International Journal of Engineering Research And Management (IJERM)
ISSN : 2349- 2058, Volume-03, Issue-01, January 2016

Neutron Yield Calculation of As (p,n) Se reaction with Odd Neutron Numbers for Energy Range (50-100) MeV

Khalid H. Mahdi, Raafat Abdul H. Muslim, Aseel A. Yousife

***Abstract*— As the difficulty of obtaining cross-sections for most of the isotopes and definite Energies in international ,we have extract unified set of semi-empirical formulas for calculating Neutron's yield depending on the mass number of the target and energy of projectile, either energy is single or a range .Data of cross-sections was collected against energies for the energy range (50-100) MeV from International Libraries (Koning, AJ; TENDL-2010-2012), for every interaction , then the stopping power of the incident proton by SRIM program was calculated , Neutron 's yield by (MATLAB) program (viir 2008 a) that being designed for this purpose; and the asymmetry energy for each isotopes also calculated ,then mathematical formulas has been extracted through a best fitting process between – asymmetry energy and Neutron's yield at energies (50,60,70,80,90,100 MeV) for targets with odd numbers of Neutron. The parameters that extracted from these formulas were tabled and drown with energy to get unified equation ,that we can corresponding the energy as a parameter in these equation when these equation drown in addition to the experimental and theoretical results they have good agreement with international theoretical results**

***Index Terms*— Cross-Section, Neutron Yield, stopping power, Asymmetry and empirical formula**

I. INTRODUCTION

Two-particle collision between the projectile m_1 and target m_2 resulting , in general , in products of m_3 and m_4 are referred to as nuclear reactions and are governed by the conversation [1] Nuclear Reaction The term, direct reaction, is used for a variety of nuclear processes including inelastic nuclear collisions, stripping, and its inverse, the pick-up reaction. A direct reaction is one which proceeds without the formation of a compound nucleus. The time during which the incident partical and target nucleus interact is very much shorter than the life of a corresponding compound nucleus. Because of this, the reaction products exhibit certain characteristics which are entirely different from those seen if the reaction has proceeded through a compound-nucleus formation [2]

The Cross Section is The probability of occurrence of a nuclear reaction is conveniently expressed in terms of the concept of cross section [3]. Therefore to obtain information on the nuclear reactions, it is necessary to have a quantitative measure of probability of a given reaction [4].

Is a measure of the effect of a substance on the kinetic energy of a charged particle passing through it. Stopping power is often quoted relative to that of a standard substance, usually air or aluminum [5].For hydrogen projectiles, the nuclear stopping power are very small for all energies of interest [6].

II. THE CROSS SECTION

We can define a flux ϕ as a number of particles crossing the unit area perpendicular to the direction of motion per unit time. If all particles have the same speed v, the flux is given by:

$$\emptyset = n_p v \qquad \text{----- (1)}$$

Where n_p the density of projectiles in the beam. In general, there is a distribution of particle speeds and if $n_p(v)\,dv$ is the density of projectiles with speed between (v) and $v + dv$, the flux is given by the integral [4].

$$\emptyset = \int v\, n_p(v)\, dv \quad \text{-----(2)}$$

Suppose a given reaction $A(a,b)B$ is accruing at a certain rate. If the nuclei in the target act independently, the event rate (or reaction rate) per nucleus exposed to the beam is the a proportional to the incident flux. The constant of proportionality is called the cross section (σ), which can be written as [4].

$$\sigma = (event\ rate\ per\ nucleus)/(incident\ flux)$$

And , if N target nuclei are exposed to the beam , we have a reaction rate:

$$R = N \sigma \emptyset \quad \text{--------- (3)}$$

The beam intensity is $I = \phi S$ particles per unit time, where S is the cross-sectional area of the beam, and we can write down an alternative expression for the reaction rate in terms of (I) and thickness (t):

$$R = \frac{N\sigma I}{S} = I\sigma n_t t \quad \text{--------(4)}$$

Where n_t is the number of target nuclei per unit volume. If the target consists of a certain isotopic species of atomic mass M_A (in atomic mass units). We know that:

$$n\_t = (\rho N_A)/M_A \quad \text{……(5)}$$

Where ρ is the density of the target and N_A is Avogadro's number.

The Stopping Power

Manuscript received Jan 02, 2016

Khalid H. Mahdi, Physics Department, College of Ibn Al-Haytham, University of Baghdad
Raafat Abdul H. Muslim, Ministry of Education, D.G of Curreulum, Iraq
Aseel A. Yousife, Physics Department, College of Ibn Al-Haytham, University of Baghdad

The electronic stopping power is found to be proportional to projectile velocity, the specific dependence [7] being given by:

$$S_e = Z_1^{1/6} \times 8\pi e^2 a_o \frac{Z_1 Z_2}{(Z_1^{2/3} + Z_2^{2/3})^{3/2}} x \frac{v}{v_B}, \; v < v_0 Z_1^{2/3} \qquad \text{-----(6)}$$

where Z_1 and Z_2 are the atomic numbers of projectile and target, respectively,

v is the projectile velocity,

a_o, v_o are the Bohr radius of the hydrogen atom and the Bohr velocity.

In the present work, we used the formulas proposed by Varelas and Biersack cited in Ziegler [6]

$$S_e = \frac{S_{Low} S_{High}}{(S_{Low} + S_{High})} \qquad \text{---(7)}$$

Where S_{Low} (Low energy stopping) is

$$S_{Low} = B_1 E^{1/2} \qquad \text{---(8)}$$

and S_{High} (High energy stopping) is

$$S_{High} = \frac{B_2}{E} \ln(1 + \frac{B_3}{E} + EB_4) \qquad \text{---(9)}$$

where B_1, B_2, and B_3 are fitting constants (tables), and

$B_4 = 4\ m / I\ M$

where m is the electron mass,

I is the mean ionization potential,

M is the projectile mass

Neutron Yield:

For an accelerating beam traversing a target, the occurred nuclear reactions produce N light product particles per unit time.

$$Y(x) = I_o N_d \sigma x \qquad \text{---(10)}$$

Experimentally, the yield of neutrons detected per incident particle, Y_n, for an ideal, thin and uniform target and mono-energetic beam of energy E is given by

$$Y_n = (N_d x)\, \sigma(E_b)\, \eta(E_b) \qquad \text{---(11)}$$

where $(N_d x)$ is the real number density of target atoms, and 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 [8]

$$Y_n = \int_{E_0}^{E_0} \frac{\sigma(\acute{E})\eta(\acute{E}) f\, d\acute{E}}{\frac{dE}{dx}(\acute{E})} \qquad \text{---(12)}$$

in which $E_t = E_b - \Delta E$, where ΔE is the energy loss of the beam in the target, f is the number of target atoms in each target molecule, and $dE/dX(E)$ is the stopping power per target molecule,

If 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 [9]

$$Y(E_n) = \int_{E_{thr}}^{E_b} \frac{\sigma(E)\, dE}{\frac{dE}{dx}} \qquad \text{---(13)}$$

where E_{thr} is the reaction threshold energy.

Thus, by measuring the yield at two closely spaced energies E_1 and E_2, one can determine the average value of the integrand over this energy interval as follows [9]:

$$\left[\frac{\sigma(E)}{\frac{dE}{dx}} \right] E_b = \frac{Y(E_2) - Y(E_1)}{E_2 - E_1} \qquad \text{---(14)}$$

where E_b is the average of E_1 and E_2. If $\sigma(E)$ are available as a function of projectile energy E_b for natural elements, then the neutron yield can be calculated using eq.[6]

If neutron yield is available as a function of projectile energy E_b, then eq.[6] can be used to calculate $\sigma(E)$ as a function of E_b. Thus, consequently the neutron yield can be calculated using eq.[6]

For natural elements and if only one stable isotope is available in nature, then [10]

$$Y_o = Y(E) \qquad \text{---(15)}$$

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 [10]

$$Y_o = \frac{a}{c}\, Y(E) \qquad \text{---(16)}$$

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

If there exists 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 [10]

Results and desiccation

Interpolation for cross- sections of interaction isotopes that the targets have odd numbers of neutrons was made by depending on the data from Libraries (Koning, AJ; TENDL-2010-2012)[11], stopping power was calculated by using program (SRIM 2013) also the neutron yield using the equation 13 the results were tabled in tables (1 -5) then from the best fitting between asymmetry and neutron yield semi-empirical formula was extracted as follow .

$$Y = a\ (b)^S\ (S)^c \text{ --------- } (18)$$

From the fitting of equation (18) the initial parameters were extracted anther fitting was made to get another set of semi-empirical equations depending on the energy of the incident particle, the equation (18) well be

$$a = C1E^{C2} + C3\exp(C4\, E) \qquad \ldots\ldots\ldots(19)$$

$$b = C5\ E\text{^}((C6\, E + C7\ E\text{^}2)) + C8\ln(E) \qquad \ldots\ldots\ldots\ (20)$$

$$c = (C9/E) + C10\exp(C11\, E) \qquad \ldots\ldots\ldots\ (21)$$

then the final set of parameters were extracted and tabled in table no.7 from this set of b equations the neutron yield will calculated depending on mass number no and energy of incident particle.

CONCLUSIONS

From this work we conclude that the neutron yield increase with the increase of incident proton energy as in Figure 1, as well as we note that the in neutron yield increase with decreasing in mass number of target isotopes. The Reasons behind that relate to the increase of instability of (N / Z) as that indicted in Table 8, as well as from the figures (2 to 6) Semi-empirical formula that dependent on the incident particle energy and the mass number . of the target a show good agreement with the theoretical results that calculated from energy and cross -sections .

Table(1) The cross section and calculated data of stopping and neutron yield for $^{76}As(p,n)^{76}Se$ reaction

Yield proton $(\frac{N}{10^6})$	Stopping power $(\frac{Mev}{\frac{mg}{cm^2}})$	Cross_ section (mbarn)	Energy (Mev)	Yield proton $(\frac{N}{10^6})$	Stopping power $(\frac{Mev}{\frac{mg}{cm^2}})$	Cross_ section (mbarn)	Energy (Mev)
5.448593	0.007598	20.69896	50	62.247625	0.005582	10.18931	76
10.722763	0.007388	19.48335	52	65.794915	0.005471	9.704241	78
15.812319	0.007179	18.26774	54	69.234323	0.005361	9.219172	80
20.726918	0.006985	17.16382	56	72.579209	0.005273	8.819238	82
25.478275	0.006807	16.1716	58	75.826377	0.005186	8.419305	84
30.057638	0.006629	15.17938	60	78.972468	0.005098	8.019371	86
34.505878	0.006476	14.40385	62	82.013946	0.00501	7.619438	88
38.816639	0.006323	13.62832	64	84.947086	0.004923	7.219505	90
42.998530	0.00618	12.92135	66	87.800906	0.004851	6.92206	92
47.061416	0.006046	12.28294	68	90.573030	0.004779	6.624616	94
50.999933	0.005913	11.64452	70	93.260971	0.004708	6.327172	96
54.846228	0.005803	11.15945	72	95.862127	0.004636	6.029728	98
58.596723	0.005692	10.67438	74	98.373775	0.004565	5.732284	100

Table(2) The cross section and calculated data of stopping and neutron yield for $^{78}As(p,n)^{78}Se$ reaction

Energy (Mev)	Cross_ section (mbarn)	Stopping power $(\frac{Mev}{\frac{mg}{cm^2}})$	Yield proton $(\frac{N}{10^6})$	Energy (Mev)	Cross_ section (mbarn)	Stopping power $(\frac{Mev}{\frac{mg}{cm^2}})$	Yield proton $(\frac{N}{10^6})$
50	19.26255	0.007403	5.204152	76	9.363762	0.005439	58.978163
52	18.05445	0.007199	10.220205	78	8.916985	0.005331	62.323335
54	16.84636	0.006995	15.037180	80	8.470207	0.005224	65.566259
56	15.80682	0.006806	19.682354	82	8.105884	0.005138	68.721420
58	14.93583	0.006632	24.186510	84	7.741562	0.005053	71.785846
60	14.06484	0.006458	28.542066	86	7.377239	0.004967	74.756407
62	13.32732	0.006309	32.766603	88	7.012916	0.004881	77.62980

							9
64	12.58979	0.006161	36.853790	90	6.648594	0.004796	80.402582
66	11.91764	0.006021	40.812382	92	6.376468	0.004726	83.101046
68	11.31087	0.005891	44.652369	94	6.104343	0.004656	85.722980
70	10.7041	0.005761	48.368397	96	5.832217	0.004587	88.266058
72	10.25732	0.005654	51.996998	98	5.560092	0.004517	90.727850
74	9.81054	0.005546	55.534782	100	5.287967	0.004447	93.105811

Table(3) The cross section and calculated data of stopping and neutron yield for ^{80}As(p,n)^{80}Se reaction

Energy (Mev)	Cross_ section (mbarn)	Stopping power $\left(\frac{Mev}{\frac{mg}{cm^2}}\right)$	Yield proton $\left(\frac{N}{10^6}\right)$	Energy (Mev)	Cross_ section (mbarn)	Stopping power $\left(\frac{Mev}{\frac{mg}{cm^2}}\right)$	Yield proton $\left(\frac{N}{10^6}\right)$
50	16.95681	0.007218	4.698722	76	8.379317	0.005302	53.754076
52	15.96199	0.007018	9.247374	78	7.984508	0.005198	56.826480
54	14.96718	0.006819	13.637186	80	7.589699	0.005093	59.807087
56	14.07035	0.006635	17.878454	82	7.286301	0.005009	62.716205
58	13.27151	0.006466	21.983403	84	6.982904	0.004926	65.551412
60	12.47266	0.006297	25.944720	86	6.679506	0.004842	68.310161
62	11.81732	0.006152	29.786771	88	6.376109	0.004759	70.989772
64	11.16197	0.006006	33.503771	90	6.072711	0.004676	73.587419
66	10.58019	0.00587	37.108700	92	5.829051	0.004608	76.117543
68	10.07197	0.005743	40.616023	94	5.58539	0.00454	78.578127
70	9.563745	0.005617	44.021345	96	5.34173	0.004472	80.967060
72	9.168936	0.005512	47.348187	98	5.098069	0.004404	83.282136
74	8.774127	0.005407	50.593505	100	4.854409	0.004336	85.521044

Table(4) The cross section and calculated data of stopping and neutron yield for ^{82}As(p,n)^{82}Se reaction

Energy (Mev)	Cross_ section (mbarn)	Stopping power $\left(\frac{Mev}{\frac{mg}{cm^2}}\right)$	Yield proton $\left(\frac{N}{10^6}\right)$	Energy (Mev)	Cross_ section (mbarn)	Stopping power $\left(\frac{Mev}{\frac{mg}{cm^2}}\right)$	Yield proton $\left(\frac{N}{10^6}\right)$
50	15.4135	0.007041	4.377905	76	7.473069	0.005173	49.726467
52	14.45721	0.006847	8.600826	78	7.10181	0.005071	52.527485
54	13.50091	0.006653	12.659703	80	6.730551	0.004969	55.236699
56	12.67593	0.006473	16.576344	82	6.446452	0.004887	57.874793
58	11.98227	0.006308	20.375419	84	6.162353	0.004806	60.43935

							7
60	11.2886	0.006143	24.050619	86	5.878254	0.004724	62.927855
62	10.71069	0.006001	27.620217	88	5.594155	0.004643	65.337620
64	10.13278	0.005859	31.079092	90	5.310056	0.004561	67.665841
66	9.592429	0.005726	34.429370	92	5.097883	0.004495	69.933963
68	9.089637	0.005603	37.673874	94	4.88571	0.004429	72.140190
70	8.586845	0.00548	40.807847	96	4.673537	0.004363	74.282642
72	8.215586	0.005378	43.863328	98	4.461364	0.004297	76.359353
74	7.844327	0.005275	46.837276	100	4.24919	0.00423	78.368266

Table(5) The cross section and calculated data of stopping and neutron yield for ^{84}As(p,n)^{84}Se reaction

Energy (mev)	Cross_ section (mbarn)	Stopping power $(\frac{Mev}{\frac{mg}{cm^2}})$	Yield proton $(\frac{N}{10^6})$	Energy (mev)	Cross_ section (mbarn)	Stopping power $(\frac{Mev}{\frac{mg}{cm^2}})$	Yield proton $(\frac{N}{10^6})$
50	12.90964	0.006872	3.756963	76	6.430008	0.005049	43.173231
52	12.15958	0.006683	7.395867	78	6.132479	0.004949	45.651301
54	11.40953	0.006494	10.909829	80	5.83495	0.00485	48.057684
56	10.73856	0.006319	14.308885	82	5.590385	0.00477	50.401598
58	10.14667	0.006157	17.604710	84	5.34582	0.004691	52.680926
60	9.554785	0.005996	20.791752	86	5.101255	0.004611	54.893444
62	9.055121	0.005858	23.883522	88	4.85669	0.004532	57.036810
64	8.555456	0.005719	26.875406	90	4.612125	0.004452	59.108556
66	8.109018	0.00559	29.776843	92	4.429157	0.004388	61.127418
68	7.715807	0.005469	32.598387	94	4.24619	0.004323	63.091813
70	7.322596	0.005349	35.336441	96	4.063223	0.004259	65.000089
72	7.025066	0.005249	38.013207	98	3.880256	0.004194	66.850517
74	6.727537	0.005149	40.626310	100	3.697289	0.004129	68.641286

Table(6) The initial Parameters Extracted from lethality Banalatnazer first and neutron yield of As (p,n) Se

E	**A**	**b**	**c**	r^2
50	6.987855	0.793921	0.205835	0.99245
60	38.16249	0.804458	0.177387	0.995231
70	64.52449	0.808041	0.168506	0.995471
80	87.31944	0.811719	0.158373	0.996816
90	107.0523	0.812115	0.158568	0.998022
100	123.9861	0.811013	0.163911	0.998757

Table(7) The final Parameters Extracted between the second Alguetk between the initial parameters and the corresponding energy of As (p,n) Se

parameters	value
C1	27.5502503
C2	0.39786587
C3	-317.81552
C4	-0.0188814
C5	0.40871231
C6	-0.0004048
C7	-1.755E-06
C8	0.10816212
C9	137.591819
C10	1.02302229
C11	-1.956989

Table (8) : neutron number and ration N/Z.

As	**N**	**N/Z**
^{76}As	43	1.30303
^{78}As	45	1.3636
^{80}As	47	1.424241
^{82}As	49	1.484847
^{84}As	51	1.54545

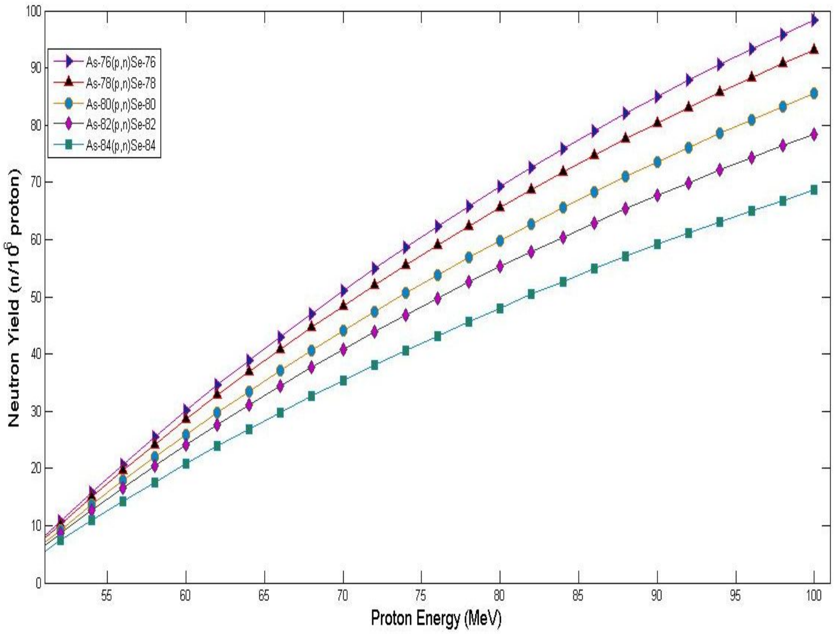

Figure (1): The neutron yield of of As(p,n)Sc reactions

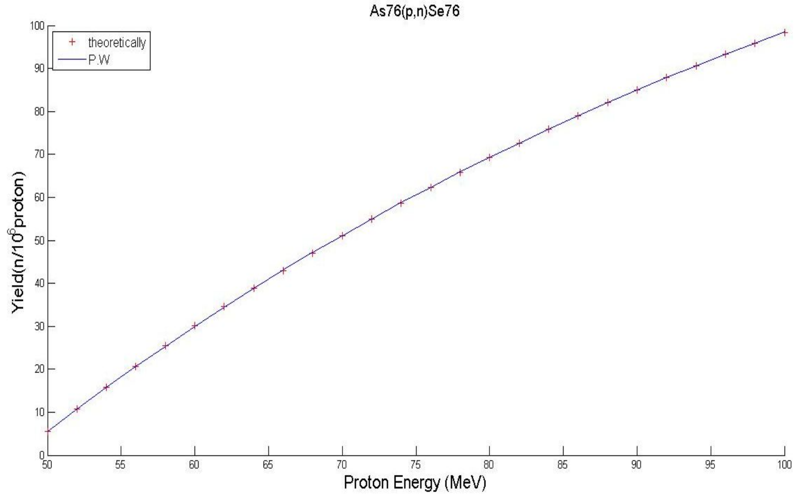

Figure (2): The comparison between neutron yields calculated from the theoretically relationship and fitting expressions for $^{76}As(p,n)^{76}Se$

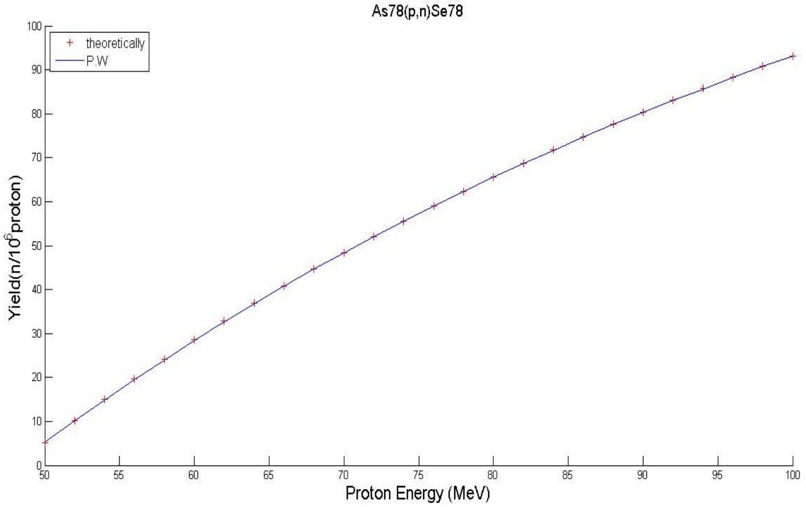

Figure (3): The comparison between neutron yields calculated from the theoretically relationship and fitting expressions for $^{78}As(p,n)^{78}Se$

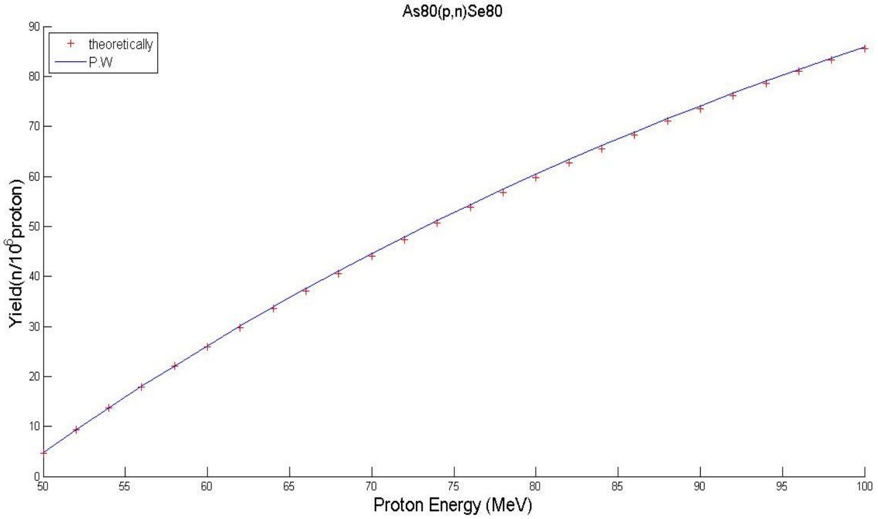

Figure (4): The comparison between neutron yields calculated from the theoretically relationship and fitting expressions for $^{80}As(p,n)^{80}Se$

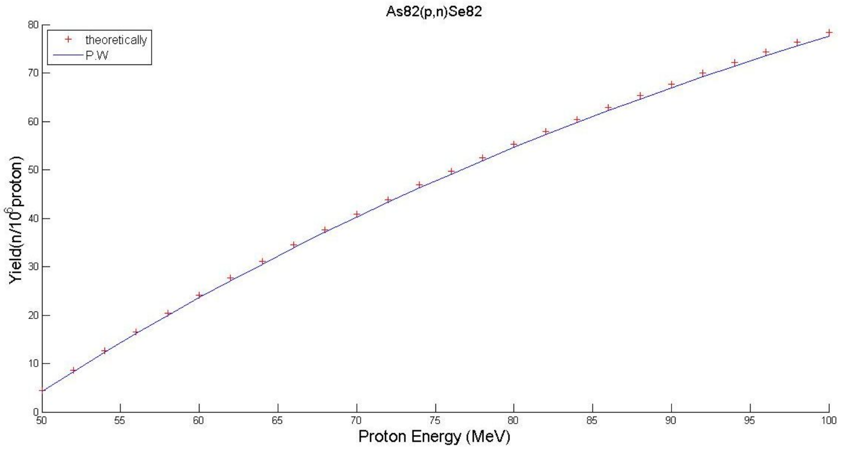

Figure (5): The comparison between neutron yields calculated from the theoretically relationship and fitting expressions for ^{82}As(p,n)^{82}Sei

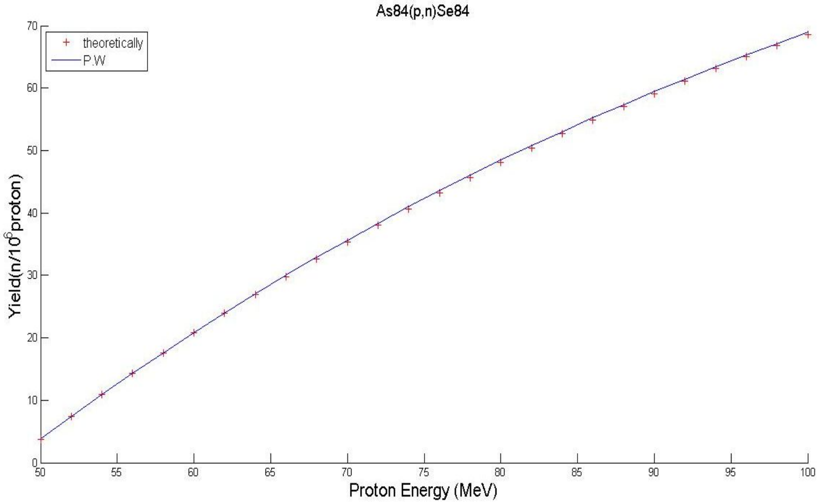

Figure (6): The comparison between neutron yields calculated from the theoretically relationship and fitting expressions for ^{84}As(p,n)^{84}Se

REFERENCES

1) Podgoršak E. B. ;"Radiation Physics for Medical Physicists" ,(2005).
2) Feshbach H., Proc. Conf. Direct Interactions Nucl. Reaction Mech., p. 215, Gordon and Breach, Science Publishers Inc., New york, (1963).
3) Meyerhof W." Element of Nuclear physics " Mc Graw–Hill Book INC. (1967).
4) Lilley J. " Nuclear physics " John Wiley & Sons, Ltd . (2001).
5) Arora E.D. ; "Dictionary of Physics" ," Low Cost Text Book Publishers ,"Delhi, India, (2003)
6) Anderson H.H. and Ziegler J.F., "Hydrogen: Stopping Powers and Ranges in all elements " vol.3, Pergamon Press, Oxford (1977).
7) Linhard J. and Scharff M., Phys. Rev. 124, 128 (1961).
8) Wrean P.R., Ph.D. Thesis, California Institute of Technology, (1998).U.S.A.
9) Norman E.B., Chupp T.E., Lesko K.T., Grant P.J., & Woodruff G.L. : Phys. Rev. C 30, 1339 (1984).
10) Abdulla R. H., Ph.D. thesis, University of Baghdad, (1999).
11) Koning,A.J.; TENDL-2010,2012 in ENDF-6 format, http://www.nds.iaea.org/ exfor/endf.htm.