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Stopping Power of Electrons in Water and Glass

Wafaa N. Jassim* and Ali N. Jassim

Physics Department College for Girls Kufa 54001, Iraq

ABSTRACT

Background: In this research study for calculation of electronic stopping power of one type of light charge particle, which it is electrons with energy (0.01-100MeV) when they are travel in water and glass. Materials and methods: The electronic stopping power were calculated using ester program and also by do fitting on this results then we get a semi empirical equation and after that a comparison where made with the theoretical results of James E. Turner only for water and we draw. All equation programing and drawing by matlab language. Results: The relationship between them on curve which have good agreement with all results of both track have shown. Conclusion: The stopping power of electrons take greatest values at low energy of electrons and at the high energies, elastic scattering arises gradually. However elastic scattering affects electron passage through resending of the electron paths, it does not contribute in the stopping power.

Keywords: Electron, Stopping power, Bethe, Excitation.

Introduction

When heavy charge particles throw in some medium, they are loss their energy continually by more collisions and interaction firstly with the electrons of atoms and then with nucleus of atoms by ionization or excitation of atoms. Energy loss models of electrons, positrons and protons transitory through matter are necessary for some radiological and several technological applications such as, applied material science, nuclear safety, medical physics and fission and fusion applications [1]. Average linear ratio of that energy loss of the heavy charged particle in any medium is essential importance in radiation Physics and dosimeter, the quantity $-dE/dx$, is denoted the stopping power of any medium of the particle [2]. By stopping power, we mean an average energy loss of the particle to the unit path length designated by -dE/dx and measured. More that the stopping power must be depended on energy, the type of the particle and the features of the medium, which it passes. Stopping power denotes to the property of the material while the loss of energy to unit the path length refer to what occurs to the particle [3]. But numerical values and units are like for both amounts. Total stopping power produce by the addition of the stopping powers, which they due to electronic and nuclear interactions therefore total stopping power can be representation by [4]:

$$\frac{dE}{dx} = \left(\frac{dE}{dx}\right)_{col} + \left(\frac{dE}{dx}\right)_{rad} \quad \ldots..(1)$$

Where $\left(\frac{dE}{dx}\right)_{col}$ the electronic energy loss due to Coulomb interactions $\left(\frac{dE}{dx}\right)_{rad}$ is the nuclear energy loss .The first successful try to derive a relation for the energy loss knowledgeable by an ion moving in the electromagnetic field of an electron was made by Neil Bohr. If relativistic quantum mechanics was using, Bethe obtained the following formula [5]:

$$-\frac{dE}{dx} = \frac{4\pi k_{\circ}^2 z^2 e^4 n}{mc^2\beta^2}\left[ln\frac{2mc^2\beta^2}{I(1-\beta^2)} - \beta^2\right] \quad \ldots..(2)$$

In this relation

$k_{\circ} = 8.99\times10^9$ Nm² C⁻²
z = atomic number of the heavy particle,
e = the electron charge,
n = number of electrons per unit volume in the medium,
m = electron rest mass,
c = speed of light in vacuum,
$\beta = v/c$ = speed of the particle relative to c,
I = mean excitation energy of medium.

The study of behave heavy charge particles when they penetrated some medium will make us understand and calculate stopping power of these particles in several mediums then that made us understand the relationship between stopping power of these particles and them energy. Finally, we can clear what are the operators which made they undergoes to this behaves which it is the aim of this study in this paper.

* Corresponding author: Wafaan.jasim@uokufa.edu.iq or ali_1986i@yahoo.com

Materials and Methods

The behavior of electrons so differently with the heavy charged particles behavior when passing through matter because electrons have very small mass with compared to heavy charged particles. The low mass of electrons made they portable so fast that their velocity might become very near to the light velocity. At an electron beam passes through a material there are number of ways to interact the electrons, which be individual in the beam with the target atoms or molecules. As heavy charged particles, electrons can excite and ionize atoms. Hereafter stopping power of a material for electrons contains of two components: collisional and radiate [4, 6]:

$$S_{electrons} = S_{collisional} + S_{radiative} \quad \ldots..(3)$$

The forms of the collisional and radiate components of the total stopping power for electrons are given as fallow [7]:

$$-\left(\frac{dE}{dx}\right)^{\pm}_{coll} = \frac{4\pi k^2 e^4}{mc^2\beta^2}\left[\ln\frac{mc^2\tau\sqrt{\tau+2}}{I\sqrt{2}} + F^{\pm}(\beta)\right] \quad \ldots..(4)$$

Where for electron

$$F(\tau)^- = 1 - \beta^2 + \frac{\frac{\tau^2}{8} - (2r+1)ln2}{(\tau+1)^2} \quad \ldots..(5)$$

But for positrons

$$F(\tau)^+ = ln2\frac{\beta^2}{24}\left[23 + \frac{14}{\tau+2} + \frac{10}{(\tau+2)^2} + \frac{4}{(\tau+2)^3}\right] \quad \ldots..(6)$$

Here $\tau = T/mc^2$ is the kinetic energy T which for the electron or positron expressed in multiples of the electron rest energy mc^2.

The electron energy loss by radiation occur when electrons which have high energy reach to close distance from K-orbit because coulomb attractive F between electrons and nuclei. When the electron closed on distance which called impact parameter, they will deflected and there are photons emitted because the nuclei try to stop the electrons by coulomb's force then the electrons accelerated because the electromagnetic field of nuclei and attach this progress emitted radiation which called bremsstrahlung. The electron energy which loss by bremsstrahlung on unit of length is [8]:

$$\left(\frac{dE}{dx}\right)_{rad} = \frac{4z(z+1)e^4NE}{137m_e^2c^2}\left[ln\left(183Z^{-1/2} + 0.125\right)\right] \quad \ldots..(7)$$

This relation represent stopping power of electron by radiation when electron energy is great $(E > m_e c^2)$, but if E is small we can neglected the electron energy loss by radiation.

Results

In this research we study the stopping power of an electrons where they penetration the water and glass and we find the semi empirical equation to calculated the stopping power by using the fitting of the results estar program and compare with it to study the behavior of these electrons. We compare stopping power of electrons in water with the results of James E. Turner and we get a good agreement among with James E. Turner, the semi empirical equation and estar results, the equation we get it for calculate stopping power in water and glass is:

$$-\frac{dE}{dx} = ae^{bT} + ce^{dT} \quad \ldots..(8)$$

Where a,b,c,d are constants we can explain them in the table (1) :

Table 1: The value of a,b,c,d constant.

Constant	Water	Glass
a	31.28	23.8
b	-45.55	-44.01
c	2.308	1.889
d	0.00688	0.01043

Discussion

From fig.(1) and fig.(2) we can notice the stopping power of electrons decrease with increase energy of electrons if the penetration medium were water or glass because ionization, excitation, and scattering of electrons which happen through passing them in water or glass. Add these process electrons will be slow then undergo almost a random diffusion and the electrons can be scattered elastically by atomic electrons of medium.

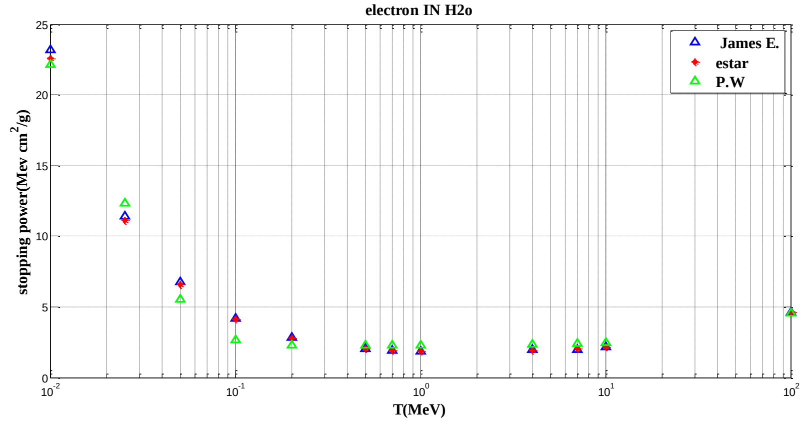

Fig.1 Stopping power of electrons in water.

Figure (1) show three curve for stopping power of electrons vs. energy of electrons with energy range (0.01-100) MeV, which transport in water. We found a good agreement among the present work, results of James E. Turner and the result of estar program, since the stopping power is smaller at high energies also we notice the clustering of events, mostly in the middle part of the tracks.

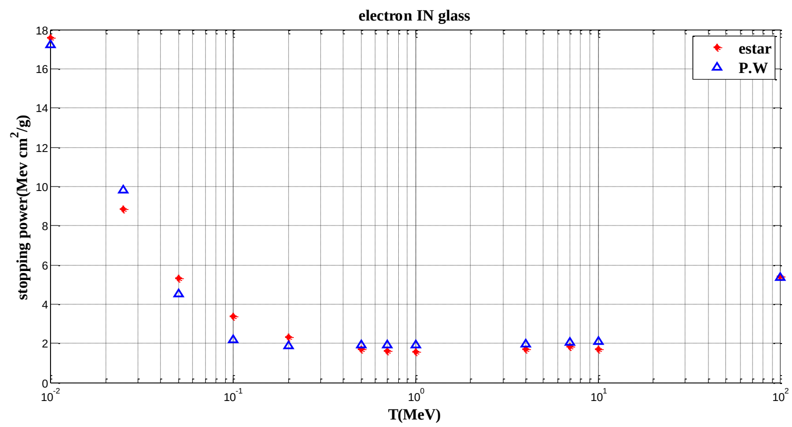

Fig.2 Stopping power of electrons in glass.

Figure (2) show two curve for stopping power of electrons vs. energy of electrons with energy range (0.01-100) MeV, which transport in glass. We found a good agreement between the present work and result of estar program, also as stopping power of electrons in water we since the stopping power is smaller at high energies and we notice the clustering of events, mostly in the middle part of the tracks.

Conclusion

1- The stopping power of electrons take greatest values at low energy of electrons because the electrons are light particles decelerate through penetration the mediums and the excitation and ionization possibilities increase sharply from the lowest energies.

2- At the high energies, elastic scattering arises gradually. Though elastic scattering affects electron passage through resending of the electron paths, it does not contribute in the stopping power, because there is not associated energy loss, this cause low in stopping power with energy of electrons.

3- The stopping power of electrons in water is greater than it in glass may be back to the structure chemically with water molecules.

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