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Surface Tension of Binary Mixtures.

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ABSTRACT

Measurements of thermodynamic and transport properties have been adequately employed in understanding the nature of molecular systems and physico-chemical behaviour in liquid mixtures. These properties are important from practical and theoretical point of view to understand liquid theory. Surface tension (σ) , Density (ρ) and Excess Molar Volume (V^E) have been measured for binary liquid mixture at room temperature .Various combination of chemicals like Benzene, Aniline , Acetone , Carbon tetrachloride and Ethyl alcohol were used for making the binary mixtures over various composition range. The deviation level from purity of each compound was compared and studied .The molecular interactions existing between the components were also discussed.

Keywords: Surface tension; Density; Excess properties; Molecular interactions.

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INTRODUCTION

The study of surfaces has received increasing attention in many scientific arena such as chemistry and chemical engineering, environmental sciences, material sciences, physics, and electronics. The thermo physical property that has been most widely used to characterize surfaces is the surface tension[1].Surface tension plays a significant role in several industries, such as paints, detergents, agrochemicals, and petroleum. In extraction processes, oil has to travel through capillary channels, and this type of flow is strongly dominated by surface tension effects. Binary liquid mixtures due to their unusual behaviour have attracted considerable attention. Data on some of the properties associated with the liquids and liquid mixtures like surface tension and densities find extensive application in chemical engineering process simulation, solution theory and molecular dynamics. These properties are important from practical and theoretical point of view to understand liquid theory. The main objective of this work was to determine surface tension of some pure and binary mixtures, not available in the literature or for which the reported data was incomplete .The values of surface tension were plotted to their composition and their deviation were studied. Literature survey showed that no measurements have been previously reported for the mixture studied in this paper [2,3].

MATERIAL AND METHODS

The chemicals used were of analytical grade. All the measurements were done by using electronic balance Shimadzu Corporation Japan Type BL 2205 accurate to 0.01 g. The possible uncertainty in the mole fraction was estimated to be less than ±0.0001.

Surface tension

Surface tension of pure liquids and binary mixtures over the whole composition range was determined using Interfacial tensiometer (ASTM D.971) with 1No. 1cm platinum ring as per IS 6104 with reference to [6]. All samples were equilibrated at 308.15 K under atmospheric pressure. It was calibrated with distilled water. The accuracy of the surface tension measurement was estimated to be 0.03mNm^{-1}.The excess properties have been studied with help of the equation mentioned below.

$$\Delta\sigma = \sigma - (x1\sigma - \sigma\ 1 + x2\ \sigma\ 2) \quad \text{--(1)}$$

Where σ, σ1 and σ2 are the surface tension of the mixture, surface tension of pure components 1 and 2 respectively

Density (ρ) and Excess Molar Volume (V^E)

The density of some equimolar binary mixtures were determined by using specific gravity bottle and calibrated with deionised double distilled water with 0.9960 x 10^3 Kg.m^{-3} as its density at temperature 308.15 K. The specific gravity bottle was filled with air bubble free experimental liquids and weight was measured in electronic weighing machine. The experimentally determined mass(M) data have been used to calculate the density(ρ).

The determined density data have been used to calculate the excess molar volumes, V^E, using the following equation

$$V^E = (x_1M_1 + x_2 M_2) / \rho_m - (x_1M_1 / \rho_1 + x_2 M_2 / \rho_2) \quad \text{-- (2)}$$

Where x1 and x2 refer to the mole fraction of components 1 and 2. ρ1, ρ2 and ρm refer to the Density of pure components 1, 2 and mixture respectively.

RESULTS AND DISCUSSION

Table 1 lists the measured surface tension value and the calculated deviation of surface tension of benzene and its binary mixtures .Similarly table 2, 3, 4 and 5 lists the measured and calculated surface tension deviation of aniline, acetone, carbon tetra chloride and ethyl alcohol respectively. Table 6 and 7 lists the calculated value of Density and excess molar volume of equimolar binary mixtures of benzene and aniline respectively. A detailed observation of the Table 1 shows that the surface tension of the benzene binary mixture increases with decrease in mole fraction for aniline and acetone .Whereas the surface tension of benzene binary mixture decreases with decrease in mole fraction for ethyl alcohol and carbon tetra chloride. According to Karla Granados strong interaction in the liquid mixture decreases the σ value of the mixture. This means that interactions in the mixture are strong when benzene was mixed with less viscous chemicals .From table 2 it is observed that the surface tension of aniline mixtures increases with decrease in its mole fraction, this shows that there is no strong interaction in the liquid mixtures of aniline. From table 3 it is observed that the surface tension of acetone mixtures decreases with decrease in its mole fraction, this shows that there is a strong interaction in the liquid mixtures of acetone. From table 4 and 5 it is observed that the surface tension of carbon tetra chloride and ethyl alcohol mixtures increases with decrease in its mole fraction ,this shows that there is no strong interaction in the liquid mixtures [4-6].

Table 1: Surface Tension and its Deviation in Binary mixture (Benzene).

MOLE FRACTION OF BENZENE	BINARY MIXTURE	SURFACE TENSION (σ) (Dynes/cm)	DEVIATION(Δσ)= σ - (x1σ – σ 1 + x2 σ 2)*10^3 (Dynes/cm)
1	BENZENE+ANILINE	17.6	0.0352
0.8		22.6	0.0362
0.6		23.0	0.0326
0.4		24.4	0.03
0.2		25.3	0.0269
0		20.0	0.0176
1	BENZENE+ACETONE	17.6	0.0352
0.8		21.0	0.03618
0.6		22.0	0.03256
0.4		21.0	0.02994
0.2		19.0	0.02682
0		20.10	0.0175
1	BENZENE+CCl_4	17.6	0.0352
0.8		16.6	0.03714
0.6		16.4	0.03448
0.4		15.5	0.03282
0.2		15.4	0.03066
0		15.3	0.0223
1	BENZENE+ETHYL ALCOHOL	17.6	0.0352
0.8		16.9	0.0372
0.6		16.6	0.0346
0.4		16.2	0.033
0.2		15.7	0.0309
0		15	0.0226

Table 2: Surface Tension and its Deviation in Binary mixture (Aniline).

MOLE FRACTION OF ANILINE	BINARY MIXTURE	SURFACE TENSION (σ) (Dynes/cm)	DEVIATION(Δσ)= σ - (x1σ – σ 1 + x2 σ 2)*10^3 (Dynes/cm)
1	ANILINE+ETHYL ALCOHOL	20	0.02
0.8		24.5	0.0219
0.6		21.4	0.02256
0.4		19.5	0.0227
0.2		17.5	0.022
0		15	0.02
1	ANILINE+BENZENE	17.6	0.02
0.8		22.6	0.02052
0.6		23.0	0.0212
0.4		24.4	0.02264
0.2		25.3	0.02424
0		20.0	0.02
1	ANILINE+ACETIC ACID	20	0.02
0.8		21.7	0.02106
0.6		20.2	0.02152
0.4		19.5	0.02186
0.2		18	0.02128
0		16.4	0.02
1	ANILINE+CCl_4	20	0.02
0.8		21.6	0.02126
0.6		21.5	0.02248
0.4		21.4	0.02366
0.2		19	0.02296
0		15.3	0.02
1	ANILINE+NITROBENZENE	20	0.02
0.8		24.7	0.01944
0.6		26.1	0.01944
0.4		26.8	0.01958
0.2		26.9	0.01952
0		27.5	0.02

Table 3: Surface Tension and its Deviation in Binary mixture (Acetone).

MOLE FRACTION OF ACETONE	BINARY MIXTURE	SURFACE TENSION (σ) (Dynes/cm)	DEVIATION(Δσ)= σ - (x1σ – σ 1 + x2 σ 2)*10^3 (Dynes/cm)
1	ACETONE+ETHYL ALCOHOL	20.1	0.0201
0.8		18.9	0.02088
0.6		17.5	0.0211
0.4		17.4	0.02154
0.2		17	0.0217
0		15	0.0201
1	ACETONE+BENZENE	20.1	0.0201
0.8		19	0.02038
0.6		21	0.02146
0.4		22	0.02274
0.2		21	0.02282
0		17.6	0.0201
1	ACETONE+CCl_4	20.1	0.0201
0.8		20	0.02104
0.6		19	0.02158
0.4		23.5	0.02502
0.2		19.4	0.02338
0		15.3	0.0201

Table 4: Surface Tension and its Deviation in Binary mixture (CCl_4).

MOLE FRACTION OF CCl_4	BINARY MIXTURE	SURFACE TENSION (σ) (Dynes/cm)	DEVIATION(Δσ)= σ - (x1σ – σ 1 + x2 σ 2)*10^3 (Dynes/cm)
1	CCl_4+ANILINE	15.3	15.3
0.8		19	15.1
0.6		21.4	15.86
0.4		21.5	16.2
0.2		21.6	16.58
0		20	15.3
1	CCl_4+BENZENE	15.3	15.3
0.8		15.4	14.86
0.6		15.5	14.46
0.4		16.4	14.58
0.2		16.6	14.5
0		17.6	15.3
1	CCl_4+ACETONE	15.3	15.3
0.8		19.4	15.16
0.6		23.5	16.66
0.4		19	14.64
0.2		20	15.22
0		20.10	15.3

Table 5: Surface Tension and its Deviation in Binary mixture (Ethyl alcohol).

MOLE FRACTION OF ETHYL ALCOHOL	BINARY MIXTURE	SURFACE TENSION (σ) (Dynes/cm)	DEVIATION(Δσ)= σ - (x1σ – σ 1 + x2 σ 2)*10^3 (Dynes/cm)
1	ETHYL ALCOHOL +ANILINE	20	0.015
0.8		24.5	0.0186
0.6		21.4	0.01584
0.4		19.5	0.0148
0.2		17.5	0.0145
0		15	0.015
1	ETHYL ALCOHOL +BENZENE	17.6	0.015
0.8		16.9	0.01444
0.6		16.6	0.0144
0.4		16.2	0.01444
0.2		15.7	0.01462
0		15	0.015
1	ETHYL ALCOHOL +ACETONE	20.1	0.015
0.8		18.9	0.01404
0.6		17.5	0.01344
0.4		17.4	0.01392
0.2		17	0.01438
0		15	0.015

Table 6: Variance in Excess Molar Volume (V^E) of equimolar binary mixtures (Benzene)

EQUIMOLAR BINARY MIXTURES		Density(ρ_m)	Excess Molar volume (V^E)
BENZENE+	ETHYL ALCOHOL	805	-1.7898*10^{-3}
	ANILINE	1124.5	-0.021171
	CCl_4	1084.5	-2.6115*10^{-3}

Table 7: Variance in Excess Molar Volume (V^E) of equimolar binary mixtures (Aniline)

EQUIMOLAR BINARY MIXTURES		Density(ρ_m)	Excess Molar volume(V^E)
ANILINE +	BENZENE	1124.5	-0.02117
	NITROBENZENE	1069	-4.39547*10^{-3}
	ETHYL ALCOHOL	850.5	9.847577*10^{-4}
	CCl_4	1121	-1.32127*10^{-3}

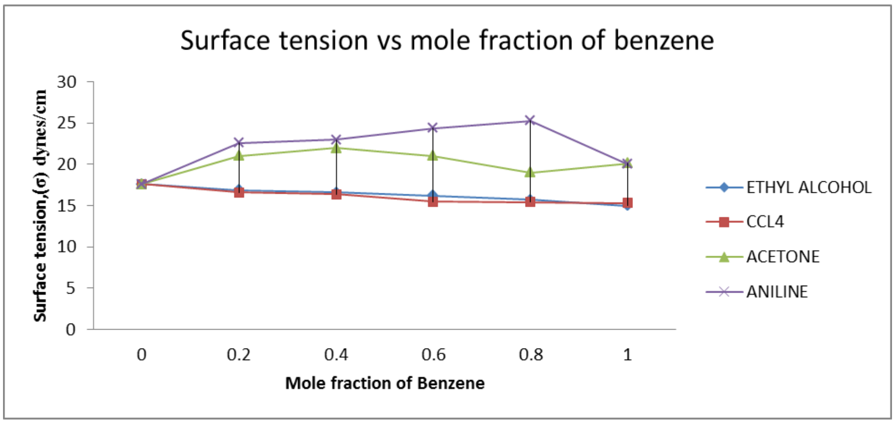

Figure 1: Surface tension of Benzene with its Binary Mixtures at Different Compositions.

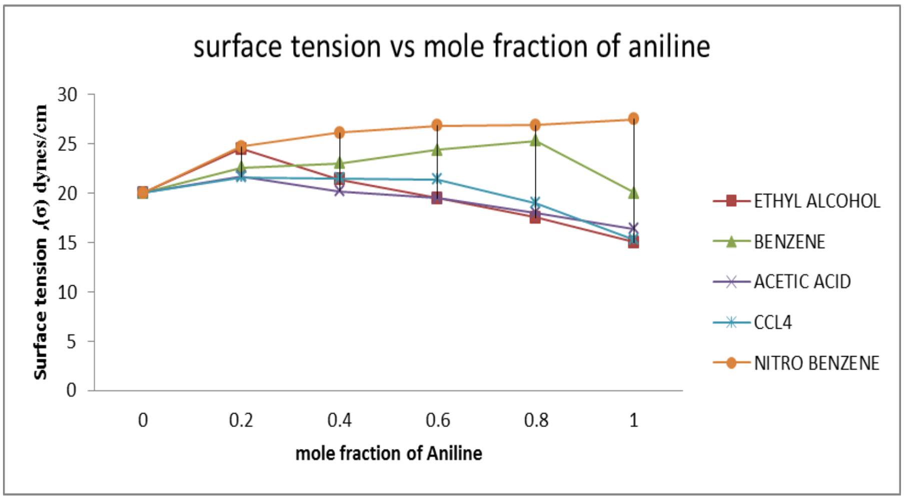

Figure 2: Surface tension of Aniline with its Binary Mixtures at Different Compositions.

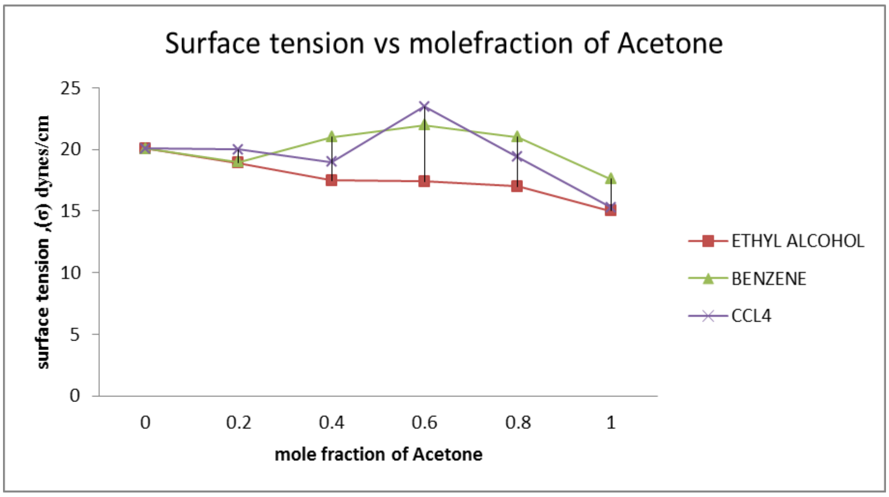

Figure 3: Surface tension of Acetone with its Binary Mixtures at Different Compositions.

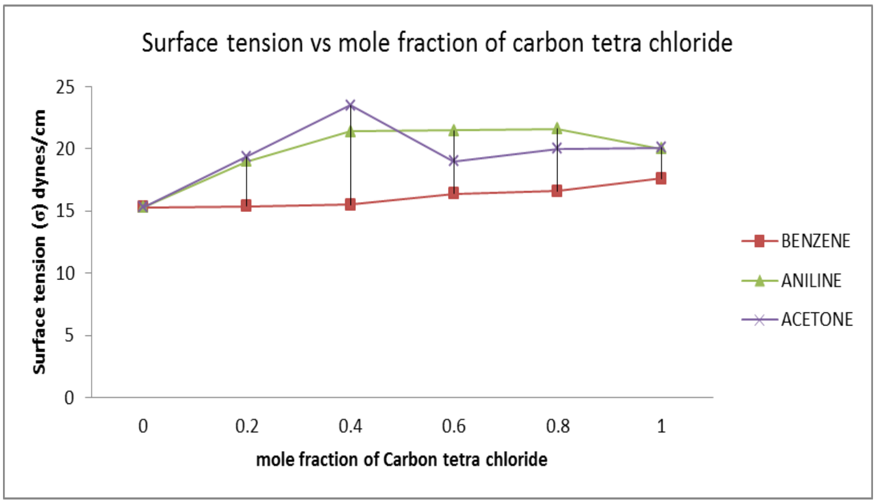

Figure 4: Surface tension of CCl_4 with its Binary Mixtures at Different Compositions.

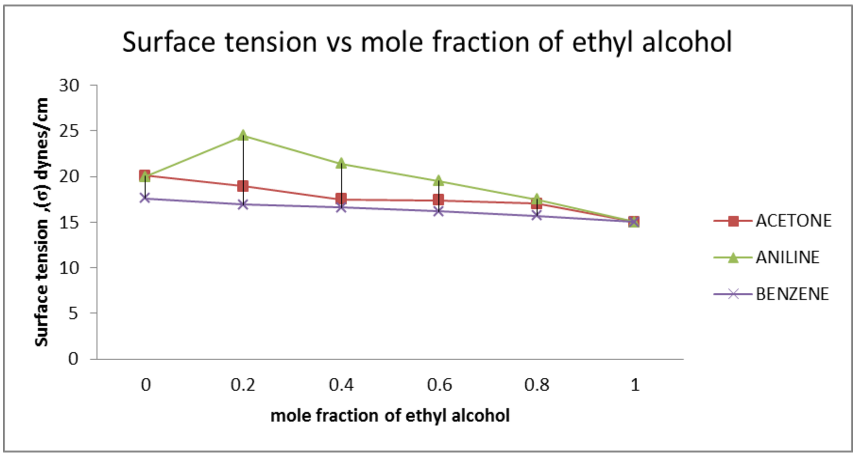

Figure 5: Surface tension of Ethyl alcohol with its Binary Mixtures at Different Compositions.

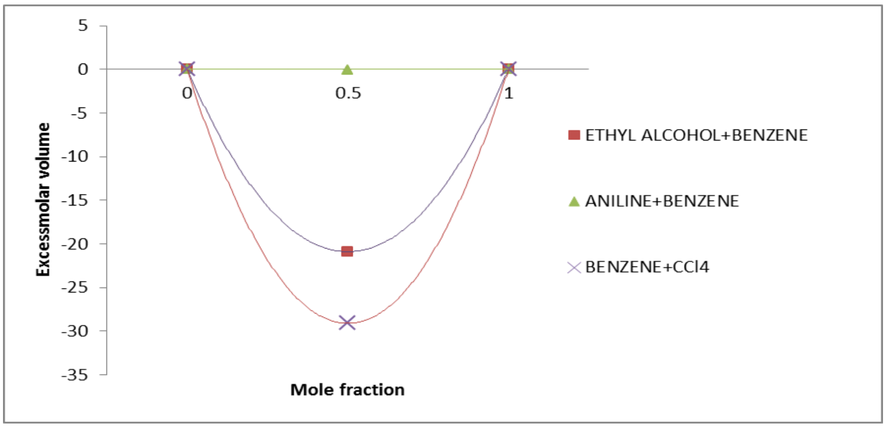

Figure 6: Variance in Excess Molar Volume (V^E) of equimolar binary mixtures (Benzene)

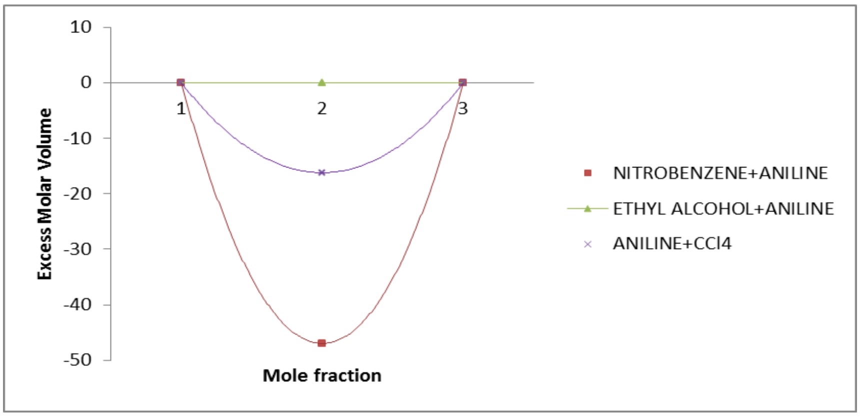

Figure 7: Variance in Excess Molar Volume (V^E) of equimolar binary mixtures (Aniline)

It is said that excess values may be affected by three factors. The first factor is the specific forces between molecules, such as hydrogen bonds, charge transfer complexes, breaking of hydrogen bonds and complexes bringing negative excess value. The second factor is the physical intermolecular forces, including electrostatic forces between charged particles and between a permanent dipole and so on induction forces between a permanent dipole and an induced dipole and forces of attraction and repulsion between non polar molecules. Physical intermolecular forces are weak and the sign of excess value may be positive and negative. Third factor is the structural characteristics of the component arising from geometrical fitting of one component in to other structure due to the differences in shape and size of the components and free volume. Our study shows that excess molar volume of benzene follows first order because of specific strength of inter molecular forces and the sign of excess values are negative .On the other hand aniline binary system follows the above mentioned second factor and hence physical intermolecular forces are weak and the sign of excess values are positive or negative. In the present investigation the behaviour of these systems has been interpreted qualitatively.

CONCLUSION

Experimental data of the surface tension and density of various binary mixtures have been measured. And these data have been used to compute the excess properties of the system. The surface tension of the benzene binary mixture increases with decrease in mole fraction for aniline and acetone .Whereas the surface tension of benzene binary mixture decreases with decrease in mole fraction for ethyl alcohol and carbon tetra chloride. This means that interactions in the mixture are strong when benzene was mixed with less viscous chemicals .The surface tension of acetone mixtures decreases with decrease in its mole fraction ,this shows that there is a strong interaction in the liquid mixtures of acetone .The surface tension of aniline , carbon tetra chloride and ethyl alcohol mixtures increases with decrease in its mole fraction ,this shows that there is no strong interaction in the liquid mixtures.

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