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Study of the Magnetic Moments of the Tellurium Isomers by Nuclear Orientation

L. VANNESTE,* R. COUSSEMENT, G. DUMONT, H. PATTYN,
E. SCHOETERS and R. E. SILVERANS**

Instituut voor Kern- en Stralingsfysika, Leuven University, Belgium

§1. Introduction

Few magnetic moments of spin isomers of nuclei in the mass region 110–140 have been reported up-to-now. Their study is becoming interesting for several reasons.

First of all, with the surge of interest in the explanation of "intruder" states in this region, one may test the three-quasiparticle character of the $9/2^-$ states, by comparing their g-factor to the one of the $11/2^-$ state.

Secondly, systematic measurements of a series of magnetic moments provide a test of the pairing-plus-quadrupole model which has met reasonable success in this region. It has been shown that spin polarization calculations lead to good agreement with the four already known magnetic moments of the $11/2^-$ states in this region (^{109}Cd,[1] ^{113m}Cd,[2] ^{115m}Cd,[3] ^{115}Sn[4]). For these isomers a particular configuration can be pointed out. In the tellurium isomers however, several neutrons are filling the $h_{11/2}$-shell. It is obvious that additional information on the wave functions is needed, such as given by the pairing plus quadrupole model.[5]

There is no agreement at all however between the already known moments and the values quoted in the latter reference. The same is true for the moments we report here, but we will show at the same time that the apparent disagreement is only due to the choice of theoretical parameters.

§2. Measurements

We measured the anisotropy of gamma-rays from the decay of ^{123m}Te, ^{125m}Te, ^{127m}Te and ^{129m}Te in low temperature nuclear orientation experiments. The $3/2^+ \rightarrow 1/2^+$ transition was used in the case of ^{123m}Te for magnetic moment determination; in the three other cases the $11/2^- \rightarrow 3/2^+$ transition (multipolarity M4) was used. The gamma-ray associated with the latter transition is strongly converted: on the other hand there is a limit on the source strength by the fact that the tellurium has to be implanted by electromagnetic isotope separator into an iron lattice. In all cases the maximum implantation dose was kept below 0.2 at %. Mössbauer spectra taken on equivalent sources[6] as well as time differential angular correlation tests on ^{129m}Te showed that the activity is implanted substitutionally.

The requirement of low implantation dose led to small counting rates in the experiment, esp. with the highly converted M4 transition. Several days of counting at temperatures below 20 mK are needed in order to reach an accuracy of 5% on the value of the magnetic moment: a helium isotope refrigerator was used in order to be able to accumulate sufficient statistics. Anisotropies for the 159.0 keV γ-ray of ^{123m}Te and for the 109.5 keV γ-ray of ^{125m}Te are shown in Figs. 1 and 2. Similar curves were obtained for the M4-transitions of ^{127m}Te and ^{129m}Te.

§3. Results and Discussion

Fits to these curves, using the general theoretical expression

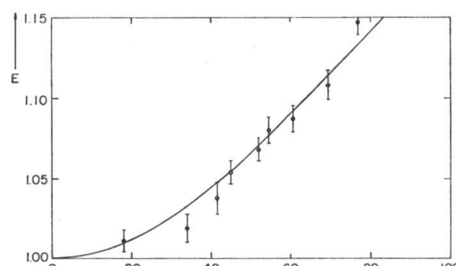

Fig. 1. The anisotropy $W(0)/W(90)$ for the 159 keV γ-ray of ^{123m}Te vs $1/T$.

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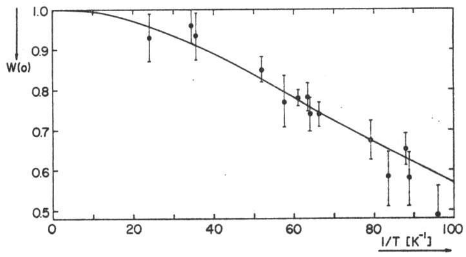

Fig. 2. The function $W(\theta)$ in the direction of the magnetic field vs $1/T$ for the 109.5 keV γ-ray of ^{125m}Te.

$$W(\theta) = \sum_k B_k U_k F_k Q_k P_k(\cos\theta)$$

were made, having the magnetic moment as free parameter. The values obtained in this way are listed in the second column of Table I.

In the third column we show the results of our theoretical calculations. Using occupation coefficients from pairing-plus-quadrupole theory, we calculated the weights of configurations of seniority one: The contributions to the magnetic moment from higher seniority configurations, are calculated by perturbation theory using a residual interaction of the δ-type, between all particles. Unlike Kisslinger and Sorensen we used a strength parameter $C = 30$ MeV for this interaction in agreement with the pairing energy in the $h_{11/2}$ shell, this leads to reasonable agreement with experiment. Using this parameter,

Table I. Comparison of experimental $\mu(11/2^-)$ values with theory.

Isotope	μ_{exp}	μ_{th}
^{123m}Te	-1.00 ± 0.05	-1.18
^{125m}Te	-0.93 ± 0.05	-1.05
^{127m}Te	-0.91 ± 0.05	-1.13
^{129m}Te	-1.15 ± 0.05	-1.28

Table II. Comparison of experimental $g(11/2^-)$ and $g(9/2^-)$ values in ^{125}Te.

$g(11/2^-)$	$g(9/2^-)$
-0.169 ± 0.009[a]	-0.47[b]
	-0.202 ± 0.016[b]
	-0.204 ± 0.007[b]
	-0.15 ± 0.02[b]

a) This work b) ref. 7

reasonable agreement can be obtained with the four previously reported $\mu(11/2^-)$ also. Collective contributions were estimated as well, they are non-negligible only in the case of the Cd-isotopes however.

Finally we mention a test of the character of the low-lying $9/2^-$ state in ^{125}Te. If this state is to be considered as a three-quasiparticle state, on the $11/2^-$ state, the g-factors of both states should be equal. This is borne out in a comparison of our result to the values measured for the $g(11/2^-)$, if one discards the first published result for $g(9/2^-)$, cfr. Table II.

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