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Calculation of the Stopping Power and Range for alpha particles in Some Materials and Tissues

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By

Taghreed Abdul Jabbar Younis Al - Rubaii

B.Sc.in physics, College of Education for Pure Ibn Al- Haitham,

University of Baghdad in 1998

M.Sc. in Science of physics

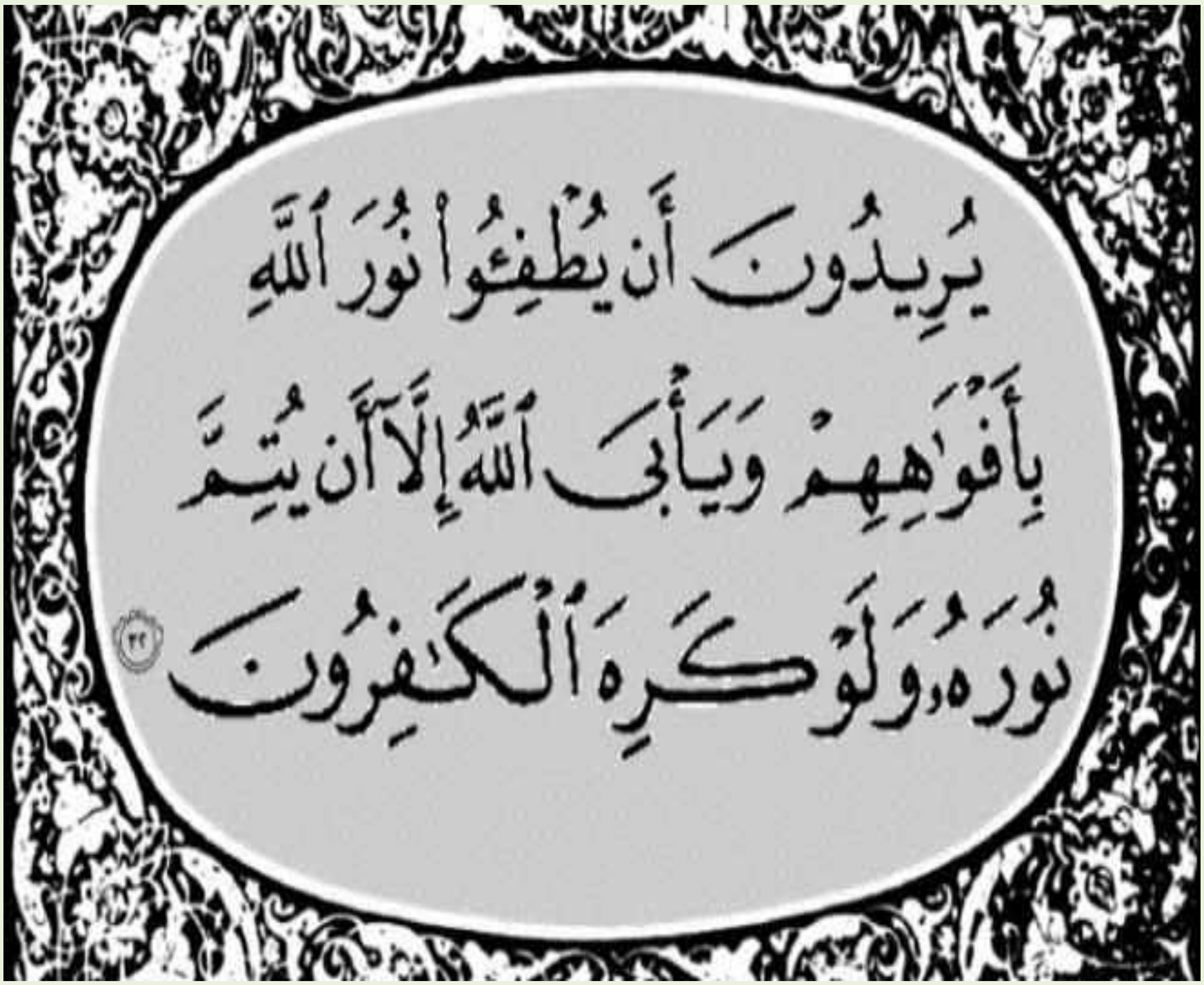
College of Education for Pure Science Ibn Al-Haitham

University of Baghdad in 2006

Supervised By

Prof. Dr. Bashair Mohammed Saied

2018 A.D. **1439 A.H.**



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Supervisors Certification

We certify that this thesis entitled:

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Signature:

Name: **Dr. Bashair Mohammed Saied**

Scientific Position: **Professor**

Address: College of Education for Pure Science Ibn Al- Haitham

University of Baghdad PDF Reducer Demo

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In view of the available recommendations, I forward this thesis for debate by the examination committee.

Signature:

Name: **Dr. Karim Ali Jassim**

Head of the Physics Department

Scientific Position: **Professor**

Address: College of Education for Pure Science Ibn Al- Haitham

University of Baghdad

Date: / / 2018

Examination Committee Certification

We certify that have read this thesis entitled (**Calculation of the Stopping Power and Range for alpha particles in Some Materials and Tissues**) submitted by (**Taghreed Abdul Jabbar Younis Al – Rubaii**), and as an examining committee, we examined the student in its contents and that in our opinion it is adequate for the partial fulfillment of the requirements needed to the award the degree of Doctor of Philosophy (Ph.D.) in Physics.

Chairman
Signature:
Name: **Prof. Dr. Saad N. Abood**
Address: College of Science / University of Al-Nahrain
Date: / /2018

Member
Signature:
Name: **Assist. Prof. Dr. Nada F. Kadhim**
Address: College of Science/University of Al- Mustansiriyah
Date: / /2018

Member
Signature:
Name: **Assist. Prof. Dr. Ahmed F. Mkhaiber**
Address: College of Education for pure Science Ibn Al- Haitham / University of Baghdad
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Member
Signature:
Name: **Assist. Prof. Dr. Ahmed M. Shweikh**
Address: College of Education for pure Science Al- Haitham / University of Baghdad
Date: / /2018

Member
Signature:
Name: **Assist. Prof. Dr. Mahmood S. Karem**
Address: College of Education /University of Ibn Al- Mustansiriyah
Date: / /2018

Member (Supervisor)
Signature:
Name: **Prof. Dr. Bashair M. saied**
Address: College of Education for pure Science/Ibn Al- Haitham / University of Baghdad
Date: / /2018

Approved by the Council of College of education for Pure Science /Ibn- Al-Haitham
Signature:
Name: **Prof. Dr. Khalid Fahad Ali**
Dean of the College of Education for Pure Scince /Ibn Al- Haitham
Date: / /2018

Dedication

I wish to dedicate my thesis to the soul of my father who lives in my memory to the end of my life and to my mother .To my brothers Laith, Hayder and Ali .To my sisters, especially Heba and Suzan. To my husband Adeel and to the love of my heart , my children Abdullah and Fatema.

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Abstract

Recent developments confirm the ability of alpha particles to generate radiation in a highly toxic localized manner because of its high ionization and its short range. Therefore, the amount of ionization energy loss and the range of alpha particles within human tissues, tissue thickness, linear energy transfer, as well as the amount of radiation dose and the equivalent and effective dose must be precisely defined to control the killing of cancer cells.

In this study, the interactions of alpha particle with matter have been studied and the stopping powers of alpha particle with four tissues of the human body, namely (Breast, Ovary, Lung and Muscle), and three materials ($Silicon\ dioxide$ (SiO_2), Aluminum Dioxide (AL_2O_3) and $Zirconium\ Dioxide$ (ZrO_2)) have been calculated, using four methods (Beth-Bloch equation, Zeigler formula and SRIM2013 software , ASTAR program) also the Range of alpha particle and Liner Energy Transfer (LET) and Thickness of these tissues and materials. As well as Dose ,equivalent and Effective Dose for this particle have been calculated by using Matlab Language over an energy range from (0.01 to 200)MeV .

We have produced two semi-empirical formulas, one for calculating the stopping power of alpha particles and the other for calculating its range in these tissues and materials by knowing alpha particle energy.

One of the important results we obtained in our study is the Bragg Curve which can calculate the maximum value of energy lost at a specified value of particle energy, through which we calculate the thickness of the corresponding materials so we can give the processor table in these values.

Comparing our results of the calculated stopping power of muscle tissue and silicon dioxide (SiO_2) with ICRU-49 we find very good agreement between them, this confirms the ability of our result to be used in such cancer treatment and other field where these quantities are used.

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List of some Symbols	
Symbols	**Description**
δ – rays	Dealta –ray
$(-dE/\rho dx)$	Mass stopping power
ρ	Density of material or target or tissue
$(-dE/dx)$	Stopping power or linear energy transfer
LET	Linear energy transfer
Pc	The particle momentum
ICRU	International commission on radiation units and measurements
W_R	The radiation weighting factor (quality factor=20 for alpha particle)
D	Absorbed dose
RBE	The relative biological efficacy
ICRP	International commission on radiological protection
W_T	Tissue weighting factor
n	The number of electrons per unit volume in the material
m_0	Rest mass of electron
v	The speed of the particle
e	Electron charge
I	Mean excitation energy of the target
c	Velocity of light
E	Energy of particle
M	Mass of particle
Q_{max}	The maximum energy transfer
h	Plank constant
i	The number of ion pairs produced per unit path
W	The average amount of energy lost from heavy particles in the production of a pair of ion
$\boldsymbol{b_{max}}$ and $\boldsymbol{b_{min}}$	The maximum and minimum impact parameters.
$\delta/2$	The density effect correction
ΔE	An energy transfer
w_i	The weight fraction of i th kind of atom in a compound:
$Z_{effetive}$	an effective atomic number
A_i	Atomic weight of i the element
Z_i	Atomic number of i the element
N_iZ_i	The electron densities
n_a	Concentrate of atoms in the material.
N_A	The Avogadro number
A	The atomic mass of the material (in g/mol)
E_0	The initial energy for alpha particle
E_1	The smaller energy for alpha particle
R	The range of alpha particle into target
T	Thickness of target

Gy, mGy	Absorption dose measurement units
Sv , rem	Equivalent and effective dose measurement units
H_T	The equivalent dose
IMRT	Intensity modulated radiation therapy
CAB	The core and bond
E_n	Each transitions the potential energy and oscillator strengths corresponding to the target atom.
I	Mean excitation energy of the target
S_n	Nuclear stopping power
S_e	Electronic stopping power

Introduction

(1.1) Preface

In radiation processes, particles or electromagnetic radiation are emitted from the nucleus. The most common forms of radiation are classified into alpha, beta, and gamma radiation. Nuclear radiation occurs in other forms, such as the emission of protons or neutrons or the spontaneous fission of a large nucleus [1]. The stopping power and losing the energy of charged particles as they pass through the material have been of great interest for 100 years [2,3] because of its wide applications such as elementary particle physics, nuclear physics, ion implantation and radiation damage [3], also the range, dose and the equivalent dose of ions in the air, tissues, materials and polymers are very important in many areas of research and application, such as [4, 5].:

1. Measurement of radiation doses
2. Radiation biology
   - Cell lethality
   - Cytogenesis changes
   - Genetic mutations
   - Recombination DNA
3. Radiation chemistry
4. Radiation therapy
5. Nuclear physics

The main objectives for calculating the amount of energy loss per distance expressed the stopping power and the range of fallen particles resulting from its interaction with the material are:

1. Assess the amount of the gross loss of particle energy.

2. Evaluate the radiation dose, which is very important in radiotherapy and thus estimate the potential damage to the vicinity of the tissue.

Charged particles are used in radiation therapy because:

1- The charged particles have a well-defined penetration in the tissue. The depth of the penetration depends on:
   - The nature of the irradiated material
   - The energy of the fallen mass.
2- Charged particle (protons, deuterons, and alpha particles) has an important effect in radiation therapy as they have the ability to deliver their energies to the target [6, 7].
3- When heavy charged particles are used, the acute Bragg peaks can be formed to deposit most of the heavy charged energy in the tumor mass. Because the linear energy transfer is relatively lower before the Bragg peaks and then falls suddenly to zero. This physical characteristic of the heavy charged particles makes it much better in the treatment of tumors than photons where the Bragg peaks do not appear [8].

(1.2)Radioactivity

In nature, the nuclei of most atoms are stable. However, certain atoms have unstable nuclei due to an excess of either protons or neutrons, or an excess of both. They are described as radioactive, and are known as radioisotopes or radionuclides , which automatically change to other atomic nuclei that may be radioactive or may not be. This shift is known as disintegration. This is accompanied by the emission of different types of radiation. Achemical element can therefore have both radioactive isotopes and non-radioactive isotopes. For example ${}^{12}_{6}c$ is not radioactive, but ${}^{14}_{6}c$ is.[9]

(1.3)Alpha radiation properties

a. Alpha particle is the nucleus of the helium atom **(** ${}^{4}_{2}\mathrm{He}^{+2}$**).**

b. Consists of two protons and two neutrons**.**

c. The rest mass of the alpha particle is 6.64424×10^{-27}kg**, or** 3.7273×10^{9} eV

d. An atomic weight of 4.002602 amu**.**

e. Possesses alpha particle low penetration power (Can be easily stopped by a sheet of paper) so its range is short. The figure (1-1) shows this

f. When energy $7.5\ MeV$ generally fail to penetrate dead layers of cells covering the skin.

g. Alpha particles play an important role in nuclear fusion processes within stars**.**

h. The spontaneous of the alpha mass occurs when the mass number of the element is greater than 150, such as uranium, thorium and plutonium, through the process of decomposition. In this process, the atomic number of the element is reduced by two units and the mass number by four units

i. Alpha particles have a net spin of zero.

j. Statistically, alpha particles is considered of bosons [10].

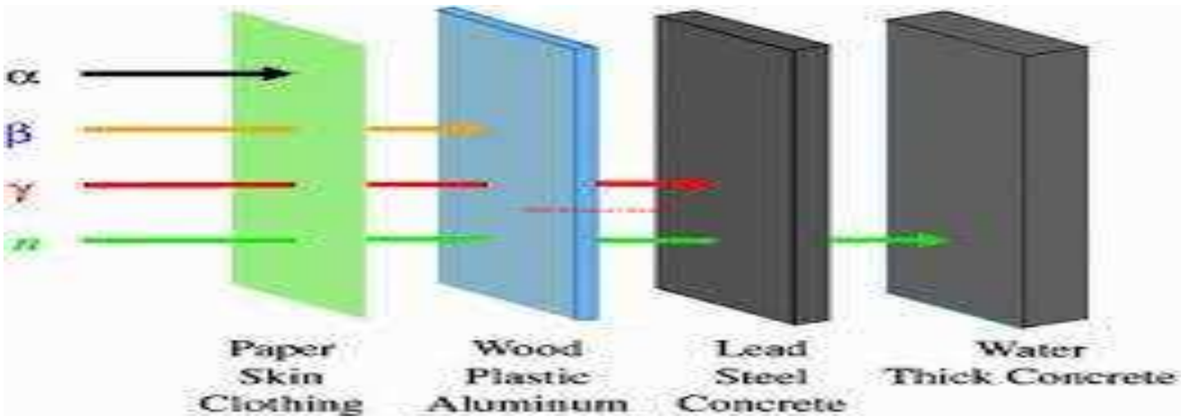


Fig.(1-1) Penetration of alpha particle for material [11]

(1.4) Sources of alpha particles

- **Natural sources of ionizing radiation**: Cosmic radiation, terrestrial radiation, ingestion ,inhalation, human body like ${}^{40}_{19}K, {}^{14}_{6}C$.

- **Artificial (man-made) sources of ionizing radiation**: Medical sources, industrial sources, nuclear fuel cycle, atmospheric testin

There is a large number of naturally occurring radioisotopes that emit Alpha particles: **(1.4.1) Accelerator –based sources** :Alpha particles are produced by collisions of high energy particles with fixed target substances called spallation reactions away from the target nuclei in their components. Two neutrons plus two protons form a very stable nucleus such reactions produce Alpha particles together with protons and neutrons [12].

(1.4.2)Radioactive sources of alpha particles **:**There are numerous radionuclides that emit alpha particles, some of which are listed in table (1-1).

Table (1-1) Common alpha particles emitters, the energies of their most probable emissions [13]

Source	Half-Life	Alpha Particle Kinetic Energy (with Uncertainty) in MeV
^{148}Gd	93y	3.182787±0.000024
^{232}Th	$1.4\times 10^{10}y$	4.012±0.005 3.953±0.008
^{238}U	$4.5\times 10^{9}y$	4.196±0.004 4.149±0.005
^{235}U	$7.1\times 10^{8}y$	4.598±0.002 4.401±0.002 4.374±0.002 4.365±0.002 4.219±0.002
^{236}U	$2.4\times 10^{7}y$	4.494±0.003 4.445±0.005
^{230}Th	$7.7\times 10^{4}y$	4.6875±0.0015 4.6210±0.0015
^{234}U	$2.5\times 10^{5}y$	4.7739±0.0009 4.7220±0.0009
^{231}Pa	$3.2\times 10^{4}y$	5.0590±0.0008 5.0297±0.0008 5.0141±0.0008 4.9517±0.0008
^{239}Pu	$2.4\times 10^{4}y$	5.1554±0.0007 5.1429±0.0008 5.1046±0.0008
^{240}Pu	$6.5\times 10^{3}y$	5.16830±0.00015 5.12382±0.00023
^{243}Am	$7.4\times 10^{3}y$	5.2754±0.0010 5.2335±0.0010
^{210}Po	138d	5.30451±0.00007
^{241}Am	433y	5.48574±0.00012 5.44298±0.00013
^{238}Pu	88y	5.49921±0.00020 5.4565±0.0004
^{244}Cm	18y	5.80496±0.00005 5.762835±0.000031
^{243}Cm	30y	6.067±0.003 5.992±0.002 5.7847±0.0009 5.7415±0.0009
^{242}Cm	163d	6.11292±0.00008 6.06963±0.00012
^{254}Es	276d	6.4288±0.0015
^{253}Es	20.5d	6.63273±0.00005 6.5916±0.0002

(1.5) Radiation Types

Radiation can be broken down into four types. [13]

1- Charged particle radiation { Fast electrons and positrons ($\beta +$ and $\beta -$) / Heavy charged particles including α particles

2- Uncharged radiation { Electromagnetic radiation / Neutrons

(1.5.1) The types of ionizing radiation

Ionizing radiation: is the radiation that causes the ionization of the medium atoms by passing through it (e. g. Alpha particles, photons, electrons, positrons, protons, neutrons, nuclei, etc

The directly Ionizing radiation is consists directly of high energy charged particles that have the ability to ionize material atoms because of Coulomb's interaction with their electrons, such as Beta, Alpha radiation, and various other nuclei.

Indirectly ionizing radiation: is a radiation whose atoms do not ionize directly or are ionized but very infrequently, but due to the interactions of those particles with high-energy material the free charged particles are emitted at times. These particles directly ionize the medium atoms and examples of indirect ionizing radiation, High-energy photons: ultraviolet rays, X-rays, gamma rays, and neutrons in any energy [14].

(1.6) Interaction of radiation with matter

We need to understand how the various radiations react with the material in order to predict the levels of exposure and thickness required of shielding.

The mode of interaction is a function of the following:

- Radiation type
- Radiation energy
- The media type

The material absorption of the radiation varies depending on the type of radiation.Alpha and beta particles and neutrons can be fully absorbed by the material ,gamma rays and X-rays can be reduced to safe levels only.

(1.6.1)Interaction of heavy charged particles with matter

Alpha particles possess a double positive charge due to the two protons present. This permits ionization to occur within a given substance (solid, liquid, or gas) by the formation of ion pairs due to coulombic attraction between a traversing alpha particle and atomic electrons of the atoms within the material the alpha particle travels. The two neutrons of the alpha particle give it additional mass, which further facilitates ionization by coulombic interaction or even direct collision of the alpha particle with atomic electrons. The much greater mass of the alpha particle, 4 atomic mass units (u), in comparison with the electron ($5 \times 10^{-4} u$) facilitates the ejection of atomic electrons of atoms through which it passes, either by direct collision with the electron or by passing close enough to it to cause its ejection by coulombic attraction[15].

The ion pairs formed consist of the positively charged atoms and the negatively charged ejected electrons. The alpha particle continues along its path suffering, for the most part, negligible deflection by these collisions or coulombic interactions because of the large difference in mass between the alpha particle and the electron. Thus an alpha particle travels through matter producing thousands of ion pairs in such a fashion until its kinetic energy has been completely dissipated within the substance it traverses. [15].

The thousands of interactions between a traveling alpha particle and atomic electrons can be abstractly compared with a traveling bowling ball colliding with stationary ping-pong balls. Because of the large mass difference of the two, it will take thousands of ping-pong balls to stop a bowling ball. The additional stopping force of electrons is the binding energy of the atomic electrons.[15] In addition to ionization, another principle mechanism by which alpha particles and charged particles, in general, may impart their energy in matter is via electron excitation. This occurs when the alpha particle fails to impart sufficient energy to an atomic electron to cause it to be ejected from the atom. Rather, the atoms or molecules of a given material may absorb a portion of the alpha-particle energy and become elevated to a higher energy state[15]. Depending on the absorbing material, the excited atoms or molecules of the material may immediately fall back to a lower energy state or ground state by dissipating the absorbed energy as photons of visible light. This process, referred to as fluorescence [15]. Because the atomic “radius” is so very much larger ($\approx 10^{-10}$ m) than the “radius” of the nucleus ($\approx 10^{-14}$ m), the interactions of alpha particles with matter via direct collision with an atomic nucleus are few and far between. In this case, though, the large mass of the nucleus causes deflection or ricocheting of the alpha particle via coulombic repulsion without generating any change within the atom[15].

Heavy charged particles exceed their mass electron mass by a large factor, thus transferring part of their energy to the material through the following processes:

A. Inelastic collisions with the electrons, resulting in excitation or ionization. This type of energy loss is designated ionization loss.
B. Elastic collisions with the nuclei, where part of the energy is transferred to the recoil atoms .The total kinetic energy of the colliding particles remains unchanged
C. Inelastic collisions with the nuclei, leading to the excitation of nuclear levels or to nuclear reactions [16].

Ionization and excitation processes are usually called collision loss process or collision process. The subsequent collision by the electromagnetic field associated with the charge of incoming particles and target materials results in the formation of the initial ionization.

Fast electrons resulting from ionization are called δ-rays. If they have sufficient energy they can excite and ionize the atoms,thus, a secondary ionization process will take place. However, the deposited energy per unit path inside the medium is usually lower than the energy lost by collisions, because the fastest δ – rays can be completely absorbed far from where they were generated or escape from the medium [17].

Scattering of alpha particles at angles below 90 degrees may occur by columbic repulsion between the nucleus and the particle passing near the nucleus. These perverted particles continue to move until sufficient energy is lost by forming ion pairs. These deflected particles continue traveling until sufficient energy is lost via the formation of ion pairs. Therefore the formation of ion pairs remains the main interaction between alpha particle and matter [15].

Using the laws of energy conservation and momentum, we can prove that the energy that can be transmitted by non-relative particle with mass M to an electron with mass m_e

equal to $4m_eE/M$, where E is the kinetic energy of particle. Using the same laws, it is possible to prove that the largest possible angle between the particle motion direction after the reaction and its direction before the reaction is equal m_e/M, since the mass of alpha is greater than the mass of the electron . This means that the decrease of energy of a heavy charged particle due to a single excitation or ionization event is much smaller than the total kinetic energy of the particle and the incident particle practically does not change its direction of motion when it interacts with an atom. The change of the direction of particle motion is called scattering [14].

The paths taken by heavy charged particles in their slowing down process are schematically. Only at the very end, the paths tend to be quite straight because the particles do not deviate greatly by any one encounter, and interactions occur in all directions simultaneously. Charged particles are therefore characterized by a definite range in a given absorber material. The products of these encounters in the absorber are either excited atoms or ion pairs. Ionic pairs have a natural tendency to recombine to form neutral atoms [13].

(1.7)Biological effects of ionizing radiation

Ionization is essential to understand how radiation can cause changes and damage in materials that interact with them and how radiation can be detected. Ionizing radiation differs from other types of radiation in that it adds enough energy to atoms to remove electrons from their orbits and leave charged atoms or ions. At the molecular level ionization leads to :-

- Broken bonds
- Disrupting natural biochemical processes
- The formation of highly reactive free radicals **[**18**].**

When radiation interacts with a cell, ionizations and excitations are produced in either biological macromolecules or in the medium in which the cellular organelles are suspended, predominantly water. Based on the site of interaction, the radiation-cellular interactions may be termed as either direct or indirect.

(1.7.1)Direct action: It occurs when the ionizing particle reacts with and absorbed macromolecules in a cell (DNA, RNA, protein, enzymes, etc.). These molecules become abnormal structures that begin events which lead to biological changes.

(1.7.2)Indirect action: Is the absorption of ionizing radiation in the medium where the molecules are suspended **.**

The molecule that mediates most of this work is water. Through a number of complex interactions water molecules will ionize and form free radicals .The most important target of radiation in the cell is DNA in the nucleus

- Biological effects appear for the following reasons:-

❖ Damage to DNA is not repaired

❖ Damage to the DNA is repaired incorrectly

❖ Extensive damage to DNA can lead to cell death. The death of large numbers of cells can lead to organ failure and individual death

❖ Damaged or incorrectly repaired DNA can develop into cancer of lymph nodes and cancers in somatic cells [19].

(1.8)Ionization in tissue

When the charged particle ionizes or excites an atom, it losses energy until no longer has enough energy to interact; the final result of these energy losses is a minute rise in the temperature of the material of which the atom is a part. In this way all energy stored in biological tissues is dissipated by ionizing radiation by increasing the vibrations of the atomic and molecular structure. This is the initial ionization and chemical changes that cause harmful biological effects. [15]. The cell consists of 80% water and 20% complex biological compounds. When ionizing radiation passes through the cellular tissues it will produce water molecules. This leads to the formation of free radicals such as free hydroxyl radicals (OH) which are composed of oxygen and hydrogen atoms. Free radicals are a highly chemically reaction that can alter important molecules in the cell [15].

(1.9) Alpha particles therapy

There are more than 100 alpha emitting radioisotopes, but most decay is very fast to be useful for treatment of target radionuclides. Alpha particles have short range and high linear transfer energy (LET). The biological effect of alpha particles is 3-7 times greater than that of x-rays [20, 21]. The very high energy deposition of α-particles causing the production of $2000 - 7000\, ion\, pairs\, /\mu m$ at a very small distance can cause irreversible DNA double strand breaks, while beta particles produce less than $20\, ionic\, pairs/\mu m$ cause only single-strand DNA breaks. Cells are best equipped to repair single-strand DNA breaks than double-strand DNA breaks [22, 23]. High energy leads to radioactive decay of water inside cells, resulting in highly toxic chemical roots and chemicals that destroy the cell. Because of the high energy of the alpha complex and its very short range, the target cells will absorb high doses while nearby healthy cells may receive little radiation or may not receive any radiation. Therefore, the method of measurement of traditional internal medical dosages may not be appropriate for this preparation, and microdosimetric methods have been devised [24].

(1.10)Mass stopping power

- The mass stopping power of a material is obtained by dividing the stopping power by the density (ρ).
- Unit for mass stopping power ($-dE/\rho dx$) is $\mathrm{Mev.\,cm^2\,g^{-1}}$.
- The mass stopping power is a useful quantity because it expresses the rate of energy loss of charged particle $\mathrm{g/cm^2}$ of the medium traversed.
- In a gas, for example, $(-dE/dx)$ depends on pressure, but $(-dE\,/\rho dx)$ does not, because dividing by the density exactly compensates for the pressure.
- Mass stopping power is not very different in materials with similar atomic composition.

- Heavy atoms are less efficient on the basis of g/cm^2 to slow the movement of heavy charged particles, because their electrons are strongly bound in the internal shells to participate effectively in the energy absorption process [25].

- The mass stopping power is the loss of energy per unit path length in g/cm^2. As a result, the materials that possess a low atomic number (Z) have a greater mass stopping power than the high (Z) materials because high (Z) materials scatter the proton at a larger angle without much energy loss so that those materials are used to spread out the beam [26].

(1.11)Energy loss mechanisms

- The energy is transferred from the radioactive particles to the electrons of the absorption medium.
- If the radiation energy is transferred quickly to the material in a short distance, the number of electrical excitations and ionization of the reacting atoms is very high and this leads to more damage to the interacting matter.
- At any given time the particle is interacting with many electrons, so the net electric charge decreases its velocity continuously until the particle is stopped [27].
- A moving α particle penetrates matter , the main interaction is the collision between alpha particles and orbital electrons
- The collision of alpha particles with the nucleus is very rare because of the very small nucleus size [28, 29].
- The energy transferred by alpha particle to an orbital electron is only a small fraction because the mass of the electron is very small compared to alpha particle mass.
- The amount of energy transmission from the alpha particle to the electron is the maximum when the collision is ahead on with an electron [30].

(1.12) Linear energy transfer

LET refers to the number of ionization caused by this radiation per unit of distance traveled. The linear energy transfer of beta particles is far less than linear energy transfer of alpha particles [20]. The LET of charged particle in a medium is defined as the average amount of energy locally imparted to the absorbing material by a charged particle of specified energy in traversing a suitably small (ideally infinitesimal) distance within the absorbing material .It is defined as an average value because the amount of energy imparted by a charged particle to an absorbing material, even over a very small distance may change especially near the end of its path, and also because secondary particle produced by indirectly ionizing radiation such as photons or neutrons are not all of the same energy [31]. LET is a term used extensively when the effect of ionizing radiation on biological material is being considered and its exact meaning and value is thoroughly discussed in the radiation biology literature. Since heavy charged particles lose all their energy in a relatively short path length, they are known as high-LET particle. Light charged particles; like electrons experience many changes in path direction and lose their energy over a relatively long distance (the ionization produced is dispersed over a longer path or track length). Hence, these particles are known as low-LET particles. As for indirectly ionizing particles, photons interacting with matter generally produce light charged particles and so are Low-LET particles, whereas neutrons usually produce heavy charged particles and fission fragment and so are high-LET particles [31].

(1.12.1) The importance of linear energy transmission (LET)

1- The LET and calculated values of linear energy transfer for different types of radiation and energies can help us to interpret and predict the effects of ionizing radiation on the material.
2- Linear energy transfer helps us predict the penetration force and the degree of energy dissipation in the absorbed body. This information is important in the study of radiation chemistry, radiation therapy and dosimetry
3- The linear energy transfer values vary according to the types of radiation x-rays, gamma rays, and electrons possess low LET .Higher LET is more destructive to biological material than low LET radiation at the same dose. The radiation used in nuclear medicine is typically low LET radiation[31].

(1.13) Range of alpha particles in matter

Particles charged as they pass through the material ionize and thus lose energy in many steps until their energy reaches almost zero. Because Coulomb's force has an infinite range the particle interacts simultaneously with many electrons and thus loses its energy gradually but continuously along its path. After the departure of a certain distance is then losing all its energy. This distance is called alpha particle range. Thus, the range of the alpha particle is the average distance traveled before the alpha particle loses all its original kinetic energy [32]. The range of charged particle is computed by numerical integration of the stopping power. It is difficult to visualize the alpha-particle distance of the travel values of the range when expressed in units of mass thickness. However, the shortest path length of the alpha particle occurs when (The largest charge on the nucleus absorbs, The atomic weight gain of absorption Increasing the absorption density) [15].

(1.13.1) Factor which affect range:

The energy of alpha particle the higher the alpha particles energy , the stronger their penetration through a given substance because the more Colombian interactions between the particles of alpha and absorption electrons will be required to dissipate energy before coming to rest [15].

(1.14) The Bragg curve

A region of large energy transfers from charge particle. It is the region where a high dose is deposited at the end of the particle range in the tissue [33].

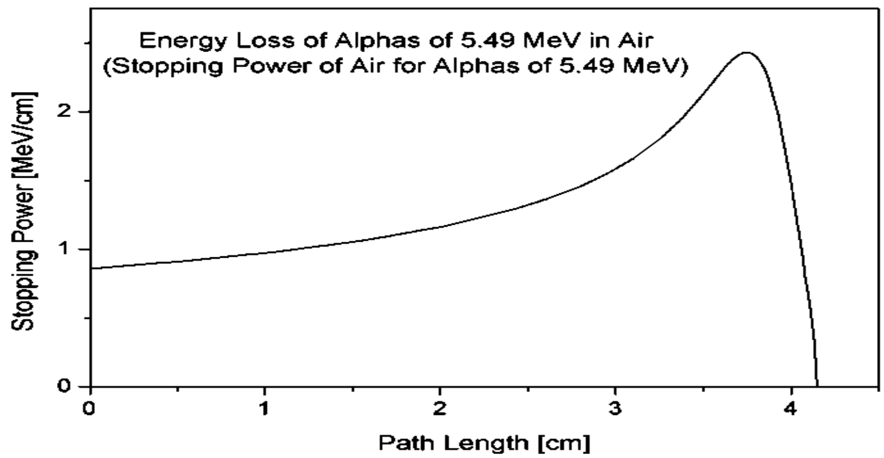


Fig.(1-2) Bragg Curve for 5.49 MeV Alpha Particles in air at STP [34]

Fig.(1-2) shows how the stopping power for a 5.49 MeV α particle in air steadily increases as the particle energy is reduced, reaches a maximum and drops rapidly once the particle has been neutralized. This type of figure is known as a Bragg curve [34]. Heavy charged ions such as alpha particles, however, deposit energy very differently along their tracks for a much shorter range. Alpha particles slow down due to energy loss, resulting in increased interaction with more materials, resulting in higher end-tracks known as Bragg peaks. So the location of the Bragg peaks is linked to the primary energy of alpha particles [35].

In radiotherapy with heavy ionic radiation, Bragg peaks must be formed sharply to deposit most of the energy in the tumor mass .Because LET is relatively less before the Bragg peaks and then drops to zero after that, this physical characteristic of the heavy ion particles provides a much better therapeutic ratio between the tumors and the natural tissues of the photons that do not appear in the Bragg peaks [35].

- In modern-day ion beam therapy:

  - A very high LET peak is achieved as the particle approaches the end of its path (The Bragg peak), thus increasing the delivery of biologically active radiation to deep tumors.

  - The relative decrease LET avoids surrounding tissue from heavy ionic radiation [8].

  - The phenomenon(Bragg Beak) is exploited in particle therapy of cancer, to concentrate the effect of light ion beams on the tumor being treated while minimizing the effect on the surrounding healthy tissue [36]

(1.15) Penetrate the alpha particles of matter

One of the most important characteristics of ionizing radiation is its ability to penetrate the material .The ability of penetration depends on the following:-

1- Radiation energy: The depth of penetration of radiation increases as its energy increases.
2- Type of radiation : The depth of penetration varies from one type of radiation to another for the same amount of energy ,as shown in fig.(1-3)
3- The mass of the particle and its charge: With charged particles such as alpha and beta particles the depth of penetration also depends on the mass of the particle and its charge. For equal energies, a beta particle will penetrate to a much greater depth than an alpha particle.

Alpha particles are not dangerous unless taken in the body through breathing, eating or through skin wounds because alpha particles scarcely penetrate the dead outer layer of human skin. Beta particles are dangerous to surface tissues but not to internal organs unless they are taken in the body too because they penetrate a centimeter of tissues. The radiation of Gamma and neutrons : degree of penetration depends on the nature of their interactions with the tissues and are dangerous both outside and inside as they pass through the body [15].

At nuclear energies, the momentum of the particles is of the order of $Pc \approx 1$ MeV, and particles will, on average, scatter over a very large angle in one radiation length. After one radiation length the information about the original direction is essentially lost. However, alpha particles or protons of a few MeV have a range that is only a very small fraction of the radiation length. Hence, they will stop before they have scattered over a large angle. Electrons, on the other hand, can penetrate to a significant depth in the material, and electrons will therefore be strongly affected by multiple scattering. Figure shows typical trajectories for an electron, a proton and an alpha particle of 10 MeV in silicon. The path of an electron in matter can be several centimetres, but the distance travelled according to a straight line is usually much shorter than the actual length of the trajectory. Electrons do not have a well-defined range [37].

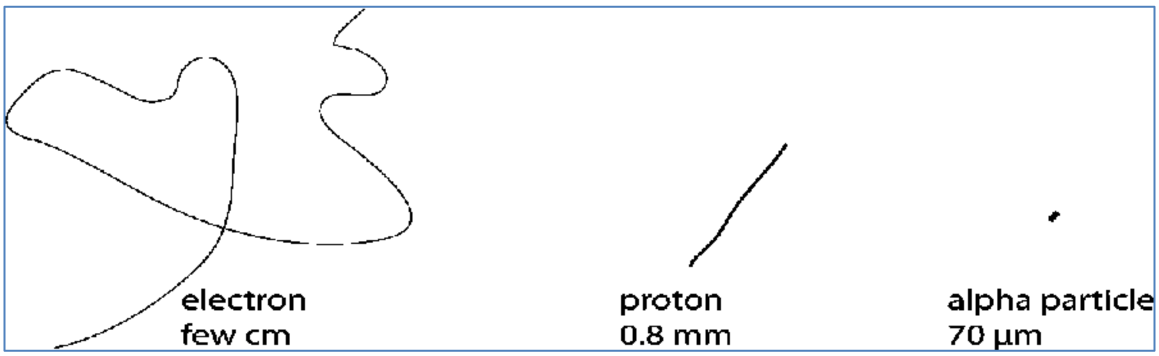


Fig.(1-3) A typical trajectory for an electron, a proton and an alpha particle of 10 MeV in silicon. The electron trajectory is drawn on a scale 10 times smaller than the trajectory of the proton and the alpha particle [37]

(1.16)The Bethe-Bloch equation

The stopping of high velocity light ions in matter, the two main simplifications are usually assumed in the theoretical stopping:

1. The ion moves much faster than target electrons and is completely stripped of its electrons
2. The ion is much heavier than the target electrons

Considerations of partial ion neutralization at lower velocities determine the minimum energy, while the maximum energy is restricted by the absence of empirical data

An extensive review of the early concepts of Bohr , Bethe and Block, with significant additions using quantum-mechanical perturbation treatments [38]. The Bohr's model did not take into account the separate energy of the target electrons. A few years later Bohr noted that the binding effects are very important during the deceleration process. Distant collisions are treated as free-electron scattering by the projectile ion. However, interactions at small distances such as electromagnetic excitation were considered to be evidence of harmonic oscillation, and could not be described by classical mechanics. Hans Bethe treated the process of energy loss by quantum mechanics by using the first Borne approximation [39]. The momentum was used instead of the coefficient of influence to characterize collisions. Beth Block's expression of the power of stopping for charged particle derived using relative quantum mechanics is given by[25]:-

$$-\frac{dE}{dx} = \frac{4\pi n Z^2 {K_0}^2 e^4}{m_0 v^2}\left[\ln\frac{2m_0 v^2}{I} - \ln\left(1-\frac{v^2}{C^2}\right) - \frac{v^2}{C^2}\right] \ldots\ldots.(1\text{-}1)$$

Where

Ze= charge of incoming particle

n= The number of electrons per unit volume in the material

m_0= rest mass of electron

v = the speed of the particle

e= electron charge

K_0= 1/4πεo

I= mean excitation energy of the target and it is usually dealt with as an experiment.

The formula shows dependence of dE/dx on the speed of the particle but in $\left(\frac{2m_0 v^2}{I}\right)$ gives almost no difference or little difference on v For α - particles having an energy < 10MeV, the velocity (v) is less than 2.3% of the speed of light. Consequently, the $\frac{v^2}{C^2}$ term in the above equation are negligible, and can be ignored. The Bohr formula for heavy particle is given by [25]:-

$$-\frac{dE}{dx} = \frac{4\pi n Z^2 {K_0}^2 e^4}{m_0 v^2}\left[\ln\frac{2m_0 v^2}{I}\right] \ldots\ldots.(1\text{-}2)$$

• Only the charge Ze and speed *v* of the heavy charged particle enter the expression for stopping power.

• For the medium, only the electron density n is important [40].

The following are the main reasons why Bethe-Block formula of interaction of charged particles with matter does not apply to electrons.

1. The derivation of the above formula assumes that the incident particle is practically undeflected. But the incident particle acquires a transverse component of momentum per collision approximately equal to that given to the absorbing electron. If the incident particle is itself an electron the transverse velocity corresponding to the momentum will not be negligible as assumed in the case of aheavy incident particle. Thus if the incident particle is an electron it will be deflected through much larger angles and its path will be very irregular and not at all straight as is the path of the heavy charged particle.
2. Electrons have a continuous distribution of initial energy whereas heavy charged particles are mono-energetice.
3. Collision between identical particles involves an energy exchange phenomenon which has to be taken into account for electron-electron collisios.
4. Electrons of energy very much less than 1MeV lose energy mostly by excitation or ionization of the atom of the material through which they pass. The change on the electron never changes nd the electron loses energy by ionization even at very low energies unlike the heavy positively charged particles which lose their charge by recombination at lower energies.
5. Bremsstrahlung: Electrons with energies very much greater than 1MeV radiate considerable fraction of their energy in the form of X-rays due to their inelastic collisions with coulomb field of atomic nuclei and also with electrons [41].

(1.17)Ziegler equation

Relative quantum mechanics allows a completely different approach to analyze the transmission of energy from a particle to the material. The results of using different theoretical procedures are sometimes difficult to compare. All attempts to set up scales for the high-energy ions stopping powers require normalization of the theory into experimental data to obtain accurate values [38] .Ziegler has calculated_^{4}H_implantation range and distributions into materials using the formalism of Lindhard, Scharff, and Schiott, widely called the LSS theory, using different electronic and nuclear stopping powers from those which they proposed ,which will be mentioned in chapter two [42].

(1.18)SRIM program

SRIM (stopping and range of ions in matter) is a group of programs, which calculates the range and stopping of ions (up to 2 GeV/u) into matter using a quantum mechanical treatment of ion-atom collisions [27]. SRIM is a software package concerning the stopping and range of ions in matter [28]. A recent SRIM – describes in detail the fundamental physics of the software. Until this time, corrections have been made based on new experimental data. Major changes occur in SRIM about every six years. The last major changes were in 1995 and 1998 and 2003. In 1995 a complete overhaul was made of the stopping of relativistic light ions with energies above 1 MeV/u. In 1998, special attention was made to the Barkas effect and the theoretical stopping of Li ions. In 2010, significant changes were made to correct the stopping of ions in compounds [43].

(1.18.1) Typical SRIM applications include:

1- **Ion stopping and range in targets**:

- Calculation of most aspects of the loss of energy from the ions in the material , in SRIM program, the stopping power and the range of the ions in the material.
- The program includes fast calculations that produce tables of stopping powers, range and straggling distributions for any ion at any energy in any elemental target. More elaborate calculations include targets with complex multi-layer configurations.

2- **Ion implantation**: Ion packages are used for the purpose of modifying samples by injecting atoms to change the chemical and electronic properties of the target. The ionic beam causes the displacement of the atom and thus damage to the solid targets.

3- **Sputtering:** Is knock out target atoms, by ion beam. The SRIM package includes a sputtering account for any ion at any energy.

4- **Ion transmission**: Ion beams can be followed through mixed gas/solid target layers, as occur in ionization chambers or in energy degrader blocks used to reduce ion beam energies.

5- Ion beam therapy: Ion beam are used in medical treatment [28]**.**

- SRIM uses several different stop theories to evaluate the accuracy of experimental stopping powers. Specifically, calculations of all ions are performed in individual target which eliminates common difficulties with target dependent amounts such as shell corrections and mean ionization potentials.
- Calculations are also made of a single heavy ion in all solids which eliminates some difficulties with ion-approved quantities such as ion stripping.
- Calculations are made from fundamental theories like the Brandt-Kitagawa theory and LSS theory [44].
- If experimental values are reasonably consistent with these theoretical calculations, experimental values are weighted by theoretical values to obtain final values
- Sometimes large errors and deviation in experimental stop values occur from theoretical values that are completely ignored[44].

(1.19) ASTAR program

- ESTAR, PSTAR and ASTAR: are three computer programs that calculate the stopping and range for electrons, protons and helium ions.
- ESTAR is Applying to any element, compound or mixture.
- PSTAR and ASTAR are Applying to 74 materials, including many of interest in biomedical dosimetry.

The original versions of PSTAR and ASTAR are based on calculations with a fixed set of mean excitation energies [45].

(1.20)Bragg's rule

The stopping power of the compound can be calculated by the linear combination of the stopping powers of the individual elements. This law is used to find the stopping power for multi-element targets [46].

Bragg and Kleeman, in 1903:

- Studied experimentally how stopping power depends on the atomic weight of the target
- Calculated the contribution of stopping hydrogen and carbon atoms in target hydrocarbons by assuming a linear addition based on the chemical composition of H and C atoms in the targets.
- The measurement of the stopping of ions in the compounds usually deviates less than 20% of those predicted by Bragg's rule [43].

(1.21)Chemical compositions

The chemical composition of human tissues is important in the study of micro-distributions in irradiated humans. The initial reactions of photons are almost independent of the chemical composition at high energies (the Compton region), but the secondary reactions responsible for the biological effects depend on the chemical composition. The chemical composition of human tissues is usually given in terms of biological molecules (lipid, protein, vitamins, etc.). Human tissue represents through atomic structures (weight of elements %). Mean atomic compositions of various biological molecules are readily available; the average atomic compositions of human tissues can be calculated from these data.

The chemical composition of human tissues generally depends on(Strain, diet, age, sex, health, etc.) .It may vary significantly among individuals of human beings [29].

(1.22) Types of tissues

(1.22.1) Muscle tissue: Muscle tissue is soft tissue and leads to the ability of muscles to contract. It is formed during embryonic development through a process known as muscle formation. There are three types of muscle tissue: skeletal, cardiac and smooth muscle [47], In the lean somatic muscle they supposed 75% water, 20% protein, and other elements are (H_2, C, N_2 , O_2, Na, P, CL, K, and S) [29]

(1.22.2) Lung tissue: The lungs are located in the chest on both sides of the heart in the rib cage. They are conical with a narrow round top at the top, and a large concave base that lies on the convex surface of the diaphragm [48]. The two main biological components of lung are water 79% ,and protein; in addition ,Lung contains lipid 3%,and traces of other elements are (H_2, C, N_2 , O_2, Na, P, CL, K, and S) [49].

(1.22.3) Breast tissue : Breast is a binary device in which females undergo dramatic changes in size, shape, and function in conjunction with the baby's growth, puberty, pregnancy, lactation, and postmenopausal regression [50,51] located on the upper abdominal region of the trunk of the primates. In females, it acts as a mammary gland, which produces and secrete milk and nourishes infants [52] . The chemical compositions of the breast tissue are (H_2, C, N_2 , O_2, Na, P, CL, and S) [49].

(1.22.4) Ovary tissue : The ovaries act as the gonads as well as the endocrine glands, the primary physiological source of sexual stimulants. ovary follicles are the basic units of ovaries and each produces a single egg (germ cell), steroids, and protein hormones to regulate reproductive cycles in females [53] .The ovary is located in the side wall of the basin in an area called the ovarian fossa [54]. The composition of ovary is for a non-pregnant woman, and it was taken to be 78.5% water, 6% protein, 0.16 % cholesterol, 0.03% ascorbic acid, and 0.012% inositol [29].

(1.23)Types of materials

(1.23.1) Silicon dioxide, SiO_2

Silicon dioxide, SiO2, is the main component of rock formation metals in metamorphic rocks. It is also an important element of sediments and soils. It also forms a 75% silicate by weight of the earth's crust. Free silica occurs mostly as quartz, which forms 12-14% by weight of the lithosphere. Depending on the temperature, pressure and composition of precursor phases, etc., many different crystal modifications are formed. In the industry, quartz sand and silica rocks are widely used as raw material to produce glass, ceramics and silicon. Single crystals of quartz are artificially grown for application as resonant crystals in clocks, communication technology, and computer electronics. Both natural and synthetic silica powders are used as fillers to improve the mechanical properties of plastics [55].Silicon dioxide was one of the most extensively studied materials in materials science and condensed matter physics. The main engine of this intense effort is its crucial role in the semiconductor oxide metal field effect transistor (MOSET), which dominates the contemporary integrated circuit technology (IC). Non-amorphous SiO2 is also a material of choice, for example, optical fibers and solar cells, making their role in modern technology more important [56].

(1.23.2) Aluminum dioxide AL_2O_3

Also known as Alumina is the widely used oxide ceramic material. Its applications include : spark plugs, tap washers, pump seals, electronic substrates, grinding media, abrasion resistant tiles, cutting tools, bio ceramics, (hip-joints), body arm our, laboratory ware and wear parts for the textile and paper industries. It is also used mixed with other materials such as flake graphite where even more severe applications are envisaged, such as pouring spouts and sliding gate valves[57].

(1.23.3) Zirconium dioxide (ZrO_2)

Synonyms: Zirconia, zircon, zirconium dioxide, zirconium oxide. Physical properties: White amorphous powder, insoluble in water, slightly soluble in acid. Vapor pressure at 20 °C ,melting point is 2710 °C [58].

Applications In ceramics for making ceramic pigments, porcelain glaze, etc, making artificial jewelry, making abrasive, insulating and fire-retarding materials,and the powder exhibits optical properties, hence used for optical storage, light shutters and stereo television glasses [59].

(1.24) Previous studies

1- Altshuler, B.; Nelson, N.and Kuschner, M., (1964) calculated the effective dose for Lung tissue .They estimated the cancer-related dose, taken as the largest dose to exceptionally shallow basal cells, associated with one working level of radon daughters is estimated to be 20 rads/yr for nose breathing at 15 l./min, and it may be higher [60].

2- E. Rotondi , (1968) reported that the measurement of the stopping power of alpha particles for CO_2, O_2, N_2, and CH_4 over an energy range from 0.1 to 5.3 MeV. He measured stopping cross sections of alpha particles in tissue ($H,$ 10.1%; $C,$ 12.1%; $N,$ 4.0%; $O,$ 73.6 % by weight), and concluded that stopping power at energies less than 1MeV are 50% greater than those calculated by Neufeld and Snyder [61].

3- Walsh, P. J. and Pendergrass, F., (1972), measured the energy loss of alpha particles in tissue-equivalent plastics(TEP) over an alpha energy range of 1-5.476 MeV. The results were compared with previous calculations of energy loss of alpha molecules in the tissue gas equivalent. His technique was used in the preparation of thin films of TEP and the method used to determine the stopping power in the TEP are outlined [62].

4- A. K. CHAUBEY and H. V. GUPTA,(1977) introduced some new empirical relations for stopping powers of protons and alpha particles in the energy range 0.7 to 12 MeV/amu. They obtained the range formulas by integrating the stopping power formulas of protons and alpha particles. They used these relations to calculate stopping powers and ranges in semiconductor detectors, they also discussed practical applications of the these empirical relations [63].

5- J.C. Oberlin , et.al ,(1982) , reported that the determination of the stopping power cross section and straggling of protons and helium ions in erbium films evaporated in vacuum using the backscattering technique in the energy range 0.2 to 2.0 MeV for protons, and 0.3 to 3.1 MeV for helium ions. Experimental data for stopping power were fitted by means of Brice's formula, were in agreement with Ziegler's semi-empirical measurements. They estimated the accuracy of the calculations at ± 3%. The energy straggling results for protons in erbium are in agreement with the predictions of Bethe and Livingston. They explained that the defference of the experimental results with the theoretical of helium ions is due to the thickness differencein the target [64].

6- L.E. Porter ,(1995), extracted the parameter values from the modified Bethe - Bloch theory by analyzing the previous calculations of the stopping powers of alpha particles of AL_2O_3 and SiO_2 for $(0.2-2\,)MeV$ and 5.48 MeV. Two-parameter fits were conducted for values of mean excitation energy and one of two available Barkas-effect parameters. Resulting mean excitation energies lay below additivity-based predictions, whereas Barkas-effect parameters essentially coincided with values prescribed by the formalism [65].

7- K.N. Yu , et.al, (2003), reported the comparison of the energy loss of alpha particles in the air obtained from the experiments, the stopping powers given in the (ICRU) and stopping powers and range of ions in the material-2000(SRIM-2000). Also they determined the experimental alpha particles energy losses for each of the ^{241}Am and ^{230}Th sources by using the spectral analysis method of alpha particles, they noted that these losses deviated far from those calculated. The deviations indicated that the SRIM-2000 stopping powers may be too great and ICRU may be greater [66].

8- Hasan Gumus, (2003) reported the calculation of the ranges of heavy ions in amorphous silicon dioxide by using a technique based on solution of first-order ODE's. Br, Au, Hg, Bi representing fallen ions. He used Bragg's rule to calculate electronic and nuclear stopping powers in the compound. He performed numerical solutions by using Fehlberg fourth-fifth order Runge−Kutta method. He compared the results with experimental data, as well as with the result of the Monte Carlo programs SRIM and other standard procedures such as projected range algorithm (PRAL). He found that the agreement between his method and the experiment is good and within 10% [67].

9- Onder Kabadayi, (2004) calculated the stopping power of proton and alpha particle in NaI by using the theoretical treatment of Montenegro et. al. ,and calculated the range by using a technique that he developed in his the earlier works ,and compared the results with Monte Carlo simulation program SRIM2003 and PRAL [45].

10- Elsevier BV,(2005), determined the stopping powers for ^{4}He, ^{12}C, ^{16}O, ^{27}AL and ^{28}Si ions in alumina (AL_2O_3) experimentally over an energy range from $(40\text{–}1250)keV/nucleon$. He extracted the continuous stopping curves from sets of backscattering spectra by two independent analysis methods based on Simulated Annealing and Bayesian inference techniques. .He found that Bayesian analysis to be very adequate for providing systematic estimations of the confidence level for the results [68].

11- Santiago Heredia-Avalos , et.al,(2005) : reported that calculation of the electronic stopping power and the straggling energy loss parameter of swift, He, Li, B and N ions moving through several oxides, namely SiO_2, AL_2,O_2 and ZrO_2. The evaluation of these stopping magnitudes was done in the framework of the dielectric formalism. They described target properties by means of a combination of Mermin-type energy-loss functions that characterize the response of valence-band electrons, together with generalized oscillator strengths to take into account the ionization of inner-shell electrons. They considered that the difference in the state of the charge is due to electron loss and electrons capture processes during its movement in the target. They described the electron density for each charge state by using the Brandt-Kitagawa statistical model and, for He and Li ions [69].

12- HelmutPaul,(2006) compared the stopping table from (ICRU Report 73), Ziegler's SRIM 2003 table and MSTAR table with experimental data from his large data base, for ions from 3Li to 18Ar. He compared the three tables at the same targets at the same energy (0.025–1000 MeV/nucleon), corresponding to the range of the ICRU-73 table. He found that the method of MSTAR and SRIM were similar in the description of experimental data with deviation between 6% and 8% ,where he described the agreement by the mean normalized difference Δ and by its standard deviation σ. For solid compounds, the agreement is similar as for solid elements [70].

13- M. Behar , et.al. , (2010) , studied the results of an experimental-theoretical on the stopping power of zirconium dioxide films for swift hydrogen and helium ion beams. They done experiments, using the Rutherford Backscattering technique, for protons with incident energies in the range 200–1500 keV and for alpha particles with energies in the range 160–3000 keV. While the theoretical measurements were done using the MELF-

GOS model to account for the zirconium dioxide target electronic response. They noted that the agreement between theory and experiment is quite remarkable [71].

14- Hong Song , et,al.,(2012) reviewed the radiobiology of high-LET radiation learned from beam-ion studies and determined the features that also apply to the development of alpha-labeled antibody-labeled antibodies. And he discussed the molecular mechanisms behind the double-stranded DNA strand repair response to the high-lite radiation [8].

15- Levent AKSU ,(2014) estimated radiation dose. He used a program CARI-6 which executed new program in Excel on the computer to calculate cosmic radiation dose [72].

16- SunilKumar,(2015) reported that measurement of Energy loss and straggling in Ag and Sn metallic foils for α-particles, using 241Amare source, he compared his results with the predicted values based on Benton and Henke, Grande and Schiwietz (CasP), Ziegler et al. (SRIM) formulations and ICRU-49 report (ASTAR). He compared between measured straggling values of α-particles with the computed values adopting practically used four collisional (Bohr, Lindhard and Scharff, Bethe–Livingston, and Titeica) formulations and one collisional plus charge exchange (Yang et al.) straggling formulation [73].

17- Saman KE,(2016), calculated the stopping power and range of alpha particle in the elements involved in human bone structure with the energy interval $(0.1 - 4.5)\ MeV$ using SRIM Computer Programs [74].

18- M.O. El- Ghossain,(2017), studied interaction of Ions radiations and alpha particles with matter; he calculated the stopping power and range from the theory of Bethe-Bloch formula for water, bone, muscle and tissue at different energies of the ions. He used different programs; SRIM, STAR and Matlab,and fitting model to obtain total stopping power by summation the electronic collisional and radioactive stopping power of the targets, and then he used the continuous slowing down approximation (CSDA) to calculate the range of ion water. He concluded that the total stopping power is proportional to atomic number for target Z/A, and ionization potential , increases rapidly at low energies, reaches a maximum and decreases gradually with increasing energy [75].

19- P.K. Prajapati,(2017) reported that measurement of energy loss of alpha particle from radioactive source, estimated thickness of thin foil with help of known stopping power. He used SRIM to calculate stopping power. Different metallic thin foils (Al, Fe, Cu, Se, Ag, Sn, Pb and Bi) with Mylar backing and self-supported film were used for thickness determination by alpha particle spectroscopy and SRIM program [76].

(1.25) The aim of the present work

1. Study the interactions of alpha particles with different human tissues and different materials by calculating the stopping power and range of this particle
2. Determine the maximum value of the alpha particle energy that can lose as it travels through the tissues (breast, ovary, lung and muscle) and the materials (SiO_2, AL_2O_3, ZrO_2) .
3. Determine the maximum distance that alpha particle can pass through (breast, ovary, lung and muscle) tissues and materials (SiO_2, AL_2O_3, ZrO_2) before losing all their energy (range of alpha particle).
4. Determine the maximum thickness of the targets (breast, ovary, lung and muscle) tissues and materials (SiO_2, AL_2O_3, ZrO_2) can be alpha particle penetration.
5. Determines the maximum liner energy transfer for alpha particle that can loss along its path in (breast, ovary, lung and muscle) tissues, and materialsSiO_2, AL_2O_3, ZrO_2 .
6. Determination of maximum absorbed dose which corresponds to the maximum mass stopping power of alpha particle and maximum range of alpha particle can pass into the target and the maximum thickness of the target that the alpha particle can penetrate for (breast, ovary, lung and muscle) tissues and materials (SiO_2, AL_2O_3, ZrO_2).
7. Determination equivalent dose and effective dose for (breast, ovary, lung, muscle) tissues.
8. Provide the information for these quantities in order to achieve the best treatment and less harm to the patient.

Theory

(2.1) Mecanisms of charged particle loss energy

Charged particles interact mostly with electrons and loose energy through different mechanisms**:**

1- Ionization and excitation of atoms encountered along the path
2- Bremsstrahlung
3- Cherenkov Radiation
4- Transition Radiation In addition, charged particles undergo multiple scattering that produces a series of small deviations from the path that increases its effective length[77]**.**

(2.1.1) Energy Loss by Ionization and excitation of atoms encountered along the path

A charged particle in matter looses energy by ionization and excitation of the atoms along the path, transferring energy to the atomic electrons. The key parameter is the maximum amount of energy transferred in a single collision. The energy loss is different for heavy particles and electrons/positrons, due to their mass, that must be compared with the mass of target electrons. The energy loss per unit length of heavy charged particles, or stopping power, is described by the Bethe-Bloch equation[77].

During the interaction of the charged particle with the medium, there will be fluctuations in the energy loss, whose properties depend on the thickness of the absorber material. The Bethe-Bloch equatio describes only the average energy loss of particles. The distribution of the energy loss is a Gaussian with thick absorbers, due to the large number of collisions, but becomes asymmetrical in thin absorbers, where it is described by the Landau distribution[77]. The ionization energy loss of electrons is different from the ionization of heavy particles since the projectile and the target share the same mass and differs also from the energy loss of positrons. The maximum energy transfer from incident electrons to atomic electrons is half the kinetic energy**.** In addition to loosing energy by ionization, a charged particle traversing a medium undergoes multiple scattering events due to the Coulomb interaction with nuclei, according to the Rutherford scattering law. During its path, the charge will experience a large number of scatterings with small deviations from the original trajectory. The multiple Coulomb scattering is described by the Moliere theory [77].

(2.1.2)Bremsstrahlung

For the production of electron Bremsstrahlung two mechanisms of the electron–atom interaction are of importance:

• Ordinary Bremsstrahlung: Electron Bremsstrahlung as a result of photon emission of a charged particle decelerated in the field of a target electron or nucleus.

• Polarizational Bremsstrahlung (atomic Bremsstrahlung) as a result of the dynamical polarization of the atom by the incident particle (photon emission of the target electrons virtually excited by the projectile)[78].

(2.1.3)Cherenkov Radiation

When a charged particle travels inside a medium, it can drive the medium to emit coherent electromagnetic energy called Cerenkov radiation (CR)

(1). Extensively used in particle detectors and counters

(2) Cerenkov radiation in a conventional material possesses three key characteristics:

a. Cerenkov radiation occurs only when the particle’s velocity exceeds the medium’s phase velocity.
b. the energy propagates only in the forward direction.
c. there is a forward-pointing conical wavefront. [79] .

(2.1.4)Transition Radiation

Transition Radiation is emitted by charged particles when crossing the boundary between two media with different indices of refraction. There are various situations of experimental interest where transition Radiation may play a relevant role in detection, for instance Earth-skimming neutrinos inducing a shower inside the Earth’s crust that emerges from ground into air, or an ultrahigh-energy cosmic rays (UECR) developing a particle shower in the atmosphere and arriving at ground[80].

(2.2) Maximum energy transfer in a single collision

Investigators assume that the particle moves rapidly compared with the electron and that the energy transferred is large compared with the binding energy of the electron in the atom. Under these conditions the electron can be considered to be initially free and at rest, and the collision is elastic. They treat the problem classically and then give the relativistic results. Figure (2-1) (a) shows schematically a charged particle (mass M and velocity V) approaching an electron (mass m, at rest). After the collision, which for maximum energy transfer is head-on, the particles in (b) move with speeds V_1 and $v_1$along the initial line of travel of the incident particle. Since the total kinetic energy and momentum are conserved in the collision, we have the two relationships[81]:-

$$\frac{1}{2}MV^2 = \frac{1}{2}MV_1^2 + \frac{1}{2}mv_1^2 \;\ldots\ldots\ldots.(2-1)$$

$$MV = MV_1 + mv_1 \ldots\ldots\ldots\ldots.\ldots.(2-2)$$

If we solve Eq. (2-2) for v_1 and substitute the result into (2-1), we obtain

$$V_1 = \frac{(M-m)V}{M+m} \ldots\ldots\ldots\ldots.(2-3)$$

Using this expression for V_1,we find for the maximum energy transfer

$$Q_{max} = \frac{1}{2}MV^2 - \frac{1}{2}MV_1^2 = \frac{4mME}{(M+m)^2} \ldots\ldots\ldots\ldots \;(2-4)$$

Where $E = MV^2/2$ is the initial kinetic energy of the incident particle

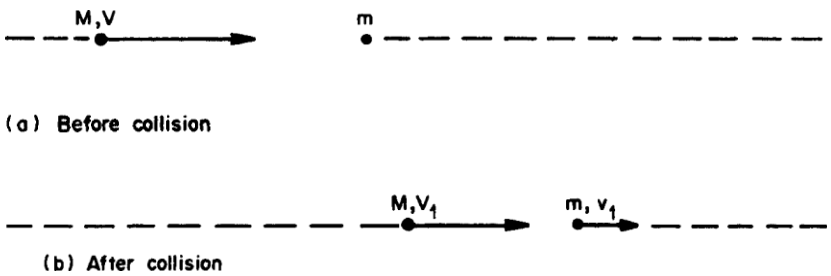


Fig.(2-1) Head-collision between the particle (M) and electron(m) [81]

When the incident particle is an electron or positron, the special circumstance arises in which its mass is the same as that of the struck particle: M = m. Equation (2-4) then implies that $Q_{\max} = E$, and so its entire energy can be transferred in a single, billiard-ball-type collision. Electrons and positrons can therefore experience relatively large losses in energy and deviations, contributing to the tortuous of winding paths in matter. The next largest particle of the electron is the muon, having a mass of M = 207m. The maximum fraction of energy that a muon can transfer in a single collision is, from Eq. (2-4) [81].

$$\frac{Q_{\max}}{E} = \frac{4m(207m)}{(208m)^2} \cong \frac{4}{208} = 0.0192 \ldots\ldots\ldots\ldots \quad (2-5)$$

Thus, the muon (and all heavy charged particles) travels essentially straight paths in matter, except for occasional large-angle deflections by atomic nuclei. The exact relativistic expression for the maximum energy transfer, with m and M denoting the rest masses of the electron and the heavy particle, is:-

$$Q_{\max} = \frac{2\gamma^2 mV^2}{1+\frac{2\gamma m}{M}+\frac{m^2}{M^2}} \ldots\ldots\ldots\ldots..(2-6)$$

Where $\gamma = 1/\sqrt{1-\beta^2}$,$\beta = \frac{V}{c}$, and c is the speed of light .Except at extreme relativistic energies, $\frac{\gamma m}{M} \ll 1$, in which cace (2-6) reduces to:-

$$Q_{\max} = 2\gamma^2 mV^2 = 2\gamma^2 mV^2\beta^2 \ldots\ldots..(2-7)$$

This is the usual relativistic result [81].

(2.3) Single-collision energy-loss spectra

Analysis Q_{max} can understand part of the physical basis of the different types of tracks seen for electrons and charged heavy particles in the material. More details on the penetration of charged particles are embodied in the spectra of single-energy losses of collisions to atomic electrons. These spectra include the effects of the bonding of electrons in atoms. [81].

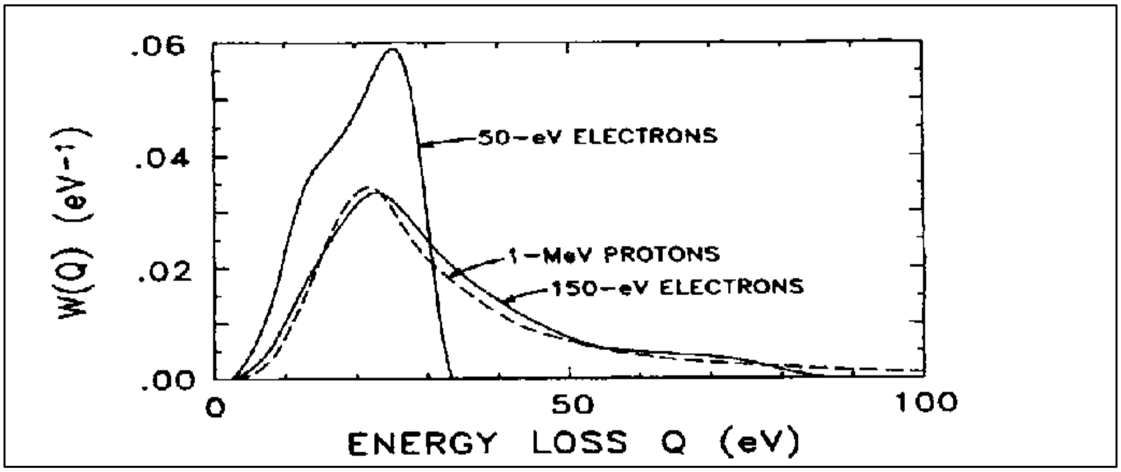


Fig.(2-2) Single-collision energy-loss spectra for 50-eV and 150-eV electrons and 1-MeV protons in liquid water. [81]

It is also seen in figure (2-2) that energy is not lost by particles charged with arbitrary small amounts. Connecting the electrons in separate energy states of the medium requires that the minimum or threshold, Q_{min}> 0, be transferred for excitation or ionization of an atom [81].

(2.4) Stopping power

When fast charged particles enter the material, they interact with the electrons and nuclei of the material and begin the process of loss of energy during penetration. Interactions can be seen as individual collisions between charged particles and atomic electrons surrounding the nucleus, which are considered separate. The energy emitted during these collisions leads to the ionization and production of pairs of ions and electrons and can also appear in the form of electromagnetic radiation and this process is called bremsstrahlung (braking radiation). Charged particles are called heavy if their rest mass is much larger than the rest mass of electrons. So, the mesons, protons, alpha particles, and fission fragments are all considered as heavy charged particles, while electrons and positrons are light charged particles [6, 82].

If the nuclear forces are ignored and the interactions generated by the Coulomb forces are taken into consideration, we will find four types of interactions of charged particles:-

(i) Inelastic collision with the atomic electrons of the target material: This collision is the main process of energy transfer, especially if the speed of particles is less the level where bremsstrahlung is significant, this leads to the excitation and ionization of the electrons. (Inelastic here refers to the excitation of electronic levels).

(ii) Inelastic collision with target material nuclei: This collision causes the nucleus to be excited state or the particle can radiate (bremsstrahlung)

(iii) Elastic collision with the atomic electrons of the target material. The process is elastic deviation which results in a small amount of energy transfer. It is significant only for charged particles that are low-energy electrons.

(iv) Elastic collision with target material nuclei: This process is known as Rutherford. This process is characterized by the following:

- Do not get excited to target nucleus
- Do not get a radiation emission
- Particles lose their energy only by recoil the target nucleus

In general, the first reaction, sometimes called collision reaction, is dominant to loss of energy, unless the charged particle has a kinetic energy exceeding its rest mass energy; in this case, the second reaction is the important in the loss of energy [6, 82].

(2.5) Stopping power: energy loss of charged particles in matter

The charged particle suffers from loss of energy per unit of distance, which is referred as$-dE/dx$ is conventionally known as the stopping power. This basic quantity is calculated using quantum and mechanical quantum theories. It is important to express $-dE/dx$ in terms of the properties specifying the incident charged particle, such as its velocity v and charge ze, and the properties pertaining to the atomic medium, the charge of the atomic nucleusZe, the density of atoms n , and the average ionization potentialI. R.D. Evan and W.E. Meyerhof consider only a crude, approximate derivationof the formula for$-dE/dx$. They begin with an estimate of the energy loss suffered by an incident charged particle when it interacts with a free and initially stationary electron. Referring to a collision cylinder whose radius is the impact parameter b and whose length is the small distance traveled dx shown in Fig. (2-3) [6, 82].

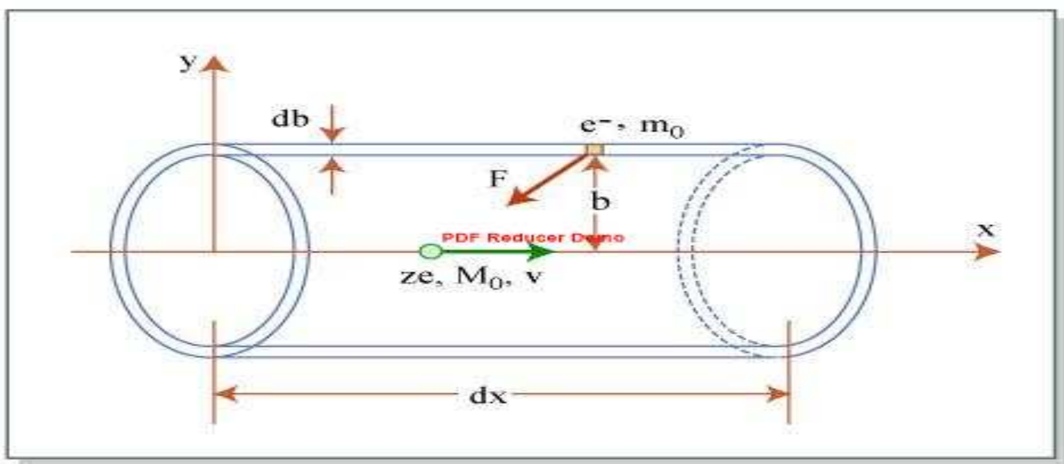


Fig.(2-3) Encounter between a heavy charged particle of mass M_0 and a free electron of mass m_0 . The impact parameter b is indicated [6, 82].

They see that the net momentum transferred to the electron as the particle moves from one end of the cylinder to the other end is essentially entirely directed in the perpendicular direction along the negative y-axis (as F_x changes sign, so the net momentum along the horizontal direction vanishes), so R.D. Evan and W.E. Meyerhof can write [6, 82].

$$\int F_x(t)\,dt \approx 0 \;\ldots\ldots\ldots\ldots\ldots..(2-8)$$

$$p_e = \int F_y(t)\,dt \ldots\ldots\ldots\ldots\ldots\; (2-9)$$

$$p_e = \frac{ze^2}{x^2+b^2}\frac{b}{(x^2+b^2)^{1/2}}\frac{dx}{v}$$

$$p_e \cong \frac{ze^2 b}{v}\int_{-\infty}^{\infty}\frac{dx}{(x^2+b^2)^{3/2}} = \frac{2ze^2}{vb}\ldots\ldots\ldots\ldots..(2-10)$$

The kinetic energy transferred to the electron is therefore:

$$Q = \frac{p_e^2}{2m_e} = \frac{2(ze^2)^2}{m_e b^2 v^2}\ldots\ldots\ldots\ldots\ldots\ldots\; (2-11)$$

Assume this is equal to the energy loss of the charged particle, then multiplying by $nZ(2\pi bdbdx)$, the number of electrons in the collision cylinder, they obtain

$$-\frac{dE}{dx} = \int_{b_{min}}^{b_{max}} nZ(2\pi bdb)\frac{2}{m_e}\left(\frac{ze^2}{vb}\right)^2 \;\ldots\ldots..(2-12)$$

$$-\frac{\boldsymbol{dE}}{\boldsymbol{dx}} = \frac{4\pi(ze^2)^2 nZ}{m_e v^2}\ln\left(\frac{b_{max}}{b_{min}}\right)\ldots\ldots\ldots\ldots\ldots..(2-13)$$

Where b_{max} and b_{min} are the maximum and minimum impact parameters [6, 92].

In reality the atomic electrons are of course not free electrons, so the charged particle must transfer at least an amount of energy equal to the first excited state of the atom. If they take the time interval of energy transfer to be $\Delta t \approx b/v$, then $(\Delta t)_{max} \approx b/v$, where $h\nu \approx \bar{I}$ is the mean ionization potential . Then [6, 82].

$$b_{max} \approx \frac{hv}{\bar{I}}\ldots\ldots\ldots\ldots.(2-14)$$

An empirical expression for $\bar{I}$ is $\bar{I} \approx$ kZ , with $k \sim 19$ eV for H and ~ 10 eV for Pb. Next they estimate b_{min} by using the uncertainty principle to say that the electron position cannot be specified more precisely than its deBroglie wavelength (in the relative coordinate system of the electron and the charged particle). Since electron momentum in the relative coordinate system is $m_e v$, they have:

$$b_{min} \approx \frac{h}{m_e v} \dots\dots\dots. (2-15)$$

Combining these two terms they obtain

$$-dE/dx = \frac{4\pi z^2 e^4 nZ}{m_e v^2} \ln(\frac{2m_e v^2}{\bar{I}}) \dots\dots\dots\dots \ (2-16)$$

Eq. (2-16) describes the energy loss due to particle collisions in the non- relativistic regime. One can include relativistic effects by replacing the logarithm by

$$\ln(\frac{2m_e v^2}{I}) - ln\left[1-\frac{v^2}{c^2}\right] - \frac{v^2}{c^2} \dots\dots\dots\dots\dots..(2-17)$$

Eq. (2-17) is a relatively simple expression, yet one can gain much insight into the factors that govern the energy loss of a charged particle by collisions with the atomic electrons. In a collision with a nucleus the stopping power would increase by a factor equals to atomic number Z [6, 82]. Empirically, collision energy loss is measured by the number of ion pairs formed along the path of the charged particle path. Suppose that heavy charged particles lose the average amount of energy W in producing a pair of ion, electron and ion. Then the number of ion pairs produced per unit path is [6, 82].

$$i = \frac{1}{W}(-\frac{dE}{dx}) \dots\dots\dots (2-18)$$

Eq.(2-16) is valid only in a certain energy range because of the assumptions they have made in its derivation. The stopping power of the atom changes with energy as shown below.

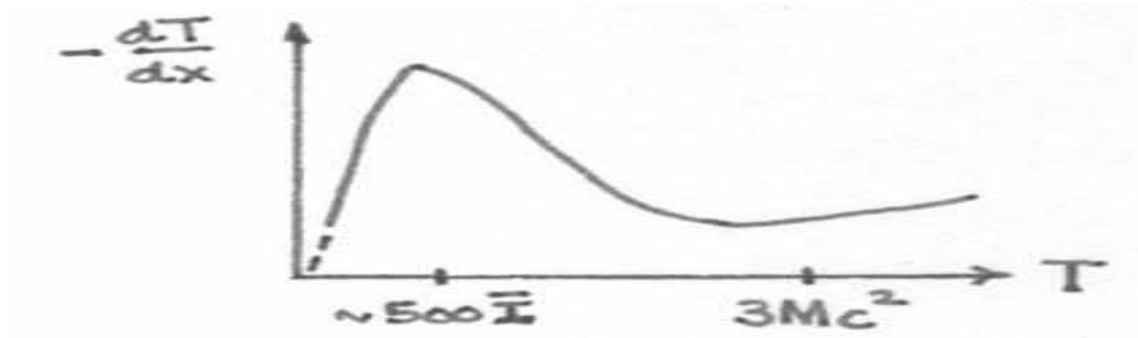


Fig. (2-4) Schematic of overall behavior of the stopping power of particles charged with the rest mass M [6, 82].

In figure(2-4) the intermediate energy region, $500\, I < E \leq Mc^2$, where M is the mass of the charged particle, the stopping power behaves like $1/E$, which is roughly what is predicted by (2-16). In this region the relative correction is small and the logarithm factor is differentiated slowly. At high-energy zone, the logarithm factor works side by side with the relative correction condition and leads to a gradual increase so that a broad minimum is set up in the neighborhood of $\sim 3\, Mc^2$. At energies below the maximum stopping power, E < $500\, I$, Eq.(2-16) are incorrect because charged particles move slowly enough to pick up electrons and begin to lose charge [6, 82].

Fig.(2-5) shows the correlation between the mean charge of a charged particle and its velocity. This is a difficult region to analyze theoretically. For α -particles and protons the range begins at $\sim 1\ MeV$ and $0.1\ MeV$ respectively [83].

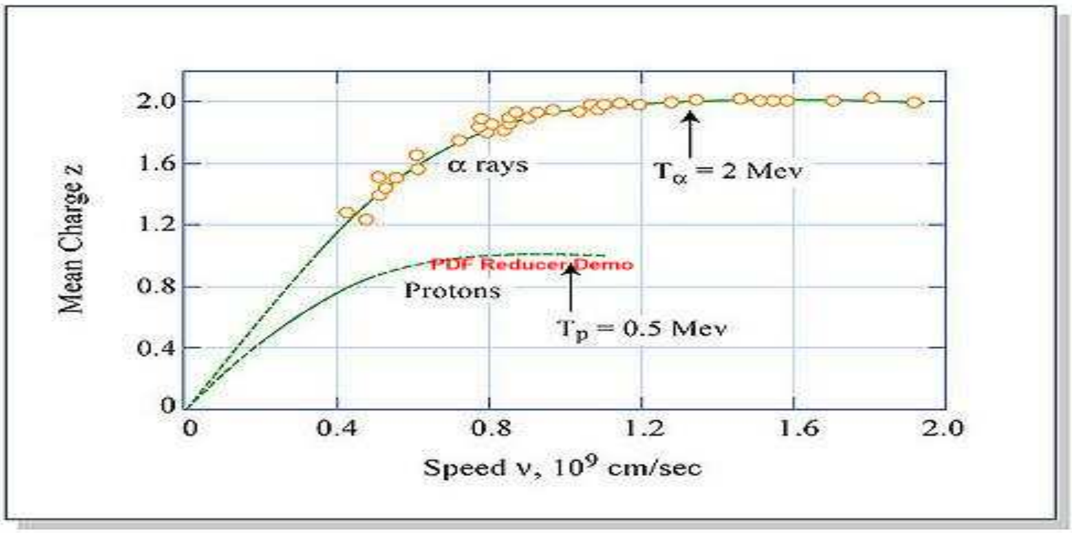


Fig. (2-5) Loss of charge with speed as a charged particle slows down [6,82]

(2.6) The Bethe –Bloch equation:

Eq. (2-16) is generally known as the Bethe formula. It is a quantum mechanical result derived on the basis of the Born approximation which is essentially an assumption of weak scattering . The result is valid provided [6,82].

$$\frac{ze^2}{\hbar v} = \left(\frac{e^2}{\hbar c}\right)\frac{z}{(\frac{v}{c})} = \frac{z}{137\,(\frac{v}{c})} << 1 \;\ldots\ldots\ldots\ldots\; (2-19)$$

On the other hand, Bohr has used classical theory to derive a somewhat similar expression for the stopping power:-

$$-(\frac{dE}{dx})_{class} = \frac{4\pi z^2 e^4 nZ}{m_e v^2} ln[\frac{M\hbar v}{2ze^2(\,m_e + M\,)}\frac{2m_e v^2}{\bar{I}}] \ldots\ldots\ldots..(2-20)$$

This holds if

$$\frac{ze^2}{\hbar v} \gg 1 \ldots\ldots\ldots\; (2-21)$$

The Bethe formula,(2-16), is appropriate for heavy charged particles. For fast electrons (relativistic) one should use [6, 82]

$$-\frac{dE}{dx}=\frac{2\pi e^4 nZ}{m_e v^2}\left[ln\left(\frac{m_e v^2 E}{\overline{I}^{\,2}(1-\beta^2)}\right)-\beta^2\right] \dots\dots\dots\dots (2-22)$$

The stopping of high velocity light ions in matter usually assumes two major simplifications in stopping theory:

(1) The ion is moving much faster than the target electrons and is fully stripped of its electrons

(2) The ion is much heavier than the target electrons. In general, light ions $(H, He$ and $Li)$ with energies between $1\ MeV/u$ to $10\ GeV/u$ [38].

By considering the minimum and maximum values of the impact parameter b as $b_{min}\sim Z_1 e^2/mv^2$ and $b_{max}\sim v/\omega$.

Inserting these values for b_{min} and b_{max} the energy loss becomes:

$$-\frac{dE}{dx}=4\pi Z_2\frac{Z_1^2 ne^4}{mv^2}\ln[\frac{mv^3}{Z_1 e^2\omega}] \dots\dots\dots\dots.(2-23)$$

The relativistic form of this equation is made by equating the particle energy, E $=\gamma M_1 c^2$, where Z_1 is particle atomic number, M_1 is particle mass(u) , Z_2 is target atomic number , M_2 is target atomic weight (u) .This expands $b_{max}\sim\gamma v/\omega$, and $b_{min}\sim\frac{Z_1 e^2}{\gamma mv^2}$ [38].

$$-\frac{dE}{dx}=\frac{4\pi Z_2 e^4}{mv^2}Z_1^2\ln[\frac{\gamma^2 mv^3}{Z_1 e^2\omega}] \dots\dots\dots\dots\dots (2-24)$$

Where ω=orbital frequency

Bohr used this expression to form the basis of his evaluation of the energy loss of a heavy particle to a medium of harmonically bound electrons.

Block evaluated the differences between the classical (Bohr) and quantum mechanical (Bethe) approaches for particle with velocities much larger than the target electrons. The original Bethe-Block relativistic stopping formulae, $-dE/dx$ may be stated as: [38]

$$-\frac{dE}{dx} = \frac{4\pi e^4 Z_2}{m_e v^2} Z_1^2 \left[ln\frac{2mv^2}{\langle I \rangle} - \ln(1-\beta^2) - \beta^2 + \psi(Z_1) \right] \ldots\ldots\ldots..(2-25)$$

Where $\langle \boldsymbol{I} \rangle$ is the averaged excitation potential per electron

The final term, $\boldsymbol{\psi}(Z_1)$ in Eq. (2-25), is a small term which contains Block's error so that the Block result does not reduce to the Bethe result for the limit $Z_1\alpha/\beta \rightarrow 0$, where $\alpha =$ the fine structure constant, $e^2/\hbar c$=1/127 . [38]

(2.6.1)Variations of the Bethe-Block equation

Fano published various extensions of the work of Beth and Bluch which summed up most theoretical work in the previous fifty years.

Fano’s approach was to consider the momentum, p, transferred to a bound electron with an energy transfer, ΔE. Consider three regions for the energy transfer to an atomic electron at a distance, x, from the particle:

1. For small ΔE, one assumes that p. x << ħ, so that the interaction between the particle and electron reduces to dipole matrix elements.

2. For mid-ΔE (the definition of mid-ΔE is quite complex), one assumes that only the longitudinal electromagnetic terms of the interaction contribute to the momentum transfer [38].

3. For large ΔE, one assumes that the target electrons may be considered to be unbound, and the transfer can be reduced to standard two-particle relativistic interactions.

Assuming these approximations, Fano described a relativistic version of the Bethe-Bloch energy loss formula where two additional corrective terms are included, the Shell Correction term, C/Z_2, and the Density Effect correction term $\frac{\delta}{2}$ [38].

$$-\frac{dE}{dx}=\frac{4\pi e^4 Z_2}{m_e v^2}Z_1^2[ln\ \frac{2mv^2}{\langle I\rangle}-ln(1-\beta^2)-\beta^2-\frac{C}{Z_2}-\frac{\delta}{2}]\ \dots\dots\dots..(2-26)$$

Which is usually simplified using the definitions [38]:-

$$r_0=\frac{e^2}{m_e c^2}$$ (the Bohr electron radius)

$$f(\beta)=\ln[2mc^2\,\beta^2/(1-\beta^2)]-\beta^2\ \dots\dots..(2-27)$$ (combining the relativistic terms)

$$-\frac{dE}{dx}=\frac{4\pi r_0^2 m_e c^2 Z_2}{\beta^2}Z_1^2[f(\beta)-ln\langle I\rangle-\frac{C}{Z_2}-\frac{\delta}{2}]\ \dots\dots\dots\dots(2-28)$$

There have been many corrections proposed to improve on Fano's theoretical approximations. Traditionally, this is done by expanding this equation in powers of Z_1, which can be used to add additional corrections to the ion and target interaction.

The Bethe-Bloch stopping power formula is commonly expressed as:

$$-\frac{dE}{dx}=\frac{kZ_2}{\beta^2}Z_1^2[L_0(\beta)+Z_1L_1(\beta)+Z_2^2L_2(\beta)\ \dots]\ \dots\dots..(2-29)$$

Where $k=4\pi r_0^2 m_e c^2$, the term,L_0, contains all the correction factors of the Fano formulation, Eq. (2-28) and extra higher order terms are added, L_1, L_2 …, which will be discussed below. The term in the brackets of Eq. (2-29) is defined as the Stopping Number, L(β),and this expansion will contain all the corrections to the basic two-particle energy loss process [38]

$$L(\beta)\equiv[L_0(\beta)+Z_1L_1(\beta)+Z_1^2L_2(\beta)]\ \dots\dots\dots\ (2-30)$$

This reduces the Bethe-Bloch formula to its simplest notation:

$$-\frac{dE}{dx}=\frac{kZ_2}{\beta^2}Z_1^2L(\beta)\ \dots\dots\dots\ (2-31)$$

The second term of the stopping number expansion,L_1, is usually called the Barkas correction or the Z_1^3 correction, and the third term, L_2, is called the Bloch correction or the Z_1^4 correction. Note that only the stopping number term L_1 contains an odd power of Z_1, and hence would be sensitive to the sign of the particle's charge (positive or negative). Barkas correction should apply to the sum of all odd-power terms of Z_1 in Eq. (2-29) because it is based in part on the stopping differences between particles with opposite charge signs $(+\, or\ -)$ [38]

(2.6.2)Failure of Bethe –Block approximation

The Bethe –Block model becomes invalid at low energies :

1- When the velocity of the charged particle is comparable with K shell electron
2- Charge exchange the ion picks up electrons from the medium reducing its charge
3- Nuclear interactions dominate below 0.01 MeV [84].

(2.7) Energy loss in compounds and mixtures

It is usual to think of a compound or mixture as made up of thin layers of the pure elements in the right proportion (Bragg additivity). Let w_i be the weight fraction of i th kind of atom in a compound [85, 86]

$$\langle\frac{dE}{dx}\rangle = \sum_i w_i \frac{dE}{dx}\ \Big|_i \ldots\ldots\ldots\ldots (2-32)$$

Since the electrons in a compound are more tightly bound than in the constituent elements, the effective I_j are in general higher than those of the constituent elements. But exceptions are provided by diatomic gases and by metals in metallic alloys or compounds. The right way to it is to do it right, but Berger and Seltzer discuss ways to extend the Bragg additivity rule.

If the particle moves in a compound or a mixture instead of a pure element, an effective atomic number $Z_{effetive}$ is [85]:-

$$Z_{effective} = \frac{\sum_{i=1}^{L}(\frac{W_i}{A_i})Z_i^2}{\sum_{i=1}^{L}(\frac{W_i}{A_i})Z_i} \ldots\ldots\ldots\ldots..(2-33)$$

Where L=number of elements in the compound or mixture

$A_i =$ Atomic weight of I the element

$W_i =$Wight fraction of I the element

$Z_{i=}$ Atomic number of I the element

(2.8) Mean excitation energies

Using relativistic quantum mechanics, Bethe derived the equation for the stopping power of a uniform medium for a heavy charged particle is:

$$-\frac{dE}{dx} = \frac{4\pi k_0^2 z^2 e^4 n}{mc^2\beta^2}[ln\frac{2mc^2\beta^2}{I(1-\beta^2)} - \beta^2] \ldots\ldots\ldots\ldots\ldots.(2-34)$$

Where k_0=8.99× 10^{+9} Nm^2C^{-2}

Mean excitation energies I for a number of elements have been calculated from the quantum-mechanical definition obtained in the derivation of Eq. (2-34). They can also be measured in experiments in which all of the quantities in Eq. (2-34) except I are known. The following approximate empirical formulas can be used to estimate the I value in eV for an element with atomic number Z_2 [81]:

$$I \cong \begin{cases} 19.0\ eV\ , Z_2 = 1(\ Hydrogen) \\ 11.2 + 11.7Z_2\ eV, 2 \leq Z_2 \leq 13 \\ 52.8 + 8.71\ Z_2\ eV, Z_2 > 13 \end{cases} \ldots\ldots\ldots(2\text{-}35)$$

An approximate equation for I , which gives good results for Z>12, is [87]

$$I(eV) = \left(9.76 + 58.8\ {Z_2}^{-1.19}\right)Z_2 \ldots\ldots\ldots.(2-36)$$

Since only the logarithm of I enters the stopping-power formula, values obtained by using these formulas are accurate enough for most applications. The value of I for an element depends only to a slight extent on the chemical compound in which the element is found and on the state of condensation of the material, solid, liquid, or gas (Bragg additivity rule). When the material is a compound or mixture, the stopping power can be calculated by simply adding the separate contributions from the individual constituent elements. If there are N_i atoms cm^{-3} of an element with atomic number Z_i and mean excitation energy I_i, then in formula (2-34) one makes the replacement [81].

$$n \ln I = \sum_i N_i Z_i \ln I_{i} \ldots \ldots \ldots \ldots (2-37)$$

Where n is the total number of electrons cm^{-3} in the material ($n = \sum_i N_i Z_i$). In this way the composite $\ln I_i$ value for the material is obtained from the individual elemental $\ln I_i$ values weighted by the electron densities $N_i Z_i$ of the various elements [81].

(2.9) The linear energy transfer (LET)

Is the rate of energy transfer per unit distance along the path of charged particle .As such, LET had to stopping power equivalent. In 1962 the International Commission on Radiation Units and Measurements (ICRU) defined LET as ($-dE_L/dx$), where dE_L is the average energy locally imparted to a target by a charged particle in traversing a distance dx. In 1980, the ICRU defined LET_ as the restricted stopping power for energy losses not exceeding Δ [81] [88]:

$$LET_{\Delta} = (-dE/dx)_{\Delta} \ldots \ldots \ldots (2-38)$$

$$LET = -\frac{dE}{dX} \times \rho \ldots \ldots \ldots (2-39)$$

High-LET radiation: Alpha-particles, low-energy protons, and accelerated ions are classified as high-LET radiation ,which deposits great energy through the direct effect of ionizing radiation and energy transmission concentrated along the path. The dose delivered by high-LET particles increases with depth and reaches its maximum at the end of the particle track, the Bragg peak, with a sharp edge and with little scatter. Such dense ionizations can cause complex DNA damage [89].

(2.10) Mass stopping power

The main parameter of materials that determines the magnitude of ionizing energy loss from charged particles is the concentration of the electron in the material. If the material consists of atoms of one chemical element, then[90]

$$n = Zn_a \dots \dots \dots . (2-40)$$

Where Z is the atomic number of the element ,(the number of electrons in one atom) and n_a concentrate of atoms in the material. Concentrate of atoms (in cm^{-3}) is equal to $\rho\ N_A / A$, where ρ is density of the material (in g/cm^3), $N_A = 6{,}022 \cdot 1023\ mol^{-1}$ is the Avogadro number and(A) is the atomic mass of the material (in g/mol). Therefore, electron concentration (cm^{-3}) is equal to [90]:

$$n = \frac{Z}{A} N_A \rho \dots \dots \dots (\mathbf{2-41})$$

The ratio Z / A vary from 0.5 for light atoms (for H $Z / A = 1$) to 0.4 for heavy atoms. Ionization energy losses are directly proportional to density of the material ρ, and the coefficient of proportionality is almost the same in all materials. Ionization stopping power depends on two characteristics of the incident particle:

- Speed of particle (v)
- Charge of particle(z)

And on two parameters of the material:

- Density of material ρ
- the mean atomic excitation energy I

In addition, the quantities z and ρ enter the expression of the stopping power as a multiplicative factor$z^2\rho$, velocity v is uniquely determined by particle kinetic energy$E$, and dependence on I is logarithmic, i. e. weak. Thus, [90]

$$-\frac{dE}{dx} = z^2 \rho f(E) \ldots \ldots (2-42)$$

Where f depends only on particle energy. The quantity $-dE/(\rho dx)$ is called mass stopping power. From (2-42) it follows that mass stopping power due to ionization energy losses is relatively weakly affected by chemical composition of the material. Therefore, if energy is lost mainly due to atomic ionization and excitation, then the total path of a given particle with a given initial energy (i. e., the length of the path where the particle loses all its kinetic energy, "range"), is mainly determined by density of the material and is inversely proportional to the latter. The expressions of stopping power do not include the mass of the incident particle. This means that ionization stopping powers of different particles with equal velocity and equal absolute values of electric charge Z (for example, electron and proton) are equal. However, stopping powers of electrons and protons with equal energies are very different. This is because velocity of a particle with a given energy is strongly dependent on the particle mass. For example, velocity v and kinetic energy E of a non-relativistic particle are related as follows [90]:-

$$v^2 = 2E/M \ldots \ldots (2-43)$$

where M is the particle mass. After replacing v^2 in Eq. (1-1) with the expression (2-43) and taking into account that for non-relativistic particles $\beta << 1$, we obtain:

$$-\frac{dE}{dx} = \frac{1}{8\pi\varepsilon_0^2} \frac{Z^2 e^4 nM}{m_e E} \ln \frac{4m_e E}{I\,M} \ldots \ldots (2-44)$$

note that ionization energy losses of non-relativistic particles are directly proportional to the mass of the particle. Therefore, ionization stopping power of heavy charged particles (e. g. alpha particle) is much larger than ionization stopping power of electrons with the same energy. Hence, a heavy charged particle is able to travel a much smaller distance in a material than an electron with the same energy [90].

(2.11) Range of alpha particle

Because the stopping power depends on the energy of particle, then it is possible to calculate the path of the particle which corresponds to the lower particle energy from the initial valueE_0 to some smaller valueE_1 . Based on the definition of the stopping power, that path is equal to the integral [90]:-

$$R = \int_{E_1}^{E_0} \frac{dE}{-\frac{dE}{dx}} \ldots\ldots\ldots.(2-45)$$

The range is the total length of the particle path. The range can be expressed via the stopping power of the material. That expression is a separate case of a more general relation (4-45), with E_1equal to 0 [90]:-

$$R = \int_{0}^{E_0} \frac{dE}{-\frac{dE}{dx}} \ldots\ldots\ldots.(2-46)$$

In general, the particle's range is not the same as the particle's penetration depth. The penetration depth is defined as the largest distance between the surface of the material and the particle as it travels inside the material. The penetration depth depends on the shape of the particle's trajectory and is always smaller than the range. Since interaction with atoms of the material is of random nature, different particles will be deflected differently, so that their penetration depths will be different (even if those particles are identical and have equal initial energies). However, their ranges in the material will be very similar (practically equal to each other). The difference between range and penetration depth is especially pronounced in the case of electrons, because of their erratic paths . In contrast, the range of heavy charged particles is practically equal to their penetration depth (if the beam of particles is normal to the surface of the material), because heavy charged particles move in straight lines [90].

If ionization energy losses dominate, then the particle range can be expressed by equation (2-47), where E_1 = 0:

$$R = \frac{1}{Z^2\rho}\int_0^{E_0}\frac{dE}{F(E)} \equiv \frac{1}{Z^2\rho}\emptyset(E_0)\ldots\ldots(2-47)$$

Where $\emptyset(E_0)$ is a universal function of the particle's initial energy [90].

From eq.(2-47) we note that range of particle in material is proportional to a universal function of particle initial energy. Having measured the range of α particles in a given material and knowing the function $\emptyset(E_0)$ and density ρ of the material, it is possible to calculate approximate energy of the α particle. Since now there are detectors whose signal height directly reflects particle energy, such indirect methods of energy measurements are [90].

(2.12) Thickness of target: For absorbers that are penetrated by a given charged particle, the thickness can be calculated from [88] :

$$\mathrm{T} = R/\rho \quad \ldots\ldots\ldots(2-48)$$

(2.13) RADIATION EXPOSURE AND DOSE

Because of their importance in personnel protection at radiation-producing facilities and in the medical applications of radiation, the concepts of radiation exposure and dose play prominent roles in radiation measurements [13].

(2.13.1). Gamma-Ray Exposure

The concept of gamma-ray exposure was introduced early in the history of radionuclide research. Defined only for sources of X- or gamma rays, a fixed exposure rate exists at every point in space surrounding a source of fixed intensity. The exposure is linear, in that doubling the source intensity also doubles the exposure rate everywhere around the source. The basic unit of gamma-ray exposure is defined in terms of the charge dQ due to ionization created by the secondary electrons formed within a volume element of air and mass dm, when these secondary electrons are completely stopped in air. The exposure value X is then given by dQ/dm [13] .The SI unit of gamma-ray exposure is thus the coulomb per kilogram (C/kg), which has not been given a special name. The historical unit has been the roentgen (R), defined as the exposure that results in the generation of one electrostatic unit of charge (about 2.08 x 109 ion pairs) per 0.001293 g (1 cm3 at STP) of air. The two units are related by [13] :-

$$1R = 2.58 \times 10^{-4} C/Kg$$

The exposure is therefore defined in terms of the effect of a given flux of gamma rays on a test volume of air and is a function only of the intensity of the source integrated over the measurement time, the geometry between the source and test volume, and any attenuation of the gamma rays that may take place between the two. Its measurement fundamentally requires the determination of the charge due to ionization produced in air under specific conditions. Inherent in the above definition is the obligation to track each secondary electron created by primary gamma-ray interactions in the test volume under consideration, and to add up the ionization charges formed by that secondary electron until it reaches the end of its path[13].

The gamma-ray exposure is often of interest in radiation protection dosimetry. It is therefore sometimes convenient to be able to calculate the exposure rate at a known distance from a point radionuclide source. If we assume that the yield per disintegration of X- and gamma rays is accurately known for the radioisotope of interest, the exposure rate per unit activity of the source at a known distance can simply be expressed under the following conditions:

1. The source is sufficiently small so that spherical geometry holds (i.e., the photon flux diminishes as $\frac{1}{d^2}$, where d is the distance to the source).

2. No attenuation of the X- or gamma rays takes place in the air or other material between the source and measuring point.

3. Only photons passing directly from the source to the measuring point contribute to the exposure, and any gamma rays scattered in surrounding materials may be neglected[13].

(2.13.2)Absorbed dose

Two different materials, if subjected to the same gamma-ray exposure, will in general absorb different amounts of energy. Because many important phenomena, including changes in physical properties or induced chemical reactions, would be expected to scale as the energy absorbed per unit mass of the material, a unit that measures this quantity is of fundamental interest. The mean energy absorbed from any type of radiation per unit mass of the absorber is defined as the absorbed dose. The historical unit of absorbed dose has been the rad, defined as 100 ergs/gram[13]. As with other historical radiation units, the rad has been replaced by its SI equivalent, the gray (Gy) defined as 1 joule/kilogram. The two units are therefore simply related by[13]: -

$$1\ \text{Gy} = 100\ \text{rad}$$

The absorbed dose is a reasonable measure of the chemical or physical effects created by agiven radiation exposure in an absorbing material.

If water is substituted for the air, its absorption properties per unit mass do not differ greatly because the average atomic number of water is close to that of air. For absorbing materials of greatly dissimilar atomic numbers, however, the interaction mechanisms have different relative importance, and therefore the absorbed dose per unit exposure would show greater differences[13].

In order to measure absorbed dose in a fundamental manner, some type of energy measurement must be carried out. One possibility is a calorimetric measurement in which the rate of rise of the temperature in a sample of absorber is used to calculate the rate of energy deposition per unit mass. Because of their difficulty, these measurements are not commonplace for routine application since the thermal effects created even by large doses of radiation are very small. Instead, indirect determinations of absorbed dose are much more common, in which its magnitude is inferred from ionization measurements carried out under proper [13]. The absorbed dose reflects the intensity of the energy deposited in any small amount of tissue found anywhere in Body of organism [91] [92].

$$\text{Absorbed dose(rad)} = \frac{\text{E}}{\text{1gram}} \frac{1.6\times10^{-13}\text{J}}{\text{1MeV}} \frac{10^{7}\text{erg}}{\text{1J}} \frac{\text{1 rad}}{\frac{\text{100erg}}{\text{gram}}} \ldots\ldots\ldots (2-49)$$

(2.13.3) Equivalent dose

The absorbed doses in the tissue or organ due to radiation [93] .In 1973, ICRU [94, 95] defined equivalent dose H which is used to take into account the fact that different particle types have biological effects that are enhanced, per given absorbed dose, over those due to the standard reference radiation taken to be 200 keV photons. This quantity has the same physical dimensions as absorbed dose. The SI unit of measure is the sievert (Sv). The concept of equivalent dose is applied only to radiation

exposures received by human beings. Equivalent dose is defined as the product of Q and D, where D is the absorbed dose and Q is the quality factor at that point [96].

The dimensionless quality factor Q is dependent on both particle type and energy, and for any radiation field, its value is an average over all components. It is formally defined to have a value of unity for 200 keV photons. In the 1973 system, Q ranges from unity for photons, electrons of most energies and high-energy muons to a value as large as 20 for a-particles (i.e. 4 He nuclei) of a few MeV in kinetic energy. For neutrons, Q ranges from 2 to >10 in the 1973 system. Q is defined to be a function of linear energy transfer (LET). LET is the radiation energy lost per unit length of path through a material. For the common situation where a spectrum of energies and a mixture of particle types are present, the value of Q for the complete radiation field is an average over the spectrum of LET present weighted by the absorbed dose as a function of LET, D (LET). ICRP uses radiation weighting factors $\mathbf{W_R}$ to connect absorbed dose to the protection quantity dose equivalent[96]. For diagnostic radiation: The equivalent dose in mille-Sievert (mSv) = the absorbed dose in mGy [96] .

$$H_T = \sum_R W_R \times D \dots\dots (2-50)$$

Where W_R = Weighting factor =20 for Alpha particle [97]

(2.13.4)Effective dose :

The tissues differ in their sensitivity to the late effects of radiation, which represent the biological responses to the tissue, which are delayed for a long period of time, often several years. The effective dose is used to estimate the incidence of delayed effects in the future. If a part of the body such as the lungs receives a radiation dose, it represents a risk factor of lung cancer. If the same dose is given to another organ, it causes a different risk factor and is called the dose measured by the effective dose, is designated E. It is defined in the following way [98]:-

$$E=W_1H_1 + W_2H_2 + \cdots \ldots \ldots . . (2-51)$$

Here W_1 represents a weighting factor for organ 1 and H_1 is the equivalent dose (given in Sv) for organ number 1, H_2 for organ number 2 and so on.

Tissue weighting factor: is the factor by which the equivalent dose is weighed in tissues or organs.it represents the relative contribution of the organ or tissue from the total damage caused by the uniform radiation of the whole body, as shown in table (2-1).

Table (2-1) Organ or tissue weighting factors [96]

Organ/tissue	W_T (weighting factors)
Bone marrow, colon, lung, stomach, breast, remainder	**0.12**
Gonads	**0.08**
Bladder, liver, esophagus, thyroid	**0.04**
Bone surface, skin, brain, salivary glands	**0.01**

The effective dose is associated with two different weight factors:

• First, the radiation weight factor W_R and

• Second, the tissue weight factorW_T.

These factors have been proposed by ICRP. The body has been divided into 15 organs and each organ has a certain weighting factorW_T. If all weights factors are added, the total will be 1 or 100% . One organ or tissue is called "remainder" [99].

Effective dose is a calculated value. There are three factors that have been taken into account when calculating:

a. The absorbed dose to all organs of the body,

b. The relative harm level of the radiation

c. The sensitivities of each organ to radiation [91].

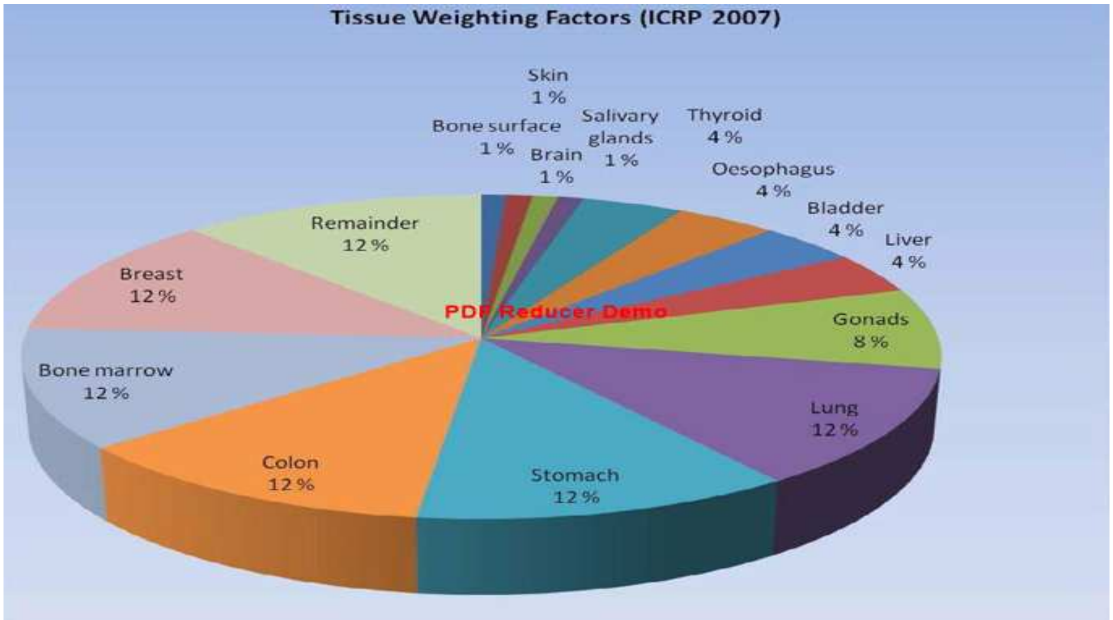


Fig.(2-6)Tissue Weighting factors (ICRP (2007) [99]

(2.14) Chemical and biological effects of radiation

Biological effects of ionizing radiation are a consequence of the ionization of atoms of biomolecules, which might cause chemical changes and alter or eradicate its functions. Energy transmitted by radiation may act directly causing ionization of the biological molecule or may act indirectly through the free radicals resulting from the ionization of the water molecules that surround the cell [100].Due to ionization, proteins can lose the functionality of its amino groups and modify its behavior, thus increasing its chemical responsiveness; enzymes would be deactivated; lipids will suffer peroxidation; carbohydrates will dissociate; and nucleic acids chains will experiment ruptures and modifications of structure[100].

But from all possible combined alterations, DNA is the primary target for radiation because it contains genes/chromosomes that hold information for cell functioning and reproduction that are critical to cell survival. As a result of radiolytic decomposition of water by ionization and excitation, hydrogen, and hydroxyl radicals could combine to form toxic substances as hydrogen peroxide (H_2O_2), which can also contribute to the destruction of cells. The deposition of energy by ionizing radiation is a random process. Even at very low doses there is some probability that enough energy may be deposited into a critical volume within a cell to result in cellular changes or cell death [100].

(2.14.1) Time frame for radiation effects

Chemical changes resulting from ionizing radiation in water are related to the understanding of biological effects. Mammalian cells consist of $\sim 70-85\%$ water, $\sim 10-20\%$ proteins, $\sim 10\%$ carbohydrates, and $\sim 2-3\%$ lipids. Ionizing radiation produces secondary electrons in the water with energies in the range $\sim 10-70\ eV$ [81].

(2.14.2) Physical and prechemical chances in irradiated water

Radiation leads to initial changes in water:

1- The formation of ionized and excited molecules, H_2O^+ and H_2O^*

2- Free, sub excitation electrons [81]

Table (2-2) Time frame for effects of ionizing radiation [81]

Physical stage ($\leq 10^{-15} s$)	**Formation of H_2O^*, H_2O^+, and subexcitation electrons, e^-, in local track regions ($\leq 0.1 \mu m$)**
Prechemical stage $\sim 10^{-15}$ s to $\sim 10^{-12}$ s	**Three initial species replaced by H_3O^+, OH, e^-_{aq}, H, and H_2**
Chemical stage $\sim 10^{-12}$ s to $\sim 10^{-6}$ s	**The four species H_3O^+, OH, e^-_{aq}, and H diffuse and either react with one another or become widely separated . Intratrack reactions essentially complete by $\sim 10^{-6}$ s**
Biological stages	
$\leq 10^{-3}$ s	**Radical reactions with biological molecules complete**
$\leq$ 1s	**Biochemical changes**
Minutes	**Cell division affected**
Days	**Gastrointestinal and central nervous system changes**
Weeks	**Lung fibrosis develops**
Years	**Cataracts and cancer may appear ;genetic effects in offspring**

Radiation leads to the following changes:-

First, in about 10^{-14} s, an ionized water molecule interacts with a nearby water molecule and produces a hydronium ion and a hydroxyl radical:

$$H_2O^+ + H_2O \rightarrow H_3O^+ + OH \ldots\ldots\ldots (2-52)$$

Second, the excited water molecule gets rid of its energy in one of two ways:

1 - Loss of the electron, and thus becomes an ion and begins according to the interaction (2-52)

2 - Molecular disintegration

$$H_2O^* \rightarrow \left\{ \begin{matrix} H_2O^+ + e^- \\ H + OH \end{matrix} \right\} \dots\dots\dots\dots (2-53)$$

The Vibration periods of water molecule are $\sim 10^{-14}$ s, which is time that distinguishes the process of disintegration.

3- Sub-excitement electrons will migrate, loss of energy by oscillation and rotation of excitation of water molecules and become thermal by times $\sim 10^{-12}$s. Moreover, the thermalized electrons orient the permanent dipole moments of neighboring water molecules, forming a cluster, called a hydrated electron. We denote the thermalization–hydration process symbolically by writing: $e^- \rightarrow e^-_{aq}$. Where aq refers, to the fact that the electron aqueous solution. These changes are summarized in table (2-1) [81].

(2.14.3) Chemical stage

At $\sim 10^{-12}$ s , chemically active species H_2O^+, OH, e^-_{aq}, and H are located near the positions of the original H_2O^+, H_2O^*, and e^- that triggered their formation. Three of the new reactants, OH, e^-_{aq},and H, are free radicals, that is, chemical species with unpaired electrons. The reactants begin to migrate randomly about their initial positions in thermal motion. As their diffusion in the water proceeds, individual pairs can come close enough to react chemically. The fundamental reactions that occur in the path of particles charged in water at this stage are the following [81]:

$$OH + OH \rightarrow H_2O_2 \dots\dots\dots\dots (2-54)$$

$$OH + e^-_{aq} \rightarrow OH^- \dots\dots\dots\dots (2-55)$$

$$OH + H \rightarrow H_2O \dots\dots\dots\dots (2-56)$$

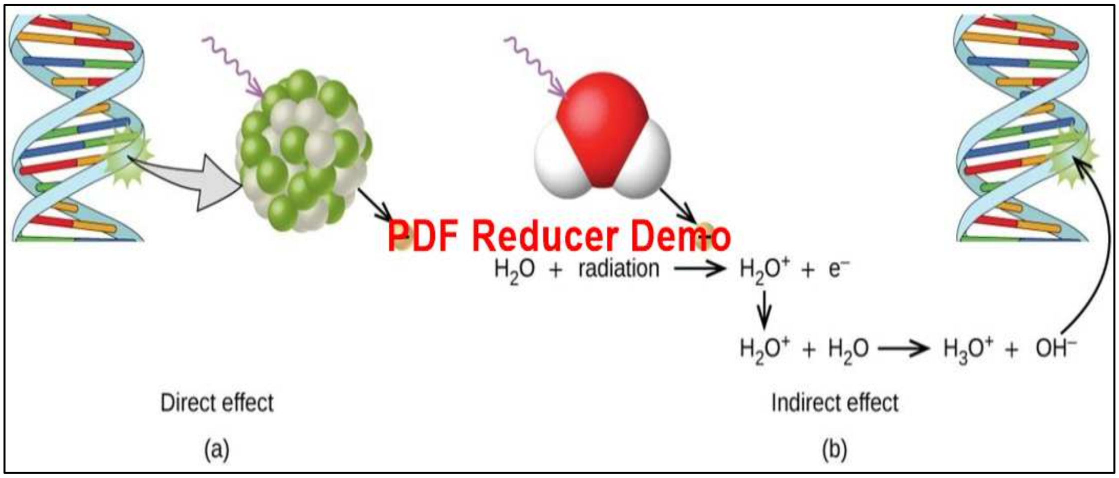
$$H_2O^+ + e^-_{aq} \rightarrow H + H_2O \dots\dots\dots (2-57)$$

$$e^-_{aq} + e^-_{aq} + 2H_2O \rightarrow H_2 + 2OH^- \dots\dots (2-58)$$

$$e^-_{aq} + H + H_2O \rightarrow H_2 + OH^- \dots\dots\dots\dots (2-59)$$

$H + H \rightarrow H_2 \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots. (2-60)$

With the passage of time, the reactions (2-54)-(2-60) proceed until the remaining reactants are spread away from each other so that the probability for additional interactions is small. This occurs by $\sim 10^{-6}$ s, and the chemical evolution of the path in pure water then is essentially over [81].



PDF Reducer Demo

Fig.(2- 7)Chemical effects of Radiation [101]

(2.14.4) Biological effects

The biological effects on the cell result from:

A- Direct action of radiation: an effect is produced by the initial action of the radiation itself. Such as is breaking a strand in DNA caused by ionization in the same molecule.

B- Indirect action of radiation: are the effects of later chemical action from free radicals and other radioactive products. Such as a strand break that results when an OH radical attacks a DNA sugar at a later time is (between $\sim 10^{-12}$ s and $\sim 10^{-9}$ s) [81].

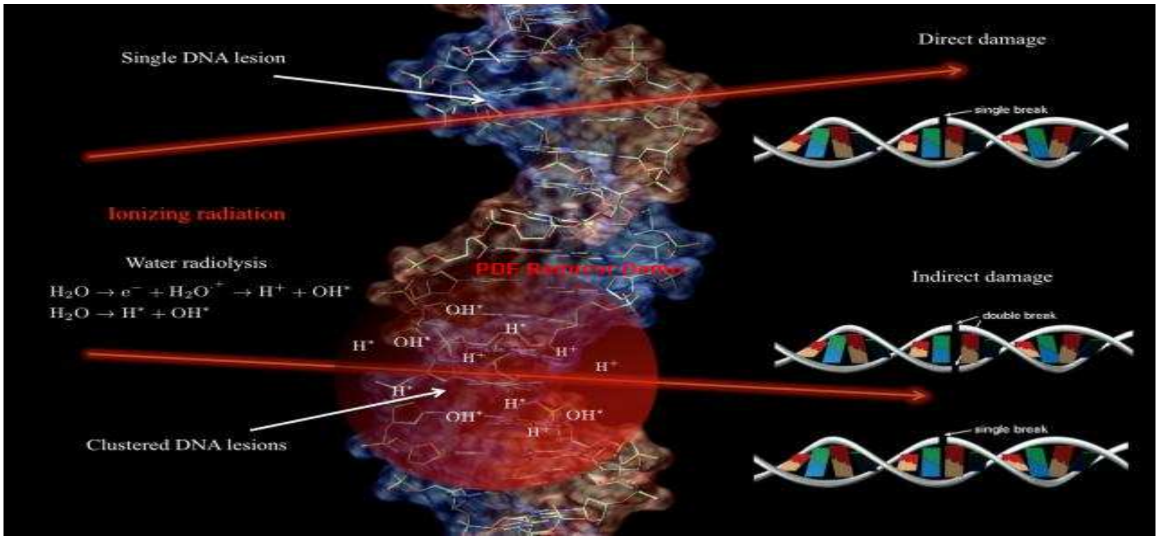


Fig.(2-8)The biological effects of radiation on the cell [102]

-Biological effects differ depending on : the Dose and kind of radiation.

- Biological effects differ in time of their occur:

A. very quickly: charged particles during their track in the biological system will produce free radicals, and these roots interact in their entirety during a very small time up to 10^{-3}s.
B. Some biochemical processes occur immediately in less than one second.
C. Cell division in the matter can occur within minutes.
D. When the whole body is exposed to a large and severe dose of radiation, the blood components of the person will die in about a month.
E. The higher dose leads to damage to the nervous system, which may lead to premature death within one to two weeks.
F. At higher doses within 100 Gry range, blood vessels in the brain will be damaged and thus die within a day or two.
G. The development of lung fibrosis takes several months.
H. Cataracts and cancer occur years after exposure to radiation
I. Genetic effects have an impact on future generations [81].

The biological effects are divided into two parts:

A. Stochastic and deterministic
B. Non -stochastic

Stochastic and deterministic; are effects that are obtained statistically, such as cancer. If a large number of people are exposed to a large amount of carcinogens such as radiation, we will certainly expect a high rate of cancer. We can also predict the magnitude of the increase in cases, but at the same time we cannot determine which individuals were exposed to cancer as a result of exposure to radiation. To the presence of individuals infected with cancer naturally without any exposure to radiation. The deterministic effects of radiation in humans and other organisms appear only at relatively high doses. In the case of low doses there is no agreement between experts on [81].

(2.15)Medical radiation

The following examples illustrate some findings from medical exposures of humans.

1- X rays : Treatments could deliver a substantial incidental dose to a child's thyroid, one of the most sensitive tissues for cancer induction by radiation.

2- X rays : using X rays to treat ringworm of the scalp in children. A dose of several Gy was administered to the scalp to cause (temporary) epilation, so that the hair follicles could be more effectively treated with medicines. This procedure also resulted in a substantial thyroid dose [81].

(2.15.1)Delayed somatic effects

The table (2-2) shows some of the biological effects of radiation that take a long time to become apparent. These changes are called delayed or late, somatic effects. In contrast to the genetic effects that appear in the offspring of parents, the delayed physical effects occur in the individual at risk. Documentation of late somatic effects resulting from radiation and its risk assessment, especially at low doses, is complicated because the same effects occur spontaneously [81].

(2.15.2) Cancer

A- Leukemia

Acute myelogenous leukemia (AML), chronic myelogenous leukemia (CML), and acute lymphoblastic leukemia (ALL) have been linked to past radiation exposure. Bone marrow disorder that can turn into acute leukemia, has also been linked to past radiation exposure [81].

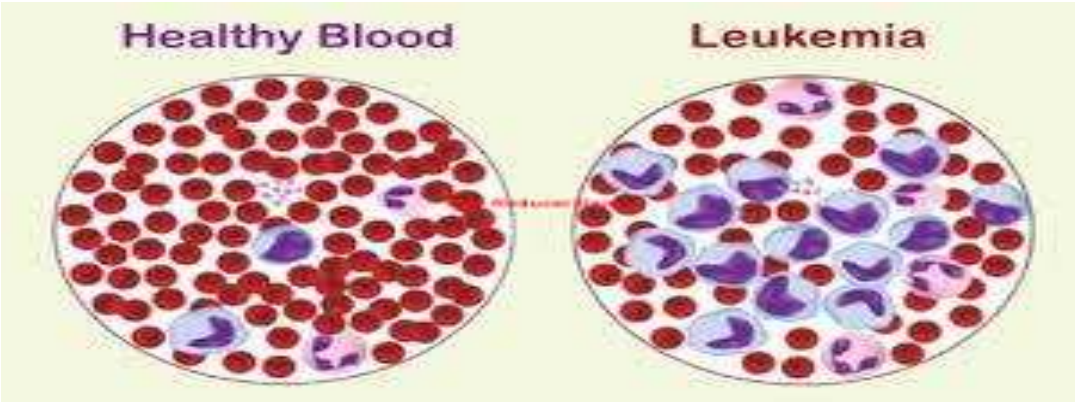


Fig.(2-9) Leukemia[103]

B- Solid tumors

Solid tumors are another type of cancer that takes about 10 years to appear after radiotherapy and more than 15 years to be diagnosed.

The effect of radiation on the risk of developing a solid tumor cancer depends on such factors as:

1- Radiation dose: The risk of developing a solid tumor after radiotherapy increases with increased dose of radiation. Some cancers require higher doses of radiation compared to others and some techniques require more radiation. For example, intensity modulated radiation therapy (IMRT) helps to protect tissues that are more easily injured by radiation, but a larger dose of radiation overall must be used.
2- The area treated: The treated area is important, because these cancers tend to develop in or near the area that has been treated with radiation. The most likely organs to develop cancer after radiation are breast and thyroid [104].

3- Age of the patient when treated with radiation in general. Age at the time of treatment affects the risk of solid tumors. An example of breast cancer risk after radiation is greater in those who were treated when they were young than adults .The risk of breast cancer after radiation is greatest in children. Risk decreases with age increase at the time of radiation with little or no increase in the risk of breast cancer among women who have been exposed to radiation after age 40. Age at the time of radiation therapy has the same effect on the development of solid tumors, such as lung, thyroid, bone and digestive cancers [104].

Other factors can also affect the risk of radiation-related cancers.

- Smoking: increases the risk of lung cancer after radiation even more.
- Early menopause can lower the risk of radiation-related breast cancer.
- Some cancers, the risk is higher if chemotherapy was given along with radiation. [104].

(2.15.3) Life shortening

The evidence suggests that shortening radiation life at low doses is very specific, mainly due to increased leukemia and cancer. Some investigations have reported a longer average life expectancy in animals exposed to low levels of whole-body radiation than in unexposed controls. Such reports are offered by some as evidence of radiation hormesis—that is, the beneficial effect of small doses of radiation. Radiation hormesis has also been extensively investigated in plants, insects, algae, and other systems. As with other low-dose studies of biological effects of radiation, one deals with relatively small effects in a large statistical background of naturally occurring endpoints .

Theoretical grounds can be offered in support of low-level radiation hormesis stimulation of DNA repair mechanisms that reduce both radiation-induced and spontaneous damage [81].

(2.15.4) Cataract

New findings, including those in population groups exposed to much lower doses of radiation and in subjects as diverse as astronauts, medical workers, atomic bomb survivors, people at risk of exposure and those undergoing diagnostic or radio therapy, indicate lower doses. A proposal to reduce the proposed radiative cataract threshold to 0.5 g / year and maximum exposure to occupational lenses to 20 mSv / year, Prolonged, or chronic exposure [105].

(2.15.5) Irradiation of mammalian embryo and fetus

The division of cells and tissues in which cells are constantly replaced is among the most sensitive cells for radiation: the gonads, the digestive system, the hematopoietic organs, the lymphatic system and the skin. The developing fetus and the fetus, in particular, are highly susceptible to harmful radiological effects, which have been documented in humans and in experimental animals [81].

The main effects of intrauterine radiation are as follows:

- premature death
- developmental delays
- congenital malformations

There have been observed types of biological damage in the uterus of animals irradiated in high doses; however, these effects do not occur the same degree in humans except damage to the central nervous system [81].

(2.15.6) Genetic effects

Radiation can alter the genetic information contained in the fertilized egg (germ cell). Genetic changes may be unequal to an individual from a later generation or they may pose a serious impediment. If adult males receive a moderate dose of radiation, they do not suffer from an immediate reduction in fertility. Permanent or temporary infertility depends on the size of the radiation dose and how to divide it in time. The normal human cell has 46 chromosomes, half from the father and the other half from the mother. Each chromosome contains a gene that codes attributes of the individual. Genetic changes caused by radiation can result from genetic mutations and chromosomal alterations. A genetic mutation occurs when the DNA is changed, even by losing or replacing a single base. A mutation is called a mutation point when there is a change in the location of one gene. Radiation can also cause fracture and other damage to chromosomes. Some mutations involve deletion of part of the chromosome [81].

(2.16) Theoretical method use for calculation:

SRIM is a software package related to the stopping and the range of ions in the matter. Since its introduction in 1985, major upgrades have been made for every six years

The main improvements introduced to the 2010 system are as follows

a. 2800 new experimental stopping powers have been added to the database, increasing it to more than 28,000 stop values
b. Make corrections to the stopping power of ions in compounds.
c. The new calculations of the heavy ion stopping power led to significant improvements in the accuracy of the SRIM.
d. A self-contained SRIM module has been included to allow for SRIM stopping and range values to be programmed and read by other software applications.
e. Individual inter atomic potentials have been included for all ion/atom collisions, and these potentials are now included in the SRIM package. Full forms of stopping power can be downloaded at www.SRIM.org [43].

(2.16.1) SRIM-2010 stopping accuracy

The statistical improvements in SRIM's stopping power accuracy when comparing to the experimental data, In addition to the SRIM-1998. And the percentage of data points within 5% and 10% of the SIRIM calculation. . The experimental stopping power of heavy ions has more scatter than light ions, so there are bigger errors for heavy ions. The accuracy of the SRIM-2010 of individual ions or targets can be determined by displaying shapes that compare experimental values with equivalent SRIM calculations. Figure (2-10) shows a typical comparison of a light ion, He, in Ag. While the figure (2-11) shows that the shapes are similar for all heavy ions Be (4) – U (92) in Ag. Note that the scatter of data points is much higher than for the case of He ions in Ag, which increases the perceived error of SRIM [43].

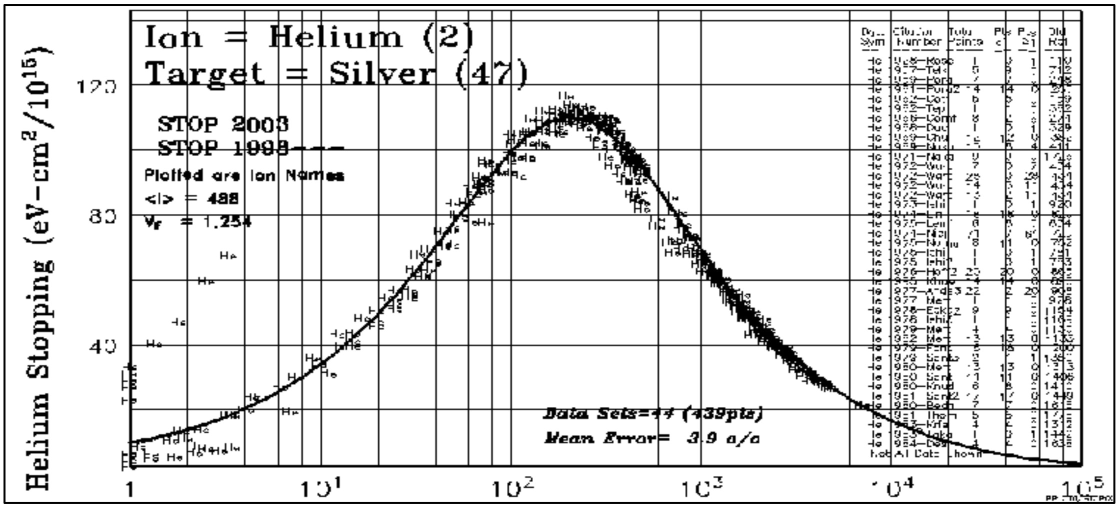


Fig.(2-10) The stopping of He ions in Ag targets [43]

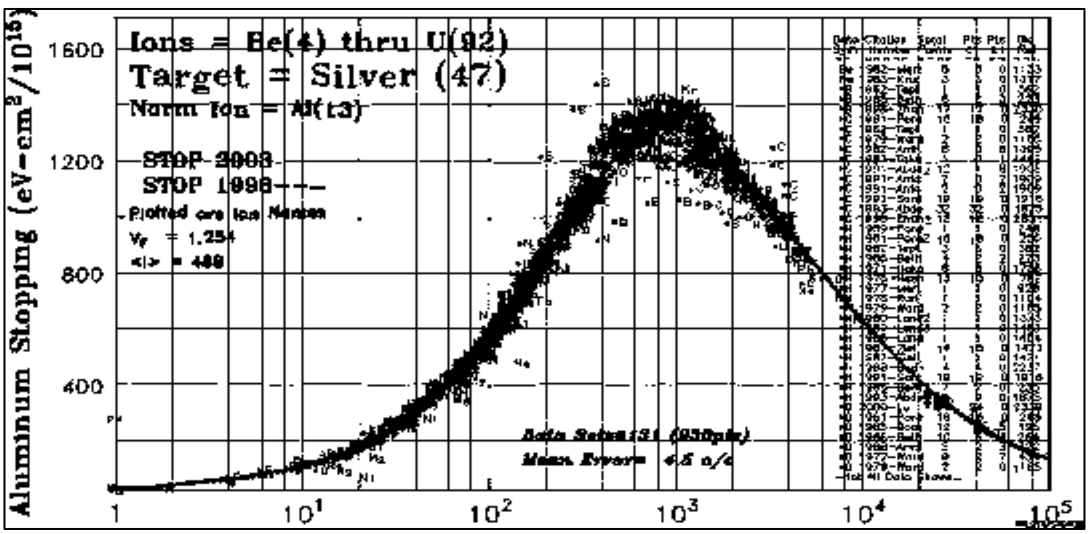


Fig.(2-11) The stopping of Heavy Ions in Ag targets [43]

(2.16.2) Stopping of ions in compounds

Bragg and Kleeman concluded that the stopping power of the compound can be estimated by linearly combining the stopping powers of individual elements. This concept is known as the Bragg's Rule.

- The measurement of the stopping power of ions in compound deviates by less than 20% from those predicted by the Bragg's rule

- The rule of Bragg becomes inaccurate if there are any differences between the bonding in the base material and the compounds. Changes in bonding can alter the transient ion charge and thus change the strength of its interaction with the target. Bragg rule is limited because the loss of energy of the electrons in any material depends on the detailed orbital structure and excitation of the matter.

- Core and Bond (CAB) suggested that stopping powers in compounds can be predicted using the superposition of stopping by atomic "cores" and then adding the stopping corresponding to the bonding electrons. The core stopping would simply follow Bragg's rule for the atoms of the compound, where they linearly add the stopping from each of the atoms in the compounds. Thus, the chemical bonds of the compound contain the necessary correction of the stopping. They are estimated according to the simple chemical nature of the compound. For example, for hydrocarbons, carbon in C-C, C=C and C≡C structures would have different bonding [43].

SRIM used the CAB approach in order to generate corrections between the Bragg's base and compounds containing common elements H, C, N, O, F, S and Cl.. These light atoms have a greater correlation effect on the stopping powers. Heavier atoms are assumed not to contribute anomalously to stopping because of their bonds. When using SRIM, we have the option to use compound dictionary that contains chemical bonding information for about 150 compounds. When a particular compound is selected, the chemical bond diagram will be shown and calculate the best correction of the stopping power [43].

(2.16.3) Stopping of high energy heavy ions

Bohr suggested that active heavy ions lose any of the electrons that were a classical speed slower than the speed of the ion. The connotation was improved through the suggestion of BK that one should instead consider losing any electrons that were slower than the relative velocity of the ion to the target medium. This significantly improved the calculation of stopping powers .This reduced the charge state of heavy ions since the relative velocity of the ion is less than its absolute velocity. Then a method was introduced to calculate the relative velocity of these ions on the basis of the target to be a perfect Fermi conductor [43]. This greatly improves the calculation of stopping power.

In Bethe-Bloch, two large components are not well described by pure theoretical considerations:

(1) The mean ionization energy of the target (2) The shell corrections for the target, calledC/Z_2.

The value for a target corrects for the quantized energy levels of the target electrons and also any band gap and target phase correction. The C/Z_2 term corrects for the Bethe-Bloch assumption that the ion velocity is much greater than the target electron velocities. Correction of the shell is calculated by detailed calculations of the interaction of particles with each electronic orbit of different elements. Since these terms depend solely on the target it is assumed to be the same for heavier and lighter ions [43].

(2.16.4) Anomalous heavy ion stopping values

SRIM has used many theories to estimate the accuracy of experimental stop powers.

1- Calculate the stopping power of all ions in individual targets ,which eliminates common difficulties with target-based quantities such as shell correction and mean ionization potential.
2- Calculate stopping power for heavy ion in all solids, which eliminates some difficulties with ion-dependent quantities such as the degree of ion stripping

Calculations are made from fundamental theories like the Brandt-Kitagawa theory and LSS theory. If experimental values are within a reasonable agreement with these theoretical calculations, experimental values are weighted by theoretical values to obtain the final values. Sometimes large errors occur and deviate from theoretical values so they must be completely ignored [43].

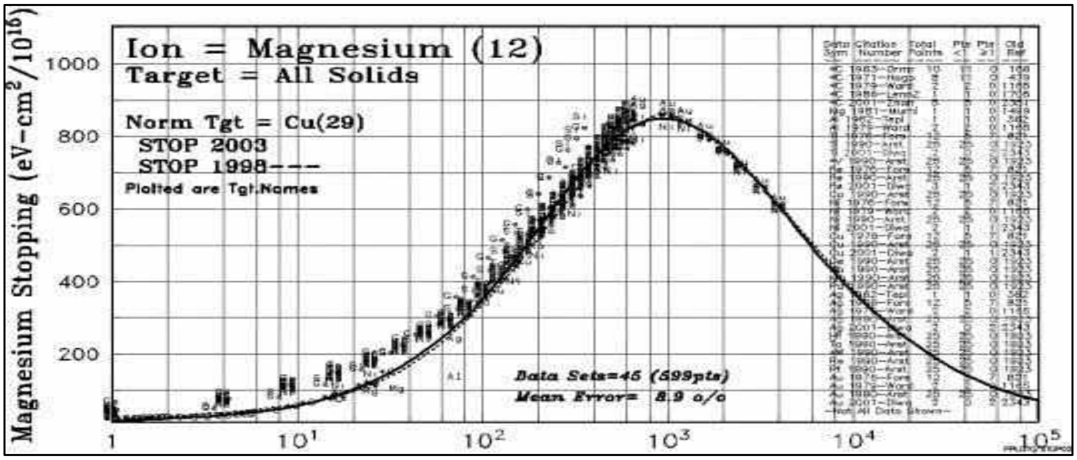


Fig.(2-12) The stopping of Mg ions in all solids [43]

(2.17) PSTAR and ASTAR databases for protons and helium ions

(2.17.1)Overview

There are two ways to use PSTAR and ASTAR databases. . The full version provides the user with many capabilities such as graphs and structured tables [30].

(2.17.2)Output of PSTAR and ASTAR

The following quantities are calculated:

a. Electronic (collision) stopping power, MeV cm^2/g;
b. Nuclear stopping power, MeV cm^2/g;
c. Total stopping power (sum of a and b), MeV cm^2/g;
d. CSDA (continuous-slowing-down approximation) range, g/cm^2
e. Projected range, g/cm^2;
f. Detour factor (ratio of projected range to CSDA range).

The significance of these quantities

a. **Collision stopping power**: Is the average rate of energy loss per unit of length resulting from Coulomb collision. The collision stopping power of heavy charged particles is called electronic stopping power [30].

b. **Density-effect correction**: Enters into the equation for the collision stopping power and takes into the calculation of the reduction of the collision stopping power due to the polarization of the target by the fallen electron .

c. **Radiative stopping power**: Is the rate of energy loss per unit path length due to collisions with target atoms and their emitting electrons. It is important only for electrons

d. **Nuclear stopping power**: Is the average rate of energy loss per unit path length due to the transfer of energy to the recoiling atoms in flexible collisions is important for heavy charged particles.

e. **Total stopping power**: For protons and alpha particles,it is the sum of nuclear and collisions stopping powers ,while electrons are the sum of the radiated and collision stopping powers.

f. **CSDA range**: A very close approximation to the average path length traveled by a charged particle as it slows down to rest, calculated in the continuous-slowing-down approximation. In this approximation, the rate of energy loss at every point along the track is assumed to be equal to the total stopping power. Energy-loss fluctuations are neglected. The CSDA range is obtained by integrating the reciprocal of the total stopping power with respect to energy [30].

g. **Projected range**: The average depth penetrated by the charged particle in the deceleration path of rest. This depth is measured along the initial direction of the particles.

h. **Detour factor**: Ratio of the projected range to the CSDA range. As the result of multiple scattering, the trajectory of the particle is wiggly rather than straight, and the detour factor is always smaller than unity.

i. **Radiation yield**: The average part of the primary kinetic energy of an electron that is converted into bremsstrahlung energy slows down particles to rest.It is important only for electrons [30].

(2.17.3) List of materials The list includes 26 elements, 48 compounds and mixtures. The information used by PSTAR and ASTAR consists of:

a. The atomic numbers and fractions by weight of the constituent atoms;

b. The density at 20 °C, 101 325 Pa (1 atm);

c. The mean excitation energy of the material, which is a key parameter in Bethe's stopping power formula.

(2.17.4) List of energies

Energies must be $\leq 0.001\,\mathrm{MeV}$, or $\geq 10\,000\,\mathrm{MeV}$ for protons or $1000\,\mathrm{MeV}$ for helium ions [30].

(2.17.5) Nuclear stopping powers

Cross sections for the flexible scattering of charged particles can be calculated by means of a classical mechanical calculation of the orbit using a method of Everhart, Stone and Carbone . The nuclear stopping powers are calculated using the relationship between the angles of the deviation and the energy transferred to the recoil atom in the flexible collision [30].

(2.18) Ziegler formulae

According to Bohr's ideas, nuclear nuclei with heavy nuclei are positively charged. Bohr concluded that the loss of energies for ions is divided into two components: nuclear stopping power, which represents the loss of energy to the atomic positive and the electronic stopping power, which represents the loss of energy to the electrons targeted. Ziegler correctly deduced that the discontinuation of electrons was greater than the nuclear halt of active ions and his account was limited because he did not know the state of the ion in this substance, such as an effective charge in its interaction with the target atoms. The most useful way appeared to be [42]

$$\frac{S_{HI}(V, Z_2)}{(Z_{HI}^*(V))^2} = \frac{S_P(V, Z_2)}{(Z_P^*(V))^2} \dots\dots\dots\dots(2-61)$$

Where $S_{HI}(V, Z_2)$ is the electronic stopping of a heavy ion of atomic number, Z_{HI} at some velocity, V, and with an effective charge at that velocity of Z_{HI}^*. This is related to similar quantities for protons, p, at the same velocity in the same material.

- This expression is not theoretically justified.
- It is assumed that the effective charge of energetic ions does not depend on the material in it, which is a function of ion velocity only
- It is assumed that protons and heavy ions interact in a similar manner to the same material.
- It is assumed that all the insulating effects between heavy ionic electrons and electrons in the solids do not contribute significantly to stopping.
- . This expression remains the basis of most scaling tables because it is the most accurate method that has been detected to predict stopping for partially stripped energetic ions
- In practice most authors use for values of Z_p^* the average charge state of protons out of thin foils. [42]

(2.18.1) ^{4}He Stopping at high energies (above 10 MeV)

High energy stopping can be defined as a stop of projectiles that are energetic enough to be completely abstract from electrons

The Bethe-Block stopping power formula may be written as: [42]

$$-\frac{dE}{dx}=\frac{4\pi e^4 Z_2}{m_e V^2 M_2} Z_1^2[L_{0+}Z_1L_1+Z_1^2L_2] \;\ldots\ldots..(2-62)$$

Where $L_0=f(\beta)-\ln I-\sum\frac{C_i}{Z_2}-\frac{\delta}{2}\;\ldots\ldots\ldots(2-63)$

$$L_1=\frac{2L_0}{Z_2^{1/2}}F\left(\frac{V}{V_0 Z_2^{1/2}}\right)\ldots\ldots\ldots\ldots.(2-64)$$

$$L_2=-1.2(V_0/V)^2\ldots\ldots\ldots\ldots.(2-65)$$

Where the terms are defined as:

V =relativistic velocity , V_0 =Bohr velocity $=2.188\times10^8\ cm/sec$

I= Means the excitation energy that is constant for each target element

C_i=Shell correction of the i shell of the target atom

δ= Density correction at very high energies

$$f(\beta) = \ln\left(\frac{2m_e c^2\beta^2}{I-\beta^2}\right) - \beta^2$$

$F(x)$ =a function for the Z_1^3 correction, calculated by Ashley et. al. , and also Jackson and McCarthy. A convenient analytical form they have found to be[42] :

$F(x) = (\frac{1}{x^2})$ exp -(1.045+0.09833x) ... . (2 − 66)

Which is valid for values F(x) $> x^{-2}$(for use in eq.(2-64) the value of $x = \frac{V}{V_0} Z_2^{-1/2}$).

The termL_0, defined by eq. (2-63), is the traditional term for high stopping power. Its basic term is the average potential of excitement, I, while the term (C_i/Z_2) is a second order shell correction term. The mean excitation potential, I, is theoretically defined by the formula [42].

lnI=$\sum_n f_n\, lnE_n$ ... . (2 − 67)

Where E_n ,and f_n are all possible energy transitions and corresponding oscillator strengths for target atom . The third term in L_0 is the shell correction term [42] .This term has been examined and its analytic expressions have been derived for each target element in [106]. The final term in L_0 is the density correction term, which is called the Z_1^4 correction, eq. (2-65), is merely the next term of the Bloch expansion. Lindhard has evaluated it as $L_2 = -1.2(V_0/V)^2$ [42]

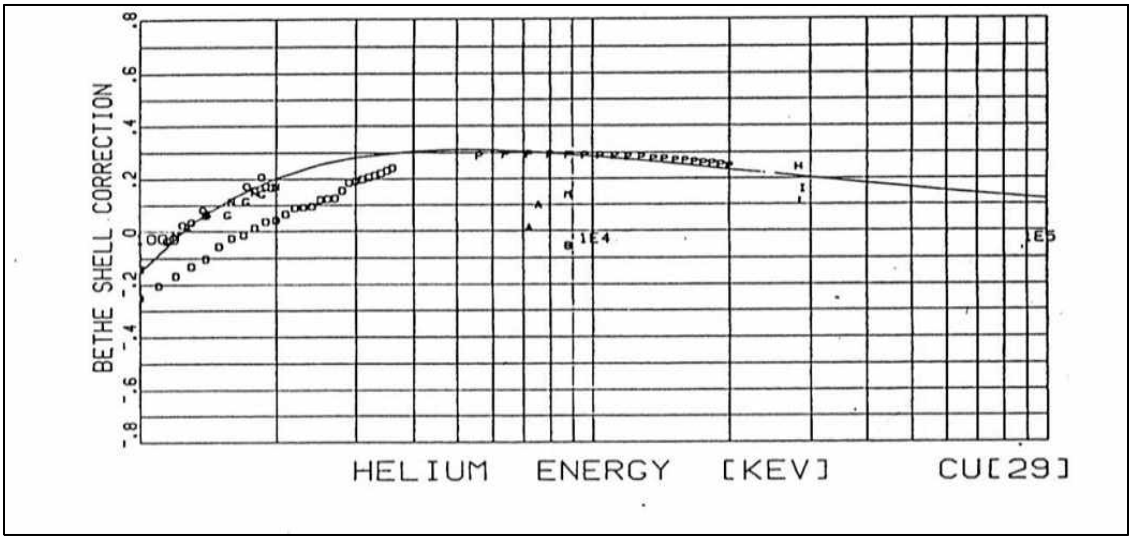


Figure (2-13) Typical shell-correction terms are shown for high energy He stopping in Cu. [42]

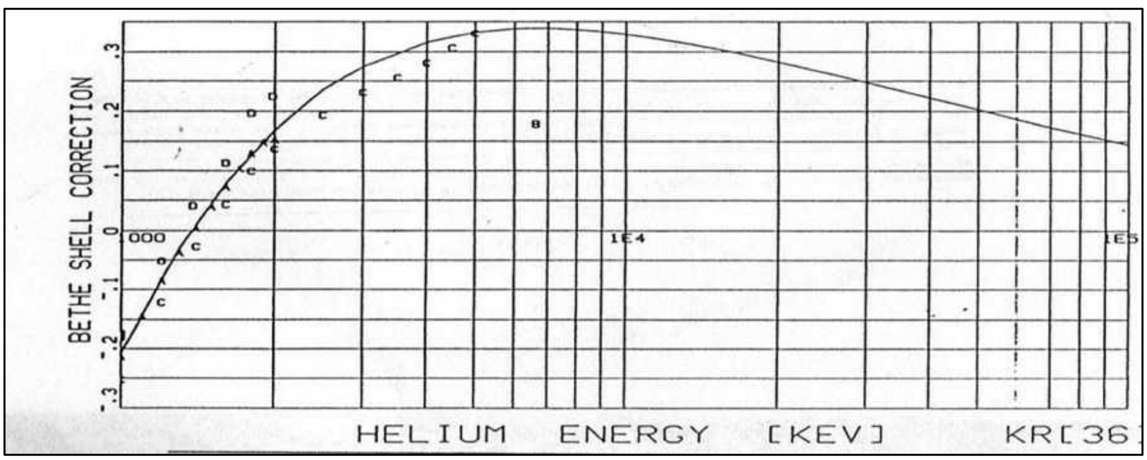


Fig.(2-14) Bethe shell-correction term for high energy He in Kr [42]

They have evaluated the high energy stopping of He ions in matter by building the first curves to correct the shell term of eq. (2-62). This has been done by taking the H shell correction curves of [107], removing the Z_1^3 and Z_1^4 effects which were included in them, and then displaying new curves evaluated for He ions. The data were superimposed on these curves. The curves were shifted to go through the data. This was especially important for targets with an atomic number of less than 15, where shifts of several percent (of stopping) were required. Then new curves were created to correct the shell for all elements for which there were no data by assuming shifts linearly interpolated from nearby element for which there were data. Figures (2-13) and (2-14), showed typical fitted shell-correction terms [42].

(2.18.2)^{4}He stopping at low energies (lkeV − 10 MeV)

(2.18.2.1)Low energy: stopping theory

If there is a target element and there are no suitable experimental data there are two types of information about the detailed stopping information available are:.

- Experimental data for the stopping of ^{4}He ions in elements with an atomic number similar to that element. For example, there are no reported stopping values for ^{4}He ions in Zn ($Z_2 = 30$), but considerable data exist for Cu(29) and Ge(3 2). Theoretical calculations allow us to interpolate between Cu and Ge to obtain stopping values for Zn [42].
- The second type of data available is the larger data-base of experimental hydrogen ion stopping in matter which is catalogued in [108]. If we can scale from H to He ions, we can use the experimental stopping data of H in Zn to predict the stopping of He in Zn [42]. The theoretical calculations are done in two steps:-

  First, evaluate the accuracy of the theoretical calculations and then use these calculations in a limited manner for the purpose of interpolation and extrapolation from the available empirical data. The only way that a user can judge the accuracy of the results is to compare the theory and experience of the expected curves of He stopping power. They have looked at two different theoretical approaches to stopping the low energy of ions in dielectric media [42].

The local oscillator model of stopping on the basis of formalism of Nesbet and Ziegler. Advantages of this model , that it is easy to calculate with one expression to be evaluated for all ion speeds. The free-electron gas model of stopping, on the basis of formalism of Lindhard and Scharff as expanded by Lindhard and Winther . This approach is much more detailed in its view of the interaction between the ion and the target medium. Both theories are based on approximation of disturbances, so the loss of energy is proportional to the square of particle charge. The ions are assumed to be completely devoid of their electrons. They both treat the interactions as a property of the target only, so that a linear description of these properties may be applied. If the theoretical approach is accurate, the effective charge of the ion can be defined as [42] :

$$[\, Z_1^*(V, Z_2)]^2 \equiv \frac{(-\frac{dE}{dx})_{exp.}}{(-\frac{dE}{dx})_{Theory}} Z_1^2 \;\ldots\ldots\ldots\ldots\; (2-68)$$

Where Z_1^* the effective is charge of the ion and will vary with ion speed and target element.

It is noted that this definition of effective charge differs from the definition of the mean charge state of the ion. Therefore definition put into Z_1^*. [42]

(2.18.2.2) Low-energy: ion effective charge

They have defined an empirical ion effective charge, Z_1^*, in eq. (2-68) because they do not know an accurate theoretical way to calculate this quantity. The theoretical approaches to stopping this problem were avoided by neglecting any dynamic interaction of the target on the ion ,where they basically assumes a simple stopping function [42]:

$$-\frac{dE}{dx} = \frac{\text{Projectile}}{P(\,p_{z_1}{}^*, V\,)} \times \frac{\text{Target}}{T(p_{z_2}, V)} \ldots\ldots\ldots\ldots (2\text{-}69)$$

Where P is only a function of ion properties $p_{z_1}{}^*$ it is the dynamic distribution of ion charge, V is speed of ion , and T it is a function of the distribution of the target charge, p_{z_2} [42].

_**Greatly simplified rules of ion stopping powers:**

A. The stopping power depends on the distribution of individual ions
B. The distribution of charge the target material
C. It does not depend on the dynamic details of ion-target interaction
D. It is possible to predict the stopping of the ion if we can approximate the function of P. We can also know to stop another ion in the same material, at the same speed

E. Solid targets differ from dense gas targets in that ionic effective charge distribution is different [42].

It is not expected that eq. (2-69) and corollaries (A-E) a above will be quite accurate, because there must be conditions for dynamic interaction terms between solid and ions, and specific interactions to the relative target/ion electron energy levels. But they can provide great evidence proving that the term interaction is remarkably small for the energies and objectives which have experimental data. If this term is small they can predict the stopping of He ions in any element by looking not only at the published stopping data for this element, but also the stop data in the nearby elements as well as the hydrogen ion stopping in this element. [42]

(2.18.3) Heavy ion stopping

The first evidence in evaluating the validity of eq. (2-69) is the determination of whether a unique ion function, P, exists, they have evaluated the situation for energetic heavy ions, and have obtained an empirical analytic representation of function P, based, upon the work of Northcliffe and Forster et al. They compare the ratio of the stopping of a heavy ion, $(-\frac{dE}{dx})_{HI}$, to that of a proton, $(-\frac{dE}{dx})_{P}$ at the same velocity in the same material, they have from eq. (2-69) [42] :

$$\frac{(-\frac{dE}{dx})_{HI}}{(-\frac{dE}{dx})_{P}} = \frac{P(Z_{HI}^{*}.V)}{P(Z_{P}^{*}.V)} \times \frac{T(Z_2.V)}{T(Z_2.V)} \dots\dots\dots (2-70)$$

Where the target functions, T, will be identical and cancel out. They have found from an analysis of many heavy ion stopping measurements, which included 127 ion-target combinations, that to an accuracy of about 5% they have: [42]

$$\frac{P(Z_{HI}^{*}.V)}{P(Z_{P}^{*}.V)} = Z_{HI}^{2}[1-[1.034-0.1777\exp(-0.08114\,Z_{HI})]\exp(-V_2)]^2 \dots\dots\dots (2-71)$$

Where $V_2 = V_1 + 0.0378\sin(\frac{V_1\pi}{2})$, and $V_1 = 0.886(\frac{V}{V_0})Z_{HI}^{-2/3}$

Note that this function contains only the ion parameters Z_1 and V, and it is valid for all target materials. They can plot the results by defining an experimental and calculated reduced stopping $<(-\frac{dE}{dx})>$: [42]

$$<(-\frac{dE}{dx})>_{exp.} = \frac{(-\frac{dE}{dx})_{HI}}{Z_{HI}^2(-\frac{dE}{dx})_P} \ldots\ldots..(2-72)$$

Where $(-\frac{dE}{dx})_{HI}$ and $(-\frac{dE}{dx})_P$ are experimental stopping powers, and

$$<(-\frac{dE}{dx})>_{cale.} = (\frac{1}{Z_{HI}})^2 \frac{P(Z_{HI}^*.V)}{P(Z_P^*.V)} \ldots\ldots\ldots.(2-73)$$

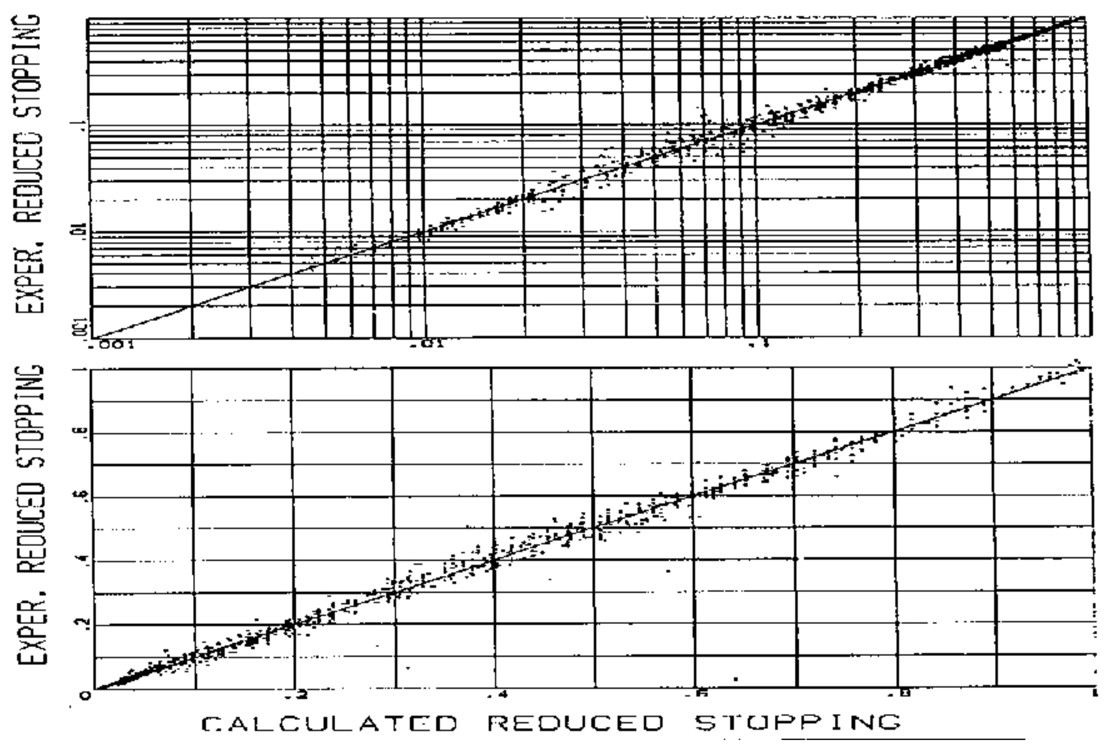


Fig.(2-15) Showed are the reduced stopping powers of 127 ion – target combination of energetic heavy ions in solids. [42]

Where the ion function P ratio , is given by eq. (2-71). Figure (2-15) shows the comparison between experimental and calculated reductions, which includes ions ranging from C to U, in both solid and gaseous targets ranging from Be to Au, at energies above 0.2 MeV/amu. They believe that this minimum limit on energy may be caused by the fact that eq. (2-71) describes the numerator only , $P(Z^*_{HI}.V)$, which is the effective charge of the heavy ion, while $P(Z^*_P.V)$ is a constant which means that the proton is completely [42] stripping for energy above200 keV . Eq. (2-71) becomes inaccurate below 200 keV/amu, perhaps due to the need to account for the proton effective charge term, $P(Z_P, V)$ at lower energies. [42]

(2.18.4) Formulae for fitted stopping powers

$$\text{Reduced} = I \equiv \frac{32.53 M_2 E}{Z_1 Z_2 (M_1+M_2)(Z_1^{2/3}+Z_2^{2/3})^{1/2}} \ldots\ldots..(2-74)\ [42]$$

Where E=ion energy in KeV

For $I < 0.1$ $\quad S_n = 1.593 I^{1/2} \ldots\ldots\ldots.(2-75)$

$$0.01 \leq I \leq 10 \qquad S_n = 1.7 I^{1/2}\left[\frac{\ln(I + exp1)}{1 + 6.8I + 3.4I^{3/2}}\right] \ldots\ldots\ldots(2-76)$$

$$I > 10 \qquad S_n = \frac{ln 0.47I}{2I} \ldots\ldots\ldots.(2-77)$$

S_n=Nuclear stopping power

Low energy electronic stopping (S_e) [42]

Formulae valid for (1KeV-10MeV)

Energy in KeV , Coefficients are in table (3-5) for solids

$$\frac{1}{S_e} = \frac{1}{S_{LOW}} + \frac{1}{S_{HIGH}} \ldots\ldots.(2-78)$$

$$S_{LOW} = A_1 E^{A_2} \ldots\ldots..(2-79)$$

$$S_{HIGH} = \left(\frac{A_3}{E/1000}\right)\ln\left[1 + \left(\frac{A_4}{E/1000}\right) + \left(\frac{A_5 E}{1000}\right)\right] \ldots\ldots\ldots\ldots(2-80)$$

High energy electronic stopping (S_e) [42]

Formulae valid for E>10 MeV, coefficients are in table (3-5)

$$S_e = \exp(A_6 + A_7 EE + A_8 EE^2 + A_9 EE^3 \ldots\ldots\ldots..(2-81)$$

Where $EE = \ln\frac{1}{E}$ and E= ion energy in MeV [42] .

Data Reduction and Analysis

(3.1) Chemical compositions of the human tissues and materials

The chemical composition of human tissues is of great importance in the study of micro-distributions in the treatment of human radiation. At high energies, initial interactions of photons are almost independent of chemical composition, whereas secondary reactions primarily responsible for biological effects depend on chemical composition [29].

The chemical composition of human tissues is usually given in terms of biological molecules (eg, protein, fat, vitamins, etc.), and they are not readily adaptable to dosimetry calculations. In the usual energies of machine therapy, the effects of molecular association are negligible, and one can represent human tissue through its atomic structures (% by weight of elements). The average atomic structures of various biological molecules are readily available, and the average atomic structures of human tissues can be calculated from these data [29] .The chemical composition of human tissues generally depends on strain, diet, age, sex, health, etc., and may vary significantly (5-10%) among individuals [29].

In this study, the mass stopping power of the alpha- particle interacting with four human tissues and three solid materials which are:

1- Muscle tissue
2- Breast tissue
3- Ovary tissue
4- Lung tissue
5- Aluminum dioxide (AL_2O_3)
6- Zirconium dioxide(ZrO_2)
7- Silicon dioxide(SiO_2)

Table (3-1) shows the chemical composition for Breast, Ovary ,Lung and Muscle, tissues.

Table (3-1) Chemical composition of various human tissues and fractional weight of the elements per tissue [29,49]

Human Tissue	Density g/cm^3	Composition (element: fraction) by weight[								
		H	C	N	O	Na	P	S	Cl	K
Breast tissue	1.020	0.106	0.332	0.030	0.527	0.001	0.001	0.002	0.001	------
Ovary tissue	1.050	0.105	0.093	0.024	0.768	0.002	0.002	0.002	0.002	0.002
Lung tissue	1.050	0.103	0.105	0.031	0.749	0.002	0.002	0.003	0.003	0.002
Muscle tissue	1.0599	0.103	0.099	0.032	0.757	0.001	0.002	0.003	0.001	0.003

Table (3-2) Chemical composition for AL_2O_3 , ZrO_2, SiO_2 and fractional weight of the elements [70]

substances	Density g/cm^3	Chemical Composition		
		Symbol	Atomic number	Fraction by weight
SiO_2	2.32	Si	14	0.467435
		O	8	0.532565
AL_2O_3	3.97	AL	13	0.529251
		O	8	0.470749
ZrO_2	5.68	Zr	40	0.7403
		O	8	0.2597

The atomic number for (breast, ovary, lung and muscle) tissues and ZrO_2, AL_2O_3 . SiO_2 were calculated according to eq.(2-33) .The results tabulated in table (3-3).

Table (3-3) The effective atomic number for (breast, ovary, lung and muscle) tissues and ZrO_2, AL_2O_3 . SiO_2 materails

Material	$Z_{effective}$	Tissue	$Z_{effective}$
SiO_2	10.8046	Breast	6.5982
AL_2O_3	10.5992	Ovary	7.1290
ZrO_2	30.8565	Lung	7.1287
		Muscle	7.1310

(3.2) Mass stopping power for alpha particle interaction with tissues and materials

(3.2.1) Bethe formulae

The mass stopping power for each element in (breast, ovary, lung and muscle) tissues ,and each element in(ZrO_2, AL_2O_3 . SiO_2) were calculated according to eq.(1-2) for alpha particle energies from (0.01-200) MeV.The results are tabulated in table (3-6).

Ionization energy ($I_{ave.}$) was calculated for each elements involved in the composition of each of the four tissues and the three substances using the eq. (2-36).Table (3-4) gives the ionization potential for each elements considered in this study.

Table (3-4) Ionization potential and atomic numbers of elements considered in this study

Atomic number	Symbol	Atomic weight (amu)	Density		Ionization potential$\times 10^{-4}$ (MeV)
			gm/cm^3	$atoms/cm^3 \times 10^{+22}$	
1	H_2	1.00794	0.0715	4.2716	0.6856
6	C	12.011	2.2530	11.296	1.0039
7	N_2	14.00674	1.0260	4.4111	1.0895
8	O_2	15.9994	1.4260	5.367	1.1769
11	Na	22.989768	0.97	2.5408	1.4464
13	AL	26.981539	2.7020	6.0305	1.6300
14	Si	28.0855	2.3212	4.977	1.7225
15	P	30.973762	1.8219	35.422	1.8155
16	S	32.066	2.0686	3.8848	1.9088
17	CL	35.4527	1.8956	3.2189	2.0024
19	K	39.0983	0.8632	1.3295	2.1905
40	Zr	91.224	6.49	4.2845	4.1957

(3.2.2) Ziegler formulae

The mass stopping power of the alpha particle interaction with the chemical composition of human tissues (breast, ovary, lung and muscle) and materials (SiO_2, AL_2O_3 , ZrO_2) for the energy range(0.01-200) MeV is calculated using Ziegler equations (2-74),(2-75),(2-76),(2-77),(2-78),(2-79),(2-80) and (2-81) were programmed using the Matlab program and tabulated in tables (3-7) where $A_1 A_2$,A_3,A_4,A_5,A_6,A_7,A_8 and $A_9$are fitting constants which are shown in table (3-5)

Table(3-5) Coefficients for mass stopping power of helium[42]

Target	Coefficients for Low Energy Helium Stopping					Coefficients for High Energy Helium Stopping			
	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9
$_{1}H$	0.9661	0.4126	6.92	8.831	2.582	2.371	0.5462	-0.07932	-0.006853
$_{6}C$	4.232	0.3877	22.99	35.00	7.993	3.588	0.3921	-0.09935	-0.007804
$_{7}N$	2.510	0.4752	38.26	13.02	1.892	3.759	0.4094	-0.09646	-0.007661
$_{8}O$	1.766	0.5261	37.11	15.24	2.804	3.782	0.3734	-0.1011	-0.007874
$_{11}Na$	9.894	0.3081	23.65	0.384	92.93	3.898	0.3191	-0.1086	-0.008271
$_{13}AL$	2.500	0.6250	45.70	0.100	4.359	4.024	0.3113	-0.1093	-0.008306
$_{14}Si$	2.100	0.6500	49.34	1.788	4.133	4.077	0.3074	-0.1089	-0.008219
$_{15}P$	1.729	0.6562	53.41	2.405	3.845	4.124	0.3023	-0.1094	-0.008240
$_{16}S$	1.402	0.6791	58.98	3.528	3.211	4.164	0.2964	-0.1101	-0.008267
$_{17}CL$	1.117	0.7044	69.69	3.705	2.156	4.210	0.2936	-0.1103	-0.008270
$_{19}K$	8.554	0.3817	83.61	11.84	1.875	4.300	0.2903	-0.1103	-0.008259
$_{40}Zr$	10.99	0.41	163.9	7.1	1.052	4.548	0.1572	-0.1256	-0.008901

(3.2.3) SRIM program

The mass stopping power of the alpha particle interaction with the chemical composition of human tissues (breast, ovary, lung and muscle) and materials (SiO_2, AL_2O_3 , ZrO_2) for the energy range (0.01-200) MeV is calculated by SRIM program . The results were tabulated in table (3-8)

(3.2.4)ASTAR program

The mass stopping power of the alpha particle interaction with the materials (SiO_2, AL_2O_3) for the energy range (0.01-200) MeV is calculated by ASTAR program. The results were tabulated in Table (3-9)

(3.2.5)Energy loss for alpha particle in tissues and materials

The calculation of mass stopping power due to alpha particle travelling in (breast, ovary, lung and muscle) tissues and materials (SiO_2, AL_2O_3, ZrO_2) as a compound of several elements, eq.(2-32) for the compound is used. And by using the Matlab computer program the total mass stopping power to the (breast, ovary lung and muscle) ,and, (SiO_2, AL_2O_3, ZrO_2) for Bethe and Ziegler formulae ,SRIM program , were calculated in addition to the method of ASTAR in (SiO_2, AL_2O_3) .The computer program calculated the average mass stopping power for three methods for all tissues and ZrO_2,and for four methods in AL_2O_3 , SiO_2 that have been used in the present work for all these tissues and materiales. The results were tabulated in tables (3-10), (3-11), (3-12), (3-13), (3-14).

Table (3-6) Mass stopping power for alpha particle interacts with the chemical composition of human tissues (breast, ovary,lung and muscle) and with the chemical composition of materials (SiO_2, AL_2O_3, ZrO_2) **by Bethe**

E(MeV)	Mass Stopping power$\times 10^3$ MeV/(gm/cm^2) By Bethe											
	H	C	N	O	Na	P	S	CL	K	Si	AL	Zr
0.0100	-	-	-	-	-	-	-	-	-	-	-	-
0.0110	-	-	-	-	-	-	-	-	-	-	-	-
0.0120	-	-	-	-	-	-	-	-	-	-	-	-
0.0130	-	-	-	-	-	-	-	-	-	-	-	-
0.0140	-	-	-	-	-	-	-	-	-	-	-	-
0.0150	-	-	-	-	-	-	-	-	-	-	-	-
0.0160	-	-	-	-	-	-	-	-	-	-	-	-
0.0170	-	-	-	-	-	-	-	-	-	-	-	-
0.0180	-	-	-	-	-	-	-	-	-	-	-	-
0.0200	-	-	-	-	-	-	-	-	-	-	-	-
0.0225	-	-	-	-	-	-	-	-	-	-	-	-
0.0250	-	-	-	-	-	-	-	-	-	-	-	-
0.0275	-	-	-	-	-	-	-	-	-	-	-	-
0.0300	-	-	-	-	-	-	-	-	-	-	-	-
0.0325	-	-	-	-	-	-	-	-	-	-	-	-
0.0350	-	-	-	-	-	-	-	-	-	-	-	-
0.0375	-	-	-	-	-	-	-	-	-	-	-	-
0.0400	-	-	-	-	-	-	-	-	-	-	-	-
0.0450	-	-	-	-	-	-	-	-	-	-	-	-
0.0500	-	-	-	-	-	-	-	-	-	-	-	-
0.0550	-	-	-	-	-	-	-	-	-	-	-	-
0.0600	-	-	-	-	-	-	-	-	-	-	-	-
0.0650	-	-	-	-	-	-	-	-	-	-	-	-
0.0700	-	-	-	-	-	-	-	-	-	-	-	-
0.0800	-	-	-	-	-	-	-	-	-	-	-	-
0.0900	-	-	-	-	-	-	-	-	-	-	-	-
0.1000	-	-	-	-	-	-	-	-	-	-	-	-
0.1100	-	-	-	-	-	-	-	-	-	-	-	-
0.1200	-	-	-	-	-	-	-	-	-	-	-	-
0.1300	0.6698	-	-	-	-	-	-	-	-	-	-	-
0.1400	1.8239	-	-	-	-	-	-	-	-	-	-	-
0.1500	2.7467	-	-	-	-	-	-	-	-	-	-	-
0.1600	3.4910	-	-	-	-	-	-	-	-	-	-	-
0.1700	4.0954	-	-	-	-	-	-	-	-	-	-	-
0.1800	4.5889	-	-	-	-	-	-	-	-	-	-	-
0.2000	5.3263	0.5018	0.0340	-	-	-	-	-	-	-	-	-
0.2250	5.9231	1.0445	0.6290	0.2368	-	-	-	-	-	-	-	-
0.2500	6.2878	1.4219	1.0482	0.6955	-	-	-	-	-	-	-	-
0.2750	6.5032	1.6889	1.3493	1.0289	0.1634	-	-	-	-	-	-	-
0.3000	6.6198	1.8798	1.5686	1.2751	0.4674	-	-	-	-	-	0.0314	-
0.3250	6.6699	2.0168	1.7297	1.4588	0.7012	-	-	-	-	0.1172	0.3006	-

0.3500	6.6742	2.1148	1.8483	1.5969	0.8830	0.1739	0.0157	-	-	0.3504	0.5126	-
0.3750	6.6470	2.1842	1.9355	1.7010	1.0256	0.3663	0.2248	0.0759	-	0.5370	0.6813	-
0.4000	6.5980	2.2321	1.9991	1.7794	1.1382	0.5222	0.3950	0.2482	0.0019	0.6875	0.8167	-
0.4500	6.4592	2.2834	2.0764	1.8812	1.2984	0.7543	0.6500	0.5079	0.2928	0.9097	1.0146	-
0.5000	6.2918	2.2959	2.1097	1.9342	1.3993	0.9124	0.8256	0.6884	0.4979	1.0592	1.1455	-
0.5500	6.1133	2.2853	2.1162	1.9567	1.4618	1.0215	0.9485	0.8160	0.6454	1.1606	1.2324	-
0.6000	5.9331	2.2607	2.1057	1.9596	1.4988	1.0972	1.0351	0.9071	0.7529	1.2293	1.2897	-
0.6500	5.7564	2.2276	2.0846	1.9498	1.5184	1.1493	1.0961	0.9725	0.8319	1.2752	1.3262	-
0.7000	5.5856	2.1895	2.0568	1.9317	1.5259	1.1845	1.1387	1.0192	0.8903	1.3049	1.3483	-
0.8000	5.2664	2.1067	1.9906	1.8812	1.5179	1.2214	1.1870	1.0750	0.9646	1.3322	1.3638	0.0551
0.9000	4.9784	2.0222	1.9191	1.8220	1.4926	1.2308	1.2045	1.0992	1.0030	1.3335	1.3566	0.1803
1.0000	4.7198	1.9405	1.8477	1.7604	1.4587	1.2245	1.2044	1.1049	1.0199	1.3204	1.3371	0.2680
1.1000	4.4875	1.8631	1.7788	1.6995	1.4210	1.2092	1.1939	1.0995	1.0235	1.2992	1.3111	0.3306
1.2000	4.2782	1.7908	1.7135	1.6408	1.3820	1.1888	1.1772	1.0875	1.0189	1.2737	1.2818	0.3758
1.3000	4.0889	1.7234	1.6522	1.5851	1.3431	1.1656	1.1569	1.0714	1.0090	1.2459	1.2511	0.4087
1.4000	3.9170	1.6608	1.5947	1.5324	1.3051	1.1410	1.1348	1.0530	0.9958	1.2173	1.2201	0.4326
1.5000	3.7603	1.6027	1.5410	1.4829	1.2685	1.1159	1.1116	1.0333	0.9806	1.1886	1.1895	0.4499
1.6000	3.6169	1.5486	1.4908	1.4364	1.2334	1.0909	1.0882	1.0129	0.9641	1.1604	1.1596	0.4623
1.7000	3.4851	1.4983	1.4439	1.3927	1.1999	1.0663	1.0649	0.9925	0.9471	1.1328	1.1307	0.4709
1.8000	3.3636	1.4514	1.4000	1.3517	1.1680	1.0422	1.0420	0.9722	0.9298	1.1061	1.1029	0.4766
2.0000	3.1469	1.3665	1.3203	1.2768	1.1089	0.9964	0.9980	0.9328	0.8954	1.0556	1.0507	0.4818
2.2500	2.9161	1.2745	1.2335	1.1948	1.0430	0.9437	0.9469	0.8866	0.8541	0.9980	0.9917	0.4808
2.5000	2.7202	1.1952	1.1583	1.1236	0.9849	0.8960	0.9003	0.8442	0.8156	0.9463	0.9390	0.4750
2.7500	2.5516	1.1262	1.0927	1.0611	0.9333	0.8530	0.8581	0.8055	0.7800	0.8998	0.8919	0.4666
3.0000	2.4048	1.0655	1.0348	1.0059	0.8873	0.8141	0.8197	0.7702	0.7473	0.8579	0.8495	0.4568
3.2500	2.2758	1.0117	0.9833	0.9567	0.8460	0.7787	0.7848	0.7380	0.7172	0.8200	0.8113	0.4464
3.5000	2.1613	0.9636	0.9373	0.9126	0.8087	0.7466	0.7529	0.7085	0.6895	0.7856	0.7767	0.4358
3.7500	2.0590	0.9204	0.8959	0.8728	0.7750	0.7172	0.7237	0.6815	0.6640	0.7542	0.7452	0.4252
4.0000	1.9669	0.8814	0.8583	0.8367	0.7442	0.6903	0.6969	0.6566	0.6404	0.7255	0.7165	0.4148
4.5000	1.8078	0.8134	0.7929	0.7737	0.6902	0.6426	0.6494	0.6124	0.5984	0.6747	0.6657	0.3950
5.0000	1.6749	0.7561	0.7377	0.7204	0.6442	0.6017	0.6085	0.5742	0.5620	0.6313	0.6224	0.3766
5.5000	1.5620	0.7072	0.6905	0.6748	0.6047	0.5662	0.5730	0.5411	0.5302	0.5937	0.5849	0.3598
6.0000	1.4647	0.6648	0.6495	0.6351	0.5701	0.5351	0.5418	0.5119	0.5021	0.5608	0.5522	0.3444
6.5000	1.3800	0.6278	0.6136	0.6004	0.5398	0.5076	0.5142	0.4860	0.4772	0.5317	0.5233	0.3302
7.0000	1.3055	0.5950	0.5819	0.5696	0.5128	0.4830	0.4895	0.4629	0.4549	0.5058	0.4976	0.3173
8.0000	1.1802	0.5397	0.5283	0.5175	0.4670	0.4412	0.4474	0.4234	0.4166	0.4616	0.4538	0.2944
9.0000	1.0788	0.4947	0.4845	0.4750	0.4294	0.4067	0.4126	0.3907	0.3849	0.4252	0.4178	0.2748
10.0000	0.9948	0.4573	0.4481	0.4395	0.3980	0.3777	0.3834	0.3632	0.3581	0.3947	0.3876	0.2579
11.0000	0.9241	0.4256	0.4173	0.4095	0.3713	0.3529	0.3584	0.3397	0.3352	0.3687	0.3619	0.2431
12.0000	0.8635	0.3985	0.3908	0.3837	0.3483	0.3316	0.3369	0.3193	0.3153	0.3463	0.3398	0.2301
13.0000	0.8111	0.3748	0.3678	0.3612	0.3283	0.3129	0.3180	0.3015	0.2979	0.3267	0.3204	0.2186
14.0000	0.7652	0.3541	0.3476	0.3415	0.3106	0.2964	0.3013	0.2858	0.2825	0.3094	0.3034	0.2083
15.0000	0.7246	0.3358	0.3297	0.3240	0.2950	0.2817	0.2865	0.2718	0.2688	0.2940	0.2882	0.1990
16.0000	0.6885	0.3194	0.3137	0.3083	0.2809	0.2686	0.2732	0.2592	0.2565	0.2802	0.2747	0.1907
17.0000	0.6561	0.3047	0.2993	0.2943	0.2683	0.2568	0.2612	0.2479	0.2454	0.2678	0.2624	0.1830
18.0000	0.6268	0.2914	0.2863	0.2816	0.2569	0.2460	0.2503	0.2376	0.2353	0.2566	0.2514	0.1760
20.0000	0.5761	0.2683	0.2637	0.2594	0.2370	0.2272	0.2313	0.2196	0.2176	0.2369	0.2320	0.1637
22.5000	0.5240	0.2445	0.2404	0.2366	0.2164	0.2078	0.2116	0.2010	0.1992	0.2166	0.2120	0.1508
25.0000	0.4812	0.2248	0.2212	0.2178	0.1993	0.1917	0.1952	0.1855	0.1840	0.1997	0.1955	0.1399
27.5000	0.4453	0.2084	0.2050	0.2019	0.1850	0.1781	0.1814	0.1724	0.1711	0.1855	0.1815	0.1307
30.0000	0.4148	0.1943	0.1913	0.1884	0.1728	0.1665	0.1696	0.1613	0.1601	0.1734	0.1696	0.1227

32.5000	0.3885	0.1822	0.1794	0.1767	0.1622	0.1564	0.1594	0.1516	0.1505	0.1628	0.1593	0.1157
35.0000	0.3655	0.1716	0.1690	0.1665	0.1529	0.1476	0.1504	0.1431	0.1421	0.1536	0.1502	0.1096
37.5000	0.3453	0.1622	0.1598	0.1575	0.1447	0.1398	0.1425	0.1355	0.1347	0.1455	0.1422	0.1041
40.0000	0.3274	0.1540	0.1517	0.1495	0.1375	0.1328	0.1354	0.1288	0.1281	0.1382	0.1351	0.0993
45.0000	0.2970	0.1398	0.1378	0.1359	0.1251	0.1210	0.1234	0.1174	0.1167	0.1259	0.1230	0.0908
50.0000	0.2721	0.1283	0.1264	0.1247	0.1149	0.1112	0.1134	0.1080	0.1074	0.1157	0.1130	0.0839
55.0000	0.2513	0.1186	0.1169	0.1154	0.1063	0.1030	0.1051	0.1001	0.0996	0.1071	0.1047	0.0780
60.0000	0.2336	0.1104	0.1088	0.1074	0.0990	0.0960	0.0980	0.0933	0.0929	0.0999	0.0975	0.0729
65.0000	0.2184	0.1033	0.1019	0.1006	0.0928	0.0900	0.0919	0.0875	0.0871	0.0936	0.0914	0.0686
70.0000	0.2052	0.0971	0.0958	0.0946	0.0873	0.0848	0.0865	0.0824	0.0821	0.0881	0.0860	0.0647
80.0000	0.1834	0.0869	0.0857	0.0847	0.0782	0.0760	0.0776	0.0739	0.0737	0.0790	0.0771	0.0583
90.0000	0.1660	0.0787	0.0777	0.0768	0.0710	0.0690	0.0705	0.0671	0.0669	0.0717	0.0700	0.0532
100.0000	0.1518	0.0721	0.0712	0.0703	0.0650	0.0633	0.0646	0.0616	0.0614	0.0657	0.0642	0.0489
110.0000	0.1399	0.0665	0.0657	0.0649	0.0601	0.0585	0.0597	0.0569	0.0568	0.0608	0.0593	0.0453
120.0000	0.1299	0.0618	0.0610	0.0603	0.0558	0.0544	0.0556	0.0530	0.0529	0.0565	0.0551	0.0423
130.0000	0.1213	0.0577	0.0570	0.0564	0.0522	0.0509	0.0520	0.0496	0.0495	0.0529	0.0516	0.0396
140.0000	0.1139	0.0542	0.0536	0.0530	0.0491	0.0479	0.0489	0.0466	0.0465	0.0497	0.0485	0.0373
150.0000	0.1073	0.0511	0.0505	0.0500	0.0463	0.0452	0.0462	0.0440	0.0440	0.0469	0.0458	0.0353
160.0000	0.1015	0.0484	0.0478	0.0473	0.0439	0.0428	0.0438	0.0417	0.0417	0.0444	0.0433	0.0335
170.0000	0.0964	0.0460	0.0454	0.0449	0.0417	0.0407	0.0416	0.0397	0.0396	0.0422	0.0412	0.0319
180.0000	0.0917	0.0438	0.0433	0.0428	0.0397	0.0388	0.0396	0.0378	0.0378	0.0402	0.0392	0.0304
200.0000	0.0838	0.0400	0.0395	0.0391	0.0363	0.0355	0.0363	0.0346	0.0346	0.0368	0.0359	0.0279

Table (3-7) The mass stopping power for alpha particle interacts with the chemical composition of human tissues (breast, ovary, lung and muscle) and with the chemical composition of materials (, SiO_2, AL_2O_3, ZrO_2) **by Ziegler**

E(MeV)	Mass Stopping power× 10^3 MeV/(gm/cm^2) By Ziegler											
	H	C	N	O	Na	P	S	CL	K	Si	AL	Zr
0.0100	1.5252	0.5219	0.3260	0.2267	0.5285	0.1547	0.1282	0.0983	0.3194	0.2037	0.2377	0.1877
0.0110	1.5831	0.5412	0.3408	0.2380	0.5439	0.1644	0.1365	0.1049	0.3310	0.2164	0.2520	0.1951
0.0120	1.6382	0.5595	0.3548	0.2489	0.5583	0.1739	0.1446	0.1113	0.3420	0.2287	0.2658	0.2021
0.0130	1.6906	0.5768	0.3683	0.2593	0.5718	0.1830	0.1524	0.1176	0.3525	0.2407	0.2791	0.2088
0.0140	1.7408	0.5933	0.3813	0.2694	0.5846	0.1920	0.1601	0.1237	0.3625	0.2524	0.2921	0.2151
0.0150	1.7889	0.6092	0.3938	0.2791	0.5968	0.2007	0.1676	0.1297	0.3720	0.2638	0.3047	0.2212
0.0160	1.8353	0.6243	0.4058	0.2886	0.6084	0.2092	0.1750	0.1356	0.3812	0.2749	0.3170	0.2271
0.0170	1.8800	0.6390	0.4175	0.2977	0.6195	0.2176	0.1822	0.1414	0.3900	0.2858	0.3290	0.2328
0.0180	1.9232	0.6530	0.4288	0.3067	0.6301	0.2257	0.1893	0.1470	0.3985	0.2964	0.3407	0.2382
0.0200	2.0056	0.6798	0.4505	0.3238	0.6500	0.2416	0.2030	0.1581	0.4146	0.3171	0.3634	0.2486
0.0225	2.1021	0.7110	0.4760	0.3442	0.6729	0.2608	0.2197	0.1716	0.4335	0.3420	0.3905	0.2608
0.0250	2.1924	0.7402	0.5001	0.3635	0.6940	0.2791	0.2357	0.1846	0.4510	0.3659	0.4164	0.2722
0.0275	2.2776	0.7675	0.5229	0.3819	0.7135	0.2969	0.2512	0.1972	0.4675	0.3890	0.4412	0.2829
0.0300	2.3583	0.7934	0.5447	0.3995	0.7316	0.3141	0.2663	0.2095	0.4831	0.4113	0.4649	0.2930
0.0325	2.4350	0.8179	0.5655	0.4164	0.7485	0.3308	0.2810	0.2214	0.4979	0.4329	0.4878	0.3027
0.0350	2.5083	0.8412	0.5854	0.4327	0.7645	0.3470	0.2953	0.2331	0.5119	0.4539	0.5099	0.3119
0.0375	2.5785	0.8635	0.6046	0.4484	0.7795	0.3629	0.3093	0.2446	0.5254	0.4744	0.5312	0.3208
0.0400	2.6458	0.8849	0.6232	0.4637	0.7936	0.3783	0.3229	0.2558	0.5383	0.4943	0.5518	0.3292
0.0450	2.7731	0.9252	0.6584	0.4928	0.8199	0.4082	0.3494	0.2777	0.5626	0.5328	0.5910	0.3453
0.0500	2.8918	0.9626	0.6916	0.5205	0.8438	0.4368	0.3749	0.2988	0.5852	0.5696	0.6278	0.3603

0.0550	**3.0033**	**0.9977**	**0.7230**	**0.5467**	**0.8656**	**0.4644**	**0.3995**	**0.3192**	**0.6064**	**0.6050**	**0.6624**	**0.3744**
0.0600	**3.1083**	**1.0307**	**0.7529**	**0.5719**	**0.8857**	**0.4910**	**0.4234**	**0.3390**	**0.6264**	**0.6390**	**0.6949**	**0.3877**
0.0650	**3.2078**	**1.0619**	**0.7814**	**0.5959**	**0.9044**	**0.5167**	**0.4465**	**0.3583**	**0.6452**	**0.6719**	**0.7255**	**0.4003**
0.0700	**3.3024**	**1.0915**	**0.8086**	**0.6191**	**0.9218**	**0.5416**	**0.4690**	**0.3772**	**0.6632**	**0.7036**	**0.7543**	**0.4124**
0.0800	**3.4784**	**1.1465**	**0.8600**	**0.6630**	**0.9533**	**0.5893**	**0.5122**	**0.4135**	**0.6966**	**0.7640**	**0.8070**	**0.4349**
0.0900	**3.6396**	**1.1967**	**0.9078**	**0.7041**	**0.9813**	**0.6344**	**0.5534**	**0.4483**	**0.7273**	**0.8208**	**0.8538**	**0.4557**
0.1000	**3.7883**	**1.2430**	**0.9524**	**0.7428**	**1.0064**	**0.6772**	**0.5927**	**0.4818**	**0.7556**	**0.8743**	**0.8955**	**0.4750**
0.1100	**3.9260**	**1.2859**	**0.9944**	**0.7794**	**1.0290**	**0.7178**	**0.6303**	**0.5139**	**0.7820**	**0.9248**	**0.9325**	**0.4930**
0.1200	**4.0542**	**1.3259**	**1.0340**	**0.8142**	**1.0495**	**0.7565**	**0.6664**	**0.5450**	**0.8066**	**0.9725**	**0.9656**	**0.5100**
0.1300	**4.1739**	**1.3632**	**1.0715**	**0.8473**	**1.0683**	**0.7934**	**0.7010**	**0.5749**	**0.8297**	**1.0175**	**0.9952**	**0.5259**
0.1400	**4.2858**	**1.3981**	**1.1071**	**0.8789**	**1.0855**	**0.8286**	**0.7343**	**0.6039**	**0.8515**	**1.0600**	**1.0218**	**0.5410**
0.1500	**4.3908**	**1.4310**	**1.1410**	**0.9092**	**1.1013**	**0.8622**	**0.7663**	**0.6319**	**0.8721**	**1.1002**	**1.0458**	**0.5553**
0.1600	**4.4893**	**1.4618**	**1.1734**	**0.9382**	**1.1159**	**0.8942**	**0.7972**	**0.6590**	**0.8915**	**1.1380**	**1.0675**	**0.5689**
0.1700	**4.5820**	**1.4910**	**1.2043**	**0.9660**	**1.1294**	**0.9247**	**0.8268**	**0.6853**	**0.9100**	**1.1737**	**1.0871**	**0.5818**
0.1800	**4.6691**	**1.5185**	**1.2338**	**0.9927**	**1.1419**	**0.9538**	**0.8553**	**0.7107**	**0.9275**	**1.2072**	**1.1050**	**0.5942**
0.2000	**4.8283**	**1.5690**	**1.2891**	**1.0432**	**1.1643**	**1.0079**	**0.9091**	**0.7592**	**0.9600**	**1.2683**	**1.1364**	**0.6172**
0.2250	**5.0020**	**1.6248**	**1.3519**	**1.1011**	**1.1881**	**1.0682**	**0.9706**	**0.8154**	**0.9965**	**1.3342**	**1.1687**	**0.6432**
0.2500	**5.1512**	**1.6735**	**1.4087**	**1.1540**	**1.2080**	**1.1211**	**1.0261**	**0.8672**	**1.0290**	**1.3893**	**1.1952**	**0.6666**
0.2750	**5.2787**	**1.7160**	**1.4599**	**1.2023**	**1.2246**	**1.1670**	**1.0760**	**0.9146**	**1.0579**	**1.4348**	**1.2170**	**0.6877**
0.3000	**5.3870**	**1.7531**	**1.5062**	**1.2465**	**1.2386**	**1.2065**	**1.1205**	**0.9580**	**1.0837**	**1.4717**	**1.2350**	**0.7067**
0.3250	**5.4781**	**1.7852**	**1.5480**	**1.2869**	**1.2502**	**1.2402**	**1.1600**	**0.9974**	**1.1068**	**1.5010**	**1.2500**	**0.7238**
0.3500	**5.5537**	**1.8131**	**1.5857**	**1.3237**	**1.2598**	**1.2686**	**1.1948**	**1.0331**	**1.1273**	**1.5235**	**1.2622**	**0.7392**
0.3750	**5.6154**	**1.8369**	**1.6195**	**1.3573**	**1.2677**	**1.2921**	**1.2252**	**1.0651**	**1.1456**	**1.5402**	**1.2722**	**0.7531**
0.4000	**5.6644**	**1.8572**	**1.6499**	**1.3878**	**1.2740**	**1.3113**	**1.2515**	**1.0938**	**1.1617**	**1.5519**	**1.2803**	**0.7655**
0.4500	**5.7295**	**1.8885**	**1.7009**	**1.4405**	**1.2829**	**1.3383**	**1.2929**	**1.1415**	**1.1884**	**1.5629**	**1.2914**	**0.7865**
0.5000	**5.7573**	**1.9089**	**1.7406**	**1.4830**	**1.2876**	**1.3530**	**1.3213**	**1.1776**	**1.2085**	**1.5615**	**1.2973**	**0.8028**
0.5500	**5.7549**	**1.9205**	**1.7703**	**1.5166**	**1.2890**	**1.3582**	**1.3391**	**1.2037**	**1.2231**	**1.5516**	**1.2989**	**0.8151**
0.6000	**5.7282**	**1.9246**	**1.7915**	**1.5424**	**1.2878**	**1.3564**	**1.3480**	**1.2210**	**1.2327**	**1.5358**	**1.2973**	**0.8240**
0.6500	**5.6822**	**1.9226**	**1.8051**	**1.5613**	**1.2845**	**1.3493**	**1.3500**	**1.2311**	**1.2383**	**1.5164**	**1.2931**	**0.8298**
0.7000	**5.6211**	**1.9154**	**1.8122**	**1.5741**	**1.2795**	**1.3385**	**1.3465**	**1.2350**	**1.2402**	**1.4947**	**1.2868**	**0.8330**
0.8000	**5.4672**	**1.8895**	**1.8104**	**1.5846**	**1.2656**	**1.3097**	**1.3278**	**1.2290**	**1.2354**	**1.4482**	**1.2697**	**0.8328**
0.9000	**5.2880**	**1.8525**	**1.7923**	**1.5793**	**1.2481**	**1.2762**	**1.2996**	**1.2103**	**1.2218**	**1.4012**	**1.2485**	**0.8258**
1.0000	**5.0979**	**1.8088**	**1.7626**	**1.5624**	**1.2283**	**1.2412**	**1.2666**	**1.1841**	**1.2019**	**1.3558**	**1.2249**	**0.8138**
1.1000	**4.9065**	**1.7611**	**1.7251**	**1.5374**	**1.2071**	**1.2065**	**1.2319**	**1.1540**	**1.1779**	**1.3127**	**1.2000**	**0.7985**
1.2000	**4.7195**	**1.7118**	**1.6826**	**1.5070**	**1.1850**	**1.1729**	**1.1971**	**1.1224**	**1.1511**	**1.2723**	**1.1745**	**0.7809**
1.3000	**4.5405**	**1.6622**	**1.6373**	**1.4731**	**1.1626**	**1.1408**	**1.1632**	**1.0907**	**1.1229**	**1.2345**	**1.1489**	**0.7620**
1.4000	**4.3712**	**1.6132**	**1.5909**	**1.4374**	**1.1401**	**1.1103**	**1.1307**	**1.0597**	**1.0941**	**1.1990**	**1.1236**	**0.7424**
1.5000	**4.2124**	**1.5656**	**1.5443**	**1.4009**	**1.1177**	**1.0814**	**1.0999**	**1.0299**	**1.0652**	**1.1658**	**1.0988**	**0.7226**
1.6000	**4.0642**	**1.5197**	**1.4985**	**1.3644**	**1.0957**	**1.0542**	**1.0707**	**1.0016**	**1.0368**	**1.1346**	**1.0745**	**0.7031**
1.7000	**3.9263**	**1.4758**	**1.4540**	**1.3284**	**1.0741**	**1.0283**	**1.0431**	**0.9748**	**1.0092**	**1.1053**	**1.0510**	**0.6840**
1.8000	**3.7981**	**1.4338**	**1.4110**	**1.2934**	**1.0529**	**1.0039**	**1.0171**	**0.9496**	**0.9824**	**1.0776**	**1.0283**	**0.6654**
2.0000	**3.5681**	**1.3562**	**1.3306**	**1.2271**	**1.0123**	**0.9587**	**0.9693**	**0.9034**	**0.9321**	**1.0267**	**0.9852**	**0.6306**
2.2500	**3.3233**	**1.2702**	**1.2409**	**1.1519**	**0.9647**	**0.9083**	**0.9166**	**0.8528**	**0.8756**	**0.9703**	**0.9356**	**0.5915**
2.5000	**3.1167**	**1.1949**	**1.1626**	**1.0853**	**0.9207**	**0.8635**	**0.8703**	**0.8089**	**0.8258**	**0.9203**	**0.8905**	**0.5573**
2.7500	**2.9403**	**1.1289**	**1.0945**	**1.0266**	**0.8801**	**0.8233**	**0.8292**	**0.7704**	**0.7821**	**0.8758**	**0.8495**	**0.5273**
3.0000	**2.7879**	**1.0707**	**1.0349**	**0.9747**	**0.8427**	**0.7871**	**0.7924**	**0.7362**	**0.7436**	**0.8358**	**0.8122**	**0.5012**
3.2500	**2.6546**	**1.0190**	**0.9827**	**0.9286**	**0.8082**	**0.7543**	**0.7592**	**0.7057**	**0.7095**	**0.7997**	**0.7782**	**0.4782**
3.5000	**2.5369**	**0.9728**	**0.9366**	**0.8875**	**0.7764**	**0.7244**	**0.7291**	**0.6781**	**0.6792**	**0.7669**	**0.7470**	**0.4578**
3.7500	**2.4320**	**0.9313**	**0.8956**	**0.8506**	**0.7469**	**0.6970**	**0.7017**	**0.6531**	**0.6521**	**0.7369**	**0.7183**	**0.4397**
4.0000	**2.3377**	**0.8937**	**0.8590**	**0.8173**	**0.7195**	**0.6718**	**0.6765**	**0.6302**	**0.6276**	**0.7095**	**0.6920**	**0.4235**
4.5000	**2.1744**	**0.8281**	**0.7960**	**0.7594**	**0.6704**	**0.6270**	**0.6318**	**0.5898**	**0.5852**	**0.6608**	**0.6450**	**0.3956**

5.0000	**2.0372**	**0.7728**	**0.7438**	**0.7108**	**0.6277**	**0.5883**	**0.5933**	**0.5551**	**0.5497**	**0.6189**	**0.6044**	**0.3723**
5.5000	**1.9198**	**0.7254**	**0.6997**	**0.6692**	**0.5902**	**0.5546**	**0.5597**	**0.5248**	**0.5193**	**0.5826**	**0.5691**	**0.3526**
6.0000	**1.8178**	**0.6842**	**0.6617**	**0.6330**	**0.5570**	**0.5248**	**0.5302**	**0.4982**	**0.4929**	**0.5506**	**0.5379**	**0.3355**
6.5000	**1.7279**	**0.6480**	**0.6285**	**0.6013**	**0.5275**	**0.4984**	**0.5039**	**0.4745**	**0.4697**	**0.5223**	**0.5103**	**0.3205**
7.0000	**1.6480**	**0.6159**	**0.5992**	**0.5731**	**0.5011**	**0.4748**	**0.4804**	**0.4532**	**0.4491**	**0.4971**	**0.4856**	**0.3072**
8.0000	**1.5117**	**0.5613**	**0.5496**	**0.5250**	**0.4557**	**0.4342**	**0.4400**	**0.4166**	**0.4138**	**0.4539**	**0.4434**	**0.2845**
9.0000	**1.3991**	**0.5165**	**0.5090**	**0.4855**	**0.4182**	**0.4006**	**0.4065**	**0.3861**	**0.3846**	**0.4182**	**0.4085**	**0.2656**
10.0000	**1.3042**	**0.4790**	**0.4749**	**0.4522**	**0.3866**	**0.3723**	**0.3782**	**0.3602**	**0.3599**	**0.3882**	**0.3791**	**0.2496**
11.0000	**1.2031**	**0.4455**	**0.4412**	**0.4208**	**0.3608**	**0.3477**	**0.3533**	**0.3364**	**0.3364**	**0.3623**	**0.3540**	**0.2349**
12.0000	**1.1211**	**0.4178**	**0.4136**	**0.3950**	**0.3394**	**0.3275**	**0.3328**	**0.3170**	**0.3170**	**0.3412**	**0.3332**	**0.2227**
13.0000	**1.0502**	**0.3936**	**0.3895**	**0.3725**	**0.3207**	**0.3097**	**0.3148**	**0.2999**	**0.3000**	**0.3226**	**0.3149**	**0.2119**
14.0000	**0.9883**	**0.3723**	**0.3683**	**0.3526**	**0.3041**	**0.2939**	**0.2988**	**0.2847**	**0.2849**	**0.3061**	**0.2987**	**0.2022**
15.0000	**0.9338**	**0.3534**	**0.3494**	**0.3350**	**0.2893**	**0.2799**	**0.2846**	**0.2712**	**0.2714**	**0.2914**	**0.2843**	**0.1935**
16.0000	**0.8852**	**0.3364**	**0.3326**	**0.3191**	**0.2760**	**0.2672**	**0.2718**	**0.2590**	**0.2593**	**0.2782**	**0.2713**	**0.1856**
17.0000	**0.8418**	**0.3212**	**0.3174**	**0.3049**	**0.2640**	**0.2558**	**0.2602**	**0.2480**	**0.2483**	**0.2662**	**0.2596**	**0.1785**
18.0000	**0.8028**	**0.3074**	**0.3037**	**0.2919**	**0.2531**	**0.2454**	**0.2497**	**0.2380**	**0.2383**	**0.2554**	**0.2490**	**0.1719**
20.0000	**0.7351**	**0.2833**	**0.2798**	**0.2694**	**0.2341**	**0.2272**	**0.2312**	**0.2204**	**0.2208**	**0.2364**	**0.2303**	**0.1602**
22.5000	**0.6660**	**0.2584**	**0.2551**	**0.2460**	**0.2142**	**0.2082**	**0.2120**	**0.2021**	**0.2025**	**0.2166**	**0.2109**	**0.1480**
25.0000	**0.6094**	**0.2379**	**0.2347**	**0.2267**	**0.1978**	**0.1925**	**0.1960**	**0.1869**	**0.1873**	**0.2001**	**0.1948**	**0.1377**
27.5000	**0.5623**	**0.2206**	**0.2176**	**0.2104**	**0.1839**	**0.1791**	**0.1824**	**0.1740**	**0.1745**	**0.1862**	**0.1812**	**0.1289**
30.0000	**0.5223**	**0.2058**	**0.2030**	**0.1965**	**0.1720**	**0.1677**	**0.1708**	**0.1629**	**0.1634**	**0.1743**	**0.1696**	**0.1213**
32.5000	**0.4880**	**0.1931**	**0.1904**	**0.1844**	**0.1617**	**0.1578**	**0.1607**	**0.1533**	**0.1538**	**0.1639**	**0.1595**	**0.1146**
35.0000	**0.4582**	**0.1820**	**0.1794**	**0.1739**	**0.1527**	**0.1491**	**0.1519**	**0.1449**	**0.1454**	**0.1549**	**0.1506**	**0.1087**
37.5000	**0.4321**	**0.1721**	**0.1697**	**0.1646**	**0.1447**	**0.1414**	**0.1440**	**0.1375**	**0.1380**	**0.1468**	**0.1427**	**0.1035**
40.0000	**0.4090**	**0.1634**	**0.1611**	**0.1564**	**0.1376**	**0.1345**	**0.1371**	**0.1308**	**0.1313**	**0.1397**	**0.1358**	**0.0988**
45.0000	**0.3699**	**0.1486**	**0.1464**	**0.1423**	**0.1254**	**0.1228**	**0.1251**	**0.1194**	**0.1199**	**0.1274**	**0.1238**	**0.0907**
50.0000	**0.3382**	**0.1364**	**0.1344**	**0.1308**	**0.1154**	**0.1131**	**0.1153**	**0.1101**	**0.1106**	**0.1174**	**0.1140**	**0.0840**
55.0000	**0.3118**	**0.1263**	**0.1244**	**0.1212**	**0.1070**	**0.1050**	**0.1070**	**0.1022**	**0.1027**	**0.1089**	**0.1058**	**0.0784**
60.0000	**0.2895**	**0.1177**	**0.1159**	**0.1130**	**0.0999**	**0.0981**	**0.1000**	**0.0955**	**0.0960**	**0.1017**	**0.0988**	**0.0735**
65.0000	**0.2705**	**0.1102**	**0.1086**	**0.1059**	**0.0938**	**0.0921**	**0.0939**	**0.0897**	**0.0902**	**0.0955**	**0.0927**	**0.0693**
70.0000	**0.2540**	**0.1038**	**0.1022**	**0.0998**	**0.0884**	**0.0869**	**0.0886**	**0.0847**	**0.0851**	**0.0901**	**0.0875**	**0.0656**
80.0000	**0.2268**	**0.0931**	**0.0917**	**0.0896**	**0.0795**	**0.0782**	**0.0798**	**0.0762**	**0.0767**	**0.0811**	**0.0787**	**0.0594**
90.0000	**0.2053**	**0.0846**	**0.0833**	**0.0815**	**0.0724**	**0.0713**	**0.0728**	**0.0695**	**0.0699**	**0.0739**	**0.0717**	**0.0544**
100.0000	**0.1879**	**0.0777**	**0.0765**	**0.0749**	**0.0666**	**0.0656**	**0.0670**	**0.0640**	**0.0644**	**0.0680**	**0.0660**	**0.0503**
110.0000	**0.1734**	**0.0719**	**0.0708**	**0.0693**	**0.0618**	**0.0609**	**0.0622**	**0.0594**	**0.0598**	**0.0631**	**0.0612**	**0.0468**
120.0000	**0.1613**	**0.0670**	**0.0660**	**0.0647**	**0.0577**	**0.0569**	**0.0581**	**0.0555**	**0.0559**	**0.0590**	**0.0571**	**0.0439**
130.0000	**0.1509**	**0.0628**	**0.0619**	**0.0607**	**0.0541**	**0.0534**	**0.0545**	**0.0521**	**0.0525**	**0.0554**	**0.0537**	**0.0413**
140.0000	**0.1419**	**0.0592**	**0.0583**	**0.0572**	**0.0511**	**0.0504**	**0.0515**	**0.0492**	**0.0496**	**0.0522**	**0.0506**	**0.0391**
150.0000	**0.1340**	**0.0560**	**0.0552**	**0.0541**	**0.0484**	**0.0478**	**0.0488**	**0.0466**	**0.0470**	**0.0495**	**0.0480**	**0.0371**
160.0000	**0.1271**	**0.0532**	**0.0524**	**0.0514**	**0.0460**	**0.0455**	**0.0464**	**0.0444**	**0.0447**	**0.0471**	**0.0456**	**0.0354**
170.0000	**0.1209**	**0.0507**	**0.0500**	**0.0490**	**0.0439**	**0.0434**	**0.0443**	**0.0423**	**0.0427**	**0.0449**	**0.0435**	**0.0338**
180.0000	**0.1154**	**0.0484**	**0.0477**	**0.0469**	**0.0419**	**0.0415**	**0.0424**	**0.0405**	**0.0408**	**0.0430**	**0.0416**	**0.0324**
200.0000	**0.1059**	**0.0446**	**0.0439**	**0.0432**	**0.0387**	**0.0383**	**0.0391**	**0.0374**	**0.0377**	**0.0396**	**0.0384**	**0.0300**

Table (3-8) Mass stopping power for alpha particle interacts with the chemical composition of human tissues (breast, ovary, lung and muscle) and materials (SiO_2, AL_2O_3, ZrO_2) **by SRIM**

E(MeV)	Mass Stopping power× 10^3 MeV/(gm/cm^2) By SRIM										
	H	C	N	O	Na	P	S	CL	K	SiO_2	AL_2O_3	ZrO_2
0.0100	1.3357	0.5117	0.3663	0.3197	0.3258	0.2825	0.2318	0.1988	0.1756	0.2990	0.3087	0.1771
0.0110	1.3671	0.5300	0.3779	0.3296	0.3381	0.2901	0.2417	0.2055	0.1823	0.3086	0.3200	0.1840
0.0120	1.4002	0.5477	0.3891	0.3393	0.3500	0.2983	0.2515	0.2121	0.1890	0.3178	0.3309	0.1906
0.0130	1.4334	0.5648	0.4002	0.3486	0.3617	0.3081	0.2613	0.2184	0.1957	0.3269	0.3416	0.1970
0.0140	1.4664	0.5815	0.4110	0.3578	0.3730	0.3192	0.2711	0.2248	0.2024	0.3358	0.3519	0.2034
0.0150	1.4998	0.5978	0.4214	0.3667	0.3841	0.3313	0.2810	0.2310	0.2090	0.3448	0.3620	0.2095
0.0160	1.5325	0.6136	0.4317	0.3756	0.3949	0.3440	0.2908	0.2373	0.2155	0.3536	0.3719	0.2154
0.0170	1.5663	0.6290	0.4418	0.3842	0.4054	0.3568	0.3005	0.2434	0.2219	0.3625	0.3817	0.2213
0.0180	1.5990	0.6440	0.4517	0.3927	0.4157	0.3695	0.3103	0.2494	0.2285	0.3713	0.3911	0.2270
0.0200	1.6656	0.6730	0.4708	0.4091	0.4358	0.3948	0.3297	0.2614	0.2413	0.3887	0.4094	0.2380
0.0225	1.7464	0.7072	0.4937	0.4289	0.4597	0.4251	0.3537	0.2763	0.2572	0.4102	0.4313	0.2513
0.0250	1.8261	0.7393	0.5158	0.4478	0.4828	0.4540	0.3775	0.2910	0.2729	0.4310	0.4523	0.2640
0.0275	1.9050	0.7694	0.5370	0.4662	0.5049	0.4817	0.4011	0.3056	0.2883	0.4512	0.4724	0.2762
0.0300	1.9825	0.7978	0.5574	0.4838	0.5262	0.5080	0.4244	0.3202	0.3035	0.4708	0.4916	0.2880
0.0325	2.0584	0.8242	0.5771	0.5009	0.5467	0.5335	0.4475	0.3349	0.3184	0.4900	0.5102	0.2994
0.0350	2.1323	0.8491	0.5962	0.5174	0.5666	0.5579	0.4703	0.3495	0.3332	0.5085	0.5280	0.3104
0.0375	2.2052	0.8723	0.6147	0.5334	0.5859	0.5815	0.4929	0.3642	0.3478	0.5265	0.5453	0.3212
0.0400	2.2769	0.8940	0.6326	0.5491	0.6047	0.6043	0.5152	0.3789	0.3622	0.5440	0.5619	0.3315
0.0450	2.4179	0.9334	0.6672	0.5791	0.6407	0.6476	0.5590	0.4082	0.3903	0.5777	0.5937	0.3516
0.0500	2.5539	0.9685	0.6999	0.6076	0.6749	0.6882	0.6018	0.4377	0.4178	0.6099	0.6237	0.3707
0.0550	2.6853	1.0004	0.7314	0.6350	0.7075	0.7265	0.6435	0.4670	0.4445	0.6405	0.6520	0.3889
0.0600	2.8137	1.0301	0.7613	0.6612	0.7386	0.7627	0.6841	0.4959	0.4706	0.6699	0.6791	0.4065
0.0650	2.9391	1.0580	0.7902	0.6863	0.7684	0.7970	0.7236	0.5244	0.4959	0.6981	0.7049	0.4234
0.0700	3.0611	1.0849	0.8180	0.7106	0.7971	0.8295	0.7620	0.5522	0.5205	0.7251	0.7295	0.4396
0.0800	3.2968	1.1362	0.8708	0.7567	0.8510	0.8895	0.8355	0.6045	0.5681	0.7763	0.7759	0.4706
0.0900	3.5232	1.1869	0.9203	0.8000	0.9009	0.9438	0.9047	0.6516	0.6132	0.8238	0.8187	0.4996
0.1000	3.7397	1.2347	0.9670	0.8408	0.9474	0.9930	0.9697	0.6928	0.6562	0.8682	0.8586	0.5271
0.1100	3.9471	1.2797	1.0111	0.8795	0.9906	1.0376	1.0310	0.7284	0.6970	0.9097	0.8958	0.5530
0.1200	4.1471	1.3239	1.0535	0.9162	1.0306	1.0780	1.0874	0.7593	0.7359	0.9487	0.9306	0.5775
0.1300	4.3407	1.3642	1.0929	0.9513	1.0680	1.1155	1.1409	0.7870	0.7728	0.9854	0.9634	0.6010
0.1400	4.5258	1.4036	1.1313	0.9847	1.1035	1.1490	1.1904	0.8128	0.8080	1.0194	0.9942	0.6233
0.1500	4.7052	1.4400	1.1687	1.0165	1.1361	1.1796	1.2370	0.8377	0.8414	1.0519	1.0236	0.6447
0.1600	4.8779	1.4745	1.2032	1.0470	1.1667	1.2083	1.2796	0.8623	0.8732	1.0835	1.0502	0.6650
0.1700	5.0438	1.5071	1.2368	1.0766	1.1953	1.2330	1.3193	0.8870	0.9035	1.1121	1.0768	0.6846
0.1800	5.2039	1.5377	1.2694	1.1052	1.2220	1.2567	1.3560	0.9120	0.9322	1.1397	1.1015	0.7031
0.2000	5.5067	1.5930	1.3307	1.1576	1.2695	1.2972	1.4214	0.9627	0.9854	1.1901	1.1459	0.7382
0.2250	5.8524	1.6532	1.4000	1.2189	1.3209	1.3376	1.4899	1.0254	1.0443	1.2455	1.1963	0.7780
0.2500	6.1627	1.7037	1.4645	1.2733	1.3634	1.3702	1.5444	1.0849	1.0959	1.2940	1.2408	0.8138
0.2750	6.4394	1.7482	1.5220	1.3239	1.3991	1.3948	1.5870	1.1396	1.1416	1.3366	1.2794	0.8462
0.3000	6.6845	1.7847	1.5746	1.3685	1.4287	1.4135	1.6207	1.1883	1.1803	1.3732	1.3130	0.8753
0.3250	6.8979	1.8164	1.6222	1.4101	1.4544	1.4262	1.6464	1.2300	1.2140	1.4049	1.3427	0.9014
0.3500	7.0824	1.8421	1.6659	1.4468	1.4752	1.4360	1.6652	1.2658	1.2438	1.4326	1.3684	0.9249
0.3750	7.2391	1.8638	1.7047	1.4806	1.4919	1.4418	1.6780	1.2956	1.2676	1.4573	1.3912	0.9459

0.4000	**7.3690**	**1.8825**	**1.7394**	**1.5113**	**1.5057**	**1.4456**	**1.6858**	**1.3204**	**1.2884**	**1.4781**	**1.4110**	**0.9645**
0.4500	**7.5561**	**1.9081**	**1.7970**	**1.5619**	**1.5254**	**1.4453**	**1.6904**	**1.3551**	**1.3211**	**1.5107**	**1.4416**	**0.9957**
0.5000	**7.6606**	**1.9238**	**1.8417**	**1.6016**	**1.5371**	**1.4380**	**1.6842**	**1.3739**	**1.3419**	**1.5334**	**1.4643**	**1.0194**
0.5500	**7.6943**	**1.9305**	**1.8744**	**1.6313**	**1.5419**	**1.4268**	**1.6689**	**1.3817**	**1.3547**	**1.5472**	**1.4791**	**1.0372**
0.6000	**7.6732**	**1.9312**	**1.8962**	**1.6531**	**1.5417**	**1.4126**	**1.6487**	**1.3815**	**1.3595**	**1.5550**	**1.4879**	**1.0491**
0.6500	**7.6073**	**1.9260**	**1.9080**	**1.6669**	**1.5375**	**1.3954**	**1.6256**	**1.3743**	**1.3603**	**1.5578**	**1.4917**	**1.0569**
0.7000	**7.5095**	**1.9168**	**1.9118**	**1.6757**	**1.5304**	**1.3773**	**1.6004**	**1.3632**	**1.3562**	**1.5556**	**1.4905**	**1.0608**
0.8000	**7.2491**	**1.8895**	**1.9015**	**1.6764**	**1.5101**	**1.3381**	**1.5452**	**1.3340**	**1.3400**	**1.5413**	**1.4793**	**1.0596**
0.9000	**6.9460**	**1.8543**	**1.8723**	**1.6622**	**1.4819**	**1.2989**	**1.4900**	**1.2988**	**1.3148**	**1.5171**	**1.4590**	**1.0495**
1.0000	**6.6312**	**1.8141**	**1.8311**	**1.6380**	**1.4518**	**1.2597**	**1.4358**	**1.2616**	**1.2867**	**1.4869**	**1.4329**	**1.0324**
1.1000	**6.3254**	**1.7719**	**1.7839**	**1.6069**	**1.4186**	**1.2216**	**1.3837**	**1.2245**	**1.2555**	**1.4528**	**1.4027**	**1.0113**
1.2000	**6.0358**	**1.7288**	**1.7328**	**1.5717**	**1.3845**	**1.1855**	**1.3345**	**1.1894**	**1.2234**	**1.4177**	**1.3706**	**0.9886**
1.3000	**5.7673**	**1.6857**	**1.6817**	**1.5346**	**1.3494**	**1.1514**	**1.2884**	**1.1553**	**1.1913**	**1.3816**	**1.3375**	**0.9642**
1.4000	**5.5198**	**1.6426**	**1.6305**	**1.4965**	**1.3153**	**1.1183**	**1.2454**	**1.1242**	**1.1593**	**1.3455**	**1.3044**	**0.9392**
1.5000	**5.2934**	**1.6005**	**1.5815**	**1.4584**	**1.2823**	**1.0882**	**1.2053**	**1.0932**	**1.1292**	**1.3104**	**1.2723**	**0.9145**
1.6000	**5.0851**	**1.5594**	**1.5354**	**1.4214**	**1.2502**	**1.0592**	**1.1682**	**1.0651**	**1.0991**	**1.2773**	**1.2413**	**0.8900**
1.7000	**4.8948**	**1.5203**	**1.4903**	**1.3853**	**1.2181**	**1.0311**	**1.1332**	**1.0381**	**1.0711**	**1.2442**	**1.2102**	**0.8662**
1.8000	**4.7185**	**1.4823**	**1.4483**	**1.3502**	**1.1881**	**1.0061**	**1.1011**	**1.0130**	**1.0440**	**1.2132**	**1.1811**	**0.8432**
2.0000	**4.4050**	**1.4102**	**1.3711**	**1.2841**	**1.1310**	**0.9584**	**1.0410**	**0.9652**	**0.9932**	**1.1541**	**1.1260**	**0.7997**
2.2500	**4.0715**	**1.3291**	**1.2870**	**1.2100**	**1.0649**	**0.9060**	**0.9765**	**0.9121**	**0.9363**	**1.0890**	**1.0629**	**0.7505**
2.5000	**3.7881**	**1.2560**	**1.2119**	**1.1429**	**1.0058**	**0.8598**	**0.9204**	**0.8647**	**0.8858**	**1.0299**	**1.0069**	**0.7068**
2.7500	**3.5428**	**1.1899**	**1.1469**	**1.0829**	**0.9529**	**0.8189**	**0.8716**	**0.8220**	**0.8408**	**0.9772**	**0.9570**	**0.6682**
3.0000	**3.3285**	**1.1308**	**1.0888**	**1.0288**	**0.9047**	**0.7825**	**0.8284**	**0.7835**	**0.8005**	**0.9302**	**0.9117**	**0.6339**
3.2500	**3.1403**	**1.0768**	**1.0358**	**0.9802**	**0.8611**	**0.7497**	**0.7902**	**0.7484**	**0.7643**	**0.8879**	**0.8709**	**0.6034**
3.5000	**2.9721**	**1.0277**	**0.9890**	**0.9365**	**0.8216**	**0.7202**	**0.7558**	**0.7167**	**0.7316**	**0.8498**	**0.8339**	**0.5762**
3.7500	**2.8219**	**0.9832**	**0.9463**	**0.8969**	**0.7855**	**0.6934**	**0.7250**	**0.6876**	**0.7019**	**0.8151**	**0.8003**	**0.5518**
4.0000	**2.6867**	**0.9423**	**0.9072**	**0.8607**	**0.7524**	**0.6688**	**0.6970**	**0.6611**	**0.6749**	**0.7835**	**0.7697**	**0.5298**
4.5000	**2.4535**	**0.8706**	**0.8387**	**0.7976**	**0.6943**	**0.6257**	**0.6481**	**0.6143**	**0.6275**	**0.7281**	**0.7156**	**0.4921**
5.0000	**2.2582**	**0.8092**	**0.7802**	**0.7440**	**0.6447**	**0.5887**	**0.6069**	**0.5743**	**0.5871**	**0.6811**	**0.6696**	**0.4608**
5.5000	**2.0941**	**0.7564**	**0.7297**	**0.6980**	**0.6020**	**0.5569**	**0.5715**	**0.5399**	**0.5524**	**0.6406**	**0.6298**	**0.4342**
6.0000	**1.9529**	**0.7103**	**0.6855**	**0.6579**	**0.5648**	**0.5289**	**0.5408**	**0.5098**	**0.5221**	**0.6052**	**0.5951**	**0.4116**
6.5000	**1.8298**	**0.6698**	**0.6466**	**0.6228**	**0.5321**	**0.5042**	**0.5139**	**0.4832**	**0.4955**	**0.5742**	**0.5646**	**0.3920**
7.0000	**1.7217**	**0.6340**	**0.6120**	**0.5916**	**0.5031**	**0.4821**	**0.4899**	**0.4597**	**0.4719**	**0.5466**	**0.5374**	**0.3748**
8.0000	**1.5425**	**0.5731**	**0.5529**	**0.5386**	**0.4541**	**0.4445**	**0.4494**	**0.4198**	**0.4319**	**0.4996**	**0.4910**	**0.3458**
9.0000	**1.4663**	**0.5282**	**0.5158**	**0.5002**	**0.4217**	**0.4105**	**0.4149**	**0.3993**	**0.3994**	**0.4630**	**0.4547**	**0.3228**
10.0000	**1.3712**	**0.4861**	**0.4786**	**0.4629**	**0.3906**	**0.3789**	**0.3831**	**0.3760**	**0.3691**	**0.4282**	**0.4203**	**0.3009**
11.0000	**1.2591**	**0.4524**	**0.4454**	**0.4310**	**0.3649**	**0.3541**	**0.3582**	**0.3515**	**0.3453**	**0.3994**	**0.3919**	**0.2825**
12.0000	**1.1650**	**0.4234**	**0.4169**	**0.4036**	**0.3427**	**0.3328**	**0.3367**	**0.3303**	**0.3246**	**0.3747**	**0.3676**	**0.2665**
13.0000	**1.0860**	**0.3983**	**0.3922**	**0.3799**	**0.3234**	**0.3142**	**0.3180**	**0.3118**	**0.3066**	**0.3532**	**0.3465**	**0.2525**
14.0000	**1.0169**	**0.3763**	**0.3706**	**0.3592**	**0.3064**	**0.2978**	**0.3015**	**0.2955**	**0.2908**	**0.3343**	**0.3279**	**0.2400**
15.0000	**0.9573**	**0.3568**	**0.3514**	**0.3408**	**0.2913**	**0.2832**	**0.2869**	**0.2810**	**0.2767**	**0.3175**	**0.3115**	**0.2289**
16.0000	**0.9048**	**0.3395**	**0.3343**	**0.3244**	**0.2777**	**0.2702**	**0.2737**	**0.2681**	**0.2640**	**0.3025**	**0.2968**	**0.2189**
17.0000	**0.8582**	**0.3239**	**0.3190**	**0.3097**	**0.2656**	**0.2584**	**0.2619**	**0.2563**	**0.2525**	**0.2891**	**0.2835**	**0.2099**
18.0000	**0.8166**	**0.3098**	**0.3052**	**0.2963**	**0.2544**	**0.2477**	**0.2511**	**0.2457**	**0.2422**	**0.2769**	**0.2716**	**0.2017**
20.0000	**0.7452**	**0.2853**	**0.2811**	**0.2731**	**0.2352**	**0.2291**	**0.2323**	**0.2272**	**0.2241**	**0.2555**	**0.2506**	**0.1873**
22.5000	**0.6731**	**0.2600**	**0.2562**	**0.2492**	**0.2152**	**0.2098**	**0.2128**	**0.2081**	**0.2053**	**0.2335**	**0.2290**	**0.1723**
25.0000	**0.6146**	**0.2392**	**0.2358**	**0.2295**	**0.1987**	**0.1938**	**0.1967**	**0.1922**	**0.1898**	**0.2154**	**0.2112**	**0.1598**
27.5000	**0.5662**	**0.2217**	**0.2186**	**0.2129**	**0.1848**	**0.1803**	**0.1830**	**0.1788**	**0.1767**	**0.2001**	**0.1962**	**0.1492**
30.0000	**0.5254**	**0.2069**	**0.2040**	**0.1988**	**0.1729**	**0.1688**	**0.1714**	**0.1674**	**0.1654**	**0.1870**	**0.1834**	**0.1400**
32.5000	**0.4905**	**0.1941**	**0.1914**	**0.1866**	**0.1626**	**0.1588**	**0.1613**	**0.1574**	**0.1557**	**0.1757**	**0.1723**	**0.1321**
35.0000	**0.4604**	**0.1829**	**0.1804**	**0.1759**	**0.1535**	**0.1500**	**0.1524**	**0.1487**	**0.1471**	**0.1659**	**0.1626**	**0.1251**

37.5000	0.4340	0.1730	0.1707	0.1665	0.1455	0.1422	0.1445	0.1411	0.1396	0.1571	0.1541	0.1189
40.0000	0.4106	0.1642	0.1621	0.1581	0.1384	0.1353	0.1375	0.1342	0.1328	0.1494	0.1464	0.1133
45.0000	0.3713	0.1493	0.1474	0.1439	0.1263	0.1235	0.1256	0.1225	0.1213	0.1361	0.1335	0.1038
50.0000	0.3393	0.1371	0.1354	0.1323	0.1162	0.1138	0.1158	0.1129	0.1119	0.1252	0.1228	0.0958
55.0000	0.3129	0.1269	0.1253	0.1225	0.1079	0.1057	0.1075	0.1048	0.1039	0.1161	0.1138	0.0892
60.0000	0.2904	0.1183	0.1168	0.1142	0.1006	0.0987	0.1005	0.0979	0.0970	0.1084	0.1062	0.0835
65.0000	0.2713	0.1108	0.1095	0.1071	0.0945	0.0927	0.0943	0.0919	0.0912	0.1017	0.0996	0.0786
70.0000	0.2547	0.1042	0.1030	0.1007	0.0891	0.0874	0.0890	0.0867	0.0860	0.0958	0.0939	0.0743
80.0000	0.2275	0.0935	0.0924	0.0905	0.0801	0.0787	0.0801	0.0781	0.0775	0.0861	0.0844	0.0671
90.0000	0.2059	0.0850	0.0840	0.0822	0.0730	0.0717	0.0731	0.0711	0.0707	0.0784	0.0768	0.0613
100.0000	0.1883	0.0780	0.0771	0.0755	0.0671	0.0660	0.0672	0.0655	0.0651	0.0720	0.0706	0.0565
110.0000	0.1738	0.0722	0.0714	0.0699	0.0622	0.0612	0.0624	0.0607	0.0604	0.0667	0.0654	0.0525
120.0000	0.1615	0.0672	0.0665	0.0652	0.0581	0.0572	0.0583	0.0567	0.0564	0.0623	0.0610	0.0491
130.0000	0.1511	0.0630	0.0623	0.0611	0.0545	0.0537	0.0547	0.0532	0.0529	0.0584	0.0572	0.0462
140.0000	0.1420	0.0593	0.0587	0.0576	0.0514	0.0506	0.0516	0.0502	0.0500	0.0551	0.0540	0.0436
150.0000	0.1341	0.0561	0.0555	0.0545	0.0487	0.0480	0.0489	0.0476	0.0473	0.0521	0.0511	0.0414
160.0000	0.1271	0.0533	0.0527	0.0517	0.0462	0.0456	0.0465	0.0452	0.0450	0.0495	0.0485	0.0394
170.0000	0.1209	0.0508	0.0502	0.0493	0.0441	0.0435	0.0443	0.0431	0.0429	0.0472	0.0463	0.0376
180.0000	0.1153	0.0485	0.0480	0.0471	0.0421	0.0416	0.0424	0.0413	0.0411	0.0451	0.0442	0.0360
200.0000	0.1058	0.0446	0.0441	0.0433	0.0388	0.0383	0.0391	0.0380	0.0378	0.0415	0.0407	0.0332

Table (3-9)Mass stopping power for alpha particle interacts with (SiO_2, AL_2O_3) **By ASTAR**

E(MeV)	Mass Stopping power$\times 10^3$ M eV/($\frac{gram}{cm^2}$)							
	SiO_2	AL_2O_3	E(MeV)	SiO_2	AL_2O_3	E(MeV)	SiO_2	AL_2O_3
0.0100	0.2817	0.2977	0.2750	1.1760	1.1970	8.0000	0.4787	0.4644
0.0110	0.2909	0.3084	0.3000	1.2120	1.2250	9.0000	0.4407	0.4276
0.0120	0.2999	0.3189	0.3250	1.2440	1.2500	10.0000	0.4089	0.3969
0.0130	0.3086	0.3290	0.3500	1.2720	1.2720	11.0000	0.3820	0.3708
0.0140	0.3171	0.3390	0.3750	1.2970	1.2910	12.0000	0.3587	0.3484
0.0150	0.3254	0.3487	0.4000	1.3190	1.3080	13.0000	0.3385	0.3287
0.0160	0.3336	0.3582	0.4500	1.3550	1.3360	14.0000	0.3206	0.3115
0.0170	0.3416	0.3675	0.5000	1.3810	1.3560	15.0000	0.3048	0.2961
0.0180	0.3494	0.3766	0.5500	1.3990	1.3710	16.0000	0.2906	0.2824
0.0200	0.3645	0.3943	0.6000	1.4120	1.3810	17.0000	0.2778	0.2701
0.0225	0.3827	0.4156	0.6500	1.4200	1.3860	18.0000	0.2663	0.2589
0.0250	0.4002	0.4360	0.7000	1.4230	1.3880	20.0000	0.2461	0.2393
0.0275	0.4170	0.4556	0.8000	1.4210	1.3830	22.5000	0.2252	0.2191
0.0300	0.4332	0.4745	0.9000	1.4080	1.3720	25.0000	0.2079	0.2023
0.0325	0.4489	0.4928	1.0000	1.3890	1.3540	27.5000	0.1934	0.1882
0.0350	0.4641	0.5104	1.1000	1.3730	1.3370	30.0000	0.1809	0.1761
0.0375	0.4788	0.5275	1.2000	1.3580	1.3190	32.5000	0.1701	0.1656
0.0400	0.4932	0.5441	1.3000	1.3420	1.3000	35.0000	0.1606	0.1564
0.0450	0.5207	0.5758	1.4000	1.3230	1.2780	37.5000	0.1522	0.1483
0.0500	0.5469	0.6058	1.5000	1.3020	1.2550	40.0000	0.1448	0.1410
0.0550	0.5719	0.6342	1.6000	1.2780	1.2290	45.0000	0.1321	0.1287
0.0600	0.5959	0.6611	1.7000	1.2520	1.2020	50.0000	0.1216	0.1185
0.0650	0.6189	0.6867	1.8000	1.2240	1.1740	55.0000	0.1128	0.1100
0.0700	0.6410	0.7110	2.0000	1.1640	1.1170	60.0000	0.1054	0.1027
0.0800	0.6830	0.7562	2.2500	1.0880	1.0450	65.0000	0.0989	0.0964
0.0900	0.7223	0.7974	2.5000	1.0220	0.9834	70.0000	0.0933	0.0909
0.1000	0.7593	0.8350	2.7500	0.9648	0.9292	80.0000	0.0839	0.0818
0.1100	0.7941	0.8695	3.0000	0.9145	0.8808	90.0000	0.0764	0.0745
0.1200	0.8270	0.9013	3.2500	0.8698	0.8389	100.0000	0.0703	0.0686
0.1300	0.8582	0.9305	3.5000	0.8301	0.8019	110.0000	0.0652	0.0636
0.1400	0.8879	0.9577	3.7500	0.7948	0.7683	120.0000	0.0608	0.0593
0.1500	0.9161	0.9830	4.0000	0.7628	0.7376	130.0000	0.0571	0.0557
0.1600	0.9429	1.0070	4.5000	0.7068	0.6840	140.0000	0.0538	0.0525
0.1700	0.9685	1.0290	5.0000	0.6595	0.6386	150.0000	0.0510	0.0497
0.1800	0.9929	1.0490	5.5000	0.6189	0.5995	160.0000	0.0485	0.0473
0.2000	1.0380	1.0870	6.0000	0.5837	0.5657	170.0000	0.0462	0.0451
0.2250	1.0900	1.1290	6.5000	0.5527	0.5358	180.0000	0.0442	0.0431
0.2500	1.1350	1.1650	7.0000	0.5252	0.5093	200.0000	0.0407	0.0397

Table (3-10) Mass stopping power for alpha particle in **Breast tissue**

E(MeV)	Mass Stopping power× 10^3 MeV/(gm/cm^2)			For Breast Tissue	
				Present work	
	Bethe	SRIM	Ziegler	Average S.P.	S.P(P.W)
0.0100	-	0.4922	0.4652	0.4787	0.4954
0.0110	-	0.5072	0.4842	0.4957	0.5087
0.0120	-	0.5221	0.5023	0.5122	0.5218
0.0130	-	0.5366	0.5196	0.5281	0.5348
0.0140	-	0.5508	0.5361	0.5435	0.5476
0.0150	-	0.5649	0.5520	0.5585	0.5603
0.0160	-	0.5786	0.5674	0.5730	0.5729
0.0170	-	0.5922	0.5822	0.5872	0.5853
0.0180	-	0.6055	0.5965	0.6010	0.5976
0.0200	-	0.6315	0.6239	0.6277	0.6217
0.0225	-	0.6626	0.6561	0.6593	0.6511
0.0250	-	0.6925	0.6863	0.6894	0.6798
0.0275	-	0.7213	0.7149	0.7181	0.7077
0.0300	-	0.7489	0.7420	0.7455	0.7348
0.0325	-	0.7754	0.7679	0.7716	0.7612
0.0350	-	0.8009	0.7927	0.7968	0.7869
0.0375	-	0.8254	0.8165	0.8210	0.8119
0.0400	-	0.8491	0.8394	0.8442	0.8363
0.0450	-	0.8942	0.8828	0.8885	0.8831
0.0500	-	0.9365	0.9235	0.9300	0.9275
0.0550	-	0.9765	0.9619	0.9692	0.9698
0.0600	-	1.0149	0.9982	1.0066	1.0099
0.0650	-	1.0517	1.0327	1.0422	1.0481
0.0700	-	1.0874	1.0657	1.0765	1.0845
0.0800	-	1.1556	1.1275	1.1416	1.1523
0.0900	-	1.2210	1.1846	1.2028	1.2143
0.1000	-	1.2830	1.2376	1.2603	1.2713
0.1100	-	1.3419	1.2872	1.3145	1.3240
0.1200	-	1.3986	1.3337	1.3662	1.3731
0.1300	-	1.4524	1.3775	1.4149	1.4189
0.1400	-	1.5040	1.4189	1.4615	1.4622
0.1500	-	1.5532	1.4580	1.5056	1.5031
0.1600	-	1.6002	1.4951	1.5477	1.5422
0.1700	-	1.6454	1.5303	1.5879	1.5796
0.1800	-	1.6887	1.5637	1.6262	1.6156
0.2000	-	1.7689	1.6259	1.6974	1.6841
0.2250	-	1.8602	1.6955	1.7778	1.7647
0.2500	-	1.9407	1.7573	1.8490	1.8407
0.2750	-	2.0134	1.8121	1.9128	1.9127
0.3000	-	2.0768	1.8608	1.9688	1.9805
0.3250	-	2.1334	1.9038	2.0186	2.0441
0.3500	-	2.1823	1.9418	2.0621	2.1032
0.3750	2.3862	2.2251	1.9751	2.1955	2.1575
0.4000	2.4409	2.2624	2.0041	2.2358	2.2067
0.4500	2.5003	2.3192	2.0508	2.2901	2.2870
0.5000	2.5165	2.3577	2.0843	2.3195	2.3342

0.5500	**2.5066**	**2.3801**	**2.1065**	**2.3311**	**2.3456**
0.6000	**2.4809**	**2.3902**	**2.1193**	**2.3301**	**2.3311**
0.6500	**2.4457**	**2.3891**	**2.1241**	**2.3196**	**2.3135**
0.7000	**2.4047**	**2.3803**	**2.1222**	**2.3024**	**2.2930**
0.8000	**2.3150**	**2.3435**	**2.1027**	**2.2537**	**2.2446**
0.9000	**2.2231**	**2.2911**	**2.0680**	**2.1941**	**2.1881**
1.0000	**2.1339**	**2.2302**	**2.0233**	**2.1291**	**2.1260**
1.1000	**2.0494**	**2.1657**	**1.9728**	**2.0626**	**2.0608**
1.2000	**1.9702**	**2.1005**	**1.9191**	**1.9966**	**1.9946**
1.3000	**1.8964**	**2.0364**	**1.8643**	**1.9324**	**1.9292**
1.4000	**1.8278**	**1.9741**	**1.8098**	**1.8706**	**1.8660**
1.5000	**1.7641**	**1.9144**	**1.7563**	**1.8116**	**1.8058**
1.6000	**1.7048**	**1.8576**	**1.7046**	**1.7557**	**1.7491**
1.7000	**1.6495**	**1.8039**	**1.6550**	**1.7028**	**1.6960**
1.8000	**1.5980**	**1.7527**	**1.6076**	**1.6528**	**1.6463**
2.0000	**1.5048**	**1.6581**	**1.5199**	**1.5609**	**1.5562**
2.2500	**1.4037**	**1.5540**	**1.4228**	**1.4602**	**1.4572**
2.5000	**1.3166**	**1.4618**	**1.3383**	**1.3722**	**1.3697**
2.7500	**1.2407**	**1.3800**	**1.2645**	**1.2951**	**1.2917**
3.0000	**1.1739**	**1.3072**	**1.1997**	**1.2269**	**1.2222**
3.2500	**1.1147**	**1.2420**	**1.1424**	**1.1664**	**1.1606**
3.5000	**1.0619**	**1.1832**	**1.0913**	**1.1121**	**1.1062**
3.7500	**1.0143**	**1.1302**	**1.0456**	**1.0634**	**1.0579**
4.0000	**0.9713**	**1.0819**	**1.0043**	**1.0192**	**1.0147**
4.5000	**0.8964**	**0.9978**	**0.9327**	**0.9423**	**0.9394**
5.0000	**0.8334**	**0.9266**	**0.8724**	**0.8775**	**0.8751**
5.5000	**0.7795**	**0.8656**	**0.8208**	**0.8220**	**0.8191**
6.0000	**0.7329**	**0.8128**	**0.7759**	**0.7739**	**0.7701**
6.5000	**0.6921**	**0.7665**	**0.7365**	**0.7317**	**0.7272**
7.0000	**0.6560**	**0.7255**	**0.7015**	**0.6943**	**0.6898**
8.0000	**0.5951**	**0.6565**	**0.6420**	**0.6312**	**0.6278**
9.0000	**0.5455**	**0.6119**	**0.5929**	**0.5834**	**0.5783**
10.0000	**0.5043**	**0.5669**	**0.5517**	**0.5410**	**0.5367**
11.0000	**0.4694**	**0.5259**	**0.5122**	**0.5025**	**0.5005**
12.0000	**0.4394**	**0.4910**	**0.4798**	**0.4701**	**0.4683**
13.0000	**0.4134**	**0.4609**	**0.4516**	**0.4420**	**0.4395**
14.0000	**0.3906**	**0.4346**	**0.4267**	**0.4173**	**0.4140**
15.0000	**0.3703**	**0.4115**	**0.4047**	**0.3955**	**0.3917**
16.0000	**0.3523**	**0.3910**	**0.3850**	**0.3761**	**0.3722**
17.0000	**0.3361**	**0.3726**	**0.3673**	**0.3587**	**0.3552**
18.0000	**0.3214**	**0.3559**	**0.3513**	**0.3429**	**0.3401**
20.0000	**0.2959**	**0.3272**	**0.3235**	**0.3155**	**0.3142**
22.5000	**0.2697**	**0.2978**	**0.2947**	**0.2874**	**0.2865**
25.0000	**0.2480**	**0.2736**	**0.2710**	**0.2642**	**0.2625**
27.5000	**0.2298**	**0.2533**	**0.2511**	**0.2447**	**0.2422**
30.0000	**0.2144**	**0.2361**	**0.2342**	**0.2282**	**0.2256**
32.5000	**0.2010**	**0.2213**	**0.2195**	**0.2139**	**0.2121**
35.0000	**0.1893**	**0.2084**	**0.2068**	**0.2015**	**0.2005**
37.5000	**0.1790**	**0.1970**	**0.1955**	**0.1905**	**0.1902**
40.0000	**0.1699**	**0.1869**	**0.1855**	**0.1808**	**0.1808**
45.0000	**0.1543**	**0.1698**	**0.1686**	**0.1642**	**0.1642**

50.0000	0.1415	0.1558	0.1547	0.1507	0.1502
55.0000	0.1308	0.1441	0.1431	0.1393	0.1383
60.0000	0.1218	0.1342	0.1333	0.1298	0.1281
65.0000	0.1140	0.1257	0.1248	0.1215	0.1194
70.0000	0.1072	0.1182	0.1175	0.1143	0.1120
80.0000	0.0959	0.1060	0.1053	0.1024	0.1000
90.0000	0.0869	0.0962	0.0956	0.0929	0.0910
100.0000	0.0795	0.0883	0.0878	0.0852	0.0839
110.0000	0.0734	0.0817	0.0812	0.0788	0.0783
120.0000	0.0682	0.0761	0.0757	0.0733	0.0736
130.0000	0.0637	0.0713	0.0710	0.0687	0.0695
140.0000	0.0598	0.0671	0.0668	0.0646	0.0659
150.0000	0.0564	0.0635	0.0632	0.0610	0.0626
160.0000	0.0534	0.0602	0.0600	0.0579	0.0595
170.0000	0.0507	0.0574	0.0572	0.0551	0.0566
180.0000	0.0483	0.0548	0.0547	0.0526	0.0537
200.0000	0.0441	0.0503	0.0503	0.0482	0.0482

Table (3-11) Mass stopping power for alpha particle in **Ovary tissue**

E(MeV)	Mass Stopping power$\times 10^3$ MeV/(gm/cm^2) For Ovary Tissue				
				Present Work	
	Bethe	SRIM	Ziegler	Average S.P.	S.P.(P.W)
0.0100	-	0.4446	0.3931	0.4189	0.4208
0.0110	-	0.4575	0.4101	0.4338	0.4349
0.0120	-	0.4704	0.4263	0.4484	0.4488
0.0130	-	0.4830	0.4419	0.4625	0.4623
0.0140	-	0.4955	0.4568	0.4761	0.4757
0.0150	-	0.5077	0.4712	0.4895	0.4887
0.0160	-	0.5197	0.4851	0.5024	0.5015
0.0170	-	0.5317	0.4986	0.5152	0.5141
0.0180	-	0.5434	0.5117	0.5275	0.5264
0.0200	-	0.5663	0.5367	0.5515	0.5504
0.0225	-	0.5940	0.5661	0.5800	0.5792
0.0250	-	0.6206	0.5939	0.6072	0.6068
0.0275	-	0.6465	0.6202	0.6333	0.6332
0.0300	-	0.6715	0.6453	0.6584	0.6585
0.0325	-	0.6957	0.6693	0.6825	0.6829
0.0350	-	0.7191	0.6923	0.7057	0.7064
0.0375	-	0.7418	0.7144	0.7281	0.7290
0.0400	-	0.7640	0.7357	0.7499	0.7509
0.0450	-	0.8067	0.7764	0.7915	0.7926
0.0500	-	0.8473	0.8146	0.8310	0.8319
0.0550	-	0.8862	0.8507	0.8685	0.8692
0.0600	-	0.9236	0.8850	0.9043	0.9048
0.0650	-	0.9597	0.9178	0.9387	0.9388
0.0700	-	0.9946	0.9491	0.9718	0.9716
0.0800	-	1.0614	1.0080	1.0347	1.0341
0.0900	-	1.1248	1.0627	1.0938	1.0930
0.1000	-	1.1849	1.1137	1.1493	1.1490

0.1100	-	1.2421	1.1616	1.2018	1.2025
0.1200	-	1.2969	1.2067	1.2518	1.2536
0.1300	-	1.3492	1.2494	1.2993	1.3023
0.1400	-	1.3992	1.2898	1.3445	1.3488
0.1500	-	1.4471	1.3282	1.3877	1.3930
0.1600	-	1.4931	1.3647	1.4289	1.4352
0.1700	-	1.5373	1.3995	1.4684	1.4753
0.1800	-	1.5800	1.4327	1.5063	1.5137
0.2000	-	1.6592	1.4946	1.5769	1.5861
0.2250	-	1.7504	1.5645	1.6574	1.6710
0.2500	-	1.8315	1.6271	1.7293	1.7523
0.2750	-	1.9053	1.6832	1.7942	1.8306
0.3000	-	1.9703	1.7334	1.8519	1.9033
0.3250	-	2.0290	1.7782	1.9036	1.9408
0.3500	-	2.0803	1.8182	1.9492	1.9839
0.3750	-	2.1258	1.8537	1.9897	2.0253
0.4000	2.3195	2.1658	1.8851	2.1235	2.0644
0.4500	2.3922	2.2282	1.9368	2.1857	2.1340
0.5000	2.4189	2.2723	1.9755	2.2222	2.1901
0.5500	2.4178	2.3000	2.0030	2.2403	2.2304
0.6000	2.3993	2.3151	2.0209	2.2451	2.2542
0.6500	2.3702	2.3184	2.0307	2.2398	2.2618
0.7000	2.3345	2.3141	2.0337	2.2274	2.2547
0.8000	2.2534	2.2842	2.0230	2.1869	2.2068
0.9000	2.1682	2.2371	1.9959	2.1337	2.1342
1.0000	2.0844	2.1803	1.9580	2.0742	2.0582
1.1000	2.0042	2.1189	1.9131	2.0121	1.9906
1.2000	1.9288	2.0559	1.8641	1.9496	1.9338
1.3000	1.8581	1.9936	1.8134	1.8884	1.8838
1.4000	1.7922	1.9327	1.7622	1.8290	1.8357
1.5000	1.7308	1.8743	1.7116	1.7722	1.7860
1.6000	1.6735	1.8187	1.6624	1.7182	1.7337
1.7000	1.6201	1.7660	1.6149	1.6670	1.6794
1.8000	1.5702	1.7157	1.5694	1.6184	1.6245
2.0000	1.4796	1.6230	1.4847	1.5291	1.5197
2.2500	1.3813	1.5209	1.3906	1.4309	1.4090
2.5000	1.2964	1.4305	1.3084	1.3451	1.3243
2.7500	1.2223	1.3504	1.2366	1.2698	1.2595
3.0000	1.1570	1.2791	1.1735	1.2032	1.2056
3.2500	1.0991	1.2154	1.1177	1.1441	1.1559
3.5000	1.0473	1.1581	1.0681	1.0912	1.1073
3.7500	1.0007	1.1064	1.0236	1.0436	1.0593
4.0000	0.9585	1.0595	0.9835	1.0005	1.0124
4.5000	0.8851	0.9776	0.9139	0.9255	0.9262
5.0000	0.8232	0.9085	0.8553	0.8623	0.8542
5.5000	0.7702	0.8494	0.8052	0.8083	0.7970
6.0000	0.7243	0.7982	0.7617	0.7614	0.7522
6.5000	0.6842	0.7533	0.7235	0.7203	0.7158
7.0000	0.6486	0.7136	0.6895	0.6839	0.6845
8.0000	0.5886	0.6466	0.6317	0.6223	0.6293
9.0000	0.5398	0.6037	0.5840	0.5758	0.5787

10.0000	**0.4991**	**0.5600**	**0.5439**	**0.5343**	**0.5329**
11.0000	**0.4646**	**0.5195**	**0.5050**	**0.4964**	**0.4927**
12.0000	**0.4351**	**0.4850**	**0.4731**	**0.4644**	**0.4587**
13.0000	**0.4094**	**0.4554**	**0.4454**	**0.4367**	**0.4306**
14.0000	**0.3868**	**0.4295**	**0.4210**	**0.4124**	**0.4074**
15.0000	**0.3668**	**0.4067**	**0.3993**	**0.3909**	**0.3882**
16.0000	**0.3490**	**0.3864**	**0.3800**	**0.3718**	**0.3720**
17.0000	**0.3330**	**0.3683**	**0.3626**	**0.3546**	**0.3577**
18.0000	**0.3185**	**0.3519**	**0.3468**	**0.3391**	**0.3447**
20.0000	**0.2933**	**0.3236**	**0.3194**	**0.3121**	**0.3210**
22.5000	**0.2673**	**0.2945**	**0.2911**	**0.2843**	**0.2937**
25.0000	**0.2459**	**0.2707**	**0.2677**	**0.2614**	**0.2684**
27.5000	**0.2279**	**0.2506**	**0.2481**	**0.2422**	**0.2458**
30.0000	**0.2126**	**0.2337**	**0.2314**	**0.2259**	**0.2261**
32.5000	**0.1993**	**0.2190**	**0.2170**	**0.2118**	**0.2094**
35.0000	**0.1878**	**0.2063**	**0.2044**	**0.1995**	**0.1956**
37.5000	**0.1776**	**0.1950**	**0.1933**	**0.1886**	**0.1841**
40.0000	**0.1685**	**0.1850**	**0.1835**	**0.1790**	**0.1746**
45.0000	**0.1531**	**0.1681**	**0.1667**	**0.1626**	**0.1595**
50.0000	**0.1404**	**0.1543**	**0.1530**	**0.1492**	**0.1476**
55.0000	**0.1299**	**0.1428**	**0.1416**	**0.1381**	**0.1374**
60.0000	**0.1209**	**0.1330**	**0.1319**	**0.1286**	**0.1282**
65.0000	**0.1131**	**0.1246**	**0.1235**	**0.1204**	**0.1198**
70.0000	**0.1064**	**0.1172**	**0.1163**	**0.1133**	**0.1123**
80.0000	**0.0952**	**0.1051**	**0.1043**	**0.1015**	**0.0998**
90.0000	**0.0863**	**0.0954**	**0.0947**	**0.0921**	**0.0905**
100.0000	**0.0790**	**0.0875**	**0.0869**	**0.0845**	**0.0835**
110.0000	**0.0729**	**0.0810**	**0.0805**	**0.0781**	**0.0781**
120.0000	**0.0677**	**0.0754**	**0.0750**	**0.0727**	**0.0737**
130.0000	**0.0633**	**0.0707**	**0.0703**	**0.0681**	**0.0699**
140.0000	**0.0594**	**0.0666**	**0.0662**	**0.0641**	**0.0663**
150.0000	**0.0561**	**0.0629**	**0.0627**	**0.0606**	**0.0630**
160.0000	**0.0531**	**0.0597**	**0.0595**	**0.0574**	**0.0597**
170.0000	**0.0504**	**0.0569**	**0.0567**	**0.0547**	**0.0566**
180.0000	**0.0480**	**0.0543**	**0.0542**	**0.0522**	**0.0536**
200.0000	**0.0439**	**0.0500**	**0.0498**	**0.0479**	**0.0479**

Table (3-12) Mass stopping power for alpha particle in **Lung tissue**

E(MeV)	Mass Stopping power× 10^3 MeV/(gm/cm^2) For Lung Tissue				
				Present Work	
	Bethe	SRIM	Ziegler	Average S.P.	S.P.(P.W)
0.0100	-	0.4450	0.3945	0.4198	0.4262
0.0110	-	0.4580	0.4115	0.4348	0.4393
0.0120	-	0.4710	0.4278	0.4494	0.4522
0.0130	-	0.4836	0.4433	0.4634	0.4650
0.0140	-	0.4961	0.4583	0.4772	0.4776
0.0150	-	0.5084	0.4727	0.4905	0.4900
0.0160	-	0.5205	0.4866	0.5035	0.5022
0.0170	-	0.5324	0.5001	0.5162	0.5143
0.0180	-	0.5441	0.5132	0.5287	0.5262
0.0200	-	0.5672	0.5382	0.5527	0.5495
0.0225	-	0.5949	0.5676	0.5813	0.5777
0.0250	-	0.6216	0.5954	0.6085	0.6050
0.0275	-	0.6475	0.6217	0.6346	0.6314
0.0300	-	0.6725	0.6468	0.6597	0.6569
0.0325	-	0.6968	0.6707	0.6837	0.6816
0.0350	-	0.7202	0.6937	0.7069	0.7055
0.0375	-	0.7429	0.7159	0.7294	0.7287
0.0400	-	0.7651	0.7372	0.7511	0.7511
0.0450	-	0.8077	0.7778	0.7927	0.7941
0.0500	-	0.8482	0.8160	0.8321	0.8345
0.0550	-	0.8870	0.8520	0.8695	0.8728
0.0600	-	0.9243	0.8863	0.9053	0.9092
0.0650	-	0.9602	0.9190	0.9396	0.9437
0.0700	-	0.9950	0.9503	0.9727	0.9767
0.0800	-	1.0616	1.0091	1.0354	1.0387
0.0900	-	1.1248	1.0637	1.0942	1.0962
0.1000	-	1.1847	1.1147	1.1497	1.1502
0.1100	-	1.2417	1.1625	1.2021	1.2014
0.1200	-	1.2963	1.2075	1.2519	1.2504
0.1300	-	1.3484	1.2501	1.2993	1.2975
0.1400	-	1.3983	1.2904	1.3444	1.3430
0.1500	-	1.4459	1.3287	1.3873	1.3869
0.1600	-	1.4917	1.3651	1.4284	1.4293
0.1700	-	1.5357	1.3998	1.4678	1.4702
0.1800	-	1.5782	1.4329	1.5056	1.5093
0.2000	-	1.6570	1.4946	1.5758	1.5822
0.2250	-	1.7477	1.5643	1.6560	1.6620
0.2500	-	1.8283	1.6267	1.7275	1.7299
0.2750	-	1.9016	1.6826	1.7921	1.7905
0.3000	-	1.9662	1.7326	1.8494	1.8552
0.3250	-	2.0245	1.7772	1.9008	1.9329
0.3500	-	2.0753	1.8170	1.9461	1.9758
0.3750	-	2.1204	1.8524	1.9864	2.0169
0.4000	2.3140	2.1601	1.8836	2.1192	2.0556
0.4500	2.3866	2.2220	1.9350	2.1812	2.1246

0.5000	2.4135	2.2655	1.9734	2.2175	2.1802
0.5500	2.4124	2.2930	2.0006	2.2353	2.2206
0.6000	2.3941	2.3078	2.0184	2.2401	2.2450
0.6500	2.3650	2.3110	2.0280	2.2347	2.2538
0.7000	2.3295	2.3065	2.0308	2.2223	2.2482
0.8000	2.2486	2.2767	2.0198	2.1817	2.2028
0.9000	2.1637	2.2297	1.9926	2.1287	2.1306
1.0000	2.0800	2.1732	1.9546	2.0693	2.0522
1.1000	2.0001	2.1120	1.9096	2.0072	1.9809
1.2000	1.9248	2.0493	1.8607	1.9449	1.9209
1.3000	1.8543	1.9873	1.8100	1.8839	1.8700
1.4000	1.7885	1.9268	1.7588	1.8247	1.8232
1.5000	1.7273	1.8686	1.7083	1.7681	1.7766
1.6000	1.6701	1.8132	1.6592	1.7142	1.7278
1.7000	1.6168	1.7607	1.6117	1.6631	1.6766
1.8000	1.5670	1.7107	1.5663	1.6147	1.6240
2.0000	1.4767	1.6183	1.4817	1.5256	1.5202
2.2500	1.3785	1.5166	1.3877	1.4276	1.4058
2.5000	1.2938	1.4265	1.3057	1.3420	1.3159
2.7500	1.2198	1.3468	1.2340	1.2669	1.2477
3.0000	1.1547	1.2757	1.1710	1.2005	1.1935
3.2500	1.0969	1.2122	1.1154	1.1415	1.1458
3.5000	1.0453	1.1551	1.0658	1.0887	1.1002
3.7500	0.9988	1.1036	1.0214	1.0413	1.0549
4.0000	0.9567	1.0567	0.9813	0.9982	1.0102
4.5000	0.8833	0.9752	0.9118	0.9234	0.9251
5.0000	0.8216	0.9062	0.8534	0.8604	0.8512
5.5000	0.7687	0.8473	0.8034	0.8065	0.7912
6.0000	0.7229	0.7962	0.7599	0.7597	0.7441
6.5000	0.6828	0.7514	0.7218	0.7187	0.7072
7.0000	0.6474	0.7117	0.6879	0.6823	0.6771
8.0000	0.5875	0.6449	0.6301	0.6208	0.6268
9.0000	0.5387	0.6020	0.5825	0.5744	0.5808
10.0000	0.4981	0.5584	0.5425	0.5330	0.5365
11.0000	0.4637	0.5180	0.5037	0.4951	0.4950
12.0000	0.4342	0.4837	0.4719	0.4633	0.4576
13.0000	0.4086	0.4542	0.4443	0.4357	0.4253
14.0000	0.3861	0.4284	0.4199	0.4115	0.3982
15.0000	0.3661	0.4056	0.3983	0.3900	0.3761
16.0000	0.3483	0.3854	0.3790	0.3709	0.3583
17.0000	0.3323	0.3673	0.3617	0.3538	0.3439
18.0000	0.3179	0.3510	0.3460	0.3383	0.3321
20.0000	0.2927	0.3228	0.3186	0.3114	0.3131
22.5000	0.2668	0.2938	0.2904	0.2837	0.2927
25.0000	0.2454	0.2700	0.2671	0.2608	0.2721
27.5000	0.2275	0.2500	0.2475	0.2417	0.2507
30.0000	0.2122	0.2331	0.2309	0.2254	0.2296
32.5000	0.1990	0.2185	0.2165	0.2113	0.2101
35.0000	0.1874	0.2058	0.2039	0.1990	0.1946
37.5000	0.1772	0.1946	0.1928	0.1882	0.1848
40.0000	0.1682	0.1846	0.1830	0.1786	0.1791

45.0000	0.1528	0.1677	0.1663	0.1623	0.1581
50.0000	0.1402	0.1540	0.1526	0.1489	0.1364
55.0000	0.1296	0.1424	0.1412	0.1377	0.1275
60.0000	0.1206	0.1326	0.1316	0.1283	0.1217
65.0000	0.1129	0.1243	0.1232	0.1201	0.1167
70.0000	0.1062	0.1169	0.1160	0.1130	0.1119
80.0000	0.0950	0.1048	0.1040	0.1013	0.1031
90.0000	0.0861	0.0952	0.0945	0.0919	0.0950
100.0000	0.0788	0.0873	0.0867	0.0843	0.0875
110.0000	0.0727	0.0808	0.0803	0.0779	0.0806
120.0000	0.0676	0.0753	0.0748	0.0726	0.0742
130.0000	0.0632	0.0705	0.0701	0.0679	0.0683
140.0000	0.0593	0.0664	0.0661	0.0639	0.0629
150.0000	0.0560	0.0628	0.0625	0.0604	0.0579
160.0000	0.0530	0.0596	0.0594	0.0573	0.0533
170.0000	0.0503	0.0568	0.0566	0.0546	0.0491
180.0000	0.0479	0.0542	0.0541	0.0521	0.0452
200.0000	0.0438	0.0498	0.0497	0.0478	0.0382

Table (3-13) Mass stopping power for alpha particle in **Muscle tissue**

E(MeV)	Mass Stopping power× 10^3 MeV/(gm/cm^2)(ForMuscle Tissue)				
				Present Work	
	Bethe	SRIM	Ziegler	Average S.P.	S.P.(P.W)
0.0100	-	0.4443	0.3931	0.4187	0.4250
0.0110	-	0.4573	0.4101	0.4337	0.4381
0.0120	-	0.4702	0.4263	0.4482	0.4510
0.0130	-	0.4828	0.4419	0.4624	0.4637
0.0140	-	0.4952	0.4568	0.4760	0.4763
0.0150	-	0.5075	0.4712	0.4893	0.4887
0.0160	-	0.5196	0.4851	0.5023	0.5009
0.0170	-	0.5315	0.4986	0.5151	0.5129
0.0180	-	0.5432	0.5116	0.5274	0.5248
0.0200	-	0.5662	0.5366	0.5514	0.5480
0.0225	-	0.5938	0.5660	0.5799	0.5762
0.0250	-	0.6204	0.5937	0.6070	0.6034
0.0275	-	0.6463	0.6200	0.6331	0.6297
0.0300	-	0.6713	0.6451	0.6582	0.6552
0.0325	-	0.6955	0.6690	0.6823	0.6798
0.0350	-	0.7189	0.6920	0.7055	0.7037
0.0375	-	0.7416	0.7141	0.7278	0.7268
0.0400	-	0.7638	0.7355	0.7497	0.7492
0.0450	-	0.8063	0.7760	0.7912	0.7920
0.0500	-	0.8468	0.8142	0.8305	0.8324
0.0550	-	0.8856	0.8503	0.8680	0.8706
0.0600	-	0.9229	0.8845	0.9037	0.9069
0.0650	-	0.9588	0.9172	0.9380	0.9414
0.0700	-	0.9937	0.9485	0.9711	0.9743
0.0800	-	1.0602	1.0073	1.0337	1.0361

0.0900	**-**	**1.1234**	**1.0619**	**1.0927**	**1.0935**
0.1000	**-**	**1.1833**	**1.1129**	**1.1481**	**1.1473**
0.1100	**-**	**1.2404**	**1.1607**	**1.2006**	**1.1984**
0.1200	**-**	**1.2949**	**1.2058**	**1.2503**	**1.2472**
0.1300	**-**	**1.3471**	**1.2484**	**1.2978**	**1.2941**
0.1400	**-**	**1.3969**	**1.2887**	**1.3428**	**1.3394**
0.1500	**-**	**1.4446**	**1.3270**	**1.3858**	**1.3831**
0.1600	**-**	**1.4904**	**1.3635**	**1.4269**	**1.4253**
0.1700	**-**	**1.5345**	**1.3982**	**1.4663**	**1.4660**
0.1800	**-**	**1.5770**	**1.4313**	**1.5042**	**1.5050**
0.2000	**-**	**1.6558**	**1.4931**	**1.5745**	**1.5774**
0.2250	**-**	**1.7466**	**1.5629**	**1.6547**	**1.6568**
0.2500	**-**	**1.8273**	**1.6254**	**1.7263**	**1.7242**
0.2750	**-**	**1.9007**	**1.6814**	**1.7911**	**1.7844**
0.3000	**-**	**1.9654**	**1.7315**	**1.8485**	**1.8487**
0.3250	**-**	**2.0238**	**1.7762**	**1.9000**	**1.9377**
0.3500	**-**	**2.0748**	**1.8161**	**1.9455**	**1.9840**
0.3750	**-**	**2.1200**	**1.8516**	**1.9858**	**2.0282**
0.4000	**2.3504**	**2.1598**	**1.8829**	**2.1310**	**2.0697**
0.4500	**2.4283**	**2.2219**	**1.9345**	**2.1949**	**2.1433**
0.5000	**2.4583**	**2.2657**	**1.9731**	**2.2324**	**2.2020**
0.5500	**2.4593**	**2.2934**	**2.0005**	**2.2511**	**2.2439**
0.6000	**2.4422**	**2.3084**	**2.0184**	**2.2563**	**2.2685**
0.6500	**2.4138**	**2.3118**	**2.0282**	**2.2513**	**2.2764**
0.7000	**2.3785**	**2.3075**	**2.0312**	**2.2391**	**2.2692**
0.8000	**2.2973**	**2.2778**	**2.0205**	**2.1985**	**2.2206**
0.9000	**2.2116**	**2.2310**	**1.9935**	**2.1454**	**2.1471**
1.0000	**2.1269**	**2.1746**	**1.9556**	**2.0857**	**2.0702**
1.1000	**2.0457**	**2.1134**	**1.9107**	**2.0233**	**2.0022**
1.2000	**1.9692**	**2.0507**	**1.8619**	**1.9606**	**1.9454**
1.3000	**1.8974**	**1.9887**	**1.8112**	**1.8991**	**1.8958**
1.4000	**1.8305**	**1.9281**	**1.7601**	**1.8396**	**1.8484**
1.5000	**1.7680**	**1.8699**	**1.7096**	**1.7825**	**1.7994**
1.6000	**1.7097**	**1.8145**	**1.6604**	**1.7282**	**1.7474**
1.7000	**1.6554**	**1.7620**	**1.6129**	**1.6768**	**1.6931**
1.8000	**1.6045**	**1.7119**	**1.5674**	**1.6279**	**1.6380**
2.0000	**1.5123**	**1.6194**	**1.4828**	**1.5382**	**1.5322**
2.2500	**1.4121**	**1.5176**	**1.3888**	**1.4395**	**1.4204**
2.5000	**1.3254**	**1.4275**	**1.3067**	**1.3532**	**1.3353**
2.7500	**1.2498**	**1.3477**	**1.2349**	**1.2775**	**1.2703**
3.0000	**1.1832**	**1.2766**	**1.1719**	**1.2106**	**1.2159**
3.2500	**1.1241**	**1.2130**	**1.1161**	**1.1511**	**1.1652**
3.5000	**1.0712**	**1.1559**	**1.0666**	**1.0979**	**1.1151**
3.7500	**1.0237**	**1.1043**	**1.0221**	**1.0500**	**1.0654**
4.0000	**0.9806**	**1.0575**	**0.9820**	**1.0067**	**1.0170**
4.5000	**0.9055**	**0.9759**	**0.9125**	**0.9313**	**0.9288**
5.0000	**0.8423**	**0.9069**	**0.8540**	**0.8677**	**0.8566**
5.5000	**0.7881**	**0.8479**	**0.8040**	**0.8133**	**0.8010**
6.0000	**0.7412**	**0.7968**	**0.7605**	**0.7662**	**0.7585**
6.5000	**0.7002**	**0.7520**	**0.7223**	**0.7248**	**0.7247**
7.0000	**0.6639**	**0.7123**	**0.6884**	**0.6882**	**0.6955**

8.0000	**0.6025**	**0.6455**	**0.6306**	**0.6262**	**0.6422**
9.0000	**0.5525**	**0.6026**	**0.5830**	**0.5794**	**0.5910**
10.0000	**0.5109**	**0.5588**	**0.5430**	**0.5376**	**0.5428**
11.0000	**0.4757**	**0.5185**	**0.5041**	**0.4994**	**0.5002**
12.0000	**0.4454**	**0.4841**	**0.4724**	**0.4673**	**0.4642**
13.0000	**0.4191**	**0.4546**	**0.4447**	**0.4395**	**0.4347**
14.0000	**0.3961**	**0.4287**	**0.4203**	**0.4150**	**0.4108**
15.0000	**0.3756**	**0.4060**	**0.3987**	**0.3934**	**0.3913**
16.0000	**0.3574**	**0.3858**	**0.3794**	**0.3742**	**0.3747**
17.0000	**0.3410**	**0.3677**	**0.3620**	**0.3569**	**0.3600**
18.0000	**0.3261**	**0.3513**	**0.3463**	**0.3412**	**0.3465**
20.0000	**0.3003**	**0.3231**	**0.3189**	**0.3141**	**0.3215**
22.5000	**0.2737**	**0.2940**	**0.2906**	**0.2861**	**0.2927**
25.0000	**0.2518**	**0.2702**	**0.2673**	**0.2631**	**0.2671**
27.5000	**0.2334**	**0.2502**	**0.2478**	**0.2438**	**0.2454**
30.0000	**0.2177**	**0.2333**	**0.2311**	**0.2274**	**0.2276**
32.5000	**0.2042**	**0.2187**	**0.2167**	**0.2132**	**0.2131**
35.0000	**0.1923**	**0.2059**	**0.2041**	**0.2008**	**0.2012**
37.5000	**0.1819**	**0.1947**	**0.1930**	**0.1899**	**0.1910**
40.0000	**0.1726**	**0.1848**	**0.1832**	**0.1802**	**0.1819**
45.0000	**0.1568**	**0.1679**	**0.1665**	**0.1637**	**0.1655**
50.0000	**0.1439**	**0.1541**	**0.1528**	**0.1503**	**0.1509**
55.0000	**0.1330**	**0.1426**	**0.1414**	**0.1390**	**0.1382**
60.0000	**0.1238**	**0.1328**	**0.1317**	**0.1294**	**0.1279**
65.0000	**0.1159**	**0.1244**	**0.1233**	**0.1212**	**0.1197**
70.0000	**0.1090**	**0.1170**	**0.1161**	**0.1140**	**0.1133**
80.0000	**0.0975**	**0.1049**	**0.1041**	**0.1022**	**0.1038**
90.0000	**0.0884**	**0.0953**	**0.0946**	**0.0928**	**0.0963**
100.0000	**0.0809**	**0.0874**	**0.0868**	**0.0850**	**0.0895**
110.0000	**0.0747**	**0.0809**	**0.0803**	**0.0786**	**0.0833**
120.0000	**0.0694**	**0.0753**	**0.0749**	**0.0732**	**0.0775**
130.0000	**0.0649**	**0.0706**	**0.0702**	**0.0686**	**0.0721**
140.0000	**0.0609**	**0.0665**	**0.0661**	**0.0645**	**0.0670**
150.0000	**0.0574**	**0.0629**	**0.0626**	**0.0610**	**0.0623**
160.0000	**0.0544**	**0.0597**	**0.0594**	**0.0578**	**0.0579**
170.0000	**0.0516**	**0.0568**	**0.0566**	**0.0550**	**0.0539**
180.0000	**0.0492**	**0.0543**	**0.0541**	**0.0525**	**0.0501**
200.0000	**0.0449**	**0.0499**	**0.0498**	**0.0482**	**0.0432**

Table (3-14) Mass stopping power for alpha particle in **(SiO_2 , AL_2O_3 , ZrO_2)**

E(MeV)	Mass Stopping power× 10^3 M(eV/(gm/cm^2)																
	SiO2						AL2O3						ZrO2				
	Bethe	Ziegler	SRIM	ASTAR	Average S.P.	S.P. (P.W)	Bethe	Ziegler	SRIM	ASTAR	Average S.P.	S.P. (P.W)	Bethe	Ziegler	SRIM	Average S.P.	S.P. (P.W)
0.0100	-	0.2159	0.2990	0.2817	0.2655	0.2684	-	0.2325	0.3087	0.2977	0.2796	0.2838	-	0.1979	0.1771	0.1875	0.1898
0.0110	-	0.2279	0.3086	0.2909	0.2758	0.2777	-	0.2454	0.3200	0.3084	0.2913	0.2941	-	0.2063	0.1840	0.1952	0.1965
0.0120	-	0.2395	0.3178	0.2999	0.2857	0.2869	-	0.2578	0.3309	0.3189	0.3025	0.3043	-	0.2143	0.1906	0.2024	0.2032
0.0130	-	0.2506	0.3269	0.3086	0.2954	0.2960	-	0.2698	0.3416	0.3290	0.3135	0.3143	-	0.2219	0.1970	0.2095	0.2097
0.0140	-	0.2614	0.3358	0.3171	0.3048	0.3049	-	0.2814	0.3519	0.3390	0.3241	0.3242	-	0.2292	0.2034	0.2163	0.2160
0.0150	-	0.2719	0.3448	0.3254	0.3140	0.3138	-	0.2927	0.3620	0.3487	0.3345	0.3339	-	0.2363	0.2095	0.2229	0.2223
0.0160	-	0.2822	0.3536	0.3336	0.3231	0.3226	-	0.3036	0.3719	0.3582	0.3446	0.3435	-	0.2431	0.2154	0.2293	0.2284
0.0170	-	0.2922	0.3625	0.3416	0.3321	0.3312	-	0.3143	0.3817	0.3675	0.3545	0.3530	-	0.2496	0.2213	0.2354	0.2345
0.0180	-	0.3019	0.3713	0.3494	0.3409	0.3398	-	0.3247	0.3911	0.3766	0.3641	0.3623	-	0.2560	0.2270	0.2415	0.2404
0.0200	-	0.3207	0.3887	0.3645	0.3580	0.3566	-	0.3448	0.4094	0.3943	0.3828	0.3806	-	0.2681	0.2380	0.2531	0.2519
0.0225	-	0.3432	0.4102	0.3827	0.3787	0.3770	-	0.3687	0.4313	0.4156	0.4052	0.4028	-	0.2824	0.2513	0.2669	0.2658
0.0250	-	0.3646	0.4310	0.4002	0.3986	0.3969	-	0.3915	0.4523	0.4360	0.4266	0.4242	-	0.2959	0.2640	0.2799	0.2791
0.0275	-	0.3852	0.4512	0.4170	0.4178	0.4161	-	0.4132	0.4724	0.4556	0.4471	0.4449	-	0.3086	0.2762	0.2924	0.2918
0.0300	-	0.4050	0.4708	0.4332	0.4363	0.4349	-	0.4341	0.4916	0.4745	0.4667	0.4649	-	0.3207	0.2880	0.3044	0.3041
0.0325	-	0.4241	0.4900	0.4489	0.4543	0.4531	-	0.4542	0.5102	0.4928	0.4857	0.4843	-	0.3322	0.2994	0.3158	0.3158
0.0350	-	0.4426	0.5085	0.4641	0.4717	0.4708	-	0.4736	0.5280	0.5104	0.5040	0.5030	-	0.3433	0.3104	0.3269	0.3271
0.0375	-	0.4606	0.5265	0.4788	0.4886	0.4880	-	0.4923	0.5453	0.5275	0.5217	0.5212	-	0.3539	0.3212	0.3375	0.3380
0.0400	-	0.4780	0.5440	0.4932	0.5051	0.5047	-	0.5103	0.5619	0.5441	0.5388	0.5387	-	0.3642	0.3315	0.3479	0.3486
0.0450	-	0.5115	0.5777	0.5207	0.5366	0.5370	-	0.5448	0.5937	0.5758	0.5714	0.5722	-	0.3836	0.3516	0.3676	0.3686
0.0500	-	0.5434	0.6099	0.5469	0.5667	0.5675	-	0.5773	0.6237	0.6058	0.6023	0.6036	-	0.4019	0.3707	0.3863	0.3873
0.0550	-	0.5740	0.6405	0.5719	0.5955	0.5967	-	0.6079	0.6520	0.6342	0.6314	0.6331	-	0.4191	0.3889	0.4040	0.4050
0.0600	-	0.6033	0.6699	0.5959	0.6230	0.6244	-	0.6370	0.6791	0.6611	0.6591	0.6610	-	0.4355	0.4065	0.4210	0.4218
0.0650	-	0.6314	0.6981	0.6189	0.6495	0.6509	-	0.6645	0.7049	0.6867	0.6854	0.6873	-	0.4511	0.4234	0.4373	0.4378
0.0700	-	0.6586	0.7251	0.6410	0.6749	0.6763	-	0.6907	0.7295	0.7110	0.7104	0.7122	-	0.4661	0.4396	0.4529	0.4531
0.0800	-	0.7102	0.7763	0.6830	0.7232	0.7241	-	0.7392	0.7759	0.7562	0.7571	0.7583	-	0.4941	0.4706	0.4824	0.4821
0.0900	-	0.7586	0.8238	0.7223	0.7682	0.7685	-	0.7833	0.8187	0.7974	0.7998	0.8001	-	0.5202	0.4996	0.5099	0.5092
0.1000	-	0.8043	0.8682	0.7593	0.8106	0.8101	-	0.8236	0.8586	0.8350	0.8391	0.8384	-	0.5445	0.5271	0.5358	0.5349
0.1100	-	0.8474	0.9097	0.7941	0.8504	0.8492	-	0.8604	0.8958	0.8695	0.8752	0.8738	-	0.5674	0.5530	0.5602	0.5594
0.1200	-	0.8882	0.9487	0.8270	0.8880	0.8862	-	0.8943	0.9306	0.9013	0.9087	0.9068	-	0.5890	0.5775	0.5833	0.5828
0.1300	-	0.9269	0.9854	0.8582	0.9235	0.9215	-	0.9256	0.9634	0.9305	0.9398	0.9377	-	0.6094	0.6010	0.6052	0.6051

0.1400	-	0.9636	1.0194	0.8879	0.9570	0.9551	-	0.9546	0.9942	0.9577	0.9688	0.9668	-	0.6288	0.6233	0.6261	0.6264
0.1500	-	0.9985	1.0519	0.9161	0.9888	0.9873	-	0.9815	1.0236	0.9830	0.9960	0.9943	-	0.6472	0.6447	0.6460	0.6466
0.1600	-	1.0316	1.0835	0.9429	1.0193	1.0179	-	1.0066	1.0502	1.0070	1.0213	1.0203	-	0.6648	0.6650	0.6649	0.6659
0.1700	-	1.0631	1.1121	0.9685	1.0479	1.0472	-	1.0301	1.0768	1.0290	1.0453	1.0449	-	0.6816	0.6846	0.6831	0.6840
0.1800	-	1.0930	1.1397	0.9929	1.0752	1.0750	-	1.0522	1.1015	1.0490	1.0676	1.0681	-	0.6977	0.7031	0.7004	0.7012
0.2000	-	1.1484	1.1901	1.0380	1.1255	1.1263	-	1.0925	1.1459	1.0870	1.1085	1.1103	-	0.7278	0.7382	0.7330	0.7330
0.2250	-	1.2101	1.2455	1.0900	1.1819	1.1819	-	1.1369	1.1963	1.1290	1.1541	1.1551	-	0.7621	0.7780	0.7700	0.7691
0.2500	-	1.2640	1.2940	1.1350	1.2310	1.2289	-	1.1758	1.2408	1.1650	1.1939	1.1922	-	0.7932	0.8138	0.8035	0.8031
0.2750	-	1.3110	1.3366	1.1760	1.2745	1.2697	-	1.2101	1.2794	1.1970	1.2288	1.2246	-	0.8213	0.8462	0.8337	0.8352
0.3000	-	1.3518	1.3732	1.2120	1.3123	1.3104	0.6169	1.2404	1.3130	1.2250	1.2595	1.2589	-	0.8469	0.8753	0.8611	0.8609
0.3250	0.8317	1.3870	1.4049	1.2440	1.3453	1.3585	0.8458	1.2673	1.3427	1.2500	1.2867	1.2882	-	0.8700	0.9014	0.8857	0.8959
0.3500	1.0143	1.4171	1.4326	1.2720	1.3739	1.3797	1.0231	1.2912	1.3684	1.2720	1.3105	1.3098	-	0.8910	0.9249	0.9080	0.9118
0.3750	1.1569	1.4428	1.4573	1.2970	1.3990	1.4000	1.1614	1.3123	1.3912	1.2910	1.3315	1.3304	-	0.9100	0.9459	0.9280	0.9276
0.4000	1.2690	1.4645	1.4781	1.3190	1.4205	1.4191	1.2699	1.3309	1.4110	1.3080	1.3500	1.3499	-	0.9271	0.9645	0.9458	0.9429
0.4500	1.4271	1.4977	1.5107	1.3550	1.4476	1.4538	1.4225	1.3616	1.4416	1.3360	1.3904	1.3853	-	0.9563	0.9957	0.9760	0.9717
0.5000	1.5252	1.5197	1.5334	1.3810	1.4898	1.4830	1.5168	1.3847	1.4643	1.3560	1.4305	1.4154	-	0.9794	1.0194	0.9994	0.9970
0.5500	1.5846	1.5330	1.5472	1.3990	1.5159	1.5064	1.5734	1.4014	1.4791	1.3710	1.4562	1.4397	-	0.9973	1.0372	1.0173	1.0177
0.6000	1.6182	1.5393	1.5550	1.4120	1.5311	1.5238	1.6050	1.4127	1.4879	1.3810	1.4717	1.4582	-	1.0106	1.0491	1.0298	1.0333
0.6500	1.6345	1.5403	1.5578	1.4200	1.5382	1.5352	1.6198	1.4193	1.4917	1.3860	1.4792	1.4706	-	1.0198	1.0569	1.0383	1.0436
0.7000	1.6387	1.5370	1.5556	1.4230	1.5386	1.5407	1.6229	1.4221	1.4905	1.3880	1.4809	1.4773	-	1.0255	1.0608	1.0432	1.0489
0.8000	1.6246	1.5209	1.5413	1.4210	1.5270	1.5360	1.6074	1.4179	1.4793	1.3830	1.4719	1.4752	0.5293	1.0281	1.0596	1.0438	1.0470
0.9000	1.5937	1.4960	1.5171	1.4080	1.5037	1.5145	1.5757	1.4042	1.4590	1.3720	1.4527	1.4566	0.6066	1.0215	1.0495	1.0355	1.0345
1.0000	1.5547	1.4658	1.4869	1.3890	1.4741	1.4823	1.5363	1.3838	1.4329	1.3540	1.4268	1.4272	0.6556	1.0082	1.0324	1.0203	1.0179
1.1000	1.5124	1.4324	1.4528	1.3730	1.4427	1.4451	1.4939	1.3588	1.4027	1.3370	1.3981	1.3929	0.6861	0.9904	1.0113	1.0009	1.0004
1.2000	1.4692	1.3973	1.4177	1.3580	1.4106	1.4073	1.4508	1.3310	1.3706	1.3190	1.3679	1.3577	0.7043	0.9695	0.9886	0.9790	0.9821
1.3000	1.4266	1.3616	1.3816	1.3420	1.3779	1.3715	1.4083	1.3015	1.3375	1.3000	1.3368	1.3242	0.7142	0.9467	0.9642	0.9554	0.9612
1.4000	1.3851	1.3260	1.3455	1.3230	1.3449	1.3386	1.3671	1.2713	1.3044	1.2780	1.3052	1.2933	0.7182	0.9229	0.9392	0.9311	0.9366
1.5000	1.3454	1.2910	1.3104	1.3020	1.3122	1.3083	1.3276	1.2410	1.2723	1.2550	1.2740	1.2647	0.7182	0.8988	0.9145	0.9067	0.9081
1.6000	1.3074	1.2570	1.2773	1.2780	1.2799	1.2798	1.2899	1.2110	1.2413	1.2290	1.2428	1.2374	0.7153	0.8748	0.8900	0.8824	0.8769
1.7000	1.2712	1.2241	1.2442	1.2520	1.2479	1.2520	1.2541	1.1816	1.2102	1.2020	1.2120	1.2107	0.7103	0.8513	0.8662	0.8588	0.8449
1.8000	1.2369	1.1926	1.2132	1.2240	1.2167	1.2241	1.2200	1.1531	1.1811	1.1740	1.1821	1.1837	0.7039	0.8285	0.8432	0.7919	0.8140
2.0000	1.1734	1.1334	1.1541	1.1640	1.1562	1.1668	1.1572	1.0990	1.1260	1.1170	1.1248	1.1283	0.6883	0.7855	0.7997	0.7578	0.7604
2.2500	1.1028	1.0670	1.0890	1.0880	1.0867	1.0942	1.0873	1.0374	1.0629	1.0450	1.0581	1.0582	0.6662	0.7371	0.7505	0.7179	0.7123
2.5000	1.0407	1.0082	1.0299	1.0220	1.0252	1.0258	1.0259	0.9822	1.0069	0.9834	0.9996	0.9930	0.6435	0.6944	0.7068	0.6816	0.6787
2.7500	0.9857	0.9561	0.9772	0.9648	0.9710	0.9662	0.9715	0.9329	0.9570	0.9292	0.9477	0.9366	0.6210	0.6570	0.6682	0.6487	0.6510
3.0000	0.9367	0.9098	0.9302	0.9145	0.9228	0.9168	0.9231	0.8887	0.9117	0.8808	0.9011	0.8899	0.5994	0.6241	0.6339	0.6191	0.6244
3.2500	0.8928	0.8684	0.8879	0.8698	0.8797	0.8760	0.8798	0.8490	0.8709	0.8389	0.8597	0.8512	0.5789	0.5951	0.6034	0.5925	0.5981

3.5000	0.8532	0.8311	0.8498	0.8301	0.8410	0.8413	0.8407	0.8131	0.8339	0.8019	0.8224	0.8178	0.5596	0.5694	0.5762	0.5684	0.5724
3.7500	0.8174	0.7975	0.8151	0.7948	0.8062	0.8104	0.8053	0.7806	0.8003	0.7683	0.7886	0.7874	0.5414	0.5464	0.5518	0.5465	0.5482
4.0000	0.7847	0.7669	0.7835	0.7628	0.7745	0.7814	0.7731	0.7510	0.7697	0.7376	0.7579	0.7586	0.5244	0.5258	0.5298	0.5267	0.5260
4.5000	0.7274	0.7133	0.7281	0.7068	0.7189	0.7263	0.7165	0.6989	0.7156	0.6840	0.7037	0.7033	0.4933	0.4901	0.4921	0.4918	0.4884
5.0000	0.6788	0.6679	0.6811	0.6595	0.6718	0.6749	0.6685	0.6545	0.6696	0.6386	0.6578	0.6527	0.4659	0.4602	0.4608	0.4623	0.4591
5.5000	0.6369	0.6287	0.6406	0.6189	0.6313	0.6296	0.6272	0.6162	0.6298	0.5995	0.6182	0.6092	0.4416	0.4348	0.4342	0.4369	0.4359
6.0000	0.6004	0.5945	0.6052	0.5837	0.5960	0.5917	0.5912	0.5827	0.5951	0.5657	0.5837	0.5737	0.4199	0.4128	0.4116	0.4148	0.4165
6.5000	0.5683	0.5644	0.5742	0.5527	0.5649	0.5608	0.5596	0.5531	0.5646	0.5358	0.5533	0.5451	0.4004	0.3934	0.3920	0.3953	0.3992
7.0000	0.5398	0.5375	0.5466	0.5252	0.5373	0.5354	0.5315	0.5268	0.5374	0.5093	0.5263	0.5214	0.3828	0.3763	0.3748	0.3780	0.3831
8.0000	0.4914	0.4918	0.4996	0.4787	0.4904	0.4945	0.4838	0.4818	0.4910	0.4644	0.4803	0.4808	0.3523	0.3470	0.3458	0.3484	0.3534
9.0000	0.4517	0.4540	0.4630	0.4407	0.4524	0.4588	0.4447	0.4447	0.4547	0.4276	0.4429	0.4433	0.3268	0.3227	0.3228	0.3241	0.3270
10.0000	0.4186	0.4223	0.4282	0.4089	0.4195	0.4251	0.4121	0.4135	0.4203	0.3969	0.4107	0.4084	0.3051	0.3022	0.3009	0.3027	0.3038
11.0000	0.3904	0.3935	0.3994	0.3820	0.3913	0.3945	0.3843	0.3854	0.3919	0.3708	0.3831	0.3782	0.2863	0.2832	0.2825	0.2840	0.2838
12.0000	0.3662	0.3698	0.3747	0.3587	0.3674	0.3682	0.3604	0.3623	0.3676	0.3484	0.3597	0.3534	0.2700	0.2675	0.2665	0.2680	0.2667
13.0000	0.3451	0.3492	0.3532	0.3385	0.3465	0.3463	0.3396	0.3420	0.3465	0.3287	0.3392	0.3333	0.2557	0.2536	0.2525	0.2539	0.2521
14.0000	0.3265	0.3309	0.3343	0.3206	0.3281	0.3282	0.3213	0.3241	0.3279	0.3115	0.3212	0.3163	0.2429	0.2413	0.2400	0.2414	0.2397
15.0000	0.3100	0.3146	0.3175	0.3048	0.3117	0.3125	0.3050	0.3082	0.3115	0.2961	0.3052	0.3009	0.2315	0.2303	0.2289	0.2302	0.2290
16.0000	0.2952	0.3000	0.3025	0.2906	0.2971	0.2981	0.2905	0.2938	0.2968	0.2824	0.2909	0.2865	0.2212	0.2203	0.2189	0.2201	0.2197
17.0000	0.2819	0.2868	0.2891	0.2778	0.2839	0.2847	0.2774	0.2809	0.2835	0.2701	0.2780	0.2730	0.2119	0.2113	0.2099	0.2110	0.2114
18.0000	0.2699	0.2748	0.2769	0.2663	0.2720	0.2722	0.2656	0.2692	0.2716	0.2589	0.2663	0.2608	0.2034	0.2031	0.2017	0.2027	0.2039
20.0000	0.2489	0.2539	0.2555	0.2461	0.2511	0.2515	0.2449	0.2487	0.2506	0.2393	0.2459	0.2414	0.1886	0.1886	0.1873	0.1882	0.1906
22.5000	0.2272	0.2322	0.2335	0.2252	0.2295	0.2332	0.2236	0.2274	0.2290	0.2191	0.2248	0.2242	0.1731	0.1734	0.1723	0.1729	0.1763
25.0000	0.2093	0.2142	0.2154	0.2079	0.2117	0.2171	0.2060	0.2098	0.2112	0.2023	0.2073	0.2077	0.1601	0.1608	0.1598	0.1602	0.1637
27.5000	0.1943	0.1991	0.2001	0.1934	0.1967	0.1992	0.1911	0.1950	0.1962	0.1882	0.1926	0.1891	0.1492	0.1501	0.1492	0.1495	0.1526
30.0000	0.1814	0.1861	0.1870	0.1809	0.1838	0.1811	0.1785	0.1822	0.1834	0.1761	0.1801	0.1710	0.1398	0.1408	0.1400	0.1402	0.1408
32.5000	0.1702	0.1748	0.1757	0.1701	0.1727	0.1657	0.1675	0.1712	0.1723	0.1656	0.1691	0.1564	0.1316	0.1328	0.1321	0.1322	0.1339
35.0000	0.1605	0.1650	0.1659	0.1606	0.1630	0.1542	0.1579	0.1616	0.1626	0.1564	0.1596	0.1461	0.1244	0.1257	0.1251	0.1251	0.1261
37.5000	0.1519	0.1563	0.1571	0.1522	0.1544	0.1462	0.1494	0.1531	0.1541	0.1483	0.1512	0.1393	0.1180	0.1194	0.1189	0.1188	0.1191
40.0000	0.1443	0.1486	0.1494	0.1448	0.1468	0.1406	0.1419	0.1455	0.1464	0.1410	0.1437	0.1345	0.1123	0.1138	0.1133	0.1131	0.1128
45.0000	0.1312	0.1354	0.1361	0.1321	0.1337	0.1328	0.1291	0.1325	0.1335	0.1287	0.1310	0.1273	0.1026	0.1041	0.1038	0.1035	0.1023
50.0000	0.1205	0.1245	0.1252	0.1216	0.1229	0.1263	0.1185	0.1219	0.1228	0.1185	0.1204	0.1210	0.0945	0.0962	0.0958	0.0955	0.0938
55.0000	0.1115	0.1154	0.1161	0.1128	0.1140	0.1202	0.1097	0.1130	0.1138	0.1100	0.1116	0.1150	0.0877	0.0895	0.0892	0.0888	0.0870
60.0000	0.1039	0.1077	0.1084	0.1054	0.1064	0.1144	0.1022	0.1055	0.1062	0.1027	0.1041	0.1093	0.0819	0.0837	0.0835	0.0830	0.0814
65.0000	0.0973	0.1011	0.1017	0.0989	0.0998	0.1089	0.0957	0.0989	0.0996	0.0964	0.0977	0.1039	0.0769	0.0788	0.0786	0.0781	0.0768
70.0000	0.0916	0.0953	0.0958	0.0933	0.0940	0.1037	0.0901	0.0933	0.0939	0.0909	0.0920	0.0988	0.0725	0.0745	0.0743	0.0738	0.0729
80.0000	0.0820	0.0856	0.0861	0.0839	0.0844	0.0940	0.0807	0.0838	0.0844	0.0818	0.0827	0.0892	0.0652	0.0672	0.0671	0.0665	0.0666
90.0000	0.0744	0.0780	0.0784	0.0764	0.0768	0.0851	0.0732	0.0763	0.0768	0.0745	0.0752	0.0806	0.0593	0.0614	0.0613	0.0607	0.0617

100.0000	0.0682	0.0717	0.0720	0.0703	0.0706	0.0771	0.0670	0.0702	0.0706	0.0686	0.0691	0.0727	0.0545	0.0566	0.0565	0.0559	0.0575
110.0000	0.0630	0.0664	0.0667	0.0652	0.0653	0.0698	0.0619	0.0650	0.0654	0.0636	0.0640	0.0657	0.0504	0.0527	0.0525	0.0519	0.0537
120.0000	0.0585	0.0620	0.0623	0.0608	0.0609	0.0632	0.0576	0.0607	0.0610	0.0593	0.0597	0.0593	0.0470	0.0493	0.0491	0.0485	0.0503
130.0000	0.0547	0.0582	0.0584	0.0571	0.0571	0.0572	0.0538	0.0570	0.0572	0.0557	0.0559	0.0535	0.0440	0.0463	0.0462	0.0455	0.0471
140.0000	0.0514	0.0549	0.0551	0.0538	0.0538	0.0518	0.0506	0.0537	0.0540	0.0525	0.0527	0.0483	0.0414	0.0438	0.0436	0.0429	0.0440
150.0000	0.0485	0.0520	0.0521	0.0510	0.0509	0.0469	0.0477	0.0509	0.0511	0.0497	0.0498	0.0436	0.0391	0.0415	0.0414	0.0407	0.0411
160.0000	0.0460	0.0494	0.0495	0.0485	0.0484	0.0424	0.0452	0.0484	0.0485	0.0473	0.0474	0.0393	0.0371	0.0395	0.0394	0.0387	0.0383
170.0000	0.0437	0.0471	0.0472	0.0462	0.0460	0.0384	0.0429	0.0461	0.0463	0.0451	0.0451	0.0354	0.0353	0.0378	0.0376	0.0369	0.0356
180.0000	0.0416	0.0451	0.0451	0.0442	0.0440	0.0347	0.0409	0.0441	0.0442	0.0431	0.0431	0.0320	0.0336	0.0362	0.0360	0.0353	0.0331
200.0000	0.0380	0.0415	0.0415	0.0407	0.0404	0.0284	0.0374	0.0406	0.0407	0.0397	0.0396	0.0260	0.0308	0.0334	0.0332	0.0325	0.0283

(3.3)Linear energy transfer (LET) .

(3.3.1) Linear energy transfer (LET) in tissues

Linear energy transfer (LET) resulting from alpha particle reaction with human tissues (breast, ovary,lung and muscle) for the energy range (0.01-200) MeV is calculated by using eq.(2-39) . Results are tabulated in tables (3-15),(3-16),(3-17), and (3-18) , where ρ the density of tissue and its values are listed in the table (3-1).

(3.3.2)Linear energy transfer (LET) in materials

Linear energy transfer (LET) resulting from alpha particle reaction with (SiO_2, AL_2O_3 , ZrO_2) materials for the energy range (0.01-200) MeV is calculated by using eq.(2-39). Results are tabulated in table (3-19) . Where ρ the density of material and its values are listed in the table (3-2).

(3.4) The range of alpha particle

(3.4.1) The range of alpha particle in tissues

The Range of the alpha particle in (breast, ovary, lung and muscle) tissues were calculated by linear integration of reciprocal stopping power to each tissue (the limits of integration were between (0.01-200 MeV) by using eq. (2-45). And then finding the semi-imperical equation by using Matlab program. This equation represents range of alpha particle in the tissue. Results are tabulated in tables (3-15),(3-16),(3-17), and (3-18).

(3.4.2) The range of alpha particle in materials

The range of the alpha particle in materials (SiO_2, AL_2O_3 , ZrO_2) is calculated by linear integration of reciprocal stopping power to each material (the limits of integration are between 0.01-200 MeV) by using eq. (2-45). And then finding the semi-imperical equation by use Matlab program. This equation represents range of alpha particle in the material. Results are tabulated in table (3- 19).

(3.5) Penetrate the alpha particles of matter (The thickness of the material)

(3.5.1)The thickness of the tissues

The depth of penetration of alpha particle for human tissues (breast, ovary,lung and muscle) for the energy range (0.01-200) MeV is calculated by using eq.(2-48) . Results are tabulated in tables (3-15),(3-16),(3-17), and (3-18) ,where ρ is the density of tissue and its values are listed in the table (3-1)

(3.5.2)The thickness of the material

The depth of penetration of alpha particle for materials (SiO_2, AL_2O_3, ZrO_2) for the energy range(0.01-200) MeV is calculated by using eq.(2-48) . Results are tabulated in table (3-19) ,where ρ is the density of material and its values are listed in the table (3-2).

(3.6) Absorbed dose :

(3.6.1 Absorbed dose of tissues The energy deposited by alpha particles per gram of the human tissues (breast, ovary, lung and muscle) for the energy range (0.01-200) MeV is calculated by using eq.(2-49) . Results are tabulated in tables (3-15),(3-16),(3-17), and (3-18).

(**3.6.2**)**Absorbed dose of materials** The energy deposited by alpha particles per gram of the materails (SiO_2, AL_2O_3 , ZrO_2) for the energy range (0.01-200) MeV is calculated by using eq.(2-49) . Results are tabulated in table (3-19).

(3.7)Equivalent dose is defined as the absorbed doses in the tissue or organ due to radiation[103].The absorbed doses in the human tissues (breast, ovary, lung and muscle,) due to alpha particle for the energy range(0.01-200) MeV is calculated by using eq.(2-50) . Results are tabulated in table (3-15),(3-16),(3-17), and (3-18) ,where (w_R is represents the quality factor of tissue =20 for alpha particle) .

(3.8)Effective dose :The tissue-weighted sum of the equivalent doses in all specified tissues and organs of the body. Effective dose of the human tissues (breast, ovary ,lung and muscle) for the energy range (0.01-200) MeV calculated by usin eq.(2-51).Results are tabulated in tables(3-15),(3-16),(3-17),(3-18) where W_T *is* tissue weighting factor and its values are listed in the table (2-1). which represents the relative contribution of that organor tissue to the total detriment resulting from uniform irradiation of the whole body.

Table (3-15) (Range, thickness, linear energy transfer, absorbed Dose, equivalent dose, and Effective dose) in **Ovary tissue**

E(MeV)	Range $(\frac{gm}{cm^2})$	Thickness (cm)	LET $\times 10^3$ $(\frac{MeV}{cm})$	Absorbed Dose $\times 10^{-8}$ (rad)	Equivalent Dose$\times$ 10^{-5} (rem)	Effective Dose$\times$ 10^{-8} rem)
0.0100	0.0024	0.0023	0.4418	0.0160	0.0003	0.0384
0.0110	0.0052	0.0050	0.4566	0.0176	0.0004	0.0422
0.0120	0.0076	0.0073	0.4712	0.0192	0.0004	0.0461
0.0130	0.0098	0.0093	0.4854	0.0208	0.0004	0.0499
0.0140	0.0117	0.0111	0.4995	0.0224	0.0004	0.0538
0.0150	0.0134	0.0127	0.5131	0.0240	0.0005	0.0576
0.0160	0.0149	0.0142	0.5266	0.0256	0.0005	0.0614
0.0170	0.0163	0.0155	0.5398	0.0272	0.0005	0.0653
0.0180	0.0176	0.0168	0.5527	0.0288	0.0006	0.0691
0.0200	0.0199	0.0189	0.5779	0.0320	0.0006	0.0768
0.0225	0.0223	0.0212	0.6082	0.0360	0.0007	0.0864
0.0250	0.0243	0.0232	0.6371	0.0400	0.0008	0.0960
0.0275	0.0261	0.0248	0.6649	0.0440	0.0009	0.1056
0.0300	0.0276	0.0263	0.6914	0.0480	0.0010	0.1152
0.0325	0.0290	0.0276	0.7170	0.0520	0.0010	0.1248
0.0350	0.0302	0.0287	0.7417	0.0560	0.0011	0.1344
0.0375	0.0312	0.0298	0.7655	0.0600	0.0012	0.1440
0.0400	0.0322	0.0307	0.7884	0.0640	0.0013	0.1536
0.0450	0.0339	0.0323	0.8322	0.0720	0.0014	0.1728
0.0500	0.0354	0.0337	0.8735	0.0800	0.0016	0.1920
0.0550	0.0366	0.0349	0.9127	0.0880	0.0018	0.2112
0.0600	0.0377	0.0359	0.9500	0.0960	0.0019	0.2304
0.0650	0.0387	0.0368	0.9857	0.1040	0.0021	0.2496
0.0700	0.0395	0.0376	1.0202	0.1120	0.0022	0.2688
0.0800	0.0410	0.0390	1.0858	0.1280	0.0026	0.3072
0.0900	0.0422	0.0402	1.1477	0.1440	0.0029	0.3456
0.1000	0.0432	0.0411	1.2065	0.1600	0.0032	0.3840
0.1100	0.0441	0.0420	1.2626	0.1760	0.0035	0.4224
0.1200	0.0449	0.0427	1.3163	0.1920	0.0038	0.4608
0.1300	0.0455	0.0434	1.3674	0.2080	0.0042	0.4992

0.1400	**0.0461**	**0.0439**	**1.4162**	**0.2240**	**0.0045**	**0.5376**
0.1500	**0.0467**	**0.0445**	**1.4627**	**0.2400**	**0.0048**	**0.5760**
0.1600	**0.0472**	**0.0449**	**1.5070**	**0.2560**	**0.0051**	**0.6144**
0.1700	**0.0476**	**0.0454**	**1.5491**	**0.2720**	**0.0054**	**0.6528**
0.1800	**0.0480**	**0.0457**	**1.5894**	**0.2880**	**0.0058**	**0.6912**
0.2000	**0.0488**	**0.0464**	**1.6654**	**0.3200**	**0.0064**	**0.7680**
0.2250	**0.0495**	**0.0472**	**1.7546**	**0.3600**	**0.0072**	**0.8640**
0.2500	**0.0502**	**0.0478**	**1.8399**	**0.4000**	**0.0080**	**0.9600**
0.2750	**0.0507**	**0.0483**	**1.9221**	**0.4400**	**0.0088**	**1.0560**
0.3000	**0.0512**	**0.0488**	**1.9985**	**0.4800**	**0.0096**	**1.1520**
0.3250	**0.0516**	**0.0492**	**2.0378**	**0.5200**	**0.0104**	**1.2480**
0.3500	**0.0520**	**0.0496**	**2.0831**	**0.5600**	**0.0112**	**1.3440**
0.3750	**0.0524**	**0.0499**	**2.1266**	**0.6000**	**0.0120**	**1.4400**
0.4000	**0.0527**	**0.0502**	**2.1676**	**0.6400**	**0.0128**	**1.5360**
0.4500	**0.0532**	**0.0507**	**2.2407**	**0.7200**	**0.0144**	**1.7280**
0.5000	**0.0537**	**0.0511**	**2.2996**	**0.8000**	**0.0160**	**1.9200**
0.5500	**0.0541**	**0.0515**	**2.3419**	**0.8800**	**0.0176**	**2.1120**
0.6000	**0.0544**	**0.0518**	**2.3669**	**0.9600**	**0.0192**	**2.3040**
0.6500	**0.0569**	**0.0542**	**2.3749**	**1.0400**	**0.0208**	**2.4960**
0.7000	**0.0570**	**0.0543**	**2.3674**	**1.1200**	**0.0224**	**2.6880**
0.8000	**0.0574**	**0.0546**	**2.3171**	**1.2800**	**0.0256**	**3.0720**
0.9000	**0.0577**	**0.0550**	**2.2409**	**1.4400**	**0.0288**	**3.4560**
1.0000	**0.0580**	**0.0553**	**2.1611**	**1.6000**	**0.0320**	**3.8400**
1.1000	**0.0584**	**0.0556**	**2.0901**	**1.7600**	**0.0352**	**4.2240**
1.2000	**0.0587**	**0.0559**	**2.0305**	**1.9200**	**0.0384**	**4.6080**
1.3000	**0.0591**	**0.0562**	**1.9780**	**2.0800**	**0.0416**	**4.9920**
1.4000	**0.0594**	**0.0566**	**1.9275**	**2.2400**	**0.0448**	**5.3760**
1.5000	**0.0597**	**0.0569**	**1.8753**	**2.4000**	**0.0480**	**5.7600**
1.6000	**0.0600**	**0.0572**	**1.8204**	**2.5600**	**0.0512**	**6.1440**
1.7000	**0.0604**	**0.0575**	**1.7634**	**2.7200**	**0.0544**	**6.5280**
1.8000	**0.0607**	**0.0578**	**1.7057**	**2.8800**	**0.0576**	**6.9120**
2.0000	**0.0613**	**0.0584**	**1.5957**	**3.2000**	**0.0640**	**7.6800**
2.2500	**0.0621**	**0.0592**	**1.4795**	**3.6000**	**0.0720**	**8.6400**
2.5000	**0.0629**	**0.0599**	**1.3905**	**4.0000**	**0.0800**	**9.6000**
2.7500	**0.0637**	**0.0607**	**1.3225**	**4.4000**	**0.0880**	**10.5600**
3.0000	**0.0645**	**0.0614**	**1.2659**	**4.8000**	**0.0960**	**11.5200**
3.2500	**0.0653**	**0.0622**	**1.2137**	**5.2000**	**0.1040**	**12.4800**
3.5000	**0.0660**	**0.0629**	**1.1627**	**5.6000**	**0.1120**	**13.4400**
3.7500	**0.0668**	**0.0636**	**1.1123**	**6.0000**	**0.1200**	**14.4000**
4.0000	**0.0675**	**0.0643**	**1.0630**	**6.4000**	**0.1280**	**15.3600**
4.5000	**0.0690**	**0.0657**	**0.9725**	**7.2000**	**0.1440**	**17.2800**
5.0000	**0.0704**	**0.0671**	**0.8969**	**8.0000**	**0.1600**	**19.2000**
5.5000	**0.0719**	**0.0684**	**0.8368**	**8.8000**	**0.1760**	**21.1200**
6.0000	**0.0732**	**0.0697**	**0.7898**	**9.6000**	**0.1920**	**23.0400**
6.5000	**0.0746**	**0.0710**	**0.7516**	**10.4000**	**0.2080**	**24.9600**
7.0000	**0.0759**	**0.0723**	**0.7187**	**11.2000**	**0.2240**	**26.8800**
8.0000	**0.0785**	**0.0748**	**0.6608**	**12.8000**	**0.2560**	**30.7200**
9.0000	**0.0810**	**0.0772**	**0.6076**	**14.4000**	**0.2880**	**34.5600**
10.0000	**0.0835**	**0.0795**	**0.5595**	**16.0000**	**0.3200**	**38.4000**
11.0000	**0.0858**	**0.0817**	**0.5173**	**17.6000**	**0.3520**	**42.2400**
12.0000	**0.0881**	**0.0839**	**0.4816**	**19.2000**	**0.3840**	**46.0800**

13.0000	0.0903	0.0860	0.4521	20.8000	0.4160	49.9200
14.0000	0.0925	0.0881	0.4278	22.4000	0.4480	53.7600
15.0000	0.0946	0.0901	0.4076	24.0000	0.4800	57.6000
16.0000	0.0967	0.0921	0.3906	25.6000	0.5120	61.4400
17.0000	0.0987	0.0940	0.3756	27.2000	0.5440	65.2800
18.0000	0.1006	0.0959	0.3619	28.8000	0.5760	69.1200
20.0000	0.1045	0.0995	0.3371	32.0000	0.6400	76.8000
22.5000	0.1091	0.1039	0.3084	36.0000	0.7200	86.4000
25.0000	0.1136	0.1082	0.2818	40.0000	0.8000	96.0000
27.5000	0.1180	0.1124	0.2581	44.0000	0.8800	105.6000
30.0000	0.1223	0.1165	0.2374	48.0000	0.9600	115.2000
32.5000	0.1266	0.1206	0.2199	52.0000	1.0400	124.8000
35.0000	0.1308	0.1245	0.2054	56.0000	1.1200	134.4000
37.5000	0.1349	0.1285	0.1933	60.0000	1.2000	144.0000
40.0000	0.1390	0.1324	0.1833	64.0000	1.2800	153.6000
45.0000	0.1471	0.1401	0.1675	72.0000	1.4400	172.8000
50.0000	0.1550	0.1477	0.1550	80.0000	1.6000	192.0000
55.0000	0.1628	0.1550	0.1443	88.0000	1.7600	211.2000
60.0000	0.1702	0.1621	0.1346	96.0000	1.9200	230.4000
65.0000	0.1774	0.1690	0.1258	104.0000	2.0800	249.6000
70.0000	0.1843	0.1755	0.1179	112.0000	2.2400	268.8000
80.0000	0.1971	0.1877	0.1048	128.0000	2.5600	307.2000
90.0000	0.2089	0.1989	0.0950	144.0000	2.8800	345.6000
100.0000	0.2201	0.2096	0.0877	160.0000	3.2000	384.0000
110.0000	0.2315	0.2204	0.0820	176.0000	3.5200	422.4000
120.0000	0.2438	0.2322	0.0774	192.0000	3.8400	460.8000
130.0000	0.2576	0.2453	0.0734	208.0000	4.1600	499.2000
140.0000	0.2732	0.2602	0.0696	224.0000	4.4800	537.6000
150.0000	0.2902	0.2763	0.0662	240.0000	4.8000	576.0000
160.0000	0.3077	0.2931	0.0627	256.0000	5.1200	614.4000
170.0000	0.3247	0.3092	0.0594	272.0000	5.4400	652.8000
180.0000	0.3394	0.3233	0.0563	288.0000	5.7600	691.2000
200.0000	0.3588	0.3418	0.0503	320.0000	6.4000	768.0000

Table (3-16) (Range, thickness, linear energy transfer, absorbed dose, equivalent dose, and Effective dose) in **Breast tissue**

E(MeV)	Range $(\frac{gm}{cm^2})$	Thickness (cm)	LET $\times 10^3$ $(\frac{MeV}{cm})$	Absorbed Dose $\times 10^{-8}$ (rad)	Equivalent Dose$\times 10^{-5}$ (rem)	Effective Dose$\times 10^{-8}$ rem)
0.0100	0.0022	0.0021	0.5053	0.0160	0.0003	0.0384
0.0110	0.0046	0.0045	0.5189	0.0176	0.0004	0.0422
0.0120	0.0067	0.0065	0.5322	0.0192	0.0004	0.0461
0.0130	0.0085	0.0084	0.5455	0.0208	0.0004	0.0499
0.0140	0.0102	0.0100	0.5586	0.0224	0.0004	0.0538
0.0150	0.0117	0.0115	0.5715	0.0240	0.0005	0.0576
0.0160	0.0130	0.0128	0.5844	0.0256	0.0005	0.0614
0.0170	0.0143	0.0140	0.5970	0.0272	0.0005	0.0653
0.0180	0.0154	0.0151	0.6096	0.0288	0.0006	0.0691
0.0200	0.0174	0.0171	0.6341	0.0320	0.0006	0.0768
0.0225	0.0195	0.0191	0.6641	0.0360	0.0007	0.0864
0.0250	0.0213	0.0209	0.6934	0.0400	0.0008	0.0960
0.0275	0.0229	0.0224	0.7219	0.0440	0.0009	0.1056
0.0300	0.0242	0.0238	0.7495	0.0480	0.0010	0.1152
0.0325	0.0254	0.0249	0.7764	0.0520	0.0010	0.1248
0.0350	0.0265	0.0260	0.8026	0.0560	0.0011	0.1344
0.0375	0.0275	0.0269	0.8281	0.0600	0.0012	0.1440
0.0400	0.0283	0.0278	0.8530	0.0640	0.0013	0.1536
0.0450	0.0299	0.0293	0.9008	0.0720	0.0014	0.1728
0.0500	0.0312	0.0306	0.9461	0.0800	0.0016	0.1920
0.0550	0.0323	0.0316	0.9892	0.0880	0.0018	0.2112
0.0600	0.0333	0.0326	1.0301	0.0960	0.0019	0.2304
0.0650	0.0341	0.0334	1.0691	0.1040	0.0021	0.2496
0.0700	0.0349	0.0342	1.1062	0.1120	0.0022	0.2688
0.0800	0.0362	0.0355	1.1753	0.1280	0.0026	0.3072
0.0900	0.0373	0.0366	1.2386	0.1440	0.0029	0.3456
0.1000	0.0382	0.0375	1.2967	0.1600	0.0032	0.3840
0.1100	0.0390	0.0383	1.3505	0.1760	0.0035	0.4224
0.1200	0.0397	0.0389	1.4006	0.1920	0.0038	0.4608
0.1300	0.0403	0.0396	1.4473	0.2080	0.0042	0.4992
0.1400	0.0409	0.0401	1.4914	0.2240	0.0045	0.5376
0.1500	0.0414	0.0406	1.5332	0.2400	0.0048	0.5760
0.1600	0.0418	0.0410	1.5730	0.2560	0.0051	0.6144
0.1700	0.0423	0.0414	1.6112	0.2720	0.0054	0.6528
0.1800	0.0426	0.0418	1.6479	0.2880	0.0058	0.6912
0.2000	0.0433	0.0425	1.7178	0.3200	0.0064	0.7680
0.2250	0.0440	0.0431	1.8000	0.3600	0.0072	0.8640
0.2500	0.0446	0.0437	1.8775	0.4000	0.0080	0.9600
0.2750	0.0451	0.0442	1.9510	0.4400	0.0088	1.0560
0.3000	0.0456	0.0447	2.0201	0.4800	0.0096	1.1520
0.3250	0.0460	0.0451	2.0850	0.5200	0.0104	1.2480
0.3500	0.0463	0.0454	2.1453	0.5600	0.0112	1.3440
0.3750	0.0467	0.0457	2.2007	0.6000	0.0120	1.4400

0.4000	0.0469	0.0460	2.2508	0.6400	0.0128	1.5360
0.4500	0.0475	0.0465	2.3327	0.7200	0.0144	1.7280
0.5000	0.0479	0.0469	2.3809	0.8000	0.0160	1.9200
0.5500	0.0483	0.0473	2.3925	0.8800	0.0176	2.1120
0.6000	0.0507	0.0497	2.3777	0.9600	0.0192	2.3040
0.6500	0.0509	0.0499	2.3598	1.0400	0.0208	2.4960
0.7000	0.0510	0.0500	2.3389	1.1200	0.0224	2.6880
0.8000	0.0514	0.0504	2.2895	1.2800	0.0256	3.0720
0.9000	0.0517	0.0507	2.2319	1.4400	0.0288	3.4560
1.0000	0.0520	0.0510	2.1685	1.6000	0.0320	3.8400
1.1000	0.0524	0.0513	2.1020	1.7600	0.0352	4.2240
1.2000	0.0527	0.0517	2.0345	1.9200	0.0384	4.6080
1.3000	0.0530	0.0520	1.9678	2.0800	0.0416	4.9920
1.4000	0.0534	0.0523	1.9033	2.2400	0.0448	5.3760
1.5000	0.0537	0.0526	1.8419	2.4000	0.0480	5.7600
1.6000	0.0540	0.0530	1.7841	2.5600	0.0512	6.1440
1.7000	0.0543	0.0533	1.7299	2.7200	0.0544	6.5280
1.8000	0.0547	0.0536	1.6792	2.8800	0.0576	6.9120
2.0000	0.0553	0.0542	1.5873	3.2000	0.0640	7.6800
2.2500	0.0561	0.0550	1.4863	3.6000	0.0720	8.6400
2.5000	0.0569	0.0558	1.3971	4.0000	0.0800	9.6000
2.7500	0.0577	0.0565	1.3175	4.4000	0.0880	10.5600
3.0000	0.0584	0.0573	1.2466	4.8000	0.0960	11.5200
3.2500	0.0592	0.0580	1.1838	5.2000	0.1040	12.4800
3.5000	0.0599	0.0588	1.1283	5.6000	0.1120	13.4400
3.7500	0.0607	0.0595	1.0791	6.0000	0.1200	14.4000
4.0000	0.0614	0.0602	1.0350	6.4000	0.1280	15.3600
4.5000	0.0629	0.0616	0.9582	7.2000	0.1440	17.2800
5.0000	0.0643	0.0630	0.8926	8.0000	0.1600	19.2000
5.5000	0.0657	0.0644	0.8355	8.8000	0.1760	21.1200
6.0000	0.0671	0.0658	0.7855	9.6000	0.1920	23.0400
6.5000	0.0684	0.0671	0.7417	10.4000	0.2080	24.9600
7.0000	0.0697	0.0684	0.7036	11.2000	0.2240	26.8800
8.0000	0.0723	0.0709	0.6404	12.8000	0.2560	30.7200
9.0000	0.0748	0.0733	0.5899	14.4000	0.2880	34.5600
10.0000	0.0772	0.0757	0.5474	16.0000	0.3200	38.4000
11.0000	0.0795	0.0780	0.5105	17.6000	0.3520	42.2400
12.0000	0.0818	0.0802	0.4777	19.2000	0.3840	46.0800
13.0000	0.0840	0.0823	0.4483	20.8000	0.4160	49.9200
14.0000	0.0861	0.0844	0.4223	22.4000	0.4480	53.7600
15.0000	0.0882	0.0865	0.3995	24.0000	0.4800	57.6000
16.0000	0.0902	0.0885	0.3796	25.6000	0.5120	61.4400
17.0000	0.0922	0.0904	0.3623	27.2000	0.5440	65.2800
18.0000	0.0942	0.0923	0.3469	28.8000	0.5760	69.1200
20.0000	0.0980	0.0960	0.3205	32.0000	0.6400	76.8000
22.5000	0.1026	0.1006	0.2922	36.0000	0.7200	86.4000
25.0000	0.1070	0.1049	0.2677	40.0000	0.8000	96.0000
27.5000	0.1114	0.1092	0.2470	44.0000	0.8800	105.6000
30.0000	0.1156	0.1133	0.2301	48.0000	0.9600	115.2000
32.5000	0.1198	0.1175	0.2163	52.0000	1.0400	124.8000
35.0000	0.1240	0.1215	0.2045	56.0000	1.1200	134.4000

37.5000	0.1281	0.1255	0.1940	60.0000	1.2000	144.0000
40.0000	0.1321	0.1295	0.1844	64.0000	1.2800	153.6000
45.0000	0.1401	0.1374	0.1675	72.0000	1.4400	172.8000
50.0000	0.1480	0.1451	0.1532	80.0000	1.6000	192.0000
55.0000	0.1557	0.1526	0.1411	88.0000	1.7600	211.2000
60.0000	0.1631	0.1599	0.1307	96.0000	1.9200	230.4000
65.0000	0.1702	0.1669	0.1218	104.0000	2.0800	249.6000
70.0000	0.1771	0.1736	0.1142	112.0000	2.2400	268.8000
80.0000	0.1898	0.1861	0.1020	128.0000	2.5600	307.2000
90.0000	0.2015	0.1976	0.0928	144.0000	2.8800	345.6000
100.0000	0.2127	0.2085	0.0856	160.0000	3.2000	384.0000
110.0000	0.2242	0.2198	0.0799	176.0000	3.5200	422.4000
120.0000	0.2366	0.2320	0.0751	192.0000	3.8400	460.8000
130.0000	0.2507	0.2458	0.0709	208.0000	4.1600	499.2000
140.0000	0.2666	0.2614	0.0672	224.0000	4.4800	537.6000
150.0000	0.2841	0.2785	0.0639	240.0000	4.8000	576.0000
160.0000	0.3023	0.2964	0.0607	256.0000	5.1200	614.4000
170.0000	0.3201	0.3138	0.0577	272.0000	5.4400	652.8000
180.0000	0.3360	0.3294	0.0548	288.0000	5.7600	691.2000
200.0000	0.3586	0.3516	0.0492	320.0000	6.4000	768.0000

Table (3-17) (Range, thickness, linear energy transfer, absorbed dose, equivalent dose, and effective dose) in **Lung tissue.**

E(MeV)	Range $(\frac{gm}{cm^2})$	Thickness (cm)	LET $\times 10^3$ $(\frac{MeV}{cm})$	Absorbed Dose $\times 10^{-8}$ (rad)	Equivalent Dose$\times$ 10^{-5} (rem)	Effective Dose$\times$ 10^{-8} rem)
0.0100	0.0024	0.0023	0.4475	0.0160	0.0003	0.0384
0.0110	0.0052	0.0049	0.4613	0.0176	0.0004	0.0422
0.0120	0.0076	0.0072	0.4748	0.0192	0.0004	0.0461
0.0130	0.0097	0.0093	0.4883	0.0208	0.0004	0.0499
0.0140	0.0116	0.0111	0.5015	0.0224	0.0004	0.0538
0.0150	0.0133	0.0127	0.5145	0.0240	0.0005	0.0576
0.0160	0.0149	0.0142	0.5273	0.0256	0.0005	0.0614
0.0170	0.0163	0.0155	0.5400	0.0272	0.0005	0.0653
0.0180	0.0176	0.0167	0.5525	0.0288	0.0006	0.0691
0.0200	0.0198	0.0189	0.5770	0.0320	0.0006	0.0768
0.0225	0.0222	0.0212	0.6066	0.0360	0.0007	0.0864
0.0250	0.0243	0.0231	0.6352	0.0400	0.0008	0.0960
0.0275	0.0260	0.0248	0.6630	0.0440	0.0009	0.1056
0.0300	0.0276	0.0262	0.6897	0.0480	0.0010	0.1152
0.0325	0.0289	0.0275	0.7157	0.0520	0.0010	0.1248
0.0350	0.0301	0.0287	0.7408	0.0560	0.0011	0.1344
0.0375	0.0312	0.0297	0.7651	0.0600	0.0012	0.1440
0.0400	0.0322	0.0306	0.7887	0.0640	0.0013	0.1536
0.0450	0.0339	0.0323	0.8338	0.0720	0.0014	0.1728
0.0500	0.0353	0.0336	0.8762	0.0800	0.0016	0.1920
0.0550	0.0366	0.0348	0.9164	0.0880	0.0018	0.2112

0.0600	0.0376	0.0358	0.9547	0.0960	0.0019	0.2304
0.0650	0.0386	0.0368	0.9909	0.1040	0.0021	0.2496
0.0700	0.0394	0.0376	1.0255	0.1120	0.0022	0.2688
0.0800	0.0409	0.0390	1.0906	0.1280	0.0026	0.3072
0.0900	0.0421	0.0401	1.1510	0.1440	0.0029	0.3456
0.1000	0.0431	0.0411	1.2077	0.1600	0.0032	0.3840
0.1100	0.0440	0.0419	1.2615	0.1760	0.0035	0.4224
0.1200	0.0448	0.0427	1.3129	0.1920	0.0038	0.4608
0.1300	0.0455	0.0433	1.3624	0.2080	0.0042	0.4992
0.1400	0.0461	0.0439	1.4102	0.2240	0.0045	0.5376
0.1500	0.0466	0.0444	1.4562	0.2400	0.0048	0.5760
0.1600	0.0471	0.0449	1.5008	0.2560	0.0051	0.6144
0.1700	0.0476	0.0453	1.5437	0.2720	0.0054	0.6528
0.1800	0.0480	0.0457	1.5848	0.2880	0.0058	0.6912
0.2000	0.0487	0.0464	1.6613	0.3200	0.0064	0.7680
0.2250	0.0495	0.0471	1.7451	0.3600	0.0072	0.8640
0.2500	0.0501	0.0477	1.8164	0.4000	0.0080	0.9600
0.2750	0.0507	0.0483	1.8800	0.4400	0.0088	1.0560
0.3000	0.0512	0.0487	1.9480	0.4800	0.0096	1.1520
0.3250	0.0516	0.0491	2.0295	0.5200	0.0104	1.2480
0.3500	0.0520	0.0495	2.0746	0.5600	0.0112	1.3440
0.3750	0.0523	0.0498	2.1177	0.6000	0.0120	1.4400
0.4000	0.0526	0.0501	2.1584	0.6400	0.0128	1.5360
0.4500	0.0532	0.0506	2.2308	0.7200	0.0144	1.7280
0.5000	0.0536	0.0511	2.2892	0.8000	0.0160	1.9200
0.5500	0.0540	0.0515	2.3316	0.8800	0.0176	2.1120
0.6000	0.0544	0.0518	2.3573	0.9600	0.0192	2.3040
0.6500	0.0568	0.0541	2.3665	1.0400	0.0208	2.4960
0.7000	0.0570	0.0543	2.3606	1.1200	0.0224	2.6880
0.8000	0.0573	0.0546	2.3129	1.2800	0.0256	3.0720
0.9000	0.0577	0.0549	2.2371	1.4400	0.0288	3.4560
1.0000	0.0580	0.0552	2.1548	1.6000	0.0320	3.8400
1.1000	0.0583	0.0556	2.0799	1.7600	0.0352	4.2240
1.2000	0.0587	0.0559	2.0169	1.9200	0.0384	4.6080
1.3000	0.0590	0.0562	1.9635	2.0800	0.0416	4.9920
1.4000	0.0593	0.0565	1.9144	2.2400	0.0448	5.3760
1.5000	0.0597	0.0568	1.8654	2.4000	0.0480	5.7600
1.6000	0.0600	0.0571	1.8142	2.5600	0.0512	6.1440
1.7000	0.0603	0.0575	1.7604	2.7200	0.0544	6.5280
1.8000	0.0607	0.0578	1.7052	2.8800	0.0576	6.9120
2.0000	0.0613	0.0584	1.5962	3.2000	0.0640	7.6800
2.2500	0.0621	0.0592	1.4761	3.6000	0.0720	8.6400
2.5000	0.0629	0.0599	1.3817	4.0000	0.0800	9.6000
2.7500	0.0637	0.0607	1.3101	4.4000	0.0880	10.5600
3.0000	0.0645	0.0614	1.2532	4.8000	0.0960	11.5200
3.2500	0.0652	0.0621	1.2031	5.2000	0.1040	12.4800
3.5000	0.0660	0.0629	1.1552	5.6000	0.1120	13.4400
3.7500	0.0668	0.0636	1.1076	6.0000	0.1200	14.4000
4.0000	0.0675	0.0643	1.0607	6.4000	0.1280	15.3600
4.5000	0.0690	0.0657	0.9714	7.2000	0.1440	17.2800
5.0000	0.0704	0.0671	0.8938	8.0000	0.1600	19.2000

5.5000	0.0718	0.0684	0.8308	8.8000	0.1760	21.1200
6.0000	0.0732	0.0697	0.7813	9.6000	0.1920	23.0400
6.5000	0.0746	0.0710	0.7426	10.4000	0.2080	24.9600
7.0000	0.0759	0.0723	0.7110	11.2000	0.2240	26.8800
8.0000	0.0785	0.0748	0.6581	12.8000	0.2560	30.7200
9.0000	0.0810	0.0772	0.6098	14.4000	0.2880	34.5600
10.0000	0.0835	0.0795	0.5633	16.0000	0.3200	38.4000
11.0000	0.0858	0.0818	0.5198	17.6000	0.3520	42.2400
12.0000	0.0881	0.0839	0.4805	19.2000	0.3840	46.0800
13.0000	0.0904	0.0861	0.4466	20.8000	0.4160	49.9200
14.0000	0.0925	0.0881	0.4181	22.4000	0.4480	53.7600
15.0000	0.0946	0.0901	0.3949	24.0000	0.4800	57.6000
16.0000	0.0967	0.0921	0.3762	25.6000	0.5120	61.4400
17.0000	0.0987	0.0940	0.3611	27.2000	0.5440	65.2800
18.0000	0.1007	0.0959	0.3487	28.8000	0.5760	69.1200
20.0000	0.1046	0.0996	0.3288	32.0000	0.6400	76.8000
22.5000	0.1092	0.1040	0.3073	36.0000	0.7200	86.4000
25.0000	0.1137	0.1083	0.2857	40.0000	0.8000	96.0000
27.5000	0.1181	0.1125	0.2632	44.0000	0.8800	105.6000
30.0000	0.1225	0.1166	0.2411	48.0000	0.9600	115.2000
32.5000	0.1267	0.1207	0.2206	52.0000	1.0400	124.8000
35.0000	0.1309	0.1247	0.2043	56.0000	1.1200	134.4000
37.5000	0.1351	0.1286	0.1940	60.0000	1.2000	144.0000
40.0000	0.1392	0.1326	0.1881	64.0000	1.2800	153.6000
45.0000	0.1473	0.1403	0.1660	72.0000	1.4400	172.8000
50.0000	0.1553	0.1479	0.1432	80.0000	1.6000	192.0000
55.0000	0.1630	0.1553	0.1339	88.0000	1.7600	211.2000
60.0000	0.1706	0.1624	0.1278	96.0000	1.9200	230.4000
65.0000	0.1778	0.1693	0.1225	104.0000	2.0800	249.6000
70.0000	0.1847	0.1759	0.1175	112.0000	2.2400	268.8000
80.0000	0.1977	0.1883	0.1083	128.0000	2.5600	307.2000
90.0000	0.2097	0.1997	0.0998	144.0000	2.8800	345.6000
100.0000	0.2211	0.2106	0.0919	160.0000	3.2000	384.0000
110.0000	0.2329	0.2218	0.0846	176.0000	3.5200	422.4000
120.0000	0.2457	0.2340	0.0779	192.0000	3.8400	460.8000
130.0000	0.2602	0.2478	0.0717	208.0000	4.1600	499.2000
140.0000	0.2766	0.2634	0.0660	224.0000	4.4800	537.6000
150.0000	0.2947	0.2806	0.0608	240.0000	4.8000	576.0000
160.0000	0.3136	0.2986	0.0560	256.0000	5.1200	614.4000
170.0000	0.3321	0.3163	0.0516	272.0000	5.4400	652.8000
180.0000	0.3489	0.3323	0.0475	288.0000	5.7600	691.2000
200.0000	0.3737	0.3559	0.0401	320.0000	6.4000	768.0000

Table (3-18) (Range, thickness, linear energy transfer, absorbed dose, equivalent dose, and effective dose) in **Muscle tissue**.

E(MeV)	Range $(\frac{gm}{cm^2})$	Thickness (cm)	LET $\times 10^3$ $(\frac{MeV}{cm})$	Absorbed Dose $\times 10^{-8}$ (rad)	Equivalent Dose$\times 10^{-5}$ (rem)	Effective Dose$\times 10^{-8}$ rem)
0.0100	0.0024	0.0023	0.4505	0.0160	0.0003	0.0384
0.0110	0.0052	0.0049	0.4643	0.0176	0.0004	0.0422
0.0120	0.0076	0.0072	0.4780	0.0192	0.0004	0.0461
0.0130	0.0097	0.0092	0.4915	0.0208	0.0004	0.0499
0.0140	0.0116	0.0110	0.5048	0.0224	0.0004	0.0538
0.0150	0.0134	0.0126	0.5180	0.0240	0.0005	0.0576
0.0160	0.0149	0.0141	0.5309	0.0256	0.0005	0.0614
0.0170	0.0163	0.0154	0.5436	0.0272	0.0005	0.0653
0.0180	0.0176	0.0166	0.5562	0.0288	0.0006	0.0691
0.0200	0.0199	0.0187	0.5808	0.0320	0.0006	0.0768
0.0225	0.0223	0.0210	0.6107	0.0360	0.0007	0.0864
0.0250	0.0243	0.0229	0.6395	0.0400	0.0008	0.0960
0.0275	0.0261	0.0246	0.6674	0.0440	0.0009	0.1056
0.0300	0.0276	0.0261	0.6944	0.0480	0.0010	0.1152
0.0325	0.0290	0.0273	0.7205	0.0520	0.0010	0.1248
0.0350	0.0302	0.0285	0.7459	0.0560	0.0011	0.1344
0.0375	0.0313	0.0295	0.7703	0.0600	0.0012	0.1440
0.0400	0.0322	0.0304	0.7941	0.0640	0.0013	0.1536
0.0450	0.0339	0.0320	0.8394	0.0720	0.0014	0.1728
0.0500	0.0354	0.0334	0.8823	0.0800	0.0016	0.1920
0.0550	0.0366	0.0346	0.9227	0.0880	0.0018	0.2112
0.0600	0.0377	0.0356	0.9612	0.0960	0.0019	0.2304
0.0650	0.0387	0.0365	0.9978	0.1040	0.0021	0.2496
0.0700	0.0395	0.0373	1.0327	0.1120	0.0022	0.2688
0.0800	0.0410	0.0387	1.0982	0.1280	0.0026	0.3072
0.0900	0.0422	0.0398	1.1590	0.1440	0.0029	0.3456
0.1000	0.0432	0.0408	1.2160	0.1600	0.0032	0.3840
0.1100	0.0441	0.0416	1.2702	0.1760	0.0035	0.4224
0.1200	0.0449	0.0423	1.3219	0.1920	0.0038	0.4608
0.1300	0.0456	0.0430	1.3716	0.2080	0.0042	0.4992
0.1400	0.0462	0.0436	1.4196	0.2240	0.0045	0.5376
0.1500	0.0467	0.0441	1.4659	0.2400	0.0048	0.5760
0.1600	0.0472	0.0445	1.5107	0.2560	0.0051	0.6144
0.1700	0.0477	0.0450	1.5538	0.2720	0.0054	0.6528
0.1800	0.0481	0.0453	1.5951	0.2880	0.0058	0.6912
0.2000	0.0488	0.0460	1.6719	0.3200	0.0064	0.7680
0.2250	0.0496	0.0468	1.7560	0.3600	0.0072	0.8640
0.2500	0.0502	0.0474	1.8275	0.4000	0.0080	0.9600
0.2750	0.0508	0.0479	1.8913	0.4400	0.0088	1.0560
0.3000	0.0513	0.0484	1.9594	0.4800	0.0096	1.1520
0.3250	0.0517	0.0488	2.0538	0.5200	0.0104	1.2480
0.3500	0.0521	0.0491	2.1028	0.5600	0.0112	1.3440
0.3750	0.0524	0.0495	2.1497	0.6000	0.0120	1.4400

0.4000	0.0527	0.0498	2.1937	0.6400	0.0128	1.5360
0.4500	0.0533	0.0503	2.2717	0.7200	0.0144	1.7280
0.5000	0.0537	0.0507	2.3339	0.8000	0.0160	1.9200
0.5500	0.0541	0.0511	2.3783	0.8800	0.0176	2.1120
0.6000	0.0545	0.0514	2.4044	0.9600	0.0192	2.3040
0.6500	0.0548	0.0517	2.4128	1.0400	0.0208	2.4960
0.7000	0.0570	0.0538	2.4051	1.1200	0.0224	2.6880
0.8000	0.0574	0.0541	2.3536	1.2800	0.0256	3.0720
0.9000	0.0577	0.0545	2.2757	1.4400	0.0288	3.4560
1.0000	0.0581	0.0548	2.1942	1.6000	0.0320	3.8400
1.1000	0.0584	0.0551	2.1221	1.7600	0.0352	4.2240
1.2000	0.0587	0.0554	2.0619	1.9200	0.0384	4.6080
1.3000	0.0591	0.0557	2.0094	2.0800	0.0416	4.9920
1.4000	0.0594	0.0560	1.9591	2.2400	0.0448	5.3760
1.5000	0.0597	0.0563	1.9072	2.4000	0.0480	5.7600
1.6000	0.0600	0.0566	1.8521	2.5600	0.0512	6.1440
1.7000	0.0604	0.0570	1.7945	2.7200	0.0544	6.5280
1.8000	0.0607	0.0573	1.7361	2.8800	0.0576	6.9120
2.0000	0.0613	0.0579	1.6240	3.2000	0.0640	7.6800
2.2500	0.0621	0.0586	1.5055	3.6000	0.0720	8.6400
2.5000	0.0629	0.0594	1.4153	4.0000	0.0800	9.6000
2.7500	0.0637	0.0601	1.3464	4.4000	0.0880	10.5600
3.0000	0.0645	0.0608	1.2887	4.8000	0.0960	11.5200
3.2500	0.0652	0.0616	1.2350	5.2000	0.1040	12.4800
3.5000	0.0660	0.0623	1.1819	5.6000	0.1120	13.4400
3.7500	0.0667	0.0630	1.1292	6.0000	0.1200	14.4000
4.0000	0.0675	0.0637	1.0779	6.4000	0.1280	15.3600
4.5000	0.0689	0.0650	0.9844	7.2000	0.1440	17.2800
5.0000	0.0704	0.0664	0.9079	8.0000	0.1600	19.2000
5.5000	0.0718	0.0677	0.8490	8.8000	0.1760	21.1200
6.0000	0.0732	0.0690	0.8039	9.6000	0.1920	23.0400
6.5000	0.0745	0.0703	0.7681	10.4000	0.2080	24.9600
7.0000	0.0758	0.0715	0.7372	11.2000	0.2240	26.8800
8.0000	0.0784	0.0740	0.6807	12.8000	0.2560	30.7200
9.0000	0.0809	0.0763	0.6264	14.4000	0.2880	34.5600
10.0000	0.0833	0.0786	0.5753	16.0000	0.3200	38.4000
11.0000	0.0857	0.0808	0.5302	17.6000	0.3520	42.2400
12.0000	0.0879	0.0830	0.4920	19.2000	0.3840	46.0800
13.0000	0.0901	0.0850	0.4607	20.8000	0.4160	49.9200
14.0000	0.0923	0.0871	0.4354	22.4000	0.4480	53.7600
15.0000	0.0944	0.0890	0.4147	24.0000	0.4800	57.6000
16.0000	0.0964	0.0910	0.3971	25.6000	0.5120	61.4400
17.0000	0.0984	0.0929	0.3816	27.2000	0.5440	65.2800
18.0000	0.1004	0.0947	0.3673	28.8000	0.5760	69.1200
20.0000	0.1042	0.0983	0.3408	32.0000	0.6400	76.8000
22.5000	0.1088	0.1027	0.3102	36.0000	0.7200	86.4000
25.0000	0.1133	0.1069	0.2831	40.0000	0.8000	96.0000
27.5000	0.1177	0.1110	0.2601	44.0000	0.8800	105.6000
30.0000	0.1220	0.1151	0.2412	48.0000	0.9600	115.2000
32.5000	0.1262	0.1190	0.2259	52.0000	1.0400	124.8000
35.0000	0.1303	0.1230	0.2133	56.0000	1.1200	134.4000

37.5000	**0.1345**	**0.1269**	**0.2024**	**60.0000**	**1.2000**	**144.0000**
40.0000	**0.1385**	**0.1307**	**0.1928**	**64.0000**	**1.2800**	**153.6000**
45.0000	**0.1466**	**0.1383**	**0.1754**	**72.0000**	**1.4400**	**172.8000**
50.0000	**0.1545**	**0.1457**	**0.1599**	**80.0000**	**1.6000**	**192.0000**
55.0000	**0.1621**	**0.1530**	**0.1465**	**88.0000**	**1.7600**	**211.2000**
60.0000	**0.1696**	**0.1600**	**0.1356**	**96.0000**	**1.9200**	**230.4000**
65.0000	**0.1767**	**0.1668**	**0.1269**	**104.0000**	**2.0800**	**249.6000**
70.0000	**0.1836**	**0.1732**	**0.1201**	**112.0000**	**2.2400**	**268.8000**
80.0000	**0.1964**	**0.1853**	**0.1100**	**128.0000**	**2.5600**	**307.2000**
90.0000	**0.2082**	**0.1964**	**0.1021**	**144.0000**	**2.8800**	**345.6000**
100.0000	**0.2195**	**0.2071**	**0.0949**	**160.0000**	**3.2000**	**384.0000**
110.0000	**0.2311**	**0.2180**	**0.0883**	**176.0000**	**3.5200**	**422.4000**
120.0000	**0.2438**	**0.2300**	**0.0821**	**192.0000**	**3.8400**	**460.8000**
130.0000	**0.2581**	**0.2435**	**0.0764**	**208.0000**	**4.1600**	**499.2000**
140.0000	**0.2742**	**0.2587**	**0.0710**	**224.0000**	**4.4800**	**537.6000**
150.0000	**0.2921**	**0.2756**	**0.0660**	**240.0000**	**4.8000**	**576.0000**
160.0000	**0.3108**	**0.2932**	**0.0614**	**256.0000**	**5.1200**	**614.4000**
170.0000	**0.3291**	**0.3105**	**0.0571**	**272.0000**	**5.4400**	**652.8000**
180.0000	**0.3457**	**0.3262**	**0.0531**	**288.0000**	**5.7600**	**691.2000**
200.0000	**0.3703**	**0.3493**	**0.0458**	**320.0000**	**6.4000**	**768.0000**

Table (3-19) (Range, thickness ,linear energy transfer, and absorbed dose) in **Materials (SiO_2, AL_2O_3, ZrO_2)**

E(MeV)	SiO_2				AL_2O_3				ZrO_2			
	Range $(\frac{gm}{cm^2})$	Thickness (cm)	LET $\times 10^3$ $(\frac{MeV}{cm})$	Absorbed Dose $\times 10^{-8}$ (rad)	Range $(\frac{gm}{cm^2})$	Thickness (cm)	LET $\times 10^3$ $(\frac{MeV}{cm})$	Absorbed Dose $\times 10^{-8}$ (rad)	Range $(\frac{gm}{cm^2})$	Thickness (cm)	LET $\times 10^3$ $(\frac{MeV}{cm})$	Absorbed Dose $\times 10^{-8}$ (rad)
0.0100	0.0035	0.0015	0.6227	0.0160	0.0036	0.0009	1.1267	0.0160	0.0053	0.0009	1.0781	0.0160
0.0110	0.0080	0.0034	0.6443	0.0176	0.0077	0.0019	1.1676	0.0176	0.0115	0.0020	1.1161	0.0176
0.0120	0.0119	0.0051	0.6656	0.0192	0.0113	0.0028	1.2081	0.0192	0.0168	0.0030	1.1542	0.0192
0.0130	0.0153	0.0066	0.6867	0.0208	0.0144	0.0036	1.2478	0.0208	0.0216	0.0038	1.1911	0.0208
0.0140	0.0183	0.0079	0.7074	0.0224	0.0172	0.0043	1.2871	0.0224	0.0258	0.0045	1.2269	0.0224
0.0150	0.0210	0.0090	0.7280	0.0240	0.0197	0.0050	1.3256	0.0240	0.0296	0.0052	1.2627	0.0240
0.0160	0.0234	0.0101	0.7484	0.0256	0.0220	0.0055	1.3637	0.0256	0.0330	0.0058	1.2973	0.0256
0.0170	0.0256	0.0110	0.7684	0.0272	0.0240	0.0061	1.4014	0.0272	0.0361	0.0064	1.3320	0.0272
0.0180	0.0276	0.0119	0.7883	0.0288	0.0259	0.0065	1.4383	0.0288	0.0389	0.0069	1.3655	0.0288
0.0200	0.0311	0.0134	0.8273	0.0320	0.0292	0.0074	1.5110	0.0320	0.0439	0.0077	1.4308	0.0320
0.0225	0.0349	0.0150	0.8746	0.0360	0.0327	0.0082	1.5991	0.0360	0.0492	0.0087	1.5097	0.0360
0.0250	0.0380	0.0164	0.9208	0.0400	0.0356	0.0090	1.6841	0.0400	0.0537	0.0094	1.5853	0.0400
0.0275	0.0406	0.0175	0.9654	0.0440	0.0381	0.0096	1.7663	0.0440	0.0575	0.0101	1.6574	0.0440
0.0300	0.0430	0.0185	1.0090	0.0480	0.0403	0.0101	1.8457	0.0480	0.0608	0.0107	1.7273	0.0480
0.0325	0.0450	0.0194	1.0512	0.0520	0.0422	0.0106	1.9227	0.0520	0.0638	0.0112	1.7937	0.0520
0.0350	0.0468	0.0202	1.0923	0.0560	0.0439	0.0111	1.9969	0.0560	0.0664	0.0117	1.8579	0.0560
0.0375	0.0484	0.0209	1.1322	0.0600	0.0454	0.0114	2.0692	0.0600	0.0687	0.0121	1.9198	0.0600
0.0400	0.0498	0.0215	1.1709	0.0640	0.0468	0.0118	2.1386	0.0640	0.0708	0.0125	1.9800	0.0640
0.0450	0.0524	0.0226	1.2458	0.0720	0.0492	0.0124	2.2716	0.0720	0.0745	0.0131	2.0936	0.0720
0.0500	0.0545	0.0235	1.3166	0.0800	0.0512	0.0129	2.3963	0.0800	0.0776	0.0137	2.1999	0.0800
0.0550	0.0563	0.0243	1.3843	0.0880	0.0529	0.0133	2.5134	0.0880	0.0802	0.0141	2.3004	0.0880
0.0600	0.0578	0.0249	1.4486	0.0960	0.0544	0.0137	2.6242	0.0960	0.0825	0.0145	2.3958	0.0960
0.0650	0.0592	0.0255	1.5101	0.1040	0.0557	0.0140	2.7286	0.1040	0.0846	0.0149	2.4867	0.1040
0.0700	0.0604	0.0260	1.5690	0.1120	0.0569	0.0143	2.8274	0.1120	0.0864	0.0152	2.5736	0.1120
0.0800	0.0625	0.0269	1.6799	0.1280	0.0589	0.0148	3.0105	0.1280	0.0895	0.0157	2.7383	0.1280
0.0900	0.0642	0.0277	1.7829	0.1440	0.0605	0.0152	3.1764	0.1440	0.0920	0.0162	2.8923	0.1440

0.1000	0.0656	0.0283	1.8794	0.1600	0.0619	0.0156	3.3284	0.1600	0.0942	0.0166	3.0382	0.1600
0.1100	0.0668	0.0288	1.9701	0.1760	0.0631	0.0159	3.4690	0.1760	0.0960	0.0169	3.1774	0.1760
0.1200	0.0679	0.0293	2.0560	0.1920	0.0641	0.0161	3.6000	0.1920	0.0976	0.0172	3.3103	0.1920
0.1300	0.0688	0.0297	2.1379	0.2080	0.0650	0.0164	3.7227	0.2080	0.0990	0.0174	3.4370	0.2080
0.1400	0.0696	0.0300	2.2158	0.2240	0.0658	0.0166	3.8382	0.2240	0.1003	0.0177	3.5580	0.2240
0.1500	0.0704	0.0303	2.2905	0.2400	0.0665	0.0168	3.9474	0.2400	0.1014	0.0179	3.6727	0.2400
0.1600	0.0710	0.0306	2.3615	0.2560	0.0671	0.0169	4.0506	0.2560	0.1024	0.0180	3.7823	0.2560
0.1700	0.0716	0.0309	2.4295	0.2720	0.0677	0.0171	4.1483	0.2720	0.1033	0.0182	3.8851	0.2720
0.1800	0.0722	0.0311	2.4940	0.2880	0.0683	0.0172	4.2404	0.2880	0.1042	0.0183	3.9828	0.2880
0.2000	0.0731	0.0315	2.6130	0.3200	0.0692	0.0174	4.4079	0.3200	0.1057	0.0186	4.1634	0.3200
0.2250	0.0742	0.0320	2.7420	0.3600	0.0702	0.0177	4.5857	0.3600	0.1073	0.0189	4.3685	0.3600
0.2500	0.0750	0.0323	2.8510	0.4000	0.0710	0.0179	4.7330	0.4000	0.1086	0.0191	4.5616	0.4000
0.2750	0.0757	0.0326	2.9457	0.4400	0.0718	0.0181	4.8617	0.4400	0.1097	0.0193	4.7439	0.4400
0.3000	0.0764	0.0329	3.0401	0.4800	0.0724	0.0182	4.9978	0.4800	0.1107	0.0195	4.8899	0.4800
0.3250	0.0769	0.0332	3.1517	0.5200	0.0729	0.0184	5.1142	0.5200	0.1116	0.0196	5.0887	0.5200
0.3500	0.0774	0.0334	3.2009	0.5600	0.0734	0.0185	5.1999	0.5600	0.1124	0.0198	5.1790	0.5600
0.3750	0.0778	0.0336	3.2480	0.6000	0.0739	0.0186	5.2817	0.6000	0.1131	0.0199	5.2688	0.6000
0.4000	0.0782	0.0337	3.2923	0.6400	0.0742	0.0187	5.3591	0.6400	0.1137	0.0200	5.3557	0.6400
0.4500	0.0789	0.0340	3.3728	0.7200	0.0749	0.0189	5.4996	0.7200	0.1148	0.0202	5.5193	0.7200
0.5000	0.0795	0.0343	3.4406	0.8000	0.0755	0.0190	5.6191	0.8000	0.1157	0.0204	5.6630	0.8000
0.5500	0.0800	0.0345	3.4948	0.8800	0.0760	0.0191	5.7156	0.8800	0.1165	0.0205	5.7805	0.8800
0.6000	0.0804	0.0347	3.5352	0.9600	0.0764	0.0192	5.7891	0.9600	0.1172	0.0206	5.8691	0.9600
0.6500	0.0808	0.0348	3.5617	1.0400	0.0768	0.0193	5.8383	1.0400	0.1178	0.0207	5.9276	1.0400
0.7000	0.0844	0.0364	3.5744	1.1200	0.0810	0.0204	5.8649	1.1200	0.1183	0.0208	5.9578	1.1200
0.8000	0.0849	0.0366	3.5635	1.2800	0.0815	0.0205	5.8565	1.2800	0.1234	0.0217	5.9470	1.2800
0.9000	0.0854	0.0368	3.5136	1.4400	0.0819	0.0206	5.7827	1.4400	0.1241	0.0218	5.8760	1.4400
1.0000	0.0858	0.0370	3.4389	1.6000	0.0824	0.0208	5.6660	1.6000	0.1248	0.0220	5.7817	1.6000
1.1000	0.0863	0.0372	3.3526	1.7600	0.0829	0.0209	5.5298	1.7600	0.1254	0.0221	5.6823	1.7600
1.2000	0.0868	0.0374	3.2649	1.9200	0.0834	0.0210	5.3901	1.9200	0.1261	0.0222	5.5783	1.9200
1.3000	0.0872	0.0376	3.1819	2.0800	0.0839	0.0211	5.2571	2.0800	0.1268	0.0223	5.4596	2.0800
1.4000	0.0877	0.0378	3.1056	2.2400	0.0843	0.0212	5.1344	2.2400	0.1275	0.0224	5.3199	2.2400
1.5000	0.0882	0.0380	3.0353	2.4000	0.0848	0.0214	5.0209	2.4000	0.1282	0.0226	5.1580	2.4000
1.6000	0.0886	0.0382	2.9691	2.5600	0.0853	0.0215	4.9125	2.5600	0.1289	0.0227	4.9808	2.5600
1.7000	0.0891	0.0384	2.9046	2.7200	0.0857	0.0216	4.8065	2.7200	0.1295	0.0228	4.7990	2.7200

1.8000	0.0895	0.0386	2.8399	2.8800	0.0862	0.0217	4.6993	2.8800	0.1302	0.0229	4.6235	2.8800
2.0000	0.0904	0.0390	2.7070	3.2000	0.0871	0.0219	4.4794	3.2000	0.1315	0.0232	4.3191	3.2000
2.2500	0.0915	0.0395	2.5385	3.6000	0.0883	0.0222	4.2011	3.6000	0.1331	0.0234	4.0459	3.6000
2.5000	0.0926	0.0399	2.3799	4.0000	0.0894	0.0225	3.9422	4.0000	0.1347	0.0237	3.8550	4.0000
2.7500	0.0937	0.0404	2.2416	4.4000	0.0905	0.0228	3.7183	4.4000	0.1363	0.0240	3.6977	4.4000
3.0000	0.0948	0.0408	2.1270	4.8000	0.0916	0.0231	3.5329	4.8000	0.1379	0.0243	3.5466	4.8000
3.2500	0.0958	0.0413	2.0323	5.2000	0.0927	0.0233	3.3793	5.2000	0.1394	0.0245	3.3972	5.2000
3.5000	0.0969	0.0417	1.9518	5.6000	0.0937	0.0236	3.2467	5.6000	0.1409	0.0248	3.2512	5.6000
3.7500	0.0979	0.0422	1.8801	6.0000	0.0948	0.0239	3.1260	6.0000	0.1424	0.0251	3.1138	6.0000
4.0000	0.0989	0.0426	1.8128	6.4000	0.0958	0.0241	3.0116	6.4000	0.1439	0.0253	2.9877	6.4000
4.5000	0.1009	0.0435	1.6850	7.2000	0.0978	0.0246	2.7921	7.2000	0.1468	0.0258	2.7741	7.2000
5.0000	0.1028	0.0443	1.5658	8.0000	0.0998	0.0251	2.5912	8.0000	0.1496	0.0263	2.6077	8.0000
5.5000	0.1047	0.0451	1.4607	8.8000	0.1018	0.0256	2.4185	8.8000	0.1524	0.0268	2.4759	8.8000
6.0000	0.1066	0.0459	1.3727	9.6000	0.1037	0.0261	2.2776	9.6000	0.1551	0.0273	2.3657	9.6000
6.5000	0.1084	0.0467	1.3011	10.4000	0.1055	0.0266	2.1640	10.4000	0.1577	0.0278	2.2675	10.4000
7.0000	0.1102	0.0475	1.2421	11.2000	0.1074	0.0270	2.0700	11.2000	0.1602	0.0282	2.1760	11.2000
8.0000	0.1136	0.0490	1.1472	12.8000	0.1109	0.0279	1.9088	12.8000	0.1651	0.0291	2.0073	12.8000
9.0000	0.1169	0.0504	1.0644	14.4000	0.1142	0.0288	1.7599	14.4000	0.1697	0.0299	1.8574	14.4000
10.0000	0.1200	0.0517	0.9862	16.0000	0.1174	0.0296	1.6213	16.0000	0.1742	0.0307	1.7256	16.0000
11.0000	0.1231	0.0530	0.9152	17.6000	0.1205	0.0304	1.5015	17.6000	0.1784	0.0314	1.6120	17.6000
12.0000	0.1260	0.0543	0.8542	19.2000	0.1235	0.0311	1.4030	19.2000	0.1825	0.0321	1.5149	19.2000
13.0000	0.1288	0.0555	0.8034	20.8000	0.1264	0.0318	1.3232	20.8000	0.1864	0.0328	1.4319	20.8000
14.0000	0.1315	0.0567	0.7614	22.4000	0.1292	0.0325	1.2557	22.4000	0.1901	0.0335	1.3615	22.4000
15.0000	0.1342	0.0578	0.7250	24.0000	0.1319	0.0332	1.1946	24.0000	0.1937	0.0341	1.3007	24.0000
16.0000	0.1367	0.0589	0.6916	25.6000	0.1345	0.0339	1.1374	25.6000	0.1972	0.0347	1.2479	25.6000
17.0000	0.1392	0.0600	0.6605	27.2000	0.1371	0.0345	1.0838	27.2000	0.2005	0.0353	1.2008	27.2000
18.0000	0.1417	0.0611	0.6315	28.8000	0.1396	0.0352	1.0354	28.8000	0.2038	0.0359	1.1582	28.8000
20.0000	0.1464	0.0631	0.5835	32.0000	0.1444	0.0364	0.9584	32.0000	0.2101	0.0370	1.0826	32.0000
22.5000	0.1520	0.0655	0.5410	36.0000	0.1501	0.0378	0.8901	36.0000	0.2175	0.0383	1.0014	36.0000
25.0000	0.1574	0.0679	0.5037	40.0000	0.1557	0.0392	0.8246	40.0000	0.2246	0.0395	0.9298	40.0000
27.5000	0.1627	0.0701	0.4621	44.0000	0.1611	0.0406	0.7507	44.0000	0.2315	0.0408	0.8668	44.0000
30.0000	0.1679	0.0724	0.4202	48.0000	0.1664	0.0419	0.6789	48.0000	0.2382	0.0419	0.7997	48.0000
32.5000	0.1730	0.0746	0.3844	52.0000	0.1716	0.0432	0.6209	52.0000	0.2447	0.0431	0.7606	52.0000
35.0000	0.1780	0.0767	0.3577	56.0000	0.1767	0.0445	0.5800	56.0000	0.2512	0.0442	0.7162	56.0000

37.5000	0.1831	0.0789	0.3392	60.0000	0.1819	0.0458	0.5530	60.0000	0.2577	0.0454	0.6765	60.0000
40.0000	0.1880	0.0810	0.3262	64.0000	0.1870	0.0471	0.5340	64.0000	0.2641	0.0465	0.6407	64.0000
45.0000	0.1979	0.0853	0.3081	72.0000	0.1971	0.0496	0.5054	72.0000	0.2768	0.0487	0.5811	72.0000
50.0000	0.2076	0.0895	0.2930	80.0000	0.2070	0.0522	0.4804	80.0000	0.2894	0.0510	0.5328	80.0000
55.0000	0.2172	0.0936	0.2789	88.0000	0.2168	0.0546	0.4566	88.0000	0.3018	0.0531	0.4942	88.0000
60.0000	0.2264	0.0976	0.2654	96.0000	0.2263	0.0570	0.4339	96.0000	0.3138	0.0552	0.4624	96.0000
65.0000	0.2353	0.1014	0.2526	104.0000	0.2354	0.0593	0.4125	104.0000	0.3253	0.0573	0.4362	104.0000
70.0000	0.2438	0.1051	0.2406	112.0000	0.2441	0.0615	0.3922	112.0000	0.3363	0.0592	0.4141	112.0000
80.0000	0.2594	0.1118	0.2181	128.0000	0.2601	0.0655	0.3541	128.0000	0.3564	0.0627	0.3783	128.0000
90.0000	0.2736	0.1179	0.1974	144.0000	0.2746	0.0692	0.3200	144.0000	0.3743	0.0659	0.3505	144.0000
100.0000	0.2869	0.1237	0.1789	160.0000	0.2882	0.0726	0.2886	160.0000	0.3910	0.0688	0.3266	160.0000
110.0000	0.3005	0.1295	0.1619	176.0000	0.3019	0.0761	0.2608	176.0000	0.4079	0.0718	0.3050	176.0000
120.0000	0.3154	0.1360	0.1466	192.0000	0.3169	0.0798	0.2354	192.0000	0.4265	0.0751	0.2857	192.0000
130.0000	0.3324	0.1433	0.1327	208.0000	0.3339	0.0841	0.2124	208.0000	0.4479	0.0789	0.2675	208.0000
140.0000	0.3518	0.1516	0.1202	224.0000	0.3530	0.0889	0.1918	224.0000	0.4725	0.0832	0.2499	224.0000
150.0000	0.3729	0.1607	0.1088	240.0000	0.3737	0.0941	0.1731	240.0000	0.4994	0.0879	0.2334	240.0000
160.0000	0.3946	0.1701	0.0984	256.0000	0.3945	0.0994	0.1560	256.0000	0.5268	0.0927	0.2175	256.0000
170.0000	0.4151	0.1789	0.0891	272.0000	0.4137	0.1042	0.1405	272.0000	0.5523	0.0972	0.2022	272.0000
180.0000	0.4325	0.1864	0.0805	288.0000	0.4291	0.1081	0.1270	288.0000	0.5735	0.1010	0.1880	288.0000
200.0000	0.4572	0.1971	0.0659	320.0000	0.4471	0.1126	0.1032	320.0000	0.6052	0.1065	0.1607	320.0000

Results & Discussions

(4.1) Mass stopping power for tissues and materials

(4.1.1) Bethe formulae

The mass stopping power for alpha particle interaction with the chemical compositions existed in (breast, ovary, lung and muscle) tissues and the chemical compositions for materials (SiO_2, AL_2O_3, ZrO_2) are represented in table (3-6) .And By considering the percentage values for each element presented in tissues and materials we used in equation (2-32) for compounds or mixture. The results of mass stopping power for alpha particle interaction are tabulated in tables (3-10),(3-11),(3-12) ,(3-13) , and (3-14) and plotted in fig.(4-1), (4-2),(4-3), (4-4), (4-5), (4-6), and (4-7), which show the variation of mass stopping power as a function of energies.

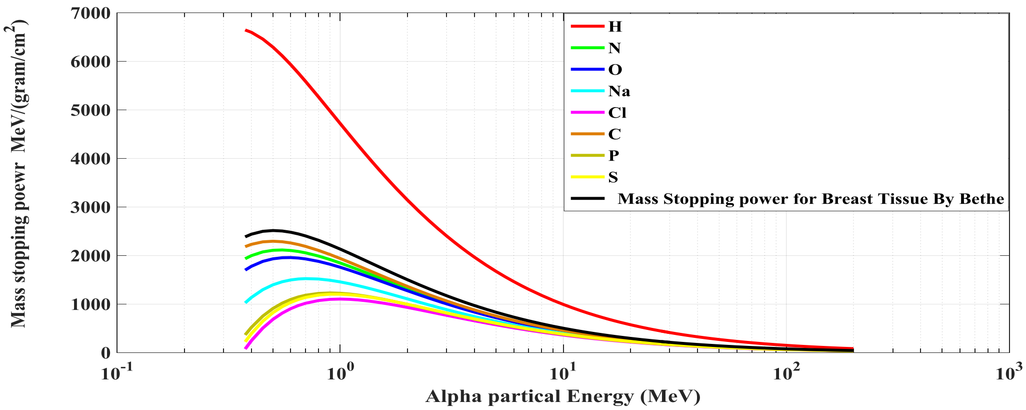


Fig. (4- 1) Mass stopping power for alpha particle in elements presented in Breast tissue using **Bethe equation**

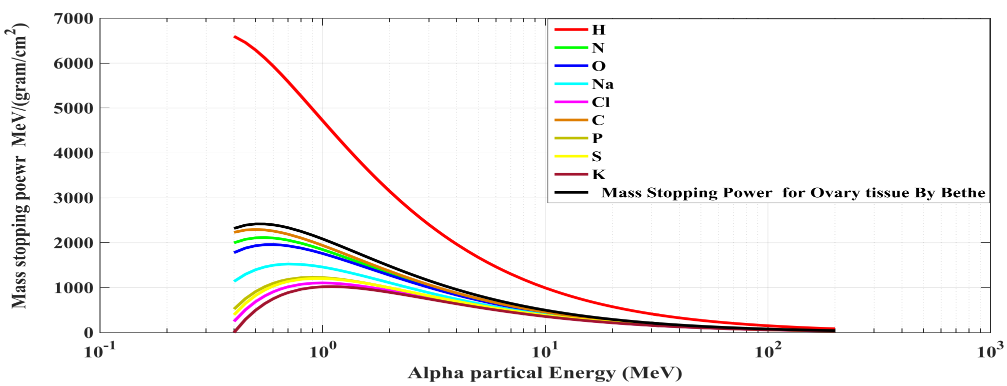


Fig. (4- 2) Mass stopping power for alpha particle in elements presented in **Ovary tissue** using **Bethe equation**

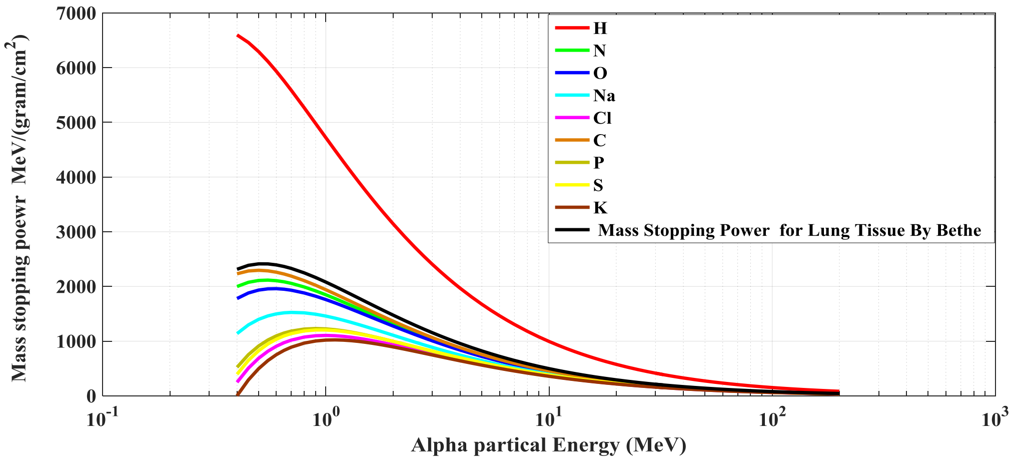


Fig.(4-3) Mass stopping power for alpha particle in elements presented in Lung tissue using Bethe equation

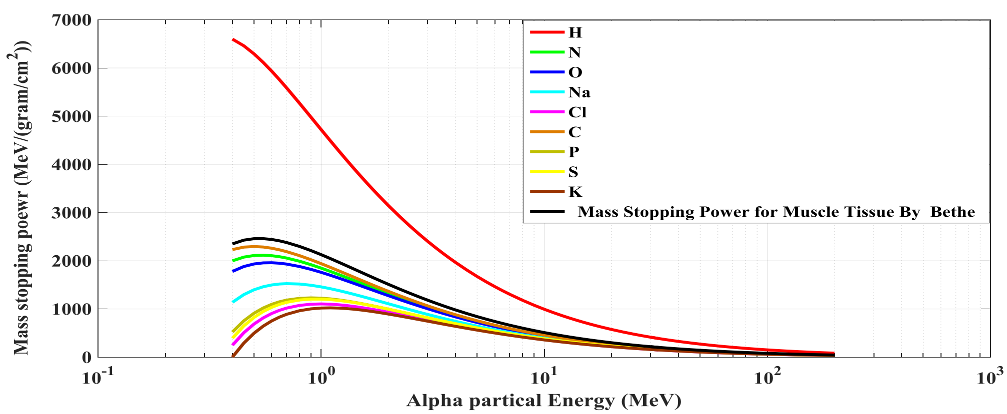


Fig.(4- 4) Mass stopping power for alpha particle in elements presented in Muscle tissue using Bethe equation.

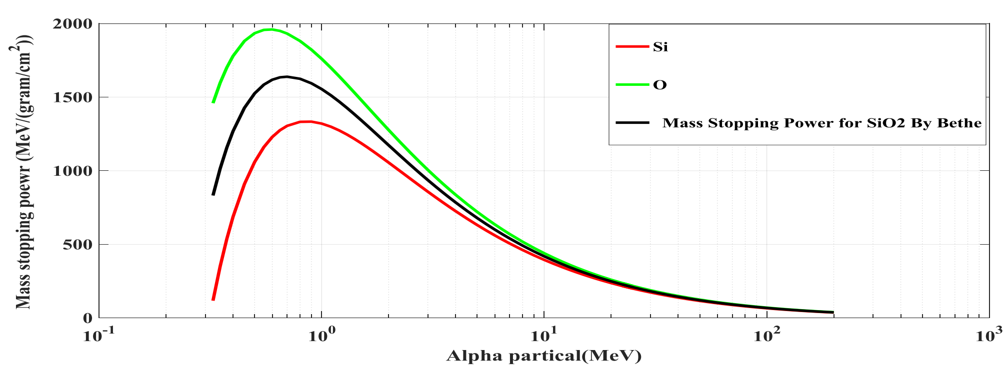


Fig. (4- 5) Mass stopping power for alpha particle in elements presented in SiO_2 using Bethe equation.

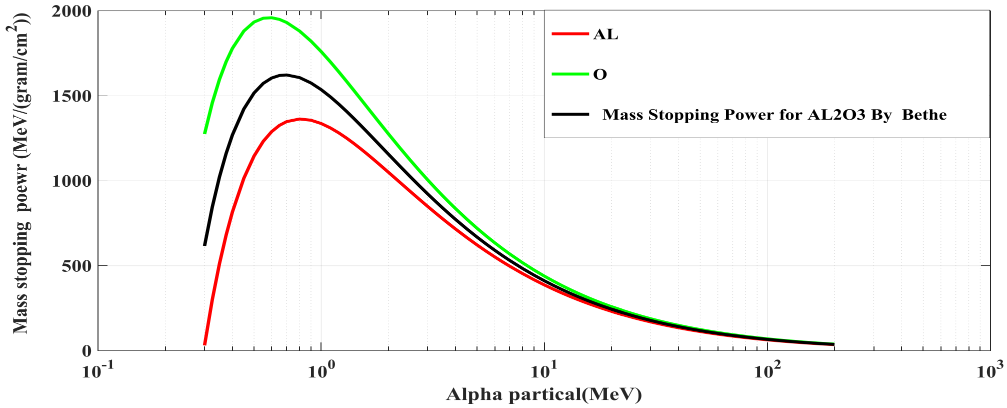


Fig. (4- 6) Mass stopping power for alpha particle in elements presented in AL_2O_2 using Bethe equation.

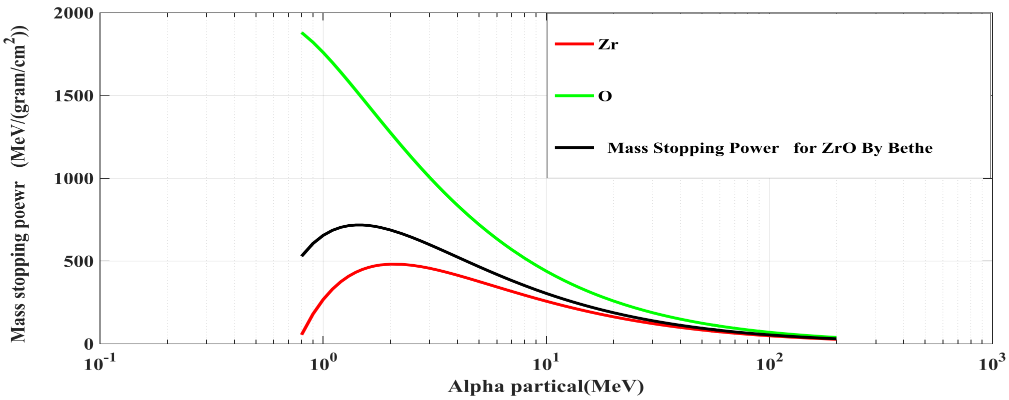


Fig. (4- 7) Mass stopping power for alpha particle in elements presented in ZrO_2using Bethe equation**.**

(4.1.2)Ziegler formula

By using Ziegler equations [42] ,the mass stopping power for alpha particle interaction with the chemical composition of (breast, ovary, lung and muscle) tissues and the chemical composition materials of (SiO_2, AL_2O_3, ZrO_2)) are tabulated in table (3-7) .And By considering the percentage values for each element presented in tissues and materials and using eq. (2-32) for compounds or mixture. The results of mass stopping power for alpha particle interaction are tabulated in tables (3-10), (3-11),(3-12) ,(3-13), and (3-14) and plotted in figures (4-8), (4-9), (4-10), (4-11), (4-12), (4-13), and (4-14).

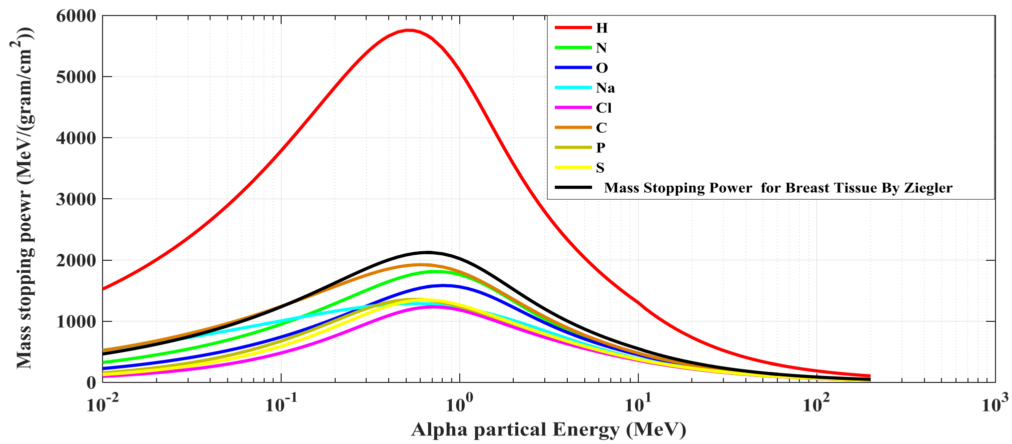


Fig.(4-8) Mass stopping power for alpha particle in elements presented in Breast tissue using Ziegler equation

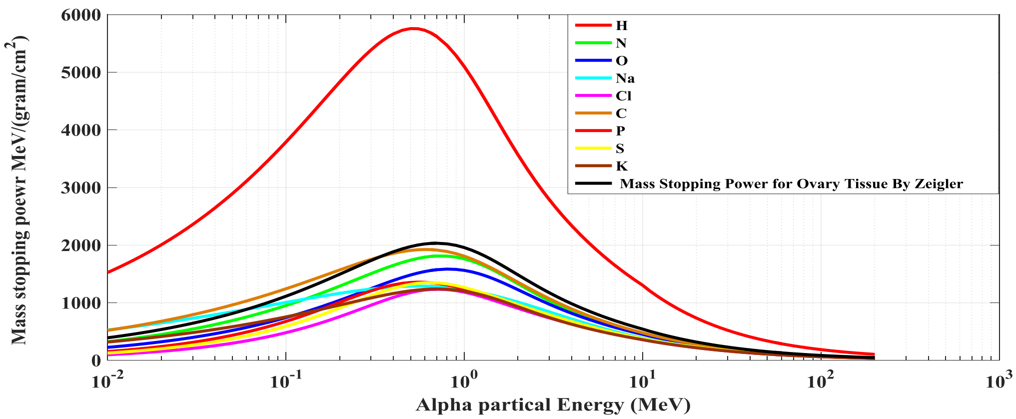


Fig.(4-9) Mass stopping power for alpha particle in elements presented in Ovary tissue using Ziegler equation

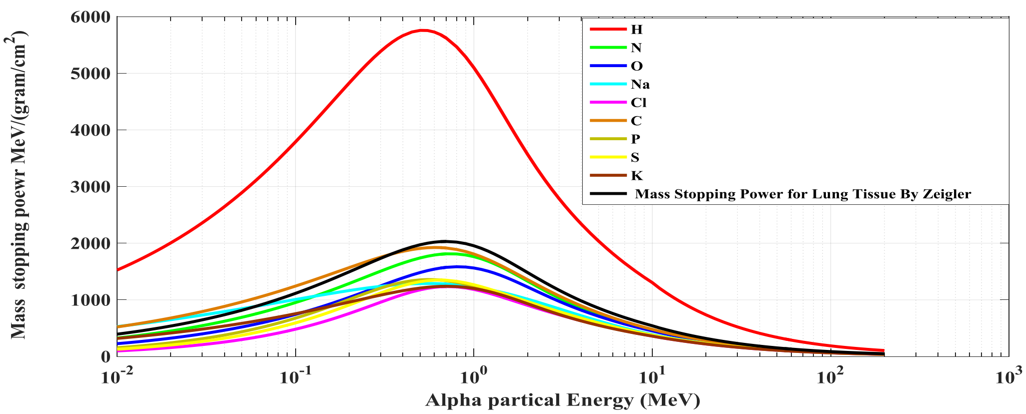


Fig.(4-10) Mass stopping power for alpha particle in elements presented in Lung tissue using Ziegler equation

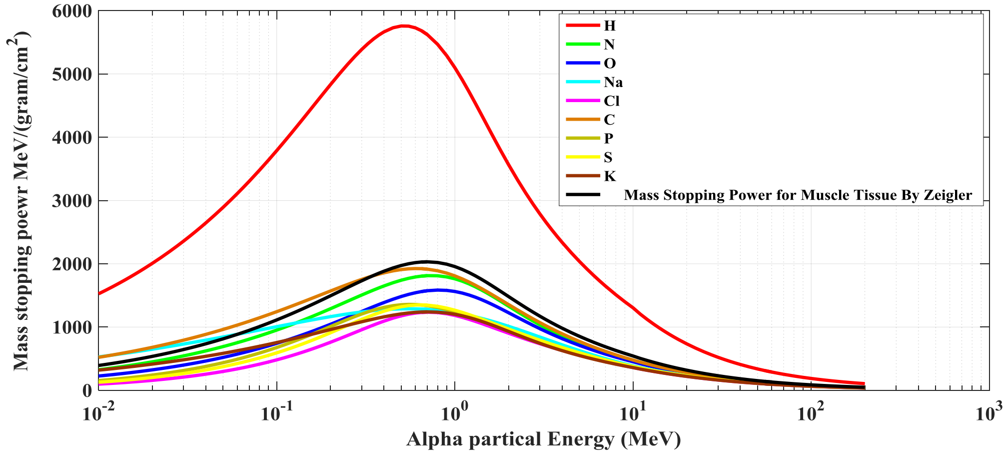


Fig.(4- 11) Mass stopping power for alpha particle in elements presented in Muscle tissue using Ziegler equation.

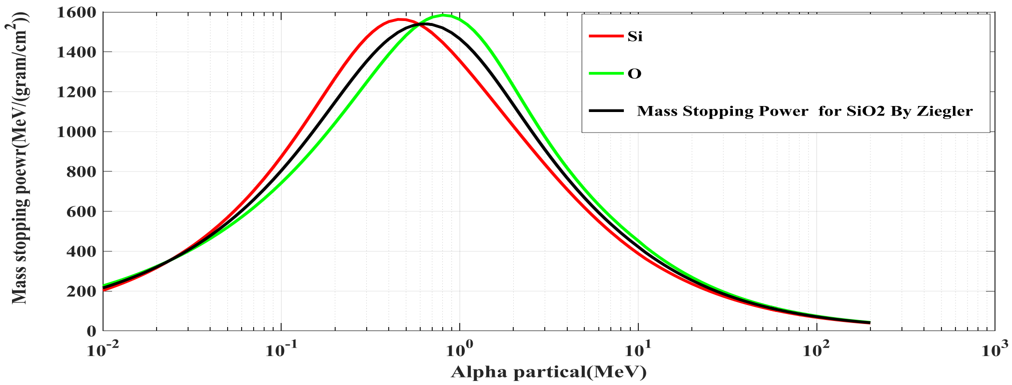


Fig.(4-12) Mass stopping power for alpha particle in elements presented in SiO_2 tissue using Ziegler equation

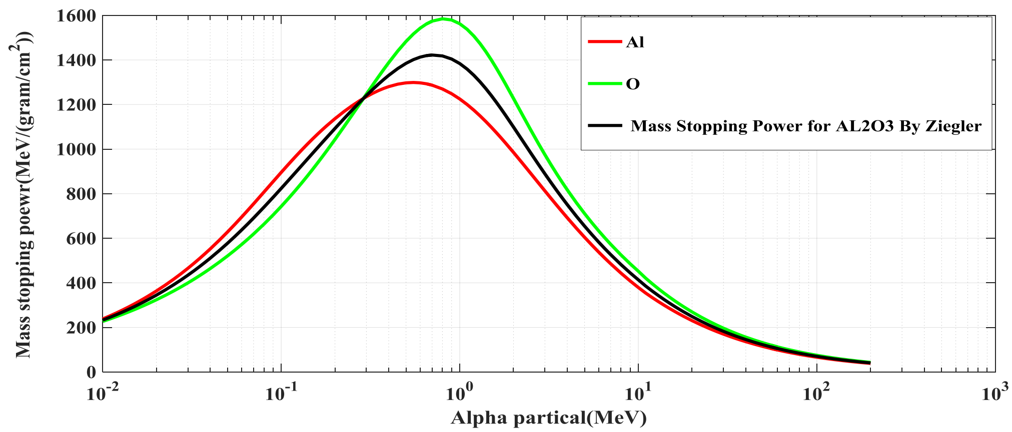


Fig.(4-13) Mass stopping power for alpha particle in elements presented in AL_2O_3 using Ziegler equation

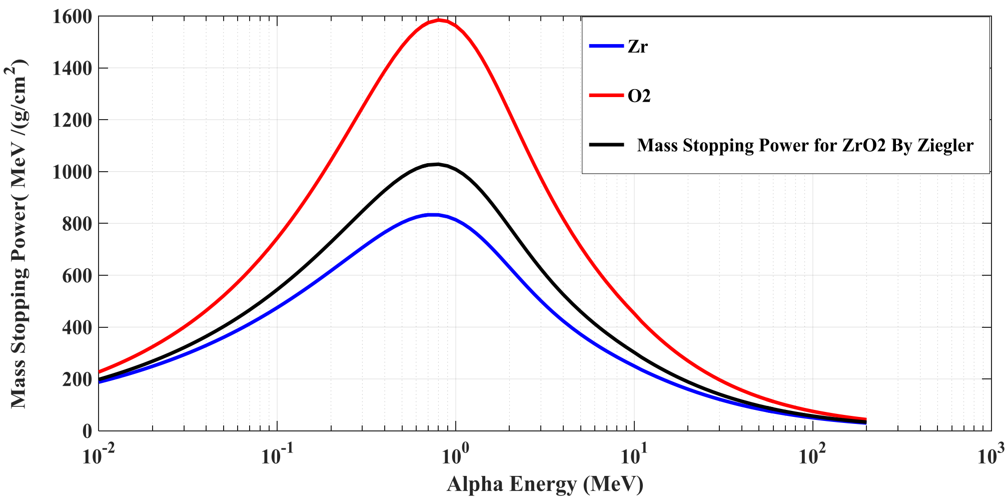


Fig.(4-14) Mass stopping power for alpha particle in elements presented in ZrO_2 using Ziegler equation

In Ziegler equation, we respect the coefficients for stopping powers which are fitted parameters and different from element to another.

(4.1.3) SRIM program

The mass stopping power for alpha particle which interacts with chemical composition for (breast, ovary, lung and muscle) tissues and with materials (SiO_2, AL_2O_3, ZrO_2) using SRIM program is tabulated in table (3-8). The results are plotted in figures (4-15), (4-16),(4-17),(4-18),(4-19),(4-20), and (4-21).

By considering the percentage values for each element presented in (breast, ovary, lung and muscle), and using eq. (2-32) for compounds or mixture. The results of mass stopping power for Alpha particle interaction are tabulated in tables (3-10),(3-11),(3-12) , and (3-13) and plotted in figures (4-15), (4-16),(4-17), and (4-18) .

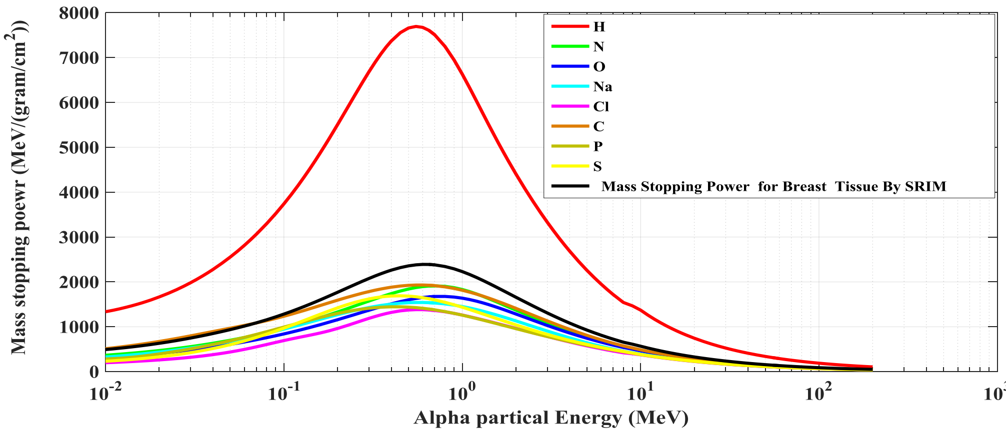


Fig.(4-15) Mass stopping power for alpha particle in elements presented in Breast tissue using SRIM program

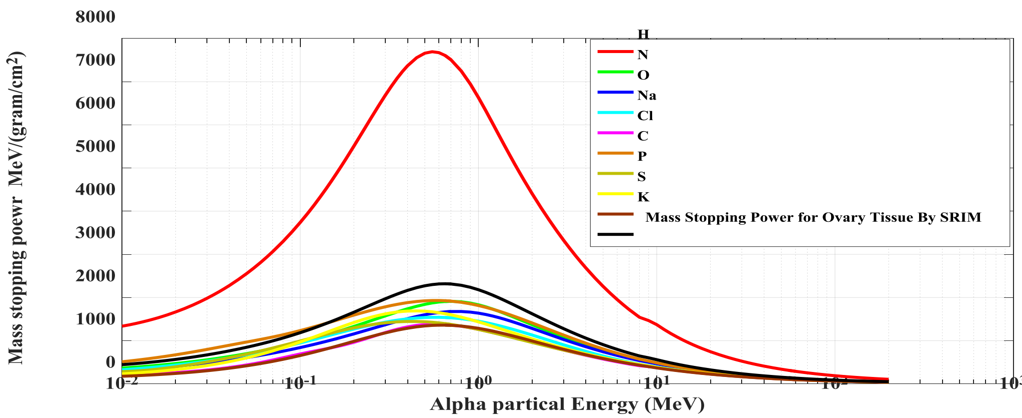


Fig.(4-16) Mass stopping power for alpha particle in elements presented in Ovary tissue using SRIM program

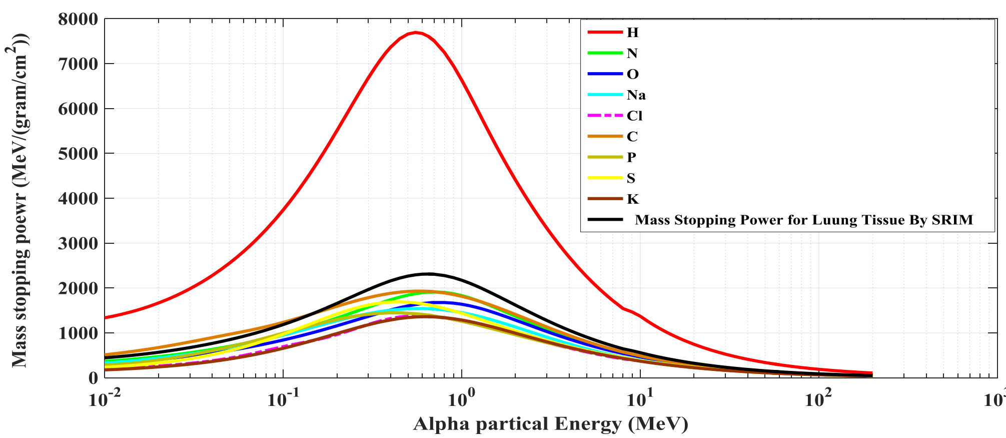


Fig.(4-17) Mass stopping power for alpha particle in elements presented in Lung tissue using SRIM program

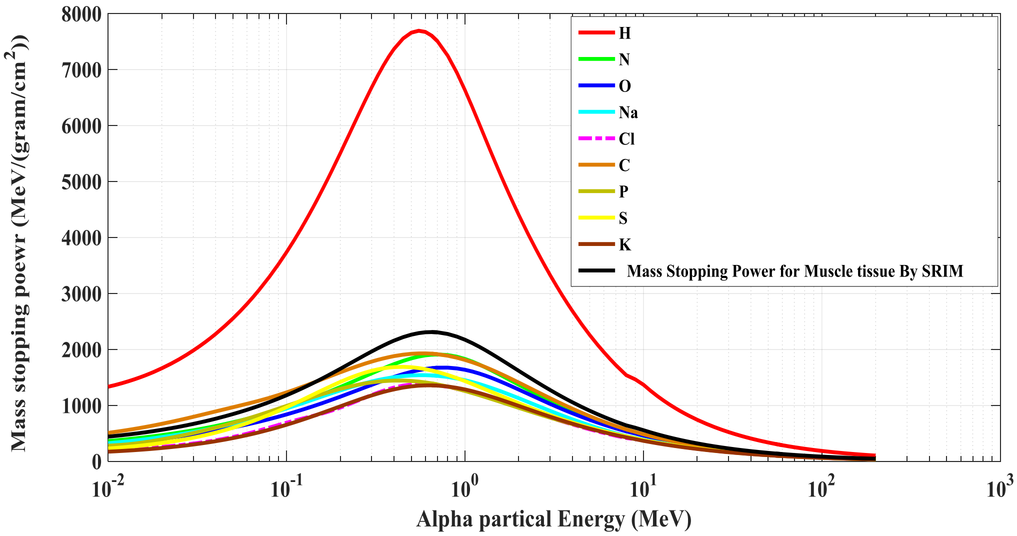


Fig. (4- 18) Mass stopping power for alpha particle in elements presented in Muscle tissue using SRIM program

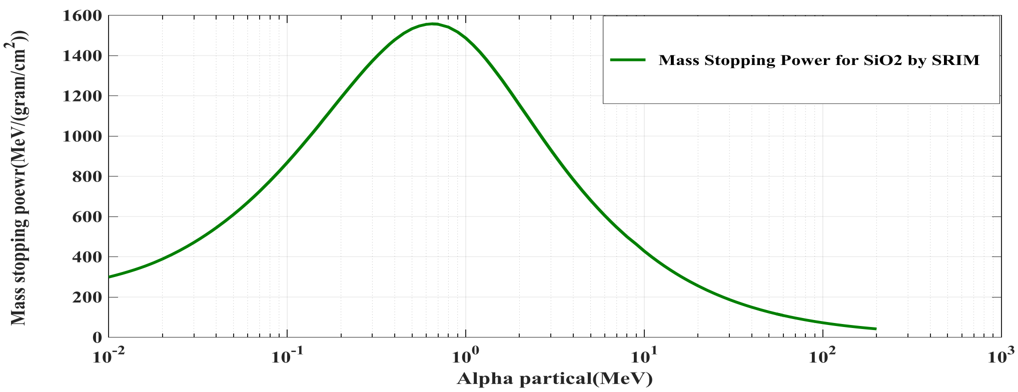


Fig. (4-19) Mass stopping power for alpha particle in elements presented in SiO_2 using SRIM program

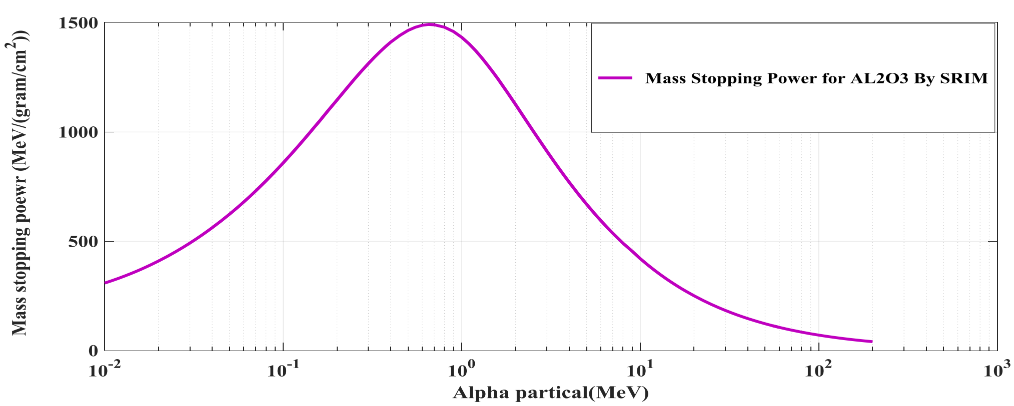


Fig. (4-20) Mass stopping power for alpha particle in elements presented in AL_2O_3 using SRIM program

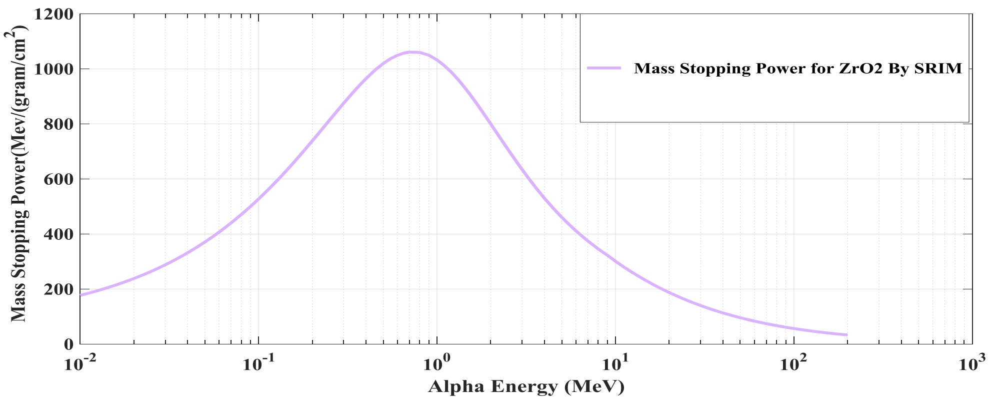


Fig. (4-21) Mass stopping power for alpha particle in elements presented in ZrO_2 using SRIM program

(4.1.4)ASTAR program

The mass stopping power for alpha particle interacts with material (SiO_2 , AL_2O_3) using ASTAR program tabulated in (3-9) and are plotted in figures (4-22), and (4-23).

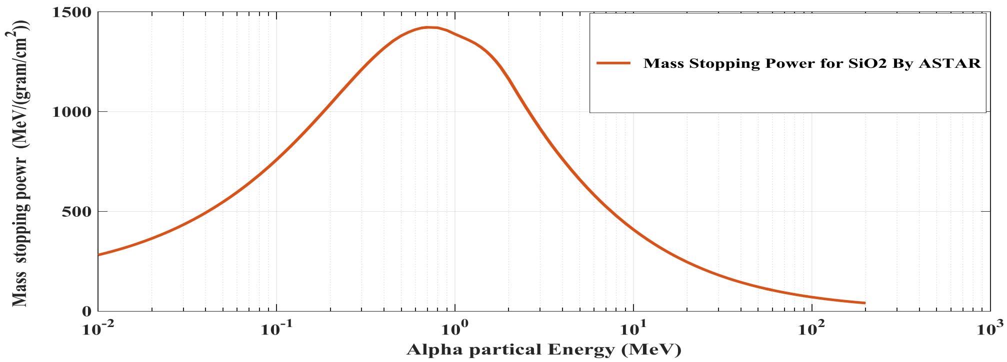


Fig. (4-22) Mass stopping power for alpha particle in elements presented in SiO_2 using ASTAR program

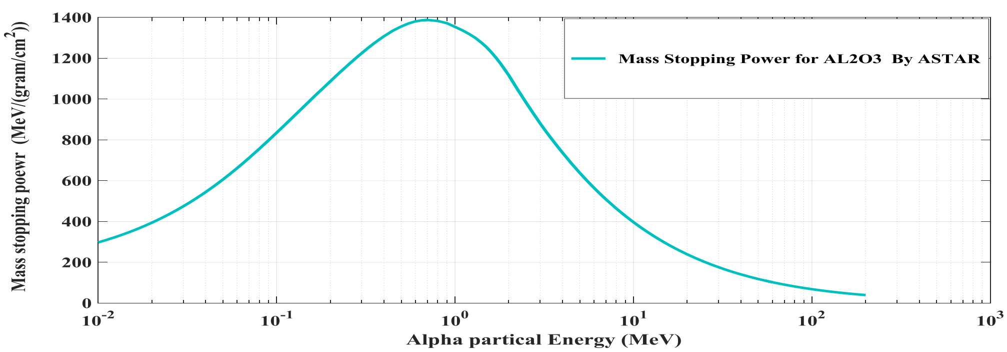


Fig. (4-23)Mass stopping power for alpha particle in elements presented in AL_2O_3 using ASTAR program

It is clear from the above figures

A- At low energy: the Bethe formula begins to fail at low particles energy, where charge exchange between the particle and absorber becomes important. The positively charged particle will then tend to pick up electrons from the absorber, which effectively reduce its charge and consequent linear energy loss. At the end of its track, the particle has accumulated ***z*** electrons and becomes a neutral atom. This result was agreed with the reference [13]. Zeigler's formula and SRIM program and ASTAR program were successful in that. Whereas the mass stopping power increases rapidly at low energies reaches a maximum.

B-At high energy: in Bethe the mass stopping power varies as $1/v^2$, or inversely with particle energy. This behavior can be heuristically explained by noting that the charged particle spends a greater time in the vicinity of any given electron when its velocity is low, the impulse felt by the electron, and hence the energy transfer, is the largest. This result was agreed with reference [13] . We also find the same behavior in Ziegler's formula , SRIM program ASTAR program .Whereas the mass stopping power decreases gradually with increasing energy **.**

C-The maximum value of mass stopping power at the same energy is found in Hydrogen element, because Hydrogen was molecules in the traversing path of the alpha particle ions and hence the more probability of interaction and more energy lost , these results were studied by [109] . We conclude that the Hydrogen atoms are most responsible to Energy losing in the human tissues.

(4.1.5)Semi-empirical equation

The semi-empirical formulas for mass stopping power by calculation of weighted average for mass stopping power were calculate by using Matlab software ,compared with three methods in all tissues and ZrO_2, and compared with four methods in (SiO_2, AL_2O_3) are tabulated in tables(4-1),(4-2)

Table (4-1) Semi-empirical formulas for mass stopping power for alpha particle interaction with (breast, ovary, lung, and muscle) tissues

Tissue	E(MeV)	F(E)			
Ovary Tissue	$E \le 0.3$	$p_1E^7 + p_2E^6 + p_3E^5 + p_4E^4$ $+p_5E^3 + p_6E^2 + p_7E + p_8$	$p_1 = 4.527 \times 10^{+7}$ $p_2 = -6.2 \times 10^{+7}$ $p_3 = 3.565 \times 10^{+7}$ $p_4 = -1.0 \times 10^{+7}$ $p_5 = 1.82 \times 10^{+7}$ $p_6 = -1.9 \times 10^{+7}$ $p_7 = 1.76 \times 10^{+7}$ $p_8 = 262$		
	$E > 0.3$	$a_1 * exp(-((E-b_1)/(c_1)^2)$ $+ a_2 * exp(-((E-b_2)/c_2)^2)$ $+ a_3 * exp(-((E-b_3)/c_3)^2)$ $+ a_4 * exp(-((E-b_4)/c_4)^2)$ $+ a_5 * exp(-((E-b_5)/c_5)^2)$ $+ a_6 * exp(-((E-b_6)/c_6)^2)$ $+a_7 * exp(-((E-b_7)/c_7)^2)$	$a_1 = 516.4$ $a_2 = 659$ $a_3 = 486.5$ $a_4 = 402.4$ $a_5 = 88.53$ $a_6 = 218.3$ $a_7 = 215$	$b_1 = 0.5461$ $b_2 = 0.9671$ $b_3 = 1.782$ $b_4 = 2.283$ $b_5 = 11.32$ $b_6 = 5.501$ $b_7 = -323.9$	$c_1 = 0.42$ $c_2 = 0.9837$ $c_3 = 2.422$ $c_4 = 7.043$ $c_5 = 48.32$ $c_6 = 19.01$ $c_7 = 427.6$
Breast Tissue	$E \le 0.50$	$p_1E^6 + p_2E^5 + p_3E^4 + p_4E^3$ $+p_5E^2 + p_6E + p_7$	$p_1 = -4.636 \times 10^5$ $p_2 = 9.178 \times 10^5$ $p_3 = -7.588 \times 10^5$ $p_4 = 3.322 \times 10^5$ $p_5 = 3.322 \times 10^5$ $p_6 = 1.493 \times 10^4$ $p_7 = 1.493 \times 10^4$		
	$E > 0.5$	$a_1 * exp(-((E-b_1)/(c_1)^2)$ $+ a_2 * exp(-((E-b_2)/c_2)^2)$ $+ a_3 * exp(-((E-b_3)/c_3)^2)$ $+ a_4 * exp(-((E-b_4)/c_4)^2)$ $+ a_5 * exp(-((E-b_5)/c_5)^2)$ $+ a_6 * exp(-((E-b_6)/c_6)^2)$ $+a_7 * exp(-((E-b_7)/c_7)^2)$	$a_1 = 464.9$ $a_2 = 351.7$ $a_3 = 1015$ $a_4 = 252.5$ $a_5 = 85.33$ $a_6 = 23.35$ $a_7 = 1.788 \times 10^{+15}$	$b_1 = 0.3763$ $b_2 = 0.7928$ $b_3 = -1.558$ $b_4 = 3.941$ $b_5 = -13.53$ $b_6 = 18.48$ $b_7 = -1690$	$c_1 = 0.9041$ $c_2 = 1.657$ $c_3 = 5.187$ $c_4 = 8.789$ $c_5 = 281.2$ $c_6 = 7.54$ $c_7 = 313.1$

Lung Tissue	E ≤ 0.3	$p_1E^5 + p_2E^4 + p_3E^3 + p_4E^2 + p_5E + p_6$	$p_1 = 2 \times 10^{+6}$ $p_2 = -1.791 \times 10^{+6}$ $p_3 = 6.205 \times 10^{+5}$ $p_4 = -1.125 \times 10^{+5}$ $p_5 = 1.53 \times 10^{+4}$ $p_6 = 283.8$		
	E > 0.3	$a_1 * exp(-((E-b_1)/(c_1)^2)$ $+ a_2 * exp(-((E-b_2)/c_2)^2)$ $+ a_3 * exp(-((E-b_3)/c_3)^2)$ $+ a_4 * exp(-((E-b_4)/c_4)^2)$ $+ a_5 * exp(-((E-b_5)/c_5)^2)$ $+ a_6 * exp(-((E-b_6)/c_6)^2)$ $+a_7 * exp(-((E-b_7)/c_7)^2)$	$a_1 = 565.7$ $a_2 = 664.8$ $a_3 = 530$ $a_4 = 457.7$ $a_5 = 17.33$ $a_6 = 149.9$ $a_7 = 4.155 \times 10^{+15}$	$b_1 = 0.5472$ $b_2 = 1.008$ $b_3 = 1.824$ $b_4 = 2.978$ $b_5 = 41.9$ $b_6 = 15.18$ $b_7 = -7560$	$c_1 = 0.4445$ $c_2 = 1.025$ $c_3 = 2.63$ $c_4 = 8.111$ $c_5 = 5.138$ $c_6 = 17.69$ $c_7 = 1365$
Muscle Tissue	E ≤ 0.3	$p_1E^5 + p_2E^4 + p_3E^3 + p_4E^2 + p_5E + p_6$	$p_1 = 1.99 \times 10^{+6}$ $p_2 = -1.782 \times 10^{+6}$ $p_3 = 6.176 \times 10^{+5}$ $p_4 = 6.176 \times 10^{+5}$ $p_5 = 1.526 \times 10^{+4}$ $p_6 = 283$		
	E > 0.3	$a_1 * exp(-((E-b_1)/(c_1)^2)$ $+ a_2 * exp(-((E-b_2)/c_2)^2)$ $+ a_3 * exp(-((E-b_3)/c_3)^2)$ $+ a_4 * exp(-((E-b_4)/c_4)^2)$ $+ a_5 * exp(-((E-b_5)/c_5)^2)$ $+ a_6 * exp(-((E-b_6)/c_6)^2)$ $+a_7 * exp(-((E-b_7)/c_7)^2)$	$a_1 = 580.4$ $a_2 = 677$ $a_3 = 577.7$ $a_4 = 369.5$ $a_5 = 218.3$ $a_6 = 54.24$ $a_7 = 5.263 \times 10^{+8}$	$b_1 = 0.5348$ $b_2 = 0.9891$ $b_3 = 1.765$ $b_4 = 3.571$ $b_5 = 7.677$ $b_6 = 27.96$ $b_7 = -4227$	$c_1 = 0.4318$ $c_2 = 0.9661$ $c_3 = 2.421$ $c_4 = 6.268$ $c_5 = 15.31$ $c_6 = 23.58$ $c_7 = 1096$

Table (4-2)Semi-empirical formulas for mass stopping power for alpha particle interaction with in materials (SiO_2, AL_2O_3, ZrO_2)

Material	E(MeV)	F(E)			
AL_2O_3	$E \le 0.3$	$p_1E^5 + p_2E^4 + p_3E^3$ $+p_4E^2 + p_5E + p_6$	$p_1 = 1.213 \times 10^{+6}$ $p_2 = -1.129 \times 10^{+6}$ $p_3 = 4.193 \times 10^{+5}$ $p_4 = -8.466 \times 10^{+4}$ $p_5 = 1.194 \times 10^{+4}$ $p_6 = 172.5$		
	$E > 0.3$	$a_1 * exp(-((E - b_1)/(c_1)^2)$ $+ a_2 * exp(-((E - b_2)/c_2)^2)$ $+ a_3 * exp(-((E - b_3)/c_3)^2)$ $+ a_4 * exp(-((E - b_4)/c_4)^2)$ $+ a_5 * exp(-((E - b_5)/c_5)^2)$ $+ a_6 * exp(-((E - b_6)/c_6)^2)$ $+a_7 * exp(-((E - b_7)/c_7)^2)$	$a_1 = 344.5$ $a_2 = 537.2$ $a_3 = 378$ $a_4 = 330.1$ $a_5 = 88.71$ $a_6 = 60.94$ $a_7 = 5.62 \times 10^{+15}$	$b_1 = 0.5512$ $b_2 = 1.015$ $b_3 = 2.237$ $b_4 = 5.041$ $b_5 = 13.08$ $b_6 = 21.34$ $b_7 = -6160$	$c_1 = 0.5915$ $c_2 = 1.321$ $c_3 = 2.581$ $c_4 = 5.614$ $c_5 = 5.458$ $c_6 = 8.745$ $c_7 = 1107$
SiO_2	$E \le 0.3$	$p_1E^5 + p_2E^4 + p_3E^3$ $+p_4E^2 + p_5E + p_6$	$p_1 = 1.0 \times 10^{+6}$ $p_2 = -9.\times 10^{+5}$ $p_3 = 3.4 \times 10^{+5}$ $p_4 = -6.\times 10^{+4}$ $p_5 = 1.0 \times 10^{+4}$ $p_6 = 168.5$		
	$E > 0.3$	$a_1 * exp(-((E - b_1)/(c_1)^2)$ $+ a_2 * exp(-((E - b_2)/c_2)^2)$ $+ a_3 * exp(-((E - b_3)/c_3)^2)$ $+ a_4 * exp(-((E - b_4)/c_4)^2)$ $+ a_5 * exp(-((E - b_5)/c_5)^2)$ $+ a_6 * exp(-((E - b_6)/c_6)^2)$ $+a_7 * exp(-((E - b_7)/c_7)^2)$	$a_1 = 362.1$ $a_2 = 511.5$ $a_3 = 382.2$ $a_4 = 338.5$ $a_5 = 53.53$ $a_6 = 64.19$ $a_7 = 5.362 \times 10^{+15}$	$b_1 = 0.5514$ $b_2 = 1.049$ $b_3 = 2.141$ $b_4 = 5.063$ $b_5 = 14.59$ $b_6 = 21.28$ $b_7 = -6336$	$c_1 = 0.5971$ $c_2 = 1.323$ $c_3 = 2.808$ $c_4 = 6.801$ $c_5 = 4.963$ $c_6 = 9.467$ $c_7 = 1140$
ZrO_2	$E \le 0.3$	$p_1E^6 + p_2E^5 + p_3E^4 + p_4E^3$ $+p_5E^2 + p_6E + p_7$	$p_1 = -7.221 \times 10^{+6}$ $p_2 = 7.482 \times 10^{+6}$ $p_3 = -3.093 \times 10^{+6}$ $p_4 = 6.605 \times 10^{+5}$ $p_5 = 8.259 \times 10^{+4}$ $p_6 = 8273$ $p_7 = 114.7$		
	$E > 0.3$	$a_1 * exp(-((E - b_1)/(c_1)^2)$ $+ a_2 * exp(-((E - b_2)/c_2)^2)$ $+ a_3 * exp(-((E - b_3)/c_3)^2)$ $+ a_4 * exp(-((E - b_4)/c_4)^2)$ $+ a_5 * exp(-((E - b_5)/c_5)^2)$ $+ a_6 * exp(-((E - b_6)/c_6)^2)$ $+a_7 * exp(-((E - b_7)/c_7)^2)$	$a_1 = 187.3$ $a_2 = 187.3$ $a_3 = 169.4$ $a_4 = 212$ $a_5 = 1.864 \times 10^{+5}$ $a_6 = -1.368 \times 10^{+4}$ $a_7 = 139$	$b_1 = 0.5644$ $b_2 = 1.122$ $b_3 = 1.662$ $b_4 = 1.662$ $b_5 = -260.7$ $b_6 = 30.72$ $b_7 = -201.$	$c_1 = 0.4109$ $c_2 = 0.6977$ $c_3 = 2$ $c_4 = 8.174$ $c_5 = 102.6$ $c_6 = 0.2418$ $c_7 = 318.4$

(4.1.6) Present work

The mass stopping power for Alpha particle interaction with the tissues (breast , ovary, lung and muscle) and materials(SiO_2, AL_2O_3 ,ZrO_2) using Bethe and Ziegler equations and SRIM ,ASTAR programs and average for these values are tabulated in tables (3-10), (3-11),(3-12),(3-13), and (3-14) and plotted in figures (4-24) ,(4-25), (4-26), (4-27), (4-28),(4-29), and (4-30).

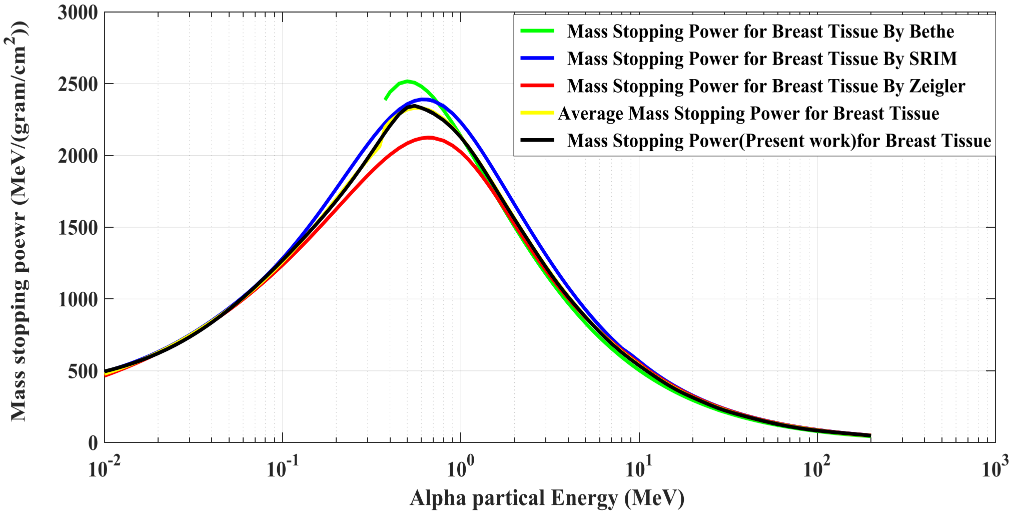


Fig. (4-24) Mass stopping power for alpha particle in Breast tissue (present work)

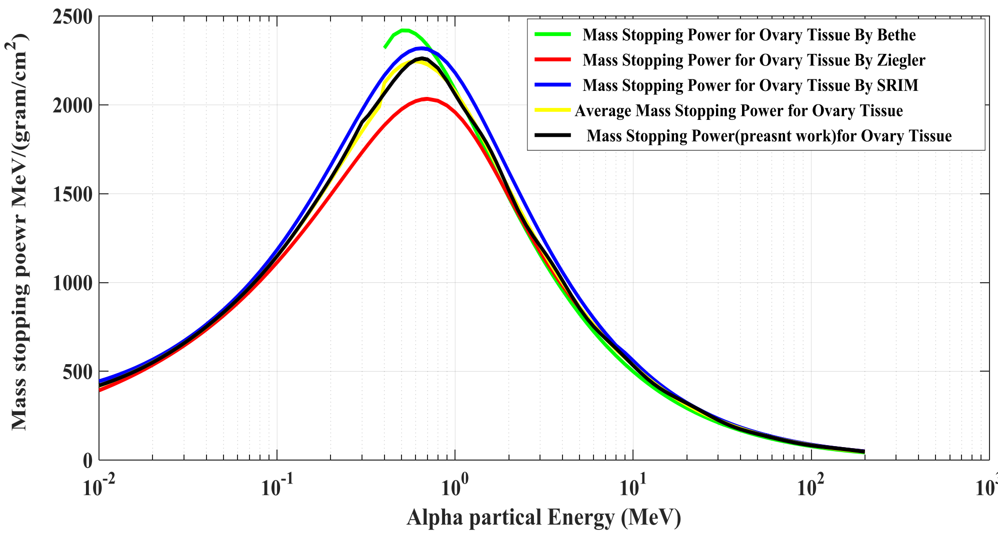


Fig. (4-25) Mass stopping power for alpha particle in Ovary tissue (present work)

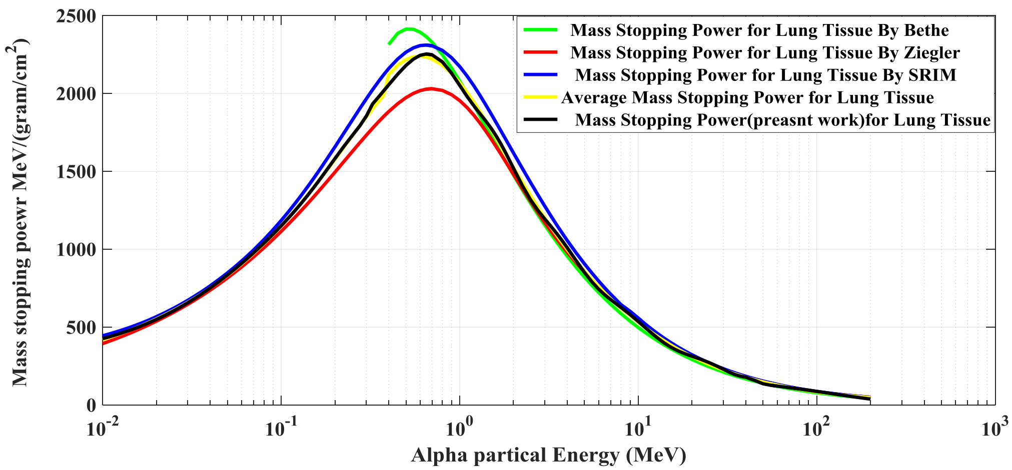


Fig. (4-26) Mass stopping power for alpha particle in Lung tissue (present work)

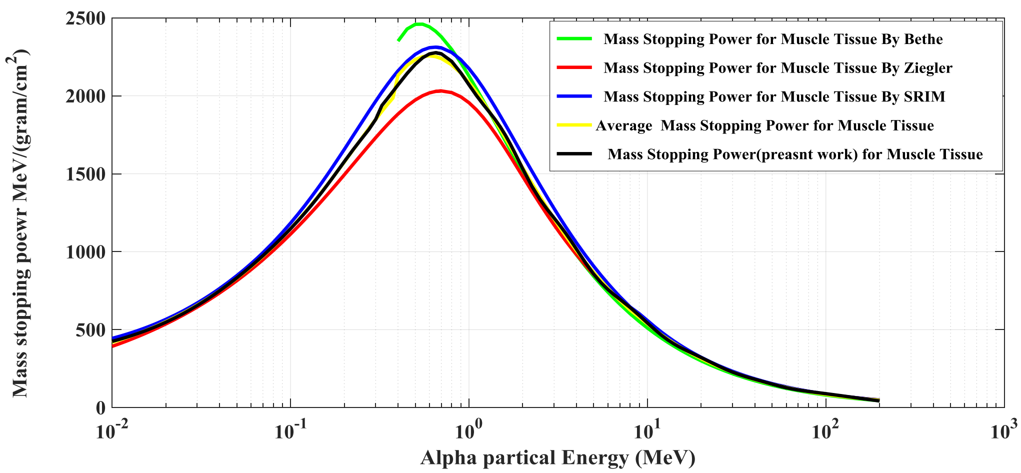


Fig. (4-27) Mass stopping power for alpha particle in Muscle tissue (present work)

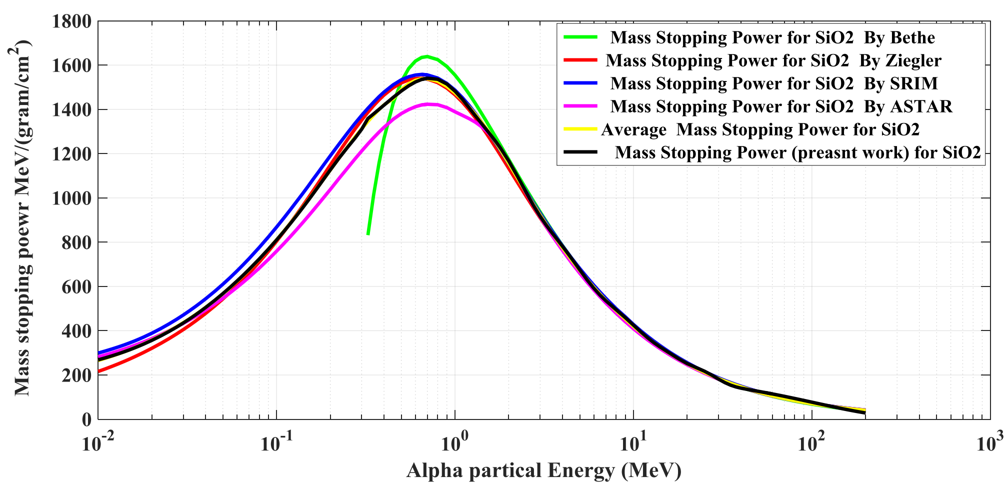


Fig. (4-28) Mass stopping power for alpha particle in SiO_2 (present work)

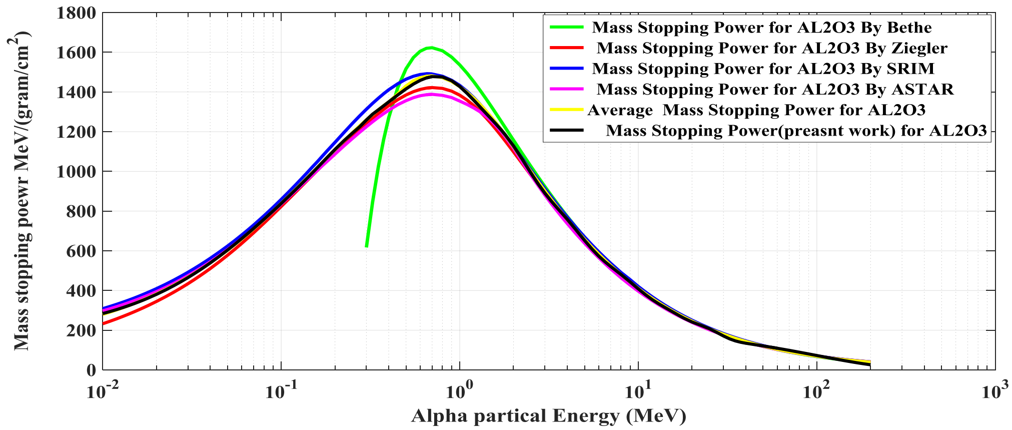


Fig. (4-29) Mass stopping power for alpha particle in AL_2O_3(present work)

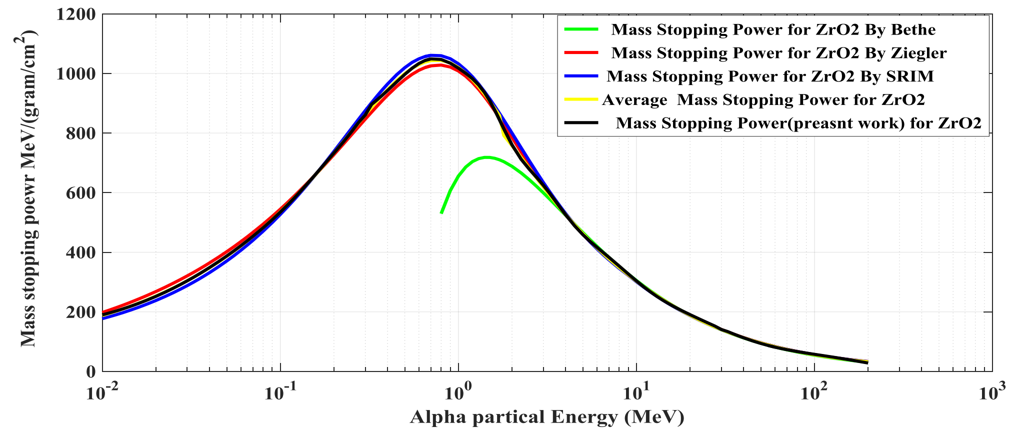


Fig. (4-30) Mass stopping power for alpha particle in ZrO_2 (present work)

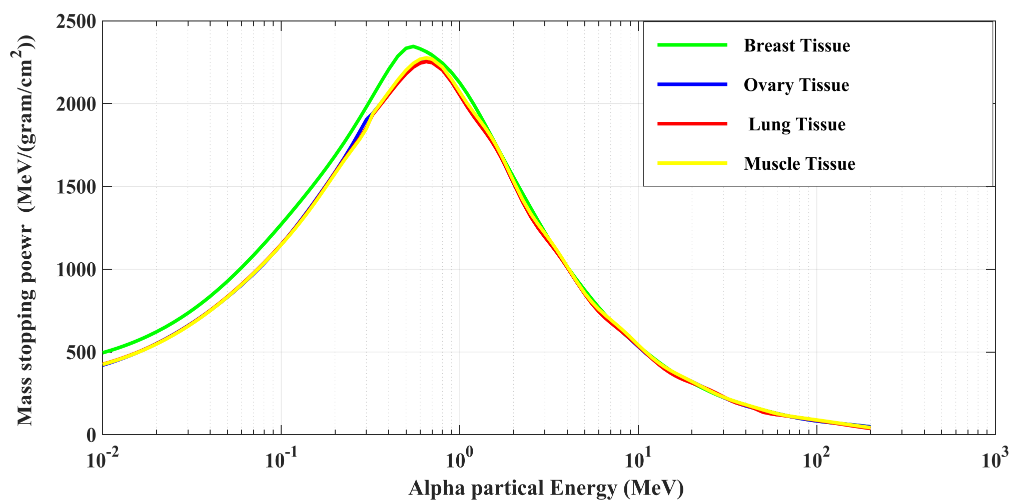


Fig.(4-31) Mass stopping powers as a function to alpha particle energy for in (Breast , Ovary , Lung and Muscle) tissues

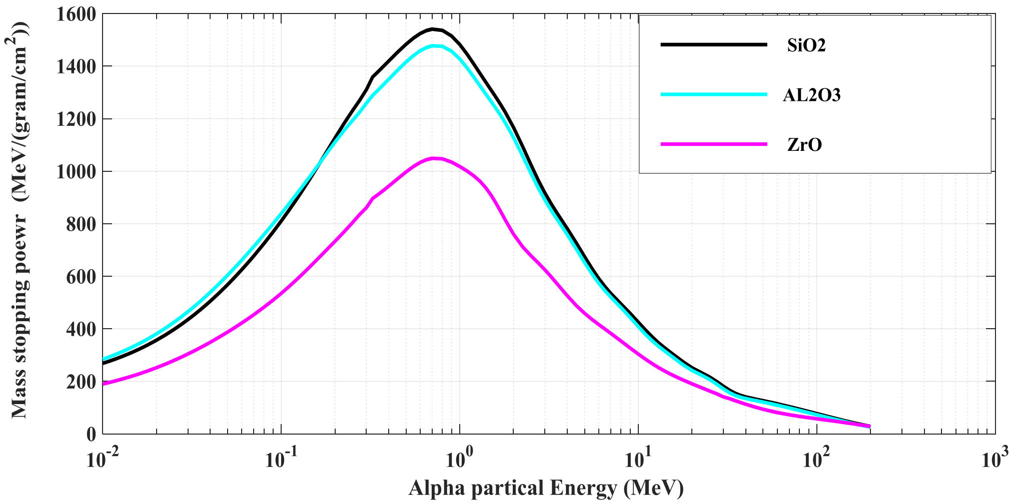


Fig.(4-32) Mass stopping powers as a function to alpha particle energy for in materials (SiO_2, AL_2O_3, ZrO_2)

From figures (4-31) and (4-32) we can determine the maximum value of energy the alpha particles can lose along its path in the targets (breast, ovary, lung and muscle) tissues and materials (SiO_2, AL_2O_3, ZrO_2) .The results are tabulated in tables(4-3) and (4-4)

Table (4-3) The maximum value of energy the alpha particles can lose along its path in (breast, ovary, lung and muscle) tissues

Tissue	E(MeV)	The maximum value of energy the alpha particles can lose along its path in the tissue $(MeV/(\frac{gram}{cm^2})$
Breast	0.55	2.3456×10^3
Ovary	0.65	2.2618×10^3
Lung	0.65	2.2538×10^3
Muscle	0.65	$2.2764 \times 10^{+3}$

Table (4-4) The maximum value of energy the alpha particles can lose along its path the materials (SiO_2, AL_2O_3, ZrO_2)

Material	E(MeV)	The maximum value of energy the alpha particles can lose along its path in the material $(MeV/(\frac{gram}{cm^2}))$
SiO_2	0.7	$1.5407 \times 10^{+3}$
AL_2O_3	0.7	$1.4773 \times 10^{+3}$
ZrO_2	0.7	$1.0489 \times 10^{+3}$

- So it can be able to tell the doctor how much alpha energy to be used for the treatment and mass stopping power in the tissues (breast, ovary, lung and muscle) and materials (SiO_2, AL_2O_3, ZrO_2) to achieve the best treatment and decreased the damage of tissues surrounding the tumor.

It is clearly observed from Figures (4-31) and (4-32)

-At low energies: the mass stopping power of alpha particle increases with the increase of its energy.
-At high energies: the mass stopping power of alpha particle decreases with the increase of its energy.
A slow alpha particle (low energy) loses more energy by ionizing atoms than a fast alpha particle (high energy), since the slower particle spends a longer time in an atom, and thus there is a greater probability that an electronic transition will occur in the atom.

-Table (4-31) shows that the values of the mass stopping power of alpha particles in tissues are converged, because mass stopping power does not differ greatly for materials with similar atomic composition [25], also that the effective atomic numbers of the tissues are almost equals.

- The table (4-32) shows that the values of the mass stopping power of alpha particles in SiO_2 and $AL_2O_3$are converged ,while the values of the mass stopping power of alpha particles in ZrO_2 are less than its mass stopping power in SiO_2 and AL_2O_3, because of the difference of the effective atomic numbers.

Mass stopping power is the loss of energy per unit of length. Thus, materials with a low atomic number have a greater mass stopping power than materials with a large atomic number because materials with a large atomic number scatter the proton at a larger angle, resulting in less energy loss, so that those materials are used to spread out the beam [26]. Also light atoms have a greater correlation effect on the stopping powers. Heavier atoms are assumed not to contribute anomalously to stop because of their bonds, because changes in bonding can alter transient ion charge and thus change the strength of their interaction with the target, because the loss of the energy of electrons in any material depends on the detailed orbital structure and excitation matter [43]. This means that the heavy atoms that have a large atomic number, the correlation of their electrons in their orbits is greater than the light atoms, so their contribution to the loss of energy is less .

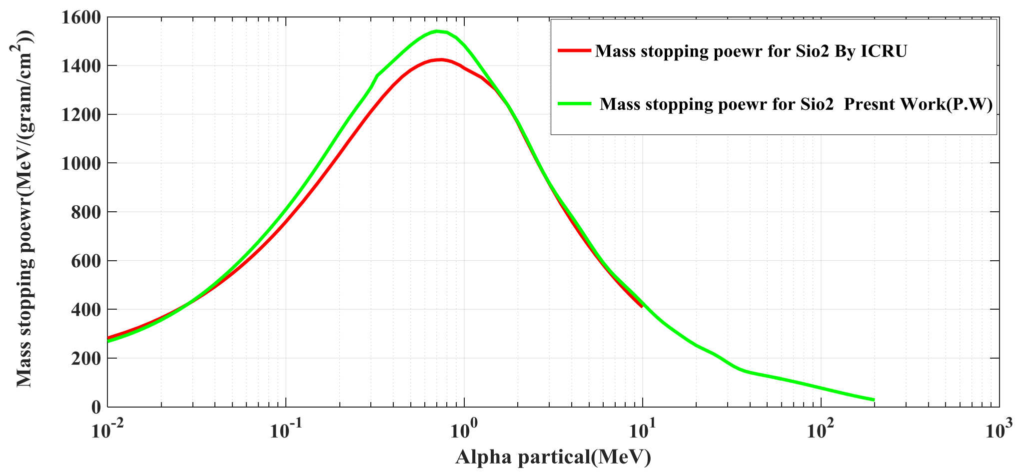


Fig.(4-33) Comparison between values of mass stopping power (P.W.) and ICRU[107] in SiO_2

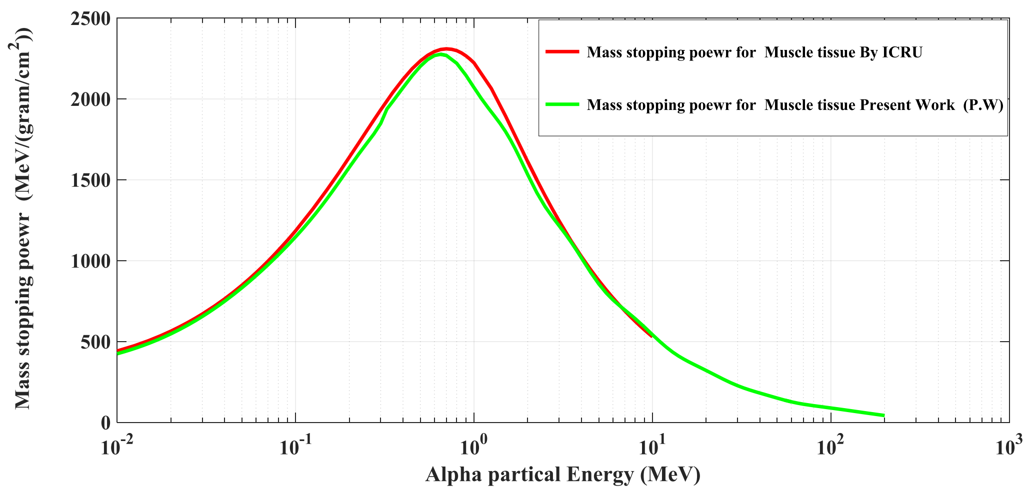
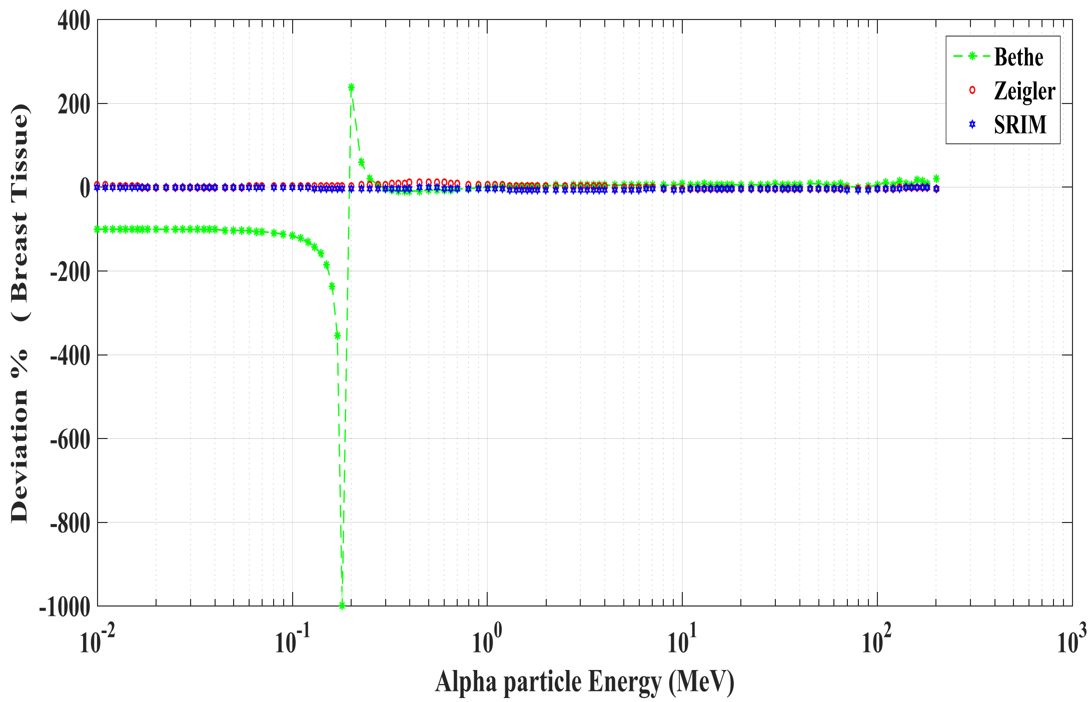


Fig.(4-34) Comparison between values of mass stopping power (P.W.) and ICRU[107] in Muscle tissue

From figures (4-33) and (4-34) note that the values of the mass stopping power are largely consistent with those calculated by ICRU for muscle tissue and SiO_2.

(4.2)Percentage deviation:

The energy behavior of percentage deviation [$\frac{S_{cal}-S_{exp}}{S_{exp}}$]$\times 100$ % between the experimental and the calculated mass stopping power values using (Bethe and Zeigler Formula and SRIM2013, ASTAR program) of the tissues (breast , ovary ,lung and muscle) and materials(, SiO_2, AL_2O_3, ZrO_2) for alpha particles have energy range of (0.01-200) MeV are shown in Figures (4-35) ,(4-36),(4-37),(4-38), (4-39),(4-40) , and (4-41).



Figure(4-35) The percentage deviation of the mass stopping power values calculated using SRIM2013program and Bethe , Zeigler Formula as a function of energy in Breast tissue for alpha particles in the range (0.01-200) MeV

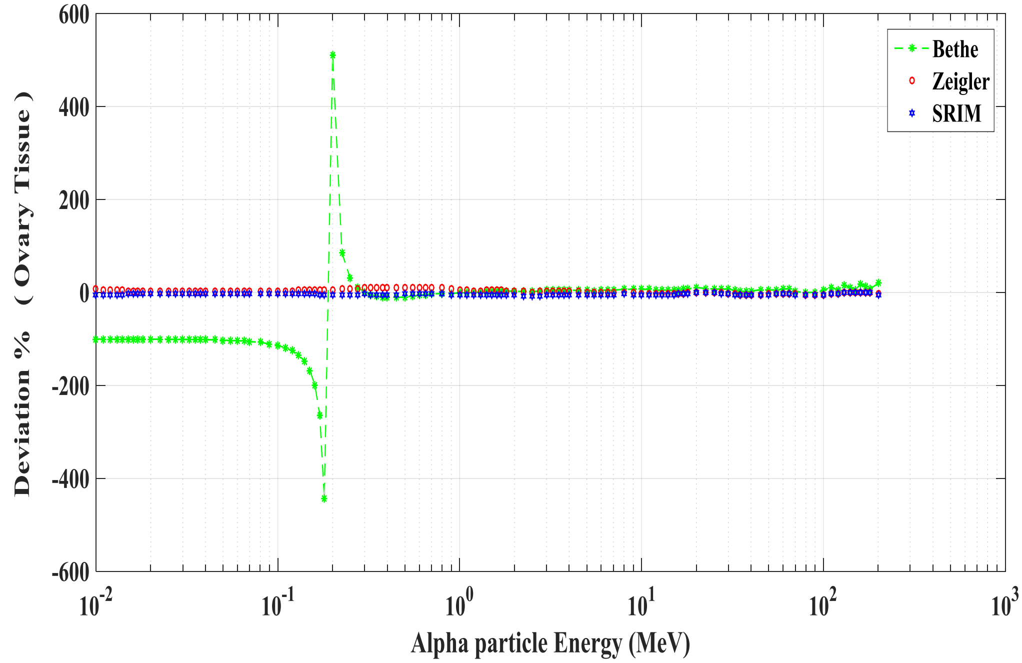
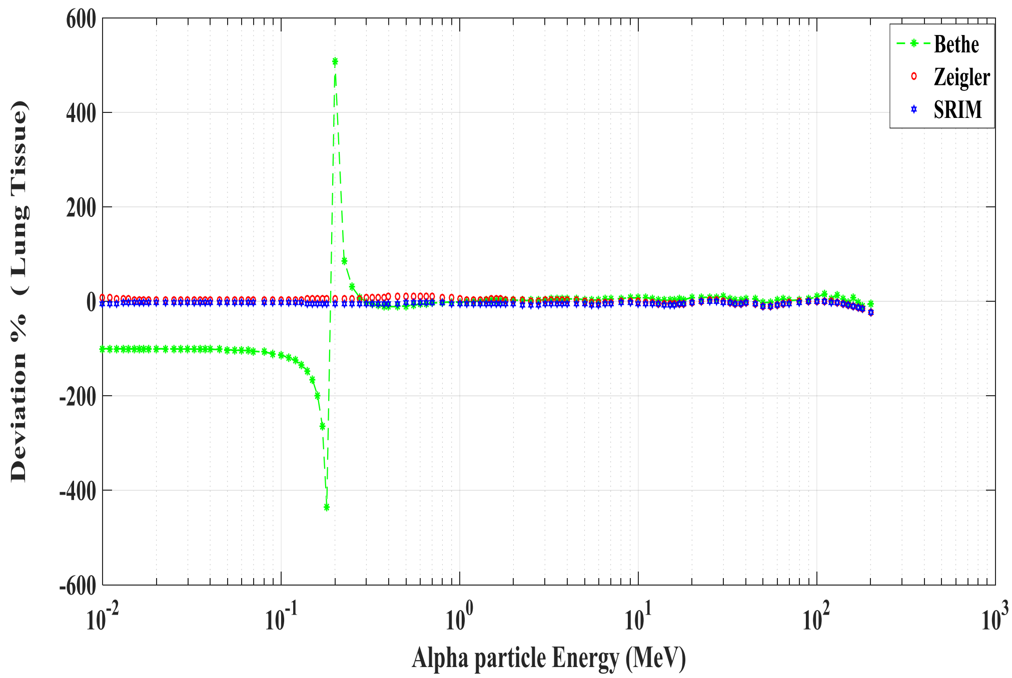
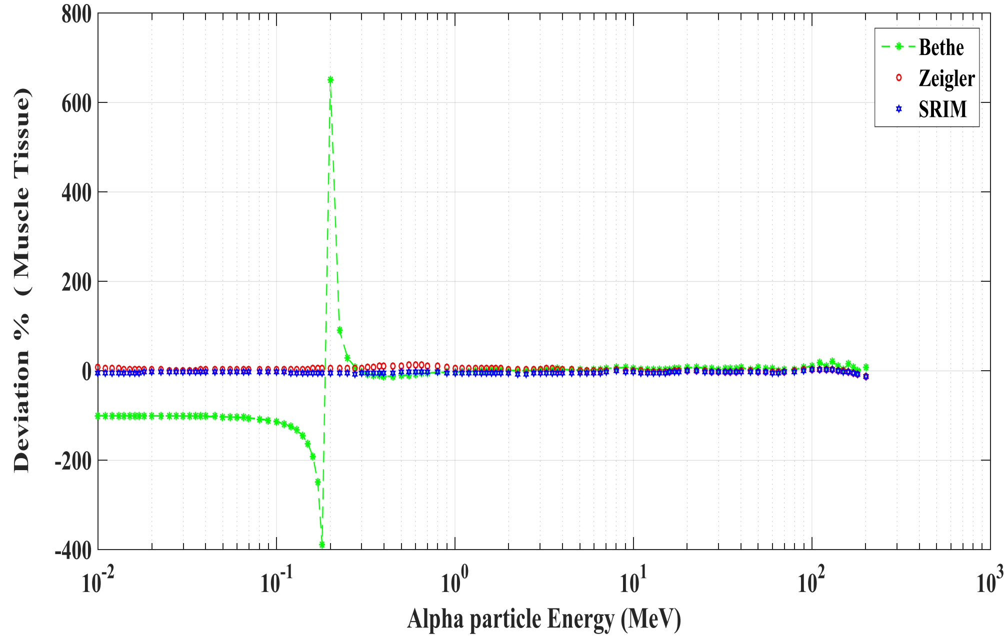


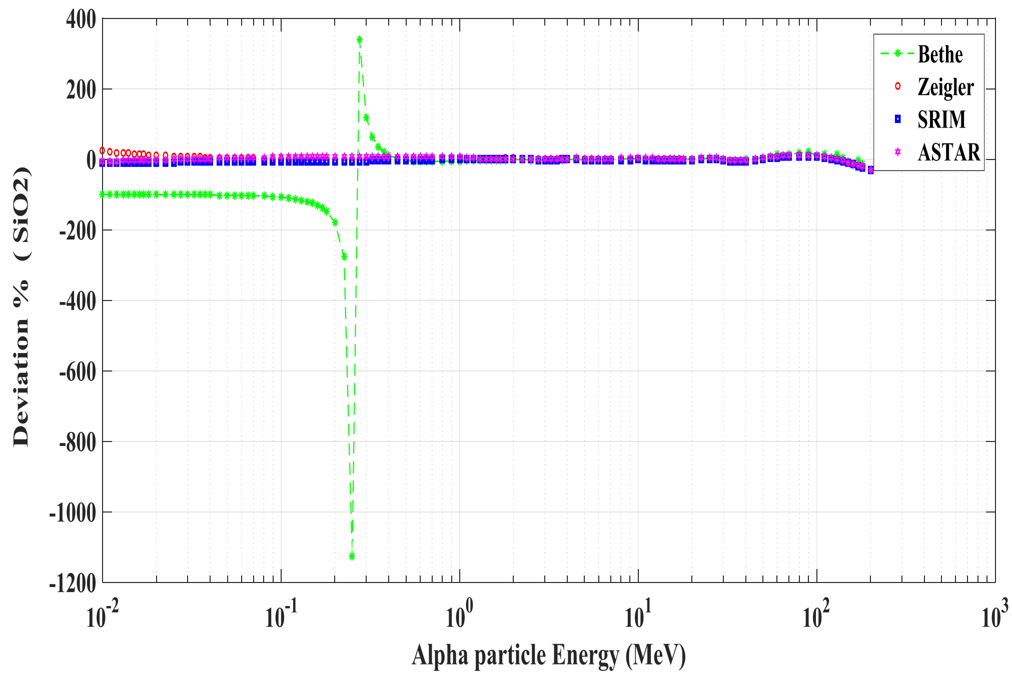
Figure (4-36) The percentage deviation of the mass stopping power values calculated using SRIM2013program and Bethe , Zeigler Formula as a function of energy in Ovary tissue for alpha particles in the range (0.01-200) MeV



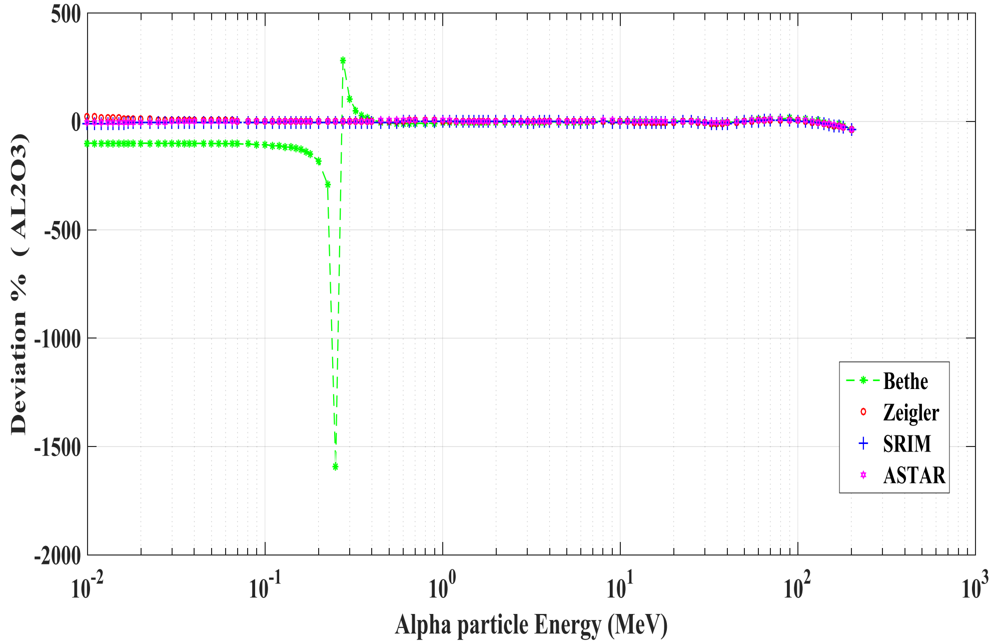
Figure(4-37) The percentage deviation of the mass stopping power values calculated using SRIM2013program and Bethe , Zeigler Formula as a function of energy in Lung tissue for alpha particles in the range (0.01-200) MeV



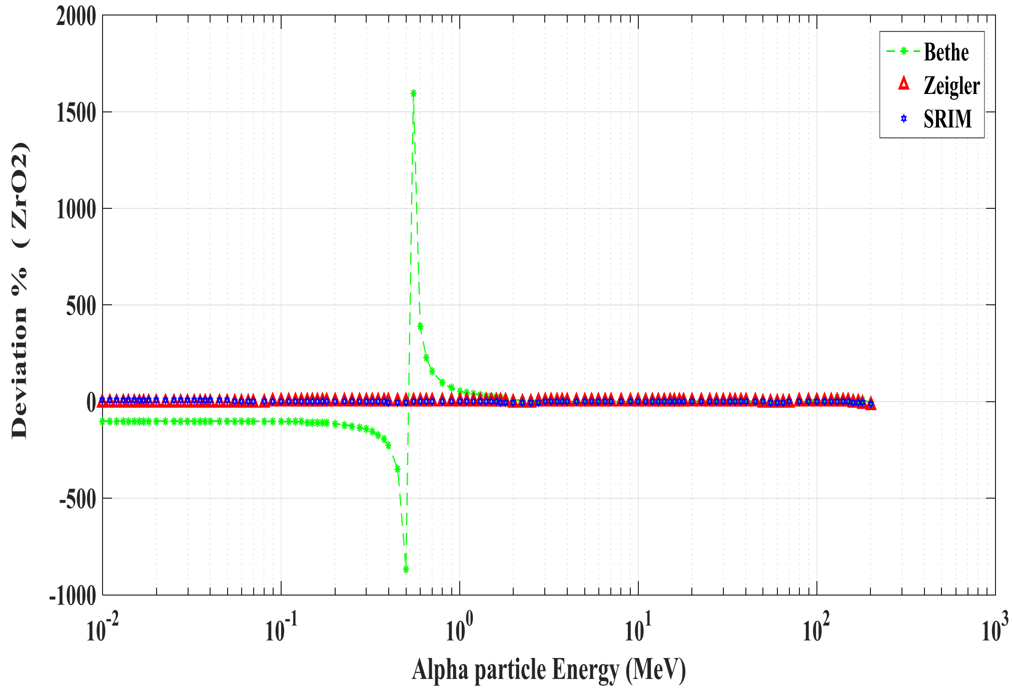
Figure(4-38) The percentage deviation of the mass stopping power values calculated using SRIM2013program and Bethe , Zeigler Formula as a function of energy in Muscle tissue for alpha particles in the range (0.01-200) MeV



Figure(4-39) The percentage deviation of the mass stopping power values calculated using SRIM2013program,ASTAR program and Bethe , Zeigler Formula as a function of energy in SiO_2 for alpha particles in the range (0.01-200) MeV



Figure(4-40) The percentage deviation of the mass stopping power values calculated using SRIM2013program and Bethe , Zeigler Formula as a function of energy in AL_2O_3 for alpha particles in the range(0.01-200) MeV



Figure(4-41) The percentage deviation of the mass stopping power values calculated using SRIM2013program,ASTAR program and Bethe , Zeigler Formula as a function of energy in ZrO_2 for alpha particles in the range (0.01-200) MeV .

The maximum percentage deviation for all methods used are shown in tablen (4-5)

Table (4-5) Maximum of percentage deviation%

Tissue or Material	(Bethe) Error%	E(MeV)	(Ziegler) Error%	E(MeV)	(SRIM2013) Error%	E(MeV)	ASTAR Error%	E(MeV)
Breast Tissue	**236.8200**	**0.2**	**11.9896**	**0.5**	**0.6501**	**0.01**	**-**	**-**
Ovary Tissue	**510.0385**	**0.2**	**11.5444**	**0.6**	**0.1590**	**150**	**-**	**-**
Lung Tissue	**508.5385**	**0.2**	**11.2284**	**0.6**	**0.7656**	**25**	**-**	
Muscle Tissue	**651.1429**	**0.2**	**12.3932**	**0.6**	**2.9835**	**110**	**-**	
SiO_2	**337.8**	**0.275**	**24.2955**	**0.01**	**9.1366**	**80**	**11.9983**	**80**
AL_2O_3	**282.7**	**0.275**	**22.0826**	**0.01**	**5.6954**	**80**	**9.0549**	**80**
ZrO_2	**1596.2**	**0.55**	**2.9739**	**0.325**	**7.1718**	**0.01**	**-**	**-**

It is clearly observed from figures (4-35), (4-36),(4-37), 4-38), (4-39),(4-40) , and (4-41) and table (4-5) the following :

1- Bethe formula:

A- Note that the maximum deviation is recorded when calculating the mass stopping power of the tissues and materials at low energies. This indicates the failure of Bethe equation at low energies. This result is fully consistent with what is stated in the reference [13].

B- There is a number of values for mass stopping power of materials at a very high deviation at low energies .Therefore, it should be neglected even if it is positive because the rate of error is very high.

2- Ziegler formula: Note that the maximum deviation is at low energies so this method is better in calculating the stopping power at high energies.

3- SRIM program : Note that the values of mass stopping power of the alpha particles calculated for tissues and materials by the present work record the least deviation from those calculated in a SRIM program at the same energies.

4- Not any regular trend is observed among the energy behavior and deviation shown by the values predicted by SRIM2013, ASTAR, Bethe and Zeigler formula.

5- It is clear that the Zeigler formula gives much less mass stopping power values as compared with the present work, but SRIM2013 and ASTAR can give much better results as compared to the theoretical Bethe and Zeigler.

(4.3)The Range

The semi-empirical equations were obtained for range of particles in the tissues (breast, ovary, lung and muscle) tissues and materials (SiO_2, AL_2O_3, ZrO_2) are shown in table (4- 6) and (4-7).

Table (4-6) Semi-empirical equations of range for alpha particles in (breast, ovary, lung and muscle) tissues

Tissue	E(MeV)	F(E)	a	b	c	p_1	p_2	p_3	p_4	p_5	p_6	p_7	p_8
Ovary Tissue	$E \le 0.6$	$ax^b + c$	-0.006064	-0.497	0.06225	-	-	-	-	-	-	-	-
	E> 0.6	$p_1E^7 + p_2E^6 + p_3E^5 + p_4E^4 + p_5E^3 + p_6E^2 + p_7E + p_8$	-	-	-	7.898×10^{-16}	-5.889×10^{-13}	1.705×10^{-10}	-2.442×10^{-8}	1.863×10^{-6}	-8.032×10^{-5}	0.003526	0.0546
Breast Tissue	E ≤ 0..55	$ax^b + c$	-0.005996	-0.4775	0.05623	-	-	-	-	-	-	-	-
	E > 0..55	$p_1E^7 + p_2E^6 + p_3E^5 + p_4E^4 + p_5E^3 + p_6E^2 + p_7E + p_8$	-	-	-	7.96×10^{-16}	-5.927×10^{-13}	1.714×10^{-10}	-2.451×10^{-8}	1.866×10^{-6}	-8.012×10^{-5}	0.003494	0.04862
Lung Tissue	$E \le 0.6$	$ax^b + c$	-0.006077	-0.4964	0.0622	-	-	-	-	-	-	-	-
	$E > 0.6$	$p_1E^7 + p_2E^6 + p_3E^5 + p_4E^4 + p_5E^3 + p_6E^2 + p_7E + p_8$	-	-	-	7.95×10^{-16}	-5.923×10^{-13}	1.714×10^{-10}	-2.453×10^{-8}	1.871×10^{-6}	-8.062×10^{-5}	0.003536	0.05454
Muscle Tissue	$E \le 0.65$	$ax^b + c$	-0.006096	-0.4962	0.06234	-	-	-	-	-	-	-	-
	$E > 0.65$	$p_1E^7 + p_2E^6 + p_3E^5 + p_4E^4 + p_5E^3 + p_6E^2 + p_7E + p_8$	-	-	-	7.888×10^{-16}	-5.876×10^{-13}	1.7×10^{-10}	-2.432×10^{-8}	1.854×10^{-6}	-7.989×10^{-5}	0.003505	0.05463

Table (4-7) Semi-empirical equations of range for alpha particles in the materials(SiO_2, AL_2O_3, ZrO_2)

	E(MeV)	F(E)	a	b	c	p_1	p_2	p_3	p_4	p_5	p_6	p_7	p_8
AL_2O_3	$E \le 0.65$	$ax^b + c$	-0.006682	-0.5436	0.08524	-	-	-	-	-	-	-	-
	E> 0.65	$p_1E^7 + p_2E^6 + p_3E^5 + p_4E^4 + p_5E^3 + p_6E^2 + p_7E + p_8$	-	-	-	1.397×10^{-15}	-1.028×10^{-12}	2.957×10^{-10}	-4.238×10^{-8}	3.24×10^{-6}	-0.0001368	0.00508	0.07748
SiO_2	E ≤ 0.65	$ax^b + c$	-0.00635	-0.5643	0.08889	-	-	-	-	-	-	-	-
	E > 0..65	$p_1E^7 + p_2E^6 + p_3E^5 + p_4E^4 + p_5E^3 + p_6E^2 + p_7E + p_8$	-	-	-	1.351×10^{-15}	-9.941×10^{-13}	2.86×10^{-10}	-4.098×10^{-8}	3.133×10^{-6}	-0.0001325	0.004949	0.08103
ZrO_2	$E \le 0.7$	$ax^b + c$	-0.01125	-0.5257	0.1319	-	-	-	-	-	-	-	-
	$E > 0.7$	$p_1E^7 + p_2E^6 + p_3E^5 + p_4E^4 + p_5E^3 + p_6E^2 + p_7E + p_8$	-	-	-	2.138×10^{-15}	-1.569×10^{-12}	4.523×10^{-10}	-6.53×10^{-8}	5.053×10^{-6}	-0.0002154	0.007366	0.1176

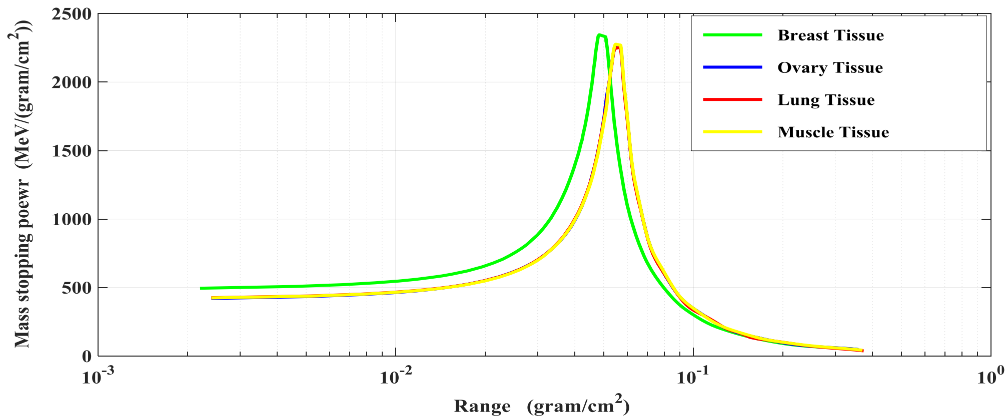


Fig. (4-42) Range as a function mass stopping power (P.W.) in (breast, ovary, lung and muscle) tissues.

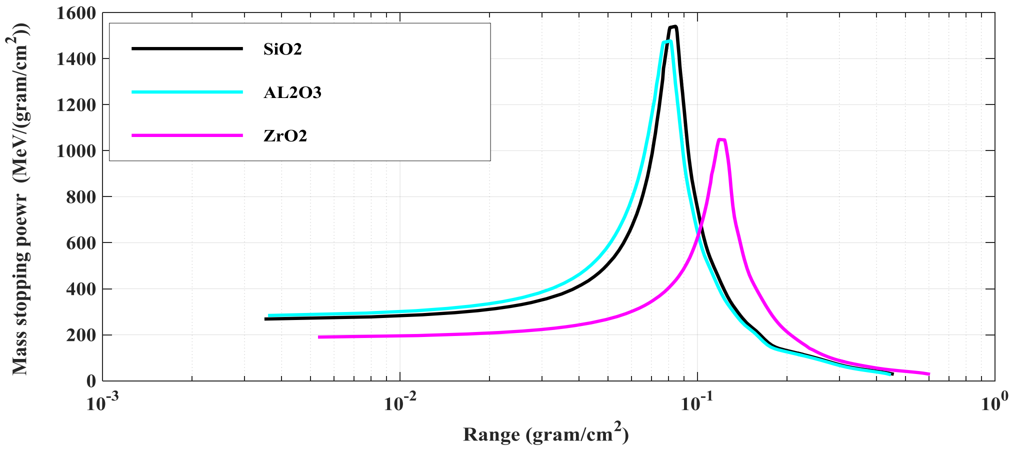


Fig.(4-43) Range as a function mass stopping power (P.W) in materials(SiO_2, AL_2O_3, ZrO_2)

From figures (4-42) and (4-43) we can determine the maximum range of alpha particle can pass into the target and which corresponds to the maximum mass stopping power for (breast, ovary, lung and muscle) tissues and materials (SiO_2, AL_2O_3,ZrO_2) .The results are tabulated in tables(4-8), (4-9)

Table (4-8) The maximum range of alpha particle can pass into the tissues (breast, ovary, lung and Mmuscle)

Tissue	E(MeV)	Maximum of Range($gram/cm^2$)
Breast	**0.55**	**0.0483**
Ovary	**0.65**	**0.0569**
Lung	**0.65**	**0.0568**
Muscle	**0.65**	**0.0548**

Table (4-9) The maximum range of alpha particle can pass into the materials (SiO_2, AL_2O_3, ZrO_2) .

Material	E(MeV)	Maximum of Range($gram/cm^2$)
SiO_2	0.7	0.0844
AL_2O_3	0.7	0.0810
ZrO_2	0.7	0.1183

So it can be able to tell the doctor how much alpha particle energy to use for the treatment and Range it in the tissues(breast, ovary, lung and muscle) and materials (SiO_2, AL_2O_3, ZrO_2) to achieve the best treatment and less damage to tissues surrounding the tumor.

At low energies, the particles have a low speed, so they will stay longer in the target, so the probability of electronic transmission will increase, causing increase of loss of their energies. The slower particle spends a longer time in an atom; therefore its range will be short.

At high energies, particles have a high speed so their stay time in the target will be small therefore its range will be longer.

A heavy charged particle, such as an alpha particle, has a fairly definite range in a gas, liquid. The particle loses energy primarily by the excitation and ionization of atoms in its path; it loses all its kinetic energy and comes to rest. The distance traversed is called the Range, and depends on the energy of the alpha particle. This effect can be observed in the ionization along the path of a single alpha particle; the number of ions produced per unit distance is small at the beginning of the path, rises to a maximum near the end of the path, and then falls sharply to zero when the alpha particle becomes too slow for any further ionization (the end point of the range). A plot of the specific ionization (number of ions formed per unit distance of beam path) versus distance from the alpha particle source for a beam of alpha particles is called a Bragg curve. Figures (4-42), (4-43) shows this.

- The values of the range of alpha particles in tissues are converged
- The values of the range of alpha particles in SiO_2 and AL_2O_3 are converged
- The values of the range of alpha particles in ZrO_2 are more than its range in $SiO_2$and AL_2O_3. Due to the effect of the effective atomic number of the material and the nature of the material.

(4.4)The thickness of the absorbent target

From figures (4-44) and (4-45) we can determine the maximum thickness of the target that the alpha particle can penetrate and which corresponds to the maximum mass stopping power and maximum range for (breast, ovary, lung and muscle) tissues and materials (SiO_2, AL_2O_3 , ZrO_2) .The results are tabulated in table (4-10) and (4-11).

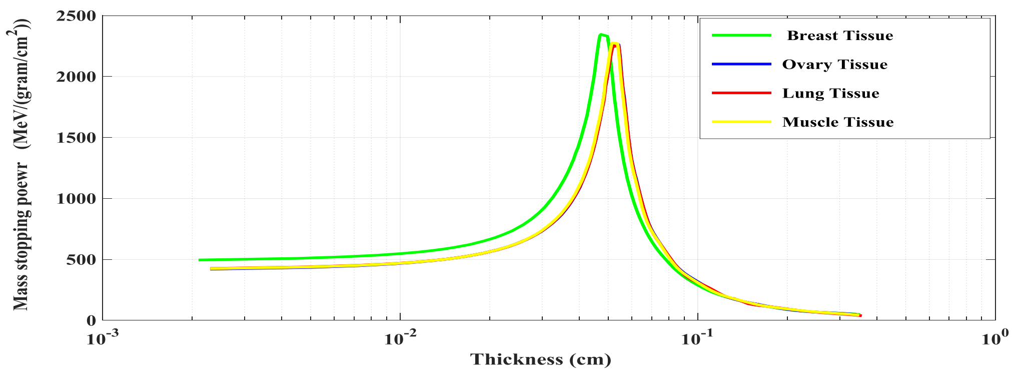


Fig.(4-44) Thickness of target as a function mass stopping power (P.W.) in (breast, ovary,lung and muscle) tissues

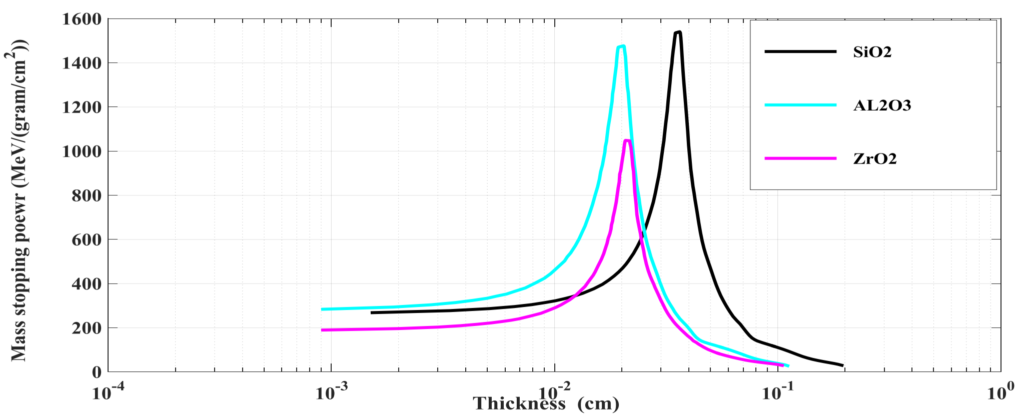


Fig.(4-45) Thickness of target as a function mass stopping power (P.W.) materials(SiO_2, AL_2O_3,ZrO_2)

Table (4-10) Maximum thickness of the target that the alpha particle can penetrate into (Breast, Ovary, Lung and Muscle) tissues

Tissue	E(MeV)	maximum thickness of the target that the alpha particle can penetrate (cm)
Breast	**0.55**	**0.0473**
Ovary	**0.65**	**0.0542**
Lung	**0.65**	**0.0541**
Muscle	**0.65**	**0.0517**

Table (4-11) Maximum thickness of the target that the alpha particle can penetrate into materials (SiO_2, $AL_2O_3ZrO_2$)

Material	E(MeV)	Maximum thickness of the target that the alpha particle can penetrate(cm)
SiO_2	**0.7**	**0.0364**
AL_2O_3	**0.7**	**0.0204**
ZrO_2	**0.7**	**0.0208**

From the tables(4-10),(4-11) it is calculated that the alpha particle energy that must be used for the treatment and maximum thickness of the (breast , ovary, lung and muscular) tissues and materials (SiO_2, AL_2O_3, ZrO_2) ,that the alpha particle can penetrate to achieve the best treatment and less damage to tissues surrounding the tumor.

a. At low energies : the target thickness of which the alpha particle can penetrate increases as its energy increases, but the amount of increase is small.
b. At high energies : the target thickness of which the alpha particle can penetrate increases as its energy increases, but the amount of increase is larger.
c. The target thickness of which the alpha particle can penetrate it at low energy is less than it can penetrate thickness at high energy.
d. The values of the thickness of tissues that the alpha particle can penetrate are converged.
e. From figures (4-42)and (4-44) note that the range of alpha particles in tissues is roughly equal to their penetration thickness
f. From figures (4-43),(4-45) note that the range of alpha particles in materials are more than its absorbent thickness in tissues at same energy.

g. The thickness of the silicon dioxide, which can be penetrated by alpha particle, is greater than the thickness of aluminum dioxide and zirconium dioxide at same energies.

The reasons for the points above:-

- The depth of penetration being dependent on the nature of irradiated material and the incident energy of particles [6,7] .
- A penetration of the particle in the target with low density is more than its penetration for the target with higher density
- As a result of multiple scattering of heavy atoms it becomes a particle path and wiggly instead of straight.
- The range of particles is not the same the penetration of particles where the depth of penetration is the largest distance between the surface of matter and particles as it travels inside the material. The depth of the penetration depends on the shape of the particle's path and is always smaller than range of particle. The interaction of the atoms of the material is of random nature so, the different particles deviate differently , so that their depths of penetration are different even if those particles are identical and have equal initial energies .However, their ranges in materials are very similar (practically equal to each other). The difference is almost equal to each other between the range and depth of penetration is particularly evident in the case of electrons, because of their irregular paths. By contrast, the range of heavy charged particles is practically equal to the depth of their penetration because heavy charged particles travel in straight lines [90]

(4.5) Liner energy transfer

The maximum liner energy transfer for alpha particle that can be lost along its path in (breast , ovary ,lung and muscle) tissues and materials (SiO_2, $AL_2O_3ZrO_2$) were tabulated in tables (4-12) and (4-13) which corresponds to the maximum mass stopping power and maximum range and maximum penetrate thickness.

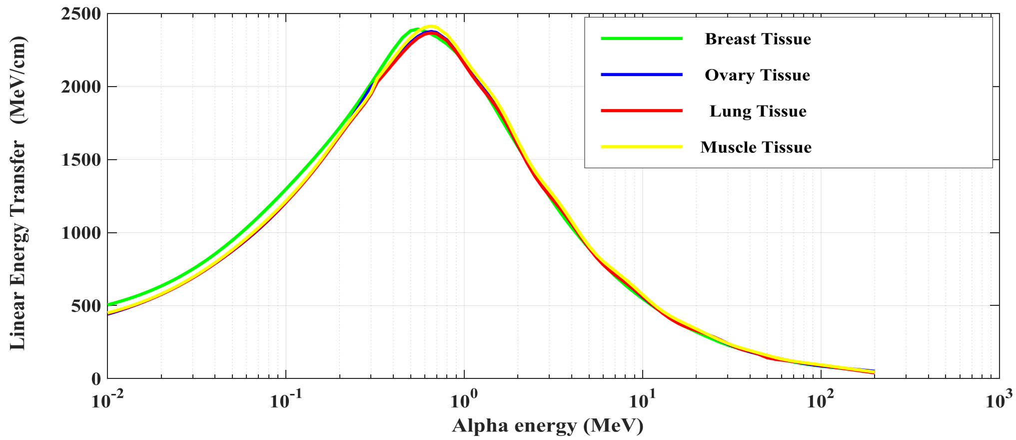


Fig. (4-46) Linear energy transfer as a function to alpha particle energy for in (breast , ovary , lung and muscle) tissues

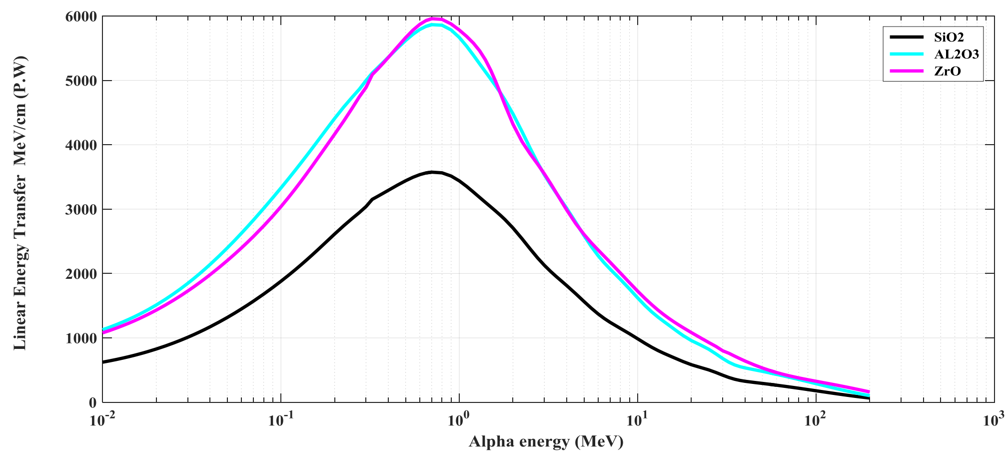


Fig.(4-47) Linear energy transfer as a function to alpha particle energy for materials (SiO_2, $AL_2O_3ZrO_2$)

Table (4- 12) The maximum liner energy transfer for alpha particle that can loss along its path in (breast, ovary, lung and muscle) tissues

Tissue	E(MeV)	Maximum Liner Energy Transfer the alpha particle that can loss along its path in target (MeV/cm)
Breast	0.55	2.3925×10^3
Ovary	0.65	2.3749×10^3
Lung	0.65	2.3665×10^3
Muscle	0.65	2.4128×10^3

Table (4-13) The maximum liner energy transfer for alpha particle that can loss along its path in materials(SiO_2, AL_2O_3, ZrO_2)

Material	E(MeV)	Maximum Liner Energy Transfer the alpha particle that can loss along its path in target (MeV/cm)
SiO_2	0.7	3.5744×10^3
AL_2O_3	0.7	5.8649×0^3
ZrO_2	0.7	5.9578×10^3

LET will help doctor predict the penetration depth and the energy dissipation in an absorber body, which is critical information in radiation therapy, and dosimeter.

It is clear from figures (4-46) and (4-47)

- At low energies: linear energy transfer values increases with increased energy for alpha particle in tissues and materials.

- At high energies: linear energy transfer values decrease with increased energy for alpha particle in tissues and materials.

While mean mass stopping power refers to the energy lost by the particles beam traversing the surrounding media, linear energy transfer (LET) refers to the energy absorbed by the media per unit of distance travelled by the ionizing radiation [106].

-The values of linear energy transfer (LET) in tissues are converged

-The values of linear energy transfer (LET) in ZrO_2 and AL_2O_2 are converged

-The energy absorbed by the media per unit of distance (LET) of SiO_2 are less than the energy absorbed by the media per unit of distance (LET) of ZrO_2 and AL_2O_3 .

Because $-dE/dx$ is directly proportional to density of material ,and this quantity, is called the stopping power of the medium for the particle **[** 75**].**

(4.6)The Absorbed doses:

The maximum absorbed doses which corresponds to the maximum mass stopping power of alpha particle and the maximum range of alpha particle can pass into the target and the maximum thickness of the target that the alpha particle can penetrate for (breast

,ovary, lung and muscle) tissues and materials (SiO_2, AL_2O_3, ZrO_2) are tabulated in tables (4-14),(4-15).

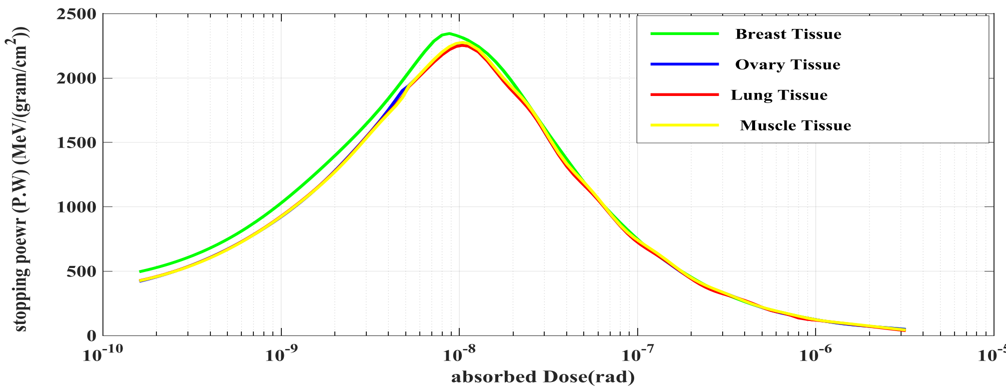


Fig. (4-48) Maximum Absorbed Doses for (breast , ovary ,lung and muscle) tissues

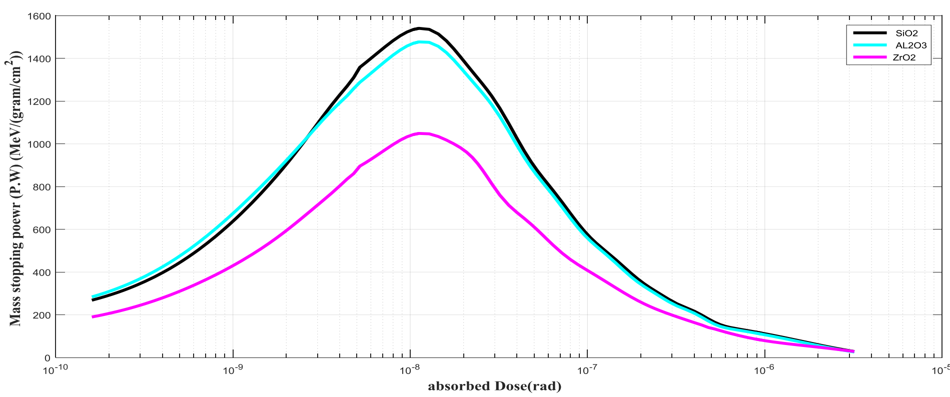


Fig. (4-49) Maximum absorbed doses for materials (SiO_2, AL_2O_3, ZrO_2)

Table (4-14) The maximum of absorbed doses for (breast, ovary, lung and muscle) tissues

Tissue	E(MeV)	The maximum Absorbed Doses(rad)
Breast	0.55	0.88×10^{-8}
Ovary	0.65	1.04×10^{-8}
Lung	0.65	1.04×10^{-8}
Muscle	0.65	1.04×10^{-8}

Table (4-15) The maximum of absorbed doses for materials(SiO_2, AL_2O_3, ZrO_2)

Material	E(MeV)	The maximum Absorbed Doses(rad)
SiO_2	0.7	1.12×10^{-8}
AL_2O_3	0.7	1.12×10^{-8}
ZrO_2	0.7	1.12×10^{-8}

We can state that how much alpha energy to be used for the treatment in(breast ,ovary , lung and muscle) tissues and materials(SiO_2, AL_2O_3, ZrO_2) and the maximum Dose to be given to the patient, in order to achieve the best treatment and less damage to tissues surrounding the tumor.

(4.7) The equivalent dose

Maximum equivalent dose were calculated by eq.(2-50) . The results are tabulated in table (4-16)

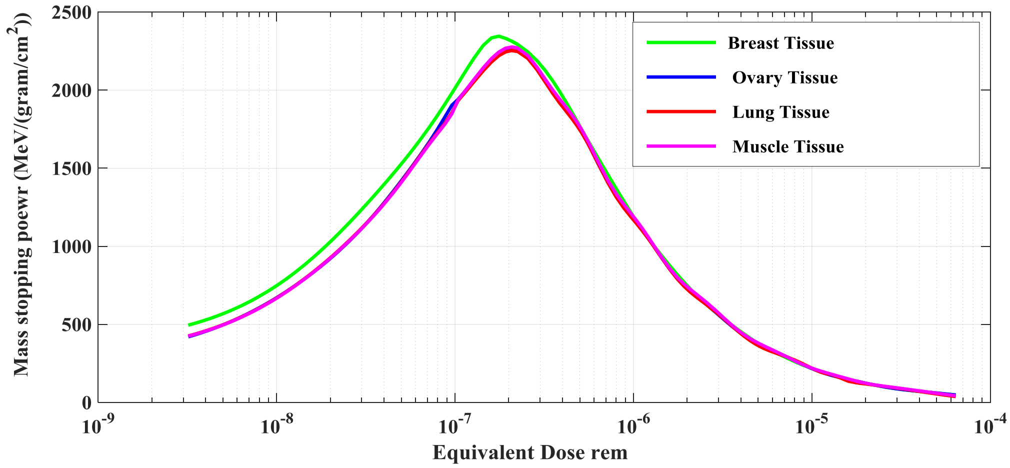


Fig.(4-50) The Maximum of equivalent dose for (breast , ovary , lung , muscle) tissues

Table(4-16) The Maximum of equivalent dose **for (breast, ovary, lung, muscle) tissues**

Tissue	E(MeV)	Maximum of Equivalent Dose(rem)
Breast	**0.55**	$\mathbf{17.6 \times 10^{-8}}$
Ovary	**0.65**	$\mathbf{20.8 \times 10^{-8}}$
Lung	**0.65**	$\mathbf{20.8 \times 10^{-8}}$
Muscle	**0.65**	$\mathbf{20.8 \times 10^{-8}}$

(4.8) Effective dose

Maximum effective dose were calculated by eq.(2-51). The results tabulated in table (4-17).

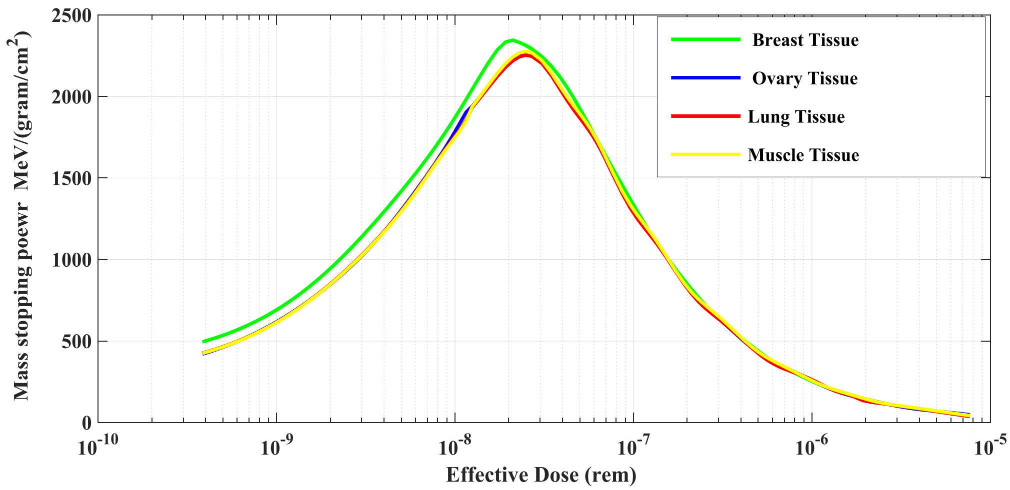


Fig.(4-51) The Maximum of effective dose for **(breast, ovary, lung,muscle) tissues**

Table (4-17) The Maximum of effective dose **for (breast, ovary, lung,muscle) tissues**

Tissue	E(MeV)	Maximum of Effective Dose(rem)
Breast	**0.55**	$\mathbf{2.112 \times 10^{-8}}$
Ovary	**0.65**	$\mathbf{2.4960 \times 10^{-8}}$
Lung	**0.65**	$\mathbf{2.4960 \times 10^{-8}}$
Muscle	**0.65**	$\mathbf{2.4960 \times 10^{-8}}$

(4.9) Conclusion

From this study we conclude that :

1. The failure of Bethe equation when calculating the mass stopping power of the tissues at low energies.
2. The Zeigler formula give much less mass stopping power values as compared with the present work, but SRIM2013 and ASTAR can give much better results as compared to the theoretical Bethe and Zeigler.
3. A slow (low energy) alpha particle loses more energy by ionizing atoms than a fast (high energy) alpha particle, since the slower particle spends a longer time in an atom, and thus there is a greater probability that an electronic transition will occur in the atom.
4. Bragg curve: the number of ions produced per unit distance is small at the beginning of the path, rises to a maximum near the end of the path, and then falls sharply to zero when the alpha particle becomes too slow for any further ionization (the end point of the range). A plot of the specific ionization (number of ions formed per unit distance of beam path) versus distance from the alpha particle source for a beam of alpha particles is called a Bragg curve. Figures (4-42), (4-43),(4-44), and (4-45) show this relation .
5. The magnitude of the range of alpha particle depends on the effective atomic number of the target material and its nature.
6. At higher alpha energy , its penetration depth in agiven substance will be greater because the columbic interaction of these particle with electrons of the absorber will be more in order to disipate its energy before coming to rest.
7. A penetration of the particle in the target with low density more than its penetration for the target with high density.
8. The range of alpha particles in materials are more than its absorbent thickness at same energy, this indicates deviation of alpha from its straight path as a result of multiple scattering of heavy atoms it becomes a particle path and wiggly instead of straight.
9. The linear energy transfer represents the amount of target resistance against the fallen mass, therefore it is proportional to the density of the target material.

10. The values of the mass stopping power we obtained in the current research were in good agreement with ICRU for muscle tissue and SiO_2. Table (4-18) and (4-19) shows conclosion of all these results .

Table (4-18) Summary of search results

Tissue or material	Energy (MeV)	Maximum Mass stopping power for alpha particle ($\frac{MeV}{\frac{gram}{cm^2}}$) $\times 10^3$	Maximum Range for alpha particle $gram/cm^2$	Maximum thickness of the target that is alpha particle can penetrate (cm)	Maximum value of the linear energy transfer for alpha particle (MeV/cm)$\times 10^3$	Maximum absorbed dose(rad) $\times 10^{-8}$	Maximum equivalent dose(rem) $\times 10^{-8}$	Maximum effective dose(rem)$\times 10^{-8}$
Breast	0.55	2.3456	0.0483	0.0473	2.3925	0.88	17.6	2.112
Ovary	0.65	2.2618	0.0569	0.0542	2.3749	1.04	20.8	2.4960
Lung	0.65	2.2538	0.0568	0.0541	2.3665	1.04	20.8	2.4960
Muscle	0.65	2.2764	0.0548	0.0517	2.4128	1.04	20.8	2.4960
SiO_2	0.7	1.5407	0.0844	0.0364	3.5744	1.12	-	-
AL_2O_3	0.7	1.4773	0.0810	0.0204	5.6498	1.12	-	-
ZrO_2	0.7	1.0489	0.1183	0.0208	5.9578	1.12	-	-

Table (4-19) Beaver of alpha particle at high and low energies

	At low energies	**At high energies**
Mass stopping power	Increases with the increase of its energy. The particles that have low speed will stay longer in the target, so the probability of electronic transmission will increase, causing increase of loss of their energies.	Decreases with the increaseof its energy. The particles that have high speed will stay shorter in the target, so the probability of electronic transmission will decrease, causing decrease of loss of their energies.
Range of alpha particle	Increases with the increase of its energy The slower particle spends a longer time in an atom; therefore its range will be short. The ranges of heavy ions in materials are very similar (practically equal to each other).	Increases with the increase of its energy Particles have a high speed so their stay time in the target will be small therefore its range will be longer. • The ranges of heavy ions in materials are very similar (practically equal to each other). • The range of alpha particle depends on its energy.
Thickness	Increases as its energy increases, but the amount of increase is small This is due to the fact that the low particle energy leads to a decrease in its velocity and thus an increase in the number of reactions and thus the loss of all energy at the lowest thickness	increases as its energy increases, but the amount of increase is larger This is due to the fact that the high particle energy leads to an increase in its velocity and thus a decrease in the number of reactions and thus the loss of all energy at the longer thickness
Linear energy transfer (LET)	increase with the increase of its energy Linear energy transfer (LET) refers to the energy absorbed by the media per unit of distance travelled by the ionizing radiation. The higher the particle's loss of energy, the greater the absorption of the target atoms of this energy.	decrease with the increase of its energy Linear energy transfer (LET) refers to the energy absorbed by the media per unit of distance travelled by the ionizing radiation. The lower the particle's loss of energy, the lower the absorption of the target atoms of this energy.

(4-10) Recommendations and future works:

In this study we provided the doctor with important information to achieve the best treatment for the affected area and less damage to the neighboring area. In order to develop this study, the following studies were proposed:-

1- Comparison between the mass stopping powers of light and heavy ions for the same materials.

2- Comparison between of the ranges of light and heavy particles in different materials.

3- The effect of atomic number affecting different materials.
4- Study of mass stopping power and range for alpha particle in other human tissues.
5- Study the stopping power and range ,and polarization in plasma by circularmotion of charged particles.

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الخلاصة

تؤكد التطورات الحديثة قدرة جسيمات ألفا على توليد الإشعاع بطريقة موضعية شديدة السمية بسبب تأينها العالي ومداها القصير. ولذلك، فإن مقدار فقدان طاقة التأين لجسيمات الفا ومداها داخل الأنسجة البشرية, وسماكة الأنسجة ومقدارالطاقة الخطيةالمنتقلة ، فضلا عن كمية جرعة الإشعاع والجرعة المكافئة والفعالة يجب أن تحدد بدقة للسيطرة على قتل الخلايا السرطانية .

في هذه الدراسة، تم دراسة تفاعلات جسيمات ألفا مع المادة وحساب قدرة ايقاف جسيمات ألفا في أربعة أنسجة بشرية وهي (الثدي والمبيض والرئة والعضلات) وثلاثة مواد (ثاني أكسيد السيليكون (SiO_2) وثاني أكسيد الألومنيوم(AL_2O_3) وثاني أكسيد الزركونيوم(ZrO_2)) باستخدام أربع طرق (معادلة بيث بلوخ(Beth-Bloch equation) ، صيغة زيكلر(Zeigler formula) , برنامج SRIM2013، وبرنامج ASTAR) وكذلك تم حساب مدى جسيمات الفا في تلك الانسجة والمواد و مقدار تحول الطاقة الخطيةالمنتقلة و سمك هذه الأنسجة والمواد.بالاضافة الى حساب مقدار الجرعة والجرعة المكافئة و الجرعة الفعالة لهذا الجسيم , حيث تم حسابها باستخدام لغة الماتلاب ضمن مدى طاقي MeV(0.01 to 200).

تم التوصل الى صيغتين شبة تجريبيتين ،احداهما لحساب قدرة ايقاف جسيمات ألفا والاخرى لحساب مداها في هذه الأنسجة والمواد عن طريق معرفة طاقتها .

من النتائج الهامة التي تم الحصول عليها في دراستنا هو منحني براك ،الذي يمكن من خلاله حساب اعلى قيمة للطاقة المفقودة عند مقدار محدد من طاقة الجسيم والذي يمكن من خلاله معرفة سمك المادة الذي يقابله وبذلك يمكننا اعطاء جدول للمعالج بهذه القيم .

تم مقارنة نتائج قدرة الايقاف الكتلية المحسوبة للنسيج العضلي وثاني أكسيد السيليكون(SiO_2) مع ICRU-49 فوجدنا انها كانت متفقة الى حد كبير معها.

جمهورية العراق

وزارة التعليم العالي والبحث العلمي

جامعة بغداد

كلية التربية للعلوم الصرفة / ابن الهيثم

حساب قدرة الايقاف والمدى لجسيمات الفا في بعض المواد والانسجة

اطروحة مقدمة

الى كلية التربية – ابن الهيثم – جامعة بغداد كجزء من متطلبات نيل درجة دكتوراه فلسفة في علوم الفيزياء

من قبل

تغريد عبد الجبار يونس الربيعي

بكلوريوس في الفيزياء , كلية التربية للعلوم الصرفة/ ابن الهيثم

جامعة بغداد 1998

ماجستير في علوم الفيزياء , كلية التربية للعلوم الصرفة / ابن الهيثم

جامعة بغداد 2006

بأشراف

أ.د. بشائر محمد سعيد

1439 هجرية **2018 م**

جامعة بغداد

وقل رب زدني علما

1957 ١٣٧٨