Kinetic energy release in N_2 fragmentation by swift highly charged ions

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We studied the multiple ionization and fragmentation of N_2 in collisions with swift highly charged ions using a position- and time-sensitive multi-particle detector which allows the coincident measurement of the momenta of correlated fragment ions. Collimated beams of 4.7 MeV/u Bi^{q+} (q=25,57) and 5.9 MeV/u Xe^{q+}-ions (q=17,18,43) provided by UNILAC interact with a N_2 gas target. The slow ions and electrons generated in the collision process were separated by a weak homogeneous electric field. Electrons were detected by a channeltron at one side of the interaction region; positive ions were accelerated towards the time- and position sensitive multi-particle detector [1] at the other side. For each positive fragment ion the position on the detector and the time-of-flight relative to the electron signal were recorded. Thereby, the experimental setup is sensitive to all reaction channels resulting in at least one electron and one or more positive ions. Furthermore, if all fragments from a particular fragmentation are detected, a *kinematically complete* study of the molecular break-up process is possible and the dissociation energy as well as angular correlations can be derived [2].

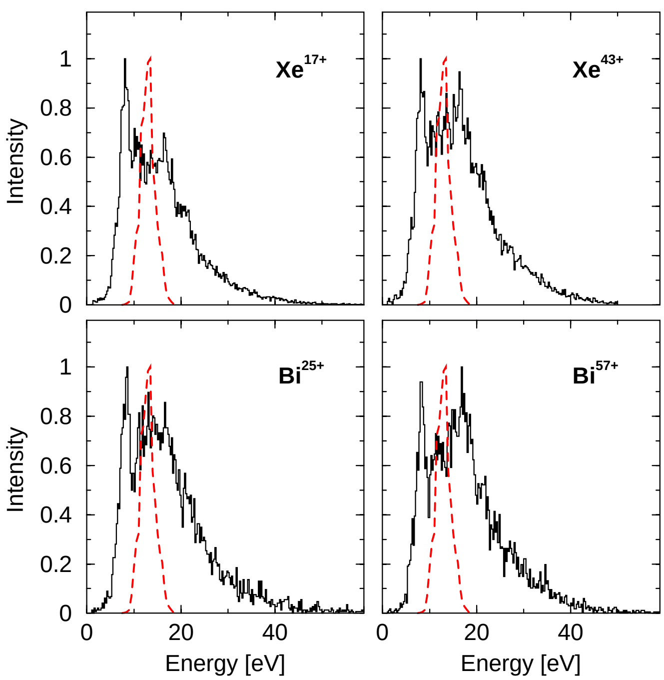

Figure 1: Kinetic energy release of coincident N^++N^+ fragments in collisions with 4.7 MeV/u Bi^{q+} and 5.9 MeV/u Xe^{q+}. The dashed line is the prediction of the Coulomb explosion model.

In the studied collision systems we observed "Coulomb-explosion" processes $N_2 \longrightarrow N^{q+} + N^{p+}$ with a total charge $p+q$ upto 12. For most of these reaction channels spectra of the kinetic energy release (KER) can be derived. With the exception of the N^++N^+-spectrum all measured spectra have a simple shape with one maximum. Fig. 1 shows the KER observed in N^++N^+ fragmentation. Although the dependence on the projectile type is less striking than observed in collisions with H^+,He^+, and Ar^{q+} at projectile energies of 100–300 kV·q [3] the spectra significantly vary with projectile charge and velocity. As was shown in previous work [2, 4, 5] this behavior clearly indicates that a simple Coulomb-explosion model is in general insufficient to describe the experimental data and that individual states of the intermediate molecular ion must be taken into account. Whereas for $q > 2$ all potential curves of the $(N_2)^{q+}$ system are of similar (repulsive) shape the $(N_2)^{2+}$ states have different shapes: in particular several (meta-)stable states exist here. For higher ionized fragment ions these molecular effects are less important and the KER distributions are practically independent of the projectile charge and velocity. However, the existence of an increasing number of excited states results in a measured width much larger than predicted by the CE model.

Another interesting feature occurs for ion pairs which correspond to different dissociation channels of the same intermediate molecular ion. As an example Fig. 2 shows the KER spectra observed for N^{2+}+N^{2+} and N^++N^{3+} ion pairs which are practically identical. Apparently the final charge state is not always fixed during the collision. A possible explanation of this behavior is the existence of crossings between potential curves corresponding to different asymptotic charge states at large distances where the KER is already nearly determined.

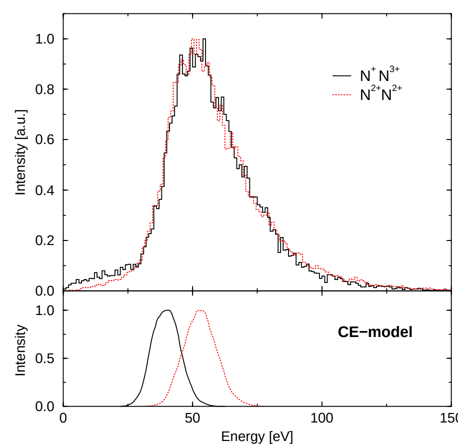

Figure 2: Kinetic energy release of coincident N^++N^{3+} and N^{2+}+N^{2+} fragments in collisions with 5.9 MeV/u Xe^{43+}. The lower diagram shows the predictions of the Coulomb explosion (CE) model.

References

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