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Research Article

Experimental Study for the Energy Levels of Europium by the Clinic LINAC

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Abstract: It has been investigated the energy levels of ^{150}Eu and ^{152}Eu radioisotopes. In this purpose, the Europium Oxide (99,9% purely) sample has been activated by the bremsstrahlung photon beam of 18 MeV end-point energies produced by the clinical electron linear accelerator (cLINAC) at Akdeniz University Nuclear Research and Application Center. The obtained experimental results are in good agreement with the NUDAT database.

1. Introduction

The analysis of photoactivation used at variety applications is a quite popular in recent years. Especially, it has become more important with developing accelerator and detector systems. Initially, the bremsstrahlung photons produced low-energy accelerator were limited to isomeric structures [1,2] only, but now offer the opportunity to examine nuclear reactions with longer cross section from high-energy (20-30 MeV) accelerator and high resolution detector systems [3,4,5].

In recent times, beside large accelerator systems clinical linacs have begun to take part in photoactivation experiments. P. Mohr et al were indicated the cLINAC is convenient for photoactivation analysis with their ^{197}Au(γ,n)^{196}Au studies in 2007 [6]. In Turkey, these experiments are begun in nuclear research center of Akdeniz University in 2013 [7,8]. In this center, the experiments are performed with cLINAC.

In the present work, we have focused on the energy levels of Eu radioisotopes producing by photonuclear reactions using cLINAC.. Spectrum analysis and energy calibration were performed with gf3 [9] and ROOT [10] programs. The obtained results compared with NuDat database [11]. It was observed that the results were consistent.

2. Experimental Setup

In this study, Philips SLI-25 cLINAC of Electa TM Synergy TM [12] has been used as a photon source. It has a capacity to produce bremsstrahlung photons with end-point energies of 4, 6, 18 MeV and average electron beam current was about 300 μA. The schematic representation of the cLINAC, which is used in our experiment, is given in figure 1.

The Europium oxide powder sample (99,9% purity) was placed 58 cm away from electron target (Tungsten) and exposure to bremsstrahlung photons end-point energy 18 MeV for about 30 minutes. This energy range is sufficient to investigate of energy levels for Eu radioisotopes since, threshold energies of ^{153}Eu(γ,n)^{152}Eu reaction is 8.55 MeV, ^{151}Eu(γ,n)^{150}Eu reaction is 7,93 MeV. Eu has two stable isotopes. These are ^{151}Eu and ^{153}Eu with 47.81% and 52.19% natural abundances, respectively. When the Europium sample irradiated by bremsstrahlung photon beams, ^{153}Eu emits neutron producing unstable ^{152}Eu. It has an isomeric transition with main gamma energy of 89.849 keV (69.7%) and it also decays to unstable ^{152}Gd (73%) by β emission, ^{152}Sm (27%) by positron emission [13] ^{151}Eu emits neutron producing unstable ^{150}Eu, in this process, either stable ^{150}Gd is produced by β emission or unstable ^{150}Sm is produced by positron emission [14].

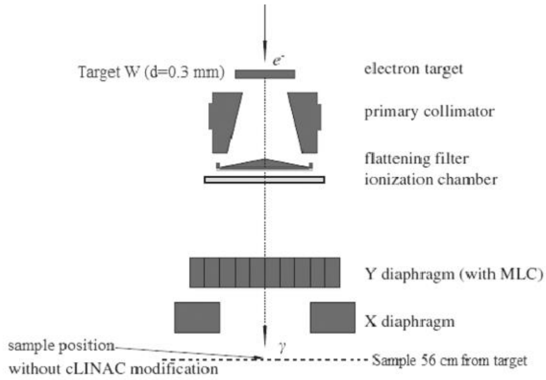

Figure 1. *Schematic representation of cLINAC*

The gamma spectra of the activated Eu sample were analyzed with the high purity germanium detector (HpGe) at the Physics Department of Akdeniz University. The HpGe detector (AMATEK-ORTEC) has a resolution with 768 eV FWHM at 122 keV for ^{57}Co source and 1,85 keV FWHM at 1332 keV for ^{60}Co and it's relative efficiency is 40% [15]. The process of γ-ray counting continued for three days. The gamma spectrum obtained after counting at the HpGe detector is given in figure 2. Co-60, Na-22, Mn-54, Cd-109, Co-57, Cs-137 and Ba-133 isotopes were used as standard calibration sources for the detector calibration. In addition, soil samples containing different natural radioactive elements (K-40, Ra-226, Th-232) provided by the Turkish Atomic Energy Authority (TAEK) were also used.

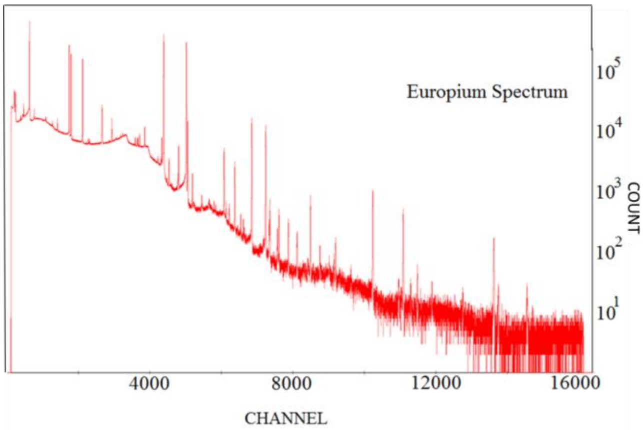

Figure 2. *Gamma spectrum for Eu sample after counting.*

3. Results and Discussions

In this experiment, data acquisition was carried out with MAESTRO32 software. The spectrum analysis was performed with RadWare code, which is developed by David Radford at Oak Ridge National Laboratory. ROOT analysis was used for energy calibration. The ROOT program fitted the centroids and energies and appropriate fit functions are derived as linear, quadratic and cubic forms. It was observed that cubic fit function was good convenient. The χ^2/n.d.f was determined 1.17 for cubic fit. Then we used the cubic fit function for the energy calibration. At the result of data analyses, obtained the gamma energy levels for ^{150}Eu and ^{152}Eu radioisotopes were presented in table 1.

The calculated error values for energy levels are smaller than the error values of the NuDat. It can be said that our results were measured with higher sensitivity than the literature.

Table 1. *The comparison of experimental results and NUDAT values for Eu gamma energy levels.*

Element	Pruduct Nucleus	E(keV)	σ_E	E_{NUDAT} (keV)	σ_{NUDAT}
	^{150}Eu	333.9561	0.0023	333.9	0.1
		344.2824	0.0026	344.29	0.03
		406.4923	0.0030	406.5	0.1
		712.1095	0.0126	712.2	0.1
^{151}Eu		841.5105	0.0120	841.63	0.04
		921.5143	0.0563	921.7	0.7
		1165.6778	0.0240	1165.7	0.2
		1222.9935	0.0250	1223.0	0.2
		1629.5296	0.0346	1629.4	0.3
		1963.5078	0.0379	1963.0	0.3
	^{152}Eu	89. 8452	0.0012	89.849	0.006
		121.7977	0.0051	121.77	0.03
		344.2824	0.0026	344.29	0.03
^{153}Eu		562.9774	0.0068	562.98	0.03
		963.2645	0.0153	963.38	0.04
		970.2643	0.0159	970.33	0.01
		1314.5199	0.0248	1314.61	0.06
		1388.9519	0.0266	1389.03	0.04

4. Conclusions

In the present experimental study, we have calculated the gamma energy levels for Eu radioisotopes which from (γ,n) photonuclear interactions via bremsstrahlung photon beam with endpoint energy of 18 MeV. Our results are compatible with the NuDat database.

The rates of error for the gamma energy values were calculated ROOT analysis and the results with higher sensitivity than literature were obtained. Thus, this study has once again shown that photonuclear interactions for various nuclei can be successfully investigated.

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References

[1] C. Engelmann, (1964)**,.**French Commissariat a L'Energie Atomique, Report CEA-R 2559**,** Saclay, France, July.

[2] P. Albert, Proc. (1961). International Conf. on Modern Trends in Activation Analysis, College Station, Texas, Dec.**,** 78-85.

[3] P. Mohr, J. Enders, T. Hartmann, H. Kaiser, D. Schiesser, S. Schmitt, S. Volz, F. Wissel, A. Zilges, (1999). Real Photon Scattering up to 10 MeV: the improved facility at the Darmstadt electron accelerator S-DALINAC, Nucl. Instrum. Methods Phys. Res. A **423**, 480.

[4] K. Sonnabend, D. Savran, J. Beller, M. B¨ussing, A. Constantinescu, M. Elvers, J. Endres, M. Fritzsche, J. Glorius, J. Hasper, J. Isaak, B. L¨oher, S. M¨uller, N. Pietralla, C. Romig, A. Sauerwein, L. Schnorrenberger, C. W¨alzlein, A. Zilges, M.Zweidinger, (2011). The Darmstadt High-Intensity Photon Setup (DHIPS) at the S-DALINAC, Nucl. Instrum. Methods Phys. Res. A 640, 6.

[5] R. Schwengner, R. Beyer, F. D¨onau, E. Grosse, A. Hartmann, A. Junghans, S. Mallion, G. Rusev, K. Schilling, W. Schulze, A. Wagner, (2005). Nucl. Instrum. Methods Phys. Res. A 555, 211.

[6] P. Mohr, S. Brieger, G. Witucki and M. Maetz, (2007). Photoactivation at a Clinical LINAC: The ^{197}Au(γ, n) ^{196}Au Reaction Slightly Above Threshold, Nucl. Instrum. Meth. A, 580, 1201-1208.

[7] I. Boztosun, H.Dapo, S.F.Özmen, Y. Çeçen, M.Karakoç, A.Çoban, A.Cesur, T.Caner, E.Bayram, G.B.Keller, B.Küçük, A.Guvendi, M.DermaN, D.Kaya, (2014). The results of the first photonuclear reaction performed in Turkey: the zinc example. Turk. J. Phys. 38, 1–9.

[8] I.Boztosun, H.Dapo, M.Karakoç, S.F.Özmen, Y.Çeçen, A.Çoban, T.Caner, E.Bayram, T.R.Saito, T.Akdoğan, V.Bozkurt, Y.Kuçuk, D.Kaya, M.N.Harakeh, (2015). Photonuclear reactions with zinc: a case for clinical linacs. Eur. Phys. J. 130, 185.

[9] D. Radford, (1995). Nucl. Instrum. Methods Phys. Res. A 361, 297.

[10] R.Brun, F.Rademakers, (1997). ROOT: an object oriented data analysis framework. Nucl. Instr. Methods A 389, 81–86.

[11] NuDat 2.6, 2016, http://www.nndc.bnl.gov/nudat2/.

[12] Elekta, Elekta Digital Accelerator, Technical Training Guide, 2003, https://www. elekta.com/services/education-and-training.html.

[13] M. J. Martin (2013). Nucl. Data Sheets, 114-1497.

[14] S. K. Basu, A. A. Sonzogni (2013). Nucl. Data Sheets, 114-435.

[15] MAESTRO,A65-b32-maestro-32-emulation software.