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A Theoretical Study of Internal Pressure of Multicomponent Liquid Mixtures

Prakash Chandra[1], Rakesh Kumar Singh[2], Nitya Kumar Soni[3], Priyanka[4]
[1]*Department of Chemistry, Bundelkhand University, Jhansi 2814128(U.P.) India*
[2]*Department of Chemistry, Govt. Degree College Pawanikala Sonebhadra 231216 (U.P.)*
[3,4]*Department of Chemistry, Govt. PG college Charkhari, Mahoba (U.P.)*

Abstract-The estimation of internal pressure ($\partial U/\partial V)_T$ of four ternary liquid mixtures [viz. Dimethylcarbonate+Methanol+Cyclohexane(I),Toluene+n-Heptane+n-Hexane(II), Cyclohexane+n-Heptane+n-Hexane(III) & n-Hexane+n-Heptane+n-Decane(IV)] and four quaternary liquid mixtures [viz Pentane+n-Hexane+Cyclohexane+Benzene(I), Pentane+n-Hexane+Benzene+Toluene(II), n-Pentane+Toluene+n-Heptane+Cyclohexane(III) & n-Decane+n-Hexane+Cyclohexane+Benzene(IV)] by using correct approach and generalized hole theory has been employed for the first time , to estimate internal pressure of multicomponent liquid mixtures at 298.15K quite good agreement has been obtained demonstrating the applicability of assuming volume fraction ideality.

Key words- Internal pressure, Hole theory, Multicomponent Liquid mixtures.

I. INTRODUCTION

Significance of the study of cohesive forces in the light of internal pressure has been emphasized during recent years by a number of workers1-10. Earlier the measurements and applications of this property were discussed by various instigations11-18. The excess internal pressure of binary liquid mixtures has been found to be related with the molecular interactions. Considering the erroneous additivity of mole fraction scale in calculating the internal pressure of binary ideal mixtures, Marczak17 and Pandey et al18 computed excess internal pressures of several binary liquid mixtures correctly. Similarly, the mole fraction additivity has also been considered wrongly in evaluating internal pressure of ideal mixture in the case of multicomponent systems19. In the present work an attempt has been made to estimate internal pressure of ternary and quaternary liquid systems by using correct approach. In addition, generalized version of hole theory, recently developed20-24, has been employed for the first time, to estimate internal pressure of four ternary and four quaternary liquid mixtures. Depending on the availability of input data for the estimation of Pint, the following mixtures are considered:

Ternary Systems
Dimethylcarbonate + Methanol + Cyclohexane(I)
Toluene + n-Heptane + n-Hexane(II),
Cyclohexane + n-Heptane + n-Hexane(III)
n-Hexane + n-Heptane + n-Decane(IV)

Quaternary Systems:
n-Pentane + n-Hexane + Cyclohexane + Benzene(I),
n-Pentane + n-Hexane + Benzene + Toluene(II),
n-Pentane + Toluene + n-Heptane + Cyclohexane(III) ,
n-Decane + n-Hexane + Cyclohexane + Benzene(VIII)

II. MATHEMATICAL FORMULATIONS

Using the thermodynamic equation of state and other relevant equations, internal pressures, Pint, is defined as:

$$P_{\text{int}} = \left(\frac{\partial U}{\partial V}\right)_T = \frac{\alpha T}{\beta_T} - P \tag{1}$$

where all the symbols have their usual notations.

Very recently, Merczak17 and Pandey et al18 proposed a new theoretical approach for estimating internal pressure. In this approach, they computed ideal internal pressure by using volume fraction additivity in terms of thermal expansion coefficient(α) and isothermal compressibility (β_T). This is evidently true since both thermal expansion coefficient and isothermal compressibility are very well known to be the volume fraction additive. In case of mole fraction additivity, the ideal value of Pint for multicomponent liquid systems is obtained using the expression

$$\left(P_{\text{int}}\right)_{idl} = \sum_{i=1}^{n}\left(P_{\text{int}}\right)_i x_i \tag{2}$$

where, x_i the mole fraction of ith component and "idl" is denotes ideal value of mixture.

$\left(P_{\text{int}}\right)_{idl}$ is given by

$$\left(P_{\text{int}}\right)_{idl} = \left(\frac{\left(\alpha\right)_{idl} T}{\left(\beta_T\right)_{idl}} - P\right) \tag{3}$$

$$\left(\alpha\right)_{idl} = \sum_{i=1}^{n} \phi_i \alpha_i$$

where,

$$\left(\beta_T\right)_{idl} = \sum_{i=1}^{n} \phi_i \beta_{T_i}$$

$$\phi_i = \frac{x_i V_i}{\sum_{i=1}^{n} x_i V_i}$$

□i is the volume fraction of the ith component.

Hence, Eq. (5) can be written as

$$\left(P_{\text{int}}\right)_{idl} = \frac{T\sum_{i=1}^{n} \phi_i \alpha_i}{\sum_{i=1}^{n} \phi_i \beta_{T_i}} - P \tag{4}$$

On the basis of recently developed hole theory25, P_{int} values have been computed using the relation

$$\left(P_{\text{int}}\right)_h = \frac{\left(\alpha\right)_h T}{\left(\beta_T\right)_h} - P \tag{5}$$

where "h" represents the hole theory, thermal expansion coefficient $\left(\alpha\right)_h$ and isothermal compressibility $\left(\beta_T\right)_h$ have been computed through the recently developed hole theory22.

III. RESULTS AND DISCUSSION

In the present investigation we have considered four ternary liquid systems namely, Dimethylcarbonate+Methanol+Cyclohexane(I),Toluene+n-Heptane+n-Hexane(II), Cyclohexane+n-Heptane+n-Hexane(III) & n-Hexane+n-Heptane+n-Decane(IV), and four quaternary liquid systems viz Pentane+n-Hexane+Cyclohexane+Benzene(I), Pentane+n-Hexane+Benzene+Toluene(II), n-Pentane+Toluene+n-Heptane+Cyclohexane(III) & n-Decane+n-Hexane+Cyclohexane+Benzene(IV) at 298.15K. The experimental values of density(□), ultrasonic velocity(u) and other thermodynamic parameters, e.g. isothermal compressibility(□T) and thermal expansion coefficient(□) of the pure component liquids are given in Table-1. All the necessary data needed for the computation have been collected from different sources27,28.

The internal pressure values of all the four ternary liquid mixtures, undertaken for the present investigation, have been computed by different approaches outlined in the theoretical section. One needs the experimental values of thermal expansivity (□) and isothermal compressibility (□T) of multicomponent systems for the computation of Pint,m.. No measurements have been done, so far, for the estimation of □ □and □T in the case of multicomponent systems. Recently26 two empirical relations for calculating □ □and □T from sound velocity and density data have

been proposed. These relations have been verified by various workers27, and found to hold for any type of systems. In the present case, the values of □ and □T of multicomponent systems are obtained from these relations. Experimental values of □ □and u for all the multicomponent systems were taken from the literature27,28, and collected in Tables 2 and 3. In order to verify the present approach, in which volume fraction additivity is considered to obtain (Pint)idl, the values are obtained from Eq (4). The mole fraction additive values of (Pint)idl, are deduced from Eq (2). Internal pressure of ternary liquid mixtures has been calculated using two different approaches, vide Eqs (1) and (5). In applying Eq (1), for multicomponent systems, the Pint,m, is given by

$$P_{\text{int},m} = \frac{\alpha_m T}{\beta_{T,m}} - P \approx \frac{\alpha_m T}{\beta_{T,m}} \tag{6}$$

α_m and $\beta_{T,m}$ are obtained from the experimental equations mentioned earlier as

$$\alpha_m = \frac{75.6\times10^{-3}}{T^{1/9}u^{1/2}\rho^{1/3}} \tag{7}$$

$$\beta_{T,m} = \frac{1.71\times10^{-3}}{u^2\rho^{4/3}T^{4/9}} \tag{8}$$

where um and □m are respectively the sound velocity and density of multicomponent mixtures. In the second approach Pint,m, is obtained from newly developed generalized hole theory using Eqn (5). The detail are given elsewhere18.

The calculated values of $P_{\text{int},idl}$ for four ternary liquid mixtures are presented in Table-2. Two sets of data are generated. One involving the mole fraction additivity of $P_{\text{int},idl}$ i.e P_{int,idl,x_i}, and the other involving volume fraction additivity i.e $P_{\text{int},idl,\phi_i}$. These values are recorded in columns five and six respectively. Internal pressure of multicomponent liquid mixtures has been deduced from Eq (6) in conjuction with Eqs (7) and (8). The values of $P_{\text{int},mix,}$, thus obtained are reported in column seventh of Table-2 for four ternary liquid mixtures at 298.15K. In the second set of calculation, the generalized hole theory has been used to compute $P_{\text{int},mix,h}$ from Eq (5). The details of formulation are described elsewhere17-20. These values are recorded in eight column of this table.

As mentioned earlier Similar calculations were done for the four quaternary liquid mixtures. The values of α_m and $\beta_{T,m}$, needed for the calculation of internal pressure of afrosaid systems are obtained from the experimental sound velocity and density data using the empirical relations (7) and (8). Calculated values of P_{int,idl,x_i} and $P_{\text{int},idl,\phi_i}$ for all the quaternary liquid systems are enlisted in sixth and seventh columns of Table-3. Similarly the calculated $P_{\text{int},mix,}$ and $P_{\text{int},mix,h}$ values for the aforesaid quaternary systems are recorded respectively in columns eight and nine of this table.

Calculated values of P_{int,idl,x_i} and $P_{\text{int},idl,\phi_i}$, reported in columns fifth and sixth of Table-2 for four ternary systems I, II, III and IV, show similar trend in variation with mole fractions but differ slightly in magnitude. Similar

results were obtained for P_{int,idl,x_i} and $P_{\text{int},idl,\phi_i}$ in case of four quaternary liquid mixtures as evident from Table-3. In this case the difference in magnitude is large as compared to the ternary systems. In all cases the ideal internal pressure values are very close to the internal pressure of real mixture. As the addition of extra component beyond binary reduces the intermolecular forces, and mixture approaches to ideality.

There is quite good agreement between the $P_{\text{int},m}$ calculated from experimental values of α_m and $\beta_{T,m}$ (deduced from empirical relations) and $P_{\text{int},m,h}$ obtained from generalized version of hole theory in case of all the multicomponent systems (Table-2 & 3). This demonstrate the validity of the hole theory. A slight deviation in the magnitude of $P_{\text{int},m}$ is due to the values of α_m and $\beta_{T,m}$ obtained from empirical relations (7) and (8).

IV. CONCLUSION

Internal pressure values of four ternary solutions (Dimethylcarbonate + Methanol + Cyclohexane (I), Toluene + n-Heptane + n-Hexane(II), Cyclohexane + n-heptane + n-Hexane(III), & n-Hexane + n-Heptane + n-Decane (IV)) and four quaternary solutions (Pentane + n-Hexane + Cyclohexane + Benzene(I), n-Pentane + n-Hexane + Benzene + Toluene(II), n-Pentane + Toluene + n-Heptane + Cyclohexane(III) and n-Decane + n-Hexane + Cyclohexane + Benzene(IV)) have been computed from □ □ □and □T deduced from experimental □ □and u data, as well as using the generalized hole theory developed recently. Quite good agreement has been obtained demonstrating the applicability of new approach. The values of ideal internal pressure of aforesaid solutions were calculated by assuming the volume fraction ideality which has been suggested recently to be the correct approach instead of mole fraction ideality. Both the values are compared.

Table -1 Properties of pure component liquids at 298.15K

Component	V	u	□ □10-3	□T*1012	□ □103	Pint
	(cc mol-1)	(ms-1)	(kg m-3)	(cm2 dyne-1)	(K-1)	(atm)
Pentane	116.08	991.2	0.6216	212.30	1.6225	2249.00
Hexane	131.57	1078.0	0.6552	171.00	1.3897	2546.00
Heptane	147.47	1131.0	0.6791	142.00	1.2480	2620.36
Benzene	89.82	1299.9	0.8732	96.70	1.2265	3732.00
Toluene	106.81	1304.0	0.8627	92.20	1.0740	3473.03
Decane	195.94	1224.0	0.7262	116.20	1.0500	2694.13
Cyclohexane	108.76	1253.9	0.7734	114.00	1.2170	3136.00
Dimethyl Carbonate	84.69	1196.0	1.0635	87.52	1.1371	3822.74
Methanol	40.73	1102.0	0.7866	154.12	1.3099	2500.73

Table -2 Experimental □, u and the calculated values of internal pressure Pint using different methods for ternary liquid systems at 298.15K

System (I) Dimethyl Carbonate(1)+Methanol(2)+Cyclohexane(3)

x1	x2	□ □10-3	u(mix)	P_{int,idl,x_i}	$P_{\text{int},idl,\phi_i}$	$P_{\text{int},m}$	$P_{\text{int},m,h}$
		(kg m-3)	(m s-1)	(atm)	(atm)	(atm)	(atm)
0.0587	0.0624	0.7833	1220	3008.14	3003.49	2900.74	2901.31
0.0471	0.9072	0.8060	1106	2585.35	2614.57	2576.37	2567.06
0.1011	0.0923	0.7920	1202	3028.83	3018.20	2868.29	2798.84
0.0849	0.1946	0.7912	1190	2965.31	2983.32	2822.59	2801.57
0.1129	0.2993	0.8011	1170	2937.43	2968.60	2786.16	2712.87
0.1106	0.3839	0.8035	1160	2894.15	2939.73	2758.76	2802.23
0.1153	0.4527	0.8072	1150	2864.42	2917.67	2735.70	2712.45
0.1087	0.5858	0.8102	1133	2793.83	2857.44	2685.21	2656.77
0.1074	0.7004	0.8167	1119	2736.71	2797.43	2656.74	2634.98
0.0973	0.7967	0.8212	1111	2681.20	2730.73	2642.78	2667.46

0.1980	0.0938	0.8136	1184	3108.82	3071.65	2880.58	2874.23
0.2075	0.1865	0.8201	1167	3071.40	3055.90	2841.28	2818.49
0.1996	0.3039	0.8245	1153	3007.41	3019.86	2805.28	2798.73
0.2722	0.2299	0.8405	1157	3104.07	3086.87	2874.61	2856.38
0.1135	0.6222	0.8140	1127	2780.03	2842.97	2676.40	2635.98
0.1690	0.6329	0.8379	1123	2821.03	2875.07	2740.33	2739.44
0.2069	0.6798	0.8620	1121	2829.66	2878.84	2811.62	2789.97
0.3810	0.0711	0.8595	1173	3272.35	3192.85	3000.78	2997.89
0.2825	0.1885	0.8404	1161	3132.89	3103.30	2889.19	2846.67
0.3080	0.2813	0.8557	1151	3108.75	3099.33	2903.86	2921.56
0.2870	0.4064	0.8612	1139	3030.08	3049.84	2876.94	2846.56
0.2884	0.4981	0.8728	1134	2986.41	3020.87	2896.51	2868.26
0.3043	0.5909	0.8952	1132	2954.27	2998.58	2962.99	2921.57

Table -2 continue…

0.3624	0.1026	0.8567	1169	3241.46	3174.66	2975.72	2941.87
0.3941	0.1795	0.8732	1161	3230.26	3184.19	3001.95	2989.67
0.3942	0.2934	0.8866	1152	3174.64	3162.21	3012.64	3000.87
0.3512	0.4327	0.8895	1142	3070.70	3092.53	2983.23	2963.23
0.3683	0.5129	0.9112	1141	3045.73	3082.78	3051.99	3019.67
0.4473	0.1105	0.8825	1167	3308.31	3235.68	3057.47	3041.12
0.4853	0.1786	0.9021	1164	3306.67	3257.07	3113.33	3100.57
0.4607	0.3101	0.9141	1156	3221.87	3215.35	3122.28	3096.47
0.4807	0.4034	0.9406	1156	3192.90	3216.55	3212.79	3198.56
0.5854	0.0928	0.9249	1172	3432.01	3352.74	3224.98	3200.39
0.5700	0.2038	0.9379	1170	3364.90	3330.50	3261.94	3213.76
0.5711	0.3251	0.9637	1168	3306.49	3320.44	3343.08	3300.89
0.6655	0.1156	0.9574	1178	3487.58	3428.82	3363.97	3354.68
0.6918	0.1999	0.9863	1181	3468.26	3457.90	3478.76	3438.56
0.7834	0.1108	1.0027	1187	3588.14	3558.98	3563.59	3563.59
0.8731	0.0723	1.0301	1191	3681.68	3665.71	3679.49	3621.27
0.1999	0.3816	0.8295	1146	2969.66	2996.43	2796.63	2728.59
0.1973	0.5072	0.8376	1133	2906.07	2950.12	2776.02	2736.71
0.2976	0.0907	0.8382	1174	3193.30	3133.37	2930.16	2900.92
0.0637	0.7809	0.8026	1113	2660.94	2719.94	2589.90	2527.49

System(II) Toluene(1)+n-Heptane(2)+n-Hexane(3)

x1	x2	□ □10-3	u(mix)	P_{int,idl,x_i}	$P_{\text{int},idl,\phi_i}$	$P_{\text{int},m}$	$P_{\text{int},m,h}$
		(kg m-3)	(m s-1)	(atm)	(atm)	(atm)	(atm)
0.1210	0.1838	0.7506	1106.2	2240.81	2136.43	2399.94	2401.96
0.1459	0.2011	0.7529	1112.1	2282.50	2158.85	2426.58	2428.60
0.1698	0.2170	0.7570	1116.9	2322.36	2180.94	2455.60	2457.63
0.1929	0.2358	0.7635	1122.0	2361.67	2203.91	2493.67	2495.70
0.2160	0.2544	0.7682	1128.3	2400.93	2227.62	2530.18	2532.21
0.2390	0.2726	0.7732	1135.8	2439.95	2251.96	2572.09	2574.11
0.2641	0.2875	0.7791	1139.9	2481.40	2278.13	2605.76	2607.79
0.2849	0.3060	0.7835	1145.3	2517.16	2302.32	2639.12	2641.15
0.3088	0.3222	0.7849	1151.5	2557.08	2329.66	2665.33	2667.36
0.3330	0.3391	0.7938	1158.0	2597.62	2358.56	2718.41	2720.44
0.3559	0.3553	0.8000	1164.4	2636.03	2387.03	2762.39	2764.41
0.3760	0.3735	0.8036	1170.3	2670.66	2414.15	2795.93	2797.96
0.3983	0.3908	0.8089	1177.2	2708.42	2444.43	2839.30	2841.33

0.4204	0.3974	0.8188	1183.0	2743.41	2472.19	2895.32	2897.34
0.4433	0.4045	0.8324	1189.6	2779.74	2502.17	2968.07	2970.10

System (III) Cyclohehane(1)+n-Heptane(2)+n-Hexane(3)

x1	x2	□ □10-3	u(mix)	P_{int,idl,x_i}	$P_{\text{int},idl,\phi_i}$	$P_{\text{int},m}$	$P_{\text{int},m,h}$
		(kg m-3)	(m s-1)	(atm)	(atm)	(atm)	(atm)
0.1189	0.1823	0.6832	1101.8	2172.34	2119.26	2171.42	2173.44
0.1140	0.2102	0.6863	1107.1	2173.99	2123.23	2197.03	2199.05
0.1650	0.2202	0.6897	1111.3	2225.70	2155.43	2220.49	2222.51
0.1879	0.2379	0.6922	1115.0	2251.95	2173.84	2239.67	2241.70
0.2060	0.2484	0.6943	1119.0	2271.89	2187.86	2258.57	2260.60
0.2346	0.2729	0.6979	1126.1	2305.22	2212.71	2291.92	2293.95
0.2564	0.2903	0.6999	1129.5	2330.34	2231.90	2308.91	2310.93
0.2799	0.3073	0.7036	1135.1	2357.01	2252.69	2338.40	2340.42
0.3031	0.3266	0.7072	1140.2	2383.91	2274.53	2366.22	2368.25
0.3249	0.3424	0.7098	1144.7	2408.66	2294.99	2388.99	2391.02
0.3487	0.3599	0.7129	1150.6	2435.73	2318.07	2418.00	2420.03
0.3700	0.3776	0.7157	1155.5	2460.43	2339.93	2443.02	2445.05
0.3933	0.3948	0.7190	1161.9	2486.95	2363.92	2474.70	2476.73
0.4143	0.4030	0.7217	1164.8	2509.18	2384.01	2493.30	2495.33
0.4364	0.4103	0.7240	1169.2	2532.26	2405.36	2515.43	2517.46

Systen(IV) n-Hexane(1)+n-Heptane(2)+n-Decane(3)

x1	x2	□ □10-3	u(mix)	P_{int,idl,x_i}	$P_{\text{int},idl,\phi_i}$	$P_{\text{int},m}$	$P_{\text{int},m,h}$
		(kg m-3)	(m s-1)	(atm)	(atm)	(atm)	(atm)
0.1735	0.2759	0.7167	1125.4	2456.99	2459.66	2351.47	2353.49
0.2260	0.2185	0.7128	1115.0	2447.19	2449.49	2306.33	2308.35
0.2769	0.3158	0.7105	1105.6	2367.67	2369.78	2269.88	2271.90
0.3563	0.2797	0.7071	1101.4	2329.63	2331.31	2246.15	2248.18
0.3213	0.3524	0.7074	1100.1	2320.41	2322.09	2243.13	2245.16
0.3676	0.3504	0.7046	1099.8	2289.50	2290.81	2233.34	2235.36
0.4069	0.3878	0.7029	1098.6	2245.38	2246.07	2224.30	2226.33
0.4019	0.4291	0.7007	1096.2	2229.91	2230.31	2210.08	2212.11
0.3569	0.4377	0.7047	1095.8	2256.89	2257.72	2221.48	2223.51
0.3478	0.4849	0.7050	1093.4	2241.54	2242.06	2215.13	2217.15
0.3464	0.5192	0.7022	1093.0	2226.80	2227.00	2205.12	2207.15
0.3854	0.5504	0.6980	1092.4	2185.72	2185.02	2190.13	2192.15
0.4258	0.5421	0.6964	1092.0	2161.75	2160.58	2183.91	2185.93
0.4737	0.4943	0.6937	1090.3	2150.72	2149.51	2170.36	2172.39
0.4500	0.5179	0.6947	1088.9	2156.20	2155.01	2169.30	2171.33

Table –3 Experimental □, u and the calculated values of internal pressure Pint for quaternary liquid systems at 298.15K using different methods

System (I) n-Pentane(1)+n-Hexane(2)+Cyclohexane(3)+Benzene(4)

x1	x2	x3	□ □10-3	u(exp)	P_{int,idl,x_i}	$P_{\text{int},idl,\phi_i}$	$P_{\text{int},m}$	$P_{\text{int},m,h}$
			(kg m-3)	(m s-1)	(atm)	(atm)	(atm)	(atm)
0.0448	0.1238	0.1831	0.8051	1240.1	3365.02	3207.84	3055.46	3097.97
0.0658	0.1078	0.2036	0.8004	1239.9	3340.95	3173.53	3036.88	3079.15
0.0813	0.0934	0.2238	0.7998	1237.2	3323.24	3150.67	3024.70	3066.80
0.1006	0.0778	0.243	0.7995	1236.6	3301.96	3122.08	3021.37	3063.43

0.118	0.0629	0.2615	0.7941	1230.2	3283.05	3097.73	2977.69	3019.17
0.1243	0.0466	0.2842	0.7908	1240.1	3279.56	3097.78	3001.19	3042.98
0.141	0.1304	0.3129	0.7709	1205.4	3140.15	2950.46	2803.73	2842.90
0.156	0.1262	0.1513	0.7828	1213.5	3218.16	2981.59	2875.75	2915.88
0.1285	0.1192	0.5888	0.7549	1206.2	3009.27	2899.05	2748.27	2786.71
0.1537	0.0925	0.1685	0.7906	1226.4	3250.86	3020.96	2950.84	2991.97
0.1649	0.1013	0.5177	0.7547	1194.3	3018.76	2879.43	2706.98	2744.88
0.1368	0.1258	0.1507	0.7855	1210.5	3247.09	3018.62	2874.98	2915.10
0.091	0.1721	0.6137	0.7509	1201.6	2987.59	2898.43	2718.09	2756.13
0.0649	0.1378	0.1103	0.8048	1263.7	3362.04	3171.04	3141.92	3185.58
0.181	0.1656	0.297	0.7542	1197.4	3049.75	2853.30	2715.73	2753.74

System(II) n-Pentane(1)+n-Hexane(2)+Benzene(3)+Toluene(4)

x1	x2	x3	□ □10-3	u(exp)	P_{int,idl,x_i}	$P_{\text{int},idl,\phi_i}$	$P_{\text{int},m}$	$P_{\text{int},m,h}$
			(kg m-3)	(m s-1)	(atm)	(atm)	(atm)	(atm)
0.0943	0.0918	0.4587	0.8216	1260.1	3346.94	3118.47	3193.81	3238.15
0.13	0.1373	0.2974	0.8011	1233.2	3220.96	2957.21	3014.94	3056.91
0.1278	0.1288	0.3589	0.8054	1237.3	3247.11	2982.16	3046.25	3088.64
0.1492	0.1384	0.3421	0.7974	1217.9	3208.19	2930.96	2945.48	2986.54
0.1843	0.1484	0.2711	0.7855	1200.1	3138.49	2854.75	2838.01	2877.64
0.1823	0.164	0.3613	0.7838	1197.9	3149.69	2852.26	2824.08	2863.53
0.1819	0.1601	0.3842	0.7824	1200.1	3159.59	2860.42	2826.81	2866.29
0.125	0.1665	0.2455	0.7975	1223.1	3187.02	2919.93	2964.59	3005.90
0.1691	0.2041	0.2218	0.7769	1201.3	3093.29	2808.51	2811.15	2850.42
0.1866	0.0826	0.125	0.7995	1229.3	3158.57	2908.69	2994.65	3036.36
0.1372	0.1579	0.5548	0.7926	1211.4	3259.21	2958.12	2904.20	2944.71
0.066	0.1053	0.7033	0.8273	1268.1	3431.30	3205.16	3246.64	3291.69
0.0524	0.1434	0.4201	0.8176	1260.5	3340.48	3113.24	3179.77	3223.93
0.1568	0.0468	0.4582	0.8184	1256.3	3312.48	3064.56	3166.99	3210.98

System(III) n-Pentane(1)+Toluene(2)+n-Heptane(3)+Cyclohexane(4)

x1	x2	x3	□ □10-3	u(exp)	P_{int,idl,x_i}	$P_{\text{int},idl,\phi_i}$	$P_{\text{int},m}$	$P_{\text{int},m,h}$
			(kg m-3)	(m s-1)	(atm)	(atm)	(atm)	(atm)
0.0404	0.6358	0.1544	0.8023	1270.1	3192.53	3133.74	3155.98	3199.83
0.0560	0.5737	0.1284	0.8026	1256.3	3171.45	3111.42	3105.85	3149.03
0.0735	0.5474	0.1120	0.7997	1243.5	3155.73	3088.91	3047.45	3089.86
0.0935	0.5282	0.0959	0.7965	1230.2	3140.02	3064.61	2986.69	3028.29
0.1145	0.5054	0.0793	0.7927	1223.7	3122.50	3038.60	2948.92	2990.02
0.1134	0.4948	0.0660	0.7909	1232.3	3126.71	3046.23	2973.29	3014.71
0.1511	0.4602	0.0487	0.7857	1218.7	3091.00	2993.82	2904.98	2945.50
0.1709	0.4395	0.0338	0.7840	1213.2	3074.37	2970.09	2879.09	2919.27
0.1071	0.4099	0.0783	0.7855	1234.5	3097.73	3023.27	2960.90	3002.16
0.1126	0.4267	0.1137	0.7837	1218.1	3080.49	2996.78	2895.45	2935.84
0.1783	0.2174	0.1637	0.7498	1201.5	2927.91	2823.58	2713.76	2751.75
0.1991	0.2200	0.1674	0.7465	1199.2	2908.68	2798.55	2694.07	2731.79
0.1794	0.6020	0.1481	0.7842	1233.2	3062.81	2936.32	2951.33	2992.46
0.1351	0.1100	0.1484	0.7492	1217.2	2937.79	2853.03	2764.91	2803.58
0.0948	0.3338	0.2524	0.7615	1227.5	2994.58	2910.15	2846.05	2885.79

System(IV) n-Decane(1)+n-Hexane(2)+Cyclohexane(3)+Benzene(4)

x1	x2	x3	□ □10-3	u(exp)	P_{int,idl,x_i}	$P_{\text{int},idl,\phi_i}$	$P_{\text{int},m}$	$P_{\text{int},m,h}$
			(kg m-3)	(m s-1)	(atm)	(atm)	(atm)	(atm)
0.1171	0.1768	0.1883	0.7719	1255.3	3245.55	2670.36	2983.41	3024.97
0.1217	0.1853	0.1972	0.7672	1254.2	3225.65	2670.30	2961.42	3002.68
0.1169	0.1772	0.2769	0.7636	1255.8	3193.17	2718.87	2953.16	2994.32
0.1164	0.1774	0.3287	0.7597	1256.7	3162.98	2742.67	2941.38	2982.38
0.117	0.1769	0.3968	0.7553	1257.3	3122.89	2770.68	2926.30	2967.10
0.1244	0.1893	0.4098	0.7509	1258.0	3093.15	2766.16	2911.68	2952.29
0.1245	0.1889	0.4607	0.7479	1256.0	3063.58	2784.04	2893.14	2933.50
0.1275	0.3826	0.208	0.7303	1251.8	2982.42	2579.13	2810.90	2850.17
0.1244	0.3438	0.2035	0.7379	1252.6	3033.66	2590.31	2843.01	2882.70
0.1222	0.3055	0.2008	0.7342	1253.5	3082.33	2604.25	2831.67	2871.21
0.1195	0.2478	0.1951	0.7558	1254.8	3155.99	2629.04	2919.65	2960.36
0.1181	0.2109	0.1924	0.7627	1255.5	3202.20	2649.20	2948.70	2989.79
0.1158	0.1758	0.1911	0.7708	1256.4	3246.40	2672.61	2983.15	3024.70
0.1142	0.1425	0.188	0.7779	1257.1	3288.84	2698.13	3013.21	3055.17
0.1243	0.1898	0.4087	0.7506	1254.2	3093.32	2765.38	2897.48	2937.90
0.1223	0.2196	0.3842	0.7474	1253.4	3074.90	2734.49	2882.09	2922.31
0.1241	0.2570	0.3445	0.7431	1253.5	3052.63	2695.22	2865.99	2905.99
0.1266	0.2963	0.2984	0.7399	1251.4	3031.18	2655.01	2846.48	2886.22

System(IV) continue….

0.1253	0.3435	0.2560	0.7346	1252.3	3002.21	2614.69	2829.21	2868.72
0.1276	0.3854	0.2068	0.7297	1248.7	2979.75	2577.66	2798.26	2837.36
0.1252	0.4161	0.1828	0.7267	1254.7	2960.39	2556.41	2806.70	2845.91
0.2694	0.2068	0.2210	0.7419	1254.8	3035.20	2692.85	2865.68	2905.68
0.2366	0.1992	0.2154	0.7476	1255.4	3080.98	2689.64	2890.04	2930.36
0.2025	0.1953	0.2108	0.7519	1256.6	3123.18	2684.57	2910.83	2951.43
0.1749	0.1908	0.2045	0.7577	1255.7	3160.43	2679.77	2929.93	2970.78
0.1451	0.181	0.1946	0.7653	1257.5	3208.25	2675.96	2965.68	3007.00
0.117	0.1766	0.1894	0.7717	1258.0	3245.24	2671.18	2992.34	3034.01
0.0897	0.1727	0.1863	0.7768	1259.0	3279.59	2667.09	3015.71	3057.69

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