Ultrasonic study of Reactive Orange 86 in Water at Different Temperature

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Abstract

The densities, viscosities and ultrasonic velocities were measured for aqueous solutions of reactive dye at different temperature and at different concentrations.Using the experimental data, adiabatic compressibility, intermolecular free length acoustic impedance etc were calculated. These parameters were used to study the solute-solvent interaction in experimental solution.

Key words: Reactive dyes, adiabatic compressibility, acoustic impedance, intermolecular free length.

Introduction

The investigation of various physical properties by ultrasonic investigation is a non-destructive technique and can be used for wide range of application in consumer industries, pharmaceutical, medical field process industries,chemical engineering,solution chemistry, physical chemistry, biochemistry, and process control for a fundamental understanding of many phenomena in solutions and liquid systems [1], The measurement of ultrasonic velocity, density, viscosity etc. can be used to investigate the physicochemical behaviour and molecular interactions involved in any solution [2]. Ultrasonic velocity, density, viscosity and other acoustic parameters such as adiabatic compressibility, intermolecular free length, specific acoustic impedance, relative association constant are very useful parameters to know the molecular interactions in pure liquids, aqueous solution [3] and liquid mixtures [4].

The reactive dyesare used in textile industry and it is one of the pollutants, present in wastewater from textile industry along with various pollutants along with organic matter, additives, and surfactants. Structure of dyes contain aromatic molecular structure which possibly comes from coal tar-based hydrocarbons such asbenzene, anthracene, toluene, naphthalene, xylene etc [5]. Dye has obtained notoriety as hazardous substances, because most of them are toxic. These dyes are harmful for environment [6]. Viscosity and density data provide useful information about various types of interactions occurring in ionic solutions. These studies are of great help in characterizing the structure and properties of solutions. Various types of interactions exist between the ions in solution and out of them; ion-ion and ion-solvent interactions are of current interest, in all branches of chemistry. Temperature is a very important parameter which affects the solution properties. So it was thought worthwhile to study the effect of temperature on the acoustical parameters. Solutions of dyes were prepared in distilled water. The acoustical parameters were derived from ultrasonic velocity, viscosity and density at 293 K, 298 K, 303K, 308K and 313 K temperatures

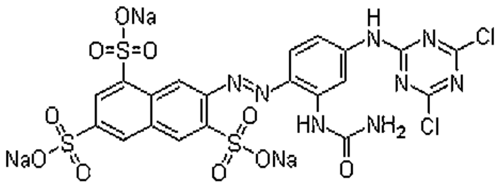
Materials and methods

Chemicals

The dye, reactive Orange 86 used as solutes was collected from dye industry Ludhiyana. It is an azo dye commonly available as a chloride salt and is readily soluble in water, ethanol and DMF. Commercial name of reactive orange 86 is YS3R. Its IUPAC name is Trisodium 7-[2-[(amino carbonyl) amino]-4-[(4, 6-dichloro-1, 3, 5-triazin-2-yl) amino] phenyl] azo] naphthalene-1, 3, 6-trisulphonate. It is widely used for cellulose fiber dyeing.

The double distilled water was used as solvent in this investigation. The dye was dried in a vacuum oven and then stored in desiccators over fused calcium chloride and used without further purification.

Table 1: Properties of Reactive Orange 86

CAS No.	Molecular Formula	Formula Weight	Structure
57357-00-9	$C_{20}H_{11}N_8O_{10}S_3Cl_2Na_3$	759.41	

Solutions

An initial stock solution of 100 ppm was obtained by weighing. Other solutions of various concentrations were prepared by the gradual dilution of the stock solutions by volume. Solutions of reactive dye were prepared in double distilled water.

Viscosity, Density and ultrasonic velocity measurements

Ultrasonic velocities, densities and viscosities were measured at 293.15 K, 298.15 K, 303.15 K, 308.15 K and 313.15 K. The experimental water bath temperature was maintained constant with temperature stability ±0.1°C by circulating the coolant liquid from the electronically digitally operated (Plasto Craft Industries) low temperature bath model LTB-10. The densities of the solutions were measured at different temperature by the hydrostatic plunger method.Ostwald Viscometer was used to determine viscosities of the solutions and solvent at different temperature by suspending viscometer in experimental bath. The ultrasonic velocity was measured in aqueous solutions of Reactive Orange 86 by using an ultrasonic interferometer (model F-81 was supplied by M/s Mittal Enterprises, New Delhi.) at a fixed frequencyof 2 MHz having facility to measure ultrasonic velocity at different. The temperature of experimental liquid in measuring cell can be maintained by circulating water through the measuring cell which is specially designed with a double walled cylinder provided with an inlet and outlet. By using thermostat (accuracy ±0.1 K), water is circulated at any desired constant temperature through the outer wall of the cell.

Theoretical equations:

From the experimental data of density, viscosity and ultrasonic velocity, various acoustical parameters are evaluated using standard equations:

Adiabatic compressibility

From the ultrasonic velocity (U)and density (d)the adiabatic compressibility can be calculated from the following equation.

$$\beta = 1/\ U^2\rho \text{ kg}^{-1} \text{ ms}^{-2}$$

Intermolecular Free Length

Intermolecular Free is used to determine the interaction between the ion and the solvent molecule. The free path length was calculated using the equation

$$L_f = K\sqrt{\beta}$$

Where, *K* is Jacobson's constant which is a temperature dependent coefficient. Jacobson determined the value of K empirically between 0 and 50°C. Pandey *et al* [7-8] carried out a critical discussion of temperature and pressure dependence of Jacobson constant and L_f

Acoustic impedance (Z)

The acoustic impedance is given by the product of ultrasonic velocity and density as shown below:

$$Z = U \times \rho \text{ kg m-2s-1}$$

Where ρ is the density and U is the ultrasonic velocity in the liquid system.

Relative Association (RA)

The relative association can be calculated as

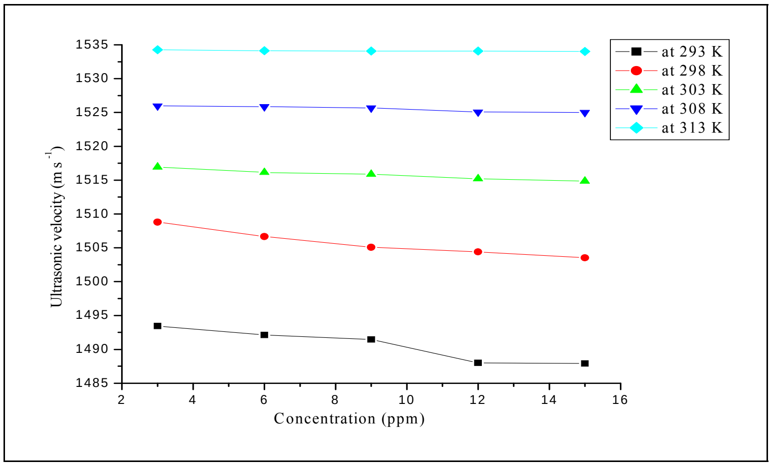
$$RA = (\rho\ /\rho_0)\ (\upsilon_0 / \upsilon)^{1/3}$$

where ρ_0 = density of solvent, υ_0 = ultrasonic velocity of solvent.

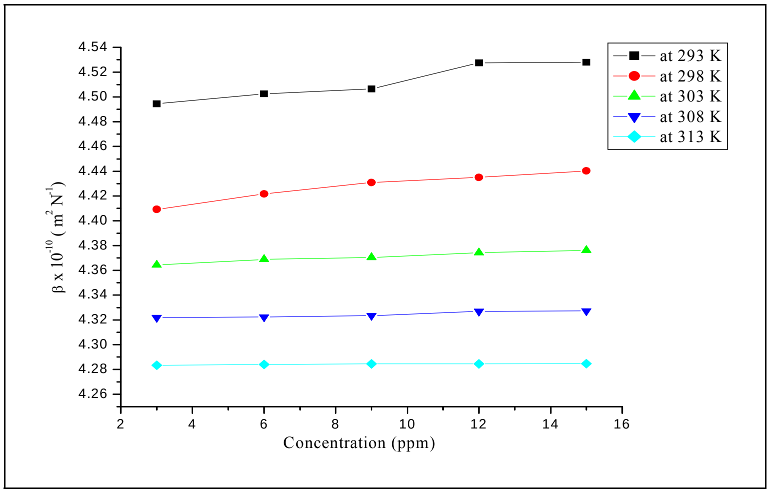
EXPERIMENTAL AND COMPUTED DATA

Table-1: Ultrasonic speeds (U) and acoustical parameters like adiabatic compressibility (β), intermolecular free length (L_f), and relative association RA of Reactive Orange 86 at different temperature.

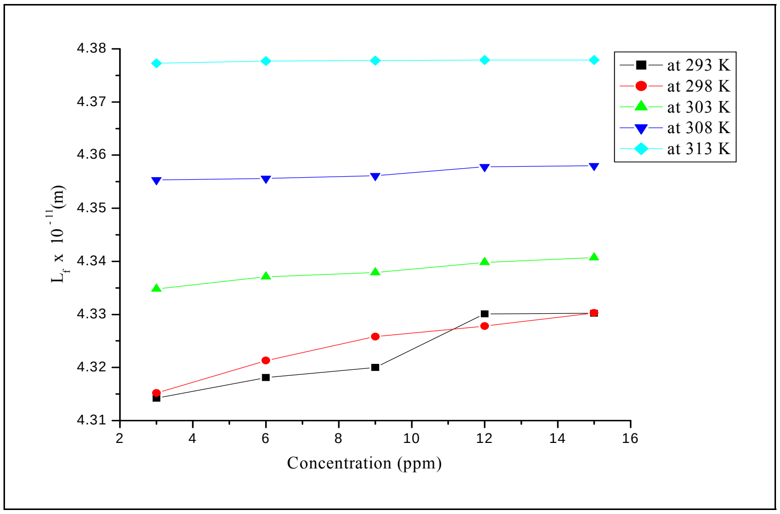
Temp. (K)	**Conc. (ppm)**	**U (ms^{-1})**	**β (10^{-10} m^2N^{-1})**	**L_f (10^{-11} m)**	**RA**
293	3	1493.47	4.4944	4.3142	0.9975
	6	1492.13	4.5025	4.3181	0.9978
	9	1491.47	4.5065	4.3200	0.9980
	12	1488.00	4.5275	4.3301	0.9988
	15	1487.93	4.5279	4.3302	0.9988
298	3	1508.80	4.4093	4.3152	0.9975
	6	1506.67	4.4218	4.3213	0.9980
	9	1505.10	4.431	4.3258	0.9983
	12	1504.40	4.4351	4.3278	0.9985
	15	1503.53	4.4402	4.3303	0.9987
303	3	1516.93	4.3643	4.3348	0.9969
	6	1516.13	4.3689	4.3371	0.9971
	9	1515.87	4.3704	4.3379	0.9971
	12	1515.20	4.3742	4.3398	0.9973
	15	1514.87	4.3761	4.3407	0.9974
308	3	1525.96	4.3218	4.3553	1.0004
	6	1525.87	4.3224	4.3556	1.0005
	9	1525.67	4.3235	4.3561	1.0005
	12	1525.07	4.3269	4.3578	1.0007
	15	1525.00	4.3272	4.3580	1.0007
313	3	1534.27	4.2834	4.3773	0.9999
	6	1534.13	4.2841	4.3777	0.9999
	9	1534.07	4.2845	4.3778	0.9999
	12	1534.06	4.2845	4.3779	0.9999
	15	1534.03	4.2847	4.3779	0.9999



a) Variation of ultrasonic velocity with concentration at different temperature.



b) Variation of adiabatic compressibility with concentration at different temperature.



c) Variation of free length with concentration at different temperature

Figures: Plot of variation of ultrasonic velocity, adiabatic compressibility, and free length with concentration at different temperature.

Result and discussions

Characteristics of the adsorbent

It is observed that, density of the solution increases linearly with the increase in the concentration of the solute for Reactive Orange 86 under investigation at all the temperatures. The density of the solution decreases with increase inthe temperature of the solution which may be due to the movement of solute molecules away from each other at elevated temperature.

As a result, the viscosity of reactive orange 86 solutions decreases with increase in temperature. An examination of Table 1 shows that velocity increases with increase in temperature. With increase in temperature, kinetic energy of molecules increase and less number of molecules will be available in a given space. This results in decrease of density and viscosity with temperature. As the molecules are moving apart, the intermolecular distance increases which results in increase in L_f. The values of acoustical parameters show that RA increase while β decreases with increase in temperature which may be ascribed to the decrease in strength of intermolecular attraction, The increase of L_f and Z with rise in temperature may be attributed to the fact that the attraction and association solution decreases with rise in temperature and intermolecular forces weaken.

Moreover, intermolecular free length is a predominant factor in determining the variation of ultrasonic velocity in solutions. The inter dependence of 'L_f' and 'U' has been evolved from a model for sound propagation proposed by A. Ali *et al* [10]. According to the proposed theory, the decrease in the value of 'L_f' with increase in ultrasonic velocity further strengthens the possibility of dipole-dipole interaction. It can be seen that the acoustic impedance changes similarly with mole fraction and temperature.

The increase in U, L_f and RA can be explained by taking into consideration the fact that the loss of weakly polar association and difference in size and shape of component molecules. Such an increase may also be attributed to lose packing of molecules which may be brought by weakening of intermolecular forces [11]. The free length increases with increase in temperature as expected due to thermal expansion of the liquids [12-13]. The increase in free length for some cryogenic liquids[14-15] was observed by earlier workers. An increase in intermolecular free length suggests a looser packing of molecules or weak interaction [16]. Relaxation time decreases for all used dyes with increases in temperature.

The increase of relative association with concentration of solute in the systems indicates presence of molecular association between solute and solvent with addition of solute, which is in accordance with that reported by Jahagirdar and Shankarwar [17]. Mehrotra and Upadhyaya [18] also observed the increase in relative association for some palmitates in mixed organic solvents. At lower concentration, fewer molecules are available but with increase in the concentration, more and more molecules are getting available for the association.

Conclusion

The density of the solution decreases with increase in the temperature of the solution which may be due to the movement of solute molecules away from each other at high temperature. Also, the interaction decreases at elevated temperature. Thus, dyes are selected at moderate concentration in water at room temperature for further removal so that other interaction will be minimized.

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