

XV. MAGNETIC RESONANCE*

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RESEARCH OBJECTIVES

1. Nuclear Spin Interactions in Solids

We are investigating a variety of rather elaborate transient NMR experiments whose general aim is to add to the information obtainable about spin interactions in solids. For example, we have shown that by applying RF and DC magnetic fields of appropriate intensities, directions, and time sequences it is possible to measure: (a) a modified fourth moment for dipolar interactions, (b) a modified sixth moment for dipolar interactions, and (c) small chemical shifts in the presence of large dipolar interactions.

2. Nuclear Relaxation and Inelastic Scattering in Gases

We have completed a study of nuclear relaxation in H₂-He mixtures and related it to the anisotropic H₂-He intermolecular potential by means of quantum-scattering calculations. Similar work is now being carried on in HCl-He, ¹³CO-He, and other systems.

3. Kerr Effect in Nonideal Gases

We are setting up an apparatus for accurate measurement of the Kerr electro-optical effect and equation of state in gases. The nonidealities displayed in these experiments are related to the intermolecular potential, and are expected to give new information about its anisotropic part. The first experiments are being conducted in HCl.

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A. NMR LINE NARROWING IN SOLIDS

A multiple-pulse NMR experiment, whose aim is the elimination of the effects of static dipolar broadening in solids without eliminating resonance shifts and scalar couplings, has been successfully tested. The pulse train consists of repeated applications of a cycle of four 90° pulses P₁-P₄, timed according to the schedule

$$P_1, 2\tau, P_2, \tau, P_3, 2\tau, P_4, \tau,$$

where τ is chosen to be of the order of T₂ or smaller. P₁ and P₂ differ by 180° in

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carrier phase, as do P_3 and P_4 . The carrier phases of P_3 and P_4 are in quadrature with P_1 and P_2 .

The experiment has been performed on a single crystal of uranium-doped CaF_2 (^{19}F resonance). In the orientation employed the Bloch decay has a lifetime of $\sim 15 \mu\text{sec}$. The lifetime of the transverse magnetization in the multiple-pulse experiment has been observed to be as long as 10 msec, and the decay shows the expected sinusoidal modulations when the Zeeman field is set off resonance. This result corresponds to an effective line narrowing of three orders of magnitude, from $\sim 20 \text{ kHz}$ to $\sim 30 \text{ Hz}$.

The theory of this and similar experiments is discussed in a forthcoming paper in the Journal of Chemical Physics.

A related experiment that we are about to test involves the application of a train of identical equally spaced pulses. Each pulse consists of a magnetic field applied to the sample by a coil whose axis is inclined at an angle α to the Zeeman field H_0 . The magnetic field pulse consists of two simultaneously applied parts: (a) an oscillating radio-frequency carrier (near resonance) of amplitude $2H_1$, and (b) a "DC" pedestal of intensity H_p . Conditions are adjusted so that

$$\frac{H_1}{H_p} \tan \alpha = \sqrt{2}.$$

This experiment is analogous to the Lee-Goldburg experiment¹ and has two advantages over it:

1. The RF fields are applied in separated pulses, so that the precessing magnetization can be observed "continuously" in the windows between them; and
2. The fields H_1 and H_p are applied by the same coil, so that the cancelling of dipolar interactions becomes independent, to first order, of the homogeneity of the field of the coil.

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References

1. M. Lee and W. I. Goldburg, Phys. Rev. 140, A1261 (1965).