Ionization and fragmentation of small molecules in collisions with Xe^{43+} and Xe^{17+} at 5.9 MeV/u

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We studied the multiple ionization and fragmentation of N_2 and H_2O in collisions with 5.9 MeV/u Xe^{17+} and Xe^{43+} using a position- and time-sensitive multi-particle detector which allows the coincident measurement of the momenta of correlated fragment ions. Of special interest are the "Coulomb-explosion" processes $N_2 \longrightarrow N^{q+} + N^{p+}$ and $H_2O \rightarrow O^{q+} + 2H^+$: if all fragments from a particular break-up process are detected information about the fragmentation dynamics as well as the structure of the intermediate molecular ion can be derived. In contrast to the fragmentation $H_2 \rightarrow H^+ + H^+$ which is well described by a point charge Coulomb-explosion (CE) model [1], in case of N_2 and H_2O this model is insufficient to explain the measured kinetic energy release which shows a distinct dependence on the projectile type and energy [2–4]. In case of N_2 the number of contributing states is quite large and a convincing analysis seems possible only in cases where few states are accessible. This condition is often approached at higher ionization degrees which can be effectively reached in collisions with highly charged ions [5].

Collimated beams of 5.9 MeV/u Xe^{17+} and Xe^{43+}-ions provided by UNILAC interact with a N_2 and H_2O gas target, respectively. 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, 6].

In collisions with highly charged ions processes leading to correlated $N^{q+} + N^{p+}$ fragment ion pairs with a total charge up to 12 are observed. With the current resolution most channels with $p + q \leq 8$ may be clearly separated, so that individual spectra of e.g. the kinetic energy release can be derived. Fig. 1 shows the dissociation energy of correlated $N^+ + N^+$ and $N^{2+} + N^{2+}$ fragments in comparison with the prediction of the Coulomb-explosion model. In particular the $N^+ + N^+$ channel shows a characteristic structure which is inconsistent with the CE-model. Even at higher degrees of ionization the measured kinetic energy spectra are considerably broader than expected by the CE-model. Apart from the charge state distribution this finding is consistent with the results of our previous work on collisions with 4.7 MeV/u Bi^{57+} [7].

The coincidence plot in fig. 2 gives an overview on the two-particle events detected in collisions of 5.9 MeV/u Xe^{17} with H_2O. Among the various observed reaction channels only the "Coulomb-explosions" $H^+ + OH^+$ and $H^+ + H^+ + O^{q+}$ fulfill the conditions for a kinematically complete description of the fragmentation process. In collisions with highly charged Xe-ions processes with at least $q \leq 6$ are observed. For these reaction channels the kinetic energy release as well as angular correlations may be derived [2]; the data analysis is not yet completed.

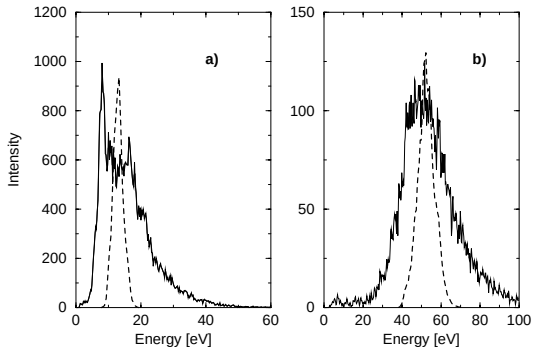

Figure 1: Total kinetic energy of coincident fragments in collisions with 5.9 MeV/u Xe^{17+}. a: $N^+ + N^+$ b: $N^{2+} + N^{2+}$. The dashed lines are the predictions of the Coulomb explosion model.

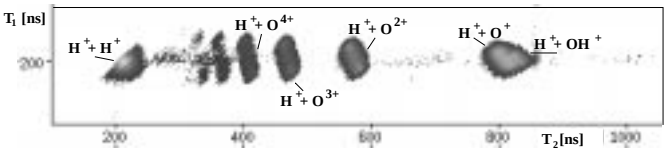

Figure 2: Coincidence map of correlated positive fragment-ion pairs from collisions of 5.9 MeV/u Xe^{43+} on H_2O. T_1 and T_2 are the flight times of the first and second fragments, respectively.

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