

## VII. MAGNET LABORATORY RESEARCH

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### A. QUADRUPOLE MOMENT OF SODIUM

Two of the hyperfine structure separations of the  $3P_{3/2}$  state of sodium have been measured. The possible values of the total angular momentum quantum number,  $F$ , for the  $P_{3/2}$  state are 3, 2, 1, 0. We found the 3 - 2 separation to be  $61 \pm 2$  Mc/sec and the 2 - 1 separation to be  $36 \pm 3$  Mc/sec. This gives  $(\pm 0.1 \pm 0.08) \times 10^{-24}$  cm<sup>2</sup> for the nuclear electric quadrupole moment (note typographical error in the Quarterly Progress Report, October 15, 1952). An attempt is being made to take the data again with improved signal-to-noise ratio.

On a one-particle model the quadrupole moment of sodium should be negative. The magnitude is about twice as large as one would expect for such a light nucleus. An attempt is being made to compute an order of magnitude for the quadrupole moment on the assumption that the ground state of the sodium nucleus is a  $(d_{3/2})^3$  term, as suggested by M. Goeppert Mayer (Phys. Rev. 78, 16, 1950).

P. L. Sagalyn

### B. LOW FIELD SUSCEPTIBILITIES OF METALS

Magnetization curves have been obtained for samples of bismuth, cadmium, and tellurium with the device described in previous Quarterly Progress Reports. The data were obtained for fields from 400 g to 2300 g for bismuth, from 200 g to 1200 g for cadmium, and from 200 g to 2300 g for tellurium. The following values were obtained:

$$\frac{(\chi/\rho)_{\text{Te}}}{(\chi/\rho)_{\text{Bi}}} = 0.25$$

$$\frac{(\chi/\rho)_{\text{Cd}}}{(\chi/\rho)_{\text{Bi}}} = 0.06.$$

The same quantities computed from data in "Handbook of Chemistry and Physics" are 0.229 and 0.133, respectively. The disagreement for  $(\chi/\rho)_{\text{Cd}}$  should not be regarded as significant because the small signal obtained from the cadmium sample makes the measurement imprecise.

There is no indication of any anomalously high susceptibilities at low fields for any of the three samples used.

J. R. Stanley

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### C. PARAMAGNETIC SUSCEPTIBILITIES AT HIGH FIELDS

The method previously reported for measuring the magnetic moment of small paramagnetic samples at high fields has been adapted for use in the large Zeeman-effect magnet of the Microwave Spectroscopy Laboratory. This method has involved a horizontal oscillatory motion of the sample between two oppositely-wound, balanced coils placed in the homogeneous portion of the magnetic field.

To eliminate effects due to magnetization of the sample holder, external pickup, vibrations of the apparatus, and fluctuations of the magnetic field, it has been arranged to take readings with the sample either in the detector coils or far removed from them at each value of the field.

With this arrangement, a curve was drawn of the magnetization of a 0.1-g sample of pure iron up to a field of about 90,000 gauss (see Fig. VII-1). Within the accuracy of the magnetization measurement (approximately 1 percent) the magnetization did not increase after saturation.

In a further refinement, it was arranged to move the sample holder to several positions so that at a given field and temperature, readings could be taken of magnetization of the sample holder and two different samples. One of these may be a standard sample in terms of which we may measure the magnetic field.

H. H. Plotkin

### D. NUCLEAR MAGNETIC RESONANCES

#### 1. Field Homogeneity

To improve the homogeneity of the barrel-shaped electromagnet further we have constructed two arrays of coils, 16 on each pole face, and an array of 32 potentiometers

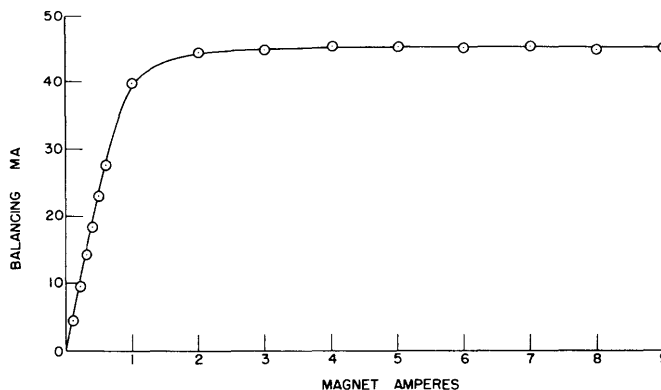


Fig. VII-1

Magnetization curve of iron.

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which allow independent control of the current in each coil. Homogeneity of about 4 parts in  $10^7$  (total linewidth at half-amplitude) in a field of 15 kg over a cylindrical sample approximately 3/16 inch in both length and diameter has been obtained. The limitation appears to be due not to the coils but rather to the difficulty of obtaining quickly a measure of change of linewidth for linewidths of the order of 5 mg to 10 mg or less; this difficulty was probably caused by relaxation effects. Since each of the 32 controls must be optimized with respect to minimum linewidth, and the adjustments must interact, speed is necessary.

N. I. Adams III, T. F. Wimett

### 2. Deuteron-Proton Moment Ratio

Some preliminary results have been obtained on the deuteron-proton magnetic moment ratio. High-precision measurements of the ratios of nuclear resonance frequencies have been made in hydrogen gas samples at 15,000 gauss in the recently improved barrel-shaped electromagnet. Resolved fine structure (1, 2, 3) has been observed directly for the first time in absorption lines of both isotopes (see Fig. VII-2) in hydrogen deuteride gas.

The gas sample was confined in a volume of approximately  $0.01 \text{ cm}^3$  by a teflon cylinder, which was in turn inclosed in a thick brass chamber. Two rf coils for detecting the proton and deuteron resonances independently were wound around the gas volume with axes perpendicular to each other. Coil leads were brought out of the brass chamber through neoprene gaskets.

Radiofrequency voltage was delivered to the two detecting coils from two oscillators, which were "locked in" to a frequency made up of harmonics, plus subharmonics, of a single crystal oscillator, located in a temperature-controlled oven. The oscillator for the deuteron coil was locked in directly to a frequency of 193.2 times the crystal frequency (50 kc). In order to allow for adjustments of the frequency ratio, the proton oscillator was made variable but related to the crystal frequency by locking in its frequency to 1258.6 times the crystal frequency minus a variable audiofrequency of the

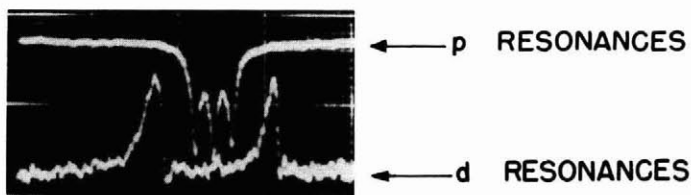


Fig. VII-2

Proton and deuteron resonances  
in HD at 150 atm in 15 kg field.

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order of a thousand cycles. This audiofrequency was supplied by a stable oscillator (General Radio interpolation oscillator) and was set at discrete frequencies, determined by stopping rotation of the Lisajou pattern obtained when a subharmonic of the crystal is applied to one set of deflecting plates of an oscilloscope and the audio oscillator to the other set of plates. By this means the proton-driving frequency could be set to a fraction of a cycle and would remain for several minutes within that precision. Since the deuteron frequency was locked in (in phase) with the crystal, the ratio of the two frequencies was known to the precision of the proton-frequency determination, which is of the order of a few parts in a billion and can produce only negligible error in the present experiment. The principal advantage of the above method is the extremely high stability of both the frequencies and their ratio. The unique feature of this frequency control system is that it produces essentially monochromatic radiofrequency.

Resonance was detected by observing the change in rf voltage across a sample coil as the magnetic field was slowly changed. Special null circuits were used to nullify the relatively large voltage across the sample coils and at the same time produce a small unbalanced output whose phase was set to select either the absorption or dispersion components of the resonance with negligible mixing. The output of each of the two null circuits was connected to a narrow-band amplifier and detector. The detector was in turn connected to a dc amplifier which drives one of the sets of vertical deflecting plates of a dual-beam oscilloscope. The horizontal deflection plates were driven by the same saw-tooth voltage which was used to sweep the magnetic field. This procedure allows for simultaneous observation of both resonances which are produced in the same sample; hence, in the same field.

The following preliminary results have been obtained:

Sample	Number of Determinations	Ratio
HD            80-150 atm	200	$\frac{\mu_d}{\mu_p} \approx 2 \frac{\nu_d}{\nu_p} = 0.307012189 \pm 0.000000030^{**}$
H <sub>2</sub> + D <sub>2</sub> * 68 atm D <sub>2</sub> 88 atm H <sub>2</sub>	50	$2 \frac{\nu_d}{\nu_p} = 0.307012177 \pm 0.000000030^{**}$

\* D<sub>2</sub> splitting  $\delta = 42.6 \pm 2$  cycles

\*\*  $\pm$  value indicates the spread of the observation

The spread given includes essentially all the determinations. The probable error has not yet been determined but is substantially less than the spread. Instability of the magnetic field is responsible for the greater part of the uncertainty in these

measurements. Measurement of the shifts between resonance lines is limited by any departures from linear field sweeping over the entire linewidth. No automatic field control was used in these experiments.

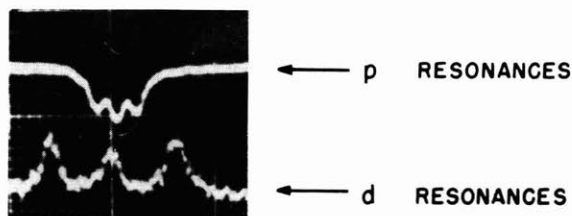


Fig. VII-3  
Resonance lines in HD plus  $D_2$ .

To combat field fluctuations it was found necessary to sweep the field at rates so high as to induce slight "wiggles" or transients in the deuteron resonance lines. This causes line asymmetry as seen in Fig. VII-2.

As suggested by N. F. Ramsey (4), the HD determination provides the best measure of the isotopic moment ratio because of the absence of zero-point vibration corrections in molecular shielding which must be made in the  $H_2$ - $D_2$  experiment. The difference between the two determinations therefore provides a direct measurement of the difference between zero-point shielding corrections in  $H_2$  and  $D_2$ .

Figure VII-3 demonstrates the relative positions of the deuteron lines in  $D_2$  and HD molecules. The resonances were observed in a mixture of HD and  $D_2$  with partial pressures of 150 atm and 35 atm, respectively. From measurements of deuteron line displacements in this gas mixture, the difference between the magnetic shielding in HD and  $D_2$  is being determined. Results will be reported later.

T. F. Wimett

#### References

1. N. F. Ramsey, E. M. Purcell: Phys. Rev. 85, 143, 1952
2. B. Smaller, E. L. Yasaitis, E. C. Avery, D. A. Hutchison: Phys. Rev. 88, 414, 1952
3. H. Y. Carr, E. M. Purcell: Phys. Rev. 88, 415, 1952
4. N. F. Ramsey: Phys. Rev. 85, 688, 1952