Neutron Photoproduction in ^{232}Th and ^{238}U Nuclei

ODAIR LELIS GONÇALEZ
Instituto de Estudos Avançados/CTA - São José dos Campos, SP - C. Postal 6044, CEP 12231-970
FERMIN GARCIA VELASCO, JOEL MESA HORMAZA, J. D. T. ARRUDA-NETO
Instituto de Física da Universidade de São Paulo, São Paulo, SP - Caixa Postal 66318 - CEP 05315-970
LUIZ PAULO GERALDO, RENATO SEMMLER
Instituto de Pesquisas Energéticas e Nucleares, São Paulo, SP - Caixa Postal 11049 - CEP 05422-970

Measurements of neutron photoproduction cross sections for ^{232}Th and ^{238}U at 30 discrete values of excitation energies, within the interval from 5607.75 to 10829.18 KeV, were recently carried out[1], using gamma rays with high resolution in energy (5 to 20 eV), produced by thermal neutron capture in an experimental arrangement at the IPEN-IEA-R1 2 MW research reactor. In this energy interval, the neutron photoproduction cross section $\sigma_{\gamma,N}(E)$ is expressed by: $\sigma_{\gamma,N}(E) = \sigma_{g,n}(E) + \nu(E)\sigma_{\gamma,f}(E)$ where $\sigma_{\gamma,n}(E)$ is the photoneutron emission cross section, $\nu(E)$ is the average number of prompt neutrons per fission, $\sigma_{\gamma,f}(E)$ is the photofission cross section and E is the excitation energy.

The neutron photoproduction cross sections at the main gamma line energies were determined after appropriately unfolding [2] the set of experimental results obtained with the gamma ray spectra produced by the 30 capture targets. The experimental data obtained for ^{232}Th and ^{238}U are shown in Figures 1 and 2 respectively, together with the smooth curves fitted to the results reported by Caldwell [3] and Dickey[4].

In the present work it was performed an statistical calculation for the neutron photoproduction cross section using the expression:

$$\sigma_{\gamma,N}(E) = \sigma_a(E)\left[\frac{\Gamma_n(E)}{\Gamma_\gamma(E)+\Gamma_f(E)+\Gamma_n(E)} + \nu(E)\frac{\Gamma_f(E)}{\Gamma_\gamma(E)+\Gamma_f(E)+\Gamma_n(E)}\right] \quad (1)$$

where

$\sigma_a(E)$ is the photoabsorption cross section from the giant dipole resonance (GRD)[3], $\nu(E)$ is the photofission prompt neutron multiplicity[5] and $\Gamma_i(E)$ is the partial width for gamma scattering ($i = \gamma$), fission ($i = f$) and neutron emission ($i = n$). The partial widths have been calculated by means of a modified version of the STAPRE[6] code, which was adapted for photonuclear reactions. The level densities at the equilibrium state and at the saddle points deformations were calculated through a combined semi-microscopic method [7,8]. The nuclear deformation parameters used in the calculation of the quasi-particle states in a deformed potential are presented in Table I. For the transmission coefficients calculation, the level densities have been integrated within energy intervals of 250 KeV and 150 KeV for the ^{232}Th and ^{238}U targets respectively, as a means to simulate the energy resolution of the experiments of Caldwell[3] (250 KeV) and Dickey[4] (100-400 KeV). The parameters of the double-humped fission barriers (three parabola smoothly joined) used for the fission width calculation were:

a) For ^{232}Th : E_I = 5.8 MeV; $\hbar w_I$= 1.04 MeV; E_{II} = 6.2 MeV and $\hbar w_{II}$= 0.60 MeV.

b) For ^{238}U : E_I = 5.9 MeV; $\hbar w_I$= 1.18 MeV; E_{II} = 6.1 MeV and $\hbar w_{II}$= 0.63 MeV.

Table I Nuclear Deformation Parameters

Nuclide	Equilibrium State		First Saddle Point		Second Saddle Point		
	ε	α_4	ε	α_4	ε	α_3	α_4
^{238}U	0.23	0.06	0.38	-0.07	0.70	0.11	0.03
^{237}U	0.23	0.06					
^{232}Th	0.22	0.07	0.44	-0.03	0.71	0.11	0.04
^{231}Th	0.21	0.07					

All parameter calculations were based on a microscopic description of the nuclear structure, except for $\sigma_a(E)$ and $\nu(E)$ which were taken from the literature. The results obtained in the present work are compared with the experimental data in Figures 1 and 2. As can be seen, the theoretical data are in reasonable agreement with the experimental measurements performed with gamma ray sources of gross energy resolution [3,4] . For gamma source of high energy resolution (capture gamma rays) they represent approximately an average trend of the experimental data points.

References:

1) O. L. Gonçalez et al., Nucl. Sci. Eng. (submited to publication on Apr 30, 1998)

2) O. L. Gonçalez, PhD Thesis, Instituto de Pesq. Energéticas e Nucleares, USP, S.Paulo (1998)
3) J. T. Caldwell et al., Phys.Ver..,C21,1215-1231(1980)
4) P. A. Dickey and P. Axel, Phys. Ver.,35,501-503(1975)
5) J. T. Caldwell et al., Nucl. Sci. Eng.,73,153-163(1980)
6) M. Uhl, B. Strohmaier: Report IRK-76/01, IRK Vienna (1976)
7) F.Garcia et al., J.Phys.G: Nucl. Part. Phys.19,2157-2166(1993)
8) F. Garcia et al., Computer Physics Communications, 86, 129-146(1995).

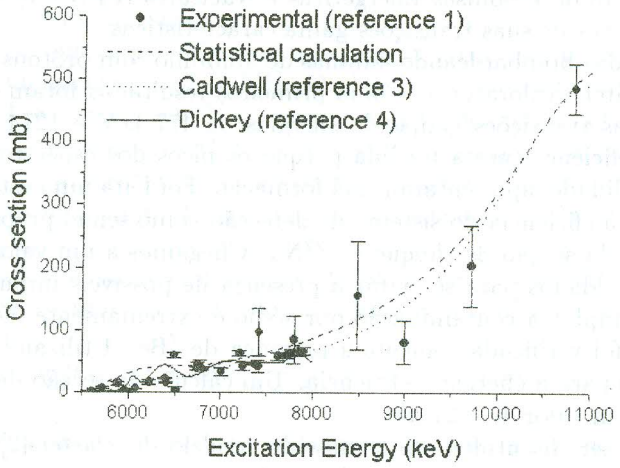

Figure 1 : Neutron Photoproduction Cross section for ^{232}Th

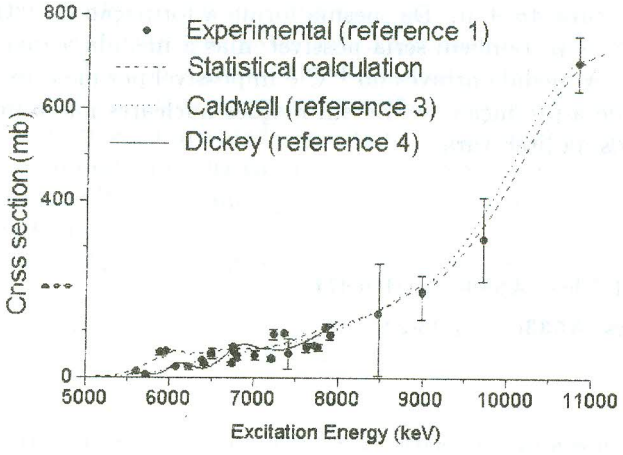

Figure 2 : Neutron Photoproduction Cross Section for ^{238}U.