Long-lived super-heavy elements evidenced through direct fission time measurements in Uranium induced reactions at moderate excitation energy.


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Even if experimental evidence of fusion processes for very heavy systems is washed out by the increasingly dominant contribution of quasi-fission, the two mechanisms may be disentangled as quite different time distributions are predicted for each of them. Taking advantage of the sensitivity of the blocking technique to long lifetime components \((\geq 10^{-18} \text{ s})\) that can exist only after fusion process, lifetime measurements have been undertaken at GANIL to look for evidence for compound nucleus formation, even with very weak cross-sections.

The blocking patterns in the target single crystal were measured at 11° (for projectile elastic scattering) and 20° (for fission-like events) by 3 specially designed telescopes providing us with the atomic number, energy and emission angle (with a resolution better than 0.02°) of heavy fragments \((Z \geq 6)\). All the other charged reaction products were detected on a solid angle close to \(4\pi\) by INDRA [1], allowing thus a control on the mechanisms involved. Different types of processes have been selected: elastic scattering products, deep inelastic partners, uranium projectile fission fragments and fragments arising from the fission of SHE nuclei produced either by quasi-fission or fusion-fission mechanisms.

The \(^{238}\text{U} + \text{Ni}\) reaction at 6.62 MeV/u has been studied in a first experiment [2] in which SHE \(Z=120\) is formed at 80 MeV excitation energy. The blocking patterns associated with elastic scattering events indicate, as expected, very short interaction times. In contrast, the sequential fission of weakly excited uranium-like nuclei is associated with very long lifetimes, in agreement with previous measurements [3]. The fission fragments from \(Z=120\) composite exhibit a blocking behavior intermediate between the elastic products and the sequential fission one. Furthermore these SHE fission fragments arise from pure binary reactions in which only light charged particles, with a multiplicity of less than 0.10, are emitted. The blocking pattern associated with these events cannot therefore result from any sequential emission and appears to be compatible only with \(Z=120\) compound nucleus formation. In addition, their angular distributions in the center of mass frame exhibit forward and backward emission components with similar cross-sections. Within our experimental errors the angular distributions are compatible with at most 20% of non-equilibrium quasi-fission events. From these data, a minimum fusion cross-section of 22 mb can be inferred.

Very recently the same experimental setup has been used to study \(^{238}\text{U} + \text{Ge}\) and \(^{208}\text{Pb} + \text{Ge}\) reactions in which elements of \(Z=124\) and 114 respectively are formed at the same excitation energy, to bring more experimental information on the stability of SHEs in this region as a function of neutron and proton numbers.

References
