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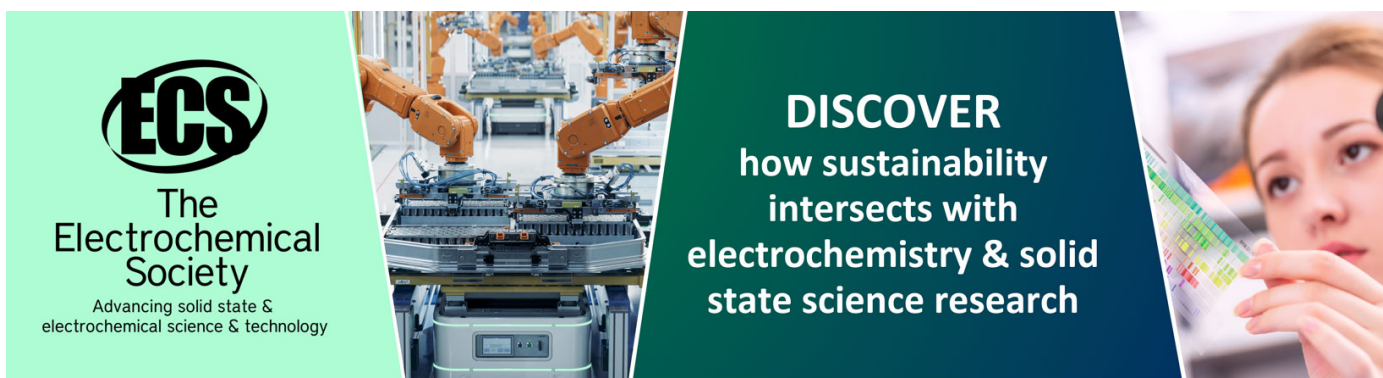
Studying of loss energy For Protons And alpha particle in the polymers C₂H₄, C₁₂H₂₂O₂N₂ and C₄₃H₃₈O₇

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Studying of loss energy For Protons And alpha particle in the polymers C₂H₄, C₁₂H₂₂O₂N₂ and C₄₃H₃₈O₇

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Abstract. In this research the electronic stopping power was calculated theoretically by use modified Bethe-Bloch theory (Bloch's, Barkas and shell corrections). Protons and alpha particle loss energy were calculated in the polymers (C₂H₄, C₁₂H₂₂O₂N₂ and C₄₃H₃₈O₇) at energy range of [0.3-1000] MeV. The equations were programmed by using (MATLAB) language. The calculations were compared with the practical results of the SRIM 2013. There is some simple difference between practical and theoretical results. The effect of Bloch is the highest in consistency with the practical results and the Shell correction and Barkas correction values are convergent, but they move away at the practical values from the beginning of the period to the range of approximately 10 MeV.

Key words: Shell Correction, Barkas Correction, Bloch's Correction, Stopping power, Bloch theory.

1. Introduction:

Heavy charged particles interact with matter, such as protons and alpha particle. These particles can pass through a medium with electron and the nuclei of the material by Coulomb force. This mechanism of interaction wastes energy by ionization or excitation of atom. This is why alpha particles are the most serious to health. And offline, Semiconductor radiation detectors are widely used for detection and measurement of heavy charged particles [1].

Stopping power, i.e. energy loss of energetic particles per unit length in matter, has been studied experimentally and theoretically since the beginning of the 20th century because of its wide application area, such as ion implantation, fundamental particle physics, nuclear physics, radiation damage, radiology, and structure analysis of solid target by Rutherford backscattering spectroscopy. Results of theoretical efforts on heavy-ion stopping date back to N. Bohr [2]. The stopping power due to ionization and excitation is known as collisional stopping power. The calculation of energy loss due to emission of "Bremsstrahlung" is more complicated than the calculations of stopping power due to ionization and excitation and there are no exact results used in such calculations but there are only approximate equations [3]. There are several physical theories that describe the stopping power.



However, it is difficult to represent the entire interactions involved due to large number of collisions and the frequently change of ion charge state that traverse the material [4]. For example, the Bethe theory considers the stopping power in high energy range as momentum transfer between ion and electrons of the target. Theoretically it is very difficult to determine the accurate loss energy and thus various programs yield Non-similar stopping power depending on the manner of calculations and considerations.

2. Stopping power

The energy loss of charged particles traversing matter arrive at a general stopping power function [5]

$$-\frac{dE}{dx} = \frac{4\pi z_2 e^4 z_1^2}{m_e v^2} N L(v) \quad (1)$$

Where N is the target density, z_1 and z_2 the atomic number of projectile and target respectively, v the projectile velocity and $L(v)$ is stopping number, m_e , e are the electron mass and charge

There have been many corrections proposed to improve on Bethe theoretical [6]

$$L = L_0 + Z_1 L_1 + Z_1^2 L_2 + \quad (2)$$

L_0 Born Correction

$Z_1 L_1$ Barkes Correction

$Z_1^2 L_2$ Bloch correction

The loss energy term, L_0 , contains the largest corrections to the basic high-energy stopping power function Where you write:

$$L_0 = \ln\left(\frac{2m_e c^2 \beta^2}{1 - \beta^2}\right) - \beta^2 - \frac{C}{Z_2} - \ln\langle I \rangle - \frac{\delta}{2} \quad (3)$$

$\frac{C}{Z_2}$: shell correction

$\ln\langle I \rangle$: mean ionization energy correction

$\frac{\delta}{2}$: density effect correction

β Relative particle velocity

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

3. shell correction

The original Bethe function is valid when the velocity of the projectile is much higher than that of electron in target atoms. Shell corrections should be taken into account at lower projectile velocities. The total shell correction can be written as following form [7].

$$\Delta L_{shell} = -\frac{C}{Z_2} \quad (4)$$

on can written the shell correction in Bethe formula [8]

$$\left(-\frac{C}{Z_2}\right)_{\text{Bethe}} = \epsilon \left[3 + \epsilon \left(\frac{5}{2} + \frac{7}{2} \epsilon \right) \right] \quad (5)$$

4. Barkes Correction

The Barkas effect, associated with a z^3 correction to the loss energy, is very pronounced at low energies. The correction is due to target polarization effects for low-energy distant collisions [7] and can be written for by the following expression [9]

$$Z_1 L_1 = \frac{3\pi Z_1 e^2 \omega}{2m v^3} \ln \left[\frac{v}{1.7 \omega a_\omega} \right] \quad (6)$$

ω is the free electron gas plasma frequency and $a_\omega = \sqrt{\hbar/2m_e \omega}$

5. Bloch correction

L_{Bloch} is the stopping number and the standard expression of Bloch's formula is given by the following equation [10]

$$\Delta L_{\text{Bloch}} = \Psi(1) - \text{Re} [\Psi(1 + i\eta)] \quad (7)$$

Where Ψ is Digamma function. η Sommer field factor

$$\eta = \frac{Z_1 e^2}{\hbar v}$$

Bichsel has proposed a simple parameterization of the Bloch correction which accurately fits a large range of high velocity stopping results [10,6].

$$Z_1^2 L_2 = -\eta^2 [1.202 - \eta^2 (1.042 - 0.855\eta^2 + 0.343\eta^4)] \quad (8)$$

where the velocities is low, the value of $Z_1^2 L_2 \rightarrow -0.58 - \ln(\eta)$, and thus the Bloch effect provides and For high velocities, $Z_1^2 L_2 \rightarrow -1.2 \eta^2$. As will be shown in the next section, this term is Always quite small.

6. Results and discussion

The figures represents the relationship between the calculated stopping power by shell, Barkas and Bloch correcting as a function of energy. The calculations were compared with the practical results of the SRIM 2013 [11].

The figure(1) The polymer C_2H_4 was projected to proton of (1) atomic number, where the equation no.(5,6,8) was programmed after compensating it with equation no.(1). shows that the Bloch correction calculated from equation (2) of the protons is consistent with the experimental results. At the beginning of the range there is distance in stopping power of Bloch correction followed by high consistency with the experimental results. This is due to the increase of the atomic number of the medium resulting in little energy at the beginning of the range and because the Bloch equation is a quantity suitable for high energies. After the Bloch correction comes the Barkas correction values which record a slight difference and by continuously increasing the range it further approaches the experimental results. As for the shell correction, it appears in low energies but by increasing the energy the shell correction fades and approaches to zero because the stopping power approaches zero in high energies.

The figure(2) The polymer $C_{12}H_{22}O_2N_2$ was projected to proton of (1) atomic number, where the equation no.(5,6,8) was programmed after compensating it with equation no.(1).

shows the same behavior of protons in C₂H₄ compound with different values of calculated stopping power to Bloch, shell and Barkas corrections.

The figure (3) The polymer C₄₃H₃₈O₇ was projected to proton of (1) atomic number ,where the equation no.(5,6,8) was programmed after compensating it with equation no.(1) .

The three corrections are close to SRIM at the beginning of the range and becomes closer with increasing the range used, but the Bloch corrections remain the closest to experimental results.

The figure (4) The polymer C₂H₄ was projected to alpha particle of (2) atomic number ,where the equation no.(5,6,8) was programmed after compensating it with equation no.(1) .

indicates that the effect of Bloch is the highest in consistency with the experimental results since the beginning of the range. It gets more consistent when the range increases reaching full consistency at high energies. The calculated electronic stopping power values for Barkas and shell correction begin with high values at the beginning of the range and then gradually decreases at increasing energy until recording values approximant to SRIM2013. This is because the energy values in this region are low for the falling alpha particles which have a large mass when compared to protons. and also the role of Z₁ for the projectile the more it is the more the stopping power which is calculated for the entire range and also the role of the average ionization voltage of the medium but when 20MeV power increase significant results are noticed with SRIM2013.

The figure (5) The polymer C₁₂H₂₂O₂N₂ was projected to alpha particle of (2) atomic number ,where the equation no.(5,6,8) was programmed after compensating it with equation no.(1) .

illustrated similar behavior of alpha particles in C₂H₄ compound with different values of calculated stopping ability to Bloch, shell and Barkas corrections. There is difference in Bloch correction at 0.3MeV where it is less than the practical value and then become higher at the range 0.5MeV

The figure (6) The polymer C₄₃H₃₈O₇ was projected to alpha particle of (2) atomic number ,where the equation no.(5,6,8) was programmed after compensating it with equation no.(1) .

high lights that the values of calculated stopping power for the Bloch correction are the closest since the range 0.5MeV up to the end of the range used because they are suitable for high energies. The area from (0.3-0.5) MeV represents the nuclear stopping zone and the largest area of 2MeV represents the electronic stopping zone between the two regions represents an area of ionization or irritation. The Shell correction and Barkas correction values are convergent, but they move away at the experimental values from the beginning of the period to the range of approximately 10MeV.

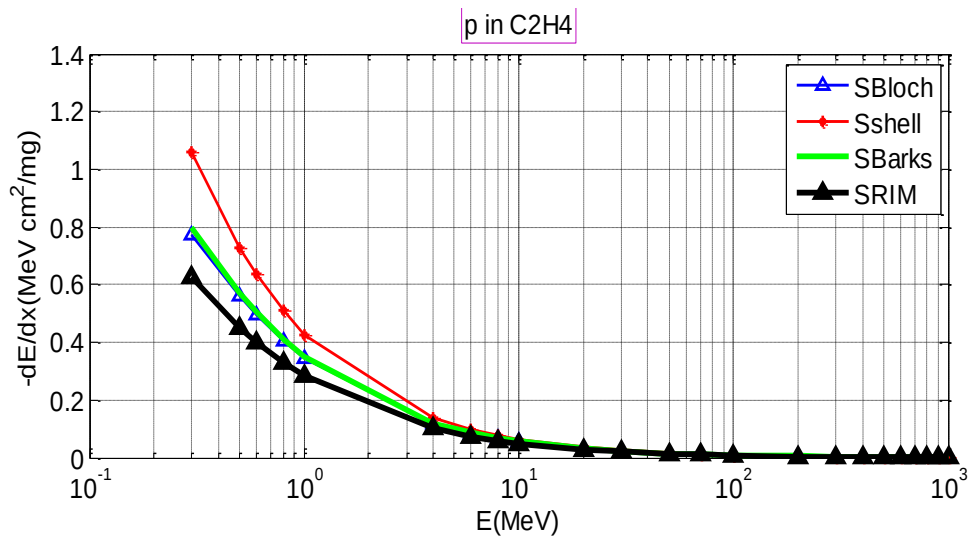


Fig.(1) stopping power for proton in (C₂H₄)

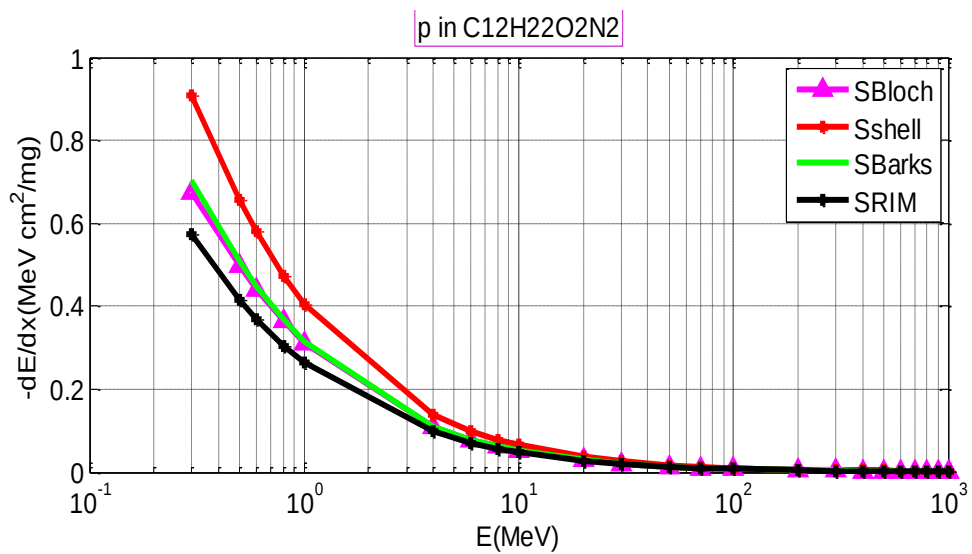


Fig.(2) stopping power for proton in (C₁₂H₂₂O₂N₂)

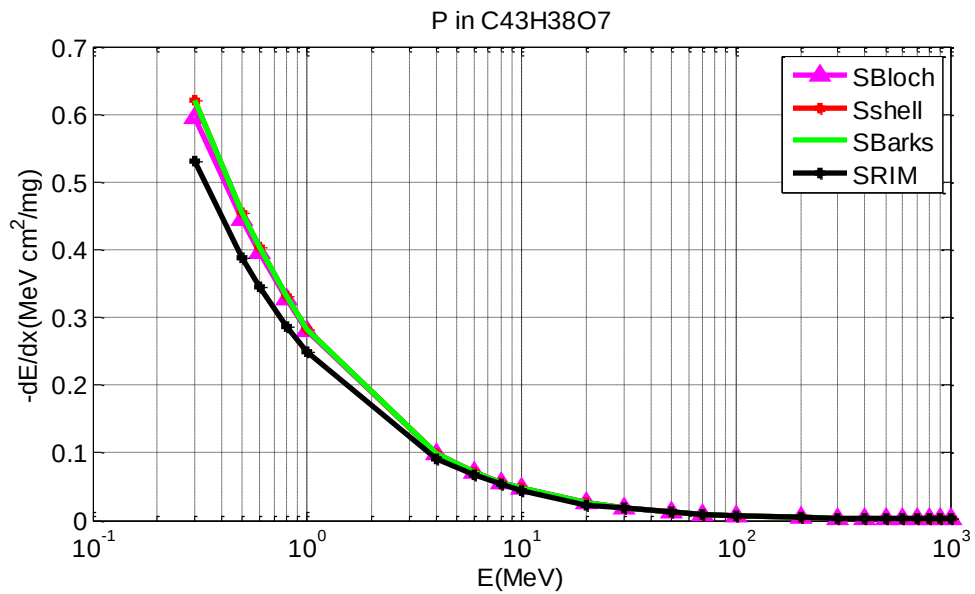


Fig.(3) stopping power for proton in ($C_{43}H_{38}O_7$)

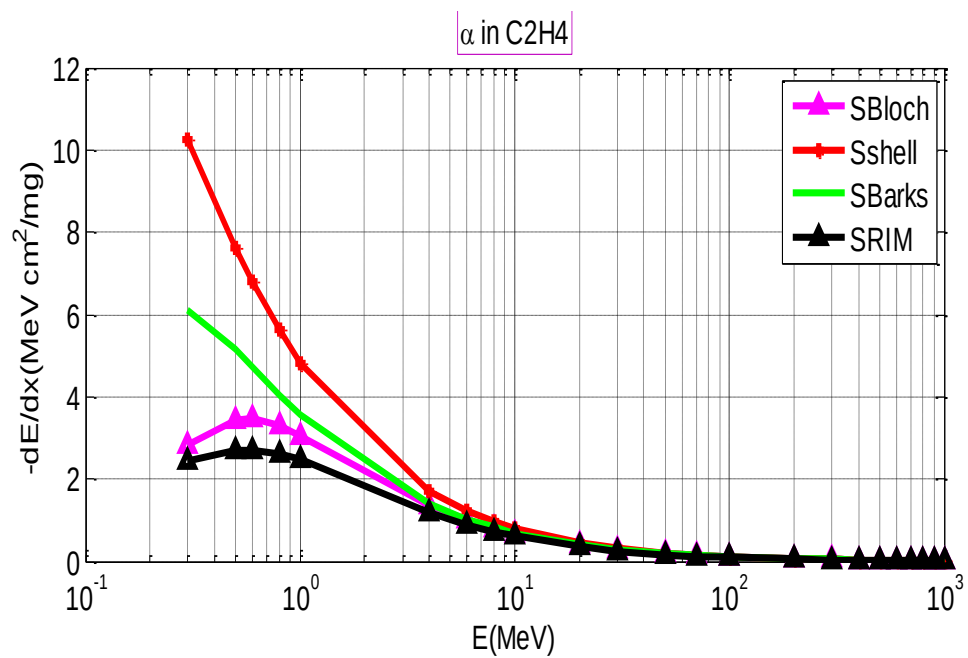


Fig.(4) stopping power for alpha particle in (C_2H_4)

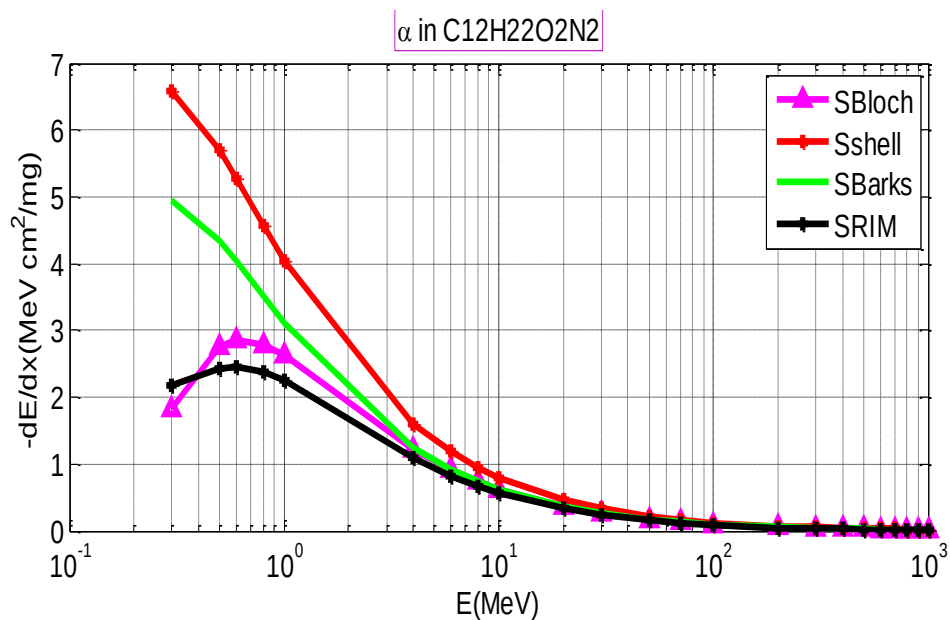


Fig.(5) stopping power for alpha particle in ($C_{12}H_{22}O_2N_2$)

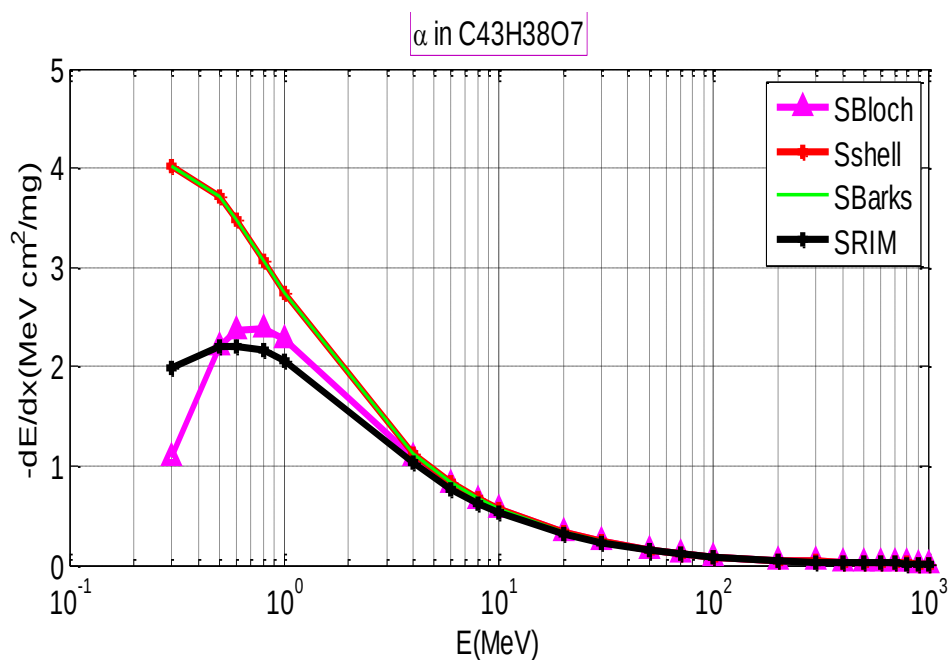


Fig.(6) stopping power for alpha particle in ($C_{43}H_{38}O_7$)

7. Conclusion

- 1- Beth's equation with Bloch correction is the best result in comparison with Shell correction and Barks correction
- 2 - shell Correcting and Barks correction records good results at energies higher than (10)MeV.

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