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Theories of ultrasonic velocities and their application in binary liquid mixtures of o-chlorophenol with some aliphatic esters at different temperatures

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ABSTRACT

Ultrasonic velocities and densities of the binary liquid mixtures of o-chlorophenol with different aliphatic esters like methylacetate, ethylacetate and butylacetate are measured at temperatures 303.15, 308.15, 313.15 and 308.15K and atmospheric pressure. Theoretical velocities have been evaluated by using Nomoto (NOM), impedance (IMP), Van Dael and Vangeel (VDV), Junjie (JUN) and Rao's specific velocity (RAO) models. A good agreement is found between experimental and theoretical values. U_{exp}^2 / U_{imx}^2 has also been evaluated for non-ideality in the mixtures. Chi-square test for the goodness of the fit is applied to understand the relative applicability of these theories to the present systems. The results are discussed in terms of intermolecular interactions between the component molecules in these binary liquid mixtures.

Keywords: o-chlorophenol, theoretical velocities, ultrasonics, Chi-square test, interaction parameter.

INTRODUCTION

The measurement of ultrasonic velocities finds extensive applications in understanding Physico-chemical behaviour of liquid mixtures [1-3]. The molecular interactions in pure and binary liquid mixtures have been studied by measuring ultrasonic velocities by several researchers [4-12]. The theoretical values of ultrasonivc velocity have been evaluated by using Nomoto [13], impedance relation [14], Van Deal and Vangeel ideal mix relations [15], Junjie [16] and Rao's Specific velocity relation [17] and the results are interpreted in terms of molecular interactions. The present work is a continuation of our research programme on a comparison of experimental ultrasonic velocity with various theoretical models for the binary mixtures of several systems at various temperatures [18-22].

In this paper, we report the experimental and theoretical ultrasonic velocities of the binary liquid mixtures of ochlorophenol (OCP) with methylacetate (MA), ethylacetate (EA) and n-butylacetate (BA) evaluated by using various theories such as Nomoto, impedance relation, Van Dael and Vangeel, , Junjie's and Rao's specific velocity relation at 303.15-318.15K over entair composition range. Further, a comparative study of theoretical results with experimental values using Chi-square test and the study of molecular interactions from the deviation (α) in the value of U^2_{exp}/U^2_{imx} (from unity) have also been studied. Of these models, Nomoto relation and Impdance relation were reported to be in good agreement with the experimental results for the binary mixture at all temperatures under study and the results are interpreted in terms of intermolecular interactions between the binary component liquid mixtures.

MATERIALS AND METHODS

The commercially available pure solvents were used in the present investigation. OCP (Merk > 99%) and MA,EA,BA of AR grade procured from S.D fine chemicals (India) were purified by the standard methods described by A.Weissberger [23] and the purity of the chemicals was assessed by comparing their measured densities (ρ) and ultrasonic velocities (U) which were in good agreement with literature values. The mixtures were prepared gravimetrically using an electronic balance (Shimadzu AY120) with an uncertainty of $\pm 1 \times 10^{-7}$ Kg and were stored in air-tight glass bottles. The uncertainty in the mole fraction was estimated to be less than $\pm 1 \times 10^{-4}$. It was ensured that the components were adequately mixed before being transferred in to the apparatus. The required properties were measured within one day of the mixture preparation.

The densities, ρ , of pure liquids and their mixtures determined using a 10^{-5} m³ Double - arm pycnometer, and the values from triplicate replication at each temperature are reproducible within 2 x 10^{-1} kg m³ and the uncertainty in the measurement of density is found to be 2 parts in 10^4 parts. The reproducibility in mole fractions was within ± 0.0002 Temperature control for the measurement of viscosity and density is achieved by using a microprocessor assisted circulating water bath, (supplied by Mac, New Delhi) regulated to ± 0.01 K, using a proportional temperature controller. Adequate precautions were taken to minimize evaporation losses during the actual measurements. The ultrasonic velocity of sound (U) is measured using an ultrasonic interferometer (Mittal Enterprises, New Delhi model F05) operating at 2 MHz. The measured speeds of sound have a precision of 0.8 m. sec⁻¹ and an uncertainty less than ± 0.1 m. sec⁻¹. The temperature stability was maintained within ± 0.01 K.by circulating water bath around the measuring cell through a pump.

THEORETICAL CONSIDERATIONS:

1.1 Nomoto theory : Nomoto's empirical formula is based on the assumption of the linear dependence of the molecular sound velocity on concentration and the additivity of the molar volume in the liquid mixture. The sound velocity U is given by

$$U = \left[\frac{\sum_{i=1}^{n} x_i R_i}{\sum_{i=1}^{n} x_i V_i}\right]^3$$

where the molar sound velocity $R = x_1 R_1 + x_2 R_2$.

Hence, ultrasonic velocity (U) is given by

In the above equation $R_i = (M_i/\rho_i) U_i^{1/3} = V_i (U_i)^{1/3}$

1.2 Impedance relation: The specific acoustic impedance of the pure liquids are used for evaluating the ultrasonic velocity in the liquid mixtures by the following relation:

where Z_i is acoustic impedance and ρ_i is the density of the mixture.

1.3 Van Dael and Vangeel relation: Van Dael and Vangeel obtained the formula for ultrasonic velocity in the liquid mixtures adopting the adiabatic compressibilities of the pure liquids based on ideal mixing of the liquids. Van Dael and Vangeel assumed that the adiabatic compressibility (β_{ad}) of the mixture is given by

$$\beta_{ad} = \phi_A (\beta_{ad})_A + \phi_B (\beta_{ad})_B$$

and suggested the following relation for sound velocity in homogeneous liquid mixtures.

$$\beta_{ad}^{im} = \phi_{\rm A} \; \frac{\gamma_{\rm A}}{\gamma^{im}} \; (\beta_{ad})_A + \phi_{\rm B} \; \frac{\gamma_{\rm B}}{\gamma^{im}} \; (\beta_{ad})_B$$

Where ϕ and γ refer the volume function and principal specific ratio.

It holds true if the mixture is an ideal one and also $\gamma_A = \gamma_B = \gamma_{im}$. It can be transformed into a linear combination of the mole fractions if the additional assumption $v_A = v_B$ is made $\beta_{ad}^{\ im} = x_A \ (\beta_{ad})_A + x_B \ (\beta_{ad})_B$

The sound velocities appropriate to the above equations are given by

1.4 Junjie relation: This relation derived by Junjie for the ultrasonic velocity of the mixture in terms of the mole fraction, molecular weight and density of the mixture.

$$U = \frac{\sum_{i=1}^{n} x_i V_i}{(\sum_{i=1}^{n} x_i M_i)^{1/2} (\sum_{i=1}^{n} x_i V_i / \rho_i u_i^2)^{1/2}} \qquad \dots \dots (4)$$

where the symbols have their usual meanings.

1.5 Rao's relation: Using the ratio of the temperature coefficient of velocity and expansion coefficient, Rao derived a formula for ultrasonic velocity (U)

$$\mathbf{U} = \left(\frac{R}{V}\right)^3 \tag{5}$$

where V is the molar volume and R is called Rao's constant or molar sound velocity, which is constant for a liquid at a temperature.

CHI-SQUARE TEST FOR GOODNESS OF FIT:

According to Karl Pearson, Chi-square value is evaluated for the binary liquid mixtures under study using the formula

$$\chi^{2} = \sum_{n}^{n} ((U_{\text{(obs)}} - U_{\text{(cal)}})^{2} / U_{\text{(cal)}}) \qquad(6)$$

i=1

where n is the number of data used,

and 'U $_{(obs)}$ = experimental values of ultrasonic velocities $U_{(cal)}$ = computed values of ultrasonic velocities

AVERAGE PRECENTAGE OF ERROR (SdU):

The Average percentage error is calculated by using the relation

 $SdU = 1/n \sum ((U_{(obs)} - U_{(cal)}) / U_{(obs)}) X 100\%$ (7)

where n is the number of data used.

U (obs) = experimental values of ultrasonic velocities

MOLECULAR ASSOCIATIONS:

The degree of intermolecular interaction or molecular association is given by

 $\boldsymbol{\alpha} = [\mathbf{U}_{exp}^2/\mathbf{U}_{imx}^2] - 1$

.....(8)

RESULTS AND DISCUSSION

The experimental ultrasonic velocities and the theoretical values evaluated by Nomoto's Relation (NOM), Impedance Relation (IMP), Vandeal Vangael Ideal Mixing Relation (VDV), Junjie's relation (JUN), Rao's specific velocity method (RAO) are compared for all the three binaries OCP+MA, OCP+EA, OCP+BA along with the percentage of deviations are presented in TABLES 1-3 at all the four temperatures 303.15, 308.15, 313.15, 318.15 K and atmospheric pressure. The validity of different theoretical formulae is checked by the chi-square test for all the mixtures at all the temperatures and the values are given in TABLE-4.

| TABLE-1 IVERDIA 2017 ALANDA TERCORFICALIZATION CONTRACTOR MODIFICATION DI TERCORFICACIONI MA | | | | | | | | | | | | |
|--|------------------|---------------|---------------|---------------|-------------------------|-------------------|--------|-------------|----------------|--------------|---------------|-----------------|
| EXPERIMENTAL AND THEORETICAL VALUES OF VELOCITIES WITH THEIR % DEVIATIONS FOR THE SYSTEM OCP+MA. AT 303.15K | | | | | | | | | | | | |
| ×1 | ECP | NCIM | MP | VDV | | RAC | XINCIM | XMP | SVDV | 79LIN | XRAO | Alpha |
| 0.0000 | 1192.4 | 11324 | 1132.4 | 11324 | 1132.4 | 11324 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.0000 |
| 0.0805 | 1155.6 | 1155.8 | 1158.9 | 11285 | 1141.7 | 1208.4 | 0.02 | 0.28 | -255 | -1.21 | 457 | 0.0487 |
| 0 1641 | 1179.4 | 1179.6 | 1185.0 | 11,27,9 | 1153.4 | 1281.6 | 0.01 | 0.47 | -4.37 | -2.21 | 8.66 | 0.0935 |
| 0.2519 | 1203.8 | 1203.7 | 1210.7 | 11311 | 1167.8 | 1349.8 | -0.02 | 0.57 | -6.04 | -2.99 | 12.12 | 0.1328 |
| 0.3437 | 1228.7 | 1228.1 | 1236.1 | 1138.7 | 1185.1 | 1409.4 | -0.05 | 0.60 | -7.32 | -3.55 | 14.71 | 0.1643 |
| 0.4399 | 1254.0 | 1252.8 | 1261.2 | 1151.7 | 1205.7 | 14571 | -0.09 | 0.57 | -8.15 | -3.55 | 15.20 | 0.1354 |
| 0.5409 | 1279.5 | 1277.8 | 1285.9 | 11714 | 1230.1 | 1489.2 | -0.13 | 0.49 | -1.45 | -3.25 | 16.35 | 0.1951 |
| 0.6470 | 1305.3 | 1303.2 | 1310.2 | 1199.9 | 1258.9 | 1501.3 | -0.16 | 0.38 | -8.07 | -3.55 | 15.02 | 0.1894 |
| 0.7586 | 1331.0 | 1328.9 | 1334.3 | 1240.2 | 1293.0 | 1489.5 | -0.15 | 0.25 | -6.82 | -2.85 | 11.91 | 0.1518 |
| 0.8761 | 1356.5 | 1355.0 | 1358.0 | 1297.6 | 1333.3 | 1450.3 | -0.11 | 0.11 | -4.34 | -171 | 6.92 | 0.0927 |
| 1.0000 | 1381.4 | 1381.4 | 1351.4 | 1381.4 | 1381.4 | 1381.4 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.0000 |
| | | | ÷ | | | AT 305.15K | | | | | | |
| x1 | ĐØP | NCIN | MP | VDV | лж | RAO | XINGM | XMP | %WDV | | 12 40 | Alpha |
| 0.0000 | 1102.9 | 1102.9 | 1102.9 | 1102.9 | 1102.9 | 1102.9 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.0000 |
| 0.0505 | 1126.5 | 1126.9 | 1130_3 | 1099.5 | 1112.4 | 1184.6 | 0.04 | 0.34 | -2.40 | -125 | 5.17 | 0.0497 |
| 0.1641 | 1150.6 | 11514 | 1157.3 | 1099.4 | 1124.4 | 1263.6 | 0.06 | 0.58 | -4,46 | -2.28 | 9.82 | 0.0955 |
| 0.2519 | 1175.5 | 1176.1 | 1183.9 | 1103.0 | 1139.1 | 1337.3 | 0.05 | 0.72 | -6.17 | -3.10 | 13.76 | 0.1358 |
| 0.3437 | 1201.0 | 1201.3 | 1210.2 | шші | 1156.8 | J401.7 | 0.03 | 0.77 | -7,48 | -3.68 | 16.72 | 0.1683 |
| 0.4399 | 1226.9 | 1226.8 | 1235.0 | 1124.5 | 1177.9 | 1453.0 | -0.01 | 0.74 | -8.34 | -3.99 | 18.43 | 0.1904 |
| 0.5409 | 1253.3 | 1252.7 | 1261.5 | 1144.7 | 1203.0 | 1485.7 | -0.05 | 0.66 | -8.66 | -4.01 | 18.63 | 0.1985 |
| 0.6470 | 1280.0 | 1278.9 | 1285.7 | 1173.8 | 1232.6 | 1498.3 | -0.05 | 0.52 | -8.29 | -3.70 | 17.06 | 0.1590 |
| 0.7585 | 1305.8 | 1905.6 | 1311.4 | 1215.0 | 1257.8 | 1483.2 | -0.09 | 0.4 | -7.02 | -2.99 | 13.50 | 0.1558 |
| 0.8761 | 1333.6 | 1392.6 | 1335.9 | 1273.8 | 1309.7 | 1437.8 | -0.07 | 0.18 | -4,45 | -1.79 | 7.82 | 0.0960 |
| 1.0000 | 1360.0 | 1360.0 | 1960.0 | 1360.0 | 1350.0 | 1360.0 | 0.00 | 0.00 | 0.00 | 8.00 | 0.00 | 0.0000 |
| | | | | | | AT 313.15K | | | | | | |
| x1 | ECP | NCIN | MP | VDV | JUN | RAC | SENCIM | XMP | %WDV | | XEAO | Alpha |
| 0.0000 | 1063.5 | 1083.5 | 1053.5 | 1083.5 | 1063.5 | 1083.5 | 0.00 | 0.00 | 0.00 | 8.00 | 0.00 | 0.0000 |
| 0.0503 | 1107.5 | 1107.5 | 1111.2 | 1080.3 | 1093.2 | 1169.5 | 0.03 | 0.34 | -2/6 | -1.29 | 5.62 | 0.0530 |
| 0.1641 | <u>1132.2</u> | 11326 | 1138.6 | 3080.5 | 1105.4 | 1253.3 | 0.03 | 0.56 | -457 | -2.36 | 10.70 | 0.0961 |
| 0.2519 | 1157.5 | 1157.6 | 1365.5 | 1084.3 | 1120.3 | 1991.4 | 0.01 | 0.69 | -6.33 | -3.21 | 15.02 | 0.1395 |
| 0.3437 | 1183.4 | <u>1183.1</u> | 1192.1 | 1092.6 | <u>1135.3</u> | 1399.5 | -0.02 | 0.74 | -7.67 | -3.82 | 18.26 | 0.1752 |
| 0.4399 | 1209.8 | 1209.0 | 1218.3 | 1106.2 | 1159.6 | 1453.4 | -0.07 | 0.71 | -8.56 | -4.15 | 20.14 | 0.1960 |
| 0.5409 | 1296.5 | 1255.2 | 1244.2 | 1126.7 | 1184.9 | 1488.2 | -0.11 | 0.62 | -8.89 | -4.17 | 20.55 | 0.2045 |
| 0.6470 | 1263.5 | 1261.8 | 1269.6 | 1156.0 | 1214.9 | 1498.8 | -0.14 | 0.48 | -851 | -3.85 | 18.62 | 0.1945 |
| 0.7585 | 1290.6 | 1288.8 | 1294.8 | 11975 | 1250.5 | 1480.5 | -0.14 | 0.32 | -7.22 | -3.11 | 14.71 | 0.1636 |
| 0.8761 | 1317.5 | 1316.2 | <u>1319.6</u> | 1256.8 | 1292.9 | 14295 | -0.10 | 0.15 | <u>-4.61</u> | -1.87 | 8.50 | 0.0990 |
| 1.0000 | 1344.0 | 1344.0 | 1344.0 | 1344.0 | 1344.0 | 1344.0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.0000 |
| | احجم | امرودهو | | له جودي و | | AT318.15K RACI | | ا در رو مو | gramed | امور وربي | أحسمو | - |
| x1 0.0000 | 1062 9 | NCM 1062.9 | 1052.9 | VDV 1062.9 | JUN 1062 9 | 1062 9 | | %INP | 500V | | 52AC) 0.00 | Alpha 0.0000 |
| 0.0503 | | 1087.3 | 1090_9 | 1062.9 | | 11534 | -0.01 | 0.32 | -2.53 | -1.37 | 6.06 | 0.0575 |
| 0 1641 | 1087.5 1112.6 | 11121 | 1118.5 | 1060.0 | 1072.6 | 1241.2 | -0.05 | | | -1.57 | 11.55 | 0 1012 |
| 0.2519 | 1138.4 | 1137.3 | 1145.7 | 1060.3 | <u>1084.7</u> 1099.6 | 1323.4 | -010 | 0.53 | -4.70 | -251 | 16.25 | 0.1441 |
| 0.3437 | 1164.7 | 11629 | 1172.5 | 1072.7 | 1035.0 | 1395.0 | -0.16 | 0.67 | -7.90 | -3.41 | 19.78 | 0.1789 |
| 0.4399 | 1191.4 | 1188.9 | 1198.8 | 1072.7 | 1138.8 | 13551.4 | -0.21 | 0.63 | -7_90 -8.81 | -4.00 | 21.82 | 0.2025 |
| 0.5409 | 1218.4 | 1215.3 | 1224.9 | 1107.0 | 1154.2 | 14514 14871 | -025 | 0.53 | -8.81 -9.15 | -4AI -4A5 | 22.06 | 0.2115 |
| 0.6470 | 1245.5 | 1242.2 | 1250.5 | 1136.3 | 1194.4 | J496.7 | -0.27 | 0.40 | -117 | -4_10 | 20_16 | 0.2014 |
| 0.7585 | 1272.6 | 1269.4 | 1275.7 | 1178.0 | 1250.3 | 1475.0 | -0.5 | 0,70 | -7.43 | -3.32 | 15.91 | 0.1671 |
| 0.8761 | 1299.2 | 1297.1 | 1300.6 | 1237.5 | 1230.3 | 14183 | -0.26 | 023 | -745 | -3.32 | 9.17 | 0 1073 |
| 1.0000 | 1325.2 | 13752 | 1325.2 | 1325.2 | 1325.2 | 1325.2 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.0000 |
| | گر تکھید | للاطع | گ دکاند | كالكانع | كالالكافات | للاتكاند | וטעע | الاست | لاست | لانبدو | لاست | لالالالالا |

| TABLE-2 | | | | | | | | | | | | | |
|---|--|--|--|--|--|--|---|--------------------------------------|----------------------------------|---|---|--|--|
| EXPERIMENTAL AND THEORETICAL VALUES OF VELOCITIES WITH THEIR % DEVIATIONS FOR THE SYSTEM OCP+EA | | | | | | | | | | | | | |
| AT 303.15K | | | | | | | | | | | | | |
| z1 | ETP | NOM | m | VDV | JUN | RAO | X2NOM | XDAP | XVDV | %JUN | %R.40 | Algha | |
| 0.0000 | 11173 | 1117.3 | 1117.3 | 1117.3 | 1117.3 | 1117.3 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.0000 | |
| 0.0971 | 1141.8 | 1142.0 | 1152.1 | 1123.7 | 1125.6 | 1191.6 | 0.02 | 0.91 | -1.58 | -1./Q | 4.36 | 0.0324 | |
| 0.1949 | 1166.7 | 1167.2 | 1184.6 | 1133.1 | 1136.6 | 1259.8 | 0.04 | 1.53 | -2.55 | -15 | 7.9\$ | 0.0602 | |
| 0.2932 | 11920 | 1192.6 | 1214.9 | 1145.7 | 1150.7 | 1322.6 | 0.05 | 1.92 | -3.29 | -3AT | 10.96 | 0.0026 | |
| 0.39722 | 1217.8 | 1218.5 | 1243.2 | 1161.9 | 1168.2 | 1376.0 | 0.05 | 2.09 | -4.59 | -4.08 | 12.99 | 0.0985 | |
| 0.4919 | 1244.0 | 1244.7 | 1269.8 | 1182.2 | 1189.4 | 1415.2 | 0.05 | 2.08 | 497 | 439 | 13.76 | 0.1073 | |
| 0.59722 | 1270.6 | 1271.3 | 1294.8 | 1207 <i>A</i> | 1215.0 | 1439.5 | 0.05 | 1.90 | -498 | 438 | 13.29 | 0.1076 | |
| 0.6931 | 1297.7 | 1298.2 | 1318.4 | 1238.3 | 1245.7 | 1447.1 | 0.04 | 1.59 | -4.58 | -4.00 | 11.51 | 0.0983 | |
| 0.7948 | 13252 | 1325.6 | 1340.6 | 1276.2 | 1202.7 | 1438.2 | 0.03 | 1.16 | -3.70 | -3.21 | 8.58 | 0.0782 | |
| 0.8970 | 1353.1 | 1353.3 | 1361.6 | 1323.0 | 1327.2 | 1417.5 | 0.02 | 0.63 | -17 | -1.91 | 4.76 | 0.069 | |
| L0000 | 13\$1.4 | 13\$1.4 | 1381.4 | 1381.4 | 1381.4 | 13\$L4 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.0000 | |
| | | - | | | 1 | LT 308.15K | | | | | | | |
| z1 | EXP | NOM | M | VDV | JUN | RAO | 2210M | 70 0 0 | XVDV | XION | 72.40 | Algina | |
| 0.0000 | 1095.2 | 1095.2 | 1095.2 | 1095.2 | 1095.2 | 1095.2 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.0000 | |
| 0.0971 | 1120.0 | 1120.0 | 1130.2 | 1101.7 | 1103.5 | 1176.5 | -0.01 | 0.90 | -1.64 | -1.45 | 5.04 | 0.0335 | |
| 0.1949 | 11453 | 1145.1 | 1162.7 | 11111 | 1114.6 | 125L1 | -0.01 | 1.52 | -2.9\$ | -2.68 | 9.24 | 0.0624 | |
| 0.2932 | 1170.8 | 1170.6 | 1193.1 | 1123.8 | 1128.6 | 1316.2 | -0.02 | 1.90 | -4.02 | -3.60 | 1242 | 0.0855 | |
| 0.3922 | 1196.8 | 1196.5 | 1221.5 | 1140.0 | 1146.0 | 1369.9 | -0.02 | 2.07 | 4.74 | 424 | 14.46 | 0.1021 | |
| 0.4919 | 1223.1 | 1222.8 | 1248.2 | 1160.4 | 1167.3 | 1410.0 | -0.03 | 2.05 | -5.13 | 457 | 15.28 | 0.1111 | |
| 0.5922 | 1249.8 | 1249.4 | 1273.3 | 11855 | 1192.9 | 1434.6 | -0.03 | 1.55 | -515 | 4.56 | 14.78 | 0.1114 | |
| 0.6931 | 1276.8 | 1276.5 | 1296.9 | 1216.4 | 1723.6 | 1442.3 | -0.03 | 1.57 | 4.73 | -4.17 | 12.96 | 0.1018 | |
| 0.7948 | 1304.3 | 1303.9 | 1319.1 | 1254.4 | 1260.7 | 1432.6 | -0.03 | 1.14 | -3.12 | -3.34 | 9.84 | 0.0810 | |
| 0.8970 | 1331.9 | 1331.8 | 1340.1 | 1301.4 | 1305.4 | 1404.9 | -0.01 | 0.61 | -2.30 | -1.99 | 5,48 | 0.0675 | |
| 1.0000 | 1360.0 | 1360.0 | 1360.0 | 1360.0 | 1360.0 | 1360.0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.0000 | |
| | | | | | | T 313 15K | | | | | | | |
| x1 | EXP | NOM | MP | VDV | JUN | RAO | 2210M | 70AP | XYDY | XION | 72.40 | Alatia | |
| 0.0000 | 1080.7 | 1080.7 | 1080.7 | 1050.7 | 1080.7 | 1050.7 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.0000 | |
| 0.0971 | 1105.6 | 1105.3 | 11155 | 1057.2 | 1088.8 | 1166.9 | -0.03 | 0.90 | -1.66 | -1.52 | 5.54 | 0.0341 | |
| 0.1949 | 1130.8 | 1130.2 | 1147.9 | 1095.6 | 1099.7 | 1245.9 | -0.06 | 1.51 | -3.03 | -275 | 10.17 | 0.0635 | |
| 0.2932 | 11564 | 1155.5 | 1178.2 | 1109.2 | 1113.6 | 1314.7 | -0.08 | 1.88 | -4.09 | -3.70 | 13.69 | 0.0570 | |
| 0.3922 | 11823 | 11\$1.2 | 1206.5 | 11253 | 1130.8 | 1370.9 | -0.09 | 2.04 | -4.12 | 435 | 15.95 | 0.1039 | |
| 0.4919 | 1208.6 | 1207.4 | 1233.0 | 11455 | 1151.8 | 1412.2 | -0.10 | 2.02 | -522 | -4.69 | 16.25 | 0.1131 | |
| 0.5922 | 1235.1 | 1233.9 | 1257.9 | 1170.5 | 1177.3 | 1436.4 | -0.10 | 1.85 | -5.23 | -4.68 | 16.30 | 0.1134 | |
| 0.6931 | 1261.9 | 1260.8 | 1281.3 | 1201.2 | 1207.9 | 1442.0 | -0.09 | 1.54 | -4.81 | -4.28 | 14.27 | 0.1036 | |
| 0.7948 | 1289.0 | 1288.1 | 1303.4 | 1239.0 | 1244.7 | 14228.5 | -0.07 | 1.12 | -3.55 | -3.44 | 10.52 | 0.0524 | |
| 0.8970 | 13164 | 1315.8 | 1324.3 | 1285.7 | 1289.4 | 1395.5 | -0.04 | 0.60 | -2.33 | -2.05 | 6.01 | 0.0483 | |
| 1.0000 | 1344.0 | 1344.0 | 1344.0 | 1344.0 | 1344.0 | 1344.0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.0000 | |
| | | | | | | TILIT | | | | | | | |
| x1 | EXP | NOM | IMP | VDV | אסנ | RAO | 2210M | %D.(P | XVDV | XJUN | XR.AO | Algin | |
| 0.0000 | 10525 | 1052.5 | 1072.5 | 1052.5 | 1052.5 | 1052.5 | 000 | 0.00 | 0.00 | 0.00 | 0.00 | 0.0000 | |
| 0.0971 | 1078.4 | 1077.8 | 1088.6 | 1059.4 | 1061.0 | 1144.1 | -0.05 | 0.95 | -1.76 | -1.61 | 6.09 | 0.0361 | |
| 0.1949 | | 1103.6 | 11722 | 1069.2 | 1072.3 | 1778.3 | -0.09 | 1.59 | -3.20 | -292 | 11.20 | 0.0673 | |
| | | | هـمد د د | | | | -0.13 | 1_98 | -4.32 | -3.94 | 15.08 | 0.0924 | |
| | 1104.6 | | 11525 | 1 /1873 al | | | | | | | | | |
| 0 2932 | 1131.1 | 1129.7 | 1153.5 | <u>1062.3</u> 1062.9 | 1086.6 | 1301.8 | | | 5 10 | | | | |
| 0.2932 | 1131.1 11 58.0 | 1129.7 1156.3 | 1152.5 | 1098.9 | 1104.4 | 1 36 1.7 | -0.15 | 2.14 | -5.10 | 463 | 17.59 | 0.1105 | |
| 0.2932 0.3922 0.4919 | 1131.1 1158.0 1185.2 | 1129.7 1156.3 1183.4 | 11 82.8 1210.3 | 1 098.9 1119.7 | 1104.4 1126.0 | 1361.7 1405.5 | -0.15 -0.16 | 2.14 2.11 | -5.53 | -4.63 -5.00 | 17.59 18.58 | 0.1105 0.1204 | |
| 0.2932 0.3922 0.4919 0.5922 | 1131.1 1158.0 1185.2 1212.7 | 1129.7 1156.3 1183.4 1210.8 | 1182.8 1210.3 1236.1 | 1098.9 1119.7 1145.4 | 1104.4 1126.0 1152.1 | 1361.7 1405.5 1430.5 | -0.15 -0.16 -0.16 | 2.14 2.11 1.92 | -5.53 -5.55 | -4.63 -5.00 -5.00 | 17.59 18.58 17.96 | 0.1105 0.1204 0.1209 | |
| 0.2932 0.3922 0.4919 0.5922 0.6931 | 1131.1 1158.0 1185.2 1212.7 1240.5 | 1129.7 1156.3 1183.4 1210.8 1238.7 | 11 82.8 1210.3 1236.1 1260.3 | 1098.9 1119.7 1145.4 1177.1 | 1104.4 1126.0 1152.1 1183.7 | 1361.7 1405.5 1430.5 1435.3 | -0.15 -0.16 -0.16 -0.14 | 2.14 2.11 1.92 1.60 | -5.53 -5.55 -5.11 | -4.63 -5.00 -5.00 -4.58 | 17.59 18.58 17.96 15.71 | 0.1105 0.1204 0.1209 0.1105 | |
| 0.2932 0.3922 0.4919 0.5922 0.6931 0.7948 | 1131.1 1158.0 1185.2 1212.7 1240.5 1268.5 | 1129.7 1156.3 1183.4 1210.8 1238.7 1267.1 | 11828 12103 12361 12603 12832 | 1098.9 1119.7 1145.4 1177.1 1216.1 | 1104.4 1126.0 1152.1 1183.7 1221.8 | 1361.7 1405.5 1430.5 1435.3 1419.3 | -0.15 -0.16 -0.16 -0.14 -0.11 | 2.14 2.11 1.92 1.60 1.16 | -5.53 -5.55 -5.11 -4.13 | -4.63 -5.00 -5.00 -4.58 -3.68 | 17.59 18.58 17.96 15.71 11.88 | 0.1105 0.1204 0.1209 0.1105 0.0881 | |
| 0.2932 0.3922 0.4919 0.5922 0.6931 | 1131.1 1158.0 1185.2 1212.7 1240.5 | 1129.7 1156.3 1183.4 1210.8 1238.7 | 11 82.8 1210.3 1236.1 1260.3 | 1098.9 1119.7 1145.4 1177.1 | 1104.4 1126.0 1152.1 1183.7 | 1361.7 1405.5 1430.5 1435.3 | -0.15 -0.16 -0.16 -0.14 | 2.14 2.11 1.92 1.60 | -5.53 -5.55 -5.11 | -4.63 -5.00 -5.00 -4.58 | 17.59 18.58 17.96 15.71 | 0.1105 0.1204 0.1209 0.1105 | |

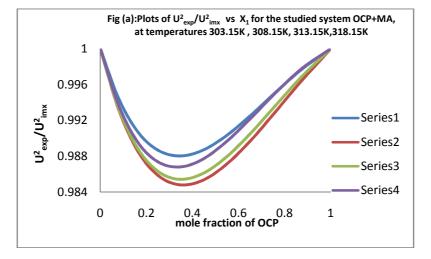
The data reveals that the velocities computed from Nomoto's relation (NOM) and Impdance relation (IMP) exhibit more satisfactory agreement with the experimental values in the temperature range 303.15K to 318.15K than other approaches in the binary systems. It is observed that the experimental values show deviation with the theoretical values of ultrasonic velocities which confirms the existence of molecular interactions [22]. This may be due to interactions occurring between the hetero molecules of the binaries. Higher deviations are observed in Rao's specific and slight variations in Junjie's theories. There are higher variations in some intermediate concentration range suggesting the existence of strong tendency of association between component molecules as a result of dipole-dipole interactions. However, there is reasonably a good agreement between the experimental and theoretical velocities of Nomoto's relation and Impedance relation. Nomoto's theory proposes that the volume does not change upon mixing. Therefore, no interaction between the components of liquid mixtures has been taken into account. Similarly, the assumption for the formation of ideal mixing relation is that, the ratios of specific heats of ideal mixtures and the volumes are also equal. Again no molecular interactions are taken into account. But upon mixing, interactions between the molecules occur because of the presence of various types of forces such as dispersion forces, charge transfer, hydrogen bonding dipole-dipole and dipole-induced dipole interactions. Thus, the observed deviation of theoretical values of velocity from the experimental values shows that the molecular interactions are taking place between the unlike molecules in the liquid mixtures. From the Tables it is observed that maximum positive deviation exhibiting a minimum of approximately 0.5 mole fraction for all the three systems at all the temperatures. The ratio U_{exp}^2/U_{imx}^2 is an important tool to measure the non ideality in the mixtures especially in such cases where the properties other than sound velocity are not known.

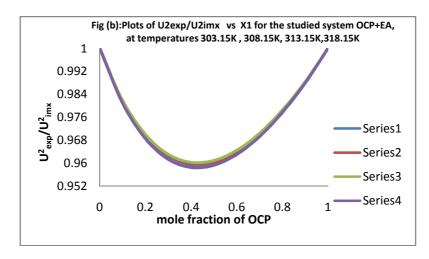
| | | | | | | TABLE-3 | | | | | | | |
|---|--|--|--|--|--|--|--|---|--|---|---|--|--|
| EXI | ERIMENT | AL AND T | | AL VALUE | | | | . S DEVIA | TONS ROR | THE SYST | EMOCH | BA. | |
| EXPERIMENTAL AND THEORETICAL VALUES OF VELOCITIES WITH THEIR % DEVIATIONS FOR THE SYSTEM OCP+BA AT 303.15K | | | | | | | | | | | | | |
| x1 | EXP | NOM | MP | ADA | ามส | RAO | 2010M | አገለዋ | XVDV | XJUN | 78.AO | Alpia | |
| 0.0000 | 1165.2 | 1165.2 | 1165.2 | 1165.2 | 1165.2 | 1165.2 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.0000 | |
| 0.1263 | 1192.2 | 1185.7 | 1202.4 | 1184.4 | 1170.4 | 1230.3 | -0.54 | 0.86 | -0.65 | -1.83 | 3.20 | 0.0131 | |
| 0.2454 | 1217.8 | 1205 5 | 1234.2 | 1204.2 | 1178.3 | 1284 5 | -0.93 | 1.35 | -1.11 | -1 24 | 5.48 | 0 0226 | |
| 0.3580 | 1242.0 | 1227.5 | 1261.5 | 1224.5 | 1189.1 | 1328.0 | -1.17 | 1.56 | -1.41 | -4.26 | 6.92 | 0.0288 | |
| 0,4645 | 1265.1 | 1248.7 | 1285.3 | 12453 | 1203.1 | 1361.1 | -1.29 | 1.60 | -1.56 | -4.90 | 7.59 | 0.0320 | |
| 0 5654 | 12569 | 1270.2 | 1306.2 | 1366.6 | 1220.5 | 1384.4 | -1.30 | 1.49 | -1.58 | -5.16 | 151 | 0.0333 | |
| 0.6612 | 1307.7 | 1252.0 | 1324.7 | 1265 5 | 1241.9 | 1398.6 | -1.20 | 1.29 | -1.47 | -5.03 | 695 | 0.0301 | |
| 0 7522 | 1827 5 | 1314.0 | 1341 1 | 1310.9 | 1267 7 | 1404.6 | -1 02 | 1 05 | -1 25 | 1.50 | 581 | 0 0255 | |
| 0.5355 | 1346.3 | 1336.2 | 1355.9 | 1333.8 | 1298.9 | 1403.1 | -0.75 | 0.71 | -0.93 | -3.53 | 4.72 | 0.0188 | |
| 0.9213 | 1364.3 | 1358.7 | 1369.3 | 13573 | 1336.3 | 1395.1 | -0.41 | 0.37 | -0.51 | -2.05 | 226 | 0.0103 | |
| 1.0000 | 1381.4 | 1381.4 | 1381.4 | 1381.4 | 1381.4 | 1381.4 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.0000 | |
| | | | | | | AT 308 15K | | | | | | | |
| x 1 | EXP | NOM | IMP | VDV | រហៅ | RAO | 7010M | XIMP | XVDV | XIUN | 7 RAO | Alpha | |
| 0.0000 | 1149.4 | 1149.4 | 1149.4 | 1149.4 | 1149.4 | 1149.4 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.0000 | |
| 01263 | 1176.0 | 1169.4 | 1185.7 | 1168.2 | 1154.4 | 1224.4 | -0.56 | 0.92 | -0.67 | -1.\$4 | 411 | 0.0135 | |
| 0.2454 | 1201.2 | 1189.6 | 1216.6 | 1187.5 | 1162.0 | 1285.9 | -0.96 | 1.28 | -1_14 | -1.15 | 7_06 | 0.0232 | |
| 0.3580 | 1225.0 | 1210.1 | 1243.2 | 1207.3 | 1172.6 | 1334.1 | -1.21 | 1.49 | -1.44 | -4.28 | 8.91 | 0.0295 | |
| 0,4645 | 1247.5 | 1230.8 | 12664 | 1227.6 | 1195.2 | 1369.2 | -1.33 | 1.52 | -1.59 | 491 | 9.76 | 0.0327 | |
| 0.5654 | 1268.8 | 1251.7 | 1286.7 | 1248.4 | 1203.2 | 1392.0 | -1.34 | 1.42 | -1.61 | -5.17 | 9.71 | 0.0329 | |
| 0.6612 | 1269.0 | 1272.9 | 1304.7 | 1369.6 | 1204.0 | 1403.6 | -1.24 | 1.22 | -1.50 | -5.04 | \$.89 | 0.0306 | |
| 0.7522 | 1308.1 | 1294.3 | 1320.8 | 1291.4 | 1249.2 | 1404.9 | -1_05 | 0.97 | -1_7 | -4.50 | 7,40 | 0.0260 | |
| 0.5365 | 1326.3 | 1316.0 | 1335.2 | 1313.8 | 1279.5 | 1397.4 | -0.78 | 0.67 | -0.94 | -358 | 5.36 | 0.0192 | |
| 0.9213 | 1543.6 | 1337.9 | 1348.2 | 1336.6 | 1316.0 | 1397.4 | -0.78 | 0.35 | -0.52 | -3.35 | 2.36 | 0.0192 | |
| | A | | | | | | | | | | | | |
| 1 0000 | 12.60.0 | | | | 1260.0 | | | | | | | | |
| 1.0000 | 13 60.0 | 1360.0 | 1360.0 | 1360.0 | 1360.0 | 1360.0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.0000 | |
| | | 1360.0 | 1360.0 | 1360.0 | | 1360.0 AT 313.15K | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.0000 | |
| x 1 | EXP | 1360.0 NOM | 1360.D | 1360.0 VDV | ובבבבים אנונות | 1360.0 AT 313.15K RAO | 0.00 %2NOM | 0.00 %DMP | 0.00 VDV: | 0.00 %JUN | 0.00 73R.AO | 0.0000 Algin | |
| x1 0.0000 | EXP 1130.2 | 1360.0 NOM 1130.2 | 1360.0 IMP 1130.2 | 1360.0 VDV 1130.2 | JUN 1130.2 | 1360.0 AT 313.15K RAO 1130.2 | 0.00 300 0.00 | 0.00 %IMP 0.00 | 0.00 VCIVX 00.0 | 0.00 %JUN 0.00 | 0.00 %RAO 0.00 | 0.0000 Algin 0.0000 | |
| x1 0.0000 0.1263 | EXP 11302 11572 | 1360.0 NOM 1130.2 1150.5 | 1360.0 IMP 1130.2 1167.0 | 1360.0 VDV 1130.2 1149.2 | JUN 1130.2 1135.4 | 1360.0 AT 313.15K RAO 1130.2 1215.4 | 0.00 %NOM 0.00 -0.58 | 0.00 %IMP 0.00 0.15 | 0.00 %VDV 0.00 -0.69 | 0.00 %JUN 0.00 -1.88 | 0.00 %RAO 0.00 5.03 | 0.0000 Algin 0.0000 0.0140 | |
| x1 0.0000 0.1263 0.2454 | EXP 11302 11572 11827 | 1360.0 NOM 1130.2 1150.5 1171.0 | 1360.0 IMP 1130.2 1167.0 1198.4 | 1360.0 VDV 1130.2 1149.2 1168.7 | JUN 1130.2 1135.4 1143.3 | 1360.0 AT 313.15K RAO 1130.2 1215.4 1284.9 | 0.00 %NOM 0.00 -0.58 -0.99 | 0.00 %IMP 0.00 0.15 1.33 | 0.00 %VDV 0.00 -0.69 -1.18 | 0.00 %JUN 0.00 -1.98 -3.33 | 0.00 %RAO 0.00 5.03 8.65 | 0.0000 Alpin 0.0000 0.0140 0.0241 | |
| x1 0.0000 0.1263 0.2454 0.3580 | EXP 11302 11572 11827 12068 | 1360.0 NOM 1130.2 1150.5 1171.0 1191.7 | 1360.0 IMP 1130.2 1167.0 1198.4 1225.4 | 1360.0 VDV 1130.2 1149.2 1168.7 1188.7 | JUN 1130.2 1135.4 1143.3 1154.0 | 1360.0 AT 313.15K RAO 1130.2 1215.4 1214.9 1338.6 | 0.00 %NOM 0.00 -0.58 -0.99 -1.25 | 0.00 %IMP 0.00 0.15 1.33 1.54 | 0.00 %VDV 0.00 -0.69 -1.18 -1.50 | 0.00 %JUN 0.00 -1.88 -3.33 -4.38 | 0.00 %RAO 0.00 5.03 8.65 10.52 | 0.0000 Alpin 0.0000 0.0140 0.0241 0.0307 | |
| x1 0.0000 0.1263 0.2454 0.3580 0.4645 | EXP 11302 11572 11827 12068 1229.6 | 1360.0 NOM 1130.2 1150.5 1171.0 1191.7 1212.8 | 1360.0 IMP 1130.2 1167.0 1198.4 1225.4 1248.9 | 1360.0 VDV 1130.2 1149.2 1168.7 1188.7 1209.2 | JUN 1130.2 1135.4 1143.3 1154.0 1167.8 | 1360.0 AT 31 3.15K RAO 1130.2 1215.4 1204.9 1338.6 1376.6 | 0.00 %NOM 0.00 -0.58 -0.99 -1.25 -1.37 | 0.00 %IMP 0.00 0.15 1.33 1.54 1.57 | 0.00 %VDV 0.00 -0.69 -1.18 -1.50 -1.66 | 0.00 %JUN 0.00 -1.33 -3.33 -4.38 -5.05 | 0.00 7/28.AO 0.00 5.03 8.65 10.92 11.95 | 0.0000 Algin 0.0000 0.0140 0.0241 0.0307 0.0340 | |
| x1 0.0000 0.1263 0.2454 0.3580 0.4645 0.5654 | EXP 11302 1157.2 1182.7 1205.8 1229.6 1251.3 | 1360.0 NOM 1130.2 1150.5 1171.0 1191.7 1212.8 1234.0 | 1360.0 IMP 1130.2 1167.0 1198.4 1225.4 1248.9 1269.6 | 1360.0 VDV 1130.2 1149.2 1168.7 1188.7 1209.2 1230.3 | JUN 1130.2 1135.4 1143.3 1154.0 1167.8 1185.0 | 1360.0 AT 313.15K RAO 1130.2 1215.4 1204.9 1338.6 1376.6 1399.9 | 0.00 %NOM 0.00 -0.58 -0.99 -1.25 -1.37 -1.38 | 0.00 %IMP 0.00 0.45 1.33 1.54 1.57 1.47 | 0.00 %VDV 0.00 -0.69 -1.18 -1.50 -1.66 -1.68 | L00 %JUN 0.00 -1.33 -1.33 -4.38 -5.03 -5.29 | 0.00 %RAO 0.00 5.03 8.65 10.92 11.95 11.88 | 0.0000 Algin 0.0000 0.0140 0.0241 0.0347 0.0340 0.0344 | |
| x1 0.0000 0.1263 0.2454 0.3580 0.4645 0.5654 0.5654 0.6612 | EXP 1130.2 1157.2 1182.7 1206.8 1229.6 1251.3 1271.8 | 1360.0 NOM 1130.2 1150.5 1171.0 1191.7 1212.8 1234.0 1255.5 | 1360.0 1MP 1130.2 1167.0 1198.4 1225.4 1225.4 1248.9 1269.6 1287.9 | 1360.0 VDV 1130.2 1149.2 1168.7 1188.7 1209.2 1230.3 1251.9 | JUN 1130.2 1135.4 1143.3 1154.0 1167.8 1185.0 1205.1 | 1360.0 AT 31 3.15K RAO 1130.2 1215.4 1284.9 1338.6 1376.6 1399.9 1409.7 | 0.00 %NOM 0.00 -0.58 -0.99 -1.25 -1.37 -1.38 -1.28 | 0.00 %IMP 0.00 0.15 1.33 1.54 1.57 1.47 1.27 | 0.00 %VDV 0.00 -0.69 -1.18 -1.50 -1.66 -1.68 -1.56 | L00 %JUN 0.00 -1.18 -3.33 -4.38 -5.03 -5.16 | 0.00 %RAO 0.00 5.03 8.65 10.92 11.95 11.95 11.95 | 0.0000 Algin 0.0000 0.0140 0.0341 0.0307 0.0340 0.0344 0.0320 | |
| x1 0.0000 0.1263 0.2454 0.3380 0.4645 0.5654 0.5654 0.6612 0.7522 | EXP 1130.2 1157.2 1182.7 1206.8 1229.6 1251.3 1271.8 1291.2 | 1360.0 NOM 1130.2 1150.5 1171.0 1191.7 1212.8 1234.0 1255.5 1277.2 | 1360.0 1147.0 1130.2 1167.0 1198.4 1225.4 1225.4 1248.9 1269.6 1287.9 1304.2 | 1360.0 VDV 1130.2 1149.2 1168.7 1188.7 1209.2 1230.3 1251.9 1274.1 | JUN 1130.2 1135.4 1143.3 1154.0 1167.8 1185.0 1205.1 1251.6 | 1360.0 AT 31 3.15K RAO 1130.2 1215.4 1214.9 1338.6 1376.6 1399.9 1409.7 1407.5 | 0.00 72NGM 0.00 -0.58 -0.99 -1.25 -1.37 -1.38 -1.28 -1.08 | 0.00 %IMP 0.00 0.85 1.33 1.54 1.57 1.47 1.27 1.00 | 0.00 %VDV 0.00 -0.69 -1.18 -1.50 -1.66 -1.64 -1.56 -1.33 | 1.00 %JUN 0.00 -1.88 -3.33 -4.38 -5.03 -5.16 -5.16 -4.62 | 0.00 %RAO 0.00 5.03 8.65 10.92 11.95 11.95 11.95 10.94 9.00 | 0.0000 Algin 0.0000 0.0140 0.0341 0.0307 0.0340 0.0344 0.0320 0.0271 | |
| x1 0.0000 0.1263 0.2454 0.3580 0.4645 0.5654 0.6612 0.7522 0.8388 | EXP 1130.2 1157.2 1182.7 1206.8 1229.6 1251.3 1271.8 1291.2 1309.7 | 1360.0 NOM 1130.2 1150.5 1171.0 1191.7 1212.8 1234.0 1255.5 1277.2 1299.2 | 1360.0 IMP 1130.2 1167.0 1198.4 1225.4 1248.9 1287.9 1304.2 1318.8 | 1360.0 VDV 1130.2 1149.2 1168.7 1188.7 1209.2 1230.3 1251.9 1274.1 1296.8 | JUN 1130.2 1135.4 1143.3 1154.0 1167.8 1185.0 1206.1 1231.6 1262.4 | 1360.0 AT 31 3.15K RAO 1130.2 1215.4 1204.9 1338.6 1376.6 1379.9 1409.7 1407.5 1394.5 | 0.00 0.00 0.058 -0.59 -1.25 -1.37 -1.38 -1.28 -1.08 -0.80 | 0.00 %IMP 0.00 0.85 1.33 1.54 1.57 1.47 1.27 1.00 0.70 | 0.00 %VDV 0.00 -0.69 -1.18 -1.56 -1.68 -1.56 -1.56 -1.33 -0.99 | 1.00 %JUN 0.00 -1.88 -3.33 -4.38 -5.03 -5.16 -5.16 -4.62 -3.62 | 0.00 72RAO 0.00 5.03 8.65 10.92 11.95 11.95 11.95 11.94 9.00 6.47 | 0.0000 Algin 0.0000 0.0140 0.0241 0.0340 0.0340 0.0320 0.0271 0.0200 | |
| x1 0.0000 0.1263 0.2454 0.3580 0.4645 0.5654 0.5654 0.6612 0.7522 0.8388 0.9213 | EXP 1130.2 1157.2 1182.7 1206.8 1229.6 1251.3 1271.8 1291.2 1309.7 1327.3 | 1360.0 NOM 1130.2 1150.5 1171.0 1191.7 1212.8 1234.0 1255.5 1277.2 1299.2 1321.5 | 1360.0 IMP 1130.2 1167.0 1198.4 1225.4 1225.4 1248.9 1269.6 1287.9 1304.2 1318.8 1332.0 | 1360.0 VDV 1130.2 1149.2 1168.7 1188.7 1209.2 1230.3 1251.9 1274.1 1296.8 1320.1 | JUN 1130.2 1135.4 1143.3 1154.0 1167.8 1185.0 1206.1 1231.6 1262.4 1289.3 | 1360.0 AT 31 3.15K RAO 1130.2 1215.4 1214.9 1338.6 1376.6 1399.9 1409.7 1407.5 1394.5 1373.0 | 0.00 0.00 0.58 0.99 -1.25 -1.38 -1.28 -1.28 -1.08 0.80 -0.44 | 0.00 %IMP 0.05 1.33 1.54 1.57 1.47 1.27 1.00 0.70 0.36 | 0.00 %VDV 0.00 -0.69 -1.18 -1.56 -1.56 -1.56 -1.55 -1.33 -0.99 -0.54 | L00 %JUN 0.00 -1.98 -3.33 -4.38 -5.03 -5.16 -5.16 -4.62 -3.162 -3.162 | 0.00 7/28.40 0.00 5.03 8.65 10.92 11.95 11.95 10.94 9.00 6.47 3.44 | 0.0000 0.0140 0.0341 0.0340 0.0340 0.0340 0.0340 0.0340 0.0320 0.0271 0.0200 0.0109 | |
| x1 0.0000 0.1263 0.2454 0.3580 0.4645 0.5654 0.6612 0.7522 0.8388 | EXP 1130.2 1157.2 1182.7 1206.8 1229.6 1251.3 1271.8 1291.2 1309.7 | 1360.0 NOM 1130.2 1150.5 1171.0 1191.7 1212.8 1234.0 1255.5 1277.2 1299.2 | 1360.0 IMP 1130.2 1167.0 1198.4 1225.4 1248.9 1287.9 1304.2 1318.8 | 1360.0 VDV 1130.2 1149.2 1168.7 1188.7 1209.2 1230.3 1251.9 1274.1 1296.8 | JUN 1130.2 1135.4 1143.3 1154.0 1167.8 1185.0 1206.1 1251.6 1252.4 1289.3 1344.0 | 1360.0 AT 31 3.15K RAO 1130.2 1215.4 1284.9 1338.6 1376.6 1379.9 1409.7 1409.7 1407.5 1394.5 1394.5 1373.0 | 0.00 0.00 0.058 -0.59 -1.25 -1.37 -1.38 -1.28 -1.08 -0.80 | 0.00 %IMP 0.00 0.85 1.33 1.54 1.57 1.47 1.27 1.00 0.70 | 0.00 %VDV 0.00 -0.69 -1.18 -1.56 -1.68 -1.56 -1.56 -1.33 -0.99 | 1.00 %JUN 0.00 -1.88 -3.33 -4.38 -5.03 -5.16 -5.16 -4.62 -3.62 | 0.00 72RAO 0.00 5.03 8.65 10.92 11.95 11.95 11.95 11.94 9.00 6.47 | 0.0000 Alph 0.0000 0.0140 0.0241 0.0307 0.0340 0.0344 0.0320 0.0271 0.0200 | |
| x1 0.0000 0.1263 0.2454 0.3380 0.4645 0.5654 0.5654 0.7522 0.8348 0.9213 1.0000 | EXP 1130.2 1157.2 1157.2 1206.8 1251.3 1271.8 1291.2 1309.7 1327.3 1344.0 | 1360.0 NOM 1130.2 1150.5 1171.0 1191.7 1212.8 1234.0 1255.5 1277.2 1289.2 1321.5 1344.0 | 1360.0 IMP 1130.2 1167.0 1198.4 1225.4 1248.9 1269.6 1287.9 1304.2 1318.8 1332.0 1344.0 | 1360.0 VDV 1130.2 1149.2 1168.7 1188.7 1209.2 1230.3 1251.9 1274.1 1296.8 1320.1 1344.0 | JUN 1130.2 1135.4 1143.3 1154.0 1167.8 1185.0 1206.1 1251.6 1252.4 1289.3 1344.0 | 1360.0 AT 31 3.15K RAO 1130.2 1215.4 1284.9 1338.6 1376.6 1379.9 1409.7 1409.7 1409.7 1394.5 1394.5 1373.0 1344.0 XT 318.15K | 0.00 %NCM 0.00 -0.58 -0.99 -1.25 -1.37 -1.38 -1.28 -0.80 -0.44 0.00 | 0.00 %DMP 0.00 0.15 1.33 1.54 1.57 1.47 1.47 1.27 1.00 0.70 0.36 0.00 | 0.00 %VDV 0.00 -0.69 -1.18 -1.56 -1.66 -1.66 -1.56 -1.56 -1.56 -1.56 -1.56 -0.99 -0.54 0.00 | 0.00 %JUN 0.00 -1.18 -3.33 -4.38 -5.03 -5.03 -5.16 -4.62 -3.62 -3.11 0.00 | 0.00 7/2R.AO 0.00 5.03 8.65 10.92 11.95 11.95 11.95 11.95 11.95 10.94 9.00 6.47 3.44 0.00 | 0.0000 0.0140 0.0241 0.0347 0.0344 0.0344 0.0344 0.0344 0.0320 0.0271 0.0200 0.0109 0.0109 | |
| x1 0.0000 0.1263 0.2454 0.3380 0.4645 0.5654 0.5654 0.6612 0.7522 0.7522 0.7522 0.3388 0.9213 1.0000 x1 | EXP 1130.2 1157.2 1157.2 1206.8 1251.3 1271.8 1291.2 1309.7 1327.3 1344.0 EXP | 1360.0 NOM 1130.2 1150.5 1171.0 1191.7 1212.8 1234.0 1255.5 1277.2 1259.2 1321.5 1 | 1360.0 IMP 1130.2 1167.0 1198.4 1225.4 1248.9 1269.6 1287.9 1304.2 1318.8 1332.0 1344.0 IMP | 1360.0 VDV 1130.2 1149.2 1168.7 1188.7 1209.2 1230.3 1251.9 1274.1 1296.8 1320.1 1344.0 VDV | JUN 1130.2 1135.4 1143.3 1154.0 1167.8 1185.0 1206.1 1252.4 1252.4 1289.3 1344.0 JUN | 1360.0 AT 31 3.15K RAO 1130.2 1215.4 1284.9 1338.6 1376.6 1379.9 1409.7 1409.7 1409.7 1394.5 1393.5 1394.5 1373.0 1344.0 XI 318.15K RAO | 0.00 %NCM 0.00 -0.58 -0.99 -1.25 -1.37 -1.38 -1.28 -1.28 -0.80 -0.44 0.00 %NCM | 0.00 %DMP 0.00 0.15 1.33 1.54 1.57 1.47 1.27 1.27 1.00 0.70 0.70 0.36 0.00 | 0.00 %VDV 0.00 -0.69 -1.12 -1.50 -1.66 -1.66 -1.57 -1.56 -1.57 -1.56 -1.57 | 0.00 %JUN 0.00 -1.18 -3.33 -4.38 -5.03 -5.16 -5.16 -4.62 -3.62 -3.11 0.00 | 0.00 788.40 0.00 5.03 8.65 10.92 11.95 11. | 0.0000 Alpin 0.0000 0.0140 0.0341 0.0307 0.0344 0.0344 0.03271 0.02200 0.0109 0.0109 0.0000 | |
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| x1 0.0000 0.1263 0.2454 0.3580 0.4645 0.5654 0.5654 0.5654 0.5654 0.7522 0.8388 0.9213 1.0000 x1 0.0000 0.1263 | EXP 1130.2 1157.2 1182.7 1206.8 1251.3 1271.8 1291.2 1309.7 1327.3 1344.0 EXP 1110.4 1138.0 | 1360.0 NOM 1130.2 1150.5 1171.0 1191.7 1212.8 1234.0 1255.5 1277.2 1299.2 1321.5 1344.0 NOM 1110.4 1130.7 | 1360.0 IMP 1130.2 1167.0 1198.4 1225.4 1248.9 1269.6 1287.9 1304.2 1318.8 1332.0 1344.0 IMP 1110.4 1147.4 | 1360.0 VDV 1130.2 1149.2 1168.7 1188.7 1209.2 1230.3 1251.9 1274.1 1296.8 1320.1 1344.0 VDV 1110.4 1129.4 | JUN 1130.2 1135.4 1143.3 1154.0 1167.8 1185.0 1206.1 1231.6 1262.4 1289.3 1344.0 JUN 110.4 | 1360.0 AT 31 3.15K RAO 1130.2 1215.4 1204.9 1338.6 1376.6 1379.9 1407.5 1394.5 1373.0 1344.0 AT 318.15K RAO 1110.4 1203.2 | 0.00 5%NGM 0.00 -0.58 -0.99 -1.25 -1.37 -1.38 -1.28 -1.28 -1.080 -0.60 0.00 -0.64 | 0.00 %IMP 0.00 0.15 1.33 1.54 1.57 1.47 1.27 1.00 0.70 0.36 0.00 %IMP 0.00 0.13 | 0.00 %VDV 0.00 -0.69 -1.18 -1.50 -1.65 -1.65 -1.65 -1.56 -0.59 | 0.00 %JUN 0.00 -1.18 -3.33 -4.38 -5.03 -5.03 -5.03 -5.03 -5.03 -5.16 -4.62 -3.62 -3.62 -3.62 -3.11 0.00 -1.96 | 0.00 7/2RAO 0.00 5.03 8.65 10.92 11.95 11.95 11.95 11.95 11.95 10.94 9.00 6.47 3.44 0.00 6.47 3.44 0.00 5.73 | 0.0000 0.0140 0.0241 0.0357 0.0340 0.0340 0.0340 0.0320 0.0271 0.0200 0.0200 0.0000 0.0000 0.0153 | |
| x1 0.0000 0.1263 0.2454 0.3580 0.4645 0.5654 0.5654 0.5654 0.5654 0.5654 0.5523 0.2338 1.0000 x1 0.0000 0.1263 0.2454 | EXP 1130.2 1157.2 1182.7 1206.8 1251.3 1251.3 1271.8 1291.2 1309.7 1327.3 1344.0 EXP 1110.4 1138.0 1163.9 | 1360.0 NOM 1130.2 1150.5 1171.0 1191.7 1212.8 1234.0 1255.5 1277.2 1299.2 1321.5 1344.0 NOM 1110.4 1130.7 1151.3 | 1360.0 IMP 1130.2 1167.0 1198.4 1225.4 1248.9 1269.6 1287.9 1304.2 1318.8 1332.0 1344.0 IMP 1110.4 1147.4 1178.9 | 1360.0 VDV 1130.2 1149.2 1168.7 1188.7 1209.2 1230.3 1251.9 1274.1 1296.8 1320.1 1320.1 1344.0 VDV 1110.4 1129.4 1129.4 1148.9 | JUN 1130.2 1135.4 1143.3 1154.0 1167.8 1185.0 1206.1 1281.6 1282.4 1299.3 1344.0 JUN 1110.4 1115.7 1123.6 | 1360.0 AT 31 3.15K RAO 1130.2 1215.4 1204.9 1338.6 1376.6 1379.9 1409.7 1409.7 1409.7 1409.7 1409.7 1409.7 1409.7 1394.5 1373.0 1344.0 AT 318.15K RAO 1110.4 1203.2 1278.7 | 0.00 5%NGM 0.00 -0.58 -0.99 -1.25 -1.37 -1.38 -1.28 -1.28 -1.08 -0.80 -0.44 0.00 -0.64 -1.08 | 0.00 %IMP 0.00 0.15 1.33 1.54 1.57 1.47 1.27 1.00 0.70 0.36 0.00 %IMP 0.00 0.13 1.29 | 0.00 %VDV 0.00 -0.69 -1.18 -1.50 -1.66 -1.56 -1.56 -1.56 -1.56 -1.57 -0.99 -0.54 0.00 -0.00 -0.00 -0.00 -0.00 -0.00 -0.00 -0.00 -0.00 -0.00 -0.00 -1.18 -1.50 -1.55 -0.59 | 0.00 %JUN 0.00 -1.18 -3.33 -4.38 -5.03 -5.03 -5.16 -4.62 -3.62 -3.62 -3.10 0.00 -1.95 -3.46 | 0.00 7/2RAO 0.00 5.03 8.65 10.92 11.95 11. | 0.0000 0.0140 0.0241 0.0307 0.0340 0.0340 0.0340 0.0320 0.0271 0.0200 0.0109 0.0109 0.0109 0.0109 0.0109 0.0109 0.0109 0.0109 0.0109 0.0109 0.0109 0.0109 0.0109 0.0109 0.0109 0.0109 0.0100 0.0153 0.0263 | |
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| x1 0.0000 0.1263 0.3380 0.4645 0.5654 0.5654 0.5654 0.7522 0.2388 0.9213 1 0000 0.1263 0.2454 0.3880 0.4645 0.5654 0.5654 0.5654 | EXP 1130.2 1157.2 1182.7 1206.8 1251.3 1271.8 1291.2 1309.7 1327.3 1344.0 EXP 1110.4 1138.0 1163.9 1175.2 1175 | 1360.0 NOM 1130.2 1150.5 1171.0 1191.7 1212.8 1234.0 1255.5 1277.2 1299.2 1321.5 1344.0 NOM 1110.4 1130.7 1151.3 1172.2 1193.2 1214.6 1236.2 | 1360.0 IMP 1130.2 1167.0 1198.4 1225.4 1248.9 1269.6 1287.9 1304.2 1318.8 1332.0 1344.0 IMP 1110.4 1178.9 1206.1 1229.7 1250.5 1268.9 | 1360.0 VDV 1130.2 1149.2 1168.7 1188.7 1230.3 1251.9 1274.1 1296.8 1320.1 1344.0 VDV 1110.4 1129.4 1119.4 1149.9 1169.0 1119.6 1210.7 1232.4 | JUN 1130.2 1135.4 1143.3 1154.0 1167.8 1185.0 1205.1 1205.1 1251.6 1265.1 1265.1 1265.1 1265.4 1289.3 1344.0 JUN 1110.4 1115.7 1123.6 1144.2 1165.5 1186.7 | 1360.0 AT 31 3.15K RAO 1130.2 1215.4 1215.4 1214.9 1338.6 1379.9 1409.7 1407.5 1394.5 1373.0 1344.0 AT 318.15K RAO 1110.4 1203.2 1778.7 1336.5 1376.7 1400.1 | 0.00 0.00 0.58 0.99 -1.25 -1.37 -1.38 -1.28 -1.28 -1.08 0.00 0.00 -0.44 0.00 -0.44 0.00 -0.64 -1.08 -1.08 -1.50 -1.51 -1.50 -1.51 -1.40 | 0.00 %IMP 0.05 1.33 1.54 1.57 1.47 1.57 1.47 1.27 1.00 0.70 0.36 0.03 0.036 0.00 %IMP 0.00 0.13 1.29 1.49 1.51 1.40 1.21 | 0.00 %VDV 0.00 -0.69 -1.18 -1.56 -1.68 -1.56 -1.68 -1.56 -1.57 -1.56 -1.57 -1.56 -1.57 -1.56 -1.57 -1.56 -1.57 | L00 XJUN 0.00 -1.188 -3.33 -4.38 -5.16 -5.16 -5.16 -4.62 -3.62 -1.11 0.00 -1.96 -4.55 -4.55 -5.22 -5.49 -5.35 | 0.00 7/8.40 0.00 5.03 8.65 10.97 11.95 11.95 11.97 11.97 11.98 9.00 6.47 3.44 0.00 6.47 3.44 0.00 5.73 9.96 12.46 13.64 13.54 13.54 | 0.0000 0.0140 0.0307 0.0307 0.0307 0.0304 0.0304 0.0304 0.0200 0.0109 0.0000 0.0109 0.0000 0.0103 0.0000 0.0103 0.0000 0.0103 0.0000 0.0103 0.0000 0.0103 0.0000 0.0103 0.0000 0.0103 0.0000 0.0103 0.0000 0.0100 0.0100 0.0000 0.0100 0.00000 0.00000 0.000000 | |
| x1 0.0000 0.1263 0.3380 0.4645 0.5654 0.5654 0.5654 0.57522 0.8388 0.97213 1 0000 0.1263 x1 0.0000 0.1263 0.3380 0.3454 0.3580 0.3584 0.5654 0.5654 0.5654 0.5654 | EXP 1130.2 1157.2 1157.2 1296.8 1229.6 1251.3 1271.8 1291.2 1309.7 1327.3 1344.0 EXP 1110.4 1138.0 1163.9 1188.4 1233.2 1253.7 1273.1 | 1360.0 NOM 1130.2 1150.5 1171.0 1191.7 1212.8 1234.0 1255.5 1277.2 1299.2 1321.5 1344.0 NOM 1110.4 1130.7 1151.3 1172.2 1193.2 1214.6 1236.2 1258.1 | 1360.0 IMP 1130.2 1167.0 1198.4 1225.4 1269.6 1287.9 1304.2 1318.8 1332.0 1344.0 IMP 1110.4 1178.9 1206.1 1229.7 1250.5 1268.9 1285.2 | 1360.0 VDV 1130.2 1149.2 1168.7 1188.7 1209.2 1230.3 1251.9 1274.1 1296.8 1320.1 1344.0 VDV 1110.4 1129.4 1169.0 1169.0 1189.6 1210.7 1232.4 1254.7 | JUN 1130.2 1135.4 1143.3 1154.0 1167.8 1185.0 1265.1 1251.6 1265.4 1269.3 1344.0 JUN 1110.4 1115.7 1123.6 1134.4 1148.2 1165.5 1186.7 1212.2 | 1360.0 AT 31 3.15K RAO 1130.2 1215.4 1204.9 1338.6 1376.6 1399.9 1409.7 1407.5 1394.5 1373.0 1344.0 AT 318.15K RAO 1110.4 1203.2 1378.7 1378.7 1378.5 1376.7 1376.7 1400.1 1408.5 1403.3 | 0.00 2.NOM 0.00 -0.58 -0.99 -1.25 -1.37 -1.38 -0.80 -0.80 -0.44 0.00 -0.44 0.00 -0.44 0.00 -0.64 -1.08 -1.50 -1.51 -1.40 -1.18 | 0.00 %IMP 0.00 0.15 1.33 1.54 1.57 1.47 1.47 1.27 1.00 0.70 0.36 0.00 %IMP 0.00 0.13 1.29 1.49 1.51 1.40 1.21 0.95 | 0.00 %VDV 0.00 -0.69 -1.18 -1.56 -1.66 -1.68 -1.56 -1.33 -0.59 -0.54 0.00 %VDV 0.00 -0.76 -1.20 -1.61 -1.61 -1.62 -1.70 -1.44 | L00 %JUN 0.00 -1.188 -3.33 -4.38 -5.29 -5.16 -4.62 -3.62 -1.11 0.00 -1.96 -3.46 -4.55 -5.22 -5.49 -5.35 -4.78 | 0.00 5.03 8.65 10.97 11.95 11.95 11.95 11.95 11.95 11.95 10.94 9.00 6.47 3.44 0.00 5.73 9.96 12.46 13.54 13.54 13.54 12.35 10.23 | 0.0000 0.0140 0.0241 0.0307 0.0340 0.0340 0.0320 0.0271 0.0200 0.0271 0.0200 0.0109 0.0200 0.0109 0.0000 0.0153 0.0335 0.0335 0.0335 0.0375 0.0375 | |
| x1 0.0000 0.1263 0.3380 0.4645 0.5654 0.5654 0.5752 0.12388 0.9713 1 0000 0.1263 0.9713 1 0000 0.1263 0.2454 0.3380 0.4645 0.5654 0.5654 0.56512 0.5654 0.56512 0.5654 | EXP 1130.2 1157.2 1157.2 1206.8 1229.6 1251.3 1271.8 1291.2 1309.7 1327.3 1344.0 EXP 1110.4 1138.0 1163.9 1188.4 1233.2 1253.7 1273.1 1291.4 | 1360.0 NOM 1130.2 1150.5 1171.0 1191.7 1212.8 1234.0 1255.5 1277.2 1299.2 1321.5 1321.5 1324.0 NOM 1110.4 1130.7 1151.3 1172.2 1193.2 1214.6 1236.2 1258.1 1280.2 | 1360.0 IMP 1130.2 1167.0 1198.4 1225.4 1225.4 1269.6 1257.9 1269.6 1257.9 1318.8 1332.0 1344.0 IMP 1110.4 1147.4 1178.9 1206.1 1229.7 1250.5 1268.9 1285.2 1285.2 1289.9 | 1360.0 VDV 1130.2 1149.2 1168.7 1188.7 1209.2 1230.3 1251.9 1274.1 1296.8 1320.1 1344.0 VDV 1110.4 1129.4 1148.9 1169.0 1189.6 1210.7 1232.4 1232.4 1232.4 | JUN 1130.2 1135.4 1143.3 1154.0 1167.8 1185.0 1206.1 1251.6 1265.24 1209.3 1344.0 1110.4 1115.7 1123.6 1134.4 1148.2 1165.5 1186.7 1212.2 1203.1 | 1360.0 AT 31 3.15K RAO 1130.2 1215.4 1284.9 1338.6 1376.6 1376.6 1379.9 1409.7 1407.5 1394.5 1373.0 1344.0 AT 318.15K RAO 1110.4 1203.2 1376.7 1336.5 1376.7 | 0.00 2.NOM 0.00 -0.58 -0.99 -1.25 -1.37 -1.38 -0.80 -0.44 0.00 -0.44 0.00 -0.44 0.00 -0.44 -1.08 -1.08 -1.08 -1.08 -1.08 -1.08 -1.18 -1.50 -1.51 -1.40 -1.18 -0.87 | 0.00 %IMP 0.00 0.15 1.33 1.54 1.57 1.57 1.77 1.77 1.00 0.70 0.36 0.00 %IMP 0.00 0.13 1.29 1.49 1.51 1.40 1.21 0.95 0.66 | 0.00 %VDV 0.00 -0.69 -1.18 -1.56 -1.66 -1.66 -1.66 -1.56 -1.33 -0.59 -0.54 0.09 -0.54 0.00 -0.74 -0.00 -0.75 -1.20 -1.81 -1.81 -1.82 -1.70 -1.44 -1.07 | €00 %JUN €000 -1.188 -3.33 -4.38 -5.03 -5.16 -4.62 -3.62 -3.62 -3.11 0.00 -1.96 -3.46 -3.45 -3.49 -5.22 -5.49 -5.35 -4.78 -3.74 | 0.00 5.03 8.65 10.97 11.95 11.95 11.95 11.95 10.94 9.00 6.47 3.44 0.00 5.73 9.96 12.46 13.64 13.54 13.54 13.54 | 0.0000 0.0140 0.0341 0.0377 0.0340 0.0340 0.0340 0.0320 0.0271 0.0200 0.0109 0.0200 0.0109 0.0000 0.0133 0.0355 0.0351 0.0355 0.0355 0.0355 0.0355 0.0355 0.0355 0.0355 | |
| x1 0.0000 0.1263 0.3380 0.4645 0.5654 0.5654 0.5654 0.57522 0.8388 0.97213 1 0000 0.1263 x1 0.0000 0.1263 0.3380 0.3454 0.3580 0.3584 0.5654 0.5654 0.5654 0.5654 | EXP 1130.2 1157.2 1157.2 1296.8 1229.6 1251.3 1271.8 1291.2 1309.7 1327.3 1344.0 EXP 1110.4 1138.0 1163.9 1188.4 1233.2 1253.7 1273.1 | 1360.0 NOM 1130.2 1150.5 1171.0 1191.7 1212.8 1234.0 1255.5 1277.2 1299.2 1321.5 1344.0 NOM 1110.4 1130.7 1151.3 1172.2 1193.2 1214.6 1236.2 1258.1 | 1360.0 IMP 1130.2 1167.0 1198.4 1225.4 1269.6 1287.9 1304.2 1318.8 1332.0 1344.0 IMP 1110.4 1178.9 1206.1 1229.7 1250.5 1268.9 1285.2 | 1360.0 VDV 1130.2 1149.2 1168.7 1188.7 1209.2 1230.3 1251.9 1274.1 1296.8 1320.1 1344.0 VDV 1110.4 1129.4 1169.0 1169.0 1189.6 1210.7 1232.4 1254.7 | JUN 1130.2 1135.4 1143.3 1154.0 1167.8 1185.0 1265.1 1251.6 1265.4 1269.3 1344.0 JUN 1110.4 1115.7 1123.6 1134.4 1148.2 1165.5 1186.7 1212.2 | 1360.0 AT 31 3.15K RAO 1130.2 1215.4 1204.9 1338.6 1376.6 1399.9 1409.7 1407.5 1394.5 1373.0 1344.0 AT 318.15K RAO 1110.4 1203.2 1378.7 1378.7 1378.7 1378.5 1376.7 1400.1 1408.5 1403.3 | 0.00 2.NOM 0.00 -0.58 -0.99 -1.25 -1.37 -1.38 -0.80 -0.80 -0.44 0.00 -0.44 0.00 -0.44 0.00 -0.64 -1.08 -1.50 -1.51 -1.40 -1.18 | 0.00 %IMP 0.00 0.15 1.33 1.54 1.57 1.47 1.47 1.27 1.00 0.70 0.36 0.00 %IMP 0.00 0.13 1.29 1.49 1.51 1.40 1.21 0.95 | 0.00 %VDV 0.00 -0.69 -1.18 -1.56 -1.66 -1.68 -1.56 -1.33 -0.59 -0.54 0.00 %VDV 0.00 -0.76 -1.20 -1.61 -1.61 -1.62 -1.70 -1.44 | L00 %JUN 0.00 -1.188 -3.33 -4.38 -5.29 -5.16 -4.62 -3.62 -1.11 0.00 -1.96 -3.46 -4.55 -5.22 -5.49 -5.35 -4.78 | 0.00 5.03 8.65 10.97 11.95 11.95 11.95 11.95 11.95 11.95 10.94 9.00 6.47 3.44 0.00 5.73 9.96 12.46 13.54 13.54 13.54 12.35 10.23 | 0.0000 Alpin 0.0000 0.0140 0.0341 0.0307 0.0340 0.0320 0.0320 0.0271 0.0200 0.0109 0.0109 0.0000 0.0153 0.0000 0.0153 0.0335 0.0335 0.0348 0.0395 | |

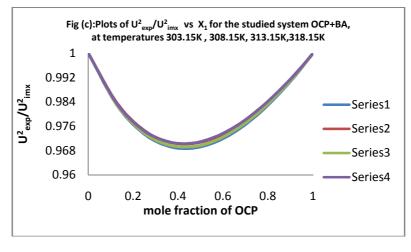
Figures a, b and c represent the variation of U_{exp}^2/U_{imx}^2 with the mole fraction of OCP for all three binary systems studied, and the ratio of U_{exp}^2/U_{imx}^2 gives an idea of extent of interaction taking place between molecules of the mixtures. The positive deviation for three systems infers strong interactions between the components. The percentage of deviation in velocity is reflecting both negative and positive magnitudes, indicating non ideal behaviour of liquid mixtures. The evaluated interaction parameters are positive for all the systems, indicating strong interactions between the mixing molecules. The negative values of interaction parameter indicates the dominance of dispersion forces arising from the breakage of hydrogen bonds in the associates. But a positive value of (α) in all the system clearly indicates the existence of strong tendency for the formation of association in mixture through strong dipole-dipole / hydrogen bonding interactions and higher values of percentage deviation indicates maximum departure of the particular theory from experiment at that particular concentration and magnitude of the chi-square

value finally determines the overall validity of the theory. The chi square values along with average percentage error are given in TABLE- 4.

| | TABLE-4 | | | | | | | | | | | | |
|-------------------|---|------|---------------|-------|--------------|--------|--------|--------|--------|-------|--|--|--|
| | VALUES OF CHI-SQUARE AND SIGMA RELATIVE DEVIATION FOR ALL | | | | | | | | | | | | |
| | THE BINARY MIXTURES OF OCP AT DIFFERENT TEMPERATURES | | | | | | | | | | | | |
| SYSTEM-I (OCP+MA) | | | | | | | | | | | | | |
| | | 12 | | | | SđU | | | | | | | |
| T(K.) | NOM | MP | VDV | ЛIN | RAO | NOM | MP | VDV | JUN | RAO | | | |
| 303.15K. | 0.01 | 0.22 | 48.60 | 16.25 | 177.60 | -0.007 | 0.113Y | -0.601 | -8.266 | 0.942 | | | |
| 308.15K | 0.00 | 0.36 | 50.00 | 10.84 | 224.25 | -0.001 | 0.048 | -0.617 | -0.277 | 1.052 | | | |
| 313.15K | 0.01 | 0_32 | 51 .94 | 11.55 | 263.54 | -0.005 | 0.046 | -0.634 | -0.288 | 1.135 | | | |
| 31 8.1 5K | 0.04 | 0.25 | 54.22 | 12.89 | 304.24 | -0.015 | 0.040 | -0.654 | -0.307 | 1.215 | | | |
| | | | | SYSI | EM-II (OCI | HEA) | | • | | | | | |
| | | 12 | | | | SđU | | | | | | | |
| T(K.) | NOM | MP | VDV | ЛIN | RAO | NOM | MP | VDV | JUN | RAO | | | |
| 303.15K | 000 | 2.90 | 17.65 | 13.24 | 120.36 | 0.004 | 0.136 | -0.348 | -1.315 | 0.795 | | | |
| 308.15K | 0_00 | 2.78 | 17.19 | 14.09 | 149.67 | -0.002 | 0.134 | -0.360 | -0.318 | 0.887 | | | |
| 313.15K | 0.01 | 2.67 | 18.27 | 14.70 | 179.54 | -0.007 | 0.132 | -0.366 | -4.327 | 0.966 | | | |
| 318.15K | 0.02 | 2.86 | 20.16 | 16.49 | 213.61 | -0.010 | 0.138 | -0_390 | -0.350 | 1.051 | | | |
| | | | • | SYST | EM-III (OC | P+BA) | | | • | | | | |
| | | 12 | | | | SdU | | | | | | | |
| T(K) | NOM | M | VDV | ЛIN | RAO | NOM | MP | VDV | JUN | RAO | | | |
| 303_15K | 1.16 | 1.67 | 1.72 | 18.65 | 39.38 | -0.087 | 0.101 | -0.106 | -0.360 | 0.471 | | | |
| 308.15K | 1.23 | L48 | 1.76 | 18.46 | 6.83 | -0.090 | 0.096 | -0.108 | -0.361 | 0.594 | | | |
| 313.15K | 1.28 | 157 | 1.89 | 19_10 | 93.86 | -0.093 | 0100 | -0.113 | -0.370 | 0.713 | | | |
| 318.15K | 1.51 | 1_42 | 2.20 | 20.23 | 120.05 | -0.101 | 0.096 | -0.123 | -0.385 | 0.803 | | | |







CONCLUSION

From the values of experimental and evaluated velocity values, it may be concluded that, the Nomoto's relation, Impedance relation have provided good agreement. Thus, the linearity of molar sound velocity and additivity of molar volumes, as suggested by Nomoto, and Impedance relation in deriving the empirical relations have been truly observed in the aforementioned binary liquid mixtures. The success of Nomoto's relation in predicting the experimental ultrasonic velocities for polar-polar liquid mixtures has also been emphasized by others [24].

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