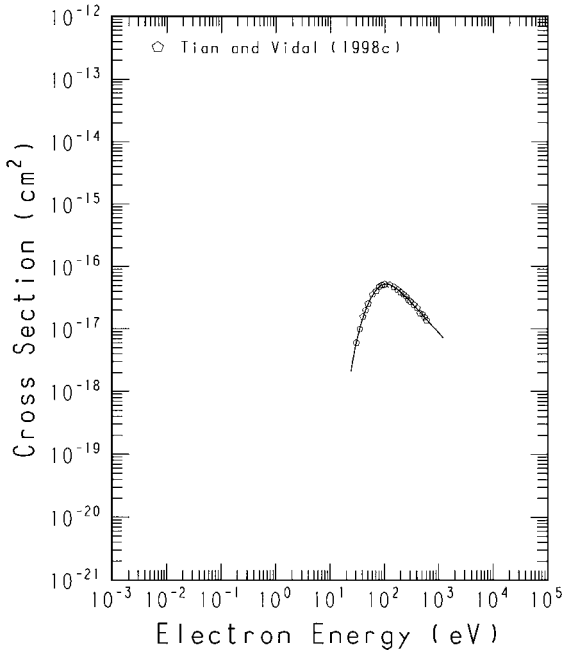
GRAPH 78

C^+ Production/C_2H_4



GRAPH 80

H^+ Production/C_2H_4



GRAPHS. Cross Section vs Electron Energy

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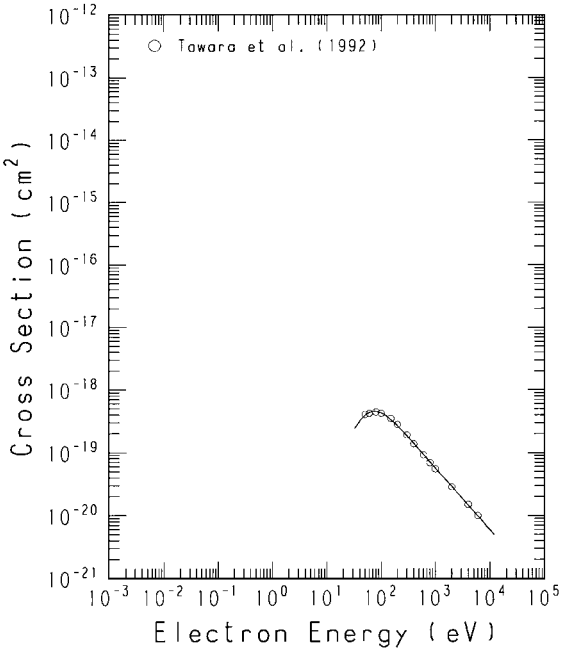
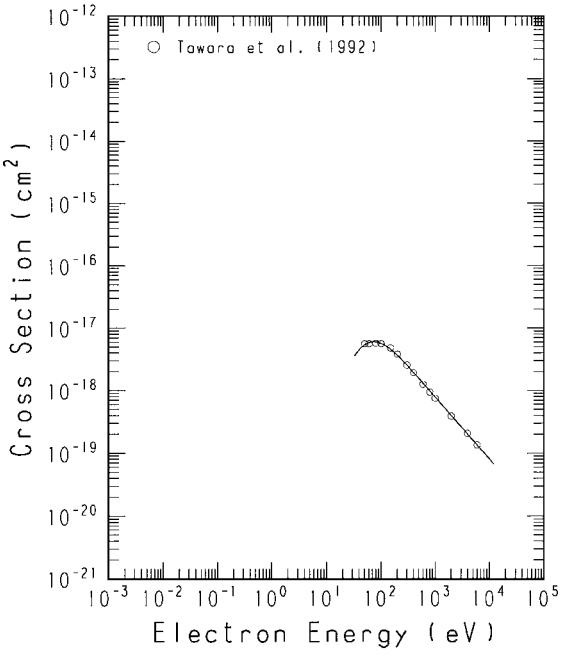
GRAPH 81

H(2s) Production/C_2H_4



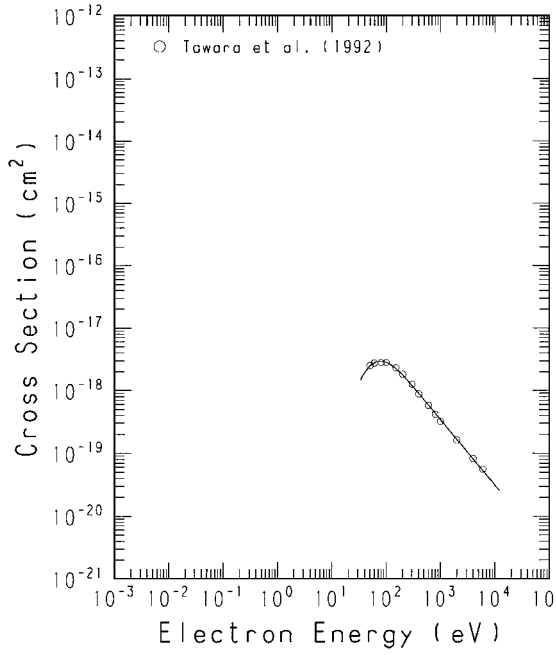
GRAPH 82

Ly-α Emission/C_2H_4



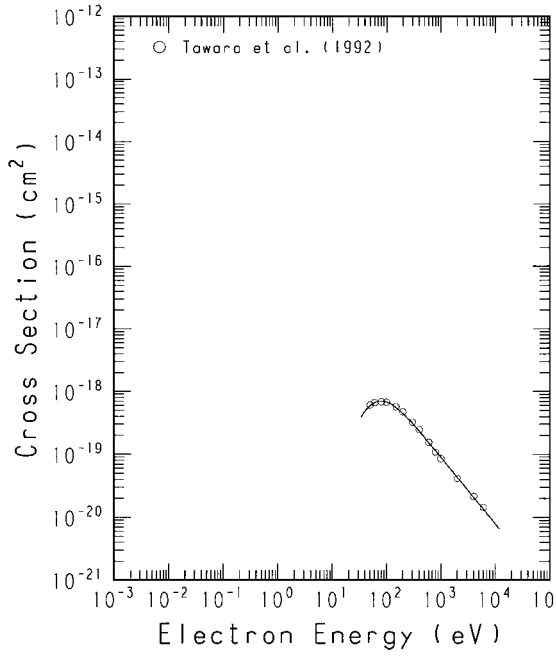
GRAPH 83

H-α Emission/C_2H_4



GRAPH 84

H-β Emission/C_2H_4



GRAPHS. Cross Section vs Electron Energy

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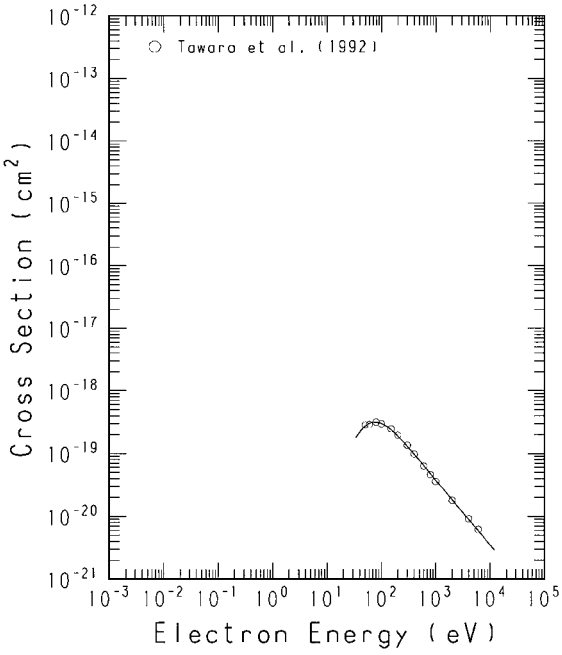
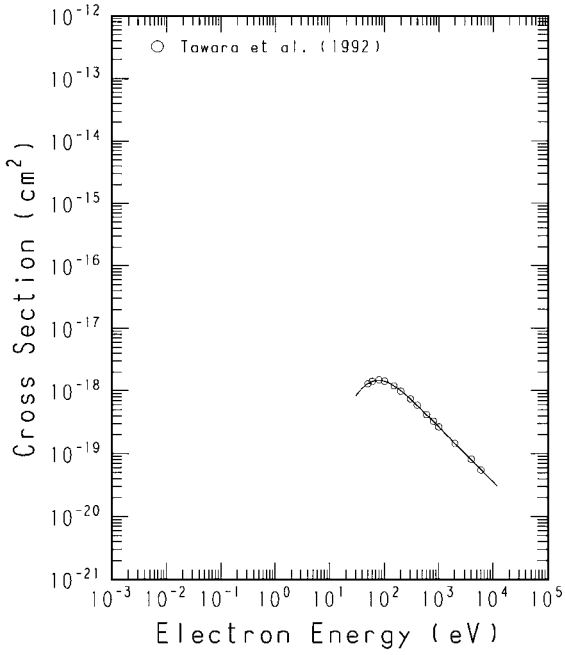
GRAPH 85

H-γ Emission/C_2H_4



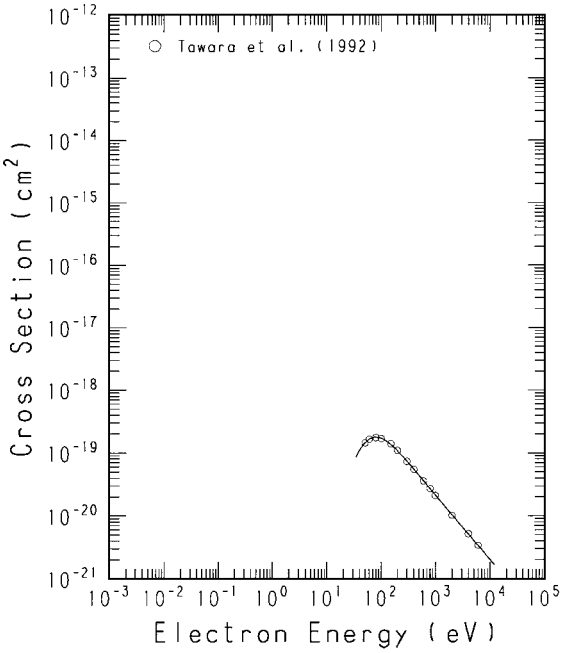
GRAPH 87

CH(420-440nm) Emission/C_2H_4



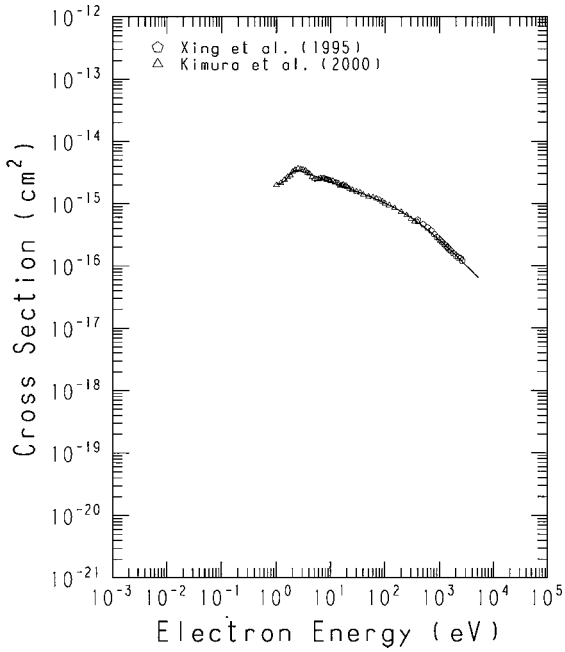
GRAPH 86

H-δ Emission/C_2H_4



GRAPH 88

Total Scattering/C_2H_2



GRAPHS. Cross Section vs Electron Energy

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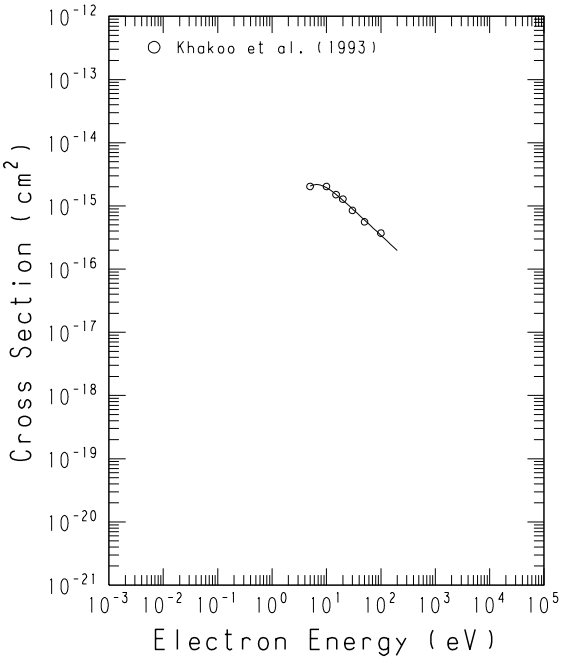
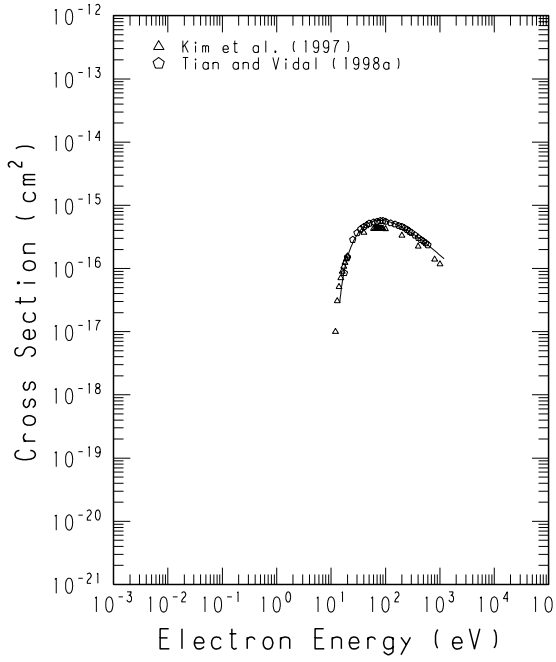
GRAPH 89

Elastic Scattering/C_2H_2



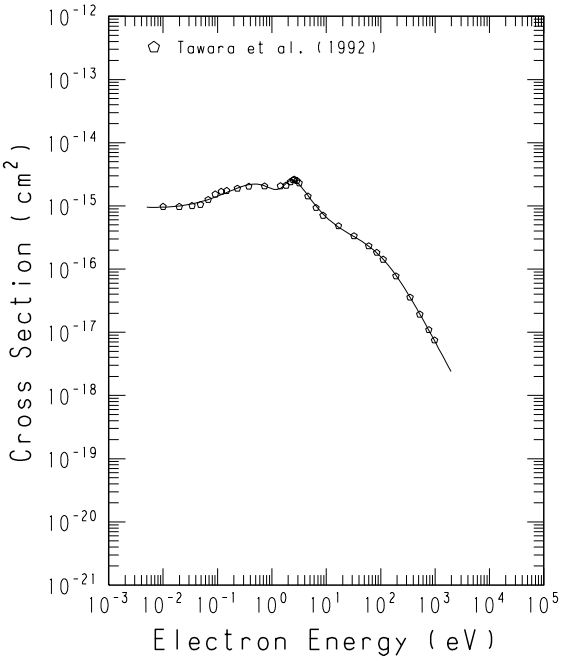
GRAPH 91

Total Ionization/C_2H_2



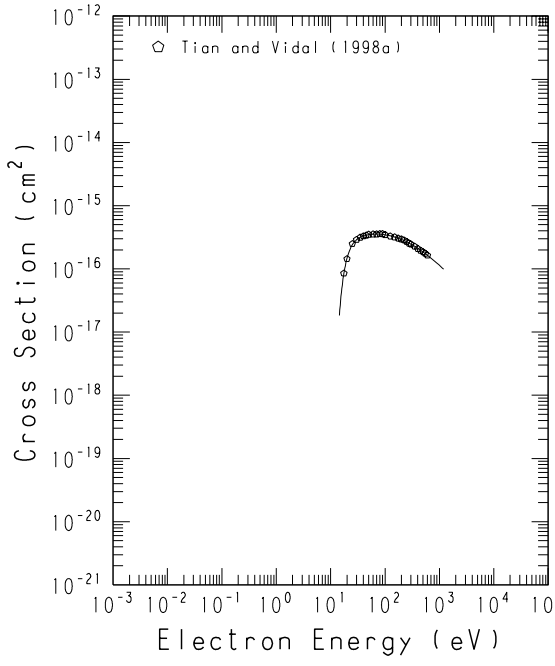
GRAPH 90

Momentum Transfer/C_2H_2



GRAPH 92

$C_2H_2^+$ Production/C_2H_2



GRAPHS. Cross Section vs Electron Energy

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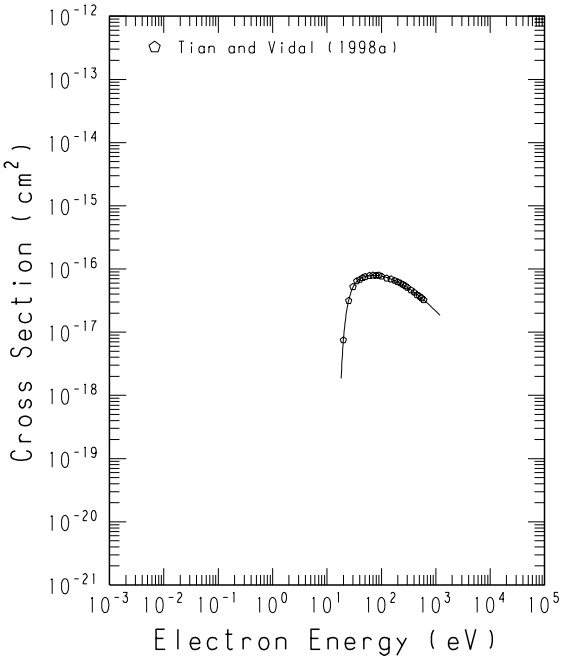
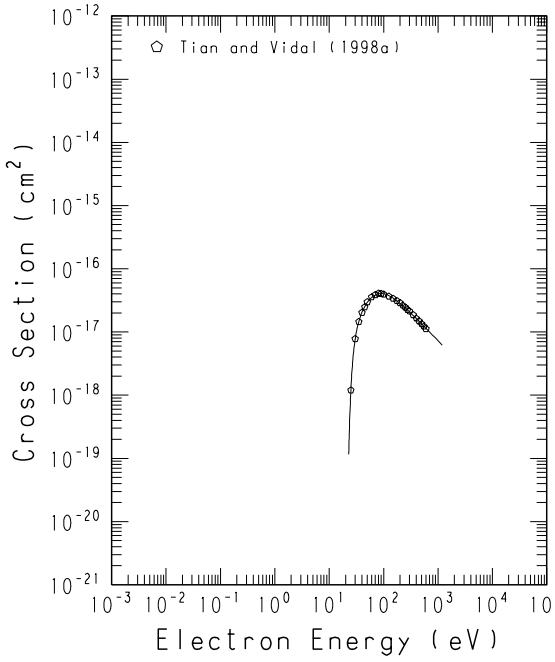
GRAPH 93

C_2H^+ Production/C_2H_2



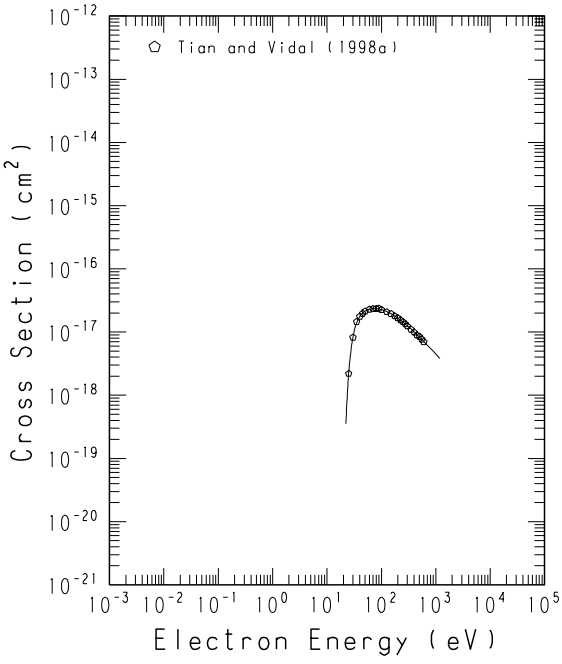
GRAPH 95

CH^+ Production/C_2H_2



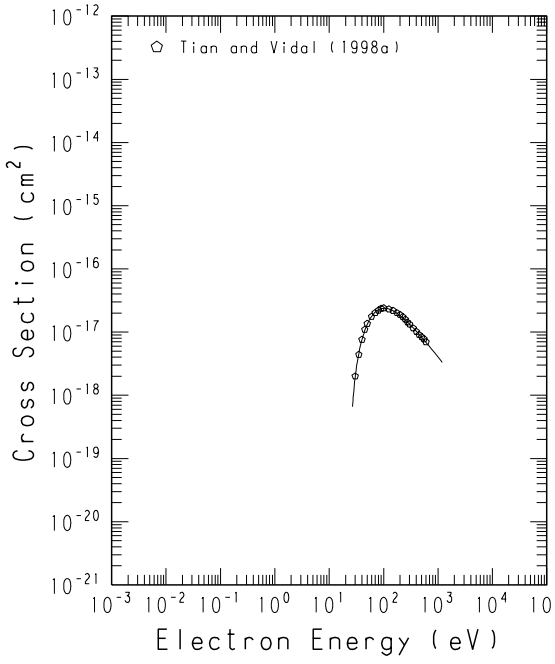
GRAPH 94

C_2^+ Production/C_2H_2



GRAPH 96

C^+ Production/C_2H_2



GRAPHS. Cross Section vs Electron Energy

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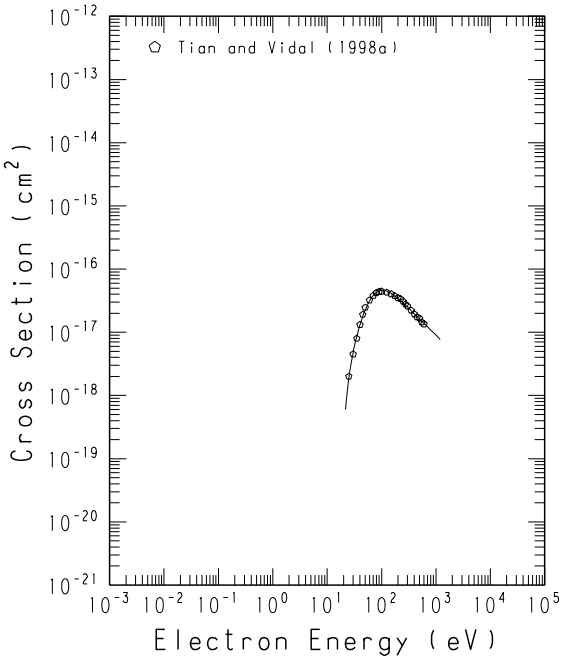
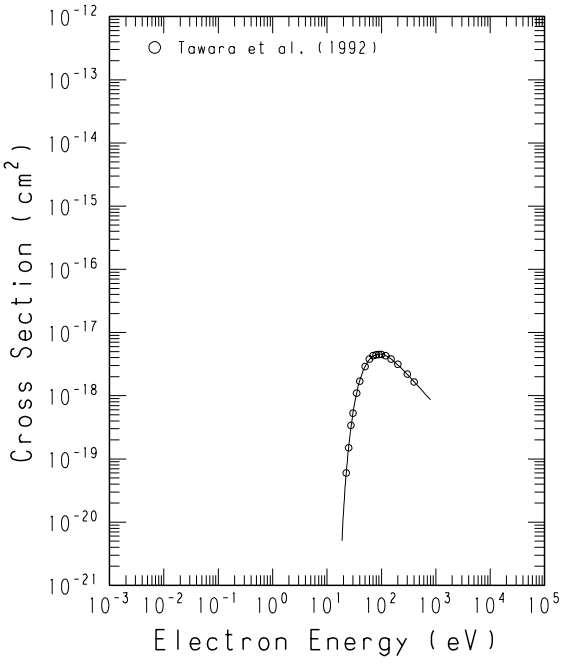
GRAPH 97

H^+ Production/C_2H_2



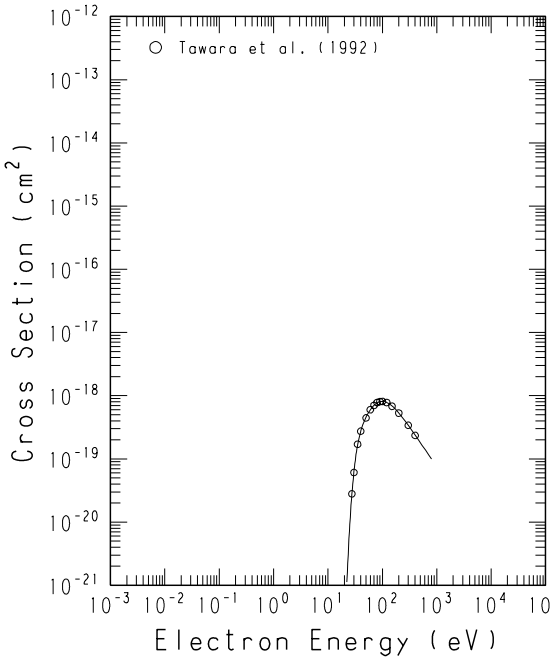
GRAPH 98

Ly-α Emission/C_2H_2



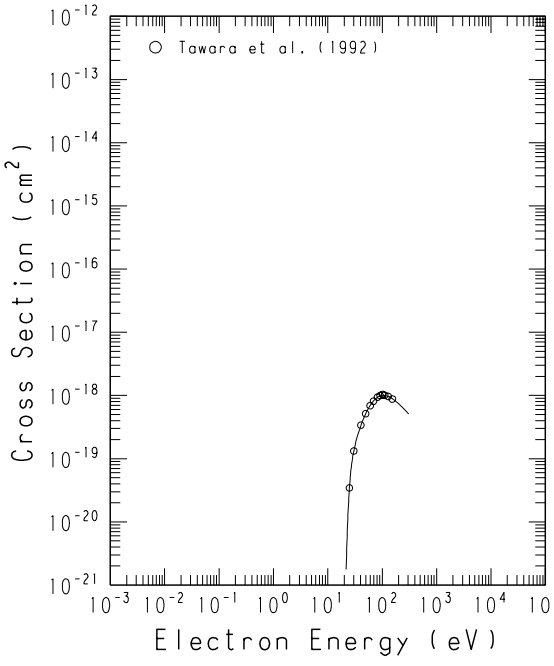
GRAPH 99

Ly-β Emission/C_2H_2



GRAPH 100

H-β Emission/C_2H_2



GRAPHS. Cross Section vs Electron Energy

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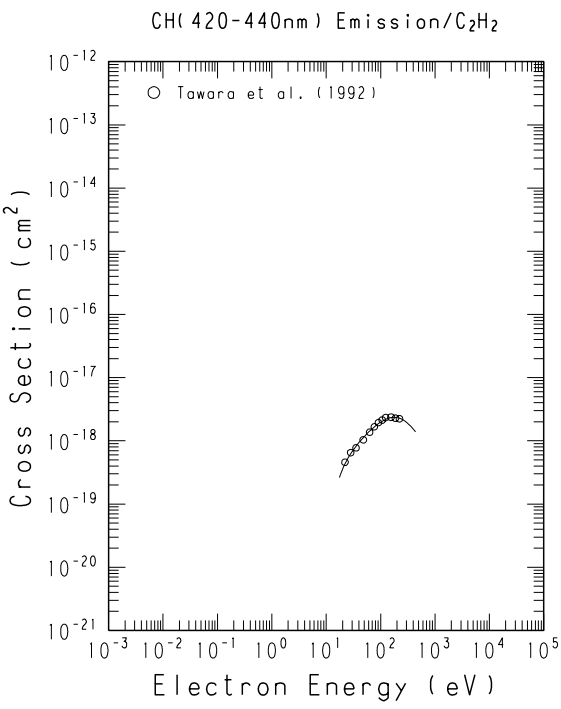
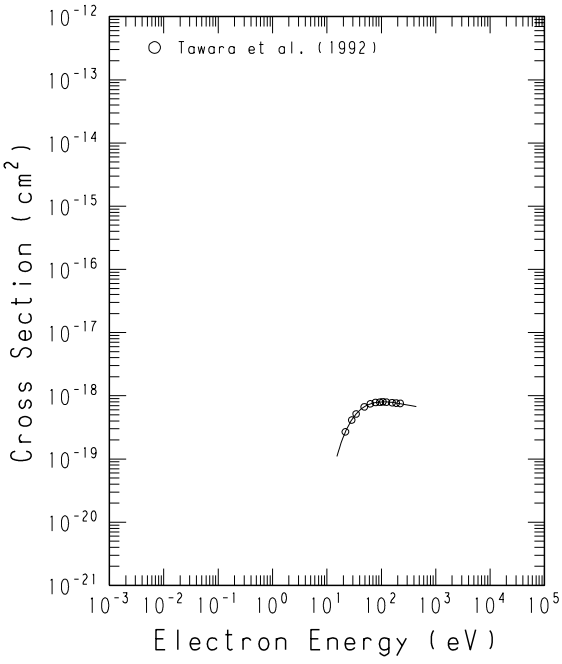
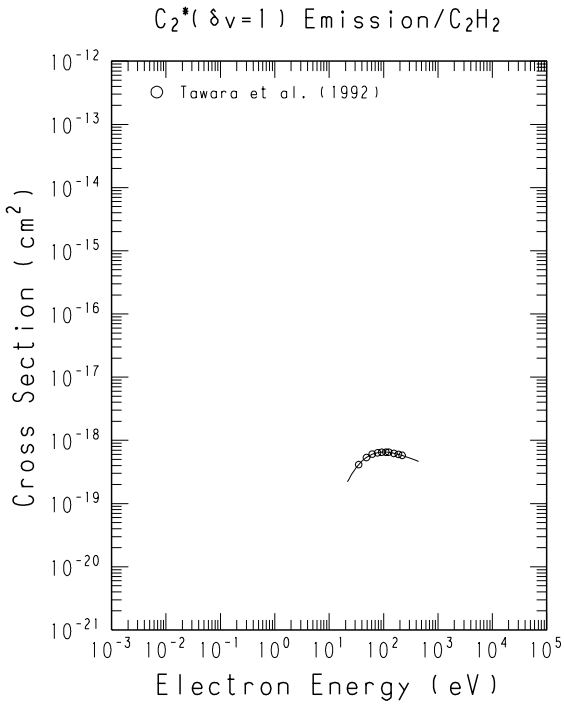
GRAPH 101



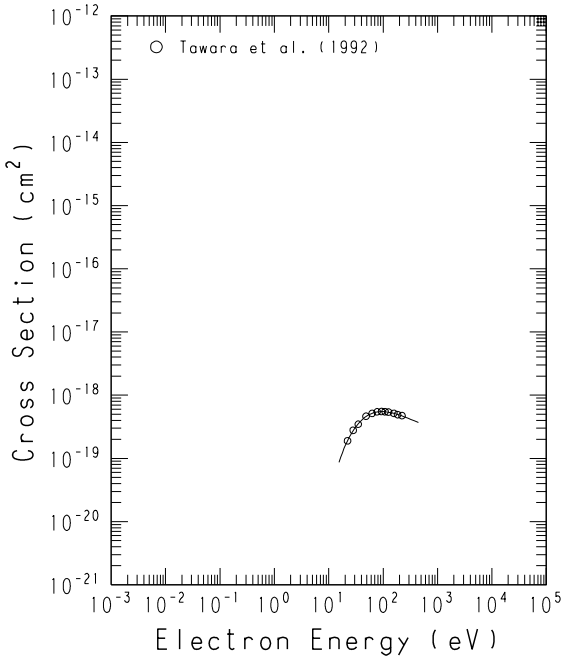
GRAPH 102



GRAPH 103



GRAPH 104



GRAPHS. Cross Section vs Electron Energy

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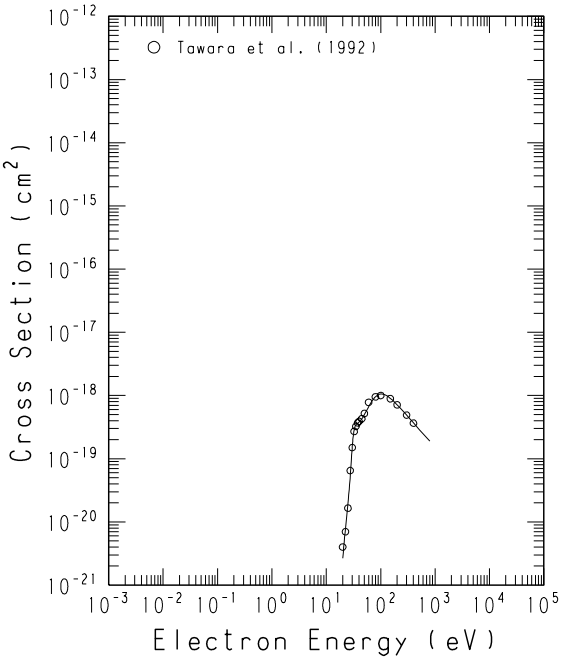
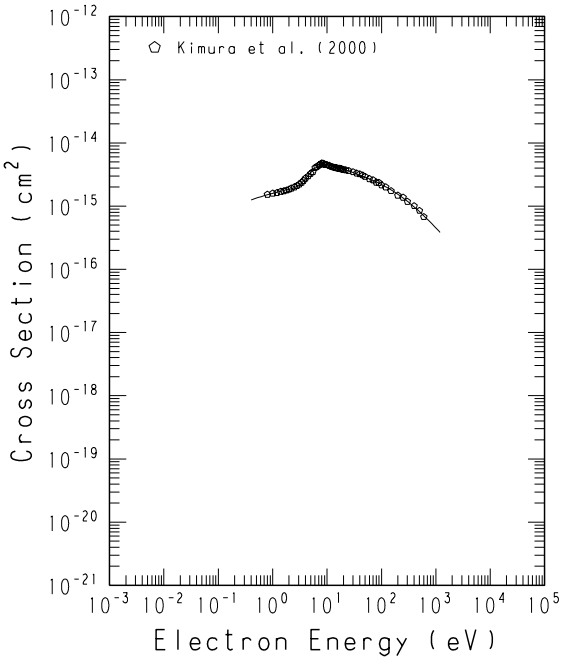
GRAPH 105

C(165.7nm) Emission/C_2H_2



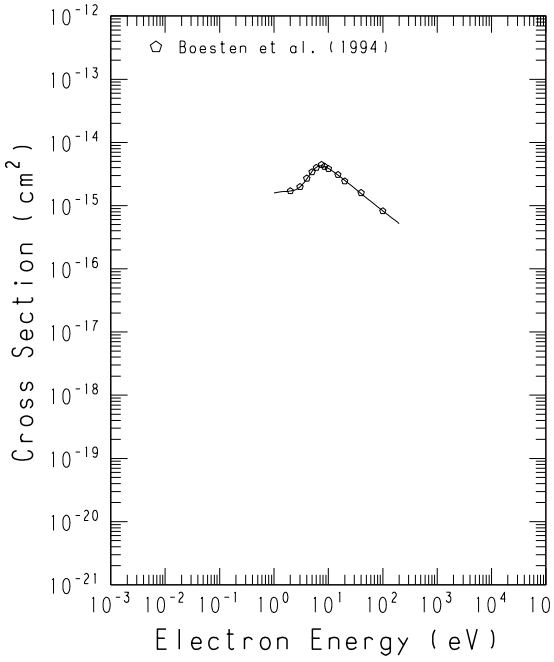
GRAPH 106

Total Scattering/C_3H_8



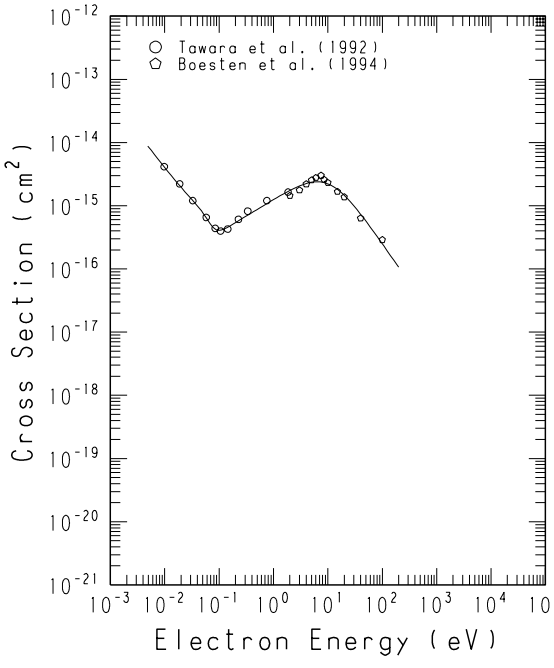
GRAPH 107

Elastic Scattering/C_3H_8



GRAPH 108

Momentum Transfer/C_3H_8



GRAPHS. Cross Section vs Electron Energy

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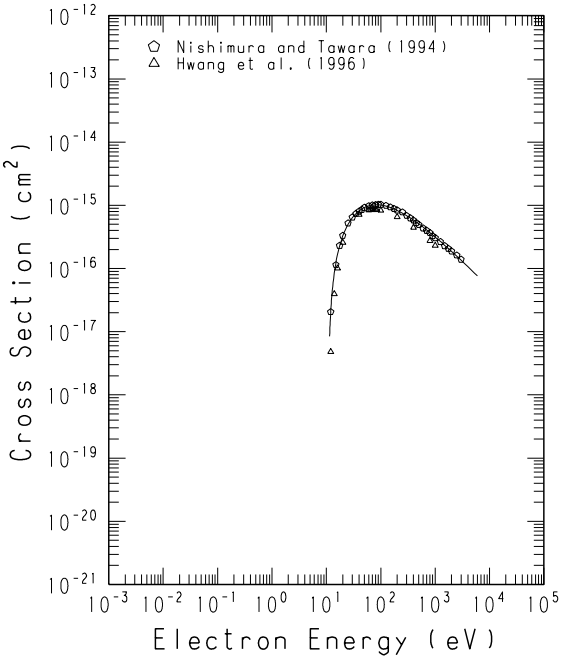
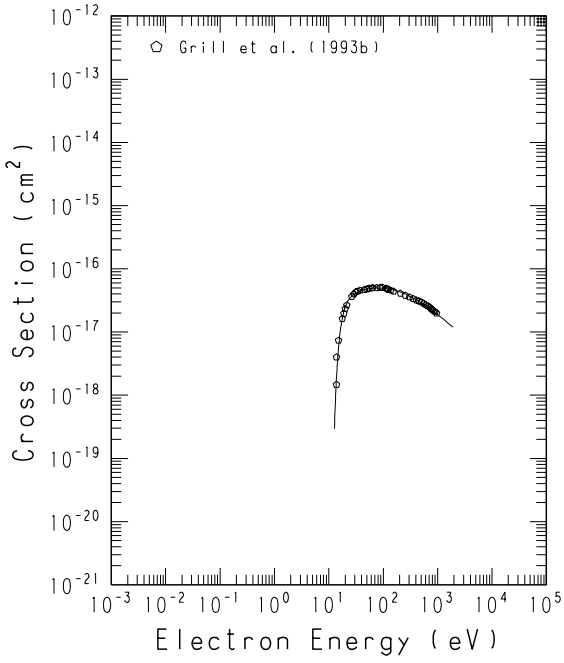
GRAPH 109

Total Ionization/C_3H_8



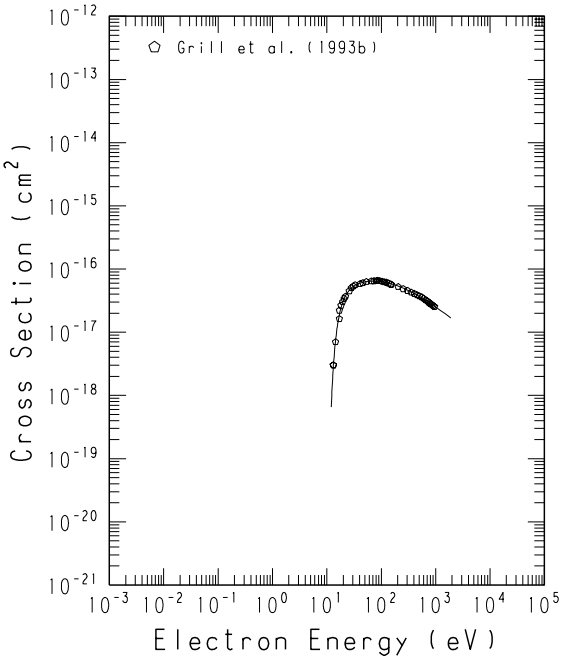
GRAPH 111

$C_3H_7^+$ Production/C_3H_8



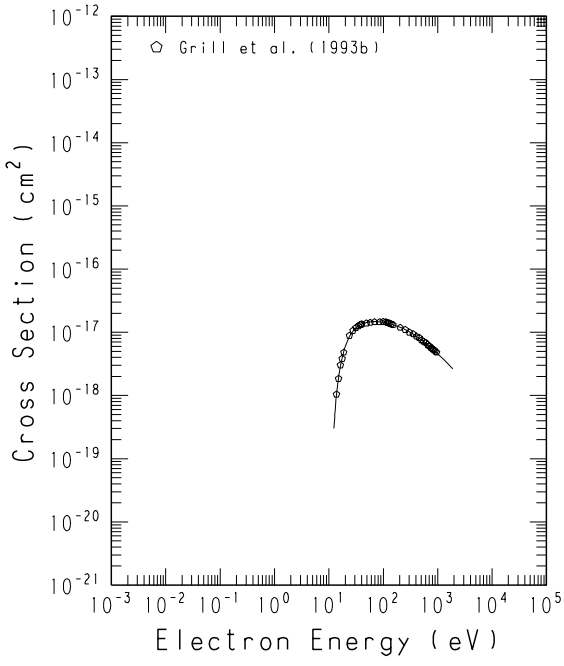
GRAPH 110

$C_3H_8^+$ Production/C_3H_8



GRAPH 112

$C_3H_6^+$ Production/C_3H_8



GRAPHS. Cross Section vs Electron Energy

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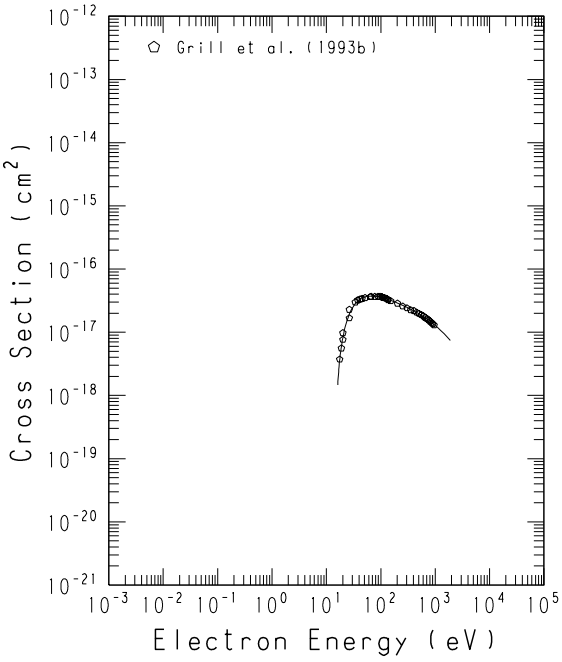
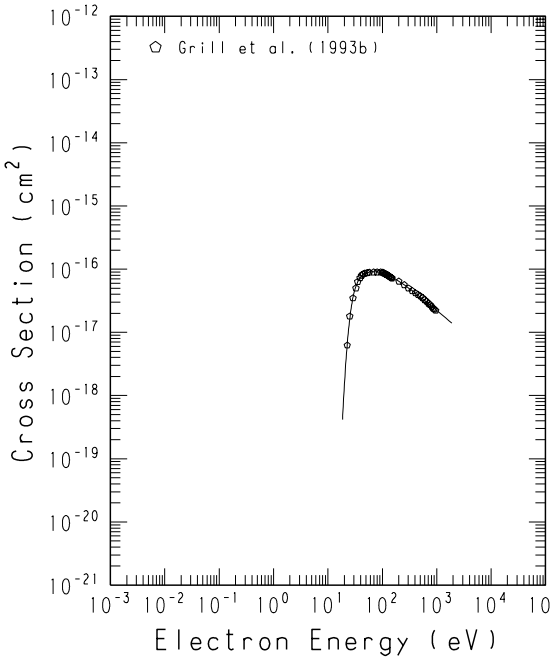
GRAPH 113

$C_3H_5^+$ Production/C_3H_8



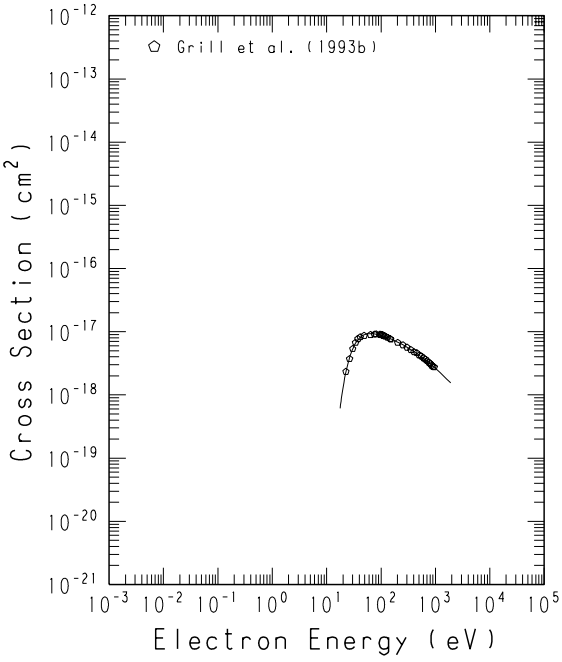
GRAPH 115

$C_3H_3^+$ Production/C_3H_8



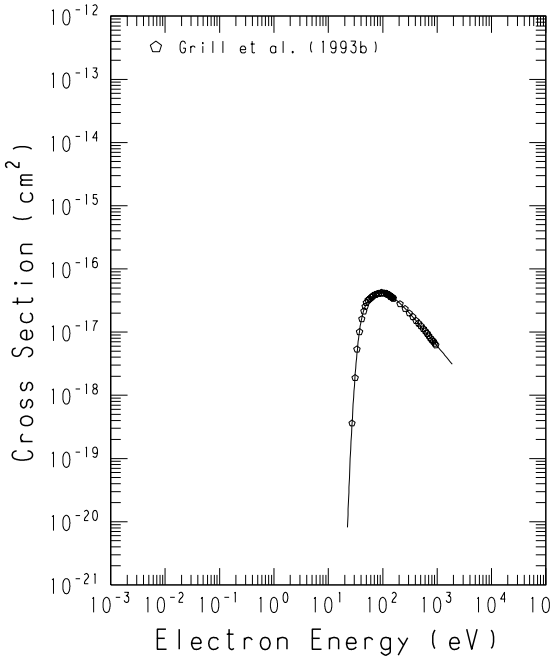
GRAPH 114

$C_3H_4^+$ Production/C_3H_8



GRAPH 116

$C_3H_2^+$ Production/C_3H_8



GRAPHS. Cross Section vs Electron Energy

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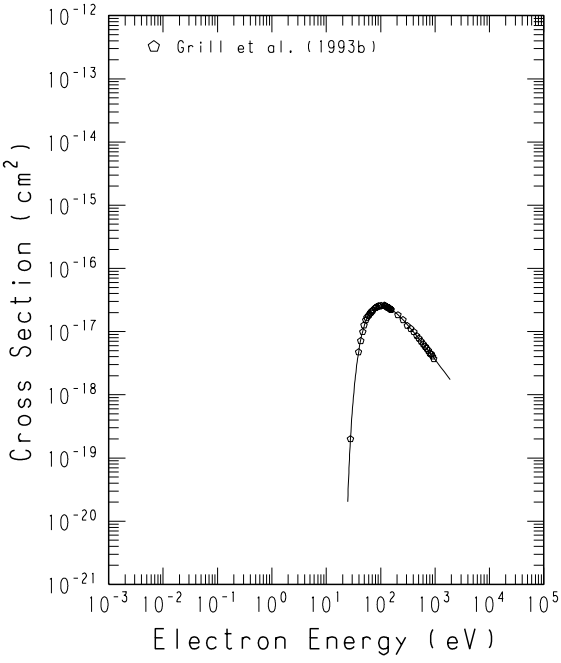
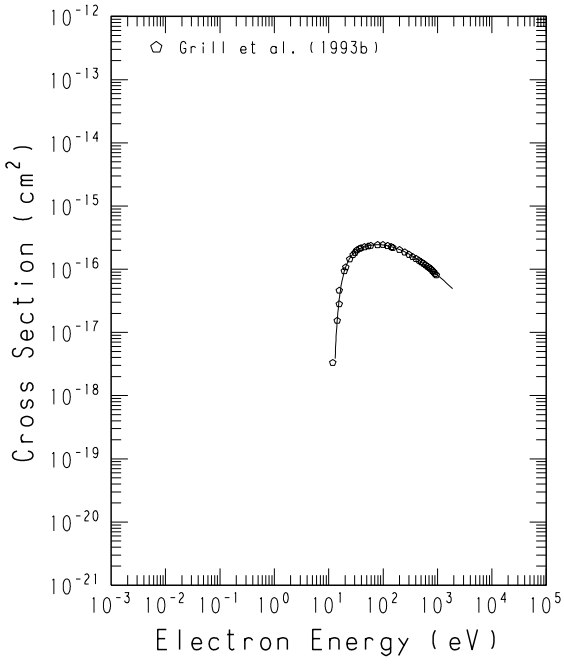
GRAPH 117

C_3H^+ Production/C_3H_8



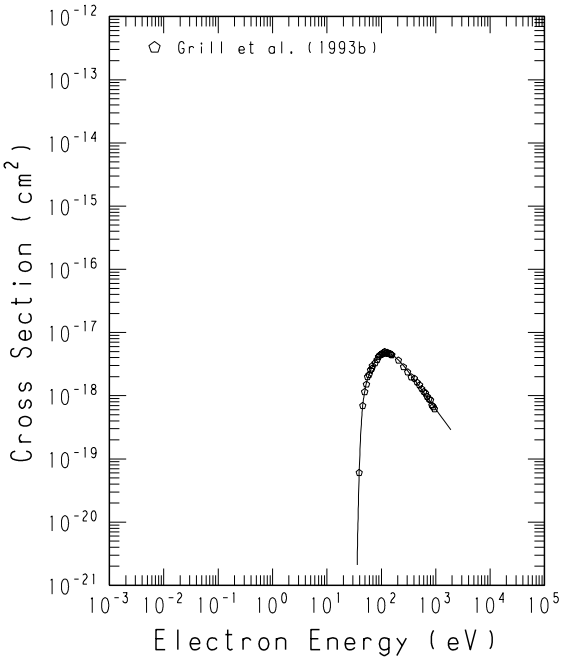
GRAPH 119

$C_2H_5^+$ Production/C_3H_8



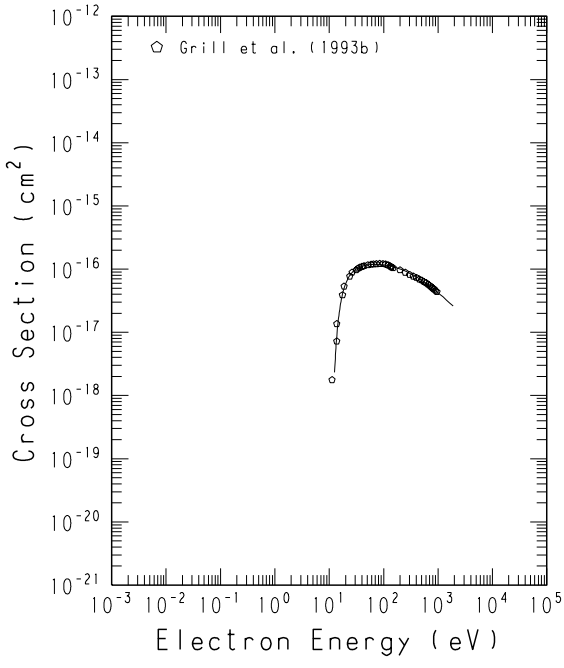
GRAPH 118

C_3^+ Production/C_3H_8



GRAPH 120

$C_2H_4^+$ Production/C_3H_8



GRAPHS. Cross Section vs Electron Energy

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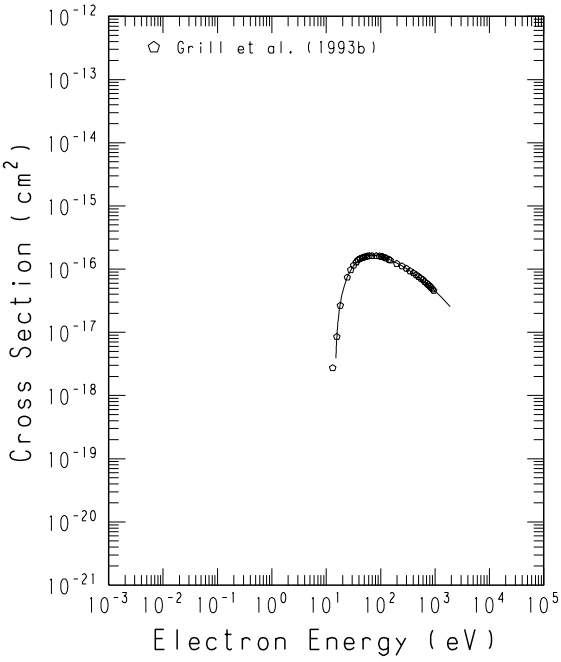
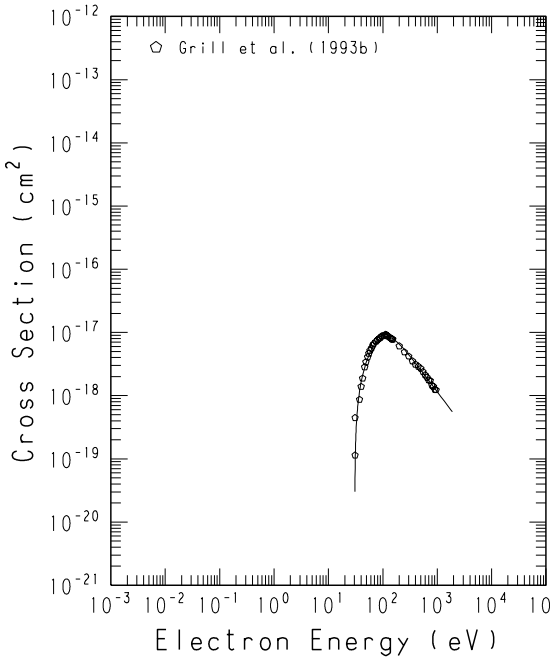
GRAPH 121

$C_2H_3^+$ Production/C_3H_8



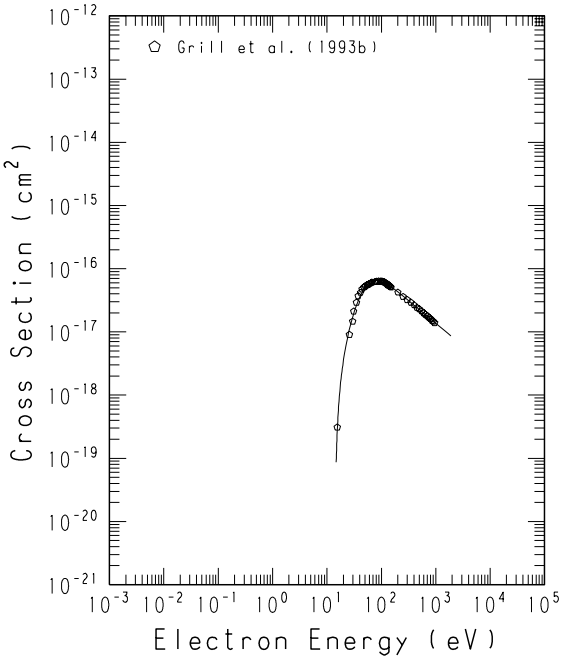
GRAPH 123

C_2H^+ Production/C_3H_8



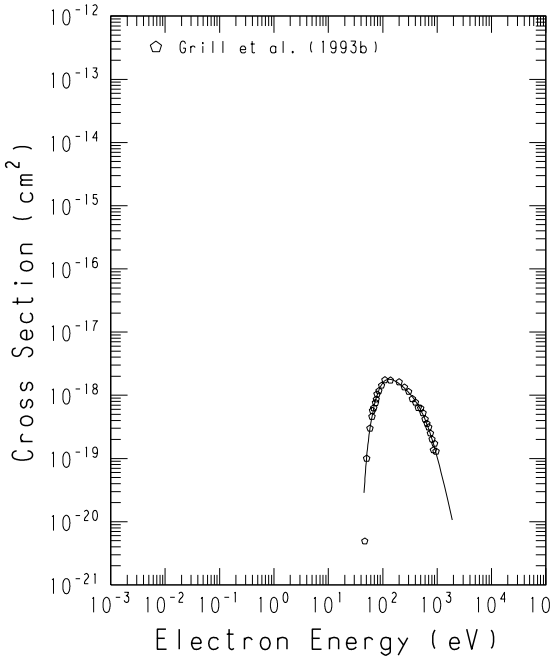
GRAPH 122

$C_2H_2^+$ Production/C_3H_8



GRAPH 124

C_2^+ Production/C_3H_8



GRAPHS. Cross Section vs Electron Energy

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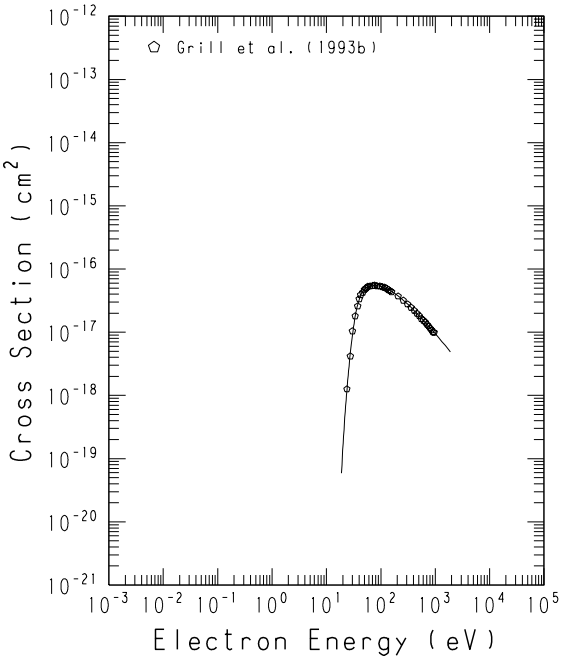
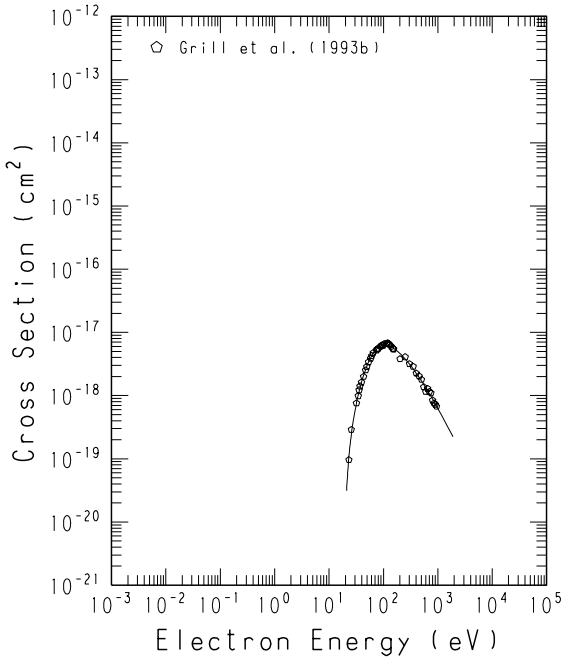
GRAPH 125

CH_3^+ Production/C_3H_8



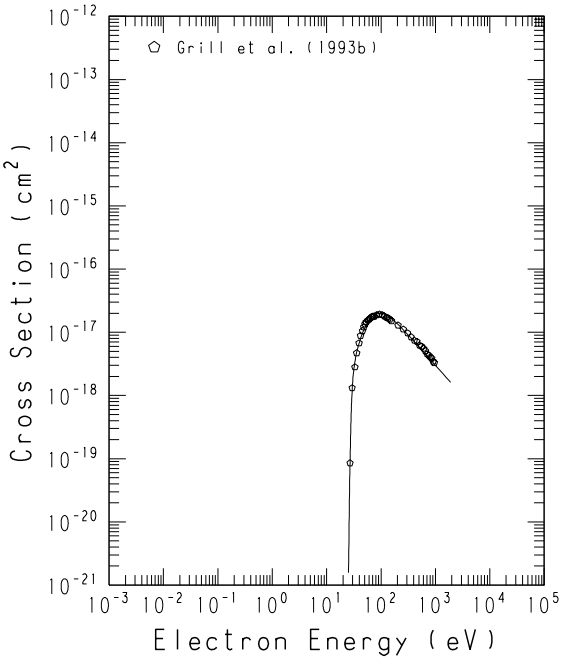
GRAPH 127

CH^+ Production/C_3H_8



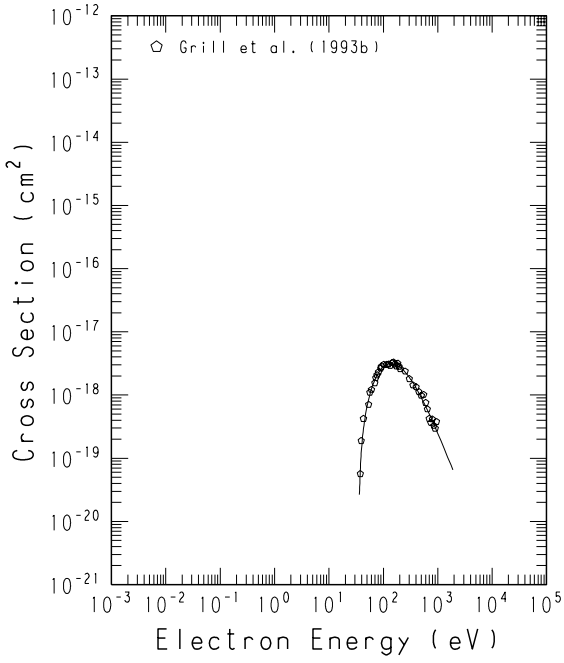
GRAPH 126

CH_2^+ Production/C_3H_8



GRAPH 128

C^+ Production/C_3H_8



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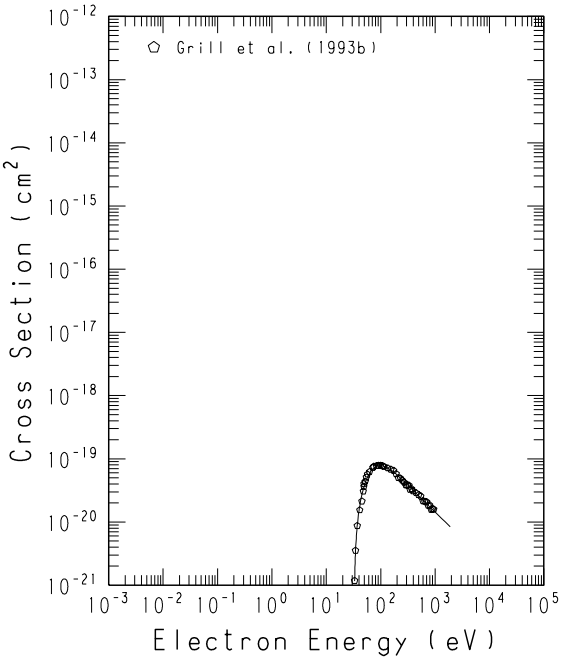
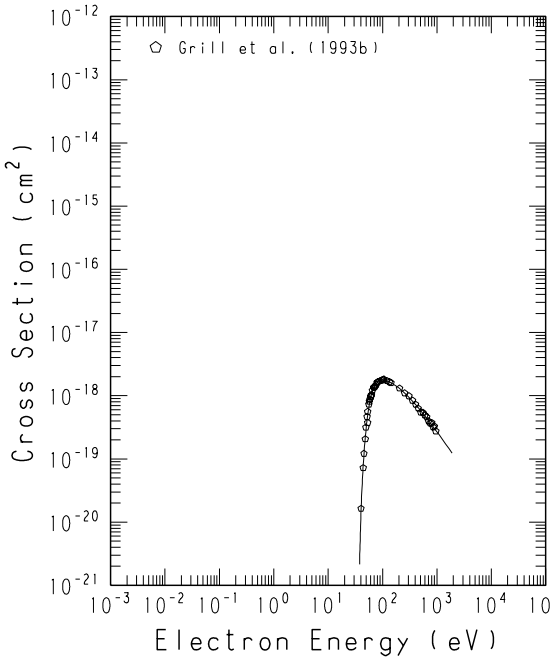
GRAPH 129

$C_3H_5^{2+}$ Production/C_3H_8



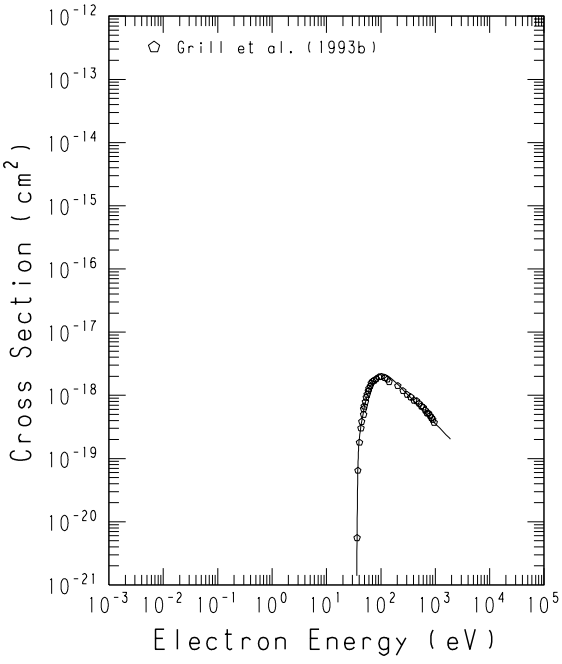
GRAPH 131

$C_3H_3^{2+}$ Production/C_3H_8



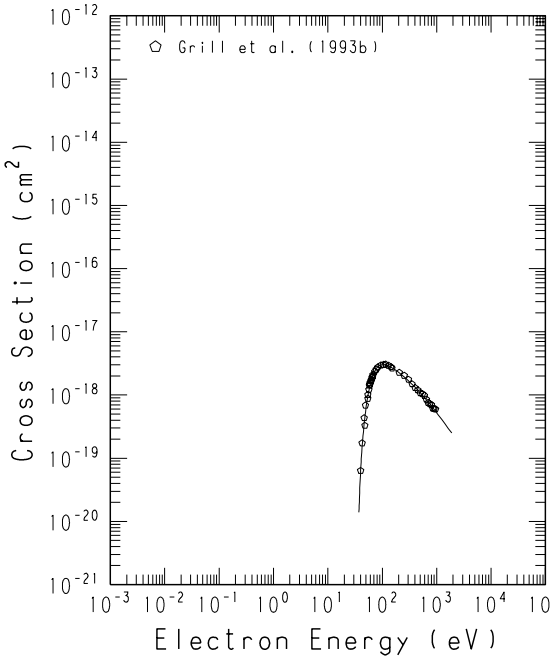
GRAPH 130

$C_3H_4^{2+}$ Production/C_3H_8



GRAPH 132

$C_3H_2^{2+}$ Production/C_3H_8



GRAPHS. Cross Section vs Electron Energy

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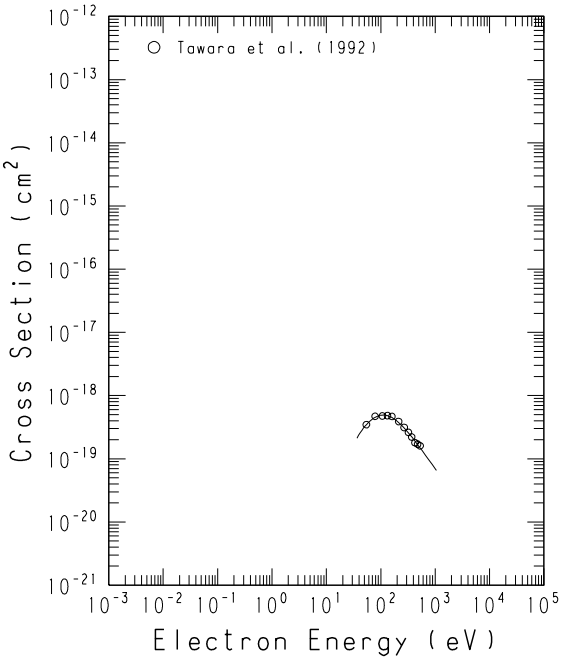
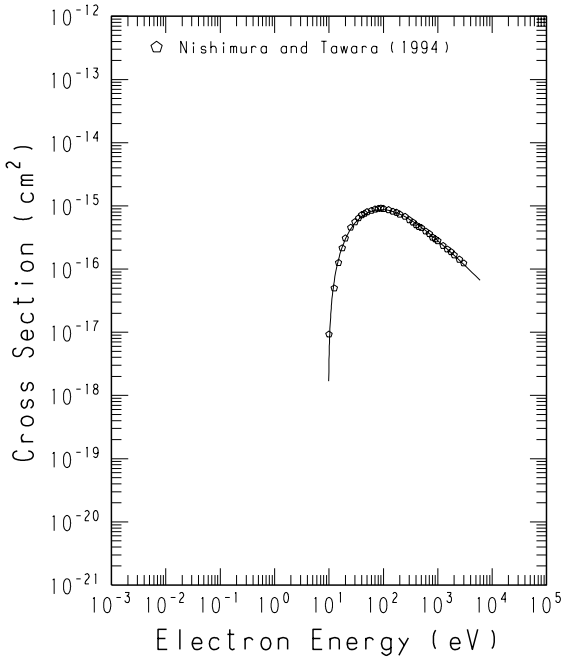
GRAPH 133

H-β Emission/C_3H_8



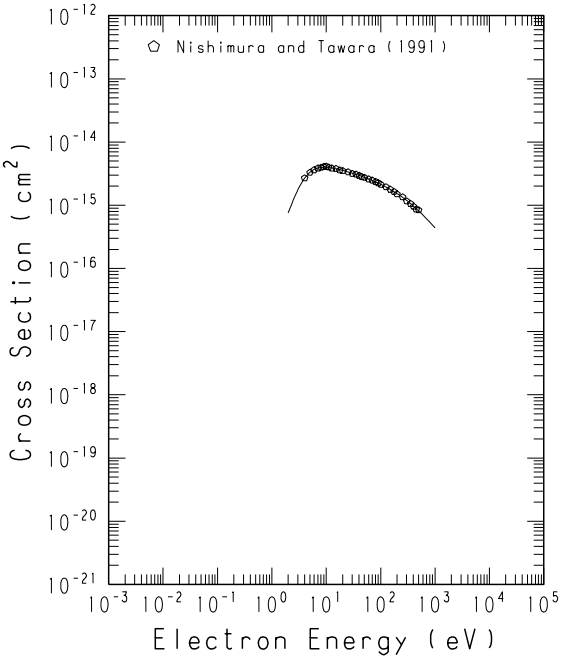
GRAPH 135

Total Ionization/C_3H_6 (propene)



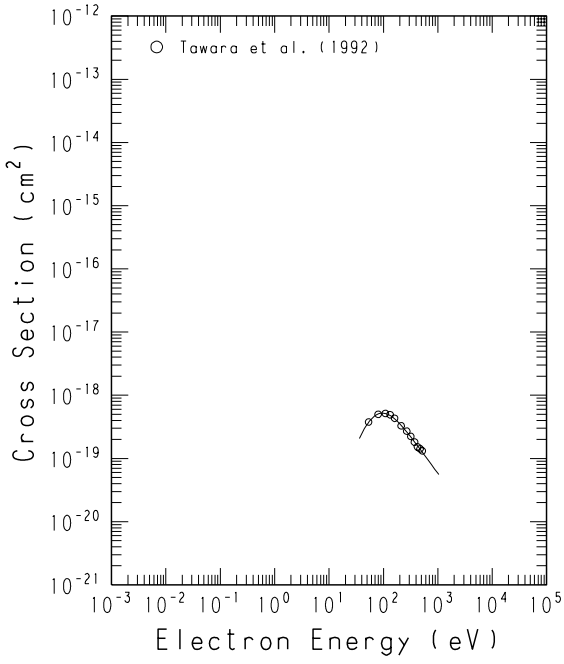
GRAPH 134

Total Scattering/C_3H_6 (propene)



GRAPH 136

H-β Emission/C_3H_6 (Propene)



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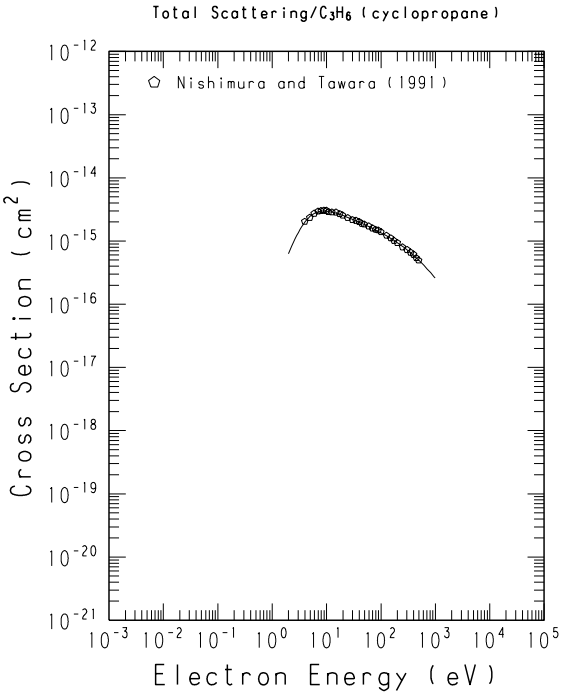
GRAPH 137



GRAPH 138