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Analysis of Pre-equilibrium fraction (FR) in iron isotopes for (n,p) reactions in energy range 0-20 Mev

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ABSTRACT
Pre-equilibrium fraction (FR) for ^{54}Fe (n,p)^{54}Mn, ^{56}Fe (n,p)^{56}Mn, ^{57}Fe (n,p)^{57}Mn and ^{58}Fe (n,p)^{58}Mn have been calculated using exciton model of Griffin in combination with Hauser Feshbach model in energy range 0-20Mev. Dependence of FR on excitation energy has been studied. Analysis of data indicate considerable amount of pre-equilibrium emission and isotopic effect in the studied reactions.
Keywords: Pre-equilibrium fraction (FR), pre-equilibrium emission, isotopic effect

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INTRODUCTION

It is now well established fact that in nuclear reactions at moderate excitation energies, both the pure compound and the direct reaction mechanism have not been adequate and that a significant part of the reaction proceeds through the pre-equilibrium (PE) emission [1]. The PE emission which may be considered as a bridge between the two extreme approaches (i.e. , the compound and the direct reactions) is assumed to proceed through two-body collisions inside the nucleus during relaxation process after the initial projectile-target interaction with a finite probability of the particle emission after each collision. Each stage of the interaction may be characterized by the particle hole (ph) pair together called excitons. The particles which are emitted before the establishment of statistical equilibrium of the compound system are called pre-equilibrium particles or sometimes referred to as the pre-compound particles. The probability of emission of PE-particles is expected to decrease from a stage to the next on account of the available energy getting distributed throughout the compound system with the lapse of time, resulting ultimately in the statistical equilibrium. Pre-equilibrium particle emissions during decay process of a compound nuclear are very important and have been studied by different researchers. The aim of this work is to understand PE emission more deeply and to have a quantitative estimate of PE fraction (FR) in (n,p) reactions for iron isotopes from energy 0-20 Mev. As the analysis of excitations function allows one to deduce the pre-equilibrium fraction as a function of incident projectile energy, the calculations of the excitation function have been performed using amixture of equilibrium and PE emissions. Brief details of these calculations are presented in Section 2, while the results and discussion are given in Section 3 of this paper.

MATERIAL AND METHODS

Calculations

The theoretical calculations have been performed using the statistical models. The CN calculations have been performed using the Hauser-Feshbach model [2] while the exciton model of Griffin [3] has been used for simulating the PE contributions. Cross-section of the reactions have been calculated from energy 0-20 Mev with the help of given formula.

$$\sigma_R(n,P:E) = \sigma_{PE}(n,P:E) + \sigma_{CN}(n,P:E) \ldots\ldots\ldots 1$$

Where $\sigma_R$represent the total cross-section, σ_{PE} the pre-equilibrium cross-section and σ_{CN} the compound nuclear cross-section. The details of the calculations are described elsewhere [4]. Fraction of pre-equilibrium emission FR has been calculated from the expression:

$$\frac{d\sigma}{dE}(n,p) = [1 - FR]\frac{d\sigma_{CN}}{dE}(n,p) + \frac{d\sigma_{PE}}{dE}(n,p)\ldots\ldots\ldots\ldots\ldots\ldots 2$$

Where the terms used have their usual meaning.

A computer code ACT [4] developed on the lines of code STAPRE, has been used for these calculations. The computer code ACT takes sequential evaporation of the particles and considers pre-equilibrium emission in the first step of de-excitation of the compound system where the excitation energy is sufficiently large. The pre-compound and compound nucleus models used to calculate the cross sections for (n,p) reactions in this work have been chosen to meet the following criteria:

(i) Both the models should be set free of adjustable parameters as much as possible.

(ii) All input parameters common to the two models are to be determined in advance and used in a unified way [5,6].

RESULT AND DISCUSSION

The pre-equilibrium fractions for the reactions ^{54}Fe(n,p)^{54}Mn, ^{56}Fe (n,p)^{56}Mn, ^{57}Fe (n,p)^{57}Mn and ^{58}Fe (n,p)^{58}Mn have been calculated in the energy range 0-20Mev. The FR is taken to be proportional to the cumulative sum of the probability of finding any particle in continuum for energy possible configuration during the process of equilibrium use have defined FR as:

$$FR(E) = \frac{\sigma_{PE\,(n,P:E)}}{\sigma_{R\,(n,P:E)}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3$$

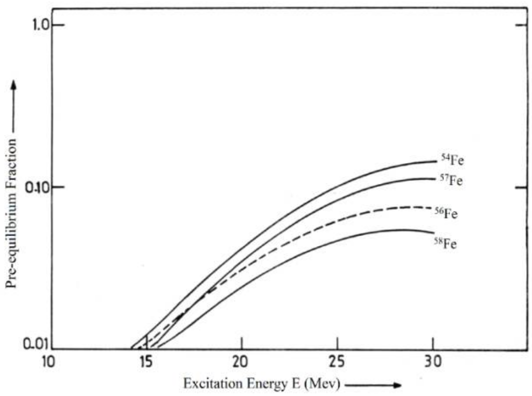

Fig. 1

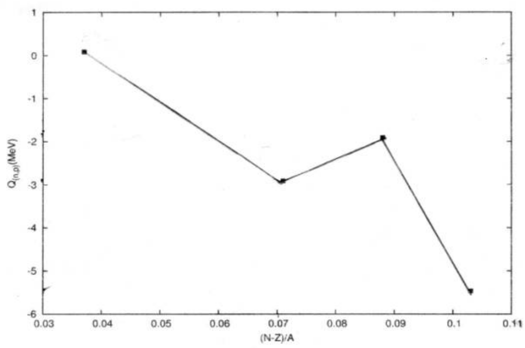

Fig. 2

Fig 1 shows the variation of FR as a function of excitation energy E of the compound nucleus in the energy range 0-20Mev.It may be seen from this figure that pre-equilibrium fraction increases almost linearly with increase in neutron energy.It is interesting to note that FR start building up from the excitation energy of 10Mev, for all the cases of isotope. A considerable amount of FR has been found in (n,p) reactions studied. The probability of pre-equilibrium emission at a given energy is large in lighter nucleus than in heavier ones, because of lower value of coulomb barrier for the system of higher mass number reduces the probability of the proton emission for heavy isotope. But in case of ^{57}Fe, since the reaction Q value is higher than that of ^{56}Fe Fig 2 the decrease of coulomb barrier with increase in aasymmetry parameter is more than compensated by increasing Q value. As a net result probability of proton emission of ^{57}Fe increase and FR trend for ^{57}Fe is above the trend of ^{56}Fe.

CONCLUSION

From the above analysis it may be concluded that the pre-equilibrium process play an important role in the reaction induced by neutron of energy 0-20Mev. Many researches have explained this isotopic effect earlier, Gardner [7] as a Q value effect and Molla and Qaim [8] interpreted I terms of proton binding energy.As the mass number increases, contribution of PE emission in also increase which shows agreement with the isotopic effect. Though the present data on FR are limited, it requires further investigation to complete the systematic study and confirmation of the trends.

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