Studying the Range of Incident Alpha Particles on Cu , Ge , Ag , Cd ,Te And Au, With Energy (4-15 MeV)

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***Abstract* :** In this paper theoretical calculation of the range for alpha particles with the energy range (4 – 15)MeV when passing in some metallic media (Cu , Ge , Ag , Cd , Te and Au) . Semi empirical formula was used in addition to (SRIM-2012) program . The Semi empirical equation was programmed to calculate the range using Matlab Language .The results of the range in these media were compared with the results obtained from SRIM-2012 and ((2011)Andnet) results . There was good agreement among the semi empirical equation result , SRIM- 2012 results and with ((2011)Andnet) results in the low energy .The results showed exponential relation between the range of alpha particles in these media and the velocity of the particles . By recourse with SRIM- 2012 results and application them in Matlab program and by using Curve Fitting Tool we extraction equation with its constants to calculate the range of alpha particles in any element of these six elements with the energy range (4 – 15)MeV .The maximum deviation between the results from the semi empirical calculation and SRIM-2012 results was calculated the statistical test (kstest2) in Matlab program

Key word:-stopping power ,stopping number, range , heavy charged particles.

دراسة مدى جسيمات ألفا الساقطة على Cu , Ge , Ag , Cd , Te , Au بطاقة (4-15 MeV)

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الخلاصة :

أجريت في هذا البحث دراسة نظرية لحساب مدى جسيمات ألفا ذات طاقة (4-15 MeV) خلال مرورها في بعض الأوساط المعدنية وهي(النحاس (Cu) , الجرمانيوم (Ge) , الفضة (Ag), كادميوم (Cd), تلريوم (Te),الذهب(Au)) باستخدام معادلة شبه تجريبية وباستخدام برنامج SRIM-2012 .إضافة إلى برمجة تلك المعادلة شبه التجريبية للمدى بالاعتماد على برنامج Matlab Language وقورنت قيم المدى مع نتائج برنامج SRIM-2012 ونتائج (Andnet (2011)) فكان هناك توافق جيد بين نتائج المعادلة شبه التجريبية مع نتائجSRIM-2012 ونتائج (Andnet (2011)) عند الطاقات الواطئة . أظهرت النتائج إن مدى جسيمات ألفا في تلك الأوساط يعتمد على سرعتها بشكل أسي . وبالاستعانة بنتائج برنامج الـ SRIM 2012 وتطبيقها في برنامج الماتلاب MATLAB باستخدام أداة مطابقة المنحني Curve Fitting Tool تم استخراج معادلة مع ثوابتها لحساب مدى جسيمات الفا في اي عنصر من العناصر الستة بمدى طاقة (4-15 MeV). حُسب أقصى اختلاف بين نتائج المعادلة شبه التجريبية المستخدمة لحساب المدى مع نتائج برنامج SRIM-2012 باستخدام اختبارk (kstest2) الإحصائي في برنامج الـMatlab .

الكلمات المفتاحية: قدرة الإيقاف ,عدد الإيقاف , المدى ,الجسيمات المشحونة الثقيلة .

Introduction : The study of stopping power and range theory has attracted physicists for the nine decades since the days Madame Curie discovered radioactivity in materials. Hundreds of papers and dozens of review articles have been written on this vast subject. The stopping power is defined as the mean energy loss per unit path length– *dE*/*dx* [1] . In passing through matter , charged particles ionize and thus loss energy in many steps , until their energy is (almost) zero . Because of Coulomb force has infinite range , the particle interacts simultaneously with many electrons and thus loss energy gradually but continuously along its path. After travelling a certain distance, it has lost all of its energy; this distance is called the range of the particle ,[2] predictable distance inside the medium. Formally this can be written as [3]:

$$R = \int_{U}^{E} \frac{dE}{S(E)} \qquad \ldots\ldots(1)$$

where *R* is the range of the ion, *U* the visibility threshold for the track and *E* is the initial energy . If *S(E)* is the mean stopping power value, we obtain the mean range for the ions.

Theory : An energetic ion penetrating in a medium interacts with the target atoms. It collides with the nuclei and electrons of the target. The interactions lead to a loss of the ion's energy. In the energy range of 0 - 10 KeV/amu, in which we are mainly interested, the energy loss per unit length i.e. the **stopping power**, can be divided into nuclear stopping and electronic stopping terms . The nuclear stopping governs the energy losses caused by elastic collisions between the ion and the nuclei of atoms in the target. The electronic stopping term governs the energy losses caused by the electronic interactions , which can be further divided into several different contributions depending on the nature of the interaction [3,4].The total stopping power is then just the sum of the stopping powers due to electronic and nuclear interactions[5]:

$$S_{total} = -\frac{dE}{dx} \qquad \ldots..(2)$$

$$-\frac{dE}{dx} = S_{electronic} + S_{nuclear} \qquad \ldots..(3)$$

Here the negative sign signifies the fact that the particles lose energy as they pass through the material . For most practical purposes the nuclear component of the stopping power can also be ignored as it is generally only a fraction of the total stopping power. For particles such as electrons, this statement is always valid since they are not affected at all by the strong nuclear force. For heavy positive charges , such as α-particles, this holds if the particle energy is not high enough for it to penetrate so deep into the atom that the short range nuclear forces of nuclear particles become appreciable. Hence the stopping power can be written as a function of the electronic component only.

$$-\frac{dE}{dx} = S_{electronic} \qquad \ldots\ldots(4)$$

The first successful attempt to derive a relation for the energy loss experienced by an ion moving in the electromagnetic field of an electron was made by Neils Bohr[5].Later on Bethe derived another expression for the stopping power using quantum mechanics[6]:

$$S = \frac{4\pi Z_1^2 e^4 Z_2}{mv^2} L_{beth} \qquad \ldots..(5)$$

$$L_{bethe} = ln\frac{2mv^2}{\hbar\omega} \qquad \ldots..(6)$$

(L_{Beth} : stopping number for Bethe)

$$I = \hbar\omega \qquad \ldots..(7)$$

It is very tempting to try to compute the average distance a particle beam will travel (also called range) in a medium by integrating the stopping power over the full energy spectrum of the incident particles, such as[5]:

$$R(T)=\int_0^T\left[-\frac{dE}{dx}\right]^{-1}dx \qquad .....(8)$$

It is apparent that theoretical computation of range is a difficult task. A number of experiments turned to empirical means of measuring this quantity and modeling the behavior on the basis of their results[7].Several empirical and semi-empirical formulae have been proposed to compute range of α-particles in air . For example[5]:

$$R_{\alpha(mm)}^{air}=\begin{cases} e^{1.61\sqrt{E_\alpha}} & for E_\alpha<4MeV \\ (0.05E_\alpha+2.85)E_\alpha^{3/2} & for\ 4MeV\le E_\alpha\le 15MeV \end{cases} \quad .....(9)$$

$$R_\alpha^{air}[Cm]=\begin{cases} 0.56E_\alpha & for E_\alpha<4MeV \\ 1.24E_\alpha-2.62 & for\ 4MeV\le E_\alpha\le 15MeV \end{cases} \quad .....(10)$$

Ranges of alpha particles as well as other charged particles such as protons and deuterons of a given energy in absorber elements of atomic number Z > 10 in units of absorber mass thickness can be calculated directly by comparison to the calculated range of the same charged particles of the same energy in air according to the following formula described by Friedlander et al. (1964)[8,9]

$$\frac{R_z}{R_{air}}=0.90+0.0275Z+(0.06-0.0086Z)\log\frac{E}{M} ...(11)$$

where R_z is the range of the charged particle in mass thickness units $mgcm^{-2}$, R_{air} is the range of the charged particle in air in the same mass thickness units, Z is the atomic number of the absorber element, E is the particle energy in MeV, and M is the mass number of the particle (i.e.,1 for protons, 2 for deuterons, and 4 for alpha particles).The formula provided by Eq. (11) is applicable to charged particles over a wide range of energies(approximately over the range (0.1‑1000MeV) and for absorber elements of Z> 10. For lighter absorber elements the term 0.90+0.0275Z is replaced by the value 1.00 with the exception of hydrogen and helium, where the value of 0.30 and 0.82 are used, respectively (Friedlander et al., 1964) For two heavy charged particles at the same initial speed β, the ratio of their ranges is simply [10]

$$\frac{R_1(\beta)}{R_2(\beta)}=\frac{Z_2^2M_1}{Z_1^2M_2} \qquad .....(12)$$

where $M1$ and $M2$ are the rest masses and Z_1 and Z_2 are the charges. If particle number 2 is a proton (M_2 = 1 and Z_2 = 1), then we can write for the range R of the other particle (mass $M_1=M$ proton masses and charge Z_1 = Z) .

$$R(\beta)=\frac{M}{Z^2}R_P(\beta) \qquad .....(13)$$

where $R_p(\beta)$ is the proton range.

Results and Discussion:

In this paper introduce we suggested semi empirical equation to calculate the range of the alpha particle in some metallic media (Cu , Ge , Ag , Cd , Te and Au) with energy from (4 -15MeV) which is:

$$R_\alpha=0.173E^{3/2}A^{1/3}+\log(E) ....(14)$$

We programming this equation depended on Matlab Language .As well as we using the SRIM2012 program ,which have been written in the mathlab program and using coincidence tool(curve fitting tool) we achieved finding equation (15) with its constants in any medium of six element :

energy		Function	Element	Constant
4-15MeV	Power2	$f(x)=ax^b+c$ $R_\alpha=aE^b+c$ ....(15)	Cu	a = 0.522 b = 1.623 c = 1.963
			Ge	a = 0.5561 b = 1.617 c =1.922
			Ag	a = 0.6879 b =1.601 c = 1.697
			Cd	a = 0.7265 b =1.58 c = 1.792

			Te	a = 0.8076 b =1.571 c =1.356
			Au	a = 1.156 b = 1.527 c = 2.589

Table(1) the equation which represent the range of alpha particles in some element

The figures (1-6) are plots of the range versus the incident alpha particle energy from (4 - 15Mev) for the elements Cu , Ge , Ag , Cd ,Te and Au by using Matlab Language . These figures represented comparison among the range calculated from equation (14), the corresponding values obtained from SRIM-2012 program , ((2011)Andnet) results and the fitting results to the the SRIM-2012 results for the same elements .We found a good agreement among the present semi empirical results equation (15)) , SRIM-2012 table and ((2011)Andnet) results for figures (1,2,3,4,5) which is the plot of the range versus the incident alpha particle energy from(4- 15Mev) for the elements Cu , Ge , Ag , Cd ,Te, but we noticed there is no good agreement with, the present semi empirical results(equations (14)) for figure (6) which is the plot of the range versus the incident alpha particle energy from (4 - 15MeV) for the element Au. This shows the present semi empirical results do not have a good agreement with the values of SRIM-2012 tables for elements having large atomic number. To show The maximum deviation between the curves we use the statistical test k (kstest2Two-sample test) by using Matlab program .The maximum difference between the present semi empirical results(equations (14)) and values of SRIM-2012 tables for figure (1,2,3,4,5) which for Cu , Ge , Ag , Cd gave k = 0.0667 but, in the case of Au from figure (6), we get k=0.1333.This shows the present semi empirical results do not have good agreement with the values of SRIM-2012 tables for elements having large atomic number.

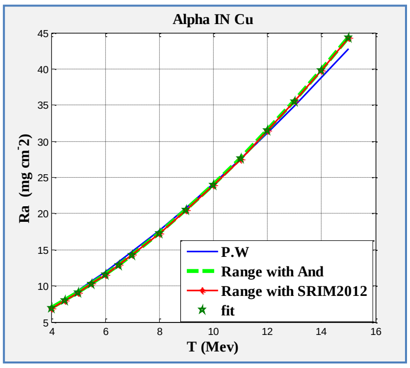

Figure (1)the range of alpha particle in Cu

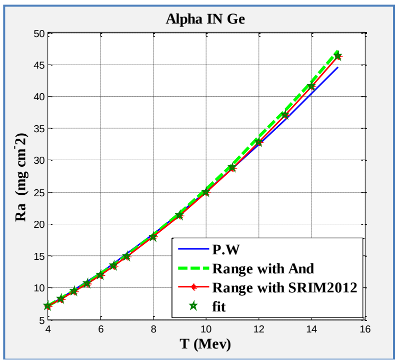

Figure (2)the range of alpha particle in Ge

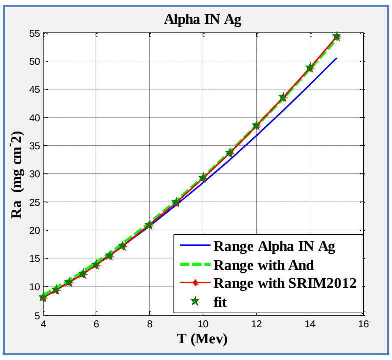

Figure (3)the range of alpha particle in Ag

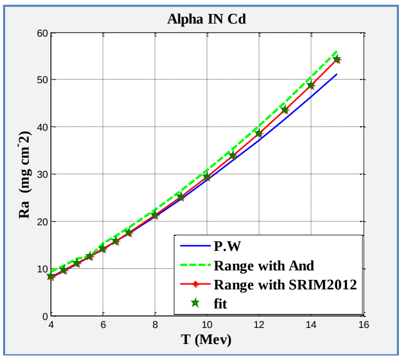

Figure (4)the range of alpha particle in Cd

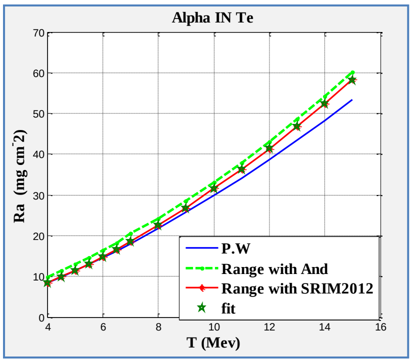

Figure (5)the range of alpha particle in Te

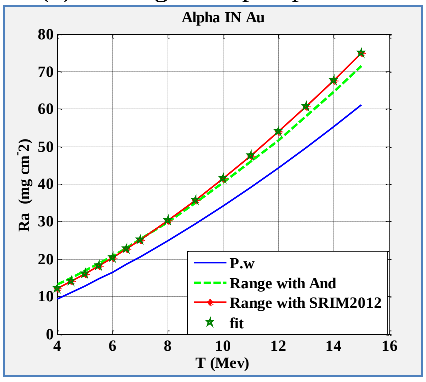

Figure (6)the range of alpha particle in Au

Conclusion

1-The range of Alpha particle increases with increasing alpha particles energy for all atomic mediums which we use .

2- From above curves we notice the large effective of atomic number for the stopping elements on the range of alpha particles . This effective increases with increasing atomic number of the stopping element .It is also noted that in figure (1) which is the plot of the range versus the incident alpha particle energy for the elements Cu with atomic number 29 but in figure (6) for Au with atomic number 79 ,the range became large .

3-The range of Alpha particle inversely Proportional with mean energy loss and stopping power according to the relation:

$$R \propto E \propto \frac{1}{S.P.}.$$

Where S.P. is the stopping power for absorber medium.

4-By using the test statistic k (kstest2) we get the present semi empirical results do not have good agreement with the values of SRIM-2012 tables for elements having large atomic number.

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