Can superheavy elements be formed in the r-process?

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With the advent of up-to-date nuclear data and more accurate fission rates for actinium series [1], it becomes possible to consider the opportunity of nucleosynthesis prolongation and the formation of superheavy elements in the r-process (if neutron flow is sufficiently high).

We determine the r-process yields in the neutron star merger model [2], depending on calculation of the exploded matter composition. In this model, the r-process under high neutron density environment ($Y_e \approx 0.1$) and big neutron-to-seed ratio (about few hundred neutrons by one seed nucleus) leads to a fast conversion of seed nuclei to actinium area, to fission via neutron-induced fission and recycling fission products as new seed nuclei.

The decay of newly formed isotopes near the region of superheavy elements goes on usually via α-decay, that gives an additional evidence in favor of high values of fission barriers of nuclei with neutron numbers close to 184. Only mass predictions on the basis of the ETFSi mass model [3] lead to high barriers and, as a result, to small fission rates for the isotopes from this region. Experimental data on decay modes [4] confirm the rates calculated on the basis of the ETFSi mass predictions.

The present calculations of nucleosynthesis show, that a nucleosynthesis wave, driven by the r-process, goes though the region of nuclei with $180 < N$ and $N < 188$, where the fission rates are small; then some superheavy nuclei can be formed.

With the utilization of ETFSi mass and fission barrier predictions in the r-process model, superheavy elements (SHE) can be formed. Their yields strongly depend on a scenario and nuclear data predictions as well. A preliminary value of Y(SHE)/Y(U) at the end of the r-process is $\sim 10^{-14}$ (with the uncertainty of 1-2 orders of magnitude). For more accurate results, the fission rate calculations should be performed also for Z>110 region.

References

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