Scholars LITERATURE

La Prensa Medica Argentina

Research Article

DOI: https://doi.org/10.47275/0032-745X-220
Volume 106 Issue 4

Stopping Power of Electrons in Bone, Brain Tissues, and Eyes

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Abstract

In this research, the ability to stop collision and radiation as well as the total ability to stop electrons was calculated using the relative Bethe-Bloch equation in human tissues (bone, brain, and eyes) in the energy range (0.01-1000) MeV and the equations were programmed using the MATLAB language. The obtained results showed that the collision stopping power is the dominant of radiation from the total stopping power. An appropriate curve instrument was used as two semi-empirical equations with their constants were obtained. The calculated results were compared to the results of the E-Star code and showed good agreement with practical values.

Keywords: Stopping power; Bethe-Bloch; Human tissue

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Citation: Kadhim RO, Yassin ZA (2020) Stopping Power of Electrons in Bone, Brain Tissues, and Eyes. Prensa Med Argent, Volume 106:4. 220. DOI: https://doi.org/10.47275/0032-745X-220

Received: February 18, 2020; **Accepted:** March 03, 2020; **Published:** March 11, 2020

Introduction

When charged particles pass through the physical media, they lose a portion of their energy continuously in many collisions, ionize atomic electrons, move at velocity v, with a charge of Z1e, and a mass of m [1]. And since the movement of the charged particles generates an electromagnetic force on the electrons in the atom, it provides it with a card, and this energy added to the atom may succeed in removing an electron from the atom and its atomization or leaving The atom is in an irregular state [2]. The stopping power evaluations two different ways : the first is to consider the interactions of incoming of the electron and positron with target electrons , which is called collisional stopping power while the second is considered the fact that accelerated charged particles is radiated, which is called radiative stopping power or Bremsstrahlung Loss [3], the primary goal of the theoretical understanding of these processes is to predict the rate of lost energy ratio of the particle for each unit of the transmission distance as a function of the energy of the particle. MeV.cm^{-1}. Divide the stopping power by the density of the material ρ that gives a close relationship to it: mass stopping power ((-dE)/ρdX) and express it in units of MeV.cm^2.g^{-1} [4].

Theory

The stopping power is defined as the loss of energy for every distance in the target material that can be written (-dE / dx) which depends on the charge of the projectile and on the target material [5]. The study of the stopping power is one of the topics that take up a large area in physics. These studies were theoretical and experimental using different methods [6], that the total stopping powers of electrons, as well as that of positrons, depend not only upon the incident kinetic energy of these particles but also on the nature of the material through which they traverse [7], for vehicles, the added Bragg base was found to work well. The rule states that the collective stopping power of a substance that contains several elements is equal to the weighted amount of the mass stopping power of the constituent atoms [8].

$$\left(\frac{-dE}{\rho dX}\right)_{com} = \sum_i w_i \left(\frac{-dE}{\rho dX}\right)_i \quad (1)$$

where:

$$\omega_i = \frac{n_i A_i}{A_{com}}$$

ω_i : the ratio of the weight of the elements in the compound

n_i: number of atoms of the j^{th} kind of atoms in a compound or mixture

A_i: atomic mass of medium

ρ: *the density of the medium*

$(-dE/\rho dx)_{com}$: *mass stopping power of compound*

$(-dE/\rho dx)_i$: *mass stopping power for the elements in the compound*

Bragg rule is [9]:

$$(-dE)/\rho dx)_i = \frac{\omega_1}{\rho_1}(-dE)/dx)_1 + \frac{\omega_2}{\rho_2}(-dE)/dx)_2 + \dots \quad (2)$$

The mass collision stopping power for electrons and positrons are given by [10].

$$S_{coll} = (dE/\rho dx)coll = K\left[Ln\left\{\frac{\tau^2(\tau+2)}{2\left(\frac{1}{m_0c^2}\right)^2}\right\} + F^{\pm}(\tau) - \delta(\beta\gamma) - \frac{2C}{Z}\right] \quad (3)$$

$$C = \pi\left(\frac{N_A Z}{A}\right)\left(\frac{e^2}{m_0 c^2}\right)^2$$

where:

$$K = \frac{2Cm_0c^2}{\beta^2} = \frac{0.1535Z}{A\beta^2}$$

$$\beta = \frac{v}{c}$$

$$\tau = \frac{E}{m_0 c^2}$$

τ is the kinetic energy of the electrons in unites of m_0c^2

$$F^-(\tau) = 1 - \beta^2 + \frac{1}{(\tau+1)^2}\left[\frac{\tau^2}{8} - (2\tau+1)\ln 2\right] \quad \textit{for electrons} \qquad (4)$$

And

$$F^+(\tau) = 2\ln 2 - \frac{\beta^2}{12}\left[23 + \frac{14}{(\tau+2)} + \frac{10}{(\tau+2)^2} + \frac{4}{(\tau+2)^3}\right] \quad \textit{for positrons} \qquad (5)$$

where

C/Z is shell correction accounting for non-participation of K-shell electrons at low energies and; δ is for the polarization or density effect correction in condensed media [11]

$$\delta = 0 \qquad X < X_0$$

$$\delta = (4.606 \times X) + \left[a(X_i - X)^m\right] \qquad X_0 < X < X_i$$

$$\delta = (4.606 \times X) + C \qquad X > X_i$$

Where

$$X = \log\left(\log\frac{\beta}{\sqrt{1-\beta^2}}\right)$$

The parameters X_0, X_i, a, m and C parameters for elements and many compounds and mixtures were published

Bethe and Heitler have obtained an approximate relationship between the Scoll collision and the Srad in the relationship:[12]

$$S_{tot} = S_{coll} + S_{rad} \qquad (6)$$

$$= S_{coll}\left(\frac{EZ}{800}\right) \qquad (7)$$

$$S_{tot} = S_{coll}\left(1 + \frac{EZ}{800}\right) \qquad (8)$$

Results and Discussion

The MATLAB program was used to program the modified Beth-Bloch equation for electrons to calculate the rate of energy lost in bone, brain and eye lens tissue transformations. The collective collision energy loss of electrons in the electron energy range from 0.01 MeV to 1000 MeV. Using E-Star data and applying it to the MATLAB program to compare it with the calculated results, and the curve match was performed where two semi-empirical equations were obtained with their constants (Table 1), Equation (8) was used to calculate the total stopping power. (Figures 1-3) show the total stopping power in the studied media.

Table 1: Showing semi-empirical equations that represent the ability to block electrons in Bone, Brain and Eye les tissues.

	Bone	Brain	Eye Lens
Fitting1 = a.*T1.^b+c	a=0.3792	a=0.4055	a=0.4334
	b =-0.8569	b=-0.8610	b=-0.8466
	c=1.497	c=1.551	c=1.399
Fitting2= a2.*T2.^b2+c2	a2=0.03200	a2=0.02743	0.02677=a2
	b2=1.001	b2= 0.9967	b2=0.9969
	c2=1.718	c2=1.86	c2=1.841

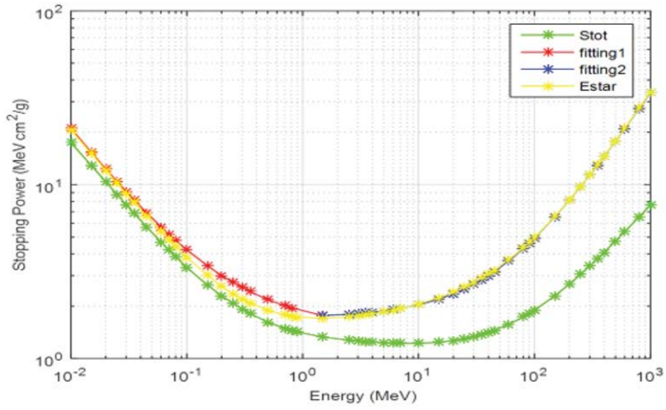

Figure 1: Comparison of the present work and E-star results for total stopping power of electrons in the Bone.

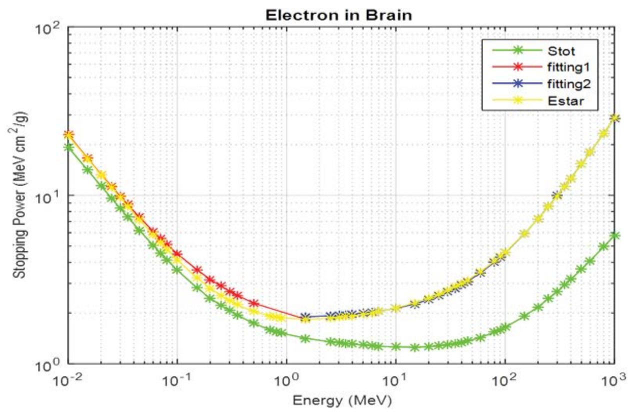

Figure 2: Comparison of the present work and E-star results for total stopping power of electrons in the Brain.

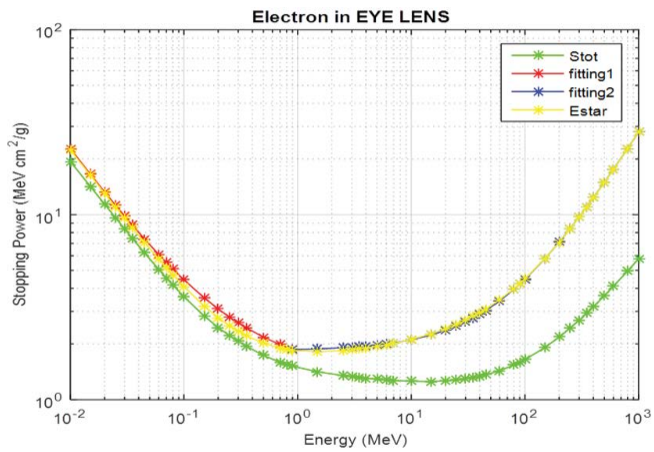

Figure 3: Comparison of the present work and E-star results for total stopping power of electrons in the eyes

Conclusion

Through the results of this research work, we can conclude the following: Calculations indicate that S_tot decreases with increasing energy of the incident particle at the energies (0.01-10) MeV because of the collision stopping power is the effect, then the total stopping power increases by increasing the energy of in incident electrons because the radiative stopping power is effective, and this energy depends on the speed of the particles that limit the type of interactions with the target and depends on the speed of the particles that determine the type of interactions with the target. The value of 〚S〛 tot depends on the energy of the transverse particle, but its dependence is weak on the atomic number of the target. It was concluded that the Beth- Bloch equation is good for calculating the stopping power of electrons in the studied tissues while the results of the curve match are close to the results of the process.

Acknowledgement

The authors are grateful to Dr. Basim Almayahi, University of Kufa (basimnajaf@yahoo.com) for assisting throughout conducting the present research.

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