Photonuclear reactions on stable isotopes of zirconium and tungsten at bremsstrahlung end-point energies of 10-23 MeV

1. Description of the project:

The study of photonuclear reactions is an important source of information on the structure and properties of atomic nuclei. When γ-rays interact with nuclei, a broad maximum known as giant dipole resonance (GDR), is observed in the photo-absorption cross section, which lies in the range of 8–40 MeV. The main decay channels of giant dipole resonance (GDR) are the emission of neutrons or protons. Currently, there is an extensive database of experimental data on photoneutron reactions found in the stable isotopes of natural mixtures of zirconium and tungsten. Nevertheless, the data is not yet complete nor is it properly explained. The proton channel, despite a small cross section of the (γ,p) reaction, is interesting with regards to isospin splitting of GDR.

2. Purpose of the project:

The aim of the project is to enable the students to gain practical experience in using the TALYS framework to calculate cross sections and to process experimental data obtained from the spectra of irradiated targets.

3. Short description of the practical work:

The experiments will be carried out using the MT-25 (Fig. 1*a*) microtron's output electron beam. The electron energies range from 10 to 23 MeV, with an energy step of 1 MeV. Once the radiation levels in the experimental hall are safe, the targets will be transferred to a different measurement room, and the induced activity of the irradiated target will then be measured. A high purity germanium (HPGe) γ-detector with a resolution of 16 keV at 1332 keV is used together with standard measurement electronics and a 16K ADC/MCA (Multiport II Multichannel Analyser, CANBERRA). (Fig. 1*b*). The spectra of each sample will be taken many times over intervals of 0.5, 1, 12, and 24 hours.

Figure 1. Microtron MT-25 (*a*) and HPGe spectrometer CANBERRA GC3018

The students will perform the following tasks:

3.1. Calculate cross section of the reactions. Compare simulation results with literature data.
3.2. Take part in the preparation of targets for irradiation, determine the element composition using the X-ray fluorescence analysis method.
3.3. Participate in measurements of irradiated targets.
3.4. Compute radioactive half-lives and select appropriate spectra for each isotope's activity. The activity will be typically measured using the highest intensity, well-separated, interference-free, and correctable γ-ray.
3.5. Calculate the yield of the reactions based on experimental measured spectra of the irradiated targets.

Form for presenting results:

Dependences of the yields of ^{nat}Zr(γ,p)^{90,91,93,95}Y and ^{nat}W(γ,p)^{182,183,185}Ta reactions on the bremsstrahlung end-point energy, shown in tables and figures.

4. Requirements

4.1. Basic knowledge of nuclear physics and radiochemistry.
4.2. Good knowledge of python programming.
4.3. Experience of using the Geant4 toolkit and TALYS framework is not necessary, but helpful.

5. References:

1. Geant4 home page: http://cern.ch/geant4

2. TALYS framework: https://nds.iaea.org/talys/

3. O.D. Maslov, S.N. Dmitriev, Use of MT-25 microtron for scientific and applied investigations, https://inis.iaea.org/collection/NCLCollectionStore/_Public/35/022/35022466.pdf

4. Rasulova F.A., Aksenov N.V., Alekseev S.I. et. al. Photonuclear reactions on the stable isotopes of selenium at bremsstrahlung end-point energies of 10-23 MeV // Chinese Physics C. – 2024. – Vol. 48. – № 2 – p. 024002.

5. Rasulova F.A., Aksenov N.V., Alekseev S.I., et. al. Photonuclear reactions on stable isotopes of molybdenum at bremsstrahlung end-point energies of 10-23 MeV // Phy. Rev. C – 2025. – Vol. 111. – p. 024604.

6. Rasulova F.A., Kuznetsov A.A., Khushvaktov J.H. et. al. Photonuclear reactions on stable isotopes of platinum at bremsstrahlung end-point energies of 10-23 MeV // Phy. Rev. C – 2025. – Vol. 112. – p. 054610.

6. The number of participating students is limited to 2.

7. Contacts of the project coordinator

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