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Short note

Half-life measurements for the 50 keV and 162 keV states in ^{132}I

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Abstract. ^{132}Te was produced via the ^{232}Th (α, fission) reaction at the Variable Energy Cyclotron , Calcutta. ^{132}Te was separated in carrier-free form from the fission products by radiochemical separation and the half-lives for the 50 keV and 162 keV states of ^{132}I were determined to be 2.94±0.11 ns and 0.55±0.04 ns respectively. The present results differ significantly from the previously reported half-lives of 7.14 ns and 3.57 ns for the 50 keV and 162 keV states respectively.

PACS. 21.10.Tg Lifetimes – 23.40.-s β decay; double β decay; electron and muon capture – 95.30.Ky Atomic and molecular data, spectra, and spectral parameters Copacities, rotation constants, line identification, oscillator strengths, gf values, transition probabilities, etc.

Two half-lives for the 50 keV state in ^{132}I have been reported previously. These two measurements, 0.96(3) ns measured for the 50 keV state of ^{132}I by γ(plastic) - γ(plastic) TAC spectrum[1] and 7.14(14) ns measured for the same level of ^{132}I by γ(plastic) - γ(NaI(Tl)) TAC spectrum[2], are not consistent with each other. The half-life of the 162 keV 2^+ state of ^{132}I has only been measured by Yousif et al[2]. Therefore, the half-lives for both the 50 keV and 162 keV states in ^{132}I have been remeasured.

In our experiment, the low-lying excited states in ^{132}I were populated by the β^- decay of ^{132}Te. ^{132}Te was produced by the ^{232}Th(α, fission) reaction using 40 MeV α-particles obtained from Variable Energy Cyclotron , Calcutta. To stop the fission products, thorium metal target of thickness 0.012 mm was sandwiched between two high purity 0.025 mm thick aluminium foils. Following irradiation, the aluminium catcher foils were cooled for about 72 hours to allow decay of short-lived fission activities. The aluminium catcher foils were then dissolved in concentrated hydrochloric acid and tellurium was separated in carrier-free form by coprecipitation with palladium carrier followed by anion exchange separation of tellurium from palladium. The detail radiochemical separation procedure has been described elsewhere [3].

To monitor the degree of purification of ^{132}Te from other fission products, the radiochemically separated carrier-free tellurium activity was analysed γ-spectroscopically using a 25% HPGe detector with a thin beryllium window coupled to a 4K PC

based multichannel analyser (Ortec Model 919). Besides ^{132}Te and ^{131}Te, other fission products were almost quantitatively removed by the ion-exchange separation. Since the fission activities were cooled for about 72 hours, γ-rays due to the decay of ^{131}Te ($t_{1/2}$=30h) were also negligible. The daughter activities ^{132,131}I were found to grow with time and complicate the γ- spectrum. Therefore, to keep the γ- spectrum clean during lifetime measurements, iodine daughter activities were periodically removed by solvent extraction into chloroform.

For lifetime measurements, two NaI(Tl) scintillators of dimensions 37 mm x 37 mm and 20 mm x 20 mm coupled to EMI Thorn Model 9887B photomultipliers were used. Scintillation detectors were preferred to germanium detectors because of superior timing characteristics of scintillators. The large NaI(Tl) detector was used for gating the 228 keV γ-ray feeding the 50 keV state in ^{132}I, while the small detector was used to gate the 50 keV γ-ray depopulating the 50 keV state of ^{132}I. The 50 keV gate was set carefully so that the iodine x-rays do not interfere with the 50 keV γ-gate. Since the γ -spectrum of the radiochemically separated ^{132}Te was clean, the γ-gates were free from any other contaminant peak. A conventional fast-slow coincidence circuit was used to generate TAC spectrum from which the half-life was determined. Under the present experimental condition, the time resolution for the annihilation radiation of ^{22}Na was measured to be 1.8 ns. The prompt time spectrum in the experimental energy gates was obtained using a ^{22}Na source. The time spectrum was analysed by the convolution method in which the experimental prompt time distribution was deconvoluted from the measured delayed distribution using least squares fitting. Figure 1a shows the time spectrum for the 228(start) - 50 keV(stop) coincidences. From our experi-

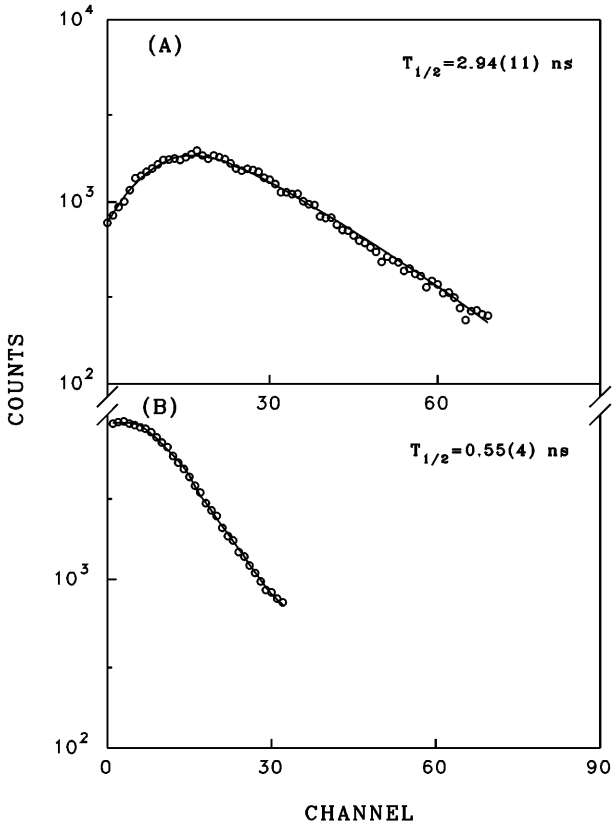

Fig. 1. a. The time spectrum of the 228.2–49.7 keV γ-ray cascade for the measurement of half-life of the 3^+ 49.7 keV state in ^{132}I. Open circles represent the experimental data. The solid line is the least squares fit of experimental data. TAC calibration is 0.179 ns/channel, **b** The time spectrum of the 116.3 - 111.8 keV γ-ray cascade for the measurement of half-life of the 2^+ 161.5 keV state in ^{132}I. 116 and 112 keV γ-rays could not be resolved and were gated together in both start and stop side. One half of the TAC spectrum which was symmetric around the prompt peak has been displayed

ment, the half-life for the 50 keV state of ^{132}I was deduced to be 2.94±0.11 ns which is in disagreement with previous two measurements. In order to establish the reliability of the present measurement including TAC calibration, the well established half-life for the 81 keV state of ^{133}Cs was redetermined using identical experimental set up by measuring 356 - 81 keV coincidences. The half-life for the 81 keV state of ^{133}Cs was found to be 6.33±0.18 ns which agrees very well with the literature value of 6.27 ±0.04 ns[4].

Preliminary expriments suggested that the half-life of the 162 keV state in ^{132}I was shorter than that of 50 keV state. Therefore, to determine the half-life of the 162 keV state, two CsI detectors of dimensions 40 mm x 40 mm coupled to EMI Thorn 9814QA photomultipliers were used. Gamma ray energy resolution of CsI detectors were similar to that of NaI(Tl) detectors but the time resolution of CsI detector system was better. In the present experimental set up, the TAC resolution of 1.1 ns was obtained for the annihilation radiation of ^{22}Na. The γ-rays populating and depopulating the 162 keV state are 116 keV and 112 keV respectively. Since these two γ-rays could not be resolved by any fast-response scintillator detector, γ-gates were set such that in both start and stop side both the γ-rays are registered. Random or chance coincidences were determined by delaying significantly the energy signal of one detector with respect to the other in the slow coincidence and the random coincidences were subtracted from the TAC distribution before analysis of the TAC data. Analysis of the TAC spectrum displayed in Fig. 1b indicates a half-life of 0.55±0.04 ns for the 162 keV state of ^{132}I. Similarly using identical experimental condition, the half-life of the 122 keV state in ^{152}Sm was determined by measuring the 244 - 122 keV coincidences. The half-life was measured to be 1.30±0.10 ns which is in good agreement with the reported value of 1.396 ± 0.008 ns[5].

Table 1. The half-lives and transition probabilities of γ-ray transitions in ^{132}I

E_{Level} (keV)	Eγ (keV)	$T_{1/2}$ [a)] (ns)	$T_{1/2}$ [b)] (ns)	$B(M1)_{exp}/B(M1)_{sp}$ (W.u)
49.72	49.72	2.94(11)	7.14(14)	0.0092
161.52	111.76	0.55(4)	3.57(7)	0.0127

a) Present work (Average of at least two determinations)
b) From Ref 2.

The present results are in sharp disagreement with that of Yousif et al [2]. The major difference between the two measurements is that instead of two NaI(Tl) or CsI scintillators, plastic and NaI(Tl) scintillator combination was used by the previous investigators. Eventhough plastic scintillators offer very good timing resolution, the energy resolution of plastic scintillator is rather very poor. Table 1 shows the half-lives of the low lying excited states of ^{132}I. The experimental transition probabilities, B(M1), shown in Table 1, are deduced from the present lifetimes and known [6] mixing ratios and conversion coefficients of the γ-transitions involved. It may be noted that both the M1 transitions are retarded by a factor of about 100. Similar M1 retardations have also been observed in neighbouring nuclei viz. ^{131}I [7] and ^{134}I [8].

In iodine nuclei, $\pi g_{7/2}$ or $\pi d_{5/2}$ proton orbitals lie close to the Fermi surface. In odd-A ^{129,131}I, the ground state is described [9] by $\pi g_{7/2}$ configuration. Therefore, for odd-odd ^{132}I, the 4^+ ground state configuration is expected to be formed by the coupling of $\pi g_{7/2}$ orbital to $\nu d_{3/2}$ neutron orbital. But for excited states, the admixture of $\pi d_{5/2}$ orbital can not be ruled out. The likely configuration of the 50 keV 3^+ and the 162 keV 2^+ states in ^{132}I is mixture of $\pi g_{7/2}$ and $\pi d_{5/2}$ orbitals coupled to $\nu d_{3/2}$. The admixture of $\pi d_{5/2}$ is responsible (due to l forbiddenness) for the observed retarded M1 transitions between 2^+ to 3^+ and 3^+ to 4^+ states in ^{132}I.

The nucleus $^{132}_{53}I_{79}$ has three proton particles and three neutron holes with respect to the doubly closed shell configuration of ^{132}Sn. The ground state of ^{132}I with Q = +0.09 is known [10] to be slightly prolate deformed. De-

formed shell model calculations may be in principle able to provide realistic estimate of the extent of $\pi d_{5/2}$ admixtures in the low-lying excited states in ^{132}I. The experimentally known data like excitation energies and transition probabilities should be helpful to fix the parameters of nuclear structure model.

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