Calculated yields of the produce Gallium from the induced proton on Zinc target element

حساب نواتج الكاليوم من البروتونات المستحثة في الزنك

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Abstract

Stopping power and calculated yields for induced protons to produce Copper from Zinc isotopes ($^{64}_{30}Zn_{34}$, $^{66}_{30}Zn_{36}$, $^{67}_{30}Zn_{37}$, $^{68}_{30}Zn_{38}$ and $^{70}_{30}Zn_{40}$) in the energy range from threshold energy up to 85 MeV proton energy have been calculated except for $^{70}_{30}Zn_{40}(p,x)^{67}_{31}Ga_{36}$ reaction where the proton energy have 350.8 MeV. Complete energy range starting from threshold energy for each reaction have been analyzed statistically and the adopted cross sections were reproduced in fine steps of incident proton energy in 0.01 MeV intervals with their corresponding errors. The stopping power according to Zeigler formula was used in order to obtain the cross sections and calculated yield for each reaction based on the complete spectrum of cross sections.

Keywords: Cross sections; Stopping power; Gallium yields, induced protons, Zinc target element.

الخلاصة

لقد تم حساب قدرة الايقاف ونواتج البروتونات المستحثة لانتاج الكاليوم من نظائر الزنك المتوسطة ($^{64}_{30}Zn_{34}$, $^{66}_{30}Zn_{36}$, $^{67}_{30}Zn_{37}$, $^{68}_{30}Zn_{38}$ and $^{70}_{30}Zn_{40}$) بمدى طاقي من طاقة العتبة الى 85MeV لطاقات البروتون, ماعدا تفاعل. $^{70}_{30}Zn_{40}(p,x)^{67}_{31}Ga_{36}$ حيث تصل طاقة البروتون الى 350.8MeV حيث تم تحليل كامل لمدى الطاقة ابتداءا من طاقة العتبة لكل تفاعل للحصول على المقاطع العرضية المختارة وقد تم معالجتها احصائيا لحساب المقاطع العرضية لفترات صغيرة من طاقة البروتون الساقطة مقدارها 0.01MeV مع الاخطاء المصاحبة لكل قراءة. لقد تم استخدام صيغة زكلر لحساب قدرة الايقاف الناتجة وبذلك تمكنا من تقيم النواتج المحسوبة لكل تفاعل بعد الحصول على طيف متكامل للمقاطع العرضية.

1. Introduction

This study concerns with the nuclear reactions used in the production of Gallium from induced protons on Zinc target element which are important in medical applications. The calculated yields for induced proton on Zinc isotopes to produce Gallium have been intensively studied with high energy resolution up to energies accessible with conventional electrostatic accelerators. In addition to the intrinsic value of calculated yields for induced proton on Zinc to produce Gallium cross section in the investigation of nuclear spectroscopy and reaction mechanisms, such data are essential for the polarization of calculated yields for induced proton on Zinc to produce Gallium [1→5]. The cross sections evaluation for calculated yields for induced proton on Zinc to produce Gallium, Zinc target elements are calculated according to the available International Atomic Energy Agency (IAEA) libraries and other experimental published data. The 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. The yield for a target having any thickness can be defined as the ratio of the number of nuclei formed in the nuclear reaction to the number of particles incident on the target. Thick target yield is defined for a fixed macroscopic energy loss, E_{in}-E_{out}, in a thick target. Integral yield is defined for a finite energy loss down to the threshold of the reaction, E_{in}-E_{th}. The recommended cross sections discussed in the present work and the target stopping powers of Ziegler [6,7] and SRIM program (2003) were used to Evaluation the calculated yields for a target of significant thickness. The cross

sections of calculated yields for induced proton on Zinc to produce Copper published by different authors [9-31] in the energy range (0.927 – 350.8) MeV. Adopted values have been calculated, the cross sections were reproduced in fine steps of incident proton energy in 0.01 MeV intervals with the corresponding errors. In this study the stopping power have been calculated using SRIM program and Ziegler formulae [6,7] corpuscle to three regions based on the velocity of the incident proton (V). The calculated adopted cross sections for these reactions have been evaluated and a systematic behavior of calculated yields with proton energy and target numbers (Z) have been observed throughout the studied isotopes.

2. Theoretical part
a. Stopping Power
Incident protons with certain energy will lose all their energies in a definite distance in a medium before it stopped completely. The mechanism for the stopping power of ions penetrating condensed matter depends on the charge and velocity of the incident corpuscle and the nature of the matter, for that reason one can be compilation the energy loss of the charge corpuscle to three regions (high, intermediate and low energy). The behavior of ions in each region can be explained as the following [32]:

i. The high energy region
This region can occurs when the velocity of the incident corpuscle (V) is ($V \geq 2V_0Z_1$) where (Z_1) is the atomic number of ion and (V_0) represents the Bohr velocity ($V_0 = 2.18 \times 10^6$ m/s) and this is about the velocity of the conduction electrons in solid. Ions with velocity below (V_0) have adiabatic collisions with target electrons and hence small stopping power. The stopping power increases with decreasing ion-velocity [33].

The electronic stopping power (S_e) is to prevail with Bethe (1933) equation applies in this region [34]:

$$-\frac{dE}{dx} = NS_e = \frac{4\pi K^2 e^4 Z_1^2}{mV^2} NZ_2 \left[\ln\left(\frac{2mV^2}{I}\right) - \ln\left(1-\beta^2\right) - \beta^2 \right] \qquad \dots (1)$$

Where: $-\frac{dE}{dx}$: The energy loss of the particle per unit path called stopping power .

N: is the atomic density of the medium [N=N$_a$ (ρ/A)].

N_a: is the Avogadro's number ($N_a=6.022\times10^{23}$mole^{-1}).

ρ: is the density of matter.

A: is the mass number.

e,m: are the charge and mass of the electron respectively.

Z_1, Z_2: are the atomic numbers of ion and target respectively.

β: is the ratio between incident corpuscle velocity and the velocity of light $\beta = \frac{V}{c}$.

I: is the mean ionization and excitation potential.

K: is the coulomb constant $K = \frac{1}{4\pi\varepsilon_0} = 8.99\times10^9$Nm^{2}C^{-2}.

ii. The intermediate energy region
The intermediate energy region occurs when the velocity (V) of the incident corpuscle is in the range ($2V_0Z_1 > V \geq V_0Z_1^{2/3}$); it includes the maximum stopping power. In this region the effect of effective charge is clear and that is because of loss its energy which is mean decrease of corpuscle velocity and charge Z_1 decreased too, and that because of loss or acquire electrons and there will be elastic collision with the nuclei of atoms occur. Thus equation (1) was modified, and its express electronic stopping power as Bethe-Bloch (1933) [34].

$$-\frac{dE}{dx} = NS_e = \frac{4\pi K^2 e^4 Z_1^2}{mV^2} NZ_2 L \qquad \dots (2)$$

Where L is the stopping atomic number and depends on the velocity of incident corpuscle and the medium of the target.

$L = L_0 + Z_1 L_1 + Z_1^2 L_2$ ...(3)

Where $L_0 = \ln(2wv^{1/2} / I) - C/Z_2$ ...(4)

C/Z_2 is the shell correction.

$Z_1 L_1$ is the Barkas effect correction from the polarization.

$Z_1^2 L_2$ is Bloch-correction to transform from quantum to classical form.

iii. The low energy region

It occurs when the incident corpuscle velocity (V) ($V < V_0 Z_1^{2/3}$) in this region, to calculate the cross section for electronic stopping on the Thomas-Fermi potential as a function of velocity. The equation for this region is given by [35,36]:

$$S_e = 8\pi e^2 a_0 \frac{Z_1^{7/6} Z_2}{Z^{2/3}} \left(\frac{V}{V_0} \right) \qquad \dots (5)$$

Where $Z^{2/3} = Z_1^{2/3} + Z_2^{2/3}$ ... (6)

and a_0 represents the Bohr radius, $\qquad a_0 = \dfrac{h^2}{me^2} = 5.29 \times 10^{-11} \overset{\circ}{A}$ ...(7)

In the scope of this work, the electronic stopping powers were programmed and using the empirical formulae given by Ziegler as flows [6]:

1- Energy range $(1-10) \times 10^{-3}$ MeV

$$-\frac{dE}{dx} = A_1 E^{1/2} \qquad \dots (8)$$

2- Energy range $(10-999) \times 10^{-3}$ MeV

$$\left(-\frac{dE}{dx} \right)^{-1} = \left(-\frac{dE}{dx} \right)^{-1}_{Low} + \left(-\frac{dE}{dx} \right)^{-1}_{High} \qquad \dots (9)$$

$$\left(-\frac{dE}{dx} \right)_{Low} = A_2 E^{0.45} \qquad \dots (10)$$

$$\left(-\frac{dE}{dx} \right)_{High} = \left(\frac{A_3}{E} \right) \ln \left[1 + \left(\frac{A_4}{E} \right) + A_5 E \right] \qquad \dots (11)$$

3- Energy range $(1000-100.000) \times 10^{-3}$ MeV

$$\left(-\frac{dE}{dx} \right) = \left(\frac{A_6}{\beta^2} \right) \left[\ln \left(\frac{A_7 \beta^2}{1-\beta^2} \right) - \beta^2 - \sum_{i=0}^{4} A_{i+8} (\ln E)^i \right] \qquad \dots (12)$$

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

A_i: are the coefficients given by Ziegler [6, 37].

β: is the ratio between incident projectile velocity and the light velocity.

b. Calculated Yield

The Yield of calculated detected per incident particle, Y, for an ideal, thin, and uniform target and monoenergetic particles beam of incident energy E_b is given by [38].

$$Y = (nt)\sigma(E_b)\varepsilon(E_b) \qquad \dots (13)$$

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

t: is the target thickness.

σ: is the reaction cross section.

ε: is the proton-detection efficiency.

For target which is not infinitesimally thin, the beam loses energy as it passes through the target, and the Yield is then given by [39,40].

$$Y = \int_{E_{thr}}^{E_b} \frac{n\sigma(E)\varepsilon(E)fdE}{-\dfrac{dE}{dx}(E)} \qquad \dots (14)$$

In which ($E_{thr} = E_b - \Delta E$)

Where E_{thr} : is the reaction threshold energy.

$\quad\quad \Delta E$: is the energy loss of the beam in the target.

$\quad\quad f$: is the number of target atoms in each target molecule.

$-\dfrac{dE}{dx}(E)$: is the stopping power of the medium as a function of the beam energy.

If the target is sufficiently thick, and there exist one atom per each molecule (i.e., $f = 1$) and taking the efficiency $\varepsilon(E) = 1$, then the resulting calculated yield is called the thick-target yield which is given by [28]:

$$Y(E_b) = \int_{E_{thr}}^{E_b} \frac{n\sigma(E)dE}{-(dE/dx)} \qquad \dots (15)$$

Since stopping power $= \dfrac{1}{n}\left(-\dfrac{dE}{dx}\right)$.

3. Data Reduction and Analysis

Method used to obtain the adopted cross sections is as the following:

a. The sets of experimental cross sections data were collected for different authors and with different energy intervals. The cross sections with their corresponding errors for each value are re-arranged according to the energy interval 0.01 MeV for available different energy range for each author.

b. The normalization for the statistical distribution of cross sections errors to the corresponding cross section values for each author has been done.

c. The interpolation for the nearest data for each energy interval as a function of cross sections and their corresponding errors have been done using Matlab-7.0.

d. The interpolated values were calculated to obtain the adopted cross section which is based on the weighted average calculation according to the following expressions [42]:

$$\sigma_{w.a.} = \frac{\displaystyle\sum_{i=1}^{n} \frac{\sigma_i}{(\Delta\sigma_i)^2}}{\displaystyle\sum_{i=1}^{n} \frac{1}{(\Delta\sigma_i)^2}} \qquad \dots (16)$$

Where the standard deviation error is:

$$S.D. = \frac{1}{\sqrt{\displaystyle\sum_{i=1}^{N} \frac{1}{(\Delta\sigma_i)^2}}} \qquad \dots (17)$$

Where σ_i: is the cross section value.

$\quad\quad \Delta\sigma_i$: is the corresponding error for each cross section value.

4. Results and Discussion

Table (1) present the international atomic energy Agency (IAEA) libraries (EXFOR) used in the present work for available measuring data collected for calculated yields for induced proton on Zinc to produce Gallium. The available data in the literature, taken from EXFOR library, concerning the measurement of the calculated yields for induced proton on Zinc to produce Gallium cross sections for the target Zinc mentioned in table-1were evaluated in the present work in order to calculate the

adopted cross sections using adopt.m program, which is written in the present work using Matlab-7.0. The adopted evaluated cross sections are calculated (using adopt.m program) and plotted as a function of incident proton energy starting from threshold energy for each reaction. The results for each calculated yields for induced proton on Zinc to produce Gallium are discussed as follows:

Table(1):International libraries used for available measuring data collection for induced proton on Zinc isotopes.

Target Element	Reaction		Target Element	Reaction	
	Library	Product		Library	Product
$^{64}_{30}Zn_{34}$	EXFOR ...	$(p,\gamma)^{65}_{31}Ga_{34}$		EXFOR ENDF-B-VII	$(p,2n)^{66}_{31}Ga_{35}$
$^{66}_{30}Zn_{36}$	EXFOR ...	$(p,n)^{66}_{31}Ga_{35}$	$^{68}_{30}Zn_{38}$	EXFOR ...	$(p,2n)^{67}_{31}Ga_{36}$
	EXFOR* ENDF-B-VII	$(p,2n)^{65}_{31}Ga_{34}$		EXFOR ...	$(p,n)^{68}_{31}Ga_{37}$
	EXFOR* ENDF-B-VII	$(p,\gamma)^{67}_{31}Ga_{36}$		EXFOR ...	$(p,3n)^{66}_{31}Ga_{35}$
$^{67}_{30}Zn_{37}$	EXFOR ...	$(p,n)^{67}_{31}Ga_{36}$	$^{70}_{30}Zn_{40}$	EXFOR ...	$(p,n)^{70}_{31}Ga_{39}$
	EXFOR* ENDF-B-VII	$(p,\gamma)^{68}_{31}Ga_{37}$		EXFOR* ...	$(p,x)^{67}_{31}Ga_{36}$

 * only one author gives data.

1- $^{64}_{30}Zn_{34}(p,\gamma)^{65}_{31}Ga_{34}$ **Reaction**

 The cross sections data published by Krivonosov G.A..et al.(1977) [9], Skakun E,A. et al. (2008) [10] and Famian M.A.et al. (2008) [11] for this reaction have been plotted, interpolated, and recalculated in steps of 0.01 MeV from threshold energy 0.927 up to 3.61 MeV of the incident proton energy in order to obtain the adopted cross sections of this reaction. The results of adopted cross sections and the experimental results for the authors mentioned above are shown in figures (1).

2- $^{66}_{30}Zn_{36}(p,n)^{66}_{31}Ga_{35}$ **Reaction**

 The cross sections data published by Hille M. et al. (1972) [13], Little E. and Lagunas-Solar C. (1983) [14], Tarkanyi G.et al. (1990) [15], Levkovskij V.N. (1991) [12], Hermanne A. (1991) [16], Szelecsenyi F. et al. (1994) [17], Hermanne A. (1997) [18], Szelecsenyi F. et al. (1998) [19], Szelecsenyi F. et al. (1998) [19] and Szelecsenyi F. (2003) [20],or this reaction have been plotted, interpolated, and recalculated in steps of 0.01 MeV from threshold energy 4.5 up to 66.9 MeV of the incident proton energy in order to obtain the adopted cross sections of this reaction. The results of adopted cross sections and the experimental results for the authors mentioned above are shown in figures (2).

3- $^{66}_{30}Zn_{36}(p,2n)^{65}_{31}Ga_{34}$ **Reaction**

 The cross sections data published by Levkovskij V.N. (1991) [12],for this reaction have been plotted, interpolated, and recalculated in steps of 0.01 MeV from threshold energy 15.8 up to 29.5 MeV of the incident proton energy in order to obtain the adopted cross sections of this reaction. The results of adopted cross sections and the experimental results for the authors mentioned above are shown in figures (2).

4- $^{66}_{30}Zn_{36}(p,\gamma)^{67}_{31}Ga_{36}$ **Reaction**

The cross sections data published by Skakun E.A. et al.(2008) [10] for this reaction have been plotted, interpolated, and recalculated in steps of 0.01 MeV from threshold energy 1.204 up to 2.684 MeV of the incident proton energy in order to obtain the adopted cross sections of this reaction. The results of adopted cross sections and the experimental results for the authors mentioned above are shown in figures (3).

5- $^{67}_{30}Zn_{37}(p,n)^{67}_{31}Ga_{36}$ **Reaction**

The cross sections data published by Tarkanyi F. et al. (1990) [15], Levkovskij V.N. (1991) [12], Szelecsenyi F. et al. (1994) [17], Hermanne A. (1997) [18], Szelecsenyi F. et al. (1998) [19] and Szelecsenyi F. et al. (1998) [19], for this reaction have been plotted, interpolated, and recalculated in steps of 0.01 MeV from threshold energy 2 up to 29.5 MeV of the incident proton energy in order to obtain the adopted cross sections of this reaction. The results of adopted cross sections and the experimental results for the authors mentioned above are shown in figures (5).

6- $^{67}_{30}Zn_{37}(p,\gamma)^{68}_{31}Ga_{37}$ **Reaction**

The cross sections data published by Krivonosov G.A.et al. (1977) [9],for this reaction have been plotted, interpolated, and recalculated in steps of 0.01 MeV from threshold energy 1.47 up to 29.2 MeV of the incident proton energy in order to obtain the adopted cross sections of this reaction. The results of adopted cross sections and the experimental results for the authors mentioned above are shown in figures (6).

7- $^{67}_{30}Zn_{37}(p,2n)^{66}_{31}Ga_{35}$ **Reaction**

The cross sections data published by Tarkanyi F. et al.(1990) [15], Levkovskij V.N. (1991) [12], Szelecsenyi F. et al. (1994) [17] and Szelecsenyi F. et al. (1998) [19] for this reaction have been plotted, interpolated, and recalculated in steps of 0.01 MeV from threshold energy 13.6 up to 29.5 MeV of the incident proton energy in order to obtain the adopted cross sections of this reaction. The results of adopted cross sections and the experimental results for the authors mentioned above are shown in figures (7).

8- $^{68}_{30}Zn_{38}(p,2n)^{67}_{31}Ga_{36}$ **Reaction**

The cross sections data published by Mcgee T. et al.(1970) [21], Litte E. and Lagunas-Solar C. (1983) [14], Tarkanyi F. et al.(1989) [22], Levkovskij V. N.(1991) [12], Hermanne A. et al. (1991) [16], Szelecsenyi F. et al.(1994) [17], Hermanne A.(1997) [18], Szelecsenyi F. et al.(1998) [19] and Szelecsenyi F. et al.(1998) [19].for this reaction have been plotted, interpolated, and recalculated in steps of 0.01 MeV from threshold energy 3.766 up to 85 MeV of the incident proton energy in order to obtain the adopted cross sections of this reaction. The results of adopted cross sections and the experimental results for the authors mentioned above are shown in figures (8).

9- $^{68}_{30}Zn_{38}(p,n)^{68}_{31}Ga_{37}$ **Reaction**

The cross sections data published by Mcgee T. et al.(1970) [21], Hille M. et al. (1972) [13], Barrandon J.N. et al.(1975) [23], Kotelnikova G. V. et al.(1980) [24], Hsat M.T. et al. (1979) [25], Tarkanyi F. et al.(1990) [15], Levkovskij V.N.(1991) [12], Hermanne A. et al.(1991) [16], Vinogradov V.M. et al.(1993) [26] and Zhuravlev Yu. Yu. et al. (1995) [27] for this reaction have been plotted, interpolated, and recalculated in steps of 0.01 MeV from threshold energy 3.766 up to 85 MeV of the incident proton energy in order to obtain the adopted cross sections of this reaction. The results of adopted cross sections and the experimental results for the authors mentioned above are shown in figures (9).

10- $^{68}_{30}Zn_{38}(p,3n)^{66}_{31}Ga_{35}$ **Reaction**

The cross sections data published by Mcgee T. et al.(1970) [21], Levkovskij. V.N. (1991) [12], Hermanne A. et al.(1991) [16], Szelecsenyi F. et al.(1994) [17], Hermanne A. (1997) [18], Szelecsenyi F. et al.(1998) [19], Szelecsenyi F. et al.(1998) [19], Hermanne A. et al.(1999)

[28], Stoll T. et al.(2002) [29], and Szelecsenyi F. et al.(2005) [30], for this reaction have been plotted, interpolated, and recalculated in steps of 0.01 MeV from threshold energy 3.766 up to 85 MeV of the incident proton energy in order to obtain the adopted cross sections of this reaction. The results of adopted cross sections and the experimental results for the authors mentioned above are shown in figures (10).

11- $^{70}_{30}Zn_{40}(p,n)^{70}_{31}Ga_{39}$ Reaction

The cross sections data published by Vinogradov V.M.et al. (1993) [26], and Zhuravlev Yu. Yu.et al.(1995) [27] for this reaction have been plotted, interpolated, and recalculated in steps of 0.01 MeV from threshold energy 4.903 up to 6.776 MeV of the incident proton energy in order to obtain the adopted cross sections of this reaction. The results of adopted cross sections and the experimental results for the authors mentioned above are shown in figures (11).

12- $^{70}_{30}Zn_{40}(p,x)^{67}_{31}Ga_{36}$ Reaction

The cross sections data published by Fassbender M.et al.(1997) [31], for this reaction have been plotted, interpolated, and recalculated in steps of 0.01 MeV from threshold energy 79 up to 350.8MeV of the incident proton energy in order to obtain the adopted cross sections of this reaction. The results of adopted cross sections and the experimental results for the authors mentioned above are shown in figures (12).

When the widths of unstable states are small compared with their separation, the states are distinct and observable. And if the states are overlap and strongly mixed, these states do not have distinctly observable wave functions. Because of the instability of the compound nucleus, results in an uncertainty in the energy of these states. The energy uncertainty is given by the width of the resonance and lifetime of the state. Therefore, the resonance will have the character of the energy distribution of any decaying state of width, lifetime, and a maximum total cross section.

In analyzing for induced proton on Zinc to produce Gallium in sections we note that the discrete nuclear states that are populated in ordinary decays have discrete separations, widths, and lifetimes. Thus if we were to calculate the cross sections at a given incident proton energy of a nuclear state, it is very unlikely that the overlap of the energy distributions of two different states could cause confusion as to the stationary state resulting from the decay.

The stopping power of medium target elements for proton-particles has been calculated in the present work using two methods:

1-We adopt SRIM (2003) [4], as an experimental results where SRIM is a program build for Ziegler empirical formulae.

2- We used Ziegler empirical formulae and Ziegler coefficients mentioned in table (2), as a theoretical calculation results.

Table (2): Coefficients for stopping of proton used in the Zeigler formula [6,37].

Target Element	A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8	A-9	A-10	A-11	A-12
H	1.262	1.44	242.6	1.20E+04	0.1159	0.0005099	54360	-5.052	2.049	-0.3044	0.01966	-0.0004659
$_{30}Zn$	4.21	4.75	6953	295.2	0.006809	0.0153	3194	-11.57	4.394	-0.598	0.03506	-0.0007537
$_{31}Ga$	5.041	5.697	7173	202.6	0.006725	0.01581	3154	-11.95	4.537	-0.6169	0.03613	-0.0007759

For energies 1-10 KeV/amu use coefficients A-1.
For energies 10-999 KeV/amu use coefficients A-2 to A-5.
For energies above 1000 KeV/amu use coefficients A-6 to A-12.

For these calculations, the (stop. m) program has been written in Matlab-7.0 for this
purpose.

The calculated yields for induced proton on Zinc to produce Gallium are very important quantity as well as the cross sections in analyzing problems of diagnosis, physical therapy, and medicine treatments as the following :

Gallium -66,67,68 finds significant application in medical field .The production possibility in different energy region via different nuclear reactions are clarified in the following discussion :

a- Important uses of $^{66}_{31}Ga_{35}$ [1,2,3]

1- Slow dynamic processes (such as Lymphatic transport) by (PET).

2-Detecting and staging of tumors and other lesions after dosimetric studies using its high energy positrons

3- used for the radiolabelling of blood cells.

4- used as a gamma multi-line standard source for high energy calibration of Germanium detectors.

b- The gallium radionuclide $^{67}_{31}Ga_{36}$ is widely used in nuclear medicine for radio diagnostic as follows [4]:

1-Gallium-67 is a tumor seeking isotope for soft tissue tumors as well as bone seeking and dynamic studies.

2- It is used in Auger electron therapy, also used in Tumor imaging application

c- The Gallium radionuclide $^{68}_{31}Ga_{37}$ is widely used in nuclear medicine is follows [4]:

1- for diagnosing tumors, Gallium-68 tracers is being in many neuroendocrine tumor studies in human.

2-Gallium-68 decays principally by positron emission and it used in conjunction with positron emission tomography (PET) scanners for imaging various organs and their physiological functions. This is an economical source of $^{68}_{31}Ga_{37}$ in hospitals .

3- Gallium-68 finds significant application in assessment to detect blood-brain barrier defect to image tumor .

Therefore, the calculated yield for Zinc target ($^{64}_{30}Zn_{34}$, $^{66}_{30}Zn_{36}$, $^{67}_{30}Zn_{37}$, $^{68}_{30}Zn_{38}$ and $^{70}_{30}Zn_{40}$) were calculated in the present work using equation (15).

The main aim of this study is to increase a calculated yields for induced proton on Zinc to produce Gallium by increasing the energy of proton beams which can interact with different targets. The stopping power and calculated yields of the for induced proton on Zinc to produce Gallium for Zinc target isotopes maintained above have been obtained. The results have been shown in figure (13) respectively for each target element.

In all figures, the calculated yields of most of the for induced proton on Zinc to produce Gallium seem to depend strongly on the structure of the individual nucleus, the incident proton energy, and stopping power of the target element.

Generally, the behavior of the stopping power decreases with increasing the calculated yields which agrees with Ref. [37,38]. It is clear from the calculated results shown in these figures that for the calculated yield values for 20-100% abundance target element $^{64}_{30}Zn_{34}$, $^{68}_{30}Zn_{38}$ and $^{70}_{30}Zn_{40}$ follow the trend in the asymmetry parameter of proton excess (N-Z)/A so that by increasing this parameter the maximum calculated yields will be decrease as shown in table (3). This increment may be attributed to the fact that by decrease the number of neutrons the outer shells are populated by an excess calculated which increases the occurrence probability for induced proton on Zinc to produce Gallium.

Table (3): The maximum calculated yield and the asymmetry parameter for the 20-100% abundance elements.

Reactions	Maximum neutron yield (atom*1.0E-9)	(N-Z)/A
$^{66}_{30}Zn_{36}\,(p,2n)\,^{65}_{31}Ga_{34}$	3950.700	0.0910
$^{68}_{30}Zn_{38}\,(p,3n)\,^{66}_{31}Ga_{35}$	5390.800	0.1176
$^{70}_{30}Zn_{40}\,(p,n)\,^{70}_{31}Ga_{39}$	830.290	0.1429

For even-even elements with Z=N the asymmetry parameters are zero; i.e. the elements are symmetric (Z=A/2, N=A/2). The binding energy, the Q-values, and the calculated yields differ by much larger amounts among the medium elements than within any group.

Hence, for even-Z and even-A target elements $^{66}_{30}Zn_{36}$, $^{68}_{30}Zn_{38}$ and $^{70}_{30}Zn_{40}$ for induced proton on Zinc to produce Gallium the maximum calculated yield were found to be a function of the target neutron number (N) and the asymmetry parameter (N-Z)/A, where the maximum calculated yield decrease with increasing (N) and increasing asymmetry parameter.

5- Conclusions
1- The characteristic feature of cross sections is the appearance of many sharp resonances. Each resonance in the induced proton on Zinc to produce Gallium is higher by the same amount (close to threshold energy).

2- The yield production by proton incident to produce Gallium from Zinc isotopes as target elements which have large cross sections for yield production, and they could have influence on safety design and operation of these facilities. Hence, accelerators using protons are used in such fields as physics, biology, proton therapy and medicines .

3- The most important results of the calculated yields studies can be summarized as described calculations of calculated yields, with the use of different targets, should be performed in order to determine the proton scaling shielding. The use of different medium target element showed a change in dynamics of the incident proton energy .

4- In case of incident proton on Zinc for the production of Gallium , a comparison of all experimental and theoretical results showed that cross section theory was successful in reproducing most experimental data . The recommended excitation functions and calculated integral yields help to optimize the energy range for each nuclear reaction for the production of Gallium seem to be the most useful .
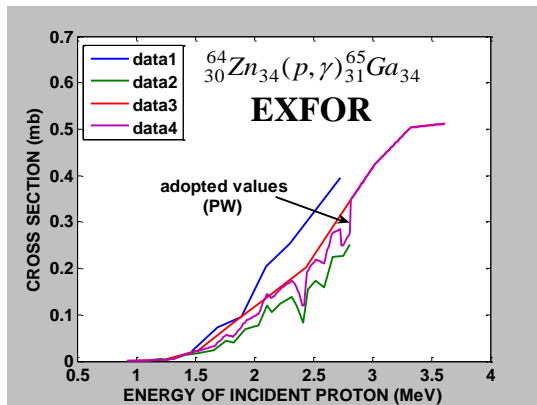
Figure (1): The adopted cross section of the $_{30}^{64}Zn_{34}$ target element (present work) compared with EXFOR Library. Data 1:Ref. No.[9]; Data 2:Ref. No.[10]; Data 3:Ref.
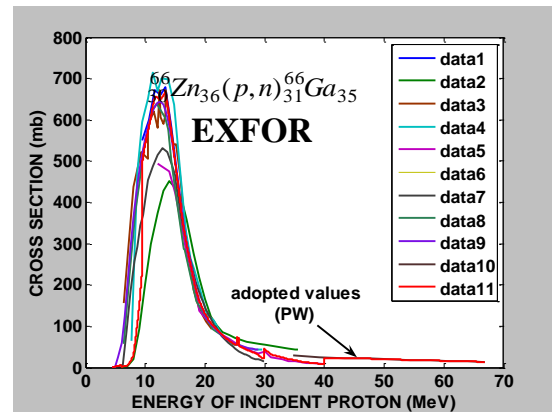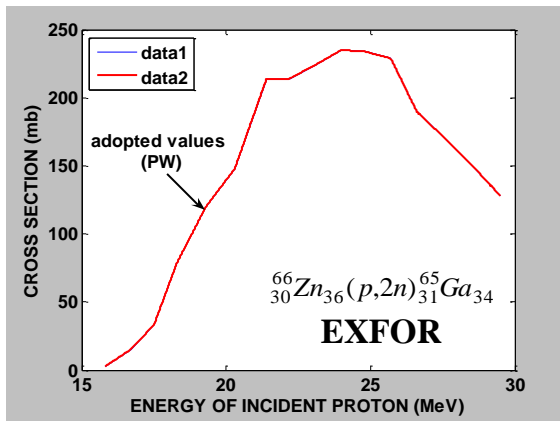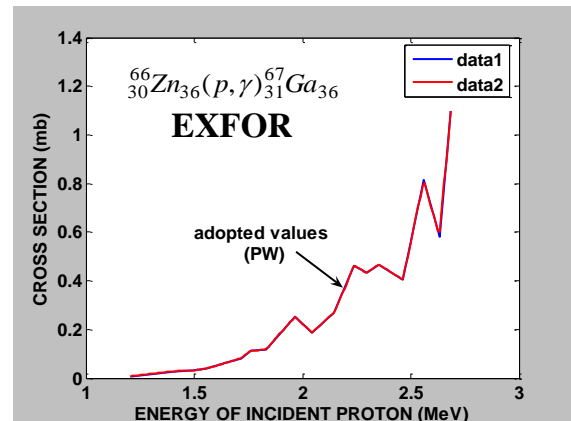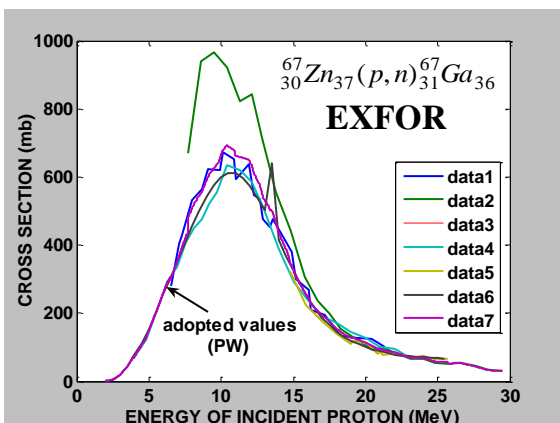

Figure (2): The adopted cross section of the $_{30}^{66}Zn_{36}$ target element (present work) compared with EXFOR Library. Data 1:Ref. No.[13]; Data 2:Ref. No.[14]; Data 3:Ref. No.[15]; Data 4:Ref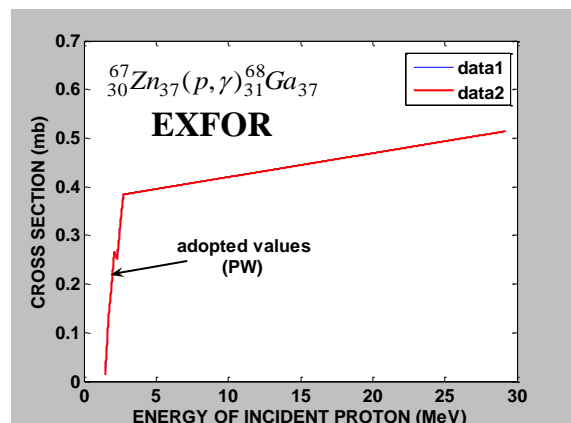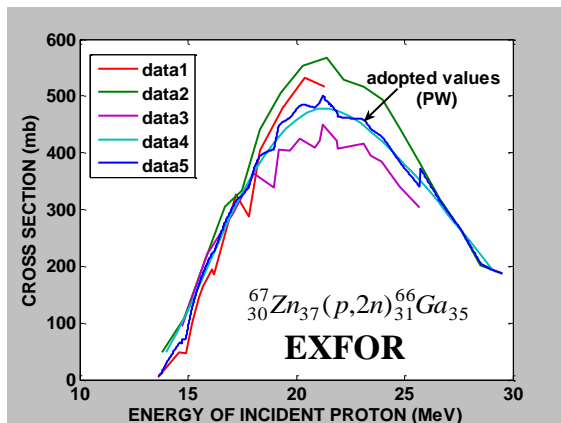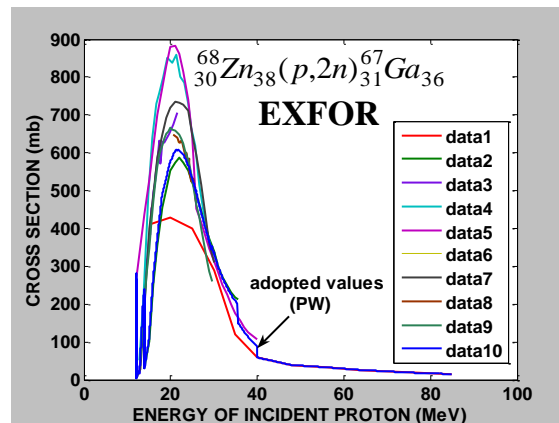. No.[12]; Data 5:Ref. No.[16]; Data 6:Ref. No.[17]; Data 7:Ref. No.[18]; Data 8:Ref. No.[19]; Data 9:Ref. No.[19]; Data 10:Ref. No.[20]; Data 11: (PW).
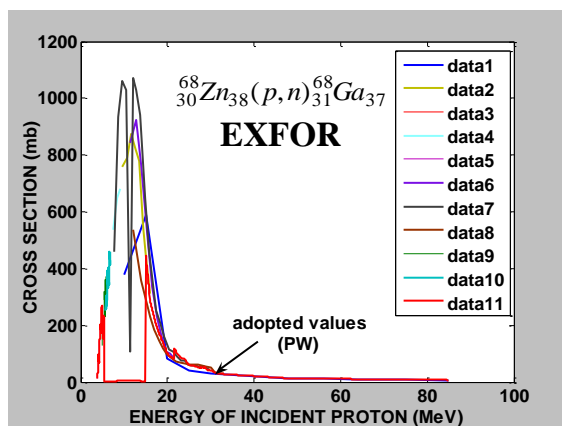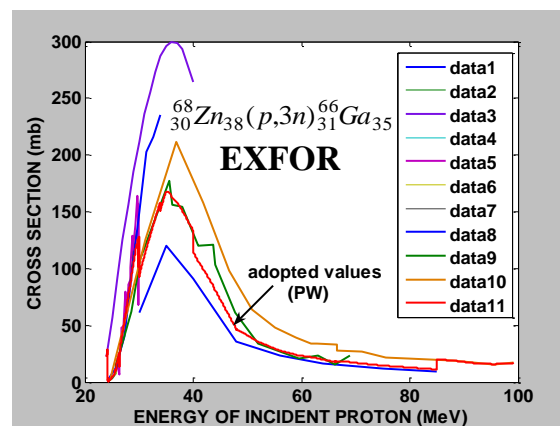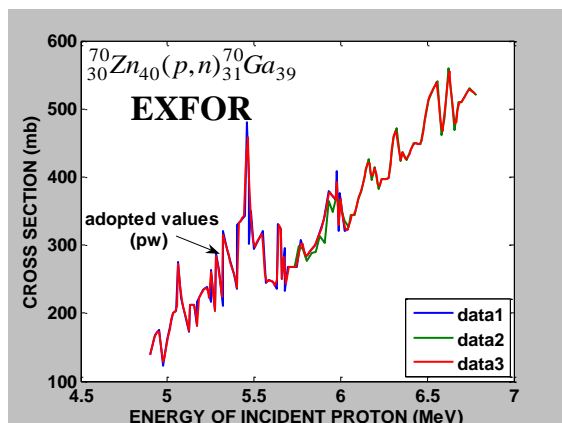

Figure (3): The adopted cross section of the $_{30}^{66}Zn_{36}$ target element (present work) compared with EXFOR Library. Data 1:Ref. No.[12]; Data 2: (PW).

Figure (4): The adopted cross section of the $_{30}^{66}Zn_{36}$ target element (present work) compared with EXFOR Library. Data 1:Ref. No.[10]; Data 2: (PW).

Figure (5): The adopted cross section of the $_{30}^{67}Zn_{37}$ target element (present work) compared with EXFOR Library. Data 1:Ref. No.[15]; Data 2:Ref. No.[12]; Data 3:Ref. No.[17]; Data 4:Ref. No.[18]; Data 5:Ref. No.[19]; Data 6:Ref. No.[19]; Data 7: (PW)

Figure (6): The adopted cross section of the $_{30}^{67}Zn_{37}$ target element (present work) compared with EXFOR Library. Data 1:Ref. No.[9]; Data 2: (PW).

Figure (7): The adopted cross section of the $^{67}_{30}Zn_{37}$ target element (present work) compared with EXFOR Library. Data 1:Ref. No.[15]; Data 2:Ref. No.[12]; Data 3:Ref. No.[17]; Data 4:Ref. No.[19]; Data 5: (PW).

Figure (8): The adopted cross section of the $^{68}_{30}Zn_{38}$ target element (present work) compared with EXFOR Library. Data 1:Ref. No.[21]; Data 2:Ref. No.[14]; Data 3:Ref. No.[22]; Data 4:Ref. No.[12]; Data 5:Ref. No.[16]; Data 6:Ref. No.[17]; Data 7:Ref. No.[18]; Data 8:Ref. No.[19]; Data 9:Ref. No.[19]; Data 10: (PW).

Figure (9): The adopted cross section of the $^{68}_{30}Zn_{38}$ target element (present work) compared with EXFOR Library. Data 1:Ref. No.[21]; Data 2:Ref. No.[13]; Data 3:Ref. No.[23]; Data 4:Ref. No.[24]; Data 5:Ref. No.[25]; Data 6:Ref. No.[15]; Data 7:Ref. No.[12]; Data 8:Ref. No.[16]; Data 9:Ref. No.[26]; Data 10: Ref. No. [27]; Data 11: (PW).

Figure (10): The adopted cross section of the $^{68}_{30}Zn_{38}$ target element (present work) compared with EXFOR Library. Data 1:Ref. No.[21]; Data 2:Ref. No.[12]; Data 3:Ref. No.[16]; Data 4:Ref. No.[17]; Data 5:Ref. No.[18]; Data 6:Ref. No.[19]; Data 7:Ref. No.[19]; Data 8:Ref. No.[28]; Data 9:Ref. No.[29]; Data 10: Ref. No. [30]; Data 11: (PW).

Figure (11): The adopted cross section of the $^{70}_{30}Zn_{40}$ target element (present work) compared with EXFOR Library. Data 1:Ref. No.[26]; Data 2: Ref. No.[27]; Data 3: (PW).
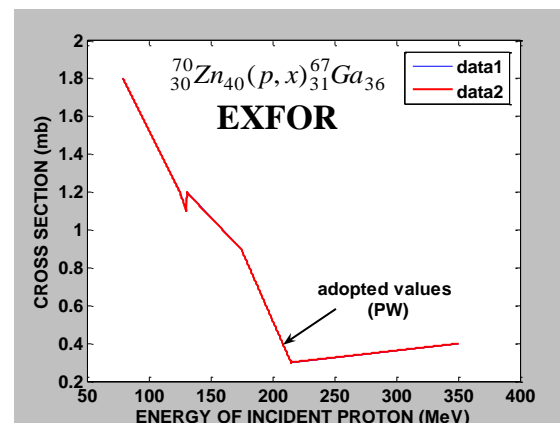

Figure (12): The adopted cross section of the $^{70}_{30}Zn_{40}$ target element (present work) compared with EXFOR Library. Data 1:Ref. No.[31]; Data 2: (PW).
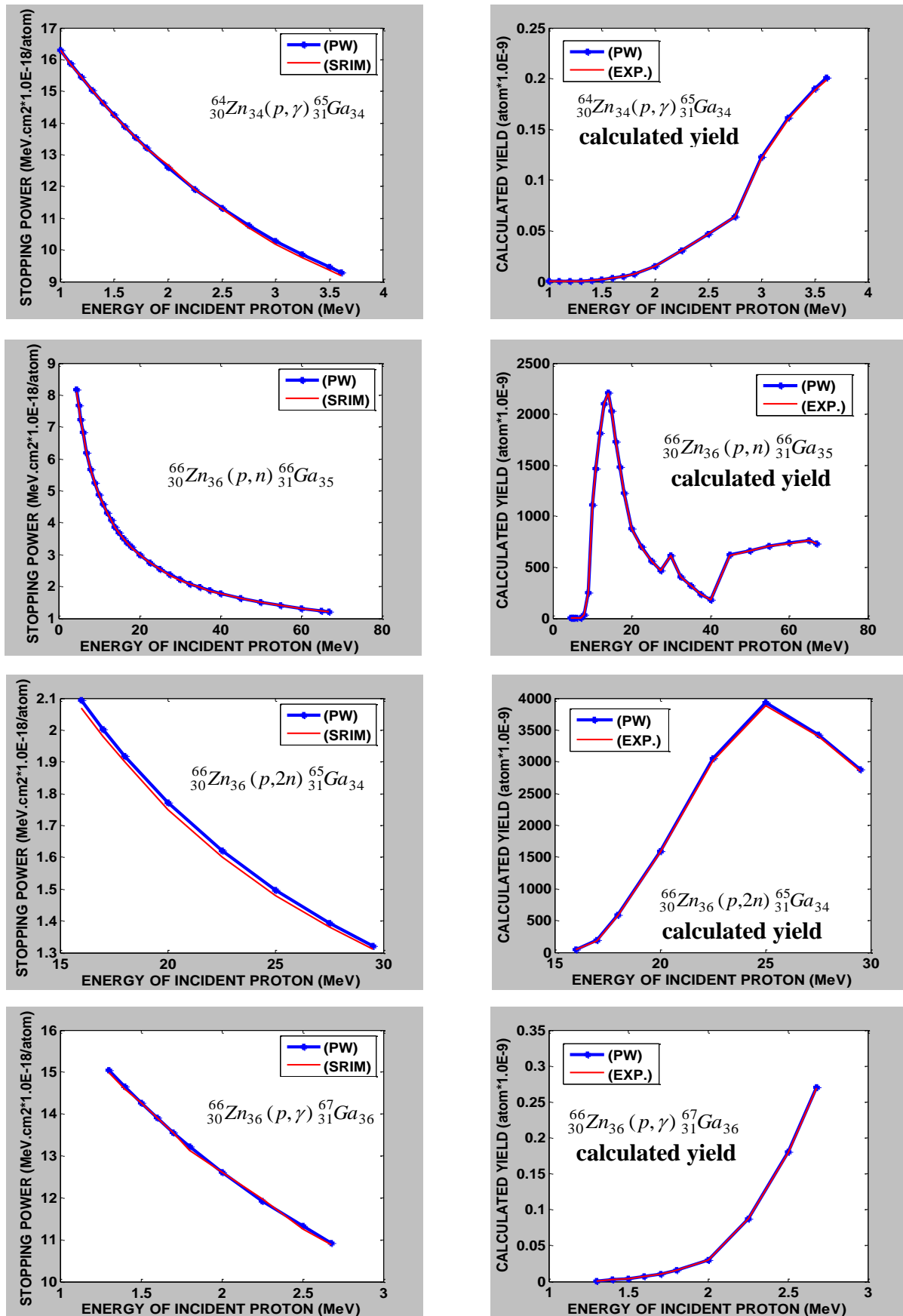
Figure (4-13): Left side; the comparison between the calculated stopping power in the present work (pw) and SRIM (2003) of incident proton in Zn. Right side; the calculated yield as calculated in the present work compared with experimental results based on the adopted cross section of incident proton in Zn reaction.
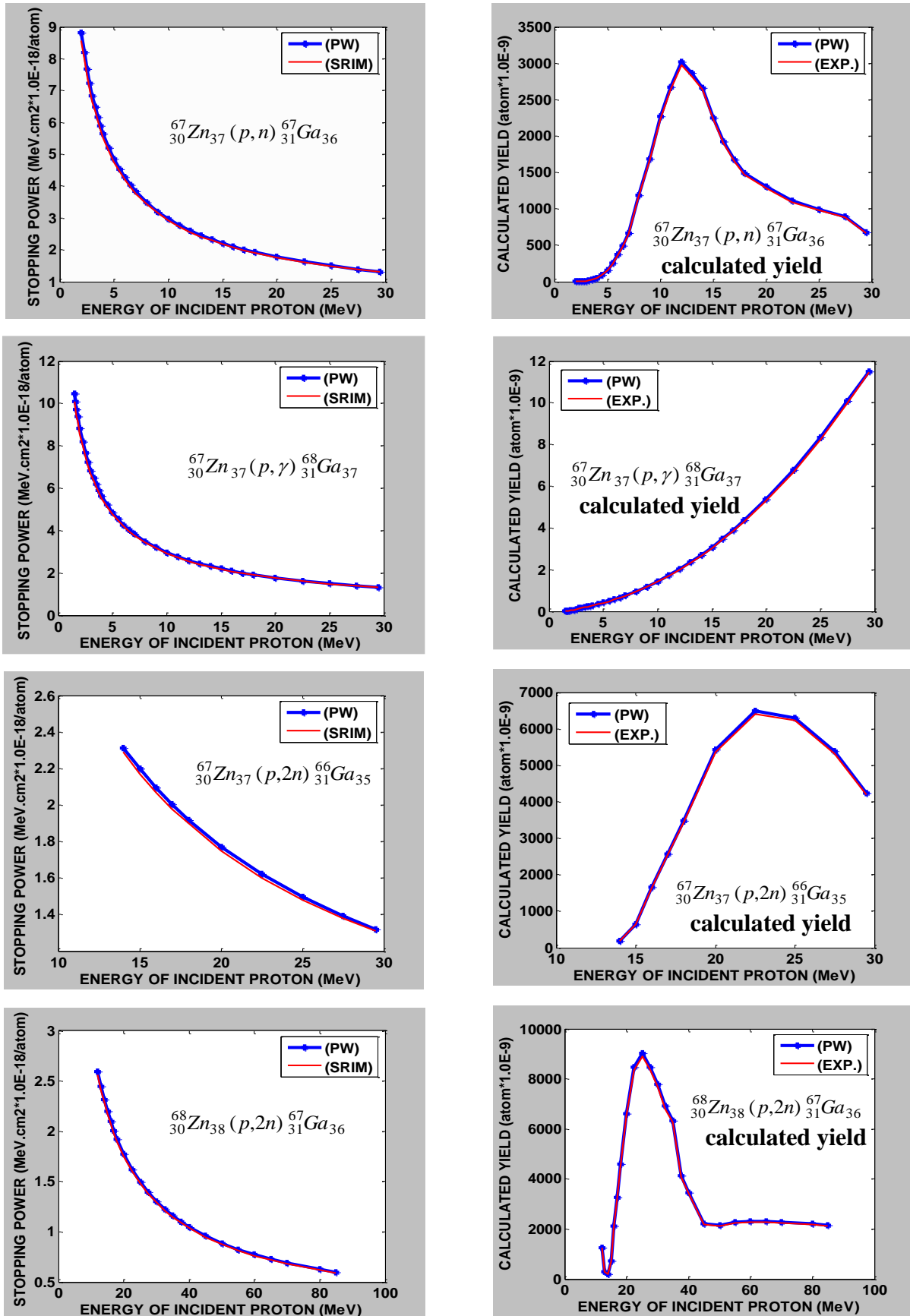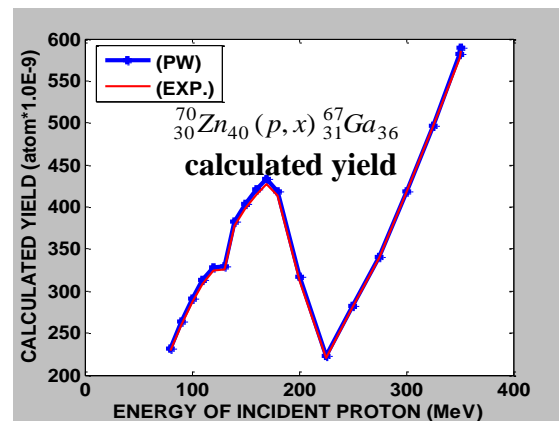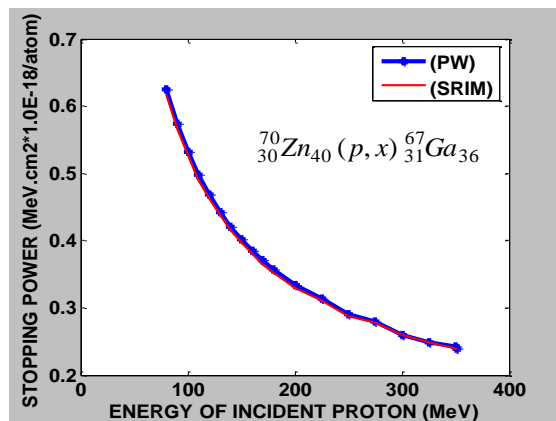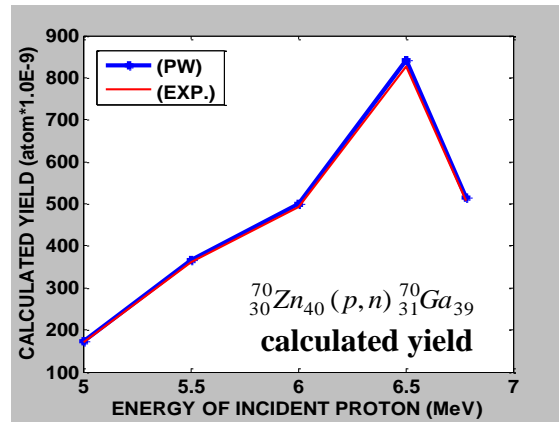
Figure (4-13) : To be continued (2/2).
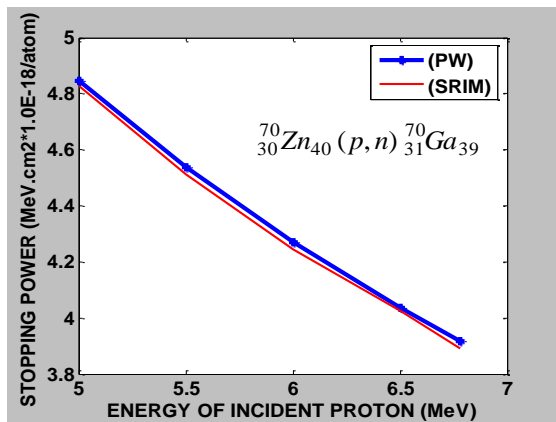
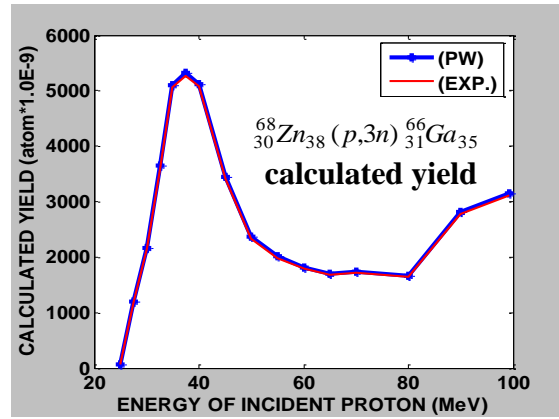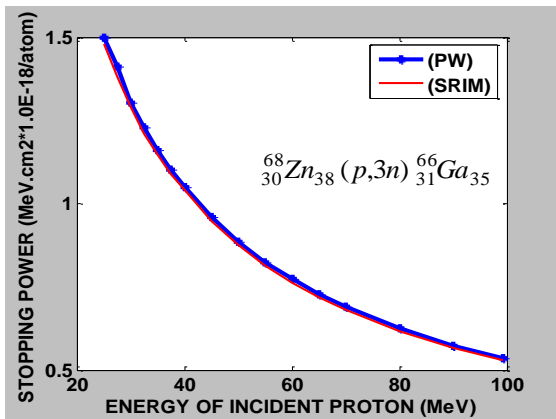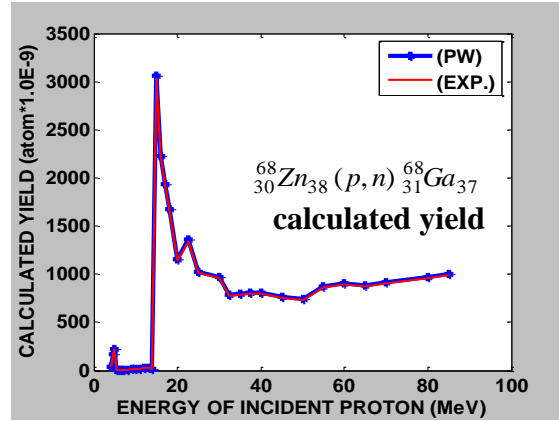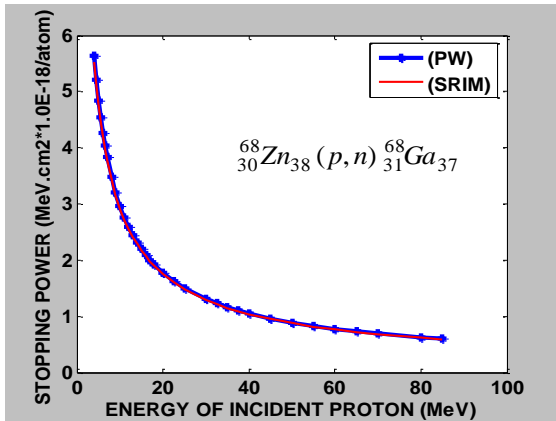Figure (4-13) : To be continued (2/2).

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