STUDY OF PROTON INDUCED REACTION -CROSS SECTION FOR VARIOUS ENERGIES ON YTTRIUM AND SCANDIUM

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IT IS A GREAT PLEASURE TO EXPRESS MY HEART FELT GRATITUDE TO ALL WHO DIRECTLY OR INDIRECTLY GAVE THEIR UNFORGOTTEN ASSISTANCE IN THE COURSE OF STUDY IN PARTICULAR TO MY ADVISOR AND INSTRUCTOR PROFESSOR ASHOK K.CHAUBEY WHO, SUGGESTED THE THSIS PROBLEM, IS KEEN ON PROVIDING THE NECESSARY REFERENCES AND PROPER FOLLOUP AND GUIDANCE DURING THE COURSE OF THE WORK.

FINALY FOR ALL-ROUNDED SUPPORTS THEY PRVIED ME, I WOULD LIKE TO THANK MY BELOVED KEBEBUSH BIRUK AND MY CHILDREN.

Abstract

Reaction cross section for (p, n) reaction in 45-Y and 89-Sc were studied for various incident energy of proton and experimental results have been compared with the theoretical calculated ones. Targets were isotopes of Yttrium and Scandium in the intermediate mass ranges .Excitation functions (EFs) for both reactions due to the various energies from the threshold have been studied. The theoretical analysis of the EFs has been done employing both semi-classical and quantum mechanical codes which include compound nucleus and pre equilibrium emission into consideration. Effects of various free parameters used in the calculations have also been discussed by the means of the graphs.

Introduction

This work is focused, basically on the analyses of reaction cross section for proton induced reaction at intermediate energies on intermediate masses of target nucleus. More experimental nuclear reaction data are needed to determine the optimum irradiation for the production yield of various isotopes .More recently these reaction cross sections are in demand in order to determine the transmutation probabilities for the proposed accelerator driven system [1].

Particle scattering has been one of the standard methods to probe the structure of the target nucleus .In a scattering process after an interaction with the nucleus, both the target and the projectile might have their internal energies unchanged.This is called an elastic scattering which data can be reproduced using optical model.

The optical potential is used to describe a complex many- body problem in terms of a one -body potential. Nuclei are described by a real potential while a complex potential is used to accommodate the removal of particles from the elastic channel in the scattering process.[2.3,4]

The target and the projectile can be left in the excited state .The projectile may be absorbed and different particles might be emitted, there occur a particle transfer between the target and the projectile and the target and/or the projectile might break up.All these nuclear reactions are inelastic reaction.[2,4,5]

The probability that the projectile will undergo an inelastic reaction with the target is termed as reaction cross section .These reaction cross section data are useful for different theoretical and practical purposes. From the point of view of application of nuclear data at intermediate energies nuclear data are steadily becoming of great interest to such fields as medicine, astrophysics, fusion, fission and accelerator driven systems for transmutation of nuclear wastes and energy conversion.

The computer codes ALICE-91[1] is used to reproduce data and do analyses. Analyses of reaction cross section for proton induced reaction on Yttrium and Scandium isotopes at various energies are done by comparing the results obtained using the computer code and the those from EXOFOR data library source[6] .These results are plotted simultaneously for comparison.

Chapter One: Nuclear reaction Theory

1-1-1 Nuclear Reaction

When a projectile such as proton, neutron, alpha particle, deuteron, etc come close enough to interact with the target nucleus either elastic or inelastic scattering may take place or one or more nucleons which are altogether different may be knocked out of the nucleus or the incident nucleon may have been captured and a gamma ray emitted. When the mass number and /or atomic number of the target nuclei change after the bombardment, we say that a nuclear reaction has taken place. Typically a nuclear reaction between a projectile 'a ' and a target 'X' which yield a residual nucleus 'Y' and an out going particle (ejectile) 'b' is written in equation form as[4,7,8]

$$X(a, b)Y \qquad \text{----------(1)}$$

Examples of nuclear reaction:

$$\left.\begin{array}{l} {}^{63}Cu(p,n){}^{63}Zn \\ {}^{63}Cu\ (p,2n){}^{62}Zn \\ {}^{60}Ni\ (\alpha, n){}^{63}Zn \end{array}\right\} \text{--(2)}$$

$${}^{60}Ni(\alpha, pn)\,{}^{62}Cu,\text{etc.}$$

1-1-2: Types of nuclear reaction

On the basis of projectile used ,the particle detected and residual nucleus, nuclear reaction are classified as scattering ,pick up and stripping ,capture, photodisintegration reaction heavy ion reaction, elementary particle reaction, fission fusion and compound nuclear reaction.[2,5,8,9]

a)Scattering reaction

In this reaction the projectile and the emitted particle are same (a=b and X=Y).

The scattering is called elastic if the residual nucleus is left in its ground state; and the reaction is called inelastic when the residual nucleus is left in its excited state. Further more in an elastic scattering the kinetic energies of the projectile and the emitted particle are the same in the center of mass system.

b)Inelastic scattering reaction

In this reaction the kinetic energy of the emitted particle is less than the kinetic energy of the projectile in the CM system .This energy of the projectile is shared between the target and the residual nucleus [2,10].

c)Pick up and stripping reaction

When the projectile and the target nucleus exchange nucleons and the projectile gains nucleons from the target the reaction is said to be pick up and if the projectile losses

nucleons(the target gains nucleons) the reaction is called stripping. Since both processes involve nucleons exchange between the target and the projectile the reaction also called nucleon transfer reaction[2].

Examles

$^{16}O\ (^{2}H,^{3}H)^{15}O$----------pickingup

$^{16}O\ (^{4}He,\ ^{2}H)^{18}F$ ----------stripping } ----------(3)

Both pick up and stripping reactions are direct reaction because the nucleons involved in the reaction process enter or leave the target nucleus without disturbing the other nucleons of the target nucleus. Interaction with only surface nucleons takes place.not with the nucleus as a whole.

d) Capture reaction

It is a reaction type in which emission of particles do not take place and the compound system emits gamma-radiation to be stable or the residual nucleus may give delayed emission of radiation .The reaction equation is [2,8]

$$X\ (a,\gamma)Y \quad \text{----------(4)}$$

Examples

$$^{1}P + {}^{25}Mg \rightarrow {}^{27}Al + \gamma \quad \text{---------- (5)}$$

$$^{1}n + {}^{115}In \rightarrow {}^{116}In^{*} \rightarrow {}^{116}Sn + \beta-$$

e)Photodisintegration

When γ-radiations fall on a nucleus a neutron may be emitted. Interaction of γ-ray with deuteron may yield a neutron and a proton. Thus the target nucleus is disintegrated into small fragments by gamma radiation, which is known as photodisintegration

Example

$$\gamma + {}^{2}H \text{ ---------- } {}^{1}n + {}^{1}H \text{ ----------(6)}$$

f)Heavy ion reaction

Heavy ions, beginning from alpha to ^{238}U can react to give heavy and /or super heavy new elements. When a nucleus captures a neutron it often tries to correct for its neutron excess by beta decay ,turning a neutron into a proton and thus creating an atom with atomic number greater than the initial value by one (Z+1). This suggests a way to create new elements of increased atomic number and to create even massive elements [11]

$^{1}n + {}^{238}U$---------- ^{239}Np-

$^{2}d + {}^{238}U$ ---------- $2(^{1}n) + {}^{238}Np$ ----------(7)

$^{239}Pu + {}^{4}He$ ---------- $^{242}Cm + {}^{1}n$,etc.

g) Elementary nuclear particle interaction

The interaction between one neutron and another neutron and that between one proton and another proton are the results of the exchange of neutral pions ($\prod^0$)between them The interaction between a proton and a neutron is the result of the exchange of charged pions ($\prod^+$ and $\prod^-$)between them .These interactions are called elementary particle[12] interactions.

$$\pi^- + {}^1p \rightarrow \pi^0 + {}^1n$$
$$\pi^0 + {}^+p \rightarrow k^+ + \lambda^0 \quad \text{----------(8)}$$

1-2:Nuclear cross section

1-2-1- Definition of Cross section

In nuclear physics, a measure of the probability that a given atomic nucleus will exhibit a specific reaction (absorption, scattering, or nuclear fission) in relation to a particular incident particle. Cross section is expressed in terms of area, and its value is chosen so that, if the bombarding particle hits a circular target of this size perpendicular to its path and centered at the nucleus, the given reaction occurs.

The unit of cross section is the barn, which equals 10^{-24} sq cm. Cross-section values for a given nucleus depend on the energy of the bombarding particle and the kind of reaction and are often different from the actual cross-sectional area (geometrical area) of the nucleus.

In nuclear and particle physics, the concept of a cross section is used to express the likelihood of interaction between particles. It can therefore characterize the probability that a particular nuclear reaction will take place, or the statistical nature of scattering events. Further more, it can be defined as the probability that an event may occur when a single nucleus is exposed to a beam of a particle of flux of one particle pr unit area; it is a chance that an event may occur when a single particle is shot perpendicularly at a target having one nucleus per unit area. Suppose that N number of each event is produced by incident particle of flux I. The probability of nuclear interaction, P is [2]

$$P=N/I \quad \text{----------(9)}$$

This can also be expressed by the ratio of effective area as seen by the projectile to the total area of the target;

$$P= (\sigma\, n\, A\, dx)/A \quad \text{----------(10)}$$

Equating the expressions for P yields

$$\sigma=N/(In\, dx) \quad \text{----------(11)}$$

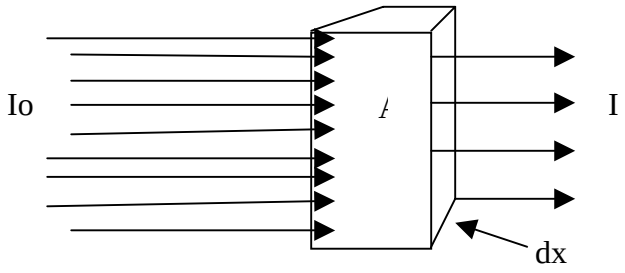


Fig. 1. Attenuation of incident beam

Where n=ρ Na /A –is the nuclear density,
Na-Avogadro's number of nuclei,
A -atomic weight and ρ-is the density of the target.
If Io is the incident flux of say proton beam as it penetrate a distance x in the target, the flux decreases by dI in passing through the element of distance dx given by

$$dI = -I \sigma n \, dx \quad \text{----------(12)}$$

Which follows $I=I_0 \exp(-\sigma n \, dx)$ ----------(13)

Thus the cross section can be measured experimentally by the attenuation of the incident beam.

1-2-2:Differential cross section

In scattering, a differential cross section is defined by the probability to observe a scattered particle in a given quantum state per solid angle unit, such as within a given cone of observation, if the target is irradiated by a flux of one particle per unit surface area[13]:

$$\left.\frac{d\sigma}{d\Omega} = \frac{\text{Scattered flux / Unit of solid angle}}{\text{Incident flux / Unit of surface}}\right\} \quad \text{------(14)}$$

The total cross-section is the integral of the differential cross section on the whole sphere of observation (4π steradian):

$$\sigma = \int d\Omega \, \frac{d\sigma}{d\Omega}. \quad \text{----------(15)}$$

A cross section is therefore a measure of the effective surface area seen by the impinging particles.

1-3:Energetic of nuclear reaction

a)Reaction energy(Q-value)

The nuclear disintegration energy (Q) of a given nuclear reaction defined by the equation

X (a, b) Y ----------(16)

equals to the change in the total kinetic energy of the system. Since the total mass and energy are conserved, we have

$$E_a + M_a C^2 + M_X C^2 = E_Y + M_Y C^2 + E_b + M_b C^2 \quad \text{-------(17)}$$

Where, Ea-is the kinetic energy of the projectile, $M_a C^2$ -is the rest energy of the projectile and similarly E_Y and $M_Y C^2$, E_b, $M_b c^2$ and $M_X c^2$.

The target nucleus X is assumed to be at rest (Vx=0, Ex=0). The Q-value is expressed as

$$Q = Ey + E_b - Ea = [(E_X + m_a) - (My + m_b)]\, C^2 \text{----------(18)}$$

The reaction energy, Q is positive for exoergic reaction and negative for endoergic reaction. The reaction energy can also be written as [18] (using conservation of energy and linear momentum)

$$Q = E_b\left(1 + \frac{m_b}{m_Y}\right) - E_a\left(1 - \frac{m_a}{m_Y}\right) - \frac{2[m_a m_b E_a E_b]^{\frac{1}{2}} \cos\theta}{m_Y} \text{----------(19)}$$

Since the Q equation is based on mass-energy conservation in a nuclear reaction it holds for all types of reaction. The energy of the ejectile, E_b as a function of the energy of the projectile for a fixed Q can be obtained by simplifying the quadratic equation in $\sqrt{E_b}$ from equation (22) and (23). Thus

$$E_b^{\frac{1}{2}} = \frac{\cos\theta\,[m_a\, m_b\, E_a]^2}{M_Y + m_a} \pm \frac{2[m_a m_b \cos^2\theta + (M_Y + m_b)[M_Y Q + (My - m_a)E_a]\}^{1/2}}{M_Y + m_a} \quad (20)$$

b)The threshold energy

The minimum energy for a nuclear reaction to occur is called threshold energy. This energy can be obtained by letting the second term of the right side of equation (20) equal to zero and solving for E_a(minimum value of the projectile energy) one can obtain the threshold energy for the reaction to be

$$E_{th} = \frac{-Q(M_X + m_a)}{M_X} \text{----------(21)}$$

(The assumption $Q >> M_x$ and $M_Y + M_a = M_x + M_y$ is used to obtain this result).

When E_b is positive and real, the reaction is energetically possible. E_b is imaginary, implying that no reaction takes place or no particle is emitted, i.e., the energy of the projectile is insufficient to start the reaction.

In an endoergic reaction the energy Q is needed to excite the compound nucleus sufficiently so that the CN will break up. Thus the projectile must supply this energy in the form of kinetic out of which some energy is used for excitation and the rest is distributed among the product of the reaction

1-4: Reaction mechanism

Nuclear reaction mechanism may be classified as direct reaction, compound nuclear reaction, and pre-equilibrium reaction.

1-4-1: **Direct reaction**

It takes place within the time the projectile takes to traverse the target nucleus (about 10^{-22}s). In this reaction the projectile interacts with a nucleon, a group of nucleons or the whole nucleus and emission takes place immediately.

When the projectile energy is high, it enters the nucleus of the target; as it interacts with one or more surface nucleons and some energy must be lost so that the emitted particle leaves the system with energy slightly less than that of the projectile such as (p,p'),(n,n'),etc.The interaction takes place with very small portion of the target nucleus (just outside the closed shell)and it takes very small time for the process in the order of 10^{-22}-10^{-23}sec.

The main characteristics of direct reactions are:

1) the presence of large number of high energy emitted particles in the spectrum
2) large number of forward peaked particles (small value of scattering angle in the order of 0-7^0)
3) Monotonic change of cross section with energy for the given channel with out distinct resonance, i.e. as the threshold energy of a certain reaction is reached the cross section decreases and this continues. Exchange of nucleon is the typical feature of direct reactions as in the case of stripping and pick up reaction. The angular distribution of direct reaction is explained by the modified plane wave born approximation calculations.

Elastic scattering is the simplest direct reactions which leave the target nucleus in its ground states.

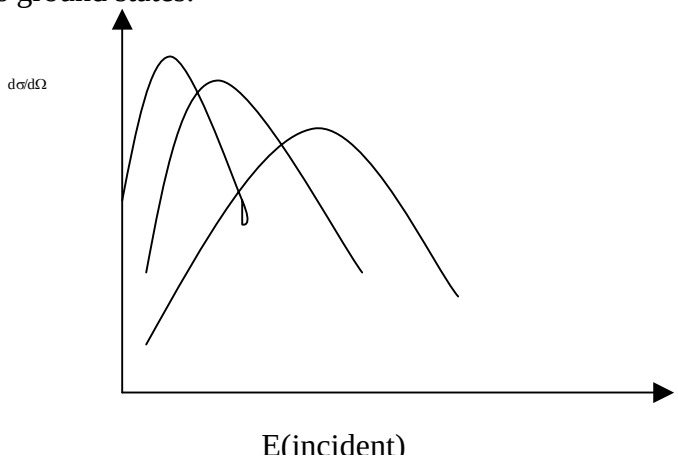


Fig.2 Monotonic change of cross section with energy in direct reaction

1-4-2: Inelastic scattering

Inelastic scattering most dominantly excites collective states, one nucleon transfer reactions excite single particle states, and multi-nucleon transfer excites cluster states. It is a scattering process that takes place in two ways; namly direct and compound nucleus formation processes and these are, respectively, called shape elastic and compound elastic scattering.

The direct process is too short (10^{-22}-10^{-23} s) while the compound nucleus process takes much longer time (10^{-16}-10^{-17} s).If many strongly overlapping resonances contribute and the cross section is average over sufficiently large energy intervals to include very many resonances, the two processes (shape & compound) are incoherent so their cross sections are calculated independently and added to fit the experimental data.

Shape elastic scattering takes place at all energies whereas compound elastic scattering is important at low energies .As the incident energy increases more channels for the decay of compound nucleus become open and so the flux through the elastic channel falls rapidly to zero .Since the coulomb barrier keeps low energy charged particles well away from all but the lighter nuclei, compound elastic scattering is mainly important for the neutron scattering at low energies.

A measurement of total cross section for each of these states, the angular distributions of the particles and of the polarization of the ejectiles allows one to study structures of these states.

1-4-3:Pre-equilibrium reaction

It can happen that a particle is neither emitted immediately after the interaction as in the direct reaction case nor after long time by statistical decay of the compound nucleus. The projectile may share its energy among a small number of nucleons which may further interact with other nucleons and during this cascade of nucleon –nucleon interaction through which the projectile energy is progressively shared among the target nucleons a particle may be emitted long before the attainment of statistical equilibrium. These processes are referred to as
pre-equilibrium reaction.

In the case of proton projectiles, protons are repelled by electrostatic field of the nucleus and are scattered elastically with a cross section, given by Rutherford formula in a direct reaction at low energy. Compound elastic scattering on light nuclei occurs if the proton energy is sufficient to surmount the coulomb barrier and interact with the nucleus.

Nuclear reaction cross section can be explained by a very simple model called optical model. In this model the interaction between the incident nucleon and the nucleus by one body –complex potential that depends mainly on the nuclear dimension and the nuclear shape.

After the first interaction the nucleon may leave the nucleus immediately by direct reaction or it may interact with a nucleon in the nucleus and start the cascade of nucleon-nucleon interaction from which pre equilibrium emission may occur.

During this cascade the energy shared among an increasing number of nucleons until eventually compound nucleus is formed. The CN may decay into elastic or any of the reaction channels that are allowed energetically. The shape elastic and compound elastic processes combine to give the measured elastic scattering cross-section.
Similarly the direct pre-equilibrium and compound nucleus processes combine to give the inelastic and all other non-elastic reaction.

At incident energies about above 10MeV it is possible for particle emission to take place after the direct stage, but long before the attainment of statistical equilibrium .Their time scale is between the direct (fast)and the compound nucleus formation(slow) reactions. .More direct evidence for pre-equilibrium reaction is provided by the energy spectra of emitted particles .Spectra produced by the proton energy of 29,39 and 62 MeV in elastically scattered by ^{54}Fe is a good example[2] .

Compound nucleus theory explains Maxwell distribution statistical equilibrium is established during the period of 10^{-15}-10^{-16}sec. As the lower states are having discrete values energy, circulation is large, level width is small so emitted particles will have discrete value of energy distribution on the low energy side of the spectrum; excited state is decaying to higher energy levels of daughter products where levels are closely spaced or overlapped so that emitted particles have got continuous energy distribution.

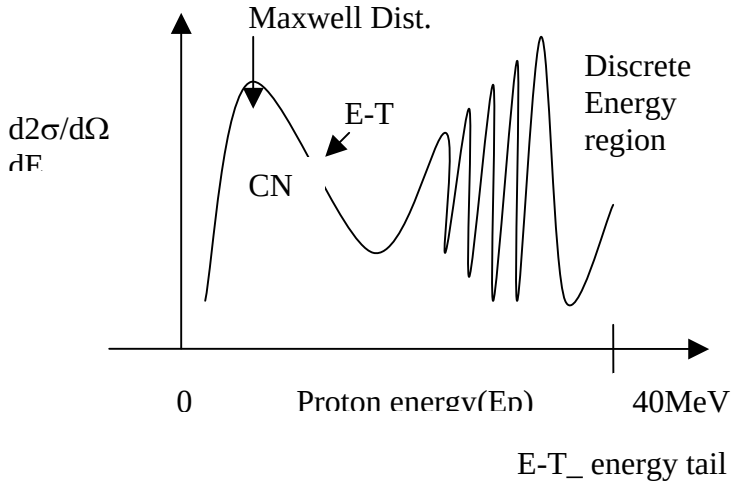


Fig.3 Energy spectrum of emitted particles

In Fig.3 plot of double differential cross section with respect to solid angle Ω and energy E the compound nucleus reaction at low energy and Maxwellian distribution of emitted particles, the high energy tail (pre –equilibrium reaction),the discrete energy of direct reaction products of emitted particles are shown.

The spectra has three distinct components:
A Maxwellian peak at low energy of proton corresponds to evaporation of particles from compound nucleus; a structureless continuum weakly depend on the ejectile energy and finally at higher energy sharp peaks corresponding to reaction to individual states of the target nucleus .Investigations showed that the Maxwellian peak is symmetric about 90^0 confirming its CN origin [2] .

The sharp peak at the higher energies corresponds to the selective excitation of states whose configurations depend on the particular reaction considered and show rapidly varying diffraction like forward peaked structure confirming that they come from a direct process.

The continuum has greater cross section at low energy than given by the compound nucleus reaction theory .At high energies the angular distribution of these

Pre-equilibrium particles are forward peaked but lucked the diffraction structure. They also do not show nuclear structure dependence characteristics of the particles emitted in the direct process.

Comparisons of cross sections for proton –induced reaction on heavy nucleus may be estimated from the maxima of the EF of the (p,xn),x=1,2,3,---- where CN evaporation dominates and the total cross section calculated from the optical model is another evidence for the presence of pre-equilibrium reaction.

The energy of the projectile is shared among the nucleons of the target by a cascade of nucleon-nucleon interactions that excite particle-hole state of increasing complexity.

A pre-equilibrium reaction corresponds to emission of an unbound particle from one of these particle-hole states when the composite nucleus is not yet equilibrated.

The cross section are those of reactions to a continuum of final state and the absence of fluctuations in this continuum spectra shows that (to a high degree of accuracy)there are no interference effects so that pre-equilibrium cross sections can be calculated by adding incoherently the cross sections from each stage of the nucleon-nucleon interaction cascade.

1-4-4:Pre-equilibrium reaction model, Exciton model

The exciton model of Griffin provided the first explanation of the spectral shape of the nucleons emitted with continuous spectra for energy in excess of those characteristics of equilibrium evaporation .Several years after the exciton model was proposed its basic premise was extended to permit a priori prediction of the magnitude as well as the spectral shapes of these compound or pre-equilibrium particles

In this model the composite state are characterized by the number of excited particles and holes called exciton at any stage of the N-N cascade. In the case of nucleon induced reaction, it is a two particles and one hole configuration due to the interaction of the incident nucleon and the nucleon of the target which is excited from the state below to a state above the Fermi energy [2, 16].

$$\text{Exciton} = n = p + h \quad \text{----------(22)}$$

Selection rule on the course of cascade of interaction:

$$\Delta p = 0, \pm 1, \quad \Delta n = 0, \pm 1, \text{ and } \Delta n = 0, \pm 2 \quad \text{----------(23)}$$

The two possible sequences of events in the exciton model are:

1) the incident particle as well as the excited particle are all bound,
2) the incident particle and one struck nucleon which attained a high energy are in the continuum..

The exciton model assumes that

1) at each state of the cascade all the state with the same configurations and the same total energy are equiprobable and

2) at each state of the cascade all the processes which may occur are equiprobable .

The first assumption gives immediately the energy distribution of excited states. The number dNp(p,h,E.ε) of excitons with energy between ε and ε+dε in a configuration of any p, particles and h holes with total energy E is given by the state between the number of states in which one particle has energy between ε and ε+dε and the remaining p-1 particles and h holes have energy E-ε and the number of states of the particles p & h hole configuration at the energy E. If the density of state [2, 16] is given by

$$\rho_{p,h}(E) = g\frac{(g^{E})^{p+h-1}}{p!h!(p+h-1)!} \quad \text{----------(24)}$$

Then $\rho_{p-1,h}(E-\varepsilon)$ is the density of state of a single particle states (in which one usually assume the Fermi model expression g= 3A/ ($2E_F$), dNp(p,h,E, ε) is given by

$$\text{dNp (p, h,E, } \varepsilon) = \frac{\rho_{p-1,h}(E-\varepsilon)gd\varepsilon}{\rho_{p,h}(E)} \quad \text{----------(25)}$$

The second assumption simplifies the evaluation of the cross section reaction. The probability per unit time for the emission into the continuum of an unbound particle v with energy ε called escape width and spread width for nucleon –nucleon interaction which spreads the excitation energy among an increasing number of exciton are decay rates for the corresponding processes are related by the equation

$$\Gamma = W\hbar \quad \text{---------- (26)}$$

When a particle is emitted a residual nucleus with p-1 excited particles and h holes is created .If $\rho_{p,}h(E)$ and $\rho_{p-1,}h(u)$ are the composite and the residual nucleus states the escape width (from detailed balance principle) for emission of a particle v with energy ε and ε+dε and any possible directions is[2])

$$\Gamma(v,\varepsilon/E,p,h)d\varepsilon = \hbar w(v,\varepsilon_v/E,p,h)d\varepsilon_v$$
$$= \frac{\hbar}{\rho_{p,h}(u)}\left(\frac{u_v\sigma_{inv}(\varepsilon_v)}{V}\rho_{p-1,h}(u)\rho_{\varepsilon}(\varepsilon)d\varepsilon_v\right) \quad \text{----(28)}$$

where v is the emitted particle velocity the cross section with subscript inv is the inverse process cross section and

$$\rho_{\varepsilon}(\varepsilon_v) = \frac{1}{\pi^2\hbar^3}\frac{(2Sv+1)m_v\varepsilon_v V}{V_0} \quad \text{----------(29)}$$

is the density of translational continuum states of the emitted particle as predicted by the Fermi gas model, V is the laboratory volume .

From time dependent perturbation theory, the simplest estimate of the spread width is

$$\Gamma_{nn'}(E) = 2\pi\left|\overline{M}\right|^2\rho_f \quad \text{----------(30)}$$

for a transition from a state of configuration of n exciton to that of n' exciton.ρ_f is the density of states which may be excited in the N-N interaction and M is the transition matrix element whose module is given by[2,16]

$$\left\langle\left|M\right|^2\right\rangle = KA^{-3}E^{-1} \quad \text{----------(31)}$$

and the value of K varies from 400-700MeV.

At high excitation energies for not too low energies and two –body interaction

n'=n or n=± 2, and with the condition $\Gamma_{n,n+2} >> \Gamma_{n,n} >> \Gamma_{n,n-2}$ due to the rapid increases of the final density of state with the exciton number .The dominant width ($\Gamma_{n,n+2}$)is given by

$$\Gamma_{n,n+2}(E) = 2\pi\left|\overline{M}\right|^2 \frac{g^3E^2}{2(n+1)} = 2\pi\left|\overline{M}\right|^2 \frac{(3A/2\varepsilon_F)^3E^2}{2(n+1)} \text{ ----------—(32)}$$

where $\left|\overline{M}\right|^2$ from large body data analysis ,its mass –energy dependent average ,is expressed by

$$2\left|\overline{M}\right|^2 = KA^{-3}E^{-1} \text{ ----------(33)}$$

At high excitation energy, the estimation of the dominant width is obtained from the evaluation of he number of collision per unit time of a nucleon having velocity v as:

$$W(v) = \frac{v}{\overline{\lambda}} = v\rho\overline{\sigma} \text{ ----------(34)}$$

Where $\overline{\lambda}$ is the nucleon mean free path, ρ is the nuclear density and σ is the nucleon-nucleon cross section averaged over the relative energy of the nucleon and any other possible nucleon considers the contribution of all the interactions which may occur.

1-5:Compound nucleus reaction:-

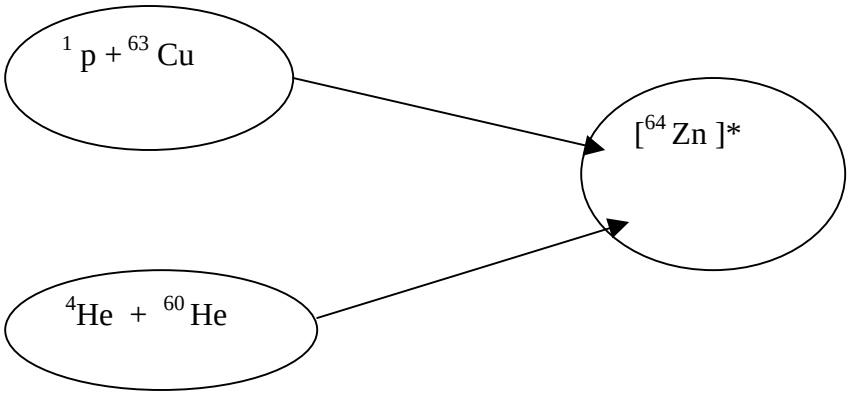
In this reaction, the projectile is captured by the target nucleus and its energy is shared among the nucleons of the compound nucleus until its energy reaches a state of statistical equilibrium. After a time much longer than the transient time a nucleon or a group of nucleons near the surface may, by statistical fluctuation, receive enough energy to escape just as a molecule may evaporates from a heated drop of liquid .This energy is near the smallest possible energy and for charged particle it is the height of coulomb potential, at the nuclear surface, known as the coulomb barrier.

1-5-1:Theory of compound nucleus

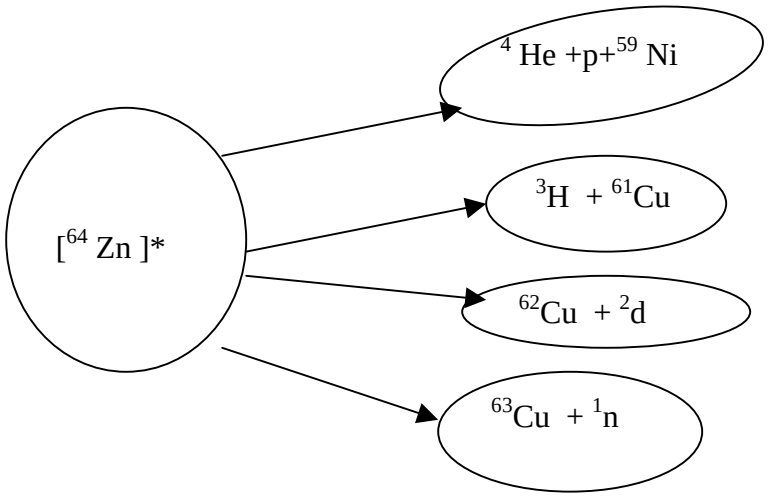
When a projectile strike a target nucleus and the two combine to form a new nucleus, a compound nucleus(CN) is formed .The CN mass number and atomic number are respectively equal to the sum of the mass and atomic numbers of the projectile and the target .The CN has no memory of its formation .Since its nucleons are mixed together, regardless of origin and energy brought into it by the incident particle is shared among all of the nucleons.

$$
\left.
\begin{array}{llllll}
^{14}\mathrm{N} & + & ^{1}\mathrm{n} & - - - - - & \rightarrow & [\,^{15}\mathrm{N}[^{*} \\
^{12}\mathrm{C} & + & ^{1}\mathrm{P} & - - - - & \rightarrow & [\,^{13}\mathrm{N}]\ ^{*} \\
^{12}\mathrm{C} & + & ^{2}\mathrm{H} & - - - -- & \rightarrow & [\,^{14}\mathrm{N}]\ ^{*} \\
^{11}\mathrm{C} & + & ^{3}\mathrm{H} & - - - - - & \rightarrow & [\,^{14}\mathrm{N}]\ ^{*} \\
^{11}\mathrm{Be} & + & ^{3}\mathrm{He} & - - - & \rightarrow & [\,^{14}\mathrm{N}]\ ^{*} \\
^{10}\mathrm{B} & + & ^{4}\mathrm{He} & - - - & \rightarrow & [\,^{14}\mathrm{N}]\ ^{*}
\end{array}
\right\} \qquad (35)
$$

Compound nuclei are excited by an amount equal to at least the binding energy of the incident particle in them.C.N have life time of the order of 10^{-16}sec or so which while too short as to prevent actually observing such nuclei, are nevertheless long relative to the 10^{-21}sec or so required a nuclear particle with an energy of several MeV to pass through a nucleus [2,9] .The compound nucleus may decay in one or more different ways depending up on the excitation energy. Thus decay takes place independently to the formation of CN.
Fig.4 formation of CN and its decay



a)Formation of the CN



b) Independent decay of the CN

If the excitation energy is a constant, the mode of formation does not affect the mode of decay. The formation of C.N has an interesting interpretation on the basis of the liquid drop nuclear model. In terms of this model an excited nucleus is analogous to a drop of hot liquid with the binding energy of the emitted particle corresponding to the heat of vaporization of the liquid molecule .Such a drop of liquid will eventually evaporates one or more molecules there by cooling down.

The evaporation process occurs when statistical fluctuation in the energy distribution within the drop cause a particular molecule to have enough energy to escape .Similarly CN persists in its excited state until a particular nucleon or group of nucleons momentarily happen to have a sufficiently large fraction of the excitation energy to leave the nucleus The time interval between the formation and decay of a C.N fits very well with this picture.

1-5-2: Resonance in Excited state of compound nucleus

Information about excited states of nuclei can be gained from a nuclear reaction as well as from a radio active decay .The presence of excited state can be detected by the pulse peak in the cross-section vs energy curve of a particular reaction.

Such a peak is called resonance .A compound nucleus more likely to be formed when the excitation energy provided exactly matches with one of the energy levels than if the excitation energy have some other values. The uncertainty principle in the form

$$\Delta E\, \Delta t = \hbar \quad \text{----------(36)}$$

Where,$\Delta E = \Gamma$,level width and $\Delta t = \tau$(mean life time of the CN, enable us to relate $\Gamma$and τ as

$$\tau = \frac{\hbar}{\Gamma} \quad \text{----------(37)}$$

1-5-3:Coulomb barrier potential

Every nucleon surrounded by an electrostatic potential that opposes the entry and escape of the positively charged particles (proton, alpha, deuteron ,etc.).Neutrons which are neutral particles are not faced coulomb barrier and accordingly are more readily absorbed and emitted by nuclei than are charged particles

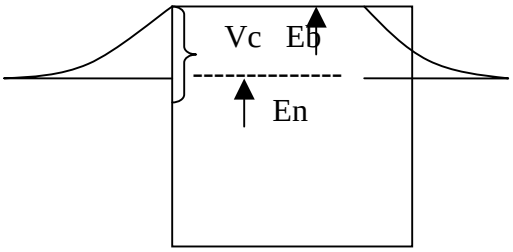


Fig 5 :Proton and neutron potential energy near a nucleus Eb-proton barrier enrgy ,En-neutron binding energy

The coulomb barrier is about 3MeV for carbon ,13MeV for silver and 20MeV for lead nuclei. When a proton approaches a nucleus, it faces with a potential hill and

1) classically it would have to posses at least as much the energy as the height of the barrier in order to enter the nucleus,
2) quantum mechanically, proton can get in with energy less than this (less probability which is different from zero).

Thus the height of coulomb barrier represents effective threshold energy for nuclear reaction initiated by the charged particle (proton).

The proton cross-section increases with increasing energy because of the presence of coulomb barrier while the neutron cross section decreases with increasing energy ,because the likelihood that a neutron be captured depends up on how much time is spent near a particular nucleus which is inversely proportional to its speed The coulomb barrier also impedes the emission of a charged particle from the CN .

1-5-4:The compound nucleus reaction cross-section

When a projectile enters a nucleus, it interacts with the nucleons of the target nucleus. Large number of collisions may occur in which there is exchange of energy and momentum and strong mixing of incoming particle with nucleons of the target nucleus. As compound nucleus sate is excited states and this gives resonance when the energy brought in by the projectile plus the captured Q-value coincides with the energy of one of its states. These states are excited one by one as the energy of the proton increases and each corresponds to a resonance. The Subsequent emission of a neutron with energy equal to that of the incident one requires a concentration of excitation energy on a single particle through a complicated process which needs a long time (10^{-15} s).

The formation of compound nucleus (C.N) requires several stages:

1) in the case of a nucleon-induced reaction, firstly, the excitation of a single particle is the doorway state, for instance a single –particle state in the potential well.
2) then following the two –body interactions between the incident nucleon and nucleons of the target nucleus the excitation of the particle-hole of increasing complexity called hall way takes state place
3) finally, as a result of a long sequence of two body nucleon-nucleon interactions the long-lived compound nucleus.

A low resolution measurement shows the door way states, a higher resolution the hall way state and the highest resolution the individual compound nucleus state. In the course of nucleon –nucleon interactions all the states corresponding the various configurations are excited with equal probabilities.

Eventually when the C.N is created, all the possible states corresponding to a given quantum numbers E, J M, II from the single particle to the complex many particle states are equally probable. The C.N is then in statistical equilibrium since the probability of occurrence of a given configuration is simply proportional to its statistical weights.

The reaction cross section (corresponding to the decay of the C.N into different channels from the initial one) [2] is given by

$$\sigma_R = \sigma_{CN}(\alpha)\frac{\Gamma_R}{\Gamma} \qquad \text{----------(38)}$$

This equation shows that the cross section at resonance is proportional to the width to dictate in the particular channel considered.

A resonance occurs in a partial wave and this has the scattering amplitude [4,17]

$$f_l(\theta) = \frac{1}{2ik}\sum(2l+1)(\eta_l - 1)P_l(\cos\theta) \quad \text{----------(39)}$$

At the resonance energy Es the cross section is maximum and this occurs when $\delta_l = \frac{\pi}{2}$.

The shape of the resonance can be found by expanding δ_l around $\pi/2$:

$$\delta_l = \pi/2 \ \text{- (Es-E)}\frac{\partial\delta}{\partial E} + \ldots \quad \text{----------(40)}$$

where $\frac{d\delta}{dE}$ determines the sharpness of the resonance .

Let's define $\Gamma = 2(\frac{d\delta}{dE})^{-1}$,----------(41)

where the factor 2 is introduced to insure that the width is defined in the usual way .

From equation (43) and(44) one can obtain

$$\tan(\delta_l) = \frac{\Gamma}{2}/(Es - E)) \text{----------(42)}$$

So that the total scattering crosses section around the resonance becomes [2,4]

$$\sigma_{el} = \int |f_l(\theta)|^2 \, d\Omega = \frac{\pi}{k^2}(2l+1)\frac{\Gamma^2}{(Es-E)^2 + \frac{\Gamma^2}{4}} \text{----------(43)}$$

This is the famous Breit -Wigner formula for the cross section of a single isolated resonance in the elastic channel for the orbital angular momentum l when all other channels are closed.

At large distances from the nucleus where nuclear forces are negligible (also l=0) the asymptotic form of the wave function is given by [4]

$$\psi = \frac{1}{2ik}(e^{-ikr} - \eta_0 e^{ikr}) = \frac{u(r}{r}) \text{----------(44)}$$

The reaction cross section contribute from l=0 term is

$$\sigma_R = \pi R^2(1 - |\eta_l|^2) \text{----------(45)}$$

Let's define the logarithmic derivative of the internal and external wave functions in the regions r<R and r>R at r =R as

$$f_0 = \frac{R}{u}\frac{du}{dr}$$ ----------(46

One easily can find the expression for η_0 as

$$\eta_0 = \frac{f_0 + ikR}{f_0 - ikR} e^{-2ikR}$$ ----------(47)

The reaction cross section becomes

$$\sigma_R = \frac{\pi}{k^2} \frac{-4kRimf_0}{\text{Re } f_0^{\,2} + (imf_0 - kR)^2}$$ ----------(48)

Reaction takes place when $imf_0 < 0$. Since the reaction cross section is maximum when $\eta_0 = 0$, to a first approximation ,let's assume the expression for f_0 will be

$$f_0 = -a(E - Es) - ib$$ ----------(49)

where Es is resonance energy and a and b are positive real parameters whose values are deduced from the best fit of the data.Thus the reaction cross section becomes

$$\sigma_R = \frac{\pi}{k^2}\{\frac{4kR\frac{b}{a^2}}{(E - E_s)^2 + [(b - kR/a)]^2}\}$$ ----------(50)

If the reaction cross section has resonance at E=Es with FWHM equal to Γ_s then

$$\sigma_R(\text{Es-}\frac{\Gamma_s}{2}) = \sigma_R(\text{Es+}\frac{\Gamma_s}{2}) = \frac{\sigma_s(Es)}{2}$$ ---------- (51)

and hence $\Gamma_s = 2\frac{b + kR}{a}$ ---------- -(52)

The elastic scattering cross section ,taking only l=0 term is

$$\sigma_{el} = \frac{\pi}{k^2}\left|1 - \eta_0\right|^2$$ ---------- (53)

$$= \frac{\pi}{k^2}\left|2^{2ikR} - 1 - \frac{2ikR}{\text{Re } f_0 + (imf_0 - kR)}\right|^2$$ ---------- (54)

$$= \frac{\pi}{k^2}\left|2^{2ikR} - 1 - \frac{2ikR/a}{(E - Es) - i(b + kR)/a)}\right|^2$$ ---------- -(55)

here $\sigma_{el} = \frac{\pi}{k^2}\left|A_{pot} + A_{res}\right|^2$ ----------(56)

where the amplitudes of scattering potential and resonance are defined, respectively, as

$A_{pot} = \frac{1}{2ik}(e^{2ikR} - 1)$ and ----------(57)

$A_{res} = \frac{1}{2ik}\left(\frac{2ikR/a}{(E - Es) + i(b - kR)/a}\right)$ ----------(58)

If Ares>>Apot, the elastic scattering cross section reduces to the compound elastic cross section given by

$$\sigma_{ce} = \frac{\pi}{k^2}\left[\frac{4k^2R^2/a^2}{E - Es)^2 + ((b + kR)/a)^2}\right] \text{----------(59)}$$

The compound nucleus cross section is equal to the sum of the reaction and the compound elastic cross section

$$\sigma_{CN} = \sigma_R + \sigma_{el} = \frac{\pi}{k^2}\frac{4kR(b + kR)/a^2}{(E - Es)^2 + [(b + kR)/a]^2} = \frac{\pi}{k^2}\frac{2kR\Gamma_s/a}{(E - Es)^2 + \Gamma_s{}^2/4} \quad \text{----------(60)}$$

At E=Es, $\sigma_{el} = \sigma_\alpha(\alpha) = \sigma_{CN}\frac{\Gamma_{s,\alpha}}{\Gamma_s}$ ----------(61)

And $\Gamma_{s,\alpha} = 2kR/a$ and $\Gamma_{s,R} + \Gamma_s - \Gamma_{s,\alpha}$ =2b/a ----------(62)

If α is the incident channel, the CN the compound elastic and the reaction cross section as a function of the Γ_s at the S^{th} resonance are

$$\sigma_{CN} = \frac{\pi}{k^2}\frac{\Gamma_s\Gamma_{s,\alpha}}{(E - Es)^2 + \Gamma_s{}^2/4} \quad \text{----------(63)}$$

$$\sigma_{cel} = \frac{\pi}{k^2}\frac{\Gamma_{s,\alpha}{}^2}{(E - Es)^2 + \Gamma_s{}^2/4} \quad \text{----------(64)}$$

and $\sigma_R = \frac{\pi}{k^2}\frac{\Gamma_{s,\alpha}\Gamma_{s,R}}{(E - Es)^2 + \Gamma_s{}^2/4}$ ----------(65)

The spin consideration of the projectile and the target i and I need multiplying the equations of cross section above by $\frac{2J+1}{(2i+1)(2I+1)}$ which is the probability that the two randomly directed i and I are coupled to give J [2.4,16]

Chapter- two:-Principle of measurement and Experimental technique

2-1 Principle of measurement

The reaction cross-section is related to the probability of the removal of particles from the elastic scattering channel. Consequently, an experimental determination of reaction cross-section requires a measurement of

1) the number of incident particles
2) the number of particles in the residual beam that passes the target without interaction and
3) the number of elastically scattered particles.

Due to infinite range of coulomb potential, there is no distinct boundary between unaffected by the target and those elastically scattered in the forward direction. Different experimental arrangements vary in the way incident particles are counted before interaction and in the way, elastically scattered particles are separated from those non-elastically scattered.

Another method is to deduce reaction cross-section from a series of measurements of stopping reaction probabilities in detector

Apparatus for the reaction cross-section measurement consists of three parts[8]:

a) the particle identification before the target
b) the target system itself and
c) the particle identification after the target, including the energy measurement of the outgoing particles. The target must be sufficiently thin so that the energy specification of the projectile is not significantly compromised by the energy loss of the projectile in the target.

The identification of the incoming particle is done by a transmission telescope that consists of a large number of transmission scintillators. Series of target-in and target –out measurements are used to measure the decreases in the number of non-reacting particles due to the presence of the target.

The stopping reaction probability is in essence to calculate the reaction cross-section from the stopping reaction probability in the detector material in the energy determining detectors. If the full energy of a particle deposited in the detector material, the detector produces a pulse from which the energy of the particle can be determined. If a particle undergoes a reaction in the detector, the output pulse is deduced from the changes (the reaction may consume part of the projectile energy).

A nuclear reaction occurs when a projectile strikes a target nucleus .The typical Experimental arrangement for the study of nuclear reaction is an accelerator producing a collimated incident beam, a target containing the nuclei being studied and detectors of the emerging particles (ejectiles)[8]

.The beam of accelerated particle is deflected by a magnet along different beam lines with different equipment such as

a) Scattering chambers, which contain the target and detector, which measure the energy distribution of ejectiles for various emission angles with respect to the incident beam.
b) Multidetector arrays which measure the coincident emission of several ejectiles and/or gamma rays and their correlation
c) time of flight lines which measure the time taken by the ejectiles to go from the target to the detector ,thus measuring the velocity and

d) Magnetic spectrographs, which measure with extreme accuracy the ejectiles energy

The quantity analyzed can be the excitation function, namely the angle integrated cross- section for (p, xn) reaction as a function of projectile (proton) energy, the scattering cross section, the reaction cross section and/ or the total cross section This is very easily measured when the reaction produces radioactive residue, by detecting the activity induced in the target and/or a set of absorbers down stream from the target. This gives the number of residues which are produced from which one deduces the total cross section for the (p, xn) reaction.

2-2 Experimental technique

The samples of Yttrium and Scandium materials have been prepared and the stacked foil activation technique would have been used. The samples are deposited on aluminum backing of 6.75mg/cm^2 using vacuum evaporation technique [18].

The aluminum-degraders of suitable thickness are placed between the samples to cover broad energy range. The foils will separately be irradiated by proton beam of various energies at the variable energy cyclotron. The proton beam currents monitored directly on the faraday cup. Then off-line counting of irradiated samples carried out using HPGe γ-spectrometer detector having known calibration and geometry dependent efficiency coupled to multichannel analyzer. The intensity of γ –lines from each residual nucleus can be measured and the cross section at different energy would be computed.

Chapter Three

The computer code ALICE-91 and model calculation and formulation

3-1 ALICE- 91 model calculation

Computer codes are programs used to calculate numerically the statistical weights of nuclear interactions and the interaction products which are the results of reaction mechanisms using modified and improved models on time that verifies the theoretical predictions and fit the experimental data.

The computer codes are thus designed to simplify the complicated numerical analyses of nuclear reactions at different stages of interaction and decay processes. ALICE-91,ACT, exiton,etc are some of the computer codes which are designed for the prediction and analyses of the excitation functions energy spectrum of reaction products of different type at different stages. In this paper ALICE_91 code is used to obtain the prediction of excitation function for the compound nucleus proton induced reaction on Yttrium and Scandium nuclei, using the Weiss Kopf-Ewing models [5]while the pre-equilibrium components is simulated employing the geometric dependent hybrid model(GDH) of Blann[15].

At different stages of nuclear reaction the evaporation of particles (neutrons protons alpha particles deuteron and their combination), depending up on the excitation energies, the binding energy of the composite system energy spectrum of the reaction products cross section of different sorts and distribution of particles can be calculated.

In ALICE-91 code the level densities of nuclei involved in the evaporation chains the mean free path multiplier and the initial exciton number are important parameters. The level density which affects the shape and the height of the excitation functions is given by [8]

$$a=A/K \qquad \text{----------(1)}$$

where A-is the mass number of the compound system and K is a constant which may be varied to match the excitation function.

The initial exciton configuration of the compound system is defined by its initial exciton number [2] n_0 as

$$n_0= p + h \qquad \text{----------(2)}$$

where p-is number of interacting particles and h-is the number of holes created and a value $n_0=3$ is taken for the calculation because it is reasonable to assume that an incident proton in its first interaction with the target nucleus excites a particle above the Fermi level leaving a hole behind, i.e., in all two particles and one hole giving the initial exciton state.

- The mean free path (MFP) in this code is generated using free nucleon –nucleon scattering cross section .The calculated MFP for two –body residual interaction may differ from the actual MFP. To account for that the parameter COST is provided .IN this computer code, the MFP is multiplied by (COST+1).

Thus by varying the parameter COST the MFP can be adjusted to fit the experimental data .A choice of K =9.0, n_0 = 3 and COST=10 for proton induced reactions on Yttrium

and Scandium gave reproduction of the measured EXFOR (2004) data of EFs for charged particles induced reaction for the reaction $^{89}Y(p,xn)^{8x}Zr$ and $^{45}Sc(p,xn)^{4x}Ti$.
Most of the parameters employed in the EFs analyses are calculated internally by the computer code[6]):

- the Q- value for the formation of C.N and the proton binding energy in the evaporation chain, have been calculated using Myers-Swiatechi/Lysekil mass (msl) formula.
- the pairing energy δ is calculated from the back shifted model [1]. In this calculation pairing energy is zero for even-even nuclides - δ for odd-even and -2δ for odd-odd nuclides respectively with δ having expression

$$\delta = 11/\sqrt{A} \quad \text{----------(3)}$$

- the inverse cross section are calculated from the optical model subroutine, which uses the Bechetti and Greeness optical parameters[2].
- (2) The intra-nuclear transition is done keeping the mean free path to be a constant at 3.0.the level density parameter influence the shape as well as the height of the calculated excitation function [16].

3-2 Formulation

The equation of reaction cross section developed for the experimental observation can be obtained as follows;
Consider a constant proton beam of flux ϕ and a sample having initial number of nuclei N_0, irradiated for time $t_1$and the activity in the sample is recorded for time t_2 after a lapse of time t_3 by a detector of geometric dependent efficiency Gε .The reaction cross section is given by [16]

$$\sigma_r = \frac{C_p \lambda \exp(-\lambda t_3)}{N_0 \phi \theta k \, G_\varepsilon \{(1-\exp(-\lambda t_1))(1-\exp(-\lambda t_2)\}} \qquad \text{-----(4)}$$

where C_p –is the count under photo peak.
λ –is the decay constant of the residual nuclei
Θ -is the branching ratio of the particular radiation
K –is the γ-ray absorption correction for the material of the sample ; and is given by

$$K=[1-\exp(\mu d)]/\mu d , \quad \text{----------(5)}$$

where μ is the γ-ray absorption coefficient for the sample and d is the thickness of the sample.

Chapter Four: Results data analysis and conclusion

The theoretically calculated results are obtained using the modified computer code ALICE-91 for the compound reactions of proton induced (p,n),(p,2n),(p,3n) and (p,4n)reaction for Yttrium and (p, n) & (p,2n) for Scandium and are plotted as shown on below and next pages.

Table 1:**Estimated data for ^{45}Sc(p,n)^{45}Ti reaction cross section**

Proton energy(MeV)	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Cross section(mb)	185	225	300	335	345	360	365	370	350	275	200	140	110	80	60

Table 2:**Estimated data for ^{45}Sc(p,2n)^{44}Ti reaction cross section**

Proton energy(MeV)	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85
Cross section(mb)	18	24	42	68	55	50	35	28	23	18	17	16	16	15	15

Table 3:**Estimated data for ^{89}Y(p,n)^{89}Zr reaction cross section**

Proton energy(MeV)	10	12	14	15	16	17	18	21	24	27	30
Cross section(mb)	731	902	884	753	732	302	280	124	85	62	35

Table 4:**Estimated data for ^{89}Y(p,2n)^{88}Zr reaction cross section**

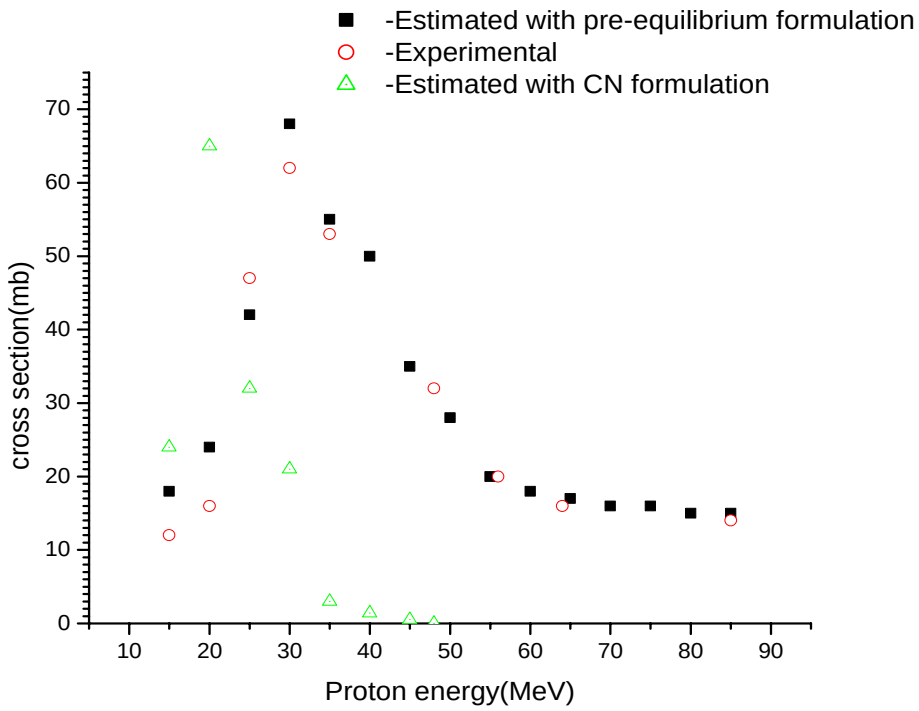
Proton energy(MeV)	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85
Cross section (mb)	45	348	1200	1000	495	170	95	92	90	90	90	90	90	90	90

Table 5:**Estimated data for $^{89}Y(p,3n)^{87}Zr$ reaction cross section**

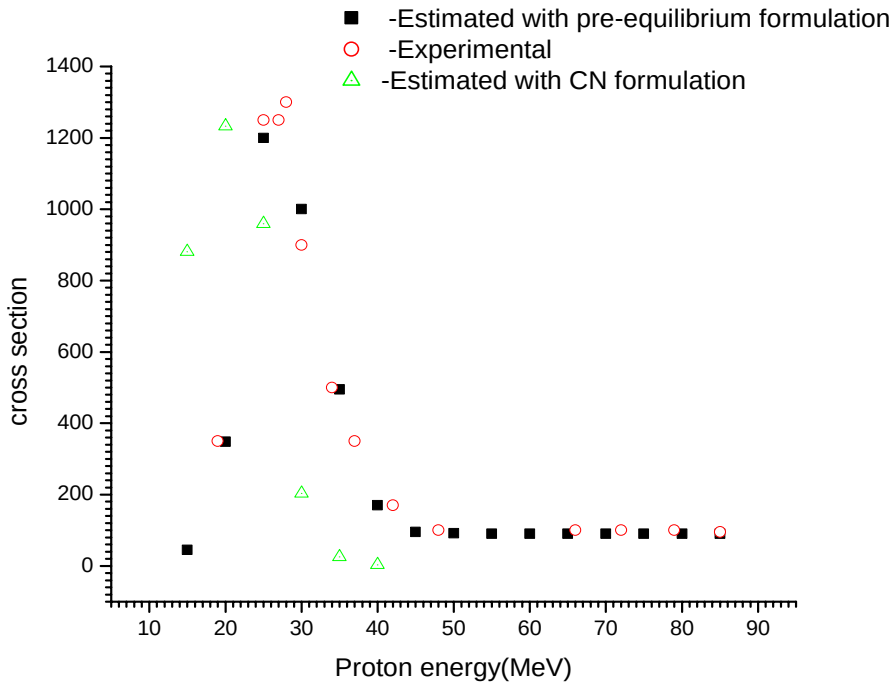
Proton energy(MeV)	30	35	40	45	50	55	60	65	70	75	80	85
Cross section (mb)	55	125	390	305	180	100	72	58	42	39	37	32

Table 6:**Estimated data for $^{89}Y(p,4n)^{86}Zr$ reaction cross section**

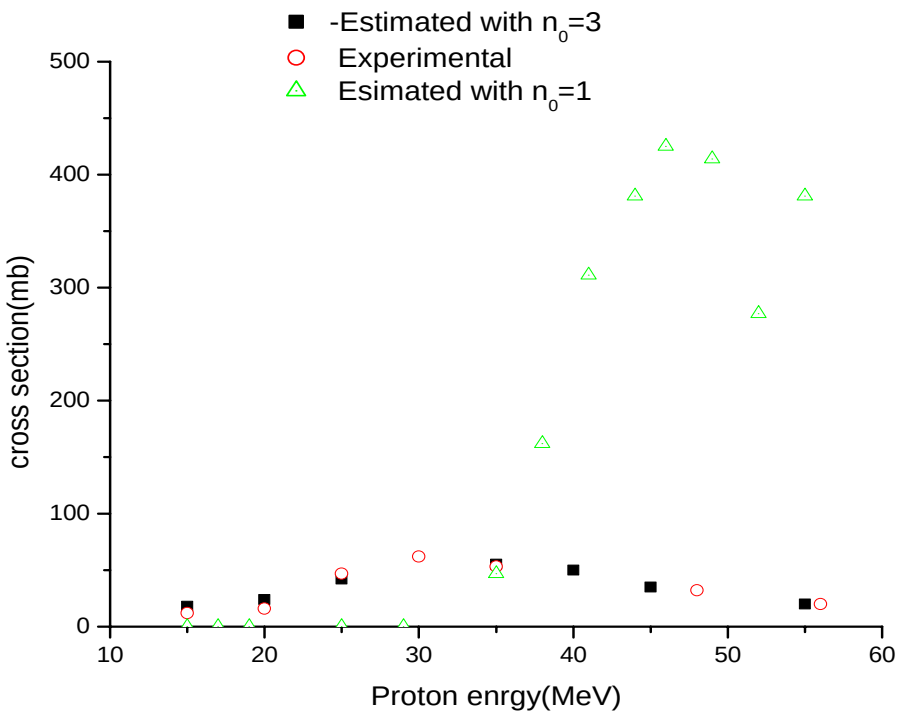
Proton energy(MeV)	30	35	40	45	50	55	60	65	70	75	80	85
Cross section (mb)	0	18	24	35	54	86	72	48	42	34	28	16



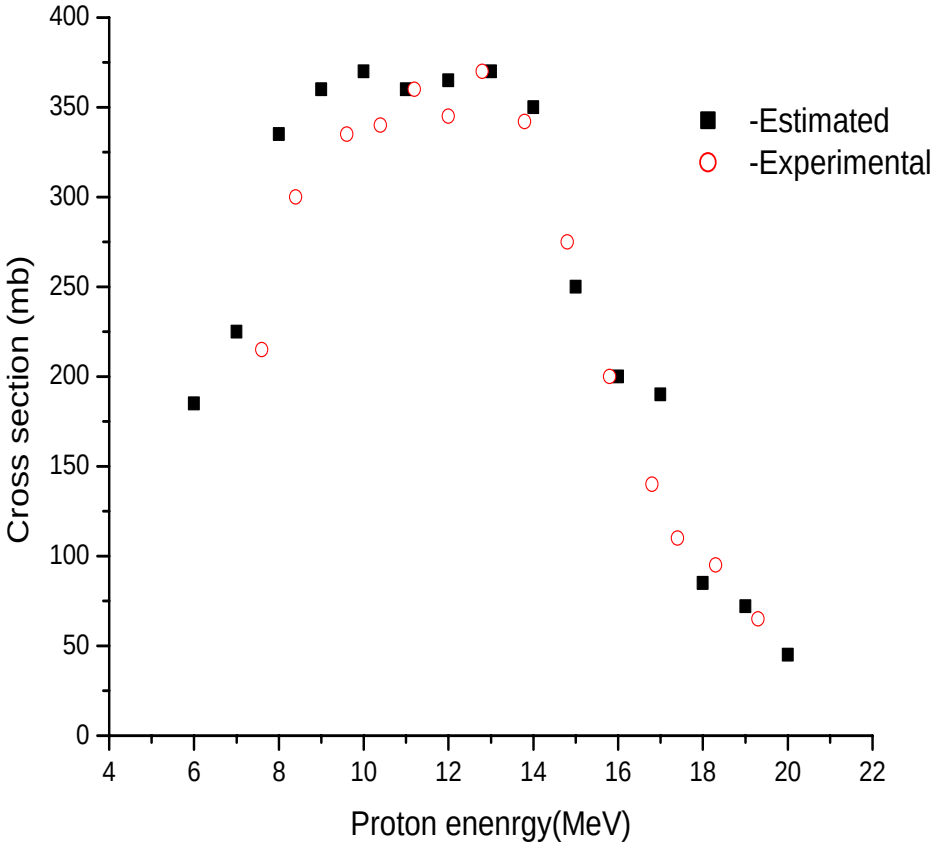
Graph 1: Comparison of EF for Y(p,2n) reaction with CN and pre-equilibrium formulation estimated curves and experimental observation



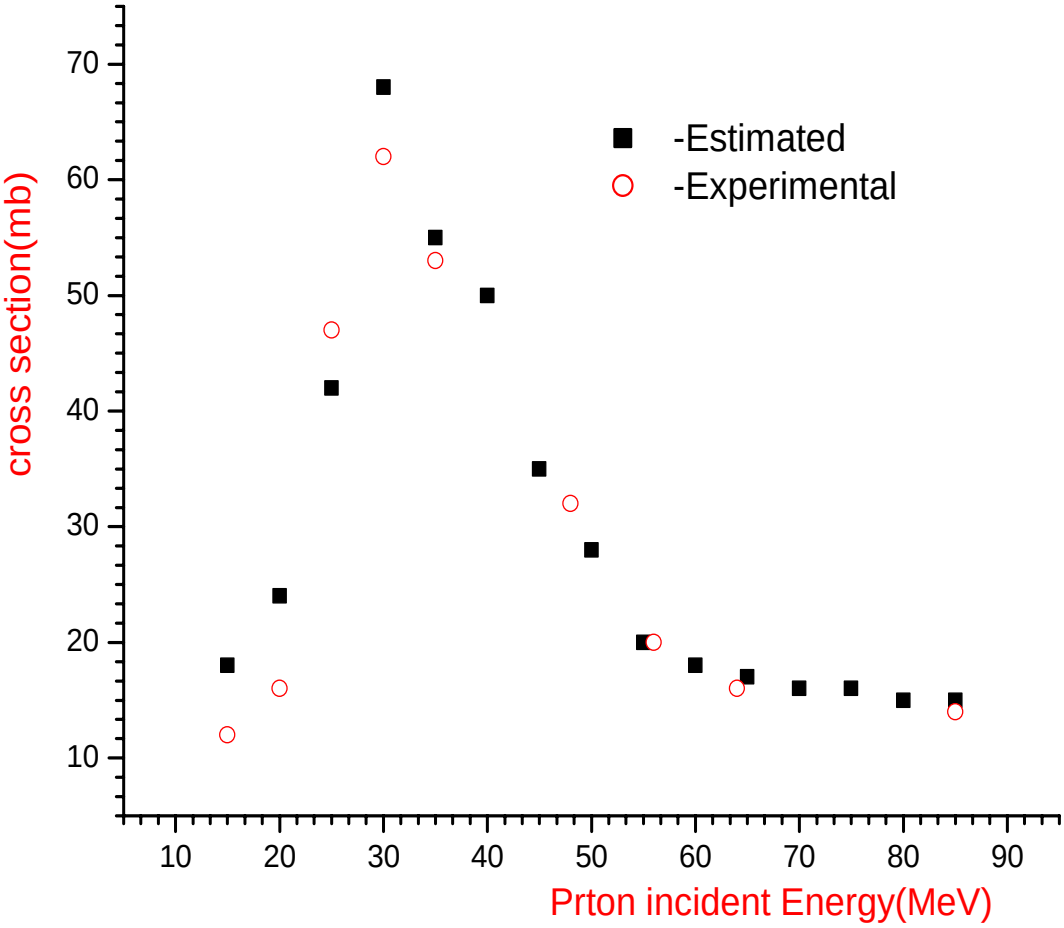
Graph 2: Comparison of EF for Y(p,2n) reaction with CN and pre-equilibrium formulation estimated curves and experimental observation



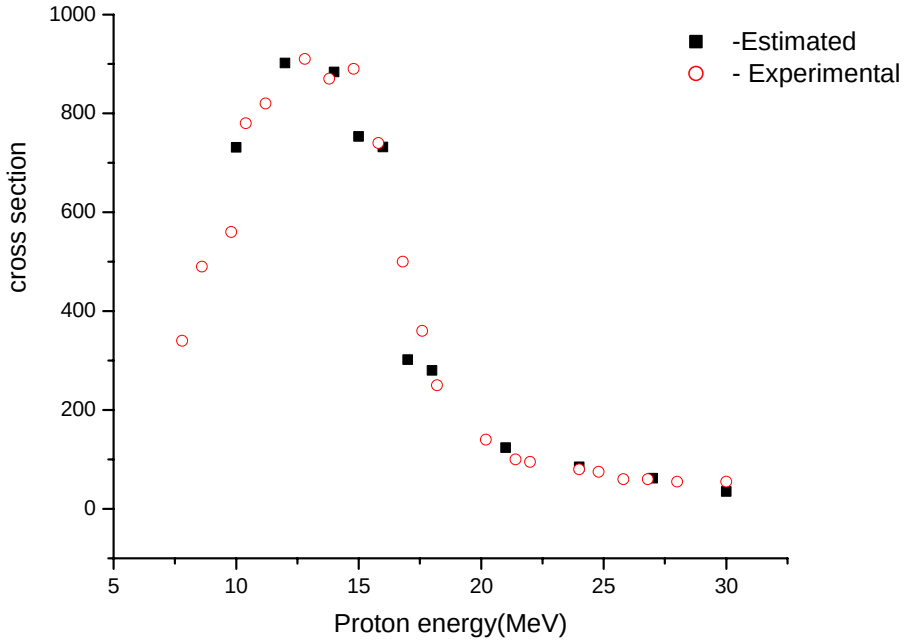
Graph 3:Comparison of EFs for Sc(p,2n)Ti reaction on Exciton number n_0=1 and n_0=3 in the given energy range



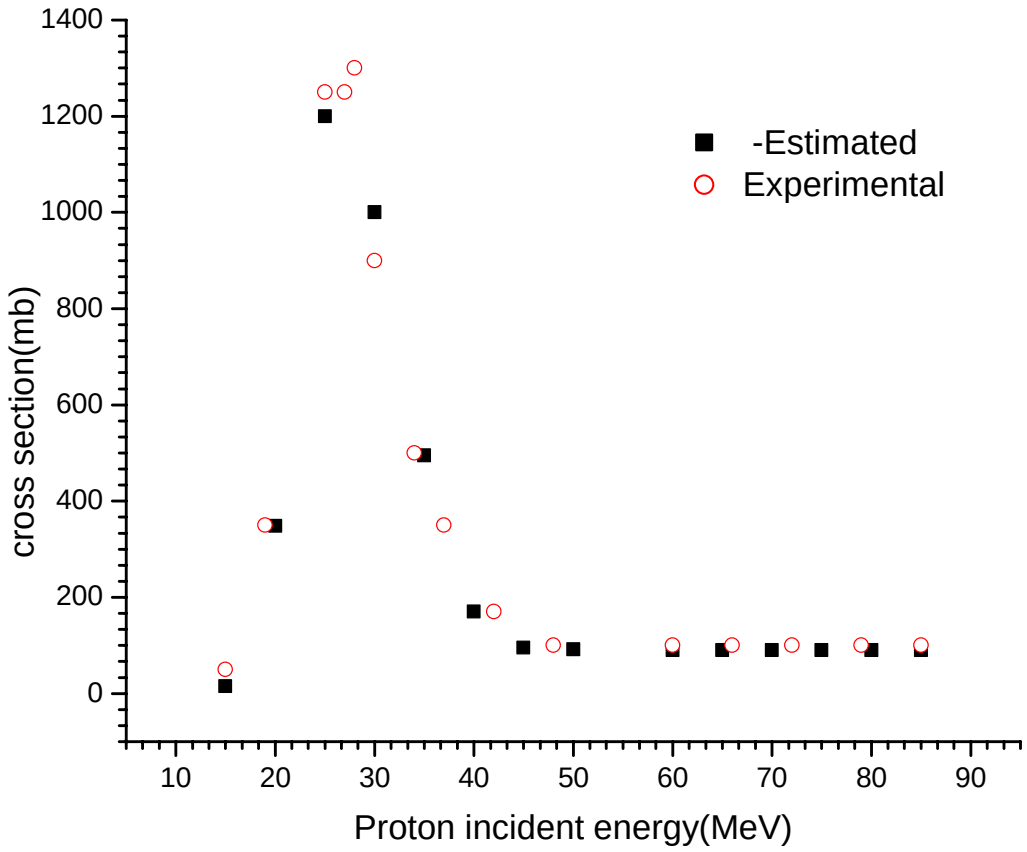
Graph 4: EF for $^{45}Sc\ (p,n)\ ^{44}Ti$ reaction



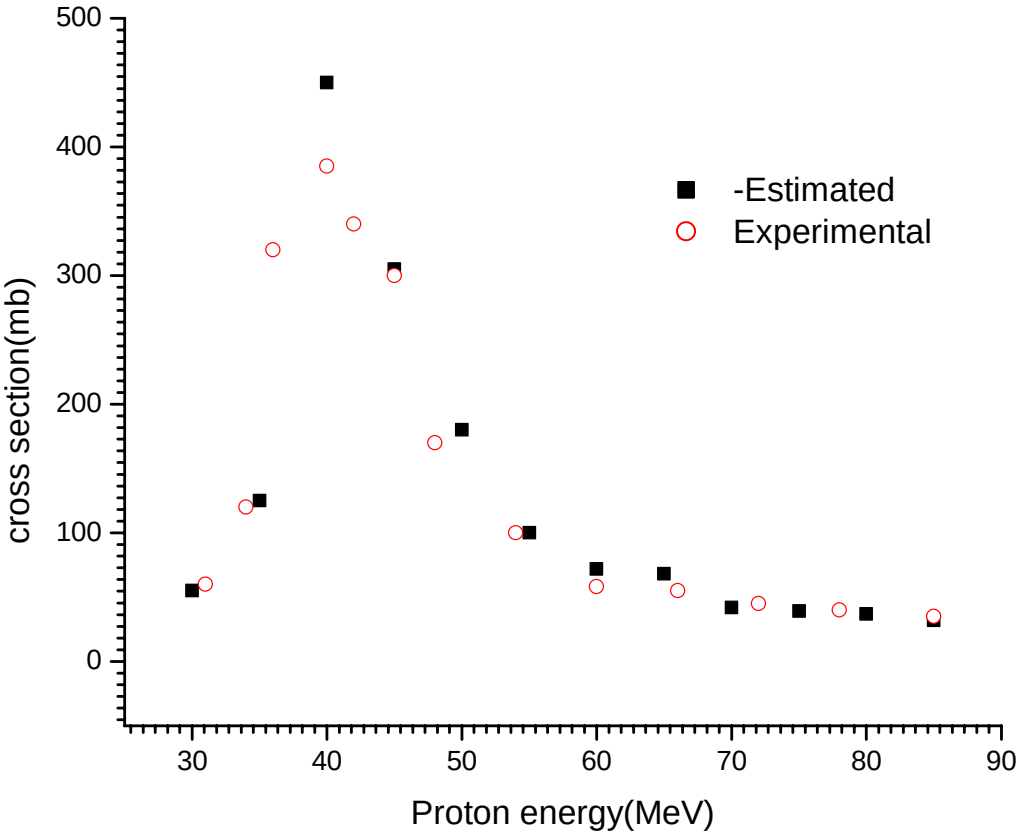
Graph 5: EF for $^{45}Sc\ (p,2n)\ ^{44r}Ti$ reaction



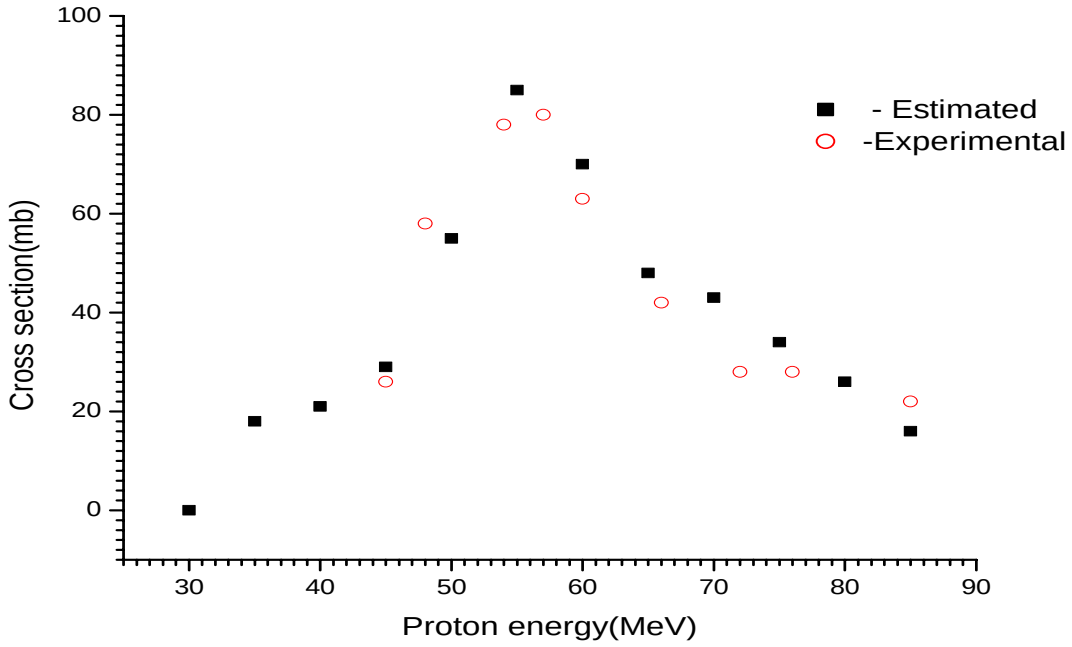
Graph 6: EF for $^{89}Y\ (p,n)\ ^{89}Zr$ reaction



Graph 7: EF for $^{89}Y\ (p,2n)\ ^{88}Zr$ reaction



Graph 8: EF for $^{89}Y(p,3n)^{87}Zr$ reaction



Graph 9: EF for $^{89}Y(p,4n)^{86}Zr$ reaction

Conclusion

Results of the present work are summarized on Graphs 1-9,where experimental and theoretical best fit excitation function graphs for ^{89}Y(p,n)89Zr, 89Y(p,2n)88Zr,89Y(p,3n)87Zr,89Y(p,4n)86Zr and ^{45}Sc((p,n)45Ti,45Sc(p,2n)44Ti are plotted .The high energy tail portion of the excitation functions can be satisfactorily reproduced if the pre-equilibrium components are included in the calculations. The compound nucleus calculation is not found to fit the experimental results for higher energies of incident protons .This shows that the CN theory does not explain well the cases of high incident energies of the projectile. This is shown by the first two graphs (1 and 2). Thus for higher energies pre-equilibrium formulation is used in this work. Further a choice of initial exciton number n_0=3 is the best fit for the model calculation. Thus for proton induced reaction experimental results fit the estimated theoretical values of reaction cross section with initial exciton number n_0=3 ,but not with exciton number n0=1and this is shown by the third graph. With a suitable choice of other parameters such as the level density of the code Alice -91 gives more or less good description of the data in the peak region as well as the tail regions from the point of view of the CN mechanism and pre-equilibrium reaction mechanism .The data obtained through the code calculations are almost similar to those recorded in the EXFOR data table[6].For the EFs of the two targets the calculated values are above the experimentally observed ones for low energy incident protons and at high energies the experimental results fall slowly .The shape and height of the EFs are in good agreement with the experimental observations so far done by different experimentalists.

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DECLARATION

I hereby declare that this thesis is my original work and has not been presented for degree in any other University. All sources of materials used for the thesis have been duly acknowledged.

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