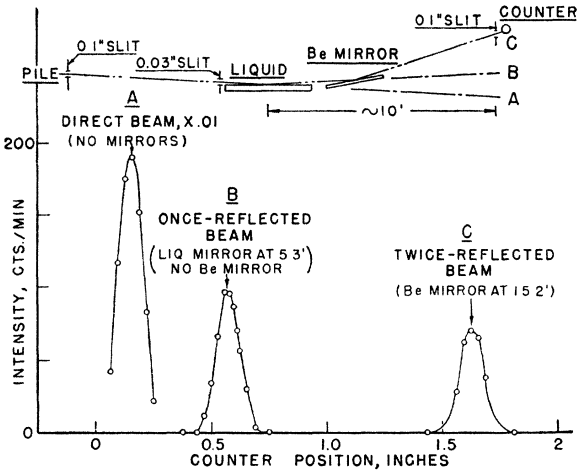

FIG. 1. Experimental arrangement of mirrors and the variation of the beam intensity with counter position.

that an accuracy of one percent in the amplitude would require measurement of a 10′ critical angle to 0.05′. Because of the difficulty of such an experiment, no plans for its performance were made.

Recently, however, we have devised a method which gives the coherent hydrogen amplitude very exactly with only a moderately accurate measurement of the critical angle. In this method, neutrons are specularly reflected from tri-ethyl benzene, a liquid containing a hydrogen to carbon ratio of 1.5 ($C_{12}H_{18}$). This compound is chosen because the (positive) amplitude of carbon is slightly greater than 1.5 times the (negative) amplitude of hydrogen. The critical angle, θ_c, for neutron reflection from the liquid is then proportional to $(a_C+1.5a_H)^{\frac{1}{2}}$, and a certain error in θ_c implies a much smaller error in a_H (approximately $\frac{1}{10}$th the error in θ_c for tri-ethyl benzene). If the two amplitudes are balanced more closely by changing the C−H ratio, the required accuracy in the critical angle becomes even less, but the angle would be so small that its measurement would not be feasible. With a carbon to hydrogen ratio of 1.5 and the previously accepted value for a_H, a critical angle of 6′ for a neutron wave-length of 8A was expected.

In spite of many misgivings, it proved to be extremely simple to reflect neutrons from the liquid surface. A thermal neutron beam (obtained from the Argonne pile) was collimated by 0.1-in. slits 10 ft. apart, and was incident on the liquid surface at an angle of 5.3′, as measured by the position of the reflected neutron beam relative to the direct beam (Fig. 1). The incident neutrons contained all the wave-lengths of the Maxwell distribution, hence all wave-lengths longer than the wave-length, λ_c, whose critical angle is 5.3′, were reflected. In order to measure λ_c, the beam of neutrons leaving the liquid was in turn reflected at a Be mirror. The intensity reflected by the Be mirror remains constant until the angle of incidence reaches the Be critical angle for the wave-length λ_c. The critical angle for the Be mirror as a function of wave-length had already been determined with monochromatic neutrons, hence λ_c could be obtained from the observed Be critical angle. As a second method of obtaining λ_c the transmission of the reflected neutrons in a standardized plate of gold was measured and λ_c calculated from the transmission and the known (Maxwellian) velocity distribution. The angle of incidence at the liquid mirror was then changed and the new λ_c measured again by both methods.

The critical wave-length, λ_c, for a particular angle, θ_c, at the liquid mirror then gives the amplitude $(a_C+1.5a_H)$:

$$\theta_c=\lambda_c[N(a_C+1.5a_H/\pi]^{\frac{1}{2}},$$

where N is the number of C atoms per cm³. The value of a_C is known to 0.5 percent from total cross-section measurements at energies slightly above thermal[9] and is taken to be 6.63×10^{-13} cm (corresponding to a free atom cross section of 4.7 barns). The value for a_H then becomes

$$a_H=-(3.75\pm0.03)\times10^{-13}\text{ cm}.$$

The standard error, 0.9 percent, is based on the statistics of the present measurement alone and does not include the (smaller) uncertainty in the carbon amplitude. Although there is no known source of systematic error, the measurement could be repeated with a different liquid to lessen the possibility of unknown errors and to push the accuracy even higher. Our result is five percent lower than the value of the hydrogen amplitude obtained in references 4 and 5 and is outside the error of those experiments as quoted by Blatt and Jackson[2] and Bethe.[3]

The changes in the nuclear force constants which will result from the present experiment can be estimated roughly from the curves given by Blatt, and Blatt and Jackson. From Fig. 2, reference 1, and Fig. 7, reference 2, it is seen that the new value of the hydrogen amplitude will raise the triplet n-p range to 1.71×10^{-13} cm and produce an increase in the singlet range of about 1×10^{-13} cm. This change in the singlet range is about half the amount needed to make the n-p range equal to the p-p range. Errors which are involved in the other constants necessary to infer the ranges may well make up the rest of the difference and thus attain consistency of the experimental constants with charge-independence of nuclear forces.

We wish to extend our thanks to Dr. R. Dodson, H. Prosser, and R. C. Anderson of the Brookhaven National Laboratory Chemistry Department for the purification of the tri-ethyl benzene, to Dr. M. Hamermesh for valuable help in the planning and analysis of the experiment, and to Dr. A. Wattenberg for his assistance while the measurements were being made at Argonne Laboratory.

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[1] J. M. Blatt, Phys. Rev. **74**, 92 (1948).
[2] J. M. Blatt and J. D. Jackson, Phys. Rev. **76**, 18 (1949).
[3] H. A. Bethe, Phys. Rev. **76**, 38 (1949).
[4] Sutton, Hall, Anderson, Bridge, De Wire, Lavatelli, Long, Snyder, and Williams, Phys. Rev. **72**, 1147 (1947).
[5] Shull, Wollan, Morton, and Davidson, Phys. Rev. **73**, 842 (1948).
[6] M. Hamermesh, Phys. Rev. **77**, 140 (1950).
[7] E. Fermi and L. Marshall, Phys. Rev. **71**, 666 (1947).
[8] D. J. Hughes and M. T. Burgy, Phys. Rev. **76**, 1413 (1949).
[9] W. W. Havens and L. J. Rainwater, Phys. Rev. **75**, 1296 (1949); W. B. Jones, Phys. Rev. **74**, 364 (1948); C. T. Hibdon and C. O. Muelhause, Phys. Rev. **76**, 100 (1949); C. G. Shull and E. O. Wollan (private communication); W. Selove (private communication).

Interatomic Distances in CF_3Br, CF_3I, and CF_3CN*

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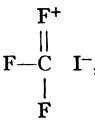
INVESTIGATIONS of the microwave spectra of CF_3Br, CF_3I, and CF_3CN have been made which allow a partial determination of the structures of these molecules. Attempts are being made to obtain molecules with other stable isotopes concentrated so that an unambiguous assignment of the atomic distances can be made.

$C^{12}F_3Br^{79}$ and $C^{12}F_3Br^{81}$.—Measurements of the $J=8\rightarrow9$, $10\rightarrow11$, and $11\rightarrow12$ transitions have been made. The analysis of the hyperfine structure is incomplete. The moments of inertia I_B are 399.9×10^{-40} g/cm² for CF_3Br^{79} and 403.7×10^{-40} g/cm² for CF_3Br^{81}. If tetrahedral bond angles to the carbon are assumed, the distance $d_{CF}=1.32_6$A and $d_{CBr}=1.93_3$A are obtained. These are in close agreement with the corresponding values in fluoroform,[1] $d_{CF}=1.326$A, and in methyl bromide,[2] $d_{CBr}=1.936$A. The CF distance is considerably smaller than the added covalent radii[3] (1.51A), while the CBr distance is, within experimental error, equal to the added covalent radii (1.94A) of C and Br.

CF_3I.—The $J=14\rightarrow15$ and $11\rightarrow12$ transitions were observed for CF_3I. Analysis of the hyperfine structure has not been completed. The moment of inertia I_B is equal to 551.0×10^{-40} g/cm². If tetra-

hedral angles are assumed and $d_{CF}=1.326$A, as in fluoroform and CF_3Br, the resulting value for d_{CI} is 2.16_2A. This is significantly longer than the added covalent radii (2.12A). A plausible explanation for the larger d_{CI} is that ionic structures of the type,



make significant contributions to the ground state. Though in this structure the positive charge is on the most electronegative atom, the unfavorable charge distribution may be counterbalanced by the strong tendency of F to form double bonds. As has been pointed out by Pauling,[4] the tendency of atoms to form multiple bonds decreases rapidly with descending rows in the periodic table. In this connection, it is of interest that the d_{CCl} distance 1.765A in CF_3Cl recently determined from microwave spectroscopy by Coles and Hughes[5] is slightly less than the added covalent radii, and that d_{CF} in CF_3F is considerably less than that in CH_3F.[6] It seems plausible that d_{CX} in CF_3X is lengthened or shortened in accord with the relative contributions of the above type of ionic structure and those containing $C=X^+$, the latter gaining predominance in the sequence X=I, Br, Cl, F.

CF_3CN.—The $J=5\rightarrow6$ and $7\rightarrow8$ transitions have been observed and the moment of inertia, $I_B=284.7\times10^{-40}$ g/cm^2 obtained for $C^{12}F_3C^{12}N^{14}$. If tetrahedral angles, $d_{CF}=1.326$A (as in CHF_3), and $d_{CN}=1.160$ are assumed, the d_{CC} obtained is 1.49_2A. The hyperfine structure due to N^{14} quadrupole coupling was barely resolvable.

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[1] Gilliam, Edwards, and Gordy, Phys. Rev. **75**, 1014 (1949).
[2] Gordy, Simmons, and Smith, Phys. Rev. **74**, 243 (1948).
[3] For F the revised radius proposed by Shomaker and Stevenson (J. Am. Chem. Soc. **63**, 37 (1941)) and for C the revised value suggested by Gordy (J. Chem. Phys. **15**, 81 (1947)) is employed.
[4] L. Pauling, *The Nature of the Chemical Bond* (Cornell University Press, Ithaca, 1940), p. 232.
[5] D. K. Coles and R. H. Hughes, Phys. Rev. **76**, 858 (1949).
[6] L. O. Brockway, J. Phys. Chem. **41**, 185 (1937).

The Scattering of Light by Light

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IN a recent paper, F. J. Dyson[1] has shown that the divergencies which occur in quantum electrodynamics may be consistently eliminated by the use of mass and charge renormalization, to all orders of approximation. One of the processes which might be thought to give rise to divergencies and which has to be discussed is the scattering of light by light. The divergence may be isolated in a logarithmically divergent integral which is not gauge invariant, and it is conjectured that this term vanishes for reasons of symmetry as is the case to lowest order in e^2. It seems that a formal proof can be given as follows.

The integral in question, in Dyson's notation, is $\int R_{\lambda\mu\epsilon\nu}(0, p^i)dp^i$, where p^i represent the internal variables corresponding to the degrees of freedom of a certain irreducible graph having only four external photon lines incident, and therefore a finite number of closed electron loops connected by internal photon lines. The energy-momenta of the external photons is put equal to zero. From the independent variables p^i, we may take a set t^i, one for each of the closed loops, corresponding to the energy-momenta with which the virtual electrons propagate within their own loops. The effect of the incident external photon lines will now be to replace $S_F(p)$ by $S_F(p)\gamma_\mu S_F(p)$ in particular electron lines of the reduced graph obtained by leaving out the external photon lines entirely. But there is the relation $(1/2\pi)(\partial/\partial t_\mu{}^i)S(p)=S(p)\gamma_\mu S(p)$ for electron lines in the loop carrying the variable t^i.

Hence the total effect of inserting external photon lines in all electron lines of the reduced graph is to give

$$\sum_{jklm}\int\frac{\partial}{\partial t_\lambda{}^j}\frac{\partial}{\partial t_\mu{}^k}\frac{\partial}{\partial t_l{}^e}\frac{\partial}{\partial t_\nu{}^m}[M(p^i)]dp^i,$$

where this expression also accounts correctly for the possible insertion of two or more photon lines at one electron line.

Since M is uniformly small for large t, this vanishes on integration over the energy momenta of the virtual electrons.

[1] F. J. Dyson, Phys. Rev. **75**, 1736 (1949).

Ferromagnetic Resonance Absorption by Mo Permalloy at 2920 Mc/Sec.

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FERROMAGNETIC resonance absorption at microwave frequency has been studied by several authors.[1,2] Except in the first experiment, the frequency used was greater than 8000 mc/sec. usually about 30,000 mc/sec. We performed the experiment at 2920 mc/sec.

The resonance condition for plane specimen is given by the equation:[3]

$$\omega=\gamma(BH)^{\frac{1}{2}}, \qquad (1)$$

where ω is the angular frequency of microwave, γ is the gyromagnetic ratio of electron, B is the magnetic induction, and H is the magnetic field strength. Since the resonance field is very low for 2920 mc/sec., we used Mo Permalloy for the absorbing material,* which saturates magnetically at few oersteds and whose saturation magnetic induction is 8500 gauss.

The apparatus used is a magic tee and a high Q resonant cavity of rectangular cross section (7.0×3.5 cm^2). The cavity is of one wave-length size and is connected to a wave guide which forms one branch of the magic tee, by a rectangular slot. On the end plate, a thin plate of Mo Permalloy is sometimes soldered and sometimes set by screws. On the front half of the cavity, a finely adjustable plunger is put on, by which the resonant frequency of the cavity can be changed very finely.

First, keeping the cavity always at resonance by adjusting the plunger, the absorption by Mo Permalloy is measured as a function of static magnetic field which is perpendicular to the high frequency magnetic field. The result obtained is shown in Fig. 1.

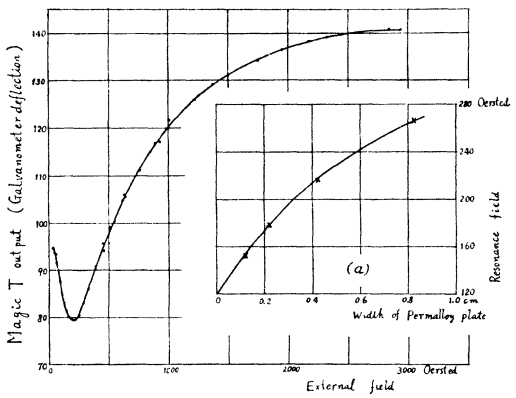

FIG. 1. Absorption curve by Mo Permalloy (2.9×3.4 cm^2 in area and 0.053 cm in thickness) at 2920 mc/sec. (a) Magnetic field strength at maximum absorption.