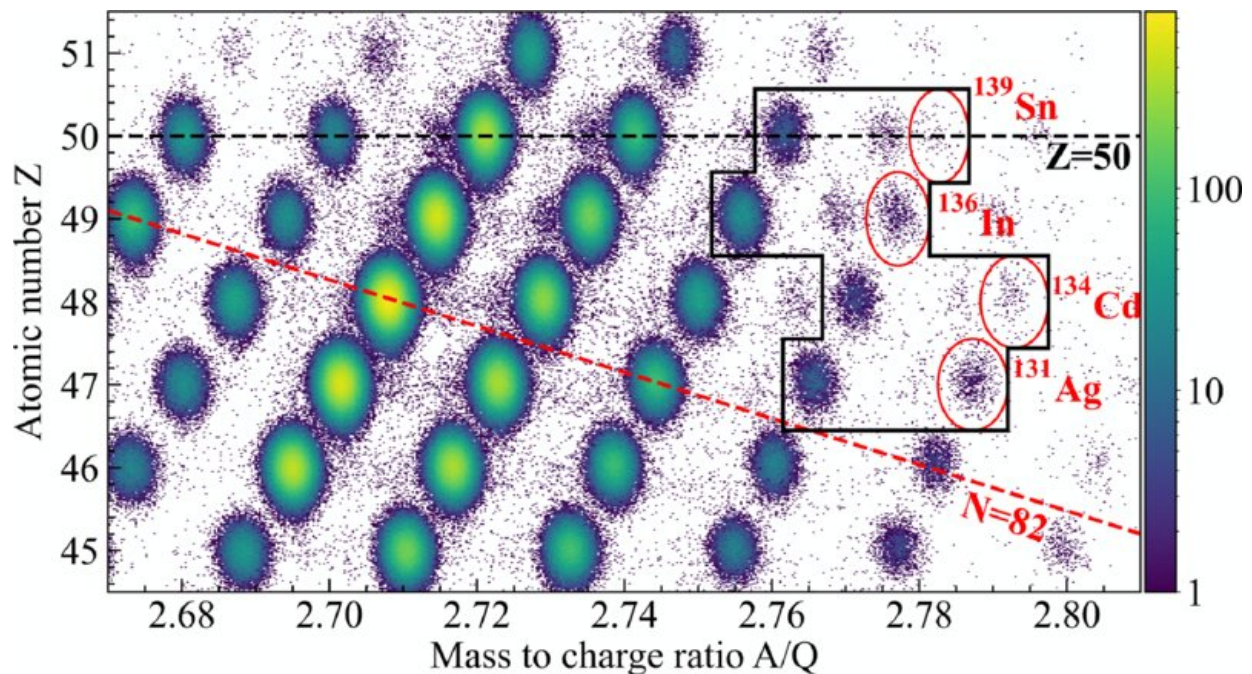


Neutron-rich nuclei reveal how heavy elements form

March 10 2023



Particle identification plot of ions implanted in AIDA. The black contour highlights the isotopes with P_n measured for the first time in this Letter. The heaviest isotope reported in this Letter is labeled for each element. Credit: *Physical Review Letters* (2022). DOI: 10.1103/PhysRevLett.129.172701

Models for how heavy elements are produced within stars have become more accurate thanks to measurements by RIKEN nuclear physicists of the probabilities that 20 neutron-rich nuclei will shed neutrons.

Stars generate energy by fusing the [nuclei](#) of light elements—first hydrogen nuclei and then progressively heavier nuclei, as the hydrogen and other lighter elements are sequentially consumed. But this process can only produce the first 26 elements up to iron.

Another process, known as rapid neutron capture, is thought to produce nuclei that are heavier than iron. As its name suggests, this process involves nuclei becoming larger by rapidly snatching up stray neutrons. It requires extremely high densities of neutrons and is thus thought to occur mainly during events such as mergers of neutron [stars](#) and supernova explosions.

The neutron-rich elements produced by rapid neutron capture can lose neutrons through another process known as beta-delayed neutron emission.

Ultimately, astrophysicists dream of developing models that can accurately reproduce the natural abundances of the elements in the Universe. To achieve this goal, they need to combine astrophysical observations with measurements on nuclei in the lab.

Now, Shunji Nishimura of the RIKEN Nishina Center for Accelerator-Based Science and his co-workers have measured the possibilities that 20 neutron-rich nuclei will emit one or two neutrons.



An illustration depicting two neutron stars merging. Such collisions are believed to be responsible for generating heavy elements by a process known as rapid neutron capture. Measurements by RIKEN researchers on neutron-rich nuclei have helped tighten models of element production by this process. Credit: National Science Foundation/Ligo/Sonoma State University/A. Simonnet/Science Photo Library

Using the RIKEN Radioactive Isotope Beam Factory—one of only a handful of facilities in the world capable of performing such measurements—the team accelerated large uranium nuclei to about 70%

of the speed of light and smashed them into beryllium, which produced unstable nuclei by a fission reaction. They then measured the probabilities of neutron emission when these unstable nuclei decayed.

When the results were put into models that predict the abundances of the elements, they improved their agreement with the abundances observed in the solar system.

These measurements are important for tightening up theoretical models of element production, removing nearly 30% of their inherent uncertainty.

"While we still have a long way to go before we can determine the natural abundances of the elements, our [measurements](#) have helped close in on the fine structure in the region of elements near tin, which is determined by the so-called freeze-out time of rapid neutron capture," explains Nishimura. "So we're very close to having a good understanding of this part of the nuclei chart."

The research is published in the journal *Physical Review Letters*.

The team now intends to investigate the impact of about 200 delayed [neutrons](#) on the production of elements up to bismuth by rapid neutron capture.

More information: V. H. Phong et al, β -Delayed One and Two Neutron Emission Probabilities Southeast of Sn132 and the Odd-Even Systematics in r-Process Nuclide Abundances, *Physical Review Letters* (2022). [DOI: 10.1103/PhysRevLett.129.172701](https://doi.org/10.1103/PhysRevLett.129.172701)

Provided by RIKEN

Citation: Neutron-rich nuclei reveal how heavy elements form (2023, March 10) retrieved 2 May 2024 from <https://phys.org/news/2023-03-neutron-rich-nuclei-reveal-heavy-elements.html>

This document is subject to copyright. Apart from any fair dealing for the purpose of private study or research, no part may be reproduced without the written permission. The content is provided for information purposes only.