Electron Stopping Powers of Chitin and Chitosan

Zahraa A. Abdul Muhsin1*, Ahmed Saad Aldhamin1**, and Shafik S. Shafik2, 3
1Department of Biology, College of Science, University of Baghdad, Baghdad, Iraq
2University of Alayen, Thi-Qar, Iraq
3Department of Physics, College of Science, University of Baghdad, Baghdad, Iraq
1*Email: Zaa84@yahoo.com
1**Email: ahmed.aldhamin@uob.iq
2,3Corresponding author: shafeqsh76@gmail.com

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Abstract
Chitosan can be deduced from chitin by simple chemical process. Chitosan has many applications and one of the promise application is used as nuclear shield by adopted it with some materials. Electron stopping power (SP) represents important parameter in tested the ability of any material to use it as nuclear shield. Therefore, stopping powers of electrons incident with different energies on chitin and chitosan have been calculated by using codes of National Institute of Standards and Technology (NIST) after modified it by built in the chemical structure and some other properties of chitin and chitosan in the codes. The results of total SP showed that chitosan has values larger than chitin but the differences are small and the maximum percentage difference ratio is 6.8% at 4 MeV electron energy. Total SP has approximately 35 Mev.cm²/g at 0.01 MeV electron energy, and decreasing with energy till to 1 MeV, then slowly increasing. In addition to total SP, the collision SP, radiative SP, density effect parameter, radiation yield, and electron range were calculated. The behaviors of the calculated parameters have been studied and explained. The obtained results suggested that chitosan may be used after mixing it with other materials as a shield from nuclear radiation, especially in low energies.

1. Introduction
Chitin is a natural compound of a group of sugars containing nitrogen. It is also called "the sixth element." Chitin is found in fairly large quantities in the organisms of some insects, various crustaceans, in the stems and leaves of plants [1]. It should be noted that in nature, according to its production data, it comes second after cellulose. For hundreds of years, chitin was considered a residue, because its formula was not able to dissolve in dilute alkalis, acids and many other solvents, or in water. Chitin advantage is the high operating cost of direct use, unlike cellulose [2].


Scientific and technical discoveries have allowed humans to discover chitin with a number of exciting properties that cellulose does not possess. For example, today this substance is the core of the only edible animals in the world [3]. It should be noted that chitin is exclusively shipped with positive ions. In addition, it is made up of minerals, vitamins, fats, sugars and proteins, which give every right the sixth vital component of a human being an important component.

Once in the human body, chitin actively absorbs negatively charged fatty acids. Thus, this substance prevents their absorption into the intestine [4]. Gradually, chitin removes negatively charged fatty acids from the body. Chitosan, which is obtained by removing acetylcholine from chitin, activates the active activity of cells of the human body. At the same time, it significantly improves nervous self-regulation and hormonal secretion. Scientific studies [5-6] have shown that chitosan has the ability to reduce the concentration of cholesterol in the blood. Consequently, it is not allowed to settle in the liver and prevent its absorption into the small intestine.

In addition to medical uses, there are many industrial uses. As example, after mixing chitosan with some materials, composite materials can be obtained with good properties that can be used in the manufacture of biodegradable packaging materials, such as mixing chitosan with Poly Vinyl Alcohol (PVA) [7]. It can also be used to remove heavy elements and heavy radioisotopes from water. We are also planning in the near future to manufacture a mixture containing chitosan in its composition and used as a shield from nuclear radiation.

One of the most important parameters to be studied and known when making a nuclear shield is the stopping power (SP) and the attenuation factor for this material [8]. The stopping power of a specific material varies with the incident particle, such as an electron, proton, or alpha particle, when the energy is constant. The stopping power can be defined as the process of losing energy to the particles and ions charged during the path unit and that the process of calculating it relied on the basic factors of the incident particle and the target material through speed, charge and mass in relation to the incident particle as well as on the characteristic of that target (i.e. the target material) so therefore, the process differs energy loss through the nature and type of incident particle [9].

However, in this paper, the electron stopping power for chitin and chitosan have been calculated by simulation method. To achievement this goal, National Institute of Standards and Technology (NIST) codes have been used and the chemical composition of chitin and chitosan was incorporated into these codes [10].

2. Chitosan and Chitin Compositions
Chitosan, which has \((C56H103N9O39)\) chemical formula, is a substance consisting mainly (as mentioned above) of chitin, which is a chain of carbohydrates (sugars) that are extracted from the outer structure of shells, shellfish and marine shellfish such as "shrimp" and other various shellfish. Chitin has \([(C8H13O5N)n]\) chemical formula [6].
Briefly, these shells and crustaceans are grinded together, and then they undergo a simplified chemical process that deals with extracting a portion of these substances called Deacetylation. After extracting this part, the basic formula of chitosan is almost ready as:

![Image](image_url)

**Figure (1):** the chimachal fomula of chitin and the Deacetylase process to produce chitosan [11]

### 3. The Stopping Power (SP)

By using the first Born approximation, Bethe (in 1930) depends on quantum mechanics approach [9] to calculate the electronic stopping power (the electronic energy loss). However, the cross section of stopping in c.g.s. units, is given by [12]:

\[
S_e = \frac{4\pi Z_1^2 e^4}{m v^2} Z_2 \ln\left(\frac{2 m v^2}{I}\right)
\]  

where \( v \) is the projectile’s speed, \( Z_{1e} \) is the nuclear charge of the projectile, \( Z_{2e} \) is the nuclear charge of the target, \( m \) and \( e \) are mass and charge of the electron, and \( I \) is the mean excitation energy of the target.

By adopting the relativistic effects, equation (1) becomes:

\[
S_e = \frac{4\pi Z_1^2 e^4}{m v^2} Z_2 \left[ \ln\left(\frac{2 m v^2}{I}\right) - \ln(1 - \beta) - \beta^2 \right]
\]  

where \( \beta = \frac{v}{c} \)  

The linear electronic stopping power is related to the electronic stopping cross section as follows:

\[
S_{lin} = - \frac{dE}{dx} = nS_e
\]  

where \( n \) is the no. of target atoms. The mass stopping power can be given by:

\[
S_{lin/\rho} = \frac{4\pi r_0^2 m e^2}{\beta^2} \frac{Z_2}{u} \frac{1}{A_2} Z_1^2 \left[ \ln\left(\frac{2 m u^2}{I}\right) - \ln(1 - \beta) - \beta^2 \right]
\]  

where \( r_0 \) is the classical electron radius, \( u \) is the atomic weight of the target, and \( A_2 \) is the mass number of the target.
\[ S_{\text{lin}}/\rho = (0.307075 \text{ MeV cm}^2/\text{g}) \frac{Z_2}{A_2} Z_1^2 \left[ \ln \left( \frac{2m_e v^2}{I} \right) - \ln(1 - \beta) - \beta^2 \right] \] ....(6)

where \( r_e^2 = \frac{e^2}{mc^2} \) is the classical electron radius, \( u \) is the atomic mass unit, \( A_2 \) is the relative isotopic mass of the target atom, and standard values of the various atomic constants have been used.

In addition, electron SP can be divided into collision stopping power, which is "average rate of energy loss per unit path length, due to Coulomb collisions that result in the ionization and excitation of atoms, and radiative stopping power, which is "average rate of energy loss per unit path length due to collisions with atoms and atomic electrons in which bremsstrahlung quanta are emitted". The total stopping power for electrons is "the sum of the collision and radiative stopping powers".

In this work, the collision and radiative SP of electrons incident on chitin and chitosan have been, also calculated by depending on the procedure illustrated in reference [13]. Furthermore, some useful and important parameters have been estimated, such as density-effect correction, radiation yield, and the incident electron range. Density-effect correction: enters into the formula for the collision stopping power and takes into account the reduction of the collision stopping power due to the polarization of the medium by the incident electron [14]. Radiation yield: average fraction of the initial kinetic energy of an electron that is converted to bremsstrahlung energy as a particle slows down to rest, calculated in the continuous-slowing-down approximation. The incident electron range is "a very close approximation to the average path length traveled by incident electron as it slows down to rest, calculated in the continuous-slowing-down approximation" [15]. In this approximation, the rate of energy loss at every point along the track is assumed to be equal to the total stopping power. The range is obtained by integrating the reciprocal of the total stopping power with respect to energy [16].

4. Results and Discussions

In this work, electron SP for both collision and radiative SP, Density – effect correction, and radiation yield have been calculated for chitin and chitosan. Figure (1) illustrated the percentage ratio of the difference between the total SP for chitin and chitosan, and one can clearly note that the differences don’t exceed 6.8%. Therefore, the results of chitosan which have higher values of chitin will be adopted. This convergence of behavior is considered normal and the increase in chitosan values is, also, considered normal because the molecular weight of chitosan is greater than chitin.

The total, collision, and radiative SP for chitosan have been shown in figure (2). By examining this figure, it can be observed that the total stopping power can take three actions. The first one is a decrease in SP by increasing the energy of the incident electron energy till to 0.9 MeV point. From 1 to 11 MeV, total SP has constant behavior. After that, the total SP increases with increasing energy. This behavior is
very beneficial, especially in low energies, which simulate the energies of beta particles that accompany gamma rays from naturally occurring isotopes, and this means that chitosan can be used as a basic material in producing a protective shield for beta particles and also when mixed with materials having a high atomic number, one can produce from it Shield against gamma rays. Figure (2) also shows the radiative SP as a function of the incident electron energy, which increases with increasing energy, meaning that at low energies the collision stopping power is predominant, and this confirms the importance of chitosan in making a shield against beta rays. In figure (3), the density effect parameter was plotted as a function of incident electron energy, whereas figure (4) illustrated the radiation yield behavior, and figure (5) showed the electron range. As expected, these three parameters increase with increasing incident electron energy. The known of the behaviors and values of these parameters is very important in the manufacturing of nuclear shield.

![Figure (2); The percentage difference ratio of total electron stopping powers of chitin and chitosan as a function of incident electron energy](image)
Figure (3); The collision, radiative, and total SP of electrons incident on chitosan with different energies

Figure (4); Density effect parameter as a function of incident electron energy for chitosan
Figure (5); The radiation yield of electron stopping powers of chitosan as a function of incident electron energy

Figure (6); The electron range in chitosan as a function of incident electron energy
5. Conclusions

The results of the stopping power calculations showed the preference of chitosan over chitin and that it can be used as a nuclear radiation shield when mixed with other materials, especially at low energies. Furthermore, the collision SP is predominant till to 11 MeV incident electron energy.

6. References

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