

Data status and needs for heavy-particle collision processes in fusion edge/divertor plasmas

R.K. Janev

Macedonian Academy of Sciences
and Arts, Skopje, Macedonia

Scope:

- Species, categories
- Relevant collision energies
- Processes
- Data availability, data collections
- Data needs
- Ongoing work (within RC No. 15689)
- Research plans (RC No.15689)

Edge/divertor plasma light element species and important processes:

- **Primaries:** e, H^+, H, H_2
- **Secondaries** (impurities): $He, Aq^+(q=0 - Z), A_xH_y, A_xH_y^+$

$A = Li, Be, B, C, N, O$

- Important collision processes:
 - among the primaries,
 - between primaries and secondaries

He: Data status and needs

1. Proton impact: Excitation

Available: $E \approx 10 - 1000$ keV

- * $1S \rightarrow nL$ ($L = S, P, D$ singlets), $n = 2-5$, exp.
- * $1S \rightarrow nP$ (singl.), $n = 2-5$, theory (AOCC)
- * $2S(\text{sing.}) \rightarrow 2P, 3L$ ($L = S, P, D$ sing.), th. (AOCC)
- * $1S \rightarrow nL$ ($L = S, P, D$ singlets), $n \geq 6$, scaling
(see: APID, vol. 3(1992))

p-impact excitation: needs

- $2P(\text{singl.}) \rightarrow nL(=S,P,D \text{ singl.}), n = 3,4,5$
- $2S,2P(\text{tripl.}) \rightarrow nL(=S,P,D \text{ tripl.}), n = 3,4,5$
- $3S,P,D(\text{singl.}) \rightarrow nL(=S,P,D,F \text{ singl.}), n = (3), 4,5$
- $3S,P,D(\text{tripl.}) \rightarrow nL(=S,P,D,F \text{ tripl.}), n = (3), 4,5$
- **Excitation via intermediary capture dominant

(Chibisov, Janev 2001)

2. p-impact on He: ionization

- Availability:

For He(1S) – accurate exp. & theor. data exist
(including diff. cross sections)

- Needs:

- * ionization from excited states with $n=2,3,4$

- * scaling for $n > 4$

3. p-impact on He: charge exchange

- Availability:
p + He(1S): exp.(Gilbody)& theory (various methods)
- Needs:
p + He(nL), n=2, 3, 4
*** strong coupling of CX and Exc channels
- TI: weak process

He⁺, He²⁺ collisions with H, H₂ and He

1. H target:

** Excitation: exp.&theor. data exist (up to n=5 for He²⁺)

** Ionization: exp. data for H(1s) exist

** Charge exchange: exp.&theor. Data exist for H(1s); theor. data for H(2s) with He²⁺

2. H₂ target:

** data for ionization at high E

** CX: limited exp.& theor. data (low accuracy)

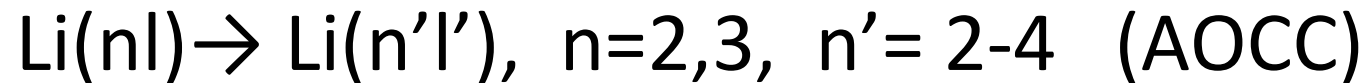
3. He target:

- ** Excitation: exp. data up to $n=4,(5)$ above 10keV (Shartner)
- ** Ionization of He(1S): available at high E
- ** CX: reliable data (exp&theor)
He⁺/He, He²⁺/He : 1e, 2e resonant transfer

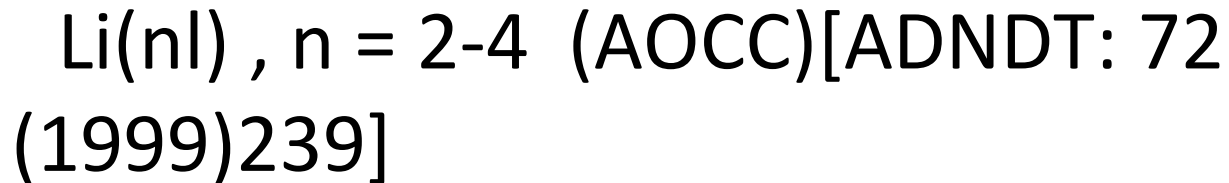
Li: Data status and needs

1. Proton impact processes (Li target)

** Excitation:



** Electron loss(Ion. +CX):



** CX, Ion : exp. data exist for Li(2s) only;

(scaling relations for Li(nl) [ADNDT: 65(1997)

155]

2. Liq+ (q=1,2,3) impact on H, H2

- Li3+ on H: (ADNDT v.94, 161 (2008))
 - ** Excitation: $H(n) \rightarrow H(n')$, $n=1-3$, $n' = 2-6$
 $n > 3$: scaling
 - ** Ionization: $H(n)$, $n=1-3$; $n > 3$: scaling
 - ** CX: $H(1s)$: total and state-selective σ ;
 $H(n > 1)$: total σ (scaling)

- Liq+ (q=1,2) on H:

- ** Excitation: MOCC (q=1), CDW (q=1,2)

- ** Ionization: q=1,2; exp. (Gilbody)

- ** CX: exp. Gilbody(q=1,2), Salzborn (q=2)

- theory: MOCC (q=1,2), AOCC (q=2),
CDW (q=1,2)

- Liq+ (q=1,2,3) on H2:

- exp. data for CX and Ion. (Gilbody)

- MOCC data for CX: q=1 only (Madrid group)

Be,B: Data status and needs

1. Proton impact on Be, B

** Excitation: -----

** Ionization: 1st Born, CDW-EIS (for Be only)

** CX: MOCC for Be (Madrid group, 2008)

MOCC for B (Beijing group, in progress)

2. Beq+, Bq+ on H, H2 and He

❖ IAEA CRP (1993-95); Results in: Phys. Scripta v. T62 (1996)

□ In divertor plasmas:

- * Excitation and ionization of H not important processes (too small cross sections)
- * Charge exchange with He also not important

- CX of Be⁴⁺, B⁵⁺ with H, H₂
- H target:
 - ** Very accurate theor. cross sections (both total and nl-state selective) available.
 - The most accurate:
 - Toshima: AOCC, E = 1 – 1000 keV/u
 - Harel et al : MOCC, E = 0.25 – 25 keV/u
 - Data for E < 250 eV also available
- H₂ target: Be⁴⁺ (MOCC, Madrid group)

- Beq+, Bq+ on H, H2 (q<Z)

- H target:

 - ** Beq+: MOCC, CTMC, CDW

 - ** Bq+ : MOCC, CTMC, AOCC (q=2-4), CDW

- H2 target: B3+ (MOCC)

- ❖ Critical issues:

 - i) the choice of model potential (except for the MOCC); ii) two-e processes for the H2 target

Remarks on C, N, O ion CX

- $q=Z$: both total and nl-selective data exist for H target; few data for H₂
- $q<Z$: limited amount of sufficiently accurate data (mainly for closed shell/subshell ions and H target)
- Data gaps for $Nq^+ / H, H_2$ especially numerous

Ongoing work within RC 15686

- e-BeH⁺: vibrationally resolved excitation of first several excited states (Coulomb-Born approx.)
 - Collaboration with Univ. of Bari
- CX and target excitation in Liq⁺, Beq⁺, Bq⁺/H collisions w. improved model potentials (AOCC)
 - Collaboration with IAPCM, Beijing
- Critical assessment of heavy-particle collision data for He.

Research program within RC 15686

- e- impact excitation and ionization (including dissociative channels) for Li, Be, B, C hydrides and their ions;
- CX and target excitation in collisions of Aq^+ ($A=Li, Be, B, C, N, O; q < Z$) with H, H(2s), He;
- CX of H^+ with light element hydrides;
- Critical assessment of heavy-particle collision data for N, N₂

Collaborations:

- IAPCM, Beijing (J.G. Wang)
- University of Bari (R. Celiberto)
- University of Louvain-la-Neuve (P. Defrance)
- Forschungszentrum Jülich (D. Reiter)
- NIST (Yu. Ralchenko)

