

IX. MAGNETIC RESONANCE*

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RESEARCH OBJECTIVES

Our work in magnetic resonance is aimed mainly at finding and exploiting new ways in which the basic magnetic resonance phenomenon can be applied to the solution of scientific and technical problems. Accordingly, we are involved in the study of the interaction of magnetic spins with their surroundings (which leads us into chemical physics) and at the same time in problems of instrumentation. Most of our current effort can thus be outlined under two headings.

1. Spin-Lattice Relaxation and Random Atomic Motions

The theory of magnetic relaxation involves time correlation functions of various fluctuating operators associated with the lattice motion. The measurable spin relaxation times depend upon the Fourier intensities of these correlation functions at characteristic frequencies determined by the strength of the applied magnetic field in which the experiment is done. It is commonly assumed (and sometimes justifiably) that the correlation functions are all exponential with a common correlation time, whereupon the dependence of relaxation times on field strength is determined. We are now setting up an experiment to study the effect of field strength on relaxation time in order to determine directly, by Fourier inversion of the spectral intensities, the form of the lattice correlation functions for simple lattice motions in solids. The experiment, to be worth while, must be done at field strengths varying over a factor of the order of 1000. Accordingly, all spectroscopic manipulations and observations of the spin system are made in a strong field with a fixed-frequency spectrometer, and the spin system is adiabatically demagnetized to various lower fields during the time when relaxation is occurring. (Such experiments have been performed previously in other connections by Solomon, Schumacher, and others.)

Another set of experiments bearing on the nature of lattice correlation functions requires measurement of relaxation time at only two field strengths in liquids and gases where one has reason to think that the spins feel their surroundings only through (i) the anisotropy of the chemical screening, and (ii) the spin-rotational interaction. Separation of the effects of these mechanisms, through the characteristic dependence of the former on magnetic-field intensity, permits a determination of correlation times for (i) the orientation, and (ii) the angular velocity of the spin-bearing molecule. The relationship between these times, quite apart from their individual values, depends on the statistical character, rather than simply the rate, of the molecular motion. Thus, without the uncertainties associated with a detailed molecular theory of the fluid, we hope to learn something about where, in the continuum between classical hydrodynamics and the free molecule, the proper description of molecular motion lies.

We are also studying nuclear relaxation in gases as it depends on temperature and

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density, this being a continuation of work that our group has been carrying on for some time. The object here is to exploit the theoretical simplicity of dilute gasdynamics to obtain detailed information about intermolecular forces, in particular about their angle-dependent parts. We are completing a set of measurements of proton relaxation in mixtures of H_2 and He, and are doing distorted-wave scattering calculations in an attempt to fit a model of the anisotropic H_2 -He potential to the measurements.

We are also doing some chemically oriented experiments on the electron spin resonance and nuclear relaxation in solutions of alkali and rare-earth metals in liquid ammonia. The ESR results, thus far, indicate an unusual free-electron line-broadening interaction in $Eu-NH_3$ solutions. In an effort to understand the dynamics of the electrons in such solutions, we are studying the dependence of proton longitudinal and transverse relaxation times on temperature and concentrations of metal and paramagnetic salts.

2. Instrumentation

Transient nuclear magnetic resonance studies in substances with long relaxation times require the use of radiofrequency transmitter gates with unusually high on-off ratios. We have been working on the development of simple gating systems that meet this criterion, including simple diode networks and schemes generating the desired frequency from a higher frequency source by means of gated frequency dividers. The last scheme has, in principle, an infinite on-off ratio, and the digital circuit techniques employed are particularly applicable to low radio frequencies, where the more usual schemes encounter conflicts between the requirements of on-off ratio and rise time.

We are also completing the development of a digital averaging device which is adapted to the retrieval of transient nuclear resonance signals from noise with automatic correction of gain and base-line fluctuations.

We are beginning work on a dual-frequency scheme for the precise labelling and detection of segments of a flowing liquid, to be used in possible flowmeter applications.

J. S. Waugh