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Magnetic Moment of the 6^+ Isomeric State of ^{134}Te†

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The inherent alignment of the prompt fission fragments was used to measure the g factor of the 6^+ isomeric state of ^{134}Te by the time-differential perturbed angular-correlation method. The experimental result $g_{exp} = 0.846 \pm 0.025$ is close to effective g factors of $g_{7/2}$ protons in nuclei with 82 neutrons. The deviation from the Schmidt value is discussed in terms of the polarization of the $^{132}_{50}Sn_{82}$ core by the $g_{7/2}$ protons.

Angular distributions of specific γ rays emitted in the ground-state bands of even-even fragments from spontaneous fission of ^{252}Cf were found[1,2] to be peaked in the direction of the fission fragments with an average anisotropy of $N(0°)/N(90°) = 1.50$,[2] thus showing alignment of the angular momentum of the fragments in a plane normal to the fission direction. In this work, we show that the inherent alignment of the fission fragments can be used for g-factor measurements. Specifically, the magnetic moment of the 6^+ isomeric state in ^{134}Te has been determined by a time-differential perturbed-angular-correlation measurement.

The isotope ^{134}Te has two protons outside the $^{132}_{50}Sn_{82}$ core which is the only accessible double magic nucleus between ^{56}Ni and ^{208}Pb. This isotope lies far from the β-stability line on the neutron-rich side in a region of nuclei that have been reached solely through fission of actinides. ^{134}Te has a 6^+ isomeric state ($T_{1/2} = 163$ nsec) at 1691 keV, decaying by an $E2$, 115.3-keV transition to a 4^+ state and subsequently by a $4^+ \rightarrow 2^+ \rightarrow 0^+$ cascade to the ground state. It was identified both in experiments involving isomeric decay of prompt fission products,[3,4] and in β decay of the mass separated $A = 134$ chain.[5] This state is believed[6,7] to be composed predominantly of the $\pi(g_{7/2})^2$ configuration, with the two protons coupled to maximum angular momentum.

We have measured, in an experiment described elsewhere,[2] the angular distribution of the 115.3-keV, $6^+ \rightarrow 4^+$ transition in ^{134}Te with respect to the fission direction and found it to be

$$W(\theta) = 1 + (0.25 \pm 0.09)P_2(\cos\theta) - (0.17 \pm 0.11)P_4(\cos\theta).$$

The yield of this transition, $(60 \pm 4) \times 10^{-4}$ photons per fission,[3,4] is large enough to permit a time-differential measurement.

The experimental setup is shown schematically in Fig. 1. A thin, 10^7 fissions/min, ^{252}Cf source having an active area of 3 mm^2, and plated on a copper foil of 25 mg/cm^2 thickness was placed in a magnetic field of 7.57 ± 0.15 kG normal to the plane of Fig. 1. γ rays emitted by fragments stopped in the copper backing at three angles (45°, 0°, −45°) with respect to the fission axis were detected in a planar 2-cm^3 Ge(Li) detector. The fission direction was determined by the complementary fragments which were detected in any one of three surface-barrier detectors. A multiparameter experiment was performed in which the kinetic energy of the fission fragments, the γ-ray energy, and the time difference between detection of a fission fragment and a γ ray were simultaneously recorded on magnetic tape. The time resolution, after correction for walk, was 10 nsec full width at half-maximum (FWHM) at

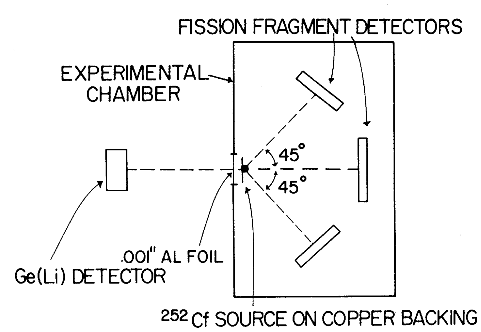

FIG. 1. Schematic description of the experimental system.

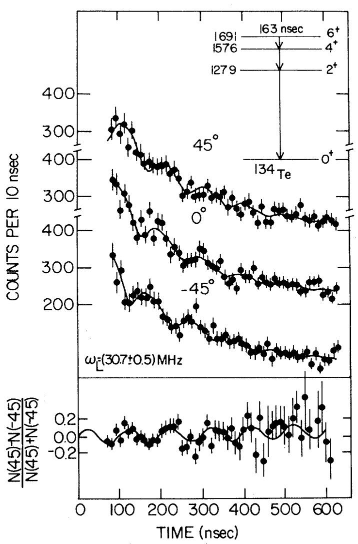

FIG. 2. Time spectra of the 115.3-keV radiation of ^{134}Te at three angles with respect to the fission direction. Normalized differences between the intensities at 45° and −45° are given in the lower part of the figure. The solid lines were obtained by a least-squares fit to the data. The decay scheme of ^{134}Te as determined in Refs. 3, 4, and 5 is also shown.

100 keV. The energy resolution at 100 keV was 1.0 keV FWHM.

The intensity of the 115.3-keV transition as a function of time following fission, in 10-nsec intervals, is shown in Fig. 2, for the three angles. A Larmor frequency of $\omega_L = 30.7 \pm 0.5$ MHz was obtained by a least-squares fit to the time spectra at the three angles and to the normalized differences (also given in Fig. 2). The effective magnetic field at the site of the Te nucleus in the copper lattice was taken to be the applied magnetic field. A small change due to the Knight shift is usually almost canceled by the diamagnetic shielding. Both effects are of the order of 0.5%.[8,9] Therefore no correction was attempted. The g factor obtained from the Larmor frequency is

$$g_{\rm exp} = +0.846 \pm 0.025.$$

The single-particle g factor for a pure $\pi(g_{7/2})^2$ configuration is the same as that of a single $g_{7/2}$ proton, and is equal to

$$g_{\rm sp} = 0.491.$$

An admixture of the $(g_{7/2}d_{5/2})$ configuration and core polarization of the $^{132}_{50}\mathrm{Sn}_{82}$ core by the $g_{7/2}$ protons may enhance the g factor above the single-particle value.

Detailed calculations regarding the structure of the ^{134}Te levels were performed by Heyde, Waroquier, and Vanden Berghe[6] and Wildenthal and Larson,[7] who attempted to fit the energy level spacings and transition rates. The first 6^+ state was calculated by both to be predominantly a $\pi(g_{7/2})^2$ configuration with an admixture of the $(g_{7/2}d_{5/2})$ configuration of 2.3% (Heyde, Waroquier, and Vanden Berghe) and 13.7% (Wildenthal and Larson). These admixtures give an increase of the single-particle g factor of 0.013 and 0.082, respectively.

The effect of the core polarization due to $\pi(g_{9/2}^{-1}g_{7/2})$ and $\nu(h_{11/2}^{-1}h_{9/2})$ excitations on the magnetic moment of $^{133}_{51}\mathrm{Sb}_{82}$ was evaluated following Arima and Horie[10] who used a δ-function interaction, and was found to increase the g factor by $\delta g_{\rm cp} = 0.192$.

The calculated g factor, obtained by adding the above contributions and assuming the $\delta g_{\rm cp}$ for the two-proton state in ^{134}Te to be the same as that of the one-proton state in ^{133}Sb, is 0.696 for a 2.3% admixture[6] of the $(g_{7/2}d_{5/2})$ configuration and 0.765 for a 13.7% admixture.[7] The latter value is lower by 10% than the experimental result. Altogether configuration admixture and core polarization leave unexplained 42% (for 2.3% admixture) and 22% (for 13.7% admixture) of the difference $g_{\rm exp} - g_{\rm sp}$. Here it should be emphasized that the above value of $\delta g_{\rm cp}$ is due to an admixture of 0.4% of particle-hole states to the pure $g_{7/2}$ proton state. An admixture of 0.9% of particle-hole states would have given $\delta g_{\rm cp} = 0.35$, thus accounting for the entire deviation of the experimental g factor from the Schmidt value.

The experimental value of the g factor of the 6^+ state in $^{134}_{52}\mathrm{Te}_{82}$ is somewhat higher than the g factors of the $\frac{7}{2}^+$ ground states of $^{133}_{55}\mathrm{Cs}_{82}$ (0.8118) and $^{139}_{57}\mathrm{La}_{82}$ (0.7952).[11] This seems to indicate blocking of the core polarization by the presence of additional protons in the $g_{7/2}$ orbit. Measurements of g factors in ^{209}Bi and ^{210}Po by Yamazaki *et al.*[12] demonstrated the lack of a blocking effect in the lead region. Yamazaki *et al.*[12] have measured the g factor of the 8^+ isomeric state ($T_{1/2} = 110$ nsec) in ^{210}Po which is analogous to the 6^+ state in ^{134}Te, both having two protons coupled to the maximum angular momentum outside a double-magic core. However, only half of the deviation from the Schmidt value of the measured g factor of the 8^+ state in ^{210}Po could be explained by the core polarization as calculated by Arima and Horie.[10] As was seen above, in our case 20–40% of the difference $g_{\rm exp} - g_{\rm sp}$ remains unexplained. It was suggested[12] that g_l is not equal to

1, and thus can be responsible for the deviation in the lead region. Our experimental result is not in contradiction with such an approach.

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Heavy-Ion-Produced High-Resolution Si-*K*-X-Ray Spectra from a Gas and Solid

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Si-$K\alpha$-x-ray spectra produced by 45-MeV Cl-ion bombardment using thin solid Si and SiH_4 targets are measured. The Si satellite lines shift in energy and change in relative intensity between the solid and gas spectra indicating that different electronic states are produced in the two collisions. The effective fluorescence yield varies by a factor of 2 between the two systems affecting interpretation of comparisons of heavy-ion-induced x-ray-production cross sections.

High-resolution x-ray spectra produced by high-energy heavy-ion bombardment have previously been studied using both gas[1] and solid[2] targets, but x-ray spectra from the same element in solid and gaseous form have not been investigated. In this Letter we report measurements of the high-resolution spectra of Si produced by 45-MeV Cl projectiles in a gas and in a thin solid target. The x-ray satellite lines are observed to shift to higher energy in the gas with respect to the solid. The large shift is consistent with calculated energies of transitions in Si ions having no M-shell electrons present. An enhancement of the relative intensities of the more highly ionized states is observed in the gas spectra compared with the solid. Single-hole L-shell decay rates are too small to explain the differences in terms of filling of the L-shell vacancy before K-x-ray emission.

With use of the observed relative intensities,