Production of ^{244}Bk by ^{11}B+^{238}U reaction for spectroscopic investigations

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Introduction

Spectroscopic investigation of trans-actinides is an important area of research. Transactinides up to atomic number 98 have been produced in weighable quantities following a series of (n,γ) reactions starting with Pu target[1]. An alternate path to produce heavier actinides is charged particle induced reactions on lighter actinide targets. For example, berkelium isotopes have earlier been produced by (α,xn) reaction on ^{241}Am and ^{243}Am targets [2]. One of the limitations of heavy-ion induced transactinide production is very low formation cross section of these elements. Thus radiochemical separation or mass analyzer is necessary to isolate these small quantities of transactinides from the bulk of fission products. The decay scheme of Bk isotopes is also not fully established. With an objective of carrying out spectroscopic investigations, the possibility of producing ^{244}Bk by ^{11}B+^{238}U reaction for has been explored in the present experiment. Radiochemical separations have been carried out to remove uranium and fission products.

Experimental

Natural uranium target having thickness of about 30 mg/cm^2 was irradiated with ^{11}B beam at BARC-TIFR, Pelletron accelerator, Mumbai. Irradiation was carried out at an internal irradiation positions without selecting charge state. The Coulomb barrier for the present reaction system in center of mass system is 53 MeV as calculated by the code CCFUS [3]. Thus, at the terminal voltage of 10.5 MV, ^{11}B ions with 5+ charge states were having sufficient energy to fuse with ^{238}U. Irradiation was carried out for about 24 hrs. The berkelium isotopes were separated from uranium and most of the fission products using various steps of solvent extraction. The extracted fraction containing berkelium isotopes was counted using a segmented clover detector and a HPGe detector. The four segments of the clover detector were treated as separate detectors and data was acquired in list mode. The coincidence spectra were then built using this list mode data. The half life of ^{244}Bk was measured by following the activity of two listed gamma-lines of 217 keV and 890 keV of the separated berkelium fraction as a function of time in the HPGe detector.

Results

The expected cross sections of the evaporation residue (ER) were obtained using HICOL Based on these calculations the beam energy was chosen to be 63 MeV. At this beam energy the cross section of 5n product (^{244}Bk) was expected to be ~50 times higher than the neighboring berkelium isotopes. However, the fission cross section was 500 times more than the ER cross section. Hence it was necessary to separate the fission products as much as possible to identify and study the berkelium isotopes. The reaction products were initially separated from the bulk target by dissolution followed by solvent extraction with TBP. The bulk of the fission products were further removed using solvent extraction steps with appropriate reagents. The radiochemical separation procedures removed the major fission product

activity thereby reducing the complexity of the gamma spectra. The reported gamma-lines of ^{244}Bk were 217.6 ± 0.3 keV and 891.5 ± 1.0 keV [3]. These were identified in the γ-spectra and their decay profiles were followed. The measured half life from the above gamma-lines was 5.56 ± 1.16 h. The decay profile of 217.4 keV gamma-line is shown in figure 1. The only reported value of half life of ^{244}Bk is 4.35 ± 0.15 h [4]. The most abundant gamma-lines of none of the other possible radionuclides {having half-life between 4 to 8 h and expected gamma around 216 to 218 keV} were seen in our spectra. Treating each of the segments of the Clover as separate detectors, the coincidence spectra were build from the list mode data with a gate on 217.4 keV on other 3 segments. The gated coincidence spectra are shown in figure 2. The gamma-line at 1243.5 ± 1.5 keV was found to be in coincidence with 217.4 keV. There is also a signature of another gamma-line at 2401 ± 2 keV. These gamma-lines have not been reported earlier. The 1243.5 keV gamma-line was not clearly seen in the singles spectrum due to Compton background.

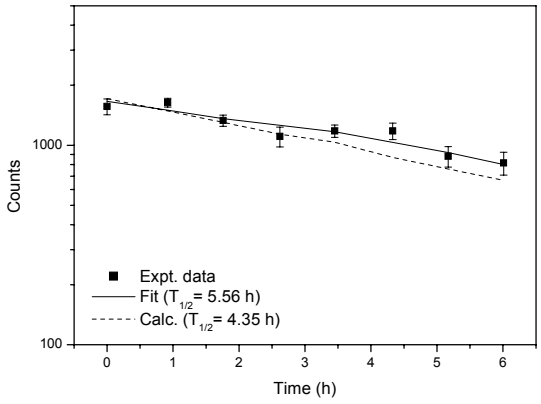

Fig 1: Decay profile of 217.4 keV gamma-line.

Conclusion

Two gamma-lines of ^{244}Bk were identified and the half life was found to be 5.56 ± 1.16 h. The half-life and decay scheme has to be confirmed by further experimentation.

References

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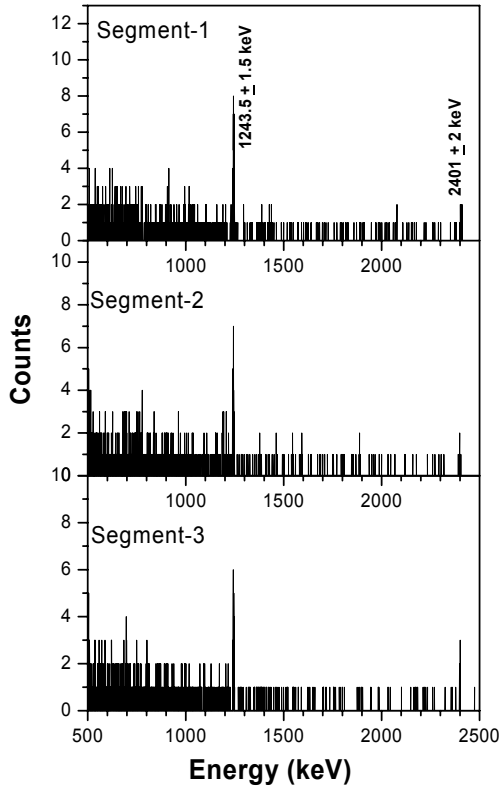

Fig. 2: Coincidence spectra gated with 217 ± 1 keV.