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Study of α- induced nuclear reaction in the energy range upto 60MeV on ^{54}Fe

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ABSTRACT

α–cluster cross- section production by α- induced reaction was calculated at different energies using excitation model and an analysis in the framework of pre-equilibrium excitation model with geometry dependent hybrid model depend on pickup mechanism. Comparison with our calculation gives remarkable agreement with experimental data. The cross-section has been estimated for the target ^{54}Fe (α, Xn), X = 1 to4, with different energies.

Keywords: α–cluster, Pre-equilibrium, Cross-section.

INTRODUCTION

The mechanism of the emitted particle in the nuclear reaction is an important to provide information about nucleus. The excitation model [1] is one of many models used to explain nuclear emission before equilibrium. This model assumes the reaction proceed via a gradation of states characterized by excitation pairs of particle-hole (p-h). The evaluation of p-h excitations can be described by the master equation which is first proposed by Kalbach and Blann [2] in the spin-independent formulation of this model.

Also, the calculated results for nucleon induced alpha particle emission was compared with many researchers [3] and the results showed that there are some large conflict among calculated values and experimental data especially in pre-equilibrium process that dominate above 20 MeV. Pre-equilibrium emission of cluster has two opposite mechanisms; pre-formed α-particle that treated as a single excitation [4] and coalescence model that assuming forms a cluster in the course of a reaction from excitations [5] and applied more generally for all type of light complex particles. On the other hand, phenomenological models [6, 9] are proposed to describe nuclear reactions for nucleon and cluster induced reaction and emission by fitting many variables parameters to experimental energy spectra.

The analysis of the measured excitation functions was done using a consistent set of parameters. In the literature [10-17] reported the cross-sections for the reactions ^{54}Fe (α, Xn), X = 1, 2 up to 50 MeV only.

The present work is adopted to compare between pre-equilibrium models for α-particle emission by nucleon induced reactions at energy up to 60 MeV on target nuclei 54Fe and comparison these calculations with available experimental works.

MATERIALS AND METHODS

The expression for the cross-section of a nuclear reaction may be written from the consideration of decay rate equation governing the nuclear transformation and decay of the activated product. If a target is irradiated by a projectile of constant flux Φ, then the rate of production R_p can be written as,

$R_{\mathbf{p}} = \sigma\Phi\, N_{\mathbf{0}}$ (1.1)

Where σ – is activation cross-section
$N_{\mathbf{0}}$ – is the no. of target nuclei of isotope under investigation present in the sample, in my case ^{54}Fe.

The expression for N0 can be given as,

$N_{\mathbf{0}} = mNf/A_{\mathbf{0}}$ (1.2)

Where m- is the mass of the sample
N – Is the Avogadro No.
f- is the abundance of the isotope in the target.

Let t_1 – be the time of irradiation of the target by a constant flux incident beam to produce a radioactive reaction product R. The equation that governs the growth of activity during production can be written as,

$dR/dt = \sigma\Phi\, N_{\mathbf{0}} - R\lambda$ (1.3)

Where λ – is decay constant
R – Type of activated nuclei, R is the number of radioactive atoms present.

The activity of R type nuclei at the instant of stopping the irradiation is given by

$W = R\lambda$

$W = \sigma\Phi\, N_{\mathbf{0}}\, [1-\exp(-\lambda t_{\mathbf{1}})]$ (1.4)

The term $[1-\exp(-\lambda t_{\mathbf{1}})]$ is called the saturation factor of the reaction.

If the activity of radioactive nucleus R is measured after a time "t'" from the time stopping irradiation, then it will be given by,

$dR/dt = W \exp(-\lambda t)$

$dR = \sigma\Phi\, N_{\mathbf{0}}\, [\, 1-\exp(-\lambda t_{\mathbf{1}})]\, [\, 1-\exp(-\lambda t_{\mathbf{1}})]\, dt$ (1.5)

If 'D' be the actual number of disintegrations of the sample during a time period of t_3 starting after a time t_2 from the stop of irradiation, then DA can be obtained by integrating 'dR' with respect to time limits of t_2 to $t_2 + t_3$.

$DA = \int dR$

$$DA = \sigma\Phi \frac{N_0\, [\, 1-\exp(-\lambda t_1)]\, [\, 1-\exp(-\lambda t_3)]}{\lambda\, [\, 1-\exp(-\lambda t_{\mathbf{2}})]} \quad (1.6)$$

If 'A' is the number of counts observed by the detector during the time interval 't_3', 'G ε ' is geometry dependent detector efficiency of the detector ,'θ ' is the absolute intensity of the particular gamma ray and 'k' is the self absorption correction factor of the gamma ray in disc shaped target, which is given as the

$k = [1-\exp(-\mu d)] / \mu d$ (1.7)

Where μ – is gamma ray absorption coefficient
d - is the thickness of target under investigation for my case ^{54}Fe.
Then the actual number of disintegration DA will be given as,

$DA = A / G\varepsilon\theta k$ (1.8)

Relating equation (1.6) and (1.8), the activation cross-section of a nuclear reaction will be –

$$\sigma = A\,\lambda[\,1\text{-exp}(-\lambda t_2)] \,/\, \Phi\, N_0\, [\,1\text{-exp}(-\lambda t_1)]\,[\,1\text{-exp}(-\lambda t_3)]\; G\varepsilon\theta k \tag{1.9}$$

This expression has been widely used to calculate the activation cross-section for the alpha induced reaction on different isotopes.

RESULTS AND DISCUSSION

The theoretical and experimental cross-sections are plotted against the projectile energy and are shown in Fig. (1.1) to (1.4).The excitation functions for the theoretical calculations are shown by a solid line triangle point (green) for the pre-equilibrium model and with a dash line circular point on it (red line) while the experimental results are shown by a solid line square point on it(blue line).The cross-sections are measured in mili – barn (mb) and the projectile energy in MeV . The experimental data for the reaction channels ^{54}Fe (α, n) and ^{54}Fe (α, 2n) is taken from the author [18].The data is chosen from the author, because it has the smallest possible errors in both the cross-section and energy measurement. In addition to this the energy points are of lowest size which fits the theoretically used energy size. It can be seen from Fig. (1.1) and (1.2) that the excitation functions both the pre-equilibrium and pure equilibrium models show a Maxwellian curve at low energies by which the reaction mechanism can be explained by the compound nucleus theory. From the figures, it is evident that the pre-equilibrium modified GDH model better agrees with the experimental data than the pure equilibrium model.

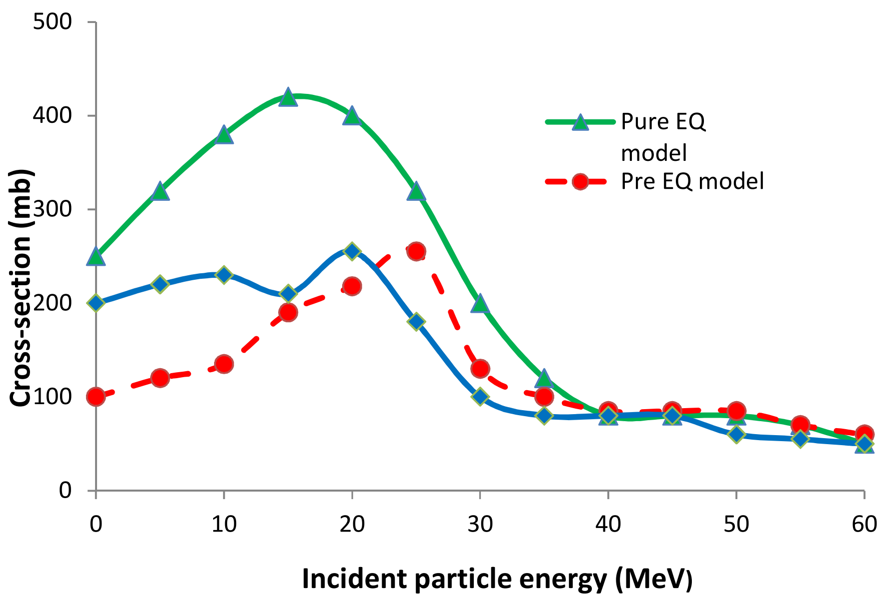

Fig.1.1 Graph showing excitation function of ^{54}Fe (α, n)

The ^{54}Fe (α, 3n) and ^{54}Fe (α, 4n) reaction channels experimental data is taken from authors [19]. It may be seen from Fig. (1.3) that the pre-equilibrium contributions to the excitation function is more significant than the excitation functions in Fig. (1.1) and Fig.(1.2). From Fig (1.3) and Fig. (1.4), we see that the pre-equilibrium model is still fits the experimental result but the two curves do not have nearly the same peaks as those in the other figures. In these reaction channels the experimental excitation function peaks more than the theoretically calculated one. This may be explained by considering the fact that at higher energies, the angular momentum imparted by the projectile creates more rest states which inhibits particle emission. The reactions with alpha emission are affected with the Coulomb potential. The effect of this is observed in the shape of the excitation function which shows a barely visible compound nucleus to that of the increasing shape as seen in the Fig. (1.4) of the reaction channel ^{54}Fe (α, 4n). In this reaction both the experimental and the theoretical curves show only rising parts showing compound nucleus contributions which are almost insignificant at energies lower than about 40Mev. But it may be seen from this figure that above this energy, the compound nucleus bump is just evident in both theoretical and experimental results. The agreement between the experimental and the theoretical excitation functions can be judged from their peak positions and widths.

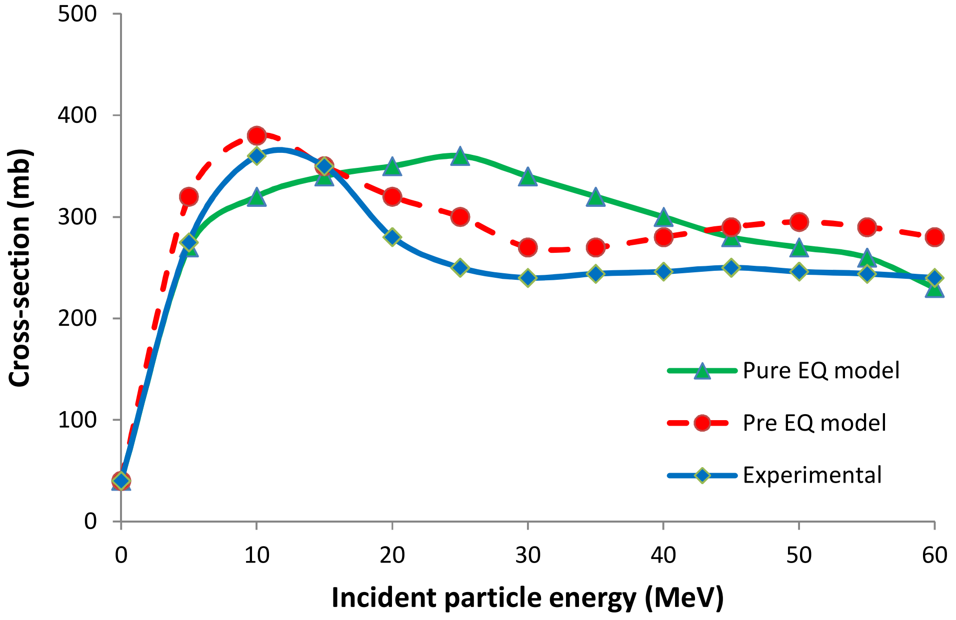

Fig.1.2 Graph showing excitation function of ^{54}Fe (α, 2n)

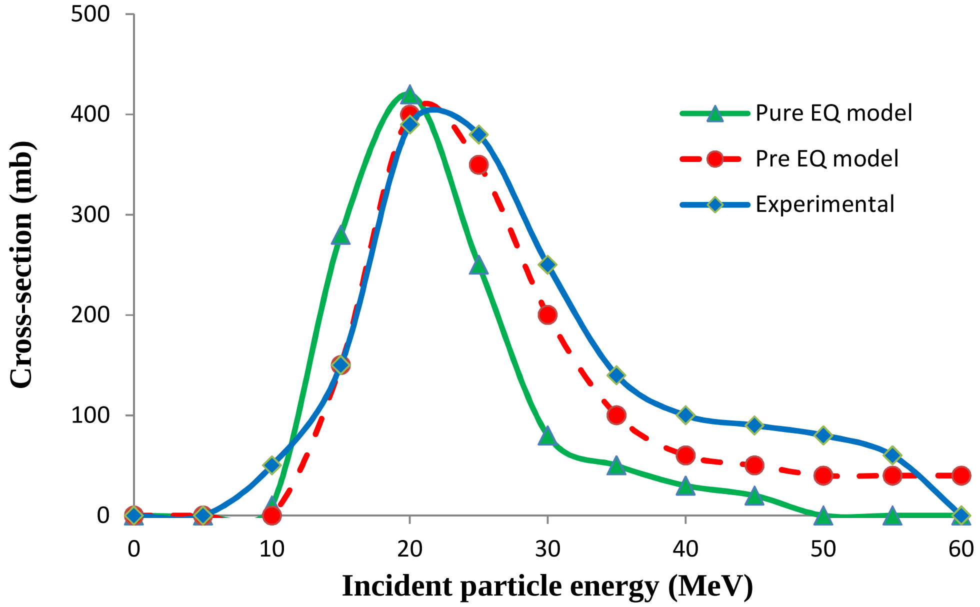

Fig.1.3 Graph showing excitation function of ^{54}Fe (α, 3n)

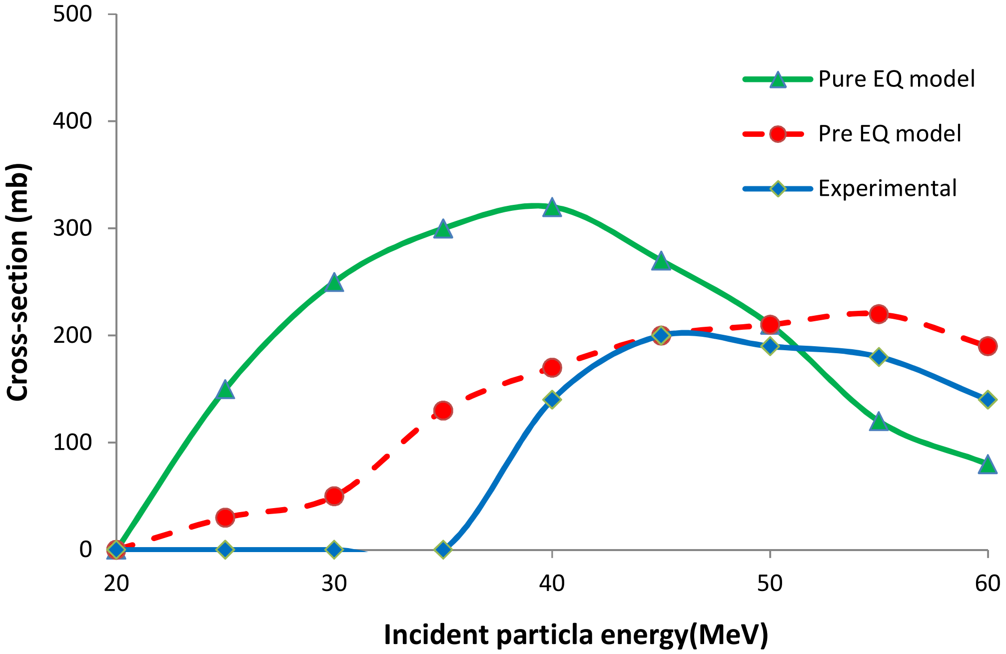

Fig.1.4 Graph showing excitation function of ^{54}Fe (α, 4n)

CONCLUSION

In this work, the differential cross section of alpha particle emitted by nucleon induced reactions is calculated for the nuclei-^{54}Fe. The calculations of this work have been made in the framework of the pre-equilibrium nuclear reaction region using equilibrium model comparing with GDH model and experimental data. We found that model have a cross section in small range compare with Kalbach for all choice nucleus. Since excitation model applied to many experimental data and has had much success, studied during the pre-equilibrium stage give a small excitation number. But there remain some opacity in the formulation of the composite particle emission to explain the transformation from the closed shell to open shell in the ^{54}Fe case.

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