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Cross-Section Calculations of (γ,xn) and (p,xn) Reactions for ^{197}Au

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Abstract: In this study, cross–sections of (γ,n), (γ,2n), (γ,3n) and (p,xn) reactions for ^{197}Au have been calculated. The main aim of this study is to investigate the pre–equilibrium and equilibrium effects on ^{197}Au. While the Weisskopf–Ewing and equilibrium models have been used for the equilibrium process in the calculations, the hybrid, geometry dependent hybrid and two component exciton nuclear reaction models have been used for the pre–equilibrium process. For this purpose, the TALYS 1.6, EMPIRE 3.2 and ALICE/ASH codes have been used. The calculated results have been discussed and compared with the experimental data.

Keywords: ^{197}Au, Cross Section, TALYS 1.6, EMPIRE 3.2.

^{197}Au için (γ,xn) ve (p,xn) Reksiyonlarının Tesir Kesiti Hesaplamaları

Özet: Bu çalışmada, ^{197}Au için (γ,n), (γ,2n), (γ,3n) ve (p,xn) reaksiyonlarının tesir kesitleri hesaplanmıştır. Bu çalışmanın ana amacı, ^{197}Au üzerindeki denge öncesi ve denge etkilerinin incelenmesidir. Denge hesaplamaları için Weisskopf-Ewing ve denge modelleri kullanılırken, denge öncesi hesaplamaları için hibrid, geometri bağımlı hibrit ve iki bileşenli eksiton model kullanılmıştır. Bu amaçla, TALYS 1.6, EMPIRE 3.2 ve ALICE/ASH kodları kullanılmıştır. Hesaplanan değerler, teorik veriler ile kıyaslanmıştır.

Anahtar kelimeler: ^{197}Au, Tesir Kesiti, TALYS 1.6, EMPIRE 3.2.

1. INTRODUCTION

Recently, many experimental techniques have been developed to obtain and detect neutrons and charged particles of different energies and to measure the cross–sections of the different particle–induced reactions [1]. Therefore, the neutron and proton induced nuclear reaction cross–section data are very important for several technical applications. For instance, the method of energy measurements by means of velocity determination is a widely used technique and known as time of flight (TOF) [2]. There are several new technological applications on the fields of fast neutrons such as accelerator-driven incineration/transmutation of the long-lived radioactive nuclear wastes in to short-lived or stable isotopes [3-5].

As well, there can be found several biomedical applications i.e., production of radioisotopes and cancer therapy. Especially, neutron scattering cross sections and emission differential data have a critical importance on fusion reactor neutronics. These data can be extensively used for the investigation of the structural materials of the fusion reactors, radiation damage of metals and alloys, tritium breeding ratio, neutron multiplication and nuclear heating in the components, neutron spectrum, and reaction rate in the blanket and neutron dosimetry. Therefore, many experiments have been carried out to obtain and detect neutrons for different energy ranges.

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2. CALCULATION METHODS

The pre-equilibrium calculations on the excitation functions were carried out with, ALICE/ASH code [7] for hybrid model and the geometry dependent hybrid model, TALYS 1.6 code [8] for two-component exciton model and EMPIRE 3.2 code [9] for exciton model. And also the reaction equilibrium component in ALICE/ASH computer code are done traditional compound nucleus model of Weisskopf and Ewing [10].

The ALICE/ASH code is an advanced and modified version of the ALICE-91 code [11]. The ALICE/ASH code can be applied for the calculation of excitation functions, energy and angular distribution of secondary particles in nuclear reactions induced by nucleons and nuclei up to an energy range of 300 MeV. The generalized superfluid nuclear model [12] has been applied for nuclear level density calculations in the ALICE/ASH code. Model parameters were taken from ref. [13]. We used the initial exciton number as no = 3 (1 proton, 1 neutron and 1 hole). A detailed description of the ALICE/ASH code can be found in ref. [8].

In the Two–Component Exciton model, which is the default model for TALYS reaction cross section computations, the particles and holes are followed throughout the reaction. The notation for the following equation gives the numbers of particles –which could be proton or neutron – and holes as $p_\pi(p_\nu)$ and $h_\pi(h_\nu)$, respectively. From this, the proton exciton number is defined as $n_\pi = p_\pi + h_\pi$ and the neutron exciton number as $n_\nu = p_\nu + h_\nu$ which give us to construct the charge independent particle number as $= p_\pi + p_\nu$, the hole number as $h = h_\pi + h_\nu$ and the exciton number as $n = n_\pi + n_\nu$.

3. RESULTS and DISCUSSION

In this study, cross–sections of (γ,n), (γ,2n), (γ,3n) and (p,xn) reactions for ^{197}Au have been calculated. The main aim of this study is to investigate the pre–equilibrium and equilibrium effects on ^{197}Au. While the Weisskopf–Ewing and equilibrium models have been used for the equilibrium process in the calculations, the hybrid, geometry dependent hybrid and two component exciton nuclear reaction models have been used for the pre–equilibrium process. For this purpose, the TALYS 1.6, EMPIRE 3.2 and ALICE/ASH codes have been used

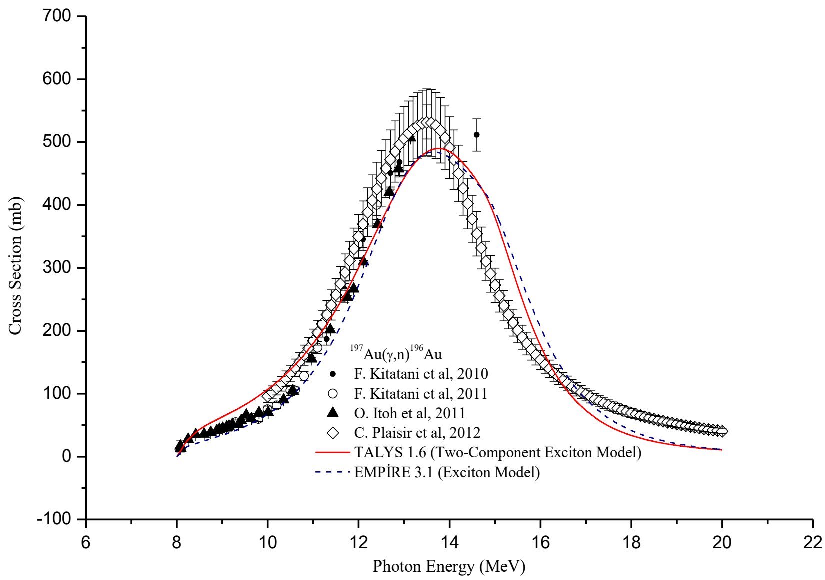

Figure 1. The $^{197}Au(\gamma,n)^{196}Au$ reaction computation with EXFOR experimental data.

The calculated production cross–sections of $^{197}Au(\gamma,n)^{196}Au$ reaction have been compared with the experimental measurements in Fig. 1. All model results display similar structure with the experimental data up to 14 MeV photon energy.

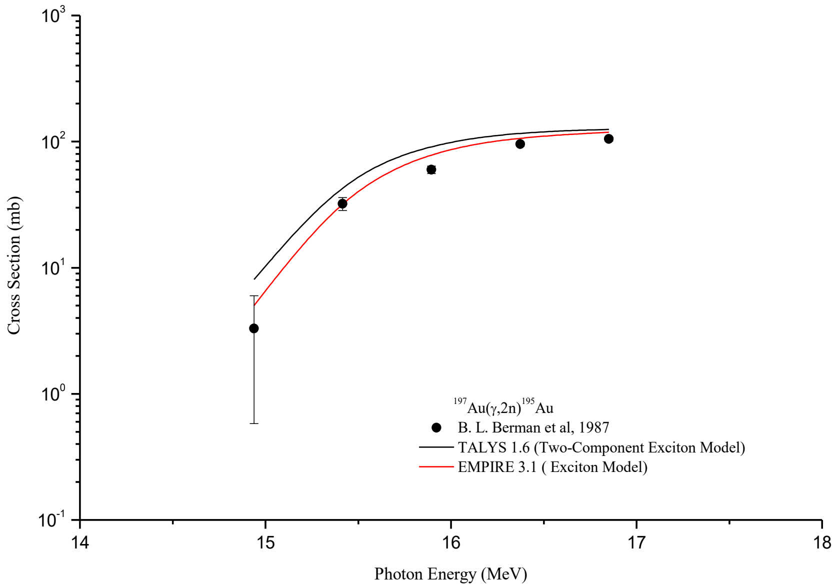

Figure 2. The $^{197}Au(\gamma,2n)^{195}Au$ reaction computation with EXFOR experimental data.

$^{197}Au(\gamma,2n)^{195}Au$ reaction cross–section results have been given in Fig. 3. TALYS 1.6 and EMPIRE 3. calculations show an agreement between each other and experimental data.

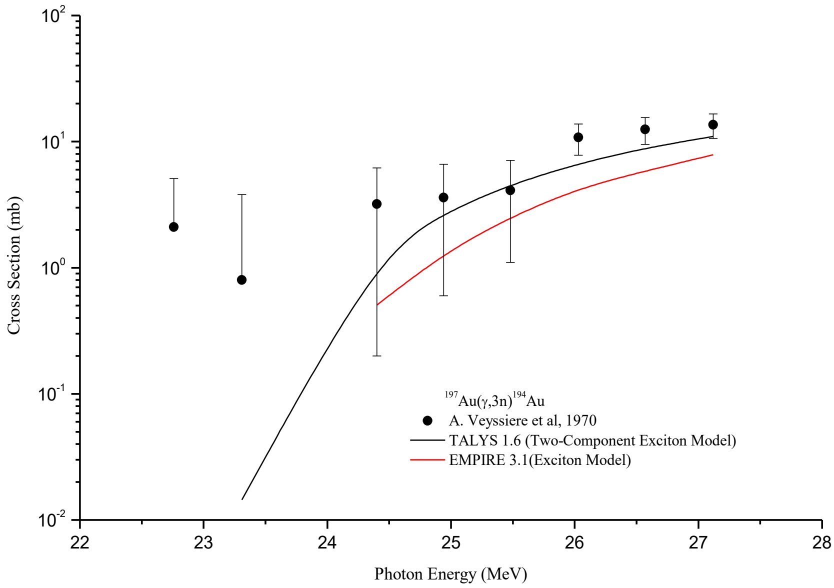

Figure 3. The ^{197}Au(γ,3n)^{194}Au reaction computation with EXFOR experimental data.

In Fig. 3, the cross–section results of ^{197}Au(γ,3n)^{194}Au have been given. TALYS 1.6 results show best agreement with experimental data. Both calculation results give similar structure with EXFOR data after 24 MeV photon energy.

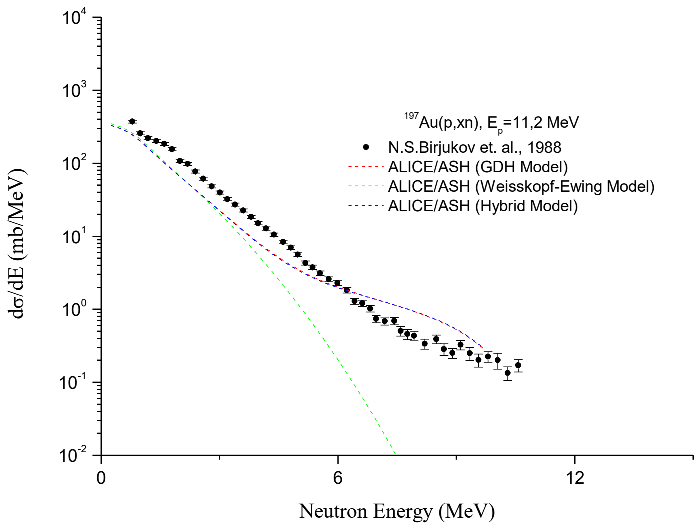

Figure 4. The comparison of neutron emission spectra of ^{197}Au(p,xn) reaction with the values reported in literature at 11.2 MeV incident proton energy.

In Fig. 4, the neutron energy spectrum of results of ^{197}Au(p,xn) have been given. GDH and Hybrid Model calculation results have good harmony with EXFOR data. However, the Weisskopf-Ewing Model calculations display similar structure with experimental data up to 4 MeV neutron energy.

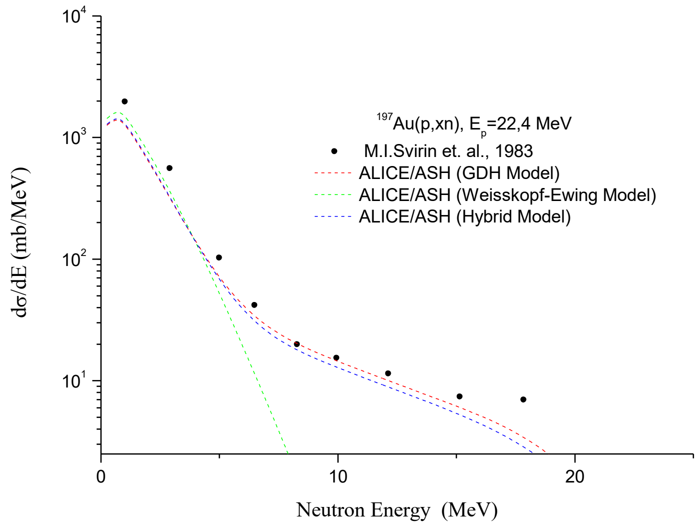

Figure 5. The comparison of neutron emission spectra of ^{197}Au(p,xn) reaction with the values reported in literature at 22.4 MeV incident proton energy.

In Fig. 5, GDH and Hybrid Model calculation results have good harmony with EXFOR data. However, the Weisskopf-Ewing Model calculations display similar structure with experimental data up to 6 MeV neutron energy.

4. SUMMARY AND CONCLUSIONS

For the investigation of the equilibrium and pre-equilibrium effects on ^{197}Au, (γ,n), (γ,2n), (γ,3n) and (p,xn) reactions have been investigated in this study. The obtained results have been compared with the exist experimental values in the literature.

Generally the calculated cross sections with two-component exciton model by using TALYS 1.6 code shows the best agreement with the experimental data. Hybrid and GDH model calculations are in good harmony with experimental data for neutron energy spectrum in Figs. 4,5.

As a consequence two-component exciton model can be chosen if the experimental data are unavailable or are improbably to be produced because of experimental problems for photo-neutron cross section studies.

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