Range calculation of water and Kapton for alpha particles and Oxygen

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Abstract. Background: The aim of study is to calculated the range using mathematical equations due of the charged particles of heavy (alpha particles and oxygen) falling on the water and Kapton compound in energy range of (0.01-1000) MeV. Materials and Methods: The calculations were compared with the experimental data of the ASTAR code for alpha particles and SRIM2013 program for alpha particles and oxygen. Results: This comparison showed a good agreement with experimental data with a correlation coefficient (r= 0.99). Range values obtained from the application of equations are increased by increasing the energy of heavy charged particles. A stopping power in matter described using $-\frac{dE}{dx}=a(E) + b(E)E$. The results of these stopping power are contributions and continuous-slowing-down ranges given to elements, compounds, mixtures, and biological material of incident kinetic energy. Tables of the contributions to $b(E)$ are given for the same materials. Conclusion: The correlation coefficient values calculated are 0.99 for water and Kapton compound.

1. Introduction

When charged particles pass through the physical media, they interact with many electrons in the medium, since heavy charged particles do not experience any deviation in their path in case of any small individual collision. Due to the random nature of particle energy loss processes in its path, this causes the range of single-energy particles to vary in the same medium. The distance that stops half the number of charged particles falling on the material is known as the average range. This means that the particles lose their energy during their transition in the medium and the remaining kinetic energy depends on the distance traveled in the material. If this distance is equal to the range in the medium, the energy of the particles is completely depleted and therefore the path of the heavily charged particles tends to be completely straight except at the end of its path when it has lost almost all its kinetic energy. In this case we can estimate the range of particles, (the distance after which cannot penetrate material) [1, 2]. An important application of our formula is the accurate estimation of effective atomic number of any composite material by measuring its MSP [3]. The aim of study is to calculated the range using mathematical equations due of the charged particles of heavy (alpha particles and oxygen) falling on the water and Kapton compound.

2. Materials and Methods

The extent of the charged particle is the length of the straight distance the particle travels in the direction of its fall in this material [4]. The collision of the falling particle with the electrons is a purely statistical process. The distance between the collisions may vary, and therefore the length of the impact varies.
slightly, resulting in a slight difference in the range of the same and single-energy particles [5]. Determining the extent of particles accurately is not difficult because there are statistical differences in the amount of energy lost in the path length unit (dE/dX) [6], the range can be written in terms of stopping power as follows [7]:

\[
R = \int_{E_0}^{E} \frac{1}{dE/dx} dE = \int_{0}^{E} \frac{1}{dE/dx} dE
\]  

(1)

It is very interesting to try to calculate the average transmission distance of a beam of particles in the medium by integration of the stopping power as a function of the energy of the falling particles i.e.

\[
R(T) = \int_{0}^{T} \left[ \frac{dE}{dX} \right]^{-1} dE
\]  

(2)

Theoretical calculation of range makes a very difficult task [7, 8]. There are some experimental equations to calculate that amount and make adjustments based on their results. (Ahmed, 2007) [9] give a formula to calculate the magnitude range in the medium if its range is known in the other medium as in the following equation [10]:

\[
\frac{R_1}{R_2} = \frac{\rho_2}{\rho_1} \left[ \frac{A_1}{A_2} \right]^{1/2}
\]  

(3)

where \(\rho_1, \rho_2\) are the density of 1st and 2nd mediums, \(A_1, A_2\), represent the mass number to 1st and 2nd mediums.

The ratio between the ranges of the charged particles can be written at the same initial velocity \(\beta\) as follows [11]:

\[
\frac{R_1(\beta)}{R_2(\beta)} = \frac{Z_2^2 M_1}{Z_1^2 M_2}
\]  

(4)

3. Where \(M_1\) and \(M_2\) are the static mass of the two particles, \(Z_2\) and \(Z_1\) are the atomic number of both particles.

The range of the other grave can be written as follows:

\[
R(\beta) = \frac{M}{Z^2 R_p(\beta)}
\]  

(5)

Where \(R_p(\beta)\) is the range of protons and \(M, Z\) is the charge and mass of the other particle respectively.

There are formulas for calculating the alpha particles range in the air [12]:

\[
R_{\alpha}^{air} (mm) = \begin{cases} 
0.05E_{\alpha} + 2.85 & \text{for } E_{\alpha} < 4 MeV \\
e^{1.61\sqrt{E_{\alpha}}} & \text{for } 4 MeV \leq E_{\alpha} \leq 15 MeV 
\end{cases}
\]  

(6)

\[
R_{\alpha}^{air} (cm) = \begin{cases} 
0.56E_{\alpha} & \text{for } E_{\alpha} < 4 MeV \\
1.24E_{\alpha} - 2.62 & \text{for } 4 MeV \leq E_{\alpha} \leq 8 MeV 
\end{cases}
\]  

(7)

Alpha particles range in liquids and steel. It is shorter because of high density. The collisions number of particles along the transition path. The alpha range in liquids and steel is close to the range in air as in:
\[ R(cm) = 0.00032 \left( \frac{A^{1/2}}{\rho} \right) R_{air} \]  

(8)

Where \( \rho \) is the density of the absorbent medium and it is measured in mg cm\(^{-3} \)

If we multiply the range of alpha particles in the absorbing medium by the density of the absorbing medium in mg cm\(^{-2} \), the range of alpha particles in the absorbent medium can be expressed in mg cm\(^{-2} \) units as follows:

\[ R(mg/cm^2) = (R(cm))(\rho) \]  

(9)

The alpha particles range by mass thickness unit can be calculated by [13] as follows:

\[ R(mg/cm^2) = 0.173E^{3/2}A^{1/3} \]  

(10)

where, \( E \) = Alpha gravitational energy (MeV). \( A \) = Atomic weight of the absorbent medium.

The range of charged particles in composite materials can be calculated from the range for all components of the compound using the following formula [2]:

\[ R_c = \frac{M_c}{\sum n_i A_i \left( \frac{A_i}{R_i} \right)} \]  

(11)

\( n_i \): number of atoms of \( i \), \( A_i \): atomic weight of element: \( R_i \), Range of \( i \), \( M_c \): molecular weight of compound.

3. Results and Discussion

The range of alpha particles in the five targets within the energy range MeV (0.01-1000) is calculated by applying equation (10) in calculating the range of alpha particles using the MATLAB2018 language program. Figure 1.2 shows the comparison between the calculated range values and the experimental values of (SRIM2013). It is noted that increasing the energy of alpha particles leads to an increase in the range. It is also observed that there is a match between the calculated results of the objectives and the results of the process of (A-STAR, SRIM) within the energy (2 <E <25) MeV.

Figure 1: Comparison of the present work, ASTAR and SRIM2013 range of water as a function of projectile energy for alpha particles
Figure 2: Comparison of the present work, ASTAR and SRIM2013 range of kapton as a function of projectile energy for alpha particles

The range of oxygen ions within the MeV energy range (0.01-1000) is also calculated by applying equation (10) in calculating alpha range and then applying equation (4) to calculate the extent of oxygen ions as the second particle which is the alpha particle MATLAB. Fig (3,4) show the comparison between the calculated range values and the experimental values of (SRIM2013). It is observed that the increase of energy for oxygen ions leads to an increase in the range in the objectives studied in this research. It is also observed that there is a match between the calculated values and the practical values of (2013SRIM) within the energy (0.8 <E <4) MeV of water and the Kapton compound.

Figure 3: Comparison of the present work and SRIM2013 for range of water as a function of projectile energy for oxygen ions.
Stopping power in matter described using \(-dE/dx=a(E) + b(E)E\), \(a(E)\) and \(b(E)\) are slowly-varying functions of \(E\). It is contribution and continuous-slowing-down approximation ranges are found of a selection of elements, compounds, mixtures, and biological materials. The contributions to \(b(E)\) are getting of the same materials, where radiative effect is very important.

4. Conclusions
Range values obtained from the application of equations (4) and (10) are increased by increasing the energy of heavy charged particles. The correlation coefficient values calculated are 0.99 for water and Kapton compound.

Acknowledgments
The author acknowledges the financial support of University of Kufa, Iraq. The author is grateful to Dr. Basim Almayahi, University of Kufa (basimnajaf@yahoo.com) for assisting me throughout conducting the present research.

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