

Determination of surface tension of binary mixtures of Methanol, Propanol, iso-Propanol with o-Xylene

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ABSTRACT

Surface tension data of binary mixtures of methanol, propanol, iso-propanol with o-xylene were measured over the entire concentration range at temperatures from 30 to 70°C with intervals of 10°C. The experimental values were correlated with temperature and concentration respectively and were found to have a linear relationship.

Key words: surface tension, o-xylene, methanol, propanol, iso-propanol

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INTRODUCTION

The surface tension of pure liquids and liquid mixtures is an important physical property in mass transfer process such as liquid - liquid extraction, gas absorption, distillation, and condensation. The surface tension is also a property that represents changes in molecular interaction and could thus be used as a means of interpreting behavior of binary mixtures.

This physical property needed in several chemical engineering design calculations such as interfacial area, plate spacing, slot opening, entrainment rate and liquid holdup in problems relating to two-phase flow, nucleate boiling heat transfer and the design of distillation columns. Therefore, it has been thought fit to determine the surface tension of binary mixtures of methanol, propanol, iso-propanol with o-xylene on which recent experimental data are not

available, and also to study the effect of temperature and composition on the surface tension of these mixtures.

MATERIALS AND METHODS

Chemicals used are o - Xylene (99.8%), Methanol (99.8%), Propanol (99.9%), iso - propanol (99.9%). All the chemicals are AR grade, purchased from S.D.Chemicals Ltd., pure liquids used in the present work are prepared from the AnalaR/guaranteed reagent grade, further purified according to the methods described by Weissberger and Reddick and Bunger [1]. The pure liquids are estimated to be of purity better than 99.5% and the composition of the mixtures reported are within ± 0.01 mole percent of their true values.

In view of the ease and rapidity of measurements and easy adoption to the study of temperature effects, Bubble pressure method is chosen for the present work. A tensiometer operating on the general principles outlined by Catchpole and Ellis [2] and described in detail by Ashok kumar [3] is used in the present study. The method involves the measurement of the maximum pressure differential developed by a dry gas when the bubble detaches from: (a) uniform capillary of about 1 mm bore and (b) a very fine capillary, both immersed to the same depth into the test liquid maintained at the desired temperature to within $\pm 0.05^\circ\text{C}$. experiments were conducted in the temperature range $30-70^\circ\text{C}$, on the binary mixtures formed by o-xylene with methanol, propanol, iso-propanol. The empirical relation given by Sugden [4] is accurate to 1 part in 1000 for the surface tension (dyne/cm). Provided $0.2 > r_2 > 0.1$ and $r_1 < 0.001$. The Sugden[4] equation is

$$\sigma = \rho A g (h_1 - h_2) [1 + 0.69 r_2 D / \rho (h_1 - h_2)] \text{ ----- (1)}$$

Where A = apparatus constant, determined by calibration, r_2 is radius of larger capillary tube a(cm), D is density of liquid sample (gram/cc), ρ is density of manometer liquid (gram/cc), g is $981 \text{ (cm/sec}^2\text{)}$. The above equation is used to calculate the values of surface tension for pure compounds as well as for liquid mixtures. The apparatus constant (A) is determined by using chemical for which surface tension data is known, eg: Toluene, o-xylene, methanol. Values of surface tension reported in this work are believed to be accurate to within $\pm 0.1\%$.

RESULTS AND DISCUSSION

Fig.1-3 gives the measured surface tension values of mixtures of methanol, propanol, iso-propanol with o-xylene at various concentrations and at various temperatures.

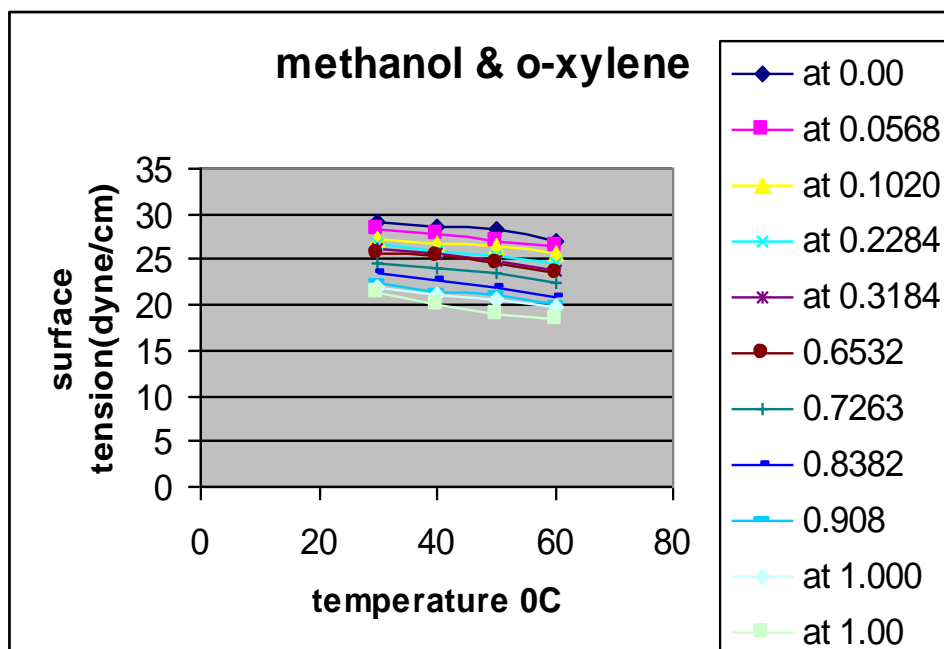


Fig 1: Surface tension of methanol (1) + o-xylene (2) as a function of temperature at different mole fractions of methanol (x_1).

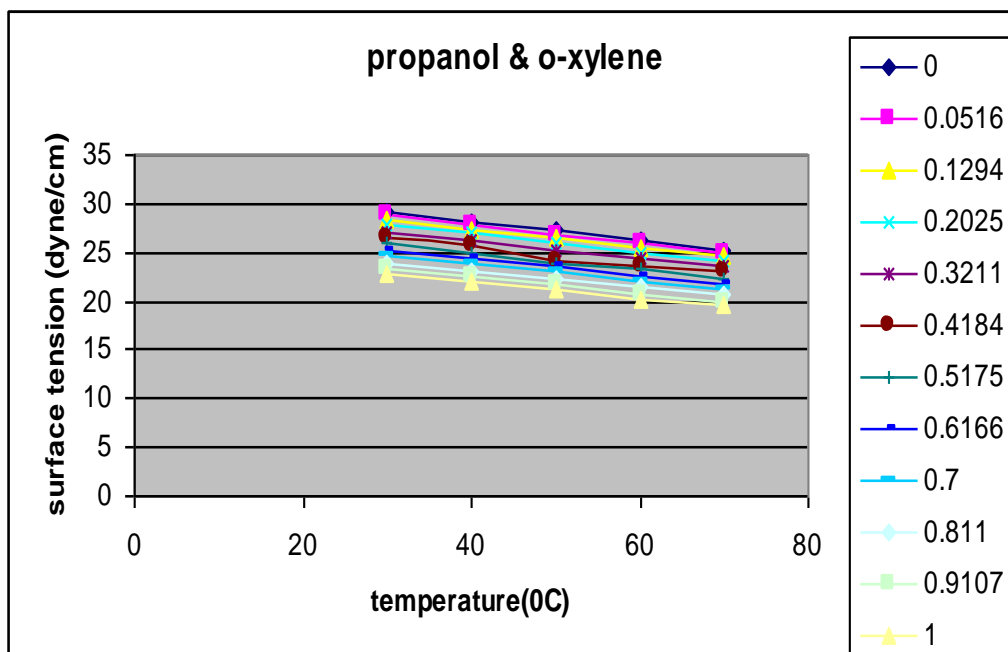


Fig 2: Surface tension of propanol (1) + O-Xylene (2) as a function of temperature at Different mole fractions of propanol (x_1).

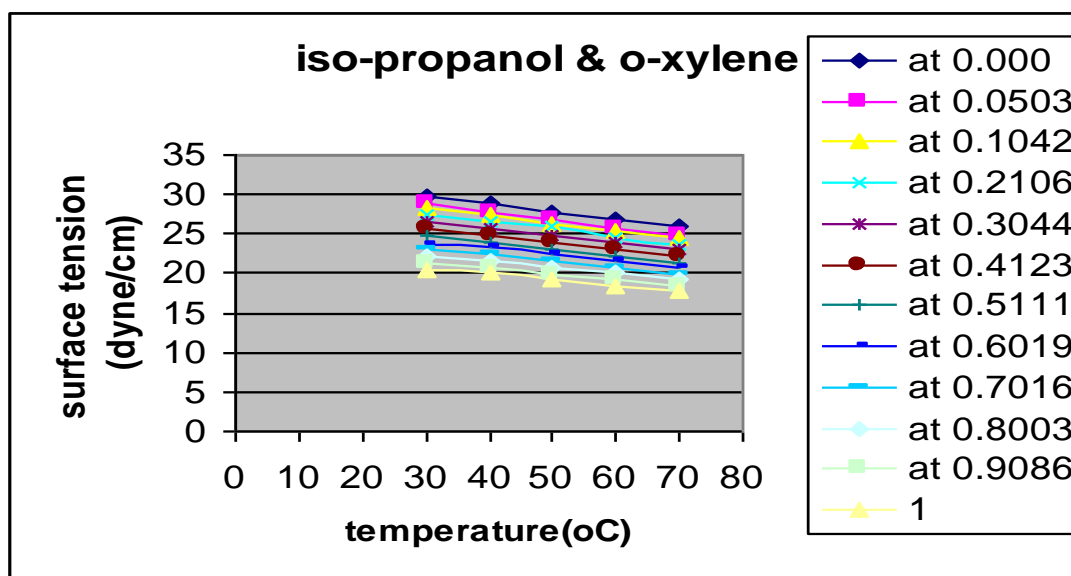


Fig 3: Surface tension of iso - propanol (1) + o-xylene (2) as a function of temperature

At different mole fractions of iso - propanol (x_1).

It is observed that in all the systems studied, the surface tension decreased with increasing temperature at any mole fraction. For a given temperature the surface tensions of all binary mixtures investigated here decreased with an increase of the alcohol mole fraction and it shows that there is almost a linear relationship between surface tension and temperature. The surface tension of binary mixtures was correlated with temperature by the following linear expression [5], proposed for pure component:

$$\sigma \text{ (dyne/cm)} = K_1 - K_2 (t^\circ\text{C}) \quad \text{-----} \quad (2)$$

Equation(2) also fitted the data of methanol, Propanol and iso-Propanol for each concentration, with an average deviation of less than 1%. The fitted values of K_1 and K_2 are given in Tables(1-3).

Table 1. Surface tension parameters K_1 & K_2 for Methanol (1) & o-xylene (2).

| x_1 | 0.000 | 0.056 | 0.1020 | 0.228 | 0.3184 | 0.3718 | 0.5260 | 0.6532 | 0.7263 | 0.8382 | 0.9080 | 1.000 |
|-------|-------|-------|--------|-------|--------|--------|--------|--------|--------|--------|--------|--------|
| K_1 | 31.1 | 29.7 | 29.2 | 28.8 | 27.5 | 27.1 | 25.9 | 24.9 | 24.2 | 23.4 | 22.6 | 22.00 |
| K_2 | 0.100 | 0.10 | 0.088 | 0.10 | 0.0916 | 0.0777 | 0.0909 | 0.0833 | 0.0833 | 0.0869 | 0.0818 | 0.0782 |

Table 2. Surface tension parameters K_1 & K_2 values for Propanol (1) & o-xylene (2)

| x_1 | 0.000 | 0.0516 | 0.1294 | 0.2025 | 0.3211 | 0.4184 | 0.5175 | 0.6166 | 0.6991 | 0.9107 | 1.00 |
|-------|-------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| K_1 | 31.1 | 30.3 | 29.8 | 29.3 | 28.6 | 27.9 | 27.1 | 26.5 | 25.9 | 24.60 | 24.00 |
| K_2 | 0.100 | 0.100 | 0.0823 | 0.0888 | 0.0909 | 0.0777 | 0.0916 | 0.0833 | 0.0856 | 0.0700 | 0.0800 |

Table 3. Surface tension parameters K_1 & K_2 values for Iso-propanol (1) & o-xylene (2)

| x_1 | 0.000 | 0.503 | 0.104 | 0.210 | 0.3044 | 0.4123 | 0.5111 | 0.6019 | 0.7016 | 0.8003 | 1.00 |
|-------|-------|-------|--------|--------|--------|--------|--------|--------|--------|--------|-------|
| K_1 | 31.1 | 30.2 | 29.7 | 27.9 | 27.0 | 26.39 | 25.3 | 24.5 | 24.5 | 23.6 | 21.9 |
| K_2 | 0.100 | 0.933 | 0.0583 | 0.0941 | 0.0857 | 0.0823 | 0.0823 | 0.0900 | 0.0875 | 0.0800 | 0.066 |

Connors and Wright [6] proposed an equation of the following form that has been used successfully in the chemical literature [7-10]:

$$\sigma^* = (\sigma_2 - \sigma) / (\sigma_2 - \sigma_1) = \{(1+ax_2)/(1-bx_2)\}x_1 \quad \text{-----} \quad (3)$$

Where σ_2 is the surface tension of the second compound, σ_1 is the surface tension of the first compound, σ is the surface tension of the mixture, σ^* is dimensionless surface tension, and a , b are the constants. Equation (3) describes the effect of composition on the mixture surface tension. The dimensionless surface tension, σ^* is weak function of temperature over most of the concentration range. The σ^* vs. x_1 curve is shown in Fig 4-6 for temperatures of 30°C & 70°C.

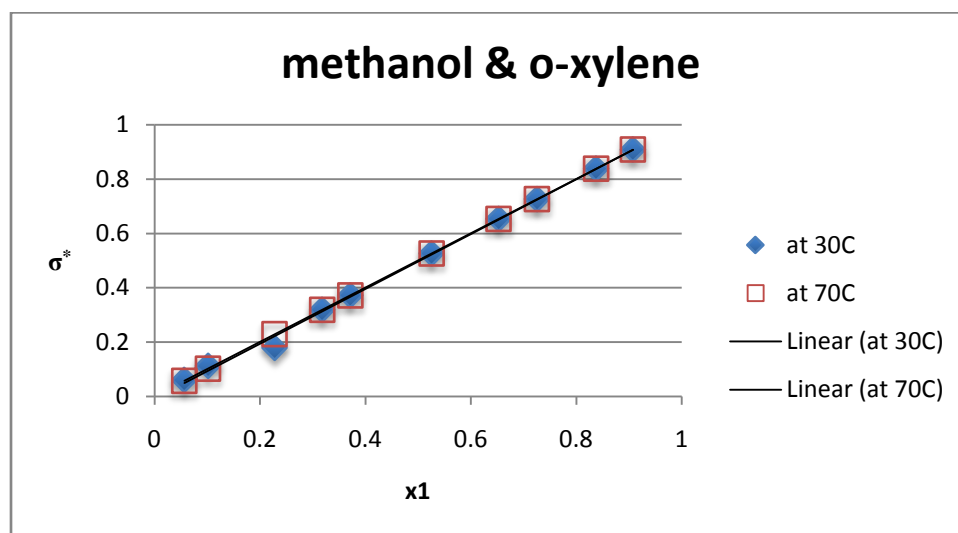


Fig 4: Dimensionless surface tension σ^* vs. the mole fraction of Methanol at temperatures of 30°C & 70°C.

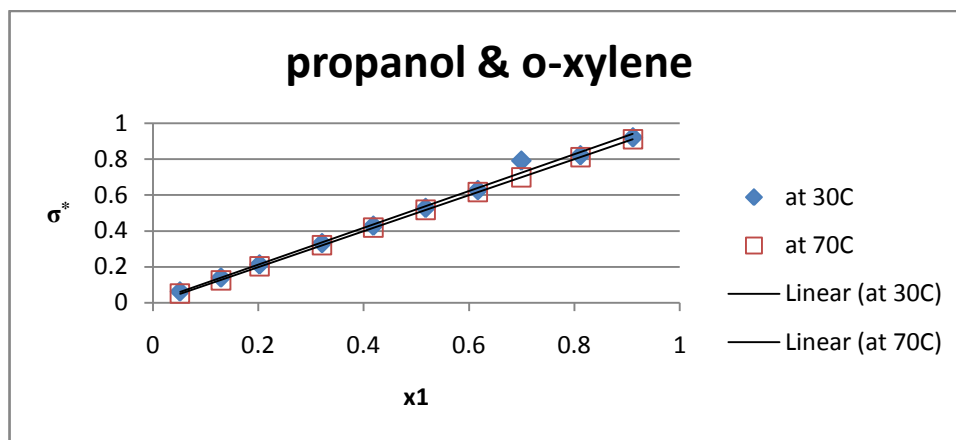


Fig 5: Dimensionless surface tension σ^* vs. the mole fraction of propanol at temperatures of 30°C & 70°C.

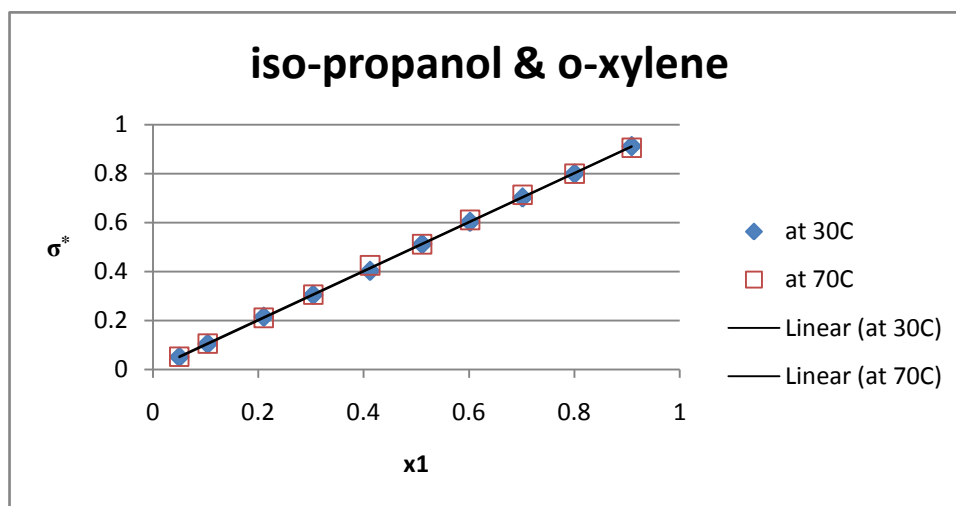


Fig 6: Dimensionless surface tension σ^* vs. the mole fraction of iso-propanol at temperatures of 30°C & 70°C.

The relation between the σ^* and x_1 (equ.3) is nonlinear, so for finding the values of the fitted parameters **a** and **b** in equation (3), we define a simple method. By linearization of equation (3) we obtain

$$x_1 / (\sigma^* - x_1) = 1/ax_2 - b/a \quad \text{-----} \quad (4)$$

The plots of $x_1 / (\sigma^* - x_1)$ vs. $1/x_2$ shown in Fig.7-9 give a straight line with slope equal to $1/a$ and intercept equal to $-b/a$, so that the fitted parameters **a** and **b** were determined at each temperature from slope and intercept, respectively. The values of **a** and **b** are listed in the Table 4 for each temperatures. The values of the fitted parameters **a** and **b** in equ.3 or 4 are linear functions of temperature.

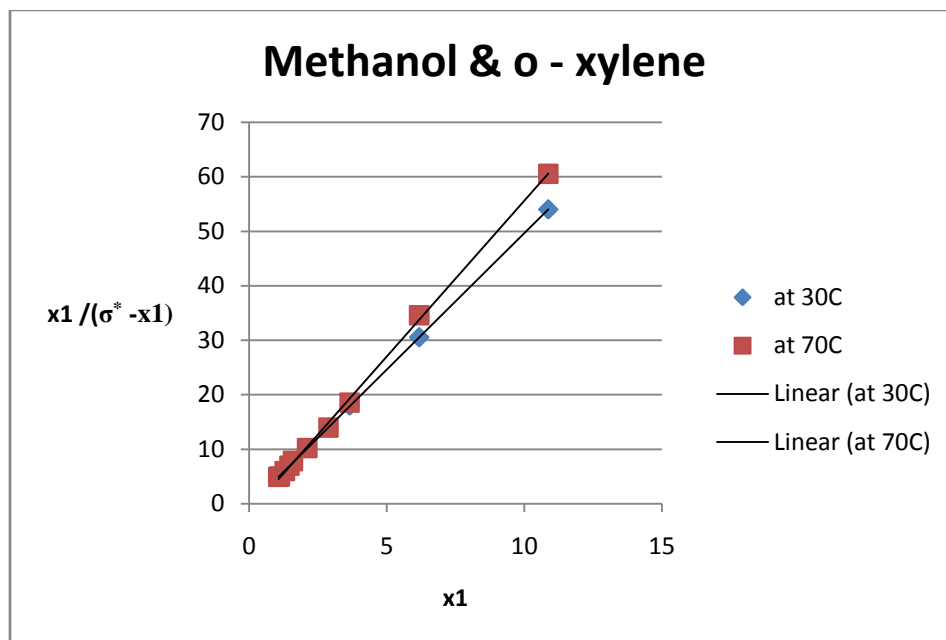


Fig 7: Plot of $x_1 / (\sigma^* - x_1)$ vs. $1/x_2$ for methanol (1) & o-xylene (2).

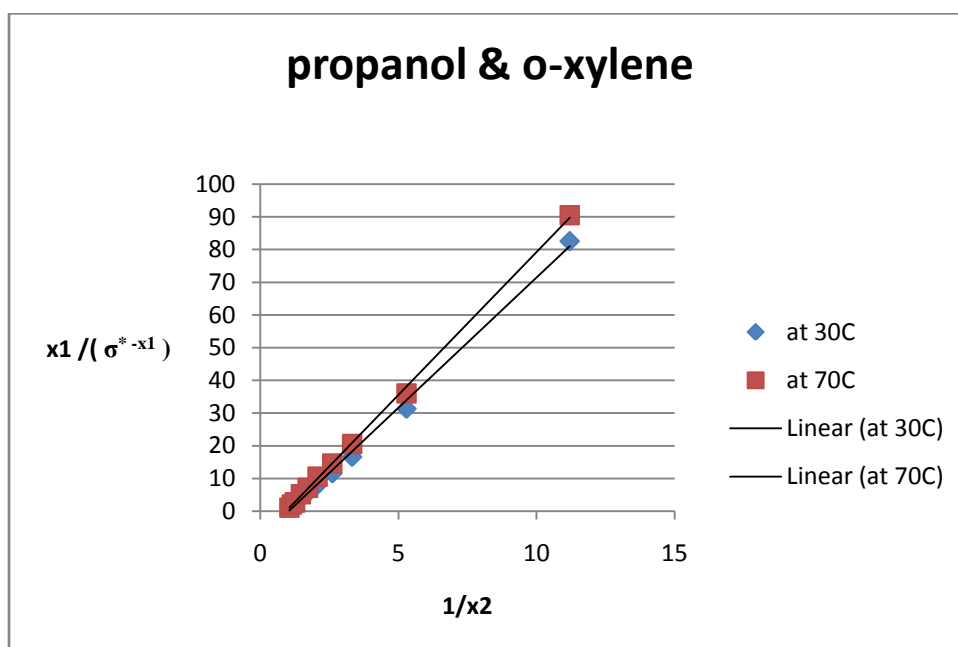


Fig 8: Plot of $x_1 / (\sigma^* - x_1)$ vs. $1/x_2$ for propanol (1) & o-xylene (2)

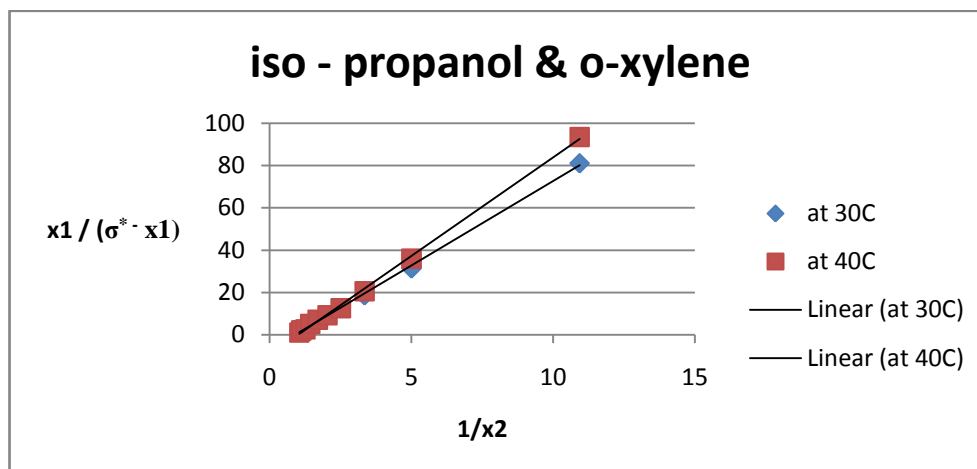


Fig 9: Plot of $x_1 / (\sigma^* - x_1)$ vs. $1/x_2$ for iso-propanol & o- xylene

Table 4. Surface tension parameters a and b for methanol, propanol & iso-propanol with o-xylene

| Temperature ⁰ C | 30 | 40 | 50 | 60 | 70 |
|--|--------|--------|--------|--------|--------|
| (a) methanol & o-xylene | | | | | |
| a | 0.1034 | 0.1032 | 0.1030 | 0.1028 | - |
| b | 0.517 | 0.516 | 0.515 | 0.514 | - |
| (b) propanol & o-xylene | | | | | |
| a | 0.1036 | 0.1034 | 0.1032 | 0.1030 | 0.1028 |
| b | 0.5698 | 0.5687 | 0.5676 | 0.5665 | 0.5654 |
| (c) iso-propanol & o-xylene | | | | | |
| a | 0.1038 | 0.1039 | 0.1035 | 0.1028 | 0.1026 |
| b | 0.6228 | 0.6222 | 0.621 | 0.6168 | 0.6156 |

Similar correlations were also obtained for binary mixtures of ethanol and ethylene glycol [11]

CONCLUSIONS

- The effect of temperature on surface tension for pure compounds was studied. As the temperature increases and surface tension decreases.
- The effect of temperature and composition on surface tension for binary mixtures was studied. As the temperature and composition increases and surface tension decreases.
- The surface tension of pure and binary mixtures was found to vary linearly with temperature and composition respectively.

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