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Measurement of the nuclear elements suspension involved in bones ability

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Abstract: In this study, the nuclear stopping capacity of the elements involved in the synthesis of the nodules and the input in the following reactions was measured (^{28}Si (p,n)^{28}P, ^{29}Si (p,n)^{29}P, ^{30}Si (p,n) ^{30}P, ^{31}P (p,n)^{31}S , ^{40}Ca (a,n) ^{43}Ti ,^{44}Ca (p,n)^{45}Sc, ^{26}Mg (p,n)^{26}Al,^{64}Zn (p,n)^{64} Ga and ^{61}Cu (a,n)^{64} Zn reaction by using Zekler equations (SRIM) program . Using the Matlab program, the stopping capacity of energies ranging from (11 MeV to 116 MeV) was calculated with energy steps of (5 MeV). The results showed that the maximum value of the stopping power is in the reaction ^{40}ca (a,n) ^{43}Ti in the energy (11 MeV) is (0.2913 MeV/(mg/cm^2)) and that the lowest stopping power was in the reaction ^{44}Ca (p,n)^{45}Sc and in the energy (16 MeV) is (0.0043 MeV/(mg/cm^2). Drawn and tabulated the results.

Keywords: Neutron, Proton, Nuclear reaction, Target nucleus, Stopping Power.

INTERODUCTION

Nuclear reaction are usually produced by bombarding a target nucleus with a nuclear projectile in most case a nucleon (neutron or proton) or a light nucleus such as a deuteron or an α-particle[1]. The equation for Nuclear reaction may be shown in a form similar to chemical equation for which invariant mass must balance for each side of the equation , the final products can be different from the initial ones[2].A typical nuclear reaction is written :

$$a+ X \rightarrow Y+b \qquad \ldots(1)$$

Where (a) is the accelerated projectile coming from an accelerator or from a radioactive substance, X is the target (usually stationary in the laboratory), b is the light particle that can be detected and measured while Y will be a heavy product that stops in the target and is not directly observed[3]. In all nuclear reactions, the following entities must be conserved[4]

1. The mass number A and the charge Z must balance on each side of the reaction arrow.
2. The total energy before the reaction must equal the total energy after the reaction. The total energy includes the particle kinetic energy plus the energy equivalent of the particle rest masses, $E=mc^2$.
3. Linear momentum before and after the reaction must be equal.
4. Quantum rules govern the balancing of the angular momentum, parity, and is spin of the nuclear levels.

The nuclear data on (α, n) reactions play an important role in the field of radiation shielding and criticality safety relating to storage, transport and handling of spent fuel[5].

THEORY

Stopping Power: 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[6]. 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, and the nuclear stopping power, that is,

$$S_{tot} = S_n + S_e \qquad \ldots (2)$$

Where (S_{tot}) is total stopping power, (S_n) is nuclear stopping power and(S_e) electric stopping power .The nuclear stopping power (S_n) of the α-particle with different energy ranges have been presented by Ziegler [6] as follows:

$$S_n = 1.593\varepsilon^{1/2} \quad (\varepsilon < 0.01 \text{ MeV}) \qquad \ldots (3)$$

$$S_n = 1.7(\varepsilon^{1/2})\left[\frac{\ln(\varepsilon+e^1)}{1+6.8\varepsilon+3.4\varepsilon^{3/2}}\right] \quad (0.01\leq\varepsilon\leq 10\text{MeV}) \qquad \ldots (4)$$

$$S_n = (\ln 0.47\varepsilon)/2\varepsilon \quad (\varepsilon > 10 \text{ MeV}) \qquad \ldots (5)$$

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

$$Reduced\ Ion\ Energy = \varepsilon = \frac{32.53 M_2\, E}{Z_1 Z_2 (M_1+M_2)\left(Z_1^{2/3}+Z_2^{2/3}\right)^{1}/\boldsymbol{\varepsilon}} \qquad \ldots (6)$$

Where (E) is ion energy in keV, (M_1, M_2) are the masses of the projectile and target element in atomic mass unite respectively and (Z_1,Z_2) are the atomic number of the projectile and target respectively .The electronic stopping powers (S_e) were calculated using the Ziegler formulae[6] expressions valid for the energy range (10-140) keV.

$$\left(\frac{1}{S_e}\right)=\left(\frac{1}{S_{Low}}\right)+\left(\frac{1}{S_{High}}\right) \qquad \ldots (7)$$

$$S_{Low} = A_1 E^{A_2} \qquad \dots (8)$$

$$S_{High} = \left(\frac{A_3}{E/1000}\right) \ln\left[1 + \left(\frac{A_4}{E/1000}\right) + \left(\frac{A_5 E}{1000}\right)\right] \qquad \dots (9)$$

Where (A_i) are coefficients given by Ziegler[6].

RESULTS AND DISCUSSION

The results of stopping power for proton and alpha interaction with bone are calculated by using Bethe and Ziegler formula (SRIM) program are plotted in **Fig. 1 to 9**.

In **Fig. (1)** The Stopping power of interaction ^{28}Si (p,n) ^{28}P ranges between (0.0325 -0.0053 (MeV/(mg/cm^2))) , It is considered the greatest value of Stopping power Compared to the studied interactions , as these values decrease logarithmically with energy . In **Fig.(2)** The stopping power decreases with the increase in power as the values range between(0.0314 MeV/(mg/cm^2)) in (11 MeV) and (0.0051 MeV/(mg/cm^2)) in (116 MeV) .

In **Fig.(3)** and **Fig.(4)** The difference between the values of the nuclear stopping capacity of the two reactors ^{30}Si (p,n) ^{30}P and ^{31}P (p,n)^{31}S are very low and the energy range is between (11 MeV) to (116 MeV) .

In **Fig.(5)** to **Fig.(9)** interaction Alpha particle with calcium and copper Where alpha is a heavy nucleus and does not penetrate the substance only a very small extent Where the highest value of the stopping power is in the interaction ^{40}Ca (a,n) ^{43}Ti as shown in **Table (1) and Table (2)** .

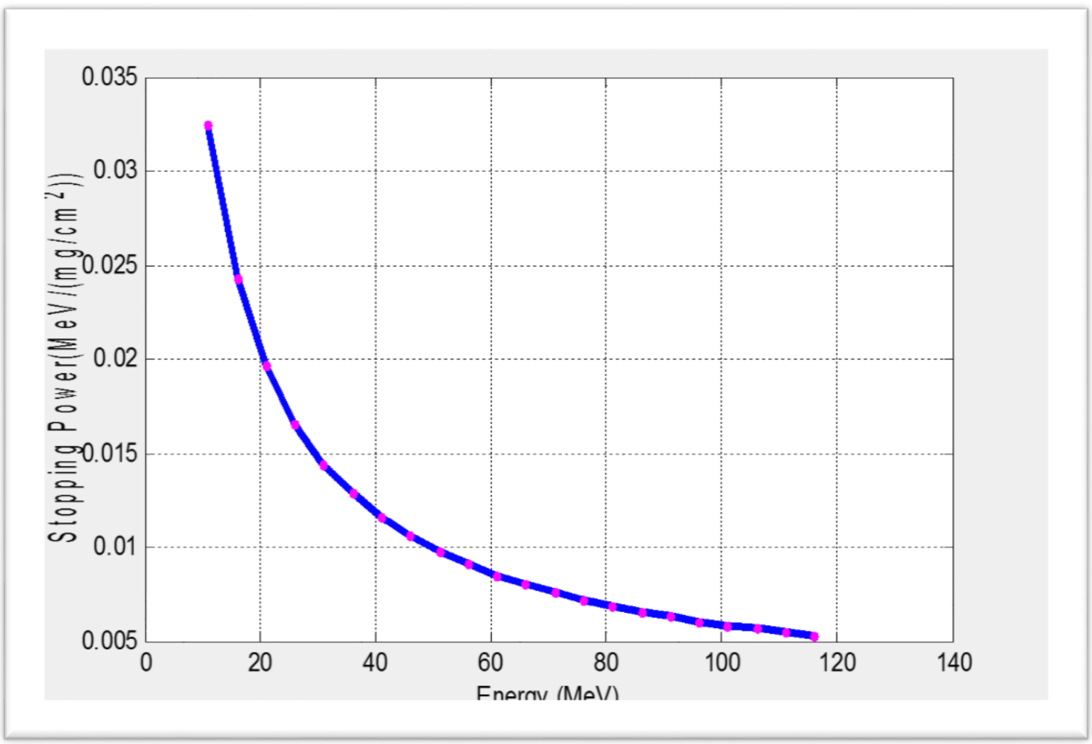

Fig. (1): The stopping power of proton in ^{28}Si (p,n)^{28}P reaction(p.w.)

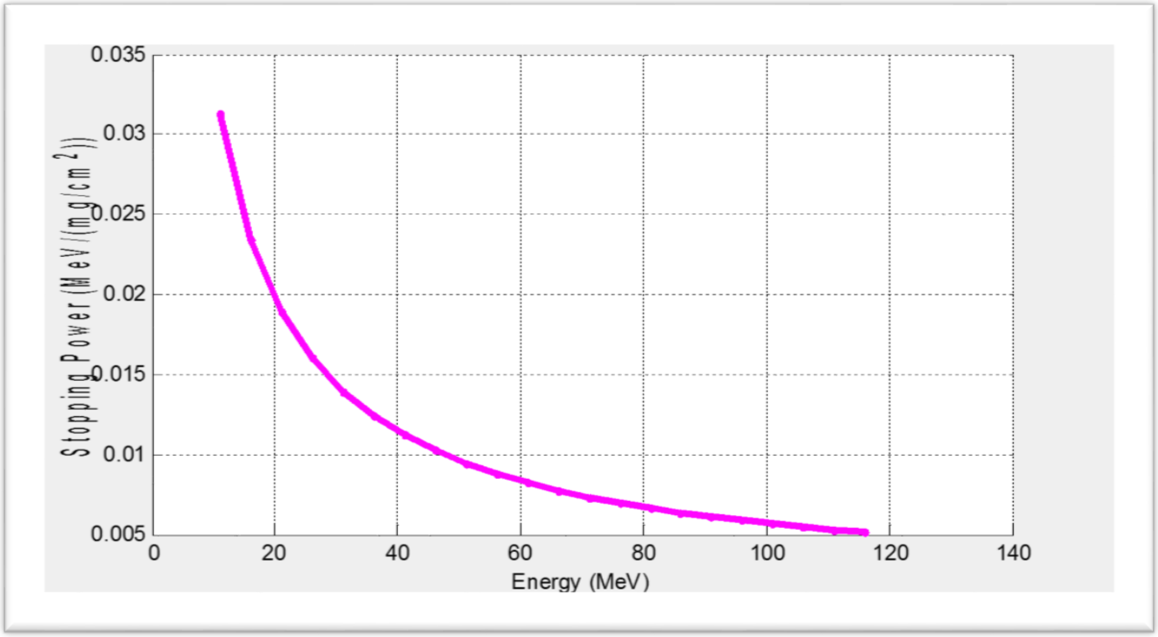

Fig. (2): The stopping power of proton in ^{29}Si (p,n)^{29}P reaction(p.w.)

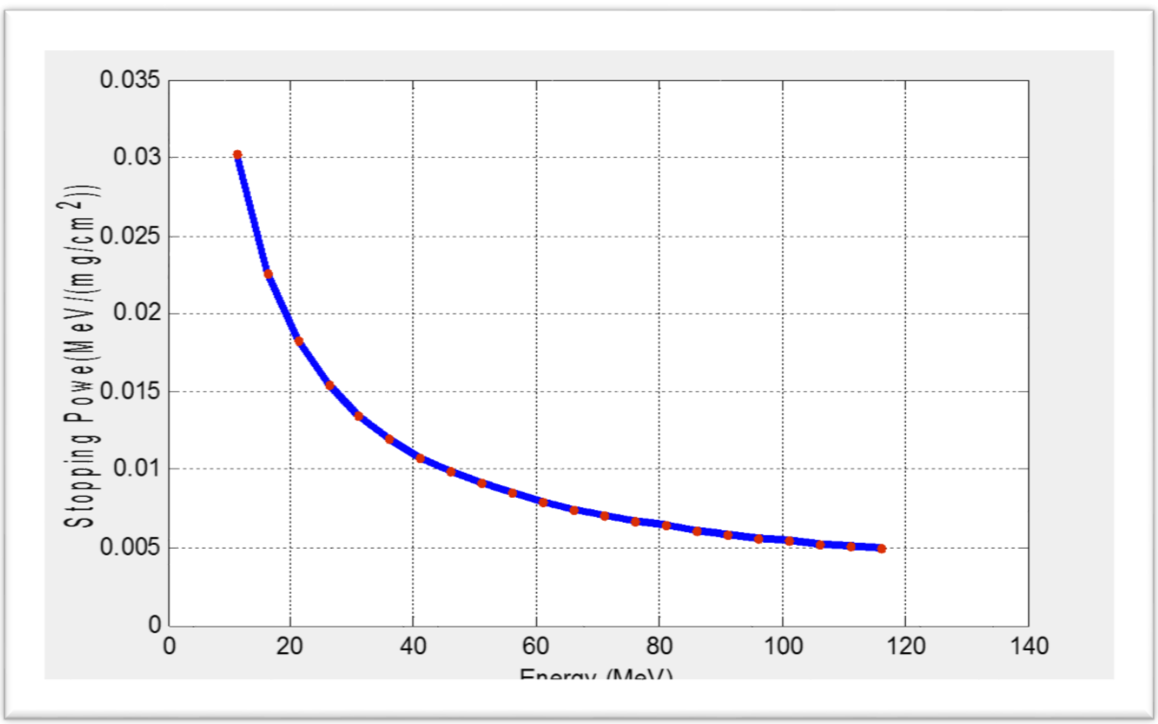

Fig. (3): The stopping power of proton in ^{30}Si (p,n)^{30}P reaction(p.w.)

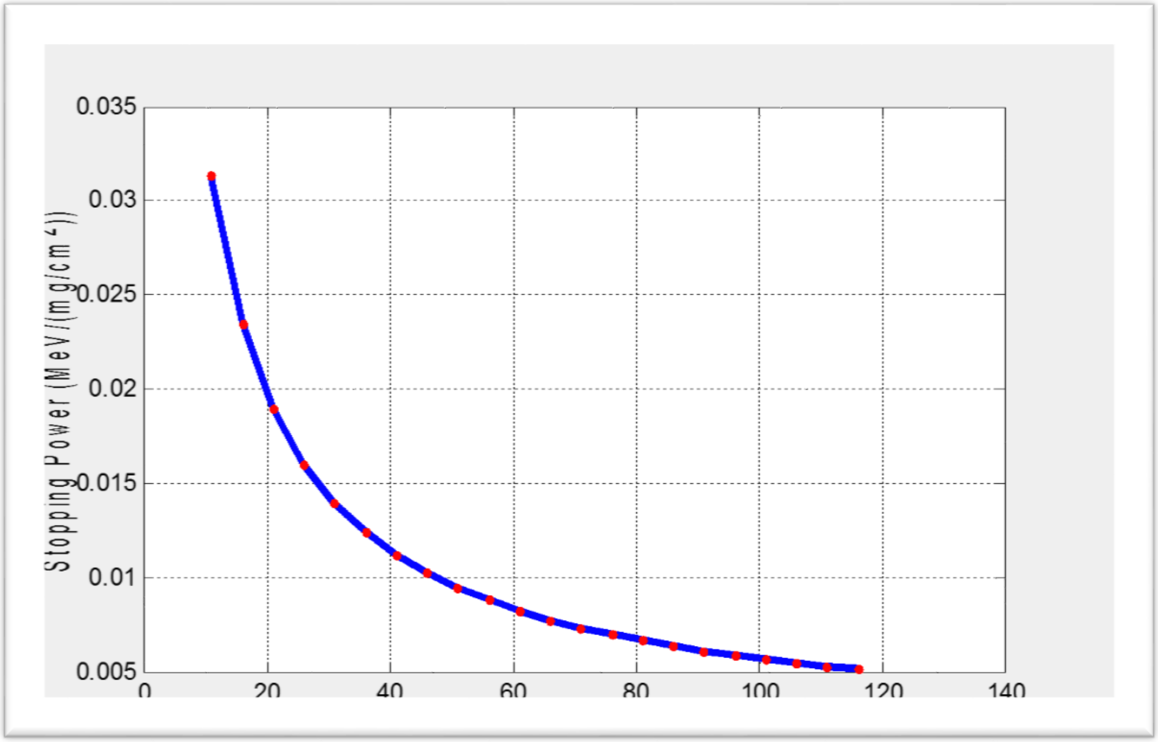

Fig. (4): The stopping power of proton in ^{31}P (p,n)^{31}S reaction(p.w.)

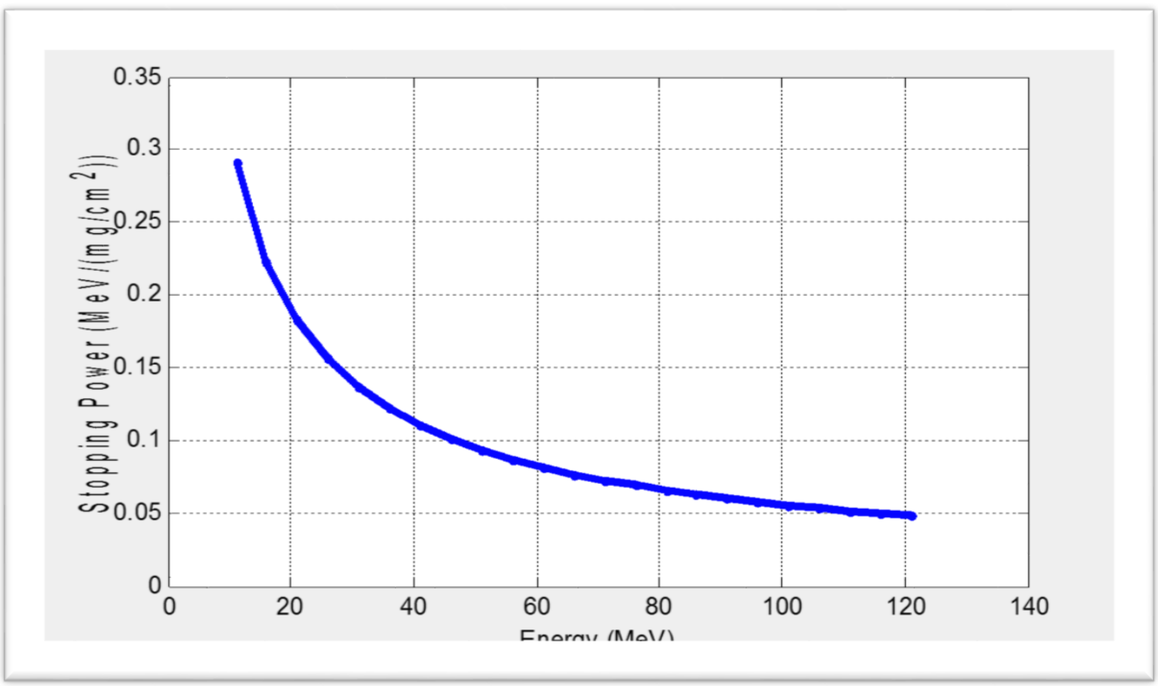

Fig. (5): The stopping power of proton in ^{40}Ca (a,n)^{43}Ti reaction(p.w.)

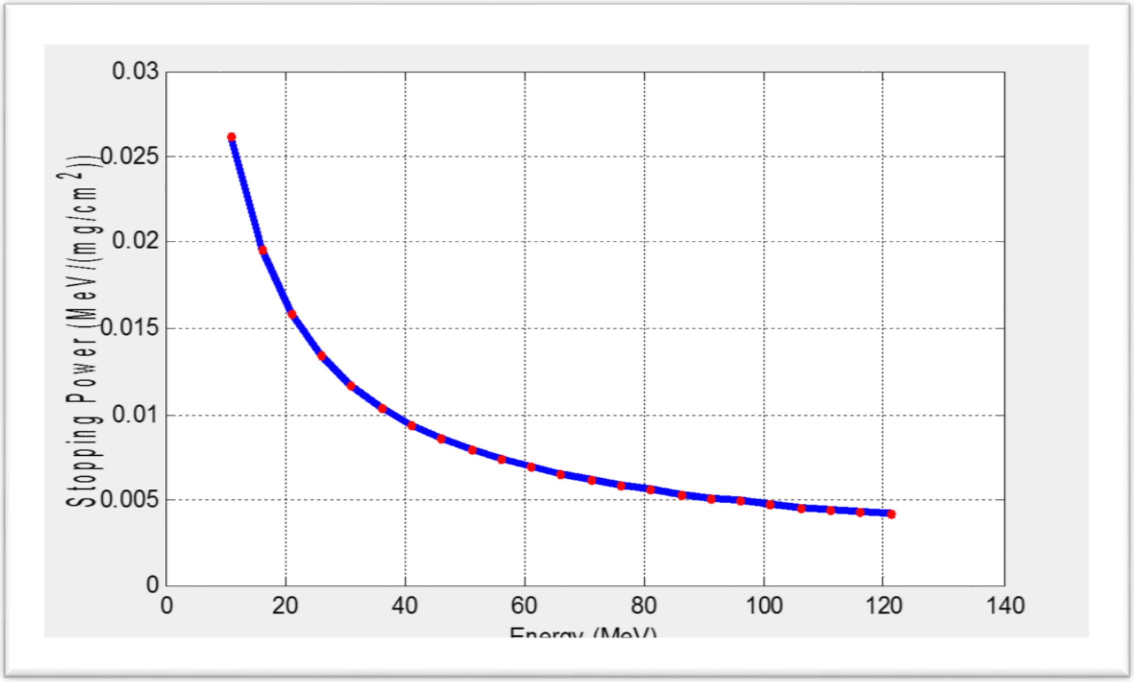

Fig.(6): The stopping power of proton in ^{44}Ca (p,n)^{45}Sc reaction(p.w.)

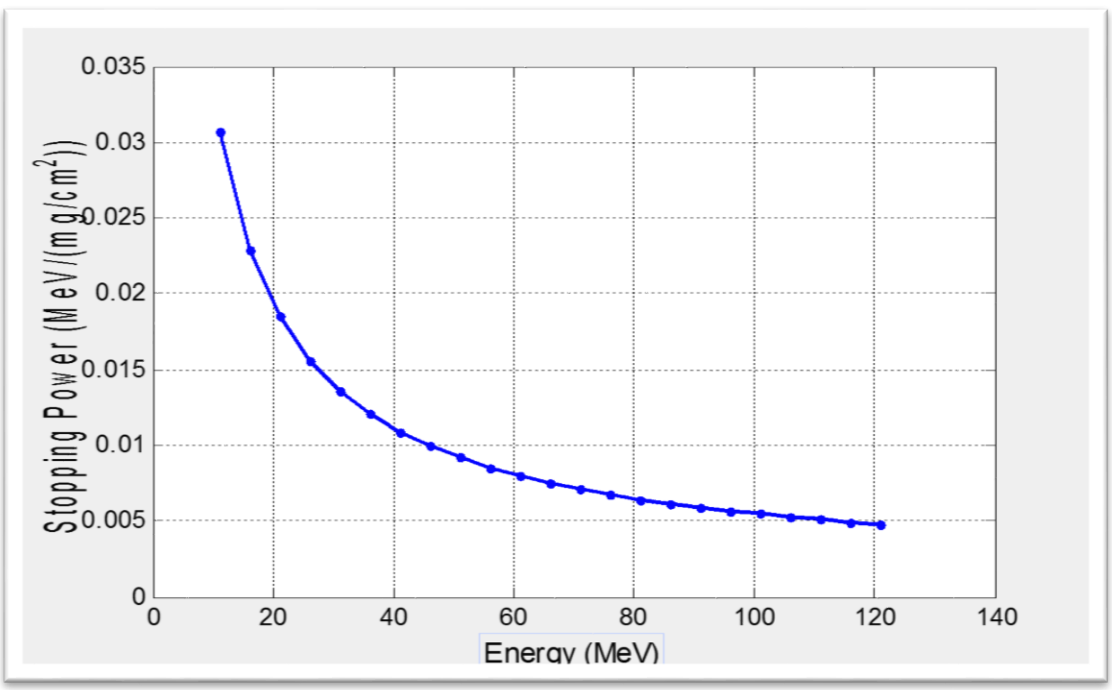

Fig.(7): The stopping power of proton in ^{26}Mg (p,n)^{26}Al reaction(p.w.)

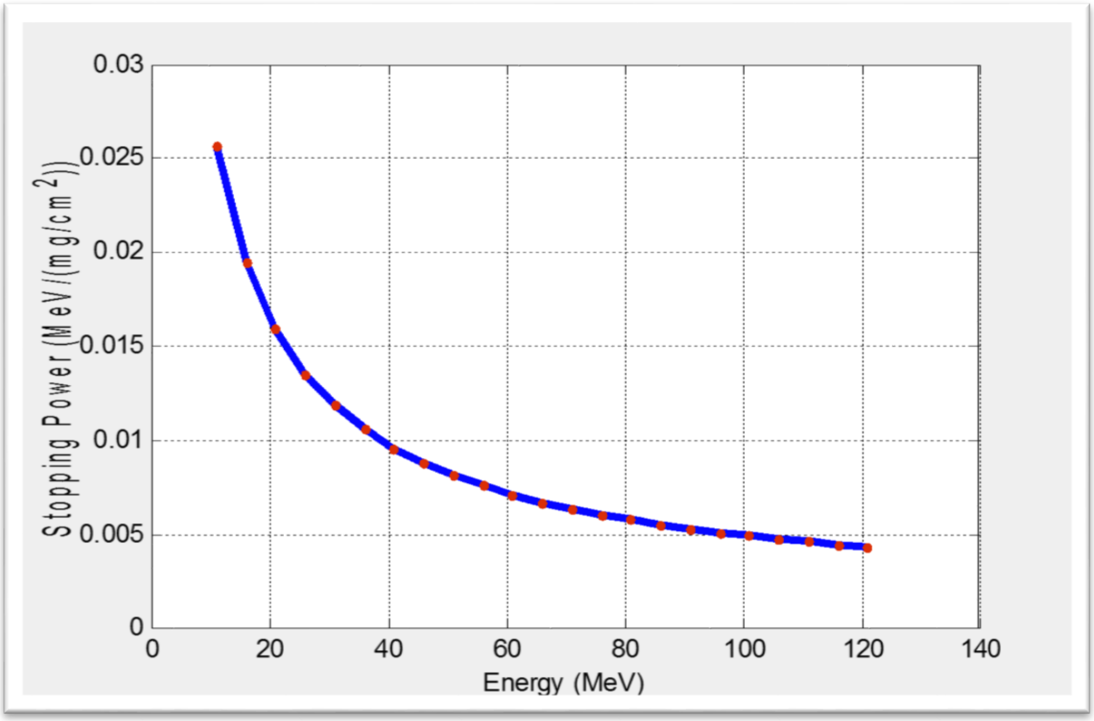

Fig. (8): The stopping power of proton in ^{64}Zn (p,n)^{64}Ga reaction(p.w.)

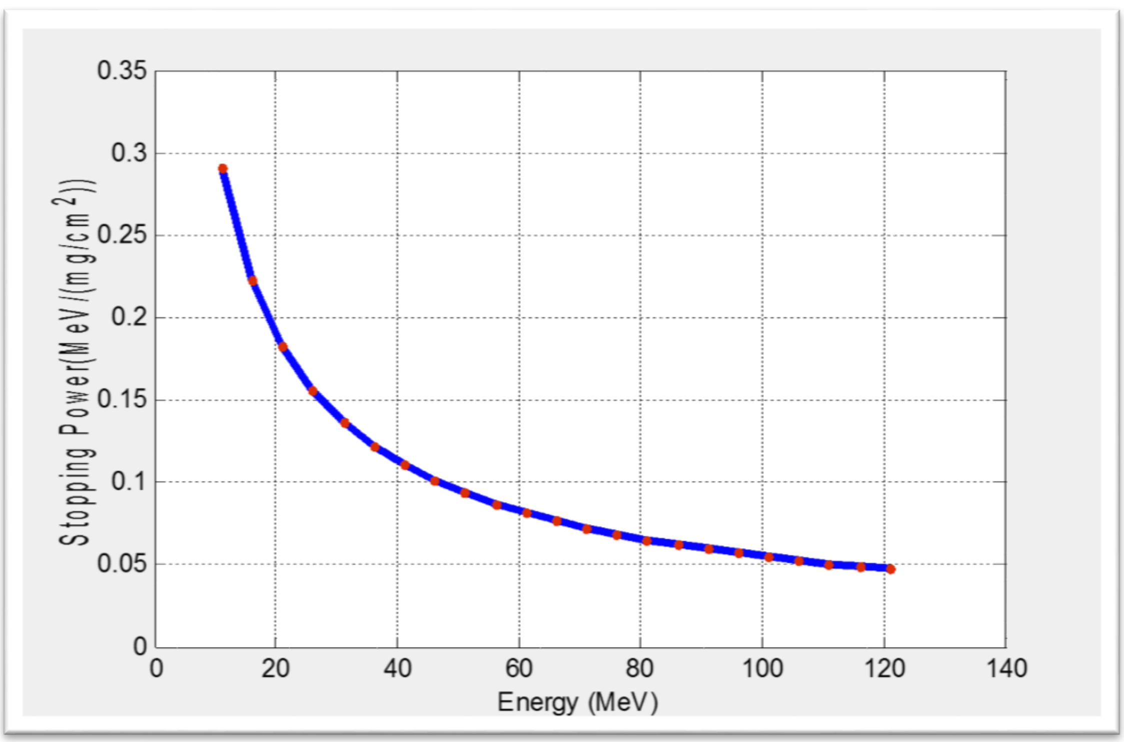

Fig. (9): The stopping power of proton in ^{61}Cu (a,n)^{64} Zn reaction(p.w.)

Table(1) : The stopping power of proton for ^{28}Si (p,n)^{28}P , ^{29}Si (p,n)^{29}P, ^{30}Si (p,n) ^{30}P , ^{31}P (p,n)^{31}S, and ^{40}Ca (a,n) ^{43}Ti reactions.

Energy (Mev)	Stopping power (MeV/(mg/cm^2))				
	^{28}Si (p,n)^{28}P	^{29}Si (p,n)^{29}P	^{30}Si (p,n) ^{30}P	^{31}P (p,n)^{31}S	^{40}Ca (a,n) ^{43}Ti
11	0.0325	0.0314	0.0303	0.0314	0.2913
16	0.0243	0.0234	0.0227	0.0235	0.2231
21	0.0197	0.019	0.0184	0.019	0.1833
26	0.0166	0.016	0.0155	0.0161	0.1563
31	0.0145	0.014	0.0135	0.014	0.1369
36	0.0128	0.0124	0.012	0.0124	0.1222
41	0.0116	0.0112	0.0108	0.0112	0.1107
46	0.0106	0.0103	0.0099	0.0103	0.1013
51	0.0098	0.0095	0.0091	0.0095	0.0936
56	0.0091	0.0088	0.0085	0.0088	0.087
61	0.0085	0.0082	0.008	0.0082	0.0814
66	0.008	0.0078	0.0075	0.0078	0.0766
71	0.0076	0.0073	0.0071	0.0073	0.0724
76	0.0072	0.007	0.0068	0.007	0.0688
81	0.0069	0.0066	0.0064	0.0066	0.0653
86	0.0066	0.0064	0.0061	0.0064	0.0624
91	0.0063	0.0061	0.0059	0.0061	0.0596
96	0.0061	0.0059	0.0057	0.0059	0.0572
101	0.0058	0.0056	0.0055	0.0056	0.0549
106	0.0056	0.0055	0.0053	0.0055	0.0529
111	0.0055	0.0053	0.0051	0.0053	0.051
116	0.0053	0.0051	0.0049	0.0051	0.0493

Table(2) : The stopping power of proton for ^{44}Ca (p,n)^{44}Sc , ^{26}Mg (p,n)^{26}Al , ^{64}Zn (p,n)^{64} Ga and ^{61}Cu (a,p)^{64} Zn reactions.

Energy (Mev)	Stopping power (MeV/(mg/cm^2))			
	^{44}Ca (p,n)^{44}Sc	^{26}Mg (p,n)^{26}Al	^{64}Zn (p,n)^{64} Ga	^{61}Cu (a,p)^{64} Zn
11	0.0262	0.0307	0.0257	0.2757
16	0.0196	0.0229	0.0195	0.2157
21	0.0159	0.0185	0.0159	0.1795
26	0.0135	0.0156	0.0135	0.1545
31	0.0117	0.0136	0.0119	0.1363

36	0.0104	0.0121	0.0106	0.1222
41	0.0094	0.0109	0.0096	0.1113
46	0.0086	0.01	0.0088	0.1022
51	0.008	0.0092	0.0081	0.0947
56	0.0074	0.0085	0.0076	0.0883
61	0.0069	0.008	0.0071	0.0828
66	0.0065	0.0075	0.0067	0.078
71	0.0062	0.0071	0.0064	0.0739
76	0.0059	0.0068	0.0061	0.0703
81	0.0056	0.0064	0.0058	0.0669
86	0.0054	0.0062	0.0055	0.064
91	0.0051	0.0059	0.0053	0.0612
96	0.005	0.0057	0.0051	0.0588
101	0.0048	0.0055	0.0049	0.0565
106	0.0046	0.0053	0.0048	0.0546
111	0.0045	0.0051	0.0046	0.0526
116	0.0043	0.005	0.0045	0.0509

CONCLUSION

Nuclear stopping capacity of the elements involved in the synthesis of the nodules and the input in the some reactions measured by using Zekler equations (SRIM) program. Calculated the stopping capacity of energies having in the ranging from (11 MeV to 116 MeV) with energy steps of (5 MeV).we have found the maximum value of the stopping power is in the reaction ^{40}Ca (a,n) ^{43}Ti in the energy (11 MeV) is (0.2913 MeV/(mg/cm^2)) and that lowest stopping power in the reaction ^{44}Ca (p,n)^{45}Sc and in the energy (16 MeV) is (0.0043 MeV/(mg/cm^2)) .

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