Some physical properties derived from density, refractive index and viscosity measurements for quaternary system of Cyclohexane with some n-alkanes and alcohols at different temperatures.

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Abstract

This study concerned with measurement the densities, ρ, refractive indices, n_D, and viscosities, η, over the range of temperatures 298.15, 308.15, 318.15, and 328.15K for quaternary mixtures cyclohexane+n-heptane+n-decane+n-hexane, and cyclohexane+1-pentanol+3-hexanol+n-hexane. From experimental data of densities, refractive indices, and viscosities, the excess molar volumes, V^E , excess refractive indices, n^E , and excess viscosities, η^E , were calculated for quaternary mixtures. The excess function results for these mixtures were observed rocking between positive and negative deviation from ideality depending on molecular interactions in these mixtures. The Flory theory has been extended for the theoretical prediction of excess molar volume of quaternary mixtures studied here depending on the pure component liquid parameters. .The theory predicted the volumetric behavior and magnitudes of V^E_{1234} well. Refractive indices for quaternary mixtures studied in this work can be predicted by using different refractive indices mixing rules , we found good agreement between the experimental and the predicted values of the refractive indices for the quaternary mixtures studied here. In this study Heric-Coursey equation was used to calculate the excess viscosities for ternary mixtures studied here. The theoretical results of excess viscosity exert good agreement with the experimental results of excess viscosity for these mixtures.

الخلاصة

تتضمن هذه الدراسة قياس الكثافة ومعامل الانكسار واللزوجة على مدى اربع درجات حرارية للمخاليط رباعية المكون والتي تتضمن cyclohexane+n-heptane+n-decane+n-hexane و cyclohexane+1-pentanol+3-hexanol+n-hexane ومن النتائج العملية لقياس الكثافة ومعامل الانكسار واللزوجة تم حساب الحجوم المولارية الفائضة V^E , معامل الانكسار الفائض n^E , واللزوجة الفائضة η^E للمخاليط الرباعية ومن نتائج الخواص الفائضة لهذه المخاليط أتضح أن المخاليط في هذه الدراسة تتأرجح بين الانحراف الموجب والسالب عن المثالية أعتماداًعلى التأثيرات الجزيئية (molecular interactions) بين مكونات هذه المخاليط . تم تطبيق نظرية فلوري لحساب الحجوم المولارية الفائضة للمخاليط الرباعية المكون وقد أظهرت القيم النظرية للحجوم المولارية الفائضة تطابقاً عالياً مع الحجوم المولارية الفائضة المحسوبة عملياً لهذه المخاليط

في الاشارة والقيمة . طبقت معادلات الخلط (mixing rules) لحساب معامل الانكسار نظرياً وقد وجد تطابقاً كبير على مدى الكسر المولي . معادلة (Heric – Coursey) تم استخدامها لحساب اللزوجة الفائضة وأظهرت النتائج تطابقاً جيداً بين القيم النظرية والعملية للمخاليط المدروسة .

Introduction

Acknowledgement of chemical and physical properties of pure liquids and their mixtures is important both academically and industrially. Many industrial processes use mixtures of solvents and knowledge of the subject area is critical to the efficient utilization-preparation development and economic design of appropriate equipment for these processes are only possible if the chemical and physical properties of the solvent or substances to be processed are known. For this reason, many attempts have been made to correlate these data using semi-empirical or theoretical approaches considerable programs have also been made in the development of statistical theories. The calculation of physical properties using statistical theories is still not yet possible for complicated molecules such as long chain molecules, because of the range of different conformations, which can occur and the effect of these various structures on the intermolecular interactions[1] .The intensive properties may include density, viscosity (or fluidity), refractive index, speed of sound and relative permittivity. The practical studies of quaternary mixtures reveal the importance of molecular interactions (hydrogen bonding, charge-transfer complexes, dipole- dipole, dipole-induced dipole, interstitial accommodate chain alignment …etc.) on the physical properties of these mixtures [2] . Knowledge of the mixing properties are useful in design and simulation processes, in the synthesis of pharmaceuticals, lacquers, resins, polymers, oxygenated fuels, and paint[3,4] . Some of these properties are density, reflective index, and viscosity.Recently, few equations for estimating the excess thermodynamic and other physicochemical properties of multicomponent systems from the observed properties of their various contributory of the components has been developed and applied to various multicomponent liquid systems [5,6]. Computer-stimulated calculations and neutron-scattering experiments [7] have been insight into the relations between molecular structure and macroscopic behavior. Considerable progress has also been made in the development statistical theories over recent years [8]. The calculation of physical properties using a computer statistical theory is still not yet possible for complicated molecules such as long-chain hydrocarbons, because of the range of different conformationswhich can occur and the effects of there various structures on the intermolecular interactions [9].

Experimental

(a)Materials:

All the chemicals used were supplied by Fluka AG (Buchs , Switzerland) and Aldrich Chemical Company Inc.(Milwaukee , U.S.A) . The purities of all substances were better than 99.95 mass% as found by GLC analysis . The purity of the chemicals was checked by comparing the densities , refractive indices and viscosities of the components with those reported in the literature[10-14].

(b)Measurements :

1- Densities Measurements

Densities were measured at 298.15 ,308.15 ,318.15 and 328.15K with an Anton Paar digital densimeter (Model DMA 60/601) and controlled thermostatically with a precision of ± 0.0 1 K by a (HAKKE- D1-G) temperature controller . Densities were measured with a precision of $2x10^{-5}g.cm^{-3}$. The maximum uncertainty in the excess molar volumes is expected to be less than $3x10^{-3}$ $cm^3.mol^{-1}$.

2-Refractive Indices Measurements.

Refractive index, of the pure component liquids and quaternary mixtures were measured at 298.15 ,308.15 ,318.15 and 328.15K using an Abbe refractometer (Tafesa) by the reflection method using sodium line (λ = 5893 Aº) with a precision of the reading of ± 0.0002. In all refractive indices measurements, the temperature was kept constant with in ± 0.01 K using as chott – Gerate (T1150) thermostat water bath, and a Hewlett – Packard model 201 a quartz thermometer.

3-Viscosities Measurements *:*

In the present work, the viscosity (η) of the solutions was measured using (Cannon- Ubbelohde semi Micro) viscometer. This viscometer had an approximate constant (0.0078 at 298.15 K, 0.0075 at 308.15 K, 0.0069 at 318.15K, and 0.0065 at 328.15K centistokes/second), a capillary length is about (8cm) and diameter about (0.36 mm). The relationship used to obtain the absolute viscosity of liquid was:-

$\eta_{(cp)} = c.t.\rho$ …….. [1]

Where (c)the viscosity constant,(t) the flow time and(ρ)represents the density ($g.cm^{-3}$).

The temperature of the solution was brought to the desired value by immersing the test viscometer in a controlled temperature water bath with a precision of ± 0.01 K. A temperature regulation called (Temp- Unite) type (Kottermann) was used.

Results :

Experimental results of the densities, ρ_m of the quaternary mixtures cyclohexane + n- heptane + n- decane + n – hexane and cyclohexane + 1-pentanol + 3- hexanol + n-hexane at (298.15, 308.15, 318.15, and 328.15K) are listed in Table (1).

The excess molar volumes for quaternary mixtures studied here were calculated from the measured densities using the following equation [15] :

$$V^{E}_{1234}/(cm^3.mol^{-1}) = [\frac{x_1M_1 + x_2M_2 + x_3M_3 + x_4M_4}{\rho_m}] - [x_1\frac{M_1}{\rho_1} + x_2\frac{M_2}{\rho_2} + x_3\frac{M_3}{\rho_3} + x_4\frac{M_4}{\rho_4}] \ldots\ldots\ldots [2]$$

where $x_{(1,2,3,4)}M_{(1,2,3,4)}$ and $\rho_{(1,2,3,4)}$ are respectively the mole fraction molar mass and density of the pure component liquid $_{(1,2,3,4)}$, ρ_m is the density mixture. The obtained results of V^{E}_{1234} are listed in Table (3) and plotted as a function of the mole fraction x_1, x_2, x_3 and x_4 for the four components at four temperatures in Figures (1 and 2).

The statistical concept of Flory theory has been extended for the theoretical prediction of excess molar volume of the quaternary mixture assuming two body interactions [16]. The excess molar volumes (V^E) calculated directly from characteristic and reduced volumes and the segment fraction using thermal expansion coefficient (α) of the pure four component liquids, and using the equation:

$$V^{E} = (x_1 V_1^* + x_2 V_2^* + x_3 V_3^* + x_4 V_4^*)[\tilde{V} - (\phi_1 \tilde{V}_1 + \phi_2 \tilde{V}_2 + \phi_3 \tilde{V}_3 + \phi_4 \tilde{V}_4)] \ldots\ldots\ldots [3]$$

where ϕ_1, ϕ_2, ϕ_3 and ϕ_4 are the segment fractions of components 1, 2, 3, and 4 and defined by the relations:

$$\phi_1 = (1 - \phi_2 - \phi_3 - \phi_4) \ldots\ldots [4]$$

$$\varphi_2 = x_2 / [x_2 + x_3 (\frac{V_3^*}{V_2^*}) + x_4 (\frac{V_4^*}{V_2^*}) + x_1 (\frac{V_1^*}{V_2^*})] \ldots\ldots [5]$$

$$\phi_3 = x_3 / [x_3 + x_4 (\frac{V_4^*}{V_3^*}) + x_1 (\frac{V_1^*}{V_3^*}) + x_2 (\frac{V_2^*}{V_3^*})] \ldots\ldots [6]$$

$$\phi_4 = x_4 / [x_4 + x_1 (\frac{V_1^*}{V_4^*}) + x_2 (\frac{V_2^*}{V_4^*}) + x_3 (\frac{V_3^*}{V_4^*})] \ldots\ldots [7]$$

$\tilde{V}$ in equation (3) is the reduced volume of quaternary mixture which is obtained by the following equation:

$$\tilde{V} = V / x_1 V_1^* + x_2 V_2^* + x_3 V_3^* + x_4 V_4^* \ldots\ldots\ldots [8]$$

where V is the molar volume of the mixture, given by :

$$V = (x_1 M_1 + x_2 M_2 + x_3 M_3 + x_4 M_4) / \rho_m \ldots\ldots\ldots [9]$$

where ρ_m is the density of the mixture.

By using the equation of state parameters of pure liquids, Table (2) and applied equations (3-9) , we calculated the excess molar volumes for the quaternary mixtures studied here. Table (3) present the theoretical prediction of V^E values at 298.15K with experimental values for comparison for quaternary mixtures studied here. The maximum percent average deviation is less than 0.94%, which means that Flory theory for predicting the excess molar volumes of quaternary mixtures studied here is quite reasonable, as evident from this excellent agreement in both sign and magnitude.

Table(1)Experimental values of the densities (ρ) for q̄uaternary mixtures at four temperatures

x_1 Cyclohexane + x_2 n- Heptane + x_3 n- Decane + x_4 n- Hexane

x_1	x_2	x_3	ρ ($g.cm^{-3}$) 298.15k	ρ ($g.cm^{-3}$) 308.15k	ρ ($g.cm^{-3}$) 318.15k	ρ ($g.cm^{-3}$) 328.15k
0.2924	0.4670	0.1867	0.90563	0.90629	0.90668	0.90710
0.2761	0.3160	0.3381	1.23962	1.24065	1.24120	1.24164
0.2608	0.1613	0.4911	1.85765	1.86001	1.86114	1.86290
0.1564	0.0120	0.7302	5.09107	5.10352	5.11458	5.11685
0.0369	0.0902	0.7605	6.37168	6.37903	6.38255	6.39606
0.7903	0.0396	0.0086	0.74877	0.74883	0.74890	0.74904
0.6681	0.0331	0.0162	0.88566	0.88575	0.88591	0.88615
0.5088	0.0245	0.0256	1.16165	1.16186	1.16270	1.16341
0.3524	0.0160	0.0351	1.67254	1.67325	1.67457	1.67690
0.1814	0.0088	0.0453	3.18281	3.18770	3.19267	3.19950
0.3452	0.1451	0.3594	1.52317	1.52386	1.52486	1.52616
0.4255	0.0646	0.2784	1.46712	1.46721	1.46826	1.46910
0.3229	0.1751	0.1792	1.34788	1.34847	1.34867	1.34910
0.3977	0.1037	0.1033	1.28510	1.28558	1.28569	1.28587
0.4381	0.0655	0.0718	1.25721	1.25770	1.25823	1.25826
0.0751	0.1776	0.3567	2.75934	2.76155	2.76480	2.76562
0.1200	0.1342	0.4309	2.89263	2.89513	2.89676	2.89833
0.1614	0.0933	0.3156	2.74938	2.75007	2.75306	2.75430
0.2871	0.0513	0.1017	1.87513	1.87660	1.87734	1.87806

x_1 Cyclohexane + x_2 1- Pentanol + x_3 3- Hexanol + x_4 n- Hexane

x_1	x_2	x_3	ρ ($g.cm^{-3}$) 298.15k	ρ ($g.cm^{-3}$) 308.15k	ρ ($g.cm^{-3}$) 318.15k	ρ ($g.cm^{-3}$) 328.15k
0.0347	0.2069	0.0814	0.80598	0.80628	0.80631	0.80657
0.0506	0.3574	0.0660	0.82705	0.82668	0.82683	0.82690
0.0676	0.5103	0.0497	0.84783	0.84803	0.84803	0.84827
0.0821	0.6597	0.0354	0.86906	0.87074	0.87074	0.87098
0.0922	0.7827	0.0258	0.89063	0.89096	0.89101	0.89142
0.1614	0.0139	0.7942	0.88690	0.88673	0.88686	0.88723
0.2845	0.0143	0.6770	0.84064	0.84047	0.84062	0.84078
0.5419	0.0148	0.5177	0.78253	0.78248	0.78255	0.78266
0.0623	0.0306	0.3337	0.72669	0.72670	0.72682	0.72679
0.7747	0.0335	0.1877	0.68248	0.68248	0.68257	0.68260
0.1312	0.3785	0.1341	0.82702	0.82706	0.82702	0.82726
0.2123	0.2932	0.2188	0.81315	0.81329	0.81331	0.81339
0.3035	0.1984	0.3118	0.79841	0.79859	0.79846	0.79845
0.3761	0.1225	0.3866	0.78746	0.78759	0.78749	0.78743
0.4354	0.0610	0.4470	0.77886	0.77896	0.77890	0.77879
0.1557	0.5865	0.0681	0.84595	0.84611	0.84606	0.84603
0.2965	0.4543	0.1039	0.80199	0.80216	0.80222	0.80206
0.4105	0.3348	0.1053	0.77214	0.77225	0.77236	0.77218
0.5307	0.2120	0.1969	0.74169	0.74172	0.74183	0.74147

Table (2) Parameters for the pure liquids according to the Flory Theory at 298.15k. * references [17-22]

Liquid	V	V^*	$\tilde{V}$	T^*	$\tilde{T}$	$P^*/J.cm^{-3}$ *	$\alpha \times 10^{-3}/k^{-1}$ *	$S/A^{\circ -1}$ *
Cyclohexane	108.774	84.282	1.291	4717.56	0.0632	530	1.217	0.93
n- hexane	131.554	99.549	1.323	4430.16	0.0673	423	1.391	1.04
n-heptane	147.480	104.191	1.297	4653.00	0.0640	432	1.235	1.02
n-decane	196.014	155.826	1.258	5096.58	0.0585	448	1.050	0.96
1- pentanol	115.9105	91.846	1.262	5331.17	0.0559	412	0.905	0.97
3- hexanol	125.827	101.448	1.240	5428.06	0.0549	426	0.948	0.99

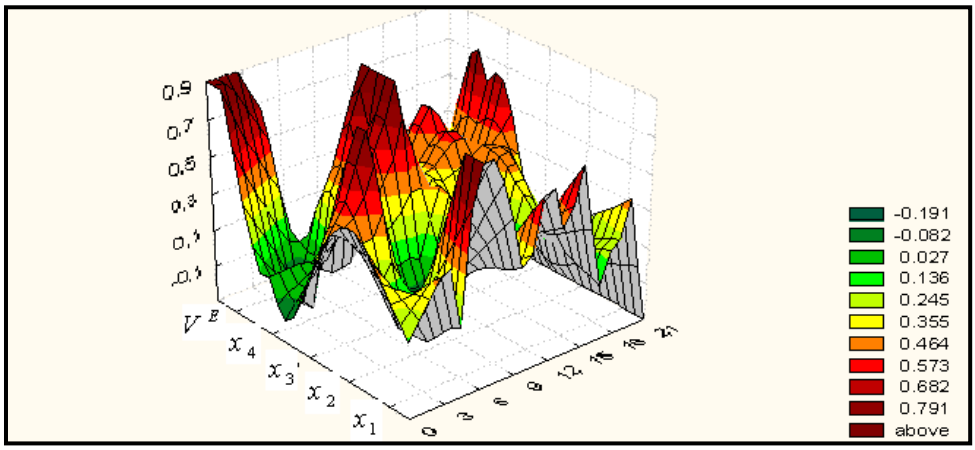
Table(3): Experimental and theoretical prediction of V^E for quaternary mixtures

x_1 Cyclohexane + x_2 n- Heptane + x_3 n- Decane + x_4 n- Hexane

x_1	x_2	x_3	$V^E_{exp.}$ ($cm^3.mol^{-1}$) 298.15k	$V^E_{pred.}$ ($cm^3.mol^{-1}$) 298.15k	V^E_{1234} ($cm^3.mol^{-1}$) 308.15k	V^E_{1234} · ($cm^3.mol^{-1}$) 318.15k	V^E_{1234} ($cm^3.mol^{-1}$) 328.15k
0.2924	0.4670	0.1867	0.6972	0.4883	0.6145	0.5653	0.5120
0.2761	0.3160	0.3381	0.5211	0.5398	0.4481	0.4092	0.3774
0.2608	0.1613	0.4911	0.3915	0.3303	0.3123	0.2746	0.2157
0.1564	0.0120	0.7302	0.2468	-0.0695	0.1859	0.1320	0.1210
0.0369	0.0902	0.7605	0.1184	0.0784	0.0949	0.0837	0.0407
0.7903	0.0396	0.0086	-0.0810	0.0245	-0.0917	-0.1023	-0.1242
0.6681	0.0331	0.0162	-0.1061	0.0166	-0.1152	-0.1330	-0.1595
0.5088	0.0245	0.0256	-0.1282	-0.0108	-0.1413	-0.1954	-0.2411
0.3524	0.0160	0.0351	-0.1409	-0.0389	-0.1630	-0.2041	-0.2762
0.1814	0.0088	0.0453	-0.1977	-0.0441	-0.2398	-0.2824	-0.3408
0.3452	0.1451	0.3594	-0.1231	0.2492	-0.1552	-0.2018	-0.2620
0.4255	0.0646	0.2784	-0.0962	-0.0393	-0.1002	-0.1500	-0.1901
0.3229	0.1751	0.1792	0.1391	0.1946	0.1072	0.0963	0.0734
0.3977	0.1037	0.1033	0.1425	0.0582	0.1155	0.1092	0.0992
0.4381	0.0655	0.0718	0.1613	0.0045	0.1329	0.1031	0.1009
0.0751	0.1776	0.3567	0.2076	0.2144	0.1762	0.1294	0.1187
0.1200	0.1342	0.4309	0.1569	0.1487	0.1237	0.1020	0.0811
0.1614	0.0933	0.3156	0.1015	0.0269	0.0919	0.0508	0.0337
0.2871	0.0513	0.1017	0.0945	-0.0466	0.0563	0.0370	0.0182

x_1 Cyclohexane + x_2 1- Pentanol + x_3 3- Hexanol + x_4 n- Hexane

x_1	x_2	x_3	$V^E_{exp.}$ ($cm^3.mol^{-1}$) 298.15k	$V^E_{pred.}$ ($cm^3.mol^{-1}$) 298.15k	V^E_{1234} ($cm^3.mol^{-1}$) 308.15k	V^E_{1234} ($cm^3.mol^{-1}$) 318.15k	V^E_{1234} ($cm^3.mol^{-1}$) 328.15k
0.0347	0.2069	0.0814	0.0020	-0.1079	-0.0373	-0.0412	-0.0769
0.0506	0.3574	0.0660	0.0084	0.0200	0.0549	0.0362	0.0273
0.0676	0.5103	0.0497	0.1649	0.2100	0.1411	0.1407	0.1123
0.0821	0.6597	0.0354	0.4087	0.2846	0.2133	0.2132	0.1862
0.0922	0.7827	0.0258	0.3295	0.1807	0.2928	0.2877	0.2428
0.1614	0.0139	0.7942	0.3795	0.1020	0.4010	0.3836	0.3373
0.2845	0.0143	0.6770	0.2562	0.1131	0.2789	0.2582	0.2361
0.5419	0.0148	0.5177	0.0916	0.0619	0.0993	0.0884	0.0716
0.0623	0.0306	0.3337	-0.0861	-0.0439	-0.0865	-0.1071	-0.1034
0.7747	0.0335	0.1877	-0.2287	-0.0821	-0.2286	-0.2471	-0.2521
0.1312	0.3785	0.1341	0.2472	0.2075	0.2415	0.2470	0.2150
0.2123	0.2932	0.2188	0.2449	0.2926	0.2259	0.2239	0.2130
0.3035	0.1984	0.3118	0.2296	0.3239	0.2043	0.2232	0.2245
0.3761	0.1225	0.3866	0.2167	0.2711	0.1968	0.2123	0.2211
0.4354	0.0610	0.4470	0.2105	0.1634	0.1936	0.2038	0.2200
0.1557	0.5865	0.0681	0.3909	0.3679	0.3713	0.3778	0.3804
0.2965	0.4543	0.1039	0.3048	0.3949	0.2817	0.2729	0.2952
0.4105	0.3348	0.1053	0.0874	0.1672	0.0719	0.0544	0.0810
0.5307	0.2120	0.1969	0.1401	-0.0781	0.1355	0.1180	0.1755



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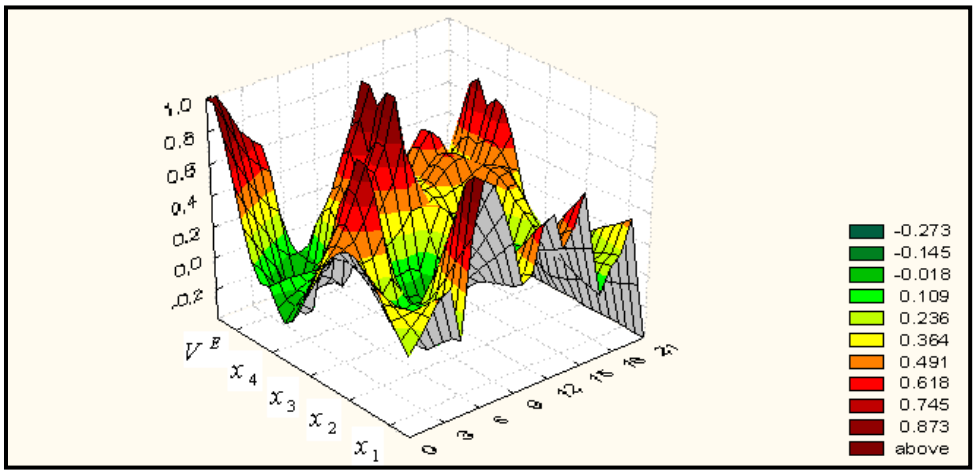

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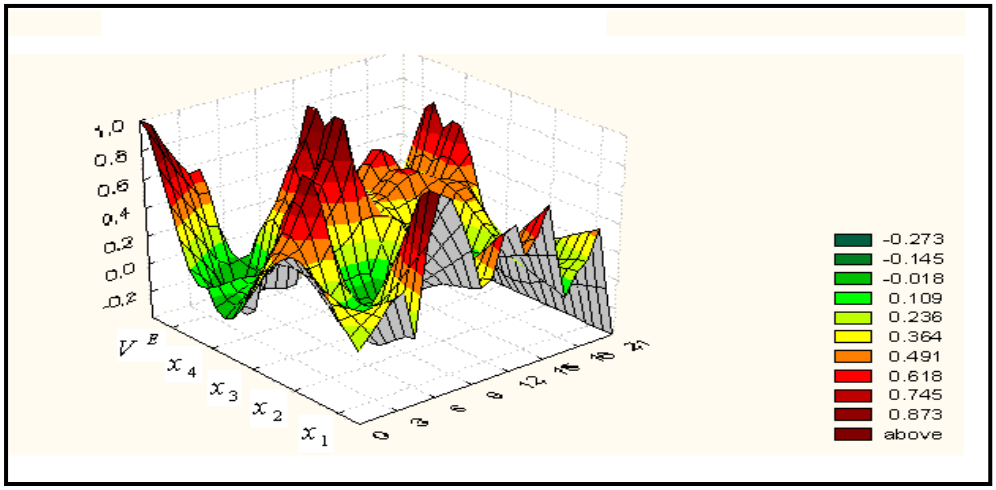

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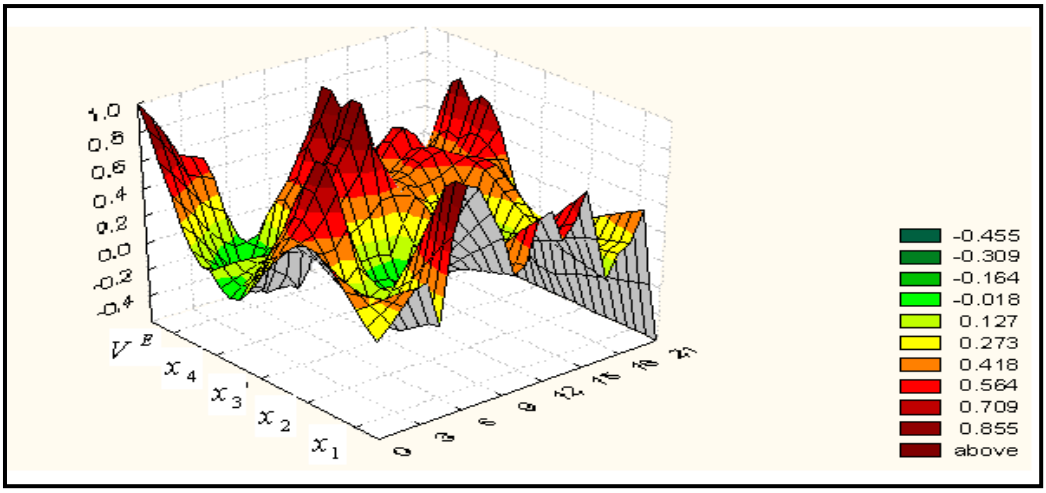
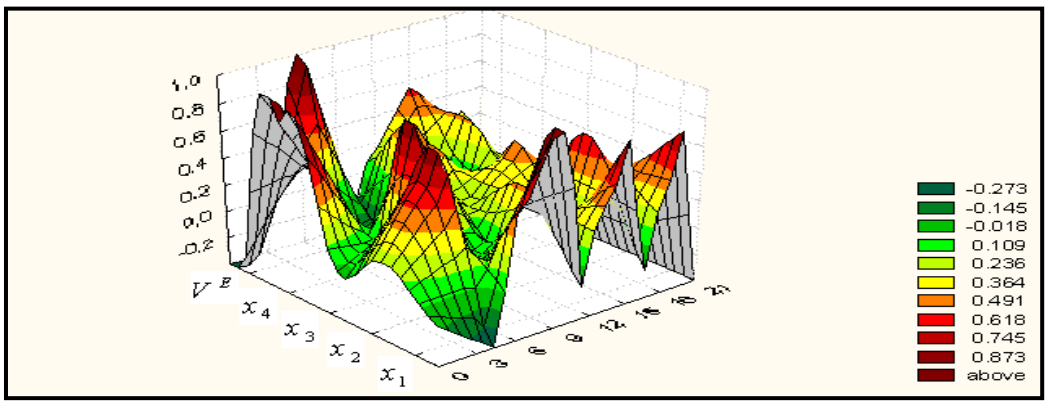


(d)

Figure (1) Excess molar volumes$V^E_{1234}$for quaternary system versus X_1 cyclohexane + X_2 n-heptane + X_3 n-decane + X_4 n-hexane at (a) 298.15k, (b) 308.15k, (c) 318.15k, and (d) 328.15k.



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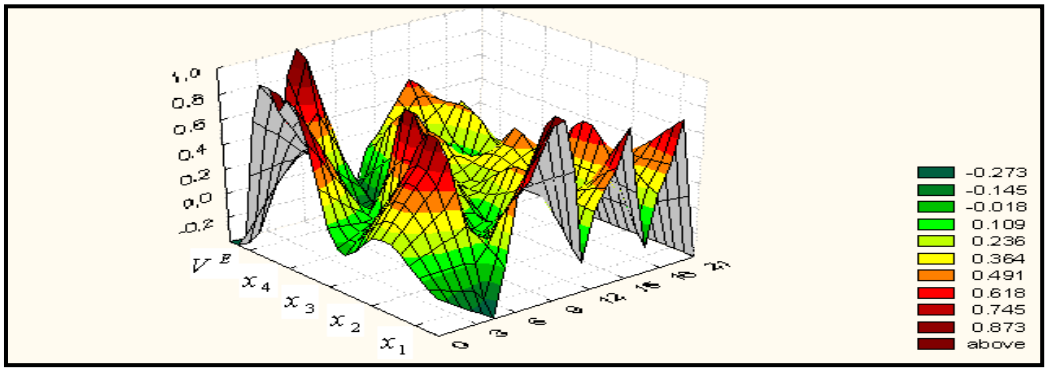

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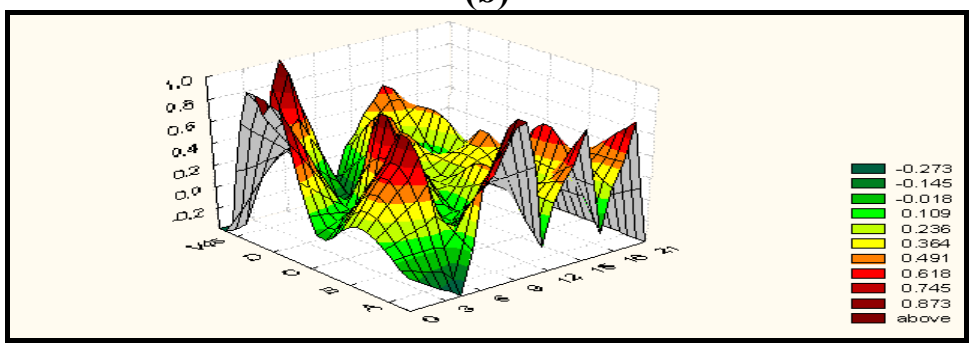
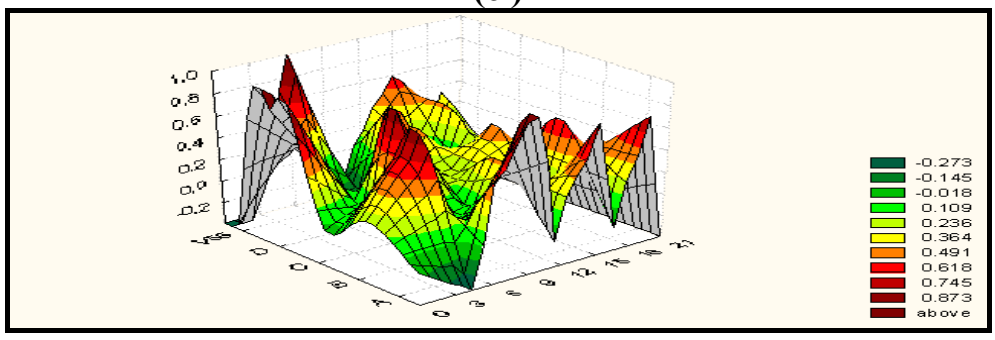


(c)



(d)

Figure (2) Excess molar volumes V^E_{1234} for quaternary system versus X_1 cyclohexane + X_2 1-pentanol + $X_3$3-hexanol + X_4 n-hexane at (a) 298.15k, (b) 308.15k, (c) 318.15k, and (d) 328.15k.

Experimental results of refractive indices of quaternary mixtures studied here at (298.15, 308.15, 318.15, and 328.5K) are listed in Table (4).

Excess refractive indices for quaternary mixtures at 298.15, 308.15,318.15, and 328.5K were calculated from measurements of the refractive indices of the mixture and the pure liquids by equation (10) [23].

$$n^E = n_{D,m} - \sum_{s=i,i,k}^{m} x_s n_{D,S} \text{.....[10]}$$

The obtained results are listed in Table (5) and plotted as a function of mole fraction, x_1, x_2, x_3, and x_4 for the four components at four temperatures in Figures (3 and 4).

Many equations were proposed using mixing rules for the analysis of the data for quaternary mixtures. In order to check their validity, the measured refractive indices of mixtures were compared with that calculated from different equations . Arago and Biot [24] attempts to describe the refractive properties of the solutions using the following equation:

$n = \phi_1 n_1 + \phi_2 n_2$……..[11]

where n, n_1 and n_2 are the refractive indices of mixtures component 1, and 2 , respectively, and ϕ_1 and ϕ_2 are the volume fraction of the respective components in the mixture.

Gladstone and Dale [24] formulated the following relation:

$n-1 = \phi_1(n_1-1) + \phi_2(n_2-1)$……[12]

This may be reduced to equation (11) if one assumers volume additively (no change in volume on mixing). Lorentz and Lorenz [24] gave more commonly used mixing rule in the analysis of refractive index:

$$\frac{n^2-1}{n^2+2} = \phi_1\left[\frac{n_1^2-1}{n_1^2+2}\right] + \phi_2\left[\frac{n_2^2-1}{n_2^2+2}\right]$$

……[13]

Wiener [24] derived an equation that may be applied to isotropic bodies of spherical and symmetrical shape and that is valid for binary system is volume additively is assumed.

$$\frac{n^2-n_1^2}{n^2+2n_1^2} = \phi_2\left[\frac{n^2-n_1^2}{n^2+2n_1^2}\right] \text{...[14]}$$

Helaler et al [24]derived an equation by summing the equivalent of the light scattering equations of Debye and Kayleigh, in the form:

$$\frac{n-n_1}{n_1} = \frac{3}{2}\phi_2\left[\frac{(n_2/n_1)-1}{(n_2/n_1)+2}\right] \text{...[15]}$$

the calculated refractive indices from these equations are listed in Table (6) for quaternary mixtures studied have at 298.15, 308.15, 318.15 and 328.15K. We found good agreement between the experimented data and the calculated.

Table (4) Experimental values of the refractive indices (n_D) for quaternary mixtures at 298.15, 308.15, 318.15 and 328.15K.

x_1 Cyclohexane + x_2 n- Heptane + x_3 n- Decane + x_4 n- Hexane

x_1	x_2	x_3	n_D	n_D	n_D	n_D
			298.15K	308.15K	318.15K	328.15K
.2924	0.4670	0.1867	1.4015	1.4005	1.3995	1.3985
0.2761	0.3160	0.3381	1.3995	1.3980	1.3970	1.3915
0.2608	0.1613	0.4911	1.3980	1.3975	1.3960	1.3955
0.1564	0.0120	0.7302	1.3960	1.3950	1.3940	1.3925
0.0369	0.0902	0.7605	1.3950	1.3935	1.3925	01.391
0.7903	0.0396	0.0086	1.3920	1.3900	1.3895	01.388
0.6681	0.0331	0.0162	1.3895	1.3880	1.3865	1.3845
0.5088	0.0245	0.0256	1.3880	1.3860	1.3845	1.3825
0.3524	0.0160	0.0351	1.3870	1.3855	1.3835	01.381
0.1814	0.0088	0.0453	1.3840	1.3825	1.3815	1.3805
0.3452	0.1451	0.3594	1.3865	1.3850	1.3835	1.3795
0.4255	0.0646	0.2784	1.3880	1.3865	1.3855	1.3785
0.3229	0.1751	0.1792	1.3895	1.3875	1.3870	01.376
0.3977	0.1037	0.1033	1.3910	1.3900	1.3890	1.3745
0.4381	0.0655	0.0718	1.3935	1.3910	1.3900	01.373
0.0751	0.1776	0.3567	1.3970	1.3935	1.3910	01.372
0.1200	0.1342	0.4309	1.3995	1.3955	1.3925	1.3715
0.1614	0.0933	0.3156	1.4015	1.3975	1.3945	1.3705
0.2871	0.0513	0.1017	1.4030	1.3990	1.3965	1.3695

Cyclohexane + x_2 1- Pentanol + x_3 3- Hexanol + x_4 n- Hexane

x_1	x_2	x_3	n_D	n_D	n_D	n_D
			298.15K	308.15K	318.15K	328.15K
0.0347	0.2069	0.0814	1.4060	1.4020	1.3985	1.3905
0.0506	0.3574	0.0660	1.4020	1.3980	1.3940	1.3862
0.0676	0.5103	0.0497	1.3980	1.3940	1.3892	1.3820
0.0821	0.6597	0.0354	1.3940	1.3900	1.3850	1.3780
0.0922	0.7827	0.0258	1.3910	1.3870	1.3810	1.3740
0.1614	0.0139	0.7942	1.3900	1.3850	1.3780	1.3715
0.2845	0.0143	0.6770	1.3850	1.3800	1.3730	1.3660
0.5419	0.0148	0.5177	1.3780	1.3730	1.3665	1.3590
0.0623	0.0306	0.3337	1.3710	1.3660	1.3600	1.3515
0.7747	0.0335	0.1877	1.3820	1.3785	1.3728	1.3640
0.1312	0.3785	0.1341	1.3860	1.3800	1.3745	1.3660
0.2123	0.2932	0.2188	1.3885	1.3850	1.3800	1.3725
0.3035	0.1984	0.3118	1.3900	1.3880	1.3820	1.3745
0.3761	0.1225	0.3866	1.3920	1.3885	1.3827	1.3750
0.4354	0.0610	0.4470	1.3930	1.3895	1.3835	1.3760
0.1557	0.5865	0.0681	1.4015	1.3993	1.3940	1.3868
0.2965	0.4543	0.1039	1.4030	1.4000	1.3945	1.3870
0.4105	0.3348	0.1053	1.4045	1.4015	1.3952	1.3875
0.5307	0.2120	0.1969	1.4050	1.4020	1.3960	1.3880

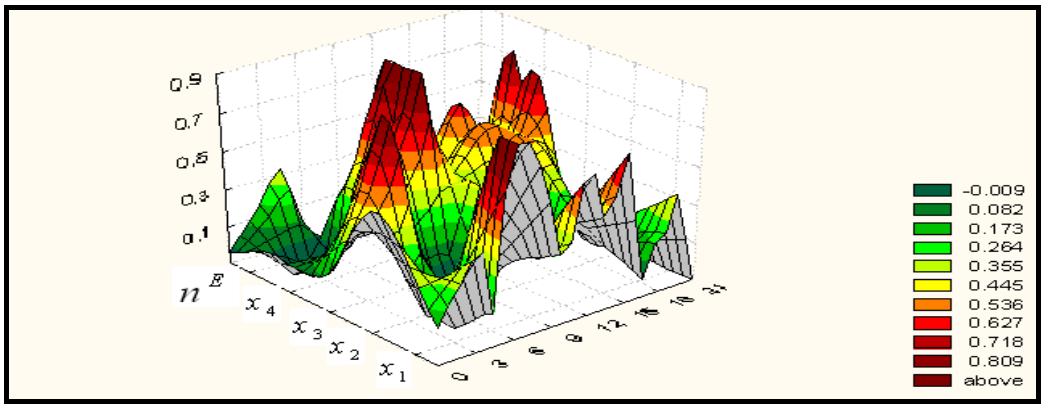
Table(5): Experimental values of excess refractive indices (n^E) for quaternary mixtures at 298.15, 308.15, 318.15,and 328.15K.

x_1 Cyclohexane + x_2 n- Heptane + x_3 n- Decane + x_4 n- Hexane

x_1	x_2	x_3	n^E	n^E	n^E	n^E
			298.15K	308.15K	318.15K	328.15K
.2924	0.4670	0.1867	0.0142	0.0150	0.0206	0.0258
0.2761	0.3160	0.3381	0.0084	0.0087	0.0142	0.0152
0.2608	0.1613	0.4911	0.0031	0.0044	0.0093	0.0155
0.1564	0.0120	0.7302	-0.0052	-0.0048	0.0007	0.0059
0.0369	0.0902	0.7605	-0.0087	-0.0090	-0.0032	0.0015
0.7903	0.0396	0.0086	0.0098	0.0109	0.0150	0.0225
0.6681	0.0331	0.0162	0.0008	0.0026	0.0052	0.0122
0.5088	0.0245	0.0256	-0.0090	-0.0077	-0.0056	0.0012
0.3524	0.0160	0.0351	-0.0183	-0.0163	-0.0153	-0.0090
0.1814	0.0088	0.0453	-0.0303	-0.0281	-0.0267	-0.0191
0.3452	0.1451	0.3594	-0.0073	-0.0067	-0.0024	0.0008
0.4255	0.0646	0.2784	-0.0065	-0.0055	-0.0015	-0.0005
0.3229	0.1751	0.1792	-0.0080	-0.0074	-0.0031	-0.0064
0.3977	0.1037	0.1033	-0.0070	-0.0051	-0.0019	-0.0082
0.4381	0.0655	0.0718	-0.0046	-0.0040	-0.0011	-0.0096
0.0751	0.1776	0.3567	-0.0096	-0.0109	-0.0083	-0.0204
0.1200	0.1342	0.4309	-0.0050	-0.0069	-0.0045	-0.0185
0.1614	0.0933	0.3156	-0.0048	-0.0063	-0.0047	-0.0212
0.2871	0.0513	0.1017	-0.0029	-0.0037	-0.0027	-0.0214

x_1 Cyclohexane + x_2 1- Pentanol + x_3 3- Hexanol + x_4 n- Hexane

x_1	x_2	x_3	n^E	n^E	n^E	n^E
			298.15K	308.15K	318.15K	328.15K
0.0347	0.2069	0.0814	-0.0121	-0.0126	-0.0130	-0.0133
0.0506	0.3574	0.0660	-0.0123	-0.0131	-0.0134	-0.0138
0.0676	0.5103	0.0497	-0.0126	-0.0137	-0.0142	-0.0142
0.0821	0.6597	0.0354	-0.0843	-0.0855	-0.0855	-0.0852
0.0922	0.7827	0.0258	-0.0132	-0.0148	-0.0153	-0.0158
0.1614	0.0139	0.7942	-0.0154	-0.0175	-0.0176	-0.0183
0.2845	0.0143	0.6770	-0.0156	-0.0177	-0.0181	-0.0187
0.5419	0.0148	0.5177	-0.1396	-0.1415	-0.1413	-0.1408
0.0623	0.0306	0.3337	0.7543	0.7505	0.7475	0.7416
0.7747	0.0335	0.1877	-0.0077	-0.0082	-0.0084	-0.0087
0.1312	0.3785	0.1341	-0.0228	-0.0258	-0.0268	-0.0281
0.2123	0.2932	0.2188	-0.0166	-0.0171	-0.0172	-0.0175
0.3035	0.1984	0.3118	-0.0109	-0.0100	-0.0107	-0.0110
0.3761	0.1225	0.3866	-0.0057	-0.0062	-0.0063	-0.0068
0.4354	0.0610	0.4470	-0.0020	-0.0026	-0.0026	-0.0029
0.1557	0.5865	0.0681	0.1397	0.1397	0.1393	0.1382
0.2965	0.4543	0.1039	0.0067	0.0064	0.0061	0.0059
0.4105	0.3348	0.1053	0.0730	0.0727	0.0714	0.0710
0.5307	0.2120	0.1969	0.0145	0.0143	0.0138	0.0136



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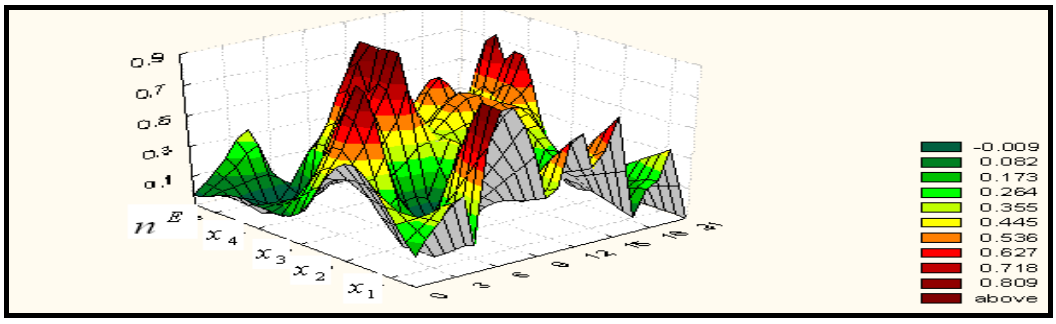

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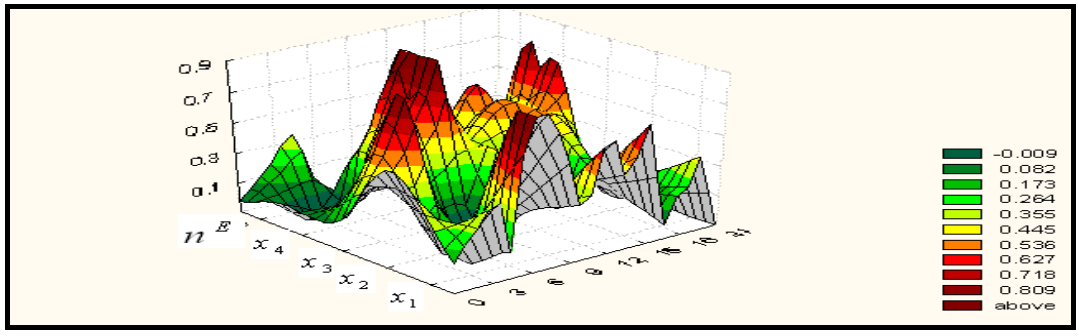

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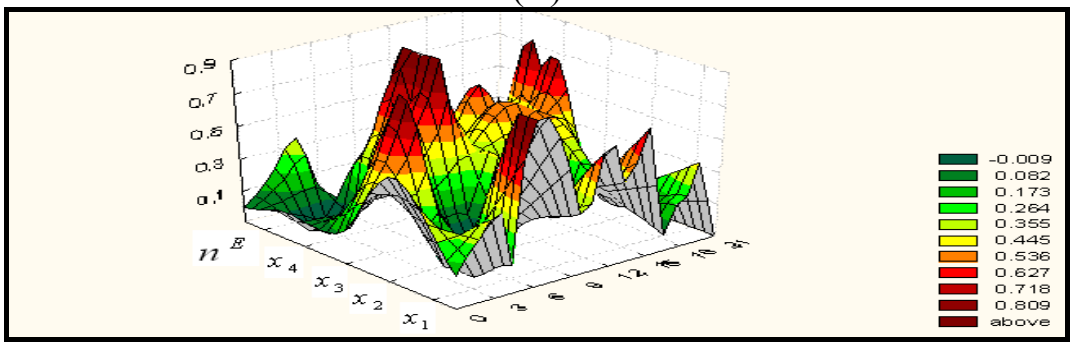
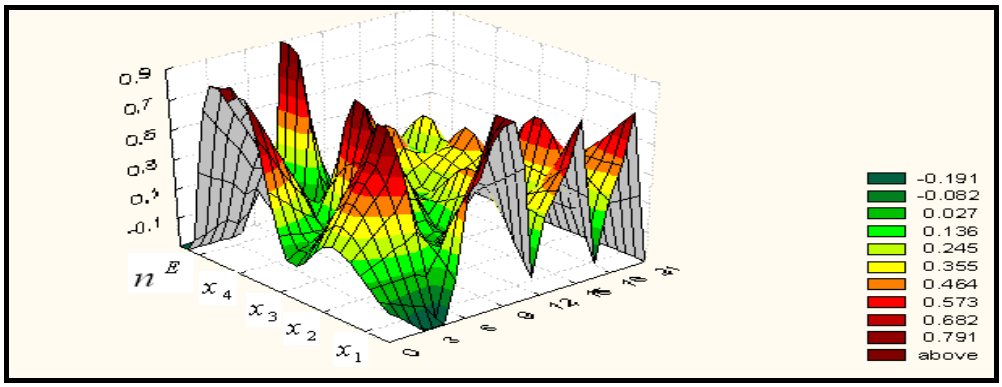


(d)

Figure (3): Excess refractive indices N^E for quaternary system versus X_1cyclohexane + X_2 n-heptane + X_3 n-decane + X_4 n-hexane at (a) 298.15K (b) 308.15K (c) 318.15K and (d) 328.15K.



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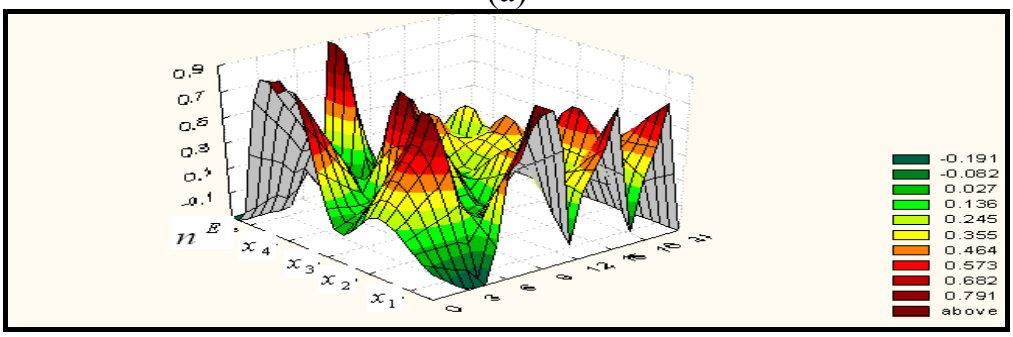

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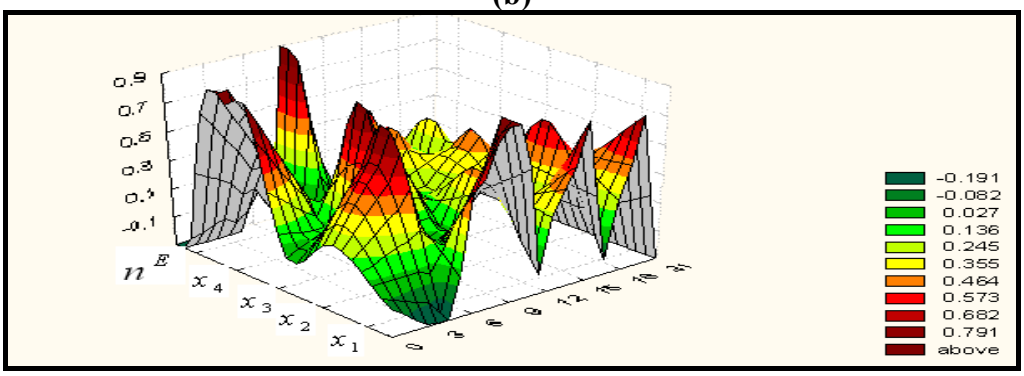

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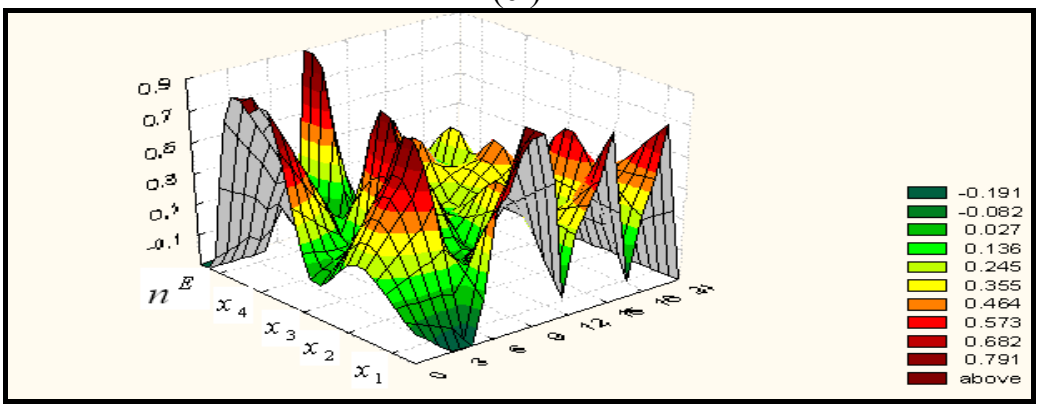


(d)

Figure (4) Excess refractive indices N^E for quaternary system versus X_1cyclohexane + X_2 1-pentanol + X_3 3-hexanol + X_4 n-hexane at (a) 298.15K (b) 308.15K (c) 318.15K and (d) 328.15K.

Table (6) The predicted refractive indices (n_D) for quaternary mixtures at 298.15k, 308.15k, 318.15k,and 328.15k.

x_1 Cyclohexane + x_2 n- Heptane + x_3 n- Decane + x_4 n- Hexane

x_1	x_2	x_3	$n_{D\ pred}$	$n_{D\ pred}$	$n_{D\ pred}$	$n_{D\ pred}$
			298.15K	308.15K	318.15K	328.15K
.2924	0.4670	0.1867	1.4013	1.4047	1.3991	1.3982
0.2761	0.3160	0.3381	1.3989	1.3988	1.3973	1.3911
0.2608	0.1613	0.4911	1.3981	1.3971	1.3958	1.3948
0.1564	0.0120	0.7302	1.3957	1.3946	1.3937	1.3923
0.0369	0.0902	0.7605	1.3951	1.3939	1.3921	1.3915
0.7903	0.0396	0.0086	1.3922	1.3909	1.3889	1.3887
0.6681	0.0331	0.0162	1.3890	1.3881	1.3864	1.3849
0.5088	0.0245	0.0256	1.3885	1.3862	1.3842	1.382
0.3524	0.0160	0.0351	1.3878	1.3848	1.3833	1.3809
0.1814	0.0088	0.0453	1.3838	1.3827	1.3811	1.3801
0.3452	0.1451	0.3594	1.3862	1.3852	1.3832	1.3796
0.4255	0.0646	0.2784	1.3868	1.3866	1.3848	1.3788
0.3229	0.1751	0.1792	1.3891	1.3871	1.3872	1.3771
0.3977	0.1037	0.1033	1.3915	1.3907	1.3895	1.3748
0.4381	0.0655	0.0718	1.3933	1.3919	1.3899	1.3739
0.0751	0.1776	0.3567	1.3969	1.3933	1.3917	1.3721
0.1200	0.1342	0.4309	1.3998	1.3948	1.3923	1.3711
0.1614	0.0933	0.3156	1.4011	1.3969	1.3948	1.3699
0.2871	0.0513	0.1017	1.4038	1.3992	1.3966	1.3691

x_1 Cyclohexane + x_2 1- Pentanol + x_3 3- Hexanol + x_4 n- Hexane

x_1	x_2	x_3	$n_{D\ pred}$	$n_{D\ pred}$	$n_{D\ pred}$	$n_{D\ pred}$
			298.15K	308.15K	318.15K	328.15K
0.0347	0.2069	0.0814	1.4066	1.4019	1.3988	1.3901
0.0506	0.3574	0.0660	1.4029	1.3975	1.3942	1.3866
0.0676	0.5103	0.0497	1.3973	1.3941	1.3895	1.3818
0.0821	0.6597	0.0354	1.3938	1.3907	1.3846	1.3782
0.0922	0.7827	0.0258	1.3911	1.3873	1.3811	1.3739
0.1614	0.0139	0.7942	1.3907	1.3844	1.3779	1.3711
0.2845	0.0143	0.6770	1.3857	1.3806	1.3734	1.3665
0.5419	0.0148	0.5177	1.3781	1.373	1.3666	1.3593
0.0623	0.0306	0.3337	1.3704	1.3658	1.3603	1.3518
0.7747	0.0335	0.1877	1.3822	1.3777	1.3722	1.3646
0.1312	0.3785	0.1341	1.3857	1.3803	1.3741	1.3659
0.2123	0.2932	0.2188	1.3888	1.3851	1.3808	1.3721
0.3035	0.1984	0.3118	1.3909	1.3877	1.3817	1.3743
0.3761	0.1225	0.3866	1.3919	1.3882	1.3824	1.3754
0.4354	0.0610	0.4470	1.3935	1.3898	1.3831	1.3762
0.1557	0.5865	0.0681	1.4006	1.399	1.3949	1.3866
0.2965	0.4543	0.1039	1.4028	1.4007	1.3950	1.3873
0.4105	0.3348	0.1053	1.4043	1.4011	1.3955	1.3879
0.5307	0.2120	0.1969	1.4051	1.4017	1.3962	1.3883

The absolute viscosity (η_m) was calculated for quaternary mixtures in this study by measuring the flow time (t) and using the densities values shown in Table(1)at the range of degrees of temperature (298.15,308.15,318.15, and 328.5K) and by using equation [25] .

$\eta = C. t . \rho_m$ ……(16)

Table (7) presents the experimental values of absolute viscosities for quaternary mixtures studied here at the range of degrees of temperature .

Excess Viscosities , η^E_{1234} for quaternary mixtures at the range of degrees of temperature (298.15, 308.15, 318.15 and 328.5K) were calculated from measurements of the viscosity of the mixture and the pure liquid by the following equation [26]

$$\eta^E_{1234} = \eta_{mix} - x_1\eta_1 - x_2\eta_2 - x_3\eta_3 - x_4\eta_4 \quad .....(17)$$

where x_1, x_2, x_3, x_4, , η_1, η_2, η_3, and η_4 are the mole fractions and the viscosities of components 1, 2, 3, and 4 respectively η_{mix} is the viscosity of the mixture.

The obtained result of η^E_{1234} are listed in Table (8) and plotted as a function of the mole fractions x_1, x_2, x_3, and x_4 for the four components at four temperatures in Figures (5 and 6).

Several empirical equations have been proposed to calculate excess viscosity of multi component systems based on the available experimental results of viscosities of mixture and pure components. the equation of Heric and Coursey (27)was used.

$\eta^E = \ln \eta_m - \Sigma\ x_i \ln \eta_i$ ……(18)

Where η_{mix} is the viscosity of the mixture, x_i and η_i are mole fraction and viscosity for pure component respectively. Table (9) Shows the predicted values of excess viscosity from equation (18) for the quaternary mixtures studied here at 298.15, 308.15, 318.15 and 328.15K.

Table (7) Experimental values of the viscosity (η) viscosity for quaternary mixtures at 298.15, 308.15, 318.15 and 328.15K.

x_1 Cyclohexane + x_2 n- Heptane + x_3 n- Decane + x_4 n- Hexane

x_1	x_2	x_3	η	η	η	η
			298.15K	308.15K	318.15K	328.15K
.2924	0.4670	0.1867	1.0242	0.9312	0.8070	0.6077
0.2761	0.3160	0.3381	1.5083	1.3399	1.1561	0.9067
0.2608	0.1613	0.4911	2.5217	2.1901	1.8749	1.5227
0.1564	0.0120	0.7302	7.8626	6.5069	6.0991	4.8338
0.0369	0.0902	0.7605	1.1823	9.4250	7.9462	6.3423
0.7903	0.0396	0.0086	1.3900	1.1794	0.9766	0.8029
0.6681	0.0331	0.0162	1.7754	1.5013	1.2408	1.0761
0.5088	0.0245	0.0256	2.4464	2.1087	1.7569	1.4888
0.3524	0.0160	0.0351	3.4310	2.9491	2.4726	2.0897
0.1814	0.0088	0.0453	6.3306	5.4270	4.6041	3.8371
0.3452	0.1451	0.3594	2.8632	2.5143	2.1148	1.7280
0.4255	0.0646	0.2784	2.5061	2.2228	1.9350	1.5453
0.3229	0.1751	0.1792	2.1552	1.9215	1.6099	1.2744
0.3977	0.1037	0.1033	1.8844	1.6487	1.4371	1.1803
0.4381	0.0655	0.0718	2.0102	1.8110	1.5106	1.2224
0.0751	0.1776	0.3567	4.4982	4.1630	3.5484	2.9091
0.1200	0.1342	0.4309	4.8735	4.5164	3.8758	3.2235
0.1614	0.0933	0.3156	4.8037	4.5170	3.9891	3.3216
0.2871	0.0513	0.1017	3.4078	3.1667	2.8239	2.5669

x_1 Cyclohexane + x_2 1- Pentanol + x_3 3- Hexanol + x_4 n- Hexane

x_1	x_2	x_3	η	η	η	η
			298.15K	308.15K	318.15K	328.15K
0.0347	0.2069	0.0814	1.0247	0.9131	0.7900	0.6917
0.0506	0.3574	0.0660	1.1547	1.0044	0.8957	0.7700
0.0676	0.5103	0.0497	1.2631	1.1066	0.9888	0.8638
0.0821	0.6597	0.0354	1.3760	1.2408	1.0754	0.9628
0.0922	0.7827	0.0258	1.7159	1.4032	1.2173	1.0810
0.1614	0.0139	0.7942	1.7917	1.5229	1.2728	1.1829
0.2845	0.0143	0.6770	1.7966	1.5821	1.3340	1.2449
0.5419	0.0148	0.5177	1.7639	1.5727	1.3337	1.2375
0.0623	0.0306	0.3337	1.5814	1.4225	1.2036	1.1151
0.7747	0.0335	0.1877	1.4000	1.2898	1.0879	1.0061
0.1312	0.3785	0.1341	1.5868	1.4949	1.2725	1.1473
0.2123	0.2932	0.2188	1.4397	1.3358	1.1953	1.0953
0.3035	0.1984	0.3118	1.3389	1.1978	1.0908	1.0110
0.3761	0.1225	0.3866	1.2284	1.0868	0.9726	0.9021
0.4354	0.0610	0.4470	1.3425	1.1742	1.0695	1.0018
0.1557	0.5865	0.0681	1.5374	1.3960	1.1967	1.1280
0.2965	0.4543	0.1039	1.5326	1.4077	1.2509	1.1338
0.4105	0.3348	0.1053	1.5478	1.4363	1.2364	1.1589
0.5307	0.2120	0.1969	1.5330	1.4185	1.2387	1.1674

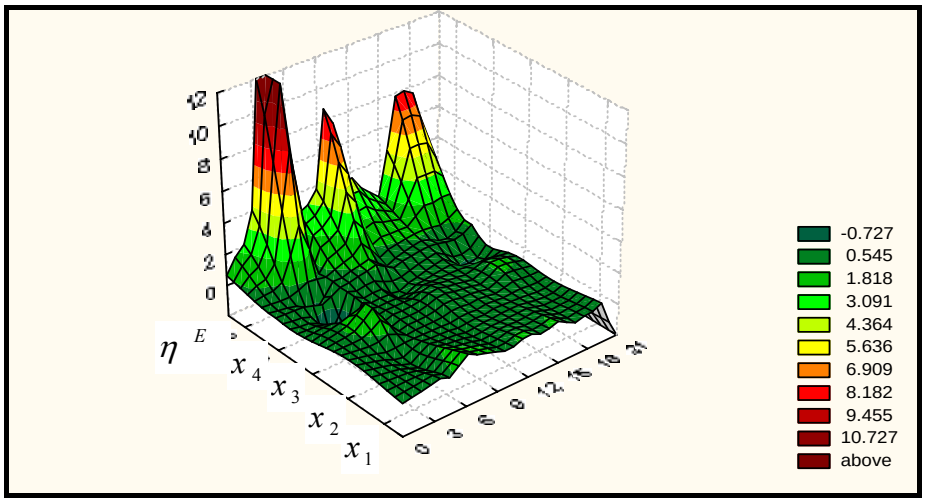
Table (8) Experimental values of the excess viscosity (η^E_{1234}) for quaternary mixtures at 298.15, 308.15, 318.15 and 328.15K.

x_1 Cyclohexane + x_2 n- Heptane + x_3 n- Decane + x_4 n- Hexane

x_1	x_2	x_3	η^E_{1234}	η^E_{1234}	η^E_{1234}	η^E_{1234}
			298.15K	308.15K	318.15K	328.15K
.2924	0.4670	0.1867	0.6365	0.6151	0.5482	0.4130
0.2761	0.3160	0.3381	1.0813	0.9992	0.8789	0.6660
0.2608	0.1613	0.4911	2.0547	1.8245	1.5788	1.2346
0.1564	0.0120	0.7302	7.3334	6.1008	5.7730	4.5086
0.0369	0.0902	0.7605	10.633	9.0031	7.6089	6.0504
0.7903	0.0396	0.0086	1.0201	0.8805	0.7293	0.4193
0.6681	0.0331	0.0162	1.3384	1.1499	0.9555	0.6867
0.5088	0.0245	0.0256	1.9217	1.6887	1.4219	1.0918
0.3524	0.0160	0.0351	2.8203	2.4617	2.0889	1.6852
0.1814	0.0088	0.0453	5.6267	4.8668	4.1675	3.4253
0.3452	0.1451	0.3594	2.3983	2.1474	1.8180	1.4192
0.4255	0.0646	0.2784	2.0243	1.8420	1.6280	1.1945
0.3229	0.1751	0.1792	1.6433	1.5127	1.2831	0.9551
0.3977	0.1037	0.1033	1.3584	1.2282	1.1018	0.8233
0.4381	0.0655	0.0718	1.4794	1.3866	1.1724	0.8464
0.0751	0.1776	0.3567	3.9018	3.6920	3.1764	2.6051
0.1200	0.1342	0.4309	4.3010	4.0667	3.5191	2.9117
0.1614	0.0933	0.3156	4.2027	4.0428	3.6147	2.9792
0.2871	0.0513	0.1017	2.7966	2.6800	2.4406	2.1838

x_1 Cyclohexane + x_2 1- Pentanol + x_3 3- Hexanol + x_4 n- Hexane

x_1	x_2	x_3	η^E_{1234}	η^E_{1234}	η^E_{1234}	η^E_{1234}
			298.15K	308.15K	318.15K	328.15K
0.0347	0.2069	0.0814	-0.7021	-0.3381	-0.0780	0.0278
0.0506	0.3574	0.0660	-0.9031	-0.4771	-0.1307	-0.0009
0.0676	0.5103	0.0497	-1.1276	-0.6066	-0.1972	-0.0153
0.0821	0.6597	0.0354	-1.3893	-0.7370	-0.2948	-0.0453
0.0922	0.7827	0.0258	-1.2940	-0.7399	-0.2626	0.0031
0.1614	0.0139	0.7942	-2.5399	-1.3204	-0.3721	0.0682
0.2845	0.0143	0.6770	-1.9438	-0.8797	-0.1001	0.2658
0.5419	0.0148	0.5177	-1.1976	-0.3909	0.1686	0.4265
0.0623	0.0306	0.3337	-0.3239	0.1672	0.4708	0.6169
0.7747	0.0335	0.1877	0.0629	0.3738	0.5019	0.5703
0.1312	0.3785	0.1341	-0.7901	-0.1832	0.1440	0.3172
0.2123	0.2932	0.2188	-1.0416	-0.3872	0.0719	0.2797
0.3035	0.1984	0.3118	-1.2529	-0.5714	-0.0247	0.2128
0.3761	0.1225	0.3866	-1.4535	-0.7205	-0.1374	0.1174
0.4354	0.0610	0.4470	-1.4112	-0.6632	-0.0356	0.2284
0.1557	0.5865	0.0681	-1.0132	-0.4083	-0.0334	0.2333
0.2965	0.4543	0.1039	-0.8236	-0.2549	-0.1254	0.3095
0.4105	0.3348	0.1053	-0.3933	0.0688	0.3132	0.4790
0.5307	0.2120	0.1969	-0.4573	0.0439	0.3462	0.5174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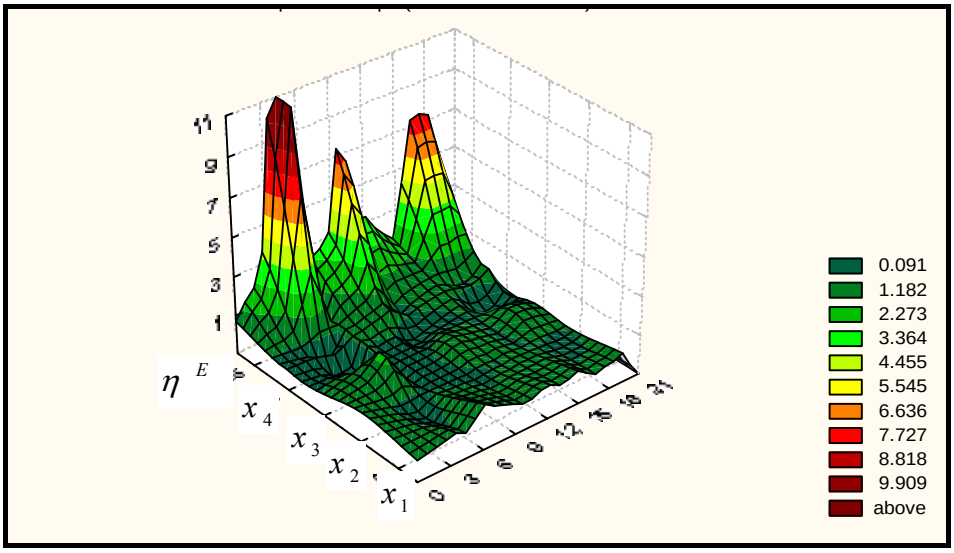
9.455
10.727
above

(a)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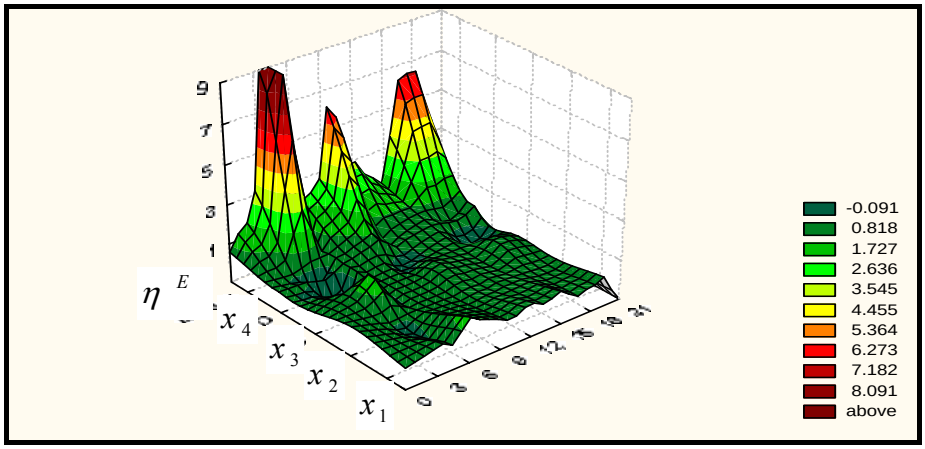
above

(b)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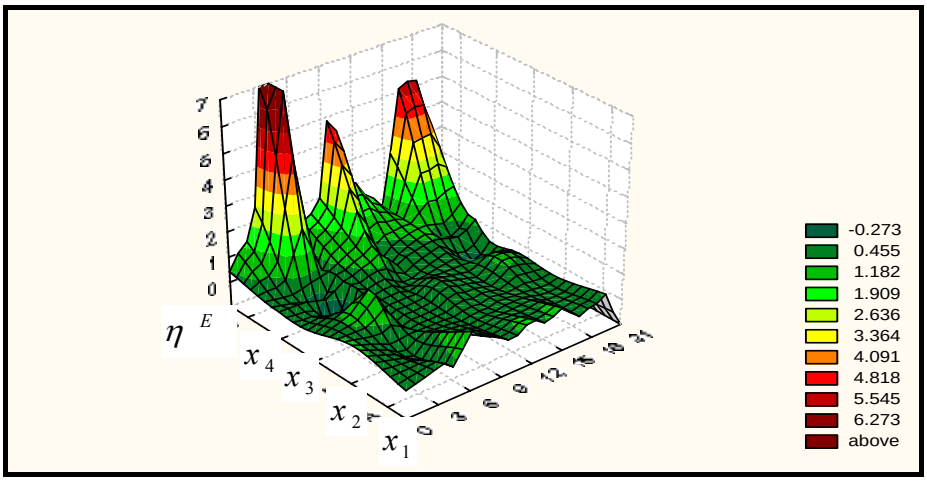
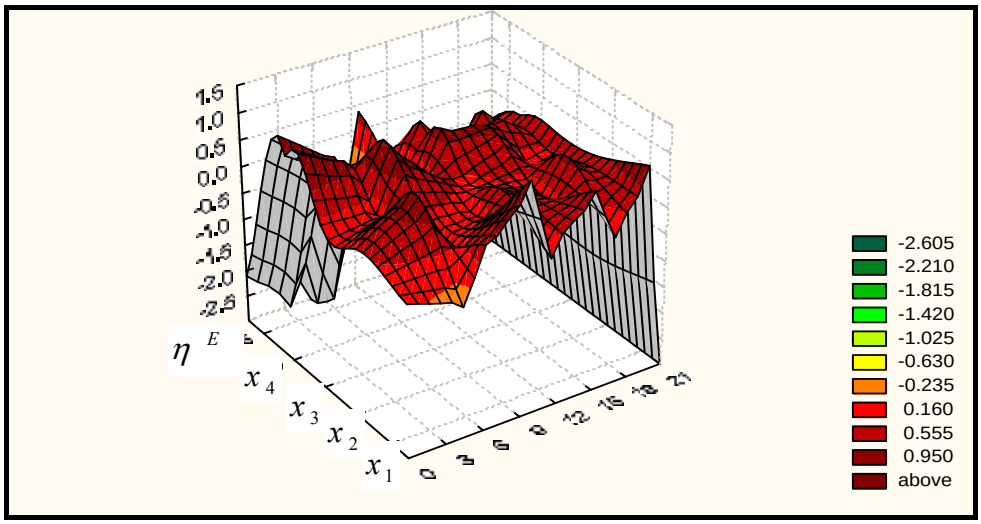
6.273
7.182
8.091
above

(c)

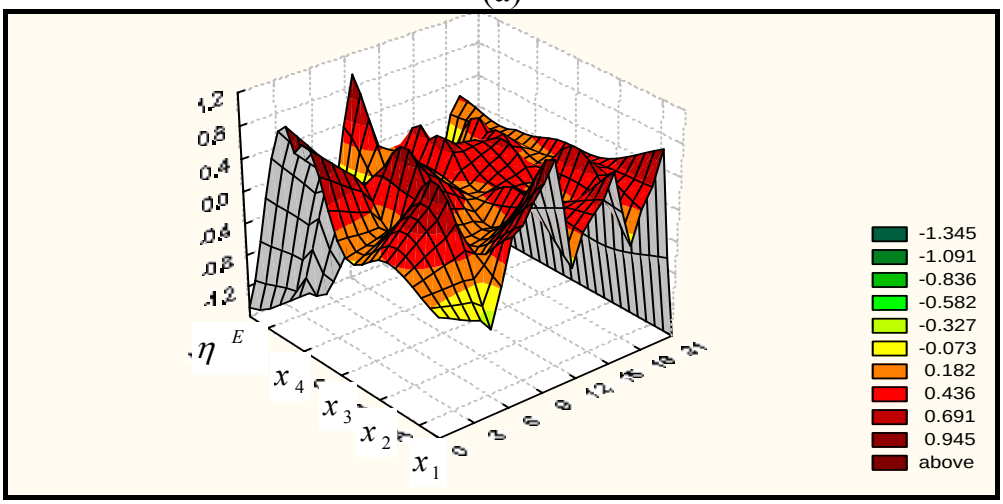


(d)

Figure(5)Excess viscosities $\eta^{E}_{12\ 34}$for quaternary system($x_1$cyclohexane+x_2n-heptane+ x_3 n-decane + x_4 n- hexane) at (a) 298.15k, (b) 308.15k, (c) 318.15k, and (d) 328.15k.



(a)



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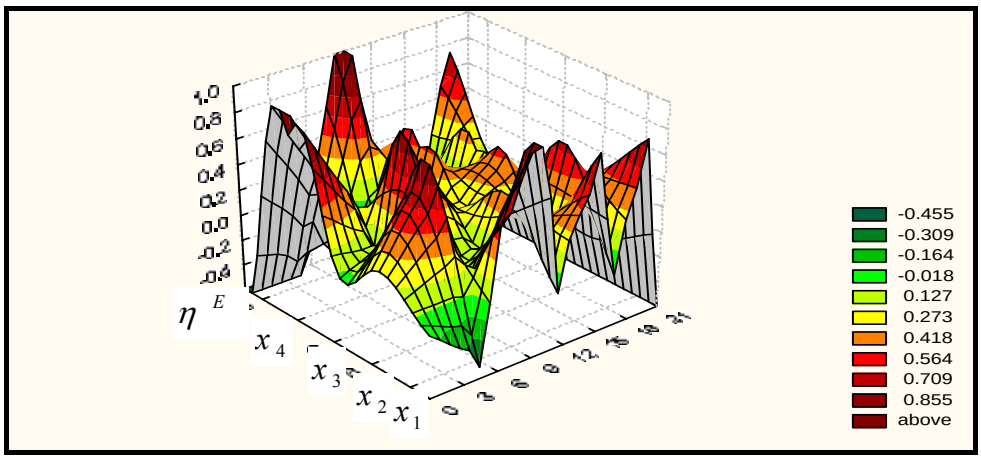

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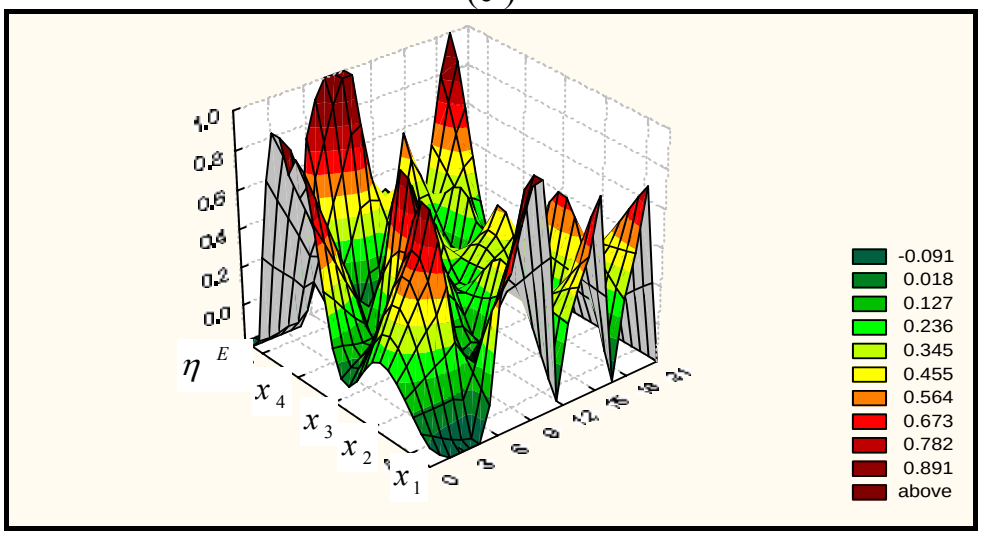

(d)

Figure (6) Excess viscosities $\eta^E_{12\ 34}$ for quaternary system ($x_1$cyclohexane +x_2 1-pentanol+ x_3 3-hexanol + x_4 n- hexane) at (a) 298.15 (b) 308.15 (c) 318.15and (d) 328.15K.

Table (9) The predicted values of the excess viscosity ($\eta^{E}_{pred.}$) for quaternary mixtures at 298.15, 308.15, 318.15 and 328.15K.

x_1 Cyclohexane + x_2 n- Heptane + x_3 n- Decane + x_4 n- Hexane

x_1	x_2	x_3	$\eta^{E}_{pred.}$	$\eta^{E}_{pred.}$	$\eta^{E}_{pred.}$	$\eta^{E}_{pred.}$
			298.15K	308.15K	318.15K	328.15K
.2924	0.4670	0.1867	0.6361	0.6171	0.5477	0.4118
0.2761	0.3160	0.3381	1.0808	0.9990	0.8786	0.6663
0.2608	0.1613	0.4911	2.0559	1.8243	1.5780	1.2359
0.1564	0.0120	0.7302	7.3355	6.1003	5.7728	4.5084
0.0369	0.0902	0.7605	10.630	9.0011	7.6092	6.0508
0.7903	0.0396	0.0086	1.0220	0.8814	0.7284	0.4191
0.6681	0.0331	0.0162	1.3380	1.1486	0.9592	0.6870
0.5088	0.0245	0.0256	1.9216	1.6890	1.4205	1.0916
0.3524	0.0160	0.0351	2.8212	2.4622	2.0896	1.6840
0.1814	0.0088	0.0453	5.6277	4.8698	4.1676	3.4233
0.3452	0.1451	0.3594	2.3968	2.1458	1.8176	1.4199
0.4255	0.0646	0.2784	2.0238	1.8417	1.6275	1.1934
0.3229	0.1751	0.1792	1.6417	1.5147	1.2832	0.9542
0.3977	0.1037	0.1033	1.3577	1.2295	1.1044	0.8210
0.4381	0.0655	0.0718	1.4781	1.3845	1.1730	0.8484
0.0751	0.1776	0.3567	3.9035	3.6913	3.1790	2.6019
0.1200	0.1342	0.4309	4.3016	4.0668	3.5184	2.9101
0.1614	0.0933	0.3156	4.2028	4.0457	3.6123	2.9783
0.2871	0.0513	0.1017	2.7964	2.6817	2.4413	2.1818

x_1 Cyclohexane + x_2 1- Pentanol + x_3 3- Hexanol + x_4 n- Hexane

x_1	x_2	x_3	$\eta^{E}_{pred.}$	$\eta^{E}_{pred.}$	$\eta^{E}_{pred.}$	$\eta^{E}_{pred.}$
			298.15K	308.15K	318.15K	328.15K
0.0347	0.2069	0.0814	-0.7026	-0.3390	-0.0777	0.0280
0.0506	0.3574	0.0660	-0.9013	-0.4763	-0.1311	-0.0010
0.0676	0.5103	0.0497	-1.1264	-0.6067	-0.1970	-0.0160
0.0821	0.6597	0.0354	-1.3898	-0.7374	-0.2943	-0. 0459
0.0922	0.7827	0.0258	-1.2932	-0.7382	-0.2625	0.0017
0.1614	0.0139	0.7942	-2.5365	-1.3209	-0.3719	0.0679
0.2845	0.0143	0.6770	-1.9422	-0.8780	-0.1011	0.2661
0.5419	0.0148	0.5177	1.1977	-0.3910	0.1685	0.4261
0.0623	0.0306	0.3337	-0.3247	0.1674	0.4702	0.6160
0.7747	0.0335	0.1877	0.0659	0.3726	0.5016	0.5700
0.1312	0.3785	0.1341	-0.7903	-0.1842	0.1439	0.3169
0.2123	0.2932	0.2188	-1.0434	-0.3873	0.0710	0.2791
0.3035	0.1984	0.3118	-1.2525	-0.5716	-0.0240	0.2133
0.3761	0.1225	0.3866	-1.4529	-0.7208	-0.1375	0.1180
0.4354	0.0610	0.4470	-1.4111	-0.6613	-0.0360	0.2289
0.1557	0.5865	0.0681	-1.0124	-0.4096	-0.0331	0.2340
0.2965	0.4543	0.1039	-0.8227	-0.2566	-0.1251	0.3099
0.4105	0.3348	0.1053	-0.3935	0.0682	0.3129	0.4785
0.5307	0.2120	0.1969	-0.4563	0.0451	0.3461	0.5182

Discussion

The experimental excess molar volumes V^{E}_{1234} for the quaternary mixtures studied here at 298.15, 308.15, 318.15 and 328.15K are rocking between positive and negative deviation from ideality, Table (3) and Figures (1 and 2). Such volumetric behavior may be explained by long range orientational order in n-alkanes for the first quaternary mixture (n-hexane, n-heptane and n-decane) which do not allow the globular molecules of cyclohexane to disturb this orientation. It means that cyclohexane molecules are interstitial accommodate between n-alkanes molecules and result less packed structure which is responsible about the negative and positive V^{E}_{1234} for this quaternary mixture. In the second quaternary mixture (cyclohexane + 1-pentonol + 3-hexanol + n-hexane), the globular molecule cyclohexane distorting the hydrogen bonding interaction in alkanol and n-hexane molecules are interstitial accommodate between alkanols and result less packed structure which is responsible about the negative and positive V^{E}_{1234} for this quaternary mixture.

The Flory theory [16] has been extended for the theoretical prediction of excess molar volume of quaternary mixtures studied here depending on the pure component liquid parameters. The obtained excess molar volumes V^{E}_{1234} by extended Flory theory for the quaternary mixtures studied here are presented in Table (3) with the experimental data for comparison .The theory predicted the volumetric behavior and magnitudes of V^{E}_{1234} well. The researcher conclude that Flory theory could be extended to multicomponent liquid mixtures based on the pure component liquid parameters [16].

The excess refractive indices n^{E}_{1234} behavior for the quaternary mixtures studied here show a similar volumetric behavior: Table (5) and Figures (3 and 4) . Refractive indices for quaternary mixtures studied in this work can be predicted by using different refractive indices mixing rules and presented in Table (6). The researcher found good agreement between the experimental and the predicted values of the refractive indices for the quaternary mixtures studied here.

Experimental data of mixture viscosity η_m and excess viscosity η^{E}_{1234} are listed in Tables (7 and 8) and plotted as a function of the mole fractions x_1, x_2, x_3 and x_4 for the four components at four temperatures in Figures (5 and 6) for the quaternary mixtures studied here. The viscometric behavior for (cyclohexane + n-heptane +n-decane + n-hexane) mixture show a positive deviation from ideality at four temperatures; but the viscometric behavior for (cyclohexane + 1-pentanol +3-hexanol + n-hexane) mixture shows a similar volumetric and excess refractive indices behavior. Heric and Coursey equation was used to calculate excess viscosity of quaternary mixtures studied here from experimental results of viscosities of mixtures and pure components. Table (9) shows good agreement between the experimental values of the excess viscosities for the quaternary mixtures studied in this work with the predicted values from Heric and Coursey equation.

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