NEWS AND VIEWS

Superheavy Elements in Meteorites

THE mounting evidence for the presence of nuclei with atomic numbers of at least 92 in the cosmic radiation impinging on the Earth and the possible existence of the much discussed island of stability at mass numbers around 284 and atomic number about 110 have been an incentive to the continuing search for transuranic elements both in the cosmic radiation and in meteorites and lunar rocks. It now seems that there is very compelling evidence for the existence of superheavies in meteorites at some time in the past.

The techniques used in the two cases are, however, completely different; the identity of a charged cosmic ray nucleus has to be extracted from measurements of the amount of ionization it produces as it passes through either a stack of photographic emulsions whose grains are rendered developable by ionization or through a plastic detector in which the path of the particle can be etched chemically. On the other hand, any very heavy nuclei which were condensed out into meteorites some 4.5×10^9 years ago would have quite a high probability of undergoing spontaneous fission into two or three fragments which are themselves still fairly heavy. This phenomenon can be studied by the rather elegant methods for detecting fission fragments or cosmic ray nuclei in certain clear minerals present in meteorites and lunar rocks. It is a rather careful study of the ionization trails of nuclei in such mineral samples which has allowed Bhandari *et al.* of the Tata Institute of Fundamental Research, Bombay (see page 219 of this issue of *Nature*), to state unequivocally that they have detected fission fragments from the breakup of elements with atomic numbers around 114.

Bhandari *et al.* have made use of the fact that in many non-conducting substances the ionization damage done by a charged particle can be made visible under a microscope by chemical etching. In the past, experimentalists using this technique have only been able to etch the tracks at a fractured crystal surface and the separation of the tracks caused by cosmic ray nuclei from those caused by the fission of an ultraheavy element is open to considerable criticism. But Bhandari *et al.* have succeeded in applying a technique which allows them to look at ionization tracks within the body of a suitable crystal where the number of cosmic ray tracks is severely depleted because of the surrounding material. The secret is to etch strongly a very long track or fissure which passes from the surface into the body of a crystal so that other tracks which cross the fissure are also made visible.

The length of the visible track of a charged particle in an extraterrestrial mineral is a fairly direct measure of the nuclear charge and energy of the particle and it is essentially on an examination of the distributions of measured track lengths that the establishment of the existence of superheavy elements depends. Bhandari *et al.* found that the most amenable tracks for this sort of measurement were those which were etched in the fissures (the so-called TINCLES—"tracks in the cleavage"). Remarkably, the track densities observed along such fissures were often much larger than expected theoretically, probably because of the movement of the small number of plutonium, uranium and other heavy elements towards the flaw planes ("differentiation") during the initial condensation process. Instead of seeing about five tracks per 100 μm of fissure, up to five hundred tracks per 100 μm were often measured. In practice the upper limit of track density for which reasonable measurements could be made was about one hundred tracks per 100 μm. (The existence of such a wide variety of track densities was in fact confirmed by inducing fission artificially within the meteorite samples with neutrons and examining the distribution of the tracks.)

It is possible to calculate the track lengths expected for fission products of plutonium and uranium isotopes as well as of superheavy elements and also to measure the track lengths of ^{235}U fission products by neutron activation. Bhandari *et al.* found that the theoretical track lengths were short by about 2 μm or so, chiefly because at the end of their range fragments do not have sufficient ionizing power to produce etchable tracks in the mineral. Basically, the track lengths seen in the meteorites can be divided into three groups. The 10 to 13 μm division is thought to be caused by cosmic ray iron group nuclei and the 13 to 16 μm range by heavier cosmic rays and uranium and plutonium fission products. The 16 to 22 μm interval almost certainly contains tracks of fission products of the superheavy elements (in fact, these are probably greater than 18 μm long, this being the upper limit for neutron induced fission tracks in ^{235}U). In the sample from the Angra dos Reis meteorite seven tracks longer than 18 μm were discovered among 1,500 tracks and two of these were as long as 21.6 and 25.8 μm. According to calculations for this sample, cosmic rays were responsible for fewer than 0.1 per cent of the tracks so it seems clear that these seven tracks were caused by fission of superheavy elements.

The cosmic ray contributions to the tracks visible in the other meteorite samples and in the Apollo rocks and "fines" could not, however, be ignored immediately but they were nonetheless shown not to affect the conclusion in any way. The proof of this lay in a comparison of the track length distributions for several different values of the very variable track density along the fissures for the TINCLES. As TINCLE densities increased, it was found that the proportion of the 13 to 16 and 16 to 22 μm tracks relative to the 10 to 13 μm group (cosmic ray iron group nuclei) also increased. In other words, this was additional support for the supposition that the uranium and other heavy nuclei were in fact sometimes concentrated at the fissures (possibly grain boundaries). Such excess fission tracks are also found in the Apollo "fines" but not in the Apollo rocks which are presumably too young to have contained very much fissionable material on solidification.

Now that the fission products of superheavy elements have been detected with a fair degree of certainty in meteorites, interest is bound to concentrate once again on the cosmic ray measurements at the Earth to see whether definitive proof of the existence of superheavy cosmic ray nuclei can be found.