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# Refractive index studies of binary liquid mixtures containing 1, 4-butanediol + o- cresol/m-cresol/p-cresol

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**ABSTRACT**

Refractive index ($n_D$) and related properties such as molar refraction (R) have been investigated for binary system (1, 4-Butanediol with o-cresol/m-cresol/p-cresol) at temperatures T = (303.15, 308.15, 313.15 and 318.15) K. Some hypothetical and observational connections have been utilized to think about the reliance of the deliberate and inferred amounts on twofold creation and on temperature. Refractive index deviation, $\Delta n_D$, molar refraction deviation, $\Delta R$, have also been calculated. Redlich-Kister polynomial equation is used to get the flexible parameters and standard deviations between the deliberate and fitted qualities, separately. The results obtained have been discussed based on specific intermolecular interactions between different species.

**KEY WORDS:** Refractive Index, Binary Mixtures, 1, 4-Butanediol, Cresol**.**

## 1. INTRODUCTION

Refractive index of pure liquids and liquid mixtures constitutes an important property for different engineering applications. The data related to refractive indices of binary liquids gives the knowledge to comprehend the sub-atomic communications between the liquids. For continuing study of thermodynamic and transport properties of binary liquids containing 1, 4-butanediol (1, 4-BD) with o-cresol/m-cresol/p-cresol, we present some studies about refractive properties of binary liquids of 1,4-butanediol (1, 4-BD) with o-cresol/m-cresol/p-cresol at different temperatures.

The chemicals chosen for this study are important in industrial and scientific context because of their applications. 1, 4-BD is a reasonable gooey fluid, which is miscible with water and most polar natural solvents. It is utilized as a part of the produce of a few kinds of plastics and flexible strands. Also it is suitable as a useful chemical intermediate in the manufacture of many chemical products. Cresols can be used as second generation bio-oils/fuels, emerging as an alternative to fossil fuels that contribute to the reduction of global warming, minimizing the generation of greenhouse gases and those harmful to the ozone layer.

In this paper we report the refractive index, $n_D$ at T = (303.15, 308.15, 313.15 and 318.15) K for 1, 4-BD with o-cresol/m-cresol/p-cresol over the entire composition range. Some empirical and theoretical relationships (Arago, 1806; Eykman, 1895; Eyring, 1969; Gladstone, 1858; Heller, 1945; Lorentz, 1880; Kurtz, 1936; Oster, 1948; Weiner, 1910) have been connected to ponder the reliance of the deliberate and determined amounts on temperature and on paired structure. Several researchers (Bhatia, 2002; Lal, 2000; Narendra, 2011; Srinivasu, 2016) has been tested the validity of these mixing rules. Refractive index deviation, $\Delta n_D$, molar refraction deviation, $\Delta R$, have also been calculated. To acquire the movable parameters and standard deviations between the deliberate and fitted qualities, results have been fitted to Redlich-Kister polynomial equation. The results obtained have been discussed based on specific intermolecular interactions between different species.

## 2. EXPERIMENTAL

1, 4-BD and o-cresol, m-cresol and p-cresol (Sigma-Aldrich, USA, mass fraction purity 0.99) used in the present investigation were purified by standard methods (Aminabhavi, 1984; Mosterio, 2001). Before utilize, all synthetic substances were put away more than 0.4nm sub-atomic strainers for 72 hrs to evacuate the water content, assuming any, and were degassed at low weight. The blends were set up by mass and were kept in extraordinary water/air proof plug glass jugs to maintain a strategic distance from dissipation. All examples were arranged promptly preceding estimations utilizing an electronic adjust (CPA-225D, Sartorius, Germany) accurately within $\pm 1\times10^{-5}$g. The uncertainty in the mole part was evaluated to be within $\pm 1\times10^{-4}$. The refractive indices in pure liquids and in their binary mixtures was measured using an Abbe Refractometer (Sravankumar, 2011). The temperature was regulated by using a circulation pump connected with a temperature water bath. Adjustment of the instrument was finished by estimating the refractive indices of doubled refined water and toluene at known temperatures. The example blends were specifically infused into the crystal gathering of the instrument by methods for a sealed shut hypodermic syringe. The refractive indices were measured, when the liquid mixture attained constant temperature. A normal of three to four estimations was taken for each sample blend. The density and refractive index data of the liquid mixtures have been included in table.1.

**Theory:** The 'mixing rules' tested are,

Arago-Biot (A-B):

$$n_m = \phi_1 n_1 + \phi_2 n_2 \quad (1)$$

Eykman's (E):

$$\left(\frac{n_m^2 - 1}{n_m + 0.4}\right) V_m = \left(\frac{n_1^2 - 1}{n_1 + 0.4}\right) \frac{M_1 x_1}{\rho_1} + \left(\frac{n_2^2 - 1}{n_2 + 0.4}\right) \frac{M_2 x_2}{\rho_2} \quad (2)$$

Where, symbols have their usual meaning.

Eyring and John (E-J):

$$n = n_1 \phi_1^2 + 2(n_1 n_2)^{1/2} \phi_1 \phi_2 + n_2 \phi_2^2 \quad (3)$$

Gladstone-dale (G-D):

$$(n_m - 1) = \phi_1 (n_1 - 1) + \phi_2 (n_2 - 1) \quad (4)$$

Heller's (H):

$$\left(\frac{n_m - n_1}{n_1}\right) = \frac{3}{2}\left(\frac{m^2 - 1}{m^2 + 2}\right) \phi_2 \quad (5)$$

Where m = $\frac{n_2}{n_1}$

Lorentz-Lorenz (L-L):

$$\left(\frac{n_m^2 - 1}{n_m^2 + 2}\right) \frac{1}{\rho_m} = \left(\frac{n_1^2 - 1}{n_1^2 + 2}\right) \frac{w_1}{\rho_1} + \left(\frac{n_2^2 - 1}{n_2^2 + 2}\right) \frac{w_2}{\rho_2} \quad (6)$$

Newton (N):

$$(n_m^2 - 1) = \phi_1 (n_1^2 - 1) + \phi 2 (n_2^2 - 1) \quad (7)$$

Oster (OS):

$$\frac{(n^2 - 1)(2n^2 + 1)}{n^2} = \frac{(n_1^2 - 1)(2n_1^2 + 1)}{n_1^2} \phi_1 + \frac{(n_2^2 - 1)(2n_2^2 + 1)}{n_2^2} \phi_2 \quad (8)$$

Weiner's (W):

$$\left(\frac{n_m^2 - n_1^2}{n_m + 2n_1^2}\right) = \left(\frac{n_2^2 - n_1^2}{n_2^2 + 2n_1^2}\right) \phi_2 \quad (9)$$

In the above equations, $n_m$ is the refractive index of the mixture; $n_1$ and $n_2$ are the refractive indices of the pure components 1 and 2 respectively. $\varphi_i$ is volume fraction of component i. $\phi_i = x_i V_i / \sum x_i V_i$, $V_i$ is the molar volume of component i and $x_i$ is the mole fraction of component i.

The average percentage deviations (APD) by different approaches have been computed using the expression:

$$APD = \frac{1}{n} \sum \frac{A_{\exp} - A_{theoritical}}{A_{\exp}} X 100 \quad (10)$$

Where A is refractive index and n is the number of data points.

Molar refraction (R) obtained by using Lorentz-Lorenz equation

$$R = \left(\frac{n_m^2 - 1}{n_m^2 + 2}\right) V_m \quad (11)$$

The deviation in molar refraction ΔR gives the strength of interaction in the mixture and is a sensitive function of wavelength, temperature and mixture composition.

ΔR and $\Delta n_D$ are calculated using the following equations:

$$\Delta R = R - (x_1 R_1 + x_2 R_2) \quad (12)$$

$$\Delta n_D = n_D - (x_1 n_{D1} + x_2 n_{D2}) \quad (13)$$

Where, $x_i$ is the mole fraction, and $R_i$ is the molar refraction of component i.

## 3. RESULTS AND DISCUSSION

The values of density and refractive index of pure and binary liquid mixtures with mole fraction of 1, 4-BD are listed in Table 1.Variation of refractive index deviation and molar refraction deviation with mole fraction of 1, 4-BD have been depicted in Figs.1 and 2 respectively. The deviation parameters are fitted to Redlich-Kister equation (Redlich, 1979), the adjustable parameters and standard deviations have been given in Table.2. Table.3, summarizes the APD values between the experimental $n_D$ values and those calculated for each mixing rule. It is evident that all selected relations can be profitably used if only a rough approximation in predictive calculations is required.

**Table.1. Comparison of refractive index $n_D$ and viscosity η of pure liquids with their literature values at T = 303.15, 308.15, 313.15 and 318.15K**

| Compounds | T(K) | $\rho$/kg.m$^{-3}$ | | $n_D$ | |
|---|---|---|---|---|---|
| | | (Expt.) | (Lit.) | (Expt.) | (Lit.) |
| 1, 4-butanediol | 303.15 | 1009.4 | 1009.67[a] | 1.4435 | |
| | 308.15 | 1006.8 | 1006.70[a] | 1.4413 | |
| | 313.15 | 1003.8 | 1003.73[a] | 1.4393 | |
| | 318.15 | 1000.4 | 1000.76[a] | 1.4379 | |
| o-cresol | 303.15 | 1036.6 | 1036.90[b] | 1.5395 | |
| | 308.15 | 1030.9 | 1031.60[b] | 1.5375 | |
| | 313.15 | 1026.3 | 1026.00[b] | 1.5358 | |
| | 318.15 | 1021.4 | 1021.10[c] | 1.5340 | |
| m-cresol | 303.15 | 1025.7 | 1026.10[b] | 1.5347 | 1.535[d] |
| | 308.15 | 1021.9 | 1022.10[b] | 1.5331 | |
| | 313.15 | 1017.4 | 1017.00[c] | 1.5324 | |
| | 318.15 | 1013.6 | 1013.50[c] | 1.5306 | |
| p-cresol | 303.15 | 1026.6 | 1026.30[b] | 1.5313 | |
| | 308.15 | 1022.4 | 1022.40[b] | 1.5297 | |
| | 313.15 | 1019.0 | 1018.10[c] | 1.5285 | |
| | 318.15 | 1014.3 | 1013.90[c] | 1.5267 | |

[a]Nain (2007), [b]Bhatia (2011), [c]Narendra (2011), [d]Maimoonan (2011)

**Table.2. Densities, ρ, and refractive indices, $n_D$, as a function of mole fraction 1, 4-BD at T= (303.15 – 318.15) K at atmospheric pressure 0.1MPa**

| $x_1$ | ρ (kg.m$^{-3}$) | $n_D$ | ρ (kg.m$^{-3}$) | $n_D$ | ρ (kg.m$^{-3}$) | $n_D$ | ρ (kg.m$^{-3}$) | $n_D$ |
|---|---|---|---|---|---|---|---|---|
| **1,4-Butanediol + o-cresol** | | | | | | | | |
| | **T=303.15K** | | **T=308.15K** | | **T=313.15K** | | **T=318.15K** | |
| 0.0000 | 1036.6 | 1.5395 | 1030.9 | 1.5375 | 1026.3 | 1.5358 | 1021.4 | 1.5340 |
| 0.1001 | 1035.7 | 1.5334 | 1030.0 | 1.5319 | 1025.3 | 1.5305 | 1020.3 | 1.5292 |
| 0.2001 | 1034.2 | 1.5263 | 1028.7 | 1.5248 | 1023.9 | 1.5236 | 1019.1 | 1.5223 |
| 0.3002 | 1032.3 | 1.5185 | 1027.0 | 1.5169 | 1022.4 | 1.5156 | 1017.7 | 1.5143 |
| 0.4002 | 1030.0 | 1.5100 | 1025.1 | 1.5083 | 1020.7 | 1.5069 | 1016.0 | 1.5056 |
| 0.5002 | 1027.5 | 1.5007 | 1022.8 | 1.4990 | 1018.6 | 1.4975 | 1014.2 | 1.4962 |
| 0.6002 | 1024.6 | 1.4904 | 1020.4 | 1.4887 | 1016.3 | 1.4872 | 1012.0 | 1.4860 |
| 0.7002 | 1021.6 | 1.4794 | 1017.6 | 1.4777 | 1013.7 | 1.4762 | 1009.5 | 1.4750 |
| 0.8001 | 1018.2 | 1.4677 | 1014.4 | 1.4659 | 1010.8 | 1.4643 | 1006.7 | 1.4633 |
| 0.9001 | 1014.3 | 1.4556 | 1010.9 | 1.4537 | 1007.4 | 1.4521 | 1003.7 | 1.4508 |
| 1.0000 | 1009.4 | 1.4435 | 1006.8 | 1.4413 | 1003.8 | 1.4393 | 1000.4 | 1.4379 |
| **1, 4-Butanediol + m-cresol** | | | | | | | | |
| | **T=303.15K** | | **T=308.15K** | | **T=313.15K** | | **T=318.15K** | |
| 0.0000 | 1025.7 | 1.5347 | 1021.9 | 1.5331 | 1017.4 | 1.5324 | 1013.6 | 1.5306 |
| 0.0992 | 1025.6 | 1.5286 | 1021.6 | 1.5274 | 1017.0 | 1.5271 | 1013.0 | 1.5257 |
| 0.1986 | 1024.9 | 1.5215 | 1020.9 | 1.5204 | 1016.3 | 1.5200 | 1012.2 | 1.5187 |
| 0.2982 | 1024.1 | 1.5137 | 1020.1 | 1.5124 | 1015.4 | 1.5118 | 1011.3 | 1.5105 |
| 0.3979 | 1022.9 | 1.5052 | 1019.0 | 1.5038 | 1014.4 | 1.5031 | 1010.2 | 1.5018 |
| 0.4979 | 1021.4 | 1.4962 | 1017.6 | 1.4947 | 1013.1 | 1.4938 | 1009.0 | 1.4926 |
| 0.5979 | 1019.7 | 1.4865 | 1016.0 | 1.4850 | 1011.7 | 1.4841 | 1007.6 | 1.4830 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 0.6982 | 1017.8 | 1.4760 | 1014.2 | 1.4745 | 1010.1 | 1.4735 | 1006.1 | 1.4726 |
| 0.7986 | 1015.5 | 1.4652 | 1012.1 | 1.4636 | 1008.3 | 1.4624 | 1004.4 | 1.4615 |
| 0.8992 | 1012.7 | 1.4544 | 1009.6 | 1.4525 | 1006.2 | 1.4510 | 1002.6 | 1.4500 |
| 1.0000 | 1009.4 | 1.4435 | 1006.8 | 1.4413 | 1003.8 | 1.4393 | 1000.4 | 1.4379 |
| **1, 4-Butanediol + p-cresol** | | | | | | | | |
| | **T=303.15K** | | **T=308.15K** | | **T=313.15K** | | **T=318.15K** | |
| 0.0000 | 1026.6 | 1.5313 | 1022.4 | 1.5297 | 1019.0 | 1.5285 | 1014.3 | 1.5267 |
| 0.0961 | 1026.3 | 1.5252 | 1022.0 | 1.5239 | 1018.3 | 1.5230 | 1013.5 | 1.5215 |
| 0.1931 | 1025.7 | 1.5181 | 1021.3 | 1.5167 | 1017.5 | 1.5157 | 1012.7 | 1.5143 |
| 0.2909 | 1024.7 | 1.5105 | 1020.4 | 1.5090 | 1016.6 | 1.5079 | 1011.7 | 1.5065 |
| 0.3895 | 1023.5 | 1.5023 | 1019.3 | 1.5008 | 1015.4 | 1.4996 | 1010.6 | 1.4982 |
| 0.4890 | 1022.0 | 1.4936 | 1017.9 | 1.4920 | 1014.0 | 1.4908 | 1009.3 | 1.4895 |
| 0.5894 | 1020.2 | 1.4843 | 1016.3 | 1.4826 | 1012.5 | 1.4812 | 1007.9 | 1.4800 |
| 0.6907 | 1018.2 | 1.4741 | 1014.4 | 1.4724 | 1010.7 | 1.4711 | 1006.3 | 1.4700 |
| 0.7929 | 1015.8 | 1.4638 | 1012.2 | 1.4621 | 1008.6 | 1.4607 | 1004.5 | 1.4598 |
| 0.8960 | 1012.8 | 1.4536 | 1009.7 | 1.4518 | 1006.4 | 1.4503 | 1002.6 | 1.4492 |
| 1.0000 | 1009.4 | 1.4435 | 1006.8 | 1.4413 | 1003.8 | 1.4393 | 1000.4 | 1.4379 |

**Table.3. Redlich–Kister coefficients, $A_j$ along with standard deviation σ for binary mixture of 1, 4-BD with cresols**

| Parameter | T/K | a | b | c | d | e | σ |
|---|---|---|---|---|---|---|---|
| **1, 4-Butanediol + o-cresol** | | | | | | | |
| $\Delta n_D$ | 303.15 | 0.0367 | -0.0034 | -0.0082 | -0.0052 | 0.0048 | 0.00003 |
| | 308.15 | 0.0004 | -0.0032 | -0.0034 | -0.0080 | 0.0043 | 0.00004 |
| | 313.15 | 0.0398 | -0.0039 | -0.0020 | -0.0075 | 0.0086 | 0.00007 |
| | 318.15 | 0.0412 | -0.0030 | 0.0014 | -0.0111 | 0.0075 | 0.00004 |
| ΔR | 303.15 | 0.0842 | -0.0198 | -0.0534 | -0.0312 | 0.0194 | 0.00008 |
| | 308.15 | 0.0948 | -0.0215 | -0.0339 | -0.0397 | 0.0403 | 0.00021 |
| | 313.15 | 0.1060 | -0.0292 | -0.0042 | -0.0338 | 0.0327 | 0.00035 |
| | 318.15 | 0.1140 | -0.0246 | 0.0206 | -0.0560 | 0.0286 | 0.00020 |
| **1, 4-Butanediol + m-cresol** | | | | | | | |
| $\Delta n_D$ | 303.15 | 0.0276 | -0.0067 | -0.0076 | -0.0038 | 0.0068 | 0.00006 |
| | 308.15 | 0.0292 | -0.0057 | -0.0015 | -0.0085 | 0.0031 | 0.00005 |
| | 313.15 | 0.0313 | -0.0047 | 0.0013 | -0.0115 | 0.0057 | 0.00007 |
| | 318.15 | 0.0328 | -0.0034 | 0.0042 | -0.0124 | 0.0094 | 0.00005 |
| ΔR | 303.15 | 0.0405 | -0.0371 | -0.0464 | -0.0185 | 0.0412 | 0.00038 |
| | 308.15 | 0.0540 | -0.0341 | -0.0119 | -0.0384 | 0.0255 | 0.00034 |
| | 313.15 | 0.0703 | -0.0299 | 0.0077 | -0.0558 | 0.0282 | 0.00027 |
| | 318.15 | 0.0842 | -0.0221 | 0.0321 | -0.0706 | 0.0265 | 0.00025 |
| **1, 4-Butanediol + p-cresol** | | | | | | | |
| $\Delta n_D$ | 303.15 | 0.0209 | -0.0080 | -0.0128 | -0.0035 | 0.0143 | 0.00006 |
| | 308.15 | 0.0220 | -0.0071 | -0.0097 | -0.0056 | 0.0160 | 0.00003 |
| | 313.15 | 0.0234 | -0.0065 | -0.0103 | -0.0063 | 0.0243 | 0.00002 |
| | 318.15 | 0.0247 | -0.0054 | -0.0048 | -0.0066 | 0.0218 | 0.00006 |
| ΔR | 303.15 | 0.0113 | -0.0430 | -0.0703 | -0.0161 | 0.0767 | 0.00026 |
| | 308.15 | 0.0225 | -0.0407 | -0.0508 | -0.0215 | 0.0838 | 0.00019 |
| | 313.15 | 0.0361 | -0.0379 | -0.0458 | -0.0313 | 0.1190 | 0.00015 |
| | 318.15 | 0.0486 | -0.0324 | -0.0194 | -0.0374 | 0.1050 | 0.00030 |

**Table.4. Calculated APD for different "Mixing rules" applied to the selected binary systems at T = 303.15 to 318.15 K**

| T / K | A-B | E | E-J | G-D | H | L-L | N | Os | W |
|---|---|---|---|---|---|---|---|---|---|
| **1, 4-BD + o-cresol** | | | | | | | | | |
| 303.15 | 0.206 | 0.280 | 0.221 | 0.206 | 0.239 | 0.240 | 0.175 | 0.299 | 0.218 |
| 308.15 | 0.226 | 0.300 | 0.242 | 0.226 | 0.259 | 0.260 | 0.195 | 0.319 | 0.238 |
| 313.15 | 0.246 | 0.321 | 0.262 | 0.246 | 0.280 | 0.281 | 0.215 | 0.341 | 0.259 |
| 318.15 | 0.265 | 0.340 | 0.281 | 0.265 | 0.299 | 0.300 | 0.234 | 0.359 | 0.278 |
| **1, 4-BD + m-cresol** | | | | | | | | | |
| 303.15 | 0.116 | 0.183 | 0.130 | 0.116 | 0.146 | 0.147 | 0.088 | 0.200 | 0.127 |
| 308.15 | 0.139 | 0.207 | 0.153 | 0.139 | 0.169 | 0.170 | 0.110 | 0.224 | 0.150 |
| 313.15 | 0.163 | 0.233 | 0.178 | 0.163 | 0.195 | 0.196 | 0.134 | 0.251 | 0.175 |
| 318.15 | 0.188 | 0.258 | 0.203 | 0.188 | 0.220 | 0.220 | 0.159 | 0.276 | 0.200 |
| **1, 4-BD + p-cresol** | | | | | | | | | |
| 303.15 | 0.052 | 0.114 | 0.065 | 0.052 | 0.080 | 0.080 | 0.026 | 0.130 | 0.062 |
| 308.15 | 0.067 | 0.130 | 0.080 | 0.067 | 0.096 | 0.096 | 0.041 | 0.146 | 0.077 |
| 313.15 | 0.086 | 0.150 | 0.100 | 0.086 | 0.115 | 0.116 | 0.059 | 0.167 | 0.097 |
| 318.15 | 0.106 | 0.170 | 0.119 | 0.106 | 0.135 | 0.135 | 0.079 | 0.186 | 0.116 |

The premise of these blending tenets of refractive index rules is e. m. hypothesis of light, which regards the atoms as dipoles or congregations of dipoles by an outer field. Refractive lists rely upon nature of fluid, weight and temperature and are straightforwardly identified with various physical parameters of the fluid, for example, dielectric consistent, thickness, molar refractivity and so on. An endeavor has been made to consider the legitimacy of nine blending rules for anticipating the refractivity of parallel fluid framework, over the whole mole portion.

From Table.3, it can be observed that the APD values are smaller for Newton relation and larger for Oster relation, even if the relative merits of the checked equations are comparable in magnitude to each other. The equations used in this paper for investigation is limited to some literature models which can be applied when preliminary knowledge of liquid mixture density is available. Some other equations are also available for prediction of refractive indices but the applicability of those models needs a priori knowledge of one or more empirical parameters other than density for each mixed liquid.

Figure.1, shows the profiles of $\Delta n_D$ against the mole fraction of 1, 4-BD at 303.15K for all the studied mixtures. The trends are always positive for the mixtures studied, with a sharp maximum at $x_1 = 0.5$ which becomes higher as temperature increases. At all studied temperatures the same trends have been observed. The maximum values may indicate the presence of a complex adduct.

The sign and size of ΔnD likewise changes with the basic attributes of the fluid parts emerging from the geometrical fitting of one segment into the structure of other segment because of the distinction in the sub-atomic size and state of the segments. In the event that the not at all like particles have nearly a similar molar volumes, this impact ought to be critical as proposed by Aminabhavi (1979). In any case, regardless of whether slight contrast in the free volume between various species could encourage the infiltration of one part into the other and as the distinction of the free volumes of the two unadulterated species builds, the more positive ought to be the commitment to ΔnD.

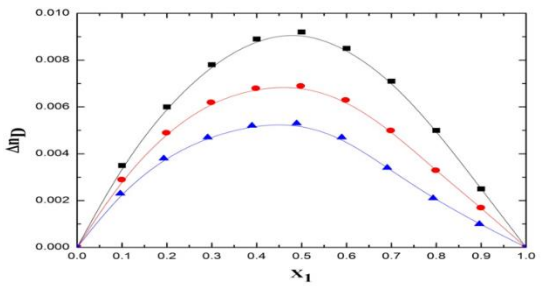


**Figure.1. Deviation in refractive index $\Delta n_D$ vs mole fraction ($x_1$) of 1,4-Butanediol in the binary mixture of 1, 4-Butanediol + o-cresol (■), + m-cresol (●) and + p-cresol (▲) at 303.15K**

With the point of social affair assist informations about the specific intermolecular interactions in these binary mixtures, we have investigated the molar refraction R. R being affected by any variation of the chemical environment of a real species, its functional dependecne on temeprature and binary composition provides information

about the intermolecualr interactions and driving forces acting on the liquid structure of the binary mixtures. According to Ciocirlan (2008), the molar refraction values depends only on the λ of light used for the measurements.

Starting from the R data, it is possible to study the related deviaiton ΔR, obtained by applying the relation (12). The results of this analysis are plotted in Fig. 2 for the systems at temperature 303.15K. Increasing ΔR values are observed for increase in temperature.

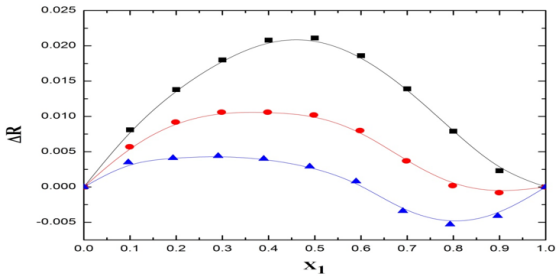


**Figure.2. Deviation in molar refraction ΔR vs mole fraction ($x_1$) of 1,4-Butanediol in the binary mixture of 1, 4-Butanediol + o-cresol (■), + m-cresol (●) and + p-cresol (▲) at 303.15K**

The deviations of hypothetical qualities from exploratory ones are temperature-autonomous. This might be ascribed to the way that variety in refractive list with temperature is repaid by the adjustment in thickness of the fluid blend. Nonetheless, in situations where the variety is huge with change in temperature, it can be utilized for deciphering the structure and interactions in the liquid by computing other dielectric, optical and acoustical properties using experimental data. If the concept of excess volume (which is an indirect measure of interaction) is taken into consideration in various mixing rules, the deviations of hypothetical qualities from exploratory ones are reduced.

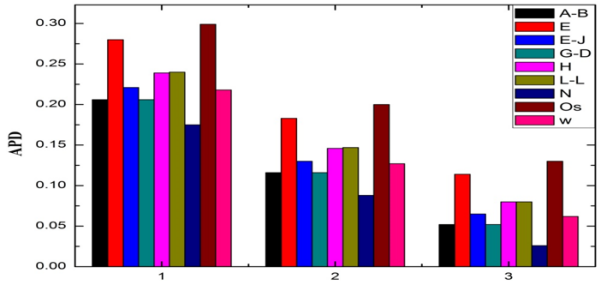


**Figure.3. The APD values for different mixing relations in the binary liquid mixtures 1, 4-BD + o-cresol (1), 1, 4-BD + m-cresol (2) and 1, 4-BD + p-cresol (3) at temperature T = 303.15 K**

## 4. CONCLUSION

Various mixing rules of refractive index were used to test their legitimacy for binary mixtures by using the measured values of density and refractive index. It may be observed that all the blending rules talked about are interrelated in a straightforward quantitative way and perform well inside the points of confinement of exploratory mistake. Negative and positive deviations are seen amongst trial and hypothetical qualities calculated by using various theories/models. The lowest deviations for the calculated refractive indices have been obtained by using Newton's equation, whereas the Oster equation gives the highest deviations at all temperatures for the mixtures studied. Deviations in refractive index and molar refraction are observed to be positive for all the temperatures studied.

## REFERENCES

Aminabhavi TM, Munk P, Preferential adsorption onto polystyrene in mixed solvent system, Macromolecules, 12, 1979, 607-613.

Aminabhavi TM, Use of mixing rules in the analysis of data for binary liquid mixtures, J. Chem. Eng. Data, 29, 1984, 54-55.

Arago DFJ, Biot JB, Refractive properties of binary mixtures, Mem. Acad. Fr., 1806, 7-9.

Bhatia SC, Rani R, Bhatia R. Densities, speeds of sound and refractive indices of binary mixtures of decane-1-ol with anisole, o-cresol, m-cresol and p-cresol at T = (298.15, 303.15, 308.15) K, J. Chem. Eng. Data, 56, 2011, 1669-1674.

Bhatia SC, Tripathi N, Dubey GP, Refractive index of binary liquid mixtures of decane + benzene and hexadecane + benzene or + hexane at 303.15 K, 308.15K and 313.15K, Indian J Chem. 41, 2002, 266-269.

Ciocirlan O, Iulian O, Vapor pressure, density, viscosity and refractive index of dimethyl sulfoxide + 1, 4-dimethylbenzene system, J Serb. Chem. Soc., 73 (1), 2008, 73-85.

Eykman JF, Reflectometric Research, Rec. Trav. Chim., 14, 1895, 185-202.

Eyring H, John MS, Significant liquid structures, John Wiley, New York, 1969.

Gladstone F, Dale D, Researches on the refraction, dispersion and sensitiveness of liquids, Philos. Trans. R. Soc.,148, 1858, 887.

Heller W, Remarks on refractive index mixtures rules, Phys. Rev., 68, 1945, 5.

Krishnan L, Neelima T, Dubey GP, Refractive indices of binary liquid mixtures using various mixing rules at 308.15 K, Indian J Pure Appl. Phys., 38, 2000, 842-844.

Kurtz SS, Ward AL, The refractivity intercept and the specific refraction equation of Newton, J Franklin Inst., 222, 1936, 563-569.

Lorentz HA, About the relationship between the velocity of propagation of light of body density, Weid. Ann., 9, 1880, 641-665.

Maimoonan Y, Manisha G, Jagdish PS, Experimental and computational study on viscosity and optical dielectric constant of solutions of poly (ethylene glycol) 200, J Mol. Liq., 160, 2011, 22-29.

Mosterio L, Mascato E, Cominges BE de, Iglesias TP, Legido JL. Density, speed of sound, refractive index and dielectric permittivity of (diethyl carbonate + n-decane) at several temperatures, J Chem. Thermodyn, 33, 2001, 787-801.

Nain AK, Densities and volumetric properties of binary mixtures of formamide with 1- butanol, 2-butanol, 1,3-butanediol and 1, 4-butanediol at temperatures between 293.15 and 318.15 K, J. Sol. Chem., 36, 2007, 497-516.

Narendra K, Narayanamurthy P, Srinivas Ch, Refractive indices of binary liquid mixtures at different temperatures, Asian J Appl. Sciences, 4, 2011, 535-541.

Narendra K, Srinivasu Ch, Fakruddin Sk, Narayanamurthy P, Excess properties of binary mixtures of anisaldehyde with o-cresol, m-cresol and p-cresol at T = (303.15, 308.15, 313.15 and 318.15)K, J Chem. Thermodyn, 43, 2011, 1604-1611.

Oster G, The scattering of light and its applications to chemistry, Chem. Rev., 43, 1948, 319-365.

Redlich O, Kister AT, Algebraic representation of thermodynamic properties and classification of solutions, Ind. Eng. Chem., 40, 1979, 1061.

Saravanakumar K, Baskaran R, Kubendran TR, Density, Viscosity, Refractive Indices, Ultrasonic Velocities and Thermo Acoustical Parameters of Acetophenone + Isoamyl Acetate at 303.15, 313.15 and 323.15 K, Asian J Chem., 23 (6), 2011, 2643-2647.

Srinivasu JV, Narendra K, SubbaRao B, Refractive properties of binary mixtures of 1,4-butanediol with methylpyridine isomers. Int. J Scientific Research Chem. Sciences, 3 (1), 2016, 1-12.

Weiner O, Refractive indices of binary mixtures of 1-iodobutane with aromatic hydrocarbons, Leipz. Ber., 62, 1910, 256-260.