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Quasi-equilibrium in charge state evolution for swift heavy ions after passing through carbon foils

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Non-equilibrium and equilibrium charge state distributions for 2.0 MeV/u Sq+ (q = 6–16) and Cq+ (q = 2–6) ions after penetrating carbon foils have been investigated experimentally. Those wide ranges of the initial charge states have proved that charge state distributions, mean charge states, and distribution widths for projectile ions without K-shell holes, Sq+ (q = 6–14) and Cq+ (q = 2–4), once coincided at a target thickness of 6.9 and 5.7 micro-g/cm2, respectively, showing a “quasi-equilibrium”, and simultaneously evolved to establish a real equilibrium when the foil thickness was increased further. Those for projectile ions with K-shell hole(s), S15, 16+ and C5, 6+, evolved differently and directly to the real equilibrium, established at a target thickness of around 100 micro-g/cm2 or greater for S ions and at over 10 micro-g/cm2 for C ions. The quasi- and real-equilibrium mean charge states for 2.0 MeV/u S ions were 12.3 and 12.68, respectively, whereas those for 2.0 MeV/u C ions were 5.48 and 5.57. Simulations using ETACHA code and solution of simpler rate equations showed that the quasi-equilibrium was brought by a difference between the reaction-rates for K- and L-shell processes.

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