Measurement of Decay Half Lives in Tb-Isotopes

A. Pal[1,3*], D. Banerjee[2], S. Basak[1,3], D. Kumar[1,3] and T. Bhattacharjee[1,3]
[1]*Variable Energy Cyclotron Centre, 1/AF Bidhan Nagar, Kolkata – 700 064, India*
[2]*Radiochemistry Division (BARC), VECC, 1/AF, Bidhan Nagar, Kolkata-700064, India*
[3]*Homi Bhabha National Institute, Mumbai, India, PIN – 400094*
aq.pal@vecc.gov.in

Introduction

The measurement of decay half-life provides valuable information for the measurement of nuclear reaction cross-section as well as validation of different statistical model calculations and choosing appropriate input parameters. The half-life values are also required for modeling the nucleosynthesis of heavy elements. Again an inaccurate nuclear input parameters used in the reaction rate calculations may lead to the fact that the nucleosynthesis models are not able to reproduce well the heavy element abundances observed in nature [1, 2]. The determination of half-life is also important for the radioisotope to be used as nuclear medicine. Several members of the lanthanide group are becoming increasingly important in the field of labeled compounds [3]. Amongst the lanthanides, terbium (Tb) offers a set of radionuclides which are potentially suitable for diagnosis using SPECT (^{155}Tb, $T_{1/2}$ = 5.32 d) and PET (^{152}Tb, $T_{1/2}$ = 17.5 h). Some Tb-isotopes along with their decay properties are furnished below in Table 1.

Table 1: Decay properties of Tb-isotopes.

Nuclide	Half-life	γ-rays (keV)	Intensity (%)
^{151}Tb	17.609	251.9	26.3
	(14) h	287.3	28.3
^{152}Tb	17.5 (1) h	271.1	8.6
		344.3	65.0
		586.3	9.4
^{153}Tb	2.34 (1) d	212	31
^{154}Tb	21.5 (4) h	1291	7
^{154m1}Tb	9.4 (4) h	540	20
^{154m2}Tb	22.7 (5) h	427	17
^{155}Tb	5.32 (6) d	105.3	31.5
		86.6	46

Considering ^{155}Tb isotope, it does not have any long lived isomer and the half-life of its ground state is 5.32 ± 0.06 d [4]. The situation for ^{154}Tb is, however, more complicated [5]. Its ground state decays by β+ emission and electron capture (EC) to ^{154}Gd with a half-life of 21.5 ± 0.4 h. ^{154}Tb has two long-lived isomeric states. The m1 isomer decays both by internal transition (IT) to the ground state and by β+ and EC to ^{154}Gd with a half-life of 9.4 ± 0.4 h. The m2 isomer decays almost exclusively by β+ and EC to ^{154}Gd. There is a weak internal transition to the m1 state. It may be noted that the uncertainty in half-life of the m1 isomer is more than 4%.

In the present work, determination of half-life of ^{155}Tb and different isomers of ^{154}Tb has been attempted. Tb isotopes have been produced both from alpha and proton induced reactions on natural Eu and enriched Gd targets respectively. Enriched Gd-target contains 67% ^{154}Gd and 21% ^{155}Gd isotopes.

Experiment

Eu and Gd targets were prepared by electro-deposition method on 0.7 mil Al backing foil and thickness of the targets was kept in the range of 1.2 - 1.5 mg/cm^2. ^{154}Tb was produced both from ^{nat}Eu (α, xn) reaction using 40 MeV alpha beam and ^{154}Gd (p, n) reaction using 12 MeV p-beam from K 130 cyclotron at Variable Energy Cyclotron Centre, Kolkata. ^{155}Tb was produced both from ^{153}Eu (α, 2n) and ^{155}Gd (p, n) reactions. Six α-irradiations and one p-irradiation were carried out for a duration of 6 - 12 h. Irradiated foil was counted on 50% HPGe detector. The half-life of ^{155}Tb was measured using 50% HPGe detector from 86.7 keV γ-line. During the counting with HPGe detector, the background was reduced by applying ~10 cm thick lead shielding . Acquisition was performed using Genie-2000 software.

Tb-isotope	Half life	
	This work	Lit.
^{152}Tb	19.3 (17) h	17.5 (1) h
^{155}Tb	5.7 (3) d	5.32 (6) d

Results and Discussion

A typical γ-spectrum from the present experiment is shown in fig. 1 for α-induced reaction on ^{nat}Eu target.

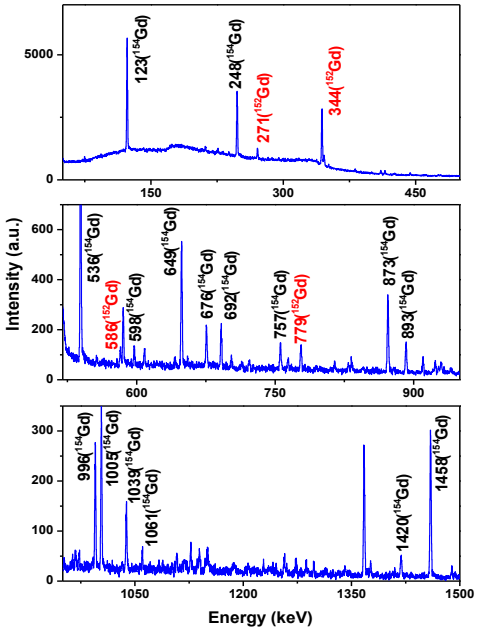

Fig 1: γ-ray spectrum taken with 50% HPGe detector for ^{nat}Eu(α, xn) reaction (blue: ^{154}Tb decay lines and red: ^{152}Tb decay lines)

All the γ-lines could be assigned to the decay of ^{152}Tb and ^{154}Tb isotopes. The production of ^{155}Tb isotope could not be observed from ^{nat}Eu(α, xn) reaction and this experimental observation could be supported by PACE4 calculation. The production yield for ^{152}Tb from ^{151}Eu (α, 3n) reaction was calculated to be 89.8% with a cross-section value of 1.44 b. Again the production yield for ^{154}Tb from ^{153}Eu (α, 3n) reaction was calculated to be 89.4% with a cross-section value of 1.45 b. ^{155}Tb was produced from ^{155}Gd (p, n) reaction and the half-life of the isotope was determined. The necessary plot is given in Fig. 2 and the half-life value is furnished in Table below.

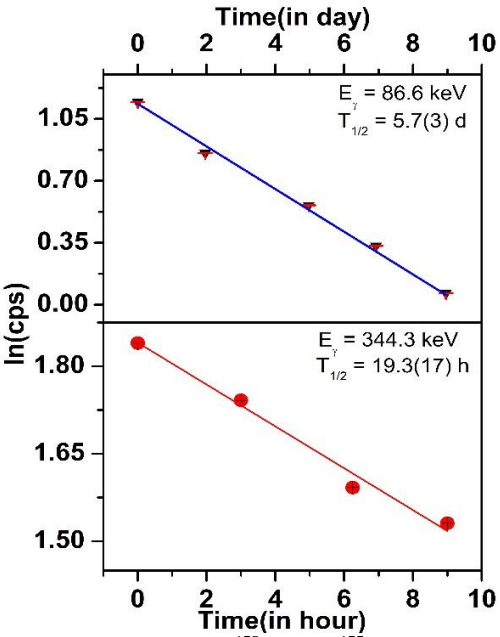

Fig. 2: Decay plots of ^{152}Tb and ^{155}Tb-isotopes.

Above shown results are from the analysis of first few data set and it matches reasonably well with existing value within quoted error. Detailed analysis with significantly more statistics and analysis for other isotopes is in progress and will be presented.

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