of detectors separated by a few kilometres, and Weber has been cautiously optimistic (*Physical Review Letters*, **18**, 498; 1967). With detectors as far apart as 1,000 km, the chances of coincidences due to the same electromagnetic or seismic disturbances must be correspondingly lessened, and this time Weber is confident that gravitational waves are being recorded. All told, four detectors were used in the 81 days of the experiment, all of them aluminium cylinders 153 cm long and between 61 cm and 96 cm in diameter, tuned to respond to gravitational waves within a narrow band near 1,660 Hz.

As much as anything, the kilohertz frequency band was chosen because the laboratory equipment is reasonably convenient. The only other band accessible at present is the millihertz range which can be covered using the Earth instead of the aluminium cylinders as a resonating body, and seismometers as detectors. But the choice of 1,660 Hz can also be justified on the grounds that a collapsing object, such as a supernova, will emit a spectrum of gravitational waves in the kilohertz band (according to unpublished work of F. J. Dyson and R. L. Forward), the frequency increasing as the collapse proceeds. So far, however, there is no way of pinning down where the gravitational waves are coming from—the equipment can receive waves coming from a 70° spread in the azimuthal plane and from all directions at right angles. Although the energy density of gravitational waves is not clearly specified by general relativistic theory, Weber estimates that the coincidences correspond to an energy density of at least 10^{-32} g cm^{-3} over the narrow bandwidth of 0·1 rad s^{-1}.

The next steps are to improve the time resolution of the Argonne–Maryland equipment and then to look for gravitational waves at lower frequencies, in the domain where the Earth can be used as a detector. Another approach which Weber and his colleagues are considering is to place seismic detectors on the Moon to look for gravitational waves corresponding to the Moon's normal modes of oscillation. The argument goes that the Moon should be seismically relatively quiet, so that detectors there will have a better chance of success. In any case, coincidences between terrestrial and lunar detectors should provide evidence for the existence of gravitational radiation. Another possibility which has arisen is that of detecting gravitational waves from pulsars (*Nature*, **222**, 1027; 1969), and here the advantage is that the frequencies expected are known in advance—the typically 1 Hz repetition frequencies of the radio bursts. Both Weber (*Physical Review Letters*, **21**, 395; 1968) and Dyson (*Astrophysical Journal*, **156**, 529; 1969) have worked out that detection of these gravity signals seismically is out of the question, unless the calculations are blessed with quite exceptional luck. But there is a chance that detectors on the Moon would do the trick, or that laboratory equipment based on the Argonne and Maryland detectors could be developed for low frequency work.

FERROMAGNETISM

More Rare Earth Magnets

Two more elements have been added to the list of known ferromagnetic materials with the discovery that the face-centred cubic phases of Pr and Nd become ferromagnetic at 8·7 K and 29 K respectively. The interest of this observation, however, lies not so much in the extension of this list but in the way it bears out recent speculations about the way in which essentially non-magnetic materials may be converted into ferromagnets by exchange interaction within the lattice. The new development is reported from the Bell Telephone Laboratories by E. Bucher, C. W. Chu, J. P. Maita, K. Andres, A. S. Cooper, E. Buehler, and K. Nassau (*Phys. Rev. Letters*, **22**, 1260; 1969). Theoretical expectations stem from the work of B. Bleaney (*Proc. Roy. Soc.*, A, **276**, 10; 1963), but B. R. Cooper has been prominent among those responsible for more recent calculations of this form of induced magnetism.

How does it come about that materials which consist of atoms without residual magnetic moments can be converted into a ferromagnetic form? The first step is to acknowledge that interaction between the electronic structure of an atom and the lattice in which it is embedded may create other electronic ground states in which the non-magnetic symmetry is destroyed. Both the rare earth elements now shown to be ferromagnets are indeed possessed of singlet ground states, but interaction with the conduction electrons splits the ground state into levels which are magnetic. This, certainly, is what the experiments imply, but not enough is known about the fine structure of the electronic structures concerned for the behaviour of Pr and Nd to be predictable.

The face-centred cubic forms of the two elements have been recognized as the most likely candidates, and the first problem is to ensure that these can be taken down to liquid helium temperatures. The onset of the ferromagnetic phases is recognized by a simple measurement of the susceptibility as a function of temperature. Thermal measurements show no detectable abnormality of the specific heat at the Curie temperature, which agrees well with the expectation that the entropy term in the free energy is almost exactly balanced by the energy of the crystal field splitting. Briefly, it seems that near the absolute zero, the preferred condition of Pr and Nd is one in which there is ferromagnetic order at the expense of a slightly enhanced internal energy.

SPIN DYNAMICS

How Iron Behaves

from our Solid State Physics Correspondent

THE study of the spin dynamics of iron is at a fascinating stage. M. F. Collins *et al.* (*Phys. Rev.*, **179**, 417; 1969) have made an extensive and revealing set of measurements at the Brookhaven National Laboratory in which the collective movements of the elementary magnets in a single crystal of iron were studied by observing the wave vectors and frequencies of slow neutrons magnetically scattered from the metal. Apart from obtaining fuller dispersion curves than earlier experimenters, they have found that diffusive modes in the spin wave region are absent and also a steady and uncritical change of properties at large wave-vectors as iron is taken through the Curie temperature.

The exact behaviour of the spins in iron is still something of a mystery. Broadly, the magnetic properties of iron can be divided into three regions, depending on the temperature of the metal and wave-vector of the modes under consideration. For tem-