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# LIFETIME MEASUREMENTS OF EXCITED STATES IN $^{73}$As

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The excited states of $^{73}$As have been investigated via the $^{73}$Ge(p, n$\gamma$)$^{73}$As reaction with proton beam energies from 2.5–4.3 MeV. The lifetimes of the levels at 769.6, 860.5, 1177.8, 1188.7, 1274.9, 1344.1, 1557.1 and 1975.2 keV excitation energies have been measured for the first time using the Doppler shift attenuation method. 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 eight $\gamma$-transitions have been newly measured.

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

## 1. Introduction

Information about the $^{73}$As nucleus has been obtained by gamma-ray spectroscopy from $\beta$-decay,[1–3] (p, n$\gamma$)[4–6] and heavy-ion reactions.[7] The structure of this nucleus has also been investigated via single proton transfer reactions[8–10] and the (p, t) reaction.[11] However, these studies are somewhat inconsistent with each other. Theoretical calculations[12–17] of energy levels of this nucleus have been made in terms of pairing-plus-quadrupole and single-particle core coupling models. The inclusion of Coriolis and residual interactions of the pairing type in the statistically deformed collective model has made it possible to describe the positive and the negative parity states of $^{73}$As. The experimental analysis of $^{73}$As by Van der Merwe *et al.*[4] from (p, n$\gamma$) and (p, n) reactions and the radioactive decay of $^{73}$Se$^m$ has provided information about a few low-lying levels. The high spin states are populated by heavy-ion reaction studies.[7] Recently, Bucurescu *et al.*[6] have reported lifetimes of some levels below 2 MeV excitation using the (p, n$\gamma$) reaction. However, the lifetimes of various levels below 2 MeV are still unknown.

The study of $^{73}$As is a continuation of our previous work[18,19] for lifetime measurements of nuclei with $A < 100$. The aim of the present investigation was to provide additional experimental information about the existing level structure[20] and the lifetimes of some of the levels of $^{73}$As 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 $\gamma$-rays. The branching ratios for various transitions were measured from the $\gamma$-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 the Interacting Boson Fermion model calculations.[5,6] The preliminary results of this study were reported earlier.[21]

## 2. Experimental Procedure

A thick self-supporting pellet of spectroscopically pure natural Ge was used as a target. The proton beam of 2.5–4.3 MeV energies was bombarded to excite the levels of $^{73}$As through the $^{73}$Ge(p, n$\gamma$) reaction (Q-value = −1.12 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 $\gamma$-rays were detected with a 70 cm$^3$ coaxial HPGe detector with a resolution of 1.9 keV for the 1332 keV line of $^{60}$Co. The excitation functions of various $\gamma$-rays have been 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 other details of the experimental procedure are given in our earlier publications.[18,19]

## 3. Data Analysis

The gamma-ray spectra were analyzed using the computer code PEAKFIT.[22] 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 analyzed carefully 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 relative branching ratios used for further analysis are the weighted average 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 $\cos\theta$ for a few transitions are shown in Fig. 2. The straight line represents the least square fit. The experimental values of the attenuation factors $F(\tau)$ were calculated from the slope of the straight line. The values of theoretical $F(\tau)$ were obtained using Lindhard, Scharff and Schiott theory[23] for stopping power along with the Blaugrund correction[24] for atomic scattering. The details of the DSAM analysis are given in the earlier publications[25,26] from our cyclotron laboratory. The values of the measured lifetimes of various levels are given in Table 1 along with their respective experimental $F(\tau)$ values.

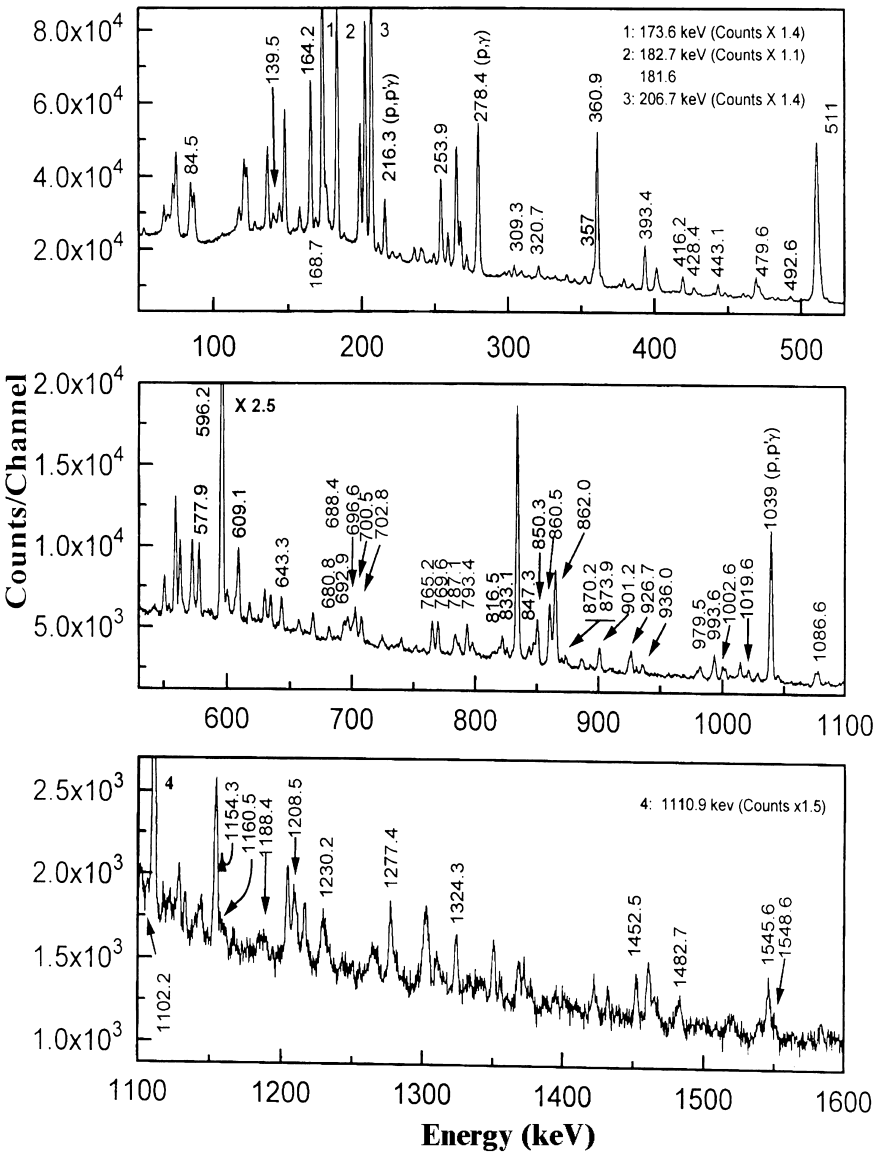



Fig. 1. A typical gamma-ray spectrum at 90° from $^{73}$Ge(p, n$\gamma$)$^{73}$As reaction at 4.3 MeV.

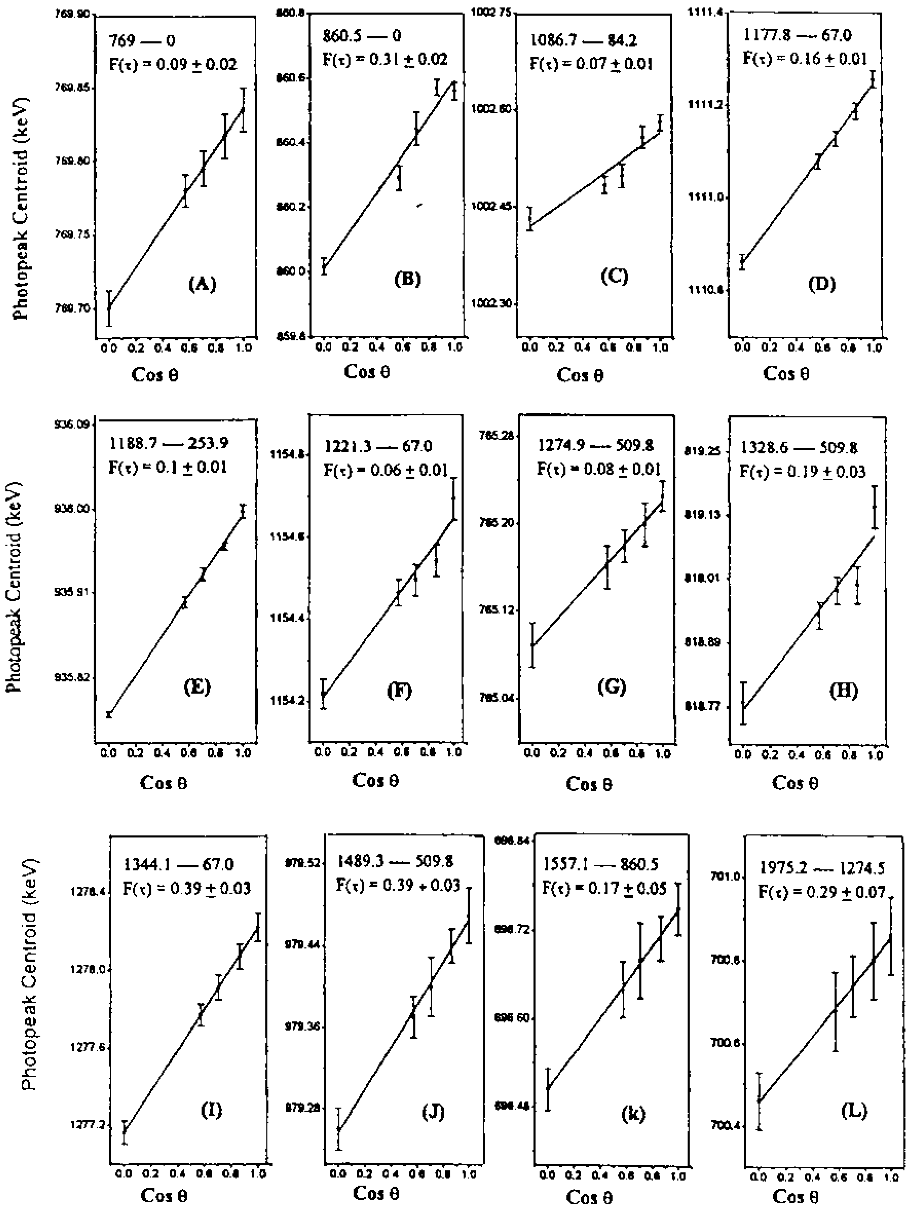
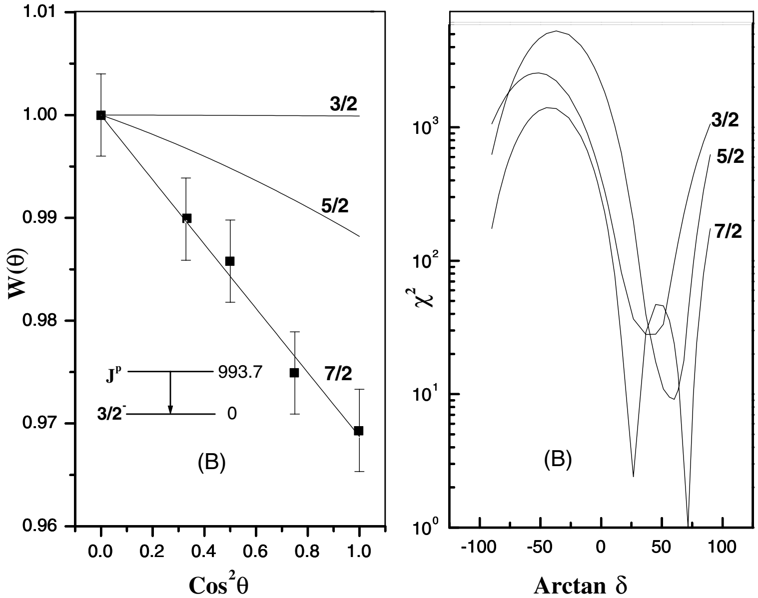



Fig. 2. Plots of photo peak centroids versus $\cos\theta$ for various transitions (keV): (a) 769.6 → 0; (b) 860.5 → 0; (c) 1086.4 → 84.2; (d) 1177.8 → 67.0; (e) 1188.7 → 253.9; (f) 1221.3 → 67.0; (g) 1274.9 → 509.8; (h) 1328.6 → 509.8; (i) 1344.1 → 67.0; (j) 1489.3 → 509.8; (k) 1557.1 → 860.5; (l) 1975.2 → 1274.5.

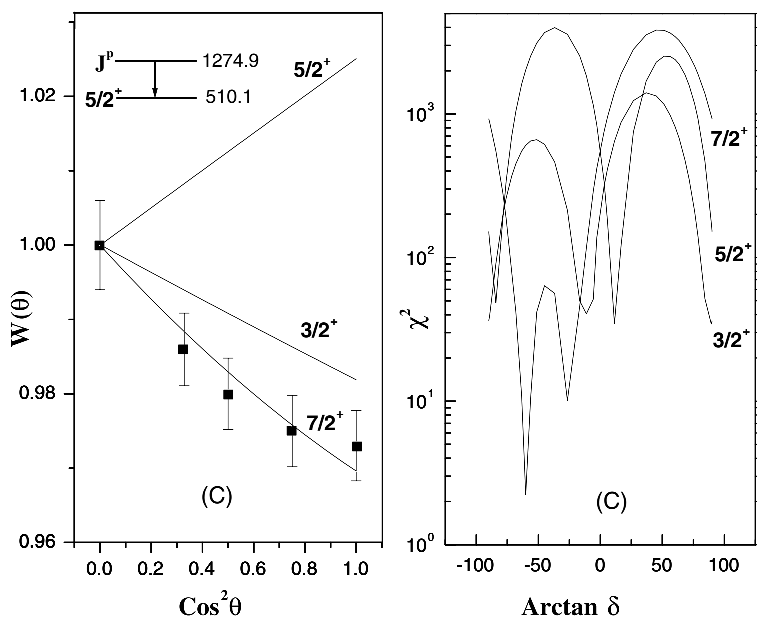
Table 1. $F(\tau)$ values and mean lifetimes of the levels in $^{73}$As.

| Level (keV) | $\gamma$-ray (keV) | Present $F(\tau)$ | | Lifetimes (fs) | |
|---|---|---|---|---|---|
| | | $F(\tau)$ | Mean $F(\tau)$ | Present work | Ref. 6 |
| 769.6 | 702.8 | $0.08 \pm 0.01$ | $0.084 \pm 0.02$ | $880^{+120}_{-182}$ | |
| | 769.6 | $0.09 \pm 0.02$ | | | |
| 860.5 | 860.5 | $0.31 \pm 0.02$ | $0.31 \pm 0.02$ | $194^{+18}_{-16}$ | |
| 1086.7 | 1002.4 | $0.07 \pm 0.01$ | $0.07 \pm 0.01$ | $1022 \pm 132$ | $410^{+400}_{-170}$ |
| | 1019.0 | $0.07 \pm 0.01$ | | | |
| 1177.8 | 1110.9 | $0.16 \pm 0.01$ | $0.16 \pm 0.01$ | $422^{+28}_{-26}$ | |
| 1188.7 | 934.8 | $0.10 \pm 0.01$ | $0.10 \pm 0.01$ | $816^{+110}_{-92}$ | |
| 1221.3 | 643.2 | $0.08 \pm 0.01$ | $0.07 \pm 0.01$ | $1050 \pm 132$ | $500^{+140}_{-120}$ |
| | 1154.1 | $0.06 \pm 0.01$ | | | |
| 1274.9 | 765.1 | $0.08 \pm 0.01$ | $0.08 \pm 0.01$ | $938 \pm 112$ | |
| | 847.3 | $0.08 \pm 0.01$ | | | |
| 1328.6 | 818.7 | $0.19 \pm 0.03$ | $0.21 \pm 0.03$ | $312^{+90}_{-60}$ | $130 \pm 30$ |
| | 900.8 | $0.23 \pm 0.02$ | | | |
| 1344.1 | 1277.2 | $0.39 \pm 0.03$ | $0.39 \pm 0.03$ | $136 \pm 18$ | |
| 1489.3 | 451.8 | $0.37 \pm 0.03$ | $0.38 \pm 0.03$ | $142 \pm 18$ | $420^{+200}_{-130}$ |
| | 979.3 | $0.39 \pm 0.03$ | | | |
| 1557.1 | 696.5 | $0.17 \pm 0.05$ | $0.17 \pm 0.05$ | $402^{+194}_{-108}$ | |
| 1975.2 | 700.5 | $0.29 \pm 0.07$ | $0.295 \pm 0.07$ | $202^{+140}_{-68}$ | |
| | 1547.5 | $0.30 \pm 0.07$ | | | |

The extraction of multipole mixing ratios of the observed transitions and the assignment of spin values to the excited levels were made from the $\chi^2$-fitting of angular distribution data at 4.3 MeV proton beam energy. The optical model parameter sets given by Perey and Perey,[27] which are based on the results of Perey[28] for protons and Wilmore and Hodgson[29] for neutrons, were used to calculate the transmission coefficients. Besides the observed neutron channel, all known (p, p$'\gamma$) channels and (p, $\gamma$) channels were included as competing channels. The Moldauer width fluctuation correction[30] was also taken into account. The typical experimental angular distributions of some of the observed transitions together with theoretical curves for different possible spins of the levels and the respective $\chi^2$-fitting are shown in Fig. 3. The 0.1% confidence limit was used to exclude unacceptable spins and $\delta$ values. The experimental values of the $A_2$ and $A_4$ coefficients along with the multipole mixing ratios ($\delta$) are given in Table 2. The reduced transition probabilities $B$(M1) and $B$(E2) extracted from the measured values of lifetimes and multipole mixing ratios are given in Table 3.

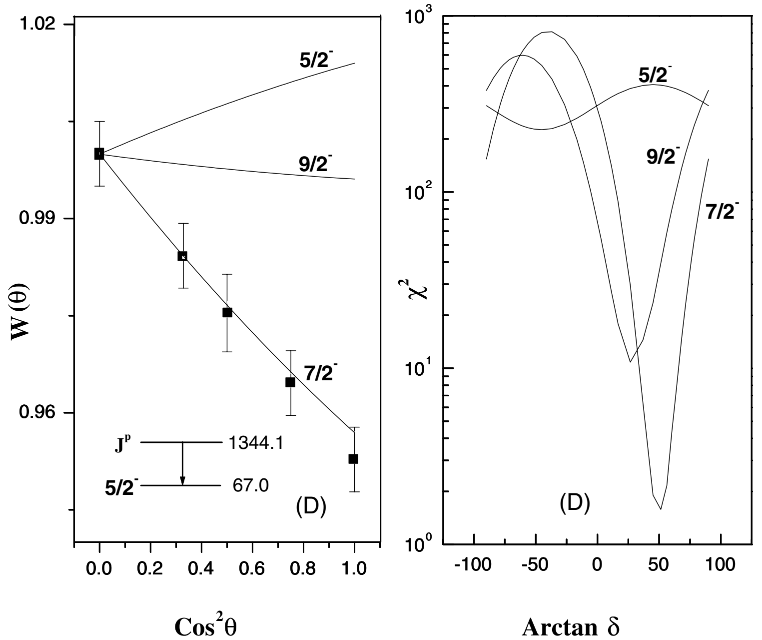



(a)

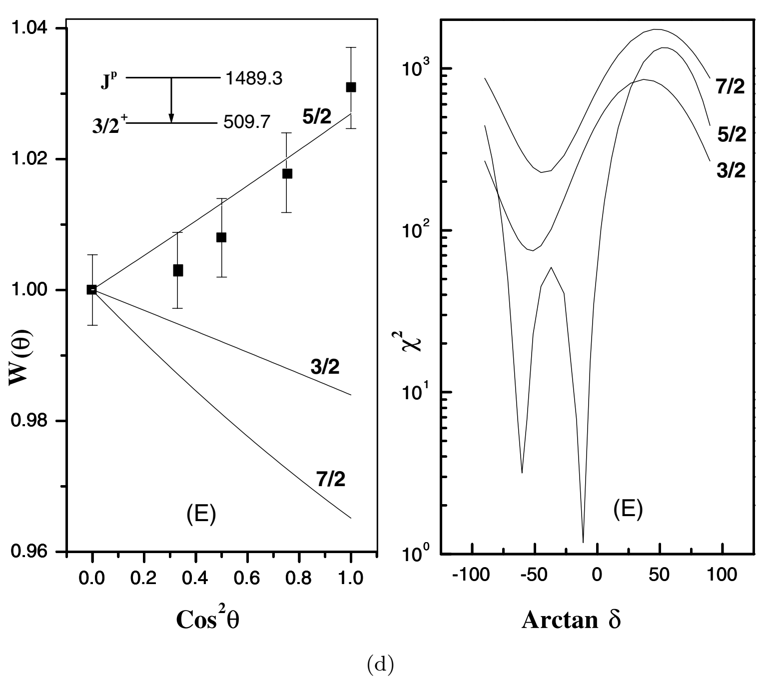



(b)

Fig. 3. Angular distributions of de-excited gamma-rays from various transitions (keV): (a) 993.7 → 0; (b) 1274.9 → 509.8; (c) 1344.1 → 67.0; (d) 1489.3 → 509.8; (e) 1557.1 → 860.5; (f) 1612.2 → 67.0; (g) 1975.2 → 1274.5.

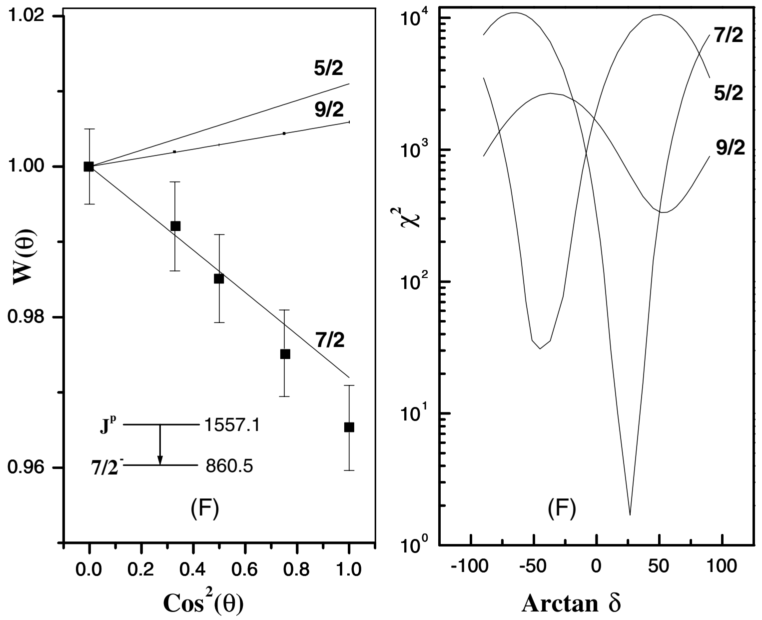



(c)

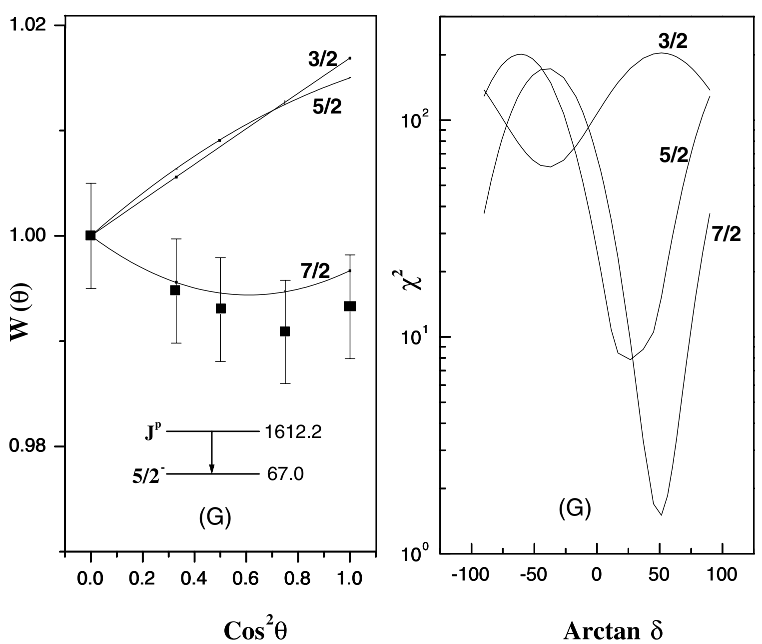



(d)

Fig. 3. (*Continued*)

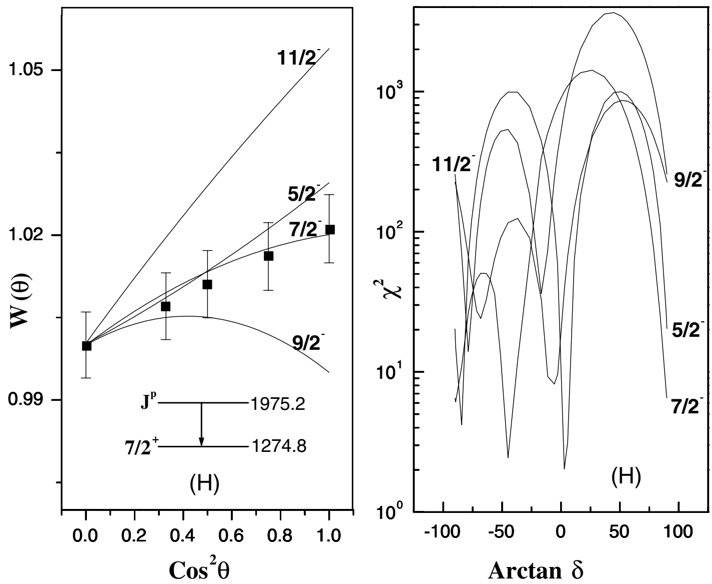



(e)




(f)

Fig. 3. (*Continued*)




(g)

Fig. 3. (*Continued*)

## 4. Results and Discussion

The excitation energies of the various levels in $^{73}$As were found to be comparable with the values reported earlier.[5,6,19] The branching ratios for various transitions were also compared with the reported values[4–6] and almost all the values were found in agreement with the literature except a few transitions having small deviation. Table 1 gives the measured values of lifetimes of the twelve levels at 769.6, 860.5, 1086.7, 1177.8, 1188.7, 1221.3, 1274.9, 1328.6, 1344.1, 1489.3, 1557.1 and 1975.2 keV excitation energies. Out of these, the lifetimes of eight levels are measured for the first time in the present experiment. The spins of a few levels are also confirmed using the angular distribution data. The discussion of some of the levels in detail is given below.

### 4.1. *The 769.6 keV level*

This level was observed to decay via two $\gamma$ transitions, one to the ground state and the other to the 67.0 keV state with the branching ratios of 60.5% and 39.5%, respectively, which are in agreement with earlier values[5] within the experimental errors. The angular distributions and $\chi^2$-fitting of the 769.6 keV $\gamma$-ray confirm the spin of this level as 5/2 and provide the mixing ratio as $-0.74 \pm 1.6$. Merwe *et al.*[4] have assigned 5/2 as the probable spin for this level from intensity measurements.

Table 2. The results of the angular distribution measurements in $^{73}$As.

| Transitions | Gamma rays (keV) | $J_i^\pi \to J_f^\pi$ | $A_2$ | $A_4$ | Multipole mixing ratios: Present work | Multipole mixing ratios: Ref. 4 |
|---|---|---|---|---|---|---|
| 674.0 → 509.8 | 164.2 | $\frac{5}{2}^- \to \frac{5}{2}^+$ | −0.034(5) | −0.001(5) | $1.39^{+0.8}_{-0.6}$ | — |
| 769.6 → 0 | 769.6 | $\frac{5}{2}^- \to \frac{3}{2}^-$ | 0.065(23) | 0.009(24) | $-0.74 \pm 1.6$ | $+5.1 < \delta < -6.3$ |
| 850.4 → 0 | 850.4 | $\frac{5}{2}^- \to \frac{3}{2}^-$ | −0.003(16) | −0.000(16) | $0.2^{+0.1}_{-0.2}$ | $0.2 \pm 0.2$ or $+5.4 < \delta < -6.3$ |
| 860.5 → 0 | 860.5 | $\frac{7}{2}^- \to \frac{3}{2}^-$ | 0.004(37) | 0.004(42) | $-1.0 \pm 0.3$ | $-0.09^{+0.4}_{-0.8}$ or $+3.7 < \delta < -1.2$ |
| 993.7 → 0 | 993.7 | $\frac{7}{2}^- \to \frac{3}{2}^-$ | −0.033(35) | 0.003(36) | $0.5 \pm 0.1$ or $3.0^{+0.6}_{-0.7}$ | — |
| 1037.0 → 427.8 | 609.1 | $\frac{13}{2}^+ \to \frac{9}{2}^+$ | 0.096(6) | 0.001(6) | $10.6^{+0.02}_{-0.03}$ | $12.7^{+3.6}_{-4.1}$ |
| 1086.7 → 84.2 | 1002.4 | $\frac{5}{2}^- \to \frac{1}{2}^-$ | −0.035(58) | −0.007(58) | $1.5 \pm 0.01$ | — |
| 1177.8 → 67.0 | 1110.9 | $\frac{7}{2}^- \to \frac{5}{2}^-$ | 0.002(16) | −0.003(16) | $0.5^{+0.2}_{-0.1}$ | |
| 1221.3 → 67.0 | 1154.1 | $\frac{7}{2}^- \to \frac{5}{2}^-$ | 0.027(30) | 0.006(30) | $-0.3 \pm 0.1$ | $-0.8^{+0.4}_{-0.6}$ |
| 1274.9 → 509.8 | 765.1 | $\frac{7}{2}^+ \to \frac{5}{2}^+$ | −0.013(53) | −0.008(54) | $-1.8^{+0.12}_{-0.06}$ | $-1.6^{+0.6}_{-0.7}$ |
| 1344.1 → 67.0 | 1277.2 | $\frac{7}{2}^- \to \frac{5}{2}^-$ | −0.032(50) | 0.001(51) | $1.3^{+0.5}_{-0.4}$ | $-0.8^{+0.4}_{-0.8}$ |
| 1489.3 → 509.8 | 979.3 | $\frac{5}{2} \to \frac{5}{2}^+$ | 0.018(72) | 0.011(73) | $-1.8 \pm 0.1$ or $-0.2 \pm 0.1$ | — |
| 1557.1 → 860.5 | 696.5 | $\frac{7}{2} \to \frac{7}{2}^-$ | −0.023(50) | 0.003(50) | $0.5 \pm 0.1$ | — |
| 1612.2 → 67.0 | 1545.3 | $\frac{7}{2} \to \frac{5}{2}^-$ | −0.045(60) | 0.001(60) | $-1.3^{+1.0}_{-0.6}$ | — |
| 1975.2 → 1274.9 | 700.5 | $\frac{5}{2} \to \frac{7}{2}^+$ | 0.014(75) | 0.000(77) | $0.05^{+0.02}_{-0.08}$ | — |
| | | $\frac{7}{2} \to \frac{7}{2}^+$ | | | $-0.97 \pm 0.05$ | — |

The mean lifetime of this level has been measured by us as $880^{+120}_{-182}$ fs, for the first time (Fig. 2(a)). The $B$(E2) value for this transition was obtained from the present results as $40.7 \pm 24.8$ w.u.

### 4.2. *The 860.5 keV level*

The level at 860.5 keV energy is found to decay via 793.4 and 860.5 keV transitions with branching ratios of 34.0% and 66.0%, respectively, which are in close agreement with the reported[4,5] values. The angular distributions and $\chi^2$-fitting of the 860.5 keV $\gamma$-ray confirm the existing spin of this level as 7/2 and the mixing ratio of the transition as $-1.0 \pm 0.3$. The mean lifetime of this level has been measured in the present experiment for the first time as $194^{+18}_{-16}$ fs (Fig. 2(b)).

Table 3. Electromagnetic transition rates in $^{73}$As.

| Level (keV) | $\gamma$-ray (keV) | Multipole mixing ratios | Reduced transition probabilities (w.u.) Present work $B$(E2) | $B$(M1) $\times 10^{-3}$ | IBF model[5] $B$(E2) | $B$(M1) $\times 10^{-3}$ |
|---|---|---|---|---|---|---|
| 769.6 | 769.6 | $-0.7^{+0.7}_{-0.8}$ | $40.7 \pm 24.8$ | $31^{+15}_{-25}$ | 0.02 | 0.42 |
| 860.6 | 860.6 | $-1.0 \pm 0.3$ | $162.8^{+44.0}_{-43.0}$ | $85 \pm 23$ | 5.52 | — |
| 1086.7 | 1002.4 | $1.5 \pm 0.01$ | $8.8 \pm 1.0$ | $3.0 \pm 0.4$ | 14.8[a] | — |
| 1177.8 | 1110.9 | $0.5^{+0.2}_{-0.1}$ | $12.2^{+6.0}_{-3.0}$ | $44^{+6}_{-3}$ | — | — |
| 1221.3 | 1154.1 | $-0.3 \pm 0.1$ | $1.4^{+0.5}_{-0.7}$ | $15 \pm 2$ | — | — |
| 1274.9 | 765.1 | $-1.8 \pm 0.1$ | $67.9 \pm 9.0$ | $9 \pm 1$ | 16.0 | 66 |
| 1344.1 | 1277.3 | $1.3^{+0.5}_{-0.4}$ | $43.6^{+15}_{-13}$ | $32^{+17}_{-14}$ | 25.0 | — |
| 1489.3 | 979.4 | $-0.2 \pm 0.1$ | $9.2^{+5.0}_{-7.0}$ | $160^{+23}_{-21}$ | — | — |
| 1557.1 | 696.5 | $0.5 \pm 0.1$ | $73.4^{+42.0}_{-33.0}$ | $100^{+52}_{-30}$ | — | — |

(a) Ref. 6.

### 4.3. *The 993.7 keV level*

This level decays via four transitions, one to the ground state and the others to 67, 393.4 and 577.9 keV states with the branching ratios of 39.7%, 31.9%, 23.9% and 4.5%, respectively, which are consistent with the previous values[4] within experimental error. This level has been reported from $\gamma$–$\gamma$ coincidence measurements[5] to decay also via two weak transitions to 509.8 keV and 769.6 keV states. However, due to the background we could not resolve these transitions in the present work. The angular distribution measurement and $\chi^2$-fitting of the 993.7 keV $\gamma$-ray indicate that the spin of this level is 7/2 (Fig. 3(a)), which agrees with the result of a previous[5] study. The present work suggests two alternative multipole mixing ratios as $0.5 \pm 0.1$ or $3.0 \pm 0.6$ for the 993.7 keV $\gamma$-ray, for the first time.

### 4.4. *The 1086.7 keV level*

This level decays via five transitions, one to the ground state and the others to 67.0, 84.2, 253.9 and 393.4 keV states, with the branching ratios of 12.4%, 25.8%, 29.5%, 23.4% and 9.0%, respectively, which are consistent with the previous values of Sohler *et al.*[5] They have also reported four extra weak transitions from this level to 860.5, 769.6, 655.4 and 574.4 keV states in their $\gamma$–$\gamma$ coincidence measurements, but due to mixing of these transitions with the background, we could not identify them. The angular distribution measurement and $\chi^2$-fitting of the 1002.4 keV $\gamma$-ray indicate that the spin of this level is 5/2, which is in agreement with Sohler *et al.*'s[5] assignment. The multipole mixing ratio of the 1002.4 keV transition was measured to be $1.5 \pm 0.01$, through $\chi^2$-fitting. Internal conversion coefficient measurement[5] of this transition has also reported the nature of this transition as E2 + M1. The mean lifetime of this level has been measured as $1022 \pm 132$ fs (Fig. 2(c)). The $B$(E2) value was obtained to be $8.8 \pm 1.0$ w.u., for the 1002.4 keV transition, using the present results.

### 4.5. *The 1177.8 keV level*

This level has been reported to decay via a single transition to the 67.0 keV state.[4] Sohler *et al.*[5] have reported three more weak transitions from this level to 577.9, 769.6 and 860.5 keV levels in their coincidence experiments. In the present investigations we observed only a single transition from this level to the 67.0 keV state. The angular distribution measurements and $\chi^2$-fitting of the 1110.9 keV $\gamma$-ray indicate that the spin of this level is 7/2, which is in agreement with Sohler *et al.*'s[5] assignment. The multipole mixing ratio of the 1110.9 keV $\gamma$-ray was measured to be $0.5^{+0.2}_{-0.1}$ for the first time, which indicates that this transition is mixed (E2 + M1) in character. The lifetime of this level was measured to be $422^{+28}_{-26}$ fs (Fig. 3(d)), for the first time. The $B$(E2) value for the 1110.9 keV transition was obtained to be $12.2^{+6.0}_{-3.0}$ w.u., using the present results.

### 4.6. *The 1188.7 keV level*

This level has been reported to decay via a single $1/2 \rightarrow 1/2$ transition to the 253.9 keV state by Sohler *et al.*,[5] which is in agreement with the present measurement. The angular distribution measurement of the 934.8 keV transition indicates that this transition is isotropic as expected for such a transition. The lifetime of this level was measured as $816^{+110}_{-92}$ fs (Fig. 2(e)), for the first time.

### 4.7. *The 1221.3 keV level*

This level decays via three transitions to 67.0, 577.9 and 769.6 keV levels, with the branching ratios of 79.6%, 11.0% and 9.4%, respectively, which are consistent with the previous values.[4] The angular distribution and $\chi^2$-fitting of the 1154.1 keV transition indicate that the spin of this level is 7/2, which is in agreement with Sohler *et al.*[5] and Merwe *et al.*'s[4] assignments. The multipole mixing ratio of 1154.1 keV transition was extracted to be $-0.3 \pm 0.1$. The mean lifetime of this level was measured to be $1050 \pm 132$ fs (Fig. 2(f)). The $B$(E2) value for this transition was obtained to be $1.4^{+0.5}_{-0.7}$ w.u., using the present results.

### 4.8. *The 1274.9 keV level*

This level has been reported to decay via two transitions to the 427.8 and 509.8 keV states, with the branching ratios of 39.4% and 60.6%, respectively by Sohler *et al.*[5]

The present work measured the respective branching ratios as 40.6% and 59.4%, which are in agreement with the previous values within experimental errors. The angular distribution and $\chi^2$-fitting of the 765.1 keV transition indicate that the spin of this level is 7/2 (Fig. 3(b)), which is in agreement with Merwe *et al.*'s[4] assignment. The multipole mixing ratio of the 765.1 keV transition is $-1.8^{+0.12}_{-0.06}$. The total internal conversion coefficient measurement by Sohler *et al.*[5] has also indicated that the 765.1 keV transition has a mixed character. The mean lifetime of this level is measured as $938 \pm 112$ fs (Fig. 2(g)), for the first time. The $B$(E2) value for this transition was obtained to be $67.9 \pm 9.0$ w.u.

### 4.9. *The 1328.6 keV level*

This level has been reported to decay via two transitions to the 427.8 and 509.8 keV states, with the branching ratios of 76.9% and 23.1%, respectively by Sohler *et al.*[5] The present work measured the respective branching ratios as 77.2% and 22.8%, which are consistent with the previous values within experimental errors. The present work has assigned two possible spin values for this level as 7/2 and 5/2. The mean lifetime of this level was measured to be $312^{+90}_{-60}$ fs (Fig. 2(h)).

### 4.10. *The 1344.1 keV level*

This level decays via two transitions to the 67.0 and 655.4 keV states, with the branching ratios of 73.1% and 26.9%, respectively, which are consistent with previous values.[4] The angular distribution and $\chi^2$-fitting of the 1277.2 keV transition show that the spin of this level is 7/2 (Fig. 3(c)). Sohler *et al.*[5] have assigned $7/2^-$ spin to this level on the basis of their total internal conversion coefficient measurement. The multipole mixing ratio of the 1277.2 keV transition was measured to be $1.3^{+0.5}_{-0.4}$, which is in agreement with Merwe *et al.*'s[4] value. The mean lifetime of this level was measured as $136 \pm 18$ fs, for the first time (Fig. 2(i)). The $B$(E2) value was obtained to be $43.6^{+15}_{-13}$ w.u.

### 4.11. *The 1489.3 keV level*

This level has been reported to decay via two $\gamma$-rays to the 509.8 and 1037.0 keV states, with the branching ratios of 74.5% and 25.5%, respectively, by Merwe *et al.*[4] The present investigation measured the respective branching ratios as 67.9% and 32.1%, which are consistent with the earlier values within experimental errors. The angular distributions and $\chi^2$-fitting of 979.3 keV transition assign the spin of this level for the first time as 5/2 (Fig. 3(d)). The multipole mixing ratio of the 979.3 keV transition was measured to be $-1.8 \pm 0.1$ or $-0.2 \pm 0.1$. The mean lifetime of this level was measured to be $142 \pm 18$ fs (Fig. 2(j)). The $B$(E2) value for this transition was obtained to be $9.2 \pm 6.0$ w.u. from the measured lifetime and mixing ratio.

### 4.12. *The 1557.1 keV level*

This level decays via three transitions to the 769.6, 860.5 and 1077.5 keV levels, with the branching ratios of 27.2%, 55.7% and 17.1%, respectively, which are in agreement with the previous data[4] within experimental error. The angular distributions and $\chi^2$-fitting of the 696.5 keV transition assign spin 7/2 (Fig. 3(e)) for this state and the multipole mixing ratio as $0.5 \pm 0.1$ to the 696.5 keV transition for the first time. The lifetime of this level was measured to be $402 \pm 194$ fs, for the first time (Fig. 2(k)). The $B$(E2) value was obtained to be $73.4 \pm 37.5$ w.u. for this transition.

### 4.13. *The 1612.2 keV level*

This level has been reported[4] to decay via two transitions to the 67.0 and 509.8 keV levels with the branching ratios of 79.5% and 20.5%, respectively. The present investigation has measured the respective branching ratios as 69.8% and 30.2%, which are in agreement with the previous results[4] within experimental errors. The angular distributions and $\chi^2$-fitting of the 1545.3 keV transition have assigned the spin of this level as 7/2, and the multipole mixing ratio of the transition is found to be $-1.3 \pm 1.0$ for the first time (Fig. 3(f)).

### 4.14. *The 1975.2 keV level*

This level has been proposed earlier[5] to decay via three transitions to 427.8, 1274.9 and 1294.4 keV states. The present work has measured the branching ratios for these transitions as 31.9%, 45.4% and 22.6%, respectively. The angular distribution and $\chi^2$-fitting of 700.5 keV transition have assigned, for the first time, two possible spins for this level as 5/2 and 7/2 (Fig. 3(g)). The multipole mixing ratio of the 700.5 keV transition was measured to be $0.05 \pm 0.02$ for spin 5/2, and $-0.97 \pm 0.05$ for spin 7/2. The mean lifetime of this level was measured to be $202 \pm 140$ fs (Fig. 2(l)) for the first time.

## 5. Summary

The aim of the present study was to provide additional experimental information on the existing level structure of $^{73}$As 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 $^{73}$As. 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 investigations.

The attempts have been made to describe the low-lying states of $^{73}$As by Toki and Faessler[12] on the basis of their model in which a particle is coupled to a triaxial rotor with a variable moment of inertia. Ten Brink *et al.*[3] used the cluster vibrational model[13] using a cluster of three protons coupled up to three phonons of a harmonic vibrator core. Due to poor availability of the experimental information about $^{73}$As, the results were very much limited. Sohler *et al.*[5] also described the nuclear structure of $^{73}$As up to 1.5 MeV excitations in the framework of the interacting boson-fermion model (IBFN) using the latest experimental results available at that time. But these calculations described the experimental situation less satisfactorily than usually achieved for other nuclei in the same mass region. Recently Bucurescu *et al.*[6] also presented IBFM calculations by employing the IBFM-1 version of this model, which does not distinguish between neutron and proton degrees of freedom. The $^{73}$As nucleus is described as a fermion coupled to a $^{72}$Ge boson core. Almost all the levels up to 1.5 MeV excitation are explained reasonably well by them. If additional electromagnetic decay data, i.e. lifetimes and mixing ratios are available, such model calculations can be improved further. Since the electromagnetic transition probabilities (hence the lifetimes) and the mixing ratios are more sensitive to nuclear wave functions than the excitation energies of the levels, the present results on lifetimes and mixing ratios will help to test these model calculations more critically for this nucleus.

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