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MOLAR EXTINCTION COEFFICIENTS OF SOME ALKALI METAL SALTS IN AQUEOUS SOLUTIONS

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ABSTRACT

Molar extinction coefficients of aqueous solutions of some commonly used alkali metal salts have been measured using well-collimated narrow beam transmission geometry at 279, 356, 662, 1173 and 1332 keV. Molar extinction coefficients of pure solid solutes have also been obtained from their solutions by mixture rule without obtaining them in pure crystalline form. A good agreement has been obtained between the experimental results with the theoretical values evaluated through XCOM calculations.

Keywords: Molar extinction coefficient, Alkali metal, Gamma ray, Aqueous solutions, XCOM.

1. INTRODUCTION

The knowledge of gamma ray interaction parameters in inorganic and organic materials is of significant interest for medicine, tomography, gamma ray fluorescence studies, radiation biophysics, nuclear industry and space research applications etc [1, 2]. Most previous experimental determinations of photon attenuation coefficients have been concerned with crystalline samples in solid form. The use of absorbers in the form of solutions has some definite advantages as compared with solid absorbers; the criterion of homogeneity of the

absorber is satisfied without any problem and the strength of the absorber can easily be varied by changing the relative amount of solute and solvent.

In view of promising advantages of molar extinction coefficient of solutions, Gagandeep et. al. [3] developed mathematical formulations for aqueous solutions of soluble salts and made measurements at different energies. Singh et al. [4, 5] and Sandhu et al. [6] continued to determine these coefficients for amino acids, carbohydrates and fatty acids respectively using gamma ray transmission method. Kumar et. al. [7] has measured the molar extinction coefficients for twelve commonly used solvents at various energies. Recently Singh and Gerward [8] have reviewed X-ray and gamma ray attenuation in solutions. Teli et. al. [9, 10] determined gamma ray attenuation coefficients of magnesium chloride, zinc sulphate and sodium chloride at 123 keV. Later on, attenuation in solutions of sodium chloride and ferrus sulphate at 123 and 662 keV respectively were studied by Teli and Chaudhary [11]. Kaur et al. [12] and Singh et al. [13] reformulated the equation used by Teli et. al. [9] and established the solution method as an another method to obtain mass attenuation coefficients of solid solutes from their solutions.

In the present study molar extinction coefficients of some commonly used alkali salts (Lithium chloride, sodium chloride, potasium chloride, lithium bromide, sodium carbonate, potasium carbonate, lithium hydroxide, sodium hydroxide, potasium hydroxide, lithium sulphate, sodium sulphate, sodium iodide and potasium iodide) in aqueous solutions as well as in pure form have been determined using narrow beam gamma ray transmission geometry at 279, 356, 662, 1173 and 1332 keV. The results are also compared with their theoretical calculations.

2. THEORY

The attenuation of radiation in homogeneous solutions is given by

$$I = I_0 \exp(-\sigma N_A c x) \qquad (1)$$

where I_0 and I are the intensities of gamma radiations traversed through the cell without and with the solution, σ (barn/molecule) is the interaction cross section, N_A is the Avogadro number, c (mol/L) is the molar concentration of the solution and x (cm) is the length of the cell containing the solution.

This expression is identical to the "Lambert-Beer law" which is used to describe the radiation attenuation in homogeneous solutions, which can be written as:

$$I = I_0 10^{-\varepsilon x c} \qquad (2)$$

where ε (L mol^{-1}cm^{-1}) is called the molar extinction coefficient.

Comparing Eqs. (1) and (2), we have

$$\varepsilon = \sigma N_A Log_{10} e = 0.4343 \sigma N_A = 0.4343 M \left(\mu / \rho\right) \qquad (3)$$ where μ (cm^{-1}) is the linear attenuation coefficient, M (g/mol) is the molar mass and ρ (g/cm^3) is the density of the solution.

According to mixture rule the molar extinction coefficient of a solution is given by

$$Log\left(I_o / I\right) = \varepsilon c x = \varepsilon_s c_c x + \varepsilon_w c_w x \qquad (4)$$

where ε_s and ε_w are the molar extinction coefficients of the pure solid solute and pure water respectively, c_s and c_w are their respective molar concentrations. Eq. (4) can be used to determine the molar extinction coefficient of the pure solid solute.

The molar extinction coefficient of pure water can be determined as follows:

$$\varepsilon_w = \left(1 / c_w x\right) Log\left(I_o / I\right) \qquad (5)$$

3. EXPERIMENTAL DETAILS

The narrow beam transmission geometry (sample-detector solid angle < 5 x10^{-5} Sr), similar to one used by Cesareo et.al. [14], has been used for the present measurements. The NaI (Tl) detector (4.5-cm diameter and 5.1 cm thickness) with an energy resolution of 9.67% at 662 keV was used for the photon counting. The radioactive sources ^{203}Hg, ^{133}Ba, ^{137}Cs and ^{60}Co of strength 5 mCi approx. were procured from Bhabha Atomic Research Centre, Mumbai, India. The solutions were filled in the perspex box and were properly covered. Spectra were recorded with the help of multichannel analyzer (2K) supplied by EG & G ORTEC (USA) plugged in personal computer combined with Maestro II software. The thicknesses of the samples were selected in such a way that the criteria of Creagh and Hubbell [15] were satisfied. The intensities of the photons without (I_o) and with (I) samples respectively were measured by placing the sample between the source and detector. The uniformity of each

sample thickness was checked by determining the transmitted intensities exposing different parts of the sample material to the incident beam. The stability and reproducibility of the arrangement was tested before and after each set of runs in the usual manner. It was observed that any discrepancy in the intensities in each case was within the counting statistics.

4. RESULTS AND DISCUSSION

The experimental values of the molar extinction coefficients for the chosen aqueous solutions of alkali salts have been determined by the use of Eq. (2). The molar extinction coefficients of the pure solid solutes have been obtained from the above data by applying the mixture rule given by Eq. (4) and are shown in Table 1. These values are compared with the theoretical values obtained through XCOM [16] calculations using Eq. (3). The experimental values are within 5% of the theoretical ones.

The variation of the molar extinction coefficient with the energy of the incident gamma rays is shown in Figure 1. The solid continuous curves have been drawn for the polynomial fits to the calculated molar extinction coefficients using XCOM whereas the measured molar extinction coefficients have been shown by data points. The molar extinction coefficient decreases with increase in energy of the incident gamma radiation because the attenuation produced by the medium decreases as we increase the energy of the incident radiations due to the dominance of Compton scattering in the selected energy region. The precise measurement of the molar extinction will be useful in the determination of the total interaction cross section using Eq. (3).

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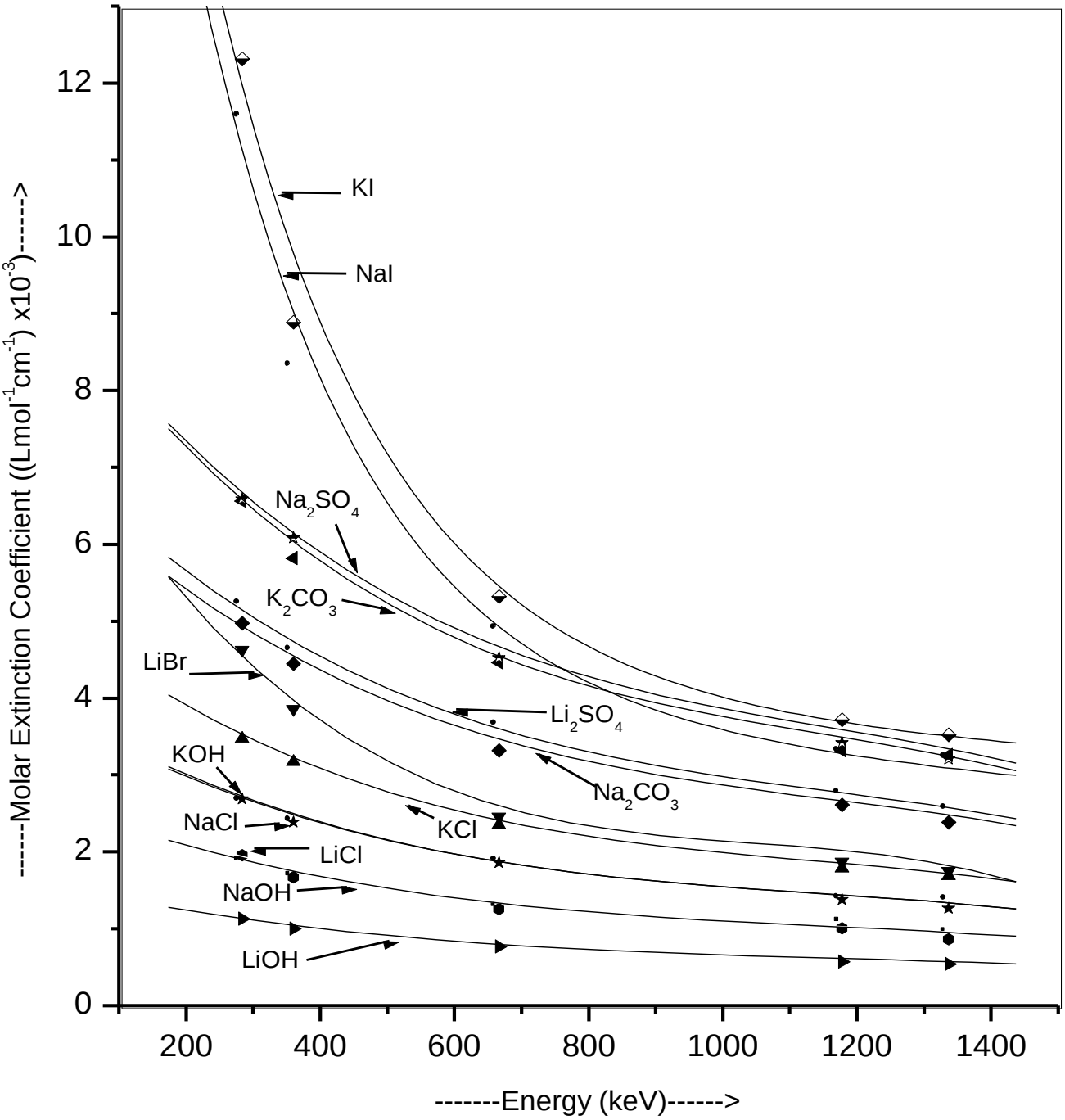

Figure 1. Variation of Molar Extinction Coefficient With Incident Energy for Some Pure Alkali Metal Salts.

Table 1

Molar Extinction Coefficients (L $mol^{-1}cm^{-1}$) of Pure Alkali Metal Salts in Aqueous Solutions

Alkali Metal Salt	Density of Solution (g/ml)		Molar Extinction Coefficient x 10^{-3} (L $mol^{-1}cm^{-1}$)				
			279 keV	356 keV	662 keV	1173 keV	1332 keV
LiCl	1.037	A	1.959	1.768	1.349	1.024	0.960
		B	1.892	1.685	1.289	1.088	0.966
NaCl	1.064	A	2.731	2.468	1.887	1.433	1.344
		B	2.666	2.401	1.884	1.395	1.380
KCl	1.055	A	3.568	3.205	2.434	1.845	1.730
		B	3.510	3.209	2.386	1.823	1.723
LiBr	1.067	A	4.673	3.858	2.674	1.980	1.855
		B	4.666	3.898	2.502	1.909	1.788
Na_2CO_3	1.104	A	4.976	4.532	3.491	2.658	2.491
		B	5.012	4.489	3.356	2.653	2.423
K_2CO_3	1.085	A	6.651	6.002	4.585	3.482	3.264
		B	6.603	5.856	4.505	3.356	3.298
LiOH	1.047	A	1.144	1.043	0.805	0.613	0.574
		B	1.169	1.042	0.802	0.609	0.576
NaOH	1.105	A	1.916	1.744	1.343	1.022	0.958
		B	1.998	1.712	1.296	1.050	0.901
KOH	1.066	A	2.753	2.481	1.890	1.434	1.345
		B	2.723	2.423	1.898	1.412	1.301
Li_2SO_4	1.065	A	5.190	4.719	3.629	2.761	2.588
		B	5.226	4.623	3.650	2.759	2.556
Na_2SO_4	1.088	A	6.737	6.120	4.705	3.579	3.355
		B	6.621	6.122	4.559	3.456	3.245
NaI	1.067	A	11.99	8.671	4.988	3.481	3.248
		B	11.56	8.321	4.901	3.302	3.222
KI	1.031	A	12.83	9.408	5.535	3.892	3.634
		B	12.31	8.925	5.356	3.756	3.559

A: stands for theoretical values.

B: stands for experimental values.