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Zr, I, Pr, Au and Pb Photoneutron Reaction Cross Sections

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Abstract: : In this work, Zr, I, Pr, Au and Pb photoneutron reaction cross sections were calculated by using TALYS 1.6 computer code near the peak of the giant dipole resonance. The calculated results were compared with the measured values available in the literature. Similarities and discrepancies among previous studies were discussed.

***Key words**:* Cross section, photoneutron, giant dipole resonance

Zr, I, Pr, Au ve Pb Fotonötron Reaksiyon Tesir Kesitleri

Özet: Bu çalışmada Zr, I, Pr, Au ve Pb fotonötron reaksiyon tesir kesitleri TALYS 1.6 bilgisayar kodu kullanılarak büyük dipol rezonans piki yakınlarında hesaplandı. Heaplama sonuçları literatürde olan deneysel verilerle karşılaştırıldı. Daha önceki çalışmalarda olan benzerlik ve farklılıklar vurgulandı.

Anahtar kelimeler: Tesir kesiti, fotonötron, büyük dipol rezonans

1. Indroduction

The photoneutron reaction cross sections are essential for various applications such as; Shielding, Monitoring, Medical-processes, Astrophysics [1]. Therefore several measurments were done and made available in open literature. However there is still need for more precise measurements and theoretical calculations near Giant Dipole Resonance(GDR).

In this study the cross section measurements available in the literature obtained from EXFOR [2] were compared with the cross sections calculations done by using TALYS 1.6 Monte Carlo particle transportation computer code [3] in the range of 0-30 MeV. Similarities and discrepancies between experimental and calculated data were discussed.

2. Material and Method

The photoneutron reaction cross sections were calculated by using TALYS 1.6 code [3]. TALYS is a powerfull simulation code using FORTRAN complier and is capable of simulating nuclear reactions with default physical models as well as specific options that can be assigned by user to address the physics of the reaction such as gamma strength functions, preequilibrium, optical model parameters, fission parameters and level density parameters.

Gamma-ray transmission coefficients are important for the description of the gamma emission channel in nuclear reactions. Gamma rays, in general, may accompany emission of any other emitted particle. Like the particle transmission coefficients that emerge from the optical model, gamma-ray transmission coefficients enter the Hauser-

Feshbach model for the calculation of the competition of photons with other particles [3]. The gamma-ray transmission coefficient for multipolarity ℓ of type X (where X = M or E) is given by

$$T_{xl}\left(E_{\gamma}\right)=2\pi f_{xl}\left(E_{\gamma}\right)E_{\gamma}^{2l+1} \tag{1}$$

where E_{γ} denotes the gamma energy and $f_{X\ell}(E_{\gamma})$ is the energy-dependent gamma-ray strength function [15]. TALYS has 4 models for the gamma-ray strength function. The first is the so-called Brink-Axel option, in which a standard Lorentzian form describes the giant dipole resonance shape [4]. At present, we use the Brink-Axel option for all transition types other than E_1. For E_1 radiation, the default option used in TALYS is the generalized Lorentzian form of Kopecky and Uhl [5]

$$f_{E1}\left(E_{\gamma},T\right)=K_{E1}\left[\frac{E_{\gamma}\tilde{\Gamma}_{E1}\left(E_{\gamma}\right)}{\left(E_{\gamma}^{2}-E_{E1}^{2}\right)^{2}+E_{\gamma}^{2}\tilde{\Gamma}_{E1}\left(E_{\gamma}\right)^{2}}+\frac{0.7\tilde{\Gamma}_{E1}4\pi^{2}T^{2}}{E_{E1}^{3}}\right]\sigma_{E1}\tilde{\Gamma}_{E1} \tag{2}$$

where the energy-dependent damping width $\tilde{\Gamma}(E_{\gamma})$ is given by

$$\tilde{\Gamma}_{E1}\left(E_{\gamma}\right)=\Gamma_{E1}\frac{E_{\gamma}^{2}+4\pi^{2}T^{2}}{E_{E1}^{2}} \tag{3}$$

and T is the nuclear temperature given by

$$T=\sqrt{\frac{E_{n}+S_{n}-\Delta-E_{\gamma}}{a\left(S_{n}\right)}} \tag{4}$$

where S_n is the neutron separation energy, E_n the incident neutron energy, Δ the pairing correction and a the level density parameter at S_n.

Certain nuclides have a split GDR, i.e. a second set of Lorentzian parameters. For these cases, the incoherent sum of two strength functions is taken. For all transitions other than E_1, systematic formulae compiled by Kopecky [5], for the resonance parameters are used. For E_1 transitions for which no tabulated data exist, TALYS [3] use

$$\sigma_{E1}=1.2\times120\frac{NZ}{\left(A\pi\Gamma_{E1}\right)}mb,\; E_{E1}=31.2A^{-1/3}+20.6A^{-1/6}MeV,\; \Gamma_{E1}=0.026E_{E1}^{1.91}MeV \tag{5}$$

For E_2 transitions

$$\sigma_{E2}=0.00014Z^{2}\frac{E_{E2}}{\left(A^{1/3}\Gamma_{E2}\right)}mb,\; E_{E2}=63\cdot A^{-1/3}MeV,\; \Gamma_{E2}=6.11-0.012A \tag{6}$$

For multipole radiation higher than E_2

$$\sigma_{El} = 8.10^{-4}\sigma_{E(l-1)} \; , \; E_{El} = E_{E(l-1)} \; , \; \Gamma_{El} = \Gamma_{E(l-1)} \tag{7}$$

For M_1 transitions

$$f_{M1} = 1.58A^{0.47} \; , \; E_{M1} = 41.A^{-1/3}MeV \; , \; \Gamma_{M1} = 4MeV \tag{8}$$

For multipole radiation higher than

$$M_1 \sigma_{Ml} = 8.10^{-4}\sigma_{M(l-1)} \; , \; E_{Ml} = E_{M(l-1)} \; , \; \Gamma_{Ml} = \Gamma_{M(l-1)} \tag{9}$$

3. Results and Discussion

The comparison between calculated cross sections and the experimental data is shown in figures below.

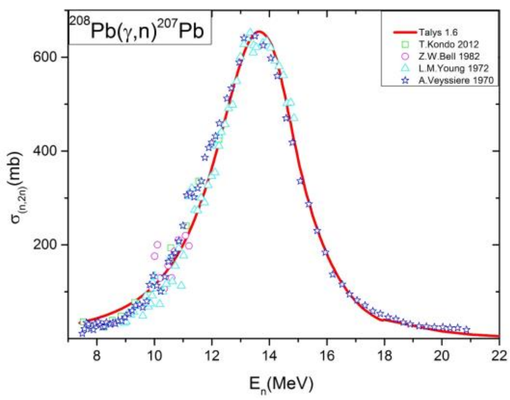

Figure 1. Comparison of the calculated Talys 1.6 ^{208}Pb(γ,n) ^{207}Pb reaction cross section data with the Refs. [6,7,8,9]

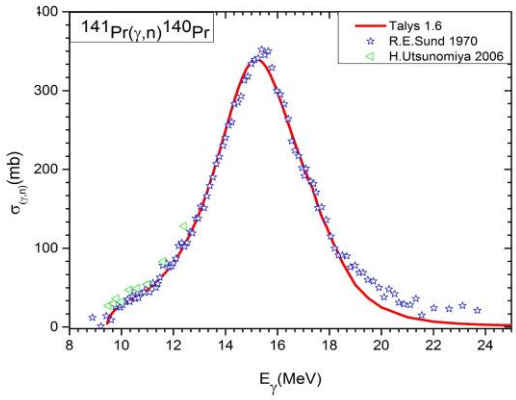

Figure 3. Comparison of the calculated Talys 1.6 ^{141}Pr(γ,n) ^{140}Pr reaction cross section data with the Refs. [12,13]

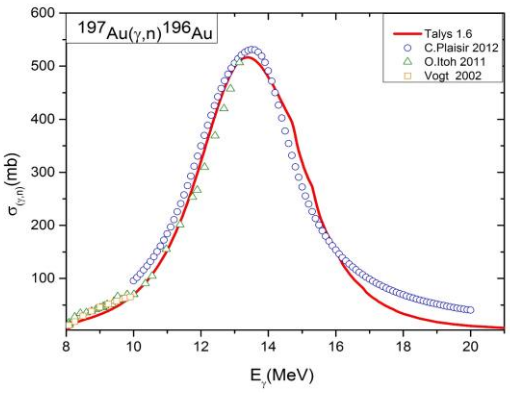

Figure 2. Comparison of the calculated Talys 1.6 ^{197}Au(γ,n) ^{196}Au reaction cross section data with the Refs. [10,11,1,]

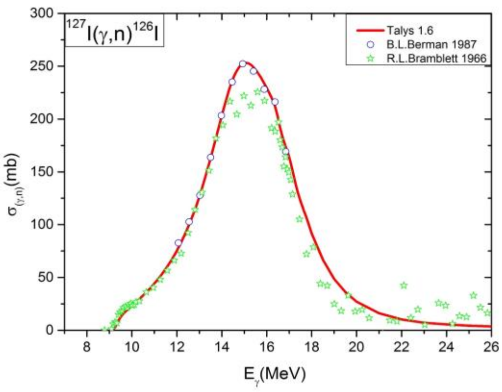

Figure 4. Comparison of the calculated Talys 1.6 ^{127}I(γ,n) ^{126}I reaction cross section data with the Refs. [14,15]

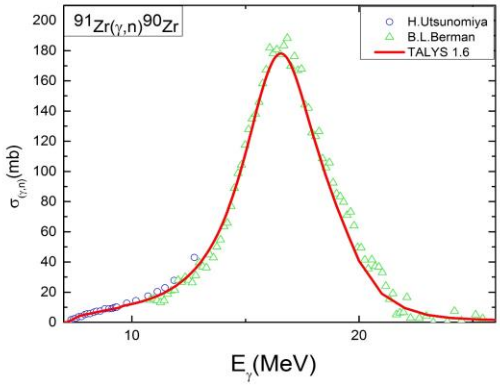

Figure 5. Comparison of the calculated Talys 1.6 $^{91}Zr(\gamma,n)^{90}Zr$ reaction cross section data with the Refs. [16,17]

These calculations were done using TALYS 1.6 [3] with gamma strentgh function models 1-2 (Kopecky-Uhl generalized Lorentzian, Brink-Axel Lorentzian) [4-5]. The calculated cross sections have been compared with the experimental data obtained from EXFOR [2].

4. Conclusions

The calculated $^{208}Pb(\gamma,n)^{207}Pb$ reaction cross sections were compared with the experimental data measured by A. Veyssiere *et al.* [6], T. Kondo *et al.* [7], Z. W. Bell *et al.* [8], L. M. Young *et al* [9]. Present calculation is in good agreement with experimental data. More specifically in GDR region the agreement is excellent. (see Fig.1) The calculated $^{197}Au(\gamma,n)^{196}Au$ reaction cross sections were compared with the experimental data measured by C. Plaisir *et al.* [10], O. Itoh *et al.* [11], K.Vogt *et al.* [1] and the curves show good agreement generally, however after 15 MeV we believe there is $(\gamma,2n)$ cross section effect present in the experimental data. (see Fig.2) The calculated $^{141}Pr(\gamma,n)^{140}Pr$ reaction cross sections were compared with the experimental data measured by R. E. Sund *et al.* [12] and H. Utsunomiya *et al.* [13] Both experimental data shows excellent agreement throughout 8-18 MeV region, including GDR region, with the calculated cross sections. Our calculations show $(\gamma,2n)$ threshold starts at 17.4 MeV (E_{thr}=17.4 MeV). (see Fig.3) The calculated $^{127}I(\gamma,n)$ ^{126}I reaction cross sections were compared with the experimental data measured by B. L. Berman *et al.* [14] and R. L. Bramblett *et al.* [15]. While our calculations are in excellent agreement with B.L. Berman *et al.* [14] especially around GDR region, there are big gaps between R. L Bramblett *et al.* [15] and our curve in GDR region. (see Fig.4) The calculated $^{91}Zr(\gamma,n)$ ^{90}Zr reaction cross sections were calculated with the experimental data measured by H.Utsunomiya et al. [13] and B. L. Berman *et al.* [14]. Our calculations show very small differences around peak. (see Fig.5)

All calculated results are in good agreement with the experimental measurements data obtained from EXFOR [2]. One way concludes that TALYS 1.6 [3] can provide reliable data where experimental data is absent.

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