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Density, Viscosity, Molar Volume, Speed of Sound and Excess Properties for the Binary Mixtures of 3-Bromoanisole and Methanol at 293.15 K Temperature

Abstract: *Experimental values of density, viscosity and speed of sound at 293.15 K temperature for the binary mixtures of 3-bromoanisole (3-BA) with methanol (MeOH) were presented over the whole range of mixture composition. From these data, excess molar volume, excess viscosity and excess speed of sound have been calculated. The excess results were fitted to the Redlich-Kister (RK) type polynomial equation.*

Introduction

Physical properties of liquid mixtures are required in most engineering calculations where fluid flow or mixing is an important factor in many practical problems concerning mass transport applications [1,2]. From the measured physical properties, excess properties of the binary mixtures can be calculated. To understand the nature of molecular interactions the excess functions of physical parameters of binary liquid mixtures are considerably important [3]. Many attempts have been made by researchers to understand the nature and degree of interactions in liquid mixtures using excess properties [2,4-6]. 3-bromoanisole (3-BA) is a derivative of anisole and is an aromatic compound of the ether group. Anisole and its derivatives are used as solvents and are useful in chemical reactions as intermediates to obtain target materials like dyes, perfumery, agrochemicals and pigments [7,8]. On the other hand, methanol (MeOH) is an associative liquid and are wildly used in industrial fields like oil industry, refrigeration, air conditioning and others [2]. Physical properties of anisole with different solvents have been reported by many researchers [1,2,9,10]. But no such study of bromo-substituted anisole is reported in literature. The focus of the present study is to see the effects of concentration variation on the physical properties of the mixture constituents (MeOH and 3-BA) and also to understand the molecular interaction with the help of physical properties and its excess function.

Chemicals, Sample Preparation and Measurements

3-BA (extra pure, 99% purity) and MeOH (HPLC grade, 99.7 purity) were supplied by Spectrochem Pvt. Ltd. (India) and Ranbaxy Pvt. Ltd. (India) respectively. Total eleven different binary mixture samples were prepared by volume fraction of 3-BA in MeOH. Density of pure liquids and their mixtures were measured using double arm Pycnometer and a capillary bore with an internal diameter of 1 mm. The densities are accurate to ±0.1 kg m^{-3}. Viscosity of pure liquid and their binary mixtures were measured using the Ostwald viscometer. The error in the measurement of viscosity is within ±0.1%. Speed of sound were measured with an ultrasonic interferometer (Model F-81s). The temperature was maintained using a constant temperature water bath with an accuracy of ± 0.1 K.

Evaluation of Different Parameters

The measured density (In TABLE 1) was used to find the molar volume of the mixture and were calculated from following equation [11]

$$V_m = \frac{X_1M_1+X_2M_2}{\rho_m} \qquad 1$$

Where X is mole fraction, M is molecular weight and suffix 1, 2 represent compound 3-BA and MeOH respectively. The excess of molar volume, viscosity and speed of sound of these binary mixtures were calculated using the general relation [11]

$$A^E = A_m - (A_1X_1 + A_2X_2) \quad 2$$

Where A cab be taken as molar volume (V), viscosity (η) and speed of sound (u).

Different excess parameters were fitted to following Redlich-Kister equation [11, 8]

$$Q = X_1X_2 \sum_i B_i(X_1 - X_2)^i \quad 3$$

Where i = 0, 1, 2,...n. and B is Redlich-Kister coefficient. The B_i coefficients (where i=0, 1, 2 and 3) and standard deviation (σ) of the Redlich-Kister equation for liquid mixture are reported in TABLE 2.

Results and Discussion

The measured density, viscosity, speed of sound and molar volume for the binary mixture of 3-BA and MeOH at 293.15 K temperature are reported in TABLE 1. The behavior of density and viscosity shows nonlinear variation with increase in mole fraction of 3-BA in the mixture and it is shown in FIGURE 1. The measured density of MeOH is 0.7912 gcm^{-3} at 293.15 K and that of in literature is 0.79119 gcm^{-3} [12] at the same temperature. The experimental density of pure MeOH shows good agreement with literature. However literature value of density of 3-BA at 293.15 K temperature is not available for comparison. The value of molar volume of binary mixture of 3-BA and MeOH is found to increase with increase in mole fraction of 3-BA in the mixture.

TABLE 1: Density (ρ), viscosity (η), speed of sound (u) and molar volume (V_m) of the binary mixture of 3-BA and MeOH at 293.15 K.

X_1	ρ (gcm^{-3})	η (mPas)	u (m/s)	V_m (cm^3mol^{-1})
0	0.7912	0.6301	1132	40.4954
0.0347	0.8825	0.6815	1115	42.4087
0.0749	0.9598	0.7737	1118	45.4793
0.1219	1.0493	0.8694	1133	48.5416
0.1776	1.1265	0.9609	1149	52.8793
0.2447	1.2146	1.1333	1170	57.6049
0.3270	1.2945	1.3192	1196	63.9081
0.4305	1.3753	1.4921	1220	71.8130
0.5644	1.4328	1.6708	1249	83.4179
0.7446	1.4862	1.9184	1257	99.2123
1	1.4962	2.2351	1250	125.0095

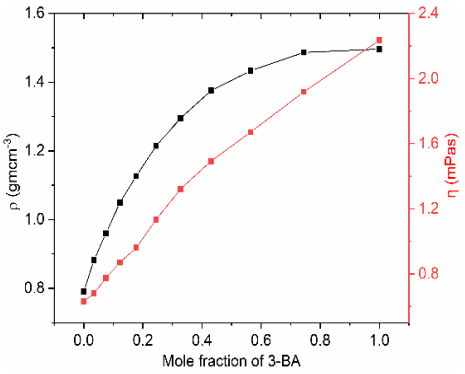

FIGURE 1: Plot of density and viscosity as function of mole fraction of 3-BA in MeOH at 293.15 K temperat.

FIGURE 2 shows the plot of excess molar volume for the binary mixture of 3-BA and MeOH at 293.15 K temperature. The negative value of V_m^E over the entire concentration range is attributed to specific interactions of the H-bond type between the 3-BA and MeOH compound [13]. Excess viscosity (η^E) as function of 3-BA in MeOH at 293.15 K is shown in FIGURE 3. The η^E plot shows initially negative and then positive value with increase in the mole fraction of 3-BA. Similar behavior was observed by Aminabhavi *et al.* [14] in system of ethenylbenzene with bromoform and dioxane at 298.15 K temperature. The value of the excess of speed of sound in FIGURE 4 very from negative to positive with mole fraction of 3-BA in mixture. The data of u^Ereported by Aminabhavi *et al.* [14] shows quiet similar behavior for the system of ethenylbenzene + dioxane.

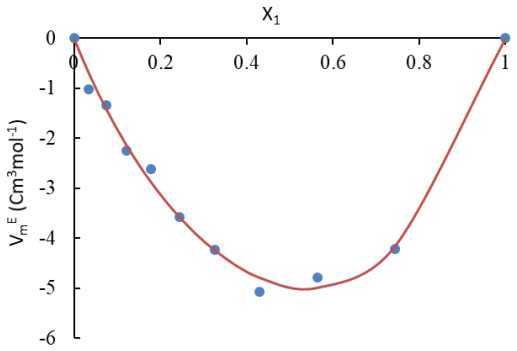

FIGURE 2: Plot of excess molar volume (V_m^E) versus mole fraction of 3-BA (X_1) in MeOH at 293.15 K temperature. Continuous lines shows the fitted line of Redlich–Kister equation.

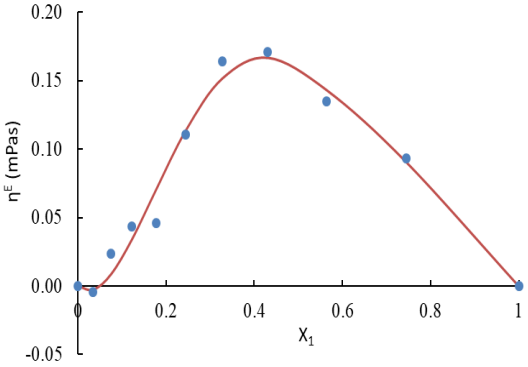

FIGURE 3: Plot of excess viscosity (η^E) versus mole fraction of 3-BA (X_1) in MeOH at 293.15 Ktemperature. Continuous lines shows the fitted line of Redlich–Kister equation.

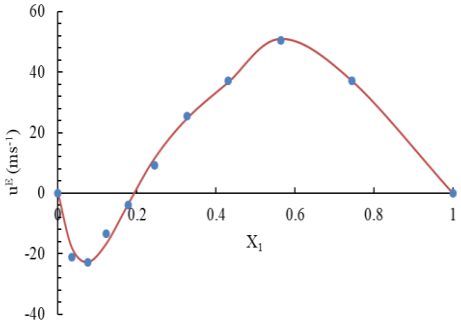

FIGURE 4: Plot of excess speed of sound versus mole fraction of 3-BA (X_1) in MeOH at 293.15 K temperature. Continuous lines shows the fitted line of Redlich–Kister equation

TABLE 2: Coefficients of Redlich–Kister equation and standard deviation

RK cofficients	V_m^E (cm^3mol^{-1})	η^E (mpas)	u^E (ms^{-1})
B_0	-19.8917	0.6351	177.2466
B_1	2.8949	0.3876	-225.9988
B_2	-2.9455	-0.3414	114.5582
B_3	-1.4556	-0.9592	417.4978
B_4	-	-	-1249.8748
σ	0.2084	0.0131	2.1811

Conclusion

The concentration dependent density, viscosity, speed of sound and molar volume for the binary mixture of 3-BA and MeOH were reported at 293.15 K temperature. The density and viscosity of the studied system increase nonlinear with an increase mole fraction of 3-BA in MeOH. The speed of sound and molar volume increases with an increase mole fraction of 3-BA in MeOH. The excess of molar volume, excess viscosity and excess speed of sound were calculated and fitted to the Redlich-Kister equation. The values of excess molar volume are positive for the liquid mixture. The excess value of viscosity and speed of sound very negative to positive with an increase mole fraction of 3-BA in MeOH.

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