Ion-Molecule Reactions of Light Elements: Missing Information

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Radiative cooling of tokamak plasmas due to multiply-charged Fe impurity ions

J.Q.S.R.T.*17,139-147*,1977

J. Davis, V.L. Jacobs, P.C. Kepple, M. Blaha

- **Abstract**
- Calculations are presented for the rates of radiative energy loss from tokamak plasmas arising from radiation processes involving collisions between electrons and multiply-charged Fe impurity ions. The distribution of ionization states is determined from the steady-state corona model. The inclusion of dielectronic recombination raises the temperature at which each ion has its maximum equilibrium abundance. For certain nonhydrogenic ions, the dielectronic recombination rates obtained from previous calculations are found to be overestimated due to the neglect of autoionization into an excited state of the recombining ion. Electron impact excitation of resonance line radiation in the far ultraviolet and X-ray regions is the dominant radiative cooling mechanism at temperatures where ions with bound electrons are abundant. However, the radiation emitted during dielectronic recombination can be more important than direct recombination radiation and bremsstrahlung.

Dielectronic Recombination Recombination Cross Section Measurements

- J.B.A. Mitchell et al. Phys. Rev. Lett. 50, 335, 1983
- D.S. Belic et al. Phys. Rev. Lett. 50, 339, 1983
- P.F. Dittner et al. Phys. Rev. Lett. 51,31,1983
- J.F. Williams Phys. Rev. A29, 2936, 1984
- A.R. Young, Phys. Rev. A49, 357, 1995
- Crossed Beams and Merged Beams

- L.H. Andersen et al. Phys. Rev. Lett. 62, 2656, 1989
- Single Pass Merged Beam + cooler

- Followed by a host of storage ring experiments

Compilation of Anicich

JPL Publication 03-19

An Index of the Literature for Bimolecular Gas Phase Cation-Molecule Reaction Kinetics

Vincent G. Anicich

ABSTRACT

This is an index to the literature for gas phase bimolecular positive ion-molecule reactions. Over 2300 references are cited. Reaction rate coefficients and product distributions of the reactions are abstracted out of the original citations where available. This index is intended to cover the literature from 1936 to 2003. This is a continuation of several surveys: the original (Huntress *Astrophys. J. Suppl. Ser.*, **33**, 495 (1977)), an expansion (Anicich and Huntress, *Astrophys. J. Suppl. Ser.* **62**, 553 (1986)), a supplement (Anicich, *Astrophys. J. Suppl. Ser.* **84**, 215 (1993)), and an evaluation (Anicich, V. G. *J. Phys. Chem. Ref. Data* **22**,1469 (1993b). The "Table of Reactions" is listed by reactant ion.

Anicich Compilation

- JPL-03-19-Anicich.pdf

Existing Data

- Ion-molecule reactions for:

- H^+, H_3^+, H_2^+,
- He^+, He^{++}, He_2^+, HeH^+
- Li^+
- Be^+
- Multiply charged ions?

Clues from Astrophysics

INSTITUTE OF PHYSICS PUBLISHING JOURNAL OF PHYSICS B: ATOMIC, MOLECULAR AND OPTICAL PHYSICS

J. Phys. B: At. Mol. Opt. Phys. **35** (2002) R57–R80 PII: S0953-4075(02)93670-9

TOPICAL REVIEW

Atomic and molecular processes in the early Universe

S Lepp[1], P C Stancil[2] and A Dalgarno[3]

Lithium Chemistry

(38)	$LiH + H \rightarrow Li + H_2$	2.52 − 10	1.0	2.50 + 3	19
		2.15 − 10	0.28	—	
(39)	$LiH + H^+ \rightarrow Li^+ + H_2$	2.00 − 15	—	—	20
(40)	$LiH + H^+ \rightarrow LiH^+ + H$	2.00 − 15	—	—	20
(41)	$LiH^+ + e^- \rightarrow Li + H$	3.80 − 7	−0.47	—	21

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

$Li + H^- \rightarrow LiH + e^-$.

Estimated rate 4 x 10^{-10} $cm^3 s^{-1}$

(20)	$Li^+ + H^- \rightarrow Li + H$	2.93 − 7	−4.77 − 1	−2.32 + 4	9
(21)	$Li^- + H^+ \rightarrow Li + H$	1.80 − 7	−4.77 − 1	−2.32 + 4	7
(22)	$Li^+ + D^- \rightarrow Li + H$	3.71 − 7	−5.10 − 1	−4.41 + 4	11
(23)	$Li^- + D^+ \rightarrow Li + D$	2.28 − 7	−5.10 − 1	−4.41 + 4	12

Table 1. Gas-phase reactions and their rate coefficients. The rate coefficient fits are given by the relation $\alpha = a_1(T/300)^{a_2} \exp(-T/a_3)$.

Langevin Equation

- $\sigma_L = \pi q(2\alpha/E)^{1/2}$
- $k_L = 2\pi q(\alpha/M_r)^{1/2}$

{Note: k independent of E (i.e. T)}

- Good for exothermic reactions
- M_r = reduced mass
- α = polarizability
- Q = ionic charge

PHYSICAL REVIEW A **73**, 042712 (2006)

Ion-neutral chemical reactions between ultracold localized ions and neutral molecules with single-particle resolution

B. Roth, P. Blythe, H. Wenz, H. Daerr, and S. Schiller

TABLE I. Experimental and Langevin reaction coefficients and experimental uncertainties Δk_{expt}. The values for the electric dipole polarizabilities used in Eq. (8) to obtain k_L are (in units of 10^{-24} cm^3): 0.8042 (H_2), 0.7976 (HD), 0.7921 (D_2), and 1.5812 (O_2) [27].

Reaction	k_{expt} (cm^3/s)	Δk_{expt} (cm^3/s)	k_L (cm^3/s)
$Be^+ + H_2$	1.3×10^{-9}	0.4×10^{-9}	1.6×10^{-9}
$Be^+ + HD$	1.1×10^{-9}	0.2×10^{-9}	1.4×10^{-9}
$Be^+ + D_2$	1.3×10^{-9}	0.1×10^{-9}	1.3×10^{-9}
$H_3^+ + O_2$	1.1×10^{-9}	0.4×10^{-9}	1.7×10^{-9}

Effect of Kinetic Energy

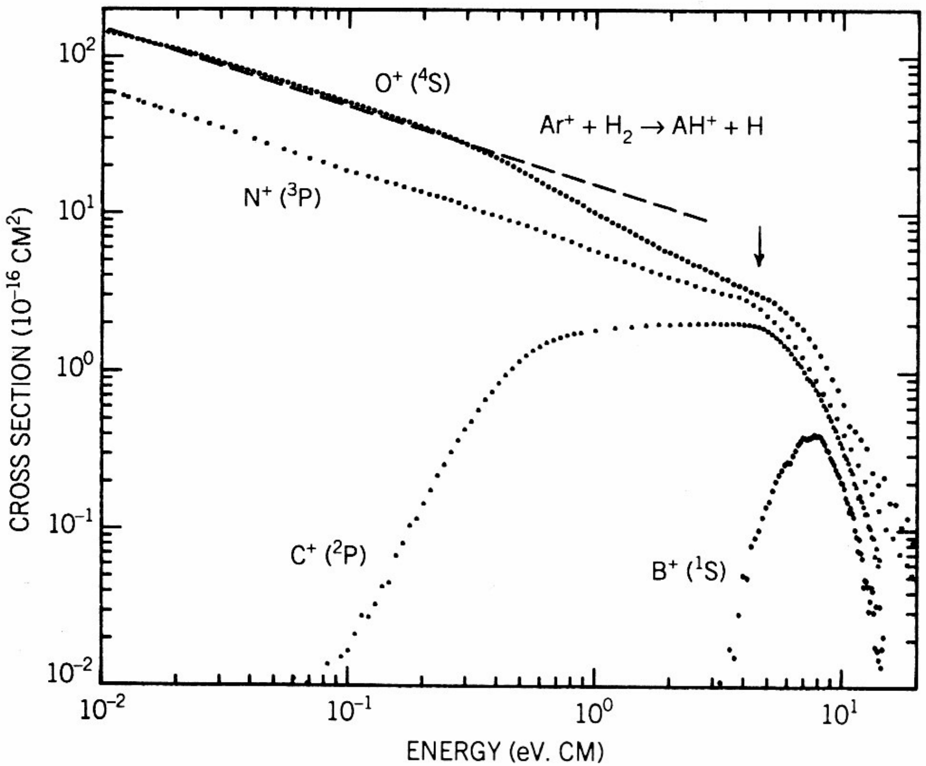

Figure 3-8-5. Cross sections for the reactions $A^+ + H_2 \rightarrow AH^+ + H$ with $A^+ = B^+(^1S)$, $C^+(^2P)$, $N^+(^3P)$, and $O^+(^4S)$. The dashed line gives the Langevin cross section (Note 3-1). [From Armentrout, (1990.]

[Electron transfer collisions of Be^{2+} with H_2 and Be]

Chemical Physics Letters, ***Volume 174***, *Issues 3-4*, *9 November 1990*, *Pages* ***301****-303*

Shigu Tu, D.A. Church

- The rate coefficient for electron transfer from H_2 to Be^{2+} ions has been measured using a radio-frequency (Paul) ion trap. The Be ions were produced by electron impact ionization of a Be atom beam passing through the trap. Electron capture from Be atoms was also observed. The rate coefficients are $k(Be^{2+}, H_2)=1.55(0.6)\times10^{-9}$ cm^3/s and $k(Be^{2+}, Be)=1.8^{+1.6}_{-0.5}\times10^{-9}$ cm^3/s.

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Electron capture from H_2 to highly charged Th and Xe ions trapped at center-of-mass energies near 6 eV

G. Weinberg,[1,*] B. R. Beck,[2] J. Steiger,[2] D. A. Church,[1] J. McDonald,[2] and D. Schneider[2]

TABLE I. Mean total rate coefficients and total cross sections for electron capture from H_2 to Xe^{q+} ions ($35 \leqslant q \leqslant 46$) and Th^{q+} ions ($73 \leqslant q \leqslant 80$), determined relative to the Ar^{11+} cross section and then scaled as described in the text. The scaling total cross section $\sigma_s = 1.4 \times 10^{-14}$ cm^2.

Charge state	Total rate coefficient (10^{-8} cm^3 s^{-1})	Total cross section (10^{-14} cm^2)
11+	3.5 (1.1)	1.4 (0.2)
35+	5.5 (3.3)	2.7 (1.1)
43+	8.1 (4.8)	2.9 (1.1)
44+	11.3 (3.6)	4.0 (1.6)
45+	15.2 (5.6)	5.4 (2.1)
46+	8.9 (5.1)	3.1 (1.5)
73+	24.4 (7.5)	10.8 (4.1)
74+	26.1 (8.9)	11.5 (4.4)
75+	28.0 (9.3)	12.3 (4.6)
76+	27.8 (8.9)	12.2 (4.6)
79+	25.0 (7.5)	11.0 (4.2)
80+	25.1 (7.5)	11.1 (4.4)

Other processes

- Photon stimulated processes

$$h\nu + e + A^{z+} \rightarrow A^{(z-1)+} + 2h\,\nu$$

- Dust particle processes
  - Low ionization potentials
  - Nano-effects – intense electron emission
  - Dusty plasma effects