International Journal of Scientific Engineering and Applied Science (IJSEAS) – Volume-6, Issue-10, October 2020
ISSN: 2395-3470
www.ijseas.com

Mass Stopping Power and range of Alpha particles in Adipose Tissue(ICRU-44)

By

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Abstract

In this work we present a simple relation for mass stopping power (in MeVcm^2/g) and range (in g/cm^2) of alpha particles in energy range 10-100MeV in Adipose tissue and its compositions (H, C, N, O, Na, S, Cl). The proposed relations have been described in terms of alpha particle energy only.

Keyword: Mass stopping power, Range, Alpha particle energy, Adipose Tissue.

1- Introduction

The stopping power and energy dissipation of charged particles through matter has been a subject of great interest for 100 years [1,2,3] because of its wide area of applications, such as ion implantation, fundamental particle physics, nuclear physics, radiation damage, radiology [2,3]. Heavy charged particles passing through matter lose energy primarily through ionization and excitation of atom [4].

Mass Stopping Power is defined as the amount of energy that a particle loses in every unit of length from its path through the materials divided

by the density of the materials. Therefore, the process of energy loss of the charged particle passing through the target material must be very accurate through direct practical measurement or through theoretical calculation and study The property of the target material and how it responds to the interaction with the charged particles. The charged particle when it travels through the material is that its interaction with the target atoms is caused by electrostatic forces between the charged particles and that reaction is divided into two elastic collisions with all the atoms and inelastic collisions with the target material electrons. As we Know that the electron Cloud occupies more space than the nuclei of atoms, so the loss of energy caused by the non-elastic collisions are expected to be greater than the loss of energy by elastic collisions.

In this paper, the mass stopping powers of alpha particles and range in adipose tissue are calculated using Bethe- Bloch formula in alpha particle energy range 10-100MeV [5,6]. The mass stopping power and range of alpha particles in composition of adipose tissue (H,C,N,O,Na,S,Cl) are calculated by ASTAR code [2].

2. Theory and Calculation Method:

The following Bethe-Bloch stopping power equation [5,6] has been used for energy range 10-100MeV:

$$-\frac{dE}{dx} = \frac{5.08 \times 10^{-31} z^2 n}{\beta^2}[F(\beta) - ln(I)] \qquad (1)$$

Where β is V/c where v is the alpha particle velocity and c is light velocity, z is atomic number of alpha particle, I is the excitation energy of the materials and F(β) is given by

$$F(\beta) = ln\frac{1.02\times10^{6}\beta^{2}}{1-\beta^{2}} - \beta^{2}$$

n is electron density and is calculated using the following relation:

$$n = \frac{N_a \rho Z}{A} \qquad (2)$$

Where N_a Avogadro number, ρ is the density of substances and $\frac{Z}{A}$ is the ratio of atomic number to the mass number of substances.

The basic data for adipose tissue are given in Table(1) and the compositions of Adipose tissue is given in Table(2).

The equations for calculated mass stopping power for adipose is given by equation (3) based on Bethe-Bloch equations after substituting the constants from Table (1)

$$-\frac{dE}{\rho dx} = \frac{0.680}{\beta^{2}}[F(\beta) - 4.17] \qquad (3)$$

The mass stopping powers of alpha particles in other compositions of adipose tissue are calculated using ASTAR code [2] .

The range of alpha particles in adipose tissue is calculated by the following relation

$$R = \int \frac{dE}{\frac{dE}{\rho dx}} \qquad (4)$$

3. Results

The results for mass stopping powers for the present work with other data available in ASTAR code are given in Table (3). We have plotted graphs between available mass stopping powers versus alpha particle energy. We observed that the mass stopping powers are decreasing with increasing alpha particle energy which are presented in fig(1). Using the fitted graph of adipose tissue we have been able to find a simple empirical relation for mass stopping power of alpha particles in energy range 10-100MeV by the following relation:

$$Y = a\,X^{b} \qquad (5)$$

Where Y is the mass stopping power in MeVcm^2/g, X is the alpha particles energy in MeV, **a = 3746.1 and b =-0.818**

The equation for calculating range of alpha particles in adipose tissue is given by

$$\mathbf{R = a\,x^{b}} \qquad (6)$$

Where R is the range in g/cm^2, X is the alpha particles energy in MeV, **a =1.47× 10^{-4} and b =1.818**

Comparison between mass stopping powers and ranges calculated in the present work with that calculated by ASTAR code is given in Tale(4).

Fig(2) shows the stopping powers of alpha particles in Adipose tissue and that of its compositions. The range of alpha particles in Adipose tissue calculated in present work with that calculated by ASTAR code are shown in Fig(3).

Table (1): Basic Data for calculating mass stopping powers

Substances	Density(ρ) g/cm^3	$\langle Z/A \rangle$	N (Electrons/m^3)	I(eV)
Adipose Tissue (ICRU-44)	0.95	0.55579	3.18×10^{29}	64.8

Table(2): Compositions of Adipose Tissue (ICRU-44)

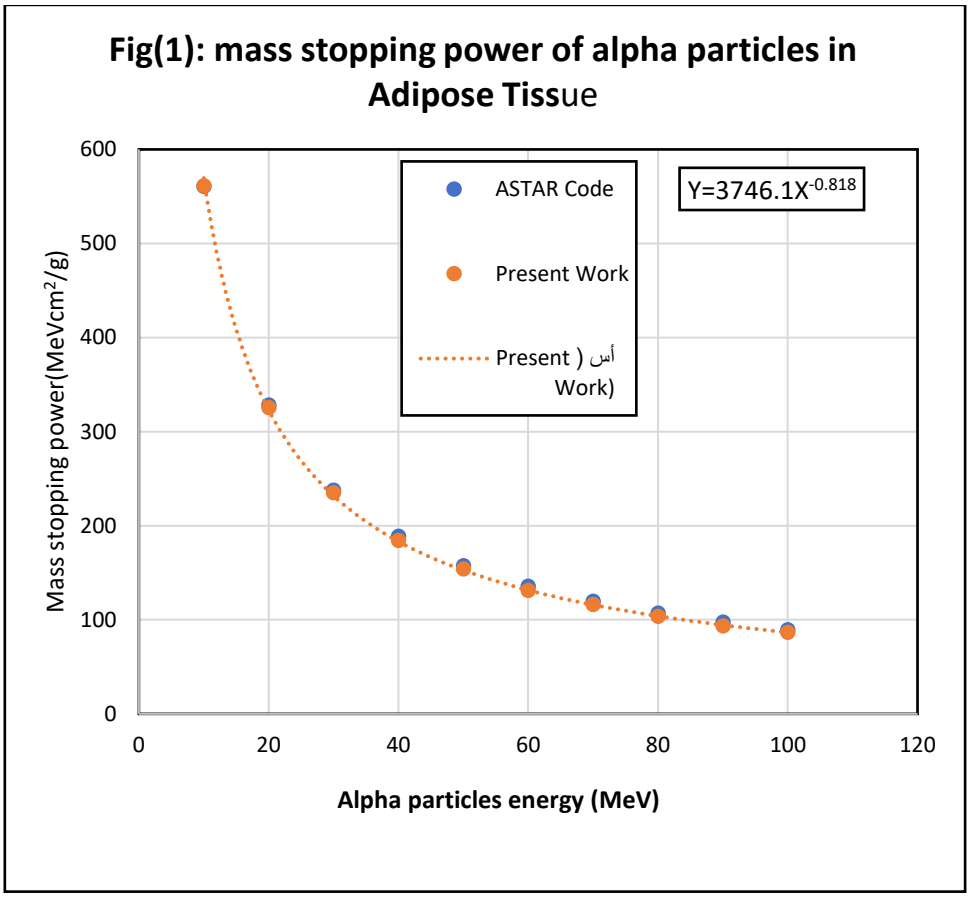
Substance	Composition Z fraction by weight
H	0.114000
C	0.598000
N	0.007000
O	0.278000
Na	0.001000
S	0.001000
Cl	0.001000

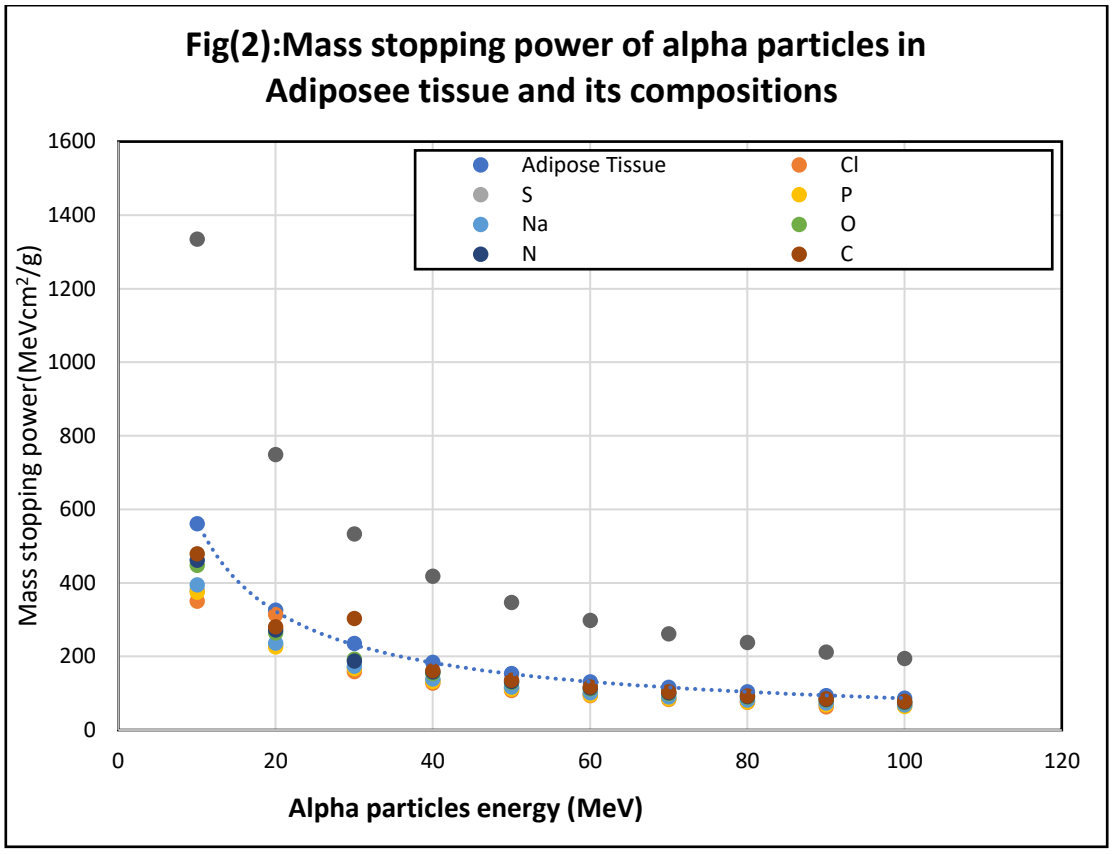
Table(3); mass stopping power of alpha particles in Adipose Tissue (ICRU-44) **and its compositions**

Alpha particle energy (MeV)	Mass Stopping Power ($MeVcm^2/g$)								
	H	C	N	O	Na	P	S	Cl	Adipose Tissue (ICRU-44)
10	1335	478.6	461.8	447.3	394.6	374.1	380.2	350.1	561.19
20	749.2	280.1	271.7	264.4	236.2	225.8	229.9	314.0	325.38
30	532.8	303.3	187.6	192.8	173.2	166.2	169.4	158.4	235.03
40	418.3	161.6	157.4	153.8	138.7	131.6	134.3	127.5	184.07
50	346.7	135.3	131.9	128.9	116.6	110.9	113.2	107.6	153.82
60	297.6	116.9	114.1	111.6	101.1	95.0	97.1	93.7	130.96
70	261.5	103.4	100.9	98.9	89.7	84.5	86.	83.2	116.00
80	237.9	92.9	90.8	88.9	80.8	75.9	77.50	75.1	103.67
90	212.0	84.6	82.7	81.0	73.7	68.5	70.0	63.3	93.29
100	194.7	77.7	76.0	74.5	67.9	63.69	65.1	68.6	86.51

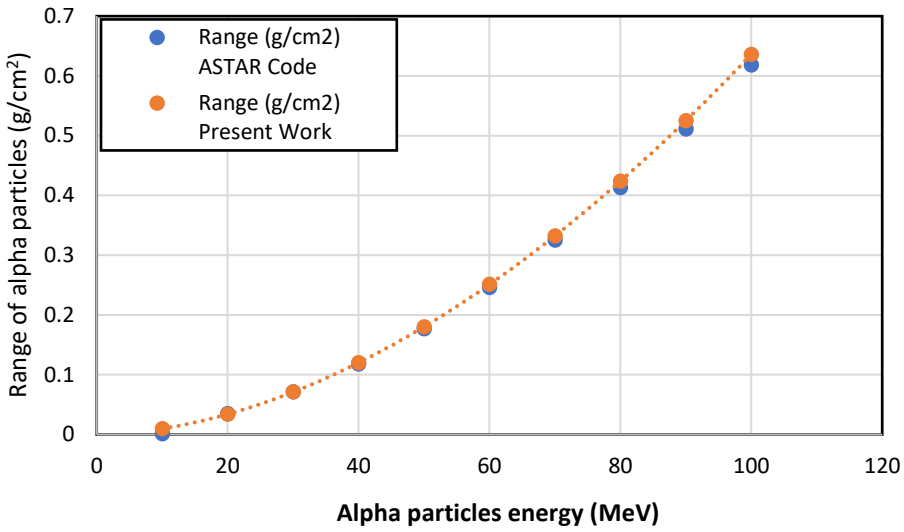
Table(4): Comparison between present calculation of mass stopping power of alpha particles and range in adipose tissue and that calculated by ASTAR

Alpha particle energy (MeV)	Mass Stopping Power ($MeVcm^2/g$)		Range (g/cm^2)	
	Present Work	ASTAR Code	Present Work	ASTAR Code
10	561.19	560.60	0.0096	0.001
20	325.38	328.20	0.034	0.035
30	235.03	237.70	0.071	0.071
40	184.07	188.50	0.120	0.118
50	153.82	157.30	0.180	0.177
60	130.96	135.60	0.251	0.246
70	116.00	119.50	0.332	0.325
80	103.67	107.10	0.424	0.413
90	93.29	97.36	0.525	0.511
100	86.51	89.34	0.636	0.618


Fig(1): mass stopping power of alpha particles in Adipose Tissue
Mass stopping power(MeVcm²/g)
600
500
400
300
200
100
0
0
20
40
60
80
100
120
Alpha particles energy (MeV)
ASTAR Code
Present Work
Present) أس Work)
Y=3746.1X-0.818


Fig(2):Mass stopping power of alpha particles in Adiposee tissue and its compositions
Mass stopping power(MeVcm²/g)
Alpha particles energy (MeV)
Adipose Tissue
S
Na
N
Cl
P
O
C
0
200
400
600
800
1000
1200
1400
1600
0
20
40
60
80
100
120

Fig(3): Range of alpha particles in Adipose Tissue



Conclusions

From the above results obtained using the proposed relations for mass stopping power calculations of alpha particle in Adipose Tissue (ICRU-44) and its compositions and the range of alpha particle in adipose tissue the following conclusions are drawn:

1-It observed that the mass stopping power and range can be expressed in term of alpha particle energy only.

2- It is also noteworthy that the proposed relations are simpler, widely applicable

3- Also we notice that the mass stopping power decreasing with increasing the alpha particle energy while the range is increasing with alpha particle energy.
4- The present proposed equations for mass stopping power and the range are simple and are applied to a large range of alpha particle energy up to 100MeV
5- The equations proposed in the current study give important information for those interested in charged particles radio therapy and radiation protection.
6- The results obtained for both mass stopping and ranges are in good agreement with the results obtained by ASTAR code calculations.

Acknowledgement

The author thank Department of physics - Qassim University for supporting this work.

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