MAX-PLANCK-INSTITUT FÜR PLASMAPHYSIK

GARCHING BEI MÜNCHEN

Collisional-Radiative Model for a Carbon-Hydrogen Plasma, Part I

B. Napiontek, P. Bachmann[1], H.J. Belitz[2]

IPP 8/11 February 1997

Max-Planck-Institut für Plasmaphysik, EURATOM Association,
Boltzmannstr. 2, 85748 Garching
[1] MPI für Plasmaphysik, Bereich Plasmadiagnostik,
Mohrenstr. 41, 10117 Berlin
[2] Institut für Plasmaphysik, Forschungszentrum Jülich GmbH,
Association EURATOM-KFA, Postfach 1913, 52425 Jülich

Collisional-Radiative Model for a Carbon-Hydrogen Plasma, Part I

B. Napiontek[1] , P. Bachmann[2] , H.J. Belitz[3]

[1] Max-Planck-Institut für Plasmaphysik, Garching,
EURATOM Association, Boltzmannstr. 2,
D-85748 Garching bei München, Germany
e-mail: Napiontek@ipp.mpg.de
[2] Max-Planck-Institut für Plasmaphysik, Bereich Plasmadiagnostik,
EURATOM Association, Mohrenstr. 41,
D-10117 Berlin, Germany
e-mail: Bachmann@ipp.mpg.de
[3] Institut für Plasmaphysik, Forschungszentrum Jülich GmbH,
Association EURATOM-KFA, Postfach 1913,
D-52425 Jülich, Germany

February 12, 1997

Abstract

We present a set of rate coefficients based on a data compilation for calculating the population of ground and metastable states of carbon in a hydrogen plasma. The radiation loss and electron cooling rates are also given. Using a least square fit procedure we derived fits for all rate coefficients which are presented here and can be submitted as data file by e-mail.

We limit the range of T_e and n_e in the data fits to the conditions of the boundary layer and divertor plasmas in fusion devices. The effect of a finite density of neutral hydrogen is included. It influences the ionization balance and thus the radiation losses substantially.

Rate coefficients are given for all ground states and metastable states of carbon. Thus the results of calculations with the given data are suitable for comparisons with spectroscopic experiments. The application of the data will be demonstrated on a few examples.

Symbols

$A_{k,i}$ transition probabillity for transitions from level k to i

$B_{l,k}$ branching ratio for transitions from level l to k

$C6_{i,j}$ electron collisional coefficient, i - depopulated, j - populated state, s. page 3

$F6_i$ charge exchange radiation losses due to recombination of an ion in state i, s. page 4

$L6_{i,j}$ charge exchange recombination rate, i - initial, j - final state, s. page 4

M mach number

$R6_i$ radiation loss rate of carbon in state i (except radiation losses due to charge exchange), s. page 4

$S_{i,k}$ ionization rate, i - initial, k - final state

$S6_{i,j}$ radiation losses due to charge exchange, i - initial, j - final state s. page 4

T_e, T_i, T_H electron, ion and neutral hydrogen temperature, resp.

Z charge state

i, j, k, l indices labeling the number of the carbon state, s. page 2

n_e, n_i, n_H electron, ion and neutral hydrogen density, resp.

n_k population density of state k of carbon

$q_{i,k}$ electron collision excitation rate, i - initial, k - final level

t residence time of carbon in the plasma

v_{flow} flow velocity of carbon ions in the plasma

$\alpha_{i,k}$ total recombination rate, i - initial, k - final state, s. page 3, eq. 1

$\alpha^{CXR}, \alpha^{DR}, \alpha^{RR}$ charge exchange, dielectronic and radiative recombination rate, resp.

τ_{dwell} duration of the flow of carbon ions through the divertor plasma from the boundary layer to the target plates

Contents

1 Introduction

The mechanism of energy dispersion and erosion in the divertor is one of the main problems for future fusion devices [1]. It is therefore necessary to investigate the related phenomena both experimentally and theoretically. Due to the low density the plasma is far from thermodynamic equilibrium. Therefore a detailed analysis of atomic processes is essential. The radiation depends on collision processes leading to excited states and on the distribution of ionization stages. The latter is also important for erosion because of the charge stage dependent acceleration of ions in the sheath in front of a surface.

Besides the possibility of introducing additional impurities like neon [2] into the plasma there are always intrinsic impurities. The most important of these impurities is carbon, concerning present and next step fusion devices. Thus we confine ourselves to the behaviour of carbon in a hydrogen plasma.

In the divertor of Asdex Upgrade radiation in the visible and near UV range was measured with good spatial, temporal and spectral resolution [3]. Further more a spectrometer in the VUV spectral range was used which can also observe the divertor plasma [4]. Our aim is here to give a tool for analyzing basic features of such measurements and to conclude for effects of radiation and power balance in the divertor.

In the second chapter we will describe a 0-dimensional collisional-radiative model for carbon in a hydrogen[1] plasma. We have included metastable states, charge exchange between hydrogen and carbon ions and the finite dwell time of particles in the plasma. With this model we analyze in chapter 3 basic effects of radiation in divertor plasmas. In chapter 4 the origin of the data is given. Finally we present in chapter 7 fits to effective rate coefficients used in the collisional-radiative model which can be easily applied to other calculations, e.g. 0- or 1-dimensional codes. The comprehensive form of the data given leads to a strong reduction in programming effort.

In Part II of these investigations we will present a 0-dimensional model including the collisional-radiative model given here together with particle and energy balance to make it possible to study radiative instabilities.

---

[1] The model presented here is applicable for deuterium too, unless we will state hydrogen only.

2 Collisional-Radiative Model

We present here a collisional-radiative model for carbon in a typical divertor plasma of a tokamak. Therefore the charge exchange recombination $C^{q+} + H \rightarrow C^{(q-1)+} + H^+$ due to collisions of carbon ions with atomic hydrogen is included. The importance of this recombination process is experimentally and theoretically evident [5, 6]. The model calculates the time evolution of the population density for all ground and metastable states for all ionization stages of carbon. All levels which cannot depopulate by allowed radiative transitions are considered as metastable. Those levels are depopulated by electron collisions in the relevant parameter range considered here. Thereby the time evolution of their population densities is not directly connected to the ground state. This raised a definite ratio between the population of ground and metastable states in an equilibrium which is determined mainly by excitation by electron collisions. This ratio can be considerably influenced also by ionization and recombination depending on the rates and times considered. In the latter case it is necessary to include state-selective rates in the model. All ground and metastable states of carbon are itemized in Tab. 1. Ions and atoms in

	configuration	type	nb.
C^0 (CI)	$1s^22s^22p^2\,{}^1S$	m	1
-||-	$1s^22s^22p^2\,{}^1D$	m	2
-||-	$1s^22s^22p^2\,{}^3P$	g	3
C^+ (CII)	$1s^22s^22p\,{}^2P^o$	g	4
-||-	$1s^22s2p^2\,{}^4P$	m	5
C^{2+}(CIII)	$1s^22s^2\,{}^1S$	g	6
-||-	$1s^22s2p\,{}^3P^o$	m	7
C^{3+} (CIV)	$1s^22s\,{}^2S$	g	8
C^{4+} (CV)	$1s^2\,{}^1S$	g	9
-||-	$1s2s\,{}^1S$	m	10
-||-	$1s2s\,{}^3S$	m	11
C^{5+} (CVI)	$1s\,{}^2S$	g	12
C^{6+}	bare nucleus		13

Table 1: Ionization stages of carbon with their spectroscopic notation and all levels considered in the model. The numbers are used to label the data fits in section 7. g – ground state, m – metastable state

a metastable state can represent a substantial partition of the species. The calculations have shown that only the state 1s2s^{1}S of CV has an unessential population density in the whole parameter range and can be neglected.

In order to calculate the population densities a system of coupled differential equations has to be solved:

$$\begin{aligned}
\frac{dn_{i(Z)}}{dt} = \quad & n_e \left(\sum_{k(Z-1)} n_k S_{k,i}(T_e) - \sum_{k(Z+1)} n_i S_{i,k}(T_e) \right) \\
+ \quad & n_e \left(\sum_{k(Z+1)} n_k \alpha_{k,i}(T_e, n_e) - \sum_{k(Z-1)} n_i \alpha_{i,k}(T_e, n_e) \right) \\
+ \quad & \sum_{k(Z)} n_k (A_{k,i} + n_e q_{k,i}(T_e)) - \sum_{k(Z)} n_i (A_{i,k} + n_e q_{i,k}(T_e)) \\
+ \quad & \sum_{k(Z)} \sum_{l(Z)} n_k n_e B_{l,i} q_{k,l}(T_e) - \sum_{k(Z)} \sum_{l(Z)} n_i n_e B_{l,k} q_{i,l}(T_e), \qquad (1) \\
\alpha(T_e, n_e, n_H) = \quad & \alpha^{RR}(T_e) + \alpha^{DR}(T_e, n_e) + \alpha^{CXR}(T_e) \frac{n_H}{n_e}. \qquad (2)
\end{aligned}$$

The summation has to be done over all levels of the marked ionization stage. The time evolution of the population densities $n_{i(Z)}$ is determined by ionization ($S_{i,k}$), recombination ($\alpha_{i,k}$), transition probability for forbidden transitions ($A_{i,k}$) between metastable and ground states, excitation by electron impact ($q_{i,k}$) between these states and the rearrangement due to excitation to higher levels ($q_{i,l}$) and sequencing transition of a portion $B_{l,k}$ in another then the initial state. For the latter process excited levels up to $n = 3$ are considered for all ions. In the case of neutral carbon only excitation rates between states with dipole coupling are available. Therefore it was not possible to include in the model this kind of rearrangement for CI. Radiative (α^{RR}), dielectronic (α^{DR}) and charge exchange recombination (α^{CXR}) are taken into account as recombination processes. Thus the recombination rate (α) and with that the time evolution of the population densities depends on the density of neutral hydrogen. We assume $T_H \approx T_e$ in order to exclude the additional dependence on the mean energy of the hydrogen atoms. As far as the divertor and boundary layer plasma is concerned this is not a substandial reduction of accuracy.

In order to reduce the computing effort we provide data fits for electron collisional coefficients $C6_{i,j}$, where i, j label the depopulated and populated level, respectively. These coefficients include all processes causing an electron transfer from level i to level j mentioned above except charge exchange recombination. The charge exchange rates $L6_{i,j}$ are given separately because of there dependence on the neutral hydrogen density. In addition the radiation loss rate $R6_i$ and the electron cooling rate $S6_i$ for each level are presented. The radiation loss rate includes line and continuum radiation resulting from collisional excitation, dielectronic and radiative recombination. Bremsstrahlung was proofed to be neglectable by several orders of magnitude under plasma conditions in the divertor and the boundary layer. The electron cooling rates include excitation and deexcitation collisions, radiative and dielectronic recombination. The charge exchange recombination leads to direct radiation losses. The reason for that is the electron capture in highly excited states due to recombination in a plasma which has a low temperature compared with the ionization energy of the recombined ion. These radiation losses are given separately ($F6_i$), again to distinguish the dependencies from electron and neutral hydrogen density.

3 Application of the Model

We used the collisional-radiative model described above for the calculation of radiation losses due to carbon with special emphasis on the effect of hydrogen [7] and for the interpretation of line emission including the effect of metastable states [7, 8, 9]. To illustrate this model and the data given in the next chapter we describe here the time evolution of population densities and radiation losses.

The time evolution of radiation loss rate and mean charge state of neutral carbon entering the plasma is displayed in Fig. 1 for the case without neutral hydrogen and in Fig. 2 with a neutral hydrogen density $n_H = 0.01 \cdot n_e$. Without charge exchange recombination there is a strong dependence of radiation losses on the temperature and the dwell time of carbon in the plasma. The reduction of radiation losses of orders of magnitude is due to the dominance of He-like carbon. C^{4+} is rapidly built up by ionization but it does not contribute significantly to radiation losses. The reason is the high excitation energy of about $300\,eV$. In Fig. 2 there is no such reduction of radiation losses. The charge exchange recombination due to hydrogen establishes an equilibrium distribution of ionization stages with a considerably lower mean charge state. The time for reaching the equilibrium is much shorter then without charge exchange. The relative density of $n_H = 0.01 \cdot n_e$ is a typical value for a divertor plasma. The effect of charge exchange results in higher radiation losses due to neutral carbon entering the plasma and a reduced dependence of radiation losses on electron temperature and carbon dwell time.

The principle of increasing radiation losses in relatively cold divertor and boundary layer plasmas by reducing the portion of higher charge stages due to charge exchange recombination is also important for highly ionized carbon entering those plasma regions. Such a situation is given in a divertor tokamak where ions from the hot core plasma streaming via the boundary layer into the divertor plasma. For the discussion of the effect of charge exchange the dwell time of the ions in the divertor has to be estimated. This is the time in which the ions flow along magnetic field lines through the divertor plasma. In the divertor plasma the ions will rapidly thermalize. Therefore the temperature of the divertor plasma is also relevant for calculating the flow velocity v_{flow} of the highly ionized

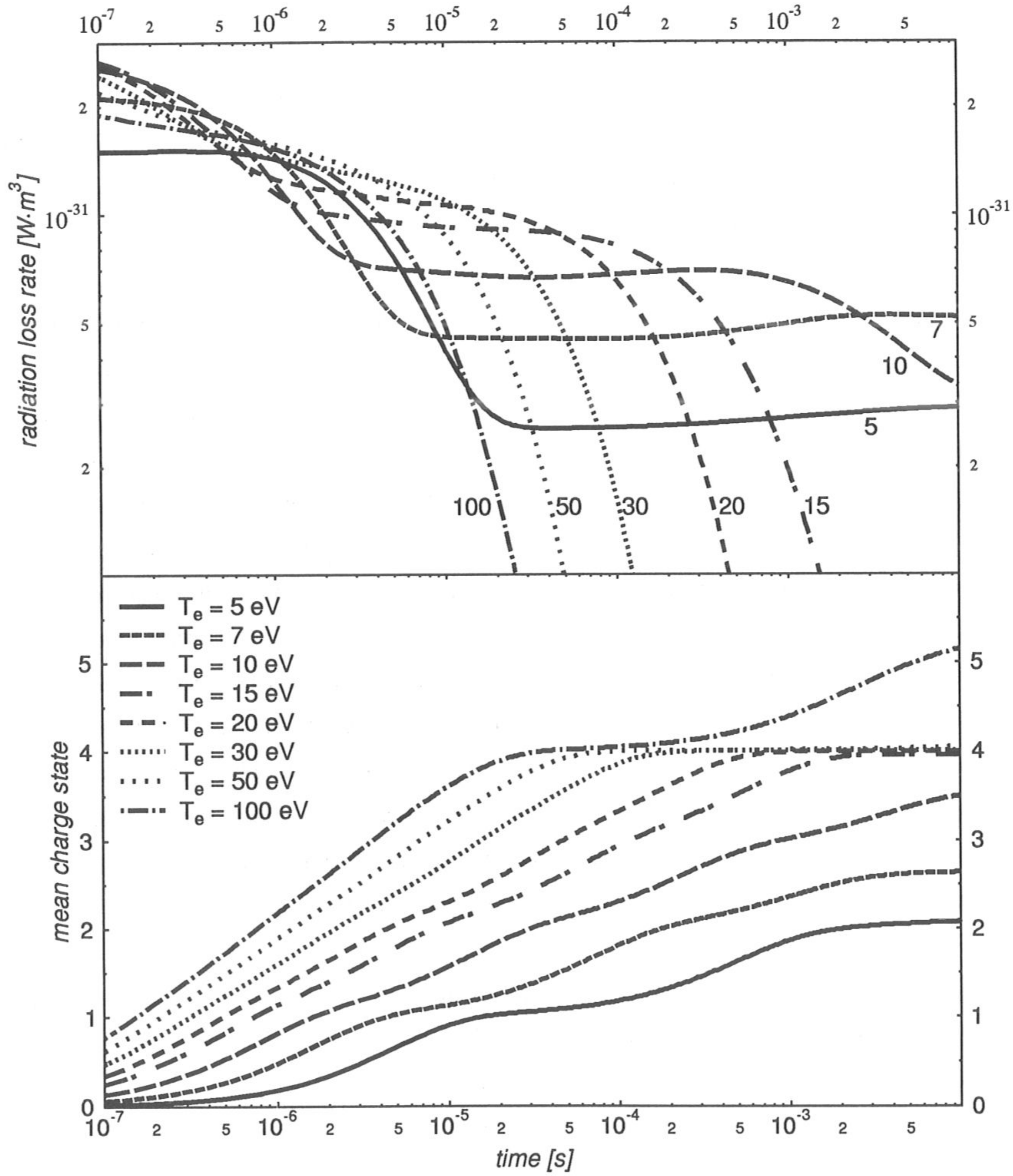

Figure 1: Time evolution of radiation losses and mean charge state of carbon for different electron temperatures. Initial state: CI, ground state; $n_e = 10^{20}\, m^{-3}$, $n_H/n_e = 0$.

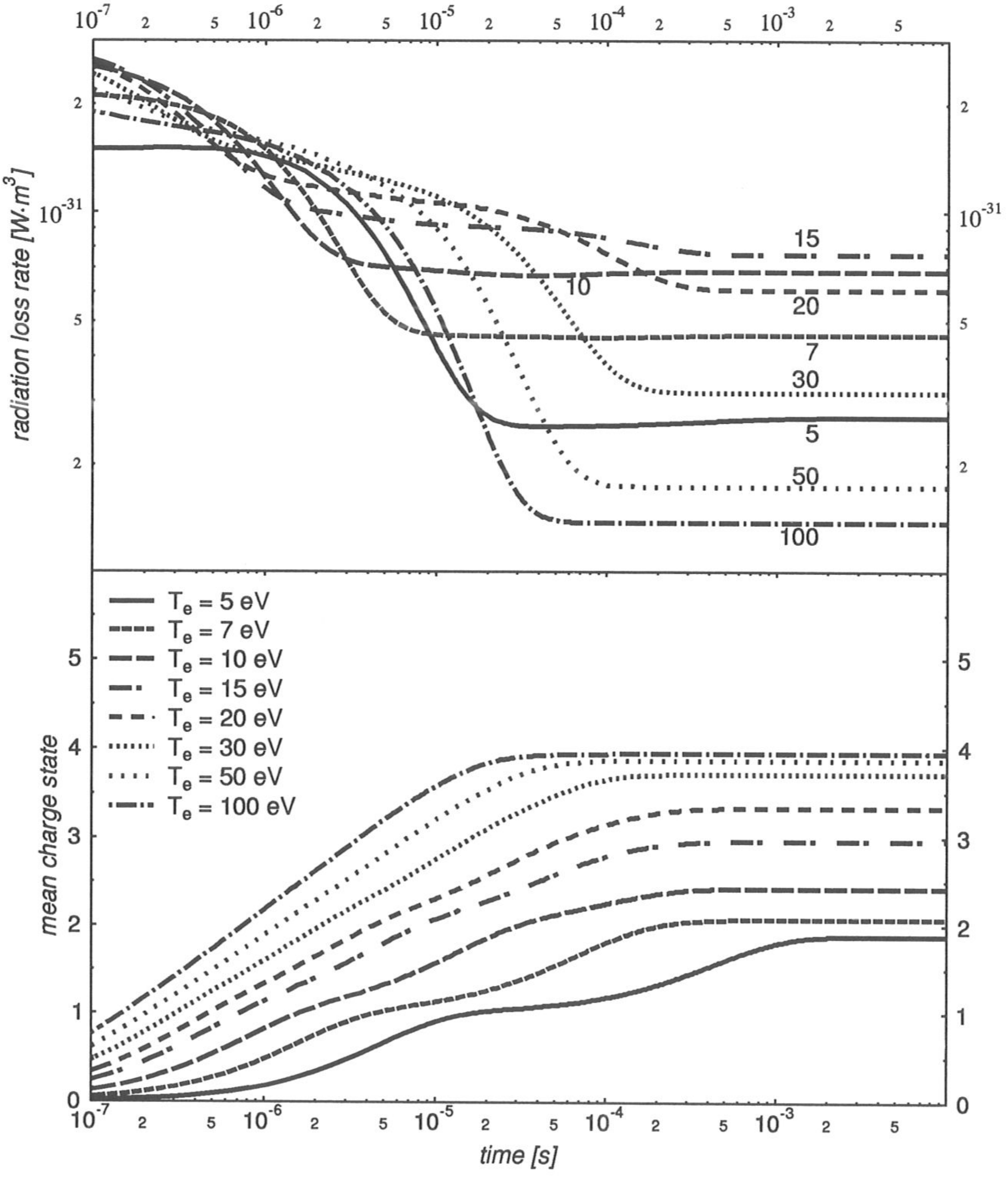

Figure 2: Time evolution of radiation losses and mean charge state of carbon for different electron temperatures. Initial state: CI, ground state; $n_e = 10^{20}\,m^{-3}$, $n_H/n_e = 0.01$.

ions to the target plate. This velocity is given by

$$v_{flow} = M \cdot v_s, \quad \text{with} \quad v_s = \sqrt{\frac{T_e + 3T_i}{m_i}} \tag{3}$$

in which M is the Mach number, v_s the velocity of sound for ions with mass m_i and temperature T_i. In the divertor of ASDEX Upgrade the Mach number was determined experimentally to be in the range $M = 0.3 \ldots 0.5$ [10]. According to a connection length through the divertor of $6\,m$ and taking the highest value for the Mach number of 0.5 the dwell time for a temperature range of $T_i = T_e = 5 \ldots 100\,eV$ is estimated as follows

$$0.21\,ms\,(100\,eV) \leq \tau_{dwell} \leq 0.95\,ms\,(5\,eV). \tag{4}$$

The time evolution of radiation losses and mean charge state for H-like carbon entering the divertor plasma is shown in Figs. 3 and 4. In Fig. 4 the dwell time of the ions is marked. The reduction of the mean charge state in Fig. 4 within the dwell time of the ions is a result of charge exchange. This follow from a comparison with the case without neutral hydrogen in Fig. 3. Hence, the ions entering the divertor through the boundary layer reach the equilibrium distribution of charge states and therefore contribute to radiation losses as efficient as the eroded carbon.

The radiation loss function in Fig. 4 has a high value even when hydrogen- or helium-like ions are dominant. This is a result of radiation originating from charge exchange. The electrons are captured in highly excited states. The excitation energy is radiated. This energy was transported from the highly ionized ions from the core plasma; there is no contribution to electron cooling in the divertor. The reduction of potential energy of the ions by recombination leads to a reduction of energy deposition on the divertor plates. In addition the ions are less accelerated in the electrical field in front of the surface due to there lower charge state. As an example the sputtering yield of carbon on tungsten is reduced two orders of magnitude by reducing the mean charge state from 5 to 2.

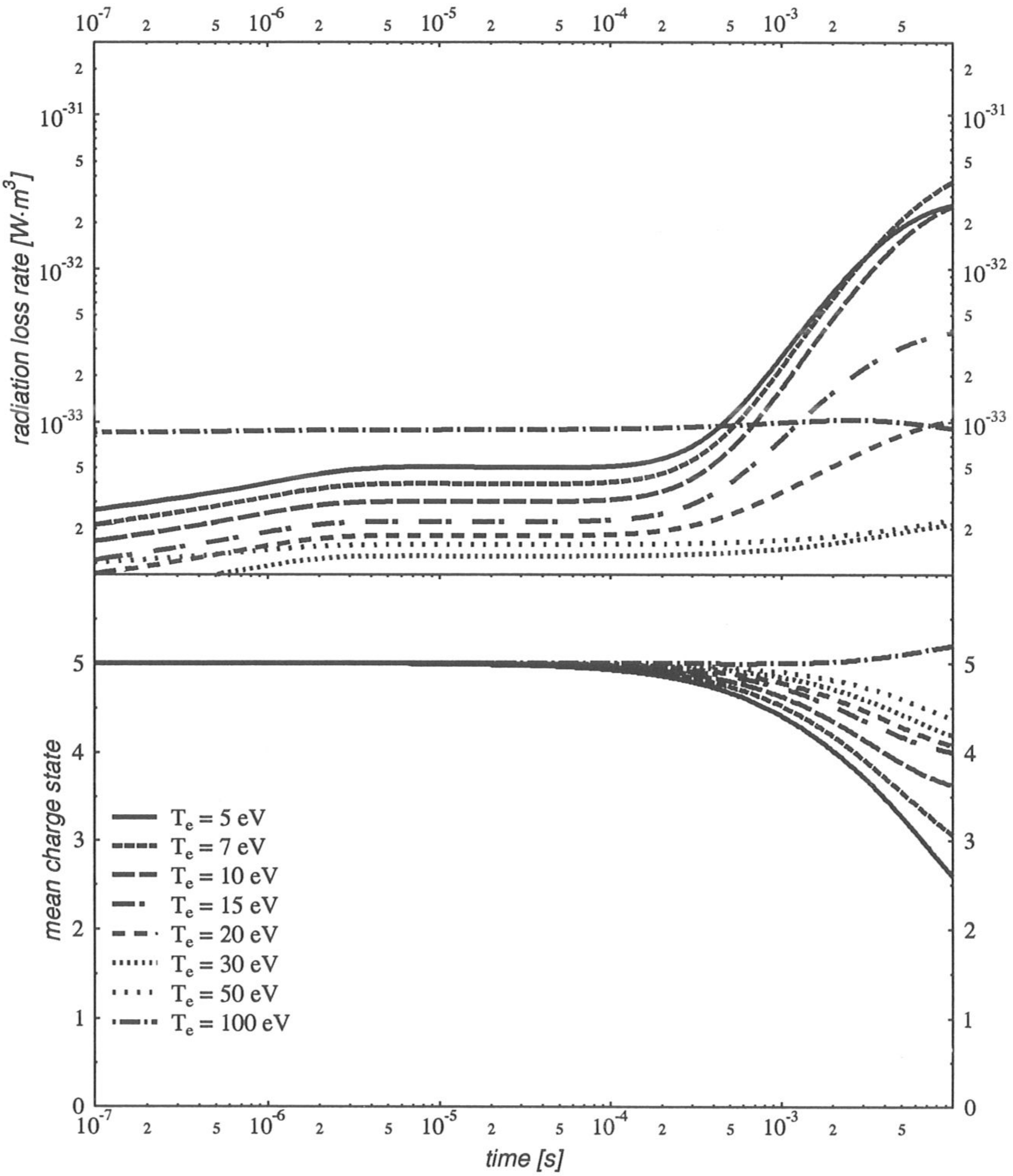

Figure 3: Time evolution of radiation losses and mean charge state of carbon for different electron temperatures. Initial state: CVI, ground state; $n_e = 10^{20}\,m^{-3}$, $n_H/n_e = 0$.

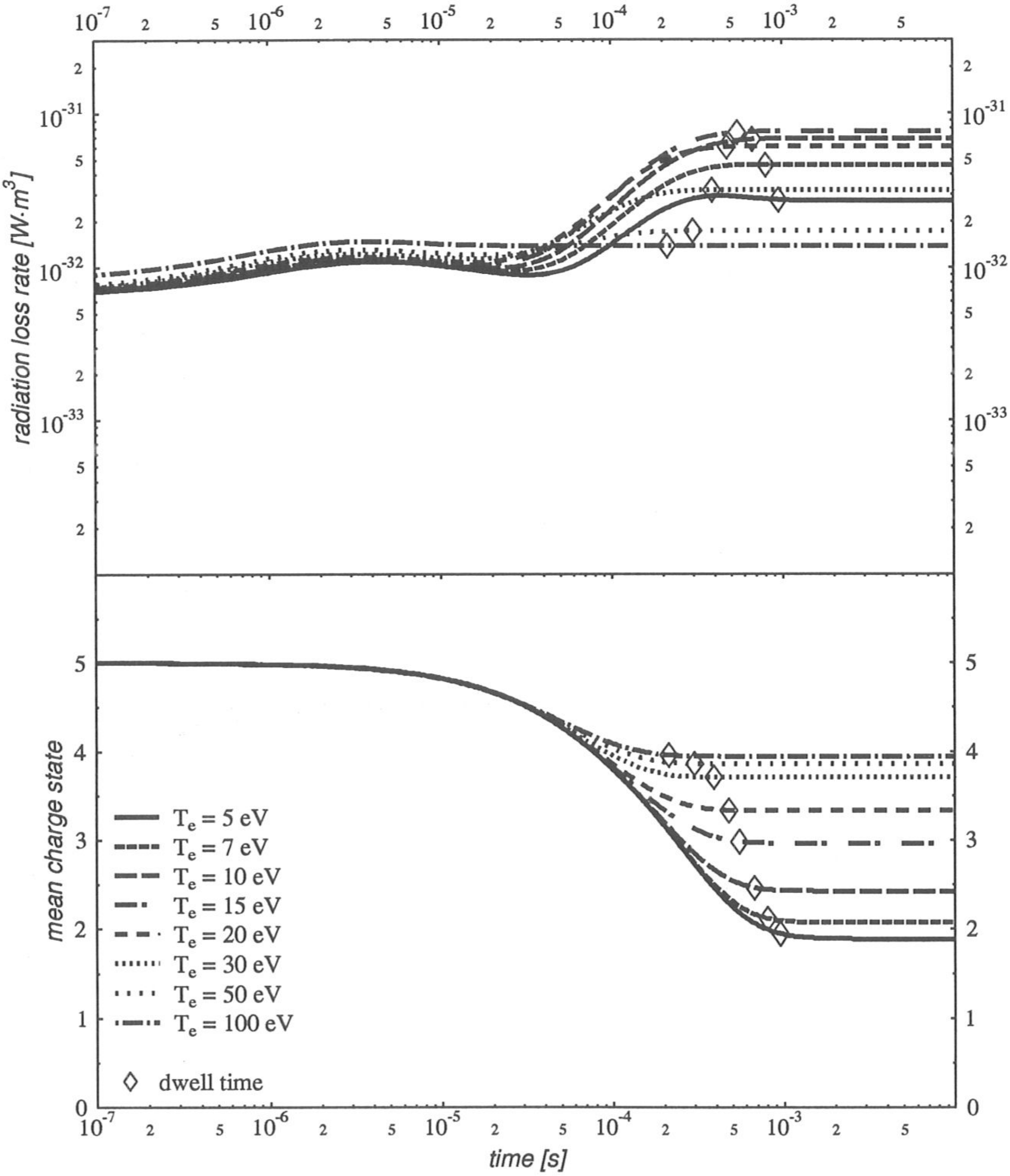

Figure 4: Time evolution of radiation losses and mean charge state of carbon for different electron temperatures. Initial state: CVI, ground state; $n_e = 10^{20}\,m^{-3}$, $n_H/n_e = 0.01$. Dwell time according to eq. 3 with $M = 0.5$, $T_i = T_e$ and a connection length along magnetic field lines between X-point and target plates of $6\,m$.

4 Data Sources

The atomic data have been taken from several sources. As a fundamental source the recommended data presented in [11] were used.

Excitation rates between ground and metastable states for ions are given in [11]. The rates for CI were taken from [12]. Excitation rates to higher levels could be taken into account only for dipole transitions. The rates were calculated with van Regemorter's formula [13] using oscillator strengths $f_{i,k}$ given in [14]:

$$q_{i,k} = \frac{1.6 \cdot 10^{-5} f_{i,k} \langle g \rangle}{E_{i,k}\sqrt{T_e}} \, e^{-\frac{E_{i,k}}{T_e}}, \tag{5}$$

Here $E_{i,k}$ is the excitation energy and $\langle g \rangle$ is the mean gaunt factor which is set equal 1 for neutral carbon. Excitations up to levels with principal quantum number $n = 10$ are calculated according to this approximation. This simple approach is adequate, because the contribution of CI to the whole carbon radiation persists small in the considered range of electron temperature $T_e \geq 5\,eV$ due to short ionization time. For all ions excitation rates up to $n = 3$-levels were considered in an exact manner. All rates not contained in [11] were completed by using data given in [15, 16]. In addition some rates for CII and CIII taken from the ADAS data base [17] were included. Transitions between $n = 1, 2, 3$-levels give raise to the essential partition of line radiation and to the rearrangement of electrons between ground and metastable states. As a correction of line radiation excitation rates for optically allowed transitions for all ions up to $n = 10$-levels are included in the model according to the method described by Post et al. in [18]. The rates were calculated using eq. (5) with $f_{i,k}$ and $\langle g \rangle$ according to the equations given in [18]. As a value for $E_{i,k}$ the mean energy of all levels with principal quantum number n was used [19].

In order to determine state-selective ionization rates the method described by Behringer et al. in [20] was used. This method based on a semi-empirical formula for ionization rate S_i from a state i:

$$S_i(T_e) = 1.0885 \cdot 10^{-8} \frac{C\omega(T_e)\xi_i}{T_e E_i} \int_{E_i/T_e}^{\infty} \frac{e^{-x}}{x}\, dx, \tag{6}$$

where E_i is the binding energy of state i and ξ_i is the number of electrons in this state. C is a constant scaling factor, ω describes a scaling depending on T_e with respect to measured or calculated values. This scaling leads to an improved formula especially for low electron temperatures. Since in contrast to investigations carried out in the boundary layer plasma in front of a limiter [20] the inequality

$$\frac{E_i}{T_e} \ll 1 \tag{7}$$

does not hold for conditions found in a divertor plasma, so $\omega \equiv 1$ is not applicable here. Therefore $\omega(T_e)$ was calculated under the condition that the summed ionization rate from ground state has to match the rate given in [11].

The rates for radiative recombination were calculated using the formula

$$\alpha^{RR} = 1.9 \cdot 10^{-13} \frac{q}{2} \sqrt{\frac{q^2}{T_e}} \left[1 - e^{-\frac{E_i}{T_e}\left(1+\frac{1}{n}\left(\frac{\eta}{n_i^2}-1\right)\right)} \right] \sqrt{\left(ln\,\frac{E_i}{T_e}\right)^2 + 2} \tag{8}$$

which is given in [21]. Here n is the principal quantum number, η the number of holes in the outermost incomplete shell, q is the charge of the ion and E_i the ionization energy of the recombined ion. The partitioning into ground and metastable states of the recombined ion was made according to the statistical weights taking into account the different ionization energies of the final states.

Dielectronic recombination was included using the data set calculated by Hahn [22, 23]. The lowering of the rates due to collisions between free electrons with an captured electron in a state with high n was considered following Burgess and Seaton (s. [18]). The ratio of rates from ground and metastable states could be taken from [24] for C^+ and C^{2+}. Only for C^+ there is a preferred recombination into ground state terms because of the low lying autoionizing states in the quartet system [25]. In the case of He-like carbon dielectronic recombination from metastable states can be neglected in the parameter range of relevance here. In spite of the fact that the cross sections for these process have a maximum at very low energies [26, 27] the rates are about two orders of magnitude lower than electron excitation rate to the state $1s2p^1P$. The latter process is followed by a transition to the ground state. A further excitation to a metastable state can be neglected due to the large energy separation from ground state of about $300\,eV$.

Charge exchange recombination of carbon ions due to collisions with atomic hydrogen is included in the model using the rates given in [11]. The total rates were divided into state-selective rates by means of state-selective cross sections compiled in [28, 29].

The formulation of the model and the data used therein allow the use of the model in the range

$$5\,eV \leq T_e \leq 200\,eV, \quad n_e \lesssim 2 \cdot 10^{20}\,eV, \tag{9}$$

and finite density n_H of atomic hydrogen. The lower temperature limit is given by the range of validity of the rate coefficients. The upper limit describes the interesting range for divertor and scrape off layer plasmas. It is not a serious problem to enlarge the upper temperature limit. Essentially the complicated temperature dependence of state-selective charge exchange rate coefficients has to be considered. The limit of the electron density follows from the neglection of three-body recombination. With the exception of very low electron temperatures the parameter range of T_e, n_e and n_H includes all relevant conditions for divertor and scrape off layer plasmas.

5 Outline of Fit Procedure

Using a least square fit procedure we derived fits for all rate coefficients so that these processes can be evaluated easily in numerical codes (cp. [30]). At first this concerns the following rate coefficients which represent functions $f(x)$ of one variable x:

$$f(x): \; L6(T_e), \; S6(T_e), \; R6(T_e), \; F6(T). \tag{10}$$

The polynomial fits are made for $\ln f$ in terms of $\ln x$:

$$\ln f(x) \; = \; \sum_{n=0}^{NPOL} \; a(n) \; (\ln x)^n. \tag{11}$$

Second we prepared double polynomial fits for the remaining rate coefficients which are functions $f(x,p)$ of two variables where the second one p is considered as parameter:

$$f(x,p): \; C6(T_e, n_e). \tag{12}$$

The 9×9 double polynomial fits are calculated for $\ln f$ in terms of $\ln x$ and $\ln p$:

$$\ln f(x,p) \; = \; \sum_{m=0}^{NPOLP} \; \sum_{n=0}^{NPOLX} \; b(n,m) \; (\ln x)^n \; (\ln p)^m; \; NPOLX = 8, \; NPOLP = 8. \tag{13}$$

All rate coefficient are displayed in chapter 6. The fit parameters $NPOL, a(n)$ for (10) and $b(n,m)$ for (13) are tabulated in chapter 7. They can be provided as data file corac.dat and submitted by e-mail.

6 Figures for the Rate Coefficients

6.1 $C6_{i,j}$ – Electron collisional coefficients

$$matrix\ \ C6\ \ =$$

0	$c_{1,2}$	$c_{1,3}$	$c_{1,4}$									
$c_{2,1}$	0	$c_{2,3}$	$c_{2,4}$									
$c_{3,1}$	$c_{3,2}$	0	$c_{3,4}$	$c_{3,5}$								
$c^*_{4,1}$	$c^*_{4,2}$	$c^*_{4,3}$	0	$c_{4,5}$	$c_{4,6}$	$c_{4,7}$						
$c^*_{5,1}$	$c^*_{5,2}$	$c^*_{5,3}$	$c_{5,4}$	0		$c_{5,7}$						
			$c^*_{6,4}$	$c^*_{6,5}$	0	$c_{6,7}$	$c_{6,8}$					
			$c^*_{7,4}$	$c^*_{7,5}$	$c_{7,6}$	0	$c_{7,8}$					
					$c^*_{8,6}$	$c^*_{8,7}$	0	$c_{8,9}$	$c_{8,10}$	$c_{8,11}$		
							$c^*_{9,8}$	0	$c_{9,10}$	$c_{9,11}$	$c_{9,12}$	
							$c_{10,8}$	$c^*_{10,9}$	0	$c_{10,11}$	$c_{10,12}$	
							$c_{11,8}$	$c^*_{11,9}$	$c_{11,10}$	0	$c_{11,12}$	
								$c^*_{12,9}$	$c_{12,10}$	$c^*_{12,11}$	0	$c_{12,13}$
											$c_{13,12}$	0

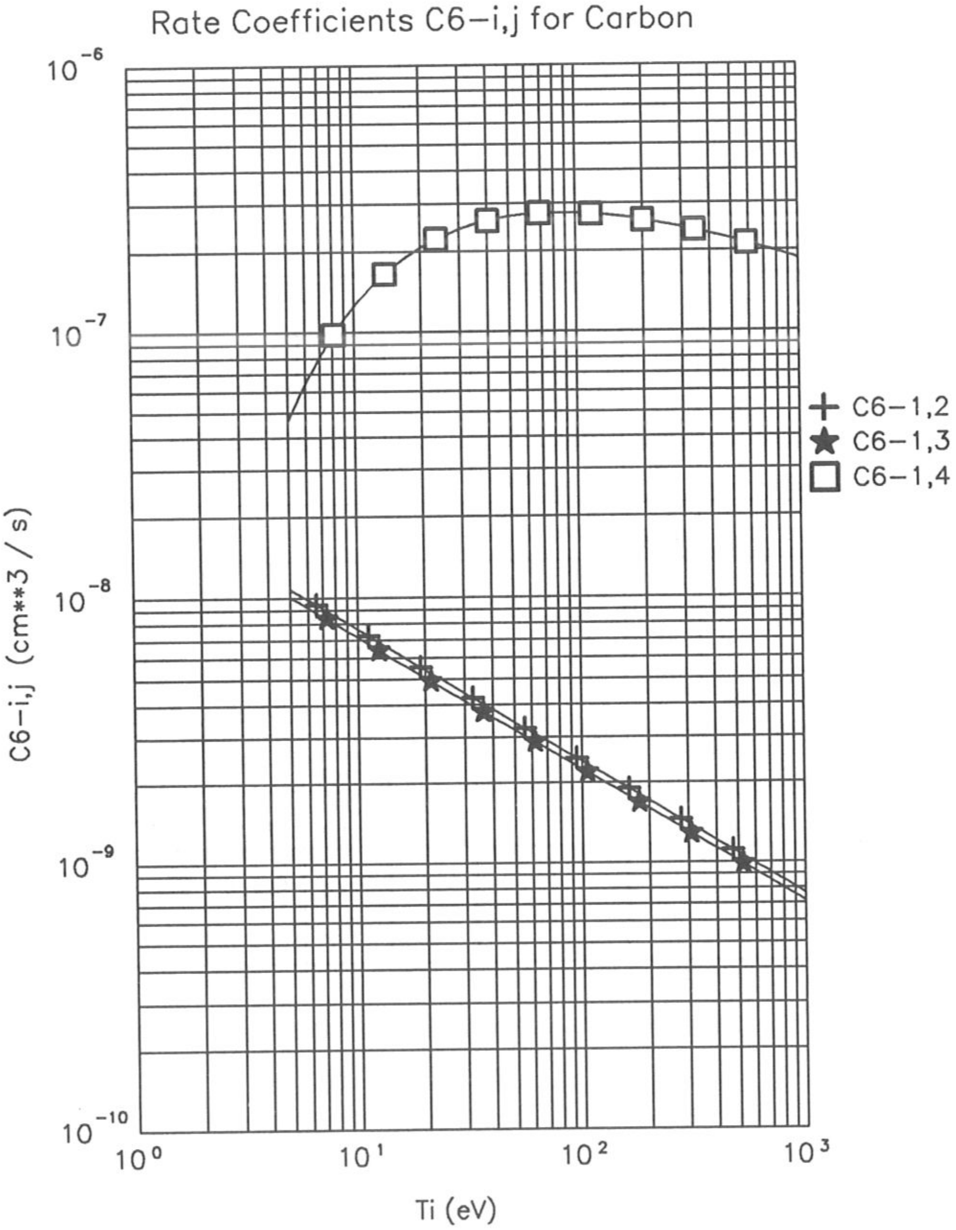

Figure 5: Electron collisional coefficients $C6_{1,2}$, $C6_{1,3}$, $C6_{1,4}$

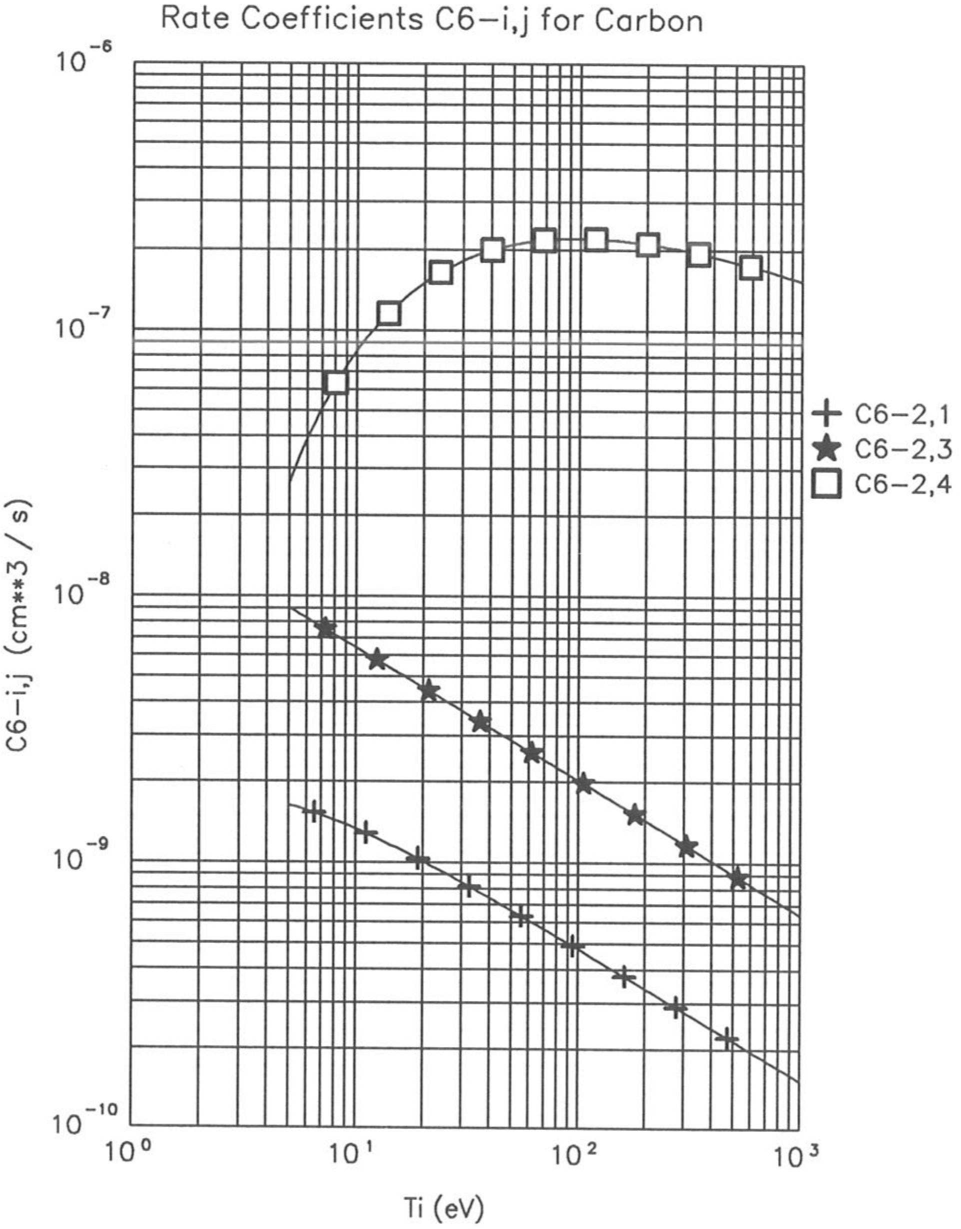

Figure 6: Electron collisional coefficients $C6_{2,1}$, $C_{2,3}$, $C6_{2,4}$

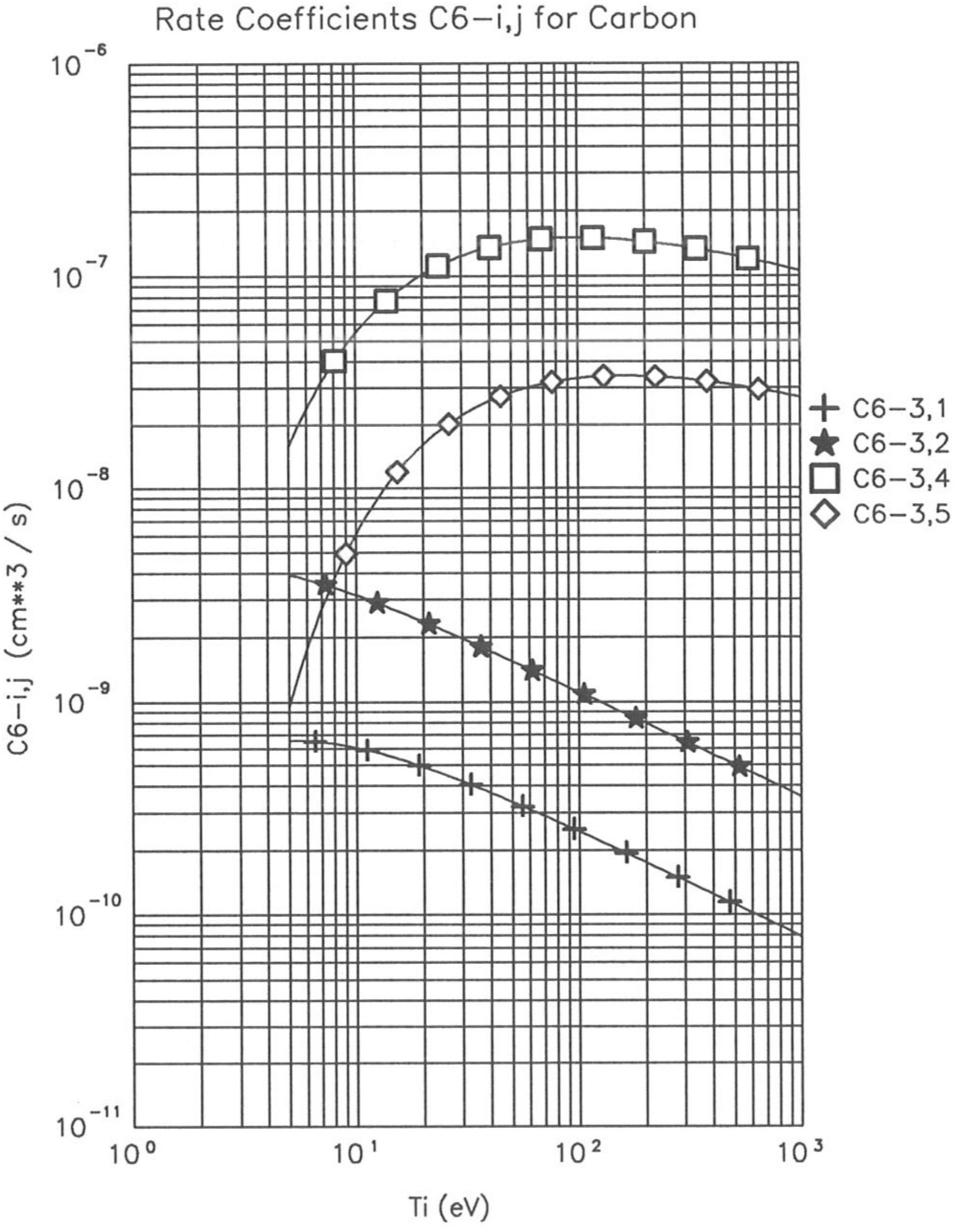

Figure 7: Electron collisional coefficients $C6_{3,1}$, $C_{3,2}$, $C6_{3,4}$, $C6_{3,5}$

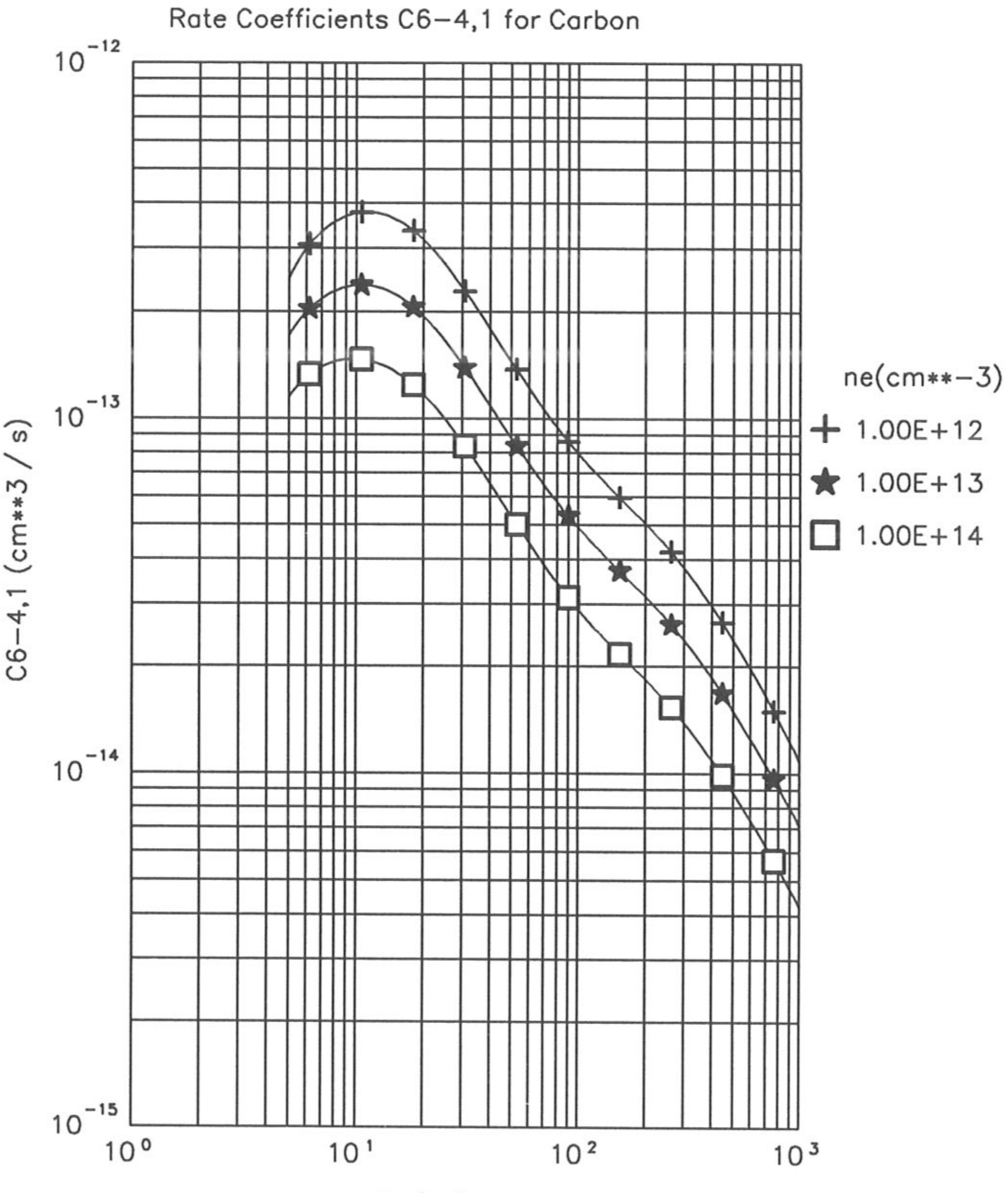

Figure 8: Electron collisional coefficient $C6_{4,1}$

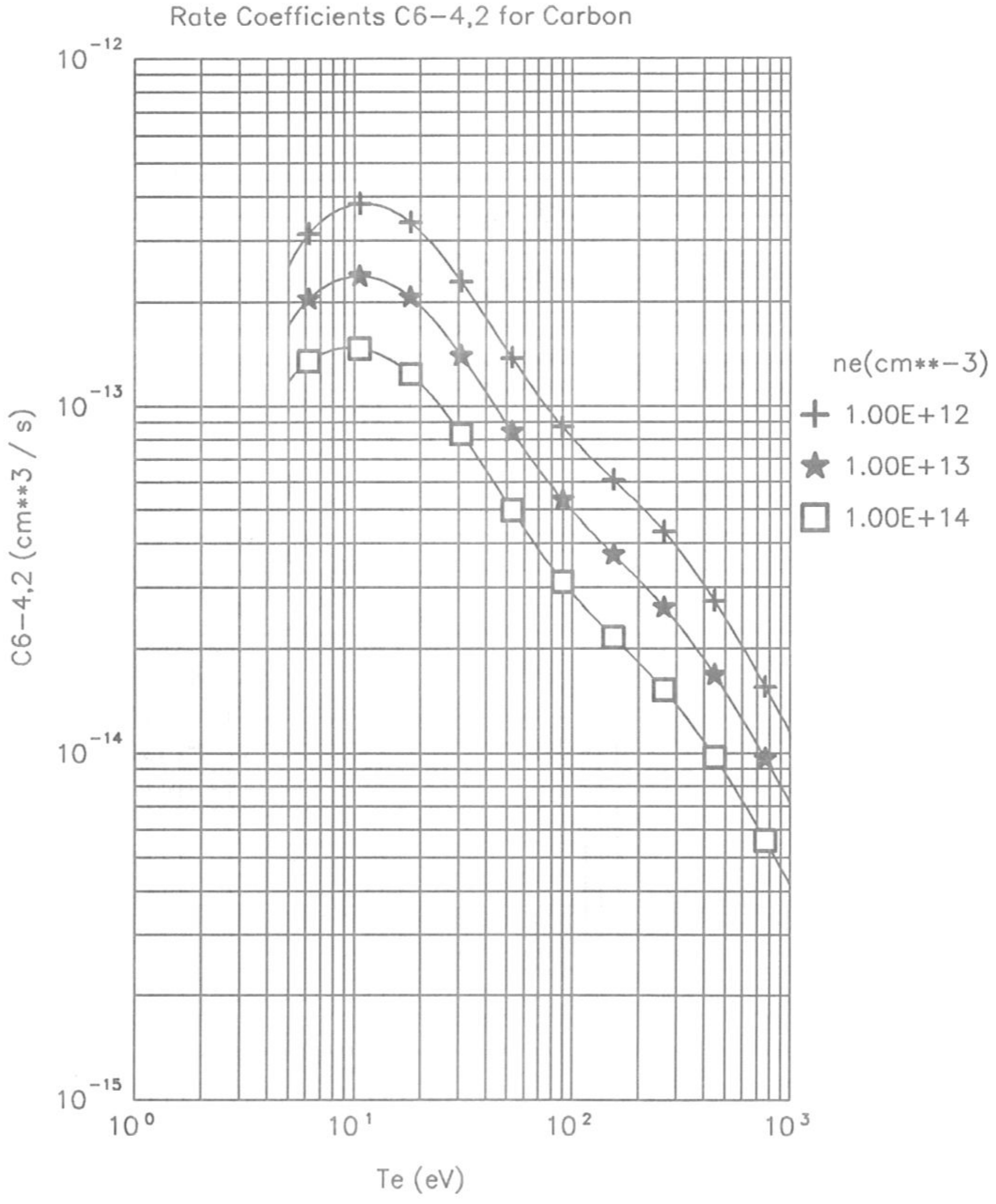

Figure 9: Electron collisional coefficient $C6_{4,2}$

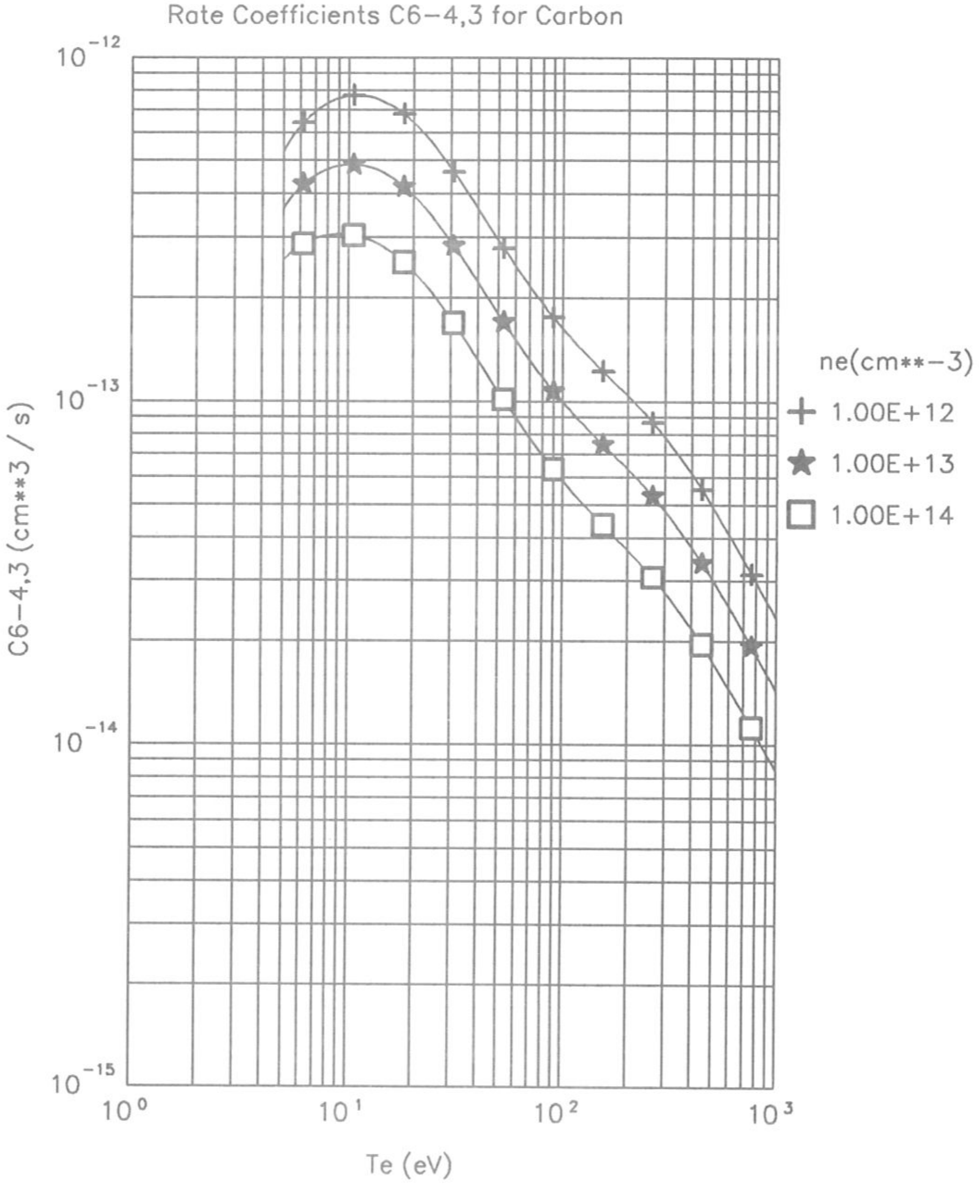

Figure 10: Electron collisional coefficient $C6_{4,3}$

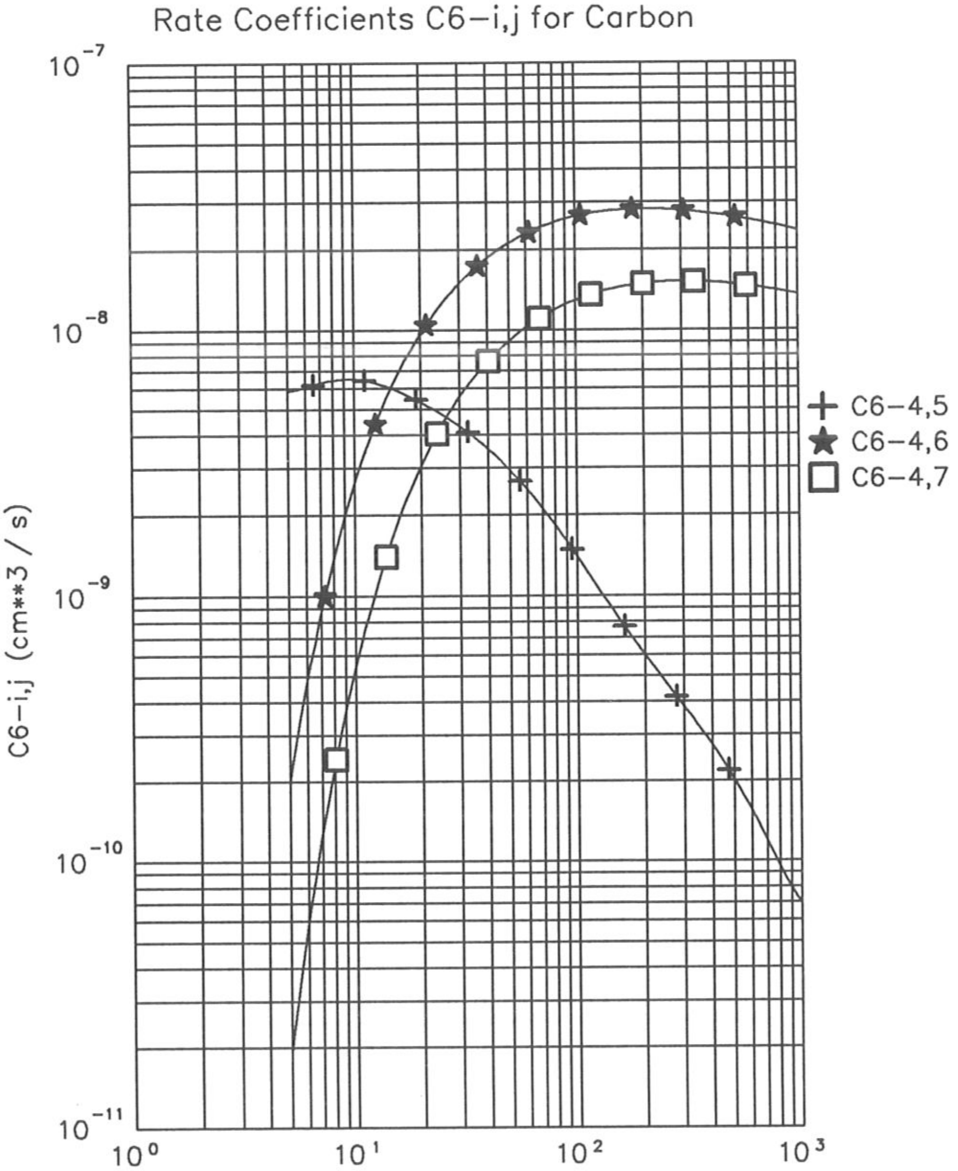

Figure 11: Electron collisional coefficients $C6_{4,5}$, $C6_{4,6}$, $C6_{4,7}$

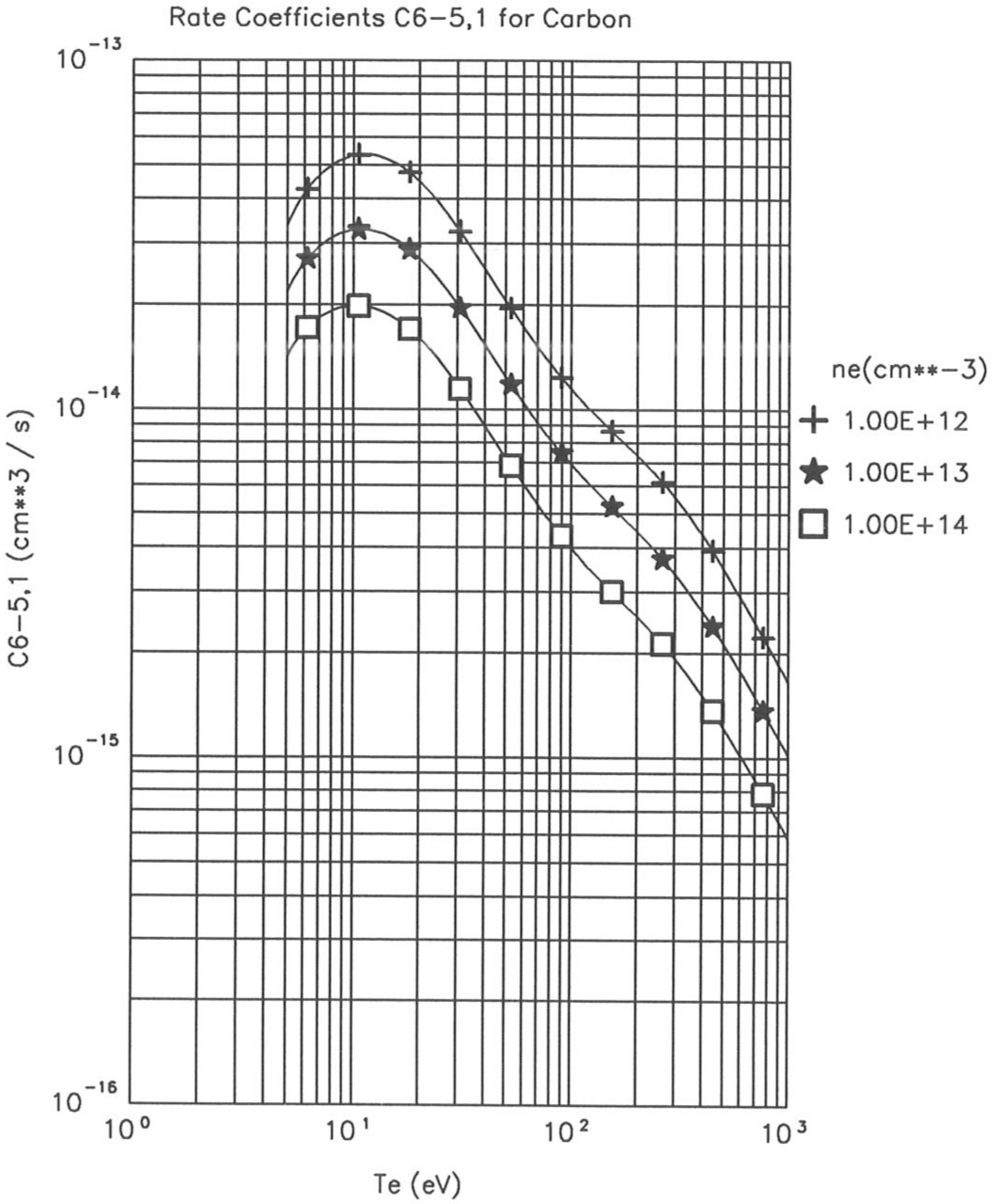

Figure 12: Electron collisional coefficient $C6_{5,1}$

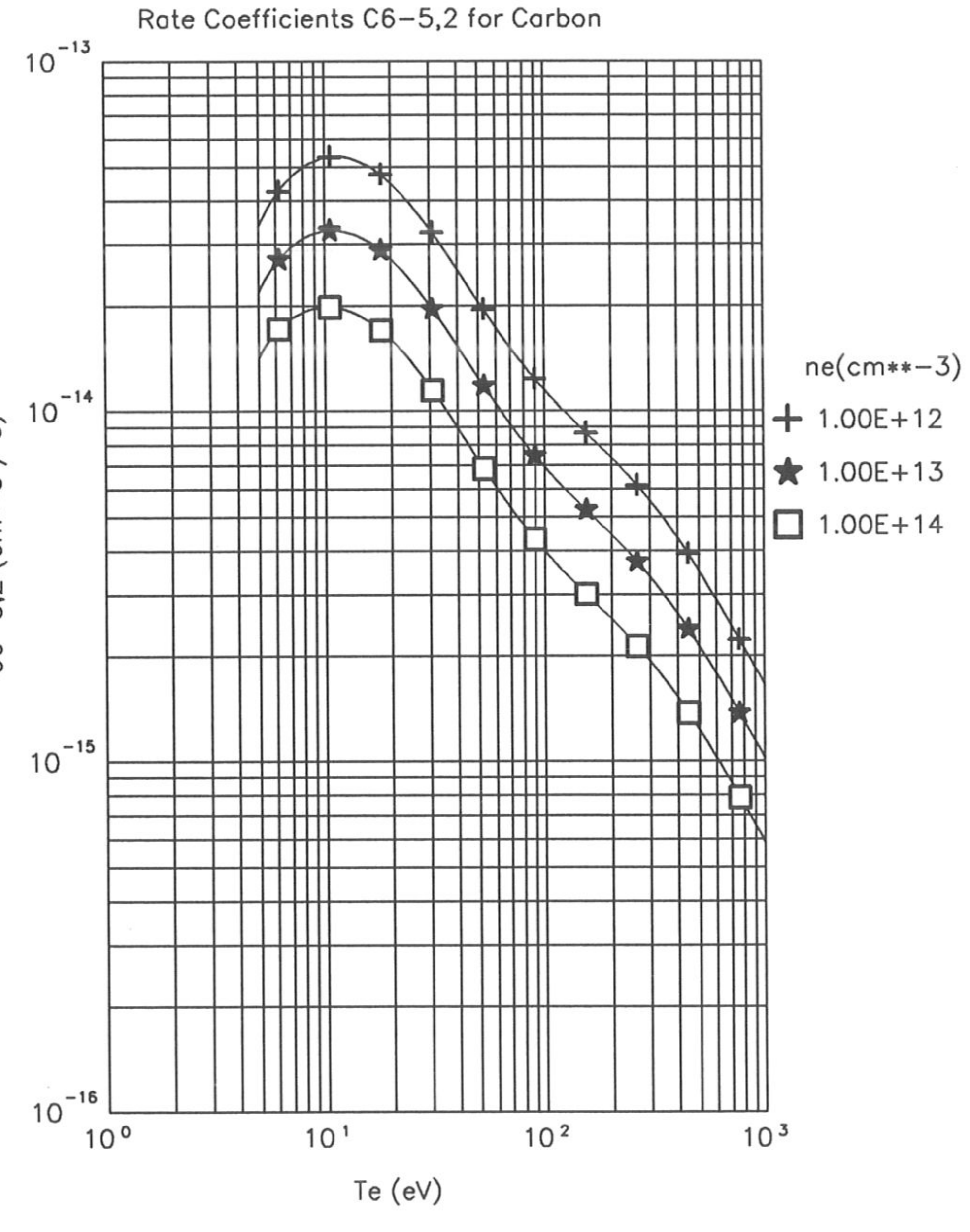

Figure 13: Electron collisional coefficient $C6_{5,2}$

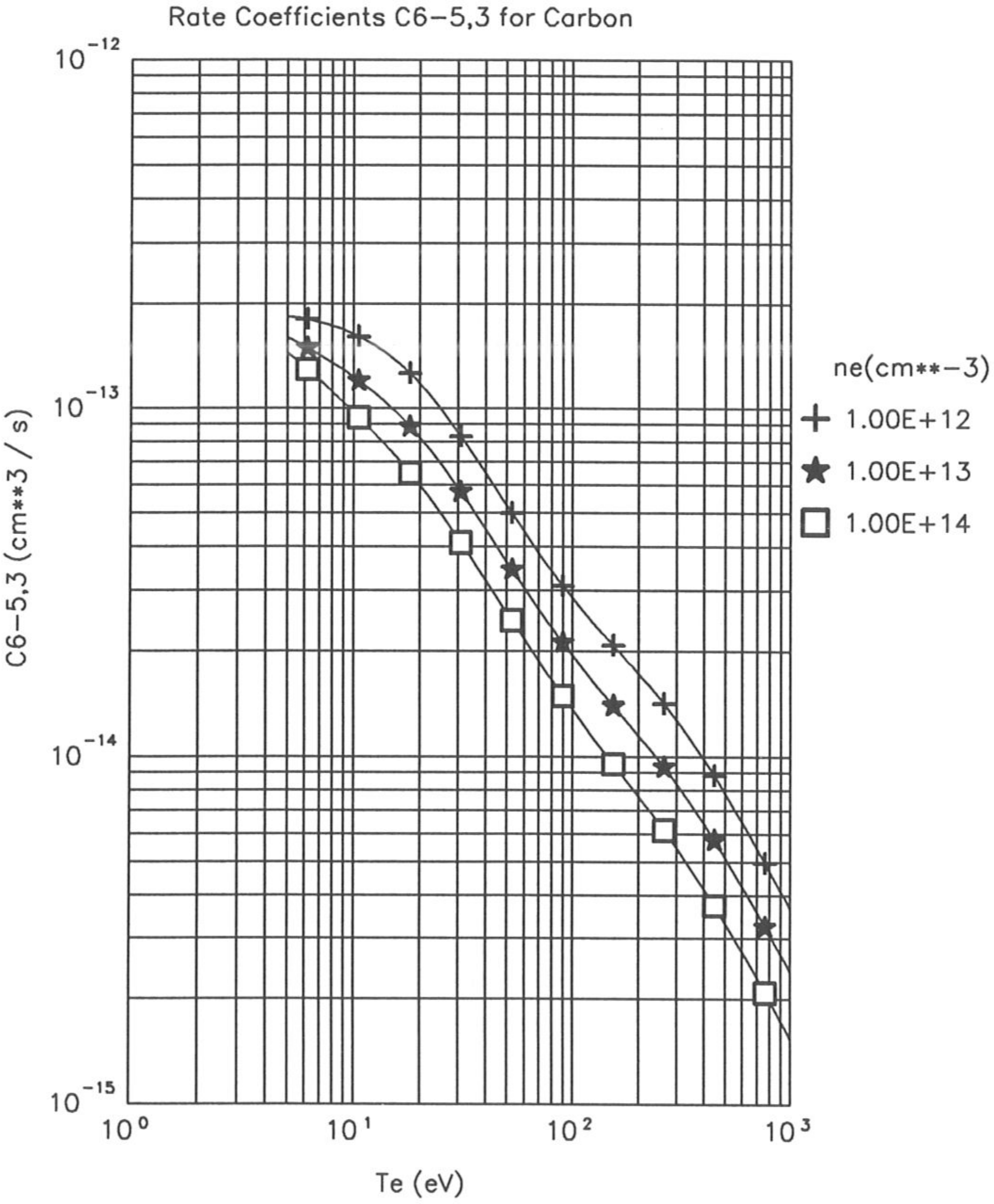

Figure 14: Electron collisional coefficient $C6_{5,3}$

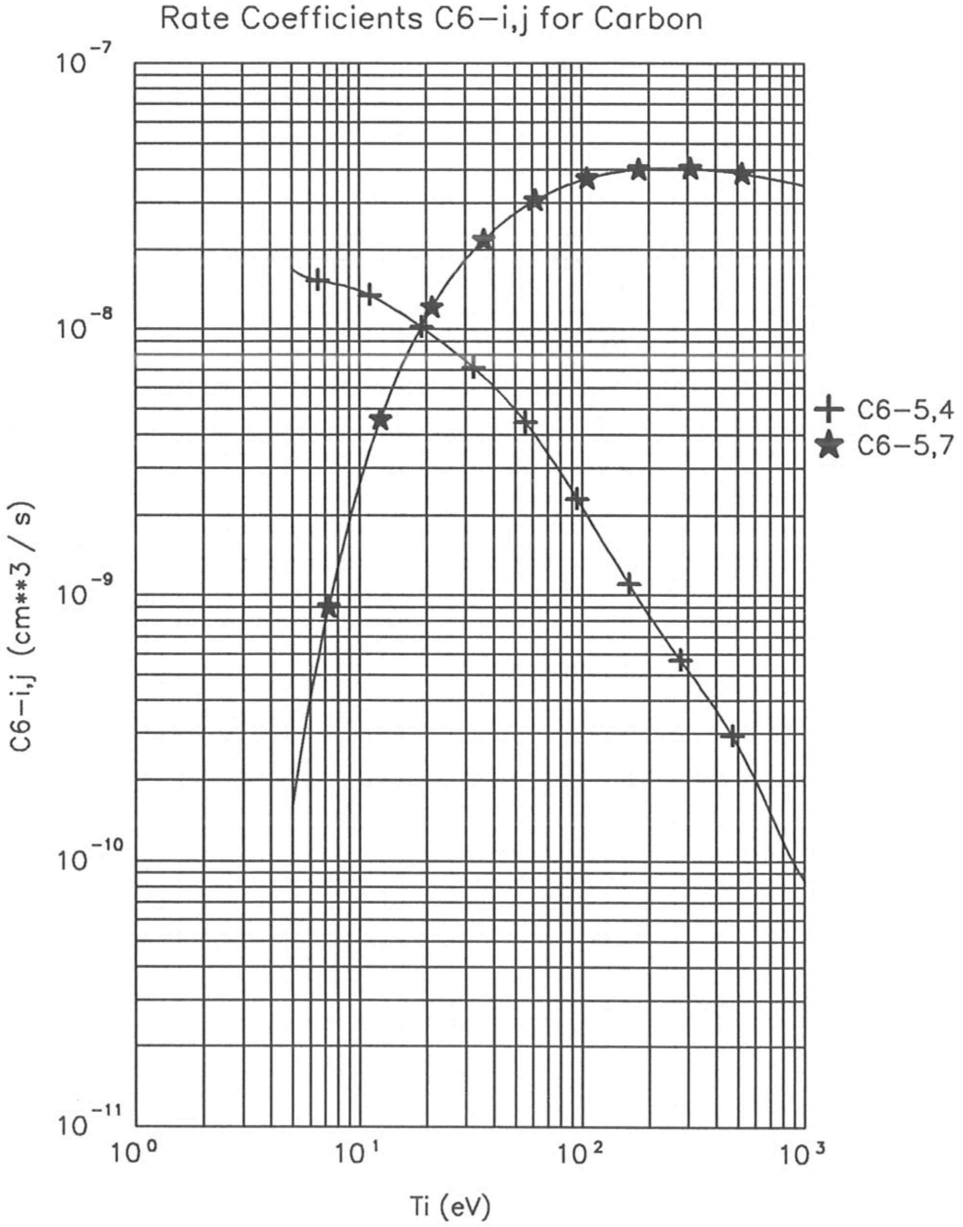

Figure 15: Electron collisional coefficients $C6_{5,4}$, $C6_{5,7}$

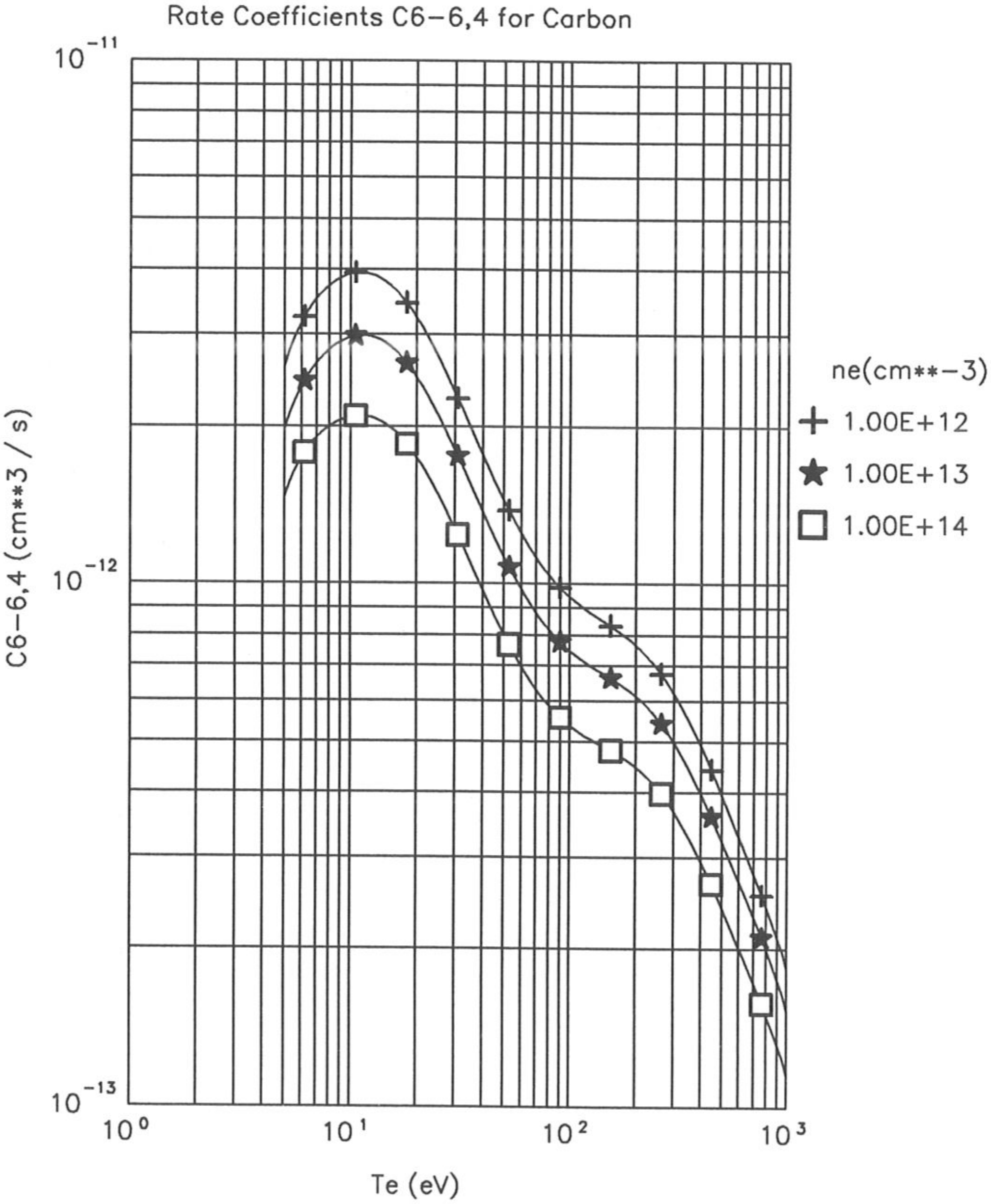

Figure 16: Electron collisional coefficient $C6_{6,4}$

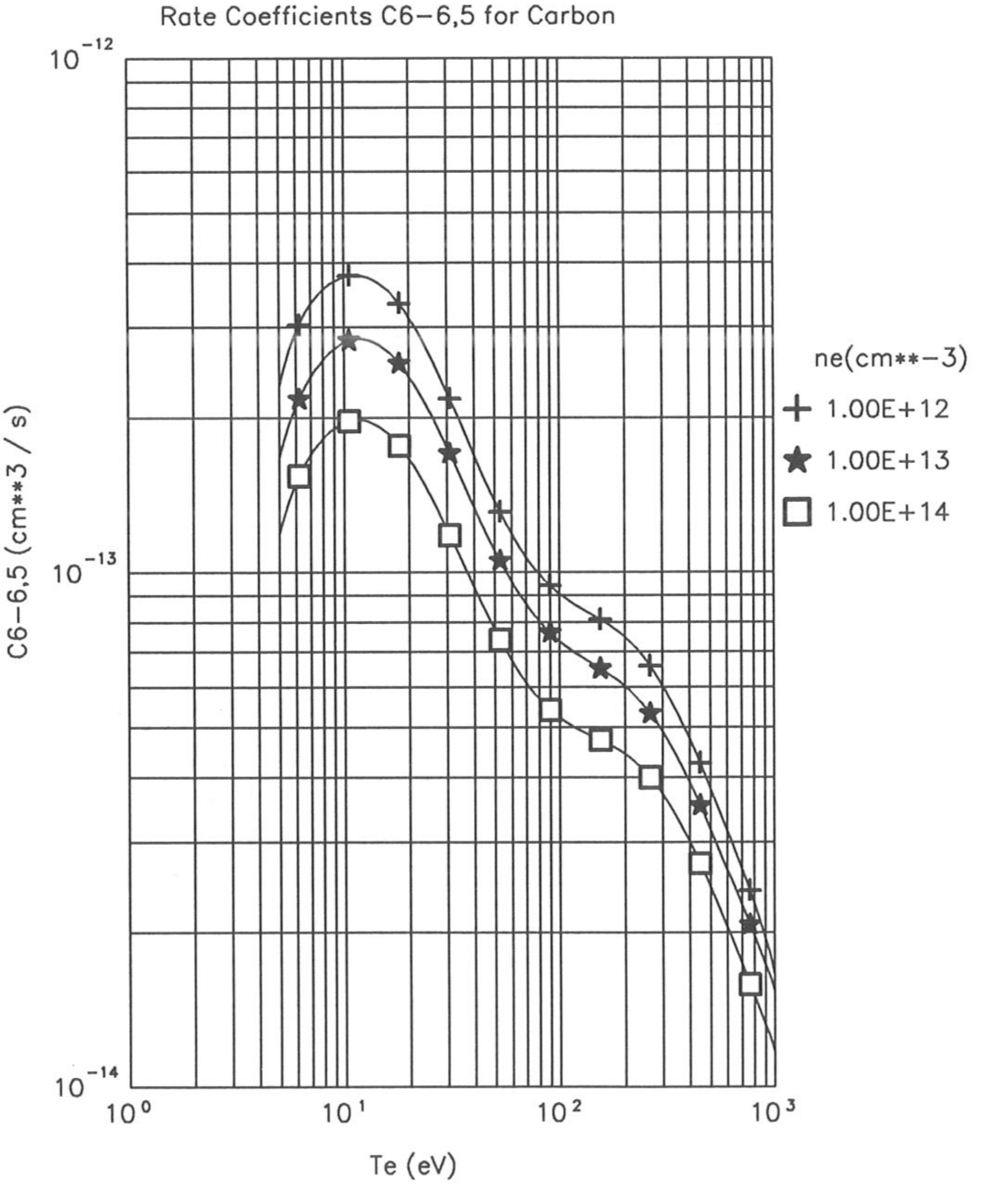

Figure 17: Electron collisional coefficient $C6_{6,5}$

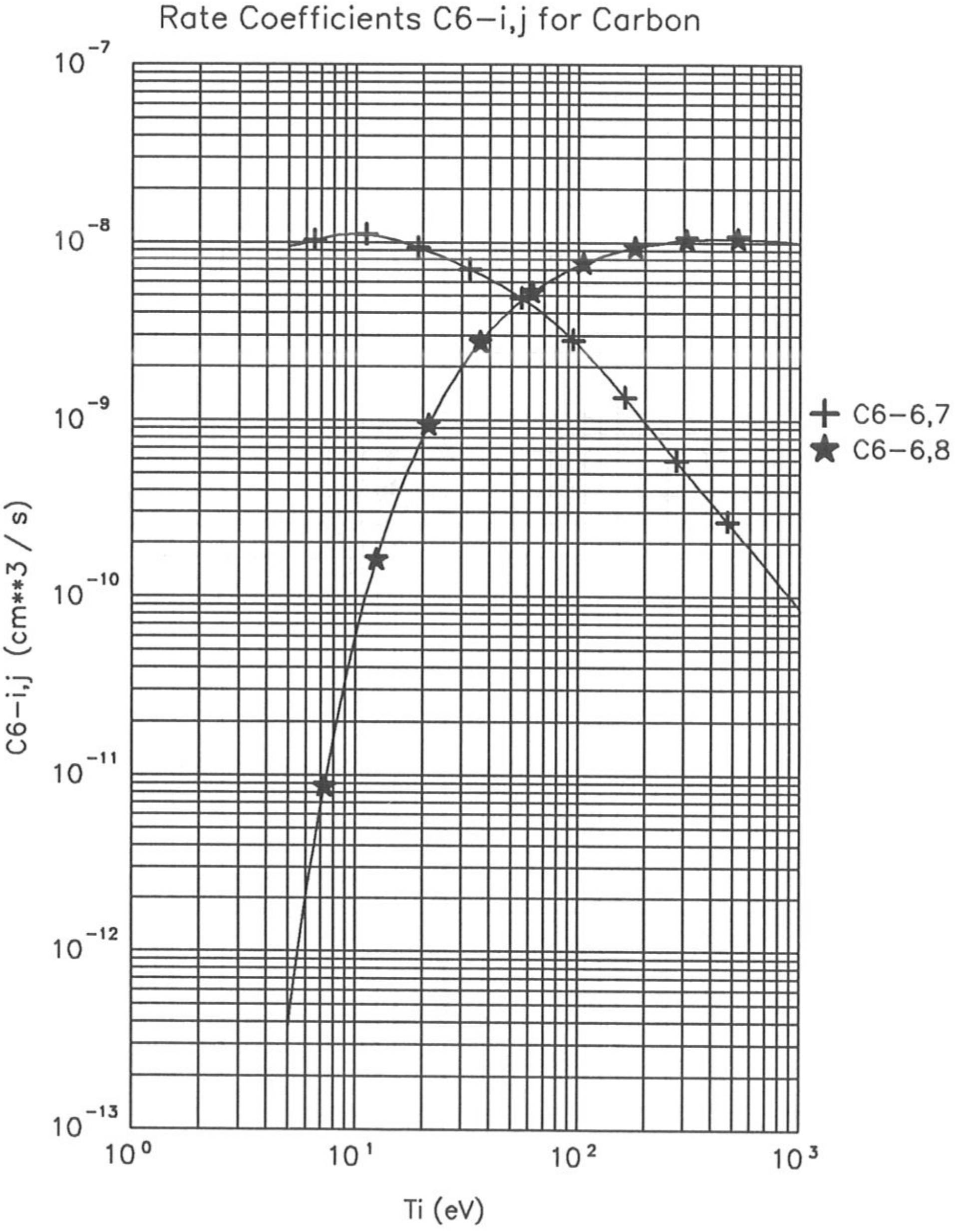

Figure 18: Electron collisional coefficients $C6_{6,7}$, $C6_{6,8}$

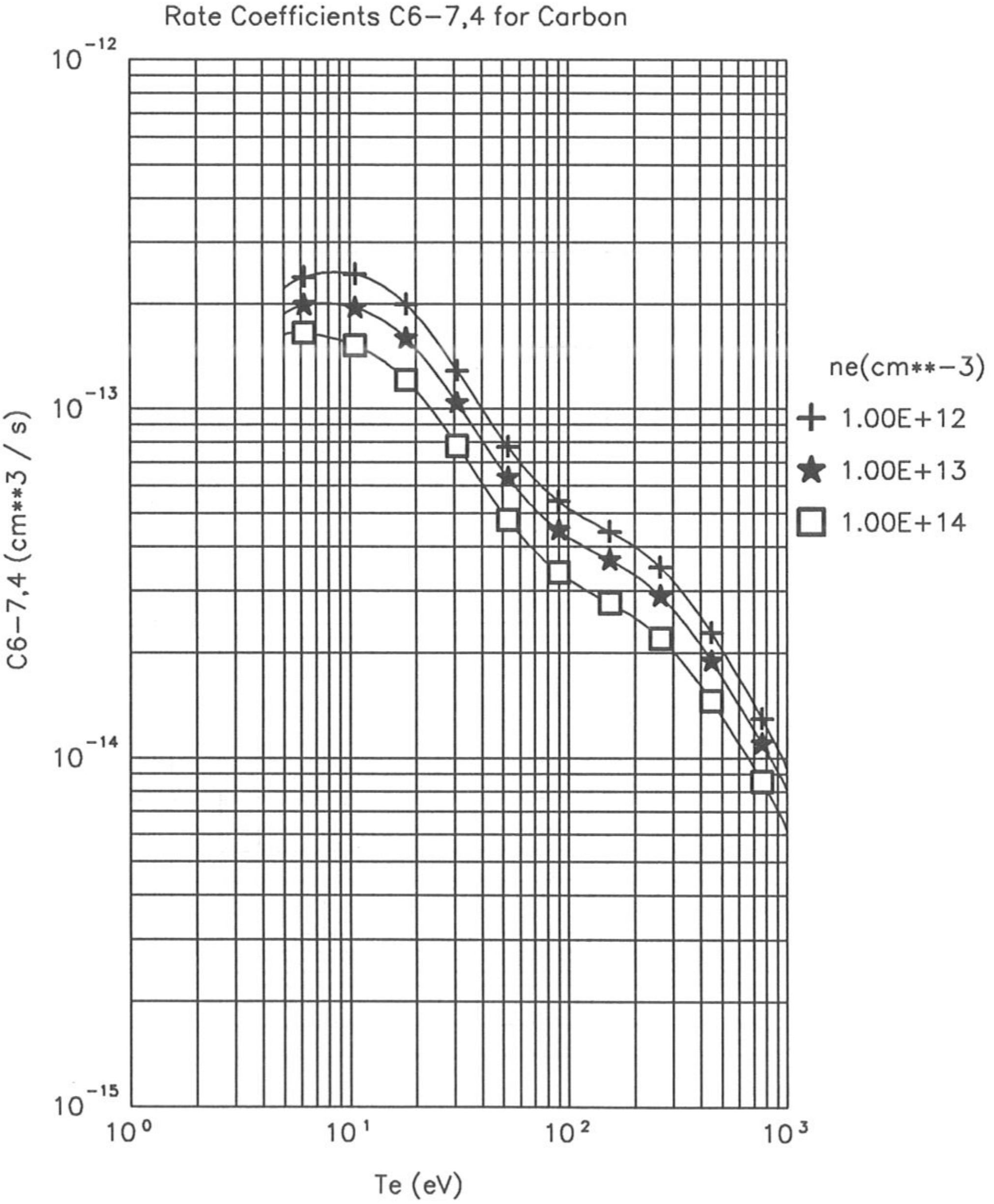

Figure 19: Electron collisional coefficient $C6_{7,4}$

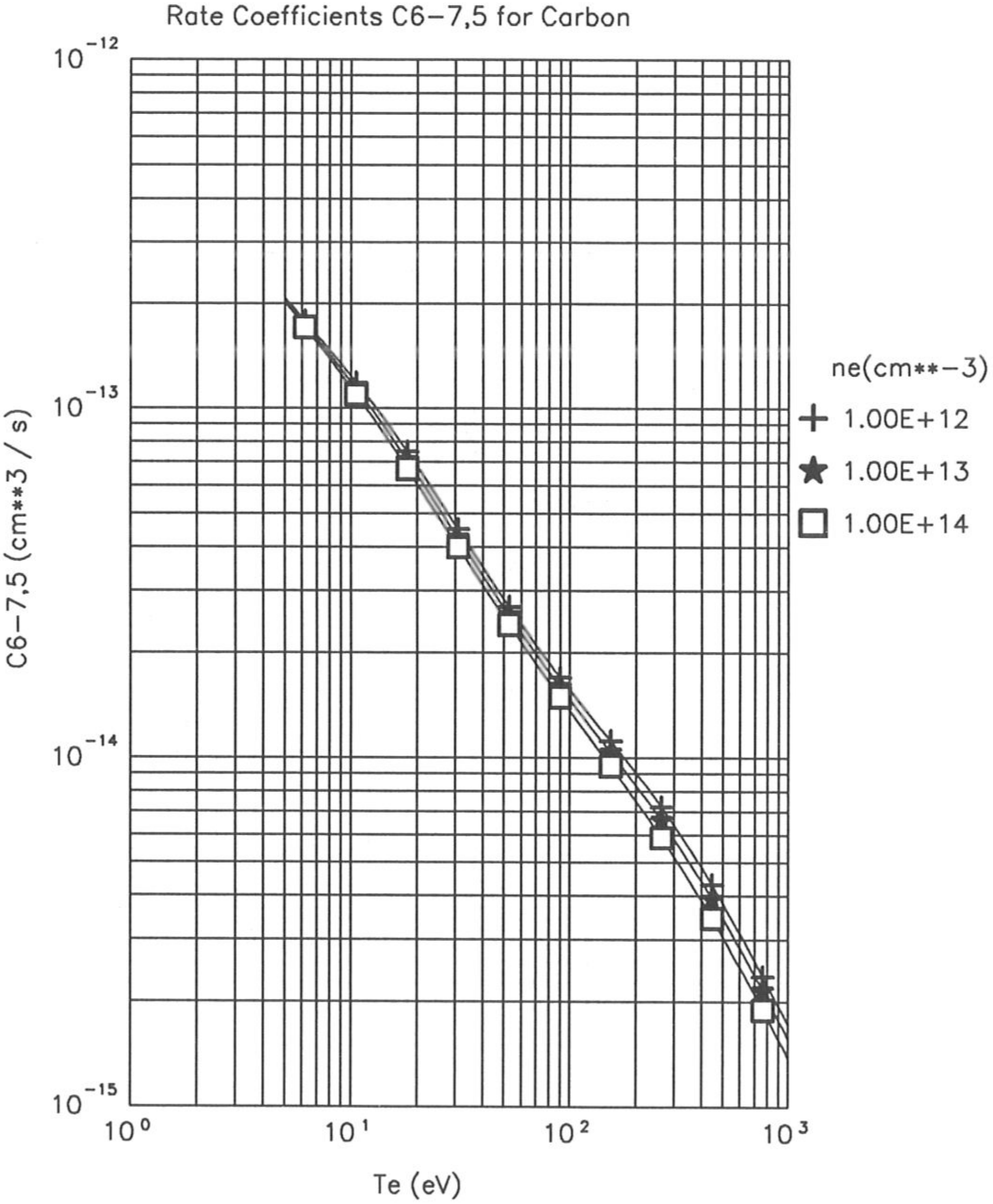

Figure 20: Electron collisional coefficient $C6_{7,5}$

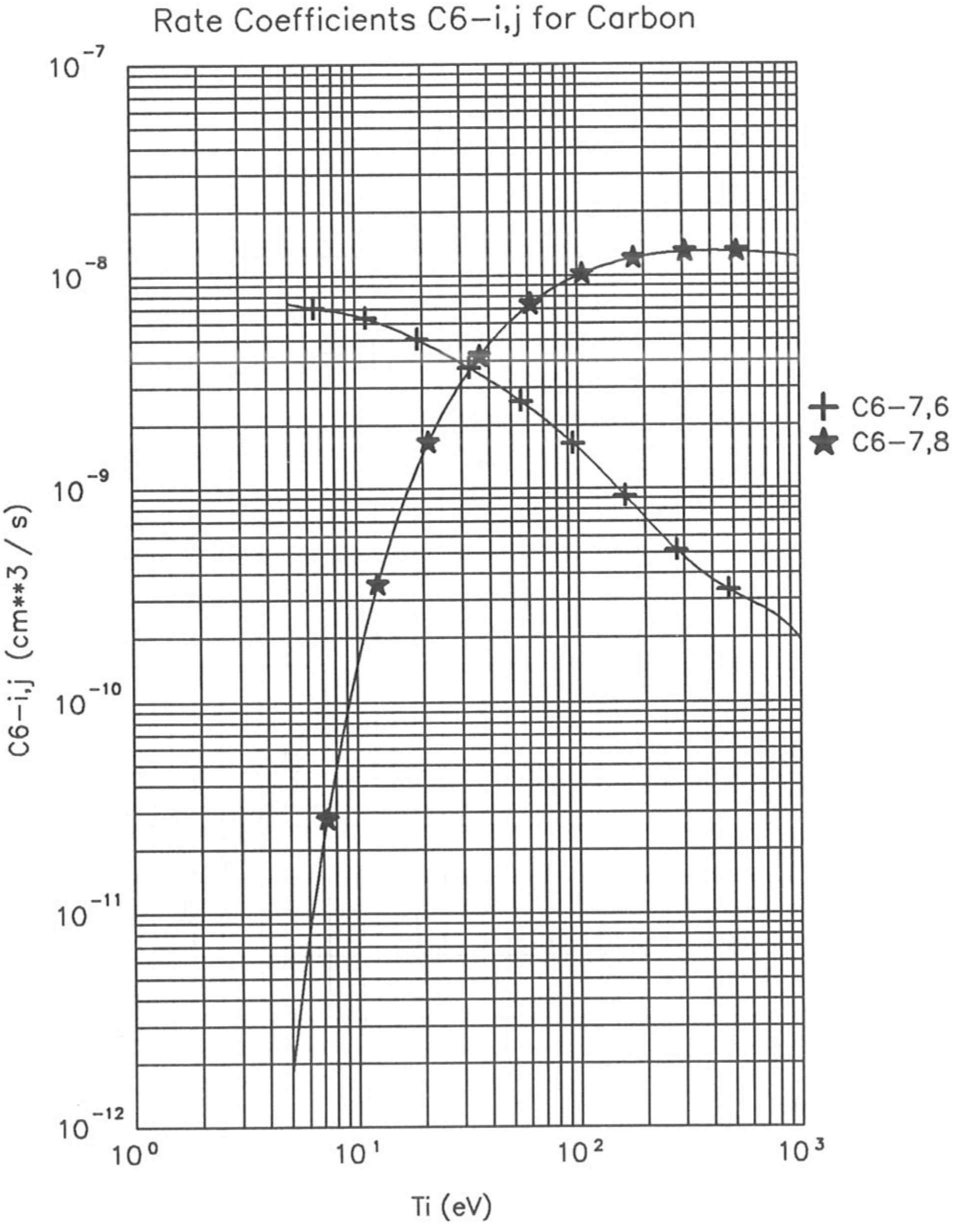

Figure 21: Electron collisional coefficients $C6_{7,6}$, $C6_{7,8}$

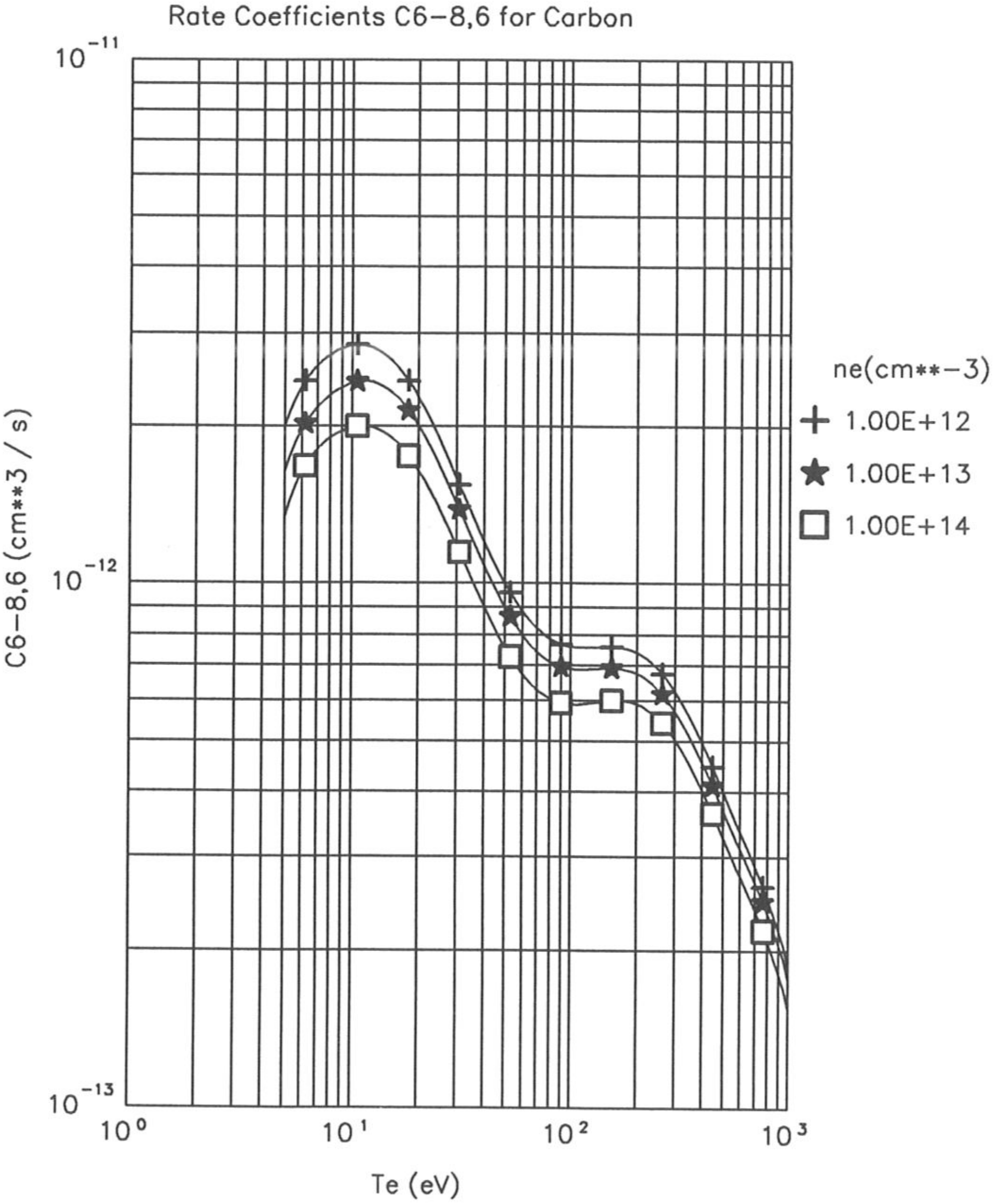

Figure 22: Electron collisional coefficient $C6_{8,6}$

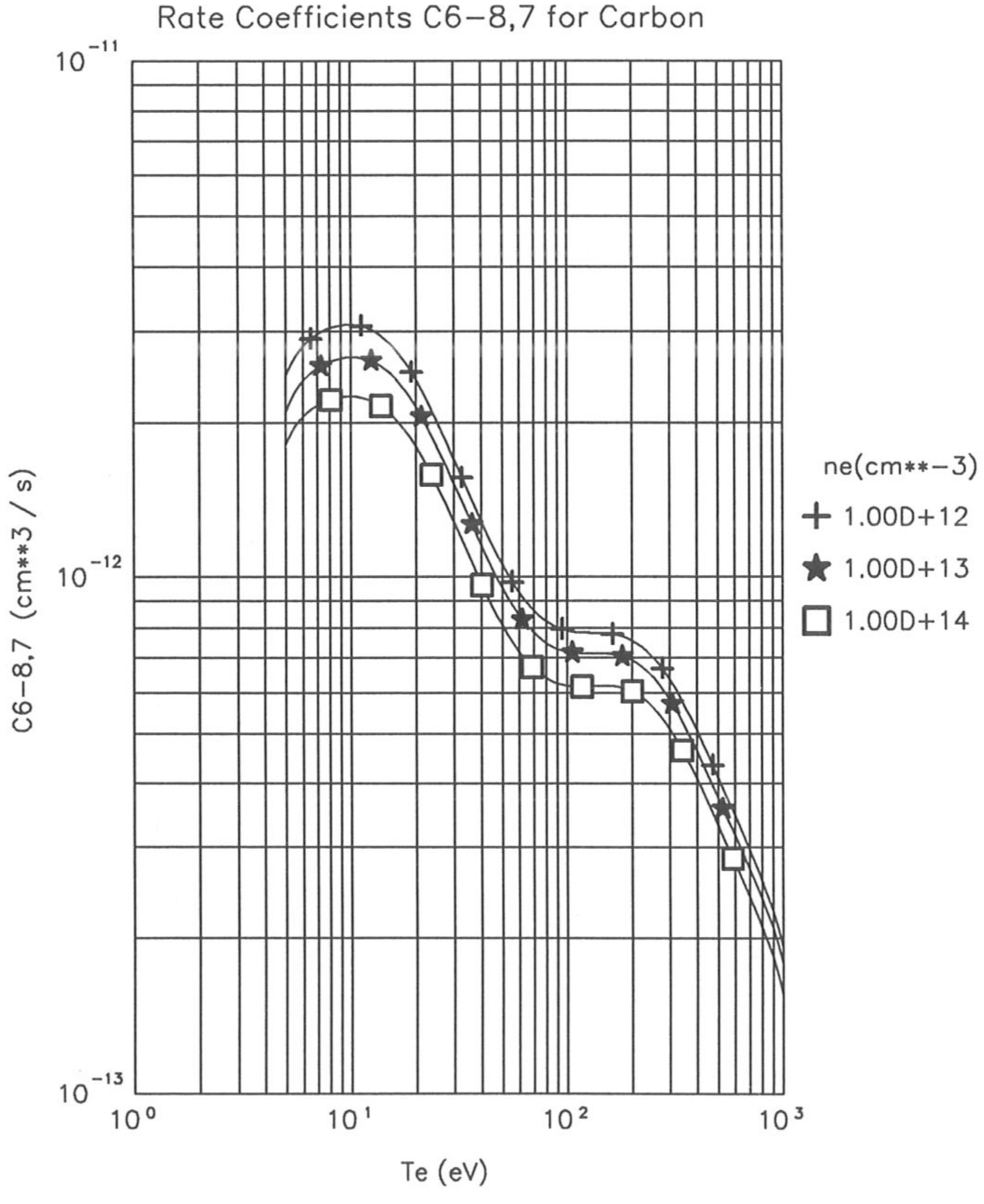

Figure 23: Electron collisional coefficient $C6_{8,7}$

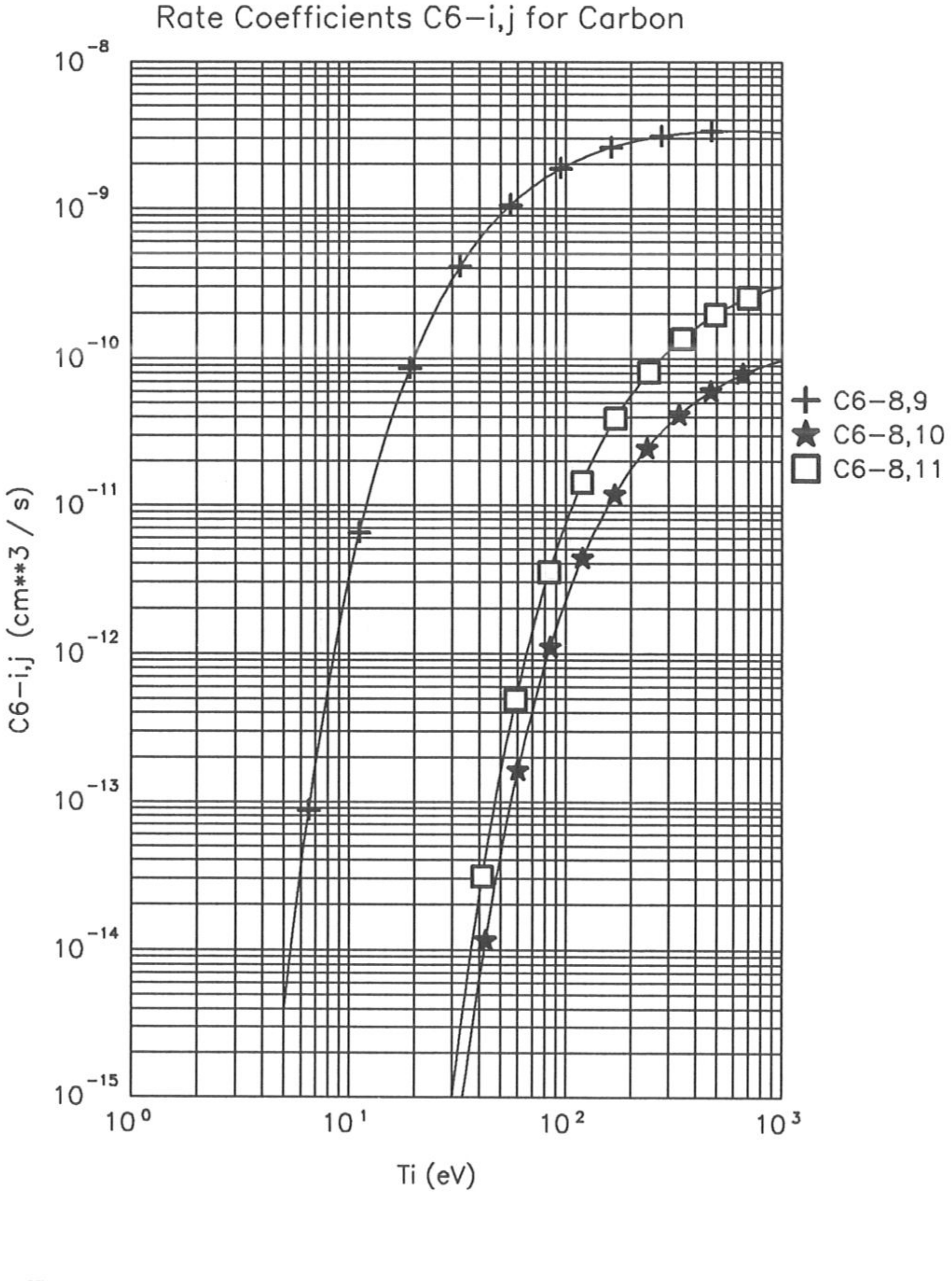

Figure 24: Electron collisional coefficients $C6_{8,9}$, $C6_{8,10}$, $C6_{8,11}$

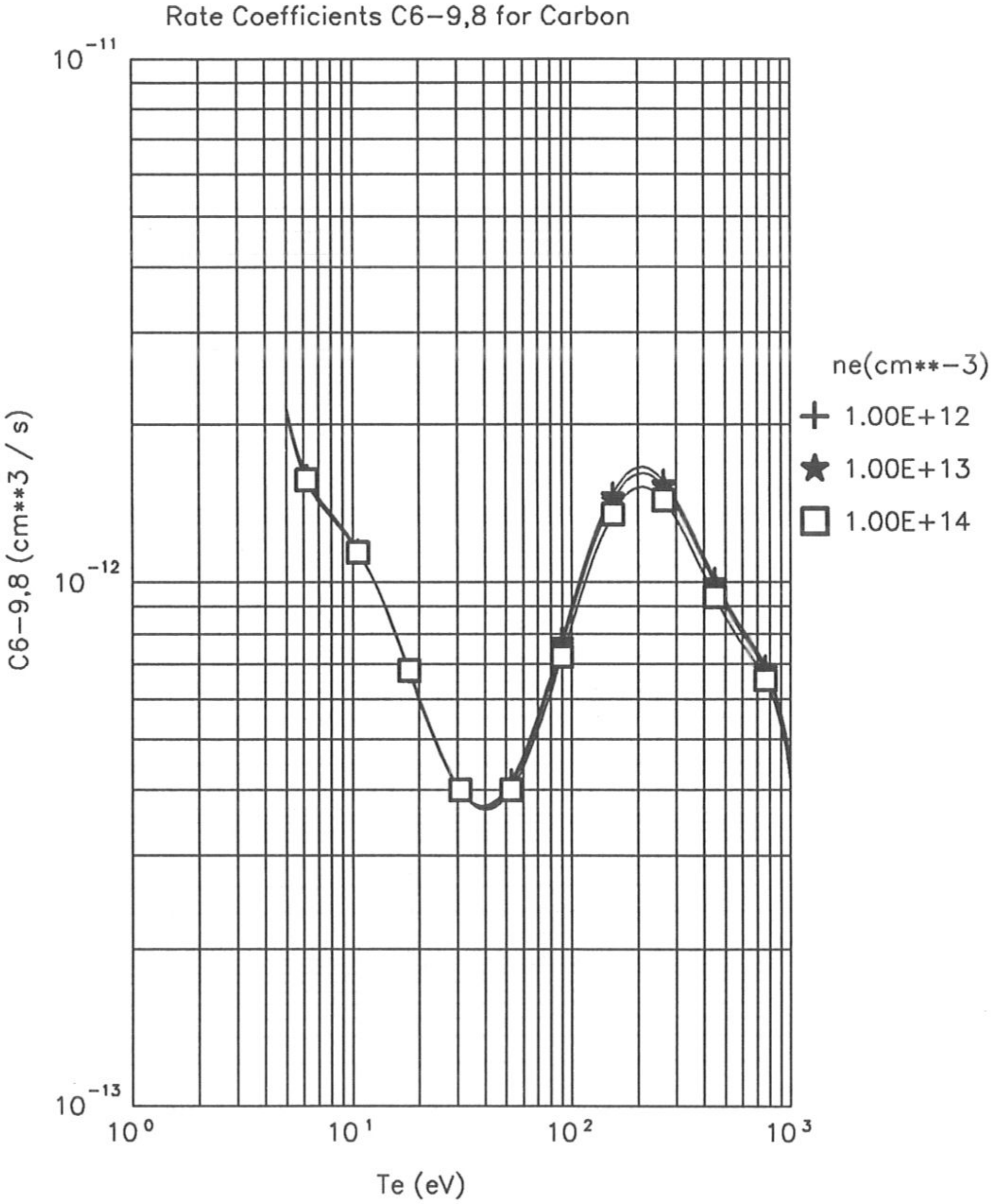

Figure 25: Electron collisional coefficient $C6_{9,8}$

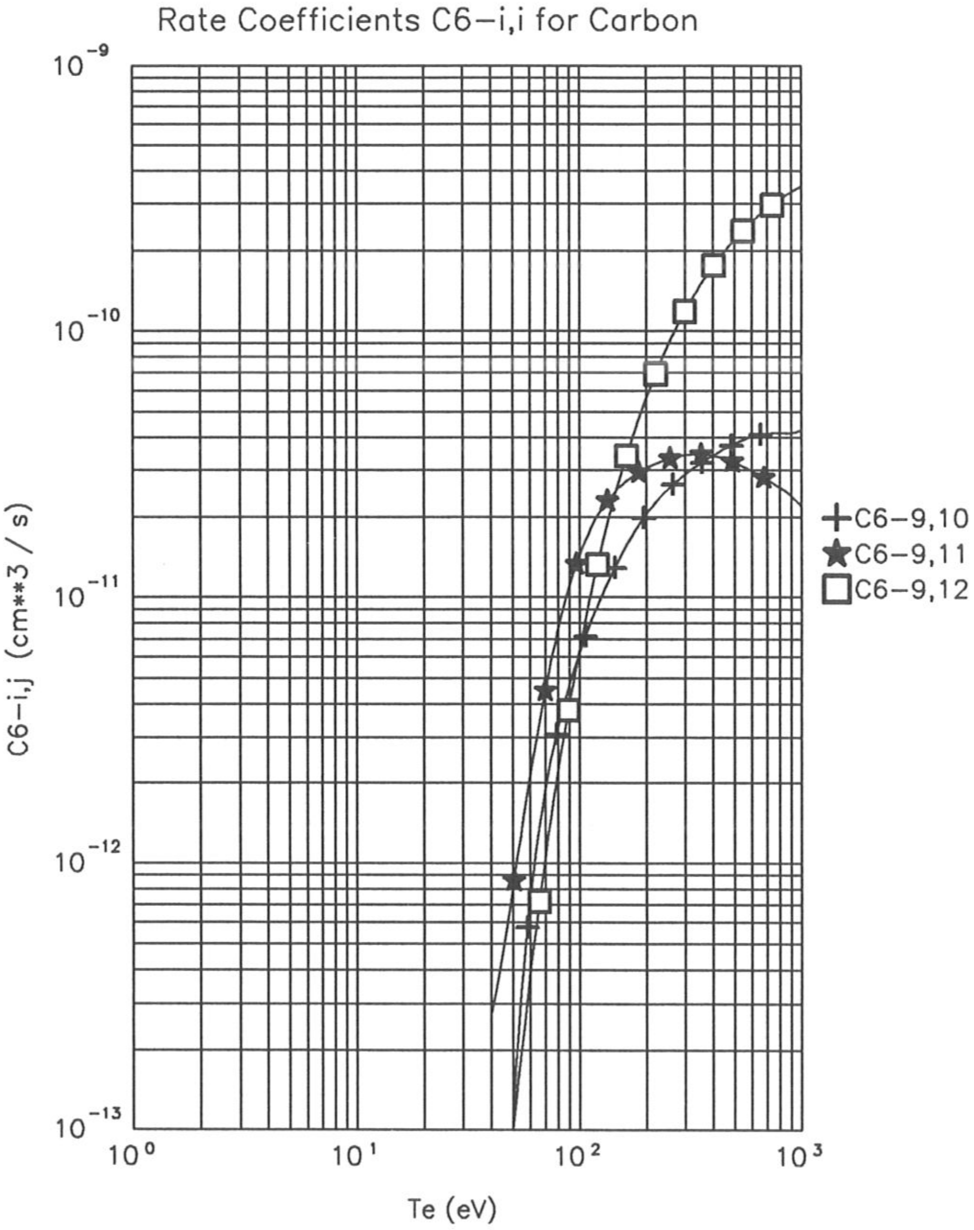

Figure 26: Electron collisional coefficients $C6_{9,10}$, $C6_{9,11}$, $C6_{9,12}$

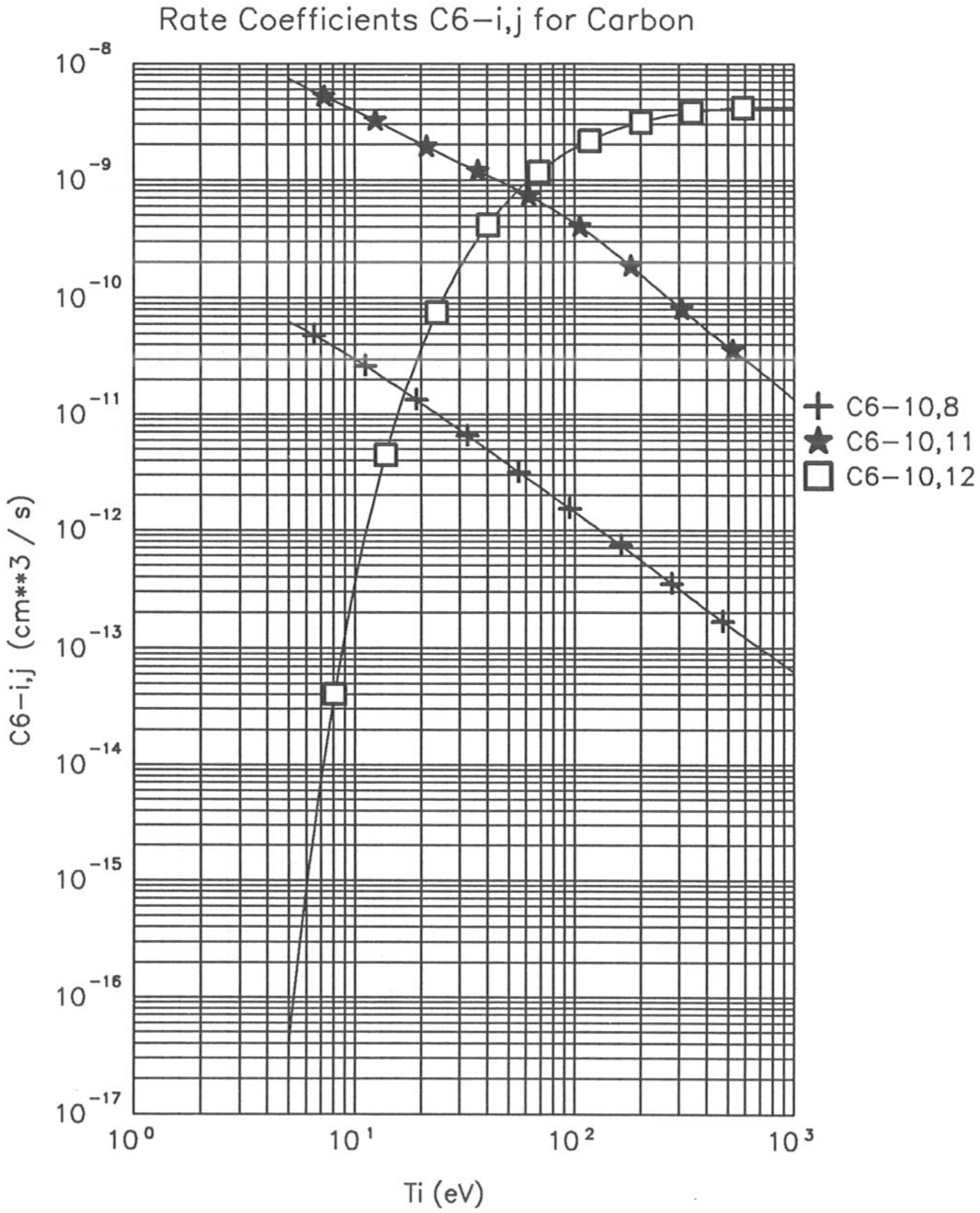

Figure 27: Electron collisional coefficients $C6_{10,8}$, $C6_{10,11}$, $C6_{10,12}$

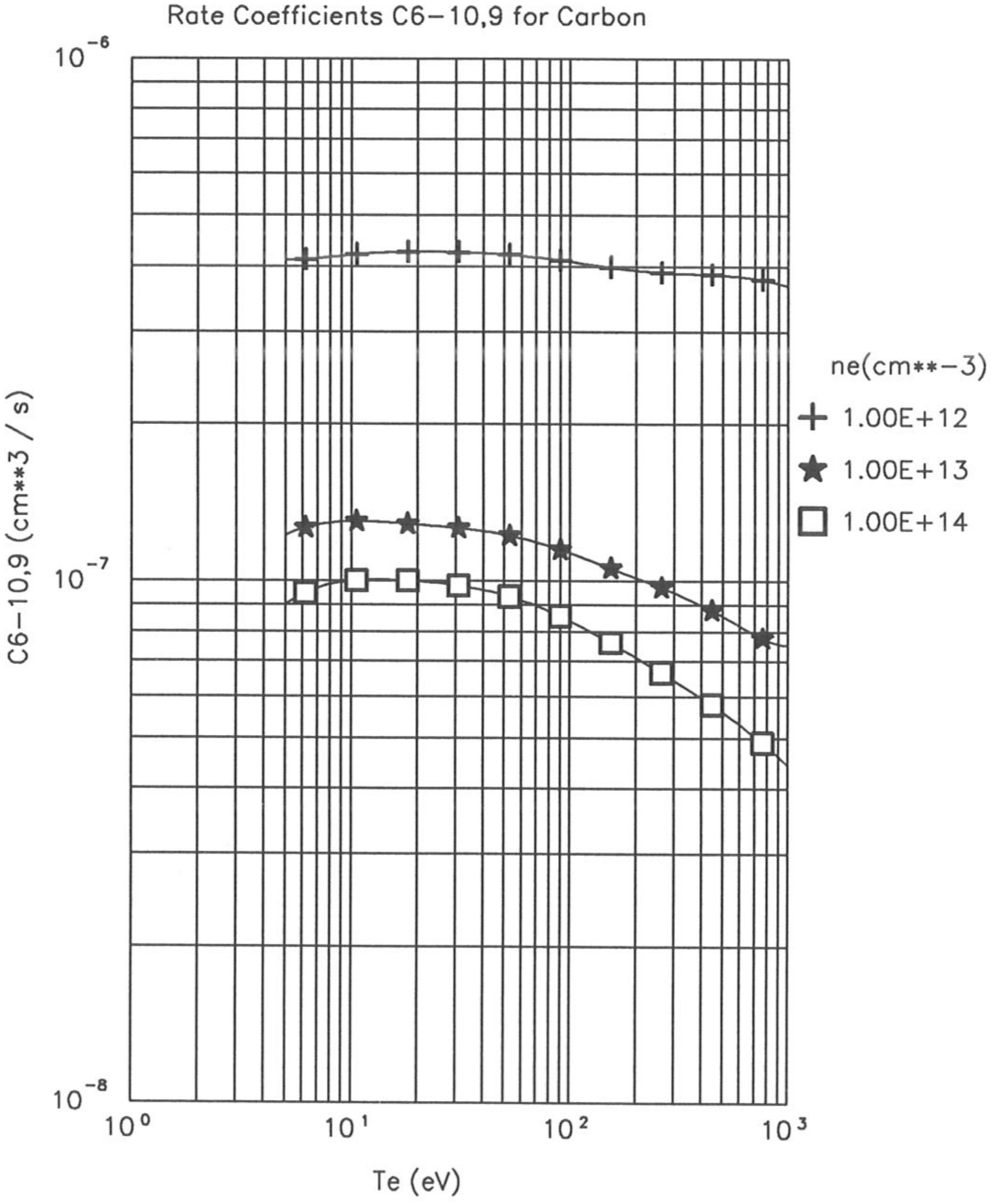

Figure 28: Electron collisional coefficient $C6_{10,9}$

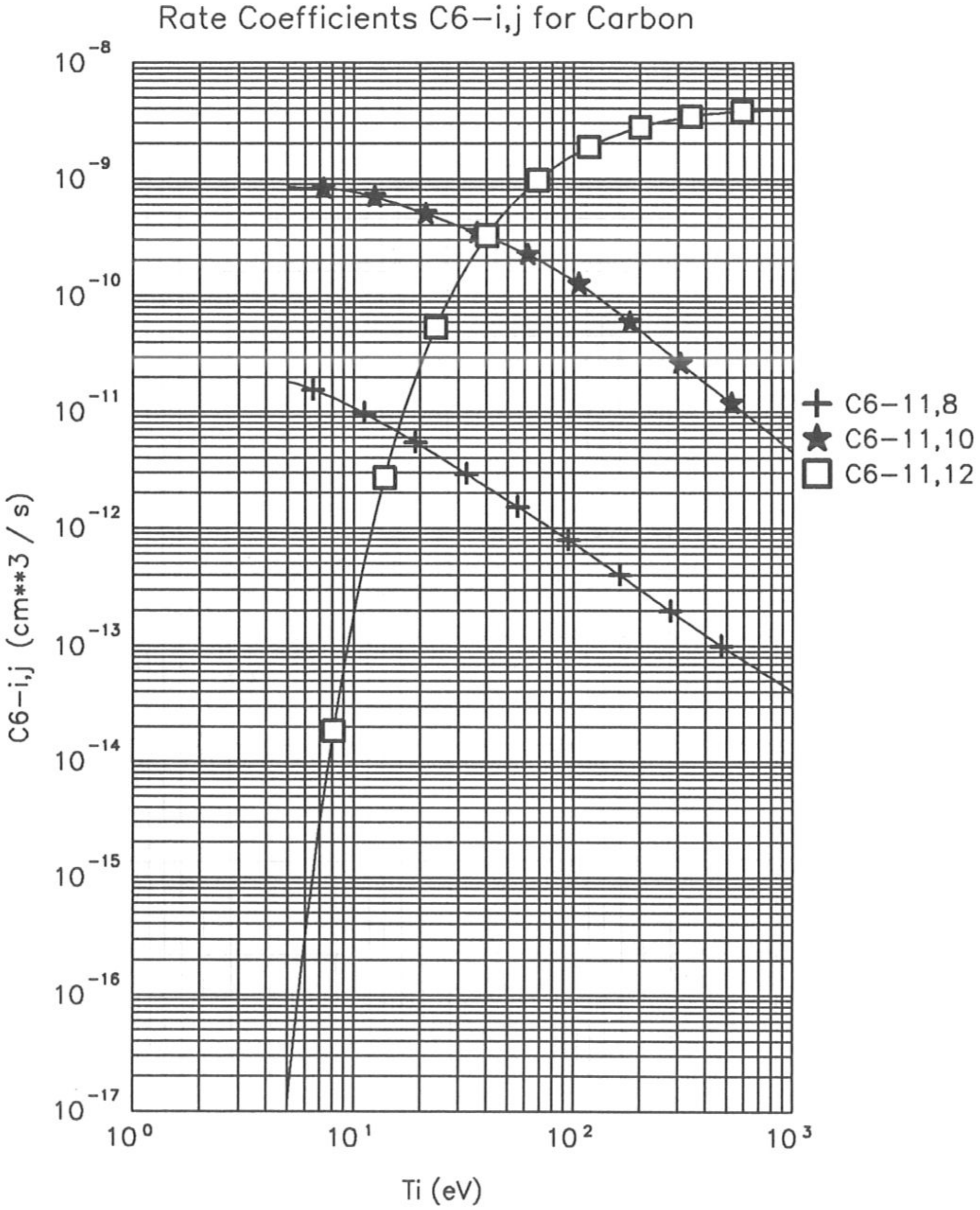

Figure 29: Electron collisional coefficients $C6_{11,8}$, $C6_{11,10}$, $C6_{11,12}$

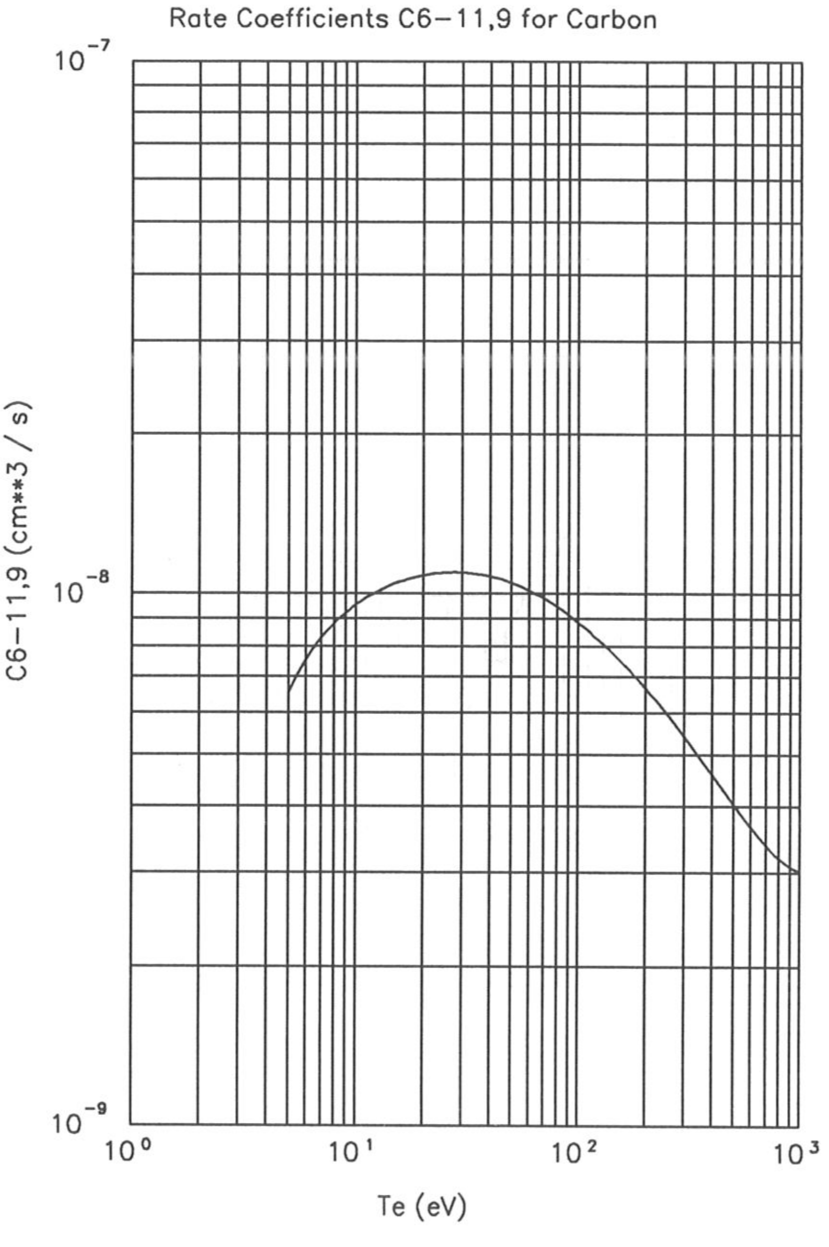

Figure 30: Electron collisional coefficient $C6_{11,9}$

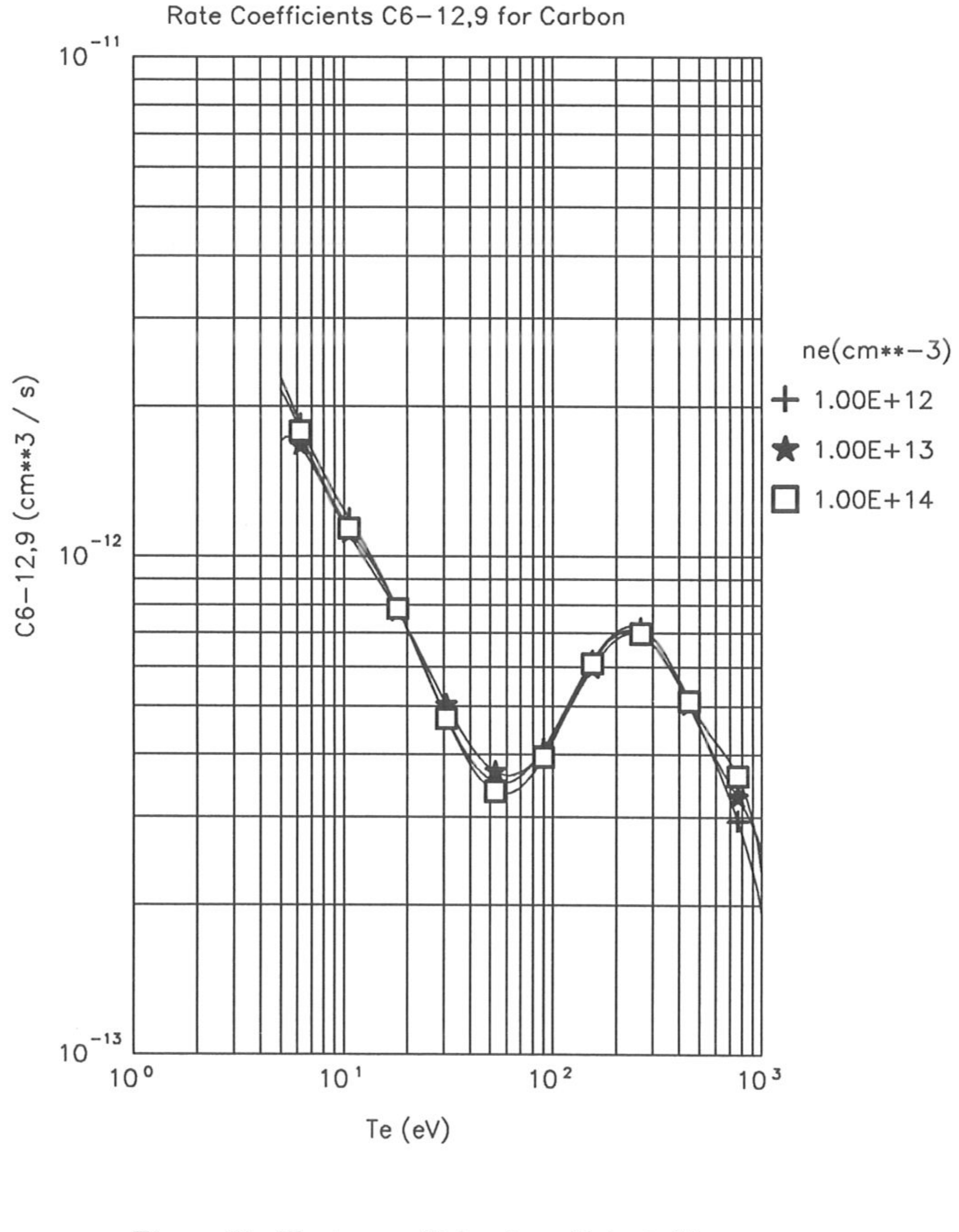

Figure 31: Electron collisional coefficient $C6_{12,9}$

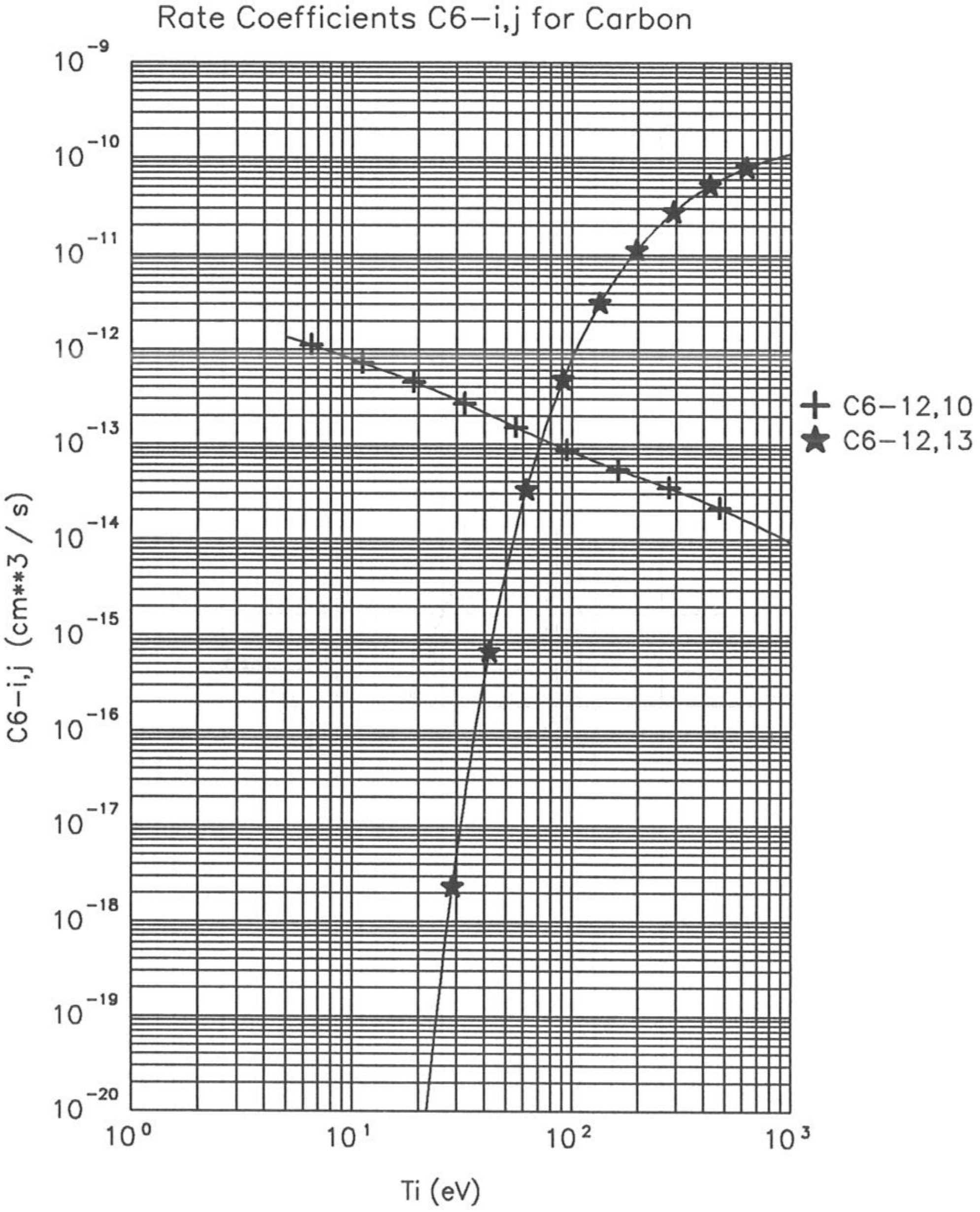

Figure 32: Electron collisional coefficients $C6_{12,10}$, $C6_{12,13}$

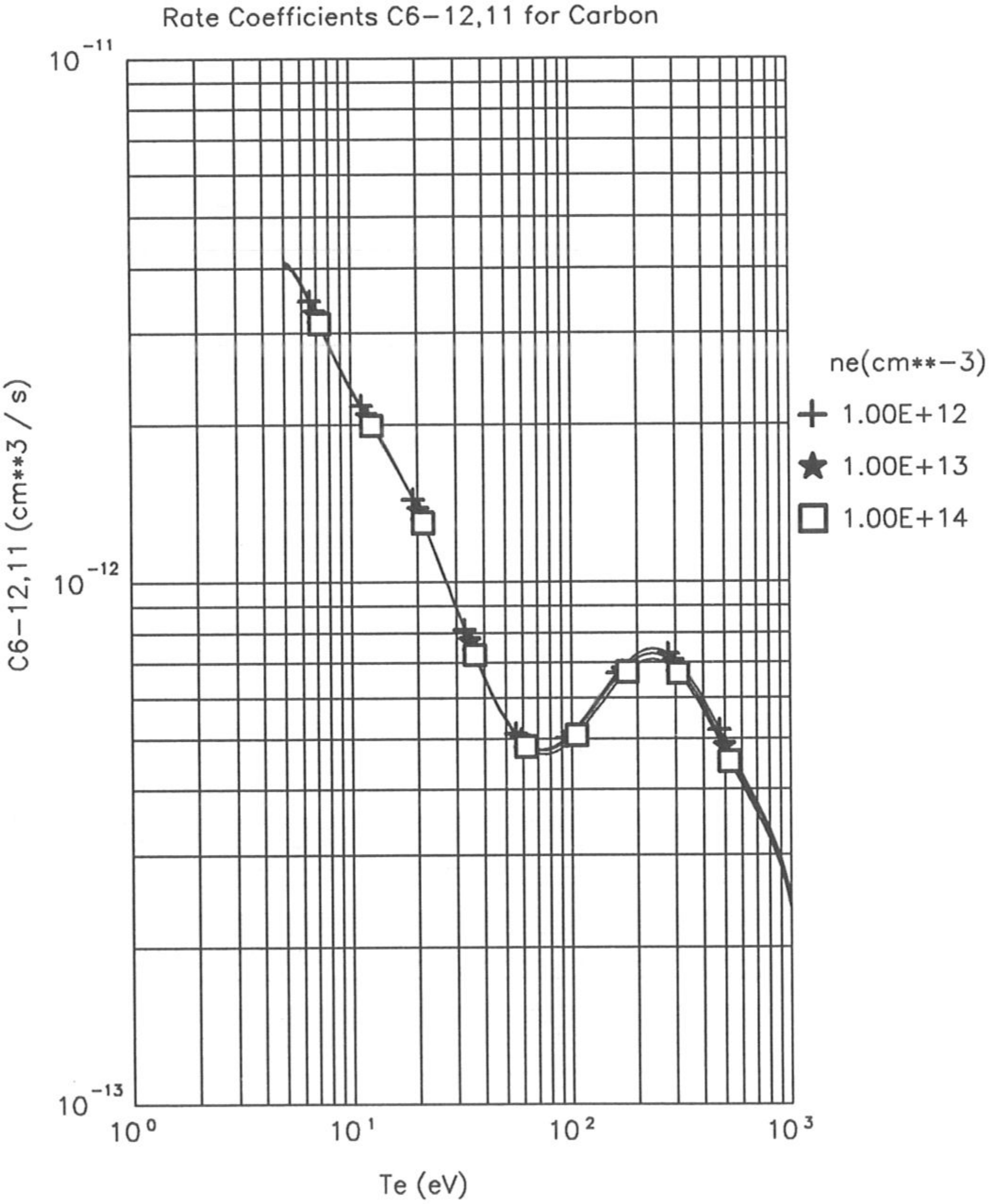

Figure 33: Electron collisional coefficient $C6_{12,11}$

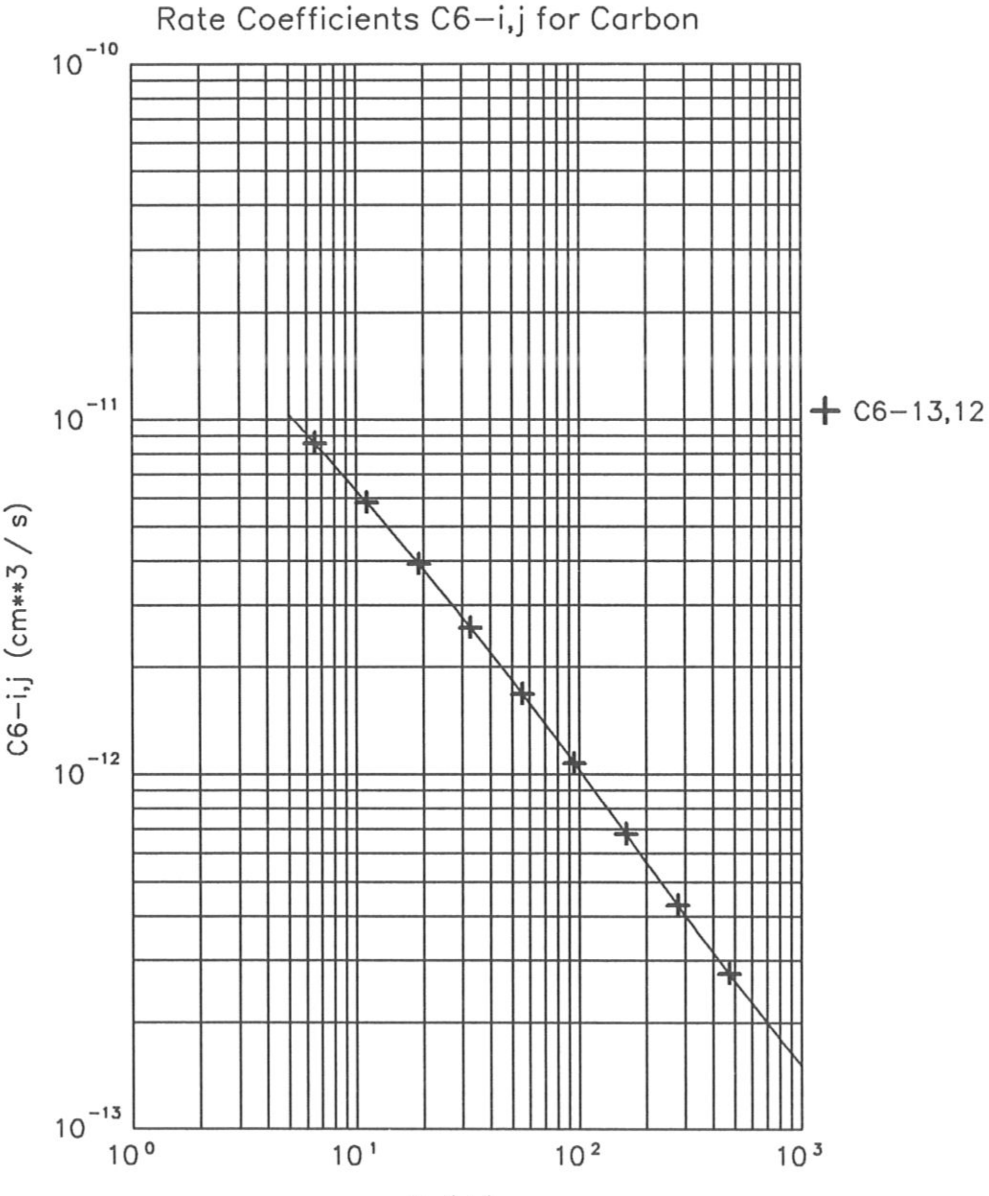

Figure 34: Electron collisional coefficient $C6_{13,12}$

6.2 $L6_{i,j}$ – Charge exchange rates

$$matrix \;\; L6 \;\; =$$

0												
	0											
		0										
$L_{4,1}$	$L_{4,2}$	$L_{4,3}$	0									
				0								
			$L_{6,4}$		0							
			$L_{7,4}$			0						
					$L_{8,6}$	$L_{8,7}$	0					
							$L_{9,8}$	0				
									0			
										0		
								$L_{12,9}$		$L_{12,11}$	0	
											$L_{13,12}$	0

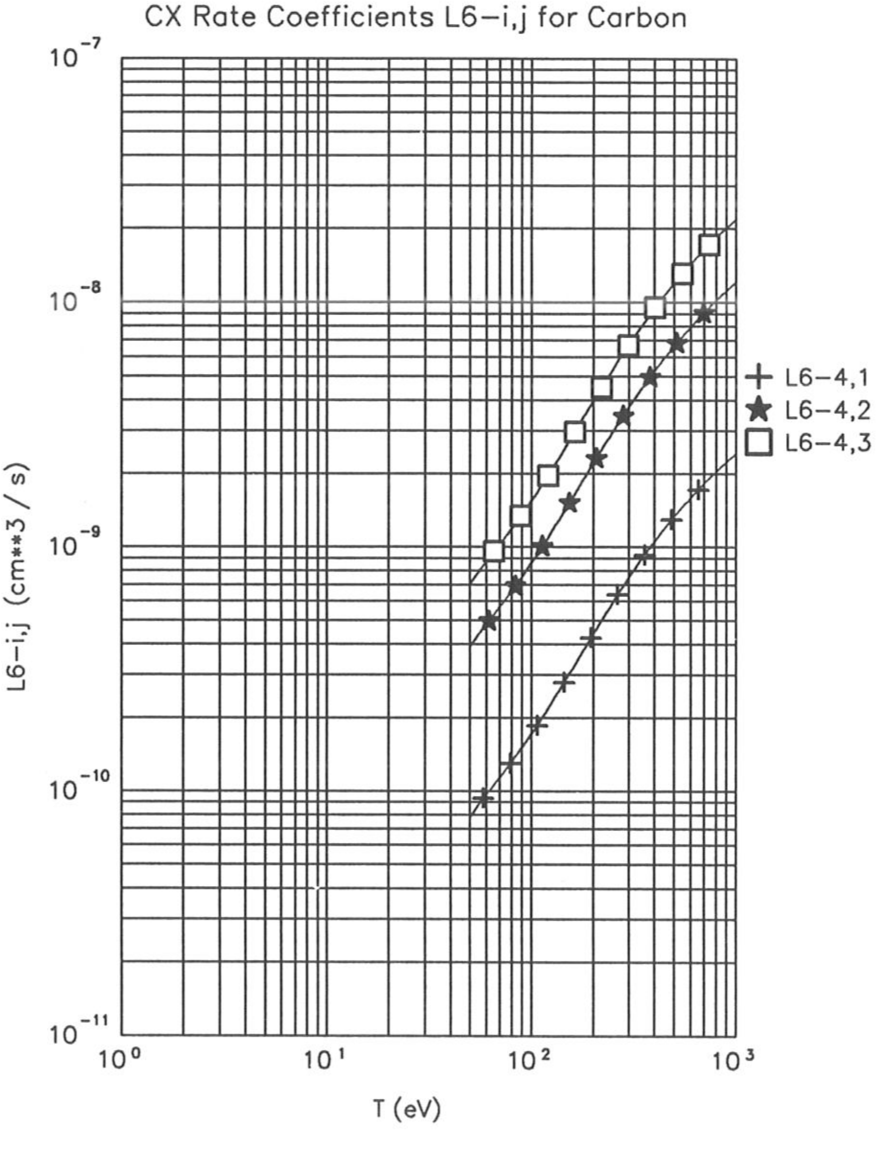

Figure 35: Charge exchange rates $L6_{4,1}$, $L6_{4,2}$, $L6_{4,3}$

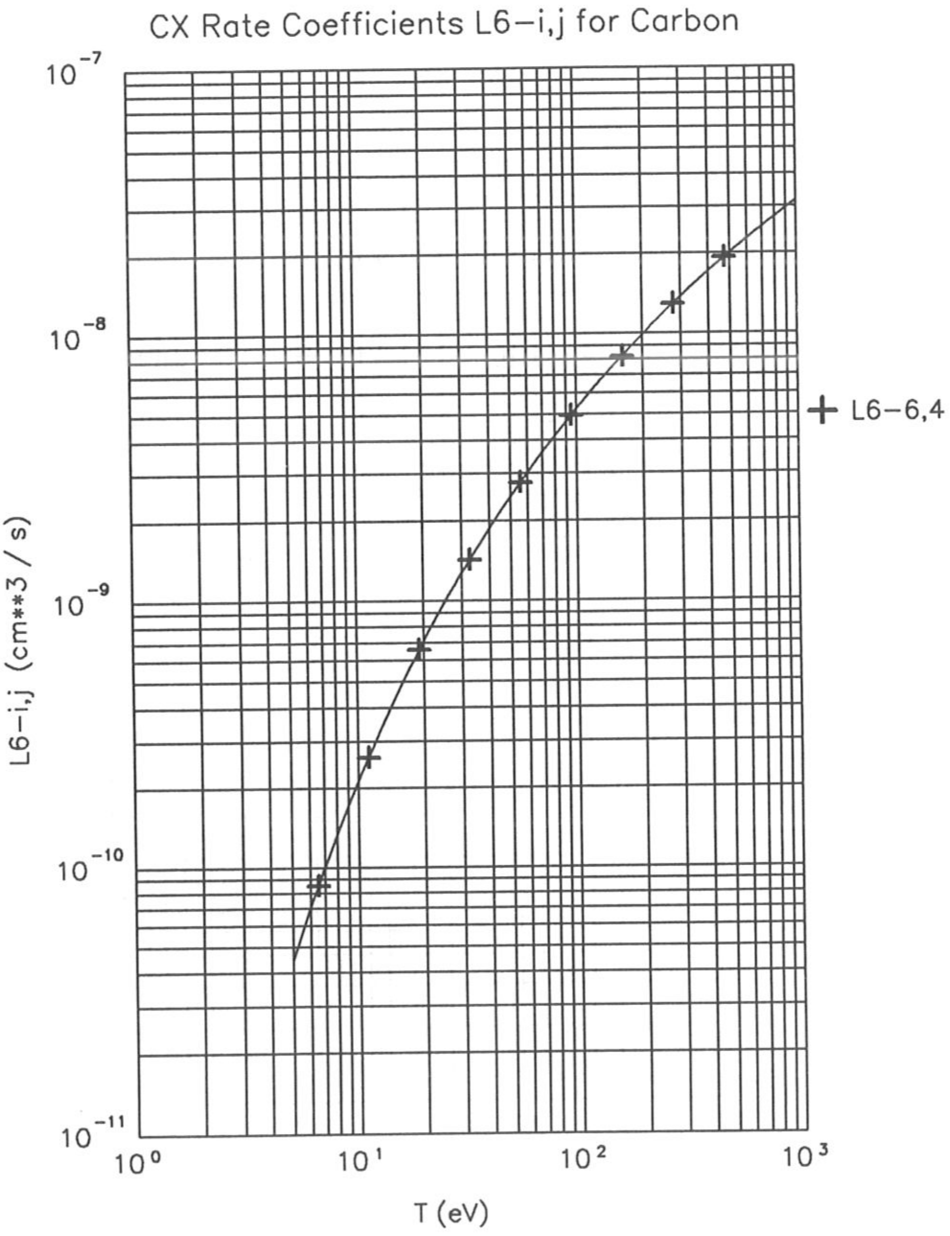

Figure 36: Charge exchange rate $L6_{6,4}$

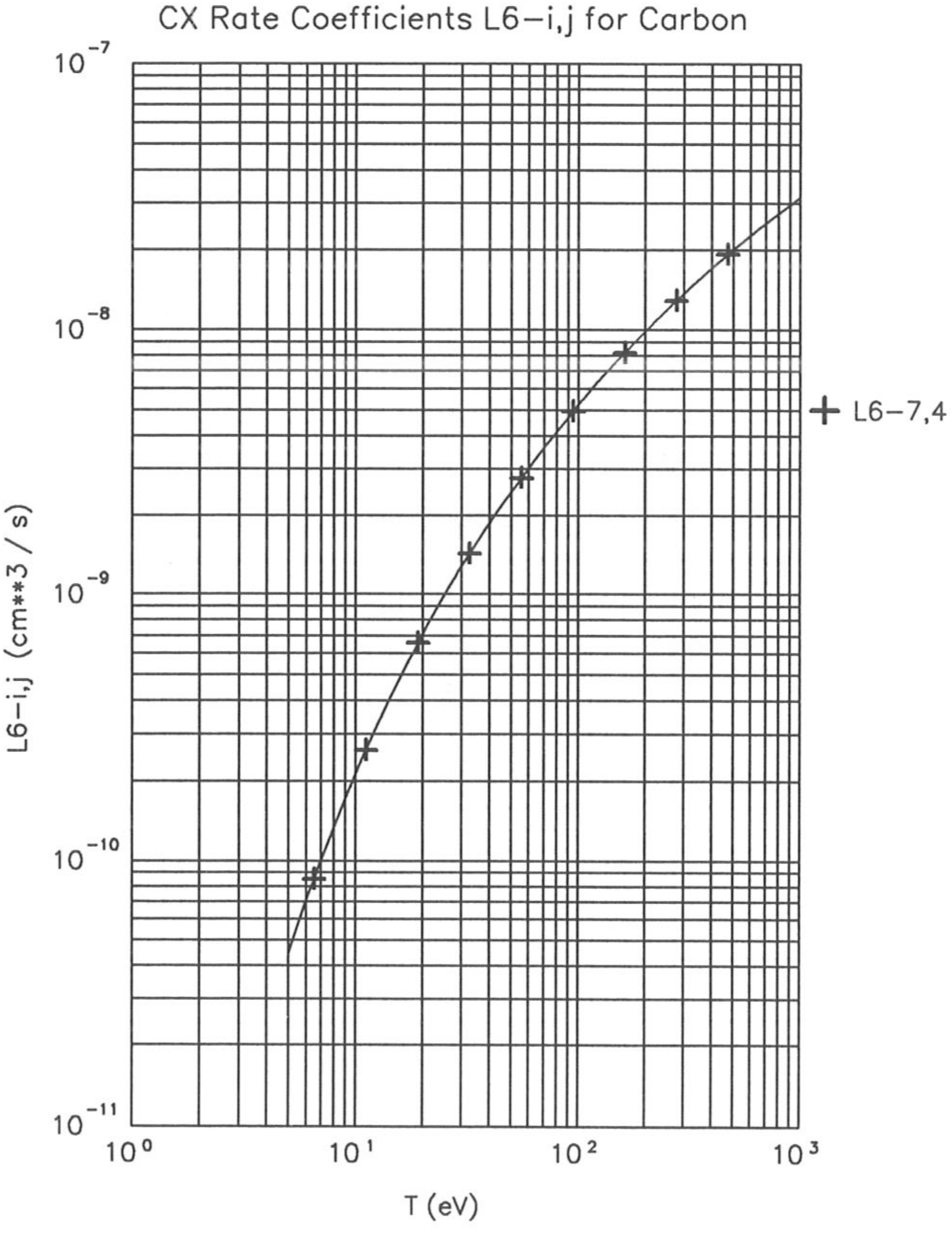

Figure 37: Charge exchange rate $L6_{7,4}$

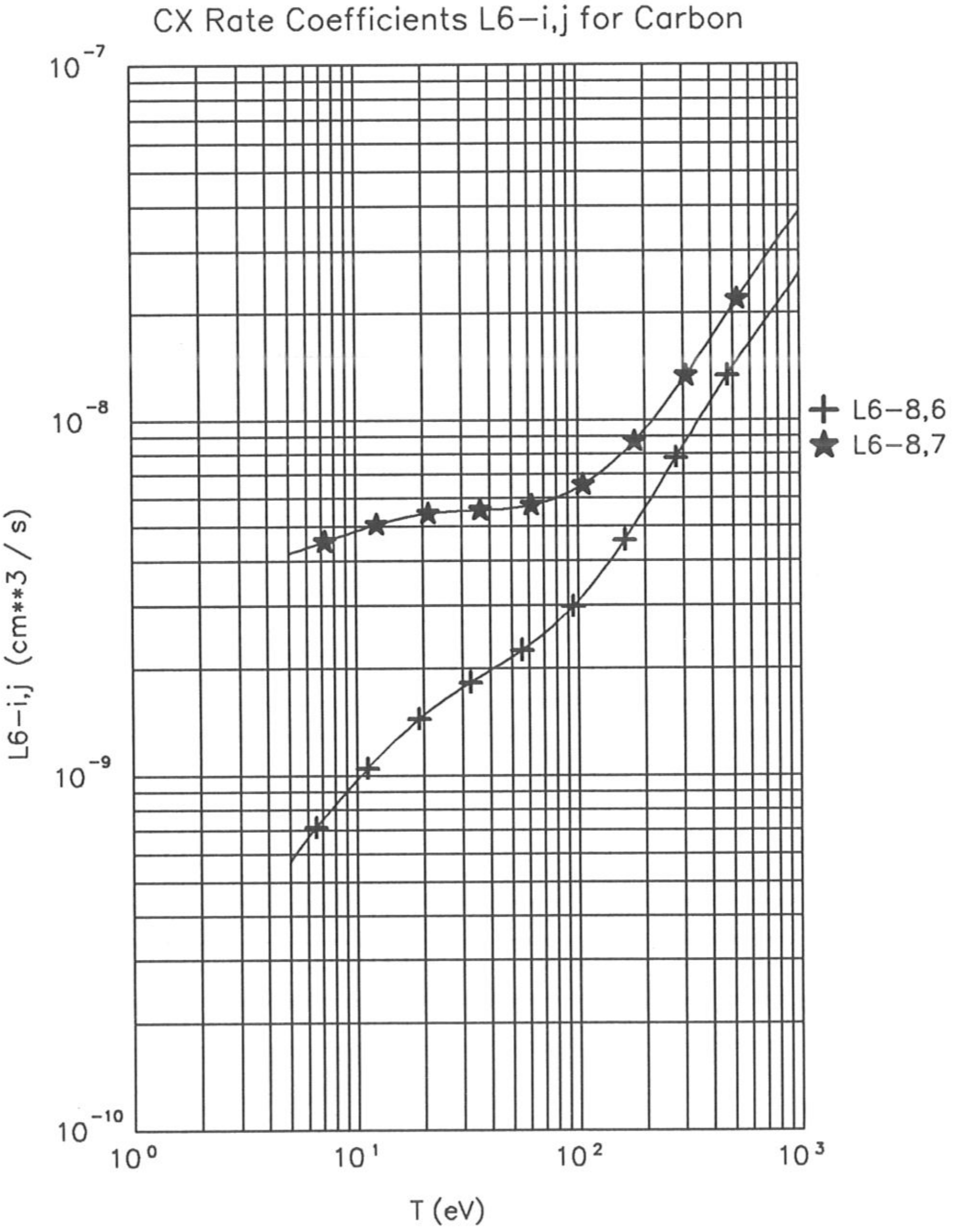

Figure 38: Charge exchange rates $L6_{8,6}$, $L6_{8,7}$

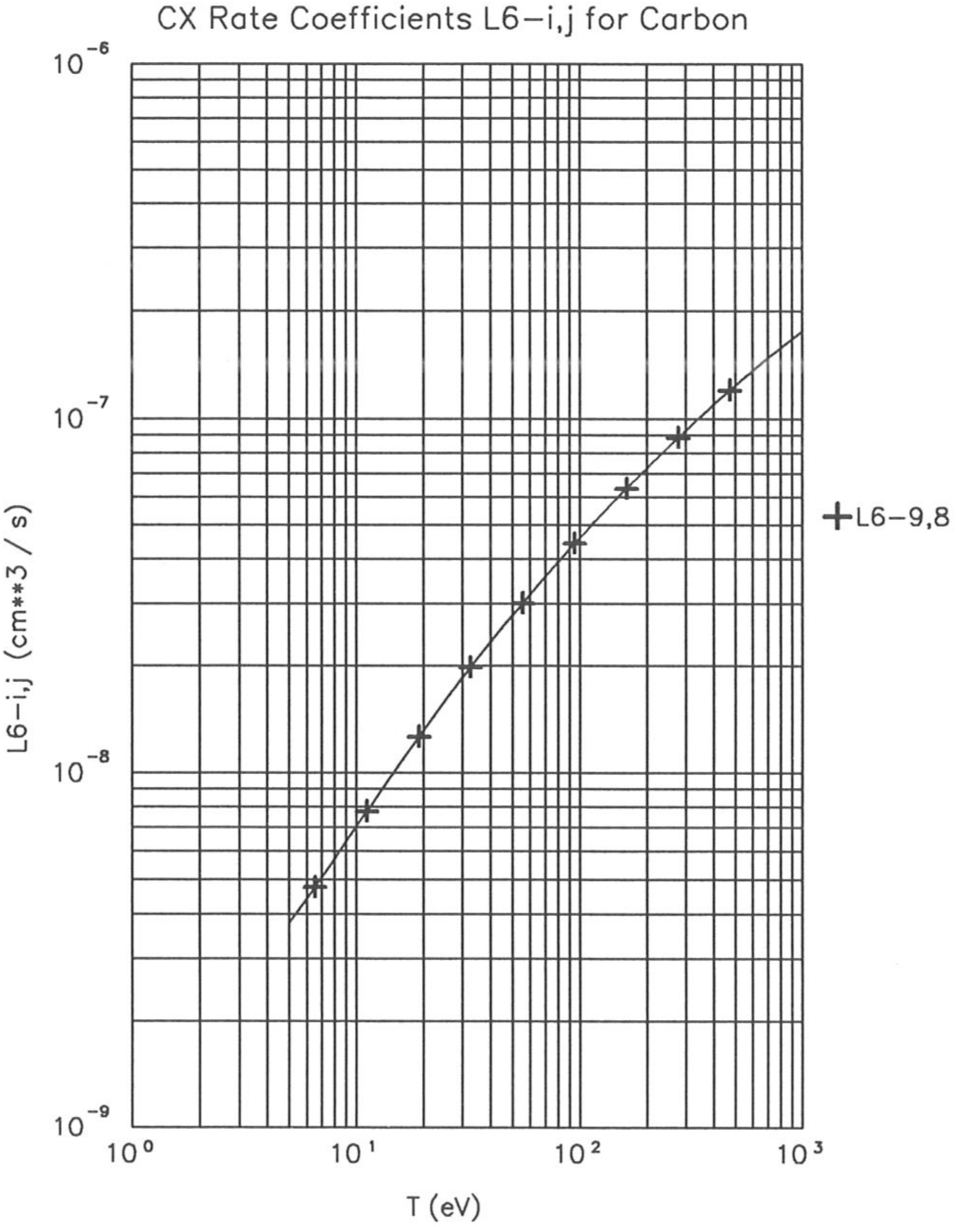

Figure 39: Charge exchange rate $L6_{9,8}$

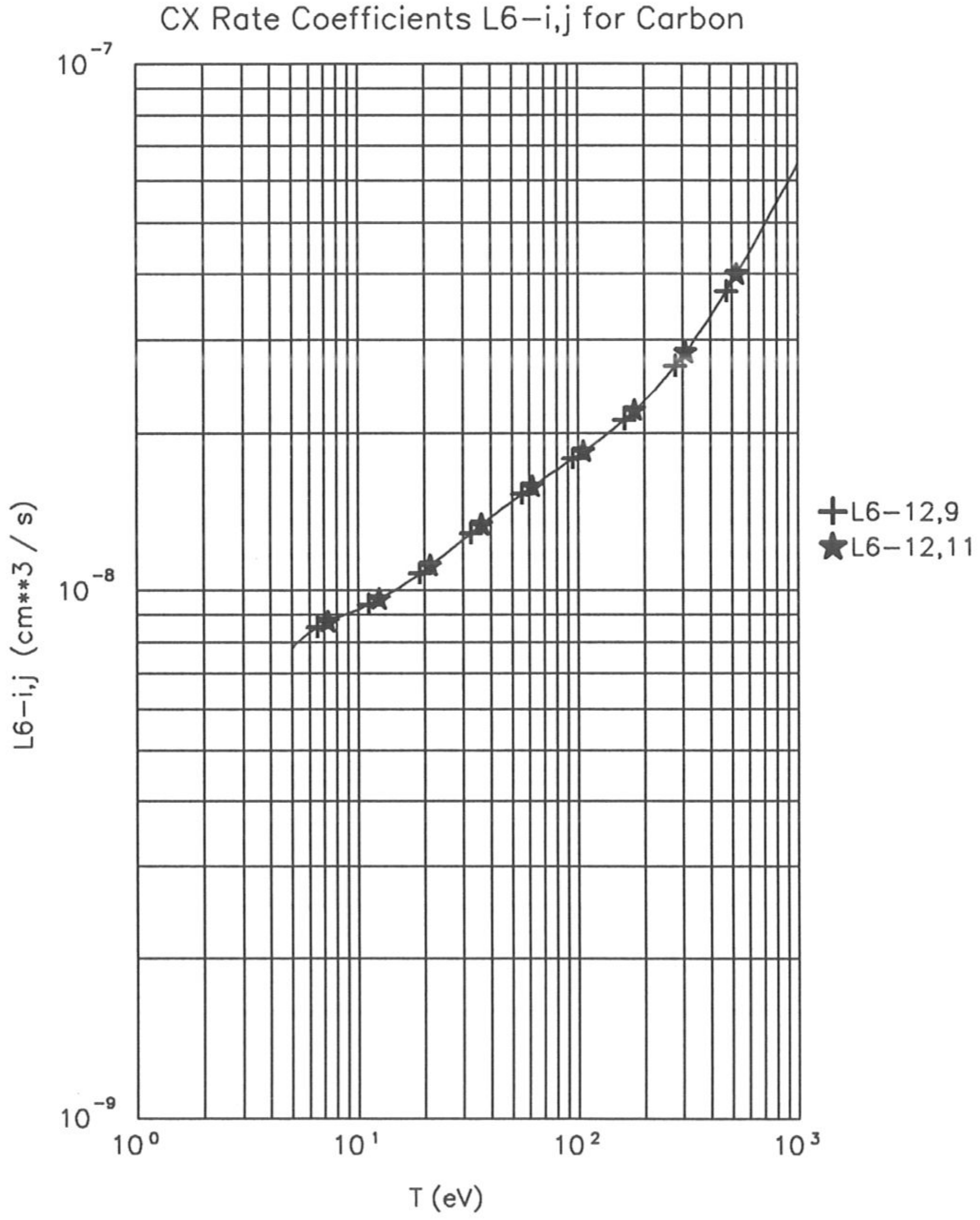

Figure 40: Charge exchange rates $L6_{12,9}$, $L6_{12,11}$

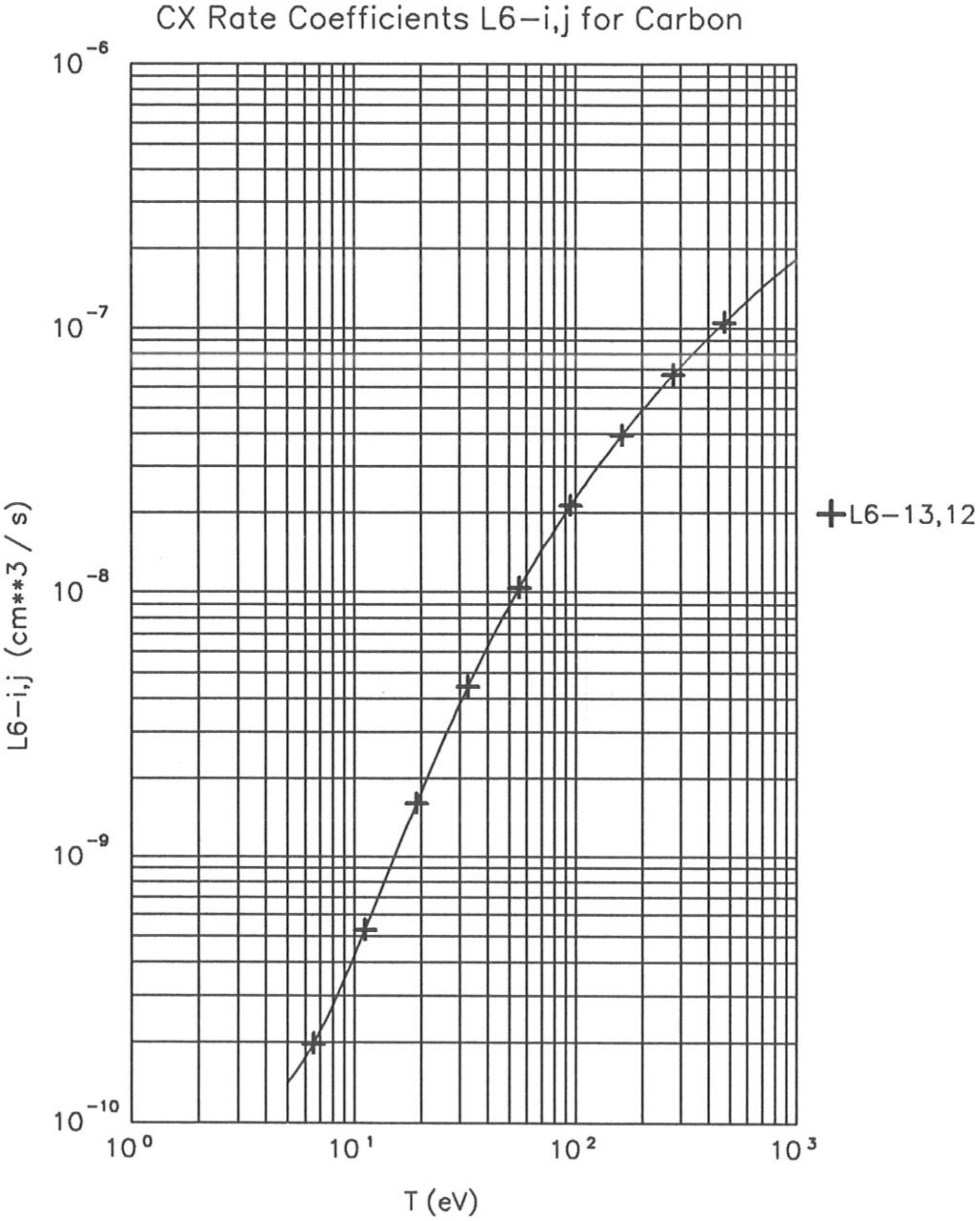

Figure 41: Charge exchange rate $L6_{13,12}$

6.3 $S6_i$ – Electron cooling rates

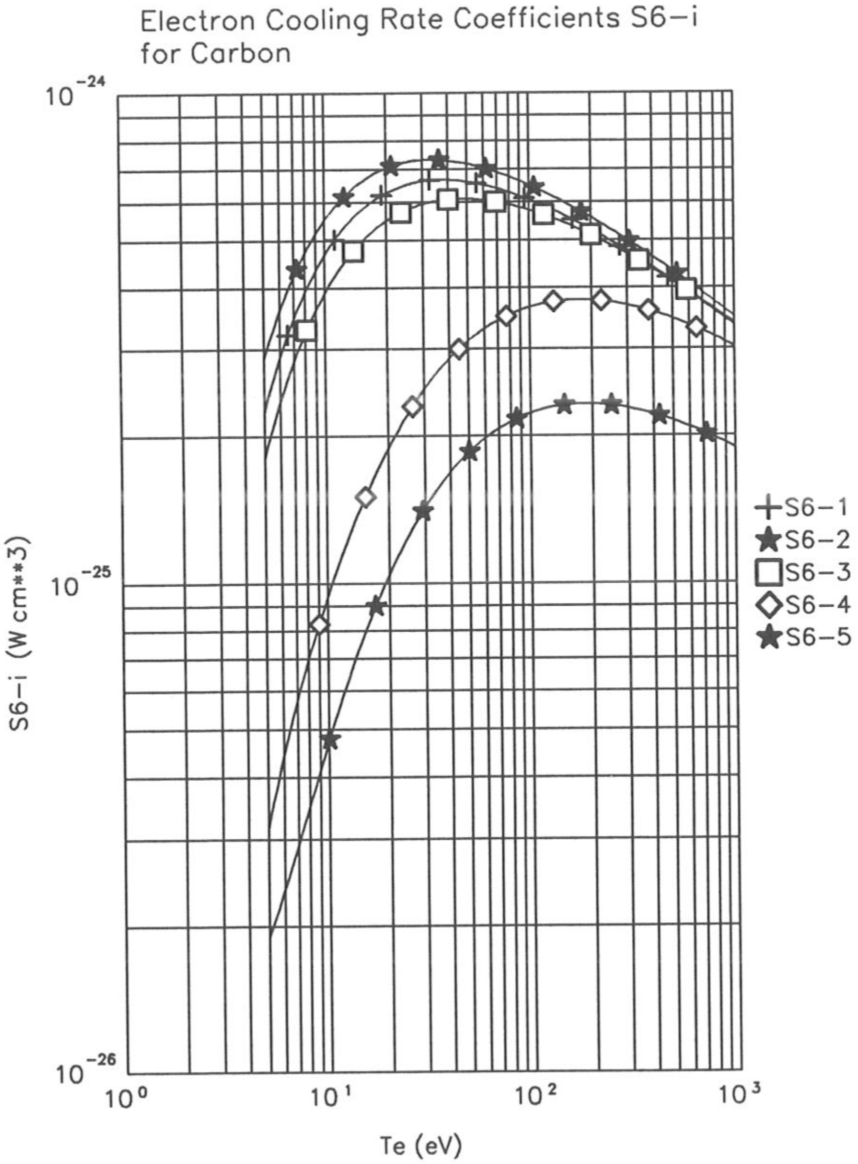

Figure 42: Electron cooling rates $S6_1$, $S6_2$, $S6_3$, $S6_4$, $S6_5$

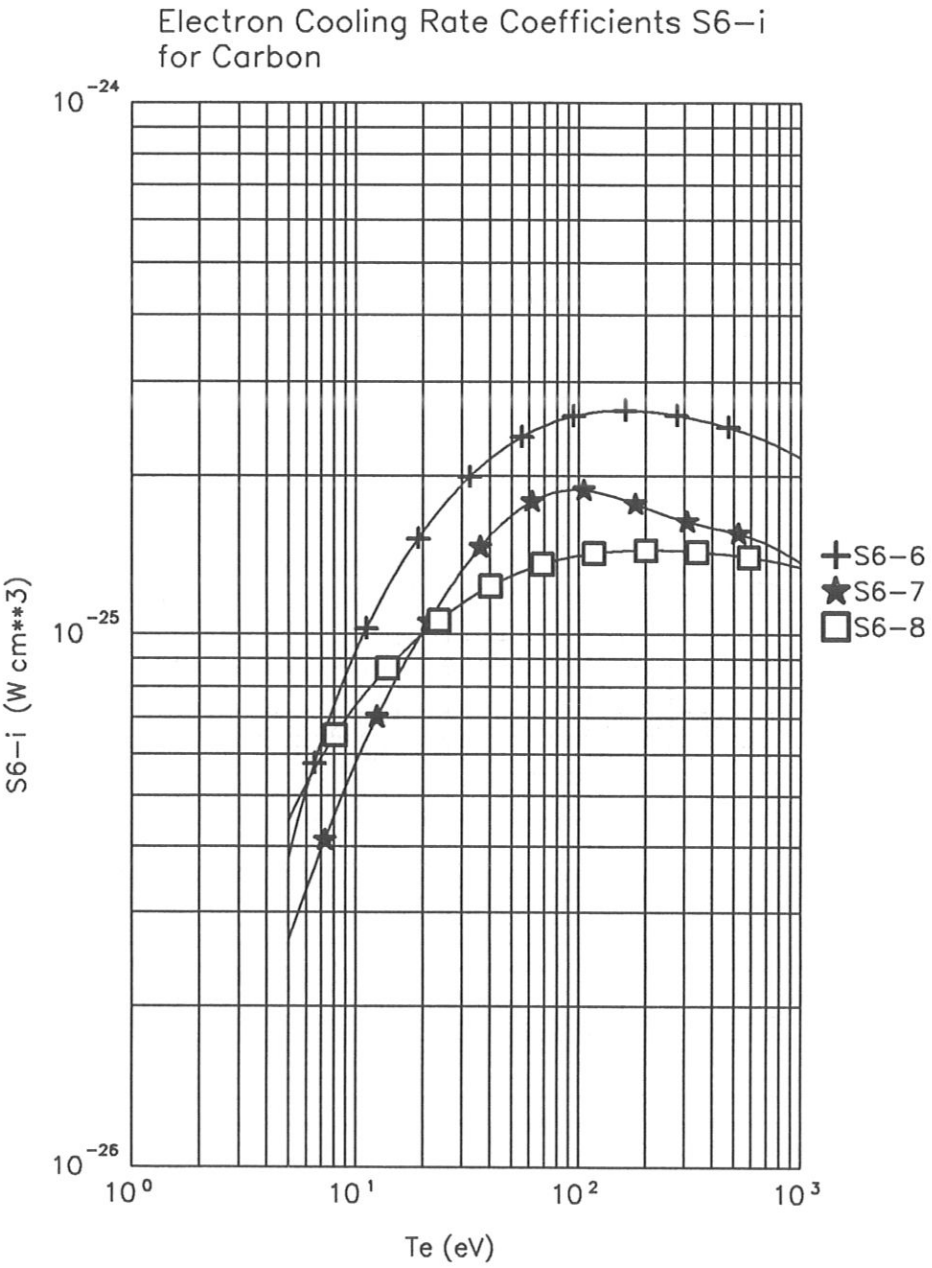

Figure 43: Electron cooling rates $S6_6$, S_7, $S6_8$

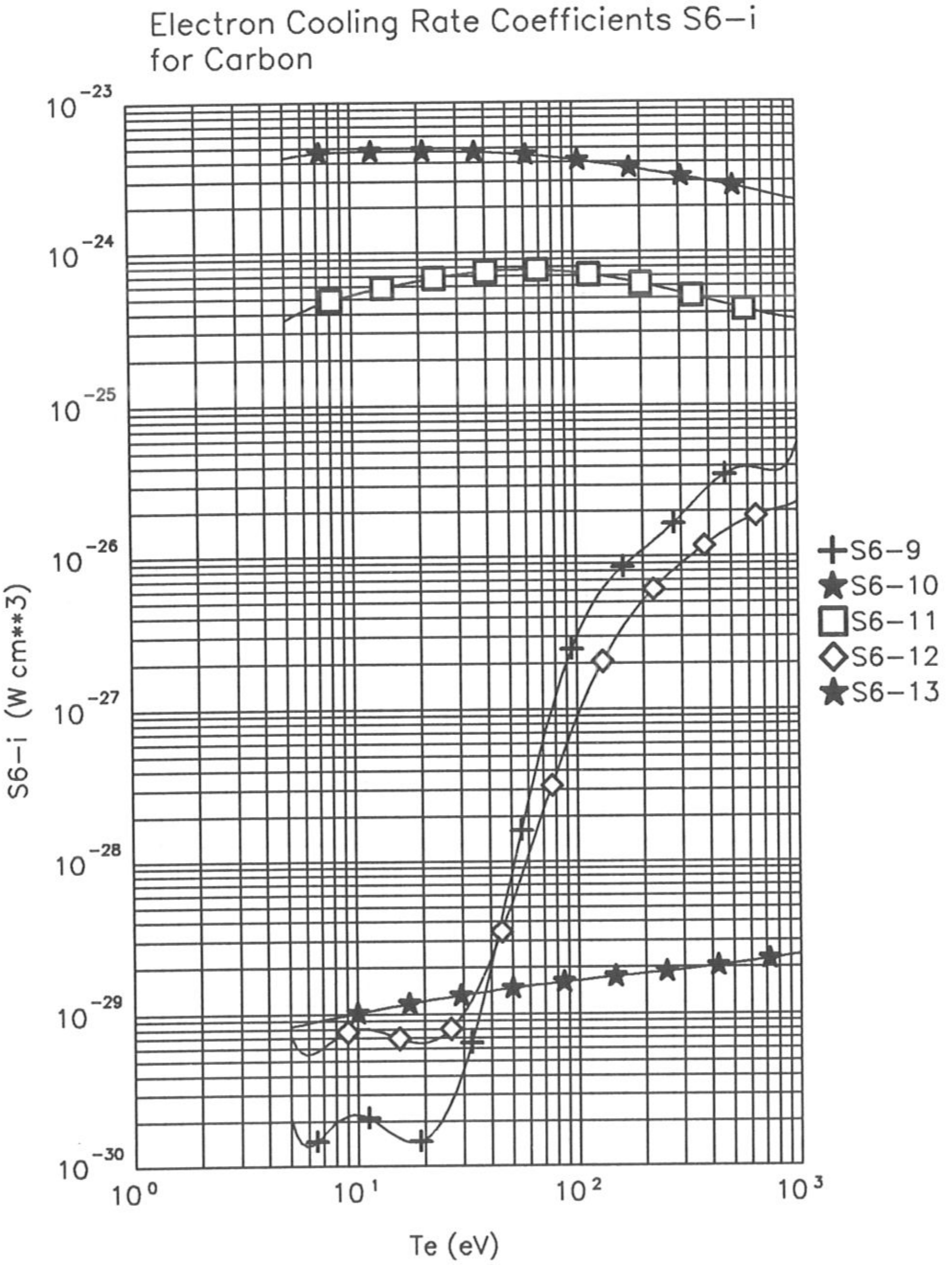

Figure 44: Electron cooling rates $S6_9$, S_{10}, $S6_{11}$, $S6_{12}$, $S6_{13}$

6.4 $R6_i$ – Radiation loss rates

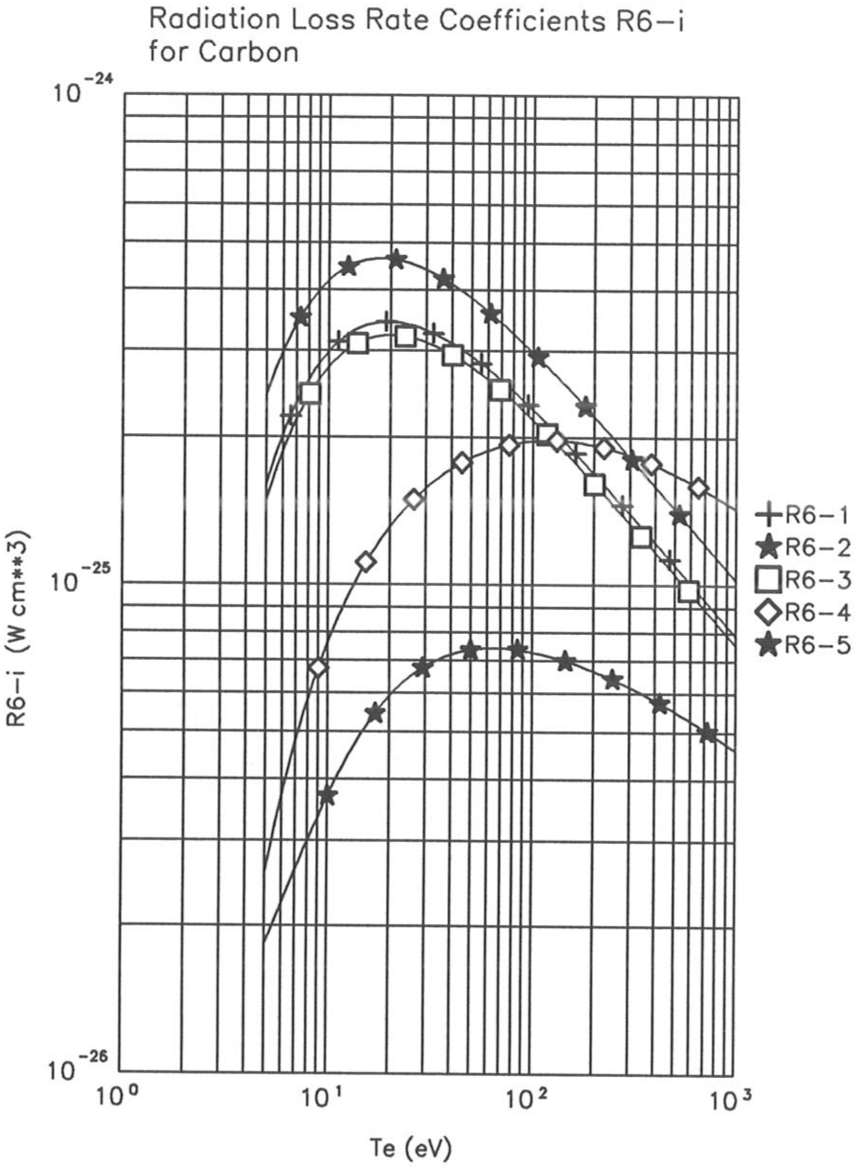

Figure 45: Radiation loss rates $R6_1$, $R6_2$, $R6_3$, $R6_4$, $R6_5$

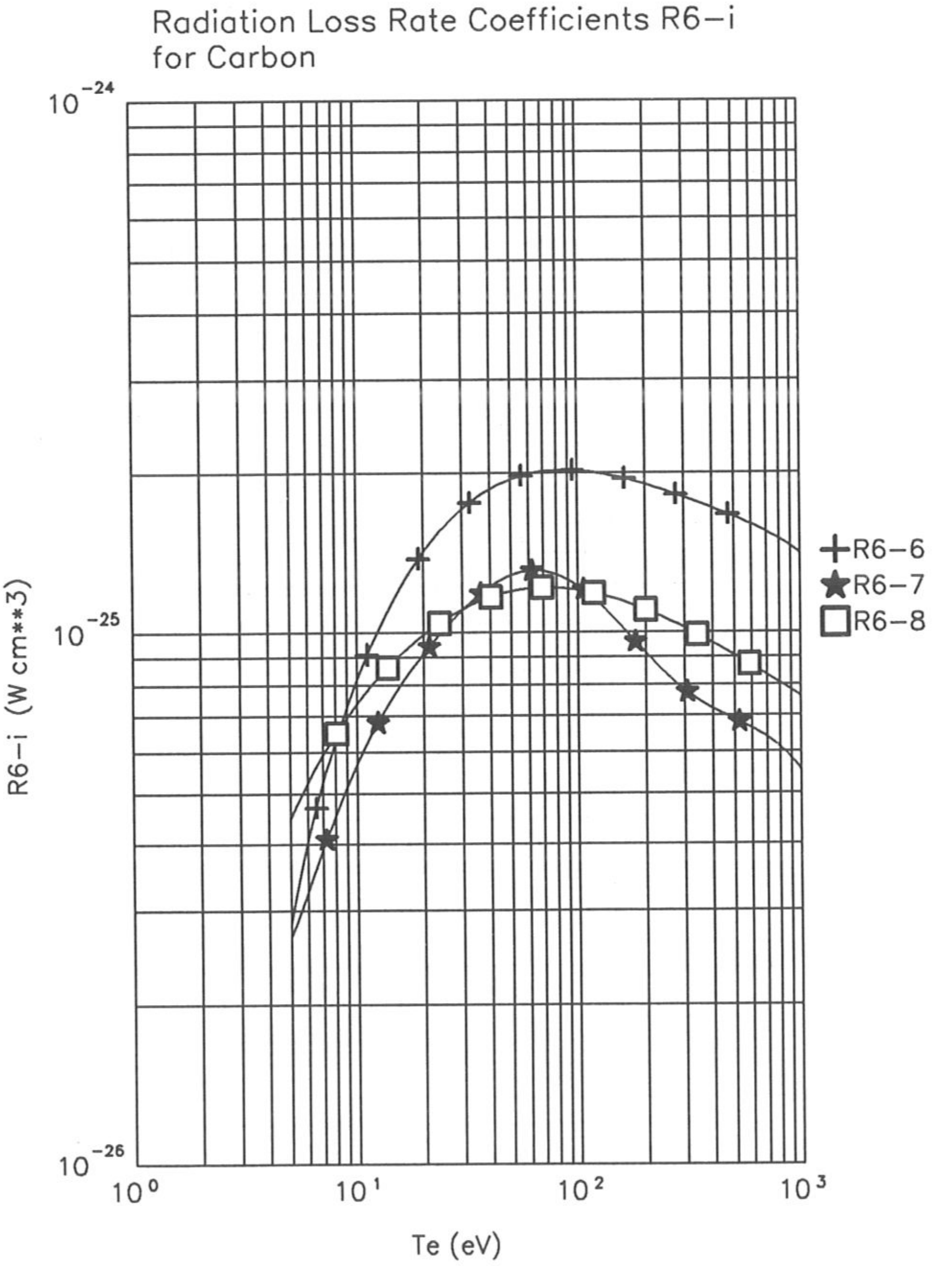

Figure 46: Radiation loss rates $R6_6$, R_7, $R6_8$

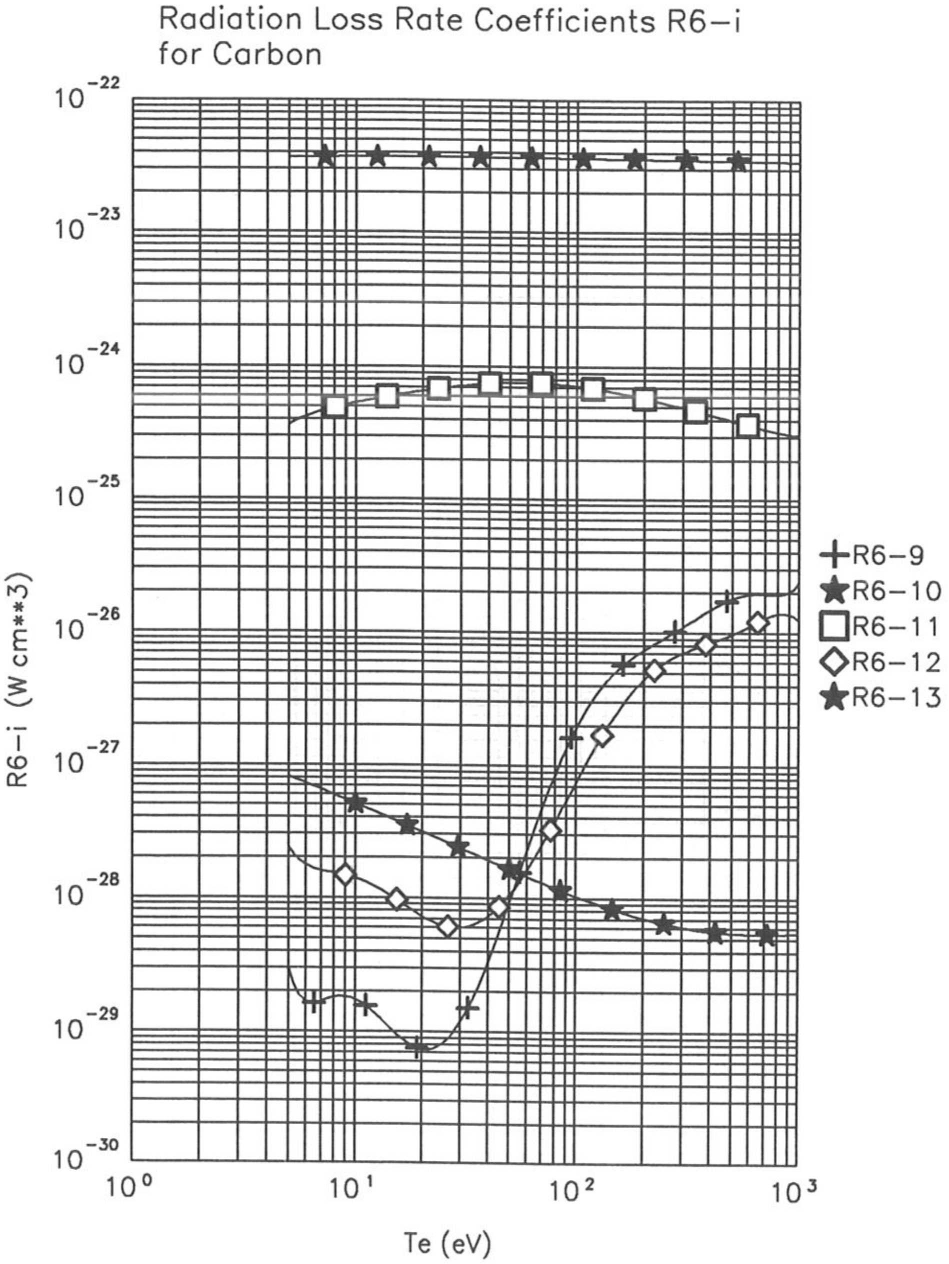

Figure 47: Radiation loss rates $R6_9$, R_{10}, $R6_{11}$, $R6_{12}$, $R6_{13}$

6.5 $F6_i$ – CX induced radiation loss rates

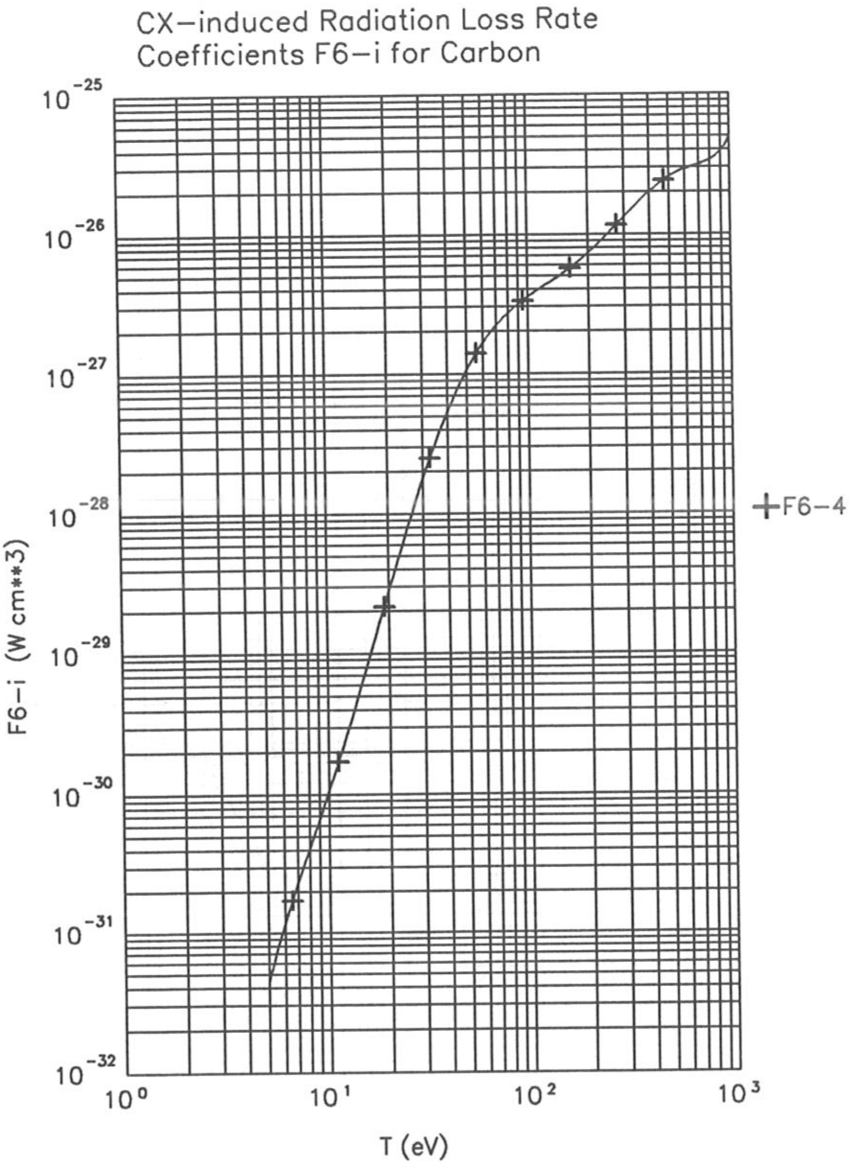

Figure 48: CX induced radiation loss rate $F6_4$

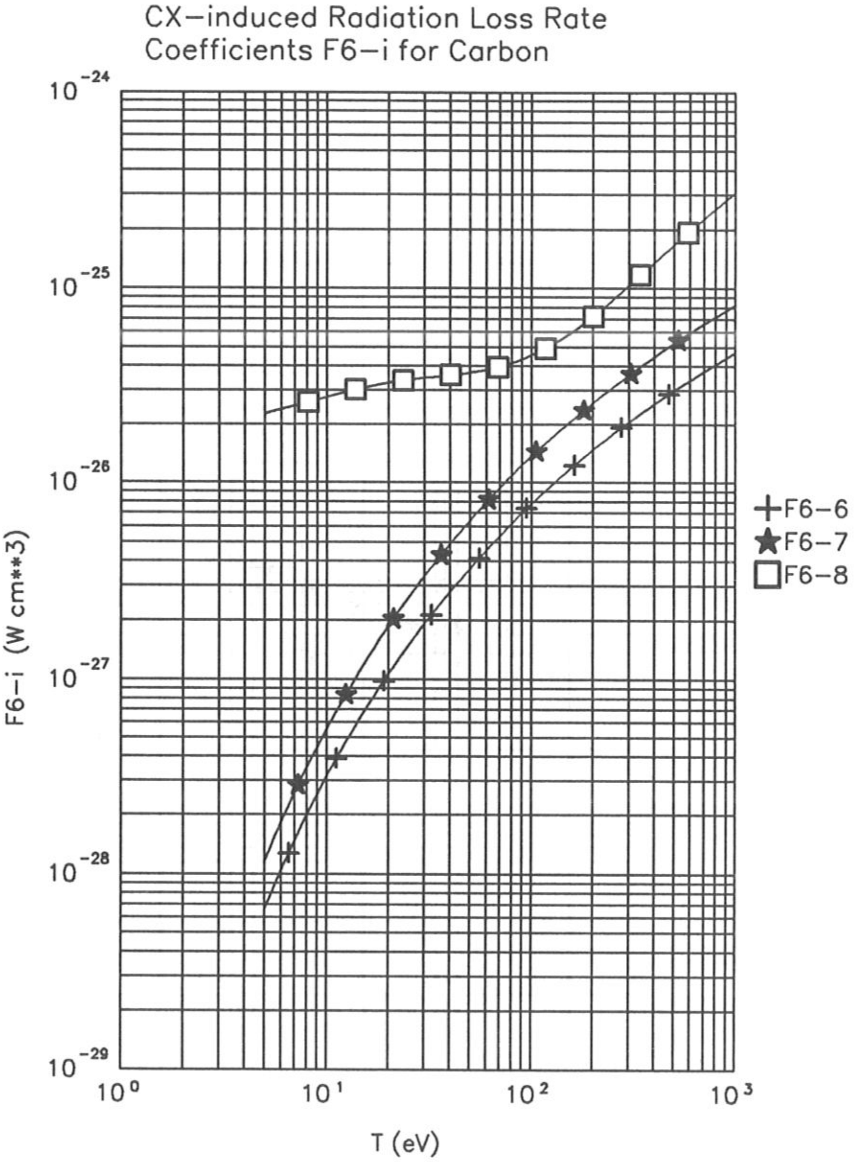

Figure 49: CX induced radiation loss rates $F6_6$, $F6_7$, $F6_8$

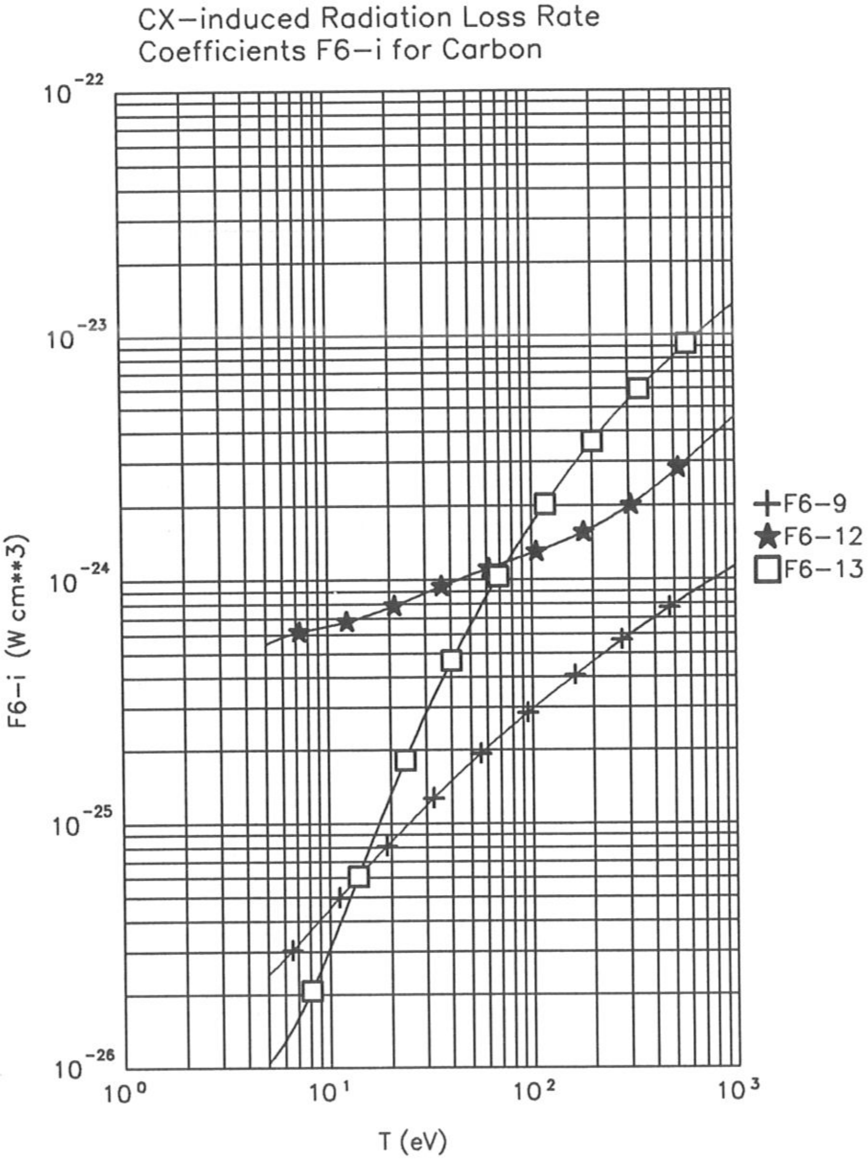

Figure 50: CX induced radiation loss rates $F6_9$, $F6_{12}$, $F6_{13}$

7 Data Fits for the Rate Coefficients

```
Rate Coefficients C6-1,2 for Carbon

  NPOL = 1

   a0 -1.753698825404D+01    a1 -4.999617250495D-01

Rate Coefficients C6-1,3 for Carbon

  NPOL = 1

   a0 -1.760615291628D+01    a1 -5.000007734390D-01

Rate Coefficients C6-1,4 for Carbon

  NPOL = 7

   a0 -2.402099484789D+01    a1  8.271468946078D+00    a2 -3.536877779510D+00
   a3  9.304195414933D-01    a4 -1.604313196546D-01    a5  1.750282167425D-02
   a6 -1.094722474738D-03    a7  2.986198714251D-05

Rate Coefficients C6-2,1 for Carbon

  NPOL = 6

   a0 -2.046266612031D+01    a1  6.843293533216D-01    a2 -4.815058000909D-01
   a3  1.111073237860D-01    a4 -1.506337646801D-02    a5  1.119898234001D-03
   a6 -3.524503336665D-05

Rate Coefficients C6-2,3 for Carbon

  NPOL = 1

   a0 -1.771244793119D+01    a1 -4.999995694440D-01

Rate Coefficients C6-2,4 for Carbon

  NPOL = 7
```

```
  a0 -2.569108866690D+01    a1  9.590628656071D+00    a2 -4.121367852559D+00
  a3  1.090090088986D+00    a4 -1.884353660332D-01    a5  2.057993792996D-02
  a6 -1.287573070640D-03    a7  3.511863959164D-05

Rate Coefficients C6-3,1 for Carbon

 NPOL = 6

  a0 -2.228760567005D+01    a1  1.735110783942D+00    a2 -9.087154945619D-01
  a3  2.096898079495D-01    a4 -2.843018392788D-02    a5  2.113880148970D-03
  a6 -6.653835077721D-05

Rate Coefficients C6-3,2 for Carbon

 NPOL = 6

  a0 -1.946763546895D+01    a1  5.498832501316D-01    a2 -4.265903806195D-01
  a3  9.836695478741D-02    a4 -1.332639169691D-02    a5  9.900694307346D-04
  a6 -3.113952547213D-05

Rate Coefficients C6-3,4 for Carbon

 NPOL = 7

  a0 -2.721882591681D+01    a1  1.094842914559D+01    a2 -4.839071583312D+00
  a3  1.307613203970D+00    a4 -2.288641840445D-01    a5  2.515389957542D-02
  a6 -1.577602044920D-03    a7  4.303614464266D-05

Rate Coefficients C6-3,5 for Carbon

 NPOL = 7

  a0 -3.415560145755D+01    a1  1.568962522640D+01    a2 -6.838256745235D+00
  a3  1.831317014927D+00    a4 -3.179333515150D-01    a5  3.474807264001D-02
  a6 -2.172232285960D-03    a7  5.916675825732D-05
```

Rate Coefficients C6-4,1 for Carbon

X-Index:	0	1	2
P-Index:			
0	9.403966507248D+03	-1.134072043079D+03	3.377092399947D+01
1	4.241963578692D+02	-1.508027003877D+02	1.401013083548D+01
2	4.688715823843D+02	-8.846436564230D+01	3.875113254371D+00
3	1.233343756116D+02	-4.293398018921D+00	3.337105207529D-01
4	-2.358885532218D+01	-8.653326890420D-01	7.018103961539D-02
5	6.826422538273D+00	-4.241866100838D-01	1.357572506342D-02
6	3.626444590553D-01	-3.516397488561D-02	1.439594619417D-03
7	-1.527588274782D-01	8.108970082361D-03	-6.421540970871D-05
8	8.686224626216D-03	-8.530600640713D-06	-5.385047404357D-05

X-Index:	3	4	5
P-Index:			
0	8.822550534938D-01	-6.478923375529D-02	8.646804373181D-04
1	-1.940040378033D-01	-2.280018373966D-02	7.703576345197D-04
2	-3.465481810385D-02	-1.200134791842D-03	8.579223347898D-05
3	-2.009021927423D-02	1.111243731346D-04	6.491105260835D-06
4	1.157161568571D-03	-6.388057007867D-05	-4.796254743595D-07
5	-2.636647777426D-04	4.233057830907D-07	3.308724738107D-07
6	-5.756443056776D-05	-8.388356154254D-07	6.890110032341D-08
7	1.186074225220D-05	-6.525163139186D-07	3.352196879136D-09
8	1.961299569217D-06	-5.217508665647D-09	-1.845913407926D-10

X-Index:	6	7	8
P-Index:			
0	9.823010206657D-06	-2.922138692721D-07	1.596988324532D-09
1	4.056113938647D-06	-4.109897399735D-07	3.906028670480D-09
2	-3.467741649620D-06	3.962708856486D-08	1.947812030125D-10
3	8.562806485051D-08	4.501372972019D-09	-1.987615880404D-10
4	7.791856434996D-09	-6.892177619428D-10	2.652439450270D-11
5	-8.789494481079D-09	6.405740181183D-11	-5.493160344900D-13
6	8.001391388817D-10	-5.517287787783D-11	4.588824609587D-13
7	2.613684660710D-10	-4.176795015088D-12	2.142313800416D-14
8	-1.872062000903D-11	5.209393476707D-13	-3.820889777479D-15

Rate Coefficients C6-4,2 for Carbon

X-Index:	0	1	2
P-Index:			
0	-2.972535486906D+02	2.669260521498D+01	-2.587171088167D+00
1	3.351958922645D+02	-3.331501440590D-01	-1.044379796215D+00
2	-2.909587306913D+02	8.271597677612D+00	-1.547963345620D-01
3	1.392040003418D+02	-5.133305308781D+00	6.799754335054D-02
4	-2.341423958312D+01	1.967803836708D-01	2.076405191693D-02
5	2.141302785055D+00	-1.242867330835D-02	2.640151409438D-03
6	-9.744515421146D-02	-7.915667762813D-04	-2.246057230872D-04
7	3.560571068269D-02	-3.833980929964D-03	1.155219340113D-04
8	-2.444318874918D-03	2.528802633144D-04	-5.212581591550D-06

X-Index:	3	4	5
P-Index:			
0	1.659431548528D-01	-3.871980427075D-03	-7.097411424774D-05
1	3.282103594244D-02	-3.001053959421D-04	-4.474766455995D-05
2	2.392227109570D-02	-4.031291144928D-04	-1.165163207874D-05
3	-4.828769137926D-03	6.910001989951D-05	2.253859797976D-06
4	3.151402931305D-04	-3.221650862134D-05	8.672626858424D-07
5	-1.255718302016D-04	5.005323511467D-07	-1.650054607727D-09
6	-4.897420178537D-06	3.890176425453D-08	-6.547804563664D-09
7	2.998691799086D-06	-1.086059463729D-07	2.357148200672D-09
8	-1.540517761498D-07	-4.939527582495D-09	5.501857523689D-10

X-Index:	6	7	8
P-Index:			
0	5.545984289795D-06	-1.122572007452D-07	8.591073690339D-10
1	3.408658148423D-06	-7.741868544490D-08	4.919666318588D-10
2	-3.256252316307D-07	1.772550861961D-08	-9.065509732300D-11
3	1.343442172564D-07	-3.961392688932D-09	-1.085469423423D-11
4	-4.287131489867D-08	4.381462111176D-10	9.857204041405D-12
5	4.288481875029D-09	-7.177594407824D-11	-7.266699304601D-13
6	9.048317615574D-10	-1.899915777822D-11	9.906612033729D-14
7	-1.601198814855D-10	2.805258022602D-12	-1.151618518288D-15
8	-1.135776902157D-11	1.518915824248D-13	-1.888283107875D-15

```
Rate Coefficients C6-4,3 for Carbon


        X-Index:    0                      1                      2
  P-Index:
        0   -1.368371595196D+02    6.036411513852D+00    4.801800678939D-01
        1    3.250318451720D+01    3.934117448894D-01   -3.342299735957D-03
        2   -4.329708401692D+00   -3.188938448448D+00    1.477685386759D-01
        3    9.203738329165D+00    4.354368105070D-01   -9.367384115417D-03
        4   -3.168709196424D+00   -4.550468572718D-02   -3.722120764298D-03
        5    4.066428090163D-01    1.886470018643D-02    7.092452653503D-04
        6   -3.050760350225D-03   -3.716122846588D-03   -1.394703601282D-04
        7   -8.251693043127D-03    8.404867352233D-04    6.628937220982D-08
        8    5.423916696266D-04   -3.599335788986D-05   -7.707392722546D-07

        X-Index:    3                      4                      5
  P-Index:
        0   -5.896432735581D-02    1.913356337789D-03   -6.878611493850D-06
        1   -3.113545386413D-03    3.332571325802D-04   -1.077826833809D-05
        2   -2.954065787218D-03   -9.028924907684D-05    4.147537403974D-06
        3    7.298108450098D-04   -1.387867014926D-06    3.098788577817D-07
        4   -7.060811419805D-05   -3.547897083899D-06   -6.345771516614D-08
        5    2.366545787450D-05    6.981319773289D-07    7.958682322871D-09
        6   -3.236490932698D-06   -9.972638153776D-09   -6.588613543104D-10
        7    2.073117573597D-07   -2.884833437526D-09    1.631696104292D-10
        8    3.656615487332D-08   -4.122582610242D-10    2.164650999770D-11

        X-Index:    6                      7                      8
  P-Index:
        0   -9.140663641532D-07    1.900947471022D-08   -1.042022368554D-10
        1    1.198189849251D-07    2.077234815523D-09   -6.822442377900D-11
        2   -7.177901146656D-08   -4.097029743560D-10    4.162628119067D-11
        3   -4.816898405736D-09    2.083258771829D-10   -1.694561512612D-11
        4    1.759967023479D-09    1.195018927862D-11    3.789121668960D-12
        5   -4.293895984050D-10   -9.830466894133D-12   -5.484969882786D-13
        6   -4.517544319369D-12    2.761821817581D-12    4.686226965671D-14
        7    1.578516314073D-12   -2.822203671919D-13   -1.977038454287D-15
        8   -2.060008415821D-12    5.828653270720D-14   -3.568568707822D-16
```

Rate Coefficients C6-4,5 for Carbon

```
  NPOL = 8

    a0  2.167083151312D+01    a1 -1.027951805236D+02    a2  1.083870935943D+02
    a3 -6.238651655299D+01    a4  2.155193819147D+01    a5 -4.594226472305D+00
    a6  5.911260615778D-01    a7 -4.204262677171D-02    a8  1.267957044655D-03
```

Rate Coefficients C6-4,6 for Carbon

```
  NPOL = 7

    a0 -4.187552496514D+01    a1  2.339211712635D+01    a2 -1.050330542104D+01
    a3  2.858847157510D+00    a4 -4.976342541546D-01    a5  5.410125649990D-02
    a6 -3.350068303958D-03    a7  9.021608956958D-05
```

Rate Coefficients C6-4,7 for Carbon

```
  NPOL = 7

    a0 -4.911210896628D+01    a1  2.889467379718D+01    a2 -1.275184125567D+01
    a3  3.439432593646D+00    a4 -5.970425511931D-01    a5  6.506074479381D-02
    a6 -4.051758225665D-03    a7  1.099438936562D-04
```

```
Rate Coefficients C6-5,1 for Carbon


        X-Index:     0                    1                    2
  P-Index:
        0    -5.423404997540D+02   7.804694778637D+01  -4.220654102020D+00
        1    -1.664905086188D+02   2.252738542104D+01  -5.784639481142D-01
        2    -1.649060977580D+01  -1.356915845566D+00  -7.382806912713D-05
        3     1.888156261102D+01   8.134895741848D-03  -2.225528957477D-02
        4    -5.444212458492D+00   8.501702849729D-02  -1.067105278198D-03
        5     2.306885245471D-01   2.825212276651D-02   2.387676959260D-04
        6     6.060888166584D-02  -4.267407189731D-03  -3.195582201661D-04
        7    -9.153943526140D-03   2.897953566849D-04   3.050353153980D-05
        8     1.515180791503D-04   3.124967172583D-05  -3.400319008805D-06

        X-Index:     3                    4                    5
  P-Index:
        0     6.303980209125D-02   1.626643068355D-03  -2.421156890406D-05
        1    -1.460706720592D-02   3.397317367424D-04   4.061968164629D-05
        2     2.070721536284D-03   4.205983486288D-05  -5.965843793138D-06
        3     5.151367806469D-04   3.397936712821D-05   1.655200496018D-07
        4    -2.984442085597D-05  -1.342108057656D-05  -1.180920907970D-07
        5     4.500103757443D-06   2.112145134052D-06   2.551610536048D-08
        6     2.758781110015D-06  -1.926922131460D-09  -6.332577975991D-09
        7     5.808295147988D-07  -4.192830261877D-08   4.949863436723D-10
        8     2.265225572021D-08   1.298162711954D-09   2.460580840886D-11

        X-Index:     6                    7                    8
  P-Index:
        0    -2.143446158245D-06   6.376484420805D-08  -4.930772293650D-10
        1    -1.707060605495D-06   2.661933850755D-08  -1.998184448567D-10
        2    -1.020857707672D-07   6.517267284338D-09  -2.657052142732D-11
        3     4.122920905859D-08  -1.807247913569D-09  -1.589306507907D-12
        4     1.500020281701D-10   2.139519185362D-10   3.304961517487D-12
        5    -6.723721821723D-10  -1.087557291504D-11  -9.955019161382D-13
        6     9.847305542149D-11  -1.832355945323D-12   1.705686263390D-13
        7     6.158499913571D-12   2.101802001717D-13  -1.525576910320D-14
        8    -2.072025016979D-12   1.918413419083D-14   3.582295786475D-16
```

```
Rate Coefficients C6-5,2 for Carbon


       X-Index:     0                    1                    2
  P-Index:
          0   -5.423404997540D+02   7.804694778637D+01  -4.220654102020D+00
          1   -1.664905086188D+02   2.252738542104D+01  -5.784639481142D-01
          2   -1.649060977580D+01  -1.356915845566D+00  -7.382806912713D-05
          3    1.888156261102D+01   8.134895741848D-03  -2.225528957477D-02
          4   -5.444212458492D+00   8.501702849729D-02  -1.067105278198D-03
          5    2.306885245471D-01   2.825212276651D-02   2.387676959260D-04
          6    6.060888166584D-02  -4.267407189731D-03  -3.195582201661D-04
          7   -9.153943526140D-03   2.897953566849D-04   3.050353153980D-05
          8    1.515180791503D-04   3.124967172583D-05  -3.400319008805D-06

       X-Index:     3                    4                    5
  P-Index:
          0    6.303980209125D-02   1.626643068355D-03  -2.421156890406D-05
          1   -1.460706720592D-02   3.397317367424D-04   4.061968164629D-05
          2    2.070721536284D-03   4.205983486288D-05  -5.965843793138D-06
          3    5.151367806469D-04   3.397936712821D-05   1.655200496018D-07
          4   -2.984442085597D-05  -1.342108057656D-05  -1.180920907970D-07
          5    4.500103757443D-06   2.112145134052D-06   2.551610536048D-08
          6    2.758781110015D-06  -1.926922131460D-09  -6.332577975991D-09
          7    5.808295147988D-07  -4.192830261877D-08   4.949863436723D-10
          8    2.265225572021D-08   1.298162711954D-09   2.460580840886D-11

       X-Index:     6                    7                    8
  P-Index:
          0   -2.143446158245D-06   6.376484420805D-08  -4.930772293650D-10
          1   -1.707060605495D-06   2.661933850755D-08  -1.998184448567D-10
          2   -1.020857707672D-07   6.517267284338D-09  -2.657052142732D-11
          3    4.122920905859D-08  -1.807247913569D-09  -1.589306507907D-12
          4    1.500020281701D-10   2.139519185362D-10   3.304961517487D-12
          5   -6.723721821723D-10  -1.087557291504D-11  -9.955019161382D-13
          6    9.847305542149D-11  -1.832355945323D-12   1.705686263390D-13
          7    6.158499913571D-12   2.101802001717D-13  -1.525576910320D-14
          8   -2.072025016979D-12   1.918413419083D-14   3.582295786475D-16
```

```
Rate Coefficients C6-5,3 for Carbon


        X-Index:     0                    1                    2
  P-Index:
        0    -5.158448707245D+02   4.911630940534D+01  -1.702411954162D+00
        1     3.650684829905D+02  -2.877879854155D+01   5.168292593160D-01
        2    -1.043795298514D+02   4.725233130557D+00  -1.082431449467D-01
        3     2.581978204671D+01  -2.483372891331D-01   1.232228187601D-02
        4    -5.705170342036D+00  -3.757923254932D-02  -3.122020814070D-03
        5     1.006563606307D+00  -8.442696855224D-03   2.270876445870D-03
        6    -8.380742961907D-02  -2.136774858927D-03  -2.118835191845D-04
        7     8.012634987645D-03   1.536516279918D-05   1.314760752211D-05
        8    -1.162738828253D-03   9.439328343914D-05  -2.401664849931D-06

        X-Index:     3                    4                    5
  P-Index:
        0     5.117978737032D-02  -4.423851974415D-03   2.356659846370D-04
        1     1.392467632721D-02   9.959612127601D-08  -3.471944266309D-05
        2     4.284621715465D-03  -2.305281460114D-04   5.424753300017D-06
        3    -1.145258380132D-03   5.748321988586D-05  -1.896829042292D-06
        4     6.570401920747D-05  -5.351832532820D-06   1.328081477589D-07
        5    -1.429885526951D-05   1.518454492323D-07  -2.819490020320D-08
        6     2.391178148681D-06  -8.922516816411D-08   2.725001995399D-09
        7    -2.150501316544D-07   5.118644528695D-09   1.273253719458D-09
        8    -6.779321866731D-08   2.377557129336D-09   1.896566846541D-11

        X-Index:     6                    7                    8
  P-Index:
        0    -5.780547470634D-06   6.117429339624D-08  -1.768110625114D-10
        1     8.894049796562D-07  -1.822015448654D-09  -1.163903919160D-10
        2    -5.513275357006D-08  -8.952825563491D-10   3.858353975444D-11
        3     6.364772786985D-08  -1.251776772808D-09   2.353236887141D-12
        4     6.816038253405D-09  -2.028603291712D-10   2.586608227434D-12
        5    -1.378456359312D-09   2.538373784633D-11   1.405886344496D-14
        6     1.652587664939D-10   3.490623532069D-12  -1.388337194066D-13
        7    -7.702473248921D-11   5.022353883975D-13   1.120443290734D-14
        8    -1.457865652988D-12   5.822286990462D-14  -9.265554640492D-16
```

```
Rate Coefficients C6-5,4 for Carbon

  NPOL = 8

    a0  4.002973154964D+01    a1 -1.415638714689D+02    a2  1.460108860241D+02
    a3 -8.297329296705D+01    a4  2.841098962280D+01    a5 -6.012822845513D+00
    a6  7.687510964965D-01    a7 -5.435907357501D-02    a8  1.630572282139D-03

Rate Coefficients C6-5,7 for Carbon

  NPOL = 7

    a0 -4.287479357804D+01    a1  2.396556658105D+01    a2 -1.054007326279D+01
    a3  2.837717865470D+00    a4 -4.925665307494D-01    a5  5.370309288831D-02
    a6 -3.346334200689D-03    a7  9.084153724793D-05
```

```
Rate Coefficients C6-6,4 for Carbon


        X-Index:     0                    1                    2
  P-Index:
        0    -5.739613482879D+03   7.121493126470D+02  -2.829098194635D+01
        1     9.859113696089D+02  -3.085589733311D+01  -3.066214386204D+00
        2    -2.927876545818D+02  -5.924434290732D-01   8.900004931151D-01
        3     5.413079660151D+01   4.727906536490D+00  -3.542271392019D-01
        4    -2.167037395029D+01   6.374303966021D-01  -2.950560551939D-02
        5     1.570219449376D+00   5.317465348920D-02  -1.653840349574D-03
        6    -7.268653484222D-02   5.562991069413D-03  -1.156733655600D-03
        7    -7.643329859913D-03   6.631145189719D-04  -1.024398080482D-05
        8     3.391049041067D-03  -4.209173837740D-04   1.522086884869D-05

        X-Index:     3                    4                    5
  P-Index:
        0     1.019658157534D-01   1.553431475008D-02   1.335553501178D-06
        1     1.289501271492D-01   2.588500590758D-03  -1.181495860971D-04
        2    -4.684752365419D-03  -2.146242815926D-03   7.842532532613D-05
        3     6.665807456998D-03   7.812128435518D-05   2.858674401937D-07
        4     8.358457863290D-05  -2.717829271513D-05   1.189876109005D-06
        5     3.214608705341D-04   4.503749151103D-06  -3.927653878570D-07
        6    -3.778642202287D-06  -1.195007256089D-06   5.137551156561D-08
        7     4.449977928004D-06   7.886982839126D-08  -7.564285975965D-09
        8     5.881001579072D-08  -2.233180484176D-08   4.044651921784D-11

        X-Index:     6                    7                    8
  P-Index:
        0    -1.537005696682D-05   3.115028576428D-07  -1.845533855978D-09
        1    -3.301358716899D-06   1.629208054403D-07  -1.611571897055D-09
        2    -9.057285398039D-07   1.931039290327D-09  -3.568178436613D-11
        3    -1.410015719468D-07  -5.686338025628D-10   7.828959514060D-11
        4     9.723770880071D-09   4.760397493181D-10  -2.991657946558D-11
        5    -7.001354939763D-09   5.986009482349D-11   6.155923792316D-12
        6     1.184482808484D-09   2.209692333066D-12  -1.132663723629D-12
        7     4.224076659972D-11  -3.276884371237D-12   1.212409874218D-13
        8     2.960649936245D-11  -5.496479287061D-13   3.932095750744D-16
```

```
Rate Coefficients C6-6,5 for Carbon


       X-Index:     0                     1                     2
  P-Index:
             0     3.384603883998D+03  -5.523980471205D+02   2.989002624391D+01
             1    -7.406387327923D+02   1.004072644000D+02   4.156164368914D-01
             2     4.665828519265D+02  -7.127469197691D+01   4.352679640591D-01
             3     1.063531900967D+02   1.212992094381D+01  -1.837571283810D-01
             4    -7.861525969420D+01  -5.936765480494D-01  -7.168618218300D-04
             5     1.878599786648D+01  -1.509767074617D-01   1.511146456675D-03
             6    -1.805705340651D+00  -3.594845517692D-02   2.223249195357D-03
             7     5.177804618402D-02   7.158505305793D-03  -1.814162226002D-04
             8     1.321631697487D-02  -1.766392028249D-03   4.673508307166D-05

       X-Index:     3                     4                     5
  P-Index:
             0    -7.213681210370D-01   3.180188216446D-02  -2.797416646891D-03
             1    -4.267694354080D-01   2.908766059424D-02  -1.038219082681D-03
             2     2.530099766808D-02   4.630238902879D-03  -2.365993320224D-04
             3    -7.757724937491D-04  -4.129551053738D-04  -2.142445463315D-05
             4     2.525466390398D-03  -6.966481778897D-06   3.262527485390D-06
             5    -7.321989107052D-05  -1.430076718811D-05   4.084554520007D-08
             6     2.468725175927D-06  -2.083203955961D-06   9.447389764856D-08
             7    -1.275549701316D-07  -6.433246670681D-08  -3.860049562052D-09
             8     6.636540371800D-07  -2.445574255088D-08  -7.989581974706D-10

       X-Index:     6                     7                     8
  P-Index:
             0     1.223437219214D-04  -2.436601927073D-06   1.830367360316D-08
             1     1.449147946397D-05   7.560529473214D-08  -2.398326889137D-09
             2     6.507082773877D-06  -1.336861406361D-07   1.028043454253D-09
             3     9.630549393266D-07  -6.797090131715D-09   1.155175205514D-10
             4     2.064272716973D-11  -1.164840587650D-09  -6.008538000750D-11
             5    -1.703893815979D-08  -2.304712069706D-11   2.158398661108D-11
             6     2.172784104569D-09   9.642280487184D-12  -3.249571501769D-12
             7     2.464460550254D-10  -1.644754882177D-11   4.026814989750D-13
             8     2.699026062970D-11   3.947906268506D-13  -1.586535587622D-14
```

```
Rate Coefficients C6-6,7 for Carbon

 NPOL = 8

  a0  1.696282198929D+01    a1 -8.715174609159D+01    a2  8.837929704940D+01
  a3 -4.841815388723D+01    a4  1.578304158099D+01    a5 -3.153669314990D+00
  a6  3.784793167717D-01    a7 -2.502876336528D-02    a8  7.007717186103D-04
```

```
Rate Coefficients C6-6,8 for Carbon

 NPOL = 8

  a0 -6.706222065388D+01    a1  4.666912719071D+01    a2 -2.185775058572D+01
  a3  6.481171910697D+00    a4 -1.302271928877D+00    a5  1.777418879537D-01
  a6 -1.582642603667D-02    a7  8.295602159180D-04    a8 -1.939965020454D-05
```

Rate Coefficients C6-7,4 for Carbon

X-Index:	0	1	2
P-Index:			
0	-8.988146920143D+00	-8.439502881819D+01	8.912062280050D+00
1	2.354165510854D+02	-1.168643964388D+01	1.547938979407D+00
2	8.704937631010D+01	-2.709360192207D+01	1.992406054156D+00
3	7.128694825900D+01	-1.215467283497D+01	5.021164391828D-01
4	3.020755307264D+01	-2.662543674488D+00	6.958798703387D-02
5	3.283067950868D-01	-5.572535023598D-02	1.398790569790D-02
6	-9.614588497812D-01	4.207290181169D-02	-8.002878303184D-04
7	8.713322734815D-02	-9.482182399754D-04	-9.574398613434D-05
8	-9.966887548462D-04	-1.662687948263D-04	5.535014853873D-06

X-Index:	3	4	5
P-Index:			
0	-2.867632753039D-01	1.320753642204D-03	6.659322142882D-05
1	-1.774236044965D-01	1.892516546806D-03	4.376181360851D-04
2	-5.497244194245D-03	-3.064503114300D-03	1.361512307726D-05
3	-2.846697760804D-03	3.292976742370D-04	-1.863054093949D-05
4	-1.218135550110D-03	-5.166869909452D-05	1.164805023561D-06
5	-2.689442485644D-04	-7.291602221354D-06	3.171010844796D-07
6	2.037570641052D-05	-1.754526378917D-06	8.804224533356D-08
7	-1.110187585617D-06	-7.516429466566D-08	1.441516859389D-08
8	4.213329208790D-08	2.639434073414D-08	-1.491798067193D-09

X-Index:	6	7	8
P-Index:			
0	-2.641293641710D-06	1.181648278364D-07	-1.752548263066D-09
1	-1.668342325345D-05	1.440923084594D-07	6.810287599395D-10
2	2.328481864063D-06	-9.758874517065D-09	-5.292423399188D-10
3	4.587171203690D-07	-1.361643823686D-08	1.880990747462D-10
4	5.223531119615D-08	-1.615464522327D-09	1.717612066883D-11
5	7.003637498350D-10	3.309863247238D-11	-4.372113543231D-12
6	-3.474469325459D-09	3.590515695471D-11	5.647350504872D-13
7	-2.668800184562D-10	1.187304042862D-12	-4.043083373089D-14
8	6.616092184151D-12	5.890261857564D-13	-6.172563742743D-15

```
Rate Coefficients C6-7,5 for Carbon


      X-Index:     0                     1                     2
  P-Index:
           0   -1.399291797654D+02   1.316669991621D+01   3.430068430539D-01
           1    7.015939105683D+01  -4.477210302692D+00   3.461996764940D-02
           2   -9.243363669334D+01   5.057094904710D+00  -5.912002797834D-02
           3    3.318104452392D+01  -1.525157107842D+00  -1.397246115058D-02
           4   -2.513659676785D+00  -4.518783294561D-02   5.934521545479D-03
           5   -1.311522744133D-01   4.949511671641D-02  -7.752958144947D-04
           6   -1.313042270233D-02  -7.576929626033D-03   2.212338489008D-04
           7    2.062258949127D-02  -1.104435926937D-03   2.370277948120D-05
           8   -1.492143367582D-03   1.101005543617D-04  -3.118424148441D-06

      X-Index:     3                     4                     5
  P-Index:
           0   -1.177440161622D-01   5.528353560163D-03  -1.488171011777D-06
           1    1.301100910205D-02  -7.289116013893D-04  -2.564958611128D-05
           2    3.564760989962D-03  -8.957382638698D-05  -8.500861741088D-06
           3    3.086960996655D-04   6.829428492782D-05  -2.737476720554D-07
           4   -1.025901030174D-04  -2.094209764714D-06  -1.043587082504D-07
           5   -3.823847201858D-06  -8.737446305347D-07   3.560998428185D-08
           6    9.143431854428D-06  -4.164131791554D-07  -8.507446283632D-09
           7   -6.432250129434D-07  -2.795340946983D-09   1.784537485571D-09
           8    5.509271254879D-08   9.012298951066D-10  -1.043764835186D-10

      X-Index:     6                     7                     8
  P-Index:
           0   -6.587169723707D-06   1.792840091331D-07  -1.491455960254D-09
           1    3.326786361656D-06  -9.373715118215D-08   8.116182836818D-10
           2    8.688789911947D-08   6.638782215434D-09  -6.970518597112D-11
           3   -8.517743407061D-09  -3.500908369793D-10  -1.476071894654D-11
           4   -5.988220985742D-09   6.257032659134D-11   8.504428826685D-12
           5    2.254007455723D-09  -2.375509014080D-11  -1.824728050243D-12
           6    2.772910051111D-10  -3.892977320225D-12   2.131340752138D-13
           7    6.776259820463D-12  -1.894756680519D-12   1.469558794542D-14
           8   -1.947114054472D-12   1.782302180379D-13  -2.027924198246D-15
```

```
Rate Coefficients C6-7,6 for Carbon

  NPOL = 8

   a0 -2.845000684032D+00    a1 -3.561156539219D+01    a2  3.302475545165D+01
   a3 -1.639158563525D+01    a4  4.715255415894D+00    a5 -7.980248889223D-01
   a6  7.557527670685D-02    a7 -3.433008258675D-03    a8  4.521400376994D-05

Rate Coefficients C6-7,8 for Carbon

  NPOL = 8

   a0 -6.036391568260D+01    a1  4.041965288605D+01    a2 -1.891900478930D+01
   a3  5.616525044034D+00    a4 -1.131444269826D+00    a5  1.549080166845D-01
   a6 -1.383856089745D-02    a7  7.277525019215D-04    a8 -1.707414099486D-05
```

Rate Coefficients C6-8,6 for Carbon

X-Index:	0	1	2
P-Index:			
0	-2.609217513763D+03	1.051320267678D+02	1.459303936701D+01
1	2.524616285238D+03	-2.477659593767D+02	7.552411593922D+00
2	-3.404311966490D+02	-2.339205055294D+00	8.428064755160D-01
3	1.108948477963D+02	6.252434827397D+00	-3.250011676466D-01
4	-4.066873598042D+01	-1.961888844157D-01	4.528988577585D-02
5	2.858091353711D+00	1.055004081529D-01	3.638049628121D-03
6	6.067414653537D-01	-4.958434515472D-02	-1.120925430863D-03
7	-7.100714523199D-02	2.266599539730D-03	1.900123750201D-04
8	1.190300813934D-04	3.253976502343D-04	-2.297051150649D-05

X-Index:	3	4	5
P-Index:			
0	-1.072662137613D+00	1.312211958887D-02	5.308913532222D-04
1	2.102748607933D-02	-3.463377920950D-03	5.662216330781D-05
2	-3.035421080984D-02	8.996586949680D-04	-5.178765172566D-06
3	-7.942679037723D-03	1.922700776649D-04	1.377956791105D-05
4	6.312861912458D-04	-4.294752148211D-05	-1.539801433357D-06
5	-1.907315088759D-04	2.725842757133D-06	2.463117821778D-07
6	2.291893854205D-05	-7.653186525423D-08	1.052551103822D-08
7	2.231801721885D-06	-1.111125423568D-07	-7.963985608661D-09
8	-2.245453630988D-07	2.330346027734D-08	1.895345260028D-10

X-Index:	6	7	8
P-Index:			
0	-7.393551204205D-06	-2.864489560395D-07	5.060238743545D-09
1	-7.799176881816D-06	3.525359277030D-07	-4.422246470943D-09
2	-1.574010115955D-07	-2.979293814671D-08	7.277224447865D-10
3	-2.501935378639D-07	9.895709927867D-10	-4.470260253421D-11
4	1.318469536939D-08	1.561370316630D-09	-2.306461328175D-11
5	-7.033786499398D-09	-1.914249403268D-10	5.995885162120D-12
6	1.193353753584D-09	-1.927091650356D-11	-4.090582007802D-13
7	8.681335132029D-11	2.521717359173D-12	3.461381069906D-16
8	-1.488583167460D-11	1.440982168057D-13	-1.242539224685D-15

```
Rate Coefficients C6-8,7 for Carbon


        X-Index:     0                     1                    2
  P-Index:
        0    -3.384749061963D+03    4.855636018888D+02   -3.119893525666D+01
        1     7.482645512100D+02   -5.635412083405D+01   -1.116551870060D-02
        2    -8.549233299197D+01    7.636115214156D+00   -3.802131160321D-01
        3     4.538348204474D-01    6.742535054936D-01    8.736717337267D-02
        4    -1.166103606886D+00   -2.271012095003D-01   -4.123286945090D-02
        5    -1.021263326444D+00    2.648793118442D-01   -1.698514035613D-03
        6    -3.291808666572D-02   -1.313707060317D-02   -7.771291253690D-04
        7    -3.758349565089D-02    6.272084741998D-03   -2.137569082702D-04
        8     1.531507536718D-03   -6.989916623220D-05   -1.235059849277D-05

        X-Index:     3                     4                    5
  P-Index:
        0     1.328749050531D+00   -4.375067680130D-02    8.851200430186D-04
        1     7.778238875887D-02    3.442040481694D-04   -3.573587387560D-05
        2    -2.560128046263D-03   -2.879254417290D-05    4.056702996703D-06
        3     2.350674039906D-03   -9.966178962732D-05    1.490251115350D-06
        4     3.620275224019D-04   -9.920129358581D-06    1.901471793113D-07
        5     5.707105292545D-05    2.299814067317D-06    1.670983929836D-07
        6     1.207958147756D-05   -8.442059802391D-07    1.975496194154D-08
        7     5.495010940257D-06   -3.619668130435D-08    2.073296881131D-09
        8     6.944829082286D-07   -1.221608542148D-08    1.555661580727D-11

        X-Index:     6                     7                    8
  P-Index:
        0    -3.423707552541D-06   -1.952374446987D-07    2.479596937728D-09
        1    -3.319860308258D-06    1.333862883821D-07   -1.373754019183D-09
        2     8.229943371581D-08   -3.834111035845D-09    8.300014607744D-11
        3     4.135198656834D-08   -2.604779858810D-09    4.364238833596D-12
        4    -1.723974404517D-08    9.417126168341D-10   -3.538887372862D-12
        5    -7.473455496132D-09   -1.072903665173D-11   -1.395535149018D-13
        6    -3.346008396465D-10    1.665324257211D-11   -4.048334644743D-14
        7    -1.324957967314D-10    2.270929585290D-12   -2.517444266451D-14
        8    -3.544549706534D-12    1.952393267074D-13   -1.749216486458D-15
```

```
Rate Coefficients C6-8,9 for Carbon

  NPOL = 8

   a0 -8.472059856212D+01    a1  6.264509803730D+01    a2 -2.938675121296D+01
   a3  8.704338139975D+00    a4 -1.744620745070D+00    a5  2.375513924146D-01
   a6 -2.111687693786D-02    a7  1.105956186349D-03    a8 -2.586147519459D-05
```

```
Rate Coefficients C6-8,10 for Carbon

  NPOL = 8

   a0 -3.889334419277D+02    a1  3.551142606351D+02    a2 -1.671939759672D+02
   a3  4.937173835281D+01    a4 -9.851590492808D+00    a5  1.338014692614D+00
   a6 -1.188928202679D-01    a7  6.232490607047D-03    a8 -1.459420637122D-04
```

```
Rate Coefficients C6-8,11 for Carbon

  NPOL = 8

   a0 -3.826293767722D+02    a1  3.509330618774D+02    a2 -1.657242784574D+02
   a3  4.911026593077D+01    a4 -9.837291024007D+00    a5  1.341472745419D+00
   a6 -1.196868914423D-01    a7  6.299385953973D-03    a8 -1.480848607280D-04
```

Rate Coefficients C6-9,8 for Carbon

```
        X-Index:     0                    1                    2
  P-Index:
        0     8.519112613405D+03   -9.789216604172D+02    3.284191137222D+01
        1    -4.052294948567D+03    3.709927651288D+02   -1.063181972869D+01
        2     9.536868669173D+02   -3.771273386250D+01   -2.628603384485D-01
        3    -2.216844076121D+02   -4.979585755744D-02    4.922686540048D-01
        4     4.558718334513D+01   -1.074654825900D+00   -2.828042716996D-02
        5    -8.125587706056D-01   -3.711271169748D-02    7.292956085002D-03
        6    -6.237785970272D-01   -3.607682500019D-03    1.060497317209D-03
        7     6.193535543158D-02    2.768648822483D-03   -2.248835085300D-04
        8     9.353752576948D-04   -4.897347611873D-04    1.711005748299D-05

        X-Index:     3                    4                    5
  P-Index:
        0     2.192163465199D-01   -2.956459877732D-02    1.387411415844D-04
        1    -1.793229958001D-02    5.295781667158D-03   -2.027646131359D-05
        2     2.910895671587D-02   -1.606365413042D-03    3.838198215390D-05
        3    -4.644513399042D-03    1.249781818385D-04   -1.676632160155D-06
        4    -1.063794932992D-03    9.597623164619D-06    5.041464586698D-07
        5    -9.661273627524D-05   -6.311264140842D-08    1.547850841895D-07
        6     4.341791570521D-06   -1.049589966114D-06   -2.414990852424D-09
        7     1.996851626337D-06   -7.109947393090D-08    3.113939529902D-09
        8     4.174124418148D-07   -2.729307408629D-08    7.346262172184D-10

        X-Index:     6                    7                    8
  P-Index:
        0     1.398895190152D-05   -1.882348425539D-07   -1.896104859701D-10
        1     7.728752158699D-07   -1.395870150175D-07    2.456913968127D-09
        2     9.929259136102D-08    1.793251651208D-08   -6.763842684449D-10
        3    -4.646309587686D-07    4.434001731633D-09    1.408280023273D-10
        4     2.404846178717D-08    9.433035228349D-10   -3.932481408633D-11
        5    -3.006420147559D-09   -5.935089070090D-11    1.279461233318D-12
        6     3.175592769824D-10   -4.007962809906D-11    1.020045401897D-12
        7     1.280367113432D-10    3.854832851031D-14   -9.295947233474D-14
        8    -2.564658791157D-11    3.425397743575D-13    1.338060770149D-15
```

```
Rate Coefficients C6-9,10 for Carbon

  NPOL = 8

   a0 -1.123933201976D+04    a1  1.251651794724D+04    a2 -5.540131555255D+03
   a3  1.134224169153D+03    a4 -5.979308590282D+01    a5 -1.949186936647D+01
   a6  4.250732970735D+00    a7 -3.437904141211D-01    a8  1.044653884727D-02

Rate Coefficients C6-9,11 for Carbon

  NPOL = 8

   a0  5.288957803992D+03    a1 -6.232909216149D+03    a2  2.853450359363D+03
   a3 -5.910256096271D+02    a4  2.663686744550D+01    a5  1.225787391346D+01
   a6 -2.588255215002D+00    a7  2.097593189517D-01    a8 -6.417207639199D-03

Rate Coefficients C6-9,12 for Carbon

  NPOL = 6

   a0 -3.083818490488D+02    a1  2.240906511848D+02    a2 -7.714410518070D+01
   a3  1.480637502369D+01    a4 -1.652988687369D+00    a5  1.009151601828D-01
   a6 -2.616027628043D-03

Rate Coefficients C6-10,8 for Carbon

  NPOL = 8

   a0 -2.395075632542D+01    a1  3.065970164738D+00    a2 -3.463090317444D+00
   a3  1.781161243932D+00    a4 -6.127124674953D-01    a5  1.363902615769D-01
   a6 -1.862236489561D-02    a7  1.407818034588D-03    a8 -4.492115599574D-05
```

```
Rate Coefficients C6-10,9 for Carbon


        X-Index:      0                    1                    2
  P-Index:
        0   -2.445511442365D+03   9.932390935306D+02  -1.312047171233D+02
        1    3.003784891802D+03  -3.121638213013D+02   1.460338288786D+01
        2   -1.977313711525D+03   1.608371044973D+02  -1.491043354651D+00
        3    3.266020188823D+02  -2.753508618517D+01   3.266690981800D-01
        4   -1.903360648161D+00   6.239080823474D-01  -1.265543296959D-01
        5    2.213178595975D+00   4.920579289236D-03   7.467700060091D-03
        6   -1.135762467605D+00   4.692131658536D-02  -1.139487859652D-03
        7   -1.180606981173D-02   4.496799854108D-03   2.469278095908D-04
        8    1.340747534195D-02  -1.200936096329D-03  -1.878024820978D-05

        X-Index:      3                    4                    5
  P-Index:
        0    7.745432881084D+00  -1.906592468683D-01  -6.494420211912D-04
        1   -6.338615880336D-01   1.911967990751D-02   6.067561839898D-05
        2   -7.373949356200D-02  -3.541090097892D-03   1.301350739938D-04
        3    8.492056175205D-03   6.266787060318D-04  -1.216849850474D-05
        4    8.431385451024D-03  -2.207032867706D-04   1.992759128437D-06
        5   -7.296510609595D-04   9.019636630629D-06   1.468200530759D-07
        6    4.966518377012D-05   3.141044839941D-07  -4.988552323756D-08
        7   -3.032112140670D-05   6.209227095342D-07  -8.291445929608D-09
        8    3.993656275544D-06  -1.039295885260D-07   1.051348706953D-09

        X-Index:      6                    7                    8
  P-Index:
        0    1.326109332682D-04  -2.491150500975D-06   1.465664124291D-08
        1   -1.528031400769D-05   1.844609845079D-07   7.119828722383D-10
        2    2.505903546663D-06  -6.884850344421D-08  -1.809332893364D-10
        3   -7.273699830492D-07   5.078180341713D-09   2.685443036963D-10
        4   -8.488979684710D-08   6.684296089814D-09  -1.246870333817D-10
        5    6.104264055410D-11  -2.624197715050D-10   7.357333647529D-12
        6    3.618280729108D-09  -1.500857852358D-10   1.672945857437D-12
        7    3.361463524025D-10  -1.770735747674D-12  -6.178529453487D-14
        8   -3.540175636601D-11   9.381979309372D-13  -6.389012738278D-15
```

```
Rate Coefficients C6-10,11 for Carbon

  NPOL = 8

   a0  1.459029408551D+01    a1 -7.618704349586D+01    a2  7.447962806865D+01
   a3 -4.025057816694D+01    a4  1.299331934549D+01    a5 -2.567959213085D+00
   a6  3.040727122293D-01    a7 -1.978914432245D-02    a8  5.440049532928D-04

Rate Coefficients C6-10,12 for Carbon

  NPOL = 8

   a0 -1.075523139996D+02    a1  8.500742138831D+01    a2 -3.993683875680D+01
   a3  1.182327078741D+01    a4 -2.366797045682D+00    a5  3.220064358598D-01
   a6 -2.862218022761D-02    a7  1.499878362856D-03    a8 -3.510761429956D-05


Rate Coefficients C6-11,8 for Carbon

  NPOL = 8

   a0 -2.630153023152D+01    a1  4.174379958801D+00    a2 -3.848415680591D+00
   a3  1.928417641442D+00    a4 -6.832703647055D-01    a5  1.600784907085D-01
   a6 -2.303653029194D-02    a7  1.824572582943D-03    a8 -6.054662113307D-05

Rate Coefficients C6-11,9 for Carbon

  NPOL = 7

   a0 -2.671581078130D+01    a1  1.336508204560D+01    a2 -9.612410577273D+00
   a3  3.933068609636D+00    a4 -9.635357597876D-01    a5  1.394855548765D-01
   a6 -1.106090712884D-02    a7  3.714705196418D-04

Rate Coefficients C6-11,10 for Carbon

  NPOL = 8

   a0  8.169389991326D+00    a1 -7.102974222198D+01    a2  7.207743797979D+01
   a3 -3.955565376646D+01    a4  1.285885597616D+01    a5 -2.550440466754D+00
```

```
   a6  3.025954504196D-01    a7 -1.971639281999D-02    a8  5.424191029946D-04


Rate Coefficients C6-11,12 for Carbon


  NPOL = 8


   a0 -1.130204865881D+02    a1  9.022840731226D+01    a2 -4.240160557618D+01
   a3  1.255274348895D+01    a4 -2.512645643831D+00    a5  3.418712466126D-01
   a6 -3.039474849511D-02    a7  1.593315480741D-03    a8 -3.730992680627D-05
```

Rate Coefficients C6-12,9 for Carbon

P-Index: \ X-Index:	0	1	2
0	-1.258936009777D+04	-2.216982650195D+02	1.792929679734D+02
1	7.334246156082D+03	-9.659999277165D+02	8.591535670530D+00
2	1.346783857659D+03	2.561960992142D+02	-1.588389585820D+01
3	-1.615117481716D+03	2.937295448472D+01	7.124524143938D-02
4	3.257274750832D+02	-2.285917558082D+00	-3.891742240499D-01
5	-4.092534064449D+01	1.356685995742D+00	4.110878325685D-02
6	2.505617404052D+00	-5.468661231603D-01	2.629937444505D-02
7	7.278205915714D-01	-2.694851872269D-02	-4.824893606667D-04
8	-3.130453710640D-02	3.694509674165D-04	7.360598989736D-05

P-Index: \ X-Index:	3	4	5
0	-7.502317172118D+00	-2.488114292291D-01	2.463550563600D-02
1	1.361068317238D+00	-5.629439700233D-03	-4.137654346412D-04
2	2.707324167856D-01	-1.885074736607D-02	6.118828335429D-04
3	9.519284389879D-02	-8.843187573487D-04	4.952620781235D-05
4	-5.993476650053D-03	3.814612349556D-05	-1.798208613046D-06
5	-2.468049251801D-03	1.320520486399D-05	2.138010702360D-06
6	-5.923910220660D-05	-7.432043384377D-06	-2.299823699691D-07
7	5.007298798357D-06	7.451716385377D-07	-4.879468787166D-08
8	-8.841451313455D-08	-6.676594239838D-08	-2.746819043888D-09

P-Index: \ X-Index:	6	7	8
0	-6.646938403500D-04	7.786428107115D-06	-3.434851567563D-08
1	-4.630359539119D-05	1.448892899299D-06	-8.945828223464D-09
2	-2.205715560073D-06	1.208903738916D-07	-4.535355673905D-09
3	-4.625837074433D-06	1.948317146895D-08	1.104880741910D-09
4	2.964723910877D-07	2.985051595153D-09	-1.074100188144D-10
5	2.080910564705D-08	-7.535408458367D-10	-2.978453845657D-11
6	4.075665293508D-09	-5.196749560405D-10	1.573649588005D-11
7	1.436842420610D-09	5.842854180416D-11	-1.918115623917D-12
8	2.854972269441D-10	-1.029911881078D-11	1.390234415717D-13

```
Rate Coefficients C6-12,10 for Carbon

  NPOL = 8

    a0 -4.396031746101D+01    a1  4.184507260674D+01    a2 -4.239483951475D+01
    a3  2.296111438403D+01    a4 -7.396557411895D+00    a5  1.450731516260D+00
    a6 -1.696449603065D-01    a7  1.085759404907D-02    a8 -2.924827728128D-04
```

```
Rate Coefficients C6-12,11 for Carbon


        X-Index:     0                    1                    2
  P-Index:
        0    -2.620058147799D+03   3.745147633503D+02  -2.016356082792D+01
        1    -4.209411731893D+02   5.937622238149D+01  -2.891076371160D+00
        2     1.606516342775D+01   8.504737846493D+00  -1.324896911725D+00
        3     1.964087436135D+01  -1.227112176966D-01   3.501765343579D-01
        4    -2.117102178806D+01  -1.203597078383D-02  -3.815203399478D-02
        5     4.936629672818D+00   6.047643429932D-02   3.715064429585D-03
        6    -5.398883090632D-01  -1.833419399509D-02   4.682206173865D-05
        7    -4.261695548771D-03   4.396311552848D-03   1.729289442029D-05
        8     3.421399197898D-03  -3.189572225655D-04  -1.236117555812D-05

        X-Index:     3                    4                    5
  P-Index:
        0     4.798391775259D-01  -4.383474114500D-03  -1.116196543204D-04
        1     3.231071286851D-02   5.405499398982D-03  -2.264934725655D-04
        2    -3.183119117662D-03   2.224207313485D-03  -5.385324189742D-05
        3    -4.797113229969D-03  -1.113413543422D-04   8.137216211375D-07
        4    -8.783046167322D-04   1.115901846212D-05   7.737777192534D-07
        5     1.473494268417D-04   3.266484621683D-06  -2.454701607812D-08
        6    -4.433512188082D-05  -1.191421126435D-07   5.338844332923D-08
        7    -2.047019647922D-06   4.976146349100D-08  -1.766252785748D-09
        8     1.160740784062D-06  -2.109340018943D-08  -2.747278346623D-10

        X-Index:     6                    7                    8
  P-Index:
        0     9.080776803806D-06  -2.531799183315D-07   2.457862659506D-09
        1     7.801071374104D-07   9.802353635184D-08  -1.406991300894D-09
        2    -9.320290253157D-08   1.231649008393D-08   5.559449908694D-12
        3     2.605178357946D-07  -6.898513925793D-09   1.066536505997D-11
        4    -4.245982137257D-08   7.092477902013D-10   9.576698068731D-12
        5    -8.513341037246D-09   3.197005815225D-10  -6.189616299423D-12
        6    -8.391611573351D-10  -2.446074696935D-11   8.589895601461D-13
        7     6.778371546344D-11   5.956673176298D-13  -5.231366830199D-14
        8     9.470957798342D-12  -4.213354838596D-14   5.607737986025D-16
```

```
Rate Coefficients C6-12,13 for Carbon

  NPOL = 8

   a0 -4.972653221295D+02    a1  4.485848699407D+02    a2 -2.016345350762D+02
   a3  5.545252445842D+01    a4 -1.003095643165D+01    a5  1.201829719648D+00
   a6 -9.169646810774D-02    a7  4.014443680117D-03    a8 -7.610194893748D-05

Rate Coefficients C6-13,12 for Carbon

  NPOL = 8

   a0 -2.488614171532D+01    a1  9.663526244461D-01    a2 -1.635421140743D+00
   a3  8.954354660283D-01    a4 -2.989518662239D-01    a5  6.194735464797D-02
   a6 -7.856286251915D-03    a7  5.610731440316D-04    a8 -1.728080910629D-05

CX Rate Coefficients L6-4,1 for Carbon

  NPOL = 8

   a0 -8.232576109279D+02    a1  9.078162394991D+02    a2 -4.135515341557D+02
   a3  9.157772178715D+01    a4 -8.014740623213D+00    a5 -5.643090616866D-01
   a6  1.935438299320D-01    a7 -1.656920607400D-02    a8  5.038479156162D-04


CX Rate Coefficients L6-4,2 for Carbon

  NPOL = 8

   a0 -8.195891567362D+02    a1  9.053367335825D+02    a2 -4.123509334832D+02
   a3  9.129486086668D+01    a4 -7.988729045087D+00    a5 -5.621146152204D-01
   a6  1.927714576551D-01    a7 -1.649825094349D-02    a8  5.015213327757D-04

CX Rate Coefficients L6-4,3 for Carbon

  NPOL = 8

   a0 -8.200325245083D+02    a1  9.065461492529D+02    a2 -4.128949560385D+02
   a3  9.139613755355D+01    a4 -7.986684994248D+00    a5 -5.664695173378D-01
```

```
   a6  1.935686959967D-01    a7 -1.656188495620D-02    a8  5.034954937249D-04

CX Rate Coefficients L6-6,4 for Carbon

  NPOL = 7

   a0 -2.986533313985D+01    a1  5.267089890309D+00    a2 -1.207504401874D+00
   a3  1.850976228026D-01    a4 -1.450340798364D-02    a5 -2.974394811358D-05
   a6  8.918051921845D-05    a7 -4.506328190108D-06

CX Rate Coefficients L6-7,4 for Carbon

  NPOL = 7

   a0 -2.986533313985D+01    a1  5.267089890309D+00    a2 -1.207504401874D+00
   a3  1.850976228026D-01    a4 -1.450340798364D-02    a5 -2.974394811358D-05
   a6  8.918051921845D-05    a7 -4.506328190108D-06

CX Rate Coefficients L6-8,6 for Carbon

  NPOL = 8

   a0 -3.244881347845D+01    a1  2.438332841731D+01    a2 -2.359365350599D+01
   a3  1.285891707278D+01    a4 -4.139993289897D+00    a5  7.982950648319D-01
   a6 -8.973380437700D-02    a7  5.373632617055D-03    a8 -1.310140775105D-04

CX Rate Coefficients L6-8,7 for Carbon

  NPOL = 8

   a0 -2.475011696342D+01    a1  1.369668792566D+01    a2 -1.468150018229D+01
   a3  8.578498332283D+00    a4 -2.927590091345D+00    a5  5.964841485677D-01
   a6 -7.121364669390D-02    a7  4.599027756813D-03    a8 -1.242727691182D-04

CX Rate Coefficients L6-9,8 for Carbon

  NPOL = 7

   a0 -1.873679908115D+01    a1 -2.980744426164D+00    a2  2.843689440489D+00
```

```
  a3 -1.085677339405D+00    a4  2.377970761957D-01    a5 -3.058191534936D-02
  a6  2.146856155600D-03    a7 -6.362458026388D-05

CX Rate Coefficients L6-12,9 for Carbon

 NPOL = 8

  a0 -2.871107096924D+01    a1  1.978625481543D+01    a2 -1.603564718643D+01
  a3  6.941444371268D+00    a4 -1.726660710294D+00    a5  2.507498590891D-01
  a6 -2.036508996646D-02    a7  8.068790986861D-04    a8 -1.017503739264D-05

CX Rate Coefficients L6-12,11 for Carbon

 NPOL = 8

  a0 -2.871107096924D+01    a1  1.978625481543D+01    a2 -1.603564718643D+01
  a3  6.941444371268D+00    a4 -1.726660710294D+00    a5  2.507498590891D-01
  a6 -2.036508996646D-02    a7  8.068790986861D-04    a8 -1.017503739264D-05

CX Rate Coefficients L6-13,12 for Carbon

 NPOL = 8

  a0 -2.614205742098D+01    a1  1.178430869046D+01    a2 -1.681259430403D+01
  a3  1.181661692477D+01    a4 -4.427063289513D+00    a5  9.619983350250D-01
  a6 -1.223001314079D-01    a7  8.465267258341D-03    a8 -2.468525122824D-04

Electron Cooling Rate Coefficients S6-1 for Carbon

 NPOL = 7

  a0 -6.341892861602D+01    a1  8.230953297367D+00    a2 -3.825958670146D+00
  a3  1.040216117644D+00    a4 -1.796664420943D-01    a5  1.930131197795D-02
  a6 -1.179105079308D-03    a7  3.132434571376D-05

Electron Cooling Rate Coefficients S6-2 for Carbon

 NPOL = 7
```

```
 a0 -6.243153781317D+01    a1  7.274387334382D+00    a2 -3.335523424573D+00
 a3  8.879700066172D-01    a4 -1.501151033592D-01    a5  1.579053486955D-02
 a6 -9.454704141331D-04    a7  2.465176951322D-05

Electron Cooling Rate Coefficients S6-3 for Carbon

NPOL = 6

 a0 -6.290923016774D+01    a1  6.819658902190D+00    a2 -2.752924620494D+00
 a3  6.194991852965D-01    a4 -8.264280569394D-02    a5  6.048706234829D-03
 a6 -1.872841196797D-04

Electron Cooling Rate Coefficients S6-4 for Carbon

NPOL = 8

 a0 -6.808277571256D+01    a1  1.420711703564D+01    a2 -1.000274619926D+01
 a3  4.638998120632D+00    a4 -1.381292460235D+00    a5  2.596406618805D-01
 a6 -2.982272615043D-02    a7  1.912682223743D-03    a8 -5.251696026887D-05

Electron Cooling Rate Coefficients S6-5 for Carbon

NPOL = 8

 a0 -5.460561108608D+01    a1 -1.161749454213D+01    a2  9.712991337079D+00
 a3 -3.674721840723D+00    a4  7.596259635573D-01    a5 -8.702763112768D-02
 a6  4.750578189574D-03    a7 -3.222270887600D-05    a8 -5.218278695699D-06

Electron Cooling Rate Coefficients S6-6 for Carbon

NPOL = 8

 a0 -6.924542613899D+01    a1  1.687198905976D+01    a2 -1.158511954580D+01
 a3  4.811596800192D+00    a4 -1.245843787132D+00    a5  2.023600897070D-01
 a6 -2.015423273089D-02    a7  1.132830966450D-03    a8 -2.775208552069D-05

Electron Cooling Rate Coefficients S6-7 for Carbon

NPOL = 8
```

```
  a0 -4.231553542317D+01     a1 -4.494569396158D+01     a2  4.796191307312D+01
  a3 -2.711151292946D+01     a4  9.138896359887D+00     a5 -1.890517692170D+00
  a6  2.347570754311D-01     a7 -1.603603897151D-02     a8  4.627475139224D-04

Electron Cooling Rate Coefficients S6-8 for Carbon

 NPOL = 8

  a0 -6.168601564965D+01     a1  3.393247329241D+00     a2 -7.059084943731D-01
  a3 -3.730989894108D-01     a4  2.926001557481D-01     a5 -8.551897416592D-02
  a6  1.296554819093D-02     a7 -1.010227555975D-03     a8  3.201833637783D-05

Electron Cooling Rate Coefficients S6-9 for Carbon

 NPOL = 8

  a0  6.768156410798D+02     a1 -1.812828695408D+03     a2  1.845152836040D+03
  a3 -1.025878583593D+03     a4  3.410000634345D+02     a5 -6.954961360059D+01
  a6  8.532208673226D+00     a7 -5.780140276788D-01     a8  1.662019969192D-02

Electron Cooling Rate Coefficients S6-10 for Carbon

 NPOL = 8

  a0 -5.648379105950D+01     a1  3.569574480569D+00     a2 -1.209373919985D+00
  a3 -3.873584646049D-01     a4  4.211024850923D-01     a5 -1.370423384961D-01
  a6  2.223409965665D-02     a7 -1.825135017308D-03     a8  6.046593071990D-05

Electron Cooling Rate Coefficients S6-11 for Carbon

 NPOL = 8

  a0 -6.375913402127D+01     a1  1.172443986306D+01     a2 -7.052335749263D+00
  a3  1.944169404022D+00     a4 -1.118821744302D-01     a5 -6.870361319210D-02
  a6  1.794161706813D-02     a7 -1.771010864953D-03     a8  6.507483582482D-05

Electron Cooling Rate Coefficients S6-12 for Carbon
```

```
  NPOL = 8

   a0  2.981788637377D+02   a1 -8.631918696815D+02   a2  8.503554312906D+02
   a3 -4.561285590343D+02   a4  1.458855820242D+02   a5 -2.857476111989D+01
   a6  3.363337795373D+00   a7 -2.185905865108D-01   a8  6.033174816798D-03
```

Electron Cooling Rate Coefficients S6-13 for Carbon

```
  NPOL = 8

   a0 -6.815986042147D+01   a1  1.957346979709D+00   a2 -1.627098346476D+00
   a3  8.911823219186D-01   a4 -2.976443833574D-01   a5  6.170060691145D-02
   a6 -7.828416776781D-03   a7  5.593521731720D-04   a8 -1.723636840106D-05
```

Radiation Loss Rate Coefficients R6-1 for Carbon

```
  NPOL = 7

   a0 -6.355294642443D+01   a1  8.079400463015D+00   a2 -3.747751459857D+00
   a3  9.828693271793D-01   a4 -1.645619400305D-01   a5  1.731620389650D-02
   a6 -1.045694244183D-03   a7  2.764474900812D-05
```

Radiation Loss Rate Coefficients R6-2 for Carbon

```
  NPOL = 7

   a0 -6.241960162780D+01   a1  7.172814119754D+00   a2 -3.301842906227D+00
   a3  8.516351676918D-01   a4 -1.401783929486D-01   a5  1.450978613288D-02
   a6 -8.629819914240D-04   a7  2.250306991142D-05
```

Radiation Loss Rate Coefficients R6-3 for Carbon

```
  NPOL = 6

   a0 -6.296581053170D+01   a1  6.853854502091D+00   a2 -2.831709258861D+00
   a3  6.181856431892D-01   a4 -7.950671263646D-02   a5  5.635408738052D-03
   a6 -1.700775545887D-04
```

Radiation Loss Rate Coefficients R6-4 for Carbon

```
  NPOL = 8

   a0 -7.013335970484D+01    a1  1.641159729794D+01    a2 -1.044653454604D+01
   a3  4.234347758062D+00    a4 -1.130024649630D+00    a5  1.967679017041D-01
   a6 -2.149649190180D-02    a7  1.335711380299D-03    a8 -3.596736306040D-05

Radiation Loss Rate Coefficients R6-5 for Carbon

  NPOL = 8

   a0 -5.600961808102D+01    a1 -9.762746353165D+00    a2  9.439505930543D+00
   a3 -4.273272296578D+00    a4  1.114402897157D+00    a5 -1.789033258271D-01
   a6  1.758048424232D-02    a7 -9.762465869276D-04    a8  2.358792113093D-05

Radiation Loss Rate Coefficients R6-6 for Carbon

  NPOL = 8

   a0 -7.411067195357D+01    a1  2.596640423910D+01    a2 -1.963597007481D+01
   a3  8.985455776141D+00    a4 -2.587713055237D+00    a5  4.713355293934D-01
   a6 -5.284652683301D-02    a7  3.339192515142D-03    a8 -9.124857522059D-05

Radiation Loss Rate Coefficients R6-7 for Carbon

  NPOL = 8

   a0 -2.825115296667D+01    a1 -7.781612876540D+01    a2  7.996082001616D+01
   a3 -4.404694198645D+01    a4  1.447738062237D+01    a5 -2.920621496567D+00
   a6  3.538183916903D-01    a7 -2.358515036841D-02    a8  6.641122754648D-04

Radiation Loss Rate Coefficients R6-8 for Carbon

  NPOL = 8

   a0 -6.374209642148D+01    a1  8.594868832651D+00    a2 -6.208757736657D+00
   a3  2.796978803342D+00    a4 -7.934865290612D-01    a5  1.415164618845D-01
   a6 -1.548591982299D-02    a7  9.536911754955D-04    a8 -2.536589598722D-05
```

```
Radiation Loss Rate Coefficients R6-9 for Carbon

  NPOL = 8

   a0  5.281572138505D+02    a1 -1.420937479080D+03    a2  1.422655017434D+03
   a3 -7.779720258155D+02    a4  2.542221145884D+02    a5 -5.096211891423D+01
   a6  6.145550044877D+00    a7 -4.094070846131D-01    a8  1.158298349148D-02

Radiation Loss Rate Coefficients R6-10 for Carbon

  NPOL = 8

   a0 -5.201265807324D+01    a1  4.896086611464D-01    a2 -1.997812355458D-01
   a3 -2.067017395740D-02    a4  4.372712990396D-02    a5 -1.547303308970D-02
   a6  2.603628503296D-03    a7 -2.183530038351D-04    a8  7.340197983502D-06

Radiation Loss Rate Coefficients R6-11 for Carbon

  NPOL = 8

   a0 -6.355931280139D+01    a1  1.127507029794D+01    a2 -6.571445497109D+00
   a3  1.646046776172D+00    a4  1.967926742417D-03    a5 -9.559094946061D-02
   a6  2.173535076609D-02    a7 -2.064043894956D-03    a8  7.461829225491D-05

Radiation Loss Rate Coefficients R6-12 for Carbon

  NPOL = 8

   a0  2.696167672796D+01    a1 -1.828737703836D+02    a2  1.459708298904D+02
   a3 -5.757063008544D+01    a4  1.085840364147D+01    a5 -4.793591213527D-01
   a6 -1.529657418609D-01    a7  2.426973373170D-02    a8 -1.078602536979D-03

Radiation Loss Rate Coefficients R6-13 for Carbon

  NPOL = 6

   a0 -6.157432185243D+01    a1 -4.921229181791D-02    a2 -5.184313103634D-01
   a3  2.200908332607D-01    a4 -5.173791540360D-02    a5  6.172578212318D-03
   a6 -2.783207587846D-04
```

```
CX-induced Radiation Loss Rate Coefficients F6-4 for Carbon

  NPOL = 8

   a0 -1.105585113010D+02    a1  4.726975601459D+01    a2 -7.548554437173D+00
   a3 -1.687356480630D+01    a4  1.285119647856D+01    a5 -4.110883612828D+00
   a6  6.835442325370D-01    a7 -5.798724453597D-02    a8  1.986511154489D-03

CX-induced Radiation Loss Rate Coefficients F6-6 for Carbon

  NPOL = 7

   a0 -7.091141263553D+01    a1  5.263703483623D+00    a2 -1.204883420944D+00
   a3  1.840276605924D-01    a4 -1.425402106530D-02    a5 -6.299534577264D-05
   a6  9.153243857218D-05    a7 -4.574448008788D-06

CX-induced Radiation Loss Rate Coefficients F6-7 for Carbon

  NPOL = 7

   a0 -7.035182370527D+01    a1  5.266561577783D+00    a2 -1.207029218479D+00
   a3  1.848891045546D-01    a4 -1.445491063459D-02    a5 -3.565094911366D-05
   a6  8.951373648659D-05    a7 -4.511940299200D-06

CX-induced Radiation Loss Rate Coefficients F6-8 for Carbon

  NPOL = 8

   a0 -6.602098518019D+01    a1  1.682193583558D+01    a2 -1.743261785867D+01
   a3  9.892953340642D+00    a4 -3.283837678622D+00    a5  6.503612227343D-01
   a6 -7.516174682696D-02    a7  4.659174817995D-03    a8 -1.192797812071D-04

CX-induced Radiation Loss Rate Coefficients F6-9 for Carbon

  NPOL = 7

   a0 -5.832580661556D+01    a1 -2.980593608086D+00    a2  2.843521937116D+00
   a3 -1.085599451809D+00    a4  2.377791048727D-01    a5 -3.057985480798D-02
```

```
   a6  2.146758434579D-03    a7 -6.362404008782D-05

CX-induced Radiation Loss Rate Coefficients F6-12 for Carbon

  NPOL = 8

   a0 -6.590285289579D+01    a1  1.979446963626D+01    a2 -1.604501272452D+01
   a3  6.947189359845D+00    a4 -1.728741016000D+00    a5  2.512073417326D-01
   a6 -2.042507486852D-02    a7  8.111892110920D-04    a8 -1.030559889774D-05

CX-induced Radiation Loss Rate Coefficients F6-13 for Carbon

  NPOL = 8

   a0 -6.329082736387D+01    a1  1.179089307855D+01    a2 -1.682056315500D+01
   a3  1.182170335441D+01    a4 -4.428966907716D+00    a5  9.624304548396D-01
   a6 -1.223586443922D-01    a7  8.469611991112D-03    a8 -2.469885613903D-04
```

References

[1] JANESCHITZ, G., BORRASS, K., FEDERICI, G., IGITKHANOV, Y., KUKUSHKIN, A., PACHER, H. D., PACHER, G. W., and SUGIHARA, M., J. Nucl. Mater. **220-222** (1995) 73.

[2] KALLENBACH, A. et al., Nucl. Fusion **35** (1995) 1231.

[3] LIEDER, G., NAPIONTEK, B., RADTKE, R., FIELD, A., FUSSMANN, G., KALLENBACH, A., KIEMER, K., MAYER, H.-M., and the ASDEX Upgrade Team, Interpretation of low ionized impurity distribution in the ASDEX Upgrade divertor, in *Europhysics Conference Abstracts (Proc. of the 20th EPS Conference on Controlled Fusion and Plasma Physics, Lisboa, 1993)*, edited by COSTA CABRAL, J. A., MANSO, M. E., SERRA, F. M., and SCHÜLLER, F. C., volume 17C, pages 579–82, Geneva, 1993, EPS.

[4] FIELD, A. R., FINK, J., DUX, R., FUSSMANN, G., WENZEL, U., and SCHUMACHER, U., Rev. Sci. Instrum. **66** (1995) 5433.

[5] POST, D., HULSE, R., and STOTLER, D., Contr. Plasma Phys. **34** (1994) 300.

[6] NAPIONTEK, B., FUSSMANN, G., LIEDER, G., and RADTKE, R., CX-induzierte Strahlung im Divertor von ASDEX Upgrade, in *Verhandl. DPG (VI)*, volume 29, page 317, 1994.

[7] NAPIONTEK, B., *Untersuchung der Strahlungsbilanz im Divertor von ASDEX Upgrade*, PhD thesis, Humboldt-Universiät Berlin, 1996.

[8] WENZEL, U., DUX, R., FIELD, A. R., and NAPIONTEK, B., Fusion Eng. Design (to be published 1996).

[9] WENZEL, U., THOMA, T., BÜCHL, K., DUX, R., HERRMANN, A., HIRSCH, S., KALLENBACH, A., KASTELEWICZ, H., LAUX, M., and NAPIONTEK, B., J. Nucl. Mater. (to be published 1997).

[10] GAFERT, J., DORN, C., NIETHAMMER, M., and SCHUMACHER, U. E., Plasma Phys. Controlled Fusion (to be published 1997).

[11] PHANEUF, R. A., JANEV, R. K., and PINDZOLA, M. S., *Collisions of carbon and oxygen ions with electrons*, volume ORNL-6090/V5 of *Atomic Data for Fusion*, Controlled Fusion Atomic Data Center, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831, 1987.

[12] PÉQUIGNOT, D. and ALDROVANDI, S. M. V., Astron. Astrophys. **50** (1976) 141.

[13] VAN REGEMORTER, H., Astrophys. J. **136** (1962) 906.

[14] VICTOR, G. A. and ESCALANTE, V., At. Data Nucl. Data Tables **40** (1988) 203.

[15] ITIKAWA, Y., HARA, S., KATO, T., NAKAZAKI, S., PINDZOLA, M. S., and CRANDALL, D. H., At. Data Nucl. Data Tables **33** (1985) 149.

[16] SHEVELKO, V. P., VAINSHTEIN, L. A., and YUKOV, E. A., Physica Scripta **T28** (1989) 39.

[17] SUMMERS, H. P., Atomic data and analysis structure, Technical Report JET-IR 06, JET Joint Undertaking, 1994.

[18] POST, D. E., JENSEN, R. V., TARTER, C. B., GRASBERGER, W. H., and LOKKE, W. A., At. Data Nucl. Data Tables **20** (1977) 397.

[19] BASHKIN, S. and STONER, J. O., *Atomic energy levels and Grotrian diagrams*, volume 1, Hydrogen I - Phosphorus XV, North-Holland Publ. Comp., 1978.

[20] BEHRINGER, K., SUMMERS, H. P., DENNE, B., FORREST, M., and STAMP, M., Plasma Phys. Controlled Fusion **31** (1989) 2059.

[21] HUTCHINSON, I. H., *Principles of plasma diagnostics*, Cambrige University Press, 1987.

[22] HAHN, Y., J. Quant. Spec. Rad. Transf. **49** (1993) 81, Corrigendum: [23].

[23] HAHN, Y., J. Quant. Spec. Rad. Transf. **51** (1994) 663.

[24] BADNELL, N. R. and PINDZOLA, M. S., Phys. Rev. A **39** (1989) 1685.

[25] BADNELL, N. R., PINDZOLA, M. S., ANDERSEN, L. H., BOLKO, J., and SCHMIDT, H. T., J. Phys. B **24** (1991) 4441.

[26] ANDERSEN, L. H., BOLKO, J., and KVISTGAARD, P., Phys. Rev. A **41** (1990) 1293.

[27] BADNELL, N. R., PINDZOLA, M. S., and GRIFFIN, D. C., Phys. Rev. A **41** (1990) 2422.

[28] TAWARA, H., Total and partial cross sections for electron capture for $C^{q+}(q = 6-2)$ and $O^{q+}(q = 8-2)$ ions in collisions with H, H_2 and He atoms, Technical Report IPPJ-AM-56, Institute of Plasma Physics, Nagoya University, Chikusa-ku, Nagoya 464, Japan, 1987.

[29] TAWARA, H., KATO, T., and NAKAI, Y., At. Data Nucl. Data Tables **32** (1985) 235.

[30] JANEV, R. K., LANGER, W. D., EVANS, JR., K., and POST, JR., D. E., *Elementary Processes in Hydrogen-Helium Plasmas*, Springer-Verlag, 1987.