The Magnetic Moment of the Deuteron

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RECENTLY Nafe, Nelson, and Rabi[1] have made very precise measurements of the hfs separations of the $^2S_{\frac{1}{2}}$ ground state of the hydrogen and deuterium atoms. The ratio of the hfs separations depends theoretically only on the ratio of the nuclear magnetic moments and the ratio of the reduced masses of the hydrogen and deuterium atoms:

$$\frac{\nu_H}{\nu_D}=\frac{4}{3}\frac{\mu_H}{\mu_D}\left(\frac{m_H}{m_D}\right)^3. \quad (1)$$

The initial experimental value of ν_H/ν_D reported[1] did not agree with the computed value. Halpern[2] has given reasons why the reduced masses might enter to the $\frac{3}{2}$ power rather than the cube. Since the precision of the computed value depends upon the precision of measurement of μ_H/μ_D, we have undertaken to improve the precision of this value. Previous measurements gave the value 3.2571 ± 0.001.[3,4]

The measurements were carried out by means of the nuclear r-f absorption techniques of Purcell, Torrey, and Pound[5] and the author.[6] Two series of measurements were made in fields near 8000 gausses. In one series separate samples of D_2O and H_2O were placed in a magnetic field made as homogeneous as possible, and resonance absorption was detected simultaneously, using two detectors. The frequencies at which resonance occurred for both samples at the same value of the magnetic field were measured. The samples were then interchanged and the measurements repeated.

In the second series, a single sample of 85 percent D_2O was used, and two coils were wound about it; resonance was detected as before.

The results of the measurements are

$$\mu_H/\mu_D=3.25731\pm0.00015.$$

The precision of these results was limited by a phenomenon we have not been able to explain. The deuteron resonance, displayed on a cathode-ray tube sweep, did not appear at two points on the sweep corresponding to the same value of the magnetic field, as does the proton resonance when sine-wave magnetic-field modulation is used. Instead, two rather indefinite series of wiggles appeared on the trace at values of the magnetic field which were not equal, but corresponded to times slightly later than those at which resonance was expected to occur. The displacement was roughly constant in magnetic field, at about 3 gausses above and below the resonant field, respectively. The type of signal observed was not affected by the addition of $FeCl_3$ to the D_2O, by switching from the bridge type of detection to the super-regenerative detector, or by changing the amplitude of the magnetic-field modulation.

Because of this effect the measurements could not be made by superposing the deuteron and proton resonances, as had originally been intended. Instead, the proton resonances had to be located on the trace at points corresponding to a field midway between the values at which the deuteron signals appeared.

The computed value of the hfs separation rate ν_H/ν_D, using Eq. (1) and the new value for μ_H/μ_D, is 4.33954 ±0.0002. A $\frac{3}{2}$ power dependence of the reduced mass gives a computed value of 4.34131 ± 0.0002.

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Disintegration Scheme of 1.7-Year Cs^{134}

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THE disintegration of the long-lived isomer of Cs^{134} has been studied with a short magnetic lens β-ray spectrometer together with coincidence techniques.

The shape of the β-ray spectrum was studied down to the low energy cut-off of the counter window ($\sim$0.015 Mev) by use of a source of thickness $\sim$0.1 mg/cm^2 mounted on a mica backing ($\sim$1.0 mg/cm^2). A Fermi plot of this spectrum, using the exact Fermi function of (Z, η) for $Z=55$, is shown in Fig. 1. The spectrum has a maximum energy

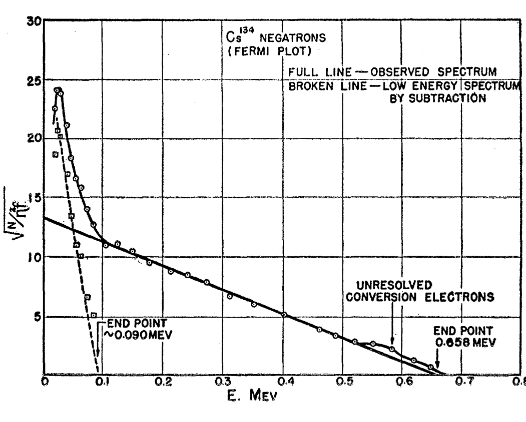

FIG. 1. Fermi plot of β-ray spectrum of Cs^{134}.

of 0.658 ± 0.030 Mev, and the Fermi plot is very closely represented by a straight line down to an energy of $\sim$0.09 Mev. To determine whether the rise at low energies is due to the β-spectrum being complex, a calibrated γ-counter was placed behind the source in the β-ray spectrometer, and coincidences were observed between γ-rays and β-rays above and below the break in the Fermi plot. The two β-ray energies selected were 0.250 Mev and 0.035 Mev, respectively. An observation of the number of coincidences per recorded β-ray showed that, on the average, each β-ray at the 0.035-Mev point is accompanied by 1.20 ± 0.03 times as much γ-ray energy as each high energy β-ray. This indi-

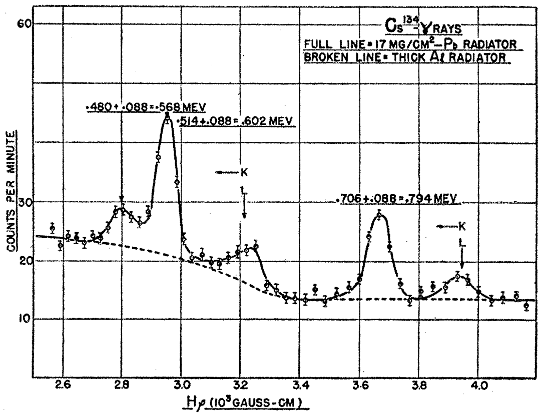

FIG. 2. Secondary-electron spectrum of photoelectric conversion of Cs^{134} γ-rays.

cates that there is a separate low energy β-spectrum superposed on the main β-spectrum. The above ratio remained unchanged when 3-mm Pb was placed in front of the γ-counter, thus demonstrating that the γ-ray quanta accompanying electrons of the low energy spectrum have energies of the same order as those accompanying the high energy spectrum. When the spectra are extrapolated to zero energy and subtracted under the assumption that each spectrum is represented by a straight line on a Fermi plot, the integrated number of electrons in the low energy spectrum represents about 28 percent of all the disintegration electrons.

The secondary-electron spectrum obtained by photoelectric conversion of the γ-rays in a thin (17 mg/cm²) Pb radiator is shown in Fig. 2. Three γ-rays are observed, whose energies are, respectively, 0.568 ± 0.015, 0.602 ± 0.015, and 0.794 ± 0.015 Mev, with relative intensities of 0.26, 1.0, and 1.0, respectively, after allowing for the energy variation of the photoelectric cross section.

These results are consistent with the disintegration scheme proposed in Fig. 3. The order of the 0.602- and 0.794-Mev γ-rays is unknown. The portion of this scheme associated with the 0.658-Mev β-spectrum is in agreement with the results given by Siegbahn and Deutsch,[1] within the combined experimental errors. The activity available for the present work was not sufficient to observe the 5 percent crossover transition which was observed by Siegbahn and Deutsch. It should be pointed out that if the alternative level arrangement shown as a broken line in Fig. 3 is adopted, the crossover transition may occur from the 1.964-Mev level to the 0.602-Mev level. The accuracy of the energy measurements of the crossover γ-ray reported by Siegbahn and Deutsch is insufficient to decide between the two alternatives.

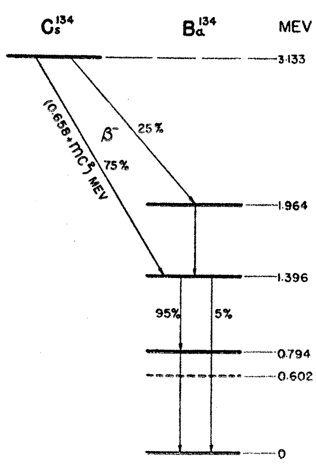

FIG. 3. The disintegration scheme of Cs^{134} (1.7 years).

It is interesting to note that the fractional occurrence of the 0.09-Mev β-disintegrations obtained by extrapolation of the Fermi plot ($\sim$28 percent) agrees closely with that obtained from the γ-ray intensities ($\sim$25 percent). This suggests that the true shapes of these β-spectra may continue as a straight line on a Fermi plot to zero energies.

A more detailed report of this work will be submitted for publication in the Canadian Journal of Research.

[1] K. Siegbahn and M. Deutsch, Phys. Rev. 71, 483(A) (1947).

A Modified Stark-Effect Modulation Spectrograph for Microwaves*

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HUGHES and Wilson[1] have described a novel form of microwave spectrograph which utilized a Stark-effect modulation at radiofrequency. In this instrument the usual type of absorption wave-guide section was fitted with a central electrode in the form of a flat brass strip inserted parallel to the broad sides of the wave guide and insulated from the walls.[2] An oscillator (80 Kc) supplied a radiofrequency to this electrode, which could also be given a d.c. bias if desired. The Klystron reflector was modulated with a saw-tooth voltage at 20 cycles per second; this saw-tooth voltage was also applied to the horizontal plates of an oscilloscope. When the frequency of the Klystron passed through an absorption frequency of the gas in the cell, a part of the microwave energy was modulated because of the varying absorption of the gas as the Stark components were varied in frequency by the alternating 80-Kc field. A narrow-band radio receiver was tuned to 80 Kc or a multiple of this frequency and used to amplify the appropriate radiofrequency components of the single-crystal detector output. Hughes and Wilson reported that this type of spectrograph was more sensitive than the types previously described. The shape of the curve (corresponding to an absorption line) displayed on the oscilloscope screen is a complicated function of the nature of the Stark effect for the molecule being studied and of the modulating voltage. Since the publication of their first note, Wilson and his colleagues have improved their spectrograph by using a square-wave modulation voltage on the central