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Magnetic Moment of the Second Excited State of F^{19}

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The magnetic moment of the second excited state (200 kev) of F^{19} was deduced from the change, caused by a magnetic field, in the angular distribution of the de-excitation radiation following (p,p') by F^{19}. The Larmor precession of the excited nucleus displayed in the angular distribution and the rotational change of the angular distribution was measured as a function of the magnetic field strength. If one disregards the influences of the surrounding atoms, the apparent value of the magnetic moment was deduced as $\mu(F^{19*},5/2^+) = +(3.0\pm0.7)\mu_N$. If one considers these effects, the value obtained gives a lower limit.

THE low-lying states of the nuclide F^{19} have been extensively studied by many workers,[1–3] and the properties of the second excited state (200 kev) are well known, i.e., the spin $I=5/2^+$, and the lifetime of this state for the radiative transition to the ground state $\tau=(1.0\pm0.2)\times10^{-7}$ sec.[2] It was also reported[1] that the angular distribution of the 200-kev radiation in the reaction $F^{19}(p,p')F^{19*}$ was anisotropic and can be expressed as $W(\theta)=1+A_2P_2(\cos\theta)$.

An attempt was made to observe the influence of the magnetic field on the angular distribution of the 200-kev radiation in the reaction $F^{19}(p,p')F^{19*}$. A uniform magnetic field was applied to the target, in a direction vertical to the incident proton beam and the plane of the gamma-ray measurement. Classically, the magnetic field induces a precession of the nucleus through an angle $\omega\tau$ during the mean life τ of the excited state, $\omega=\mu H/I\hbar$ being the Larmor frequency. Disregarding the influences of the surroundings, the angular distribution of the gamma rays can be represented by the relation,[4,5]

$$W(\theta,H)=\int_0^\infty \exp(-t/\tau)\{1+A_2P_2[\cos(\theta+\omega t)]\}dt. \quad (1)$$

The precession displayed in the change of the angular distribution and the magnetic moment μ of the excited state can be obtained by measuring $W(\theta,H)$. During the course of this experiment, the same magnetic moment was measured independently by the same principle but in a slightly different way.[6,7]

The protons were accelerated by the electrostatic generator of Osaka University. The energy of the protons was analyzed by a proton-resonance-controlled magnet. A fluorine target was prepared by evaporation of a thin CaF_2 film on a 10-micron copper foil. This target was mounted in a thin aluminum container. The effective thickness of the target was examined by utilizing the 1.09-Mev resonance of the reaction and was estimated to be 9 kev at this energy.

Gamma rays were detected with a 1.5-in. diameter ×1.5-in. NaI(Tl) scintillation spectrometer. The crystal was located at the mean distance of 23 cm from the target. For the observation of the 200-kev radiation, two single-channel discriminators were employed, one of which was set to count the full-peak portion of the 200-kev radiation in the pulse-height spectrum, and the other to count just the upper portion of the spectrum for the background determination.

Because of the large anisotropy and intense yield of the 200-kev radiation at the 1.381-Mev resonance for this reaction, the bombarding energy of the protons was set at this resonance peak.

Angular distributions were measured at magnetic field strengths of 0, ±425, ±750, ±1200, and ±1700 oersteds. Typical examples of the angular distributions are shown in Fig. 1. At zero magnetic field, the distribution is expressed as $1+(0.30\pm0.03)P_2(\cos\theta)$, in agreement with the measurement of Peterson *et al.*[1] No

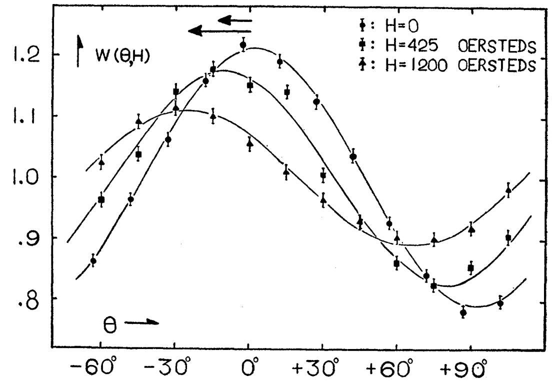

FIG. 1. The angular distribution of the 200-kev radiation in the reaction $F^{19}(p,p')F^{19*}$. The bombarding energy of protons was 1.38 Mev. The cases for the magnetic field of 0, −425, −1200 oersteds are plotted. The precession of the nucleus displayed in the angular distribution can be seen. The solid curves are least-squares fits of the distributions to the form $W(\theta,H)=1+a(\cos2\theta - b\sin2\theta)$.

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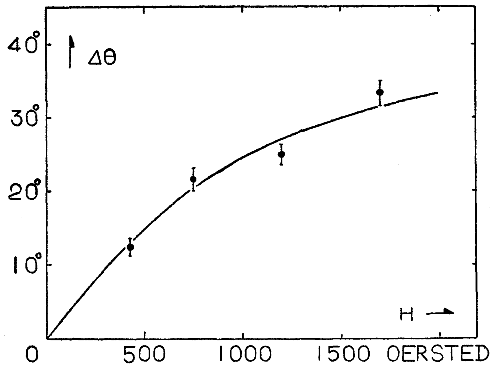

FIG. 2. The rotation of the angular distribution *vs* the magnetic field. The solid curve shows the relation $\Delta\theta=\frac{1}{2}\tan^{-1}2\omega\tau$ with the values $\mu=3.0\mu_N$ and $\tau=1.0\times10^{-7}$ sec; $\omega=\mu H/I\hbar$.

correction was applied for the absorption and scattering of gamma rays or for the finite solid angle subtended by the detector, but these corrections were estimated to be small. Because of some ambiguities in the subtraction of the background for the yield determination of the 200-kev radiation, the computation of the rotational change in the angular distribution was more reliable than the amplitude attenuation of the angular distribution caused by the magnetic field. The rotation of the angular distribution was computed from the measured angular distribution for each field strength by the method of least squares. For each field strength, two measurements corresponding to the reverse field directions were averaged, and corrected for the deflection of the incident proton beam by the magnetic field. The values of the rotation angle $\Delta\theta$ as a function of the magnetic field are plotted in Fig. 2.

From the relation (1), $\Delta\theta$ is calculated to be

$$\Delta\theta=\tfrac{1}{2}\tan^{-1}2\omega\tau. \qquad (2)$$

TABLE I. Summary of the results.

H in oersteds	$\Delta\theta$ in degrees	$\mu\tau\times10^7$ in μ_N sec[a]
425	13.5±1.2	3.13±0.33
750	21.6±1.4	3.27±0.34
1200	25.1±1.4	2.61±0.29
1700	33.4±2.0	3.57±0.84
		Mean 3.0 ±0.2

[a] μ_N is one nuclear magnetron.

The apparent value of $\omega\tau$ can be computed by the relation (2). The results are summarized in Table I. Inserting the known value of τ, the magnetic moment of the 200-kev level becomes

$$\mu(\mathrm{F}^{19},5/2^{+})=+(3.0\pm0.7)\mu_N.$$

As pointed out by Christy[3] and others,[1] the effect of the surroundings attenuates the angular distribution, and their results showed 20–40% attenuation of A_2. It is very difficult to estimate in detail the effect of these distrubances for the present case, because the energies of the F^{19*} recoils range up to 240 kev. Considering these effects, it may be said that the present value of μ gives a lower limit and must presumably be increased at most by 20–40% to give the correct value. This measurement is in good agreement with the results of previous work.[6,7] A detailed report will be published elsewhere.

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