Meteoritics

Isotopic anomalies in meteorites explained?

from J. H. Reynolds

TWO young chemists at the University of California at San Diego have just reported in *Science* (219, 1073; 1983) a novel isotopic effect. The work by M. H. Thiemens and J. E. Heidenreich III may provide a simple 'chemical' explanation for isotopic anomalies in meteorites, discovered a decade ago by R. Clayton, L. Grossman and T. Mayeda of the University of Chicago. The anomalies have been widely attributed to a nuclear process and have focused much attention on the possible roles played by supernovae in the early history of the Solar System. The new explanation proposed for these effects is so simple that meteorite cosmochemists might well be embarrassed by its having been overlooked.

Mass spectroscopists express isotopic anomalies in ' δ values'. The δ value for an isotopic ratio is simply the fractional difference between the ratio and a standard value for that ratio, expressed in per cent, per mil, or even parts per 10,000 if the effect is very small.

In oxygen, $\delta 17$ and $\delta 18$ refer to the ratios $^{17}\text{O}/^{16}\text{O}$ and $^{18}\text{O}/^{16}\text{O}$ respectively. For oxygen from terrestrial samples the measured δ values almost invariably plot on a line of slope 1/2 when $\delta 17$ is the ordinate and $\delta 18$ is the abscissa. This behaviour corresponds to 'mass-dependent fractionation' and means that the terrestrial processes for isotope separation in oxygen are twice as effective when the mass difference involved is twice as great.

Clayton *et al.*'s discovery in 1973 that oxygen samples from carbonaceous meteorites define a line of slope 1 instead of slope 1/2 was an outstanding one for meteoritics. Using the effect, Clayton has been able, for example, to classify Solar System material according to its isotopic patterns for oxygen, an achievement which should eventually be an important boundary condition in discussing the origin of the Solar System. Because the chemical processes which operate terrestrially on oxygen have always produced samples on the line of slope 1/2, the meteoritic effect has been attributed to a nuclear process.

The experiment by Thiemens and Heidenreich is elegantly simple. They subject oxygen gas at reduced pressure to a Tesla discharge in a vessel which is partially immersed in liquid nitrogen. The ozone produced in the discharge freezes out on the cooled walls, so that after a time the residual oxygen can be pumped away and collected and the condensed ozone then warmed up and collected as a second fraction.

The isotopic compositions of the oxygen

in the complementary samples have been measured in two different laboratories and show complementary displacements from the starting material precisely on the line of slope 1. The extent of the separation depends on how long the discharge is applied, with δ values of up to 8 per cent having been observed. The experiment immediately establishes that nuclear processes need not necessarily be invoked to account for isotopic compositions in oxygen which are displaced from normal on a line of slope 1.

Royal Greenwich Observatory

Satellite laser ranging in the UK

from A. J. Meadows

THE new satellite laser-ranging facility at the Royal Greenwich Observatory is nearing completion and is expected to obtain usable data by April this year and fully calibrated data by the autumn. A workshop was held at the Observatory last month to discuss plans for the laser and to examine how ranging data should be processed, analysed and exploited in the UK.

Satellite laser ranging developed rapidly during the 1970s as a method of determining the distance of satellites from observing stations on the Earth's surface with high accuracy. The resultant data not only provide a better picture of the forces acting on satellites, but they can also be used to fix very precisely the position and motion of the observing station. Much of the work in this area has been carried out in the US, with NASA playing a leading part, but several European countries have also participated. The UK has so far been conspicuous by its absence.

For most applications of satellite laser-ranging data, it is necessary to combine information from more than one station. International cooperation is therefore essential, and an agreement has already been reached between SERC and NASA for the exchange of data. However, the UK results will not simply extend the existing number of observations. The laser facility to be installed at the Royal Greenwich Observatory is one of the first third-generation systems to come into operation and should ultimately be capable of measuring distances to satellites with errors of a centimetre or so. This is nearly an order of magnitude improvement over older systems and increases the likelihood that a number of effects of geophysical interest, including continental drift, will be

Thiemens and Heidenreich think it most likely that a shielding effect is operative in a photochemical step in their reaction. If the Tesla discharge produces a band of 'white' ultraviolet radiation which is responsible for dissociating the oxygen molecules and initiating the reaction which leads to ozone, the photons which liberate ^{17}O are predominantly those tuned to dissociating the $^{17}\text{O}^{16}\text{O}$ molecule and are distinct in wavelength from those tuned to the $^{16}\text{O}_2$ molecule. In a one-dimensional geometry where the photons travel from a source plane through a slab of gas of length L , the initial dissociation ratio for those two types of molecule (labelled 2 and 1 respectively) can easily be shown to be:

$$Q_2/Q_1 = [1 - \exp(-N_2\sigma_2L)] / [1 - \exp(-N_1\sigma_1L)]$$

with a similar expression for the initial dissociation ratio Q_3/Q_1 where the subscript 3 refers to the $^{18}\text{O}^{16}\text{O}$ molecule.

detected. At the moment UK observing possibilities are limited to ten satellites, as only satellites fitted with retro-reflectors can be ranged by laser. Retro-reflectors are, fortunately, very easy to fit to satellites so the number is expected to increase considerably over the next decade.

Two areas of particular interest were identified. First, the facility should be ready in time to allow participation in the international MERIT campaign, aimed to provide better measurements of Earth rotation, from September 1983 to October 1984. Second, laser ranging to satellites equipped with altimetry instruments may reduce uncertainties in defining their orbits, so improving observations of land and sea profiles around the UK.

Laser-ranging measurements are relevant to much geophysical and geodetic research and it was agreed that all interested workers should be alerted to the proposals emanating from the workshop. It was also thought that it would be valuable to obtain feedback on possible longer-term developments — should, for example, an attempt be made to link the stationary laser facility at the Royal Greenwich Observatory to a mobile laser in order to increase the scope of UK geophysical and geodetic measurements? One immediate result of the workshop will therefore be a general meeting, to be held later this year, where information on the possibilities of the satellite laser-ranging facility will be presented to the widest possible audience. □

A. J. Meadows is Professor in the Department of Astronomy and History of Science, University of Leicester, University Road, Leicester LE1 7RH.