# Relative Permittivities, Speeds of Sound, Viscosities, and Densities of Cyclohexanone + *cis*-Decalin and Cyclohexanone + *trans*-Decalin Mixtures at 283.15, 293.15, and 303.15 K

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Relative permittivities, speeds of sound, viscosities, and densities for the binary mixtures of cyclohexanone + *cis*-decalin and cyclohexanone + *trans*-decalin have been measured over the whole composition range at (283.15, 293.15, and 303.15) K. The excess volumes and the deviations in viscosity, speed of sound, isentropic compressibility, and molar polarization were calculated. The results were fitted to a Redlich−Kister type polynomial equation, and the corresponding parameters have been derived. The Kirkwood correlation factor was also calculated.

## Introduction

Studies on excess functions of binary mixtures are of considerable importance in understanding the nature of molecular interactions. Continuing our work for the study of thermodynamic properties of binary organic solutions,[1,2] we report in this paper the relative permittivities, speeds of sound, viscosities, and densities for the binary mixtures of cyclohexanone + *cis*-decalin and cyclohexanone + *trans*-decalin at (283.15, 293.15, and 303.15) K. From these results the excess volumes and the deviations in viscosity, speed of sound, isentropic compressibility, and molar polarization have been derived. The Kirkwood correlation factor was also calculated using relative permittivity data. All materials used in this work are of industrial interest.

Cyclohexanone is a polar cyclic ketone having relative permittivity $\epsilon = 16.3$ (293.15 K) and dipole moment $\mu = 3.01$ D, and it is used as a solvent for vinyl resins, crude rubber, waxes, fats, and shellac. It also is used for the production of adipic acid and resins. *cis*-Decalin and *trans*-decalin are diastereomer cycloalkanes with zero dipole moment and almost identical relative permittivities, $\epsilon_{cis} = 2.5$ and $\epsilon_{trans} = 2.4$ (293.15 K). Decalin is used as a solvent for naphthalene, fats, resins, oils, and waxes and is often a replacement for turpentine in lacquers, shoe polishes, and floor waxes and also for motor fuel and lubricants. The aim of this work is to test whether the presence of polar molecules of cyclohexanone induces dipoles in the decalin molecules.

Thermodynamic properties of cyclohexanone with alkanes[3] and aromatic hydrocarbons[4] have been reported in the literature. A survey in the literature showed that mixtures of cyclohexanone + *cis*-decalin and cyclohexanone + *trans*-decalin have not been studied.

## Experimental Section

***Materials.*** Cyclohexanone (Riedel-de Häen, >99.8%), *cis*-decalin (Merck, >98.0%), and *trans*-decalin (Merck, >98.0%) were used without purification. The purity of the liquids was assessed by comparing the experimental densities and refractive indices with the literature values (Table 1).

**Table 1. Comparison of Experimental Densities ($\rho$) and Refractive Indices ($n_D$) of the Pure Liquids with Literature Values at 293.15 K**

| liquid | $\rho_{(exp)}$/g·cm$^{-3}$ | $\rho_{(ref)}$/g·cm$^{-3}$ | $n_{D(exp)}$ | $n_{D(ref)}$ |
|---|---|---|---|---|
| cyclohexanone | 0.940 20[a] | 0.937 4[a−c] | 1.446 1[a] | 1.446 3[a−c] |
| *cis*-decalin | 0.896 71 | 0.896 60[d] | 1.481 3 | 1.481 1[d] |
| | | 0.896 71[e] | | 1.480 98[e] |
| *trans*-decalin | 0.870 01 | 0.869 00[d] | 1.469 5 | 1.469 3[d] |
| | | 0.869 71[e] | | 1.469 32[e] |

[a] Values at 303.15 K. [b] Aralaguppi et al., 1999 (ref 3). [c] Aralaguppi et al., 1999 (ref 4). [d] Korosi and Kovats, 1981 (ref 5). [e] Camin and Rossini, 1955 (ref 6).

The binary mixtures were prepared by mass using an electronic balance (Mettler A210P, ±0.01 mg). The mole fractions were known from ±0.0001 to ±0.0005 in all cases.

***Measurements.*** Densities were measured with an Anton Paar (DMA 58) microcomputer controlled precision densimeter with a built-in solid state thermostat. The estimated uncertainty of the measured densities was ±0.000 01 g·cm$^{-3}$. The DMA cell was calibrated with dry air and doubly distilled water at atmospheric pressure. The sample thermostat was controlled to ±0.01 K.

Flow times of the solvent mixtures were measured with a viscosity measuring unit (Schott Geräte AVS 310), equipped with an Übbelohde capillary viscometer. The time measurement tolerance was ±0.005%, and the display accuracy was ±0.01 s. The temperature was maintained constant within ±0.03 K. The viscosities were averaged from four readings. The uncertainty in the viscosity values was ±0.001 mPa·s.

Relative permittivities were measured by a Hewlett-Packard impedance analyzer (HP 4291A RF). The frequency range was 1 MHz to 1.8 GHz, and the precision in the relative permittivity values was 1%. The calibration

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10.1021/je020084m CCC: $22.00 
Published on Web 10/10/2002

**Table 2. Experimental Densities ($\rho$), Viscosities ($\eta$), Speeds of Sound ($u$), Isentropic Compressibilities ($k_s$), Relative Permittivities ($\epsilon$), and Kirkwood Correlation Factors ($g$) of Cyclohexanone (1) + Decalin (2) Mixtures at 283.15, 293.15, and 303.15 K**

| $x_1$ | $\rho$/g·cm$^{-3}$ | $\eta$/mPa·s | $u$/m·s$^{-1}$ | $k_s$/TPa$^{-1}$ | $\epsilon$ | $g$ | $x_1$ | $\rho$/g·cm$^{-3}$ | $\eta$/mPa·s | $u$/m·s$^{-1}$ | $k_s$/TPa$^{-1}$ | $\epsilon$ | $g$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cyclohexanone (1) + *cis*-Decalin (2) | | | | | | | Cyclohexanone (1) + *trans*-Decalin (2) | | | | | | |
| 283.15 K | | | | | | | 283.15 K | | | | | | |
| 0.0000 | 0.904 40 | 4.092 | 1499.4 | 492 | 2.4 | | 0.0000 | 0.877 39 | 2.578 | 1439.0 | 550 | 2.4 | |
| 0.0500 | 0.905 89 | 3.971 | 1495.6 | 494 | 2.6 | 0.520 | 0.0500 | 0.879 76 | 2.562 | 1438.0 | 550 | 2.6 | 0.534 |
| 0.1446 | 0.908 46 | 3.788 | 1488.6 | 497 | 3.4 | 0.803 | 0.1500 | 0.884 46 | 2.540 | 1435.3 | 549 | 3.3 | 0.721 |
| 0.2281 | 0.911 34 | 3.643 | 1483.7 | 498 | 4.0 | 0.767 | 0.2415 | 0.889 59 | 2.534 | 1435.0 | 546 | 4.1 | 0.780 |
| 0.3500 | 0.916 18 | 3.458 | 1477.1 | 500 | 5.1 | 0.774 | 0.3447 | 0.896 02 | 2.543 | 1435.3 | 542 | 5.1 | 0.803 |
| 0.4482 | 0.920 81 | 3.332 | 1473.7 | 500 | 6.3 | 0.814 | 0.4511 | 0.903 37 | 2.570 | 1436.7 | 536 | 6.0 | 0.767 |
| 0.5559 | 0.926 34 | 3.218 | 1470.5 | 499 | 8.3 | 0.919 | 0.5088 | 0.907 71 | 2.592 | 1438.1 | 533 | 6.7 | 0.781 |
| 0.6271 | 0.930 42 | 3.156 | 1469.0 | 498 | 9.5 | 0.939 | 0.6731 | 0.921 80 | 2.686 | 1444.7 | 520 | 8.8 | 0.790 |
| 0.7252 | 0.936 61 | 3.089 | 1468.1 | 495 | 11.0 | 0.932 | 0.6779 | 0.922 25 | 2.689 | 1444.9 | 519 | 9.3 | 0.843 |
| 0.8051 | 0.942 12 | 3.050 | 1468.3 | 492 | 12.3 | 0.925 | 0.7761 | 0.932 00 | 2.769 | 1452.1 | 509 | 10.8 | 0.842 |
| 0.8571 | 0.946 02 | 3.033 | 1469.0 | 490 | 13.5 | 0.944 | 0.8609 | 0.941 14 | 2.852 | 1458.7 | 499 | 12.6 | 0.873 |
| 0.9322 | 0.952 11 | 3.019 | 1470.7 | 486 | 15.0 | 0.945 | 0.9315 | 0.949 50 | 2.932 | 1466.3 | 490 | 13.5 | 0.843 |
| 1.0000 | 0.957 99 | 3.018 | 1473.1 | 481 | 16.5 | | 1.0000 | 0.957 99 | 3.018 | 1473.3 | 481 | 16.5 | |
| 293.15 K | | | | | | | 293.15 K | | | | | | |
| 0.0000 | 0.896 71 | 3.361 | 1456.1 | 526 | 2.5 | | 0.0000 | 0.870 01 | 2.118 | 1397.1 | 589 | 2.4 | |
| 0.0500 | 0.898 08 | 3.262 | 1452.3 | 528 | 2.7 | 0.544 | 0.0500 | 0.872 29 | 2.114 | 1396.1 | 588 | 2.6 | 0.561 |
| 0.1446 | 0.900 51 | 3.118 | 1445.3 | 532 | 3.4 | 0.763 | 0.1500 | 0.876 76 | 2.103 | 1393.3 | 588 | 3.2 | 0.681 |
| 0.2281 | 0.903 33 | 3.006 | 1440.4 | 534 | 4.0 | 0.759 | 0.2415 | 0.881 85 | 2.105 | 1392.8 | 585 | 4.0 | 0.777 |
| 0.3500 | 0.907 98 | 2.863 | 1433.8 | 536 | 5.0 | 0.761 | 0.3447 | 0.888 12 | 2.119 | 1393.0 | 580 | 4.9 | 0.789 |
| 0.4482 | 0.912 49 | 2.767 | 1430.6 | 536 | 6.2 | 0.820 | 0.4511 | 0.895 32 | 2.147 | 1394.4 | 574 | 5.9 | 0.787 |
| 0.5559 | 0.917 90 | 2.680 | 1427.3 | 535 | 8.1 | 0.926 | 0.5088 | 0.899 60 | 2.168 | 1395.7 | 571 | 6.5 | 0.787 |
| 0.6271 | 0.921 90 | 2.634 | 1425.9 | 534 | 9.3 | 0.955 | 0.6731 | 0.913 42 | 2.253 | 1402.0 | 557 | 8.5 | 0.797 |
| 0.7252 | 0.927 92 | 2.586 | 1424.9 | 531 | 10.5 | 0.923 | 0.6779 | 0.913 78 | 2.256 | 1402.5 | 556 | 9.1 | 0.864 |
| 0.8051 | 0.933 33 | 2.560 | 1425.2 | 528 | 12.2 | 0.961 | 0.7761 | 0.923 40 | 2.326 | 1408.4 | 546 | 10.5 | 0.858 |
| 0.8571 | 0.937 20 | 2.549 | 1425.9 | 525 | 13.3 | 0.975 | 0.8609 | 0.932 39 | 2.397 | 1415.6 | 535 | 12.1 | 0.878 |
| 0.9322 | 0.943 12 | 2.543 | 1427.7 | 520 | 14.8 | 0.979 | 0.9315 | 0.940 61 | 2.466 | 1422.7 | 525 | 13.0 | 0.851 |
| 1.0000 | 0.949 11 | 2.546 | 1430.2 | 515 | 16.3 | | 1.0000 | 0.949 11 | 2.546 | 1430.6 | 515 | 16.3 | |
| 303.15 K | | | | | | | 303.15 K | | | | | | |
| 0.0000 | 0.889 11 | 2.641 | 1412.8 | 563 | 2.5 | | 0.0000 | 0.862 51 | 1.767 | 1356.6 | 630 | 2.4 | |
| 0.0500 | 0.890 32 | 2.558 | 1409.1 | 566 | 2.7 | 0.572 | 0.0500 | 0.864 63 | 1.758 | 1355.3 | 630 | 2.6 | 0.590 |
| 0.1446 | 0.892 69 | 2.471 | 1402.1 | 570 | 3.4 | 0.801 | 0.1500 | 0.868 96 | 1.744 | 1352.5 | 629 | 3.2 | 0.716 |
| 0.2281 | 0.895 41 | 2.399 | 1397.2 | 572 | 3.9 | 0.751 | 0.2415 | 0.873 92 | 1.737 | 1351.8 | 626 | 3.9 | 0.771 |
| 0.3500 | 0.899 88 | 2.302 | 1390.5 | 575 | 4.9 | 0.772 | 0.3447 | 0.880 13 | 1.737 | 1351.9 | 622 | 4.8 | 0.800 |
| 0.4482 | 0.904 31 | 2.231 | 1387.4 | 574 | 6.1 | 0.841 | 0.4511 | 0.887 21 | 1.744 | 1353.2 | 616 | 5.8 | 0.806 |
| 0.5559 | 0.909 59 | 2.159 | 1384.2 | 574 | 7.9 | 0.943 | 0.5088 | 0.891 42 | 1.750 | 1354.5 | 611 | 6.4 | 0.810 |
| 0.6271 | 0.913 50 | 2.115 | 1382.8 | 573 | 9.0 | 0.964 | 0.6731 | 0.904 90 | 1.784 | 1360.4 | 597 | 8.3 | 0.814 |
| 0.7252 | 0.919 41 | 2.060 | 1381.9 | 570 | 10.4 | 0.961 | 0.6779 | 0.905 33 | 1.785 | 1360.7 | 597 | 8.9 | 0.885 |
| 0.8051 | 0.924 70 | 2.019 | 1382.0 | 566 | 12.0 | 0.993 | 0.7761 | 0.914 70 | 1.815 | 1366.7 | 585 | 10.2 | 0.873 |
| 0.8571 | 0.928 50 | 1.995 | 1383.8 | 562 | 13.0 | 1.000 | 0.8609 | 0.923 59 | 1.848 | 1373.4 | 574 | 11.6 | 0.881 |
| 0.9322 | 0.934 26 | 1.964 | 1385.6 | 557 | 14.4 | 1.000 | 0.9315 | 0.931 71 | 1.880 | 1380.3 | 563 | 12.7 | 0.873 |
| 1.0000 | 0.940 20 | 1.915 | 1388.1 | 552 | 16.0 | | 1.0000 | 0.940 20 | 1.915 | 1388.3 | 552 | 16.0 | |

was carried out by capacitors of standard values (0 S, 0 Ω, and 50 Ω) supplied by the manufacturer.

Experimental details of measurements of density, viscosity, and relative permittivity are the same as those described previously.[1,2,7]

The speeds of sound were measured with an Anton Paar (DSA 48) sound analyzer. The temperature was maintained constant within ±0.01 K. The sound analyzer was calibrated with distilled water and air at the experimental temperatures. The uncertainty of the measured speeds of sound was ±1 m·s$^{-1}$. The isentropic compressibility ($k_s$) was calculated from density ($\rho$) and speed of sound ($u$) data, as $k_s = 1/(u^2\rho)$.

## Results and Discussion

The values of density ($\rho$), viscosity ($\eta$), speed of sound ($u$), isentropic compressibility ($k_s$), and relative permittivity ($\epsilon$) are given in Table 2. The calculations of excess molar volumes ($V^E$) and the deviations in viscosity ($\Delta\eta$), speeds of sound ($\Delta u$), isentropic compressibilities ($\Delta k_s$), and molar polarizations ($\Delta P$) were carried out from the general equation

$$\Delta Y = Y_m - \sum c_i Y_i \qquad (1)$$

where $\Delta Y$ refers to $V^E$/cm$^3$·mol$^{-1}$, $\Delta\eta$/mPa·s, $\Delta k_s$/TPa$^{-1}$, $\Delta u$/m·s$^{-1}$, and $\Delta P$/cm$^3$·mol$^{-1}$; $Y_m$ and $Y_i$ refer to the mixture property and to the respective property of the $i$th pure component; and the term $c_i$ is the mixture composition expressed in mole fraction ($x_i$) for the calculation of $V^E$, $\Delta\eta$, $\Delta u$, and $\Delta P$ and in volume fraction ($\varphi_i$) for the calculation of $\Delta k_s$.

The molar polarizations of the mixture ($P_m$) and of the $i$th pure component ($P_i$) were calculated using the Clausius−Mossotti equation:[8]

$$P_m = \frac{(\epsilon - 1)}{(\epsilon + 2)} \frac{\sum x_i M_i}{\rho} \qquad (2)$$

$$P_i = \frac{(\epsilon_i - 1)}{(\epsilon_i + 2)} \frac{M_i}{\rho_i} \qquad (3)$$

where $M_i$ is the molar mass of the $i$th pure component.

The values of $V^E$, $\Delta\eta$, $\Delta u$, $\Delta P$, and $\Delta k_s$ were fitted to the Redlich−Kister[9] equation:

$$\Delta Y = c_1 c_2 \sum_{k=0}^{n} A_k (2c_1 - 1)^k \qquad (4)$$

where $A_k$ represent the parameters.

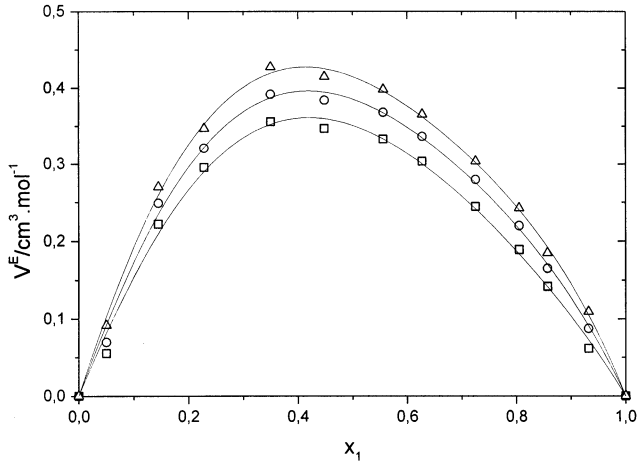


**Figure 1.** Excess molar volume ($V^E$) versus the mole fraction ($x_1$) for cyclohexanone (1) + *cis*-decalin (2) mixtures at the following temperatures: □, 283.15 K; ○, 293.15 K; △, 303.15 K.

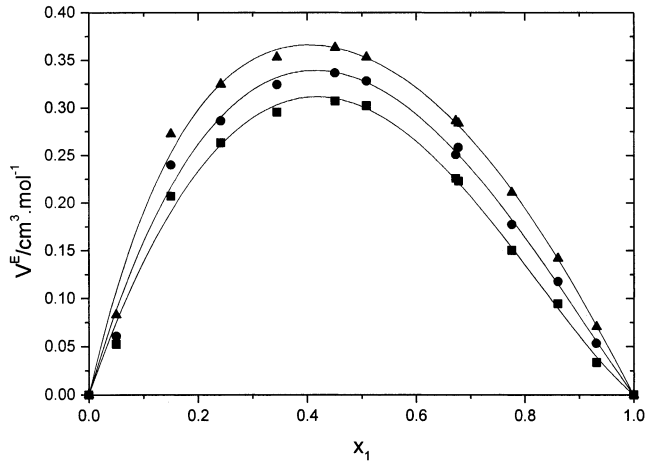


**Figure 2.** Excess molar volume ($V^E$) versus the mole fraction ($x_1$) for cyclohexanone (1) + *trans*-decalin (2) mixtures at the following temperatures: ■, 283.15 K; ●, 293.15 K; ▲, 303.15 K.

**Table 3. Parameters of the Redlich−Kister Equation and Standard Deviations ($d$) of Excess Functions of Cyclohexanone + *cis*-Decalin and Cyclohexanone + *trans*-Decalin Mixtures at 283.15, 293.15, and 303.15 K**

| function | $A_0$ | $A_1$ | $A_2$ | $A_3$ | $d$ |
|---|---|---|---|---|---|
| Cyclohexanone + *cis*-Decalin | | | | | |
| 283.15 K | | | | | |
| $V^E$/cm$^3$·mol$^{-1}$ | 1.4035 | −0.4908 | 0.0442 | 0.2209 | 0.0133 |
| $\Delta\eta$/mPa·s | −1.1192 | −0.0071 | −0.1116 | 0.1510 | 0.0026 |
| $\Delta u$/m·s$^{-1}$ | −57.488 | −4.849 | −4.672 | −2.551 | 0.1721 |
| $\Delta k_s$/TPa$^{-1}$ | 48.520 | −14.188 | 5.753 | −2.887 | 0.1506 |
| $\Delta P$/cm$^3$·mol$^{-1}$ | 75.911 | −1.683 | −10.171 | −13.168 | 1.0301 |
| 293.15 K | | | | | |
| $V^E$/cm$^3$·mol$^{-1}$ | 1.5420 | −0.5036 | 0.1987 | 0.2916 | 0.0115 |
| $\Delta\eta$/mPa·s | −0.9191 | −0.0045 | −0.1107 | 0.1459 | 0.0026 |
| $\Delta u$/m·s$^{-1}$ | −58.028 | −5.043 | −6.098 | −3.769 | 0.1902 |
| $\Delta k_s$/TPa$^{-1}$ | 54.296 | −15.125 | 7.845 | −2.750 | 0.1766 |
| $\Delta P$/cm$^3$·mol$^{-1}$ | 69.122 | 3.533 | −11.728 | −12.194 | 0.8885 |
| 303.15 K | | | | | |
| $V^E$/cm$^3$·mol$^{-1}$ | 1.6605 | −0.5435 | 0.3393 | 0.3399 | 0.0089 |
| $\Delta\eta$/mPa·s | −0.3275 | 0.0427 | −0.0900 | 0.4702 | 0.0051 |
| $\Delta u$/m·s$^{-1}$ | −60.153 | −8.158 | −4.170 | 1.110 | 0.3711 |
| $\Delta k_s$/TPa$^{-1}$ | 61.945 | −14.853 | 6.028 | −7.724 | 0.3122 |
| $\Delta P$/cm$^3$·mol$^{-1}$ | 67.002 | 8.262 | −10.177 | −20.065 | 0.8435 |
| Cyclohexanone + *trans*-Decalin | | | | | |
| 283.15 K | | | | | |
| $V^E$/cm$^3$·mol$^{-1}$ | 1.2063 | −0.4771 | −0.1508 | −0.0930 | 0.0115 |
| $\Delta\eta$/mPa·s | −0.8391 | −0,0468 | −0.0097 | 0.0058 | 0.0004 |
| $\Delta u$/m·s$^{-1}$ | −73.648 | −16.063 | 1.826 | 14.747 | 0.3318 |
| $\Delta k_s$/TPa$^{-1}$ | 39.397 | −16.295 | −0.733 | −9.492 | 0.2597 |
| $\Delta P$/cm$^3$·mol$^{-1}$ | 69.755 | −24.954 | −11.975 | 22.705 | 0.9728 |
| 293.15 K | | | | | |
| $V^E$/cm$^3$·mol$^{-1}$ | 1.3159 | −0.4716 | 0.0419 | −0.1024 | 0.0144 |
| $\Delta\eta$/mPa·s | −0.6699 | −0.0508 | −0.0125 | −0.0951 | 0.0011 |
| $\Delta u$/m·s$^{-1}$ | −73.692 | −15.883 | −6.018 | 3.011 | 0.2481 |
| $\Delta k_s$/TPa$^{-1}$ | 44.922 | −15.132 | 5.112 | −7.954 | 0.2378 |
| $\Delta P$/cm$^3$·mol$^{-1}$ | 66.942 | −18.880 | −19.672 | 15.891 | 0.9482 |
| 303.15 K | | | | | |
| $V^E$/cm$^3$·mol$^{-1}$ | 1.4185 | −0.4563 | 0.3376 | −0.2293 | 0.0126 |
| $\Delta\eta$/mPa·s | −0.3669 | −0.0252 | −0.0012 | 0.0016 | 0.0003 |
| $\Delta u$/m·s$^{-1}$ | −72.862 | −15.048 | −8.875 | 2.215 | 0.1941 |
| $\Delta k_s$/TPa$^{-1}$ | 50.257 | −15.699 | 9.245 | −11.144 | 0.2187 |
| $\Delta P$/cm$^3$·mol$^{-1}$ | 65.150 | −14.827 | −21.701 | 5.364 | 0.8081 |

A nonlinear least-squares method was used to estimate the parameters $A_k$. The optimum number of the parameters was obtained through examination of the standard deviation ($d$). The values of $A_k$ and $d$ are presented in Table 3.

The $V^E$ values are positive (Figures 1 and 2), the $\Delta\eta$ values are negative (Figures 3 and 4), and both increase with increasing temperature. The positive $V^E$ values indicate that the interactions between like molecules are stronger than the interactions between unlike molecules. The fact that the $\Delta\eta$ values are negative shows that dispersion forces are dominating.

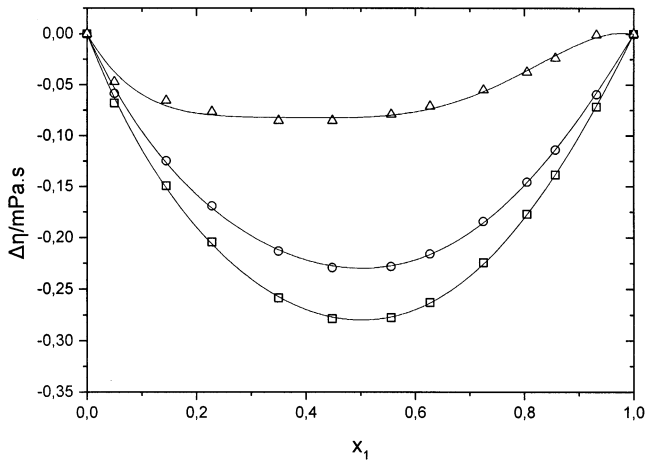


**Figure 3.** Deviations in viscosity ($\Delta\eta$) versus the mole fraction ($x_1$) for cyclohexanone (1) + *cis*-decalin (2) mixtures at the following temperatures: □, 283.15 K; ○, 293.15 K; △, 303.15 K.

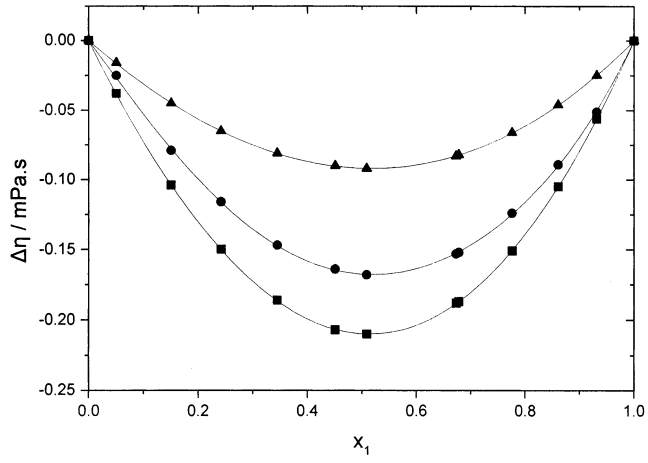


**Figure 4.** Deviations in viscosity ($\Delta\eta$) versus the mole fraction ($x_1$) for cyclohexanone (1) + *trans*-decalin (2) mixtures at the following temperatures: ■, 283.15 K; ●, 293.15 K; ▲, 303.15 K.

The $\Delta k_s$ values, presented in Figure 5, are positive and increase with increasing temperature, indicating that the elasticity of the solution is diminished.

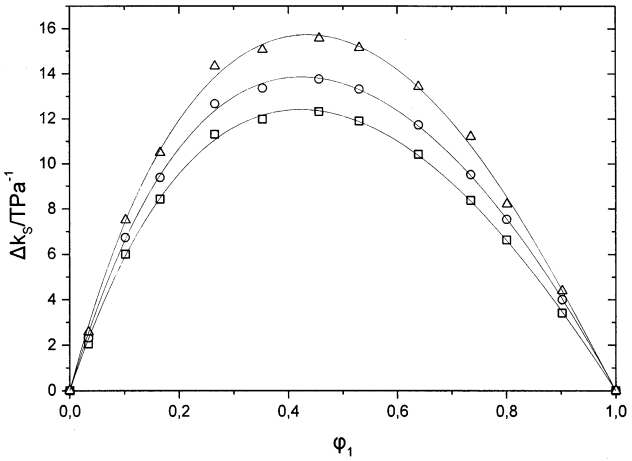


**Figure 5.** Deviations in isentropic compressibility ($\Delta k_s$) versus the volume fraction ($\varphi_1$) for cyclohexanone (1) + *cis*-decalin (2) mixtures at the following temperatures: □, 283.15 K; ○, 293.15 K; △, 303.15 K.

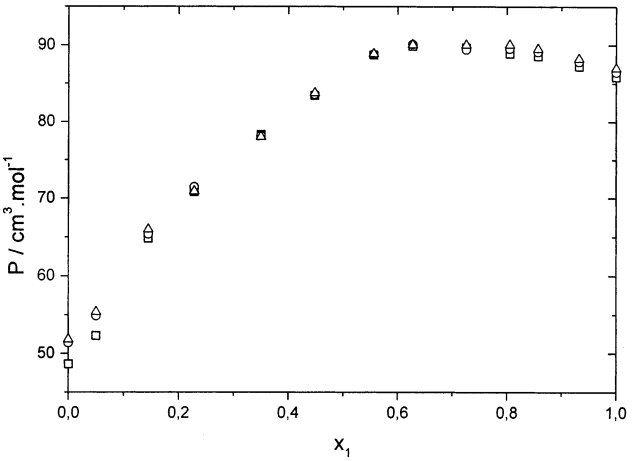


**Figure 6.** Molar polarization ($P$) versus the mole fraction ($x_1$) for cyclohexanone (1) + *cis*-decalin (2) mixtures at the following temperatures: □, 283.15 K; ○, 293.15 K; △, 303.15 K.

The $\Delta P$ values are positive and are approximately independent of temperature. The molecular polarization values $P$ increase with the cyclohexanone concentration, as is expected (Figure 6).Figures 5 and 6 refer to cyclohexanone + *cis*-decalin mixtures. The corresponding figures for *trans*-decalin mixtures are not displayed, as they are very similar. It is observed that the values af all properties are lower for mixtures containing *trans*-decalin.This fact can be attributed to the different geometries of the *trans*- and *cis*-decalin molecules.

The relative permittivity results were used for the calculation of the Kirkwood[10] correlation factor ($g$) according to the equation

$$g = \frac{9k_BT}{4\pi N\mu^2 x_1}\frac{(2\epsilon+\epsilon_\infty)^2}{(\epsilon_\infty+2)^2(2\epsilon+1)}\left[V\frac{(\epsilon-1)}{\epsilon} - \frac{3x_2V_2(\epsilon_2-1)}{(2\epsilon+\epsilon_2)} - \frac{3x_1V_1(\epsilon_\infty-1)}{(2\epsilon+\epsilon_\infty)}\right] \quad (5)$$

where $\mu$ is the dipole moment of cyclohexanone; $V$, $V_1$, and $V_2$ are the molar volumes of the mixture, cyclohexanone, and decalin, respectively; $\epsilon$ and $\epsilon_2$ are the relative permittivities of the mixture and decalin, respectively; $\epsilon_\infty$ is taken as the square of the refractive index of cyclohexanone; $k_B$ is the Boltzmann constant; $N$ is Avogadro's number; and $T$ is the temperature.

The Kirkwood parameter $g$ is a measure of short-range orientational correlations and is expresed as the ratio $\mu^*/\mu$, where $\mu^*$ is the dipole moment of a sphere where the central molecule has a steady orientation while the other molecules are oriented in the sphere by structural factors, and $\mu$ is the dipole moment of the polar molecule in the liquid. The departure of $g$ from unity is a measure of the degree of hindered molecular orientation. Positive deviations from unity indicate parallel alignment of the dipoles of the neighboring molecules, and negative deviations, that antiparallel orientation is favored.[11,12]

In this work is observed a monotonic increase of the correlation factors with the increase of cyclohexanone molar fraction. The values tend to unity for pure cyclohexanone (Table 2), indicating that the decalin molecules exhibit a structure breaking behavior to the cyclohexanone multimers.

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Received for review May 8, 2002. Accepted August 23, 2002. This work was financially supported by the Special Research Account of the National and Kapodistrian University of Athens.

JE020084M