Photofission of ^{238}U Nuclei

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Abstract. The spectrum of the ^{238}U(γ, f) photofission reaction which is obtained using bremsstrahlung photon beams from a clinical e-linac is analyzed. The following nuclei ^{94}Y, ^{134}Te, ^{136}Pr, ^{142}Ba, ^{138}Xe, ^{104}Tc in the spectrum of our experiment have been identified. The gamma ray energies of the produced nuclei are compared with the literature values. This work is a proof-of-concept experiment which is the first of in the series of our future planned photofission experiments using a clinical e-linac operated with different endpoint energies.

1. Introduction

Nuclear fission studies are still attractive and widespread since 1940s. Photofission is one of the way to create nuclear fission products. It is the result of the process which is called as photon-induced nuclear (photonuclear) reaction that is important in a variety of applications such as basic science, activation analyses, preparation of medical isotopes and characterization and transmutation of nuclear wastes [1-7].

Photonuclear reactions are nuclear experiment methods performed with bremsstrahlung photons obtained from the deceleration of fast electrons within the vicinity of target nuclei such as tungsten. Bremsstrahlung photons have a continuous spectrum. The average energy of the fission barrier is about 7-8 MeV. Therefore to obtain photofission products the photons have to have at least this much energy. In this experimental method, the target nuclei can be converted to other nuclei with just one or more proton/neutron ejection or may undergo fission reaction depending on the nature of the target nuclei and the energy of the photons. The experimental yields of the photonuclear reactions can be determined by detection and analysis of the characteristic gamma rays emitted from the product nuclei.

Neutrons are often used as a source to create the fission of ^{235}U, because it has high fission cross section with neutrons. ^{238}Uexist in nature with a high abundance has low fission cross section with neutrons. For reaction to take place high flux of fast neutrons are required. Therefore experimental cross section measurement of^{238}U is easier for photon induced fission than neutron induced fission [8]. Therefore, this work is a proof-of-concept experiment which is the first of in the series of our future planned photofission experiments with a clinical e-linac operated with different endpoint energies.

2. Experimental Procedure

The photofission reaction has been performed using Elekta™ Synergy™ clinical e-linac accelerator as the source of bremsstrahlung photons, its technical documentation can be found in [9].The target nuclei ^{238}U, inside compound $UO_2(NO_3)_2$, was prepared with appropriate geometry for the irradiation.

The sample target was placed at 58 cm in distance from the photon source and was irradiated for 1 hour with18 MeV end-point energy.

In order to measure the spectra of the ^{238}U sample a well-shielded high-purity germanium detector (HPGe) has been used. The sample is placed 15 min after irradiation and counted for two days. The detector used is a p-type, coaxial, electrically cooled, HPGe gamma-ray spectrometer AMATEK-ORTEC (GEM40P4-83) with 40% relative efficiency and 768 eV FWHM at 122 keV for ^{57}Co and 1.85 keV FWHM at 1332 keV for ^{60}Co [10].

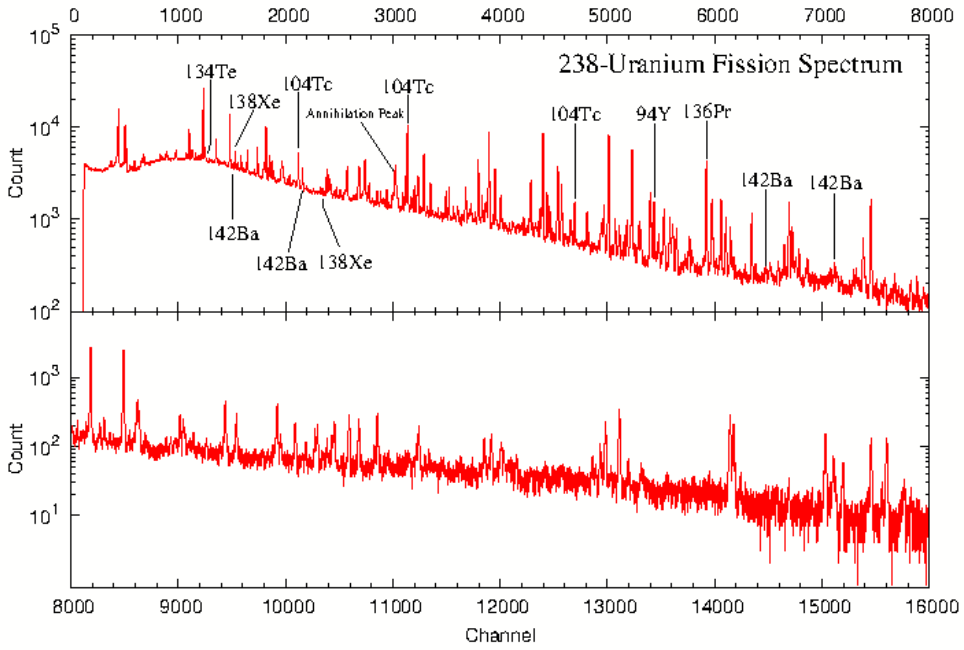

Figure 1. Fission spectrum of^{238}U for the irradiated sample after 2 days of counting.

3. Results and Discussion

The irradiated ^{238}U sample spectrum without background subtractions is shown in Figure 1. This spectrum is analyzed with gf3 RadWare [11] peak-fitting program to identify the photofission fragments. The energy and half lives of the fragment nuclei are determined using the area and the channel of each peak. Then, these obtained values have been used to identify the photofission fragments by comparing them with the values found in NNDC (National Nuclear Data Center) [12].

Analyzing the ^{238}U fission spectrum and identifying the fission fragments still continues. In this initial study we were able to show, as proof-of-principle, the concept and the idea behind determining the fission fragments via gamma spectroscopy. However in order to calculate yields of fission fragments more experimental data is necessary. At the very least one more end-point energy of the linac is necessary. At this time we are investigating how to change the end-point energy of medical linac used in the present experiment. After this process is completed detailed amount of the fission yield will be obtained. Then it will be possible to obtain the photofission cross sections using these fission yields.

In conclusion, we have presented the photofission process of ^{238}U analysis with gamma spectroscopy and availability of medical linac in nuclear physics experiments. We have positively identified several elements in this analysis. The results of the present study have demonstrated the feasibility of studying photofission in the way that presented in this paper.

Table 1. Gamma-ray energies of observed photofission fragments from ^{238}U irradiation and values found in the literature (NUDAT). σ_E and σ are statistical errors.

	Present study		*NUDAT* [a]	
Element	*E (keV)*	σ_E *(keV)*	*E (keV)*	σ *(keV)*
134Te	210.5739	0.0162	210.465	0.016
94Y	917.7587	0.0094	918.74	0.05
136Pr	999.8549	0.0042	1000.7	0.2
142Ba	255.0362	0.0428	255.300	0.012
142Ba	364.2100	0.0125	363.96	0.03
142Ba	1093.1321	0.1388	1094.1	0.1
142Ba	1202.1080	0.0895	1202.4	0.1
138Xe	258.2187	0.0110	258.411	0.020
138Xe	396.2359	0.0806	396.513	0.010
104Tc	357.6323	0.0068	358.0	0.1
104Tc	529.4958	0.0027	530.5	0.1
104Tc	792.6276	0.0118	792.5	0.1

[a]NNDC [12].

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