Alchemy for beginners

To turn base metals into gold, first boil your nuclei

THE atomic nucleus behaves so much like a drop of liquid, it can actually boil, say physicists who have measured the properties of nuclear "vapour" for the first time. Their discovery is helping to explain how heavy elements such as gold, lead and uranium are made inside supernovae.

Strong nuclear forces hold protons and neutrons together in nuclei in much the same way that electromagnetic forces bind the molecules in a droplet of water. In nuclear reactions the minuscule "droplet" can spin, bulge or split, but until now no one had found a way to discover whether it can boil. "You can't stick a thermometer in the nucleus," James Elliott at Lawrence Berkeley National Laboratory in California points out.

Now Vic Viola of Indiana University in Bloomington and his colleagues have cracked the problem. At Brookhaven National Laboratory in New York, they accelerated particles called pions to 99.9 per cent of the speed of light and smashed them into gold nuclei. By looking at the size of the nuclear blobs that were thrown out, they were able to measure the nuclei's transition from liquid to vapour.

PURE AND SIMPLE: atomic nuclei vaporise and condense just like drops of water

As the energy of the pions increased, so did the size of the blobs. But eventually they stopped getting bigger—showing that the additional energy was being used to change the state of the nuclei from liquid to gas. And when the researchers cranked up the energy even further, the chunks suddenly got smaller. This indicates that all the nuclei have been vaporised, says Viola. "If you vaporise a drop of water and look at the gas coming off, you see small clusters of just two or three molecules," he says.

When researchers at Lawrence Berkeley and Michigan State University used Viola's data to calculate the boiling points of different nuclei, they found they are typically billions of times greater than those of atoms, around 100 billion degrees kelvin. And when they measured the density of the nuclear vapour, its pressure was proportional to its temperature, just as in an ordinary gas.

This new understanding of nuclear matter is already helping other researchers to model supernovae—exploding stars that generate heavy elements such as gold from nuclei no heavier than iron. No one fully understands how the nuclei capture the extra neutrons to form heavy elements, but Chikako Ishizuka and colleagues at Hokkaido University in Sapporo, Japan, say that when nuclei boil, it's easier for them to incorporate extra neutrons. Then they can condense into heavy elements as they cool.

Viola says knowing how nuclei change from one state to another is crucial to understanding a range of processes. "Now we can describe nuclear physics under any conditions," he says. **Eugenie Samuel**

More at: *Physical Review Letters* (vol 88, p 022701)