MOLECULAR AND ATOMIC MOTIONS BY RADIO-FREQUENCY METHODS

MAXWELL-A.M.P.E.R.E. CONFERENCE

A JOINT meeting of the Colloque A.M.P.E.R.E. (Atoms et Molecules par Etudes Radio-Electriques) and the British Radio Frequency Spectroscopy Group was held during April 1–3 at Queen Mary College, University of London. The meeting was attended by more than two hundred scientists, mostly from the British Isles but with strong representation from France, Holland, Switzerland and the Eastern European countries in particular. The subject for discussion at the Conference was, "Molecular and atomic motions in liquids and solids by radio frequency methods". In the tradition of the A.M.P.E.R.E. meetings the subjects covered were, dielectrics, nuclear magnetic resonance, quadrupole magnetic resonance and electron spin resonance. However, the range of the papers was constrained somewhat more than has been usual at the A.M.P.E.R.E. conferences by the specification of a subject for discussion, albeit rather widely interpreted.

The forty-four papers presented showed the power and range of the radio-frequency methods in studying molecular and atomic motion and there was an impressive consistency and similarity in the information produced by the very different experimental methods. It was regrettable that time did not allow the inclusion of mechanical and ultrasonic absorption measurements although these received mention in several of the papers.

Since many people versed in one discipline attended lectures in another, the occasion was a suitable one for having a general introductory lecture in each subject, and these were given by Prof. H. Fröhlich (Liverpool) on "Dielectric Theory", Dr. J. G. Powles (London) on "Motional Effects in Nuclear Magnetic Resonance" and by Dr. M. Buyle-Bodin (Grenoble) on "Motional Effects in Pure Quadrupole Resonance". Even so, many of the discussions became extremely technical and specialized and the difficulty in having a meeting on a subject which cuts across the traditional interests and compartments of science was apparent. This difficulty is a common one in conferences these days although highly specialized discussion is said to be evidence of 'maturity' of a subject. It is regrettable that the cross-fertilization which should be brought about by conferences such as this one is so difficult to achieve. It is therefore very valuable to have organizations 'd'informations mutuelles' such as the Colloque A.M.P.E.R.E. and the British Radio Frequency Spectroscopy Group, the membership of which cuts across the traditional disciplines and contrasts with the extreme specialization of many organizations.

It was a source of great sorrow to all present, and particularly to the writer, that Prof. Freymann (Paris), the inspiration of the Groupement A.M.P.E.R.E., was unable to be present owing to illness, and that this should be the first A.M.P.E.R.E. Conference he has missed.

The conference overcame in large measure the difficulties occasioned by the fact that it was held outside France for the first time (apart from a foray to Geneva in 1957) and was well attended by French scientists. Although some 50 per cent of the papers were presented in French, the British members appeared to survive the ordeal without severe discomfort, and it may be that the teaching of French in our grammar schools is not as ineffective as is commonly supposed. The language difficulty was lessened by the provision of pre-prints of most of the papers.

It would obviously be impracticable to mention all of forty-four papers and a brief summary only will be presented in an attempt to give some idea of the scope of the conference.

The conference was opened by Prof. H. Fröhlich, who gave a masterly summary of the present situation in the theory of dielectrics, the main point of which was that the whole of the general theory has been worked out. The continuing appearance of papers on 'general theory' are no more than mathematical exercises, and whether these results are correct or not they are irrelevant. This point of view was undoubtedly novel to many present. He elaborated his position by discussing the whole field of dielectric loss in which he distinguished four types all but one of which are well understood. He was particularly concerned with the extent to which the theory can be dealt with macroscopically, which is of first importance because of the long-range nature of dipolar forces, and with the number of independent parameters required for an *understanding* of the phenomena involved. He did point out nevertheless that a great deal of work remains to be done in the theory of dielectrics but that this should be concerned with the detailed interpretation, using models and so forth, and in the search for information about materials and processes.

This lecture led on naturally to the more detailed discussion of a number of papers on dielectric loss in liquids and solutions, which depends in large measure on molecular properties and in which the 'model' aspect was very evident.

J. D. Hoffman (National Bureau of Standards, Washington) introduced a session on solids with an account of his work on systems having multiple relaxation times leading to bimodal, or even multimodal, loss curves which he explains in terms of multiple minima in the energy as a function of the orientation of a dipole. A paper by H. Gränicher and C. Jaccard (Zurich) summarized the present position in the interpretation of the dielectric properties of ice. B. Szigeti (Liverpool) described his recent work on a so far unobserved librational absorption process which should be found in crystalline long-chain substances.

There were a number of papers on the dielectric properties of systems in which water or a gas was adsorbed on materials such as silica gel.

The session on nuclear magnetic resonance was opened by J. G. Powles (London), who gave a summary of motional effects which can be studied by nuclear magnetic resonance, including numerous examples of the various types of effect which may occur. He pointed out that examples of many of these would be found in the following papers but gave a number of extra ones in order to provide a balanced picture of the potentialities of the method.

There were several papers on motional effects in hydrocarbons which were concerned with the elucidation of the molecular motions occurring in these molecular crystals. E. R. Andrew (Bangor) summarized his recent work on macroscopic motional effects, extending his considerations to quadrupolar effects and showing in particular how macroscopic motional experiments may help in deciding the nature of a magnetic interaction. A paper by K. Luszczynski (London) discussed the rather complex motional effects in the polymer poly*iso*butylene. J. A. E. Kail and J. G. Powles (London) had studied the molecular motion in *iso*butyl bromide, which is of interest since it is readily obtained either as a crystal or as a supercooled liquid over a wide temperature-range. The value of nuclear magnetic resonance measurements made at kilocycle frequencies was pointed out by G. Hochstrasser (Geneva). The interest in comparing nuclear resonance and self-diffusion parameters in mobile liquids of long-chain compounds was discussed by D. Cutler and J. G. Powles (London). M. P. McDonald (Heston) presented high-resolution results on amphiphilic solutions which have liquid crystal phases. D. J. Kroon and C. v. d. Stolpe (Eindhoven) reported nuclear resonance measurements which throw light on the movement of hydrogen in the alloy Th_2Al, which is used as a getter. H. Winkler (Leipzig) discussed the nuclear resonance of water sorbed on alumina, which links up nicely with the corresponding measurements reported in the Dielectrics Session by G. Ebert (Leipzig). I. Solomon (Saclay) reported a new method of measuring long nuclear resonance relaxation times.

The session on pure quadrupole resonance was opened by M. Buyle-Bodin (Grenoble), who gave an excellent summary of the motional effects which are to be found and included an appreciation of his own valuable contributions in this field. J. L. Ragle (Amherst, Mass.) reported work which indicated the motional effects in 1,2-dichloroethane. It was reported by F. Herlach, H. Gränicher and D. Itschner (Zurich) that a new phase transition had been found in potassium iodate by nuclear quadrupole resonance, and the value of this method in detecting such 'weak' transitions was pointed out.

Time was then given to an informal discussion on commercial instrumentation in magnetic resonance. A number of firms briefly described their products and this was followed by a general discussion. The time and occasion were appropriate since the amount of commercial instrumentation available is at present rapidly increasing. It was of interest to note the great difference in tone and objectivity between a commercial and a scientific discussion.

In the session on electron spin resonance it was evident that motional effects are less important and appear very much as a by-product. D. J. E. Ingram, M. Fujimoto and M. C. Saxena (Southampton) reported experiments indicating two types of motion: one in which rate of radical diffusion in an organic glass could be measured, and another in which the spectrum differed with temperature, which was taken to indicate an effect due to reorientation of methyl groups within the radical. It was unfortunate that no paper was offered in which the motional averaging of the anisotropic hyperfine splitting was discussed. In a striking paper, K. H. Hausser (Heidelberg) showed how the resolution of hyperfine spectra in free-radical solutions depends on the optimum condition for observation of detail in the spectrum, which is essentially a motional effect and which must be arranged to give optimum relaxation parameters. Presumably motional effects can be studied in this way although this was not emphasized in the paper. A. Landesman (Saclay) reported a study of the $(SO_3)_2NO^{2-}$ ion in solution by measurement of the solvent protons.

During a session on motional effects in irradiated materials, J. S. van Wieringen and A. Kats (Eindhoven) reported paramagnetic resonance spectra of irradiated fused silica at liquid-nitrogen temperature which were due to hydrogen atoms formed from water impurities. The variation of these signals with temperature and time was used to study the motion of the hydrogen atoms. A. Lösche (Leipzig) reported proton magnetic resonance measurements on nylon-6 which had been subjected to doses of comparatively weak γ-radiation over periods of several months. The radiation causes chemical changes which affect the molecular mobility of the polymer and hence the nuclear signals. It was suggested that this might be a suitable method of measuring integrated radiation doses when the intensity is rather low.

The papers presented at the conference, but not the discussions, are being published in a special issue of *Archives des Sciences* (price 25 Swiss francs). Copies may be obtained by writing to the Secretariat A.M.P.E.R.E., Institut de Physique, Bd. d'Yvoy, Geneva, Switzerland.

The next Colloque A.M.P.E.R.E. will be held in Pisa, Italy, in September 1960. J. G. POWLES

SEMICONDUCTING SILICON CARBIDE

ONE of the most important aspects of semiconductor physics in recent years has been the search for materials which yield devices capable of operating at higher temperatures than germanium and silicon. In this search, silicon carbide has been regarded as an important candidate, although, indeed, there are others. For silicon carbide, the high temperature of formation implies a high degree of stability at all temperatures likely to be encountered by devices. Moreover, the material can be regarded simply as silicon in which half the atoms have been replaced by the chemically similar carbon. In this way, much of the available information concerning, for example, the effect of impurities in germanium and silicon should be applicable to silicon carbide also, considering that the bonds are almost wholly covalent. Again, the relatively wide band gap would promise a large measure of electrical stability over a wide range of temperature. These advantageous features tend, unfortunately, to be balanced by a major practical difficulty, namely, that of growing single crystals with a controlled content of additives and crystal defects.

In order to explore these problems and to make a general assessment of our present knowledge, a major conference was recently held at Boston during