

Lifetime measurements and decay spectroscopy of ^{132}I

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Abstract. The low-lying states of odd-odd ^{132}I , the 3p-3h nucleus with respect to the doubly magic ^{132}Sn , have been characterized from decay spectroscopy. The neutron rich Iodine and Tellurium isotopes have been produced as fission product of alpha-induced fission of ^{235}U and radiochemically separated. The life-time of the first excited state of ^{132}I have been precisely measured using $\text{LaBr}_3(\text{Ce})$ scintillators from the decay of ^{132}Te . The IT decay of the high spin isomer (8^-) in ^{132}I has been measured with a Low Energy Photon Spectrometer (LEPS) of segmented planar Ge detector.

1 Introduction

The structure of nuclei around the doubly magic neutron rich ^{132}Sn ($Z=50$ and $N=82$) is of special importance and has been the topic of extensive experimental [1-3] and theoretical [4] research in recent years. The odd-odd nuclei in this mass region are of particular interest to understand the proton-neutron residual interaction in the single particle orbits, available for the nuclei towards neutron-rich side. In this context, the studies on low-lying level structure of nuclei with a few identical valance particles or holes are important. The nucleus ^{132}Sb , with one proton particle and one neutron hole ($1p-1h$) configuration with respect to ^{132}Sn , was studied in details with identification of all the multiplets of ($\pi g_{7/2} \nu d_{3/2}^{-1}$) configuration [3]. In the present work, the low-lying states of odd-odd ^{132}I , with ($3p-3h$) configuration, have been characterized from decay spectroscopy.

The low lying level structure of ^{132}I has been derived by the decay of ^{132}Te [5]. The lifetime of the first excited state of ^{132}I , reported in the literature using either plastic or inorganic scintillators, is found to have wide variations, ranging from 7.14ns [6] to 2.94ns [7]. Recently, measurements have been carried out with BaF_2 scintillators from the decay of ^{132}Te radioactive beam [8]. However, BaF_2 detectors, though have a very good time resolution, are not suitable for precise energy selection because of their poor energy resolution. The latest generation $\text{LaBr}_3(\text{Ce})$ scintillators, with their good time resolution as well as good energy resolution, can overcome this problem. In the present work, the lifetime of the first excited state of ^{132}I have been measured from the decay of ^{132}Te , ($T_{1/2}=3.204$ d) using $\text{LaBr}_3(\text{Ce})$ scintillators. In addition to the previously mentioned low-lying states, the presence of a high spin (8^-) isomer ($T_{1/2}=83.6$ min) in ^{132}I is also reported [9] and an intermediate state at around 22 keV (5^+) was proposed other than the observation of a 98 keV isomeric transition. Due to the presence of Ag-X rays (as contamination of fission products), which is also 22 keV, the presence of this low energy transition could not be confirmed.

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2 Experiment

The nuclei around ^{132}Sn are difficult to produce in conventional fusion-evaporation reaction with reasonable yields. Fission processes are known to be the most efficient routes for the production of neutron rich nuclei in this region. With the recent advancement of novel techniques of separation and identification, it is now possible to obtain precise information related to a particular nucleus without any contamination. In the present work, the neutron-rich Iodine and Tellurium isotopes have been produced by alpha-induced fission of ^{235}U . Alpha beam of 40 MeV was obtained from K-130 cyclotron at Variable Energy Cyclotron Centre (VECC), Kolkata and incident on a stack of ^{235}U electrodeposited targets ($\sim 1\text{mg}/\text{cm}^2$) separated by $6.84\text{ mg}/\text{cm}^2$ Aluminium catcher foils, in which fission products were collected. To populate the levels of ^{132}I from the decay of ^{132}Te ($T_{1/2}=3.2\text{d}$), a two days of irradiation was carried out. To study the decay of high spin isomeric state ($T_{1/2}=83\text{ min}$) in ^{132}I , the targets were irradiated for 2hr to restrict the population of other long-lived isotopes of Iodine.

2.1 Radiochemical separation

To separate Tellurium (Te), the Aluminium catcher foils containing the fission products were dissolved in hydrochloric acid. Inactive Te carrier in the form of Telluric acid was added to this solution. This was further boiled with hydrazine sulphate and subsequently with sodium sulphate. Te activity in the form of Te metal was precipitated and washed thoroughly with water and put for counting with $\text{LaBr}_3(\text{Ce})$ detector setup.

For Iodine separation, the Al catcher foils were dissolved in sodium hydroxide solution. Potassium iodide was added as carrier of Iodine. This solution was acidified with nitric acid and hydrogen peroxide was used to oxidise iodide to iodine, which was then extracted into carbon tetrachloride, leaving, in the aqueous phase, other fission products. Carbon tetrachloride phase containing iodine isotopes was counted in LEPS and Clover HPGe setup, described later in the text.

The radioactive solutions of fission products before and after the radiochemical separation were counted with HPGe detector to ensure the clean separation of respective isotopes.

2.2 $\text{LaBr}_3(\text{Ce})$ setup for lifetime measurements

For the lifetime measurements, a setup of three 30mm x 30mm $\text{LaBr}_3(\text{Ce})$ detectors coupled with XP2020URQ fast PMT were used. The γ - γ -t coincidence measurements were carried out with a fast-slow coincidence circuit based on NIM electronics and CAMAC data acquisition system. The singles energy spectrum of $\text{LaBr}_3(\text{Ce})$ detector for a separated Tellurium sample is shown in Fig.1, where the γ rays corresponding to the decay of various Te isotopes are clearly visible.

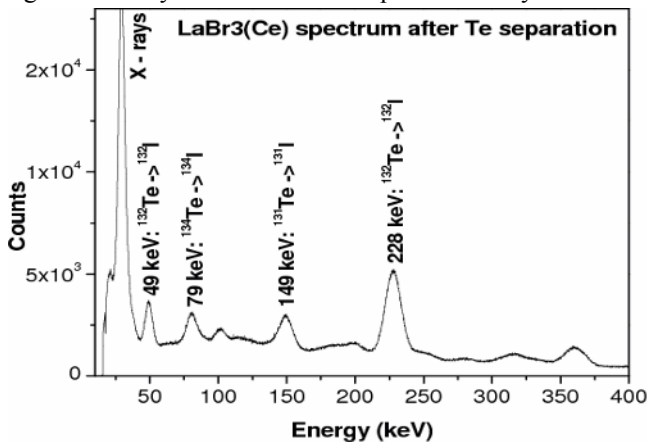


Figure 1. The spectrum of $\text{LaBr}_3(\text{Ce})$ detector for sample counted after the radiochemical separation of Te.

2.3 Isomeric transition decay measurement

The decay measurement from both the 8^- isomer and the ground state in ^{132}I were performed using a high resolution four-fold segmented planar Low Energy Photon Spectrometer (LEPS) of planar HPGe detector, having enhanced efficiency below 100 keV and a Clover HPGe detector for the detection of γ rays of energies greater than 500 keV. LIST mode data were obtained using a CAMAC based data acquisition system and the gain matched spectra of all four segments of LEPS detector and the add-back spectrum of Clover detector were generated. The decays from the ground state as well as the isomeric state were accumulated with a purified sample of Iodine in a time window of 10min.

3 Results and discussion

3.1 Lifetime of 49.7 keV 3^+ state

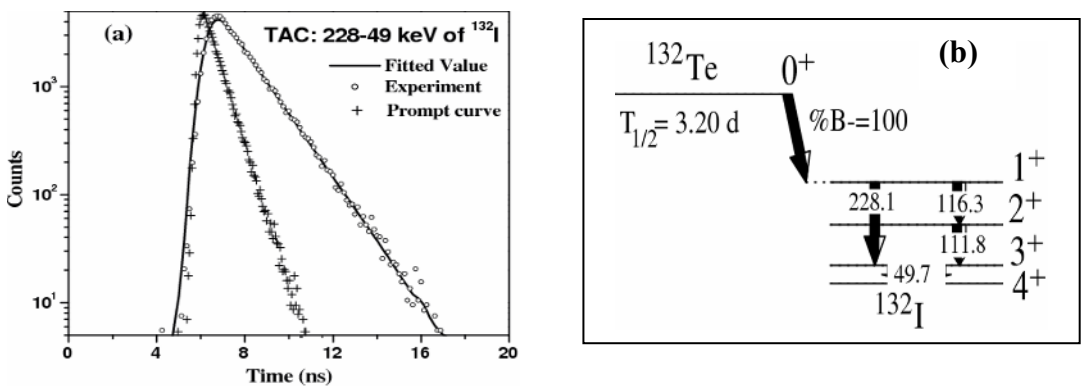


Figure 2. (a) The decay (TAC) spectrum of 228-49 keV cascade of ^{132}I and (b) the corresponding decay scheme.

After setting the gates at 228.1 keV and 49.7 keV as ‘START’ and ‘STOP’ transitions in the time measurement with $\text{LaBr}_3(\text{Ce})$ detectors, the corresponding decay spectrum was projected and shown in Fig.2(a). The corresponding decay scheme of ^{132}Te decay is shown in Fig.2(b). The prompt curve, also shown in Fig.2(a), was obtained by gating on same energy windows in the Compton part of the spectrum of ^{106}Ru source. The prompt component has been de-convoluted from the decay spectrum to extract the half life of the 49.7 keV level as 1.002(7) ns. A similar value has also been obtained by fitting the slope of the decay curve. The prompt time resolution (FWHM) of the setup was estimated as 340 ± 10 ps for 511-511 cascade of a ^{22}Na source, which is close to that of BaF_2 detector system.

3.2 Decay of 8^- isomer

The decay of the high spin isomer (8^-), which was populated directly in alpha-induced fission, has been precisely measured by separating Iodine from the fission products and following its IT decay with a LEPS detector and Clover HPGe detector. A representative LEPS spectrum is shown in Fig.3(a), where the isomeric transition of 96.7 keV is identified, in agreement with the reported value of 98.0 keV [9]. The corresponding decay curve of 96.7 keV is shown in Fig.3(b), from which the half-life of the 8^- isomer of ^{132}I is extracted as 89.4 ± 4.7 min, compared to the previously reported value of 83.6 ± 1.7 min [9]. A low energy transition of 22 keV, observed in the present work, could be the possible decay from the 22 keV (5^+) state tentatively placed in Ref.[9]. The absence of any γ rays corresponding to the decay of Ag isotopes excludes the possibility of any contamination of the observed 22 keV due to the Ag X-rays. In addition, in the present experiment, Iodine was not separated as AgI , which could have been a source of 22 keV Ag X-rays [9]. Fig.4 shows the

transitions corresponding to the β -decay of the 8^- isomer and the ground state of ^{132}I , as well as the decay of other Iodine isotopes, identified in the γ spectrum of Clover HPGe detector.

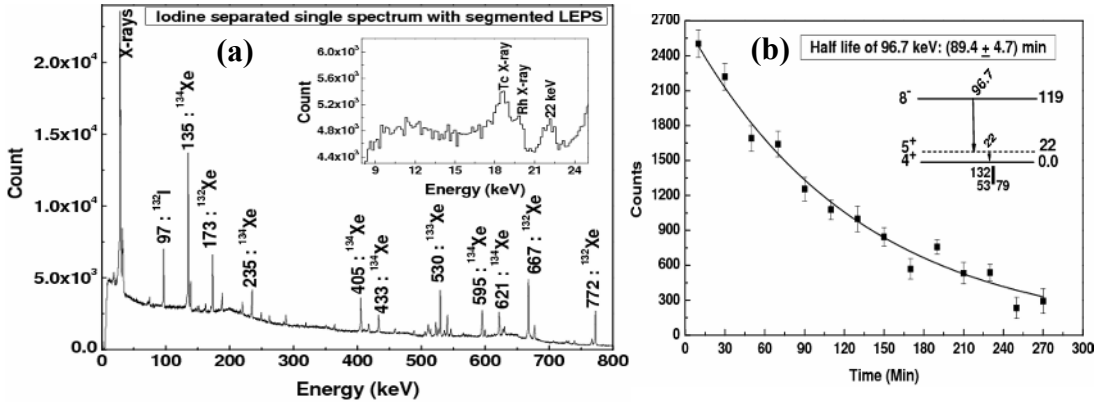


Figure 3. (a) LEPS spectrum of Iodine sample, the lower energy part of the spectrum is shown in inset and (b) the decay curve of 96.7 keV from the 8^- isomer.

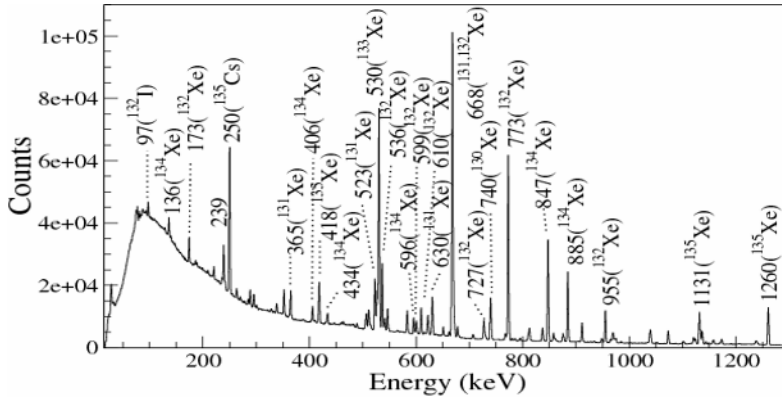


Figure 4. The γ spectrum of Iodine sample obtained with Clover HPGe detector showing all decay products.

4 Summary

The neutron rich Iodine and Tellurium isotopes have been produced by alpha induced fission of ^{235}U and were radio-chemically separated. The lifetime of 49.7 keV 3^+ state of ^{132}I , from ^{132}Te decay, has been measured using $\text{LaBr}_3(\text{Ce})$ detectors. The IT decay of 8^- isomer has been studied with LEPS and Clover HPGe detectors. Indication of presence of an intermediate 5^+ state has been obtained.

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