Isomeric and ground state energy level measurements of natural tellurium isotopes via $(\gamma,n)$ reaction

M Tamkas$^{1,2}$, O Akcalı$^2$ and A Durusoy$^2$

$^1$Istanbul Arel University, Mathematics and Computer Department, TR 34537, Istanbul, Turkey
$^2$Yildiz Technical University, Physics Department, Davutpasa Campus, 34220, Istanbul, Turkey

E-mail: makbuletamkas@arel.edu.tr

Abstract. We have planned to measure isomeric and ground state energy levels in $^{120}\text{Te}(\gamma,n)^{119m}\text{Te}$, $^{122}\text{Te}(\gamma,n)^{121m}\text{Te}$, $^{128}\text{Te}(\gamma,n)^{127m}\text{Te}$, $^{130}\text{Te}(\gamma,n)^{129m}\text{Te}$ photonuclear reactions of natural tellurium induced by bremsstrahlung photons with end-point energy at 18 MeV. The sample was irradiated in the clinical linear electron accelerator (Philips SLi-25) at Akdeniz University Hospital. The gamma spectrum of the tellurium sample was measured using HP(Ge) semiconductor detector (ORTEC) and multi channel analyzer. We used both MAESTRO (ORTEC) and home made root based gui program (Theia) for data analyzing. The obtained experimental data values are compared with NUDAT energy values.

Keywords: isomeric state, ground state, energy level

1. Introduction

There are many nuclear reactions that populate both the ground state and the metastable(isomeric) state of daughter nucleus. Isomeric activities can be induced in many stable nuclides that occur in the region of closed nuclear shells, by gamma activation [1-4]. Gamma activation excites the target nucleus from the ground state to one of its activation energy levels above the metastable isomeric state [5].

The investigation of the properties of excited states in a nuclear reaction such as the energy and spin distributions, the probability of excitation, and different decay modes allow one to acquire important information about interaction mechanism. It is particularly efficient when the excited states last for a adequately long period of time as the isomeric and ground state. It is well known that in the same experimental conditions the isomeric and ground states are formed simultaneously during nuclear reaction process. For this reason, isomeric ratio studies have gained importance from past to the present [1-8]. Today, the isomeric ratios can be determined with high accuracy benefiting from

---

M Tamkas, Istanbul Arel University, Mathematics and Computer Department, K 34537 Tepekent-Büyükçekmece Istanbul, Turkey
developed experimental measurement equipments and theoretical models. But in the isomeric ratio studies, the determination of ground state and isomeric state energy levels will improve the accuracy of this studies.

The aim of this work, is to determine the isomeric and ground state energy levels of natural tellurium induced by bremsstrahlung photons with end-point energy at 18 MeV. The nuclear reactions considered in this investigation are $^{120}\text{Te}(\gamma,n)^{119m,g}\text{Te}$, $^{122}\text{Te}(\gamma,n)^{121m,g}\text{Te}$, $^{128}\text{Te}(\gamma,n)^{127m,g}\text{Te}$, $^{130}\text{Te}(\gamma,n)^{129m,g}\text{Te}$ photonuclear reactions.

2. Experimental Technique
In our experiment, we used the photo activation technique. Research was performed with the use of bremmstrahlung beam obtained from a clinical linear electron accelerator (cLinac), Philips SLi-25, at the Akdeniz University Hospital.

The cLINAC which is used as the source of bremsthalung photons for phohonuclear reactions is a standard and up-to-date Elekta TM Synergy TM accelerator, SLi-25 [9]. The accelerator’s primary electron beam is generated by a gun with an energy of 50 keV. After that the electrons are accelerated in a copper cavity by a 3 GHz (2856MHz to be exact) radio-frequency with peak power of about 5 MW [10]. For an electron energy of about 10 MeV, the typical average electron current is about 300 μA. Figure 1 shows the schematic view of cLinac.

In this experiment, we used 0.7 g of natural tellurium, which is obtained from Sigma-Aldrich Laboratory, with purity of 99.99% in small ore pieces. The sample was irradiated for 50 minutes at 18 MeV end-point energy.

![Figure 1. Schematic view of the photon beam production at the cLinac](image)

The sample was placed coaxially at 6 cm distance from the High-Purity Germanium (HPGe) detector. Multi spectrum scaling technique is used to collect gamma-ray spectrum with 5 min cooling time and sampling times were adjusted to 3s, 30s, 180s and 900s to sum up to 20 h counting time. Except for the last time interval 200 cumulative spectrums were recorded to be able to correct spectrums due to different half-lives. The detector used was a p-type, coaxial, electrically cooled, HPGe gamma-ray spectrometer AMATEK- ORTEC (GEM40P4-83) 40% relative efficiency. It is connected to a NIM
consisting of ORTEC bias supply, 672 spectroscopy amplifier, 927 multi-channel analyzer and a
computer. For detector energy calibration, a mixed calibration source supplied by the Çekmece
nuclear Research and Training Center emitting gamma rays in the energy range between 47 and 1836
keV was used.

2.1. Gamma-Ray Spectra Calculations

Throughout the data acquisition period Maestro software was used to acquire and analyse the data for
consistency. After data acquisition, a home made ROOT (Root 5.26.00) [11] based graphical user
interface program named as “Theia” is used to analyse photo peaks and for calculation of the peak
parameters (figure 2 and figure 3) Theia designed to enable methodological access to some desired
futures of ROOT in a simpler manner while providing Compton background correction for all photo
peaks which are assumed to be in Gaussian form.

![Figure 2. Full energy range spectrum of natural Tellurium (γ,n) reaction (a) and the photopeaks of the analyzed region (b)](image)

![Figure 3. The screen shot of Theia with 487.062 keV photopeak parameters](image)
3. Conclusion
The obtained experimental data values are compared with NUDAT energy values (table 2). As seen, gamma energy values which was determined by analysis programs Theia and Maestro. Calculated values by both software are very close to NUDAT energy values. All of the planned isotopes could not be determined because only the results of 20 h count could be reached. Our study continues to determine gamma energy levels and half-life of the long half-life isotopes.

| Reaction Product | Spin | Half Life | Reac.Threshold (MeV) | Gamma Energy (keV) (Err) | Gamma Int(%) (Err) | Theia Energy (keV)(Err) | Energy Maestro (keV)(Err) |
|------------------|------|-----------|----------------------|--------------------------|--------------------|------------------------|--------------------------|
| $^{121}$Te       | 1$^+$ | 16.8 d    | 17.29                | 573.139(0.011)           | 60.4(0.22)         | 572.89 (0.04)          | 572.95 (0.15)            |
| $^{129}$Te       | 3+   | 69.5 min  | 8.39                 | 459.60(0.05)             | 7.70(0.06)         | 459.272 (0.159)        | 459.33 (0.15)            |
|                  |      |           |                      | 487.39(0.05)             | 1.42(0.10)         | 487.062 (0.015)        | 487.24 (0.15)            |
| $^{127}$Te       | 3+   | 9.35 h    | 8.75                 | 360.30(0.1)              | 0.135(0.14)        | 360.054 (0.072)        | 360.19 (0.15)            |
|                  |      |           |                      | 417.90(0.1)              | 0.99(0.14)         | 417.712 (0.012)        | 417.58 (0.15)            |

4. References
[1] Chertok B T and Booth E C 1965 Nucl. Phys. 66 230.
[2] Booth E C and Brownson J 1967 Nucl. Phys. A 98 529 .
[3] Veres A 1980 Atom. Energy Rev. 18 271 .
[4] Ljubicic A, Pisk K and Logan B A 1981 Phys. Rev. C 23 2238 .
[5] Venkataraman R and Fleming R F 1994 Nuclear Instruments and Methods in Phys. Research A 353 (1994) 425-428
[6] Mazur V M, Symochko D M, Derechkey P S and Bigan Z M 2013 Ukr. J. Phys. 58 No. 1
[7] Tran D T, An T T, Cuong P V, Khat N t, Vinh N T, Belov A G and Maslov 2011 J. Rad. Nucl. Chem. 289 637-645
[8] Nguyen V D, Pham D K, Kim T T and Tran D T 2007 J. Korean Phys. Soc. 50 417-425
[9] Elekta Digital Accelerator, Technical Training Guide, 2003.
[10] Boztosun I et al. 2013 Turk J. Phys 1-9
[11] Antcheva I et al. 2009 Comp. Phys. Comm. 180 2499-2512