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Cross Sections Calculation of (γ,N) Reactions for Some Elements

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Photonuclear processes can play an important role in the detection of nuclear materials. For this purpose, in this study, the (γ,n) and (γ,p) cross sections as functions of photon energy in medium weight nuclei were calculated. Calculations have been made of the cross sections for some of the (γ,n) and (γ,p) reactions in ^{28}Si, ^{32}S, ^{56}Fe and ^{63}Cu nuclei using the TALYS 1.6 nuclear code with incident photons of 7–40 MeV. These calculated cross sections are compared with each other and with the earlier experimental results from the literature (EXFOR). Calculated results (^{56}Fe(γ,n), ^{63}Cu(γ,n), ^{56}Fe(γ,p) and ^{63}Cu(γ,p) cross sections) are in very good agreement with the experimental data. However, because of the Coulomb barrier, the photoproton cross sections for ^{32}S, ^{56}Fe and ^{63}Cu target nuclei, are smaller than the photoneutron cross sections.

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1. Introduction

The usage of high energy gamma-quanta as projectiles in nuclear reactions has some essential advantages for studying of nuclear structure and nuclear reactions mechanisms. As a rule, characteristics of photonuclear reactions are well studied in the energy region of giant dipole resonance (GDR) [1]. Photonuclear processes can play an important role in the detection of nuclear materials. However, at intermediate energies, the (γ,N) reaction (N = p, n) provides a very significant information about nuclear structure.

Despite the years of investigation, the nuclear structure is still an open question and the study of nuclear reactions, which has been complicated by the appearance of many nuclear models, is still important to investigate [2, 3]. In the energy region of giant dipole resonances (E = 10−30 MeV), the absorption process is dominated by the electric dipole excitations. The giant dipole resonance (GDR) has been of significant interest in studies of nuclear structure and nuclear reactions [4]. The photon interaction with the nucleus is weak and it is more evident at high energies. However, the interaction with the nucleus of photons, that have an intermediate level of interaction energy, is not yet clearly understood. For this reason, a wide range (γ,N (N = n, p, α, d,. . .)) of reaction studies are performed [5].

2. Theoretical models and results

TALYS is a computer code system for the simulation, analysis and prediction of nuclear reactions. The basic objective behind its construction is the simulation of nuclear reactions that involve neutrons, photons, protons, deuterons, tritons, 3He and alpha particles. TALYS integrates the optical model, direct, preequilibrium, fission and statistical nuclear reaction models in one calculation scheme and gives a prediction for all the open reaction channels. The preequilibrium reactions are considered using the two-component exciton model. In TALYS, the two-component exciton model of Kalbach is used as the preequilibrium model.

Pre-equilibrium nuclear reaction models have been used in presented calculations. Theoretical cross section calculations are based on theoretical nuclear reaction models. For this purpose, two component exciton and preequilibrium models of TALYS 1.6 [6] have been used to calculate photoneutron cross sections.

2.1. Cross sections

The calculated (γ,n) and (γ,p) reaction cross sections for ^{28}Si, ^{32}S, ^{56}Fe and ^{63}Cu targets are shown in Figs. 1–8. The obtained results have been compared with the experimental data existing in the EXFOR [7] databases.

3. Conclusions

It can be concluded from this work that the giant dipole resonance (GDR) effect occurs at photon energies in the range of about 10–35 MeV. This was also shown by other researchers [8, 9]. It can be seen from the figures, that the calculated results are in good agreement with the experimental data. Especially, it is true for the ^{56}Fe(γ,n), ^{63}Cu(γ,n), ^{56}Fe(γ,p) and ^{63}Cu(γ,p) cross sections (see Figs. 5–12).

It is known that, (γ,n) and (γ,p) cross sections are of the similar magnitude in light nuclei. However, this study shows that the calculated cross sections for the ^{28}Si(γ,n),

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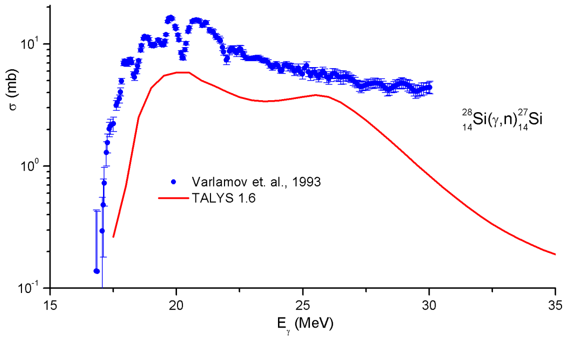

Fig. 1. The cross section for ^{28}Si(γ,n) reaction.

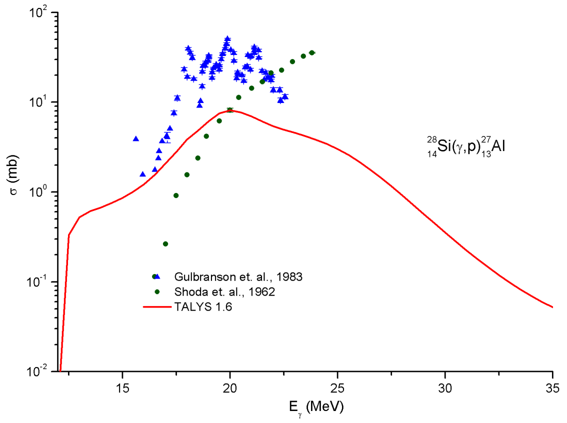

Fig. 2. The cross section for ^{28}Si(γ,p) reaction.

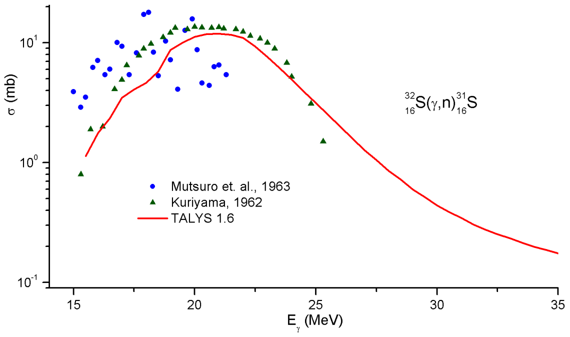

Fig. 3. The cross section for ^{32}S(γ,n) reaction.

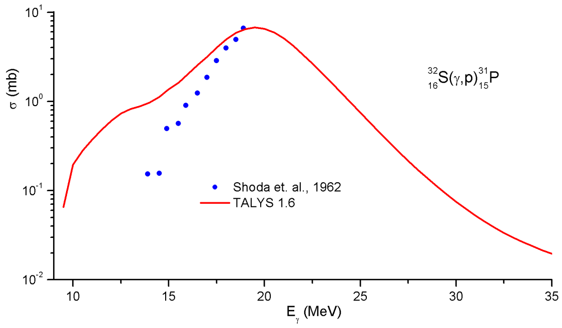

Fig. 4. The cross section for ^{32}S(γ,p) reaction.

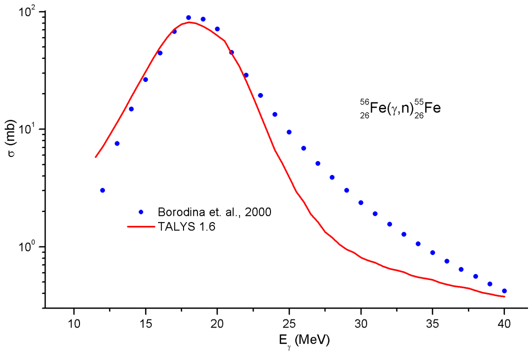

Fig. 5. The cross section for ^{56}Fe(γ,n) reaction.

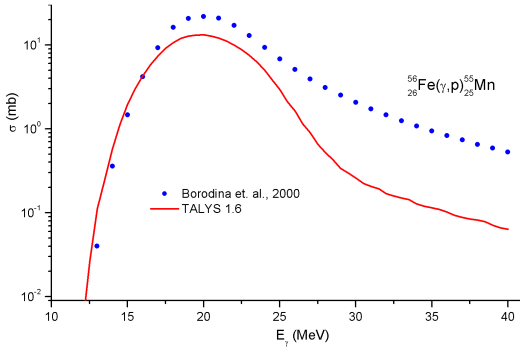

Fig. 6. The cross section for ^{56}Fe(γ,p) reaction.

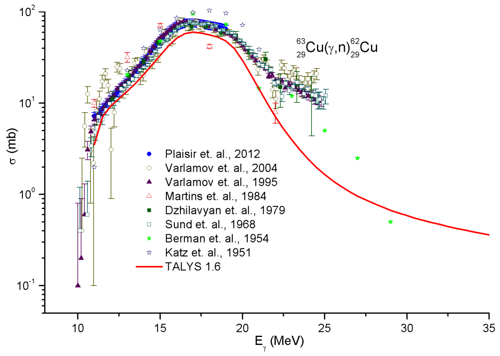

Fig. 7. The cross section for ^{63}Cu(γ,n) reaction.

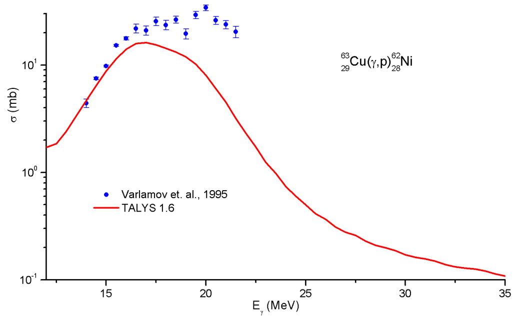

Fig. 8. The cross section for ^{63}Cu(γ,p) reaction.

^{32}S(γ,n), ^{56}Fe(γ,n), ^{63}Cu(γ,n) and ^{28}Si(γ,p),^{32}S(γ,p), ^{56}Fe(γ,p), ^{63}Cu(γ,p) reactions, when compared, are not of a similar magnitude. In general, because of the Coulomb barrier, the photoproton cross sections for the considered target nuclei, with the exception of ^{28}Si, (^{32}S, ^{56}Fe and ^{63}Cu), are smaller than the photoneutron cross sections. This can be seen in Figs. 1–8, and can be explained by the diversity, related to the isospin splitting of the GDR.

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