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

P. LEHMANN, A. LEVEQUE, AND R. PICK
Section des Réactions Nucléaires à Basse Energie du Service de Physique Nucléaire, Centre d'Etudes Nucléaires de Saclay, GIF-sur-YVETTE, France

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The perturbation of the angular distribution of the 197-kev gamma rays following inelastic scattering of protons in F^{19} has been measured as a function of an external magnetic field and the magnetic moment of the 197-kev state has been extracted from these measurements. A value of $+(3.70\pm0.45)$ nuclear magnetons has been found. The lifetime of this state has been determined precisely: $\tau=(1.23\pm0.07)\times10^{-7}$ sec.

I. INTRODUCTION

INTERMEDIATE coupling calculations have recently been carried out for nuclei of mass 18 and 19,[1,2] and the properties of the even-parity levels of these nuclei were found to agree well with the experimental values. It is therefore of interest to accumulate more experimental information about these levels.

The lifetime[3,4] of the 197-kev state in F^{19} is long enough for a static magnetic field H to cause a strong perturbation of the angular distribution of the anisotropic γ rays. A quantitative determination of this effect as a function of H can then yield a value of the magnetic moment of the intermediate nuclear state μ. For a liquid source, this angular distribution, measured in a plane perpendicular to the applied field, has been shown[5] to be of the form

$$\omega(\theta)=\int_0^\infty \{1+A_2e^{-\lambda_2 t}P_2[\cos(\theta-\omega t)]\}e^{-\lambda t}dt, \quad (1)$$

where A_2 is the coefficient of the unperturbated distribution; λ and λ_2 are the decay constant of the γ emitting state and the quadrupole interaction constant,[5] respectively; $\omega=\mu H/I\hbar$ is the Larmor frequency.

II. EXPERIMENTAL METHOD

The 197-kev state was excited by inelastic scattering of protons on F^{19} in a liquid medium, and the ratio of the counting rates of two γ detectors arranged symmetrically with respect to the proton beam was measured as a function of the applied magnetic field. For $\theta=45°$, the ratio

$$R=W(\theta,\omega)/W(-\theta,\omega)=W(-\theta,-\omega)/W(+\theta,-\omega) \quad (2)$$

goes through an extremum for a field strength H_m corresponding to a Larmor frequency of

$$\omega_m=\tfrac{1}{2}(\lambda+\lambda_2). \quad (3)$$

It has been shown[6] that λ_2 is roughly proportional to the macroscopic viscosity of the solution. Experiments made with two different viscosities should then allow extrapolation to zero viscosity ($\lambda_2=0$).

III. EXPERIMENTAL ARRANGEMENT

The proton beam from the Saclay 5-Mev electrostatic accelerator entered a liquid cell through a platinum window 5 μ thick. The continuously circulating liquid was a solution of potassium fluoride in water with a concentration of 600 g/l or 300 g/l. The gamma-ray detectors were 1×1 inch NaI(Tl) crystals mounted on EMI 6260 photomultipliers. The detectors were carefully shielded from the magnetic stray field and from the scattered gamma rays. The magnet itself was designed to minimize the scattering of gamma rays by keeping the coils away from the gap as much as possible. The magnet was carefully demagnetized between the measurements and its field was measured with a coil meter.

The outputs of the amplifiers following the multipliers were connected to 10-channel pulse-height selectors of the standard Saclay type.

The measurements were made in the following order: (i) without any field, (ii) field in one direction, (iii) field in the opposite direction, (iv) without any field, and repeated twice in this order for every value of the field.

IV. RESULTS

Figure 1 shows the results obtained with the 600-g/l solution. The curves have the form predicted by Eq. (1) The best fit is obtained for $H_m=(587\pm12)$ gauss.

Another curve obtained with the 300 g/l solution yields essentially the same value. A careful comparison of the two curves shows that the position of the maxima cannot differ by more than 5%.

The ratio of the viscosities of the solutions was measured both at 5°C and 33°C with a Baumé viscosimeter and can be estimated to be around two at the unknown local temperature in the region of the proton beam. In the result the possibility of quadrupole effects has been taken into account by assuming a systematic error of 2.5%±2.5%

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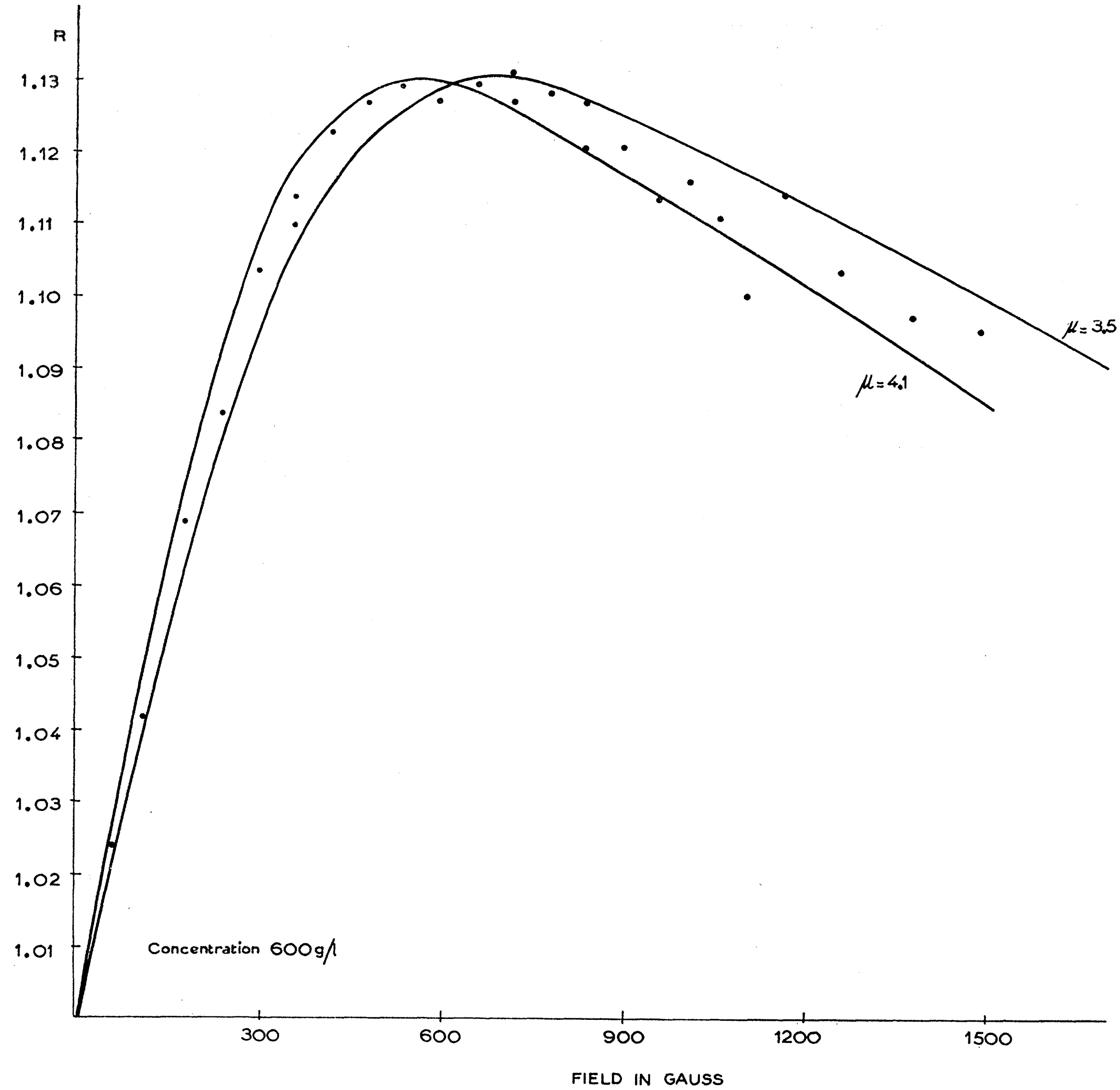

FIG. 1. Experimental points showing the ratio of the counting rates of the two detectors as a function of the magnetic field. The two solid lines are theoretical curves calculated for $\mu=+4.1$ and $\mu=+3.5$.

The precision of the value of μ was limited by the 20% error of the lifetime of the 197-kev state given in the literature.[4] A somewhat more accurate measurement has been performed using the delayed coincidence method. This experiment has been described previously.[7] The result, $\tau=(1.23\pm0.07)\times10^{-7}$ sec or $\lambda=(0.81\pm0.05)\times10^{7}$ sec^{-1}, yields a value for the magnetic moment of $+3.70\pm0.45$ nuclear magnetons, in agreement with the value 3.3 obtained by Elliot in preliminary calculations.[8,*]

The present value is somewhat larger than those obtained using a solid target and neglecting quadrupole effects.[9,10]

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* *Note added in proof.*—Similar experiments using liquid sources of O^{19} have been made at Cavendish Laboratory [Phillips, Jones, and Johnson (to be published)]. The results are in good agreement with ours.

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