*Thermochimica Acta*, 76 (1984) 255–264
Elsevier Science Publishers B.V., Amsterdam – Printed in The Netherlands

# ACTIVITY COEFFICIENTS AND EXCESS GIBBS FREE ENERGIES OF 1,1,1-TRICHLOROETHANE WITH 1-BUTANOL AND 1-PENTANOL

K. DAYANANDA REDDY and M.V. PRABHAKARA RAO

*Chemical Laboratories, Sri Venkateswara University, Tirupati 517 502 (A.P.) (India)*

M. RAMAKRISHNA

*Regional Research Laboratory, Hyderabad 500 009 (India)*

(Received 8 December 1983)

## ABSTRACT

Vapour–liquid equilibrium data for the systems 1,1,1-trichloroethane(1)–1-butanol(2) and 1,1,1-trichloroethane(1)–1-pentanol(2) have been measured by an indirect method from composition vs. boiling point ($x-t$) measurements made in a Swietoslawski type ebulliometer. The measurements were made at 200 and 700 mm Hg. The experimental $t-x$ data were used to estimate Wilson parameters, these, in turn, are used to calculate vapour compositions, boiling points and activity coefficients; from the activity coefficients $G^E$ is calculated.

## INTRODUCTION

Evaporation operation has been conducted as an effective means of separation in chemical processing. An accurate and complete knowledge of vapour–liquid equilibrium (VLE) data on the mixtures under consideration is necessary for the design of distillation equipment. Generally, VLE data are obtainable under two fixed conditions; namely, isothermal and isobaric. Most distillation processes are carried out at constant pressure rather than constant temperature. Therefore, isobaric vapour–liquid equilibrium data for the binary systems 1,1,1-trichloroethane(1)–1-butanol(2) and 1,1,1-trichloroethane(1)–1-pentanol(2) at 200 and 700 mm Hg are presented in this communication. The data have been interpreted in terms of dissociation of alcohol aggregates, interstitial accommodation of chloroethane in alcohol aggregates, and possible interaction of the type Cl · · · H–O between unlike molecules.

## EXPERIMENTAL

1,1,1-Trichloroethane (Koch-Light Laboratories), 1-butanol (BDH) and 1-pentanol (Merck) were purified as described previously [1,2]. The purity of

0040-6031/84/$03.00

the samples was checked by measuring densities, refractive indices and boiling points. The densities were measured using a standard bi-capillary pycnometer which gave an accuracy of 5 parts in $10^5$. Refractive indices were determined using an Abbe's refractometer which gave an accuracy of ±0.0002. The boiling points were measured using a Swietoslawski type ebulliometer, which gave an accuracy of ±0.2°C. The measured values are in good agreement with the literature values [3,4].

The vapour–liquid equilibrium measurements were studied in a Swietoslawski type ebulliometer [5]. The ebulliometer was connected to a vacuum system. The pressures were measured using a mercury manometer which gave an accuracy of ±1 mm Hg. The temperatures were measured using a PT100 thermometer with an accuracy of ±0.1°C. The detailed experimental procedure has been described previously [5].

### *Isobaric binary systems*

The boiling points of the systems 1,1,1-trichloroethane(1)–1-butanol(2) and 1,1,1-trichloroethane(1)–1-pentanol(2) were determined over the entire range of composition. Mixtures of different compositions were prepared by taking quantities (by weight) of the pure compounds. The boiling points for the known binary compositions were measured at 200 and 700 mm Hg. The boiling temperature of a specified composition was first measured at 200 mm Hg. The pressure was raised to 700 mm Hg and the boiling point was determined. The system was brought back to 200 mm Hg, where the boiling point measurement was repeated and, finally, the measurement was repeated at 700 mm Hg, thereby obtaining duplicate sets of the boiling points at each pressure of interest. This procedure also helps in detecting any possible dissociation and loss of materials under study.

## RESULTS

In the present work, isobaric $t$–$x$ measurements are used for the data reduction. The model chosen for expressing the composition and temperature dependence is the Wilson equation [6]

$$\ln \nu_1 = -\ln(x_1 + \Lambda_{12}x_2) + x_2\left(\frac{\Lambda_{12}}{x_1 + \Lambda_{12}x_2} - \frac{\Lambda_{21}}{x_2 + \Lambda_{21}x_1}\right) \tag{1}$$

$$\ln \nu_2 = -\ln(x_2 + \Lambda_{21}x_1) + x_1\left(\frac{\Lambda_{21}}{x_1 + \Lambda_{21}} - \frac{\Lambda_{12}}{x_1 + \Lambda_{12}x_2}\right) \tag{2}$$

where

$$\Lambda_{12} = \frac{V_2^{\mathrm{L}}}{V_1^{\mathrm{L}}}\exp\left(\frac{\lambda_{12} - \lambda_{11}}{RT}\right) \tag{3}$$

TABLE 1

Wilson parameters with standard deviation

| System | $\Lambda_{12}$ | $\Lambda_{21}$ | Standard deviation ($\sigma$) |
|---|---|---|---|
| 1,1,1-Trichloroethane(1)–1-butanol(2) at 200 mm Hg | 103.340 | 383.791 | 0.13 |
| 1,1,1-Trichloroethane(1)–1-butanol(2) at 700 mm Hg | 267.606 | 5.789 | 0.25 |
| 1,1,1-Trichloroethane(1)–1-pentanol(2) at 200 mm Hg | −226.559 | 1780.720 | 0.23 |
| 1,1,1-Trichloroethane(1)–1-pentanol(2) at 700 mm Hg | −274.116 | 288.749 | 0.49 |

$$\Lambda_{21} = \frac{V_1^{\mathrm{L}}}{V_2^{\mathrm{L}}} \exp\left( \frac{\lambda_{12} - \lambda_{22}}{RT} \right) \tag{4}$$

Where $V_1^{\mathrm{L}}$ and $V_2^{\mathrm{L}}$ are liquid molal volumes $(\lambda_{12} - \lambda_{11})$ and $(\lambda_{12} - \lambda_{22})$ are temperature independent (to some extent) Wilson parameters; $\lambda$ is the energy of interaction between the molecules designated in the subscripts. The optimum Wilson parameters $\Lambda_{12}$ and $\Lambda_{21}$ are obtained by minimising the objective function $\phi$

$$\phi = \Sigma \left( \frac{P_{\mathrm{cal}}}{P_{\mathrm{exp}}} - 1.0 \right)^2 \tag{5}$$

The optimum Wilson parameters are obtained by minimising the above objective function using Nelder–Mead optimization techniques. The Wilson parameters thus obtained are presented in Table 1 along with the standard deviation of the fit.

## DISCUSSION

Since the prediction of vapour–liquid equilibrium data involves the vapour pressure measurements of the pure compounds, the same has been measured for 1,1,1-trichloroethane, 1-butanol and 1-pentanol. The Antoine constants for the pure components were obtained by non-linear regression analyses of the experimental data, and are presented in Table 2 along with the standard deviation. The measured boiling points, calculated boiling points from the Wilson equation and ideal boiling points are presented in Tables 3–6. The excess Gibbs free energies were calculated using the following equation

$$\frac{G^{\mathrm{E}}}{RT} = x_1 \ln \nu_1 + x_2 \ln \nu_2 \tag{6}$$

TABLE 2

Antoine constants for the pure compounds with standard deviation

| Compound | $A$ | $B$ | $C$ | $\sigma_P$ (%) |
|---|---|---|---|---|
| 1,1,1-Trichloroethane | 15.0010 | 2276.62 | 197.94 | 0.35 |
| 1-Butanol | 18.1868 | 3722.47 | 204.58 | 0.3 |
| 1-Pentanol | 17.8107 | 3786.78 | 21.29 | 0.4 |

TABLE 3

1,1,1-Trichloroethane(1)–1-butanol(2) $t-x$ data at 200 mm Hg

| $x$ | $t_{exp}$ (°C) | $t_{cal}$ using Wilson equation (°C) | $t_{ideal}$ (°C) | $t_{exp}-t_{cal}$ (°C) |
|---|---|---|---|---|
| 0.1251 | 61.0 | 61.0 | 73.6 | 0.0 |
| 0.1251 | 61.0 | 61.0 | 73.6 | 0.0 |
| 0.4068 | 45.5 | 45.5 | 56.1 | 0.0 |
| 0.4068 | 45.5 | 45.5 | 56.1 | 0.0 |
| 0.5852 | 42.0 | 42.1 | 48.6 | 0.1 |
| 0.5852 | 42.0 | 42.1 | 48.6 | 0.1 |
| 0.6764 | 41.0 | 40.9 | 45.4 | 0.1 |
| 0.6764 | 41.0 | 40.9 | 45.4 | 0.1 |
| 0.7454 | 40.1 | 40.0 | 43.3 | 0.1 |
| 0.7454 | 40.0 | 40.0 | 43.3 | 0.0 |
| 0.8076 | 39.4 | 39.3 | 41.5 | 0.1 |
| 0.8076 | 39.5 | 39.3 | 41.5 | 0.2 |
| 0.9668 | 37.0 | 37.2 | 37.5 | −0.2 |
| 0.9668 | 37.0 | 37.2 | 37.5 | −0.2 |

TABLE 4

1,1,1-Trichloroethane(1)–1-butanol(2) $t-x$ data at 700 mm Hg

| $x$ | $t_{exp}$ (°C) | $t_{cal}$ using Wilson equation (°C) | $t_{ideal}$ (°C) | $t_{exp}-t_{cal}$ (°C) |
|---|---|---|---|---|
| 0.1251 | 101.5 | 101.5 | 107.8 | 0.0 |
| 0.1251 | 101.5 | 101.5 | 107.8 | 0.0 |
| 0.3161 | 91.0 | 90.8 | 97.2 | 0.2 |
| 0.3161 | 91.0 | 90.8 | 97.2 | 0.2 |
| 0.4068 | 87.2 | 87.4 | 92.8 | −0.2 |
| 0.4068 | 87.4 | 87.4 | 92.8 | 0.0 |
| 0.5852 | 81.7 | 81.9 | 85.1 | −0.2 |
| 0.5852 | 81.6 | 81.9 | 85.1 | −0.3 |
| 0.6764 | 79.5 | 79.5 | 81.6 | 0.0 |
| 0.6764 | 79.5 | 79.5 | 81.6 | 0.0 |
| 0.7454 | 78.1 | 77.7 | 79.2 | 0.4 |
| 0.7454 | 78.1 | 77.7 | 79.2 | 0.4 |
| 0.8076 | 77.0 | 76.1 | 77.2 | 0.9 |
| 0.8076 | 77.1 | 76.1 | 77.2 | 1.0 |

TABLE 5

1,1,1-Trichloroethane(1)–1-pentanol(2) $t-x$ data at 200 mm Hg

| $x$ | $t_{exp}$ (°C) | $t_{cal}$ using Wilson equation (°C) | $t_{ideal}$ (°C) | $t_{exp}-t_{cal}$ (°C) |
|---|---|---|---|---|
| 0.1043 | 81.2 | 80.8 | 85.4 | 0.4 |
| 0.1043 | 81.2 | 80.8 | 85.4 | 0.4 |
| 0.1924 | 69.5 | 69.4 | 75.1 | 0.1 |
| 0.1924 | 69.5 | 69.4 | 75.1 | 0.1 |
| 0.2928 | 60.0 | 60.1 | 66.2 | −0.1 |
| 0.2928 | 60.1 | 60.1 | 66.2 | 0.0 |
| 0.3818 | 54.1 | 54.1 | 59.9 | 0.0 |
| 0.3818 | 54.3 | 54.1 | 59.9 | 0.2 |
| 0.4515 | 50.0 | 50.2 | 55.9 | −0.2 |
| 0.4515 | 50.0 | 50.2 | 55.9 | −0.2 |
| 0.5233 | 46.8 | 46.9 | 52.3 | −0.1 |
| 0.5233 | 47.0 | 46.9 | 52.3 | 0.1 |
| 0.5989 | 43.5 | 44.0 | 49.0 | −0.5 |
| 0.5989 | 43.6 | 44.0 | 49.0 | −0.4 |
| 0.6488 | 42.0 | 42.4 | 47.1 | −0.4 |
| 0.6488 | 42.2 | 42.4 | 47.1 | −0.2 |
| 0.7471 | 39.6 | 39.8 | 43.6 | −0.2 |
| 0.7471 | 39.6 | 39.8 | 43.6 | −0.1 |
| 0.8485 | 38.0 | 37.8 | 40.6 | 0.2 |
| 0.8485 | 38.1 | 37.8 | 40.6 | 0.3 |
| 0.9602 | 36.8 | 36.8 | 37.7 | 0.0 |
| 0.9602 | 36.9 | 36.8 | 37.7 | 0.1 |

TABLE 6

1,1,1-Trichloroethane(1)–1-pentanol(2) $t-x$ data at 700 mm Hg

| $x$ | $t_{exp}$ (°C) | $t_{cal}$ using Wilson equation (°C) | $t_{ideal}$ (°C) | $t_{exp}-t_{cal}$ (°C) |
|---|---|---|---|---|
| 0.1043 | 120.1 | 119.8 | 123.2 | 0.3 |
| 0.1043 | 120.2 | 119.8 | 123.2 | 0.4 |
| 0.1924 | 109.5 | 109.4 | 114.4 | 0.1 |
| 0.1924 | 109.6 | 109.4 | 114.4 | 0.2 |
| 0.2928 | 99.2 | 100.0 | 105.7 | −0.8 |
| 0.2928 | 99.4 | 100.0 | 105.7 | −0.6 |
| 0.3818 | 93.0 | 93.1 | 99.2 | −0.1 |
| 0.3818 | 93.0 | 93.1 | 99.2 | −0.1 |
| 0.4515 | 88.5 | 88.6 | 94.7 | −0.1 |
| 0.4515 | 88.6 | 88.6 | 94.7 | 0.0 |
| 0.5233 | 84.5 | 84.6 | 90.6 | −0.1 |
| 0.5233 | 84.7 | 84.6 | 90.6 | 0.1 |
| 0.5989 | 81.7 | 80.9 | 86.7 | 0.8 |
| 0.5989 | 81.8 | 80.9 | 86.7 | 0.9 |
| 0.8485 | 72.0 | 72.8 | 76.4 | −0.8 |
| 0.8485 | 72.2 | 72.8 | 76.4 | −0.6 |
| 0.9602 | 71.6 | 71.4 | 72.7 | 0.2 |
| 0.9602 | 71.7 | 71.4 | 72.7 | 0.3 |

TABLE 7

Vapour compositions, activity coefficients and excess Gibbs free energies for the system 1,1,1-trichloroethane(1)–1-butanol(2) at 200 mm Hg

| $x$ | $y_{cal}$ | $t_{cal}$ (°C) | $\nu_1$ | $\nu_2$ | $G^E$ (J $mol^{-1}$) |
|---|---|---|---|---|---|
| 0.05 | 0.4567 | 72.2 | 2.5536 | 1.0023 | 136 |
| 0.10 | 0.6555 | 64.1 | 2.3818 | 1.0093 | 257 |
| 0.15 | 0.7555 | 58.4 | 2.2166 | 1.0213 | 364 |
| 0.20 | 0.8126 | 54.3 | 2.0628 | 1.0387 | 459 |
| 0.25 | 0.8484 | 51.3 | 1.9222 | 1.0619 | 541 |
| 0.30 | 0.8727 | 49.0 | 1.7950 | 1.0915 | 610 |
| 0.35 | 0.8901 | 47.2 | 1.6803 | 1.1284 | 667 |
| 0.40 | 0.9032 | 45.7 | 1.5774 | 1.1737 | 710 |
| 0.45 | 0.9135 | 45.5 | 1.4852 | 1.2287 | 740 |
| 0.50 | 0.9220 | 43.5 | 1.4028 | 1.2956 | 757 |
| 0.55 | 0.9292 | 42.7 | 1.3293 | 1.3768 | 759 |
| 0.60 | 0.9355 | 41.9 | 1.2640 | 1.4758 | 747 |
| 0.65 | 0.9414 | 41.2 | 1.2062 | 1.5976 | 719 |
| 0.70 | 0.9472 | 40.6 | 1.1555 | 1.7490 | 675 |
| 0.75 | 0.9529 | 40.0 | 1.1117 | 1.9400 | 614 |
| 0.80 | 0.9591 | 39.4 | 1.0745 | 2.1852 | 535 |
| 0.85 | 0.9662 | 38.8 | 1.0440 | 2.5075 | 436 |
| 0.90 | 0.9746 | 38.2 | 1.0208 | 2.9436 | 315 |
| 0.95 | 0.9853 | 37.5 | 1.0056 | 3.5560 | 171 |

TABLE 8

Vapour compositions, activity coefficients and excess Gibbs free energies for the system 1,1,1-trichloroethane(1)–1-butanol(2) at 200 mm Hg

| $x$ | $y_{cal}$ | $t_{cal}$ (°C) | $\nu_1$ | $\nu_2$ | $G^E$ (J $mol^{-1}$) |
|---|---|---|---|---|---|
| 0.05 | 0.2563 | 108.7 | 1.8399 | 1.0026 | 101 |
| 0.10 | 0.4160 | 103.6 | 1.6915 | 1.0101 | 186 |
| 0.15 | 0.5231 | 99.7 | 1.5680 | 1.0219 | 256 |
| 0.20 | 0.5999 | 96.5 | 1.4655 | 1.0376 | 313 |
| 0.25 | 0.6580 | 93.8 | 1.3804 | 1.0568 | 342 |
| 0.30 | 0.7042 | 91.5 | 1.3095 | 1.0791 | 392 |
| 0.35 | 0.7422 | 89.5 | 1.2505 | 1.1044 | 414 |
| 0.40 | 0.7745 | 87.7 | 1.2011 | 1.1324 | 427 |
| 0.45 | 0.8027 | 86.0 | 1.1599 | 1.1631 | 431 |
| 0.50 | 0.8279 | 84.4 | 1.1255 | 1.1964 | 426 |
| 0.55 | 0.8507 | 82.9 | 1.0968 | 1.2322 | 412 |
| 0.60 | 0.8716 | 81.5 | 1.0731 | 1.2704 | 392 |
| 0.65 | 0.8910 | 80.2 | 1.0536 | 1.3111 | 364 |
| 0.70 | 0.9092 | 78.9 | 1.0378 | 1.3541 | 329 |
| 0.75 | 0.9263 | 77.6 | 1.0253 | 1.3996 | 288 |
| 0.80 | 0.9425 | 76.3 | 1.0156 | 1.4475 | 241 |
| 0.85 | 0.9579 | 75.1 | 1.0085 | 1.4979 | 189 |
| 0.90 | 0.9726 | 73.9 | 1.6037 | 1.5508 | 131 |
| 0.95 | 0.9866 | 72.7 | 1.009 | 1.6062 | 68 |

TABLE 9

Vapour compositions, activity coefficients and excess Gibbs free energies for the system 1,1,1-trichloroethane(1)–1-pentanol(2) at 200 mm Hg

| $x$ | $y_{\text{cal}}$ | $t_{\text{cal}}$ (°C) | $\nu_1$ | $\nu_2$ | $G^E$ (J mol$^{-1}$) |
|---|---|---|---|---|---|
| 0.05 | 0.4074 | 90.4 | 1.3403 | 1.0000 | 43 |
| 0.10 | 0.6258 | 81.5 | 1.3214 | 1.0000 | 79 |
| 0.15 | 0.7500 | 74.4 | 1.3064 | 0.9999 | 111 |
| 0.20 | 0.8251 | 68.6 | 1.2944 | 0.9998 | 141 |
| 0.25 | 0.8733 | 63.7 | 1.2842 | 0.9997 | 168 |
| 0.30 | 0.9056 | 59.6 | 1.2753 | 0.9997 | 194 |
| 0.35 | 0.9281 | 56.1 | 1.2669 | 1.0001 | 218 |
| 0.40 | 0.9444 | 53.0 | 1.2587 | 1.0010 | 242 |
| 0.45 | 0.9565 | 50.3 | 1.2502 | 1.0030 | 264 |
| 0.50 | 0.9656 | 47.9 | 1.2409 | 1.0065 | 286 |
| 0.55 | 0.9726 | 45.8 | 1.2304 | 1.0127 | 306 |
| 0.60 | 0.9781 | 44.0 | 1.2184 | 1.0229 | 324 |
| 0.65 | 0.9824 | 42.3 | 1.2042 | 1.0396 | 339 |
| 0.70 | 0.9859 | 40.9 | 1.1875 | 1.0668 | 351 |
| 0.75 | 0.9889 | 39.7 | 1.1676 | 1.1121 | 357 |
| 0.80 | 0.9909 | 38.7 | 1.1440 | 1.1904 | 356 |
| 0.85 | 0.9928 | 37.8 | 1.1159 | 1.3369 | 340 |
| 0.90 | 0.9943 | 37.2 | 1.0826 | 1.6571 | 303 |
| 0.95 | 0.9955 | 36.8 | 1.0434 | 1.6761 | 222 |

TABLE 10

Vapour compositions, activity coefficients and excess Gibbs free energies for the system 1,1,1-trichloroethane(1)–1-pentanol(2) at 700 mm Hg

| $x$ | $y_{\text{cal}}$ | $t_{\text{cal}}$ (°C) | $\nu_1$ | $\nu_2$ | $G^E$ (J mol$^{-1}$) |
|---|---|---|---|---|---|
| 0.05 | 0.1875 | 130.4 | 0.8239 | 0.9997 | −32 |
| 0.10 | 0.3436 | 125.9 | 0.8816 | 0.9986 | −63 |
| 0.15 | 0.4721 | 121.5 | 0.8397 | 0.9966 | −92 |
| 0.20 | 0.5771 | 117.2 | 0.8483 | 0.9936 | −119 |
| 0.25 | 0.6623 | 113.0 | 0.8573 | 0.9895 | −143 |
| 0.30 | 0.7312 | 109.1 | 0.8669 | 0.9840 | −168 |
| 0.35 | 0.7868 | 105.3 | 0.8768 | 0.9770 | −185 |
| 0.40 | 0.8315 | 101.7 | 0.8872 | 0.9683 | −202 |
| 0.45 | 0.8675 | 98.3 | 0.8980 | 0.9477 | −215 |
| 0.50 | 0.8965 | 95.1 | 0.9092 | 0.9448 | −224 |
| 0.55 | 0.9198 | 92.0 | 0.9205 | 0.9294 | −229 |
| 0.60 | 0.9386 | 89.1 | 0.9321 | 0.9112 | −230 |
| 0.65 | 0.9536 | 86.4 | 0.9436 | 0.8898 | −226 |
| 0.70 | 0.9657 | 83.8 | 0.9550 | 0.8649 | −216 |
| 0.75 | 0.9754 | 81.3 | 0.9659 | 0.8361 | −201 |
| 0.80 | 0.9830 | 79.1 | 0.9762 | 0.8029 | −178 |
| 0.85 | 0.9891 | 76.9 | 0.9853 | 0.7650 | −148 |
| 0.90 | 0.9938 | 74.9 | 0.9928 | 0.7219 | −109 |
| 0.95 | 0.9973 | 73.1 | 0.9980 | 0.6735 | −60 |

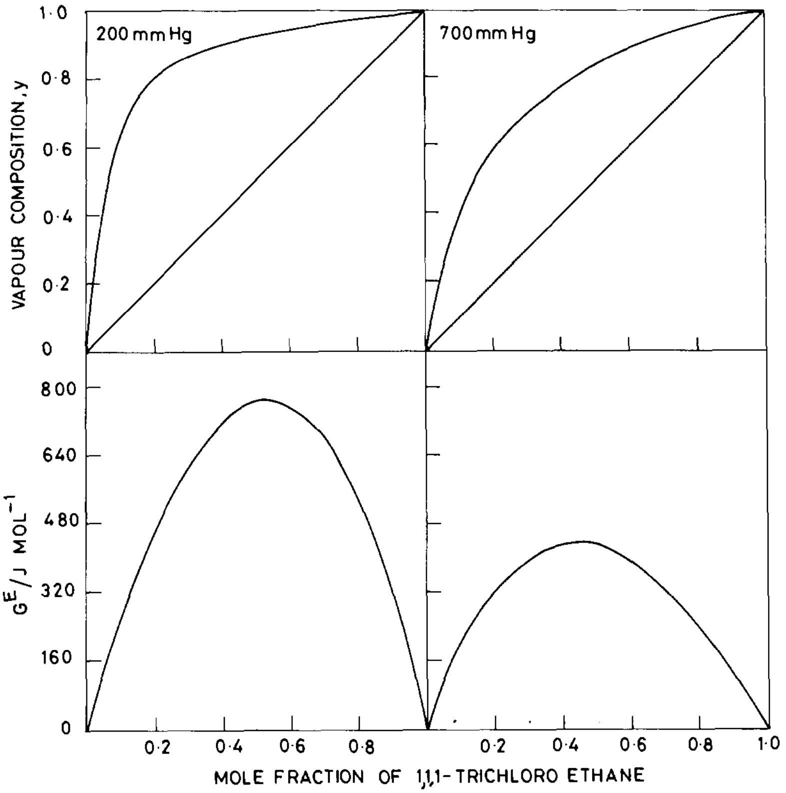

Fig. 1. Vapour compositions and excess Gibbs free energies for the system 1,1,1-trichloroethane(1)–1-butanol(2) at 200 and 700 mm Hg.

The vapour compositions, activity coefficients and excess Gibbs free energies are presented in Tables 7–10. The mole fraction vs. vapour composition and excess Gibbs free energies are represented in Figs. 1 and 2. The calculated $G^E$ values are positive over the entire range of composition, except in the system 1,1,1-trichloroethane(1)–1-pentanol(2) at 700 mm Hg. The $G^E$, values decrease from 1,1,1-trichloroethane(1)–1-butanol(2) to 1,1,1-trichloroethane(1)–1-pentanol(2) at 200 mm Hg.

The same trend has been observed at 700 mm Hg. The decrease in $G^E$, values from 1-butanol to 1-pentanol can be attributed to the interstitial accommodation of chloroalkane in the aggregates of alcohols and to weak hydrogen bond interactions of the type Cl $\cdots$ H–O between unlike molecules. From the plot of vapour composition ($y$) vs. mole fraction ($x$), it can be concluded that both systems are non-ideal.

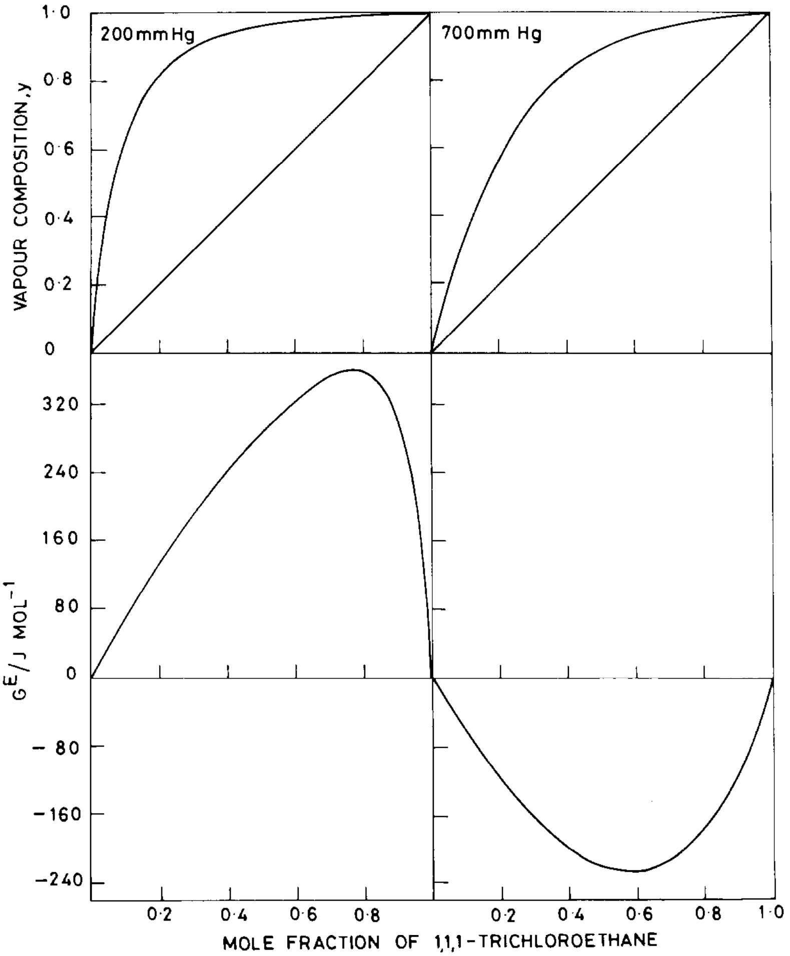

Fig. 2. Vapour compositions and excess Gibbs free energies for the system 1,1,1-trichloroethane(1)–1-pentanol(2) at 200 and 700 mm Hg.

## ACKNOWLEDGEMENTS

One of the authors (K.D.R.) is grateful to the Council of Scientific and Industrial Research for the award of a senior Research Fellowship, and to the Director and Head, Chemical Engineering Division, Regional Research Laboratory, Hyderabad, for providing the necessary facilities.

## REFERENCES

1 J.A. Reddick and W.B. Bunger, Organic Solvents, Wiley-Interscience, New York, 1970.
2 M.V.P. Rao and P.R. Naidu, Can. J. Chem., 52 (1974) 788.

3 J. Timmermans, Physico Chemical Constants of Pure Organic Compounds, Elsevier, Amsterdam, 1950.
4 J.A. Dean, Langes Handbook of Chemistry, 11th edn., McGraw-Hill, New York, 1973.
5 E. Hala, J. Pick, V. Fried and O. Vilim, Vapour–Liquid Equilibrium, Pergamon Press, Oxford, 1967.
6 G.M. Wilson, J. Am. Chem. Soc., 86 (1964) 127.