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The Determination of the Maximum Range and Energy of α-Particles in Isotope (^{239}Pu) by Employing Scintillation Counter

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1. Abstract

The aim of the present practical research is determing the maximum range and energy of α – particles in radioactive source isotope ^{239}Pu using scintillation counter by changing the intensity of radiation for various time rates, as well as the adopting of the natural logarithm of the pulse radiation (Ln I) per unit time from the change for the alpha particles Rα have been determing the maximum range. Hence, it is found from the results obtained that the maximum energy at the range 3.5 cm is (5 Mev) when the voltage works is 700 V.

2. Introduction:-

Since the alpha particles had been explored by the English RutherFord in 1899, scientists and researchers in the nuclear field carry out several experiments to study the characteristics and features of these particles and of the various isotopes and their potential impact on human life.

Plutonium is the of elements that have been studied, such as by researchers from Harvard University in 1990 to the isotope plutonium-238 study charged alpha particles as they calculate parameters that isotope, including the expense of range and energy (5.545 MeV , 3.834 cm) respectively [7].

In 2002 Alpha particles Energy for ^{239}Pu have been measured by researchers using Windowless Electret Ion Chambers [6].

This study concerned with the possibility of calculating maximum range and energy for alpha particles emitted by the isotope plutonium-239 using scintillation counter. The research discusses the ability of these particles on the penetration of the material.

3. Theory Part

The charged particles, lost their energy and slow down as they pass through matter as a result of collision with atoms and molecules. Energy is transferred to absorbing matter in the process of ionization and excitation of atoms and molecules.
Alpha particle, interact with matter primarily through coulomb forces between their positive charge and the negative charge of the orbital electrons within the absorber atom. Coulomb interactions of the particle with nuclei also are possible but they have very little influence on the loss in energy of a charged particle.
Upon entering any absorbing medium, the α particle immediately interacts simultaneously with many electrons. In any one such encounter, the electron feels an impulse from the attractive coulomb force as the particle passes its vicinity. Depending on the proximity of the encounter, the impulse may be sufficient either to raise the

electron to a higher – lying shell within the absorber atom (*excitation*) or to remove or addition electron from or to atom (ionization). The energy that is transferred to the electron must come at the expense of the charged particle, and it is velocity is therefore decreased as a result of the encounter [2].
The linear stopping power S for charged particles in a given absorber is defined as the differential energy loss *dE* for that particles within the material divided by corresponding differential path length *dx* :

$$S = -\frac{dE}{dx} \qquad (1)$$

S is also called specific energy loss of the particle. For particles with a given charge state, S increases as the particle velocity is decreased. The classical expression that describes the specific energy loss is known as the Bethe formula and is written briefly as :

$$-\frac{dE}{dx} \approx q^2 n\varphi\left(\frac{1}{v_x^{\ 2}}\right) \qquad (2)$$

where n is the electrons density in the absorbing medium, q is the charge of particle, and v is its velocity.
It is experimentally determined that the average for creating one pair of ions is almost independent of the kind and energy of bombarding particle and amounts to 35 eV. Therefore an alpha particle of energy:

$$E_\alpha = 5MeV$$

will create $\frac{5\times10^6}{35}$ ion pairs at its absorption[2].
Since the specific energy loss of a charged particle varies as $1/v^2$, or inversely proportional to the particle energy, the change in the number of created ion pairs along the track (depth of penetration, R) will change in manner shown in Fig.1. This curve is known as a Bragg curve [4].

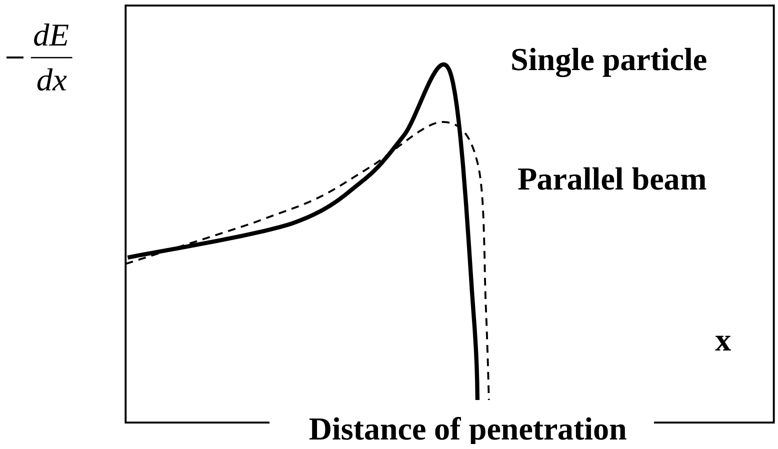

Fig.2. The specific energy loss along an alpha track

The range [illegible] nt characteristics.
The range represents a distance beyond which no particles will penetrate. The mean

range of alpha-particles is inversely proportional to the specific energy loss and it could be determined by integration the Eq.2 :

$$R = \int_0^E \left(-\frac{dE}{dx} \right)^{-1} dE = \frac{1}{k} v^3 \qquad (3)$$

where K represent Boltizman Constant = 1.08 × 10^{23} m^2 s^{-3}

from this equitation and the equation for kinetic energy $E = \frac{mv^2}{2}$ we obtain the following relation between the range and energy of the charged particle :

$$R = \frac{1}{k} \left(\frac{2E}{m} \right)^{3/2} = k_1 E^{3/2} \qquad (4)$$

or

$$E = \frac{m \sqrt[3]{R^2 k^2}}{2} \qquad (5)$$

The determination of α-particles energy is one of the most important problems [3].

4. Practical Part

In this research work a *scintillation counter* is used for measuring the range of alpha particles in air. a brief description of the principles of operation for this detector. More details will be given in the in the next Module 3 Radiation Detectors.
The main pairs of the scintillation counter are the *photomultiplier tube* (PMT) and the crystal. The choice of the crystal depends on the type of detected radiation (for example, crystals of ZnS(Cu) are suitable for α-particles registration). By means of the dynodes beneath the PMT the electron current is multiplied. The resistor divider network provides the necessary HV supply of the dynodes. [3]
The scintillator counter must be very carefully isolated from the outside sun-light. For this purpose the scintillator must be covered by suitable shielding. However, it is very difficult to ensure this condition when α-particles are detected (it is well known that the α-particles are completely absorbed in a sheet of paper).
In order prevent the PMT from the sun light in this research work the scintillation counter and the α-source are includes together in special sheathing (Fig.1), [4].
Used equipments, Scintillation, . α – source (^{239}Pu), Micrometric screw, Scale, HV-high voltage supply and LA-liner Amplifier.

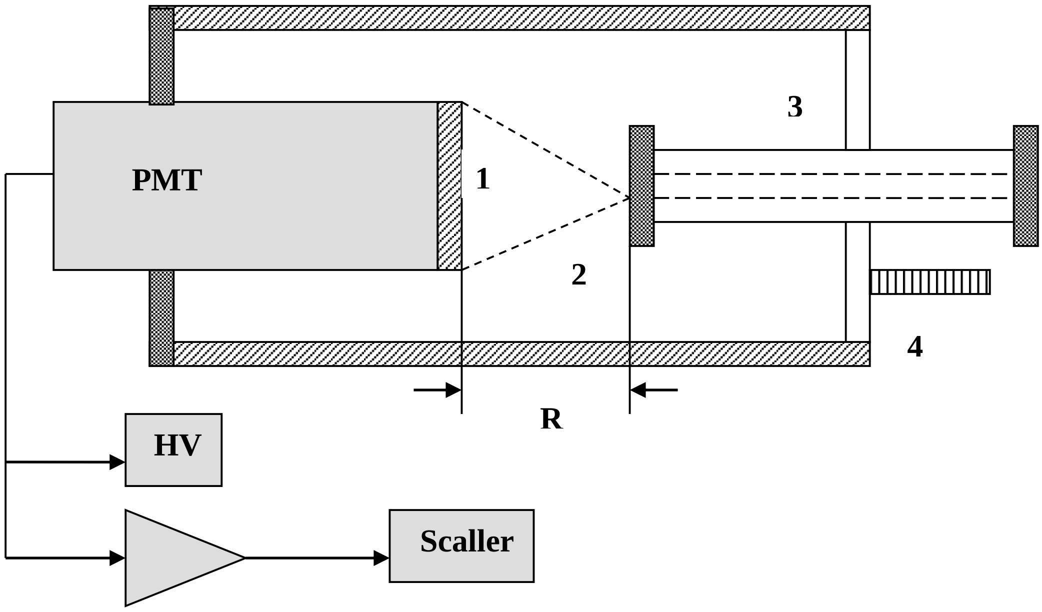

Fig.1. The experimental arrangement [1].

Connect the Scintillation counter and turn on electronic device Robotron 20046 according to the instruction of instructor (see Fig.3). Power switch ON (the red push-button), with H.V. its minimum setting. Slowly increase the high voltage HV to the work voltage U = -700 V. Take three counts of the α- source at different distances between the source (Plutonium- ^{239}Pu) and the scintillator changing the time of measurement : 10,20,40,60, and 100 sec.
Record counts as shown in the following Table(1), where t is the measuring time. Plot the dependence Ln I = f(r) and determine the α-particles range , (see Fig.1). Calculate the energy E_α by means of Eq.(5). Take into account that : $m_\alpha = 6.6\times10^{-27}$ kg, k = 1.08×10^{23} m^2. s^{-3} , and the range *R* in meters.

5. Results and Conclusion:-

From the Present study it has been concluded that experimental value of energy for α-particle of plutonium 239(^{239}Pu) is (E_α = 5.0056 Mev) by the equation (5). It is calculated that value of the maximum range of alpha particles using graphic in fig.(4) is $R_{\alpha-\max} = 3.5cm = 3.5\times10^{-2}m$. This means that the range of alpha particle is short because of its interaction with the medium (α-particle is charged with charge of positive) and this cause the phenomenon of ionization or what is called ions pairs.
Energy Calibration Line has been determined according to the range; that means (when the relationship between the energy of Alpha and range is linear relationship as long

as the distance between the isotope and the detector energy increases) as it is shown in (fig.5).
It is concluded that the energy spectrum of alpha particles, The specific energy loss along an alpha track, as it is shown in (fig.6).
Hence, it is found from the results obtained that the voltage works is 700 V.
It is concluded that the average for creating one pair of ions is almost independent of the kind and energy of bombarding particle and amounts to 35 eV, Therefore an alpha particle of energy: E_α = 5 MeV will create ($5 \times 10^6 / 35$) ion pairs at its absorption (detector crystal of ZnS(Cu)).
From this study it is clear that the ability of these particles on the penetration is relatively small and do not require thick barriers to stop and Prevention.

6. Tables

Table 1: Results obtained and accounts

Range R, cm	*Time t, sec*	*Number counts N, imp/s*	*N_{av} , imp/sec*	*Intensity $I=N_{av}/t$, Imp/s*	*Ln I*	$E = \frac{m\sqrt[3]{R^2k^2}}{2}$, *MeV*
0.6	10	23477	23480	2348	7.761319	1.54446
		23550				
		23417				
1.0	20	48119	47770	2388.5	7.7784	2.17108
		47784				
		47406				
1.5	40	45610	45560	1139	7.0378	2.8449
		45682				
		45387				
2.0	60	19409	19316.5	322	5.774	3.4463
		19120				
		19420				
2.5	100	1825	1854.5	18.55	2.920	3.9991
		1769				
		1969				
3.0	100	157	161	1.6	0.474	4.5160
		166				
		159				
3.5	100	105	92	0.92	-0.0833	5.0048
		89				
		82				
4.0	100	74	69	0.69	-0.371	5.4707
		70				
		63				

7. Graphic

Ln I

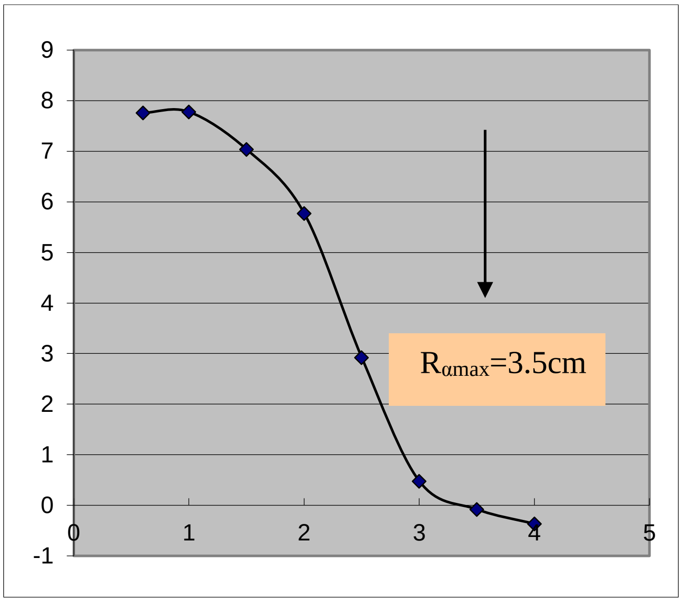

Fig.4. represent the dependence of natural logarithm of the impulse per unit time verses us the range of α – particle.

The range, R_α cm

Energy E, MeV

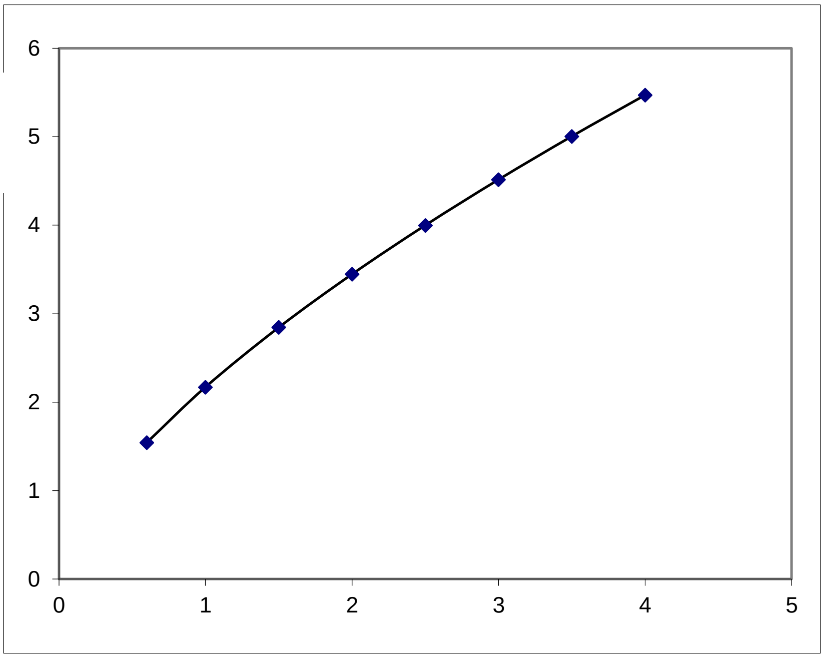

Fig. 5: Energy calibration of the range

The average count

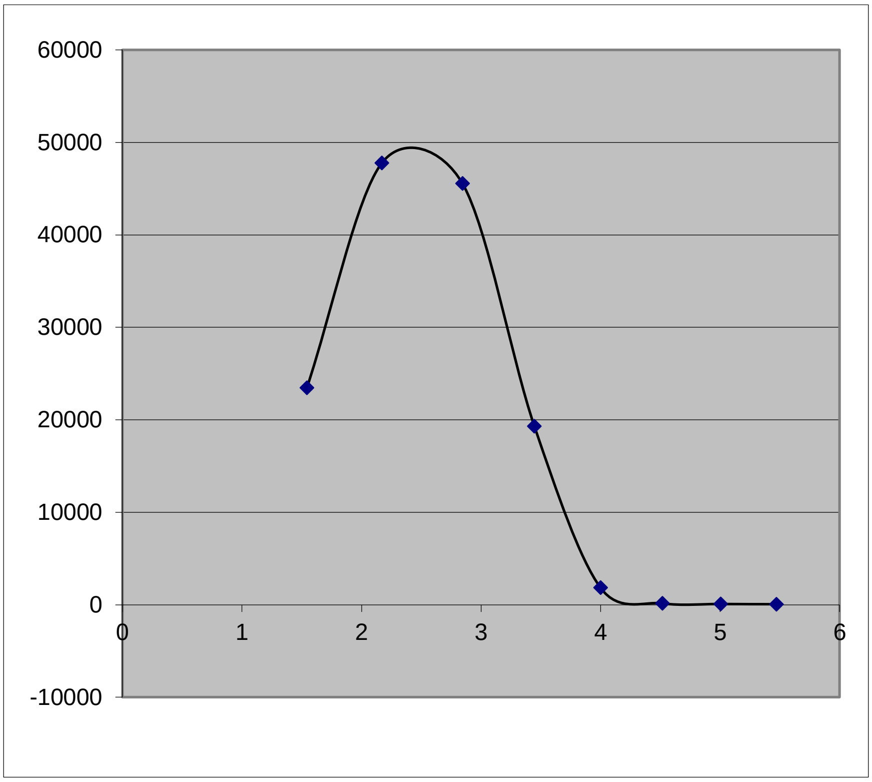

Fig. 6: The energy spectrum of alpha particles, The specific energy loss along an alpha track

Energy E, MeV

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حساب أعظم مدى وطاقة لجسيمات ألفا المنبعثة من نظير البلوتونيوم 239 باستخدام العداد الوميضي

قصي حبيب حطيحط الغالبيّ
قسم الفيزياء / كلية التربية / جامعة القادسية

الخلاصة:-

استهدفت هذه الدراسة العملية حساب أعظم مدى وطاقة لجسيمات ألفا لـــ البلوتونيوم 239 باستخدام العداد الوميضـــي من خلال التغير لشـــدة الإشـــعاع بالنســـبة للزمن بالاظافة إلى اعتماد اللوغاريتم الطبيعي للنبضـــة الإشـــعاعية (Ln I) لكل وحدة زمنية من خلال التغير بالنســـبة لمدى جســـيمات ألفا R_α ومنه تم تحديد أعظم مدى. والنتائج التي تم الحصـــول عليها ، إن أقصـــى طاقة عند المدى 3.5 cm هو (5 Mev) عند فولتية تشغيل بمقدار 700 V.