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Studies on some of the Acoustic properties of Binary Liquid Mixtures of Benzene and Carbon tetrachloride with Cumene and Pseudocumene

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ABSTRACT

The study of equilibrium properties of the binary system benzene+carbon tetrachloride have been measured as a function of mole fraction by using ultrasonic interferometer at 303.15K and 298.15K to understand the nature of molecular interactions. In this study the theoretical ultrasonic velocities were derived on the basis of Nomoto's relation and ideal mixture relation due to Van Deal. Percentage deviation of ultrasonic velocity from Nomoto's relation, Percentage deviation of Rao's constant, percentage deviation of Wada's constant, molecular interaction term (α) and available volume of Rao's constant (R) have also been calculated. Since excess functions are better measure of the extent of interaction present between the component molecules of any system. It is used in several fields of scientific research in physics, chemistry, biology, medicine and industry.

Keywords: Binary system, Rao's constant, Wada's constant, Van Deal, Interferometer.

INTRODUCTION

This study is concerned with evaluation of some of the acoustic properties of binary liquid mixtures in order to make critical assessment of various theories of liquid-liquid mixture on non-electrolytes i.e. the measurement of experimental ultrasonic velocities and densities have been widely employed in understanding the nature of molecular interaction in liquids[1,2] . The theoretical ultrasonic velocities derived on the basis of Nomoto's relation and ideal mixture relation[3] due to Van Deal, percentage deviation of ultrasonic velocity from Nomoto's relation[4], percentage deviation of Rao's constant[5] ,percentage deviation of Wada's constant[6], molecular interaction term (α) available volume as well as Rao's constant (R)[6] have also been used in understanding the molecular interaction nature of the liquid system. The binary liquid system benzene + carbon tetrachloride gives Nomoto's velocity, ideal mixture velocity, percentage deviation of ultrasonic velocity, Rao's constant and Wada's constant as well as interaction volume (V_a) and molecular interaction. The technique of using ultrasonic instruments is in the tremendous use in measuring the rate of flow of blood through human body and getting images of vital organs of the body like kidney, liver, blood vessel and foetus etc. Some investigators[8,9] have been working for explaining it in terms of the properties of pure liquid. The ultrasonic velocity and density of barium soaps in water and ophthalmic solution in aqueous medium were determined [10,11]. The others

showed molecular interaction studies on fructose amylase solution and acrolein in methanol[12,13] and ultrasonic study of ligand mixture [14,15].

MATERIALS AND METHODS

Carbon tetrachloride and benzene (ARBDH) were vigorously shaken with dilute NaOH solution [16] and conc. H_2SO_4 respectively to remove the impurity present if any. Finally distilled fractionally over P_2O_5. Both cumene and pseudocumene (Fluka Chemika) were distilled thrice by fractional distillation process[17]. The purities of different component liquids were verified by density measurement. Binary liquid mixtures of varying composition were prepared.

The volume of mixing of binary liquid mixtures is given by -

$$V_m = V - x_1v_1 - x_2v_2 \quad \text{----------} \quad (1)$$

where V is the molar volume, v_1 and v_2 are molal volumes of pure components 1and 2 having mole fractions x_1 and x_2 respectively.

RESULTS AND DISCUSSION

Rao's constant (R) can be calculated by using the formula –

$$R = V \cdot u^{1/3} \quad \text{----------} \quad (2)$$

where

V = M/d = Molar volume , M = Molecular mass, d = density , u= ultrasonic velocity.

Wada's constant (W) can be calculated by using equation –

$$W = V \cdot K_s \quad \text{----------} \quad (3)$$

where W = Wada constant, V = Molecular volume, K_s = Adiabatic compressibility

By using equation (2) ultrasonic velocity due to Nomoto's can be given the following equation –

$$U = [x_1R_1 + x_2R_2 / x_1V_1 + x_2V_2] \quad \text{--------} \quad (4)$$

where R1 and R2 are Rao's constants of pure components, v1 and v2 are their molar volumes, x_1 and x_2 are their mole-fractions in binary mixtures. Ultrasonic velocity from Van Deal and Vongeel relation (U_{im}) has been calculated using the equation –

$$[1/x_1M_1 + x_2M_2] U_{im} = x_1/M_1U_1 + x_2/M_2U_2 \quad \text{----------} \quad (5)$$

where M_1 and M_2 are molecular weights of pure components. The percentage deviation of properties are given by the equation –

$$[A_{expt} - A_{theo}/A_{expt}] \% = \Delta A/A \%$$

where A represents the properties such as ultrasonic velocity (U), Rao's constant ($R= V. U^{1/3}$), Wada's constant ($W = V. w^{1/7}$).

$$A_{theo} = x_1A_1 + x_2A_2 \quad \text{----------} \quad (6)$$

where A_1 and A_2 are the concerned properties of liquid (1) and (2) respectively. The molecular interaction term α is given by –

$$\alpha = (U_{expt} V_{im}) - 1 \quad \text{----------} \quad (7)$$

The available volume (V_a) can be calculated by the equation –

$$V_a = V(1-U/U\infty) \quad \text{----------} \quad (8)$$

where U = ultrasonic velocity and U∞ = 1600 m sec^{-1}.

Data for acoustic properties viz. Nomoto's velocity, ideal mixture velocity, percentage deviation of ultrasonic velocity from Nomoto's relation, Rao's constant, available volume and molecular interaction have been recorded in table-1 to 4.

TABLE1. CUMENE + BENZENE, TEMPERATURE 303.15K

Mole-fraction of cumene	Ultrasonic velocity m sec^{-1}	Nomoto' velocity m sec^{-1}	Ideal mix. velocity m sec^{-1}	Δu/u%	ΔR/R%	ΔW/W%	V_a c.c.mol^{-1}	α
0.0000	1272.8	1272.79	1272.79	0.0000	0.0000	0.0000	18.3784	0.0000
0.1180	1271.2	1274.23	1261.70	0.2038	0.0317	–0.0273	19.6807	0.0151
0.2987	1278.0	1276.12	1250.05	0.2105	0.1308	0.1272	21.1157	0.0452
0.3638	1283.6	1276.73	1248.00	0.6033	0.2825	0.2431	21.3631	0.0578
0.6656	1288.0	1279.12	1251.41	0.7460	0.3187	0.2726	23.9850	0.0593
0.7081	1287.8	1279.41	1253.64	0.7029	0.2735	0.2334	24.4236	0.0552
0.9110	1285.4	1280.68	1270.42	0.3849	0.1410	0.1202	26.5722	0.0237
1.0000	1281.2	1281.17	1281.19	0.0000	0.0000	0.0000	27.7913	0.0000

TABLE.2 PSEUDOCUMENE + BENZENE ,TEMPERATURE 303.15K

Mole-fraction of pseudocumene	Ultrasonic velocity m sec^{-1}	Nomoto's velocity m sec^{-1}	Ideal Mix. velocity m sec^{-1}	Δu/u%	ΔR/R%	ΔW/W%	V_a c.c.mol^{-1}	α
0.0000	1272.8	1272.79	1272.79	0.0000	0.0000	0.0000	18.3784	0.0000
0.1060	1276.8	1281.33	1265.29	-0.1549	0.0146	0.0568	19.1920	0.0182
0.3123	1284.4	1295.69	1259.64	-0.4682	-1.1932	0.9280	20.4567	0.0396
0.5122	1307.6	1307.33	1265.19	0.4521	-1.5029	-1.1107	20.5411	0.0681
0.7336	1307.2	1318.23	1284.56	-0.5335	-2.4595	-1.8722	22.5411	0.0355
0.8100	1320.2	1321.58	1294.77	0.1299	0.0872	0.4567	22.4466	0.0393
1.0000	1329.2	1329.19	1329.19	0.0000	0.0000	0.0000	23.2160	0.0000

TABLE3. CUMENE + CARBONTETRACHLORIDE, TEMPERATURE 303.15K

Mole-Fraction of cumene	Ultrasonic velocity m sec^{-1}	Nomoto's velocity m sec^{-1}	Ideal Mix velocity m sec^{-1}	Δu/u%	ΔR/R%	ΔW/W%	V_a c.c.mol^{-1}	α
0.0000	902.2	902.18	902.19	0.0000	0.0000	0.0000	42.6559	0.0000
0.1113	951.2	954.01	932.57	0.7167	-0.0597	-0.0401	41.5515	0.0403
0.2047	988.4	995.35	959.69	0.8719	-0.1725	-0.2042	40.6728	0.0607
0.3366	1025.8	1050.57	1000.94	-0.3871	-0.7027	-0.8440	40.1716	0.0502
0.4130	1051.6	1080.96	1026.55	-0.6777	-0.8154	-1.0954	32.4665	0.0493
0.6108	1107.4	1154.64	1070.20	-2.3743	-1.4478	-1.3651	37.9332	0.0707
0.7200	1144.5	1192.45	1084.48	-2.6719	-1.4234	-0.9186	36.3704	0.1137
0.8210	1174.2	1225.77	1099.73	-3.3270	-2.2600	-1.3800	34.8484	0.1410
1.0000	1281.2	1281.17	1281.19	0.0000	0.0000	0.0000	27.7983	0.0000

TABLE 4. PSEUDOCUMENE + CARBONTETRACHLORIDE, TEMPERATURE 298.15K

Mole-Fraction of pseudocumene	Ulrasonic velocity m sec^{-1}	Nomoto's velocity m sec^{-1}	Ideal Mix. velocity m sec^{-1}	Δu/u%	ΔR/R%	ΔW/W%	V_a c.c.mol^{-1}	α
0.0000	918.4	918.38	918.39	0.0000	0.0000	0.0000	41.6585	0.0000
0.1853	1013.7	1010.91	974.36	1.6818	0.1519	0.6516	38.5374	0.0824
0.3285	1077.6	1077.51	1022.77	1.8969	0.0958	0.8004	36.2055	0.1100
0.3500	1092.5	1087.15	1030.48	2.4090	0.2689	0.9620	35.4280	0.1241
0.5330	1186.9	1165.74	1102.59	3.6532	0.7114	1.3592	30.7051	0.1587
0.7112	1276.8	1236.60	1154.77	4.5411	1.1571	1.5663	25.4358	0.2225
0.7281	1291.4	1243.04	1186.82	5.0681	1.3555	1.7135	24.4172	0.1839
0.8010	1314.6	1270.34	1226.32	4.4011	1.2107	1.2255	23.0908	0.1491
0.9000	1330.6	1306.10	1280.52	2.4079	0.6075	0.9677	22.4342	0.0797
1.0000	1340.8	1340.78	1340.79	0.0000	0.0000	0.0000	22.2211	0.0000

The analysis of results of the acoustic parameters, U_{Nomoto} and V_{id} which are ultrasonic velocities due to Nomoto and Van Deal Vongeel respectively. The percentage deviation of ultrasonic velocities from Nomoto's velocity is Δu/u%. The percentage deviation of Rao's constant is ΔR/R%. The percentage deviation of Wada's constant is ΔW/W%. V_a, the available volume and α, the molecular interaction term have been calculated and enlisted in the tables . Molecular interaction term (α) has been plotted against mole fraction of cumene/pseudocumene for the binary mixtures at temperature 303.15K (fig.1) shows the extent of molecular interaction existing in binary liquid mixtures under investigation.

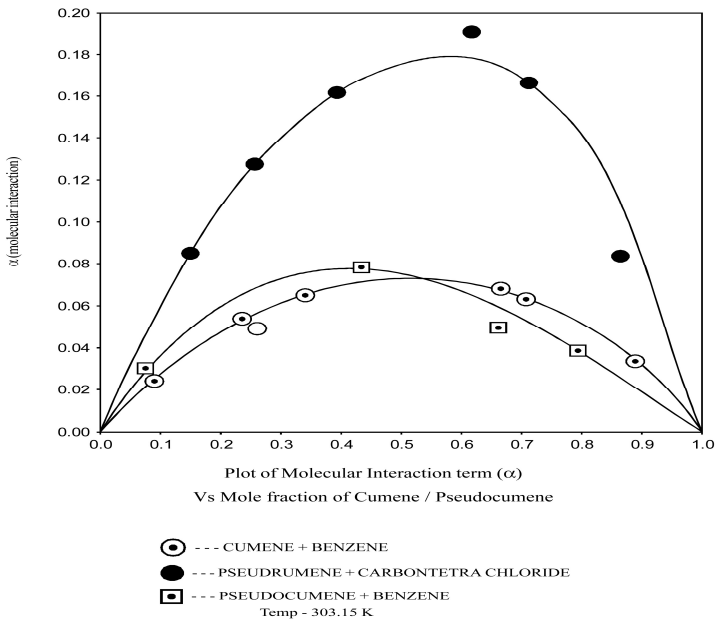

Fig 1. α vs mole fraction of cumene/pseudocumene for the binary mixtures.

APPLICATIONS

This method can be applied for the determination of the nature of molecular interaction between the liquids of binary liquid mixtures. It can also be used to make critical assessment of various theories of liquid-liquid mixture on non-electrolytes.

CONCLUSIONS

Molecular interactions (α) have been calculated for our binary systems to assess the extent of net molecular interactions in all our binary systems. All of these except pseudocumene + benzene are found to be positive in sign for binary systems under investigation. The extent of molecular interactions for cumene + benzene and pseudocumene + benzene is nearly the same while this has been found much higher in case of pseudocumene + carbon tetrachloride. This further suggests the complex formation between pseudocumene and carbon tetrachloride.

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