

## Comparison of Experimental Viscosities by Theoretically for 1-bromopropane in Chlorobenzene Mixture at (303.15, 308.15, 313.15 and 318.15) K

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### Abstract

Viscosities of liquid mixtures provide information for the elucidation of the fundamental behaviour of liquid mixtures, aid in the correlation of mixture viscosities with those of the pure components, and provide a basis for the selection of physicochemical methods of analysis. The viscosity ( $\eta$ ) of the binary mixtures of 1-bromopropane with chlorobenzene have been determined over the entire range of molefraction at temperatures ranging (303.15, 308.15, 313.15 and 318.15) K. From the experimental data viscosity values were correlated to the models of Kendall–Monroe, Grunberg and Nissan, Tamura and Kurata, Hind–McLaughlin Ubbelohde, Katti–Chaudhary viscosity models.

**Keywords:** Viscosity, 1-bromopropane, chlorobenzene, molecular interactions

### 1. Introduction

As an extension of our previous studies to measure the physical properties of the binary liquid mixture, we report in this work the experimental results of viscosity ( $\eta$ ) at temperatures (303.15, 308.15, 313.15 and 318.15) K and atmospheric pressure for pure components and binary mixtures of 1-bromopropane with chlorobenzene [1]. A molecular view of liquids can be used for a qualitative picture of the process of decrease in the shear (or bulk) viscosity of a simple fluid with temperature. As the temperature increases, the time of interaction between neighbouring molecules of a liquid decreases. The macroscopic effect is that the intermolecular force appears to decrease and so does the bulk (or shear) viscosity.

In chemical process industries, materials are normally handled in fluid form, and as a consequence, the physical, chemical, and transport properties of fluids, assume importance. Thus, data on some of the properties associated with the liquids and liquid mixtures like viscosity find extensive application in solution theory and molecular dynamics. These findings made it of obvious interest to study the viscosity of liquid mixtures of the two molecules.

1-Bromopropane composition is disclosed, which stays stable even under the condition that it is repeatedly used at high temperatures over an extended period of time as in vapour degreasing. 1-Bromopropane based fluids have found widespread use in industry for solvent cleaning, *i.e.*, vapor degreasing, cold cleaning and ultrasonic cleaning of complex metal parts, circuit boards, electronic components, implantable prosthetic devices, optical equipment and others [2]. Chlorobenzene is a polar molecule and is important component in synthetic chemistry (produce latex systems), in medicine and biological processes (fungicides, drugs, flavouring extracts, and antiseptics) and are

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widely used in preparing industrial solvents [3]. The viscosity of the blend of two or more liquids can be estimated using the Refutas equation.

**Table 1. Comparison of Experimental and Literature Values of Viscosities ( $\eta$ ) for Pure Compounds**

Liquid	T/K	$\eta / 10^{-3} \text{ Ns.m}^{-2}$	
		Exptl	Lit
1-bromopropane	303.15	0.4745	---
	308.15	0.4511	---
	313.15	0.4275	0.4274 <sup>4</sup>
	318.15	0.4095	---
chlorobenzene	303.15	0.7151	0.714 <sup>5</sup>
	308.15	0.6776	0.677 <sup>5</sup>
	313.15	0.6319	0.6310 <sup>6</sup>
	318.15	0.5904	---

The viscosity data have been correlated using Kendall–Monroe [7], Grunberg–Nissan [8], Tamura–Kurata [9], Hind–Mclaughlin Ubbelohde [10] and Katti–Chaudhary [11] at different temperatures to test their relative validity.

## 2. Experimental Techniques

The chemicals used were of AR/Merck quality. Mixtures were prepared by mixing appropriate volumes of liquids in airtight bottles to minimize the evaporation losses and weighed in a single-pan Mettler balance to an accuracy of  $\pm 0.001\text{mg}$ . Preferential evaporation losses of solvents from mixtures were kept to a minimum as evidenced by repeated measurement of the physical properties over an interval of 2-3 days, during which no changes in physical properties were observed. The possible error in molefractions is estimated to be around  $\pm 0.0001$ .

The temperatures were controlled by circulating water around the liquid cell from a thermostatically controlled water bath (accuracy  $\pm 0.1^\circ\text{C}$ ). The temperature of the cell was measured using a thermocouple (at the crystal) and was found to be accurate to  $\pm 0.25^\circ\text{C}$ . The viscosity at different temperature was measured using Oswald's Viscometer and stop clock with an accuracy of  $\pm 0.0001 \text{ Nsm}^{-2}$  and  $\pm 0.1\text{s}$ .

In the experiment, the viscosity for one composition sample were measured at different temperatures. Viscosities of pure compounds are reported in Table 1 together with the corresponding literature values.

### Theoretical Aspect:

Viscosity was measured using the relation

$$\eta = \eta_1 \left( \frac{t_2 \cdot \rho_2}{t_1 \cdot \rho_1} \right) \quad (1)$$

Where  $\eta_1$  is viscosity of water,  $\eta_2$  is viscosity of experimental liquid,  $\rho_1$  is density of water,  $\rho_2$  is density of experimental liquid,  $t_1$  is time of flow of water and  $t_2$  is time of flow of experimental liquid.

The following theoretical viscosities were calculated:

1. Kendall and Monroe derived the following equations for analyzing the viscosity of binary liquid mixtures based on zero adjustable parameter:

$$\eta = (x_1\eta_1^{1/3} + x_2\eta_2^{1/3})^3 \quad (2)$$

2. Grunberg and Nissan suggested the following semi empirical model containing one adjustable parameter to estimate the dynamic viscosity of binary liquid mixtures in terms of pure component data and to interpret the molecular interactions in these mixtures:

$$\eta = \exp \left[ \sum_{i=1}^j (x_i \ln \eta_i) + G_{12} \prod_{i=1}^j x_i \right] \quad (3)$$

where  $G_{12}$  is an interaction parameter which is a function of the composition and temperature of binary liquid mixtures.

3. Tamura and Kurata proposed the following relation between the viscosity of binary liquid mixtures and their pure components:

$$\eta = \sum_{i=1}^j x_i \phi_i \eta_i + 2T_{12} \prod_{i=1}^j [x_i \phi_i]^{1/2} \quad (4)$$

where  $T_{12}$  is the interaction parameter and  $\phi_i$  is the volume fraction of the  $i^{\text{th}}$  pure component in the binary mixtures.

4. Hind–McLaughlin Ubbelohde suggested the following viscosity model to interpret the molecular interactions:

$$\eta = \sum_{i=1}^j x_i^2 \eta_i + 2H_{12} \prod_{i=1}^j x_i \quad (5)$$

where  $H_{12}$  is the Hind interaction parameter and is attributed to unlike pair interactions.

5. Katti and Chaudhary proposed the following expression to interpret the molecular interactions.

$$\ln \eta V = x_1 \ln V_1 \eta_1 + x_2 \ln V_2 \eta_2 + x_1 x_2 W_{vis} / RT \quad (6)$$

where  $W_{vis}$  is an adjustable parameter and  $V_1$  and  $V_2$  are molar volumes of the first and second components, respectively.

### 3. Results and Discussion

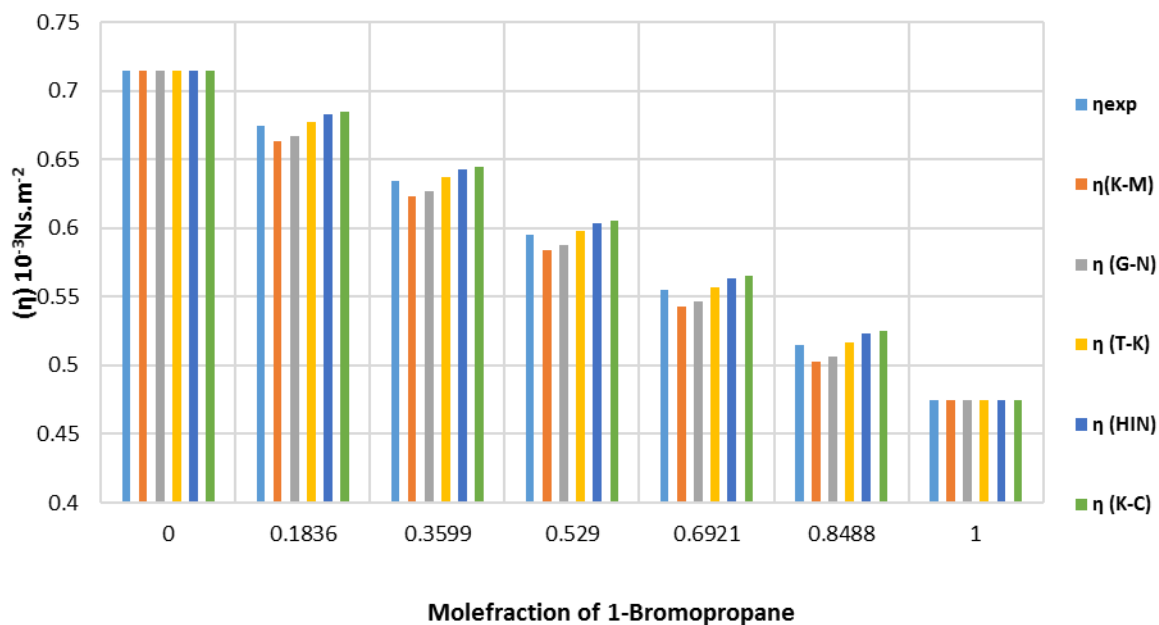
In liquids viscosity is independent of pressure (except at very high pressure) and viscosity tends to fall as temperature increases. It will be evident that a general viscosity equation can be applicable only to normal systems, and cannot include mixtures in which any changes of molecular state occur. In liquids, the additional forces between molecules become important. This leads to an additional contribution to the shear stress though the exact mechanics of this are still controversial. The viscometric information includes viscosity as a function of composition on the bases of weight, volume, and mole fraction, comparison of experimental viscosities with those calculated with several different equations. Viscosity itself is consequently not a simple additive property.

When you consider a liquid at room temperature, the molecules are tightly bound together by attractive inter-molecular forces (e.g., Vander Waal forces). It is these attractive forces that are responsible for the viscosity since it is difficult for individual molecules to move because they are tightly bound to their neighbours. The increase in temperature causes the kinetic or thermal energy to increase and the molecules become more mobile. The attractive binding energy is reduced and therefore the viscosity is

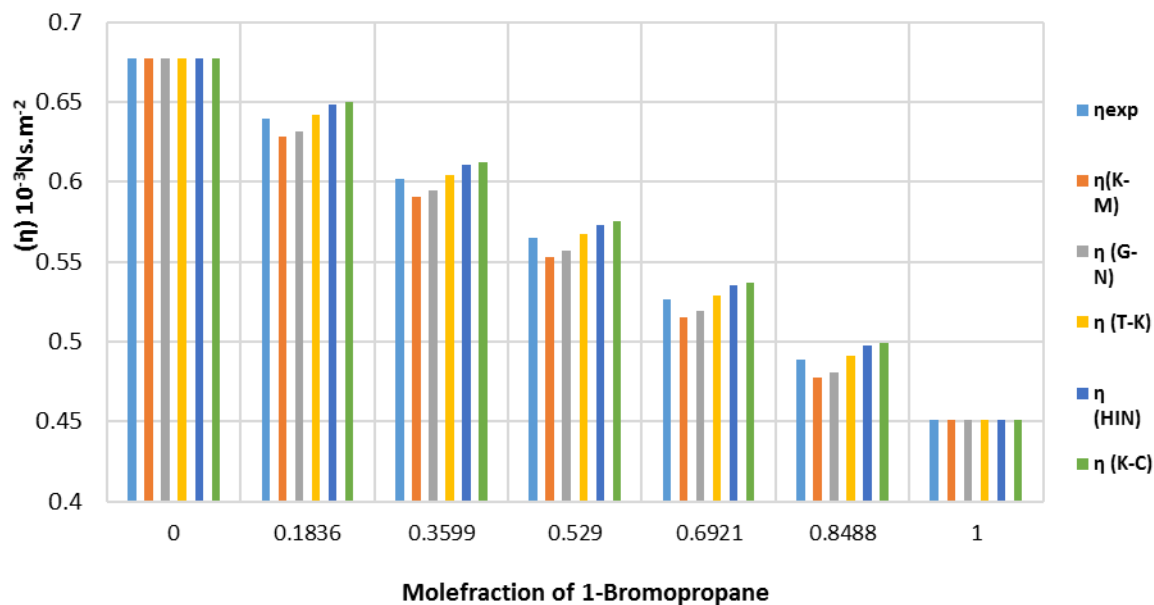
reduced. If you continue to heat the liquid the kinetic energy will exceed the binding energy and molecules will escape from the liquid and it can become a vapour.

**Table 2. Experimental Values of Viscosity  $\eta$  and Theoretical Values of Viscosity by Various Models (Kendall–Monroe, Grunberg–Nissan, Tamura–Kurata, Hind–Mclaughlin Ubbelohde and Katti–Chaudhary) for 1-bromopropane + Chlorobenzene at T = (303.15, 308.15, 313.15 and 318.15) K**

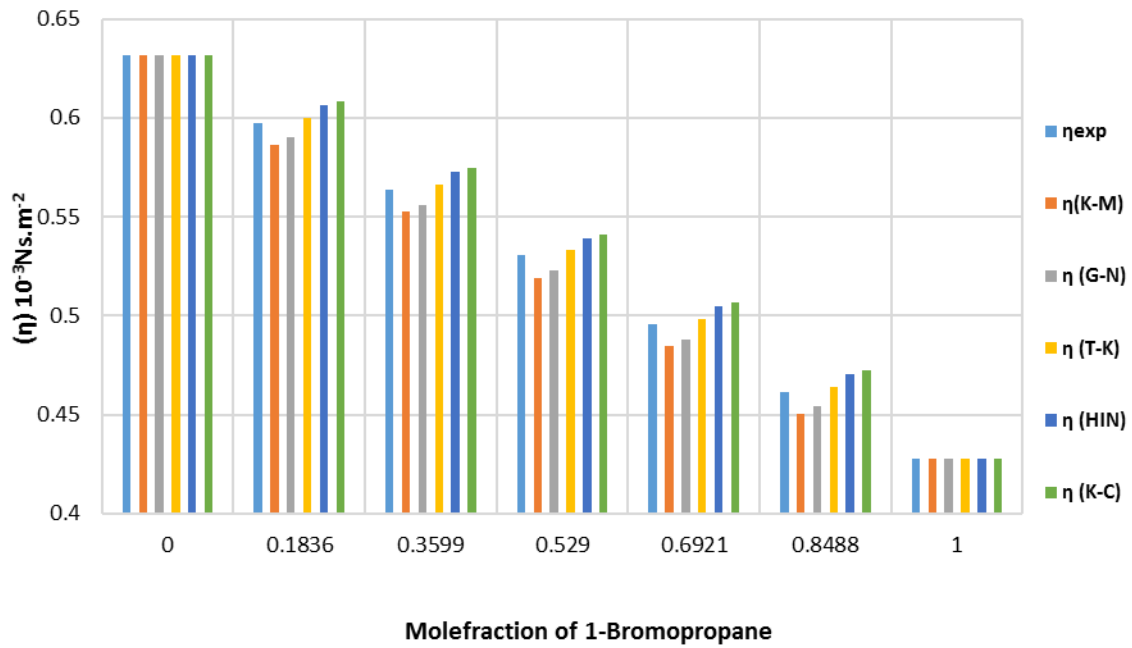
$X_1$	$\eta_{exp}$ ( $10^{-3}$ Ns.m $^{-2}$ )	$\eta$ (K-M) ( $10^{-3}$ Ns.m $^{-2}$ )	$\eta$ (G-N) ( $10^{-3}$ Ns.m $^{-2}$ )	$\eta$ (T-K) ( $10^{-3}$ Ns.m $^{-2}$ )	$\eta$ (HIN) ( $10^{-3}$ Ns.m $^{-2}$ )	$\eta$ (K-C) ( $10^{-3}$ Ns.m $^{-2}$ )
<b>303.15 K</b>						
0.0000	0.7151	0.7151	0.7151	0.7151	0.7151	0.7151
0.1836	0.6747	0.6656	0.6670	0.6773	0.6833	0.6852
0.3599	0.6346	0.6231	0.6269	0.6372	0.6432	0.6451
0.5290	0.5950	0.5835	0.5873	0.5976	0.6036	0.6055
0.6921	0.5547	0.5432	0.5470	0.5573	0.5633	0.5652
0.8488	0.5145	0.5030	0.5068	0.5171	0.5231	0.5250
1.0000	0.4745	0.4745	0.4745	0.4745	0.4745	0.4745
<b>308.15 K</b>						
0.0000	0.6776	0.6776	0.6776	0.6776	0.6776	0.6776
0.1836	0.6395	0.6280	0.6318	0.6421	0.6481	0.6500
0.3599	0.6020	0.5905	0.5943	0.6046	0.6106	0.6125
0.5290	0.5647	0.5532	0.557	0.5673	0.5733	0.5752
0.6921	0.5266	0.5151	0.5189	0.5292	0.5352	0.5371
0.8488	0.4888	0.4773	0.4811	0.4914	0.4974	0.4993
1.0000	0.4511	0.4511	0.4511	0.4511	0.4511	0.4511
<b>313.15 K</b>						
0.0000	0.6319	0.6319	0.6319	0.6319	0.6319	0.6319
0.1836	0.5976	0.5861	0.5899	0.6002	0.6062	0.6081
0.3599	0.5639	0.5524	0.5562	0.5665	0.5725	0.5744
0.5290	0.5305	0.5190	0.5228	0.5331	0.5391	0.5410
0.6921	0.4959	0.4844	0.4882	0.4985	0.5045	0.5064
0.8488	0.4617	0.4502	0.4540	0.4643	0.4703	0.4722
1.0000	0.4275	0.4275	0.4275	0.4275	0.4275	0.4272
<b>318.15K</b>						
0.0000	0.5904	0.5904	0.5904	0.5904	0.5904	0.5904
0.1836	0.5601	0.5486	0.5524	0.5627	0.5687	0.5706
0.3599	0.5307	0.5192	0.5230	0.5333	0.5393	0.5412
0.5290	0.5012	0.4897	0.4935	0.5038	0.5098	0.5117
0.6921	0.4705	0.4590	0.4628	0.4731	0.4791	0.4810
0.8488	0.4399	0.4284	0.4322	0.4425	0.4485	04504
1.0000	0.4095	0.4095	0.4095	0.4095	0.4095	0.4095



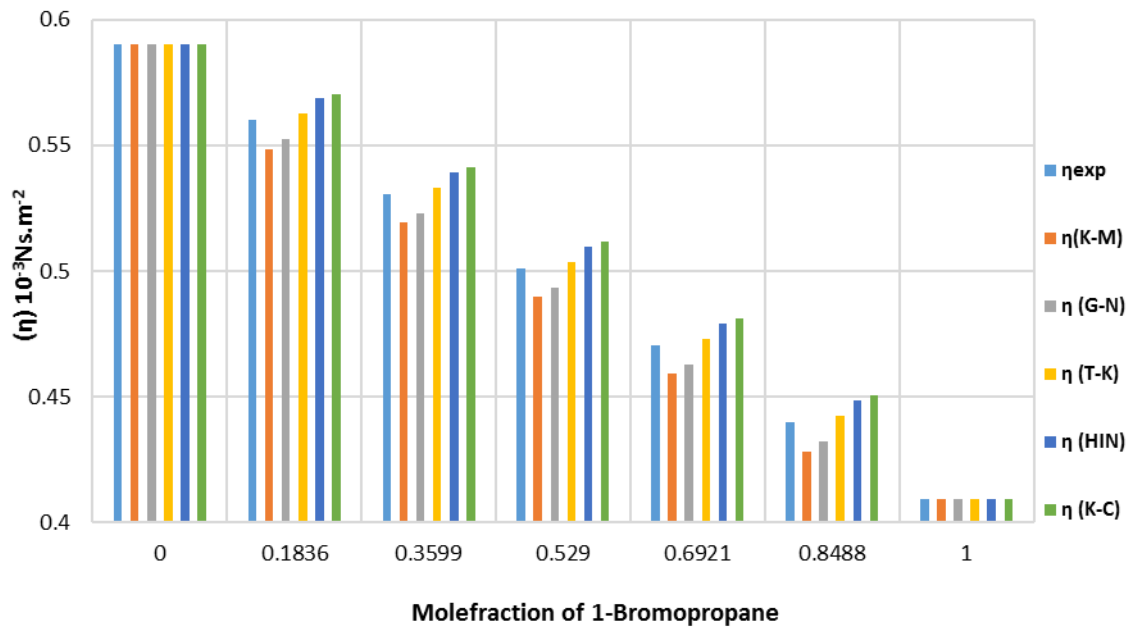
**Figure 1. Experimental Viscosity ( $\eta_{Exp}$ ) and Viscosity Calculated by Various Models Versus Molefraction of 1-bromopropane at 303.15 K for Binary Mixtures of 1-bromopropane with Chlorobenzene**



**Figure 2. Experimental Viscosity ( $\eta_{Exp}$ ) and Viscosity Calculated by Various Models Versus Molefraction of 1-bromopropane at 308.15 K for Binary Mixtures of 1-bromopropane with Chlorobenzene**



**Figure 3. Experimental Viscosity ( $\eta_{Exp}$ ) and Viscosity Calculated by Various Models versus Molefraction of 1-bromopropane at 313.15 K for Binary Mixtures of 1-bromopropane with Chlorobenzene**



**Figure 4. Experimental Viscosity ( $\eta_{Exp}$ ) and Viscosity Calculated by Various Models versus Molefraction of 1-bromopropane at 318.15 K for Binary Mixtures of 1-bromopropane with Chlorobenzene**

From the values which are presented in Table 2 it has been observed that the values for experimental viscosity and viscosity calculated using various viscosity models including Kendall–Monroe, Hind–McLaughlin Ubbelohde, Grunberg–Nissan, Tamura–Kurata and Katti–Chaudhary are similar. The levels in bar graph for experimental viscosity and viscosity calculated using Kendall–Monroe, Hind–McLaughlin Ubbelohde and Katti–Chaudhary viscosity models are almost same but levels for Grunberg–Nissan and Tamura–Kurata are little deviated as compared to the levels for the experimental values of viscosity from figures (1-4) at four temperatures 303.15, 308.15, 313.15 and 318.15 K. In this binary system it is recognized that considerable interaction between the two components has taken place. Hence the experimental viscosity correlated well with the viscosity calculated using various viscosity models [12-14].

The values of experimental viscosity ( $\eta$ ) obtained using various viscosity models for all the binary mixtures decrease with the increase of temperature. These values show that the above relations predict between theoretical and experimental viscosities adequately for the system under study. The best correlation method giving the relatively lowest is found to be the Tamura–Kurata equation [15-16].

#### 4. Conclusion

In this paper we report experimental data for viscosity of 1-bromopropane + chlorobenzene binary mixture at temperatures between (303.15 and 318.15) K along with theoretical viscosities to support the experimental data. Of all semi-empirical relations used to predict the viscosities of the present binary mixture provided a better representation of viscosity data. Thus, the present study further supports the effectiveness of a sample.

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