

# Temperature Dependent Thermo-Acoustic and Molecular Interaction Studied of Methyl Propyl Ketone and 1-Butanol Binary Mixtures

Kadam Madhav<sup>1</sup>, Narwade Bhanudas<sup>2</sup>, Sanket Delmade<sup>3</sup>, Athwale Hansraj<sup>4</sup>, Karhale Govind<sup>5</sup>

<sup>1</sup>N.E.S. Science College Nanded

<sup>2</sup>Department of Physics, Degloor College, Degloor, Nanded (M.S.)  
Email.: narwadebs123[at]gmail.com

<sup>3</sup>Department of Physics, Yeshwant College Nanded (M.S.)

<sup>4</sup>Shree Shivaji College Parbhani

<sup>5</sup>Department of Physics MP College, Palam Dist. Parbhani (M.S.)

**Abstract:** The Density ( $\rho$ ), refractive index ( $n_D$ ), viscosity ( $\eta$ ) and ultrasonic velocity ( $U$ ) of pure components Methyl Propyl Ketone (MPK), 1-Butanol and their binary liquid mixtures, have been determined as functions of composition at different temperatures ( $T=303.15$  K, 313.15 K, and 323.15 K) at a fixed frequency of 2 MHz over a different concentration ranges. The values of adiabatic compressibility ( $\beta_{ad}$ ), intermolecular free length ( $L_f$ ), acoustic impedance ( $Z$ ), free volume ( $V_f$ ), relaxation time ( $\tau$ ), were computed using experimental data at different temperature. The observed behavior of these parameters concerning different compositions have been discussed in terms of their molecular interactions between the unlike molecules of the binary mixtures. Also, the thermodynamic parameters such as Gibb's free energy ( $G$ ), Wada's constant ( $W$ ) Rao's constant ( $R$ ) and various excess parameters calculated. The variation in these parameters has been discussed in terms of nature and strength of molecular interactions at varying temperature with composition of liquid mixtures.

**Keywords:** Ultrasonic velocity, acoustic parameters, excess parameters

## 1. Introduction

Alcohols and ketones are important classes of organic compounds having wide industrial, pharmaceutical and chemical applications. 1-Butanol is a primary alcohol extensively used as a solvent in paints, coatings, resins, plasticizers, and in the manufacture of butyl acrylate and glycol ethers. It also finds application as an intermediate in organic synthesis and as a potential biofuel component due to its favorable energy content and lower hygroscopic nature compared to ethanol. The presence of hydroxyl (-OH) group in 1-Butanol enables strong intermolecular hydrogen bonding, which significantly influences its thermodynamic behavior in pure as well as mixed status.

Methyl propyl ketone (MPK), also known as 2-Pentanone, is an important aliphatic ketone widely employed as an industrial solvent in coatings, adhesives, pharmaceuticals, and chemical processing industries. The carbonyl (C=O) functional group present in MPK is highly polar and capable of dipole-dipole interactions. However, unlike alcohols, ketones do not exhibit self-associated hydrogen bonding but can participate in hydrogen bond formation with hydrogen bond donor molecules such as alcohols.

When an alcohol like 1-Butanol is mixed with a ketone such as methyl propyl ketone, specific intermolecular interactions such as hydrogen bonding between the hydroxyl hydrogen of alcohol and the carbonyl oxygen of ketone are expected. These interactions may lead to the formation of molecular complexes and structural rearrangements in the liquid mixtures.

The study of such binary mixtures is therefore of considerable importance in understanding molecular association, structural effects, and deviation from ideal behavior.

Acoustic and transport property investigations provide valuable information regarding intermolecular interactions in liquid mixtures. Measurements of Density, Viscosity, Ultrasonic velocity over the entire composition range at different temperatures help in evaluating excess parameters and understanding the nature and strength of molecular interactions. Variations in these properties with concentration and temperature can reveal the presence of hydrogen bonding, dipole interactions, and possible complex formation in the system.

Although several studies have been reported on alcohol-ketone systems, detailed investigations on the thermos-acoustical behavior of the binary mixture of 1-Butanol and Methyl Propyl Ketone over a range of temperatures are still limited. Hence the present investigation is aimed at studying the Density, Viscosity, Ultrasonic Velocity etc. of binary mixtures of 1-Butanol and Methyl Propyl Ketone at different temperatures and compositions. The results are expected to provide useful insight into the molecular interactions and complex formation in this binary liquid system.

## 2. Experimental Details

1-Butanol and Methyl Propyl Ketone (MPK) used were of AR grade with minimum assay of 99.9% procured from S.D. fine chemicals and Spectrochem Pvt. Ltd. Mumbai. These chemicals are used without further purification. Samples of

solution with different mole fraction Methyl Propyl Ketone (MPK) were prepared. The density ( $\rho$ ), viscosity ( $\eta$ ) and refractive index ( $n_D$ ) of pure liquids and liquid mixtures were determined by using 10 ml Specific gravity bottle, Ostwald's viscometer AND Abbe's refractometer using Sodium D light respectively at temperatures range ( $T=303.15$  K,  $313.15$  K, and  $323.15$  K). The Ultrasonic velocity ( $U$ ) in the liquid and liquids mixtures has been measured using an Ultrasonic Fixed-frequency interferometer (Mittal type Model F-05) [1]. The interferometer is fixed frequency (2MHz). The measuring cell of the interferometer is a specially designed double walled vessel with provision to circulate water at various constant temperature ( $T=303.15$  K,  $313.15$  K, and  $323.15$  K). The high frequency generator excites a quartz crystal fixed at the bottom of the vessel, at its resonant frequency. A fine micrometer screw at the top of the cell is used to raise or lower the reflector plate in the liquid through a known distance. The measuring cell is connected to the output terminals of the high frequency generator through a cable. Ultrasonic waves normal to quartz crystal are reflected from the reflector plate. Stationary waves are formed in the region between reflector plate and the quartz crystal. The micrometer is slowly moved till a number of maximum readings ( $N$ ) of the anode current is passed. The total distance ( $d$ ) moved by the micrometer is noted. The velocity of ultrasonic waves in the binary liquid mixture was determined using the relation.  $U = \lambda f$  Where  $\lambda = 2d/N$  = wavelength of the ultrasonic waves in the binary liquid mixture and  $f$  is the frequency of the generator. The experimental values of density ( $\rho$ ), viscosity ( $\eta$ ) and ultrasonic velocity ( $U$ ) were used to calculate various acoustical parameters such as adiabatic compressibility ( $\beta_{ad}$ ), Acoustical impedance ( $Z$ ), free length ( $L_f$ ), relaxation time ( $\tau$ ) Rao's constant ( $R$ ), Wada's constant ( $W$ ) and Gibb's free energy using following expressions [1, 2]

$$\beta_a = \frac{U^2}{\rho} \quad \dots(i)$$

$$Z = U\rho \quad \dots(ii)$$

$$L_f = K_T \beta_a^{1/2} \quad \dots(iii)$$

$$\tau = \frac{4}{3} \eta \beta_a \quad \dots(iv)$$

$$W = \frac{\beta^{-1/3} \times M_{eff}}{\rho} \quad \dots(v)$$

$$R = \frac{U^{1/3} \times M_{eff}}{\rho} \quad \dots(vi)$$

$$\Delta G = 2.303 K_B T \log_{10} \left( \frac{K_B T \tau}{h} \right) \quad \dots(vii)$$

Where,  $K_T$  is temperature dependent constant having value of  $199.53 \times 10^{-8}$  in MKS system and  $K$  is temperature dependent constant whose value is  $4.28 \times 10^9$  in MKS system

$$M_{eff} = \sum X_i M_i \quad (VIII)$$

Where  $X$  is mole fraction and  $M$  is molecular weight in of  $i^{th}$  components

The strength of interaction between the component molecules is well reflected in the deviations, in excess viscosity ( $\Delta\eta$ ) Excess Adiabatic compressibility ( $\Delta\beta_{ad}$ ), Excess Acoustic impedance ( $\Delta Z$ ), Excess intermolecular free length ( $\Delta L_f$ ) excess free volume ( $\Delta V_f$ ) etc. These parameters were calculated using the relation.

$$\Delta Y = Y_m - (X_1 Y_1 + X_2 Y_2) \quad (ix)$$

Where,  $\Delta Y$  is any excess parameter, and  $Y$  refers to above

mentioned parameter. The subscripts  $m$ ,  $1$  and  $2$  used in the above equation are respectively for the mixture, component  $1$  and component  $2$ ,  $X_1$  and  $X_2$  are the mole fractions of two components in the liquid mixture.

### 3. Result and Discussion

The experimental values of density ( $\rho$ ), viscosity ( $\eta$ ) and ultrasonic velocity ( $U$ ) were used to calculate various acoustical parameters such as adiabatic compressibility ( $\beta_{ad}$ ), Acoustical impedance ( $Z$ ), free length ( $L_f$ ), free volume ( $V_f$ ), relaxation time ( $\tau$ ) for 1-Butanol, 1-butanol and Methyl Propyl Ketone (MPK) and their binary mixtures at various constant temperature ( $T=303.15$  K,  $313.15$  K, and  $323.15$  K). are listed in table (1)

Ultrasonic velocity of sound waves in a medium is fundamentally related to the binding forces between the molecules. From fig. (1), the ultrasonic velocity in the MPK–1-Butanol system shows a generally decreasing trend with increasing mole fraction of MPK [3,6]. Pure 1-butanol has a strong self-associated hydrogen-bonded structure, and the introduction of MPK partially disrupts these associations [7,8]. The non-linear variations at intermediate compositions indicate competing effects between the formation of MPK–butanol hetero-associations and the disruption of butanol self-association. At higher temperatures, the ultrasonic velocity decreases for all compositions due to thermal expansion and weakening of intermolecular forces [4].

The variation in the values of intermolecular free length  $L_f$  mole fraction of MPK at various temperature are shown in fig.2. This indicates that the average distance between neighbouring molecules increases as MPK replaces 1-butanol, consistent with the disruption of the compact hydrogen-bonded structure of pure butanol [6,9]. The longer alkyl chain of 1-butanol provides efficient molecular packing through van der Waals interactions, and the replacement by the bulkier MPK molecule leads to looser packing and increased free length [5].

The adiabatic compressibility increases with increasing mole fraction of MPK at all temperatures. This increasing trend is consistent with the decrease in ultrasonic velocity and indicates that the mixture becomes progressively more compressible as MPK replaces 1-butanol [9]. The disruption of the strongly hydrogen bonded structure of pure 1-butanol leads to increased free volume and greater compressibility [6,8]. At higher temperatures, the compressibility increases further due to thermal disruption of remaining intermolecular associations [3].

The values of Gibbs free energy, Wada's constant and Rao's constant with mole fraction of MPK at various temperature are shown in table2. Wada's constant and Rao's constant are linked with the molecular compressibility providing important insight into the molecular interactions within the liquid mixture. From table 2 it is found that both Wada's constant and Rao's constant increases with mole fraction of MPK in the mixture suggest the stronger solute –solute molecular interaction leading to closer structure formation [10].

The excess parameters of a binary liquid system is a measure of

deviation from the ideal behavior of the mixture and are more sensitive towards the molecular interactions in the liquid mixture

The respective excess parameters have been calculated and plots are drawn in figures 4 to 6 The molecular packing of the systems determines a quantity called specific acoustic impedance <sup>[11]</sup>. The sign and magnitude of excess acoustic impedance provide valuable insights into the nature of molecular interactions. The Positive excess acoustic impedance values (Fig.5) suggest strong interactions. The relaxation time reflect the time taken for excitation energy to translate into molecular motion and provides insight into relaxation process. Variation of excess relaxation time with

mole fraction of MPK is illustrated in fig.6. The negative deviation of these values indicates formation of molecular association between unlike molecules. Thus, the strong interaction existing between the components were confirmed.

#### 4. Conclusion

- 1) Acoustic parameters in 1-Butanol and MPK system suggest strong molecular interaction in unlike molecules of system.
- 2) Non-linear behavior of excess acoustic and thermodynamic parameters suggest the formation of molecular association in the binary mixtures

**Table 1:**

The values of density ( $\rho$ ), viscosity ( $\eta$ ), Refractive Index ( $n_D$ ), ultrasonic velocity ( $U$ ), adiabatic compressibility ( $\beta_{ad}$ ), intermolecular free length ( $L_F$ ), Acoustic impedance ( $Z$ ), and relaxation times ( $\tau$ ) of the binary liquid mixture of 1-butanol + MPK with mole fraction ( $X_{MPK}$ ) of MPK at various constant temperature ( $T=303.15$  K,  $313.15$  K, and  $323.15$  K).

| At temperature $T=303.15$ K |                             |                                 |         |           |                    |                           |            |            |
|-----------------------------|-----------------------------|---------------------------------|---------|-----------|--------------------|---------------------------|------------|------------|
| $X_{MPK}$                   | $\rho$ (kg/m <sup>3</sup> ) | $\eta$ (x10 <sup>-3</sup> Pa.s) | $n_D$   | $U$ (m/s) | $\beta_{ad}$ (m/N) | $Z$ (kg/m <sup>2</sup> s) | $L_F$ (m)  | $\tau$ sec |
| 0.0000                      | 805.8142                    | 2.2597                          | 1.3975  | 1226.4    | 8.2509E-10         | 988250.5349               | 5.6992E-11 | 2.4859E-09 |
| 0.0870                      | 805.1010                    | 1.5831                          | 1.39474 | 1217.6    | 8.3780E-10         | 980290.9776               | 5.7429E-11 | 1.7684E-09 |
| 0.1760                      | 804.8570                    | 1.3208                          | 1.39381 | 1226.4    | 8.2607E-10         | 987076.6248               | 5.7026E-11 | 1.4548E-09 |
| 0.2690                      | 804.4156                    | 1.0265                          | 1.39282 | 1213.2    | 8.4461E-10         | 975917.0059               | 5.7662E-11 | 1.1560E-09 |
| 0.3640                      | 803.5860                    | 0.8588                          | 1.39187 | 1220      | 8.3608E-10         | 980374.92                 | 5.7370E-11 | 9.5731E-10 |
| 0.4620                      | 803.7211                    | 0.7196                          | 1.39092 | 1214      | 8.4422E-10         | 975717.4154               | 5.7649E-11 | 8.1002E-10 |
| 0.5630                      | 802.5138                    | 0.6469                          | 1.38988 | 1205.6    | 8.5732E-10         | 967510.6373               | 5.8094E-11 | 7.3945E-10 |
| 0.6670                      | 802.4363                    | 0.6131                          | 1.38888 | 1202.8    | 8.6140E-10         | 965170.3816               | 5.8232E-11 | 7.0418E-10 |
| 0.7740                      | 802.2960                    | 0.5709                          | 1.38778 | 1200      | 8.6557E-10         | 962755.2                  | 5.8373E-11 | 6.5885E-10 |
| 0.8850                      | 801.7337                    | 0.5157                          | 1.38684 | 1198      | 8.6907E-10         | 960476.9726               | 5.8491E-11 | 5.9763E-10 |
| 1.0000                      | 801.5016                    | 0.4819                          | 1.38578 | 1190.4    | 8.8046E-10         | 954107.5046               | 5.8873E-11 | 5.6576E-10 |

| At temperature $T=313.15$ K |                             |                                 |         |           |                    |                           |            |            |
|-----------------------------|-----------------------------|---------------------------------|---------|-----------|--------------------|---------------------------|------------|------------|
| $X_{MPK}$                   | $\rho$ (kg/m <sup>3</sup> ) | $\eta$ (x10 <sup>-3</sup> Pa.s) | $n_D$   | $U$ (m/s) | $\beta_{ad}$ (m/N) | $Z$ (kg/m <sup>2</sup> s) | $L_F$ (m)  | $\tau$ sec |
| 0.0000                      | 796.8765                    | 1.7449                          | 1.39161 | 1190.8    | 8.8498E-10         | 948920.5362               | 6.0050E-11 | 2.0589E-09 |
| 0.0870                      | 796.2781                    | 1.3982                          | 1.39056 | 1188.8    | 8.8862E-10         | 946615.4053               | 6.0174E-11 | 1.6566E-09 |
| 0.1760                      | 795.1886                    | 1.0587                          | 1.3895  | 1187.6    | 8.9164E-10         | 944365.9814               | 6.0276E-11 | 1.2586E-09 |
| 0.2690                      | 795.0599                    | 0.8769                          | 1.38843 | 1178.8    | 9.0515E-10         | 937216.6101               | 6.0731E-11 | 1.0583E-09 |
| 0.3640                      | 794.3413                    | 0.7533                          | 1.38737 | 1176      | 9.1029E-10         | 934145.3688               | 6.0903E-11 | 9.1428E-10 |
| 0.4620                      | 793.9043                    | 0.6649                          | 1.38633 | 1175.6    | 9.1141E-10         | 933313.8951               | 6.0941E-11 | 8.0805E-10 |
| 0.5630                      | 793.2016                    | 0.5802                          | 1.38522 | 1170      | 9.2097E-10         | 928045.872                | 6.1259E-11 | 7.1243E-10 |
| 0.6670                      | 793.0098                    | 0.5142                          | 1.38414 | 1166.8    | 9.2625E-10         | 925283.8346               | 6.1435E-11 | 6.3499E-10 |
| 0.7740                      | 792.4532                    | 0.4589                          | 1.38297 | 1151.2    | 9.5219E-10         | 912272.1238               | 6.2289E-11 | 5.8267E-10 |
| 0.8850                      | 792.0675                    | 0.4368                          | 1.38195 | 1160      | 9.3826E-10         | 918798.3                  | 6.1832E-11 | 5.4643E-10 |
| 1.0000                      | 791.1739                    | 0.4126                          | 1.3071  | 1158      | 9.4256E-10         | 916179.3762               | 6.1973E-11 | 5.1849E-10 |

| At temperature $T=323.15$ K |                             |                                 |         |           |                    |                           |            |            |
|-----------------------------|-----------------------------|---------------------------------|---------|-----------|--------------------|---------------------------|------------|------------|
| $X_{MPK}$                   | $\rho$ (kg/m <sup>3</sup> ) | $\eta$ (x10 <sup>-3</sup> Pa.s) | $n_D$   | $U$ (m/s) | $\beta_{ad}$ (m/N) | $Z$ (kg/m <sup>2</sup> s) | $L_F$ (m)  | $\tau$ sec |
| 0.0000                      | 787.0569                    | 1.4504                          | 1.38744 | 1160      | 9.4423E-10         | 912986.004                | 6.3088E-11 | 1.8260E-09 |
| 0.0870                      | 787.0424                    | 1.1369                          | 1.38631 | 1155.2    | 9.5211E-10         | 909191.3805               | 6.3351E-11 | 1.4433E-09 |
| 0.1760                      | 785.2554                    | 0.8743                          | 1.38517 | 1150      | 9.6293E-10         | 903043.71                 | 6.3710E-11 | 1.1225E-09 |
| 0.2690                      | 785.873                     | 0.7377                          | 1.38401 | 1143.2    | 9.7365E-10         | 898410.0136               | 6.4064E-11 | 9.5765E-10 |
| 0.3640                      | 785.5148                    | 0.6001                          | 1.38287 | 1136.8    | 9.8509E-10         | 892973.2246               | 6.4439E-11 | 7.8819E-10 |
| 0.4620                      | 784.2924                    | 0.5498                          | 1.38175 | 1125.6    | 1.0064E-09         | 882799.5254               | 6.5131E-11 | 7.3767E-10 |
| 0.5630                      | 781.5075                    | 0.4748                          | 1.38054 | 1125      | 1.0110E-09         | 879195.9375               | 6.5282E-11 | 6.3999E-10 |
| 0.6670                      | 780.4109                    | 0.4218                          | 1.37935 | 1122.8    | 1.0164E-09         | 876245.3585               | 6.5455E-11 | 5.7159E-10 |
| 0.7740                      | 776.8591                    | 0.3899                          | 1.37811 | 1120      | 1.0262E-09         | 870082.192                | 6.5769E-11 | 5.3342E-10 |
| 0.8850                      | 775.7464                    | 0.3704                          | 1.37705 | 1114      | 1.0387E-09         | 864181.4896               | 6.6171E-11 | 5.1299E-10 |
| 1.0000                      | 774.1833                    | 0.3555                          | 1.3757  | 1112.8    | 1.0431E-09         | 861511.1762               | 6.6309E-11 | 4.9441E-10 |

Table 2

The values of Gibbs free energy( $\Delta G$ ), Wada's constant ( $W$ ) and Rao's constant for binary mixtures of 1-Butanol + MPK) of the binary liquid mixture of 1-Butanol + MPK with mole fraction ( $X_{MPK}$ ) of MPK at various constant temperature ( $T=303.15$  K, 313.15 K, and 323.15 K).

| Temp   | 303.15K                    |                    |                    | 313.15K                    |                    |                    | 323.15K                    |                    |                    |
|--------|----------------------------|--------------------|--------------------|----------------------------|--------------------|--------------------|----------------------------|--------------------|--------------------|
| XMPK   | $\Delta G \times 10^{-19}$ | $W \times 10^{-4}$ | $R \times 10^{-4}$ | $\Delta G \times 10^{-19}$ | $W \times 10^{-4}$ | $R \times 10^{-4}$ | $\Delta G \times 10^{-19}$ | $W \times 10^{-4}$ | $R \times 10^{-4}$ |
| 0.0000 | -6.1471                    | 7.8904             | 4.2560             | -6.487                     | 7.821              | 4.2126             | -6.491                     | 7.900              | 4.262              |
| 0.0870 | -6.1613                    | 8.4186             | 4.5399             | -6.489                     | 8.350              | 4.4968             | -6.493                     | 8.462              | 4.567              |
| 0.1760 | -6.1695                    | 9.0542             | 4.8846             | -6.491                     | 8.959              | 4.8244             | -6.495                     | 9.085              | 4.903              |
| 0.2690 | -6.1791                    | 9.7387             | 5.2515             | -6.493                     | 9.688              | 5.2193             | -6.496                     | 9.816              | 5.299              |
| 0.3640 | -6.1870                    | 1.0590             | 5.7129             | -6.494                     | 10.516             | 5.6659             | -6.497                     | 10.659             | 5.755              |
| 0.4620 | -6.1940                    | 1.1548             | 6.2281             | -6.494                     | 11.496             | 6.1944             | -6.499                     | 11.649             | 6.291              |
| 0.5630 | -6.1978                    | 1.2706             | 6.8519             | -6.495                     | 12.661             | 6.8225             | -6.501                     | 12.824             | 6.925              |
| 0.6670 | -6.1999                    | 1.4120             | 7.6135             | -6.498                     | 14.103             | 7.6022             | -6.503                     | 14.238             | 7.686              |
| 0.7740 | -6.2026                    | 1.5883             | 8.5633             | -6.498                     | 15.881             | 8.5615             | -6.502                     | 16.002             | 8.637              |
| 0.8850 | -6.2067                    | 1.8152             | 9.7873             | -6.501                     | 18.159             | 9.7909             | -6.503                     | 18.277             | 9.864              |
| 1.0000 | -6.2090                    | 21.128             | 11.389             | -6.498                     | 21.191             | 11.4286            | -6.503                     | 21.261             | 11.472             |

## References

- [1] Dash Ashok Kumar and Paikarar Rita, RES.j. Chem.Sci. Vol 4(3), March 2014, 45-53
- [2] Sunanda Aswale, Shashikant Aswale, Aparna Dhote, European J. of Applied Eng. Sci. Res. Vol 1 (2) 2012, 73-79
- [3] R. Padmanaban, A. Gayathri, A. I. Gopalan, D.-E. Lee, and K. Venkatramanan, "Comparative evaluation of viscosity, density and ultrasonic velocity using deviation modelling for ethyl-alcohol based binary mixtures," Appl. Sci., vol. 13, no. 13, art. 7475, 2023.
- [4] V. A. Rana, N. S. Shah, K. N. Shah, and H. P. Vankar, "Dielectric spectroscopy and molecular dynamic simulation study of binary mixtures of benzaldehyde and methanol at 303.15 K," J. Mol. Liq., vol. 369, art. 120829, 2023.
- [5] Y. Chabouni and F. Amireche, "Some physicochemical properties of binary mixtures of glycerol with butanol isomers in the temperature range 293.15 318.15 K and ambient pressure," J. Chem. Eng. Data, vol. 65, no. 4, pp. 1679 1694, 2020.
- [6] A. Ayad, A. Belabbaci, A. Negadi, A. Hernández, B. Kabane, I. Bahadur, F. Mohammad, A. A. Soleiman, and L. Negadi, "Measurements and modeling of thermodynamic properties of binary systems comprising 2-amino-2-methyl-1 propanol with acetonitrile, toluene, 1-pentanol or 1-hexanol at different temperatures," J. Chem. Eng. Data, vol. 68, no. 11, pp. 2789–2806, 2023
- [7] R. J. Sengwa, S. Sankhla, and N. Shinyashiki, "Dielectric parameters and hydrogen bond interaction study of binary alcohol mixtures," J. Solution Chem., vol. 37, no. 2, pp. 137–153, 2008.
- [8] A. Belabbaci, A. Ayad, A. Negadi, A. Hernandez, B. Kabane, I. Bahadur, F. Mohammad, I. Mokbel, and L. Negadi, "Intermolecular interactions of binary mixtures comprising 2-benzylaminoethanol with alcohols (C1–C3) at different temperatures: experimental and modeling," ChemistrySelect, vol. 9, no. 4, art. e202302523, 2024.
- [9] P. A. Chalikwar, A. R. Deshmukh, and A. C. Kumbharkhane, "Dielectric relaxation of tripropylene glycol–water mixture using time domain reflectometry," Phys. Chem. Liq., vol. 55, no. 3, pp. 410–418, 2017.
- [10] D. Dragoescu A. Hernandez Int. J. of Thermophysics 46 (3), 2025, 33
- [11] Anita Kanwar and Pritee Mhatre, IJERT Vol.3 2014, 2080-2092

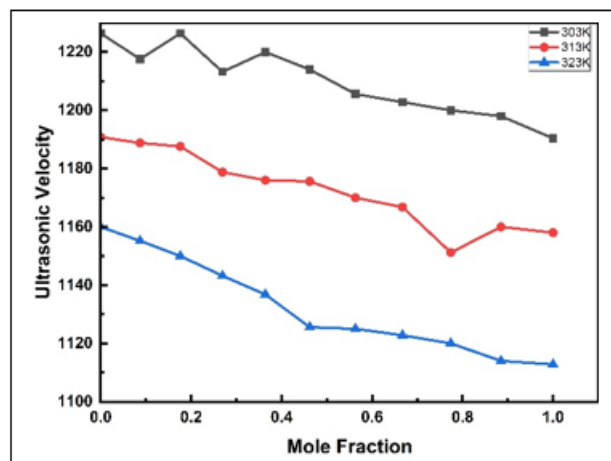


Figure 1: Variation of ultrasonic velocity V/S Mole fraction of MPK at various temperature

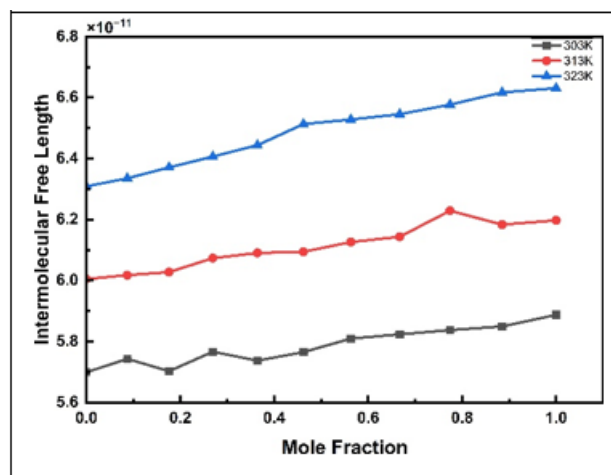


Figure 2: Variation of intermolecular free length V/S mole fraction of MPK at various temperature

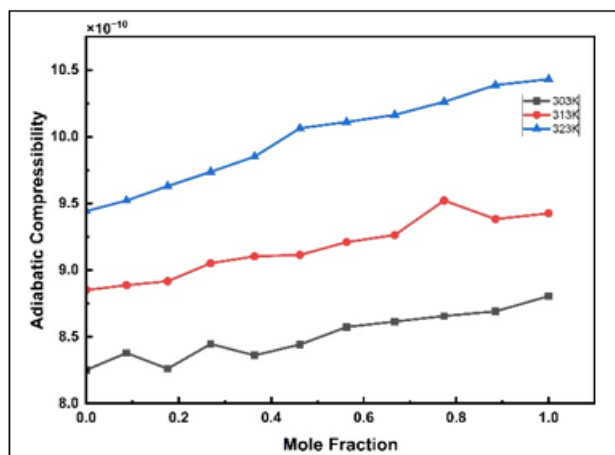


Figure 3: Variation of adiabatic compressibility V/S mole fraction of MPK at various temperature

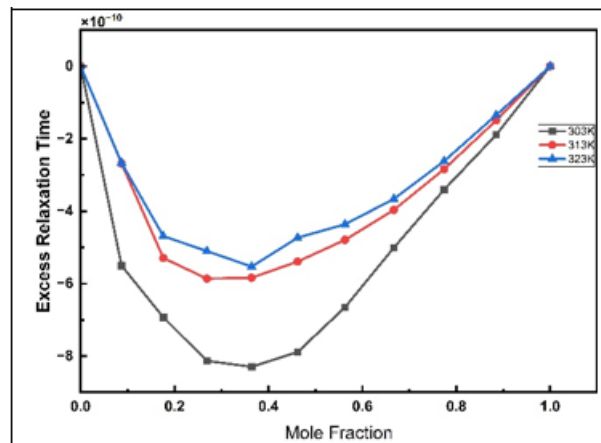


Figure 6: Variation of excess Relaxation Time V/S mole fraction of MPK at various temperature

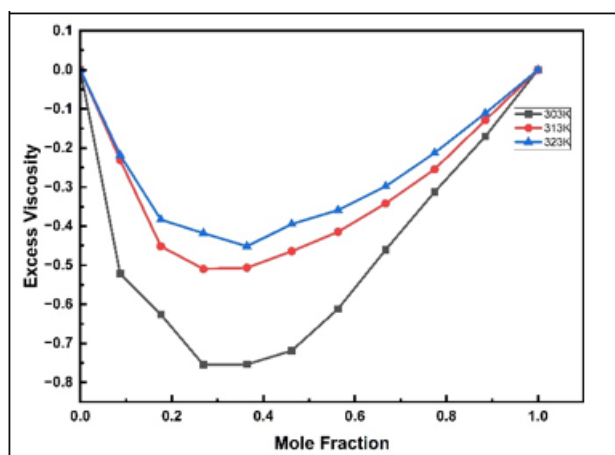


Figure 4: Variation of excess viscosity V/S mole fraction of MPK at various temperature

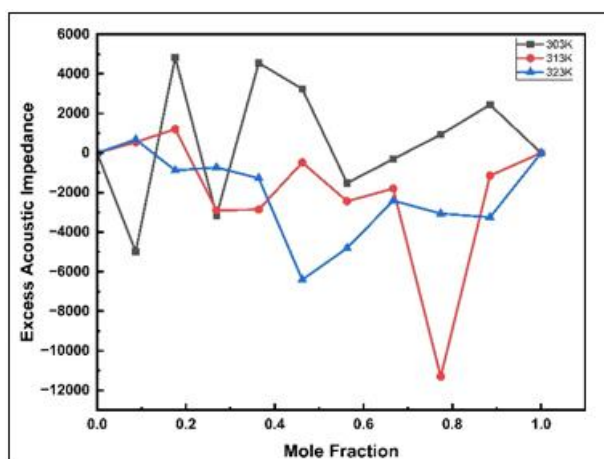


Figure 5: Variation of excess Acoustic impedance V/S mole fraction of MPK at various temperature