where $P_L(\cos\theta)$ is the Legendre polynomial and the γ_L are in what amounts to closed form, i.e., free of magnetic quantum number sums.

I wish to thank Professor S. M. Dancoff for criticism and encouragement.

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[4] Giulio Racah, Phys. Rev. **62**, 438 (1942).

Quantum Effects in the Interaction of Electrons with High Frequency Fields

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IN a paper with the above title, Smith[1] has calculated the interchange of energy between a beam of electrons and a microwave field inside a resonator. An experiment to observe the quantum nature of the energy transfer will be performed shortly in this laboratory. In order to detect this effect it is clear that the energy of the electrons must be defined with an uncertainty which is less than the quantum energy, and it is this condition that produces the experimental difficulties. By means of a time-of-flight velocity focusing tube it is hoped to produce 1000-ev electrons with a spread of 10^{-5} v.

The approximation made in Smith's treatment is essentially to treat the electron as classical and the field as quantized. It would seem, however, more appropriate to the experimental conditions to treat the electron as quantized and the field as classical. Under these conditions the phase integral approximation should give an accurate prediction of the probabilities of energy transfer. Assuming an electric field $E_0 \sin\omega t$ across the resonator gap of width a, it is found that the probability of an electron gaining or losing r quanta in passing through the field is $J_r^2(z)$, where $J_r(z)$ is the Bessel function of rth order, and $z=(eaE_0/\hbar\omega)(\sin\frac{1}{2}\theta/\frac{1}{2}\theta)$. θ is the transit angle defined by $\theta=a\omega/v$, with v the electron velocity.

This result may be understood from the fact that the Broglie waves of the electron are phase-modulated as they pass though the gap. In the limit of large numbers of quanta transferred, this distribution tends to the classical distribution.

[1] L. P. Smith, Phys. Rev. **69**, 195 (1946).

Self-Diffusion in Cobalt

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RADIOACTIVE Co^{60}, obtained from the AEC[1] was used as a tracer element in the study of self-diffusion in cobalt. This isotope has two gamma-ray spectra of energies 1.30 and 1.16 Mev, and a beta-ray spectrum of energy 0.31 Mev, necessitating a careful determination of the absorption coefficient which is essential in the method used for calculating the self-diffusion coefficient. In the present work this quantity was determined directly, in such a way as to approximate as nearly as possible the conditions present in the diffusion samples.

Samples of pure cobalt were coated with radioactive Co^{60} and placed in pairs, with active faces together, into a furnace which was evacuated to a pressure of less than 10^{-5} mm of Hg. Diffusion runs were made at temperatures of 1050°C, 1150°C, and 1250°C for 18 hours.

The mathematical analysis given by Steigman, Shockley, and Nix[2] relating the fraction of counts remaining after diffusion to the diffusion coefficient, D, was used to determine D. A plot of $\ln D$ *versus* $1/T$ gave the activation constant, A, and the activation energy, Q, where

$$D=Ae^{-Q/RT}.$$

The data indicate that the self-diffusion coefficient for cobalt is given approximately by

$$D=0.367e^{-67000/RT}\ \mathrm{cm^2\ sec.^{-1}}.$$

Good agreement was found between the value of Q obtained from the plot of $\ln D$ *versus* $1/T$ and the value obtained from the Langmuir-Dushman equation

$$D=(Qd^2/Nh)e^{-Q/RT},$$

where N is 6.06×10^{23} mole^{-1}, h is Planck's constant, and d is the lattice constant.

* This work was supported by the ONR.

[1] AEC, Isotopes Branch: Catalog and Price List No. 3, July, 1949.

[2] Steigman, Shockley, and Nix, Phys. Rev. **56**, 13 (1939).

A New Method of Integration of Weak Nuclear Magnetic Resonance Signals

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SUBSTANTIAL increases in our knowledge of nuclear magnetic resonance and its application to the study of the crystalline state of matter could be achieved if it were possible to obtain a high signal-to-noise ratio for nuclear magnetic resonance signals. The method employed heretofore to attain high signal-to-noise ratio consisted in reducing the band width of the detecting system. This, however, necessitates a scanning of the nuclear magnetic resonance signals point by point. High discrimination against noise could be effected if it were possible to add algebraically the signals obtained in individual observations. One method of doing this has been attempted by Bloch[1] and others who made use of the integrating property of photographic materials. However, this method is quite tedious as it requires taking several thousand photographs, and ultimately depends on the contrast qualities of the photographic materials. The limitation imposed by this method is due to the fact that photographic materials integrate positive quantities only, whereas to get true discrimination against noise, algebraic addition is necessary.

A method of doing this based on the principle of magnetic recording of sound has been developed in this laboratory. The method is as follows. A hollow steel cylinder is mounted coaxially on the shaft of an alternator which supplies the a.c. required to modulate the nuclear magnetic resonance. By means of a small magnetic recording head similar to those used in sound recording, nuclear magnetic resonance signals are recorded in a close spiral on the steel cylinder by slowly traversing the length of the cylinder as it rotates. The pick-up head covers the whole length of the cylinder. In this, the noise being random, it mostly gets canceled whereas the signal adds up. It is also possible that a direct addition of magnetism takes place at the place where signals are close. This, however, is small. Thus on the whole, recordings of nuclear resonance signals over a period of time taken to fill the steel cylinder are averaged and large discrimination against noise is possible. The equivalent number of observations for a period of one minute is about 1500 using an alternator giving 25≈. It is possible to see the signal on an oscilloscope separated out from noise as the time of integration increases. This method also gives a fair idea of the shape of the resonance signal.

In this connection, it is suggested that magnetic recording may be helpful in investigating the transient effects in nuclear magnetic resonance.

[1] F. Bloch and D. H. Garber, Phys. Rev. **76**, 585 (1949).