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LIFETIMES OF LEVELS IN ^{71}Ge

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The low-lying states of ^{71}Ge have been studied the via the ^{71}Ga (p, $n\gamma$) ^{71}Ge reaction using proton beam energies of 2.5–4.3 MeV. The angular distributions have been used to assign the spins and the multipole mixing ratios using statistical theory for compound nuclear reactions. The ambiguity in the spin values for the various levels has been removed. The multipole mixing ratios for a few γ-transitions have been newly measured. The lifetimes of the levels at 747.0, 808.0, 831.1, 1377.8, 1406.6, 1414.4, 1422.1, 1558.8 and 1566.1 keV excitation energies have been measured for the first time using the Doppler shift attenuation method.

Keywords: Lifetimes; DSAM; mixing ratio; HPGe detector; proton beam.

1. Introduction

Information about the ^{71}Ge nucleus has been obtained from experimental studies by β-decay,[1,2] (p, $n\gamma$),[3–6] ($\alpha, n\gamma$) reactions[7–9] as well as neutron transfer (p, d)[10] and (d, p) reaction studies.[11] Bhat[12] has compiled the experimental information about ^{71}Ge from various types of studies. The theoretical study of the structure of ^{71}Ge nucleus has been carried out by Ichello *et al.*[13] within the framework of the interacting boson-fermion model-1 (IBFM-1) and by Fedorets *et al.*[3] from the dynamical collective model. But due to limited knowledge of the lifetimes of the levels, these calculations have produced ambiguous results. Later, Ivascu *et al.*[5] re-investigated this nucleus in terms of the IBFM using the measured lifetimes of the levels via the (p, $n\gamma$) reaction. This study has produced results only up to 1.5 MeV excitation energy and more experimental information (lifetimes) are still required for the qualitative as well as quantitative study of this nucleus beyond this excitation energy.

The aim of the present study is to provide additional experimental information about existing level structure and lifetimes of some of the levels of ^{71}Ge through the (p, $n\gamma$) reaction. In this work, we have measured the lifetimes of the levels using the Doppler Shift Attenuation (DSA) technique. The spin values and the multipole mixing ratios were also extracted from the angular distributions of de-excitation γ-rays.

The branching ratios for various transitions were measured from the γ-ray spectra recorded at 55°. Finally, from the measured experimental values of lifetimes, spins and multipole mixing ratios for various transitions, the reduced transition probabilities B(M1) and B(E2) were calculated and compared with Interacting Boson Fermion (IBF) model calculations.[1] The preliminary results of this experiment were reported earlier.[14]

2. Experimental Procedure

A thick self-supporting pellet of spectroscopically pure natural Ga was used as a target. A 2.5–4.3 MeV proton beam was used to excite the levels of ^{71}Ge through the ^{71}Ga (p, $n\gamma$) reaction (Q-value = −1.017 MeV). The target was placed at an angle of 45° with respect to the beam direction and was thick enough to stop incident protons. The angular distributions were measured at 0°, 30°, 45°, 55°, 75° and 90°. The γ-rays were detected with a 70 cm^3 coaxial HPGe detector with a resolution of 1.9 keV for the 1332 keV γ-ray of ^{60}Co. The detector was placed at a distance of 10 cm from the target and a graded filter consisting of Pb, Cu and Al was placed in front of the detector to suppress the high flux of X-rays and very low-energy gamma rays. A 5″ × 5″ NaI(Tl) detector was placed at −90° to act as a monitor for the angular distribution measurements. The target with an electron suppresser acted as a Faraday cup. The signals from the HPGe detector were stored using a Multichannel Pulse-Height-Analyser. Electronic drift in the amplifier gain, if any, was monitored using background photopeaks at 440, 1461, 1779.1 and 2614.1 keV. At each angle a number of spectra were recorded and the drift in the gain was found to be negligible. The excitation functions of various γ-rays were measured at 55° in the range of 2.5–4.3 MeV beam energies to ascertain that the channel of the compound decay is dominant as compared to the Coulomb excitation at the incident proton energy of 4.3 MeV. The energies of the gamma-rays were measured from the spectra recorded at 90° to avoid any shift due to the Doppler effect.

3. Data Analysis

The Gamma-ray spectra were analyzed using the computer program PEAKFIT.[15] A typical gamma-ray spectrum at 90° for an incident proton energy of 4.3 MeV is shown in Fig. 1. The excitation functions of all the observed gamma-rays were functions of all the observed gamma-rays were carefully analyzed as a function of energy and those from the (p, $n\gamma$) reaction were easily identified with a characteristic rise above their threshold energy. The level scheme for ^{71}Ge, constructed on the basis of the observed gamma-rays, is shown in Fig. 2. The gamma-ray energies and the relative branching ratios, as shown in Table 1, are the weighted averages of the respective values at 4.0 and 4.3 MeV bombarding energies.

The mean lifetimes were determined using the Doppler Shift Attenuation (DSA) method from the single gamma-ray spectra obtained at various angles between 0° and 90°. The plots of the centroids of the photopeaks at different angles versus

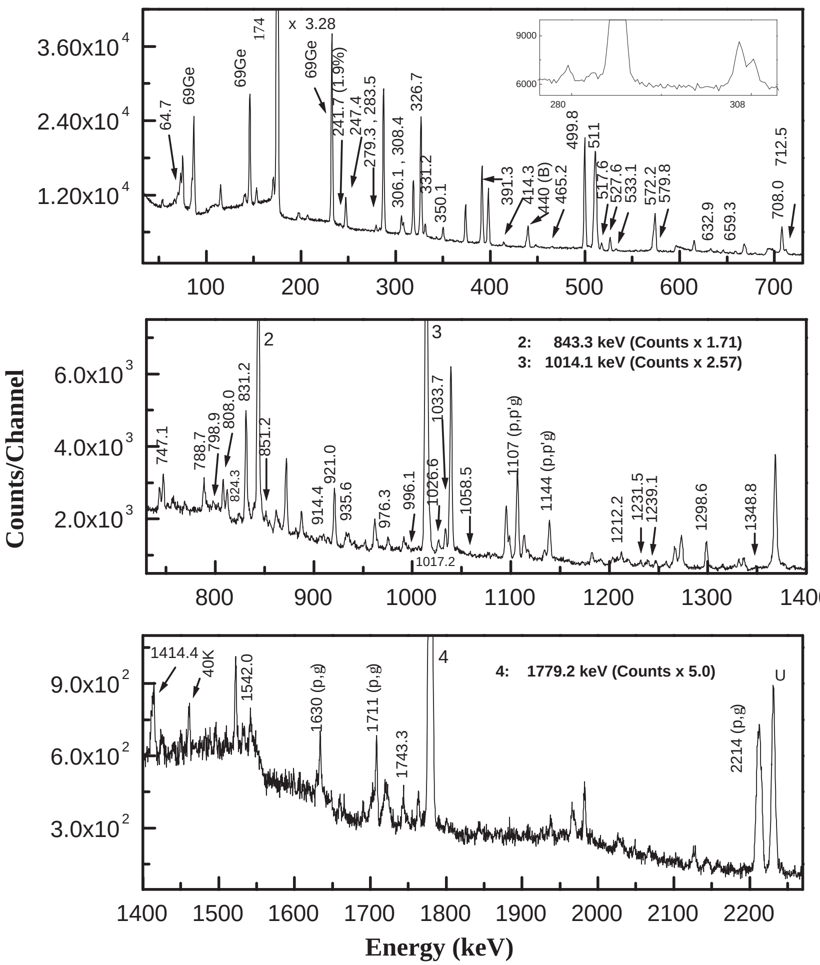


Fig. 1. A typical gamma-ray spectrum at 90° from $^{71}Ga(p, n\gamma)^{71}Ge$ reaction at 4.3 MeV.

$\cos\theta$ for a few transitions are shown in Fig. 3. The straight line represents the least squares fit. The experimental values of the attenuation factor $F(\tau)$ were calculated from the slope of the straight line. The values of theoretical $F(\tau)$ were obtained using the Lindhard, Scharff and Schiott theory[16] for stopping power along with the Blaugrund correction[17] for atomic scattering. The details of the DSAM analysis are given in earlier publications[18,19] from our laboratory. The values of the measured lifetimes of various levels are given in Table 2 along with their respective experimental $F(\tau)$ values.

The extraction of multipole mixing ratios of the observed transitions and the assignment of spin values to the excited levels were made from the χ^2-fitting of angular distribution data at 4.3 MeV proton beam energy. The optical model parameter sets given by Perey and Perey,[20] which are based on the results of Perey[21]

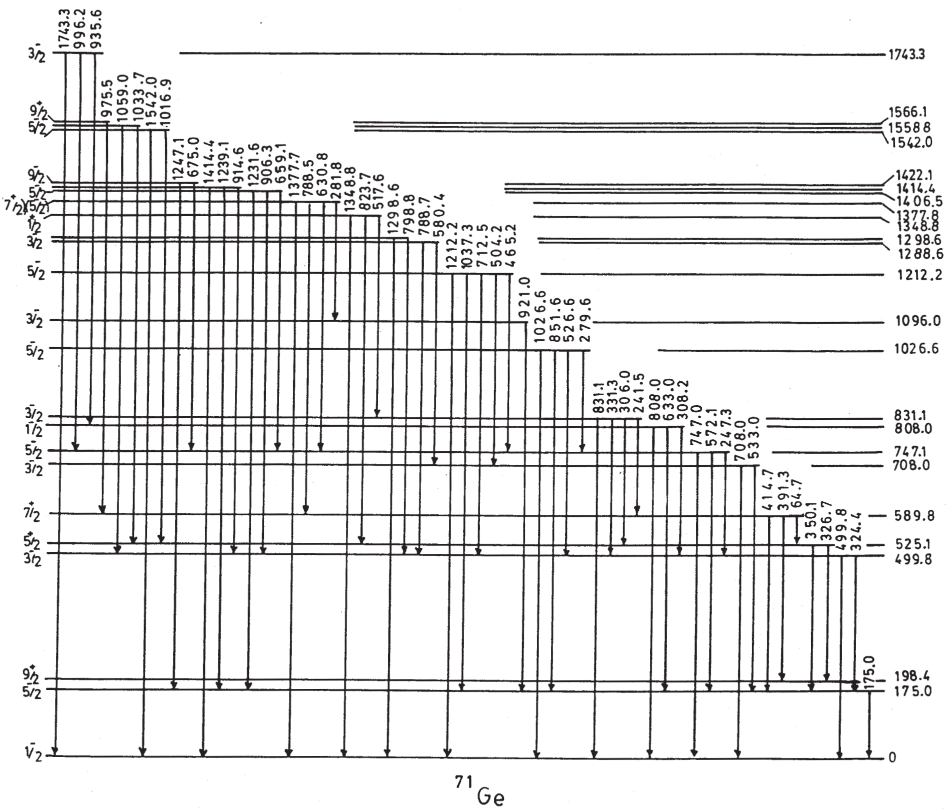


Fig. 2. Level scheme of ^{71}Ge.

for protons and Wilmore and Hodgson[22] for neutrons, were used to calculate the transmission coefficients. Besides the observed neutron channel, all known $(p, p'\gamma)$ channels and (p, γ) channels were included as competing channels. Moldauer width fluctuation correction[23] was also taken into account. The typical experimental angular distributions of some of the observed transitions together with the theoretical curves for different possible spins of the levels and the respective χ^2-fitting are shown in Fig. 4. The 0.1% confidence limit was used to exclude unacceptable spins and δ values. The experimental values of the A_2 and A_4 coefficients alongwith multipole mixing ratios (δ) are given in Table 3. The reduced transition probabilities B(M1) and B(E2), extracted from the measured values of lifetimes and multipole mixing ratios, are given in Table 4.

4. Experimental Results

The excitation energies of the various levels in the ^{71}Ge nucleus were compared with the values reported earlier.[5,6,12] The level energies measured in the present work are in general agreement with previous measurements. The branching ratios,

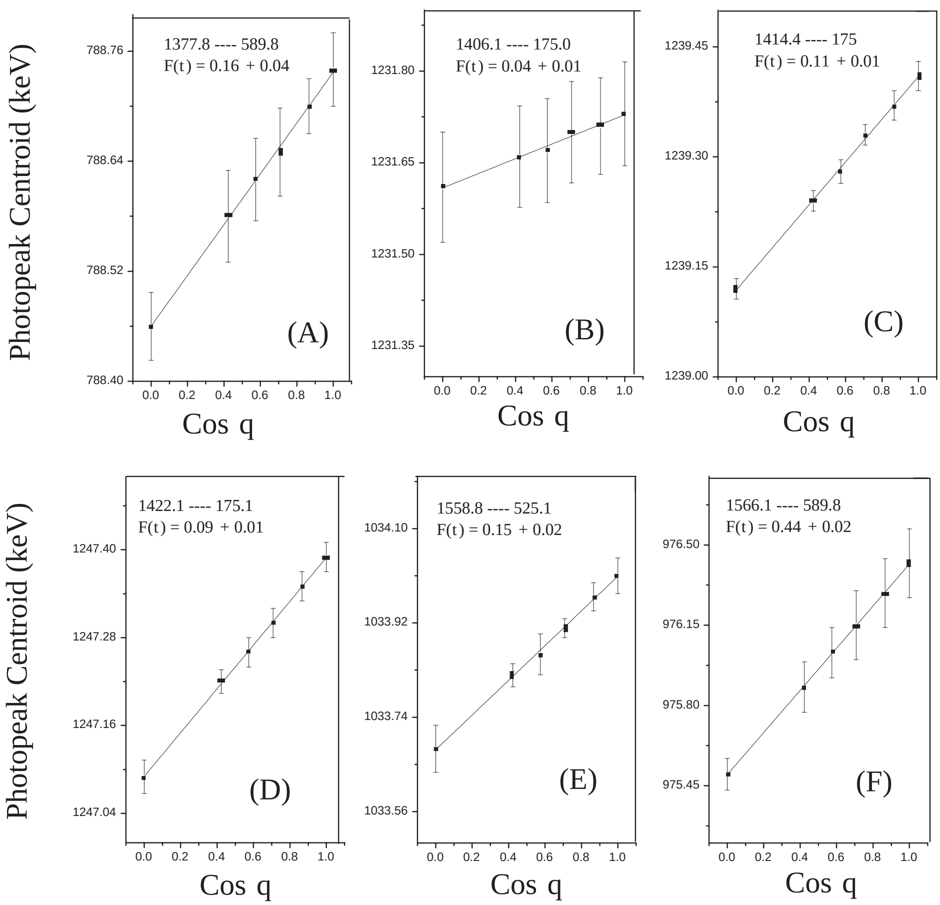
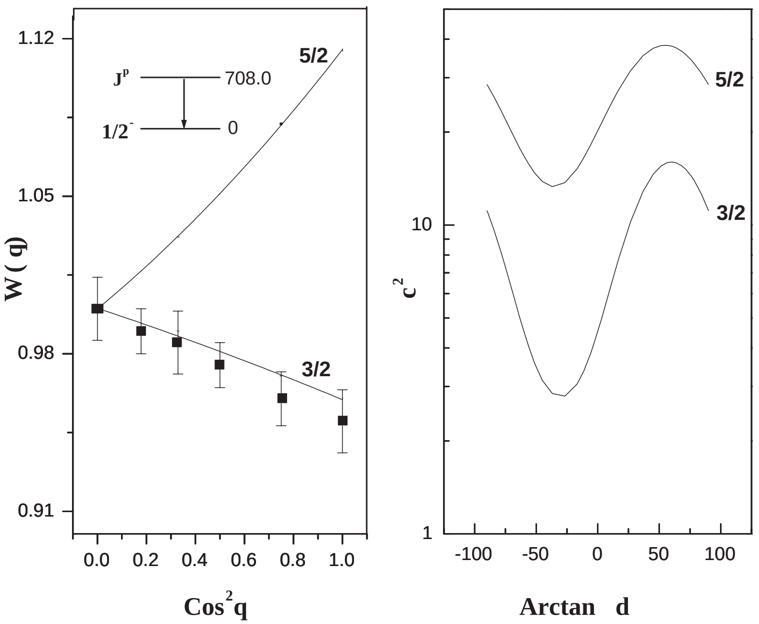


Fig. 3. Plots of photopeaks centroids versus $\cos(\theta)$ for various transitions (keV): (A) 1377.8 $\rightarrow$ 598.8, (B) 1406.6 $\rightarrow$ 175.0, (C) 1414.4 $\rightarrow$ 175.0, (D) 1422.1 $\rightarrow$ 175.0, (E) 1558.8 $\rightarrow$ 525.1 and (F) 1566.1 $\rightarrow$ 589.8.

as shown in Table 1 for various transitions, are compared with the reported values[6] and almost all the values are in agreement with the literature except for a few transitions having small deviations. Table 2 gives the measured values of lifetimes of the sixteen levels at 708.0, 747.0, 808.0, 831.1, 1026.6, 1096.0, 1212.2, 1298.6, 1348.8, 1377.8, 1406.1, 1414.4, 1422.1, 1558.8, 1566.1 and 1743.3 keV excitation energies. These results are also compared in this table with the previous results.[5] From these measurements, the lifetimes of nine levels at 747.0, 808.0, 831.1, 1377.8, 1406.6, 1414.4, 1422.1, 1558.8 and 1566.1 keV excitation energies were measured for the first time in the present experiment. Figures 3(a)–3(f) give the experimental values of $F(\tau)$ for six levels from the plots of photopeak centroids versus $\cos\theta$. Angular distributions of de-excited γ-rays are shown in Figs. 4(a)–4(f). Using the χ^2-fitting method, we assigned spin values as well as removed ambiguities in these

(A) 708.0 → 0.0



(B) 747.0 → 175.0

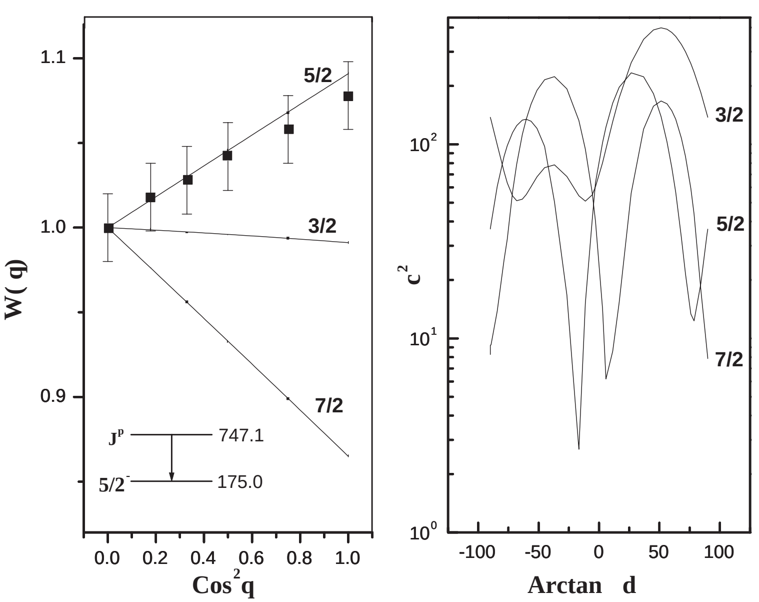
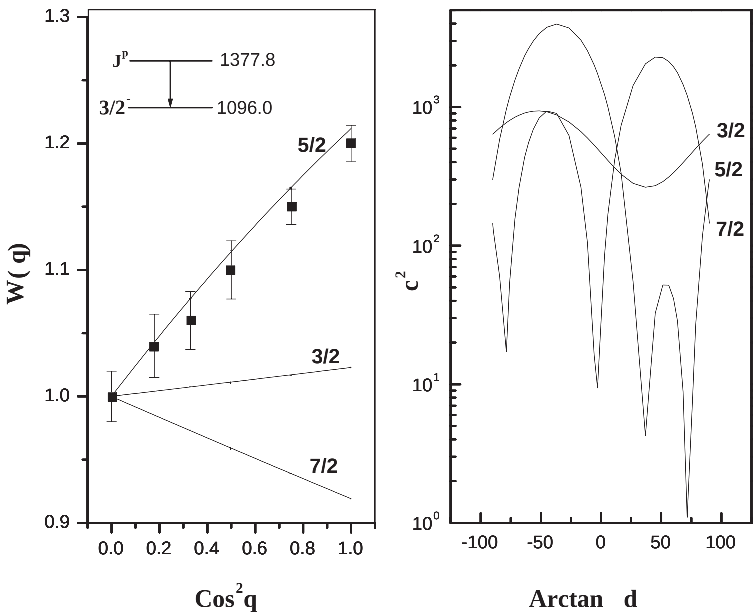


Fig. 4. Angular distributions of de-excited gamma-rays from transitions (keV).

(C) 1377.8 → 1096.0



(D) 1406.6 → 175.0

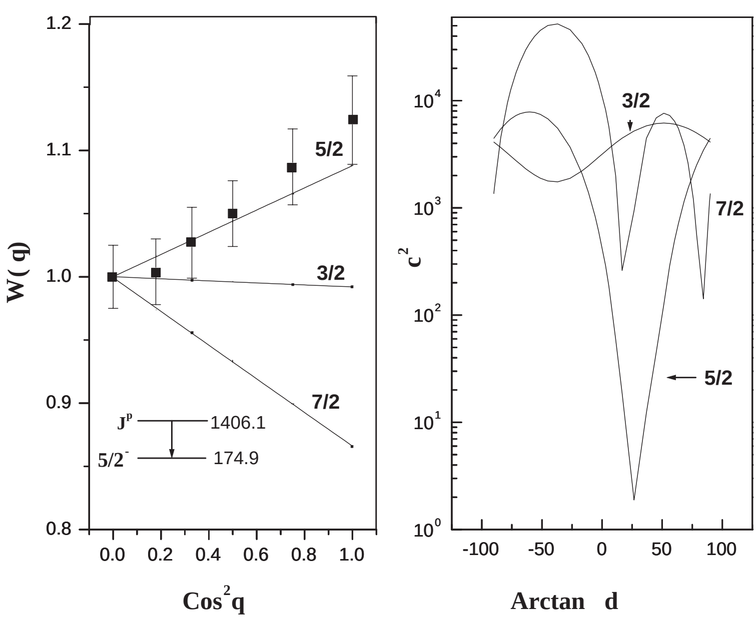
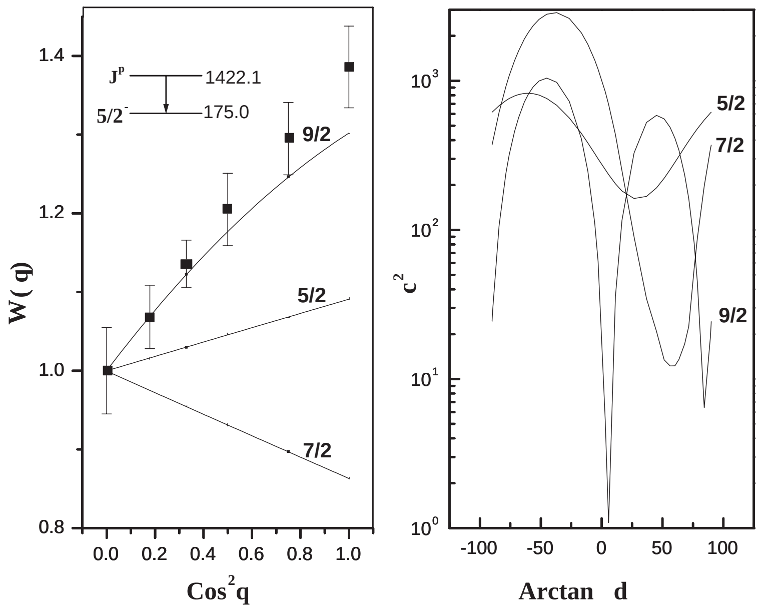


Fig. 4. (*Continued*).

(E) 1422.1 → 175.0



(F) 1743.3 → 0.0

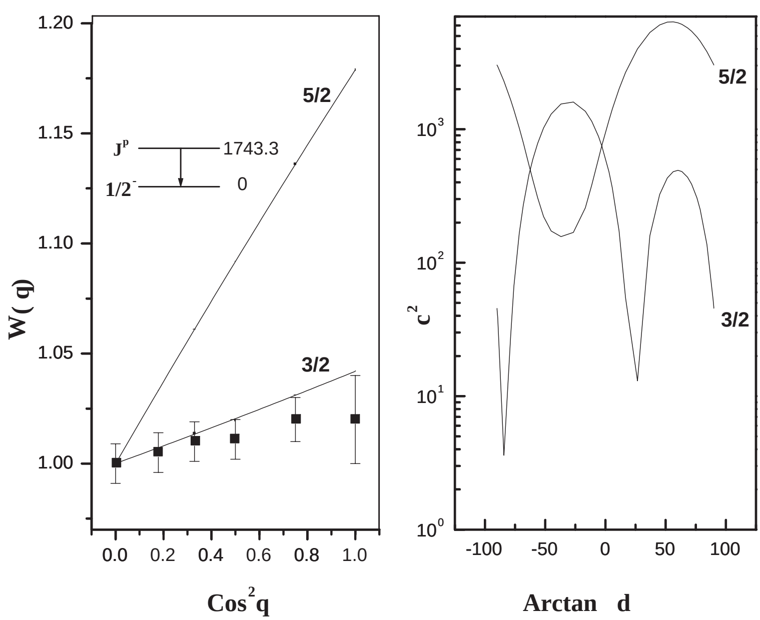


Fig. 4. (*Continued*).

values for some levels in the present experiment. The spin values of other levels are also confirmed in the present work. We have also extracted the multipole mixing ratios (δ) of ten transitions for the first time. Table 3 shows the angular distribution coefficients A_2, A_4 and the mixing ratios (δ) along with the comparison of the previous results.[2] The details of the results of some of the levels are given below.

4.1. *The 1026.6 keV level*

We observed four branches from this level to the ground state and 175.0, 499.8 and 747.1 keV states with the branching ratios of 20.3%, 10.5%, 58.1% and 11.1%, respectively, against the repective reported values[6] of 19.5%, 7.4%, 55.2% and 12.4%. The angular distribution and χ^2-fitting of the 526.6 keV γ-ray assigned the spin to this level as 5/2 and provided a mixing ratio for the 526.6 keV transition as -0.75 ± 0.13. The multipole mixing ratio for the 1026.6 keV transition was measured to be 1.5 ± 0.3. The lifetime of this level measured as 678^{+210}_{-132} fs, which compares with the previous value[6] of > 1.6 ps.

4.2. *The 1212.2 keV level*

In the present investigation, this level is reported to decay via five transitions to the ground state and 175.0, 499.8, 708.0 and 747.1 keV states, with the branching ratios of 24.9%, 21.3% 31.4%, 14.6% and 7.8%, respectively. These results are in good agreement with the previous values.[6] The angular distributions and χ^2-fitting of the 712.5 keV transition indicate that the spin of this level is 5/2. Two values of multipole mixing ratio for this transition were obtained as 0.49 ± 0.18 or -1.54 ± 0.2. Hamilton *et al.*[2] also measured two values of mixing ratio for this transition and these are in close agreement with our results. The lifetime of the level was measured as 440^{+106}_{-60} fs, which disagrees with the reported value[6] of > 1.7 ps.

4.3. *The 1377.8 keV level*

We observed four transitions from this level to the ground, 589.8, 747.1 and 1096.0 keV levels with the branching ratios of 24.0%, 54.0%, 10.0% and 12.0%, respectively. The angular distributions and χ^2-fitting of the 282.0 keV transition assigned a unique spin of 5/2 for this level for the first time. The multipole mixing ratio of this transition was measured to be 2.9 ± 0.1. The mean lifetime of this level was obtained for the first time as 308^{+112}_{-68} fs. The B(E2) values were obtained using the present results for 282.0 and 630.8 keV transitions as 10.1 ± 3.6 and 30.4 ± 22.5 w.u., respectively.

4.4. *The 1406.6 keV level*

In the previous work,[6] this level was reported to decay through three transitions to 175.0, 499.8 and 747.1 keV levels with the branching ratios of 40.0%, ≥10% and

50%, respectively. Our measurements suggest that the decay modes of this level are 1406.5 → 175.0 (39.3%), 1406.5 → 499.8 (9.2%) and 1406.5 → 747.1 (51.5%), respectively. The angular distributions of the 906.3 and 1231.6 keV transitions and the χ^2-fitting for the first time confirm the spin of this level as 5/2. The multipole mixing ratios of these transitions are extracted as -0.2 ± 0.1 and 0.49 ± 0.13. The newly measured lifetime in the present work is 1240^{+300}_{-214} fs.

4.5. *The 1414.4 keV level*

This level decays via three transitions to ground, 175.0 and 499.8 keV levels, with the branching ratios of 53.5%, 30.5% and 16.0%, respectively. The angular distributions and χ^2-fitting of the 1239.1 keV transition indicate that this level has two possible spins of 5/2 or 7/2. The multipole mixing ratios for this transition through χ^2-fitting are -2.0 ± 1.2 for spin 5/2 and 0.06 ± 0.05 or -4.8 ± 0.08 for spin 7/2. The lifetime of this level was measured for the first time as 482 ± 50 fs.

4.6. *The 1422.1 keV level*

In the present work, we have observed two transitions from this level to 175.0 and 747.1 keV levels with branching ratios 79.6% and 20.4%, respectively. The angular distributions and χ^2-fitting of the 1247.1 keV transition have assigned the possible spin of 9/2 for this level and the mixing ratio for this transition as 0.1 ± 0.05, for the first time. The lifetime of the level was found to be 630^{+20}_{-16} fs. Eberth *et al.*[8] also used the DSA technique and obtained an $F(\tau)$ value (0.86) which is close to our value (0.09). But the lifetime extracted by Eberth *et al.* has a discrepancy which is probably due to their theoretical calculation of $F(\tau)$ without using any standard code as mentioned in their work.

4.7. *The 1558.8 keV level*

We observed two branches from this level to 499.8 and 525.1 keV levels with branching ratios of 12.9% and 87.1%, respectively, compared with the reported values[6] of 9.1% and 90.9%. The angular distributions and χ^2-fitting of the 1033.7 keV transition confirm the spin of this level as 5/2 and give the multipole mixing ratio for this transition as 0.48 ± 0.15. The present measured δ-value is within the reported range ($-0.26 \leq \delta \leq 3.0$) in the previous measurement.[2] The lifetime of this level was measured for the first time as 342^{+58}_{-42} fs which gives the $B(\text{E2})$ value of 18.9 ± 9.0 for the 1033.7 keV transition.

4.8. *The 1743.3 keV*

We observed three branches from this level to ground, 747.1 and 808.0 keV levels with branching ratios of 45.3%, 16.1% and 38.5%, respectively. Onizuka *et al.*[6] have reported the decay of this level as 1743.3 → 0 (50%) and 1743.3 → 808.0 (50%).

Perhaps due to poor efficiency and the coarse resolution of their detector, they could not observe the 996.2 keV transition in the spectrum. The angular distributions of the 1743.3 keV transition assigned 3/2 spin to this level with a mixing ratio of the transition of -11.52 ± 3.9 for the first time. We also measured the δ value for the 935.6 keV transition. The lifetime of the level was found to be 94^{+16}_{-13} fs.

5. Summary and Discussion

The aim of the present study was to provide additional experimental information on the existing level structure of ^{71}Ge through the (p, $n\gamma$) reaction. We have measured the gamma-ray energies, branching ratios, lifetimes of the excited levels and multipole mixing ratios of various transitions in ^{71}Ge. We have also deduced the reduced transition probabilities, i.e. B(E2) and B(M1) values, for some of the transitions observed in the present investigation.

Some attempts have been made[1,2] to explain the structure of ^{71}Ge within the framework of IBFM-1. But due to the poor availability of experimental data, the theoretical calculations were found with some ambiguities. It was suggested[1,2] that some of the low-lying levels had an "intruder" character. Ivascu *et al.*[5] re-investigated the structure of ^{71}Ge by considering ^{70}Ge as the core nucleus. These calculations were found to be in reasonable agreement with the experimental results for low-lying levels up to 1.5 MeV, and the higher spin yrast states below 2.5 MeV. Thus, according to Ivascu *et al.*[5] the levels in ^{71}Ge up to 1.5 MeV can be explained satisfactorily by the coupling of the odd particle occupying the valence shell orbitals to collective excitations of the core. The higher levels may have other excitation modes which require detailed experimental information to explain them qualitatively and quantitatively. Since the electromagnetic transition probabilities, and hence the lifetimes, are more sensitive to nuclear wave-functions than the excitation energies of the levels, the new results on lifetimes will help to test these models more critically for this nucleus.

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The tables referred to in this paper were omitted. They should have appeared as in the following.

Table 1. Level energies, gamma-ray energies and branching ratios in ^{71}Ge.

Level (keV)	γ-ray (keV)	Branching ratios: Present work	Ref. 6
175.0	175.0 ± 0.01	100	100
499.8	324.4 ± 0.11	2.9 ± 1.5	—
	499.8 ± 0.01	97.1 ± 4.7	100
525.1	326.7 ± 0.01	90.3 ± 0.5	89.0 ± 2.7
	350.1 ± 0.01	9.7 ± 0.1	11.0 ± 0.7
589.8	64.7 ± 0.10	4.3 ± 0.3	—
	391.3 ± 0.01	91.3 ± 0.7	100
	414.7 ± 0.06	4.5 ± 0.02	—
708.0	533.0 ± 0.09	5.1 ± 0.1	2.8 ± 1.0
	708.0 ± 0.01	94.9 ± 1.3	97.2 ± 4.8
747.1	247.3 ± 0.01	30.8 ± 0.4	35.7 ± 2.1
	572.1 ± 0.03	46.8 ± 0.8	42.0 ± 1.7
	747.0 ± 0.03	22.4 ± 0.6	22.3 ± 1.9
808.0	308.2 ± 0.02	31.8 ± 0.9	35.7 ± 1.6
	633.0 ± 0.07	24.8 ± 1.1	20.9 ± 1.6
	808.0 ± 0.04	43.4 ± 0.6	43.5 ± 3.9
831.1	241.5 ± 0.20	1.9 ± 0.1	1.6 ± 0.2
	306.0 ± 0.02	18.6 ± 0.3	18.3 ± 1.3
	331.3 ± 0.02	15.4 ± 0.3	16.0 ± 0.8
	831.1 ± 0.01	64.1 ± 0.8	64.1 ± 1.3
1026.6	279.6 ± 0.06	11.1 ± 0.6	12.4 ± 2.3
	526.6 ± 0.02	58.1 ± 0.9	55.2 ± 6.4
	851.6 ± 0.14	10.5 ± 1.0	7.4 ± 4.6
	1026.6 ± 0.11	20.3 ± 1.1	19.5 ± 0.8
1096.0	921.0 ± 0.03	100	100

Table 1. (*Continued*)

Level (keV)	γ-ray (keV)	Branching ratios	
		Present work	Ref. 6
1212.2	465.2 ± 0.16	7.8 ± 0.6	8.1 ± 0.6
	504.2 ± 0.08	14.6 ± 0.8	14.4 ± 0.4
	712.5 ± 0.07	31.4 ± 1.5	30.7 ± 2.5
	1037.3 ± 0.01	21.3 ± 3.1	21.5 ± 2.2
	1212.2 ± 0.07	24.9 ± 1.3	25.2 ± 0.9
1288.6	580.4 ± 0.16	12.9 ± 1.8	9.9 ± 2.7
	788.7 ± 0.04	87.1 ± 4.1	90.1 ± 2.7
1298.6	798.8 ± 0.10	8.3 ± 1.2	8.6 ± 0.8
	1298.6 ± 0.03	91.7 ± 2.4	91.4 ± 0.8
1348.8	517.6 ± 0.04	61.9 ± 1.8	65.8
	823.7 ± 0.11	20.1 ± 0.3	21.0
	1348.8 ± 0.15	18.0 ± 0.3	13.2
1377.8	281.8 ± 0.08	12.0 ± 0.8	—
	630.8 ± 0.07	10.0 ± 1.2	—
	788.5 ± 0.04	54.0 ± 2.4	—
	1376.8 ± 0.15	24.0 ± 2.0	100
1406.5	659.1 ± 0.10	51.5 ± 2.7	50
	906.3 ± 0.12	9.2 ± 2.7	< 10
	1231.6 ± 0.20	39.3 ± 3.1	40
1414.4	914.6 ± 0.12	16.0 ± 2.4	12.5
	1239.1 ± 0.14	30.5 ± 3.3	25
	1414.4 ± 0.10	53.5 ± 6.0	62.5
1422.1	675.0 ± 0.21	20.4 ± 3.7	—
	1247.1 ± 0.13	79.6 ± 2.9	—
1542.0	1016.9 ± 0.04	92.7 ± 1.9	—
	1542.0 ± 0.01	7.3 ± 0.8	—
1558.8	1033.7 ± 0.05	87.1 ± 4.4	90.9
	1059.0 ± 0.11	12.9 ± 2.0	9.1
1566.1	975.5 ± 0.07	100	100
1743.3	935.6 ± 0.08	38.5 ± 4.1	50
	996.2 ± 0.12	16.1 ± 3.2	—
	1743.3 ± 0.01	45.3 ± 2.3	50

Table 2. $F(\tau)$ values and mean lifetimes of the levels in ^{71}Ge.

Level (keV)	γ-ray (keV)	$F(\tau)$, present work		Lifetimes	
		$F(\tau)$	Mean $F(\tau)$	Present work (fs)	Ref. 5 (ps)
708.0	708.0	0.082 ± 0.01	0.082 ± 0.01	662^{+86}_{-74}	< 15.4
747.0	747.0	0.13 ± 0.02	0.13 ± 0.01	406^{+82}_{-60}	
808.0	633.0	0.17 ± 0.03	0.17 ± 0.03	298^{+72}_{-52}	
831.1	831.1	0.086 ± 0.01	0.086 ± 0.01	630^{+58}_{-52}	
1026.6	526.6 1026.6	0.073 ± 0.02 0.086 ± 0.02	0.079 ± 0.02	678^{+210}_{-132}	> 1.6
1096.0	921.0	0.077 ± 0.01	0.077 ± 0.01	708^{+118}_{-80}	0.90 ± 0.20
1212.2	1212.2	0.12 ± 0.02	0.12 ± 0.02	440^{+78}_{-60}	> 1.7
1298.6	1298.6	0.12 ± 0.02	0.12 ± 0.02	440^{+78}_{-60}	0.61 ± 0.13
1348.8	517.6	0.11 ± 0.02	0.11 ± 0.02	482^{+118}_{-80}	0.66 ± 0.16
1377.8	788.5 1376.8	0.16 ± 0.04 0.16 ± 0.04	0.16 ± 0.04	308^{+112}_{-68}	
1406.1	659.1 1231.6	0.048 ± 0.01 0.04 ± 0.01	0.044 ± 0.01	1240^{+300}_{-214}	
1414.4	1239.1	0.11 ± 0.01	0.11 ± 0.01	482^{+50}_{-56}	
1422.1	1247.1	0.09 ± 0.01	0.09 ± 0.01	630^{+20}_{-16}	
1558.8	1033.7	0.15 ± 0.02	0.15 ± 0.02	342^{+58}_{-42}	
1566.1	975.5	0.44 ± 0.02	0.44 ± 0.02	88^{+22}_{-6}	
1743.3	935.6 1743.3	0.42 ± 0.07 0.38 ± 0.07	0.40 ± 0.07	94^{+16}_{-13}	0.61 ± 0.21

Table 3. The results of the angular distribution measurements in ^{71}Ge.

Transitions	γ-ray (keV)	$J_i^\pi \to J_f^\pi$	A_2	A_4	Multipole mixing ratios: Present work	Multipole mixing ratios: Ref. 2
$525.1 \to 198.4$	326.7	$\frac{5}{2}^+ \to \frac{9}{2}^+$	−0.009(5)	0.010(5)	$0.10^{+0.05}_{-0.02}$	—
$589.8 \to 198.4$	391.3	$\frac{7}{2}^+ \to \frac{9}{2}^+$	0.004(6)	−0.017(6)	$-0.11^{+0.03}_{-0.02}$	—
$708.0 \to 0$	708.0	$\frac{3}{2}^- \to \frac{1}{2}^-$	−0.115(12)	0.060(12)	$-0.61^{+0.78}_{-2.2}$	—
$747.1 \to 175.0$	572.1	$\frac{5}{2}^- \to \frac{5}{2}^-$	0.026(22)	−0.027(22)	$-0.3^{+0.05}_{-0.08}$	—
$831.1 \to 525.1$	306.0	$\frac{3}{2}^- \to \frac{5}{2}^+$	−0.003(20)	−0.016(20)	$0.1^{+0.05}_{-0.02}$ or	—
					$-11.7^{-3.4}_{+4.4}$	—
$831.1 \to 0$	831.1	$\frac{3}{2}^- \to \frac{1}{2}^-$	−0.114(13)	0.032(13)	-0.5 ± 0.1	—
$1026.6 \to 499.8$	526.6	$\frac{5}{2}^- \to \frac{3}{2}^-$	−0.173(13)	−0.006(13)	$-0.75^{+0.14}_{-0.12}$	-0.16 ± 0.03
$1026.6 \to 0$	1026.6	$\frac{5}{2}^- \to \frac{1}{2}^-$	0.359(75)	−0.237(75)	12.5 ± 0.25	$E2$
$1096.0 \to 175.0$	921.0	$\frac{3}{2}^- \to \frac{5}{2}^-$	−0.326(25)	0.093(25)	$-1.0^{+0.57}_{-0.80}$	0.36 ± 0.14 or
						$3.7 \le \delta \le \infty$
$1212.2 \to 499.8$	712.5	$\frac{5}{2}^- \to \frac{3}{2}^-$	0.037(56)	−0.060(64)	$-0.49^{+0.09}_{-0.26}$	$-0.19^{+0.11}_{-0.09}$ or
					-1.54 ± 0.2	$-1.8^{+0.5}_{-0.4}$
$1298.6 \to 0$	1298.6	$\frac{3}{2}^- \to \frac{1}{2}^-$	−0.154(20)	0.090(30)	$-0.61^{0.74}_{-1.8}$	-1.88 ± 0.11 or
						0.04 ± 0.03
$1377.8 \to 1096.0$	281.8	$\frac{5}{2} \to \frac{3}{2}^-$	0.103(950)	0.005(950)	2.9 ± 0.1	—
$1406.5 \to 175.0$	1231.6	$\frac{5}{2}^- \to \frac{5}{2}^-$	0.078(98)	0.011(103)	$0.49^{+0.15}_{-0.11}$	—
$1406.5 \to 499.8$	906.3	$\frac{5}{2}^- \to \frac{3}{2}^-$	−0.095(128)	0.002(139)	-0.2 ± 0.1	—
$1422.1 \to 175.0$	1247.1	$\frac{9}{2}^- \to \frac{5}{2}^-$	0.230(63)	−0.009(63)	0.1 ± 0.07	—
$1558.8 \to 525.1$	1033.7	$\frac{5}{2}^+ \to \frac{5}{2}^+$	0.072(39)	0.005(44)	$0.48^{+0.26}_{-0.18}$	$-0.26 < \delta < 3.0$
$1566.1 \to 589.8$	975.5	$\frac{9}{2}^+ \to \frac{7}{2}^+$	−0.177(98)	−0.004(108)	$-1.54^{+0.22}_{-0.16}$	—
$1743.3 \to 808.0$	935.6	$\frac{3}{2}^- \to \frac{1}{2}^-$	−0.055(129)	0.005(143)	$-0.5^{+0.4}_{-0.8}$	—
$1743.3 \to 0$	1743.3	$\frac{3}{2}^- \to \frac{1}{2}^-$	0.015(30)	−0.002(31)	$-11.59^{+4.3}_{-3.5}$	—

Table 4. Electromagnetic transition rates in ^{71}Ge.

Level (keV)	γ-ray (keV)	Multipole mixing ratios	Reduced transition probabilities (w.u.)			
			Present work		IBFM [1]	
			B (E2)	B (M1) $\times 10^{-3}$	B (E2)	B (M1) $\times 10^{-3}$
708.0	708.0	$-0.61^{+0.8}_{-2.2}$	101.9 ± 26.9	93 ± 69	—	—
747.0	572.1	-0.3 ± 0.1	72.7 ± 31.8	180 ± 33	—	—
831.1	306.0	$0.1^{+0.05}_{-0.02}$	50.3 ± 35	320 ± 28	—	—
	831.1	-0.5 ± 0.1	24.0 ± 8	45 ± 6	—	—
1026.6	526.6	$-0.75^{+0.14}_{-0.12}$	105.1 ± 20	120 ± 35	53.8	150
	1026.6	1.5 ± 0.3	8.5 ± 2.4	3 ± 1	2.1	—
1096.0	921.0	$-1.0^{+0.6}_{-0.8}$	80.2 ± 56.6	46 ± 32	20	6
1212.2	712.5	$-0.5^{+0.1}_{-0.3}$	35.1 ± 22.1	50 ± 14	—	—
1377.8	282.0	0.03 ± 0.1	10.1 ± 3.6	540 ± 200	—	—
	630.8	$0.5^{+0.4}_{-0.3}$	30.4 ± 22.5	33 ± 15	—	—
1406.5	906.3	-0.2 ± 0.1	0.2 ± 0.2	3 ± 1	—	—
	1231.6	$0.5^{+0.2}_{-0.1}$	1.0 ± 0.5	4 ± 1	—	—
1422.1	1247.1	0.1 ± 0.05	0.3 ± 0.2	27 ± 2	—	—
1558.8	1033.7	$0.5^{+0.2}_{-0.1}$	18.9 ± 9	60 ± 14	7	75
1743.3	935.6	$0.5^{+0.3}_{-0.2}$	53.5 ± 28	130 ± 66	—	—
	1743.3	$-11.6^{+4.3}_{-3.5}$	13.9 ± 2.3	0.2 ± 0.2	—	—