Viscosity of *n*-Decane in the Liquid Phase

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Experimental *n*-decane viscosity data are presented for temperatures from 100° to 340° F. and pressures from 200 to 8000 p.s.i.a.

THIS investigation is one of several efforts by the authors to provide viscosity data for pure hydrocarbons and mixtures.

The experimental data presented in this paper are in the liquid phase for temperatures from 100° to 340° F. and pressures from 200 to 8000 p.s.i.a. No previous work was found in the literature for this system for the conditions studied and reported in this paper. The only correlation considered herein is that of the residual viscosity. Recommended values for *n*-decane viscosity are presented for temperatures from 100° to 460° F. and for pressures from 200 to 8000 p.s.i.a.

APPARATUS AND MATERIALS

The capillary-tube viscometer used for this investigation has been described previously in detail (*3, 4*). Although this viscometer is an absolute instrument, the viscosity of nitrogen at 77° F. and 1000 and 2000 p.s.i.a. was measured before and after the experimental program of *n*-decane. This is to ensure that the instrument behaves properly. The data for nitrogen checked within ±0.1% with those reported by Michels and Gibson (*6*). The *n*-decane used was Phillips Petroleum Company's pure grade, certified 99 mole % minimum purity.

EXPERIMENTAL DATA

All of the data are for the liquid phase. They were obtained for pressures up to 8000 p.s.i.a. for 100° F., 7000 p.s.i.a. for 160° F., 6000 p.s.i.a. for 220° and 280° F., and 5000 p.s.i.a. for 340° F.

Isobars of *n*-decane viscosity are presented in Figure 1, and a crossplot of viscosity *vs.* pressure is presented in Figure 2. Experimental data are presented as points in these two figures. Detailed tables of the experimental data have been prepared and are available from ADI.

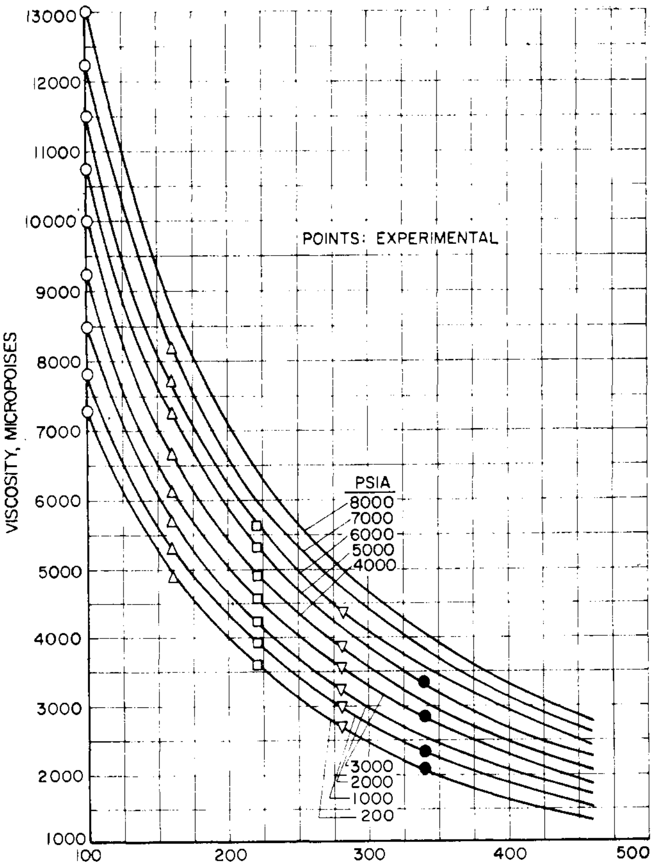

Figure 1. Viscosity of *n*-decane *vs.* temperature

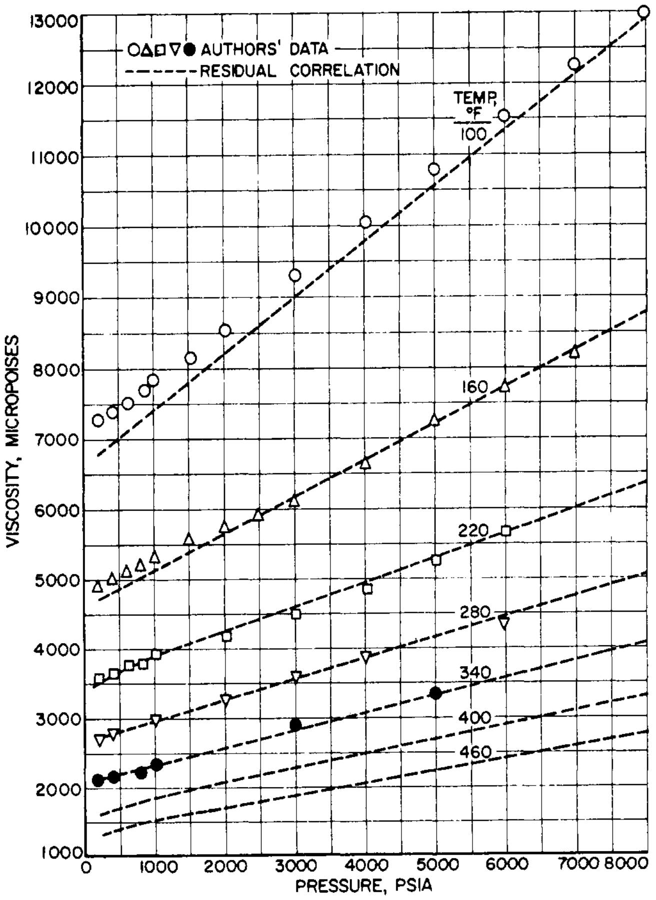

Figure 2. Viscosity of *n*-decane *vs.* pressure

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CORRELATION

The residual viscosity concept which has been discussed elsewhere (*1, 2*) was used in this work. Residual viscosity is defined as the difference between the viscosity at a given pressure and temperature and μ_0, the viscosity at gas phase which is usually at 1 atm. pressure for most light hydrocarbons and gases, and the same temperature.

The residual viscosity is then plotted *vs.* density on linear coordinates; usually a smooth continuous curve is obtained. If the density values for a system are known for various temperatures and pressures, the viscosity values at those conditions may be interpolated from the plot. Therefore, to use this correlation to construct the residual viscosity-density plot, it is essential to know the viscosity values at gas phase, the density values of the system, and experimental viscosity data.

Because of the high critical temperature of *n*-decane, 654° F., and the critical pressure, 306 p.s.i.a., the gas phase of the system is below 1 atm. pressure for the conditions investigated. The gas phase viscosity values, μ_0, are estimated by the method of Lee and Eakin (*5*). This equation has the form,

$$\mu_0 = \frac{(7.43 + 0.0133M)T^{3/2}}{T + 75.4 + 13.9M}$$

where T is temperature in °R. and M is the molecular weight. The residual viscosity-density plot was constructed (Figure 3). The residual viscosity shows temperature de-

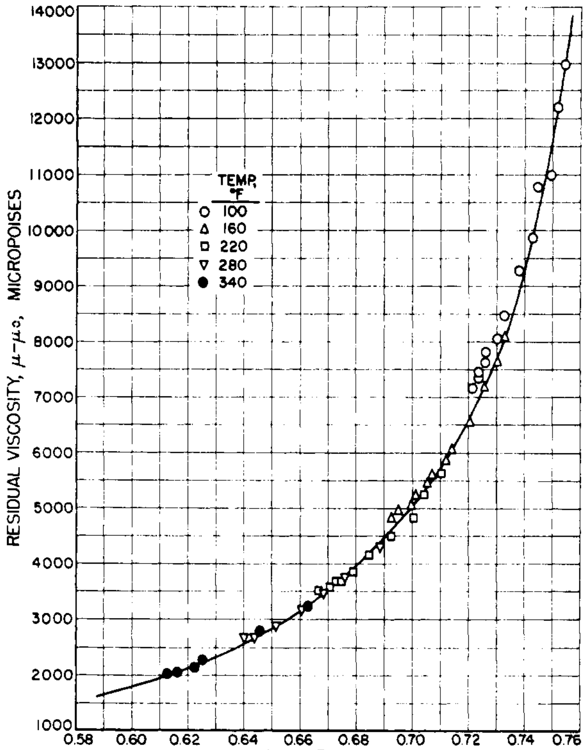

Figure 3. Residual viscosity of *n*-decane vs. density

Table I. Viscosity of *n*-Decane

Pressure, P.S.I.A.	Density, G./Cc.	Visc., μp.		Density, G./Cc.	Visc., μp.		Density, G./Cc.	Visc., μp.		Density, G./Cc.	Visc., μp.
		100° F.			160° F.			220° F.			
200	0.7212	7265	(7264.9)	0.6927	4910	(4911.6)	0.6664	3580	(3585.4)		
300	0.7221	7320	...	0.6944	4945	...	0.6680	3620	...		
400	0.7235	7367	(7367.7)	0.6948	5000	(5015.5)	0.6703	3650	(3652.9)		
500	0.7235	7450	...	0.6970	5040	...	0.6713	3700	...		
600	0.7235	7525	(7523.6)	0.6991	5095	(5105.2)	0.6723	3760	(3759.7)		
800	0.7258	7690	(7692.7)	0.6991	5190	(5189.6)	0.6743	3790	(3788.3)		
1000	0.7258	7850	(7898.7)	0.7012	5300	(5312.4)	0.6783	3900	(3903.1)		
1250	0.7281	8000	...	0.7034	5400	...	0.6803	3980	...		
1500	0.7305	8200	(8115.4)	0.7056	5540	(5537.4)	0.6824	4075	...		
1750	0.7305	8380	...	0.7078	5650	...	0.6824	4160	...		
2000	0.7328	8550	(8502.9)	0.7078	5760	(5719.5)	0.6844	4230	(4211.7)		
2500	0.7352	8950	...	0.7122	6000	(5912.1)	0.6885	4425	...		
3000	0.7376	9320	(9356.9)	0.7144	6250	(6105.6)	0.6927	4600	(4549.7)		
3500	0.7400	9580	...	0.7167	6500	...	0.6948	4790	...		
4000	0.7424	10020	(10029.1)	0.7212	6730	(6679.9)	0.6991	4960	(4887.3)		
4500	0.7448	10400	...	0.7235	6990	...	0.7012	5125	...		
5000	0.7448	10800	(10850.5)	0.7258	7240	(7242.9)	0.7034	5320	(5317.1)		
6000	0.7500	11520	(11542.9)	0.7305	7730	(7729.2)	0.7100	5685	(5685.9)		
7000	0.7522	12260	(12265.0)	0.7328	8220	(8205.8)	0.7144	6000	...		
8000	0.7547	13020	(13019.6)	0.7424	8730	...	0.7189	6350	...		
		280° F.			340° F.			400° F.		460° F.	
200	0.6402	2720	(2719.6)	0.6127	2120	(2116.2)	0.5799	...		0.5439	...
300	0.6420	2740	...	0.6143	2140	...	0.5814	...		0.5468	...
400	0.6438	2790	(2798.6)	0.6160	2160	(2155.0)	0.5844	1670		0.5492	1360
500	0.6453	2800	...	0.6176	2195	...	0.5859	1700		0.5524	1380
600	0.6475	2830	...	0.6193	2220	...	0.5874	1725		0.5545	1400
800	0.6493	2890	...	0.6227	2270	(2240.6)	0.5920	1790		0.5599	1440
1000	0.6512	2960	(2986.7)	0.6244	2340	(2344.9)	0.5951	1845		0.5641	1480
1250	0.6549	3020	...	0.6278	2400	...	0.5998	1900		0.5698	1535
1500	0.6568	3100	...	0.6313	2460	...	0.6029	1950		0.5755	1580
1750	0.6587	3180	...	0.6348	2520	...	0.6061	2005		0.5799	1630
2000	0.6606	3260	(3300.4)	0.6366	2580	...	0.6094	2075		0.5844	1695
2500	0.6644	3400	...	0.6420	2720	...	0.6160	2170		0.5920	1760
3000	0.6683	3550	(3579.9)	0.6456	2870	(2898.7)	0.6227	2270		0.5982	1850
3500	0.6723	3700	...	0.6493	2970	...	0.6278	2370		0.6045	1950
4000	0.6763	3850	(3854.8)	0.6549	3080	...	0.6331	2470		0.6110	2050
4500	0.6803	4000	...	0.6587	3210	...	0.6366	2575		0.6160	2120
5000	0.6824	4150	...	0.6625	3345	(3346.2)	0.6420	2675		0.6210	2220
6000	0.6885	4420	(4386.5)	0.6703	3570	...	0.6493	2880		0.6296	2400
7000	0.6948	4730	...	0.6763	3820	...	0.6568	3085		0.6384	2580
8000	0.7012	5040	...	0.6824	4060	...	0.6644	3300		0.6456	2750

pendence to a certain degree. This behavior could be due to the lack of information of μ_0, the gas phase viscosity data.

RECOMMENDED VALUES

Recommended values for viscosity of *n*-decane for temperatures from 100° to 460° F. and pressures from 200 to 8000 p.s.i.a. are presented in Table I, in which experimental data are also presented in parentheses. The density values were those of Sage and Lacey (*7*).

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Liquid Phase Diffusion of Nonelectrolytes at High Dilution

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A correlation is presented for the prediction of diffusivities at high dilution in binary liquid solutions of nonelectrolytes. The correlation is based upon the empirical observation that $D\mu/T$ is nearly constant for self diffusion. The correlation is simple in nature, contains three constants and fits available data in the normal range of viscosities with a lower standard error than provided by other existing correlations.

THERE HAVE BEEN several recent significant theoretical contributions to the understanding of liquid phase diffusion. Despite this fact, empirical or semiempirical methods will likely continue to provide the most convenient and the most reliable estimation methods for liquid diffusivities for some time to come. The most widely used correlation for diffusion at high dilution is that of Wilke and Chang (*50, 51*); several others have put forward modifications or other equations (*17, 29, 39, 41*). All of these correlations have shortcomings when applied to the entire spectrum of available data; for example, difficulties have been encountered when the solute is highly polar (*10, 27*), when the solute has a low molecular weight, and when the solvent has a relatively large viscosity. The Wilke-Chang correlation also requires the estimation of an association parameter for polar solvents.

Despite the existence of several different theoretical approaches to liquid phase diffusion, it is possible to draw some general conclusions concerning the nature of independent variables which should affect the diffusion process. Diffusion rates are probably influenced by parameters reflecting molecular size and the strength of intermolecular forces. Although the necessary importance of solute-solvent interaction forces has been previously recognized (*28*), the only existing diffusivity correlation which allows for such effects is that of Sitamaran, Ibrahim, and Kuloor (*41*).

Several theoretical approaches (*2, 16, 35, 52*) suggest that the group $D\mu/T$ should be essentially constant with respect to temperature for a given solute-solvent pair. This prediction is borne out by available data with major exceptions occurring only at relatively high viscosities. The group $D\mu/T$ should then depend upon temperature-insensitive variables reflecting solute and solvent properties.

SELF DIFFUSION

Table I shows available data for self diffusion. Most theoretical approaches (*52*) indicate that for self diffusion the group $D\mu/T$ should be dependent upon variables reflecting molecular size, intermolecular forces, number of nearest neighbors, etc. However, the most striking feature of Table I is the relative constancy of $D\mu/T$ from one liquid to another. This conclusion is particularly apparent if water is treated as an exception along with substances such as liquid metals (*21*). The standard deviation of $D\mu/T$ in Table I is only 9%, without water. Obviously $D\mu/T$ (a nondimensionless group) will not have one and the same value for self-diffusion in all common liquids, but taking $D\mu/T$ to be empirically constant appears to be more in accord with the facts than taking $D\mu/T$ to vary inversely as $V^{1/3}$ (*35*) and/or inversely with the cohesive energy (*6*).

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