A Study of Some Physical Properties for Binary System of Cyclohexane with n-decane and 1-pentanol at Different Temperatures

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Abstract:

The experimental densities, ρ , refractive indices, n_D , and viscosities, η , of binary mixtures of cyclohexane + n-decane and cyclohexane + 1-pentanol have been measured at 298.15, 308.15, 318.15, and 328.15 K over the whole mole fraction range. From these results, excess molar volumes, V^E , have been calculated and fitted to the Flory equations. The V^E values are negative and positive over the whole mole fraction range and at all temperatures. The excess refractive indices n^E and excess viscosities η^E have been calculated from experimental refractive indices and viscosity measurements at different temperature and fitted to the mixing rules equations and Heric – Coursey equation respectively to predict theoretical refractive indices, we found good agreement between them for binary mixtures in this study.

The variation of these properties with composition and temperatures of the binary mixtures are discussed in terms of molecular interactions.

Key words: Binary system, Cyclohexane with n-decane, Cyclohexane 1-pentanol, phscial properties.

Introduction:

Multi component excess molar properties, necessary for process design, are normally estimated from binary mixing values. The important role played by solvents in chemistry has long been recognized. The model of thermo physical properties of mixed solvent has received increasing attention as unimportant tool both at molecular level and for practical applications[1].

The alkane (normal or cyclo) the simplest class of organic compounds, contain no functional group, and smaller alkanes play an important role as model molecules for the behavior of large compounds.

On the other hand, alcohols are most well, known solvents with protic and self-associated properties, cyclohexane, and ether alkanol, shows physical chemical properties between protic and dipolar aprotic solvents [2].

Studies on excess functional of binary liquid mixtures are of considerable importance in understadying the nature of molecular interactions. To determine the extent and type of such interaction , the excess molar volume, refractive indices and viscosities of the binary mixtures of cyclohexane + n- decane and cyclohexane +1- pentanol have been measured.

Materials and Methods:

The chemical materials that were used in this research with their degree of purity and the name of the

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supplying company as shown in Table(1).

Table (1): The chemical materials used with their degree of purity and name of supplier.

Chemical material	Degree of purity	Name of supplier
Cyclohexane	99.9%	BDH
n-decane	99.9%	BDH
1-pentanol	99.5%	Fluka

The solvent was kept on activated molecular sieves type 4A° for 24 hours then filtered before use. Doubly distilled water was used as the standard liquid with conductivity less than. 5×10^{-7} ohm.cm^{-1}.

The mixtures were prepared by mass using (sartorius) balance with an accuracy of $\pm 10^{-4}$ g covering the whole composition range and kept in air tight stoppered bottle to prevent any contamination. The possible error in mole fraction is estimated to be less than $\pm 1\times 10^{-4}$.

The purities of the compound were checked by determining their densities, refractive indices and viscosities over a range temperature 298.15, 308.15, 318.15 and 328.15 K, which were reasonably in accordance with values found in the literature[3] as shown in table (2).

Table (2): Densities (ρ), Refractive indices (n_D) and viscosities (η) of pure liquids at 298.15, 308.15, 318.15 and 328.15K.

Chemical material	ρ				n_D				η			
	298.15 K	308.15 K	318.15 K	328.15 K	298.15 K	308.15 K	318.15 K	328.15 K	298.15 K	308.15 K	318.15 K	328.15 K
Cyclohexane	0.76055	0.75610	0.72820	0.71620	1.4251	1.4210	1.4195	1.4110	0.8186	0.6514	0.5024	0.4270
n-decane	0.72510	0.70650	0.70194	0.68912	1.4043	1.4035	1.3960	1.3900	0.7748	0.6835	0.4891	0.4201
1-pentanol	0.95996	0.94450	0.92650	0.89830	1.4050	1.4030	1.3970	1.3910	3.5342	2.5147	1.7389	1.2579

Densities of pure liquids and their mixtures were determined using digital densimeter (Anton paur DMA 60/602), the density values were reproducible to within 1×10^{-5} g.cm^{-3} . The experimental technique has been described previously.[4] The refractive indices were measured with an Abbe refractometer (Tafesa) with a precision of the reading of ± 0.0002. Both apparatuses were connected to aschott-Gerate 1150, circulating water bath with proportional temperature control and an automatic drift correction system that kept the samples at the desired temperatures with an accuracy of ± 0.01 K.

On other, the viscosity of pure liquids and binary liquid mixtures were measured using cannon-ubbeloude semi Micro viscometer thermostated with digital water bath (Kotterm).

The flow times were determined electronically with an electric timer of precision ± 0.015 sec..

Results:

The experimental results for the pure components are reported in table (2). The experimental data of densities ρ , viscosities η , refractive indices n_D , and excess molar volumes V^E , of binary mixtures (cyclohexane + n-decane, cyclohexane + 1-pentanol , at 298.15, 308.15, 318.15, and 328.15 K over the whole mole fraction range are listed in table (3) and illustrated in figures(1-2). The excess molar volumes for binary mixtures were calculated from the following relation [5] .

$$V_{12}^{E}/(cm^3.mol^{-1})=[\frac{x_1M_1+x_2M_2}{\rho_m}]-[x_1\frac{M_1}{\rho_1}+x_2\frac{M_2}{\rho_2}] \quad \text{.....(1)}$$

where x_1, M_1 and ρ_1 are the mole fraction, molar mass and density of component(1) respectively. X_2, M_2 and ρ_2 are the mole fraction, molar mass and density of component (2) respectively. ρ_m is the density of mixture. The experimental V^E results of the binary mixtures over the four temperatures are presented in table (3).

Table (3) Experimental values of the densities (ρ) and excess molar volumes (V_{12}^{E}) for binary mixtures at the four temperatures.

x_1 Cyclohexane + x_2 n- Decane								
x_2	ρ (g.cm^3) 298.15K	ρ (g.cm^3) 308.15K	ρ (g.cm^3) 318.15K	ρ (g.cm^3) 328.15K	V_{12}^{E} (cm^3.mol^{-1}) 298.15K	V_{12}^{E} (cm^3.mol^{-1}) 308.15K	V_{12}^{E} (cm^3.mol^{-1}) 318.15K	V_{12}^{E} (cm^3.mol^{-1}) 328.15K
0.0000	0.76055	0.73610	0.72820	0.71620	0.0000	0.0000	0.0000	0.0000
0.0922	0.75491	0.73146	0.72414	0.71204	0.0349	0.0291	0.0250	0.0217
0.0991	0.75451	0.73113	0.72385	0.71174	0.0395	0.0325	0.0287	0.0231
0.1506	0.75171	0.72880	0.71968	0.70962	0.0581	0.0480	0.4196	0.0374
0.2100	0.74877	0.72633	0.71960	0.70737	0.0722	0.0638	0.0561	0.0492
0.2989	0.74474	0.72297	0.71659	0.70426	0.0990	0.0877	0.0810	0.0768
0.3672	0.74200	0.72067	0.71455	0.70216	0.1077	0.0981	0.0916	0.0855
0.4476	0.73907	0.71823	0.71237	0.69991	0.1150	0.1021	0.0970	0.0912
0.4901	0.73756	0.71695	0.71125	0.69878	0.1336	0.1200	0.1092	0.0998
0.5216	0.73644	0.71598	0.71041	0.69838	0.1549	0.1470	0.1284	0.0110
0.5415	0.73603	0.71567	0.71009	0.69757	0.1121	0.1003	0.0961	0.0901
0.6106	0.73411	0.71405	0.70868	0.69611	0.0802	0.0749	0.0660	0.0597
0.6890	0.73210	0.71241	0.70722	0.69459	0.0431	0.0313	0.0257	0.0193
0.7396	0.73093	0.71142	0.70633	0.69365	0.0086	0.0028	0.0014	0.0002
0.7537	0.73060	0.71113	0.70611	0.69341	0.0025	0.0001	-0.0102	-0.0110
0.8060	0.72940	0.71015	0.70523	0.69252	-0.0175	-0.0236	-0.0296	-0.0371
0.8693	0.72798	0.70896	0.70414	0.69140	-0.0281	-0.0364	-0.0344	-0.0412
0.8850	0.72757	0.70926	0.70386	0.69111	-0.0149	-0.1966	-0.0289	-0.0353
1.0000	0.72510	0.70650	0.70194	0.68912	0.0000	0.0000	0.0000	0.0000

x_1 Cyclohexane + x_2 1- Pentanol								
x_2	ρ (g.cm^3) 298.15K	ρ (g.cm^3) 308.15K	ρ (g.cm^3) 318.15K	ρ (g.cm^3) 328.15K	V_{12}^{E} (cm^3.mol^{-1}) 298.15K	V_{12}^{E} (cm^3.mol^{-1}) 308.15K	V_{12}^{E} (cm^3.mol^{-1}) 318.15K	V_{12}^{E} (cm^3.mol^{-1}) 328.15K
0.0000	0.76055	0.73610	0.72820	0.71620	0.0000	0.0000	0.0000	0.0000
0.1050	0.77777	0.75426	0.92639	0.73237	0.0714	0.0086	0.0107	0.0138
0.1503	0.78543	0.76230	0.92632	0.73950	0.0834	0.0160	0.0173	0.0225
0.1781	0.79026	0.76728	0.92626	0.74389	0.0869	0.0211	0.0236	0.0333
0.2247	0.79852	0.77578	0.92616	0.75142	0.0878	0.0284	0.0333	0.0422
0.3223	0.81628	0.79412	0.92606	0.76758	0.0842	0.0351	0.0435	0.0563
0.3884	0.82868	0.80693	0.92598	0.77883	0.0823	0.0420	0.0519	0.0672
0.4861	0.84755	0.82652	0.92589	0.79599	0.0804	0.0494	0.0611	0.0791
0.5334	0.85696	0.83628	0.92587	0.80452	0.0753	0.0515	0.0638	0.0825
0.5474	0.85981	0.83921	0.92586	0.80707	0.0695	0.0520	0.0643	0.0832
0.5697	0.86446	0.84391	0.92586	0.81118	0.0524	0.0524	0.0649	0.0840
0.5729	0.86532	0.84461	0.92585	0.81178	0.0300	0.0525	0.0650	0.0841
0.6356	0.87844	0.85808	0.92586	0.82352	0.0034	0.0523	0.0648	0.0839
0.7723	0.90789	0.88878	0.92593	0.85012	-0.0232	0.0468	0.0582	0.0802
0.7926	0.91240	0.89354	0.92600	0.85431	-0.0259	0.0415	0.0513	0.0664
0.8335	0.92155	0.90319	0.92606	0.86266	-0.0295	0.0359	0.0444	0.0575
0.8774	0.93151	0.91377	0.92615	0.87180	-0.0300	0.0285	0.0353	0.0457
0.8983	0.93632	0.91895	0.92630	0.87631	-0.0286	0.0190	0.0200	0.0300
1.0000	0.95996	0.94450	0.92650	0.89830	0.0000	0.0000	0.0000	0.0000

The values of V^E for each mixture were fitted to the Flory equation. [6-12]

$$V^E=(x_1V_1^*+x_2V_2^*)\tilde{V}^E \quad \ldots\ldots\ldots\ldots(2)$$

Where the v* characteristic volume of component (1) , V^E Excess reduced volume . By using the equation of state parameters of the pure liquids, the V_{12}^E of the binary mixtures were calculated at 298.15 K the results obtained were tabulated in table (4) and plotted as function of the mole fraction, x_2 with the compare experimental data in the figures (3-4)

Table (4) Excess molar volumes ($V^E_{exp.}$) for experimental and ($V^E_{Thereo.}$) predicted by Flory theory for binary mixtures at 298.15K.

x_1 Cyclohexane + x_2 n-Decane			x_1 Cyclohexane + x_2 1-Pentanol		
x_2	$V^E_{exp.}$	$V^E_{Thereo.}$	x_2	$V^E_{exp.}$	$V^E_{Thereo.}$
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0922	0.0349	0.0267	0.1050	0.0714	0.0019
0.0991	0.0395	0.0297	0.1503	0.0834	0.0032
0.1506	0.0581	0.0537	0.1781	0.0869	0.0040
0.2100	0.0722	0.0819	0.2247	0.0878	0.0054
0.2989	0.0990	0.1161	0.3223	0.0842	0.0081
0.3672	0.1077	0.1304	0.3884	0.0823	0.0097
0.4476	0.1150	0.1306	0.4861	0.0804	0.0114
0.4901	0.1336	0.1235	0.5334	0.0753	0.0119
0.5216	0.1549	0.1152	0.5474	0.0695	0.0120
0.5415	0.1121	0.1087	0.5697	0.0524	0.0121
0.6106	0.0802	0.0803	0.5729	0.0300	0.0121
0.6890	0.0431	0.0411	0.6356	0.0034	0.0121
0.7396	0.0086	0.0156	0.7723	-0.0232	0.0101
0.7537	0.0025	0.0088	0.7926	-0.0259	0.0095
0.8060	-0.0175	-0.0130	0.8335	-0.0295	0.0083
0.8693	-0.0281	-0.0293	0.8774	-0.0300	0.0066
0.8850	-0.0149	-0.0290	0.8983	-0.0286	0.0057
1.0000	0.0000	0.0000	1.0000	0.0000	0.0000

Excess refractive indices for binary mixtures at 298.15K, 308.15K, 318.15K, and 328.15K were calculated from measurements of the refractive indices of the mixture and the pure liquids using the following equation[13].

$$n^E = n_{D,m} - \Sigma^m x_s n_{D,S} \text{.....(3)}$$

where $n_{D,m}$ is the refractive indices of the mixtures , $n_{D,S}$ is the refractive indices of the pure component and Xs mole fraction of pure component .

The experimental results of the excess refractive indices are listed in table (5) and plotted as a function of X_2 the mole fraction of the second component, figures (5-6). Excess refractive indices n^E are positive over the entire composition range for all binary system studied here at the four temperatures.

Many equations that use mixing rules for computing the refractive indices of the pure component liquids were reported in the literature[6]. In order to check the validity and the relative merits of the results obtained , the equations average for mixing rules have been used to calculate the refractive indices of the mixtures. The calculated values of n_D for all binary mixtures studied in this work are presented in Table (6) with experimental values for comparison.

We found good agreement between the experimental values of the refractive indices for the two binary mixtures studied in this work and with predicted values using the equations of mixing rules at 298.15K, 308.15K, 318.15K,and 328.15K.

Table (5): Experimental values of the refractive indices (n_D) and excess refractive indices (n^E) for binary mixtures at 298.15,308.15, 318.15, and 328.15K.

x_1 Cyclohexane + x_2 n- Decane								
x_2	n_D	n^E	n_D	n^E	n_D	n^E	n_D	n^E
	298.15K		308.15K		318.15K		328.15K	
0.0000	1.4251	0.0000	1.4210	0.0000	1.4195	0.0000	1.4110	0.0000
0.0922	1.4237	0.0064	1.4206	0.0009	1.4185	0.0012	1.4105	0.0015
0.0991	1.4233	0.0097	1.4200	0.0015	1.4179	0.0017	1.4000	0.0020
0.1506	1.4223	0.0012	1.4191	0.0016	1.4170	0.0019	1.4090	0.0021
0.2100	1.4211	0.0014	1.4180	0.0018	1.4151	0.0020	1.4080	0.0022
0.2989	1.4203	0.0015	1.4165	0.0019	1.4132	0.0021	1.4065	0.0023
0.3672	1.4185	0.0016	1.4155	0.0018	1.4110	0.0023	1.4050	0.0024
0.4476	1.4160	0.0013	1.4140	0.0016	1.4095	0.0019	1.4030	0.0022
0.4901	1.4150	0.0011	1.4130	0.0014	1.4083	0.0016	1.4020	0.0019
0.5216	1.4140	0.0009	1.4120	0.0012	1.4075	0.0014	1.4000	0.0017
0.5415	1.4135	0.0008	1.4110	0.0011	1.4070	0.0013	1.3990	0.0016
0.6106	1.4128	0.0007	1.4100	0.0008	1.4065	0.0011	1.3975	0.0015
0.6890	1.4117	0.0006	1.4090	0.0007	1.4060	0.0008	1.3960	0.0010
0.7396	1.4090	0.0005	1.4075	0.0006	1.4030	0.0007	1.3945	0.0008
0.7537	1.4087	0.0004	1.4061	0.0005	1.4015	0.0006	1.3935	0.0007
0.8060	1.4080	0.0003	1.4053	0.0004	1.4005	0.0005	1.3925	0.0006
0.8693	1.4073	0.0002	1.4046	0.0003	1.3995	0.0003	1.3915	0.0004
0.8850	1.4067	0.0001	1.4040	0.0002	1.3980	0.0002	1.3910	0.0003
1.0000	1.4043	0.0000	1.4035	0.0000	1.3960	0.0000	1.3900	0.0000
x_1 Cyclohexane + x_2 1- Pentanol								
x_2	n_D	n^E	n_D	n^E	n_D	n^E	n_D	n^E
	298.15K		308.15K		318.15K		328.15K	
0.0000	1.4251	0.0000	1.4210	0.0000	1.4159	0.0000	1.4110	0.0000
0.1050	1.4240	0.0010	1.4205	0.0013	1.4188	0.0028	1.4108	0.0015
0.1503	1.4232	0.0011	1.4198	0.0015	1.4180	0.0038	1.4100	0.0020
0.1781	1.4228	0.0012	1.4195	0.0017	1.4175	0.0045	1.4096	0.0021
0.2247	1.4220	0.0014	1.4188	0.0018	1.4168	0.0051	1.4090	0.0024
0.3223	1.4203	0.0015	1.4172	0.0020	1.4152	0.0053	1.4080	0.0034
0.3884	1.4190	0.0015	1.4160	0.0019	1.4135	0.0049	1.4065	0.0032
0.4861	1.4170	0.0016	1.4145	0.0022	1.4115	0.0047	1.4045	0.0032
0.5334	1.4157	0.0013	1.4135	0.0021	1.4100	0.0041	1.4030	0.0026
0.5474	1.4150	0.0009	1.4130	0.0018	1.4095	0.0039	1.4025	0.0024
0.5697	1.4145	0.0008	1.4125	0.0017	1.4086	0.0034	1.4020	0.0023
0.5729	1.4140	0.0004	1.4120	0.0013	1.4080	0.0029	1.4015	0.0019
0.6356	1.4127	0.0003	1.4108	0.0012	1.4063	0.0024	1.4000	0.0017
0.7723	1.4098	0.0002	1.4080	0.0009	1.4032	0.0018	1.3970	0.0014
0.7926	1.4094	0.0002	1.4075	0.0007	1.4025	0.0015	1.3965	0.0013
0.8335	1.4085	0.0001	1.4065	0.0005	1.4015	0.0013	1.3955	0.0011
0.8774	1.4076	0.0001	1.4056	0.0003	1.4002	0.0008	1.3945	0.0010
0.8983	1.4071	0.0000	1.4050	0.0001	1.3995	0.0005	1.3935	0.0004
1.0000	1.4050	0.0000	1.4030	0.0000	1.3970	0.0000	1.3910	0.0000

Table (6) Experimental and the predicted refractive indices (n_D) for binary mixtures at 298.15,308.15, 318.15, and 328.15K.

x_1 Cyclohexane + x_2 n- Decane								
x_2	$n_{D\ exp.}$	$n_{D\ Thereo.}$	$n_{D\ exp.}$	$n_{D\ Thereo.}$	$n_{D\ exp.}$	$n_{D\ Thereo.}$	$n_{D\ exp.}$	$n_{D\ Thereo.}$
	298.15K		308.15K		318.15K		328.15K	
0.0000	1.4251	1.4255	1.4210	1.4207	1.4195	1.4199	1.4110	1.4111
0.0922	1.4237	1.4239	1.4206	1.4204	1.4185	1.4183	1.4105	1.4107
0.0991	1.4233	1.4237	1.2400	1.4201	1.4179	1.4177	1.4000	1.4006
0.1506	1.4223	1.4222	1.4191	1.4197	1.4170	1.4165	1.4090	1.4093
0.2100	1.4211	1.4214	1.4180	1.4183	1.4151	1.4153	1.4080	1.4085
0.2989	1.4203	1.4208	1.4165	1.4166	1.4132	1.4131	1.4065	1.4062
0.3672	1.4185	1.4183	1.4155	1.4158	1.4110	1.4107	1.4050	1.4054
0.4476	1.4160	1.4162	1.4140	1.4151	1.4095	1.4090	1.4030	1.4033
0.4901	1.4150	1.4145	1.4130	1.4140	1.4083	1.4082	1.4020	1.4021
0.5216	1.4140	1.4141	1.4120	1.4133	1.4075	1.4077	1.4000	1.4009
0.5415	1.4135	1.4133	1.4110	1.4112	1.4070	1.4071	1.3990	1.3998
0.6106	1.4128	1.4127	1.4100	1.4099	1.4065	1.4063	1.3975	1.3972
0.6890	1.4117	1.4116	1.4090	1.4091	1.4060	1.4055	1.3960	1.3966
0.7396	1.4090	1.4091	1.4075	1.4077	1.4030	1.4038	1.3945	1.3947
0.7537	1.4087	1.4084	1.4061	1.4068	1.4015	1.4019	1.3935	1.3938
0.8060	1.4080	1.4074	1.4053	1.4055	1.4005	1.4008	1.3925	1.3925
0.8693	1.4073	1.407	1.4046	1.4043	1.3995	1.3999	1.3915	1.3919
0.8850	1.4067	1.4069	1.4040	1.4041	1.3980	1.3985	1.3910	1.3913
1.0000	1.4043	1.4042	1.4035	1.4033	1.3960	1.3964	1.3900	1.3905

x_1 Cyclohexane + x_2 1- Pentanol								
x_2	$n_{D\ exp.}$	$n_{D\ Thereo.}$	$n_{D\ exp.}$	$n_{D\ Thereo.}$	$n_{D\ exp.}$	$n_{D\ Thereo.}$	$n_{D\ exp.}$	$n_{D\ Thereo.}$
	298.15K		308.15K		318.15K		328.15K	
0.0000	1.4251	1.4253	1.4210	1.4216	1.4159	1.4155	1.4110	1.4113
0.1050	1.4240	1.4241	1.4205	1.4208	1.4188	1.4184	1.4108	1.4106
0.1503	1.4232	1.4233	1.4198	1.4199	1.4180	1.4181	1.4100	1.4101
0.1781	1.4228	1.4226	1.4195	1.4193	1.4175	1.4173	1.4096	1.4092
0.2247	1.4220	1.4225	1.4188	1.4185	1.4168	1.4162	1.4090	1.4089
0.3223	1.4203	1.4209	1.4172	1.4171	1.4152	1.4156	1.4080	1.4084
0.3884	1.4190	1.4192	1.4160	1.4166	1.4135	1.4133	1.4065	1.4066
0.4861	1.4170	1.4174	1.4145	1.4147	1.4115	1.4111	1.4045	1.4047
0.5334	1.4157	1.4158	1.4135	1.4133	1.4100	1.411	1.4030	1.4033
0.5474	1.4150	1.4157	1.4130	1.4131	1.4095	1.4093	1.4025	1.4028
0.5697	1.4145	1.4144	1.4125	1.4127	1.4086	1.4085	1.4020	1.4021
0.5729	1.4140	1.4141	1.4120	1.4122	1.408	1.4082	1.4015	1.4015
0.6356	1.4127	1.4125	1.4108	1.4109	1.4063	1.4064	1.4000	1.4007
0.7723	1.4098	1.4096	1.4080	1.4085	1.4032	1.4039	1.3970	1.3978
0.7926	1.4094	1.4092	1.4075	1.4073	1.4025	1.4022	1.3965	1.3964
0.8335	1.4085	1.4088	1.4065	1.4067	1.4015	1.4017	1.3955	1.3959
0.8774	1.4076	1.4073	1.4056	1.4055	1.4002	1.4009	1.3945	1.3942
0.8983	1.4071	1.4069	1.4050	1.4051	1.3995	1.3998	1.3935	1.3938
1.0000	1.4050	1.4054	1.4030	1.4032	1.3970	1.3973	1.3910	1.3915

Viscosity for binary system mixtures at 298.15, 308.15, 318.15 and 328.15 K were calculated from measurement of viscosity of the mixture of pure liquids using the following equation[14].

$$\eta_{12}^{E} = \eta_{mix} - X_1\eta_1 - X_2\eta_2 \text{.....(4)}$$

Where X_1,X_2 , $\eta_1$and η_2 are the mole fraction and the viscosities of pure components respectivily . η_{mix} is the viscosity of the mixture[15] .

The experimental results for the viscosity (η) are presented in table (7), figures (7-8) showed the variation of viscosity as a function of the mole fraction of cyclohexane.

Several empirical equations have been proposed to calculate excess viscosity of multi component systems based on the available experimental results of mixture and pure components. The equation of Heric and Coursey[16] was used :

$$\eta^{E} = \ln \eta_{mix} - \Sigma\, x_i \ln \eta_i \quad \text{.....(5)}$$

where $\eta_{mix.}$ is the viscosity of the mixture, x_i and η_i are mole fraction and viscosity for pure component respectively . Table(8) shows the predicted values with the experimental values of excess viscosity for comparison for binary mixtures studied here at 298.15,308.15,318.15 and328.15 K.

Table (7) : Experiment values of the viscosity η and excess viscosity η_{12}^{E} for binary mixtures at 298.15,308.15, 318.15,and 328.15K.

x_1 Cyclohexane + x_2 n- Decane								
x_2	η	η_{12}^{E}	η	η_{12}^{E}	η	η_{12}^{E}	η	η_{12}^{E}
	298.15K		308.15K		318.15K		328.15K	
0.0000	0.8186	0.0000	0.6514	0.0000	0.5025	0.0000	0.4271	0.0000
0.0922	0.7713	-0.0432	0.6254	-0.0290	0.4896	-0.1047	0.4150	-0.0114
0.0991	0.7533	-0.0610	0.6196	-0.0350	0.4794	-0.0981	0.4101	-0.0163
0.1506	0.7387	-0.0732	0.6067	-0.0495	0.4667	-0.0671	0.3946	-0.0314
0.2100	0.7300	-0.0794	0.5937	-0.0644	0.4518	-0.0335	0.3838	-0.0417
0.2989	0.7145	-0.0910	0.5747	-0.0863	0.4301	-0.0177	0.3680	-0.0569
0.3672	0.7003	-0.1022	0.5513	-0.1119	0.4190	-0.0552	0.3622	-0.0623
0.4476	0.6860	-0.1130	0.5332	-0.1325	0.4030	-0.1002	0.3423	-0.0816
0.4901	0.7133	-0.0838	0.5592	-0.1079	0.4073	-0.1202	0.3511	-0.0725
0.5216	0.7237	-0.0720	0.5745	-0.0936	0.4166	-0.1332	0.3602	-0.0631
0.5415	0.7291	-0.0658	0.5904	-0.0784	0.4213	-0.1417	0.3645	-0.0587
0.6100	0.7329	-0.0589	0.6105	-0.0605	0.4303	-0.1735	0.3684	-0.0544
0.6890	0.7423	-0.0461	0.6198	-0.0537	0.4391	-0.2099	0.3769	-0.0453
0.7396	0.7468	-0.0393	0.6349	-0.0402	0.4483	-0.2324	0.3857	-0.0362
0.7537	0.7579	-0.0277	0.6506	-0.0249	0.4579	-0.2366	0.3902	-0.0316
0.8060	0.7623	-0.0209	0.6551	-0.0222	0.4622	-0.2614	0.3990	-0.0224
0.8693	0.7665	-0.0140	0.6646	-0.0146	0.4712	-0.2903	0.4030	-0.0180
0.8850	0.7718	-0.0080	0.6755	-0.0042	0.4808	-0.2954	0.4121	-0.0088
1.0000	0.7748	0.0000	0.6835	0.0000	0.4891	0.0000	0.4201	0.0000

x_1 Cyclohexane + x_2 1- Pentanol								
x_2	η	η_{12}^E	η	η_{12}^E	η	η_{12}^E	η	η_{12}^E
	298.15K		308.15K		318.15K		328.15K	
0.0000	0.8186	0.0000	0.6514	0.0000	0.5025	0.0000	0.4247	0.0000
0.1050	0.8554	-0.2485	0.7467	-0.3571	0.6321	-0.0003	0.4858	-0.0264
0.1504	0.8761	-0.3508	0.7890	-0.4379	0.6762	-0.0121	0.5118	-0.0382
0.1781	0.8999	-0.4024	0.8056	-0.4967	0.6966	-0.0260	0.5301	-0.0430
0.2248	0.9592	-0.4698	0.8495	-0.5795	0.7274	-0.0530	0.5522	-0.0598
0.3223	1.0506	-0.6433	0.9232	-0.7707	0.7409	-0.1600	0.6260	-0.0673
0.3884	1.0924	-0.7810	0.9683	-0.9051	0.8108	-0.1719	0.6650	-0.0833
0.4862	1.1966	-0.9423	1.0538	-1.0850	0.9123	-0.1913	0.7376	-0.0922
0.5334	1.2967	-0.9704	1.1290	-1.1381	0.9314	-0.2005	0.7686	-0.1006
0.5474	1.4084	-0.8967	1.2273	-1.0778	1.0166	-0.1627	0.7980	-0.0828
0.5697	1.5643	-0.8013	1.3165	-1.0492	1.0711	-0.1357	0.8319	-0.0674
0.5730	1.6199	-0.7047	1.3503	-1.0034	1.1096	-0.1013	0.8462	-0.0559
0.6356	1.7130	-0.6518	1.5231	-0.9916	1.2038	-0.0846	0.9206	-0.0337
0.7723	2.0864	-0.6248	1.8975	-0.8584	1.3818	-0.0756	1.0480	-0.0201
0.7927	2.1441	-0.5970	1.9569	-0.8042	1.4489	-0.0336	1.0749	-0.0102
0.8335	2.5302	-0.5518	2.0773	-0.7000	1.5056	-0.0274	1.1106	-0.0086
0.8774	2.6738	-0.5275	2.2443	-0.5969	1.5620	-0.0253	1.1492	-0.0065
0.8984	3.0455	-0.2127	2.3472	-0.4402	1.5933	-0.0199	1.1686	-0.0047
1.0000	3.5342	0.0000	2.5147	0.0000	1.7389	0.0000	1.2579	0.0000

Table (8) Experimental and the predicted excess viscosities (η^E) for binary mixtures at 298.15, 308.15, 318.15, and 328.15 K.

x_1 Cyclohexane + x_2 n- Decane								
x_2	$\eta^E_{exp.}$	$\eta^E_{Thereo.}$	$\eta^E_{exp.}$	$\eta^E_{Thereo.}$	$\eta^E_{exp.}$	$\eta^E_{Thereo.}$	$\eta^E_{exp.}$	$\eta^E_{Thereo.}$
	298.15K		308.15K		318.15K		328.15K	
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0922	-0.0432	-0.0430	-0.0290	-0.0289	-0.1047	-0.1045	-0.0114	-0.0110
0.0991	-0.0610	-0.0609	-0.0350	-0.0351	-0.0981	-0.0989	-0.0163	-0.0160
0.1506	-0.0732	-0.0729	-0.0495	-0.0495	-0.0671	-0.0670	-0.0314	-0.0314
0.2100	-0.0794	-0.0795	-0.0644	-0. 0643	-0.0335	-0.0335	-0.0417	-0.0416
0.2989	-0.0910	-0.0912	-0.0863	-0.0861	-0.0177	-0.0179	-0.0569	-0.0570
0.3672	-0.1022	-0.1025	-0.1119	-0.1120	-0.0552	-0.0553	-0.0623	-0.0622
0.4476	-0.1130	-0.1133	-0.1325	-0.1322	-0.1002	-0.1002	-0.0816	-0.0810
0.4901	-0.0838	-0.0835	-0.1079	-0.1080	-0.1202	-0.10211	-0.0725	-0.0725
0.5216	-0.0720	-0.0718	-0.0936	-0.0935	-0.1332	-0.1327	-0.0631	-0.0630
0.5415	-0.0658	-0.0658	-0.0784	-0.0785	-0.1417	-0.1420	-0.0587	-0.0585
0.6100	-0.0589	-0.0592	-0.0605	-0.0610	-0.1735	-0.1733	-0.0544	-0.0545
0.6890	-0.0461	-0.0460	-0.0537	-0.0540	-0.2099	-0.2089	-0.0453	-0.0455
0.7396	-0.0393	-0.0392	-0.0402	-0.0409	-0.2324	-0.2325	-0.0362	-0.0362
0.7537	-0.0277	-0.0279	-0.0249	-0.0250	-0.2366	-0.2345	-0.0316	-0.0317
0.8060	-0.0209	-0.0213	-0.0222	-0.0219	-0.2614	-0.2610	-0.0224	-0.0222
0.8693	-0.0140	-0.0141	-0.0146	-0.0145	-0.2903	-0.2900	-0.0180	-0.0181
0.8850	-0.0080	-0.0060	-0.0042	-0.0040	-0.2954	-0.955	-0.0088	-0.0089
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
x_1 Cyclohexane + x_2 1- Pentanol								
x_2	$\eta^E_{exp.}$	$\eta^E_{Thereo.}$	$\eta^E_{exp.}$	$\eta^E_{Thereo.}$	$\eta^E_{exp.}$	$\eta^E_{Thereo.}$	$\eta^E_{exp.}$	$\eta^E_{Thereo.}$
	298.15K		308.15K		318.15K		328.15K	
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.1050	-0.2485	-0.2483	-0.3571	-0.3570	-0.0003	-0.0006	-0.0264	-0.0260
0.1504	-0.3508	-0.3511	-0.4379	-0.4380	-0.0121	-0.0125	-0.0382	-0.0385
0.1781	-0.4024	-0.4025	-0.4967	-0.4966	-0.0260	-0.0262	-0.0430	-0.0433
0.2248	-0.4698	-0.4690	-0.5795	-0.5799	-0.0530	-0.0526	-0.0598	-0.0599
0.3223	-0.6433	-0.6430	-0.7707	-0.7709	-0.1600	-0.1602	-0.0673	-0.0675
0.3884	-0.7810	-0.7809	-0.9051	-0.9055	-0.1719	-0.1721	-0.0833	-0.0829
0.4862	-0.9423	-0.9423	-1.0850	-1.0848	-0.1913	-0.1915	-0.0922	-0.0923
0.5334	-0.9704	-0.9710	-1.1381	-1.1385	-0.2005	-0.2009	-0.1006	-0.1010
0.5474	-0.8967	-0.8970	-1.0778	-1.0770	-0.1627	-0.1630	-0.0828	-0.0822
0.5697	-0.8013	-0.8004	-1.0492	-1.0498	-0.1357	-0.1355	-0.0674	-0.0674
0.5730	-0.7047	-0.7051	-1.0034	-1.0030	-0.1013	-0.1019	-0.0559	-0.0560
0.6356	-0.6518	-0.6518	-0.9916	-0.9910	-0.0846	-0.0850	-0.0337	-0.0335
0.7723	-0.6248	-0.6244	-0.8584	-0.8584	-0.0756	-0.0755	-0.0201	-0.0209
0.7927	-0.5970	-0.5965	-0.8042	-0.8040	-0.0336	-0.0332	-0.0102	-0.0108
0.8335	-0.5518	-0.05510	-0.7000	-0.7008	-0.0274	-0.0277	-0.0086	-0.0091
0.8774	-0.5275	-0.5269	-0.5969	-0.5970	-0.0253	-0.0250	-0.0065	-0.0066
0.8984	-0.2127	-0.2125	-0.4402	-0.4400	-0.0199	-0.0192	-0.0047	-0.0041
1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Discussion:

Figures (1-2) explain that the experimental excess molar volumes V_{12}^E, for cyclohexane + 1- pentanol system are positive over the whole mole fraction range at 308.15, 318.15,

and 328.15 K .But at 298.15 K the system exhibite positive deviation from ideality at low mole fraction of 1-pentanol $0 < X_2 < 0.7$ and the deviation become negative at high mole fraction of 1-pentanol $0.7 < X_2 < 1.0$ for figure(2). The other system(cyclohexane + n-decane) shows, positive deviation from ideality at low mole fraction of n-decane $0 < X_2 < 0.75$ and the deviation become negative at high mole fractions $0.75 < X_2 < 1.0$ at 298.15, 308.15, 318.15 and 328.15 K fig.(1).

V_{12}^{E} become more and more positive with increasing the chain length of n- alkanes and alkanols and with decreasing the temperature. This suggests that the globular molecule cyclohexane disturbing the orientational order in n-alkanes and hydrogen bonding interaction in alkanols and result less packed structure. It seems that in addition to the above discussed molecular interactions, the size and the molar volume of n- alkanes and alkanols could increase the deviation from ideality with increasing the molar volumes of n- alkane and alkanols.

For all binary mixtures studied here, the researcher planned to predict the excess molar volumes at 298.15k of those mixtures from Flory theory[6-12]. Pure component liquid parameters table (2) and equations (1-2) and V_{12}^{E} were predicted and the results listed in table (4) with the experimental data and plotted as a function of mole fraction X_2 with experimental values for comparison, figures (3-4). The researcher observed poor agreement between the experimental values and the predicted ones for mixtures containing globular molecule cyclohexane. This explains that Flory theory did not take in account the shape of the molecules of hydrocarbons.

Excess refractive indices n^E, are positive over the entire composition range for all binary mixtures studied here at a four temperatures and the positive deviation from ideality increase when increasing the chain length of n- alkanes and alkanols and when increasing the temperature. In this study the researcher has attempted to test the validity of different refractive indices mixing rules. Good agreement was found between the experimental values of the refractive indices for all binary mixtures studied in this work and with predicted values using the equations of mixing rules, table(6).

Excess viscosities η_{12}^{E} are negative over the entire composition range for all binary mixtures studied at 298.15K, 308.15K, and 318.15K. The negative deviation from ideality decreases when increasing the chain length of n- alkanes and alkanols and when increasing the temperature figures (7-8). In 328.15K for cyclohexane + 1- pentanol η_{12}^{E} are positive from ideality at low mole fraction x_2 for 1- pentanol $0 < x_2 < 0.05$ becomes negative at high mole fractions x_2 figures (8).

Heric and Coursey equation[13] was used for prediction excess viscosities from experimental results of viscosities of mixture and pure components for all binary mixtures studied here at four temperatures. Table (8) shows the predicted values of excess viscosity from equation(4) with experimental values for comparison. The researcher observed good agreement between the experimental values and the predicted ones.

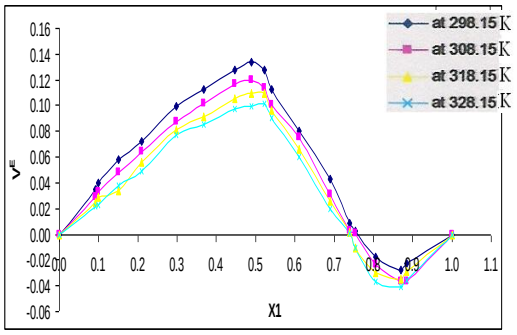


Fig.(1): Excess molar volumes V^E versus X_1 for cyclohexane + X_2 n-decane_at □298.15K, Δ308.15K, ○318.15K, and ◊328.15K.

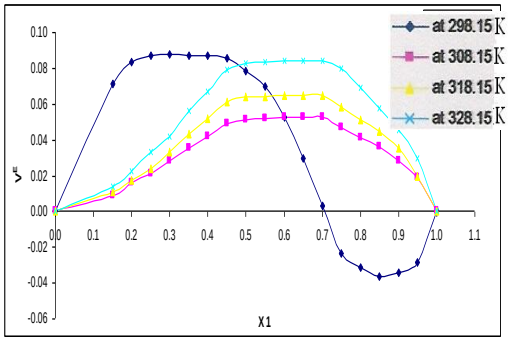


Fig.(2): Excess molar volumes V^E versus X_1 for cyclohexane + X_2 1-pentanol_at ◊298.15K, □308.15K, Δ318.15K, and ×328.15K.

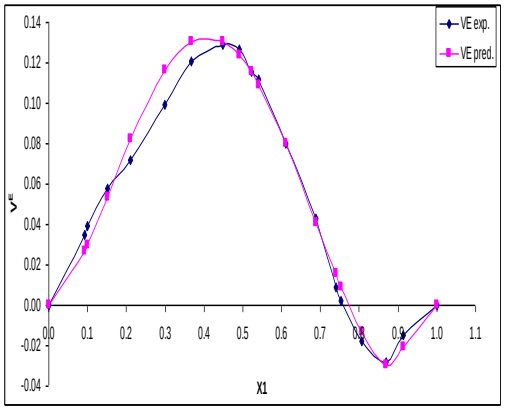


Fig.(3): Excess molar volumes v^E versus X_1 for cyclohexane.+ X_2 n-decane at 298.15K.

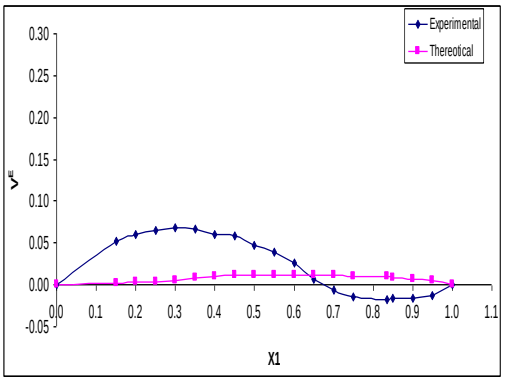


Fig. (4): Excess molar volumes v^E versus X_1 for cyclohexane.+ X_2 1-pentanol at 298.15K.

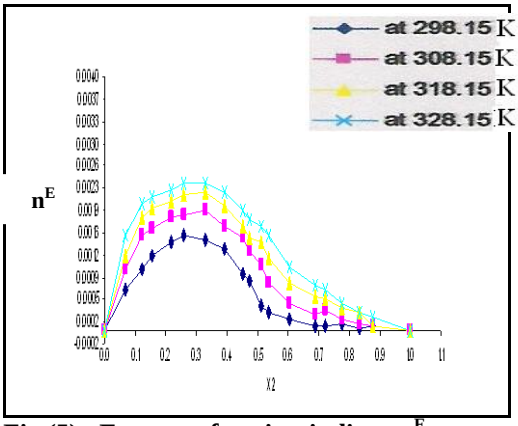


Fig.(5): Excess refractive indices n^E versus x_2 for x_1 cyclohexane + x_2 n-decane at ◊298.15K, □308.15K, Δ318.15K, and ×328.15K.

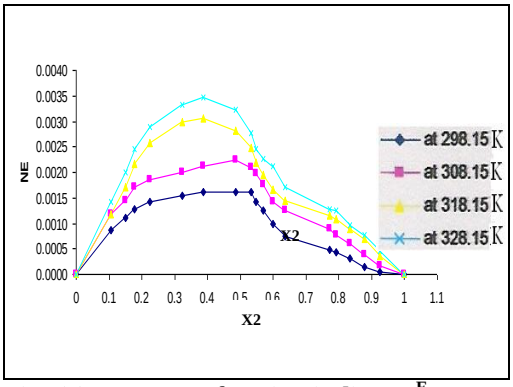
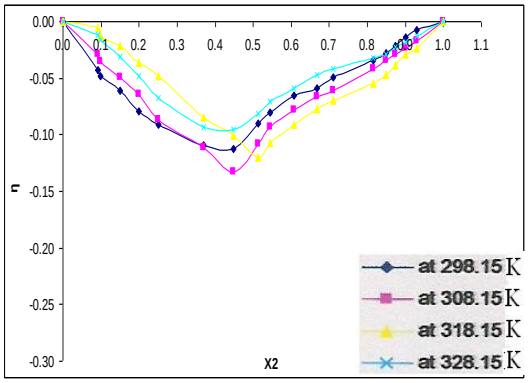
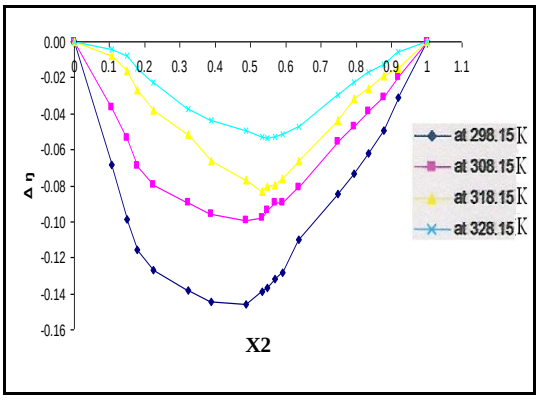


Fig. (6): Excess refractive indices n^E versus x_2 for x_1 cyclohexane + x_2 1-pentanol at ◊298.15K, □308.15K, Δ318.15K, and ×328.15K .



η_{12}^{E}

Fig.(7): Excess viscosities η_{12}^{E} versus x_2 for x_1 cyclohexane + x_2 n-decane at ◊298.15K, □308.15K, Δ318.15K, and ×328.15K.



η_{12}^{E}

Fig.(8): Excess viscosities η_{12}^{E} versus x_2 for x_1 cyclohexane + $x_2$1-pentanol at ◊298.15K, □308.15K, Δ318.15K, and ×328.15K.

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دراسة بعض الخواص الفيزيائية للنظام الثنائي للسايكلوهكسان مع n-decane و 1-pentanol عند درجات حرارية مختلفة

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الخلاصة :

تم قياس الكثافة ومعامل الانكسار واللزوجة للمخاليط الثنائية والتي تتضمن cyclohexane + n-decane و cyclohexane + 1-pentanol على مدى اربع درجات حرارية هي 298.15 و308.15 و 318.15 و 328.15 K على مدى جميع الكسور المولية المدروسة من نتائج العملية .

تم حساب الحجوم المولارية الفائضة V^E وتم تطبيق معادلة فلوري حيث تبين ان قيم V^E تراوحت بين القيم الموجبة والقيم السالبة على مدى جميع الكسور المولية وفي كل الدرجات الحرارية المدروسة .

تم حساب معامل الانكسار الفائض n^E واللزوجة الفائضة η^E وتم تطبيق معادلات الخلط ومعادلة Heric-Coursey على التوالي وقد وجد تطابقاً جيداً بين القيم النظرية والعملية للمخاليط المدروسة .

تم مناقشة الاختلاف في هذه الصفات التركيبية للمخاليط الثنائية مع درجات الحرارة من خلال التداخلات الجزيئية .