Calculation of Multi-step Compound Pre-equilibrium Cross Sections for Deuteron Emission in Some Proton-induced Nuclear Reactions

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ABSTRACT

This study adapted the computer code GAMME (which was originally written for single particle emission) for deuteron emission, calculated the multistep compound reaction cross sections using the Feshbach-Kerman-Koonin (FKK) theory and compared the results with the appropriate experimental data. This was with a view to generating MSC nuclear parameters for (p,d) reactions.

A computer code "GAMME" written by Bonetti and Chadwick was modified to calculate the multistep compound (MSC) double-differential emission cross sections for $^{90}Zr(p, d)$, $^{58}Ni(p, d)$ and $^{209}Bi(p, d)$ at 42 MeV incident energy. Zero-range and Yukawa forms were used for the residual proton-deuteron interaction potential. To calculate the wavefunctions for the projectile and the ejectile, the optical potential parameters , and Perey were used for protons while the parameters of Perey-Perey and those of Lohr-Haeberli were used for the deuterons. The level density parameters of Gilbert and Cameron were also used in the calculations. The calculated double-differential cross sections at the backward angle of 150^o were compared to the experimental data of Watanabe *et al*.,(1998, 1999). This was done because it was believed that at this angle, the MSC processes made the most significant contribution to the cross section. Compound nucleus reaction contribution to the reaction cross section was also calculated in order to find better agreement between theoretical values and experimental values of the cross section.

A good correlation was obtained between the theory and experiment by adjusting the value of the residual potential strength, $V_{0,}$ that was used for the MSC calculation. The contribution of compound nucleus (CN) emission to the total cross sections was found to be negligible for ^{90}Zr reaction. For ^{58}Ni and ^{209}Bi reactions, CN emissions contributed significantly at the lower energies

(17-18 MeV), but at the higher energies (25 MeV and above), the contributions were negligible. Also, the V_0 of the Yukawa potential was much larger than the one obtained for the Zero range. This showed that the Yukawa potential was weaker than zero range at the backward angles. The calculated double-differential cross section showed significant sensitivity in magnitude, to deuteron-particle optical potentials but showed little response to proton optical potentials.

The study concluded that the contribution of the MSC reaction to the total pre-equilibrium reaction cross sections for the (p, d) reaction was significant, although there were discrepancies at the higher energy regions attributable to multi-step direct (MSD) emission which were not included in the calculation.

Keywords: Deuteron emission, Feshbach-Kerman-Koonin,Nuclear Reaction, GAMME,Bechetti-Greenlees, Perey,

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CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Accelerator-driven systems (ADS) with intense high energy proton beams will create a large amount of spallation products, mainly neutrons and protons, with energies covering the full range up to the GeV region. Thus, feasibility calculations on such systems require nuclear data for reactions induced by these products on target materials, structure materials as well as on fission products over a wide energy range. This huge amount of data required cannot be provided by experiments alone. Thus one has to rely on theoretical model calculations, which have to be validated on the few existing experimental data. This is of particular interest in the region up to 150 MeV, in which in the future the basic nuclear data for ADS should consist of evaluated data libraries.

Depending upon the time at which they occur, nuclear reactions may be classified into compound nucleus, direct and pre-equilibrium reactions. The energy domain of importance of these processes can be seen in a typical nuclear reaction emission spectrum as illustrated in Figure 1.1, where the total cross section for the production of a nucleon at energy E_{out} is plotted as a function of the energy of the emitted particle.

A nuclear reaction is initiated when a nucleon or nucleus collides with another nucleon or nucleus. At low incident energies, nuclear reactions take place mainly by the compound nucleus process, in which the projectile enters the target nucleus, it interacts with a number of nucleons and energy-momentum transfer takes place. Nucleons which share in projectile energy also interact further with other nucleons and large number of nucleons get involved in the energy-momentum transfer. Compound nucleus so formed has life time of about 10^{-16} seconds.

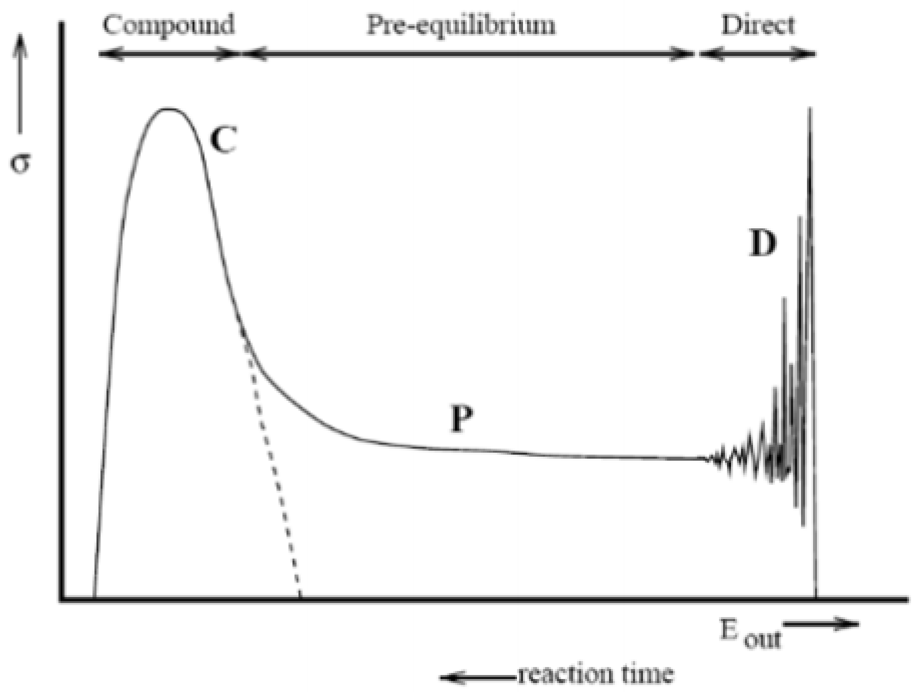

Figure 1.1: Schematic Spectrum of Particles Emitted in a Reaction (Feshbach *et al.*, 1980).