The Nuclear Magnetic Moment of Scandium[45]

ROBERT E. SHERIFF* AND DUDLEY WILLIAMS
Ohio State University, Columbus, Ohio
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THE nuclear magnetic resonance due to Sc^{45} has been located in a magnetic field of 5000 gauss at 5.14 Mc/sec. by means of the super-regenerative detection method.[1,2] A strong signal of the same order of intensity as for the Br^{79} signal in saturated aqueous NaBr was found in a saturated aqueous solution of $ScCl_3$. Our preliminary value of the ratio of the resonance frequency of the Sc^{45} signal to that of the Br^{79} signal in the same magnetic field is:

$$\nu(Sc^{45})/\nu(Br^{79}) = 0.96954 \pm 0.00006.$$

Using Zimmerman and Williams' value[1] for the ratio of the Br^{79} and proton resonance frequencies in the same magnetic field, we find:

$$\nu(Sc^{45})/\nu(H^1) = 0.24296 \pm 0.00005.$$

Making a diamagnetic correction[3] of 0.260 percent and using the value 2.79255 nuclear magnetons for the proton's magnetic moment[4] we find for the nuclear g-value of Sc^{45}:

$$g(Sc^{45}) = 1.3605 \pm 0.0003.$$

The spin of Sc^{45} is known to be 7/2 from hyperfine structure studies.[5,6] Thus the magnetic moment is:

$$\mu(Sc^{45}) = 4.7617 \pm 0.0010 \text{ nuclear magnetons.}$$

This value agrees very closely with the best spectroscopic value[7] of 4.8 nuclear magnetons.

* AEC Research Fellow.
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The Half-Life of Strontium[90]*

RUTH I. POWERS AND A. F. VOIGT
Institute for Atomic Research and Chemistry Department, Iowa State College, Ames, Iowa
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THE long-lived strontium isotope, Sr^{90}, one of the nuclides resulting from uranium fission, is important because of its high yield in fission, about five percent, as well as its long half-life. In any fission product mixture more than a few years old, this nuclide and its daughter, the 62-hr. Y^{90}, together constitute a large fraction of the total activity. Consequently the half-life of the parent Sr^{90} assumes some importance in calculations dealing with long term use or storage of the fission products.

This nuclide was first reported in this country by Nottorf,[1] of this laboratory,[2] in 1943. The decay of several samples which he prepared have now been followed for seven years, by means of a Lauritsen electroscope, and the half-life resulting from these measurements is sufficiently different from that currently used to warrant its publication at this time. The currently accepted value of 25 yr. is an average between the 23±3-yr. value reported by Nottorf[3] as a result of measurements over two and one-half years, and the value of 24 to 30 yr. estimated by Glendennin,[4] and Coryell[5] from fission yield data.

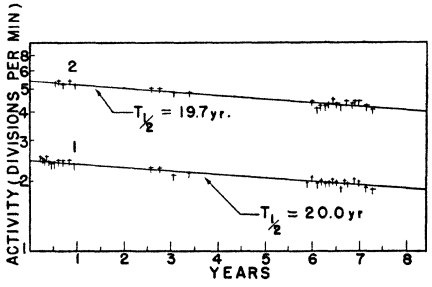

FIG. 1. Decay curve of Sr^{90}.

The original samples, after separation from cyclotron bombarded uranyl nitrate, were purified by repeated carbonate precipitations, and mounted as strontium carbonate.

In order not to measure any of the 55-day Sr^{89}, which was originally present, sample 1 was read with 746 mg/cm² of aluminum absorber, while sample 2 was read with 714 mg/cm². The beta-ray from Sr^{89} has an energy of 1.5 Mev and a range of 680 mg/cm² of aluminum. Before each reading the stability of the electroscope was checked with a uranium standard. Noteworthy is the fact that the Lauritsen electroscope has remained stable over this period of seven years.

The method of least squares[6] was used to draw the best possible straight line through each set of data (Fig. 1). From this, a half-life of 20.0 yr. was obtained with sample 1, while sample 2 gave 19.7 yr. Therefore the half-life of Sr^{90} may be taken as 19.9±0.3 yr.

* This work was performed at the Ames Laboratory of the U. S. AEC.
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[2] Present address, E. I. du Pont de Nemours and Company, Parlin, New Jersey.
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The Angular Distribution of Protons from the $B(\alpha, p)C$, C^* Reaction

J. L. PERKIN
Wheatstone Laboratory, King's College, London, England
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USING a 5-mc polonium α-particle source and a cloud chamber, Roy[1] examined the angular distribution of protons from the reaction $B(\alpha, p)C$, C^*. The angular distributions of the two groups with Q-values of 0.42 and 0.09 Mev were found to be roughly isotropic within the wide limits of statistical fluctuation imposed by the small number of protons recorded.

Creagan[2] examining the emission of protons at 0° and 90° found the intensity of protons from transitions to the ground state (Q=4.07 Mev) in the forward direction to be small compared with that observed at 90°.

The present experiments were performed using a 1.4-mc polonium α-particle source, unbacked boron targets, and Ilford C2 photographic plates to record the emitted protons.

The photographic plates were held in a frame by retaining screws such that the plane of the emulsion lay 3 mm below the line joining the source and target.

Boron targets were made by smearing a suspension of boron powder in a collodion-ether solution on glass plates. In this way unbacked and fairly uniform tagets could be obtained with thicknesses as low as 0.2 mg/cm². Microscopic examination showed that the relative amount of collodion in the film could be reduced to quite small proportions before the target became too fragile.

The source holder and collimating arrangement were designed so that the spread of the α-beam at the target was ±10°, and so that the maximum angle at which the plate could see all the target was as much as 170° in one case.

Non-resonance experiment. For the first exposure (14 days) the energy of the α-particles at the target was set at 4.3 Mev. This corresponded to the top of the potential barrier of the B^{10} nucleus. A target of thickness 0.35 mg/cm² was used.

About 4000 proton tracks were measured and groups corresponding to Q-values of 4.08±0.12, 3.35±0.25, 0.65±0.15, 0.15±0.15, and −0.57±0.15 Mev, were observed. The over-all intensities of the first four of these groups were in the ratio 10:1:100:50. Comparison of the Q-values found with the more precise ones obtained by Creagan[3] since this work was completed,

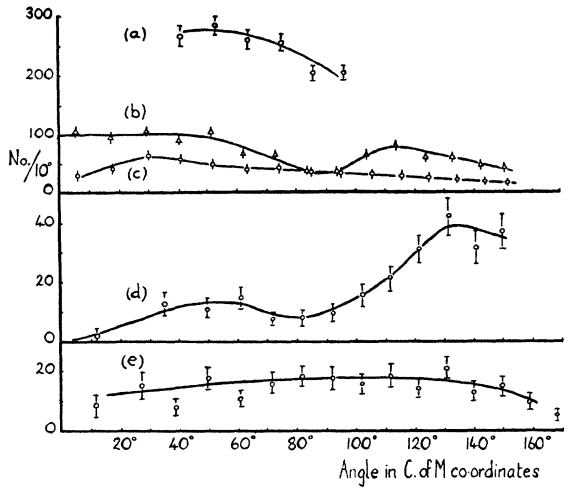

FIG. 1. Angular distribution of protons from the reaction $B(\alpha, p)C$, C^*.
(a) $E=4.3$ Mev $Q=-0.57$ Mev.
(b) $Q=0.65$ Mev.
(c) $Q=0.15$ Mev.
(d) $Q=4.08$ Mev.
(e) $E=2.9$ Mev $Q=4.08$ Mev.

indicates that the group observed at 0.15 Mev is probably the superposition of two groups at $Q=0.31$ and 0.07 Mev. The weak group observed at $Q=3.35$ Mev was not found by Creagan.

The angular distributions of the protons from the groups with Q-values 4.08, 0.65, 0.15, and -0.57 Mev, are shown in Fig. 1.

The vertical lines indicate the statistical error. The groups at $Q=0.65$ and 0.15 Mev were only partially resolved and are subject to an additional error ($\sim$10 to 20 percent) due to the empirical method of dividing these groups at any angle. Contamination by recoil protons in the forward direction and by α-particle background at higher angles severely restricted the distribution of the group at $Q=-0.57$ Mev.

All the angular distributions for this non-resonance experiment show some degree of anisotropy and asymmetry. The ground state group in particular has a very low minimum at 0° and a pronounced maximum in the backward direction confirming the results of Creagan discussed earlier. An examination of Roy's results for the groups at 0.42 and 0.09 Mev corresponding to the groups found at 0.65 and 0.15 Mev shows that his results are not in contradiction to those observed. The statistical accuracy of the cloud-chamber work was not sufficient however to establish the shape of these distributions with any certainty.

Resonance experiment. The α-particle energy at the target for the second exposure (28 days) was reduced to 3.4 Mev. (i.e., below the energy necessary to penetrate through the top of the barrier of the B^{10} nucleus as found by Miller *et al.*[4] The target was replaced with one of stopping power 1.4 mg/cm^2. One high energy proton group was observed which, if it is assumed to be due to ground state protons, gives a value of 2.9 Mev for the α-particle resonance energy.

It is energetically impossible for this group to be formed in a reaction with the heavier boron isotope B^{11}. Miller *et al.*[4] using an ionization chamber were the first to find this resonance level. Their experiments, however, were not decisive as the proton groups they were able to observe ($Q=0.4$ and -0.1 Mev) could have been assigned to the $B^{11}(\alpha, p)C^{14}$, C^{14*} reaction.

Examination of the distribution (*e*) in Fig. 1 shows that the distribution of this ground state group at resonance is practically isotropic between the limits 30 to 150°.

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Theoretical Hall Coefficient Expressions for Impurity Semiconductors*

V. A. JOHNSON AND K. LARK-HOROVITZ
Purdue University, Lafayette, Indiana
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IN the analysis of impurity semiconductors, the carrier density n (per cm^3) and the Hall coefficient R (cm^3/coulomb) are assumed to be related by

$$R=\pm 3\pi/(8ne), \tag{1}$$

where e is the electronic charge in coulombs. The derivation of Eq. (1) assumes that the mean free path of a conduction electron is independent of its kinetic energy and that the applied magnetic field is weak. The effects upon Eq. (1) of certain deviations from these assumptions have been calculated.

The theory of the Hall effect yields a general expression for the ratio

$$r=\frac{|R|}{(1/ne)}=\frac{3n}{4\pi m}\frac{I_2}{I_1^2+(eH/m)^2 I_2^2} \tag{2}$$

where H is the magnetic field, m is the effective electron mass, and

$$I_1=\int_0^\infty \frac{lv^3}{1+(eHl/mv)^2}\frac{\partial f_0}{\partial \epsilon}dv; \quad I_2=\int_0^\infty \frac{l^2v^2}{1+(eHl/mv)^2}\frac{\partial f_0}{\partial \epsilon}dv,$$

in which l is the mean free path, f_0 the unperturbed distribution function, and $\epsilon=mv^2/2$. If one uses classical statistics and replaces ϵ/kT by x, then

$$r=(3\pi^{\frac{1}{2}}/4)J_2(J_1^2+\alpha J_2^2)^{-1} \tag{3}$$

where

$$J_1=\int_0^\infty lx^2e^{-x}(x+\alpha l^2)^{-1}dx; \quad J_2=\int_0^\infty l^2x^{\frac{1}{2}}e^{-x}(x+\alpha l^2)^{-1}dx;$$

$$\alpha=e^2H^2/(2mkT).$$

In the weak field approximation ($\alpha\approx 0$) Eq. (3) leads to Eq. (1) if l is independent of the energy ϵ. However, if l is proportional to ϵ^2, as in the Rutherford-type scattering by impurity ions,[1] Eq. (3) yields $r=315\pi/512$. It has been found that the resistivity ρ of impurity semiconductors can be explained[2] as the sum of ρ_L, resistivity due to scattering by lattice ions, and ρ_I, resistivity due to scattering by impurity ions. The mean free path l_L associated with ρ_L is independent of ϵ, while l_I is proportional to ϵ^2. The effective mean free path l is found by reciprocal addition

$$l=l_Ll_I/(l_L+l_I). \tag{4}$$

From resistivity theory one obtains

$$l_L=3(2\pi mkT)^{\frac{1}{2}}(4ne^2\rho_L)^{-1} \tag{5a}$$

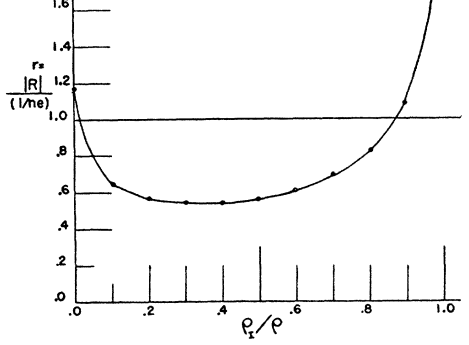

FIG. 1. The dependence of $r=|R|/(1/ne)$ on the ratio of ρ_I, resistivity due to Rutherford-type scattering by impurity ions, to ρ, the total resistivity.