Experimental Measurement of Viscosity of N-Octane at Elevated Pressure and Temperature

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Abstract: *We have measured the viscosity of normal octane at temperature 30° C, 50° C, 75° C, and 100°Catpressure up to 5.5 kbar by using the rolling-ball viscometer. The estimated accuracy in the viscosity data is ± 1 percent. The experimental data obtained have been compared with values reported by other authors in the literature and found to be in good agreement. The results for pressure variation are represented by an empirical relation. We have also checked upto4 kbar the validity of some observations made by Kiran and Senregarding the relationship between viscosity and density of n-octane.*

Keywords: Viscosity, Rolling-ball Viscometer, Density, Pressure, Temperature, n-Octane

1. Introduction

A study of variation of viscosity of liquids as a function of pressure and temperature has considerable importance both for understanding of the fundamental problem of the liquid state and for ever increasing engineering application. The effect of pressure and temperature on the viscosity of liquids is strongly dependent on molecular structure which, in turn, determines properties such as specific volume, phase transition, dielectric relaxation etc. 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%). Dymond etal [3-5] investigated extensively the viscosity behavior of several pure hydrocarbons including n-octane for pressures up to 5 k bar in the temperature range 25 to 100° C (error + 2%). Using a vibrating crystal, Kashiwagi and Makita [6] 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 [7] 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. Hseen O. Baled etal [8] determined experimentally viscosity of n-octane and isooctane at pressures between 4 and 242MPa and temperatures between 303K and 523K. 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.

2. Experimental and Materials

In this work viscosity measurements have been carried out for n-octane by using the rolling-ball viscometer. The pressure range in our experiments is up to 5.5kbar. The measurements are carried out at temperatures 30°C, 50°C 75 and 100°C. Procedure and other details used in this measurement have been described in [10]. The normal octane used in this study is obtained from E. Merc (Germany), who claim purity of 99.5 percent.

3. 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 5.5 kbar at temperatures 30°C, 50°C, 75 °C and 100°C using relation

$$\eta = (K/L)\,(\rho_b - \rho)\,t\,\mathrm{Sin}\boldsymbol{\theta} \qquad (1)$$

Where η is the coefficient of viscosity, K is the calibration constant, $\boldsymbol{\theta}$ 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 $\mathrm{Log}_{10}\boldsymbol{\eta}_r$ (logarithm base 10 of relative viscosity) versus pressure at different temperatures. It is clear from the figure that as expected, the viscosity increases with pressure and decreases with temperature.

Table 1: Relative viscosity (ηr) of n-Octane 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	0.997	1	1	1.002	1	1	1.002	1	1	1.005
412	1.446	1.454	415	1.496	1.487	475	1.575	1.569	396	1.523	1.504
815	1.993	1.993	798	2.011	2.021	751	1.955	1.951	753	1.996	2.007

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1039	2.4	2.336	1213	2.69	2.689	1032	2.377	2.375	1037	2.421	2.431
1452	3.061	3.057	1568	3.328	3.335	1423	2.997	3.018	1391	2.978	2.985
1880	3.955	3.951	2009	4.27	4.247	1718	3.544	3.546	1789	3.639	3.651
2040	4.337	4.332	2535	5.526	5.54	2035	4.156	4.159	2163	4.315	4.339
2541	5.731	5.737	3012	6.947	6.971	2526	5.235	5.225	2508	4.982	5.048
3029	7.478	7.496	3521	8.893	8.857	3033	6.552	6.523	3025	6.329	6.286
3540	9.852	9.873	4004	11.055	11.061	3515	7.99	8.001	3521	7.628	7.674
4060	13.017	12.951	4512	13.839	13.842	4011	9.81	9.822	4045	9.244	9.222
4602	16.792	16.823	5023	16.984	17.014	4529	12.012	12.045	4601	10.507	10.51
			5316	18.86	18.845	5031	14.433	14.398			
						5515	16.547	16.554			
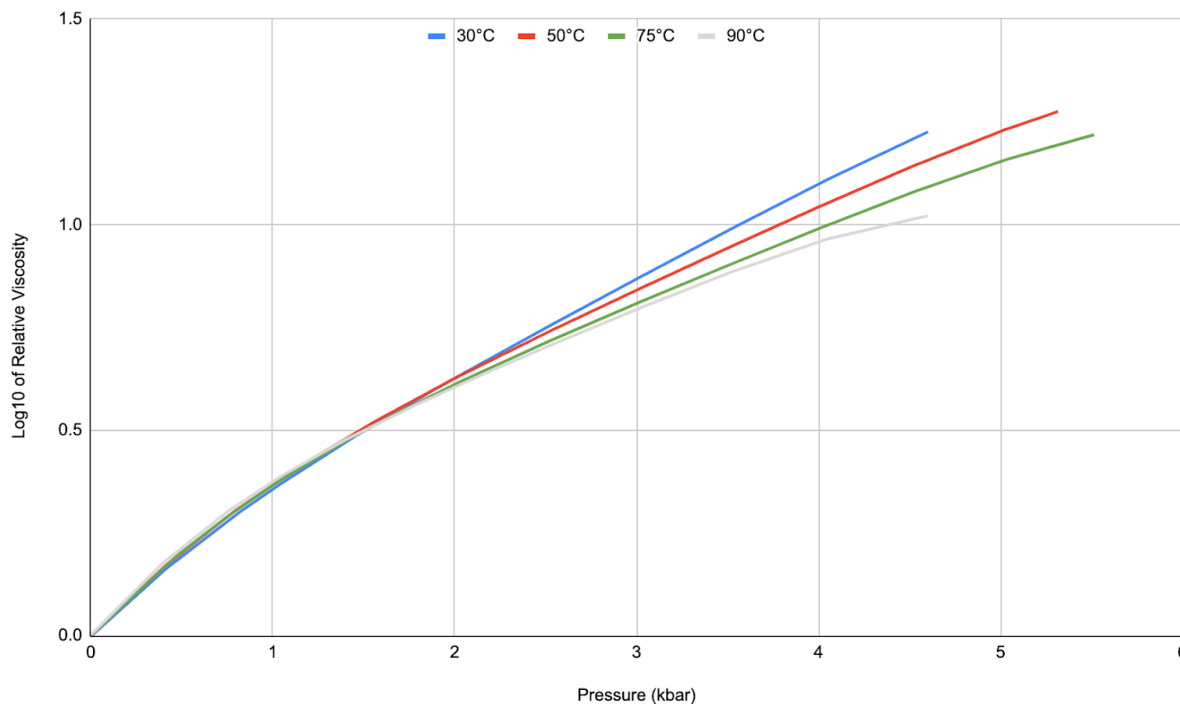
Figure 1: Relative viscosity (ηr) of n-Octane as a function of pressure and temperature

At each temperature our results could be fitted to polynomial equation

$$\mathrm{Log_{10}}\eta_r = \sum_{i=0}^{n} a_i \, p^i \qquad (2)$$

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 representative of our results within the estimated accuracy of $\pm$ 1 percent. The estimated error in the present viscosity data is $\pm$ 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 x 10^3	a_1 x 10^4	a_2 x 10^7	a_3 x 10^{11}	a_4 x 10^{15}
30	1.1149	4.3161	-0.91965	1.993	-1.6811
50	0.42655	4.5417	-1.051	2.0247	-1.5165
75	1.0838	4.585	-1.1296	2.1301	-1.5654
100	2.0219	5.0117	-1.6249	3.8477	-3.5573

We show some illustrative comparison of our results with other author's data at 50°C in Fig.2. In this figure, our smoothed values from Eq. 2 are shown in a yellow line curve while the results of other authors in the form reported by them are shown by a black line (Dickinson), redline (Dymond) and green line (Kashiwagi) curve.

It is clear from the figure that the limited pressure results of Kashiwagi and Makita [6] up to 1 kbar are in good agreement with ours while those of Dymond etal [5] and Dickinson [11] show respectively progressively increasing negative and positive deviations. In the former case the maximum deviation is 2% while in the latter case it is 3%. Details of comparisons in later two cases are given quantitatively in Table 3

Table 3: Quantitative comparison between present results, Dickinson and Dymond's data at 50°C

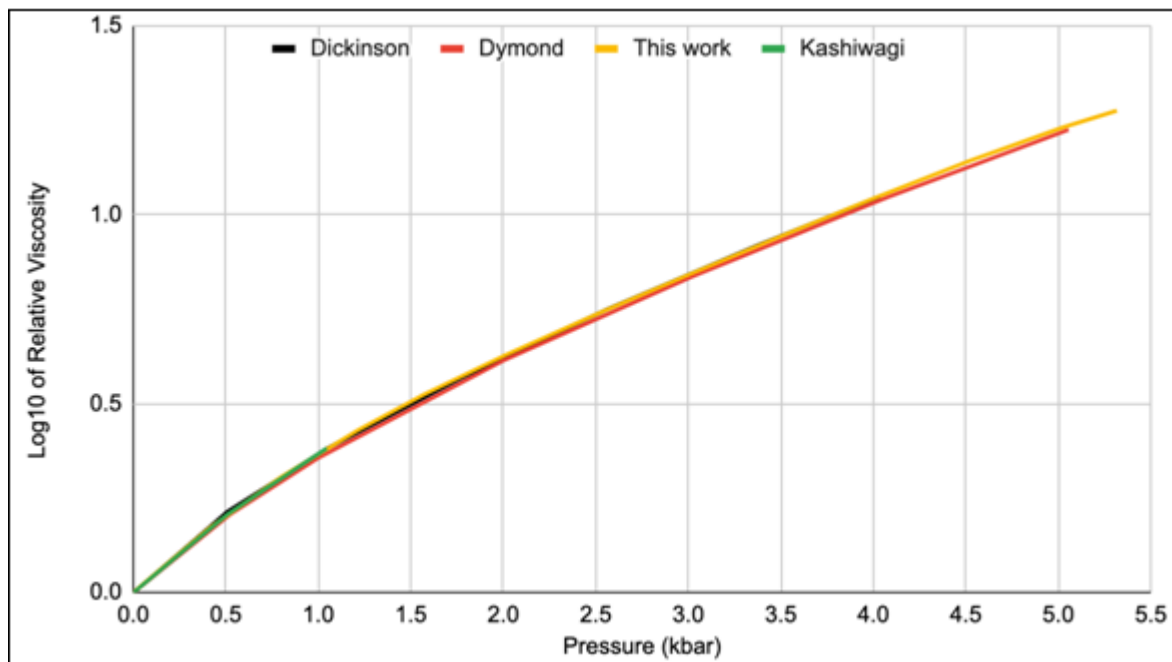| P (bar)	This work	Dickinson	P (bar)	This work	Dymond etal
1	1	1	1	1	1
510	1.612	1.637	524	1.631	1.612
1045	2.408	2.402	999	2.333	2.271
1780	3.757	3.716	2002	4.232	4.116
2565	5.623	5.629	3020	6.998	6.858
3380	8.293	8.321	4080	11.491	11.147
4035	11.22	11.18	5055	17.209	16.788

Figure 2: A comparison between present results, Kashiwagi, Dickinson and Dymond' s data at 50°C

Lastly, we also analyzed our viscosity data using a three-parameter relation given by Kiran and Sen [7] 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 k bar. We have, however, tried Eq. (3) for the representation of viscosity data for pressures up to 4 kbar. This, however, makes it necessary to B_1, B_2, B_3 to be temperature dependent. The values of these parameters are given in Table 4. 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 2.0 percent.

Table 4: Values of the coefficients in eq 3

Temp (°C)	$B_1 \times 10^{11}$	$B_2 \times 10^2$	B3 (mPa.S)	MD (%)
30	1.1878	2.3684	0.327	2
50	21.338	2.0084	0.214	0.9
75	119.32	1.7777	0.164	1.4
100	378.01	1.6216	0.129	1.6

4. Conclusion

The present study contributed to a reliable experimental database for n-octane at temperatures 30° C, 50° C, 75° C, and 100° C and pressures range up to 5.5 kbar. It is evident from illustrations that as expected, the viscosity increases with pressure and decreases with temperature. Based on the measured data, empirical relation is developed which is found to give a good representative of our results within the estimated accuracy of $\pm$ 1 percent. The estimated error in the present viscosity data is $\pm$ 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 2.0 percent. It is hoped that this data could be useful to physicists, chemists and engineers for scientific and practical applications.

References

[1] P.W. Bridgman, Proc. Am. Acad. Sci. 61, 57(1926).
[2] D.L. Hogenboom, W. Webb and J.A. Dixon. J. Chem. Phys. 46, 2586(1967).
[3] J.H. Dymond, K.J. Young and J.D. Isdale, Int. J. Thermo-phys. 1,345(1980).
[4] J.H. Dymond, J. Robertson and J.D. Isdale, Int. J. Thermophys. 2,133(1981).
[5] J.H. Dymond, J. Robertson and J.D. Isdale, Int. J. Thermophys. 2,223(1981).
[6] H. Kashiwagi and T. Makita, Int. J. Thermophys. 3,289(1982).
[7] E. Kiran and Y.L. Sen, Int. J. Thermophys. 13,411(1992)
[8] Hseen O. Baled etal Fuel, 164 ,199(2016)
[9] A. Darysafar and Khalil Shahbzi, Petroleum Science & Tech, 36,333(2018)
[10] Jamuna Prasad,IJARIIE, volume 8,Issue1,124(2022)
[11] E. Dickinson, J. Phys. Chem. 81, 2108(1977).