

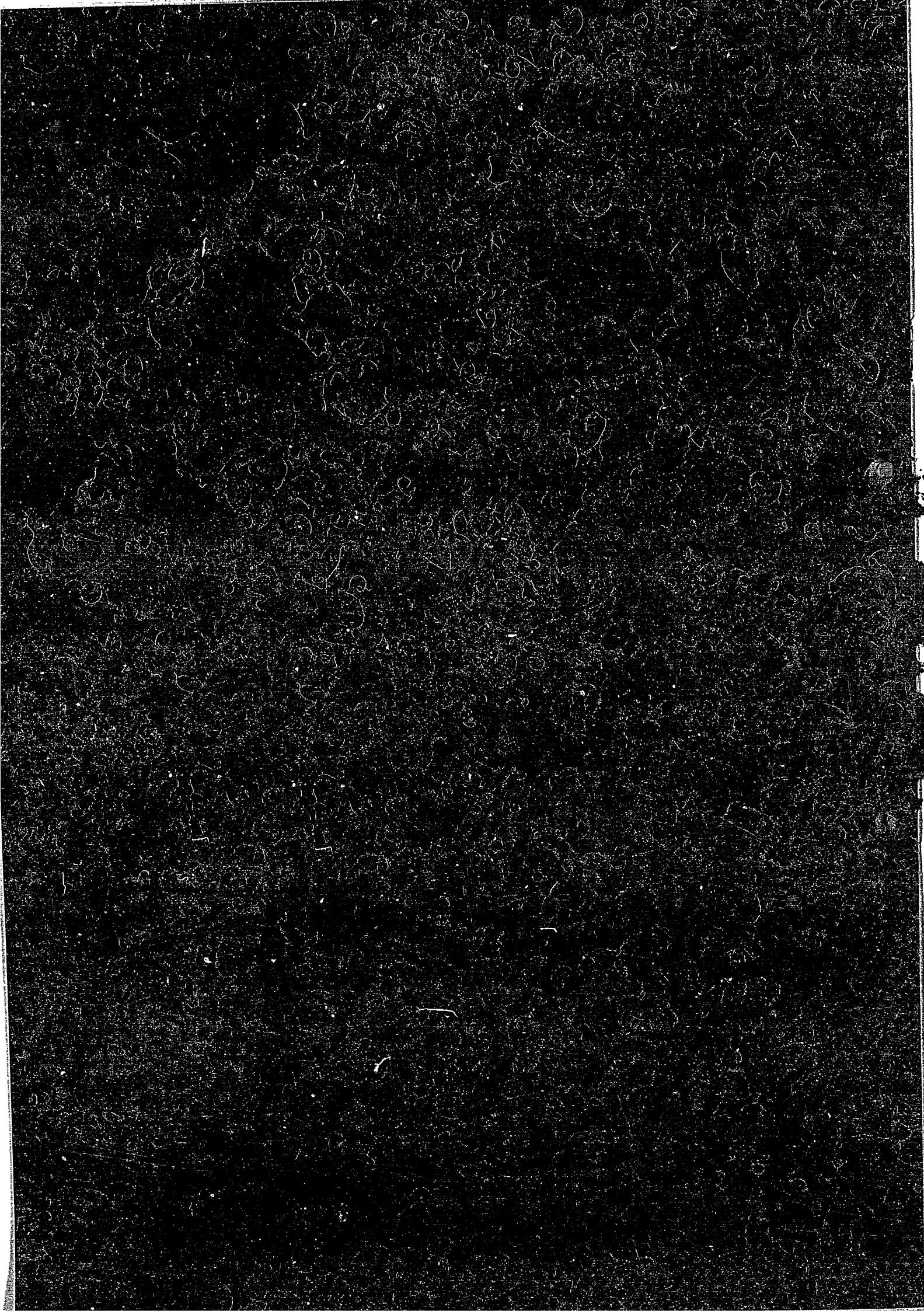
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BIBLIOGRAPHY
ON IONIZATION AND CHARGE TRANSFER PROCESSES
IN ION-ION COLLISION

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**BIBLIOGRAPHY ON IONIZATION AND CHARGE TRANSFER PROCESSES
IN ION-ION COLLISION**

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Abstract

A bibliographic compilation is given on the experimental and theoretical investigations on the charge transfer and ionization processes in ion-ion collisions.

PREFACE

The collision process between ions, which is one of the basic fields in atomic physics, astrophysics and plasma physics, is now realized to play a key role in realization of the inertial confinement fusion (ICF) reactors as well as of the magnetic confinement reactors. Theoretical treatments of the ion-ion collision processes are similar, in many aspects, to those in ion-atom collision processes and a number of calculations of the relevant cross sections have been made. On the other hand, measurements of the cross sections need the sophisticated techniques and experimental data are still scarce up to now.

This is our first bibliographical compilation of experimental and theoretical investigations on the charge transfer and ionization processes in ion-ion collisions. In Section I is given a list of the review articles. In Section II are listed experimental works, meanwhile theoretical works are compiled in Section III. Table I and Table II show the ion-ion combination.

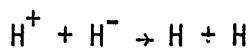
This bibliographical compilation covers works published up to March, 1983. No preliminary works reported in short abstracts of conference proceedings are included.

I. REVIEW ARTICLES

- R1 R.H. Neynaber
Advances in Atomic and Molecular Physics (Academic Press, 1960)
p. 57-108 (vol. 8)
Experiments with merging beams
- R2 M.F.A. Harrison
Methods of Experimental Physics (Academic Press 1968) 7a, p. 95-115
Electron impact ionization and excitation of positive ions.
- R3 K.T. Dolder
Case Studies in Atomic Collision Physics 1, p.249-334 (North-Holland Publishing Co., 1969)
Experiments with colliding charged-particle beams.
- R4 J.T. Moseley, R.E. Olson, and J.R. Peterson
Case Studies in Atomic Physics (North-Holland Publishing Co., 1975)
p. 1-45
Ion-ion mutual neutralization.
- R5 K.T. Dolder and B. Peart
Reports on Progress in Physics 39, p. 693-749 (1976)
Collisions between electrons and ions.
- R6 K.T. Dolder
Electronic and Atomic Collisions (Proc. XI-ICPEAC, North-Holland Publishing Co., 1980) p. 281-294
Collisions between charged particles.
- R7 K.T. Dolder
Atomic and Molecular Processes in Controlled Thermonuclear Fusion
(ed. by M.R.C. McDowell and A.M. Ferendeci, Plenum Press, 1980) p. 348
Some experimental aspects of inelastic electron-atom collisions and collisions between charged particles.
- R8 H.B. Gilbody
Physics of Electronic and Atomic Collisions (North-Holland Publishing Co., 1982) p. 223
Collisions between positive ions
- R9 K.T. Dolder
Comments on Atomic and Molecular Physics 11, 211 (1982).
Ion-ion collisions
- R10 F. Brouillard (ed.)
Physics of Ion-Ion and Electron-Ion Collisions (Plenum Press, 1983)

II. EXPERIMENTAL WORKS

- 67E1 T. Sinda, C. Manus, and J. Guidi
Comptes Rendus 264, 755 (1967)
 Etude des interactions inelastiques entre deux faisceaux d'ions.
- $$\text{H}_2^+ + \text{N}_2^+ \rightarrow \text{H}^+, \text{H}_2^0 + \text{H}^0$$
- E=50 - 250 keV
- 69E1 R.D. Rundel, K.L. Aitken, and M.F.A. Harrison
J. Phys. B 2, 954 (1969)
 A measurement of the cross section for charge exchange in $\text{H}^+ - \text{H}^-$ collisions.
- $$\text{H}^+ + \text{H}^- \rightarrow \text{H} + \text{H}$$
- E=0.25 - 10 keV (rel.)
- 70E1 T.D. Gaily and M.F.A. Harrison
J. Phys. B 3, L25 (1970)
 A remeasurement of the cross section for charge exchange in $\text{H}^+ - \text{H}^-$ collisions.
- $$\text{H}^+ + \text{H}^- \rightarrow \text{H} + \text{H}$$
- E=0.6 - 4.0 keV (rel.)
- 70E2 T.D. Gaily and M.F.A. Harrison
J. Phys. B 3, 1098 (1970)
 A measurement of the charge exchange cross section in $\text{He}^+ - \text{H}^-$ collisions.
- $$\text{He}^+ + \text{H}^- \rightarrow \text{He} + \text{H}$$
- E=0.2 - 8.0 keV (rel.)
- 70E3 R.E. Olson, J.R. Peterson, and J. Moseley
J. Chem. Phys. 53, 3391 (1970)
 Ion-ion recombination total cross sections-atomic species.
- $$\text{O}^+ + \text{O}^- \rightarrow \text{O} + \text{O} : \quad \text{He}^+ + \text{D}^- \rightarrow \text{He} + \text{D}$$
- $$\text{H}^+ + \text{H}^- \rightarrow \text{H} + \text{H};$$
- $$\text{N}^+ + \text{O}^- \rightarrow \text{N} + \text{O} : \quad \text{He}^+ + \text{H}^- \rightarrow \text{He} + \text{H}$$
- E=0.1 - 10,000 eV (rel.)
- 70E4 J. Moseley, W. Aberth, and J.R. Peterson
Phys. Rev. Letters 24, 435 (1970)
 $\text{H}^+ - \text{H}^-$ mutual neutralization cross section obtained with superimposed beams.



$$E = 0.15 - 300 \text{ eV (rel.)}$$

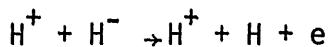
- 70E5 W.H. Aberth and J.R. Peterson
Phys. Rev. A1, 158 (1970)
Ion-ion mutual neutralization cross sections measured by a superimposed beam technique.
- $$N^+ + O^- \rightarrow N + O : N_2^+ + D_2^- \rightarrow N_2 + D_2$$
- $$O_2^+ + O_2^- \rightarrow O_2 + O_2$$
- $$E = 0.1 - 98 \text{ eV (rel.)}$$
- 71E1 J.R. Peterson, W.H. Aberth, and J.T. Moseley
Phys. Rev. A3, 1651 (1971)
Ion-ion mutual neutralization cross sections measured by a superimposed beam technique. II. $O_2^+ - O_2^-$, $O_2^+ - NO_2^-$ and $NO^+ - NO_2^-$.
- $$O_2^+ + O_2^- \rightarrow O_2 + O_2 : O_2^+ + NO_2^- \rightarrow O_2 + NO_2$$
- $$NO^+ + NO_2^- \rightarrow NO + NO_2$$
- $$E = 0.15 - 200 \text{ eV (rel.)}$$

- 71E2 J. Weiner, M.B. Peatman, and R.S. Berry
Phys. Rev. A4, 1824 (1971)
Charge transfer in $Na^+ - O^-$ collisions at low relative energy
- $$Na^+ + O^- \rightarrow Na (3d \rightarrow 3p; 3p \rightarrow 3s; 4p \rightarrow 3s)$$
- $$E = 0.1 - 7 \text{ eV (rel.)}$$

- 76E1 B. Peart, R. Grey, and K.T. Dolder
J. Phys. B 9, L369 (1976)
Measurements of cross sections for the mutual neutralization of H^+ and H^- ions.
- $$H^+ + H^- \rightarrow H + H$$
- $$E = 20 - 3000 \text{ eV (rel.)}$$

- 76E2 B. Peart, R. Grey, and K.T. Dolder
J. Phys. B 9, L373 (1976)
Measurements of cross sections for the mutual neutralization of He^+ and H^- ions.
- $$He^+ + H^- \rightarrow He + H$$
- $$E = 35 - 4550 \text{ eV (rel.)}$$

- 76E3 B. Peart, R. Grey, and K.T. Dolder
 J.Phys. B 9, 3047 (1976)
 Measurements of cross sections for electron detachment from H^- ions by proton impact.



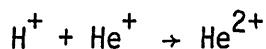
$$E = 1.49 - 35.2 \text{ keV (rel.)}$$

- 77E1 J.B.A. Mitchell, K.F. Dunn, G.C. Angel, R. Browning, and H.B. Gilbody
 J.Phys. B 10, 1897 (1977)
 Ionization and charge transfer in fast $H^+ - He^+$ collisions using an interesting beam technique.



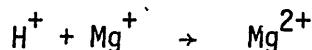
$$E = 72 - 402 \text{ keV (c.m.)}$$

- 77E2 B. Peart, R. Grey, and K.T. Dolder
 J.Phys. B 10, 2675 (1977)
 Measurements of cross sections for the formation of He^{2+} ions by collisions between protons and He^- .



$$E = 2.98 - 28.5 \text{ keV (rel.)}$$

- 77E3 B. Peart, D.M. Gee, and K.T. Dolder
 J.Phys. B 10, 2683 (1977)
 Measurements of cross sections for the formation of Mg^{2+} ions by collisions between protons and Mg^- .



$$E = 0.98 - 44.5 \text{ keV (rel.)}$$

- 78E1 G.C. Angel, K.F. Dunn, E.C. Sewell, and H.B. Gilbody
 J.Phys. B 11, L49 (1978)
 Ionization and charge transfer in fast $H^+ - He^+$ collisions : further measurements of improved accuracy.



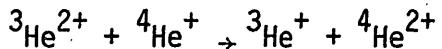
$$E = 40 - 386 \text{ keV (c.m.)}$$

- 78E2 G.C. Angel, E.C. Sewell, K.F. Dunn, and H.B. Gilbody
 J.Phys. B 11, L297 (1978)
 Charge transfer and ionization in fast $H^+ - He^+$ collision: further measurements using coincidence technique.



$$E = 60 - 182 \text{ keV (c.m.)}$$

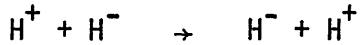
- 78E3 A. Jognaux, F. Brouillard, and S. Szucs
J.Phys. B 11, L669 (1978)
 Charge exchange on low energy $\text{He}^+ - \text{He}^{2+}$ collisions.



$$E = 10 - 1700 \text{ eV (rel.)}$$

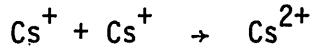
- 78E4 G. Poulaert, F. Brouillard, and W. Claeys
J.Phys. B 11, L671 (1978)
 H_2^+ formation in low energy $\text{H}^+ - \text{H}^-$ collisions.
- $$\text{H}^+ + \text{H}^- \rightarrow \text{H}_2^+ + \text{e}$$
- $$E = 0.001 - 3 \text{ eV (rel.)}$$

- 79E1 B. Peart and R.A. Forrest
J.Phys. B 12, L23 (1979)
 Measurements of cross sections for double charge transfer in collisions between H^+ and H^- ions.



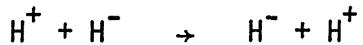
$$E = 44 - 570 \text{ eV (rel.)}$$

- 79E2 K.F. Dunn, G.C. Angel, and H.B. Gilbody
J.Phys. B 12, L623 (1979)
 An experimental study of charge transfer and ionization in $\text{Cs}^+ - \text{Cs}$ collisions.



$$E = 40 - 280 \text{ keV (c.m.)}$$

- 79E3 F. Brouillard, W. Claeys, G. Poulaert, G. Rahmat, and G. Van Wassenhove
J.Phys. B 12, 1253 (1979)
 Double charge transfer in $\text{H}^+ - \text{H}^-$ collisions.



$$E = 30 - 200 \text{ eV (c.m.)}$$

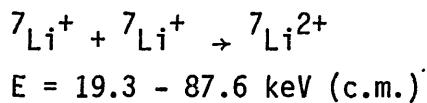
- 79E4 B. Peart, and K.T. Dolder
J.Phys. B 12, 4155 (1979)
 Measurements of cross sections for charge exchange between He^{2+} and He^{3+} ions.



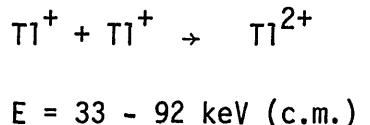
E = 0.1 - 20 keV (rel.)

- 80E1 E.C. Sewell, S.C. Angel, K.F. Dunn, and H.B. Gilbody
J.Phys. B 13, 2269 (1980)
Ionization and charge transfer in fast $H^+ - Li^+$ collisions.
 $H^+ + Li^+ \rightarrow Li^{2+}; H + Li^{2+}$: deduce $H^+ + Li^{2+} + e^-$
E = 62 - 350 keV (c.m.)
- 80E2 G.C. Angel, K.F. Dunn, P.A. Neil, and H.B. Gilbody
J.Phys. B 13, L391 (1980)
Charge transfer and ionization in $Xe^+ - Xe^+$ collisions.
 $Xe^+ + Xe^+ \rightarrow Xe^{2+}$
E = 38 - 303 keV (c.m.)
- 81E1 B. Peart, R.A. Forrest, and K. Dolder
J.Phys. B 14, L383 (1981)
Measurements of cross sections for charge transfer between Cs^+ ions.
 $Cs^+ + Cs^+ \rightarrow Cs + Cs^{2+}$
E = 28 - 68 keV (c.m.)
- 81E2 B. Peart, R.A. Forrest, and K. Dolder
J.Phys. B 14, L603 (1981)
Measurements of inelastic collisions between homonuclear ions:
 Na^+ , K^+ and Rb^+ .
 $Na^+ + Na^+ \rightarrow Na^{2+}$
 $K^+ + K^+ \rightarrow K^{2+}$
 $Rb^+ + Rb^+ \rightarrow Rb^{2+}$
E = 19.3 - 87.6 keV (c.m.)
- 81E3 B. Peart, R.A. Forrest, and K. Dolder
J.Phys. B 14, 1655 (1981)
Measurements of inelastic collisions between Cs^+ ions.
 $Cs^+ + Cs^+ \rightarrow Cs^{2+}$
E = 19 - 79 keV (c.m.)
- 81E4 B. Peart, R.A. Forrest, and K. Dolder

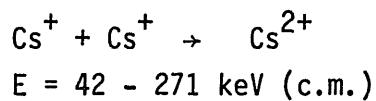
J.Phys. B 14, 3457 (1981)
Measurements of cross sections for the formation of ${}^7\text{Li}^{2+}$ by
collisions between Li^+ ions.



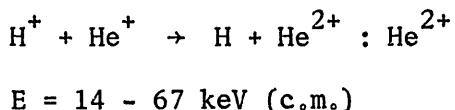
82E1 R.A. Forrest, B. Peart, and K. Dolder
J.Phys. B 15, L45 (1982)
Measurements of inelastic collisions between Tl^+ ions.



82E2 P.A. Neil, G.C. Angel, K.F. Dunn, and H.B. Gilbody
J.Phys. B 15, 4219 (1982)
Collisions between Cs^+ ions - a further experimental study.



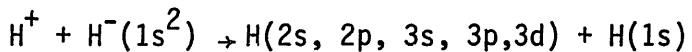
83E1 B. Peart, K. Rinn and K. Dolder
J.Phys. B 16, 1461 (1983)
Measurements of charge transfer and ${}^4\text{He}^{2+}$ production in collisions
between protons and He^+ ions.



III. THEORETICAL WORKS

(see the explanation of the abbreviations for the models given in the last part of this section)

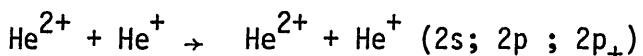
- 55T1 D.R. Bates and J.T. Lewis
 Proc. Phys. Soc. A 68, 173 (1955)
 Inelastic heavy particle collisions involving potential energy curves III. charge transfer from negative ions of atomic hydrogen to proton.



$$E = 10^{-1} - 10^4 \text{ eV}$$

(LZ)

- 62T1 D.R. Bates and A.H. Boyd
 Proc. Phys. Soc. 79, 710 (1962)
 Effect of Coulomb repulsion between charged atomic systems on excitation and ionization cross sections.



(FB)

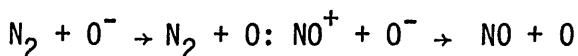
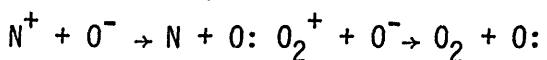
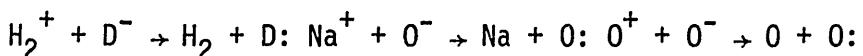
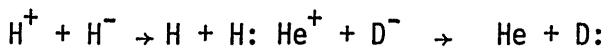
- 62T2 D.R. Bates and A.H. Boyd
 Proc. Phys. Soc. 80, 1301 (1962)
 Effect on symmetrical resonance charge transfer cross sections of change in relative motion during encounter.



$$E = 10 \text{ eV} - 10^4 \text{ eV (rel.)}$$

(FB)

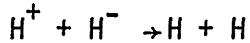
- 72T1 R.E. Olson
 J. Chem. Phys. 56, 2979 (1972)
 Absorbing-sphere model for calculating ion-ion recombination total cross sections.



$$E = 10^{-2} - 10^2 \text{ eV, rate coefficient}$$

(ASM-LZ)

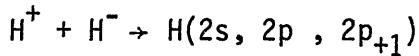
- 73T1 R. Gayet, R.K. Janev, and A. Salin
J.Phys. B 6, 993 (1973)
Electron detachment from negative ions by charged particle collisions I. proton impact.



$$E = 1.56 - 400 \text{ keV}$$

(CB)

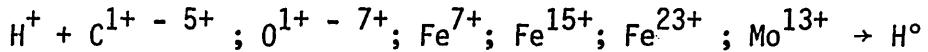
- 73T2 K. Roy and S.C. Mukherjee
Phys. Rev. A 7, 130 (1973)
Charge transfer in $H^- - H^-$ collisions.



$$E = 0.5 - 8 \text{ keV}$$

(AE)

- 76T1 K. Fujiwara
J.Phys. Soc. Japan 41, 1350 (1976)
Coulomb-Born calculation of charge transfer cross sections of highly-ionized atoms.
Erratum; J. Phys. Soc. Japan 45, 1053 (1978)



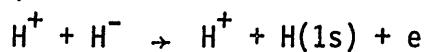
$$E = 1 \text{ keV} - 100 \text{ MeV}$$

(CB)

- 76T2 V.P. Zhdanov
Sov. J.-Tech. Phys. 21, 117 (1976)
Resonance charge exchange in ion-ion collisions
- $$He^{2+} + He^+ \rightarrow He^+ + He^{2+} : Li^{3+} + Li^{2+} \rightarrow Li^{2+} + Li^{3+} :$$
- $$Be^{4+} + Be^{3+} \rightarrow Be^{3+} + Be^{4+} : B^{5+} + B^{4+} \rightarrow B^{4+} + B^{5+} :$$
- $$C^{6+} + C^{5+} \rightarrow C^{5+} + C^{6+} : N^{7+} + N^{6+} \rightarrow N^{6+} + N^{7+}$$
- $$E=0.01 - 10^4 \text{ eV}$$
- (IP)

- 77T1 V.P. Zhdanov and M.I. Chibisov
Fiz. Plasmy 3, 712 (1977); *Sov.J.-Plasma Phys.* 3, 406 (1977)
 Charge exchange between protons and singly ionized metal atoms.
- $$H^+ + A^+ \rightarrow H(1s) + A^{2+} \quad (A=Mg, Fe, Zn, Mo, Cd, W)$$
- $$E=1 - 10^4 \text{ eV}$$
- (LZ)
- 78T1 R.E. Olson
J.Phys. B 11, L227(1978)
 Ionization and charge transfer cross sections for H^+ , He^{2+} + He^+ .
- $$H^+ + He^+ \rightarrow H^+ + He^{2+} + e; \quad H + He^{2+};$$
- $$He^{2+} + He^+ \rightarrow He^{2+} + He^{2+} + e; \quad He^+ + He^{2+}$$
- $$E=100 - 500 \text{ keV/amu}$$
- (CTMC)
- 78T2 D.S.F. Crother and N.R. Todd
J. Phys. B 11, L663(1978)
 Response to Nikitin and Reznikov: Total cross sections for proton-Be charge transfer.
- $$H^+ + Be^+ \rightarrow H + Be^{2+}$$
- $$E=10^2 - 10^7 \text{ eV}$$
- (IP)
- 78T3 J.C. Moore and K.E. Banyard
J. Phys. B 11, 1613 (1978)
 Continuum-distorted-wave calculation for electron capture from hydrogen negative ions by fast protons.
- $$H^+ + H^- \rightarrow H(1s, 2s, 2p) + H(1s, 2s)$$
- $$E=5 - 2000 \text{ keV}$$
- (CDW)
- 78T4 K.E. Banyard and J.C. Moore
 Electron capture from H^- by fast alpha particles.
J. Phys. B 11, 3899 (1978)
- $$He^{2+} + H^- \rightarrow He^+(1s, 2s, 2p) + H(1s, 2s)$$
- $$E=500 - 8000 \text{ keV}$$
- (CDW)

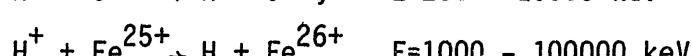
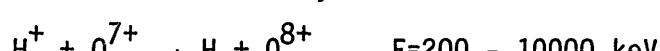
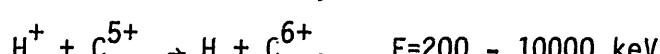
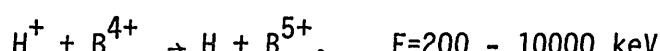
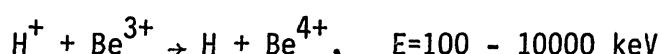
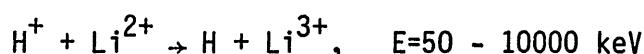
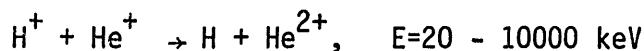
- 78T5 K.L. Bell, A.E. Kingston, and P.J. Madden
 J. Phys. B 11, 3977 (1978)
 Electron detachment from H⁻ ions by proton impact.



E=1.5 - 1000 keV

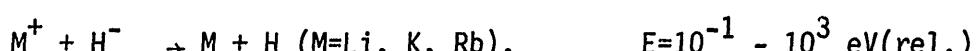
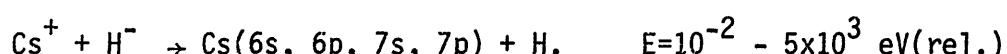
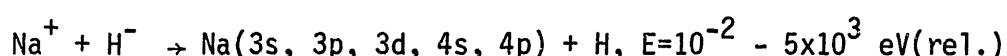
(FB)

- 78T6 M. LaT, A.N. Tripathi, and M.K. Srivastava
 J. Phys. B 11, 4249 (1978)
 Charge transfer cross sections for protons colliding with hydrogenic ions I.



(CPB)

- 78T7 B.K. Janev and Z.M. Radulovic
 Phys. Rev. A 17, 889 (1978)
 Ion-ion recombination and ion-pair formation processes in alkali-hydrogen diatomic systems.



rate coefficient.

(LZ)

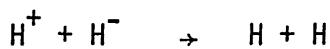
- 78T8 S. Mukherjee, K. Bhadra, N.C. Sil, and D. Basu
 Phys. Letters 65A, 285 (1978)
 Capture in proton-He⁺ collisions.



E = 40 - 100 keV

(CB)

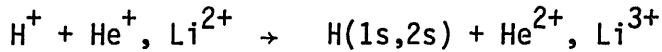
- 78T9 V.P. Zhdanov and M.I. Chibisov
Sov. Phys. -Tech. Phys. 23, 532 (1978)
Effect of level degeneracy on charge exchange at a term pseudointersection.



E = 0.01 - 2519 eV

(LZ)

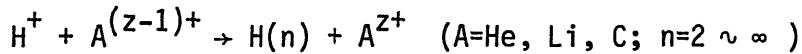
- 79T1 S. Mukherjee, N.C. Sil, and D. Basu
J.Phys. B 12, 1259 (1979)
Electron capture by protons from some hydrogen-like ions.



E = 5 - 1000 keV

(CB)

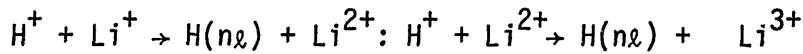
- 79T2 C. Sinha, S. Mukherjee, and N.C. Sil
J.Phys. B 12, 1391 (1979)
Electron capture in an arbitrary excited state by protons passing through hydrogenic ions.



E = 50 - 400 keV

(CB)

- 79T3 K.E. Banyard, and G.W. Shirtcliffe
J.Phys. B 12, 3247 (1979)
Electron capture from lithium and its ions by high-energy protons.

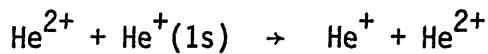


(n ℓ =1s,2s,2p)

E = 200 - 10000 keV

(CDW)

- 79T4 A.S. Dickinson and D.J.W. Hardie
J.Phys. B 12, 4147 (1979)
Symmetric resonance charge transfer in $He^+(1s) - He^{2+}$ collisions.



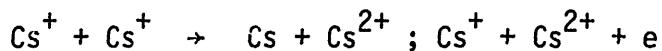
E = 0.02 - 20 keV

(PSS)

79T5 R.E. Olson

ANL-79-41 (1979) p.171

Charge changing cross sections for $\text{Cs}^+ + \text{Cs}^+$ collisions.



E = 100 keV

(MO)

79T6 S Sramek, G. Gallup, and J. Macek

ANL-79-41 (1979) p.183

Preliminary estimate of heavy ion electron transfer cross sections.



E = 100 - 300 keV

(CC-MO)

79T7 J. Macek

ANL-79-41 (1979) p.191

Charge exchange cross sections for the reaction



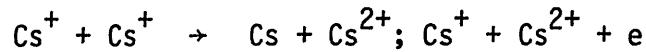
E = 150 keV

(MO)

79T8 G. Das, R.C. Raffenetti, and Y.K. Kim

ANL-79-41 (1979) p.195

Low-lying state of $(\text{Cs}_2)^{++}$.



(MO)

79T9 B.H. Choi, R.T. Poe, and T.K. Tang

ANL-79-41 (1979) p.201

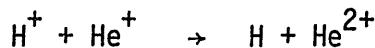
Charge exchange between singly ionized helium ions.



E = 10 - 100 keV

(PWBA)

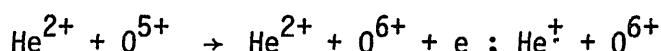
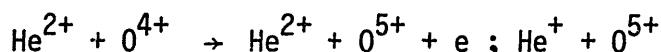
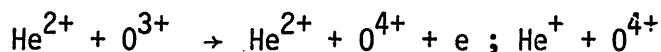
- 79T10 C. Sinha and N.C. Sil
Phys. Letters 71A, 201 (1979)
Charge transfer in proton-positive-ion collisions producing hydrogen atoms in any arbitrary p state.



E = 50 - 400 keV

(CB)

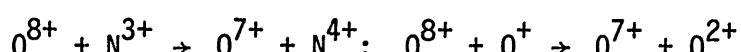
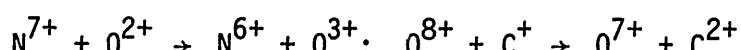
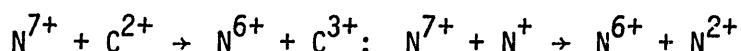
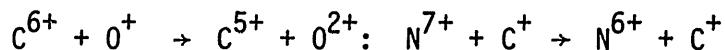
- 79T11 R.E. Olson
Phys. Letters 71A, 341 (1979)
Cross sections for alpha particles colliding with oxygen ions: Loss of alpha heating in Tokamak plasmas.



E = 0.25 - 1.0 MeV/amu

(CTMC)

- 79T12 V.A. Bazylev and M.I. Chibisov
Sov. J.-Plasma Phys. 5, 327 (1979)
Charge exchange in collisions of multiply charged ions



E=1 - 5 keV

(LZ)

- 79T13 A.P. Hickman
J. Chem. Phys. 70, 4872 (1979)

Approximate scaling formula for ion-ion mutual neutralization rates.

chemical reactions, rate constant

(LZ)

79T14 Dz. Belkic, G. Gayet, and A. Salin

Phys. Report 56, 279 (1979)

Electron capture in high-energy ion-atom collisions



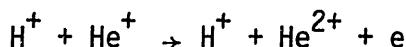
E=30 - 450 keV

(CDW)

80T1 Dz. Belkic

J. Phys. B 13, L589 (1980)

Charge dependence of ionization cross sections.

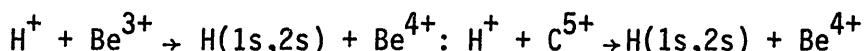
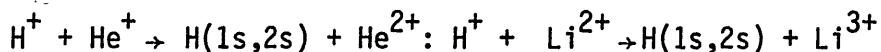


E=40 - 500 keV

(CDW)

80T2 S. Mukherjee and N.C. Sil

Ion-ion capture collisions in the continuum-distorted-wave approximation.



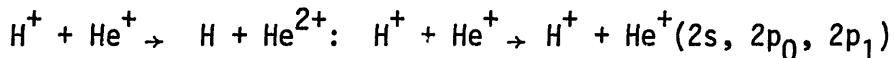
E=0.4 - 2.0 MeV

(CDW)

80T3 T.G. Winter, G.J. Hatton, and N.F. Lane

Phys. Rev. A22, 930 (1980)

Molecular-state treatment of collisions between protons and He^+ ions.



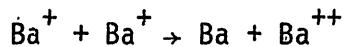
E=1.6 - 14 keV (c.m.)

(MO)

80T4 S.J. Sramek, J.H. Macek, and G.A. Gallup

Phys. Rev. A22, 1467 (1980)

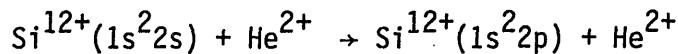
Computed cross sections for electron transfer in $Ba^+ + Ba^+$ collisions.



E=25 - 500 keV

(SLCT)

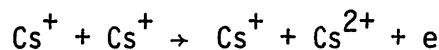
- 80T5 J.H. McGuire and P.R. Simony
Phys. Rev. A22, 2270 (1980)
Calculation of cross sections for 2s-2p excitation of one-electron ions by He^{2+} and He^+ .



E(F)=5 - 45 MeV; E(Si)=5 - 60 MeV

(PWBA)

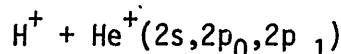
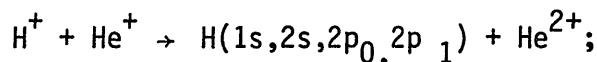
- 81T1 R.E. Olson and B. Liu
J. Phys. B14, L279 (1981)
Interactions of Cs^+ with Cs^+ .



Molecular orbital energy level. Cross sections estimated.

(MO)

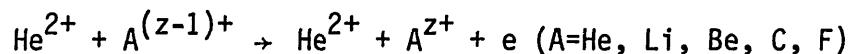
- 81T2 B.H. Bransden and C.J. Noble
J. Phys. B14, 1849 (1981)
Charge transfer in $\text{H}^+ + \text{He}^+$ and $\text{He}^{2+} + \text{H}$ collisions.



E=3.725 - 227.5 keV

(TCAE)

- 81T3 J.H. McGuire, N. Stolterfoht, and P.R. Simony
Phys. Rev. A24, 97 (1981)
Screening and antiscreening by projectile electrons in high velocity atomic collisions.

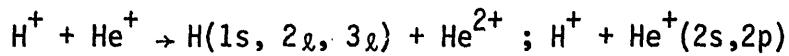


E=10 - 10^4 keV/amu

(PWBA)

- 81T4 M. Kimura and W.R. Thorson
Phys. Rev. A24, 3019 (1981)

Molecular-state study of He^{2+} - $\text{H}(1s)$ and H^+ - $\text{He}^+(1s)$ collisions.



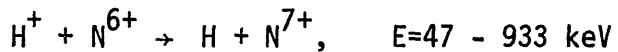
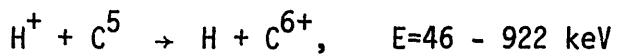
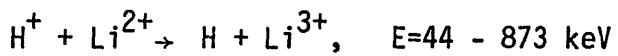
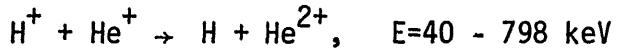
$E = 1 - 20$ keV

(CC - MO)

82T1 C. Sinha and N.C. Sil

Indian J. Pure and Appl. Phys. 20, 26 (1982)

A modified Coulomb-Born approximation and charge transfer in proton-positive ion collisions.

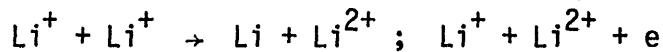


(MCB)

82T2 A.M. Ermolaev, J.E. Miraglia, and B.H. Bransden

J. Phys. B15, L677 (1982)

Ionization and charge exchange in collisions between Li^+ ions at intermediate energies.



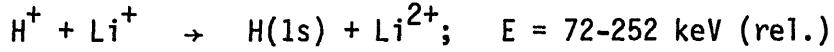
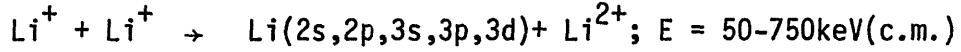
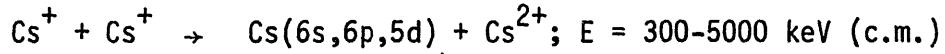
$E = 5 - 1000$ keV/amu

(FB)

82T3 A.M. Ermolaev, C.J. Noble, and B.H. Bransden

J. Phys. B 15, 457 (1982)

Charge exchange between Cs^+ ions and related studies.

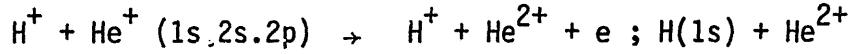


(TSAE)

82T4 J.F. Reading, A.L. Ford, and R.L. Becker

J. Phys. B 15, 625 (1982)

One-and a-half-centered calculations of ionization and charge transfer in $\text{H}^+ + \text{He}^+ + \text{H}$ collisions.



E = 20 - 485 keV

(OHCE, SCE)

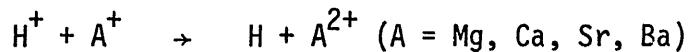
- 82T5 W. Frisch and C.D. Lin
J.Phys. B 15, 1255 (1982)
Close coupling calculations for inelastic processes in intermediate energy ion-atom collisions.



E = 1.5 - 500 keV

(TCAE)

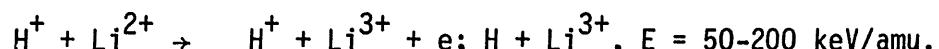
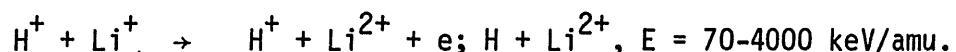
- 82T6 C. Sinha, S. Guha, and N.C. Sil
J.Phys. B 15, 1759 (1982)
Electron capture by protons in collisions with some alkali-like ions using a model potential approach.



E = 10 - 1000 keV

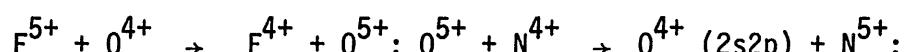
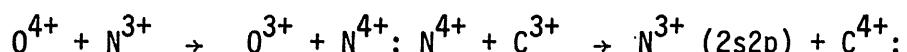
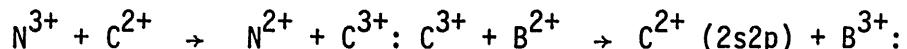
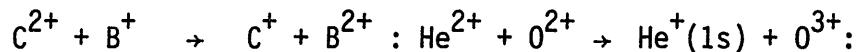
(CB)

- 82T7 A.L. Ford, J.F. Reading, and B.L. Becker
J.Phys. B 15, 3257 (1982)
Coupled-channel calculations of ionization and charge transfer in p + Li^{+,2+} and transfer in Li^{2+,3+} + H(1s) collisions.



(OHCE,SCE)

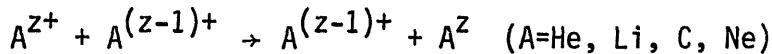
- 82T8 R.K. Janev and D.S. Belic
J.Phys. B 15, 3479 (1982)
Quasi-resonant charge exchange collisions between multiply charged ions.



E = 0.1 - 100 keV (c.m.)

(RZD)

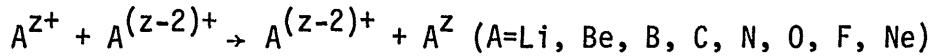
- 82T9 J.P. Maikagan, R.D. Piacentini, and R.D. Rivarola
Phys. Letters 88A, 128 (1982)
Differential cross sections for one-electron two center symmetric systems.



E=25 keV/amu

(TSAE-VC)

- 82T10 R.K. Janev and D.S. Belic
Phys. Letters 89A, 190 (1982)
Double resonant charge exchange in ion-ion collisions.



E=threshold - 1 MeV

(IP)- scaling

- 82T11 T.G. Winter
Phys. Rev. A25, 697 (1982)
Electron transfer in p-He⁺ and He²⁺ - H collisions using Sturmian basis.
 $H^+ + He^+ \rightarrow H + He^{2+}$
E = 4 - 120 keV (c.m.)

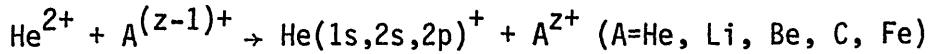
(CC-S)

- 82T12 J. Macek and S. Alston
Phys. Rev. A 26, 250 (1982)
Theory of electron capture from a hydrogenic ion by a bare ion.
erratum: Phys. Rev. A 27, 1708 (1983)

any ion (scaling)

(SPB)

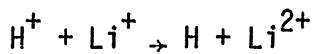
- 82T13 M. Lal, M.K. Srivastava, and A.N. Tripathi
Phys. Rev. A26, 305 (1982)
Charge-transfer cross sections for particles colliding with hydrogenic ions.



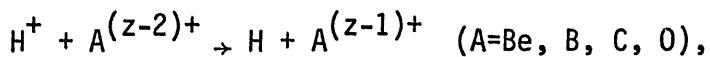
E=20 - 500000 keV

(CPB) - scaling

82T14 C. Sinha, S. Guha, P.K. Roy, and N.C. Sil
Phys. Rev. A 26, 2586 (1982)
Electron capture by protons passing through helium-like ions.



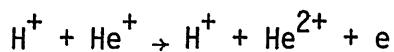
$$E = 20 - 1000 \text{ keV}$$



$$E = 50 - 1000 \text{ keV}$$

(CB, MCB)

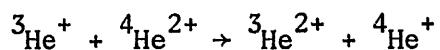
83T1 J.E. Miraglia
J. Phys. B16, 1029 (1983)
Ion-atom single ionization at high and intermediate energies



$$E = 30 - 300 \text{ keV}$$

(MCDW, MSA)

83T2 C.A. Falcon
J. Phys. B 16, 1793 (1983)
Charge exchange in low-energy $^3He^+$ - $^4He^{2+}$ collisions



$$E = 20-100 \text{ eV (c.m.)}$$

(PSS)

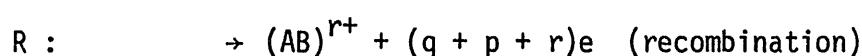
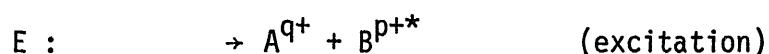
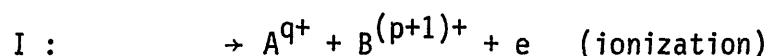
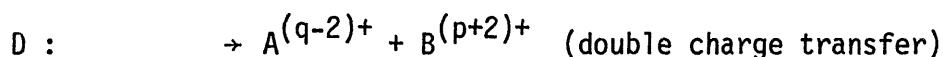
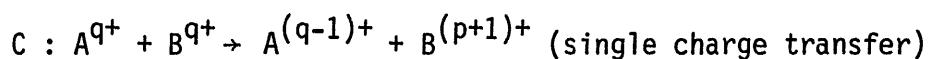
Abbreviation for theoretical models used in calculation of the charge transfer and the ionization cross sections in ion-ion collisions

1. AE : atomic expansion method
2. ASM : absorbing-sphere model
3. CB : Coulomb-Born approximation
4. CC- : close-coupling model
 - MO : molecular orbitals
 - AO : atomic orbitals
 - S : Sturmians
5. CDW : continuum distorted-wave approximation
6. CPB : Coulomb-projected Born approximation
7. CTMC : classical trajectory Monte Carlo method
8. FB : first Born approximation
9. IP : impact parameter method
10. LZ : Landau-Zener model
11. MCB : modified Coulomb-Born approximation
12. MCDW : modified continuum distorted-wave approximation
13. MO : molecular orbital model
14. MSA : multiple scattering approximation
15. OHCE : one-and-a-half centered expansion method
16. PSS : perturbed stationary state approximation
17. PWBA : plane-wave Born approximation
18. RZD : Rosen-Zener-Demkov model
19. SCE : single-centered expansion method
20. SLCT : straight line classical trajectory method
21. SPB : strong potential Born approximation
22. TCAE : two-center atomic expansion method
23. TSAE-VC : two-state atomic expansion method with variable charge

Table 1 Ion-ion combinations investigated experimentally

P \ T	H ⁻	D ⁻	He ⁺	Li ⁺	O ⁻	Na ⁺	Mg ⁺	K ⁺	Rb ⁺	Xe ⁺	Cs ⁺	Tl ⁺
H ⁺	C,I D,R		C+I C,I	C+I C,I			C+I					
He ⁺	C	C										
He ²⁺			C									
Li ⁺				C+I								
N ⁺					C							
O ⁺					C							
Na ⁺					C	C+I						
K ⁺							C+I					
Rb ⁺								C+I				
Xe ⁺									C+I			
Cs ⁺										C+I C,I		
Tl ⁺											C+I	

Note the following notations (A^{q+} : projectile P; B^{p+} target T) :



(C + I) in the table indicates that the sums of the cross sections for the processes (C) and (I) are measured.

Table 2 Ion-ion combinations investigated theoretically

Note the following notations are used: $A^{g_1} + B^{p_1} \rightarrow A^{(q_1)} + B^{(p_1)}, \dots, (C)$, $A^{g_1} + B^{(p_1)} + e \dots (I)$, $A^{(p_1)} \dots (D)$, $A^{g_1} + B^{p_1} \dots (E)$

IV INDEX FOR PROCESSES INVESTIGATED

$H^+ + H^-$	69E1, 70E1, 70E3, 70E4, 76E1, 76E3, 78E4, 79E1, 79E3	55T1, 72T1, 73T1, 73T2, 78T3, 78T5, 78T9, 79T1
$+ He^+$	77E1, 77E2, 78E1, 78E2, 83E1	78T1, 78T6, 78T8, 79T2, 79T10, 80T1, 80T2, 80T3, 81T2, 81T4, 82T1, 82T4, 82T5, 82T11, 83T1
$+ Li^+$	80E1	79T3, 82T3, 82T7, 82T14
$+ Li^{2+}$		78T6, 79T1, 79T2, 79T3, 80T2, 82T1, 82T7
$+ Be^+$		78T2
$+ Be^{2+}$		82T14
$+ Be^{3+}$		78T6, 80T2
$+ B^{3+}$		82T14
$+ B^{4+}$		78T6
$+ C^+$		76T1
$+ C^{2+}$		76T1
$+ C^{3+}$		76T1
$+ C^{4+}$		76T1, 80T2, 82T4
$+ C^{5+}$		76T1, 78T6, 79T2, 80T2, 82T1
$+ N^{6+}$		78T6, 82T1
$+ O^+$		76T1
$+ O^{2+}$		76T1
$+ O^{3+}$		76T1
$+ O^{4+}$		76T1
$+ O^{5+}$		76T1
$+ O^{6+}$		76T1, 82T14
$+ O^{7+}$		76T1, 78T6
$+ Mg^+$		77T1, 82T6
$+ Ca^+$		82T6
$+ Fe^+$		77T1
$+ Fe^{7+}$		76T1
$+ Fe^{15+}$		76T1
$+ Fe^{23+}$		76T1
$+ Fe^{25+}$		78T6
$+ Zn^+$		77T1
$+ Sr^+$		82T6
$+ Mo^+$		77T1
$+ Mo^{13+}$		76T1
$+ Mo^{31+}$		76T1

H^+	$+ Cd^+$	77T1
	$+ Ba^+$	82T6
	$+ W^+$	77T1
He^+	$+ H^-$	70E2, 70E3, 76E2
	$+ D^-$	70E3
	$+ He^+$	72T1
He^{2+}	$+ H^-$	79T9
	$+ He^+$	78T4
	$+ Li^{2+}$	62T1, 62T2, 76T2, 78T1, 79T4,
	$+ Be^{3+}$	80T2, 81T3, 82T9, 82T13, 83T2
	$+ C^{5+}$	80T2, 81T3, 82T13
	$+ O^{2+}$	81T3, 81T13
	$+ O^{3+}$	82T8
	$+ O^{4+}$	79T11
	$+ O^{5+}$	79T11
	$+ F^{7+}$	79T11
	$+ F^{8+}$	80T5
	$+ Si^{12+}$	81T3
	$+ Fe^{25+}$	80T5
Li^+	$+ H^-$	82T13
	$+ Li^+$	78T7
	$+ Li^+$	82T2, 82T3
Li^{3+}	$+ Li^+$	82T10
	$+ Li^{2+}$	82T9
Be^{4+}	$+ Be^{2+}$	82T10
	$+ Be^{3+}$	76T2
B^{5+}	$+ B^{3+}$	82T10
	$+ B^{4+}$	76T2
C^{2+}	$+ B^+$	82T8
C^{3+}	$+ B^{2+}$	82T8
C^{6+}	$+ C^{4+}$	82T10
	$+ C^{5+}$	76T2, 82T9
	$+ O^+$	79T12
N^+	$+ O^-$	70E3, 70E5
	$+ C^{2+}$	72T1
N^{3+}	$+ C^{2+}$	82T8
N^{4+}	$+ C^{3+}$	82T8
N^{7+}	$+ C^+$	79T12
	$+ C^{2+}$	79T12
	$+ N^+$	79T12
	$+ N^{5+}$	82T10

N^{7+}	$+ N^{6+}$	76T2
	$+ O^{2+}$	79T12
O^{+}	$+ O^{-}$	72T1
O^{4+}	$+ N^{3+}$	82T8
O^{5+}	$+ N^{4+}$	82T8
O^{8+}	$+ C^{+}$	79T12
	$+ N^{3+}$	79T12
	$+ O^{+}$	79T12
	$+ O^{3+}$	79T12
	$+ O^{6+}$	82T10
F^{5+}	$+ O^{4+}$	82T8
F^{9+}	$+ F^{7+}$	82T10
Ne^{6+}	$+ F^{5+}$	82T8
Ne^{10+}	$+ Ne^{8+}$	82T10
	$+ Ne^{9+}$	82T9
Na^{+}	$+ H^{-}$	78T7
	$+ O^{-}$	71E2
Na^{+}	$+ Na^{+}$	81E2
K^{+}	$+ H^{-}$	78T7
	$+ K^{+}$	81E2
Rb^{+}	$+ H^{-}$	78T7
	$+ Rb^{+}$	81E2
Xe^{+}	$+ Xe^{+}$	80E2
Xe^{8+}	$+ Xe^{8+}$	79T7
Cs^{+}	$+ H^{-}$	78T7
	$+ Cs^{+}$	79E2, 81E1, 81E3, 82E2
Ba^{+}	$+ Ba^{+}$	79T6, 80T4
Tl^{+}	$+ Tl^{+}$	82E1

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