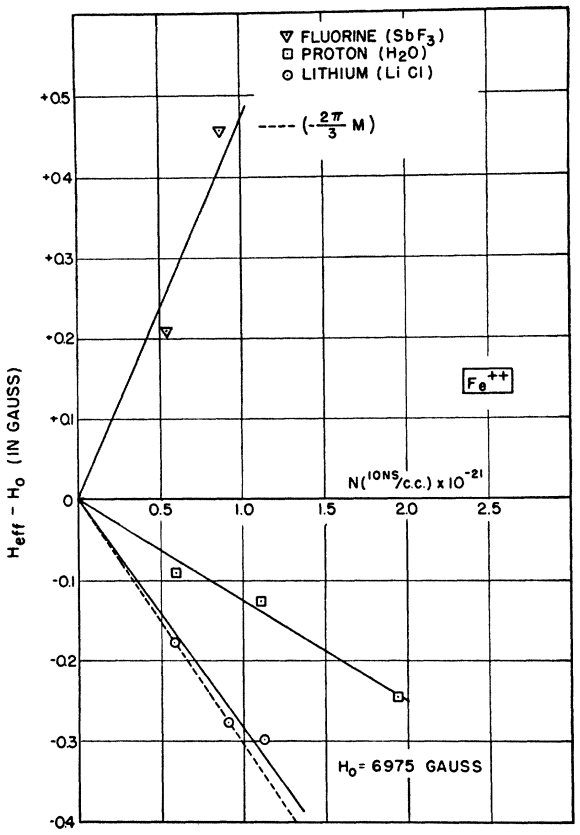

FIG. 1. The shift of the magnetic resonance of F^{19}, H^1, and Li^7 in aqueous solutions containing various amounts of $FeCl_2$. The samples have the shape of a long cylinder with the axis perpendicular to H_0. For $q=0$ the dotted line would result.

in single crystals.[7,8] A static calculation of $g_{\parallel}$ and $g_{\perp}$ is permissible if the motion in the liquid, and therefore the change in the electric field, is described by frequencies which are small compared to the multiplet splitting of the paramagnetic ion. This is a reasonable assumption. The magnetic moment of 1 cc of the solution, containing N ions, is then given by averaging the Langevin formula over all angles

$$M=Ng^2\beta^2H_0S(S+1)/3kT=N(g_{\parallel}^2+2g_{\perp}^2)\beta^2H_0S(S+1)/9kT. \quad (3)$$

The time average local magnetic field at the position of the F^{19} nucleus is obtained by first multiplying the moment of a single paramagnetic ion averaged over the spin orientations by $(-1+3\cos^2\theta)a^{-3}$, where a is the distance between the two ions in the ion pair. Then we take the average over all angles, and finally multiply by the probability $4\pi Nb^3/3$ to find a paramagnetic ion in the sphere of attraction of the F^{19} nucleus. The result, which in general will not vanish, is

$$qM=4\pi Nb^3a^{-3}(4/15)(g_{\parallel}^2-g_{\perp}^2)\beta^2H_0S(S+1)/9kT. \quad (4)$$

Dividing Eq. (4) by Eq. (3) an expression for q is found. The experimental value of q for the F^{19} resonance in a solution of $FeCl_2$ can be explained by giving $g_{\parallel}^2-g_{\perp}^2$ a value which is comparable to those observed in crystals. Of course, there is considerable uncertainty in the geometrical factor b^3a^{-3}, which was introduced in a rather crude way. One must expect, however, that the q value for the Li^7 resonance is much smaller, as has been observed experimentally. The average distance of approach between a Li^+ and a Fe^{++} ion will be much larger and consequently not only the factor a^{-3} is smaller, but also the anisotropic electric field at the Fe^{++} ion, and therefore the anisotropy factor $g_{\parallel}^2-g_{\perp}^2$. In the case of protons, bound in water molecules, more elaborate considerations would be necessary. Even for single ions the geometrical situation has been oversimplified. It seems fruitless to attempt to calculate the detailed configurations of ions and molecules in these concentrated solutions. An experimental determination of the shift for each different type of solution seems necessary. But the order of magnitude of the experimental shift can be understood from the theoretical model, which also leaves room for negative q-values.

It is conceivable that other effects of the same order of magnitude also contribute to the shift. An exchange effect between the F^- and Fe^{++} ion, in which an unbalanced electron spin has a small but finite probability to be found on the fluorine ion, has been suggested by Purcell.[9] The unbalanced spin would create a very large magnetic field at the F^{19} nucleus for a small fraction of the time. This exchange effect would also depend strongly on the distance a, and a much smaller shift for Li^7 is again expected.

* This work has been supported in part by the Signal Corps, the Air Materiel Command, and the ONR.
** Society of Fellows.
[1] Bloembergen, Purcell, and Pound, Phys. Rev. **73**, 679 (1948).
[2] H. A. Lorentz, *Theory of Electrons* (Teubner, Leipzig, 1909), p. 138.
[3] W. C. Dickinson, Phys. Rev. **77**, 736 (1950).
[4] E. M. Purcell and N. F. Ramsey, Phys. Rev. **78**, 807 (1950).
[5] W. G. Proctor and F. C. Yu, Phys. Rev. **77**, 717 (1950).
[6] J. H. Van Vleck, *Electric and Magnetic Susceptibilities* (Oxford University, Press, New York, 1932), p. 285.
[7] D. Polder, Physica **9**, 709 (1942).
[8] B. Bleaney and D. J. E. Ingram, Nature **164**, 116 (1949).
[9] Private communication.

Coincidence Studies of the Disintegration of Sc^{44}*

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INVESTIGATIONS of the radioactivity of Sc^{44} have been made by Smith[1] and by Hibdon, Pool, and Kurbatov.[2] These authors showed that the disintegration of Sc^{44} involves an isomeric transition in the parent nucleus since two periods, 52 and 4.1 hr. were found. Smith showed that the 52-hr. state lies higher than the 4.1-hr. state and feeds the lower state by an internally converted gamma-ray of 0.27 Mev energy. The 4.1-hr. state emits positrons of 1.45 Mev energy. Hibdon, Pool, and Kurbatov showed that an additional gamma-ray was emitted and determined its energy, by lead absorption, as 1.33 Mev.

In the present experiments coincidence and absorption techniques have been employed in order to get further information on the decay scheme of this element. The sources were prepared by

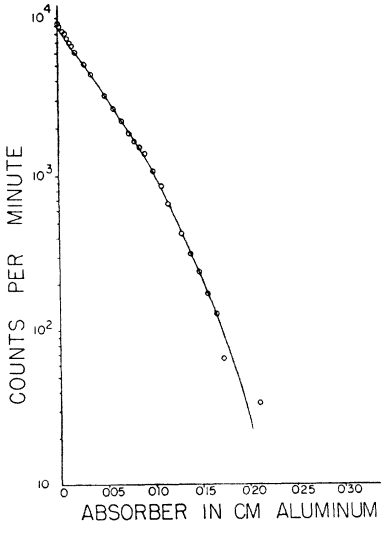

FIG. 1. Absorption of positrons in aluminum.

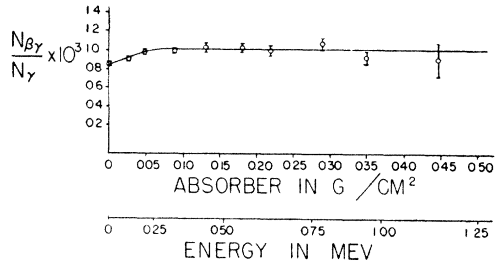

FIG. 2. Beta-gamma-coincidences in Sc^{44}.

bombarding separated K^{41}, obtained from the Y-12 plant of Oak Ridge, by 23-Mev α-particles with the cyclotron. The scandium was separated chemically and enough time was allowed to elapse before the beginning of the experiments so that the decay followed the 52-hr. period of the isomeric state.

A beta-ray absorption curve was taken using an end-window counter with a mica window of surface density 4 mg/cm². The absorption curve is shown in Fig. 1, in which the logarithm of the intensity is plotted against absorber thickness in centimeters of aluminum. An analysis of the data by the method of Bleuler and Zunti[3] yields a value of 1.54 Mev for the positron end point. In addition, the slight rise in the curve at 0.015 cm of aluminum shows the presence of the internal conversion electrons from the gamma-ray at 0.27 Mev.

The energy of the gamma-rays was determined by measuring the coincidence absorption of Compton electrons. The curve shows an "end point" corresponding to a gamma-ray of 1.2 Mev energy, with a break at lower energies corresponding to annihilation radiation. A Bleuler-Zunti analysis of the data gives 1.18 Mev for the energy of the harder gamma-ray.

Beta-gamma-coincidences were measured in the usual manner using a lead cathode counter as the gamma-counter and an end-window counter as the beta-counter. The results are shown in Fig. 2 in which $N_{\beta\gamma}/N_\beta$ is plotted against the range of the positrons. The number of beta-gamma-coincidences per disintegration is independent of the energy of the positrons from 0.25 to 1.2 Mev, indicating that there is only one positron group. The decrease in $N_{\beta\gamma}/N_\beta$ from 1.01×10^{-3} at 0.25 Mev to 0.85×10^{-3} at the lowest energies obtained is caused by the internal conversion electrons of the 0.27-Mev line. From a knowledge of the efficiency of the counter[4] and the value for $N_{\beta\gamma}/N_\beta=1.01\times10^{-3}$, one obtains a value of about 1.0 Mev for the energy of the coincident gamma-ray in Sc^{44}. It would appear, therefore, that, following the isomeric transition, the 4.1-hr. state disintegrates by the emission of one positron group of about 1.5 Mev energy followed by a 1.18-Mev gamma-ray.

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[1] G. P. Smith, Phys. Rev. **61**, 578 (1942).
[2] Hibdon, Pool, and Kurbatov, Phys. Rev. **67**, 289 (1945).
[3] E. Bleuler and W. Zunti, Helv. Phys. Acta **19**, 375 (1946).
[4] E. T. Jurney and F. Maienschein, Rev. Sci. Inst. **20**, 932 (1949).

Ferromagnetic Resonance in Manganese Ferrite and the Theory of the Ferrites

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WE have observed microwave ferromagnetic resonance absorption at room temperature at a frequency of 24,164 Mc/sec. in polycrystalline specimens of manganese ferrite $Fe(MnFe)O_4$ in the form of spheres ranging from 0.035 to 0.060 cm in diameter. Typical results are shown in Fig. 1. The observed g-value in the resonance equation $\hbar\omega=g\mu_B H$, as deduced from the average of runs on four separate spheres of various sizes, is found to be 1.99(7) with a mean deviation of ±0.003. The half-width at half-power of the resonance line is about 240 oersteds. The field intensities were measured by proton resonance.

On the simplest picture of the electronic structure of manganese ferrite the carriers of the magnetic moments are to be found among the Mn^{++} and Fe^{+++} ions. Each of these ions has a half-filled $3d$ shell and a ^6S ground state, leading to a predicted g-value very close to the free spin value 2.00. It is to be noted that our experimental results are in good agreement with the theory.

Measurements of the saturation magnetization were made earlier by one of us[1] on the specimen employed in the microwave work, and give σ_∞ (0°K) = 110.6 for the moment per gram extrapolated to infinite fields at 0°K. From this value we calculate

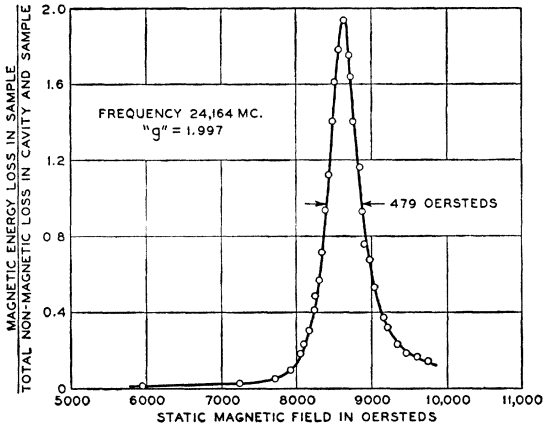

FIG. 1. Resonance absorption in polycrystalline manganese ferrite (0.024-in. diameter sphere).

that the contribution of each manganous ion is $4.6\mu_B$, where we have used Néel's hypothesis[2] that only the manganous ions Mn^{++} contribute to the magnetization, the Fe^{+++} ions being in an antiferromagnetic arrangement. Other measurements by Gorter[3] give $5.0\mu_B$.

This type of hypothesis had been anticipated by Guillaud[4] in the case of the ferromagnetic alloy Mn_2Sb, where one imagines that two types of manganese ions on two different sites are oriented antiparallel. Since, however, in manganese ferrite the Mn^{++} and Fe^{+++} ions are isoelectronic, the predicted g-value of 2.00 is independent of the particular way in which component ions are coupled together. It is in any case a satisfying confirmation of the simple ionic model of the electronic structure of ferrites that the observed g-value is in agreement with expectation.

[1] C. Guillaud, Comptes Rendus **230**, 1256 (1950).
[2] L. Néel, Ann. de physique **3**, 137 (1948).
[3] E. W. Gorter, Comptes Rendus **230**, 192 (1950).
[4] C. Guillaud, thesis, Strasbourg (1943).

Isomerism in Pb^{204} and "Memory" in Angular Correlation*

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THE only even-even nucleus for which a fairly long-lived metastable state is known is Pb^{204}. Here a lifetime of 65 to 68 minutes has been reported[1] for an isomeric transition with an energy of about 1 Mev. It seemed to be of interest to investigate this rather unique case further. In order to do so we obtained Pb^{204m} as a daughter of Bi^{204} (12 hr.) which in turn was produced by a $(d, 2n)$ reaction from lead in the M.I.T. cyclotron. In some experiments, lead enriched in the Pb^{204} isotope was used.[2] The lead