Letters to the Editor

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The Hyperfine Structure of Atomic Hydrogen and Deuterium*

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September 29, 1947

IN a recent Letter to the Editor, Nafe, Nelson, and Rabi[1] reported on measurements of the hyperfine structure separations of the ground states of atomic hydrogen and of atomic deuterium. We have performed very similar atomic-beam magnetic-resonance experiments and have obtained similar values of these constants.

Figure 1 shows the variation with magnetic field of the energy levels for atoms with a $^2S_{\frac{1}{2}}$ electronic ground state and with nuclear spins $\frac{1}{2}$ and 1. These are appropriate to hydrogen and deuterium, respectively, and the transitions indicated by arrows are the ones being reported here. The molecular-beam apparatus used here is similar to that reported by one of us in a paper[2] on the spin of K^{40}. The major differences between the present apparatus and that one is that the source and detector are appropriate to atomic hydrogen and the frequencies are measured by direct comparison with the 5-megacycle standard signal of the Bureau of Standards radio station WWV. Unfortunately, the magnet used to produce the homogeneous field in which the transitions occur is unduly influenced by stray fields of the deflecting and refocusing magnets, with the result that the line widths are considerably larger than could theoretically be expected from the relation $\Delta\nu\Delta T\sim 1$. This effect is larger in the case of hydrogen than deuterium because in weak fields the transition frequencies ν_4 and ν_5 are almost independent of field, whereas the transition frequencies ν_1 and ν_2 are dependent on field for all values of the field.

The value of $\Delta\nu$ for hydrogen is obtained simply and rigorously by subtracting ν_1 from ν_2. Using frequencies obtained for several different values of magnetic field, we obtain $(\Delta\nu)_H = 1420.47 \pm 0.05$ Mc. The large error quoted is due to the magnetic field broadening of the two lines observed. For deuterium the value of $(\Delta\nu)_D$ is calculated by the Breit-Rabi formula from ν_4 and ν_5, unresolved, evaluating the magnetic field from the value of ν_3. ν_6 is used only as a consistency check on ν_3. The value of $(\Delta\nu)_D$ for deuterium is more precise and is 327.380 ± 0.003 Mc.

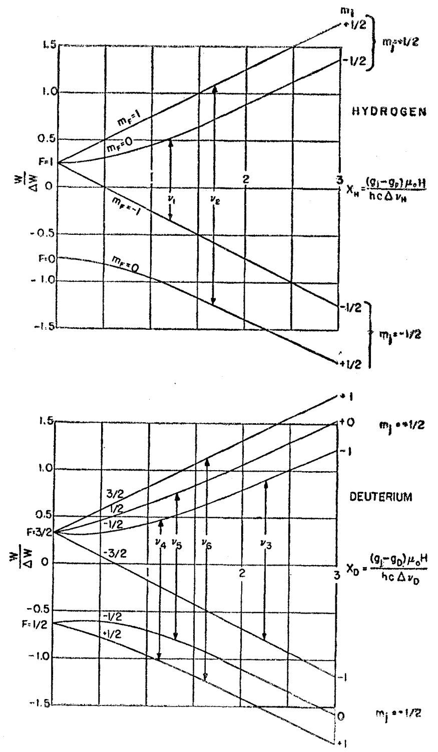

FIG. 1. Hyperfine structure of hydrogen and deuterium; energy levels in a magnetic field.

Like the results of Nafe, Nelson, and Rabi, the absolute values of the $\Delta\nu$'s are in violent disagreement with those calculated using the Fermi formula[3] and the proton and deuteron magnetic moments published by Millman and Kusch.[4] The modification of the Fermi formula, proposed by Halpern,[5] does not improve this situation. On the other hand, the ratio $(\Delta\nu)_H/(\Delta\nu)_D$ is 4.33890 ± 0.00016, and this is to be compared with the ratio as calculated by the Fermi formula, using the ratio of the nuclear moments given by Kellogg, Rabi, Ramsey, and Zacharias,[6] $\mu_P/\mu_D = 3.2570 \pm 0.001$. The calculated ratio $(\Delta\nu)_H/(\Delta\nu)_D$ is 4.3391 ± 0.0013. The agreement is better than one could expect from the uncertainty in the moment ratio.

It is our intention to improve our results both by improvements in the uniformity of the field and by measurements of transitions in hydrogen which are not sensitive to field. We are given to understand that Nafe, Nelson, and Rabi have obtained results considerably improved over their former values and that they are in agreement with ours.

* This work was supported in part by the Joint Service Contract No. W-36-039 sc 32037.

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