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Mass attenuation coefficients and Range of β^- Particles in Aluminum and Gold: A Comparison study

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Abstract

Beta particle has a huge applications in industry, medicine and research fields. The aim of the present study is to calculate the mass attenuation coefficients $(\mu / \rho)_{\beta^-}$ and the range of R_{β}- for negative beta particles within the energy range (0.257-2.25) MeV for ^{13}Al and ^{79}Au respectively. Use the equation of Kisse and Vertes to calculate the mass attenuation coefficient and the Tabata equations to calculate the range of electrons in the same elements. All the equations were adopting by the program (Visual studio professional 2012). The results we obtained were compared with the available experimental one, indicating that they are in good agreement, thus supporting the possibility of applying them to other elements effectively. As for the range it is a function of the negative beta particle energy and then the range in the aluminum is greater than the of the values in gold due to the electronic density of the gold element.

Key words: Beta particle β^- , Empirical equations , mass attenuation coefficients, Range.

1 - Introduction

Every thing over the earth surface exposure continouslly to radiations like cosmic rays , sun light as well as radioactive materils inside the earth core, or may be from man – made radioactive sources such α-rays, fall out from nuclear tests of weapons. All the ionizing radiations has sufficient energies when incident on the target material, and loses its kinetic energy gradually ,by give off some of its energy to the atoms or molecules conformed the materials . this will causes a damages in living Tissues and crystals of solid state [1].

This refers to that the damage of material due to the radiation, depends upon the incident energy, Intensity and the nature of target material . The study of mass attenuation coefficients of an importance in radio-theory, incident in experiments in nuclear and solid state physics. When Beta particles (light particles) on a material, their behaviour differ significantly from that of heavy- particles , that is its path inside matter is not straight line (such as α- particles), but is torture. Due to the necessity negative effects[2], many researchers investigated the mass attenuation coefficients and ranges of beta particles for five element by Nathurama et al [3] by results are many empirical formulae in the energy ranges [0.3 Kev – 30 Mev], which their are in agreement with Comparison experimental data[4]. the mass attenuation coefficient for beta particle in eight elements by adoping a theoretical equations in energy ranges (0.2 -3) MeV which where in good agreement with the experimental data of Burek et al, 1996. In (2009), Khalid etal evaluated the beta particles range and alpha particles in cadium doped with the impurities: S, Se, Te using semi –empirical equations [5]. Sabah etale studies the mass attenuation and range in three elements in energy range (0.176 -3.6)MeV which in good agreement with experimental results.

The aim of the present study is to evaluate two atomic factors of beta particle: mass attenuation coefficients and range, in aluminium and gold in the energy range (0.176 -3.6)MeV by using several semi empirical equations by using Visual studio professional 2012 [6].

2 – Calculation

2.1 Mass attenuation coefficient $(\mu/\rho)_\beta$

The mass attenuation coefficient is a constant of reduction the amount of radiation, intesity, particle density, or energy density when it penetrates a certain substance. This constant is measured by unit (g / cm^2) which included several interactions of the radiation with the material such as absorption, scattering, multiple scattering, etc. In generaly, attenuation coefficient depends on the incident energy, The atomic number of the target material Z as well as the thickness of the material. When the energy of incident electrons on the target material is large, it interacts with the electric field of the charged of the nucleus or electrons, Its velocity changes as it travels through the material in this case the deviates incident Electron produced a radiation in the form of Bremsstrahlung[8]. For calculation the mass attenuation coefficient $(\mu/\rho)_\beta$ of negative beta particles β^- , we use the following empirical equation for (Veters and Kiss):

$$(\mu/\rho)_\beta = \frac{7.7\, Z^{0.31}}{E_\beta^{1.14}} \qquad Z \geq 13 \quad \ldots\ldots (1)$$

Where : E_β: Beta - incident particle energy. Z : Atomic number of target material.

2.2 Beta particle Range (R)

Range (R) is a non linear distance that the charged particle travels through the material until it stops[9]. The range of charged particles Considered as the thickness of the layer that the particle enters it until reaches to thermal equilibrium and is implanted in the absorbent material [10]. It depends in fact on the particle's energy, type and nature of absorbent material (the density of matter). To calculate the range of negative beta particles, we used an empirical equations adopted by Tabata etal , Which defined in the following form [7,11]:

$$R(g/cm^2) = \frac{a_1}{10}\left[\frac{\ln[1+a_2(\gamma-1)]}{a_2} - \frac{a_3(\gamma-1)}{1+a_4\,(\gamma-1)^{a_5}}\right. \quad \ldots\ldots (2)$$

$a_1 = 2.335 \frac{A}{Z^{1.209}}$
$a_2 = 1.78 \times 10^{-4}$
$a_3 = 0.9891 - 3.01 \times 10^{-4} z$
$a_4 = 1.468 - 1.18 \times 10^{-2} z$ .... (3)
$a_5 = \frac{1.232}{z^{0.109}}$
$\gamma = \frac{E_\beta + mc^2}{mc^2}$

Where: A: Atomic weight. Z: Atomic number. E_β: Beta particle energy

3 - Results and Discussion

Table (1, 2) contains Values of mass attenuation coefficients $(\mu/\rho)_{\beta-}$ for the elements: aluminum and gold by using the equation (1) within the energy range of (0.257 - 2.25) MeV. The results in the tables above refers to, decrement in the values of $(\mu/\rho)_{\beta-}$with increasing energy of the beta particle. This result can be explained as when the negative beta particle enters into the material suffers two type of scattering:

- **Inelastic scattering**: During this process, a beta particle interacts in two ways either with loosely bound electron, which leads to release secondary electron with lower energy that it interacts with nuclei to makes a beta particle loset its energy in Coulomb field and produces continuous x-ray spectrum given by the following formula:

$f_{\beta = constant\ E\ Z^2}$ ....(4)

Whenever a beta particle increased its energy the ratio of the energy converted to X-rays or what is known as Bremsstrahlung will increased.

from tables 1 and 2 , we note that the values $(\mu/\rho)_{\beta-}$ of the (Au) are greater than $(\mu/\rho)_{\beta-}$of the (Al) this is due to the electronic density of gold in comparsion the aluminum element, according to the following relationship:

$n = \left(\frac{Z}{A}\right) N_A (\frac{\rho}{M_n})$ .... (5)

Where NA is Avogadros number, ρ material density and Mn is the Molecular weigh .respectively.

- **Elastic scattering**: The Beta particle Suffering from the elastic scattering in which an electron interacts with the nucleus of the atoms of Al and Au, resulting a significant deflection in Trajectories but they loses a fraction of their energy this is due to the large amount of the electric field of the nuclei of the target material. It also has two types of scattering: Rutherford scattering which make when the coulomb field of the nucleus as a single event, resulting in a significant change in the direction of its path .In some cases exceeding 90^0 the second type from scattering is the multiple scattering its includes several scatteres successive where this interaction does not include any actual contact between the negative beta particle with the orbital electrons according to the following equation:

$k = E_{loss} - I$ ..... (6)

Where k is the kinetic energy of the liberated electrons and that I is the average Ioniezation energy for each atom as shown in Figs (1, 2), and (3) represents is a comparison of the attenuation coefficients of the aluminum and gold. Tables 3 and 4 represents value range in aluminum and gold (as shown in figs 4, 5and 6) resulting from the application of Equations (2, 3). These tables refers the increasing range with increased beta particle energy there is a possibility that a beta particle spends most of its interactions with the nuclear field by increasing its energy as it penetrates the orbital electrons without being affected too much. As for Table 5, which shows a comparison of the range of the aluminum and gold elements, this table shows that range values for aluminum are larger for the same incident beta particle energy in comparsion to gold this is due to the sensitivity of range values on the density of the element as the gold density is greater than the density of the aluminum with about 7 times $\rho_{Al} = 2.79 \left(\frac{g}{cm^3}\right)$, $\rho_{Au} = 19.309 \left(\frac{g}{cm^3}\right)$

This property has a direct correlation with the electronic numerical density of each element as in equation (5) this behavior is similar to beta particle behavior in many different elements within previous studies.

4 - conculsions

Due to the light mass of Beta particle , its range in matter is not linear. The comparision of our present value of $(\mu/\rho)_{\beta-}$ with experimental data shows some in consistency, which may be results from hypothesis and approximation methods which are employed in formulating the equations we adopted here.

Table (1): the mass attenuation coefficient values of aluminum theoretically and experimentally

E (MeV)	$(\mu/\rho)_\beta$	$(\mu/\rho)_\beta$ EXP **[12,13.14]**.
0.257	80.25	141
0.318	62.95	60.7
0.546	33.99	37.15
0.766	23.1	21.92
1.463	11.05	9.15
1.986	7.8	6.3
2.25	6.76	5.31

Table (2): the mass attenuation coefficient values of gold theoretically and experimentally.

E (MeV)	$(\mu/\rho)_\beta$	$(\mu/\rho)_\beta$ .EXP [12,13,14].
0.257	140.42	151
0.318	110.15	112.5
0.546	61.39	59.9
0.766	40.43	38.92
1.463	19.33	14.72
1.986	13.64	9.7
2.25	11.6	9.06

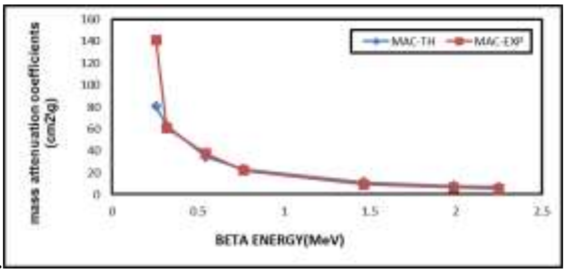

Fig (1): Comparison of mass attenuation coefficient for beta particles calculated with the practical values of the aluminum element

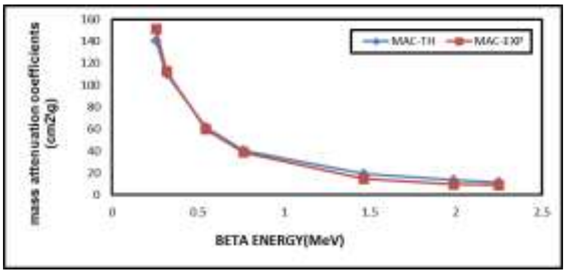

Fig (2): Comparison of mass attenuation coefficients of beta particles calculated with the practical values of the gold element

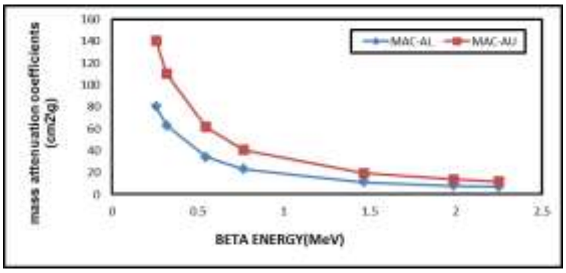

Fig (3): Comparison of theoretical values of mass attenuation coefficients of beta particles in the aluminum and gold elements

Table (3): Theoretical values of the range of the negative beta particles calculated in a tabata form of the aluminum element.

E (MeV)	Range(ITO) (g/cm^2)
0.257	0.0595
0.318	0.0821
0.546	0.1782
0.766	0.2809
1.463	0.6318
1.986	0.9056
2.25	1.0453

Table (4): Theoretical values of the range of the negative beta particles calculated in a tabata form of the gold element

E (MeV)	Range(ITO) (g/cm^2)
0.257	0.0309
0.318	0.0425
0.546	0.0899
0.766	0.1511
1.463	0.362
1.986	0.5353
2.25	0.6393

Table 5: Comparison of theoretical values of the range of beta particles in aluminum and gold.

E (MeV)	Range(ITO) **(AL)**	Range(ITO) **(AU)**
0.257	0.0595	0.0309
0.318	0.0821	0.0425
0.546	0.1782	0.0899
0.766	0.2809	0.1511
1.463	0.6318	0.362
1.986	0.9056	0.5353
2.25	1.0453	0.6393

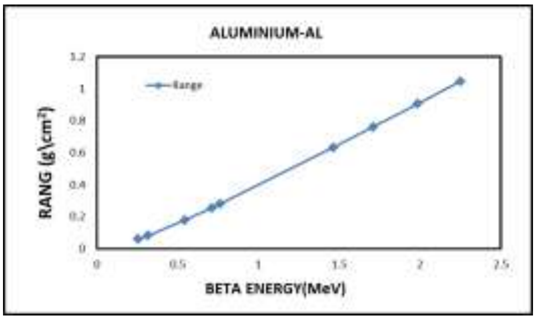

Fig (4): The relationship between the energy of beta particles and their range in the aluminum element

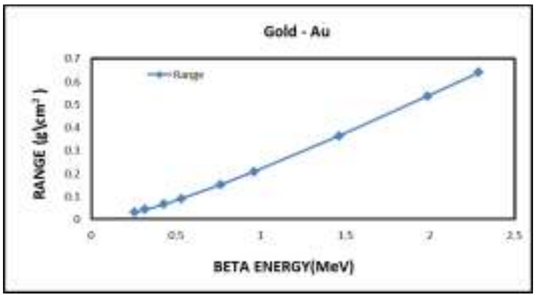

Fig (5): The relationship between the energy of beta particles and their range in the gold element

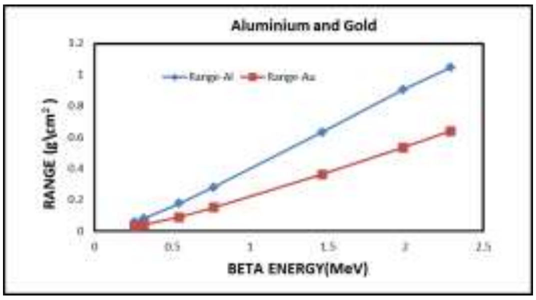

Fig (6): Comparison of the theoretical values calculated by tabata method in the aluminum and gold elements

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معاملات التوهين الكتلي والمدى لجسيمات بيتا β^- في عنصري المنيوم والذهب: دراسة مقارنة

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الملخص

لجسيمات بيتا تطبيقات هائلة في الصناعة – الطب والدراسات البحثية كافة. تهدف هذه الدراسة لحساب معاملات التوهين الكتلي $(\mu/\rho)_{\beta^-}$ والمدى R_{β^-} لجسيمات بيتا السالبة ضمن مدى الطاقة (0.257 – 2.25) مليون الكترون فولت لعنصري المنيوم ^{13}Al والذهب ^{79}Au على التوالي. استخدم معادلة كايس– فيتراس لحساب معامل التوهين الكتلي ومعادلات تاباتا وجماعته لحساب مدى الكترونات في هذه العناصر, حيث تم برمجة المعادلات المذكورة وفق برنامج (studio professional 2012 Visual). تم مقارنة النتائج التي حصلنا عليها مع مامتوفر من نتائج عملية, اذ تشير الى ان هناك تطابق جيد مما يدعم امكانية تطبيقها لعناصر اخرى بشكل فعال وخصوصا عند الطاقات الواطئة لجسيم بيتا السالبة. اما بالنسبة للمدى فهو دالة الطاقة جسيم بيتا السالب وقيم المدى في عنصر الالمنيوم هي الاعلى مما هو للذهب بفعل الكثافة الالكترونية للعنصر الاخير.

الكلمات الدالة: المدى , جسيمات بيتا β^- , معامل التوهين الكتلي , معادلات تجريبية.