Study of the ^{58}Ni(p,d)^{57}Ni Reaction with Direct Reaction Model

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Abstract

The ^{58}Ni(p,d)^{57}Ni reaction has been studied with 42 MeV protons for the laboratory angles of 75^o, 90^o, 120^o and 150^o. Spectrum regions are treated with an analysis using direct reaction model, i.e., several tens of MeV energy regions. The analysis is based on the DWBA method and the asymmetric Lorentzian form strength function having an energy dependent spreading width. Results of the comparisons between the experimental and calculated spectra are described here and a fairly good agreement is found between the theoretical and experimental spectra.

***Keywords*:** Double differential cross section, ^{58}Ni(p,d)^{57}Ni, nuclear reactions, direct reaction model, DWBA analysis

1. Introduction

Nuclear data have diversified uses. They are required not only to make our lives comfortable but also to save our lives. So nuclear data from several tens of MeV to a few GeV are recently required for some applications, such as, transmutation of nuclear waste, energy production, space expedition, cancer therapy etc. But, it is always difficult to have experimental data of differential cross sections for a wide range of energy and for various nuclei.

Therefore, an approach such as proposed by Lewis [1] is suggested to be employed, in parallel with the prediction models described by Crawley [2] and Gales et al. [3]. This approach is applied for analyzing the continuum spectrum in the direct reaction region, i.e., several tens of MeV energy region. We have worked here on the direct reaction region because the models available for nuclear data analysis are not well established as those used in the direct reaction region [4]. In agreement with Lewis [1], Matoba et al. [5, 6] have advanced an analysis using an asymmetric Lorentzian shaped strength function having energy dependent spreading widths and DWBA-based cross section. Previously, this model has been successful in predicting the double differential cross sections for the (p,d) reaction on ^{27}Al, ^{48}Ca, ^{58,60,62,64}Ni, ^{96,100}Mo, ^{197}Au and ^{209}Bi over the incident energy range 42-68 MeV [7-15].

The present work is concerned with the analysis of the double differential cross section for the ^{58}Ni(p,d)^{57}Ni reaction at four different laboratory angles, namely 75^o, 90^o,120^o and 150^o. Here the incident energy is 42 MeV. The experiment was performed at the TIARA facility of JAERI. Details of the experimental procedure and the results have been reported in ref. [16]. Since the direct reaction model is valid in the excitation energy up to about tens of MeV, we confined our analyses to the highest of 10 MeV energy domains of particle production spectra.

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2. Materials and Methods

2.1 Theoretical Calculations

In the present method, the theoretical calculations of the double differential cross-sections have been done by considering a direct reaction model as an incoherent sum of the direct reaction components, which are based on the DWBA predictions and expressed as shown below:

$$\frac{d^2\sigma}{d\Omega dE} = 2.30\sum_{l,j}\left[\frac{C^2 s_{l,j}(E)}{2j+1}\times\left(\frac{d\sigma}{d\Omega}\Big|_{l,j}^{DW}(E)\right)\right], \quad (1)$$

where $d\sigma/d\Omega\big|_{l,j}^{DW}(E)$ is the cross-section calculated by the DWBA code, DWUCK-4 [17] and $C^2S_{l,j}(E)$, is the spectroscopic factor expressed as

$$C^2S_{l,j}(E) = \left(\sum C^2S_{l,j}\right)\times f_{l,j}(E). \quad (2)$$

where $\sum C^2S_{l,j}$ is the sum of the spectroscopic factors of all the predicted states and the distribution of strength function over the spectra is obtained by using an asymmetric Lorentzian function [5, 6, 18]

$$f_{l,j}(E) = \frac{n_0}{2\pi}\frac{\Gamma(E)}{\left(|E-E_F|-E_{l,j}\right)^2+\Gamma^2(E)/4}, \quad (3)$$

and

$$\int_0^{\alpha} f_{l,j}(E)dE = 1 \quad (4)$$

where n_0 is the renormalization constant and E_F is the Fermi energy. The Fermi energy can be calculated by using an empirical formula given in [19]. The sums of spectroscopic