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Stereodynamics of asymmetric ion-pair formation in collisions of highly-charged ions with rare gas dimers

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Synopsis Stereodyanamical effects are analyzed for multiple ionization of rare gas dimers by slow highly charged ions using the three-center Coulombic over-barrier model previously developed by the present authors.

More than ten years ago, we proposed a three-center Coulombic over-barrier model to describe sequential multiple ionization of a rare gas dimer BC collided by a slow highly charged ion A^{q+} [1]. In more recent works [2, 3], we modified the model so as to introduce the effect of partial screening during a collision for non-active target atomic site (either B or C) and also for projectile site (A) in respective steps of electron removal. The model predicts the population distribution over charge-states (Q, Q') of dissociating ion pairs just after the collision. Measured result [4, 5] of the ion pair distribution in $Ar^{9+} + Ar_2$ collisisons was reasonably reproduced in the model by taking a screening parameter as $s = 0.3 \sim 0.4$ [3].

In the present work, stereodynamical effects are examined in relation to the screening effect. We have calculated the ion pair formation cross sections as a function of the orientation angle, $\cos\theta = \hat{\boldsymbol{d}} \cdot \hat{\boldsymbol{v}}$, where $\boldsymbol{d}$ denotes a molecular axis vector from C to B with $\boldsymbol{v}$ being the projectile beam velocity. In addition, to obtain a physical insight more clearly, we introduce a pair of atomic impact parameters $b_{\rm B}$ and $b_{\rm C}$ respectively defined as the vertical distances from sites B and C to the incident trajectory (see Fig.1). Hence, we distinguish the *near* and *far* sites; thereby discuss the ion-pair formation cross section $\sigma(Q_{\rm near}, Q_{\rm far})$. The near and far sites would be determined through the measurement of momentum transfer.

Figure 2 shows the angular dependence of the cross sections $\sigma(Q_{\rm near}, Q_{\rm far})$ for $(Q_{\rm near}, Q_{\rm far})$ = (2,1), (1,2), (3,2), and (2,3). It is seen from the figure that the $(2,1)$ population overwhelms $(1,2)$, and similarly $(3,2)$ overwhelms $(2,3)$. All the curves in the figure are symmetric with respect to $\cos\theta$. We see two maxima in $(2,1)$ and $(3,2)$ cross sections, and two cusps in $(1,2)$ and $(2,3)$ at $\cos\theta = \pm 1$. These behaviors come from the geometry of saddle point formation in the three-center Coulombic potential [2, 3].

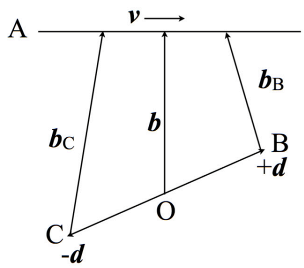

Figure 1. Atomic impact parameters $b_{\rm B}$ for $A^{q+} + B$ and $b_{\rm C}$ for $A^{q+} + C$ with molecular impact parameter b for $A^{q+} + BC$.

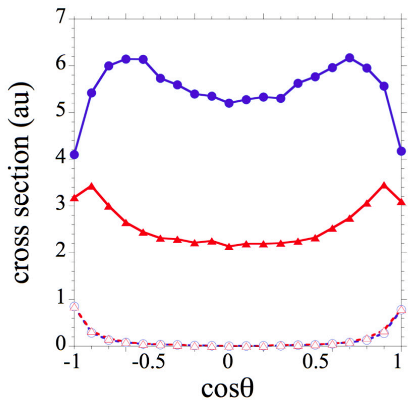

Figure 2. Angular dependence of the ion-pair formation cross sections $\sigma(Q_{\rm near}, Q_{\rm far})$ in $Ar^{9+} + Ar_2$ collisions; those for (2,1) are indicated by closed circles (●), those for (1,2) by open circles (○), those for (3,2) by closed triangles (▲), and those for (2,3) by open triangles (△).

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