

Double impulse effects in ion-molecule collisions at hyperthermal energies

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Synopsis The possibility of double impulse phenomenon in a single collision event is studied by the hard-shell model. Such an effect would be observed if the projectile is as heavy as target and the interaction potential has a strong anisotropy.

Short range repulsive force dominates the dynamics in the close collision between ions with molecules at hyperthermal energies. Generally, such a collision would be impulsive and the hard-shell model [1] and the hard-potential model [2, 3] are applicable to estimate the energy and angular momentum transfers. In these models, an impulse is exerted at a point on the hard-shell, which is given by the equipotential surface at the collision energy. As a result, the energy-loss spectrum at a fixed angle presents a double-peaked structure. If the angular momentum transfer and/or energy transfer from projectile to target is large in the first impulse, the projectile may be largely decelerated and it is plausible that the second impulse [4] takes place. In fact, Tanuma *et al.* [5] have observed collapse of the double-peaked structure in the energy-loss spectra in $\text{Na}^+ - \text{N}_2$ and concluded that it is due to the 'double collisions' between the projectile and the target through the classical trajectory calculation.

Here we discuss the possibility of *double impulse* effect in a single collision event within a framework of the hard-shell model. Let \mathbf{l}_i be the initial orbital angular momentum of relative motion and \mathbf{J} the rotational angular momentum of the molecule after the first impulse. The direction of angular momentum transfer can be categorized into the following two cases; $\mathbf{l}_i \cdot \mathbf{J} > 0$ (normal torque) and $\mathbf{l}_i \cdot \mathbf{J} < 0$ (anomalous torque) [6]. The double impulse effect would be observed in the latter case.

In Fig.1, we present the results of model calculation for $\text{K}^+ - \text{N}_2$. The hard-shell is given by a sum of monopole and quadrupole deformations as $r_s(\gamma) = r_0(1 + \beta_2 P_2(\cos \gamma))$ with the anisotropy parameter $\beta = 0.3$ (0.4) in the left (right) panel.

Trajectories of a projectile ion scattered by the hard-shell is shown in a molecular-fixed frame. We observe that the projectile contacts the shell again in the right panel, while it does not in the left panel. We find that the double impulse effect likely occurs in the collisions where the projectile mass is heavier than the target and the potential anisotropy is large.

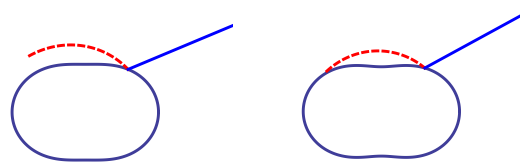


Figure 1. Trajectories of projectile ion scattered by the hard-shell in the molecular fixed frame for $\text{K}^+ - \text{N}_2$; incident and scattered trajectories are shown by solid lines and dashed curves, respectively. The anisotropy parameter $\beta_2 = 0.3(0.4)$ in the left (right) panel.

References

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