Precise measurement of Half-life of ^{139}Ba

L. S. Danu[1],* P. K. Joshi[2], S. Mukhopadhyay[1], P. N. Prashanth[1], L. A. Kinage[1], D. C. Biswas[1], A. Goswami[3], and R. K. Choudhury[1]

[1]*Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai - 400085, INDIA*

[2]*Tata Institute of Fundamental Research, Mumbai - 400085, INDIA*

[3]*Radio Chemistry Division, Bhabha Atomic Research Centre, Mumbai - 400085, INDIA*

* *email: lsdanu@barc.gov.in*

Introduction

Spectroscopy of ^{139}La is important for understanding the collective and the single particle states as it is one of nuclei with N = 82 shell closure [1]. Also, because of the high yield (6.6%) of mass 139 in the thermal-neutron induced fission of ^{235}U, the nuclides in the ^{139}Xe $\rightarrow$ ^{139}Cs $\rightarrow$ ^{139}Ba $\rightarrow$ ^{139}La decay chain are important for many reactor-related problems. In applications, such as isotopic monitoring and fission product decay heat, it is necessary to know the emission probabilities per β-decay (absolute intensities) of the associated γ-radiation. In ^{139}Ba, approximately 99% of its β-decay populates the ground and the first excited states in ^{139}La. The remaining 1% of the β-decay populates higher excited states (up to about 2.1 MeV), with over 80% of the remainder populating the 1420-keV level [2]. Thus, only a small fraction ~ 0.06% of β-decay populates the other levels in this nucleus between 1200- and 2100-keV, which has contributed to the scarcity of detailed experimental information on these levels. This calls for a precise measurement of energies, relative intensities and coincidence relations among the electromagnetic transitions in ^{139}La.

With this motivation, an offline singles as well as coincidence measurement of γ-rays of ^{139}La (following ^{139}Ba β-decay) has been undertaken. In this paper, we present the results of the half-life measurement of ^{139}Ba.

Experimental details

The ^{139}Ba sources were produced by irradiating 40 mg samples of enriched (99%) barium in form of $Ba(NO_3)_2$ in a thermal neutron flux of ~ 5× 10^{13} n/cm^2/sec n the DHRUVA Reactor at BARC, Mumbai, each for a duration of 1 min. The γ-rays were measured using four Compton suppressed Clover Ge detectors. All four detectors were kept at a distance of 25 cm from the source, at angles 36°, 72°, 108° and 144°. The multi parameter data acquisition was carried out using the CAMAC based LAMPS software. The master gate for the data acquisition was generated by OR'ing the timing signals of all four Clover detectors. The TAC signals were also generated and subsequently recorded along with the γ-ray energies.

Results and discussions

Two sets of data were collected in the present work, one using 5-mm thick Pb absorber, and the other without any absorber. The Pb absorber was used to attenuate a significant fraction of the highly intense 166-keV γ-ray. This made it possible to measure the ^{139}Ba sample with high activity to obtain good statistics of the very weak high-energy transitions (between 1200 and 2100 keV) in ^{139}La. The high energy region of the γ-ray spectrum recorded with the Pb absorber is shown in Fig.1.

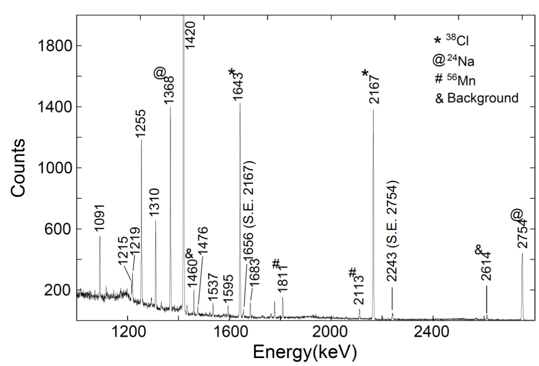

Fig.1: Representative singles spectrum of ^{139}La.

All the contaminations (long and short-lived nuclides) produced from trace impurities in the ^{138}Ba sources have been identified from the spectrum. The contaminations are from ^{38}Cl, ^{24}Na and ^{56}Mn. The γ-rays from the decay of these nuclei along with the natural background lines are marked in the Fig. 1.

Half-life measurements

The data for the half life measurement were collected in batch mode with each file of 600 s duration. The ^{137}Cs source was counted simultaneously with the ^{139}Ba sample in order to take into account the count rate loss. The count rate loss occurs due to the dead time of the detection system including the random and coincidence summing of the γ-rays. The reference γ lines of 662-keV (from ^{137}Cs source) and 1460-keV (natural background from ^{40}K) were considered to estimate the count rate loss.

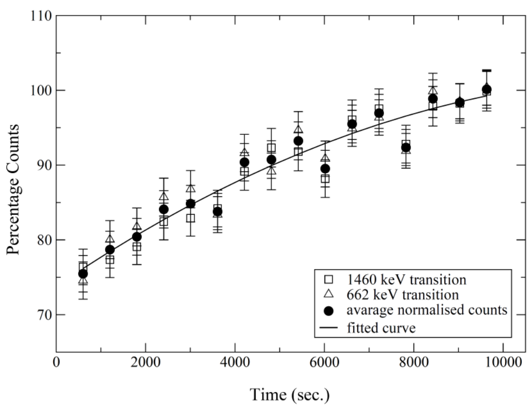

Fig. 2: Estimation of count rate loss

The percentage of counts recorded for these γ-rays are depicted in Fig. 2. It is evident from the Fig. 2 that only 76% counts were recorded at the beginning of the measurement as the activity of the sample was high. The recorded percentage counts approached to 100% after 8000 sec. (approx.) when the activity of the sample was reduced. The data were corrected for the count rate loss by using the parameters obtained from the fit in Fig. 2.

The half-life of ^{139}Ba was measured by fitting three different γ transitions of daughter ^{139}La (166-keV, 1420-keV and 1310-keV). The quality of the fittings is presented in Fig. 3. From these fits, the average half-life value was found to be **83.06 ± 0.15** min. The uncertainty of 0.15 min comes from the count rate loss correction factor, and due to the statistical uncertainties. The half life of ^{139}Ba was reported as $T_{1/2}$ = 84.6 min by C.B. Zamboni *et.al.*[2]. However the half-life extracted from the present measurement is in good agreement with the value 83.06 ± 0.28 min reported by R, J. Gehrke [3].

The half lives of the nuclei ^{38}Cl and ^{56}Mn (contaminations) were also extracted from the corrected data. The values were measured as $t_{1/2}$ = 37.25 min for ^{38}Cl, and $t_{1/2}$ = 154.88 min for ^{56}Mn. The numbers are also in good agreement with the adopted half lives for ^{38}Cl and ^{56}Mn from literatures ($t_{1/2}$ = 37.24 min and 154.734 min, respectively).

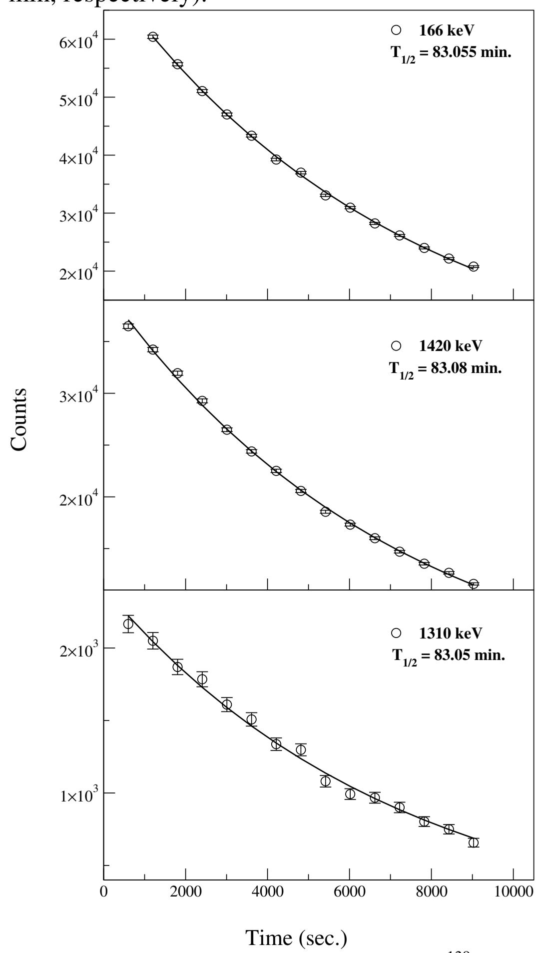

Fig. 3: Precise half-life measurement of ^{139}Ba

Acknowledgement

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References

[1] M. Waroquier, K. Heyde,. Nucl. Phys. A144, 481(1970).

[2] C.B. Zamboni *et.al*. Applied Radiations and Isotopes **55** 477-483 (2001).

[3] R, J. Gehrke,. International Journal of Applied Radiation and Isotopes **31** 37-40 (1979)