



## NOTE

### Surface Tension of Binary Liquid Mixture

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Surface tension of binary mixture of *n*-pentane + *n*-heptane at 293.15 and 323.15 K has been evaluated from the Brock and Bird relation, Eberhart relation and ideal mixing rule and their results have been made to ascertain their validity and assumption on which their derivation are based. The merits and limitation of these relations have also been accessed. The average percentage deviation in the surface tension of the mixture have been used to evaluate extent and magnitude of interaction with in the component of the binary mixture.

**Key Words:** Brock and Bird, Eberhart, Ideal mixing rule, Surface tension, Binary mixture.

Several attempts<sup>1-10</sup> have been made to predict surface tension of pure liquids and liquid mixture. In the present studies, we have computed the surface tension of binary liquid mixture of *n*-pentane and *n*-heptanes at 293.15 and 323.15 K at wide range of composition using Brock and Bird<sup>11</sup> relation, Eberhart relation<sup>12,13</sup> and ideal mixing rule. Results have been compared in the light of percentage deviation. Merits and limitations of every method have been discussed.

Brock and Bird relation<sup>11</sup> have been extended for binary liquid mixture, using the relation:

$$\frac{\sigma_{\text{mix}}}{(\text{Pc}_m^2 \text{Tc}_m)^{1/3}} = \left( -0.951 + \frac{0.432}{Zc_m} \right) (1 - \text{Tr}_m)^{11/9} \quad (1)$$

where  $\text{Pc}_m$ ,  $\text{Vc}_m$  and  $\text{Tc}_m$  are pseudo critical constant of the mixture and may be obtained for the mixture from critical constants of pure components as their mole fraction average *i.e.*,

$$\begin{aligned} \text{Pc}_m &= X_1 \text{Pc}_1 + X_2 \text{Pc}_2 \\ \text{Vc}_m &= X_1 \text{Vc}_1 + X_2 \text{Vc}_2 \\ \text{Tc}_m &= X_1 \text{Tc}_1 + X_2 \text{Tc}_2 \end{aligned} \quad (2)$$

where  $X_1$  and  $X_2$  are mole fractions of first and second components and  $\text{Pc}$ ,  $\text{Vc}$ ,  $\text{Tc}$ , respectively are critical pressure, critical volume and critical temperature of the pure components. Suffixes 1, 2 represent first and second component, respectively.  $\text{Tr}_m$  and  $Zc_m$  are obtained by the relation:

$$\text{Tr}_m = \frac{T}{\text{Tc}_m} \quad (3)$$

$$Zc_m = \frac{\text{Pc}_m \cdot \text{Vc}_m}{R \text{Tc}_m} \quad (4)$$

where  $R$  is gas constant, taken as 0.08205 lit atm deg<sup>-1</sup> mol<sup>-1</sup>.

Eberhart<sup>12</sup> gave a relation for surface tension of binary liquid mixture as:

$$\sigma_{\text{mix}} = \frac{SX_1\sigma_1 + X_2\sigma_2}{SX_1 + X_2} \quad (5)$$

where  $X_1$ ,  $X_2$  represents mole fractions of first and second component and  $\sigma_1$  and  $\sigma_2$  are surface tension of first and second component.  $S$  is termed as surface tension enrichment factor which is temperature dependent. The other notations have their usual meaning.

The ideal surface tension for the mixture is obtained from the relations:

$$\sigma_{\text{mix}} = X_1\sigma_1 + X_2\sigma_2 \quad (6)$$

where  $X_1$ ,  $X_2$  are the mole fraction and the  $\sigma_1$  and  $\sigma_2$  are surface tension of pure component 1 and 2.

Percentage deviation of the surface tension values can be obtained by the relation:

$$\Delta\% = \left( \frac{\sigma_{\text{mix,exp}} - \sigma_{\text{mix,calc}}}{\sigma_{\text{mix,exp}}} \right) \times 100 \quad (7)$$

where  $\sigma_{\text{mix,exp}}$  is the experimental value of surface tension of the mixture and  $\sigma_{\text{mix,calc}}$  is the value of surface tension of the binary liquid mixture calculated from various equations (eqns. 4-6).

TABLE-1  
SURFACE TENSION OF *n*-PENTANE + *n*-HEPTANE MIXTURE FROM VARIOUS RELATIONS

X1	$\sigma_{(\text{exp})}$ (Ref. 14)	$\sigma_{(\text{BB})}$ (eqn. 1)	$\sigma_{(\text{Eb})}$ (eqn. 5)	$\sigma_{(\text{ideal})}$ (eqn. 6)	$\% \Delta_{(\text{BB})}$ (eqn. 7)	$\% \Delta_{(\text{Eb})}$ (eqn. 7)	$\% \Delta_{(\text{ideal})}$ (eqn. 7)
Temperature = 293.15 K							
0.165	19.62	18.75	19.57	19.47	4.3979	0.2252	0.7387
0.308	19.11	18.24	19.05	18.89	4.5408	0.2679	1.1053
0.432	18.60	17.86	18.58	18.39	39.631	0.0664	1.0804
0.542	18.15	17.57	18.15	17.95	3.1524	-0.0034	1.0703
0.640	17.71	17.36	17.74	17.56	1.9517	-0.1987	0.8424
0.727	17.29	17.20	17.37	17.21	0.4827	-0.4732	0.4615
0.877	16.65	17.00	16.69	16.60	-2.1265	-0.2780	0.2661
0.971	16.08	16.92	16.25	16.22	-5.2357	-1.0633	-0.9133
Average percentage deviation (%)					1.3908	-0.1821	0.5814
Temperature = 323.15 K							
0.165	16.33	15.87	16.32	16.37	2.7661	0.0295	-0.2654
0.308	15.55	15.31	15.58	15.65	1.4885	-0.2131	-0.6875
0.432	14.88	14.88	14.95	15.03	-0.0445	-0.4802	-1.0462
0.542	14.40	14.54	14.40	14.48	-0.9865	-0.0006	-0.5873
0.640	13.93	14.26	13.91	13.99	-2.4015	0.1031	-0.4565
0.727	13.41	14.04	13.49	13.55	-4.7003	-0.6037	-1.1016
0.877	12.60	13.69	12.77	12.80	-8.7279	-1.3515	-1.6367
0.971	12.12	13.51	12.32	12.33	-11.5000	-1.6994	-1.7763
Average percentage deviation (%)					-3.0136	-0.5270	-0.9447

Surface tension of liquids mixture of *n*-pentane and *n*-heptane are evaluated at 293.15 and 323.15 K at wide range of composition using Brock and Bird (eqn. 1), Eberhart relation (eqn. 5) and ideal mixing rule (eqn. 6). The necessary data required for the calculation have been taken from various literatures<sup>14-17</sup>. The results obtained have been presented in Table-1. Surface tension from Brock and Bird relation, Eberhart relation and from ideal mixing rule have been shown in the column 3, 4 and 5th, respectively of the Table-1.

The percentage deviation obtain from these relations using eqn. 7 have been tabulated in column 6, 7 and 8th of the Table-1. A look on the average percentage deviation of the surface tension obtained from the other three relations reveals that the Eberhart relation predicts the most satisfactory values of the surface tension and is not much more beyond the experimental values followed by Brock and Bird and ideal mixing rule relation. Thus eberhart relation shows its superiority over the other two relations.

Brock and Bird relation has its own limitation, limited to only non-polar liquids and extended to multicomponent system, by obtaining pseudo critical constant of the mixture  $P_{c_m}$ ,  $V_{c_m}$  and  $T_{c_m}$  using mole fraction average method, which is an approximation.

Eberhart relation thus may be used successfully for predicting surface tension of binary liquid mixtures at wide range of temperature and composition, better than Brock and Bird and ideal mixing rule procedure.

A very low values of average percentage deviation in surface tension, reveals that their occurs very low magnitude of interaction between the components of the mixture which is also evident from the structure of *n*-pentane and *n*-heptane hydrocarbons. Thus the binary mixture of *n*-pentane + *n*-heptanes behaves more as ideal mixture, with no appreciable interaction, with in the components.

## Conclusion

The study shows that Eberhart equation is much better than Brock and Bird and ideal mixing rule for evaluating surface tension of binary liquid mixture.

The average percentage deviation in the surface tension of the mixture, evaluated in the present work can be successfully utilized to study the extent and magnitude of interaction within the component of the multi component system. The extent and magnitude of interaction can reveal the structural change in the molecule when they are mixed together. The study has its importance in the field of chemical engineering and solution chemistry.

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