Magnetic Moments of Deuterium-2, Lithium-7 and Fluorine-19

THE exceptionally small natural line-widths obtainable with the magnetic resonance absorption method^{1,2} or nuclear induction method^{3,4} makes these methods suitable for precision measurements of nuclear magnetic moments. We have constructed an apparatus for this purpose, and have paid special attention to the problem of getting a magnetic field which fulfils the rather extreme requirements of field homogeneity. In this case it was also important that the homogeneity was of such an extension that two different probes could be investigated at the same time on two different places in the field. The pole-pieces of the magnet were 30 cm. in diameter, separated by spacers 4.2 cm. apart. Both the pole-pieces and the spacers were polished optically flat, so that the air gap was the same within 1μ everywhere.

For the detection of the resonances we have used the balance method first proposed and used by Purcell, Torrey and Pound¹. The field was carefully mapped by inserting a water probe in the field and observing the difference in resonance frequency for protons in different places. We have been able to find two extremely homogeneous places in the field where resonance absorption simultaneously can be studied, one for protons and the other for the unknown magnetic moment. The homogeneity was such that the line-widths in the two places were about 0.1 gauss. The very small difference in magnetic field between the two places (2 in 10^6) was determined by observing simultaneously the proton resonances in both places.

The signals from the two high-frequency bridges were fed to a double-beam oscillograph, and the two frequencies were adjusted to get the two signals to coincide. Any displacement between the signals on the screen was corrected for by photographing the screen. The total amplitude of sweep on the screen

usually corresponded to about 0.3 gauss and was synchronized with the modulation of the magnetic field.

Every magnetic moment has been measured several times at different field-strengths. The two frequencies to be compared were measured by a General Radio Frequency Standard (Type 1100-A, form 664-A), which permits an accuracy of 1 in 10^6 in the frequency determination. Our determinations of the nuclear magnetic moments of D², Li⁷ and F¹⁹ are summarized in Tables 1, 2 and 3 (the diamagnetic correction is not included).

All moments are expressed in the proton moment as a unit. For deuterium-2 we obtained $\mu_D/\mu_P = 0.3070183 \pm 0.0000015$; for lithium-7 $\mu_{Li^7}/\mu_P = 1.165833 \pm 0.000050$; and for fluorine-19 $\mu_{F^{19}}/\mu_P = 0.940934 \pm 0.000015$.

All our individual measured values fall inside the limits given here. Only the deuteron moment has been determined before by this method, and our value agrees within the limits of error with the determination by Bitter *et al.*⁵ ($\mu_D/\mu_P = 0.307021 \pm 0.000005$), but falls a little outside the value obtained by Bloch *et al.*⁶ (0.3070126 ± 0.0000020).

The μ -values of lithium-7 and fluorine-19 have not previously been measured accurately by the new method. The values obtained with Rabi's method⁷ ($\mu_{Li^7}/\mu_P = 1.16622 \pm 0.00090$ and $\mu_{F^{19}}/\mu_P = 0.9410 \pm 0.0013$) are given with considerably higher limits of error, but are consistent with our new values.

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Table 1

Magnetic field (in gauss)	ν_D (in Mc.)	ν_P (in Mc.)	$\frac{\mu_D}{\mu_P} = \frac{2\nu_D}{\nu_P}$
about 3530	2.357340	15.356360	0.3070185
" 5250	3.500000	22.800000	0.3070176
" 5250	3.500000	22.800000	0.3070176
" 5700	3.801091	24.761325	0.3070183
" 5700	3.801073	24.761120	0.3070195

Mean value, 0.3070183; maximum error, ± 0.0000015 .

Table 2

Magnetic field (in gauss)	ν_{Li^7} (in Mc.)	ν_P (in Mc.)	$\frac{\mu_{Li^7}}{\mu_P} = \frac{3\nu_{Li^7}}{\nu_P}$
about 5800	9.7249	25.0250	1.165883
" 5900	9.7778	25.1615	1.16581
" 5900	9.7765	25.1575	1.16584
" 5900	9.7776	25.1604	1.16583
" 6810	11.2893	29.0504	1.16583
" 6810	11.2896	29.0501	1.16588

Mean value, 1.16584; maximum error, ± 0.00004 .

Table 3

Magnetic field (in gauss)	$\nu_{F^{19}}$ (in Mc.)	ν_P (in Mc.)	$\frac{\mu_{F^{19}}}{\mu_P} = \frac{\nu_{F^{19}}}{\nu_P}$
about 4600	18.411164	19.566660	0.940946
" 4600	18.414476	19.570116	0.940949
" 4500	18.410958	19.566764	0.940930
" 4600	18.410966	19.566828	0.940927
" 4600	18.410985	19.566736	0.940933
" 5710	22.975250	24.417890	0.940919
" 5710	22.975350	24.417600	0.940934

Mean value, 0.940934; maximum error, ± 0.000015 .

Slow-Neutron Capture in Helium

THE cross-section for capture of thermal neutrons in helium according to the reaction

has been measured relative to the similar reaction in nitrogen for which the cross-section is given as 1.7 barns¹:

Cloud-chamber photographs of the helium reaction by slow neutrons have recently been obtained by Hughes and Egger², who found an energy release of 740 keV. The cross-section for such a reaction might be expected to be large.

Briefly, the method was to compare the counting-rates produced in a gridded ionization chamber filled alternately with atmospheric helium, containing 1.20×10^{-6} parts³ of helium-3, and argon, containing a small known admixture of nitrogen, irradiated in a thermal neutron flux of approximately