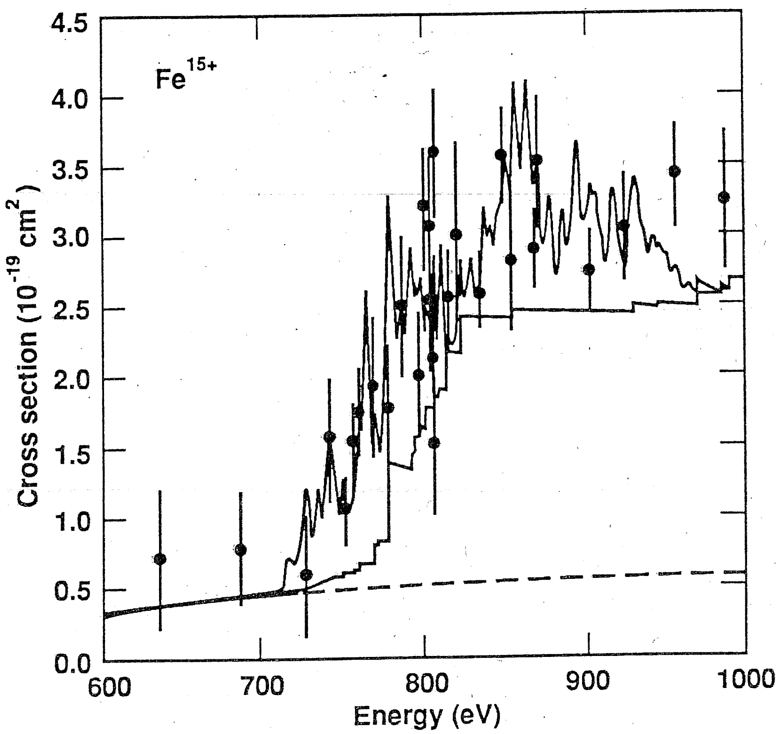
FUTURE DIRECTIONS IN

ELECTRON - ION COLLISION PHYSICS



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Electron-ion Recombination in The Close-Coupling Approximation

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A new computational method has been developed for the *total* electron-ion recombination, incorporating both the radiative recombination (RR) and the dielectronic recombination (DR). The detailed photoionization cross sections, σ_{PI}, and DR cross sections are obtained in the close coupling approximation using R-matrix method and using the same target (residual ion) wave function expansion. The general scattering theory of DR by Bell and Seaton[1] has been employed to calculate the DR collision strengths for the first time. Total recombination rate coefficients α_R for C I, N II, O III, F IV and Ne V of the carbon isoelectronic sequence are obtained.

The earlier treatments consider RR and DR independently and using different approximations though the separation is nonphysical. Also "low T" DR and "high T" DR are treated separately, thus requiring 3 different sets of results to obtain the total recombination rate coefficients. In the present formalism one set is provided for the total recombination rates. Fig. 1 shows α_R for O III where the solid curve represents the present total recombination rate coefficients in the temperature range of $3.5 \leq \log_{10}T \leq 6.0$, the dashed curve represents RR rate coefficients of Aldrovandi and Pequignot[2], dotted curve to "low T" DR rate coefficients by Nussbaumer and Storey[3] and asterisks to "high T" DR rate coefficients of Badnell and Pindzola[4]. The two other curves, dotted chain and dashed chain, represent low n and high n contributions as explained below of the new computational method.

The present method divides the recombination problem into two regions, (i) low n bound states region ($n \leq N_o$), where RR dominates for low Z, and (ii) high n bound states region ($N_o < n \leq \infty$), where DR dominates.

For the low n region, all the bound states with $n \leq N_o = 10$ and $\ell \leq \ell_{max} = 3$ are considered which increases with high ion charge (see the Table). Detailed photoionization cross sections including autoionizing resonances (Fig. 2 shows an example for C I) are calculated for all these states in the close coupling approximation. The resonances are resolved using fine quantum defect mesh. Milne relation is used for the recombination cross sections from σ_{PI}. As calculation of photoionization cross sections include Rydberg series of autoionizing resonances and their detailed profiles, we can obtain total effective, for both RR and DR, recombination rate coefficients from these cross sections.

In high n region, recombination proceeds mainly through DR, and Bell and Seaton theory is employed to obtain averaged DR collision strengths (Fig. 3 shows an example for N II). All states with $n \geq 10$ and $\ell \leq \ell_{max} = 9$ are considered and DR rate coefficients are obtained.

Fig 4. shows the total α_R for C I, N II, O III, F IV and Ne V of C sequence where peak at high T in each curve is mainly due to DR contributions.

Present method enables computing total electron-ion recombination rate coefficients in a consisting manner using the same eigenfunction expansion for both electron impact excitation and photoionization. Future extensions of the present work will include fine structure and external field effects.

References

1. R. H. Bell and M. J. Seaton, J. Phys. B 18, 1589 (1985)
2. S. M. W. Aldrovandi and D. Pequignot, Astron. Astrophys. 25, 137 (1973)
3. H. Nussbaumer and P. J. Storey, Astron. Astrophys. 126, 75 (1983)
4. N. R. Badnell and M. S. Pindzola, Phys. Rev. A 39, 1690 (1989)

Figure Captions

Fig. 1. Recombination rate coefficients, α_R, of O III. The solid curve represents the present total α_R, the dotted chain to contributions from states $n \leq 10$, dashed-chain to the DR contribution from $n > 10$. The dashed curve represents RR rate coefficients by Aldrovandi and Pequignot, the dotted curve to low temperature DR rate coefficients by Nussbaumer and Storey, and asterisks to high temperature DR rate coefficients by Badnell and Pindzola.

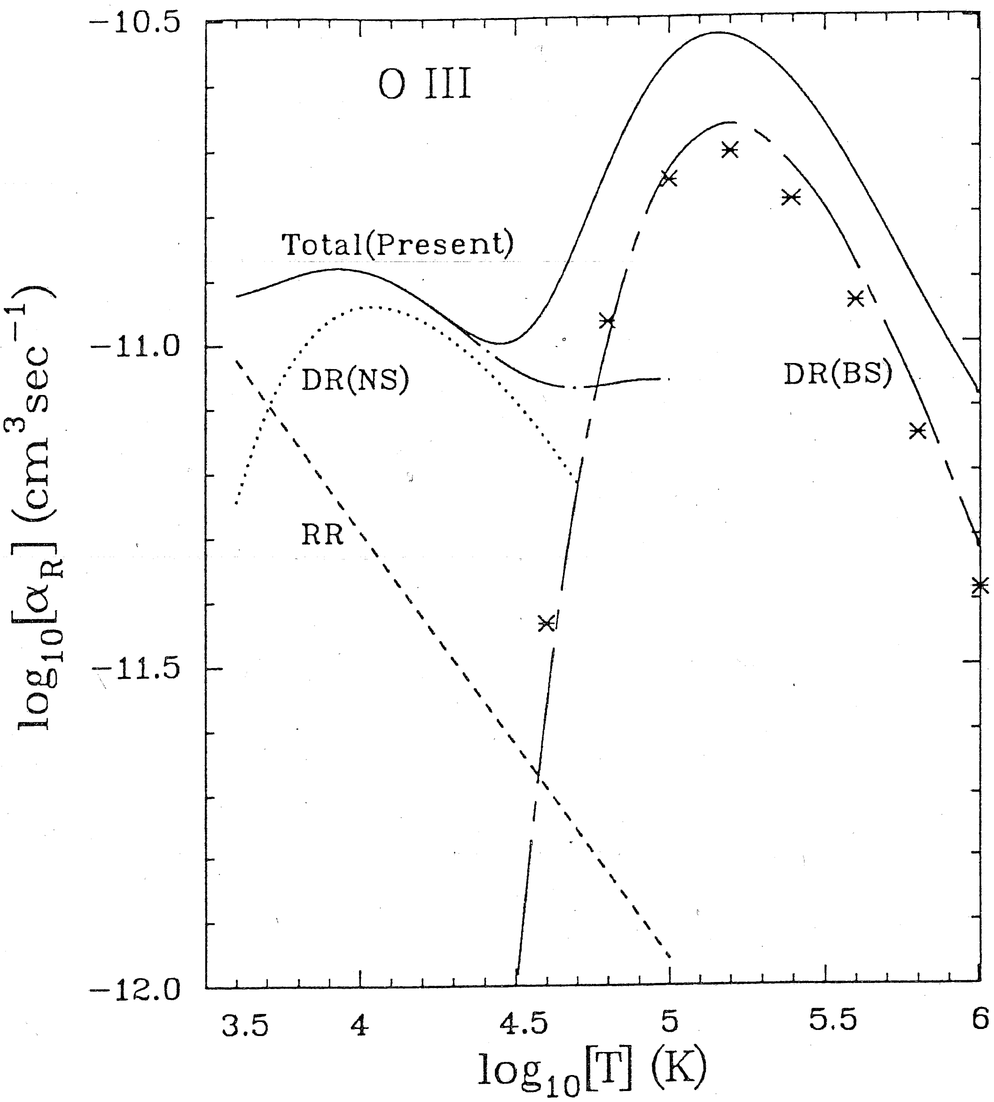
Fig. 2. Photoionization cross sections of the ground $2s^2 2p^2 (^3P)$ and excited $2s2p^3 (^3D^o)$, $2s^2 2p3d (^3F^o)$ of C I.

Fig. 3. Averaged collision strength for dielectronic recombination, $<\Omega(DR)>$, of e+N III $\rightarrow$ N II (solid curve). The filled circles represent collision strength for electron impact excitations, Ω(EIE), for transitions $^2P^o \rightarrow (^2D, ^2S, ^2P)$.

Fig. 4. Total recombination rate coefficients, α_R, for C I, N II, O III, F IV, and Ne V.

Photoionization cross sections of ground and all excited bound states N_{bnd} are obtained:

Ion	N_{bnd}	Ion	N_{bnd}
C^0	159	F^{3+}	231
N^+	171	Ne^{4+}	256
O^{2+}	194		



O III
Total(Present)
DR(NS)
DR(BS)
RR
−10.5
−11.0
−11.5
−12.0
3.5
4
4.5
5
5.5
6
$\log_{10}[\alpha_R]$ (cm^{3}sec^{-1})
$\log_{10}$[T] (K)

Figure 1

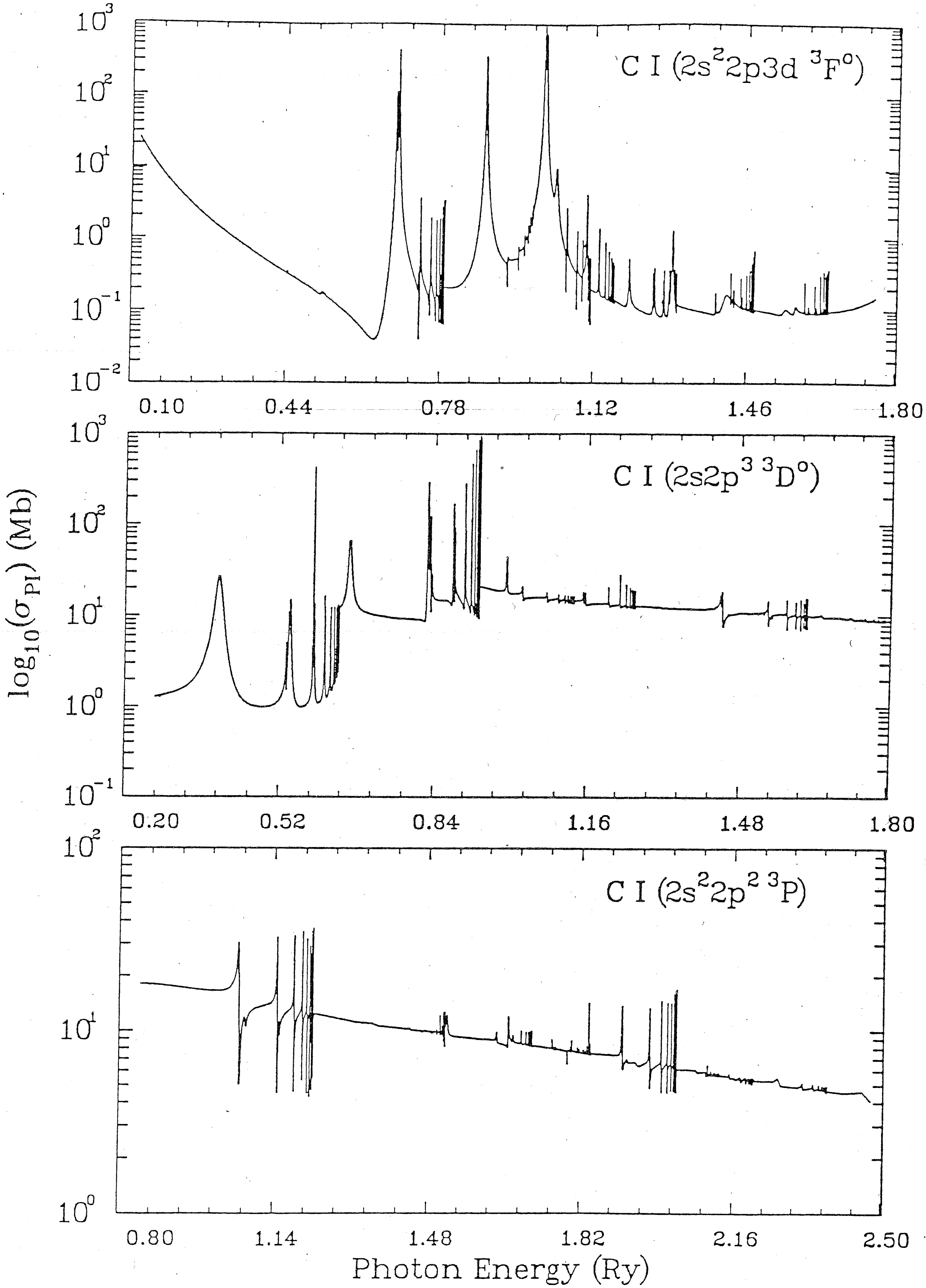

C I (2s²2p3d ³F°)
C I (2s2p³ ³D°)
C I (2s²2p² ³P)
log10(σPI) (Mb)
Photon Energy (Ry)
0.10 0.44 0.78 1.12 1.46 1.80
0.20 0.52 0.84 1.16 1.48 1.80
0.80 1.14 1.48 1.82 2.16 2.50

Figure 2

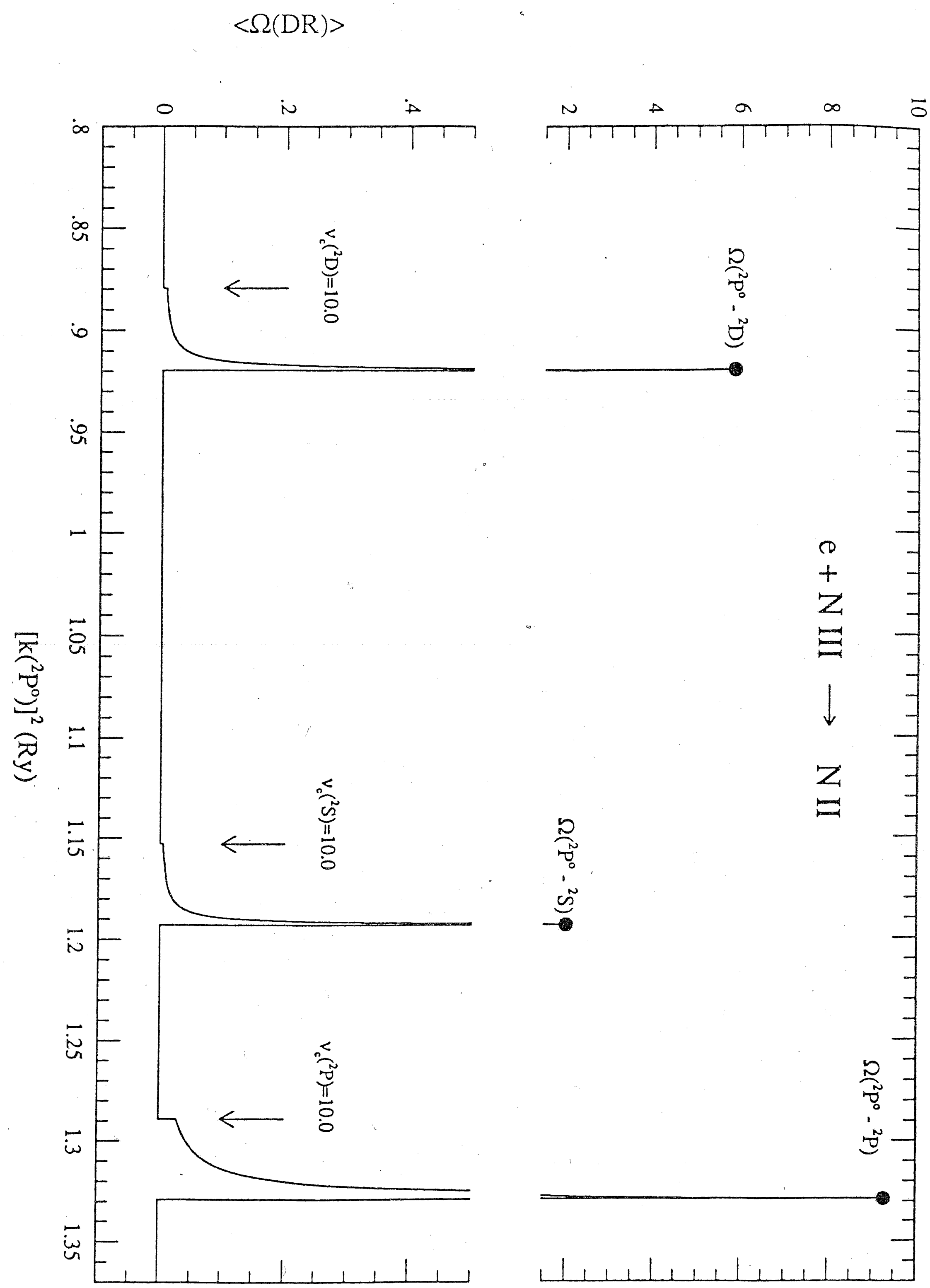
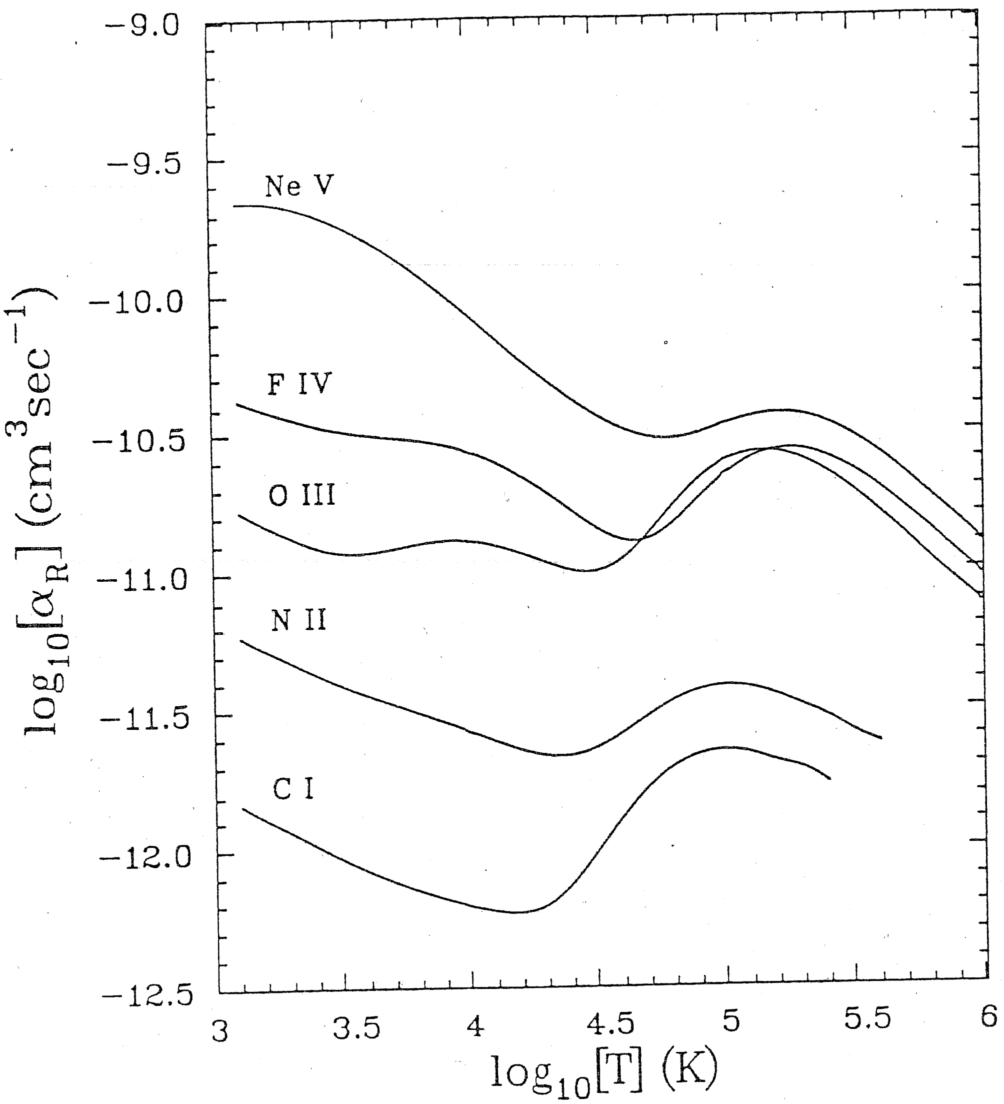

e + N III → N II
Ω(²P° - ²D)
Ω(²P° - ²S)
Ω(²P° - ²P)
v_c(²D)=10.0
v_c(²S)=10.0
v_c(²P)=10.0
<Ω(DR)>
[k(²P°)]² (Ry)
10
8
6
4
2
.4
.2
0
.8
.85
.9
.95
1
1.05
1.1
1.15
1.2
1.25
1.3
1.35

Figure 3



-9.0
-9.5
-10.0
-10.5
-11.0
-11.5
-12.0
-12.5
$\log_{10}[\alpha_R]$ (cm^{3}sec^{-1})
Ne V
F IV
O III
N II
C I
3
3.5
4
4.5
5
5.5
6
$\log_{10}[T]$ (K)

Figure 4