Synthesis of superheavy nuclei: A search for new production reactions

- “Cold” fusion reactions
- “Hot” fusion reactions (beyond $^{48}\text{Ca}$)
- Fusion of accelerated fission fragments
- Radioactive ion beams
- Summary

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Synthesis of superheavy elements (cold and hot fusion)

Cold synthesis:
$^{208}\text{Pb} + ^{41}\text{Ni}, ^{70}\text{Zn}, \ldots \rightarrow ^{278}110, ^{278}112, \ldots$

Hot synthesis:
$^{238}\text{U}, \ldots, ^{249}\text{Cf} + ^{48}\text{Ca} \rightarrow ^{286}112, \ldots, ^{297}118$
We are still far from the line of stability

Shift by 8 neutrons increases half-life by 5 orders of magnitude
“Cold” synthesis of SHE

\[ \sigma_{\text{ER}}^{Xn}(E) = \frac{\pi}{k^2} \sum_{l=0}^{\infty} (2l+1) \cdot P_{\text{cont}}(E,l) \cdot P_{\text{CN}}(l^*,l) \cdot P_{\text{sn}}(E^*,l) \]

\[ P_{\text{CN}}(E^*,l) = \frac{P_{0}}{1 + \exp \left[ \frac{E_{\text{B}} - E_{\text{int}}(l)}{\Delta} \right]} \]

- Graph showing cross section versus energy for different elements.
- Equation for reaction cross section.
- Probability expression for CN formation.
“Cold” and “Hot” synthesis of SHE

\[ \sigma_{\text{cap}}(E^* = 35 \text{ MeV}) \]

\[ \sigma_{\text{CN}}(E^* = 35 \text{ MeV}) \]

\[ \sigma_{\text{CN}}(E^* = 15 \text{ MeV}) \]

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Beyond $^{48}$Ca: How much $^{50}$Ti is worse?

\[ \frac{\sigma^{(48 \text{Ca})}}{\sigma^{(50 \text{Ti})}} \times \text{two orders of magnitude} \]

\begin{tabular}{c|c|c|c|c}
Isotope & $B_{LD}$ & $\delta W$ & $B_f$ & $E_n$ \\ 
$^{256}102$ & 1.26 & 4.48 & 5.7 & 7.1 \\ 
$^{256}104$ & 0.77 & 4.49 & 5.3 & 7.8 \\ 
\end{tabular}
Beyond $^{48}\text{Ca}$: $^{50}\text{Ti}$ - induced fusion reactions
Fusion of “fission fragments”: $^{136}\text{Xe} + ^{136}\text{Xe} \rightarrow ^{272}\text{Hs}$

if OK then $^{132}\text{Sn} + ^{176}\text{Yb} \rightarrow ^{308}\text{Hs}$

Accelerated fission fragments hardly may be used for production of SH nuclei
Radioactive Ion Beams
for the production of neutron rich superheavy nuclei
Transfer reactions in damped collision of very heavy nuclei?
Production of SHE along the stability line in low-energy collisions of actinide nuclei
$^{238}\text{U} + ^{248}\text{Cm}$, $E_{\text{c.m.}} = 780$ MeV
primary fragments
Production of neutron-rich SHE in low-energy collisions of heavy actinide nuclei
• Resources of the cold synthesis (with Pb and Bi targets) seems to be exhausted.

• The production of SH elements in fusion reactions with accelerated fission fragments does not look very encouraging. Only if an extremely high beam intensity were to be attained would the chances increase.

• The use of light and medium-mass neutron-rich radioactive beams may help us to obtain and explore SH neutron-rich nuclei in the region of 102<Z<112.

• In the hot fusion reactions of $^{50}\text{Ti}$ and $^{54}\text{Cr}$ with actinide targets the SH elements $Z=120-122$ might be synthesized with the cross sections of 10-50 fb

• SH neutron-rich nuclei close to the island of stability can be produced in low-energy damped collisions of actinide nuclei ($\text{U} + \text{Cm}$).

• Low-energy multi-nucleon transfer reactions allow us to fill and explore also the “blank spot” at the north-east part of the nuclear map (important for astrophysics investigations)