that more than one pain-inhibiting pathway may exist. Mayer, Akil, and Liebeskind found that naloxone blockage of analgesia produced by stimulation in the central gray matter was incomplete. Mayer and R. L. Hayes, who is now at the National Institute for Dental Research, showed that exposing rats to stressful stimuli produces analgesia that is not abolished by naloxone.

The pain response they studied was a spinal reflex that does not require the transmission of the pain signals to the brain. However, cutting the spinal cord prevented the reduction of the response that resulted from stress-induced analgesia. This indicates that the analgesia depends on the integrity of nerves coming down from the brain although apparently not those in the dorsolateral tract. Just cutting the fibers in this tract has the expected effect of diminishing the analgesia evoked by morphine but has no effect on that caused by stress. Finally, Akil and her colleagues have noted that stress evokes an analgesia that is incompletely blocked by the opiate antagonist. The idea of an opiate-independent path is intriguing because it raises the possibility of designing nonaddictive drugs that produce pain relief by activating this pathway.

The experiments with stress bear on a major unanswered question regarding the identity of the normal signals for activating the pain-inhibiting systems. One theory holds that these systems may be turned on only in life-threatening situations. Another is that the systems perform at a low level all the time and are more active in times of stress or danger. If this were the case, naloxone, by blocking at least the opiate-sensitive path, should make the animal more sensitive to pain. The results of experiments designed to test this hypothesis have been mixed. Some investigators have found that the antagonist does make animals hyperreactive whereas others have found no effect. In view of the importance of the clinical goal of designing more effective but nonaddictive analgesic drugs and of the general interest in research on pain inhibition, this question and others regarding the body's built-in system for pain relief will continue to attract much attention.—JEAN L. MARX

# Superheavy Elements: Confirmation Fails to Materialize

Few nuclear scientists now believe that the x-ray spectra reported last summer by a team of investigators from the Oak Ridge National Laboratory (ORNL), the University of California at Davis (UCD), and Florida State University (FSU) constitute evidence for the existence of superheavy elements with atomic numbers near 126. A principal stumbling block to acceptance has been the failure of numerous and widely varied experimental attempts to come up with any confirmatory evidence. Moreover, even without this accumulation of negative results, many scientists feel that the discovery by FSU scientists of an alternative explanation for the x-ray peak regarded as the most convincing indication of superheavy elements made the original interpretation untenable.

Thus, as the magnetic monopole episode of less than a year earlier taught only too well, in the absence of reproducible data, scientists simply will not accept evidence of a new discovery, no matter how well it fits the data, when a more conventional explanation is even remotely possible.

No one is accusing the seven-man team led by Robert Gentry (Columbia Union College and ORNL), Thomas Cahill (UCD), and Neil Fletcher (FSU) of hastily or prematurely publishing their data. Says D. Allan Bromley of Yale University, "If one believes that the function of *Physical Review Letters* (the journal in which the investigators published their data) is to include stimulating discussion of new developments, then the investigators acted responsibly by not sitting on their results until every detail was checked out." And, unlike the monopole, some (but not all) of the samples remained intact to be run again and again, if need be.

The evidence presented last July certainly seemed solid enough to merit publishing (*Science*, 16 July 1976, p. 219). Using a technique known as particle-induced x-ray emission (PIXE), the team of investigators focused a beam of protons from a Van de Graaff accelerator at FSU onto tiny monazite [(Ce, La, Th)$PO_4$] crystals. The x-ray spectra produced were best interpreted (best statistical fit) as being due to elements with atomic numbers 126, 124, and (possibly) 127. Because x-ray peaks ascribed to element 126 were found in five of the six monazite crystals examined, evidence for its existence was thought strongest.

The work of theorists in the middle 1960's had indicated the possibility of relatively stable elements with atomic numbers near 110 to 114, although elements with atomic numbers greater than 100 generally become progressively less stable and shorter lived. These predictions stimulated numerous searches for such superheavy elements in nature, but all failed to turn up any evidence for them. Recent attempts to produce them in accelerators at the Lawrence Berkeley Laboratory and at the Joint Institute for Nuclear Research, Dubna, U.S.S.R., which are capable of bombarding targets containing heavy elements, such as curium, with medium weight ions, such as calcium, in the hope they would fuse together to make a superheavy element, have also been unsuccessful.

Thus, the announcement of x-ray evidence for superheavy elements caused quite a stir among physicists. The excitement was compounded by two findings: The elements appeared to have higher atomic numbers than expected (atomic weights were not known), and the monazite crystals in which they resided were present in mineral formations that have been shown by dating techniques to be about 1 billion years old. Both aspects raised serious questions for theorists, answers to which would have required some revision of existing theories of nuclear structure and nucleosynthesis. Recent theoretical attempts to recalculate half-lives or otherwise assess the stability of these elements have been inconclusively divided pro and con.

In addition to its intrinsic interest, the evidence for superheavies, if it had been confirmed, would have provided a much needed shot in the arm to nuclear physics, which some have described as being in the doldrums in recent years. And it would have shown that fundamental discoveries can still come from outside the "big science" laboratories.

The most serious damage to the superheavy element evidence was that caused by the discovery by John Fox and his collaborators at FSU of a gamma ray with the same energy as the x-ray peak for element 126. The gamma ray is emitted when an excited praseodymium nucleus relaxes after being created from cerium (a principal constituent of monazite) during bombardment by protons. Not previously known to exist, the gamma ray provided a natural explanation of what had been thought an x-ray peak from an unusual element.

In addition, the original report did not adequately explain how the spectral backgrounds were generated, a crucial item, since the height of the background determines the statistical significance of the peaks. Moreover, one figure was mislabeled, lending further confusion to the background determination. This became an issue when Dirk Schwalm of the GSI laboratory in Darmstadt, West Germany, and his collaborators contended that proper selection of the background together with inclusion of the gamma ray from the praseodymium nucleus completely wiped out the element 126 x-ray peak. Fletcher at FSU has recently reconsidered the background problem and contends that a logical evaluation of the data does not eliminate element 126.

These revelations destroyed the credibility of the superheavy element evidence in the minds of many nuclear scientists. According to Joseph Weneser of Brookhaven National Laboratory, "When you begin arguing about how to adjust the background, it is time to get more data." And John Shiffer of Argonne National Laboratory adds that there is no "compelling evidence for new elements."

#### Halting the Experiment Temporarily

One way to resolve questions of this type is simply to rerun the experiment enough times to generate irrefutable statistics. This procedure unfortunately could not be followed at FSU because the proton beam there (30 to 50 micrometers in diameter) tended to wander off the monazite samples (50 to 100 micrometers in diameter) in the space of an hour. Thus, the spectra from run to run were from different parts of the crystal and could not be easily added together. In addition, several monazite crystals were accidentally lost or destroyed during the experiments, causing the investigators to cease running experiments until the accelerator beam control could be improved enough to give better data, which should be accomplished during the next few months.

In the meantime, confirmatory evidence for superheavies from other experiments would have helped, but none was forthcoming. None of these experiments have conclusively ruled out superheavy elements because not all monazite crystals are "equal" with respect to superheavies. The PIXE experiments were done on monazites that had been imbedded in another mineral, biotite mica. And only those monazite inclusions that were surrounded by discolored regions called giant halos evinced any indication of the new elements. All the inclusions studied at FSU came from a single slab of mica from the Malagasy Republic, although monazite also exists in bulk form and occurs in various places throughout the world.

Of all the experimental attempts to confirm the x-ray evidence for superheavy elements, only two have dealt with the same inclusions as those bombarded at FSU. The first of these took place at the Atomic Energy Research Establishment Harwell laboratory in England. A proton accelerator there has a much more finely focused beam and is better controlled than the FSU accelerator beam. The experiments at Harwell were carried out by John Cookson of Harwell, along with Fletcher, Cahill, and their associates. No evidence was found for either element, however.

The second and possibly definitive experiment by a group from ORNL led by Cullie Sparks and Subramanian Raman involved one monazite crystal that had shown evidence of as many as four different superheavy elements in the PIXE experiments at FSU. Although it was also an x-ray experiment, the ORNL study used high-intensity 37.5-kev x-rays from the Stanford Synchrotron Radiation Project (SSRP) facility as the source of excitation for x-rays from the monazite.

According to Sparks and Raman, x-ray excitation offers the possibility of overcoming two problems with the PIXE technique. First, the 4.7- to 5.7-Mev proton beam at FSU excited many different x-ray transitions simultaneously, but the x-ray beam from SSRP can be tuned with the use of a monochromator to excite specific x-ray transitions within the target material. And, second, the protons can cause nuclear reactions that result in the emission of gamma rays, which must then be distinguished from the x-rays being analyzed, whereas the SSRP x-rays do not.

Those who have seen the raw data agree there is no obvious evidence of superheavy elements in large concentrations, but the experimenters insist that nothing conclusive can be said until they have analyzed all the spectra. However, the group did not withdraw from publication, as it indicated it would if dramatic evidence of superheavies was found in the latest experiment, a report of negative findings with the same technique on 11 monazite crystals that had giant halos around them and were taken from the same slab of biotite mica as those reported on by the originial researchers. In the ORNL study, begun last July, the investigators concluded there was no evidence for the presence of superheavy elements in concentrations greater than about one part per million, comparable to Cahill's recent downward estimate for the amount of element 126 in another crystal. The ORNL researchers feel the latest experiments may turn out to be five to ten times more sensitive yet.

Numerous other attempts to find superheavy elements have been carried out on monazite, but not on material associated with giant halos. The rationale for some of these is based in part on the original estimates of several hundred picograms of element 124 in a crystal weighing about 1 microgram and the reasonable assumption that giant halos are distributed more or less uniformly throughout the monazite deposits near that from which giant halo samples were taken. Thus, if an experimenter has a sufficiently sensitive technique for trace element analysis, he can study bulk samples and hope to find detectable amounts of superheavies.

#### Elements Inhomogeneously Distributed

Researchers led by C. Stéphan of the Institute of Nuclear Physics, Orsay, France, irradiated monazite sand with neutrons in the hope of stimulating fission events in superheavy elements, but they found no evidence of superheavy elements to a concentration of 1 part to $10^{12}$. In another experiment, by Bruce Ketelle and his colleagues at ORNL, the incidence of spontaneous fission events in monazites was measured. The researchers calculated they could have detected between 8 and 300 parts in $10^{12}$, but found nothing.

Cahill believes that one explanation for these and many other negative results lies in the evidence for an inhomogeneous distribution of superheavy elements, not only among monazites, but also within a specific inclusion. Pockets of superheavies within an inclusion could account for the different spectra obtained from different runs on a given crystal because the wandering beam spot might not always be focused on the pocket. This inhomogeneity is the basis of his downward revision of the estimates of the concentrations of the new elements to levels too small to be detected in other experiments. Fletcher is less enthusiastic about this theory but strongly believes that a real effect was seen in the PIXE experiments and, superheavies or not, it is worth being explained.

Regardless of the eventual outcome of the superheavy element interpretation, which most nuclear scientists no longer believe valid, many observers are happy that the incident has spurred a renewed interest in nuclear physics, in trace element analysis, and in the mystery of giant halos, a mystery that dates back to the 1920's.—Arthur L. Robinson