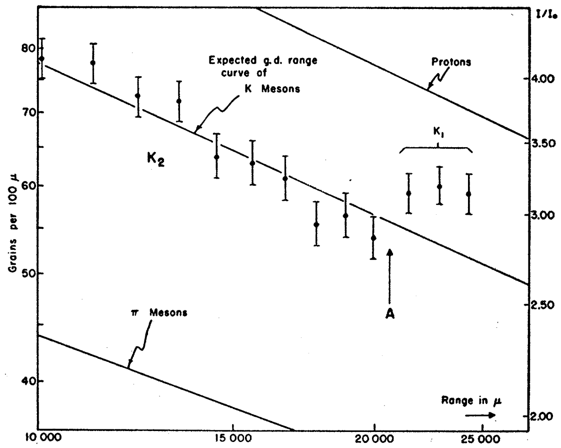

FIG. 2. Grain density *vs* range measurements (log-log scale) of K_2. Solid lines: expected curves for protons, K mesons, and π mesons. (Note: the three points of K_1 are plotted as a function of their distance from the endpoint of K_2. Therefore, it is not the correct grain density-range plot of K_1.)

may be argued. From the relative grain density, the velocity of K_2 is about 1.05 times the velocity of Y_1. Since the angle of deflection is only 10°, the Q value of the decay $Y_1 \rightarrow K_2 +$neutral is about 5 Mev no matter what the neutral particle is. Therefore, the mass of Y_1^- will essentially be the mass of K_2 plus the mass of the neutral particle. The known hyperons, Λ^-, Ω^-, have masses equivalent to 1200 and 1320 Mev, respectively. $Y_1^- \rightarrow K_2^- + n$ would require $M(Y_1) = 1440$ Mev, and $Y_1^- \rightarrow K_2^- + K^0$ would require $M(Y_1) = 1000$ Mev. Thus the possibility of an alternate two-body mode of decay of a known hyperon is ruled out.

If it is a three-body decay process, nothing can be said about the Q value. But, even in this case, it seems unlikely to be an alternate three-body decay scheme of a known hyperon because of the following argument. The scheme $Y_1^- \rightarrow K_2^- + n$ (or Λ^0)+neutral+Q can be discarded since it gives for the mass of Y_1^- at least 1440 Mev, which is much over the masses of the known hyperons. If $Y_1^- \rightarrow K_2^- + K^0$ (or π^0)+neutral+Q, by a proper choice of Q and the neutral particle, one can make the mass of Y_1^- agree with the mass of Λ^- or Ω^-. But, by assuming the last decay scheme, we are admitting the possibility that hyperons, which may be regarded as a combination of nucleons and mesons, especially since they are produced at cosmotron energies[2] much below the nucleon production threshold, are capable of disintegrating into mesons only. That would mean annihilation of a nucleon in the decay process, which we do not like to believe possible.

On the assumption that Y_1 is a new particle, we obtain:

$$\text{if } Y_1^- \rightarrow K_2^- + n + Q, \text{ then } M(Y_1) \approx 2830\ m_e;$$
$$\text{if } Y_1^- \rightarrow K_2^- + \Lambda^0 + Q, \text{ then } M(Y_1) \approx 3160\ m_e.$$

A search for a Λ^0 particle in the direction determined by the second of the above schemes failed to yield positive results. The chances of finding the Λ^0, if it existed, were about 25 percent. The direct mass measurements of Y_1 by scattering *vs* ionization gave $M(Y_1) = (3200^{+1200}_{-500})$ electron masses. Either one of the above schemes agrees with the observed mass of Y_1. All errors quoted in the discussion are standard statistical errors.

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[1] Biswas, George, and Peters, Proc. Indian Acad. Sci. **38**, 418 (1953).
[2] Fowler, Shutt, Thorndike, and Whittemore, Phys. Rev. **93**, 861 (1954).

Measurement of the Spin and Gyromagnetic Ratio of C^{13} by the Collapse of Spin-Spin Splitting

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A PRECISE and interesting measurement of the ratio of the resonance frequency of C^{13} to that of H^1 has been obtained in the course of some experiments on indirect spin-spin interactions between nuclei in molecules.[1-3] The multiplet structure in the nuclear resonance of a given nucleus caused by spin-spin interaction with another nucleus of like or different atomic species can be reduced to a single line by irradiating the second nucleus with an rf magnetic field of its own resonance frequency.[4,5]

The transmitter section of a standard nuclear induction probe was modified so that it tuned to both 30 Mc/sec and 7.5 Mc/sec simultaneously. The proton spectrum of CH_3I enriched with 51 percent C^{13} was observed at 30 Mc/sec under "slow passage" conditions with the high-resolution spectrometer.

The oscilloscope trace showed three peaks, of which the central one was caused by those protons attached to C^{12} (Fig. 1). The two outer proton peaks were separated by 11 milligauss from the central peak as a result of the spin-spin interaction between C^{13} and its companion H^1 nuclei. The number and relative amplitudes

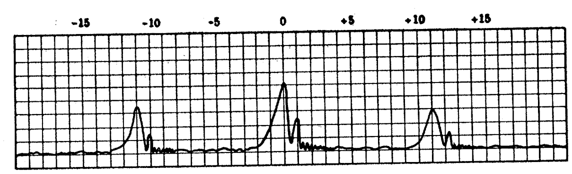

FIG. 1. Proton spectrum at 30 Mc/sec of CH_3I enriched with 51 percent C^{13}. The two outside lines are split by the spin-spin interaction between C^{13} and H^1.

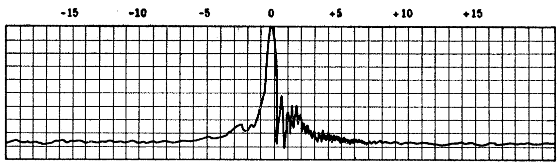

FIG. 2. Proton spectrum at 30 Mc/sec of CH_3I enriched with 51 percent C^{13} with strong $7\frac{1}{2}$ Mc/sec rf-coupled into the transmitter. The side peaks are almost completely collapsed.

of the peaks give a spin of $\frac{1}{2}$ for the C^{13} nucleus, verifying the earlier result obtained by Jenkins from hyperfine structure measurements.[6]

An auxiliary transmitter was link-coupled into the transmitter section of the probe and its frequency varied slightly around 7.544 Mc/sec. At the C^{13} resonance frequency, the two side peaks of the 30-Mc/sec proton spectrum coalesced with the central peak, which doubled in amplitude and became quite sharp (Fig. 2). The frequency of the auxiliary transmitter at which this occurred and the frequency of the 30-Mc/sec transmitter were then counted with a frequency counter.

A comparison of the resonant frequency of C^{13} in CH_3I to that of H^1 in the same molecule gave

$$\nu(C^{13})/\nu(H^1)=0.2514431\pm0.0000005.$$

This result is in excellent agreement with that previously obtained by Poss.[7] The proton resonances in CH_3I and in mineral oil occur, within experimental error, at the same frequency; hence a direct comparison of the above result with that of Poss is justified.

The C^{13} line is a quadruplet, being split into $2I+1$ equally spaced lines, where I refers to the total spin of $\frac{3}{2}$ for the three protons in CH_3I. Since the side peaks of the proton resonance split out symmetrically as a function of frequency as the auxiliary oscillator is tuned above and below the coalition frequency, that frequency was assumed to be at the center of the C^{13} quadruplet.

It is interesting to note that although the 7.5-Mc/sec rf field had a peak-to-peak amplitude of 0.75 gauss, a shift in frequency of 30 to 40 cps was sufficient to broaden the central peak markedly and to decrease its amplitude proportionately. This is more sensitive by a factor of ten than one is led to expect on the basis of rf line broadening. The crystal controlled auxiliary oscillator could be varied about 300 cps above and below the C^{13} frequency, a variation sufficient for the irradiated doublet to be in part reconstituted. Nine measurements of the C^{13} and H^1 frequencies in CH_3I were made, the maximum discrepancy between any two C^{13} measurements being 20 cps.

The magnetic field was swept with a 50-milligauss recurrent sawtooth sweep, and it was suggested that the measurement of the frequency ratio might be in question by the amount by which the position of the proton resonance in the magnetic field was undetermined. The uncertainty was minimized by keeping the sweep frequency low enough to ensure "slow passage" through the resonance.

The incorporation of both the nucleus to be measured and the reference nucleus into a single sample, and the measurement of both resonance frequencies with a single coil gives assurance that any field difference at the two nuclei must be a chemical shift inherent in the molecule since all external experimental factors are the same. A merit of this technique is that it was possible to determine the C^{13} frequency by observing a sensitive change in the strong narrow H^1 resonance with a high resolution spectrometer. No sweep field calibration is involved, the measurement being reduced to the simultaneous determination of two frequencies. Both H_1 and F^{19} give strong sharp lines and make excellent companions for more refractory nuclei.

The author wishes to thank C. Reilly of Shell Development Research Laboratories, Emeryville, California for supplying the sample of $C^{13}H_3I$ used in this experiment.

[1] N. F. Ramsey and E. M. Purcell, Phys. Rev. **85**, 143 (1952).
[2] E. L. Hahn and D. E. Maxwell, Phys. Rev. **84**, 1246 (1951).
[3] Gutowsky, McCall, and Slichter, Phys. Rev. **84**, 589 (1951).
[4] J. Shoolery and M. Packard (to be published).
[5] Bloch, Arnold, and Anderson have reported by private communication the application of this technique to the protons in ethyl alcohol.
[6] F. A. Jenkins, Phys. Rev. **72**, 169 (1947).
[7] H. L. Poss, Phys. Rev. **75**, 600 (1949).

Differential Cross-Section Measurements for 1-Mev Bremsstrahlung*

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THE energy and angular distribution of the bremsstrahlung, produced in thin targets of beryllium and gold by electrons with a kinetic energy of one Mev, has been measured with a large NaI(Tl) scintillation spectrometer. The electron beam from the NBS constant-potential accelerator[1] passed through baffle openings into the target chamber, which was electrically insulated from the accelerator tube to serve as a Faraday cup. Target currents from 10^{-10} to 10^{-6} amperes were measured with 2-percent accuracy by a Higinbotham-Rankowitz type current integrator.[2] The targets used were a 0.22-mg/cm² gold foil, a 0.43-mg/cm² gold foil, and a 4.3-mg/cm² beryllium foil. The results obtained with the two gold targets indicated that electron energy loss and scattering in the foils were negligible. The radiation emitted from the target at an angle θ with respect to the direction of the incident electron beam was detected by the spectrometer with an angular resolution of approximately one degree.