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Transmission Study of Beta Particles in Some Elements and Polymers

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Abstract: The linear attenuation coefficients, the practical ranges and the stopping powers of beta particles in three elements and eight polymers have been determined. Beta particles of kinetic energy 2.288 MeV obtained from the radio-isotope ^{90}Y are uded in transmission technique with and without collimator, the comparison between the two arrangements is discussed in terms of build up factor. Empirical formula of the linear attenuation coefficients of broad beam and their dependencies on the material density and the source detector distance are also discussed. A good agreement of our values with those published previously are obtained for aluminum, copper and iron.

Key words: Aluminum, iron, linear, elements, coefficients, detector

INTRODUCTION

The knowledge of the mass attenuation coefficient, the total stopping power and the ranges of beta particles is generally required for radiation technology and semiconductor detector fabrication. Measurements on the transmission of electron and positrons in different materials have been reported, since, the discovery of radioactivity (Cosslett and Thomas, 1964; Thontadarya and Umakantha, 1971). The range of B-particles has been determined using their respective mass attenuation coefficient and assuming the validity of the exponential law of attenuation down to 0.1 transmission (Thontadarya, 1985). A new experimental technique has been used to investigate the penetration of electron and positron in some elements and multi elemental materials (Takhar, 1967). A simple empirical formula for the total stooping power of positrons and electrons of kinetic energy 500 keV has been determined (Batra and Sehgal, 1970).

In this investigation the linear attenuation coefficient (U_{exp}), the Range (R_{exp}) and the Stopping powers (S*) of three elements and eight polymers are calculated using B-particles of kinetic energy 2.288 MeV obtained from radionuclide ^{90}Y, the experimental results of the linear attenuation coefficient (U_{exp}) are taken with and without collimators. The dependence of the linear attenuation coefficient and the range of B-particles on the material density P and the source-detector distance d are also discussed.

MATERIALS AND METHODS

Theoretical considerations: It is well known that B-particles, on passing through various media, undergo inelastic as well as elastic interaction with the atom of an absorber, this fact is utilized to determine the practical range of electrons in matter. Therefore, the range off electrons of kinetic Energy E, under the continuous slowing down approximation is given by Batra and Sehgal (1970):

$$R(E) = {}_{O}S^{E}\left[\left(\frac{dE}{dX}\right)\right]_{tot}^{-1} dE \qquad (1)$$

where, (dE/dX) is the energy loss due to the collision (ionization plus excitation loss) and bremsstrahlung. The energy loss due to collision process and bremsstrahlung are proportional to (Z/A) and (Z^2/A) of any incident energy, respectively. The stopping power of B-particles of kinetic energy E is given by:

$$S^*(E) = {}_{O}S^{E}\left(\frac{dE}{dX}\right)dE \qquad (2)$$

The exponential law of the attenuation of B-particles of energy E in an absorber is given by:

$$I(X) = I\exp(-ux) \qquad (3)$$

where, x is the thickness of the absorber which reduces the intensity from I (with zero absorber) to I(x) and u is the linear attenuation coefficient in cm^{-1}. The value I(x)/I for an absorber of B-particles is given by:

$$-In(I / I.) = u.R_p \qquad (4)$$

The range of B-particles and corresponding to 1 and 0.1% transmission, respectively can be obtained using the following equations:

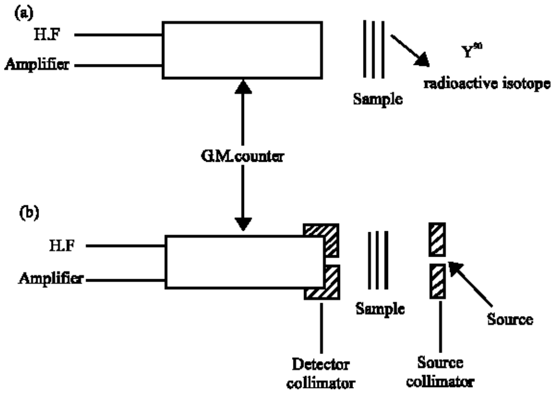

Fig. 1: Schematic diagram of the geometrical set up used: a) Without collimator and b) With collimator

$$R_{0.01} = (4.604)u^{-1} \quad (5)$$

$$R_{0.001} = (6.909)u^{-1} \quad (6)$$

Experimental details: The essential part of the apparatus are shown in Fig. 1a, b in the first part the transmission is measured without collimator where the source-detector distance varies between 2-6 cm. The second part is narrow been configuration where the source-detector distance is fixed and the solid angle is Sr, Fig. 1b. The B-particles resulting from have a nominal activity 1 UCI and kinetic energy 2.288 MeV.

The samples are divided into two categories the first one is elements such as aluminum, iron and copper. The second category is polymers such as polypropylene, paraffin, polyethylene, PVC cellulose-tri acetate, prespex, and bakelite. The density of the samples are in the range 0.5-8.16 g/cm^{-9}.

Geiger-muller counter type Nucleus is attached to a high voltage power supply with amplifier built in. The errors in the linear attenuation coefficient (Su) are calculated from:

$$Su = \frac{1}{x} - \frac{111_0 - 1_0 S_1}{11_0} \quad (7)$$

where, SI$_0$ and SI $_0$are the statistical errors due to the count readings with and without absorber, respectively. The uncertainty of the readings is calculated and its value is about 3%.

RESULTS AND DISCUSSION

Table 1: The linear attenuation coefficients of B-particles (E = 2.288 MeV for some elements and polymers of the density range 0.5-8.16 g/cm$^{-3\,(10)}$.

	Densities linear attenuation coefficient				
Materials	p g/cm^{-3}	u_{exp}	u_{th}	u_b	f (p) = u_b/u_{exp}
Copper	8.160	35	34	40	1.100
Iron	6.770	30.8	29	36	1.206
Aluminum	2.699	12.75	13	16.7	1.304
Bakkelite	1.400	6.01	-	8.5	1.416
Prespex	1.300	5.9	-	8.19	1.365
Cellulose	1.150	5.75	-	8.6	1.458
Polyethelene	1.000	4.4	-	7.3	1.613
PVC	0.900	4.01	-	6.24	1.560
Paraffin	0.860	3.75	-	5.8	1.530
Paper	0.800	3.2	-	5.9	1.600
Polyprolen	0.505	2.5	-	4.8	1.920

Table 2: The material density as function of the particle range, the ranges calculated from Eq. 4 and 5 the stopping power of the B-particle used (E-2.288 MeV). # Theoretical value of the range are taken from (Thontadarya, 1985)

Materials	R_p	$R_{th}^{(6,10)}$	$R_{0.01}$	$R_{0.1}$	$S^{\#}_{mev/cm}$
8.16	0.154	0.192	0.10	0.150	14.88
6.77	0.152	-	0.10	0.150	15.00
2.7	0.518	0.518	0.35	0.525	4.40
1.4	1.340	-	0.66	0.990	1.70
1.3	1.450	-	0.60	1.035	1.57
1.15	1.550	-	0.74	1.110	1.40
1.0	1.750	-	0.90	1.350	1.30
0.9	1.830	-	1.09	1.635	1.24
0.86	1.890	-	1.17	1.755	1.08
0.8	2.100	-	1.23	1.845	1.08
1.5	2.700	-	1.44	2.160	0.84

Figure 2 shows the relation between the intensity (In I) and the thickness (X in g/cm^{-2}) of the samples with and without collimator. From this Fig. 1 it can be seen that the intensities with collimator are larger than that without collimator. Table 1 comprises the materials, the densities P, the theoretical values U_{th}, the experimental values of narrow and broad beams.

u_{exp}, u_b of the linear attenuation coefficients, our results of for the elements Cu, Fe and Al are also in general agreement with the theoretical values u_{th} (Thontadarya, 1985) of some elements.

Figure 3 shows that and are exponentially increased as the material densities increases. Also, Table 2 and Fig. 4 declare the changes of the range of the B-particles with the material density for the two arrangements. The ranges of the narrow beam for Cu and Al are in good consistency with those published previously. Table 2 contains the material densities and the values of the range corresponding to 1 and 0.1% transmission calculated according to Eq. 4 and 5, respectively. The maximum range of B-particles is obtained by using values and assuming the possible validity of the exponential law of attenuation to 0.1 and 1% transmission for large and small material densities, respectively. The stopping power of the used energy with the material density is represented in column 6 (Table 2).

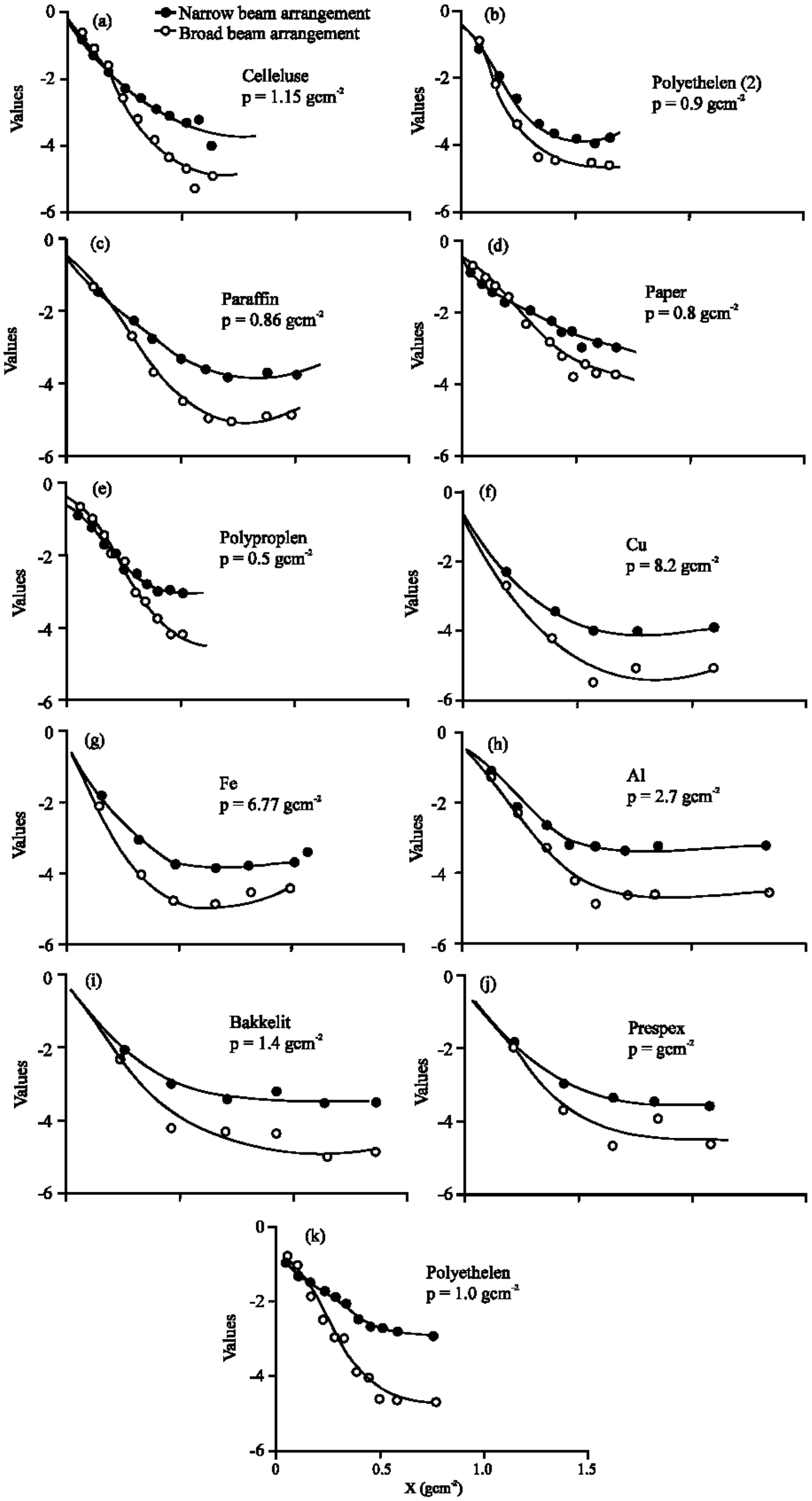

Fig. 2: The relation between the intensity InI and the thickness x of the samples for the two arrangements

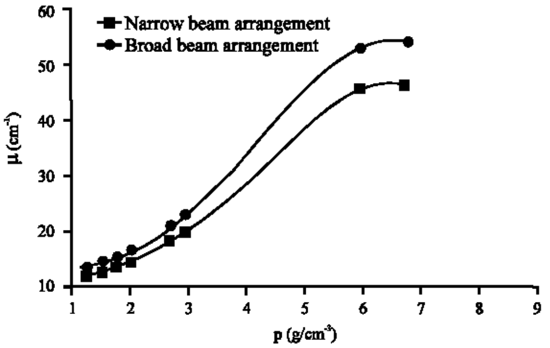

Fig. 3: The relation between the linear attenuation coefficient μ and the density p

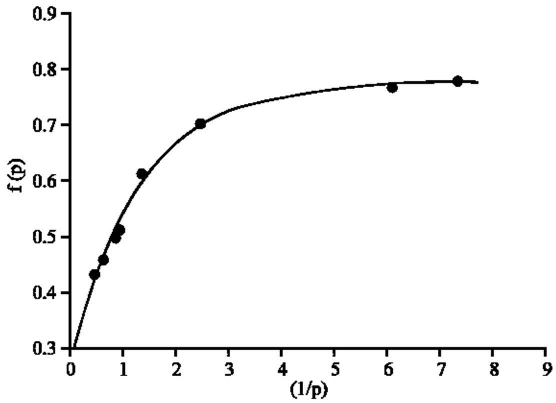

Fig. 4: The relation between the buid up factor f (p) due to den-sity variation and the resiprocal of densities (1/p)

The transmission without collimator

Density variation: Figure 2 shows that the slopes of the curves of the narrow beam are larger than those of broad bam. fon the small material densities of tow curves, at small thickenesses are overlapped and intereacted as the material density decreased which is due to the small electron density in such materials. The B-particles undergo an inelastic interaction with the electrons of the materials and are scattered to the detector by small angles. This phenomenon occurs also in materials of large density and small thickness. This could be represented by the build up factor which is defined as the increase of the counts due to scattered electrons with small angles. The difference between the values of and is attributed to this factor. Table 1 represents the value of the build nup factor f (which is equal to u_0/u_{exp}) and the material density, the build up factor due to the density f(p) decreases exponentially as the material density increases. Figure 4 shows the value of (p) may be saturated for relatively large densities ($p>3$ g/cm^{-3}), f(p) can be represented by:

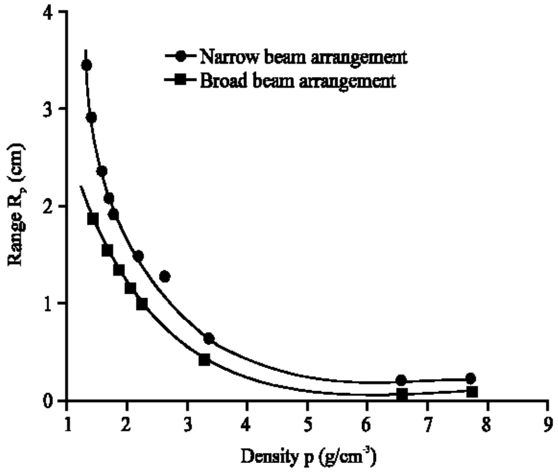

Fig. 5: The relation between the range of the B-particles and the densities at the two arrangements used

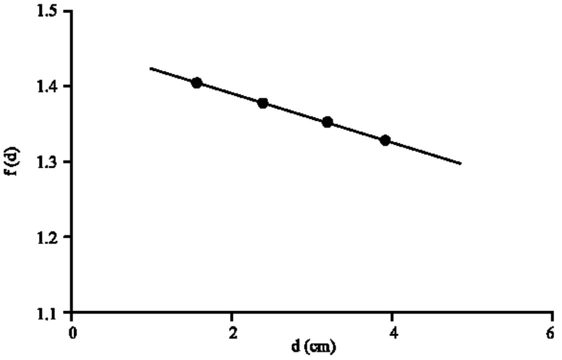

Fig. 6: The relation between the bulld up factor f (p) and the source detecor distance d for aluminlum

$$f(P) = A\left[1\text{-EXP}(\text{-}B/P)\right] \tag{8}$$

where, A and B are constants for the geometrical set up used. Their values are 0.8895 and 1.015, respectively. Figure 5 show the relation between the range of the B-particle and the densities, at the two arrangements used from Fig. 5 it can be seen that the range of particles for the broad beam set up is smaller than for the narrow beam. This is the direct result of the secondary electrons scattered by B-particles with small scattering angles.

The source-detector distance variation: Figure 6 demonstrate the linear relation between the build up factor f(d) and the source-detector distance d for Al. From this Fig. 6 it can be seen that u_0 increases as R_{exp} decreases for small distances. The kinetic energy of the scattered B-particles is lower than that of the incident particles. These scattered particles will undergo interactions with the atoms of air, so, the probability that these particles each the detector is large when the source-detector is small. The increasing of scattering particles behind the transmitted ones are decreased by u_b. The relation between f(d) and d is given by the following linear Eq. 9:

$$f(d) = f_0(d) - C(d - d_0) \tag{9}$$

where, $f_0(d)$ is the build up factor due to zeros source-detector distance, C is a constant equal to 0, 9 in our experiment and d_0 is the distance where the build up factor f(d) equals to zero, i.e., there is no scattering particles reaching the detector.

CONCLUSION

The linear attenuation coefficient (u) and the Range (R) of beta particles of kinetic Energy E = 2.288 MeV are compared in two arrangements (with and without collimator). (u) and (R) values are in consistent with the previously published values in the transmission technique with collimator. This is not the case in the transmission technique without collimator. There are two factors affecting the affecting the (u) and (R) values without collimator: the density variation and source-detector distancevariation. There are two empirical relations of the build up factor for the density and the source detector distance. The constants of these two relations are valid for our geometrical set up.

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