ISSN: 0974-2115
www.jchps.com Journal of Chemical and Pharmaceutical Sciences

Experimental Measurement of Transport properties and Thermodynamic Consistency Test of Binary Liquid Mixtures

K. Sathya[1*], R. Baskaran[2], T. R. Kubendran[3]
[1]Department of Biotechnology, Rajalakshmi Engineering College, Chennai-602105.
[2]Department of Chemical Engineering, St.Joseph's College of Engineering, Chennai-600119.
[3]Department of Chemical Engineering, A.C. College of Technology, Anna University, Chennai-600025.
***Corresponding author: E-Mail: sathyak80@gmail.com**

ABSTRACT

The chemical process industries utilizes materials mostly in fluid form, thereby the physical, chemical, and transport properties of fluids presume to be significant. Using mass transfer operations like distillation and extraction, the fluid mixtures are segregated into various components. The quantitative estimation of fluid mixture properties are essential for the design of such operations. In the present scenario, there is a considerable growth in the studies on molecular interactions and the structure of liquid mixture. To examine the relation that exists between the internal structure and its physical properties, the transport property of the liquid mixture within wide range of composition and temperature are used as worthful source. In this research, density and viscosity and ultrasonic velocity of Para anisaldehyde – methyl acetate binary mixture was measured over the entire mole fractions at (308.15, 318.15 and 328.15) K. Thermodynamic consistency of experimental data was tested using Redlich-Kister method at different temperatures.

KEY WORDS: Viscosity, Density, Thermodynamic consistency.

1. INTRODUCTION

The thermodynamic, sound and transport properties are used to study the interaction between the different molecules found in the mixture. Those properties can also be used to understand the engineering applications corresponding to heat transfer, mass transfer and fluid flow. The measurement of thermo physical properties associated in the liquid and its mixtures posse's wide usage in solution theory and molecular dynamics. The obtained results are essential for elucidation of thermo chemical, biochemical and kinetic studies. The applications of the present study under investigation are listed below.

a) Used in pharmaceuticals and perfumery as an intermediate for synthesis of organic compound.
b) In thin layer chromatography, para anisaldehyde in acid and ethanol used as staining agent.
c) Alkyl acetates can be applied as staining agent, synthetic fruit flavoring in food and also as a solvent for personal care products.

2. MATERIALS AND METHODS

Only analytical grade chemicals obtained from Lobo Chemie Pvt. Ltd., India, were used for this study, were degasified and dehydrolysed before usage. The purity of chemicals was verified by matching the observed physical properties with the literature. Binary system was made by addition of suitable volumes of the liquid species in the air tight glass bottles with Teflon coated caps and mass size were carried on a BL 2205 electronic balance - Shimadzu Corporation Japan, by accuracy of ± 0.01 mg.

The necessary properties are calculated instantaneously with the prepared composition. The uncertainty of the mole fraction was ± 0.001. For all measurements, temperatures were maintained by flowing the water throughout a thermostat (Technico, Madras, India) by maintaining the temperature variations within ±0.03K.

2.1. Density: The 25cm^3 bicapillary pycnometer was used for determining density of the liquid mixture. The calibration of pycnometer was done by deionized DD water of a density of 996.0 kg ·m^{-3} at a temperature of 308.15 K. The constant temperature was maintained in a thermostat for 15 min to attain thermal equilibrium. To obtain the liquid level, the travelling microscope which could read to 0.01 mm was used. The sensitivity of the density measurements was approximated to be ± 0.03 g ·cm$^{-3.}$

2.2. Viscosity: The Ostwald viscometer was used to evaluate the viscosities of liquid mixture which was previously calibrated using water. The time was noted with an accuracy of 0.01s, and the uncertainty in the viscosity was found to be less than 0.03 mPa·s. The kinematic viscosity was obtained from the following equation

$$\vartheta = a\,t + b/t \qquad (1)$$

Where the two constants a, b were calculated by quantifying the flow time t of benzene.

2.3. Sound Speed: The variable path monocrystal interferometer (Mittal Enterprises, New Delhi) at a rate of 2 MHz was used to determine the ultrasonic velocity of binary system. The interferometer was standardized using toluene. The interferometer cell was packed by means of the reference liquid, and the temperature of the solution was maintained constant within ± 0.01 K by flow of liquid through the water jacketed cell. The ambiguity was found to be 2 ms^{-1}.

3. RESULTS AND DISCUSSION

The excess Gibbs free energy of binary system was estimated from equation (2)

$$\Delta G^E = RT\,[\ln(\eta V_m) - (X_1 \ln(\eta_1 V_1) + X_2 \ln(\eta_2 V_2))] \quad (2)$$

Where R is the universal gas constant, T is the absolute temperature, V_1 and V_2 are the molar volumes of component 1 and 2, x_1 and x_2 represents the mole fraction of component 1 and 2. V_m is obtained from equation (3), $\eta 1$, η_2 and η_m are the viscosity of component 1 and 2 and mixture respectively.

$$V_m = x_1 m_1 + x_2 m_2 / \rho_m \quad (3)$$

Where ρm is the density of mixture.

The excess Gibbs free energy was estimated from the experimental statistics has been used to check the thermodynamic consistency by using Redlich-Kister method. The values of densities, viscosities and ultrasonic velocities of binary system at various temperatures are measured and shown in the figures 1, 2 and 3. The variation of viscosity, density and ultrasonic velocity with the mole fraction of component 1 is also depicted in the same figures.

The result shows that the decrease in density, viscosity and ultrasonic velocity is due to more molecular interaction between the binary liquid mixtures. These thermo physical properties provide the information about the molecular interactions and macroscopic behaviour of fluid mixtures which can be used to test and improve thermodynamic models for calculating and predicting fluid phase equilibrium. The magnitude of ΔG^E represents the strength of interaction among unlike molecules.

For all temperatures, excess Gibbs free energy was observed to be +ve. The +ve values show the occurrence of specific and strong interaction in the system. The calculated excess Gibbs free energy was helpful to obtain the activity coefficient of liquid mixture. The net area of curve shown in figures 4, 5 and 6 was calculated, which was zero shows that all experimental data were thermodynamically consistent according to Redlich-Kister method.

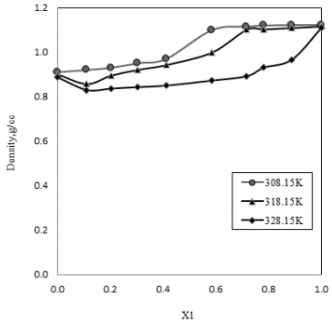

Fig.1.Effect of temperature on density of Paraanisaldehyde – methyl acetate mixture

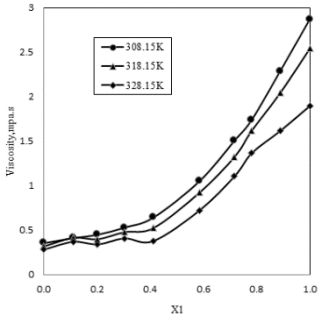

Fig.2.Effect of temperature on viscosity Paraanisaldehyde – methyl acetate mixture

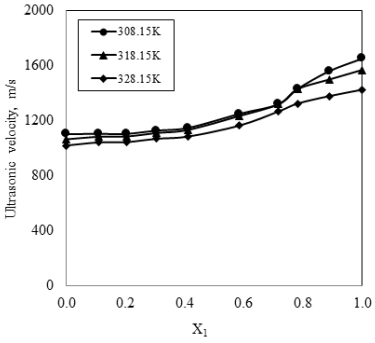

Fig.3.Effect of temperature on Ultrasonic velocity Paraanisaldehyde – methyl acetate mixture

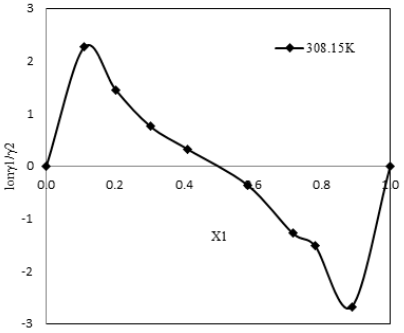

Fig.4.Thermodynamic consistency test at 308.15K

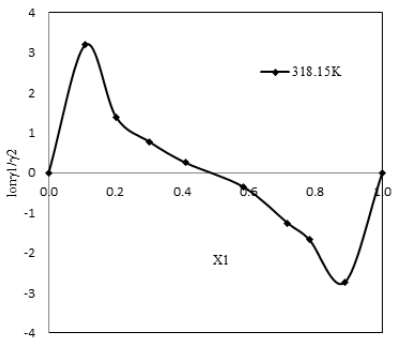

Fig.5.Thermodynamic consistency test at 318.15K

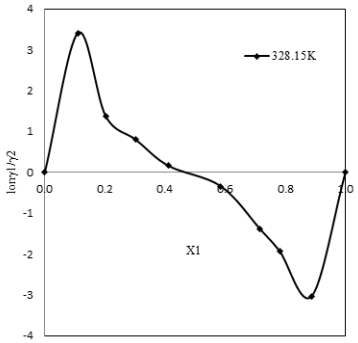

Fig.6.Thermodynamic consistency test at 328.15K

4. CONCLUSIONS

Densities, viscosities and ultrasonic velocities of Para anisaldehyde – methyl acetate binary mixture was deliberated experimentally at different temperature over wide concentration range. The effects of temperature on densities, viscosities and ultrasonic velocities on mixture have been reported.

There is intermolecular interaction among the species of the binary mixtures leading to hydrogen bond formation between the unlike molecules confirming hydrogen bonding formation between mixtures. The thermodynamic consistency of the experimentally measured data tested by the Redlich-Kister method.

5. ACKNOWLEDGEMENT

The authors thank the Institute authorities for providing the necessary facilities to carry out the work.

REFERENCES

Baskaran R, and Kubendran T.R, Thermo Physical Properties of 4-Hydroxy 4-Methyl Pentanone with Nitrobenzene or Ethyl Benzene at Temperatures of (303.15, 313.15, and 323.15) K and a Pressure of 0.1 MPa, J. Chem. Eng. Data, 53, 2008, 1956.

Baskaran R, and Kubendran T.R, Thermophysical Properties of para-Anisaldehyde (1) + Chlorobenzene (2) at Temperatures of (303.15, 313.15, and 323.15) K and a Pressure of 0.1 MPa, J. Chem. Eng. Data, 53, 2008, 978.

Bindhani S.K, Roy G.K, Mohanty Y.K, and Kubendran T.R, Effect of Temperature and Concentration on Density, Viscosity and Ultrasonic Velocity of the Binary Liquid Mixture, Russian Journal of Physical Chemistry A, 88 (7), 2014, 1255–1264.

Emilio J. Gonzalez, Begona Gonzalez, and Eugenia A. Macedo, Thermophysical Properties of the Pure Ionic Liquid 1-Butyl-1-methylpyrrolidinium Dicyanamide and Its Binary Mixtures with Alcohols, J. Chem. Eng. Data, 58 (6), 2013, 1440.

Ewing M.B, Levian B.J, and Marsh K.N, Excess enthalpies, excess volume and excess Gibbs free energy for mixtures of cyclooctane +cyclo pentane at 288.15 K, 298.15 K and 308.15 K, J. Chem. Thermdyn., 2, 1970, 689-691.

Ezekiel D Dikio, Simphiwe M Nelana, David A Isabirye, Eno E Ebenso, Density, Dynamic Viscosity and Derived Properties of Binary Mixtures of Methanol, Ethanol, n-Propanol, and n-Butanol with Pyridine at T = (293.15, 303.15, 313.15 and 323.15) K, Int. J. Electrochem. Sci., 7, 2012, 11101 – 11122.

Grundberg L, and Nissan A, Mixture law of viscosities, Nature, 164, 1949, 799-800.

Hind R.K, Mclaughlin E, and Ubbelohde R, Structure and viscosity of liquids, Trans. Faraday Soc., 56, 1960, 328-330.

Jose M. Resa, Jose M. Goenaga, Ana I. Sanchez-Ruiz, and Miguel Iglesias, Density, Refractive Index, Speed of Sound at 298.15 K, and Vapor−Liquid Equilibria at 101.3 kPa for Binary Mixtures of Ethyl Acetate + Ethyl Lactate and Methyl Acetate + Ethyl Lactate, J. Chem. Eng. Data, 51 (3), 2006, 1294.

Jouyban A, Khoubnasabjafari M, Vaezgharamaleki Z, Fekari Z, and Acree W.E, Calculation of the viscosity of binary liquid mixture at various temperatures using Jouyban - Acree model, Chem. Pharm. Bull., 53, 2005, 519-523.

Kenart C.M, and Kenart W, Physico chemical methods used to study internal structures of liquid binary mixtures, Phys. Chem. Liq., 38, 2000, 155-180.

Kondaiah M, and Krishna Rao D, Correlation of excess molar volumes with Redlich-Kister polynomial and evaluation of partial molar volumes, excess partial molar volumes in some binary mixtures at 308.15 K, Int.J.Research in Pure and Applied Physics, 2013.

Lavanya T.G, Sararavanan K, Baskaran R and Kubendran T.R, Density, viscosity, sound speed and thermoacoustical parameters of benzaldehyde with chlorobenzene or nitrobenzene at 303.15K, 308.15K and 313.15K, Int. J. Thermophys., 34, 2013, 1280.

Mchaweh A, Alsaygh A, and Moshfeghian M.A, Simplified method for calculating saturated liquid densities, Fluid Phase Equilib., 224, 2004. 157-167.

Monica Garcia-Mardones, Santiago Martin, Ignacio Gascon, and Carlos Lafuente, Thermophysical Properties of the Binary Mixture 1-Propylpyridinium Tetrafluoroborate with Methanol, J. Chem. Eng. Data, 59 (5), 2014, 1564.

Oswal S.L, and Patel N.B, Speed of Sound, Isentropic Compressibility, Viscosity, and Excess Volume of Binary Mixtures, 2. Alkanenitriles + Dimethylformamide, + Dimethylacetamide, and + Dimethyl Sulfoxide, J. Chem. Eng. Data, 40 (4), 1995, 845-849.

Perrin D.D, and Armerego W.L.F, Purification of Laboratory chemistry, 3rd ed., Pergamon press, Oxford, 1988.

Redlich O, and Kister A.T, Algebraic representation of thermodynamic properties and the classification of solutions, Ind. Eng. Chem., 40, 1948, 345-349.

Riddick J.A, Bunger W.B, and Sakano T.K, Organic solvents: physical properties and methods of purification, 4th Ed., Wiley- Interscience, New York, 1986.

Satyanarayana Nallani, Sathyanarayana Boodida, and Savitha J. Tangeda, Density and Speed of Sound of Binary Mixtures of N-Methylacetamide with Ethyl Acetate, Ethyl Chloroacetate, and Ethyl Cyanoacetate in the Temperature Interval (303.15 to 318.15) K, J. Chem. Eng. Data, 52, 2007, 405-409.

Treszczanowicz A.J, Kiyohara O, and Benson G.C, Excess volumes for *n*-alkanols +*n*-alkanes IV. Binary mixtures of decan-1-ol +*n*-pentane, +*n*-hexane, +*n*-octane, +*n*-decane, and +*n*-hexadecane, J. Chem.Thermodyn., 13, 1981, 253.