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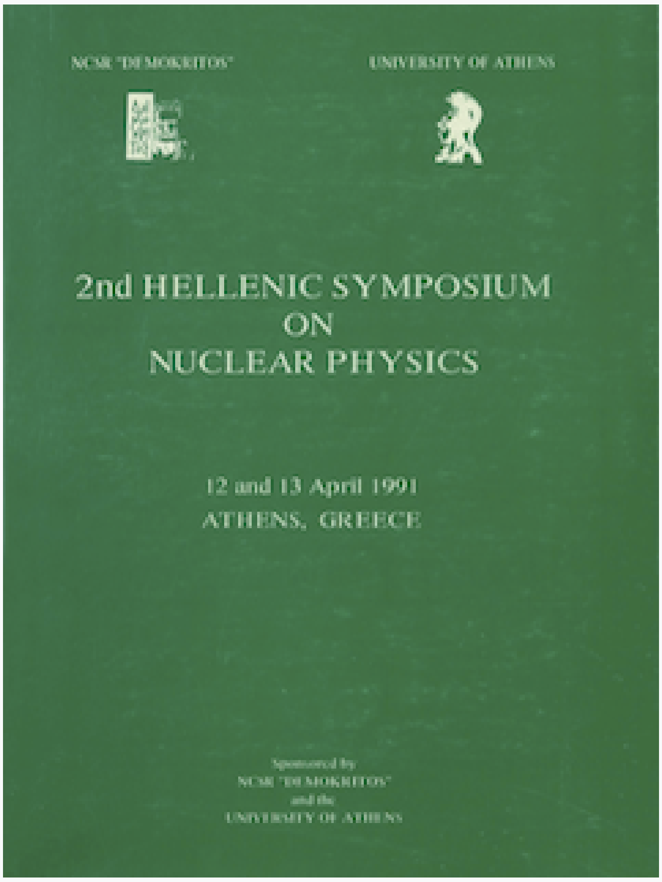

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THE 19/2$^-$ g-FACTOR IN ^{39}K USING A TRANSIENT FIELD–FUSION REACTION TECHNIQUE

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Abstract

The magnetic moment of the 19/2$^-$ state in ^{39}K has been measured by the transient field technique. The state was excited by the inverse reaction ^{12}C(^{32}S,pα)^{39}K and the recoil nucleus traversed a thin Gd foil. Its absolute g-factor, g= 0.35(3), was obtained by an internal calibration, which makes use of the magnetic moment of the 15/2$^+$ state in ^{41}Ca also excited in the same reaction.

The experimental result agrees well within shell model predictions.

1. Introduction

The transient field technique has been used for the last twenty years and several magnetic moments were obtained, mainly of low spin states. In these measurements a Coulomb excitation technique was most widely employed to both excite and recoil the nuclei through a ferromagnet. But, as the demand for high spin moments was becoming more and more evident, a new excitation technique has being sought, and as such, the fusion-evaporation reaction seems the most promising. However this technique has been so far hindered mainly by either the large time spread observed in the population of discrete high spin states or the complicated level schemes extended over various energy bands.

To apply the conventional transient field technique, the precise knowledge of the particular state the nucleus is in, at the critical time during which it traverses the ferromagnet, is vital. Therefore, to make unambiguous measurements, either additional handles must be invoked or nuclei and reactions with sufficiently simple feeding patterns must be selected. In the heavy mass region a combination of transient fields and plunger measurements are at an exploratory stage in this and other laboratories, while two measurements[1,2] have already been reported. In the mass region A $\approx$ 70 a few attempts with the conventional transient field method have been limited either to mean g-factors[3] or have yielded results[4,5] valid, under certain feeding assumptions.

In the present work, we report g-factor measurements in the A$\approx$40 region, through the conventional transient field method[6] and by utilizing, as an excitation process, the inverse reaction ^{32}S + ^{12}C, which leads to the residual nucleus via simple patterns. The measurement was motivated by the following reasons:

a) The well known γ-ray spectroscopy in the region concerning energy levels, spins and lifetimes.[7-14]

b) Results of CASCADE[15] statistical calculations which demonstrate, that the residual nucleus is left at a rather low excitation energy of 12 MeV. In this energy region a rather low density level scheme is predicted, which can lead only to a discrete γ-ray pattern.

c) The well known magnetic moment[17,18] of the rather long lived (τ= 4500 ps) $15/2^+$ state in ^{41}Ca, but still accessible with a transient field technique, which allows an unambigous calibration of the field.

d) Existing shell model calculations describe the $19/2^-$ state as an ^{36}Ar $(0^+) \oplus f^3_{3/2}$ state. If this description is adequate, a g-factor similar to that of ^{43}Sc, g=0.328(7) [Ref.16] can be expected. On the other hand, contributions of the $f_{5/2}$ orbit and configuration mixing of the ^{36}Ar core may likely change this value.

2. Experimental Details

Since the thin- foil transient field method has been described by Benczer-Koller et al[6] and the details of our set up have been outlined in previous publications[19,20], we will present here only the features particular to this work.

The experiment was designed to observe the integral rotation of the gamma-ray angular correlation pattern, which precesses in the transient magnetic field, as the nuclei are moving through a polarized ferromagnetic layer.

The target foil was a five-layer sandwich. A $5mg/cm^2$ gadolinium foil was separated both, from the $500\mu g/cm^2$ carbon layer and the $25mg/cm^2$ silver backing, by two indium layers of 300 mg/cm^2 each. Initially the indium layers, used to ensure good adherence of the target and backing materials, were evaporated on the front and back face of the gadolinium foil. Subsequently the carbon layer and silver backing foil were pressed on the front and back face of the three layer In-Gd-In foil all together. The thickness of the carbon target plus the indium layer allowed a time of 100 fs for any fast feeding to take place before the nuclei enter into the ferromagnet. The thick silver backing foil used to stop the beam and recoiling ions, acted also as a good thermal dissipator.

The gadolinium foil, supplied by Good fellow Metals, was first rolled down to the desired thickness, annealed at 600° for a few minutes in a vacuum of 10^{-7} bar and then cleaned with glow discharge. Subsequently it was tested for magnetization in a double magnetometer and found to be 79% magnetized . The thickness of the foil was measured both with an Am α source and by estimating its weight and surface area.

The target sandwich was clamped between the poles of an electromagnet and was polarized in a filed of 0.270 Tesla which was reversed periodically. Due to the low applied field, sufficient however for polarizing the gadolinium goil, beam bending effects were negligible and corrections in the rotations of long lived states were kept minimum. The temperature of the target was maintained at 88K by cooling with liquid nitrogen.

The inverse reaction $^{12}C(^{32}S,\alpha p)^{39}K$ was used to populate the states of interest at a beam energy of 115 MeV supplied by the 17 MV XTU tandem accelerator of LNL

(Laboratori Nationali di Legnaro). In the same experiment, states in ^{41}Ca and ^{36}Ar were also populated and studied under identical conditions.

Prompt γ-rays from the various reaction channels were detected in four Compton-suppressed, 25% efficiency, Ge detectors from the LNL facility. The detectors were located at $\pm$ 65°, $\pm$115° with respect to the beam, and at a distance of 17 cm from the target.

Slope measurements were carried out several times during the course of the experiment. For this purpose the detectors were moved automatically every $\approx$ 20 min by $\pm$ 3° from their original position, to mimic the rotation of the γ-ray distribution. Furthermore an angular distribution measurement was carried out by one detector which was placed successively at 100°, 115°, 137°, 145°, the only technically accessible positions, while two detectors were set at fixed positions and served as monitors.

3. Reduction of Data and Results

Our data analysis is based on the observation that the $19/2^-$ state in ^{39}K is directly populated. In more detail, any discrete or continuum feeding was excluded for the following reasons:

Discrete feeding: No γ rays depopulating higher states than the $19/2^-$ state were identified in our spectra. Moreover no such lines were reported previously[13], when a similar reaction was studied, ^{28}Si(^{16}O,αp)39K, leading to the same compound nucleus and where $\gamma - \gamma$ coincidences were performed.

Continum feeding : The continuum feeding, if any, was reported [21] to be fast in this mass region and less than 200 fs. If we consider that the recoil nucleus needs about 100 fs before entering the gadolinium foil and that the transit time in Gd is about 500 fs, such feeding will be only of a small fraction of the total yield and thus negligible.

Applying same arguments as above we considered for the analysis that the $15/2^+$ and the 5^- states were the highest accessible states in ^{41}Ca and ^{36}Ar correspondingly.

The nuclear precessions of the γ-ray distribution under reversal of the external magnetic field, were deduced by forming double ratio of counting rates for adjacent pairs of detectors[20]. The results are summarized in Table 1.

Table 1. Summary of experimental precession angles and slopes for states studied in the present experiment.

Nucleus	J_i	$\tau(ps)$	slope(65°)	$-\Delta\theta(mrad)$	g-*adopted*
^{39}K	$19/2^-$	20.0(15)	0.62(3)	13.53(87)	0.35(3)
^{41}Ca	$15/2^+$	4500(200)	0.63(2)	11.57(7)*	0.296(17)†
^{36}Ar	5^-	127(5)	0.56(6)	19.8(29)	
	3^-	3.3(4)	0.31 (6)	24.3(64)	
	2^+	0.46(4)	0.48(5)	19.7(31)	
			$\Delta\theta_{mean}$	=20.2(20)	0.52(6).

* Corrected by a factor 1.7 ±0.17 mrad due to the external polarizing field B= 0.270(20) Tesla

†Calibration point [Ref. 17,18]

g-factors were deduced by comparing measured rotations with the rotation and the well known g-factor of ^{41}Ca (g=0.296±0.017) and they are also shown in Table 1. The g-factor of 0.52(6) deduced for ^{36}Ar is in excellent agreement with the self-conjugate nature of the nucleus, supporting the internal calibration of the field.

4. Discussion

The g-factor : Traditionally the determination of magnetic moments has helped to elucidate the structure of states, since they distinguish between single particle and collective configurations. In particular nuclei, like ^{39}K, close in mass to doubly magic nuclei, have often provided useful tests for nuclear models.

Several shell-model[22] weak, intermediate and phonon-particle coupling[8,23] calculations, concerning energy levels and spin assignments, exist in the literature. A detailed discussion of these calculations may be found in reference 14. However most of them concern the lower energy levels.

We have performed shell model calculations in the $d_{3/2}f_{7/2}$ subspace by adjusting only the $f_{7/2}$ binding energy. The limited configuration space is certainly an oversimplification, however it is not realistically feasible to take into account fully the s-d and f-p shells. In our model the 19/2 state is described by a 70% $f^{3}_{7/2}$ contribution while the rest is spread over many hole states. Adopting this configuration a g-factor equal to 0.3 was obtained and found to be insensitive to binding energy variations and quenching of the single particle spin g-factor. On the other hand, if we assume a pure $f^{3}_{7/2}$ configuration and by using the generalized Lande formula and effective g-factors from ^{41}Sc, ^{42}Ca for the $\pi f_{7/2}$, $\nu f_{7/2}$ particles, we obtain a g–factor of 0.31. Our experimental value while close to both predictions can not differentiate between them but possibly points out the need for more elaborate calculations in an extended subspace.

The transient field : Although determining the transient field was not in our initial intentions, it should be pointed out here that the transient field observed in the present measurement was unexpectedly big. Comparing our result with previous overall parametrizations we determine a ratio of

R= $\Delta\theta(measured)/\Delta\theta(Rutgers - param.)$=1.92(14).

Summary

It has been shown that in favorable circumstances, unambigous individual g-factors can be obtained for picosecond states by using the conventional transient field technique. The high field observed in gadolinium, opens the possibility for performing rather precise measurements in this mass region.

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