4 - 7 Progress of Atomic & Molecular Spectroscopy Group in 2022

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In 2022, the Atomic & Molecular Spectroscopy Group made progresses on angular distribution of the Lyman-α_1 transition of Xe^{53+*} ions following nonradiative electron capture, double K-shell ionization of Ar by 197-MeV/u Xe^{54+} ions, K-X-ray measurements of low-energy O^{q+} (q=3, 5, 6) and N^{q+} ($q = 3$, 5) ions at nickel surface, the theory of momentum computed tomography (MCT), crystal spectrometer for LEAF facility, beam pulse position and time structure monitor for fast extraction mode of HIRFL-CSR, and carried out two rounds of experiments at HIRFL-CSRm.

We measured the angular distribution of the subsequently emitted Lyman-α_1 transition of Xe^{53+*} ions following nonradiative electron capture in collisions of 197 MeV/u Xe^{54+} projectiles with gaseous krypton target. The alignment of the projectile $2p3/2$ state and the relative population of its magnetic substates were further deduced. In contrast to the available lower energy results (Yang, *et al*, Phys. Rev. A, 102(2020)042803), it is found that at 197 MeV/u the Lyman-α_1 radiation becomes much less anisotropic and the magnetic substates are nearly statistically populated. When compared with the results of the REC mechanism, a remarkably different energy-dependence of the magnetic-substate population is found. The present findings might be used to reveal further formation mechanism of excited ionic substates in fast collisions of high-Z ions with heavy targets.

We experimentally studied the double K-shell ionization of argon in single collisions by Xe^{54+} ions at 197 MeV/u. The target K X-ray satellite and hyper-satellite lines were analyzed with a fitting model and the cross-section ratio of double to single K-shell ionization is derived. The experimental cross-section ratio shows a reasonable agreement with the calculated value from the relativistic time-dependent two-center theory. However, the mean number of the spectator L-vacancies extracted from the experiments is a number that is nearly one less than that of the theory.

We established an experimental platform for X-ray measurements and measured the X-ray emission spectra by1.5∼20 keV/q O^{q+} (q = 3, 5, 6) and N^{q+} (q = 3, 5) ions with nickel surface. It is discovered that the measured X-ray yield and production cross section increase rapidly as increasing the impact energy, but have no discernible dependence on the charge state of incident ions. The experimental results reveal that the incident ions have been neutralized and achieved charge state equilibration before the K-shell electron is ionized. The experimental ionization cross sections clearly deviate from the binary-encounter approximation calculations when the impact energy is less than 5 keV/q. The discrepancy at the low collision energy is discussed and explained based on a multi-electron excitation model.

We lay down the theory of momentum computed tomography (MCT), developed a wide-band, high-resolution vacuum flat crystal spectrometer for LEAF facility, and realized a beam pulse position and time structure monitor for fast extraction mode of HIRFL-CSR.

In addition, we carried out two rounds of experiments at HIRFL-CSRm with 150 MeV/u $^{209}Bi^{36+}$ ions in April and 460 MeV/u $^{78}Kr^{26+}$ in November. The magnetic oscillations in solid targets following bombardments of these energetic heavy-ion pulses in a magnetic field have been measured.

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