Available online at www.scholarsresearchlibrary.com

Scholars Research Library

Scholars Research Library

European Journal of Applied Engineering and Scientific Research, 2015, 4 (3):18-23
(http://scholarsresearchlibrary.com/archive.html)

ISSN: 2278 – 0041
CODEN(USA): EJAEAJ)

Experimental and theoretical excitation functions for ^{85}Rb(α,xn) in the energy range upto 60MeV

Anika Johari and A. K. Saxena

Department of Physics, N. M. S. N. Dass PG College, Budaun, UP, India

---

ABSTRACT

Excitation functions for the ^{85}Rb (α, xn) reactions are measured up to the energy range 60 MeV using the stacked foil technique. In the cases of the ^{85}Rb (α, xn) reaction pairs, the excitation functions for individual reactions were deduced using theoretical calculations. Excitation functions are also calculated theoretically using the compound-nucleus model with and without the inclusion of a pre-equilibrium emission. As expected, inclusion of a pre-equilibrium contribution based on the exciton model along with compound-nucleus calculations using the Hauser-Feshbach formalism reproduces well the measured excitation functions. Analysis of the data indicates a preference for a first chance neutron emission over charge d particle emission, and interesting trends in the energy and mass-number dependence of the pre-equilibrium fraction are observed.

Keywords: Rubidium, Excitation function, Alpha induced nuclear reactions.

INTRODUCTION

The rubidium has found applications in many fields of biology and of medicine. The most effective routes for their production are neutron capture reactions for β-emitters and proton induced reactions for neutron deficient radioisotopes. The element Rb has two stable isotopes: ^{85}Rb (72.165%) and ^{87}Rb (27.835%). Nuclear reaction data are important both for natural isotopic composition and also for highly enriched targets [1].

In α-induced reactions initiated by particles with energies of few tens of mega- electron volts, the reaction mechanism is considered to proceed through equilibrium (EQ) as well as pre-equilibrium (PE) emission of particles. The relative contributions of these processes depend both on the excitation energy and the projectile-target pair.

Blann [2-4] has pointed out the relative importance of reactions in which PE nucleons or clusters of nucleons are emitted preferentially in the beam direction with much higher energies than expected from the equilibrated compound system. Though the PE emission is still not well understood, it probably arises from the collisions between individual nucleons of the target and the projectile. At the first interaction a few nucleons may be emitted, the remaining undergo further scattering, some being emitted and others leading to the more and more intricate particle hole (p, h) states leading ultimately to the equilibrated compound nucleus (CN). Pre-equilibrium emission is characterized by the slowly descending tails on the excitation functions, forward-peaked angular distribution of particles, and stretched particle distribution in the angular-momentum space. The study of excitation functions may give information of considerable value about pre-equilibrium emission. Though a large body of experimental data on excitation functions exists in the literature, in most cases the experimental excitation functions measured by the

different groups differ from each other by large factors, or they do not cover the whole energy range of the excitation function. Further, the older data generally were measured using detectors of low resolution and thus contain larger errors. Moreover, different workers [5-9] have analyses their experimental data using different theories and different sets of parameters. With a view to studying pre-equilibrium emission, programs of the precise measurement of the excitation functions for a-induced reactions in a large number of nuclei, covering the whole range of A values, was undertaken [10-11]

The analysis of the measured excitation functions was done using a consistent set of parameters. As part of this programmed the excitation functions for the reactions ^{85}Rb (α, xn) were measured in the energy range up to 60 MeV using the stacked foil technique. In the literature Keiichi Shibata *et* al. [12] reported the cross-sections for the reactions ^{85}Rb(α, n)and ^{85}Rb(α, 2n) up to20 MeV, while Avinash Agrawal *et al.* [13] reported the excitation function for two reactions, i.e. ^{85}Rb(α, n)and ^{85}Rb(α, 3n), up to 50 MeV only. Since the Q -values of the reactions ^{85}Rb(α, n)and ^{85}Rb(α, 3n) are - 6.88 and – 20.5 MeV, respectively, excitation functions for these reactions have broad peaks at or below 30 MeV. As the pre-equilibrium emission is more effective in the higher excitation energy region, i.e., in the tail portion of the excitation functions, earlier measurements are not likely to give information about PE emission. In these measurements, excitation functions for the above reactions are measured up to 60 MeV to cover the tail portion. The analysis of the compound nucleus component in this work is made with the statistical Hauser-Feshbach (HF) model [14] and the PE contribution is simulated by employing the exciton model (EM) of Griffin [15].

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,

$$R_p = \sigma\Phi N_0 \text{ ..... } (1.1)$$

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 ^{85}Rb.

The expression for N0 can be given as,

$$N_0 = mNf/A_0 \text{ .....} (1.2)$$

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,

$$dR/dt = \sigma\Phi N_0 - R\lambda \text{ .....} (1.3)$$

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

$$W = R\lambda$$

$$W = \sigma\Phi N_0 [1-\exp(-\lambda t_1)] \text{ ..... } (1.4)$$

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,

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

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 $t_2 + t_3$.

$DA = \int dR$

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

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

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

Where μ – is gamma ray absorption coefficient

d - Is the thickness of target under investigation for my case ^{85}Rb.

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

$$DA = A / G\varepsilon\theta k \quad \text{.....} \quad (1.8)$$

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

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

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 [16] for compound nucleus decay and hybrid/geometry dependent hybrid (GDH) model [17] 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 [18]. 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 5 as was suggested by Blann [19]. 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

The measured excitation functions for the reactions ^{85}Rb (α, n), ^{85}Rb (α, 2n), ^{85}Rb(α, 3n) and ^{85}Rb(α,4n) are shown in Fig.(1) to Fig. (4).The theoretical calculation is done taking at the first the initial exciton number n_0 = 4 with configuration (2n + 2p + 0h), pld-level density parameter, A = acn/pld = 10.0.Later the values of the parameters are

changed to see the effect on calculated values of excitation functions. When we compare theoretical excitation functions of Fig.(1) and Fig.(2) which are calculated for different pld(level density parameters) without changing exciton number and also when we compare theoretical excitation functions of Fig.(3) and Fig.(4) which are calculated for different exciton number (exciton number is changed only for pre-compound nucleus) reaction without changing pld we conclude from these comparisons that even though changing of PLD-Level density parameter in calculating excitation functions of nuclear reaction has no appreciable effect special in excitation function of pre-compound nuclear reaction, there is slight change in case of compound nucleus decay. Change of exciton number (n_0) has a considerable change on excitation function of pre-compound nuclear reaction [20].

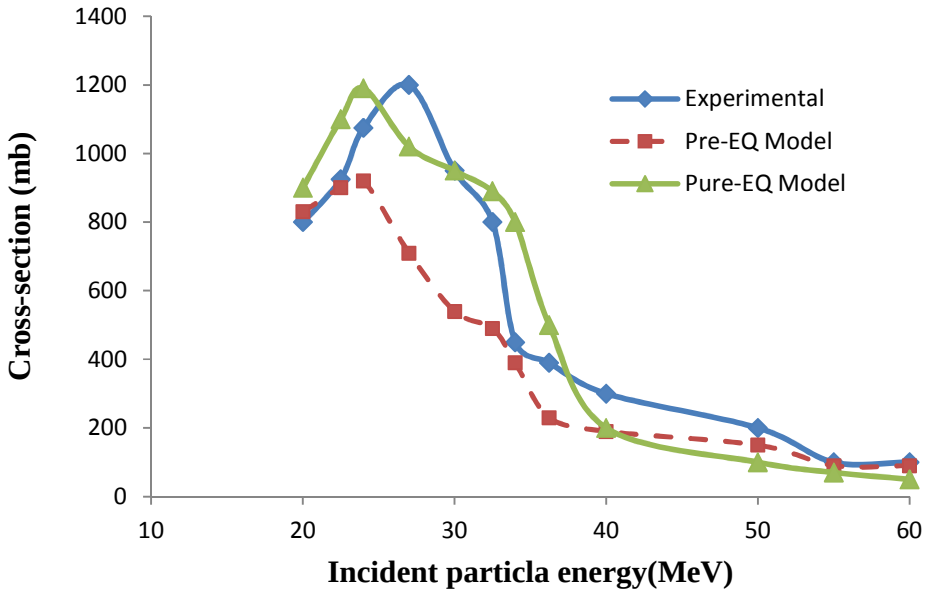

Fig.(1)- Graph of excitation function for ^{85}Rb(α, n)

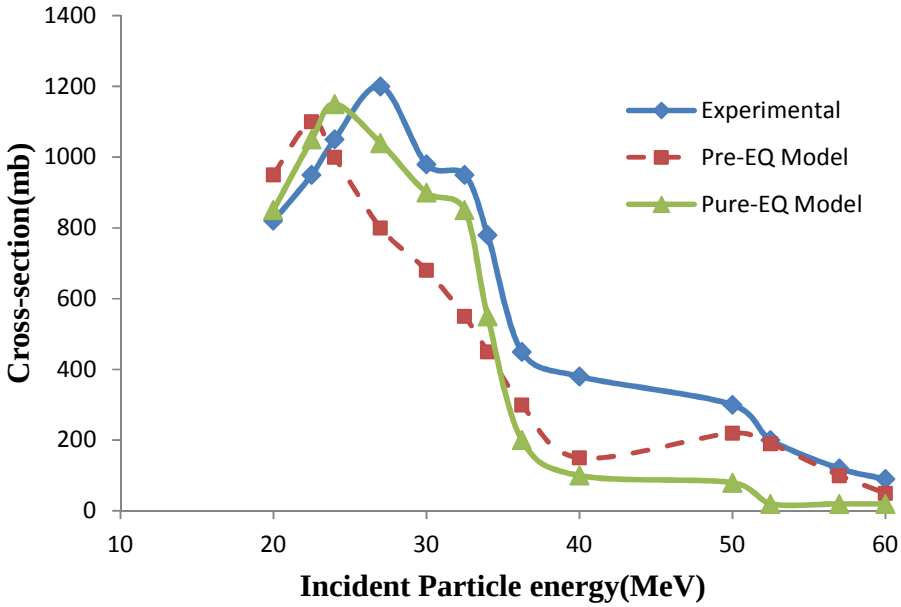

Fig.(2)- Graph of excitation function for ^{85}Rb(α, 2n)

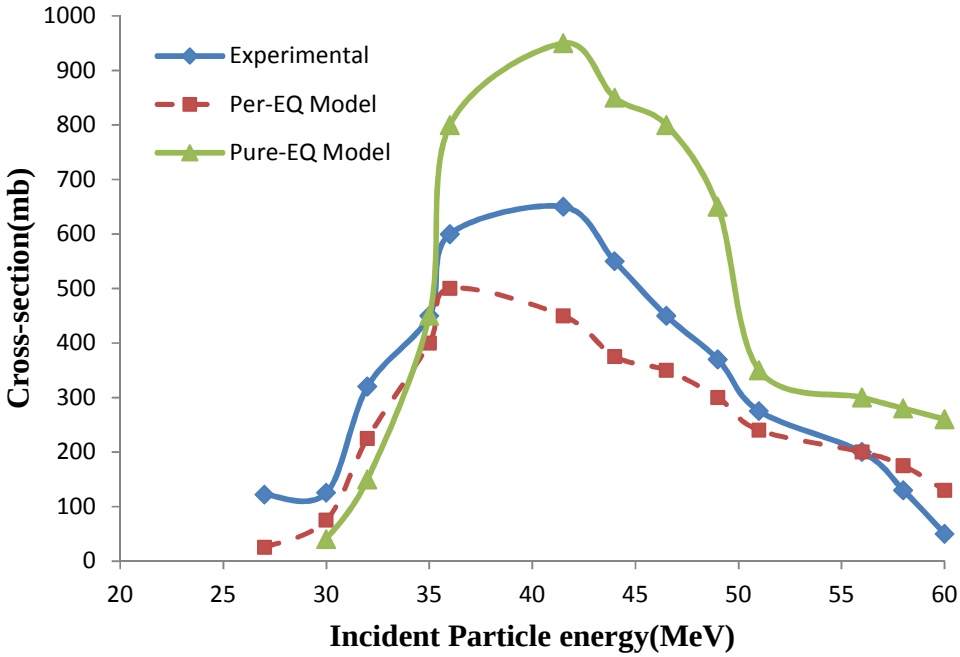

Fig.(3)- Graph of excitation function for ^{85}Rb(α, 3n)

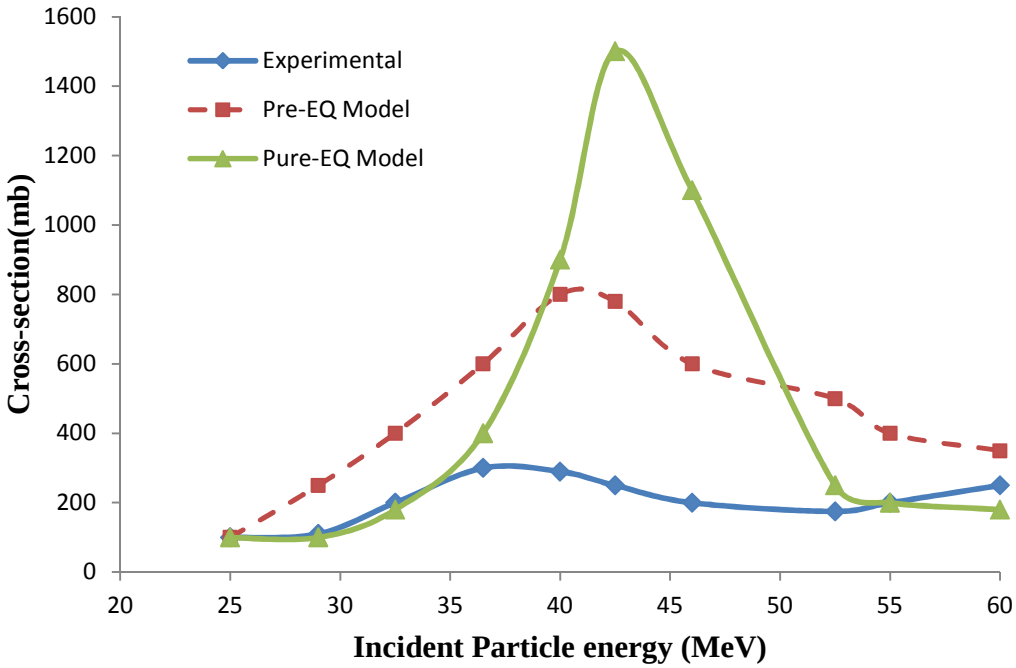

Fig.(4)- Graph of excitation function for ^{85}Rb(α, 4n)

CONCLUSION

From the present study of excitation function, it is concluded that, there is a qualitative/quantitative agreement between the experimental findings of the authors and the theoretical predictions made under the framework of geometry dependent hybrid model. It is quite evident from Fig.-(3) and Fig.-(4) that pre-equilibrium of multi-particles is necessary before the system is equilibrated. Therefore, the high energy tail observed in excitation functions as shown in Fig.-(1) and (2) can be explained only when the proper admixture of semi-classically treated pre-equilibrium emission followed by equilibrium decay is taken in to consideration.

REFERENCES

[1] [1] S.M. Judge, M.J.Wood, S.L.Waters, K.R.Butler, *Int. J. Appl. Radiat. Isot*, **1987**, 38,185.
[2] M. Blann and H.K.Vonach:*Phys.Rev.C*, **1983**, 28, 147.
[3] K.Chen,G.Friedlander,G.D.Harp and J.M.Miller:*Phys.Rev.* **1966**, 166, 949.
[4] M.Blann, *Phys. Rev.Lett*., **1972**, 28, 757.
[5] M.C. Lagunas-Solar, *Nucl .Instr. Meth.B*, **1992,** 69, 452.
[6] B.L. Zhuikov, V.M. Kokhanyuk, V.N. Gluschenko et.al, *Radiochemistry*, **1994**, 36, 548.
[7] T. Horiguchi, H. Noma, Y. Yoshizawa, H. Takemi, H. Hasai, Y. Kiso, *Int. J. Appl. Radiat. Isot.* **1980**, 31,141.
[8] D.R. Phillips, E.J. Peterson, W.A. Taylor, et al. *Radiochimica Acta* **2000**, 88,149.
[9] A.Hermann, M.Sonck, S.Tacaks, *Nucl.Instr. and Meth.B*, **2000,** 178, 163.
[10] T. Idoi, A. Hermanne, F. Ditroi, Z. Szucs et. al. *J. Nucl.Sci. and Tech*. **2002**, Supplement 2, pp. 1310-1313.
[11] I. Dillmann, M. Heil, F. Ka¨ppeler et al *PhysRev.C*, **2006**, 73, 015803.
[12] Keiichi Shibata, Akira Ichihara and Satoshi Kunieda, *J. Nucl. Sci. and Tech*., **2010**, 47, pp.11, 1055–1064.
[13] Avinash Agrawal et. al. *Ind.J. Pure andAppl. Phys*. **2003**, 41, pp. 829-832
[14] W. Hauser and H. Feshbach, *Phys. Rev*. **1952**, 87,366.
[15] J.J.Griffin, *Phys. Rev. Lett*. **1966,** 17,438.
[16] W.F.Woisskopf, D.H.Ewing, *Phys. Rev*.**1940**,57, 472.
[17] J.Ernst, R.Iowski, H.Klampil, H.Machner et. al. *Z.Phys. A*, **1982**, 308,301.
[18] W.D.Myers, W.J.Swiatecki, *Ark.Frys*.**1967**, 36, 343.
[19] M.Blann, *Phys. Rev. Lett.* **1971**,27,337.
[20] B. V. Zhuralev, A. A. Lychagin, N. N. Titarenko, V. G. Demenkov, and V. I. Trykova, *Physics of Atomic Nuclei* ,**2011,** 74, 3.