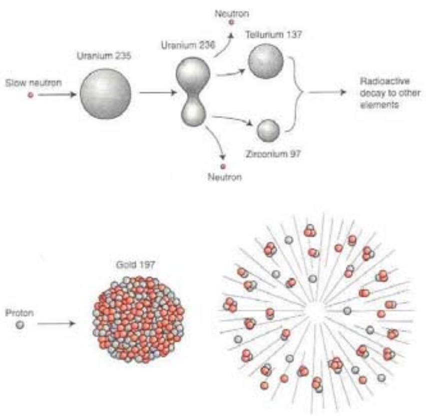
HIGH-ENERGY PHYSICS

Atom Smasher Probes Realm of Nuclear 'Gas'

"Oh, that this too too liquid nucleus would evaporate." If Hamlet were a nuclear physicist, he might be feeling a bit more cheerful. Strange as it may seem, atomic nuclei do sometimes act like liquids, and when blasted apart at high enough energies they can sizzle into gas. Now scientists working at Brookhaven National Laboratory in Upton, New York, have charted the conditions under which gold nuclei make that leap, information that might help unravel the secrets behind the birth of a neutron star.



Steamed. Physicists gave liquid-drop model of fission (top) a new twist by "evaporating" gold nuclei (bottom).

ILLUSTRATION: C. SLAYDEN

The work builds on a model that physicists cooked up in the 1930s to explain the fission of uranium. A neutron striking a nucleus more than 200 times its mass doesn't just knock off a chip or two; it splits the nucleus neatly in two. Physicists realized that the uranium nucleus is behaving like an oversized drop of water. When it is struck by a neutron, the nucleus oscillates, stretches out, and then blurps into two roughly equal parts (throwing off a few smaller fragments, such as neutrons, in the process). "Everyday garden-variety nuclei behave like a liquid," says Victor Viola, a physicist at Indiana University, Bloomington. "It's a very successful description."

Viola and colleagues decided to take the liquid analogy one step further by determining the nucleus's equation of state—the relations between pressure and temperature that govern when the nucleus behaves like a gas and when it behaves like a liquid. At Brookhaven, they shot protons, pions, and antiprotons at thin gold foil, adding energy that brought the gold nuclei to a boil. Meanwhile, a device called the Indiana Silicon Sphere (ISiS)—a beach ball–sized sphere studded with 450 detectors —kept careful track of the size and energy of the particles that flew off.

The physicists analyzed the readings in two different ways. The first starts with the distribution of the sizes of chunks that fly out of the nucleus. "In boiling water, you don't get individual water molecules coming off," says Viola. "You get dimers, trimers, tetramers. The temperature of the vapor is related to the relative numbers of those clusters." By comparing the energy added to the nucleus (hence its "temperature") with the relative abundances of fragments, the physicists figured out the properties of the nuclear "liquid," including its critical temperature: the point above which the liquid phase can no longer exist, which they calculate at about 7 million electron volts (MeV). The second analysis directly models the breaking and making of nuclear bonds and comes up with a slightly higher critical temperature, slightly above 8 MeV.

"I do think it's a really nice piece of work they've done," says Joseph Natowitz, a physicist at Texas A&M University in College Station, who thinks that physicists will resolve the discrepancy once they get a better grip on how the nucleus expands and breaks up after the collision. "I have some ideas."

Even though wrinkles need to be ironed out, the results have given physicists a new tool for understanding the "evaporation" of nuclei. They might also shed light on the reverse process, the condensation of nuclei from smaller parts. "It's relevant to what happens in the formation of neutron stars," says Viola. If so, the work is likely to be a hit—a palpable hit.

—CHARLES SEIFE