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STUDY OF THE RATES AND CROSS SECTIONS OF PHOTONUCLEAR REACTIONS IN $^{\mathrm{nat}}\mathrm{Ni}$ NUCLEI AT ENERGIES OF UP TO 20 MeV

To study photonuclear reactions, bremsstrahlung rays produced by electron accelerators are probably used the most . Intensity of such bremsstrahlung radiation is high enough to have a good statistical accuracy, but the energy spectrum is continuous, and, thus, the interpretation of results (i.e. obtaining the cross section for a particular photon energy) is model-dependent.
In our work, we conducted research to improve our knowledge of photonuclear reactions in stable isotopes of the element magnesium. The experiments were carried out at the LINAC-200 Linear Electron Accelerator [1]. A tungsten converter 4.5 x 4.5 x 0.5 cm was used to generate bremsstrahlung gamma rays. In this work, we used the accelerated electrons with an energy of 20 MeV. The sample are of natural nickel with sizes of 1.0 x 1.0 x 0.03 cm. For irradiation, it was placed behind the tungsten converter.
The irradiated nickel sample were transferred to the measurement room, and their gamma spectra were measured using the HPGe detector (CANBERRA). The gamma spectra obtained were processed using the DEIMOS32 program [2] , which fits the count area of the full-energy peaks with a Gaussian function. The areas of the peaks identified were determined by taking into account the background from the Compton scattering.
Currently, the Geant4 program [3] is the most widely used Monte Carlo radiative transport code for the study of photonuclear reactions. We compare the experimental results obtained in this study with the Geant4 prediction based on the Monte Carlo simulation (MC) for the flow of photons, electrons and neutrons in the samples. For photonuclear interactions in Geant4, the G4PhotoNuclearProcess Class [4] was used. Cross sections σ(E) of the photonuclear reactions studied were calculated with the TALYS-1.96 program [5].
The experimental yields 5.65(59)E-29 $atom^{-1}$ • $electron^{-1}$, 1.92(21)E-28 $atom^{-1}$ • $electron^{-1}$, 7.60(79)E-30 $atom^{-1}$ • $electron^{-1}$ of photoneutron ($^{58}\mathrm{Ni}(\gamma,n)^{57}\mathrm{Ni}$) and photoproton ($^{58}\mathrm{Ni}(\gamma,p)^{57}\mathrm{Co}$, $^{62}\mathrm{Ni}(\gamma,p)^{61}\mathrm{Co}$) reactions, in the $^{58}\mathrm{Ni}$, $^{62}\mathrm{Ni}$ nuclei per one 20-MeVelectron incident onto a tungsten converter and corresponding results of MC calculations 9.63E-29 $atom^{-1}$ • $electron^{-1}$, 2.01E-28 $atom^{-1}$ • $electron^{-1}$, 7.55E-30 $atom^{-1}$ • $electron^{-1}$, respectively.
The absolute yields of photonuclear reactions with bremsstrahlung beams in experiments with different geometries differ from each other due to the differencein fluxes of bremsstrahlung photons. In order to compare results of different experiments, it is necessary to assume that the shapes of the bremsstrahlung spectra in the compared experiments do not differ. The difference is observed only in the total number of photons. Thus, the experimental cross section per equivalent photon $_{\mathrm{q}}$ and the flux weighted average cross sections $< \ >$ were calculated. A quasi-monochromatization method [6] was used to determine the reaction cross section. In this method, the quasi-monochromatic photon spectrum for a particular energy can be obtained from the comparison of several calculated bremsstrahlung spectra with the end points near the energy. The cross sections from the TALYS software 20.23 mb ($^{58}\mathrm{Ni}(\gamma,n)^{57}\mathrm{Ni}$), 44.15 mb ($^{58}\mathrm{Ni}(\gamma,p)^{57}\mathrm{Co}$), 3.52 mb ($^{62}\mathrm{Ni}(\gamma,p)^{61}\mathrm{Co}$) and those determined from the experimental data by the quasi-monochromatization method 10.81 ± 2.52 mb, 31.89 ± 5.79 mb, 3.25 ± 0.49 mb for photoneutron and photoproton reactions, respectively.

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Section

Nuclear physics (Section 1)

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