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Electronic Stopping Powers for Protons in Polymers $C_5H_8O_2$, C_2H_3CL and C_2F_4

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Abstract

The electronic stopping power of the proton reaction in the polymers $C_5H_8O_2$, C_2H_3CL ,C_2F_4 for the energy ranging between (20-10000) MeV was studied. Numerical calculations and analysis of the results were carried out using the Matlab program for the Bohr and Beth equation and SRIM 2013 program. All theoretical and practical values and results are presented in graphs. The stopping time of each polymer in protons was calculated.

Key words: stopping power, time stopping, srim2013, Polymers

Introduction

In radiation physics, chemistry, biology, and medicine, it is often important to have accurate information about the stopping power of various media for charged particles, that is, the average rate at which the charged particles lose energy along their tracks [1] It consists of two parts, the Electronic Stopping Power and Nuclear Stopping Power. The former results in due to the slowing down of ion and are attributed to interaction of incidence ions with the bound electron of the material as a result of inelastic collisions. The last process expresses that the energy is lost by the ions that are dissipated out of electron cloud into thermal vibrations of the material. The collisions involved both excitations of electron cloud and bound electrons of the material[2].

$$(-\frac{dE}{dx})_{tot} = (-\frac{dE}{dx})_{nuc} + (-\frac{dE}{dx})_{elec} \qquad (1)$$

Many studies on energy loss have been adopted , B. Rani et.al [3] calculated The energy loss for swift heavy ions, covering Z=3-29, in the elemental absorbers like C, Al and Ti. The present calculations are based on Bohr's approach applicable in both classical and quantum mechanical regimes. The major input parameter, the effective charge, has been calculated in a different way without any empirical/semi empirical parameterization. The calculated energy loss values have been compared with the available experimental data which results in a close agreement. S. Heredia-Avalos et.al [4] studied the electronic energy loss cross section and the energy loss straggling of swift light ions)H+ and He+) moving through several compound semiconductors (GaAs, ZnSe, InP and SiC) as a function of the incident projectile energy data shows a good agreement in a wide range of incident projectile energies. A. Akkermana et al. [5] According to The energy loss for 10 solid organic materials and water in the range of proton energies 50-500 keV. Most of the presented results are new and are in good agreement with existing experimental data. The calculated data might be useful for applications in radiobiology and space research. Z.Hussein , R. Owaid [6] studied the values of radiative stopping power collisional stopping power ,the total loss energy and stopping time for electrons in C_2H_4O ,C_3H_6 and C_3H_3N adopted Bethe- Bloch relativistic formula in the energy range of 0.01-1000 MeV .

1-Stopping power

The amount of energy loss by an particle heavy - unit path length is commonly called as the energy loss of the medium, as defined

$$S = -\frac{dE}{dx} \qquad (2)$$

Where E is the charged particle kinetic energy and x is the path length. The amount of –dE / dx along a particle track is also known as specific energy loss. Thus, the quantity S is referred to as a specific energy loss. This amount can represent the total energy loss per number of interacting particles. It is proportional to the square of the charge of the incoming particle, and it is inversely proportional to it is velocity. So, the stopping power increases when velocity of particle is decreased. Also, the stopping power can be referred to the term linear energy transfer, which is used an approximation of the stopping power of penetrating particles [7]

$$-\left(\frac{dE}{dx}\right)_{elec} = \frac{4\pi Z_1^2 Z_2 e^4}{mv^2} N\, L_{elec} \qquad (3)$$

The differential stopping power of charged particles in accordance with the theoretical work which has been started by Bohr as a classical formula at non-relativistic velocities:

$$L_{elec} = L_{Bohr} \approx \ln\left(\frac{Cm_e v^3}{|z_1 e^2| w}\right) \qquad (4)$$

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Where: $C=2e^{-d}$, d=0.5772

and
z_1- atomic number of the projectile

m - mass of electron.

z_2- atomic number of the target material.

I - the mean excitation potential of target material.

v is the velocity of the projectile
w is the free electron gas plasma frequency

Bethe obtained a similar expression from a quantum mechanical approach but wrote LBethe in terms of an average excitation energy (I) as[8]:

$$L_{elec} = L_{Bethe} = \ln\left[\frac{2m_e c^2 \beta^2}{1-\beta^2}\right] - \beta^2 - \ln I \qquad (5)$$

2-Stopping Time

The stopping time I the time interval required to stop a charge particle in an absorber medium. This time can be expressed in terms of the stopping power by using the chain of differentiation[9]

$$\frac{dE}{dt} = \left(\frac{dE}{\rho dx}\right)\left(\frac{\rho dx}{dt}\right) = \frac{1}{\rho}\left(\frac{dE}{dx}\right)(\rho v) = \rho v\left(\frac{dE}{\rho dx}\right) \quad (6)$$

Where v= dx/dt the velocity of the particle. Then, assuming the rate of energy loss is constant, slowing down time is given by[10]

$$t = \frac{E}{\frac{dE}{dt}} = \frac{E}{\rho V\left(\frac{dE}{\rho dx}\right)} \qquad (7)$$

Where t in unit (sec)

Results and Discussion

In figure (1), the electron stopping power of protons passing through polymer $C_5H_8O_2$ at a power range of (20-10000) MeV is shown. The results of this study were obtained by applying equation (3) to Bohr once and Beth again. We note from the Fig(1) that the Beth equation is closer to the practical results of SRIM2013 than the Bohr equation, Because Beth's equation is a quantity that works at these energies, that is, the

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highest energies. Therefore, they come closer when increasing the energy, reaching the limit of application at the range 110 to the end of the range.

We also note that the stopping power decreases by increasing the energy of the falling particle because the loss of energy is inversely proportional to the square of the particle velocity.

Figure (2)show the electron stopping power of protons passing through polymer C_2H_3CL at a power range of (20-10000) MeV. We note from Fig(2) that the protons exhibit the same behavior in the previous polymer, but the difference in stopping power values. We note that the values of the Bohr and Beth equation and practical values SRIM2013 are spaced at the beginning of the range, but start approaching closer when the range increases, ie energies above 100MeV, but the values of the Beth equation remain closer to the practical results because the amount of Beth equation is valid at high energies.

Figure (3) show the electron stopping power of protons passing through polymer C_2F_4 at a power range of (20-10000) MeV .It shows the exact applicability of the electronic stopping power values of the Beth equation from the practical values of the SRIM 2013 program from the beginning of the used range till its end. unlike the values of the Bohr equation, which are away from the beginning.

In figure (4), the electronic stopping power of the proton reaction in the polymers for the energy range (20-10000) MeV is show. Numerical calculations and analysis of the results were carried out using the Matlab program for the Bohr and Beth equation and SRIM 2013 program.

All theoretical and practical values and results are presented graphs. The stopping time of each polymer in protons was calculated.

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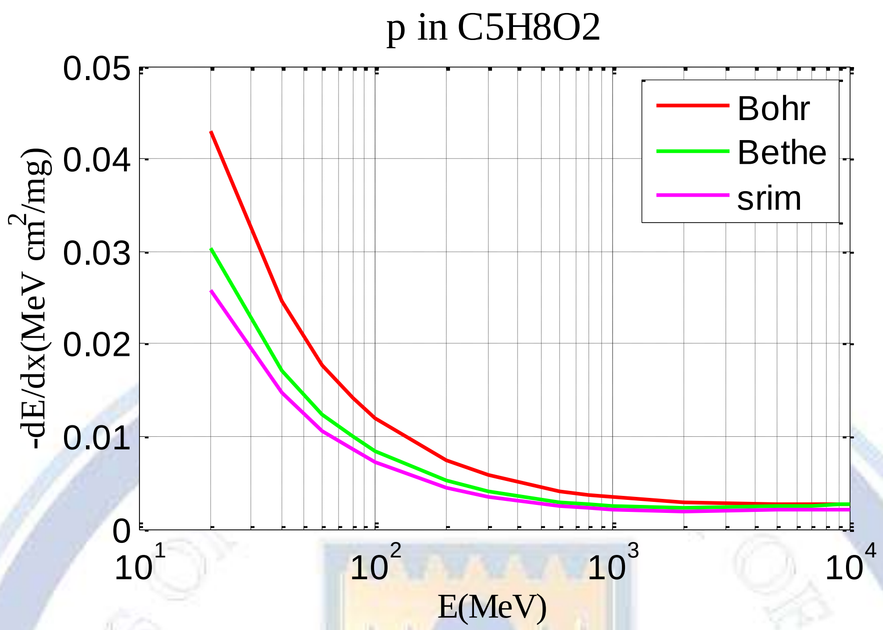

Fig.(1) the stopping power for proton in ($C_5H_8O_2$)

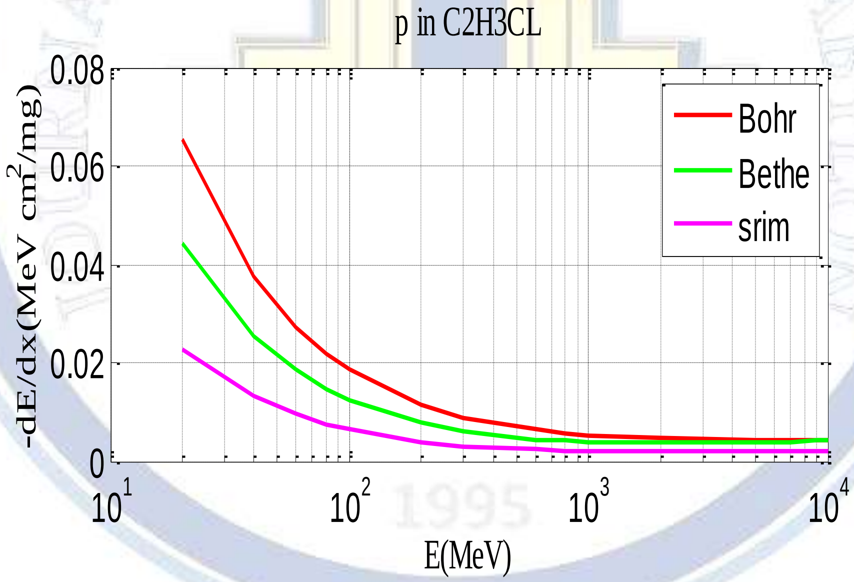

Fig.(2) the stopping power for electron in C_2H_3CL

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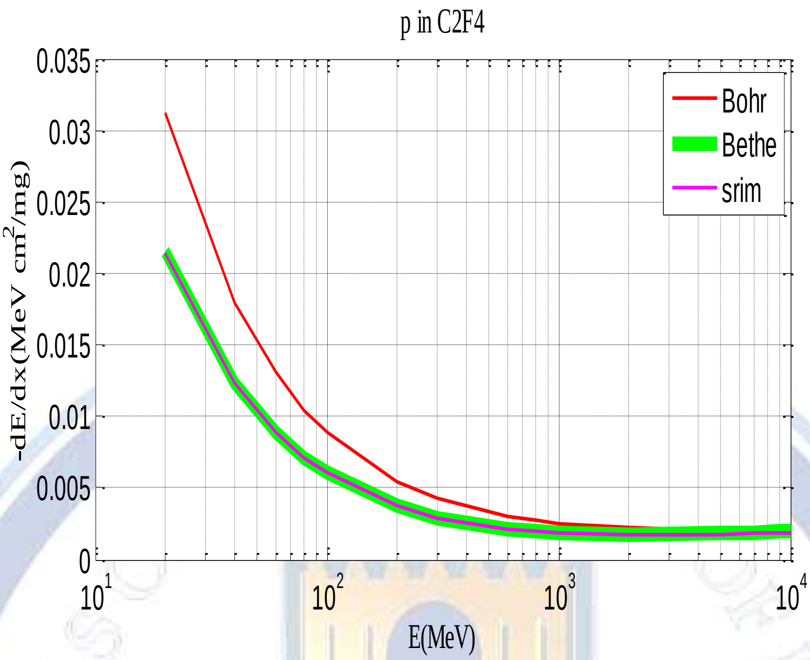

Fig.(3) the stopping power for proton in (C2F4)

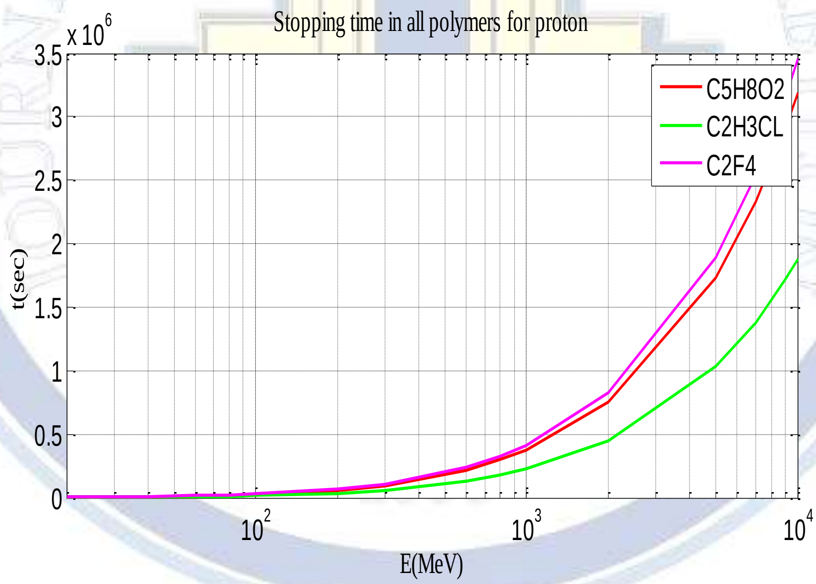

Fig.(4) the stopping time for proton in $C_5H_8O_2$, C_2H_3CL and C_2F_4

Conclusions

1- The results indicate that energy loss decreases with increasing particle incident energy, and this energy depends upon the particle speed which limits the type of interactions with the target.
2- The range of energy used to study stopping power for the heavy particles (20 – 10000)MeV is considered adequate to Bethe equation of the heavy, charged particles used.

Conflict of Interests.

There are non-conflicts of interest .

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الخلاصة

تم دراسة قدرة الايقاف الالكترونية لتفاعل البروتونات في البوليمرات C_2F_4, C_2H_3CL, $C_5H_8O_2$ لمدى طاقة (20-10000)MeV. اجريت الحسابات العددية وتحليل النتائج بأستخدام برنامج الماتلاب لمعادلة بور وبيث وبرنامج SRIM2013 وقد تم عرض كافة القيم والنتائج العملية والنظرية اشكال بيانية وقد تم حساب زمن الايقاف لكل بوليمر في البروتونات.

الكلمات الدالة: قدرة الايقاف, زمن الايقاف , بوليمرات, SRIM 2013