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Double differential cross section calculations of (n,p) reactions on ^{27}Al and ^{24}Mg targets

İsmail Hakkı Sarpün[1,2,3,*], *Eyyup* Tel[4], *Abdullah* Aydın[5], and *Unal* Yıldırır[6]

[1]Akdeniz University, Physics Department, Antalya Turkiye
[2]Akdeniz University, Faculty of Medicine, Radiation Oncology, Antalya Turkiye
[3]Akdeniz University, Nuclear Research and Application Centre, Antalya Turkiye
[4]Osmaniye Korkut Ata Uni., Fac. of Eng. and Nat. Sci, Dept. of Physics, Osmaniye, Turkiye
[5]Kirikkale Uni., Fac. of Eng. and Nat. Sci, Dept. of Physics, Kirikkale, Turkiye
[6]MEB, Goynuk Science High School, Antalya, Turkiye

Abstract. In structural fusion material research, double differential sections are necessary to determine heating and damage due to secondary particles that may occur in structural materials. Therefore, in this study, the double differential proton emission cross sections of ^{27}Al and ^{24}Mg target nuclei were calculated theoretically with the TALYS nuclear reaction code at 14 MeV neutron energy. The calculated values were compared with existing experimental data in the EXFOR library. Additionally, the contribution of direct, compound and pre-equilibrium reactions in theoretical calculations was investigated.

1 Introduction

The need for double differential cross section (DDX) data of charged particles emitted by the neutron effect has been discussed in many publications in fusion reactor structural material development studies, especially on first wall and blanket materials [1–9]. In fusion reactor building materials studies, a classification was made according to their activation properties and C, Si, Ti, Fe, Cr and V were considered as low activation elements while, Al, Ni, Mg, Ag, Co and Nb were considered as high activation elements [10–13]. In the selection of construction materials for fusion reactor components, not only mechanical properties, compatibility with other materials and irradiation performance, but also radiological properties should be taken into account [14–16]. Since neutron activity varies depending on the material irradiated, the first wall and cover materials, which are the fusion reactor components exposed to the highest neutron flux, have high radioactivity concentrations. For this reason, the selection of building materials that can be used in reactor components is very important in limiting radioactivity [17]. The DDX information is very important in material studies because it includes both the energy distribution of the emitted particles and the angular dependence. The DDX of light charged particle emission have been investigated in several studies both experimentally [3, 4, 6, 18–23] and theoretically [8, 9, 24–29]. ^{27}Al and ^{24}Mg isotopes, which have been experimentally studied in the (n,p) reaction of Al and Mg elements, which were stated to have high activation above, were used in this study. In fusion studies, especially in the D-T reaction, the emission of 14 MeV neutrons and the reaction of these neutrons with other structural elements of the reactor have great importance. Additionally, the (n,p) reaction has the highest cross section in neutron induced reactions at lower energies. In this study, the DDX of emission proton from ^{27}Al and ^{24}Mg target nuclei, structural fusion materials, induced by 14 MeV neutrons have been calculated using TALYS v1.95 [30] nuclear reaction code and the results have been compared with the available experimental data in EXFOR nuclear data library [31].

2 Calculation Methods

TALYS 1.95 code has been used in DDX calculations to describe the compound, pre-equilibrium and direct mechanisms [32]. The TALYS 1.95 code is able to simulate nuclear reactions induced by up to 1 GeV light particles for target nuclei heavier than lithium [30]. Kalbach's [33] the two-component exciton model is used for calculating the pre-equilibrium contribution while Hauser–Feshbach's [34] model is used for the compound nucleus contribution in calculations. Direct reaction contribution is calculated by ECIS-97 [35] code which is implemented in TALYS code.

3 Results

The DDX of proton emission from ^{24}Mg target nucleus at emission angles 7°, 18°, 30°, 45°, 60°, 75°, 90° and 135° have been calculated by the TALYS 1.95 code at 14 MeV incident neutron energy. The calculated values have been compared with the available experimental data of Colli et al. [36] taken from the EXFOR library in Figure 1. Similarly, the DDX of proton emission from ^{27}Al target nucleus

*e-mail: isarpun@gmail.com

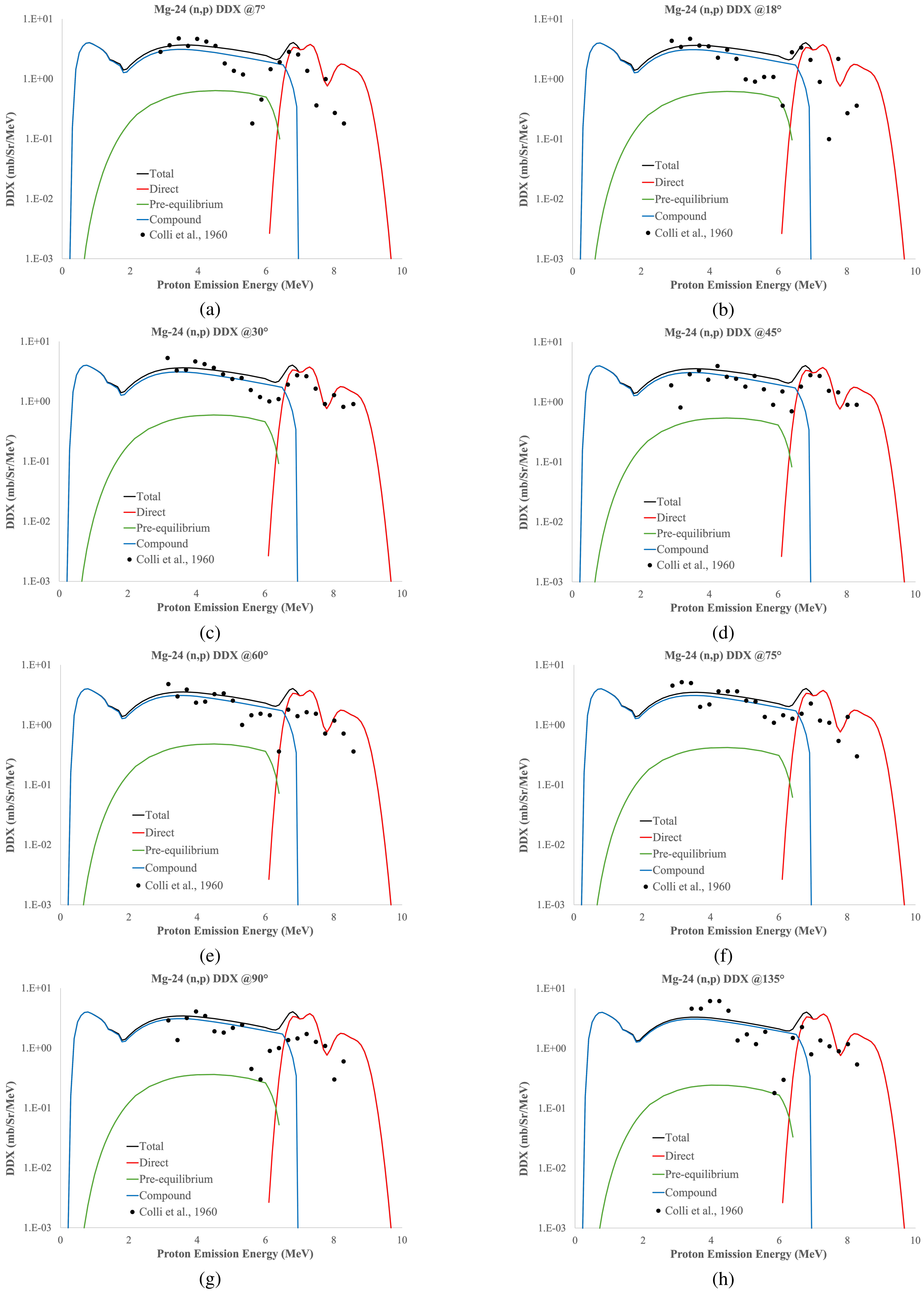

Figure 1. The DDX calculations of the different mechanisms for the ^{24}Mg(n,p) reaction at 14 MeV incident energy are compared with experimental data of Colli et al. [36] .

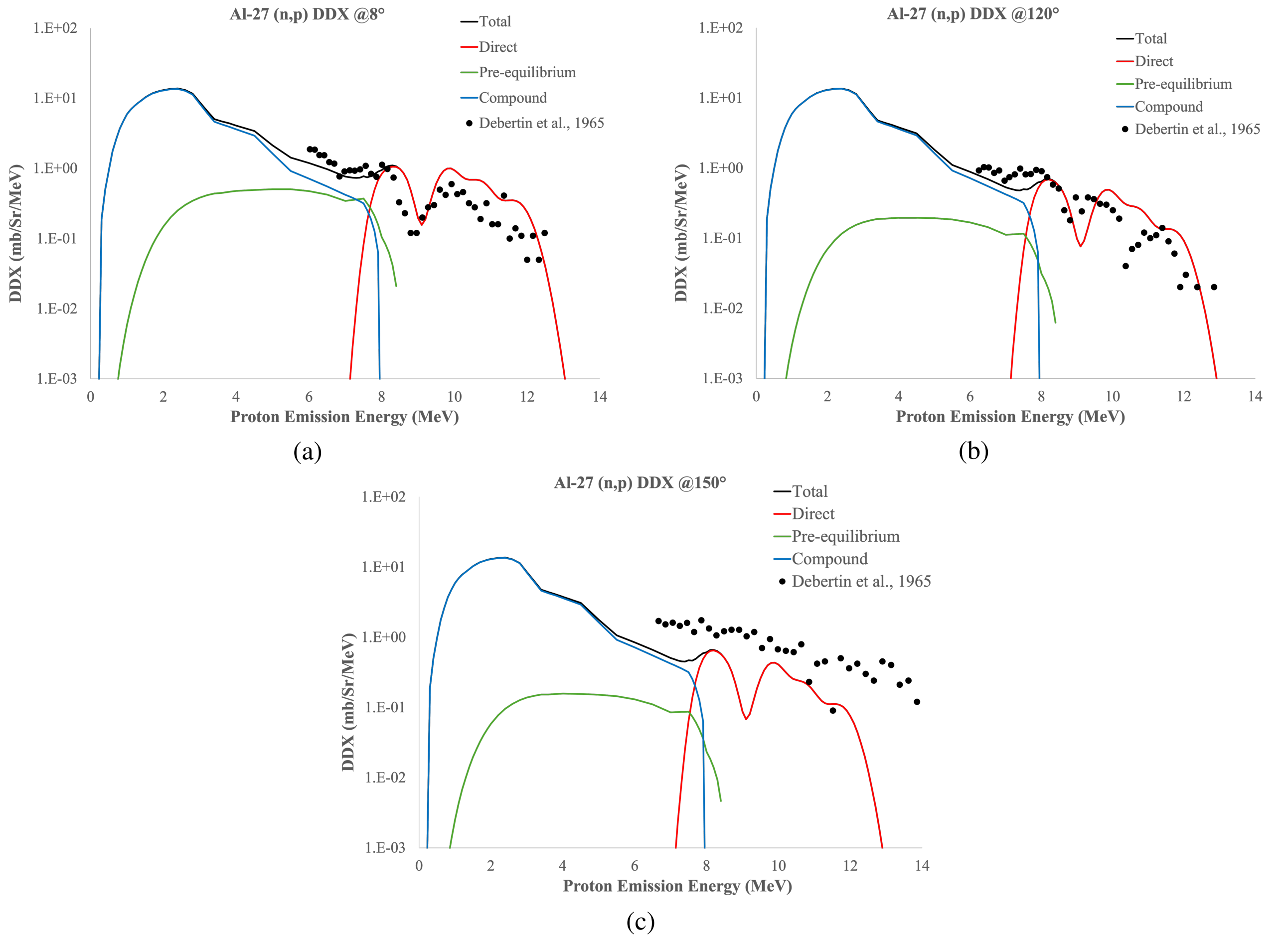

Figure 2. The DDX calculations of the different mechanisms for the ^{27}Al(n,p) reaction at 14 MeV incident energy are compared with experimental data of Deberin et al. [37] .

at emission angles 8°, 120° and 150° have been calculated by the TALYS 1.95 code at 14 MeV incident neutron energy. The results have been compared with Debertin et al. [37] in Figure 2.

4 Conclusions

Results calculated for double differential cross sections of proton emission are compared with experimental data as shown in Figures. The shape of the curve and the magnitude of calculated results at all emission angles are in agreement with experimental data. The theoretical models provide a good description of the shapes and magnitude of the double differential cross section of proton emission for given emission angles and energies. TALYS code calculations were in the framework of the pre-equilibrium exciton model and the Hauser– Feshbach model. The calculation results were compared with the available experimental data with conclusions that can be summarized as follows:

1. All double differential cross sections are consistently calculated using nuclear theory models for ^{27}Al and ^{24}Mg, target nuclei at the incident neutron energy of about 14 MeV.
2. The pre-equilibrium models provide the good description of the shapes and magnitude of the double differential cross section of proton at the incident proton energy of 14 MeV.
3. All of the present results have been transformed into ENDF formatted data files for application of obtained data to use in future studies.

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