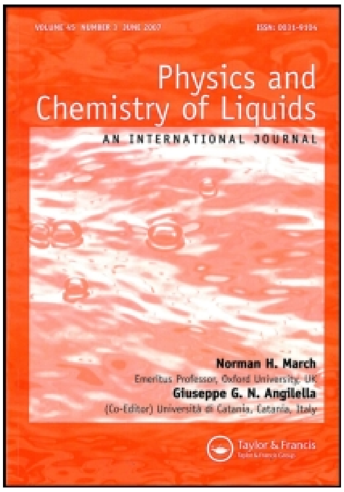

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# Excess volumes, partial molar and adiabatic compressibilities of binary mixtures of *n*-alcohols with monoethanolamine

Rebecca Dean[a]; Jonathan Moulins[a]; Amanda MacInnis[a]; Rama M. Palepu
[a] Department of Chemistry, St. Francis Xavier University, Antigonish, Nova Scotia, Canada

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# Excess volumes, partial molar and adiabatic compressibilities of binary mixtures of *n*-alcohols with monoethanolamine

Rebecca Dean, Jonathan Moulins, Amanda MacInnis and Rama M. Palepu*

*Department of Chemistry, St. Francis Xavier University, Antigonish, Nova Scotia, Canada*

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Speed of sound and densities of solution mixtures of four aliphatic alcohols with monoethanolamine were measured over a full range of composition. The density measurements were carried out from 298 to 358 K. Results of these measurements were used to calculate adiabatic compressibilities, excess adiabatic compressibilities, excess volumes and partial molar quantities. From the analysis of the results, the nature of interaction between the aliphatic alcohols and monoethanolamine is deduced.

**Keywords:** aliphatic alcohols; speed of sound; volumes; adiabatic compressibility and partial molar properties

## 1. Introduction

Aqueous solutions of monoethanolamine (MEA) have been extensively used for the removal of acidic gases in the natural gas. The removal of carbon dioxide by using chemical absorbents has been of considerable interest due to excessive discharge of carbon dioxide and methane which are primarily responsible for global warming. Aqueous monoethanolamine solutions are known to react with materials in reactor vessels, tubing lines and other process compartments. Blended mixtures of MEA with other solvents may have the potential to minimise the adverse effects to reactor vessels and tubing lines. Several investigations on the removal of acid gases by blended MEA mixtures have been reported in the literature [1–4]. Recently, Lee *et al*. [5–6] reported densities and viscosities of binary solutions of MEA with aliphatic alcohols at 303, 313 and 323 K.

Knowledge of physical properties of blended alkanolamine mixtures is useful in connection with industrial treatment of acidic gases. The properties of these mixtures at several temperatures are required for engineering design of acid gas treatment equipment and for subsequent operations as summarised by Astarita *et al*. [7]. The physical properties are also needed for predicting the absorption rates and enhancement factors of the gases, which are useful to process engineers who are interested in the problem of acidic gas removal. Volumetric data in combination with molecular theories of solutions can be used to extend our understanding of molecular interactions occurring in these systems. Derived volumetric properties can be employed to arrive at a more detailed picture of solute–solvent interactions [8].

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*Corresponding author. Email: rpalepu@stfx.ca

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Table 1. Experimental densities and speed of sound of pure compounds along with the literature values.

| | $\rho$ (g cm$^{-3}$) 298.15 K | | U (m s$^{-1}$) | |
|---|---|---|---|---|
| Compound | Expt. | Lit. | Expt. (303 K) | Lit. (298 K) |
| 1-Propanol | 0.79981 | 0.79975 [9] | 1199.0 | 1206 [9] |
| Isopropanol | 0.78125 | 0.78090 [10] | 1126.6 | 1140 [10]<br>1127 [13]* |
| 1-Hexanol | 0.81530 | 0.81534 [11] | 1288.1 | 1303 [11] |
| 1-Octanol | 0.82174 | 0.82230 [12] | 1332.2 | 1348 [12] |

Note: *The value corresponds to $T = 303.15$ K.

The present study reports density measurements of the binary mixtures of MEA with aliphatic alcohols such as 1-propanol, isopropanol, 1-hexanol and 1-octanol in the temperature of 298–358 K along with speed of sound measurements in the entire composition range at 303 K. Various derived properties such as excess volumes ($V^E$), thermal expansivity ($\alpha$), adiabatic compressibility ($\beta$), molar adiabatic compressibility ($\beta v$) and apparent molar compressibility $K_\phi$, are evaluated and discussed in terms of molecular interactions in the mixtures.

## 2. Experimental section

The ethanolamine and all aliphatic alcohols were obtained from Aldrich of stated purity at 99% by mass and used as received. The densities and sound velocity values of the pure components agreed well with the values reported in the literature [9–13]. The values are presented in Table 1. Density of mixtures were measured with an Anton Parr DMA 5000 Density meter which was calibrated with dry air and distilled water. Accuracies of our density measurements are about $\pm 3 \times 10^{-5}$ g cm$^{-3}$. The accuracy at higher temperatures may range around $\pm 8 \times 10^{-5}$ g cm$^{-3}$. Temperature was stable to $\pm 0.001^\circ$C during the course of measurements. The speed of sound measurements were carried out as described in our previous publications [14–16].

## 3. Results and discussion

The experimental densities and speed of sound measurements of the binary mixtures over the entire composition range are presented in Tables 2 and 3, respectively.

### 3.1. *Speed of sound*

The adiabatic compressibilities were calculated using the formula

$$\beta = \frac{1}{U^2 \rho}, \tag{1}$$

where $U$ is the ultrasonic speed of sound and $\rho$ is the density of the solution. The adiabatic compressibility values are found to be dependent on composition

Table 2. Densities ($g\,cm^{-3}$) of binary mixture at various temperatures.

| $X_{MEA}$ | 298 K | 308 K | 318 K | 328 K | 338 K | 348 K | 358 K |
|---|---|---|---|---|---|---|---|
| Propanol and MEA | | | | | | | |
| 0.00000 | 0.79981 | 0.79169 | 0.78342 | 0.77492 | 0.76617 | 0.75709 | 0.74762 |
| 0.05028 | 0.80932 | 0.80120 | 0.79293 | 0.78446 | 0.77575 | 0.76675 | 0.75739 |
| 0.09906 | 0.81877 | 0.81064 | 0.80237 | 0.79393 | 0.78526 | 0.77632 | 0.76706 |
| 0.20023 | 0.83232 | 0.82332 | 0.81390 | 0.80382 | 0.79297 | 0.78015 | 0.76925 |
| 0.29995 | 0.85761 | 0.84783 | 0.83668 | 0.82413 | 0.80955 | 0.79048 | 0.78302 |
| 0.40102 | 0.87964 | 0.87151 | 0.86330 | 0.85497 | 0.84649 | 0.83778 | 0.81744 |
| 0.49961 | 0.90049 | 0.89239 | 0.88420 | 0.87590 | 0.86748 | 0.85891 | 0.85016 |
| 0.60024 | 0.92214 | 0.91405 | 0.90588 | 0.89763 | 0.88927 | 0.88077 | 0.87212 |
| 0.70078 | 0.94446 | 0.93639 | 0.92826 | 0.92005 | 0.91175 | 0.90333 | 0.89477 |
| 0.79984 | 0.96682 | 0.95878 | 0.95069 | 0.94252 | 0.93428 | 0.92593 | 0.91745 |
| 0.89890 | 0.98922 | 0.98121 | 0.97316 | 0.96505 | 0.95687 | 0.94860 | 0.94021 |
| 0.94962 | 1.00051 | 0.99252 | 0.98450 | 0.97642 | 0.96827 | 0.96003 | 0.95170 |
| 1.00000 | 1.01299 | 1.00503 | 0.99704 | 0.98899 | 0.98088 | 0.97269 | 0.96441 |
| Isopropanol and MEA | | | | | | | |
| 0.00000 | 0.78125 | 0.77261 | 0.76362 | 0.75423 | 0.74434 | 0.73391 | 0.72286 |
| 0.05082 | 0.79134 | 0.78277 | 0.7739 | 0.76469 | 0.75503 | 0.74488 | 0.73360 |
| 0.09972 | 0.80109 | 0.79258 | 0.78381 | 0.77473 | 0.76525 | 0.75536 | 0.74500 |
| 0.20334 | 0.82521 | 0.81680 | 0.80821 | 0.79937 | 0.79025 | 0.78080 | 0.77095 |
| 0.29817 | 0.84374 | 0.83539 | 0.82687 | 0.81816 | 0.80921 | 0.79996 | 0.79038 |
| 0.40261 | 0.86701 | 0.85873 | 0.85032 | 0.84174 | 0.83296 | 0.82395 | 0.81467 |
| 0.50055 | 0.89020 | 0.88197 | 0.87364 | 0.86517 | 0.85653 | 0.84768 | 0.83864 |
| 0.60015 | 0.91362 | 0.90545 | 0.89719 | 0.88881 | 0.87912 | 0.86105 | 0.83832 |
| 0.69914 | 0.93787 | 0.92975 | 0.92156 | 0.91327 | 0.90486 | 0.89313 | 0.88760 |
| 0.79941 | 0.96233 | 0.95425 | 0.94611 | 0.93789 | 0.92959 | 0.92116 | 0.91261 |
| 0.90015 | 0.98778 | 0.97975 | 0.97168 | 0.96355 | 0.95534 | 0.94703 | 0.93862 |
| 0.94863 | 1.00010 | 0.99210 | 0.98406 | 0.97597 | 0.96781 | 0.95956 | 0.95121 |
| 1.00000 | 1.01299 | 1.00503 | 0.99704 | 0.98899 | 0.98088 | 0.97269 | 0.96441 |
| Hexanol and MEA | | | | | | | |
| 0.00000 | 0.81530 | 0.80807 | 0.80072 | 0.79321 | 0.78553 | 0.77765 | 0.76954 |
| 0.05658 | 0.82077 | 0.81351 | 0.80614 | 0.79865 | 0.79098 | 0.78312 | 0.77504 |
| 0.10568 | 0.82589 | 0.81860 | 0.81121 | 0.80370 | 0.79604 | 0.78819 | 0.78014 |
| 0.20224 | 0.83692 | 0.82956 | 0.82213 | 0.81458 | 0.80689 | 0.79904 | 0.79099 |
| 0.29802 | 0.84887 | 0.84145 | 0.83394 | 0.82634 | 0.81861 | 0.81073 | 0.80267 |
| 0.40231 | 0.86403 | 0.85652 | 0.84894 | 0.84127 | 0.83349 | 0.82557 | 0.81748 |
| 0.50170 | 0.88014 | 0.87255 | 0.86489 | 0.85716 | 0.84932 | 0.84135 | 0.83323 |
| 0.59897 | 0.89845 | 0.89078 | 0.88306 | 0.87525 | 0.86736 | 0.85934 | 0.85120 |
| 0.70032 | 0.92059 | 0.91284 | 0.90505 | 0.89718 | 0.88923 | 0.88117 | 0.87299 |
| 0.79989 | 0.94575 | 0.93794 | 0.93007 | 0.92214 | 0.91413 | 0.90603 | 0.89781 |
| 0.89814 | 0.97572 | 0.96783 | 0.95991 | 0.95192 | 0.94387 | 0.93572 | 0.92747 |
| 0.94670 | 0.99284 | 0.98492 | 0.97696 | 0.96896 | 0.96087 | 0.95271 | 0.94444 |
| 1.00000 | 1.01299 | 1.00503 | 0.99704 | 0.98899 | 0.98088 | 0.97269 | 0.96441 |
| Octanol and MEA | | | | | | | |
| 0.00000 | 0.82174 | 0.81476 | 0.80769 | 0.80050 | 0.79317 | 0.78568 | 0.77802 |
| 0.05011 | 0.82515 | 0.81815 | 0.8110 | 0.80387 | 0.79655 | 0.78906 | 0.78141 |
| 0.10065 | 0.82922 | 0.82218 | 0.81507 | 0.80787 | 0.80053 | 0.79305 | 0.78539 |
| 0.20057 | 0.83797 | 0.83086 | 0.82368 | 0.81641 | 0.80903 | 0.80151 | 0.79384 |
| 0.30340 | 0.84815 | 0.84094 | 0.83367 | 0.82633 | 0.81888 | 0.81131 | 0.80358 |
| 0.40153 | 0.85971 | 0.85239 | 0.84503 | 0.83759 | 0.83006 | 0.82242 | 0.81463 |
| 0.49814 | 0.87234 | 0.86493 | 0.85747 | 0.84994 | 0.84233 | 0.83460 | 0.82673 |
| 0.59863 | 0.88947 | 0.88194 | 0.87437 | 0.86674 | 0.85902 | 0.85120 | 0.84326 |
| 0.70210 | 0.91081 | 0.90316 | 0.89547 | 0.88773 | 0.87990 | 0.87198 | 0.86395 |
| 0.80010 | 0.93595 | 0.92819 | 0.92039 | 0.91254 | 0.90462 | 0.89660 | 0.88849 |
| 0.90016 | 0.96890 | 0.96104 | 0.95314 | 0.94520 | 0.93718 | 0.92908 | 0.92089 |
| 0.94911 | 0.98893 | 0.98103 | 0.97310 | 0.96511 | 0.95706 | 0.94893 | 0.94070 |
| 1.00000 | 1.01299 | 1.00503 | 0.99704 | 0.98899 | 0.98088 | 0.97269 | 0.96441 |

Table 3. Speed of sound of binary mixtures MEA and alcohols at 303 K.

| Propanol | | Isopropanol | | Hexanol | | Octanol | |
|---|---|---|---|---|---|---|---|
| $X_{\mathrm{MEA}}$ | $U$ (ms$^{-1}$) | $X_{\mathrm{MEA}}$ | $U$ (ms$^{-1}$) | $X_{\mathrm{MEA}}$ | $U$ (ms$^{-1}$) | $X_{\mathrm{MEA}}$ | $U$/ms$^{-1}$ |
| 0.0000 | 1199.0 | 0.0000 | 1126.6 | 0.0000 | 1288.1 | 0.0000 | 1332.2 |
| 0.0994 | 1232.1 | 0.0111 | 1130.6 | 0.0267 | 1293.3 | 0.0307 | 1336.3 |
| 0.1441 | 1250.6 | 0.0301 | 1138.4 | 0.1077 | 1304.2 | 0.1305 | 1344.1 |
| 0.2016 | 1275.9 | 0.0476 | 1146.1 | 0.1777 | 1316.8 | 0.1868 | 1349.5 |
| 0.2515 | 1300.5 | 0.0893 | 1164.4 | 0.2217 | 1324.4 | 0.2360 | 1356.4 |
| 0.3052 | 1323.8 | 0.1047 | 1171.3 | 0.2628 | 1333.1 | 0.2811 | 1363.6 |
| 0.3425 | 1341.4 | 0.1392 | 1180.9 | 0.2928 | 1343.6 | 0.3022 | 1367.5 |
| 0.3852 | 1360.5 | 0.1787 | 1199.3 | 0.3365 | 1353.2 | 0.3448 | 1372.2 |
| 0.4070 | 1370.9 | 0.2031 | 1210.3 | 0.3832 | 1365.2 | 0.3833 | 1377.7 |
| 0.4487 | 1391.3 | 0.2289 | 1224.9 | 0.4149 | 1373.3 | 0.4108 | 1385.5 |
| 0.4690 | 1401.5 | 0.2487 | 1233.9 | 0.4461 | 1381.3 | 0.4419 | 1391.4 |
| 0.4895 | 1413.7 | 0.2667 | 1244.2 | 0.4702 | 1388.9 | 0.4715 | 1397.4 |
| 0.5129 | 1424.6 | 0.2957 | 1259.3 | 0.4983 | 1396.6 | 0.5090 | 1406.3 |
| 0.5330 | 1436.2 | 0.3379 | 1282.2 | 0.5296 | 1407.3 | 0.5491 | 1415.9 |
| 0.5847 | 1462.4 | 0.3551 | 1291.8 | 0.5524 | 1415.6 | 0.5863 | 1426.4 |
| 0.6175 | 1479.9 | 0.4066 | 1315.8 | 0.5669 | 1421.2 | 0.6314 | 1439.8 |
| 0.6524 | 1499.7 | 0.4440 | 1337.5 | 0.5879 | 1428.7 | 0.6628 | 1451.0 |
| 0.6870 | 1519.0 | 0.4666 | 1357.7 | 0.6180 | 1441.2 | 0.6938 | 1463.0 |
| 0.7201 | 1536.5 | 0.5126 | 1386.7 | 0.6376 | 1449.0 | 0.7176 | 1472.6 |
| 0.7491 | 1552.8 | 0.5609 | 1421.0 | 0.6581 | 1459.1 | 0.7444 | 1484.7 |
| 0.7830 | 1573.6 | 0.5874 | 1431.8 | 0.7099 | 1479.7 | 0.7754 | 1502.6 |
| 0.8219 | 1595.2 | 0.6102 | 1447.6 | 0.7438 | 1498.0 | 0.7895 | 1510.4 |
| 0.8620 | 1620.3 | 0.6583 | 1477.3 | 0.7829 | 1522.0 | 0.8206 | 1529.0 |
| 0.8998 | 1641.5 | 0.7143 | 1511.8 | 0.8309 | 1553.8 | 0.8489 | 1549.3 |
| 0.9334 | 1664.3 | 0.7826 | 1557.3 | 0.8756 | 1588.2 | 0.8820 | 1575.6 |
| 0.9552 | 1675.7 | 0.8140 | 1578.6 | 0.9249 | 1629.5 | 0.9223 | 1623.6 |
| 0.9718 | 1685.2 | 0.8563 | 1607.4 | 0.9582 | 1660.0 | 0.9532 | 1669.1 |
| 0.9886 | 1694.1 | 0.8938 | 1626.4 | 0.9905 | 1692.4 | 0.9762 | 1682.2 |
| 1.0000 | 1703.7 | 0.9097 | 1642.6 | 1.0000 | 1703.7 | 0.9922 | 1694.9 |
| | | 0.9438 | 1666.2 | | | 1.0000 | 1703.7 |
| | | 0.9759 | 1688.3 | | | | |
| | | 1.0000 | 1703.7 | | | | |

as well as on the hydrophobic character of the aliphatic alcohol. Excess adiabatic compressibility coefficients as a measure of deviation from ideal behaviour are obtained as follows:

$$\Delta\beta = \beta_{\mathrm{expt}} - \beta_{\mathrm{ideal}}. \tag{2}$$

The ideal values ($\beta_{id}$) are calculated by taking the volume-fraction $\phi_1$ weighted contributions of the isothermal compressibilities [17–20]. From the relation between isothermal and adiabatic compressibilities, ($\beta_{id}$) can be expressed as follows:

$$\beta_{id} = \sum \phi_i \left( \beta_i + \frac{T V_i^* \alpha^2}{C_{P,i}} \right) - \frac{T \left( \sum \left( X_1 V_i^* \right) \sum \left( \phi_i \alpha_i \right)^2 \right)}{\sum \left( X_i C_{P,i} \right)}, \tag{3}$$

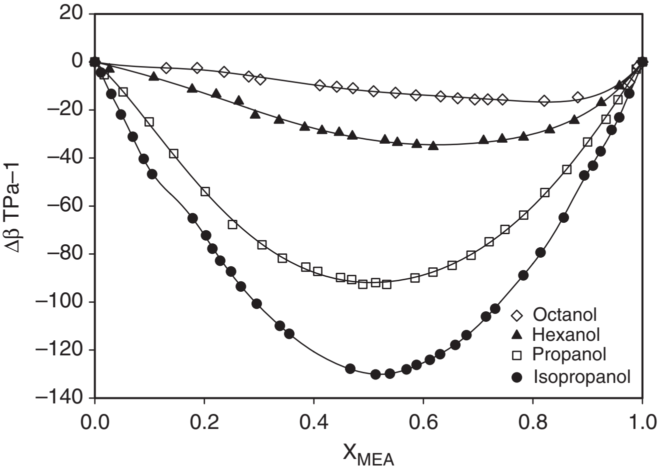

Figure 1. Plot of excess isentropic compressibilities ($\Delta\beta$) as a function of MEA mole fraction for various alcohols at 303 K.

Table 4. $(\beta)^E/10^{-12}$ Redlich parameters for MEA + alcohol at 303.15 K.

| | Propanol | Isopropanol | Hexanol | Octanol |
|---|---|---|---|---|
| A | −352.85 | −527.00 | −122.86 | −35.50 |
| B | 8.70 | 57.31 | 61.40 | 31.74 |
| C | −0.42 | 141.31 | −18.80 | −54.79 |
| D | 66.21 | −21.62 | 53.09 | 64.84 |
| E | 91.43 | −152.36 | −22.35 | – |
| $R^2$ | 0.999 | 0.999 | 0.997 | 0.986 |

where $\beta_i$, $V_i$*, $\alpha_i$ and $C_{P,i}$ are the adiabatic compressibility, molar volume, coefficient of thermal expansivity and molar heat capacity at a constant pressure of the *i*th component, respectively. The heat capacity data for the pure components is taken from the literature [21,22]. The excess property $\Delta\beta$ calculated from Equations (2) and (3) were fitted to Redlich–Kister equation [23]

$$y^E = X_1 X_2 \sum_{j=0}^{n} a_j (1 - 2X_1)^j, \tag{4}$$

where $y^E$ and $a_j$ represent the excess property in question and the polynomial coefficient of the fitting equation.

The $\Delta\beta$ plots at 303 K are shown in Figure 1 and the fitting coefficients of Equation (4) are presented in Table 4. The thermal expansivity values ($\alpha_i$) were calculated from the dependence of molar volume as a function of temperature and is given by

$$\alpha_i = \frac{1}{V_i^*}\left(\frac{\partial V_i}{\partial T}\right)_P. \tag{5}$$

Table 5. $K_{\phi} \times 10^{15}$ for MEA + alcohol at 303.15 K.

| $X_{\mathrm{MEA}}$ | Propanol | Isopropanol | Hexanol | Octanol |
|---|---|---|---|---|
| 0.0 | 4.80 | −5.76 | 15.22 | 21.36 |
| 1.0 | 44.93 | 46.28 | 79.59 | 101.16 |

The $\Delta\beta$ values were found to be negative in all cases and a pronounced minimum was observed around 0.5 mole fraction of the MEA for hydrophilic propanol and isopropanol. The negative trends indicate the strength of interaction between these species. In the case of more hydrophobic alcohols, only weak interactions are expected, resulting in similar negative values for $\Delta\beta$.

The excess molar adiabatic compressibility $(\beta V)^{\mathrm{E}}$ or $K^{\mathrm{E}}$ is given by

$$(\beta V)^E = \beta_s V - (\beta_s V)^{id}, \tag{6}$$

$$(\beta_s V)^{id} = X_1 \beta_1^* V_1^* + (1 - X_1)\beta_2^* V_2^*, \tag{7}$$

where $\beta_{\mathrm{s}}$, $\beta_1^*$, $\beta_2^*$, $V$, $V_1^*$, and $V_2^*$, are adiabatic compressibilities and volumes of the solution of components 1 and 2, respectively. The molar volumes of solutions were calculated using the following equation:

$$V = \frac{M_1 X_1 + M_2(1 - X_1)}{\rho}, \tag{8}$$

where $M_1$ and $M_2$ are the molecular weights of components 1 and 2, respectively. The apparent molar compressibilities of components were obtained from $(\beta V)^{\mathrm{E}}$ using the relations [24]

$$K_{\phi,1} = \frac{(\beta V)^{\mathrm{E}}}{X_1} + \beta_1^* V_1^* \tag{9}$$

and

$$K_{\phi,2} = \frac{(\beta V)^E}{X_2} + \beta_2^* V_2^*. \tag{10}$$

From the plots of $K_{\phi,1}$ and $K_{\phi,2}$ as a function of mole fraction of MEA, the partial molar compressibility values at infinite dilution $K_{\phi,1}^0$ and $K_{\phi,2}^0$ were obtained by means of graphical methods and are listed in Table 5. The values of $K_{\phi,2}^0$ increase in the order of increasing hydrophobic nature of the alcohols [25,26].

### 3.2. *Volumes*

The excess volume is given by:

$$V^E = V - V^{id}, \tag{11}$$

where $V^{\mathrm{id}} = V_1^* X_1 + (1 - X_1)V_2^*$ The excess volumes were plotted as a function of mole fraction of $X_{\mathrm{MEA}}$ at all temperatures and presented in Figure 2. The fitting parameters of the plots using Equation (4) are presented in Table 6. The excess volumes were found to be

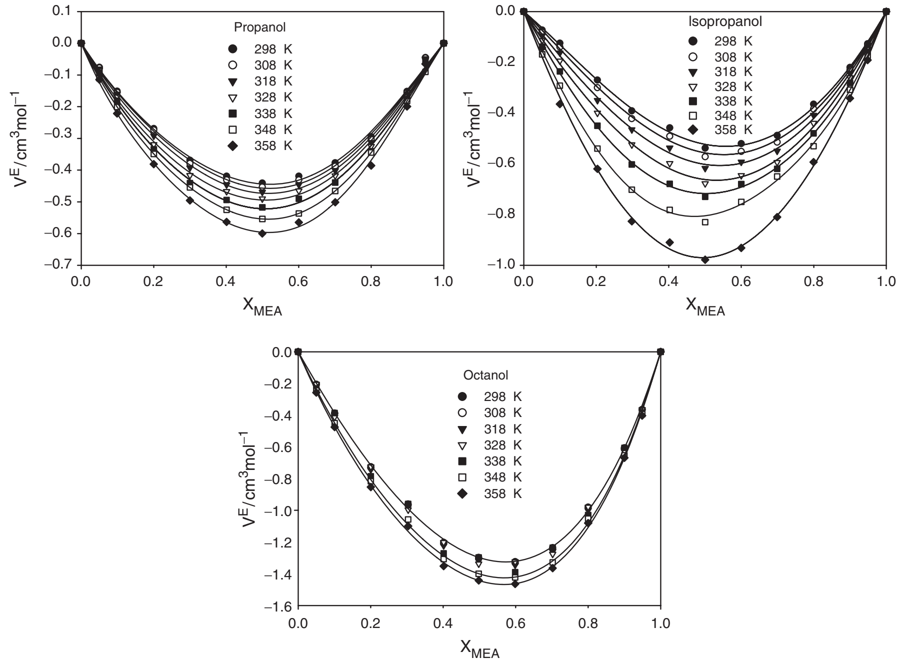

Figure 2. Plots of excess volumes for the systems MEA with alcohols as a function of temperature.

Table 6. Redlich–Kister coefficients for $V^E$ of MEA and alcohol mixtures at various temperatures.

| Parameters | 298 K | 308 K | 318 K | 328 K | 338 K | 348 K | 358 K |
|---|---|---|---|---|---|---|---|
| Propanol | | | | | | | |
| $a_0$ | −1.7762 | −1.8272 | −1.8915 | −1.9784 | −2.0869 | −2.2166 | −2.3857 |
| $a_1$ | 0.1479 | 0.1593 | 0.1405 | 0.0876 | 0.0794 | 0.1470 | 0.1694 |
| $a_2$ | 0.1741 | 0.1932 | 0.1746 | 0.1363 | 0.1455 | 0.1432 | 0.1347 |
| $a_3$ | −0.3090 | −0.3174 | −0.3222 | −0.3001 | −0.3216 | −0.4740 | −0.6175 |
| $R^2$ | 0.9957 | 0.9958 | 0.9959 | 0.9957 | 0.9961 | 0.9971 | 0.9975 |
| Isopropanol | | | | | | | |
| $a_0$ | −2.0940 | −2.2286 | −2.4096 | −2.6485 | −2.8687 | −3.2200 | −3.8790 |
| $a_1$ | 0.5453 | 0.5133 | 0.4374 | 0.3571 | 0.0355 | −0.3558 | −0.1041 |
| $a_2$ | 0.2369 | 0.2113 | 0.1427 | 0.0946 | −0.0895 | −0.2254 | 0.1634 |
| $a_3$ | 0.0897 | 0.0656 | 0.0407 | 1.0411e−3 | 0.3715 | 0.6982 | 0.1642 |
| $R^2$ | 0.9978 | 0.9980 | 0.9982 | 0.9984 | 0.9909 | 0.9973 | 0.9979 |
| Octanol | | | | | | | |
| $a_0$ | −5.1918 | −5.2234 | −5.2745 | −5.2721 | −5.3252 | −5.6010 | −5.7743 |
| $a_1$ | 1.4604 | 1.4766 | 1.4822 | 1.4763 | 1.4465 | 1.4275 | 1.4026 |
| $a_2$ | −0.4819 | −0.5227 | −0.5739 | −0.5460 | −0.6233 | −0.7979 | −0.8802 |
| $a_3$ | 0.1341 | 0.1259 | 0.1072 | 0.0938 | 0.1057 | 9.4932e−3 | −0.0420 |
| $R^2$ | 0.9957 | 0.9982 | 0.9961 | 0.9973 | 0.9979 | 0.9973 | 0.9959 |

negative, indicating negative deviation from ideality with a minimum at 0.5 mole fraction for 1-propanol and isopropanol, and around 0.6 for octanol. The excess volumes calculated for the 1-hexanol system are found to be negative within the range of experimental error and therefore were not fitted to Equation (4). The excess volumes ($V^E$) are also found to be dependant on temperature and became more negative at higher temperatures. The magnitude of $V^E$ reflects the compactness. Negative $V^E$ values indicate that more efficient packing is evident in the mixture compared to the pure liquid components. Thus, it can be assumed that the most hydrophobic alcohol interacts with MEA in a more compact form than the other hydrophilic alcohols.

## 4. Conclusions

Volumetric properties of aliphatic alcohols with MEA are found to depend on the nature of the hydrophobicity and hydrogen bonding ability of the alcohols. Alcohols with higher hydrophobic character interact more strongly with MEA, leading to larger values of $K^0_{\phi,2}$.

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