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Neutron Yield Estimation For Some Medium Isotopes Nuclei Due To Proton, Alpha And Neutron Reactions For Energy Range (10 - 50) MeV

A Thesis
Submitted to the Council of the College of Education For Pure Science Ibn Al-Haitham University of Baghdad in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy in Physics

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بسم الله الرحمن الرحيم

﴿ وَعَلَّمَكَ مَا لَمْ تكُنْ تَعْلَمُ وكَانَ
فَضْلُ اللَّهِ عَلَيْكَ عَظِيماً ﴾

صدق الله العلي العظيم

(سورة النساء: 113)

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Raafat

Dedicated to

- ***My Father***
- ***My Mather***
- ***My Wife***
- ***My Sons***

Raafat

Supervisor's Certification

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Abstract

Isotopes have a great importance in many fields such as research, industrial, medical and other. Some of them need isotopes with long half life or short half-life with high neutron yield or less for them. So this work included the study of the nuclear properties for nine medium elements (Ca, Sc, Ti, Ni, Cu, Zn, Zr, Nb and Mo), from each element we choose 10 isotopes, so the total are 90, their masses numbers were between (41 to 96), this study included the calculations of the Q-value reaction, threshold energy, reduced mass, separation energy of neutron and the binding energy for nuclear reactions , Ca(α,n)Ti , Ni(α,n)Zn ، Zr(α,n)Mo , Sc(p,n)Ti , Cu(p,n)Zn , Nb(p,n)Mo , Ti(n,n)Ti Mo(n,n)Mo and Zn(n,n)Zn for the isotopes of the above elements, also we calculated the stopping power by using a (SRIM 2013), then the neutron yield was calculated from theoretical equations depending on most recent cross-sections (2010.2012), as well as this study focused on the extraction of a set of uniform empirical equations to calculate the neutron yield in directly for (α, n) and (p, n) reactions for these elements, and each of them includes 10 isotopes so the total reactions are 60. The result of neutron yield for these equations was in a good agreement with theoretical value which is calculated from the theoretical equations. These set equations with their coefficients were put within the MATLAB program, it was designed for this purpose and by depending on the element type, the type of reaction and incident particle energy to find the neutron yield for any isotope, their mass number is between (40-100) for energy range within the (15-50) MeV. This program can be developed to include a greater number of elements with their isotopes and for larger energy range.

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Chapter One

Introduction

(1-1)Nuclear Reaction :

When two nuclear particles approach each other within a distance of 10^{-15} m, they experience a strong nuclear interaction. This process is called a nuclear reaction and involves a redistribution of energy and momentum [1], also the collision between two-particle, projectile *a* and target *X* resulting , in general , the products *Y* and out going particle *b* of these reactions are governed by the conversation laws [2]. Nuclear reaction can be shown in a form similar to chemical equation for which invariant mass must balance for each side of the equation[3], [4]. A typical nuclear reaction is written as following [5]:

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

For mechanism of the nuclear reaction, there are three important models which can be used to describe those interactions of energetic particles with the target nucleus where a new nucleus is formed [6].

a- Compound nucleus reaction

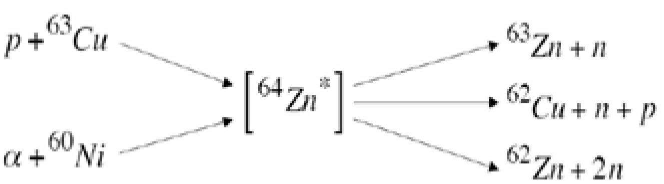
This reaction can be treated as a two-step process. In the first step the incident particle which stays in the nucleus for a relative long time (10^{-14} s) delivers its energy to many nucleons in the target nucleus, and this energy is rapidly distributed throughout the nucleus [6]. The incident particle itself becomes indistinguishable from other nucleons in the compound nucleus, and we can say that the compound nucleus 'forgets' the way in which it was formed. Due to this forgetfulness of the compound nucleus, the second step is independent and unrelated to the first step. The excitation energy of the compound nucleus is equal to the kinetic energy introduced by the incident particle plus its binding energy. This energy is statistically distributed among the nucleons, and each nucleon is rapidly colliding with the others and changing its energy. It may happen that by chance enough energy is concentrated on one nucleon that they can leave the nucleus, and a particle emission takes place as following [6,7]:

$$a + X \to C^{*} \to Y + b \qquad \text{.....} \quad (1\text{-}2)$$

Where C^{*} is the compound nucleus sometimes the different initial state gives the same compound nucleus also this nucleus produced different final state as following [8]:

$$X + a \to C^{*} \to \begin{Bmatrix} Y1 + b1 \\ Y2 + b2 \\ Y3 + b3 \\ \text{.......} \\ \text{.......} \\ \text{.......} \end{Bmatrix} \text{...................} \quad (1\text{-}3)$$

For example this reactions:



b- Precompound reaction:

With increasing projectile energy (above 10 MeV) sometimes a particle emission can occur even before the whole energy could distribute evenly among the nucleons of the compound nucleus [6].

c- Direct reaction:

This process becomes probable when the projectile spends less time in the vicinity of the target nucleus, (10^{-22} s). The interaction between the incident particle and the target nucleus takes place usually close to the surface of the nucleus. Only a few nucleons of the target nucleus take part in this process [7].

In general nuclear reactions, like chemical reactions, can occur via different reaction mechanisms. Weisskopf has presented a simple conceptual model (Figure 1-1) for illustrating the relationships between the various nuclear reaction mechanisms [9].

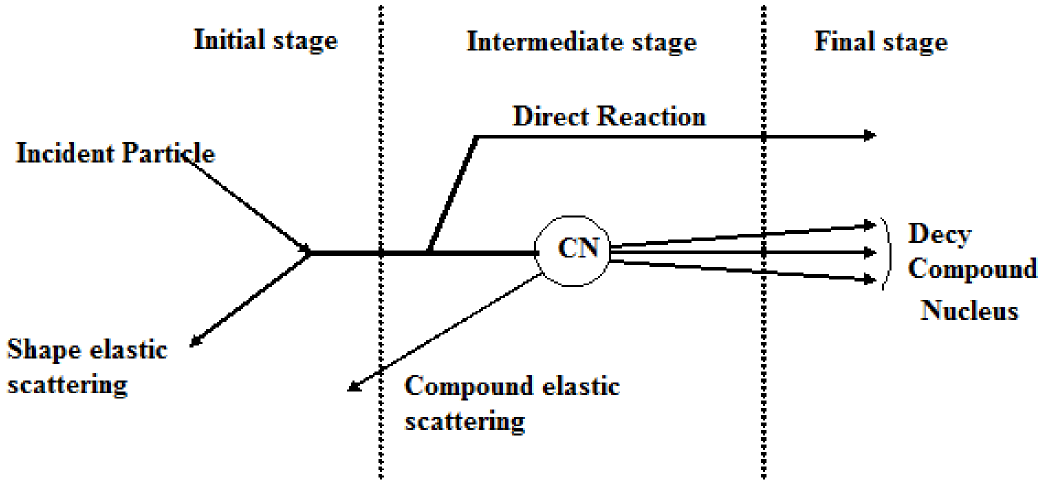


Figure 1-1. A conceptual view of the stages
of a nuclear reaction[9].

(1-2) Categorization of Nuclear Reactions **[8]***:*

Nuclear reaction have different types that we can identify them as following:

i. Charged particle reactions. [(p,n), (p,α), (α,n), heavy ion reactions].

ii. Neutron reactions. [(n,γ), (n,p) …..].

iii. Photonuclear reactions. [(γ,n), (γ,p) …].

iv. Electron induced reactions.

(1-2-1) Charged particle reactions:

When a charged particle enters into a medium, it interacts with electrons and nuclei of the medium. These interactions are called "collisions" between charged particles and the atomic electrons and nuclei [10], it loses energy mainly through collisions with electrons. This often leads to the ionization of the atoms in the matter, this case the particle leaves a trail of ionized atoms in its path. If the energy of the particles is large compared with the ionization energies of the atoms, the energy loss in each encounter with an electron will be only a small fraction of the particle's energy. A heavy particle cannot lose a large fraction of its energy to a free electron because of conservation of momentum [11].

A charged particle is called heavy, if its mass is greater than the rest mass of the electron such as alpha, proton and some fission products, it losses a negligible amount of energy in a collision with nucleus. Interaction of charged particles depend on the relative size of the impact parameter (b), (i.e. shortest distance between the center of the atom and the path of the charged particle), and the radius of the atom (a) as shown in (Figure 1-2), we can consider four types of interactions [10]:

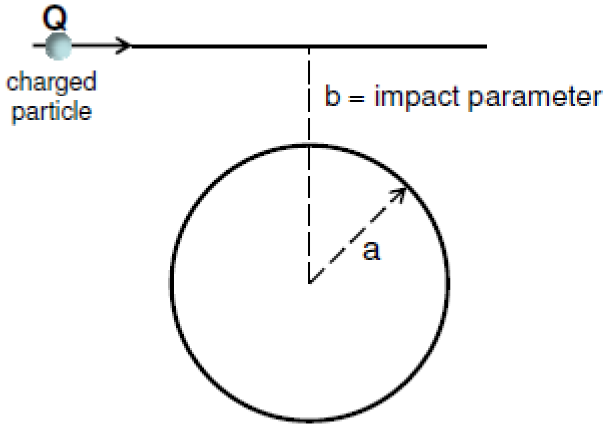


Figure 1-2. Impact parameter (b) and classical radius of atom (a) [10].

i. Inelastic or soft collisions ($b>>a$):

The influence of the particle's Coulomb force field affects the atom as a whole. The atom can be excited to a higher energy level, or ionized by ejection of a valence electron; and therefore the atom receives a small amount of energy (~eV). This is the main process of energy transfer for charged particle interactions with matter leading to excitation of the atomic [12].

ii. Hard collisions ($b \approx a$):

Interaction with a single atomic electron (treated as free), which gets ejected with a considerable kinetic energy. The interaction probability is different for different particles. Ejected γ-ray dissipates energy along its track, also is produced characteristic x-ray or Auger electron [10].

iii. Inelastic collisions with a nucleus ($b \ll a$):

In this type, Coulomb force interaction is mainly with the nucleus. If the particle is an electron, Bremstrahlung can occur. If (b < a) and charged particle has enough energy, inelastic interaction with the nucleus can leave the nucleus in the excited state, excited nucleus then decays by emission of nucleons or γ-rays [10].

iv. Elastic collisions with a nucleus ($b \ll a$):

This type of interactions is known as Rutherford scattering. There is no excitation or radiation. Particle losses energy through recoil of the nucleus [12].

(1-2-2) Neutron reactions:

Rutherford et al. suggested in 1920 that an uncharged particle resulted from the neutralization of the electrical charge on a proton by an electron. This hypothetical particle was called a neutron. Chadwick proved in 1932 that neutrons did exist and showed that the results of other experimenters in this field could be fully explained [13]. Neutrons can be classified according to their kinetic energies as following [14,15]:

1- Cold neutrons < 0.003 eV.

2- Slow (thermal) neutrons 0.003 eV – 0.39 eV.

3- Slow (epithermal) neutrons 0.4 eV – 99 eV.

4- Intermediate neutrons 100 eV – 199 keV.

5- Fast neutrons 200 keV – 10 MeV.

6- High energy (relativistic) neutrons > 10 MeV.

(1-3)Neutron Sources:

The nuclei created with excitation energy greater than the neutron binding energy can decay by neutron emission, these highly excited states are not produced as a result of any convenient radioactive decay process. The possible choices for radioisotope neutron sources are much more limited and are based on either spontaneous fission or on nuclear reactions for which the incident particle is the product of a conventional decay process [16]. The major categories of neutron sources:

(1-3-1) Spontaneous Fission

Heavy nuclides have an appreciable spontaneous fission decay probability. Several fast neutrons are promptly emitted in each fission event, so a sample of such a radionuclide can be a simple and convenient isotopic neutron source. Prompt fission gamma rays and the beta and gamma activity of the fission products accumulated within the sample. When we used it as a neutron source, the isotope is generally encapsulated in a sufficiently thick container so that only the fast neutrons and gamma rays emerge from the source [16] for example the following:

$$^{87}Br \rightarrow {}^{87}Kr^{*} + \beta^{-}$$
$$\hookrightarrow {}^{86}Kr + n$$

The isotope ^{252}Cf is the only spontaneous fission (SF) source of neutrons easily available. It provides fission spectrum neutrons with an average energy of 2.3 MeV [17].

(1-3-2) Isotopic Sources (*Radioactive neutron sources*)*:*

Radioactive sources are usually relatively small in volume. Thus they are readily portable and adaptable to particular experimental arrangements. These sources also can be calibrated quite accurately [18]. Energetic alpha particles are available from the direct decay of a number of convenient radionuclide’s, it is possible to fabricate a small self-contained neutron source by mixing an alpha-emitting isotope with a suitable target material. Several different target materials can lead to (α, n) reactions for the alpha particle energies that are readily available in radioactive decay. The maximum neutron yield is obtained when beryllium is chosen as the target, and neutrons are produced through the reaction [16].

$$ {}^{4}_{2}He + {}^{9}_{4}Be \rightarrow {}^{1}_{0}n + {}^{12}_{6}C \quad \text{-------} \quad (1\text{-}4) $$

The ^{9}Be(α, n) sources not only emit neutrons but also give off penetrating γ-rays of 4438 keV. This fact has been utilised in, for example, several industrial gauging instruments and for the interrogation of unidentified materials as required in nuclear safeguards applications [19]. Another type of installed neutron source that is widely used is a photoneutron source. Since binding energy of deuteron is very low, if energy greater than 2.22 MeV is supplied to deuterium nucleus, in principle it has to be disintegrated into proton and neutron. When Beryllium is exposed to γ -rays, neutrons are produced. This reaction can be represented as ^{9}Be(γ,n)^{8}Be reaction [1].

$$ \gamma + {}^{9}_{4}Be \rightarrow {}^{1}_{0}n + {}^{8}_{4}Be \qquad \text{--------} \; (1\text{-}5) $$

(1-3-3) Nuclear Reactor :

Nuclear reactor is a device in which the fission chain reaction takes place, in a controlled manner, for the production of energy and neutrons. Nuclear fission is the source of energy in a nuclear reactor. In addition to energy, the nuclear reactor is thus a strong source of neutrons [1]. Nuclear reactors are broadly classified as [13]:

- Research reactors
- Production reactors
- Power reactors

The design and operation of these reactors in the three categories is different in order to serve different purposes. Neutrons are produced in the fuel of the reactor core by Uranium fission reactions, which means that slow neutrons are captured by a (${}^{235}U$) nucleus, which then decays into two nuclei of medium atomic number. An example of such a reaction is [20]:

$$ {}^{1}_{0}n + {}^{235}_{92}U \rightarrow \left({}^{236}_{92}U^{*}\right) \rightarrow {}^{148}_{57}La + {}^{85}_{35}Br + 3\,{}^{1}_{0}n + 200\ MeV \quad \text{---- (1-6)} $$

Most of the energy liberated by the fission process is converted to kinetic energy of the fission products. About (7 MeV) are carried away as prompt (γ) radiation, and on average, (5 MeV) are transferred to each neutron as kinetic energy. The fast neutrons, by collision with the atomic nuclei of the matter present in the reactor core, lose their energy; they become moderated [21].

(1-3-4) Neutron Generator :

It is obvious that accelerators, which can impart energies to beams of charged particles in excess of the threshold energy for release of neutrons in a target, are adaptable as source of neutrons. In those cases where the reaction in the target is exoergic, a particle of quite low energy can be used in the accelerator. As the control of the energy of the charged particles in the beams measuring the energy of the beam, it has become possible to generate neutrons with fairly well defined energies [18].

Accelerator produces fast neutrons as products of charged particle reactions. Many accelerators of nuclear charged particles such as the most popular device is the so called neutron generator, which operates on the (D-T) reaction:

$$ {}^{2}_{1}H + {}^{3}_{1}H \rightarrow {}^{1}_{0}n + {}^{4}_{2}H \; + 1\ .5\ \ 7M8 \qquad \text{------ (1-7)} $$

The maximum neutron flux provided by a neutron generator is of the order of (10^{12}) (neutrons/m^2.s) with energy E_n= 14MeV. Neutrons with an average of about (2.5 MeV) are produced by the (*D-D*) reaction:

$$ {}^{2}_{1}H + {}^{2}_{1}H \rightarrow {}^{1}_{0}n + {}^{3}_{2}H \; + 3.2 \quad M\ \ e \qquad \text{----- (1-8)} $$

The (*D-D*) reaction offers neutron fluxes of the order of (10^9) neutrons/m^2.s . It is important to note that both the (*D-T*) and the (*D-D*) reactions produce essentially monoenergetic neutrons [17,22]. A few accelerators have been used to produce neutrons by (α, n) reaction. When alpha particles with energies of the order of 20 MeV energy are available, the (α, n) reaction has not been found very useful as a source of neutron in accelerators. The chief reason seems to be that production of alpha-particle beams is difficult and the neutron yield is low [18].

The (p, n) reaction has been much more popular than the (α, n) reactions as a source of neutrons in accelerators. The lower threshold energies and greater yield of neutrons have contributed to this popularity [18]. Generating neutrons via the $^{7}Li(p,n)^{7}Be$ reaction, is one of the optimal choices for this kind of neutron source. Neutron yield data versus incident energy are necessary in order to select the proper incident energy and for estimating how high the incident proton current should be [23]. The equation for the reaction is:

$$^{7}Li + ^{1}H \rightarrow ^{7}Be + ^{1}n \quad \ldots\ldots.. \quad (1\text{-}9)$$

(1-4) The Types Of Neutron Reactions:

The neutron may interact with nuclei by one or more of the following ways:

(1-4-1) Absorption Reaction X(n,x)Y:

Most absorption reactions result in loss of a neutron and disappear inside the nucleus and this leads to appear the various secondary radiation, where (*x*) may be p,d,t,α,2n,3n,………or fission fragment [24].

i. Charged-Particle Reaction X(n,x)Y: A nucleus may absorb a neutron forming a compound nucleus, which lead to emitting a charged particle, either a p, α, d and t, which produces a nucleus of different element [25], An example can be ^{16}O (n, p) ^{16}N reaction [18].

$$^{1}_{0}n + ^{16}_{8}O \rightarrow ^{16}_{7}N + ^{1}_{1}P \quad \ldots\ldots\ldots \quad (1-10)$$

ii. Neutron-Production X(n,inc)Y: i= 2,3,….etc, n=neutron and c=charged particles such as p, d, t, α, f,…..etc .In this reaction two or more neutrons are extracted from the struck nucleus [25]. This kind of reaction is also called neutron emission reaction [26].

iii. Neutron Capture $^{A}X(n,\gamma)^{A+1}X$: The neutron is captured by a nucleus and a compound nucleus is produced .This compound nucleus then emits γ -rays

.This reaction produces a nuclide that is isotopic with nuclide that absorbs the neutron[26].

iv. Fission Reaction: A neutron interaction with certain heavy nuclei may cause the nucleus to split apart [26] , each fission provides generally two fission fragments. The fission products fall into two definite groups, one intermediate group with a mass number of around 95 and a heavy group with a mass number of around 140. The fission yield of a nuclide is a fraction or the percentage of the total number of fissions, which leads directly or indirectly to that nuclide. The total fission yield is 200%. In addition, some fission products undergo successive decays, leading to the production of decay products forming a fission decay chain [27].

(1-4-2) Scattering Reaction:

A neutron scattering reaction occurs when a nucleus, after having been struck by a neutron, emits a single neutron, the net effect of the reaction is as if the projectile (neutron) had merely scattered from, the nucleus. The two categories of scattering reactions are elastic and inelastic scattering. In an elastic scattering (n,n) interaction is only between a neutron and a target nucleus, there is no energy transferred in to nuclear excitation. Momentum and kinetic energy of a system are conserved, although there is usually some transfer of kinetic energy from the neutron to the target nucleus. While in inelastic scattering (n,ń), the incident neutron is absorbed by the target nucleus, forming a compound nucleus. The compound nucleus will then emit a neutron of lower kinetic energy, which leaves the original nucleus in an excited state, the nucleus then usually, decayed by emitting one or more gamma emission, emit this excess energy to reach its ground state [18].

(1-5) Neutron Cross Sections:

Cross section (σ), gives the probability of the nuclear reaction between the two colliding particles, which is a measure of the probability that the system changes from the entrance channel to a definite exit channel. which is defined as the following [29].

$$\sigma = \frac{\text{number of reactions/unit time}}{\text{number of incident particles/(unit time} \cdot \text{unit area)}} \quad \text{..........} \quad \textbf{(1-11)}$$

Units of the cross-section in atomic and nuclear physics is barn (1 b = 10^{-28} m^2).

The cross-section depends on the projectile-target combination, and on the incident energy [28]. The probability of a neutron interacting with a nucleus for a particular reaction is dependent on the kind of nucleus involved. Also, upon the type of reaction involved [29]. There are two types of cross sections:

i. The microscopic cross section:

When a neutron moves through a material there is a particular probability that it will interact with the nuclei of the material. To quantify this thin layer of the material taken into account. If the layer is sufficiently thin, no atoms are shielded by other atoms. In this case the interaction rate is proportional to the intensity of the neutron beam and the number of atoms in the layer. This gives the following equation [30]:

$$\sigma = \frac{R}{IN} \qquad \dots\dots\dots\dots \quad (1-12)$$

Where R is the interaction rate in [cm^{-2}. s^{-1}], I is the neutron beam intensity in [cm^{-2}. s^{-1}], N is the number of atoms in the layer in (atoms/cm^3) and σ is the constant of proportionality in [cm^2]. This constant σ is called the microscopic cross section. Since the nuclear radius is roughly 10^{-12} cm, the geometrical cross section is in the order of 10^{-24} cm^2. The real microscopic cross section σ is often measured in units of this size, called barns [30]. The atom density (N), is the number of atoms of a given type per unit volume of the material. To calculate the atom density of a substance we use the following equation [31]:

$$N = \frac{\rho N_A}{M} \qquad \dots\dots\dots\dots \quad (1-13)$$

Where ρ is the density (g/cm^3), N_A is Avogadro's number (6.022 x 10^{23} atoms/mole) and M is the gram atomic weight. There are basically two different ways of interaction between neutrons and nuclei: absorption and scattering. These can be subdivided as shown in figure (1-3). The scattering cross section contains two parts: elastic scattering and inelastic scattering. In the case of elastic scattering, the target nucleus remains in the ground state. After inelastic scattering the target nucleus is left in an excited state. This nucleus will relax by emitting a gamma ray. The sum of these two cross sections is the total scatter cross section σ_s. There are more possible types of absorption cross sections. The absorbed neutron can induce fission, or emission of gamma radiation, new neutrons or other particles. The total microscopic cross section is given by the sum of the different parts [30]:

$$\sigma_t = \sigma_s + \sigma_a = \sigma_e + \sigma_{in} + \sigma_f + \sigma_{n,\alpha} + \sigma_{n,2n} + \sigma_\gamma + \dots. \qquad \dots. (1\text{-}14)$$

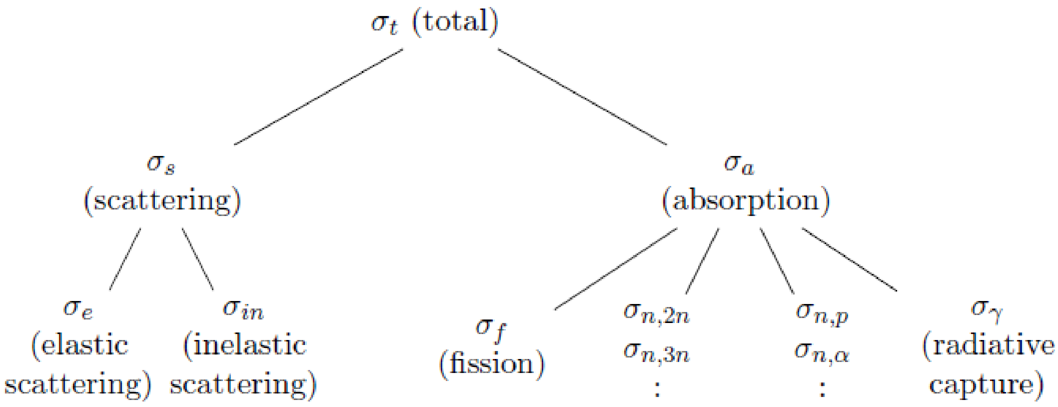


Figure 1-3: schematic representation of different cross sections [30].

ii. Macroscopic cross section:

The macroscopic cross section $(\sum)$ represents the effective target area that is presented by all of the nuclei contained in 1 cm^2 of the material. The macroscopic cross section is the probability of a given reaction occurring per unit travel of the neutron. $(\sum)$ is related to the microscopic cross section (σ) by the relationship shown [31,32].

$$\sum = N\sigma \qquad \text{.........(1-15)}$$

(1-6) Cross Section of (α,n) and (p,n) reactions :

The development of analytical methods for the control and protection from nuclear fuel radiation, were is the production of neutron and isotopic energy sources based on alpha emitting radio nuclides. This application requires the knowledge of the yield of neutrons resulting from the absorption of alpha particles by nuclei of elements. Nuclear data such as cross section for neutron-productions reactions induced by α-particles are required in the fields of design and operation of nuclear fuel-cycle facilities [33].

Many of (p,n) cross sections exhibit additional structure in the rise from threshold. This behavior is due primarily to the discrete level spectrum provided. These effects arise from the spacing of the discrete levels, which can be relatively large (as much as a few MeV) in the lower mass regions of the periodic chart, and particularly large for closed shell nuclei [33]. The (*p*,*n*) reactions induced by bombardment of light elements have been intensively studied with high energy resolution up to energies accessible with conventional electrostatic accelerators. In addition to the intrinsic value of (*p*,*n*) cross section in the investigation of nuclear spectroscopy and reaction mechanisms, such data are essential for the utilization of (*p*,*n*) reactions as neutron sources[34].

(1-7) Previous Work:

(1-7-1) Cross Section:

The experimental and theoretical cross section of *(α,n)* reactions for intermediate elements have been extensively studied the most important are :

A) Cross Section for (α,n) Reaction:

i) Cross Section for Ca(α,n)Ti Reaction:

1- Barker D. L.; [35] (1974): Measurement of Reaction Cross Sections for ^{48}Ca(α,n)^{51}Ti with Applications to Nucleosynthesis in Stars which measured for energies(3.5 to 9.0) MeV, These cross sections have been used to calculate reaction rates as a function of temperature for stellar interior and compared to theoretical predictions of the "Equivalent Square Well" model.

2- Fitz W.; Kienle F.; Maschuw R.; Zeitnitz B.; Scobel W. and Eberhard K.A., [36] (1976): Study of the cross sections for the production of neutron yield from the bombardment of ^{40}Ca, ^{44}Ca with alpha particles with energy 24.1 MeV.

3- Cheng C. W. and King J. D.; [37] (1979): The Measurement of $^{42}Ca(\alpha,n)^{45}Ti$ cross section that has not been reported previously. Then all cross sections compared with a statistical model calculation.

ii) Cross Section for Ni(α,n)Zn Reaction:

1- Hille M.; Hille P.; Uhl M. and Weisz W.; [38](1972): Calculated the cross section of $^{60}Ni(\alpha,n)^{63}Zn$ reaction for alpha energies(18.8, 20.4, 22, 23.5) MeV. Then the values comparison with other studies.

2- Grimes S. M.; Anderson J. D.; McClure J. W.; Pohl B. A. and Wong C.; [39] (1974): Study The cross section of $^{60}Ni(\alpha,n)^{63}Zn$ reaction that measuring for alpha particle energies(10 to 20) MeV.

3- Levkovskij V.N.; [32](1991): Calculate the cross section of $^{60}Ni(\alpha,n)^{63}Zn$ reaction at alpha energies (7.4 to 45.9) MeV.

4- Sonck M.; Vanhoyweghen J. and Hermanne A.; [40] (2001): The use of cross section data for monitoring charged particle beam parameters. The cross section of $^{nat}Ni(\alpha,n)^{63,65}Zn$ reaction was measured for energies from threshold up to 42 MeV.

5- Yadav A.; Singh P. P.; Sharma M. K.; Singh D. P.; Singh B. P.; Prasad R. and Musthafa M. M.; [41](2008): Study the cross section of $^{60}Ni(\alpha,n)^{63}Zn$ reaction which measured for alpha energies(29,36, 40) MeV.

iii) Cross Section for Zr(α,n)Mo Reaction:

1- Vedoya M. D.; Wasilevsky C. and Nassiff S. J.; [42] (1981): Study the target of Zirconium were bombarded with beams of alpha particle at energies $\leq$ 50 MeV for the production of ^{90}Mo, ^{93}Mo.

2- Soppera N.; Dupont E. and Bossant M.; [43] (2012): Determine the cross section of $^{96}Zr(\alpha,n)^{99}Mo$ reaction for alpha energies(10 to 50) MeV.

B) Cross Section for (p,n) Reaction:

i) Cross Section for Sc(p,n)Ti Reaction:

1- Humes R.M.; DellJr G.F.; Ploughe W.D. and Hausman H.J.; [44] (1963): Study the cross section of ^{45}Sc(p,n)^{45}Ti reaction which measured at proton energies(6.75) MeV.

2- Thomas R.G. and Bartolini W.; [45] (1968): Measured the cross section of ^{45}Sc(p,n)^{45}Ti reaction for proton energies(7.8 to 14.4) MeV.

3- Mcgee T.; Rao C.L.; Saha G.B. and Yaffe L.; [46] (1970): The cross section of ^{45}Sc(p,n)^{45}Ti reaction was measured for energies(10 to 64) MeV.

4- Ejnisman R.; Goldman I.D.; Pascholati P.R.; Dacruz M.T.F.; Oliveira R.M.; Norman E.B.; Zlimen I.; Wietfeldt F.E.; Larimer R.M.; Chan Y.D.; Lesko K.T. and Garcia A.; [47] (1996): Study the cross section of ^{45}Sc(p,n)^{45}Ti reaction and measured at proton energies(10 to 64) MeV.

ii) Cross Section for Cu(p,n)Zn Reaction:

1- Williams I.R. and Fulmer C.B.; [48] (1967): The cross section of ^{65}Cu(p,n)^{65}Zn reaction was calculated for proton energies(14.2 to 22.1) MeV.

2- Greene M.W. and Lebowitz E.; [49] (1972): The cross section of ^{65}Cu(p,n)^{65}Zn reaction was measured with proton energies(16 to 32.8) MeV.

3- Colle R.; Kishore R. and Cumming J.B.; [50] (1972): Calculate the cross section of ^{63}Cu(p,n)^{63}Zn reaction at proton energies from 3.99MeV to 25.02MeV.

4- Alharbi A.A. and Azzam A.; [51] (2012): theoretical calculations of the reaction for proton induced reactions on natural copper using ALICE-IPPE code were cross section of ^{63,65}Cu(p,n)^{63,65}Zn reaction was measured from the threshold energy of each reaction up to 50 MeV.

iii) Cross Section for Zr(p,n)Mo Reaction:

1- Johnson C.H.; Galonsky A. and Ulrich J.P.; [52] (1958): Concert on the cross section of $^{93}Np(p,n)^{93}Mo$ reaction and its measured at proton energies(1.265 to 2.054) MeV.

2- Chodil G.; Jopson R.C.; Mark H. and Swift C.D.; [53] (1967): study the cross section of $^{93}Np(p,n)^{93}Mo$ reaction was measured for energies(7 to 15) MeV.

C) Cross Section for (n,n) Reaction:

i) Cross Section for Ti(n,n)Ti Reaction:

1- Shull C.; Wilkinson M. and Mueller M.; [54] (1960): Calculation of the cross section of $^{46,48,49,50}Ti(n,n)^{46,48,49,50}Ti$ reaction with neutron energy (0.0253) eV.

2- Kinney W. E. and Perey F. G. ;[55] (1973): Natural titanium neutron elastic and inelastic scattering cross sections from 4.07 MeV to 8.56 MeV. The cross section of $^{48}Ti(n,n)^{48}Ti$ reaction was measured for neutron energies from 4.07MeV to 8.56 MeV.

3- Korzh I.A.; Mishchenko V.A.; Mozhzhukhin E.N.; Pravdivij N.M. and Sanzhur I.E.; [56] (1977): Study the cross section of $^{48}Ti(n,n)^{48}Ti$ reaction which measured at neutron energies(1.5 to 3) MeV.

4- Mughaghab S.F.; [57] (2006): Measured the cross section of $^{47}Ti(n,n)^{47}Ti$ reaction at neutron energy (0.0253) eV.

ii) Cross Section for Zn(n,n)Zn Reaction:

1- Holmqvist B.; Johansson S. G.; Kiss A.; Lodin G. and Wiedling T.; [58] (1968): Neutron Elastic Scattering Cross Sections of Iron and Zinc in the Energy Region 2.5 to 8.1 MeV. The cross section of Zn(n,n)Zn reaction was measured for energies(2.5 to 8.1) MeV.

2- Korzh I.A.; Mishchenko V.A.; Mozhzhukhin E.N.; Golubova A.A.; Pravdivyj N.M.; Sanzhur I.E. and Pasechnik M.V.; [59] (1975): The cross section of $^{64,66,68}Zn(n,n)^{64,66,68}Zn$ reaction was measured for energies(1.5 t0 3) MeV.

3- Mughaghab S.F.; [57] (2006): Calculated the cross section of $^{64,66,68,70}Zn(n,n)^{64,66,68,70}Zn$ reaction for neutron energy (0.0253) eV.

iii) Cross Section for Mo(n,n)Mo Reaction:

1- Lambropoulos P.; Guenther P.; Smith A. and Whalen J.; [60] (1973): The cross section of $^{92}Mo(n,n)^{92}Mo$ reaction was measured for energies(0.32 to 1,5) MeV.

2- Mcdaniel F.D.; Brandenberger J.D.; Glasgow G.P.; Mcellistrem M.T. and Weil J.L.; [61] (1977): The cross section of $^{92}Mo(n,n)^{92}Mo$ reaction was calculated for neutron energy (2.52) MeV.

3-Rapaport J.; Cheema T. S.; Bainum D. E.; Finlay R. W. and Carlson J. D.; [62] (1979): Neutron elastic scattering from $^{92, 96, 98, 100}Mo$ between E_n = 7 and 26 MeV. The cross section of $^{92,96,98,100}Mo(n,n)^{92,96,98,100}Mo$ reaction was measured for energies(7 to 26) MeV.

4-Mughaghab S.F.; [57] (2006): The cross section of $^{92,94,95,96}Mo(n,n)^{92,94,95,96}Mo$ reaction was measured for energy (0.0253) eV.

(1-7-2) Neutron Yield:

1- Blair J'. M.; Hush J. M.; Klema E. C.; Seagondollar L. W.; Taschek R. F. and Turner C. M. [63] (1944): Determine the neutron yield for $^{45}Sc(p,n)^{45}Ti$ reaction were studied to find a source of the lowest energy neutrons that was 3 MeV.

2- Zom G.T.; Kim H. and Boyer C.N.[64] (1975): Neutron yield of 10^9 neutrons/pulse from Cu(p,n)Zn reaction at proton energy must be above 4 MeV from accelerator.

3-Yegorov A.M.; Migalenja V.Ja.; Nagaychenko V.I.; Sotnikov V.V.; Voronko V.A. and Zhuk V.V.; [65] (2004): Determination of neutron yields from the copper target for $^{63}Cu(p,n)^{63}Zn$ for proton with energy of 10 MeV.

4- Pejman R.; Amir R. J. and Mahsheed S.[66] (2005): Study the neutron yield of $^{65}Cu(p,n)^{65}Zn$ for proton with energy 30 MeV.

5- Ryan D. B.[67] (2007): This study included extract empirical formulas, for several studies of Be(α,n) reaction, as follows:

i- An empirical formula was developed by Anderson and Hertz (1971) to find the theoretical maximum number of neutrons that could be produced by alpha particles incident upon beryllium:

$$Y_{TT} = 0.080 * E_{\alpha}^{4.05} \qquad (4.1 < E_{\alpha} \le 5.7)$$
$$Y_{TT} = 0.800 * E_{\alpha}^{2.75} \qquad (5.7 < E_{\alpha} \le 10.0)$$

Where Y_{TT} is the number of neutrons produced per 10^6 alpha particles and E_α is the energy in MeV of the incident alpha particle.

ii- Similar approximations have been made and reworked by Geiger and Van der Zwan (1975) for higher energies:

$$Y_{TT} = 0.1444 * E_{\alpha}^{3.65}$$

iii- Bair and del Campo (1979),put several new empirical equations which have been created to describe the target for (α,n) neutron yield for several other targets materials.

- beryllium:

$$Y_{TT} = 0.1776 * E_{\alpha}^{3.5} \qquad (3.0 < E_{\alpha} \le 6.5)$$
$$Y_{TT} = .8392 * E_{\alpha}^{2.6796} \qquad (6.5 < E_{\alpha} \le 9.0)$$

- Fluorine:

$$Y_{TT} = 4*10^{-5} * E_{\alpha}^{7.1634} \qquad (3.5 < E_{\alpha} \leq 5.5)$$
$$Y_{TT} = .0037 * E_{\alpha}^{4.5095} \qquad (5.5 < E_{\alpha} \leq 8.0)$$

- Natural Boron:

$$Y_{TT} = 9.0179 E_{\alpha} - 29.234 \qquad (3.5 < E_{\alpha} \leq 7.5)$$

- Boron-10:

$$Y_{TT} = 1*10^{-4} * E_{\alpha}^{6.4345} \qquad (3.5 < E_{\alpha} \leq 5.5)$$
$$Y_{TT} = .007 * E_{\alpha}^{3.9779} \qquad (5.5 < E_{\alpha} \leq 7.5)$$

- Boron-11:

$$Y_{TT} = 9.0901 * E_{\alpha} - 31.163 \qquad (3.5 < E_{\alpha} \leq 7.5)$$

- Natural Lithium:

$$Y_{TT} = 2.122 * E_{\alpha}^{2} - 19.07 * E_{\alpha} + 42.286 \qquad (5.5 < E_{\alpha} \leq 6.0)$$
$$Y_{TT} = 22.859 * E_{\alpha} - 135.5 \qquad (6.0 < E_{\alpha} \leq 9.0)$$

iv- Shultis and Faw (2000) put the empirical formula for (α,n) neutron yield as following:

$$Y_{TT} = 0.115 * E_{\alpha}^{3.82} \qquad (3.5 < E_{\alpha} \leq 6.5)$$
$$Y_{TT} = E_{\alpha}^{2.64} \qquad (6.5 < E_{\alpha} \leq 10.0)$$

6- Takaaki, O.[68] (2008): Obtained empirical formulas for estimation of the prompt neutron multiplicity for actinides as a function of the incident neutron energy for eleven nuclides (^{232}Th, ^{233}U, ^{235}U, ^{238}U, ^{237}Np, ^{239}Pu, ^{240}Pu, ^{241}Pu, ^{241}Am, ^{243}Am, and ^{245}Cm).

$$\bar{\nu}(Z, A, E_n) = 2.33 + 0.06[2-(-1)^{A+1-Z}-(-1)^{Z}] + 0.15(Z-92) + 0.02(A-235) + [0.130+0.006(A-235)](E_n-E_{th}).$$

7- Thomas,D.J.; Lewis,V.E.; Klein,H. and Allisy-Roberts,P.J.; [69] (2010): In this study, They conclude that the neutron energy depends sensitively on the proton beam energy of ^{45}Sc(p,n)^{45}Ti reaction.

8- Ramadhan H. A. [70] (2013): Do tined the polynomial expressions to fit the calculated neutron yields of the mentioned light elements to determine the adopted neutron yields from the best fitting equations for energy ranged near threshold energy up to 10 MeV in steps of (0.050 MeV).

9- Toshiya, S.: Yosuke, I.: Tsuyoshi,K.: Nobuhiro,S.: David,B.: Kamran,V.: Masayuki,H.: Hee-Seock,L.: Kenji,I,: Yukio,S. and Hiroshi,N.; [71] (2014): In this study, they deduce an empirical formula {y=a(1-exp(-x/b)} from fitting to determine neutron yield at 120 GeV from proton incident on mass number (12 to 184).

(1-8)The Aim of the Work :

This work is going in two directions, the first directions is the study of the nuclear properties for 9 elements (Ca, Sc, Ti, Ni, Cu, Zn, Zr, Nb and Mo), each element includes 10 isotopes, so total isotopes are 90, to study (α,n), (p,n) and (n,n) reaction type for these isotopes, that means to study 90 reactions. The second direction which is the most important part in present study is to extracting a uniform empirical formula for all these reactions in order to calculate the neutron yield for the some mass number within the range of (40 – 100), at incident particle energy between (10 to 50) MeV, by designing a program in MATLAB for this purpose.

Chapter Two

Theory

(2-1) Reaction Kinematics :

A nuclear reaction is the process in which two nuclei, or else a nucleus of an atom and a subatomic particle (such as a proton, neutron, or high energy electron, ...) from outside the atom collide to produce products different from the initial particles. In order to change the number of nucleons in a stable target nucleus, the latter is bombarded with an appropriate projectile-either a charged particle, a neutron or a gamma photon [8].

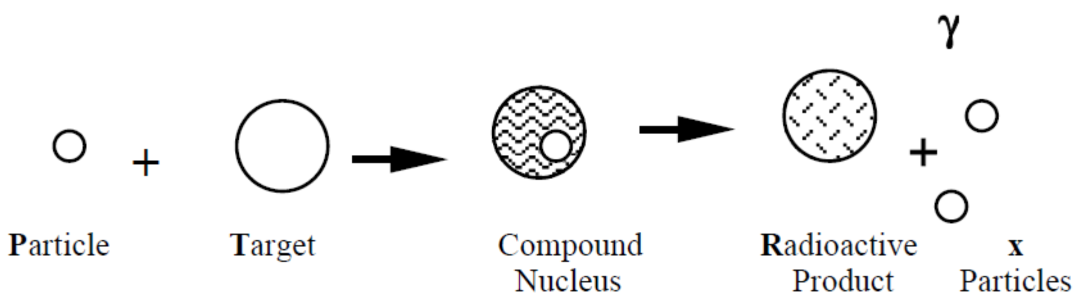


Figure (2-1): Reaction Kinematics [8].

Particle In: n, p, d, α, ^{3}He, γ (only one) with a wide range of bombarding energies.

Particles Out: number of product is energy dependent on average nuclear binding energy which is ~8 MeV/nucleon.

And target Nucleus: separated isotopes are available. The mathematical method is known as kinematics. Consider a nuclear reaction [72]:

$$\mathbf{X + a \rightarrow Y + b} \qquad \text{.........} \quad \mathbf{(2\text{-}1)}$$

Where X, a, Y, b are the target nucleus, bombarding particle, product nucleus and product particle, respectively.

In any nuclear reaction, the total energy must be conserved, which means that the total energy including the rest mass of the reactants must be equal to the total energy including the rest mass of the products. Any increase in kinetic energy must be accompanied by an equal decrease in the rest masses [73].

The reduced mass (**μ**) calculated from the following equation [74]:

$$u = \frac{m_a m_x}{m_a + m_x} \qquad \text{.........} \qquad \textbf{(2-2)}$$

Where (m_a) and (m_x) are the atomic masses of the projectile and target nucleus, respectively.

The reaction energy, or *Q*-value, is the sum of the initial masses minus the sum of the final masses, multiplied by c^2 [72]:

$$Q = [\, M_a + M_x - M_b - M_y \,]\, c^2 \qquad \text{-------} \quad \textbf{(2-3)}$$

The *Q* value of a nuclear reaction may be either positive or negative. If the rest masses of the reactants exceed the rest masses of the products, the *Q* value of the reaction is positive, with the decrease in rest mass being converted into a gain in kinetic energy [73].

If Q is positive, the reaction is said to be exo-ergic process, if Q is negative, it is endo-ergic process [75]. These reactions occur only if the required energy is supplied by the KE of the incoming particle. The reaction threshold Energy is defined by [76]:

$$E_{thr} = |-Q|\,(1+\frac{M\alpha}{Mx}) \quad \ldots\ldots\ldots \quad (2\text{-}4)$$

The loss in mass, or mass defect, is due to the conversion of mass to binding energy when the nucleus is formed [1]. The total binding energy can be calculated by finding the mass difference between the bound-state (nucleus) and the total mass of its free nucleons, and converting this mass difference into an energy difference [77].

Binding Energy = (mass of individual nucleons – mass of bound nucleus) c^2

and can write [78]:

$$B.E._{tot}\,(A,Z) = [(ZM_P + NM_n) - M(A,Z)]c^2 \quad \ldots\ldots\ldots(2\text{-}5)$$

Where: M(A,Z): is the mass of a specific nucleus. M_p: is the mass of a proton. M_n : is the mass of a neutron. A: is the mass number of the nucleus. Z: is the number of protons in a nucleus. N: is the number of neutrons in a nucleus. c^2: is the square of the speed of light in vacuum.(c^2 = 931.5 MeV/u) [74].

* The atomic mass is often given in the form [(M(A,Z) – A)] called the Mass Excess [79].

* The Binding Energy increases with mass and proton number. This is reflected in the Chart of the Nuclides, the plot of the stable nuclides as a function of N and Z Figure (2-2) [29].

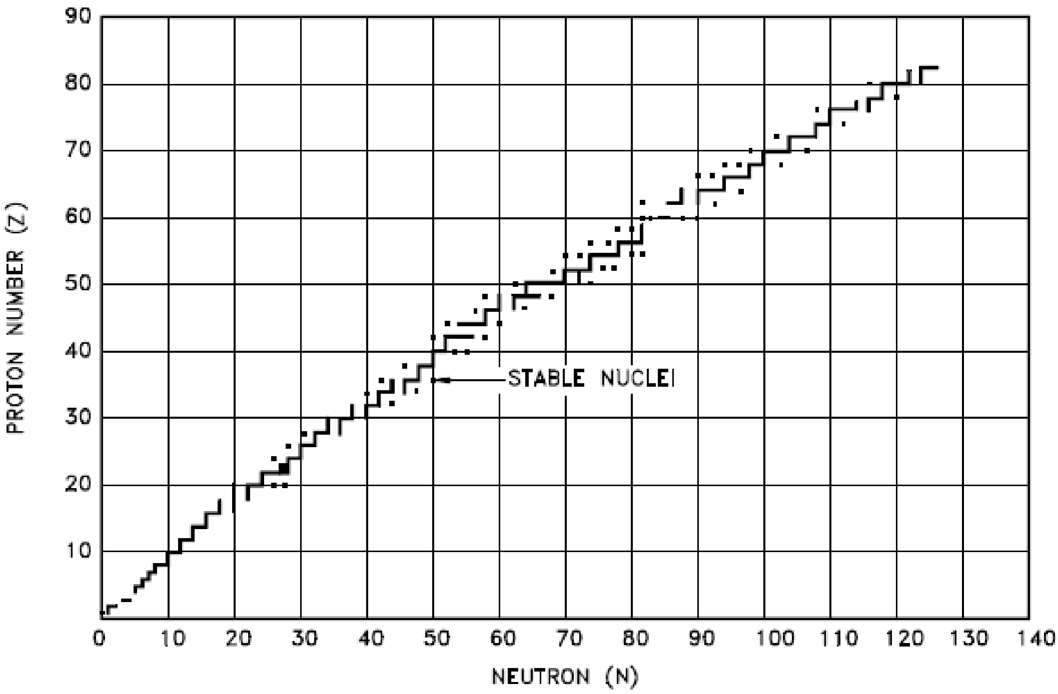


Figure (2-2) Neutron - Proton Plot of the Stable Nuclides [29].

The binding energy is usually plotted as B/A or binding energy per nucleon. This illustrates that the binding energy is overall simply proportional to A, since B/A is mostly constant as shown in figure (2-3)[80].

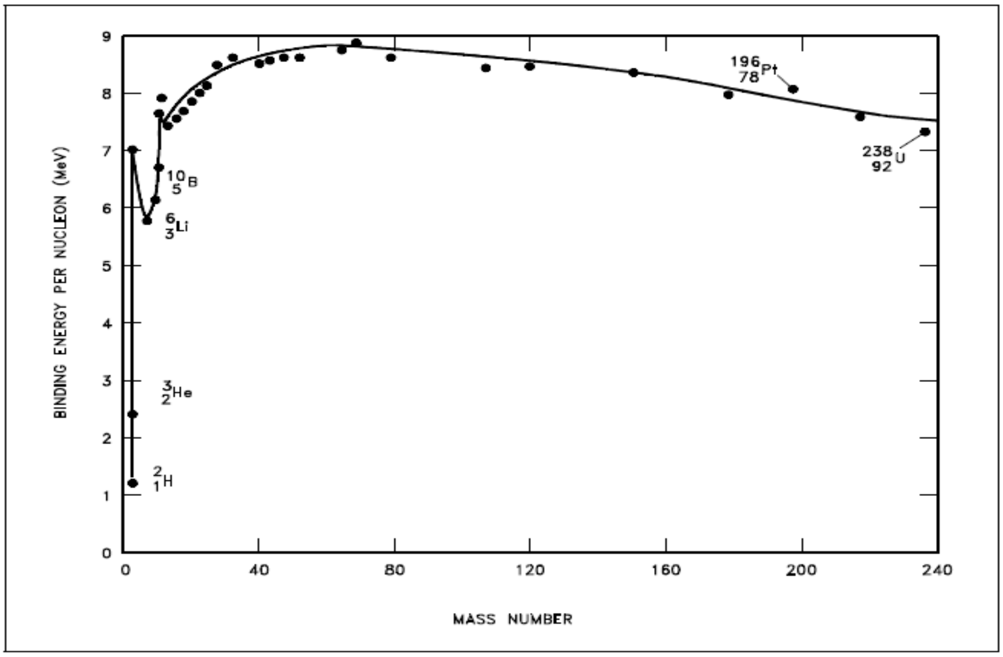


Figure (2-3): Binding energy per nucleon (B/A in MeV vs. A) [80].

The dependence of B/A on A (and Z) is captured by the semi-empirical mass formula. This formula is based on first principle considerations a model for the nuclear force and on experimental evidence to find the exact parameters defining it. In this model, which is called liquid-drop model, the semi-empirical mass formula (SEMF) is [81]:

$$B(A,Z) = a_v A - a_s A^{2/3} - a_c \frac{Z^2}{A^{1/3}} - a_a \frac{(N-Z)^2}{A} + \delta(A) \quad \ldots\ldots\ \textbf{(2-6)}$$

The numerical values of the parameters must be determined empirically, but the *A* and *Z* dependence of each term reflects simple physical properties as flowing [82]:

- The first term is a volume term which reflects the nearest-neighbor interactions, and which by itself would lead to a constant binding energy per nucleon B/A ~ 16 MeV.

- The second term, which lowers the binding energy, is a surface term. Internal nucleons feel isotropic interactions whereas nucleons near the surface of the nucleus feel forces coming only from the inside. Therefore this is a surface tension term, proportional to the area $4\pi R^2 \sim A^{2/3}$.

- The third term is the Coulomb repulsion term of protons, proportional to Q^2/R, i.e.~ $Z^2/A^{1/3}$. This term is calculable. It is smaller than the nuclear terms for small values of Z. It favors a neutron excess over protons.

- Conversely, the asymmetry term a favors symmetry between protons and neutrons. In the absence of electric forces, Z = N is energetically favorable. The asymmetry term is $a_a \frac{(N-Z)^2}{A}$. It can be more easily understood by considering the fact that this term goes to zero for A =2Z and its effect is smaller for larger A [81].

- Finally, the term δ(A) is a quantum pairing term.

If we want to remove one neutron from the nucleus it "costs" energy, This leads to the definition of the neutron separation energy S_n [74]:

$$S_n = 931.5\,[\,M_{(Z,A-1)} + M_n - M_{(Z,A)}\,] \quad (MeV) \ldots\ldots \qquad (2\text{-}7)$$

This quantity is analogous to the ionization energies in atoms. Effectively they give us the amount of energy required to remove the last neutron [79].

(2-2) Stopping Power:

The linear stopping power 'S' is the energy loss of the particle per unit path length, and depends on the type and energy of the particle [1].

$$\boldsymbol{S = -dE/dx} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad \textbf{(2-8)}$$

The total stopping power is the sum of the electronic stopping power (S_e), due to inelastic interaction with the target electrons, and the nuclear stopping power (S_n) induced by elastic collisions between the projectiles and the target nucleus. If the energy per atomic mass unit E/M of the incident particles is high, the nuclear contribution compared to the electronic one is negligible. But at low energy, the electronic effects approach zero while the energy lost by elastic collisions is of importance. So it is necessary to establish relations allowing its evaluation for practical purposes [83,84].

$$\boldsymbol{S_t = S_e + S_n} \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad \mathbf{(2-9)}$$

(2-2-1) Alpha-Particle Stopping Power:

The stopping power of α-particle is mainly due to the ionization of the target electrons, excitation of the lowest levels, charge-exchange between the target and the projectile:

(2-2-1-1) Nuclear Stopping Power (S_n) :

Nuclear stopping (elastic collisions between ion and target atom) leads to change of direction, and to energy loss of ion. (No nuclear forces are involved) [84]. The energy loss of the incident ion per unit length *Sn* depends on the ion energy. The nuclear energy loss is small at very high energies, because fast particle have less interaction time with the scattering nucleus. Thus the nuclear energy loss tends to dominant towards the end of the range when ion has lost much of its energy [85].

The nuclear stopping power (S_n) of the α-particle in different energy ranges have been presented by Ziegler formulas [86] as follows:

$$S_n = 1.5 \quad \varepsilon^{1/2} \qquad (\varepsilon < 0.01 \text{ MeV}) \qquad \text{-------- (2-10)}$$

$$(0.01 \leq \varepsilon \leq 10 \text{ MeV}) \qquad \text{---- (2-11)}$$

$$S_n = (0.14\ \varepsilon \ln)/2\varepsilon \qquad (\varepsilon > 10 \text{ MeV}) \qquad \text{------ (2-12)}$$

Where ε is the reduced ion energy which is given by:

$$\varepsilon = \frac{32.53\ M_2 E}{Z_1 Z_2 (M_1 + M_2)\left(Z_1^{2/3} + Z_2^{2/3}\right)^{1/2}} \qquad \text{------ (2-13)}$$

Where:

E = ion energy in keV,

M_1 = is the mass of projectile in amu,

M_2 = is the mass of target element in amu,

Z_1 = is the atomic number of the projectile,

Z_2 = is the atomic number of the target.

(2-2-1-2) Electronic Stopping Power (S_e):

Electronic stopping power (collisions between ion and target electrons) leads primarily to excitation and ionization of target atoms, and to energy loss of ion. [85]. The electronic stopping powers were calculated using the Ziegler formulae [86] expressions valid for the energy range (10-140) keV.

$$\left(\frac{1}{S_e}\right) = \left(\frac{1}{S_{Low}}\right) + \left(\frac{1}{S_{High}}\right) \qquad \text{------ (2-14)}$$

$$S_{Low} = A_1 E^{A_2} \qquad \text{------ (2-15)}$$

$$S_{High} = \left(\frac{A_3}{E/1000}\right) \ln\left[1 + \left(\frac{A_4}{E/1000}\right) + \left(\frac{A_5 E}{1000}\right)\right] \qquad \text{------ (2-16)}$$

Where A_1 - A_5 are the coefficients given by Ziegler [86].

(2-2-2) Proton Stopping Power:

The stopping power for alpha particles is slightly larger than the stopping power for protons of the same energy so the nuclear stopping power of incident protons is very small for all energies of interest [87]. The electronic stopping power *Se* in MeV/(mg/cm^2) for an incident proton with energy: 10 keV ≤ E < 1 MeV is given by [88].

$$S_e = \frac{S_{Low} \, S_{High}}{(S_{Low} + S_{High})} \qquad \text{------ (2-18)}$$

Where S_{Low} (Low energy stopping) is

$$S_{Low} = A_2\, E^{1/2} \qquad \text{------ (2-19)}$$

And S_{High} (High energy stopping) is

$$S_{High} = \frac{A_3}{E} \ln\left(1 + \frac{A_4}{E} + A_5 E\right) \qquad \text{------ (2-20)}$$

For energies in the range 1 MeV-100 MeV the electronic stopping power Se is given by [88]:

$$S_e = \frac{A_6}{\beta^2}\left[ln \frac{A_7 \beta^2}{1-\beta^2} - \beta^2 - \sum_{i=0}^{4} A_{i=8} (lnE)^i\right] \quad \ldots\ldots. \text{ (2-21)}$$

Where E : is the proton energy in (MeV).

$A_2 - A_7, A_i$: are the coefficients given by Ziegler [88,89].

β: is the ratio between incident particle velocity and the speed of light.

(2-3) Neutron Yields :

The Yield of neutron detected per incident particle Y_n, for an ideal, thin, and uniform target and monoenergetic particles beam of incident energy E_b is given by [90].

$$Y_n = nt\, \sigma(E_b)\, \eta(E_b) \qquad \text{------ (2-22)}$$

Where n: is the number of target atoms per unit volume.

t: is the target thickness.

σ: is the reaction cross section.

η: is the neutron-detection efficiency.

For a target which is not infinitesimally thin, the beam loses energy as it passes through the target, and the yield is then given by [91,92]:

$$Y_n = \int_{E_{thr}}^{E_b} \frac{\sigma(E)\eta(E)\, f dE}{-\frac{dE}{dx}(E)} \qquad \text{------ (2-23)}$$

In which $E_{thr} = E_b - \Delta E$, where E_{thr} is the reaction threshold energy, ΔE is the energy loss of the beam in the target, f is the number of target atoms in each target molecule, and $-\frac{dE}{dx}(E`)$ is the stopping power per target molecule,

When the target is sufficiently thick, and there exists one atom per each molecule (i.e., $f = 1$) and taking $\eta(E`) = 1$, then the resulting yield is called the thick-target yield which is given by [93]

$$Y(E_b) = \int_{E_{thr}}^{E_b} \frac{\sigma(E)dE}{-dE/dx} \qquad \text{------ (2-24)}$$

For natural elements and if only one stable isotope is available in nature, then [94]:

$$Y_o = Y(E) \qquad \text{------ (2- 25)}$$

Where Y_o is the neutron yield per 10^6 bombarding particle for the natural element. If $\sigma(E)$ is calculated for a certain isotope whose concentration (enrichment) is C %, then [94]:

$$Y_o = \frac{a}{c} Y(E) \qquad \text{------ (2- 26)}$$

Where a is the abundance of the isotope in the natural element.

For more than one isotope that can be involved in the nuclear reaction and the cross sections are calculated as a function of incident energy for each isotope, then [94]

$$Y_o = \frac{a_1}{c_1} Y_1(E) + \frac{a_2}{c_2} Y_2(E) + . \qquad \text{------ (2- 27)}$$

Chapter Three

Data Reduction and Analysis

(3-1) The nuclear data of isotopes :

Nuclear data are quantitative results of scientific investigations of the nuclear properties of matter. They describe properties of atomic nuclei and the fundamental physical relationships governing their interactions, thereby characterizing the physical processes underlying all nuclear technologies. Examples of nuclear data include atomic mass, abundance, cross sections, half-lives, decay modes and decay radiation properties, and γ-rays from radionuclides. The scope of the data collections includes all 85 natural elements with 290 stable isotopes and more than 2500 radionuclides [98].

The atomic mass for selected isotopes of the elements mentioned in this study have been taken from the latest data by James E. Martin [99], which are expressed in (amu), the abundance data by Rosman and Taylor [100], and the Half-life given by G. Audi et al [101]. Spin and parity if not known from experiment, they can be estimated, in some cases, from systematic trends in neighboring nuclides with the same parities in N and Z. This is often true for odd-A nuclides, but also, not so rarely, for odd–odd ones [101]. Spin and parity (J^{π}) taken from Audi G. and Wapstra A.H. [102]. All these data are presented in Table (3-1).

Table (3-1): The data for isotopes which used in the present work

Isotopes	Atomic Mass. (amu) [99]	Abundance % [100]	Half-life [101]	Spin Parity [102]
^{41}Ca	40.96228	-	$1.02x10^5$ y	$7/2^-$
^{42}Ca	41.95862	0.647	Stable	0^+
^{43}Ca	42.95877	0.135	Stable	$7/2^+$
^{44}Ca	43.95548	2.086	Stable	0^+
^{45}Ca	44.95619	-	162.7d	$7/2^-$
^{46}Ca	45.95369	0.004	Stable	0^+
^{47}Ca	46.95455	-	4.536 d	$7/2^-$
^{48}Ca	47.95253	0.187	53 E y	0^+
^{49}Ca	48.95567	-	8.718 m	$3/2^-$
^{50}Ca	49.95752	-	13.9 s	0^+
^{44}Sc	43.95940	-	3.97 h	2^+
^{45}Sc	44.95591	100	Stable	$7/2^+$
^{46}Sc	45.95517	-	83.79 d	4^+
^{47}Sc	46.95241	-	3.349 d	$7/2^+$
^{48}Sc	47.95224	-	43.67 h	6^+
^{49}Sc	48.95002	-	57.2 m	$7/2^+$
^{50}Sc	49.95219	-	102.5 s	5^+
^{51}Sc	50.95360	-	12.4 s	$7/2^+$
^{52}Sc	51.95668	-	8.2 s	3^+
^{53}Sc	52.95961	-	3 s	$7/2^+$
^{44}Ti	43.95969	-	60 y	0^+
^{45}Ti	44.95813	-	184.8 m	$7/2^-$
^{46}Ti	45.95263	8.25	Stable	0^+
^{47}Ti	46.95176	7.44	Stable	$5/2^-$
^{48}Ti	47.94795	73.72	Stable	0^+
^{49}Ti	48.94787	5.41	Stable	$7/2^-$
^{50}Ti	49.94479	5.18	Stable	0^+
^{51}Ti	50.94661	-	5.767 m	$3/2^-$
^{52}Ti	51.9469	-	1.7 m	0^+
^{53}Ti	52.94973	-	32.7 s	$3/2^-$

To be Continued

Table (3-1) :

Isotopes	Atomic Mass. (amu) [99]	Abundance % [100]	Half-life [101]	Spin Parity [102]
^{62}Zn	61.93433	-	9.186 h	0^+
^{63}Zn	62.93321	-	38.47 m	$3/2^-$
^{64}Zn	63.92914	48.63	Stable	0^+
^{65}Zn	64.92924	-	244.06 d	$5/2^-$
^{66}Zn	65.92603	27.9	Stable	0^+
^{67}Zn	66.92713	4.1	Stable	$5/2^-$
^{68}Zn	67.92484	18.75	Stable	0^+
^{69}Zn	68.92655	-	56.4 m	$1/2^-$
^{70}Zn	69.92532	0.62	Stable	0^+
^{71}Zn	70.92772	-	2.45 m	$1/2^-$
^{62}Cu	61.932584	-	9.673 m	1^+
^{63}Cu	62.929598	69.17	Stable	$3/2^-$
^{64}Cu	63.929764	-	12.7 h	1^+
^{65}Cu	64.92779	30.83	Stable	$3/2^-$
^{66}Cu	65.928869	-	5.12 m	1^+
^{67}Cu	66.92773	-	61.83 h	$3/2^-$
^{68}Cu	67.929611	-	31.1 s	1^+
^{69}Cu	68.929429	-	2.85 m	$3/2^-$
^{70}Cu	69.932392	-	44.5 s	6^-
^{71}Cu	70.932677	-	19.4 s	$3/2^-$
^{87}Nb	86.920361	-	3.75 m	$1/2^-$
^{88}Nb	87.918332	-	14.5 m	8^+
^{89}Nb	88.913418	-	2.03 h	$9/2^+$
^{90}Nb	89.911265	-	14.6 h	8^+
^{91}Nb	90.906996	-	680 y	$9/2^+$
^{92}Nb	91.907194	-	34.7 My	7^+
^{93}Nb	92.906378	100	Stable	$9/2^+$
^{94}Nb	93.907284	-	20.3 ky	6^+
^{95}Nb	94.906836	-	34.991 d	$9/2^+$
^{96}Nb	95.908101	-	23.35 h	6^+

To be Continued

Table (3-1) :

Isotopes	Atomic Mass. (amu) [99]	Abundance % [100]	Half-life [101]	Spin Parity [102]
^{59}Ni	58.934347	-	101 ky	$3/2^-$
^{60}Ni	59.930786	26.2231	Stable	0^+
^{61}Ni	60.931056	1.1399	Stable	$3/2^-$
^{62}Ni	61.928345	3.6345	Stable	0^+
^{63}Ni	62.929669	-	100.1 y	1/2-
^{64}Ni	63.927966	0.9256	Stable	0^+
^{65}Ni	64.930084	-	2.5172 h	$5/2^-$
^{66}Ni	65.929139	-	54.6 h	0^+
^{67}Ni	66.931569	-	21 s	1/2-
^{68}Ni	67.931869	-	29 s	0^+
^{84}Zr	83.92325	-	25.9 m	0^+
^{85}Zr	84.921471	-	7.86 m	$7/2^+$
^{86}Zr	85.916474	-	16.5 h	0^+
^{87}Zr	86.914816	-	1.68 h	$9/2^+$
^{88}Zr	87.910227	-	83.4 d	0^+
^{89}Zr	88.90889	-	78.41 h	$9/2^+$
^{90}Zr	89.904704	51.45	Stable	0^+
^{91}Zr	90.905646	11.22	Stable	$5/2^+$
^{92}Zr	91.905041	17.15	Stable	0^+
^{93}Zr	92.906476	-	1.53 My	$5/2^+$
^{87}Mo	86.927327	-	14.05 s	$7/2^+$
^{88}Mo	87.921953	-	8 m	0^+
^{89}Mo	88.919480	-	2.11 m	$9/2^+$
^{90}Mo	89.913937	-	5.56 h	0^+
^{91}Mo	90.911750	-	15.49 m	$9/2^+$
^{92}Mo	91.906811	14.84	Stable	0^+
^{93}Mo	92.906813	-	4 ky	$5/2^+$
^{94}Mo	93.905088	9.25	Stable	0^+
^{95}Mo	94.905842	15.92	Stable	$5/2^+$
^{96}Mo	95.90468	16.68	Stable	0^+

Where s = seconds; m = minutes; h = hours; d = days; y = years; (1 y = 31 556 926 s or 365.2422 d) and (ky = 10^3 y kiloyear, My = 10^6 y megayear and Ey: 10^{18} y exayear) [101].

(3-2) Nuclear properties calculation:

The Q-values and threshold energies for (α,n), (p,n) and (n,n) reactions have been calculated for all reactions maintained are given in tables (3-2) for the neutron emission reaction from (Ca, Sc, Ti, Ni, Cu, Zn, Zr, Nb and Mo) isotopes that bombard by α-particle, proton and neutron using equations (2-3), (2-4).

Table (3-2): Q-Value, Threshold Energies (E_{thr}), Reduced Mass (μ), and the total Binding Energies (BE) of the targets

Reaction Type	Q – value (MeV) P.W	threshold energy (MeV) P.W	reduced mass (amu) P.W	separation energies (MeV) P.W	B.E (MeV) P.W
^{41}Ca(α,n)^{44}Ti	-3.23697	3.55327	3.646306	8.362935	352.5606
^{42}Ca(α,n)^{45}Ti	-5.18902	5.684025	3.654029	11.48078	364.0414
^{43}Ca(α,n)^{46}Ti	0.067133	0.073388	3.661453	7.933008	371.9744
^{44}Ca(α,n)^{47}Ti	-2.18375	2.382606	3.668543	11.13131	383.1057
^{45}Ca(α,n)^{48}Ti	2.028146	2.208718	3.675371	7.414908	390.5206
^{46}Ca(α,n)^{49}Ti	-0.22392	0.243427	3.681905	10.39459	400.9152
^{47}Ca(α,n)^{50}Ti	3.43893	3.732079	3.688204	7.276487	408.1917
^{48}Ca(α,n)^{51}Ti	-0.13393	0.14511	3.694243	9.945467	418.1371
^{49}Ca(α,n)^{52}Ti	2.527942	2.734626	3.700084	5.146565	423.2837
^{50}Ca(α,n)^{53}Ti	1.610368	1.739391	3.705701	6.353007	429.6367
^{44}Sc(p,n)^{44}Ti	-0.945538	0.96721	0.9853	9.702185	378.781
^{45}Sc(p,n)^{45}Ti	-2.739188	2.8006	0.9858	11.32238	390.103
^{46}Sc(p,n)^{46}Ti	1.689219	1.72627	0.9863	8.760758	398.864
^{47}Sc(p,n)^{47}Ti	-0.072741	0.074302	0.9868	10.64239	409.506
^{48}Sc(p,n)^{48}Ti	3.3242627	3.39414	0.9872	8.229802	417.736
^{49}Sc(p,n)^{49}Ti	1.3274061	1.35474	0.9876	10.13938	427.875
^{50}Sc(p,n)^{50}Ti	6.216654	6.34209	0.9880	6.050093	433.925
^{51}Sc(p,n)^{51}Ti	5.831227	5.94658	0.9884	6.758033	440.683
^{52}Sc(p,n)^{52}Ti	8.437238	8.60092	0.9888	5.202428	445.886
^{53}Sc(p,n)^{53}Ti	8.5305187	8.69287	0.9891	5.342153	451.228
^{44}Ti (n,n)^{44}Ti	0	0	0.986	16.29892	377.835
^{45}Ti (n,n)^{45}Ti	0	0	0.9865	9.524588	387.3637
^{46}Ti (n,n)^{46}Ti	0	0	0.987	13.1947	400.5529
^{47}Ti (n,n)^{47}Ti	0	0	0.9875	8.881852	409.4333
^{48}Ti (n,n)^{48}Ti	0	0	0.9879	11.62046	421.0601

Reaction Type	Q – value (MeV) P.W	threshold energy (MeV) P.W	reduced mass (amu) P.W	separation energies (MeV) P.W	B.E (MeV) P.W
^{49}Ti (n,n)^{49}Ti	0	0	0.9883	8.145967	429.2026
^{50}Ti (n,n)^{50}Ti	0	0	0.9887	10.94047	440.142
^{51}Ti (n,n)^{51}Ti	0	0	0.9891	6.376117	446.5146
^{52}Ti (n,n)^{52}Ti	0	0	0.9895	7.801313	454.323
^{53}Ti (n,n)^{53}Ti	0	0	0.9898	5.435302	459.7584
^{59}Ni(α,n)^{62}Zn	-5.6319	6.014402	3.7480	8.999135	518.462
^{60}Ni(α,n)^{63}Zn	-7.90675	8.434822	3.7520	11.38852	529.8499
^{61}Ni(α,n)^{64}Zn	-3.86497	4.118862	3.7559	7.819943	537.6702
^{62}Ni(α,n)^{65}Zn	-6.48219	6.901148	3.7596	10.59674	548.2668
^{63}Ni(α,n)^{66}Zn	-2.26079	2.404589	3.7632	6.838142	555.1047
^{64}Ni(α,n)^{67}Zn	-4.86652	5.171214	3.7668	9.657792	564.7629
^{65}Ni(α,n)^{68}Zn	-0.76648	0.813735	3.7702	6.09853	570.8611
^{66}Ni(α,n)^{69}Zn	-3.23598	3.43244	3.7735	8.951715	579.8128
^{67}Ni(α,n)^{70}Zn	0.174321	0.184746	3.7767	5.807903	585.6206
^{68}Ni(α,n)^{71}Zn	-1.78458	1.889726	3.7799	7.791997	593.4132
^{62}Cu(p,n)^{62}Zn	-2.30175	2.339215	0.9918	8.885412	543.6432
^{63}Cu(p,n)^{63}Zn	-4.04186	4.106603	0.9921	10.85291	554.4964
^{64}Cu(p,n)^{64}Zn	-0.09598	0.097494	0.9923	7.916819	562.4125
^{65}Cu(p,n)^{65}Zn	-2.02741	2.058882	0.9925	9.910228	572.3234
^{66}Cu(p,n)^{66}Zn	1.965832	1.995886	0.9928	7.066359	579.3894
^{67}Cu(p,n)^{67}Zn	-0.11367	0.115384	0.993	9.132426	588.5214
^{68}Cu(p,n)^{68}Zn	3.764876	3.820739	0.9932	6.319296	594.8411
^{69}Cu(p,n)^{69}Zn	2.00644	2.03578	0.9934	8.24098	603.0817
^{70}Cu(p,n)^{70}Zn	5.913226	5.998454	0.9936	5.311413	608.3931
^{71}Cu(p,n)^{71}Zn	3.940463	3.996456	0.9938	7.80597	616.1995
^{62}Zn(n,n)^{62}Zn	0	0	0.9925	12.89721	541.3414
^{63}Zn(n,n)^{63}Zn	0	0	0.9928	9.114728	550.4545
^{64}Zn(n,n)^{64}Zn	0	0	0.993	11.86265	562.3165
^{65}Zn(n,n)^{65}Zn	0	0	0.9932	7.978298	570.296
^{66}Zn(n,n)^{66}Zn	0	0	0.9935	11.06156	581.3553
^{67}Zn(n,n)^{67}Zn	0	0	0.9937	7.046797	588.4077
^{68}Zn(n,n)^{68}Zn	0	0	0.9939	10.20458	598.606
^{69}Zn(n,n)^{69}Zn	0	0	0.9941	6.478582	605.0882
^{70}Zn(n,n)^{70}Zn	0	0	0.9943	9.217193	614.3063
^{71}Zn(n,n)^{71}Zn	0	0	0.9945	5.835847	620.14
^{84}Zr(α,n)^{87}Mo	-9.44495	9.89541	3.8204	13.10509	722.4807
^{85}Zr(α,n)^{88}Mo	-6.09672	6.384079	3.8224	9.728586	732.2091

Reaction Type	Q – value (MeV) P.W	threshold energy (MeV) P.W	reduced mass (amu) P.W	separation energies (MeV) P.W	B.E (MeV) P.W
$^{86}Zr(\alpha,n)^{89}Mo$	-8.44816	8.841739	3.8244	12.72615	744.9358
$^{87}Zr(\alpha,n)^{90}Mo$	-4.82856	5.050929	3.8264	9.615874	754.5511
$^{88}Zr(\alpha,n)^{91}Mo$	-7.06663	7.388377	3.8283	12.3461	766.8975
$^{89}Zr(\alpha,n)^{92}Mo$	-3.71155	3.878644	3.8302	9.316863	776.2148
$^{90}Zr(\alpha,n)^{93}Mo$	-7.61147	7.950334	3.832	11.97071	788.1846
$^{91}Zr(\alpha,n)^{94}Mo$	-5.12838	5.354179	3.8338	7.193974	795.3792
$^{92}Zr(\alpha,n)^{95}Mo$	-6.39408	6.67255	3.8356	8.635005	804.0141
$^{93}Zr(\alpha,n)^{96}Mo$	-3.97422	4.145435	3.8373	6.734745	810.7487
$^{87}Nb\ (p,n)^{87}Mo$	-7.1636	7.246672	0.9964	12.42838	748.7107
$^{88}Nb\ (p,n)^{88}Mo$	-4.04837	4.094784	0.9965	9.961461	758.6721
$^{89}Nb\ (p,n)^{89}Mo$	-6.32187	6.393537	0.9966	12.64884	771.3209
$^{90}Nb\ (p,n)^{90}Mo$	-3.16435	3.199827	0.9968	10.07697	781.3982
$^{91}Nb\ (p,n)^{91}Mo$	-5.10364	5.16023	0.9969	12.04802	793.4459
$^{92}Nb\ (p,n)^{92}Mo$	-0.31867	0.322164	0.997	7.88701	801.3332
$^{93}Mo\ (p,n)^{93}Mo$	-1.08012	1.091841	0.9971	8.831551	810.1646
$^{94}Nb\ (p,n)^{94}Mo$	1.369882	1.384585	0.9972	7.227508	817.3923
$^{95}Nb\ (p,n)^{95}Mo$	0.25026	0.252917	0.9973	8.488759	825.8811
$^{96}Nb\ (p,n)^{96}Mo$	2.511482	2.537877	0.9975	6.8931	832.7744
$^{87}Mo\ (n,n)^{87}Mo$	0	0	0.9971	11.20958	741.5471
$^{88}Mo\ (n,n)^{88}Mo$	0	0	0.9972	13.07733	754.6238
$^{89}Mo\ (n,n)^{89}Mo$	0	0	0.9974	10.37505	764.999
$^{90}Mo\ (n,n)^{90}Mo$	0	0	0.9975	13.23475	778.2339
$^{91}Mo\ (n,n)^{91}Mo$	0	0	0.9976	10.10864	788.3422
$^{92}Mo\ (n,n)^{92}Mo$	0	0	0.9977	12.67213	801.0146
$^{93}Mo\ (n,n)^{93}Mo$	0	0	0.9978	8.069584	809.0845
$^{94}Mo\ (n,n)^{94}Mo$	0	0	0.9979	9.678285	818.7622
$^{95}Mo\ (n,n)^{95}Mo$	0	0	0.9981	7.369096	826.1314
$^{96}Mo\ (n,n)^{96}Mo$	0	0	0.9982	9.153851	835.2859

(3-3) Cross sections of (α,n) (p,n)and (n,n)reactions:

Data of cross-sections for this study were obtained from TALYS Evaluated Nuclear Data Library (TENDL-2010,2012) for all isotopes [105]. And there were a problem by searching for the cross-section data at energies that are needed, where they are missing. Also need to expand the scope of our investigation and the use of MATLAB software to get to the cross sections at these energies.

In this way, the results of our investigation will be useful not only to the program of radioactive isotopes that we have, but other laboratories can also use these assessments and new data. The cross section data measured in (mbarn) for these reactions after interpolated for incident particle energies from 10 to 50 MeV in steps of 0.5 MeV by using the MATLAB computer program in lab system.

(3-3-1) (α,n) cross sections:

Cross-sections for alpha particle for production of ^{44,45,46,47,48,49,50,51,52,53}Ti, ^{62,63,64,65,66,67,68,69,70,71}Zn and ^{87,88,89,90,91,92,93,94,95,96}Mo that react with target such that Ca, Ni and Zr respectively after interpolation for various incident particle energy with range (10-50)MeV which are listed in tables (3-3) to (3-12) for Ca(α,n)Ti reactions, (3-13) to (3-22) for Ni(α,n)Zn reactions and tables (3-23) to (3-32)for Zr(α,n)Mo reactions.

(3-3-2) (p,n) cross sections:

Cross section depends on particle energy which, in turn, depends on the depth of penetration. Proton particle activation cross-sections for production of ^{44,45,46,47,48,49,50,51,52,53}Ti, ^{62,63,64,65,66,67,68,69,70,71}Zn and ^{87,88,89,90,91,92,93,94,95,96}Mo that react with target of isotopes Sc, Cu and Nb respectively, after interpolation cross section data at various incident particle energy with range (10-50) MeV which are listed in tables (3-32) to (3-42) for Sc(p,n)Ti reactions, (3-43) to (3-52) for Cu(p,n)Zn reactions and tables (3-53) to (3-62)for Nb(p,n)Mo reactions.

(3-3-3) (n,n) cross sections:

The elastic cross-section depends on whether or not the scattering is due to long-range Coulomb interactions or to short-range strong interactions, for elastic neutron scattering is due to the short-range strong interaction [106]. The elastic scattering of various energies of neutrons up to 50 MeV from (Ti, Zn and Mo) isotopes, after interpolation are listed in tables (3-63) to (3-72) for Ti(n,n)Ti reactions at energies (20- 50)MeV, tables (3-73) to (3-82) for Zn(n,n)Zn reactions at energies (10-50)MeV and tables (3-83) to (3-92)for Mo(n,n)Mo reactions at energies (10-50)MeV. Some cross-sections of isotopes were missing or received a value of (0.0), because this information is not available for the cross-section at these energies.

(3-4) Stopping Power:

Stopping power depends on the type and energy of the incident particle and on the properties of the materials it passes. In passing through matter, fast charged particles ionize the atoms or molecules which they encounter. Several semi-empirical stopping power formulas have been devised. The model given by Ziegler, Biersack and Littmark (the so called "ZBL" stopping) (Ziegler 1985), implemented in different versions of the SRIM codes (http://www.SRIM.org), is used most often today. So, the stopping power in {MeV / (mg/cm^2)} units of medium target elements, has been calculated in the present work using SRIM version 2013 code [107], for the incident proton and alpha particle at energy from (10 -50) MeV. The results for incident alpha particle are listed in tables (3-

3) to (3-12) for Ca(α,n)Ti reactions, (3-13) to (3-22) for Ni(α,n)Zn reactions and tables (3-23) to (3-32)for Zr(α,n)Mo reactions. And for incident proton, they are listed in tables (3-33) to (3-42) for Sc(p,n)Ti reactions, (3-43) to (3-52) for Cu(p,n)Zn reactions and tables (3-53) to (3-62) for Nb(p,n)Mo reactions.

(3-5) Neutron Yield:

The interpolated cross sections together with stopping power which are used to calculate the neutron yield from equation (2-24) by Matlab program. The calculations results of neutron yields (Y), obtained from different isotopes of target material, at energy (E_b) for incident particles (proton and alpha), for (α,n) are listed in tables (3-3) to (3-12) for Ca(α,n)Ti reactions, (3-13) to (3-22) for Ni(α,n)Zn reactions and tables (3-23) to (3-32)for Zr(α,n)Mo reactions. And for (p,n) are listed in tables (3-33) to (3-42) for Sc(p,n)Ti reactions, (3-43) to (3-52) for Cu(p,n)Zn reactions and tables (3-53) to (3-62)for Nb(p,n)Mo reactions.

Table (3-3): The cross section and calculated data of stopping power and neutron yield for $^{41}Ca(\alpha,n)^{44}Ti$ reaction.

Alpha energy MeV	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 alpha**	**Alpha energy MeV**	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 alpha**
10	112.209	0.364335	0.153991	30.5	4.531156	0.145328	3.734917
10.5	118.573	0.352626	0.32212	31	4.376658	0.144577	3.750053
11	124.937	0.340917	0.505357	31.5	4.222161	0.143827	3.764731
11.5	128.4481	0.330859	0.69947	32	4.067664	0.143076	3.778946
12	131.9592	0.320801	0.905142	32.5	3.913166	0.142326	3.792693
12.5	133.2847	0.311944	1.118777	33	3.758669	0.141575	3.805967
13	134.6101	0.303087	1.340842	33.5	3.604171	0.140825	3.818764
13.5	131.1687	0.295281	1.56295	34	3.449674	0.140074	3.831078
14	127.7274	0.287475	1.785104	34.5	3.295177	0.139324	3.842903
14.5	117.1642	0.28057	1.9939	35	3.140679	0.138573	3.854235
15	106.6009	0.273665	2.188666	35.5	3.033692	0.137913	3.865234
15.5	93.21306	0.267461	2.362922	36	2.926705	0.137253	3.875896
16	79.82519	0.261256	2.515693	36.5	2.819718	0.136592	3.886217
16.5	68.86832	0.255652	2.650385	37	2.71273	0.135932	3.896196
17	57.91146	0.250048	2.766186	37.5	2.605743	0.135271	3.905827
17.5	49.37535	0.244944	2.866975	38	2.498756	0.134611	3.915109
18	40.83924	0.239841	2.952113	38.5	2.391769	0.133951	3.924036
18.5	34.93265	0.230934	3.027746	39	2.284782	0.13329	3.932607
19	29.02606	0.222028	3.093112	39.5	2.177794	0.13263	3.940817
19.5	25.18523	0.212772	3.152296	40	2.070807	0.131969	3.948663
20	21.3444	0.203516	3.204735	40.5	2.007347	0.130829	3.956335
20.5	19.26759	0.199688	3.252979	41	1.943887	0.129688	3.963829
21	17.19078	0.19586	3.296864	41.5	1.880426	0.128547	3.971143
21.5	15.11397	0.192033	3.336217	42	1.816966	0.127407	3.978274
22	13.03716	0.188205	3.370853	42.5	1.753506	0.126266	3.985218
22.5	12.00491	0.184978	3.403302	43	1.690045	0.125125	3.991971
23	10.97266	0.181751	3.433488	43.5	1.626585	0.123984	3.998531
23.5	9.940413	0.178524	3.461329	44	1.563124	0.122844	4.004893
24	8.908163	0.175297	3.486737	44.5	1.499664	0.121703	4.011054
24.5	8.387381	0.17252	3.511046	45	1.436204	0.120562	4.01701
25	7.866599	0.169743	3.534218	45.5	1.394115	0.119622	4.022838
25.5	7.345817	0.166966	3.556216	46	1.352027	0.118681	4.028534
26	6.825035	0.16419	3.577	46.5	1.309939	0.117741	4.034096
26.5	6.488402	0.161788	3.597052	47	1.26785	0.1168	4.039524
27	6.151769	0.159386	3.61635	47.5	1.225762	0.11586	4.044814
27.5	5.815136	0.156985	3.634872	48	1.183673	0.114919	4.049964
28	5.478504	0.154583	3.652592	48.5	1.141585	0.113978	4.054972
28.5	5.280291	0.152457	3.669909	49	1.099496	0.113038	4.059835
29	5.082078	0.150331	3.686812	49.5	1.057408	0.112097	4.064551
29.5	4.883866	0.148204	3.703289	50	1.01532	0.111157	4.069119
30	4.685653	0.146078	3.719327				

Table (3-4): The cross section and calculated data of stopping power and neutron yield for $^{42}Ca(\alpha,n)^{45}Ti$ reaction.

Alpha energy MeV	Cross section (mb)	Stopping power MeV / (mg/cm^2)	Neutron yield n/10^6 alpha	Alpha energy MeV	Cross section (mb)	Stopping power MeV / (mg/cm^2)	Neutron yield n/10^6 alpha
10	238.4108	0.355624	0.3352	30.5	10.09419	0.141844	12.49123
10.5	254.4159	0.344215	0.70476	31	9.723589	0.141114	12.52569
11	270.4211	0.332806	1.111033	31.5	9.352983	0.140383	12.559
11.5	282.388	0.322949	1.548236	32	8.982377	0.139653	12.59116
12	294.355	0.313091	2.018314	32.5	8.611771	0.138922	12.62215
12.5	303.9672	0.304485	2.517464	33	8.241166	0.138192	12.65197
13	313.5794	0.295878	3.047377	33.5	7.87056	0.137461	12.6806
13.5	320.3488	0.288273	3.603012	34	7.499954	0.136731	12.70803
14	327.1181	0.280667	4.185762	34.5	7.129348	0.136	12.73424
14.5	332.0266	0.273912	4.791844	35	6.758743	0.13527	12.75922
15	336.935	0.267157	5.422437	35.5	6.538001	0.13462	12.7835
15.5	340.3677	0.261053	6.07435	36	6.31726	0.133969	12.80708
16	343.8003	0.254949	6.748604	36.5	6.096519	0.133319	12.82994
16.5	332.1949	0.249495	7.414339	37	5.875778	0.132668	12.85209
17	320.5896	0.244041	8.071174	37.5	5.655037	0.132018	12.87351
17.5	283.0861	0.239088	8.663188	38	5.434296	0.131368	12.89419
18	245.5827	0.234134	9.187637	38.5	5.213554	0.130717	12.91413
18.5	206.7323	0.225428	9.64617	39	4.992813	0.130067	12.93333
19	167.882	0.216722	10.03349	39.5	4.772072	0.129416	12.95176
19.5	139.3905	0.207716	10.36902	40	4.551331	0.128766	12.96944
20	110.899	0.19871	10.64807	40.5	4.411513	0.127655	12.98671
20.5	96.08281	0.194958	10.89449	41	4.271696	0.126545	13.00359
21	81.26661	0.191205	11.107	41.5	4.131878	0.125434	13.02006
21.5	66.45041	0.187453	11.28425	42	3.99206	0.124323	13.03612
22	51.63421	0.1837	11.42479	42.5	3.852243	0.123213	13.05175
22.5	45.73712	0.180548	11.55145	43	3.712425	0.122102	13.06695
23	39.84003	0.177396	11.66374	43.5	3.572607	0.120991	13.08172
23.5	33.94294	0.174244	11.76114	44	3.43279	0.119881	13.09603
24	28.04585	0.171092	11.8431	44.5	3.292972	0.11877	13.1099
24.5	25.52181	0.16839	11.91888	45	3.153154	0.117659	13.1233
25	22.99777	0.165689	11.98828	45.5	3.060353	0.116739	13.1364
25.5	20.47373	0.162987	12.05109	46	2.967551	0.115818	13.14922
26	17.94968	0.160285	12.10708	46.5	2.874749	0.114898	13.16173
26.5	16.7084	0.157934	12.15998	47	2.781948	0.113977	13.17393
27	15.46711	0.155582	12.20969	47.5	2.689146	0.113057	13.18582
27.5	14.22582	0.153231	12.25611	48	2.596345	0.112136	13.1974
28	12.98454	0.150879	12.29914	48.5	2.503543	0.111216	13.20865
28.5	12.3546	0.148803	12.34065	49	2.410741	0.110295	13.21958
29	11.72467	0.146727	12.3806	49.5	2.31794	0.109375	13.23018
29.5	11.09473	0.144651	12.41895	50	2.225138	0.108454	13.24044
30	10.4648	0.142574	12.45565				

Table (3-5): The cross section and calculated data of stopping power and neutron yield for $^{43}Ca(\alpha,n)^{46}Ti$ reaction.

Alpha energy MeV	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 alpha**	**Alpha energy MeV**	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 alpha**
10	459.387	0.347414	0.661152	30.5	12.24799	0.138561	16.14083
10.5	498.2531	0.336256	1.402037	31	11.76967	0.13785	16.18352
11	537.1192	0.325097	2.228127	31.5	11.29135	0.13714	16.22469
11.5	563.9727	0.31544	3.122074	32	10.81304	0.136429	16.26432
12	590.8262	0.305783	4.088162	32.5	10.33472	0.135719	16.30239
12.5	594.071	0.297376	5.087016	33	9.856401	0.135008	16.33889
13	597.3158	0.28897	6.120541	33.5	9.378084	0.134298	16.37381
13.5	565.8047	0.281565	7.125291	34	8.899767	0.133588	16.40712
14	534.2936	0.27416	8.099712	34.5	8.42145	0.132877	16.43881
14.5	482.7968	0.267555	9.001951	35	7.943133	0.132167	16.46886
15	431.2999	0.26095	9.828354	35.5	7.677912	0.131526	16.49805
15.5	378.3433	0.254996	10.57022	36	7.412692	0.130886	16.52636
16	325.3867	0.249042	11.22349	36.5	7.147471	0.130246	16.5538
16.5	282.7339	0.243688	11.80361	37	6.88225	0.129605	16.58035
17	240.0812	0.238335	12.30727	37.5	6.617029	0.128965	16.60601
17.5	205.2125	0.233481	12.74673	38	6.351809	0.128325	16.63076
18	170.3438	0.228628	13.11927	38.5	6.086588	0.127684	16.65459
18.5	146.7608	0.220172	13.45256	39	5.821367	0.127044	16.6775
19	123.1778	0.211717	13.74346	39.5	5.556146	0.126403	16.69948
19.5	106.4017	0.202911	14.00565	40	5.290926	0.125763	16.72051
20	89.62565	0.194105	14.23651	40.5	5.123665	0.124682	16.74106
20.5	79.52318	0.190453	14.44529	41	4.956404	0.123602	16.76111
21	69.4207	0.1868	14.6311	41.5	4.789143	0.122521	16.78065
21.5	59.31823	0.183148	14.79304	42	4.621883	0.121441	16.79968
22	49.21576	0.179496	14.93014	42.5	4.454622	0.12036	16.81819
22.5	44.40322	0.176394	15.056	43	4.287361	0.119279	16.83616
23	39.59068	0.173292	15.17023	43.5	4.120101	0.118199	16.85359
23.5	34.77814	0.17019	15.27241	44	3.95284	0.117118	16.87047
24	29.9656	0.167088	15.36208	44.5	3.785579	0.116037	16.88678
24.5	27.72833	0.164436	15.44639	45	3.618319	0.114957	16.90252
25	25.49106	0.161785	15.52517	45.5	3.505039	0.114056	16.91788
25.5	23.2538	0.159133	15.59824	46	3.39176	0.113156	16.93287
26	21.01653	0.156481	15.66539	46.5	3.278481	0.112255	16.94747
26.5	19.73239	0.154205	15.72937	47	3.165202	0.111355	16.96168
27	18.44826	0.151929	15.79009	47.5	3.051922	0.110454	16.9755
27.5	17.16412	0.149652	15.84743	48	2.938643	0.109554	16.98891
28	15.87999	0.147376	15.90131	48.5	2.825364	0.108653	17.00191
28.5	15.09156	0.14535	15.95322	49	2.712084	0.107753	17.0145
29	14.30314	0.143323	16.00312	49.5	2.598805	0.106852	17.02666
29.5	13.51472	0.141297	16.05094	50	2.485526	0.105952	17.03839
30	12.7263	0.139271	16.09663				

Table (3-6): The cross section and calculated data of stopping power and neutron yield for $^{44}Ca(\alpha,n)^{47}Ti$ reaction.

Alpha energy MeV	Cross section (mb)	Stopping power MeV / (mg/cm^2)	Neutron yield n/10^6 alpha	Alpha energy MeV	Cross section (mb)	Stopping power MeV / (mg/cm^2)	Neutron yield n/10^6 alpha
10	459.7537	0.339505	0.677095	30.5	11.08797	0.135377	17.30352
10.5	494.4534	0.328596	1.429467	31	10.64955	0.134687	17.34306
11	529.153	0.317688	2.262285	31.5	10.21113	0.133997	17.38116
11.5	554.5374	0.308281	3.161687	32	9.772715	0.133306	17.41781
12	579.9218	0.298874	4.131863	32.5	9.334295	0.132616	17.45301
12.5	587.2155	0.290619	5.142149	33	8.895874	0.131925	17.48672
13	594.5091	0.282363	6.19489	33.5	8.457454	0.131235	17.51895
13.5	576.4721	0.275108	7.242611	34	8.019034	0.130545	17.54966
14	558.435	0.267852	8.285041	34.5	7.580614	0.129854	17.57885
14.5	518.9281	0.261398	9.277643	35	7.142194	0.129164	17.6065
15	479.4211	0.254943	10.21789	35.5	6.910091	0.128543	17.63337
15.5	429.718	0.249139	11.0803	36	6.677989	0.127923	17.65948
16	380.0149	0.243336	11.86114	36.5	6.445886	0.127303	17.68479
16.5	329.3438	0.238132	12.55266	37	6.213783	0.126682	17.70932
17	278.6727	0.232929	13.15085	37.5	5.981681	0.126062	17.73304
17.5	236.4139	0.228175	13.66891	38	5.749578	0.125442	17.75596
18	194.155	0.223422	14.10341	38.5	5.517475	0.124821	17.77806
18.5	163.7977	0.215167	14.48404	39	5.285373	0.124201	17.79934
19	133.4404	0.206911	14.8065	39.5	5.05327	0.123581	17.81978
19.5	114.477	0.198306	15.09513	40	4.821167	0.12296	17.83939
20	95.51366	0.1897	15.34688	40.5	4.661403	0.1219	17.85851
20.5	84.51227	0.186123	15.57391	41	4.501638	0.120839	17.87714
21	73.51088	0.182546	15.77526	41.5	4.341873	0.119778	17.89526
21.5	62.50949	0.178969	15.9499	42	4.182109	0.118718	17.91287
22	51.5081	0.175391	16.09674	42.5	4.022344	0.117657	17.92997
22.5	46.10309	0.172365	16.23048	43	3.862579	0.116597	17.94653
23	40.69809	0.169338	16.35065	43.5	3.702815	0.115536	17.96256
23.5	35.29308	0.166311	16.45675	44	3.54305	0.114475	17.97803
24	29.88807	0.163284	16.54827	44.5	3.383285	0.113415	17.99295
24.5	27.41164	0.160707	16.63356	45	3.223521	0.112354	18.00729
25	24.93521	0.158131	16.7124	45.5	3.13088	0.111474	18.02134
25.5	22.45879	0.155554	16.78459	46	3.038239	0.110593	18.03507
26	19.98236	0.152978	16.8499	46.5	2.945599	0.109713	18.0485
26.5	18.72949	0.150726	16.91203	47	2.852958	0.108832	18.0616
27	17.47663	0.148475	16.97089	47.5	2.760317	0.107952	18.07439
27.5	16.22376	0.146224	17.02636	48	2.667677	0.107071	18.08685
28	14.97089	0.143972	17.07835	48.5	2.575036	0.106191	18.09897
28.5	14.10977	0.141996	17.12804	49	2.482395	0.10531	18.11076
29	13.24864	0.14002	17.17535	49.5	2.389755	0.10443	18.1222
29.5	12.38752	0.138044	17.22022	50	2.297114	0.103549	18.13329
30	11.5264	0.136068	17.26257				

Table (3-7): The cross section and calculated data of stopping power and neutron yield for $^{45}Ca(\alpha,n)^{48}Ti$ reaction.

Alpha energy MeV	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 alpha**	**Alpha energy MeV**	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 alpha**
10	547.3121	0.331896	0.824525	30.5	10.58123	0.132384	12.19838
10.5	579.7546	0.321238	1.726901	31	10.17697	0.131704	12.23702
11	612.1972	0.31058	2.712472	31.5	9.772697	0.131024	12.27431
11.5	588.9297	0.301373	3.689549	32	9.368428	0.130343	12.31025
12	565.6623	0.292167	4.657596	32.5	8.96416	0.129663	12.34482
12.5	504.3228	0.284161	5.544984	33	8.559891	0.128983	12.378
13	442.9832	0.276156	6.347038	33.5	8.155622	0.128302	12.40978
13.5	380.6021	0.269051	7.054344	34	7.751353	0.127622	12.44015
14	318.2209	0.261946	7.661762	34.5	7.347085	0.126941	12.46909
14.5	269.0493	0.255641	8.187986	35	6.942816	0.126261	12.49658
15	219.8776	0.249337	8.62891	35.5	6.696224	0.125651	12.52323
15.5	186.0657	0.243633	9.010766	36	6.449633	0.12504	12.54902
16	152.2538	0.23793	9.330721	36.5	6.203041	0.12443	12.57394
16.5	129.9354	0.232826	9.609761	37	5.956449	0.12382	12.598
17	107.617	0.227723	9.84605	37.5	5.709858	0.123209	12.62117
17.5	92.93609	0.22312	10.05431	38	5.463266	0.122599	12.64345
18	78.2552	0.218517	10.23337	38.5	5.216674	0.121989	12.66483
18.5	68.64797	0.210412	10.3965	39	4.970082	0.121378	12.6853
19	59.04074	0.202307	10.54242	39.5	4.723491	0.120768	12.70486
19.5	52.77518	0.193851	10.67854	40	4.476899	0.120158	12.72349
20	46.50961	0.185396	10.80398	40.5	4.335837	0.119127	12.74169
20.5	42.66412	0.181919	10.92124	41	4.194775	0.118096	12.75945
21	38.81863	0.178442	11.03001	41.5	4.053712	0.117066	12.77676
21.5	34.97313	0.174965	11.12995	42	3.91265	0.116035	12.79362
22	31.12764	0.171487	11.22071	42.5	3.771588	0.115005	12.81002
22.5	28.95776	0.168536	11.30662	43	3.630526	0.113974	12.82595
23	26.78787	0.165584	11.38751	43.5	3.489463	0.112944	12.84139
23.5	24.61799	0.162632	11.4632	44	3.348401	0.111913	12.85635
24	22.44811	0.15968	11.53349	44.5	3.207339	0.110882	12.87082
24.5	21.04898	0.157154	11.60046	45	3.066277	0.109852	12.88477
25	19.64986	0.154627	11.664	45.5	2.967345	0.108991	12.89839
25.5	18.25073	0.152101	11.72399	46	2.868413	0.108131	12.91165
26	16.85161	0.149574	11.78032	46.5	2.769481	0.10727	12.92456
26.5	15.97925	0.147373	11.83454	47	2.670549	0.10641	12.93711
27	15.1069	0.145172	11.88657	47.5	2.571617	0.10555	12.94929
27.5	14.23455	0.142971	11.93635	48	2.472685	0.104689	12.9611
28	13.3622	0.140769	11.98381	48.5	2.373753	0.103829	12.97253
28.5	12.76802	0.138843	12.02979	49	2.274821	0.102968	12.98358
29	12.17385	0.136917	12.07425	49.5	2.175889	0.102108	12.99423
29.5	11.57968	0.134991	12.11714	50	2.076957	0.101247	13.00449
30	10.9855	0.133065	12.15842				

Table (3-8): The cross section and calculated data of stopping power and neutron yield for $^{46}Ca(\alpha,n)^{49}Ti$ reaction

Alpha energy MeV	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 alpha**	**Alpha energy MeV**	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 alpha**
10	548.3938	0.324787	0.844236	30.5	9.204678	0.129592	11.79811
10.5	548.3067	0.31433	1.716419	31	8.830989	0.128921	11.83236
11	548.2196	0.303872	2.618475	31.5	8.457301	0.128251	11.86533
11.5	516.625	0.294866	3.494509	32	8.083612	0.127581	11.89701
12	485.0303	0.28586	4.34288	32.5	7.709923	0.12691	11.92739
12.5	441.2641	0.278004	5.136508	33	7.336234	0.12624	11.95644
13	397.4978	0.270149	5.872209	33.5	6.962545	0.12557	11.98417
13.5	350.0276	0.263194	6.53717	34	6.588857	0.124899	12.01054
14	302.5574	0.25624	7.12755	34.5	6.215168	0.124229	12.03556
14.5	259.7251	0.250085	7.646823	35	5.841479	0.123558	12.0592
15	216.8928	0.243931	8.0914	35.5	5.640718	0.122968	12.08213
15.5	185.8236	0.238378	8.481168	36	5.439956	0.122378	12.10436
16	154.7545	0.232824	8.81351	36.5	5.239195	0.121787	12.12587
16.5	133.1276	0.227821	9.105686	37	5.038434	0.121197	12.14665
17	111.5007	0.222818	9.355892	37.5	4.837673	0.120607	12.16671
17.5	96.72983	0.218315	9.577429	38	4.636911	0.120016	12.18603
18	81.95898	0.213812	9.769091	38.5	4.43615	0.119426	12.2046
18.5	72.07229	0.205857	9.944145	39	4.235389	0.118836	12.22242
19	62.18561	0.197902	10.10126	39.5	4.034627	0.118245	12.23948
19.5	55.4678	0.189647	10.2475	40	3.833866	0.117655	12.25577
20	48.74999	0.181392	10.38187	40.5	3.706992	0.116635	12.27166
20.5	44.79499	0.17799	10.50771	41	3.580118	0.115614	12.28715
21	40.83998	0.174588	10.62467	41.5	3.453244	0.114593	12.30222
21.5	36.88498	0.171186	10.7324	42	3.326371	0.113573	12.31686
22	32.92998	0.167784	10.83054	42.5	3.199497	0.112552	12.33107
22.5	30.43242	0.164907	10.92281	43	3.072623	0.111532	12.34485
23	27.93486	0.16203	11.00901	43.5	2.945749	0.110511	12.35818
23.5	25.43731	0.159154	11.08893	44	2.818875	0.109491	12.37105
24	22.93975	0.156277	11.16232	44.5	2.692001	0.10847	12.38346
24.5	21.23677	0.153801	11.23136	45	2.565128	0.10745	12.39539
25	19.53379	0.151324	11.2959	45.5	2.48935	0.106612	12.40707
25.5	17.83081	0.148848	11.3558	46	2.413571	0.105775	12.41848
26	16.12783	0.146371	11.41089	46.5	2.337793	0.104937	12.42962
26.5	15.13495	0.14422	11.46336	47	2.262015	0.1041	12.44048
27	14.14207	0.142069	11.51314	47.5	2.186237	0.103262	12.45107
27.5	13.14919	0.139918	11.56012	48	2.110459	0.102425	12.46137
28	12.15631	0.137766	11.60424	48.5	2.034681	0.101588	12.47138
28.5	11.51182	0.13589	11.6466	49	1.958903	0.10075	12.48111
29	10.86734	0.134014	11.68715	49.5	1.883125	0.099913	12.49053
29.5	10.22285	0.132138	11.72583	50	1.807347	0.099075	12.49965
30	9.578367	0.130262	11.76259				

Table (3-9): The cross section and calculated data of stopping power and neutron yield for $^{47}Ca(\alpha,n)^{50}Ti$ reaction

Alpha energy MeV	Cross section (mb)	Stopping power MeV / (mg/cm^2)	Neutron yield n/10^6 alpha	Alpha energy MeV	Cross section (mb)	Stopping power MeV / (mg/cm^2)	Neutron yield n/10^6 alpha
10	386.2811	0.317779	0.607782	30.5	8.401385	0.126799	5.823109
10.5	342.1907	0.307572	1.164059	31	8.081421	0.126139	5.855142
11	298.1003	0.297365	1.665295	31.5	7.761458	0.125478	5.88607
11.5	256.0112	0.288559	2.108898	32	7.441495	0.124818	5.915879
12	213.9221	0.279753	2.491239	32.5	7.121532	0.124158	5.944559
12.5	179.6606	0.272048	2.82144	33	6.801568	0.123497	5.972096
13	145.3991	0.264343	3.09646	33.5	6.481605	0.122837	5.998479
13.5	123.0733	0.257538	3.335402	34	6.161642	0.122177	6.023695
14	100.7475	0.250734	3.536307	34.5	5.841678	0.121516	6.047732
14.5	86.34449	0.24468	3.712751	35	5.521715	0.120856	6.070576
15	71.9415	0.238626	3.863492	35.5	5.32789	0.120276	6.092725
15.5	63.33676	0.233222	3.999279	36	5.134064	0.119695	6.114171
16	54.73202	0.227819	4.119401	36.5	4.940239	0.119115	6.134908
16.5	48.84091	0.222916	4.228951	37	4.746414	0.118535	6.154929
17	42.94981	0.218013	4.327454	37.5	4.552588	0.117954	6.174228
17.5	38.9231	0.21361	4.418562	38	4.358763	0.117374	6.192795
18	34.89639	0.209207	4.501963	38.5	4.164938	0.116794	6.210626
18.5	32.04527	0.201402	4.581518	39	3.971112	0.116213	6.227711
19	29.19416	0.193598	4.656918	39.5	3.777287	0.115633	6.244044
19.5	27.39776	0.185543	4.730749	40	3.583462	0.115053	6.259617
20	25.60136	0.177488	4.80287	40.5	3.474563	0.114062	6.274848
20.5	24.29769	0.174161	4.872627	41	3.365664	0.113072	6.289731
21	22.99401	0.170834	4.939926	41.5	3.256765	0.112081	6.30426
21.5	21.69034	0.167507	5.00467	42	3.147867	0.111091	6.318428
22	20.38666	0.16418	5.066757	42.5	3.038968	0.1101	6.332229
22.5	19.26068	0.161354	5.126441	43	2.930069	0.10911	6.345656
23	18.13471	0.158527	5.183639	43.5	2.821171	0.108119	6.358702
23.5	17.00873	0.1557	5.238259	44	2.712272	0.107129	6.371361
24	15.88276	0.152874	5.290206	44.5	2.603373	0.106138	6.383625
24.5	15.13732	0.150447	5.340514	45	2.494475	0.105148	6.395487
25	14.39188	0.148021	5.389128	45.5	2.418415	0.104327	6.407078
25.5	13.64644	0.145595	5.435993	46	2.342356	0.103507	6.418393
26	12.901	0.143168	5.481048	46.5	2.266297	0.102686	6.429428
26.5	12.2939	0.141067	5.524623	47	2.190237	0.101866	6.440178
27	11.6868	0.138966	5.566672	47.5	2.114178	0.101045	6.45064
27.5	11.0797	0.136865	5.607149	48	2.038119	0.100225	6.460808
28	10.4726	0.134764	5.646004	48.5	1.962059	0.099405	6.470677
28.5	10.03478	0.132938	5.683747	49	1.886	0.098584	6.480242
29	9.596972	0.131111	5.720345	49.5	1.809941	0.097764	6.489499
29.5	9.15916	0.129285	5.755768	50	1.733881	0.096943	6.498442
30	8.721348	0.127459	5.78998				

Table (3-10): The cross section and calculated data of stopping power and neutron yield for $^{48}Ca(\alpha,n)^{51}Ti$ reaction

Alpha energy MeV	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 alpha**	**Alpha energy MeV**	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 alpha**
10	258.6558	0.311172	0.415616	30.5	3.833555	0.124117	4.178648
10.5	238.064	0.301215	0.810788	31	3.685405	0.123476	4.193571
11	217.4722	0.291258	1.18412	31.5	3.537255	0.122836	4.207969
11.5	192.4991	0.282603	1.524703	32	3.389105	0.122196	4.221837
12	167.5261	0.273947	1.830467	32.5	3.240955	0.121555	4.235168
12.5	143.9455	0.266442	2.100593	33	3.092805	0.120915	4.247957
13	120.3648	0.258937	2.333014	33.5	2.944654	0.120275	4.260199
13.5	102.7755	0.252283	2.536705	34	2.796504	0.119634	4.271886
14	85.18619	0.245628	2.71011	34.5	2.648354	0.118994	4.283014
14.5	72.8479	0.239674	2.862083	35	2.500204	0.118354	4.293577
15	60.50961	0.233721	2.991531	35.5	2.412114	0.117793	4.303816
15.5	51.61243	0.228417	3.104509	36	2.324023	0.117233	4.313728
16	42.71526	0.223114	3.200235	36.5	2.235933	0.116673	4.32331
16.5	36.84881	0.218311	3.28463	37	2.147842	0.116112	4.332559
17	30.98236	0.213508	3.357185	37.5	2.059752	0.115552	4.341471
17.5	27.178	0.209155	3.422156	38	1.971661	0.114992	4.350044
18	23.37365	0.204803	3.47922	38.5	1.883571	0.114432	4.358274
18.5	20.77721	0.197248	3.531888	39	1.795481	0.113871	4.366158
19	18.18078	0.189694	3.579809	39.5	1.70739	0.113311	4.373692
19.5	16.52862	0.181789	3.62527	40	1.6193	0.112751	4.380873
20	14.87647	0.173884	3.668047	40.5	1.56979	0.11177	4.387896
20.5	13.787	0.170608	3.708452	41	1.52028	0.11079	4.394757
21	12.69754	0.167331	3.746394	41.5	1.47077	0.109809	4.401454
21.5	11.60807	0.164054	3.781773	42	1.42126	0.108829	4.407984
22	10.51861	0.160777	3.814485	42.5	1.37175	0.107848	4.414343
22.5	9.823468	0.158	3.845571	43	1.32224	0.106868	4.420529
23	9.12833	0.155224	3.874975	43.5	1.27273	0.105887	4.426539
23.5	8.433193	0.152447	3.902635	44	1.22322	0.104907	4.432369
24	7.738056	0.149671	3.928485	44.5	1.17371	0.103926	4.438016
24.5	7.248062	0.147319	3.953085	45	1.1242	0.102946	4.443476
25	6.758068	0.144968	3.976394	45.5	1.090805	0.102145	4.448816
25.5	6.268075	0.142617	3.998369	46	1.057409	0.101345	4.454033
26	5.778081	0.140265	4.018966	46.5	1.024014	0.100544	4.459125
26.5	5.542302	0.138189	4.039019	47	0.990619	0.099744	4.464091
27	5.306524	0.136113	4.058512	47.5	0.957224	0.098944	4.468928
27.5	5.070745	0.134037	4.077428	48	0.923829	0.098143	4.473635
28	4.834966	0.131961	4.095747	48.5	0.890434	0.097343	4.478208
28.5	4.621651	0.13016	4.113501	49	0.857038	0.096542	4.482647
29	4.408336	0.128359	4.130673	49.5	0.823643	0.095742	4.486948
29.5	4.195021	0.126558	4.147246	50	0.790248	0.094942	4.49111
30	3.981705	0.124757	4.163204				

Table (3-11): The cross section and calculated data of stopping power and neutron yield for $^{49}Ca(\alpha,n)^{52}Ti$ reaction

Alpha energy MeV	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 alpha**	**Alpha energy MeV**	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 alpha**
10	79.95684	0.304765	0.131178	30.5	2.089703	0.121624	1.196958
10.5	67.28442	0.295008	0.245216	31	2.006505	0.120994	1.20525
11	54.612	0.285252	0.340942	31.5	1.923307	0.120364	1.21324
11.5	45.61349	0.276796	0.423337	32	1.840108	0.119733	1.220924
12	36.61498	0.268341	0.491562	32.5	1.75691	0.119103	1.228299
12.5	31.00129	0.260936	0.550966	33	1.673712	0.118473	1.235363
13	25.3876	0.253531	0.601034	33.5	1.590514	0.117842	1.242112
13.5	21.38525	0.247027	0.644319	34	1.507316	0.117212	1.248542
14	17.38289	0.240523	0.680455	34.5	1.424118	0.116582	1.254649
14.5	15.15342	0.234719	0.712735	35	1.340919	0.115951	1.260432
15	12.92395	0.228916	0.740963	35.5	1.292203	0.115391	1.266031
15.5	11.54108	0.223713	0.766758	36	1.243487	0.114831	1.271445
16	10.1582	0.218509	0.790002	36.5	1.194771	0.114271	1.276673
16.5	9.353772	0.213807	0.811877	37	1.146055	0.11371	1.281712
17	8.549344	0.209104	0.832319	37.5	1.097339	0.11315	1.286561
17.5	7.980145	0.204851	0.851797	38	1.048623	0.11259	1.291218
18	7.410946	0.200599	0.870269	38.5	0.999907	0.112029	1.295681
18.5	6.99637	0.193144	0.888381	39	0.951191	0.111469	1.299948
19	6.581795	0.18569	0.906104	39.5	0.902474	0.110909	1.304016
19.5	6.223581	0.177985	0.923587	40	0.853758	0.110349	1.307885
20	5.865367	0.170281	0.94081	40.5	0.832028	0.109398	1.311687
20.5	5.593061	0.167079	0.957547	41	0.810297	0.108448	1.315423
21	5.320754	0.163877	0.973781	41.5	0.788567	0.107497	1.319091
21.5	5.048448	0.160676	0.989491	42	0.766836	0.106547	1.32269
22	4.776141	0.157474	1.004656	42.5	0.745106	0.105596	1.326218
22.5	4.54357	0.154772	1.019335	43	0.723375	0.104646	1.329674
23	4.310998	0.152071	1.033509	43.5	0.701645	0.103695	1.333057
23.5	4.078427	0.149369	1.047161	44	0.679915	0.102745	1.336366
24	3.845856	0.146668	1.060272	44.5	0.658184	0.101794	1.339599
24.5	3.684528	0.144342	1.073035	45	0.636454	0.100844	1.342755
25	3.523201	0.142015	1.085439	45.5	0.620066	0.100057	1.345853
25.5	3.361873	0.139689	1.097473	46	0.603679	0.099271	1.348894
26	3.200546	0.137363	1.109123	46.5	0.587291	0.098485	1.351875
26.5	3.037832	0.135337	1.120346	47	0.570904	0.097698	1.354797
27	2.875118	0.133311	1.13113	47.5	0.554517	0.096912	1.357658
27.5	2.712404	0.131285	1.14146	48	0.538129	0.096125	1.360457
28	2.54969	0.129258	1.151323	48.5	0.521742	0.095339	1.363193
28.5	2.455493	0.127508	1.160951	49	0.505354	0.094553	1.365866
29	2.361296	0.125757	1.17034	49.5	0.488967	0.093766	1.368473
29.5	2.267098	0.124006	1.179481	50	0.472579	0.09298	1.371014
30	2.172901	0.122255	1.188368				

Table (3-12): The cross section and calculated data of stopping power and neutron yield for $^{50}Ca(\alpha,n)^{53}Ti$ reaction

Alpha energy MeV	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 alpha**	**Alpha energy MeV**	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 alpha**
10	31.94422	0.298659	0.05348	30.5	1.851554	0.119142	0.796494
10.5	29.77968	0.289102	0.104983	31	1.774888	0.118532	0.803981
11	27.61513	0.279546	0.154376	31.5	1.698222	0.117922	0.811182
11.5	24.05812	0.271241	0.198724	32	1.621556	0.117311	0.818093
12	20.50111	0.262935	0.237709	32.5	1.54489	0.116701	0.824712
12.5	17.95323	0.255681	0.272818	33	1.468224	0.116091	0.831036
13	15.40534	0.248426	0.303824	33.5	1.391558	0.11548	0.837061
13.5	13.6102	0.242072	0.331936	34	1.314892	0.11487	0.842784
14	11.81507	0.235718	0.356998	34.5	1.238226	0.11426	0.848203
14.5	10.67943	0.230015	0.380212	35	1.16156	0.113649	0.853313
15	9.543795	0.224311	0.401486	35.5	1.121841	0.113099	0.858273
15.5	8.82892	0.219208	0.421624	36	1.082122	0.112549	0.86308
16	8.114046	0.214105	0.440573	36.5	1.042403	0.111999	0.867734
16.5	7.534409	0.209502	0.458555	37	1.002683	0.111448	0.872232
17	6.954773	0.2049	0.475526	37.5	0.962964	0.110898	0.876574
17.5	6.477803	0.200747	0.49166	38	0.923245	0.110348	0.880757
18	6.000832	0.196595	0.506922	38.5	0.883526	0.109798	0.884781
18.5	5.737874	0.189291	0.522078	39	0.843806	0.109247	0.888643
19	5.474917	0.181986	0.53712	39.5	0.804087	0.108697	0.892341
19.5	5.265071	0.174432	0.552212	40	0.764368	0.108147	0.895875
20	5.055225	0.166878	0.567359	40.5	0.740217	0.107214	0.899327
20.5	4.864661	0.163726	0.582215	41	0.716066	0.106282	0.902696
21	4.674098	0.160574	0.596769	41.5	0.691915	0.105349	0.90598
21.5	4.483535	0.157423	0.61101	42	0.667764	0.104417	0.909177
22	4.292972	0.154271	0.624924	42.5	0.643613	0.103484	0.912287
22.5	4.057623	0.151619	0.638304	43	0.619462	0.102552	0.915307
23	3.822275	0.148968	0.651134	43.5	0.595311	0.101619	0.918237
23.5	3.586926	0.146317	0.663391	44	0.57116	0.100687	0.921073
24	3.351578	0.143665	0.675056	44.5	0.547009	0.099754	0.923815
24.5	3.185919	0.141389	0.686322	45	0.522859	0.098822	0.92646
25	3.02026	0.139113	0.697178	45.5	0.505643	0.098052	0.929039
25.5	2.854601	0.136837	0.707608	46	0.488428	0.097281	0.931549
26	2.688943	0.13456	0.7176	46.5	0.471213	0.096511	0.93399
26.5	2.585693	0.132584	0.727351	47	0.453998	0.095741	0.936361
27	2.482443	0.130608	0.736854	47.5	0.436783	0.09497	0.938661
27.5	2.379193	0.128632	0.746102	48	0.419567	0.0942	0.940888
28	2.275943	0.126656	0.755087	48.5	0.402352	0.093429	0.943041
28.5	2.189012	0.12493	0.763848	49	0.385137	0.092659	0.945119
29	2.102081	0.123204	0.772379	49.5	0.367922	0.091889	0.947121
29.5	2.015151	0.121478	0.780673	50	0.350707	0.091118	0.949046
30	1.92822	0.119753	0.788724				

Table (3-13): The cross section and calculated data of stopping power and neutron yield for $^{59}Ni(\alpha,n)^{62}Zn$ reaction.

Alpha energy MeV	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 alpha**	**Alpha energy MeV**	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 alpha**
10	40.33359	0.296813	0.067945	30.5	3.418311	0.125151	4.569358
10.5	54.80708	0.288054	0.163078	31	3.31407	0.12453	4.582664
11	69.28057	0.279296	0.287105	31.5	3.209829	0.12391	4.595617
11.5	82.36657	0.271639	0.438716	32	3.105589	0.123289	4.608211
12	95.45256	0.263982	0.61951	32.5	3.001348	0.122669	4.620445
12.5	106.1782	0.257225	0.825901	33	2.897107	0.122048	4.632314
13	116.9038	0.250469	1.059271	33.5	2.792866	0.121428	4.643814
13.5	124.9413	0.244464	1.314812	34	2.688625	0.120808	4.654941
14	132.9789	0.238459	1.593642	34.5	2.584384	0.120187	4.665693
14.5	136.1306	0.233104	1.885637	35	2.480143	0.119567	4.676064
15	139.2823	0.227749	2.191417	35.5	2.403836	0.119016	4.686163
15.5	130.3917	0.222895	2.483912	36	2.327528	0.118466	4.695987
16	121.501	0.218041	2.762532	36.5	2.25122	0.117916	4.705533
16.5	105.2835	0.213688	3.008881	37	2.174912	0.117365	4.714798
17	89.06599	0.209334	3.221617	37.5	2.098605	0.116815	4.723781
17.5	75.12561	0.205331	3.404555	38	2.022297	0.116265	4.732478
18	61.18523	0.201327	3.55651	38.5	1.945989	0.115714	4.740886
18.5	50.99238	0.194272	3.68775	39	1.869681	0.115164	4.749004
19	40.79953	0.187216	3.796713	39.5	1.793374	0.114613	4.756827
19.5	34.73718	0.179811	3.893307	40	1.717066	0.114063	4.764354
20	28.67484	0.172405	3.976469	40.5	1.66092	0.113112	4.771696
20.5	24.91283	0.169327	4.050033	41	1.604775	0.112162	4.77885
21	21.15082	0.16625	4.113644	41.5	1.548629	0.111211	4.785813
21.5	17.38882	0.163173	4.166927	42	1.492484	0.110261	4.792581
22	13.62681	0.160096	4.209486	42.5	1.436338	0.10931	4.799151
22.5	12.15	0.157469	4.248065	43	1.380193	0.108359	4.805519
23	10.67319	0.154842	4.28253	43.5	1.324047	0.107409	4.811683
23.5	9.196373	0.152215	4.312738	44	1.267902	0.106458	4.817638
24	7.71956	0.149588	4.338541	44.5	1.211756	0.105507	4.82338
24.5	7.148615	0.147336	4.362801	45	1.155611	0.104557	4.828906
25	6.57767	0.145085	4.385469	45.5	1.123814	0.10377	4.834321
25.5	6.006726	0.142833	4.406496	46	1.092018	0.102984	4.839623
26	5.435781	0.140581	4.425829	46.5	1.060221	0.102197	4.84481
26.5	5.166047	0.138605	4.444465	47	1.028425	0.101411	4.849881
27	4.896312	0.136629	4.462384	47.5	0.996628	0.100624	4.854833
27.5	4.626578	0.134652	4.479563	48	0.964832	0.099838	4.859665
28	4.356843	0.132676	4.495982	48.5	0.933036	0.099051	4.864375
28.5	4.148271	0.13095	4.511822	49	0.901239	0.098265	4.868961
29	3.939698	0.129223	4.527065	49.5	0.869443	0.097478	4.87342
29.5	3.731125	0.127497	4.541698	50	0.837646	0.096692	4.877752
30	3.522552	0.125771	4.555701				

Table (3-14): The cross section and calculated data of stopping power and neutron yield for $^{60}Ni(\alpha,n)^{63}Zn$ reaction.

Alpha energy MeV	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 alpha**	**Alpha energy MeV**	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 alpha**
10	96.99445	0.291906	0.16614	30.5	7.010601	0.123058	14.7317
10.5	134.0991	0.283297	0.402816	31	6.760756	0.122448	14.7593
11	171.2039	0.274689	0.714447	31.5	6.510912	0.121837	14.78602
11.5	198.6433	0.267132	1.086254	32	6.261068	0.121227	14.81185
12	226.0828	0.259576	1.52174	32.5	6.011224	0.120617	14.83677
12.5	245.8951	0.25297	2.007757	33	5.761379	0.120006	14.86077
13	265.7073	0.246364	2.547015	33.5	5.511535	0.119396	14.88385
13.5	281.247	0.240459	3.131829	34	5.261691	0.118785	14.906
14	296.7867	0.234554	3.764492	34.5	5.011846	0.118175	14.9272
14.5	308.1218	0.229249	4.436516	35	4.762002	0.117565	14.94746
15	319.4569	0.223945	5.149767	35.5	4.620809	0.117024	14.9672
15.5	325.3961	0.219191	5.892034	36	4.479617	0.116484	14.98643
16	331.3352	0.214437	6.664605	36.5	4.338424	0.115944	15.00514
16.5	329.4069	0.210133	7.448411	37	4.197231	0.115403	15.02332
17	327.4785	0.20583	8.24392	37.5	4.056038	0.114863	15.04098
17.5	315.54	0.201876	9.025437	38	3.914846	0.114322	15.0581
18	303.6014	0.197923	9.792404	38.5	3.773653	0.113782	15.07468
18.5	270.5376	0.191018	10.50055	39	3.63246	0.113242	15.09072
19	237.4738	0.184112	11.14547	39.5	3.491267	0.112701	15.10621
19.5	203.4736	0.176857	11.72072	40	3.350075	0.112161	15.12114
20	169.4733	0.169601	12.22034	40.5	3.250549	0.11123	15.13576
20.5	144.5514	0.166574	12.65423	41	3.151023	0.1103	15.15004
21	119.6295	0.163547	13.01997	41.5	3.051498	0.109369	15.16399
21.5	94.70758	0.16052	13.31497	42	2.951972	0.108439	15.1776
22	69.78566	0.157492	13.53652	42.5	2.852447	0.107508	15.19087
22.5	59.6186	0.154891	13.72898	43	2.752921	0.106577	15.20378
23	49.45154	0.152289	13.89134	43.5	2.653396	0.105647	15.21634
23.5	39.28448	0.149687	14.02256	44	2.55387	0.104716	15.22854
24	29.11742	0.147085	14.12154	44.5	2.454345	0.103786	15.24036
24.5	25.50694	0.144883	14.20957	45	2.354819	0.102855	15.25181
25	21.89647	0.142682	14.2863	45.5	2.285	0.102077	15.263
25.5	18.286	0.14048	14.35138	46	2.215182	0.1013	15.27393
26	14.67553	0.138279	14.40445	46.5	2.145363	0.100522	15.2846
26.5	13.37045	0.136327	14.45349	47	2.075544	0.099745	15.29501
27	12.06537	0.134376	14.49838	47.5	2.005725	0.098967	15.30514
27.5	10.76029	0.132425	14.53901	48	1.935907	0.09819	15.315
28	9.455206	0.130473	14.57524	48.5	1.866088	0.097413	15.32458
28.5	8.906516	0.128772	14.60983	49	1.796269	0.096635	15.33387
29	8.357826	0.127071	14.64271	49.5	1.72645	0.095858	15.34288
29.5	7.809135	0.12537	14.67386	50	1.656632	0.09508	15.35159
30	7.260445	0.123669	14.70321				

Table (3-15): The cross section and calculated data of stopping power and neutron yield for $^{61}Ni(\alpha,n)^{64}Zn$ reaction.

Alpha energy MeV	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 alpha**	**Alpha energy MeV**	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 alpha**
10	180.0691	0.287099	0.313601	30.5	7.06887	0.120976	17.66854
10.5	239.6115	0.278591	0.743643	31	6.812446	0.120386	17.69683
11	299.154	0.270083	1.297461	31.5	6.556021	0.119795	17.72419
11.5	351.736	0.262726	1.966857	32	6.299596	0.119205	17.75062
12	404.3181	0.25537	2.75849	32.5	6.043171	0.118614	17.77609
12.5	446.354	0.248814	3.655453	33	5.786746	0.118024	17.80061
13	488.3899	0.242258	4.663446	33.5	5.530321	0.117434	17.82415
13.5	515.8359	0.236453	5.754223	34	5.273896	0.116843	17.84672
14	543.2819	0.230649	6.93195	34.5	5.017471	0.116253	17.8683
14.5	537.996	0.225494	8.124876	35	4.761046	0.115662	17.88888
15	532.7101	0.22034	9.333714	35.5	4.60799	0.115122	17.9089
15.5	485.8877	0.215636	10.46035	36	4.454934	0.114582	17.92834
16	439.0653	0.210932	11.50113	36.5	4.301877	0.114041	17.9472
16.5	377.2002	0.206679	12.41365	37	4.148821	0.113501	17.96547
17	315.335	0.202425	13.19254	37.5	3.995765	0.112961	17.98316
17.5	264.8634	0.198572	13.85946	38	3.842709	0.11242	18.00025
18	214.3917	0.194719	14.40998	38.5	3.689652	0.11188	18.01674
18.5	179.7406	0.187864	14.88836	39	3.536596	0.11134	18.03262
19	145.0895	0.181009	15.28914	39.5	3.38354	0.110799	18.04789
19.5	122.1242	0.173903	15.64027	40	3.230484	0.110259	18.06254
20	99.15896	0.166798	15.93751	40.5	3.126674	0.109348	18.07684
20.5	85.04453	0.163821	16.19707	41	3.022865	0.108438	18.09078
21	70.93009	0.160844	16.41757	41.5	2.919056	0.107527	18.10435
21.5	56.81566	0.157867	16.59752	42	2.815247	0.106617	18.11755
22	42.70123	0.154889	16.73536	42.5	2.711438	0.105706	18.13038
22.5	37.23344	0.152338	16.85757	43	2.607629	0.104796	18.14282
23	31.76564	0.149786	16.9636	43.5	2.50382	0.103885	18.15487
23.5	26.29785	0.147234	17.05291	44	2.40001	0.102974	18.16652
24	20.83006	0.144682	17.1249	44.5	2.296201	0.102064	18.17777
24.5	18.81277	0.142506	17.1909	45	2.192392	0.101153	18.18861
25	16.79548	0.140329	17.25075	45.5	2.12933	0.10039	18.19922
25.5	14.77819	0.138153	17.30423	46	2.066269	0.099626	18.20959
26	12.7609	0.135976	17.35115	46.5	2.003207	0.098863	18.21972
26.5	11.8471	0.134075	17.39534	47	1.940145	0.098099	18.22961
27	10.93331	0.132174	17.4367	47.5	1.877083	0.097336	18.23925
27.5	10.01952	0.130272	17.47515	48	1.814021	0.096572	18.24864
28	9.105735	0.128371	17.51062	48.5	1.75096	0.095809	18.25778
28.5	8.660625	0.12667	17.5448	49	1.687898	0.095045	18.26666
29	8.215515	0.124969	17.57767	49.5	1.624836	0.094282	18.27527
29.5	7.770405	0.123268	17.60919	50	1.561774	0.093518	18.28362
30	7.325295	0.121566	17.63932				

Table (3-16): The cross section and calculated data of stopping power and neutron yield for $^{62}Ni(\alpha,n)^{65}Zn$ reaction.

Alpha energy MeV	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 alpha**	**Alpha energy MeV**	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 alpha**
10	194.8391	0.282493	0.344857	30.5	9.998125	0.119074	29.96875
10.5	259.792	0.274135	0.818697	31	9.571344	0.118484	30.00914
11	324.7449	0.265777	1.429631	31.5	9.144562	0.117893	30.04793
11.5	382.2545	0.258471	2.169085	32	8.717781	0.117303	30.08509
12	439.7641	0.251164	3.044535	32.5	8.291	0.116712	30.12061
12.5	486.705	0.244759	4.038789	33	7.864219	0.116122	30.15447
13	533.646	0.238353	5.158232	33.5	7.437438	0.115532	30.18665
13.5	571.6609	0.232649	6.386825	34	7.010656	0.114941	30.21715
14	609.6758	0.226944	7.730056	34.5	6.583875	0.114351	30.24594
14.5	639.7794	0.22184	9.172042	35	6.157094	0.113761	30.273
15	669.883	0.216735	10.71744	35.5	5.957507	0.11324	30.29931
15.5	678.9231	0.212132	12.31768	36	5.757921	0.11272	30.32485
16	687.9633	0.207528	13.97519	36.5	5.558334	0.112199	30.34962
16.5	663.5352	0.203325	15.60691	37	5.358748	0.111679	30.37361
17	639.1072	0.199121	17.21173	37.5	5.159161	0.111159	30.39681
17.5	594.7787	0.195318	18.73431	38	4.959574	0.110638	30.41923
18	550.4503	0.191516	20.1714	38.5	4.759988	0.110118	30.44084
18.5	501.9099	0.18481	21.52931	39	4.560401	0.109598	30.46165
19	453.3695	0.178105	22.80207	39.5	4.360815	0.109077	30.48164
19.5	392.3974	0.1711	23.94875	40	4.161228	0.108557	30.5008
20	331.4253	0.164095	24.95861	40.5	4.03157	0.107652	30.51953
20.5	284.2625	0.161168	25.8405	41	3.901911	0.106746	30.5378
21	237.0997	0.158241	26.58967	41.5	3.772253	0.10584	30.55562
21.5	189.9369	0.155314	27.20113	42	3.642595	0.104935	30.57298
22	142.7741	0.152387	27.66959	42.5	3.512936	0.104029	30.58987
22.5	121.1714	0.149885	28.07381	43	3.383278	0.103124	30.60627
23	99.56876	0.147383	28.4116	43.5	3.25362	0.102218	30.62218
23.5	77.96607	0.144881	28.68067	44	3.123961	0.101313	30.6376
24	56.36339	0.14238	28.8786	44.5	2.994303	0.100407	30.65251
24.5	48.82261	0.140228	29.05268	45	2.864645	0.099501	30.66691
25	41.28182	0.138077	29.20217	45.5	2.781417	0.098753	30.68099
25.5	33.74103	0.135925	29.32629	46	2.698189	0.098005	30.69476
26	26.20024	0.133774	29.42422	46.5	2.614962	0.097256	30.7082
26.5	23.51477	0.131897	29.51336	47	2.531734	0.096508	30.72132
27	20.8293	0.130021	29.59346	47.5	2.448507	0.095759	30.7341
27.5	18.14383	0.128145	29.66425	48	2.365279	0.095011	30.74655
28	15.45836	0.126269	29.72546	48.5	2.282051	0.094262	30.75865
28.5	14.2	0.124618	29.78244	49	2.198824	0.093514	30.77041
29	12.94164	0.122966	29.83506	49.5	2.115596	0.092765	30.78181
29.5	11.68327	0.121315	29.88321	50	2.032368	0.092017	30.79286
30	10.42491	0.119664	29.92677				

Table (3-17): The cross section and calculated data of stopping power and neutron yield for $^{63}Ni(\alpha,n)^{66}Zn$ reaction.

Alpha energy MeV	Cross section (mb)	Stopping power MeV / (mg/cm^2)	Neutron yield n/10^6 alpha	Alpha energy MeV	Cross section (mb)	Stopping power MeV / (mg/cm^2)	Neutron yield n/10^6 alpha
10	213.943	0.277987	0.384808	30.5	10.47918	0.117182	19.8197
10.5	283.5094	0.269779	0.910256	31	10.09206	0.116602	19.86298
11	353.0758	0.261572	1.585168	31.5	9.704943	0.116021	19.9048
11.5	416.565	0.254415	2.403838	32	9.317823	0.115441	19.94516
12	480.0541	0.247259	3.374589	32.5	8.930703	0.11486	19.98403
12.5	532.0896	0.240904	4.47895	33	8.543583	0.11428	20.02141
13	584.125	0.234549	5.724162	33.5	8.156463	0.1137	20.05728
13.5	613.2409	0.228944	7.063444	34	7.769344	0.113119	20.09162
14	642.3567	0.223339	8.501517	34.5	7.382224	0.112539	20.12442
14.5	618.3819	0.218335	9.917647	35	6.995104	0.111959	20.15566
15	594.4071	0.213331	11.3108	35.5	6.760214	0.111438	20.18599
15.5	515.3174	0.208778	12.54493	36	6.525324	0.110918	20.21541
16	436.2276	0.204224	13.61295	36.5	6.290435	0.110398	20.2439
16.5	361.0954	0.200121	14.51514	37	6.055545	0.109877	20.27145
17	285.9631	0.196018	15.24457	37.5	5.820655	0.109357	20.29807
17.5	235.4153	0.192265	15.85679	38	5.585765	0.108837	20.32373
18	184.8674	0.188512	16.34712	38.5	5.350875	0.108316	20.34843
18.5	157.2652	0.181907	16.77939	39	5.115986	0.107796	20.37216
19	129.6629	0.175302	17.14922	39.5	4.881096	0.107276	20.39491
19.5	110.2674	0.168397	17.47662	40	4.646206	0.106755	20.41667
20	90.87184	0.161492	17.75797	40.5	4.504326	0.105871	20.43794
20.5	79.58374	0.158615	18.00884	41	4.362445	0.104986	20.45872
21	68.29564	0.155738	18.22811	41.5	4.220565	0.104102	20.47899
21.5	57.00754	0.152861	18.41458	42	4.078685	0.103217	20.49875
22	45.71944	0.149984	18.56699	42.5	3.936804	0.102333	20.51798
22.5	40.8482	0.147507	18.70545	43	3.794924	0.101448	20.53669
23	35.97697	0.14503	18.82948	43.5	3.653044	0.100563	20.55485
23.5	31.10573	0.142554	18.93859	44	3.511163	0.099679	20.57246
24	26.2345	0.140077	19.03223	44.5	3.369283	0.098794	20.58951
24.5	24.09703	0.137976	19.11955	45	3.227403	0.09791	20.606
25	21.95956	0.135874	19.20036	45.5	3.132574	0.097173	20.62211
25.5	19.82209	0.133773	19.27445	46	3.037746	0.096437	20.63786
26	17.68462	0.131671	19.3416	46.5	2.942917	0.095701	20.65324
26.5	16.62751	0.12982	19.40564	47	2.848088	0.094964	20.66824
27	15.57041	0.127969	19.46648	47.5	2.75326	0.094228	20.68285
27.5	14.5133	0.126118	19.52402	48	2.658431	0.093491	20.69706
28	13.4562	0.124267	19.57816	48.5	2.563603	0.092755	20.71088
28.5	12.80872	0.12264	19.63038	49	2.468774	0.092018	20.7243
29	12.16125	0.121014	19.68063	49.5	2.373946	0.091282	20.7373
29.5	11.51378	0.119388	19.72885	50	2.279117	0.090545	20.74989
30	10.8663	0.117762	19.77499				

Table (3-18): The cross section and calculated data of stopping power and neutron yield for $^{64}Ni(\alpha,n)^{67}Zn$ reaction.

Alpha energy MeV	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 alpha**	**Alpha energy MeV**	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 alpha**
10	224.224	0.273681	0.409645	30.5	8.029978	0.11539	23.02868
10.5	296.951	0.265574	0.96872	31	7.699258	0.11482	23.06221
11	369.6781	0.257466	1.686635	31.5	7.368539	0.114249	23.09446
11.5	435.2366	0.25041	2.555682	32	7.037819	0.113679	23.12541
12	500.795	0.243354	3.584624	32.5	6.707099	0.113109	23.15506
12.5	551.7271	0.237149	4.747873	33	6.376379	0.112538	23.18339
13	602.6591	0.230944	6.052647	33.5	6.045659	0.111968	23.21039
13.5	609.7555	0.22539	7.405317	34	5.714939	0.111398	23.23604
14	616.8519	0.219835	8.808305	34.5	5.38422	0.110827	23.26033
14.5	589.4516	0.214881	10.17988	35	5.0535	0.110257	23.28325
15	562.0514	0.209927	11.51856	35.5	4.881577	0.109746	23.30549
15.5	517.6703	0.205474	12.77826	36	4.709653	0.109236	23.32705
16	473.2892	0.20102	13.95548	36.5	4.53773	0.108726	23.34792
16.5	425.1816	0.196967	15.03481	37	4.365807	0.108216	23.36809
17	377.074	0.192914	16.01212	37.5	4.193884	0.107705	23.38756
17.5	330.9746	0.189211	16.88673	38	4.021961	0.107195	23.40632
18	284.8752	0.185508	17.65456	38.5	3.850038	0.106685	23.42436
18.5	252.4721	0.179054	18.35958	39	3.678115	0.106174	23.44168
19	220.069	0.172599	18.99709	39.5	3.506191	0.105664	23.45827
19.5	189.7274	0.165794	19.56927	40	3.334268	0.105154	23.47413
20	159.3858	0.158989	20.07052	40.5	3.235068	0.104277	23.48964
20.5	138.6652	0.156137	20.51457	41	3.135867	0.103401	23.5048
21	117.9447	0.153285	20.89929	41.5	3.036666	0.102524	23.51961
21.5	97.22415	0.150433	21.22244	42	2.937466	0.101648	23.53406
22	76.5036	0.147581	21.48163	42.5	2.838265	0.100771	23.54814
22.5	66.75602	0.145155	21.71158	43	2.739065	0.099894	23.56185
23	57.00843	0.142728	21.91129	43.5	2.639864	0.099018	23.57518
23.5	47.26085	0.140301	22.07971	44	2.540663	0.098141	23.58813
24	37.51326	0.137875	22.21575	44.5	2.441463	0.097265	23.60068
24.5	32.8355	0.135798	22.33665	45	2.342262	0.096388	23.61283
25	28.15773	0.133722	22.44194	45.5	2.27491	0.095663	23.62472
25.5	23.47996	0.131646	22.53112	46	2.207558	0.094937	23.63635
26	18.80219	0.129569	22.60367	46.5	2.140206	0.094212	23.6477
26.5	17.00747	0.127768	22.67023	47	2.072854	0.093487	23.65879
27	15.21274	0.125967	22.73061	47.5	2.005502	0.092761	23.6696
27.5	13.41802	0.124166	22.78464	48	1.93815	0.092036	23.68013
28	11.62329	0.122364	22.83214	48.5	1.870799	0.09131	23.69037
28.5	10.80765	0.120763	22.87689	49	1.803447	0.090585	23.70033
29	9.991996	0.119162	22.91881	49.5	1.736095	0.089859	23.70999
29.5	9.176347	0.117561	22.95784	50	1.668743	0.089134	23.71935
30	8.360698	0.11596	22.99389				

Table (3-19): The cross section and calculated data of stopping power and neutron yield for $^{65}Ni(\alpha,n)^{68}Zn$ reaction.

Alpha energy MeV	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 alpha**	**Alpha energy MeV**	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 alpha**
10	235.9369	0.269375	0.437934	30.5	8.27184	0.113598	12.29064
10.5	309.7675	0.261418	1.030409	31	7.957817	0.113038	12.32584
11	383.5982	0.253461	1.787128	31.5	7.643794	0.112477	12.35982
11.5	440.6435	0.246506	2.680908	32	7.329771	0.111917	12.39257
12	497.6889	0.23955	3.719709	32.5	7.015748	0.111357	12.42407
12.5	480.0638	0.233445	4.747927	33	6.701725	0.110796	12.45431
13	462.4387	0.22734	5.764993	33.5	6.387702	0.110236	12.48329
13.5	405.8179	0.221885	6.67947	34	6.073679	0.109676	12.51098
14	349.1971	0.216431	7.486187	34.5	5.759656	0.109115	12.53737
14.5	294.621	0.211577	8.182437	35	5.445633	0.108555	12.56245
15	240.0449	0.206723	8.763032	35.5	5.271471	0.108055	12.58684
15.5	192.887	0.20232	9.23972	36	5.09731	0.107554	12.61054
16	145.7291	0.197917	9.607878	36.5	4.923148	0.107054	12.63353
16.5	119.9336	0.193914	9.917123	37	4.748986	0.106554	12.65582
17	94.13815	0.189911	10.16497	37.5	4.574824	0.106054	12.67739
17.5	78.12891	0.186308	10.37465	38	4.400663	0.105553	12.69823
18	62.11967	0.182705	10.54465	38.5	4.226501	0.105053	12.71835
18.5	54.09565	0.1763	10.69807	39	4.052339	0.104553	12.73773
19	46.07164	0.169896	10.83366	39.5	3.878177	0.104052	12.75636
19.5	40.53194	0.163191	10.95784	40	3.704016	0.103552	12.77425
20	34.99223	0.156486	11.06965	40.5	3.586001	0.102686	12.79171
20.5	31.90003	0.153684	11.17343	41	3.467985	0.101821	12.80874
21	28.80783	0.150883	11.2689	41.5	3.34997	0.100955	12.82533
21.5	25.71563	0.148081	11.35573	42	3.231955	0.10009	12.84147
22	22.62343	0.145279	11.43359	42.5	3.11394	0.099224	12.85717
22.5	21.02131	0.142902	11.50714	43	2.995925	0.098359	12.8724
23	19.4192	0.140526	11.57623	43.5	2.87791	0.097493	12.88716
23.5	17.81709	0.138149	11.64072	44	2.759895	0.096628	12.90144
24	16.21498	0.135772	11.70043	44.5	2.64188	0.095762	12.91523
24.5	15.30166	0.133721	11.75765	45	2.523865	0.094897	12.92853
25	14.38834	0.13167	11.81229	45.5	2.455125	0.094182	12.94156
25.5	13.47502	0.129618	11.86427	46	2.386385	0.093468	12.95433
26	12.5617	0.127567	11.9135	46.5	2.317645	0.092754	12.96682
26.5	12.0182	0.125791	11.96127	47	2.248905	0.092039	12.97904
27	11.4747	0.124015	12.00753	47.5	2.180165	0.091325	12.99097
27.5	10.9312	0.122239	12.05225	48	2.111425	0.09061	13.00263
28	10.3877	0.120462	12.09536	48.5	2.042685	0.089896	13.01399
28.5	9.937242	0.118886	12.13716	49	1.973945	0.089181	13.02505
29	9.486783	0.117311	12.17759	49.5	1.905204	0.088467	13.03582
29.5	9.036323	0.115735	12.21663	50	1.836464	0.087753	13.04629
30	8.585863	0.114159	12.25423				

Table (3-20): The cross section and calculated data of stopping power and neutron yield for $^{66}Ni(\alpha,n)^{69}Zn$ reaction.

Alpha energy MeV	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 alpha**	**Alpha energy MeV**	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 alpha**
10	154.9919	0.26537	0.29203	30.5	1.430182	0.111806	3.140511
10.5	174.9674	0.257513	0.631755	31	1.375781	0.111256	3.146694
11	194.943	0.249657	1.022177	31.5	1.321381	0.110706	3.152662
11.5	174.286	0.242801	1.381085	32	1.26698	0.110155	3.158413
12	153.629	0.235945	1.706645	32.5	1.212579	0.109605	3.163944
12.5	125.7355	0.22994	1.980054	33	1.158179	0.109055	3.169255
13	97.84203	0.223935	2.198515	33.5	1.103778	0.108504	3.174341
13.5	77.29371	0.218581	2.375323	34	1.049377	0.107954	3.179201
14	56.74539	0.213227	2.508386	34.5	0.994977	0.107404	3.183833
14.5	44.1331	0.208423	2.61426	35	0.940576	0.106853	3.188234
15	31.52081	0.20362	2.691661	35.5	0.910735	0.106363	3.192516
15.5	24.36334	0.199266	2.752794	36	0.880894	0.105873	3.196676
16	17.20586	0.194913	2.796931	36.5	0.851053	0.105383	3.200714
16.5	13.58904	0.19101	2.832503	37	0.821212	0.104892	3.204628
17	9.972213	0.187107	2.859151	37.5	0.791371	0.104402	3.208418
17.5	8.208634	0.183505	2.881517	38	0.761531	0.103912	3.212083
18	6.445054	0.179902	2.89943	38.5	0.73169	0.103421	3.21562
18.5	5.649405	0.173597	2.915702	39	0.701849	0.102931	3.219029
19	4.853755	0.167293	2.930208	39.5	0.672008	0.102441	3.222309
19.5	4.416457	0.160738	2.943946	40	0.642167	0.10195	3.225459
20	3.979158	0.154184	2.95685	40.5	0.621968	0.101101	3.228535
20.5	3.747081	0.151407	2.969224	41	0.601769	0.100251	3.231536
21	3.515004	0.14863	2.981049	41.5	0.58157	0.099402	3.234461
21.5	3.282927	0.145853	2.992303	42	0.561372	0.098552	3.237309
22	3.05085	0.143076	3.002965	42.5	0.541173	0.097703	3.240079
22.5	2.907088	0.14075	3.013292	43	0.520974	0.096853	3.242768
23	2.763326	0.138423	3.023274	43.5	0.500775	0.096004	3.245376
23.5	2.619564	0.136097	3.032897	44	0.480576	0.095154	3.247902
24	2.475802	0.13377	3.042151	44.5	0.460377	0.094305	3.250343
24.5	2.363829	0.131744	3.051123	45	0.440178	0.093455	3.252698
25	2.251856	0.129718	3.059802	45.5	0.428248	0.092752	3.255006
25.5	2.139883	0.127691	3.068182	46	0.416318	0.092049	3.257268
26	2.02791	0.125665	3.07625	46.5	0.404387	0.091345	3.259481
26.5	1.953593	0.123889	3.084135	47	0.392457	0.090642	3.261646
27	1.879277	0.122113	3.09183	47.5	0.380527	0.089938	3.263761
27.5	1.80496	0.120337	3.099329	48	0.368596	0.089235	3.265827
28	1.730644	0.118561	3.106628	48.5	0.356666	0.088532	3.267841
28.5	1.669129	0.11701	3.11376	49	0.344736	0.087828	3.269804
29	1.607613	0.115459	3.120722	49.5	0.332805	0.087125	3.271714
29.5	1.546098	0.113908	3.127509	50	0.320875	0.086421	3.27357
30	1.484583	0.112357	3.134115				

Table (3-21): The cross section and calculated data of stopping power and neutron yield for $^{67}Ni(\alpha,n)^{70}Zn$ reaction.

Alpha energy MeV	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 alpha**	**Alpha energy MeV**	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 alpha**
10	240.9269	0.261365	0.460901	30.5	5.511295	0.110205	5.41203
10.5	252.161	0.253608	0.958048	31	5.310695	0.109654	5.436245
11	263.3951	0.245852	1.493726	31.5	5.110095	0.109104	5.459664
11.5	235.2321	0.239146	1.985542	32	4.909494	0.108554	5.482277
12	207.0691	0.232441	2.430965	32.5	4.708894	0.108003	5.504077
12.5	174.2004	0.226486	2.815537	33	4.508294	0.107453	5.525055
13	141.3318	0.220531	3.135972	33.5	4.307693	0.106903	5.545202
13.5	117.1607	0.215277	3.408088	34	4.107093	0.106352	5.564511
14	92.98957	0.210023	3.629467	34.5	3.906493	0.105802	5.582972
14.5	76.28717	0.20527	3.815289	35	3.705893	0.105252	5.600577
15	59.58477	0.200516	3.963868	35.5	3.580795	0.104772	5.617666
15.5	48.50837	0.196263	4.087448	36	3.455698	0.104291	5.634233
16	37.43197	0.19201	4.184922	36.5	3.330601	0.103811	5.650275
16.5	31.86418	0.188157	4.269596	37	3.205504	0.103331	5.665786
17	26.29638	0.184304	4.340936	37.5	3.080406	0.10285	5.680761
17.5	23.36718	0.180751	4.405575	38	2.955309	0.10237	5.695196
18	20.43798	0.177199	4.463245	38.5	2.830212	0.10189	5.709084
18.5	19.02052	0.170995	4.518862	39	2.705115	0.10141	5.722422
19	17.60306	0.16479	4.572273	39.5	2.580017	0.100929	5.735203
19.5	16.4515	0.158286	4.62424	40	2.45492	0.100449	5.747423
20	15.29994	0.151781	4.674641	40.5	2.376136	0.099609	5.75935
20.5	14.5379	0.14908	4.7234	41	2.297352	0.09877	5.77098
21	13.77586	0.146378	4.770456	41.5	2.218569	0.09793	5.782307
21.5	13.01383	0.143676	4.815745	42	2.139785	0.097091	5.793327
22	12.25179	0.140974	4.859199	42.5	2.061001	0.096252	5.804033
22.5	11.66129	0.138673	4.901245	43	1.982217	0.095412	5.814421
23	11.07078	0.136371	4.941836	43.5	1.903433	0.094573	5.824484
23.5	10.48028	0.13407	4.980921	44	1.824649	0.093733	5.834217
24	9.889774	0.131768	5.018448	44.5	1.745865	0.092894	5.843614
24.5	9.430352	0.129767	5.054784	45	1.667082	0.092054	5.852669
25	8.97093	0.127766	5.089891	45.5	1.619455	0.091362	5.861532
25.5	8.511508	0.125764	5.12373	46	1.571829	0.090669	5.8702
26	8.052086	0.123763	5.15626	46.5	1.524203	0.089977	5.87867
26.5	7.752072	0.122037	5.188021	47	1.476577	0.089285	5.886939
27	7.452058	0.120311	5.218991	47.5	1.428951	0.088592	5.895004
27.5	7.152043	0.118585	5.249147	48	1.381325	0.0879	5.902861
28	6.852029	0.116859	5.278465	48.5	1.333699	0.087207	5.910508
28.5	6.566996	0.115333	5.306935	49	1.286072	0.086515	5.917941
29	6.281962	0.113807	5.334534	49.5	1.238446	0.085823	5.925156
29.5	5.996929	0.112281	5.361239	50	1.19082	0.08513	5.93215
30	5.711895	0.110755	5.387025				

Table (3-22): The cross section and calculated data of stopping power and neutron yield for $^{68}Ni(\alpha,n)^{71}Zn$ reaction.

Alpha energy MeV	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 alpha**	**Alpha energy MeV**	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 alpha**
10	58.26918	0.25746	0.113162	30.5	1.793835	0.108523	1.547188
10.5	56.40925	0.249854	0.226046	31	1.728218	0.107993	1.555189
11	54.54933	0.242248	0.338636	31.5	1.662601	0.107463	1.562925
11.5	50.49538	0.235642	0.44578	32	1.596983	0.106932	1.570392
12	46.44142	0.229037	0.547165	32.5	1.531366	0.106402	1.577589
12.5	42.04367	0.223182	0.641356	33	1.465749	0.105872	1.584511
13	37.64591	0.217328	0.727967	33.5	1.400132	0.105341	1.591157
13.5	33.54035	0.212124	0.807025	34	1.334515	0.104811	1.597523
14	29.43478	0.20692	0.878152	34.5	1.268898	0.104281	1.603607
14.5	25.75776	0.202266	0.941825	35	1.203281	0.10375	1.609406
15	22.08074	0.197613	0.997693	35.5	1.165737	0.103268	1.61505
15.5	19.06446	0.19341	1.046979	36	1.128193	0.102786	1.620538
16	16.04819	0.189206	1.089388	36.5	1.090649	0.102303	1.625869
16.5	13.76584	0.185404	1.126512	37	1.053105	0.101821	1.63104
17	11.4835	0.181601	1.158129	37.5	1.015561	0.101339	1.636051
17.5	10.04684	0.178098	1.186335	38	0.978017	0.100857	1.640899
18	8.61018	0.174596	1.210992	38.5	0.940473	0.100374	1.645584
18.5	7.749126	0.168492	1.233988	39	0.902929	0.099892	1.650104
19	6.888073	0.162388	1.255197	39.5	0.865385	0.09941	1.654456
19.5	6.291966	0.155983	1.275365	40	0.827841	0.098928	1.65864
20	5.695859	0.149579	1.294405	40.5	0.800081	0.098105	1.662718
20.5	5.334913	0.146902	1.312563	41	0.772321	0.097283	1.666687
21	4.973967	0.144225	1.329807	41.5	0.744561	0.09646	1.670547
21.5	4.613022	0.141549	1.346102	42	0.716801	0.095638	1.674294
22	4.252076	0.138872	1.361411	42.5	0.689042	0.094815	1.677928
22.5	4.014213	0.136596	1.376105	43	0.661282	0.093993	1.681446
23	3.77635	0.134319	1.390162	43.5	0.633522	0.09317	1.684845
23.5	3.538488	0.132043	1.403561	44	0.605762	0.092348	1.688125
24	3.300625	0.129766	1.416279	44.5	0.578002	0.091525	1.691283
24.5	3.139841	0.127815	1.428562	45	0.550243	0.090703	1.694316
25	2.979058	0.125864	1.440396	45.5	0.533556	0.09002	1.69728
25.5	2.818275	0.123913	1.451768	46	0.51687	0.089338	1.700172
26	2.657492	0.121961	1.462663	46.5	0.500183	0.088656	1.702993
26.5	2.54714	0.120235	1.473255	47	0.483496	0.087973	1.705741
27	2.436788	0.118509	1.483536	47.5	0.46681	0.087291	1.708415
27.5	2.326437	0.116783	1.493497	48	0.450123	0.086609	1.711014
28	2.216085	0.115057	1.503127	48.5	0.433437	0.085926	1.713536
28.5	2.126927	0.113556	1.512492	49	0.41675	0.085244	1.71598
29	2.037768	0.112055	1.521585	49.5	0.400063	0.084561	1.718346
29.5	1.94861	0.110554	1.530398	50	0.383377	0.083879	1.720631
30	1.859452	0.109053	1.538923				

Table (3-23): The cross section and calculated data of stopping power and neutron yield for $^{84}Zr(\alpha,n)^{87}Mo$ reaction.

Alpha energy MeV	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 alpha**	**Alpha energy MeV**	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 alpha**
10	7.49E-05	0.265303	0.000141	30.5	0.005381	0.115918	1.912808
10.5	0.000645	0.257845	0.001392	31	0.00523	0.115367	1.935472
11	0.001215	0.250387	0.003818	31.5	0.005078	0.114817	1.957586
11.5	0.001943	0.24388	0.007801	32	0.004927	0.114267	1.979143
12	0.002671	0.237373	0.013427	32.5	0.004775	0.113716	2.000139
12.5	0.003055	0.231567	0.020023	33	0.004624	0.113166	2.020568
13	0.003439	0.225762	0.02764	33.5	0.004472	0.112615	2.040424
13.5	0.007366	0.220607	0.044334	34	0.004321	0.112065	2.059702
14	0.011293	0.215452	0.070542	34.5	0.004169	0.111515	2.078395
14.5	0.017103	0.210847	0.111099	35	0.004018	0.110964	2.096499
15	0.022912	0.206243	0.166646	35.5	0.003913	0.110464	2.114213
15.5	0.027761	0.202039	0.235348	36	0.003809	0.109963	2.131533
16	0.03261	0.197835	0.317764	36.5	0.003705	0.109463	2.148456
16.5	0.037076	0.194032	0.413305	37	0.0036	0.108963	2.164977
17	0.041542	0.190228	0.522494	37.5	0.003496	0.108462	2.181094
17.5	0.043834	0.186725	0.639871	38	0.003392	0.107962	2.196802
18	0.046127	0.183222	0.765749	38.5	0.003287	0.107462	2.212098
18.5	0.041418	0.177067	0.882706	39	0.003183	0.106961	2.226977
19	0.03671	0.170911	0.9901	39.5	0.003079	0.106461	2.241437
19.5	0.031462	0.164456	1.085755	40	0.002974	0.105961	2.255472
20	0.026214	0.158001	1.168709	40.5	0.002886	0.105109	2.269199
20.5	0.023056	0.155273	1.242953	41	0.002797	0.104257	2.282612
21	0.019899	0.152546	1.308175	41.5	0.002708	0.103406	2.295705
21.5	0.016741	0.149819	1.364047	42	0.002619	0.102554	2.308475
22	0.013584	0.147092	1.410221	42.5	0.00253	0.101703	2.320915
22.5	0.01247	0.144765	1.453291	43	0.002442	0.100851	2.333019
23	0.011356	0.142438	1.493154	43.5	0.002353	0.099999	2.344783
23.5	0.010242	0.140111	1.529704	44	0.002264	0.099148	2.3562
24	0.009128	0.137784	1.56283	44.5	0.002175	0.098296	2.367263
24.5	0.008695	0.135783	1.594849	45	0.002086	0.097445	2.377968
25	0.008262	0.133781	1.625727	45.5	0.002029	0.096732	2.388457
25.5	0.007828	0.13178	1.655429	46	0.001972	0.09602	2.398727
26	0.007395	0.129778	1.683921	46.5	0.001915	0.095307	2.408774
26.5	0.007132	0.128002	1.711779	47	0.001858	0.094595	2.418596
27	0.006869	0.126225	1.738987	47.5	0.001801	0.093882	2.428188
27.5	0.006606	0.124449	1.765526	48	0.001744	0.09317	2.437547
28	0.006342	0.122673	1.791377	48.5	0.001687	0.092457	2.446671
28.5	0.00614	0.121122	1.816722	49	0.00163	0.091745	2.455554
29	0.005937	0.119571	1.84155	49.5	0.001573	0.091032	2.464194
29.5	0.005735	0.118019	1.865847	50	0.001516	0.09032	2.472586
30	0.005532	0.116468	1.889598				

Table (3-24): The cross section and calculated data of stopping power and neutron yield for $^{85}Zr(\alpha,n)^{88}Mo$ reaction.

Alpha energy MeV	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 alpha**	**Alpha energy MeV**	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 alpha**
10	0.001113	0.262198	0.002122	30.5	0.004158	0.114616	1.626961
10.5	0.001502	0.25484	0.005069	31	0.004038	0.114066	1.644662
11	0.001891	0.247482	0.00889	31.5	0.003918	0.113515	1.661921
11.5	0.004514	0.241026	0.018255	32	0.003799	0.112965	1.678734
12	0.007137	0.234569	0.033467	32.5	0.003679	0.112415	1.695097
12.5	0.012966	0.228864	0.061794	33	0.003559	0.111864	1.711005
13	0.018795	0.223158	0.103906	33.5	0.003439	0.111314	1.726454
13.5	0.026693	0.218053	0.165114	34	0.00332	0.110763	1.741439
14	0.034591	0.212948	0.246333	34.5	0.0032	0.110213	1.755955
14.5	0.040674	0.208394	0.343923	35	0.00308	0.109663	1.769999
15	0.046758	0.20384	0.458617	35.5	0.002988	0.109172	1.783683
15.5	0.043994	0.199686	0.568775	36	0.002896	0.108682	1.797005
16	0.04123	0.195532	0.674206	36.5	0.002803	0.108192	1.809961
16.5	0.035443	0.191779	0.766613	37	0.002711	0.107701	1.822548
17	0.029656	0.188025	0.845475	37.5	0.002619	0.107211	1.834763
17.5	0.024911	0.184572	0.912958	38	0.002527	0.106721	1.846601
18	0.020165	0.181119	0.968626	38.5	0.002435	0.10623	1.85806
18.5	0.017166	0.175014	1.017669	39	0.002342	0.10574	1.869137
19	0.014168	0.168909	1.059608	39.5	0.00225	0.10525	1.879826
19.5	0.012525	0.162503	1.098145	40	0.002158	0.104759	1.890126
20	0.010882	0.156098	1.133001	40.5	0.002092	0.103913	1.900194
20.5	0.010155	0.153421	1.166098	41	0.002027	0.103066	1.910027
21	0.009429	0.150744	1.197372	41.5	0.001961	0.102219	1.91962
21.5	0.008702	0.148067	1.226759	42	0.001896	0.101373	1.928969
22	0.007976	0.145389	1.254188	42.5	0.00183	0.100526	1.938071
22.5	0.007638	0.143088	1.280878	43	0.001764	0.09968	1.946922
23	0.0073	0.140786	1.306803	43.5	0.001699	0.098833	1.955516
23.5	0.006962	0.138484	1.331938	44	0.001633	0.097987	1.963849
24	0.006624	0.136182	1.356258	44.5	0.001568	0.09714	1.971918
24.5	0.006387	0.134206	1.380054	45	0.001502	0.096293	1.979717
25	0.006151	0.132229	1.403313	45.5	0.001459	0.09559	1.987349
25.5	0.005915	0.130253	1.426017	46	0.001416	0.094886	1.994812
26	0.005678	0.128276	1.448149	46.5	0.001373	0.094183	2.002104
26.5	0.005485	0.126525	1.469826	47	0.001331	0.093479	2.009221
27	0.005293	0.124774	1.491035	47.5	0.001288	0.092776	2.016161
27.5	0.0051	0.123022	1.511762	48	0.001245	0.092073	2.022921
28	0.004907	0.121271	1.531994	48.5	0.001202	0.091369	2.029499
28.5	0.00475	0.119745	1.551826	49	0.001159	0.090666	2.035891
29	0.004592	0.118219	1.571249	49.5	0.001116	0.089962	2.042096
29.5	0.004435	0.116693	1.590252	50	0.001073	0.089259	2.048109
30	0.004278	0.115167	1.608823				

Table (3-25): The cross section and calculated data of stopping power and neutron yield for $^{86}Zr(\alpha,n)^{89}Mo$ reaction.

Alpha energy MeV	Cross section (mb)	Stopping power MeV / (mg/cm^2)	Neutron yield n/10^6 alpha	Alpha energy MeV	Cross section (mb)	Stopping power MeV / (mg/cm^2)	Neutron yield n/10^6 alpha
10	0.000601	0.259093	0.001159	30.5	0.011914	0.113225	7.881221
10.5	0.001703	0.251836	0.00454	31	0.011557	0.112684	7.932501
11	0.002805	0.244578	0.010274	31.5	0.0112	0.112144	7.982438
11.5	0.007354	0.238222	0.025709	32	0.010843	0.111604	8.031016
12	0.011903	0.231865	0.051376	32.5	0.010486	0.111063	8.078224
12.5	0.021912	0.22621	0.099809	33	0.010129	0.110523	8.124048
13	0.031922	0.220554	0.172176	33.5	0.009772	0.109982	8.168474
13.5	0.044862	0.2155	0.276264	34	0.009415	0.109442	8.211489
14	0.057802	0.210445	0.413598	34.5	0.009058	0.108902	8.253078
14.5	0.070857	0.205941	0.58563	35	0.008701	0.108361	8.293228
15	0.083912	0.201436	0.793914	35.5	0.008462	0.107881	8.332447
15.5	0.097036	0.197333	1.039782	36	0.008223	0.107401	8.370728
16	0.110159	0.193229	1.32483	36.5	0.007984	0.10692	8.408062
16.5	0.124341	0.189526	1.652863	37	0.007744	0.10644	8.44444
17	0.138523	0.185822	2.025593	37.5	0.007505	0.10596	8.479855
17.5	0.151413	0.182419	2.440607	38	0.007266	0.105479	8.514297
18	0.164303	0.179016	2.899512	38.5	0.007027	0.104999	8.547757
18.5	0.165667	0.173011	3.378287	39	0.006787	0.104519	8.580226
19	0.167031	0.167006	3.878362	39.5	0.006548	0.104038	8.611696
19.5	0.15786	0.160651	4.369674	40	0.006309	0.103558	8.642156
20	0.148688	0.154296	4.851501	40.5	0.00613	0.10272	8.671995
20.5	0.129972	0.151644	5.280046	41	0.005951	0.101883	8.701202
21	0.111257	0.148992	5.653411	41.5	0.005773	0.101045	8.729767
21.5	0.092541	0.14634	5.969596	42	0.005594	0.100208	8.757679
22	0.073825	0.143687	6.226491	42.5	0.005415	0.09937	8.784927
22.5	0.063857	0.141411	6.452277	43	0.005237	0.098532	8.8115
23	0.053889	0.139134	6.645934	43.5	0.005058	0.097695	8.837386
23.5	0.04392	0.136857	6.806395	44	0.004879	0.096857	8.862574
24	0.033952	0.13458	6.932537	44.5	0.004701	0.09602	8.887051
24.5	0.030541	0.132629	7.047673	45	0.004522	0.095182	8.910804
25	0.027129	0.130677	7.151474	45.5	0.004398	0.094486	8.934077
25.5	0.023718	0.128726	7.243599	46	0.004274	0.093789	8.956862
26	0.020306	0.126775	7.323686	46.5	0.00415	0.093093	8.979153
26.5	0.018961	0.125048	7.399503	47	0.004026	0.092396	9.000941
27	0.017617	0.123322	7.470929	47.5	0.003902	0.0917	9.022219
27.5	0.016272	0.121596	7.537841	48	0.003779	0.091003	9.042979
28	0.014928	0.119869	7.600108	48.5	0.003655	0.090307	9.063213
28.5	0.014264	0.118343	7.660371	49	0.003531	0.08961	9.082914
29	0.013599	0.116817	7.718579	49.5	0.003407	0.088914	9.102072
29.5	0.012935	0.115291	7.774677	50	0.003283	0.088218	9.120679
30	0.012271	0.113765	7.828608				

Table (3-26): The cross section and calculated data of stopping power and neutron yield for $^{87}Zr(\alpha,n)^{90}Mo$ reaction.

Alpha energy MeV	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 alpha**	**Alpha energy MeV**	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 alpha**
10	0.002459	0.256189	0.004798	30.5	0.00942	0.111933	6.368986
10.5	0.006925	0.248982	0.018706	31	0.009109	0.111403	6.409871
11	0.011392	0.241774	0.042266	31.5	0.008799	0.110872	6.449551
11.5	0.023476	0.235468	0.092115	32	0.008488	0.110342	6.488014
12	0.035559	0.229162	0.169701	32.5	0.008178	0.109812	6.52525
12.5	0.056278	0.223606	0.295543	33	0.007867	0.109281	6.561245
13	0.076997	0.218051	0.472101	33.5	0.007557	0.108751	6.595989
13.5	0.101361	0.213046	0.709986	34	0.007246	0.108221	6.629468
14	0.125725	0.208041	1.012149	34.5	0.006936	0.10769	6.66167
14.5	0.145823	0.203587	1.370282	35	0.006625	0.10716	6.692582
15	0.16592	0.199133	1.786888	35.5	0.006426	0.10668	6.722703
15.5	0.167944	0.19508	2.217338	36	0.006228	0.106199	6.752023
16	0.169968	0.191026	2.66222	36.5	0.006029	0.105719	6.780537
16.5	0.15568	0.187323	3.077759	37	0.00583	0.105239	6.808237
17	0.141391	0.18362	3.46277	37.5	0.005631	0.104758	6.835115
17.5	0.121713	0.180267	3.80036	38	0.005433	0.104278	6.861163
18	0.102034	0.176914	4.088733	38.5	0.005234	0.103798	6.886375
18.5	0.085811	0.170959	4.339704	39	0.005035	0.103317	6.910742
19	0.069589	0.165004	4.550574	39.5	0.004836	0.102837	6.934256
19.5	0.058682	0.158749	4.735401	40	0.004638	0.102357	6.95691
20	0.047775	0.152494	4.892048	40.5	0.004499	0.101529	6.979068
20.5	0.042492	0.149867	5.033815	41	0.004361	0.100701	7.000722
21	0.037209	0.14724	5.160171	41.5	0.004223	0.099874	7.021865
21.5	0.031926	0.144612	5.270556	42	0.004085	0.099046	7.042487
22	0.026643	0.141985	5.36438	42.5	0.003947	0.098219	7.062579
22.5	0.024696	0.139759	5.452731	43	0.003809	0.097391	7.082133
23	0.022748	0.137532	5.535432	43.5	0.003671	0.096564	7.101139
23.5	0.0208	0.135305	5.612297	44	0.003533	0.095736	7.119589
24	0.018853	0.133079	5.683131	44.5	0.003394	0.094909	7.137471
24.5	0.017757	0.131127	5.750839	45	0.003256	0.094081	7.154777
25	0.016661	0.129176	5.815327	45.5	0.003165	0.093394	7.171719
25.5	0.015565	0.127224	5.876497	46	0.003073	0.092706	7.188293
26	0.014468	0.125273	5.934245	46.5	0.002981	0.092019	7.204492
26.5	0.013775	0.123572	5.98998	47	0.00289	0.091331	7.220312
27	0.013081	0.12187	6.043646	47.5	0.002798	0.090644	7.235745
27.5	0.012387	0.120169	6.095185	48	0.002706	0.089956	7.250787
28	0.011693	0.118468	6.144535	48.5	0.002615	0.089269	7.265432
28.5	0.011202	0.116967	6.192421	49	0.002523	0.088581	7.279673
29	0.010712	0.115466	6.238805	49.5	0.002431	0.087894	7.293503
29.5	0.010221	0.113965	6.283648	50	0.00234	0.087206	7.306917
30	0.00973	0.112464	6.326908				

Table (3-27): The cross section and calculated data of stopping power and neutron yield for $^{88}Zr(\alpha,n)^{91}Mo$ reaction.

Alpha energy MeV	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 alpha**	**Alpha energy MeV**	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 alpha**
10	0.001313	0.253285	0.002592	30.5	0.012132	0.110732	12.32421
10.5	0.00398	0.246177	0.010675	31	0.011657	0.110201	12.3771
11	0.006646	0.23907	0.024575	31.5	0.011181	0.109671	12.42808
11.5	0.015196	0.232814	0.057211	32	0.010706	0.109141	12.47712
12	0.023747	0.226558	0.109619	32.5	0.01023	0.10861	12.52422
12.5	0.042807	0.221053	0.206444	33	0.009755	0.10808	12.56935
13	0.061868	0.215547	0.349957	33.5	0.00928	0.10755	12.61249
13.5	0.091533	0.210643	0.567229	34	0.008804	0.107019	12.65362
14	0.121199	0.205738	0.861775	34.5	0.008329	0.106489	12.69273
14.5	0.157032	0.201284	1.251852	35	0.007853	0.105959	12.72979
15	0.192866	0.19683	1.741781	35.5	0.00761	0.105478	12.76586
15.5	0.229848	0.192827	2.337777	36	0.007367	0.104998	12.80095
16	0.26683	0.188823	3.044338	36.5	0.007125	0.104518	12.83503
16.5	0.298896	0.18522	3.851206	37	0.006882	0.104037	12.8681
17	0.330963	0.181617	4.762363	37.5	0.006639	0.103557	12.90015
17.5	0.321272	0.178264	5.663477	38	0.006396	0.103077	12.93118
18	0.311582	0.174911	6.554163	38.5	0.006153	0.102596	12.96116
18.5	0.268161	0.169056	7.347274	39	0.00591	0.102116	12.9901
19	0.22474	0.163202	8.035808	39.5	0.005667	0.101636	13.01798
19.5	0.185964	0.156997	8.628065	40	0.005424	0.101155	13.04478
20	0.147189	0.150792	9.11612	40.5	0.005265	0.100342	13.07102
20.5	0.127623	0.14819	9.546726	41	0.005107	0.099528	13.09667
21	0.108057	0.145588	9.917831	41.5	0.004948	0.098715	13.12174
21.5	0.08849	0.142986	10.22727	42	0.004789	0.097901	13.1462
22	0.068924	0.140384	10.47276	42.5	0.004631	0.097088	13.17004
22.5	0.06149	0.138182	10.69525	43	0.004472	0.096274	13.19327
23	0.054057	0.13598	10.89402	43.5	0.004314	0.09546	13.21586
23.5	0.046623	0.133779	11.06828	44	0.004155	0.094647	13.23781
24	0.039189	0.131577	11.2172	44.5	0.003996	0.093833	13.25911
24.5	0.035532	0.12965	11.35423	45	0.003838	0.09302	13.27974
25	0.031874	0.127724	11.479	45.5	0.003729	0.092339	13.29993
25.5	0.028217	0.125798	11.59115	46	0.003621	0.091659	13.31968
26	0.024559	0.123871	11.69029	46.5	0.003512	0.090979	13.33899
26.5	0.022628	0.122195	11.78288	47	0.003404	0.090298	13.35783
27	0.020697	0.120519	11.86874	47.5	0.003295	0.089618	13.37622
27.5	0.018766	0.118843	11.94769	48	0.003187	0.088937	13.39413
28	0.016835	0.117166	12.01954	48.5	0.003078	0.088257	13.41157
28.5	0.015778	0.11569	12.08773	49	0.002969	0.087576	13.42852
29	0.014721	0.114214	12.15217	49.5	0.002861	0.086896	13.44498
29.5	0.013664	0.112738	12.21277	50	0.002752	0.086215	13.46095
30	0.012607	0.111262	12.26943				

Table (3-28): The cross section and calculated data of stopping power and neutron yield for $^{89}Zr(\alpha,n)^{92}Mo$ reaction.

Alpha energy MeV	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 alpha**	**Alpha energy MeV**	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 alpha**
10	0.004375	0.250381	0.008737	30.5	0.013513	0.10944	12.33706
10.5	0.013539	0.243374	0.036551	31	0.012951	0.10892	12.39651
11	0.022702	0.236366	0.084574	31.5	0.012389	0.1084	12.45366
11.5	0.049008	0.23021	0.191017	32	0.011826	0.107879	12.50847
12	0.075315	0.224054	0.359089	32.5	0.011264	0.107359	12.56093
12.5	0.122439	0.218599	0.639142	33	0.010701	0.106839	12.61101
13	0.169563	0.213144	1.036908	33.5	0.010139	0.106318	12.65869
13.5	0.224284	0.20829	1.575303	34	0.009576	0.105798	12.70395
14	0.279005	0.203435	2.261037	34.5	0.009014	0.105278	12.74676
14.5	0.304046	0.199031	3.024852	35	0.008452	0.104757	12.7871
15	0.329087	0.194627	3.87028	35.5	0.00818	0.104287	12.82632
15.5	0.318108	0.190674	4.704447	36	0.007909	0.103817	12.86441
16	0.307128	0.18672	5.526874	36.5	0.007638	0.103346	12.90136
16.5	0.277873	0.183117	6.285604	37	0.007367	0.102876	12.93717
17	0.248618	0.179514	6.978078	37.5	0.007095	0.102406	12.97181
17.5	0.214774	0.176212	7.587498	38	0.006824	0.101935	13.00528
18	0.180929	0.172909	8.11069	38.5	0.006553	0.101465	13.03757
18.5	0.153786	0.167104	8.570841	39	0.006281	0.100995	13.06867
19	0.126643	0.161299	8.963412	39.5	0.00601	0.100524	13.09856
19.5	0.107679	0.155194	9.310328	40	0.005739	0.100054	13.12724
20	0.088715	0.14909	9.607851	40.5	0.005569	0.099247	13.1553
20.5	0.07923	0.146538	9.878193	41	0.005399	0.098439	13.18272
21	0.069746	0.143986	10.12039	41.5	0.005229	0.097631	13.2095
21.5	0.060261	0.141434	10.33343	42	0.005059	0.096824	13.23562
22	0.050777	0.138882	10.51623	42.5	0.004889	0.096016	13.26108
22.5	0.047182	0.13668	10.68883	43	0.004718	0.095209	13.28586
23	0.043587	0.134478	10.85089	43.5	0.004548	0.094401	13.30995
23.5	0.039992	0.132277	11.00206	44	0.004378	0.093594	13.33334
24	0.036397	0.130075	11.14197	44.5	0.004208	0.092786	13.35602
24.5	0.033972	0.128174	11.27449	45	0.004038	0.091979	13.37797
25	0.031547	0.126272	11.3994	45.5	0.003925	0.091306	13.39946
25.5	0.029121	0.124371	11.51648	46	0.003811	0.090634	13.42048
26	0.026696	0.12247	11.62547	46.5	0.003697	0.089961	13.44103
26.5	0.024727	0.120818	11.7278	47	0.003584	0.089289	13.4611
27	0.022757	0.119167	11.82328	47.5	0.00347	0.088617	13.48068
27.5	0.020788	0.117516	11.91173	48	0.003356	0.087944	13.49976
28	0.018818	0.115865	11.99294	48.5	0.003243	0.087272	13.51834
28.5	0.017633	0.114389	12.07001	49	0.003129	0.086599	13.5364
29	0.016447	0.112913	12.14284	49.5	0.003015	0.085927	13.55395
29.5	0.015262	0.111437	12.21132	50	0.002902	0.085254	13.57097
30	0.014076	0.109961	12.27532				

Table (3-29): The cross section and calculated data of stopping power and neutron yield for $^{90}Zr(\alpha,n)^{93}Mo$ reaction.

Alpha energy MeV	Cross section (mb)	Stopping power MeV / (mg/cm^2)	Neutron yield n/10^6 alpha	Alpha energy MeV	Cross section (mb)	Stopping power MeV / (mg/cm^2)	Neutron yield n/10^6 alpha
10	0.005171	0.247677	0.01044	30.5	0.010492	0.108239	24.15012
10.5	0.015065	0.24072	0.041731	31	0.010117	0.107719	24.19708
11	0.024958	0.233763	0.095115	31.5	0.009741	0.107198	24.24252
11.5	0.054112	0.227657	0.21396	32	0.009366	0.106678	24.28642
12	0.083266	0.221551	0.401875	32.5	0.008991	0.106158	24.32876
12.5	0.135277	0.216146	0.714805	33	0.008615	0.105637	24.36954
13	0.187288	0.210741	1.159161	33.5	0.00824	0.105117	24.40874
13.5	0.248878	0.205937	1.763421	34	0.007865	0.104597	24.44633
14	0.310469	0.201132	2.535224	34.5	0.007489	0.104076	24.48231
14.5	0.368431	0.196828	3.471143	35	0.007114	0.103556	24.51666
15	0.426393	0.192525	4.578516	35.5	0.006897	0.103095	24.55011
15.5	0.475713	0.188621	5.839544	36	0.006681	0.102633	24.58266
16	0.525033	0.184718	7.26072	36.5	0.006464	0.102172	24.61429
16.5	0.551617	0.181115	8.783558	37	0.006248	0.101711	24.645
17	0.5782	0.177512	10.41218	37.5	0.006031	0.101249	24.67479
17.5	0.572547	0.174259	12.05499	38	0.005814	0.100788	24.70363
18	0.566893	0.171006	13.71251	38.5	0.005598	0.100327	24.73153
18.5	0.540318	0.165252	15.34734	39	0.005381	0.099865	24.75847
19	0.513744	0.159497	16.95786	39.5	0.005165	0.099404	24.78445
19.5	0.425628	0.153492	18.34434	40	0.004948	0.098943	24.80946
20	0.337513	0.147488	19.48854	40.5	0.004802	0.098144	24.83392
20.5	0.278396	0.144936	20.44896	41	0.004656	0.097346	24.85783
21	0.219279	0.142384	21.21899	41.5	0.004509	0.096547	24.88119
21.5	0.160163	0.139832	21.79168	42	0.004363	0.095749	24.90397
22	0.101046	0.13728	22.15971	42.5	0.004217	0.09495	24.92618
22.5	0.086221	0.135103	22.47881	43	0.004071	0.094152	24.94779
23	0.071396	0.132927	22.74736	43.5	0.003924	0.093353	24.96881
23.5	0.056572	0.13075	22.9637	44	0.003778	0.092555	24.98922
24	0.041747	0.128573	23.12605	44.5	0.003632	0.091756	25.00901
24.5	0.036703	0.126697	23.27089	45	0.003486	0.090958	25.02817
25	0.031658	0.124821	23.3977	45.5	0.003388	0.090292	25.04694
25.5	0.026614	0.122944	23.50594	46	0.00329	0.089627	25.06529
26	0.02157	0.121068	23.59502	46.5	0.003192	0.088961	25.08323
26.5	0.019711	0.119442	23.67754	47	0.003095	0.088296	25.10076
27	0.017853	0.117816	23.7533	47.5	0.002997	0.087631	25.11786
27.5	0.015995	0.11619	23.82213	48	0.002899	0.086965	25.13453
28	0.014136	0.114563	23.88383	48.5	0.002802	0.0863	25.15076
28.5	0.013319	0.113112	23.9427	49	0.002704	0.085634	25.16655
29	0.012502	0.111661	23.99868	49.5	0.002606	0.084969	25.18188
29.5	0.011685	0.11021	24.05169	50	0.002508	0.084303	25.19676
30	0.010868	0.108759	24.10166				

Table (3-30): The cross section and calculated data of stopping power and neutron yield for $^{91}Zr(\alpha,n)^{94}Mo$ reaction.

Alpha energy MeV	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 alpha**	**Alpha energy MeV**	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 alpha**
10	0.005568	0.244873	0.011368	30.5	0.009827	0.107048	17.741
10.5	0.015918	0.238016	0.044807	31	0.009512	0.106537	17.78565
11	0.026268	0.231159	0.101625	31.5	0.009198	0.106027	17.82902
11.5	0.056367	0.225153	0.2268	32	0.008883	0.105517	17.87111
12	0.086466	0.219148	0.424077	32.5	0.008568	0.105006	17.91191
12.5	0.140424	0.213793	0.752489	33	0.008253	0.104496	17.9514
13	0.194383	0.208438	1.218774	33.5	0.007938	0.103986	17.98957
13.5	0.259444	0.203684	1.855654	34	0.007623	0.103475	18.02641
14	0.324505	0.198929	2.671283	34.5	0.007309	0.102965	18.0619
14.5	0.387169	0.194676	3.665679	35	0.006994	0.102455	18.09603
15	0.449833	0.190422	4.846828	35.5	0.006772	0.101994	18.12923
15.5	0.478861	0.186519	6.13051	36	0.006551	0.101534	18.16149
16	0.507889	0.182615	7.521108	36.5	0.006329	0.101074	18.1928
16.5	0.480502	0.179112	8.862453	37	0.006108	0.100614	18.22315
17	0.453116	0.175609	10.15258	37.5	0.005886	0.100153	18.25254
17.5	0.420972	0.172407	11.37345	38	0.005665	0.099693	18.28095
18	0.388828	0.169204	12.52244	38.5	0.005443	0.099233	18.30838
18.5	0.318544	0.163499	13.49658	39	0.005222	0.098772	18.33481
19	0.248259	0.157795	14.28323	39.5	0.005	0.098312	18.36024
19.5	0.1907	0.15179	14.9114	40	0.004779	0.097852	18.38466
20	0.133141	0.145786	15.36804	40.5	0.004642	0.097062	18.40857
20.5	0.110737	0.143284	15.75446	41	0.004505	0.096273	18.43196
21	0.088332	0.140782	16.06818	41.5	0.004368	0.095483	18.45484
21.5	0.065927	0.13828	16.30657	42	0.004231	0.094694	18.47718
22	0.043523	0.135778	16.46684	42.5	0.004094	0.093904	18.49897
22.5	0.038696	0.133627	16.61163	43	0.003957	0.093115	18.52022
23	0.03387	0.131475	16.74044	43.5	0.00382	0.092325	18.54091
23.5	0.029044	0.129323	16.85273	44	0.003683	0.091536	18.56103
24	0.024218	0.127172	16.94795	44.5	0.003546	0.090746	18.58057
24.5	0.022151	0.125321	17.03633	45	0.003409	0.089957	18.59952
25	0.020084	0.123469	17.11766	45.5	0.003314	0.089298	18.61807
25.5	0.018017	0.121618	17.19174	46	0.003218	0.08864	18.63622
26	0.01595	0.119767	17.25832	46.5	0.003122	0.087981	18.65396
26.5	0.015054	0.11814	17.32204	47	0.003026	0.087323	18.67129
27	0.014158	0.116514	17.3828	47.5	0.002931	0.086665	18.6882
27.5	0.013262	0.114888	17.44051	48	0.002835	0.086006	18.70468
28	0.012366	0.113262	17.49511	48.5	0.002739	0.085348	18.72073
28.5	0.01181	0.111836	17.54791	49	0.002643	0.084689	18.73634
29	0.011254	0.11041	17.59887	49.5	0.002548	0.084031	18.7515
29.5	0.010698	0.108984	17.64795	50	0.002452	0.083372	18.7662
30	0.010142	0.107558	17.6951				

Table (3-31): The cross section and calculated data of stopping power and neutron yield for $^{92}Zr(\alpha,n)^{95}Mo$ reaction.

Alpha energy MeV	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 alpha**	**Alpha energy MeV**	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 alpha**
10	0.005957	0.242269	0.012293	30.5	0.009313	0.105857	15.15481
10.5	0.016851	0.235462	0.048076	31	0.008983	0.105356	15.19744
11	0.027745	0.228656	0.108746	31.5	0.008654	0.104856	15.23871
11.5	0.058947	0.2227	0.241091	32	0.008324	0.104356	15.27859
12	0.090149	0.216745	0.449052	32.5	0.007995	0.103855	15.31708
12.5	0.145201	0.21144	0.792416	33	0.007666	0.103355	15.35417
13	0.200254	0.206135	1.278151	33.5	0.007336	0.102855	15.38983
13.5	0.266188	0.201431	1.938895	34	0.007007	0.102354	15.42406
14	0.332123	0.196727	2.783019	34.5	0.006678	0.101854	15.45684
14.5	0.379236	0.192523	3.76793	35	0.006348	0.101354	15.48816
15	0.426349	0.188319	4.899916	35.5	0.006151	0.100897	15.51864
15.5	0.431101	0.184466	6.068426	36	0.005954	0.100441	15.54828
16	0.435853	0.180613	7.275021	36.5	0.005756	0.099985	15.57706
16.5	0.40219	0.17716	8.410126	37	0.005559	0.099528	15.60499
17	0.368527	0.173707	9.470898	37.5	0.005362	0.099072	15.63205
17.5	0.309597	0.170504	10.37878	38	0.005164	0.098616	15.65823
18	0.250667	0.167302	11.12793	38.5	0.004967	0.098159	15.68353
18.5	0.204145	0.161697	11.75919	39	0.00477	0.097703	15.70794
19	0.157623	0.156093	12.26409	39.5	0.004572	0.097247	15.73145
19.5	0.125248	0.150188	12.68106	40	0.004375	0.096791	15.75405
20	0.092873	0.144284	13.0029	40.5	0.004245	0.096009	15.77616
20.5	0.079838	0.141782	13.28445	41	0.004116	0.095228	15.79777
21	0.066804	0.13928	13.52427	41.5	0.003986	0.094446	15.81888
21.5	0.053769	0.136778	13.72083	42	0.003857	0.093665	15.83946
22	0.040735	0.134276	13.87251	42.5	0.003727	0.092883	15.85953
22.5	0.036843	0.132175	14.01188	43	0.003597	0.092102	15.87905
23	0.032951	0.130073	14.13854	43.5	0.003468	0.09132	15.89804
23.5	0.029059	0.127972	14.25208	44	0.003338	0.090539	15.91648
24	0.025167	0.12587	14.35206	44.5	0.003208	0.089757	15.93435
24.5	0.023015	0.124019	14.44484	45	0.003079	0.088976	15.95165
25	0.020863	0.122168	14.53023	45.5	0.002989	0.088325	15.96857
25.5	0.01871	0.120316	14.60798	46	0.002899	0.087675	15.9851
26	0.016558	0.118465	14.67787	46.5	0.002809	0.087024	16.00124
26.5	0.015416	0.116864	14.74382	47	0.002719	0.086374	16.01698
27	0.014273	0.115263	14.80574	47.5	0.002629	0.085724	16.03232
27.5	0.013131	0.113662	14.8635	48	0.002539	0.085073	16.04724
28	0.011989	0.112061	14.917	48.5	0.00245	0.084423	16.06175
28.5	0.011402	0.110635	14.96853	49	0.00236	0.083772	16.07583
29	0.010815	0.109209	15.01804	49.5	0.00227	0.083122	16.08949
29.5	0.010229	0.107783	15.0655	50	0.00218	0.082472	16.1027
30	0.009642	0.106357	15.11082				

Table (3-32): The cross section and calculated data of stopping power and neutron yield for $^{93}Zr(\alpha,n)^{96}Mo$ reaction.

Alpha energy MeV	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 alpha**	**Alpha energy MeV**	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 alpha**
10	0.006321	0.239665	0.013187	30.5	0.008942	0.104755	10.34856
10.5	0.01772	0.232909	0.051228	31	0.008619	0.104255	10.3899
11	0.02912	0.226152	0.115609	31.5	0.008296	0.103755	10.42988
11.5	0.061305	0.220297	0.25475	32	0.007973	0.103254	10.46849
12	0.09349	0.214441	0.472734	32.5	0.00765	0.102754	10.50571
12.5	0.149728	0.209187	0.830616	33	0.007327	0.102254	10.54154
13	0.205967	0.203932	1.335606	33.5	0.007004	0.101753	10.57595
13.5	0.262286	0.199278	1.993696	34	0.006681	0.101253	10.60894
14	0.318604	0.194624	2.812208	34.5	0.006357	0.100753	10.64049
14.5	0.311533	0.19047	3.630008	35	0.006034	0.100252	10.67059
15	0.304462	0.186317	4.447063	35.5	0.005845	0.099802	10.69987
15.5	0.271102	0.182513	5.189755	36	0.005655	0.099352	10.72833
16	0.237743	0.17871	5.854918	36.5	0.005465	0.098902	10.75596
16.5	0.202136	0.175258	6.431602	37	0.005275	0.098451	10.78275
17	0.16653	0.171805	6.916251	37.5	0.005086	0.098001	10.80869
17.5	0.14083	0.168652	7.333769	38	0.004896	0.097551	10.83379
18	0.115131	0.1655	7.681597	38.5	0.004706	0.0971	10.85802
18.5	0.09739	0.159945	7.986044	39	0.004516	0.09665	10.88139
19	0.079649	0.154391	8.243989	39.5	0.004327	0.0962	10.90388
19.5	0.066145	0.148536	8.466644	40	0.004137	0.09575	10.92548
20	0.052641	0.142682	8.651116	40.5	0.004016	0.094976	10.94662
20.5	0.046923	0.14023	8.818423	41	0.003895	0.094203	10.9673
21	0.041204	0.137778	8.967954	41.5	0.003775	0.093429	10.9875
21.5	0.035486	0.135327	9.099066	42	0.003654	0.092656	11.00721
22	0.029767	0.132875	9.211079	42.5	0.003533	0.091882	11.02644
22.5	0.027775	0.130773	9.317275	43	0.003412	0.091109	11.04516
23	0.025783	0.128672	9.417466	43.5	0.003291	0.090335	11.06338
23.5	0.023791	0.12657	9.51145	44	0.00317	0.089562	11.08108
24	0.021799	0.124469	9.599019	44.5	0.00305	0.088788	11.09825
24.5	0.020119	0.122643	9.681044	45	0.002929	0.088015	11.11489
25	0.01844	0.120816	9.757356	45.5	0.002845	0.087371	11.13117
25.5	0.01676	0.11899	9.827781	46	0.00276	0.086728	11.14708
26	0.01508	0.117164	9.892135	46.5	0.002676	0.086084	11.16263
26.5	0.014171	0.115588	9.953436	47	0.002592	0.085441	11.1778
27	0.013263	0.114012	10.0116	47.5	0.002508	0.084798	11.19258
27.5	0.012354	0.112436	10.06654	48	0.002423	0.084154	11.20698
28	0.011445	0.110859	10.11816	48.5	0.002339	0.083511	11.22098
28.5	0.010901	0.109459	10.16795	49	0.002255	0.082867	11.23459
29	0.010356	0.108058	10.21587	49.5	0.002171	0.082224	11.24779
29.5	0.009811	0.106657	10.26186	50	0.002086	0.081581	11.26058
30	0.009266	0.105256	10.30588				

Table (3-33): The cross section and calculated data of stopping power and neutron yield for $^{44}Sc(p,n)^{44}Ti$ reaction.

proton energy MeV	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 proton**	**proton energy MeV**	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 proton**
10	216.0004	0.031386	3.441077	30.5	28.29942	0.011883	78.14323
10.5	207.3339	0.03029	6.863564	31	27.56907	0.011821	79.30933
11	198.6674	0.029194	10.26606	31.5	26.83872	0.011759	80.45053
11.5	182.6743	0.028259	13.49823	32	26.10836	0.011697	81.56656
12	166.6812	0.027323	16.5484	32.5	25.37801	0.011635	82.65715
12.5	150.1572	0.026513	19.38019	33	24.64766	0.011573	83.72204
13	133.6332	0.025702	21.97982	33.5	23.91731	0.011511	84.76094
13.5	121.2106	0.024992	24.40481	34	23.18695	0.011449	85.77357
14	108.788	0.024282	26.64495	34.5	22.4566	0.011387	86.75965
14.5	100.496	0.023656	28.76904	35	21.72625	0.011325	87.71888
15	92.20407	0.023031	30.77079	35.5	21.23318	0.011269	88.66101
15.5	86.68443	0.022476	32.69921	36	20.74012	0.011213	89.58585
16	81.16479	0.02192	34.55057	36.5	20.24705	0.011157	90.49325
16.5	77.12388	0.021415	36.35127	37	19.75398	0.011101	91.38301
17	73.08296	0.02091	38.09885	37.5	19.26092	0.011045	92.25497
17.5	70.01415	0.020459	39.80989	38	18.76785	0.010989	93.10893
18	66.94533	0.020009	41.48275	38.5	18.27478	0.010933	93.94473
18.5	64.35664	0.019229	43.15619	39	17.78172	0.010877	94.76216
19	61.76794	0.018448	44.83027	39.5	17.28865	0.010821	95.56104
19.5	59.58948	0.017643	46.51902	40	16.79559	0.010765	96.34117
20	57.41102	0.016838	48.22387	40.5	16.44716	0.010671	97.1118
20.5	55.46707	0.016505	49.90419	41	16.09873	0.010578	97.87275
21	53.52312	0.016172	51.55898	41.5	15.75031	0.010485	98.62385
21.5	51.57917	0.01584	53.18715	42	15.40188	0.010392	99.36493
22	49.63523	0.015507	54.78757	42.5	15.05345	0.010298	100.0958
22.5	47.99559	0.015232	56.36309	43	14.70503	0.010205	100.8163
23	46.35596	0.014957	57.91277	43.5	14.3566	0.010112	101.5262
23.5	44.71633	0.014681	59.43565	44	14.00817	0.010019	102.2253
24	43.07669	0.014406	60.93071	44.5	13.65975	0.009925	102.9134
24.5	41.63755	0.014171	62.3998	45	13.31132	0.009832	103.5903
25	40.19841	0.013936	63.84204	45.5	13.04856	0.009756	104.2591
25.5	38.75927	0.013701	65.25651	46	12.7858	0.009679	104.9196
26	37.32013	0.013466	66.64224	46.5	12.52304	0.009602	105.5717
26.5	36.19623	0.013263	68.00677	47	12.26028	0.009526	106.2152
27	35.07232	0.013061	69.34945	47.5	11.99752	0.009449	106.85
27.5	33.94842	0.012858	70.66957	48	11.73476	0.009373	107.476
28	32.82452	0.012655	71.96642	48.5	11.472	0.009296	108.0931
28.5	31.87583	0.012478	73.24372	49	11.20923	0.00922	108.7009
29	30.92715	0.0123	74.50089	49.5	10.94647	0.009143	109.2996
29.5	29.97846	0.012123	75.73735	50	10.68371	0.009067	109.8887
30	29.02978	0.011945	76.95248				

Table (3-34): The cross section and calculated data of stopping power and neutron yield for $^{45}Sc(p,n)^{45}Ti$ reaction.

proton energy MeV	Cross section (mb)	Stopping power MeV / (mg/cm^2)	Neutron yield n/10^6 proton	proton energy MeV	Cross section (mb)	Stopping power MeV / (mg/cm^2)	Neutron yield n/10^6 proton
10	326.6288	0.030685	5.322306	30.5	29.46132	0.011615	119.5605
10.5	330.7617	0.029614	10.9068	31	28.73233	0.011555	120.8038
11	334.8946	0.028544	16.77315	31.5	28.00334	0.011495	122.0219
11.5	338.1873	0.027633	22.89238	32	27.27435	0.011435	123.2145
12	341.4801	0.026723	29.28171	32.5	26.54536	0.011375	124.3814
12.5	338.6147	0.025927	35.8118	33	25.81637	0.011315	125.5222
13	335.7494	0.025132	42.49157	33.5	25.08737	0.011255	126.6367
13.5	304.2003	0.024441	48.71462	34	24.35838	0.011195	127.7247
14	272.6513	0.023751	54.45439	34.5	23.62939	0.011135	128.7858
14.5	233.7211	0.023136	59.50548	35	22.9004	0.011075	129.8197
15	194.7909	0.02252	63.83024	35.5	22.38982	0.011021	130.8355
15.5	165.8814	0.021975	67.60454	36	21.87924	0.010967	131.8331
16	136.972	0.02143	70.80037	36.5	21.36866	0.010913	132.8121
16.5	119.3646	0.02094	73.65059	37	20.85808	0.010858	133.7726
17	101.7572	0.020449	76.13862	37.5	20.3475	0.010804	134.7142
17.5	91.54835	0.020009	78.4263	38	19.83692	0.01075	135.6368
18	81.33946	0.019569	80.50459	38.5	19.32634	0.010696	136.5402
18.5	75.06867	0.018803	82.50073	39	18.81576	0.010642	137.4242
19	68.79788	0.018038	84.40775	39.5	18.30518	0.010588	138.2886
19.5	64.68776	0.017248	86.28301	40	17.7946	0.010534	139.1332
20	60.57764	0.016457	88.12347	40.5	17.43187	0.010442	139.9679
20.5	58.02764	0.016135	89.9217	41	17.06915	0.01035	140.7925
21	55.47765	0.015812	91.676	41.5	16.70642	0.010258	141.6067
21.5	52.92766	0.015489	93.38453	42	16.3437	0.010167	142.4105
22	50.37766	0.015167	95.04534	42.5	15.98097	0.010075	143.2037
22.5	48.71483	0.014896	96.68046	43	15.61825	0.009983	143.9859
23	47.052	0.014626	98.28892	43.5	15.25552	0.009891	144.7571
23.5	45.38916	0.014356	99.86975	44	14.8928	0.009799	145.5171
24	43.72633	0.014086	101.4219	44.5	14.53007	0.009707	146.2655
24.5	42.36795	0.013856	102.9507	45	14.16735	0.009615	147.0023
25	41.00957	0.013626	104.4556	45.5	13.90126	0.00954	147.7308
25.5	39.6512	0.013396	105.9356	46	13.63517	0.009465	148.4511
26	38.29282	0.013166	107.3899	46.5	13.36907	0.00939	149.163
26.5	37.19369	0.012966	108.8242	47	13.10298	0.009315	149.8663
27	36.09457	0.012765	110.2379	47.5	12.83689	0.00924	150.5609
27.5	34.99545	0.012565	111.6305	48	12.5708	0.009165	151.2467
28	33.89632	0.012365	113.0011	48.5	12.3047	0.00909	151.9235
28.5	32.96982	0.012193	114.3532	49	12.03861	0.009015	152.5912
29	32.04332	0.01202	115.6861	49.5	11.77252	0.00894	153.2496
29.5	31.11681	0.011847	116.9993	50	11.50643	0.008866	153.8985
30	30.19031	0.011675	118.2923				

Table (3-35): The cross section and calculated data of stopping power and neutron yield for $^{46}Sc(p,n)^{46}Ti$ reaction.

proton energy MeV	Cross section (mb)	Stopping power MeV / (mg/cm^2)	Neutron yield n/10^6 proton	proton energy MeV	Cross section (mb)	Stopping power MeV / (mg/cm^2)	Neutron yield n/10^6 proton
10	642.0229	0.030014	10.6953	30.5	40.82194	0.011365	160.8737
10.5	617.9964	0.028969	21.36193	31	39.84791	0.011305	162.6362
11	593.9698	0.027923	31.99775	31.5	38.87388	0.011245	164.3648
11.5	536.4627	0.027033	41.92025	32	37.89985	0.011185	166.0591
12	478.9555	0.026142	51.08086	32.5	36.92582	0.011125	167.7187
12.5	415.3559	0.025367	59.26789	33	35.95179	0.011064	169.3434
13	351.7562	0.024591	66.41993	33.5	34.97776	0.011004	170.9326
13.5	302.4143	0.023911	72.7437	34	34.00373	0.010944	172.4861
14	253.0724	0.023231	78.19066	34.5	33.0297	0.010884	174.0034
14.5	220.2303	0.02263	83.0565	35	32.05567	0.010824	175.4841
15	187.3883	0.02203	87.30953	35.5	31.3594	0.010772	176.9396
15.5	166.5821	0.021495	91.1845	36	30.66312	0.01072	178.3698
16	145.776	0.020959	94.66208	36.5	29.96685	0.010668	179.7743
16.5	132.6295	0.020484	97.89945	37	29.27058	0.010616	181.1528
17	119.4831	0.020009	100.8852	37.5	28.5743	0.010564	182.5052
17.5	110.8705	0.019574	103.7173	38	27.87803	0.010512	183.8312
18	102.258	0.019138	106.3889	38.5	27.18176	0.01046	185.1305
18.5	96.34253	0.018393	109.0078	39	26.48548	0.010408	186.4028
19	90.42706	0.017648	111.5699	39.5	25.78921	0.010356	187.648
19.5	86.11362	0.016877	114.121	40	25.09294	0.010304	188.8656
20	81.80019	0.016107	116.6603	40.5	24.56344	0.010214	190.068
20.5	78.7234	0.015789	119.1532	41	24.03395	0.010124	191.2549
21	75.64661	0.015472	121.5979	41.5	23.50446	0.010035	192.4261
21.5	72.56982	0.015154	123.9923	42	22.97496	0.009945	193.5812
22	69.49303	0.014836	126.3343	42.5	22.44547	0.009855	194.72
22.5	67.10166	0.014571	128.6369	43	21.91598	0.009765	195.8422
23	64.7103	0.014306	130.8985	43.5	21.38649	0.009675	196.9474
23.5	62.31893	0.014041	133.1177	44	20.85699	0.009585	198.0353
24	59.92756	0.013776	135.2928	44.5	20.3275	0.009496	199.1057
24.5	58.14353	0.013551	137.4382	45	19.79801	0.009406	200.1581
25	56.35949	0.013326	139.5529	45.5	19.47942	0.009332	201.2018
25.5	54.57545	0.0131	141.6359	46	19.16083	0.009259	202.2365
26	52.79141	0.012875	143.686	46.5	18.84224	0.009186	203.2621
26.5	51.29809	0.012683	145.7083	47	18.52365	0.009112	204.2785
27	49.80476	0.01249	147.7021	47.5	18.20506	0.009039	205.2855
27.5	48.31143	0.012298	149.6664	48	17.88648	0.008966	206.283
28	46.8181	0.012105	151.6002	48.5	17.56789	0.008892	207.2708
28.5	45.56257	0.011935	153.509	49	17.2493	0.008819	208.2488
29	44.30704	0.011765	155.392	49.5	16.93071	0.008746	209.2167
29.5	43.05151	0.011595	157.2485	50	16.61212	0.008672	210.1745
30	41.79597	0.011425	159.0777				

Table (3-36): The cross section and calculated data of stopping power and neutron yield for $^{47}Sc(p,n)^{47}Ti$ reaction.

proton energy MeV	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 proton**	**proton energy MeV**	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 proton**
10	629.3204	0.029384	10.70868	30.5	31.65157	0.011125	141.7582
10.5	591.3137	0.028358	21.13452	31	30.86182	0.011066	143.1526
11	553.307	0.027333	31.25628	31.5	30.07208	0.011007	144.5186
11.5	493.3163	0.026457	40.57923	32	29.28233	0.010948	145.8559
12	433.3256	0.025582	49.0487	32.5	28.49258	0.010889	147.1641
12.5	373.3145	0.024821	56.56877	33	27.70283	0.01083	148.4431
13	313.3034	0.024061	63.07942	33.5	26.91309	0.010771	149.6924
13.5	267.2363	0.0234	68.78948	34	26.12334	0.010712	150.9117
14	221.1691	0.02274	73.65245	34.5	25.33359	0.010653	152.1007
14.5	190.4527	0.02215	77.95164	35	24.54384	0.010594	153.2591
15	159.7363	0.02156	81.65618	35.5	23.99656	0.010543	154.3971
15.5	140.672	0.021039	84.99926	36	23.44928	0.010492	155.5146
16	121.6078	0.020519	87.96255	36.5	22.90199	0.010441	156.6113
16.5	109.7832	0.020049	90.70046	37	22.35471	0.01039	157.6871
17	97.95859	0.019579	93.20214	37.5	21.80742	0.010339	158.7417
17.5	90.37491	0.019158	95.56078	38	21.26014	0.010288	159.7749
18	82.79122	0.018738	97.76994	38.5	20.71285	0.010237	160.7866
18.5	77.71189	0.018003	99.92828	39	20.16557	0.010186	161.7764
19	72.63256	0.017267	102.0315	39.5	19.61829	0.010135	162.7443
19.5	68.95204	0.016512	104.1194	40	19.071	0.010084	163.6899
20	65.27152	0.015757	106.1906	40.5	18.68766	0.009996	164.6246
20.5	62.70605	0.015449	108.2201	41	18.30432	0.009908	165.5483
21	60.14058	0.015141	110.2061	41.5	17.92097	0.00982	166.4608
21.5	57.57511	0.014834	112.1467	42	17.53763	0.009733	167.3617
22	55.00964	0.014526	114.0402	42.5	17.15429	0.009645	168.251
22.5	53.11075	0.014266	115.9017	43	16.77094	0.009557	169.1285
23	51.21186	0.014006	117.7299	43.5	16.3876	0.009469	169.9938
23.5	49.31297	0.013746	119.5237	44	16.00425	0.009381	170.8468
24	47.41408	0.013486	121.2816	44.5	15.62091	0.009293	171.6872
24.5	45.95207	0.013265	123.0137	45	15.23757	0.009206	172.5148
25	44.49007	0.013045	124.7189	45.5	14.9708	0.009134	173.3344
25.5	43.02807	0.012825	126.3963	46	14.70404	0.009062	174.1456
26	41.56607	0.012605	128.0451	46.5	14.43727	0.00899	174.9486
26.5	40.33099	0.012415	129.6694	47	14.17051	0.008919	175.743
27	39.09592	0.012225	131.2684	47.5	13.90374	0.008847	176.5288
27.5	37.86084	0.012035	132.8414	48	13.63698	0.008775	177.3058
28	36.62576	0.011845	134.3875	48.5	13.37021	0.008703	178.0739
28.5	35.57965	0.01168	135.9106	49	13.10345	0.008632	178.833
29	34.53354	0.011515	137.4101	49.5	12.83668	0.00856	179.5828
29.5	33.48743	0.01135	138.8854	50	12.56992	0.008488	180.3232
30	32.44132	0.011184	140.3357				

Table (3-37): The cross section and calculated data of stopping power and neutron yield for $^{48}Sc(p,n)^{48}Ti$ reaction.

proton energy MeV	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 proton**	**proton energy MeV**	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 proton**
10	647.614	0.028773	11.25381	30.5	37.76412	0.010887	140.5265
10.5	569.924	0.027768	21.51622	31	36.86176	0.01083	142.2283
11	492.2341	0.026762	30.71272	31.5	35.95941	0.010773	143.8972
11.5	418.7039	0.025907	38.79375	32	35.05706	0.010716	145.5329
12	345.1737	0.025051	45.68314	32.5	34.1547	0.010659	147.1351
12.5	292.4192	0.024306	51.69857	33	33.25235	0.010602	148.7033
13	239.6648	0.02356	56.78475	33.5	32.35	0.010545	150.2371
13.5	207.6465	0.02291	61.31653	34	31.44764	0.010488	151.7363
14	175.6282	0.02226	65.26151	34.5	30.54529	0.010431	153.2005
14.5	156.9576	0.021684	68.88064	35	29.64294	0.010374	154.6292
15	138.2869	0.021109	72.15616	35.5	29.01774	0.010324	156.0346
15.5	126.3262	0.020599	75.22249	36	28.39254	0.010274	157.4164
16	114.3655	0.020089	78.06902	36.5	27.76734	0.010223	158.7744
16.5	106.6446	0.019628	80.78561	37	27.14215	0.010173	160.1085
17	98.92377	0.019168	83.36602	37.5	26.51695	0.010123	161.4182
17.5	93.75095	0.018758	85.86498	38	25.89175	0.010073	162.7034
18	88.57813	0.018348	88.27885	38.5	25.26655	0.010022	163.9639
18.5	84.48911	0.017627	90.67538	39	24.64136	0.009972	165.1994
19	80.40009	0.016907	93.05308	39.5	24.01616	0.009922	166.4097
19.5	77.13792	0.016172	95.43804	40	23.39096	0.009872	167.5944
20	73.87575	0.015436	97.83096	40.5	22.92258	0.009786	168.7656
20.5	71.41873	0.015131	100.1909	41	22.45421	0.0097	169.923
21	68.96172	0.014826	102.5166	41.5	21.98583	0.009614	171.0664
21.5	66.5047	0.014521	104.8066	42	21.51746	0.009528	172.1955
22	64.04768	0.014216	107.0593	42.5	21.04908	0.009443	173.3101
22.5	61.96525	0.013963	109.2782	43	20.58071	0.009357	174.4099
23	59.88281	0.013711	111.462	43.5	20.11233	0.009271	175.4946
23.5	57.80038	0.013458	113.6094	44	19.64396	0.009185	176.5639
24	55.71795	0.013205	115.7191	44.5	19.17558	0.009099	177.6176
24.5	54.06695	0.01299	117.8002	45	18.70721	0.009013	178.6554
25	52.41596	0.012775	119.8516	45.5	18.41188	0.008943	179.6847
25.5	50.76496	0.01256	121.8725	46	18.11655	0.008873	180.7056
26	49.11397	0.012345	123.8618	46.5	17.82122	0.008803	181.7179
26.5	47.73711	0.012157	125.8251	47	17.5259	0.008732	182.7214
27	46.36025	0.01197	127.7616	47.5	17.23057	0.008662	183.716
27.5	44.98339	0.011782	129.6706	48	16.93524	0.008592	184.7015
28	43.60653	0.011595	131.5511	48.5	16.63992	0.008522	185.6778
28.5	42.37152	0.011432	133.4043	49	16.34459	0.008452	186.6447
29	41.1365	0.011269	135.2294	49.5	16.04926	0.008381	187.6022
29.5	39.90149	0.011107	137.0257	50	15.75394	0.008311	188.5499
30	38.66647	0.010944	138.7922				

Table (3-38): The cross section and calculated data of stopping power and neutron yield for $^{49}Sc(p,n)^{49}Ti$ reaction.

proton energy MeV	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 proton**	**proton energy MeV**	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 proton**
10	501.8709	0.028183	8.903927	30.5	28.22868	0.010668	106.3158
10.5	428.8707	0.027202	16.78698	31	27.51461	0.010612	107.6122
11	355.8704	0.026222	23.57282	31.5	26.80054	0.010556	108.8816
11.5	300.329	0.025381	29.48921	32	26.08647	0.0105	110.1238
12	244.7876	0.024541	34.47659	32.5	25.3724	0.010444	111.3385
12.5	208.3554	0.02381	38.85191	33	24.65833	0.010388	112.5254
13	171.9232	0.02308	42.57642	33.5	23.94426	0.010332	113.6841
13.5	149.9104	0.022445	45.91598	34	23.23019	0.010276	114.8145
14	127.8976	0.021809	48.84815	34.5	22.51612	0.01022	115.9161
14.5	114.6138	0.021244	51.5457	35	21.80205	0.010164	116.9886
15	101.3301	0.020679	53.9958	35.5	21.32088	0.010115	118.0426
15.5	93.14445	0.020179	56.30381	36	20.83971	0.010065	119.0778
16	84.95884	0.019678	58.46251	36.5	20.35855	0.010016	120.0941
16.5	79.5504	0.019228	60.53111	37	19.87738	0.009967	121.0913
17	74.14195	0.018778	62.50529	37.5	19.39621	0.009917	122.0692
17.5	70.28194	0.018373	64.41797	38	18.91505	0.009868	123.0276
18	66.42193	0.017967	66.26637	38.5	18.43388	0.009819	123.9663
18.5	63.56585	0.017267	68.10703	39	17.95271	0.009769	124.8852
19	60.70977	0.016567	69.9393	39.5	17.47154	0.00972	125.7839
19.5	58.3052	0.015841	71.77957	40	16.99038	0.009671	126.6624
20	55.90063	0.015116	73.62862	40.5	16.65517	0.009587	127.531
20.5	53.93263	0.014818	75.44839	41	16.31996	0.009502	128.3898
21	51.96462	0.014521	77.2377	41.5	15.98475	0.009418	129.2384
21.5	49.99662	0.014223	78.99528	42	15.64955	0.009334	130.0767
22	48.02861	0.013926	80.71975	42.5	15.31434	0.00925	130.9045
22.5	46.49831	0.013678	82.41951	43	14.97913	0.009166	131.7216
23	44.968	0.01343	84.09363	43.5	14.64392	0.009082	132.5278
23.5	43.4377	0.013183	85.74115	44	14.30872	0.008998	133.323
24	41.90739	0.012935	87.36106	44.5	13.97351	0.008913	134.1068
24.5	40.63326	0.012723	88.95797	45	13.6383	0.008829	134.8792
25	39.35913	0.01251	90.53108	45.5	13.41075	0.008761	135.6446
25.5	38.08499	0.012297	92.07959	46	13.1832	0.008692	136.4029
26	36.81086	0.012085	93.60262	46.5	12.95565	0.008623	137.1541
26.5	35.74156	0.011905	95.10378	47	12.7281	0.008554	137.8981
27	34.67226	0.011725	96.5824	47.5	12.50055	0.008486	138.6347
27.5	33.60295	0.011544	98.03777	48	12.273	0.008417	139.3637
28	32.53365	0.011364	99.46915	48.5	12.04545	0.008348	140.0852
28.5	31.63593	0.011204	100.8809	49	11.81789	0.008279	140.7989
29	30.7382	0.011044	102.2725	49.5	11.59034	0.008211	141.5047
29.5	29.84048	0.010884	103.6433	50	11.36279	0.008142	142.2025
30	28.94275	0.010724	104.9928				

Table (3-39): The cross section and calculated data of stopping power and neutron yield for $^{50}Sc(p,n)^{50}Ti$ reaction.

proton energy MeV	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 proton**	**proton energy MeV**	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 proton**
10	192.476	0.027612	3.48536	30.5	35.64728	0.010459	94.32395
10.5	174.6112	0.026652	6.761173	31	34.77114	0.010404	95.99505
11	156.7464	0.025691	9.811771	31.5	33.895	0.010349	97.63271
11.5	145.27	0.024871	12.73228	32	33.01886	0.010293	99.23659
12	133.7937	0.02405	15.51382	32.5	32.14271	0.010238	100.8063
12.5	125.5252	0.023335	18.20346	33	31.26657	0.010183	102.3415
13	117.2568	0.02262	20.7954	33.5	30.39043	0.010128	103.8418
13.5	111.2278	0.021994	23.32396	34	29.51428	0.010073	105.3068
14	105.1987	0.021369	25.78545	34.5	28.63814	0.010018	106.7362
14.5	100.8027	0.020819	28.20641	35	27.762	0.009963	108.1295
15	96.40672	0.020268	30.58466	35.5	27.17202	0.009914	109.4999
15.5	92.81264	0.019778	32.931	36	26.58205	0.009865	110.8471
16	89.21856	0.019288	35.2438	36.5	25.99207	0.009817	112.1709
16.5	85.76004	0.018848	37.51888	37	25.40209	0.009768	113.4712
17	82.30151	0.018408	39.75442	37.5	24.81212	0.00972	114.7476
17.5	79.55162	0.018007	41.96328	38	24.22214	0.009671	115.9999
18	76.80172	0.017607	44.14426	38.5	23.63217	0.009622	117.2279
18.5	74.30831	0.016917	46.34054	39	23.04219	0.009574	118.4313
19	71.8149	0.016227	48.55343	39.5	22.45222	0.009525	119.6099
19.5	69.56407	0.015521	50.79437	40	21.86224	0.009477	120.7634
20	67.31325	0.014816	53.06603	40.5	21.43294	0.009394	121.9041
20.5	65.15556	0.014523	55.30918	41	21.00364	0.009312	123.0319
21	62.99786	0.014231	57.52264	41.5	20.57435	0.009229	124.1466
21.5	60.84017	0.013938	59.70517	42	20.14505	0.009147	125.2478
22	58.68247	0.013645	61.85545	42.5	19.71575	0.009064	126.3353
22.5	56.95448	0.013403	63.98018	43	19.28645	0.008982	127.409
23	55.22649	0.01316	66.07843	43.5	18.85715	0.008899	128.4684
23.5	53.4985	0.012918	68.14921	44	18.42785	0.008817	129.5134
24	51.77052	0.012675	70.19145	44.5	17.99855	0.008735	130.5437
24.5	50.22307	0.012467	72.20564	45	17.56925	0.008652	131.559
25	48.67563	0.01226	74.19083	45.5	17.29677	0.008585	132.5664
25.5	47.12819	0.012052	76.14601	46	17.02429	0.008517	133.5658
26	45.58075	0.011845	78.07013	46.5	16.7518	0.00845	134.557
26.5	44.36534	0.011667	79.97146	47	16.47932	0.008383	135.54
27	43.14993	0.011489	81.84927	47.5	16.20684	0.008316	136.5144
27.5	41.93452	0.011312	83.70285	48	15.93436	0.008248	137.4804
28	40.71911	0.011134	85.53141	48.5	15.66187	0.008181	138.4376
28.5	39.67019	0.010979	87.33802	49	15.38939	0.008114	139.386
29	38.62127	0.010824	89.12206	49.5	15.11691	0.008046	140.3254
29.5	37.57235	0.010669	90.88288	50	14.84442	0.007979	141.2556
30	36.52343	0.010514	92.61978				

Table (3-40): The cross section and calculated data of stopping power and neutron yield for $^{51}Sc(p,n)^{51}Ti$ reaction.

proton energy MeV	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 proton**	**proton energy MeV**	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 proton**
10	68.59677	0.027072	1.266951	30.5	16.41632	0.01025	44.26067
10.5	65.75295	0.026131	2.525085	31	16.01649	0.010196	45.04607
11	62.90913	0.025191	3.773745	31.5	15.61665	0.010143	45.81593
11.5	60.38771	0.02438	5.0122	32	15.21681	0.010089	46.57006
12	57.86628	0.02357	6.239748	32.5	14.81698	0.010035	47.30831
12.5	55.69349	0.022875	7.457117	33	14.41714	0.009981	48.03051
13	53.5207	0.022179	8.663669	33.5	14.0173	0.009928	48.73648
13.5	51.62286	0.021564	9.860643	34	13.61746	0.009874	49.42604
14	49.72502	0.020949	11.04748	34.5	13.21763	0.00982	50.09901
14.5	47.9846	0.020408	12.22309	35	12.81779	0.009767	50.75522
15	46.24419	0.019868	13.38687	35.5	12.53694	0.009719	51.40019
15.5	44.6308	0.019388	14.53787	36	12.25609	0.009671	52.03382
16	43.0174	0.018908	15.67543	36.5	11.97524	0.009624	52.656
16.5	41.48938	0.018477	16.79814	37	11.69439	0.009576	53.2666
17	39.96136	0.018047	17.90527	37.5	11.41354	0.009528	53.86552
17.5	38.57774	0.017657	18.99768	38	11.1327	0.009481	54.45263
18	37.19413	0.017267	20.07472	38.5	10.85185	0.009433	55.02783
18.5	35.88289	0.016592	21.15608	39	10.571	0.009386	55.59098
19	34.57166	0.015916	22.24213	39.5	10.29015	0.009338	56.14196
19.5	33.37659	0.015221	23.33853	40	10.0093	0.00929	56.68065
20	32.18152	0.014526	24.44628	40.5	9.850563	0.00921	57.21545
20.5	31.1309	0.014241	25.53932	41	9.691827	0.009129	57.7463
21	30.08027	0.013955	26.61705	41.5	9.533091	0.009048	58.27311
21.5	29.02965	0.01367	27.67883	42	9.374355	0.008967	58.79582
22	27.97902	0.013385	28.72398	42.5	9.215619	0.008886	59.31436
22.5	27.10508	0.013145	29.75498	43	9.056883	0.008805	59.82864
23	26.23114	0.012905	30.7713	43.5	8.898147	0.008725	60.33859
23.5	25.3572	0.012665	31.77239	44	8.739411	0.008644	60.84413
24	24.48326	0.012425	32.75766	44.5	8.580675	0.008563	61.34517
24.5	23.73306	0.012222	33.72856	45	8.421939	0.008482	61.84163
25	22.98285	0.01202	34.68462	45.5	8.262167	0.008416	62.33249
25.5	22.23264	0.011817	35.62533	46	8.102394	0.00835	62.81766
26	21.48244	0.011614	36.55016	46.5	7.942622	0.008284	63.29706
26.5	20.85722	0.011439	37.46181	47	7.782849	0.008218	63.77059
27	20.23201	0.011264	38.35987	47.5	7.623077	0.008152	64.23815
27.5	19.6068	0.011089	39.24393	48	7.463305	0.008086	64.69966
28	18.98159	0.010914	40.11352	48.5	7.303532	0.00802	65.155
28.5	18.44023	0.010761	40.97029	49	7.14376	0.007954	65.60408
29	17.89888	0.010609	41.81387	49.5	6.983987	0.007888	66.04679
29.5	17.35752	0.010456	42.64386	50	6.824215	0.007822	66.48302
30	16.81616	0.010304	43.45988				

Table (3-41): The cross section and calculated data of stopping power and neutron yield for $^{52}Sc(p,n)^{52}Ti$ reaction.

proton energy MeV	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 proton**	**proton energy MeV**	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 proton**
10	75.16675	0.026551	1.415508	30.5	20.31496	0.010051	53.31682
10.5	73.10272	0.025626	2.841864	31	19.85495	0.009998	54.30972
11	71.03869	0.0247	4.27988	31.5	19.39493	0.009946	55.28475
11.5	68.72587	0.02391	5.717066	32	18.93492	0.009893	56.24172
12	66.41305	0.023119	7.153366	32.5	18.47491	0.009841	57.18044
12.5	64.23202	0.022434	8.584932	33	18.0149	0.009788	58.1007
13	62.051	0.021749	10.01147	33.5	17.55489	0.009735	59.00231
13.5	60.05449	0.021149	11.43129	34	17.09488	0.009683	59.88507
14	58.05799	0.020548	12.84401	34.5	16.63487	0.00963	60.74876
14.5	56.13671	0.020018	14.24617	35	16.17486	0.009577	61.59319
15	54.21542	0.019488	15.63718	35.5	15.82433	0.009531	62.42335
15.5	52.12289	0.019013	17.00793	36	15.4738	0.009484	63.23912
16	50.03035	0.018537	18.35737	36.5	15.12328	0.009438	64.04035
16.5	48.24247	0.018117	19.68878	37	14.77275	0.009391	64.82689
17	46.45458	0.017697	21.00128	37.5	14.42223	0.009344	65.5986
17.5	44.94257	0.017312	22.29931	38	14.0717	0.009298	66.35533
18	43.43057	0.016927	23.58222	38.5	13.72118	0.009251	67.09693
18.5	42.19826	0.016266	24.87932	39	13.37065	0.009204	67.82324
19	40.96596	0.015606	26.19183	39.5	13.02013	0.009158	68.53411
19.5	39.52621	0.014926	27.51592	40	12.6696	0.009111	69.22938
20	38.08647	0.014245	28.85272	40.5	12.42634	0.009032	69.91729
20.5	36.92609	0.013965	30.17478	41	12.18307	0.008953	70.5977
21	35.76571	0.013685	31.48152	41.5	11.93981	0.008874	71.27047
21.5	34.60533	0.013405	32.77227	42	11.69654	0.008794	71.93548
22	33.44495	0.013125	34.04637	42.5	11.45328	0.008715	72.59257
22.5	32.45766	0.01289	35.30541	43	11.21001	0.008636	73.24161
23	31.47037	0.012655	36.54883	43.5	10.96675	0.008557	73.88245
23.5	30.48308	0.01242	37.77605	44	10.72348	0.008477	74.51492
24	29.49579	0.012185	38.98643	44.5	10.48022	0.008398	75.13888
24.5	28.6532	0.011987	40.18161	45	10.23695	0.008319	75.75417
25	27.81061	0.011789	41.36109	45.5	10.08489	0.008254	76.36507
25.5	26.96801	0.011592	42.52433	46	9.932837	0.008189	76.97152
26	26.12542	0.011394	43.67076	46.5	9.78078	0.008124	77.57346
26.5	25.40245	0.011222	44.80261	47	9.628723	0.00806	78.17081
27	24.67947	0.011049	45.91943	47.5	9.476667	0.007995	78.76348
27.5	23.9565	0.010876	47.02073	48	9.32461	0.00793	79.35142
28	23.23352	0.010704	48.10601	48.5	9.172553	0.007865	79.93453
28.5	22.61888	0.010554	49.1776	49	9.020496	0.0078	80.51275
29	22.00424	0.010404	50.23512	49.5	8.86844	0.007735	81.08598
29.5	21.38961	0.010254	51.27813	50	8.716383	0.007671	81.65415
30	20.77497	0.010104	52.30623				

Table (3-42): The cross section and calculated data of stopping power and neutron yield for $^{53}Sc(p,n)^{53}Ti$ reaction.

proton energy MeV	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 proton**	**proton energy MeV**	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 proton**
10	38.78251	0.026051	0.744365	30.5	10.44821	0.009861	28.16572
10.5	37.70768	0.02514	1.49431	31	10.17563	0.009809	28.68439
11	36.63286	0.02423	2.250254	31.5	9.903043	0.009758	29.19184
11.5	35.47426	0.023455	3.006489	32	9.630457	0.009706	29.68795
12	34.31565	0.022679	3.763036	32.5	9.357872	0.009654	30.17259
12.5	33.04761	0.022009	4.513817	33	9.085286	0.009603	30.64565
13	31.77957	0.021339	5.25847	33.5	8.812701	0.009551	31.10699
13.5	30.84871	0.020748	6.001875	34	8.540115	0.0095	31.55649
14	29.91784	0.020158	6.74396	34.5	8.26753	0.009448	31.99402
14.5	28.8943	0.019638	7.479643	35	7.994944	0.009396	32.41945
15	27.87076	0.019117	8.208576	35.5	7.8435	0.00935	32.83887
15.5	26.96247	0.018652	8.931342	36	7.692055	0.009305	33.25221
16	26.05419	0.018187	9.647625	36.5	7.540611	0.009259	33.65942
16.5	25.29282	0.017772	10.35922	37	7.389166	0.009213	34.06044
17	24.53146	0.017357	11.06591	37.5	7.237722	0.009167	34.4552
17.5	23.6376	0.016982	11.76189	38	7.086277	0.009121	34.84364
18	22.74374	0.016606	12.44668	38.5	6.934833	0.009076	35.2257
18.5	22.05174	0.015956	13.13769	39	6.783388	0.00903	35.60132
19	21.35973	0.015306	13.83545	39.5	6.631944	0.008984	35.97042
19.5	20.59429	0.014641	14.53879	40	6.480499	0.008938	36.33294
20	19.82885	0.013975	15.24822	40.5	6.365703	0.00886	36.69216
20.5	19.20944	0.0137	15.94928	41	6.250908	0.008783	37.04803
21	18.59002	0.013425	16.64165	41.5	6.136112	0.008705	37.40048
21.5	17.97061	0.01315	17.32495	42	6.021317	0.008627	37.74945
22	17.3512	0.012875	17.9988	42.5	5.906521	0.008549	38.09488
22.5	16.82073	0.012645	18.66393	43	5.791725	0.008472	38.43671
23	16.29026	0.012415	19.32002	43.5	5.67693	0.008394	38.77486
23.5	15.7598	0.012184	19.96674	44	5.562134	0.008316	39.10928
24	15.22933	0.011954	20.60372	44.5	5.447339	0.008239	39.43988
24.5	14.79474	0.011759	21.23278	45	5.332543	0.008161	39.76659
25	14.36014	0.011564	21.85367	45.5	5.236287	0.008097	40.08993
25.5	13.92555	0.011369	22.4661	46	5.140032	0.008034	40.40983
26	13.49096	0.011174	23.06978	46.5	5.043776	0.00797	40.72625
26.5	13.14642	0.011006	23.66699	47	4.947521	0.007907	41.03911
27	12.80189	0.010839	24.25754	47.5	4.851265	0.007843	41.34838
27.5	12.45736	0.010671	24.84123	48	4.755009	0.00778	41.65399
28	12.11283	0.010504	25.41782	48.5	4.658754	0.007716	41.95587
28.5	11.76482	0.010356	25.98584	49	4.562498	0.007653	42.25397
29	11.41681	0.010208	26.54505	49.5	4.466243	0.007589	42.54823
29.5	11.06881	0.01006	27.09517	50	4.369987	0.007526	42.83857
30	10.7208	0.009913	27.63594				

Table (3-43): The cross section and calculated data of stopping power and neutron yield for $^{62}Cu(p,n)^{62}Zn$ reaction.

proton energy MeV	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 proton**	**proton energy MeV**	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 proton**
10	190.7461	0.027774	3.433857	30.5	26.84736	0.0108	81.33104
10.5	192.0859	0.026839	7.012376	31	26.20539	0.010745	82.5505
11	193.4257	0.025903	10.74601	31.5	25.56341	0.01069	83.74621
11.5	179.9468	0.025103	14.33022	32	24.92144	0.010635	84.91792
12	166.4679	0.024302	17.75517	32.5	24.27946	0.01058	86.06539
12.5	149.9538	0.023602	20.93192	33	23.63749	0.010525	87.18836
13	133.4398	0.022901	23.84528	33.5	22.99551	0.01047	88.28657
13.5	120.0654	0.022291	26.53841	34	22.35354	0.010414	89.35977
14	106.6911	0.021681	28.99893	34.5	21.71156	0.010359	90.40768
14.5	97.22216	0.021135	31.29892	35	21.06959	0.010304	91.43003
15	87.75321	0.02059	33.42988	35.5	20.62361	0.010255	92.43556
15.5	81.26454	0.02011	35.45041	36	20.17763	0.010206	93.4241
16	74.77586	0.019629	37.3551	36.5	19.73164	0.010156	94.39548
16.5	70.28254	0.019194	39.18592	37	19.28566	0.010107	95.34954
17	65.78922	0.018759	40.93946	37.5	18.83968	0.010058	96.28611
17.5	62.58056	0.018364	42.64338	38	18.3937	0.010008	97.20502
18	59.3719	0.017969	44.29549	38.5	17.94772	0.009959	98.10608
18.5	56.95078	0.017283	45.94307	39	17.50174	0.00991	98.98913
19	54.52965	0.016598	47.58575	39.5	17.05576	0.009861	99.85398
19.5	52.58618	0.015892	49.24019	40	16.60978	0.009811	100.7005
20	50.64271	0.015187	50.9075	40.5	16.28855	0.009727	101.5377
20.5	49.1045	0.014894	52.55593	41	15.96732	0.009644	102.3656
21	47.56628	0.014602	54.18472	41.5	15.64609	0.00956	103.1839
21.5	46.02807	0.014309	55.79308	42	15.32486	0.009476	103.9925
22	44.48985	0.014016	57.38015	42.5	15.00364	0.009392	104.7912
22.5	43.24124	0.013774	58.94985	43	14.68241	0.009309	105.5798
23	41.99264	0.013531	60.50155	43.5	14.36118	0.009225	106.3582
23.5	40.74403	0.013288	62.03461	44	14.03995	0.009141	107.1261
24	39.49542	0.013046	63.54833	44.5	13.71872	0.009058	107.8835
24.5	38.3552	0.012836	65.0424	45	13.3975	0.008974	108.6299
25	37.21498	0.012626	66.51619	45.5	13.14545	0.008905	109.368
25.5	36.07475	0.012416	67.969	46	12.8934	0.008836	110.0976
26	34.93453	0.012205	69.40011	46.5	12.64135	0.008768	110.8185
26.5	33.90972	0.012025	70.81004	47	12.3893	0.008699	111.5306
27	32.8849	0.011845	72.19814	47.5	12.13725	0.00863	112.2338
27.5	31.86009	0.011665	73.56376	48	11.8852	0.008561	112.9279
28	30.83528	0.011485	74.90617	48.5	11.63315	0.008493	113.6128
28.5	29.99879	0.011327	76.23033	49	11.3811	0.008424	114.2884
29	29.16231	0.01117	77.53573	49.5	11.12905	0.008355	114.9544
29.5	28.32582	0.011012	78.82183	50	10.877	0.008286	115.6107
30	27.48934	0.010855	80.08807				

Table (3-44): The cross section and calculated data of stopping power and neutron yield for $^{63}Cu(p,n)^{63}Zn$ reaction.

proton energy MeV	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 proton**	**proton energy MeV**	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 proton**
10	332.3191	0.027334	6.078888	30.5	27.47639	0.010631	129.4862
10.5	338.9323	0.026413	12.49483	31	26.82168	0.010577	130.7542
11	345.5456	0.025493	19.27215	31.5	26.16697	0.010522	131.9975
11.5	349.9147	0.024702	26.35479	32	25.51226	0.010468	133.2161
12	354.2838	0.023912	33.76292	32.5	24.85755	0.010414	134.4095
12.5	350.468	0.023226	41.30752	33	24.20284	0.01036	135.5775
13	346.6522	0.022541	48.99689	33.5	23.54813	0.010306	136.7199
13.5	311.5584	0.021941	56.09691	34	22.89342	0.010252	137.8364
14	276.4645	0.02134	62.57442	34.5	22.23871	0.010198	138.9268
14.5	235.0155	0.020805	68.22247	35	21.584	0.010144	139.9906
15	193.5664	0.02027	72.99724	35.5	21.12447	0.010095	141.0368
15.5	164.123	0.019794	77.14293	36	20.66493	0.010046	142.0653
16	134.6796	0.019319	80.62857	36.5	20.2054	0.009998	143.0758
16.5	116.0743	0.018889	83.70112	37	19.74587	0.009949	144.0682
17	97.46905	0.018459	86.34132	37.5	19.28634	0.0099	145.0423
17.5	86.18548	0.018068	88.72629	38	18.8268	0.009851	145.9979
18	74.9019	0.017678	90.84476	38.5	18.36727	0.009802	146.9349
18.5	68.18488	0.017008	92.84927	39	17.90774	0.009753	147.8529
19	61.46785	0.016338	94.73045	39.5	17.4482	0.009704	148.7519
19.5	57.38944	0.015642	96.5649	40	16.98867	0.009655	149.6317
20	53.31104	0.014947	98.34827	40.5	16.65954	0.009573	150.5019
20.5	51.07277	0.014659	100.0903	41	16.3304	0.00949	151.3623
21	48.8345	0.014371	101.7893	41.5	16.00127	0.009408	152.2127
21.5	46.59623	0.014084	103.4435	42	15.67213	0.009326	153.0529
22	44.35797	0.013796	105.0512	42.5	15.343	0.009243	153.8829
22.5	43.03394	0.013556	106.6384	43	15.01387	0.009161	154.7023
23	41.70991	0.013316	108.2046	43.5	14.68473	0.009079	155.5111
23.5	40.38588	0.013076	109.7489	44	14.3556	0.008996	156.3089
24	39.06186	0.012836	111.2705	44.5	14.02646	0.008914	157.0957
24.5	37.9927	0.012631	112.7745	45	13.69733	0.008832	157.8712
25	36.92355	0.012425	114.2603	45.5	13.44457	0.008764	158.6382
25.5	35.8544	0.01222	115.7273	46	13.19182	0.008696	159.3967
26	34.78525	0.012015	117.1748	46.5	12.93906	0.008629	160.1464
26.5	33.93426	0.011838	118.6082	47	12.68631	0.008561	160.8873
27	33.08326	0.01166	120.0268	47.5	12.43355	0.008493	161.6193
27.5	32.23227	0.011482	121.4304	48	12.1808	0.008426	162.3421
28	31.38127	0.011305	122.8183	48.5	11.92804	0.008358	163.0557
28.5	30.56873	0.01115	124.1891	49	11.67528	0.008291	163.7598
29	29.75619	0.010995	125.5423	49.5	11.42253	0.008223	164.4544
29.5	28.94365	0.01084	126.8774	50	11.16977	0.008155	165.1392
30	28.13111	0.010685	128.1938				

Table (3-45): The cross section and calculated data of stopping power and neutron yield for $^{64}Cu(p,n)^{64}Zn$ reaction.

proton energy MeV	Cross section (mb)	Stopping power MeV / (mg/cm^2)	Neutron yield n/10^6 proton	proton energy MeV	Cross section (mb)	Stopping power MeV / (mg/cm^2)	Neutron yield n/10^6 proton
10	573.9728	0.026903	10.66728	30.5	35.12071	0.010461	142.4006
10.5	529.0968	0.025998	20.84304	31	34.28308	0.010408	144.0476
11	484.2208	0.025092	30.49181	31.5	33.44545	0.010354	145.6626
11.5	423.9009	0.024317	39.20798	32	32.60782	0.010301	147.2453
12	363.581	0.023541	46.93013	32.5	31.77019	0.010248	148.7954
12.5	312.4373	0.022866	53.76203	33	30.93256	0.010194	150.3126
13	261.2936	0.022191	59.64949	33.5	30.09493	0.010141	151.7964
13.5	224.74	0.021595	64.85293	34	29.2573	0.010088	153.2465
14	188.1865	0.021	69.33357	34.5	28.41967	0.010034	154.6626
14.5	164.1448	0.020475	73.34204	35	27.58204	0.009981	156.0443
15	140.1032	0.019949	76.85351	35.5	27.00528	0.009934	157.4036
15.5	124.9921	0.019479	80.06187	36	26.42852	0.009886	158.7403
16	109.8811	0.019009	82.95212	36.5	25.85176	0.009838	160.0541
16.5	100.5015	0.018589	85.65542	37	25.27501	0.009791	161.3449
17	91.12193	0.018168	88.16313	37.5	24.69825	0.009743	162.6124
17.5	85.19345	0.017788	90.55779	38	24.12149	0.009695	163.8563
18	79.26497	0.017408	92.83447	38.5	23.54473	0.009648	165.0765
18.5	75.28754	0.016743	95.08284	39	22.96797	0.0096	166.2728
19	71.31011	0.016077	97.30057	39.5	22.39121	0.009553	167.4448
19.5	68.38932	0.015392	99.52217	40	21.81445	0.009505	168.5923
20	65.46854	0.014707	101.748	40.5	21.39036	0.009424	169.7272
20.5	63.40229	0.014426	103.9454	41	20.96627	0.009342	170.8493
21	61.33604	0.014146	106.1134	41.5	20.54217	0.009261	171.9584
21.5	59.2698	0.013866	108.2506	42	20.11808	0.00918	173.0541
22	57.20355	0.013586	110.3558	42.5	19.69398	0.009099	174.1364
22.5	55.58906	0.013348	112.4381	43	19.26989	0.009017	175.2048
23	53.97457	0.013111	114.4965	43.5	18.84579	0.008936	176.2593
23.5	52.36008	0.012873	116.5302	44	18.4217	0.008855	177.2995
24	50.7456	0.012635	118.5382	44.5	17.9976	0.008774	178.3251
24.5	49.34754	0.012433	120.5228	45	17.57351	0.008693	179.336
25	47.94948	0.01223	122.4831	45.5	17.26485	0.008626	180.3367
25.5	46.55142	0.012028	124.4182	46	16.95619	0.00856	181.3272
26	45.15337	0.011825	126.3275	46.5	16.64753	0.008493	182.3072
26.5	43.94469	0.01165	128.2135	47	16.33887	0.008427	183.2767
27	42.73602	0.011475	130.0756	47.5	16.03021	0.00836	184.2354
27.5	41.52734	0.0113	131.9132	48	15.72154	0.008294	185.1831
28	40.31867	0.011125	133.7253	48.5	15.41288	0.008228	186.1198
28.5	39.22859	0.010972	135.5129	49	15.10422	0.008161	187.0452
29	38.13851	0.01082	137.2754	49.5	14.79556	0.008095	187.9591
29.5	37.04842	0.010667	139.012	50	14.4869	0.008028	188.8613
30	35.95834	0.010514	140.7219				

Table (3-46): The cross section and calculated data of stopping power and neutron yield for $^{65}Cu(p,n)^{65}Zn$ reaction.

proton energy MeV	Cross section (mb)	Stopping power MeV / (mg/cm^2)	Neutron yield n/10^6 proton	proton energy MeV	Cross section (mb)	Stopping power MeV / (mg/cm^2)	Neutron yield n/10^6 proton
10	657.0788	0.026493	12.40097	30.5	31.82551	0.010302	164.2257
10.5	648.3025	0.025603	25.06189	31	31.05788	0.010249	165.7409
11	639.5261	0.024712	38.00148	31.5	30.29025	0.010196	167.2262
11.5	575.5985	0.023947	50.01989	32	29.52262	0.010144	168.6815
12	511.6709	0.023181	61.05627	32.5	28.75499	0.010091	170.1062
12.5	437.5163	0.022516	70.77206	33	27.98736	0.010039	171.5002
13	363.3617	0.02185	79.08684	33.5	27.21973	0.009986	172.8631
13.5	305.3453	0.021265	86.26636	34	26.4521	0.009933	174.1946
14	247.3289	0.02068	92.24636	34.5	25.68447	0.009881	175.4943
14.5	207.9816	0.020164	97.4035	35	24.91684	0.009828	176.762
15	168.6342	0.019649	101.6946	35.5	24.38895	0.009781	178.0087
15.5	144.9952	0.019184	105.4737	36	23.86105	0.009734	179.2344
16	121.3562	0.018719	108.7153	36.5	23.33316	0.009687	180.4387
16.5	107.0342	0.018303	111.6392	37	22.80526	0.00964	181.6216
17	92.71208	0.017888	114.2307	37.5	22.27737	0.009593	182.7827
17.5	84.31731	0.017513	116.6379	38	21.74947	0.009546	183.9219
18	75.92255	0.017138	118.853	38.5	21.22158	0.009499	185.039
18.5	70.75131	0.016482	120.9993	39	20.69369	0.009452	186.1337
19	65.58006	0.015827	123.071	39.5	20.16579	0.009405	187.2058
19.5	62.28095	0.015157	125.1256	40	19.6379	0.009358	188.2551
20	58.98185	0.014486	127.1614	40.5	19.2587	0.009278	189.2929
20.5	56.92314	0.014209	129.1645	41	18.87951	0.009198	190.3192
21	54.86444	0.013931	131.1336	41.5	18.50032	0.009118	191.3337
21.5	52.80574	0.013653	133.0674	42	18.12112	0.009038	192.3361
22	50.74704	0.013376	134.9644	42.5	17.74193	0.008959	193.3263
22.5	49.38966	0.013141	136.8436	43	17.36273	0.008879	194.3041
23	48.03229	0.012906	138.7046	43.5	16.98354	0.008799	195.2692
23.5	46.67491	0.01267	140.5464	44	16.60435	0.008719	196.2214
24	45.31754	0.012435	142.3686	44.5	16.22515	0.008639	197.1604
24.5	44.16795	0.012238	144.1732	45	15.84596	0.008559	198.086
25	43.01836	0.01204	145.9596	45.5	15.56732	0.008494	199.0024
25.5	41.86876	0.011843	147.7273	46	15.28867	0.008428	199.9094
26	40.71917	0.011645	149.4757	46.5	15.01003	0.008363	200.8068
26.5	39.63397	0.011472	151.2031	47	14.73139	0.008297	201.6945
27	38.54877	0.0113	152.9088	47.5	14.45274	0.008232	202.5724
27.5	37.46357	0.011127	154.5922	48	14.1741	0.008166	203.4403
28	36.37837	0.010955	156.2527	48.5	13.89546	0.008101	204.2979
28.5	35.43206	0.010805	157.8923	49	13.61682	0.008035	205.1452
29	34.48575	0.010654	159.5107	49.5	13.33817	0.00797	205.9821
29.5	33.53944	0.010504	161.1072	50	13.05953	0.007904	206.8082
30	32.59314	0.010354	162.6811				

Table (3-47): The cross section and calculated data of stopping power and neutron yield for $^{66}Cu(p,n)^{66}Zn$ reaction.

proton energy MeV	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 proton**	**proton energy MeV**	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 proton**
10	584.4966	0.026083	11.20471	30.5	43.24712	0.010152	148.9906
10.5	503.1692	0.025207	21.1854	31	42.24305	0.010099	151.0821
11	421.8418	0.024332	29.85399	31.5	41.23898	0.010047	153.1344
11.5	358.5565	0.023576	37.4582	32	40.23491	0.009994	155.1474
12	295.2712	0.022821	43.92755	32.5	39.23084	0.009942	157.1205
12.5	253.554	0.02217	49.64585	33	38.22677	0.009889	159.0533
13	211.8369	0.02152	54.5677	33.5	37.2227	0.009836	160.9453
13.5	186.385	0.020945	59.01715	34	36.21863	0.009784	162.7962
14	160.9331	0.020369	62.96752	34.5	35.21456	0.009731	164.6056
14.5	145.2888	0.019859	66.6255	35	34.21049	0.009679	166.3728
15	129.6445	0.019349	69.97569	35.5	33.5146	0.009633	168.1125
15.5	120.1993	0.018894	73.15664	36	32.8187	0.009586	169.8242
16	110.7542	0.018438	76.16	36.5	32.12281	0.00954	171.5078
16.5	104.5594	0.018028	79.0599	37	31.42692	0.009494	173.163
17	98.36467	0.017618	81.85151	37.5	30.73102	0.009447	174.7894
17.5	94.0631	0.017248	84.57834	38	30.03513	0.009401	176.3869
18	89.76153	0.016878	87.23754	38.5	29.33924	0.009355	177.955
18.5	86.46695	0.016232	89.90098	39	28.64334	0.009308	179.4936
19	83.17238	0.015587	92.56901	39.5	27.94745	0.009262	181.0023
19.5	80.47139	0.014927	95.26459	40	27.25156	0.009216	182.4809
20	77.7704	0.014266	97.99029	40.5	26.73578	0.009137	183.9439
20.5	75.56932	0.013991	100.6909	41	26.22	0.009058	185.3912
21	73.36823	0.013716	103.3655	41.5	25.70423	0.00898	186.8224
21.5	71.16715	0.013441	106.0129	42	25.18845	0.008901	188.2373
22	68.96606	0.013166	108.6321	42.5	24.67268	0.008823	189.6356
22.5	67.14851	0.012938	111.2271	43	24.1569	0.008744	191.017
23	65.33096	0.01271	113.7971	43.5	23.64112	0.008665	192.3811
23.5	63.51341	0.012483	116.3411	44	23.12535	0.008587	193.7277
24	61.69586	0.012255	118.8583	44.5	22.60957	0.008508	195.0564
24.5	60.10114	0.012058	121.3505	45	22.0938	0.008429	196.367
25	58.50642	0.01186	123.8171	45.5	21.71161	0.008365	197.6647
25.5	56.9117	0.011662	126.257	46	21.32943	0.0083	198.9496
26	55.31698	0.011465	128.6695	46.5	20.94725	0.008236	200.2213
26.5	53.82406	0.011297	131.0517	47	20.56507	0.008171	201.4797
27	52.33113	0.01113	133.4027	47.5	20.18289	0.008107	202.7246
27.5	50.83821	0.010962	135.7215	48	19.80071	0.008042	203.9556
28	49.34529	0.010794	138.0072	48.5	19.41852	0.007978	205.1727
28.5	48.07177	0.010647	140.2648	49	19.03634	0.007913	206.3755
29	46.79824	0.010499	142.4934	49.5	18.65416	0.007849	207.5639
29.5	45.52472	0.010352	144.6923	50	18.27198	0.007784	208.7376
30	44.25119	0.010204	146.8606				

Table (3-48): The cross section and calculated data of stopping power and neutron yield for $^{67}Cu(p,n)^{67}Zn$ reaction.

proton energy MeV	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 proton**	**proton energy MeV**	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 proton**
10	377.9147	0.025702	7.351776	30.5	29.51747	0.009993	99.93319
10.5	320.4509	0.024837	13.80291	31	28.8209	0.009942	101.3826
11	262.9871	0.023971	19.28838	31.5	28.12433	0.009891	102.8044
11.5	223.5652	0.023226	24.10123	32	27.42775	0.00984	104.1981
12	184.1433	0.02248	28.19686	32.5	26.73118	0.009789	105.5634
12.5	159.3459	0.021835	31.84571	33	26.0346	0.009738	106.9002
13	134.5485	0.02119	35.02056	33.5	25.33803	0.009687	108.2081
13.5	119.4973	0.020624	37.91754	34	24.64145	0.009636	109.4867
14	104.446	0.020059	40.521	34.5	23.94488	0.009585	110.7358
14.5	95.16444	0.019559	42.95377	35	23.24831	0.009534	111.9551
15	85.88286	0.019059	45.2069	35.5	22.76172	0.009488	113.1545
15.5	80.00496	0.018608	47.3566	36	22.27513	0.009443	114.334
16	74.12706	0.018158	49.39776	36.5	21.78854	0.009397	115.4933
16.5	70.29045	0.017758	51.37689	37	21.30195	0.009352	116.6322
17	66.45383	0.017358	53.29114	37.5	20.81536	0.009306	117.7506
17.5	63.60503	0.016992	55.1627	38	20.32877	0.009261	118.8482
18	60.75622	0.016627	56.9897	38.5	19.84218	0.009215	119.9248
18.5	58.61186	0.015992	58.82224	39	19.35559	0.00917	120.9802
19	56.4675	0.015357	60.66078	39.5	18.869	0.009124	122.0142
19.5	54.81008	0.014701	62.5249	40	18.38241	0.009079	123.0266
20	53.15265	0.014046	64.41699	40.5	18.05827	0.009001	124.0298
20.5	51.70524	0.013778	66.29331	41	17.73412	0.008924	125.0234
21	50.25784	0.013511	68.15324	41.5	17.40998	0.008846	126.0075
21.5	48.81043	0.013243	69.9961	42	17.08583	0.008768	126.9818
22	47.36302	0.012975	71.8212	42.5	16.76169	0.008691	127.9461
22.5	46.15516	0.012748	73.63152	43	16.43754	0.008613	128.9003
23	44.94729	0.01252	75.4265	43.5	16.1134	0.008536	129.8442
23.5	43.73943	0.012293	77.20559	44	15.78926	0.008458	130.7775
24	42.53157	0.012065	78.96819	44.5	15.46511	0.008381	131.7002
24.5	41.38503	0.011872	80.7111	45	15.14097	0.008303	132.6119
25	40.2385	0.01168	82.43366	45.5	14.85363	0.00824	133.5133
25.5	39.09196	0.011487	84.1352	46	14.56628	0.008176	134.404
26	37.94543	0.011295	85.815	46.5	14.27894	0.008113	135.2841
26.5	36.89868	0.011127	87.47306	47	13.9916	0.008049	136.1532
27	35.85194	0.010959	89.10872	47.5	13.70426	0.007986	137.0113
27.5	34.80519	0.010792	90.72128	48	13.41692	0.007922	137.8581
28	33.75844	0.010624	92.31002	48.5	13.12958	0.007859	138.6935
28.5	32.87234	0.010479	93.87847	49	12.84224	0.007795	139.5172
29	31.98625	0.010334	95.42606	49.5	12.5549	0.007731	140.3292
29.5	31.10015	0.010189	96.95221	50	12.26756	0.007668	141.1291
30	30.21405	0.010044	98.45629				

Table (3-49): The cross section and calculated data of stopping power and neutron yield for $^{68}Cu(p,n)^{68}Zn$ reaction.

proton energy MeV	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 proton**	**proton energy MeV**	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 proton**
10	247.8463	0.025322	4.893911	30.5	38.2526	0.009848	107.596
10.5	216.6864	0.024466	9.32215	31	37.38283	0.009798	109.5037
11	185.5265	0.023611	13.25097	31.5	36.51305	0.009747	111.3767
11.5	165.3822	0.022881	16.86501	32	35.64327	0.009697	113.2146
12	145.2378	0.02215	20.14349	32.5	34.7735	0.009646	115.017
12.5	133.3602	0.021515	23.24276	33	33.90372	0.009596	116.7836
13	121.4826	0.020879	26.1519	33.5	33.03395	0.009545	118.514
13.5	113.6143	0.020324	28.94696	34	32.16417	0.009495	120.2078
14	105.746	0.019769	31.62152	34.5	31.2944	0.009444	121.8646
14.5	100.6442	0.019274	34.23246	35	30.42462	0.009394	123.484
15	95.54235	0.018778	36.77641	35.5	29.79855	0.009349	125.0777
15.5	91.8868	0.018333	39.28244	36	29.17247	0.009304	126.6455
16	88.23125	0.017888	41.74868	36.5	28.5464	0.009259	128.1871
16.5	85.4083	0.017493	44.18994	37	27.92033	0.009214	129.7022
17	82.58535	0.017097	46.60507	37.5	27.29426	0.009169	131.1905
17.5	79.90496	0.016737	48.99211	38	26.66818	0.009124	132.652
18	77.22458	0.016377	51.34981	38.5	26.04211	0.009079	134.0861
18.5	75.137	0.015752	53.73484	39	25.41604	0.009034	135.4927
19	73.04942	0.015126	56.14947	39.5	24.78996	0.008989	136.8716
19.5	70.85653	0.014486	58.59513	40	24.16389	0.008944	138.2224
20	68.66363	0.013846	61.07471	40.5	23.73285	0.008868	139.5605
20.5	66.80389	0.013581	63.53423	41	23.3018	0.008792	140.8857
21	64.94414	0.013316	65.97289	41.5	22.87076	0.008715	142.1977
21.5	63.08439	0.01305	68.38984	42	22.43972	0.008639	143.4965
22	61.22465	0.012785	70.78417	42.5	22.00867	0.008563	144.7816
22.5	59.61207	0.01256	73.15723	43	21.57763	0.008486	146.0529
23	57.99948	0.012335	75.50823	43.5	21.14659	0.00841	147.3101
23.5	56.3869	0.01211	77.83635	44	20.71554	0.008334	148.553
24	54.77432	0.011885	80.14072	44.5	20.2845	0.008257	149.7812
24.5	53.34039	0.011695	82.42124	45	19.85346	0.008181	150.9946
25	51.90645	0.011505	84.67712	45.5	19.5237	0.008119	152.197
25.5	50.47252	0.011315	86.90754	46	19.19394	0.008056	153.3883
26	49.03859	0.011125	89.11162	46.5	18.86418	0.007993	154.5683
26.5	47.62973	0.010962	91.28413	47	18.53442	0.007931	155.7368
27	46.22087	0.010799	93.42411	47.5	18.20466	0.007868	156.8937
27.5	44.81201	0.010637	95.53058	48	17.8749	0.007805	158.0388
28	43.40315	0.010474	97.60249	48.5	17.54514	0.007743	159.1718
28.5	42.33296	0.01033	99.65145	49	17.21538	0.00768	160.2925
29	41.26276	0.010187	101.6768	49.5	16.88562	0.007617	161.4009
29.5	40.19257	0.010043	103.6779	50	16.55586	0.007555	162.4966
30	39.12238	0.009899	105.654				

Table (3-50): The cross section and calculated data of stopping power and neutron yield for $^{69}Cu(p,n)^{69}Zn$ reaction.

proton energy MeV	Cross section (mb)	Stopping power MeV / (mg/cm^2)	Neutron yield n/10^6 proton	proton energy MeV	Cross section (mb)	Stopping power MeV / (mg/cm^2)	Neutron yield n/10^6 proton
10	45.13952	0.024952	0.904543	30.5	8.398445	0.009706	23.30639
10.5	39.8006	0.024111	1.729901	31	8.200566	0.009656	23.73101
11	34.46167	0.023271	2.470355	31.5	8.002687	0.009606	24.14755
11.5	31.37978	0.02255	3.16613	32	7.804808	0.009557	24.5559
12	28.29789	0.02183	3.814277	32.5	7.606929	0.009507	24.95598
12.5	26.49457	0.021205	4.439015	33	7.40905	0.009457	25.34771
13	24.69125	0.020579	5.038924	33.5	7.211171	0.009407	25.73099
13.5	23.58154	0.020029	5.627612	34	7.013292	0.009357	26.10574
14	22.47183	0.019479	6.204446	34.5	6.815413	0.009307	26.47187
14.5	21.59823	0.018993	6.77302	35	6.617534	0.009258	26.82928
15	20.72464	0.018508	7.3329	35.5	6.479526	0.009213	27.18093
15.5	20.11292	0.018073	7.88934	36	6.341518	0.009169	27.52674
16	19.5012	0.017638	8.442169	36.5	6.20351	0.009125	27.86667
16.5	18.93085	0.017242	8.991129	37	6.065502	0.00908	28.20067
17	18.36051	0.016847	9.536041	37.5	5.927494	0.009036	28.52866
17.5	17.84599	0.016497	10.07692	38	5.789486	0.008992	28.8506
18	17.33146	0.016147	10.61361	38.5	5.651478	0.008947	29.16642
18.5	16.86476	0.015532	11.15652	39	5.51347	0.008903	29.47606
19	16.39807	0.014916	11.70619	39.5	5.375462	0.008859	29.77946
19.5	15.91301	0.014281	12.26334	40	5.237454	0.008814	30.07655
20	15.42795	0.013646	12.82864	40.5	5.148578	0.008739	30.37112
20.5	15.03353	0.013383	13.39031	41	5.059703	0.008664	30.66312
21	14.63911	0.01312	13.94818	41.5	4.970828	0.008589	30.9525
21.5	14.24468	0.012858	14.50212	42	4.881953	0.008513	31.23922
22	13.85026	0.012595	15.05194	42.5	4.793078	0.008438	31.52323
22.5	13.42387	0.012375	15.59432	43	4.704203	0.008363	31.80449
23	12.99748	0.012155	16.12898	43.5	4.615327	0.008288	32.08293
23.5	12.57109	0.011935	16.65563	44	4.526452	0.008213	32.35851
24	12.1447	0.011715	17.17398	44.5	4.437577	0.008137	32.63118
24.5	11.79548	0.011527	17.68562	45	4.348702	0.008062	32.90088
25	11.44625	0.01134	18.19033	45.5	4.265486	0.008	33.16746
25.5	11.09703	0.011152	18.68787	46	4.18227	0.007939	33.43087
26	10.74781	0.010964	19.17799	46.5	4.099055	0.007877	33.69106
26.5	10.45774	0.010804	19.66195	47	4.015839	0.007816	33.94797
27	10.16768	0.010644	20.13957	47.5	3.932623	0.007754	34.20156
27.5	9.877613	0.010484	20.61064	48	3.849407	0.007692	34.45177
28	9.587549	0.010324	21.07497	48.5	3.766192	0.007631	34.69855
28.5	9.339743	0.010182	21.53361	49	3.682976	0.007569	34.94185
29	9.091937	0.01004	21.9864	49.5	3.59976	0.007507	35.18159
29.5	8.84413	0.009898	22.43317	50	3.516544	0.007446	35.41774
30	8.596324	0.009756	22.87374				

Table (3-51): The cross section and calculated data of stopping power and neutron yield for $^{70}Cu(p,n)^{70}Zn$ reaction.

proton energy MeV	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 proton**	**proton energy MeV**	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 proton**
10	97.50807	0.024591	1.982577	30.5	30.75405	0.009567	78.63132
10.5	93.58962	0.023766	3.951576	31	30.08833	0.009517	80.21201
11	89.67117	0.02294	5.90602	31.5	29.42261	0.009468	81.76575
11.5	86.69267	0.02223	7.855927	32	28.75688	0.009419	83.29225
12	83.71417	0.02152	9.800997	32.5	28.09116	0.00937	84.79123
12.5	81.21251	0.020899	11.74395	33	27.42544	0.009321	86.2624
13	78.71084	0.020279	13.68466	33.5	26.75972	0.009272	87.70546
13.5	76.57707	0.019739	15.62443	34	26.094	0.009223	89.12012
14	74.4433	0.019198	17.56323	34.5	25.42828	0.009174	90.50607
14.5	72.49178	0.018718	19.49963	35	24.76256	0.009124	91.863
15	70.54026	0.018238	21.43353	35.5	24.24339	0.009081	93.19786
15.5	68.70355	0.017808	23.36258	36	23.72423	0.009037	94.51045
16	66.86685	0.017377	25.28653	36.5	23.20507	0.008994	95.80053
16.5	65.23	0.016992	27.20594	37	22.6859	0.00895	97.0679
17	63.59315	0.016607	29.12059	37.5	22.16674	0.008906	98.31233
17.5	61.73282	0.016257	31.01925	38	21.64758	0.008863	99.5336
18	59.87248	0.015907	32.90124	38.5	21.12842	0.008819	100.7315
18.5	58.38321	0.015301	34.80902	39	20.60925	0.008776	101.9057
19	56.89393	0.014696	36.7447	39.5	20.09009	0.008732	103.0561
19.5	55.37788	0.014071	38.71253	40	19.57093	0.008688	104.1824
20	53.86183	0.013445	40.7155	40.5	19.236	0.008614	105.2989
20.5	52.49541	0.013188	42.7058	41	18.90107	0.00854	106.4055
21	51.129	0.01293	44.6829	41.5	18.56615	0.008466	107.5021
21.5	49.76259	0.012673	46.64629	42	18.23122	0.008392	108.5883
22	48.39617	0.012415	48.5954	42.5	17.89629	0.008318	109.6641
22.5	47.02824	0.012197	50.52319	43	17.56137	0.008243	110.7293
23	45.6603	0.01198	52.42892	43.5	17.22644	0.008169	111.7836
23.5	44.29237	0.011762	54.31174	44	16.89151	0.008095	112.8269
24	42.92443	0.011545	56.17081	44.5	16.55659	0.008021	113.859
24.5	41.84599	0.011362	58.0123	45	16.22166	0.007947	114.8796
25	40.76756	0.011179	59.83563	45.5	15.9624	0.007886	115.8917
25.5	39.68912	0.010997	61.6402	46	15.70315	0.007825	116.895
26	38.61068	0.010814	63.42538	46.5	15.44389	0.007764	117.8895
26.5	37.64505	0.010654	65.19206	47	15.18463	0.007704	118.8751
27	36.67943	0.010494	66.93968	47.5	14.92538	0.007643	119.8515
27.5	35.7138	0.010334	68.66765	48	14.66612	0.007582	120.8187
28	34.74817	0.010174	70.37536	48.5	14.40686	0.007521	121.7765
28.5	33.91607	0.010034	72.06535	49	14.1476	0.00746	122.7246
29	33.08397	0.009895	73.73713	49.5	13.88835	0.0074	123.6631
29.5	32.25187	0.009755	75.39018	50	13.62909	0.007339	124.5917
30	31.41977	0.009616	77.02395				

Table (3-52): The cross section and calculated data of stopping power and neutron yield for $^{71}Cu(p,n)^{71}Zn$ reaction.

proton energy MeV	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 proton**	**proton energy MeV**	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 proton**
10	29.5774	0.024241	0.610072	30.5	9.917273	0.009431	25.7944
10.5	28.78971	0.02343	1.224436	31	9.69964	0.009383	26.31128
11	28.00202	0.02262	1.843401	31.5	9.482006	0.009334	26.81919
11.5	27.26457	0.02192	2.465321	32	9.264373	0.009286	27.31803
12	26.52712	0.021219	3.090392	32.5	9.04674	0.009237	27.80771
12.5	25.85109	0.020609	3.717572	33	8.829107	0.009189	28.28812
13	25.17506	0.019999	4.34699	33.5	8.611474	0.009141	28.75918
13.5	24.62801	0.019463	4.979665	34	8.39384	0.009092	29.22077
14	24.08096	0.018928	5.615781	34.5	8.176207	0.009044	29.6728
14.5	23.49357	0.018453	6.252364	35	7.958574	0.008995	30.11517
15	22.90618	0.017978	6.889438	35.5	7.803838	0.008952	30.55102
15.5	22.37376	0.017557	7.526597	36	7.649102	0.00891	30.98029
16	21.84135	0.017137	8.163846	36.5	7.494366	0.008867	31.4029
16.5	21.33284	0.016757	8.80038	37	7.339631	0.008824	31.81881
17	20.82432	0.016377	9.436166	37.5	7.184895	0.008781	32.22793
17.5	20.25861	0.016032	10.068	38	7.030159	0.008738	32.63021
18	19.6929	0.015687	10.6957	38.5	6.875423	0.008695	33.02558
18.5	19.18198	0.015086	11.33144	39	6.720687	0.008652	33.41397
19	18.67106	0.014486	11.9759	39.5	6.565951	0.008609	33.79531
19.5	18.20138	0.013871	12.63201	40	6.411215	0.008566	34.16953
20	17.73169	0.013255	13.30086	40.5	6.301035	0.008493	34.54048
20.5	17.24414	0.013003	13.96396	41	6.190854	0.00842	34.90811
21	16.75658	0.01275	14.62108	41.5	6.080673	0.008347	35.27236
21.5	16.26902	0.012497	15.27197	42	5.970492	0.008274	35.63317
22	15.78146	0.012245	15.91638	42.5	5.860311	0.008201	35.99049
22.5	15.3443	0.01203	16.55414	43	5.750131	0.008127	36.34424
23	14.90714	0.011815	17.18502	43.5	5.63995	0.008054	36.69436
23.5	14.46998	0.0116	17.80875	44	5.529769	0.007981	37.04078
24	14.03281	0.011384	18.42506	44.5	5.419588	0.007908	37.38345
24.5	13.64418	0.011202	19.03408	45	5.309408	0.007835	37.72228
25	13.25556	0.011019	19.63555	45.5	5.218528	0.007775	38.05788
25.5	12.86693	0.010837	20.22922	46	5.127648	0.007715	38.39021
26	12.4783	0.010654	20.81483	46.5	5.036769	0.007655	38.7192
26.5	12.16457	0.010499	21.39415	47	4.945889	0.007595	39.04482
27	11.85085	0.010344	21.96698	47.5	4.855009	0.007535	39.36699
27.5	11.53713	0.010189	22.53314	48	4.76413	0.007475	39.68567
28	11.2234	0.010034	23.09242	48.5	4.67325	0.007415	40.00081
28.5	10.95128	0.009895	23.64578	49	4.58237	0.007355	40.31234
29	10.67916	0.009757	24.19305	49.5	4.491491	0.007295	40.6202
29.5	10.40703	0.009618	24.73406	50	4.400611	0.007235	40.92433
30	10.13491	0.00948	25.26863				

Table (3-53): The cross section and calculated data of stopping power and neutron yield for $^{87}Nb(p,n)^{87}Mo$ reaction.

proton energy MeV	Cross section (mb)	Stopping power MeV / (mg/cm^2)	Neutron yield n/10^6 proton	proton energy MeV	Cross section (mb)	Stopping power MeV / (mg/cm^2)	Neutron yield n/10^6 proton
10	0.017143	0.026054	0.328988	30.5	0.024266	0.010353	54.91049
10.5	0.021731	0.025203	0.760095	31	0.023788	0.010301	56.06519
11	0.026318	0.024353	1.300454	31.5	0.02331	0.010249	57.20243
11.5	0.040206	0.023622	2.151475	32	0.022832	0.010196	58.32205
12	0.054094	0.022892	3.332984	32.5	0.022354	0.010144	59.42386
12.5	0.060748	0.022251	4.698024	33	0.021877	0.010092	60.50768
13	0.067402	0.021611	6.257471	33.5	0.021399	0.01004	61.57331
13.5	0.072528	0.021046	7.980577	34	0.020921	0.009988	62.62058
14	0.077653	0.02048	9.876379	34.5	0.020443	0.009936	63.64928
14.5	0.081585	0.019985	11.91753	35	0.019965	0.009884	64.65923
15	0.085517	0.01949	14.11143	35.5	0.019582	0.009838	65.65448
15.5	0.078033	0.019039	16.16067	36	0.019199	0.009791	66.63489
16	0.070549	0.018589	18.05825	36.5	0.018816	0.009745	67.60032
16.5	0.062534	0.018189	19.77726	37	0.018432	0.009698	68.55062
17	0.054519	0.017789	21.30965	37.5	0.018049	0.009652	69.48566
17.5	0.049474	0.017423	22.72939	38	0.017666	0.009605	70.40527
18	0.044428	0.017058	24.03165	38.5	0.017283	0.009559	71.30931
18.5	0.041701	0.016423	25.30124	39	0.0169	0.009512	72.19763
19	0.038973	0.015788	26.53554	39.5	0.016516	0.009466	73.07008
19.5	0.037598	0.015127	27.77826	40	0.016133	0.009419	73.9265
20	0.036222	0.014467	29.03016	40.5	0.015846	0.00934	74.77482
20.5	0.035553	0.014194	30.28256	41	0.015559	0.00926	75.61491
21	0.034885	0.013921	31.53548	41.5	0.015272	0.009181	76.44663
21.5	0.034216	0.013649	32.78892	42	0.014985	0.009102	77.26983
22	0.033548	0.013376	34.04293	42.5	0.014698	0.009022	78.08436
22.5	0.032948	0.013149	35.29585	43	0.014411	0.008943	78.89007
23	0.032349	0.012921	36.54765	43.5	0.014124	0.008864	79.6868
23.5	0.03175	0.012693	37.7983	44	0.013837	0.008784	80.47438
24	0.03115	0.012466	39.04774	44.5	0.01355	0.008705	81.25266
24.5	0.030614	0.012268	40.29544	45	0.013263	0.008626	82.02145
25	0.030077	0.01207	41.54134	45.5	0.013038	0.008561	82.78298
25.5	0.029541	0.011873	42.78538	46	0.012814	0.008495	83.53712
26	0.029004	0.011675	44.0275	46.5	0.012589	0.00843	84.28377
26.5	0.028457	0.011508	45.26392	47	0.012364	0.008365	85.02281
27	0.027909	0.01134	46.49449	47.5	0.01214	0.0083	85.75411
27.5	0.027362	0.011172	47.71902	48	0.011915	0.008235	86.47756
28	0.026815	0.011005	48.93734	48.5	0.01169	0.00817	87.19303
28.5	0.026297	0.010855	50.14864	49	0.011466	0.008105	87.90039
29	0.025779	0.010705	51.35275	49.5	0.011241	0.008039	88.59951
29.5	0.025261	0.010555	52.54944	50	0.011016	0.007974	89.29026
30	0.024744	0.010405	53.73852				

Table (3-54): The cross section and calculated data of stopping power and neutron yield for $^{88}Nb(p,n)^{88}Mo$ reaction.

proton energy MeV	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 proton**	**proton energy MeV**	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 proton**
10	0.077436	0.025764	1.502823	30.5	0.026019	0.010233	65.08418
10.5	0.084749	0.024918	3.203386	31	0.025493	0.010182	66.33604
11	0.092062	0.024072	5.11558	31.5	0.024967	0.010131	67.56826
11.5	0.098067	0.023352	7.215339	32	0.024441	0.01008	68.78065
12	0.104072	0.022632	9.514608	32.5	0.023915	0.010028	69.97301
12.5	0.104242	0.021996	11.88416	33	0.023389	0.009977	71.14512
13	0.104412	0.021361	14.32817	33.5	0.022863	0.009926	72.29679
13.5	0.094183	0.020805	16.5916	34	0.022337	0.009875	73.42779
14	0.083954	0.02025	18.66454	34.5	0.021811	0.009823	74.53792
14.5	0.074576	0.019755	20.55209	35	0.021285	0.009772	75.62695
15	0.065199	0.019259	22.24473	35.5	0.020888	0.009726	76.70075
15.5	0.059566	0.018819	23.82732	36	0.020491	0.00968	77.75917
16	0.053933	0.018379	25.29458	36.5	0.020095	0.009634	78.80207
16.5	0.050966	0.017979	26.71198	37	0.019698	0.009588	79.82929
17	0.047999	0.017578	28.07725	37.5	0.019302	0.009542	80.84069
17.5	0.046378	0.017218	29.42402	38	0.018905	0.009496	81.83611
18	0.044758	0.016858	30.7515	38.5	0.018509	0.00945	82.81539
18.5	0.043651	0.016233	32.09603	39	0.018112	0.009404	83.77838
19	0.042544	0.015607	33.45897	39.5	0.017715	0.009358	84.72492
19.5	0.041645	0.014957	34.85115	40	0.017319	0.009312	85.65485
20	0.040747	0.014307	36.27521	40.5	0.017014	0.009234	86.57615
20.5	0.039933	0.014036	37.69769	41	0.016709	0.009155	87.4887
21	0.039119	0.013766	39.11851	41.5	0.016404	0.009077	88.39233
21.5	0.038305	0.013496	40.53762	42	0.016099	0.008998	89.28689
22	0.037491	0.013226	41.95494	42.5	0.015794	0.00892	90.17223
22.5	0.036754	0.012998	43.36871	43	0.015489	0.008841	91.04817
23	0.036016	0.012771	44.7788	43.5	0.015184	0.008763	91.91455
23.5	0.035278	0.012543	46.18508	44	0.014879	0.008684	92.77119
24	0.034541	0.012316	47.5874	44.5	0.014574	0.008606	93.61793
24.5	0.033862	0.012123	48.98401	45	0.014269	0.008528	94.45457
25	0.033183	0.01193	50.37471	45.5	0.014041	0.008463	95.28408
25.5	0.032504	0.011738	51.75932	46	0.013812	0.008399	96.10636
26	0.031826	0.011545	53.13763	46.5	0.013584	0.008334	96.92129
26.5	0.03118	0.011378	54.50788	47	0.013355	0.00827	97.72876
27	0.030535	0.01121	55.86983	47.5	0.013127	0.008205	98.52865
27.5	0.029889	0.011042	57.22322	48	0.012898	0.008141	99.32084
28	0.029244	0.010875	58.56781	48.5	0.01267	0.008077	100.1052
28.5	0.028569	0.010727	59.89943	49	0.012442	0.008012	100.8816
29	0.027894	0.01058	61.21774	49.5	0.012213	0.007948	101.65
29.5	0.02722	0.010432	62.52236	50	0.011985	0.007883	102.4101
30	0.026545	0.010284	63.81289				

Table (3-55): The cross section and calculated data of stopping power and neutron yield for $^{89}Nb(p,n)^{89}Mo$ reaction.

proton energy MeV	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 proton**	**proton energy MeV**	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 proton**
10	0.190936	0.025473	3.747773	30.5	0.039091	0.010123	154.9273
10.5	0.191592	0.024643	7.635179	31	0.038397	0.010072	156.8335
11	0.192249	0.023812	11.67196	31.5	0.037703	0.010021	158.7147
11.5	0.192544	0.023092	15.84108	32	0.037009	0.009969	160.5709
12	0.19284	0.022371	20.15107	32.5	0.036315	0.009918	162.4016
12.5	0.196694	0.021746	24.67363	33	0.035621	0.009867	164.2066
13	0.200548	0.021121	29.42133	33.5	0.034927	0.009816	165.9858
13.5	0.208773	0.020575	34.49475	34	0.034233	0.009765	167.7387
14	0.216998	0.02003	39.91162	34.5	0.033539	0.009713	169.4651
14.5	0.22743	0.01954	45.73136	35	0.032845	0.009662	171.1648
15	0.237862	0.019049	51.97469	35.5	0.03226	0.009617	172.8421
15.5	0.240877	0.018609	58.44675	36	0.031675	0.009571	174.4968
16	0.243892	0.018169	65.1586	36.5	0.03109	0.009526	176.1286
16.5	0.236642	0.017779	71.81386	37	0.030505	0.00948	177.7375
17	0.229391	0.017388	78.41	37.5	0.02992	0.009435	179.323
17.5	0.21184	0.017028	84.63032	38	0.029334	0.00939	180.8851
18	0.194289	0.016668	90.45858	38.5	0.028749	0.009344	182.4235
18.5	0.168175	0.016048	95.69848	39	0.028164	0.009299	183.9379
19	0.142061	0.015427	100.3027	39.5	0.027579	0.009253	185.4281
19.5	0.12219	0.014787	104.4344	40	0.026994	0.009208	186.8939
20	0.102318	0.014146	108.0508	40.5	0.026543	0.00913	188.3475
20.5	0.092809	0.013879	111.3944	41	0.026093	0.009053	189.7886
21	0.0833	0.013611	114.4543	41.5	0.025642	0.008975	191.2171
21.5	0.073791	0.013344	117.2194	42	0.025191	0.008898	192.6327
22	0.064283	0.013076	119.6774	42.5	0.02474	0.00882	194.0352
22.5	0.061231	0.012853	122.0594	43	0.02429	0.008743	195.4243
23	0.05818	0.012631	124.3625	43.5	0.023839	0.008665	196.7999
23.5	0.055128	0.012408	126.584	44	0.023388	0.008588	198.1616
24	0.052077	0.012185	128.7208	44.5	0.022938	0.00851	199.5093
24.5	0.050725	0.011993	130.8356	45	0.022487	0.008433	200.8427
25	0.049372	0.0118	132.9276	45.5	0.022157	0.008369	202.1664
25.5	0.04802	0.011608	134.9961	46	0.021827	0.008305	203.4805
26	0.046668	0.011415	137.0402	46.5	0.021497	0.008241	204.7847
26.5	0.045754	0.01125	139.0737	47	0.021167	0.008178	206.079
27	0.044841	0.011085	141.0963	47.5	0.020837	0.008114	207.363
27.5	0.043927	0.01092	143.1077	48	0.020507	0.00805	208.6367
28	0.043013	0.010755	145.1074	48.5	0.020177	0.007986	209.9
28.5	0.042206	0.01061	147.0965	49	0.019847	0.007923	211.1525
29	0.041399	0.010465	149.0746	49.5	0.019517	0.007859	212.3943
29.5	0.040592	0.010319	151.0414	50	0.019188	0.007795	213.625
30	0.039785	0.010174	152.9965				

Table (3-56): The cross section and calculated data of stopping power and neutron yield for $^{90}Nb(p,n)^{90}Mo$ reaction.

proton energy MeV	Cross section (mb)	Stopping power MeV / (mg/cm^2)	Neutron yield n/10^6 proton	proton energy MeV	Cross section (mb)	Stopping power MeV / (mg/cm^2)	Neutron yield n/10^6 proton
10	0.350026	0.025183	6.949665	30.5	0.037669	0.010013	164.8008
10.5	0.354318	0.024362	14.22148	31	0.036936	0.009962	166.6545
11	0.35861	0.023542	21.8379	31.5	0.036202	0.009912	168.4808
11.5	0.360639	0.022836	29.73404	32	0.035468	0.009861	170.2793
12	0.362669	0.022131	37.92771	32.5	0.034735	0.00981	172.0497
12.5	0.362588	0.021511	46.35581	33	0.034001	0.009759	173.7918
13	0.362507	0.02089	55.03225	33.5	0.033267	0.009708	175.5052
13.5	0.347778	0.020345	63.57929	34	0.032534	0.009657	177.1897
14	0.33305	0.0198	71.98981	34.5	0.0318	0.009606	178.8449
14.5	0.294356	0.019319	79.60798	35	0.031066	0.009555	180.4706
15	0.255662	0.018839	86.39341	35.5	0.030514	0.00951	182.0749
15.5	0.216534	0.018404	92.27628	36	0.029961	0.009465	183.6576
16	0.177407	0.017969	97.21286	36.5	0.029409	0.00942	185.2186
16.5	0.15123	0.017583	101.5132	37	0.028856	0.009375	186.7576
17	0.125052	0.017198	105.1489	37.5	0.028304	0.00933	188.2744
17.5	0.109862	0.016843	108.4102	38	0.027751	0.009285	189.7688
18	0.094671	0.016488	111.2812	38.5	0.027199	0.00924	191.2406
18.5	0.086175	0.015872	113.9958	39	0.026646	0.009195	192.6896
19	0.077679	0.015257	116.5415	39.5	0.026094	0.00915	194.1155
19.5	0.072665	0.014622	119.0263	40	0.025541	0.009105	195.5181
20	0.067651	0.013986	121.4447	40.5	0.025112	0.009028	196.9089
20.5	0.064888	0.013724	123.8088	41	0.024684	0.008952	198.2876
21	0.062126	0.013461	126.1164	41.5	0.024255	0.008875	199.6541
21.5	0.059363	0.013198	128.3653	42	0.023826	0.008798	201.0082
22	0.056601	0.012936	130.5531	42.5	0.023397	0.008722	202.3495
22.5	0.055031	0.012713	132.7174	43	0.022969	0.008645	203.6779
23	0.053462	0.012491	134.8575	43.5	0.02254	0.008568	204.9932
23.5	0.051893	0.012268	136.9725	44	0.022111	0.008492	206.2952
24	0.050324	0.012045	139.0614	44.5	0.021682	0.008415	207.5835
24.5	0.049191	0.011855	141.1361	45	0.021254	0.008338	208.8579
25	0.048058	0.011665	143.196	45.5	0.020901	0.008275	210.1207
25.5	0.046925	0.011475	145.2406	46	0.020548	0.008213	211.3718
26	0.045792	0.011285	147.2696	46.5	0.020196	0.00815	212.6108
26.5	0.044757	0.011122	149.2816	47	0.019843	0.008087	213.8377
27	0.043721	0.01096	151.2762	47.5	0.019491	0.008024	215.0523
27.5	0.042685	0.010797	153.2529	48	0.019138	0.007961	216.2543
28	0.04165	0.010635	155.2111	48.5	0.018785	0.007898	217.4436
28.5	0.040838	0.010492	157.1572	49	0.018433	0.007835	218.6199
29	0.040026	0.010349	159.091	49.5	0.01808	0.007772	219.783
29.5	0.039215	0.010207	161.012	50	0.017727	0.007709	220.9328
30	0.038403	0.010064	162.9198				

Table (3-57): The cross section and calculated data of stopping power and neutron yield for $^{91}Nb(p,n)^{91}Mo$ reaction.

proton energy MeV	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 proton**	**proton energy MeV**	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 proton**
10	0.336238	0.024913	6.748335	30.5	0.033711	0.009901	221.1527
10.5	0.358115	0.024097	14.179	31	0.033081	0.009851	222.8318
11	0.379993	0.023282	22.33978	31.5	0.032452	0.009801	224.4873
11.5	0.40303	0.022581	31.26379	32	0.031823	0.009751	226.1191
12	0.426066	0.021881	40.99987	32.5	0.031193	0.009701	227.7268
12.5	0.448761	0.02127	51.54883	33	0.030564	0.009651	229.3102
13	0.471456	0.02066	62.95869	33.5	0.029935	0.009601	230.8692
13.5	0.490817	0.020125	75.15305	34	0.029305	0.009551	232.4033
14	0.510177	0.019589	88.17479	34.5	0.028676	0.009501	233.9124
14.5	0.509032	0.019109	101.4939	35	0.028047	0.009451	235.3962
15	0.507888	0.018629	115.1256	35.5	0.027539	0.009406	236.86
15.5	0.447516	0.018204	127.4176	36	0.027031	0.009362	238.3037
16	0.387144	0.017778	138.3056	36.5	0.026523	0.009317	239.727
16.5	0.32008	0.017393	147.5069	37	0.026015	0.009273	241.1297
17	0.253017	0.017008	154.9451	37.5	0.025507	0.009228	242.5117
17.5	0.207465	0.016658	161.1724	38	0.024999	0.009184	243.8727
18	0.161914	0.016308	166.1368	38.5	0.024491	0.009139	245.2126
18.5	0.135652	0.015697	170.4577	39	0.023983	0.009095	246.5311
19	0.109391	0.015087	174.0831	39.5	0.023475	0.00905	247.828
19.5	0.094802	0.014462	177.3608	40	0.022967	0.009006	249.1031
20	0.080213	0.013836	180.2595	40.5	0.022582	0.00893	250.3675
20.5	0.073843	0.013576	182.9791	41	0.022196	0.008854	251.621
21	0.067472	0.013316	185.5126	41.5	0.021811	0.008778	252.8633
21.5	0.061102	0.013056	187.8526	42	0.021426	0.008702	254.0944
22	0.054731	0.012796	189.9913	42.5	0.021041	0.008627	255.3139
22.5	0.052364	0.012576	192.0733	43	0.020655	0.008551	256.5217
23	0.049997	0.012355	194.0965	43.5	0.02027	0.008475	257.7176
23.5	0.04763	0.012135	196.059	44	0.019885	0.008399	258.9013
24	0.045263	0.011915	197.9584	44.5	0.019499	0.008323	260.0727
24.5	0.044069	0.011728	199.8373	45	0.019114	0.008247	261.2315
25	0.042876	0.01154	201.695	45.5	0.018803	0.008185	262.3801
25.5	0.041682	0.011352	203.5308	46	0.018492	0.008123	263.5184
26	0.040488	0.011165	205.344	46.5	0.01818	0.00806	264.6461
26.5	0.039658	0.011002	207.1462	47	0.017869	0.007998	265.7632
27	0.038828	0.01084	208.9373	47.5	0.017558	0.007936	266.8695
27.5	0.037998	0.010677	210.7167	48	0.017247	0.007873	267.9647
28	0.037168	0.010514	212.4841	48.5	0.016935	0.007811	269.0488
28.5	0.036461	0.010374	214.2415	49	0.016624	0.007749	270.1215
29	0.035754	0.010233	215.9886	49.5	0.016313	0.007686	271.1827
29.5	0.035047	0.010092	217.7249	50	0.016002	0.007624	272.2321
30	0.03434	0.009951	219.4504				

Table (3-58): The cross section and calculated data of stopping power and neutron yield for $^{92}Nb(p,n)^{92}Mo$ reaction.

proton energy MeV	Cross section (mb)	Stopping power MeV / (mg/cm^2)	Neutron yield n/10^6 proton	proton energy MeV	Cross section (mb)	Stopping power MeV / (mg/cm^2)	Neutron yield n/10^6 proton
10	0.642614	0.024642	13.0388	30.5	0.04431	0.009793	201.0374
10.5	0.640426	0.023837	26.47232	31	0.043414	0.009743	203.2653
11	0.638239	0.023031	40.32817	31.5	0.042519	0.009694	205.4584
11.5	0.591109	0.022341	53.55742	32	0.041623	0.009644	207.6163
12	0.543979	0.021651	66.12012	32.5	0.040728	0.009595	209.7386
12.5	0.480086	0.021045	77.5262	33	0.039832	0.009546	211.825
13	0.416194	0.02044	87.70715	33.5	0.038936	0.009496	213.8752
13.5	0.352853	0.019905	96.57078	34	0.038041	0.009447	215.8886
14	0.289511	0.019369	104.0443	34.5	0.037145	0.009397	217.865
14.5	0.244583	0.018899	110.5151	35	0.036249	0.009348	219.8039
15	0.199654	0.018429	115.932	35.5	0.035596	0.009304	221.7169
15.5	0.172106	0.018003	120.7118	36	0.034943	0.00926	223.6037
16	0.144558	0.017578	124.8237	36.5	0.03429	0.009216	225.4641
16.5	0.128515	0.017198	128.56	37	0.033637	0.009172	227.2978
17	0.112473	0.016818	131.9039	37.5	0.032984	0.009128	229.1046
17.5	0.103281	0.016473	135.0389	38	0.03233	0.009084	230.8841
18	0.09409	0.016127	137.9559	38.5	0.031677	0.00904	232.6363
18.5	0.088495	0.015527	140.8057	39	0.031024	0.008996	234.3606
19	0.082901	0.014927	143.5826	39.5	0.030371	0.008952	236.057
19.5	0.079205	0.014301	146.3517	40	0.029718	0.008908	237.7251
20	0.075509	0.013676	149.1123	40.5	0.029204	0.008833	239.3783
20.5	0.07306	0.013421	151.8342	41	0.028691	0.008758	241.0164
21	0.070612	0.013166	154.5158	41.5	0.028177	0.008683	242.6391
21.5	0.068163	0.012911	157.1556	42	0.027664	0.008607	244.246
22	0.065714	0.012656	159.7519	42.5	0.027151	0.008532	245.837
22.5	0.064083	0.012438	162.328	43	0.026637	0.008457	247.4118
23	0.062451	0.01222	164.8832	43.5	0.026124	0.008382	248.9701
23.5	0.060819	0.012003	167.4168	44	0.02561	0.008307	250.5115
24	0.059187	0.011785	169.9279	44.5	0.025097	0.008232	252.0358
24.5	0.057932	0.0116	172.4249	45	0.024584	0.008157	253.5427
25	0.056676	0.011415	174.9075	45.5	0.024175	0.008096	255.0358
25.5	0.05542	0.01123	177.375	46	0.023767	0.008034	256.5149
26	0.054164	0.011045	179.827	46.5	0.023359	0.007972	257.9799
26.5	0.053008	0.010885	182.262	47	0.022951	0.007911	259.4305
27	0.051852	0.010725	184.6794	47.5	0.022543	0.007849	260.8665
27.5	0.050696	0.010564	187.0788	48	0.022134	0.007788	262.2876
28	0.04954	0.010404	189.4596	48.5	0.021726	0.007726	263.6937
28.5	0.048457	0.010264	191.8201	49	0.021318	0.007664	265.0844
29	0.047373	0.010123	194.1599	49.5	0.02091	0.007603	266.4596
29.5	0.046289	0.009983	196.4784	50	0.020501	0.007541	267.819
30	0.045206	0.009842	198.775				

Table (3-59): The cross section and calculated data of stopping power and neutron yield for $^{93}Nb(p,n)^{93}Mo$ reaction.

proton energy MeV	Cross section (mb)	Stopping power MeV / (mg/cm^2)	Neutron yield n/10^6 proton	proton energy MeV	Cross section (mb)	Stopping power MeV / (mg/cm^2)	Neutron yield n/10^6 proton
10	0.657211	0.024372	13.48286	30.5	0.037928	0.009688	183.1315
10.5	0.6494	0.023577	27.25498	31	0.037133	0.009639	185.0577
11	0.641589	0.022781	41.33656	31.5	0.036339	0.00959	186.9523
11.5	0.600144	0.022096	54.91711	32	0.035544	0.009541	188.815
12	0.5587	0.02141	67.96456	32.5	0.034749	0.009492	190.6454
12.5	0.463099	0.020815	79.08875	33	0.033954	0.009443	192.4433
13	0.367499	0.02022	88.17642	33.5	0.03316	0.009394	194.2083
13.5	0.298452	0.019694	95.75353	34	0.032365	0.009345	195.94
14	0.229406	0.019169	101.7373	34.5	0.03157	0.009296	197.6381
14.5	0.189915	0.018699	106.8156	35	0.030775	0.009247	199.3022
15	0.150423	0.018228	110.9416	35.5	0.030204	0.009203	200.9432
15.5	0.130296	0.017808	114.5999	36	0.029633	0.00916	202.5607
16	0.110169	0.017388	117.7679	36.5	0.029062	0.009116	204.1547
16.5	0.09953	0.017013	120.6931	37	0.02849	0.009073	205.7248
17	0.088892	0.016638	123.3645	37.5	0.027919	0.009029	207.2708
17.5	0.082849	0.016297	125.9062	38	0.027348	0.008986	208.7925
18	0.076805	0.015957	128.3128	38.5	0.026776	0.008942	210.2897
18.5	0.073014	0.015362	130.6893	39	0.026205	0.008899	211.7622
19	0.069223	0.014767	133.0332	39.5	0.025634	0.008855	213.2096
19.5	0.066653	0.014151	135.3882	40	0.025062	0.008812	214.6317
20	0.064083	0.013536	137.7554	40.5	0.02469	0.008737	216.0446
20.5	0.062338	0.013281	140.1023	41	0.024318	0.008663	217.4481
21	0.060593	0.013026	142.4282	41.5	0.023945	0.008589	218.8421
21.5	0.058848	0.012771	144.7322	42	0.023573	0.008515	220.2264
22	0.057103	0.012515	147.0135	42.5	0.023201	0.00844	221.6008
22.5	0.055728	0.0123	149.2788	43	0.022828	0.008366	222.9651
23	0.054353	0.012085	151.5275	43.5	0.022456	0.008292	224.3192
23.5	0.052978	0.01187	153.7591	44	0.022084	0.008218	225.6629
24	0.051603	0.011655	155.9729	44.5	0.021712	0.008143	226.9959
24.5	0.050444	0.011472	158.1714	45	0.021339	0.008069	228.3182
25	0.049284	0.01129	160.3541	45.5	0.020949	0.008008	229.6262
25.5	0.048125	0.011107	162.5205	46	0.02056	0.007947	230.9197
26	0.046966	0.010925	164.67	46.5	0.02017	0.007886	232.1984
26.5	0.045908	0.010767	166.8019	47	0.01978	0.007825	233.4623
27	0.044851	0.010609	168.9156	47.5	0.01939	0.007765	234.7109
27.5	0.043793	0.010452	171.0106	48	0.019001	0.007704	235.9441
28	0.042736	0.010294	173.0863	48.5	0.018611	0.007643	237.1617
28.5	0.041732	0.010155	175.1411	49	0.018221	0.007582	238.3633
29	0.040729	0.010016	177.1744	49.5	0.017831	0.007521	239.5488
29.5	0.039726	0.009876	179.1856	50	0.017442	0.00746	240.7178
30	0.038723	0.009737	181.174				

Table (3-60): The cross section and calculated data of stopping power and neutron yield for $^{94}Nb(p,n)^{94}Mo$ reaction.

proton energy MeV	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 proton**	**proton energy MeV**	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 proton**
10	0.543367	0.024112	11.26763	30.5	0.042295	0.009585	146.9696
10.5	0.496319	0.023326	21.90621	31	0.041456	0.009536	149.1432
11	0.449271	0.022541	31.87189	31.5	0.040618	0.009488	151.2838
11.5	0.372331	0.021861	40.38796	32	0.039779	0.009439	153.3909
12	0.295392	0.02118	47.3613	32.5	0.038941	0.009391	155.4642
12.5	0.243833	0.02059	53.28252	33	0.038102	0.009342	157.5034
13	0.192273	0.019999	58.08949	33.5	0.037263	0.009294	159.5082
13.5	0.163344	0.019479	62.28229	34	0.036425	0.009246	161.478
14	0.134414	0.018959	65.82719	34.5	0.035586	0.009197	163.4127
14.5	0.120105	0.018499	69.07352	35	0.034748	0.009149	165.3117
15	0.105796	0.018038	72.00606	35.5	0.034156	0.009106	167.1873
15.5	0.097757	0.017623	74.77961	36	0.033564	0.009062	169.0391
16	0.089718	0.017208	77.38651	36.5	0.032972	0.009019	170.867
16.5	0.085425	0.016833	79.924	37	0.032381	0.008976	172.6706
17	0.081133	0.016457	82.38893	37.5	0.031789	0.008933	174.4499
17.5	0.078266	0.016122	84.8162	38	0.031197	0.00889	176.2045
18	0.0754	0.015787	87.20424	38.5	0.030605	0.008847	177.9343
18.5	0.073042	0.015197	89.60744	39	0.030013	0.008804	179.6388
19	0.070683	0.014606	92.02704	39.5	0.029422	0.008761	181.3181
19.5	0.06899	0.013996	94.49164	40	0.02883	0.008717	182.9716
20	0.067296	0.013386	97.00536	40.5	0.028331	0.008644	184.6104
20.5	0.06571	0.013136	99.50656	41	0.027833	0.008571	186.2341
21	0.064124	0.012886	101.9948	41.5	0.027334	0.008497	187.8426
21.5	0.062538	0.012635	104.4695	42	0.026836	0.008424	189.4355
22	0.060951	0.012385	106.9301	42.5	0.026337	0.00835	191.0125
22.5	0.059803	0.012173	109.3865	43	0.025839	0.008277	192.5734
23	0.058654	0.01196	111.8386	43.5	0.02534	0.008203	194.1179
23.5	0.057505	0.011747	114.2862	44	0.024842	0.00813	195.6457
24	0.056357	0.011535	116.729	44.5	0.024343	0.008057	197.1565
24.5	0.055151	0.011352	119.1581	45	0.023845	0.007983	198.6499
25	0.053946	0.01117	121.573	45.5	0.02344	0.007923	200.1292
25.5	0.052741	0.010987	123.9731	46	0.023035	0.007863	201.594
26	0.051535	0.010805	126.358	46.5	0.022631	0.007802	203.0443
26.5	0.050396	0.010649	128.7241	47	0.022226	0.007742	204.4796
27	0.049256	0.010494	131.0709	47.5	0.021821	0.007682	205.8999
27.5	0.048116	0.010339	133.3978	48	0.021416	0.007622	207.3048
28	0.046977	0.010184	135.7041	48.5	0.021011	0.007562	208.6942
28.5	0.046016	0.010046	137.9943	49	0.020607	0.007501	210.0677
29	0.045055	0.009909	140.2679	49.5	0.020202	0.007441	211.4251
29.5	0.044094	0.009771	142.5243	50	0.019797	0.007381	212.7662
30	0.043133	0.009633	144.7632				

Table (3-61): The cross section and calculated data of stopping power and neutron yield for $^{95}Nb(p,n)^{95}Mo$ reaction.

proton energy MeV	Cross section (mb)	Stopping power MeV / (mg/cm^2)	Neutron yield n/10^6 proton	proton energy MeV	Cross section (mb)	Stopping power MeV / (mg/cm^2)	Neutron yield n/10^6 proton
10	0.394015	0.023862	8.256264	30.5	0.036595	0.009483	112.7728
10.5	0.324418	0.023081	15.28404	31	0.035842	0.009435	114.6722
11	0.254821	0.022301	20.99735	31.5	0.03509	0.009387	116.5412
11.5	0.211229	0.02163	25.88008	32	0.034337	0.009339	118.3796
12	0.167637	0.02096	29.87908	32.5	0.033584	0.009291	120.1869
12.5	0.144119	0.020375	33.41583	33	0.032832	0.009243	121.9628
13	0.120602	0.019789	36.46298	33.5	0.032079	0.009195	123.7071
13.5	0.108483	0.019274	39.27721	34	0.031326	0.009147	125.4194
14	0.096364	0.018759	41.84573	34.5	0.030574	0.0091	127.0994
14.5	0.089831	0.018303	44.29969	35	0.029821	0.009052	128.7466
15	0.083299	0.017848	46.63323	35.5	0.029272	0.009009	130.3712
15.5	0.079312	0.017438	48.90736	36	0.028723	0.008966	131.9729
16	0.075325	0.017028	51.11921	36.5	0.028173	0.008924	133.5515
16.5	0.072589	0.016657	53.29808	37	0.027624	0.008881	135.1067
17	0.069852	0.016287	55.44246	37.5	0.027075	0.008839	136.6383
17.5	0.067707	0.015952	57.56466	38	0.026526	0.008796	138.1462
18	0.065561	0.015617	59.66371	38.5	0.025977	0.008753	139.63
18.5	0.063862	0.015037	61.78724	39	0.025428	0.008711	141.0896
19	0.062162	0.014456	63.93722	39.5	0.024879	0.008668	142.5247
19.5	0.060701	0.013851	66.12845	40	0.024329	0.008625	143.935
20	0.059241	0.013246	68.3647	40.5	0.023906	0.008553	145.3326
20.5	0.057945	0.012998	70.59369	41	0.023483	0.00848	146.7172
21	0.056649	0.01275	72.81515	41.5	0.023059	0.008408	148.0885
21.5	0.055353	0.012503	75.02878	42	0.022636	0.008335	149.4464
22	0.054057	0.012255	77.23426	42.5	0.022213	0.008262	150.7906
22.5	0.052974	0.012045	79.43324	43	0.021789	0.00819	152.121
23	0.05189	0.011835	81.62549	43.5	0.021366	0.008117	153.4371
23.5	0.050807	0.011625	83.81077	44	0.020943	0.008044	154.7388
24	0.049724	0.011415	85.98881	44.5	0.020519	0.007972	156.0258
24.5	0.04865	0.011235	88.154	45	0.020096	0.007899	157.2978
25	0.047577	0.011055	90.30592	45.5	0.019776	0.007839	158.5592
25.5	0.046504	0.010875	92.44413	46	0.019456	0.00778	159.8096
26	0.045431	0.010694	94.56816	46.5	0.019136	0.00772	161.0489
26.5	0.04438	0.010539	96.6736	47	0.018816	0.007661	162.2771
27	0.043329	0.010384	98.75989	47.5	0.018496	0.007601	163.4938
27.5	0.042278	0.010229	100.8264	48	0.018176	0.007541	164.6989
28	0.041228	0.010074	102.8727	48.5	0.017856	0.007482	165.8922
28.5	0.040258	0.009938	104.8981	49	0.017537	0.007422	167.0736
29	0.039288	0.009802	106.902	49.5	0.017217	0.007362	168.2428
29.5	0.038318	0.009667	108.884	50	0.016897	0.007303	169.3997
30	0.037347	0.009531	110.8433				

Table (3-62): The cross section and calculated data of stopping power and neutron yield for $^{96}Nb(p,n)^{96}Mo$ reaction.

proton energy MeV	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 proton**	**proton energy MeV**	**Cross section (mb)**	**Stopping power** MeV / (mg/cm^2)	**Neutron yield n/10^6 proton**
10	0.223359	0.023611	4.729908	30.5	0.038769	0.009384	102.0325
10.5	0.190575	0.022841	8.901698	31	0.038016	0.009337	104.0683
11	0.157791	0.02207	12.4764	31.5	0.037263	0.00929	106.074
11.5	0.139126	0.021405	15.72625	32	0.03651	0.009242	108.0492
12	0.120462	0.02074	18.63039	32.5	0.035758	0.009195	109.9937
12.5	0.109989	0.020159	21.35838	33	0.035005	0.009147	111.9071
13	0.099516	0.019579	23.89979	33.5	0.034252	0.0091	113.7891
13.5	0.093557	0.019074	26.3523	34	0.033499	0.009052	115.6394
14	0.087598	0.018568	28.71108	34.5	0.032747	0.009005	117.4577
14.5	0.083791	0.018113	31.02407	35	0.031994	0.008958	119.2435
15	0.079985	0.017658	33.2889	35.5	0.031428	0.008915	121.0061
15.5	0.077181	0.017253	35.52566	36	0.030862	0.008873	122.7452
16	0.074376	0.016848	37.733	36.5	0.030296	0.008831	124.4605
16.5	0.072195	0.016482	39.92307	37	0.02973	0.008789	126.1519
17	0.070014	0.016117	42.0951	37.5	0.029164	0.008746	127.8191
17.5	0.068502	0.015787	44.26466	38	0.028598	0.008704	129.4619
18	0.06699	0.015457	46.43166	38.5	0.028032	0.008662	131.08
18.5	0.065295	0.014881	48.62548	39	0.027466	0.00862	132.6732
19	0.0636	0.014306	50.84828	39.5	0.0269	0.008578	134.2412
19.5	0.062237	0.013706	53.11873	40	0.026334	0.008535	135.7839
20	0.060874	0.013106	55.44118	40.5	0.025879	0.008464	137.3127
20.5	0.059605	0.01286	57.75858	41	0.025424	0.008392	138.8275
21	0.058337	0.012615	60.07072	41.5	0.024969	0.00832	140.3281
21.5	0.057068	0.01237	62.37739	42	0.024514	0.008248	141.8141
22	0.055799	0.012125	64.67837	42.5	0.024059	0.008176	143.2854
22.5	0.054702	0.011917	66.9734	43	0.023604	0.008104	144.7416
23	0.053605	0.01171	69.26227	43.5	0.023149	0.008033	146.1826
23.5	0.052507	0.011502	71.54475	44	0.022693	0.007961	147.6079
24	0.05141	0.011295	73.82061	44.5	0.022238	0.007889	149.0174
24.5	0.050272	0.011117	76.08165	45	0.021783	0.007817	150.4107
25	0.049135	0.010939	78.32739	45.5	0.021461	0.007758	151.7938
25.5	0.047997	0.010762	80.55732	46	0.021138	0.007699	153.1666
26	0.046859	0.010584	82.77093	46.5	0.020815	0.00764	154.5288
26.5	0.045903	0.01043	84.97133	47	0.020492	0.007581	155.8804
27	0.044946	0.010277	87.15815	47.5	0.020169	0.007522	157.2211
27.5	0.04399	0.010123	89.33096	48	0.019846	0.007463	158.5508
28	0.043034	0.009969	91.48934	48.5	0.019524	0.007404	159.8692
28.5	0.042156	0.009835	93.63256	49	0.019201	0.007345	161.1763
29	0.041278	0.0097	95.76019	49.5	0.018878	0.007286	162.4719
29.5	0.0404	0.009566	97.87179	50	0.018555	0.007227	163.7556
30	0.039521	0.009432	99.96692				

Table (3-63): The cross sections after interpolation for $^{44}Ti(n,n)^{44}Ti$ reaction.

n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)
20	0.201197	28	0.138726	36	0.056922	44	0.032961
20.5	0.199256	28.5	0.132249	36.5	0.054551	44.5	0.032588
21	0.197315	29	0.125772	37	0.052181	45	0.032215
21.5	0.194853	29.5	0.119289	37.5	0.04981	45.5	0.031842
22	0.192392	30	0.112806	38	0.04744	46	0.031469
22.5	0.188927	30.5	0.106821	38.5	0.045842	46.5	0.030595
23	0.185462	31	0.100836	39	0.044245	47	0.02972
23.5	0.181995	31.5	0.094851	39.5	0.042648	47.5	0.028846
24	0.178528	32	0.088866	40	0.04105	48	0.027972
24.5	0.173557	32.5	0.084124	40.5	0.040028	48.5	0.027473
25	0.168586	33	0.079382	41	0.039005	49	0.026974
25.5	0.164119	33.5	0.07464	41.5	0.037983	49.5	0.026474
26	0.159652	34	0.069898	42	0.03696	50	0.025975
26.5	0.154176	34.5	0.066654	42.5	0.03596		
27	0.1487	35	0.06341	43	0.034961		
27.5	0.143713	35.5	0.060166	43.5	0.033961		

Table (3-64): The cross sections after interpolation for $^{45}Ti(n,n)^{45}Ti$ reaction.

n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)
20	0.344953	28	0.360883	36	0.159648	44	0.088737
20.5	0.358763	28.5	0.349959	36.5	0.152918	44.5	0.086667
21	0.372572	29	0.339035	37	0.146188	45	0.084597
21.5	0.379774	29.5	0.325101	37.5	0.139458	45.5	0.082528
22	0.386977	30	0.311167	38	0.132729	46	0.080458
22.5	0.392222	30.5	0.29647	38.5	0.127716	46.5	0.07884
23	0.397468	31	0.281773	39	0.122703	47	0.077221
23.5	0.399197	31.5	0.267077	39.5	0.11769	47.5	0.075603
24	0.400926	32	0.25238	40	0.112677	48	0.073984
24.5	0.399107	32.5	0.238919	40.5	0.109462	48.5	0.072186
25	0.397288	33	0.225459	41	0.106247	49	0.070387
25.5	0.392919	33.5	0.211998	41.5	0.103032	49.5	0.068588
26	0.388549	34	0.198538	42	0.099817	50	0.06679
26.5	0.382652	34.5	0.188816	42.5	0.097047		
27	0.376754	35	0.179093	43	0.094277		
27.5	0.368819	35.5	0.16937	43.5	0.091507		

Table (3-65): The cross sections after interpolation for $^{46}Ti(n,n)^{46}Ti$ reaction.

n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)
20	0.579416	28	0.556071	36	0.356049	44	0.187789
20.5	0.484442	28.5	0.566851	36.5	0.33978	44.5	0.183552
21	0.389469	29	0.57763	37	0.323512	45	0.179314
21.5	0.300375	29.5	0.576366	37.5	0.307243	45.5	0.175077
22	0.211282	30	0.575101	38	0.290974	46	0.170839
22.5	0.142715	30.5	0.561679	38.5	0.279593	46.5	0.167321
23	0.074147	31	0.548256	39	0.268211	47	0.163803
23.5	0.037074	31.5	0.534833	39.5	0.25683	47.5	0.160285
24	0	32	0.521411	40	0.245449	48	0.156767
24.5	0.105387	32.5	0.50082	40.5	0.237111	48.5	0.154189
25	0.210775	33	0.480229	41	0.228773	49	0.151611
25.5	0.311825	33.5	0.459638	41.5	0.220435	49.5	0.149033
26	0.412875	34	0.439046	42	0.212097	50	0.146455
26.5	0.463822	34.5	0.418297	42.5	0.20602		
27	0.51477	35	0.397548	43	0.199943		
27.5	0.535421	35.5	0.376799	43.5	0.193866		

Table (3-66): The cross sections after interpolation for $^{47}Ti(n,n)^{47}Ti$ reaction.

n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)
20	0.444535	28	0.756291	36	0.351492	44	0.203349
20.5	0.222267	28.5	0.731852	36.5	0.337323	44.5	0.199168
21	0	29	0.707413	37	0.323155	45	0.194987
21.5	0.131524	29.5	0.685876	37.5	0.308986	45.5	0.190806
22	0.263048	30	0.664339	38	0.294818	46	0.186626
22.5	0.438176	30.5	0.634436	38.5	0.284685	46.5	0.182491
23	0.613305	31	0.604533	39	0.274551	47	0.178356
23.5	0.662541	31.5	0.57463	39.5	0.264418	47.5	0.174222
24	0.711778	32	0.544727	40	0.254285	48	0.170087
24.5	0.737728	32.5	0.517679	40.5	0.247208	48.5	0.167159
25	0.763677	33	0.490631	41	0.240132	49	0.16423
25.5	0.773804	33.5	0.463584	41.5	0.233055	49.5	0.161302
26	0.783931	34	0.436536	42	0.225978	50	0.158373
26.5	0.777909	34.5	0.415275	42.5	0.220321		
27	0.771888	35	0.394014	43	0.214664		
27.5	0.764089	35.5	0.372753	43.5	0.209006		

Table (3-67): The cross sections after interpolation for $^{48}Ti(n,n)^{48}Ti$ reaction.

n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)
20	0.025984	28	0.77299	36	0.353676	44	0.178441
20.5	0.021022	28.5	0.757079	36.5	0.336148	44.5	0.174464
21	0.016061	29	0.741167	37	0.318621	45	0.170488
21.5	0.011784	29.5	0.717996	37.5	0.301093	45.5	0.166511
22	0.007507	30	0.694825	38	0.283566	46	0.162535
22.5	0.003753	30.5	0.664686	38.5	0.271673	46.5	0.158557
23	0	31	0.634547	39	0.25978	47	0.154579
23.5	0.046481	31.5	0.604408	39.5	0.247887	47.5	0.150601
24	0.092962	32	0.574269	40	0.235994	48	0.146624
24.5	0.247328	32.5	0.5437	40.5	0.22806	48.5	0.143889
25	0.401693	33	0.513131	41	0.220125	49	0.141154
25.5	0.524471	33.5	0.482562	41.5	0.212191	49.5	0.13842
26	0.647249	34	0.451993	42	0.204257	50	0.135685
26.5	0.704327	34.5	0.427414	42.5	0.197803		
27	0.761405	35	0.402834	43	0.191349		
27.5	0.767198	35.5	0.378255	43.5	0.184895		

Table (3-68): The cross sections after interpolation for $^{49}Ti(n,n)^{49}Ti$ reaction.

n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)
20	0.017063	28	0.769127	36	0.331226	44	0.187955
20.5	0.129358	28.5	0.743923	36.5	0.316603	44.5	0.183657
21	0.241652	29	0.718719	37	0.30198	45	0.179359
21.5	0.30849	29.5	0.687152	37.5	0.287357	45.5	0.175061
22	0.375329	30	0.655584	38	0.272734	46	0.170762
22.5	0.472748	30.5	0.622629	38.5	0.263657	46.5	0.167257
23	0.570168	31	0.589673	39	0.25458	47	0.163752
23.5	0.640311	31.5	0.556717	39.5	0.245503	47.5	0.160247
24	0.710455	32	0.523762	40	0.236426	48	0.156742
24.5	0.74461	32.5	0.495915	40.5	0.228754	48.5	0.154729
25	0.778765	33	0.468068	41	0.221082	49	0.152716
25.5	0.79175	33.5	0.440222	41.5	0.21341	49.5	0.150702
26	0.804735	34	0.412375	42	0.205738	50	0.148689
26.5	0.802595	34.5	0.392088	42.5	0.201292		
27	0.800456	35	0.371801	43	0.196846		
27.5	0.784792	35.5	0.351514	43.5	0.192401		

Table (3-69): The cross sections after interpolation for $^{50}Ti(n,n)^{50}Ti$ reaction.

n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)
20	2.04E-07	28	0.864283	36	0.384728	44	0.201864
20.5	0.01387	28.5	0.862133	36.5	0.365776	44.5	0.196859
21	0.027741	29	0.859983	37	0.346825	45	0.191854
21.5	0.017681	29.5	0.836707	37.5	0.327873	45.5	0.186849
22	0.007622	30	0.813431	38	0.308922	46	0.181844
22.5	0.011812	30.5	0.772799	38.5	0.296257	46.5	0.179016
23	0.016001	31	0.732167	39	0.283593	47	0.176187
23.5	0.094075	31.5	0.691535	39.5	0.270929	47.5	0.173359
24	0.172149	32	0.650904	40	0.258264	48	0.17053
24.5	0.289683	32.5	0.612887	40.5	0.249843	48.5	0.166822
25	0.407217	33	0.57487	41	0.241421	49	0.163114
25.5	0.525409	33.5	0.536853	41.5	0.232999	49.5	0.159406
26	0.6436	34	0.498836	42	0.224577	50	0.155698
26.5	0.724617	34.5	0.470309	42.5	0.218899		
27	0.805634	35	0.441782	43	0.213221		
27.5	0.834959	35.5	0.413255	43.5	0.207542		

Table (3-70): The cross sections after interpolation for $^{51}Ti(n,n)^{51}Ti$ reaction.

n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)
20	0.041561	28	0.648982	36	0.230144	44	0.140232
20.5	0.361488	28.5	0.606395	36.5	0.222923	44.5	0.138791
21	0.681415	29	0.563808	37	0.215702	45	0.13735
21.5	0.71802	29.5	0.525283	37.5	0.20848	45.5	0.135909
22	0.754625	30	0.486757	38	0.201259	46	0.134468
22.5	0.785877	30.5	0.457292	38.5	0.194535	46.5	0.132129
23	0.81713	31	0.427827	39	0.187812	47	0.12979
23.5	0.832757	31.5	0.398361	39.5	0.181089	47.5	0.12745
24	0.848385	32	0.368896	40	0.174366	48	0.125111
24.5	0.841658	32.5	0.347832	40.5	0.169618	48.5	0.122913
25	0.834931	33	0.326768	41	0.16487	49	0.120715
25.5	0.812852	33.5	0.305704	41.5	0.160122	49.5	0.118517
26	0.790773	34	0.28464	42	0.155375	50	0.116319
26.5	0.761461	34.5	0.271016	42.5	0.151589		
27	0.73215	35	0.257392	43	0.147803		
27.5	0.690566	35.5	0.243768	43.5	0.144018		

Table (3-71): The cross sections after interpolation for $^{52}Ti(n,n)^{52}Ti$ reaction.

n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)
20	7.73E-05	28	0.745296	36	0.225169	44	0.132953
20.5	0.02694	28.5	0.689953	36.5	0.215213	44.5	0.130417
21	0.053803	29	0.63461	37	0.205257	45	0.12788
21.5	0.115584	29.5	0.58182	37.5	0.195301	45.5	0.125344
22	0.177366	30	0.529031	38	0.185345	46	0.122807
22.5	0.292287	30.5	0.491758	38.5	0.180157	46.5	0.121055
23	0.407208	31	0.454485	39	0.17497	47	0.119303
23.5	0.531686	31.5	0.417212	39.5	0.169782	47.5	0.117551
24	0.656164	32	0.379939	40	0.164595	48	0.115798
24.5	0.728925	32.5	0.354656	40.5	0.160698	48.5	0.11432
25	0.801687	33	0.329373	41	0.156801	49	0.112841
25.5	0.836357	33.5	0.30409	41.5	0.152903	49.5	0.111363
26	0.871027	34	0.278807	42	0.149006	50	0.109885
26.5	0.850732	34.5	0.265397	42.5	0.144993		
27	0.830437	35	0.251988	43	0.14098		
27.5	0.787866	35.5	0.238579	43.5	0.136967		

Table (3-72): The cross sections after interpolation for $^{53}Ti(n,n)^{53}Ti$ reaction.

n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)
20	0.02777	28	0.506188	36	0.186331	44	0.124303
20.5	0.295316	28.5	0.467375	36.5	0.181348	44.5	0.121275
21	0.562863	29	0.428563	37	0.176365	45	0.118246
21.5	0.614662	29.5	0.397582	37.5	0.171382	45.5	0.115218
22	0.666461	30	0.366602	38	0.166399	46	0.112189
22.5	0.694712	30.5	0.345092	38.5	0.161729	46.5	0.111114
23	0.722962	31	0.323582	39	0.15706	47	0.110038
23.5	0.7309	31.5	0.302072	39.5	0.15239	47.5	0.108963
24	0.738838	32	0.280562	40	0.14772	48	0.107888
24.5	0.728881	32.5	0.267693	40.5	0.144055	48.5	0.106232
25	0.718924	33	0.254824	41	0.14039	49	0.104576
25.5	0.685075	33.5	0.241955	41.5	0.136726	49.5	0.10292
26	0.651225	34	0.229087	42	0.133061	50	0.101264
26.5	0.611596	34.5	0.218398	42.5	0.130872		
27	0.571967	35	0.207709	43	0.128682		
27.5	0.539078	35.5	0.19702	43.5	0.126493		

Table (3-73): The cross sections after interpolation for $^{62}Zn(n,n)^{62}Zn$ reaction.

n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)
10	0.315291	20.5	0.240478	31	0.112231	41.5	0.043773
10.5	0.322184	21	0.24079	31.5	0.104506	42	0.042727
11	0.326693	21.5	0.239368	32	0.096782	42.5	0.04173
11.5	0.327922	22	0.237946	32.5	0.091547	43	0.040733
12	0.323137	22.5	0.236012	33	0.086313	43.5	0.039735
12.5	0.317185	23	0.234078	33.5	0.081078	44	0.038738
13	0.309367	23.5	0.230634	34	0.075844	44.5	0.038063
13.5	0.299348	24	0.22719	34.5	0.072353	45	0.037387
14	0.289442	24.5	0.223229	35	0.068862	45.5	0.036712
14.5	0.277506	25	0.219268	35.5	0.065371	46	0.036037
15	0.26847	25.5	0.211324	36	0.06188	46.5	0.035639
15.5	0.260022	26	0.203379	36.5	0.059636	47	0.035241
16	0.251575	26.5	0.195425	37	0.057391	47.5	0.034844
16.5	0.247053	27	0.187471	37.5	0.055146	48	0.034446
17	0.242531	27.5	0.177511	38	0.052901	48.5	0.033671
17.5	0.242032	28	0.16755	38.5	0.051404	49	0.032897
18	0.241532	28.5	0.15709	39	0.049906	49.5	0.032122
18.5	0.241545	29	0.14663	39.5	0.048409	50	0.031348
19	0.241559	29.5	0.137155	40	0.046912		
19.5	0.240863	30	0.12768	40.5	0.045866		
20	0.240166	30.5	0.119955	41	0.044819		

Table (3-74): The cross sections after interpolation for $^{63}Zn(n,n)^{63}Zn$ reaction.

n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)
10	0.684283	20.5	0.448239	31	0.185616	41.5	0.068907
10.5	0.675417	21	0.451079	31.5	0.171651	42	0.066911
11	0.659875	21.5	0.447096	32	0.157686	42.5	0.065887
11.5	0.638147	22	0.443114	32.5	0.148713	43	0.064863
12	0.61302	22.5	0.436483	33	0.13974	43.5	0.06384
12.5	0.584756	23	0.429852	33.5	0.130767	44	0.062816
13	0.556706	23.5	0.420591	34	0.121794	44.5	0.061895
13.5	0.527552	24	0.411331	34.5	0.115804	45	0.060974
14	0.500251	24.5	0.400489	35	0.109813	45.5	0.060053
14.5	0.478253	25	0.389646	35.5	0.103823	46	0.059131
15	0.458275	25.5	0.373781	36	0.097832	46.5	0.058606
15.5	0.447296	26	0.357917	36.5	0.094342	47	0.058081
16	0.436317	26.5	0.340024	37	0.090852	47.5	0.057556
16.5	0.434209	27	0.32213	37.5	0.087362	48	0.057031
17	0.432101	27.5	0.303711	38	0.083872	48.5	0.056357
17.5	0.434966	28	0.285292	38.5	0.081628	49	0.055683
18	0.437831	28.5	0.266858	39	0.079385	49.5	0.055009

18.5	0.442431	29	0.248424	39.5	0.077141	50	0.054336
19	0.44703	29.5	0.230985	40	0.074897		
19.5	0.446214	30	0.213546	40.5	0.072901		
20	0.445399	30.5	0.199581	41	0.070904		

Table (3-75): The cross sections after interpolation for $^{64}Zn(n,n)^{64}Zn$ reaction.

n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)
10	0.000278	20.5	0.740612	31	0.412564	41.5	0.174751
10.5	0.004679	21	0.503605	31.5	0.396217	42	0.169862
11	0.031074	21.5	0.370391	32	0.379871	42.5	0.166149
11.5	0.116871	22	0.237176	32.5	0.362664	43	0.162437
12	0.262164	22.5	0.169457	33	0.345458	43.5	0.158724
12.5	0.439465	23	0.101739	33.5	0.328252	44	0.155012
13	0.607957	23.5	0.068424	34	0.311046	44.5	0.152281
13.5	0.736945	24	0.035109	34.5	0.298455	45	0.149549
14	0.811884	24.5	0.017554	35	0.285865	45.5	0.146818
14.5	0.864082	25	-9.30E09	35.5	0.273274	46	0.144086
15	0.876783	25.5	0.088029	36	0.260683	46.5	0.142462
15.5	0.880967	26	0.176058	36.5	0.249359	47	0.140838
16	0.885151	26.5	0.267034	37	0.238034	47.5	0.139214
16.5	0.890681	27	0.35801	37.5	0.226709	48	0.13759
17	0.896212	27.5	0.397175	38	0.215384	48.5	0.135589
17.5	0.908157	28	0.436341	38.5	0.208893	49	0.133587
18	0.920101	28.5	0.4479	39	0.202401	49.5	0.131586
18.5	0.942035	29	0.459458	39.5	0.19591	50	0.129585
19	0.96397	29.5	0.452358	40	0.189419		
19.5	0.970794	30	0.445258	40.5	0.18453		
20	0.977619	30.5	0.428911	41	0.17964		

Table (3-76): The cross sections after interpolation for $^{65}Zn(n,n)^{65}Zn$ reaction.

n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)
10	0.150113	20.5	1.349071	31	0.56891	41.5	0.210441
10.5	0.361144	21	1.377767	31.5	0.527622	42	0.204936
11	0.599542	21.5	1.359886	32	0.486334	42.5	0.200726
11.5	0.756852	22	1.342006	32.5	0.459209	43	0.196516
12	0.880629	22.5	1.314384	33	0.432084	43.5	0.192307
12.5	0.829155	23	1.286762	33.5	0.40496	44	0.188097
13	0.78463	23.5	1.255365	34	0.377835	44.5	0.18391
13.5	0.706738	24	1.223967	34.5	0.35991	45	0.179724
14	0.675997	24.5	1.189142	35	0.341986	45.5	0.175538
14.5	0.634473	25	1.154318	35.5	0.324061	46	0.171351

15	0.592648	25.5	1.112128	36	0.306137	46.5	0.169184
15.5	0.588571	26	1.069938	36.5	0.294186	47	0.167016
16	0.584494	26.5	1.019054	37	0.282235	47.5	0.164849
16.5	0.616101	27	0.968171	37.5	0.270285	48	0.162682
17	0.647708	27.5	0.916136	38	0.258334	48.5	0.160463
17.5	0.735762	28	0.864102	38.5	0.250489	49	0.158244
18	0.823816	28.5	0.809977	39	0.242644	49.5	0.156025
18.5	1.009312	29	0.755853	39.5	0.2348	50	0.153807
19	1.194808	29.5	0.703669	40	0.226955		
19.5	1.257592	30	0.651486	40.5	0.22145		
20	1.320376	30.5	0.610198	41	0.215946		

Table (3-77): The cross sections after interpolation for $^{66}Zn(n,n)^{66}Zn$ reaction.

n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)
10	0	20.5	0.28592	31	0.912815	41.5	0.308549
10.5	1.48E-17	21	0.525414	31.5	0.851905	42	0.298851
11	1.62E-17	21.5	0.672067	32	0.790995	42.5	0.292151
11.5	6.05E-16	22	0.81872	32.5	0.742847	43	0.285451
12	1.50E-14	22.5	0.99669	33	0.694699	43.5	0.27875
12.5	4.87E-12	23	1.17466	33.5	0.64655	44	0.27205
13	1.08E-09	23.5	1.265267	34	0.598402	44.5	0.264598
13.5	5.59E-08	24	1.355875	34.5	0.567132	45	0.257147
14	1.09E-06	24.5	1.380478	35	0.535862	45.5	0.249695
14.5	1.16E-05	25	1.405081	35.5	0.504592	46	0.242244
15	7.29E-05	25.5	1.395479	36	0.473322	46.5	0.239263
15.5	0.00053	26	1.385876	36.5	0.452248	47	0.236282
16	0.000987	26.5	1.360033	37	0.431174	47.5	0.2333
16.5	0.003095	27	1.33419	37.5	0.4101	48	0.230319
17	0.005204	27.5	1.295405	38	0.389026	48.5	0.225346
17.5	0.010311	28	1.256621	38.5	0.37618	49	0.220373
18	0.015417	28.5	1.206302	39	0.363334	49.5	0.2154
18.5	0.023405	29	1.155984	39.5	0.350488	50	0.210427
19	0.031393	29.5	1.09531	40	0.337641		
19.5	0.03891	30	1.034635	40.5	0.327944		
20	0.046426	30.5	0.973725	41	0.318246		

Table (3-78): The cross sections after interpolation for $^{67}Zn(n,n)^{67}Zn$ reaction.

n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)
10	2.07E-14	20.5	1.110866	31	0.765456	41.5	0.300326
10.5	9.24E-12	21	1.305012	31.5	0.716136	42	0.291665
11	8.32E-10	21.5	1.342897	32	0.666816	42.5	0.285959

11.5	2.99E-08	22	1.380782	32.5	0.631598	43	0.280252
12	4.37E-07	22.5	1.403007	33	0.59638	43.5	0.274546
12.5	3.53E-06	23	1.425232	33.5	0.561162	44	0.268839
13	1.94E-05	23.5	1.428446	34	0.525943	44.5	0.263384
13.5	6.78E-05	24	1.43166	34.5	0.502526	45	0.25793
14	0.000184	24.5	1.418368	35	0.479109	45.5	0.252475
14.5	0.000415	25	1.405076	35.5	0.455691	46	0.24702
15	0.000934	25.5	1.369682	36	0.432274	46.5	0.243546
15.5	0.001907	26	1.334288	36.5	0.415693	47	0.240071
16	0.00288	26.5	1.280273	37	0.399113	47.5	0.236597
16.5	0.01905	27	1.226258	37.5	0.382532	48	0.233123
17	0.035219	27.5	1.167327	38	0.365952	48.5	0.229007
17.5	0.185377	28	1.108396	38.5	0.356041	49	0.224892
18	0.335535	28.5	1.046311	39	0.346131	49.5	0.220777
18.5	0.601952	29	0.984227	39.5	0.33622	50	0.216661
19	0.868369	29.5	0.924161	40	0.326309		
19.5	0.892545	30	0.864096	40.5	0.317648		
20	0.91672	30.5	0.814776	41	0.308987		

Table (3-79): The cross sections after interpolation for $^{68}Zn(n,n)^{68}Zn$ reaction.

n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)
10	0	20.5	0.002699	31	0.815121	41.5	0.210456
10.5	0	21	0.002054	31.5	0.72911	42	0.203607
11	0	21.5	0.001462	32	0.643098	42.5	0.199215
11.5	0	22	0.000869	32.5	0.593646	43	0.194823
12	0	22.5	0.000435	33	0.544194	43.5	0.190431
12.5	0	23	0	33.5	0.494742	44	0.186039
13	0	23.5	0.524748	34	0.44529	44.5	0.182137
13.5	0	24	1.049495	34.5	0.417441	45	0.178235
14	0	24.5	1.324812	35	0.389593	45.5	0.174333
14.5	1.43E-16	25	1.600129	35.5	0.361744	46	0.170431
15	3.13E-13	25.5	1.656714	36	0.333896	46.5	0.167496
15.5	2.10E-09	26	1.713298	36.5	0.318134	47	0.164561
16	4.19E-09	26.5	1.660301	37	0.302371	47.5	0.161626
16.5	4.18E-07	27	1.607303	37.5	0.286609	48	0.158691
17	8.31E-07	27.5	1.513968	38	0.270847	48.5	0.156994
17.5	1.16E-05	28	1.420633	38.5	0.260885	49	0.155298
18	2.24E-05	28.5	1.309582	39	0.250924	49.5	0.153601
18.5	0.000115	29	1.19853	39.5	0.240962	50	0.151904
19	0.000208	29.5	1.092837	40	0.231001		
19.5	0.001776	30	0.987144	40.5	0.224152		
20	0.003344	30.5	0.901133	41	0.217304		

Table (3-80): The cross sections after interpolation for $^{69}Zn(n,n)^{69}Zn$ reaction.

n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)
10	0	20.5	0.21757	31	9.467781	41.5	16.10759
10.5	0	21	0.347991	31.5	9.920617	42	16.37138
11	0	21.5	0.529695	32	10.37345	42.5	16.68108
11.5	0	22	0.7114	32.5	10.75215	43	16.99078
12	0	22.5	1.004513	33	11.13084	43.5	17.30048
12.5	0	23	1.297626	33.5	11.50953	44	17.61018
13	1.72E-18	23.5	1.713432	34	11.88823	44.5	17.93352
13.5	7.07E-16	24	2.129239	34.5	12.2254	45	18.25687
14	3.07E-13	24.5	2.624321	35	12.56257	45.5	18.58022
14.5	4.19E-11	25	3.119403	35.5	12.89974	46	18.90356
15	3.91E-09	25.5	3.696344	36	13.23692	46.5	19.20722
15.5	1.88E-06	26	4.273286	36.5	13.53424	47	19.51089
16	3.75E-06	26.5	4.839366	37	13.83157	47.5	19.81455
16.5	0.000229	27	5.405446	37.5	14.1289	48	20.11821
17	0.000455	27.5	5.956999	38	14.42623	48.5	20.29645
17.5	0.002983	28	6.508553	38.5	14.64873	49	20.47469
18	0.005511	28.5	7.02978	39	14.87123	49.5	20.65292
18.5	0.015165	29	7.551008	39.5	15.09373	50	20.83116
19	0.02482	29.5	8.056559	40	15.31624		
19.5	0.055984	30	8.56211	40.5	15.58002		
20	0.087149	30.5	9.014946	41	15.84381		

Table (3-81): The cross sections after interpolation for $^{70}Zn(n,n)^{70}Zn$ reaction.

n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)
10	0	20.5	0.077786	31	0.531484	41.5	0.161556
10.5	0	21	0.155293	31.5	0.478636	42	0.156798
11	0	21.5	0.183781	32	0.425788	42.5	0.152963
11.5	0	22	0.212268	32.5	0.3958	43	0.149129
12	0	22.5	0.330114	33	0.365812	43.5	0.145295
12.5	0	23	0.44796	33.5	0.335824	44	0.14146
13	0	23.5	0.610531	34	0.305837	44.5	0.139307
13.5	0	24	0.773101	34.5	0.289179	45	0.137153
14	0	24.5	0.899939	35	0.272522	45.5	0.134999
14.5	0	25	1.026776	35.5	0.255864	46	0.132845
15	0	25.5	1.070828	36	0.239207	46.5	0.130413
15.5	0	26	1.114881	36.5	0.229514	47	0.127981
16	0	26.5	1.088757	37	0.21982	47.5	0.125549
16.5	7.60E-17	27	1.062634	37.5	0.210127	48	0.123117
17	1.52E-16	27.5	0.997656	38	0.200434	48.5	0.121655
17.5	7.96E-11	28	0.932679	38.5	0.194283	49	0.120193
18	1.59E-10	28.5	0.859188	39	0.188133	49.5	0.118731

18.5	2.39E-07	29	0.785698	39.5	0.181982	50	0.117269
19	4.79E-07	29.5	0.711439	40	0.175831		
19.5	0.00014	30	0.63718	40.5	0.171073		
20	0.000279	30.5	0.584332	41	0.166314		

Table (3-82): The cross sections after interpolation for ^{71}Zn(n,n)^{71} Zn reaction.

n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)
10	0	20.5	0.09816	31	3.934937	41.5	10.663
10.5	0	21	0.172012	31.5	4.165539	42	11.21122
11	0	21.5	0.228717	32	4.396142	42.5	11.70879
11.5	0	22	0.285421	32.5	4.604962	43	12.20636
12	0	22.5	0.379011	33	4.813783	43.5	12.70393
12.5	0	23	0.472601	33.5	5.022604	44	13.2015
13	0	23.5	0.61084	34	5.231425	44.5	13.65656
13.5	0	24	0.749079	34.5	5.452467	45	14.11162
14	2.98E-15	24.5	0.931177	35	5.673509	45.5	14.56669
14.5	5.55E-12	25	1.113274	35.5	5.894552	46	15.02175
15	8.67E-10	25.5	1.312526	36	6.115594	46.5	15.36742
15.5	1.23E-07	26	1.511779	36.5	6.396785	47	15.7131
16	2.45E-07	26.5	1.740298	37	6.677976	47.5	16.05877
16.5	2.36E-06	27	1.968817	37.5	6.959167	48	16.40444
17	4.47E-06	27.5	2.21827	38	7.240358	48.5	16.70516
17.5	0.000151	28	2.467723	38.5	7.684852	49	17.00588
18	0.000297	28.5	2.712922	39	8.129346	49.5	17.3066
18.5	0.002432	29	2.958121	39.5	8.573839	50	17.60732
19	0.004568	29.5	3.215927	40	9.018333		
19.5	0.014438	30	3.473733	40.5	9.566554		
20	0.024307	30.5	3.704335	41	10.11478		

Table (3-83): The cross sections after interpolation for ^{87}Mo(n,n)^{87}Mo reaction.

n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)
10	0.06583	20.5	0.040659	31	0.018514	41.5	0.008436
10.5	0.063839	21	0.043886	31.5	0.01734	42	0.008287
11	0.060858	21.5	0.043888	32	0.016166	42.5	0.008137
11.5	0.058845	22	0.043891	32.5	0.015418	43	0.007988
12	0.056864	22.5	0.044394	33	0.01467	43.5	0.007838
12.5	0.052856	23	0.044898	33.5	0.013922	44	0.007689
13	0.051848	23.5	0.045045	34	0.013174	44.5	0.007539
13.5	0.048815	24	0.045191	34.5	0.012675	45	0.007388
14	0.047762	24.5	0.043746	35	0.012177	45.5	0.007238

14.5	0.046653	25	0.042301	35.5	0.011678	46	0.007088
15	0.046432	25.5	0.04011	36	0.011179	46.5	0.007038
15.5	0.047492	26	0.037919	36.5	0.010856	47	0.006989
16	0.048552	26.5	0.035377	37	0.010532	47.5	0.006939
16.5	0.04876	27	0.032835	37.5	0.010209	48	0.00689
17	0.048967	27.5	0.030491	38	0.009885	48.5	0.006789
17.5	0.047913	28	0.028147	38.5	0.009635	49	0.006688
18	0.046858	28.5	0.026149	39	0.009385	49.5	0.006587
18.5	0.044392	29	0.024151	39.5	0.009134	50	0.006486
19	0.041925	29.5	0.022507	40	0.008884		
19.5	0.039679	30	0.020862	40.5	0.008735		
20	0.037433	30.5	0.019688	41	0.008585		

Table (3-84): The cross sections after interpolation for $^{88}Mo(n,n)^{88}Mo$ reaction.

n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)
10	0.599465	20.5	0.149248	31	0.038417	41.5	0.019115
10.5	0.51131	21	0.135516	31.5	0.036372	42	0.018666
11	0.441874	21.5	0.125564	32	0.034327	42.5	0.018567
11.5	0.386268	22	0.115611	32.5	0.032881	43	0.018468
12	0.340558	22.5	0.109143	33	0.031435	43.5	0.01837
12.5	0.301733	23	0.102675	33.5	0.02999	44	0.018271
13	0.276872	23.5	0.097703	34	0.028544	44.5	0.017796
13.5	0.251015	24	0.092731	34.5	0.027646	45	0.017321
14	0.239068	24.5	0.08855	35	0.026748	45.5	0.016846
14.5	0.224151	25	0.084369	35.5	0.02585	46	0.016371
15	0.223156	25.5	0.079836	36	0.024952	46.5	0.016472
15.5	0.224143	26	0.075303	36.5	0.024427	47	0.016572
16	0.22513	26.5	0.070421	37	0.023902	47.5	0.016672
16.5	0.226605	27	0.06554	37.5	0.023377	48	0.016772
17	0.228079	27.5	0.061102	38	0.022852	48.5	0.016523
17.5	0.221023	28	0.056664	38.5	0.022255	49	0.016273
18	0.213966	28.5	0.053024	39	0.021657	49.5	0.016024
18.5	0.202307	29	0.049384	39.5	0.02106	50	0.015775
19	0.190648	29.5	0.045945	40	0.020462		
19.5	0.176814	30	0.042506	40.5	0.020013		
20	0.16298	30.5	0.040461	41	0.019564		

Table (3-85): The cross sections after interpolation for $^{89}Mo(n,n)^{89}Mo$ reaction.

n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)
10	206.1765	20.5	79.43858	31	94.49109	41.5	75.12695
10.5	216.2616	21	82.15276	31.5	93.74715	42	74.29405
11	218.534	21.5	84.80749	32	93.00322	42.5	73.54973
11.5	210.8717	22	87.46222	32.5	92.05097	43	72.80542
12	195.8336	22.5	89.96652	33	91.09872	43.5	72.0611
12.5	178.9804	23	92.47082	33.5	90.14647	44	71.31678
13	162.9989	23.5	93.99953	34	89.19422	44.5	70.7167
13.5	148.2851	24	95.52823	34.5	88.19724	45	70.11662
14	135.3759	24.5	96.20375	35	87.20026	45.5	69.51653
14.5	124.3464	25	96.87927	35.5	86.20328	46	68.91645
15	114.6669	25.5	97.23957	36	85.2063	46.5	68.66763
15.5	106.7323	26	97.59987	36.5	84.19835	47	68.41882
16	98.79769	26.5	97.62662	37	83.19039	47.5	68.17
16.5	92.72318	27	97.65336	37.5	82.18244	48	67.92118
17	86.64867	27.5	97.57146	38	81.17448	48.5	67.8912
17.5	82.74753	28	97.48957	38.5	80.28727	49	67.86121
18	78.8464	28.5	97.18099	39	79.40007	49.5	67.83123
18.5	77.27392	29	96.87241	39.5	78.51286	50	67.80124
19	75.70145	29.5	96.42568	40	77.62565		
19.5	76.21292	30	95.97895	40.5	76.79275		
20	76.7244	30.5	95.23502	41	75.95985		

Table (3-86): The cross sections after interpolation for $^{90}Mo(n,n)^{90}Mo$ reaction.

n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)
10	3.635822	20.5	0.995911	31	0.305547	41.5	0.121732
10.5	3.426837	21	0.961389	31.5	0.28389	42	0.118738
11	3.196722	21.5	0.932248	32	0.262232	42.5	0.116994
11.5	2.96381	22	0.903107	32.5	0.248034	43	0.115251
12	2.744848	22.5	0.870834	33	0.233835	43.5	0.113507
12.5	2.528024	23	0.838561	33.5	0.219637	44	0.111764
13	2.326539	23.5	0.805516	34	0.205438	44.5	0.109771
13.5	2.142865	24	0.772471	34.5	0.196475	45	0.107779
14	1.966334	24.5	0.738169	35	0.187511	45.5	0.105786
14.5	1.815415	25	0.703866	35.5	0.178547	46	0.103793
15	1.672657	25.5	0.667366	36	0.169584	46.5	0.102546
15.5	1.561145	26	0.630865	36.5	0.163851	47	0.101299
16	1.449633	26.5	0.591739	37	0.158118	47.5	0.100052
16.5	1.369942	27	0.552612	37.5	0.152385	48	0.098805
17	1.290251	27.5	0.515377	38	0.146652	48.5	0.09756
17.5	1.232874	28	0.478142	38.5	0.142668	49	0.096314

18	1.175496	28.5	0.443351	39	0.138683	49.5	0.095069
18.5	1.136006	29	0.40856	39.5	0.134699	50	0.093823
19	1.096516	29.5	0.378711	40	0.130714		
19.5	1.063474	30	0.348862	40.5	0.12772		
20	1.030432	30.5	0.327205	41	0.124726		

Table (3-87): The cross sections after interpolation for $^{91}Mo(n,n)^{91}Mo$ reaction.

n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)
10	32.02065	20.5	11.53113	31	68.11413	41.5	61.28825
10.5	37.50524	21	12.73351	31.5	68.44036	42	60.84032
11	40.08549	21.5	15.39461	32	68.76659	42.5	60.44382
11.5	39.72706	22	18.05572	32.5	68.57337	43	60.04731
12	37.19147	22.5	21.92757	33	68.38014	43.5	59.65081
12.5	33.32214	23	25.79941	33.5	68.18691	44	59.2543
13	29.00171	23.5	30.35604	34	67.99369	44.5	59.03432
13.5	24.85978	24	34.91266	34.5	67.54229	45	58.81433
14	21.15709	24.5	39.42771	35	67.0909	45.5	58.59435
14.5	18.10073	25	43.94276	35.5	66.6395	46	58.37436
15	15.71642	25.5	47.85307	36	66.1881	46.5	58.25259
15.5	14.17749	26	51.76339	36.5	65.73031	47	58.13083
16	12.63856	26.5	54.82703	37	65.27251	47.5	58.00906
16.5	11.8216	27	57.89067	37.5	64.81471	48	57.88729
17	11.00463	27.5	60.1791	38	64.35691	48.5	57.91123
17.5	10.56726	28	62.46753	38.5	63.92569	49	57.93517
18	10.1299	28.5	63.99611	39	63.49447	49.5	57.95911
18.5	9.984371	29	65.52468	39.5	63.06324	50	57.98305
19	9.838846	29.5	66.49318	40	62.63202		
19.5	10.0838	30	67.46167	40.5	62.1841		
20	10.32875	30.5	67.7879	41	61.73617		

Table (3-88): The cross sections after interpolation for $^{92}Mo(n,n)^{92}Mo$ reaction.

n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)
10	0.000697	20.5	2.220122	31	0.823011	41.5	0.281703
10.5	0.003151	21	3.05855	31.5	0.75684	42	0.274361
11	0.010098	21.5	3.035905	32	0.690669	42.5	0.268906
11.5	0.022631	22	3.01326	32.5	0.647872	43	0.263451
12	0.044237	22.5	2.834102	33	0.605076	43.5	0.257996
12.5	0.072834	23	2.654945	33.5	0.56228	44	0.252541
13	0.106078	23.5	2.449764	34	0.519483	44.5	0.248121
13.5	0.142205	24	2.244584	34.5	0.493013	45	0.243701

14	0.185354	24.5	2.089004	35	0.466543	45.5	0.23928
14.5	0.22969	25	1.933425	35.5	0.440073	46	0.23486
15	0.280993	25.5	1.814189	36	0.413604	46.5	0.231248
15.5	0.344803	26	1.694954	36.5	0.397029	47	0.227636
16	0.408613	26.5	1.589364	37	0.380455	47.5	0.224024
16.5	0.499003	27	1.483774	37.5	0.363881	48	0.220412
17	0.589393	27.5	1.389296	38	0.347307	48.5	0.21748
17.5	0.701894	28	1.294818	38.5	0.336412	49	0.214548
18	0.814394	28.5	1.206863	39	0.325517	49.5	0.211616
18.5	0.951227	29	1.118907	39.5	0.314622	50	0.208684
19	1.08806	29.5	1.03713	40	0.303728		
19.5	1.234877	30	0.955352	40.5	0.296386		
20	1.381695	30.5	0.889182	41	0.289044		

Table (3-89): The cross sections after interpolation for $^{93}Mo(n,n)^{93}Mo$ reaction.

n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)
10	0.001815	20.5	14.1387	31	58.36257	41.5	53.10139
10.5	0.006019	21	19.96859	31.5	57.9471	42	52.68052
11	0.013951	21.5	26.64171	32	57.53162	42.5	52.61553
11.5	0.023954	22	33.31482	32.5	57.29297	43	52.55054
12	0.035013	22.5	38.65283	33	57.05432	43.5	52.48555
12.5	0.046977	23	43.99083	33.5	56.81567	44	52.42056
13	0.05791	23.5	47.58503	34	56.57702	44.5	52.1482
13.5	0.070565	24	51.17923	34.5	56.47982	45	51.87585
14	0.089875	24.5	53.45962	35	56.38261	45.5	51.60349
14.5	0.108991	25	55.74002	35.5	56.28541	46	51.33114
15	0.136254	25.5	56.82655	36	56.1882	46.5	51.2804
15.5	0.163972	26	57.91307	36.5	56.03573	47	51.22966
16	0.19169	26.5	58.59997	37	55.88327	47.5	51.17892
16.5	0.217412	27	59.28686	37.5	55.7308	48	51.12819
17	0.243133	27.5	59.46204	38	55.57833	48.5	51.1977
17.5	0.27706	28	59.63722	38.5	55.27475	49	51.26721
18	0.310986	28.5	59.63344	39	54.97117	49.5	51.33673
18.5	1.028195	29	59.62966	39.5	54.66759	50	51.40624
19	1.745404	29.5	59.41159	40	54.364		
19.5	5.027113	30	59.19352	40.5	53.94313		
20	8.308821	30.5	58.77805	41	53.52226		

Table (3-90): The cross sections after interpolation for $^{94}Mo(n,n)^{94}Mo$ reaction.

n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)
10	5.89E-10	20.5	0.259533	31	0.822116	41.5	0.317548
10.5	7.40E-09	21	0.465687	31.5	0.757335	42	0.310614
11	5.17E-08	21.5	0.816172	32	0.692555	42.5	0.304669
11.5	2.25E-07	22	1.166658	32.5	0.652025	43	0.298724
12	6.77E-07	22.5	1.432835	33	0.611496	43.5	0.29278
12.5	1.78E-06	23	1.699013	33.5	0.570966	44	0.286835
13	4.07E-06	23.5	1.813939	34	0.530436	44.5	0.281875
13.5	1.01E-05	24	1.928865	34.5	0.507843	45	0.276916
14	2.71E-05	24.5	1.916273	35	0.485251	45.5	0.271956
14.5	7.18E-05	25	1.90368	35.5	0.462658	46	0.266996
15	0.000179	25.5	1.827317	36	0.440065	46.5	0.263776
15.5	0.000513	26	1.750954	36.5	0.42452	47	0.260556
16	0.000848	26.5	1.652262	37	0.408975	47.5	0.257336
16.5	0.001843	27	1.55357	37.5	0.393429	48	0.254116
17	0.002839	27.5	1.449306	38	0.377884	48.5	0.249648
17.5	0.005023	28	1.345042	38.5	0.368001	49	0.24518
18	0.007207	28.5	1.240228	39	0.358118	49.5	0.240713
18.5	0.01183	29	1.135414	39.5	0.348235	50	0.236245
19	0.016453	29.5	1.043545	40	0.338352		
19.5	0.034916	30	0.951676	40.5	0.331417		
20	0.053379	30.5	0.886896	41	0.324483		

Table (3-91): The cross sections after interpolation for $^{95}Mo(n,n)^{95}Mo$ reaction.

n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)	n - energy MeV	Cross section (mb)
10	8.01E-07	20.5	0.479134	31	0.659319	41.5	0.317033
10.5	1.79E-06	21	0.28212	31.5	0.620904	42	0.310694
11	3.80E-06	21.5	0.604338	32	0.582488	42.5	0.304478
11.5	7.54E-06	22	0.926557	32.5	0.557737	43	0.298261
12	1.41E-05	22.5	1.10534	33	0.532986	43.5	0.292045
12.5	2.47E-05	23	1.284123	33.5	0.508236	44	0.285829
13	4.06E-05	23.5	1.343821	34	0.483485	44.5	0.282699
13.5	6.67E-05	24	1.40352	34.5	0.466717	45	0.279569
14	0.000106	24.5	1.39575	35	0.449949	45.5	0.276439
14.5	0.000187	25	1.38798	35.5	0.433181	46	0.273309
15	0.000421	25.5	1.331435	36	0.416414	46.5	0.268783
15.5	0.002557	26	1.274891	36.5	0.404897	47	0.264258
16	0.004694	26.5	1.189955	37	0.39338	47.5	0.259732
16.5	0.025278	27	1.105019	37.5	0.381863	48	0.255207
17	0.045861	27.5	1.037922	38	0.370347	48.5	0.252147
17.5	0.127236	28	0.970826	38.5	0.361773	49	0.249088

18	0.208611	28.5	0.912976	39	0.353199	49.5	0.246028
18.5	0.306133	29	0.855126	39.5	0.344625	50	0.242969
19	0.403654	29.5	0.795638	40	0.336051		
19.5	0.539902	30	0.736151	40.5	0.329712		
20	0.676149	30.5	0.697735	41	0.323372		

Table (3-92): The cross sections after interpolation for ^{96}Mo(n,n)^{96}Mo reaction.

n - energy MeV	**Cross section (mb)**	**n - energy MeV**	**Cross section (mb)**	**n - energy MeV**	**Cross section (mb)**	**n - energy MeV**	**Cross section (mb)**
10	6.84E-11	20.5	1.53841	31	0.661499	41.5	0.255426
10.5	2.68E-10	21	3.044718	31.5	0.607391	42	0.249367
11	8.92E-10	21.5	3.227538	32	0.553284	42.5	0.244313
11.5	2.66E-09	22	3.410358	32.5	0.521525	43	0.239259
12	7.12E-09	22.5	3.302949	33	0.489767	43.5	0.234206
12.5	1.71E-08	23	3.195539	33.5	0.458008	44	0.229152
13	3.89E-08	23.5	2.922988	34	0.42625	44.5	0.225527
13.5	8.29E-08	24	2.650437	34.5	0.407627	45	0.221902
14	1.75E-07	24.5	2.389965	35	0.389005	45.5	0.218278
14.5	3.72E-07	25	2.129494	35.5	0.370382	46	0.214653
15	8.49E-07	25.5	1.932122	36	0.35176	46.5	0.211775
15.5	3.59E-06	26	1.734751	36.5	0.340809	47	0.208897
16	6.34E-06	26.5	1.570802	37	0.329859	47.5	0.20602
16.5	8.73E-05	27	1.406853	37.5	0.318909	48	0.203142
17	0.000168	27.5	1.279413	38	0.307959	48.5	0.200386
17.5	0.001353	28	1.151972	38.5	0.29937	49	0.197631
18	0.002539	28.5	1.045504	39	0.290782	49.5	0.194876
18.5	0.007783	29	0.939036	39.5	0.282193	50	0.19212
19	0.013027	29.5	0.854376	40	0.273604		
19.5	0.022565	30	0.769715	40.5	0.267545		
20	0.032102	30.5	0.715607	41	0.261486		

(3-7) The Program:

The calculation was represented by the formulas that were extracted from best fitting of available data of neutron yield with corresponding energies with coefficients, using within the MATLAB program, which was designed and based on the type of element and the type of reaction to find a yield neutron for any isotope has mass number between (40-100) at any energy within the (15-50)MeV. When run the program it will appear a window as shown in the figure (3-1), for input the data required such as the atomic number and the mass number of the target and the atomic number of produced nucleus, also the energy of incident particle, where they can input several energies such as (10,30,50) MeV or a range of energies by any interval as (10:0.2:40) which was (Lower energy:interval:Higher energy).

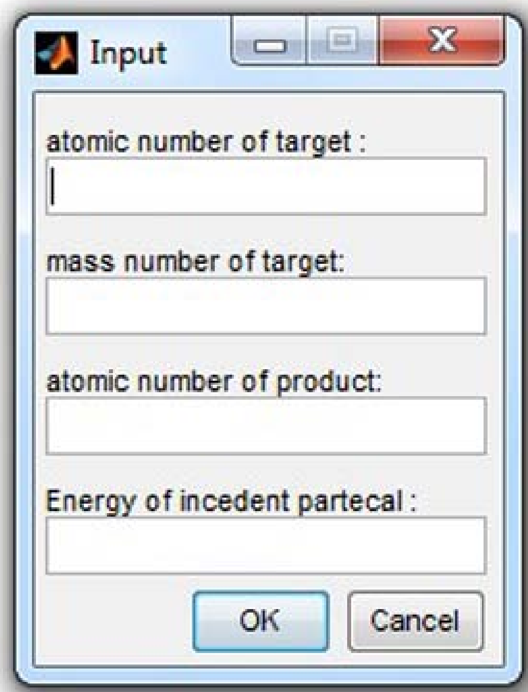


Figure (3-1): The program window to input data.

From this data the program will determine the type of the intended reaction and defines the coefficients for this reaction and then holding the calculations and show the result in the form of a table as shown in figure (3-2).

Energy (MeV)	Neutron Yield (n/10^6 particle)
15.0000	1.8834
15.5000	2.5458
16.0000	2.8438
16.5000	3.0627
17.0000	3.2397
17.5000	3.3887
18.0000	3.5171
18.5000	3.6293
19.0000	3.7284
19.5000	3.8167
20.0000	3.8960

Figure (3-2): The form of the results calculations table

In case if the energy of incident particle which has been introduced that does not exist within the program, the program will display a message tells us (Energy must be between 15-50 MeV) or give numbers of the imagination root. And in case if the reaction which has been introduced that does not exist within the program, the program will display a message tells us (This Reaction Not Found). Figure (3-3) describes the flow chart of the program.

Informed that this program can be developed and its expansion to include a larger number of isotopes of the elements and for the ranges of energy on a larger scale, to become an important source as possible to help us to calculate the yield neutron directly and get this data easily to any energy of particles incident of (α, n) and (p, n) reactions to any isotopes.

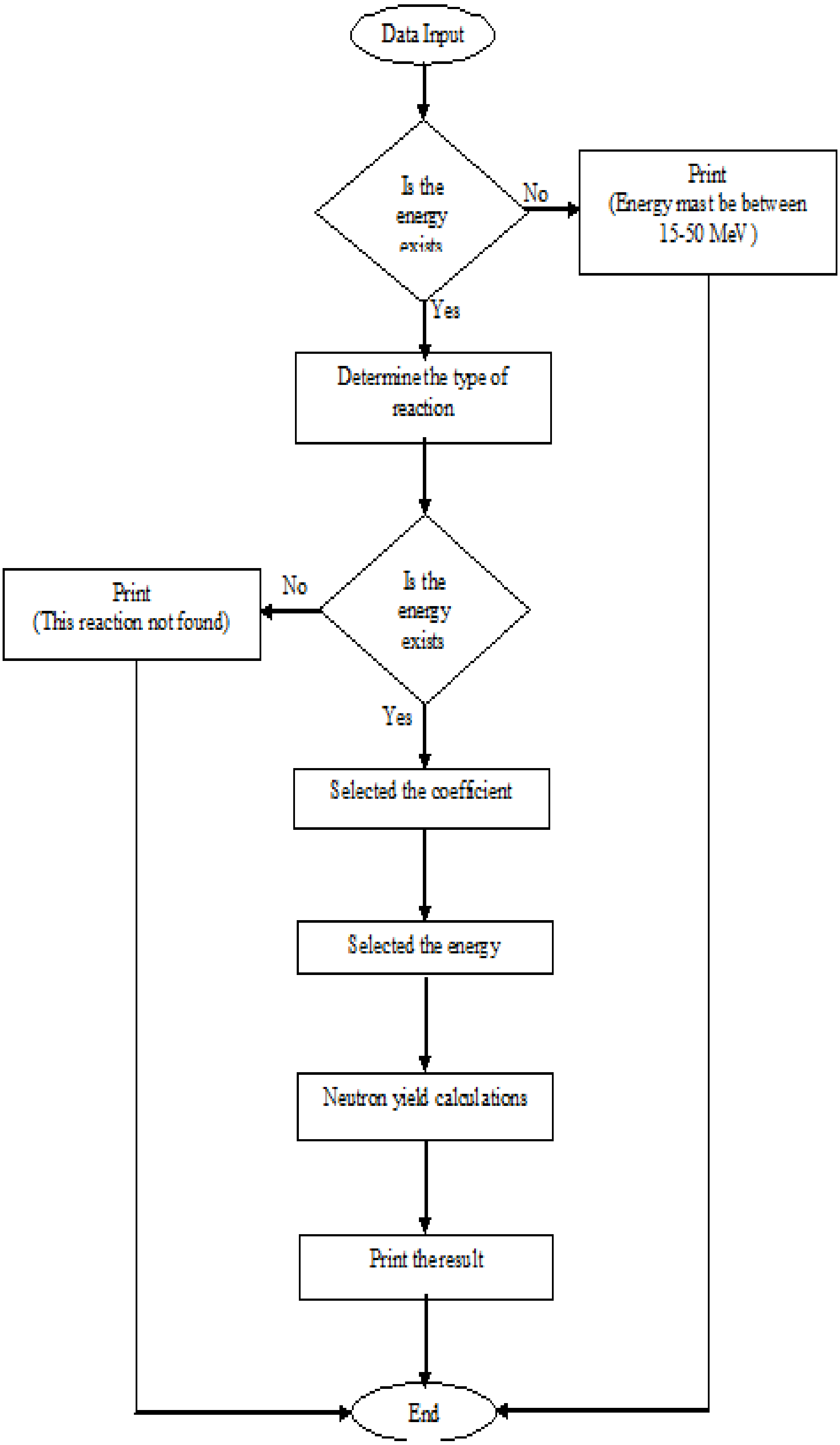


Figure (3-3): Flow chart of program

Chapter Four

Results and Discussion

(4-1) Nuclear Properties:

Table (3-1) represents data for isotopes of the elements that have been studied in this work which includes the atomic mass for available measuring data collected for (α,n), (p,n) and (n,n) reactions, also the abundance, Half-life, and spin with parity. We note from this table there are stable isotopes and others are unstable, and the elements of even atomic number (i.e. even number of proton) are characterized by having a relatively sizable number of stable isotopes.

Tables (3-2) including the Q-value for the neutron emission reactions, in general, we note the Q-value for (α,n) reactions have value of less than (p,n) for all isotopes, and (p,n) reactions have more of positive Q-values, while the (α,n) reactions have a few number of positive Q-values. Threshold energy of (α,n) reactions for most of the isotopes have the largest values than (p,n) reactions, and both the Q-value and Threshold energy of (n,n) reactions for all isotopes are zero, because they are elastic scattering reactions. The results of the calculated Q-values and threshold energies that are shown in table (3-2), are in good agreement with the calculated values which are taken from National Nuclear Data Center (NNDC).

Reduced mass (μ), neutron separation energies (Sn) and the total binding energies (BE) of the targets which were calculated by equations (2-2), (2-7) and (2-5) respectively and were shown in table (3-2). The results of neutron separation energies were very close to data which were obtained from Richard B. Firestone [103]. Also the results of binding energies were in very good agreement with data which were obtained from Audi G. et al.[104]. The neutron separation energies are largest for the nuclei of even - even than the nuclei even-odd or odd-even and odd-odd for all isotopes. While the binding energies for isotopes of the same element of the targets were increased with the increase of the mass number (increase of neutron), in fact which means with the increase of the asymmetry.

(4-2) The Cross Sections:

The neutron cross section is one main property to the production of the neutron source. Usually only neutron emission at an angle of 0° with respect to the charged particle beam is considered. As we have mentioned in chapter 3, we have got the most recent for the cross-section data from TALYS Evaluated Nuclear Data Library (in 1912 for (α,n), (p.n) reactions [105], and in 1910 for (n,n) reactions), These data have been plotted, after spline interpolated and recalculated in fine steps of (0.5)MeV by using Matlab (R2008b) program as following:

(4-2-1) The (α ,n) and (p,n)cross sections:

The cross section with incident alpha particle energy (10-50) MeV for all isotopes, of Ca(α,n)Ti reactions, Ni(α,n)Zn reactions and Zr(α,n)Mo reactions are shown in figures (4-1), (4-2) and (4-3) respectively. And the cross section with incident proton energy (10-50) MeV of Sc(p,n)Ti reactions, Cu(p,n)Zn reactions and Nb(p,n)Mo reactions, are shown in figures (4-4), (4-5) and (4-6) respectively. For target mass number with intermediate region about (A=41-96), these figures show that the cross sections depend on incident particle energy, we note that the range of energy for the highest probabilities of the neutrons production approximately between (10 – 14) MeV, while the most stable range of energy to produce the neutrons located between (15 – 50) MeV. As can be obviously seen the reaction cross sections in this range decrease by the increase of the asymmetry (i.e., with mass number A), for two different groups by the classification of nuclei into (odd-A and even-A.). So we note from these figures that the best area of stability for the probability interaction involving all the curves start at energy approximately 15MeV to 50MeV, and we expect in this region that we have adopted for the calculations to get best results.

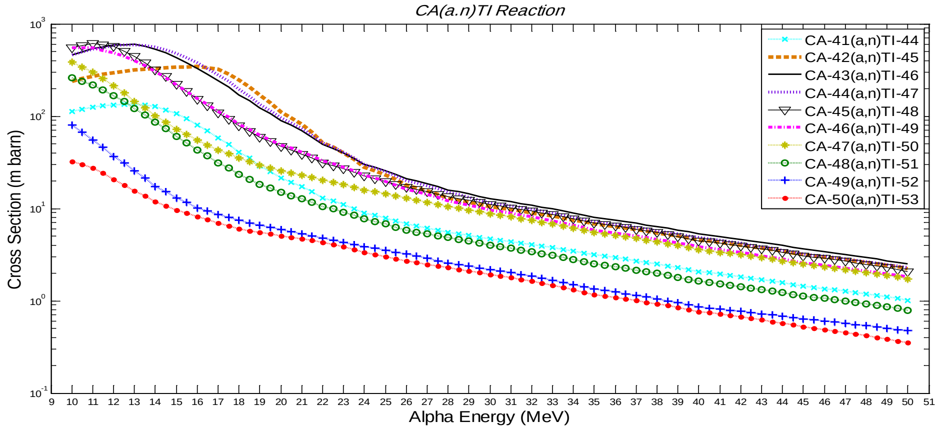


Figure (4-1): Cross sections of Ca(α,n)Ti reactions for Ti isotopes(^{44}Ti-^{53}Ti) after interpolation

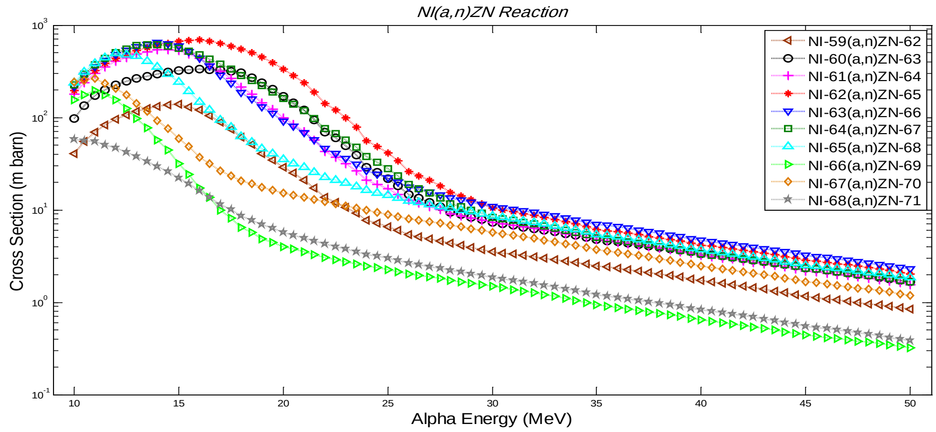


Figure (4-2): Cross sections of Ni(α,n)Zn reactions for Zn isotopes(^{62}Zn-^{71}Zn) after interpolation

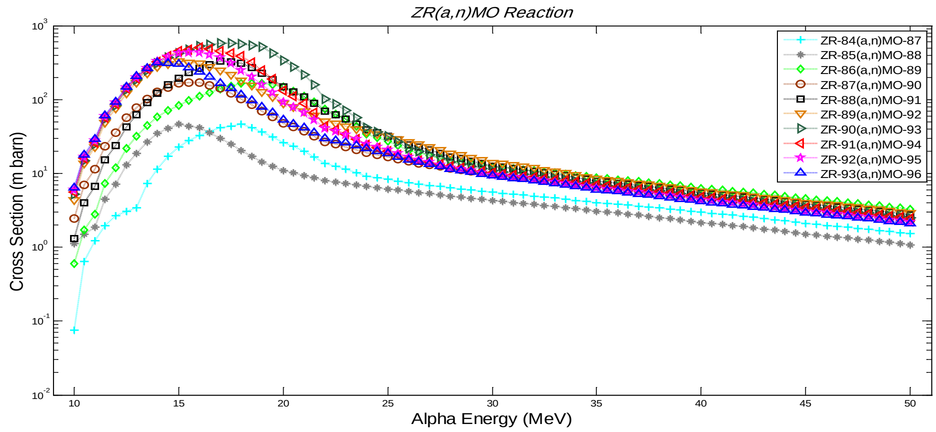


Figure (4-3): Cross sections of Zr(α,n)Mo reactions for Mo isotopes(^{87}Mo-^{96}Mo) after interpolation

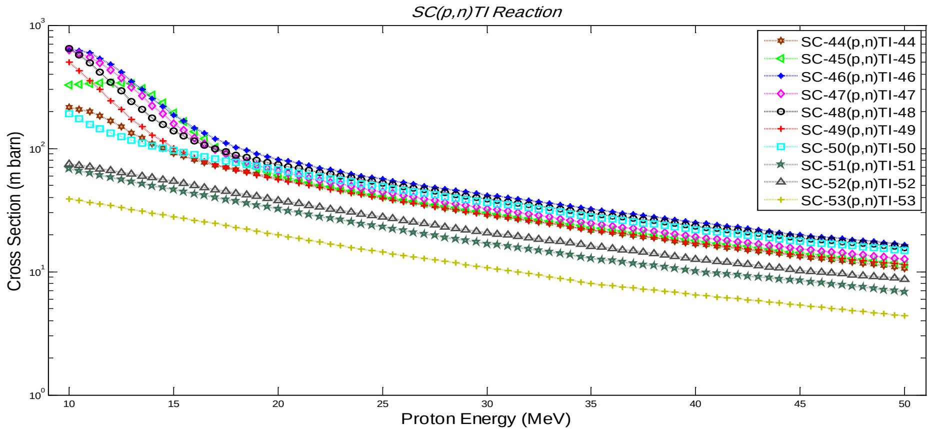


Figure (4-4): Cross sections of Sc(p,n)Ti reactions for Ti isotopes(^{44}Ti-^{53}Ti) after interpolation

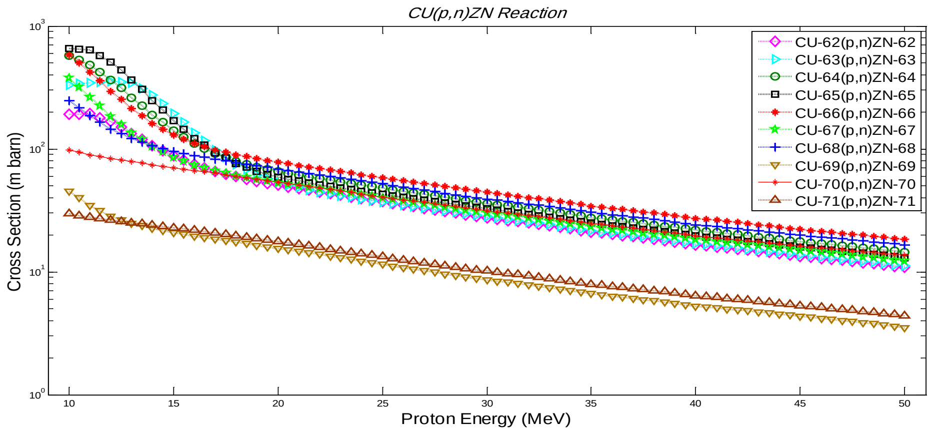


Figure (4-5): Cross sections of Cu(p,n)Zn reactions for Zn isotopes(^{62}Zn-^{71}Zn) after interpolation

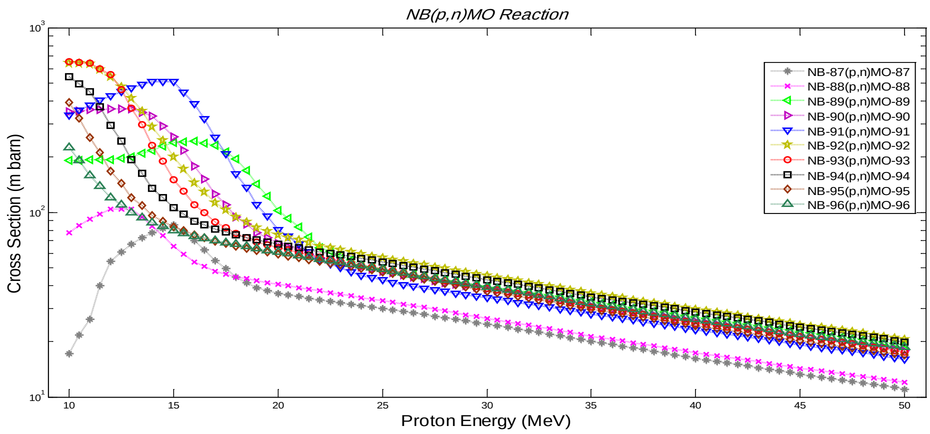


Figure (4-6): Cross sections of Nb(p,n)Mo reactions for Mo isotopes(^{87}Mo-^{96}Mo) after interpolation

(4-2-2) The (n,n)cross section:

The (n,n) reactions are represent the elastic scattering of neutron, and we note from the figures (4-7), (4-8) and (4-9) the (n,n) cross sections are the smallest from (α,n) and (p,n) cross section. It was due to neutral neutron charge that it make interaction with the nucleus which is small as compared with the interactions of charged particles with these nuclei, which was relatively larger.

From figure (4-7), we note there are two groups of isotopes that have maximum of cross section for specific energy of neutron which depended on the average banding energy for one nucleon. The first was the even-even Ti isotopes start with ^{44}Ti then ^{46}Ti, ^{48}Ti, ^{50}Ti and ^{52}Ti, the maximum cross section related to energy range from (25-30)MeV within empirical deviation. The second was even-odd group that have maximum cross section in the range from (20-27) MeV , also depending on binding energy one nucleon, the maximum cross section was for ^{50}Ti , And followed by other isotopes within empirical deviation.

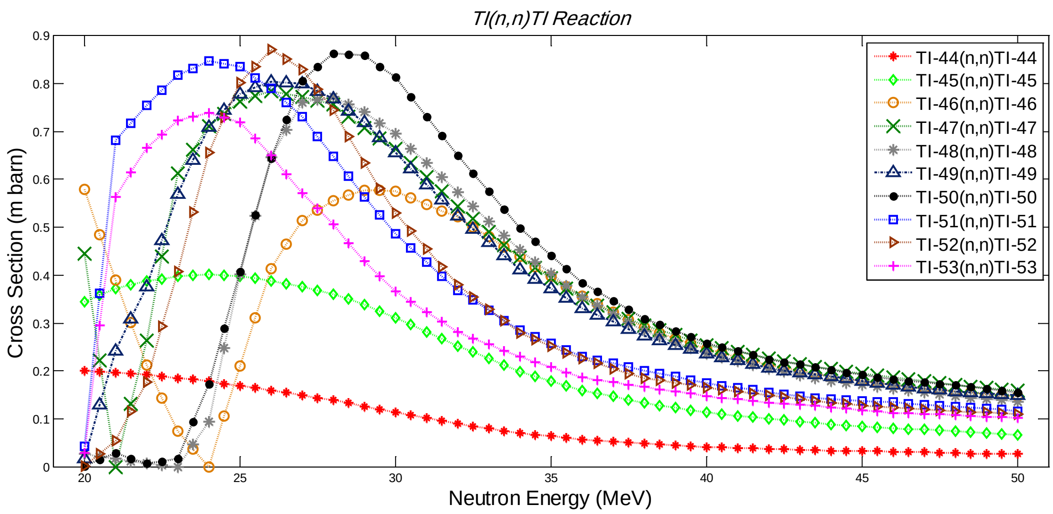


Figure (4-7): Cross sections of Ti(n,n)Ti reactions for Ti isotopes(^{44}Ti-^{53}Ti) after interpolation

We note from figure (4-8) the curves of cross sections, for masses number which less than (66) as ^{62}Zn, ^{63}Zn, ^{64}Zn and ^{65}ZN are change slightly for the energy more than10 MeV, while the curves of cross-sections for other isotopes are start change slightly for the energy more than 20 MeV, and within the empirical deviation.

Except for ^{64}Zn, which is the most abundant isotope and stable, we find that the cross-section at the energy 25 MeV was disappeared as well as the cross section of ^{68}Zn was disappeared too at energy 23 MeV, within the empirical deviation of the values of cross sections published.

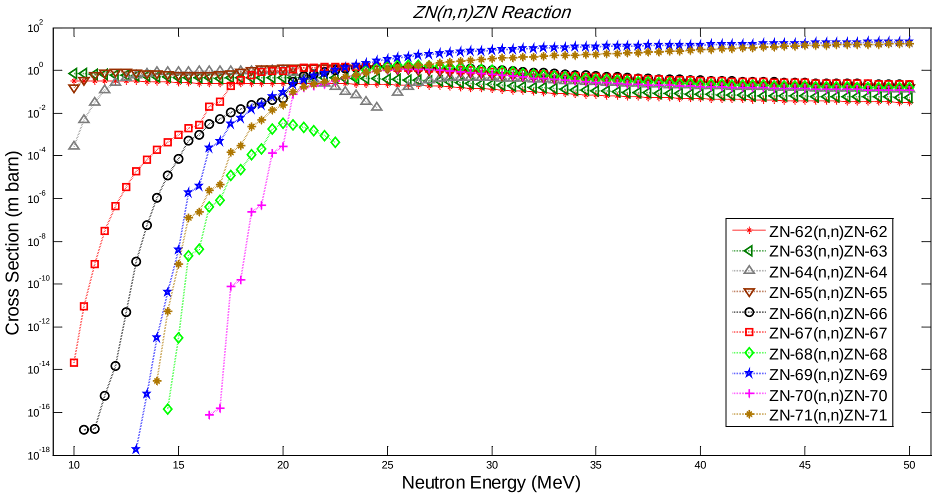


Figure (4-8): Cross sections of Zn(n,n)Zn reactions for Zn isotopes(^{62}Zn-^{71}Zn) after interpolation

From figure (4-9), in generally the carves of cross sections for low masses number are change slightly except the targets which have mass numbers ^{92}Mo, ^{93}Mo, ^{94}Mo, ^{95}Mo and ^{96}Mo. For even-even group we find that the binding energy for one nucleon have clear effect on the cross-sections, we find that the isotopes that have the highest average binding energy it need more energy for the neutron incident in order to the reaction occurs, and decreases with a decrease of mass number, as well as for the group even-odd.

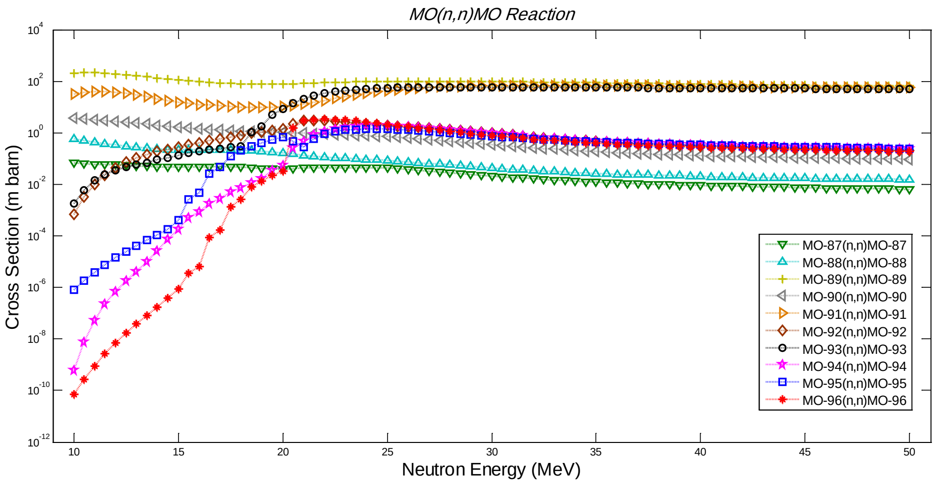


Figure (4-9): Cross sections of Mo(n,n)Mo reactions for Mo isotopes(^{87}Mo-^{96}Mo) after interpolation

(4-3) *The Neutron Yield :*

The target neutron yields from *(α,n)* and *(p,n)* reactions are very important quantity as well as the cross sections in analyzing problems of radiation shielding and criticality safety on spent fuel [34].

Therefore, the target neutron yield for (60) reactions was calculated on the basis of the evaluated *(α,n)* and *(p,n)* reactions from the stopping power of alpha particles and protons that are calculated by using SRIM version 2013 code [107] with cross-sections at corresponding energies from (10 -50) MeV, as shown in tables (3-3) to (3-32) for *(α,n)* reactions and in tables (3-33) to (3-62) for *(p,n)* reactions.

The neutron yields of *(α,n)* and *(p,n)* reactions for all isotopes have been obtained by using computer program (matlab 2008b) and plotted as shown in Figures (4-10) to (4-12) for Ca(α,n)Ti reactions, Ni(α,n)Zn reactions and Zr(α,n)Mo reactions, respectively and in Figures (4-13) to (4-15) for Sc(p,n)Ti reactions , Cu(p,n)Zn reactions and Nb(p,n)Mo reactions, respectively with energy range from (10MeV) to (50MeV) by steps of (0.5MeV).

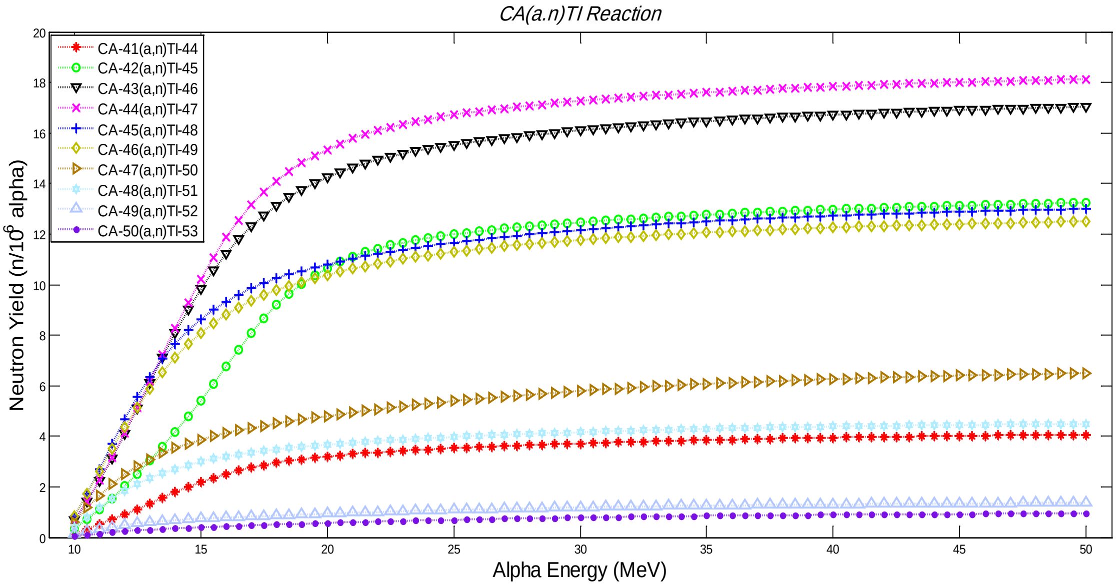


Figure.(4-10): The neutron yield of Ca(α,n)Ti reactions at energy range (10-50)MeV for Ca mass number (41-50)

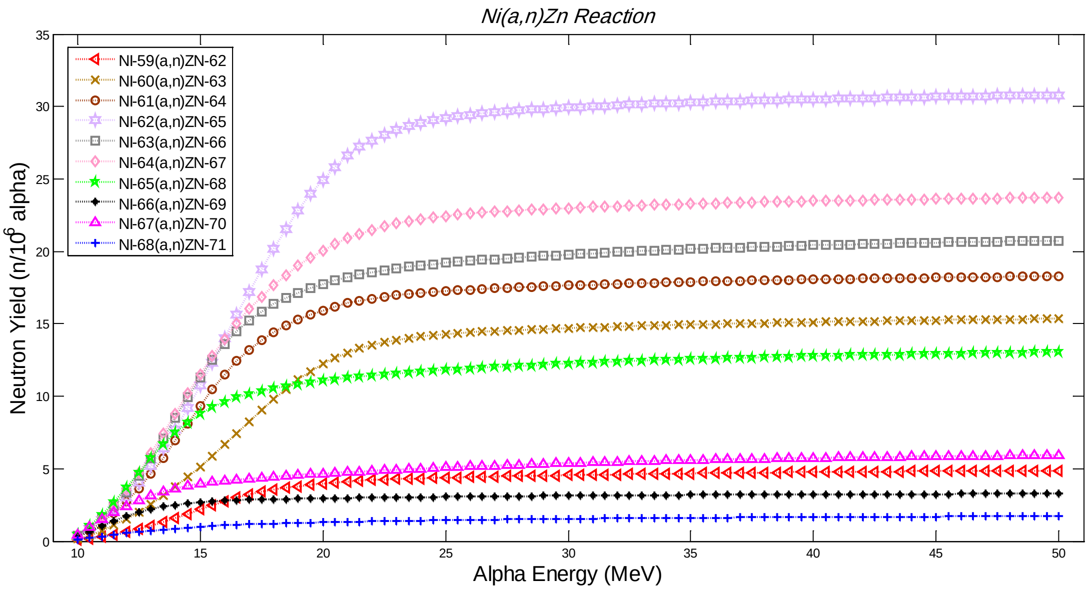


Figure.(4-11): The neutron yield of Ni(α,n)Zn reactions at energy range (10-50)MeV for Ni mass number (44-53)

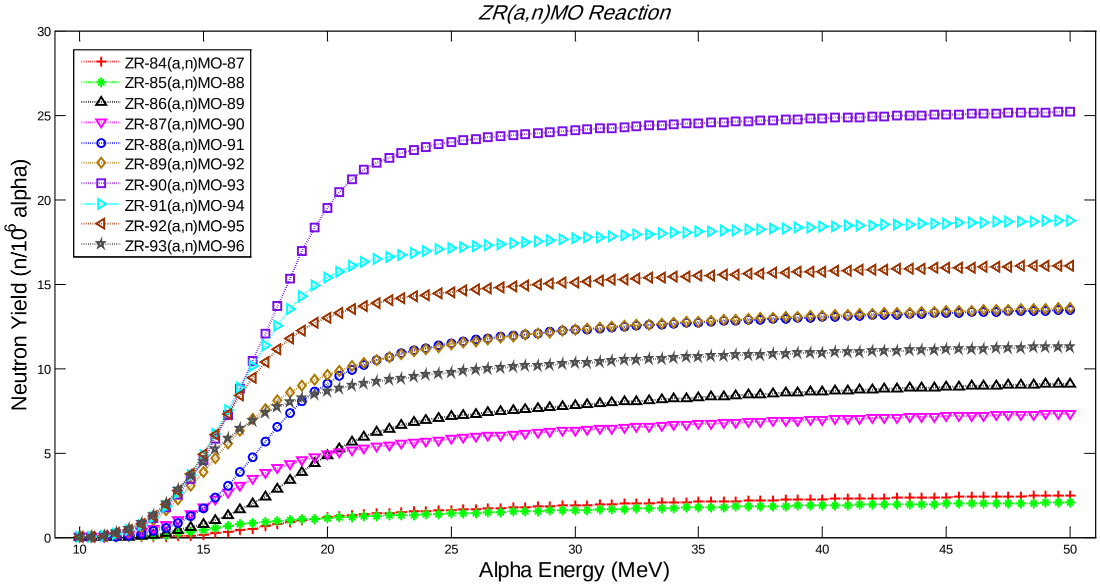


Figure.(4-12): The neutron yield of Zr(α,n)Mo reactions at energy range (10-50)MeV for Zr mass number (84-93)

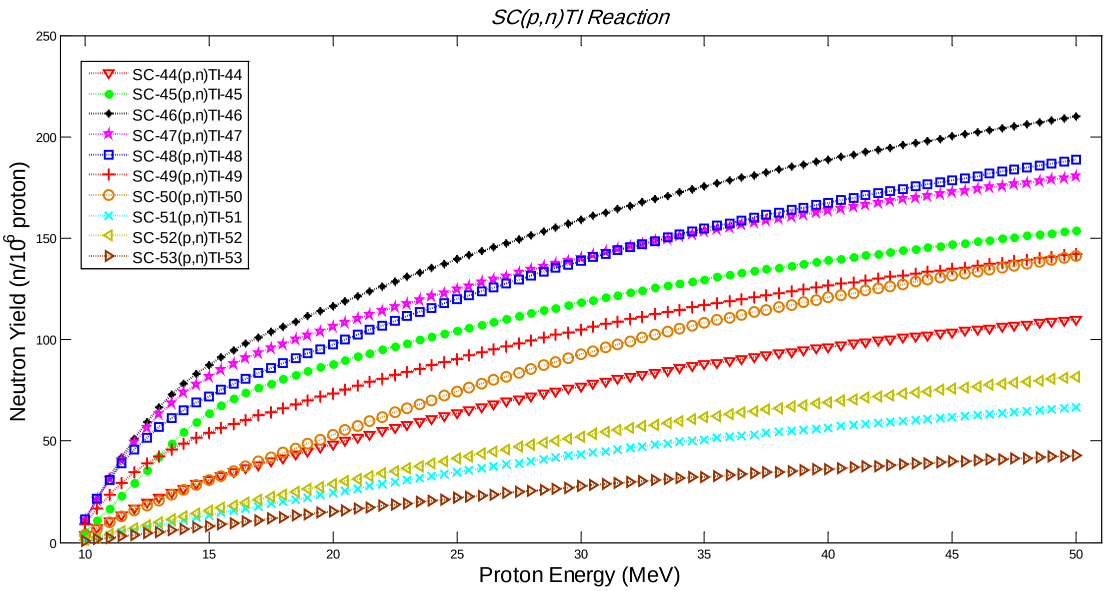


Figure.(4-13): The neutron yield of Sc(p,n)Ti reactions at energy range (10-50)MeV for Sc mass number (44-53)

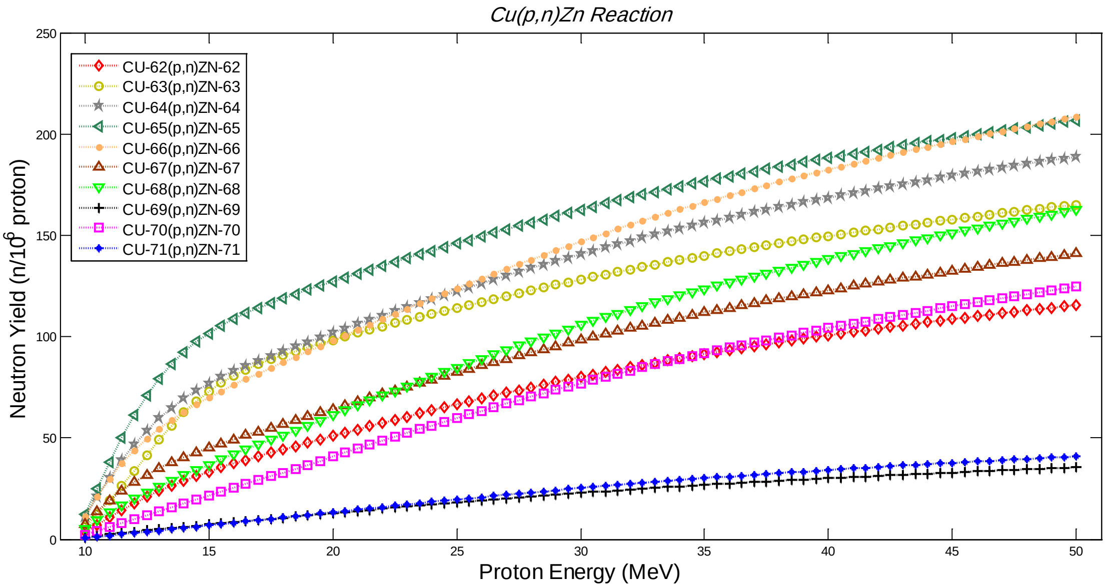


Figure.(4-14): The neutron yield of Cu(p,n)Zn reactions at energy range (10-50)MeV for Cu mass number (62-71)

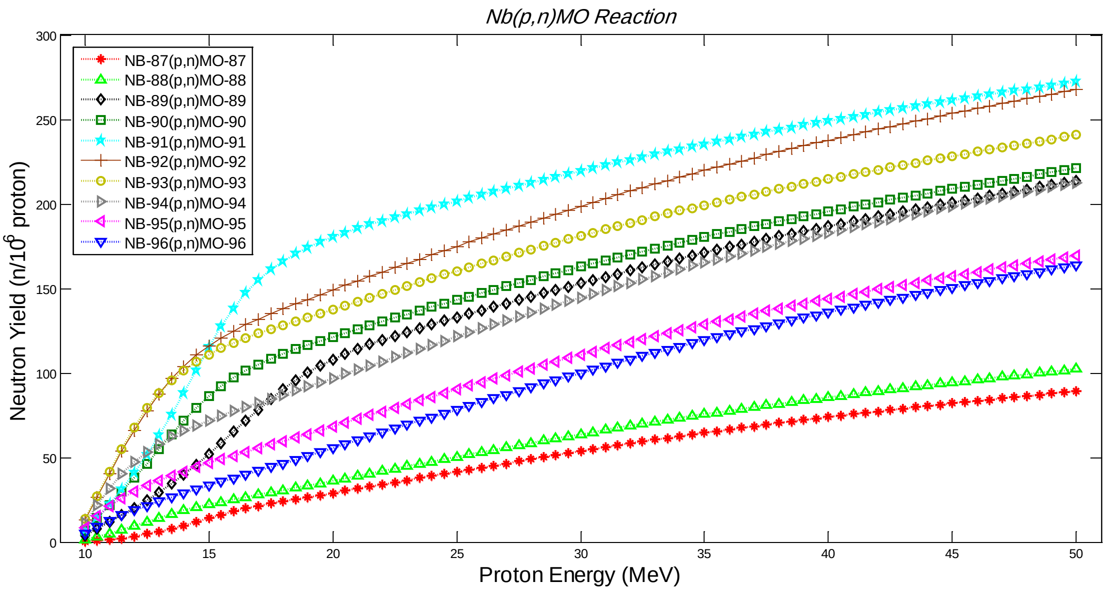


Figure.(4-15): The neutron yield of Nb(p,n)Mo reactions at energy range (10-50)MeV for Nb mass number (87-96)

We note from these figures that the neutron yield increases significantly with the increase of energy for incident alpha particle approximately from (10-20)MeV, then becomes a very small increment for energy range more than 20MeV for all *(α,n)* reactions. While for the incident proton, this increases in yield of neutron is higher and continuous along the energy range (10-50)MeV.

We know increasing the mass number with proven atomic number for the isotopes which means an increase in the number of neutrons and the result will directly affect in the asymmetry energy , that was calculated for the isotopes from $(\frac{(N-Z)^2}{A})$, which we used to extract the empirical formula between the asymmetry and neutron yield, for the incident alpha and proton energies from (10-50) MeV in fine steps of (5 MeV) as shown in figures (4-16) to (4-21) for all *(n,α)* and *(n,p)* reactions.

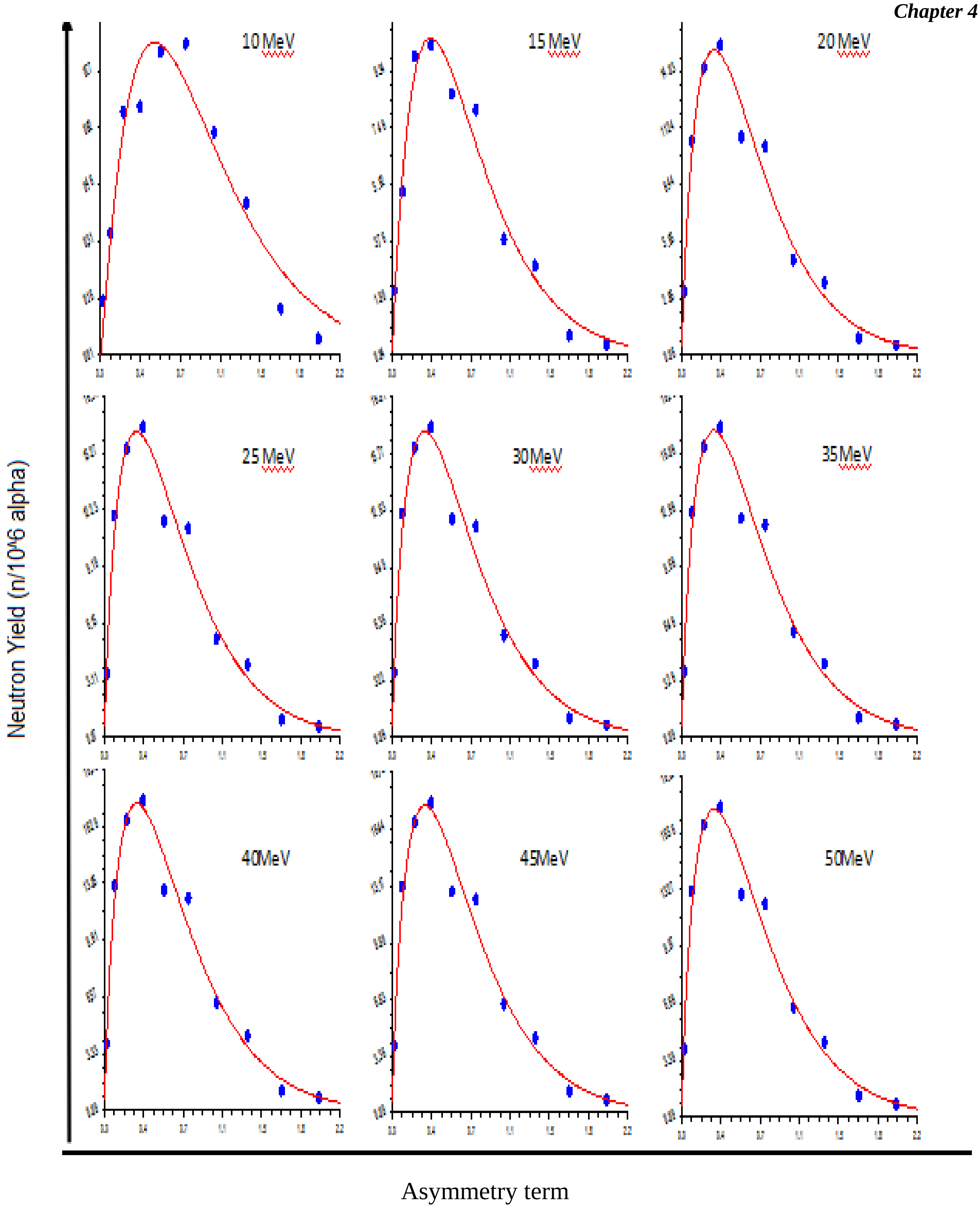


Figure (4-16).The neutron yield with asymmetry for Ca target isotopes of Ca(α,n)Ti reactions for different alpha energies induced reactions at (10 – 50) MeV

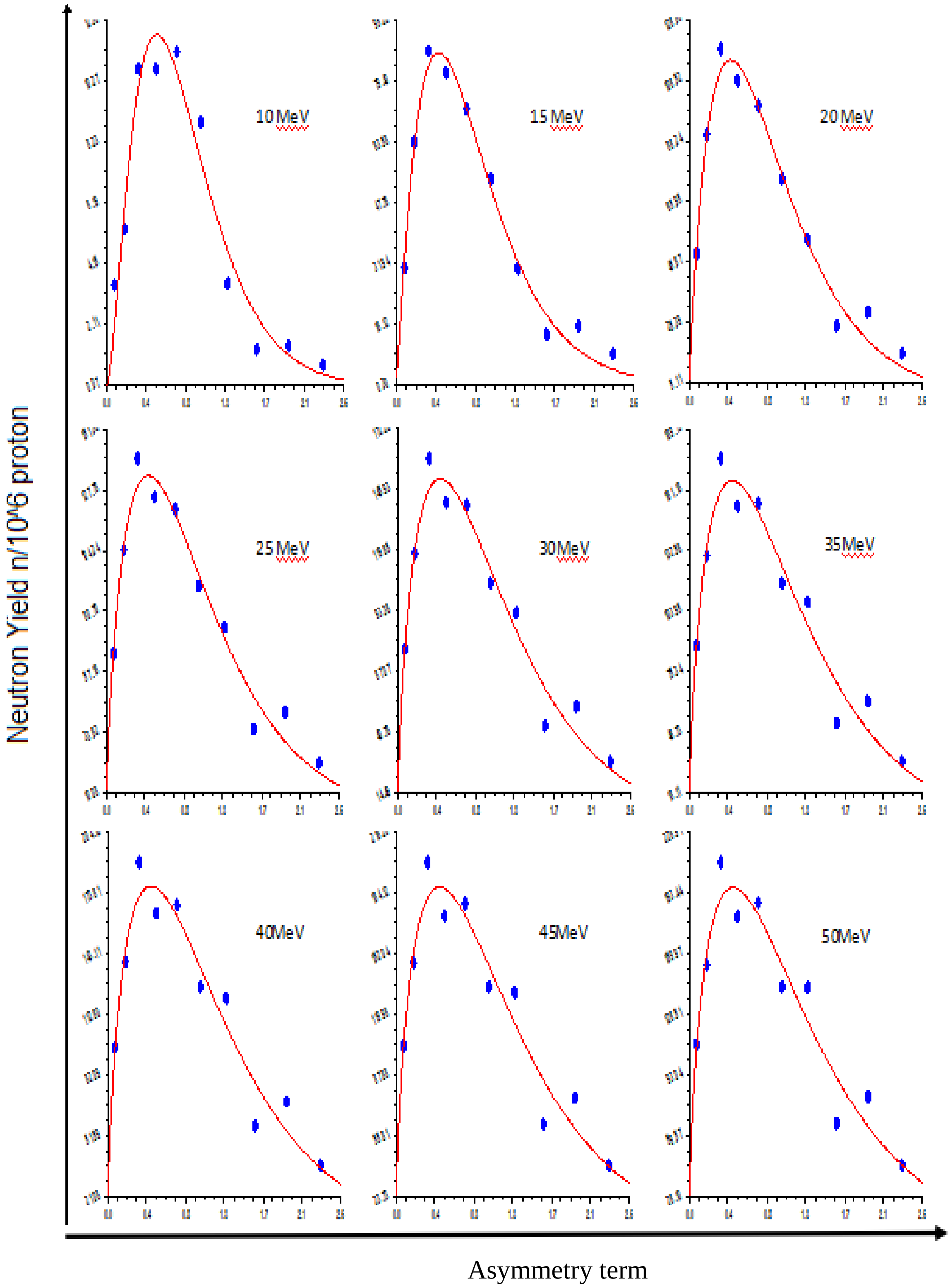


Figure (4-17).The neutron yield with asymmetry for Sc target isotopes of Sc(p,n)Ti reactions for different proton energies induced reactions at (10 – 50) MeV

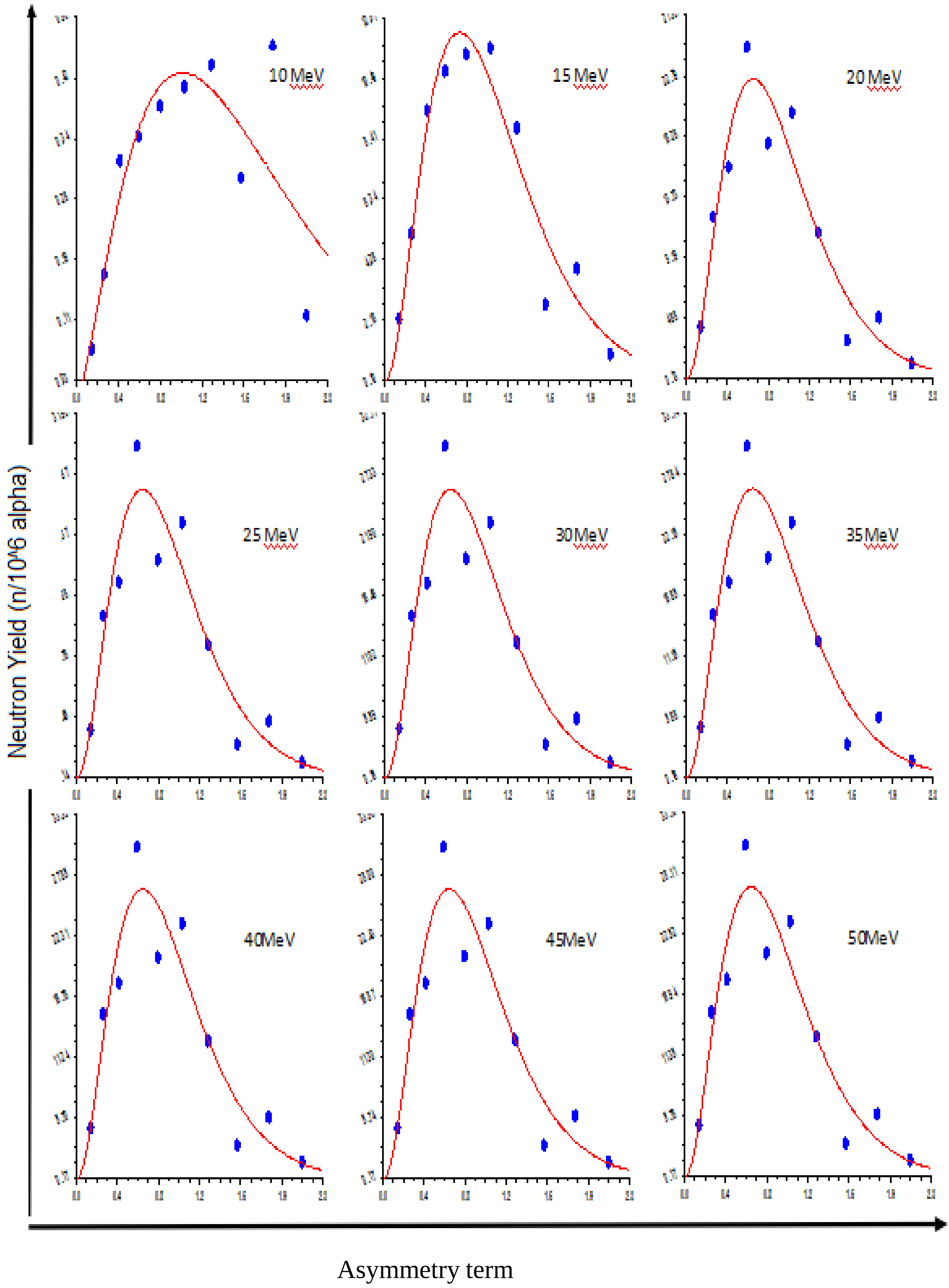


Figure (4-18).The neutron yield with asymmetry for Ni target isotopes of Ni(α,n)Zn reactions for different alpha energies induced reactions at (10 – 50) MeV

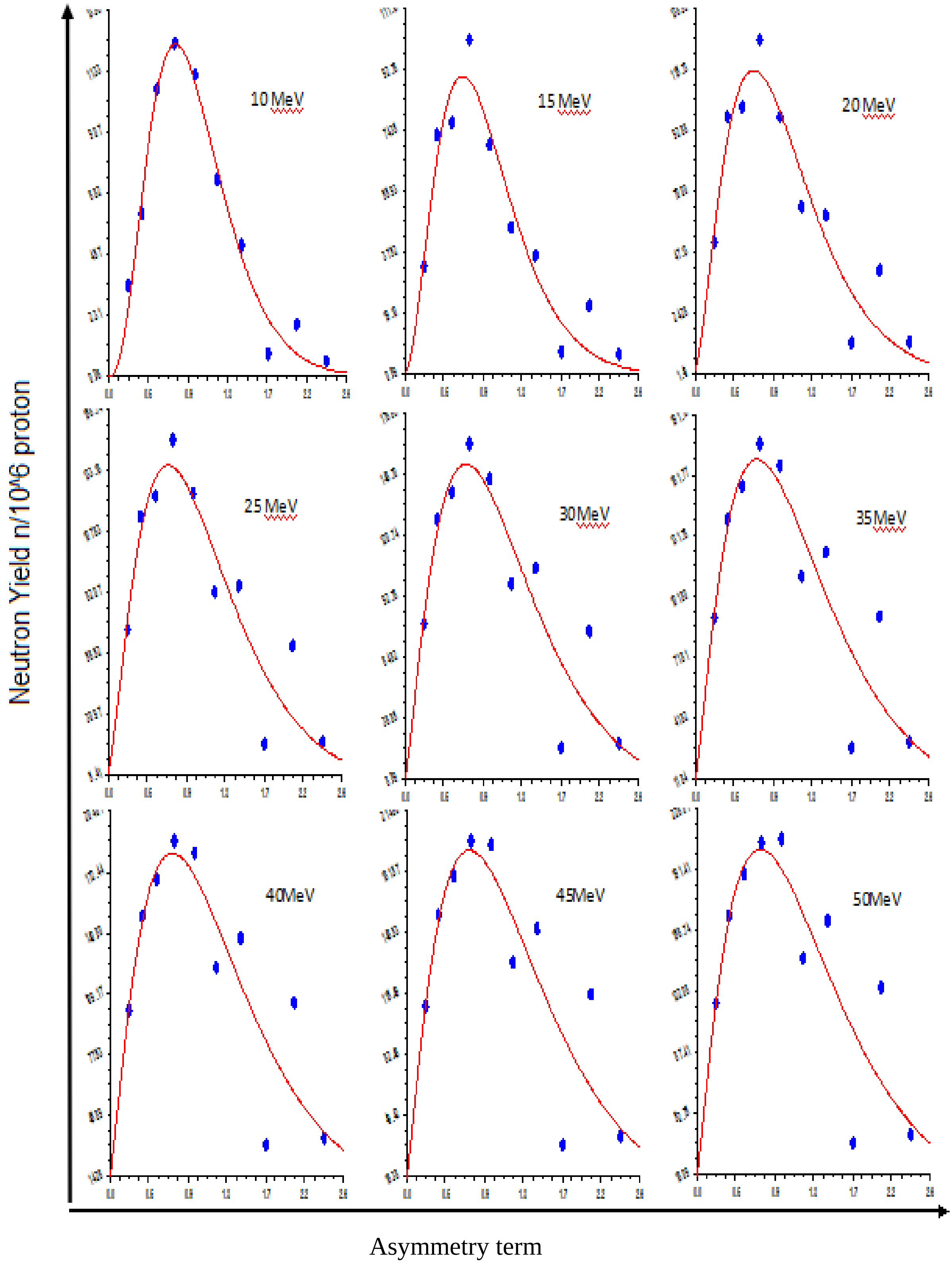


Figure (4-19).The neutron yield with asymmetry for Cu target isotopes of Cu(p,n)Zn reactions for different proton energies induced reactions at (10 – 50) MeV

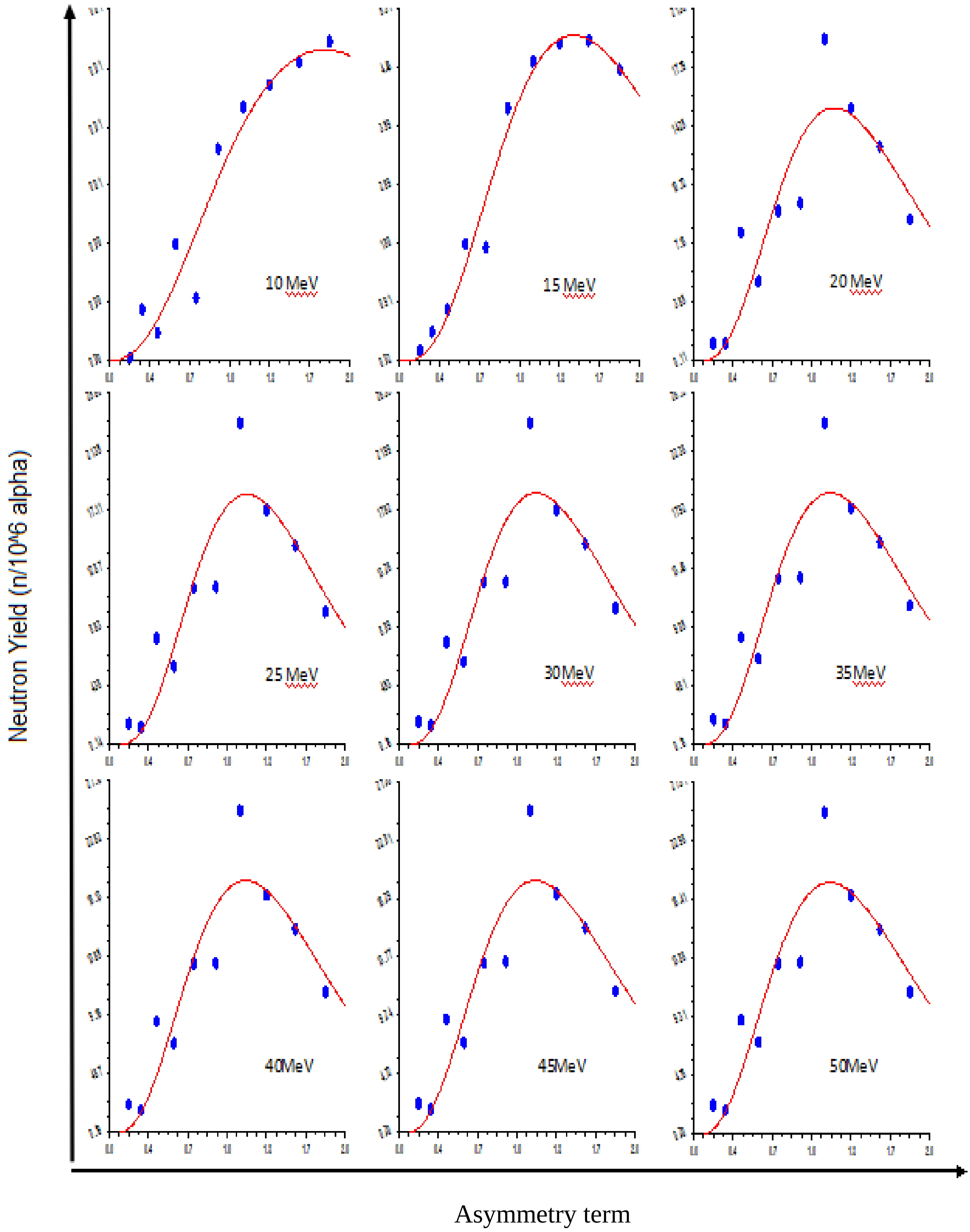


Figure (4-20).The neutron yield with asymmetry for Zr target isotopes of Zr(α,n)Mo Reactions for different alpha energies induced reactions at (10 – 50) MeV

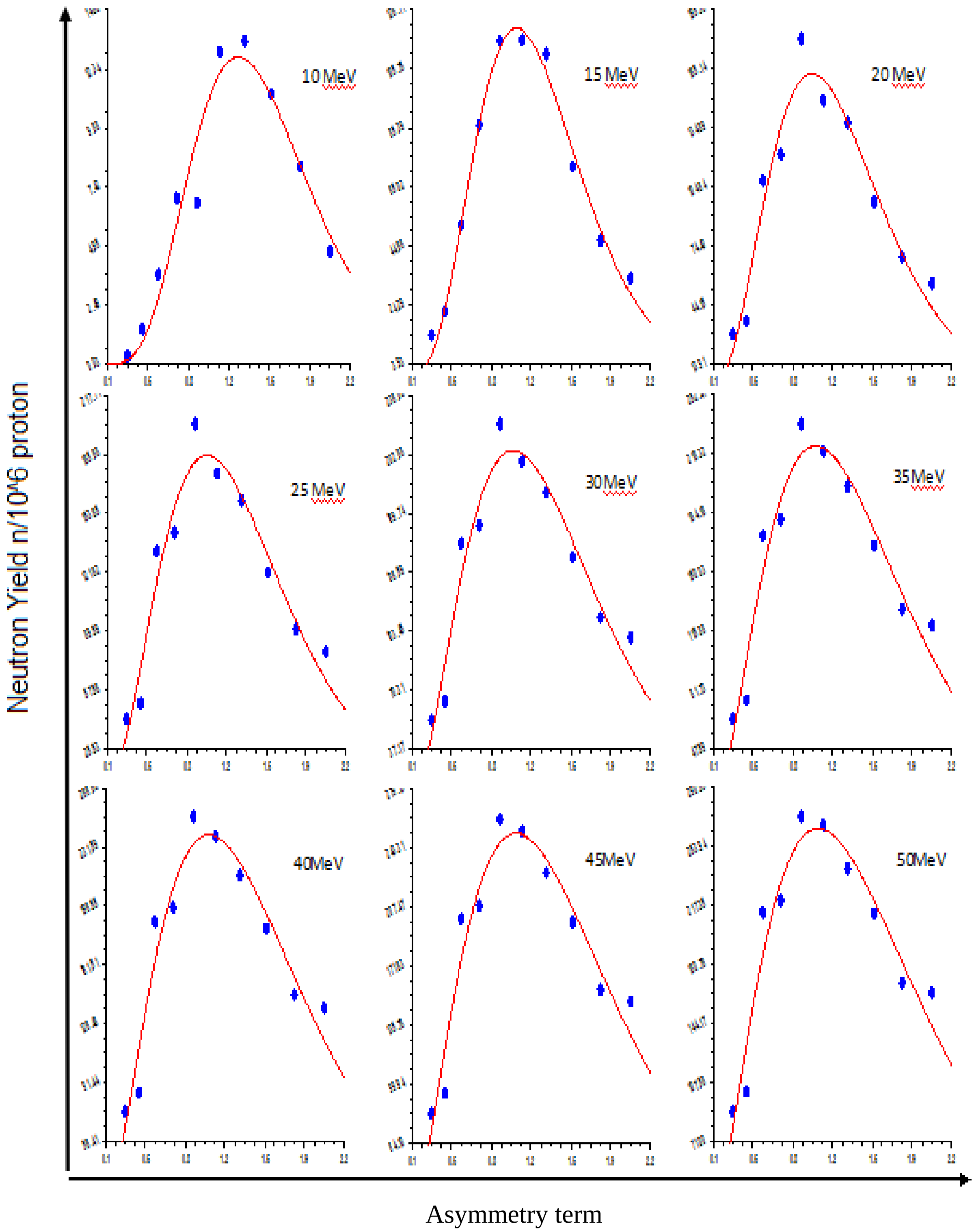


Figure (4-21).The neutron yield with asymmetry for Nb target isotopes of Nb(p,n)Mo reactions for different proton energies induced reactions at (10 – 50) MeV

And the formula that was extracted by best fitted for all these curves and for all reactions as the following:

$$Y = a(b)^{E_S} \times (E_S)^C \ldots\ldots\ldots\ldots\ldots(4-1)$$

Where (Y) is neutron yield, (E_s) is asymmetry term ($E_S = (A - 2Z)^2/A$), and a, b and c represents the initial coefficients by different values for each energy and lasted with coefficient of determination (r^2) in tables (4-1) to (4-6) for all reactions.

Table (4-1): Initial coefficients for Ca(α,n)Ti reactions at energy (10-50)MeV with coefficient of determination (r^2).

Alpha energy MeV	*a*	*b*	*c*	r^2
10	5.847246	1.02E-01	1.13795	0.928
15	7.72E+01	6.27E-02	9.83E-01	0.974
20	9.68E+01	6.11E-02	8.48E-01	0.973
25	1.01E+02	6.40E-02	8.24E-01	0.971
30	1.02E+02	6.71E-02	8.13E-01	0.972
35	1.02E+02	6.93E-02	8.05E-01	0.973
40	1.02E+02	7.08E-02	7.99E-01	0.974
45	1.02E+02	7.19E-02	7.95E-01	0.974
50	1.02E+02	7.27E-02	7.92E-01	0.974

Table (4-2): Initial coefficients for Ni(α,n)Zn reactions at energy (10-50)MeV with coefficient of determination (r^2).

Alpha energy MeV	*a*	*b*	*c*	r^2
10	2.210018	1.93E-01	1.607053	0.845
15	2.90E+02	3.57E-02	2.380853	0.965
20	8.84E+02	1.88E-02	2.529184	0.956

25	1.07E+03	1.72E-02	2.557118	0.943
30	1.06E+03	1.78E-02	2.538272	0.943
35	1.04E+03	1.84E-02	2.519609	0.943
40	1.03E+03	1.89E-02	2.505567	0.943
45	1.02E+03	1.92E-02	2.495235	0.944
50	1.01E+03	1.95E-02	2.48751	0.943

Table (4-3): Initial coefficients for Zr(α,n)Mo reactions at energy (10-50)MeV with coefficient of determination (r^2).

Alpha energy MeV	*a*	*b*	*c*	r^2
10	4.15E-02	2.08E-01	2.840191	0.969
15	5.19E+01	7.71E-02	3.690161	0.988
20	4.31E+02	3.37E-02	4.030735	0.895
25	7.05E+02	2.24E-02	4.418976	0.908
30	7.11E+02	2.54E-02	4.261844	0.915
35	6.01E+02	3.07E-02	4.029899	0.915
40	5.36E+02	3.49E-02	3.873623	0.914
45	4.94E+02	3.83E-02	3.762603	0.914
50	4.66E+02	4.09E-02	3.681367	0.913

Table (4-4): Initial coefficients for Sc(p,n)Ti reactions at energy (10-50)MeV with coefficient of determination (r^2).

Alpha energy MeV	*a*	*b*	*c*	r^2
10	2.32E+02	3.28E-02	1.83171	0.973
15	7.91E+02	6.53E-02	1.226646	0.993
20	6.53E+02	1.15E-01	9.76E-01	0.988
25	6.01E+02	1.58E-01	8.46E-01	0.983
30	5.94E+02	1.87E-01	7.76E-01	0.977

35	6.02E+02	2.08E-01	7.35E-01	0.972
40	6.15E+02	2.22E-01	7.09E-01	0.967
45	6.27E+02	2.32E-01	6.91E-01	0.964
50	6.39E+02	2.41E-01	6.78E-01	0.96

Table (4-5): Initial coefficients for Cu(p,n)Zn reactions at energy (10-50)MeV with coefficient of determination (r^2).

Alpha energy MeV	*a*	*b*	*c*	r^2
10	1.31E+03	8.07E-03	3.644761	0.988
15	3.72E+03	1.92E-02	2.656636	0.961
20	1.97E+03	4.92E-02	2.045573	0.943
25	1.46E+03	8.15E-02	1.743363	0.925
30	1.31E+03	1.06E-01	1.59125	0.907
35	1.25E+03	1.23E-01	1.502852	0.892
40	1.24E+03	1.35E-01	1.447625	0.88
45	1.23E+03	1.45E-01	1.408885	0.869
50	1.23E+03	1.53E-01	1.37954	0.86

Table (4-6): Initial coefficients for Nb(p,n)Mo reactions at energy (10-50)MeV with coefficient of determination (r^2).

Alpha energy MeV	*a*	b	*c*	r^2
10	1.34E+03	8.41E-03	5.938311	0.968
15	1.44E+04	8.28E-03	4.969583	0.99
20	8.31E+03	1.96E-02	3.861807	0.968
25	4.71E+03	3.92E-02	3.212117	0.965
30	3.33E+03	6.15E-02	2.801627	0.965
35	2.71E+03	8.23E-02	2.534372	0.964
40	2.38E+03	1.00E-01	2.354749	0.96

45	2.19E+03	1.15E-01	2.224925	0.96
50	2.06E+03	1.29E-01	2.123611	0.96

These data were plotted to get the relationship between energy and the corresponding initial coefficient; the fitted expressions for each coefficient give us the following formulas for all reactions:

$$a = B_1 e^{(B_2 E)} + B_3 e^{(B_4 E)} \text{..................}(4-2)$$

$$b = B_5 E^{B_6} + B_7 e^{(B_8 E)} \text{......................}(4-3)$$

$$c = B_9 (E - B_{10})^{B_{11}} \text{......................}(4-4)$$

Where E represent the energy of incident particle, and B_1 - B_{11} represent the final coefficients that listed in table (4-7), and which was adopted in the calculation of neutron yield.

Table (4-7) **:** Final coefficients for each reaction type at best fitted

coefficient	**Ca(α,n)Ti**	**Sc(p,n)Ti**	**Ni(α,n)Zn**	**Cu(p,n)Zn**	**Zr(α,n)Mo**	**Nb(p,n)Mo**
B_1	-3848000	269.8297	-91999809	550117.96	-65140.9	536766.6
B_2	-4.3815	0.22061	-4.2553	-1.43448	-1.141251	-0.99178
B_3	105.8426	3882.223	1239.539	-19946.24	4472.718	-32674.7
B_4	-81.5943	-0.17047	-5.0895×10^{-3}	-0.064408	-0.0266143	-0.0259603
B_5	0.9665	-2.32032	8.191973	2.190894	12.15652	0.018666
B_6	-0.5926	-0.1706	-1.44242	-0.59511	-1.255777	0.563866
B_7	-0.27937	1.566598	-0.3871	-0.94566	-0.74571	-0.13549
B_8	-0.0502	-1.795×10^{-3}	-0.0731624	-0.054448	-0.0547216	-0.024595
B_9	0.896135	1.529553	2.755242	3.254698	10.78586	12.3
B_{10}	14.9268	12.41318	10.72747	12.716244	-8.538×10^{-3}	8.35
B_{11}	-0.03539	-0.230433	-0.027975	-0.243954	-0.276004	-4.76

This set formula has been used to calculate the neutron yields (units- $n/10^6$ alpha for incident alpha particle and $n/10^6$ proton for incident proton) to each isotope at energy ranged between (15 – 50) MeV and compared with theoretical calculation for neutron yield and have shown a good agreement with it,as it is noticed from Tables (4-8) to (4-13).

Table (4).The comparison between the value of neutron yield from theoretically and present work (empirical formula) of Ca(a,n)Ti reaction

Energy = 15 MeV				Energy = 20 MeV				Energy = 25 MeV				Energy = 30 MeV			
Mass number	**Yield theory**	**Yield P.W**	**Error %**	**Mass number**	**Yield theory**	**Yield P.W**	**Error %**	**Mass number**	**Yield theory**	**Yield P.W**	**Error %**	**Mass number**	**Yield theory**	**Yield P.W**	**Error %**
41	2.18867	1.875161	14.3	41	3.20474	3.907576	21.9	41	3.53422	4.401344	24.5	41	3.71933	4.641864	24.8
42	5.42244	5.875613	8.4	42	10.64807	10.14735	4.7	42	11.98828	11.14888	7.0	42	12.45565	11.60991	6.8
43	9.82835	9.291508	5.5	43	14.23652	14.37318	0.95	43	15.52517	15.61059	0.55	43	16.09663	16.19124	0.59
44	10.21789	10.42822	2.1	44	15.34688	14.91081	2.8	44	16.7124	16.11056	3.6	44	17.26257	16.71971	3.2
45	8.62891	9.294011	7.7	45	10.80398	12.49172	15.6	45	11.664	13.48164	15.6	45	12.15842	14.04487	15.5
46	8.0914	6.93943	14.2	46	10.38187	8.859522	14.7	46	11.2959	9.579684	15.2	46	11.76259	10.04365	14.6
47	3.86349	4.476616	15.9	47	4.80287	5.466787	13.8	47	5.38913	5.936669	10.2	47	5.78998	6.277498	8.4
48	2.99153	2.547835	14.8	48	3.66805	2.991006	18.5	48	3.97639	3.268718	17.8	48	4.1632	3.492541	16.1
49	0.74096	1.297684	75.1	49	0.94081	1.469829	56.2	49	1.08544	1.619353	49.2	49	1.18837	1.751301	47.4
50	0.40149	0.598549	49.1	50	0.56736	0.655953	15.6	50	0.69718	0.729686	4.7	50	0.78872	0.799968	1.4
Energy = 35 MeV				**Energy = 40 MeV**				**Energy = 45 MeV**				**Energy = 50 MeV**			
Mass number	**Yield theory**	**Yield P.W**	**Error %**	**Mass number**	**Yield theory**	**Yield P.W**	**Error %**	**Mass number**	**Yield theory**	**Yield P.W**	**Error %**	**Mass number**	**Yield theory**	**Yield P.W**	**Error %**
41	3.85423	4.797047	24.5	41	3.94866	4.913645	24.4	41	4.01701	5.007862	24.7	41	4.06912	5.08692	25.0
42	12.75922	11.89569	6.8	42	12.96944	12.10191	6.7	42	13.1233	12.26031	6.6	42	13.24044	12.38518	6.5
43	16.46886	16.55235	0.51	43	16.72051	16.80365	0.497	43	16.90252	16.98211	0.47	43	17.03839	17.10627	0.398
44	17.6065	17.11241	2.8	44	17.83939	17.37873	2.6	44	18.00729	17.55157	2.5	44	18.13329	17.65094	2.7
45	12.49658	14.42662	15.5	45	12.72349	14.6824	15.4	45	12.88477	14.83611	15.2	45	13.00449	14.90661	14.6
46	12.0592	10.37419	13.97	46	12.25577	10.59536	13.6	46	12.39539	10.72159	13.5	46	12.49965	10.76838	13.9
47	6.07058	6.531188	7.9	47	6.25962	6.701858	7.1	47	6.39549	6.796473	6.3	47	6.49844	6.826232	5.04
48	4.29358	3.665456	14.6	48	4.38087	3.782847	13.7	48	4.44348	3.847073	13.4	48	4.49111	3.865223	13.9
49	1.26043	1.856542	47.3	49	1.30789	1.928789	47.5	49	1.34276	1.968185	46.6	49	1.37101	1.97868	44.3
50	0.85331	0.857622	0.51	50	0.89588	0.897691	0.202	50	0.92646	0.919597	0.74	50	0.94905	0.925284	2.5

Table (4).The comparison between the value of neutron yield from theoretically and present work (empirical formula) of Sc(p,n)Ti reaction

Energy = 15 MeV				**Energy = 20 MeV**				**Energy = 25 MeV**				**Energy = 30 MeV**			
Mass number	**Yield theory**	**Yield P.W**	**Error %**	**Mass number**	**Yield theory**	**Yield P.W**	**Error %**	**Mass number**	**Yield theory**	**Yield P.W**	**Error %**	**Mass number**	**Yield theory**	**Yield P.W**	**Error %**
44	30.7708	32.3403	5.1	44	48.22387	53.8323	11.6	44	63.84204	65.9601	3.3	44	76.95248	76.7616	0.23
45	63.8302	63.0341	1.3	45	88.12347	90.9352	3.2	45	104.4556	105.6928	1.2	45	118.2923	119.0896	0.67
46	87.3095	82.6962	5.3	46	116.6603	112.9242	3.2	46	139.5529	129.0181	7.6	46	159.0777	143.7541	9.6
47	81.6562	83.8021	2.7	47	106.1906	114.7695	8.1	47	124.7189	131.9881	5.8	47	140.3357	147.476	5.1
48	72.1562	69.9687	3.03	48	97.83096	100.3891	2.6	48	119.8516	118.3272	1.3	48	138.7922	133.9989	3.5
49	53.9958	49.9369	7.5	49	73.62862	77.7708	5.6	49	90.53108	95.3538	5.3	49	104.9928	110.3971	5.2
50	30.5847	31.2002	2.01	50	53.06603	54.3583	2.4	50	74.19083	70.2134	5.4	50	92.61978	83.7271	9.6
51	13.3869	17.3547	29.6	51	24.44628	34.7307	42.1	51	34.68462	47.7914	37.8	51	43.45988	59.0819	35.95
52	15.6372	8.7035	44.3	52	28.85272	20.4845	29.0	52	41.36109	30.3313	26.7	52	52.30623	39.1013	25.3
53	8.2086	3.9749	51.6	53	15.24822	11.2398	26.3	53	21.85367	18.0719	17.3	53	27.63594	24.4231	11.6

Energy = 35 MeV				**Energy = 40 MeV**				**Energy = 45 MeV**				**Energy = 50 MeV**			
Mass number	**Yield theory**	**Yield P.W**	**Error %**	**Mass number**	**Yield theory**	**Yield P.W**	**Error %**	**Mass number**	**Yield theory**	**Yield P.W**	**Error %**	**Mass number**	**Yield theory**	**Yield P.W**	**Error %**
44	87.71888	87.0958	0.71	44	96.34117	96.9098	0.59	44	103.5903	106.128	2.5	44	109.8887	114.7442	4.4
45	129.8197	131.984	1.7	45	139.1332	144.1435	3.6	45	147.0023	155.4132	5.7	45	153.8985	165.7782	7.7
46	175.4841	157.8843	10.03	46	188.8656	171.0618	9.4	46	200.1581	183.0928	8.5	46	210.1745	193.9674	7.7
47	153.2591	162.0424	5.7	47	163.6899	175.3841	7.1	47	172.5148	187.3414	8.6	47	180.3232	197.9355	9.8
48	154.6292	148.3546	4.1	48	167.5944	161.2333	3.8	48	178.6554	172.5526	3.4	48	188.5499	182.3752	3.3
49	116.9886	123.8718	5.9	49	126.6624	135.7468	7.2	49	134.8792	146.008	8.3	49	142.2025	154.7465	8.8
50	108.1295	95.6848	11.5	50	120.7634	106.1047	12.1	50	131.559	115.0008	12.6	50	141.2556	122.4657	13.3
51	50.75522	69.0673	36.1	51	56.68065	77.7379	37.2	51	61.84163	85.0953	37.6	51	66.48302	91.2087	37.2
52	61.59319	46.9383	23.8	52	69.22938	53.7705	22.3	52	75.75417	59.5657	21.4	52	81.65415	64.358	21.2
53	32.41945	30.2116	6.8	53	36.33294	35.3115	2.8	53	39.76659	39.6583	0.3	53	42.83857	43.2518	0.97

Table (4).The comparison between the value of neutron yield from theoretically and present work (empirical formula) of Ni(a,n)Zn reaction

Energy = 15 MeV				**Energy = 20 MeV**				**Energy = 25 MeV**				**Energy = 30 MeV**			
Mass number	**Yield theory**	**Yield P.W**	**Error %**	**Mass number**	**Yield theory**	**Yield P.W**	**Error %**	**Mass number**	**Yield theory**	**Yield P.W**	**Error %**	**Mass number**	**Yield theory**	**Yield P.W**	**Error %**
59	2.191417	1.19811	45.3	59	3.976469	3.791074	4.7	59	4.385469	4.5229	3.1	59	4.555701	4.8672	6.8
60	5.149767	3.588885	30.3	60	12.22034	10.25408	16.1	60	14.2863	11.8337	17.2	60	14.70321	12.6506	13.96
61	9.333714	6.940197	25.6	61	15.93751	17.71636	11.2	61	17.25075	19.7765	14.6	61	17.63932	21.089	19.6
62	10.71744	9.868624	7.9	62	24.95861	22.22936	10.9	62	29.20217	23.9706	17.9	62	29.92677	25.5752	14.5
63	11.3108	11.08106	2.0	63	17.75797	21.73954	22.4	63	19.20036	22.6018	17.7	63	19.77499	24.1866	22.3
64	11.51856	10.26778	10.9	64	20.07052	17.31546	13.7	64	22.44194	17.3182	22.8	64	22.99389	18.6259	18.99
65	8.763032	8.08729	7.7	65	11.06965	11.57202	4.5	65	11.81229	11.1079	5.96	65	12.25423	12.0282	1.8
66	2.691661	5.530577	105.5	66	2.95685	6.629994	124.2	66	3.059802	6.0931	99.1	66	3.134115	6.6537	112.3
67	3.963868	3.336591	15.9	67	4.674641	3.309994	29.2	67	5.089891	2.9054	42.9	67	5.387025	3.2041	40.5
68	0.997693	1.798092	80.2	68	1.294405	1.458594	12.7	68	1.440396	1.2199	15.3	68	1.538923	1.3604	11.6

Energy = 35 MeV				**Energy = 40 MeV**				**Energy = 45 MeV**				**Energy = 50 MeV**			
Mass number	**Yield theory**	**Yield P.W**	**Error %**	**Mass number**	**Yield theory**	**Yield P.W**	**Error %**	**Mass number**	**Yield theory**	**Yield P.W**	**Error %**	**Mass number**	**Yield theory**	**Yield P.W**	**Error %**
59	4.676064	5.0427	7.8	59	4.764354	5.1155	7.4	59	4.828906	5.1215	6.1	59	4.877752	5.0829	4.2
60	14.94746	13.08	12.5	60	15.12114	13.2237	12.6	60	15.25181	13.1653	13.7	60	15.35159	12.9696	15.5
61	17.88888	21.8451	22.1	61	18.06254	22.0695	22.2	61	18.18861	21.8839	20.3	61	18.28362	21.4141	17.1
62	30.273	26.6219	12.1	62	30.5008	26.9308	11.7	62	30.66691	26.625	13.2	62	30.79286	25.8854	15.9
63	20.15566	25.3643	25.8	63	20.41667	25.7348	26.1	63	20.606	25.386	23.2	63	20.74989	24.5228	18.2
64	23.28325	19.7223	15.3	64	23.47413	20.0981	14.2	64	23.61283	19.7931	16.2	64	23.71935	18.9963	19.9
65	12.56245	12.8854	2.6	65	12.77425	13.2049	3.4	65	12.92853	12.9892	0.47	65	13.04629	12.3837	5.1
66	3.188234	7.2244	126.6	66	3.225459	7.4535	131.1	66	3.252698	7.3259	125.2	66	3.27357	6.9369	111.9
67	5.600577	3.532	36.9	67	5.747423	3.6723	36.1	67	5.852669	3.6078	38.4	67	5.93215	3.3922	42.8
68	1.609406	1.5249	5.3	68	1.65864	1.5993	3.6	68	1.694316	1.5709	7.3	68	1.720631	1.4663	14.8

Table (4).The comparison between the value of neutron yield from theoretically and present work (empirical formula) of Cu(p,n)Zn reaction

Energy = 15 MeV				**Energy = 20 MeV**				**Energy = 25 MeV**				**Energy = 30 MeV**			
Mass number	**Yield theory**	**Yield P.W**	**Error %**	**Mass number**	**Yield theory**	**Yield P.W**	**Error %**	**Mass number**	**Yield theory**	**Yield P.W**	**Error %**	**Mass number**	**Yield theory**	**Yield P.W**	**Error %**
62	33.42988	36.5532	9.3	62	50.9075	60.6105	19.1	62	66.51619	69.1273	3.9	62	80.08807	80.1882	24.8
63	72.99724	66.4503	8.97	63	98.34827	94.8223	3.6	63	114.2603	104.0965	8.9	63	128.1938	117.9386	6.8
64	76.85351	87.4817	13.8	64	101.748	116.2573	14.3	64	122.4831	126.8640	3.6	64	140.7219	143.0312	0.59
65	101.6946	89.6487	11.9	65	127.1614	117.9553	7.2	65	145.9596	131.2523	10.1	65	162.6811	149.4489	3.1
66	69.97569	74.7858	6.9	66	97.99029	102.4387	4.5	66	123.8171	118.7388	4.1	66	146.8606	138.2391	15.5
67	45.2069	52.3446	15.8	67	64.41699	77.9046	20.9	67	82.43366	95.8208	16.2	67	98.45629	115.2887	14.6
68	36.77641	31.4160	14.6	68	61.07471	52.7404	13.7	68	84.67712	69.9735	17.4	68	105.654	87.8331	8.4
69	7.3329	16.4359	124.1	69	12.82864	32.1806	150.9	69	18.19033	46.7426	156.96	69	22.87374	61.7361	16.1
70	21.43353	7.5931	64.6	70	40.7155	17.8712	56.1	70	59.83563	28.8060	51.8	70	77.02395	40.3455	47.4
71	6.889438	3.1302	54.6	71	13.30086	9.1045	31.6	71	19.63555	16.4902	16.0	71	25.26863	24.6687	1.4

Energy = 35 MeV				**Energy = 40 MeV**				**Energy = 45 MeV**				**Energy = 50 MeV**			
Mass number	**Yield theory**	**Yield P.W**	**Error %**	**Mass number**	**Yield theory**	**Yield P.W**	**Error %**	**Mass number**	**Yield theory**	**Yield P.W**	**Error %**	**Mass number**	**Yield theory**	**Yield P.W**	**Error %**
62	91.43003	92.9182	1.6	62	100.7005	104.7175	3.98	62	108.6299	114.0485	4.98	62	115.6107	120.4111	4.2
63	139.9906	134.0502	4.2	63	149.6317	148.4665	0.78	63	157.8712	159.0843	0.77	63	165.1392	165.3832	0.15
64	156.0443	161.4461	3.5	64	168.5923	177.2680	5.2	64	179.336	188.0917	4.9	64	188.8613	193.4926	2.5
65	176.762	169.1518	4.3	65	188.2551	185.3779	1.5	65	198.086	195.7371	1.2	65	206.8082	199.9830	3.3
66	166.3728	158.1547	4.9	66	182.4809	173.9578	4.7	66	196.367	183.5080	6.6	66	208.7376	186.7499	10.5
67	111.9551	134.2437	19.9	67	123.0266	148.8945	21.0	67	132.6119	157.4448	18.7	67	141.1291	159.9769	13.4
68	123.484	104.7262	15.2	68	138.2224	117.6107	14.9	68	150.9946	125.0203	17.2	68	162.4966	127.0913	21.8
69	26.82928	75.7863	182.5	69	30.07655	86.4925	187.6	69	32.90088	92.6604	181.6	69	35.41774	94.4068	166.5
70	91.863	51.2450	44.2	70	104.1824	59.6310	42.8	70	114.8796	64.5288	43.8	70	124.5917	65.9957	47.0
71	30.11517	32.5675	8.1	71	34.16953	38.7571	13.4	71	37.72228	42.4513	12.5	71	40.92433	43.6431	6.6

Table (4).The comparison between the value of neutron yield from theoretically and present work (empirical formula) of Zr(a,n)Mo reaction

Energy = 15 MeV				Energy = 20 MeV				Energy = 25 MeV				Energy = 30 MeV			
Mass number	**Yield theory**	**Yield P.W**	**Error %**	**Mass number**	**Yield theory**	**Yield P.W**	**Error %**	**Mass number**	**Yield theory**	**Yield P.W**	**Error %**	**Mass number**	**Yield theory**	**Yield P.W**	**Error %**
84	0.166646	0.0049	97.1	84	1.168709	0.1020	91.3	84	1.625727	0.2001	87.7	84	1.889598	0.3021	84.0
85	0.458617	0.0344	92.5	85	1.133001	0.5577	50.8	85	1.403313	0.9349	33.4	85	1.608823	1.2934	19.6
86	0.793914	0.1520	80.9	86	7.851501	1.9312	75.4	86	7.851474	2.8121	64.2	86	7.828608	3.6351	53.6
87	1.786888	0.4787	73.2	87	4.892048	4.7876	2.1	87	5.815327	6.1112	5.1	87	6.326908	7.4829	18.3
88	1.741781	1.1625	33.3	88	9.11612	9.1464	0.3	88	11.479	10.2873	10.4	88	12.26943	12.0557	1.7
89	3.87028	2.2917	40.9	89	9.607851	14.1309	47.1	89	11.59402	14.0409	21.1	89	12.27532	15.8781	29.4
90	4.578516	3.8002	16.99	90	19.48854	18.2578	6.3	90	23.3977	16.0420	31.4	90	24.10166	17.6230	26.9
91	4.846828	5.4396	12.2	91	15.36804	20.2162	31.6	91	17.11766	15.7041	8.3	91	17.6951	16.8536	4.8
92	4.899916	6.8523	39.9	92	13.0029	19.5413	50.3	92	14.53023	13.4072	7.7	92	15.11082	14.1244	6.5
93	4.447063	7.7115	73.4	93	8.651116	16.7292	93.4	93	9.757356	10.1218	3.7	93	10.30588	10.5115	1.99

Energy = 35 MeV				Energy = 40 MeV				Energy = 45 MeV				Energy = 50 MeV			
Mass number	**Yield theory**	**Yield P.W**	**Error %**	**Mass number**	**Yield theory**	**Yield P.W**	**Error %**	**Mass number**	**Yield theory**	**Yield P.W**	**Error %**	**Mass number**	**Yield theory**	**Yield P.W**	**Error %**
84	2.096499	0.3964	81.1	84	2.255472	0.4703	79.6	84	2.377968	0.5174	78.3	84	2.472586	0.5368	78.3
85	1.769999	1.6002	9.6	85	1.890126	1.8082	4.3	85	1.979717	1.9045	3.8	85	2.048109	1.8979	7.3
86	8.293228	4.3168	47.95	86	8.642156	4.7167	45.4	86	8.910804	4.8147	45.97	86	9.120679	4.6554	48.95
87	6.692582	8.6437	29.2	87	6.95691	9.2347	32.7	87	7.154777	9.2192	28.9	87	7.306917	8.7134	19.3
88	12.72979	13.6894	7.5	88	13.04478	14.4277	10.6	88	13.27974	14.1870	6.8	88	13.46095	13.1818	2.1
89	12.7871	17.8785	39.8	89	13.12724	18.7246	42.6	89	13.37797	18.2415	36.4	89	13.57097	16.7391	23.4
90	24.51666	19.8234	19.1	90	24.80946	20.7609	16.3	90	25.02817	20.1371	19.5	90	25.19676	18.3200	27.3
91	18.09603	19.0624	5.3	91	18.38466	20.0729	9.2	91	18.59952	19.4681	4.7	91	18.7662	17.6174	6.1
92	15.48816	16.1567	4.3	92	15.75405	17.1897	9.1	92	15.95165	16.7336	4.9	92	16.1027	15.1060	6.2
84	2.096499	0.3964	81.1	93	10.92548	13.1985	20.8	93	11.11489	12.9399	16.4	93	11.26058	11.6827	3.8

Table (4).The comparison between the value of neutron yield from theoretically and present work (empirical formula) of Zr(a,n)Mo reaction

Energy = 15 MeV				**Energy = 20 MeV**				**Energy = 25 MeV**				**Energy = 30 MeV**			
Mass number	**Yield theory**	**Yield P.W**	**Error %**	**Mass number**	**Yield theory**	**Yield P.W**	**Error %**	**Mass number**	**Yield theory**	**Yield P.W**	**Error %**	**Mass number**	**Yield theory**	**Yield P.W**	**Error %**
87	14.11143	6.0383	57.2	87	29.03016	21.7140	25.2	87	41.54134	35.6826	14.1	87	53.73852	44.0644	18.0
88	22.24473	18.2124	18.1	88	36.27521	51.4464	41.8	88	50.37471	75.6389	50.2	88	63.81289	85.8741	34.6
89	51.97469	37.2866	28.3	89	108.0508	90.8507	15.9	89	132.9276	125.6040	5.5	89	152.9965	135.0085	11.8
90	86.39341	56.0726	35.1	90	121.4447	127.0195	4.6	90	143.196	171.9055	20.1	90	162.9198	179.0772	9.9
91	115.1256	65.2458	43.3	91	180.2595	146.2994	18.8	91	201.695	200.4999	0.6	91	219.4504	206.3935	5.94
92	115.932	60.9239	47.5	92	149.1123	142.7342	4.3	92	174.9075	203.9958	16.6	92	198.775	210.9946	6.2
93	110.9416	46.8910	57.7	93	137.7554	120.3928	12.6	93	160.3541	184.1824	14.9	93	181.174	194.2324	7.2
94	72.00606	30.3628	57.8	94	97.00536	89.1722	8.1	94	121.573	149.5066	22.97	94	144.7632	162.8689	12.5
95	46.63323	16.8092	63.95	95	68.3647	58.7145	14.1	95	90.30592	110.2328	22.1	95	110.8433	125.5285	13.3
96	33.2889	8.0608	75.8	96	55.44118	34.7102	37.4	96	78.32739	74.4376	4.96	96	99.96692	89.5772	10.4
Energy = 35 MeV				**Energy = 40 MeV**				**Energy = 45 MeV**				**Energy = 50 MeV**			
Mass number	**Yield theory**	**Yield P.W**	**Error %**	**Mass number**	**Yield theory**	**Yield P.W**	**Error %**	**Mass number**	**Yield theory**	**Yield P.W**	**Error %**	**Mass number**	**Yield theory**	**Yield P.W**	**Error %**
87	64.65923	51.1651	20.9	87	73.9265	60.2111	18.6	87	82.02145	72.8257	11.2	87	89.29026	89.4433	0.17
88	75.62695	93.7001	23.9	88	85.65485	105.1127	22.7	88	94.45457	122.3731	29.6	88	102.4101	145.6638	42.2
89	171.1648	141.2731	17.5	89	186.8939	153.3914	17.9	89	200.8427	173.9648	13.4	89	213.625	202.6621	5.1
90	180.4706	182.6228	1.2	90	195.5181	194.2463	0.7	90	208.8579	216.6487	3.7	90	220.9328	248.9216	12.7
91	235.3962	207.8815	11.7	91	249.1031	218.7712	12.2	91	261.2315	241.8412	7.4	91	272.2321	275.8008	1.3
92	219.8039	212.2962	3.4	92	237.7251	222.9342	6.2	92	253.5427	245.8929	3.0	92	267.819	279.8488	4.5
93	199.3022	197.1833	1.1	93	214.6317	208.1533	3.0	93	228.3182	230.4124	0.92	93	240.7178	262.9355	9.2
94	165.3117	168.3139	1.8	94	182.9716	179.7939	1.7	94	198.6499	200.7686	1.1	94	212.7662	230.6907	8.4
95	128.7466	133.1197	3.4	95	143.935	144.7520	0.6	95	157.2978	163.8208	4.2	95	169.3997	190.2569	12.3
96	119.2435	98.1978	17.7	96	135.7839	109.2878	19.5	96	150.4107	125.8890	16.3	96	163.7556	148.2854	9.5

It can be noticed from previous tables that the neutron yield for energies between (10-14)MeV was not included in previous tables because of the big difference between the theoretical values and the calculated values from empirical formula, and this confirms our previous analysis for the Figures of cross-sections, where we expected that the best region for the calculations is between (15-50)MeV.

The figures (4-22) to (4-27) are give us more clearer for this comparison between the present works (P.W) and theoretical calculated.

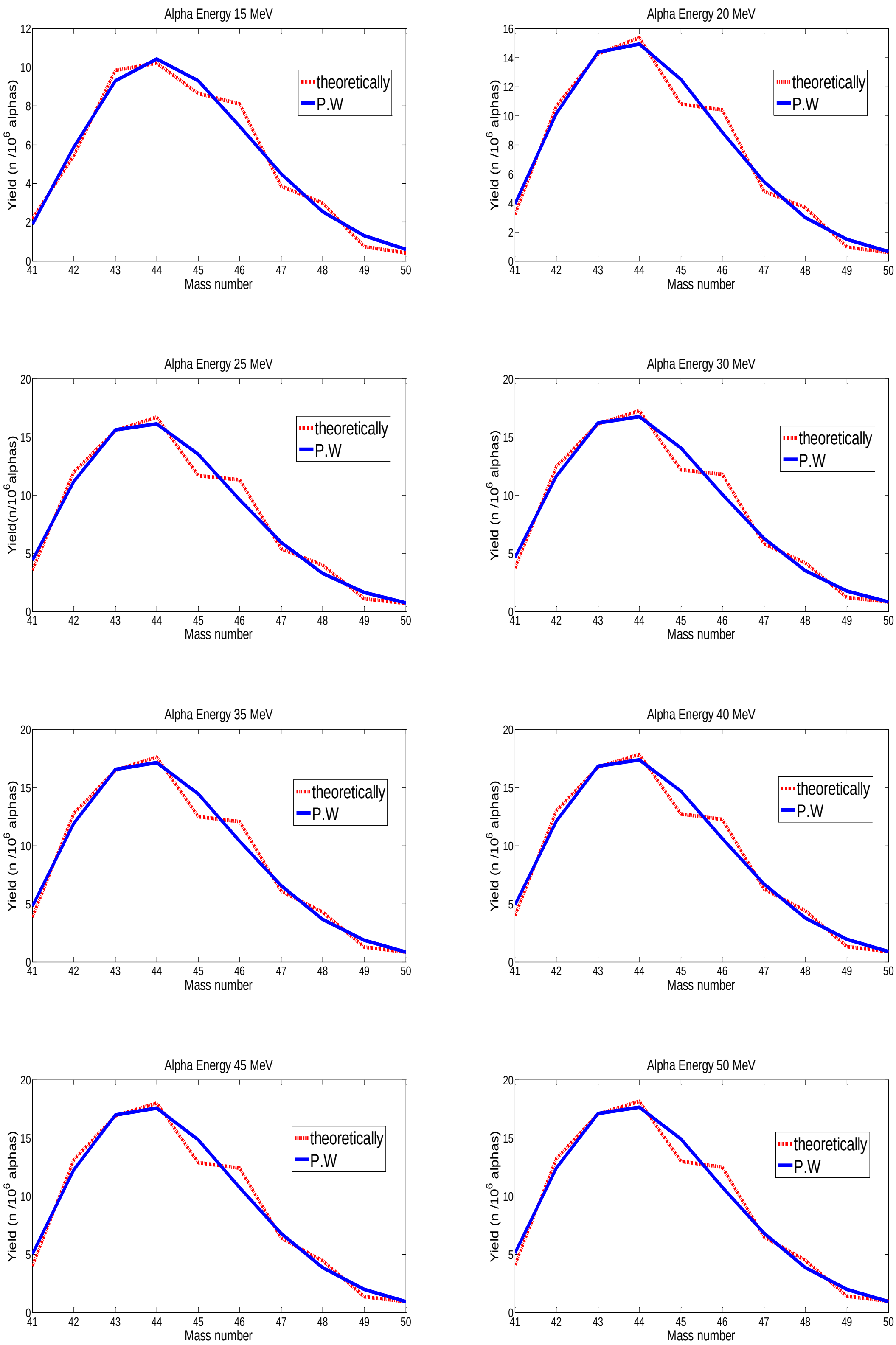


Figure (4-22): The comparison between neutron yields calculated from the theoretically relationship and fitting expressions for Ca(α,n)Ti

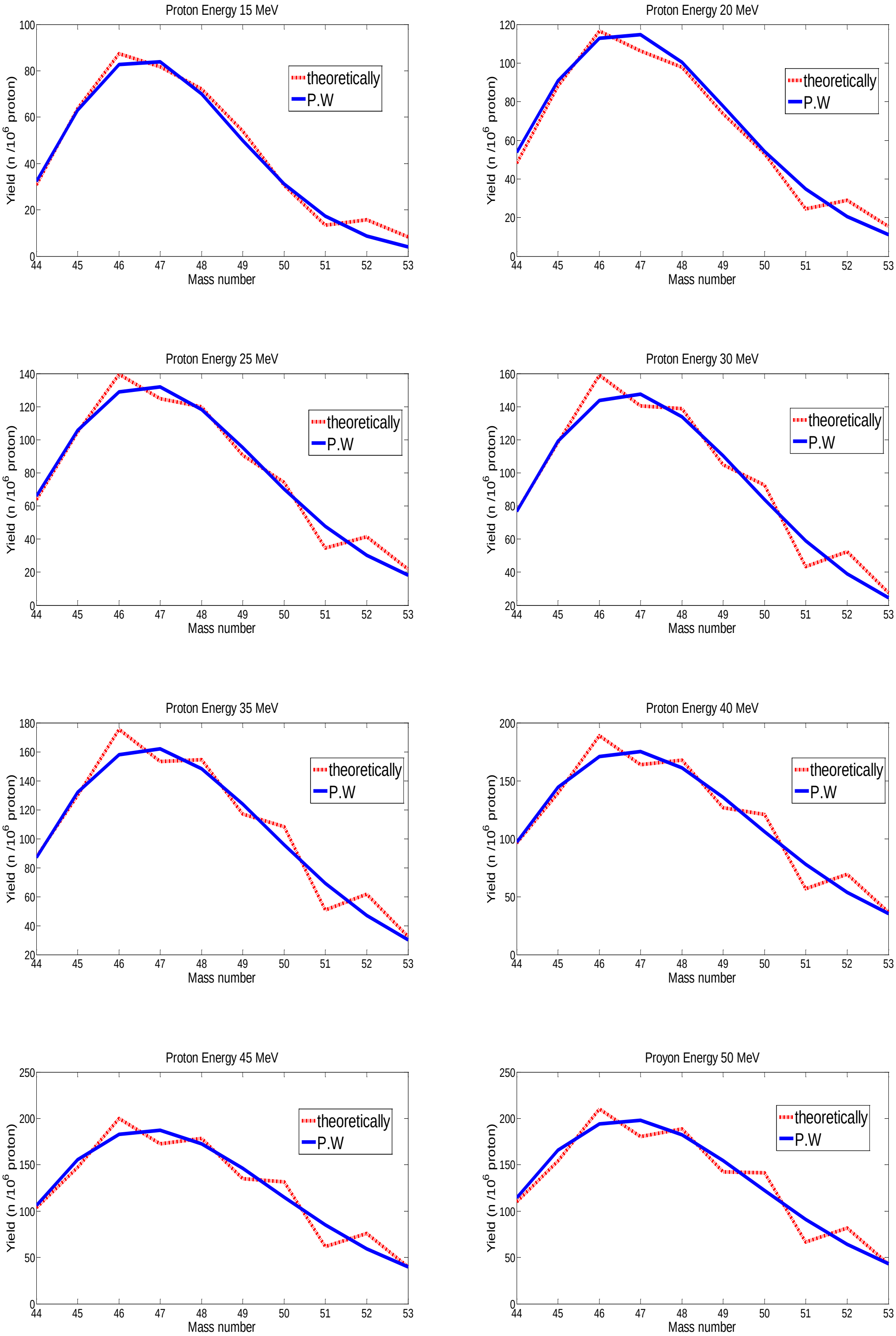


Figure (4-23): The comparison between neutron yields calculated from the theoretically relationship and fitting expressions for Sc(p,n)Ti

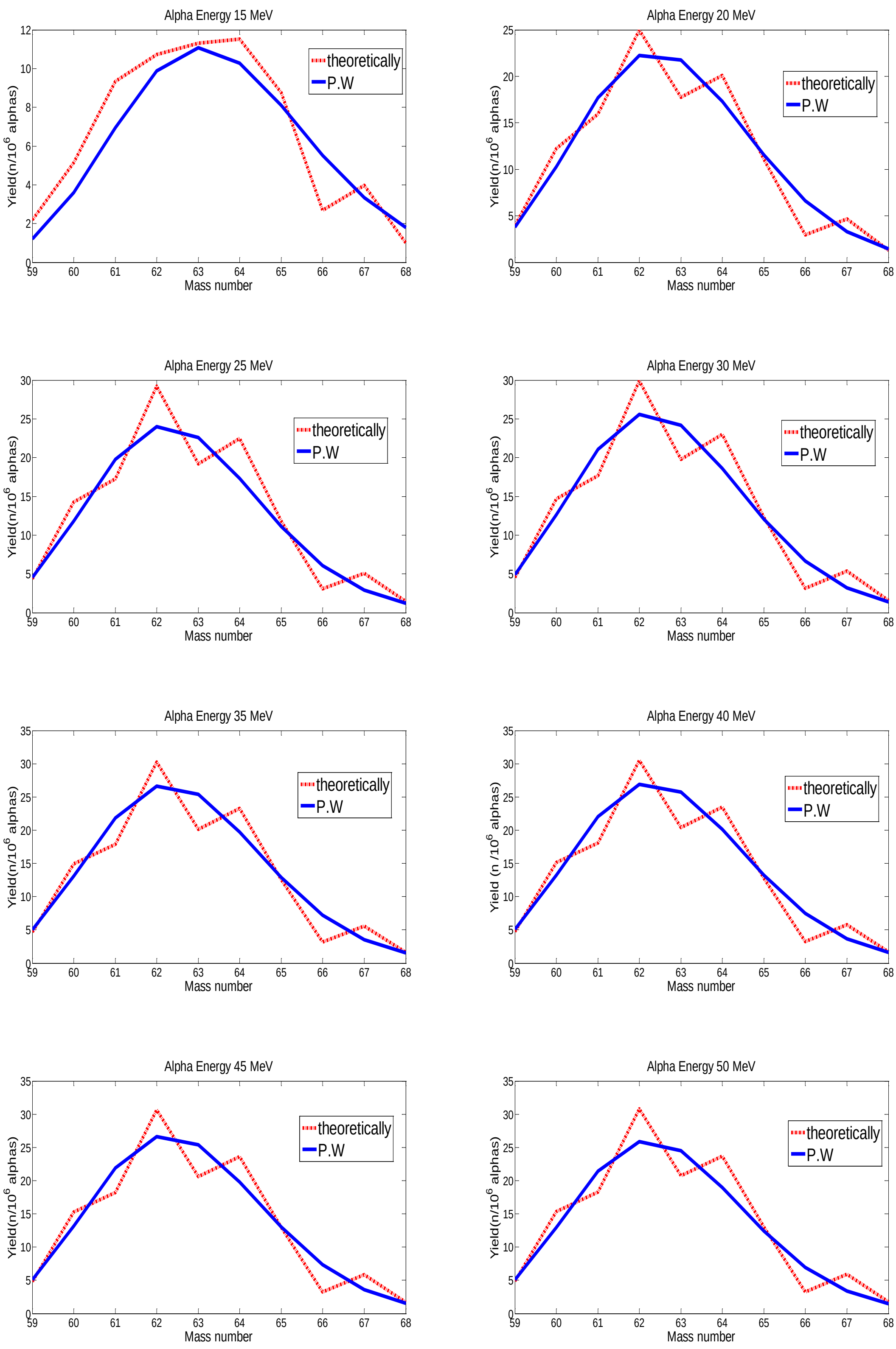


Figure (4-24): The comparison between neutron yields calculated from the theoretically relationship and fitting expressions for Ni(α,n)Zn

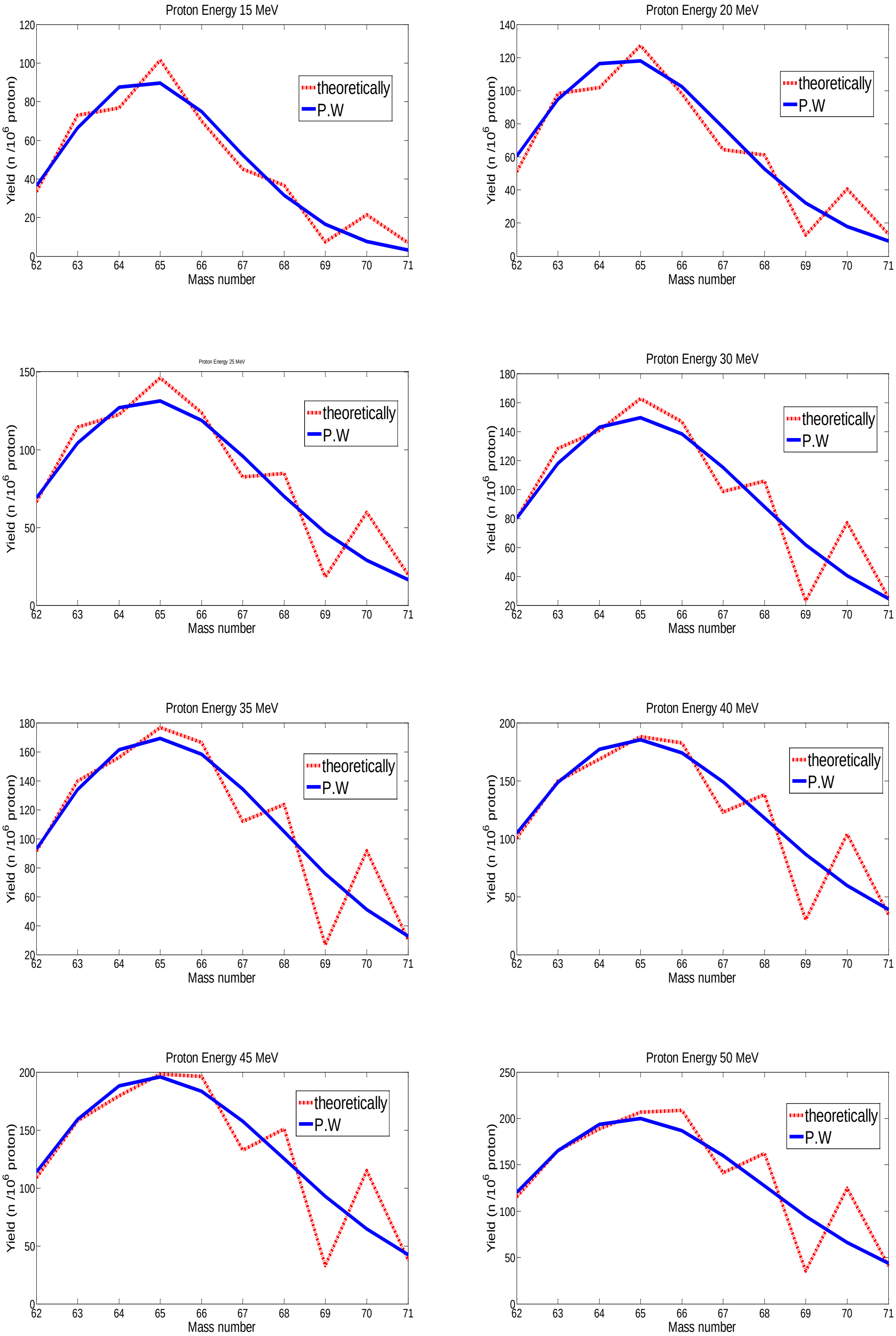


Figure (4-25): The comparison between neutron yields calculated from the theoretically relationship and fitting expressions for Cu(p,n)Zn

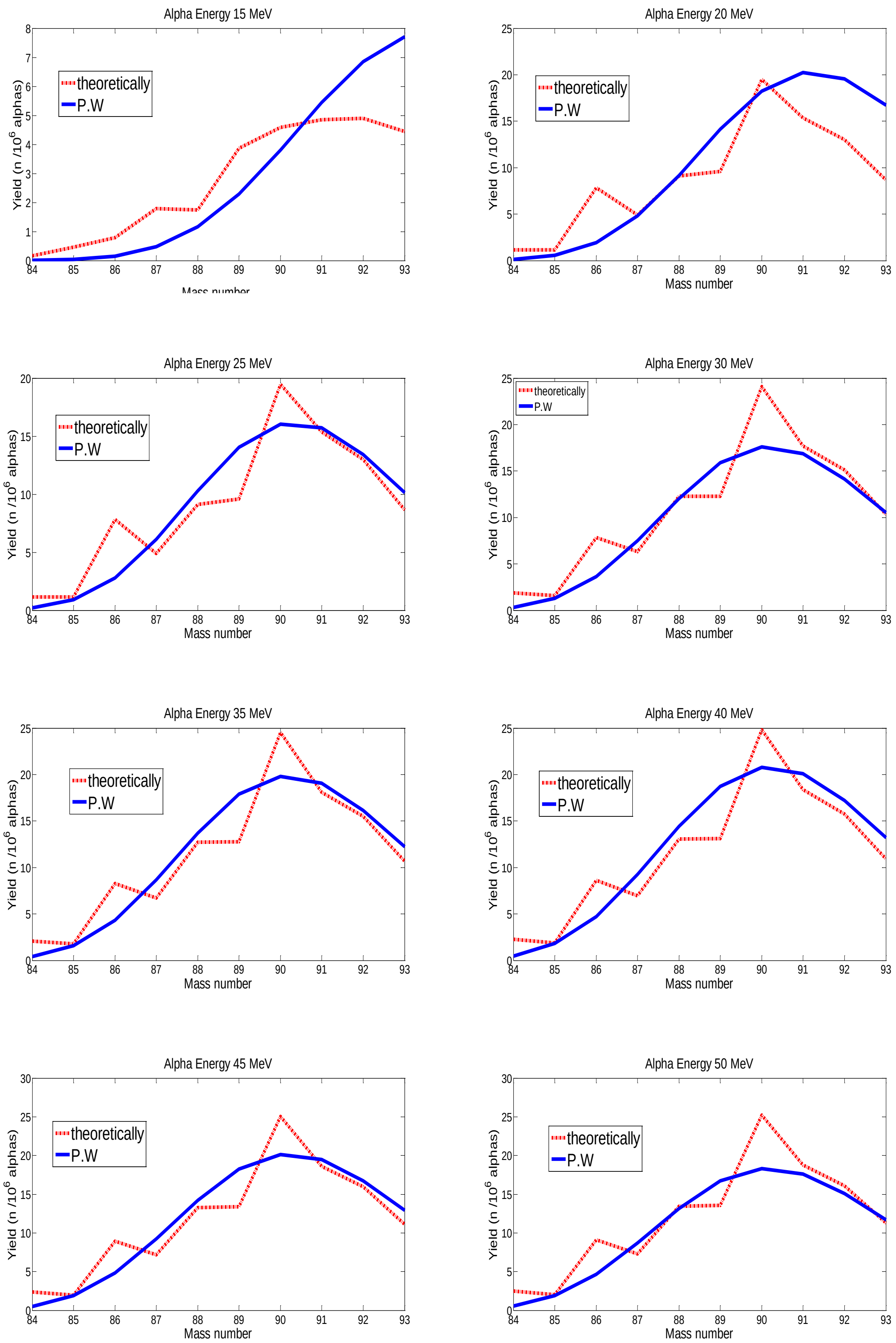


Figure (4-26): The comparison between neutron yields calculated from the theoretically relationship and fitting expressions for Zr(α,n)Mo

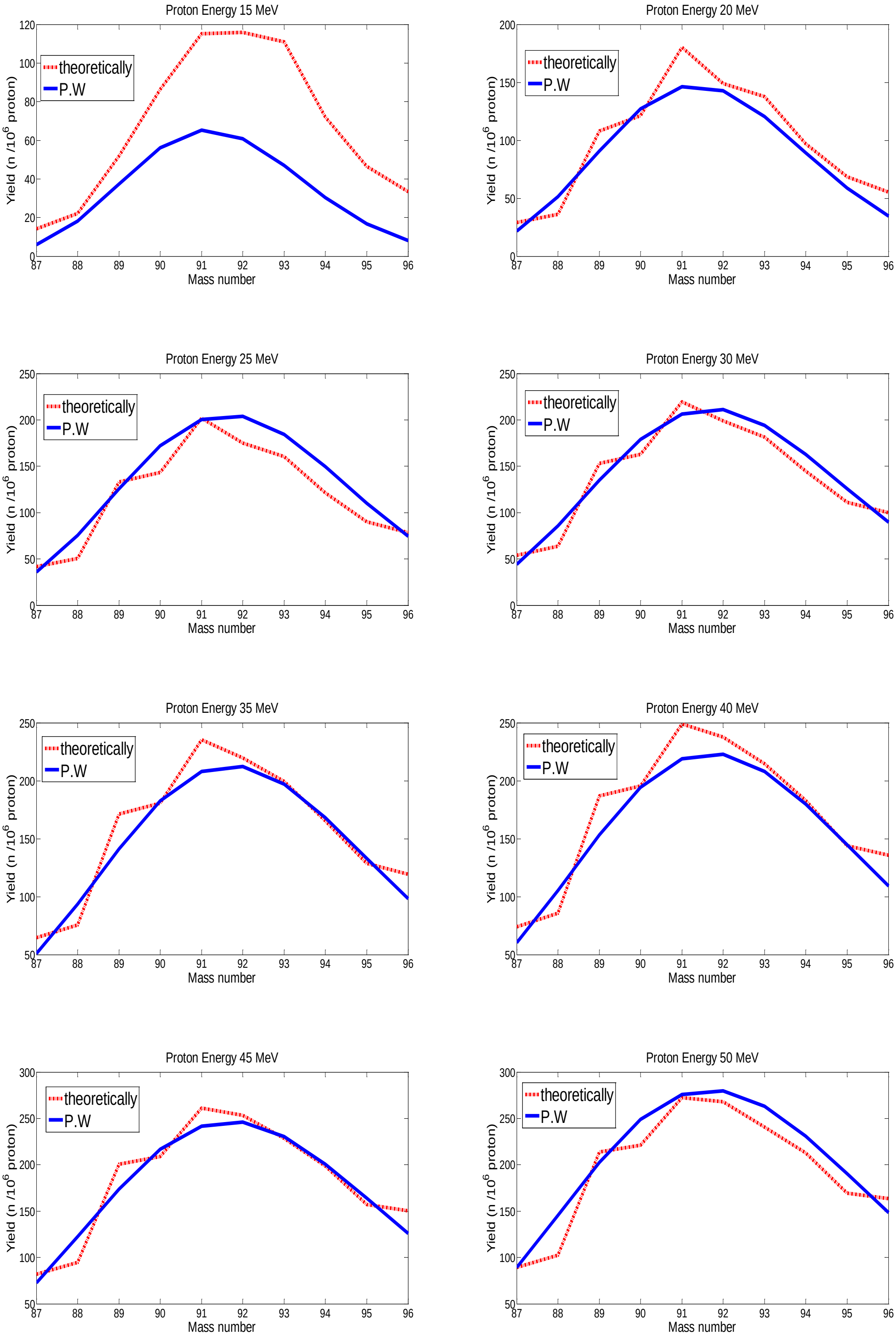


Figure (4-27): The comparison between neutron yields calculated from the theoretically relationship and fitting expressions for Nb(p,n)Mo

(4-4) Conclusion:

The results of the present study lead to the following conclusions:

1- Results of Q-values, threshold energies, neutron separation energies have different values with increasing mass numbers of isotopes, while the binding energies and reduced Mass increased with increasing mass numbers of isotopes for reactions in this study.

2- In general (n,n) cross sections are smaller than (α,n) and (p,n) cross section, and all these cross sections for three types reactions depend on the incident particle energy and mass number of the target.

3- The data of cross-sections for most reactions at some energies were not available in Internationale laboratories that leads to the inability to get a lot of calculations such as neutron yield that push us to design a program for the extract empirical formulas to calculate the neutron yield .

4- We concluded that the values of neutron yields were more acute in the range (15-50) MeV for most reactions, which show a good agreement with the theoretical calculations, and by this program which includes those extract empirical formulas can calculate the neutron yield for any reaction in this type by medium nucleids.

5- From comparison between the theoretical and empirical formulas to calculate neutron yield, its clear that there is an errors in some values which are very few that might be due to pairing term.

(4-5) Suggestions for Future Works:

1- Study the properties and neutron yield for the same types reactions of other medium nucleids (A=40-100).

2- Study the properties and neutron yield for the same isotopes in other energies (E>50 MeV).

3- Concern on the study of the region of energies (10-15)MeV, separately for (α, n) and (p, n) reactions in fine step to get more accurate for neutron yield calculations.

4- Study the effect of pairing term on neutron yield calculations obtained from this study

5- Study the properties and neutron yield for other isotopes of light and heavy nuclei for different energies.

6- Develop the program according to the information's that we get from above points in the future work to get generalized program that calculate the neutron yield for any isotope with any energy of the incident particle.

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الملخص

للنظائر اهمية كبيرة في كثير من المجالات مثل المجالات البحثية والصناعية والطبية ومجالات اخرى. فبعضها يحتاج لنظائر بنصف عمر طويل أو بنصف عمر قصير و حاصل نيتروني عالي او قليل للحالتين، لذا تضمن هذا العمل دراسة الخصائص النووية لتسعة عناصر متوسطة الاعداد الكتلية هي (Ca، Sc، Ti، Ni، Cu، Zn، Zr، Nb، Mo)، ولكل عنصر تم اختيار عشرة نظائر لذا تضمنت الدراسة 90 نظير اعدادها الكتلية بين (41 الى 96) ، شملت هذه الدراسة حساب طاقة التفاعل ، طاقة العتبة، الكتلة المختزلة، طاقة فصل النيوترون وطاقة الربط النووية لتفاعلات $Ca(\alpha,n)Ti$, $Ni(\alpha,n)Zn$ ، $Zr(\alpha,n)Mo$ ، $Sc(p,n)Ti$, $Cu(p,n)Zn$, $Nb(p,n)Mo$ ، $Ti(n,n)Ti$, $Zn(n,n)Zn$, $Mo(n,n)Mo$ لنظائر العناصر اعلاه ، كما تم حساب قدرة الايقاف بأستعمال برنامج (SRIM 2013) ومن ثم حساب الحاصل النيتروني من المعادلات النظرية اعتمادا على احدث ما نشر من المقاطع العرضية للعامين (2010، 2012)، كما تم في هذه الدراسة استخراج مجموعة من المعادلات شبه التجريبية الموحدة لحساب المحصول النيتروني لهذه العناصر بشكل مباشر لنوعين من التفاعلات (α,n) و (p,n) والتي كل منها يشتمل على عشرة نظائر ليكون المجموع 60 تفاعل، نتائج الحاصل النيوتروني المحسوبة من هذه المعادلات اعطت توافقا جيدا مع القيم النظرية التي حسبت من المعادلات النظرية . هذه المعادلات مع ثوابتها وضعت ضمن برنامج ماتلاب صمم لهذا الغرض وبالاعتماد على نوع العنصر ونوع التفاعل وطاقة الجسيم الساقط لايجاد الحاصل الفيتروني لاي نظير عدده الكتلي بين (40 – 100) لمدى طاقة يتراوح بين (15 – 50) مليون الكترون فولط. يمكن تطوير البرنامج ليشمل عدد اكبر من العناصر بنظائرها ولمديات طاقة اوسع.

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تقدير الحاصل النيتروني لبعض نوى النظائر المتوسطة نتيجة لتفاعلات البروتون وجسيمات الفا والنيوترون لمدى طاقة (E=10-50)MeV

أطروحة
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كجزء من متطلبات نيل درجة دكتوراه فلسفة
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