Density, Refractive Index, Viscosity, and Speed of Sound in Binary Mixtures of Cyclohexanone with Hexane, Heptane, Octane, Nonane, Decane, Dodecane, and 2,2,4-Trimethylpentane

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Experimental results of density, refractive index, and viscosity at 298.15, 303.15, and 308.15 K and the speed of sound at 298.15 K are presented for the binary mixtures of cyclohexanone with *n*-alkanes (C_6−C_{12}) or 2,2,4-trimethylpentane over the entire range of mixture composition scale. From these data, excess molar volume V^E, deviations in molar refraction ΔR, viscosity $\Delta\eta$, speed of sound Δu, and isentropic compressibility Δk_S have been calculated. These results are further fit to the Redlich and Kister (1948) polynomial equation to derive the binary coefficients and standard deviations between the calculated and the fit parameters. Furthermore, these results are used to study the nature of intermolecular interactions between the mixing components. All the properties have shown a systematic dependence on the chain length of alkanes.

Introduction

Cyclohexanone is a cyclic ketone used in organic syntheses and finds many industrial applications. Thermodynamic, optical, hydrodynamic, and ultrasonic properties of cyclohexanone with alkanes are important in the fundamental understanding of the mixing processes. Such a study would have an impact in chemical engineering areas especially to understand the mixing behavior of cyclohexanone in alkanes. However, alkanes also find good applications in chemical engineering areas. This prompted us to measure the physical property data such as density ρ, refractive index n_D for the sodium D-line, viscosity η, and speed of sound u in the binary mixtures of cyclohexanone with hexane, heptane, octane, nonane, decane, dodecane, and 2,2,4-trimethylpentane (TMP) over the entire composition scale of the mixtures. This study, therefore, represents an ongoing program of our research activity (Aralaguppi et al., 1991, 1996, 1996a). The results of ρ, n_D, and η have been measured at 298.15, 303.15, and 308.15 K, while those of u are measured only at 298.15 K. Experimental results have been used to calculate the excess molar volume V^E, deviations in molar refraction ΔR, speed of sound Δu, and isentropic compressibility Δk_S. Furthermore, the calculated results have been fit to the Redlich and Kister (1948) equation to derive the binary coefficients and standard deviations between the calculated and the fit quantities. Results of this study have been used to interpret the nature of mixing processes and the type of interactions occurring between cyclohexanone and alkanes.

Experimental Section

Materials. High-purity spectroscopic and AR grade samples of cyclohexanone, hexane, heptane, octane, nonane, decane, dodecane, and 2,2,4-trimethylpentane were purchased from s.d. fine Chemicals Ltd., Mumbai, India. Their GLC analyses indicated a mol % purity of 99.6, 99.8, 99.5, 99.6, 99.8, 99.4, 99.6, and 99.5 respectively. All the samples were used without further purification. Experimental results of density and refractive index of the pure liquids at 298.15 K are compared in Table 1 with the published data.

Table 1. Comparison of Data for Liquids at 298.15 K with Literature

	ρ/(g cm^{-3})		n_D	
liquids	expt	lit	expt	lit
cyclohexanone	0.9412	0.9418[a]	1.4485	1.4480[a]
hexane	0.6548	0.6549[a]	1.3736	1.3723[a]
heptane	0.6796	0.6795[a]	1.3861	1.3851[a]
octane	0.6984	0.6985[a]	1.3960	1.3951[a]
nonane	0.7149	0.7140[a]	1.4035	1.4031[a]
decane	0.7262	0.7264[a]	1.4091	1.4097[a]
dodecane	0.7464	0.7461[b]	1.4209	1.4197[b]
TMP	0.6879	0.6878[c]	1.3898	1.3892[c]

[a] Marsh, K. N. (1994). [b] Aminabhavi and Bindu (1995). [c] Aralaguppi et al. (1991).

Measurements. Experimental details about the preparation of binary mixtures, measurements of mass, density, refractive index, speed of sound, and viscosity of pure liquids and binary mixtures are the same as described previously (Aralaguppi et al., 1991). The binary mixtures were prepared by mass by mixing the calculated volumes of liquid components in airtight glass bottles. The mass measurements (±0.01 mg) were made using an electronic balance (Mettler AE 240, Switzerland). A set of nine compositions were prepared for each system, and their physical properties were measured the same day. The reproducibility in mole fraction was within ±0.0001 units. Densities of pure liquids and their mixtures were measured using a double-arm pycnometer having a bulb volume of 15 cm^3 and a capillary bore with an internal diameter of 1 mm. Doubly distilled, deionized, and degassed water with a specific conductance of 1×10^{-4} Ω^{-1} cm^{-1} was used for calibration. For all the mixtures and pure solvents, triplicate measurements were performed and the average of these values was considered in all calculations. Density values are accurate to ±0.0002 g cm^{-3}.

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10.1021/je9802266 CCC: $18.00
Published on Web 03/12/1999

Table 2. Experimental Densities (ρ), Refractive Indices (n_D), Viscosity (η), and Speed of Sound (u) of the Binary Mixtures at Different Temperatures

x_1	ρ / (g cm^{-3})	n_D	η/ (mPa s)	u/ (m s^{-1})	x_1	ρ / (g cm^{-3})	n_D	η/ (mPa s)	u/ (m s^{-1})	x_1	ρ / (g cm^{-3})	n_D	η/ (mPa s)	u/ (m s^{-1})
Cyclohexanone (1) + Hexane (2)														
298.15 K														
0.0000	0.6548	1.3736	0.302	1076	0.4029	0.7568	1.3997	0.514	1180	0.8003	0.8760	1.4314	1.131	1325
0.1011	0.6786	1.3794	0.335	1096	0.5011	0.7847	1.4070	0.607	1212	0.8989	0.9087	1.4399	1.441	1367
0.2012	0.7036	1.3858	0.381	1120	0.6043	0.8149	1.4149	0.732	1248	1.0000	0.9420	1.4485	2.229	1412
0.3052	0.7304	1.3927	0.445	1150	0.7032	0.8450	1.4231	0.898	1286					
303.15 K														
0.0000	0.6501	1.3713	0.287		0.4029	0.7520	1.3979	0.483		0.8003	0.8715	1.4295	1.033	
0.1011	0.6737	1.3774	0.318		0.5011	0.7799	1.4051	0.570		0.8989	0.9040	1.4376	1.322	
0.2012	0.6989	1.3837	0.361		0.6043	0.8101	1.4130	0.684		1.0000	0.9374	1.4463	1.799	
0.3052	0.7259	1.3911	0.418		0.7032	0.8405	1.4218	0.834						
308.15 K														
0.0000	0.6454	1.3679	0.274		0.4029	0.7476	1.3951	0.458		0.8003	0.8669	1.4271	0.961	
0.1011	0.6693	1.3743	0.305		0.5011	0.7754	1.4027	0.537		0.8989	0.8996	1.4356	1.220	
0.2012	0.6942	1.3810	0.343		0.6043	0.8056	1.4109	0.641		1.0000	0.9328	1.4439	1.635	
0.3052	0.7214	1.3881	0.396		0.7032	0.8360	1.4189	0.779						
Cyclohexanone (1) + Heptane (2)														
298.15 K														
0.0000	0.6796	1.3861	0.392	1128	0.4016	0.7642	1.4051	0.606	1208	0.8009	0.8753	1.4322	1.178	1333
0.1046	0.6992	1.3903	0.427	1145	0.5025	0.7894	1.4112	0.690	1236	0.9009	0.9081	1.4400	1.474	1371
0.2024	0.7191	1.3951	0.472	1163	0.5993	0.8155	1.4175	0.805	1264	1.0000	0.9420	1.4485	2.229	1412
0.3035	0.7411	1.4000	0.529	1185	0.7026	0.8451	1.4249	0.960	1299					
303.15 K														
0.0000	0.6753	1.3836	0.372		0.4016	0.7598	1.4029	0.564		0.8009	0.8711	1.4295	1.085	
0.1046	0.6948	1.3877	0.403		0.5025	0.7850	1.4089	0.644		0.9009	0.9042	1.4378	1.349	
0.2024	0.7147	1.3925	0.445		0.5993	0.8109	1.4151	0.750		1.0000	0.9374	1.4463	1.799	
0.3035	0.7367	1.3976	0.497		0.7026	0.8404	1.4223	0.893						
308.15 K														
0.0000	0.6709	1.3802	0.354		0.4016	0.7554	1.4008	0.530		0.8009	0.8662	1.4274	1.004	
0.1046	0.6905	1.3855	0.384		0.5025	0.7808	1.4066	0.605		0.9009	0.8991	1.4355	1.235	
0.2024	0.7103	1.3899	0.421		0.5993	0.8066	1.4125	0.701		1.0000	0.9328	1.4439	1.635	
0.3035	0.7324	1.3954	0.470		0.7026	0.8362	1.4199	0.828						
Cyclohexanone (1) + Octane (2)														
298.15 K														
0.0000	0.6984	1.3960	0.508	1180	0.4042	0.7711	1.4105	0.706	1230	0.8021	0.8735	1.4332	1.264	1336
0.0981	0.7137	1.3986	0.537	1190	0.5032	0.7932	1.4150	0.787	1250	0.8984	0.9050	1.4395	1.508	1370
0.2053	0.7321	1.4020	0.583	1200	0.6030	0.8174	1.4206	0.895	1276	1.0000	0.9420	1.4485	2.229	1412
0.3022	0.7503	1.4060	0.635	1214	0.7025	0.8441	1.4261	1.039	1305					
303.15 K														
0.0000	0.6942	1.3935	0.479		0.4042	0.7667	1.4075	0.658		0.8021	0.8690	1.4307	1.165	
0.0981	0.7095	1.3960	0.505		0.5032	0.7887	1.4125	0.733		0.8984	0.9005	1.4370	1.380	
0.2053	0.7279	1.3994	0.547		0.6030	0.8130	1.4185	0.831		1.0000	0.9374	1.4463	1.799	
0.3022	0.7458	1.4034	0.595		0.7025	0.8395	1.4240	0.960						
308.15 K														
0.0000	0.6901	1.3910	0.453		0.4042	0.7624	1.4060	0.618		0.8021	0.8645	1.4285	1.054	
0.0981	0.7053	1.3928	0.479		0.5032	0.7844	1.4103	0.686		0.8984	0.8959	1.4357	1.271	
0.2053	0.7237	1.3968	0.516		0.6030	0.8086	1.4158	0.774		1.0000	0.9328	1.4439	1.635	
0.3022	0.7417	1.4013	0.559		0.7025	0.8351	1.4218	0.894						
Cyclohexanone (1) + Nonane (2)														
298.15 K														
0.0000	0.7149	1.4035	0.661	1212	0.4032	0.7771	1.4190	0.833	1256	0.7981	0.8721	1.4355	1.321	1340
0.0999	0.7279	1.4054	0.683	1218	0.4987	0.7962	1.4178	0.909	1272	0.9006	0.9053	1.4393	1.544	1368
0.1981	0.7423	1.4085	0.726	1230	0.6007	0.8190	1.4240	1.022	1292	1.0000	0.9420	1.4485	2.229	1412
0.3012	0.7588	1.4115	0.772	1242	0.6942	0.8424	1.4277	1.134	1313					
303.15 K														
0.0000	0.7108	1.4004	0.618		0.4032	0.7727	1.4140	0.775		0.7981	0.8683	1.4334	1.210	
0.0999	0.7238	1.4024	0.639		0.4987	0.7919	1.4149	0.842		0.9006	0.9008	1.4370	1.410	
0.1981	0.7380	1.4064	0.675		0.6007	0.8145	1.4222	0.936		1.0000	0.9374	1.4463	1.799	
0.3012	0.7546	1.4086	0.718		0.6942	0.8387	1.4253	1.043						
308.15 K														
0.0000	0.7070	1.3988	0.581		0.4032	0.7687	1.4119	0.723		0.7981	0.8633	1.4305	1.116	
0.0999	0.7198	1.4006	0.600		0.4987	0.7876	1.4145	0.784		0.9006	0.8963	1.4349	1.294	
0.1981	0.7339	1.4052	0.632		0.6007	0.8103	1.4197	0.869		1.0000	0.9328	1.4439	1.635	
0.3012	0.7504	1.4067	0.672		0.6942	0.8337	1.4232	0.967						
Cyclohexanone (1) + Decane (2)														
298.15 K														
0.0000	0.7262	1.4021	0.848	1248	0.4017	0.7811	1.4211	0.991	1280	0.8000	0.8711	1.4366	1.439	1348
0.1023	0.7380	1.4135	0.870	1252	0.5042	0.7998	1.4241	1.063	1292	0.9018	0.9041	1.4432	1.625	1380
0.2073	0.7514	1.4163	0.902	1259	0.6034	0.8206	1.4276	1.143	1307	1.0000	0.9420	1.4485	2.229	1412
0.3011	0.7648	1.4180	0.937	1269	0.7030	0.8444	1.4314	1.256	1324					

Table 2. (Continued)

x_1	ρ / (g cm^{-3})	n_D	η/ (mPa s)	u/ (m s^{-1})	x_1	ρ / (g cm^{-3})	n_D	η/ (mPa s)	u/ (m s^{-1})	x_1	ρ / (g cm^{-3})	n_D	η/ (mPa s)	u/ (m s^{-1})
Cyclohexanone (1) + Decane (2) (Continued)														
303.15 K														
0.0000	0.7225	1.4094	0.793		0.4017	0.7769	1.4190	0.916		0.8000	0.8668	1.4344	1.316	
0.1023	0.7340	1.4112	0.806		0.5042	0.7956	1.4216	0.984		0.9018	0.8997	1.4407	1.480	
0.2073	0.7474	1.4139	0.836		0.6034	0.8163	1.4254	1.053		1.0000	0.9374	1.4463	1.799	
0.3011	0.7607	1.4152	0.868		0.7030	0.8400	1.4292	1.152						
308.15 K														
0.0000	0.7186	1.4079	0.740		0.4017	0.7729	1.4167	0.851		0.8000	0.8626	1.4326	1.212	
0.1023	0.7302	1.4090	0.752		0.5042	0.7915	1.4189	0.909		0.9018	0.8959	1.4384	1.357	
0.2073	0.7435	1.4117	0.779		0.6034	0.8121	1.4233	0.973		1.0000	0.9328	1.4439	1.635	
0.3011	0.7568	1.4135	0.812		0.7030	0.8357	1.4271	1.064						
Cyclohexanone (1) + Dodecane (2)														
298.15 K														
0.0000	0.7463	1.4209	1.357	1280	0.4052	0.7903	1.4256	1.393	1299	0.8014	0.8707	1.4371	1.614	1360
0.1085	0.7556	1.4222	1.348	1283	0.5049	0.8058	1.4278	1.420	1310	0.9008	0.9027	1.4419	1.750	1382
0.1979	0.7647	1.4229	1.352	1286	0.6012	0.8231	1.4302	1.474	1322	1.0000	0.9420	1.4485	2.229	1412
0.3049	0.7770	1.4244	1.368	1292	0.7012	0.8448	1.4328	1.533	1340					
303.15 K														
0.0000	0.7425	1.4187	1.243		0.4052	0.7863	1.4235	1.272		0.8014	0.8663	1.4350	1.469	
0.1085	0.7519	1.4197	1.237		0.5049	0.8017	1.4251	1.302		0.9008	0.8982	1.4396	1.623	
0.1979	0.7608	1.4205	1.238		0.6012	0.8190	1.4279	1.344		1.0000	0.9374	1.4463	1.799	
0.3049	0.7731	1.4224	1.252		0.7012	0.8404	1.4307	1.398						
308.15 K														
0.0000	0.7389	1.4163	1.142		0.4052	0.7824	1.4215	1.171		0.8014	0.8621	1.4328	1.349	
0.1085	0.7482	1.4174	1.135		0.5049	0.7976	1.4233	1.199		0.9008	0.8938	1.4374	1.483	
0.1979	0.7571	1.4183	1.139		0.6012	0.8149	1.4258	1.232		1.0000	0.9328	1.4439	1.635	
0.3049	0.7693	1.4199	1.151		0.7012	0.8363	1.4289	1.281						
Cyclohexanone (1) + TMP (2)														
298.15 K														
0.0000	0.6879	1.3898	0.492	1100	0.4044	0.7657	1.4085	0.717	1184	0.8014	0.8730	1.4342	1.309	1332
0.1030	0.7051	1.3942	0.514	1116	0.5041	0.7892	1.4141	0.808	1216	0.9008	0.9057	1.4415	1.580	1372
0.2023	0.7234	1.3979	0.563	1132	0.6035	0.8149	1.4200	0.932	1248	1.0000	0.9420	1.4485	2.229	1412
0.3000	0.7431	1.4031	0.626	1156	0.7029	0.8427	1.4263	1.104	1290					
303.15 K														
0.0000	0.6836	1.3877	0.466		0.4044	0.7612	1.4050	0.667		0.8014	0.8685	1.4318	1.199	
0.1030	0.7010	1.3916	0.485		0.5041	0.7846	1.4115	0.751		0.9008	0.9011	1.4386	1.440	
0.2023	0.7191	1.3959	0.530		0.6035	0.8105	1.4173	0.865		1.0000	0.9374	1.4463	1.799	
0.3000	0.7388	1.4001	0.589		0.7029	0.8381	1.4244	1.016						
308.15 K														
0.0000	0.6793	1.3846	0.441		0.4044	0.7570	1.4032	0.623		0.8014	0.8641	1.4290	1.106	
0.1030	0.6967	1.3892	0.458		0.5041	0.7804	1.4097	0.702		0.9008	0.8967	1.4368	1.322	
0.2023	0.7149	1.3934	0.501		0.6035	0.8060	1.4156	0.805		1.0000	0.9328	1.4439	1.635	
0.3000	0.7344	1.3983	0.556		0.7029	0.8338	1.4220	0.953						

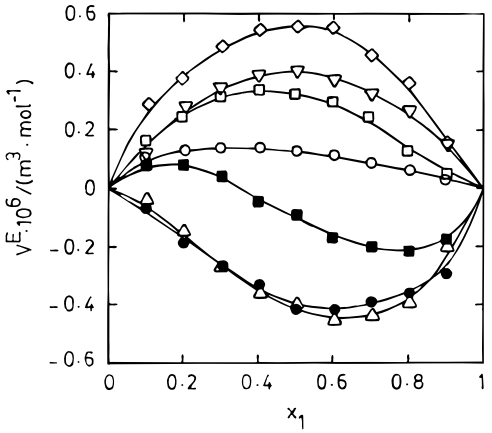

Figure 1. Excess molar volume vs mole fraction of cyclohexanone with (●) hexane, (■) heptane, (○) octane, (□) nonane, (▽), decane, (◇) dodecane, and (△)TMP at 298.15 K.

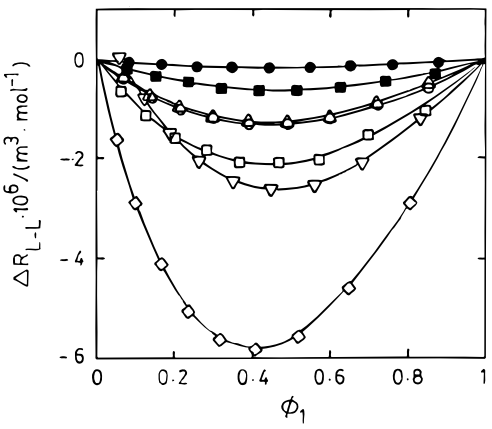

Figure 2. Deviation in molar refractivity vs mole fraction of cyclohexanone at 298.15 K. Symbols are the same as given in Figure 1.

Viscosities were measured using a Cannon Fenske viscometer (size 75, ASTM D 445 supplied by Industrial Research Glassware Ltd., Roselle, New Jersey). An electronic digital stopwatch with a readability of ±0.01 s was used for the flow time measurements. The measured viscosity values are accurate to ±0.001 mPa s. Calibrations of the pycnometer and viscometer are the same as described earlier (Aminabhavi and Bindu, 1995; Aminabhavi et al., 1994).

Refractive indices for the sodium D-line were measured using a thermostatically controlled Abbe refractometer (Atago 3T, Made in Japan). A minimum of three indepen-

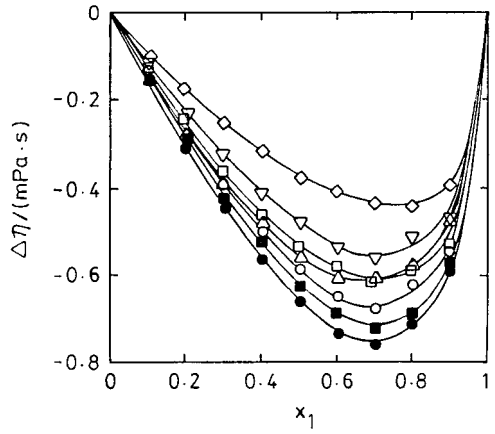

Figure 3. Deviation in viscosity vs mole fraction of cyclohexanone in binary mixtures at 298.15 K. Symbols are the same as given in Figure 1.

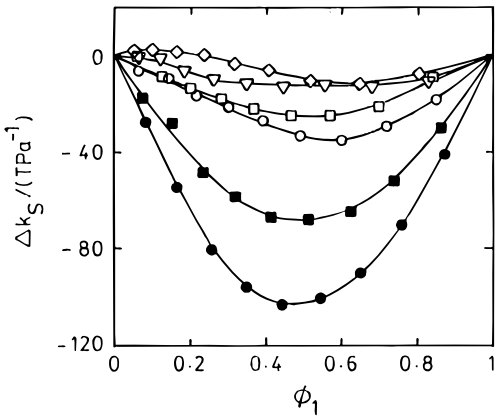

Figure 4. Deviation in isentropic compressibility vs volume fraction of cyclohexanone in binary mixture at 298.15 K. Symbols are the same as given in Figure 1.

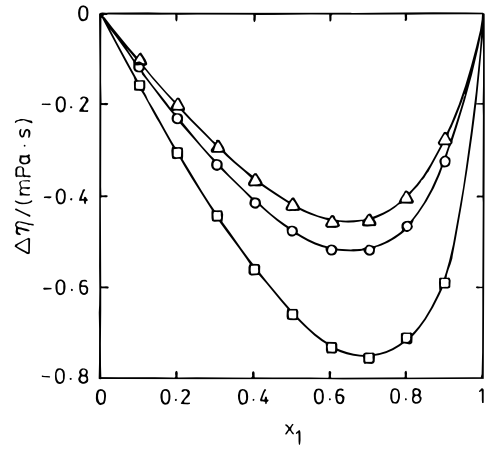

Figure 5. Deviations in viscosity vs temperature for cyclohexanone + hexane mixture at 298.15 (□), 303.15 (○), and 308.15 (△).

dent readings were taken for each composition, and their average is taken for calculation. The refractive index values are accurate to ±0.0001 units. The speed of sound values were measured using a variable-path single-crystal interferometer (model M-84, Mittal Enterprises, New Delhi). The interferometer was used at a frequency of 1 kHz and was calibrated using benzene and toluene. The speed of sound values are accurate to ±2 m s^{-1}. In all the property measurements, an INSREF, model 016 AP thermostat was used at a constant digital temperature display accurate to ±0.01 K. The results of ρ, n_D, η, and u compiled in Table 2 represent the averages of three independent measurements for each composition of the mixture.

A Julabo immersion cooler (FT 200, Julabo Labortechnik Gmbh, Germany) was used to cool the water bath. This unit was installed at the intake of a heating circulator to draw the heat away from the circulating bath liquid. The immersion probe was connected to the instrument with a flexible and insulated tube. To prevent the immersion probe from icing, it was completely immersed in the bath liquid.

Results and Discussion

Excess molar volume V^E, deviations in Lorentz−Lorenz molar refractivity ΔR, viscosity $\Delta\eta$, speed of sound Δu, and isentropic compressibility Δk_S of the binary mixtures have been calculated from the results of ρ, η, n_D, and u (Table 2) using the following general equations (Aminabhavi et al., 1996, 1997):

$$V^E = V_m - V_1x_1 - V_2x_2 \quad (1)$$

$$\Delta Y = Y_m - Y_1x_1 - Y_2x_2 \quad (2)$$

where V_m is molar volume of the mixture calculated as suggested before (Aminabhavi et al., 1994, 1995), V_1 and V_2 are the molar volumes of pure components 1 and 2, x_i represents the mole fraction of the ith component of the mixture, ΔY refers to ΔR, Δu, Δk_S, and $\Delta\eta$, Y_m is the respective mixture property, viz., molar refractivity R calculated from the Lorentz−Lorenz relation, viscosity, speed of sound, and isentropic compressibility for mixtures, and Y_i represents the respective properties of the pure components. The isentropic compressibility k_S has been calculated using the relation $k_S = 1/(u^2\rho)$. To calculate ΔR and Δk_S, the volume fraction φ_i is used in eq 2 instead of the mole fraction (Aminabhavi and Bindu, 1994, 1995).

Each set of excess functions have been fit to the Redlich and Kister (1948) polynomial

$$V^E \text{ (or } \Delta Y) = c_1c_2\sum_{j=1}^{k} A_j\,(c_2 - c_1)^{j-1} \quad (3)$$

to estimate the parameter values of A_0, A_1, and A_2 by the method of least squares using the Marquardt algorithm (1963). It was found that the best fits were obtained for the solution of eq 3 with only three adjustable parameters.

The standard deviations σ between the fitted quantities (eq 3) and the computed quantities (eqs 1 and 2) were calculated as

$$\sigma = \left(\frac{\sum(V^E_{cal} \text{ (or } \Delta Y_{cal}) - V^E_{obs} \text{ (or } \Delta Y_{obs}))^2}{n - m}\right)^{1/2} \quad (4)$$

where n represents the number of data points and m the number of coefficients. The fit parameter values along with the standard deviations are presented in Table 3.

Excess molar volumes for the mixtures of cyclohexanone with all the alkanes (C_6−C_{12}) at 298.15 K are presented in Figure 1. It is observed that for cyclohexanone (1) + hexane (2) mixtures, the V^E values are negative. A similar trend is also observed for the mixtures of cyclohexanone + 2,2,4-trimethylpentane. However, with cyclohexanone (1) + heptane (2) mixtures, the V^E curve shows a sigmoidal trend with a sign inversion from positive to negative with increasing amounts of cyclohexanone in the mixture With an increasing size of alkanes from octane to dodecane, the V^E results increase systematically. This is indicative of the

Table 3. Estimated Parameters of Excess Functions for Mixtures

function	temp/K	A_0	A_1	A_2	σ	function	temp/K	A_0	A_1	A_2	σ
					Cyclohexanone (1) + Hexane (2)						
$V^E \times 10^6/(m^3\ mol^{-1})$	298.15	−1.548	1.006	−0.468	0.031	$\Delta\eta$/(mPa s)	298.15	−2.585	2.208	−2.019	0.043
	303.15	−1.626	1.029	−0.538	0.037		303.15	−1.890	1.223	−0.809	0.010
	308.15	−1.823	1.057	−0.648	0.034		308.15	−1.671	1.044	−0.654	0.007
$\Delta R \times 10^6/(m^3\ mol^{-1})$	298.15	−0.701	0.167	−0.027	0.005	$\Delta u/(m\ s^{-1})$	298.15	−129.2	−15.21	−14.52	0.559
	303.15	−0.579	0.128	−0.141	0.018	$\Delta k_S/(TPa^{-1})$	298.15	−415.2	24.26	53.11	1.605
	308.15	−0.521	0.101	−0.042	0.008						
					Cyclohexanone (1) + Heptane (2)						
$V^E \times 10^6/(m^3\ mol^{-1})$	298.15	−0.380	1.528	−0.198	0.015	$\Delta\eta$/(mPa s)	298.15	−2.424	2.153	−2.077	0.044
	303.15	−0.371	1.709	−0.624	0.046		303.15	−1.753	1.150	−0.821	0.012
	308.15	−0.567	1.588	−0.022	0.024		308.15	−1.551	1.002	−0.713	0.012
$\Delta R \times 10^6/(m^3\ mol^{-1})$	298.15	−2.547	0.282	−0.117	0.018	$\Delta u/(m\ s^{-1})$	298.15	−140.1	1.24	2.29	0.486
	303.15	−2.566	0.202	−0.295	0.010	$\Delta k_S/(TPa^{-1})$	298.15	−276.5	−1.71	27.8	0.503
	308.15	−2.475	0.015	−0.459	0.012						
					Cyclohexanone (1) + Octane (2)						
$V^E \times 10^6/(m^3\ mol^{-1})$	298.15	0.490	0.366	0.338	0.010	$\Delta\eta$/(mPa s)	298.15	−2.282	1.981	−1.883	0.044
	303.15	0.546	0.397	0.134	0.013		303.15	−1.625	1.011	−0.653	0.014
	308.15	0.558	0.434	0.298	0.008		308.15	−1.435	0.906	−0.603	0.007
$\Delta R \times 10^6/(m^3\ mol^{-1})$	298.15	−5.230	1.293	−0.685	0.017	$\Delta u/(m\ s^{-1})$	298.15	−183.3	18.89	17.82	1.085
	303.15	−5.206	1.347	−0.996	0.019	$\Delta k_S/(TPa^{-1})$	298.15	−130.4	−47.61	22.06	1.505
	308.15	−5.131	1.438	−0.848	0.038						
					Cyclohexanone (1) + Nonane (2)						
$V^E \times 10^6/(m^3\ mol^{-1})$	298.15	1.318	0.594	−0.316	0.014	$\Delta\eta$/(mPa s)	298.15	−2.060	1.872	−1.991	0.051
	303.15	1.353	1.098	−0.621	0.036		303.15	−1.437	0.932	−0.761	0.017
	308.15	1.415	0.858	−0.034	0.019		308.15	−1.271	0.801	−0.653	0.015
$\Delta R \times 10^6/(m^3\ mol^{-1})$	298.15	−8.230	1.949	−1.446	0.058	$\Delta u/(m\ s^{-1})$	298.15	−155.5	52.0	−56.8	1.776
	303.15	−8.246	1.874	−1.007	0.098	$\Delta k_S/(TPa^{-1})$	298.15	−103.0	−0.85	−58.43	1.418
	308.15	−8.244	1.741	−0.982	0.073						
					Cyclohexanone (1) + Decane (2)						
$V^E \times 10^6/(m^3\ mol^{-1})$	298.15	1.578	0.015	−0.006	0.016	$\Delta\eta$/(mPa s)	298.15	−1.873	1.663	−1.683	0.045
	303.15	1.736	0.242	0.219	0.006		303.15	−1.272	0.730	−0.534	0.014
	308.15	1.701	0.146	−0.112	0.011		308.15	−1.127	0.632	−0.418	0.013
$\Delta R \times 10^6/(m^3\ mol^{-1})$	298.15	−10.89	0.752	5.707	0.195	$\Delta u/(m\ s^{-1})$	298.15	−154.9	49.30	−23.15	1.579
	303.15	−12.46	4.079	−0.783	0.034	$\Delta k_S/(Tpa^{-1})$	298.15	−55.75	−24.44	4.49	1.814
	308.15	−12.59	4.413	−1.144	0.042						
					Cyclohexanone (1) + Dodecane(2)						
$V^E \times 10^6/(m^3\ mol^{-1})$	298.15	2.247	0.251	0.139	0.027	$\Delta\eta$/(mPa s)	298.15	−1.424	1.405	−1.669	0.038
	303.15	2.316	0.139	0.158	0.025		303.15	−0.885	0.478	−0.332	0.008
	308.15	2.364	0.153	0.001	0.025		308.15	−0.776	0.403	−0.281	0.006
$\Delta R \times 10^6/(m^3\ mol^{-1})$	298.15	−22.449	8.568	−3.334	0.023	$\Delta u/(m\ s^{-1})$	298.15	−146.9	32.69	1.16	0.854
	303.15	−22.436	8.632	−3.422	0.023	$\Delta k_S/(TPa^{-1})$	298.15	−39.85	−46.81	38.46	0.633
	308.15	−22.302	8.574	−3.656	0.015						
					Cyclohexanone (1) + TMP (2)						
$V^E \times 10^6/(m^3\ mol^{-1})$	298.15	−1.679	1.145	0.205	0.021	$\Delta\eta$/(mPa s)	298.15	−2.159	1.625	−1.695	0.037
	303.15	−1.660	1.049	−0.206	0.027		303.15	−1.521	0.708	−0.509	0.006
	308.15	−1.833	1.114	−0.129	0.019		308.15	−1.337	0.577	−0.415	0.008
$\Delta R \times 10^6/(m^3\ mol^{-1})$	298.15	−5.189	1.431	0.134	0.024	$\Delta u(m\ s^{-1})$	298.15	−170.2	−51.23	49.7	1.518
	303.15	−5.305	1.623	−0.255	0.025	$\Delta k_S\ (TPa^{-1})$	298.15	−360.4	−51.46	67.21	2.136
	308.15	−5.146	1.306	−0.036	0.025						

dispersion type interactions between cyclohexanone and higher alkanes. Similar observations are prevalent at higher temperatures, but these results are not presented to avoid the overcrowding of curves.

The deviations in molar refraction ΔR with volume fraction φ_1 at 298.15 K are displayed graphically in Figure 2. This dependence is somewhat reverse to the V^E results; i.e., the negative ΔR values increase systematically from hexane to dodecane. The curve for cyclohexanone + TMP varies almost identically to that of the cyclohexanone + octane mixture, and the curves overlap very closely with one another.

Figure 3 shows the plots of $\Delta\eta$ vs x_1 at 298.15 K. It is observed that for all the binary mixtures, the $\Delta\eta$ values are negative and that these values increase from hexane to dodecane. The $\Delta\eta$ curve for cyclohexanone + TMP mixture is between those of cyclohexanone + nonane, or + octane mixtures.

The results of Δu are negative for all the mixtures but show no systematic variation with the size of alkanes. The values of Δu range from 32.4 m s^{-1} for hexane to 46.7 m s^{-1} for octane. However, for mixtures containing nonane, decane, and dodecane, the Δu values remain almost constant (i.e., around 37−40 m s^{-1}). In view of no systematic dependence of Δu on x_1, the plots are not displayed.

The results of Δk_S at 298.15 K are displayed in Figure 4. Large negative values observed with cyclohexanone + hexane supports the explanations given for the excess molar volumes. Also, the values of Δk_S increase with increasing size of alkanes in the mixtures. For mixtures of cyclohexanone + dodecane, a slight sigmoidal behavior is exhibited.

Although the calculated values of V^E and ΔR do not show any clear-cut dependence on temperature, the $\Delta\eta$ values show a systematic dependence on temperature for the mixures of cyclohexanone + hexane (see Figure 5).

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Received for review September 14, 1998. Accepted November 27, 1998. Authors are thankful to All India Council for Technical Education, New Delhi (F.No. 8017/RDII/PHA/208/98) for major financial support of this study.

JE9802266