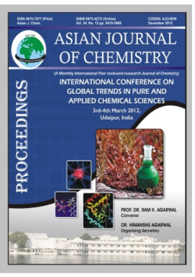
Asian Journal of Chemistry; Vol. 24, No. 12 (2012), 5953-5954

ASIAN JOURNAL OF CHEMISTRY

www.asianjournalofchemistry.co.in



Total Attenuation Cross-Sections of Several Proteins at 661.6, 1173 and 1332.5 keV†

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AJC-11806

Total attenuation cross sections of several proteins have been measured for 661.6, 1173 and 1332.5 keV photons by empirical formula $\sigma = 2.2\,A\,E^{-0.43}$. The values are compared with the values calculated with the aid of mixture rule from the data of Hubbell for the individual elements.

Key Words: Attenuation coefficient, Total attenuation cross sections, Proteins, Biomolecules, Mixture rule, Empirical formula.

INTRODUCTION

Proteins are the most abundant macro molecules in the living cells and constitute the largest fraction of living matter in all types of cells. ^{137}Cs (with photon energy 661.6 keV) and ^{60}Co (with photon energy 1173 and 1332.5 keV) radio isotopes are being increasingly used in radiation therapy and oncology. Therefore, a thorough knowledge of the photon interaction cross sections of the above energy sources for proteins is desirable. These sources are used in medical field, industry, biological studies and radiation sterilization[1] because of high energy along with its optimal long life. Data on the total attenuation cross sections of proteins for ^{137}Cs and ^{60}Co are quite useful, since these are essential to all living cells and constitute the largest fraction of living matter in all types of cells. With this end in view we have calculated the photon cross sections of several proteins for ^{137}Cs and ^{60}Co using empirical formula $\sigma = 2.2AE^{-0.43}$ [2]. The values are compared with the values calculated with the aid of mixture rule from the data of[3] for the individual elements and found to be in agreement with it.

Calculation of total attenuation cross sections

A narrow beam of monoenergetic photons is attenuated to an intensity I from an incident intensity I_0 in passing through a layer of material with mass-per-unit -area x according to the exponential absorption law:

$$I / I_0 = \exp(-\mu/\rho . x) \quad (1)$$

where μ/ρ is the mass attenuation coefficient. Equation (1) can be rewritten as:

$$(\mu/\rho) = x^{-1} \ln (I_0/I) \quad (2)$$

From which μ/ρ can be obtained from measured I_0, I and x data.

Present μ/ρ tabulations rely heavily on theoretical values of the total cross section (area) per atom σ_{tot} related to μ/ρ according to:

$$\mu/\rho = \sigma_{tot} (N_A/A_r) \quad (3)$$

in which N_A is Avogadro's number (6.022045×10^{23} mol^{-1}) and A_r is the relative atomic mass (atomic weight). The total cross section s_{tot}, in turn, can be written as the sum over contributions from the principal photon interactions.

$$\sigma_{tot} = \sigma_{coh} + \sigma_{incoh} + \tau + k + \sigma_{ph.n.} \quad (4)$$

in which σ_{coh} and σ_{incoh} are the coherent (Rayleigh) and incoherent (Compton) scattering cross sections, respectively; τ is the atomic photoeffect cross section; k is the positron-electron pair-production (including triplet) cross section; and $\sigma_{ph.n.}$ is the photonuclear cross section. The μ/ρ values (m^{2}kg^{-1}) from the data[3] is taken. It is converted in to cm^{2}g^{-1} then substitutes this value in the above formula eq. (3) for obtaining the total cross section stot. Also this value is calculated by empirical formula:

$$\sigma = 2.2AE^{-0.43}$$

RESULTS AND DISCUSSION

The values of the total attenuation cross sections are listed in Table-1 and compared with the interpolated theoretical values. The theoretical values were calculated by taking the tabulated cross sections[3] for the elements carbon, hydrogen, nitrogen, oxygen, sulphur and bromine. The tabulated values of Hubbell include the extensive atomic photoeffect calculations

†Presented at International Conference on Global Trends in Pure and Applied Chemical Sciences, 3-4 March, 2012; Udaipur, India

by[4] and new tabulations of incoherent (non-relativistic) and coherent (relativistic) scattering cross sections assembled[5]. The cross sections for individual proteins were suitably calculated with the aid of the mixture rule and interpolated to the energies of interest.

TABLE-1
TOTAL ATTENUATION CROSS SECTIONS (IN BARN/MOLECULE) OF PROTEINS

S. no.	Proteins	m.w.	Energy (keV)		
			661.6	1173	1332.5
1	Actin-N	198.14	26.62	20.87	19.76
			26.17	20.47	18.23
2	Collagen	273.34	36.73	28.80	27.26
			38.09	30.07	26.20
3	Serum Amyloid P Component	340.37	45.74	35.86	33.94
			46.55	36.68	32.16
4	Arp 2/3	394.29	52.98	41.54	39.32
			51.33	40.36	35.75
5	CFTR Inhibitor IV, PPQ-102	438.49	58.92	46.19	43.73
			58.84	46.20	37.62
6	CFTR Inhibitor 11.Gly H-101	493.15	66.26	51.95	49.18
			63.11	49.33	43.84
7	Elastin	552.71	74.27	58.23	55.12
			76.69	60.56	52.77
8	C-reactive protein	1276.49	171.52	134.47	127.30
			174.94	137.86	120.77
9	Myosin	1324.64	177.99	139.55	132.10
			182.62	144.02	125.86
10	Serum albumin	66472.10	8931.82	7002.67	6629.11
			9078.71	7155.65	6276.24

First line: Calculated total attenuation cross sections from empirical formula; $\sigma = 2.2AE^{-0.43}$. Second line: Hubbell (1982) values

From Table-1 it is clear that there is an agreement between the values of total attenuation cross sections based on empirical formula $\sigma = 2.2AE^{-0.43}$ and the theoretical values[3], at all the three energies 661.6, 1173 and 1332.5 keV. Because of the presence of H, C, N and O which are low Z elements, the contribution to the total attenuation cross sections of the proteins under consideration is almost entirely 99.9 % from incoherent scattering at the energies 661.6,1173 and 1332.5 keV.

Conclusion

It is expected that the data presented here will be very useful, particularly in the energy region of interest, in view of their importance in radiation therapy, oncology, medical field, industry, biological studies and radiation sterilization. Also to the knowledge of the authors, such data are the first of their kind at these energies and hence contribute a new pool of data on mass attenuation coefficients for proteins.

ACKNOWLEDGEMENTS

The authors are thankful to UGC for providing the financial support for Major Research Project on Attenuation Coefficient Studies of Biologically Important Compounds.

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