Study of Neutron of Photon induced nuclear reactions

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Introduction

The neutrons and the photons are the main radiations present in any reactor. They can open various reaction channels depending on their energy. The major reactions for neutrons are (n, γ), (n, p), (n, 2n), whereas for photons (γ, n), (γ, 2n), (γ, p), etc. The studies of these reactions for different materials are necessary for the fission and fusion reactors. The generations of highly reliable data are important for the updating of nuclear data libraries as well as the validation of the nuclear reaction models.

The present thesis work considers both the particle and radiation (n and γ) for the study of nuclear reactions. The energy region is selected for both the particles in context of nuclear reactor applications. The theoretical empirical formula development, codes for calculation and experimental measurements were done in the present thesis work. The brief idea of each of the work is as given below.

Study of neutron induced nuclear reactions

In this work, the three neutron sources were used for the measurements of nuclear reaction cross sections, namely, ^{252}Cf(sf), Li(p, n) and DT. The structural materials W, Gd, As, Zn, Mn, Ni, and V were taken for the irradiation. The activated samples were kept in front of the HPGe detector in order to measure the gamma activity by off-line spectrometry. The peak counts of the selected gamma were taken for the analysis. The measured data were analyzed using standard neutron activation analysis technique (NAA). The tailing correction was done for removing the contributions from the low energy neutrons in the reaction products. Further, the Monte Carlo based MCNP code was used for the calculation of different correction factors, such as self shielding and back scattering effect in volume sample for efficiency correction of the detector used. A well known method to use a neutron spectrum for the measurement of reaction cross section at average neutron energy was studied and utilized in the present work. The nuclear reactions for which the cross sections were measured at the different neutron energies are given in Table 1. The measured experimental results were supported with the evaluated data using nuclear modular codes: TALYS and EMPIRE. The published work can be found in the literature [1-3].

Photon induced nuclear reactions

In the present thesis, a new empirical formula has been developed to explain the GDR mechanism for the production of photo neutrons. Above the binding energy of a nucleus (6 - 7 MeV) the photonuclear reaction take places. There are basically three mechanism by which a photon can interact with a nuclei in context of photonuclear reactions: (1) from 6 - 30 MeV GDR mechanism, (2) 30 - 140 MeV Quasi - deuteron (QD) and (3) above 140 MeV Intra nuclear cascade mechanism takes place [4]. A photon with energy greater than nuclear binding energy can open reaction channels, (γ, p), (γ, n), (γ, 2n) etc.

The photo nuclear reactions are important in the case of a tokamak/fusion reactor when the high energy electron beam can interact with plasma and vessel wall, which generate high energy photons. High energy photons open various reaction channels. Hence this photo nuclear reaction plays an important role in reactor design.

This reaction shows a resonance at a specific energy. This mechanism is called Giant Dipole Resonance (GDR). GDR plays an important role below 30 MeV. The earlier theory for the neutron production was based on Lorentz curve dependency of energy of incident photon energy.

We have developed a new empirical formula, which is supported by the nuclear modular codes TALYS - 1.6 and EMPIRE - 3.2.2. These codes are key theoretical tools based on different nuclear models to predict the nuclear properties. The previously measured data available in EXFOR data library were used to compare and verify their reproduction of the newly developed empirical formula. This formula contains different terms, which are discussed in the published article [5]. The limitation of the formula is that it can applicable to the isotopes of the elements of mass number near to Nd and greater than it. The results will be presented during the symposium. For one of the isotope of osmium, ^{192}Os results are presented here in Figure 1.

Table 1: Studied nuclear reactions

Target	Nuclear Reaction	Neutron Energy En (MeV)
W	^{182}W(n, p)^{182}Ta	8.96, 12.47, 16.63
	^{183}W(n, p)^{183}Ta	1.70
	^{184}W(n, p)^{184}Ta	3.75
	^{186}W(n, γ)^{187}W	5.08, 8.96, 12.47, 16.63
Gd	^{154}Gd(n, 2n)^{153}Gd	12.47, 16.63
	^{160}Gd(n, 2n)^{159}Gd	12.47, 16.63
As	^{75}As(n, p)^{75}Ge	14.20
Zn	^{66}Zn(n, p)^{66}Cu	14.20
	^{64}Zn(n, p)^{64}Cu	14.20
Mn	^{55}Mn(n, p)^{55}Cr	14.20
V	^{51}V(n, p)^{51}Ti	14.20
Ni	^{58}Ni(n, p)^{58}Co	14.20

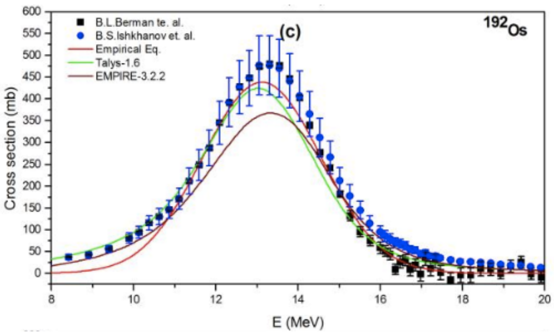

Figure 1: Results of the new empirical formula compared with EXFOR, TALYS – 1.6 and EMPIRE – 3.2.2 data for ^{192}Os

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