# Molecular Interactions of Ethyl Butyrate with Alkoxyalkanols

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## ABSTRACT

*In this work, densities and speeds of sound of binary mixtures ofalkoxyalkanols with Ethyl butyrate (EtBu) have been measured at temperatures 298.15 – 323.15K at atmospheric pressure. With the help of experimental results, a discussion is carried out on the molecular interactions and the effect of temperature on interactions through excess properties such as excess molar volumes,* $V_{\mathrm{m}}^{\mathrm{E}}$*, excess isentropic compressibility,* $\kappa_{\mathrm{s}}^{\mathrm{E}}$*, excess speeds of sound,* $u^{\mathrm{E}}$*, excess molar isentropic compressibility,* $K_{\mathrm{s,m}}^{\mathrm{E}}$*, excess isobaric thermal expansion,* $\alpha_p^E$ *.The excess properties are adequately fitted with the Redlich-Kister polynomial equation. The excess partial molar volumes,* $\bar{V}_{\mathrm{m,1}}^{\mathrm{E}}$ *and* $\bar{V}_{\mathrm{m,2}}^{\mathrm{E}}$*; excess partial molar isentropic compressibilities,* $\bar{K}_{\mathrm{s,m,1}}^{\mathrm{E}}$ *and* $\bar{K}_{\mathrm{s,m,2}}^{\mathrm{E}}$*; excess partial molar volumes,* $\bar{V}_{\mathrm{m,1}}^{\circ\mathrm{E}}$ *and* $\bar{V}_{\mathrm{m,2}}^{\circ\mathrm{E}}$*; excess partial molar isentropic compressibilities,* $\bar{K}_{\mathrm{s,m,1}}^{\circ\mathrm{E}}$ *and* $\bar{K}_{\mathrm{s,m,2}}^{\circ\mathrm{E}}$ *of the components at infinite dilution also been measured. The results have been discussed in terms of intermolecular interactions prevailing in these mixtures. The results indicated that the interactions in these systems follow the order: 2-methoxyethanol > 2-ethoxyethanol.*

**Keywords**: Density, Speed of sound, Ethyl butyrate,Alkoxy alkanols, Excess Properties.

## 1. INTRODUCTION

In view of increasing pressure to minimize greenhouse gases and the concerns over the increasing scarcity of fossil fuels replacing transport fuels with more sustainable alternatives is a pressing scientific and engineering challenge. One of the alternatives is biofuels. The fatty acid methyl esters derived from vegetable, animal orwaste oils provide alternative, renewable fuels for the motor cars [1]. They are ecologically more acceptable than conventional fuels and also conserve significantly the fossil sources of energy. Experimental study of the key thermodynamic properties of the biofuels is a very difficult task, as they are complex, largely in volatile mixtures of methyl and ethyl esters of fatty acids. Volatile Organic Acids such as Ethyl acetate (EtAc), Ethyl propionate (EtPr), and Ethyl butyrate (EtBu) are produced from low-value biomass wastes. So, they are identified as alternative bioenergy fuels. Generally, these acids have not been used in internal combustion engines because of the resistance of materials. Ethyl acetate, ethyl propionate and ethyl butyrate have been shown to be suitable fuels for a Homogeneous Charge Compression Ignition (HCCI) engine, though they ignite slower than ethanol and these are acidogenesis products. Acidogenesis is commonly used to decrease negative ecological effects of polluting compounds. The smaller ignition delay of EtBu could help reduce the inlet temperature and make the use of these esters as transportation fuels [2]. The successful implementation of these fuels may require to mix them with other fuels or to use various compositions to control the engine.

The literature survey indicates that the systematic volumetric, acoustic, optical and spectroscopic studies of binary mixtures of EtBu with 2-methoxyethanol/2-ethoxyethanol have not been reported earlier. The 2-alkoxyethanols belongs to the group of cellosolves and amphiphilic compounds which have both alcoholic - OH and partially etheric - O - in its structure, and are well-known for their proton-donating and proton-accepting ability, which makes it possible to form inter- and intra-molecular hydrogen bond [3,4]between their molecules in pure state. 2-Alkoxyethanols in pure form and in aqueous solutions are used as a solvent for electrolytes up to some extent as an aprotic solvent [5,6]. For this reason these are often defined as “quasi-aprotic” solvents. 2-Alkoxyethanol are useful in printing and other specialized coatings applications due to fast evaporation and high solubility in water and active solvency make it ideal, for a variety of cleaning applications such as cleaning fluids, paints, coatings and inks. The knowledge of the behaviour of EtBu + alkoxyethanols is important for both industry and fundamental research. Furthermore, accurate thermophysical (volumetric properties, refractive index, expansivities and isothermal compressibilities) data are required for the optimization of the design of many industrial processes [7,8].

In the present study, we report the densities, $\rho$ and speeds of sound, $u$ of the binary mixtures of EtBu with 2-methoxyethanol/2-ethoxyethanol, including those of pure liquids, over whole composition range at 298.15, 303.15, 308.15, 313.15, 318.15 and 323.15 K and atmospheric pressure. From the experimental data, various physicochemical parameters, *viz.*, $V_{\mathrm{m}}^{\mathrm{E}}$, $\kappa_{\mathrm{s}}^{\mathrm{E}}$, $u^{\mathrm{E}}$ and $K_{\mathrm{s,m}}^{\mathrm{E}}$ of the mixtures; $\bar{V}_{\mathrm{m,1}}$ and $\bar{V}_{\mathrm{m,2}}$, $\bar{K}_{\mathrm{s,m,1}}$ and $\bar{K}_{\mathrm{s,m,2}}$, $\bar{V}_{\mathrm{m,1}}^{\mathrm{E}}$ and $\bar{V}_{\mathrm{m,2}}^{\mathrm{E}}$ and $\bar{K}_{\mathrm{s,m,1}}^{\mathrm{E}}$ and $\bar{K}_{\mathrm{s,m,2}}^{\mathrm{E}}$ over whole composition range; $\bar{V}_{\mathrm{m,1}}^{\circ}$ and $\bar{V}_{\mathrm{m,2}}^{\circ}$; $\bar{K}_{\mathrm{s,m,1}}^{\circ}$ and $\bar{K}_{\mathrm{s,m,2}}^{\circ}$; $\bar{V}_{\mathrm{m,1}}^{\circ\mathrm{E}}$ and $\bar{V}_{\mathrm{m,2}}^{\circ\mathrm{E}}$ and $\bar{K}_{\mathrm{s,m,1}}^{\circ\mathrm{E}}$ and $\bar{K}_{\mathrm{s,m,2}}^{\circ\mathrm{E}}$ of the components in the mixture at infinite dilution, have been calculated. The results have been discussed in terms of intermolecular interactions in these mixtures.

## 2. EXPERIMENTAL

### 2.1. Chemicals and preparation of samples

The Ethyl butyrate(EtBu), 2-methoxyethanol and 2-ethoxyethanol were supplied by Sigma Aldrich, India with mass fraction purity > 0.99with less than 100 ppm water content. Water content of the chemicals was estimated by Karl Fischer titration using Karl Fisher coulometer (890 KF Titrando, Metrohm, USA) [9] and found to be within limits specified by the manufacturer. These liquids were purified by vacuum distillation over calcium oxide. To reduce water content, the liquids were stored in dark bottles over 0.4 nm molecular sieves; and were partially degassed in a nitrogen atmosphere under low pressure before use. The estimated mass fraction purities of alkoxyethanolsdetermined by gaschromatographic analysis were better than 0.995. The final purities and other specifications of the chemicals

| Chemical name (CAS number) | Source | Initial mass fraction purity (supplier purity) | Purification method | Analysis method | Final mass fraction purity | water in mass fraction (supplier) | Water analysis method |
|---|---|---|---|---|---|---|---|
| 2-Methoxy Ethanol (109-86-4) | Sigma Aldrich, India | > 0.99 | Vacuum distillation | GC$^a$ | > 0.996 | < 0.006 | Karl Fischer |
| 2-Ethoxy Ethanol (110-80-5) | Sigma Aldrich, India | > 0.99 | Vacuum distillation | GC$^a$ | > 0.996 | < 0.008 | Karl Fischer |
| Ethyl butyrate (105-54-4) | Sigma Aldrich, India | >0.99 | Vacuum distillation | GC$^a$ | > 0.997 | < 0.001 | Karl Fischer |

used are given in Table 1.

**Table 1.**Specification of the samples.

GC- Gas Chromatography

All the mixtures were prepared by mass and stored in Amber colored glass vials (8 mL) with screw caps having PFE septa, and a secure sealed with parafilm to prevent absorption of moisture from the atmosphere. All mixtures were prepared fresh prior to measurements using an electronic balance (CPA-225D, Sartorius, Germany) precisely within ±0.01 mg. The uncertainty in the mole fraction was estimated to be within $\pm1\times10^{-4}$.

### 2.2. Equipments and procedures

The densities and ultrasonic speeds of pure liquids and their binary mixtures were measured by using the digital vibrating tube Density and Sound Analyzer (DSA 5000M, Anton Parr, Austria) with reproducibility of $\pm1\times10^{-3}$ kg·m$^{-3}$ for density and $\pm1\times10^{-2}$ m·s$^{-1}$ for speed of sound. The densimeter was calibrated with triply-distilled freshly degassed water ($\rho$ = 997.075 kg·m$^{-3}$) and with dry air at atmospheric pressure as described earlier [10]. The operating frequency for speed of sound measurements was 3 MHz.The standard uncertainties associated with the measurements for temperature, density and speed of sound were estimated to be within ±0.01 K, ±0.5 kg·m$^{-3}$ and ±0.5 m·s$^{-1}$, respectively.

## 3. THEORY

The values of the experimental density, $\rho$, speed of sound, $u$, $V_m^E$, $\kappa_s^E$, $u^E$, $K_{s,m}^E$ and $\alpha_p^E$ of the binary mixtures of EtBu with 2-methoxyethanol and 2-ethoxyethanol as a function of mole fraction, $x_1$ of EtBuat different temperatures are given in Tables 2and3.

**Table 2.**Density ($\rho$), Speedof sound ($u$), excess molar volume ($V_m^E$), excess isentropic compressibility ($\kappa_s^E$), excess molar isentropic compressibility ($K_{s,m}^E$), excess speed of sound ($u^E$) and excess isobaric expansivity ($\alpha_p^E$) as a function of mole fraction, $x_1$ of EtBufor Ethyl butyrate + 2-Methoxyethanol at the temperatures $T$ = (298.15 to 323.15) K at pressure $p$ = 0.1 MPa.

| T/K | $\rho$ kg·m$^{-3}$ | $u$ m.s$^{-1}$ | $V_m^E$ $10^6$ m$^3$.mol$^{-1}$ | $\kappa_s^E$ $10^{10}$ m$^2$. N$^{-1}$ | $K_{s,m}^E$ $10^{14}$ kg·m$^{-3}$ | $u^E$ $10^{-2}$ m.s$^{-1}$ | $\alpha_p^E$ $10^3$ m$^3$.mol$^{-1}$ |
|---|---|---|---|---|---|---|---|
| T=298.15 K | | | | | | | |
| 0.0000 | 960.32 | 1342.5 | 0.0000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 0.1126 | 945.51 | 1307.0 | -0.0251 | -0.099 | -0.086 | 0.101 | -0.423 |
| 0.2144 | 933.78 | 1280.4 | -0.0457 | -0.146 | -0.136 | 0.138 | -0.657 |
| 0.3222 | 922.77 | 1257.0 | -0.0627 | -0.169 | -0.167 | 0.148 | -0.779 |
| 0.4394 | 912.16 | 1236.2 | -0.0768 | -0.174 | -0.184 | 0.142 | -0.792 |
| 0.5390 | 904.05 | 1221.5 | -0.0823 | -0.167 | -0.187 | 0.131 | -0.726 |
| 0.6245 | 897.65 | 1210.6 | -0.0796 | -0.154 | -0.180 | 0.117 | -0.627 |
| 0.7327 | 890.19 | 1198.4 | -0.0680 | -0.129 | -0.158 | 0.094 | -0.464 |
| 0.8248 | 884.35 | 1189.0 | -0.0517 | -0.097 | -0.124 | 0.069 | -0.305 |
| 0.9000 | 879.88 | 1181.6 | -0.0324 | -0.063 | -0.083 | 0.044 | -0.171 |
| 1.0000 | 874.31 | 1171.8 | 0.0000 | 0.000 | 0.000 | 0.000 | 0.000 |
| T=303.15 K | | | | | | | |
| 0.0000 | 955.71 | 1325.3 | 0.0000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 0.1126 | 940.77 | 1289.2 | -0.0284 | -0.109 | -0.095 | 0.106 | -0.468 |
| 0.2144 | 928.93 | 1262.1 | -0.0511 | -0.160 | -0.150 | 0.144 | -0.714 |
| 0.3222 | 917.80 | 1238.2 | -0.0687 | -0.185 | -0.185 | 0.154 | -0.835 |
| 0.4394 | 907.08 | 1217.0 | -0.0824 | -0.190 | -0.203 | 0.148 | -0.842 |
| 0.5390 | 898.88 | 1202.0 | -0.0876 | -0.183 | -0.206 | 0.136 | -0.773 |
| 0.6245 | 892.42 | 1190.8 | -0.0848 | -0.169 | -0.199 | 0.121 | -0.672 |
| 0.7327 | 884.90 | 1178.4 | -0.0740 | -0.142 | -0.175 | 0.098 | -0.507 |
| 0.8248 | 879.01 | 1168.7 | -0.0575 | -0.107 | -0.137 | 0.071 | -0.342 |
| 0.9000 | 874.49 | 1161.1 | -0.0357 | -0.068 | -0.090 | 0.045 | -0.198 |
| 1.0000 | 868.85 | 1151.1 | 0.0000 | 0.000 | 0.000 | 0.000 | 0.000 |
| T=308.15 K | | | | | | | |
| 0.0000 | 951.08 | 1308.1 | 0.0000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 0.1126 | 936.02 | 1271.5 | -0.0325 | -0.120 | -0.105 | 0.111 | -0.515 |
| 0.2144 | 924.07 | 1243.8 | -0.0566 | -0.177 | -0.167 | 0.151 | -0.773 |
| 0.3222 | 912.83 | 1219.5 | -0.0755 | -0.205 | -0.206 | 0.162 | -0.892 |
| 0.4394 | 902.00 | 1197.8 | -0.0887 | -0.211 | -0.226 | 0.155 | -0.894 |
| 0.5390 | 893.72 | 1182.5 | -0.0929 | -0.204 | -0.230 | 0.143 | -0.823 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 0.6245 | 887.20 | 1171.2 | -0.0907 | -0.189 | -0.223 | 0.128 | -0.722 |
| 0.7327 | 879.62 | 1158.5 | -0.0802 | -0.160 | -0.198 | 0.104 | -0.554 |
| 0.8248 | 873.67 | 1148.5 | -0.0626 | -0.121 | -0.157 | 0.077 | -0.384 |
| 0.9000 | 869.10 | 1140.6 | -0.0399 | -0.078 | -0.104 | 0.048 | -0.228 |
| 1.0000 | 863.40 | 1130.2 | 0.0000 | 0.000 | 0.000 | 0.000 | 0.000 |
| T=313.15 K | | | | | | | |
| 0.0000 | 946.42 | 1290.9 | 0.0000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 0.1126 | 931.24 | 1253.7 | -0.0369 | -0.134 | -0.118 | 0.118 | -0.566 |
| 0.2144 | 919.17 | 1225.6 | -0.0619 | -0.198 | -0.187 | 0.160 | -0.833 |
| 0.3222 | 907.84 | 1200.8 | -0.0821 | -0.230 | -0.232 | 0.172 | -0.947 |
| 0.4394 | 896.89 | 1178.8 | -0.0941 | -0.238 | -0.256 | 0.166 | -0.941 |
| 0.5390 | 888.53 | 1163.2 | -0.0980 | -0.231 | -0.263 | 0.153 | -0.867 |
| 0.6245 | 881.96 | 1151.7 | -0.0961 | -0.217 | -0.257 | 0.139 | -0.766 |
| 0.7327 | 874.32 | 1138.7 | -0.0860 | -0.186 | -0.232 | 0.114 | -0.600 |
| 0.8248 | 868.33 | 1128.5 | -0.0690 | -0.143 | -0.187 | 0.085 | -0.425 |
| 0.9000 | 863.71 | 1120.3 | -0.0440 | -0.094 | -0.126 | 0.055 | -0.260 |
| 1.0000 | 857.94 | 1109.0 | 0.0000 | 0.000 | 0.000 | 0.000 | 0.000 |
| T=318.15 K | | | | | | | |
| 0.0000 | 941.72 | 1273.7 | 0.0000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 0.1126 | 926.44 | 1236.0 | -0.0417 | -0.148 | -0.132 | 0.125 | -0.621 |
| 0.2144 | 914.27 | 1207.4 | -0.0687 | -0.220 | -0.209 | 0.169 | -0.896 |
| 0.3222 | 902.82 | 1182.2 | -0.0879 | -0.256 | -0.259 | 0.181 | -1.004 |
| 0.4394 | 891.77 | 1159.8 | -0.0998 | -0.266 | -0.288 | 0.176 | -0.991 |
| 0.5390 | 883.35 | 1144.0 | -0.1041 | -0.260 | -0.297 | 0.163 | -0.913 |
| 0.6245 | 876.72 | 1132.2 | -0.1022 | -0.246 | -0.293 | 0.148 | -0.814 |
| 0.7327 | 869.02 | 1119.0 | -0.0921 | -0.213 | -0.267 | 0.123 | -0.649 |
| 0.8248 | 862.98 | 1108.5 | -0.0746 | -0.166 | -0.218 | 0.093 | -0.471 |
| 0.9000 | 858.33 | 1099.9 | -0.0492 | -0.110 | -0.149 | 0.060 | -0.294 |
| 1.0000 | 852.49 | 1088.0 | 0.0000 | 0.000 | 0.000 | 0.000 | 0.000 |
| T=323.15 K | | | | | | | |
| 0.0000 | 936.89 | 1256.5 | 0.0000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 0.1126 | 921.54 | 1218.1 | -0.0471 | -0.162 | -0.145 | 0.130 | -0.679 |
| 0.2144 | 909.28 | 1189.1 | -0.0760 | -0.242 | -0.232 | 0.176 | -0.961 |
| 0.3222 | 897.73 | 1163.6 | -0.0942 | -0.283 | -0.289 | 0.190 | -1.058 |
| 0.4394 | 886.59 | 1140.9 | -0.1056 | -0.296 | -0.323 | 0.185 | -1.033 |
| 0.5390 | 878.10 | 1124.8 | -0.1090 | -0.291 | -0.334 | 0.172 | -0.955 |
| 0.6245 | 871.43 | 1112.9 | -0.1073 | -0.276 | -0.330 | 0.157 | -0.859 |
| 0.7327 | 863.69 | 1099.3 | -0.0981 | -0.240 | -0.303 | 0.131 | -0.700 |
| 0.8248 | 857.62 | 1088.6 | -0.0816 | -0.190 | -0.250 | 0.100 | -0.522 |
| 0.9000 | 852.93 | 1080.0 | -0.0541 | -0.131 | -0.177 | 0.067 | -0.334 |
| 1.0000 | 847.03 | 1067.1 | 0.0000 | 0.000 | 0.000 | 0.000 | 0.000 |

**Table 3**.Density ($\rho$), Speedof sound ($u$), excess molar volume ($V_m^E$), excess isentropic compressibility ($\kappa_s^E$), excess molar isentropic compressibility ($K_{s,m}^E$), excess speed of sound ($u^E$) and excess isobaric expansivity ($\alpha_p^E$) as a function of mole fraction, $x_1$ of EtBufor Ethyl butyrate + 2-Ethoxyethanol at the temperatures $T$ = (298.15 to 323.15) K at pressure $p$ = 0.1 MPa

| T/K | $\rho$ kg·m$^{-3}$ | $u$ m.s$^{-1}$ | $V_m^E$ 10$^6$ m$^3$.mol$^{-1}$ | $\kappa_s^E$ 10$^{10}$ m$^2$. N$^{-1}$ | $K_{s,m}^E$ 10$^{14}$ kg·m$^{-3}$ | $u^E$ 10$^{-2}$ m.s$^{-1}$ | $\alpha_p^E$ 10$^3$ m$^3$.mol$^{-1}$ |
|---|---|---|---|---|---|---|---|
| T=298.15 K | | | | | | | |
| 0.0000 | 925.17 | 1302.6 | 0.000 | 0.000 | 0.0000 | 0.0000 | 0.0000 |
| 0.1155 | 917.58 | 1280.5 | -0.122 | -0.154 | -0.1437 | 0.1370 | -0.4914 |
| 0.2144 | 911.49 | 1263.5 | -0.192 | -0.236 | -0.2330 | 0.1988 | -0.9569 |
| 0.3296 | 904.72 | 1245.9 | -0.226 | -0.286 | -0.2993 | 0.2292 | -1.4548 |
| 0.4291 | 899.22 | 1232.3 | -0.224 | -0.299 | -0.3269 | 0.2308 | -1.7830 |
| 0.5291 | 894.00 | 1219.9 | -0.198 | -0.288 | -0.3287 | 0.2162 | -1.9712 |
| 0.6292 | 889.15 | 1208.6 | -0.160 | -0.258 | -0.3066 | 0.1892 | -1.9802 |
| 0.7310 | 884.59 | 1198.1 | -0.114 | -0.211 | -0.2605 | 0.1517 | -1.7739 |
| 0.8133 | 881.19 | 1190.0 | -0.077 | -0.162 | -0.2062 | 0.1148 | -1.4304 |
| 0.9150 | 877.30 | 1180.6 | -0.033 | -0.089 | -0.1166 | 0.0619 | -0.7684 |
| 1.0000 | 874.31 | 1171.8 | 0.000 | 0.000 | 0.0000 | 0.0000 | 0.0000 |
| T=303.15 K | | | | | | | |
| 0.0000 | 920.61 | 1285.0 | 0.000 | 0.000 | 0.0000 | 0.0000 | 0.0000 |
| 0.1155 | 912.92 | 1262.4 | -0.129 | -0.165 | -0.1552 | 0.1399 | -0.5446 |
| 0.2144 | 906.67 | 1245.0 | -0.197 | -0.253 | -0.2507 | 0.2026 | -1.0356 |
| 0.3296 | 899.79 | 1227.0 | -0.233 | -0.307 | -0.3225 | 0.2332 | -1.5456 |
| 0.4291 | 894.20 | 1213.1 | -0.233 | -0.320 | -0.3525 | 0.2346 | -1.8728 |
| 0.5291 | 888.91 | 1200.4 | -0.209 | -0.309 | -0.3552 | 0.2196 | -2.0525 |
| 0.6292 | 883.98 | 1188.9 | -0.170 | -0.277 | -0.3318 | 0.1921 | -2.0476 |
| 0.7310 | 879.35 | 1178.0 | -0.124 | -0.227 | -0.2825 | 0.1539 | -1.8240 |
| 0.8133 | 875.88 | 1169.8 | -0.085 | -0.175 | -0.2238 | 0.1165 | -1.4651 |
| 0.9150 | 871.91 | 1160.1 | -0.037 | -0.096 | -0.1268 | 0.0629 | -0.7839 |
| 1.0000 | 868.85 | 1151.1 | 0.000 | 0.000 | 0.0000 | 0.0000 | 0.0000 |
| T=308.15 K | | | | | | | |
| 0.0000 | 916.03 | 1267.4 | 0.000 | 0.000 | 0.0000 | 0.0000 | 0.0000 |
| 0.1155 | 908.22 | 1244.2 | -0.135 | -0.177 | -0.1674 | 0.1430 | -0.6055 |
| 0.2144 | 901.86 | 1226.5 | -0.205 | -0.272 | -0.2708 | 0.2069 | -1.1249 |
| 0.3296 | 894.86 | 1208.2 | -0.242 | -0.331 | -0.3491 | 0.2383 | -1.6474 |
| 0.4291 | 889.18 | 1194.0 | -0.242 | -0.346 | -0.3828 | 0.2400 | -1.9725 |
| 0.5291 | 883.82 | 1181.0 | -0.219 | -0.335 | -0.3874 | 0.2251 | -2.1416 |
| 0.6292 | 878.82 | 1169.2 | -0.181 | -0.302 | -0.3637 | 0.1975 | -2.1205 |
| 0.7310 | 874.12 | 1158.1 | -0.135 | -0.249 | -0.3116 | 0.1588 | -1.8771 |
| 0.8133 | 870.58 | 1149.6 | -0.093 | -0.192 | -0.2480 | 0.1207 | -1.5012 |
| 0.9150 | 866.54 | 1139.6 | -0.043 | -0.106 | -0.1420 | 0.0656 | -0.7995 |
| 1.0000 | 863.40 | 1130.2 | 0.000 | 0.000 | 0.0000 | 0.0000 | 0.0000 |
| T=313.15 K | | | | | | | |
| 0.0000 | 911.42 | 1249.7 | 0.000 | 0.000 | 0.0000 | 0.0000 | 0.0000 |
| 0.1155 | 903.50 | 1226.1 | -0.141 | -0.192 | -0.1821 | 0.1472 | -0.6791 |
| 0.2144 | 897.03 | 1208.1 | -0.212 | -0.295 | -0.2950 | 0.2131 | -1.2304 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 0.3296 | 889.91 | 1189.4 | -0.250 | -0.360 | -0.3819 | 0.2461 | -1.7643 |
| 0.4291 | 884.15 | 1174.9 | -0.251 | -0.379 | -0.4211 | 0.2488 | -2.0835 |
| 0.5291 | 878.72 | 1161.8 | -0.231 | -0.369 | -0.4290 | 0.2345 | -2.2371 |
| 0.6292 | 873.66 | 1149.7 | -0.194 | -0.335 | -0.4061 | 0.2069 | -2.1952 |
| 0.7310 | 868.89 | 1138.3 | -0.147 | -0.278 | -0.3511 | 0.1675 | -1.9284 |
| 0.8133 | 865.30 | 1129.5 | -0.105 | -0.217 | -0.2820 | 0.1282 | -1.5341 |
| 0.9150 | 861.17 | 1119.1 | -0.049 | -0.122 | -0.1637 | 0.0705 | -0.8124 |
| 1.0000 | 857.95 | 1109.0 | 0.000 | 0.000 | 0.0000 | 0.0000 | 0.0000 |
| T=318.15 K | | | | | | | |
| 0.0000 | 906.76 | 1232.1 | 0.000 | 0.000 | 0.0000 | 0.0000 | 0.0000 |
| 0.1155 | 898.72 | 1208.0 | -0.145 | -0.207 | -0.1969 | 0.1507 | -0.7324 |
| 0.2144 | 892.15 | 1189.6 | -0.219 | -0.318 | -0.3199 | 0.2184 | -1.3058 |
| 0.3296 | 884.91 | 1170.6 | -0.257 | -0.390 | -0.4157 | 0.2528 | -1.8460 |
| 0.4291 | 879.06 | 1156.0 | -0.257 | -0.412 | -0.4603 | 0.2563 | -2.1593 |
| 0.5291 | 873.56 | 1142.6 | -0.237 | -0.404 | -0.4716 | 0.2425 | -2.3006 |
| 0.6292 | 868.44 | 1130.3 | -0.202 | -0.369 | -0.4494 | 0.2150 | -2.2429 |
| 0.7310 | 863.62 | 1118.6 | -0.156 | -0.309 | -0.3918 | 0.1751 | -1.9594 |
| 0.8133 | 859.99 | 1109.5 | -0.115 | -0.242 | -0.3174 | 0.1347 | -1.5528 |
| 0.9150 | 855.79 | 1098.6 | -0.056 | -0.138 | -0.1867 | 0.0749 | -0.8188 |
| 1.0000 | 852.49 | 1088.0 | 0.000 | 0.000 | 0.0000 | 0.0000 | 0.0000 |
| T=323.15 K | | | | | | | |
| 0.0000 | 902.07 | 1214.5 | 0.000 | 0.000 | 0.0000 | 0.0000 | 0.0000 |
| 0.1155 | 893.92 | 1189.9 | -0.150 | -0.222 | -0.2128 | 0.1541 | -0.7949 |
| 0.2144 | 887.24 | 1171.2 | -0.225 | -0.343 | -0.3463 | 0.2233 | -1.3930 |
| 0.3296 | 879.89 | 1151.9 | -0.263 | -0.422 | -0.4516 | 0.2589 | -1.9387 |
| 0.4291 | 873.96 | 1137.0 | -0.264 | -0.448 | -0.5022 | 0.2632 | -2.2435 |
| 0.5291 | 868.39 | 1123.4 | -0.245 | -0.441 | -0.5171 | 0.2499 | -2.3688 |
| 0.6292 | 863.23 | 1110.9 | -0.212 | -0.405 | -0.4962 | 0.2225 | -2.2921 |
| 0.7310 | 858.35 | 1099.0 | -0.167 | -0.341 | -0.4357 | 0.1821 | -1.9892 |
| 0.8133 | 854.68 | 1089.7 | -0.125 | -0.270 | -0.3556 | 0.1408 | -1.5691 |
| 0.9150 | 850.41 | 1078.4 | -0.063 | -0.155 | -0.2116 | 0.0790 | -0.8232 |
| 1.0000 | 847.03 | 1067.1 | 0.000 | 0.000 | 0.0000 | 0.0000 | 0.0000 |

**3.1. Excess properties**

The excess molar volume, $V_m^E$, deviations in isentropic compressibility, $\kappa_s^E$, excess speeds of sound, $u^E$, excess molar isentropic compressibility, $K_{s,m}^E$ have been calculated using the following equation [11–14]

$$V_m^E = V_m - (x_1 V_{m,1} + x_2 V_{m,2}) \quad (1)$$

$$\kappa_s^E = \kappa_s - \kappa_s^{id} \quad (2)$$

$$u^E = u - (\rho^{id} k_s^{id})^{-1/2} \quad (3)$$

$$K_{s,m}^{E} = K_{s,m} - K_{s,m}^{id} \quad (4)$$

where $V_m$ is the molar volume, subscript 1 and 2 refer to EtBuand 2-methoxyethanol/2-ethoxyethanol, respectively; $\kappa_s$ is the isentropic compressibility, $K_{s,m}$ is the molar isentropic compressibility, the superscript 'id' represents ideal mixture. The values of $V_m$, $\kappa_s$, $K_{s,m}$, $\rho^{id}$, $\kappa_s^{id}$ and $K_{s,m}^{id}$ are calculated using the relations [15,16]

$$V_m = (x_1 M_1 + x_2 M_2)/\rho \quad (5)$$

$$\kappa_s = 1/u^2 \rho \quad (6)$$

$$K_{s,m} = \kappa_s V \quad (7)$$

$$\rho^{id} = x_1 \rho_1 + x_2 \rho_2 \quad (8)$$

$$\phi_i = x_i V_{m,i} / \sum_{i=1}^{2} x_i V_{m,i} \quad (9)$$

$$\kappa_s^{id} = \phi_1 \kappa_{s,1} + \phi_2 \kappa_{s,2} + T\left[\frac{\phi_1 V_{m,1}(\alpha_{p,1})^2}{C_{p,1}} + \frac{\phi_2 V_{m,2}(\alpha_{p,2})^2}{C_{p,2}} - \frac{V_m^{id}(\alpha_p^{id})^2}{C_p^{id}}\right] \quad (10)$$

$$K_{s,m}^{id} = x_1 K_{s,m,1} + x_2 K_{s,m,2} + T\left[\frac{x_1(V_{m,1}\alpha_{p,1})^2}{C_{p,1}} + \frac{x_2(V_{m,2}\alpha_{p,2})^2}{C_{p,2}} - \frac{(V_m^{id}\alpha_p^{id})^2}{C_p^{id}}\right] \quad (11)$$

where $\alpha_p$ is the isobaric expansivity, $C_p$ is the molar isobaric heat capacity. The values of $V_m^{id}$, $\alpha_p^{id}$ and $C_p^{id}$ are calculated using the following relations

$$V_m^{id} = x_1 V_{m,1} + x_2 V_{m,2} \quad (12)$$

$$\alpha_p^{id} = \phi_1 \alpha_{p,1} + \phi_2 \alpha_{p,2} \quad (13)$$

$$C_p^{id} = x_1 C_{p,1} + x_2 C_{p,2} \quad (14)$$

The values of $\alpha_p$ are calculated the temperature dependence of the density data of pure liquids by using the relation, $(-1/\rho)(\partial\rho/\partial T)_p$.

The values of $V_m^E$, $\kappa_s^E$, $u^E$, $K_{s,m}^E$ and $\alpha_p^E$ have been fitted to a Redlich-Kister type [17] polynomial equation:

$$Y^E = x_1(1-x_1)\sum_{i=0}^{j} A_i (2x_1 - 1)^i \quad (15)$$

where $Y^E$ is $V_m^E$ or $\kappa_s^E$ or $u^E$ or $K_{s,m}^E$ or $\alpha_p^E$. The volume fraction, $\phi$ is used in place of $x$in equation (15) for fitting of $\kappa_s^E$. The values of coefficients, $A_i$ were evaluated by using the method of least squares, with all points weighted equally. The standard deviations, $\sigma$ of fit have been calculated by using the relation

$$\sigma = \left[\sum\left(Y_{m,\,Calc.}^E - Y_{m,\,Expt.}^E\right)^2 \Big/ (n-j)\right]^{1/2} \quad (16)$$

where $n$ is the number of experimental data points and $j$ is the number of $A_i$ coefficients considered ($j$+1 in the present study). The coefficients, $A_i$ and corresponding standard deviations, $\sigma$ of fit for the mixtures are listed in Table 4. The variation of $V_m^E$, $\kappa_s^E$, $u^E$, $K_{s,m}^E$

and $\alpha_p^E$ with composition and temperature, along with smoothed values from equation (15) are presented graphically in Figures 1–5, respectively.

**Table 4.**Coefficients $A_i$ of equation (13) along with standard deviations σ of binary mixture properties.

| T/K | $A_0$ | $A_1$ | $A_2$ | σ |
|---|---|---|---|---|
| EtBu + 2-Methoxyethanol | | | | |
| $V_m^E$ $10^6$ $m^3 \cdot mol^{-1}$ | | | | |
| 298.15 | -0.322 | -0.074 | 0.031 | 0.0006 |
| 303.15 | -0.344 | -0.076 | 0.001 | 0.0005 |
| 308.15 | -0.368 | -0.075 | -0.030 | 0.0003 |
| 313.15 | -0.389 | -0.076 | -0.072 | 0.0007 |
| 318.15 | -0.412 | -0.075 | -0.117 | 0.0005 |
| 323.15 | -0.432 | -0.072 | -0.177 | 0.0008 |
| $\kappa_s^E$ $10^{10} m^2.N^{-1}$ | | | | |
| 298.15 | -0.682 | 0.177 | -0.260 | 0.001 |
| 303.15 | -0.748 | 0.196 | -0.283 | 0.001 |
| 308.15 | -0.832 | 0.199 | -0.329 | 0.001 |
| 313.15 | -0.941 | 0.180 | -0.404 | 0.001 |
| 318.15 | -1.056 | 0.162 | -0.480 | 0.001 |
| 323.15 | -1.176 | 0.140 | -0.562 | 0.001 |
| $K_{s,m}^E$ $10^{14} m^5.N^{-1}.mol^{-1}$ | | | | |
| 298.15 | -0.746 | -0.028 | -0.227 | 0.0003 |
| 303.15 | -0.824 | -0.029 | -0.248 | 0.0002 |
| 308.15 | -0.921 | -0.055 | -0.300 | 0.0003 |
| 313.15 | -1.047 | -0.114 | -0.394 | 0.0008 |
| 318.15 | -1.181 | -0.176 | -0.489 | 0.0012 |
| 323.15 | -1.321 | -0.244 | -0.599 | 0.0033 |
| $u^E$ $10^{-2}$ $m.s^{-1}$ | | | | |
| 298.15 | 0.542 | -0.299 | 0.329 | 0.002 |
| 303.15 | 0.563 | -0.317 | 0.343 | 0.003 |
| 308.15 | 0.592 | -0.325 | 0.372 | 0.003 |
| 313.15 | 0.634 | -0.323 | 0.415 | 0.003 |
| 318.15 | 0.673 | -0.324 | 0.454 | 0.003 |
| 323.15 | 0.708 | -0.321 | 0.488 | 0.002 |
| $\alpha_p^E$ $10^3$ $K^{-1}$ | | | | |
| 298.15 | -3.047 | 1.487 | | 0.003 |
| 303.15 | -3.273 | 1.535 | | 0.013 |
| 308.15 | -3.517 | 1.608 | | 0.022 |
| 313.15 | -3.776 | 1.678 | | 0.036 |
| 318.15 | -4.013 | 1.768 | | 0.051 |
| 323.15 | -4.266 | 1.809 | | 0.068 |
| EtBu + 2-Ethoxyethanol | | | | |
| $V_m^E$ $10^6$ $m^3 \cdot mol^{-1}$ | | | | |
| 298.15 | -0.831 | 0.529 | | 0.002 |

| | | | | |
|---|---|---|---|---|
| 303.15 | -0.872 | 0.520 | | 0.002 |
| 308.15 | -0.918 | 0.506 | | 0.002 |
| 313.15 | -0.967 | 0.483 | | 0.003 |
| 318.15 | -1.002 | 0.464 | | 0.005 |
| 323.15 | -1.041 | 0.438 | | 0.007 |
| $\kappa_s^E$ $10^{10}$ $m^2.N^{-1}$ | | | | |
| 298.15 | -1.169 | 0.287 | -0.219 | 0.002 |
| 303.15 | -1.254 | 0.303 | -0.238 | 0.002 |
| 308.15 | -1.358 | 0.300 | -0.269 | 0.002 |
| 313.15 | -1.493 | 0.280 | -0.313 | 0.003 |
| 318.15 | -1.630 | 0.256 | -0.360 | 0.003 |
| 323.15 | -1.775 | 0.230 | -0.413 | 0.004 |
| $K_{s,m}^E$ $10^{14}$ $m^5.N^{-1}.mol^{-1}$ | | | | |
| 298.15 | -1.318 | 0.026 | -0.163 | 0.003 |
| 303.15 | -1.423 | 0.018 | -0.183 | 0.003 |
| 308.15 | -1.550 | -0.015 | -0.220 | 0.004 |
| 313.15 | -1.712 | -0.080 | -0.280 | 0.005 |
| 318.15 | -1.878 | -0.148 | -0.348 | 0.006 |
| 323.15 | -2.055 | -0.224 | -0.422 | 0.007 |
| $u^E$ $10^{-2}$ $m.s^{-1}$ | | | | |
| 298.15 | 0.884 | -0.365 | 0.279 | 0.001 |
| 303.15 | 0.898 | -0.375 | 0.289 | 0.001 |
| 308.15 | 0.920 | -0.374 | 0.304 | 0.001 |
| 313.15 | 0.957 | -0.364 | 0.323 | 0.001 |
| 318.15 | 0.988 | -0.355 | 0.341 | 0.001 |
| 323.15 | 1.016 | -0.347 | 0.359 | 0.002 |
| $\alpha_p^E$ $10^3$ $K^{-1}$ | | | | |
| 298.15 | -7.617 | -3.144 | | 0.024 |
| 303.15 | -7.969 | -2.936 | | 0.023 |
| 308.15 | -8.346 | -2.701 | | 0.021 |
| 313.15 | -8.761 | -2.361 | | 0.019 |
| 318.15 | -9.043 | -2.062 | | 0.017 |
| 323.15 | -9.341 | -1.748 | | 0.015 |

**3.2. Partial molar properties**

The partial molar properties (partial molar volume and partial molar compressibility), $\overline{Y}_{m,1}$ of component 1 (EtBu) and $\overline{Y}_{m,2}$ of component 2 (2-methoxyethanol/2-ethoxyethanol) in these mixtures over entire composition range were calculated by using the following relations [18,19]

$$\overline{Y}_{m,1} = Y^E + Y_{m,1}^* + x_2 \left(\partial Y^E / \partial x_1\right)_{T,p} \quad (17)$$

$$\overline{Y}_{m,2} = Y^E + Y_{m,2}^* - x_1 \left(\partial Y^E / \partial x_1\right)_{T,p} \quad (18)$$

where $Y$ is $V$ or $K_s$; $Y_{m,1}^*$ and $Y_{m,2}^*$ are the molar properties for pure components, EtBu and 2-methoxyethanol/2-ethoxyethanol, respectively. The derivative, $(\partial Y^E / \partial x_1)_{T,p}$ in equations

(17) and (18) was obtained by differentiation of the equation (16), which leads to the following equations for $\overline{Y}_{m,1}$ and $\overline{Y}_{m,2}$

$$\overline{Y}_{m,1} = Y^*_{m,1} + x_2^2 \sum_{i=0}^{n} A_i (2x_1 - 1)^i - 2x_1 x_2^2 \sum_{i=1}^{n} A_i (2x_1 - 1)^{i-1} \quad (19)$$

$$\overline{Y}_{m,2} = Y^*_{m,2} - x_1^2 \sum_{i=0}^{n} A_i (2x_1 - 1)^i + 2x_1^2 x_2 \sum_{i=1}^{n} A_i (2x_1 - 1)^{i-1} \quad (20)$$

The excess partial molar properties, $\overline{Y}^E_{m,1}$ and $\overline{Y}^E_{m,2}$ over the whole composition range were calculated by using the following relations

$$\overline{Y}^E_{m,1} = \overline{Y}_{m,1} - Y^*_{m,1} \quad (21)$$

$$\overline{Y}^E_{m,2} = \overline{Y}_{m,2} - Y^*_{m,2} \quad (22)$$

## 4. RESULTS AND DISCUSSION

The $V_m^E$ data for all the binary systems of EtBu with 2-alkoxyethanols were reported in Tables 2 and 3 and are graphically represented in Fig. 1. An examination of $V_m^E$ data in Fig. 1 suggests that excess volume ($V_m^E$) data for the chosen mixtures are negative over the entire composition range at all temperatures. Negative $V_m^E$ values are stemming from interactions between unlike molecules [20] or due to structural effects arising from changes in free volume and also due to variation in interstitial accommodation of one of the components with respect to the other. In case of 2-methoxyethanol, the maximum values (negative) are found associated with $x_1$ = 0.5390, nearly at equimolar region. For 2-ethoxyethanol, the maximum values (negative) are found associated with $x_1$ = 0.3296, similar behavior can be observed for all mixtures at all the temperatures studied.

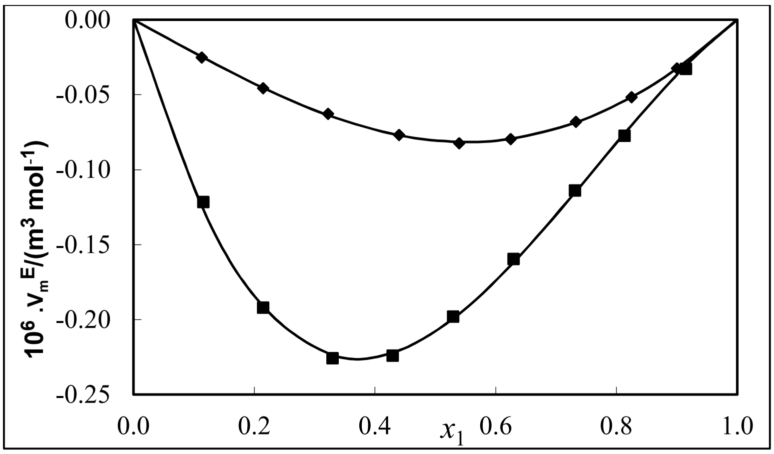


**Figure1.**Variation of excess molar volume ($V_m^E$) with mole fraction $x_1$ of Ethyl butyrate in the binary mixtures of Ethyl butyrate(1) with 2-alkoxyalkanols (2); (♦), 2 - ME; (■), 2 - EE; at T=298.15 K. The points represent experimental values and solid lines have been drawn from equation (15) using the coefficients given in Table 4.

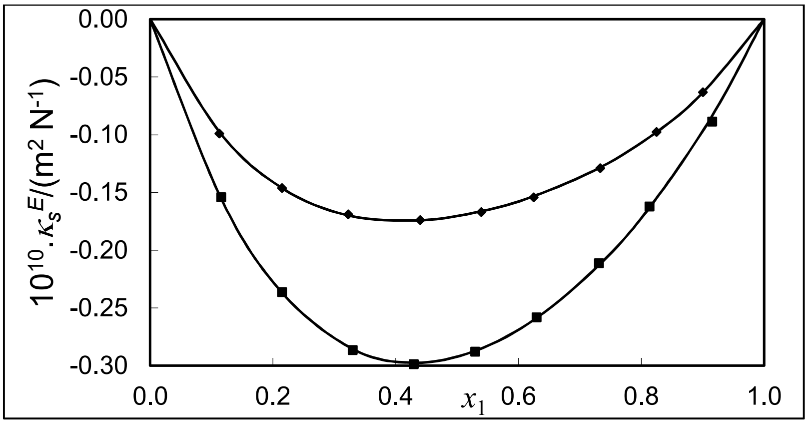


**Figure2.** Excess isentropic compressibilities ($\kappa_s^E$) with mole fraction $x_1$ of Ethyl butyrate in the binary mixtures of Ethyl butyrate (1) with 2-alkoxyalkanols (2); (♦), 2-ME; (■), 2-EE; (▲) at T=298.15 K.The points represent experimental values and solid lines have been drawn from equation (15) using the coefficients given in Table 4.

The values of excess isentropic compressibilities, $\kappa_s^E$, for the two systems over the entire concentration range are seen to be negative (Fig.2) with all of them exhibiting an increase in the values (negative) with the increase in the temperature. The excess isentropic compressibilities, $\kappa_s^E$, have been regularly investigated to study the nature and extent of intermolecular interactions [21]. In general, the values of $\kappa_s^E$ can be considered as arising from two types of interaction between the component molecules:

(i) a physical interaction, consisting of dispersion forces or weak dipole-dipole interaction making a positive contribution,

(ii) a chemical or specific interaction, which include charge-transfer forces, forming H-bonds and other complex forming interactions, resulting in a negative contribution to $\kappa_s^E$ value.

Apart from this the negative values of $\kappa_s^E$ may be due to a geometric effect, another physical contribution, that allows for the fitting of molecules of different sizes into each other's structure. In case of both EtBu + alkoxyalkanols , the excess values show an increase in the values (more negative) with increase in temperature. Furthermore, $\kappa_s^E$ values for the EtBu + 2-methoxyethanol system are seen to be the least (negative) among the two systems under investigation. The observed negative $\kappa_s^E$ values suggest the presence of significant donor–acceptor interactions between EtBu and alkoxyalkanol molecules in these mixtures. The isentropic compressibility value shows in increasing trend with the increase in EtBu concentration and similar trend at any given mole fraction with the rise in temperature. The trends in the values of isentropic compressibility are governed by the corresponding values of speed of sound and density.

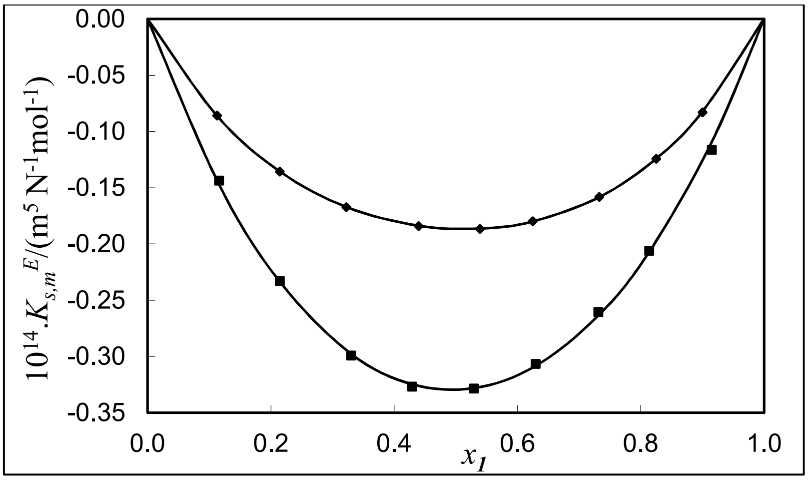


**Figure 3.** Excess molar isentropic compressibilities ($K_{s,m}^{E}$) with mole fraction $x_1$ of Ethylbutyrate in the binary mixtures of Ethyl butyrate (1) with 2-alkoxyalkanols (2); (♦), 2-ME; (■), 2-EE; (▲) at T=298.15 K.The points represent experimental values and solid lines have been drawn from equation (15) using the coefficients given in Table 4.

The behavior of $\kappa_{s,m}^{E}$, with EtBu concentration and temperature is shown in Fig.3. The $\kappa_{s,m}^{E}$, were negative for the studied binary systems and decreases with increasing temperature. The possible accommodation of small solvent molecules in free volumes of EtBu and specific interaction within binary mixtures support negative behavior of $\kappa_{s,m}^{E}$. As concentration of EtBu in binary mixtures increases, specific interaction increases leading to decrease in compressibility. Excess molar volumes $V_m^E$, excess isentropic compressibilities $\kappa_s^E$ and excess molar isentropic compressibilities $\kappa_{s,m}^{E}$ reflects packing, interaction and compressibility effects [22].

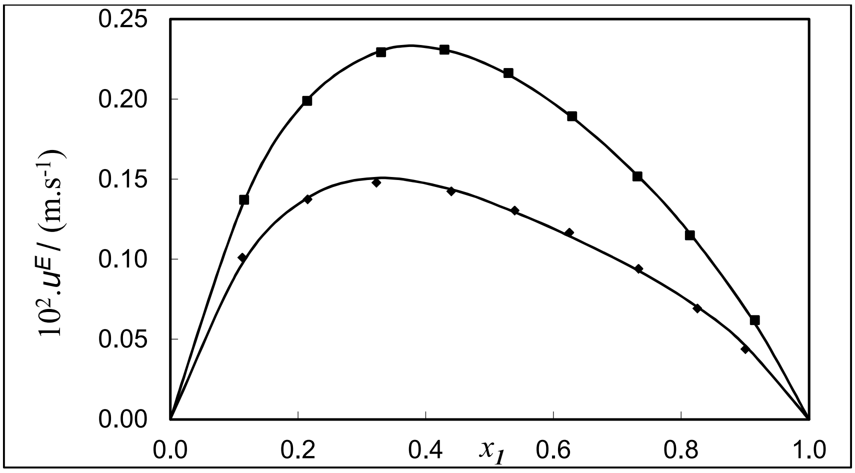


**Figure 4.** Excess speed of sound ($u^E$) with mole fraction $x_1$ of Ethyl butyrate in the binary mixtures of Ethyl butyrate (1) with 2-alkoxyalkanols (2); (♦), 2-ME; (■), 2-EE; (▲)at T=298.15 K. The points represent experimental values and solid lines have been drawn from equation (15) using the coefficients given in Table 4.

The plot of $u^E$ vs. mole fraction (Fig.4) of the first component, shows that the values are positive over the entire range of composition, with the highest deviation being exhibited at $x_1$ = 0.4. It is further seen that the deviations increase with the increase in the temperature with the highest deviations being seen at temperature 323.15 K. Furthermore it is also observed that the speed of sound values show a rising trend with the increase in the mole fraction of the first component and this trend are replicated across the entire temperature range. It has been suggested by Eyring[23] that a lowering in speed of sound occurs during mixing thereby causing an increase in the intermolecular free length [24] and may cause a lowering of the excess isentropic compressibility. All excess speed of sound values shows a similar trend when plotted against the mole fraction of EtBu.

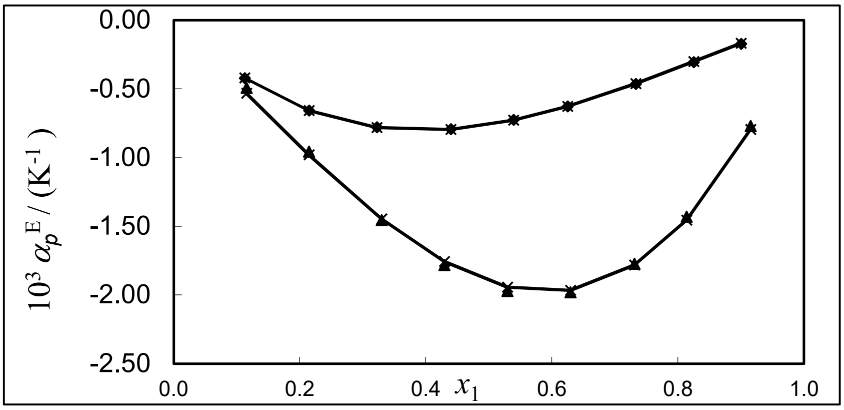


**Figure 5.** Excess isobaric thermal expansivity ($\alpha_p^E$) with mole fraction $x_1$ of Ethyl butyrate in the binary mixtures of Ethyl butyrate (1) with 2-alkoxyalkanols (2); (♦), 2-ME; (■), 2-EE; (▲) at T=298.15 K. The points represent experimental values and solid lines have been drawn from equation (15) using the coefficients given in Table 4.

The isobaric thermal expansion coefficients for binary mixtures of EtBu with alkoxyalkanols are listed in Tables 2 and 3 along with the data for pure EtBu. For further understanding the change in the structure of the solution during mixing, isobaric thermal expansions are calculated for every composition. Negative values of $\alpha_p^E$ were observed for all binary systems. The comparison of excess isobaric thermal expansivity is shown for all binary systems in Fig 5. The negative values of $\alpha_p^E$ for the investigated mixtures suggest strong dipole–dipole interactions (between EtBu with alkoxyalkanols) and more closed packing of the constituent of mixtures in mixed state as compared to pure state. Further, temperature coefficient ($\partial V^E / \partial T$) is negative. This suggest that there may be a formation of associated species in {EtBu+alkoxyalkanols} mixture with increase in temperature which results in contraction in volume of the mixture and hence negative $\alpha_p^E$ values [25].

The variations of $\bar{V}_{m,1}^E$, and $\bar{V}_{m,2}^E$ with composition at 298.15 K are presented in Fig. 6. By close look at Fig. 6 the values of $\bar{V}_{m,1}^E$, and $\bar{V}_{m,2}^E$ shows negative for the two binary mixtures over the whole composition range. It means, the molar volumes of each component in the binary mixture are less than their respective molar volume in the pure state, i.e., there is a decrease in the volume on mixing EtBu with alkoxyalkanols. In general, the negative $\overline{V}^E_{m,1}$, and $\overline{V}^E_{m,2}$ values shows the presence of significant solute–solvent interactions between unlike molecules [26] in the mixture.

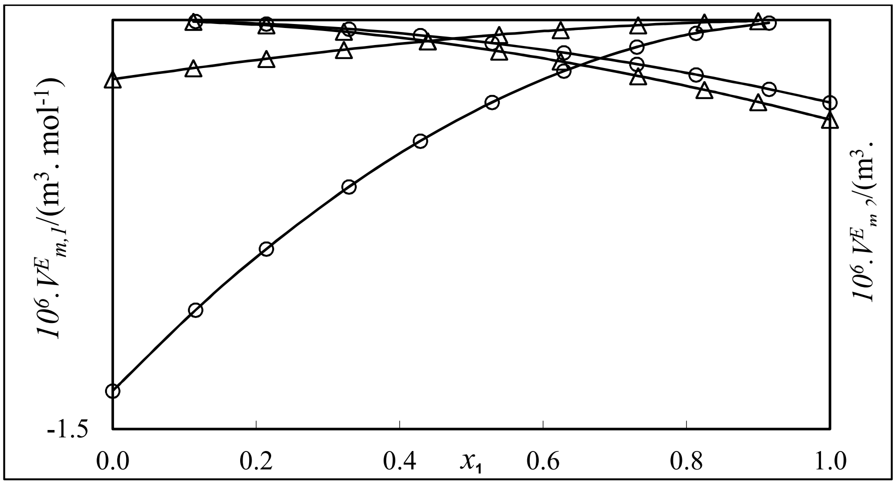


**Figure6.** Excess partial molar volume ($\overline{V}^E_{m,1}$ and $\overline{V}^E_{m,2}$) with mole fraction $x_1$ of Ethyl butyrate in the binary mixtures of Ethyl butyrate (1) with 2-alkoxyalkanols (2); (♦), 2-ME; (■), 2-EE; (▲) at T=298.15 K.

## CONCLUSIONS

In this paper, densities, and speeds of sound of binary mixtures of EtBu with alkoxy alkanols along with those of pure liquids at temperatures T = (298.15 to 323.15) K at the atmospheric pressure 0.1MPa, have been reported. Values of the excess molar volume $V^E_m$, excess isentropic compressibility $\kappa^E_s$, excess molar isentropic compressibility $\kappa^E_{s,m}$, excess speed of sound, $u^E$, and excess isobaric thermal expansivity $\alpha^E_p$ were obtained from experimentally measured densities and speeds of sound. Values of $V^E_m$, $\kappa^E_s$, $\kappa^E_{s,m}$, and $\alpha^E_p$ were negative and becomes more negative with increase in temperature. The overall negative behaviour of $V^E_m$, $\kappa^E_s$, $\kappa^E_{s,m}$, $\alpha^E_p$ and positive values of $u^E$ may be attributed to strong ion–ion/dipole-dipole interaction and easy accommodation of alkoxy alkanols in the voids of EtBu molecule.

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