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Calculation of the (p,n) Reaction Cross Section of Radionuclides Used for PET Applications

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Positron emission tomography is an imaging method which plays an important role in the diagnosis and monitoring of cancer cells using radioactive substances. In this study (p,n) reaction cross sections of some radionuclides (Cu-61, Ga-66, Br-76) were calculated using Talys 1.6 nuclear simulation code. The calculated cross-sections were compared with experimental values taken from EXFOR.

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1. Introduction

Radioisotopes release their energy by emitting gamma rays, which can be detected with modern equipment. There are many radionuclide substances which are suitable for use in diagnostics. A small part of them is used as the radiation source for therapeutic purposes.

Radioisotopes used in medical field are produced in accelerators or using nuclear reactors. In the production of artificial radioisotopes, the high energy particles of the incoming beam collide with the nuclei. Cross section of the reaction, is used to characterize the reduction of the incoming beam [1]. Cross-section plays an important role in the production of radioisotopes.

In recent years positron emission tomography (PET) imaging technique is widely used for diagnostic purposes in nuclear medicine in our country. This imaging technique is used for the early diagnosis of cancer diseases and is used in the heart-related studies. ^{18}F, ^{11}C, ^{13}N, ^{15}O positron-emitting radionuclides are produced for PET applications [2]. Nowadays however, other short-lived radionuclides such as ^{61}Cu, ^{66}Ga, ^{76}Br are under study. ^{61}Cu radioisotope is used in the PET imaging. ^{66}Ga is used in the PET imaging of biological processes in target tissues. ^{76}Br is used in DNA studies, in the studies of the nerves of the heart and in digital imaging.

After a radioactive decay process of the radionuclide, the resulting nucleus becomes stable. Meanwhile, a proton is transformed into two new particles, a positively charged positron and a neutron. Positron is thrown out from the nucleus. The advancing positron, after a short distance, collides with electrons of another atom. As a result, the energy of the destroyed mass is transformed into the energy of two gamma quanta of 511 keV, which propagate in opposite directions.

Radiation therapy is a form of cancer treatment that uses radiation to destroy malignant cells. For this purpose, ^{137}Cs is used in radiotherapy due to its appropriate physical half-live. Itx is produced during the fission the ^{235}U core. Cross sections of the (n,f) reaction have been calculated for ^{235}U in [3]. At the same time, some isotopes such as iodine are vital, especially in medical science and thus production of these isotopes is important. Cross sections of the ^{125}Te (p,xn) reaction, in which iodine can be produced, were calculated for the 5.5–100.5 MeV energy range using Talys code and compared with results obtained by ALICE/ASH code in [4].

2. Software and methods

In this study, cross-section σ values for the ^{61}Ni (p,n) ^{61}Cu, ^{66}Zn (p,n) ^{66}Ga and ^{76}Se (p,n) ^{76}Br reactions were calculated using Talys 1.6 [5] nuclear reaction simulation code.

Talys is a nuclear reaction simulation code for the analysis and prediction of nuclear reactions. Talys 1.6 program examines the interaction of protons, neutrons, deuteron, triton, gamma, alpha and 3He particles in the energy range of 1 keV–1 GeV with nuclei with mass of 12 or more. It is written in FORTRAN programming language and runs on Linux operation system.

3. Results and discussions

The calculated ^{61}Ni (p,n) ^{61}Cu, ^{66}Zn (p,n) ^{66}Ga and ^{76}Se (p,n) ^{76}Br production reaction cross sections are shown in Figs. 1–3. The obtained results have been compared with the experimental data existing in the EXFOR [6] database.

4. Conclusions

In this work production cross section values for the reactions of ^{61}Ni (p,n) ^{61}Cu, ^{66}Zn (p,n) ^{66}Ga and ^{76}Se (p,n) ^{76}Br were calculated in the energy range between 1 and 100 MeV. Our results are in fair agreement with experimental data available in the literature. The maximum cross section values are 427.307 mb at 9.5 MeV for

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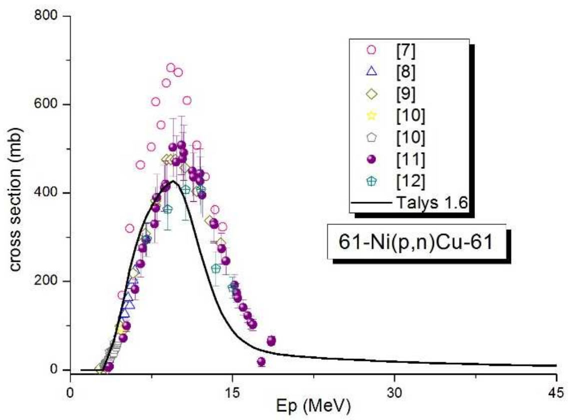

Fig. 1. The calculated cross sections of ^{61}Ni (p,n) ^{61}Cu reaction and comparison with experimental results.

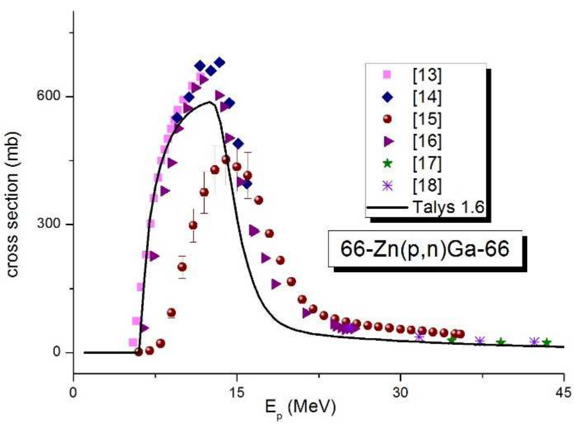

Fig. 2. The calculated cross sections of ^{66}Zn (p,n) ^{66}Ga reaction and comparison with experimental results.

^{61}Cu production, 587.871 mb at 12.5 MeV for ^{66}Ga and 767.445 mb at 13 MeV for ^{76}Br production. The most appropriate production range for ^{61}Ni (p,n) ^{61}Cu nuclear reaction is 7–11 MeV. The most appropriate production range for ^{66}Zn (p,n) ^{66}Ga nuclear reaction is 10–13 MeV.

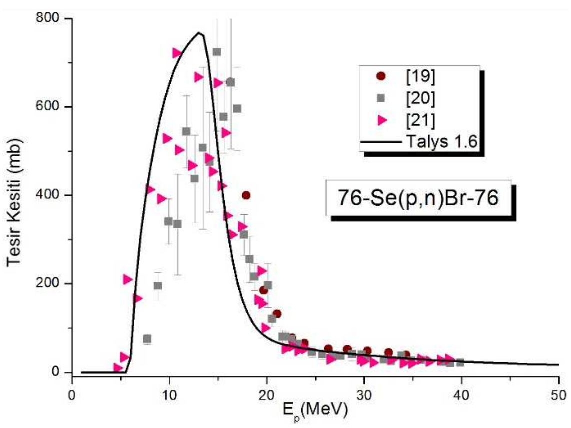

Fig. 3. The calculated cross sections of ^{76}Se (p,n) ^{76}Br reaction and comparison with experimental results.

The most appropriate production range for ^{76}Se (p,n) ^{76}Br nuclear reaction is 11–14 MeV.

Cross sections of reactions used in production of ^{61}Cu, ^{66}Ga and ^{76}Br isotopes were calculated. The calculated results were compared with the results of experimental data from the literature. It is seen from the figures that theoretical results calculated using the Talys 1.6 program are compatible with the experimental data from literature.

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