

# STATISTICAL APPROACH OF VISCOUS BEHAVIOUR OF TERNARY LIQUID MIXTURES

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## ABSTRACT:

*Thermodynamic properties of liquids and liquid mixtures play very important role in understanding the nature of molecular interactions occurring in the system. The viscosity of four ternary liquid mixtures, containing two common components, n-heptane and n-hexane have been evaluated adopting statistical theory of Flory , Bloomfield and Diwan. The present approach gives the satisfactory values of viscosity by different theories and the calculated values are compared with Frankel Method.*

**KEYWORDS:** *Flory statistical theory; Frankel Relation; Molecular Interaction; Ternary liquid mixtures, characteristic pressure characteristic temperature and reduced volume.*

## 1. INTRODUCTION

Flory statistical theory [1-2] was developed and applied by various workers [3-5] for studying the viscous behavior of binary liquid mixtures. Very few attempts [6-7] has been made to use Flory theory for study, the viscous behavior of ternary liquid mixtures.

The present investigation, aims to evaluate theoretically, the viscosity of four ternary liquid mixtures using Flory statistical theory and Bloom field & Dewan theory. The results are compared with the experimental findings. An interaction study in the mixtures is discussed in the light of excess viscosity. The ternary mixtures under the present study are:

Toluene + n-Heptane + n-hexane	I
Cyclohexane + n-Heptane + n-hexane	II
n-hexane + n-heptane + n-Decane	III
n-Hexa decane + Carbon tetra chloride + Benzene	IV

## 2. THEORETICAL

Bloom field and Dewan [4-6] developed a relation between viscosity and thermodynamic properties on the basis of absolute reaction rate theory and free volume theory of liquid state. Considering the possibility of two body interaction the statistical mechanical approach of Flory [1-2] has been used to develop and expression for the dynamic. Viscosity of ternary liquid mixtures the following expression for ternary liquid mixture has been obtained.

$$l_n \eta_m = \frac{G_m^k}{RT} + f(V) + X_1 l_n \eta_1 + X_2 l_n \eta_2 + X_3 l_n \eta_3 \quad 1$$

Where f(V) is given by-

$$f(V) = \frac{1}{(V-1)} - \left[ \frac{X}{(V_1-1)} + \frac{X}{(V_2-1)} + \frac{X}{(V_3-1)} \right]$$

And excess viscosity can be calculated by the expression-

$$\Delta l_n \eta = \frac{G_m^k}{RT} + \frac{I}{(V-1)} - \left[ \frac{X_1}{(V_1-1)} + \frac{X_2}{(V_2-1)} + \frac{X_3}{(V_3-1)} \right] \quad 2$$

This residual free energy of mixing ( $G_m^k$ ) is generally expressed by the relation-

$$G_M^R = H_M^R - T \dots \dots S_m^R \quad 3$$

Here ( $H_M^R$ ) is the enthalpy of mixing per mole and for ternary liquid mixture is given as-

$$H_M^R = \sum_{l=1}^3 X_l P_l V_l$$

Viscous behavior cannot be explained solely on the basis of free volume effects but residual entropy of mixing has been considered [2-6] to act as major additional factor of activation flow

The residual entropy of mixing ( $S_m^R$ ) can be evaluated using the relation-

$$S_M^R = \sum_{l=1}^3 \frac{3X_l P^* V^*}{T_l^*} l_n \frac{(V-1)}{(V_l-1)} \quad 4$$

Combining equations 1 to 4 the expression for viscosity of ternary liquid mixture takes the form-

$$\begin{aligned} l_n \eta_{(m)} = & \left[ X_1 l_n \eta_1 + X_2 l_n \eta_2 + X_3 l_n \eta_3 \right] - X_1 P_1^* V_1^* \left[ \left( \frac{1}{V_1} - \frac{1}{V} \right) + 3T_1 l_n \frac{V_1-1}{V-1} \right] \\ & - X_2 P_2^* V_2^* \left[ \left( \frac{1}{(V_2)} - \frac{1}{(V)} \right) + 3T_2 \ln \frac{(V_2-1)}{(V-1)} \right] - X_2 P_2^* V_2^* \left[ \left( \frac{1}{(V_1)} - \frac{1}{(V)} \right) \right] \\ & + 3T_3 l_n \frac{(V_3^{1-3} - 1)}{(V^{1-3} - 1)} + \frac{X_1 V_1^* \theta_2 X_{(1,2)}}{V_1} + \frac{X_2 V_2^* \theta_2 X_{(1,2)}}{V_2} + \frac{X_3 V_3^* \theta_2 X_{(1,2)}}{V_3} \\ & \left[ \frac{1}{(V-1)} - \left( \frac{X_1}{(V_1-1)} + \frac{X_2}{(V_2-1)} + \frac{X_3}{(V_3-1)} \right) \right] \quad 5 \end{aligned}$$

The characteristics pressure, temperature and reduced volume for the liquids are evaluated using the following equations

$$P^* = \frac{\alpha T(v)^2}{\beta_T}$$

$$T^* = \frac{T(v)^{4/3}}{[(v)^{1/3} - 1]}$$

$$V = \left( \frac{\alpha T}{3(1 + \alpha T)} + 1 \right)^3 \quad 6$$

Where T and  $\beta_T$  represents the thermal expansion coefficient temperature and isothermal compressibility respectively

The reduced volume for minute is given by

$$v = \frac{V}{X_1 V_1^* + X_3 V_3^* + X_3 V_3^*} \quad 7$$

The segment and site fractions of the ternary mixtures are calculated using following relations-

$$\psi_3 = \frac{X_3}{X_3 + X_1 \left( \frac{V_1^*}{V_2^*} \right) + X_2 \left( \frac{V_2^*}{V_3^*} \right)} \quad 8$$

$$\psi_2 = \frac{X_2}{X_2 + X_3 \left( \frac{V_3^*}{V_2^*} \right) + X_1 \left( \frac{V_1^*}{V_2^*} \right)} \quad 9$$

And  $\psi_1 = 1 - (\psi_2 + \psi_3)$

$$\theta_3 = \frac{\psi_3}{\psi_3 + \psi_1 \left( \frac{V_3^*}{V_1^*} \right)^{1/3 + \psi_1} \left( \frac{V_3^*}{V_2^*} \right)^{1/3}} \quad 10$$

$$\theta_2 = \frac{\psi_2}{\psi_2 + \psi_3 \left( \frac{V_2^*}{V_3^*} \right)^{1/3 + \psi_1} \left( \frac{V_2^*}{V_1^*} \right)^{1/3}} \quad 11$$

And  $\theta_1 = 1 - (\theta_2 + \theta_3)$

The interaction parameters are obtained using the relations-

$$X_{1,2} = P_1^* \left[ 1 - \left( \frac{P_2^*}{P_1^*} \right) \left( \frac{S_1}{S_2} \right)^{1/2} \right]^2 \quad 12$$

$$X_{2,3} = P_2^* \left[ 1 - \left( \frac{P_3^*}{P_2^*} \right) \left( \frac{S_2}{S_1} \right)^{1/2} \right]^2 \quad 13$$

$$X_{3,1} = P_3^* \left[ 1 - \left( \frac{P_1^*}{P_3^*} \right) \left( \frac{S_3}{S_1} \right)^{1/2} \right]^2 \quad 14$$

Bingham proposed for binary liquid mixture which gives the ideal viscosity of the mixture-

$$\eta = X_1\eta_1 + X_2\eta_2 \quad 15$$

For n-component mixture eq. (2.16) can be rewritten as-

$$\eta = \sum_{i=1}^n X_i\eta_i \quad 16$$

Where  $X_i$  and  $\eta_i$  are respectively the mole fraction and viscosity of pure components.

Following Kendall and Munroe the viscosity for multi component systems can be evaluated by the relation

$$l_n \eta = \sum_{i=1}^n X_i \eta_i \quad 17$$

Bingham and Kendall relations [8-11] were proposed considering the ideal mixing of solutions which is not always true.

Taking into consideration the interaction between the molecules. Frankel [9-10] with the help of Eyring's model, developed the logarithmic relation for non ideal binary liquid mixtures, given as-

$$l_n \eta = X_1^2 l_n \eta_1 + X_2^2 l_n \eta_2 + 2X_1 X_2 l_n \quad 18$$

Where  $\eta_{1,2}$  is a constant'

This equation 18 when extended to ternary liquid mixture takes the following term:

$$l_n \eta = X_1^2 l_n \eta_1 + X_2^2 l_n \eta_2 + X_3^2 l_n \eta_3 + 2(X_1 X_2 l_n \eta_{1,2} + X_2 X_3 l_n \eta_{2,3} + X_3 X_1 l_n \eta_{3,1}) + 3X_1 X_2 X_3 l_n \eta_{1,2,3} \quad 19$$

For ternary liquid mixtures, the equation suggested by Hind et al [12-15] takes the form-

$$\eta = X_1^2 \eta_1 + X_2^2 \eta_2 + X_3^2 \eta_3 + 2[X_1 X_2 \eta_{(1,2)} + X_2 X_3 \eta_{(2,3)} + X_3 X_1 \eta_{(3,1)}] + 3X_1 X_2 X_3 \eta_{1,2,3} \quad 20$$

In the present investigation, a different approach has been adopted to obtain the constant  $\eta_{(1,2)}$ ,  $\eta_{(2,3)}$ ,  $\eta_{(3,1)}$  and  $\eta_{(1,2,3)}$ . These equations are obtained from the respective pure components of the mixtures taking their equimolecular composition and following additively rule. Thus

$$\eta_{i,j} = 0.5\eta_i + 0.5\eta_j \quad 21$$

Similarly  $\eta_{(1,2,3)}$  is obtained from pure components as.

$$\eta_{(1,2,3)} = \frac{1}{3}\eta_1 + \frac{1}{3}\eta_2 + \frac{1}{3}\eta_3 \quad 22$$

### 3. RESULTS AND DISCUSSIONS

**3.1 (I):** Application of the Flory as well as Bloom field and Dewan theory for the evaluation of viscosity and the study of the ternary liquid mixtures: Toluene + n-Heptane + n-hexane (I) Cyclohexane + n-Heptane + n-hexane (II) n-hexane + n-heptane + n-Decane (III) and n-Hexa decane + Carbon tetra chloride + Benzene (IV)

The characteristic pressure ( $P^*$ ) reduced temperature ( $T$ ) and reduced volume ( $V$ ) of pure components are calculated using eqs. (6) for the above ternary systems.

The values of reduced volume ( $V$ ) and the site fraction of the mixture at different mole fraction and the values of interaction energy parameter are obtained vide eqs. (7), (10), (11), (12), (13) and (14) respectively. The values of ( $V$ ), ( $T$ ) and ( $V^*$ ) and ( $P^*$ ) of the pure components and reduced volume ( $V$ ) of the mixture and the values of energy parameter have been employed to obtain the values of excess free energy of mixing at composition with eqs. (3). The viscosity of ternary mixtures under consideration is computed through Bloom field & Dewan and Flory theory with equation (5). The computed viscosity along with their percentage deviation from experimental values are presented in table 1. The excess viscosity has been obtained using equation (2) and are also incorporate in table 1. The necessary data, required for the calculation have been taken from the literature. A perusal of table 1 shows that there is good agreement between theoretical and experimental values of viscosity showing an average percentage deviation of 3.94 for the system (I), 4.04 for the system (II) 2.16 for the system (III) and 4.29 for the system (IV) respectively. The trend of computed values of viscosities also agrees with the experimental values for all the systems under consideration.

The theoretical excess viscosities has been evaluated using eq. 2 and are also incorporated in table 1 along with experimental excess viscosities are found to be positive over the whole composition range for all the four systems under consideration. These values are in good agreement with the values of experimental excess viscosities. The sign and magnitude of may be visualized in terms of strength of interactions operating between the components of any system. According to Fort and Moore, the positive values of excess viscosity are indicative of weak interaction while negative values shows strong interaction between unlike molecules. In the present work, the four ternary systems containing two common components, chloroform and cyclo-hexane have been considered. The variation of ( $\eta^E$ ) with composition of the mixtures suggests the presence of interaction between the components. The positive values of ( $\eta^E$ ) in the systems shows the presence of weak interactions. Due to the non polar nature and inertness of cyclohexane strong interaction with cyclohexane is not expected. Therefore, only dispersive forces are dominant between benzene toluene chlorobenzene and cyclohexane.

Due to presence of C-H dipole in chloroform, it can interact considerably with the electron donating molecules such as toluene, cyclohexane, n-decane and carbon tetra chloride forming a donor acceptor complex in the case of n-hexane with n-heptane or n-decane and n-hexadecane and weak hydrogen bonding in carbon tetra chloride with benzene.

**3.2 (II)** Bingham, Kendall and Munroe, Frankel and Hinds relations are also used for the computation of theoretical viscosity in the systems: Toluene + n-Heptane + n-hexane (I), Cyclohexane + n-Heptane + n-hexane (II) , n-hexane + n-heptane + n-Decane (III). and n-Hexa decane + Carbon tetra chloride + Benzene (IV). The computed values of viscosity from these relations along with the

experimental viscosity values are recorded in table 2. The percentage deviation between theoretical and experimental values are also enlisted in table 3. The theoretical results are compared with the experimental values and the results are discussed in terms of percentage deviations. The average percentage deviation of computed viscosities values corresponding to Bingham relation (eq. 15), Kendall relation (eq 17), Frankel relation (eq. 16) and Hind relation (eq 20), are 13.5, -12.63, -9.17 and -21.27 for system (I) -10.76, -9.36, -6.08 and +19.77 for system (III) -9.38, -8.71, -5.95 and -18.52 for system (III) respectively. A close observation of average percentage deviation shows that the minimum deviation in calculated values are obtained from Frankel relation in all the four systems followed by 'Kendall' than 'Bingham's and maximum deviation is found due to 'Hind' relation.

In the present investigation we have adopted a different approach in the calculation of viscosity values by Frankel & Hind relations. The constant are obtained from the pure components using eq (19) and (20) respectively while in original Frankel method these quantities are obtained from the respective equimolecular liquid mixture composition. Thus in the present calculations of the viscosity by 'Frankel' & Hind relation. Only the viscosity of pure components are needed. Bingham's relation and additive relation take into account an idle mixing of solutions. Bingham's relation gives the idle viscosity of the mixtures while there is a logarithms additively in additive mixtures. Hind relation although considers the possible interaction fails to give good results. This discrepancy is due to the fact that this relation takes into account the simple additively of viscosity of all the components. Thus it is very clear that Frankel relation gives the best results.

To test the validity of our approach in the calculation of binary constant and ternary constant and hence in turn the validity of viscosity values obtained by Frankel relation using our approach. We have compared our results with the results obtained by other workers in table 3. Pandey et al computed the theoretical viscosity using Frankel's relation in the ternary liquid mixtures: Toluene + n-Heptane + n-hexane (I) Cyclohexane + n-Heptane + n-hexane (II) n-hexane + n-heptane + n-Decane (III), n-Hexa decane + Carbon tetra chloride + Benzene (IV). We have used the same systems for the computation of viscosity using our approach and the values of our approach results are compared with the results obtained by Pandey et al in table 5 along with percentage deviation from the experimental values.

It is clear from the table that percentage deviation for these systems are -15.88, 22.87, -16.51 and 1.119% respectively, for the system I, II, III & IV due to Pandey et al and the deviation due to present approach are 8.16, 2.76, 4.3 and -14.55 respectively. Thus it can be concluded that the present approach gives the satisfactory values of viscosity by Frankel relation.

**Table -1:** Statistical Approach of the Study of Viscous Behavior of ternary liquid systems

$x_1$	$x_2$	$G_m^R$ RT	$I_\eta \eta_v$	$\sum X_1 l_n \eta$	$I_n \eta(c.p.)$	$\eta(c.p.)$		% Deviation	$\eta^E$	
				Ideal visco (C.P.)	Theoretical	Theoretical	Experimental		Theoretical	Experimental

• **System I. Toluene (1) + n-Heptane (2) + n-Hexane (3)**

0.1015	0.5966	011187	-0.03696	-0.33850	-0.38665	0.67930	0.62900	-8.00%	0.95300	0.88200
0.2019	0.4991	0.01665	-0.02240	-0.37015	-0.40919	0.66420	0.60160	-10.40%	0.96200	0.87100
0.2998	0.4009	0.02025	-0.09896	-0.40187	-0.52108	0.59390	0.58210	-2.00%	0.88700	0.87000
0.4001	0.2997	0.20907	-0.08687	-0.43455	-0.54232	0.58140	0.57230	-1.60%	0.89800	0.88400
0.5045	0.1972	0.01845	-0.07603	-0.46776	-0.56224	0.56990	0.65380	-1.08%	0.90900	0.90000
0.6031	0.0993	0.01433	-8.06597	-0.49944	-0.57974	0.56000	0.56320	+0.56%	0.92300	0.92800
Average % deviation $\Delta$								3.94%		

• **System II. Cyclohexane (1) + n-Heptane (2) + n-Hexane (3)**

0.0911	0.5404	0.00460	-0.06103	-0.36093	-0.42655	0.65270	0.61670	-5.84	0.93640	0.88470
0.2198	0.4863	0.00556	-0.05892	-0.39171	-0.45620	0.63368	0.60210	-5.25	0.93750	0.89080
0.3004	0.3960	0.00600	-0.04291	-0.42680	-0.47571	0.62144	0.58930	-5.45	0.95220	0.90300
0.4013	0.2961	0.00696	-0.08687	-0.46703	-0.56086	0.57072	0.57080	-4.21	0.91040	0.91056
0.5016	0.1985	0.00650	-0.02178	-0.50655	-0.53433	0.58577	0.56210	-4.21	0.97210	0.93280
0.5976	0.0989	0.00631	+0.01005	-0.54611	-0.54236	0.58137	0.56180	-3.48	1.00370	0.96990
Average % deviation $\Delta$								4.04%		

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• **System III. n-Hexane (1) + n-Heptane (2) + n-Decane (3)**

0.1001	0.5965	0.00965	-0.08313	-0.31654	-0.31654	0.66410	0.5472	-2.61%	0.91139	0.88820
0.1988	0.4978	0.01433	-0.10428	-0.32682	-0.32682	0.64055	0.6455	+0.77%	0.88810	0.89502
0.3150	0.3975	0.01705	-0.08851	-0.33448	-0.33448	0.64402	0.6453	+0.20%	0.89980	0.90162
0.4005	0.3001	0.01693	-0.00942	-0.34672	-0.34672	0.68860	0.6504	-5.87%	0.97400	0.91993
0.5023	0.1995	0.01633	-0.03679	-0.35698	-0.35698	0.66860	0.6625	-0.16%	0.94820	0.94672
0.5997	0.0996	0.01422	-0.04650	-0.36783	-0.36783	0.65145	0.6740	+3.34%	0.94108	0.97365
Average % deviation $\Delta$									+2.17%	

• **System IV. n-Hexadecane (1) + Carbon tetra chloride (2) + Benzene (3)**

0.1023	0.5979	0.02090	-0.02890	-0.27580	-0.32550	0.72215	0.69130	-4.46%	0.95150	0.91080
0.2024	0.4976	0.02594	-0.10010	-0.24710	-0.37320	0.68860	0.71810	+4.11%	0.88160	0.91940
0.2981	0.4008	0.03030	-0.05610	-0.22000	-0.30640	0.73610	0.75270	+2.21%	0.91720	0.93790
0.3991	0.3097	0.03714	-0.11160	-0.18830	-0.33700	0.71390	0.77560	+7.96%	0.86180	0.93630
0.5001	0.1992	0.02990	-0.01380	-0.16200	-0.20560	0.81420	0.82110	+0.84%	0.95730	0.96550
0.6046	0.0986	0.02484	-0.00310	-0.13080	-0.15880	0.85310	0.87530	+2.54%	0.97240	0.99770
Average % deviation $\Delta$									4.30%	

**Table-2:** Theoretical Viscosities for ternary liquid system (in C.P.)

X <sub>1</sub>	X <sub>2</sub>	Bengham I	Kendall II	Frenkel III	Hind IV	Experimental	% Δ (I)	% Δ (II)	% Δ (III)	% Δ (IV)
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• **System I. Toluene (1) + n-Heptane (2) + n-Hexane (3)**

0.1015	0.3019	0.7200	0.7128	0.7005	0.7564	0.6290	-14.46%	-13.30%	-11.37%	-20.26%
0.2019	0.2990	0.6984	0.6906	0.669	0.7582	0.6016	-16.07%	-14.79%	-11.22%	-26.03%
0.2998	0.2993	0.6766	0.6690	0.6435	0.7481	0.5821	-16.23%	-14.92%	-10.55%	-28.52%
0.4001	0.3002	0.6542	0.6475	0.6225	0.7258	0.5723	-14.30%	-13.13%	-8.77%	-26.82%
0.5045	0.2983	0.6315	0.6264	0.6062	0.6905	0.5638	-12.00%	-11.90%	-7.51%	-22.47%
0.6031	0.2976	0.6098	0.6068	0.5950	0.5831	0.5632	-8.27%	-7.74%	-5.64%	-3.53%
Average % deviation Δ							-13.56%	-12.63%	-9.17%	-21.27%

• **System II. Cyclohexane (1) + n-Heptane (2) + n-Hexane (3)**

0.0911	0.3685	0.7053	0.6970	0.6849	0.4315	0.6167	-14.37%	-13.02%	-11.04%	+30.03%
0.2198	0.2939	0.6858	0.6759	0.6536	0.4994	0.6021	-13.90%	-12.26%	-8.55%	+17.06%
0.3004	0.3036	0.6625	0.6526	0.6273	0.5262	0.5893	-12.42%	-10.74%	-6.57%	+10.71%
0.4013	0.3026	0.6360	0.6269	0.6024	0.5170	0.5708	-11.42%	-9.83%	-5.53%	+10.53%
0.5016	0.2999	0.6099	0.6026	0.5831	0.4662	0.5621	-8.50%	-7.21%	-3.74%	+17.06%
0.5976	0.3035	0.5838	0.5792	0.5679	0.3750	0.5618	-3.92%	-3.10%	-1.08%	+33.25%
Average % deviation Δ							-10.76%	-9.36%	-6.08%	+19.77%

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• **System III. n-Hexane (1) + n-Heptane (2) + n-Decane (3)**

0.1001	0.3034	0.7343	0.7287	0.7180	0.7728	0.6472	-13.46%	-12.59%	-10.94%	-19.41%
0.1988	0.3034	0.7264	0.7212	0.7019	0.7907	0.6455	-12.53%	-11.73%	-8.73%	-22.49%
0.3150	0.2875	0.7202	0.7157	0.6920	0.7970	0.6453	-11.61%	-10.91%	-7.24%	-23.51%
0.4005	0.2994	0.7112	0.7070	0.6834	0.7879	0.6504	-9.35%	-8.70%	-5.07%	-21.14%
0.5023	0.2982	0.7034	0.6998	0.6804	0.7670	0.6625	-6.17%	-5.63%	-2.70%	-15.77%
0.5997	0.3007	0.6952	0.6922	0.6810	0.7334	0.6740	-3.15%	-2.70%	-1.04%	-8.81%
Average % deviation $\Delta$							-9.38%	-8.71%	-5.95%	-18.52%

• **System IV. n-Hexadecane (1) + Carbon tetra chloride (2) + Benzene (3)**

0.1023	0.5979	0.02090	0.7287	0.7180	0.7728	0.6472	-13.45%	-12.45%	-10.85%	-21.41%
0.2024	0.4976	0.02594	0.7212	0.7019	0.7907	0.6455	-12.53%	-11.72%	-8.82%	-23.39%
0.2981	0.4008	0.03030	0.7157	0.6920	0.7970	0.6453	-11.60%	-10.80%	-7.35%	-24.55%
0.3991	0.3097	0.03714	0.7070	0.6834	0.7879	0.6504	-9.35%	-8.73%	-5.04%	-22.12%
0.5001	0.1992	0.02990	0.6998	0.6804	0.7670	0.6625	-6.16%	-5.71%	-2.73%	-14.87%
0.6046	0.0986	0.02484	0.6922	0.6810	0.7334	0.6740	-3.16%	-2.67%	-1.01%	-8.79%
Average % deviation $\Delta$							-9.37%	-8.68%	-5.97%	-19.19%

**Table -3:** Comparison of viscosity values by Frankel Method.

$X_1$	$X_2$	$\eta$ Exp. (C.P.)	$\eta$ Frankel rel. present approach	$\Delta$ Present approach	SD present approach	SD Ref.
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• **System -I Toluene (1) + n-Heptane (2) + n-Hexane (3)**

0.1210	0.1838	0.3354	0.3073	8.37		
0.1459	0.2011	0.3405	0.3123	8.28		
0.1698	0.2170	0.3458	0.3170	8.31		
0.1929	0.2358	0.3528	0.3220	8.70		
0.2160	0.2544	0.3589	0.3271	8.83		
0.2390	0.2726	0.3656	0.3326	9.04		
0.2641	0.2875	0.3723	0.3386	9.06	8.16	16.20
0.2849	0.3060	0.3786	0.3445	9.00		
0.3088	0.3222	0.3844	0.3515	8.55		
0.3330	0.3391	0.3926	0.3595	8.44		
0.3559	0.3553	0.3996	0.3679	7.93		
0.3760	0.3735	0.4063	0.3768	7.27		
0.3983	0.3908	0.4146	0.3873	6.58		
0.4204	0.3974	0.4233	0.3967	6.29		
0.4433	0.4045	0.4415	0.4073	7.75		

• **System II Cyclohexane (1) + n-Heptane (2) + n-Hexane (3)**

0.1189	0.1823	0.3576	0.3356	6.16		
0.1440	0.2102	0.3689	0.3482	5.61		
0.1650	0.2202	0.3779	0.3578	5.31		
0.1879	0.2379	0.3876	0.3692	4.76		
0.2062	0.2484	0.3943	0.3781	4.10		
0.2346	0.2729	0.4176	0.3933	5.83		
0.2564	0.2903	0.4153	0.4053	2.40	2.76	23.30
0.2799	0.3073	0.4270	0.4187	1.93		
0.3031	0.3266	0.4389	0.4331	1.33		
0.3249	0.3424	0.4495	0.4470	0.56		
0.3487	0.3599	0.4629	0.4633	-0.09		
0.3700	0.3776	0.4746	0.4793	-0.99		
0.3933	0.3948	0.4986	0.4977	0.17		
0.4143	0.4030	0.5111	0.5139	-0.55		
0.4364	0.4103	0.5226	0.5316	-1.72		

• **System III. n-Hexane (1) + n-Heptane (2) + n-Decane (3)**

0.1735	0.2759	0.5601	0.5651	-0.89		
0.2260	0.3185	0.5089	0.5090	-0.01		
0.2759	0.3158	0.4899	0.4794	2.15		
0.3563	0.2797	0.4622	0.4496	2.74		
0.3213	0.3524	0.4556	0.4394	3.57		
0.3676	0.3504	0.4337	0.4049	6.64		
0.4069	0.3878	0.4098	0.3869	5.60		
0.4019	0.4291	0.3999	0.3772	5.67	4.73	18.07
0.3569	0.4377	0.4085	0.3938	3.61		
0.3478	0.4849	0.4195	0.3845	8.35		
0.3464	0.5192	0.3950	0.3762	4.76		
0.3854	0.5504	0.3709	0.3548	4.33		
0.4258	0.5421	0.3619	0.3434	5.13		
0.4737	0.4943	0.3517	0.3096	11.97		
0.4500	0.5179	0.3599	0.3403	5.46		

• **System IV n-Hexadecane (1) + Carbon tetra chloride (2) + Benzene (3)**

0.4489	0.2860	1.6725	1.8035	-7.26		
0.2523	0.2780	1.6999	1.2957	31.20		
0.2648	0.4474	1.3029	1.4684	-11.28		
0.1551	0.4100	1.0180	1.1746	-13.33		
0.1484	0.6257	1.1107	1.3138	-15.46		
0.0625	0.1453	0.7364	0.8087	-8.94	-14.55	-1.119
0.0670	0.3242	0.8052	0.9181	-12.30		
0.0704	0.5477	0.8956	1.0786	-16.97		
0.0723	0.7648	0.9894	1.2294	-19.52		
0.3318	0.2817	1.3573	1.4960	-9.27		

#### 4. CONCLUSION

- A close observation of average percentage deviation shows that the minimum deviation (calculated values) are obtained from Frankel relation in all the four systems followed by 'Kendall' than 'Bingham's' and maximum deviation is found due to 'Hind' relation.

- Bingham's relation and additive relation take into account an ideal mixing of solutions. Bingham's relation gives the ideal viscosity of the mixtures while there is a logarithm additively in additive mixtures.
- Hind relation although considers the possible interaction fails to give good results. This discrepancy is due to the fact that this relation takes into account the simple additivity of viscosity of all the components. Thus it is very clear that Frankel relation gives the best results.
- Thus it can be concluded that the present approach gives the satisfactory values of viscosity by Frankel relation.

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