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Measurement and evaluation of the excitation function in (α,xn) reactions on Au up to energy range 60MeV

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ABSTRACT

The excitation function for (α, xn) reaction up to energy range 60 MeV on Au has been calculated using stacked foil technique. Excitations have also been calculated theoretically using computer code – ACT with and without the inclusion of pre-equilibrium emission. As expected, inclusion of pre-equilibrium contribution based on the excitation model along with compound nucleus calculation using the Hauser- Feshbach formalism reproduce well the measured excitation function. Interesting trends in the pre-equilibrium fraction with projectile energy has been observed.

Keywords: Per-equilibrium reaction mechanism, Excitation function, Alpha induced nuclear reactions.

INTRODUCTION

The study of pre-equilibrium (PE) reaction mechanism in the intermediate energy regions has been a point of interest during the last decade. Enough evidence are now present to believe that both the direct and pure compound reaction mechanism are not adequate to explain the high energy tail observed in the experimental excitation functions. However, it has been found that a significant part of the reaction proceeds through the per-equilibrium emission process. Several semi-classical models [1-5], have been proposed to explain the features of the experimentally measured excitation functions.

Recently several quantum mechanical (QM) theories [6-9], have also been put forward to explain the per-equilibrium (PE) reactions. Though, the quantum mechanical (QM) theories involve the microscopic calculations, at present they are applicable mostly to the nucleon induced reactions [10]. As for a complex particle, that is, alpha-particle in the entrance channel, the quantum mechanical (QM) treatment of initial projectile target interaction becomes very much interacted. Hence the experimental data on excitation functions, for alpha- induced reaction s, is generally analyzed using semi-classical models [11-15].

With a view to studying pre-equilibrium emission, a programmed of the precise measurement of the excitation function for alpha- induced reaction, in a large number of nuclei, covering the whole range of A values, has under taken. The analysis of the measured excitation function was done using a consistent set of parameters. As part of this programmed the excitation function for the reactions ^{197}Au (α, xn) , where x = 1,1,3,4, were measured in the energy range up to 60 MeV, using the stacked foil technique. B. P. Singh et. al. [16] reported the cross –section for the reactions ^{197}Au (α, xn) Tl^{201-X}(X=1,2)in the energy range 30-60 MeV and B. Sathish et. al. [20] reported the reaction cross-section for the alpha particle induced reaction on ^{197}Au in the energy range 40-80MeV. The analysis of the

compound nucleus represent in this work is made with statistical Hauser-Feshbach (HF) model[9] .and the PE contribution is simulated by the employing the excitation model(EM) of Griffin [2].

Computational Methods and Procedures:-

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,

$$R_p = \sigma\Phi N_0 \quad (1.1)$$

Where σ – is activation cross-section

N_0 – is the no. of target nuclei of isotope under investigation present in the sample, in my case ^{197}Au.

The expression for N0 can be given as,

$$N_0 = mNf/A_0 \quad (1.2)$$

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,

$$dR/dt = \sigma\Phi N_0 - R\lambda \quad (1.3)$$

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

$$W = R\lambda$$
$$W = \sigma\Phi N_0 [1-\exp(-\lambda t_1)] \quad (1.4)$$

The term $[1-\exp(-\lambda t_1)]$ 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,

$$dR/dt = W \exp(-\lambda t)$$
$$dR = \sigma\Phi N_0 [1-\exp(-\lambda t_1)] [1-\exp(-\lambda t_1)] dt \quad (1.5)$$

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 $t_2 + t_3$.

$$DA = \int dR$$

$$DA = \frac{\sigma\Phi N_0 [1-\exp(-\lambda t_1)] [1-\exp(-\lambda t_3)]}{\lambda [1-\exp(-\lambda t_2)]} \quad (1.6)$$

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

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

Where μ – is gamma ray absorption coefficient

d - Is the thickness of target under investigation for my case ^{197}**Au**

Then the actual number of disintegration DA will be given as,

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

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

$$\sigma = A\lambda[1-\exp(-\lambda t_2)] / \Phi N_0 [1-\exp(-\lambda t_1)] [1-\exp(-\lambda t_3)] G\varepsilon\theta k \quad (1.9)$$

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

[B] Analysis with the code ACT

The code ACT is based on the Weisskopf-Ewing model [17] for compound nucleus decay and hybrid/geometry dependent hybrid (GDH) model [18] for the pre- equilibrium decay processes. This code is capable to predict the excitation functions for pure-equilibrium decay as well as with pre-equilibrium decay. In compound nucleus decay calculations, the evaporation of protons, neutrons, deuterons and alpha particles are allowed. The Q-values for the formation of compound nucleus and the neutron, proton, deuteron binding energies for all nuclides of interest in the evaporation chain, have been calculated using the Mayers-Switecki/Lysekel mass formula [19]. The pairing energy is calculated from back-shifted model. The initial excitation configuration n, which is described by the number of neutrons (n), protons (p) in excited state and number of holes (h), after the first collisions a very crucial quality in pre-equilibrium reactions. The total exciton number n, equals the sum of n, p and h. For alpha-particle induced reaction, the initial exciton number n_0 = 4 or 6 as was suggested by Blann [4]. However it was find by many investigators that n_0 = 4, fits the experimental data better than n_0 = 5. The calculations have been performed for various initial exciton configurations. However the calculation with n_0 =4 (2n +2p +0h), that is, pure particle state) gives the best fit to the present results.

RESULTS AND DISCUSSION

In Figs. (1)- (4), experimental excitation functions are compared with the theoretical ones. As can seen from these figures that experimentally measured excitation functions are reproduced well using the code ACT when an admixture of compound nucleus calculations and pre-equilibrium calculations are taken in to considerations with the value of n_0 =4 (2n +2p +0h). In the present analysis of alpha- induced reactions, it is observed that a significant part of the reaction proceeds through the pre-equilibrium emission.

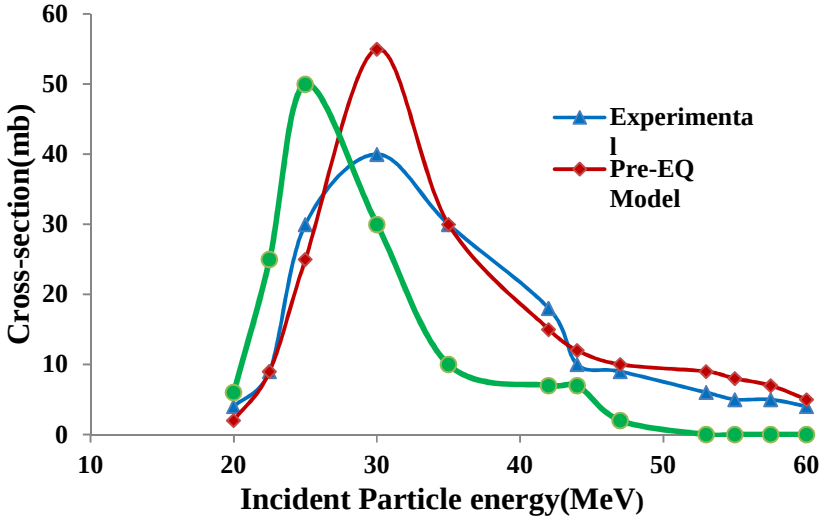

Fig.(1)- Graph of excitation function for ^{197}Au(α, n)

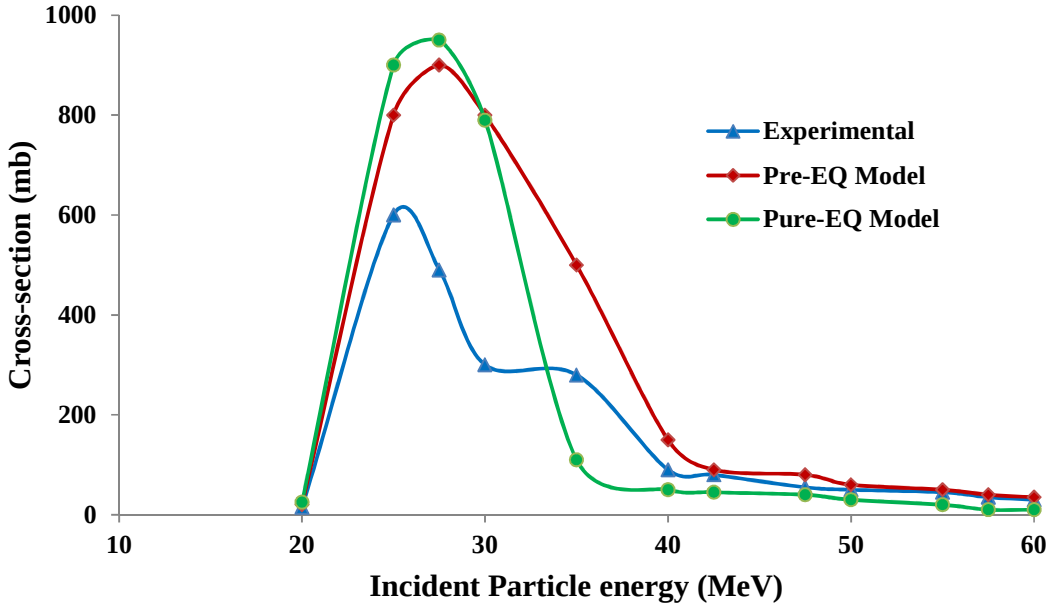

Fig.(2)- Graph of excitation function for ^{197}Au(α, 2n)

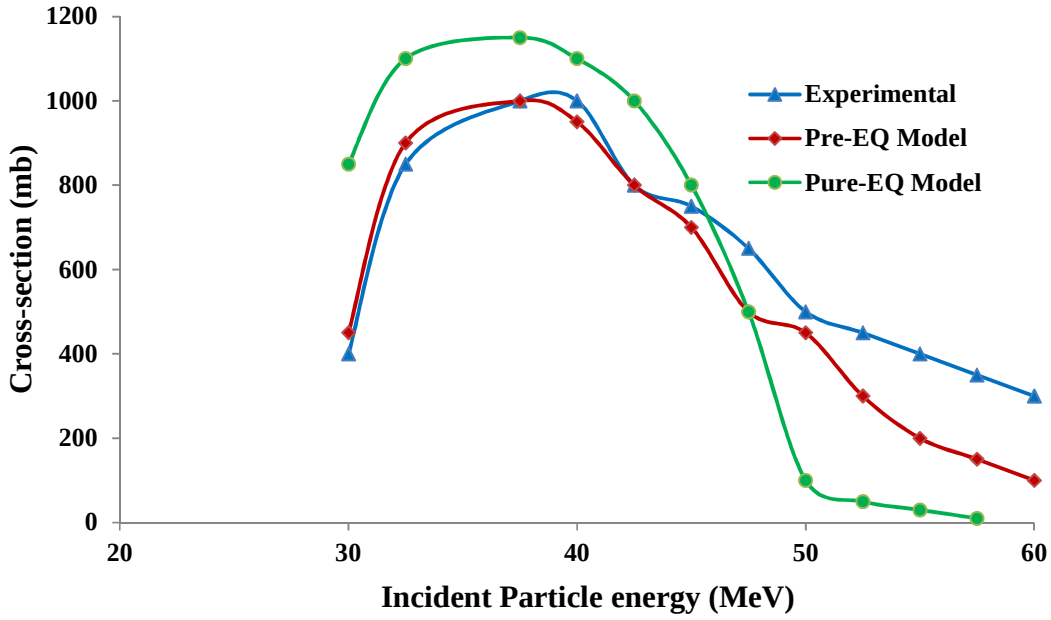

Fig.(3)- Graph of excitation function for ^{197}Au(α, 3n)

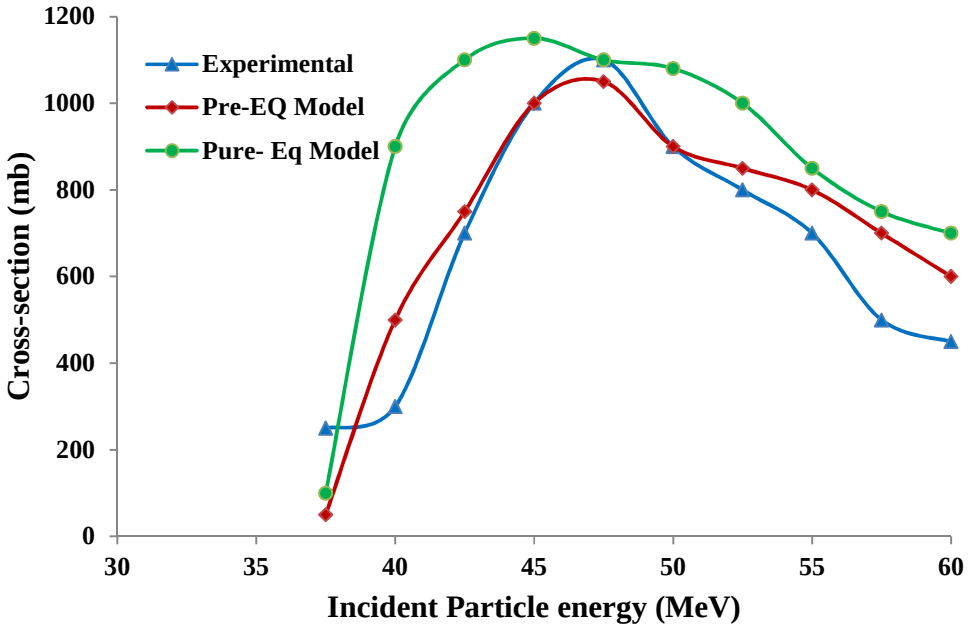

Fig.(4)- Graph of excitation function for ^{197}Au(α, 4n)

CONCLUSION

From the overall comparison of the experimental and theoretical excitation functions it may be conclude that there ia a quantitative agreement of experimental excitation functions with the theoretical excitation functions. The pre-equilibrium fraction is found to be energy dependent. Also the combination of Hauser-Feshbach model is quite adequate for alpha induced excitation functions with the choice of n_0 =4 (2n +2p +0h).

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