Beta decay spectroscopy of ^{139}La produced by neutron irradiation in CIRUS reactor

L. S. Danu[1]*, P. K. Joshi[2], P. N. Prashanth[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 nuclei around the shell closure is important from the point of understanding the collective and the single particle states. In recent years, the excited energy levels in ^{139}La (N=82) have been investigated through the ^{139}Ba EC and β-decays and with different nuclear reactions, in connection with theoretical calculations, but the experimental results are not consistent with the theoretical predictions [1-4]. Although theory predicts no levels between 200 keV and 1.0 MeV for ^{139}La, several experimental works have reported levels and γ -transitions in this energy region. From the studies of the levels populated through the EC/ β^+ and β^- decay, little information is established because in the ^{139}Cs decay the disintegration energy, Q_{EC}, is about 270 keV only, and the absence of experimental information from ^{139}Ba decay is mainly due to the fact that approximately 99% of its β^-decay populates the ground and first excited states, the remaining 1% populating higher excited states, up to about 2.1 MeV.

In the present work the states in ^{139}La through the ^{139}Ba β-decay, has been investigated to obtain complementary experimental information on the population of low-lying levels (below 2 MeV). The γ-ray spectrum of ^{139}La following the β^-decay of ^{139}Ba has been studied using the γ-γ coincidence spectroscopy techniques. Precise measurement of energies, intensities and coincidence relations among the electromagnetic transitions in ^{139}La, was carried out using two clover detectors, with high counting statistics in the region from 50 keV up to 3 MeV.

Experimental details

The radioactive sources of ^{139}Ba were obtained from the ^{138}Ba(n,γ)^{139}Ba reaction. Approximately 40 mg of enriched barium in the form of $BaNO_3$ were irradiated in a thermal neutron flux of 5×10^{12} n/cm^2 for 10 min in the CIRUS reactor at BARC, Mumbai. After irradiation, the source was let cool down for a period of 60 min; to allow for the decay of short-lived activities of ^{131}Ba^m ($T_{1/2}$ = 14.6 min)and ^{137}Ba^m ($T_{1/2}$ = 2.6 min) also formed during the irradiation.

The gamma rays emitted by ^{139}La were detected using two Compton suppressed Clover detectors, placed at 180°. Both the detectors were kept at a distance of 25 cm from the source. The Compton suppressed data were collected in an event-by-event mode using LAMPS software. The master/hardware gate was generated requiring γ-ray detected in anyone of the two Clover detectors. The TAC spectrum of the Clover detectors was recorded along-with the gamma ray energies. Thus the singles and coincidence measurements were carried out, simultaneously.

The energy resolution of both the Clover detectors was approximately 2.4 keV at 1.4 MeV in add-back mode. The time resolution of the Clover detectors was 15 ns. Gamma ray energies from 50 keV to 3 MeV were investigated with this system.

Results and discussions

The γ-γ coincidence data was used to build the E_γ-E_γ matrix, which was then, analyzed using the RADWARE software. In the present work the transition at 268 keV is observed in addition to the transitions at 1054, 1091, 1215, 1254, 1310, 1370, and 1392 keV, in coincidence with the 166 keV transition.

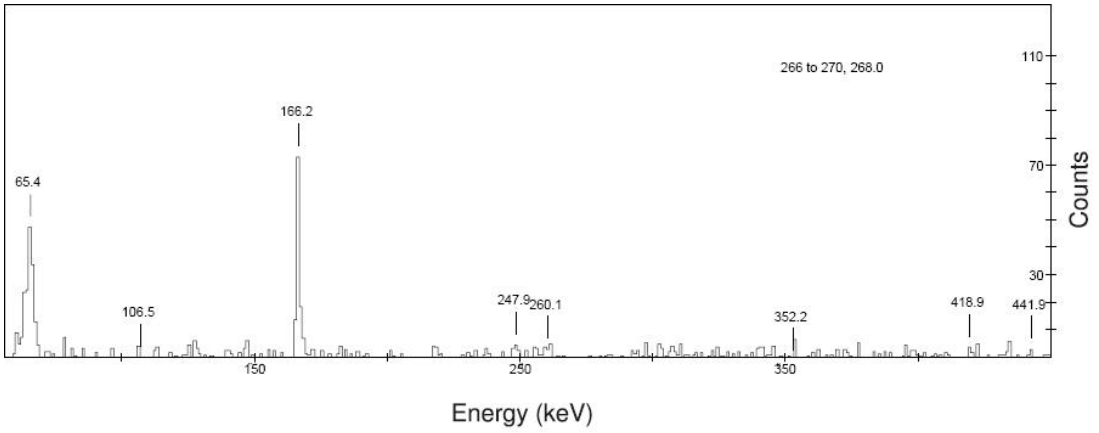

Fig.1. The γ -ray energy spectrum obtained with gate on 268 keV transition.

However, theory predicts no levels between 200 keV and 1.0 MeV for ^{139}La [4]. The 268 keV transition in coincidence with 166 keV transition was also observed by Zamboni *et.al* [4]. In that experiment they measured the gamma rays in the range 70 keV to 2.2 keV.
In this experiment gamma rays ranging from 50 keV to 3 MeV were detected. The 268 keV gated spectrum obtained in the present wok is shown in the Fig.1. We also observe a 65 keV transition along-with the 166 keV transition in the 268 keV gated spectrum, as shown in the Fig.1. Further investigation of these results is being carried out in the detailed data analysis.

The half life of ^{139}Ba was calculated by following the 166 keV γ-ray transition of ^{139}La. The data was collected in batch mode for the half life measurement. The time duration for each data set was 10 minutes and there was a difference of 2 seconds between two data sets. The counts of 166 keV γ-ray transition from the present measurement and the fitted half life is plotted in Fig.2. In the present work we obtained $T_{1/2}$ = 83.6 ± 0.6 minutes, which is in agreement with the earlier measurements.

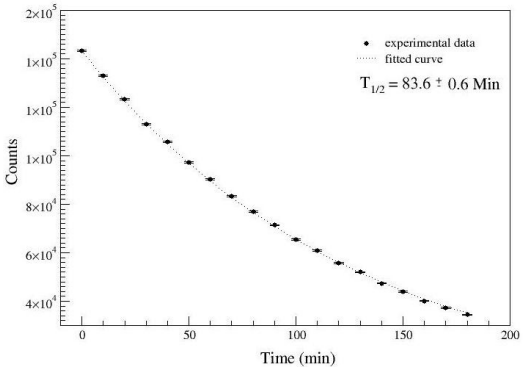

Fig.2. The counts of 166 keV transition as a function of time is plotted, the dotted curve is the fitted half life.

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