Influence of nuclear interaction on atomic ionization during ion-atom collisions

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Synopsis The influence of nuclear interaction on charge changing processes during the swift heavy ion-atom collisions has been studied. The emitted projectile ion characteristic x-rays have been measured as a function of the closest approach. Interestingly, it has been observed that the variation of the x-ray energies exhibits an unexpected enhancement near the nucleus-nucleus touching distance. The sudden increment in the projectile ionization can be explained by the subsequent contribution from the shaking processes occurring due to the sudden Coulomb interaction at nucleus-nucleus distances close to the touching distance.

The large differences in the interaction range and the coupling constant for the electromagnetic and the strong force suggests independent treatment of atomic and nuclear phenomena. However, the borderline between atomic and nuclear physics i.e. Coulomb barrier region provides an exciting playground for many fundamental nuclear and atomic processes influencing each other [1]. In the present work, we have studied the nuclear influence on the charge changing processes using the x-ray spectroscopy [2]. The emitted projectile characteristic x-rays which directly corresponds to the projectile ionization, have been measured as a function of the beam energies around the nucleus-nucleus interaction regime i.e. Coulomb barrier. Interestingly, the variation of the K_α and K_β x-ray centroid energies with respect to closest approach exhibits an unexpected enhancement near the touching distance i.e. the sum of radii of the corresponding nuclei, which can be seen more precisely in derivative spectra, as shown in the figure. The sudden increment in the x-ray energy may be explained by the sudden perturbation because of swift Coulomb interaction at nucleus-nucleus distances for very short duration, compared to the orbital motion of the electrons [3]. The suddenness of the perturbation subsequently results in the initiation of the shaking processes [1, 2]. It consequently contributes in the gradual Coulomb ionization and enhances the projectile ionization near the Coulomb barrier. Similar behavior is observed in the measured projectile equilibrium mean charge state also. Further, it has been noted that the sudden enhancement due to the nucleus-nucleus interactions occurs slightly below from the theoretical predictions. It clearly indicates the coupling of elastic channels with the nucleus-nucleus interaction channels at the sub-barrier energies. The present findings have been validated with three different asymmetric collision systems, viz. ^{12}C(^{56}Fe,^{56}Fe), ^{12}C(^{58}Ni,^{58}Ni) and ^{12}C(^{63}Cu,^{63}Cu).

The work suggests modifications in the theoretical atomic predictions by incorporating the influence of the nuclear effects during the heavy ion induced collisions around the nucleus-nucleus interaction regime. The present study may open up new directions for interdisciplinary research comprising of atomic and nuclear physics.

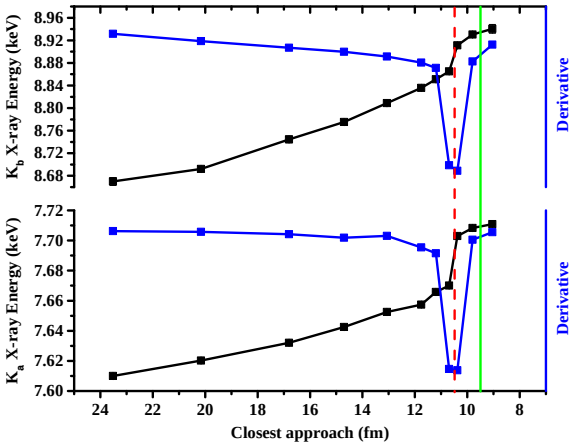

Figure 1. The projectile K_α and K_β x-ray energies versus beam energies in lab frame for ^{58}Ni on ^{12}C. Error bars are tiny and within the symbol size. All solid lines are to guide eye only. The straight and dash-vertical lines represent the touching distance and the distance where sudden ionization observed, respectively.

References

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