The Edge of Stability

Nuclear chemists have quit singing the "Is That All There Is?" blues. Although their search for linear accelerator-made superheavies — elements much heavier than those so far known — has uncovered only inconclusive evidence that elements beyond those listed on the periodic table even exist (SN: 4/15/78, p. 236), the superheavy hunters now say, "We're coming out of our depression." The recently reported observation of transfer reactions has given them new hope.

A transfer reaction is the general mechanism for certain reactions between colliding nuclei, reported a group of nuclear chemists at the recent American Chemical Society meeting in Las Vegas, Nev. Darleane C. Hoffman of Los Alamos Scientific Laboratory in Los Alamos, N.M., gives as an example the bombardment of curium 248 by oxygen 18. Because of "conventional nuclear wisdom," researchers expect the projectile (^{18}O) and target (^{248}Cm) nuclei to fuse, forming a compound nucleus with mass number 266. "But the new view," says Hoffman, "is that when ^{18}O comes near ^{248}Cm, it can transfer [for example] 4 protons and 7 neutrons, what amounts to beryllium 11, [to produce fermium 259] and a beryllium 7 goes on." In other words, Hoffman and colleagues have observed that in neutron-rich reactions, the product is not necessarily the mass-number sum of the target and projectile nuclei; rather, reaction products can have mass numbers ranging from that of the target to the mass-number sum of target and projectile, depending on how much of the projectile is "transferred" to the target.

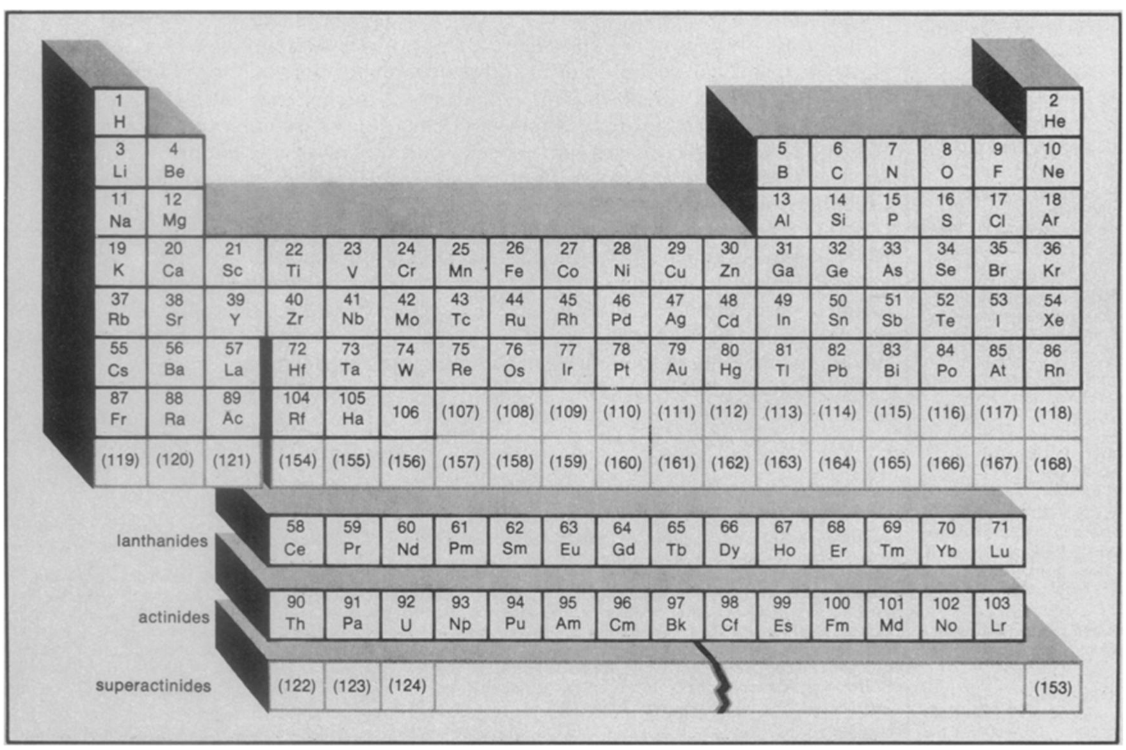
Knowledge of the transfer mechanism may allow the superheavy chasers to sit more comfortably on the "edge of stability" — that almost mystical boundary in the sea of as yet undiscovered superheavies that divides them into extremely short-lived elements that will disappear after a nuclear reaction before they can be detected and ones that are more resistant to radioactive decay. The previous belief that compound-nucleus formation was the only nuclear-reaction mechanism left virtually no hope for generating detectable superheavies.

A compound projectile-target nucleus is much too excited, or unstable, to resist prompt decay. The transfer phenomenon, on the other hand, generates a host of less-excited nuclei by carrying off extra excitation energy in untransferred fragments of the projectile nucleus. Researchers, therefore, must take the transfer phenomenon into account when analyzing products of nuclear reactions; otherwise, new sought-after nuclei could go unnoticed, Hoffman explains.

Because transfer reactions are generating a host of previously unexpected nuclear reaction products, discovery of the phenomenon has cast a shadow of doubt on the validity of claims that Soviet scientists have produced the heaviest known elements — those with atomic numbers 106 and 107. Soviet scientists have assumed that when they bombard a target nucleus with a projectile nucleus, they produce an initial compound projectile-target nucleus. It now is clear, however, that due to the transfer phenomenon, a range of products in addition to the compound nucleus can be generated — "a lot of things to confuse the situation," Hoffman says.

Moreover, the Soviets are basing their claims on the identification of the natural decay (by spontaneous fission) products of the initial, or parent, reaction product. But this method fails as "a unique fingerprint identification" of the parent, says Vic Viola of the University of Maryland at College Park: The spontaneously fissioning parent of decay products could be a transfer nucleus rather than the fused target-projectile nucleus that the Soviets assume they are producing. Nuclear reaction products can be more unambiguously identified on the basis of alpha decay — emission of an alpha particle, which is two protons and two neutrons — says Glenn T. Seaborg of the University of California at Berkeley.

In addition to fueling the 106-107 controversy and renewing hope for the superheavy hunters, the recognition of transfer reactions, says Seaborg, is "fundamental research" that contributes to "our understanding of nuclear structure." It also proves that the field of neutron-rich reactions still is "an exciting frontier," says Hoffman. "There is a lot more to be done." □



The futuristic periodic table shows predicted locations, in parentheses, for elements as heavy as atomic number 168. Although element 106 has been produced in U.S. laboratories, widespread acceptance of its discovery is being reserved until its production can be confirmed by other laboratories using alpha emission as identification.