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Effect of Adjustment of Free Parameters used in semi Classical Models for the Study of (N,P) Reactions

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Abstract - Excitation functions for some (n,p) reactions have been calculated in energy range 0-20 mev. An attempt has been made to study the effect of adjustment of free parameters used in semi-classical models for the calculation of excitation function for targets ranges A from 27 to 197.

Keywords: PE Emission, Excitation Function, Free Parameters.

Introduction- The reaction of an incident particle with an atomic nucleus can take place in terms of three different mechanisms i.e. direct, compound and pre-equilibrium nuclear reactions. The Pre-equilibrium nuclear reaction may be considered as a bridge between the two extreme approaches (i.e. , the compound and the direct reactions)

Pre-equilibrium emission [1] takes place after the first stage of the reaction but long before the statistical equilibrium of the compound nucleus is attained. It is imagined that the incident particle, step by step creates more complex states of the compound system and gradually loses its memory of initial energy and direction. Nuclear reaction models are frequently needed to provide estimates of the particle-induced reaction cross-sections, especially if the experimental data are not available or unable to measure the cross-sections due the experimental difficulty. Therefore, nuclear reaction model calculations play an important role in the nuclear data evaluation.

Various semi classical models are available for theoretical treatment of the PE emission. These Semi classical models like exciton model [2] and Hybrid Model [3] which are generally used for describing the PE emission at moderate excitation energy contain free parameters like initial exciton number n_o, inter nuclear transition matrix element $[M]^2$, level denity parameters etc. These parameters although originally treated simply as a free parameter, in later years value used for these parameters have achieved some (not very firm) validity. In this work systemic attempt has been made to study the effect of adjustment of these free parameters on the calculation of exciton functions of some (n,p) reaction for target – ^{27}Al, ^{48}Ti, ^{55}Mn ^{56}Fe, ^{76}As, ^{88}Sr, ^{109}Ag, ^{181}Ta and ^{197}Au between 0-20 Mev.

Calculations- For the equilibrium part of the analysis, the statistical model of Hauser-feshbach [4] has been adopted, while the exciton model of Griffin [2] has been used for simulating pre-equilibrium decay of the

compound system. If only the pre-compound (PE) and compound nucleus (EV) mechanism are assumed to be present, the total (n,p) reaction cross-section can be written as a sum of two component.

$$\sigma \quad (a,b:E) = \sigma_{PE}\,(a,b:E) + \sigma_{CN}\,(a,b:E)$$

Where σ_{PE} (a,b:E) represent the pre-compound cross-section and $\sigma_{CN}\,(a,b:E)$ the compound nucleus (evaporation) component of the cross-section. E is the excitation energy of the composite system. A computer code ACT [5] developed on the lines of codes STAPRE [6] has been used for these calculations.

1. Initial exciton number

One of the most important parameter in PE models is the initial exiction number. The nuclear states is characterized by the excitation energy E and the total number of particles above and holes below the Fermi surface. Particles and holes are indiscriminatelty reffered to exiton number n_o= (p+h). In order to see the effect of variation in the values of initial excition, number n_o on calculated excitation functions, calculations for different initial exciton configurations n_o = 3,5 and 7 have been studied.

2. Intranuclear transition matrix element

While the emission rates can be expressed in an unique way, the strength of the equilibrium process, which competes with the emission, is not so straightforwardly determined. Very often a value corresponding to the average transition matrix element of the residual interaction is employed as a parameter. The exciton model often use the matrix element in th form suggested by Kalbach, i.e. $[M]^2 = KA^{-3}E^{-1}$ [7] some functional dependence of such a parameter can be derived, and only the proportionality constant, remains as a free parameter, which is obtained from systematics. Parameter K (in mev^3) referred as strength factor. With the view of fixing the parameter K calculations have been performed using different values of K i.e. 430,700,1700 and 3500Mev^3

3. Level density parameter

The level density which describe the excited state of the residual nuclei at higher excitation energies, is of crucial importance in theoretical calculations. The level density determines the emission probabilities and plays an important role in deciding the shape and absolute values of the excitation functions. Involved level densities are the partial level densities of non-equilibrium configurations. In literature, several prescriptions for the level densities are available while in this work we apply the level densities by Huang Zhongfu and He-Ping [8] who extract the reasonable parts from both formulae BS formulae [9] and GC formulae [10] and combine them together in order to obtain the new sets of level density parameters.

Result and Discussion

The results of these calculations show that, most of the pre-equilibrium protons are emitted from the initial exciton states: 85-90% from n_o = 3 , 8-14% from n_o= 5 and <2% from n_o= 7. It reflect from these calculations that lower value of initial exciton number gives, larger pre-compound contributions. It is because of the fact that lower value of n_o means larger number of two-body interactions prior to the establishment of equilibrium characteristic of the compound nucleus resulting in larger pre-compound contributions. The value of n_o = 3 (2p+1h) may also be justified since the first interaction may give rise to the excitation of one particle above the Fermi level leaving behind a hole in the excited state i.e., in all two particles and one hole. This suggests a

further simplification of the calculation model by assuming that all the pre-equilibrium protons are emitted from the initial state $n_o = 3$.

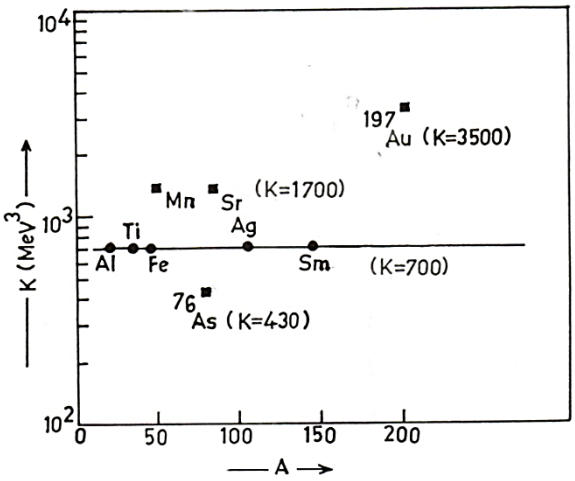

Fig. 1. Summary of the best-fit values of the parameter K used in the calculations.

Figure 1 shows a plot of the best fill values of parameter K obtained from the analysis of (n,p) reaction studied for all these nuclei. The determined best fit values of parameter K are unique (700Mev^3) except ^{75}As (430mev^3), ^{55}Mn and ^{88}Sr (1700Mev^3) ^{181}Ta and ^{197}Au (3500 Mev^3). Once the value of K has been so fixed the effect of the variation of the level density parameter 'a' for all residual nuclei corresponding to (n,p) reactions have been studied it has been observed that the change in the level density parameter 'a' (<10%) from the values given by the Huang and He-Ping, slightly effected the calculated excitation functions. These nuclei seem to exhibit structure effect which reflects upon the value of the level density parameter. As the physical nature of equilibration process does not allow for strong structure-sensitive transition rates, the structure-sensitive parameter a then causes apparent structure effects in the values of the parameter K.

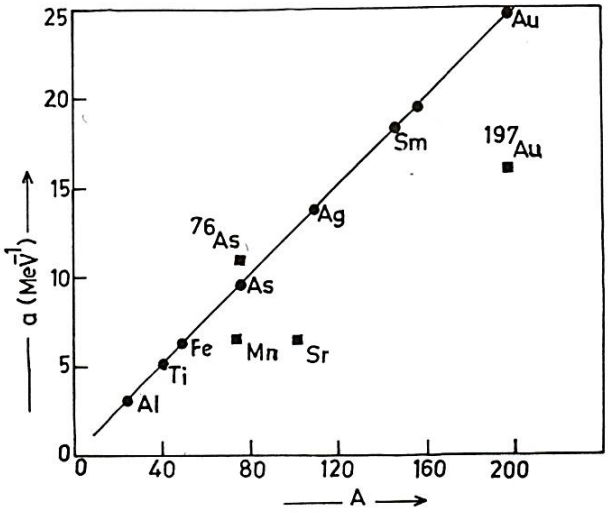

Fig. 2. The Huang–HePing estimates of the level-density parameter a_{HH} for nuclei studied in this work.

In Fig 2 we show a plot of the level-density parameters determined from Huang-HePing [8] for the nuclei studied. The Figs. 1 and 2 clearly show that whenever a_{HH} exhibits a marked departure from a, the best-fit value for the corresponding nucleus also shows a departure from the average best-fit value K=700Mev3, These departures are always in the opposite direction i.e., whenever a_{HH} is smaller than a the value of K for the corresponding nucleus is larger, and vice-versa.

Conclusions

In the present analysis it is concluded that the experimental data is well reproduced if one takes the semi-empirical value of level density parameters from the tables of Huang and He-Ping. The difference in the value of K obtained in this work is due to structure effect which reflect upon the value of the level density parameter a. Since a large atomic mass range has been observed (A= 23 to 197) in these calculations and a good agreement is found between the calculated excitation functions and the experimental data. Therefore it may be concluded that the present choice of the parameters is valid for all (n,p) reactions.

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