Ancient TL

www.ancienttl.org · ISSN: 2693-0935

Valladas, G., 1988. *Stopping power and range for alpha particles in SiO2.* Ancient TL 6(1): 7-8.
https://doi.org/10.26034/la.atl.1988.128

Stopping power and range for alpha particles in SiO_2

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Of great importance in computing the alpha fluxes in ceramics and flint fragments are the data dealing with the range-energy relation in SiO_2. Aitken and Bowman (1975) have used some interpolations between Ne and Na from the range of data given in Northcliffe and Schilling (1970), and Williamson *et al.* (1966). Zimmerman (1971) used the experimental data for aluminium from Marion and Young (1968) to predict the energy spectrum of alpha particles in ceramics, using the expression 1 + 0.29E (E = energy in MeV) for the derivative of the alpha range as a function of E.

We hope that the use of the results published by Ziegler and his co-workers (1977) should allow a better estimate of the stopping power and range in SiO_2 (in fact strong discrepancies exist between data below 5 MeV for the above referenced papers by Northecliffe and Schilling, Williamson *et al.*, Zimmerman, and Ziegler *et al.*). From the best-fit of all the available data, these authors have derived the following formula for the stopping power, S,

$$\frac{1}{S} = \frac{1}{S_1} + \frac{1}{S_2} \qquad (1)$$

where:

$$S_1 = A_1 E^{A_2} \qquad (2)$$

$$S_2 = \frac{A_3}{E} \ln(1 + \frac{A_4}{E} + A_5 E) \qquad (3)$$

and A_1.....A_5 are numerical coefficients tabulated for each element.

We have computed the stopping powers for SiO_2 , $S(SiO_2)$, and the corresponding ranges using the formula:

$$S(SiO_2) = \frac{28}{60} S(Si) + \frac{32}{60} S(O) \qquad (4)$$

where S(Si) and S(O) represent the s.p. of silicon and of "solid" oxygen, respectively. The latter have been estimated from the effective charge found for He stopping in B, C, Al and Si (Ziegler, 1977).

Although there is some evidence that the Bragg additivity rule relating the stopping power of a compound to that of its contsituents does not strictly hold, the deviations from the rule are not large and have been observed mainly in the stopping power of hydrocarbons for protons.
Northcliffe and Schilling, 1970

Values of S and R for energies ranging from 0.05 to 10 MeV are shown in Table I.

Table I

E	R	S.10^{-2}
0.05	0.198	5.42
0.1	0.272	8.03
0.15	0.328	9.97
0.2	0.374	11.47
0.3	0.454	13.51
0.4	0.525	14.64
0.6	0.657	15.39
0.8	0.787	15.21
1	0.921	14.66
2	1.698	11.33
3	2.690	9.10
4	3.893	7.67
5	5.294	6.68
6	6.885	5.94
7	8.657	5.37
8	10.60	4.92
9	12.72	4.54
10	15.01	4.22

E= energy in MeV;
R= range in g/cm^2;
S= stopping power in MeV cm^2/g.

Let Φ be the annual (omnidirectional) alpha flux in silica for a weight concentration of 1 ppm of natural uranium or thorium. We have:

$$\Phi = N \Sigma R_i \qquad (5)$$

where; N is the disintegration rate of the parent of the considered series assumed at equilibrium, and R_i the track lengths of its different nuclides. F is given for the three radioactive series in Table II.

If the values of F are increased by 3% for a better correspondence to the chemical composition of pottery they are 4 to 5% higher than the fluxes deduced from the results of Bowman (1982).
Concerning the energy derivative of the range, we obtain for silica:

$1 + 0.43E$ for $1 < E < 5$ MeV
$1 + 0.30E$ for $5 < E < 9$ MeV

Table II

Parent	N (y^{-1} g^{-1})	ΣR_i (g cm^{-2})	Φ ($y^{-1} cm^{-2}$)	
^{238}U	$3.897.10^5$	$47.53 .10^{-3}$	$1.852.10^4$)	
^{235}U	$1.82 .10^4$	$48.20 .10^{-3}$	$8.77 .10^2$)	$1.94. 10^4$
^{232}Th	$1.276.10^5$	$42.10 .10^{-3}$	$5.377.10^3$	

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This update on alpha particle ranges represents a small, but just significant, revision in the alpha particle contribution to the annual dose when any of the three track-length systems are used (see Aitken, 1985) in combination with determination of parent concentration for evaluation of alpha activity. On the other hand, if the alpha activity is evaluated by means of thick-source alpha counting, as is implicit in either the *a*-value or the *b*-value systems, there is a compensatory increase in the alpha count-rate per unit concentration.

Reference

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