PRINCIPLES OF NUCLEAR MAGNETISM*

SINCE the first successful detection of nuclear resonance signals in 1946, independently by Bloch *et al.* and Purcell *et al.*, Nuclear Magnetic Resonance or NMR spectroscopy has become an important tool of research in diverse fields, such as chemistry, metallurgy, geology and biology. The rate at which the application of this technique is developing is phenomenal. Besides its first and obvious application to the measurement of nuclear moments, currently it is the most successful method of obtaining precise information on the finer properties of matter in bulk. Structure of molecules, reaction rates and chemical equilibria, chemical bonding, crystal structures, internal motions in solids and liquids, electronic densities in metals, alloys and semiconductors, internal fields in ferromagnetic and antiferromagnetic substances, density of states in superconductors, properties of quantum liquids, are some of the topics where nuclear magnetic resonance experiments have so far provided specific and detailed information. This wealth of applications should not, however, obscure the fact that nuclear magnetism is in its own right one of the most fascinating domains of pure physics.

Following the original suggestion made by Pauli in 1924 to explain the hyperfine structure of spectral lines, it has been now well established that atomic nuclei possess in their ground state a non-zero spin angular momentum $Ih/2\pi$ (where I is an integer or half integer), and, collinear with it, a dipolar magnetic moment $\mu = \gamma I h/2\pi$, where γ is the gyromagnetic ratio which is characteristic of the nucleus. The order of magnitude of these magnetic moments is between 10^{-3} and 10^{-4} Bohr magnetons. It is these moments that give rise to 'nuclear magnetism'.

Besides the difference in the order of magnitude between nuclear magnetism and electronic magnetism, there are other differences which are worth noting. Thus, of the three aspects of magnetism, namely, ferromagnetism, diamagnetism, and paramagnetism, only the last is of interest in nuclear magnetism. It will be noted that ferromagnetism may arise when kT, the product of Boltzmann constant and the temperature of the sample, becomes comparable to the couplings between the spins. The strong exchange coupling of electrostatic origin that gives rise to electronic ferromagnetism is absent in nuclear magnetism, and further the magnetic coupling between nuclear spins is such that temperatures of the order of 10^{-7}° K. would be required for a possible observation of nuclear ferromagnetism (or antiferromagnetism). Electronic diamagnetism arises from the Larmor precession of the electronic charges in an applied magnetic field. Such a case is not easy to visualise in nuclear magnetism, and at least in bulk matter it can reasonably be expected to be negligible. Thus we are left with paramagnetism only. Here too, unlike in the case of electronic paramagnetism where there is an appreciable contribution from the orbital motion of the electrons, nuclear paramagnetism is entirely due to the spins of the nuclei and that of orbital origin is of no significance in bulk matter. Again, because of the smallness of the nuclear paramagnetism static methods of measurement as in the case of electronic paramagnetism become too insensitive to bring out the finer points in this field of study. Although a static measurement of nuclear magnetic susceptibility had been made as early as 1937 by Lazarew and Schubnikow, on solid hydrogen at 2° K., nuclear magnetism would probably have remained a simple curiosity if much more sensitive methods using the principle of resonance had not been developed. Now, it may be said that this is the one branch of modern physics where there is very close connection between theory and experiment.

While there are many books on the subject dealing with the practical applications of nuclear magnetism and NMR spectroscopy, those that are devoted to the elucidation of the fundamental aspects of the subject from necessarily a theoretical point of view are indeed few. In this context a theoretical book bringing out the underlying principles of nuclear magnetism will be a most welcome addition to the literature on the subject. The book by Prof. Abragam gives a consistent description of the various aspects of nuclear magnetism on a unified basis. The outlook is mainly theoretical and the book is obviously intended for that category of readers who would like to delve deep into this fascinating field of study. As the author says in the Preface "What I had in mind was to attempt for nuclear magnetism what Van Vleck has done for the theory of electric and magnetic susceptibilities in a book which thirty years after its publication is still *the* book on the subject." The author's expectation is not wrong. *The Principles of Magnetism* will be a book of abiding value on the subject.

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* *The Principles of Nuclear Magnetism.* By A. Abragam. (International Series of Monographs on Physics, Oxford at the Clarendon Press), 1961. Pp. xvi + 599. Price (in U.K. only) £ 4·4 *s.* net. Rs. 67·20.