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Publication Date
1970-07-01

Submitted to Physics Letters

UCRL-19925
Preprint C. 2

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July 1970

AEC Contract No. W-7405-eng-48

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AN EVIDENCE FOR OBLATE DEFORMATION OF THE 9/2- ISOMERIC STATE IN ^{199}Tl [†]

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The possibility is discussed of deducing the sign of the intrinsic quadrupole moment of a nucleus from the sign of the measured mixing ratio of E2 - M1 mixed transitions in a rotational band. By this method experimental confirmation is pointed out for the previously proposed oblate deformation of the 9/2- state in ^{199}Tl.

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It is well-known that the sign of the mixing ratio δ of an E2 - M1 mixed transition in a rotational band is given as [1];

$$\text{sign } \delta = \text{sign}\left(\frac{g_K - g_R}{Q_o}\right) \qquad (k \neq 1/2) \quad ,$$

where g_K and g_R are the intrinsic and rotational g-factors, respectively, and Q_o is the intrinsic electric quadrupole moment. In this letter we wish to point out that in some cases one can reasonably assume the sign of the $(g_K - g_R)$ term and so deduce the sign of Q_o from a measured sign of the mixing ratio δ. Since, generally, it is not easy to determine the sign of Q_o, this could provide a convenient method for determining whether a nucleus has prolate or oblate deformation

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[†] Work performed under the auspices of the U. S. Atomic Energy Commission.

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The magnetic moment of a rotational nucleus is given by

$$\mu = \frac{1}{I + 1} [g_R I(I + 1) + (g_K - g_R) K^2] .$$

From this formula we derive;

$$(g_K - g_R) = \frac{I + 1}{K^2} (\mu - g_R I) = \frac{I(I + 1)}{K^2} (g - g_R) ,$$

therefore,

$$\text{sign } (g_K - g_R) = \text{sign } (g - g_R) .$$

If the motion of all protons and neutrons are collective, the value of g_R is equal to Z/A ($\simeq 0.4$). There is experimental evidence, however, showing the value to be 0.3 - 0.4, somewhat smaller than Z/A. This is generally attributed to the different contributions to the rotational motion of protons and neutrons, due to the difference in strength of the pairing forces. One can, therefore, generally assume; $0.3 < g_R < 0.4$.

On the other hand, with very few exceptions, the values of magnetic moments are between the two Schmidt values corresponding to $I = \ell \pm 1/2$. This group includes single-particle states in rotational nuclei.

Based on these two well-known properties, one can expect a positive value of $(g - g_R)$, therefore $(g_K - g_R)$, for any odd-proton band whose intrinsic spin is larger than 5/2, and a negative value for any odd-neutron band with spin higher than 11/2 (fig. 1). As can be seen in fig. 1, these signs of $(g - g_R)$ appear to hold with high probability for somewhat lower spin states as well. Then, by determining the sign of the mixing ratio, the sign of the intrinsic quadrupole moment, Q_o, could be determined without measuring either the magnetic moment or the transition probabilities.

In a slightly different context, for nuclei with prolate deformation ($Q_o > 0$), Newton [2] has pointed out a rule that the signs of the mixing ratios are expected to be positive for $I \geqslant 5/2$ in odd-proton bands and most frequently negative in odd-neutron bands. There are many cases which follow this rule because most deformed nuclei appear to have a prolate shape. A striking exception to this is the case of the K = 9/2- band in ^{199}Tl.

Newton, Cirilov, Stephens, and Diamond [3] proposed the possibility of oblate deformation of the 9/2- isomeric state in ^{199}Tl and other odd-mass Tl isotopes (A = 191 → 201). This was done in order to explain the systematic behaviour of the 9/2- states and associated states of higher spin in these nuclei. These states of higher spin were considered to arise from a strongly Coriolis-mixed rotational band based on the 9/2- state (fig. 2). Evidence from gamma-ray branching ratios and E2 - M1 mixing ratios within the proposed band supported this conclusion; the signs of the mixing ratios were found to be negative. From the discussion above it is probably safe to assume that $(g_K - g_R) > 0$ for the K = 9/2- odd-proton state even though there is strong Coriolis mixing. Hence the observed negative sign for δ implies that Q_o must be negative, in agreement with the proposed oblate deformation.

We are indebted to Drs. J. O. Newton, S. D. Cirilov, F. S. Stephens, and R. M. Diamond for valuable suggestions and stimulating discussions.

References

1. K. Alder, A. Bohr, T. Huus, B. Mottelson, and A. Winther, Rev. Mod. Phys. 28 (1956) 435.
2. J. O. Newton, Nucl. Phys. A108 (1968) 353.
3. J. O. Newton, S. D. Cirilov, F. S. Stephens, and R. M. Diamond, Nucl. Phys. A148 (1970) 593.

Figure Captions

Fig. 1. Magnetic moments of odd-proton (a) and odd-neutron (b) nuclei. Open circles indicate nuclei of mass number $A \gtrsim 100$. Moments whose signs have not been determined are not shown unless the signs can be reasonably assumed. The moments of the high spin members in rotational bands are excluded.

Fig. 2. 9/2- band in ^{199}Tl from ref. [3].

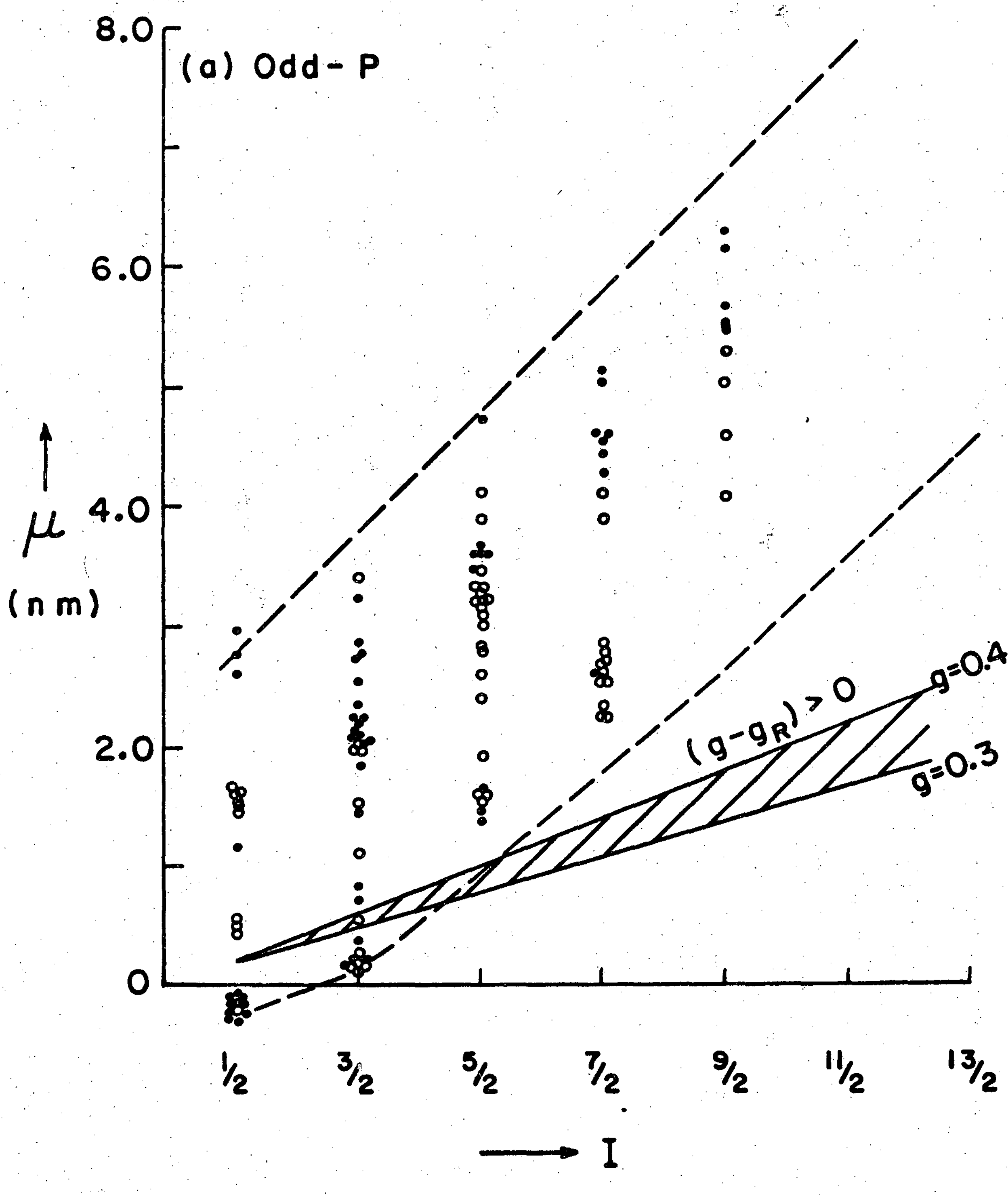

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Fig. 1. (a)

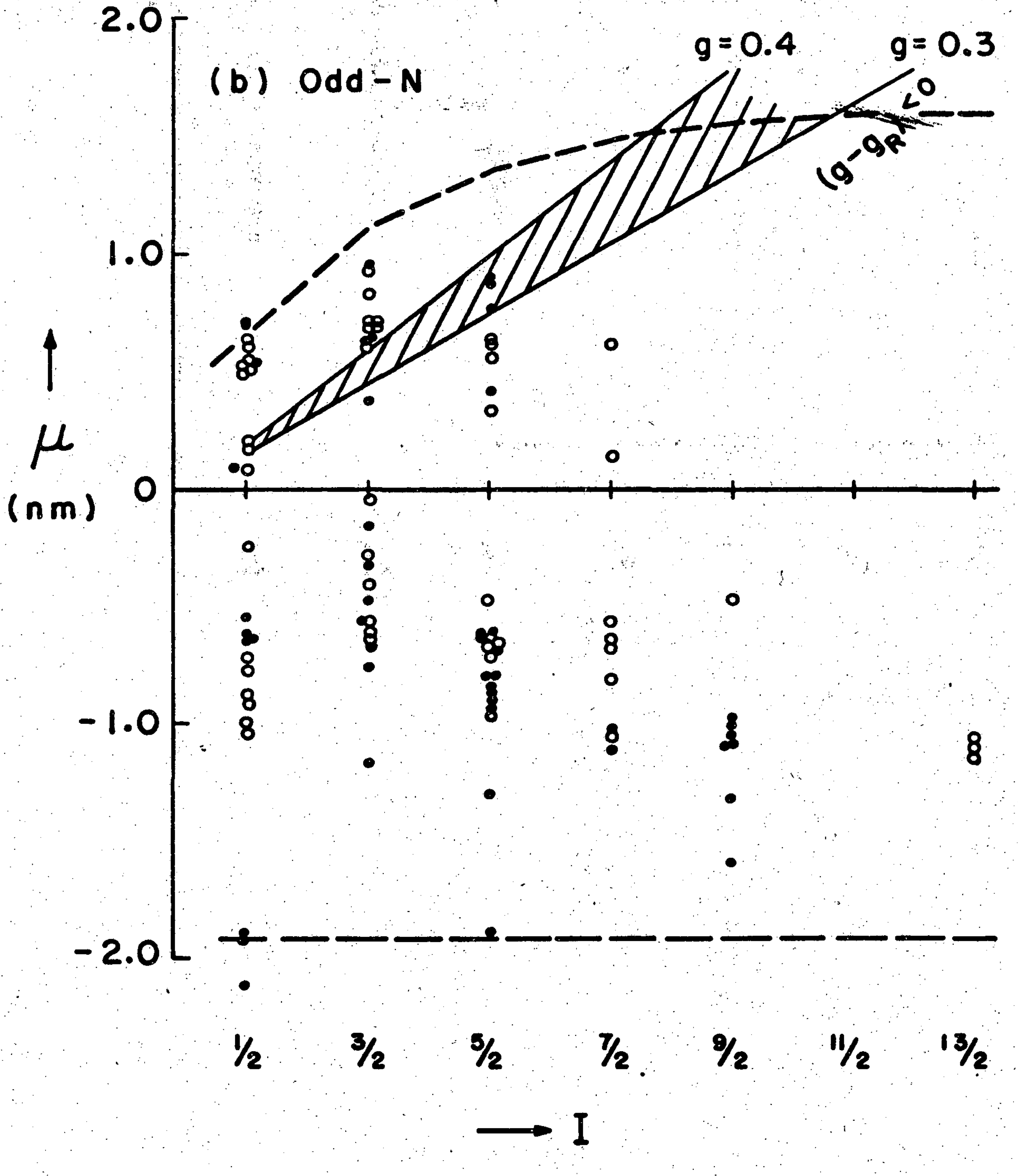
2.0
1.0
0
-1.0
-2.0
μ
(nm)
(b) Odd-N
g = 0.4
g = 0.3
(g-g_R)<0
1/2
3/2
5/2
7/2
9/2
11/2
13/2
I
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Fig. 1. (b)

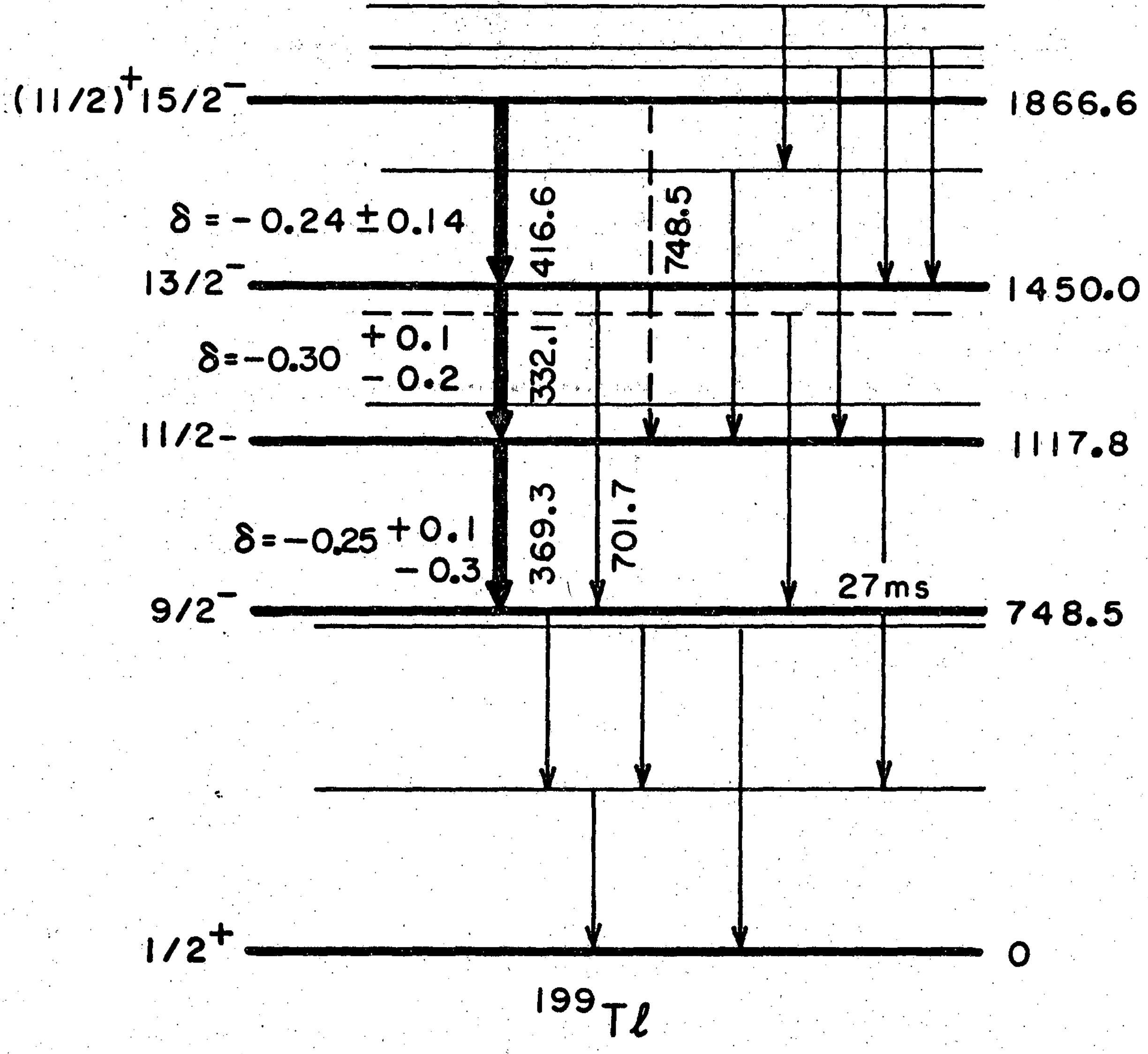

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Fig. 2

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