Recoil Momentum of Molecular Ions in Collisions of $Ar^{6+} + N_2$ at Energies below 300 eV/u

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ABSTRACT

To clarify collision energy dependence of recoil momentum for molecular ions after electron transfer, we have measured recoil momentum of non-dissociated molecular ions for single electron capture (SC) collisions of Ar^{6+} with N_2 at collision energies from 7.5 to 240 eV/u. Collision energy dependence of the experimental recoil momentum was compared with those of the theoretical one calculated using an deflection function with the polarization potential. We have obtained fairly good agreement between experimental and calculated results.

INTRODUCTION

- For the molecular-fragmentation, it is understood that the diatomic molecular target undergoes Coulomb explosion after the electron capture and then the two fragments fly in opposite directions with the kinetic energies given by the dissociation energy [1].
- In low energies below 1 keV/u, the recoil momenta of non-dissociated molecular ions depend on collision energy [2,3].
- In this work, in order to investigate collision energy dependence of recoil momentum, we have measured recoil momenta of the target for $Ar^{6+}+N_2$ collision system at energies from 7.5 to 240 eV/u.

EXPERIMENTAL SETUP

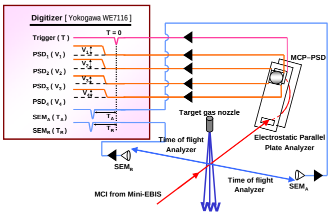

Figure 1 : Schematic diagram of experimental setup.

We have measured time difference between **projectile** and **target ions**.

Measured processes are given as follows:

$$\mathrm{Ar}^{6+} + \mathrm{N}_2 \to \mathrm{Ar}^{5+}(nl) + \mathrm{N}_2^+ + Q_1$$
$$\to \mathrm{Ar}^{4+*}(nl\ n'l') + (\mathrm{N}_2)^{2+} + Q_2$$
$$\to \mathrm{Ar}^{4+} + (\mathrm{N}_2)^{2+} + e^- + Q_3$$
$$\to \mathrm{Ar}^{4+} + \mathrm{N}^+ + \mathrm{N}^+ + e^- + Q_4$$

Q_i : reaction energy

NEWTON DIAGRAM

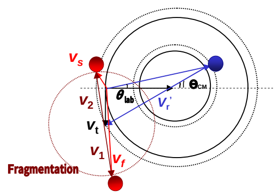

Figure 2 : The correlation diagram of the velocity vectors in the laboratory and the C-M frame.

Velocity of Molecular ions: V_t
Velocities of Fragment ion: V_f & V_s
Dissociation Velocities : V_1 & V_2

$V_1, V_2 >> V_t$

$V_f = V_t + V_1 \cong V_1$, $V_s = V_t + V_2 \cong V_2$

V_t depend on E_{CM}
V_f & V_s independent of E_{CM}

before the collision : E_{CM}
after the collision : $E_{CM} + Q \ (= E'_{CM})$

METHOD of CALCULATION

The experimental recoil momentum

$$P_\perp = \mu v'_f \sin\Theta_{CM}$$
$$\downarrow \sin\Theta_{CM} \approx \Theta_{CM}$$
$$P_\perp \propto \sqrt{E'_{CM}}\ \Theta_{CM}$$

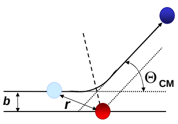

Figure 3 : The scattering of a particle in the field of a center potential[4].

The experimental recoil momentum (ref. [4])

$$\frac{d\varphi}{dr} = \pm\frac{b}{r^2}\sqrt{1-\frac{b^2}{r^2}-\frac{V(r)}{E'_{CM}}}$$

$$\Theta_{CM} = \pi - 2\int_r^\infty \frac{b}{\sqrt{1-b^2/r^2-V(r)/E'_{CM}}}\frac{dr}{r^2}$$

In the case of $V(r)$ in powers of r : $V(r) = C/r^s$

$$\Theta_{CM} \propto (b^s E'_{CM})^{-1}$$

Θ_{CM} : scattering angle in the C - M frame
μ : reduced mass
v'_f : relative velocity
b : impact parameter
r : internuclear distance
I_t : t - th ionization potential
q : charge state of incident ion
α : polarizability of N_2

The internuclear distance R
(as the internuclear distance of closest approach)

$$R = (2\sqrt{qt}+q)/I_t$$

by the Classical Over Barrier (COB) model[5] with Atomic Spectra Database of NIST[6]

The relations between b and R

$$b^2 = R^2(1 - V(R)/E'_{CM})$$

In the Coulomb potential : s =1

$$V(r) = C/R$$
$$b \cong R$$
$$\Theta_{CM} \propto (RE'_{CM})^{-1}$$
$$P_\perp \propto \left(\sqrt{E'_{CM}}R\right)^{-1}$$

In the polarization potential : s =4

$$V(r) = -(\alpha q^2)/(2r^4)$$
$$b^2 = R^2\left[1+(\alpha q^2)/(2R^4E'_{CM})\right]$$
$$\Theta_{CM} \propto \left(R^4E'_{CM}\left[1+\frac{\alpha q^2}{2R^4E'_{CM}}\right]^2\right)^{-1}$$
$$P_\perp \propto \left(\sqrt{E'_{CM}}\ R^4\left[1+\frac{(\alpha q^2)}{(2R^4E'_{CM})}\right]^2\right)^{-1}$$

RESULTS and DISCUSSION

$Ar^{6+} + N_2 \Rightarrow Ar^{5+} + (N_2)^+$

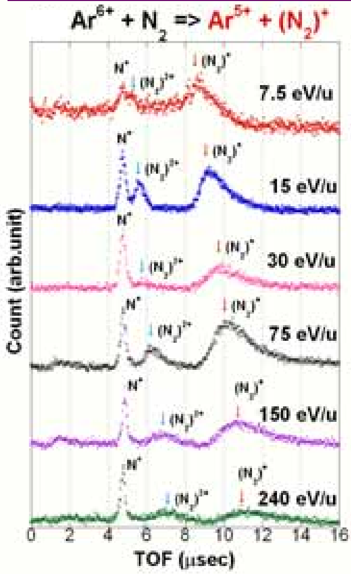

Figure 4 : TOF spectra of molecular ions and fragment ions in collisions of $Ar^{6+}+N_2$ at energies from 7.5 to 240 eV/u. The peak positions of non-dissociated N_2^+ and N_2^{2+} molecular ions depend on the collision energy.

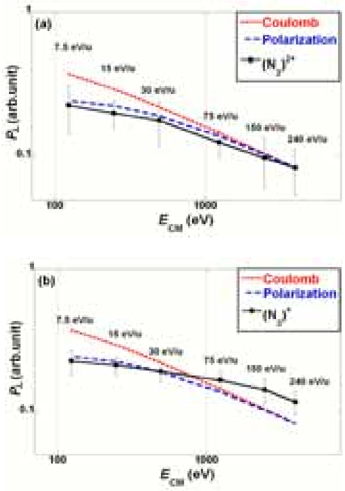

Figure 5 : The experimental and the theoretical energy dependence of recoil momenta for N_2^{2+} (a) and N_2^+ (b). The experimental results are good agreement with the theoretical one using the polarization potential rather than the Coulomb potential at energies below 30 eV/u.

SUMMARY

In order to clarify the collision energy dependence of recoil momenta for non-dissociated molecular ions, we have…

- measured recoil momenta of N_2^{2+} and N_2^+ for SC collisions.
- compared with the theoretical calculation with the Coulomb and the polarization potential for the energy dependence.

It is concluded that the polarization potential plays a crucial role in low energy region.

FUTURE PLAN

To understand more precisely, coincidence measurements of TOF spectra with energy gain spectra of the projectile after the collision is necessary.

PROGRESS REPORT

In order to clarify the charge-asymmetry effect between the far and near fragment ions from incident MCI beam axis, we have measured molecular-fragmentation of N_2 molecule in electron capture collisions of Ar^{6+} ions in the collision energy from 30 to 150 eV/u and have determined branching ratios for each reaction channel.

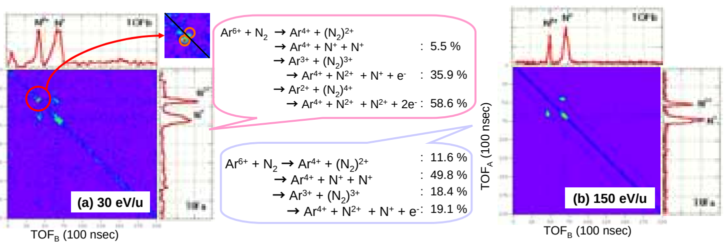

Figure 6 : Branching ratio of N_2 in double electron capture collisions of Ar^{6+} for double electron capture process at energies 30 eV/u (a) and 150 eV/u (b).

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