IJRAR.ORG E-ISSN: 2348-1269, P-ISSN: 2349-5138

INTERNATIONAL JOURNAL OF RESEARCH AND ANALYTICAL REVIEWS (IJRAR) | IJRAR.ORG

An International Open Access, Peer-reviewed, Refereed Journal

VISCOSITY OF N-HEXANE AS A FUNCTION OF TEMPERATURE FOR PRESSURE UPTO 4.6KBAR

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Abstract: We have measured the viscosity of normal hexane at temperature 30° C, 50° C, 75° C, and 100°C at pressures up to 4.6kbar by using the rolling-ball viscometer. The estimated accuracy in the viscosity data is ± 1 percent . The results for pressure variation are represented by an empirical relation which facilitates the determination of viscosity at desired pressure and given temperature. The experimental data obtained have been compared with values reported by other authors in the literature and found to be in good agreement. We have also checked the validity of some observations made by Kiran and Sen regarding the relationship between viscosity and density of n-hexane.

Keywords: Rolling-ball Viscometer, N-Hexane, Viscosity, Density, Pressure, Temperature

INTRODUCTION

A study of variation of viscosity of n-alkane with pressure and temperature has considerable scientific as well as industrial importance. As it provides information about intermolecular forces and for ever-increasing engineering applications. The effect of pressure and temperature on the viscosity of liquids is strongly dependent on molecular structure. It is observed mostly for liquids that a pressure change of a few kbar produces several orders of magnitude variation in viscosity. This type of observed behavior could be explained by any theory of viscosity of liquids.

The effect of temperature and pressure on the viscosity of n-paraffins has been investigated earlier also by several authors from time to time using diverse methods. The earliest detailed investigation in this connection is due to Bridgman [1]. He measured the viscosity of numerous liquids including four n-paraffins at pressures up to 10 kbar by the falling weight method (estimated error 2 to 5%). Hogenboom etal [2] investigated the viscosity of some liquids as a function of temperature and pressure including three n-paraffins by the rolling ball method for pressures up to 3.6 k bar (error ± 2%).Dickinson[3] measured the viscosity of n-hexane, n-octane and their mixtures by the falling weight method at 30 and 50° C and pressure up to 5kbar (error ± 2%). Dymond et al [4-6] investigated the viscosity behavior of several hydrocarbons including n-hexane for pressures up to 5 kbar in the temperature range 25 to 100° C (error ± 2%). Using a vibrating crystal, Kashiwagi and Makita [7] measured the viscosity of n-hexane, n-heptane, n-octane, n-decane and n-dodecane in the temperature range 25 to 75° C but pressure range limited to 1 kbar. Kiran and Sen [8] have reported their viscosity results for some n-paraffins over a wide temperature range lying between 37 and 177° C but their maximum pressure does not exceed 0.7 k bar. Recently, A. Darysafar and Khalil Shahbzi [9] gave a model to predict the dynamic viscosity of the n-alkanes as a function of pressure, temperature and n-alkane's molecular weight. Most recently, Prasad [10] investigated viscosity behavior of n-pentane for pressures up to 6kbar in temperature range 30 to 100° C (error $\pm$ 1%).

EXPERIMENTAL AND MATERIALS

In this work viscosity measurements have been carried out for n-hexane by using the rolling-ball viscometer. The pressure range in our experiments is up to 4.6kbar. The measurements are carried out at temperatures 30°C, 50°C , 75°C and 100°C. The experimental set up used in viscosity measurement has been described in Prasad[11]. Procedure and other details are the same as in our previous measurement Prasad[10].

The normal hexane used in this study is obtained from B.D.H. Chemicals Ltd.(England), who claim purity of 99.5 percent.

RESULTS AND DISCUSSION

Relative viscosity η_r (the ratio of viscosity at elevated pressure to the viscosity at atmospheric pressure) at each temperature is determined in the pressure range up to 4.6 kbar at temperatures 30°C, 50°C , 75 °C and 100°C using relation

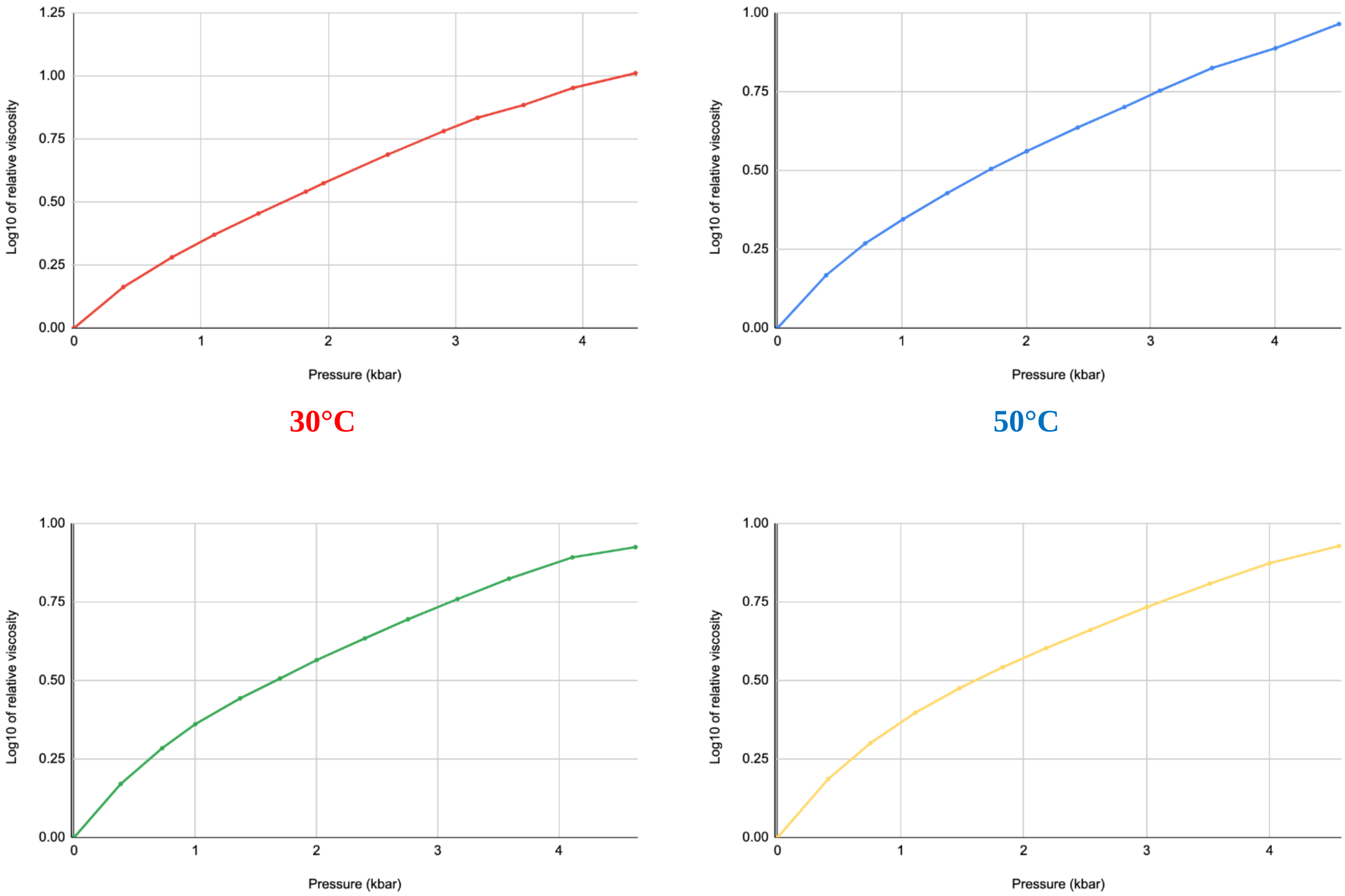
$$\eta = (KL)\,(\rho_b - \rho)\, t \,\mathrm{Sin}\,\theta \qquad - (1)$$

Where η is the coefficient of viscosity, K is the calibration constant, θ is the inclination of the rolling plane with the horizontal, ρ_b and ρ the density of the material of the ball and the liquid respectively and 't is the rolling time of the ball for covering the distance L in the tube. The experimental results of our measurements and calculated values (from eq.2) of relative viscosity are given in Table 1. In Fig.1 ,we plotted $\mathrm{Log}_{10}\eta_r$ (logarithm base 10 of relative viscosity) versus pressure at different temperatures. It is clear from the figures that as expected, the viscosity increases with pressure and decreases with temperature.

Table 1: Relative viscosity (ηr) of n hexane as a function of pressure and temperature

P (bar)	(30°C) η_r		P (bar)	(50°C) η_r		P (bar)	(75°C) η_r		P (bar)	(100°C) η_r	
	Exptl	Cal		Exptl	Cal		Exptl	Cal		Exptl	Cal
1	1.000	1.010	1	1.000	1.007	1	1.000	1.003	1	1.000	1.004
388	1.454	1.432	391	1.470	1.453	385	1.481	1.476	412	1.535	1.527
770	1.908	1.901	705	1.856	1.842	727	1.925	1.924	756	2.000	1.998
1102	2.342	2.350	1009	2.213	2.233	1001	2.297	2.289	1121	2.498	2.504
1450	2.845	2.870	1365	2.679	2.707	1370	2.774	2.783	1478	2.987	2.998
1823	3.476	3.501	1717	3.199	3.200	1698	3.207	3.232	1829	3.486	3.489
1962	3.754	3.761	2004	3.641	3.631	2002	3.675	3.669	2182	4.007	4.005
2467	4.877	4.844	2414	4.329	4.313	2399	4.308	4.294	2541	4.580	4.574
2907	6.044	5.991	2789	5.028	5.031	2755	4.955	4.928	3002	5.421	5.399
3174	6.828	6.776	3075	5.667	5.650	3164	5.747	5.755	3512	6.435	6.446

3535	7.668	7.906	3495	6.690	6.670	3589	6.675	6.698	3998	7.475	7.497
3924	8.970	9.097	4004	7.729	8.006	4111	7.804	7.800	4563	8.481	8.469
4415	10.260	10.192	4515	9.226	9.193	4632	8.413	8.407	-	-	-



30°C

50°C

75°C

100°C

Fig 1:Variation of relative viscosity (ηr) with pressure at temperature 30 ,50 ,75 and 100 °C

At each temperature our results could be fitted to polynomial equation

$$\text{Log } \boldsymbol{\eta}_r = \sum_{i=0}^{n} a_i p^{i} \qquad (2)$$

i=0 n

Where pressure P is measured in bar. The values of the coefficients in each case are given in Table 2. A fourth order polynomial is found to give a good representation of our results within the estimated accuracy of $\underline{+}$ 1 percent. The estimated error in the present viscosity data is $\underline{+}$ 1 percent, which is equal or less than reported by earlier authors .

Table 2: Values of the coefficients in eq 2

Temp (°C)	$a_0 \times 10^3$	$a_1 \times 10^4$	$a_2 \times 10^7$	$a_3 \times 10^{11}$	$a_4 \times 10^{15}$
30	3.68540	4.36130	-1.26040	3.36600	-3.58170
50	2.52520	4.62690	-1.51950	3.66460	-3.37730
75	1.00490	5.00720	-1.83730	4.57930	-4.35480
100	1.19400	5.11950	-1.83780	4.29650	-3.84040

COMPARISON OF RESULTS

We show some illustrative comparison of our smoothed results with other authors' data at 75°C in Fig. 2. It is clear from the figure that the results of Bridgman show noticeable positive deviations while those of Dymond exhibit smaller negative deviations but within their experimental accuracy.

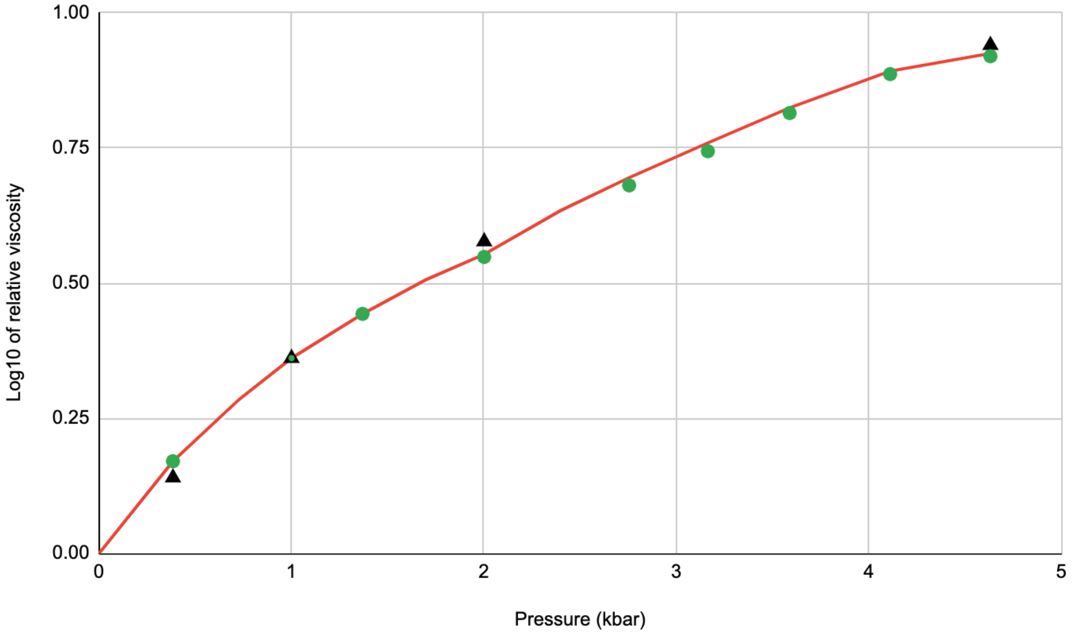


Fig 2: A comparison between present results, Bridgman and Dymond's data at 75°C

Before concluding, we have analyzed our viscosity data using a three-parameter relation given by Kiran and Sen (8) of the form

$$\eta = B_1 \exp (B_2 \times \rho) + B_3 \qquad - (3)$$

Where B_1, B_2, B_3 are parameters to be determined from the data. Evidently, according to Kiran and Sen, one set B_1, B_2, B_3 values would be needed for each n-paraffin data below 0.7 kbar. We have, however, tried Eq. (3) for the representation of viscosity data for pressures up to 4 kbar. This, however, makes it necessary to treat B_1, B_2, B_3 to be temperature dependent. The values of these parameters are given in Table 3. Average modulus of the deviation (M.D) of the values calculated from the Eq. (3) using these parameter values from our smoothed experimental values are given in Table 4. Our analysis shows that with our parameter values, MD is less than 1.7 percent.

Table 3: Values of the coefficients in eq 3

Temp (°C)	B_1 x 10^{10}	B_2 x 10^2	B_3 (mPa.S)	MD (%)
30	6.2850	1.8632	0.170	1.7
50	36.3401	1.6303	0.127	1.3
75	78.4960	1.5244	0.109	1.4
100	264.6600	1.63633	0.086	1.3

CONCLUSION

The present study contributed to a reliable experimental database for n-hexane for pressures ranging up to 4.6 kbar and temperatures from 30° C to 100° C. It is inferred from the study that as expected, the viscosity increases with increase in pressure and decreases with increase in temperature. Based on the measured data, an empirical relation is developed which is found to give a good representation of our results within the estimated accuracy of ± 1 percent. In our viscosity data the estimated error is ± 1 percent. A comparison shows that our data is in good agreement with available literature data. Average modulus of the deviation (M.D) of the values calculated from the Eq. (3) using these parameter values from our smoothed experimental values are reported. Our analysis shows that with our parameter values, MD is less than 1.7 percent. We hope that this data could be useful for scientific and practical applications.

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