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g factor of the 632 keV ($5/2^+$) level in ^{77}As

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The g factor of the 632 keV level ($T_{1/2} = 60 \pm 6$ psec) in ^{77}As, populated in the 11.3 h β^- decay of ^{77}Ge, has been measured using the perturbed angular correlation technique. Large magnetic hyperfine fields present at arsenic in an iron host are used. Measurements were made using the 558-417 keV γ cascade through the 632 keV level. From the directional correlation of this cascade and the measured mean precession angle $\omega\tau$ for the 632 keV level, the g factor for this state has been calculated. The results obtained are $\omega\tau = 0.148 \pm 0.019$ and $g = +1.01 \pm 0.16$. The measured value of the g factor is compared with the predictions of various nuclear models applicable to nuclei in this region.

[RADIOACTIVITY ^{77}Ge, measured $\gamma\gamma(\theta)$, $\gamma\gamma(\theta,H)$. ^{77}As levels, deduced g.]

I. INTRODUCTION

The energy levels of odd-A arsenic isotopes have been subject to considerable theoretical interest.[1-7] The observed level densities at low excitation energies cannot be satisfactorily explained on the basis of either single particle or collective nuclear models. These isotopes are characterized as having a ground state spin $\frac{3}{2}^-$ and at low excitation energies, apart from exhibiting a triplet with spins $\frac{1}{2}^-$, $\frac{3}{2}^-$, and $\frac{5}{2}^-$, a $\frac{9}{2}^+$ and $\frac{5}{2}^+$ doublet is also observed in their level spectrum.[8] The nature of the low lying negative parity states is well understood. The occurrence of a positive parity doublet is also a characteristic feature of odd-A isotopes of gallium, bromine, and rubidium. Recently, Scholz and Malik[3] have accounted for the occurrence of the observed positive parity states using the statically deformed collective model, with the inclusion of Coriolis coupling and a residual interaction of the pairing type. The occurrence of the $\frac{5}{2}^+$ state, however, could only be explained if the nucleus is assumed to have a prolate deformation.[3] The experimentally observed low energy level spectrum of these isotopes does not show a clear rotational spectrum[9] as would be expected on the basis of the calculations of Scholz and Malik.[3] The magnetic moments of the $\frac{9}{2}^+$ states in the arsenic isotopes have been very well explained using the single particle model after taking into account the core polarization effects.[10] Though many experimental investigations have been made on the static and transition electromagnetic moments of the odd parity states of arsenic isotopes[7, 11-14] very little information is available about the $\frac{5}{2}^+$ states. We report here g factor measurement of the $\frac{5}{2}^+$ state at 632 keV in ^{77}As using the perturbed angular correlation technique. This level is populated in the β^- decay of 11.3 h ^{77}Ge. The large hyperfine fields present at arsenic in iron are utilized for the measurements.[15, 16] The short half-life of this state[17, 18] $T_{1/2} = (60 \pm 6)$ psec, necessitates the requirement of high magnetic fields for the measurements.

II. EXPERIMENTAL PROCEDURES AND RESULTS

A. Source preparation

High purity germanium metal was irradiated by neutrons for a period of 30 min in the CIRUS reactor at Trombay. The activity besides having ^{77}Ge and its decay product ^{77}As, also contained a large amount of 80 min ^{75}Ge. The germanium activity was allowed to decay for periods of 18–24 h before starting the measurements. The spectrum of the activity on a Ge(Li) detector revealed no other impurity. The alloys of germanium with iron, containing 2 at% germanium, were made by melting in vacuum, radioactive germanium and iron in the required proportions. In an earlier measurement[14] it was seen that the field at arsenic in iron was the same for germanium concentrations of 1, 2, and 5 at%.

B. g factor measurements

The g factor measurement was done with a conventional two channel coincidence system using NaI(Tl) detectors. The levels populated in the β^- decay of ^{77}Ge are shown in Fig. 1. The 558-417 keV γ cascade through the 632 keV level was used for the investigations. A part of the γ-ray spectrum on a NaI(Tl) detector is shown in Fig. 2. The energy gates selected are also indicated. The directional correlation of this cascade done at five angles both in the "free" geometry and in the "magnet" geometry, yielded identical results,

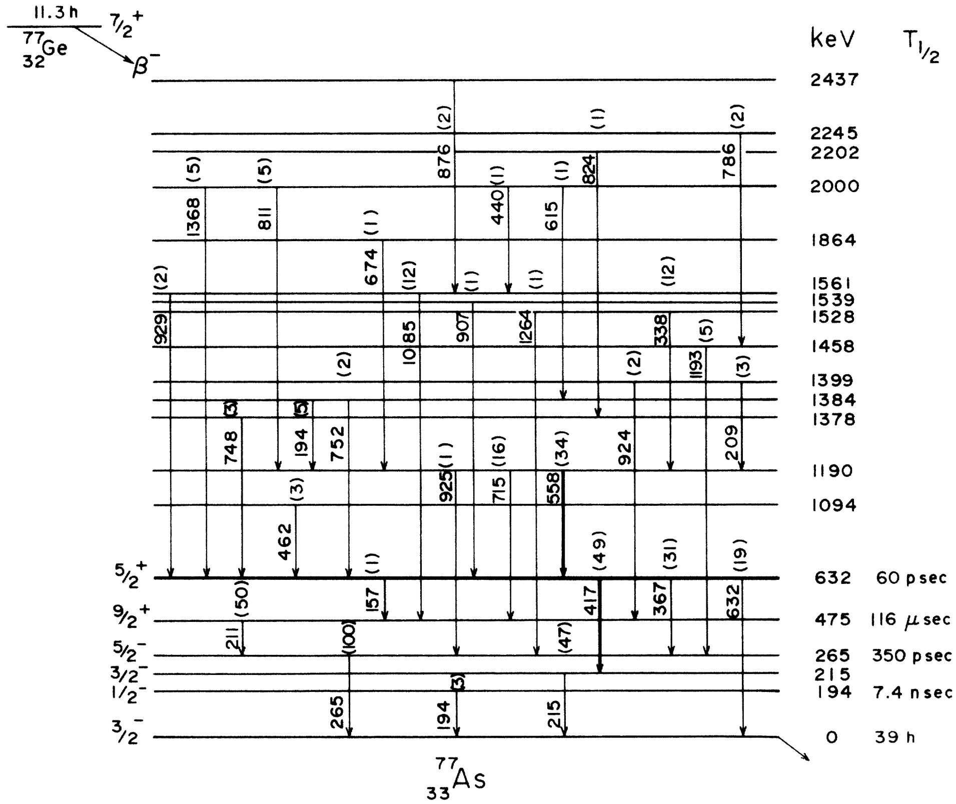

FIG. 1. Levels in ^{77}As populated in the β^- decay of 11.3 h ^{77}Ge. Not all levels populated in this decay have been shown. Only γ transitions having intensities greater than 1% of 265 keV γ ray intensity are shown (taken from Ref. 9). The relative intensities of the γ transitions are shown in parenthesis.

the latter being the geometry for measuring mean precession angle $\omega\tau$. The correlation coefficients, in the expression

$$W(\theta)=1+A_2P_2(\cos\theta)+A_4P_4(\cos\theta),$$

are obtained as $A_2=0.123\pm0.006$ and $A_4=-0.003\pm0.010$. They are corrected for finite size of the detectors used. These values are in good agreement with a recent measurement of Gualda, Saxena, and Zawislak[19] who have used Ge(Li)-NaI(Tl) coincidence system. The value reported by them is $A_2=0.140\pm0.013$ and $A_4=-0.032\pm0.017$. These results indicate that there is negligible contribution from interfering cascades in the energy gates selected in the present case and justifies the use of NaI(Tl) detectors for the experiment. Gualda *et al.*[19] have also measured the directional correlations of several cascades through the 265 keV level which has a half-life of 350 psec.[13] They have observed no change in the correlation coefficients obtained using liquid and solid form of the radioactive sources indicating that the attenuations due to extranuclear interactions are small. Because of the short half-life of the 632 keV level the attenuation of

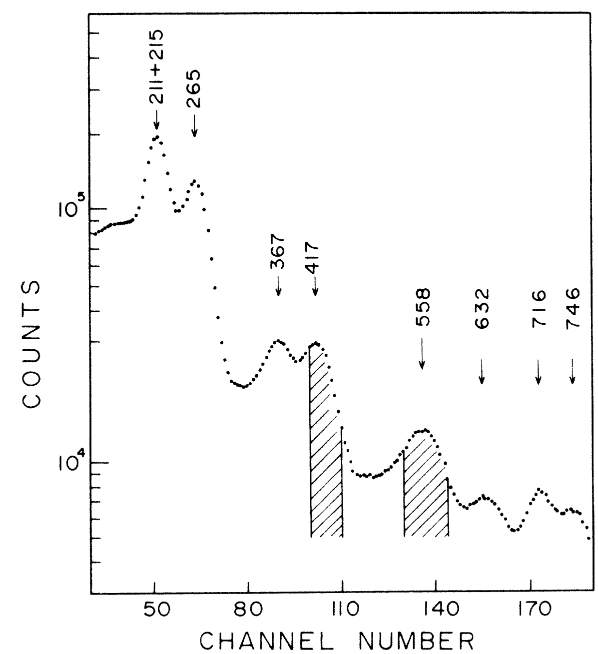

FIG. 2. A part of the γ ray spectrum taken on a 5 cm ×5 cm NaI(Tl) detector. The energy gates selected for the measurements are also indicated.

the 558-417 keV γ-γ cascade is assumed to be negligible.

The mean precession angle $\omega\tau$ for the 632 keV level was measured using the germanium iron alloy (Sec. II A). An external magnetic field of 10 kOe, provided by an electromagnet, was used to polarize the sample. The fractional change in the coincidence counting rate upon field reversal R was measured. The counters were kept at 135°. The γ ray energy gates used were the same as for the directional correlation measurement. Since no other level above 632 keV is known to have a measurable half-life, the measured rotation of the correlation is essentially due to the lifetime of this level. Moreover, most of the high energy levels feed the 632 keV level; thus any small contribution from the interfering cascades will not affect the final result so long as the energy gates are the same for directional correlation and $\omega\tau$ measurements. The value of R was obtained to be $R = 0.043 \pm 0.005$. From this value of R the value of $\omega\tau$ is calculated using the relation

$$R_{135^\circ} = -\frac{4C_2G_2\omega\tau}{1+(2G_2\omega\tau)^2}$$

where

$$C_2 = \frac{3A_2}{4+A_2}; \quad A_4 \ll A_2$$

and

$$\omega = -\frac{gH_{\text{eff}}\,\mu_N}{\hbar}; \quad H_{\text{eff}} = H_{\text{hf}} + H_{\text{ext}}.$$

G_2 is the integrated attenuation coefficient and is unity in the present case. The value of $\omega\tau$ thus obtained is $\omega\tau = 0.148 \pm 0.019$. The half-life of the 632 keV level has recently been measured by Chopra *et al.*[18] using β-γ delayed coincidence technique to be $T_{1/2} = (60 \pm 6)$ psec. This is slightly smaller than the value $T_{1/2} = (75 \pm 15)$ psec reported by Tucker and Meeker[17] using γ-γ delayed coincidence technique. Using $T_{1/2} = (60 \pm 6)$ psec and $H_{\text{hf}} = 343.9$ kOe[16] the value of g factor is obtained to be $g = +1.01 \pm 0.16$. The spin of the level being $\frac{5}{2}^+$, its magnetic moment is obtained as $\mu = (+2.53 \pm 0.40)\mu_N$. The sign of the g factor is inferred from the sense of rotation.

III. DISCUSSION

The measured value of the g factor for this state rules out it being a $d_{5/2}$ single particle state for which $g = 1.9$. It also rules out this state to be formed due to a weak coupling of the $\frac{9}{2}^+$ single particle state to the even-even core. For such a state the value of g factor is calculated to be 1.7 [using $g_{9/2} = 1.23$ (Ref. 10); $g_R = 0.4$], which is larger than the measured value. The experimental value of the g factor is consistent for this state to be either of $(g_{9/2})^3$ configuration giving rise to $\frac{5}{2}^+$ for which $g_{5/2} = g_{9/2} = 1.23$ (Ref. 10) or with a Nilsson state $\frac{5}{2}^+[422]$ for which the calculated value of g factor is 1.26 for $\eta = 2$. The tentative assignment of the $\frac{5}{2}^+$ state as the [422] Nilsson state lends support to the calculations of Scholz and Malik,[3] according to which the positive parity doublet $\frac{9}{2}^+$, $\frac{5}{2}^+$ can only be explained by assuming a prolate shape of the arsenic isotopes. This leads to an interesting result, namely, though some of the low lying negative parity states can be interpreted as spherical states arising from the coupling of a single particle state to the quadrupole vibrations of the core[7], the arsenic nucleus appears to be deformed as far as the positive parity states are concerned.

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