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

Following the first observation of photodisintegrations of deuterium and beryllium with γ-rays emitted by naturally occurring radioactive elements far back in 1934 [1], experimental and theoretical investigations of photonuclear reactions have been progressing steadily thanks to many artificial sources of high-energy photons developed around the globe.
The experiments were carried out at the LINAC-200 Linear Electron Accelerator [2]. 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 iron with sizes of 1.3 x 0.4 x 0.05 cm. For irradiation, it was placed behind the tungsten converter.
Irradiation time for sample was 40 min, pulse current was 20 mA and pulse frequency and duration were 10 Hz and 2 μs, respectively. The irradiated iron sample were transferred to the measurement room, and their gamma spectra were measured using the HPGe detector. The gamma spectra obtained were processed using the DEIMOS32 program [3].
We compare the experimental results obtained in this study with the Geant4 [4] 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 [5] was used. Cross sections σ(E) of the photonuclear reactions studied were calculated with the TALYS-1.96 program [6].
From the analysis of the measured gamma spectra, we identified the photoneutron and photoproton reactions with the release of one neutron and proton from nuclei, inelastic scattering of photons in nuclei. The experimental yields 0.51(06)E-28 $atom^{-1}$ • $electron^{-1}$, 3.66(38)E-29 $atom^{-1}$ • $electron^{-1}$ of photoneutron ($^{54}\mathrm{Fe}(\gamma,n)^{53}\mathrm{Fe}$) and photoproton ($^{57}\mathrm{Fe}(\gamma,p)^{56}\mathrm{Mn}$) reactions in the $^{54}\mathrm{Fe}$, $^{57}\mathrm{Fe}$ nuclei per one 20-MeVelectron incident onto a tungsten converter and corresponding results of MC calculations 1.57E-28 $atom^{-1}$ • $electron^{-1}$, 3.63E-29 $atom^{-1}$ • $electron^{-1}$, respectively.
Normalization of the yield to the number of photons in the bremsstrahlung spectrum from the threshold of a particular reaction provides a more detailed consideration of the cross section behavior against the bremsstrahlung gamma energy. Because the flux weighted average cross sections $<\ >$ is insensitive to the low-energy partof the bremsstrahlung spectrum. For representing the experimental photonuclear reaction data, the experimental cross section per equivalent photon $_{\mathrm{q}}$ and the flux weighted average cross sections $<\ >$ were calculated. A quasi-monochromatization method [7] 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 29.11 mb ($^{54}\mathrm{Fe}(\gamma,n)^{53}\mathrm{Fe}$), 8.72 mb ($^{57}\mathrm{Fe}(\gamma,p)^{56}\mathrm{Mn}$) and those determined from the experimental data by the quasi-monochromatization method 9.57 ± 4.77 mb, 8.19 ± 1.23 mb, for photoneutron and photoproton reactions, respectively.

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Section

Nuclear physics (Section 1)

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