COMPOUND NUCLEUS FORMATION CROSS SECTIONS IN LEAD-INDUCED REACTIONS

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The capture barrier between colliding heavy ions is formed by the Coulomb repulsion potential, nuclear attraction potential, and the centrifugal potential at distances slightly larger than the contact distance of interacting nuclei. The compound nucleus is easily formed after penetration of the capture barrier in reactions with light or medium-weight heavy ions at over-barrier collisional energies. In contrast, the formation of compound nuclei in reactions with both heavy-weight nuclei or with medium and very heavy-weight nuclei is suppressed. The suppression of the formation of compound nuclei is strong for reactions used for the synthesis of superheavy nuclei, which have small formation cross-section values.

The model for the calculation of the compound-nucleus formation cross section in heavy ion collisions is discussed here. In the framework of this model, the compound nucleus is formed within two steps. The first step is related to the penetration through the capture barrier. After passing the capture barrier, the densities of colliding ions start to overlap. Due to the dissipation induced by the density overlapping, the radial velocity of ions is quickly decreased, and the ions stop in the capture well. Therefore, the second step is considered statistically. The compound nucleus formation from the sticking nuclei in competition with the quasi-elastic scattering occurs in the second step. The ions can escape from the capture well by passing through either the quasi-elastic barrier and forming scattered ions or the compound nucleus formation barrier and fusing into the compound nucleus.

The quasi-elastic barrier is the barrier that separates the ions in the capture well from the scattered ions. The relative velocities of heavy ions are small during the passage of the quasi-elastic barrier. The height of this barrier is lower than that of the capture barrier because the shapes of ions on the quasi-elastic barrier are strongly deformed. In contrast, the shapes of ions in the capture barrier are close to the equilibrium one due to the high radial velocity of approaching nuclei at over-barrier collision energies. The shapes of ions cannot be strongly changed at fast-approaching nuclei. The compound nucleus formation barrier is the barrier that separates the ions in the capture well and the compound nucleus in an equilibrium shape. This barrier is higher than the fission barrier.

The available experimental data of the compound nucleus formation cross sections in the collisions of ^{208}Pb + ^{24,26}Mg, ^{27}Al, ^{28}Si, ^{32,36,38}S, ^{40}Ar, ^{40,48}Ca, ^{50}Ti, ^{52}Cr, ^{58}Fe, and ^{64}Ni are well described in the model.

It is shown that the heights of compound nucleus formation and quasi-elastic barriers define the probability of compound nucleus formation in the second stage of the reaction. The compound nucleus is preferably formed when the height of the compound nucleus formation barrier is substantially smaller than the height of the quasi-elastic barrier. This takes place for reactions between ^{208}Pb + ^{24,26}Mg, ^{27}Al, ^{28}Si, ^{32,36,38}S, ^{40}Ar, and ^{40}Ca. In this case, the values of the capture and compound nucleus formation cross-sections are the same. In contrast, the height of the compound nucleus formation barrier is larger than the height of the quasi-elastic barrier for reactions ^{208}Pb + ^{48}Ca, ^{50}Ti, ^{52}Cr, ^{58}Fe, and ^{64}Ni. Due to this, the formation of the compound nucleus is suppressed by the competition to the quasi-elastic decay branch of the sticking nuclei. This leads to the values of the capture cross-section being much higher than the compound nucleus formation cross-section. The suppression of the compound nucleus formation increases with the mass and charge of ions colliding with lead because the values of the compound nucleus barrier rise faster than the values of the quasi-elastic barrier. The increase in the height of the compound nucleus barrier is strongly related to the fusion reaction Q-value. The value $-Q$ increases well with the mass and charge of ions colliding with lead.

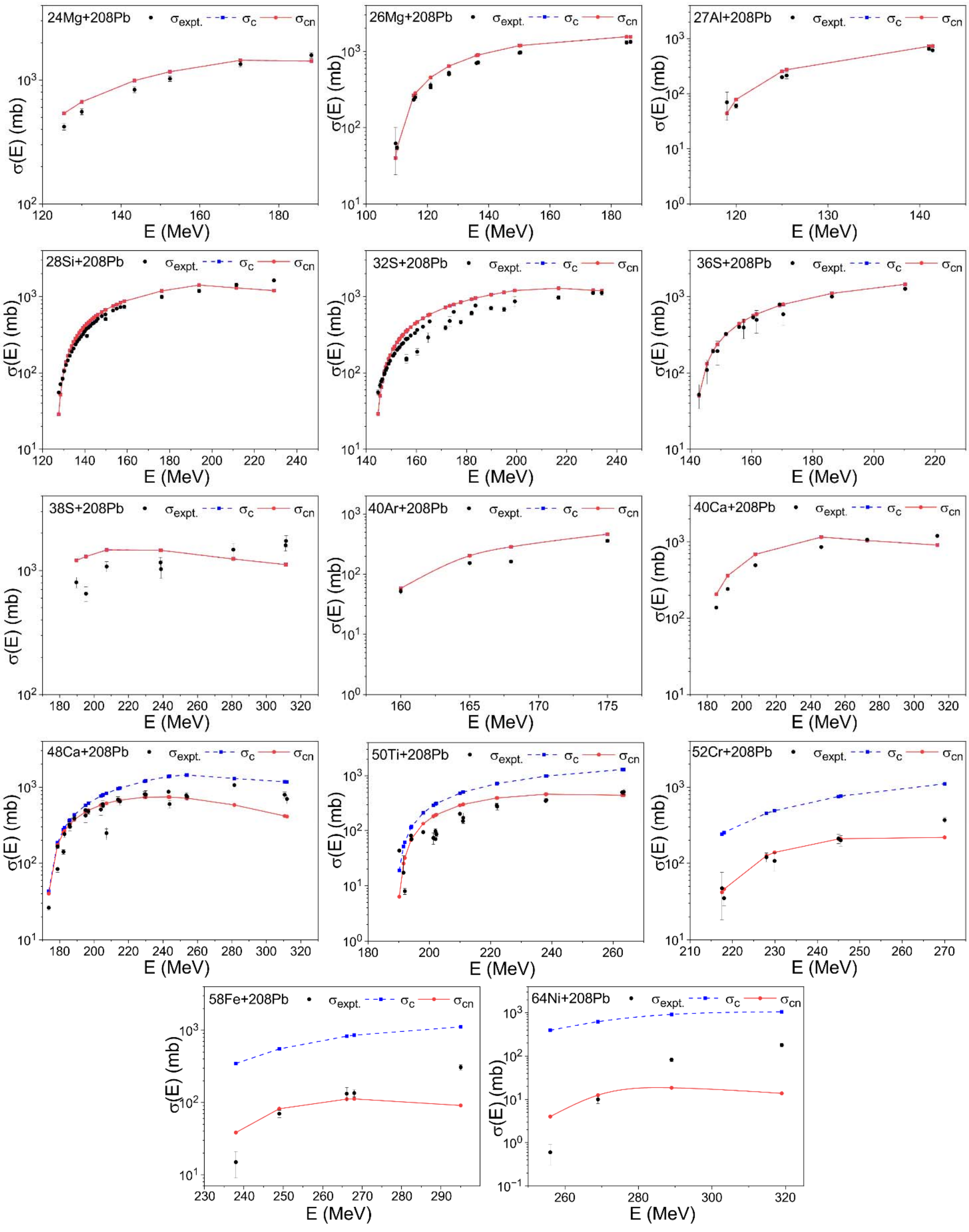

Fig. 1. The model energy dependencies of capture cross sections $\sigma_c(E)$ and compound nucleus formation cross sections $\sigma_{cn}(E)$ are compared with the available experimental data for compound nucleus formation cross sections $\sigma_{exp}(E)$ in the reactions ^{208}Pb + ^{24,26}Mg, ^{27}Al, ^{28}Si, ^{32,36,38}S, ^{40}Ar, ^{40,48}Ca, ^{50}Ti, ^{52}Cr, ^{58}Fe, and ^{64}Ni [1].

1. V.Yu. Denisov. Phys. Rev. C 111 (2025) 024601.