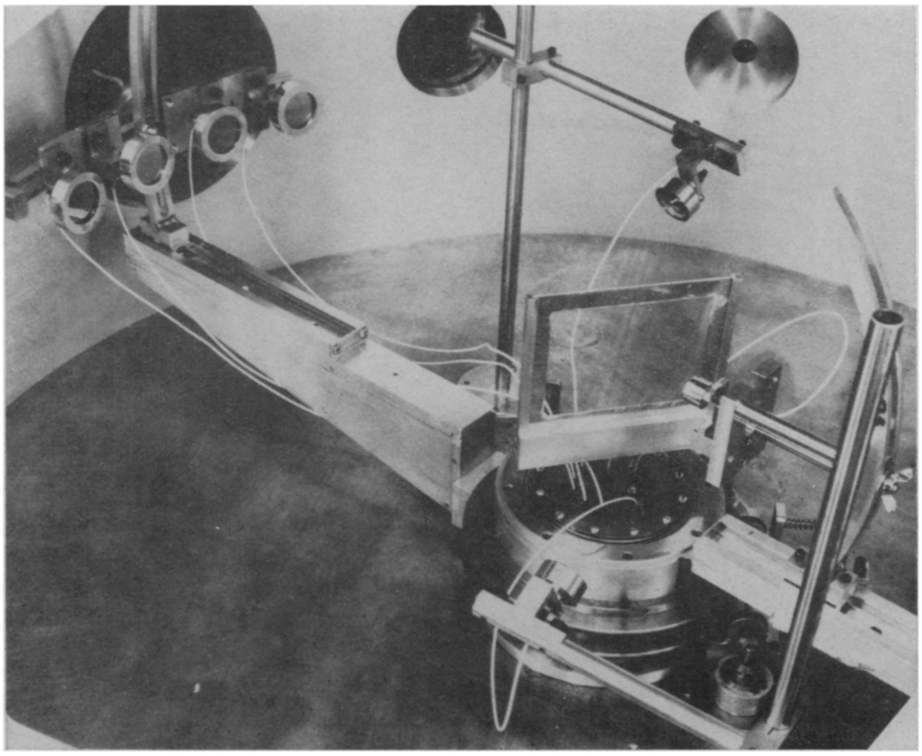
Heavy Atoms and High Energy

Nuclear chemists are surprised by results of accelerator experiments

by Carl Behrens



L. P. Remsberg, Brookhaven

Chemistry at the Cosmotron: nuclear fragments counted by four detectors.

High energy accelerators, usually viewed as tools to create sub-nuclear elementary particles, are also useful in the study of large atomic nuclei.

Much basic research is being carried out in nuclear chemistry, but unanswered questions are being raised by each experiment.

The dynamic state of nuclear chemistry is the main reason for the dismay of many chemists and lower energy physicists over the shutting down of the Brookhaven Cosmotron, which shot its last proton in December.

Dr. Gerhart Friedlander, who received the American Chemistry Society Award for Nuclear Applications in Chemistry this year, says it is "ironic that this area of research should be deemed worthy of an award by the ACS" when the machine on which the work is being done was closed down by the Atomic Energy Commission for financial reasons.

The Cosmotron is the smallest of several accelerators in the billion-electron-volt range where experiments in nuclear chemistry can be done. In all of these machines, such as the Berkeley Bevatron at the University of California and the Zero Gradient Synchrotron at Argonne, Ill., the large share of the experiments are in the field of high energy particle physics.

When the high energy experimenters lost interest in the Cosmotron, which was overshadowed by more powerful machines, the AEC's high energy division decided not to foot the bill. The chemistry section, which had been using from 10 to 15 percent of the machine's time, could not afford the whole cost of operating the accelerator.

Contrary to general belief, nuclear chemists have been working with high energy machines continually. In 1952, when the three-billion-electron-volt Cosmotron was the most powerful atom smasher in existence, Dr. Friedlander analyzed a sample of lead that had been used to tune up the Cosmotron. He found that the 3-Bev beam had done unexpected things to the lead—the elements produced were different from those resulting from exposure to lower energy beams. Experiments carried out on the same machine and others built later continued to show up unexpected results.

The complicated things that happen when an atom is struck by a high energy proton have been divided by nuclear chemists into three basic categories:

- Spallation, or chipping off a few protons or neutrons from the nucleus;
- Fission, or splitting the nucleus into two more-or-less equal pieces;
- Fragmentation, where larger chunks of nuclear particles, containing from 10 to 40 protons and neutrons, are blasted from the target nucleus.

The first two types of reactions are fairly well understood, although the catalogue of fission and spallation products for all the elements at various energies is nowhere near complete.

But fragmentation is another matter. There is no agreement on exactly what happens when larger chunks are broken off. The controversy centers on the amount of time it takes for nuclear reactions to take place.

Fission and spallation are generally considered to take place in two stages. In the first, the incoming proton, with very high energy, thrusts into the nucleus and sets all the nuclear particles into motion, just as a shotgun pellet speeding into a soup plate filled with other pellets would set them in motion. Some particles shoot out of the nucleus immediately—just as some pellets would be driven out of the soup plate.

In the next stage, the energy of any one particle isn't enough to carry it out of the nucleus, but occasionally the motion of two particles will accidently reinforce each other and a single particle will escape.

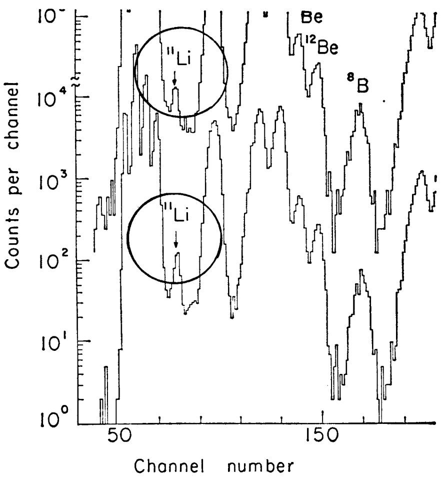
In fragmentation, the two-stage process doesn't seem to fit. To fill the gap it was theorized that local hotspots in the nucleus are created, and larger nuclear fragments spill off from the highly energized sections of the nucleus.

The need for the hotspot concept was challenged at the ACS meeting in Miami Beach, Fla., recently by Dr. J. N. Miller of Columbia University. It is part of the hotspot idea that some of the protons and neutrons have very high energies and the rest low energies. In the two-stage process that is typical of fission and spallation, the energy of the nuclear particles is pretty evenly distributed.

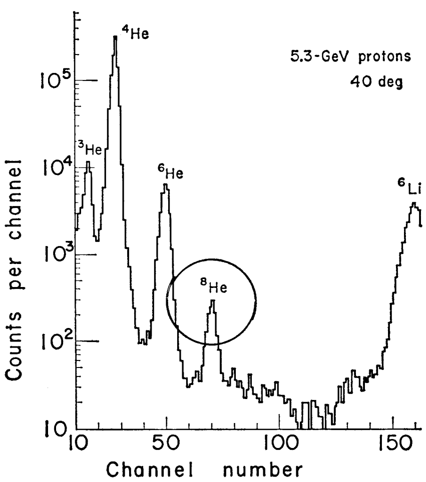
Dr. Miller calculated the amount of time necessary for excited, hotspot particles to distribute their energy to the rest of the nucleus—and he found that little time was required, compared to the two-stage process.

He concludes that the hotspot theory is not necessarily an accurate description of what happens in fragmentation. But what actually does happen is still not known.

Meanwhile, experimentation by nuclear chemists is mostly concerned with trying to identify the products that result from fission or spallation or fragmentation.



Odd elements created: Lithium 11 ...



Lawrence Radiation Lab

... and Helium 8 are unstable.

One series of experiments, reported to the ACS by Dr. L. P. Remsberg of Brookhaven, used uranium and bismuth as targets of the 3-Bev beam of the Cosmotron.

Two sets of detectors, one on each side of the target, picked up the particles blasted loose from the original atoms. One detector was very close to the target, the others farther away.

The detectors measured the energy of the particles that hit them. A timing circuit also measured the interval between hits on the close and far detectors. This gave a measure of the time it took for fragments to travel from the target to the far detectors, so their velocity could be computed. Knowing the energy and the velocity of the far particles, their mass could be computed.

Another series of experiments, carried out by Drs. Earl K. Hyde, Arthur M. Poskanzer, Joseph Cerny and Sammie Cosper at the Lawrence Radiation Laboratory of the University of California, were aimed at identifying the lightweight elements that came from bombarding gold and uranium with the 5.3-Bev protons produced by the Berkeley Bevatron accelerator.

The Hyde detector consisted of a sheet of silicon semi-conductor, four-thousandths of a centimeter thick, backed up by a heavier block of silicon. By measuring how much the particle is slowed down by the thin detector, and how far it went into the thick one, the mass and the charge of the particle can be computed. This tells exactly how many protons and neutrons make up the particle.

Results of these experiments showed that a number of extremely unlikely isotopes are being created—elements with such a disproportionate number of neutrons compared with protons that scientists had figured they would never hold together. Examples of the unstable isotopes detected were helium 8, which has two protons and six neutrons, and lithium 11, which has three protons and eight neutrons.

These experiments were valuable to pick up the smaller particles, but with heavier particles even the very thin first detector is too thick, so the particles never reach the second detector.

Experiments are also being carried out on the Brookhaven 33-Bev Alternating Gradient Synchrotron. Here, says Dr. Friedlander, more unexplained events take place.

In going from 300-Mev to 3-Bev, experimenters had found big differences in the type of fission and spallation products they observed. Now, says Dr. Friedlander, in going from 3-Bev to 33-Bev, similar changes were expected, but they haven't turned up. And everybody is wondering why.

Dr. Miller said a key to the mystery might be the production of pi mesons, elementary particles thought to be a key to the forces that hold the nucleus together. The earlier shift in patterns going up to 3-Bev was explained by supposing that more pi mesons were being created. At 33-Bev, suggested Dr. Miller, the mesons may be created, but they may be knocked out of the nucleus before they can affect the break-up process. But, says Dr. Miller, that may not be what happens at all.