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Viscosity of Liquids

Theory, Estimation, Experiment, and Data

 Springer

VISCOSITY OF LIQUIDS

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by

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Chapter 4

CORRELATIONS AND ESTIMATION OF PURE LIQUID VISCOSITY

Available experimental data reveal that the viscosity of liquids generally decreases with temperature in a rapid and non-linear fashion and is not significantly dependent on pressures up to several atmospheres. However, liquid viscosity for organic liquids¹ at high pressures changes as shown in Fig 4.1.

For practical purposes, it is often sufficient to know the viscosity of liquids at atmospheric pressure as a function of temperature. In view of the preference of industrial activities near atmospheric pressures and lack of sufficient data on the viscosity for a large number of liquids as a function of pressure, we will confine our discussions primarily to the variation of liquid viscosity with temperature, after first mentioning a few estimation methods for the variation of viscosity with pressure and methods for estimation of liquid viscosity at characteristic conditions like critical point and normal boiling point are discussed. Liquid viscosity correlation methods based on density, surface tension and other physical and molecular properties are mentioned. We have also included group contribution and corresponding states methods in subsequent sections.

4.1 EFFECT OF PRESSURE ON VISCOSITY OF LIQUIDS

Viscosity of a number of fluids has been experimentally measured, but a compilation and correlation of data (particularly as a function of pressure) appears to be scarce. The book of Stefan and Lucas² is probably the first monograph to list the variation of liquid viscosity as a function of both

temperature and pressure for 50 fluids. We will mention the most important correlations here.

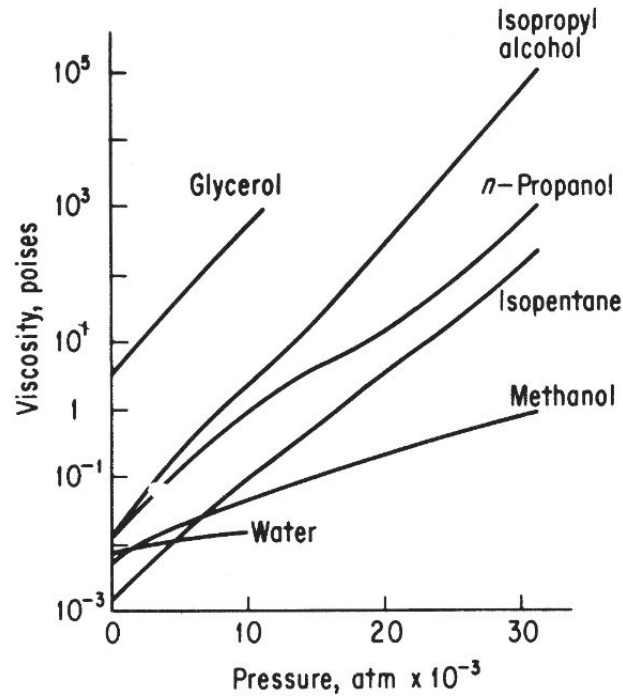


Figure 4.1. Variation of the liquid viscosity of some organic liquids with pressure at room temperature. (Adopted from R. C. Reid, J. M. Prausnitz, and T. K. Sherwood, *The Properties of Gases and Liquids*, McGraw-Hill, New York, 3rd Ed. 1977).

4.1.1 LUCAS METHOD FOR THE EFFECT OF PRESSURE

Lucas³ proposed the following equation for the effect of pressure on liquid viscosity.

$$\frac{\eta}{\eta_{SL}} = \frac{1 + D(\Delta P_R / 2.118)A}{1 + C\omega\Delta P_R} \quad (4.1)$$

where, η is the liquid viscosity at the pressure of interest P ,
 η_{SL} is the viscosity of the saturated liquid at the temperature of interest T ,
 ΔP_R is $[(P - P_{VP}) / P_C]$,

P_{VP} is the saturated vapor pressure at the temperature of interest T ,
 P_C is the critical pressure,
 ω is the acentric factor,
 A is $0.9991 - [4.674 \times 10^{-4} / (1.0523 T_R - 0.3877 - 1.0513)]$,
 D is $[0.3257 / (1.0039 - T_R^{2.573})^{0.2906}] - 0.2086$,
 C is $-0.07921 + 2.1616 T_R - 13.4040 T_R^2 + 44.1706 T_R^3 - 84.8291 T_R^4 + 96.1209 T_R^5 - 59.8127 T_R^6 + 15.6719 T_R^7$, and
 T_R is the reduced temperature ($= T/T_C$).

The estimated values of liquid viscosity using Lucas method are generally within 10 % of their experimental values.

4.1.2 NEURAL NETWORK APPROACHES FOR THE EFFECT OF PRESSURE

In recent years, neural network theory has been applied to correlate the pressure and temperature dependence of viscosity. One such method is due to Scalabrini and coworkers⁴⁻⁶. The authors initially used two approaches: the first through multilayer feedforward neural network and the other based on corresponding states approach with a scaling parameter. The corresponding states approach follows the method outlined by Teja and Thurner⁷. This method predicted the viscosity of certain hydrocarbons and refrigerants with a deviation of 5%. The authors have extended this method to mixtures. The corresponding states approach has been applied to very few compounds.

4.2 VISCOSITY AT SELECTED REFERENCE POINTS

4.2.1 LIQUID VISCOSITY AT THE CRITICAL POINT

Kim and Chair⁸ discuss a method of calculating the viscosity of fluids at the critical point. Based on a three-parameter equation of state, the authors suggested the following equation.

$$\eta_C = 78.84(n-1)(MT_C)^{0.5} \frac{0.5 + Z_C/(n-1)}{\sigma^2} \quad (4.2)$$

where, η_C is viscosity at the critical point in micropoise,
 n is the characteristic parameter in the equation of state,
 M is molecular mass in grams,
 σ is collision diameter in Å,
 T_C is the critical temperature in K, and

Z_C is the critical compressibility factor.

4.2.2 LIQUID VISCOSITY AT THE NORMAL BOILING POINT

Smith *et al.*⁹ compared three correlations (available in the literature at that time) to evaluate liquid viscosities at the normal boiling point, and support the view that a relation of the type;

$$\eta_B = C\rho_B^{0.5} \quad (4.3)$$

where, ρ_B is the density at the normal boiling point and C is a characteristic constant for a class of compounds, can be used to predict the viscosity at the normal boiling point with reasonable accuracy. Such relations in conjunction with a relation of the type

$$\eta = \eta_B P_S^{-n} \quad (4.4)$$

where, P_S is the saturated vapor pressure and n is a constant characteristic of each series of liquid hydrocarbons^{10,10a}, can be used to predict viscosity of saturated liquids.

Grain¹¹ recommends that, in the absence of a measured value for the liquid viscosity at the normal boiling point (η_B), the value indicated by the class of the substance from the following table can be used in Eq. (4.4).

Table 4.1. Liquid viscosity at normal boiling point for different classes of substances.

Class of the Substance	η_B
Alcohols (Aliphatic & Aromatic) ^a	0.45
Primary Amines (Aliphatic & Aromatic)	0.45
All Other Organic Liquids ^b	0.20

^a Not Applicable to Thiols

^b Exceptions are Benzene ($\eta_B = 0.30$) and Cyclohexane ($\eta_B = 0.40$)

4.3 EFFECT OF TEMPERATURE

Simple as well as complex expressions have been proposed for the representation of liquid viscosity as a function of temperature with the main objective of representing the available experimental data and for interpolation purposes. We will mention the different forms of temperature

dependence of viscosity proposed under correlation methods. Several methods have been proposed for the estimation of liquid viscosity from a variety of input information. We will discuss such methods under estimation methods. For most of the methods, we have tabulated the constants for the viscosity relation, to facilitate the reader in using the relation to predict viscosities for liquids of interest.

4.3.1 CORRELATION METHODS

Correlation methods in use some times have a theoretical basis but are often based on the observed behavior and optimally evolved representation. We mention below several correlation methods proposed and tested in the order of their complexity of form under the categories of: two-constant, three-constant and multi-constant equations.

4.3.1.1 Two-Constant Equations

Among several proposed relations, the simplest form of representation of liquid viscosity as a function of temperature is the relation;

$$\eta = Ae^{(B/T)} \quad (4.5)$$

where A and B are positive constants, and are characteristics of each substance. Originally proposed by de Guzman¹², the equation is popularly known as the Andrade equation.

4.3.1.1.a Duhne Representation

Duhne¹³ presented Eq. (4.5) in the logarithmic form as

$$\ln \eta = A + (B/T) \quad (4.6)$$

and evaluated the constants A and B for a number of substances. The constants A and B for several substances given by Duhne (rounded off to the necessary accuracy) along with the applicable temperature range are presented in Table 4.2. Also Table 4.2 includes experimental values of viscosity η (cP) at a specified temperature t (°C) for each substance from an evaluated data source.

Table 4.2. Constants of the logarithmic form of the temperature dependence of liquid viscosity given by Duhne¹³ [Temperature in K and Viscosity in cP].

Formula	Substance	A	B	Temperature Range, °C	$\eta, \text{cP (at, } ^\circ\text{C)}$
Br ₂	Bromine	-3.112	907.5	-4 to 29	0.99 (19.5)
CS ₂	Carbon disulfide	-3.442	713.8	-13 to 40	0.36 (20.0)
CHBr ₃	Bromoform	-3.405	1195.0	5 to 90	1.89 (25.0)
C ₂ H ₂ Br ₂	Methylene bromide	-3.353	987.6	15 to 40	1.09 (15.0)
CH ₂ O ₂	Formic acid	-5.156	1679.0	8 to 110	1.80 (20.0)
CH ₃ Cl	Methyl chloride	-5.073	981.9	0 to 130	0.18 (20.0)
CH ₃ I	Methyl iodide	-3.366	774.1	0 to 50	0.50 (20.0)
CH ₃ NO ₂	Nitro methane	-3.989	1042.0	0 to 90	0.63 (25.0)
C ₂ Cl ₃ F ₃	Trichloro trifluoro ethane	-4.219	1126.0	20 to 50	0.70 (20.0)
C ₂ Cl ₄	Tetra chloro ethylene	-3.334	946.4	0 to 117	0.88 (22.0)
C ₂ HF ₃ O ₂	Trifluoro acetic acid	-4.750	1348.0	20 to 70	0.87 (20.0)
C ₂ H ₂ Cl ₄	1,1,2,2 - Tetra chloro ethane	-4.505	1490.0	0 to 90	1.64 (25.0)
C ₂ H ₄ Br ₂	1,2 - Dibromo ethane	-3.899	1299.0	0 to 130	1.71 (20.0)
C ₂ H ₄ Cl ₂	1,1 - Dichloro ethane	-3.970	949.3	7 to 60	0.49 (19.0)
C ₂ H ₄ Cl ₂	1,2 - Dichloro ethane	-3.926	1091.0	0 to 100	0.83 (20.0)
C ₂ H ₄ F ₂	1,2 - Difluoro ethane	-3.941	735.2	0 to 70	0.25 (25.0)
C ₂ H ₄ O ₂	Methyl formate	-3.932	836.3	0 to 40	0.35 (20.0)
C ₂ H ₄ O ₂	Acetic acid	-4.519	1384.0	15 to 20	1.30 (18.0)
C ₂ H ₅ Br	Ethyl bromide	-3.859	851.5	-100 to 50	0.40 (20.0)
C ₂ H ₅ Cl	Ethyl chloride	-3.873	739.0	-20 to 40	0.27 (20.0)
C ₂ H ₅ I	Ethyl iodide	-3.467	853.9	0 to 80	0.59 (20.0)
C ₂ H ₅ NO	Acetamide	-5.470	2173.0	105 to 120	1.32 (105.0)
C ₂ H ₆ O ₂	Ethylene glycol	-7.811	3143.0	20 to 110	19.90 (20.0)
C ₃ H ₅ Br	Allyl bromide	-3.782	897.1	0 to 80	0.50 (18.0)
C ₃ H ₅ Cl	Allyl chloride	-4.015	845.7	0 to 50	0.32 (22.0)
C ₃ H ₅ F ₃ O	Trifluoro - 2 - propanol	-9.540	3115.0	15 to 60	3.67 (15.0)
C ₃ H ₅ I	Allyl iodide	-3.675	979.8	0 to 100	0.75 (17.0)
C ₃ H ₆ Br ₂	1,2 - Dibromo propane	-3.921	1290.0	0 to 140	1.49 (25.0)
C ₃ H ₆ O	2-Propanol	-5.947	1827.0	0 to 100	1.36 (20.0)
C ₃ H ₆ O	Acetone	-4.033	845.6	-80 to 60	0.32 (25.0)
C ₃ H ₆ O	Propanal	-4.817	1513.0	10 to 30	0.41 (20.0)
C ₃ H ₆ O ₂	Propionic acid	-4.116	1232.0	5 to 150	1.10 (20.0)
C ₃ H ₆ O ₂	Methyl acetate	-4.200	940.9	0 to 70	0.38 (20.0)
C ₃ H ₆ O ₂	Ethyl formate	-4.081	923.1	0 to 70	0.37 (28.0)
C ₃ H ₇ Br	Propyl bromide	-3.781	910.2	0 to 80	0.52 (19.0)
C ₃ H ₇ Br	Isopropyl bromide	-3.761	892.2	0 to 50	0.49 (20.0)
C ₃ H ₇ Cl	Propyl chloride	-3.715	999.5	0 to 100	0.73 (21.0)
C ₃ H ₇ Cl	Isopropyl chloride	-3.323	705.2	0 to 40	0.31 (22.5)
C ₃ H ₇ I	Propyl iodide	-3.715	999.5	0 to 100	0.73 (21.0)
C ₃ H ₇ I	Isopropyl iodide	-3.743	984.1	0 to 100	0.66 (23.0)
C ₃ H ₇ NO ₂	Ethyl carbamate	-6.578	2454.0	105 to 120	0.92 (105.0)
C ₃ H ₈ O	Isopro panol	-8.114	2624.0	0 to 90	0.98 (52.0)
C ₃ H ₈ O ₂	Propylene glycol	-7.577	3233.0	40 to 180	19.40 (40.0)

Formula	Substance	A	B	Temperature Range, °C	η, cP (at, °C)
C ₄ H ₄ N ₂	Succino nitrile	-5.183	2060.0	59 to 83	2.76 (59.0)
C ₄ H ₄ S	Thio phene	-4.039	1065.0	0 to 83	0.64 (22.5)
C ₆ H ₆ O ₃	Acetic anhydride	-3.173	905.4	0 to 100	0.90 (18.0)
C ₄ H ₇ F ₃ O	Trifluoro - 2 - methyl propanol	-10.01	3352.0	25 to 60	3.32 (25.0)
C ₄ H ₇ NO ₂	2 - Nitro - 2 - butene	-3.855	1101.0	30 to 70	0.81 (30.0)
C ₄ H ₈ Br ₂	1,2 - Dibromo - 2 - methyl propane	-4.335	1497.0	0 to 150	1.92 (27.0)
C ₄ H ₈ O	Methyl ethyl ketone	-4.213	975.9	0 to 80	0.42 (21.0)
C ₄ H ₈ O ₂	Butyric acid	-4.592	1475.0	0 to 160	1.54 (20.0)
C ₄ H ₈ O ₂	Iso butyric acid	-4.355	1355.0	4 to 150	1.38 (17.0)
C ₃ H ₅ Br	Allyl bromide	-3.782	897.1	0 to 80	0.50 (18.0)
C ₃ H ₅ Cl	Allyl chloride	-4.015	845.7	0 to 50	0.32 (22.0)
C ₃ H ₅ F ₃ O	Trifluoro - 2 - propanol	-9.540	3115.0	15 to 60	3.67 (15.0)
C ₃ H ₅ I	Allyl iodide	-3.675	979.8	0 to 100	0.75 (17.0)
C ₃ H ₆ Br ₂	1,2 - Dibromo propane	-3.921	1290.0	0 to 140	1.49 (25.0)
C ₃ H ₆ O	2-Propanol	-5.947	1827.0	0 to 100	1.36 (20.0)
C ₃ H ₆ O	Acetone	-4.033	845.6	-80 to 60	0.32 (25.0)
C ₃ H ₆ O	Propanal	-4.817	1513.0	10 to 30	0.41 (20.0)
C ₃ H ₆ O ₂	Propionic acid	-4.116	1232.0	5 to 150	1.10 (20.0)
C ₃ H ₆ O ₂	Methyl acetate	-4.200	940.9	0 to 70	0.38 (20.0)
C ₃ H ₆ O ₂	Ethyl formate	-4.081	923.1	0 to 70	0.37 (28.0)
C ₃ H ₇ Br	Propyl bromide	-3.781	910.2	0 to 80	0.52 (19.0)
C ₃ H ₇ Br	Isopropyl bromide	-3.761	892.2	0 to 50	0.49 (20.0)
C ₃ H ₇ Cl	Propyl chloride	-3.715	999.5	0 to 100	0.73 (21.0)
C ₃ H ₇ Cl	Isopropyl chloride	-3.323	705.2	0 to 40	0.31 (22.5)
C ₃ H ₇ I	Propyl iodide	-3.715	999.5	0 to 100	0.73 (21.0)
C ₃ H ₇ I	Isopropyl iodide	-3.743	984.1	0 to 100	0.66 (23.0)
C ₃ H ₇ NO ₂	Ethyl carbamate	-6.578	2454.0	105 to 120	0.92 (105.0)
C ₃ H ₈ O	Isopro panol	-8.114	2624.0	0 to 90	0.98 (52.0)
C ₃ H ₈ O ₂	Propylene glycol	-7.577	3233.0	40 to 180	19.40 (40.0)
C ₄ H ₄ N ₂	Succino nitrile	-5.183	2060.0	59 to 83	2.76 (59.0)
C ₄ H ₄ S	Thio phene	-4.039	1065.0	0 to 83	0.64 (22.5)
C ₆ H ₆ O ₃	Acetic anhydride	-3.173	905.4	0 to 100	0.90 (18.0)
C ₄ H ₇ F ₃ O	Trifluoro - 2 - methyl propanol	-10.01	3352.0	25 to 60	3.32 (25.0)
C ₄ H ₇ NO ₂	2 - Nitro - 2 - butene	-3.855	1101.0	30 to 70	0.81 (30.0)
C ₄ H ₈ Br ₂	1,2 - Dibromo - 2 - methyl propane	-4.335	1497.0	0 to 150	1.92 (27.0)
C ₄ H ₈ O	Methyl ethyl ketone	-4.213	975.9	0 to 80	0.42 (21.0)
C ₄ H ₈ O ₂	Butyric acid	-4.592	1475.0	0 to 160	1.54 (20.0)
C ₄ H ₈ O ₂	Iso butyric acid	-4.355	1355.0	4 to 150	1.38 (17.0)
C ₄ H ₈ O ₂	Methyl propionate	-4.173	987.2	0 to 80	0.41 (30.0)
C ₄ H ₈ O ₂	Ethyl acetate	-4.171	984.1	0 to 80	0.46 (20.0)
C ₄ H ₈ O ₂	Propyl formate	-4.238	1043.0	0 to 90	0.51 (23.0)
C ₄ H ₉ Br	n-Butyl bromide	-3.805	983.0	0 to 100	0.65 (20.0)
C ₄ H ₉ Br	1 - Bromo - 2 - methyl	-4.011	1039.0	0 to 100	0.61 (24.0)

<i>Formula</i>	<i>Substance</i>	<i>A</i>	<i>B</i>	<i>Temperature Range, °C</i>	<i>η, cP (at, °C)</i>
	propane				
C ₄ H ₉ Cl	1 - Chloro - 2 - methyl propane	- 4.240	1007.0	0 to 80	0.46 (19.0)
C ₄ H ₉ I	1 - Iodo - 2 - methyl propane	- 3.859	1089.0	0 to 120	0.84 (25.0)
C ₄ H ₉ I	Isobutyl iodide	- 3.783	1072.0	0 to 120	0.875 (20.0)
C ₄ H ₁₀	<i>n</i> - Butane	- 3.821	612.1	- 90 to 0	0.22 (-5.0)
C ₄ H ₁₀	2 - Methyl propane	- 4.093	696.6	- 80 to 0	0.27 (-20.0)
C ₄ H ₁₀ O	Isobutanol	- 3.821	2789.0	0 to 110	3.98 (19.0)
C ₄ H ₁₀ O	2 - Methyl propanol	- 11.92	397.9	20 to 90	5.89 (22.0)
C ₄ H ₁₀ O	Diethyl ether	- 4.267	813.1	- 80 to 100	0.23 (20.0)
C ₄ H ₁₀ O	Methyl propyl ether	- 4.189	814.9	0 to 40	0.25 (20.0)
C ₄ H ₁₀ S	Diethyl sulfide	- 3.925	915.6	0 to 88	0.43 (25.0)
C ₄ H ₁₁ N	Diethyl amine	- 4.759	1091.0	- 30 to 40	0.35 (25.0)
C ₅ H ₇ F ₃ O ₂	Trifluoro acetic acid - 2 -propyl ester	- 4.780	1031.0	20 to 70	0.72 (20.0)
C ₅ H ₉ NO ₂	2 - Nitro - 2 - pentene	- 3.938	1147.0	30 to 70	0.87 (30.0)
C ₅ H ₉ NO ₂	3 - Nitro - 2 - pentene	- 4.070	1206.0	30 to 70	0.93 (30.0)
C ₅ H ₁₀	1 - Pentene	- 4.023	702.9	- 90 to 0	0.24 (0.0)
C ₅ H ₁₀	2 - Methyl - 2 - butene	- 4.115	742.5	0 to 40	0.21 (20.0)
C ₅ H ₁₀ O	Diethyl ketone	- 4.123	979.8	0 to 100	0.47 (19.0)
C ₅ H ₁₀ O	Methyl propyl ketone	- 4.149	1008.0	0 to 100	0.51 (18.0)
C ₅ H ₁₀ O ₂	Valeric acid	- 4.921	1679.0	16 to 100	2.30 (20.0)
C ₅ H ₁₀ O ₂	Methyl butyrate	- 4.334	1104.0	0 to 110	0.58 (20.0)
C ₅ H ₁₀ O ₂	Ethyl propionate	- 4.289	1067.0	0 to 100	0.535 (20.0)
C ₅ H ₁₀ O ₂	Propyl acetate	- 4.406	1127.0	0 to 110	0.58 (20.0)
C ₅ H ₁₀ O ₂	Methyl iso butyrate	- 4.222	1039.0	0 to 100	0.47 (29.0)
C ₅ H ₁₁ Br	<i>n</i> - Amyl borate	- 3.881	1071.0	0 to 100	0.81 (20.0)
C ₅ H ₁₂	<i>n</i> - Pentane	- 3.958	722.2	- 130 to 40	0.225 (25.0)
C ₅ H ₁₂	2 - Methyl butane	- 4.415	845.8	- 50 to 30	0.21 (25.0)
C ₅ H ₁₂	2,2 - Dimethyl propane	- 5.715	1248.0	- 10 to 10	0.30 (5.0)
C ₅ H ₁₂ O	<i>n</i> - Pentanol	- 7.581	2651.0	0 to 140	4.40 (20.0)
C ₅ H ₁₂ O	3 - Methyl butanol	- 7.568	2645.0	0 to 140	3.86 (24.0)
C ₅ H ₁₂ O	2 - Methyl butanol	- 8.289	2900.0	0 to 140	5.11 (20.0)
C ₅ H ₁₂ O	2 - Methyl butanol-2	- 10.27	3459.0	0 to 100	5.00 (18.5)
C ₅ H ₁₂ O	Ethyl propyl ether	- 4.315	920.7	0 to 70	0.32 (20.0)
C ₅ H ₁₂ O	Methyl - iso - butyl ether	- 4.270	897.2	0 to 70	0.30 (21.0)
C ₆ H ₅ Br	Bromo benzene	- 3.869	1170.0	0 to 150	1.17 (18.0)
C ₆ H ₅ ClO	<i>o</i> - Chloro phenol	- 6.236	2262.0	0 to 160	4.21 (20.0)
C ₆ H ₅ ClO	<i>m</i> - Chloro phenol	- 11.30	4088.0	25 to 60	11.50 (25.0)
C ₆ H ₅ ClO	<i>p</i> - Chloro phenol	- 11.69	4287.0	45 to 60	6.15 (45.0)
C ₆ H ₅ F	Fluoro benzene	- 4.116	1041.0	9 to 100	0.58 (20.0)
C ₆ H ₅ I	Iodo benzene	- 3.933	1303.0	4 to 140	1.78 (17.0)
C ₆ H ₅ NO ₂	Nitro benzene	- 4.334	1480.0	0 to 200	2.02 (20.0)
C ₆ H ₅ NO ₃	<i>o</i> - Nitro phenol	- 5.195	1932.0	40 to 90	2.75 (40.0)
C ₆ H ₆ ClN	3 - Chloro nitrile	- 6.283	2242.0	25 to 60	3.50 (25.0)

<i>Formula</i>	<i>Substance</i>	<i>A</i>	<i>B</i>	<i>Temperature Range, °C</i>	<i>η,cP (at, °C)</i>
C ₆ H ₁₀	Hexadiene - 1,5	-4.029	806.2	0 to 56	0.275 (20.0)
C ₆ H ₁₀	2,3 - Dimethyl - 1 - 1,3 - butadiene	-4.270	864.0	0 to 70	0.22 (40.0)
C ₆ H ₁₁ NO ₂	2 - Nitro - 2 - hexene	-4.123	1286.0	30 to 70	1.14 (30.0)
C ₆ H ₁₂	1 - Hexene	-4.162	823.0	-55 to 70	0.25 (25.0)
C ₆ H ₁₂	Methyl cyclo pentane	-4.170	1014.0	-25 to 80	0.48 (25.0)
C ₆ H ₁₂ O	Methyl butyl ketone	-4.642	1218.0	20 to 40	0.63 (20.0)
C ₆ H ₁₂ O ₂	Caproic acid	-5.082	1827.0	16 to 100	3.23 (20.0)
C ₆ H ₁₂ O ₂	Ethyl butyrate	-4.270	1128.0	15 to 80	0.69 (20.0)
C ₆ H ₁₂ O ₂	Butyl acetate	-4.546	1238.0	0 to 50	0.73 (20.0)
C ₆ H ₁₂ O ₂	Isobutyl acetate	-4.546	1230.0	20 to 100	0.73 (20.0)
C ₆ H ₁₃ Br	<i>n</i> - Hexyl bromide	-4.001	1172.0	0 to 100	1.01 (20.0)
C ₆ H ₁₄	<i>n</i> - Hexane	-4.034	835.4	-95 to 70	0.30 (25.0)
C ₆ H ₁₄	2 - Methyl pentane	-4.247	884.5	0 to 70	0.285 (25.0)
C ₆ H ₁₄	2,2 - Dimethyl butane	-4.454	1010.0	0 to 40	0.35 (25.0)
C ₆ H ₁₄	2,3 - Dimethyl butane	-4.469	1023.0	0 to 40	0.36 (25.0)
C ₆ H ₁₄ O	<i>n</i> - Hexanol	-7.651	2716.0	20 to 60	4.37 (25.0)
C ₆ H ₁₄ O	Dipropyl ether	-4.391	1027.0	0 to 100	0.40 (25.0)
C ₆ H ₁₄ O	Ethyl isobutyl ether	-4.404	998.3	0 to 80	0.37 (22.0)
C ₆ H ₁₅ N	Triethyl amine	-4.106	921.6	-33 to 25	0.36 (25.0)
C ₇ H ₅ Cl ₃	Phenyl chloroform	-6.567	2176.0	0 to 20	2.55 (17.0)
C ₇ H ₅ F ₃	Trifluoro toluene	-3.859	962.1	20 to 70	0.57 (20.0)
C ₇ H ₆ O ₂	Benzoic acid	-1.478	6027.0	122 to 140	1.26 (30.0)
C ₇ H ₇ NO ₂	<i>o</i> - Nitro toluene	-5.093	1750.0	0 to 70	2.37 (20.0)
C ₇ H ₇ NO ₂	<i>p</i> - Nitrotoluene	-5.966	2003.0	20 to 100	2.33 (20.0)
C ₇ H ₈ O	Benzyl alcohol	-6.822	2505.0	20 to 60	5.58 (20.0)
C ₇ H ₈ O	<i>O</i> - Cresol	-9.657	3531.0	0 to 120	9.56 (20.0)
C ₇ H ₈ O	<i>m</i> - Cresol	-11.09	4111.0	0 to 120	16.40 (20.0)
C ₇ H ₈ O	<i>p</i> - Cresol	-11.29	4207.0	0 to 120	18.90 (20.0)
C ₇ H ₈ O	Methyl phenyl ether	-2.748	895.3	0 to 70	1.32 (20.0)
C ₇ H ₉ N	Benzyl amine	-4.463	1466.0	25 to 130	1.59 (25.0)
C ₇ H ₉ N	<i>n</i> - Methyl aniline	-6.333	2107.0	0 to 80	2.30 (20.0)
C ₇ H ₉ N	2 - Amino toluene	-7.009	2499.0	0 to 100	4.39 (20.0)
C ₇ H ₉ N	3 - Amino toluene	-6.036	2137.0	25 to 130	3.31 (20.0)
C ₇ H ₉ N	4 - Amino toluene	-4.779	1701.0	40 to 175	1.56 (55.0)
C ₇ H ₁₁ F ₃	Trifluoro methyl chclo hexane	-4.329	1224.0	20 to 70	0.95 (20.0)
C ₇ H ₁₄	1 - Heptene	-3.961	848.9	0 to 100	0.34 (25.0)
C ₇ H ₁₄	Methyl cyclo hexane	-4.480	1217.0	-25 to 110	0.68 (25.0)
C ₇ H ₁₄	Ethyl cyclo pentane	-4.000	998.9	-20 to 110	0.53 (25.0)
C ₇ H ₁₄ O ₂	Heptanoic acid	-5.280	1973.0	17 to 100	4.34 (20.0)
C ₇ H ₁₀ O ₂	Ethyl valerate	-4.932	1386.0	20 to 60	0.84 (20.0)
C ₇ H ₁₀ O ₂	Propyl butyrate	-4.604	1290.0	20 to 60	0.83 (20.0)
C ₇ H ₁₄ O ₂	Amyl acetate	-1.379	4035.0	11 to 30	0.81 (25.0)
C ₇ H ₁₅ Br	<i>n</i> - Heptyl bromide	-4.152	1291.0	0 to 100	1.29 (20.0)
C ₇ H ₁₆	<i>n</i> - Heptane	-4.325	1006.0	-90 to 100	0.40 (25.0)
C ₇ H ₁₆	2 - Methyl hexane	-4.270	961.2	0 to 100	0.36 (25.0)
C ₇ H ₁₆ O	<i>n</i> - Heptanol	-8.190	2964.0	15 to 100	5.68 (25.0)

<i>Formula</i>	<i>Substance</i>	<i>A</i>	<i>B</i>	<i>Temperature Range, °C</i>	<i>η, cP (at, °C)</i>
C ₈ H ₁₈ O	Aceto phenone	-4.493	1494.0	12 to 100	1.62 (25.0)
C ₈ H ₁₀ O	2 - Phenyl ethanol	-9.191	3393.0	25 to 60	7.61 (25.0)
C ₈ H ₁₀ O	Ethyl phenyl ether	-4.869	1490.0	0 to 90	1.25 (20.0)
C ₈ H ₁₀ O ₂	Phenyl acetic acid	-5.819	2471.0	77 to 140	3.54 (77.0)
C ₈ H ₁₁ N	<i>n</i> - Ethyl aniline	-5.786	1943.0	0 to 100	2.25 (20.0)
C ₈ H ₁₁ N	<i>n,n</i> - Dimethyl aniline	-3.979	1273.0	0 to 180	1.40 (20.0)
C ₈ H ₁₆	Propyl cyclo pentane	-3.959	1046.0	-20 to 120	0.64 (25.0)
C ₈ H ₁₆	1 - Octene	-4.058	964.0	0 to 125	0.45 (25.0)
C ₈ H ₁₆	Ethyl cyclo hexane	-4.153	1166.0	-25 to 125	0.785 (25.0)
C ₈ H ₁₆ O ₂	Octanoic acid	-5.980	2255.0	20 to 100	5.75 (20.0)
C ₈ H ₁₇ Br	<i>n</i> - Otyl bromide	-4.325	1412.0	0 to 100	1.63 (20.0)
C ₈ H ₁₈	<i>n</i> - Octane	-4.333	1091.0	-55 to 125	0.51 (25.0)
C ₈ H ₁₈ O	<i>n</i> - Octanol	-8.166	3021.0	15 to 100	7.21 (25.0)
C ₉ H ₁₀ O ₂	3 - Phenyl propionic acid	-6.488	2821.0	50 to 140	9.80 (50.0)
C ₉ H ₁₀ O ₂	Ethyl benzoate	-5.078	1719.0	20 to 80	2.24 (20.0)
C ₉ H ₁₂	Propyl benzene	-4.297	1215.0	-25 to 160	0.80 (25.0)
C ₉ H ₁₂	1 - Methyl - 4 - ethyl benzene	-4.008	1067.0	10 to 90	0.66 (25.0)
C ₉ H ₁₂	1,2,4 -Trimethyl benzene	-6.749	2101.0	25 to 40	1.01 (25.0)
C ₉ H ₁₈	1 - Nonene	-4.189	1085.0	0 to 125	0.58 (25.0)
C ₉ H ₁₈	Propyl cyclo hexane	-4.301	1264.0	-25 to 125	0.93 (25.0)
C ₉ H ₁₈	Butyl cyclo pentane	-4.159	1182.0	-20 to 120	0.83 (25.0)
C ₉ H ₁₈ O ₂	Nonanoic acid	-6.002	2365.0	20 to 100	8.08 (20.0)
C ₉ H ₁₉ Br	<i>n</i> - Nonyl bromide	-4.531	1535.0	0 to 100	2.05 (20.0)
C ₉ H ₂₀	<i>n</i> - Nonane	-4.447	1210.0	-50 to 150	0.67 (25.0)
C ₁₀ H ₁₄	Butyl benzene	-4.386	1298.0	-25 to 160	0.96 (25.0)
C ₁₀ H ₁₅ N	<i>n,n</i> - Diethyl aniline	-5.577	1871.0	0 to 100	2.18 (20.0)
C ₁₀ H ₂₀	1 - Decene	-4.297	1194.0	0 to 125	0.75 (25.0)
C ₁₀ H ₂₀	<i>n</i> - Butyl cyclo hexane	-4.424	1378.0	-20 to 125	1.20 (25.0)
C ₁₀ H ₂₀	Pentyl cyclo hexane	-4.309	1302.0	-20 to 120	1.06 (25.0)
C ₁₀ H ₂₀ O ₂	Decanoic acid	-5.591	2275.0	50 to 80	4.34 (50.0)
C ₁₀ H ₂₁ Br	<i>n</i> - Decyl bromide	-4.704	1641.0	0 to 100	2.55 (20.0)
C ₁₀ H ₂₂	<i>n</i> - Decane	-4.460	1286.0	-25 to 175	0.86 (25.0)
C ₁₁ H ₁₆	Pentyl benzene	-4.658	1646.0	-20 to 160	1.22 (25.0)
C ₁₁ H ₂₂	1 - Undecene	-4.422	1304.0	0 to 125	0.96 (25.0)
C ₁₁ H ₂₂	<i>n</i> - Pentyl cyclo hexane	-4.814	1569.0	-10 to 120	1.56 (25.0)
C ₁₁ H ₂₂	Hexyl cyclo pentane	-4.463	1422.0	-20 to 120	1.36 (25.0)
C ₁₁ H ₂₄	<i>n</i> - Undecane	-4.571	1394.0	-25 to 200	1.09 (100.0)
C ₁₂ H ₁₀	Biphenyl	-4.572	1690.0	70 to 450	0.95 (100.0)
C ₁₂ H ₁₁ N	Diphenyl amine	-6.629	2676.0	55 to 130	4.66 (55.0)
C ₁₂ H ₁₈	Hexyl benzene	-4.802	1575.0	-20 to 160	1.52 (25.0)
C ₁₂ H ₂₄	1 - Dodecene	-4.572	1418.0	0 to 125	1.20 (25.0)
C ₁₂ H ₂₄	<i>n</i> - Hexyl cyclo hexane	-4.997	1697.0	-10 to 120	1.99 (25.0)
C ₁₂ H ₂₄	Heptyl cyclo pentane	-4.526	1508.0	-20 to 120	1.72 (25.0)

<i>Formula</i>	<i>Substance</i>	<i>A</i>	<i>B</i>	<i>Temperature Range, °C</i>	<i>η, cP (at, °C)</i>
C ₁₂ H ₂₄ O ₂	Dodecanoic acid	-6.146	2615.0	50 to 100	7.30 (50.0)
C ₁₂ H ₂₆	<i>n</i> - Dodecane	-4.562	1454.0	-5 to 220	1.37 (25.0)
C ₁₃ H ₁₀ O	Benzo phenone	-7.181	2886.0	25 to 130	13.60 (25.0)
C ₁₃ H ₁₃ N	Benzyl phenyl amine	-6.415	2650.0	55 to 130	5.40 (55.0)
C ₁₃ H ₁₃ N	<i>n</i> - Methyl diphenyl amine	-6.328	2428.0	10 to 130	7.30 (20.0)
C ₁₃ H ₂₀	Heptyl benzene	-4.916	1673.0	-20 to 160	1.88 (25.0)
C ₁₃ H ₂₆	1 - Tridecane	-4.628	1516.0	0 to 125	1.50 (25.0)
C ₁₃ H ₂₆	<i>n</i> - Heptyl cyclo hexane	-5.164	1814.0	-10 to 120	2.47 (25.0)
C ₁₃ H ₂₆	Octyl cyclo pentane	-4.628	1602.0	-20 to 120	2.15 (25.0)
C ₁₃ H ₂₈	<i>n</i> - Tridecane	-4.605	1529.0	-5 to 240	1.71 (25.0)
C ₁₄ H ₁₂ O ₂	Diethyl phthalate	-6.589	2606.0	25 to 60	10.10 (25.0)
C ₁₄ H ₁₂ O ₂	Benzyl benzoate	-6.589	2606.0	5 to 100	8.50 (25.0)
C ₁₄ H ₂₂	Octyl benzene	-5.190	1816.0	-20 to 140	2.31 (25.0)
C ₁₄ H ₂₈	1 - Tetra decene	-4.778	1606.0	0 to 125	1.83 (25.0)
C ₁₄ H ₂₈	<i>n</i> - Octyl cyclo hexane	-5.353	1935.0	-10 to 120	3.10 (25.0)
C ₁₄ H ₂₈	Nonyl cyclo pentane	-4.732	1693.0	-20 to 120	2.63 (25.0)
C ₁₄ H ₂₈ O ₂	Tetra decanoic acid	-6.150	2705.0	60 to 100	7.43 (60.0)
C ₁₄ H ₃₀	<i>n</i> - Tetra decane	-4.615	1588.0	5 to 255	2.10 (25.0)
C ₁₅ H ₂₄	Nonyl benzene	-5.352	1924.0	-20 to 140	2.80 (25.0)
C ₁₅ H ₃₀	1 - Penta dodecene	-4.898	1720.0	0 to 125	2.24 (25.0)
C ₁₅ H ₃₀	<i>n</i> - Nonyl cyclo hexane	-5.511	2042.0	-10 to 120	3.80 (25.0)
C ₁₅ H ₃₀	Decyl cyclo pentane	-4.825	1777.0	-20 to 120	3.20 (25.0)
C ₁₅ H ₃₂	<i>n</i> - Penta decane	-4.648	1654.0	10 to 280	2.56 (25.0)
C ₁₆ H ₂₆	Decyl benzene	-5.251	1944.0	-15 to 160	3.36 (25.0)
C ₁₆ H ₃₂	1 - Hexa decene	-4.938	1767.0	5 to 125	2.70 (25.0)
C ₁₆ H ₃₂	Undecyl cylo pentane	-4.992	1882.0	-10 to 120	3.84 (25.0)
C ₁₆ H ₃₂ O ₂	Hexa decanoic acid	-6.103	2785.0	70 to 100	7.80 (70.0)
C ₁₆ H ₃₄	<i>n</i> - Hexa decane	-4.643	1700.0	20 to 280	3.09 (25.0)
C ₁₇ H ₂₈	Undecyl benzene	-5.305	2008.0	-10 to 160	4.00 (25.0)
C ₁₇ H ₃₄	1 - Hepta decene	-4.950	1820.0	15 to 125	3.24 (25.0)
C ₁₇ H ₃₄	<i>n</i> - Undecyl cyclo hexane	-5.710	2206.0	10 to 120	5.50 (25.0)
C ₁₇ H ₃₄	Dodecyl cyclo pentane	-5.100	1966.0	-5 to 120	4.56 (25.0)
C ₁₇ H ₃₆	<i>n</i> - Hepta decane	-4.624	1745.0	25 to 200	3.79 (25.0)
C ₁₈ H ₁₄	<i>o</i> - Terphenyl	-5.461	2519.0	100 to 400	4.40 (100.0)
C ₁₈ H ₁₄	<i>m</i> - Terphenyl	-4.699	2167.0	150 to 400	1.60 (150.0)
C ₁₈ H ₁₄	<i>p</i> - Terphenyl	-4.549	2098.0	250 to 400	0.60 (250.0)
C ₁₈ H ₃₀	Dodecyl benzene	-5.285	2044.0	0 to 160	4.78 (25.0)
C ₁₈ H ₃₄ O ₂	Octa decanoic acid	-5.907	2760.0	20 to 200	29.40 (25.0)
C ₁₈ H ₃₆	1 - Octa decene	-4.986	1879.0	20 to 125	3.85 (25.0)
C ₁₈ H ₃₆	<i>n</i> - Dodecyl cyclo hexane	-5.815	2285.0	15 to 120	6.50 (25.0)
C ₁₈ H ₃₆	Tridecyl cyclo pentane	-5.228	2053.0	5 to 120	5.40 (25.0)
C ₁₈ H ₃₆ O ₂	Octa decanoic acid	-4.649	1790.0	30 to 300	3.88 (30.0)
C ₁₉ H ₃₂	Tridecyl benzene	-5.351	2108.0	5 to 160	5.63 (25.0)

<i>Formula</i>	<i>Substance</i>	<i>A</i>	<i>B</i>	<i>Temperature Range, °C</i>	<i>η, cP (at, °C)</i>
C ₁₉ H ₃₈	1 - Nono decene	− 5.044	1944.0	25 to 125	4.56 (25.0)
C ₁₉ H ₃₈	<i>n</i> - Tri decyl cyclo hexane	− 5.904	2357.0	20 to 120	7.67 (25.0)
C ₁₉ H ₃₈	Tetra decyl cyclo pentane	− 5.328	2129.0	10 to 120	6.29 (25.0)
C ₁₉ H ₄₀	<i>n</i> - Nona decane	− 4.643	1827.0	35 to 300	4.00 (35.0)
C ₂₀ H ₃₄	Tetra decyl benzene	− 5.345	2147.0	15 to 160	6.60 (25.0)
C ₂₀ H ₄₀	1 - Eicosene	− 5.033	1982.0	35 to 125	4.20 (35.0)
C ₂₀ H ₄₀	Tetra decyl cyclo hexane	− 5.998	2428.0	25 to 120	9.00 (25.0)
C ₂₀ H ₄₀	Penta decyl cyclo pentane	− 5.387	2189.0	20 to 120	7.30 (25.0)
C ₂₀ H ₄₂	<i>n</i> - Eicosane	− 4.651	1868.0	40 to 300	4.14 (40.0)
C ₂₁ H ₃₆	<i>n</i> - Pentyl decyl benzene	− 5.416	2206.0	20 to 160	7.72 (25.0)
C ₂₁ H ₄₂	<i>n</i> - Pentyl decyl cyclo hexane	− 6.078	2493.0	30 to 120	8.91 (30.0)
C ₂₁ H ₄₂	Hedecyl cyclo pentane	− 5.459	2251.0	25 to 120	8.44 (25.0)
C ₂₂ H ₃₈	Hexa decyl benzene	− 5.428	2245.0	30 to 160	7.74 (30.0)
C ₂₂ H ₄₄	<i>n</i> -Hexa decyl cyclo hexane	− 6.169	2560.0	35 to 120	8.76 (35.0)

4.3.1.1.b Viswanath and Natarajan Representation

Viswanath and Natarajan in their Databook on Viscosity of Liquids¹⁴ tabulated the constants of the following (quite similar) equations for dynamic, as well as kinematic viscosity:

$$\ln \eta = A + (B/T) \quad (4.7)$$

$$\ln \nu = A' + (B'/T) \quad (4.8)$$

$$\eta = CT^D \quad (4.9)$$

$$\text{and } \nu = C'T^{D'} \quad (4.10)$$

Tables 4.3 to 4.6 summarize the representation of the experimental viscosity data on a variety of substances along with the applicable temperature range. The calculated values are generally within a few percent

of the experimental values. The complete set of experimental data, calculated values, regression analysis and references to experimental viscosity-temperature data and representation by the selected equation (including the three constant forms noted in the next section) are given in Chapter 6. The data have been taken from their book are updated to include the literature upto 2003.

Table 4.3. Summary of the representation of the temperature dependence of pure liquid dynamic viscosity in the logarithmic form given by Eq. (4.7): $\ln \eta = A + (B/T)$. [Temperature in K and Viscosity in cP]. From: D. S. Viswanath and G. Natarajan, Data Book on Liquid Viscosity, Hemisphere, New York, 1989.

<i>Name</i>	<i>Formula</i>	<i>A</i>	<i>B</i>	<i>Temperature Range, K</i>
Allyl alcohol	C ₃ H ₆ O	- 5.5749	793.29	280 to 370
Allyl bromide	C ₃ H ₅ Br	- 4.6328	389.33	270 to 350
Allyl chloride	C ₃ H ₅ Cl	- 4.7522	372.37	270 to 320
Biphenyl	C ₁₂ H ₁₀	- 4.9332	712.34	370 to 500
Boron trichloride	BCl ₃	- 4.3146	232.51	230 to 290
4-Bromo aniline	C ₆ H ₆ NBr	- 4.9978	797.61	340 to 380
Bromo decane	C ₁₀ H ₂₁ Br	- 5.4375	884.04	290 to 320
1-Bromo propane	C ₃ H ₇ Br	- 4.6262	392.13	270 to 350
2-Bromo propane	C ₃ H ₇ Br	- 4.7088	408.46	270 to 330
4-Bromo toluene	C ₇ H ₇ Br	- 4.6202	501.53	300 to 380
2-Butane thiol	C ₄ H ₁₀ S	- 4.6839	407.84	280 to 330
1-Butanol	C ₄ H ₁₀ O	- 5.9719	1007.0	220 to 390
n-Butyl aniline	C ₁₀ H ₁₅ N	- 4.9610	685.21	370 to 520
Butyl benzene	C ₁₀ H ₁₄	- 4.8735	551.98	280 to 360
s-Butyl titanate	C ₁₆ H ₃₆ O ₄ Si	- 4.7678	612.63	370 to 460
Butyraldehyde	C ₄ H ₈ O	- 4.8100	428.80	290 to 350
Butyric acid	C ₄ H ₈ O ₂	- 4.9362	623.19	270 to 430
Butyro nitrile	C ₄ H ₇ N	- 4.8220	466.49	280 to 400
Butyryl chloride	C ₄ H ₇ ClO	- 4.7391	439.79	290 to 380
Cadmium chloride (molten)	CdCl ₂	- 3.6505	889.51	840 to 1010
4 - Chloro aniline	C ₆ H ₆ ClN	- 4.8395	692.19	360 to 510
4 - Chloro bromo benzene	C ₆ H ₄ BrCl	- 3.5520	123.37	380 to 395
1 - Chloro difluoro ethane	C ₂ H ₃ F ₂ Cl	- 4.4480	279.56	240 to 340
4 - Chloro iodo benzene	C ₆ H ₄ ClI	- 4.5532	520.97	380 to 395
3 - Chloro nitro benzene	C ₆ H ₄ ClNO ₂	- 4.6623	615.49	380 to 395
1 - Chloro propane	C ₃ H ₇ Cl	- 4.7401	376.91	270 to 320
2 - Chloro propane	C ₃ H ₇ Cl	- 4.8440	395.32	270 to 310
Corn syrup	-	- 5.5478	868.35	280 to 360
Corn syrup	-	- 5.8508	924.84	280 to 360
Cumene	C ₉ H ₁₂	- 4.8910	524.64	270 to 320
4-Cyano pyridine	C ₆ H ₄ N ₂	- 4.8871	662.18	350 to 400
1,3-Cyclo headiene	C ₆ H ₈	- 4.8782	486.13	290 to 360
Cyclo hexane	C ₆ H ₁₂	- 5.1466	625.44	280 to 360
Cyclo hexanone	C ₆ H ₁₀ O	- 5.0732	708.98	280 to 430
Cyclo hexene	C ₆ H ₁₀	- 4.8401	487.75	270 to 360

<i>Name</i>	<i>Formula</i>	<i>A</i>	<i>B</i>	<i>Temperature Range, K</i>
Cyclo pentane	C ₅ H ₁₀	- 4.7916	419.62	270 to 320
Decalin	C ₁₀ H ₁₈	- 5.0322	720.71	290 to 350
Decanoic acid	C ₁₀ H ₂₀ O ₂	- 5.3278	957.82	320 to 355
1,4-Di bromo benzene	C ₆ H ₄ Br	- 5.3410	873.38	380 to 400
1,2-Di bromo ethylene	C ₂ H ₂ Br ₂	- 4.4549	421.62	270 to 380
1,4-Di chloro benzene	C ₆ H ₄ Cl ₂	- 4.6319	497.21	330 to 450
1,1 - Di chloro - 2,2 - difluoro ethane	C ₂ H ₂ Cl ₂ F ₂	- 4.8605	502.16	290 to 330
Di chloro difluoro methane	CCl ₂ F ₂	- 4.3063	213.62	210 to 330
<i>Trans</i> -1,2-Di chloro ethane	C ₂ H ₂ Cl ₂	- 4.6555	369.48	220 to 300
1,2 - Di chloro tetrafluoro ethane	C ₂ Cl ₂ F ₄	- 4.7833	400.81	200 to 340
Di ethyl amine	C ₄ H ₁₁ N	- 5.1067	479.98	280 to 330
1,4 - Di methoxy benzene	C ₈ H ₁₀ O ₂	- 4.9520	662.97	330 to 490
Di methyl amine	C ₂ H ₇ N	- 5.1197	413.84	280 to 310
2,6-Di methyl aniline	C ₈ H ₁₁ N	- 5.8154	991.16	290 to 330
2,6 - Di methyl - 4 - heptanone	C ₉ H ₁₈ O	- 5.2303	642.64	290 to 320
Di propyl amine	C ₆ H ₁₅ N	- 5.0577	528.10	270 to 390
Ethane thiol	C ₂ H ₆ S	- 4.6584	333.01	270 to 300
Ethyl caprate	C ₁₂ H ₂₄ O ₂	- 5.1557	738.39	300 to 370
Ethyl tri fluoro acetate	C ₄ H ₅ F ₃ O ₂	- 4.9103	453.77	290 to 340
Fluoro benzene	C ₆ H ₅ F	- 4.7298	438.23	270 to 360
1 - Fluoro hexane	C ₆ H ₁₃ F	- 4.8431	449.02	290 to 340
3 - Fluoro toluene	C ₇ H ₇ F	- 4.6993	434.02	290 to 340
Hexane dioic acid	C ₆ H ₁₀ O ₄	- 5.8513	1586.0	445 to 465
1 - Hexyne	C ₆ H ₁₀	- 4.9902	458.60	290 to 340
Hydrogen chloride	HCl	- 3.8799	104.76	160 to 190
Hydrogen sulfide	H ₂ S	- 4.1486	168.99	190 to 210
Indene	C ₉ H ₈	- 5.0798	686.30	270 to 400
Iodo methane	CH ₃ I	- 4.4564	336.11	270 to 320
Iso amyl amine	C ₅ H ₁₃ N	- 4.9743	536.52	270 to 360
Iso amyl cyanide	C ₆ H ₁₁ N	- 4.9258	561.33	290 to 420
Iso valeraldehyde	C ₅ H ₁₀ O	- 4.9057	484.01	290 to 370
1 - Methoxy propane	C ₄ H ₁₀ O	- 4.8065	353.61	270 to 310
Methyl benzoate	C ₇ H ₈ O ₂	- 5.4149	800.14	280 to 305
2 - Methyl -1,3 - buta diene	C ₅ H ₈	- 4.7797	326.58	270 to 310
2 - Methyl butane	C ₅ H ₁₂	- 4.8531	352.18	270 to 310
2 - Methyl - 2 - butane thiol	C ₅ H ₁₂ S	- 5.0016	534.84	280 to 340
2 - Methyl - 2 - butene	C ₅ H ₁₀	- 4.7741	322.29	270 to 310
Methyl butyrate	C ₅ H ₁₀ O ₂	- 4.8758	479.71	270 to 380
Methyl chloride	CH ₃ Cl	- 4.0591	140.54	250 to 310
3-Methyl hexane	C ₇ H ₁₆	- 4.8727	422.23	280 to 310
Methyl iso butyrate	C ₅ H ₁₀ O ₂	- 4.8272	451.96	270 to 370
Methyl oleate	C ₁₉ H ₃₆ O ₂	- 4.9869	800.18	300 to 370

<i>Name</i>	<i>Formula</i>	<i>A</i>	<i>B</i>	<i>Temperature Range, K</i>
3 - Methyl pentane	C ₆ H ₁₄	- 4.7141	357.91	270 to 310
4 - Methyl - 2 - pentanone	C ₆ H ₁₂ O	- 4.9190	493.54	290 to 340
2 - Methyl propane	C ₄ H ₁₀	- 4.8098	312.65	200 to 280
Methyl sulfide	C ₂ H ₆ S	- 4.6126	317.90	270 to 310
Nickle - nitrate hexa hydrate	Ni(NO ₃) ₂ . 6H ₂ O	- 5.9846	1482.60	330 to 350
2 - Nitro - 2 - butene	C ₄ H ₇ NO ₂	- 4.6679	477.91	300 to 340
Nitrogen dioxide	N ₂ O ₄	- 4.7244	394.75	250 to 295
2 - Nitro - 2 - heptene	C ₇ H ₁₃ NO ₂	- 4.8386	595.07	300 to 340
3 - Nitro - 2 - heptene	C ₇ H ₁₃ NO ₂	- 4.9617	634.33	300 to 340
3 - Nitro - 3 - heptene	C ₇ H ₁₃ NO ₂	- 4.9097	612.34	300 to 340
4 - Nitro - 3 - heptene	C ₇ H ₁₃ NO ₂	- 4.8737	595.53	300 to 340
2 - Nitro - 2 - hexene	C ₆ H ₁₁ NO ₂	- 4.7845	558.37	300 to 340
3 - Nitro - 2 - hexene	C ₆ H ₁₁ NO ₂	- 4.8706	578.71	300 to 340
3 - Nitro - 3 - hexene	C ₆ H ₁₁ NO ₂	- 4.7675	534.93	300 to 340
2 - Nitro - 2 - nonene	C ₉ H ₁₇ NO ₂	- 5.0352	708.95	300 to 340
3 - Nitro - 2 - nonene	C ₉ H ₁₇ NO ₂	- 5.1782	753.52	300 to 340
3 - Nitro - 3 - nonene	C ₉ H ₁₇ NO ₂	- 5.0969	720.80	300 to 340
4 - Nitro - 3 - nonene	C ₉ H ₁₇ NO ₂	- 5.1298	729.59	300 to 340
4 - Nitro - 4 - nonene	C ₉ H ₁₇ NO ₂	- 5.0884	715.18	300 to 340
5 - Nitro - 4 - nonene	C ₉ H ₁₇ NO ₂	- 5.1475	736.86	300 to 340
2 - Nitro - 2 - octene	C ₈ H ₁₅ NO ₂	- 4.9726	665.91	300 to 340
3 - Nitro - 2 - octene	C ₈ H ₁₅ NO ₂	- 5.0634	692.81	300 to 340
3 - Nitro - 3 - octene	C ₈ H ₁₅ NO ₂	- 4.9554	648.82	300 to 340
4 - Nitro - 3 - octene	C ₈ H ₁₅ NO ₂	- 4.9931	657.09	300 to 340
4 - Nitro - 4 - octene	C ₈ H ₁₅ NO ₂	- 5.0407	680.29	300 to 340
2 - Nitro - 2 - pentene	C ₅ H ₉ NO ₂	- 4.7037	498.04	300 to 340
3 - Nitro - 2 - pentene	C ₅ H ₉ NO ₂	- 4.7613	523.36	300 to 340
Nitryl fluoride	FNO ₂	- 4.0163	133.93	150 to 190
Nona decane	C ₁₉ H ₄₀	- 5.5763	976.51	300 to 350
Nona decyl benzene	C ₂₅ H ₄₄	- 5.7965	1163.9	300 to 350
1 - Nonanol	C ₉ H ₂₀ O	- 6.6238	1366.7	280 to 330
Oxirane	C ₂ H ₄ O	- 4.6446	312.90	220 to 290
Para Hydrogen	H ₂	3.6446	- 1.876	15 to 32
2 - Pentanone	C ₅ H ₁₀ O	- 4.7986	438.45	270 to 380
1 - Pentene	C ₅ H ₁₀	- 4.7345	305.20	180 to 280
1,2 - Phenyledene diamine	C ₆ H ₈ N ₂	- 5.1842	967.30	380 to 400
Potassium nitrate	KNO ₃	- 4.1228	971.07	610 to 750
1 - Propan amine	C ₃ H ₉ N	- 5.1626	518.12	280 to 320
2 - Propan amine	C ₃ H ₉ N	- 5.0248	456.33	280 to 310
1 - Propane thiol	C ₃ H ₈ S	- 4.6911	380.50	270 to 310
Propyl acetate	C ₅ H ₁₂ O ₂	- 4.9024	488.31	270 to 380
Propyl ether	C ₆ H ₁₄ O	- 4.8897	443.44	270 to 360
3 - n - Propyl - 4 - methyl sydnone	C ₆ H ₁₀ N ₂ O ₂	- 5.9837	1237.6	290 to 320
Propyl oleate	C ₂₁ H ₄₀ O ₂	- 5.3227	936.52	300 to 370
Pyrene	C ₁₆ H ₁₀	- 5.1320	1014.2	450 to 510

<i>Name</i>	<i>Formula</i>	<i>A</i>	<i>B</i>	<i>Temperature Range, K</i>
Pyridine - N - oxide	C ₅ H ₅ NO	- 4.9399	828.32	340 to 400
Sodium acetate hydrate	CH ₃ COONa. 3H ₂ O	- 6.7211	1483.7	330 to 360
Sodium carbonate hydrate	Na ₂ CO ₃ . 10H ₂ O	- 7.5193	1668.7	300 to 330
Sodium hydroxide hydrate	NaOH. H ₂ O	- 7.3900	1826.0	330 to 360
1,1,2,2 - Tetra bromo ethane	C ₂ H ₂ Br ₄	- 5.7617	1117.2	290 to 320
Tetra - n - methyl germane	Ge(CH ₃) ₄	- 4.5041	307.67	270 to 310
Trifluoro acetic acid	C ₂ HF ₃ O ₂	- 5.0399	580.67	290 to 340
1,1,1 - Trifluoro acetone	C ₃ H ₃ F ₃ O	- 5.0099	439.06	280 to 290
1,1,1 - Trifluoro isopropyl acetate	C ₅ H ₇ F ₃ O ₂	- 5.0598	562.57	290 to 340
Trifluoro methyl cyclo hexane	C ₇ H ₁₁ F ₃	- 4.8304	530.52	290 to 340
α,α,α - Trifluoro toluene	C ₆ H ₅ CF ₃	- 4.6590	414.69	290 to 340
1,1,2 - Tri fluoro 1,2,2 - trichloro ethane	C ₂ F ₂ Cl ₃	- 4.8178	487.10	280 to 320
Tri- n - propyl - ortho - phosphate	C ₉ H ₂₁ O ₄ P	- 5.4955	863.50	290 to 320
Tri - o - tolyl phosphate	C ₂₁ H ₂₁ O ₄ P	- 9.8520	2619.9	290 to 320

Table 4.4. Summary of the representation of the temperature dependence of pure liquid kinematic viscosity in the logarithmic form given by Eq. (4.8): $\ln v = A' + (B'/T)$ [Temperature in K and Viscosity in cSt]. From: D. S. Viswanath and G. Natarajan, Data Book on Liquid Viscosity, Hemisphere, New York, 1989.

<i>Name</i>	<i>Formula</i>	<i>A'</i>	<i>B'</i>	<i>Temperature Range, K</i>
n - Butyl diphenyl phosphate	C ₁₆ H ₁₉ O ₄ P	- 2.5388	1057.7	310 to 380
2 - Butyl hexyl diphenyl phosphate	C ₂₂ H ₃₁ O ₄ P	- 2.8627	1229.2	310 to 380
2 - Butyl hexyl ditolyl phosphate	C ₂₄ H ₃₅ O ₄ P	- 3.3026	1431.4	310 to 380
n - Decyl diphenyl phosphate	C ₂₂ H ₃₁ O ₄ P	- 2.6136	1143.1	310 to 380
n - Decyl ditolyl phosphate	C ₂₄ H ₃₅ O ₄ P	- 2.9999	1319.1	310 to 380
n - Decyl ortho silicate	C ₄₀ H ₈₄ O ₄ Si	- 2.0777	981.23	310 to 380
Di isobutyl carbonyl ortho silicate	C ₃₆ H ₇₆ O ₄ Si	- 3.0057	1432.0	310 to 380
2,2 - Di methyl butyl diphenyl phosphate	C ₁₈ H ₂₃ O ₄ P	- 2.8681	1219.3	310 to 380
Di penta erythritol hexa butanone	C ₃₄ H ₅₈ O ₁₃	- 3.4633	1640.6	310 to 380
Di penta erythritol hexahexanoate	C ₄₆ H ₈₂ O ₁₃	- 3.1655	1517.9	310 to 380
Di penta erythritol haxaisodecanoate	C ₇₀ H ₁₄₂ O ₁₃	- 4.5422	2177.0	310 to 380
Di penta erythritol tributanoyl tri nonate	C ₄₉ H ₈₈ O ₁₃	- 3.4349	1644.7	310 to 380
n - Dodecyl di phenyl phosphate	C ₂₄ H ₃₅ O ₄ P	- 2.6916	1190.5	310 to 380
n - Dodecyl di tolyl phosphate	C ₂₆ H ₃₉ O ₄ P	- 3.0263	1346.9	310 to 380
n - Dodecyl ortho silicate	C ₄₈ H ₁₀₀ O ₄ Si	- 2.2447	1091.1	310 to 380

<i>Name</i>	<i>Formula</i>	<i>A'</i>	<i>B'</i>	<i>Temperature Range, K</i>
2 - Ethyl butyl diphenyl phosphate	C ₁₈ H ₂₃ O ₄ P	-2.6603	1118.7	310 to 380
2 - Ethyl butyl ditolyl phosphate	C ₂₀ H ₂₇ O ₄ P	-3.0568	1307.4	310 to 380
2 - Ethyl hexyl diphenyl phosphate	C ₂₀ H ₂₇ O ₄ P	-2.7414	1162.7	310 to 380
2 - Ethyl hexyl ditolyl phosphate	C ₂₂ H ₃₁ O ₄ P	-3.2127	1380.6	310 to 380
<i>n</i> - Heptyl diphenyl phosphate	C ₁₉ H ₂₅ O ₄ P	-2.5822	1094.6	310 to 380
<i>n</i> - Heptyl ortho silicate	C ₂₈ H ₆₀ O ₄ Si	-1.8014	779.54	310 to 380
<i>n</i> - Hexa decyl diphenyl phosphate	C ₂₈ H ₄₃ O ₄ P	-2.6196	1223.2	310 to 380
<i>n</i> - Hexyl diphenyl phosphate	C ₁₈ H ₂₃ O ₄ P	-2.5945	1092.6	310 to 380
<i>n</i> - Hexyl ditolyl phosphate	C ₂₀ H ₂₇ O ₄ P	-2.9680	1273.6	310 to 380
2 - Methyl butyl diphenyl phosphate	C ₁₇ H ₂₁ O ₄ P	-2.6748	1123.4	310 to 380
3 - Methyl butyl diphenyl phosphate	C ₁₇ H ₂₁ O ₄ P	-2.6516	1112.5	310 to 380
6 - Methyl heptyl diphenyl phosphate	C ₂₀ H ₂₇ O ₄ P	-2.7338	1172.4	310 to 380
2 - Methyl pentyl diphenyl phosphate	C ₁₈ H ₂₃ O ₄ P	-2.6888	1130.0	310 to 380
2 - Methyl propyl diphenyl phosphate	C ₁₆ H ₁₉ O ₄ P	-2.7234	1135.4	310 to 380
Octa decyl (branched) diphenyl phosphate	C ₃₀ H ₄₇ O ₄ P	-4.1194	1828.1	310 to 380
<i>n</i> - Octyl diphenyl phosphate	C ₂₀ H ₂₇ O ₄ P	-2.6142	1119.1	310 to 380
<i>n</i> - Octyl di tollyl phosphate	C ₂₂ H ₃₁ O ₄	-3.0082	1303.2	310 to 380
<i>n</i> - Octyl - 9 (10) - mono acetoxystearate	C ₂₈ H ₅₄ O ₄	-2.9598	1316.2	260 to 380
<i>n</i> - Octyl ortho silicate	C ₃₂ H ₆₈ O ₄ Si	-1.8636	843.43	240 to 380
Penta erythritol butanoyl hexanoyl octanoyl tetra decanoate	C ₃₇ H ₆₈ O ₈	-3.0006	1414.8	310 to 380
Penta erythritol decanoyl heptadecanoyl di iso octanoate	C ₄₈ H ₉₀ O ₈	-3.3534	1625.0	310 to 380
Penta erythritol di butanoyl - di (4 - cyclohexyl - butanoate)	C ₃₃ H ₅₆ O ₈	-3.8122	1775.8	310 to 380
Penta erythritol di butanoyl di iso decanoate	C ₃₃ H ₆₀ O ₈	-3.7086	1711.6	310 to 380
Penta erythritol di decanoyl di octanoate	C ₄₁ H ₇₆ O ₈	-3.3806	1597.0	310 to 380
Penta erythritol di ethanoyl di dodecanoate	C ₂₉ H ₅₂ O ₈	-3.4243	1558.4	310 to 380
Pentaerythritol - di (2 - ethyl butanoyl) di iso decanoate	C ₃₇ H ₆₈ O ₈	-4.2805	1950.6	310 to 380
Penta erythritol di heptanoyl di iso decanoate	C ₃₉ H ₇₂ O ₈	-3.4067	1576.4	310 to 380
Penta erythritol diheptanoyl tetra - decanoyl-4-cyclo hexyl butanoate	C ₄₃ H ₇₈ O ₈	-3.3136	1584.4	310 to 380
Penta erythritol di hexanoyl di cyclo hexane carboxylate	C ₃₁ H ₅₂ O ₈	-4.0608	1884.4	310 to 380

<i>Name</i>	<i>Formula</i>	<i>A'</i>	<i>B'</i>	<i>Temperature Range, K</i>
Penta erythritol di hexanoyl di iso decanoate	$C_{37}H_{68}O_8$	-3.4624	1592.1	310 to 380
Penta erythritol di hexanoyl di undecanoate	$C_{39}H_{72}O_8$	-3.0970	1446.6	310 to 380
Penta erythritol di hexanoyl undecanoyl tetra decanoate	$C_{42}H_{78}O_8$	-3.1058	1469.6	310 to 380
Penta erythritol di iso decanoyl hepta decanoyl - 4 - cyclo hexyl butane	$C_{52}H_{96}O_8$	-3.7343	1801.0	310 to 380
Penta erythritol di nonanoyl benzoyl cyclo hexane carboxylate	$C_{37}H_{58}O_8$	-4.0806	1901.1	310 to 380
Penta erythritol di nonanoyl di (2 - ethyl hexanoate)	$C_{39}H_{72}O_8$	-3.4329	1576.8	310 to 380
Penta erythritol di nonanoyl di (2 - ethyl - 4 - methyl pentanoate)	$C_{39}H_{72}O_8$	-3.8452	1743.7	310 to 380
Penta erythritol di nonanoyl di iso octanoate	$C_{39}H_{72}O_8$	-3.3614	1560.2	310 to 380
Penta erythritol di nonanoyl octanoyl decanoate	$C_{41}H_{76}O_8$	-3.0042	1417.9	310 to 380
Penta erythritol di octanoyl ethanoyl hexanoate	$C_{29}H_{52}O_8$	-3.2125	1450.3	310 to 380
Penta erythritol di octanoyl di (2 - ethyl -hexanoate)	$C_{37}H_{68}O_8$	-3.4545	1591.1	310 to 380
Penta erythritol di pentanoyl di nonanoate	$C_{33}H_{60}O_8$	-2.7539	1256.9	310 to 380
Pentane erythritol di pentanoyl di tetra decanoate	$C_{43}H_{80}O_8$	-3.0442	1465.9	310 to 380
Pentane erythritol heptanoyl di undecanoyl - 4 - cyclo hexyl butane	$C_{44}H_{80}O_8$	-3.2154	1540.3	310 to 380
Penta erythritol hexanoyl - 2 - ethyl hexanoyl undecanoyl trtra decanoate	$C_{44}H_{82}O_8$	-3.1744	1512.4	310 to 380
Penta erythritol hexanoyl nonanoyl tetra decanoyl - 2 - ethyl hexanoate	$C_{42}H_{78}O_8$	-3.2909	1534.6	310 to 380
Penta erythritol nonanoyl penta decanoyl di (2 - ethyl hexanoate)	$C_{45}H_{84}O_8$	-3.3837	1619.0	310 to 380
Penta erythritol tetra (2 - ethyl butanoate)	$C_{29}H_{52}O_8$	-4.1681	1851.8	310 to 380
Penta erythritol tetra heptanoate	$C_{33}H_{60}O_8$	-2.9137	1325.5	310 to 380
Penta erythritol tetra nonoate	$C_{41}H_{76}O_8$	-2.9910	1410.9	310 to 380
Penta erythritol tetra octanoate	$C_{37}H_{68}O_8$	-2.9141	1353.9	310 to 380
Penta erythritol tetra pentanoate	$C_{25}H_{44}O_8$	-2.8592	172.7	310 to 380
Penta erythritol tri hexanoyl cyclo hexane carboxylate	$C_{30}H_{52}O_8$	-3.2303	1490.7	310 to 380
Penta erythritol tri hexanoyl tetra decanoate	$C_{37}H_{68}O_8$	-3.0576	1436.0	310 to 380
Penta erythritol trinonoyl - 4 - cyclo hexane carboxylate	$C_{39}H_{70}O_8$	-3.2993	1558.5	310 to 380

<i>Name</i>	<i>Formula</i>	<i>A'</i>	<i>B'</i>	<i>Temperature Range, K</i>
Penta erythritol trinonyl - 4 - cyclo hexyl butanoate	C ₄₂ H ₇₆ O ₈	- 3.4924	1645.4	310 to 380
Penta erythritol trinonyl - 2 - ethyl - 4 -methyl pentanoate	C ₄₀ H ₇₄ O ₈	- 3.2797	1526.2	310 to 380
Penta erythritol trinonyl phenyl ethanoate	C ₄₀ H ₆₆ O ₈	- 3.2164	1495.5	310 to 380
<i>n</i> - Pentyl diphenyl phosphate	C ₁₇ H ₂₁ O ₄ P	- 2.5961	1092.3	310 to 380
Tri decyl (branched) di toluyyl phosphate	C ₂₇ H ₄₁ O ₄ P	- 3.8316	1680.6	310 to 380
Tri (2 - ethyl hexyl) phosphate	C ₂₄ H ₅₁ O ₄ P	- 2.4906	1054.1	310 to 380
3,3,5 - Tri methyl hexyl diphenyl phosphate	C ₂₁ H ₂₉ O ₄ P	- 2.7372	1189.4	310 to 380
Tri methylol propane di decanoyl ethanoate	C ₂₈ H ₅₂ O ₆	- 3.0126	1360.1	310 to 380
Tri methylol propane di nonoyl - 4 - cyclo hexyl butanone	C ₃₄ H ₆₂ O ₆	- 3.1466	1466.3	310 to 380
Tri methyl propane di undecanoyl - 4 - cyclo hexyl butanoate	C ₃₈ H ₇₀ O ₆	- 3.0027	1449.7	310 to 380
Tri methylol propane heptanoyl di decanoate	C ₃₃ H ₆₂ O ₆	- 3.8426	1305.8	310 to 380
Tri methylol propane nonanoyl di iso decanoate	C ₃₅ H ₆₆ O ₆	- 3.4104	1564.7	310 to 380
Tri methyl propane nonanoyl di (tri methyl ethanoate)	C ₂₅ H ₄₆ O ₆	- 3.4284	1522.9	310 to 380
Tri methylol propane nonanoyl - 2 - ethyl hexanoyl cyclo hexane carboxalate	C ₃₀ H ₅₄ O ₆	- 3.5930	1632.5	310 to 380
Tri methylol propane nonanoyl - 2 - ethyl hexanoyl phenyl ethanoate	C ₃₁ H ₅₀ O ₆	- 3.0998	1401.2	310 to 380
Tri methylol propane pentanoyl - decanoyl hepta decanoate	C ₃₈ H ₇₂ O ₆	- 2.8408	1368.7	310 to 380
Tri methylol propane pentanoyl iso decanoyl - 9 - octa decanoate	C ₃₉ H ₇₄ O ₆	- 2.9295	1398.1	310 to 380
Tri methylol propane tri (2 - ethyl hexanoate)	C ₃₀ H ₅₆ O ₆	- 3.6022	1580.3	310 to 380
Tri methylol propane tri nonoate	C ₃₃ H ₆₅ O ₆	- 2.8305	1300.2	310 to 380
Tri octyl phosphate	C ₂₄ H ₅₁ O ₄ P	- 2.2406	985.34	310 to 380
Tri penta erythritol octanonanoate	C ₈₇ H ₁₆₀ O ₁₈	- 3.6095	1802.6	310 to 380
Tri penta erythritol octa pentanoate	C ₅₅ H ₉₆ O ₁₈	- 3.5271	1733.8	310 to 380

Table 4.5. Summary of the representation of the temperature dependence of pure liquid dynamic viscosity in the Logarithmic form given by Eq. (4.9): $\eta = CT^D$ [Temperature in K and Viscosity in cP]. From: D. S. Viswanath and G. Natarajan, Data Book on Liquid Viscosity, Hemisphere, New York, 1989.

<i>Substance</i>	<i>Formula</i>	<i>C</i>	<i>D</i>	<i>Temperature range, K</i>
Acetaldehyde	C ₂ H ₄ O ₂	730.00	− 2.6402	270 to 300
Acetic acid	C ₂ H ₄ O ₂	1.2106 x 10 ⁶	− 3.6612	270 to 390
Allyl thiocyanate	C ₄ H ₅ NS	1.3070 x 10 ⁵	− 3.3473	290 to 400
Amyl amine	C ₅ H ₁₃ N	4.8213 x 10 ⁷	− 4.3795	270 to 360
Bromoform	CHBr ₃	4.9008 x 10 ⁶	− 3.8075	280 to 350
Butyl amine	C ₄ H ₁₁ N	1.5597 x 10 ⁷	− 4.2168	270 to 360
Ether	C ₄ H ₁₀ O	950.69	− 2.6785	270 to 410
n-Hexyl amine	C ₆ H ₁₅ N	1.8823 x 10 ⁸	− 4.5741	270 to 380
Hexyl thio myrisate	C ₂₀ H ₄₀ OS	8.8939 x 10 ¹⁰	− 5.2656	300 to 370
Hydrogen bromide	HBr	0.25449	− 1.0769	180 to 200
Hydrogen iodide	HI	5.8043	− 1.5299	220 to 240
Methyl acetate	C ₃ H ₆ O ₂	1.4880 x 10 ⁴	− 3.0759	270 to 420
Methyl ethyl ketone	C ₄ H ₈ O	2.2926 x 10 ⁴	− 3.1332	240 to 360
Perfluoro-1-isopropoxy hexane	C ₉ F ₂₀ O	5.562 x 10 ¹⁰	− 5.4777	290 to 320

Table 4.6. Constants C' and D' of Eq. (4.10): $\nu = C'T^{D'}$, which provides the temperature dependence of the kinematic viscosity of pure liquids. [Temperature in K and kinematic viscosity in cSt]. From: D. S. Viswanath and G. Natarajan, Data Book on the Viscosity of Liquids. Hemisphere, New York, 1989.

Name	Formula	C'	D'	Temperature Range, K
2 - Butyl octyl di phenyl phosphate	$C_{24}H_{35}O_4P$	1.0026×10^{22}	-8.3719	310 to 380
2 - Butyl octyl di tolyl phosphate	$C_{26}H_{39}O_4P$	6.1112×10^{25}	-9.8085	310 to 380
Penta erythritol di heptanoyl di nonanoate	$C_{37}H_{68}O_8$	1.2951×10^{25}	-9.4900	310 to 380
Penta erythritol di hexanoyl hepta - decanoyl - 2 - ethyl hexanoate	$C_{42}H_{78}O_8$	5.5035×10^{28}	-10.821	310 to 380
Penta erythritol di hexanoyl tetra - decanoyl cyclo hexane carboxylate	$C_{38}H_{68}O_8$	3.4420×10^{28}	-10.740	310 to 380
Penta erythritol di iso decanoyl tetra - decanoyl - 4 - cyclo hexyl - butanone	$C_{49}H_{90}O_8$	3.9036×10^{32}	-12.267	310 to 380
Penta erythritol di nonanoyl di iso decanoate	$C_{43}H_{80}O_8$	1.1028×10^{28}	-10.571	310 to 380
Penta erythritol di pentanoyl di heptanoate	$C_{29}H_{52}O_8$	1.2617×10^{23}	-8.7486	310 to 380
Penta erythritol di tetra decanoyl - di - (2 - ethyl hexanoate)	$C_{49}H_{92}O_8$	4.0859×10^{29}	-11.156	310 to 380
Penta erythritol hexanoyl decanoyl - 2 - ethyl hexanoate	$C_{39}H_{72}O_8$	7.1579×10^{27}	-10.528	310 to 380
Penta erythritol penta noyl - 2 - ethyl hexanoyl undecanoyl tetra decanoyl	$C_{43}H_{80}O_8$	1.4945×10^{27}	-10.228	310 to 380
Penta erythritol tetra hexanoate	$C_{29}H_{52}O_8$	5.2613×10^{23}	-8.9845	310 to 380
Penta erythritol tetra iso octanoate	$C_{37}H_{68}O_8$	2.5160×10^{33}	-12.244	310 to 380
Penta erythritol tri heptanoyl cyclo hexane carboxylate	$C_{33}H_{58}O_8$	3.2338×10^{28}	-10.748	310 to 380

<i>Name</i>	<i>Formula</i>	<i>C'</i>	<i>D'</i>	<i>Temperature Range, K</i>
Penta erythritol tri heptanoyl - 4 - cyclo hexyl butanone	$C_{36}H_{64}O_8$	3.3645×10^{27}	-10.380	310 to 380
Penta erythritol tri hexanoyl hepta decanoate	$C_{40}H_{74}O_8$	2.6257×10^{26}	-9.9417	310 to 380
Tetra decyl (branched) diphenyl phosphate	$C_{26}H_{39}O_4P$	1.9860×10^{25}	-9.6094	310 to 380
Tridecyl (branched) di phenyl phosphate	$C_{25}H_{37}O_4P$	2.7258×10^{24}	-9.2818	310 to 380
Tri methyl propane di nonanoyl benzoate	$C_{31}H_{50}O_6$	1.1313×10^{29}	-11.003	310 to 380
Tri methylol propane di nonyl tri methyl thanoate	$C_{29}H_{54}O_6$	4.2332×10^{24}	9.3327	310 to 380
Tri methylol propane di tetra decanoyl - 4 - cyclo hexyl butanoate	$C_{44}H_{82}O_6$	5.4398×10^{27}	-10.425	310 to 380
Tri methylol propane di tetra decanoyl iso decanoate	$C_{44}H_{84}O_6$	3.1843×10^{26}	-9.9726	310 to 380
Tri methylol propane pentanoyl iso decanoyl hepta decanoate	$C_{38}H_{72}O_6$	1.7555×10^{26}	-9.8727	310 to 380
Tri methylol propane tetra decanoyl pentanoyl - 2 - ethyl hexanoate	$C_{33}H_{62}O_6$	4.9081×10^{25}	-9.6965	310 to 380
Tri penta erythritol octa butanone	$C_{47}H_{80}O_{18}$	9.9311×10^{29}	-11.207	310 to 380

4.3.1.1.c Dutt and Prasad Representation

The constants of the two-constant equation given by Eq. 4.7 were obtained Dutt and Prasad¹⁵ representing viscosity (in cP) as a function of temperature (in K) for the 100 substances that are also used in Section 4.4 for comparison of several methods for their predictive capabilities. An overall average absolute deviation of 1.4% is noted for these 100 substances. The constants are given in Table 4.7.

Table 4.7. Constants of Eq. (4.7) $\ln \eta = A + (B/T)$ calculated by Dutt and Prasad¹⁵ for determination of dynamic viscosity [Temperature in K; Viscosity in cP].

Substance	A	B	Temperature range, K
Acetaldehyde	-1.78	330.73	273 to 294
Acetic acid	-1.86	568.33	283 to 383
Acetone	-1.80	381.21	183 to 333
Acetophenone	-1.83	611.38	298 to 474
Allyl alcohol	-2.59	799.55	281 to 350
Amyl alcohol	-3.26	1140.44	248 to 310
Aniline	-3.01	1085.26	268 to 393
Benzene	-2.13	571.44	278 to 463
n-Butane	-1.71	279.56	183 to 323
Butanoic acid	-1.94	622.68	273 to 373
1-Butene	-1.68	258.05	163 to 233
n-Butyl alcohol	-2.95	1000.37	273 to 393
Butyl amine	-2.11	554.97	273 to 348
Butyl benzene	-1.88	554.64	283 to 353
Carbontetrachloride	-1.86	541.88	273 to 373
Chlorobenzene	-1.65	456.21	273 to 393
Chloroform	-1.58	390.29	248 to 333
m-Cresol	-3.68	1393.93	316 to 373
o-Cresol	-3.02	1124.15	322 to 393
Cyclohexane	-2.21	646.06	278 to 353
Cyclopentane	-1.75	406.98	253 to 323
Decane	-2.01	580.14	248 to 373
1,1-Dichloroethane	-1.72	412.30	280 to 327
Dichloromethane	-1.59	359.24	248 to 310

<i>Substance</i>	<i>A</i>	<i>B</i>	<i>Temperature range, K</i>
Diethyl amine	-2.09	473.46	283 to 323
Diethyl carbonate	-1.55	422.75	293 to 393
Diethyl ketone	-1.78	424.10	273 to 373
Diethyl sulfide	-1.74	406.09	273 to 348
Dimethyl carbonate	-2.02	529.85	293 to 353
N,N-Dimethyl formamide	-1.71	482.15	273 to 373
2,2-Dimethylpropane	-2.26	487.90	258 to 283
Dimethyl sulfide	-1.56	301.49	273 to 309
1,4-Dioxane	-2.18	670.37	288 to 348
Diphenyl ether	-2.12	791.32	313 to 473
Diphenyl methane	-1.89	693.62	333 to 434
Dipropyl amine	-2.06	527.18	273 to 373
Dodecane	-2.06	658.15	273 to 373
Ethane	-1.63	158.82	98 to 188
Ethanethiol	-1.66	334.66	270 to 298
Ethyl acetate	-2.04	498.79	273 to 463
Ethyl alcohol	-2.41	724.80	248 to 348
Ethyl benzene	-1.78	470.92	253 to 413
Ethyl bromide	-1.80	404.76	248 to 433
Ethylene	-1.79	169.30	103 to 173
Ethylene bromide	-1.68	561.22	293 to 393
Ethylene chloride	-1.83	512.37	273 to 353
Ethyl ether	-1.97	393.50	273 to 373
Ethyl formate	-1.76	400.16	273 to 328
Ethyl propionate	-1.86	463.79	273 to 373
Formic acid	-2.23	726.06	281 to 373
Furan	-1.74	387.81	248 to 303
Heptadecane	-2.03	767.33	303 to 553
Heptane	-1.91	449.20	183 to 373
Hexadecane	-2.11	771.69	298 to 393
Hexane	-1.72	355.79	213 to 343
1-Hexene	-1.82	363.33	248 to 333
1-Hexyne	-1.99	458.67	293 to 333
Isoamyl alcohol	-3.47	1215.57	283 to 373
Isobutane	-1.79	307.31	193 to 273
Isobutyl acetate	-2.01	549.61	293 to 373
Isobutyric acid	-1.88	587.27	273 to 373

<i>Substance</i>	<i>A</i>	<i>B</i>	<i>Temperature range, K</i>
Isopropyl alcohol	-3.52	1141.87	273 to 348
Isopropyl amine	-2.09	474.99	273 to 303
Methane	-1.97	116.22	88 to 113
Methyl acetate	-1.78	399.00	273 to 327
Methyl alcohol	-2.07	539.26	248 to 333
Methyl amine	-2.20	422.69	203 to 273
Methyl-n-amylketone	-2.84	800.82	293 to 353
2-Methyl butane	-1.88	362.32	273 to 303
2-Methyl-2-butene	-1.78	323.90	273 to 305
Methyl butanoate	-1.87	478.86	273 to 373
Methyl cyclopentane	-1.78	433.05	248 to 323
Methyl formate	-1.70	364.46	274 to 302
Methyl isobutyrate	-1.84	456.70	273 to 362
Methyl propionate	-1.81	429.37	273 to 348
Methyl-n-propylketone	-1.80	438.12	248 to 373
Nitromethane	-1.73	456.66	248 to 348
Nonane	-1.91	516.53	273 to 373
Octane	-2.24	853.67	273 to 373
Octadecane	-1.86	467.36	303 to 373
Pentadecane	-2.15	759.88	293 to 373
Pentane	-1.72	317.48	153 to 303
1-Pentene	-1.73	304.26	218 to 298
Phenol	-3.42	1279.67	313 to 363
Propane	-1.65	222.81	93 to 173
Propionic acid	-1.78	533.31	273 to 373
n-Propyl acetate	-1.90	487.96	273 to 373
n-Propyl alcohol	-2.90	950.27	248 to 348
Propyl formate	-1.84	454.07	273 to 348
Pyridine	-1.80	522.12	273 to 373
Pyrrole	-2.15	669.34	273 to 348
Quinoline	-2.53	911.42	288 to 373
Tetradecane	-2.16	742.57	283 to 373
Tetrahydrofuran	-1.63	387.67	248 to 323
Toluene	-1.83	469.86	253 to 383
Trichlorofluoromethane	-1.45	322.65	248 to 343

Substance	A	B	Temperature range, K
Tridecane	-2.12	702.75	273 to 373
Triethyl amine	-1.81	402.43	273 to 448
m-Xylene	-1.76	455.39	273 to 413
o-Xylene	-1.84	512.94	273 to 413

4.3.1.1.d Qung-Fang *et al.* Equation

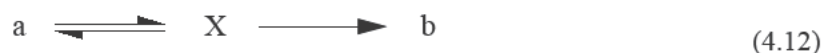
Qun-Fang and coworkers¹⁶ proposed a two-parameter model using Eyring's absolute rate theory for correlating the viscosity data of pure saturated liquids over a wide temperature range. The parameters of the proposed equation are dependent on vapor pressure, saturated liquid volume and enthalpy of vaporization.

The authors start with the absolute rate equation for liquid viscosity published by Eyring¹⁷ and Kincaid *et al.*¹⁸

$$\eta = (Nh/V) \exp(\Delta G^*/RT) \quad (4.11)$$

where η is the liquid viscosity, ΔG^* is the activation energy, V is the molar volume, h is the Planck's constant, N is the Avogadro number and R is the universal gas constant. The structure of liquid from Eyring's absolute rate theory is as shown in Fig. 4.2.

Qun-Fang *et al.* combine the rate equation with the viscous flow mechanism expressed by



which means that the molecule in position a is in thermodynamic equilibrium with activated molecule X , the equilibrium constant being K . The rate of viscous flow from position a to vacancy b depends on the rate of flow of X to vacancy b (k_f) and is equal to the opposing process (k_b) and is given by:

$$k_f = k_b = pK\gamma \exp(\Delta G^*/kT) \quad (4.13)$$

where p is the probability of having a vacancy at position b , γ is the frequency of the activated molecular flow to the vacancy b (the reciprocal of

which can be considered to be the mean residence time τ_R), k is the Boltzmann constant and ΔG^* is the energy of activation. The chemical reaction analogy of activated complex formation is used to describe the viscous flow in the liquid, and the authors arrived at the relation

$$\eta = \frac{RT}{\gamma V} \exp \left[\frac{\alpha''(1 + \alpha') \Delta U_{vap}}{RT} \right] \exp \left(\frac{PV}{RT} \right) \quad (4.14)$$

Combining some of the constants, the final equations proposed are

$$\ln(\eta V/RT) - (PV/RT) = \ln(1/\gamma) + \alpha(\Delta U_{vap}/RT) \quad (4.15)$$

$$\ln(\eta V/RT) - (PV/RT) = \ln(\tau_R) + \alpha(\Delta U_{vap}/RT) \quad (4.16)$$

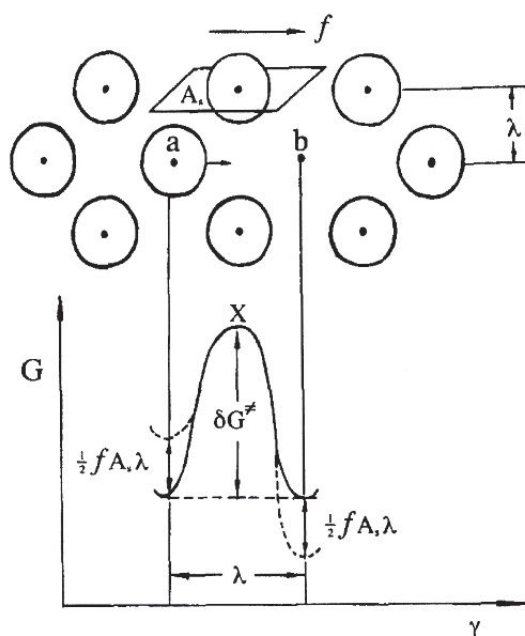


Figure 4.2. Flow cell of liquid (a) non-polar compounds, (b) polar compounds. Adopted from L. Qun-Fang, H. Yu-Chun, and L. Rui-Sen, Correlation of viscosities of pure liquids in a wide temperature range, *Fl. Ph. Equilib.* 140(1-2), 221-231 (1997).

Eqs. (4.15) and (4.16) have two constants α and γ or $\tau_R = (1/\gamma)$, which are evaluated by regression analysis. This correlation is applicable in predicting the viscosity of saturated liquids if the data on vapor pressure (P), molar volume (V) and energy of vaporization (ΔU_{vap}) are all available, in addition to the characteristic coefficients tabulated for the 106 compounds given in their paper. In view of the large amount of data required for the application of the method we have not reproduced the table of the constants α , γ and τ .

4.3.1.1.e Two Constant Representation by Other Investigators

The two constant equation in the power law form, Eq. (4.9) has also been used as a correlation equations by several investigators. The constants A and B for some substances available in the literature and quoted by Reid *et al.*¹⁹ are given in Table 4.8.

Table 4.8. Constants of the power law representation of the temperature dependence of liquid viscosity given by Eq. (4.9): $\eta = AT^B$. [Temperature in K and Viscosity in cP]¹⁹.

Chemical Formula	Name	A	B	Temperature range, °C	η at (t, °C)
CH ₃ NO	Formaldehyde	7.737×10^{23}	-9.445	0 to 25	3.30(25)
C ₂ H ₄ O	Acetaldehyde	5.140×10^7	-3.390	0 to 20	0.22(20)
C ₃ H ₄ O ₂	Acrylic acid	1.510×10^{10}	-4.089	20 to 40	—
C ₃ H ₆ O	Allyl alcohol	3.529×10^{13}	-5.445	0 to 70	1.36(20)
C ₃ H ₈ O ₃	Glycerol	3.4263×10^{73}	-28.52	0 to 30	954.00(25)
C ₅ H ₄ O ₂	Furfural	3.628×10^{14}	-5.815	0 to 25	1.49(25)
C ₅ H ₁₀ O ₂	n-Butyl formate	4.752×10^{10}	-4.394	0 to 20	0.69(20)
C ₆ H ₆ BrN	m-Bromo nitrile	7.810×10^{18}	-733.0	20 to 80	6.81(20)
C ₆ H ₁₀	Cyclo hexane	4.566×10^5	-2.367	13 to 20	0.66(20)
C ₇ H ₆ O ₃	Salicylic acid	3.343×10^{14}	-5.716	10 to 40	2.71(20)
C ₇ H ₁₄ O ₂	iso-Amyl acetate	5.394×10^{10}	-4.375	9 to 20	0.87(20)
C ₈ H ₈ O	Acetanilide	2.617×10^{16}	-6.195	120 to 140	2.22(120)
C ₈ H ₁₁ NO	o-Phenetidine	2.908×10^{33}	-13.24	0 to 30	6.08(20)
C ₆ H ₁₁ NO	p-Phenetidine	3.346×10^{33}	-13.14	20 to 30	12.90(20)
C ₁₀ H ₁₂ O ₂	Eugenol (1,2,3)	2.546×10^{36}	-14.35	0 to 40	9.22(20)
C ₁₃ H ₁₃ N	Benzyl amine	5.344×10^5	-2.168	33 to 130	2.18(33)
C ₁₄ H ₁₄ O	Benzyl ether	1.425×10^{22}	-8.678	0 to 40	5.33(20)

4.3.1.2 Three Constant Equations

A simple three-constant representation (comparable in form to the popular Antoine equation for vapor pressure) proposed originally by Vogel²⁰ is given below.

$$\ln \eta = A - \frac{B}{t + C} \quad (4.17)$$

This form of the equation is more accurate than the two-constant form and is often preferred for engineering design purposes.

4.3.1.2a Viswanath and Natarajan Representation

Viswanath and Natarajan¹⁴ utilized a similar form for both dynamic and kinematic viscosities and the constants of their equations for dynamic (η) as well as the kinematic viscosity (ν) are presented in Tables 4.9 and 4.10, respectively. The equations are as follows:

$$\log \eta = A + B/(C - T) \quad (4.18)$$

$$\log \nu = A' + B'/(C' - T) \quad (4.19)$$

4.3.1.2b Dutt and Prasad Representation

The constants of the three-constant equation were also obtained by Dutt and Prasad¹⁵ representing viscosity (in cP) as a function of temperature (in K) for the 100 substances that are listed in Table 4.7. An overall average deviation of 0.62% are noted for these 100 substances compared to 1.4% when the two-constant equation was used. The constants are shown in Table 4.11.

Table 4.9. Constants of the Antoine type equation given by Eq. (4.18):
 $\log \eta = A + B/(C - T)$ for calculation of pure liquid viscosity at different temperatures.
 [Temperature in K and Viscosity in cP]. From D. S. Viswanath and G. Natarajan, *Data Book on Liquid Viscosity*, Hemisphere, New York, 1989.

Name	Formula	A	B	C	Temp. Range, K
Acetamide	C ₂ H ₅ NO	-4.6341	-422.90	149.84	360 to 500
Acetic anhydride	C ₄ H ₆ O ₃	-4.5804	-374.60	49.411	270 to 410
Acetone	C ₃ H ₆ O	-4.6125	-298.48	26.203	180 to 320
Aceto nitrile	C ₂ H ₃ N	-4.8242	-430.37	13.170	280 to 360
Aceto phenone	C ₇ H ₈ O	-4.6251	-468.30	45.007	370 to 480
Acetyl chloride	C ₂ H ₃ ClO	-4.7447	-407.10	12.418	290 to 330
Allyl ether	C ₆ H ₁₀ O	-5.5716	-938.43	-130.23	290 to 360
Allyl iodide	C ₃ H ₅ I	-4.5436	-410.42	2.0868	270 to 380
Aluminum bromide	AlBr ₃	-4.2262	-493.82	64.743	370 to 530

<i>Name</i>	<i>Formula</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>Temp. Range, K</i>
Aluminum iodide	AlI ₃	- 3.8840	- 443.03	132.69	470 to 680
Ammonia	NH ₃	- 4.3044	- 94.129	108.28	200 to 240
<i>tert</i> -Amyl alcohol	C ₅ H ₁₂ O	- 5.0567	- 359.53	161.29	270 to 380
Amyl butyrate	C ₉ H ₁₈ O ₂	- 4.4732	- 321.43	87.301	270 to 380
Amyl titanate	C ₂₀ H ₄₄ O ₄ Ti	- 5.0964	- 493.76	214.92	400 to 490
2-Amyl undecanol	C ₁₆ H ₃₄ O	- 5.3143	- 656.98	125.18	290 to 380
2-Amyl undecyl acetate	C ₁₈ H ₃₆ O ₂	- 4.1857	- 279.19	157.02	270 to 380
Aniline	C ₆ H ₇ N	- 4.4670	- 327.72	138.45	280 to 460
<i>o</i> -Anisaldehyde	C ₈ H ₈ O	- 4.6222	- 477.93	70.529	320 to 520
Benzo nitrile	C ₇ H ₅ N	- 4.2898	- 274.62	100.95	290 to 470
Benzo phenone	C ₁₃ H ₁₀ O	- 4.6614	- 416.84	148.97	300 to 380
Benzyl alcohol	C ₇ H ₈ O	- 4.6581	- 422.73	121.75	280 to 480
Benzyl amine	C ₇ H ₉ N	- 4.7265	- 480.83	49.937	290 to 460
Benzyl benzoate	C ₁₄ H ₁₂ O ₂	- 3.9401	- 230.36	174.56	270 to 380
Benzyl chloride	C ₇ H ₇ Cl	- 3.8075	- 122.50	163.81	280 to 310
Benzyl cyanide	C ₈ H ₇ N	- 4.2563	- 292.41	109.28	290 to 420
Benzyl ether	C ₁₄ H ₁₄ O	- 4.0837	- 260.57	149.28	270 to 380
Bis dimethyl amino phosphoryl chloride	C ₄ H ₁₂ ClN ₂ OP	- 4.1079	- 297.31	118.96	240 to 350
1,3 - Bis (1 - Iso cyanato - 1- methyl) benzene	C ₁₄ H ₁₆ N ₂ O ₂	- 4.3198	- 351.17	140.96	290 to 360
Bismuth	Bi	- 3.1717	- 93.808	343.93	550 to 1250
Bismuth chloride - molten	BiCl ₃	- 5.7029	- 198.83	348.83	500 to 675
Bromal hydrate	C ₂ H ₃ Br ₃ O ₂	- 4.7271	- 303.97	223.45	310 to 380
Bromine	Br ₂	- 4.2380	- 329.88	26.153	270 to 330
Bromo ethane	C ₂ H ₅ Br	- 4.7817	- 468.12	- 47.339	200 to 300
1 - Bromo - 2 - metethyl -propane	C ₄ H ₉ Br	- 5.1273	- 731.96	- 85.418	270 to 370
2 - Bromoaniline	C ₆ H ₅ NBr	- 4.1491	- 282.29	142.43	310 to 380
3 - Bromoaniline	C ₆ H ₆ Br	- 3.8310	- 175.81	187.13	290 to 380
Bromo benzene	C ₆ H ₅ Br	- 4.2367	- 279.94	77.353	270 to 420
1 - Bromo - 2 - methyl propane	C ₄ H ₉ Br	- 5.1273	- 731.96	- 85.418	270 to 370
2 - Bromo pyridine	C ₆ H ₄ BrN	- 4.2913	- 347.61	71.653	290 to 400
2 - Bromo toluene	C ₇ H ₇ Br	- 4.1812	- 252.67	107.57	270 to 380
3 - Bromo toluene	C ₇ H ₇ Br	- 4.1955	- 258.83	92.688	270 to 380
Butane	C ₄ H ₁₀	- 5.1430	- 528.24	88.682	180 to 310
1 - Butane thiol	C ₄ H ₁₀ S	- 0.6575	- 1606.6	908.10	280 to 340
2 - Butanol	C ₄ H ₁₀ O	- 5.2749	- 452.89	134.40	280 to 370
1,3 - Butadiene	C ₄ H ₆	- 6.0528	- 973.83	-145.12	250 to 400
Butyl acetate	C ₆ H ₁₂ O ₂	- 4.7722	- 431.58	29.726	270 to 380
Butyl butyrate	C ₈ H ₁₆ O ₂	- 4.5274	- 338.81	72.283	270 to 380
2-Butyl dodecanol	C ₁₆ H ₃₄ O	- 5.2109	- 614.37	132.35	290 to 380
Butyl dodecyl acetate	C ₁₈ H ₃₆ O ₂	- 4.2089	- 287.19	154.82	270 to 380
Butyl ether	C ₈ H ₁₈ O	- 4.8090	- 449.86	20.676	270 to 380

<i>Name</i>	<i>Formula</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>Temp. Range, K</i>
Butyl formate	C ₅ H ₁₀ O ₂	-4.8197	-448.59	22.748	270 to 380
2 - Butyl - 3 -hexyl deca hydro naphthalene	C ₂₀ H ₃₈	-4.2988	328.70	75.01	270 to 380
7-Butyl-1-hexyl -deca hydronaphthalene	C ₂₀ H ₃₈	-4.2931	-341.18	165.42	270 to 380
2 - Butyl - 3 -hexyl naphthalene	C ₂₀ H ₂₈	-4.2679	-328.24	169.89	270 to 380
3 - Butyl - 2 - oxazolidone	C ₇ H ₁₃ NO ₂	-4.2198	-311.24	135.32	270 to 340
3 - <i>te t</i> - Butyl - 2 - oxazolidinone	C ₇ H ₁₃ NO ₂	-4.3212	-352.73	127.83	270 to 340
Butyl phenyl ether	C ₁₀ H ₁₄ O	-4.7979	-500.67	51.416	290 to 490
Butyl propionate	C ₇ H ₁₄ O ₂	-4.6610	-393.94	44.512	270 to 380
Butyl sydnone	C ₆ H ₁₀ N ₂ O ₂	-3.9759	-279.00	150.51	310 to 400
Butyl titanate	C ₁₆ H ₃₆ O ₄ Ti	-6.5798	-1299.5	80.807	370 to 480
<i>Tert</i> - Butyl titanate	C ₁₆ H ₃₆ O ₄ Ti	-4.8180	-598.78	44.890	310 to 410
Butyl valerate	C ₉ H ₁₈ O ₂	-4.5554	-370.73	67.95	270 to 380
Butyramide	C ₄ H ₉ NO	-5.7069	-1130.3	7.6121	390 to 490
Butyric anhydride	C ₈ H ₁₄ O ₃	-4.7648	-512.55	31.910	290 to 420
Cadmium	Cd	-3.6422	-941.06	280.31	590 to 730
Chloro difluoro methane	CHClF ₂	-4.7458	-328.78	25.019	200 to 300
Chloro fluoro methane	CH ₂ FCI	-4.5953	-281.37	12.76	190 to 320
Chloroform	CHCl ₃	-4.4573	-325.76	23.789	210 to 360
2 - Chloro - 6 - methyl aniline	C ₇ H ₈ CIN	-3.5853	-76.581	216.40	290 to 330
1 - Chloro - 2 -methyl propane	C ₄ H ₉ Cl	-5.0409	-575.22	-45.152	270 to 340
2 - Chloro phenol	C ₆ H ₅ ClO	-4.2372	-230.71	169.42	280 to 450
3 - Chloro phenol	C ₆ H ₅ ClO	-3.4776	-89.566	240.53	290 to 340
4 - Chloro phenol	C ₆ H ₅ ClO	-4.7219	-507.99	103.79	370 to 500
2 - Chloro phenyl methyl ether	C ₇ H ₇ ClO	-4.5675	-410.89	80.145	290 to 470
2 - Chloro pyridine	C ₅ H ₄ CIN	-4.5143	-420.08	33.573	290 to 400
2 - Chloro toluene	C ₇ H ₇ Cl	-4.6558	-464.57	14.885	270 to 440
3 - Chloro toluene	C ₇ H ₇ Cl	-4.5776	-405.97	26.217	270 to 440
4 - Chloro toluene	C ₇ H ₇ Cl	-4.5492	-380.43	39.664	280 to 440
Corn oil	-	-3.5581	-263.32	183.60	290 to 340
Corn syrup	-	-4.4500	-234.80	159.91	280 to 360
Corn syrup	-	-4.0137	-129.07	201.23	280 to 360
Corn syrup	-	-3.8025	-258.10	186.88	280 to 360
Corn syrup	-	-3.9975	-267.36	182.96	280 to 360
<i>m</i> - Cresol	C ₇ H ₈ O	-4.4933	-298.87	183.39	280 to 480
<i>o</i> - Cresol	C ₇ H ₈ O	-4.3697	-250.28	187.77	270 to 470
<i>p</i> - Cresol	C ₇ H ₈ O	-4.3867	-268.79	192.80	280 to 480
2 - Cyanopyridine	C ₆ H ₄ N ₂	-4.3011	-315.45	100.85	300 to 400
3 - Cyanopyridine	C ₆ H ₄ N	-4.2055	-268.49	137.40	320 to 400

<i>Name</i>	<i>Formula</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>Temp. Range, K</i>
Cyclo hexanol	C ₆ H ₁₂ O	-4.8184	-388.21	189.65	300 to 440
Cyclo hexyl amine	C ₆ H ₁₃ N	-4.6016	-357.42	109.06	280 to 410
Cyclo hexyl bromide	C ₆ H ₁₁ Br	-4.5225	-412.40	76.454	280 to 440
Cyclo hexyl chloride	C ₆ H ₁₁ Cl	-4.6971	-460.15	51.188	290 to 420
<i>Cis</i> - Decalin	C ₁₀ H ₁₈	-4.4480	-395.48	93.359	240 to 460
<i>Trans</i> - Decalin	C ₁₀ H ₁₈	-4.5844	-443.20	61.638	240 to 440
Decane	C ₁₀ H ₂₂	-4.5740	-343.92	68.462	240 to 380
1 - Decanol	C ₁₀ H ₂₂ O	-5.2085	-619.24	107.41	280 to 330
Decene	C ₁₀ H ₂₀	-4.9646	-576.81	-13.145	290 to 420
Deuterium oxide	D ₂ O	-4.2911	-164.97	174.24	280 to 310
1,2 - Diamino propane	C ₃ H ₁₀ N ₂	-4.0837	-167.55	166.21	240 to 330
1,2 - Dibromo methane	C ₂ H ₄ Br ₂	-4.2416	-300.36	90.197	280 to 400
1,2 - Dibromo - 2 - methyl propane	C ₄ H ₈ Br ₂	-4.5276	-435.27	60.001	270 to 420
1,2 - Dibromo propane	C ₃ H ₆ Br ₂	-4.7088	-562.02	1.9572	270 to 420
Dibutyl amine	C ₈ H ₁₉ N	-4.6971	-360.91	80.751	270 to 440
Dibutyl carbonate	C ₉ H ₁₈ O ₃	-3.9131	-155.55	163.43	290 to 420
Dichloro acetic acid	C ₂ H ₂ Cl ₂ O ₂	-5.1869	-929.48	-25.087	290 to 470
1,2 - Dichloro benzene	C ₆ H ₄ Cl	-4.5524	-456.48	23.531	290 to 460
1,3 - Dichloro benzene	C ₆ H ₄ Cl	-4.6277	-490.14	-1.1150	300 to 450
1,1 - Dichloro ethane	C ₂ H ₂ Cl ₂	-4.8360	-486.96	-25.909	280 to 330
1,2 - Dichloro ethane	C ₂ H ₄ Cl ₂	-4.5980	-385.16	39.584	270 to 360
<i>Cis</i> - 1,2 - Dichloro - ethylenene	C ₂ H ₂ Cl ₂	-4.4812	-315.48	-18.953	200 to 300
Dichloro fluoro methane	CHCl ₂ F	-4.6041	-336.39	-6.3451	220 to 350
Dichloro methane	CH ₂ Cl ₂	-4.5147	-316.63	18.104	200 to 380
2,6 - Diethyl aniline	C ₁₀ H ₁₅ N	-4.0635	-207.07	171.42	290 to 380
Diethyl carbonate	C ₅ H ₁₀ O ₃	-3.7980	-65.04	202.89	290 to 400
Diethylene glycol dinitrate	C ₄ H ₈ N ₂ O ₇	-3.8314	-192.04	182.51	280 to 340
<i>n,n</i> - Diethyl - <i>m</i> - toludine	C ₁₂ H ₁₇ NO	-4.9635	-683.97	-5.57	380 to 510
Difluoro acetic acid	C ₂ H ₂ F ₂ O ₂	-4.5695	-380.88	106.79	290 to 340
2,5 - Difluoro aniline	C ₆ H ₅ F ₂ N	-4.2269	-264.07	127.26	290 to 340
1,3 - Difluoro benzene	C ₆ H ₄ F ₂	-4.7875	-466.28	-8.3165	290 to 340
1,4 - Difluoro benzene	C ₆ H ₄ F ₂	-4.9046	-549.69	-28.264	290 to 340
1,1 - Difluoro ethyl acetate	C ₄ H ₆ F ₂ O ₂	-5.0140	-560.88	21.795	290 to 340
2,2 - Difluoro ethyl alcohol	C ₂ H ₄ F ₂ O	-4.7550	-380.84	118.36	290 to 340
Difluoro methane	CH ₂ F ₂	-6.6081	-1079.9	-185.87	200 to 290
Diheptyl amine	C ₁₄ H ₃₁ N	-4.5966	-429.86	91.79	290 to 430
Di iso butyl amine	C ₈ H ₁₉ N	-4.6618	-345.27	71.137	270 to 400
Di iso pentyl amine	C ₁₀ H ₂₃ N	-4.7264	-415.49	72.234	270 to 430
Diiso propenyl	C ₆ H ₁₀	-5.3047	-701.2	-109.18	270 to 330
Diiso propyl amine	C ₆ H ₁₅ N	-5.0566	-540.15	-29.009	280 to 360

<i>Name</i>	<i>Formula</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>Temp. Range, K</i>
1,3 - Dimethoxy benzene	C ₈ H ₁₀ O ₂	- 4.6919	- 461.09	70.728	310 to 490
<i>n,n</i> - Dimethyl acetamide	C ₄ H ₉ NO	- 4.8134	- 547.67	37.944	290 to 450
<i>n,n</i> - Dimethyl aniline	C ₈ H ₁₁ N	- 4.6940	- 483.96	30.46	270 to 470
2,2 - Dimethyl butane	C ₈ H ₁₄	- 1.5347	- 651.45	637.56	270 to 310
Dimethyl carbonate	C ₃ H ₆ O ₃	- 3.7328	- 35.269	227.61	290 to 380
<i>n,n</i> - Dimethyl - ethylene urea	C ₅ H ₁₂ N ₂ O	- 4.2477	- 295.33	105.93	290 to 380
<i>n,n</i> - Dimethyl formamide	C ₃ H ₇ NO	- 3.6398	- 56.047	194.25	270 to 320
2,7 - Dimethyl octane	C ₁₀ H ₂₂	- 3.7054	- 38.588	236.15	290 to 340
1,4 - Dimethyl - 5 - octyl deca hydro naphthalene	C ₂₀ H ₃₈	- 4.1480	- 302.82	168.39	270 to 380
2,6 - Dimethyl - 3 - octyl deca hydro naphthalene	C ₂₀ H ₃₈	- 4.1606	- 302.58	171.06	290 to 380
1,4 - Dimethyl - 5 - octyl naphthalene	C ₂₀ H ₂₈	- 4.1315	- 294.82	180.84	270 to 380
4,4 - Dimethyl -2 -oxa zolidine	C ₅ H ₉ NO ₂	- 4.8411	- 497.42	168.44	270 to 340
2,4 - Dimethyl -3 - pentanone	C ₇ H ₁₄ O	- 5.2591	- 791.85	- 91.339	290 to 380
2,6 - Dimethyl pyridine-N-oxide	C ₇ H ₉ NO	- 4.0622	- 218.72	179.99	290 to 400
2,4 - Dimethyl sulfolane	C ₆ H ₁₂ O ₂ S	- 4.1963	- 331.93	143.99	290 to 400
1,3 - Dimethyl - 3,4,5,6 -tetra - hydro - 2 (1H) pyridimidinone	C ₆ H ₁₂ N ₂ O	- 4.1959	- 283.40	127.74	290 to 380
<i>n,n</i> - Dimethyl - <i>o</i> - toluidine	C ₉ H ₁₃ N	- 4.8977	- 598.28	2.4885	340 to 460
<i>n,n</i> - Dimethyl - <i>p</i> - toluidine	C ₉ H ₁₃ N	- 4.9002	- 645.00	- 24.571	370 to 490
1,3-Dinitro benzene	C ₆ H ₄ N ₂ O ₄	- 3.9732	- 200.42	241.63	370 to 580
Dipentyl amine	C ₁₀ H ₂₃ N	- 4.5796	- 349.69	97.021	270 to 430
Diphenyl amine	C ₁₂ H ₁₁ N	- 4.2791	- 281.54	186.14	300 to 410
Diphenyl methane	C ₁₃ H ₁₂	- 4.8400	- 654.74	11.031	330 to 540
Ditellurium deca fluoride	Te ₂ F ₁₀	- 4.8292	- 170.32	105.09	240 to 320
2,2-Di - <i>p</i> - toly butane	C ₁₈ H ₂₂	- 4.4205	- 278.15	202.10	270 to 480
1,1-Di - <i>m</i> - tolyethane	C ₁₆ H ₁₈	- 4.4330	- 337.17	153.26	270 to 480
1,1-Di - <i>o</i> - tolyethane	C ₁₆ H ₁₈	- 4.2025	- 236.66	209.88	270 to 480
1,1-Di - <i>p</i> - tolyethane	C ₁₆ H ₁₈	- 4.5230	- 377.82	127.15	270 to 480
Dodecane	C ₁₂ H ₂₆	- 4.5578	- 375.97	76.83	270 to 380
Dodecanoic acid	C ₁₂ H ₂₄ O ₂	- 4.7935	- 643.12	78.509	320 to 440
Dodecyl thio palmitate	C ₂₈ H ₅₆ OS	- 3.8590	- 327.41	153.05	340 to 370

<i>Name</i>	<i>Formula</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>Temp. Range, K</i>
Eicosane	C ₂₀ H ₄₂	-4.5977	-509.04	81.873	310 to 500
Ethanol	C ₂ H ₆ O	-5.5972	-846.95	24.124	210 to 350
2 - Ethoxy benzenamine	C ₈ H ₁₁ NO	-4.0349	-191.08	188.20	270 to 380
3 - Ethoxy benzenamine	C ₈ H ₁₁ NO	-4.0694	-203.67	210.01	300 to 380
4 - Ethoxy benzenamine	C ₈ H ₁₁ NO	-4.1091	-226.14	191.43	290 to 380
Ethoxy benzene	C ₈ H ₁₀ O	-4.7732	-469.95	44.325	290 to 450
2 - Ethoxy toluene	C ₉ H ₁₂ O	-4.6820	-425.29	60.601	280 to 450
3 - Ethoxy toluene	C ₉ H ₁₂ O	-4.6888	-429.81	50.995	290 to 450
4 - Ethoxy toluene	C ₉ H ₁₂ O	-4.8518	-530.68	21.765	280 to 450
Ethyl acetate	C ₄ H ₈ O ₂	-4.8721	-452.07	-3.4748	270 to 350
2 - Ethyl aniline	C ₈ H ₁₁ N	-3.9240	-157.75	193.75	290 to 380
<i>n</i> - Ethylaniline	C ₈ H ₁₁ N	-4.5575	-348.74	111.51	370 to 480
Ethyl benzene	C ₈ H ₁₀	-4.8421	-519.36	-18.754	270 to 410
Ethyl butyrate	C ₆ H ₁₂ O ₂	-2.6811	-56.932	409.09	280 to 330
Ethyl caproate	C ₈ H ₁₆ O ₂	-4.7822	-488.78	19.765	300 to 370
Ethyl cyano acetate	C ₅ H ₇ NO ₂	-4.9267	-648.38	13.921	350 to 480
Ethyl cyclo hexane	C ₈ H ₁₆	-4.5094	-338.98	56.684	270 to 320
Ethylene diamine	C ₂ H ₈ N ₂	-4.8506	-458.11	72.151	290 to 390
Ethylene glycol	C ₂ H ₆ O ₂	-4.5448	-417.05	146.53	280 to 420
Ethylene glycol dinitrate	C ₂ H ₄ N ₂ O ₆	-3.8971	-190.90	167.79	280 to 340
Ethylene sulfite	C ₂ H ₄ SO ₃	-4.2577	-316.63	96.579	290 to 350
Ethyl fluoro acetate	C ₄ H ₇ FO ₂	-4.4366	-278.91	96.402	290 to 340
<i>n</i> -Ethyl formamide	C ₃ H ₇ NO	-4.4950	-403.12	79.019	290 to 350
Ethyl formate	C ₃ H ₆ O	-4.5771	-297.60	40.866	270 to 330
Ethyl heptanoate	C ₉ H ₁₈ O ₂	-4.5344	-360.05	72.643	270 to 380
2 - Ethyl - 1 - hexanol	C ₈ H ₁₈ O	-4.9651	-436.77	140.04	270 to 380
2 - Ethyl - 1 - hexene	C ₈ H ₁₆	-5.0166	-573.86	-46.195	290 to 380
Ethyl lactate	C ₅ H ₁₀ O ₃	-4.7088	-369.10	121.15	270 to 380
Ethyl laurate	C ₁₄ H ₂₈ O ₂	-4.6006	-474.53	70.200	300 to 370
<i>n</i> - Ethyl - <i>n</i> - methyl aniline	C ₉ H ₁₃ N	-4.6190	-391.17	90.088	380 to 480
Ethyl - <i>n</i> - methyl carbamate	C ₄ H ₉ NO ₂	-4.5915	-354.47	127.89	290 to 380
Ethyl myrisate	C ₁₆ H ₃₂ O ₂	-4.0528	-250.11	149.25	300 to 370
3 - Ethyl - 2 - oxazolidinone	C ₅ H ₉ NO ₂	-4.1644	-303.21	110.17	270 to 340
4 - Ethyl - 2 - oxazolidinone	C ₅ H ₉ NO ₂	-4.3902	-367.67	180.81	280 to 340
Ethyl palmitate	C ₁₈ H ₃₆ O ₂	-4.3120	-375.53	116.66	300 to 370
Ethyl propionate	C ₅ H ₁₀ O ₂	-5.0255	-577.20	36.360	270 to 370
Ethyl stearate	C ₂₀ H ₄₀ O ₂	-4.2849	-383.58	120.19	300 to 370
Ethyl sulfide	C ₂ H ₁₀ S	-5.0494	-622.24	-73.352	270 to 370
Ethyl tetra decanol	C ₁₆ H ₃₄ O	-5.0490	-572.23	135.51	290 to 380
Ethyl tetra decyl acetate	C ₁₈ H ₃₆ O ₂	-4.2793	-333.42	138.16	270 to 380
Ethyl valerate	C ₇ H ₁₄ O ₂	-4.6077	-368.04	52.281	270 to 380

<i>Name</i>	<i>Formula</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>Temp. Range, K</i>
Eugenol	C ₁₀ H ₁₂ O ₂	-4.0814	-207.80	191.38	270 to 380
Fluorine	F ₂	-4.0425	-19.965	39.377	60 to 85
2 - Fluoro aniline	C ₆ H ₆ FN	-4.4778	-349.85	108.24	290 to 340
3 - Fluoro aniline	C ₆ H ₆ FN	-3.7425	-113.06	198.67	290 to 340
4 - Fluoro aniline	C ₆ H ₆ FN	-4.1860	-247.24	144.82	290 to 340
2 - Fluoro ethanol	C ₂ H ₅ FO	-4.3059	-237.31	144.01	290 to 340
Fluoro ethyl acetate	C ₄ H ₇ FO ₂	-4.3290	-248.86	10.92	290 to 340
1 - Fluoro - 2 - nitro benzene	C ₆ H ₄ FNO ₂	-3.9207	-190.52	152.29	290 to 340
1 - Fluoro - 3 - nitrobenzene	C ₆ H ₄ FNO ₂	-3.8976	-168.21	162.25	290 to 340
1 - Fluoro - 4 - nitrobenzene	C ₆ H ₄ FNO ₂	-3.8909	-168.55	167.51	300 to 340
1 - Fluoro pentane	C ₅ H ₁₁ F	-5.5312	-970.96	-168.92	290 to 340
2 - Fluoro phenetole	C ₈ H ₉ FO	-3.8508	-114.33	182.48	290 to 330
3 - Fluoro phenetole	C ₈ H ₉ FO	-3.6435	-59.589	215.27	290 to 340
4 - Fluoro phenetole	C ₈ H ₉ FO	-4.2889	-237.60	125.43	290 to 340
2 - Fluoro toluene	C ₇ H ₇ F	-4.9997	-617.09	-43.732	290 to 340
4 - Fluoro toluene	C ₇ H ₇ F	-4.7711	-463.94	-3.3819	290 to 340
Formamide	CH ₃ NO	-5.0263	-559.54	78.757	270 to 320
Formic acid	CH ₂ O ₂	-4.4442	-311.11	109.61	280 to 380
2 - Furaldehyde	C ₅ H ₄ O ₂	-4.3068	-288.90	102.72	270 to 380
Ground nut oil		-3.9621	-407.46	151.23	290 to 340
Hepta decane	C ₁₇ H ₃₆	-4.8559	-630.57	35.939	300 to 580
Heptane	C ₇ H ₁₆	-4.7163	-356.13	24.593	190 to 370
2 - Heptane thiol	C ₇ H ₁₆ S	-4.5611	-364.98	52.252	270 to 380
Heptanoic acid	C ₇ H ₁₄ O ₂	-4.7200	-529.62	68.313	285 to 395
2 - Heptanol	C ₇ H ₁₆ O	-4.9431	-408.06	137.51	300 to 430
3 - Heptanol	C ₇ H ₁₆ O	-4.7334	-288.89	180.49	310 to 420
4 - Heptanol	C ₇ H ₁₆ O	-4.7847	-307.04	170.68	290 to 420
2 - Heptanone	C ₇ H ₁₄ O	-4.0164	-55.937	233.86	290 to 360
1 - Heptene	C ₇ H ₁₄	-4.7028	-367.41	0.52937	270 to 370
Heptyl acetate	C ₉ H ₁₈ O ₂	-4.5679	-370.42	69.112	270 to 380
Heptyl amine	C ₇ H ₁₇ N	-5.5848	-937.05	-48.457	280 to 400
Heptyl mercaptan	C ₇ H ₁₆ S	-4.5069	-354.88	61.388	270 to 380
2 - Heptyl nonanol	C ₁₆ H ₃₄ O	-5.2286	-622.89	130.58	290 to 380
2 - Heptyl nonyl acetate	C ₁₈ H ₃₆ O ₂	-4.2190	-287.54	155.19	270 to 380
Heptyl thio acetate	C ₉ H ₁₈ OS	-4.0926	-244.09	121.75	300 to 370
Heptyl thio laurate	C ₁₉ H ₃₈ OS	-3.9865	-308.04	136.82	300 to 370
Hexa decane	C ₁₆ H ₃₄	-4.8174	-578.33	46.605	290 to 520
2 - Hexa decanol	C ₁₆ H ₃₄ O	-5.3662	-672.23	124.54	290 to 380
Hexa decyl acetate	C ₁₈ H ₃₆ O ₂	-4.4106	-403.22	118.00	290 to 380
2 - Hexa decyl acetate	C ₁₈ H ₃₆ O ₂	-4.2205	-285.73	155.79	270 to 380
7 - n - Hexadecyl spiro (4,5) decane	C ₂₆ H ₅₀	-4.1827	-387.10	147.17	290 to 380
Hexane	C ₆ H ₁₄	-4.2463	-118.06	134.87	270 to 340

<i>Name</i>	<i>Formula</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>Temp. Range, K</i>
Hexane nitrile	C ₆ H ₁₁ N	-4.7800	-471.26	27.296	290 to 440
1 - Hexane thiol	C ₆ H ₁₄ S	-4.5195	-343.01	54.236	270 to 380
2 - Hexane thiol	C ₆ H ₁₄ S	-4.5945	-361.31	42.281	270 to 380
Hexyl ethanoate	C ₈ H ₁₆ O ₂	-4.6136	-390.55	59.772	300 to 370
Hexyl thiohexanoate	C ₁₂ H ₂₄ OS	-4.3053	-384.59	78.571	310 to 370
Hexyl thio laurate	C ₁₈ H ₃₆ OS	-4.1505	-371.22	112.96	310 to 370
Hydrazine	H ₄ N ₂	-4.4407	-296.75	83.603	280 to 450
Hydrogen cyanide	HCN	-4.6541	-217.40	61.204	250 to 300
2 - Hydroxy aceto phenone	C ₈ H ₈ O ₂	-4.5830	-435.71	84.205	320 to 490
3 - Hydroxy aceto phenone	C ₈ H ₈ O ₂	-4.4802	-415.71	189.61	370 to 570
4 - Hydroxy benzaldehyde	C ₇ H ₆ O ₂	-3.3974	-106.24	303.06	400 to 440
Indan	C ₉ H ₁₀	-4.2327	-250.37	114.78	270 to 400
Indium	In	-3.3239	-236.69	30.666	430 to 620
Iodine penta fluoride	F ₅ I	-3.6707	-114.50	183.24	280 to 350
Iodo benzene	C ₆ H ₅ I	-4.2107	-307.78	78.655	270 to 425
Iodo ethane	C ₂ H ₅ I	-4.6258	-446.10	-27.294	270 to 350
1 - Iodo - 2 - methyl propane	C ₄ H ₉ I	-4.6668	-470.78	7.0839	270 to 390
1 - Iodo propane	C ₃ H ₇ I	-4.3648	-292.68	56.586	270 to 380
2 - Iodo propane	C ₃ H ₇ N	-4.5880	-409.62	6.1088	270 to 360
Isoamyl ether	C ₁₀ H ₂₂ O	-4.5653	-344.08	74.225	270 to 380
Isoamyl titanate	C ₂₀ H ₄₄ O ₄ Ti	-5.2745	-506.00	232.24	400 to 490
Isobutyl acetate	C ₆ H ₁₂ O ₂	-5.8472	-1268.1	176.33	290 to 460
Isobutyl titanate	C ₁₆ H ₃₆ O ₄ Ti	-4.7234	-295.54	247.55	370 to 470
1 - (Iso cyanato - 1 - methyl ethyl) - 3 - (1 - methyl ethyl) benzene	C ₁₃ H ₁₅ NO	-4.3230	-334.25	114.34	290 to 360
Iso heptane	C ₇ H ₁₆	-5.3931	-835.48	-130.45	270 to 370
3 - Isopropyl - 2 - oxa zolidinone	C ₆ H ₁₁ NO ₂	-4.2344	-323.09	118.18	270 to 340
3 - Iso propyl sydnone	C ₅ H ₈ N ₂ O ₂	-4.1797	-338.42	141.61	330 to 400
Lead	Pb	-3.1186	-182.99	266.85	600 to 1200
Magnesium chloride hexahydrate (molten)	MgCl ₂ .6H ₂ O	-3.8293	-1261.0	90.022	990 to 1180
1 - Menthol	C ₁₀ H ₂₀ O	-5.0390	-324.74	214.31	320 to 380
Mercury	Hg	-3.1105	-51.209	124.04	290 to 380
Methanol	CH ₄ O	-4.9016	-449.49	23.551	180 to 290
<i>n</i> - 2 - Methoxy ethyl acetamide	C ₅ H ₁₁ O ₂	-4.3441	-330.03	159.45	290 to 350
2 - Methoxy phenol	C ₇ H ₈ O ₂	-4.4351	-313.21	151.10	320 to 480
3 - Methoxy phenol	C ₇ H ₈ O ₂	-4.5348	-377.59	172.18	325 to 520
4 - Methoxy phenol	C ₇ H ₈ O ₂	-4.5900	-412.70	162.01	340 to 520

<i>Name</i>	<i>Formula</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>Temp. Range, K</i>
Methyl amine	CH ₅ N	-4.6228	-198.43	71.960	200 to 300
<i>n</i> - Methyl aniline	C ₇ H ₉ N	-4.3528	-268.33	136.78	270 to 440
2 - Methyl benzene amine	C ₇ H ₉ N	-4.4107	-297.19	149.02	270 to 480
3 - Methyl benzene amine	C ₇ H ₉ N	-4.4494	-301.95	145.82	270 to 480
4 - Methyl benzene amine	C ₇ H ₉ N	-4.3612	-219.54	206.59	310 to 480
2-Methyl benzo nitrile	C ₈ H ₇ N	-4.3838	-319.82	96.496	290 to 420
3-Methyl benzo nitrile	C ₈ H ₇ N	-4.4080	-321.16	95.332	290 to 420
4-Methyl benzo nitrile	C ₈ H ₇ N	-4.4654	-360.83	80.619	300 to 420
2-Methyl-1- butanol	C ₅ H ₁₂ O	-5.3355	-551.30	113.41	290 to 400
2 - Methyl - 1 -butanol (optically active)	C ₅ H ₁₂ O	-5.6363	-703.07	82.578	270 to 400
3-Methyl-1- butanol (optically active)	C ₅ H ₁₂ O	-5.7750	-841.12	46.485	270 to 410
3-Methyl-2- butanol	C ₅ H ₁₂ O	-4.8491	-313.81	169.58	290 to 380
Methyl carbamate	C ₂ H ₅ NO	-4.3167	-280.14	166.40	320 to 370
<i>n</i> - Methyl - 2 - chloro acetamide	C ₃ H ₆ ClO	-4.4456	-371.19	140.22	320 to 350
Methyl cyclo hexane	C ₇ H ₁₄	-4.5348	-319.07	64.712	270 to 380
2-Methyl cyclo hexanol	C ₇ H ₁₄ O	-4.6708	-304.32	191.82	290 to 370
3 - Methyl cyclo hexanol	C ₇ H ₁₄ O	-5.9247	-797.76	107.35	290 to 370
4 - Methyl cyclo hexanol	C ₇ H ₁₄ O	-5.4635	-558.96	158.00	310 to 370
2 - Methyl cyclo hexanone	C ₇ H ₁₂ O	-3.8722	-133.01	172.45	280 to 340
3 - Methyl cyclo hexanone	C ₇ H ₁₂ O	-3.7405	-97.894	194.36	280 to 340
4 - Methyl cyclo hexanone	C ₇ H ₁₂ O	-3.8959	-145.00	165.50	280 to 370
Methyl cyclo pentane	C ₆ H ₁₂	-5.5016	-940.03	132.64	240 to 330
Methyl diphenyl amine	C ₁₃ H ₁₃ N	-3.8079	-170.88	191.05	270 to 360
2 - Methyl - 6 - ethyl aniline	C ₉ H ₁₃ N	-4.1038	-214.17	166.71	290 to 380
Methyl formate	C ₂ H ₂ O ₂	-4.0229	-77.194	155.67	270 to 310
2-Methyl-2 - heptanol	C ₈ H ₁₈ O	-4.8579	-419.93	121.96	270 to 380
2-Methyl- 3 - heptanol	C ₈ H ₁₈ O	-4.8686	-319.77	179.53	270 to 380
2-Methyl- 4 - heptanol	C ₈ H ₁₈ O	-5.3181	-471.17	149.48	270 to 380
2-Methyl -5 - heptanol	C ₈ H ₁₈ O	-4.8874	-430.45	86.77	270 to 380
2-Methyl - 7 -heptanol	C ₈ H ₁₈ O	-5.3070	-637.23	99.314	270 to 380
3-Methyl -1 - heptanol	C ₈ H ₁₈ O	-4.8480	-455.08	83.39	270 to 380
3- Methyl -2 -heptanol	C ₈ H ₁₈ O	-4.6390	-334.29	116.43	270 to 380
3- Methyl -3 -heptanol	C ₈ H ₁₈ O	-4.7910	-307.09	173.98	270 to 380
3 - Methyl - 4 - heptanol	C ₈ H ₁₈ O	-4.6737	-326.66	130.98	270 to 380
3-Methyl -5 - heptanol	C ₈ H ₁₈ O	-4.6993	-369.64	89.383	270 to 380

<i>Name</i>	<i>Formula</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>Temp. Range, K</i>
3-Methyl- 6 - heptanol	C ₈ H ₁₈ O	- 4.9235	- 451.64	98.852	270 to 380
3-Methyl - 7 -heptanol	C ₈ H ₁₈ O	- 5.0466	- 513.98	111.97	270 to 380
4-Methyl- 3 - heptanol	C ₈ H ₁₈ O	- 4.6307	- 325.82	102.60	270 to 380
2-Methyl - 2 - hexanol	C ₇ H ₁₆ O	- 4.8188	- 322.52	165.66	300 to 410
Methyl - 4 - hydroxy benzoate	C ₈ H ₈ O ₃	- 4.6510	- 501.30	184.86	410 to 570
2 - Methyl octane - 2 - thiol	C ₉ H ₂₀ S	- 4.5357	- 308.54	106.32	280 to 330
3 - Methyl - 2 - oxazolidinone	C ₄ H ₇ NO ₂	- 4.5133	- 469.69	52.128	270 to 340
5 - Methyl -2 - oxazolidinone	C ₄ H ₇ NO ₂	- 4.2193	- 323.59	167.86	270 to 340
2 - Methyl penta decyl acetate	C ₁₈ H ₃₆ O ₂	- 4.1461	- 291.48	148.59	270 to 380
2 - Methyl pentane	C ₆ H ₁₄	- 5.4697	- 862.57	- 149.90	270 to 330
2 - Methyl - 1 - pentene	C ₆ H ₁₂	- 2.5684	- 236.49	536.99	290 to 330
2 - Methyl - 2 - propane thiol	C ₄ H ₁₀ S	- 4.7260	- 342.80	68.37	280 to 320
2 - Methyl - 1 - propanol	C ₄ H ₁₀ O	- 6.1025	- 946.92	37.007	270 to 380
2 - Methyl - 2 - propanol	C ₄ H ₁₀ S	- 4.7679	- 239.20	198.59	300 to 360
Methyl propionate	C ₄ H ₈ O ₂	- 4.9955	- 553.64	- 41.506	270 to 350
2 - Methyl propionic acid	C ₄ H ₈ O ₂	- 4.8990	- 597.55	- 2.4824	270 to 430
Methyl salicylate	C ₈ H ₈ O ₃	- 4.6908	- 531.13	41.528	350 to 500
3 - Methyl sulfolane	C ₅ H ₆ SO ₂	- 4.2086	- 376.51	132.99	290 to 400
Methyl sulfoxide	C ₂ H ₆ OS	- 4.3585	- 323.95	102.62	290 to 400
3 - Methyl sydnone	C ₃ H ₄ N ₂ O ₂	- 3.9503	- 268.63	154.26	310 to 400
Methyl thio cyanate	C ₂ H ₃ SN	- 4.4357	- 314.04	57.847	270 to 380
Mono dimethyl amino phosphoryl chloride	C ₂ H ₆ Cl ₂ NOP	- 3.8387	- 175.69	142.04	250 to 350
Nitro benzene	C ₆ H ₅ NO ₂	- 4.4054	- 372.85	75.641	270 to 500
2 - Nitro phenol	C ₆ H ₅ NO ₃	- 4.3361	- 328.93	129.92	300 to 490
3 - Nitro phenol	C ₆ H ₅ NO ₃	- 3.9333	- 216.26	223.80	360 to 400
4 - Nitro phenol	C ₆ H ₅ NO ₃	- 5.1303	- 889.28	59.746	370 to 570
2 - Nitro phenyl methyl ether	C ₈ H ₉ NO ₃	- 4.4960	- 422.07	106.85	280 to 520
2 - Nitro resorcinol	C ₆ H ₅ NO ₄	- 4.5642	- 455.67	128.78	360 to 510
2 - Nitro toluene	C ₇ H ₇ NO ₂	- 4.4923	- 404.73	76.683	270 to 500
3 - Nitro toluene	C ₇ H ₇ NO ₂	- 4.1521	- 252.23	127.13	290 to 380
4 - Nitro toluene	C ₇ H ₇ NO ₂	- 4.4681	- 404.79	71.717	330 to 520
Nonane	C ₉ H ₂₀	- 4.7864	- 440.73	24.243	270 to 380
1 - Nonane thiol	C ₉ H ₂₀ S	- 4.3351	- 297.76	102.73	270 to 400
2 - Nonane thiol	C ₉ H ₂₀ S	- 4.4906	- 335.75	80.523	270 to 400
Nonanoic acid	C ₉ H ₁₈ O ₂	- 4.6210	- 489.09	99.881	290 to 370
5 - Nonanone	C ₉ H ₁₈ O	- 4.4816	- 346.38	76.180	290 to 380

<i>Name</i>	<i>Formula</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>Temp. Range, K</i>
Nonyl thio palmitate	C ₂₅ H ₅₀ OS	- 3.6375	- 224.63	180.63	340 to 370
Octa decane	C ₁₈ H ₃₈	- 4.3923	- 378.20	111.62	300 to 380
Octa decyl thio myrisate	C ₃₂ H ₆₄ OS	- 2.3386	- 6.4228	318.15	330 to 370
Octane	C ₈ H ₁₈	- 5.1030	- 632.42	- 51.438	270 to 400
1 - Octane thiol	C ₈ H ₁₈ S	- 4.5008	- 366.58	68.840	270 to 380
2 - Octane thiol	C ₈ H ₁₈ S	- 4.4502	- 323.68	79.120	270 to 380
Octanoic acid	C ₈ H ₁₆ O ₂	- 4.1803	- 272.88	153.08	290 to 370
<i>trans</i> - 2 - Octene	C ₈ H ₁₆	- 5.3398	- 836.02	- 115.97	290 to 380
Octyl amine	C ₈ H ₁₉ N	- 4.9093	- 501.41	57.503	270 to 340
Octyl thio myrisate	C ₂₂ H ₄₄ OS	- 3.9509	- 316.58	143.12	300 to 370
Olive oil	-	- 4.9110	- 699.70	110.30	290 to 340
Palmitic acid	C ₁₆ H ₃₂ O ₂	- 3.8383	- 267.36	188.83	340 to 370
Paracetaldehyde	C ₆ H ₁₂ O ₃	- 4.7345	- 361.18	93.813	280 to 400
Penta chloro ethane	C ₂ H ₅ Cl	- 4.5124	- 438.07	63.314	270 to 360
Penta decane	C ₁₅ H ₃₂	- 4.3494	- 323.33	114.00	290 to 380
Pentane	C ₅ H ₁₂	- 4.4907	- 224.14	31.92	150 to 330
2 - Pentane thiol	C ₅ H ₁₂ S	- 4.9446	- 565.81	- 43.074	270 to 380
1 - Pentanol	C ₅ H ₁₂ O	- 5.4786	- 696.80	68.729	220 to 410
2 - Pentanol	C ₅ H ₁₂ O	- 4.9433	- 343.89	159.69	290 to 390
3 - Pentanol	C ₅ H ₁₂ O	- 4.7586	- 254.46	191.08	290 to 390
3 - Pentanone	C ₅ H ₁₀ O	- 5.0685	- 628.20	- 68.044	270 to 380
2 - Pentene	C ₅ H ₁₀	- 4.0663	- 25.287	229.50	290 to 310
Pentyl ether	C ₁₀ H ₂₂ O	- 4.4828	- 311.96	87.694	270 to 380
Perfluoro -1,4 -di iso propoxy butane	C ₁₀ F ₂₀ O ₂	- 2.9742	- 7.0538	273.86	290 to 320
Phenethyl alcohol	C ₈ H ₁₀ O	- 4.4593	- 324.57	168.71	270 to 380
Phenol	C ₆ H ₆ O	- 4.3571	- 267.31	181.96	300 to 460
Phenyl - n - amyl ether	C ₁₁ H ₁₆ O	- 4.8009	- 510.42	58.052	290 to 510
Phenyl iso thio cyanate	C ₇ H ₅ NS	- 4.1719	- 247.72	111.40	270 to 380
2 - Phenyl - 1 - propanol	C ₉ H ₁₂ O	- 2.7359	- 26.229	270.16	290 to 330
Phenyl propyl ketone	C ₁₀ H ₁₂ O	- 4.1646	- 232.50	142.01	270 to 380
Phosphorus trichloride	PCl ₃	- 4.2542	- 270.00	21.934	200 to 340
Phosphoryl chloride	POCl ₃	- 4.2043	- 249.22	92.575	270 to 360
2 - Picoline	C ₆ H ₇ N	- 4.6362	- 402.11	33.102	270 to 360
2 - Picoline - N - oxide	C ₆ H ₇ NO	- 4.1864	- 294.26	156.24	320 to 400
3 - Picoline - N -oxide	C ₆ H ₇ NO	- 4.0257	- 241.12	184.32	310 to 400
Pinacolone	C ₆ H ₁₂ O	- 4.9656	- 559.39	- 14.42	290 to 360
Pipridine	C ₅ H ₁₁ N	- 4.5966	- 328.47	115.00	280 to 380
Potassium	K	- 4.4954	- 869.76	- 389.82	400 to 1800
1,3 - Propane sulfone	C ₃ H ₆ SO ₃	- 4.0403	- 346.70	126.85	300 to 350
2 - Propane thiol	C ₃ H ₈ S	- 4.7800	- 387.13	7.6593	270 to 320
1 - Propanol	C ₃ H ₈ O	- 5.7281	- 853.50	15.262	210 to 370

Name	Formula	A	B	C	Temp. Range, K
2 - Propanol	C ₃ H ₈ O	- 6.3050	- 1009.2	18.917	270 to 360
Propionaldehyde	C ₃ H ₆ O	- 5.1953	- 611.30	- 60.958	280 to 330
Propionamide	C ₃ H ₇ NO	- 4.3422	- 267.72	205.36	260 to 490
Propionic acid	C ₃ H ₆ O ₂	- 4.8207	- 561.55	- 8.1224	270 to 420
Propionic anhydride	C ₆ H ₁₀ O ₃	- 4.7818	- 492.35	24.606	270 to 440
Propio nitrile	C ₃ H ₅ N	- 4.7953	- 424.61	- 37.983	290 to 380
Propionyl chloride	C ₃ H ₅ ClO	- 4.7776	- 443.86	- 11.959	290 to 360
Propyl benzene	C ₉ H ₁₂ O	- 4.7786	- 473.64	53.513	280 to 460
Propyl benzene amine	C ₉ H ₁₃ N	- 4.8964	- 612.19	20.818	370 to 500
Propyl carbamate	C ₄ H ₉ NO	- 4.5234	- 342.48	164.26	330 to 380
Propylene glycol dinitrate	C ₃ H ₆ N ₂ O ₆	- 3.9605	- 196.00	168.35	280 to 340
Propyl formate	C ₄ H ₈ O ₂	- 5.3847	- 858.62	116.02	270 to 360
2 - p - propyl phenyl - 2 - p - tolyl butane	C ₂₁ H ₂₂	- 4.1543	- 233.70	213.2	320 to 480
1 - p - Propyl phenyl - p - tolyl ethane	C ₁₈ H ₂₂	- 4.4081	- 356.54	141.09	270 to 480
Propyl sulfone	C ₆ H ₁₄ O ₂ S	- 4.2525	- 290.93	156.68	300 to 400
Propyl sulfoxide	C ₆ H ₁₄ OS	- 4.2525	- 290.93	156.68	300 to 400
Propyl thioacetate	C ₅ H ₁₀ OS	- 4.4072	- 330.35	49.855	300 to 370
Propyl titanate	C ₁₂ H ₂₇ O ₄ Ti	- 5.4227	- 548.59	212.66	410 to 480
2 - Propyl tri decanol	C ₁₆ H ₃₄ O	- 5.0182	- 549.04	139.57	290 to 380
2 - Propyl tri decyl acetate	C ₁₈ H ₃₆ O ₂	- 4.1444	- 271.06	157.55	270 to 380
Pyridine	C ₅ H ₅ N	- 4.1172	- 174.52	133.66	270 to 390
Pyrrole	C ₄ H ₅ N	- 4.2156	- 216.75	131.91	250 to 350
Pyrrolidine	C ₄ H ₉ N	- 4.2850	- 204.20	117.84	210 to 340
Rape seed oil		- 4.4802	- 597.20	119.99	290 to 340
Salicylic aldehyde	C ₇ H ₆ O ₂	- 4.6526	- 502.49	49.163	340 to 470
Sodium phosphate, dibasic decahydrae	Na ₂ HPO ₄ . 12H ₂ O	- 1.9749	- 14.524	351.62	310 to 330
Sodium thiosulfate penta hydrate	Na ₂ S ₂ O ₃ .5H ₂ O	- 3.0454	- 54.28	268.25	320 to 340
Soyabean oil		- 4.4977	- 581.28	115.28	290 to 340
Spiro (4,5) decane	C ₁₀ H ₁₈	- 4.5205	- 426.25	64.537	270 to 340
Spiro (5,5) undecane	C ₁₁ H ₂₀	- 4.4509	- 406.57	84.58	270 to 380
Spiro (5,6) dodecane	C ₁₂ H ₂₂	- 4.3005	- 349.60	114.44	270 to 380
Strontium chloride hexahydrate (molten)	SrCl ₂ .6H ₂ O	- 3.6073	- 954.00	341.06	1150 to 1320
Styrene	C ₈ H ₈	- 4.6087	- 343.56	61.746	270 to 420
Sucrose	C = 26, H ₂ O	- 4.3736	- 327.15	102.69	290 to 330
Sunflower oil	-	- 3.6505	- 304.27	168.98	290 to 340
Tetra butyl germane	Ge(C ₄ H ₉) ₄	- 4.0687	- 211.37	158.55	270 to 340
Tetra decane	C ₁₄ H ₃₀	- 4.3480	- 307.14	114.12	280 to 380
Tetra decyl thiolaurate	C ₂₆ H ₅₂ OS	- 3.6644	- 241.20	176.10	300 to 370
Tetra decyl thio myristate	C ₂₈ H ₅₆ OS	- 3.7246	- 275.40	167.88	300 to 370

<i>Name</i>	<i>Formula</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>Temp. Range, K</i>
Tetra - n - ethyl germane	Ge(C ₂ H ₅) ₄	- 3.8769	- 124.05	127.22	270 to 340
Tetra - n - hexyl germane	Ge(C ₆ H ₁₃) ₄	- 4.1948	- 307.49	142.51	270 to 340
1,2,3,4 - Tetrahydro -6 - butyl -hexyl naphthalene	C ₂₀ H ₃₂	- 4.4021	- 382.01	159.74	270 to 380
1,2,3,4 -Tetra hydro - 7 -butyl - 1 - n - hexyl naphthalene	C ₂₀ H ₃₂	- 4.2780	- 335.62	163.76	270 to 380
1,2,3,4 - Tetra hydro - 1,6 -dimethyl - 7 - octyl naphthalene	C ₂₀ H ₃₂	- 4.1609	- 298.25	176.95	290 to 380
1,2,3,4 -Tetra hydro - 5,8 -dimethyl - 1 - octyl naphthalene	C ₂₀ H ₃₂	- 4.1062	- 288.48	183.98	290 to 390
Tetra - n -pentyl germane	Ge(C ₅ H ₁₁) ₄	- 3.9447	- 210.02	166.92	270 to 340
Tetra - n - propyl germane	Ge(C ₃ H ₇) ₄	- 4.2442	- 244.89	114.56	270 to 350
Thallium	Tl	- 3.1959	- 282.64	118.24	570 to 740
Thio phosphoryl chloride	PSCl ₃	- 4.1147	- 230.60	92.836	240 to 380
Tin	Sn	- 3.2469	- 207.80	88.744	510 to 770
1-m -Toly -1-p- tolyl ethane	C ₁₆ H ₁₈	- 4.5124	- 362.96	141.19	270 to 480
1 - m - Toly - 1 - o - toly ethane	C ₁₆ H ₁₈	- 4.2798	- 265.15	189.30	270 to 480
1 - o -Toly - 1 - p -toly ethane	C ₁₆ H ₁₈	- 4.3054	- 275.75	179.94	270 to 480
Tri butyl borate	C ₁₂ H ₂₇ BO ₃	- 4.8408	- 562.33	24.655	290 to 500
Tri butyl phosphate	C ₁₂ H ₂₇ O ₄ P	- 4.1597	- 282.50	131.38	205 to 340
Tri ethyl borate	C ₆ H ₁₅ BO ₃	- 4.8708	- 497.40	- 15.747	290 to 370
Tri decane	C ₁₃ H ₂₈	- 4.6835	- 453.60	61.909	270 to 480
Tri decyl thi opalmitate	C ₂₉ H ₅₈ OS	- 3.3966	- 176.63	204.38	340 to 370
1,1,1-Tri fluoro-tert- butyl alcohol	C ₄ H ₇ F ₃ O	- 4.5179	- 217.60	191.50	290 to 330
3,3,3 - Trifluoroethanol	C ₂ H ₃ F ₃ O	- 5.6152	- 735.51	40.809	290 to 340
1,1,1 - Trifluoro isopropyl alcohol	C ₃ H ₅ F ₃ O	- 5.0978	- 338.20	142.81	280 to 330
Tri hexyl amine	C ₁₈ H ₃₉ N	- 4.5462	- 412.41	105.78	280 to 430
Tri iso butyl borate	C ₁₂ H ₂₇ BO ₃	- 4.7067	- 433.43	77.578	290 to 480
Tri iso propyl borate	C ₉ H ₂₇ BO ₃	- 5.0367	- 584.29	- 2.532	290 to 410
Tri laurin	C ₃₉ H ₇₄ O ₂	- 3.9293	- 336.14	170.15	310 to 360
Tri methyl borate	C ₃ H ₉ BO ₃	- 4.1136	- 96.248	158.62	290 to 340
Tri methyl phosphite	C ₃ H ₉ O ₃ P	- 4.2594	- 195.02	102.02	240 to 380
Tri octyl phosphine oxide	C ₂₄ H ₅₁ OP	- 3.4379	- 126.97	249.94	330 to 380

<i>Name</i>	<i>Formula</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>Temp. Range, K</i>
Tri palmitin	C ₅₁ H ₉₈ O ₆	- 3.7364	- 69.231	171.28	340 to 360
Tri phenyl phosphate	C ₁₈ H ₁₅ O ₄ P	- 3.4721	- 149.45	221.84	320 to 370
Tri phenyl phosphite	C ₁₈ H ₁₅ O ₃ P	- 3.8459	- 231.62	185.13	250 to 360
Tri propyl borate	C ₃ H ₇ BO ₃	- 5.0077	- 633.51	-16.470	290 to 450
Tris dimethyl amino phosphine oxide	C ₆ H ₁₈ N ₃ OP	- 3.9327	- 226.35	143.09	280 to 350
Tris - (2 - ethyl hexyl) phosphate	C ₂₄ H ₅₁ O ₄ P	- 4.1967	- 332.10	151.17	220 to 350
Undecane	C ₁₁ H ₂₄	- 4.7592	- 466.88	38.719	260 to 480
2 - Undecanone	C ₁₁ H ₂₂ O	- 4.5021	- 364.95	92.28	290 to 420
Undecyl thio palmitate	C ₂₇ H ₅₄ OS	- 3.7452	- 275.62	166.17	340 to 370
Undecyl thio stearate	C ₂₉ H ₅₈ OS	- 3.3186	- 155.73	213.36	340 to 370
Valero nitrile	C ₅ H ₉ N	- 4.8445	- 512.47	4.9088	270 to 420
Water	H ₂ O	- 4.5318	- 220.57	149.39	270 to 380
<i>m</i> - Xylene	C ₈ H ₁₀	- 4.8271	- 505.32	- 19.347	270 to 410
<i>o</i> - Xylene	C ₈ H ₁₀	- 4.8927	- 553.59	- 14.003	260 to 420
<i>p</i> - Xylene	C ₈ H ₁₀	- 5.2463	- 826.32	- 109.48	280 to 410
Zinc	Zn	- 3.0413	- 186.99	405.78	690 to 1100
Zinc nitrate hexahydrate	ZnNO ₃ .6H ₂ O	- 2.4677	- 23.999	279.07	310 to 340

Table 4.10. Constants of the Antoine type equation [Eq. (4.19): $\log v = A' + B' / (C' - T)$] for the temperature dependence of the kinematic viscosity of pure liquids. From: D. S. Viswanath and G. Natarajan, Data Book on Viscosity of Liquids, Hemisphere, New York, 1989. [Temperature in K and Kinematic viscosity in cSt].

Name	Formula	A'	B'	C'	Temperature Range, K
n - Amyl ortho silicate	C ₂₀ H ₄₄ O ₄ Si	-0.78717	-209.01	138.38	240 to 380
Bis (ϕ' - amyl) adipate	C ₁₆ H ₃₀ O ₄	-1.3371	-383.88	157.86	290 to 470
Bis (ϕ' - amyl) glutarate	C ₁₆ H ₃₀ O ₄	-1.3783	-389.19	156.14	250 to 460
Bis (ϕ' - amyl) 3 - glutarate	C ₁₆ H ₃₀ O ₄	-1.3833	-384.66	161.46	250 to 470
Bis (ϕ' - amyl) phthalate	C ₁₈ H ₂₆ O ₄	-1.3951	-387.75	185.81	290 to 470
Bis (ϕ' - amyl) sebacate	C ₂₈ H ₃₈ O ₄	-1.2532	-388.68	157.01	290 to 470
Bis (ϕ' - butyl) 3 - methyl glutarate	C ₁₄ H ₂₆ O ₄	-1.3511	-309.44	157.13	240 to 470
Bis (ϕ' - butyl) sebacate	C ₁₈ H ₃₄ O ₄	-1.2652	-347.25	144.86	290 to 470
Bis (1 - ethyl hexyl) phthalate	C ₂₄ H ₃₈ O ₄	-1.2417	-360.48	178.64	260 to 380
Bis (2 - ethyl hexyl) sebacate	C ₂₆ H ₅₀ O ₄	-1.2046	-391.92	142.67	220 to 380
1,6 - Bis (ϕ' - heptoxy) hexane	C ₂₀ H ₄₂ O ₂	-1.3703	-387.17	155.44	245 to 380
Bis (ϕ' - heptyl) adipate	C ₂₀ H ₃₈ O ₄	-1.3571	-399.44	164.63	290 to 470
Bis (ϕ' - heptyl) 3 - methyl glutarate	C ₂₈ H ₃₈ O ₄	-1.3656	-388.52	171.31	290 to 470
Bis (ϕ' - heptyl) pinate	C ₂₃ H ₄₂ O ₄	0.37192	-98.668	240.57	290 to 470
Bis (ϕ' - hexyl) 3 - methyl glutarate	C ₁₈ H ₃₄ O ₄	-1.2709	-315.37	168.73	250 to 370
Bis (ϕ' - nonyl) 3 - tert - butyl adipate	C ₂₈ H ₅₄ O ₄	-1.2415	-367.24	191.29	290 to 470
Bis (ϕ' - nonyl) 3 - methyl glutarate	C ₂₄ H ₄₆ O ₄	-1.8101	-561.16	150.09	290 to 470
Bis (ϕ' - octyl) adipate	C ₂₂ H ₄₂ O ₄	-1.2903	-344.03	172.88	290 to 470
Bis (ϕ' - octyl) 3 - methyl glutarate	C ₂₂ H ₄₂ O ₄	-1.5185	-404.07	166.12	290 to 470
Butyl - 2 - acetoxy stearate	C ₂₄ H ₄₆ O ₄	-0.9431	-281.16	175.24	280 to 380
Butyl benzoxo - 9 (10) - mono acyloxy stearate	C ₃₁ H ₅₀ O ₆	-1.2756	-435.71	152.65	245 to 380
Butyl - P,P - bis (2 - ethyl hexyl) phosphono undecane	C ₃₁ H ₆₃ O ₃ P	-1.1567	-445.65	152.19	240 to 380

<i>Name</i>	<i>Formula</i>	<i>A'</i>	<i>B'</i>	<i>C'</i>	<i>Temperature Range, K</i>
Butyl butyrox - 9 (10) - mono acycloxy stearate	$C_{28}H_{52}O_6$	-1.1232	-370.10	145.99	245 to 380
Buty - 9,10 - di acetoxystearate	$C_{26}H_{48}O_6$	-1.0118	-331.55	178.82	280 to 380
Butyl - P,P - diethyl phosphono laurate	$C_{20}H_{41}O_5P$	-1.2634	-365.75	152.47	225 to 380
Butyl - P,P - diethyl - 9 (10) - phosphono stearate	$C_{26}H_{53}O_5P$	-1.2710	-430.96	142.05	240 to 380
Butyl - 1,2 - mono acetoxystearate	$C_{24}H_{46}O_4$	-0.8427	-277.50	171.73	260 to 380
Butyl - 1,2 - (mono methyl adipoxy) stearate	$C_{29}H_{54}O_6$	-0.8443	-306.22	170.43	260 to 380
<i>n</i> - Butyl ortho silicate	$C_{16}H_{36}O_4Si$	-0.65246	-150.77	146.79	240 to 380
Butyl phthalyl butyl glycolate	$C_{18}H_{24}O_6$	-0.9835	-279.77	192.43	290 to 380
1,10 - Deca methylene glycol di - (2 - ethyl hexanoate)	$C_{26}H_{50}O_4$	-0.67869	-221.10	186.01	270 to 380
1,10 - Decane diol bis (ϕ - butyrate)	$C_{18}H_{34}O_4$	-1.3184	-361.18	137.53	270 to 380
Diamyl adipate	$C_{22}H_{30}O_4$	-0.72794	-187.94	176.47	290 to 380
Di (2 - (2' - ethyl butoxy) ethyl) adipate	$C_{22}H_{52}O_8$	-0.78656	-261.16	171.85	270 to 380
Di (2 - butoxy ethyl) azelate	$C_{14}H_{40}O_6$	-0.82958	-266.83	163.09	270 to 380
Di butyl lauroyl oxy ethyl phosphonate	$C_{22}H_{46}O_5P$	-0.8672	-270.17	170.31	260 to 380
Di butyl lauryloxy propyl phosphate	$C_{23}H_{47}O_6P$	-5.5182	-4270.8	-341.12	310 to 380
Di butyl lauryloxy propyl phosphonate	$C_{23}H_{47}O_5$	-0.7123	-267.97	169.87	240 to 380
Di butyl phthalate	$C_{16}H_{22}O_4$	-1.0202	-274.01	174.53	270 to 380
Di butyl sebacate	$C_{18}H_{34}O_4$	-0.92084	-280.86	146.50	270 to 380
Di (1,3 - dimethyl butyl) adipate	$C_{18}H_{34}O_4$	-0.89472	-231.33	170.46	270 to 380
Di (1,3 - dimethyl butyl) sebacate	$C_{22}H_{42}O_4$	-0.90909	-274.33	164.89	270 to 380
Di (2 - (2' - ethyl butoxy) ethyl) adipate	$C_{20}H_{52}O_6$	-0.80589	-248.17	170.59	270 to 380
Di (2 - ethyl butyl) adipate	$C_{18}H_{34}O_4$	-0.94010	-262.46	156.23	270 to 380
Di (2 - ethyl butyl) azile	$C_{21}H_{40}O_4$	-0.86556	-268.48	159.80	270 to 380

<i>Name</i>	<i>Formula</i>	<i>A'</i>	<i>B'</i>	<i>C'</i>	<i>Temperature Range, K</i>
Di (2 - ethyl butyl) sebacate	C ₂₂ H ₄₂ O ₄	-0.87406	-280.58	157.69	270 to 380
Di ethylene glycol di (1,2-mono acetoxystate)	C ₄₄ H ₈₂ O ₉	-0.7439	-355.16	179.82	260 to 380
Di (2 - ethyl hexyl) adipate	C ₂₂ H ₄₂ O ₄	-0.86706	-251.38	169.92	270 to 380
Di (2 - ethyl hexyl) azelate	C ₂₅ H ₄₈ O ₄	-0.92709	-299.93	159.71	270 to 380
Di (1 - ethyl propyl) azelate	C ₁₉ H ₃₆ O ₄	-0.91797	-259.82	162.23	270 to 380
Di ethyl lauroxylo ethyl phosphate	C ₁₈ H ₃₇ O ₆ P	-2.0703	-910.32	-15.400	310 to 380
Di ethyl oleoxy butyl phosphate	C ₂₆ H ₅₁ O ₆ P	-0.8135	-307.28	163.12	280 to 380
Di ethyl oleoxyethyl phosphate	C ₂₄ H ₄₇ O ₆ P	-0.8056	-264.72	158.26	270 to 380
Di ethyl oleoxypropyl phosphate	C ₂₅ H ₄₉ O ₆ P	-1.9035	-786.53	65.381	310 to 380
Di ethyl phthalate	C ₁₂ H ₁₄ O ₄	-1.0000	-242.82	175.92	270 to 380
Di (1 - ethyl propyl) adipate	C ₁₆ H ₃₀ O ₄	-0.94831	-235.96	163.79	270 to 380
Di (1 - ethyl propyl) sebacate	C ₂₀ H ₃₈ O ₄	-0.91757	-267.18	162.19	270 to 380
Di (hepta decyl) adipate	C ₁₀ H ₇₈ O ₄	-1.0937	-376.58	172.49	270 to 380
1,6 - Di heptoxy hexane	C ₂₀ H ₄₂ O ₂	-0.59825	-157.65	191.66	290 to 380
Di heptyl pinate	C ₂₂ H ₄₂ O ₄	-1.0851	-358.73	146.78	290 to 380
Di hexyl lauroxylo propyl phosphonate	C ₂₆ H ₅₃ O ₅ P	-0.9691	-321.51	159.20	260 to 380
Di (3 - methyl butyl) adipate	C ₁₆ H ₃₀ O ₄	-0.96123	-265.85	150.38	270 to 380
Di (3 - methyl butyl) azelate	C ₁₉ H ₃₆ O ₄	-0.92713	-286.95	149.20	270 to 380
Di (3 - methyl butyl) sebacate	C ₂₀ H ₃₈ O ₄	-0.92532	-294.57	149.72	270 to 380
Di (1 - methyl ethyl) adipate	C ₁₂ H ₂₂ O ₄	-0.95376	-220.22	155.72	270 to 380
Di (1 - methyl ethyl sebacate)	C ₁₆ H ₃₀ O ₄	-0.96749	-268.56	149.78	270 to 380
Di octyl adipate	C ₂₂ H ₄₂ O ₄	-0.88427	-308.08	141.70	290 to 380
Di (tetra decyl) adipate	C ₃₄ H ₆₆ O ₄	-1.0341	-332.90	181.24	270 to 380
Di (tetra decyl) glutarate	C ₃₃ H ₆₀ O ₄	-1.0642	-335.45	180.23	290 to 380
Di (tetra decyl) sebacate	C ₃₈ H ₇₄ O ₄	-1.0140	-357.75	176.42	270 to 380
Di undecyl adipate	C ₂₈ H ₅₀ O ₄	-0.90546	-287.00	177.52	270 to 380
Di undecyl glutarate	C ₂₇ H ₄₈ O ₆	-0.88903	-274.53	179.61	270 to 380
Di undecyl sebacate	C ₃₂ H ₆₂ O ₄	-0.93484	-329.60	169.32	270 to 380

<i>Name</i>	<i>Formula</i>	<i>A'</i>	<i>B'</i>	<i>C'</i>	<i>Temperature Range, K</i>
Do decyl - P,P -dibutyl phosphono undecanoate	$C_{31}H_{63}O_5P$	-1.0782	-396.22	149.88	280 to 380
2 - Ethyl - 1 - butyl - 9 (10) -mono acetoxy stearate	$C_{26}H_{50}O_4$	-1.1931	-368.25	152.32	245 to 380
2 - Ethyl - 1 - butyl - 1,2 -mono acetoxy stearate	$C_{26}H_{50}O_4$	-1.1659	-380.22	153.98	245 to 380
2-Ethyl butyl ortho silicate	$C_{24}H_{52}O_4Si$	-0.83425	-244.28	141.00	240 to 380
Ethyl - P,P - dihexyl phosphono laurate	$C_{26}H_{53}O_5P$	-1.2763	-399.47	147.54	225 to 380
Ethylene glycol di (1,2 - mono acetoxy) stearate	$C_{42}H_{78}O_8$	-0.5599	-292.27	193.65	280 to 380
2 - Ethyl hexyl -P,P - dibutyl phosphono undecanoate	$C_{27}H_{55}O_5P$	-1.0988	-391.11	147.31	230 to 380
2 - Ethyl -P,P - diethyl - 9 (10) phosphono stearate	$C_{30}H_{61}O_5P$	-1.2897	-448.08	145.80	240 to 380
2 -Ethyl hexyl -P,P- diethyl phosphono undecanoate	$C_{23}H_{47}O_5P$	-0.9721	-336.22	158.21	240 to 380
2 - Ethyl - 1 -hexyl - 9 (10) - mono acetoxy stearate	$C_{28}H_{54}O_4$	-1.1982	-388.79	153.77	245 to 380
2 - Ethyl hexyl ortho silicate	$C_{32}H_{68}O_4Si$	-0.81487	-261.07	152.07	240 to 380
1 - Ethyl pentyl ortho silicate	$C_{28}H_{60}O_4Si$	-0.88879	-267.56	159.42	240 to 380
Ethyl phthalyl ethyl glycolate	$C_{14}H_{16}O_6$	-0.93113	-241.84	208.50	290 to 380
1 - Ethyl propyl ortho silicate	$C_{20}H_{44}O_4Si$	-0.81339	-220.03	152.92	240 to 380
1,6 - Hexa methylene glycol - di - (2 -ethyl - hexanoate)	$C_{22}H_{42}O_4$	-0.94329	-267.75	168.34	270 to 380
1,6 - Hexano diol bis (φ - butyrate)	$C_{14}H_{26}O_4$	-1.2488	-302.57	145.49	230 to 380
1,6 - Hexane diol bis (φ -heptanoate)	$C_{20}H_{38}O_4$	-1.3115	-385.81	158.74	220 to 370
1,6 - Hexanediol bsi (φ - octanoate)	$C_{22}H_{42}O_4$	-1.3725	-369.56	160.40	270 to 380
1,6- Hexane diol di octanoate	$C_{22}H_{42}O_4$	-0.84339	-270.04	157.70	290 to 380
Isooctyl - 9 (10) -mono acetoxy stearate	$C_{28}H_{54}O_4$	-1.1713	-387.26	153.61	245 to 380

<i>Name</i>	<i>Formula</i>	<i>A'</i>	<i>B'</i>	<i>C'</i>	<i>Temperature Range, K</i>
Methoxy ethyl - 1,2 - mono acetoxystearate	C ₂₃ H ₄₈ O ₅	- 0.8759	- 287.63	171.85	260 to 380
3 - Methyl butyl ortho silicate	C ₂₀ H ₄₄ O ₄ Si	- 0.9658	- 251.34	132.50	240 to 380
Methyl butyrox - 9 (10) - mono acycloxy stearate	C ₂₅ H ₄₆ O ₆	- 1.0907	- 327.98	157.74	245 to 380
1 - Methyl hexyl ortho silicate	C ₂₈ H ₆₀ O ₄ Si	- 0.84824	- 244.45	155.20	240 to 380
2 - Methyl pentyl ortho silicate	C ₂₄ H ₅₂ O ₄ Si	- 0.83643	- 243.01	150.96	240 to 380
Methyl phthalyl ethyl glycolate	C ₁₃ H ₁₄ O ₆	- 1.0000	- 249.06	214.89	270 to 380
1 - Methyl propyl ortho silicate	C ₁₆ H ₃₆ O ₄ Si	- 0.70813	- 168.62	147.37	240 to 380
2 - Methyl propyl ortho silicate	C ₁₆ H ₃₆ O ₄ Si	- 0.80601	- 198.05	138.35	240 to 380
φ' - Nonyl - 2 - ethyl hexanoate	C ₁₇ H ₃₄ O ₂	- 1.3723	- 319.28	163.32	240 to 450
Octadecyl - φ - butyrate	C ₂₂ H ₄₄ O ₂	- 1.2581	- 390.69	123.53	290 to 470
Phenoxyethyl - 1,2 - mono acetoxystearate	C ₂₈ H ₄₆ O ₅	- 0.8673	- 295.55	190.29	260 to 380
Phenyl - 1,2 - acetoxystearate	C ₂₆ H ₄₂ O ₄	- 1.0200	- 329.23	175.74	280 to 380
Phenyl - 1,2 - benzoxystearate	C ₃₁ H ₄₄ O ₄	- 1.0715	- 540.53	158.83	280 to 380
Phenyl -P,P - dibutyl phosphono undecanoate	C ₂₅ H ₄₃ O ₃ P	- 1.0183	- 350.98	166.00	260 to 380
1,2 - Propylene glycol di (1,2 - mono acetoxystearate)	C ₄₃ H ₈₀ O ₈	- 0.8786	- 385.92	174.02	260 to 380
1,3 - Propylene glycol di (1,2 - mono acetoxystearate)	C ₄₃ H ₈₀ O ₈	- 0.8329	- 380.58	174.28	280 to 380
Tri amyl tri carballylate	C ₂₁ H ₃₈ O ₆	- 0.83326	- 235.46	184.11	290 to 380
Tri butyl phosphono laurate	C ₂₉ H ₃₉ O ₃ P	- 1.4076	- 457.78	134.85	220 to 380
Tributyl -9 (10) - phosphono stearate	C ₃₀ H ₆₁ O ₃ P	- 1.3604	- 497.64	131.87	240 to 380
Tributyl -1,1 - phosphono undecanoate	C ₂₃ H ₄₇ O ₃ P	- 0.9123	- 304.38	160.71	250 to 380
Tri ethylene glycol di - (2 - ethyl - hexanoate)	C ₂₂ H ₃₂ O ₈	- 0.85248	- 238.59	178.64	270 to 380
Tri ethyl phosphono stearate	C ₂₄ H ₄₉ O ₃ P	- 0.8542	- 273.28	181.78	280 to 380

<i>Name</i>	<i>Formula</i>	<i>A'</i>	<i>B'</i>	<i>C'</i>	<i>Temperature Range, K</i>
Tri ethyl - 9 (10) - phosphono stearate	$C_{24}H_{49}O_5P$	- 1.2877	- 443.51	143.52	240 to 380
Tri hexyl phosphono caproate	$C_{29}H_{59}O_5P$	- 1.2703	- 356.36	138.54	210 to 380
Tri hexyl - 1,1 - phosphono undecanoate	$C_{29}H_{59}O_5P$	- 1.1533	- 424.06	139.62	240 to 380
3,3,5 - Tri methyl hexyl ortho silicate	$C_{36}H_{76}O_4Si$	- 0.83454	- 302.44	150.89	310 to 380
1,2,3 - Tri methylol propane tris (φ' - butyrate)	$C_{13}H_{26}O_6$	- 1.5501	- 410.89	159.64	250 to 460
Trimethyl - 9 (10) - phosphono stearate	$C_{21}H_{43}O_5P$	- 1.3641	- 449.37	150.71	240 to 380
Trimethyl - 1,1 - phosphono undecanoate	$C_{14}H_{29}O_5P$	- 0.8317	- 256.20	172.35	270 to 380
Tris (2 - ethyl hexyl) - 1,1 - phosphono undecanoate	$C_{35}H_{71}O_5P$	- 1.1816	- 428.58	150.76	240 to 380

Table 4.11. Constants of the Antoine type equation given by Eq. (4.18): $\log \eta = A + B/(C - T)$ for estimating pure liquid viscosity at different temperatures for 100 substances as obtained by Dutt and Prasad¹⁵ [Temperature in K and Viscosity in cP].

Substance	A	B	C	Temperature Range, K
Acetaldehyde	-2.4286	-803.54	-158.49	273 to 294
Acetic acid	-1.4999	-353.33	69.11	283 to 383
Acetone	-1.4195	-214.96	58.71	183 to 333
Acetophenone	-1.6579	-490.08	37.75	286 to 474
Allyl alcohol	-2.3605	-658.66	28.99	281 to 350
Amyl alcohol	-2.4787	-696.70	68.61	273 to 373
Aniline	-1.1835	-224.31	170.82	268 to 393
Benzene	-2.7173	-1071.18	-129.51	278 to 463
n-Butane	-2.2494	-599.66	-109.85	183 to 323
Butanoic acid	-1.9294	-618.81	0.98	273 to 373
1-Butene	-1.8752	-337.89	-27.80	163 to 233
n-Butyl alcohol	-2.9918	-1026.78	-4.25	273 to 393
Butyl amine	-5.9761	-5487.69	-658.54	273 to 348
Butyl benzene	-1.6246	-403.89	46.09	283 to 353
Carbon tetrachloride	-1.4708	-324.45	71.19	273 to 373
Chloro benzene	-1.5481	-390.95	24.03	273 to 393
Chloroform	-1.3917	-288.76	39.69	248 to 333
m - Cresol	-1.4585	-289.19	185.08	316 to 373
o - Cresol	-1.1810	-197.71	204.14	323 to 393
Cyclo hexane	-1.9690	-501.37	37.20	278 to 353
Cyclo pentane	-2.0803	-617.63	-65.69	253 to 323
Decane	-1.5703	-342.46	68.73	248 to 373
1,1 - Dichloro ethane	-1.7305	-420.45	-2.98	280 to 327
Dichloro methane	-1.4815	-302.66	22.64	248 to 310
Diethyl amine	-2.3523	-648.13	-51.35	283 to 323
Diethyl carbonate	-0.9512	-114.23	159.97	293 to 393
Diethyl ketone	-2.0805	-638.76	-71.73	273 to 373
Diethyl sulfide	-2.0753	-640.74	-78.66	273 to 348
Dimethyl carbonate	-0.9700	-70.28	202.34	293 to 353
n,n-Dimethyl formamide	-0.6419	-56.54	193.62	273 to 323
2,2 - Dimethyl propane	-0.9128	-30.15	202.98	258 to 283
Di methyl sulfide	-0.7751	-18.09	217.66	273 to 309
1,4 - Dioxane	-1.4827	-302.77	103.40	288 to 348

<i>Substance</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>Temperature Range, K</i>
Di phenyl ether	-1.0746	-238.51	153.06	313 to 373
Di phenyl methane	-1.8959	-697.63	-1.09	333 to 434
Di propyl amine	-2.0439	-519.82	2.21	273 to 373
Dodecane	-1.5552	-374.71	77.07	273 to 373
Ethane	-1.5478	-135.98	9.67	98 to 188
Ethane thiol	-1.6159	-307.59	11.69	270 to 298
Ethyl acetate	-3.5169	-2089.32	-364.82	273 to 463
Ethyl alcohol	-2.8857	-1032.53	-55.95	248 to 348
Ethyl benzene	-1.7041	-425.99	15.31	253 to 413
Ethyl bromide	-3.2277	-1873.31	-370.72	248 to 433
Ethylene	-2.1350	-273.67	-35.34	103 to 173
Ethylene bromide	-1.3151	-339.42	74.11	293 to 393
Ethylene chloride	-1.8197	-507.87	1.36	273 to 353
Ethyl ether	-4.4735	-3623.26	-648.55	273 to 373
Ethyl formate	-1.5812	-299.33	40.27	273 to 328
Ethyl propionate	-2.0186	-572.05	-34.88	273 to 373
Formic acid	-1.4150	-297.43	114.74	281 to 373
Furan	-1.7446	-388.37	-0.20	248 to 303
Hepta decane	-1.7847	-577.32	51.72	303 to 553
Heptane	-1.5365	-277.33	51.64	183 to 373
Hexa decane	-1.7148	-522.41	60.10	298 to 393
Hexane	-1.8040	-401.73	-16.29	213 to 343
1 - Hexene	-1.8076	-356.34	2.70	248 to 323
1 - Hexyne	-3.0941	-1404.92	-233.99	293 to 333
Isoamyl alcohol	-5.3532	-2741.77	-161.66	283 to 373
Iso butane	-2.2673	-566.04	-81.14	193 to 273
Iso butyl acetate	-2.8354	-1224.43	-161.32	293 to 373
Iso butyric acid	-1.8943	-594.97	-2.06	273 to 373
Iso propyl alcohol	-3.9124	-1399.28	-32.76	273 to 348
Iso propyl amine	-1.3472	-145.21	128.21	273 to 303
Methane	-1.5276	-44.35	37.69	88 to 113
Methyl acetate	-2.5116	-957.10	-164.01	273 to 327
Methyl alcohol	-2.2968	-675.41	-33.89	248 to 333
Methyl amine	-1.5510	-175.06	82.16	203 to 273
Methyl-n-amyl ketone	-1.0477	-61.19	229.68	293 to 353

<i>Substance</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>Temperature Range, K</i>
2 - Methyl butane	-1.8644	-351.70	3.82	223 to 303
2 - Methyl - 2 - butene	-1.8117	-342.53	-8.18	273 to 305
Methyl butanoate	-1.8739	-478.95	-0.03	273 to 373
Methyl cyclo pentane	-2.3800	-841.97	-110.74	248 to 323
Methyl formate	-1.4142	-217.54	65.39	274 to 302
Methyl iso butyrate	-2.0903	-624.72	-52.90	273 to 362
Methyl propionate	-2.0125	-565.15	-45.06	273 to 348
Methyl - n - propyl ketone	-1.8022	-440.84	-0.98	273 to 373
Nitro methane	-1.5306	-344.15	39.22	248 to 348
Nonane	-1.7903	-443.29	23.17	273 to 373
Octane	-2.1458	-664.14	-60.61	273 to 373
Octa decane	-1.3859	-375.22	112.28	303 to 373
Penta decane	-1.4073	-348.84	105.48	293 to 373
Pentane	-1.4835	-221.13	33.68	153 to 303
1 - Pentene	-1.8872	-389.41	-33.04	218 to 298
Phenol	-1.3164	-253.66	186.00	313 to 363
Propane	-1.3602	-147.59	23.80	93 to 203
Propionic acid	-1.8168	-558.84	-7.46	273 to 373
N - Propyl acetate	-1.8903	-480.50	2.42	273 to 373
N - Propyl alcohol	-2.7300	-854.52	14.96	248 to 348
Propyl formate	-1.8820	-482.16	-9.34	273 to 348
Pyridine	-0.9224	-108.01	171.49	273 to 373
Pyrrole	-1.1810	-206.12	135.32	273 to 348
Quinoline	-1.6854	-440.24	98.75	288 to 373
Tetra decane	-1.4424	-350.81	100.18	283 o 373
Tetra hydro furan	-5.9778	-6696.37	-886.12	248 to 323
Toluene	-1.7712	-433.71	12.03	253 to 383
Tri chloro fluoro methane	-0.9340	-92.22	133.28	248 to 343
Tri decane	-1.6833	-453.35	61.85	273 to 373
Tri ethyl amine	-2.5237	-963.82	-168.26	273 to 348
m - Xylene	-1.7884	-473.42	-6.46	273 to 413
o - Xylene	-1.7350	-445.93	22.25	273 to 413

4.3.1.2c Goletz and Tassios Generalization

Goletz and Tassios²¹ applied the temperature dependence (Eq. 4.17) proposed by Vogel²⁰ over the full range, from the normal boiling temperature to the freezing point, extensively and also developed a generalized form. Based on the available literature on the application of the Antoine equation for vapor pressure, its generalization and their own analysis, Goletz and Tassios proposed the calculation of C from,

$$C = 239 - 0.19T_B \quad (4.20)$$

where T_B is the normal boiling point in K. They fitted the available experimental liquid viscosity- temperature data to the form:

$$\log \eta = A + B/(C + t) \quad (4.21)$$

where t represents the temperature in °C. Incorporation of the value of C from Eq. (4.20) into Eq. (4.21) gives the following equation with two constants (A and B) and the normal boiling point (T_B).

$$\log \eta = A + B/(239 - 0.19T_B + t) \quad (4.22)$$

The method is shown to be good for the correlation of the viscosity-temperature data of liquid hydrocarbons and polar compounds (with weak or no hydrogen bonding) to within 5% of their reported values.

4.3.1.2d Dutt's Development

Dutt²² used ideas similar to those of Goletz and Tassios and proposed that the kinematic viscosity (η/ρ) of petroleum crude oil fractions can be estimated from the equation

$$\ln(\eta/\rho) = -3.0171 + [(442.78 + 1.6452t_B)/(t + (239 - 0.19t_B))] \quad (4.23)$$

In this equation, η is the dynamic viscosity in cP, ρ is the density in g/mL and t_B is the normal boiling temperature in °C. The method has been shown to predict the kinematic viscosity of 15 crude oils and their fractions at 250 data points with an average absolute deviation of 6% and shown to perform better than the other prediction methods available at that time.

When applied to pure liquids, the equation generally fared better than other methods, probably due to the fact that it has been developed from the average properties of mixtures (crude oil fractions) like density (ρ) and

normal boiling point (t_B) rather than any particular set of substances. However a careful examination of the results showed that experimental viscosity data for alcohols deviated in a systematic manner from the values predicted from Dutt's equation. To improve the performance, it is recommended that the values of the normal boiling point t_B in Dutt's equation be replaced by the dipole moment (μ in debyes) dependent expressions: $t_B' = t_B (1 + 0.6\mu)$ for aliphatic alcohols, and $t_B'' = t_B(1 + 0.3\mu)$ for other polar compounds.

Saturated liquid density (ρ) at the required temperature (T) can be calculated from the knowledge of liquid density at the reference temperature (T^{Ref}) from the following equations:

$$\rho = \frac{M}{V_S} \quad (4.24)$$

$$\text{where, } V_S = V_S^{Ref} (0.29056 - 0.0877\omega)^\varphi \quad (4.25)$$

$$\text{and } \varphi = \left(1 - \frac{T}{T_C}\right)^{\frac{2}{\omega}} - \left(1 - \frac{T^{Ref}}{T_C}\right)^{\frac{2}{\omega}} \quad (4.26)$$

Equations (4.23) to (4.26) are proposed for the calculation of the kinematic viscosity employing Eq. 4.23.

Application of this method requires the values of the normal boiling temperature (t_B), the critical temperature (T_C), the acentric factor (ω), the value of specific volume (V_S^{Ref}) or density (ρ_{Ref}) at the reference temperature, and the dipole moment (μ) in the case of alcohols. Application of the method for a set of 100 representative substances is shown in Section 4.4.

4.3.1.2e Girifalco Form

Girifalco²³ suggested the form

$$\ln \eta = A + (B/T) + (C/T^2) \quad (4.27)$$

where C is close to zero except for polar or associated liquids. Girifalco mentions that the model represents the data of different classes of liquids - non-polar, polar as well as associated liquids - to good accuracy and presents the values of the constants A , B and C for some polar and associated liquids, as noted in Table 4.12.

Table 4.12. Constants of the Girifalco²³ form given by Eq. (4.27): $\ln \eta = A + (B/T) + (C/T^2)$ for calculating liquid viscosities [Temperature in K and Viscosity in cP].

<i>Liquid</i>	<i>A</i>	<i>B x 10⁻²</i>	<i>C x 10⁻⁴</i>
Acetic acid	-3.521	15.965	-15.759
Aniline	0.7008	-13.287	38.52
Butyric acid	-1.323	2.205	6.589
n-Butyl alcohol	-2.878	9.615	0.5588
Ethyl acetate	-1.059	0.09764	5.871
Ethyl alcohol	-2.459	7.807	-1.145
Ethylene glycol	-0.4312	-5.860	32.036
Formic acid	-0.9759	-0.7629	12.819
Glycerine	10.873	-72.23	145.78
n-Propyl alcohol	9.259	3.353	-1.875
Methyl alcohol	-1.567	2.750	3.428
Sulfuric acid	-0.09771	-4.690	26.37
Water	-0.3908	-6.8992	23.611

4.3.1.2f Thorpe and Rodger Equation

Thorpe and Rodger^{24, 24a} proposed the following functional form for the variation of liquid viscosity (η in cP) with temperature (t in °C)

$$\eta = C / (1 + \alpha t + \beta t^2) \quad (4.28)$$

where C , α and β are the constants characteristic of each liquid. Table 4.13 gives a list of the constants C , α and β for several liquids.

Table 4.13. Constants of Eq. (4.28): $\eta = C / (1 + \alpha t + \beta t^2)$ proposed by Thorpe and Rodger²⁴ for calculating viscosity of liquids. [Viscosity in cP, and Temperature, t , in °C].

<i>Substance</i>	<i>α</i>	<i>$\beta \times 10^4$</i>	<i>C</i>
Acetaldehyde	0.00963	0.2953	0.002671
Acetic acid	0.01826	0.8537	0.016867
Acetic anhydride	0.01735	0.6122	0.012416
Acetone	0.01064	0.3115	0.003949
Allyl bromide	0.01177	0.2871	0.006190
Allyl chloride	0.01111	0.2629	0.004059
Allyl iodide	0.01316	0.3361	0.009296
Benzaldehyde	0.01801	0.6181	0.009296
Butyric acid	0.02109	1.1073	0.022747
iso - Butyric acid	0.01917	0.9215	0.018872
Carbon disulfide	0.00820	0.1302	0.004294
Carbon tetra chloride	0.01801	0.6747	0.013466
Chloroform	0.01149	0.2588	0.007006

<i>Substance</i>	α	$\beta \times 10^4$	C
Diallyl	0.01118	0.3107	0.003388
Ethyl benzene	0.01448	0.4530	0.008745
Ethyl bromide	0.01064	0.1822	0.004776
Ethylene bromide	0.02007	0.7018	0.024579
Ethylene chlorode	0.01653	0.5451	0.011269
Ethyl iodide	0.01113	0.2658	0.007190
Formic acid	0.02870	1.6950	0.029280
<i>N</i> - Heptane	0.01214	0.4004	0.005180
<i>iso</i> - Heptane	0.01199	0.3863	0.004767
<i>n</i> - Hexane	0.01122	0.3337	0.003965
<i>iso</i> - Hexane	0.01110	0.3599	0.003713
Isoprene	0.01002	0.1542	0.002600
Methyl ethyl ketone	0.01284	0.3639	0.005383
Methyl iodide	0.01067	0.1719	0.005940
Methyl propyl ketone	0.01325	0.3965	0.006464
<i>n</i> - Octane	0.01394	0.4296	0.007025
<i>n</i> - Pentane	0.01044	0.2301	0.002827
Propionic acid	0.01720	0.6941	0.015199
Propionic anhydride	0.02005	0.8315	0.016071
Thiophene	0.01518	0.4358	0.008708
Toluene	0.01462	0.4220	0.007684
<i>m</i> - Xylene	0.01418	0.3923	0.008019
<i>o</i> - Xylene	0.01701	0.5636	0.008457
<i>p</i> - Xylene	0.01472	0.4758	0.008457

4.3.1.2g Islam and Ibrahim Method

Islam and Ibrahim²⁵ examined the status of the applicability of the two-parameter as well as three-parameter equations with reference to the flow behavior of a set of representative liquids chosen by them from experimental studies. They attempted to answer the basic question whether a simple equation based on the molecular chaos implicit in the van der Waals' equation is adequate or whether it is necessary to imagine the presence of 'solid like' structures. Fig. 4.3 (given by Islam and Ibrahim) reveals that for glycerol, phenol and aniline, the plots of $\ln \eta$ versus $(1/T)$ show deviations from the Arrhenius behaviour in the low temperature region, which could be attributed to the presence of association in these liquids.

The plots of Fig. 4.4, showing $\log \phi$ as a function of the reciprocal of free volume $\{1/(V-V_0)\}$ where V_0 is the molar volume extrapolated to zero degrees absolute without change of phase, are linear for only those liquids which follow Arrhenius equation. Plots for liquids like glycerol, phenol, aniline, m-toluidine, o-toluidine and quinoline (not shown in the figure) deviate from the linear behavior, indicating superiority of the Dolittle equation over identical temperature intervals.

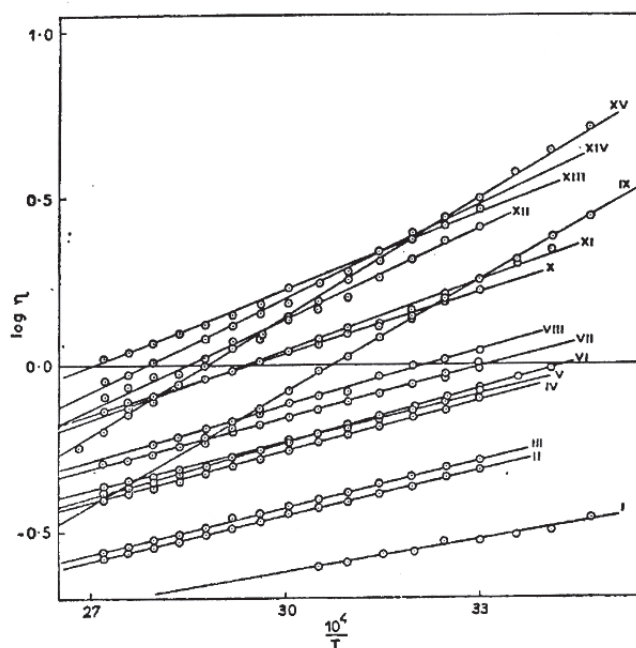


Figure 4.3. Plots of $\log \eta$ as a function of $(1/T)$ for (I) acetone, (II) n-octane, (III) toluene, (IV) acetic anhydride, (V) pyridine, (VI) carbon tetrachloride, (VII) bromobenzene, (VIII) dioxane, (IX) isopropyl alcohol, (X) nitrobenzene, (XI) n-valeric acid, (XII) m-toluidine, (XIII) quinoline, (XIV) o-toluidine, and (XV) amyl alcohol (Adopted from N. Islam and M. Ibrahim, Status models for flow behaviour of organic liquids, *Indian J. Chem.* **20A**, 963-968, 1981).

For the above substances, the applicability of the Vogel-Tammann-Fulcher (VTF) equation given by;

$$\phi = A \exp\left[-k'/(T - T_0)\right] \quad (4.29)$$

in which A and k' stand for the pre-exponential and exponential parameters respectively, has been examined. Plots of $\ln \phi$ versus $[1/(T - T_0)]$ for liquids

showing non-Arrhenius behaviour are given in Fig. 4.5. The significant parameter T_0 known as the zero mobility temperature is obtained by least-squares fit. The constants A , k' and T_0 for some characteristic liquids are noted in Table 4.14.

Table 4.14. Values of the constants A , k' and T_0 for use in Vogel-Tammann-Fulcher Equation, given by Eq. (4.29): $\phi = A \exp[-k'/(T - T_0)]$.

Liquid	A	k'	T_0
Aniline	13902.0	1412.2	70.6
Glycol	38758.0	1860.8	85.9
Phenol	54729.0	1874.3	74.1
Quinoline	4923.9	1163.0	68.6
o - Toluidine	14010.0	1433.3	67.4
m - Toluidine	15096.0	1386.3	72.2

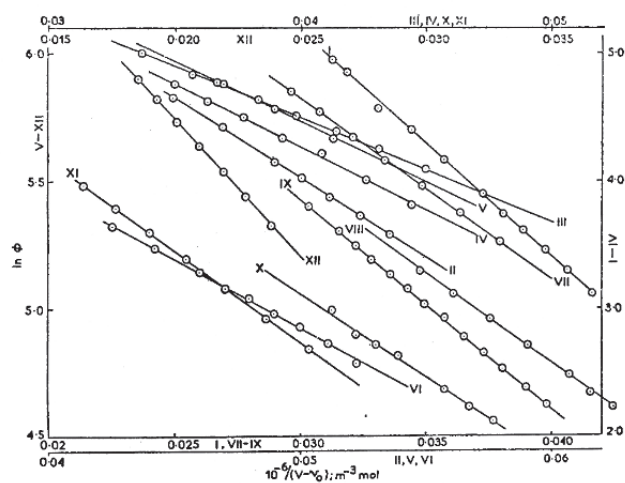


Figure 4.4. Plots of $\ln \phi$ as a function of $[1/(V - V_0)]$ for : (I) amyl alcohol, (II) isopropyl alcohol, (III) nitrobenzene, (IV) n-valeric acid, (V) acetone, (VI) pyridine, (VII) toluene, (VIII) bromobenzene, (IX) carbon tetrachloride, (X) dioxane, (XI) acetic anhydride, and (XII) n-octane (Adopted from N. Islam and M. Ibrahim, Status models for flow behaviour of organic liquids, *Indian J. Chem.* **20A**, 963-968, 1981).

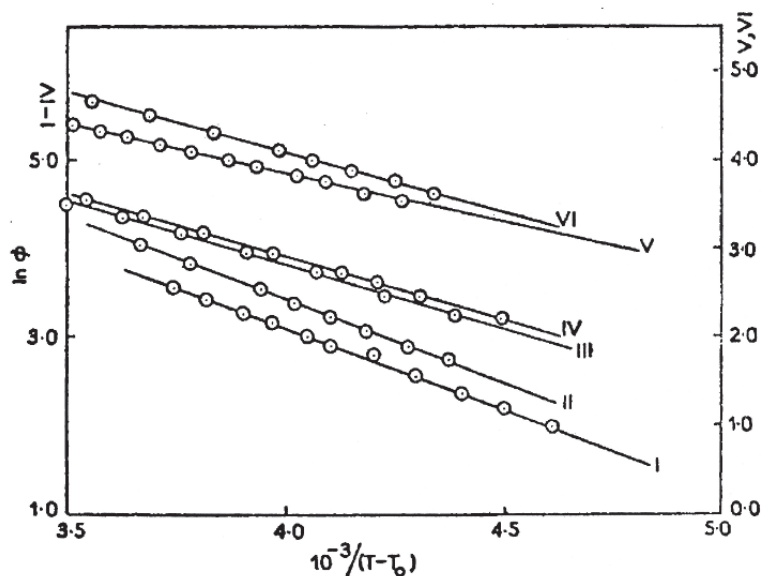


Figure 4.5. Plots of $\ln \phi$ as a function of $[1/(T-T_0)]$ for: (I) glycol, (II) phenol, (III) o-toluidine, (IV) aniline, (V) quinoline and (VI) m-toluidine (Adopted from N. Islam and M. Ibrahim, Status models for flow behaviour of organic liquids, *Indian J. Chem.* **20A**, 963-968, 1981).

Fluidity has also been expressed in the form of modified Dolittle equation

$$\phi = A' \exp[-B_0/(V - V_0)] \quad (4.30)$$

where V_0 is the molar volume at T_0 . The values of the constants of the modified Dolittle equation for some liquids selected for this study are given in Table 4.15.

Table 4.15. Values of the constants A' , B_0 and V_0 to be used in the modified Dolittle Equation, Eq. (4.30): $\phi = A' \exp[-B_0/(V - V_0)]$.

Liquid	A'	B_0	V_0
Aniline	4830.0	74.22	77.13
Glycerol	410.18	13.07	52.83
Phenol	572.19	21.02	82.59
Quinoline	2715.8	78.20	101.16
o - Toluidine	5018.3	91.23	90.19
m - Toluidine	5101.4	90.63	90.70

The fluidity data of several liquids, plotted as a function of molar volume in Fig. 4.6, resulted in straight lines over the investigated experimental conditions, except for glycerol, phenol, aniline, amyl alcohol and isopropyl alcohol. The Hildebrand volumes (V_B) are obtained from the plots by extrapolation to zero fluidity and the values of B are obtained from the slopes. While V_B is characteristic of liquid which states that the liquid will cease to flow when it acquires the molar volume equal to V_B , the values of B depend on the nature of the molecule. The molecules with less mass and free rotation will have higher values of B . While the B values for toluene, nitrobenzene and bromobenzene vary according to the order of molecular weight, the larger B value for n-octane compared to that for acetone is anomalous. Table 4.16 lists the values of V_B and B for some chosen liquids.

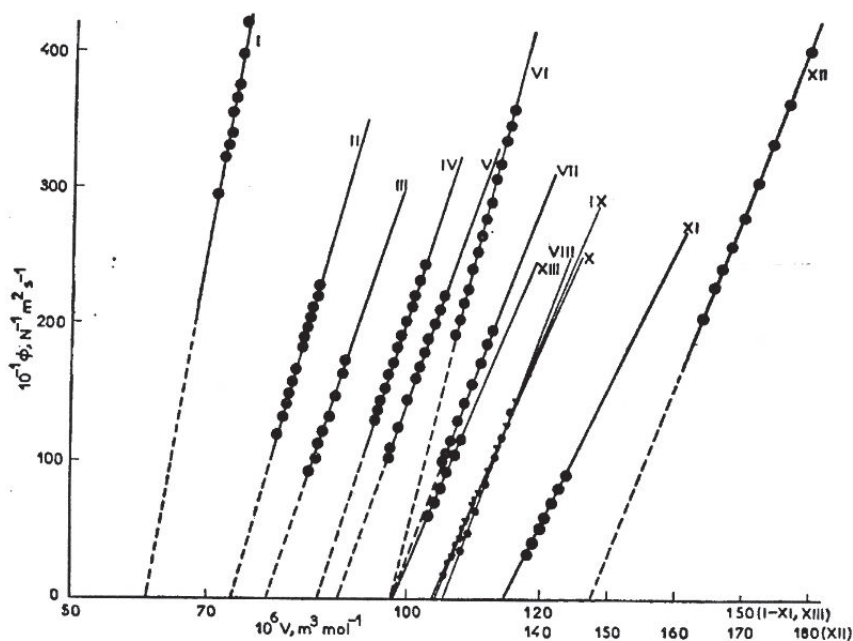


Figure 4.6. Plots of fluidity ϕ as a function of molar volume (V) for : (I) acetone, (II) pyridine, (III) dioxane, (IV) acetic anhydride, (V) carbon tetrachloride, (VI) toluene, (VII) bromobenzene, (VIII) m-toluidine, (IX) o-toluidine, (X) n-valeric acid, (XI) quinoline, (XII) n-octane and (XIII) nitrobenzene (Adopted from N. Islam and M. Ibrahim, Status models for flow behaviour of organic liquids, *Indian J. Chem.* **20A**, 963-968, 1981).

Table 4.16. Values of V_B and B for some typical liquids.

<i>Liquid</i>	$10^6 V_B (\text{m}^3 \text{mol}^{-1})$	$10^{-1} B (\text{N}^{-1} \text{m}^2 \text{s}^{-1})$
Acetic anhydride	87.75	1426.2
Acetone	61.85	1793.9
Bromo benzene	98.34	1321.9
Carbon tetra chloride	91.13	1373.7
Dioxane	80.13	1337.2
Nitro benzene	98.17	1141.8
n - Octane	148.78	1931.4
Pyridine	74.59	1375.0
Quinoline	115.80	1187.2
Toluene	98.36	2036.6
m - Toluidine	106.75	1425.2
o - Toluidine	105.65	1351.8
n - Valeric acid	105.25	1257.1

For comparison purposes, the Hildebrand equation and Arrhenius equations are written as

$$\phi = (1/\eta) = A'' \exp(-k'/T) = B[(V - V_B)/V_B] \quad (4.31)$$

and examined for the validity for some non-associated and non-polar liquids, well above their melting point.

Taking the logarithm and differentiating with respect to temperature, one can write

$$k'(V - V_B) = T^2(dV/dT) \quad (4.32)$$

indicating that the plot of $T^2(dV/dT)$ versus molar volume should be linear and the slope should give the value of k' ($= E\phi/R$) and the intercept the value of $-k'V_B$. Implicitly, for liquids which follow the Hildebrand and Arrhenius equations, it should be possible to find not only the value of activation energy of flow but also the value of the Hildebrand volume V_B without measuring the fluidity data, from the density measurements alone. This has not been possible for even simple liquids.

On further differentiation with respect to temperature, one obtains

$$k' = T^2(d^2V/dT^2)/(dV/dT) + 2T \quad (4.33)$$

For the liquids which follow the Arrhenius equation as well as the Hildebrand model, the value of $[2T + T^2(d^2V/dT^2)/(dV/dT)]$ should remain constant. In reality it has been found to increase with temperature even over small ranges of temperature.

Based on the analysis presented, Islam and Ibrahim suggested a modified Hildebrand equation for the flow behavior in the form:

$$\phi = B' \left[\left(\frac{V}{V'_B} \right)^n - 1 \right] \quad (4.34)$$

where n has been found to be a measure of the intermolecular interactions leading to self-association.

On equating Arrhenius equation and the modified form of Hildebrand equation, one can write

$$\phi = A \exp(-k'/T) = B' \left[(V - V'_B)^n - 1 \right] \quad (4.35)$$

In the logarithmic form

$$\ln A - (k'/T) = \ln(B'/V'_B)^n + \ln(V^n - V'^n_B) \quad (4.36)$$

$$\text{or, } T = \frac{k'}{c - \ln(V^n - V'^n_B)} \quad (4.37)$$

$$\text{where, } c = \ln \left(\frac{AV'^n_B}{B'} \right) \quad (4.38)$$

The three parameters: c , n and V'_B are computed from the least-squares fit of the absolute temperature (T) to the molar volume (V) according to the equation noted above. Table 4.17 lists the parameters for some typical substances.

Table 4.17. Parameters C , n and V_B' for the application of the Islam and Ibrahim²⁵ approach using Eq. (4.36).

<i>Liquid</i>	<i>C</i>	<i>n</i>	$10^6 V_B' (m^3/mol)$
Type(i) Liquids			
Acetic anhydride	14.662	2.70	86.43
Acetone	6.449	1.25	62.64
Bromo benzene	17.000	3.175	97.29
Carbon tetra chloride	20.247	3.75	89.27
Dioxane	20.495	3.94	79.04
Toluene	12.065	2.17	97.41
Type(ii) Liquids			
Aniline	72.070	14.50	87.89
Niro benzene	30.655	5.85	96.24
Pyridine	12.779	2.45	74.00
Quinoline	60.421	11.62	113.55
m – Toluidine	67.951	13.17	104.12
o – Toluidine	69.709	13.55	103.29
Type(iii) Liquids			
Amyl alcohol	87.716	16.90	104.81
Ethylene glycol	88.634	19.80	55.16
Iso propyl alcohol	73.858	15.12	72.85
Phenol	80.140	17.74	86.22
n - Valeric acid	47.680	9.16	102.94

The only liquid of this study which has n some what near one is acetone ($n = 1.25$) and the one which has $n < 2$ is n-octane ($n = 1.67$) while ethylene glycol has a value as high as 19.8. It is interesting to note that the values of B' decrease as n increases implying that n is associated with a factor that causes restrictions to free rotation in the molecule, which may be due to molecular association or mass of the molecules or any type of molecular interaction. The parameter n can thus be considered as a measure of combined intermolecular forces in the liquid state, which is found to increase with k' indicating that it is a function of activation energy for flow which depends on the molecular environment as well as molecular interactions. Consequently, n may be taken as some function of molecular interactions which depend on the structure of the liquid.

To elaborate the significance of n and B' , the liquids investigated may be categorized into there types: (i) Simple, either non-associated or insignificantly associated like acetone, n-octane, toluene, acetic anhydride, carbon tetrachloride, bromo-benzene and dioxane; (ii) nitrogen containing liquids like pyridine, nitrobenzene, quinoline, m-toludine, o-toludine and aniline, and (iii) hydroxyl containing liquids like n-valeric acid, isopropyl alcohol, amyl alcohol, phenol and glycerol.

In the non-associated liquids [type(i)], the main factor that causes the restriction in the movement and rotation of its molecules is the molecular

weight of the liquid provided that the structure of the molecules is not such that it can cause hindrance to molecular rotation. Molecular interactions are the least in the non-associated liquids and consequently the values of B' should be large and the values of n should be small.

In the type (ii) liquids, which are all aromatic, nitrogen lone pair in amines seems to be responsible for strong molecular interaction and association due to hydrogen bond formation.

The liquids of type (iii) are alcohols, except for n-valeric acid. The association in acids is there but long chains are not expected, unlike alcohols wherein long chain three dimensional network is obtained. The attraction between the cations and anions in acids prevents the rotation and mobility of the ions and non-dissociated molecules. Thus in the case of n-valeric acid the n value should be higher than, but not as high as those for alcohols.

The proposed modified Hildebrand equation is found to be applicable to all sorts of aromatic liquids – non-associated, partially associated or highly associated or whether they are aliphatic or aromatic or whether they have simple or complicated structure and the parameters V'_B , B' and n assume significance in understanding the behaviour of liquids. The parameter B' is more informative than the corresponding parameter of the original Hildebrand equation and the parameter n is a measure of the relative intermolecular interactions and explains the activation energy and the combined strength of the intermolecular forces.

4.3.1.3 Multi-Constant Equations

Some equations with more than three constants have been proposed to improve upon the accuracy of representation, particularly over wider ranges of temperature. We present in this section, some of the multi-constant equations which have been applied to rather larger number of compounds.

4.3.1.3a Polynomial Representation

Liquid viscosity available in the literature over wider ranges of temperature have been represented in the polynomial form

$$\ln \eta = A + (B/T) + CT + DT^2 \quad (4.39)$$

The constants of Eq. (4.39) for several common substances given by Reid *et al.*¹⁹ are noted in Table 4.18.

4.3.1.3b Yaws *et al.* Recommendation

Yaws *et al.*²⁶ recommended the use of an equation essentially similar to Eq. (4.39) using the logarithm to the base 10 instead of the natural logarithm and wrote

$$\log \eta = A' + (B'/T) + C'T + D'T^2 \quad (4.40)$$

For liquid viscosity between the melting and critical points, they provided coefficients for 355 liquids along with the range of applicability. Table 4.19 gives the coefficients of the liquid viscosity equation tabulated by Yaws *et al.*²⁶

Table 4.18. Constants of Eq. (4.39): $\ln \eta = A + \left(\frac{B}{T}\right) + CT + DT^2$, which is a polynomial representation of liquid viscosity [Viscosity (η) in cP and Temperature in K]. From: R. C. Reid, J. M. Prausnitz, and B. E. Poling, *Properties of Gases and Liquids*, McGraw-Hill, NY, (1987).

Formula	Name	A	B	C	D	Temperature range, °C	η , cP(at °C)
A	Argon	-28.51	1057.0	0.2429	-8.096 x 10 ⁻⁴	-189 to -124	0.25(-185)
Cl ₂	Chlorine	-1.768	348.6	-1.857 x 10 ⁻³	7.80 x 10 ⁻⁷	-101 to 144	0.34(25)
F ₂	Fluorine	-3.629	197.2	-9.378 x 10 ⁻⁴	-6.275 x 10 ⁻⁶	-219 to -185	0.73(-215)
HBr	Hydrogen bromide	-21.27	1996.0	7.902 x 10 ⁻²	-1.191 x 10 ⁻⁴	-88 to 90	0.20(25)
HCl	Hydrogen chloride	-3.488	481.0	7.062 x 10 ⁻³	-3.168 x 10 ⁻⁵	-100 to 50	0.068(25)
HF	Hydrogen fluoride	-14.04	1879.0	2.975 x 10 ⁻²	-3.060 x 10 ⁻⁵	-80 to 180	0.20(25)
HI	Hydrogen iodide	-21.58	2337.0	7.336 x 10 ⁻²	-9.717 x 10 ⁻⁵	-50 to 150	0.60(25)
H ₂	Hydrogen	-11.18	57.86	3.244 x 10 ⁻¹	-6.385 x 10 ⁻³	-258 to -140	0.016(-256)
H ₂ O	Water	-24.71	4209.0	4.527 x 10 ⁻²	-3.376 x 10 ⁻⁵	0 to 370	0.90(25)
H ₃ N	Ammonia	-19.78	2018.0	6.173 x 10 ⁻²	-8.317 x 10 ⁻⁵	-75 to 130	0.13(25)
H ₂ N ₂	Hydrazine	-18.848	2991.0	3.709 x 10 ⁻²	-3.062 x 10 ⁻⁵	2 to 370	0.90(25)
H ₂ O ₂	Hydrogen peroxide	-3.719	1160.0	8.06 x 10 ⁻⁴	-2.698 x 10 ⁻⁶	0 to 400	1.19(25)
I ₂	Iodine	-2.083	1195.0	-4.566 x 10 ⁻⁴	1.08 x 10 ⁻⁷	114 to 200	1.8(150)
NO	Nitric oxide	-11.50	548.7	8.448 x 10 ⁻²	-3.092 x 10 ⁻⁴	-160 to -90	0.35(-160)
NO ₂	Nitrogen dioxide	-19.41	2147.0	6.353 x 10 ⁻²	-8.644 x 10 ⁻⁵	-11 to 150	0.39(25)
N ₂	Nitrogen	-27.95	866.0	2.763 x 10 ⁻¹	-1.084 x 10 ⁻³	-205 to 195	0.18(-200)
N ₂ O	Nitrous oxide	1.090	50.20	-1.134 x 10 ⁻²	-9.841 x 10 ⁻⁶	-100 to 30	0.05(25)
Ne	Neon	-19.29	199.0	5.453 x 10 ⁻¹	-6.675 x 10 ⁻³	-248 to -229	0.137(-247)
O ₂	Oxygen	-4.771	214.6	1.389 x 10 ⁻²	-6.255 x 10 ⁻⁵	-218 to -120	0.47(-210)
O ₂ S	Sulfur dioxide	-6.148	936.5	1.414 x 10 ⁻²	-2.887 x 10 ⁻⁵	-70 to 155	0.26(25)
O ₃ S	Sulfur trioxide	28.94	-2277.0	-9.392 x 10 ⁻²	8.064 x 10 ⁻⁵	16 to 210	1.60(25)
CCl ₄	Carbon tetrachloride	-13.03	2290.0	233.9	-2.011 x 10 ⁻⁵	-20 to 283	0.86(25)
CO	Carbon monoxide	-5.402	242.2	1.062 x 10 ⁻²	-4.522 x 10 ⁻⁵	-200 to 140	0.21(-200)
CO ₂	Carbon dioxide	-3.097	48.86	2.381 x 10 ⁻²	-7.840 x 10 ⁻⁵	-56 to 30	0.06(25)
CHCl ₃	Chloroform	-4.172	915.3	2.70 x 10 ⁻³	-4.108 x 10 ⁻⁶	-63 to 263	0.52(25)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>Temperature range, °C</i>	<i>η, cP(at °C)</i>
CH ₄	Methane	-26.87	1150.0	1.871×10^{-1}	-5.211×10^{-4}	-180 to -84	0.14(-170)
CH ₄ O	Methanol	-39.35	4826.0	1.091×10^{-1}	-1.127×10^{-4}	-40 to 239	0.55(25)
C ₂ H ₄	Ethylene	-17.74	1078.0	8.577×10^{-2}	-1.758×10^{-4}	-169 to 9	0.031(0)
C ₂ H ₄ O	Ethylene oxide	-3.864	719.3	7.44×10^{-4}	-1.805×10^{-6}	-112 to 195	0.25(25)
C ₂ H ₆	Ethane	-1.023	668.0	4.386×10^{-2}	-9.588×10^{-5}	-183 to 32	0.032(25)
C ₂ H ₆ O	Ethanol	-6.210	1614.0	6.18×10^{-3}	-1.132×10^{-5}	-105 to 243	1.04(25)
C ₃ H ₆	Propylene	-11.53	951.4	4.078×10^{-2}	-7.120×10^{-5}	-160 to 91	0.081(25)
C ₃ H ₆	Cyclo propane	-3.074	267.6	2.55×10^{-4}	-8.83×10^{-8}	-127 to 124	0.12(25)
C ₃ H ₇ O	Propylene oxide	-2.717	700.0	-4.384×10^{-3}	5.363×10^{-6}	-112 to 209	0.30(25)
C ₃ H ₈	Propane	-7.764	721.9	2.381×10^{-2}	-4.665×10^{-5}	-187 to 96	0.091(25)
C ₃ H ₈ O	n-Propanol	-12.28	2666.0	2.008×10^{-2}	-2.233×10^{-5}	-72 to 260	1.94(25)
C ₄ H ₈	1-Butene	-10.63	981.6	3.525×10^{-2}	-5.593×10^{-5}	-140 to 146	0.17(25)
C ₄ H ₈	Iso butylene	-6.477	813.5	1.320×10^{-2}	-2.438×10^{-5}	-140 to 144	0.14(25)
C ₄ H ₈	Cyclo butane	-4.541	672.4	3.27×10^{-3}	-3.928	-90 to 190	0.19(25)
C ₄ H ₁₀ O	N – Butanol	-9.722	260.2	9.53×10^{-3}	-9.966×10^{-6}	-60 to 289	2.61(25)
C ₅ H ₈	Isoprene	-2.228	635.7	-7.32×10^{-3}	7.665×10^{-6}	-146 to 210	0.20(25)
C ₅ H ₁₀	Cyclo pentane	-6.021	1118.0	7.28×10^{-3}	-8.662×10^{-6}	-90 to 235	0.42(25)
C ₆ H ₅ Cl	Chloro benzene	-4.573	1196.0	1.37×10^{-3}	-1.378×10^{-6}	-45 to 350	0.76(25)
C ₆ H ₆	Benzene	4.612	148.9	-2.544×10^{-2}	2.222×10^{-5}	6 to 288	0.61(25)
C ₆ H ₆ O	Phenol	-1.851	4350.0	2.429×10^{-2}	-1.547×10^{-5}	41 to 420	3.25(50)
C ₆ H ₇ N	Aniline	3.569	-32370	-1.254	1.428×10^{-3}	-6 to 50	3.93(25)
C ₆ H ₁₂	Cyclo hexane	-4.398	1380.0	-1.55×10^{-3}	1.157×10^{-6}	7 to 280	0.88(25)
C ₇ H ₈	Toluene	-5.878	1287.0	4.575×10^{-3}	-4.449×10^{-6}	-40 to 315	0.55(25)
C ₈ H ₈	Styrene	-2.717	946.1	-3.173	1.683×10^{-6}	-30 to 360	0.71(25)
C ₈ H ₁₀	O – Xylene	-3.332	1039.0	1768.0	1.076×10^{-6}	-25 to 350	0.76(25)
C ₈ H ₁₀	M – Xylene	-3.820	1027.0	-6.38×10^{-4}	4.52×10^{-7}	-47 to 340	0.60(25)
C ₈ H ₁₀	P – Xylene	-7.790	1580.0	8.73×10^{-3}	-6.735×10^{-6}	13 to 340	0.61(25)
C ₈ H ₁₀	Ethyl benzene	-6.106	1353.0	5.112×10^{-3}	-4.552×10^{-6}	-40 to 340	0.64(25)
C ₉ H ₁₂	Iso propyl benzene	-8.292	1700.0	1.003×10^{-2}	-7.829×10^{-6}	-20 to 360	0.74(25)

Table 4.19. Values of the coefficients of Eq. (4.40): $\log \eta = A' + (B'/T) + C'T + D'T^2$ for the polynomial representation of viscosity [Viscosity (η) in cP and Temperature in K]. From: C. L. Yaws, X. Lin and L. Bu, Calculate viscosities for 355 liquids, *Chem. Eng.* **101**(4) 119-20, 122, 124, 126, 128, (1994).

Formula	Name	A'	B'	C'	D'	Temperature Range, K
C ₅ Cl ₆	Hexa chloro cyclotadiene	-10.4172	2.1941 x 10 ³	1.6514 x 10 ⁻²	-1.0745 x 10 ⁻⁵	298 to 746
C ₅ H ₄ O ₂	Furfural	-0.6087	2.8604 x 10 ²	4.5345 x 10 ⁻⁴	-3.0939 x 10 ⁻⁶	273 to 657
C ₅ H ₅ N	Pyridine	-6.8100	1.1496 x 10 ³	1.3229 x 10 ⁻²	-1.1661 x 10 ⁻⁵	232 to 620
C ₅ H ₆	Cyclo penta diene	-5.6949	6.5093 x 10 ²	1.5245 x 10 ⁻²	-1.7940 x 10 ⁻⁵	188 to 507
C ₅ H ₆	2 – Methyl – 1 – butene – 3 – yne	-2.9024	3.8325 x 10 ²	6.6626 x 10 ⁻³	-1.0295 x 10 ⁻⁵	160 to 492
C ₅ H ₆	1 – Pentene – 3 – yne	-3.6138	4.8914 x 10 ²	7.2390 x 10 ⁻³	-8.8128 x 10 ⁻⁶	150 to 520
C ₅ H ₆	1 – Pentene – 4 – yne	-3.0207	3.9788 x 10 ²	7.0631 x 10 ⁻³	-1.0509 x 10 ⁻⁵	150 to 503
C ₅ H ₆ N ₂	Glutano nitrile	-8.1374	1.8110 x 10 ³	1.1719 x 10 ⁻²	-7.6393 x 10 ⁻⁶	244 to 782
C ₅ H ₆ O ₂	Furfuryl alcohol	-12.3697	2.2704 x 10 ³	2.3717 x 10 ⁻²	-1.8564 x 10 ⁻⁵	259 to 632
C ₅ H ₆ O ₃	Glutaric anhydride	-8.9237	1.7641 x 10 ³	1.2843 x 10 ⁻²	-7.1214 x 10 ⁻⁶	328 to 838
C ₅ H ₆ O ₄	Citraconic acid	-26.2612	5.2278 x 10 ³	4.2998 x 10 ⁻²	-2.4625 x 10 ⁻⁵	356 to 829
C ₅ H ₆ O ₄	Itaconic acid	-10.8903	2.8916 x 10 ³	1.1869 x 10 ⁻²	-5.2006 x 10 ⁻⁶	439 to 821
C ₅ H ₇ N	n – Methyl pyrrole	-9.0619	2.8916 x 10 ³	-1.1876 x 10 ⁻³	-3.1716 x 10 ⁻⁶	217 to 610
C ₅ H ₇ NO ₂	Ethyl cyano acetate	-14.7933	3.6968 x 10 ²	2.7355 x 10 ⁻²	-1.9234 x 10 ⁻⁵	251 to 679
C ₅ H ₈	Cyclo pentene	-3.1576	2.5859 x 10 ³	6.8491 x 10 ⁻³	-9.1013 x 10 ⁻⁶	138 to 507
C ₅ H ₈	Isoprene	-9.9164	1.0172 x 10 ³	2.9353 x 10 ⁻²	-3.2692 x 10 ⁻⁵	273 to 484
C ₅ H ₈	3 – Methyl – 1,2 – butadiene	-5.0944	5.6342 x 10 ²	1.3413 x 10 ⁻²	1.6605 x 10 ⁻⁵	160 to 490
C ₅ H ₈	1,2 – Penta diene	-3.7920	4.2763 x 10 ²	9.2560 x 10 ⁻³	1.2181 x 10 ⁻⁵	136 to 500

<i>Formula</i>	<i>Name</i>	<i>A'</i>	<i>B'</i>	<i>C'</i>	<i>D'</i>	<i>Temperature Range, K</i>
C ₅ H ₈	Cis - 1,3 - Penta diene	-5.3378	5.8984 x 10 ²	1.3932 x 10 ⁻²	1.6748 x 10 ⁻⁵	186 to 499
C ₅ H ₈	Trans - 1,3 - Penta diene	-5.8162	6.5547 x 10 ²	1.4971 x 10 ⁻²	1.7425 x 10 ⁻⁵	222 to 500
C ₅ H ₈	1,4 - Penta diene	-2.6680	3.3442 x 10 ²	5.2181 x 10 ⁻³	-8.2626 x 10 ⁻⁶	125 to 479
C ₅ H ₈	2,3 - Penta diene	-4.7505	5.1167 x 10 ²	1.2667 x 10 ⁻²	1.5930 x 10 ⁻⁵	148 to 497
C ₅ H ₈	1 - Pentyne	-2.8855	3.9387 x 10 ²	7.4684 x 10 ⁻³	1.2463 x 10 ⁻⁵	167 to 481
C ₅ H ₈	3 - Methyl - 1 - butyne	-2.6844	3.6528 x 10 ²	7.3057 x 10 ⁻³	-1.3270 x 10 ⁻⁵	183 to 463
C ₅ H ₈ O	Cyclo pentanone	-53.1880	8.1650 x 10 ³	1.1041 x 10 ⁻¹	-7.9251 x 10 ⁻⁵	288 to 626
C ₅ H ₈ O	Methyl iso propenyl ketone	-7.3478	1.0035 x 10 ³	1.7021 x 10 ⁻²	-1.6781 x 10 ⁻⁵	220 to 566
C ₅ H ₈ O ₂	Acetyl acetone	-8.8988	1.3244 x 10 ³	2.0022 x 10 ⁻²	-1.8365 x 10 ⁻⁵	273 to 602
C ₅ H ₈ O ₂	Allyl acetate	-8.8594	1.2199 x 10 ³	2.1012 x 10 ⁻²	-2.0417 x 10 ⁻⁵	240 to 559
C ₅ H ₈ O ₂	Ethyl acrylate	-5.5960	8.1055 x 10 ²	1.2995 x 10 ⁻²	-1.4271 x 10 ⁻⁵	250 to 553
C ₅ H ₈ O ₂	Methyl methacrylate	-4.7825	7.3478 x 10 ²	1.0258 x 10 ⁻²	-1.1343 x 10 ⁻⁵	260 to 564
C ₅ H ₈ O ₂	Vinyl Propionate	-6.3902	9.2664 x 10 ²	1.4476 x 10 ⁻²	-1.5129 x 10 ⁻⁵	230 to 546
C ₅ H ₈ O ₃	2 - Hydroxy - ethyl acrylate	-20.5844	3.8501 x 10 ³	3.6430 x 10 ⁻²	-2.4036 x 10 ⁻⁵	260 to 662
C ₅ H ₈ O ₃	Levulinic acid	-21.8785	3.8805 x 10 ³	4.0538 x 10 ⁻²	-2.6906 x 10 ⁻⁵	308 to 723
C ₅ H ₈ O ₃	Methyl aceto acetate	-4.8619	9.5371 x 10 ²	8.8042 x 10 ⁻³	-8.6041 x 10 ⁻⁶	210 to 642
C ₅ H ₈ O ₄	Glutaric acid	-23.2118	4.5522 x 10 ³	2.3667 x 10 ⁻⁵	-2.3667 x 10 ⁻⁵	371 to 807
C ₅ H ₉ N	Valero nitrile	-4.9993	8.1288 x 10 ²	1.0342 x 10 ⁻²	-1.0939 x 10 ⁻⁵	275 to 603
C ₅ H ₉ NO	n - Methyl - 2 - pyrrolidone	-11.7394	2.0342 x 10 ⁴	2.1569 x 10 ⁻²	-1.5109 x 10 ⁻⁵	249 to 724
C ₅ H ₉ NO ₄	L - Glutamic acid	-60.7700	1.4128 x 10 ⁴	8.4987 x 10 ⁻²	-4.0318 x 10 ⁻⁵	497 to 886
C ₅ H ₁₀	Cyclo pentane	-0.5385	2.5255 x 10 ²	-2.3007 x 10 ⁻³	-2.3062 x 10 ⁻⁷	225 to 512
C ₅ H ₁₀	2 - Methyl - 1 - butene	-3.3641	4.2134 x 10 ²	7.7836 x 10 ⁻³	-1.1733 x 10 ⁻⁵	136 to 465

<i>Formula</i>	<i>Name</i>	<i>A'</i>	<i>B'</i>	<i>C'</i>	<i>D'</i>	<i>Temperature Range, K</i>
C ₅ H ₁₀	2 – Methyl – 2 – butene	-3.9960	4.7505 x 10 ²	9.9954 x 10 ⁻³	-1.3953 x 10 ⁻⁵	139 to 471
C ₅ H ₁₀	3 – Methyl – 1 – butene	-8.7648	1.0250 x 10 ³	2.3732 x 10 ⁻²	-2.7510 x 10 ⁻⁵	273 to 450
C ₅ H ₁₀	1 – Pentene	-5.5640	6.1906 x 10 ²	1.5123 x 10 ⁻²	-1.9316 x 10 ⁻⁵	175 to 465
C ₅ H ₁₀	Cis – 2 - Pentene	-3.4667	4.1022 x 10 ²	8.4927 x 10 ⁻³	-1.2319 x 10 ⁻⁵	122 to 476
C ₅ H ₁₀	Trans – 2 - Pentene	-3.7334	4.3487 x 10 ²	9.3927 x 10 ⁻³	-1.3291 x 10 ⁻⁵	133 to 475
C ₅ H ₁₀ Cl ₂	1,5 – Dichloro pentane	-2.8380	6.8497 x 10 ²	3.8366 x 10 ⁻³	-4.5639 x 10 ⁻⁶	200 to 663
C ₅ H ₁₀ O	Methyl iso propyl ketone	-5.5433	7.9650 x 10 ²	1.2368 x 10 ⁻²	-1.3239 x 10 ⁻⁵	181 to 553
C ₅ H ₁₀ O	2 – Pentanone	-7.4145	1.0492 x 10 ²	1.6999 x 10 ⁻²	-1.6941 x 10 ⁻⁵	250 to 561
C ₅ H ₁₀ O	Diethyl ketone	-9.2905	1.2716 x 10 ³	2.1925 x 10 ⁻²	-2.1036 x 10 ⁻⁵	274 to 561
C ₅ H ₁₀ O	Valeraldehyde	-2.4006	4.6830 x 10 ³	4.0666 x 10 ⁻³	-6.6593 x 10 ⁻⁶	182 to 554
C ₅ H ₁₀ O ₂	n – Butyl formate	-6.2873	9.9161 x 10 ²	1.3347 x 10 ⁻²	-1.3623 x 10 ⁻⁵	250 to 559
C ₅ H ₁₀ O ₂	Ethyl propionate	-7.3410	1.0413 x 10 ³	1.7121 x 10 ⁻²	-1.7852 x 10 ⁻⁵	250 to 546
C ₅ H ₁₀ O ₂	Iso butyl formate	-9.8983	1.4374 x 10 ³	2.2751 x 10 ⁻²	-2.1524 x 10 ⁻⁵	289 to 551
C ₅ H ₁₀ O ₂	Iso propyl acetate	-5.3287	8.2209 x 10 ²	1.1484 x 10 ⁻²	-1.2697 x 10 ⁻⁵	216 to 538
C ₅ H ₁₀ O ₂	n – Propyl acetate	-8.7395	1.0376 x 10 ³	1.1484 x 10 ⁻²	-1.2697 x 10 ⁻⁵	293 to 549
C ₅ H ₁₀ O ₂	Methyl – n – butyrate	-5.2565	8.0396 x 10 ²	1.1391 x 10 ⁻²	-1.2415 x 10 ⁻⁵	200 to 555
C ₅ H ₁₀ O ₂	2 – Methyl - butyric acid	-9.1382	1.6081 x 10 ³	1.7951 x 10 ⁻²	-1.1318 x 10 ⁻⁵	298 to 643
C ₅ H ₁₀ O ₂	Isovaleric acid	-6.7505	1.2740 x 10 ²	1.2636 x 10 ⁻²	-1.1318 x 10 ⁻⁵	244 to 634
C ₅ H ₁₀ O ₂	Valeric acid	-7.9425	1.4583 x 10 ³	1.5088 x 10 ⁻²	-1.2781 x 10 ⁻⁵	288 to 651
C ₅ H ₁₀ O ₂	Tetra hydro furfuryl alcohol	-19.7007	3.4266 x 10 ³	3.7490 x 10 ⁻²	-2.6468 x 10 ⁻⁵	250 to 639
C ₅ H ₁₀ O ₂ S	3 – Methyl sulfolane	-5.1223	1.4211 x 10 ³	5.9806 x 10 ⁻³	-4.0278 x 10 ⁻⁶	290 to 817
C ₅ H ₁₀ O ₃	Diethyl carbonate	-6.9038	1.0458 x 10 ³	1.5802 x 10 ⁻²	-1.6047 x 10 ⁻⁵	250 to 576
C ₅ H ₁₀ O ₃	Ethyl lactate	-20.0105	3.2123 x 10 ³	4.1891 x 10 ⁻²	-3.2733 x 10 ⁻⁵	247 to 588

<i>Formula</i>	<i>Name</i>	<i>A'</i>	<i>B'</i>	<i>C'</i>	<i>D'</i>	<i>Temperature Range, K</i>
$C_3H_{11}Cl$	1 – Chloro pentane	-3.9553	6.5614×10^2	7.6907×10^{-3}	8.8986×10^{-6}	174 to 568
$C_3H_{11}N$	n – Methyl pyrrolidone	-5.2640	8.7099×10^2	9.7493×10^{-3}	-9.7536×10^{-6}	183 to 550
$C_3H_{11}N$	Pipreidine	-0.5054	4.9531×10^2	-4.1245×10^{-3}	2.5391×10^{-6}	285 to 594
$C_3H_{11}NO$	Tert – Butyl formamide	11.3399	-1.0643×10^3	-2.8136×10^{-2}	1.7528×10^{-5}	289 to 692
C_3H_{12}	Iso pentane	-5.8108	7.0656×10^2	1.4826×10^{-2}	-1.8547×10^{-5}	210 to 460
C_3H_{12}	Neo pentane	-4.6261	7.8569×10^2	6.8775×10^{-3}	-8.1947×10^{-6}	258 to 434
C_3H_{12}	n – Pentane	-7.1711	7.4736×10^2	2.1697×10^{-2}	-2.7176×10^{-5}	143 to 470
$C_3H_{12}O$	2,2 – Dimethyl – 1 – propanol	-21.3537	4.0439×10^3	3.7271×10^{-2}	-2.3735×10^{-5}	327 to 550
$C_3H_{12}O$	2 – Methyl – 1 – butanol	-13.3823	2.5243×10^3	2.4256×10^{-2}	-1.9091×10^{-5}	273 to 546
$C_3H_{12}O$	2 – Methyl – 2 – butanol	-25.3557	4.2312×10^3	5.0802×10^{-2}	-3.8373×10^{-5}	264 to 545
$C_3H_{12}O$	3 – Methyl – 1 – butanol	-7.9943	1.7691×10^3	1.1475×10^{-2}	-8.9300×10^{-6}	273 to 579
$C_3H_{12}O$	3 – Methyl – 2 – butanol	-4.7191	1.3883×10^3	1.6744×10^{-3}	2.9612×10^{-7}	250 to 574
$C_3H_{12}O$	1 – Pentanol	-6.9286	1.5609×10^3	9.9633×10^{-3}	-8.3534×10^{-6}	253 to 586
$C_3H_{12}O$	2 – Pentanol	-21.4761	3.5740×10^3	4.3957×10^{-2}	-3.4712×10^{-5}	250 to 552
$C_3H_{12}O$	3 – Pentanol	-2.8804	1.1077×10^3	-1.8779×10^{-3}	2.1199×10^{-6}	222 to 547
$C_3H_{12}O$	Methyl – sec – butyl ether	-5.0497	6.4203×10^2	1.2303×10^{-2}	-1.4886×10^{-5}	150 to 498
$C_3H_{12}O$	Methyl – tert – butyl ether	-9.7896	1.2002×10^3	2.6168×10^{-2}	-2.8297×10^{-5}	219 to 497
$C_3H_{12}O$	Methyl iso butyl ether	-4.3746	5.8318×10^2	1.0287×10^{-2}	-1.3123×10^{-5}	150 to 497
$C_3H_{12}O$	Ethyl propyl ether	-5.7475	7.2196×10^2	1.4612×10^{-2}	-1.7401×10^{-5}	200 to 500
$C_3H_{12}O_2$	Ethylene glycol mono propyl ether	-70.1674	1.6490×10^3	1.1781×10^{-2}	-9.5068×10^{-6}	224 to 582
$C_3H_{12}O_2$	Neo pentyl glycol	-70.0464	1.2205×10^3	1.3211×10^{-1}	-8.4759×10^{-5}	400 to 643
$C_3H_{12}O_2$	1,5 – Pentane diol	-7.0464	2.3070×10^3	5.2107×10^{-3}	-2.3581×10^{-6}	263 to 673

<i>Formula</i>	<i>Name</i>	<i>A'</i>	<i>B'</i>	<i>C'</i>	<i>D'</i>	<i>Temperature Range, K</i>
C ₅ H ₁₂ O ₃	2 - (Methoxy ethoxy) ethanol	-9.0629	1.7101 x 10 ³	1.7174 x 10 ⁻²	-1.4454 x 10 ⁻⁵	240 to 630
C ₅ H ₁₂ O ₄	Penta erythritol	50.8517	-1.1053 x 10 ⁴	-7.2356 x 10 ⁻²	3.0441 x 10 ⁻⁵	534 to 780
C ₅ H ₁₂ S	n - Penty/ mercaptan	-4.6076	7.4223 x 10 ²	9.1728 x 10 ⁻³	-9.5706 x 10 ⁻⁶	197 to 598
C ₅ H ₁₃ N	n - Penty/ amine	-6.7617	1.1650 x 10 ³	1.3126 x 10 ⁻²	-1.2846 x 10 ⁻⁵	218 to 555
C ₅ H ₁₃ NO ₂	Methyl/diethanol amine	-12.0930	2.9675 x 10 ³	1.6516 x 10 ⁻²	-1.0129 x 10 ⁻⁵	252 to 678
C ₆ Cl ₆	Hexachlorobenzene	-33.4785	7.1609 x 10 ³	5.2053 x 10 ⁻²	-2.8454 x 10 ⁻⁵	502 to 825
C ₆ F ₆	Hexafluorobenzene	26.0147	-2.4756 x 10 ³	-7.7839 x 10 ⁻²	6.7076 x 10 ⁻⁵	278 to 517
C ₆ H ₃ ClNO ₂ O ₄	1-Chloro - 2,4 -dinitro benzene	-18.8604	3.8454 x 10 ³	3.0491 x 10 ⁻²	-1.7891 x 10 ⁻⁵	327 to 814
C ₆ H ₃ Cl ₂ NO ₂	1,2 - Dichloro - 4 -nitro benzene	-16.9196	3.2771 x 10 ³	2.9025 x 10 ⁻²	-1.8435 x 10 ⁻⁵	316 to 758
C ₆ H ₃ Cl ₃	1,2,4 -Tri chloro benzene	-7.5691	1.4901 x 10 ³	1.3010 x 10 ⁻²	-9.7071 x 10 ⁻⁶	290 to 725
C ₆ H ₃ N ₃ O ₆	1,3,5 - Tri nitro benzene	-25.8759	6.0592 x 10 ³	3.4686 x 10 ⁻²	-1.5994 x 10 ⁻⁵	398 to 1005
C ₆ H ₄ Br ₂	m - Di bromo benzene	-11.7673	2.1521 x 10 ³	2.0981 x 10 ⁻²	-1.3972 x 10 ⁻⁵	266 to 761
C ₆ H ₄ ClNO ₂	m - Chloro nitro benzene	-7.4607	1.4381 x 10 ³	1.3542 x 10 ⁻²	-1.0431 x 10 ⁻⁵	318 to 742
C ₆ H ₄ ClNO ₂	o - Chloro nitro benzene	-15.4421	2.8372 x 10 ³	2.7503 x 10 ⁻²	-1.8034 x 10 ⁻⁵	306 to 757
C ₆ H ₄ ClNO ₂	p - Chloro nitro benzene	-20.9286	3.7707 x 10 ³	3.8037 x 10 ⁻²	-2.4626 x 10 ⁻⁵	357 to 751
C ₆ H ₄ Cl ₂	m - Di chloro benzene	-4.6414	8.2076 x 10 ²	8.8567 x 10 ⁻³	-8.1810 x 10 ⁻⁶	248 to 684
C ₆ H ₄ Cl ₂	o - Di chloro benzene	-3.8623	7.8030 x 10 ²	6.3271 x 10 ⁻³	-5.8508 x 10 ⁻⁶	256 to 705
C ₆ H ₄ Cl ₂	p - Di chloro benzene	-6.6362	1.1967 x 10 ³	1.2224 x 10 ⁻²	-9.9914 x 10 ⁻⁶	326 to 685
C ₆ H ₄ N ₂ O ₄	m - Di nito benzene	-8.5112	1.8823 x 10 ³	1.3927 x 10 ⁻²	-9.7139 x 10 ⁻⁶	364 to 805
C ₆ H ₄ N ₂ O ₄	o - Di nitro benzene	-22.2948	4.6876 x 10 ³	3.5439 x 10 ⁻²	-2.0308 x 10 ⁻⁵	390 to 831

<i>Formula</i>	<i>Name</i>	<i>A'</i>	<i>B'</i>	<i>C'</i>	<i>D'</i>	<i>Temperature Range, K</i>
$C_6H_4N_2O_4$	p – Di nitro benzene	-25.9514	5.3986×10^3	4.2022×10^{-2}	-2.4436×10^{-5}	447 to 803
C_6H_3Br	Bromo benzene	-6.5135	1.0984×10^3	1.2749×10^{-2}	-1.0749×10^{-5}	242 to 670
C_6H_5Cl	Chloro benzene	-4.8717	8.2340×10^2	0.1981×10^{-3}	-8.6530×10^{-6}	250 to 632
C_6H_5ClO	m – Chloro phenol	-39.6221	6.8879×10^3	7.3543×10^{-2}	-4.6375×10^{-5}	306 to 729
C_6H_5ClO	o – Chloro phenol	-15.0741	2.6314×10^3	2.9170×10^{-2}	-2.1317×10^{-5}	282 to 675
C_6H_5ClO	p – Chloro phenol	-16.6697	3.2044×10^3	2.9330×10^{-2}	-1.9280×10^{-5}	316 to 738
$C_6H_5Cl_2N$	3,4 – Di chloro aniline	15.9808	3.0119×10^3	2.4746×10^{-2}	-1.3793×10^{-5}	345 to 800
C_6H_5F	Fluoro benzene	-6.5062	9.7585×10^2	1.4152×10^{-2}	-1.4056×10^{-5}	232 to 560
C_6H_5I	Iodo benzene	-6.7338	1.2140×10^3	1.2409×10^{-2}	-9.6198×10^{-6}	242 to 721
$C_6H_5NO_2$	Nitro benzene	-7.7710	1.4019×10^3	1.4653×10^{-2}	1.1512×10^{-5}	273 to 719
C_6H_6	Benzene	-7.4005	1.1815×10^3	1.4888×10^{-2}	-1.3713×10^{-5}	285 to 562
C_6H_6ClN	m – Chloro aniline	-14.2377	2.6141×10^3	2.4952×10^{-2}	-1.6249×10^{-5}	263 to 751
C_6H_6ClN	o – Chloro aniline	-12.7917	2.3163×10^3	2.3236×10^{-2}	-1.6047×10^{-5}	271 to 722
C_6H_6ClN	p – Chloro aniline	-10.8969	2.0918×10^3	1.9036×10^{-2}	-1.3102×10^{-5}	328 to 754
$C_6H_6N_2$	Cis – Di cyano – 1 – butene	-9.4027	2.0397×10^3	1.4323×10^{-2}	-9.9881×10^{-6}	249 to 691
$C_6H_6N_2$	Trans – Di cyano – 1 – butene	-10.3176	2.1809×10^3	1.6236×10^{-2}	-1.1299×10^{-5}	260 to 689
$C_6H_6N_2$	1,4 – Di cyano – 2 – butene	-30.6811	5.7439×10^3	5.3148×10^{-2}	-3.2357×10^{-5}	349 to 755
$C_6H_6N_2O_2$	m – Nitro aniline	-21.4002	4.5473×10^3	3.0755×10^{-2}	-1.5638×10^{-5}	387 to 815
$C_6H_6N_2O_2$	o – Nitro aniline	-15.2760	3.2868×10^3	2.1290×10^{-2}	-1.0953×10^{-5}	345 to 784
$C_6H_6N_2O_2$	p – Nitro aniline	-16.5136	3.7808×10^3	2.1340×10^{-2}	-1.0131×10^{-5}	421 to 851
C_6H_6O	Phenol	1.5349	4.2620×10^2	-9.1577×10^{-3}	6.2322×10^{-6}	318 to 694
$C_6H_6O_2$	1,2 – Benzene diol	-24.7533	4.8589×10^3	4.2834×10^{-2}	-2.6506×10^{-5}	385 to 764

<i>Formula</i>	<i>Name</i>	<i>A'</i>	<i>B'</i>	<i>C'</i>	<i>D'</i>	<i>Temperature Range, K</i>
C ₆ H ₆ O ₂	1,3 – Benzene diol	-26.2943	5.6833 x 10 ³	4.1514 x 10 ⁻²	-2.3604 x 10 ⁻⁵	400 to 810
C ₆ H ₆ O ₂	P – Hydro quinone	-67.2454	1.5146 x 10 ⁴	9.9970 x 10 ⁻²	-5.1078 x 10 ⁻⁵	445 to 822
C ₆ H ₆ O ₃	1,2,3 – Benzene triol	2.2220	1.2238 x 10 ³	-1.0975 x 10 ⁻²	6.4587 x 10 ⁻⁶	407 to 830
C ₆ H ₆ S	Phenyl mercaptan	-3.7030	7.2932 x 10 ²	6.1906 x 10 ⁻³	-5.9690 x 10 ⁻⁶	258 to 689
C ₆ H ₇ N	Aniline	-13.8625	2.5109 x 10 ³	2.5681 x 10 ⁻²	-1.8281 x 10 ⁻⁵	268 to 699
C ₆ H ₇ N	2 – Methyl pyridine	-5.4649	9.1344 x 10 ²	1.0641 x 10 ⁻²	-1.0072 x 10 ⁻⁵	220 to 621
C ₆ H ₇ N	3 – Methyl pyridine	-10.9953	1.7608 x 10 ³	2.2185 x 10 ⁻²	-1.7629 x 10 ⁻⁵	293 to 645
C ₆ H ₇ N	4 – Methyl pyridine	-8.2356	1.3239 x 10 ³	1.6712 x 10 ⁻²	-1.4085 x 10 ⁻⁵	277 to 646
C ₆ H ₈	1,3 –Cyclo hexa diene	-3.1367	5.9143 x 10 ²	4.8065 x 10 ⁻³	-5.9644 x 10 ⁻⁶	180 to 558
C ₆ H ₈	Methyl cyclo penta diene	-3.3654	5.2704 x 10 ²	5.7171 x 10 ⁻³	-6.6472 x 10 ⁻⁶	150 to 541
C ₆ H ₈ N ₂	Adipo nitrile	0.4949	4.1398 x 10 ²	-4.2058 x 10 ⁻³	1.5475 x 10 ⁻⁶	276 to 781
C ₆ H ₈ N ₂	Methyl glutaro nitrile	-4.3436	1.0468 x 10 ³	6.5095 x 10 ⁻³	-5.9407 x 10 ⁻⁶	228 to 742
C ₆ H ₈ N ₂	m – Phenylene diamine	-44.9990	8.9345 x 10 ³	7.3255 x 10 ⁻²	-4.0464 x 10 ⁻⁵	363 to 824
C ₆ H ₈ N ₂	o – Phenylene diamine	-12.6956	2.8298 x 10 ³	1.9504 x 10 ⁻²	-1.2084 x 10 ⁻⁵	377 to 781
C ₆ H ₈ N ₂	p – Phenylene diamine	-18.6581	3.9059 x 10 ³	3.0083 x 10 ⁻²	-1.8039 x 10 ⁻⁵	413 to 796
C ₆ H ₈ N ₂	Phenyl hydrazene	-29.5908	5.2240 x 10 ³	5.4755 x 10 ⁻²	-3.5011 x 10 ⁻⁵	292 to 761
C ₆ H ₈ N ₂ O	Bis (Cyano ethyl) ether	-4.7689	1.2262 x 10 ³	7.0649 x 10 ⁻³	-6.0124 x 10 ⁻⁶	247 to 783
C ₆ H ₈ O ₄	Di methyl maleate	-2.1332	6.7918 x 10 ²	2.3965 x 10 ⁻³	-3.8790 x 10 ⁻⁶	254 to 675
C ₆ H ₁₀	Cyclo hexane	-4.4683	8.1472 x 10 ²	7.3925 x 10 ⁻³	7.7551 x 10 ⁻⁶	273 to 560
C ₆ H ₁₀	2,3 – Di methyl -1,3 – buta diene	-5.6382	6.9686 x 10 ²	1.3722 x 10 ⁻²	-1.5374 x 10 ⁻⁵	197 to 526
C ₆ H ₁₀	1,5 – Hexa diene	-3.6271	4.6186 x 10 ²	8.2645 x 10 ⁻³	-1.0973 x 10 ⁻⁵	132 to 507

<i>Formula</i>	<i>Name</i>	<i>A'</i>	<i>B'</i>	<i>C'</i>	<i>D'</i>	<i>Temperature Range, K</i>
C ₆ H ₁₀	Cis,trans -2,4 - Hexa diene	-6.1222	7.2326 x 10 ²	1.5438	-1.6909 x 10 ⁻⁵	177 to 538
C ₆ H ₁₀	Trans,trans -2,4 -Hexa diene	-9.7857	1.1547 x 10 ³	2.5456 x 10 ⁻²	-2.5786 x 10 ⁻⁵	228 to 535
C ₆ H ₁₀	1 - Hexyne	-3.0390	4.3910 x 10 ²	7.8827 x 10 ⁻³	-1.2220 x 10 ⁻⁵	141 to 516
C ₆ H ₁₀	2 - Hexyne	-3.4983	5.3680 x 10 ²	7.0308 x 10 ⁻³	-8.9311 x 10 ⁻⁶	184 to 549
C ₆ H ₁₀	3 - Hexyne	-3.2573	5.0738 x 10 ²	6.4200 x 10 ⁻³	-8.5118 x 10 ⁻⁶	170 to 544
C ₆ H ₁₀ O	Cyclo hexa none	-3.5761	9.3118 x 10 ²	3.6856 x 10 ⁻³	-3.7510 x 10 ⁻⁶	275 to 629
C ₆ H ₁₀ O	Mesityl oxide	-5.4305	8.4932 x 10 ²	1.1426 x 10 ⁻²	-1.1624 x 10 ⁻⁵	220 to 600
C ₆ H ₁₀ O ₂	Epsolon Capro nitrile	-7.5834	1.3332 x 10 ³	1.2604 x 10 ⁻²	-8.4577 x 10 ⁻⁶	272 to 771
C ₆ H ₁₀ O ₂	Ethyl methacrylate	-8.0496	1.1661 x 10 ³	1.7964 x 10 ⁻²	-1.6967 x 10 ⁻⁵	223 to 577
C ₆ H ₁₀ O ₂	n - Propyl acrylate	-11.6479	1.6509 x 10 ³	2.7040 x 10 ⁻²	-2.4607 x 10 ⁻⁵	273 to 569
C ₆ H ₁₀ O ₃	Ethyl aceto acetate	-7.6190	1.3438 x 10 ³	1.4739 x 10 ⁻²	-1.2640 x 10 ⁻⁵	234 to 643
C ₆ H ₁₀ O ₃	Propionic anhydride	-11.7549	1.7933 x 10 ³	2.5883 x 10 ⁻²	-2.2100 x 10 ⁻⁵	273 to 618
C ₆ H ₁₀ O ₄	Adipic acid	-54.8285	1.1789 x 10 ⁴	8.5563 x 10 ⁻²	-4.6275 x 10 ⁻⁵	433 to 809
C ₆ H ₁₀ O ₄	Diethyl oxalate	-14.8918	2.4136 x 10 ³	3.0683 x 10 ⁻²	-2.3887 x 10 ⁻⁵	260 to 646
C ₆ H ₁₀ O ₄	Ethylene glycol di acetate	-3.1566	8.0484 x 10 ²	4.5706 x 10 ⁻³	-5.4906 x 10 ⁻⁶	242 to 653
C ₆ H ₁₀ O ₄	Ethyl edene di acetate	-14.8918	2.3887 x 10 ³	3.0890 x 10 ⁻²	-2.4126 x 10 ⁻⁵	292 to 635
C ₆ H ₁₁ N	Hexane nitrile	-3.1566	8.6235 x 10 ²	9.0581 x 10 ⁻³	-9.2062 x 10 ⁻⁶	193 to 622
C ₆ H ₁₁ NO	Epsilon - Caprolactum	-21.8927	4.6844 x 10 ³	3.4249 x 10 ⁻²	-1.9662 x 10 ⁻⁵	342 to 806
C ₆ H ₁₂	Cyclo hexane	4.7423	-2.5322 x 10 ²	-1.6927 x 10 ⁻²	1.2472 x 10 ⁻⁵	285 to 554
C ₆ H ₁₂	2,3 - Dinethyl - 1 - butene	-3.0632	4.3429 x 10 ²	6.0597 x 10 ⁻³	-8.7246 x 10 ⁻⁶	116 to 500
C ₆ H ₁₂	2,3 - Dimethyl - 2- butene	-6.1147	7.5638 x 10 ²	1.4993 x 10 ⁻²	-1.6622 x 10 ⁻⁵	199 to 524
C ₆ H ₁₂	3,3 - Dimethyl -1 -butene	-3.5056	4.7789 x 10 ²	7.6202 x 10 ⁻³	-1.0831 x 10 ⁻⁵	158 to 480

<i>Formula</i>	<i>Name</i>	<i>A'</i>	<i>B'</i>	<i>C'</i>	<i>D'</i>	<i>Temperature Range, K</i>
C ₆ H ₁₂	2 – Ethyl – 1 – butene	-3.6762	4.9545 x 10 ²	7.9274 x 10 ⁻³	1.0337 x 10 ⁻⁵	142 to 512
C ₆ H ₁₂	1 – Hexene	-6.3469	7.8976 x 10 ²	1.5694 x 10 ⁻²	-1.7747 x 10 ⁻⁵	218 to 504
C ₆ H ₁₂	Cis – 2 – Hexene	-3.5211	4.7446 x 10 ²	7.7214 x 10 ⁻³	-1.0351 x 10 ⁻⁵	132 to 513
C ₆ H ₁₂	Trans – 2 – Hexene	-3.6519	4.8838 x 10 ²	8.0942 x 10 ⁻³	-1.0694 x 10 ⁻⁵	140 to 513
C ₆ H ₁₂	Cis – 3 – Hexene	-3.6154	4.8261 x 10 ²	8.0850 x 10 ⁻³	-1.0837 x 10 ⁻⁵	135 to 509
C ₆ H ₁₂	Trans – 3 – Hexene	-4.3388	5.5486 x 10 ²	1.0354 x 10 ⁻²	-1.3080 x 10 ⁻⁵	160 to 509
C ₆ H ₁₂	Methyl cyclo pentane	-1.0639	3.1769 x 10 ²	-4.7988 x 10 ⁻⁴	-2.0504 x 10 ⁻⁶	248 to 533
C ₆ H ₁₂	2 – Methyl – 1 – pentene	-8.1875	1.0565 x 10 ³	1.9948 x 10 ⁻²	-2.0963 x 10 ⁻⁵	230 to 507
C ₆ H ₁₂	2 – Methyl – 2 – pentene	-3.7409	4.9959 x 10 ²	8.1854 x 10 ⁻³	-1.0587 x 10 ⁻⁵	138 to 514
C ₆ H ₁₂	3 – Methyl – 1 – pentene	-3.3186	4.5588 x 10 ²	7.0761 x 10 ⁻³	-9.9805 x 10 ⁻⁶	120 to 495
C ₆ H ₁₂	3 – Methyl – cis – 2 – pentene	-3.9620	5.1828 x 10 ²	8.9503 x 10 ⁻³	-1.1310 x 10 ⁻⁵	138 to 515
C ₆ H ₁₂	4 – Methyl – 1 – pentene	-3.1323	4.4203 x 10 ²	6.3382 x 10 ⁻³	-1.0661 x 10 ⁻⁶	120 to 496
C ₆ H ₁₂	4 – Methyl – cis – 2 – pentene	-3.6002	4.8538 x 10 ²	7.8742 x 10 ⁻³	-9.6896 x 10 ⁻⁵	138 to 499
C ₆ H ₁₂	4 – Methyl – trans – 2 – pentene	-3.3633	4.6465 x 10 ²	7.0194 x 10 ⁻³	-4.9208 x 10 ⁻⁶	132 to 501
C ₆ H ₁₂ N ₂	Tri ethylene diamine	11.5928	-2.4836 x 10 ³	-1.7095 x 10 ⁻²	-1.1890 x 10 ⁻⁵	434 to 655
C ₆ H ₁₂ O	Butyl vinyl ether	-4.7429	7.1709 x 10 ³	1.0233 x 10 ⁻²	-1.1890 x 10 ⁻⁵	181 to 536
C ₆ H ₁₂ O	Cyclo hexanal	-5.3792	1.8793 x 10 ³	1.7011 x 10 ⁻³	1.0187 x 10 ⁻⁷	303 to 625
C ₆ H ₁₂ O	1 – Hexanal	-1.5906	3.8705 x 10 ²	2.1713 x 10 ⁻³	-5.0434 x 10 ⁻⁶	217 to 579
C ₆ H ₁₂ O	Ethyl iso propyl ketone	-6.0045	9.1123 x 10 ³	1.2923 x 10 ⁻²	-1.3230 x 10 ⁻⁵	200 to 567
C ₆ H ₁₂ O	2 – Hexa none	-6.9812	1.0500 x 10 ³	1.5094 x 10 ⁻²	-1.4504 x 10 ⁻⁵	217 to 587
C ₆ H ₁₂ O	3 – Hexa none	-6.7371	1.0210 x 10 ³	1.4470 x 10 ⁻³	-1.4069 x 10 ⁻⁵	218 to 583
C ₆ H ₁₂ O	Methyl iso butyl ketone	-3.0570	5.0050 x 10 ²	6.5038 x 10 ⁻³	-8.8243 x 10 ⁻⁶	246 to 571
C ₆ H ₁₂ O ₂	n – Pentyl formate	-5.7440	9.1130 x 10 ²	1.2435 x 10 ⁻²	-1.3004 x 10 ⁻⁵	200 to 576
C ₆ H ₁₂ O ₂	n – Butyl acetate	-8.3884	1.3075 x 10 ³	1.7671 x 10 ⁻²	-1.3004 x 10 ⁻⁵	275 to 579

<i>Formula</i>	<i>Name</i>	<i>A'</i>	<i>B'</i>	<i>C'</i>	<i>D'</i>	<i>Temperature Range, K</i>
$C_6H_{12}O_2$	Sec - Butyl acetate	-4.2484	7.3709×10^2	8.1159×10^{-3}	-1.6145×10^{-5}	174 to 561
$C_6H_{12}O_2$	Tert - Butyl acetate	-8.1645	1.2261×10^3	1.8000×10^{-2}	-9.2626×10^{-6}	283 to 545
$C_6H_{12}O_2$	Ethyl - n - butyrate	-6.5990	1.0010×10^3	1.4580×10^{-2}	-1.7534×10^{-5}	250 to 571
$C_6H_{12}O_2$	Ethyl - iso - butyrate	-5.4028	8.4827×10^2	1.1442×10^{-2}	-1.4750×10^{-5}	185 to 553
$C_6H_{12}O_2$	Iso butyl acetate	-7.4697	1.1287×10^3	1.6664×10^{-2}	-1.2326×10^{-5}	275 to 561
$C_6H_{12}O_2$	n - Propyl propionate	-5.4369	8.7969×10^2	1.1064×10^{-2}	-1.1348×10^{-5}	197 to 578
$C_6H_{12}O_2$	Di acetone alcohol	-16.5815	2.7668×10^3	3.4806×10^{-2}	-2.8348×10^{-5}	229 to 606
$C_6H_{12}O_2$	2 - Ethyl butyric acid	-7.1034	1.3882×10^3	1.2840×10^{-2}	-1.1012×10^{-5}	258 to 655
$C_6H_{12}O_2$	n - Hexanoic acid	-6.2881	1.3092×10^3	1.0624×10^{-2}	-9.1112×10^{-6}	275 to 667
$C_6H_{12}O_3$	2 - Ethoxy ethyl acetate	-7.3105	1.2304×10^3	1.4721×10^{-2}	-1.3742×10^{-5}	225 to 597
$C_6H_{12}O_3$	Hydroxy caproic acid	-3.7600	1.5809×10^3	4.4909×10^{-5}	1.4217×10^{-8}	334 to 758
$C_6H_{12}O_3$	Paraldehyde	-14.2350	2.1910×10^3	3.1012×10^{-2}	-2.6181×10^{-5}	286 to 579
$C_6H_{13}N$	Cyclo hexyl amine	-4.4924	1.0272×10^3	6.1023×10^{-3}	-5.7699×10^{-6}	288 to 615
$C_6H_{13}N$	Hexa methylene imine	-3.5971	9.3397×10^2	3.6596×10^{-3}	-3.7383×10^{-6}	303 to 615
C_6H_{14}	2,2 - Dimethyl butane	-3.6841	6.5672×10^2	5.5269×10^{-3}	-7.1890×10^{-6}	269 to 489
C_6H_{14}	2,3 - Dimethyl butane	-12.6145	1.7240×10^3	2.9725×10^{-2}	-2.8274×10^{-5}	273 to 500
C_6H_{14}	n - Hexane	-5.0715	6.5536×10^2	1.2349×10^{-2}	-1.5042×10^{-5}	178 to 507
C_6H_{14}	2 - Methyl pentane	-5.1822	6.7047×10^2	1.2528×10^{-2}	-1.5278×10^{-5}	258 to 498
C_6H_{14}	3 - Methyl pentane	-5.2757	6.8590×10^2	1.2664×10^{-2}	-1.5109×10^{-5}	220 to 504
$C_6H_{14}N_2O_2$	Lysine	-108.5082	2.2844×10^4	1.6947×10^{-1}	-8.8781×10^{-5}	498 to 821
$C_6H_{14}O$	2 - Ethyl - 1 - butanol	-6.9398	1.7143×10^3	8.2026×10^{-3}	-6.1032×10^{-5}	237 to 580
$C_6H_{14}O$	1 - Hexanol	-9.7166	2.0060×10^3	1.5908×10^{-2}	-1.2286×10^{-4}	278 to 611

<i>Formula</i>	<i>Name</i>	<i>A'</i>	<i>B'</i>	<i>C'</i>	<i>D'</i>	<i>Temperature Range, K</i>
C ₆ H ₁₄ O	2 - Hexanol	-19.7738	3.4234 x 10 ³	3.8599 x 10 ⁻²	2.9152 x 10 ⁻⁵	230 to 586
C ₆ H ₁₄ O	2 - Methyl - 1 - pentanol	-18.4079	3.2619 x 10 ³	3.5729 x 10 ⁻²	2.7059 x 10 ⁻⁵	270 to 582
C ₆ H ₁₄ O	4 - Methyl - 2 - pentanol	-25.3841	4.1810 x 10 ³	5.2001 x 10 ⁻²	-3.9665 x 10 ⁻⁵	280 to 574
C ₆ H ₁₄ O	n - Butyl ether	-4.7316	7.1301 x 10 ²	1.0253 x 10 ⁻²	-1.2054 x 10 ⁻⁵	170 to 531
C ₆ H ₁₄ O	Di iso propyl ether	-5.5350	7.4894 x 10 ²	1.3145 x 10 ⁻²	-1.5557 x 10 ⁻⁵	188 to 500
C ₆ H ₁₄ O	Di - n - propyl ether	-3.7969	5.8653 x 10 ²	7.7642 x 10 ⁻³	-9.7923 x 10 ⁻⁶	150 to 531
C ₆ H ₁₄ O	Methyl - tert - phenyl ether	-5.1638	7.1242 x 10 ²	1.1515 x 10 ⁻²	-1.2790 x 10 ⁻⁵	160 to 534
C ₆ H ₁₄ O ₂	Acetal	-6.7319	9.0418 x 10 ²	1.6397 x 10 ⁻²	1.7543 x 10 ⁻⁵	200 to 541
C ₆ H ₁₄ O ₂	2 - Butoxy ethanol	-7.3676	1.5830 x 10 ³	1.1138 x 10 ⁻²	-8.8708 x 10 ⁻⁶	203 to 600
C ₆ H ₁₄ O ₂	1,6 - Hexane diol	-72.9906	1.3107 x 10 ⁴	1.3170 x 10 ⁻¹	-8.0122 x 10 ⁻⁵	315 to 670
C ₆ H ₁₄ O ₂	Hexylene glycol	-69.7580	1.0040 x 10 ⁴	1.6420 x 10 ⁻¹	-1.3020 x 10 ⁻⁵	230 to 621
C ₆ H ₁₄ O ₂ S	Di - n - propyl sulfone	-12.8643	2.5541 x 10 ³	2.1501 x 10 ⁻²	-1.4018 x 10 ⁻⁵	303 to 763
C ₆ H ₁₄ O ₃	Di ethylene glycol di methyl ether	-5.9960	1.0158 x 10 ³	1.2239 x 10 ⁻²	-1.2021 x 10 ⁻⁵	203 to 604
C ₆ H ₁₄ O ₃	Di propylene glycol	-13.6865	3.3862 x 10 ³	1.6049 x 10 ⁻²	-7.1661 x 10 ⁻⁶	233 to 654
C ₆ H ₁₄ O ₃	2 (2 - Ethoxy ethoxy) ethanol	-9.7859	1.8448 x 10 ³	1.8441 x 10 ⁻²	-1.5177 x 10 ⁻⁵	240 to 632
C ₆ H ₁₄ O ₄	Tri ethylene glycol	-13.8883	3.0642 x 10 ³	2.0531 x 10 ⁻²	-1.0500 x 10 ⁻⁵	285 to 700
C ₆ H ₁₄ O ₆	Sorbitol	-26.2502	5.7927 x 10 ³	3.4769 x 10 ⁻²	-1.6250 x 10 ⁻⁵	371 to 959
C ₆ H ₁₄ S	n - Hexyl mercaptan	-5.2857	8.5597 x 10 ²	1.0430 x 10 ⁻²	-1.0034 x 10 ⁻⁵	193 to 623
C ₆ H ₁₅ Al	Triethyl aluminum	-4.3627	9.9686 x 10 ²	5.9002 x 10 ⁻³	-4.1150 x 10 ⁻⁶	221 to 720
C ₆ H ₁₅ N	Di iso propyl amine	-9.4766	1.2451 x 10 ³	2.3557 x 10 ⁻²	-2.4018 x 10 ⁻⁵	250 to 523
C ₆ H ₁₅ N	Di - n - Propyl amine	-15.3095	2.0644 x 10 ³	3.7073 x 10 ⁻²	-3.3467 x 10 ⁻⁵	260 to 556
C ₆ H ₁₅ N	n - Hexyl amine	-4.3636	8.3506 x 10 ²	7.3533 x 10 ⁻³	-7.8672 x 10 ⁻⁶	252 to 583

<i>Formula</i>	<i>Name</i>	<i>A'</i>	<i>B'</i>	<i>C'</i>	<i>D'</i>	<i>Temperature Range, K</i>
C ₆ H ₁₅ N	Tri ethyl amine	-8.2302	1.0707 x 10 ³	2.0144 x 10 ⁻²	-2.0640 x 10 ⁻⁵	250 to 535
C ₆ H ₁₅ NO	6 – Amino hexanol	-42.5962	7.8271 x 10 ³	7.7049 x 10 ⁻²	-4.8866 x 10 ⁻⁵	331 to 681
C ₆ H ₁₅ NO ₂	Di iso propanol amine	-110.6700	1.8305 x 10 ⁴	2.2070 x 10 ⁻¹	-1.4706 x 10 ⁻⁴	303 to 672
C ₆ H ₁₅ NO ₃	Tri ethanol amine	-21.0078	4.7935 x 10 ³	3.1279 x 10 ⁻²	-1.7784 x 10 ⁻⁷	294 to 787
C ₆ H ₁₅ N ₃	n – Amino ethyl piperazine	-0.4594	7.1166 x 10 ²	-3.0976 x 10 ⁻³	8.2669 x 10 ⁻⁷	254 to 708
C ₆ H ₁₅ O ₄ P	Tri ethyl phosphate	-10.0212	1.7337 x 10 ³	1.8103 x 10 ⁻²	-1.1778 x 10 ⁻⁵	250 to 794
C ₆ H ₁₆ N ₂	Hexa methylene diamine	-24.6252	4.1044 x 10 ³	4.8655 x 10 ⁻²	-3.4491 x 10 ⁻⁵	314 to 663
C ₆ H ₁₈ N ₃ OP	Hexa methyl phosphor amide	-5.4288	1.2492 x 10 ³	6.6845 x 10 ⁻³	-2.8892 x 10 ⁻⁶	280 to 506
C ₆ H ₁₈ N ₄	Tri ethylene tetramine	-40.9603	7.3562 x 10 ³	7.6974 x 10 ⁻²	-5.0374 x 10 ⁻⁵	285 to 718
C ₆ H ₁₈ Osi ₂	Hexa methyl di siloxane	-3.3863	5.7418 x 10 ²	6.7648 x 10 ⁻³	-9.7088 x 10 ⁻⁶	240 to 519
C ₆ H ₁₈ O ₃ Si ₃	Hexa methyl cyclo tri siloxane	-4.3150	8.3634 x 10 ²	7.6570 x 10 ⁻³	-9.1028 x 10 ⁻⁶	337 to 554
C ₆ H ₁₉ Nsi ₂	Hexa methyl di silazane	-3.3927	6.0328 x 10 ²	6.8022 x 10 ⁻³	-9.4801 x 10 ⁻⁶	290 to 544
C ₇ H ₃ ClF ₃ NO	2,4 – Chloro – 3 – nitro benzo tri fluoride	-13.2679	2.5485 x 10 ³	2.3563 x 10 ⁻²	-1.6631 x 10 ⁻⁵	293 to 686
C ₇ H ₃ Cl ₂ F ₃	2,4 – Di chloro benzo tri fluoride	-6.6149	1.3248 x 10 ³	1.1407 x 10 ⁻²	-9.6282 x 10 ⁻⁶	267 to 646
C ₇ H ₃ Cl ₂ NO	3,4 – Di chloro phenyl iso cyanate	-23.6469	4.1728 x 10 ³	4.3080 x 10 ⁻²	-2.7652 x 10 ⁻⁵	316 to 733
C ₇ H ₄ ClF ₃	p – Chlorobenzo tri fluoride	-8.3109	1.3727 x 10 ³	1.7034 x 10 ⁻²	-1.5091 x 10 ⁻⁵	354 to 601
C ₇ H ₄ Cl ₂ O	m – Chloro benzoyl chloride	-7.4045	1.5604 x 10 ³	1.2133 x 10 ⁻²	-9.0082 x 10 ⁻⁶	280 to 724
C ₇ H ₄ F ₃ NO ₂	3 – Nitro benzo tri fluoride	-11.9324	2.1272 x 10 ³	2.2447 x 10 ⁻²	-1.6797 x 10 ⁻⁵	272 to 667

<i>Formula</i>	<i>Name</i>	<i>A'</i>	<i>B'</i>	<i>C'</i>	<i>D'</i>	<i>Temperature Range, K</i>
C_7H_5ClO	Benzoyl chloride	-11.9830	1.9357×10^3	2.3900×10^{-2}	-1.7861×10^{-5}	273 to 697
$C_7H_5ClO_2$	o – Chloro benzoic acid	-35.6472	7.0126×10^3	5.9808×10^{-2}	-3.4812×10^{-5}	415 to 792
$C_7H_5Cl_3$	Benzo tri chloride	-5.7549	1.2014×10^3	8.9628×10^{-3}	-6.7458×10^{-6}	273 to 737
$C_7H_3F_3$	Benzo tri fluoride	-8.3782	1.1826×10^3	1.9281×10^{-2}	-1.8350×10^{-5}	244 to 565
C_7H_5N	Benzo nitrile	-6.5416	1.1609×10^3	1.2160×10^{-2}	-1.0015×10^{-5}	270 to 699
$C_7H_5N_3O_6$	2,4,6 – Di chloro toluene	-14.9246	2.8645×10^3	2.8227×10^{-2}	-1.9563×10^{-5}	354 to 795
$C_7H_6Cl_2$	Benzyl dichloride	-5.2934	1.1077×10^3	7.6332×10^{-3}	-5.5580×10^{-6}	257 to 731
$C_7H_6Cl_2$	2,4 – Di chloro toluene	-7.5511	1.4411×10^3	1.3164×10^{-2}	-1.0027×10^{-5}	260 to 705
$C_7H_6N_2O_4$	2,4 – Di nitro toluene	-7.2273	1.5200×10^3	1.2525×10^{-2}	-9.1730×10^{-6}	343 to 814
$C_7H_6N_2O_4$	2,5 – Di nitro toluene	-21.6018	4.2975×10^3	3.5182×10^{-2}	-2.0389×10^{-5}	326 to 814
$C_7H_6N_2O_4$	2,6 – Di nitro toluene	-2.9240	8.1054×10^2	4.7543×10^{-3}	-5.0883×10^{-6}	339 to 770
$C_7H_6N_2O_4$	3,4 – Di nitro toluene	-7.1438	1.5239×10^3	1.1952×10^{-2}	-8.4090×10^{-6}	332 to 842
$C_7H_6N_2O_4$	3,5 – Di nitro toluene	-31.5919	6.1804×10^3	5.2284×10^{-2}	-2.9883×10^{-5}	366 to 814
C_7H_6O	Benzaldehyde	1.2039	2.2414×10	-3.9285×10^{-3}	5.5651×10^{-7}	247 to 695
$C_7H_6O_2$	Benzoic acid	-67.6079	1.3482×10^4	1.1017×10^{-1}	-6.2162×10^{-5}	396 to 751
$C_7H_6O_2$	P – Hydroxy benzaldehyde	-34.5840	7.6927×10^3	4.9247×10^{-2}	-2.4193×10^{-5}	390 to 844
$C_7H_6O_2$	Salicyl aldehyde	-9.9310	1.7245×10^3	1.9801×10^{-2}	-1.5708×10^{-5}	266 to 680
C_7H_7Br	p – Bromo toluene	-9.1633	1.5029×10^3	1.8358×10^{-2}	-1.4308×10^{-5}	300 to 699
C_7H_7Cl	Benzyl chloride	-6.4178	1.1281×10^3	1.1724×10^{-2}	-9.5598×10^{-6}	234 to 686
C_7H_7Cl	o – Chloro toluene	-5.0510	8.8285×10^2	9.5924×10^{-3}	-8.7952×10^{-6}	237 to 656
C_7H_7Cl	p – Chloro toluene	-8.5917	1.3598×10^3	1.7594×10^{-2}	-1.4550×10^{-5}	281 to 660
C_7H_7NO	Formanilide	-21.7761	4.4373×10^3	3.1566×10^{-2}	-2.0639×10^{-5}	328 to 787

<i>Formula</i>	<i>Name</i>	<i>A'</i>	<i>B'</i>	<i>C'</i>	<i>D'</i>	<i>Temperature Range, K</i>
C ₇ H ₇ NO ₂	m - Nitro toluene	-20.0665	3.4718 x 10 ³	3.6803 x 10 ⁻²	-2.3950 x 10 ⁻⁵	289 to 734
C ₇ H ₇ NO ₂	o - Nitro toluene	-9.9050	1.7941 x 10 ³	1.8107 x 10 ⁻²	-1.8107 x 10 ⁻⁵	270 to 720
C ₇ H ₇ NO ₂	p - Nitro toluene	-11.3921	2.0234 x 10 ³	2.1371 x 10 ⁻²	-1.5415 x 10 ⁻⁵	325 to 736
C ₇ H ₇ NO ₃	o - Nitro anisole	-6.0024	1.2301 x 10 ³	1.0354 x 10 ⁻²	-8.0089 x 10 ⁻⁶	284 to 782
C ₇ H ₈	Toluene	-5.11649	8.1068 x 10 ²	1.0454 x 10 ⁻²	-1.0488 x 10 ⁻⁵	200 to 592
C ₇ H ₈ O	Anisole	-8.8307	1.4337 x 10 ³	1.7992 x 10 ⁻²	-1.5096 x 10 ⁻⁵	287 to 642
C ₇ H ₈ O	Benzyl alcohol	-25.0704	4.2124 x 10 ³	4.9668 x 10 ⁻²	-3.5036 x 10 ⁻⁵	288 to 677
C ₇ H ₈ O	m - Cresol	-18.3829	3.4649 x 10 ³	3.2787 x 10 ⁻²	-2.1943 x 10 ⁻⁵	298 to 706
C ₇ H ₈ O	o - Cresol	-18.6396	3.3896 x 10 ³	3.4286 x 10 ⁻²	-2.3373 x 10 ⁻⁵	304 to 698
C ₇ H ₈ O	p - Cresol	-19.0715	3.5560 x 10 ³	3.4524 x 10 ⁻²	-2.3222 x 10 ⁻⁵	308 to 705
C ₇ H ₈ O ₂	Gaiacol	-16.0239	2.8581 x 10 ³	3.0360 x 10 ⁻²	-2.1530 x 10 ⁻⁵	305 to 697
C ₇ H ₈ O ₂	p - Methoxy phenol	-16.2546	3.3208 x 10 ³	2.7118 x 10 ⁻²	-1.7208 x 10 ⁻⁵	345 to 758
C ₇ H ₉ N	Benzyl amine	-6.0952	1.1500 x 10 ³	1.0800 x 10 ⁻²	-9.0063 x 10 ⁻⁶	227 to 684
C ₇ H ₉ N	2,6 - Dimethyl pyridene	-7.1740	1.1515 x 10 ³	1.4740 x 10 ⁻²	-1.3258 x 10 ⁻⁵	267 to 624
C ₇ H ₉ N	n - Methyl aniline	-13.7299	2.2913 x 10 ³	2.7208 x 10 ⁻²	-2.0030 x 10 ⁻⁵	250 to 702
C ₇ H ₉ N	m - Toluidine	-13.5859	2.4293 x 10 ³	2.5395 x 10 ⁻²	-1.8204 x 10 ⁻⁵	273 to 709
C ₇ H ₉ N	o - Toluidine	-11.1346	2.1223 x 10 ³	1.9780 x 10 ⁻²	-1.4453 x 10 ⁻⁵	273 to 694
C ₇ H ₉ N	p - Toluidine	-12.3169	2.2349 x 10 ³	2.2874 x 10 ⁻²	-1.6774 x 10 ⁻⁵	317 to 693
C ₇ H ₁₀	2 - Norbornene	-9.3004	1.5318 x 10 ³	1.8049 x 10 ⁻²	-1.5132 x 10 ⁻⁵	319 to 583
C ₇ H ₁₀ N ₂	Toluene diamine	-33.0277	6.1042 x 10 ³	5.7240 x 10 ⁻²	-3.3853 x 10 ⁻⁵	371 to 804
C ₇ H ₁₂ O ₂	n - Butyl acrylate	-6.9308	1.1689 x 10 ³	1.3471 x 10 ⁻²	-1.2339 x 10 ⁻⁵	250 to 598

<i>Formula</i>	<i>Name</i>	<i>A'</i>	<i>B'</i>	<i>C'</i>	<i>D'</i>	<i>Temperature Range, K</i>
$C_7H_{12}O_2$	Iso butyl acrylate	-7.4193	1.1066×10^3	1.6403×10^{-2}	-1.5787×10^{-5}	212 to 580
$C_7H_{12}O_2$	n - Propyl - methacrylate	-7.6284	1.1672×10^3	1.6216×10^{-2}	-1.4907×10^{-5}	223 to 599
$C_7H_{12}O_4$	Diethylmalonate	-9.1440	1.6103×10^3	1.7730×10^{-2}	-1.4503×10^{-5}	240 to 653
C_7H_{14}	Cyclo heptane	2.2571	-8.2344	-6.5186×10^{-3}	-1.3401×10^{-6}	265 to 604
C_7H_{14}	1,1 - Di methyl cyclo pentane	-2.9826	5.2928×10^2	5.0996×10^{-3}	-6.9685×10^{-6}	203 to 547
C_7H_{14}	Cis - 1,2 - Di methyl cyclo pentane	-3.9448	6.3812×10^2	7.6699×10^{-3}	-8.8791×10^{-6}	219 to 565
C_7H_{14}	Trans - 1,2 - Di methyl cyclo pentane	-2.8753	5.1637×10^2	4.7706×10^{-3}	-6.5528×10^{-6}	156 to 553
C_7H_{14}	Cis - 1,3 - Di methyl cyclo pentane	-2.7490	5.0276×10^2	4.4211×10^{-3}	-6.2776×10^{-6}	139 to 551
C_7H_{14}	Trans - 1,3 - Di methyl cyclo pentane	-2.7501	5.0315×10^2	4.4009×10^{-3}	-6.2776×10^{-6}	139 to 553
C_7H_{14}	Ethyl cyclo pentane	-3.1.46	5.4840×10^2	5.4107×10^{-3}	-6.2117×10^{-6}	253 to 570
C_7H_{14}	2 - Ethyl - 1 - pentene	-5.0433	6.7571×10^2	1.1550×10^{-2}	-6.9666×10^{-6}	168 to 543
C_7H_{14}	3 - Ethyl - 1 - pentene	-4.1071	5.7416×10^2	8.9597×10^{-3}	-1.2981×10^{-5}	146 to 530
C_7H_{14}	1 - Heptene	-8.3002	1.0763×10^3	2.0357×10^{-2}	-1.0906×10^{-5}	250 to 537
C_7H_{14}	Cis - 2 - Heptene	-4.1620	5.9928×10^2	8.8279×10^{-3}	-2.0890×10^{-5}	164 to 549
C_7H_{14}	Trans - 2 - Heptene	-4.4221	6.2108×10^2	9.8018×10^{-3}	-1.0428×10^{-5}	164 to 543
C_7H_{14}	Cis - 3 - Heptene	-3.4630	5.2468×10^2	6.8238×10^{-3}	-1.1566×10^{-5}	137 to 545
C_7H_{14}	Trans - 3 - Heptene	-3.6419	5.3868×10^2	7.5309×10^{-3}	-9.5346×10^{-6}	137 to 540
C_7H_{14}	Methyl cyclo hexane	-1.9879	5.0806×10^2	1.2152×10^{-3}	-2.7318×10^{-6}	248 to 572
C_7H_{14}	2 - Methyl - 1 - hexene	-4.9412	6.6561×10^2	1.1296×10^{-2}	-1.2911×10^{-5}	170 to 538

<i>Formula</i>	<i>Name</i>	<i>A'</i>	<i>B'</i>	<i>C'</i>	<i>D'</i>	<i>Temperature Range, K</i>
C ₇ H ₁₄	3 – Methyl – 1 – hexene	-4.0259	5.6592 x 10 ²	8.7407 x 10 ⁻³	-1.0790 x 10 ⁻⁵	145 to 528
C ₇ H ₁₄	4 – Methyl – 1 – hexene	-3.4368	5.1940 x 10 ²	6.8729 x 10 ⁻³	-8.9153 x 10 ⁻⁶	132 to 534
C ₇ H ₁₄	2,3,3 – Tri methyl – 1 – butene	-3.3759	4.5743 x 10 ²	7.5119 x 10 ⁻³	-9.9892 x 10 ⁻⁶	163 to 531
C ₇ H ₁₄ O	Di iso propyl ketone	-6.0698	9.6613 x 10 ²	1.2535 x 10 ⁻²	-1.2504 x 10 ⁻⁵	205 to 576
C ₇ H ₁₄ O	2 - Heptanone	-6.3072	1.0186 x 10 ³	1.2947 x 10 ⁻²	-1.2369 x 10 ⁻⁵	250 to 612
C ₇ H ₁₄ O	1 - Heptanal	-1.5042	3.8309 x 10 ²	2.2617 x 10 ⁻³	-5.1258 x 10 ⁻⁶	230 to 603
C ₇ H ₁₄ O	1 – Methyl cyclo hexanal	2.8090	8.1555 x 10 ²	-1.8028 x 10 ⁻²	1.5145 x 10 ⁻⁵	299 to 603
C ₇ H ₁₄ O	Cis – 2 – Methyl cyclo hexanol	-61.1284	9.7604 x 10 ³	1.2667 x 10 ⁻¹	-8.9897 x 10 ⁻⁵	298 to 614
C ₇ H ₁₄ O	Trans – 2 – methyl cyclo hexanol	-69.3044	1.1008 x 10 ⁴	1.4418 x 10 ⁻¹	-1.0213 x 10 ⁻⁴	280 to 616
C ₇ H ₁₄ O	Cis – 3 – Methyl cyclo hexanol	-47.3336	7.8174 x 10 ³	9.5221 x 10 ⁻²	-6.6657 x 10 ⁻⁵	289 to 618
C ₇ H ₁₄ O	Trans – 3 – Methyl cyclo hexanol	-56.2704	9.1353 x 10 ³	1.1490 x 10 ⁻¹	-8.0775 x 10 ⁻⁵	289 to 617
C ₇ H ₁₄ O	Cis – 4 – Methyl cyclo hexanol	-1.1605	1.2470 x 10 ³	-7.1483 x 10 ⁻³	6.1622 x 10 ⁻⁶	298 to 622
C ₇ H ₁₄ O	Trans – 4 – Methyl cyclo hexanol	2.2649	8.3276 x 10 ²	-1.5347 x 10 ⁻²	1.2225 x 10 ⁻⁵	298 to 622
C ₇ H ₁₄ O	5 – Methyl – 2 – hexanone	-6.0147	9.7149 x 10 ²	1.2143 x 10 ⁻²	-1.1693 x 10 ⁻⁵	199 to 601
C ₇ H ₁₄ O ₂	n – Butyl propionate	-5.3815	9.0843 x 10 ²	1.0671 x 10 ⁻²	-1.0766 x 10 ⁻⁵	184 to 594
C ₇ H ₁₄ O ₂	Ethyl iso valerate	-4.5111	8.0507 x 10 ²	8.2414 x 10 ⁻³	-8.6925 x 10 ⁻⁶	174 to 588
C ₇ H ₁₄ O ₂	Iso pentyl acetate	-4.6434	8.2935 x 10 ²	8.6638 x 10 ⁻³	-9.0386 x 10 ⁻⁶	195 to 599
C ₇ H ₁₄ O ₂	n – Pentyl acetate	-6.3879	1.0379 x 10 ³	1.3281 x 10 ⁻²	-1.2904 x 10 ⁻⁵	223 to 598

Formula	Name	A'	B'	C'	D'	Temperature Range, K
C ₇ H ₁₄ O ₂	n – Propyl – n – butyrate	-5.3652	9.0990 x 10 ²	1.0578 x 10 ⁻²	-1.0705 x 10 ⁻⁵	273 to 594
C ₇ H ₁₄ O ₂	n - Heptanoic acid	-7.2247	1.4530 x 10 ³	1.3212 x 10 ⁻²	-1.1316 x 10 ⁻⁵	280 to 680
C ₇ H ₁₄ O ₃	Ethyl – 3 – ethoxy propionate	-8.0517	1.3544 x 10 ³	1.6245 x 10 ⁻²	-1.4468 x 10 ⁻⁵	223 to 609
C ₇ H ₁₅ Br	1 – Bromo heptane	-5.9893	1.0290 x 10 ³	1.1969 x 10 ⁻²	-1.0905 x 10 ⁻⁵	240 to 651
C ₇ H ₁₅ N	n – Methyl cyclo hexyl amine	-7.3265	1.4620 x 10 ³	1.2053 x 10 ⁻²	-9.8197 x 10 ⁻⁶	265 to 622
C ₇ H ₁₆	2,2 – Di methyl pentane	-2.8909	5.7125 x 10 ²	3.5976 x 10 ⁻³	-5.2719 x 10 ⁻⁶	149 to 521
C ₇ H ₁₆	2,3 – Di methyl pentane	-3.4160	5.9455 x 10 ²	5.8631 x 10 ⁻³	-7.5893 x 10 ⁻⁶	160 to 537
C ₇ H ₁₆	2,4 – Di methyl pentane	-4.2276	6.8593 x 10 ²	8.0689 x 10 ⁻³	-9.8333 x 10 ⁻⁶	170 to 520
C ₇ H ₁₆	3,3 – Di methyl pentane	-2.9875	5.5438 x 10 ²	4.4350 x 10 ⁻³	-6.1370 x 10 ⁻⁶	139 to 536
C ₇ H ₁₆	3 – Ethyl pentane	-4.3369	6.3373 x 10 ²	9.0780 x 10 ⁻³	-1.0576 x 10 ⁻⁵	155 to 541
C ₇ H ₁₆	n – Heptane	-5.7782	8.0587 x 10 ²	1.3355 x 10 ⁻²	-1.4794 x 10 ⁻⁵	183 to 540
C ₇ H ₁₆	2 – Methyl hexane	-7.2033	9.7969 x 10 ²	1.6986 x 10 ⁻²	-1.7924 x 10 ⁻⁵	273 to 530
C ₇ H ₁₆	3 – Methyl hexane	-4.2439	6.2293 x 10 ²	8.8962 x 10 ⁻³	-1.0606 x 10 ⁻⁵	154 to 535
C ₇ H ₁₆	2,2,3 – Tri methyl butane	1.0062	1.0680 x 10 ²	-6.3684 x 10 ⁻³	3.1024 x 10 ⁻⁶	249 to 531
C ₇ H ₁₆ O	1 - Heptanol	-13.9237	2.6296 x 10 ³	2.5331 x 10 ⁻²	-1.8972 x 10 ⁻⁵	288 to 632
C ₇ H ₁₆ O	2 - Heptanol	-29.5002	4.7658 x 10 ³	6.1363 x 10 ⁻²	-4.6360 x 10 ⁻⁵	275 to 588
C ₇ H ₁₆ O	5 – Methyl-1-hexanol	-16.5523	3.0409 x 10 ³	3.0976 x 10 ⁻²	-2.3331 x 10 ⁻⁵	293 to 605
C ₇ H ₁₆ S	n – Heptyl mercaptan	-7.0230	1.1355 x 10 ³	1.4051 x 10 ⁻²	-1.2325 x 10 ⁻⁵	230 to 645
C ₇ H ₁₇ N	1 – Amino heptane	-6.2343	1.1616 x 10 ³	1.1379 x 10 ⁻²	-1.0664 x 10 ⁻⁵	254 to 607

4.3.1.3c Daubert and Danner Form

Daubert and Danner²⁷ utilized the formula:

$$\eta = \exp \left[A + \frac{B}{T} + C \ln T + DT^E \right] \quad (4.41)$$

to represent the dynamic viscosity data (in Pascal second) as a function of temperature (in Kelvin) for a large number of substances. Their representation is summarized in Table 4.20.

Table 4.20. Constants of Eq. (4.41) used for the polynomial representation of the viscosity [Viscosity (η) in Pa.s and Temperature in K]. From: T. E. Daubert and R. P. Danner, Physical and Thermodynamic Properties of Pure Chemicals –Data Compilation Design Institute for Physical Properties Data, AIChE, Taylor and Francis, Washington DC (1989-1994).

Formula	Name	A	B	C	D	E	Viscosity (Min. Temp.)	Viscosity (Max. Temp.)
-	Air	-20.008	285.15	1.784	-6.24 x 10 ⁻²²	10	3.2765 x 10 ⁻⁴ (60.00)	4.2624 x 10 ⁻⁵ (130.00)
Al	Aluminum	-75.254	11425	8.370	-	-	3.1249 x 10 ⁻³ (933.00)	1.5995 x 10 ⁻³ (1273.10)
AlCl ₃	Aluminum chloride	-35.863	3450.5	3.341	-	-	3.7427 x 10 ⁻⁴ (461.45)	2.0728 x 10 ⁻³ (549.15)
Ar	Argon	-8.858	204.3	-0.3831	-1.30 x 10 ⁻²²	10	2.9194 x 10 ⁻⁴ (84.10)	3.8103 x 10 ⁻⁵ (150.00)
BCl ₃	Boron trichloride	-10.362	680.27	0.5638	-	-	2.9131 x 10 ⁻³ (166.15)	3.1655 x 10 ⁻⁴ (284.65)
B ₂ H ₆	Di borane	0.3890	139.98	-1.941	-	-	6.1592 x 10 ⁻⁴ (107.65)	1.3333 x 10 ⁻⁴ (180.65)
BrH	Hydrogen bromide	-11.1633	316.38	0.5619	-	-	9.1481 x 10 ⁻⁴ (186.19)	8.2057 x 10 ⁻⁴ (206.45)
BrNa	Sodium bromide	-9.1070	258.30	-	-	-	1.2870 x 10 ⁻³ (1053.60)	9.3320 x 10 ⁻⁴ (1212.60)
Br ₂	Bromine	16.775	-314.0	-3.9763	-	-	1.3529 x 10 ⁻³ (265.85)	6.0213 x 10 ⁻⁴ (350.00)
CBrClF ₂	Bromo chloro difluoro methane	-6.0014	419.9	-0.5932	-	-	1.6823 x 10 ⁻³ (160.00)	2.4198 x 10 ⁻⁴ (360.00)
CBrCl ₃	Bromo tri chloro methane	-8.7132	1223.8	-0.3353	-	-	3.2996 x 10 ⁻³ (252.15)	5.7217 x 10 ⁻⁴ (378.05)
CBrF ₃	Bromo tri fluoro methane	-17.145	884.8	0.96828	-1.5638 x 10 ⁻²⁶	10	9.418 x 10 ⁻⁴ (170.00)	1.0856 x 10 ⁻⁴ (335.15)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
CBr ₂ F ₂	Di bromo difluoro methane	-9.5595	603.7	-	-	-	1.0967 x 10 ⁻³ (220.0)	5.4237 x 10 ⁻⁴ (295.94)
CClF ₃	Chloro tri fluoro methane	-14.902	673.0	0.6347	-2.70 x 10 ⁻²⁶	10	4.6012 x 10 ⁻⁴ (170.00)	1.3481 x 10 ⁻⁴ (270.00)
CClN	Cyanogen Chloride	-9.6785	99.451	-0.19824	-	-	8.6204 x 10 ⁻⁴ (266.65)	6.6055 x 10 ⁻⁴ (286.00)
CCl ₂ F ₂	Di chloro di fluoro methane	-25.135	116.13	2.2632	-1.2211 x 10 ⁻²⁶	10	1.2549 x 10 ⁻³ (170.00)	8.2577 x 10 ⁻⁵ (380.00)
CCl ₂ O	Phosgene	9.9566	-254.85	-2.9339	-	-	6.8488 x 10 ⁻⁴ (253.15)	8.2577 x 10 ⁻⁵ (380.00)
CCl ₃ F	Tri chloro fluoro methane	-21.734	1234.9	1.7274	-2.20 x 10 ⁻²⁷	10	3.704 x 10 ⁻³ (170.00)	6.5366 x 10 ⁻⁵ (470.00)
CF ₂ O	Carbonyl Fluoride	-10.921	517.25	-0.025461	-	-	5.1954 x 10 ⁻³ (89.56)	2.0974 x 10 ⁻⁴ (200.00)
CF ₄	Carbon tetra Fluoride	-10.477	962.81	-1.0851	-	-	6.0295 x 10 ⁻³ (161.89)	2.6321 x 10 ⁻³ (188.59)
CHBr ₃	Bromo form	-13.586	1295.5	0.5190	-	-	2.3526 x 10 ⁻³ (281.20)	6.2307 x 10 ⁻⁴ (422.35)
CHClF ₂	Chloro difluoro Methane	-29.062	1180.3	29300	-1.58 x 10 ⁻²⁶	10	8.4879 x 10 ⁻⁴ (170.00)	9.2302 x 10 ⁻⁵ (369.30)
CHCl ₂ F	Di chloro fluoro methane	-17.325	968.2	1.0602	-1.86 x 10 ⁻²⁷	10	2.0727 x 10 ⁻³ (170.00)	1.3060 x 10 ⁻⁴ (440.00)
CHCl ₃	Chloroform	-14.109	104.92	0.5377	-	-	1.9511 x 10 ⁻³ (210.08)	3.4096 x 10 ⁻⁴ (353.20)
CH ₃ N	Methyl amine	-26.385	132.62	2.3426	-	-	1.0663 x 10 ⁻³ (179.69)	1.5131 x 10 ⁻⁴ (332.98)
CO	Carbon Monoxide	-4.9735	97.67	-1.1088	-	-	2.6488 x 10 ⁻⁴ (68.55)	6.5153 x 10 ⁻⁵ (131.37)
COS	Carbonyl sulfide	-8.9800	478.5	-0.34802	-	-	8.0039 x 10 ⁻⁴ (134.30)	1.6391 x 10 ⁻⁴ (222.30)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
CHF ₃	Tri fluoro Methane	-20.134	763.3	1.5359	-1.67 x 10 ⁻²⁵	10	4.2804 x 10 ⁻⁴ (170.00)	8.5969 x 10 ⁻⁵ (285.00)
CNH	Hydrogen Cyanide	-21.927	1266.5	1.5927	-	-	2.7535 x 10 ⁻⁴ (259.85)	1.8327 x 10 ⁻⁴ (298.15)
CH ₂ BrCl	Bromo chloro methane	-10.774	999.07	0.014151	-	-	4.9639 x 10 ⁻³ (185.20)	4.2503 x 10 ⁻⁴ (341.20)
CH ₂ Br ₂	Di bromo Methane	-32.680	1935.2	3.3806	-	-	2.7889 x 10 ⁻³ (230.00)	5.7621 x 10 ⁻⁴ (370.10)
CH ₂ Cl ₂	Di chloro Methane	-13.071	940.03	0.3733	-	-	1.4065 x 10 ⁻³ (208.38)	2.3743 x 10 ⁻⁴ (373.93)
CH ₂ F ₂	Di fluoro Methane	-6.1798	536.49	-0.76036	-2.964 x 10 ⁻²⁶	10	5.3466 x 10 ⁻⁴ (200.28)	1.6163 x 10 ⁻⁴ (287.31)
CH ₂ I ₂	Diiodo Methane	-34.410	241.96	3.5698	-	-	3.5533 x 10 ⁻³ (279.25)	7.1407 x 10 ⁻⁴ (455.15)
CH ₂ O ₂	Formic acid	-49.959	346.13	5.6018	-	-	2.3181 x 10 ⁻³ (281.45)	5.4793 x 10 ⁻⁴ (373.15)
CH ₃ Br	Methyl bromide	-20.960	1070.4	1.6309	-	-	1.0765 x 10 ⁻³ (193.15)	2.4719 x 10 ⁻⁴ (340.00)
CH ₃ Cl	Methyl chloride	-25.132	1318.9	2.0810	-4.50 x 10 ⁻²⁷	10	3.0247 x 10 ⁻⁴ (248.9)	5.9470 x 10 ⁻⁵ (403.15)
CH ₃ F	Methyl fluoride	-10.763	4277.8	0.0086309	-	-	5.733 x 10 ⁻⁴ (131.35)	1.991 x 10 ⁻⁴ (194.82)
CH ₃ I	Methyl iodide	-7.759	642.00	-0.3599	-	-	7.6306 x 10 ⁻⁴ (250.00)	4.1333 x 10 ⁻⁴ (315.00)
CH ₃ NO	Formamide	-62.009	447.02	7.2515	-	-	6.4315 x 10 ⁻³ (275.70)	3.4657 x 10 ⁻⁴ (490.00)
CH ₃ NO ₂	Nitro methane	-17.684	1358.0	1.0110	-	-	1.3991 x 10 ⁻³ (244.60)	3.1403 x 10 ⁻⁴ (347.35)
CH ₄	Methane	-6.1572	178.15	-0.95239	-9.0606 x 10 ⁻²⁴	10	2.064 x 10 ⁻⁴ (90.69)	2.2625 x 10 ⁻⁵ (188.00)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
CH ₄ O	Methanol	-7.288	1065.3	-0.6657	-	-	1.8803 x 10 ⁻³ (230.00)	2.265 x 10 ⁻⁴ (375.00)
CO ₂	Carbon dioxide	18.775	-402.9	-4.6854	-7.0 x 10 ⁻²⁶	10	2.3975 x 10 ⁻³ (219.25)	5.4690 x 10 ⁻⁵ (304.19)
CS ₂	Carbon Disulfide	-51.111	2466.5	6.1227	-	-	7.5571 x 10 ⁻⁴ (235.00)	3.0789 x 10 ⁻³ (320.00)
C ₂ BrF ₃	Bromo tri fluoro ethylene	-10.331	1276.5	0.019011	-	-	2.1186 x 10 ⁻² (173.00)	1.4913 x 10 ⁻³ (270.65)
C ₂ Br ₂ F ₄	1,2 – Di bromo fluoro ethylene	6.6790	258.50	-2.5920	-	-	1.9426 x 10 ⁻³ (227.00)	3.2869 x 10 ⁻⁴ (378.00)
C ₂ ClF ₃	Chloro tri fluoro ethylene	-11.101	1198.2	-0.027007	-	-	4.4485 x 10 ⁻¹ (115.00)	1.7408 x 10 ⁻³ (245.30)
C ₂ ClF ₅	Chloro penta fluoro ethane	-27.495	1362.1	2.5520	-2.7252 x 10 ⁻²⁶	10	9.7087 x 10 ⁻⁴ (190.00)	1.2521 x 10 ⁻⁴ (330.00)
C ₂ Cl ₂ F ₄	1,2 – Di chloro tetrafluoro ethane	-5.4262	761.93	-0.89299	-	-	2.8859 x 10 ⁻³ (180.62)	1.5070 x 10 ⁻⁴ (390.00)
C ₂ Cl ₃ F ₃	1,1,2 – tri chloro fluoro ethane	-14.809	1325.5	0.5330	-	-	1.8430 x 10 ⁻³ (236.75)	2.69 x 10 ⁻⁴ (388.71)
C ₂ Cl ₄	Tetra chloro ethylene	-1.9780	555.0	-1.2216	-	-	1.4825 x 10 ⁻³ (250.80)	1.5884 x 10 ⁻⁴ (567.79)
C ₂ Cl ₄ F ₂	1,1,2,2 – tetra – chloro ethylene	-3.4405	1184.0	-1.2548	-	-	1.312 x 10 ⁻³ (299.15)	4.9441 x 10 ⁻⁴ (366.00)
C ₂ Cl ₄ O	Tri chloro acetyl chloride	-11.037	1375.7	-0.019943	-	-	2.2153 x 10 ⁻³ (273.15)	4.8132 x 10 ⁻⁴ (391.15)
C ₂ F ₄	Perfluoro ethylene	-10.753	1026.8	-0.07359	-	-	2.0513 x 10 ⁻² (142.00)	2.6235 x 10 ⁻³ (197.51)
C ₂ F ₅ H	Penta fluoro Ethane	-17.128	1020.4	0.9250	-	-	1.6960 x 10 ⁻³ (170.15)	1.7417 x 10 ⁻⁴ (327.55)
C ₂ F ₆	Hexa fluoro Ethane	-8.5570	446.00	-0.04331	-	-	2.7122 x 10 ⁻⁴ (173.10)	1.9299 x 10 ⁻⁴ (194.95)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
$C_2HBrClF_3$	Halothane	-10.894	1208.1	-0.03697	-	-	3.4133×10^{-3} (233.15)	6.2896×10^{-4} (323.35)
C_2HClF_2	2 – Chloro -1,1 – di fluoro ethylene	-11.172	1053.9	0.0059133	-	-	3.6296×10^{-2} (134.65)	9.128×10^{-4} (245.55)
C_2HCl_3	Tri chloro Ethylene	-20.389	1260.0	1.5179	-	-	9.4156×10^{-2} (250.00)	3.5108×10^{-4} (360.00)
C_2HCl_3O	Di chloro acetyl chloride	-10.476	979.61	-0.053729	-	-	5.5596×10^{-4} (298.00)	2.6599×10^{-4} (382.15)
C_2HCl_5	Penta chloro Ethane	-6.7520	1321.5	-0.66603	-	-	6.731×10^{-3} (244.15)	4.335×10^{-4} (433.03)
$C_2HF_3O_2$	Tri fluoro acetic acid	-22.520	1851.5	1.6233	-	-	1.7867×10^{-3} (257.90)	4.6804×10^{-4} (344.95)
C_2H_2	Acetylene	6.2240	-151.0	-2.6554	-	-	1.9578×10^{-4} (193.15)	9.8192×10^{-5} (273.15)
$C_2H_2Br_4$	1,1,2,2 – Tetra bromo ethane	-7.5336	5578.3	9.0957	-	-	1.3337×10^{-2} (284.12)	4.5149×10^{-4} (513.15)
$C_2H_2Cl_2$	1,1 – Di chloro ethylene	-2.4749	650.68	-1.3232	-	-	8.3183×10^{-3} (150.59)	3.6803×10^{-4} (304.71)
$C_2H_2Cl_2$	Cis - 1,2 – Di chloro ethylene	-13.508	964.23	0.44868	-	-	1.5331×10^{-3} (208.15)	3.3173×10^{-4} (333.65)
$C_2H_2Cl_2$	Trans -1,2 – Di - chloroethylene	-14.078	981.81	0.51300	-	-	1.0038×10^{-3} (223.15)	3.1673×10^{-4} (320.85)
$C_2H_2Cl_2O$	Chloro acetyl Chloride	-11.710	1512.9	-0.01017	-	-	3.1924×10^{-3} (251.15)	4.1585×10^{-4} (379.15)
$C_2H_2Cl_4$	1,1,1,2 – Tetra chloro ethane	-12.211	1425.1	0.15555	-	-	1.2749×10^{-2} (202.94)	4.3200×10^{-4} (403.65)
$C_2H_2Cl_4$	1,1,2,2 – Tetra chloro ethane	-29.579	2285.4	2.7189	-	-	2.5823×10^{-3} (273.15)	3.6844×10^{-4} (453.15)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
$C_2H_2F_2$	1,1 – Di fluoro ethylene	-10.944	676.53	-0.03327	-	-	3.9111×10^{-3} (129.15)	7.7574×10^{-4} (187.50)
$C_2H_2F_4$	1,1,2,2 – Tetra fluoroethane	-12.160	1073.9	-0.003162	-	-	1.7093×10^{-3} (185.00)	3.7656×10^{-4} (250.15)
C_2H_2O	Ketene	-8.4084	535.44	-0.28541	-	-	3.4174×10^{-3} (130.00)	5.4541×10^{-4} (400.00)
$C_2H_2O_2$	Gloxal	-10.899	1010.2	0.036804	-	-	7.5806×10^{-4} (200.00)	5.1877×10^{-4} (360.00)
C_2H_3Br	Vinyl bromide	-4.808	541.8	-0.8667	-	-	1.8248×10^{-3} (180.35)	3.9215×10^{-4} (288.95)
C_2H_3Cl	Vinyl chloride	2.5670	216.6	-2.1018	-	-	2.4851×10^{-3} (130.00)	7.6032×10^{-5} (400.00)
$C_2H_3ClF_2$	1 – Chloro -1,1 – difluoro ethane	15.574	-450.8	-3.8833	-	-	7.0666×10^{-4} (200.00)	1.9633×10^{-4} (360.00)
C_2H_3ClO	Acetyl chloride	6.9885	51.93	-2.6449	-	-	6.0669×10^{-4} (250.00)	2.9168×10^{-4} (323.90)
$C_2H_3ClO_2$	Chloro acetic acid	-228.76	13416	31.551	-	-	2.4928×10^{-3} (333.15)	1.8054×10^{-3} (400.00)
$C_2H_3Cl_3$	1,1,1 – Tri –chloro ethane	-16.455	1460.6	0.77524	-	-	2.0695×10^{-3} (242.75)	2.4500×10^{-4} (423.00)
$C_2H_3Cl_3$	1,1,2 – Tri –chloro ethane	0.3880	736.5	-1.7063	-	-	2.9546×10^{-3} (236.50)	3.8162×10^{-4} (386.50)
C_2H_3F	Vinyl fluoride	-10.330	466.48	-0.005236	-	-	2.0017×10^{-3} (112.65)	3.2347×10^{-4} (200.95)
$C_2H_3F_3$	1,1,1 – Tri –fluoro ethane	-12.234	505.25	0.16084	-	-	2.5011×10^{-4} (161.82)	1.0899×10^{-4} (225.75)
C_2H_3N	Aceto nitrile	14.486	-423.7	-3.6926	-	-	3.7171×10^{-4} (288.15)	2.2748×10^{-4} (354.65)
C_2H_3NO	Hydroxy aceto nitrile	-16.289	3442.7	-0.000524	-	-	2.3073 (201.00)	1.3365×10^{-4} (467.00)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
C_2H_4	Ethylene	-2.4020	194.5	-1.4576	-	-	6.5346×10^{-4} (105.00)	1.0597×10^{-4} (200.00)
$C_2H_4Br_2$	1,2 – Di bromo ethane	-17.582	1635.4	0.9932	-	-	2.0424×10^{-3} (282.85)	5.1198×10^{-4} (404.51)
$C_2H_4Cl_2$	1,1 – Di chloro ethane	-8.9910	870.2	-0.2805	-	-	4.0760×10^{-3} (176.19)	3.4065×10^{-4} (330.45)
$C_2H_4Cl_2$	1,2 – Di chloro ethane	8.8750	264.0	-2.9714	-	-	1.6717×10^{-3} (245.00)	7.8187×10^{-5} (560.00)
$C_2H_4F_2$	1,1 – Di fluoro ethane	22.332	-754.61	-4.9405	-	-	3.6762×10^{-4} (242.55)	1.7859×10^{-4} (333.15)
$C_2H_4N_2$	Amino acetonitrile	-12.634	1575.3	0.00026104	-	-	2.6549×10^{-3} (250.00)	1.6867×10^{-4} (425.00)
$C_2H_4N_2O_6$	Ethylene gly-col dinitrate	-14.694	8272.3	19.936	-	-	1.4042×10^{-2} (260.00)	1.1738×10^{-3} (380.00)
C_2H_4O	Acetaldehyde	54.304	-2050.7	-9.8077	-	-	2.9729×10^{-4} (260.00)	2.3036×10^{-4} (290.00)
C_2H_4O	Ethylene oxide	-18.557	1015.6	1.2098	-	-	1.0448×10^{-3} (190.00)	2.2381×10^{-4} (320.00)
$C_2H_4O_2$	Acetic acid	-9.0300	1212.3	-0.332	-	-	1.2654×10^{-3} (289.81)	3.8903×10^{-4} (391.05)
$C_2H_4O_2$	Methyl formate	-44.497	2301.1	5.0483	-	-	5.9998×10^{-4} (250.00)	2.7857×10^{-4} (320.00)
$C_2H_4O_2S$	Thio glycolic Acid	-12.042	1714.2	0.0005885	-	-	4.7028×10^{-3} (256.65)	1.9138×10^{-3} (493.00)
$C_2H_4O_3$	Glycolic acid	-225.11	15017.0	30.170	-	-	3.8285×10^{-3} (352.65)	2.0940×10^{-3} (372.00)
$C_2H_4O_3$	Para acetic acid	20.205	-129.49	-4.6627	-	-	1.2017×10^{-3} (293.15)	4.2884×10^{-4} (373.15)
C_2H_5Br	Ethyl bromide	-8.3081	764.58	-0.37699	-	-	5.1891×10^{-3} (154.55)	3.2947×10^{-4} (311.50)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
C ₂ H ₅ Cl	Ethyl chloride	-10.216	702.0	-0.07200	-	-	2.7483 x 10 ⁻³ (150.00)	1.5671 x 10 ⁻⁴ (373.15)
C ₂ H ₅ ClO	2 - Chloro ethanol	-44.294	3703.3	4.5470	-	-	1.4616 x 10 ⁻² (250.00)	4.7550 x 10 ⁻⁴ (401.75)
C ₂ H ₅ ClO	Chloro methyl methyl ether	-10.956	839.51	0.0004119	-	-	2.4654 x 10 ⁻³ (169.65)	2.1824 x 10 ⁻⁴ (332.65)
C ₂ H ₅ F	Ethyl fluoride	-10.758	558.81	-0.016459	-	-	1.4775 x 10 ⁻³ (129.95)	2.0872 x 10 ⁻⁴ (235.45)
C ₂ H ₅ I	Ethyl iodide	-6.7990	691.3	-0.05289	-	-	7.2191 x 10 ⁻⁴ (273.00)	3.7478 x 10 ⁻⁴ (345.45)
C ₂ H ₅ N	Ethylene imine	-11.612	967.4	-	-	-	7.9085 x 10 ⁻⁴ (250.00)	3.1299 x 10 ⁻⁴ (329.00)
C ₂ H ₅ NO	Acetamide	3.2700	1443.0	-2.3150	-	-	1.9423 x 10 ⁻³ (354.15)	2.8319 x 10 ⁻⁴ (494.15)
C ₂ H ₅ NO	N - Methyl - Formamide	9.9223	466.32	-3.1375	-	-	2.7288 x 10 ⁻³ (269.35)	2.2196 x 10 ⁻⁴ (472.66)
C ₂ H ₅ NO ₂	Nitro ethane	-4.4380	746.5	-0.9385	-	-	3.4205 x 10 ⁻³ (200.00)	3.0273 x 10 ⁻⁴ (387.22)
C ₂ H ₆	Ethane	-3.1434	197.05	-1.2193	-9.2023 x 10 ⁻²⁶	10	90.35 x 10 ⁻³ (90.35)	3.5196 x 10 ⁻⁵ (300.00)
C ₂ H ₆ O	Di methyl ether	-10.620	448.99	8.3967 x 10 ⁻⁵	-	-	7.3982 x 10 ⁻⁴ (131.65)	1.721 x 10 ⁻⁴ (230.00)
C ₂ H ₆ O	Ethanol	8.0490	776.0	-3.068	-	-	3.9570 x 10 ⁻³ (240.00)	1.4173 x 10 ⁻⁴ (440.00)
C ₂ H ₆ OS	Di methyl sulfoxide	-68.744	4434.0	8.3724	-	-	2.4217 x 10 ⁻³ (291.67)	4.1902 x 10 ⁻⁴ (462.15)
C ₂ H ₆ O ₂	Ethylene glycol	-10.352	7563.0	13.009	-	-	1.1650 x 10 ⁻¹ (260.93)	7.1975 x 10 ⁻⁴ (449.82)
C ₂ H ₆ S	Ethyl mercaptan	-9.7574	729.43	-0.14912	-	-	9.5198 x 10 ⁻³ (125.26)	2.6895 x 10 ⁻⁴ (305.26)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
C ₂ H ₆ S ₂	Di methyl sulfide	-10.577	1172.6	-014244	-	-	6.0934 x 10 ⁻³ (188.44)	2.3363 x 10 ⁻⁴ (382.90)
C ₂ H ₇ N	Di methyl amine	-10.930	699.5	-	-	-	3.3174 x 10 ⁻⁴ (239.65)	1.7338 x 10 ⁻⁴ (308.15)
C ₂ H ₇ N	Ethyl amine	-14.342	1166.5	0.3714	-	-	1.8030 x 10 ⁻³ (192.15)	2.7181 x 10 ⁻⁴ (289.73)
C ₂ H ₇ NO	Mono ethanol amine	-8.5830	3152.0	-1.0266	-	-	3.1481 x 10 ⁻² (288.15)	4.3307 x 10 ⁻⁴ (444.15)
C ₂ H ₈ N ₂	Ethyl edene amine	-70.088	4954.8	8.2824	-	-	1.6350 x 10 ⁻³ (303.15)	1.7603 x 10 ⁻⁴ (483.15)
C ₂ N ₂	Cyanogen	-11.518	4423.2	-1.8618	-	-	2.4073 x 10 ⁻² (245.25)	6.1536 x 10 ⁻⁴ (300.00)
C ₃ F ₆	Hexa fluororo propylene	-11.792	1093.9	0.058382	-	-	1.1806 x 10 ⁻¹ (116.66)	9.3059 x 10 ⁻⁴ (245.88)
C ₃ F ₆ O	Hexa fluoro acetone	-11.486	988.93	0.027866	-	-	9.5494 x 10 ⁻³ (147.70)	6.6842 x 10 ⁻⁴ (245.88)
C ₃ F ₈	Octa fluoro propane	-11.581	1012.0	0.023038	-	-	3.3261 x 10 ⁻² (125.46)	7.6609 x 10 ⁻⁴ (236.40)
C ₃ H ₃ N	Aceto nitrile	-2.9660	473.0	-1.1632	-	-	6.3350 x 10 ⁻⁴ (240.00)	1.6877 x 10 ⁻⁴ (390.00)
C ₃ H ₄	Methyl acetylene	2.8737	301.35	-1.2271	-	-	6.0450 x 10 ⁻⁴ (170.45)	8.8458 x 10 ⁻⁵ (373.15)
C ₃ H ₄	Propadiene	8.4279	-163.83	-2.9373	-	-	4.7245 x 10 ⁻⁴ (173.15)	1.0886 x 10 ⁻⁴ (333.15)
C ₃ H ₄ O	Acrolein	-12.032	867.34	0.19534	-	-	8.3797 x 10 ⁻⁴ (222.89)	2.1813 x 10 ⁻⁴ (353.22)
C ₃ H ₄ O	Propargyl alcohol	-12.265	2151.4	-0.26367	-	-	1.8887 x 10 ⁻² (221.35)	2.5529 x 10 ⁻⁴ (386.75)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
C ₃ H ₄ O ₂	Acrylic acid	-28.120	2280.2	2.3956	-	-	1.1909 x 10 ⁻³ (293.15)	2.0860 x 10 ⁻⁴ (460.00)
C ₃ H ₄ O ₂	β-Propio actone	-2.4776	467.94	-1.1975	-	-	8.3537 x 10 ⁻⁴ (293.75)	1.0355 x 10 ⁻⁴ (548.00)
C ₃ H ₄ O ₂	Vinyl formate	-10.949	831.17	0.041756	-	-	1.3991 x 10 ⁻³ (200.00)	3.003 x 10 ⁻⁴ (320.00)
C ₃ H ₄ O ₃	Ethylene carbonate	-11.653	1442.7	-	-	-	9.0006 x 10 ⁻⁴ (310.93)	4.2003 x 10 ⁻⁴ (372.04)
C ₃ H ₄ O ₃	Pyruvic acid	-12.283	1962.7	0.031355	-	-	3.0036 x 10 ⁻³ (286.75)	2.8593 x 10 ⁻⁴ (438.15)
C ₃ H ₅ Cl	2 - Chloro - propene	-10.756	794.25	0.0041346	-	-	7.5601 x 10 ⁻³ (135.75)	3.1994 x 10 ⁻⁴ (295.80)
C ₃ H ₅ Cl	3 - Chloro - propene	0.3060	353.0	-1.6754	-	-	5.3531 x 10 ⁻⁴ (250.00)	2.6424 x 10 ⁻⁴ (318.11)
C ₃ H ₅ ClO	α - Epichloro hydrin	-14.616	1394.6	0.54437	-	-	4.3969 x 10 ⁻³ (223.32)	3.2761 x 10 ⁻⁴ (422.48)
C ₃ H ₅ ClO ₂	Methyl Chloro acetate	-9.9576	1254.5	-0.19571	-	-	2.9489 x 10 ⁻³ (241.03)	3.2931 x 10 ⁻⁴ (402.97)
C ₃ H ₅ Cl ₃	1,2,3 - Tri -chloro propane	9.6558	-1777.0	-18.344	-	-	4.2641 x 10 ⁻³ (258.45)	5.1280 x 10 ⁻⁴ (430.00)
C ₃ H ₅ N	Propio nitrile	-5.7136	703.6	-0.78123	-	-	7.3714 x 10 ⁻⁴ (250.00)	1.7772 x 10 ⁻⁴ (400.00)
C ₃ H ₅ NO	Acryl amide	-12.309	2239.4	-0.02281	-	-	2.0669 x 10 ⁻³ (357.65)	4.8036 x 10 ⁻⁴ (465.75)
C ₃ H ₅ NO	Hydrocrylo nitrile	-12.242	1433.6	0.028477	-	-	3.1003 x 10 ⁻³ (227.15)	1.0472 x 10 ⁻⁴ (449.15)
C ₃ H ₆	Cyclo popane	-3.0761	291.39	-1.1627	-	-	1.0428 x 10 ⁻³ (145.59)	1.4175 x 10 ⁻⁴ (318.33)
C ₃ H ₆	Propylene	-44.830	1337.0	5.6710	-	-	1.1608 x 10 ⁻² (90.00)	2.8430 x 10 ⁻⁴ (220.00)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
$C_3H_6Cl_2$	1,2 - Di chloro ethane	11.269	1195.3	0.012736	-	-	1.3808×10^{-2} (172.71)	3.7131×10^{-4} (362.21)
C_3H_6O	Acetone	-14.918	1023.4	0.05961	-	-	8.8134×10^{-4} (223.15)	2.3506×10^{-4} (329.44)
C_3H_6O	Methyl - vinyl ether	-10.340	519.61	-0.013899	-	-	9.3774×10^{-4} (151.15)	1.9287×10^{-4} (278.65)
C_3H_6O	N - Propan aldehyde	13.392	-143.28	-3.6775	-	-	3.9302×10^{-4} (280.00)	2.4387×10^{-4} (352.00)
C_3H_6O	1,2 - Propylene oxide	-11.967	1143.5	-	-	-	1.9314×10^{-3} (200.00)	2.6313×10^{-4} (307.05)
C_3H_6O	1,3 - Propylene oxide	3.7240	-39.795	-2.1038	-	-	3.0666×10^{-4} (255.00)	1.1634×10^{-4} (416.00)
$C_3H_6O_2$	Acetol	-15.673	3180.7	-0.00011	-	-	3.8532×10^{-2} (256.15)	3.1087×10^{-4} (418.65)
$C_3H_6O_2$	Ethyl formate	-9.8417	876.4	-0.17089	-	-	7.4348×10^{-4} (245.00)	2.4864×10^{-4} (345.00)
$C_3H_6O_2$	Methyl acetate	13.557	-187.3	-3.6592	-	-	6.1350×10^{-4} (250.00)	1.1982×10^{-4} (425.00)
$C_3H_6O_2$	Propionic acid	-11.010	1166.6	-0.12281	-	-	2.1161×10^{-3} (252.45)	3.2737×10^{-4} (424.32)
$C_3H_6O_3$	Lactic acid	-13.699	4061.3	-0.54266	-	-	5.9084×10^{-2} (291.15)	3.6161×10^{-4} (447.00)
$C_3H_6O_3$	Tri oxane	-11.434	1487.3	-	-	-	1.2803×10^{-1} (335.15)	1.1423×10^{-1} (387.65)
C_3H_7Br	1 - Bromo propane	-5.4186	659.2	-0.7734	-	-	1.9886×10^{-3} (200.00)	3.2861×10^{-4} (344.15)
C_3H_7Br	2 - Bromo- propane	-90.325	4411.7	11.912	-	-	1.0012×10^{-3} (250.00)	3.7511×10^{-4} (332.56)
C_3H_7Cl	Iso propyl chloride	-15.458	1086.0	0.6540	-	-	5.5154×10^{-4} (250.00)	2.7674×10^{-4} (308.85)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
C_3H_7Cl	n - Propyl chloride	-28.768	1624.4	2.6912	-	-	6.0454×10^{-4} (250.00)	2.8427×10^{-4} (319.67)
C_3H_7I	Iso propyl Iodide	-0.8513	529.0	-1.4480	-	-	1.7595×10^{-3} (225.00)	3.6122×10^{-4} (362.65)
C_3H_7I	n - Propyl iodide	-10.638	984.0	0.1460	-	-	1.5680×10^{-3} (240.00)	3.5920×10^{-4} (357.60)
C_3H_7N	Allyl amine	-11.869	1208.5	-0.0145	-	-	4.4694×10^{-3} (184.95)	2.6100×10^{-4} (326.45)
C_3H_7NO	N,N -Di methyl formamide	-33.604	2173.0	3.3728	-	-	2.3234×10^{-3} (240.00)	3.0866×10^{-4} (375.60)
$C_3H_7NO_2$	1 - Nitro propane	-24.521	1788.6	1.9988	-	-	2.2121×10^{-3} (240.00)	3.0350×10^{-4} (326.45)
$C_3H_7NO_2$	2 - Nitro propane	-5.4102	833.52	-0.81426	-	-	6.3279×10^{-3} (181.83)	2.8686×10^{-4} (426.15)
C_3H_8	Propane	-6.9281	420.76	-0.63276	-1.713x10 ⁻²⁶	10	8.0682×10^{-3} (85.47)	4.0666×10^{-5} (360.00)
C_3H_8O	Iso propanol	-8.2300	2282.2	-0.98495	-	-	3.0037×10^{-1} (187.35)	5.1389×10^{-5} (354.45)
C_3H_8O	Methyl ethyl ether	-11.104	627.18	0.036581	-	-	2.7069×10^{-4} (133.15)	1.7036×10^{-4} (280.50)
C_3H_8O	n - Propanol	0.5710	1521.0	-2.0894	-	-	2.2713×10^{-2} (220.00)	2.0440×10^{-4} (425.00)
$C_3H_8O_2$	2 - Methoxy ethanol	-3.4217	1792.6	-1.5878	-	-	2.8227×10^{-2} (214.05)	1.1009×10^{-4} (448.05)
$C_3H_8O_2$	Methylol	-15.046	954.97	0.6630	-	-	2.5423×10^{-3} (168.35)	2.8904×10^{-4} (308.35)
$C_3H_8O_2$	1,2 - Proplene glycol	-293.07	17494	40.576	-	-	2.4359×10 (233.00)	1.7852×10^{-3} (420.00)
$C_3H_8O_2$	1,3 - Proplene glycol	-14.436	3177.9	0.012322	-	-	2.2914×10^{-1} (246.45)	3.9303×10^{-4} (487.55)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
C ₃ H ₈ O ₃	Glycerol	-237.03	16739	31.734	-	-	1.4068 (293.15)	1.7685 x 10 ⁻³ (500.00)
C ₃ H ₉ N	Iso propyl amine	-31.157	1926.0	2.9250	-	-	4.5436 x 10 ⁻⁴ (273.15)	1.2135 x 10 ⁻⁴ (453.15)
C ₃ H ₉ N	n - Propyl amine	-12.665	1281.8	0.088169	-	-	4.2480 x 10 ⁻³ (190.15)	2.8277 x 10 ⁻⁴ (321.65)
C ₃ H ₉ N	Tri methyl amine	10.142	-130.41	-3.2199	-	-	5.1564 x 10 ⁻⁴ (200.00)	1.6116 x 10 ⁻⁴ (308.15)
C ₃ H ₉ NO	1 - Amino - 2 - ropanol	-19.063	4559.2	-	-	-	8.3956 x 10 ⁻² (274.89)	1.9851 x 10 ⁻⁴ (432.16)
C ₃ H ₉ NO	3 - Amino - 1 - ropanol	-16.567	3638.2	0.0095104	-	-	2.449 x 10 ⁻² (284.15)	1.8215 x 10 ⁻⁴ (460.65)
C ₄ Cl ₆	Hexa chloro -1,3 - butadiene	-11.818	1930.2	0.027303	-	-	1.8097 x 10 ⁻² (225.15)	4.7796 x 10 ⁻⁴ (482.15)
C ₄ F ₈	Octa fluoro - 2 - butene	-11.560	1075.6	0.021432	-	-	2.5511 x 10 ⁻² (138.15)	5.7474 x 10 ⁻⁴ (270.36)
C ₄ F ₈	Octa fluoro cyclo butene	-11.805	1138.6	0.027738	-	-	9.0788 x 10 ⁻⁴ (245.00)	2.6796 x 10 ⁻⁴ (335.00)
C ₄ F ₁₀	Deca fluoro Butene	-11.536	1394.0	-0.015474	-	-	1.3589 x 10 ⁻¹ (144.95)	1.5316 x 10 ⁻³ (271.14)
C ₄ H ₂ O ₃	Maleic anhydride	-1.3320	1053.6	-1.4185	-	-	1.8202 x 10 ⁻³ (326.00)	3.9275 x 10 ⁻⁴ (473.15)
C ₄ H ₄ N ₂	Succino nitrile	-4.8640	1222.0	-0.82114	-	-	2.6355 x 10 ⁻³ (331.16)	4.4560 x 10 ⁻⁴ (531.16)
C ₄ H ₄ O	Furan	-12.149	945.97	0.18419	-	-	1.0535 x 10 ⁻³ (220.00)	3.1288 x 10 ⁻⁴ (313.15)
C ₄ H ₄ O ₃	Succinic anhydride	-10.191	1148.0	-0.12655	-	-	3.269 x 10 ⁻⁴ (393.00)	1.4382 x 10 ⁻⁴ (536.58)
C ₄ H ₄ O ₄	Fumaric acid	-20.013	2771.4	1.0117	-	-	1.7284 x 10 ⁻⁴ (560.15)	1.6150 x 10 ⁻⁴ (570.00)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
C ₄ H ₄ O ₄	Maleic acid	-13.030	2469.5	-	-	-	9.9871 x 10 ⁻⁴ (403.45)	8.9055 x 10 ⁻⁴ (411.15)
C ₄ H ₄ S	Thiophene	-16.671	1342.5	0.8388	-	-	8.6307 x 10 ⁻⁴ (273.15)	2.6354 x 10 ⁻⁴ (393.15)
C ₄ H ₅ Cl	Chloroprene	-11.214	975.27	0.019147	-	-	1.3487 x 10 ⁻² (143.15)	9.9164 x 10 ⁻⁵ (520.00)
C ₃ H ₅ N	Methacrylo nitrile	-7.3519	817.93	-0.53237	-	-	1.0943 x 10 ⁻³ (237.25)	2.7667 x 10 ⁻⁴ (357.35)
C ₄ H ₅ N	Pyrrole	-57.27	3672.0	6.7156	-	-	4.1123 x 10 ⁻³ (249.74)	3.8830 x 10 ⁻⁴ (400.00)
C ₄ H ₅ NO ₂	Methyl cyano acetate	-12.365	1936.4	-	-	-	7.3021 x 10 ⁻³ (260.08)	2.4458 x 10 ⁻⁴ (478.24)
C ₄ H ₆	1,2 - Buta diene	-9.0974	519.05	-0.2131	-9.8 x 10 ⁻²⁸	10	6.4568 x 10 ⁻⁴ (181.45)	8.1887 x 10 ⁻⁵ (431.91)
C ₄ H ₆	1,3 - Buta diene	-17.844	-310.2	-4.5058	-	-	2.5471 x 10 ⁻⁴ (250.00)	4.8797 x 10 ⁻⁵ (400.00)
C ₄ H ₆	Ethyl acetylene	-3.4644	334.50	-1.0811	-	-	5.974 x 10 ⁻⁴ (193.15)	1.2714 x 10 ⁻⁴ (373.15)
C ₄ H ₆ Cl ₂	1,4 - Di chloro trans - 2 - butene	-10.411	595.25	0.016046	-	-	2.8883 x 10 ⁻⁴ (274.15)	1.3275 x 10 ⁻⁴ (429.26)
C ₄ H ₆ O	Trans - Croton aldehyde	-10.398	906.92	0.010129	-	-	2.0505 x 10 ⁻³ (196.65)	2.2693 x 10 ⁻⁴ (377.25)
C ₄ H ₆ O	Di vinyl ether	-12.595	649.52	0.0068511	-	-	9.9124 x 10 ⁻⁴ (172.05)	1.9682 x 10 ⁻⁴ (301.45)
C ₄ H ₆ O	Allyl alcohol	-11.671	200.20	0.5530	-	-	1.7925 x 10 ⁻³ (280.56)	3.8012 x 10 ⁻⁴ (368.39)
C ₄ H ₆ O	Methacrolein	-14.527	909.76	-0.067497	-	-	2.4338 x 10 ⁻³ (192.15)	3.1838 x 10 ⁻⁴ (2.15)
C ₄ H ₆ O ₂	Cis - Crotonic acid	-12.595	1582.3	-	-	-	1.6399 x 10 ⁻³ (288.65)	2.6215 x 10 ⁻⁴ (440.00)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
C ₄ H ₆ O ₂	Trans - Crotonic acid	-11.671	1532.7	-0.0099432	-	-	6.8871 x 10 ⁻⁴ (344.55)	2.2792 x 10 ⁻⁴ (458.15)
C ₄ H ₆ O ₂	Methacrylic acid	-14.527	1497.7	0.5174	-	-	1.4926 x 10 ⁻³ (295.00)	3.6847 x 10 ⁻⁴ (430.00)
C ₄ H ₆ O ₂	Methyl acrylate	10.848	75.0	-3.297	-	-	6.288 x 10 ⁻⁴ (273.00)	1.3801 x 10 ⁻⁴ (420.00)
C ₄ H ₆ O ₂	Vinyl acetate	-22.408	1462.8	1.7006	-	-	7.7163 x 10 ⁻⁴ (250.00)	2.5697 x 10 ⁻⁴ (350.00)
C ₄ H ₆ O ₃	Acetic anhydride	-14.164	1350.3	0.4492	-	-	1.4129 x 10 ⁻³ (265.00)	2.7747 x 10 ⁻⁴ (413.15)
C ₄ H ₆ O ₄	Succinic acid	-10.674	9695.5	13.001	-	-	2.5744 x 10 ⁻³ (460.65)	7.6175 x 10 ⁻⁴ (563.00)
C ₄ H ₆ O ₅	Di glycolic acid	-13.682	2587.0	0.08995	-	-	9.1579 x 10 ⁻⁴ (421.15)	2.4230 x 10 ⁻⁴ (540.00)
C ₄ H ₇ ClO ₂	Ethyl chloro acetate	-10.763	1373.9	0.11382	-	-	2.9346 x 10 ⁻³ (247.15)	2.8649 x 10 ⁻⁴ (417.35)
C ₄ H ₇ N	N - Butyro nitrile	-7.7634	925.92	-0.49345	-	-	1.0787 x 10 ⁻² (161.25)	2.3837 x 10 ⁻⁴ (391.15)
C ₄ H ₇ N	Iso butyro nitrile	-12.142	1060.5	0.1793	-	-	2.6514 x 10 ⁻³ (201.70)	2.5771 x 10 ⁻⁴ (376.76)
C ₄ H ₇ NO	2 - Pyrrolodone	-9.0604	6780.6	11.146	-	-	1.2825 x 10 ⁻² (298.15)	7.5178 x 10 ⁻⁴ (425.00)
C ₄ H ₈	1 - Butene	-2.6725	336.1	-1.286	-	-	8.263 x 10 ⁻⁴ (160.00)	1.7916 x 10 ⁻⁴ (270.00)
C ₄ H ₈	Cis - 2 - Butene	-10.175	664.92	-0.1195	-	-	5.6226 x 10 ⁻⁴ (200.00)	1.3424 x 10 ⁻⁴ (340.00)
C ₄ H ₈	Trans - 2 - butene	-10.175	664.92	-0.1195	-	-	5.6226 x 10 ⁻⁴ (200.00)	1.1960 x 10 ⁻⁴ (360.00)
C ₄ H ₈	Cyclo butene	-2.6678	340.02	-1.1776	-	-	9.7233 x 10 ⁻⁴ (182.48)	1.6640 x 10 ⁻⁴ (367.94)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
C ₄ H ₈	Iso butene	-48.766	1907.0	5.9030	-	-	2.0887 x 10 ⁻⁴ (240.00)	1.2442 x 10 ⁻⁴ (350.00)
C ₄ H ₈ Cl ₂	1,4 - Di chloro butene	-10.09	1245.3	-0.1270	-	-	4.0714 x 10 ⁻³ (235.85)	3.5503 x 10 ⁻⁴ (427.05)
C ₄ H ₈ O	N - Buty- raldehyde	-7.8069	833.79	-0.48339	-	-	5.5863 x 10 ⁻⁴ (275.00)	2.1423 x 10 ⁻⁴ (375.00)
C ₄ H ₈ O	1,2 - Epoxy butane	-9.2718	431.64	-	-	-	1.0345 x 10 ⁻³ (180.00)	3.3906 x 10 ⁻⁴ (336.57)
C ₄ H ₈ O	Ethyl vinyl ether	-8.3337	695.51	-0.43253	-	-	2.2395 x 10 ⁻³ (157.35)	1.9160 x 10 ⁻⁴ (308.70)
C ₄ H ₈ O	Iso butyraldehyde	-10.669	972.04	-0.07416	-	-	1.6699 x 10 ⁻³ (208.15)	2.6963 x 10 ⁻⁴ (337.25)
C ₄ H ₈ O	Methyl ethyl ketone	-8.1340	509.78	-1.5324	-	-	2.1504 x 10 ⁻³ (188.71)	7.645 x 10 ⁻⁵ (533.15)
C ₄ H ₈ O	Tetra hydro furan	-10.335	883.60	-0.05265	-	-	5.3152 x 10 ⁻³ (164.65)	2.9787 x 10 ⁻⁴ (350.00)
C ₄ H ₈ O ₂	Cis - 2 -butene - 1,4 - diol	-13.957	2957.0	-	-	-	2.871 x 10 ⁻² (288.15)	2.9226 x 10 ⁻⁴ (508.15)
C ₄ H ₈ O ₂	N - Butyric acid	-11.696	1488.0	0.033	-	-	2.5818 x 10 ⁻³ (268.00)	3.0787 x 10 ⁻⁴ (436.42)
C ₄ H ₈ O ₂	1,4 - Dioxane	-36.706	2691.5	3.6741	-	-	1.4199 x 10 ⁻³ (288.15)	4.9871 x 10 ⁻⁴ (360.00)
C ₄ H ₈ O ₂	Ethyl acetate	13.216	-97.094	-3.6239	-	-	5.7015 x 10 ⁻⁴ (273.15)	9.0487 x 10 ⁻⁵ (473.15)
C ₄ H ₈ O ₂	Iso butyric acid	-11.497	1365.7	0.036966	-	-	2.9378 x 10 ⁻³ (250.00)	2.6487 x 10 ⁻⁴ (450.00)
C ₄ H ₈ O ₂	Methyl propionate	-4.6795	697.66	-0.94943	-	-	5.7764 x 10 ⁻⁴ (273.15)	2.6403 x 10 ⁻⁴ (349.00)
C ₄ H ₈ O ₂	Propyl ester	-5.2739	774.97	-0.86944	-	-	9.3534 x 10 ⁻⁴ (250.00)	2.3395 x 10 ⁻⁴ (375.00)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
C ₄ H ₈ O ₂	n - Propyl formate	-5.2739	774.97	-0.86944	-	-	9.3534 x 10 ⁻⁴ (250.00)	2.3395 x 10 ⁻⁴ (375.00)
C ₄ H ₈ O ₂ S	Sulfolane	-55.512	4380.0	6.3840	-	-	1.0894 x 10 ⁻² (300.75)	6.8354 x 10 ⁻⁴ (558.15)
C ₄ H ₈ O ₂ S	Tetra hydro thiophene	-10.843	1165.2	-	-	-	1.08941 x 10 ⁻² (293.15)	9.1247 x 10 ⁻⁴ (303.15)
C ₄ H ₉ Br	1 - Bromo butane	-8.5665	874.0	-0.3112	-	-	1.3196 x 10 ⁻³ (240.00)	3.1013 x 10 ⁻⁴ (375.75)
C ₄ H ₉ Br	2 - Bromo butane	-7.4231	818.5	-0.49436	-	-	1.7138 x 10 ⁻³ (220.00)	3.0580 x 10 ⁻⁴ (364.34)
C ₄ H ₉ Cl	n - Butyl chloride	8.9100	49.58	-2.9568	-	-	7.3434 x 10 ⁻⁴ (250.00)	2.5302 x 10 ⁻⁴ (351.58)
C ₄ H ₉ Cl	Sec - Butyl chloride	-42.417	2410.5	4.6466	-	-	8.0959 x 10 ⁻⁴ (250.00)	2.6088 x 10 ⁻⁴ (341.25)
C ₄ H ₉ Cl	Tert - Butyl chloride	-20.527	1630.1	1.2984	-	-	6.1801 x 10 ⁻⁴ (280.00)	3.3977 x 10 ⁻⁴ (323.75)
C ₄ H ₉ N	Pyrrrolidine	-67.242	3754.9	8.3228	-	-	6.1472 x 10 ⁻³ (251.31)	4.0113 x 10 ⁻⁴ (359.72)
C ₄ H ₉ NO	n,n - Di methyl cetamide	22.738	-428.5	-4.967	-	-	1.5933 x 10 ⁻³ (253.15)	2.1134 x 10 ⁻⁴ (439.25)
C ₄ H ₉ NO	Morpholine	-50.434	3611.7	5.6368	-	-	3.1108 x 10 ⁻³ (280.00)	4.7623 x 10 ⁻⁴ (402.09)
C ₄ H ₁₀	N - Butane	-7.2471	534.82	-0.57469	-4.6625 x 10 ⁻²⁷	10	2.2434 x 10 ⁻³ (134.86)	3.5664 x 10 ⁻⁵ (420.00)
C ₄ H ₁₀	Iso butane	-18.345	1020.3	1.0978	-6.1 x 10 ⁻²⁷	10	7.3533 x 10 ⁻⁴ (190.00)	5.2408 x 10 ⁻⁵ (400.00)
C ₄ H ₁₀ N ₂	Piperazine	-13.372	1678.0	0.20512	-	-	3.0171 x 10 ⁻⁴ (379.15)	2.0549 x 10 ⁻⁴ (419.15)
C ₄ H ₁₀ O	n - Butanol	-20.404	2689.0	0.9560	-	-	1.2658 x 10 ⁻² (250.00)	4.0251 x 10 ⁻⁴ (390.81)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
C ₄ H ₁₀ O	Sec - Butanol	-10.638	7434.0	13.285	-	-	4.7932 x 10 ⁻³ (288.15)	4.1659 x 10 ⁻⁴ (373.15)
C ₄ H ₁₀ O	Tert - Butanol	-216.40	13205.0	29.254	-2.4616 x 10 ⁻²⁷	10	4.3119 x 10 ⁻³ (298.15)	1.0137 x 10 ⁻⁴ (451.21)
C ₄ H ₁₀ O	Di ethyl ether	10.197	-63.8	-3.2260	-	-	4.6953 x 10 ⁻⁴ (233.15)	1.1412 x 10 ⁻⁴ (373.15)
C ₄ H ₁₀ O	Iso butanol	-48.035	4306.7	4.8948	-3.5 x 10 ⁻²⁸	10	2.4105 x 10 ⁻¹ (210.93)	4.1665 x 10 ⁻⁵ (544.26)
C ₄ H ₁₀ O ₂	1,3 - Butane diol	-151.99	11386	19.567	-	-	1.3590 x 10 ⁻¹ (293.15)	5.7107 x 10 ⁻⁴ (480.15)
C ₄ H ₁₀ O ₂	1,4 - Butane diol	-76.012	6966.8	8.7765	-	-	9.1615 x 10 ⁻² (293.15)	5.2732 x 10 ⁻⁴ (501.15)
C ₄ H ₁₀ O ₂	1,2 - dimethoxy ethane	-17.949	1257.0	1.0560	-	-	1.6053 x 10 ⁻³ (215.15)	2.6855 x 10 ⁻⁴ (357.20)
C ₄ H ₁₀ O ₂	2 - Ethoxy ethanol	13.653	2393.7	-0.10063	-	-	6.1267 x 10 ⁻² (210.00)	2.2640 x 10 ⁻⁴ (408.15)
C ₄ H ₁₀ O ₃	Di ethylene glycol	-6.2425	5966.9	6.8296	-	-	4.7927 x 10 ⁻² (288.15)	2.5046 x 10 ⁻³ (373.15)
C ₄ H ₁₀ O ₃ S	Di methyl sulfite	-10.902	1138.5	-	-	-	2.1160 x 10 ⁻³ (240.00)	5.8028 x 10 ⁻⁴ (330.00)
C ₄ H ₁₀ S	n - Butyl - mercaptan	-10.175	929.87	-11.533	-	-	7.8046 x 10 ⁻² (157.46)	2.3516 x 10 ⁻⁴ (371.61)
C ₄ H ₁₀ S	Tert - Butyl - mercaptan	29.469	1988.5	2.6988	-	-	8.5252 x 10 ⁻⁴ (274.26)	3.8407 x 10 ⁻⁴ (337.37)
C ₄ H ₁₀ S	Di ethyl sulfide	-5.1350	667.50	-0.8553	-	-	1.1130 x 10 ⁻³ (225.00)	2.3539 x 10 ⁻⁴ (365.25)
C ₄ H ₁₀ S	Sec - Butyl mercaptan	-10.903	932.82	0.023034	-	-	2.2875 x 10 ⁻² (133.02)	2.8505 x 10 ⁻⁴ (358.13)
C ₄ H ₁₁ N	n - Butyl amine	28.975	-564.10	-6.0622	-	-	7.6773 x 10 ⁻⁴ (278.15)	2.8601 x 10 ⁻⁴ (350.85)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
$C_4H_{11}N$	Sec - Butyl amine	-11.397	1353.7	-0.1313	-	-	1.7543×10^{-2} (168.65)	2.9346×10^{-4} (336.15)
$C_4H_{11}N$	Tert - Butyl amine	-98.443	5193.4	12.869	-	-	9.9978×10^{-4} (260.00)	3.5089×10^{-4} (317.55)
$C_4H_{11}N$	Di ethyl amine	-11.854	1111.6	0.01293	-	-	7.8371×10^{-4} (240.00)	2.2456×10^{-4} (329.10)
$C_4H_{11}N$	Iso butyl amine	-12.070	1361.1	-	-	-	1.3260×10^{-3} (250.00)	3.1057×10^{-4} (340.88)
$C_4H_{11}NO_2$	Di ethanol amine	-35.726	6755.5	2.1822	-	-	4.3235×10^{-1} (301.15)	1.5641×10^{-3} (420.00)
$C_4H_{12}N_2O$	n - Amino ethanol amine	-17.993	4955.1	-0.14252	-	-	5.2102×10^{-1} (273.15)	9.1503×10^{-5} (517.00)
$C_4H_{13}N_3$	Di ethylene triamine	-12.658	2157.9	0.0013379	-	-	3.2231×10^{-2} (234.15)	2.8688×10^{-4} (480.25)
C_5Cl_6	Hexa chloro penta diene	-64.926	4699.6	7.7574	-	-	6.9785×10^{-3} (298.15)	1.6742×10^{-3} (373.15)
$C_5H_4O_2$	Furfural	-69.008	3950.4	8.6550	-	-	2.5094×10^{-3} (273.00)	6.4623×10^{-4} (434.85)
C_5H_5N	Pyridine	-51.584	3135.5	5.9733	-	-	4.0141×10^{-3} (231.51)	3.7143×10^{-4} (388.41)
C_5H_6	Cyclo penta diene	-10.330	649.24	-151.25	-	-	9.5051×10^{-4} (188.15)	2.3555×10^{-4} (314.65)
$C_5H_6O_2$	Furfuryl alcohol	-37.008	3555.0	3.4664	-	-	1.8299×10^{-2} (258.52)	3.8512×10^{-4} (443.15)
$C_5H_6O_3$	Glutaric anhydride	-11.367	1264.0	0.033923	-	-	6.6427×10^{-4} (328.00)	1.3560×10^{-4} (562.69)
C_5H_6S	2 - Methyl thiophene	-8.7259	1026.7	-0.35696	-	-	1.3740×10^{-3} (250.00)	2.4481×10^{-4} (385.71)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
C_5H_6S	3 - Methyl - thiophene	-29.553	1913.6	2.7693	-	-	1.6580×10^{-3} (240.00)	1.1690×10^{-4} (340.00)
C_5H_7NO	Ethyl - cyano acetate	-13.965	2369.0	-	-	-	1.0959×10^{-2} (250.65)	1.2087×10^{-4} (479.15)
C_5H_8	Cyclo pentene	-4.8610	426.69	-0.8761	-	-	2.2664×10^{-3} (138.13)	1.1503×10^{-4} (405.60)
C_5H_8	Isoprene	6.6348	-7.8543	-2.6494	-	-	2.5977×10^{-4} (273.00)	1.9062×10^{-4} (307.20)
C_5H_8	Cis -1,3 - Penta diene	-10.387	602.52	-0.030373	-	-	6.6714×10^{-4} (186.35)	1.7294×10^{-4} (317.22)
C_5H_8	Trans -1,3 - Penta diene	-10.261	597.29	-0.049439	-	-	3.9603×10^{-4} (221.71)	1.7508×10^{-4} (315.17)
C_5H_8	1,4 - Penta diene	-10.648	611.36	0.010148	-	-	3.3371×10^{-3} (124.86)	1.9428×10^{-4} (299.11)
C_5H_8	Cyclo pentene	-4.8610	426.69	-0.8761	-	-	2.2664×10^{-3} (138.13)	1.1503×10^{-4} (405.60)
C_5H_8	Isoprene	6.6348	-7.8543	-2.6494	-	-	2.5977×10^{-4} (273.00)	1.9062×10^{-4} (307.20)
C_5H_8	Cis -1,3 - Penta diene	-10.387	602.52	-0.030373	-	-	6.6714×10^{-4} (186.35)	1.7294×10^{-4} (317.22)
C_5H_8	Trans -1,3 - Penta diene	-10.261	597.29	-0.049439	-	-	3.9603×10^{-4} (221.71)	1.7508×10^{-4} (315.17)
C_5H_8	1,4 - Penta diene	-10.648	611.36	0.010148	-	-	3.3371×10^{-3} (124.86)	1.9428×10^{-4} (299.11)
C_5H_8O	Cyclo pentanone	-23.530	5012.0	-	-	-	2.163×10^{-3} (288.15)	6.7204×10^{-5} (360.00)
$C_5H_8O_2$	Acetyl acetone	-10.956	1128.0	-	-	-	1.0848×10^{-3} (273.15)	4.0709×10^{-4} (358.15)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
C ₅ H ₈ O ₂	Allyl acetate	-10.544	1029.8	-0.091748	-	-	1.1639 x 10 ⁻³ (240.00)	2.3455 x 10 ⁻⁴ (377.15)
C ₅ H ₈ O ₂	Ethyl acrylate	0.9132	447.0	-1.7439	-	-	9.8303 x 10 ⁻⁴ (250.00)	1.864 x 10 ⁻⁴ (425.00)
C ₅ H ₈ O ₂	Methyl methacrylate	0.099	496.0	-1.5939	-	-	8.6353 x 10 ⁻⁴ (260.00)	2.290 x 10 ⁻⁴ (400.00)
C ₅ H ₈ O ₂	Vinyl propionate	-11.482	1074.6	0.046541	-	-	1.4205 x 10 ⁻³ (230.00)	2.5914 x 10 ⁻⁴ (364.35)
C ₅ H ₈ O ₃	Levulinic acid	-12.873	2295.7	-0.043631	-	-	3.4372 x 10 ⁻³ (308.15)	1.6296 x 10 ⁻⁴ (518.95)
C ₅ H ₈ O ₃	Methyl aceto acetate	-10.948	1473.6	-0.07408	-	-	1.3207 x 10 ⁻² (210.00)	2.5105 x 10 ⁻⁴ (473.15)
C ₅ H ₈ O ₄	Glutaric acid	-12.676	2236.8	0.072811	-	-	2.0082 x 10 ⁻³ (370.65)	2.4076 x 10 ⁻⁴ (576.15)
C ₅ H ₉ N	Valero nitrile	-6.250	890.0	-0.072811	-	-	9.4115 x 10 ⁻⁴ (275.00)	1.890 x 10 ⁻⁴ (450.00)
C ₅ H ₉ NO	n - Methy - 1,2 - pyrrolidone	-12.503	1850.2	-0.017697	-	-	5.6585 x 10 ⁻³ (249.15)	1.6359 x 10 ⁻⁴ (475.15)
C ₅ H ₉ NO ₄	L - Glutanic acid	-14.627	3325.5	0.092851	-	-	6.3533 x 10 ⁻⁴ (497.15)	1.1630 x 10 ⁻⁴ (670.00)
C ₅ H ₁₀	Cyclo pentane	-3.2612	614.16	-1.156	-	-	1.1220 x 10 ⁻³ (225.00)	3.1669 x 10 ⁻⁴ (325.00)
C ₅ H ₁₀	2 - Methyl - 1 - butene	-10.755	705.48	-0.011113	-	-	3.6165 x 10 ⁻³ (136.00)	2.0343 x 10 ⁻⁴ (304.30)
C ₅ H ₁₀	2 - Methyl - 2 - butene	-8.4453	639.21	-0.38409	-	-	3.1641 x 10 ⁻³ (139.39)	1.8747 x 10 ⁻⁴ (309.39)
C ₅ H ₁₀	3 - Methyl - 1 - butene	-45.435	2289.4	5.1340	-	-	2.6082 x 10 ⁻⁴ (273.15)	1.9039 x 10 ⁻⁴ (305.74)
C ₅ H ₁₀	1 - Pentene	-8.860	692.8	-0.3163	-	-	1.0131 x 10 ⁻³ (175.00)	1.7638 x 10 ⁻⁴ (310.00)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
C ₅ H ₁₀	Cis - 2 - Pentene	-10.738	661.88	0.011126	-	-	5.257 x 10 ⁻³ (121.75)	1.9556 x 10 ⁻⁴ (310.08)
C ₅ H ₁₀	Trans - 2 - Pentene	-10.815	664.14	0.023406	-	-	3.363 x 10 ⁻³ (132.89)	1.9650 x 10 ⁻⁴ (309.49)
C ₅ H ₁₀ Cl ₂	1,5 - Di chloro pentane	-8.15	1242.6	-0.43323	-	-	1.435 x 10 ⁻² (200.35)	3.1169 x 10 ⁻⁴ (453.15)
C ₅ H ₁₀ O	Di ethyl ketone	-2.8695	596.3	-1.2025	-	-	5.8835 x 10 ⁻⁴ (273.16)	2.2854 x 10 ⁻⁴ (371.97)
C ₅ H ₁₀ O	Methyl iso propyl ketone	-11.381	1052.9	0.01703	-	-	4.1687 x 10 ⁻³ (181.1)	2.2135 x 10 ⁻⁴ (367.55)
C ₅ H ₁₀ O	2 - Pentanone	-13.181	1147.0	0.31253	-	-	9.1501 x 10 ⁻⁴ (250.00)	2.3419 x 10 ⁻⁴ (375.46)
C ₅ H ₁₀ O	Valeraldehyde	-10.806	987.12	0.017407	-	-	5.0333 x 10 ⁻³ (182.00)	3.1013 x 10 ⁻⁴ (376.15)
C ₅ H ₁₀ O ₂	n - Butyl formate	-17.801	1497.8	0.9533	-	-	1.4356 x 10 ⁻³ (250.00)	2.8680 x 10 ⁻⁴ (375.00)
C ₅ H ₁₀ O ₂	Ethyl propionate	-6.205	836.3	-0.7368	-	-	9.7995 x 10 ⁻⁴ (250.00)	2.3834 x 10 ⁻⁴ (375.00)
C ₅ H ₁₀ O ₂	Iso butyl formate	-16.639	1428.0	0.7826	-	-	6.9879 x 10 ⁻⁴ (289.20)	2.8537 x 10 ⁻⁴ (371.22)
C ₅ H ₁₀ O ₂	Iso propyl acetate	-15.099	1281.5	0.57233	-	-	2.2802 x 10 ⁻³ (215.75)	2.7905 x 10 ⁻⁴ (361.65)
C ₅ H ₁₀ O ₂	Iso valeric acid	-3.857	1331.2	-1.1956	-	-	6.946 x 10 ⁻³ (243.85)	2.7831 x 10 ⁻⁴ (448.25)
C ₅ H ₁₀ O ₂	Methyl - n - butyrate	-12.206	1141.7	0.15014	-	-	3.3392 x 10 ⁻³ (200.00)	2.5391 x 10 ⁻⁴ (375.90)
C ₅ H ₁₀ O ₂	n - Propyl acetate	18.851	-303.96	-4.4468	-	-	5.8334 x 10 ⁻⁴ (293.15)	1.0297 x 10 ⁻⁴ (473.15)
C ₅ H ₁₀ O ₂	Tetra hydro furyl alcohol	8.0669	2748.2	-1.1310	-	-	3.6194 x 10 ⁻² (250.00)	1.4063 x 10 ⁻⁴ (450.00)

Formula	Name	A	B	C	D	E	Viscosity (Min. Temp.)	Viscosity (Max. Temp.)
C ₅ H ₁₀ O ₂	Valeric acid	-37.067	2856.7	3.7344	-	-	2.4704 x 10 ⁻³ (288.15)	5.2573 x 10 ⁻⁴ (400.00)
C ₅ H ₁₀ O ₂ S	3 - Methyl - sulfolane	-72.515	5360.1	8.7917	-	-	1.5237 x 10 ⁻² (290.00)	1.0149 x 10 ⁻³ (450.00)
C ₅ H ₁₀ O ₃	Di ethyl carbonate	-47.078	2783.2	5.3617	-	-	1.7629 x 10 ⁻³ (250.00)	3.3702 x 10 ⁻⁴ (399.95)
C ₅ H ₁₀ O ₃	Ethyl acetate	-22.903	3042.7	1.1815	-	-	1.6877 x 10 ⁻² (247.15)	1.7863 x 10 ⁻⁴ (427.65)
C ₅ H ₁₁ Cl	1 - Chloro pentene	-11.495	1089.5	0.060156	-	-	7.2374 x 10 ⁻³ (174.15)	2.5306 x 10 ⁻⁴ (381.54)
C ₅ H ₁₁ N	n - Methyl pyrrolidine	-11.992	1328.7	-0.013431	-	-	8.1701 x 10 ⁻³ (183.15)	2.4606 x 10 ⁻⁴ (352.30)
C ₅ H ₁₁ N	Piperidine	3.753	817.6	-2.296	-	-	1.7357 x 10 ⁻³ (285.00)	4.3998 x 10 ⁻⁴ (379.55)
C ₅ H ₁₂	Iso pentane	-12.596	889.11	0.20496	-	-	6.9775 x 10 ⁻⁴ (210.00)	1.7745 x 10 ⁻⁴ (320.00)
C ₅ H ₁₂	Neo pentane	-56.062	3029.1	6.5862	-	-	4.3014 x 10 ⁻⁴ (258.15)	2.1716 x 10 ⁻⁴ (303.15)
C ₅ H ₁₂	n - Pentane	-20.383	1054.4	1.4874	-1.01188 x 10 ⁻²²	10	3.4377 x 10 ⁻³ (143.42)	4.7179 x 10 ⁻⁵ (465.15)
C ₅ H ₁₂ O	2,2 - Dimethyl - 1 - propanol	-15.075	3253.1	-0.14998	-	-	2.4795 x 10 ⁻³ (327.15)	5.2817 x 10 ⁻⁴ (368.25)
C ₅ H ₁₂ O	Ethyl propyl ether	0.7109	386.51	-1.7754	-	-	1.1555 x 10 ⁻³ (200.00)	2.0857 x 10 ⁻⁴ (337.01)
C ₅ H ₁₂ O	2 - Methyl - 1 - butanol	-68.504	5455.0	7.850	-	-	1.1169 x 10 ⁻² (273.15)	3.7881 x 10 ⁻⁴ (403.15)
C ₅ H ₁₂ O	2 - Methyl - 2 - butanol	-195.84	11895.0	26.385	-	-	2.5201 x 10 ⁻² (264.35)	4.3758 x 10 ⁻⁴ (375.15)
C ₅ H ₁₂ O	3 - Methyl - 1 - butanol	-38.131	3773.0	3.4876	-	-	8.6295 x 10 ⁻³ (273.15)	3.8731 x 10 ⁻⁴ (403.65)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
C ₃ H ₁₂ O	3 - Methyl - 2 - butanol	24.821	937.0	-5.9198	-	-	1.6294 x 10 ⁻² (250.00)	3.4236 x 10 ⁻⁴ (384.65)
C ₃ H ₁₂ O	Methyl - tert -butyl ether	-7.3165	810.5	-0.59662	-	-	1.0747 x 10 ⁻³ (219.25)	1.0517 x 10 ⁻⁴ (449.93)
C ₃ H ₁₂ O	1 - Pentanol	-22.758	2916.9	1.2839	-	-	1.6075 x 10 ⁻² (253.15)	3.1659 x 10 ⁻⁴ (420.00)
C ₃ H ₁₂ O	2 - Pentanol	-12.233	8149.3	15.678	-	-	4.2116 x 10 ⁻² (250.00)	3.6142 x 10 ⁻⁴ (392.15)
C ₃ H ₁₂ O	3 - Pentanol	26.244	911.06	-6.1542	-	-	5.4573 x 10 ⁻² (222.15)	3.0264 x 10 ⁻⁴ (388.45)
C ₃ H ₁₂ O ₂	Neo pentyl glycol	-18.174	4809.2	-0.24754	-	-	4.8366 x 10 ⁻⁴ (400.00)	5.8478 x 10 ⁻⁵ (483.00)
C ₃ H ₁₂ O ₂	1,5 - Pentene diol	-76.248	7080.9	8.8187	-	-	8.2335 x 10 ⁻⁴ (263.15)	2.2748 x 10 ⁻⁵ (418.15)
C ₃ H ₁₂ O ₃	2-(2-Methoxy - ethoxy) -ethanol	-12.907	2157.6	-	-	-	1.9901 x 10 ⁻¹ (240.00)	4.2227 x 10 ⁻³ (420.00)
C ₃ H ₁₂ O ₄	Pentacrythritol	11.247	727.12	-3.0295	-	-	1.6320 x 10 ⁻³ (534.15)	7.9849 x 10 ⁻⁴ (631.00)
C ₃ H ₁₂ S	n - Pentyl - mercaptan	-9.7415	1016.8	-19.367	-	-	3.6411 x 10 ⁻³ (197.45)	2.3441 x 10 ⁻⁴ (399.79)
C ₃ H ₁₃ N	n - Pentyl amine	-41.834	2849.8	4.4172	-	-	6.8529 x 10 ⁻³ (218.15)	3.1081 x 10 ⁻⁴ (377.65)
C ₃ H ₁₃ NO ₂	Methyl di ethanol amine	-17.633	4360.8	0.094133	-	-	1.1996 (252.15)	1.7329 x 10 ⁻⁴ (520.15)
C ₆ Cl ₆	Hexa chloro benzene	-11.083	2251.7	-0.13581	-	-	5.8768 x 10 ⁻⁴ (501.70)	2.7495 x 10 ⁻⁴ (600.00)
C ₆ F ₆	Hexa fluoro benzene	13.687	1916.0	0.24197	-	-	4.3431 x 10 ⁻³ (278.25)	1.0640 x 10 ⁻³ (353.41)
C ₆ H ₃ Cl ₃	1,2,4 - Tri chloro benzene	-11.525	1654.6	0.0086851	-	-	3.1098 x 10 ⁻³ (290.15)	3.134 x 10 ⁻⁴ (486.15)

Formula	Name	A	B	C	D	E	Viscosity (Min. Temp.)	Viscosity (Max. Temp.)
$C_6H_3Cl_3$	1,3,5 - Tri chloro benzene	-31.798	2400.2	3.4295	-	-	8.9874×10^{-3} (336.65)	4.540×10^{-3} (425.00)
$C_6H_4ClNO_2$	m - Chloro nitro benzene	-38.422	2966.6	3.9615	-	-	2.0989×10^{-3} (317.65)	3.9211×10^{-4} (508.75)
$C_6H_4ClNO_2$	o - Chloro nitro benzene	-12.062	1975.5	-0.038019	-	-	2.9472×10^{-3} (306.15)	2.0483×10^{-4} (519.00)
$C_6H_4ClNO_2$	p - Chloro nitro benzene	-11.409	1747.3	-0.056164	-	-	1.0703×10^{-3} (356.65)	2.3221×10^{-4} (515.15)
$C_6H_4Cl_2$	m - Di chloro benzene	-30.663	2015.7	2.9903	-	-	1.7051×10^{-3} (265.15)	3.6982×10^{-4} (446.23)
$C_6H_4Cl_2$	o - Di chloro benzene	-22.216	1758.2	1.7011	-	-	2.2600×10^{-3} (265.15)	3.5844×10^{-4} (453.57)
$C_6H_4Cl_2$	p - Di chloro benzene	-12.307	1173.4	0.028397	-	-	8.5387×10^{-4} (326.14)	3.4755×10^{-4} (450.00)
C_6H_5Br	Bromo benzene	-12.307	1173.4	0.28397	-	-	2.842×10^{-3} (242.43)	3.3098×10^{-4} (429.24)
C_6H_5Cl	Chloro benzene	-20.611	1656.5	1.4415	-	-	1.419×10^{-3} (250.00)	1.2901×10^{-4} (540.00)
C_6H_5I	Iodo benzene	0.2500	535.2	-1.6207	-	-	1.5989×10^{-3} (232.15)	1.5419×10^{-4} (453.15)
C_6H_5F	Fluoro benzene	-10.064	1058.7	-0.17162	-	-	4.9103×10^{-3} (241.83)	3.4858×10^{-4} (461.48)
$C_6H_5NO_2$	Niacin	-14.539	3181.9	0.02935	-	-	2.9970×10^{-4} (509.65)	2.4706×10^{-4} (526.00)
$C_6H_5NO_2$	Nitro benzene	-34.557	2611.3	3.4283	-	-	3.1379×10^{-3} (273.15)	3.5114×10^{-4} (408.75)
C_6H_6	Benzene	6.7640	336.4	-2.6870	-	-	7.1453×10^{-4} (285.00)	3.3043×10^{-4} (350.00)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
C ₆ H ₆ ClN	m - Chloro aniline	-13.356	2315.4	-7639.1	-	-	1.0190 x 10 ⁻² (262.75)	1.5356 x 10 ⁻⁴ (501.65)
C ₆ H ₆ ClN	o - Chloro aniline	-12.674	2051.3	-0.0034418	-	-	5.9444 x 10 ⁻³ (271.05)	2.1799 x 10 ⁻⁴ (481.05)
C ₆ H ₆ ClN	p - Chloro aniline	-13.271	2456.9	-0.067184	-	-	6.5872 x 10 ⁻⁴ (387.15)	7.8295 x 10 ⁻⁵ (579.00)
C ₆ H ₆ N ₂ O ₂	o - Nitro aniline	-13.683	2589.1	-0.045521	-	-	1.6173 x 10 ⁻³ (344.65)	8.864 x 10 ⁻⁵ (588.00)
C ₆ H ₆ N ₂ O ₂	p - Nitro aniline	-13.311	2356.8	-0.01794	-	-	4.0289 x 10 ⁻⁴ (420.65)	7.0702 x 10 ⁻⁵ (609.15)
C ₆ H ₆ O	Phenol	-6.2600	2083.3	-1.0060	-	-	4.0649 x 10 ⁻³ (318.00)	5.3904 x 10 ⁻⁵ (692.00)
C ₆ H ₆ O ₂	p - Hydroxy quinone	-18.942	6247.2	0.18295	-	-	2.2896 x 10 ⁻² (444.65)	1.3710 x 10 ⁻³ (558.15)
C ₆ H ₆ O ₃	1,2,3 - Benzene triol	-15.785	5100.7	0.089054	-	-	6.6042 x 10 ⁻² (407.00)	1.5778 x 10 ⁻³ (581.85)
C ₆ H ₆ S	Phenyl mercaptan	-7.1338	962.04	-0.50460	-	-	2.0064 x 10 ⁻³ (258.27)	3.2468 x 10 ⁻⁴ (442.29)
C ₆ H ₇ N	Aniline	-98.301	6524.4	1.8548	-	-	1.2347 x 10 ⁻² (267.65)	3.9364 x 10 ⁻⁴ (457.15)
C ₆ H ₇ N	2 - Methyl - pyridine	-23.569	1733.2	-	-	-	3.3907 x 10 ⁻³ (220.00)	2.9202 x 10 ⁻⁴ (402.55)
C ₆ H ₇ N	3 - Methyl - pyridine	-11.299	1270.6	-	-	-	9.4465 x 10 ⁻⁴ (293.15)	5.6139 x 10 ⁻⁴ (335.15)
C ₆ H ₇ N	4 - Methyl - pyridine	-27.006	1981.4	2.3358	-	-	1.2167 x 10 ⁻³ (276.73)	2.8273 x 10 ⁻⁴ (418.50)
C ₆ H ₈	1,4 - Cyclo - hexa diene	-9.9507	683.11	0.65495 x 10 ⁻⁴	-	-	1.0077 x 10 ⁻³ (223.95)	3.1796 x 10 ⁻⁴ (360.15)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
$C_6H_8N_2$	Adipo nitrile	-18.181	2014.8	1.0968	-	-	9.0188×10^{-3} (275.64)	9.8198×10^{-4} (440.00)
$C_6H_8N_2$	m - Phenylene diamine	-16.675	4115.0	-	-	-	4.7787×10^{-3} (363.15)	8.9008×10^{-5} (560.00)
$C_6H_8N_2$	o - Phenylene diamine	-11.882	2507.0	-0.12095	-	-	2.6091×10^{-3} (376.95)	3.8421×10^{-4} (525.00)
$C_6H_8N_2$	P - Phenylene diamine	-12.768	2411.7	0.050809	-	-	1.3301×10^{-3} (413.00)	3.4148×10^{-4} (540.00)
$C_6H_8N_2$	Phenyl hydrazine	-17.931	4052.0	-	-	-	1.7062×10^{-2} (292.35)	4.0933×10^{-4} (400.00)
C_6H_{12}	3-Methyl-trans - 2 - pentene	-10.952	803.91	-0.0004643	-	-	6.8321×10^{-3} (134.70)	1.8137×10^{-4} (343.59)
C_6H_{12}	2,3 - Di methyl - 1 - butene	-10.885	796.97	-0.010151	-	-	1.7313×10^{-2} (115.89)	1.9951×10^{-4} (328.76)
C_6H_{12}	2,3 - Dimethyl - 2 - butene	-10.967	799.28	0.0029181	-	-	9.7463×10^{-4} (198.92)	1.7650×10^{-4} (346.35)
C_6H_{12}	2 - Ethyl - 1 - butene	-10.884	801.83	0.011203	-	-	5.1065×10^{-3} (141.61)	1.8864×10^{-4} (337.82)
C_6H_{12}	1 - Hexene	-6.9090	656.90	-0.062835	-	-	6.8812×10^{-4} (218.15)	1.8651×10^{-4} (333.15)
C_6H_{12}	Cis-2 -Hexene	-10.758	785.54	-0.01590	-	-	7.5623×10^{-3} (132.00)	1.9276×10^{-4} (342.03)
C_6H_{12}	Trans- 2 -Hexene	-10.862	788.68	-0.0003783	-	-	5.3346×10^{-3} (140.17)	1.9411×10^{-4} (341.02)
C_6H_{12}	Methyl cyclo pentane	-18.553	612.62	-1.3774	-	-	9.2883×10^{-4} (248.15)	2.7421×10^{-4} (353.15)
C_6H_{12}	2 - Methyl - 1 - pentene	-11.519	991.4	-	-	-	7.4022×10^{-4} (230.00)	1.9127×10^{-4} (335.25)
C_6H_{12}	2 - Methyl - 2 - pentene	-10.914	802.84	-0.0065431	-	-	5.9076×10^{-3} (138.07)	1.8522×10^{-4} (340.45)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
C_6H_{12}	4 - Methyl - 1 - pentene	-10.953	804.13	-0.00046565	-	-	1.4601 x 10 ⁻² (119.51)	2.0415 x 10 ⁻⁴ (327.01)
C_6H_{12}	4 - Methyl - cis- 2 -pentene	-10.680	742.56	-0.031481	-	-	8.7272 x 10 ⁻⁴ (195.35)	1.8243 x 10 ⁻⁴ (329.53)
C_6H_{12}	4 - Methyl -trans- 2-pentene	-10.724	744.61	-0.024965	-	-	9.8541 x 10 ⁻⁴ (189.35)	1.7967 x 10 ⁻⁴ (331.75)
$C_6H_{12}O$	Butyl vinyl ether	-10.676	1044.3	-0.0943	-	-	4.510 x 10 ⁻³ (181.15)	2.2728 x 10 ⁻⁴ (366.97)
$C_6H_{12}O$	Cyclo hexanol	-87.257	7419.6	10.327	-	-	2.3025 x 10 ⁻² (303.15)	4.6253 x 10 ⁻⁴ (450.00)
$C_6H_{12}O$	1 - Hexanol	-10.582	1021.4	-0.55433 x 10 ⁻⁴	-	-	2.7986 x 10 ⁻³ (217.15)	3.2294 x 10 ⁻⁴ (401.45)
$C_6H_{12}O$	2 - Hexanol	-11.477	1188.6	0.0076625	-	-	2.5615 x 10 ⁻³ (217.35)	2.1053 x 10 ⁻⁴ (400.85)
$C_6H_{12}O$	Methyl isobutyl ketone	-33.781	1955.3	3.4673	-	-	1.1803 x 10 ⁻³ (245.89)	3.0559 x 10 ⁻⁴ (393.15)
$C_6H_{12}O_2$	n-Butyl acetate	-5.4020	688.0	-0.7296	-	-	9.0064 x 10 ⁻⁴ (275.00)	1.7403 x 10 ⁻⁴ (400.00)
$C_6H_{12}O_2$	Sec-Butyl acetate	-11.413	1226.9	-0.0056273	-	-	1.2315 x 10 ⁻² (174.15)	2.5840 x 10 ⁻⁴ (385.15)
$C_6H_{12}O_2$	Ethyl - n -butyrate	-15.485	1325.6	0.6432	-	-	1.3186 x 10 ⁻³ (250.00)	2.5328 x 10 ⁻⁴ (394.65)
$C_6H_{12}O_2$	Di acetone alcohol	-325.94	16124	4.6683	-	-	1.5219 x 10 ⁻¹ (229.15)	1.8334 x 10 ⁻³ (370.00)
$C_6H_{12}O_2$	2 -Ethyl butyric acid	-12.240	1836.4	0.021868	-	-	6.7053 x 10 ⁻³ (258.15)	2.8222 x 10 ⁻⁴ (466.95)
$C_6H_{12}O_2$	Propionic acid	-12.494	1254.7	0.14339	-	-	6.9899 x 10 ⁻³ (185.00)	2.3282 x 10 ⁻⁴ (383.00)
$C_6H_{12}O_2$	Hexanoic acid	-50.189	3620.3	5.6486	-	-	5.0047 x 10 ⁻³ (275.00)	6.7902 x 10 ⁻⁴ (400.00)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
C ₆ H ₁₂ O ₂	Iso butyl acetate	24.717	-531.5	-5.3105	-	-	8.7299 x 10 ⁻⁴ (275.00)	2.4140 x 10 ⁻⁴ (390.00)
C ₆ H ₁₂ O ₂	n - Propyl propionate	-15.113	1381.7	0.54867	-	-	5.4685 x 10 ⁻³ (197.25)	2.3891 x 10 ⁻⁴ (395.00)
C ₆ H ₁₂ O ₃	Propylene glycol methyl ether acetate	-12.452	1688.3	-0.011078	-	-	1.3907 x 10 ⁻² (205.00)	2.0631 x 10 ⁻⁴ (418.65)
C ₆ H ₁₂ O ₃	2 - Ethoxy ethyl acetate	-17.334	1778.8	0.7820	-	-	5.5563 x 10 ⁻³ (225.00)	2.1367 x 10 ⁻⁴ (429.45)
C ₆ H ₁₂ O ₃	Paraldehyde	-30.920	2522.9	2.7415	-	-	1.3775 x 10 ⁻³ (285.75)	2.7821 x 10 ⁻⁴ (400.00)
C ₆ H ₁₂ O ₆	Dextrose	-2267.4	138910	320.55	-	-	2.2252 x 10 ⁻⁶ (323.15)	6.6361 x 10 ⁻¹ (418.15)
C ₆ H ₁₂ S	Cyclo hexyl Mercaptan	-11.338	1304.1	0.924 x 10 ⁻⁴	-	-	1.1553 x 10 ⁻² (189.64)	2.440 x 10 ⁻⁴ (431.95)
C ₆ H ₁₃ N	Cyclo hexyl amine	-11.338	1304.1	3.4662	-	-	2.2376 x 10 ⁻³ (288.15)	4.0462 x 10 ⁻⁴ (405.65)
C ₆ H ₁₃ N	Hexamethylene amine	-35.730	2880.6	-	-	-	1.7256 x 10 ⁻³ (330.15)	3.7679 x 10 ⁻⁴ (411.15)
C ₆ H ₁₄	2,2 - Di methyl butane	24.038	-498.77	-5.3231	-	-	4.999 x 10 ⁻⁴ (269.29)	2.5871 x 10 ⁻⁴ (322.88)
C ₆ H ₁₄	2,3 - Di methyl butane	18.940	-7718.7	-30.095	-	-	4.5661 x 10 ⁻⁴ (273.15)	1.9613 x 10 ⁻⁴ (331.13)
C ₆ H ₁₄	N - Hexane	-20.715	1207.5	1.4993	-	-	2.1182 x 10 ⁻³ (177.83)	2.1541 x 10 ⁻⁴ (343.15)
C ₆ H ₁₄	2 - Methyl - pentane	12.092	-182.7	-3.4502	-	-	4.2232 x 10 ⁻⁴ (257.51)	2.0358 x 10 ⁻⁴ (333.41)
C ₆ H ₁₄	3 - Methyl - pentane	-3.3394	529.14	-1.1568	-	-	4.0784 x 10 ⁻⁴ (265.62)	2.0402 x 10 ⁻⁴ (336.43)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
C ₆ H ₁₄ O	N - Butyl ether	-13.278	1152.9	-1.1568	-	-	6.7474 x 10 ⁻³ (170.15)	2.2597 x 10 ⁻⁴ (365.35)
C ₆ H ₁₄ O	Di iso propyl ether	-11.500	993.0	0.29272	-	-	2.2585 x 10 ⁻³ (187.65)	2.1104 x 10 ⁻⁴ (341.45)
C ₆ H ₁₄ O	Di - n - Propyl ether	-8.2119	893.52	0.02200	-	-	1.0516 x 10 ⁻² (149.95)	2.1249 x 10 ⁻⁴ (362.79)
C ₆ H ₁₄ O	2 - Ethyl - 1 - butanol	-9.2253	2722.5	-0.45940	-	-	7.2023 x 10 ⁻² (236.75)	2.8693 x 10 ⁻⁴ (419.65)
C ₆ H ₁₄ O	1 - Hexanol	-38.503	3810.4	-0.89719	-	-	8.9570 x 10 ⁻³ (278.15)	3.4387 x 10 ⁻⁴ (428.15)
C ₆ H ₁₄ O	Methyl - tert - pentyl ether	-11.276	991.96	3.5693	-	-	5.6725 x 10 ⁻³ (160.00)	1.7911 x 10 ⁻⁴ (359.45)
C ₆ H ₁₄ O	2 - Methyl - 1 - pentanol	-95.728	7010	-0.18892	-	-	2.0010 x 10 ⁻² (270.00)	3.3550 x 10 ⁻⁴ (421.15)
C ₆ H ₁₄ O	4 - Methyl - 2 - pentanol	-15.465	9891.9	203.56	-	-	9.8527 x 10 ⁻³ (280.00)	3.3248 x 10 ⁻⁴ (404.85)
C ₆ H ₁₄ O ₂	Acetal	-11.059	983.63	203.56	-	-	2.1531 x 10 ⁻³ (200.00)	2.1428 x 10 ⁻⁴ (376.75)
C ₆ H ₁₄ O ₂	2 - Butoxy ethanol	-5.6874	2197.4	-1.2979	-	-	1.7072 x 10 ⁻¹ (203.15)	1.7396 x 10 ⁻⁴ (444.47)
C ₆ H ₁₄ O ₂	1,6 - Hexane diol	-30.062	6665.6	1.0452	-	-	5.3393 x 10 ⁻² (315.15)	2.3973 x 10 ⁻⁵ (516.15)
C ₆ H ₁₄ O ₂	Hexylene glycol	-55.692	13861	-	-	-	6.1595 x 10 ² (223.15)	7.86310 ⁻³ (240.00)
C ₆ H ₁₄ O ₃	Di ethylene glycol di methyl ether	-12.272	1422.3	0.10585	-	-	9.0202 x 10 ⁻³ (203.15)	2.3782 x 10 ⁻⁴ (432.91)
C ₆ H ₁₄ O ₃	Di propylene glycol	-21.291	5207.0	0.23598	-	-	10.412 (233.00)	7.4089 x 10 ⁻⁵ (504.95)
C ₆ H ₁₄ O ₃	2 - (2 -Ethoxy ethoxy) ethanol	-13.242	2289.5	-	-	-	2.4664 x 10 ⁻² (240.00)	4.1352 x 10 ⁻⁴ (420.00)

Formula	Name	A	B	C	D	E	Viscosity (Min. Temp.)	Viscosity (Max. Temp.)
C ₆ H ₁₄ O ₄	Tri ethylene glycol	-99.75	7640.0	12.430	-	-	6.8389 x 10 ⁻² (285.00)	5.7935 x 10 ⁻⁴ (675.00)
C ₆ H ₁₄ O ₆	Sorbitol	-10.185	3978.0	-1.2798	-	-	8.8744 x 10 ⁻⁴ (370.85)	2.6368 x 10 ⁻⁵ (525.00)
C ₆ H ₁₅ Al	Tri ethyl aluminum	-2.9929	1214.3	-1.2358	-	-	1.5628 x 10 ⁻² (220.65)	3.6543 x 10 ⁻⁴ (458.15)
C ₆ H ₁₅ N	Di iso propyl amine	-1.7366	599.8	-1.4237	-	-	7.4785 x 10 ⁻⁴ (250.00)	2.1930 x 10 ⁻⁴ (357.05)
C ₆ H ₁₅ N	Di - n - propyl amine	-15.404	1390.0	0.5564	-	-	9.4542 x 10 ⁻⁴ (260.00)	2.1176 x 10 ⁻⁴ (382.35)
C ₆ H ₁₅ N	N - Hexyl amine	53.419	1608.7	-9.6679	-	-	1.7489 x 10 ⁻³ (251.85)	1.9921 x 10 ⁻⁴ (404.65)
C ₆ H ₁₅ N	Tri ethyl amine	-1.0330	458.2	-1.4867	-	-	6.0580 x 10 ⁻⁴ (250.00)	1.9720 x 10 ⁻⁴ (362.65)
C ₆ H ₁₅ NO ₃	Tri ethanol amine	-198.58	14579	26.184	-	-	8.1830 x 10 ⁻¹ (294.35)	2.7362 x 10 ⁻³ (430.00)
C ₆ H ₁₆ N ₂	Hexamethylene diamine	-15.260	2283.0	0.288	-	-	1.7778 x 10 ⁻³ (313.95)	1.7012 x 10 ⁻⁴ (475.04)
C ₆ H ₁₈ N ₃ OP	Hexamethylene Phosphor amide	-51.263	3610.7	5.8603	-	-	4.7489 x 10 ⁻³ (280.1)	4.8168 x 10 ⁻⁴ (506.15)
C ₇ H ₃ ClF ₃ NO ₂	Hexamethylene di amine	-15.260	2283.0	0.288	-	-	1.7778 x 10 ⁻³ (313.95)	1.7012 x 10 ⁻⁴ (475.04)
C ₇ H ₃ Cl ₂ F ₃	2,4 - Di chloro benzo trifluoride	-11.903	1782.0	-191.21	-	-	4.8167 x 10 ⁻³ (267.00)	3.1481 x 10 ⁻⁴ (450.65)
C ₇ H ₃ Cl ₂ NO	3,4 - Di chloro benzo tri fluoride	-13.430	2282.0	-	-	-	2.0054 x 10 ⁻³ (316.15)	1.3983 x 10 ⁻⁴ (501.00)
C ₇ H ₄ ClF ₃	p - Chloro benzo trifluoride	-32.50	2434.0	3.073	-	-	2.7364 x 10 ⁻³ (254.00)	3.0639 x 10 ⁻⁴ (412.15)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
$C_7H_4Cl_2O$	m - Chloro benzyl chloride	-11.799	1937.6	-0.024368	-	-	6.6290×10^{-3} (280.00)	3.1606×10^{-4} (498.00)
C_7H_5ClO	Benzoyl chloride	6.0360	504.0	-2.546	-	-	1.6717×10^{-3} (272.65)	2.0360×10^{-4} (462.65)
$C_7H_5ClO_2$	o - Chloro benzoic acid	-12.372	2444.9	-0.060753	-	-	1.0605×10^{-3} (415.15)	2.2673×10^{-4} (560.15)
$C_7H_5Cl_3$	Benzo tri chloride	1.6400	920.0	-1.9018	-	-	3.4890×10^{-3} (273.00)	2.5050×10^{-4} (493.79)
$C_7H_5F_3$	Benzo tri fluoride	-7.1080	880.0	-0.5964	-	-	1.1336×10^{-3} (244.14)	2.4635×10^{-4} (376.61)
C_7H_5N	Benzo nitrile	-20.236	1737.4	1.3531	-	-	1.9774×10^{-3} (270.00)	3.0091×10^{-4} (450.00)
$C_7H_5N_5O_8$	Tetryl	-20.309	7221.5	-0.3548 x 10^{-3}	-	-	9.2903×10^{-2} (402.65)	1.3096×10^{-3} (528.15)
$C_7H_6Cl_2$	2,4 - Di chloro toluene	-11.852	1685.8	0.0091988	-	-	4.9505×10^{-3} (259.65)	2.6371×10^{-4} (474.25)
C_7H_6O	Benzaldehyde	-10.563	929.1	0.14846	-	-	2.5144×10^{-3} (247.15)	5.0075×10^{-4} (451.90)
$C_7H_6O_2$	Benzoic acid	-21.720	6055.0	-	-	-	1.6433×10^{-3} (395.52)	3.9895×10^{-5} (522.40)
$C_7H_6O_2$	Salicyl aldehyde	-21.992	2127.9	1.5447	-	-	4.6486×10^{-3} (266.15)	3.4978×10^{-4} (469.65)
C_7H_7Br	p - Bromo -toluene	-25.004	1863.0	2.1060	-	-	1.1350×10^{-3} (299.95)	3.2523×10^{-4} (475.50)
C_7H_7Cl	Benzyl chloride	-1.4084	892.4	-1.4713	-	-	3.6097×10^{-3} (234.15)	2.1759×10^{-4} (452.55)
C_7H_7Cl	o - Chloro toluene	-1.2784	654.2	-1.3845	-	-	1.2609×10^{-3} (275.00)	2.5281×10^{-4} (450.00)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
C_7H_7Cl	p - Chloro toluene	-14.985	1326.3	0.6051	-	-	1.0614×10^{-3} (280.65)	2.2673×10^{-4} (460.00)
C_7H_7NO	Formanilide	-14.800	3299.8	-	-	-	8.7017×10^{-3} (328.15)	1.6072×10^{-4} (544.15)
$C_7H_7NO_2$	m - Nitro toluene	23.575	200.0	-5.339	-	-	2.5032×10^{-3} (289.20)	9.4977×10^{-5} (505.00)
$C_7H_7NO_2$	o - Nitro toluene	-11.828	1701.0	-	-	-	3.9758×10^{-3} (269.98)	2.2575×10^{-4} (495.64)
$C_7H_7NO_2$	p - Nitro toluene	-11.020	1427.0	-	-	-	1.3257×10^{-3} (324.75)	2.7407×10^{-4} (506.41)
$C_7H_7NO_3$	o - Nitro anisole	-10.748	1480.6	-	-	-	3.9768×10^{-3} (283.60)	3.2327×10^{-4} (546.15)
C_7H_8	Toluene	-13.362	1183.0	0.3330	-	-	3.4045×10^{-3} (200.00)	2.2278×10^{-4} (400.00)
C_7H_8O	Anisole	-7.8930	1100.0	-0.4770	-	-	1.1594×10^{-3} (287.00)	2.7355×10^{-4} (426.73)
C_7H_8O	m - Cresol	-124.95	8727.8	16.012	-	-	1.1793×10^{-2} (298.00)	3.7418×10^{-4} (475.20)
C_7H_8O	p - Cresol	-102.05	7478.8	12.725	-	-	7.8281×10^{-3} (307.90)	3.7907×10^{-4} (475.13)
C_7H_8O	o - Cresol	-102.80	7278.6	12.893	-	-	5.7734×10^{-3} (304.19)	3.5383×10^{-4} (463.15)
C_7H_8O	Benzyl alcohol	-14.859	2865.7	-	-	-	7.3443×10^{-3} (288.15)	3.3263×10^{-4} (427.00)
$C_7H_8O_2$	p -Methoxy phenol	-61.247	5452.3	6.8531	-	-	4.4784×10^{-3} (345.45)	3.7688×10^{-4} (517.15)
C_7H_8S	Benzyl mercaptan	-11.459	1334.4	0.00049649	-	-	2.5103×10^{-3} (243.95)	1.8308×10^{-4} (468.15)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
C ₇ H ₉ N	Benzyl amine	-12.192	1567.7	0.088259	-	-	8.1354 x 10 ⁻³ (227.15)	2.6767 x 10 ⁻⁴ (457.65)
C ₇ H ₉ N	2,6 - Di methyl pyridine	-17.863	1509.5	0.99728	-	-	1.3104 x 10 ⁻³ (267.00)	2.6716 x 10 ⁻⁴ (417.20)
C ₇ H ₉ N	n - Methyl aniline	-70.0953	4689.1	8.6022	-	-	9.9063 x 10 ⁻³ (250.00)	3.2030 x 10 ⁻⁴ (469.02)
C ₇ H ₉ N	m -Toludine	-105.05	6828.2	13.591	-	-	8.1787 x 10 ⁻³ (273.15)	3.6643 x 10 ⁻⁴ (476.55)
C ₇ H ₉ N	o - Toludine	-592.58	21015	97.020	-	-	1.0334 x 10 ⁻² (273.15)	2.9956 x 10 ⁻⁴ (473.55)
C ₇ H ₉ N	p - Toludine	-63.748	4642.7	7.4466	-	-	1.9977 x 10 ⁻³ (316.90)	3.1178 x 10 ⁻⁴ (474.00)
C ₇ H ₁₀ N ₂	Toluene diamine	-13.853	2064.1	0.19523	-	-	7.9435 x 10 ⁻⁴ (371.25)	1.3451 x 10 ⁻⁴ (557.15)
C ₇ H ₁₂	Cyclo heptane	-9.6541	977.31	-0.81038	-	-	3.7369 x 10 ⁻³ (217.15)	4.9301 x 10 ⁻⁴ (387.50)
C ₇ H ₁₂ O ₂	n - Butyl acrylate	-23.658	1830.3	1.8358	-	-	2.0284 x 10 ⁻³ (250.00)	6.0616 x 10 ⁻⁴ (325.00)
C ₇ H ₁₂ O ₂	Iso butyl acrylate	-11.604	1234.6	0.014678	-	-	3.3400 x 10 ⁻³ (212.00)	2.0996 x 10 ⁻⁴ (405.15)
C ₇ H ₁₂ O ₂	n -Propyl methyl crylate	-11.419	1256.4	-0.021579	-	-	2.7351 x 10 ⁻³ (223.00)	2.0059 x 10 ⁻⁴ (414.00)
C ₇ H ₁₂ O ₄	Di ethyl malonate	-12.410	1835.3	-	-	-	8.5407 x 10 ⁻³ (240.00)	4.0092 x 10 ⁻⁴ (400.00)
C ₇ H ₁₄	Cyclo pentane	-1.4077	805.33	-1.38110	-	-	8.6262 x 10 ⁻⁶ (391.94)	1.9895 x 10 ⁻⁵ (1000.0)
C ₇ H ₁₄	Cis - 1,2 -Di methyl cyclo pentane	-11.140	999.69	0.030639	-	-	1.6361 x 10 ⁻³ (219.26)	2.5451 x 10 ⁻⁴ (372.68)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
C ₇ H ₁₄	Trans -1,2 - Dimethyl - cyclo pentane	-10.765	985.28	-0.026512	-	-	1.0401 x 10 ⁻² (155.58)	2.6863 x 10 ⁻⁴ (365.02)
C ₇ H ₁₄	Ethyl cyclo pentane	-6.8940	818.60	-0.5941	-	-	9.6047 x 10 ⁻⁴ (253.15)	2.5985 x 10 ⁻⁴ (378.15)
C ₇ H ₁₄	1 - Heptene	-21.866	1377.2	1.6214	-	-	6.0834 x 10 ⁻⁴ (250.00)	1.8716 x 10 ⁻⁴ (375.00)
C ₇ H ₁₄	Cis - 2 - Heptene	-11.078	914.29	0.0091053	-	-	4.2679 x 10 ⁻³ (164.00)	1.9096 x 10 ⁻⁴ (371.56)
C ₇ H ₁₄	Cis - 3 - Heptene	-11.046	913.23	0.0041889	-	-	1.3094 x 10 ⁻² (136.51)	1.9438 x 10 ⁻⁴ (368.90)
C ₇ H ₁₄	Methyl cyclo hexane	-10.537	1179.7	-0.12417	-	-	1.5528 x 10 ⁻³ (248.15)	2.9782 x 10 ⁻⁴ (374.08)
C ₇ H ₁₄ O	1 - Heptanol	-11.730	1111.7	0.18352	-	-	2.7352 x 10 ⁻³ (230.15)	3.3241 x 10 ⁻⁴ (425.95)
C ₇ H ₁₄ O	2 - Heptanone	-13.565	1308.2	0.34850	-	-	1.6484 x 10 ⁻³ (250.00)	2.3134 x 10 ⁻⁴ (425.05)
C ₇ H ₁₄ O	1 - Methyl cyclo hexanol	-24.062	3092.9	-2.0047	-	-	3.0321 x 10 ⁻² (299.15)	6.2818 x 10 ⁻⁴ (430.15)
C ₇ H ₁₄ O	Cis-2-Methyl Cyclo hexanol	-21.1277	5147.2	-	-	-	1.8075 x 10 ⁻² (298.15)	2.2285 x 10 ⁻⁴ (400.00)
C ₇ H ₁₄ O	Trans-2-Methyl cyclo hexanol	-26.937	7049.3	-	-	-	1.7189 x 10 ⁻¹ (280.00)	5.2641 x 10 ⁻³ (325.00)
C ₇ H ₁₄ O	Cis-3 - Methyl cyclo hexanol	-13.478	2847.6	-	-	-	2.6657 x 10 ⁻² (289.00)	9.9820 x 10 ⁻³ (321.00)
C ₇ H ₁₄ O	Trans-3-Methyl cyclo hexanol	-16.788	3906.8	-	-	-	3.8019 x 10 ⁻² (289.00)	9.8796 x 10 ⁻³ (321.00)
C ₇ H ₁₄ O	Cis-4-Methyl cyclo hexanol	6.0809	2444.6	-3.1471	-	-	2.6120 x 10 ⁻² (298.00)	5.0028 x 10 ⁻⁴ (444.15)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
C ₇ H ₁₄ O	Trans-4- Methyl cyclo hexanol	-13.435	3586.8	-0.3329	-	-	3.7056 x 10 ⁻² (298.00)	6.1816 x 10 ⁻⁴ (444.15)
C ₇ H ₁₄ O	5- Methyl - 2 - hexanone	-10.634	1249.7	-0.14656	-	-	5.8695 x 10 ⁻³ (199.25)	1.9776 x 10 ⁻⁴ (417.95)
C ₇ H ₁₄ O ₂	n - Butyl propionate	-13.914	1430.5	0.34496	-	-	1.3225 x 10 ⁻² (183.63)	2.1985 x 10 ⁻⁴ (419.75)
C ₇ H ₁₄ O ₂	Ethyl - iso - valerate	-11.685	1325.5	0.0071708	-	-	1.7888 x 10 ⁻² (173.85)	2.2741 x 10 ⁻⁴ (407.45)
C ₇ H ₁₄ O ₂	n -Hepta noic acid	-30.329	2834.7	2.6785	-	-	6.0223 x 10 ⁻³ (280.00)	3.3867 x 10 ⁻⁴ (496.15)
C ₇ H ₁₄ O ₂	Iso - pentyl acetate	-12.128	1332.8	0.10018	-	-	8.6278 x 10 ⁻³ (194.75)	2.4497 x 10 ⁻⁴ (415.25)
C ₇ H ₁₄ O ₂	n - Pentyl acetate	-10.639	1263.6	-0.12151	-	-	3.5574 x 10 ⁻³ (223.35)	2.2934 x 10 ⁻⁴ (422.15)
C ₇ H ₁₄ O ₂	n - Propyl - n - butyrate	15.197	-66.6	-3.8837	-	-	1.0760 x 10 ⁻³ (273.15)	7.8579 x 10 ⁻⁴ (553.15)
C ₇ H ₁₆	2,2 - Di methyl pentane	-7.6415	1046.5	-0.63903	-	-	2.1642 x 10 ⁻² (149.34)	2.2063 x 10 ⁻⁴ (352.34)
C ₇ H ₁₆	2,3 - Di methyl pentane	-12.286	1128.8	0.13742	-	-	1.0742 x 10 ⁻³ (160.00)	2.3270 x 10 ⁻⁴ (362.93)
C ₇ H ₁₆	2,4 - Di methyl pentane	-18.101	1388.3	0.98736	-	-	7.7223 x 10 ⁻³ (170.00)	2.2915 x 10 ⁻⁴ (353.65)
C ₇ H ₁₆	3,3 - Di methyl pentane	-11.727	1112.4	0.047647	-	-	3.1065 x 10 ⁻² (138.70)	2.3647 x 10 ⁻⁴ (359.21)
C ₇ H ₁₆	3 - Ethyl pentane	-10.964	976.01	-0.049006	-	-	7.4776 x 10 ⁻³ (154.55)	1.8574 x 10 ⁻⁴ (366.62)
C ₇ H ₁₆	n - Heptane	-24.451	1533.1	2.0087	-	-	3.7197 x 10 ⁻³ (182.57)	2.1455 x 10 ⁻⁴ (373.15)
C ₇ H ₁₆	2 - Methyl hexane	-43.400	464.30	-1.5889	-	-	4.7701 x 10 ⁻⁴ (273.15)	1.9901 x 10 ⁻⁴ (363.20)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
C_7H_{16}	3 - Methyl hexane	-11.132	981.27	-0.02379	-	-	7.7316×10^{-3} (153.75)	1.8865×10^{-4} (365.00)
C_7H_{16}	2,2,3 - Tr imethyl butane	-22.545	1553.0	1.7221	-	-	8.0022×10^{-4} (268.57)	3.1888×10^{-4} (354.03)
$C_7H_{16}O$	1 - Heptanol	-88.623	6463.8	10.846	-	-	8.5245×10^{-3} (288.15)	3.3889×10^{-4} (448.95)
$C_7H_{16}O$	2 - Heptanol	-96.293	7180.2	11.732	-	-	1.3743×10^{-2} (275.00)	2.0730×10^{-4} (432.35)
$C_7H_{17}N$	1 - Amino heptane	-3.5830	1223.7	-1.2559	-	-	3.2692×10^{-3} (254.15)	2.3565×10^{-4} (430.05)
$C_8H_4O_3$	Phthalic anhydride	152.38	-8406.0	-23.041	-	-	1.2163×10^{-3} (405.15)	2.2508×10^{-4} (557.65)
C_8H_6	Ethynyl benzene	-2.7214	801.45	-1.2288	-	-	2.7834×10^{-3} (228.30)	1.4127×10^{-4} (520.00)
$C_8H_6O_3$	4 - Carboxy benzaldehyde	-14.186	3436.6	-0.8824 x 10^{-3}	-	-	5.0823×10^{-4} (520.15)	9.1759×10^{-5} (702.00)
$C_8H_6O_4$	Phthalic acid	-7.314	212.1	-	-	-	1.0520×10^{-3} (464.15)	1.007×10^{-3} (521.15)
C_8H_7N	Indole	27.947	443.92	-6.0250	-	-	3.8459×10^{-3} (326.15)	1.2852×10^{-4} (526.15)
C_8H_7N	Phenyl aceto nitrile	-25.663	2207.1	2.1116	-	-	5.7534×10^{-3} (249.35)	2.8699×10^{-4} (506.65)
C_8H_8	Styrene	-22.675	1758.0	1.6701	-	-	1.9191×10^{-3} (242.54)	2.2684×10^{-4} (418.31)
C_8H_8O	Aceto phenone	2.3720	807.0	-2.0158	-	-	1.7989×10^{-3} (292.80)	4.5825×10^{-4} (400.00)
C_8H_8O	P - Tolual-dehyde	-9.9707	1017.3	0.0232	-	-	1.6888×10^{-3} (293.00)	4.4659×10^{-4} (477.15)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
C ₈ H ₈ O ₂	Benzyl formate	-12.282	1737.5	0.4541 x 10 ⁻³	-	-	1.2503 x 10 ⁻² (220.00)	1.7864 x 10 ⁻⁴ (476.15)
C ₈ H ₈ O ₂	Methyl benzoate	-21.971	2267.4	1.4173	-	-	2.2989 x 10 ⁻³ (288.15)	2.1485 x 10 ⁻⁴ (472.65)
C ₈ H ₈ O ₂	o - Toluic acid	-87.910	6358.9	10.946	-	-	1.9690 x 10 ⁻³ (385.00)	7.7094 x 10 ⁻⁴ (500.00)
C ₈ H ₈ O ₂	p - Toluic acid	-12.378	2465.9	-0.062356	-	-	6.6692 x 10 ⁻⁴ (452.75)	2.554 x 10 ⁻⁴ (548.15)
C ₈ H ₈ O ₃	Methyl salicylate	-18.86	1969.4	1.0930	-	-	4.8187 x 10 ⁻³ (265.15)	3.0009 x 10 ⁻⁴ (496.65)
C ₈ H ₉ NO	Acetanilide	-12.385	2467.1	-	-	-	2.4618 x 10 ⁻³ (386.65)	3.0085 x 10 ⁻⁴ (576.95)
C ₈ H ₁₀	Ethyl benzene	-10.452	1048.4	-0.07150	-	-	2.9032 x 10 ⁻³ (210.00)	1.5080 x 10 ⁻⁴ (500.00)
C ₈ H ₁₀	m - Xylene	-9.6470	983.0	-0.01928	-	-	1.7849 x 10 ⁻³ (225.30)	1.5598 x 10 ⁻⁴ (475.00)
C ₈ H ₁₀	o - Xylene	-15.678	1404.0	0.66410	-	-	1.1970 x 10 ⁻³ (268.10)	1.7882 x 10 ⁻⁴ (475.00)
C ₈ H ₁₀	p - Xylene	-5.7750	826.2	-0.77390	-	-	6.8227 x 10 ⁻⁴ (288.10)	1.3208 x 10 ⁻⁴ (500.00)
C ₈ H ₁₀ O	3,4 - Xylenol	-68.323	5556.8	7.9483	-	-	3.6768 x 10 ⁻³ (338.25)	4.0372 x 10 ⁻⁴ (500.00)
C ₈ H ₁₀ O	2,6 - Xylenol	-15.719	3869.0	0.031176	-	-	3.2290 x 10 ⁻² (318.76)	6.1781 x 10 ⁻⁴ (474.22)
C ₈ H ₁₀ O	2,5 - Xylenol	-16.907	2303.1	0.65005	-	-	1.5269 x 10 ⁻³ (347.99)	2.9378 x 10 ⁻⁴ (484.33)
C ₈ H ₁₀ O	2,4 - Xylenol	-14.275	3662.9	-0.14822	-	-	1.0608 x 10 ⁻² (345.71)	4.8790 x 10 ⁻⁴ (484.13)
C ₈ H ₁₀ O	2,3 - Xylenol	-15.875	3863.5	0.044157	-	-	1.1780 x 10 ⁻² (345.71)	4.4479 x 10 ⁻⁴ (490.07)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
C ₈ H ₁₀ O	p - Ethyl phenol	-18.461	4974.0	0.034450	-	-	7.1915 x 10 ⁻² (318.23)	2.9751 x 10 ⁻⁴ (491.14)
C ₈ H ₁₀ O	Phenetole	-55.996	3521.6	6.5648	-	-	4.2389 x 10 ⁻³ (243.63)	3.2103 x 10 ⁻⁴ (443.15)
C ₈ H ₁₀ O	2 - Phenyl ethanol	-16.249	3383.2	0.0047964	-	-	8.0026 x 10 ⁻² (247.00)	8.7529 x 10 ⁻⁵ (492.05)
C ₈ H ₁₀ O	3,5 - Xylenol	-54.468	4873.7	5.8890	-	-	3.2762 x 10 ⁻³ (336.59)	3.0886 x 10 ⁻⁴ (494.89)
C ₈ H ₁₁ N	n,n - Di methyl anilie	-16.696	1617.8	0.81091	-	-	1.8933 x 10 ⁻³ (275.60)	2.6234 x 10 ⁻⁴ (466.69)
C ₈ H ₁₁ N	n-Ethyl aniline	-40.633	3219.2	4.1507	-	-	1.7169 x 10 ⁻² (230.00)	2.5079 x 10 ⁻⁴ (478.15)
C ₈ H ₁₂	Vinyl cyclo hexane	-5.3887	708.55	-0.88104	-	-	3.8432 x 10 ⁻³ (164.00)	8.9422 x 10 ⁻⁵ (474.00)
C ₈ H ₁₂ O ₂	Butyl methacrylate	32.827	-533.70	-6.668	-	-	3.620 x 10 ⁻³ (223.00)	1.3669 x 10 ⁻⁴ (434.00)
C ₈ H ₁₄	Cyclo octene	-10.449	1159.9	0.015441	-	-	7.0846 x 10 ⁻³ (214.15)	5.1638 x 10 ⁻⁴ (416.15)
C ₈ H ₁₄ O ₃	Butyric anhydride	-20.689	1921.5	1.3551	-	-	1.4686 x 10 ⁻³ (298.15)	2.6065 x 10 ⁻⁴ (468.15)
C ₈ H ₁₄ O ₄	Di ethyl succinate	-14.178	2434.0	-	-	-	5.7234 x 10 ⁻³ (270.00)	1.0032 x 10 ⁻⁴ (489.65)
C ₈ H ₁₆	Cyclo octane	-44.839	3413.6	4.7931	-	-	2.9013 x 10 ⁻³ (287.98)	4.1392 x 10 ⁻⁴ (423.84)
C ₈ H ₁₆	1,1 - Di methyl cyclo hexane	-10.716	1140.5	-0.047736	-	-	1.9918 x 10 ⁻³ (239.66)	3.0449 x 10 ⁻⁴ (392.70)
C ₈ H ₁₆	Cis - 1,2 - Di methyl cyclo hexane	-74.202	4193.9	9.3440	-	-	2.9267 x 10 ⁻³ (250.00)	4.3460 x 10 ⁻⁴ (402.94)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
C_8H_{16}	Trans -1,2 - di methyl cyclo hexane	-11.344	1168.9	0.045130	-	-	8.3151×10^{-3} (184.99)	2.9559×10^{-4} (396.58)
C_8H_{16}	Trans -1,3 -Di methyl cyclo hexane	-39.927	2347.1	4.3209	-	-	5.0016×10^{-3} (200.00)	2.8548×10^{-4} (397.61)
C_8H_{16}	Cis -1,4 - Di methyl cyclo hexane	-7.4864	1011.9	-0.53454	-	-	7.9830×10^{-3} (185.72)	2.9169×10^{-4} (397.47)
C_8H_{16}	Trans - 1,4 -Di methyl cyclo hexane	-35.557	2244.5	3.6330	-	-	1.4744×10^{-3} (250.00)	2.9153×10^{-4} (392.51)
C_8H_{16}	2,3 - Di methyl hexene	-11.097	923.29	-0.4086 x 10^{-3}	-	-	4.3900×10^{-3} (200.00)	2.7064×10^{-4} (383.65)
C_8H_{16}	Ethyl cyclo hexane	-22.110	1673.0	1.6410	-	-	1.8007×10^{-3} (248.15)	2.9563×10^{-4} (404.94)
C_8H_{16}	2 - Ethyl -1 - hexene	-5.5495	745.71	-0.81187	-	-	2.1131×10^{-3} (200.00)	1.9455×10^{-4} (393.15)
C_8H_{16}	Isopropyl cyclo pentene	-10.501	1084.0	-0.082854	-	-	1.4679×10^{-2} (161.79)	2.5271×10^{-4} (399.58)
C_8H_{16}	2 - Ethyl - 1 - hexene	-5.5495	754.71	0.81887	-	-	2.1131×10^{-3} (200.0)	1.9455×10^{-4} (393.15)
C_8H_{16}	1 - Octene	15.841	-194.40	-4.0180	-	-	8.0875×10^{-4} (250.00)	2.0867×10^{-4} (390.00)
C_8H_{16}	Trans - 2 - Octene	-11.321	1035.8	0.025687	-	-	3.6923×10^{-3} (185.45)	1.9053×10^{-4} (398.15)
C_8H_{16}	Trans - 3 - Octene	-10.984	1023.3	-0.026041	-	-	7.8713×10^{-3} (163.15)	1.9188×10^{-4} (396.45)
C_8H_{16}	Trans - 4 - Octene	-	1030.9	0.063717	-	-	4.4511×10^{-3} (179.37)	1.9360×10^{-4} (395.41)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
C_8H_{16}	N - Propyl cyclo pentene	-11.195	1617.8	1.8473	-	-	4.3900×10^{-3} (200.00)	2.7064×10^{-4} (404.11)
C_8H_{16}	2,4,4 - Tri methyl - 1 - pentene	-10.880	851.80	-0.021434	-	-	1.9282×10^{-3} (179.70)	1.6117×10^{-4} (374.59)
C_8H_{16}	2,4,4 - Trime-thyl- 2-pentene	-11.057	858.10	-0.021434	-	-	2.7903×10^{-3} (166.84)	1.5795×10^{-4} (378.06)
$C_8H_{16}O$	2 - Ethyl - hexanol	-10.608	1107.5	0.064988	-	-	6.4993×10^{-3} (200.00)	3.3030×10^{-4} (433.80)
$C_8H_{16}O_2$	n - Butyl - n - butyrate	8.8040	440.60	-3.0270	-	-	2.6057×10^{-3} (240.00)	1.8368×10^{-4} (438.15)
$C_8H_{16}O_2$	Iso butyl - iso - Butyrate	-11.549	1404.1	-0.03868	-	-	1.1603×10^{-2} (192.45)	2.1502×10^{-4} (420.65)
$C_8H_{16}O_2$	n - Octanoic acid	-62.073	4648.8	7.2310	-	-	6.5185×10^{-3} (289.65)	8.0335×10^{-4} (400.00)
$C_8H_{16}O_4$	Di ethylene glycol ethyl ester acetate	-1.646	2017.1	0.16301	-	-	9.8665×10^{-3} (248.15)	1.9861×10^{-4} (490.55)
C_8H_{18}	2,2 - Di methyl hexane	-11.317	1104.7	-	-	-	6.7082×10^{-3} (175.00)	2.2267×10^{-4} (379.99)
C_8H_{18}	2,3 - Di methyl hexane	-11.106	1025.9	-	-	-	6.5239×10^{-3} (272.04)	2.1027×10^{-4} (388.76)
C_8H_{18}	2,4 - di methyl hexane	-11.530	1175.4	0.019385	-	-	8.2458×10^{-4} (272.04)	2.3820×10^{-4} (382.58)
C_8H_{18}	2,5 - di methyl hexane	-12.933	1107.1	0.26798	-	-	2.5348×10^{-3} (200.00)	2.1532×10^{-4} (382.26)
C_8H_{18}	3,3 - Di methyl hexane	-11.106	1027.1	-	-	-	4.5171×10^{-3} (180.00)	2.1626×10^{-4} (385.12)
C_8H_{18}	3,4 - Di methyl hexane	-11.037	1003.0	-	-	-	6.4257×10^{-4} (272.04)	2.0946×10^{-4} (390.88)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
C ₈ H ₁₈	3 - Ethyl hexane	-8.137	909.0	-	-	-	6.0370 x 10 ⁻⁴ (272.04)	1.8350 x 10 ⁻⁴ (391.69)
C ₈ H ₁₈	2 - Methyl - 3 - ethyl pentane	-11.235	1067.7	-	-	-	1.0398 x 10 ⁻² (158.20)	1.8721 x 10 ⁻⁴ (388.80)
C ₈ H ₁₈	2 - Methyl heptane	-9.4511	995.49	-	-	-	8.0238 x 10 ⁻³ (164.16)	1.8656 x 10 ⁻⁴ (390.80)
C ₈ H ₁₈	3 - Methyl heptane	-10.247	1028.6	-0.16280	-	-	1.3233 x 10 ⁻² (152.60)	1.8494 x 10 ⁻⁴ (392.08)
C ₈ H ₁₈	4 - Methyl heptane	-11.432	1074.0	0.015358	-	-	1.3591 x 10 ⁻² (152.20)	1.8548 x 10 ⁻⁴ (390.86)
C ₈ H ₁₈	n - Octane	-20.463	1497.4	1.3790	-	-	2.1813 x 10 ⁻³ (216.38)	2.1383 x 10 ⁻⁴ (398.83)
C ₈ H ₁₈	2,2,3,3 - Tetra - methyl butane	5.5351	632.38	-2.6576	-	-	1.9986 x 10 ⁻⁴ (373.96)	8.8594 x 10 ⁻⁵ (454.00)
C ₈ H ₁₈	2,2,3 - Tri methyl pentane	-12.782	1220.4	0.21091	-	-	1.6080 x 10 ⁻² (161.00)	2.4227 x 10 ⁻⁴ (381.00)
C ₈ H ₁₈	2,2,4 - Tri methyl pentane	-15.811	1282.5	0.67791	-3.8617 x 10 ⁻²⁸	10	6.6643 x 10 ⁻⁴ (273.15)	4.5125 x 10 ⁻⁵ (541.15)
C ₈ H ₁₈	2,3,3 - Tri methyl pentane	-4.0309	990.76	-1.1771	-	-	1.3054 x 10 ⁻² (172.22)	2.0485 x 10 ⁻⁴ (387.91)
C ₈ H ₁₈	2,3,4 - Tri methyl pentane	-9.1481	1021.4	-0.3103	-	-	1.1173 x 10 ⁻² (163.95)	2.3675 x 10 ⁻⁴ (386.65)
C ₈ H ₁₈ O	Di - n - Butyl ether	8.0106	1046.1	-0.5013	-	-	1.4566 x 10 ⁻³ (246.75)	2.0482 x 10 ⁻⁴ (412.48)
C ₈ H ₁₈ O	2 - Ethyl - 1 - hexanol	8.6589	2685.5	-0.9440	-	-	6.3249 x 10 ⁻² (203.15)	1.8823 x 10 ⁻⁴ (457.75)
C ₈ H ₁₈ O	1 - Octanol	-67.577	5535.4	7.7383	-	-	1.0661 x 10 ⁻² (288.15)	4.4402 x 10 ⁻⁴ (425.00)
C ₈ H ₁₈ O	2 - Octol	-17.396	3740.1	-0.041083	-	-	5.7226 x 10 ⁻³ (300.00)	8.3551 x 10 ⁻⁵ (425.95)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
$C_8H_{18}O_3$	Di ethylene glycol mono butyl ether	-8.2623	2522.5	-1.0247	-	-	2.4131×10^{-1} (205.15)	6.5373×10^{-5} (504.15)
$C_8H_{18}O_5$	Tetra ethylene Glycol	-18.728	4056.8	0.34542	-	-	1.8868×10^{-1} (268.15)	5.7608×10^{-5} (600.45)
$C_8H_{18}S$	Tert - Octyl Mercatan	-7.7185	1071.7	-0.40448	-	-	1.1400×10^{-2} (199.00)	4.6564×10^{-4} (429.00)
$C_8H_{19}N$	Di - n - butyl amine	-25.447	2104.0	-1.9985	-	-	2.4878×10^{-3} (250.00)	2.1308×10^{-4} (432.75)
$C_8H_{19}N$	n - Octyl amine	-21.631	2151.1	1.3882	-	-	2.5838×10^{-2} (272.75)	2.2701×10^{-4} (452.75)
$C_8H_{23}N_5$	Tetra ethylene pentamide	-10.408	2077.0	-0.01169	-	-	1.4589×10^{-1} (243.00)	8.6191×10^{-4} (606.15)
$C_9H_4O_5$	Tri mellitic anhydride	-11.910	1637.0	0.072999	-	-	4.3953×10^{-4} (438.15)	1.2987×10^{-4} (658.15)
C_9H_7N	Iso quinoline	-42.468	3361.4	4.4868	-	-	3.4851×10^{-3} (299.4)	3.5972×10^{-4} (516.40)
C_9H_7N	Quinoline	-51.162	3942.4	5.6579	-	-	6.6049×10^{-3} (274.15)	2.8553×10^{-4} (510.75)
C_9H_8	Indene	-18.972	1929.9	1.0707	-	-	2.8285×10^{-3} (271.70)	2.7941×10^{-4} (455.77)
C_9H_{10}	α - Methyl styrene	-7.1110	1043.3	-0.6230	-	-	1.7007×10^{-3} (249.95)	1.9890×10^{-4} (438.65)
C_9H_{10}	Cis - 1 - Propynyl benzene	-11.320	1202.5	-0.22407 x 10 ⁻³	-	-	3.5713×10^{-3} (211.47)	1.7319×10^{-4} (452.03)
C_9H_{10}	Trans-1-Propynyl benzene	-11.318	1202.4	-0.56928 x 10 ⁻³	-	-	1.6789×10^{-3} (243.82)	1.7376×10^{-4} (451.41)
$C_9H_{10}O_2$	Benzyl acetate	-18.431	2179.5	0.8650	-	-	7.7321×10^{-3} (247.65)	1.8407×10^{-4} (486.65)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
$C_9H_{10}O_2$	Ethyl benzoate	-40.706	3035.0	4.2655	-	-	2.6663×10^{-3} (284.15)	4.604×10^{-4} (420.00)
$C_9H_{11}NO_2$	1 - Phenyl aniline	-15.287	4067.1	0.27615×10^{-3}	-	-	3.4489×10^{-4} (556.15)	1.4939×10^{-4} (628.00)
C_9H_{12}	Mesitylene	-3.0300	1026.0	-1.3080	-	-	1.0257×10^{-3} (288.46)	1.7651×10^{-4} (434.89)
C_9H_{12}	Cumene	-24.438	1785.9	1.9720	-	-	6.3442×10^{-3} (200.00)	2.3033×10^{-4} (440.00)
C_9H_{12}	m - Ethyl toluene	-11.470	1306.4	-0.075202	-	-	1.5709×10^{-2} (177.61)	2.0167×10^{-4} (434.48)
C_9H_{12}	o - Ethyl toluene	-11.809	1421.8	0.000711	-	-	1.2112×10^{-2} (192.35)	1.9143×10^{-4} (438.33)
C_9H_{12}	p - Ethyl toluene	-24.158	1686.6	1.9619	-	-	8.0506×10^{-4} (283.15)	2.7829×10^{-4} (400.00)
C_9H_{12}	n - Propyl benzene	-18.594	1566.5	1.0901	-	-	1.8914×10^{-3} (248.15)	2.3523×10^{-4} (432.39)
C_9H_{12}	1,2,3-Trime- thyl benzene	-11.756	1483.1	-0.040387	-	-	1.5909×10^{-3} (267.79)	1.6633×10^{-4} (449.27)
C_9H_{12}	1,2,4-Trime- thyl benzene	7.1680	1156.0	-0.6556	-	-	2.0783×10^{-3} (250.38)	1.9355×10^{-4} (442.53)
$C_9H_{12}O$	Bezyl ethyl ether	-11.460	1497.0	-0.043397	-	-	1.8865×10^{-3} (275.65)	2.1211×10^{-4} (458.15)?
$C_9H_{14}O$	Iso phorone	-12.505	1921.5	-	-	-	5.2087×10^{-3} (265.00)	3.5907×10^{-4} (420.00)
$C_9H_{14}O_6$	Glyceryl triacetate	-12.309	2025.7	-0.27413	-	-	5.7601×10^{-3} (277.25)	1.7090×10^{-4} (532.15)
$C_9H_{16}O_4$	Azelaic acid	-12.979	2720.6	0.071562	-	-	4.5716×10^{-3} (379.65)	2.7549×10^{-4} (629.65)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
C_9H_{18}	n - Butyl - cyclo pentane	-11.695	1235.2	0.0806400	-	-	2.2253×10^{-2} (165.18)	2.4073×10^{-4} (429.75)
C_9H_{18}	1 - Nonene	-21.920	1602.5	1.59730	-	-	8.3142×10^{-4} (273.15)	2.1253×10^{-4} (420.00)
C_9H_{18}	n - Propyl cylo hexane	-31.227	2179.0	2.9731	-	-	2.3526×10^{-3} (248.15)	2.9432×10^{-4} (429.90)
$C_9H_{18}O$	1 - Nonanol	-10.377	1110.4	0.007412	-	-	2.5188×10^{-3} (255.15)	2.4932×10^{-4} (468.15)
$C_9H_{18}O_2$	n-Heptyl acetate	-47.211	3152.6	5.2738	-	-	1.0510×10^{-2} (222.95)	3.2195×10^{-4} (465.65)
$C_9H_{18}O_2$	n-Nonanoic acid	-48.851	4095.0	5.2940	-	-	8.1601×10^{-3} (293.15)	1.7164×10^{-3} (363.15)
$C_9H_{18}O_4$	Di propylene glycol mono methyl ether	-12.926	2306.7	-0.00029876	-	-	2.9821×10^{-2} (245.00)	2.8971×10^{-4} (482.45)
C_9H_{20}	3,3 - Di methyl petane	-11.672	1088.9	0.048876	-	-	1.0392×10^{-3} (240.12)	1.5375×10^{-4} (419.34)
C_9H_{20}	2 - Methyl octane	-11.445	1154.1	0.0087285	-	-	4.4607×10^{-3} (192.78)	1.8029×10^{-4} (416.43)
C_9H_{20}	3 - Methyl octane	-11.321	1149.1	-0.010082	-	-	1.1898×10^{-2} (165.55)	1.7890×10^{-4} (417.38)
C_9H_{20}	4 - Methyl ocane	-11.276	1147.8	-0.017134	-	-	1.5192×10^{-2} (159.95)	1.8092×10^{-4} (415.59)
C_9H_{20}	n - Nonane	-21.149	1658.0	1.4540	-	-	3.1509×10^{-3} (219.63)	2.1662×10^{-4} (423.15)
C_9H_{20}	2,2,3,3 -Tetra methyl pentane	-3.4767	1208.4	-1.3623	-	-	1.5356×10^{-3} (263.26)	8.3060×10^{-5} (483.26)
C_9H_{20}	2,2,3,4 -Tetra methyl pentane	-6.5306	1195.9	-0.82227	-	-	6.0977×10^{-2} (152.06)	1.9834×10^{-4} (406.18)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
C_9H_{20}	2,2,4,4 - Tetra methyl petane	-5.1626	1307.9	-1.13400	-	-	7.5235×10^{-3} (206.95)	1.7751×10^{-4} (395.44)
C_9H_{20}	2,3,3,4 - Tetra methyl pentane	-6.036	1171.8	-0.89065	-	-	2.3220×10^{-2} (171.03)	1.1176×10^{-4} (481.03)
C_9H_{20}	2,2,5 - Tri methyl hexane	-11.294	990.04	0.0010059	-	-	4.6343×10^{-3} (167.39)	1.5139×10^{-4} (397.24)
$C_9H_{20}O$	2,6 - Di methyl -4 - heptanol	-210.29	13485.0	28.277	-	-	5.4642×10^{-2} (273.15)	4.1933×10^{-4} (400.00)
$C_9H_{20}O$	1 - Nonanol	-7.1348	2776.3	-1.2064	-	-	1.3137×10^{-2} (288.15)	5.9786×10^{-4} (400.00)
$C_9H_{20}O_4$	Tri propylene glycol	-5.9712	31872.	85.330	-	-	1.3945×10 (250.00)	6.6673×10^{-3} (350.00)
$C_9H_{21}N$	n - Nonyl amine	12.468	2047.6	0-.018554	-	-	6.2458×10^{-3} (273.15)	2.5486×10^{-4} (475.35)
$C_9H_{21}N$	Tri propyl amine	-17.102	1435.7	0.86043	-	-	4.6790×10^{-3} (200.00)	1.9477×10^{-4} (429.65)
$C_{10}H_7Cl$	1 - Chloro naphthalene	9.2058	1134.0	-3.3047	-	-	5.4655×10^{-3} (274.15)	2.1105×10^{-4} (450.10)
$C_{10}H_8$	Naphthalene	-19.308	1822.5	1.2180	-	-	9.0774×10^{-4} (353.43)	1.8923×10^{-4} (633.15)
$C_{10}H_9N$	Quinaldine	-12.757	2135.3	-	-	-	7.3654×10^{-3} (272.15)	1.7536×10^{-4} (519.75)
$C_{10}H_{10}$	m - Di vinyl benzene	-11.605	1308.4	0.0078808	-	-	5.4114×10^{-3} (265.25)	1.5252×10^{-4} (472.65)
$C_{10}H_{10}O_4$	Di methyl Phthalate	-28.482	16163	39.73	-	-	7.3654×10^{-3} (272.15)	1.7536×10^{-4} (400.00)
$C_{10}H_{10}O_4$	Di methyl tere phthalate	-37.986	1505.0	-6.8564	-	-	8.7938×10^{-4} (423.15)	4.0427×10^{-4} (523.15)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
C ₁₀ H ₁₂	Di cyclo pentadiene	-11.186	12587	-0.004513	-	-	8.1539 x 10 ⁻⁴ (307.00)	2.3121 x 10 ⁻⁴ (443.00)
C ₁₀ H ₁₂	Tetralin	-45.327	3241.8	4.9583	-	-	3.5435 x 10 ⁻² (273.15)	4.9419 x 10 ⁻⁴ (413.15)
C ₁₀ H ₁₂ O ₂	n - Propyl benzoate	-12.781	2064.1	0.0003808	-	-	3.1357 x 10 ⁻² (221.55)	1.6920 x 10 ⁻⁴ (505.15)
C ₁₀ H ₁₂ O ₄	Diallyl maleate	-11.239	1833.2	-0.077321	-	-	2.8666 x 10 ⁻² (226.15)	2.7543 x 10 ⁻⁴ (520.00)
C ₁₀ H ₁₄	n - Butyl benzene	-25.102	1949.6	2.0385	-	-	2.4661 x 10 ⁻³ (248.15)	2.3685 x 10 ⁻⁴ (456.45)
C ₁₀ H ₁₄	Sec - Butyl benzene	-124.57	6129.9	17.0290	-	-	2.9093 x 10 ⁻² (197.72)	6.7013 x 10 ⁻⁴ (360.00)
C ₁₀ H ₁₄	Tert - Butyl benzene	-11.510	1357.4	0.0088106	-	-	5.7584 x 10 ⁻³ (215.27)	2.2773 x 10 ⁻⁴ (442.30)
C ₁₀ H ₁₄	m - Cymene	-3.2349	617.62	-1.0524	-	-	2.7019 x 10 ⁻³ (209.44)	1.7467 x 10 ⁻⁴ (525.60)
C ₁₀ H ₁₄	o - Cymene	-6.9805	868.33	-0.50428	-	-	1.8519 x 10 ⁻³ (250.00)	2.0269 x 10 ⁻⁴ (529.60)
C ₁₀ H ₁₄	p - Cymene	-3.1077	614.71	-1.0737	-	-	2.9399 x 10 ⁻³ (205.25)	1.7479 x 10 ⁻⁴ (522.53)
C ₁₀ H ₁₄	m - Di ethyl benzene	-11.168	1303.2	-0.0020741	-	-	1.2389 x 10 ⁻² (189.25)	2.1904 x 10 ⁻⁴ (454.29)
C ₁₀ H ₁₄	o - Di ethyl benzene	-11.956	1541.1	0.002232	-	-	3.7963 x 10 ⁻³ (241.93)	1.9024 x 10 ⁻⁴ (456.61)
C ₁₀ H ₁₄	p - Diethyl benzene	-11.182	1302.8	-0.01860	-	-	3.6091 x 10 ⁻³ (230.32)	2.1560 x 10 ⁻⁴ (456.94)
C ₁₀ H ₁₄	3 - Ethyl - o - xylene	-12.153	1615.2	-0.6756 x 10 ⁻³	-	-	7.1953 x 10 ⁻³ (223.64)	1.6670 x 10 ⁻⁴ (467.11)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
$C_{10}H_{14}$	Iso butyl benzene	-11.681	1364.6	0.34472	-	-	4.7976×10^{-3} (221.70)	2.2248×10^{-4} (445.94)
$C_{10}H_{14}$	1,2,4,5 - Tetra methyl benzene	-11.273	1528.8	-0.0761	-	-	5.1796×10^{-4} (352.38)	1.6957×10^{-4} (469.99)
$C_{10}H_{14}O$	p - Tetra Butyl phenol	-18.295	4913.7	0.010093	-	-	6.6658×10^{-3} (371.56)	1.7488×10^{-4} (512.88)
$C_{10}H_{14}O_2$	p - Tetra Butyl cathecol	-15.839	3789.8	-0.0038813	-	-	1.4988×10^{-2} (325.00)	1.4860×10^{-4} (558.00)
$C_{10}H_{16}$	α - Pinene	-3.6988	994.27	-1.1031	-	-	7.9161×10^{-3} (209.15)	1.8412×10^{-4} (505.60)
$C_{10}H_{16}$	β - Pinene	-3.6180	1209.9	-1.2107	-	-	1.2483×10^{-2} (211.61)	1.2256×10^{-4} (541.93)
$C_{10}H_{16}O$	Camphor	-12.819	2470.0	-	-	-	6.3096×10^{-4} (453.15)	3.6744×10^{-4} (503.05)
$C_{10}H_{18}$	Cis - Decalin	-44.032	3379.6	4.7234	-	-	1.5239×10^{-2} (243.15)	4.2050×10^{-4} (468.76)
$C_{10}H_{18}$	Tras - Decalin	-28.692	2396.7	2.5297	-	-	7.2490×10^{-3} (242.79)	3.442×10^{-4} (46.46)
$C_{10}H_{18}O_4$	Sebacic acid	-12.184	2685.2	-7206.4	-	-	3.5518×10^{-3} (407.65)	3.5832×10^{-4} (625.00)
$C_{10}H_{20}$	n - Butyl cyclo hexane	-39.842	2686.6	4.2271	-	-	2.9717×10^{-3} (253.15)	3.2068×10^{-4} (454.13)
$C_{10}H_{20}$	1 - Decene	-15.858	1430.5	0.68113	-	-	-1.1140×10^{-3} (273.15)	2.0702×10^{-4} (443.75)
$C_{10}H_{20}O$	Decanol	-10.115	1111.9	-0.015659	-	-	2.3806×10^{-3} (267.15)	3.5829×10^{-4} (488.15)
$C_{10}H_{20}O_2$	n - Decanoic acid	-12.305	2324.1	-0.055494	-	-	6.7640×10^{-3} (304.75)	2.3044×10^{-4} (543.15)

Formula	Name	A	B	C	D	E	Viscosity (Min. Temp.)	Viscosity (Max. Temp.)
$C_{10}H_{20}O_2$	2 - Ethyl hexyl acetate	-13.277	1687.0	0.18690	-	-	1.4811×10^{-2} (209.15)	1.9348×10^{-4} (471.75)
$C_{10}H_{20}O_2$	Iso pentyl iso Valerate	-12.574	1614.9	0.072451	-	-	1.0587×10^{-2} (215.00)	1.8155×10^{-4} (467.15)
$C_{10}H_{20}O_2$	Octyl acetate	-13.277	1687.0	0.1869	-	-	1.4811×10^{-2} (209.15)	1.9348×10^{-4} (471.75)
$C_{10}H_{22}$	n - Decane	-16.468	1533.5	0.7511	-	-	2.3753×10^{-3} (243.49)	2.1165×10^{-4} (448.15)
$C_{10}H_{22}O$	1 - Decanol	-80.656	6325.5	9.646	-	-	1.7010×10^{-2} (288.15)	3.1108×10^{-4} (503.35)
$C_{10}H_{22}O$	Iso - Decanol	-16.063	3587.5	-0.024705	-	-	2.8637×10^{-1} (240.00)	1.3113×10^{-4} (493.00)
$C_{10}H_{23}N$	n - Decyl amine	-12.517	2140.3	-0.018354	-	-	5.4548×10^{-3} (288.85)	2.4972×10^{-4} (493.65)
$C_{11}H_{10}$	2 - Methyl naphthalene	-6.3276	4219.9	7.5549	-	-	5.4548×10^{-3} (366.00)	2.4972×10^{-4} (535.15)
$C_{11}H_{16}O_3$	p - tert - Amyl phenol	-17.932	4850.1	-0.035032	-	-	7.543×10^{-3} (366.00)	1.129×10^{-4} (535.15)
$C_{11}H_{20}O_2$	2 - Ethyl hexyl acrylate	-12.232	1716.9	0.011529	-	-	6.0953×10^{-2} (183.15)	1.7502×10^{-4} (489.15)
$C_{11}H_{22}$	1 - Undecene	-30.381	2218.0	2.8071	-	-	5.0525×10^{-3} (223.99)	2.3096×10^{-4} (465.82)
$C_{11}H_{22}O_2$	n - Nonyl acetate	-12.131	1721.7	0.38161×10^{-3}	-	-	5.7263×10^{-3} (247.15)	1.7249×10^{-4} (497.10)
$C_{11}H_{24}$	n - Undecane	-19.325	1793.3	1.1432	-	-	3.0437×10^{-3} (248.15)	2.1070×10^{-4} (468.15)
$C_{11}H_{24}O$	1 - Undecanol	-83.771	6606.1	10.065	-	-	1.7248×10^{-2} (293.15)	7.1229×10^{-4} (420.00)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
C ₁₂ H ₈	Acenaphtha lene	0.86291	334.69	-1.5499	-	-	6.436 x 10 ⁻⁴ (362.65)	1.8266 x 10 ⁻⁴ (633.60)
C ₁₂ H ₉ N ₃ O ₄	4,4' - Di nitro phenyl amine	-18.388	60805	-0.3907 x 10 ⁻³	-	-	2.4608 x 10 ⁻³ (491.05)	5.4680 x 10 ⁻⁵ (709.00)
C ₁₂ H ₁₀	Acenaphthene	20.433	103.79	-4.6073	-	-	1.5245 x 10 ⁻³ (366.56)	2.1290 x 10 ⁻⁴ (550.54)
C ₁₂ H ₁₀	Bi phenyl	-7.0860	1376.8	-0.60214	-	-	94702 x 10 ⁻⁴ (373.15)	1.0661 x 10 ⁻⁴ (723.15)
C ₁₂ H ₁₀ O	Di phenyl ether	-70.831	103.79	-4.6073	-	-	3.4909 x 10 ⁻³ (300.10)	6.8386 x 10 ⁻⁴ (420.00)
C ₁₂ H ₁₁ N	Di phenyl amine	-41.616	4158.5	4.0723	-	-	4.7449 x 10 ⁻³ (328.15)	3.3841 x 10 ⁻⁴ (500.00)
C ₁₂ H ₁₂ N ₂	Benzidine	-13.821	2982.7	0.4227 x 10 ⁻³	-	-	1.6899 x 10 ⁻³ (401.15)	8.2852 x 10 ⁻⁵ (675.85)
C ₁₂ H ₁₂ N ₂	p - Amino -phenol amine	-13.297	4158.5	4.0723	-	-	5.2950 x 10 ⁻³ (341.15)	1.1955 x 10 ⁻⁴ (627.15)
C ₁₂ H ₁₂ N ₂	Hydrazo benzene	-13.578	2992.9	0.029615	-	-	2.4916 x 10 ⁻³ (404.15)	2.8395 x 10 ⁻⁴ (573.00)
C ₁₂ H ₁₄	1,2,3 - Tri methylidene	-5.5950	799.06	-0.62620	-	-	9.7300 x 10 ⁻⁴ (344.65)	3.6211 x 10 ⁻⁴ (508.00)
C ₁₂ H ₁₄ O ₄	Diethyl - Phthalate	-14.110	2851.0	-	-	-	2.9677 x 10 ⁻² (269.15)	1.1357 x 10 ⁻⁴ (567.15)
C ₁₂ H ₁₄ O ₆	Bis - (2 -hydroxy - ethyl) tere phthalate	-24.453	9349.7	0.42131 x 10 ⁻³	-	-	8.9944 x 10 ⁻¹ (385.15)	2.1209 x 10 ⁻⁵ (683.00)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
$C_{12}H_{16}$	Cyclo hexyl benzene	-12.051	1819.4	-	-	-	3.8627×10^{-3} (280.14)	2.022×10^{-4} (513.27)
$C_{12}H_{18}$	m - Di iso propyl benzene	-11.467	1529.0	-	-	-	9.3587×10^{-3} (225.00)	2.5943×10^{-4} (476.33)
$C_{12}H_{18}$	p - Di iso propyl benzene	-11.129	1224.8	-0.020812	-	-	1.5624×10^{-3} (256.08)	1.6253×10^{-4} (483.65)
$C_{12}H_{18}$	n - Hexyl benzene	-86.584	4983.6	11.128	-	-	4.902×10^{-3} (253.15)	5.545×10^{-5} (499.26)
$C_{12}H_{20}O_4$	Di butyl maleate	-11.694	1970.8	-0.042861	-	-	2.3602×10^{-1} (188.15)	2.2446×10^{-4} (553.15)
$C_{12}H_{22}$	Bi cyclo hexyl	24.519	-9629.1	-0.38364	-	-	4.8487×10^{-3} (276.78)	6.2861×10^{-4} (360.00)
$C_{12}H_{24}$	1 - Dodecene	-29.634	2287.3	2.6757	-	-	4.611×10^{-3} (237.79)	2.3004×10^{-4} (486.50)
$C_{12}H_{24}O$	1 - Dodecanol	-10.110	1130.1	0.010396	-	-	2.2698×10^{-3} (285.15)	3.7644×10^{-4} (523.15)
$C_{12}H_{24}O_2$	n - Dodecanoic acid	-27.215	3198.5	2.1373	-	-	8.0984×10^{-3} (316.98)	3.1837×10^{-4} (571.85)
$C_{12}H_{24}O_2$	n - Decyl acetate	-22.215	2239.0	1.5281	-	-	6.3802×10^{-3} (258.12)	2.3939×10^{-4} (517.15)
$C_{12}H_{26}$	n - Do decane	-20.607	1943.0	1.3205	-	-	2.9046×10^{-3} (262.15)	2.1348×10^{-4} (488.15)
$C_{12}H_{26}O$	Di - n - hexyl ether	-11.743	1718.8	-0.0042224	-	-	1.3599×10^{-2} (230.15)	2.4269×10^{-4} (498.85)
$C_{12}H_{26}O$	1 - Do decanol	-70.023	5998.0	8.0302	-	-	1.6509×10^{-2} (29.95)	2.3313×10^{-4} (535.00)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
$C_{12}H_{26}S$	n - Do decyl mercaptn	-11.674	1669.0	0.19645	-	-	5.1445×10^{-3} (265.15)	2.0284×10^{-4} (547.75)
$C_{12}H_{26}S$	Tert - Do decyl mercaptn	-10.585	160.7	-0.15053	-	-	6.920×10^{-3} (250.00)	2.2453×10^{-4} (515.65)
$C_{12}H_{27}N$	Do decyl amine	-12.931	2307.7	0.036387	-	-	6.2921×10^{-3} (301.47)	2.226×10^{-4} (532.35)
$C_{12}H_{27}N$	Tri - n - Butyl amie	-2.279	2355.1	2.4141	-	-	5.3254×10^{-3} (240.00)	2.0251×10^{-4} (487.15)
$C_{13}H_{10}$	Fluorene	4.1850	723.30	-2.1489	-	-	1.1595×10^{-3} (387.94)	2.7885×10^{-4} (570.44)
$C_{13}H_{10}O$	Benzo phenone	-13.427	2645.0	-	-	-	5.0491×10^{-3} (325.00)	5.2652×10^{-4} (450.00)
$C_{13}H_{12}$	Di phenyl methane	-29.165	2613.0	2.5526	-	-	2.8448×10^{-3} (298.39)	3.4844×10^{-4} (480.00)
$C_{13}H_{26}$	1 - Tri decane	-34.453	2608.5	3.3704	-	-	4.4639×10^{-3} (250.08)	1.772×10^{-4} (685.00)
$C_{13}H_{28}O$	1 - Tri decanol	-16.347	3754.8	0.16359	-	-	2.0404×10^{-2} (303.75)	8.4278×10^{-5} (457.15)
$C_{14}H_{10}$	Anthracene	-833.68	59007	114.03	-3.23×10^{-28}	10	7.8691×10^{-4} (488.93)	4.0651×10^{-4} (593.15)
$C_{14}H_{10}$	Di phenyl acetylene	-11.875	1884.4	0.047303	-	-	2.5145×10^{-3} (335.65)	2.5204×10^{-4} (573.00)
$C_{14}H_{10}$	Phenanthrene	0.7186	1105.5	-2.0693	-	-	1.9107×10^{-4} (372.39)	7.4993×10^{-5} (453.15)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
$C_{14}H_{12}O_2$	Benzyl benzoate	13.503	2616.0	-	-	-	1.0452×10^{-2} (292.55)	9.4625×10^{-4} (400.00)
$C_{14}H_{14}$	1,1 - Di phenyl ethane	114.4	6938.7	15.023	-	-	1.2377×10^{-2} (265.00)	8.7308×10^{-4} (400.00)
$C_{14}H_{14}$	1,2 - Di phenyl ethane	-11.716	1820.9	-	-	-	2.2388×10^{-3} (324.34)	2.1886×10^{-4} (553.65)
$C_{14}H_{14}O$	Di benzyl ether	-13.324	2375.0	-	-	-	8.719×10^{-3} (276.75)	3.2031×10^{-4} (450.00)
$C_{14}H_{28}$	1 - Tetra decene	-40.342	2975.4	4.2237	-	-	4.4279×10^{-3} (260.30)	3.6109×10^{-4} (450.00)
$C_{14}H_{28}O_2$	Tetra decanoic acid	-13.017	2702.1	-	-	-	8.501×10^{-3} (327.55)	2.0172×10^{-4} (599.35)
$C_{14}H_{30}$	n - Tetra decane	-20.486	2088.4	1.2852	-	-	3.1395×10^{-3} (279.01)	2.0874×10^{-4} (528.15)
$C_{14}H_{30}O$	1 - Tetra decanol	-16.218	3868.0	-0.028771	-	-	1.9608×10^{-2} (310.65)	7.5244×10^{-5} (560.15)
$C_{14}H_{31}N$	Tetra decyl amine	-12.542	2385.5	-0.00992	-	-	7.1768×10^{-3} (311.34)	2.2973×10^{-4} (564.45)
$C_{15}H_{16}O$	p - Cumyl phenol	-18.733	5042.8	-0.017518	-	-	1.411×10^{-2} (346.00)	2.6108×10^{-5} (608.15)
$C_{15}H_{16}O_2$	Bisphenol - A	-2.2572	2282.4	-1.2838	-	-	8.3796×10^{-3} (433.15)	2.8829×10^{-4} (833.15)
$C_{15}H_{24}O$	2,6 - Di - tert - butyl - p - cresol	-11.716	2228.8	-0.059917	-	-	3.7467×10^{-3} (344.00)	3.5266×10^{-4} (538.00)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
$C_{15}H_{24}O$	Nonyl phenol	39.283	2785.8	-8.4414	-	-	5.5998 (279.15)	6.4453×10^{-5} (581.00)
$C_{15}H_{30}O_2$	Penta decanoic acid	-12.506	2605.4	-0.03396	-	-	9.0715×10^{-3} (325.68)	2.1028×10^{-4} (612.05)
$C_{15}H_{32}$	n - Penta decane	-19.299	2088.6	1.1091	-	-	3.4861×10^{-3} (283.07)	2.0910×10^{-4} (543.83)
$C_{16}H_{10}$	Fluoranthene	-26.811	3211.0	2.1614	-	-	3.7859×10^{-3} (383.33)	3.7194×10^{-4} (655.95)
$C_{16}H_{10}$	Pyrene	-11.909	2429.0	-	-	-	2.0777×10^{-3} (423.81)	2.5564×10^{-4} (667.95)
$C_{16}H_{12}$	1 - Phenal phthalene	-11.699	980.93	-1.3181	-	-	3.4059×10^{-3} (318.15)	3.3490×10^{-4} (607.15)
$C_{16}H_{22}O_4$	Di butyl phthalate	-250.53	14426	34.706	-	-	1.3275 (238.15)	1.9830×10^{-3} (420.00)
$C_{16}H_{26}$	n -Decyl benzene	-47.161	3622.5	5.1502	-	-	1.0590×10^{-2} (258.77)	2.9556×10^{-4} (571.04)
$C_{16}H_{32}$	1 - Hexa decene	-43.375	3289.1	4.6393	-	-	4.4149×10^{-3} (277.51)	3.8699×10^{-4} (475.00)
$C_{16}H_{32}O_2$	n - Hexa decanoic acid	-22.747	3128.1	1.4996	-	-	9.0415×10^{-3} (335.66)	3.0868×10^{-4} (624.15)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
$C_{16}H_{34}O$	n - Hexa decane	-20.182	2203.5	1.2289			3.5364×10^{-3} (291.32)	2.0538×10^{-4} (560.01)
$C_{16}H_{34}O$	1 - Hexa decanol	-16.927	4066.0	-	-	-	1.3388×10^{-2} (322.35)	3.7393×10^{-4} (450.00)
$C_{17}H_{36}$	n - Hepta decane	-19.991	2245.1	1.1982	-	-	3.8136×10^{-3} (295.13)	2.0881×10^{-4} (575.30)
$C_{17}H_{36}O$	1 - Hepta decanol	-16.785	4244.7	-0.0012913	-	-	2.0109×10^{-2} (327.05)	5.6148×10^{-5} (597.15)
$C_{18}H_{12}$	Chrysene	-13.014	2845.5	-	-	-	2.7996×10^{-4} (588.75)	1.1982×10^{-4} (714.15)
$C_{18}H_{13}N_3O_4$	4,4 - Di nitro phenyl amine	-18.834	6582.9	0.0012913	-	-	6.0867×10^{-3} (479.65)	4.699×10^{-5} (743.00)
$C_{18}H_{14}$	o - Tere phenyl	-38.408	4405.8	3.5356	-	-	4.4138×10^{-3} (373.00)	1.4155×10^{-4} (750.00)
$C_{18}H_{14}$	p - Tere phenyl	-10.360	2007.0	-0.1428	-	-	7.3326×10^{-4} (498.15)	1.9849×10^{-4} (723.15)
$C_{18}H_{30}$	n - Do decyl benzene	-37.075	3263.6	3.6495	-	-	7.1263×10^{-3} (283.15)	6.8152×10^{-4} (423.15)
$C_{18}H_{32}O_2$	Linolic acid	-13.258	2887.8	0.011419	-	-	8.8495×10^{-2} (268.15)	8.1693×10^{-4} (475.15)
$C_{18}H_{34}O_2$	Oleic acid	-40.782	4211.3	4.0554	-	-	3.4086×10^{-2} (293.15)	7.7964×10^{-4} (500.00)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
$C_{18}H_{34}O_4$	Di butyl sebacate	-12.554	2311.0	-	-	-	1.6175×10^{-2} (274.15)	6.0008×10^{-4} (450.00)
$C_{18}H_{34}O_4$	Di hexyl adipate	-12.619	2252.2	-0.014764	-	-	1.8006×10^{-2} (259.35)	1.130×10^{-4} (621.15)
$C_{18}H_{36}$	1 - Octa decane	-18.176	21383.0	0.94060	-	-	4.1433×10^{-3} (290.76)	5.0497×10^{-4} (440.00)
$C_{18}H_{36}O_2$	Stearic acid	5.4787	1616.7	-2.5466	-	-	9.3029×10^{-3} (343.15)	8.1362×10^{-4} (500.00)
$C_{18}H_{38}$	n - Octa decane	-20.5800	2308.9	1.2355	-	-	3.8698×10^{-3} (301.33)	2.0881×10^{-4} (589.86)
$C_{18}H_{38}O$	Di nonyl ether	-10.899	1969.8	-0.1193	-	-	2.1395×10^{-3} (297.15)	5.2328×10^{-4} (397.15)
$C_{18}H_{38}O$	1 - Octa decanol	-16.917	4361.3	-0.017534	-	-	7.088×10^{-3} (331.05)	1.290×10^{-3} (608.15)
$C_{19}H_{16}$	Tri phenyl methane	-12.840	2408.1	0.10823	-	-	3.6638×10^{-3} (365.30)	2.4054×10^{-4} (632.15)
$C_{19}H_{26}$	1 - n - Nonyl naphthalene	-2.7846	1345.8	-1.2385	-	-	6.4397×10^{-3} (284.15)	1.7011×10^{-4} (639.00)
$C_{19}H_{32}$	n - Tri decyl benzene	-44.14	3702.8	4.6612	-	-	8.6881×10^{-3} (283.15)	3.7369×10^{-4} (525.00)
$C_{19}H_{36}O_2$	Methyl oleate	-9.059	2116.7	-0.5587	-	-	6.6735×10^{-3} (293.05)	9.9243×10^{-5} (617.00)
$C_{19}H_{38}O_2$	Nona decanoic acid	-12.054	2667.1	-0.048148	-	-	1.0903×10^{-2} (341.23)	2.4353×10^{-4} (659.15)
$C_{19}H_{40}$	n - Nona decane	-18.530	2256.2	0.98525	-	-	4.0720×10^{-3} (305.53)	2.0668×10^{-4} (603.76)
$C_{20}H_{16}$	Tri phenyl ethylene	-6.2307	1833.2	-0.55548	-	-	1.6339×10^{-2} (342.15)	8.2115×10^{-4} (669.00)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
$C_{20}H_{18}$	1,1,2 - Tri phenyl ethane	-11.896	2449.0	0.60534×10^{-3}	-	-	1.2030×10^{-3} (327.75)	3.5097×10^{-4} (622.00)
$C_{20}H_{28}$	1 - n - Decyl naphthalene	-10.494	7404.1	13.331	-	-	2.364×10^{-2} (288.15)	6.8584×10^{-4} (500.00)
$C_{20}H_{30}O_2$	Abietic Acid	-0.76294	2619.1	-2.0391	-	-	6.4828×10^{-4} (446.65)	4.8306×10^{-4} (649.70)
$C_{20}H_{40}$	1 - Eicosene	-20.807	2399.0	1.3117	-	-	4.6651×10^{-2} (301.75)	2.065×10^{-4} (615.54)
$C_{20}H_{40}$	n - Eicosene	-20.379	2412.6	1.2445	-	-	4.3023×10^{-4} (309.59)	2.0909×10^{-5} (616.93)
$C_{20}H_{42}$	n - Eicosane	-18.315	2283.5	0.95485	-	-	4.2425×10^{-3} (309.58)	2.0780×10^{-4} (616.93)
$C_{20}H_{42}O$	1 - Eicosanol	-17.073	4578.1	-0.026701	-	-	2.4579×10^{-2} (338.55)	4.6856×10^{-5} (629.15)
$C_{22}H_{44}O_2$	n - Butyl stearate	-43.68	3845.9	4.555	-	-	8.0006×10^{-3} (298.15)	1.9523×10^{-3} (363.15)
$C_{24}H_{38}O_4$	Di octyl phthalate	-362.29	20711	50.885			5.1581×10^{-1} (233.20)	3.5642×10^{-3} (400.00)
$C_{24}H_{38}O_4$	Di octyl tere phthalate	-14.539	3654.7	0.84549×10^{-4}			2.6544×10^{-2} (335.00)	9.1191×10^{-5} (698.00)
$C_{24}H_{42}O$	Di nonyl phenol	-14.231	2996.8	-0.0068146			3.3172×10^{-3} (350.00)	4.0059×10^{-5} (722.00)
$C_{24}H_{50}$	n - Tetra cosane	-20.613	2536.0	1.2945	-7.0438×10^{-30}	10	5.003×10^{-3} (323.75)	7.732×10^{-5} (793.15)
$C_{25}H_{20}$	Tere phenyl methane	-12.084	2934.3	-0.20184×10^{-2}	-	-	1.0409×10^{-3} (561.15)	2.8929×10^{-4} (743.00)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
$C_{26}H_{20}$	Tetra phenyl ethylene	-3.5155	2128.1	-0.90765	-	-	7.7509×10^{-3} (496.15)	1.1873×10^{-3} (760.00)
$C_{26}H_{22}$	1,1,2,2-Tetra phenyl ethane	-12.128	3032.4	-0.95092×10^{-3}	-	-	2.7582×10^{-3} (485.15)	6.4598×10^{-4} (633.15)
$C_{28}H_{46}O_4$	Di iso decyl Phthalate	-16.376	4125.0	-	-	-	2.5259×10^{-4} (342.35)	4.6263×10^{-5} (823.15)
$C_{28}H_{58}$	Octa cosane	-23.166	2791.9	1.6621	-4.7423	10	7.6741×10^{-3} (349.05)	8.0662×10^{-5} (923.15)
$C_{32}H_{66}$	n - Do tria contane	-8.8892	2016.7	-0.34776	-	-	6.5525×10^{-3} (342.35)	1.5474×10^{-4} (823.15)
$C_{36}H_{74}$	n - Hexa tria contane	-29.462	3363.1	2.5545	-2.3313×10^{-30}	10	7.6741×10^{-3} (349.05)	8.0662×10^{-5} (923.15)
CaF	Calcium fluoride	-211.29	55518	23.084	-	-	8.810×10^{-4} (1772.00)	3.1223×10^{-4} (2000.00)
ClH	Hydrogen chloride	71.320	-2542.1	-0.1268	-	-	1.6483×10^{-4} (233.15)	6.3418×10^{-4} (313.15)
ClK	Potassium chloride	-10.568	2959.0	0.13119	-	-	1.0205×10^{-3} (1070.00)	3.855×10^{-4} (1710.00)
ClNa	Sodium chloride	-7.7059	2407.8	-0.20078	-	-	1.0298×10^{-3} (1080.00)	7.9214×10^{-4} (1210.00)
ClNaO ₃	Sodium chlorate	-140.36	12720	17.766	-	-	7.7824×10^{-3} (525.00)	5.4287×10^{-3} (559.15)
Cl ₂	Chlorine	-25.682	974.90	2.5575	-4.3×10^{-26}	10	7.9727×10^{-4} (190.00)	3.039×10^{-4} (300.00)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
Cl ₂ H ₂ Si	Dichloro silane	-5.0495	342.43	-0.78653	-2.5 x 10 ⁻²⁷	10	1.1933 x 10 ⁻³ (151.15)	8.9539 x 10 ⁻⁵ (413.15)
Cl ₂ OS	Thionyl chloride	-9.726	704.00	-	-	-	1.3643 x 10 ⁻³ (225.00)	4.4951 x 10 ⁻⁴ (348.75)
Cl ₂ O ₂ S	Sulfuryl chloride	-10.336	912.00	-	-	-	1.2458 x 10 ⁻³ (250.00)	4.6493 x 10 ⁻⁴ (342.55)
Cl ₃ Hsi	Trichlo silane	-10.651	782.00	-	-	-	4.4954 x 10 ⁻⁴ (265.65)	2.4673 x 10 ⁻⁴ (333.65)
Cl ₃ OP	Phosphorous oxy chloride	-50.860	2895.0	6.0174	-	-	1.4491 x 10 ⁻³ (275.15)	5.5784 x 10 ⁻⁴ (378.65)
Cl ₃ OV	Vandium oxy tri chloride	3.2595	0.8388	-1.8399	-	-	7.7949 x 10 ⁻⁴ (288.00)	4.2556 x 10 ⁻⁴ (400.00)
Cl ₃ P	Phosphorous tri chloride	-16.796	1013.2	1.0260	-	-	1.8475 x 10 ⁻³ (200.00)	3.7564 x 10 ⁻⁴ (349.25)
Cl ₃ PS	Phosphorous thio chloride	-32.276	2097.4	3.2216	-	-	2.6604 x 10 ⁻³ (242.15)	4.4343 x 10 ⁻⁴ (398.15)
Cl ₃ Sb	Antimony tri chloride	-65.986	4653.7	7.9743	-	-	2.676 x 10 ⁻³ (346.55)	8.2271 x 10 ⁻⁴ (493.40)
Cl ₄ Si	Silicon tetra chloride	16.800	-455.00	-4.0320	-	-	6.3976 x 10 ⁻⁴ (258.15)	2.8853 x 10 ⁻⁴ (354.05)
D ₂ O	Deuterium oxide	-56.433	3959.7	6.3816	-6.9862 x 10 ⁻²⁹	-	1.9360 x 10 ⁻³ (276.97)	3.1932 x 10 ⁻⁴ (374.55)
FH	Hydrogen fluoride	-55.977	2641.3	6.7795	-	-	9.3473 x 10 ⁻⁴ (204.00)	2.1367 x 10 ⁻⁴ (292.67)
FN _a	Sodium fluoride	-12.209	5310.0	0.25061	-	-	1.9621 x 10 ⁻³ (1269.00)	4.4428 x 10 ⁻⁴ (2060.00)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
F ₂	Fluorine	8.180	-75.600	-3.5148	-	-	4.0796 x 10 ⁻⁴ (69.19)	5.9539 x 10 ⁻⁵ (140.00)
F ₆ S	Sulfur hexa fluoride	3.8305	41.210	-2.1342	-	-	5.3876 x 10 ⁻⁴ (223.15)	2.3825 x 10 ⁻⁴ (318.69)
Fe	Iron	-8.0891	5391.7	-	-	-	6.0534 x 10 ⁻³ (1808.10)	1.8513 x 10 ⁻³ (3000.00)
HI	Hydrogen iodide	56.385	-1948.3	-0.10017	-	-	1.4779 x 10 ⁻³ (233.30)	1.3540 x 10 ⁻³ (236.40)
HKO	Potassium hydroxide	9.3268	1109.5	-2.6812	-	-	2.2173 x 10 ⁻³ (679.00)	5.2731 x 10 ⁻⁴ (973.15)
HNO ₃	Nitric acid	-28.86	1940.0	2.6780	-	-	2.1867 x 10 ⁻³ (240.00)	4.5125 x 10 ⁻⁴ (356.00)
HNaO	Sodium hydroxide	-46.121	5927.0	4.8301	-	-	3.9715 x 10 ⁻³ (623.10)	1.2568 x 10 ⁻³ (900.00)
H ₂	Hydrogen	-11.986	26.26	-0.1774	-4.4 x 10 ⁻¹⁶	10	2.5455 x 10 ⁻⁵ (14.00)	3.7852 x 10 ⁻⁶ (33.00)
H ₂ O	Water	-51.964	3670.6	5.7331	-5.349 x 10 ⁻²⁹	10	1.7237 x 10 ⁻³ (273.15)	5.3696 x 10 ⁻⁵ (643.15)
H ₂ O ₂	Hydrogen peroxide	17.532	246.8	-4.4103	-	-	1.8393 x 10 ⁻³ (272.74)	1.9173 x 10 ⁻⁴ (423.35)
H ₂ O ₄ S	Sulfuric acid	-17.984	10694	24.611	-	-	4.3575 x 10 ⁻² (283.46)	4.6773 x 10 ⁻³ (367.07)
H ₂ S	Hydrogen sulfide	-71.015	2332.5	9.7538	-	-	5.1991 x 10 ⁻⁴ (190.12)	4.0345 x 10 ⁻⁴ (223.18)
H ₃ N	Ammonia	-6.7430	598.30	-0.7341	-3.69 x 10 ⁻²⁷	10	5.2402 x 10 ⁻⁴ (194.51)	4.8567 x 10 ⁻⁵ (393.15)

Formula	Name	A	B	C	D	E	Viscosity (Min. Temp.)	Viscosity (Max. Temp.)
H ₃ O ₄ P	Phosphoric acid	-515.08	26794	74.366	-2.160 x 10 ⁻²⁶	10	2.6417 x 10 ⁻¹ (293.15)	4.5609 x 10 ⁻³ (413.15)
H ₃ P	Phosphine	19.153	-295.21	-4.9919	-	-	4.1374 x 10 ⁻⁴ (148.15)	1.0460 x 10 ⁻⁴ (223.15)
H ₄ N ₂	Hydrazine	12.785	316.4	3.6484	-	-	1.3032 x 10 ⁻³ (280.00)	2.9395 x 10 ⁻⁴ (386.65)
H ₄ Si	Silane	-11.060	341.95	-	-	-	2.0533 x 10 ⁻⁴ (133.10)	1.3155 x 10 ⁻⁴ (161.00)
He	Helium - 3	-13.922	0.9885	0.4026	-6.10 x 10 ⁻⁶	10	2.4018 x 10 ⁻⁶ (1.01)	1.8215 x 10 ⁻⁶ (2.50)
He	Helium - 4	-9.6312	-3.841	-1.458	-1.065 x 10 ⁻⁸	10	3.6284 x 10 ⁻⁶ (2.20)	2.5319 x 10 ⁻⁶ (5.10)
Hg	Mercury	-7.5698	31.62	0.0051174	-	-	2.0450 x 10 ⁻³ (234.31)	7.1772 x 10 ⁻⁴ (1073.10)
I	Iodine	45.173	-2026.0	-7.723	-	-	2.261 x 10 ⁻⁶ (389.00)	1.4691 x 10 ⁻⁶ (451.70)
K	Potassium	-8.033	576.5	-0.2126	-	-	5.2299 x 10 ⁻³ (336.35)	1.2930 x 10 ⁻⁴ (1037.00)
Li	Lithium	-4.5555	435.5	-0.6216	-	-	6.1267 x 10 ⁻⁴ (453.69)	1.3916 x 10 ⁻⁴ (1620.00)
MgO	Magnesium oxide	-9.724	9710.0	-	-	-	1.3647 x 10 ⁻³ (3105.00)	7.3398 x 10 ⁻⁴ (3872.20)
NNaO ₂	Sodium nitrite	-9.4297	2049.7	-	-	-	3.1802 x 10 ⁻³ (557.15)	2.5438 x 10 ⁻³ (593.15)
NNaO ₃	Sodium nitrate	29.677	345.70	-2.3485	-	-	2.9694 x 10 ⁻³ (580.15)	2.1031 x 10 ⁻³ (635.15)
NO	Nitric oxide	93.637	-458.28	-7.1026	-1.21 x 10 ⁻²³	10	3.8415 x 10 ⁻⁴ (109.50)	3.7658 x 10 ⁻⁵ (180.05)
NO ₂	Nitrogen dioxide	-32.165	-3467.4	-15.773	-	-	5.2928 x 10 ⁻⁴ (273.15)	3.1023 x 10 ⁻⁴ (313.15)

<i>Formula</i>	<i>Name</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>Viscosity (Min. Temp.)</i>	<i>Viscosity (Max. Temp.)</i>
N ₂	Nitrogen	26.236	496.9	3.9069	-1.08 x 10 ⁻²¹	10	3.0311 x 10 ⁻⁴ (63.15)	3.2577 x 10 ⁻⁵ (125.00)
N ₂ O	Nitrous oxide	-5.8164	-381.68	-4.8618	-		1.9214 x 10 ⁻¹ (214.95)	7.724 x 10 ⁻² (283.09)
Na	Sodium	-5.8164	510.10	-0.4796	-	-	6.900 x 10 ⁻⁴ (370.97)	1.5726 x 10 ⁻⁴ (1156.00)
Na ₂ O ₄ S	Sodium sulfate	-145.36	-18326	-19.106	-	-	4.9286 x 10 ⁻³ (1180.10)	3.6776 x 10 ⁻³ (1267.10)
Na ₆ O ₁₈ P ₆	Sodium hexa meta phosphate	-78.465	18062	8.6574	-	-	2.0426 (883.15)	1.5276 x 10 ⁻⁴ (1173.10)
Ne	Neon	-17.945	115.57	1.4280	2.14 x 10 ⁻¹⁷	10	1.6018 x 10 ⁻⁴ (25.09)	2.7057 x 10 ⁻⁵ (44.13)
O ₂	Oxygen	-17.270	287.5	1.2290	-1.040 x 10 ⁻²²	10	8.4974 x 10 ⁻⁴ (54.36)	5.5731 x 10 ⁻⁵ (150.00)
O ₂ S	Sulfur dioxide	-168.79	6638.5	24.393	-7.640 x 10 ⁻²⁶	10	5.6240 x 10 ⁻⁴ (239.65)	2.6125 x 10 ⁻⁴ (323.15)
O ₂ Si	Silicon dioxide	-675.73	228930	75.788	-	-	3.3633 x 10 ⁻⁷ (1883.20)	3.1966 x 10 ⁻³ (2643.50)
O ₂ Ti	Titanium dioxide	75.281	-6083.0	-9.7343	-	-	1.5919 x 10 ⁻¹ (2125.00)	2.5403 x 10 ⁻² (2625.00)
O ₃	Ozone	-41.329	988.91	5.3092	-		3.2937 x 10 ⁻³ (80.15)	2.7116 x 10 ⁻⁴ (161.85)
O ₃ S	Sulfur trioxide	-88.794	6400.7	10.709	-	-	2.4547 x 10 ⁻³ (290.15)	9.447 x 10 ⁻⁴ (318.15)
P	Phosphorous	-10.227	1231.8	-	-	-	1.7568 x 10 ⁻³ (317.25)	7.1337 x 10 ⁻⁴ (413.15)
S	Sulfur	52.077	-28595	-7.4037	9.6936 x 10 ⁻²⁹	10	9.0404 x 10 (468.00)	8.8879 x 10 ⁻² (721.15)
Zn	Zinc	-6.6105	1342.2	-0.15188	-	-	3.4608 x 10 ⁻³ (692.7)	1.4322 x 10 ⁻³ (1181.7)

4.3.2 ESTIMATION METHODS

The methods in common use for the estimation of liquid viscosity can be described under the important categories of relationships with the other physical or molecular properties and generalized relationships, although any relationship with physical properties can probably be converted into a generalized relationship and the development of any generalized relation involves (as the necessary input) several physical or molecular properties. In this section, we will discuss the development of relationships in which the temperature dependence of viscosity has been expressed in the forms which require a minimum amount of experimental viscosity data taking advantage of the interrelationships among viscosity and different physical and molecular properties of the substances.

4.3.2.1 Relationships of Viscosity with Physical Properties

In this section, we will discuss the relation of liquid viscosity as a function of temperature and its dependence on the other physical properties like normal boiling point, density and surface tension, and the methods developed for the estimation of viscosity based on relation of liquid viscosity with these properties. In the next section, we will discuss the relationships of viscosity with molecular properties.

4.3.2.1.1 Correlations Based on the Temperature Dependence of Viscosity

The discussion so far centered around the liquid viscosity-temperature relations fitted to experimental data. The constants in two-, three- or multi-parameter relations were obtained by regression analysis. Here we will consider viscosity-temperature relations which can be used with a minimum amount (or no) viscosity versus temperature data, taking advantage of the general pattern of the viscosity-temperature relation and its dependence on the other physical and/or molecular parameters. The advantage of these methods lies in the fact that the viscosity of any liquid at the required temperature can be predicted from the knowledge of the viscosity at any one temperature and/or some other physical or molecular properties.

The simplest of the liquid viscosity-temperature relations given by Eq. (4.5) can be utilized for the estimation of liquid viscosity according to the methods proposed by Lewis and Squires²⁸ and van Velzen *et al.*²⁹ These and a few other similar methods are described below.

4.3.2.1.1.a Lewis and Squires Method

Lewis and Squires²⁸ presented the temperature dependence of liquid viscosity according to Eq. (4.5) graphically as shown in Fig. 4.7. Application of the method requires the knowledge of the value of viscosity (η^{Ref}) at any reference temperature (t^{Ref}). A convenient reference temperature for this purpose is the normal boiling point (t_B). Following the recommendation of Grain¹¹, in the absence of a measured value the liquid viscosity at the normal boiling point (η_B) indicated by the class of the substance from the Table 4.1 (given in Section 4.2.2) can be used.

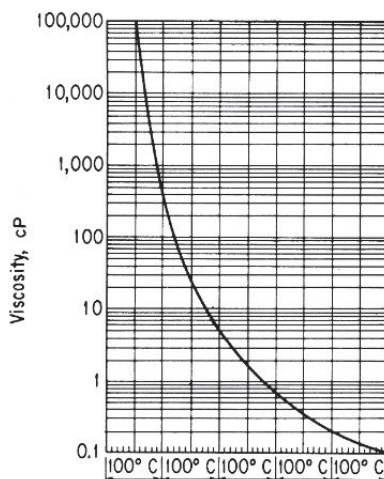


Figure 4.7. Variation of liquid viscosity (η in cP) with temperature (t in $^{\circ}\text{C}$) (Adopted from: R.C. Reid, J.M. Prausnitz and B.E. Poling, *The Properties of Gases and Liquids*, 4th Ed., McGraw Hill, New York, 1987).

The following basic steps are suggested for the application of the method to determine the value of viscosity (η) at any temperature (t)

- Estimate η_B from the Table 4.1, if a measured value is not available.
- Find the reference point on the Δt -axis corresponding to η_B on the curve in Fig. 4.7.

At the temperature of interest (t), determine the temperature difference $\Delta t = (t_B - t)$, where t_B is the normal boiling point in $^{\circ}\text{C}$. Move Δt degrees to the left from the reference point along the abscissa and locate the corresponding value of the viscosity η from the curve in Fig. 4.7.

Similar methodology is to be used in the case of substances for which the value of viscosity (η^{Ref}) at a reference temperature (T^{Ref}) is available.

Figure 4.7 can be expressed in equation form as

$$\eta^{-0.2661} = \eta_K^{-0.2661} + [(T - T_K)/233] \quad (4.42)$$

where η is the liquid viscosity at T in cP

η_K is the known value of the liquid viscosity at T_K in cP.

T and T_K may be expressed in either °C or K.

The graphical form (as well as the equation) generally predicts the values of liquid viscosity within 5 to 15 % of their true values. This shows that to predict the viscosity of any substance, one can use the data of similar compounds and construct relationships similar to Eq. (4.42).

4.3.2.1.1.b Jagannathan *et al.* Method

Starting from the determination of the constants A and B from a linear relation between the logarithm of liquid viscosity and the reciprocal of the absolute temperature

$$\ln \eta = A + (B/T) \quad (4.43)$$

for over 70 substances, Jagannathan *et al.*³⁰ developed generalized correlations based on the relation of the constants A and B to the normal boiling point for each series of compounds. The authors also proposed a generalized correlation as a plot of the dimensionless viscosity ($\eta^* = \eta/\eta^{Ref}$) as a function of the dimensionless temperature ($T^* = T/T^{Ref}$) where η^{Ref} is the viscosity of the liquid at the reference temperature T^{Ref} , chosen as 293 K, for each series of compounds. Both the approaches produced estimation methods of accuracy comparable to the other methods available for the estimation of liquid viscosity in the literature at that time. The relation between the normal boiling temperature (T_B) and the viscosity parameters A and B is shown in Figs. 4.8 and 4.9. A linear relationship is obtained for compounds in each homologous series.

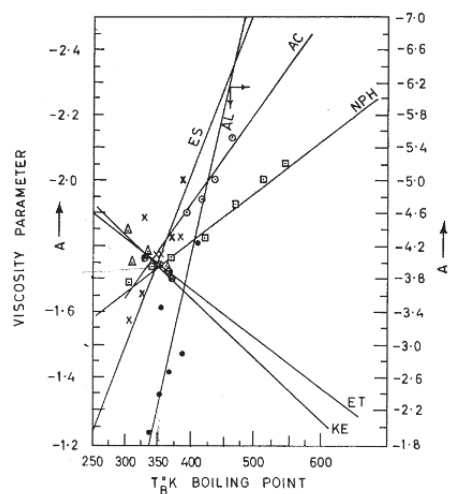


Figure 4.8. Viscosity parameter A as a function of the normal boiling point T_B (in K). AL - alcohols, ES - esters, KE - ketones, AC - acids, ET - ethers and NPH - normal paraffin hydrocarbons (Adopted from T. K. Jagannathan, D. S. Viswanath, and N. R. Koloor, Predict organic liquids viscosity, *Hydrocarbon Process.* **47**(2), 133-136, 1968).

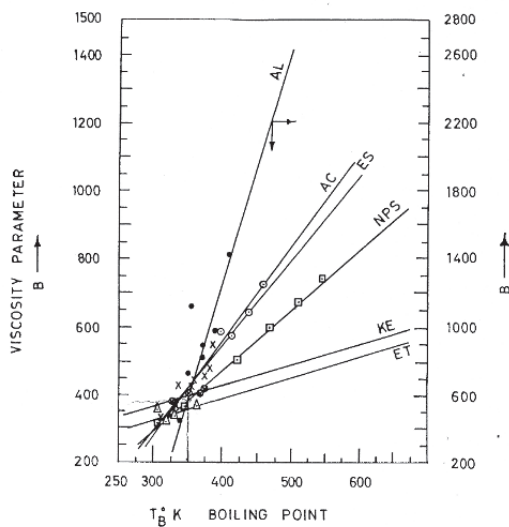


Figure 4.9. Viscosity parameter B as a function of the normal boiling point T_B (in K). AL - alcohols, ES - esters, KE - ketones, AC - acids, ET - ethers, and NPH - normal paraffin hydrocarbons (Adopted from T. K. Jagannathan, D. S. Viswanath, and N. R. Koloor, Predict organic liquids viscosity, *Hydrocarbon Process.* **47**(2), 133-136, 1968).

On applying this method, viscosities of hydrocarbons and related substances could be predicted to accuracy comparable to the other estimation methods available at that time with more uniform deviations. For quick estimation, the authors also presented plots of dimensionless viscosity as a function of dimensionless temperature (as defined in this section). This is reproduced in Fig. 4.10.

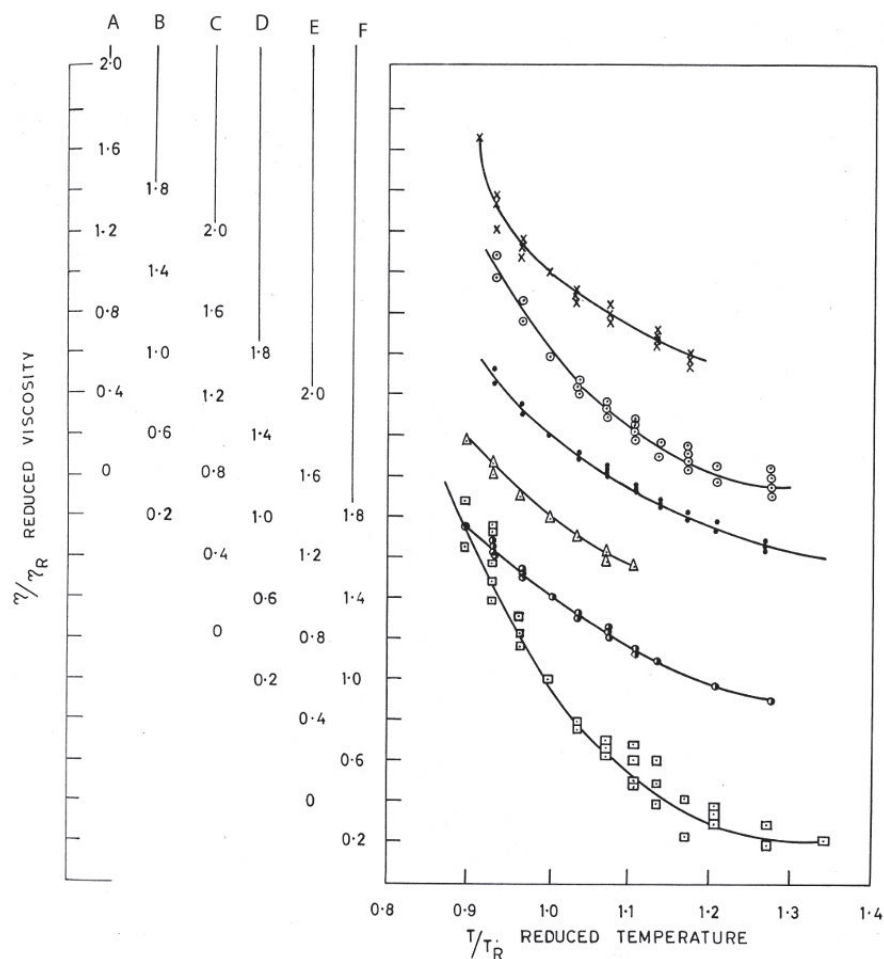


Figure 4.10. Dimensionless viscosity as a function of dimensional temperature for Aliphatic Alcohols (A), Acids (B), Ethers (C), Esters (D), Ketones (E), and Chlorides (F) (Adopted from T. K. Jagannathan, D. S. Viswanath, and N. R. Kolor, Predict organic liquids viscosity, *Hydrocarbon Process.* 47(2), 133-136, 1968).

4.3.2.1.1.c Chartterjee and Kunte Method

Chatterjee and Kunte³¹ proposed the equation

$$\log(\eta/\eta_B) = A + B(T_B/T) \quad (4.44)$$

and studied its application to different hydrocarbon groups. The parameters A and B , constant for each hydrocarbon group are noted in Table 4.21.

Table 4.21. Values of constants A and B of Eq. (4.44) proposed by Chatterjee and Kunte for different hydrocarbon groups.

Group	A	B
Acids	- 3.0944	3.1111
Alcohols	- 6.0866	6.1333
Esters	- 3.0009	2.9714
Ethers	- 2.7851	2.7742
Ketones	- 2.6105	2.6460
Normal Paraffins	- 2.6677	2.6613

The method usually predicts liquid viscosity with an average absolute deviation of about 2%, except for alcohols for which the average absolute deviation is about 7%. This method requires the values of the normal boiling point and the viscosity at the normal boiling point as the input data.

4.3.2.1.1.d van Velzen *et al.* Method

van Velzen *et al.*²⁹ proposed an estimation method for the temperature dependence of liquid viscosity based on the de Guzman-Andrade equation. They denote the temperature at which the liquid viscosity η becomes 1 by T_0 . At this condition, one can write:

$$1 = A \exp(B/T_0) \quad (4.45)$$

$$\text{Taking logarithms, } \log \eta = 0 = A' + (B/T_0) \quad (4.46)$$

where $A' = \log A$, resulting in

$$A' = -(B/T_0) \quad (4.47)$$

At any other temperature T

$$\log \eta = B \left[\left(\frac{1}{T} \right) - \left(\frac{1}{T_0} \right) \right] \quad (4.48)$$

where T and T_0 are absolute temperatures.

van Velzen *et al.* presented the following equations which enable the estimation of B and T_0 for straight-chain hydrocarbons and described the methodology for the calculation of B and T_0 for the other molecules.

For straight-chain hydrocarbons containing N carbon atoms if $N \leq 20$:

$$B = 24.79 + 66.885N - 1.3173N^2 + 0.00377N^3 \quad (4.49)$$

$$T_0 = 28.86 + 37.439N - 1.3547N^2 + 0.02076N^3 \quad (4.50)$$

if $N > 20$:

$$B = 530.59 + 13.740N \quad (4.51)$$

$$T_0 = 238.59 + 8.164N \quad (4.52)$$

For molecules other than straight-chain hydrocarbons, N is replaced by the “equivalent chain length” (NE) which is a hypothetical alkane with viscosity equal to 1 cP at the temperature at which the viscosity of the compound is 1 cP. NE is calculated as the sum of N (the total number of carbon atoms) and one or more structural or configurational factors as

$$NE = N + \sum_i \Delta N_i \quad (4.53)$$

Similarly,

$$B = B_a + \Delta B \quad (4.54)$$

where B_a is the value of B for the hypothetical alkane with equivalent chain length NE and ΔB is the correction factor that varies with the structure of the compound. If the compound contains two or more functional groups, the ΔN correction must be multiplied by the number of groups. The ΔB correction is applied only once, regardless of the number of functional groups. NE can be used in the place of N for the calculation of B and T_0 in the equations given for straight-chain hydrocarbons. Table 4.22 gives the functions for ΔN and

ΔB for the commonly occurring functional groups and structural configurations.

Table 4.22. Functions to be used for ΔN and ΔB for use in the van Velzen *et al.*²⁹ method.

Functional Groups	ΔN	ΔB
n-Alkane	0	0
Alkene	- 0.152 – 0.042 N	- 44.94 + 5.410 NE
Acid $3 \leq N \leq 10$	6.795 + 0.365 N	- 249.12 + 22.449 NE
Acid $N > 10$	10.710	- 249.12 + 22.449 NE
Ester	4.337 – 0.230 N	- 149.13 + 18.695 NE
Primary Alcohol	10.606 – 0.276 N	- 589.44 + 70.519 NE
Secondary Alcohol	11.200 – 0.605 N	497.58
Tertiary Alcohol	11.200 - 0.605 N	928.83
Diol	Alcohol Correction + Configurational Factor	557.77
Ketone	3.265 – 0.122 N	- 117.21 + 15.781 NE
Ether	0.298 + 0.209 N	- 9.39 + 2.848 NE
Primary Amine	3.581 + 0.325 N	25.39 + 8.744 NE
Secondary Amine	1.390 + 0.461 N	25.39 + 8.744 NE
Tertiary Amine	3.27	25.39 + 8.744 NE
Fluoride	1.43	5.75
Chloride	3.21	- 17.03
Bromide	4.39	- 101.97 + 5.954 NE
Iodide	5.76	- 85.32
Aromatic & 1-Nitro-	7.812 – 0.236 N	- 213.14 + 18.330 NE
2-Nitro-	5.84	- 213.14 + 18.330 NE
3-Nitro-	5.56	- 338.01 + 25.086 NE
4,5-Nitro-	5.36	- 338.01 + 25.086 NE
CONFIGURATIONAL FACTORS		
<i>Correction for Aromatic Nucleus</i>		
Alkyl-, Halogen-, Nitro- benzenes, Secondary and Tertiary Amines		
$8 \leq N \leq 15$	0.60	- 140.04 + 13.869 NE
$N > 15$	3.055 – 0.161 N	- 140.04 + 13.869 NE
Acids	4.810	- 188.04 + 9.588 NE
Esters		
Alcohols : OH Attached to the Nucleus – for all Phenolic Compounds NE = 16.17 ^b		213.68
Alcohols : OH in Side Chain	- 0.160	213.68
Ketones	2.700	- 760.65 + 50.478 NE
Ethers : All Aromatic Ethers	11.5 – N	- 140.04 + 13.869 NE

Functional Groups	ΔN	ΔB
Primary Amines : NH_2 in Side Chain	- 0.160	0
Polyphenyls	- 5.340 + 0.815 N	- 188.40 + 9.558 NE
Ortho Configuration -		
With OH Group	0.510	- 571.94
Without OH Group	0.510	54.84
Meta Configuration	0.110	27.25
Para Configuration	- 0.040	- 17.57
Cyclopentane $7 \leq N \leq 15$	$0.205 + 0.069 N$	- 45.96 + 2.224 NE
$N > 15$	$3.971 - 0.172 N$	- 339.67 + 23.135 NE
Cyclohexane $8 \leq N \leq 16$	1.480	- 272.85 + 25.041 NE
$N > 16$	$6.517 - 0.311 N$	- 272.85 + 25.041 NE
Iso Configuration		
Alkanes	$1.389 - 0.238 N$	15.510
Double iso in Alkanes (extra correction)	0.930	8.930
Alkenes	$1.389 - 0.238 N$	94.230
Alcohols	0.240	8.930
Esters, Alkylbenzenes, Halogenides, Ketones	- 0.240	-
Acids	- 0.240	-
Esters, Amines	- 0.500	8.930
Other Configurations		
-C(Cl) _x Configuration	$1.91 - 1.459 x$	- 26.38
-CCl-CCl-	0.96	0
-C(Br) _x Configuration	0.50	$81.34 - 86.85 x$
-CBr-CBr-	1.60	- 57.73
CF _x in Alcohols	- 3.93	341.68
CF _x in Other Compounds	- 3.93	25.55
Diols	- 2.50 + N	Alcohols Value

^a Includes Pyridine

^b Other Substituents like Cl, CH₃ and NO₂ are neglected for the determination of NE. For the calculation of B, they have been considered.

The following steps are recommended for the estimation of liquid viscosity by the method of van Velzen *et al.*

- Count the number of carbon atoms (N) in the molecular formula.
- Determine N correction using the above table.
- Sum N and ΔN to obtain NE .
- Calculate B_a by substituting NE into the appropriate equation given above.
- Determine the ΔB correction from the above table and add this to B_a to calculate B .

- Calculate T_0 by substituting the value of NE into the appropriate equation given above.
- Use the calculated values of T_0 and B to obtain $\log \eta$ from the equation relating $\log \eta$ to the temperature.

The authors tested 314 different compounds at a total of 4,500 data points. The method is fairly accurate, and can be used for estimation of liquid viscosity values within $\pm 10\%$. As expected, the first members of any homologous series gave large errors. In their first report on the topic, van Velzen *et al.*³² tabulated liquid viscosity data on several substances and also provided the constants of the van Velzen *et al.* representation (Eq. 4.48) derived from the experimental liquid viscosity data. Table 4.23 gives the constants of Eq. (4.48) for different substances used in their study along with the equivalent chain length NE .

4.3.2.1.1.e van Velzen *et al.* Method

Another simple method was proposed by van Velzen *et al.* which can be considered an extension of the Lewis and Squires method or a variation of the van Velzen method proposed by Grain³³. The method is based on the application of the equation expressing the linear dependence of the logarithm of liquid viscosity ($\ln \eta$) on the reciprocal of the absolute temperature ($1/T$) to the normal boiling point (T_B). The resulting expression for viscosity is:

$$\ln \eta_B = A + (B/T_B) \quad (4.55)$$

from which

$$A = \ln \eta_B - (B/T_B) \quad (4.56)$$

At any other temperature T ,

$$\ln \eta = \ln \eta_B + B[(1/T) - (1/T_B)] \quad (4.57)$$

This correlation requires the experimental or estimated value of the liquid viscosity at the normal boiling point (η_B). The viscosity at the normal boiling point can be taken from Table 4.1 depending on the type of compound, if an experimental value is not available.

Following the ideas of Eyring³⁴, the parameter B is equated to the energy of vaporization resulting in

$$B = \Delta E_v / n \quad (4.58)$$

where n is an integer. For an ideal gas, the energy of vaporization is related to the heat of vaporization according to

$$\Delta E_v = \Delta H_v - RT \quad (4.59)$$

Table 4.23. Constants B , NE at T_0 of the van Velzen et al. equation, $\left[\log \eta = B \left\{ \left(1/T \right) - \left(1/T_0 \right) \right\} \right] B$ derived from liquid viscosity measurements.

Compound	Temp. Range, °C	Viscosity Range, cP	NE	B	T_0 , K
Methane	- 180 to -165	0.188 to 0.127	0.79	114.14	57.60
Ethane	- 175 to -90	0.982 to 0.172	1.91	156.60	95.57
Propane	- 185 to - 45	8.750 to 0.215	3.13	222.67	133.41
Butane	- 90 to - 5	0.628 to 0.218	4.07	265.84	160.20
Pentane	- 125 to 35	2.890 to 0.207	4.91	313.66	182.48
Hexane	- 95 to 65	2.140 to 0.213	5.91	362.79	207.09
Heptane	- 90 to 95	3.770 to 0.216	7.04	436.73	232.53
Octane	- 55 to 120	2.120 to 0.219	7.97	437.70	251.71
Nonane	- 50 to 150	2.990 to 0.211	9.05	525.56	272.12
Decane	- 25 to 175	2.239 to 0.207	9.99	558.61	288.37
Undecane	- 25 to 195	3.182 to 0.207	11.04	605.50	305.01
Dodecane	- 5 to 215	2.558 to 0.206	11.99	631.63	318.78
Tridecane	- 5 to 235	3.348 to 0.204	12.99	664.10	332.10
Tetradecane	10 to 250	2.932 to 0.206	13.98	689.85	344.21
Pentadecane	10 to 270	3.653 to 0.202	15.02	718.51	355.92
Hexadecane	20 to 260	3.471 to 0.237	16.00	738.30	366.11
Heptadecane	25 to 300	3.700 to 0.203	17.01	757.88	375.90
Octadecane	30 to 315	3.880 to 0.200	18.01	777.40	385.00
Nonadecane	35 to 325	4.021 to 0.200	19.00	739.62	393.54
Eicosane	40 to 340	4.142 to 0.200	19.98	811.29	401.67
Iso butane	- 80 to -15	0.626 to 0.252	4.44	302.51	170.20
Iso pentane	- 50 to 25	0.550 to 0.214	5.27	367.32	191.58
Iso hexane	0 to 60	0.371 to 0.205	5.96	384.13	208.27
Neo hexane	0 to 30	0.477 to 0.330	6.77	438.44	226.67
Iso heptane	0 to 90	0.476 to 0.198	6.70	417.46	225.13
Neo pentane	- 10 to 0	0.390 to 0.327	6.40	542.12	218.42
2,3-Di methyl butane	0 to 30	0.495 to 0.342	6.87	444.19	228.86
Ethene	-165 to - 105	0.600 to 0.160	1.86	168.98	93.94
Propene	-185 to - 95	15.0 to 0.350	3.07	273.84	131.63
1 - Butene	- 115 to - 35	0.880 to 0.250	3.77	256.30	151.86
1 - Pentene	- 90 to 0	0.850 to 0.240	4.61	305.25	174.70

<i>Compound</i>	<i>Temp. Range, °C</i>	<i>Viscosity Range, cP</i>	<i>NE</i>	<i>B</i>	<i>T₀, K</i>
1 – Hexene	- 55 to 60	0.690 to 0.190	5.52	357.43	197.74
1 – Heptane	0 to 90	0.440 to 0.200	6.22	368.69	214.32
1 – Octane	0 to 115	0.611 to 0.210	7.28	418.82	237.63
1 – Nonene	0 to 115	0.836 to 0.260	8.34	471.00	258.92
1 – Decene	0 to 115	1.127 to 0.300	9.37	518.37	277.80
1 – Un decene	0 to 115	1.500 to 0.360	10.39	566.26	294.89
1 – Do decene	0 to 115	1.960 to 0.410	11.38	615.67	310.07
1 – Tri decene	0 to 115	2.530 to 0.480	12.35	658.16	323.71
1–Tetra decene	0 to 115	3.220 to 0.550	13.31	697.49	336.13
1 – Penta decene	0 to 115	4.080 to 0.620	14.26	739.13	347.46
1 – Hexa decene	5 to 115	4.420 to 0.710	15.20	767.48	357.85
1 – Hepta decene	15 to 115	4.070 to 0.790	16.15	790.25	367.61
1 – Octa decene	20 to 115	4.310 to 0.890	17.12	816.19	376.93
1 – Nona decene	25 to 115	4.560 to 0.990	18.07	844.46	385.53
1 – Eicosane	35 to 115	4.220 to 1.100	19.04	860.96	393.88
2 – Methyl – 2 - butene	0.2 to 32.6	0.253 to 0.190	4.83	322.47	180.43
Isoprene	0 to 32	0.259 to 0.194	4.91	328.49	182.48
2,3 – Dimethyl - 1,3 -butadiene	0.4 to 56.2	0.337 to 0.197	5.71	375.21	202.33
Cyclo hexane	10 to 80	1.178 to 0.410	10.14	653.62	290.84
Methyl cyclo hexane	- 25 to 100	1.545 to 0.300	9.02	528.41	271.58
Ethyl cyclo hexane	- 25 to 110	1.794 to 0.300	9.54	506.43	280.76
Propyl cyclo hexane	- 25 to 110	2.343 to 0.390	10.33	549.08	293.93
Butyl cyclo hexane	- 20 to 110	2.931 to 0.469	11.47	598.30	311.39
Pentyl cyclo hexane	- 10 to 105	3.321 to 0.539	12.52	681.52	325.99
Hexyl cyclo hexane	- 10 to 110	4.488 to 0.590	13.59	736.92	339.56
Heptyl cyclo hexane	- 10 to 110	5.922 to 0.680	14.60	787.82	351.31
Octyl cyclo hexane	- 10 to 110	7.700 to 0.768	15.54	840.25	361.42
Nonyl cyclo hexane	-10 to 110	9.890 to 0.870	16.45	886.88	370.56
Decyl cyclo hexane	0 to 110	9.260 to 0.970	17.31	925.84	378.69
Un decyl cyclo hexane	10 to 110	8.440 to 1.080	18.16	957.97	386.32
Do decyl cyclo hexane	15 to 110	8.760 to 1.190	18.93	992.43	392.95

<i>Compound</i>	<i>Temp. Range, °C</i>	<i>Viscosity Range, cP</i>	<i>NE</i>	<i>B</i>	<i>T₀, K</i>
Tri decyl cyclo hexane	20 to 110	8.920 to 1.310	19.68	1023.62	399.21
Tetra decyl cyclo hexane	25 to 110	8.960 to 1.440	20.36	1054.46	404.78
Penta decyl cyclo hexane	30 to 110	8.910 to 1.570	21.01	1082.54	410.09
Hexa decyl cyclo hexane	35 to 110	8.760 to 1.700	21.60	1111.59	414.90
Cyclo pentane	- 25 to 45	0.780 to 0.338	7.00	406.69	231.67
Methyl cyclo pentane	- 25 to 70	0.930 to 0.299	7.55	440.52	243.24
Ethyl cyclo pentane	- 20 to 100	0.960 to 0.270	7.87	433.81	249.72
Propyl cyclo pentane	- 20 to 110	1.240 to 0.300	8.62	454.23	264.22
Butyl cyclo pentane	- 20 to 110	1.710 to 0.350	9.74	513.25	284.18
Pentyl cyclo pentane	- 20 to 110	2.320 to 0.420	10.85	565.40	302.11
Hexyl cyclo pentane	- 20 to 110	3.120 to 0.490	11.98	617.57	318.65
Heptyl cyclo oentane	- 20 to 110	4.110 to 0.570	13.07	654.77	333.12
Octyl cyclo pentane	- 20 to 110	5.340 to 0.660	14.15	695.83	346.19
Nonyl cyclo pentane	- 20 to 110	6.830 to 0.750	15.19	735.19	357.74
Decyl cyclo pentane	- 20 to 110	8.630 to 0.850	16.22	771.74	368.30
Un decyl cyclo pentane	- 10 to 110	8.560 to 0.950	17.14	817.49	377.11
Do decyl cyclo pentane	- 5 to 110	9.310 to 1.070	18.07	853.90	385.53
Tri decyl cyclo pentane	5 to 110	8.800 to 1.180	18.91	891.80	392.78
Tetra decyl cyclo pentane	10 to 110	9.210 to 1.310	19.73	924.60	399.62
Penta decyl cyclo pentane	20 to 110	8.320 to 1.440	20.55	950.57	406.33
Hexa decyl cyclo pentane	25 to 110	8.440 to 1.580	21.28	977.42	412.29
Benzene	0 to 75	0.912 to 0.332	8.68	545.64	265.34
Toluene	- 25 to 105	1.170 to 0.258	8.15	467.33	255.24
Ethyl benzene	- 25 to 130	1.350 to 0.246	8.62	477.82	264.22
Propyl benzene	- 25 to 150	1.910 to 0.250	9.65	527.55	282.65
Butyl benzene	- 25 to 150	2.500 to 0.280	10.46	563.84	296.01
Pentyl benzene	- 20 to 150	3.820 to 0.320	11.67	635.80	314.27
Hexyl benzene	- 20 to 150	5.170 to 0.360	12.67	638.93	327.97

<i>Compound</i>	<i>Temp. Range, °C</i>	<i>Viscosity Range, cP</i>	<i>NE</i>	<i>B</i>	<i>T₀, K</i>
Heptyl benzene	- 20 to 150	6.930 to 0.400	13.65	726.49	340.29
Octyl benzene	- 20 to 120	9.230 to 0.610	14.48	788.79	349.96
Nonyl benzene	- 20 to 125	12.20 to 0.650	15.35	835.49	359.43
Decyl benzene	- 15 to 150	12.27 to 0.560	16.41	844.13	370.17
Un decyl benzene	- 10 to 150	12.44 to 0.610	17.30	872.17	378.59
Do decyl benzene	0 to 150	10.31 to 0.670	18.21	887.76	386.76
Tri decyl benzene	5 to 150	10.49 to 0.730	19.05	915.57	393.97
Tetra decyl benzene	15 to 150	8.940 to 0.790	19.90	932.51	401.02
Penta decyl benzene	20 to 150	8.990 to 0.850	20.67	957.98	407.31
Hexa decyl benzene	30 to 150	7.740 to 0.920	21.43	974.80	413.51
o - Xylene	- 5 to 140	1.212 to 0.253	9.38	513.54	277.98
m - Xylene	0 to 135	0.806 to 0.225	8.25	453.42	257.18
p - Xylene	16 to 135	0.696 to 0.224	8.47	475.16	261.40
Iso propyl benzene	0 to 60	1.073 to 0.489	9.28	517.17	276.22
1 - Methyl - 4 - ethyl benzene	10 to 80	0.805 to 0.381	8.72	463.17	266.08
1,2,4 -Tri - methyl benzene	25 to 35	1.008 to 0.810	10.57	872.74	297.75
Methanol	- 84.2 to 65.0	6.800 to 0.329	8.43	555.30	260.64
Ethanol	- 98.1 to 75.0	44.00 to 0.464	10.77	686.64	300.88
Propanol	0 to 95.6	3.833 to 0.477	12.66	951.04	327.83
1 - Butanol	- 50.9 to 114.1	36.10 to 0.425	13.51	1004.83	338.59
1 - Pentanol	0 to 130	8.79 to 0.390	14.45	1151.14	349.62
1 - Hexanol	25 to 50	4.370 to 2.160	14.93	1179.42	354.94
1 - Heptanol	15 to 90	8.530 to 1.000	15.58	1287.04	361.83
1 - Octanol	15 to 90	10.60 to 1.210	16.39	1312.09	379.97
Iso propanol	0.4 to 78.1	4.502 to 0.541	12.33	1139.72	323.44
Iso butanol	0.4 to 105.1	7.911 to 0.475	13.76	1211.09	341.61
Iso amyl alcohol	0.2 to 128.1	8.461 to 0.397	14.44	1148.76	349.51
D - Amyl alcohol	0 to 130	11.22 to 0.370	14.47	1259.39	349.85
Tert - Butyl alcohol	22.4 to 77.0	5.887 to 0.645	13.12	1727.96	333.75
Tert - Amyl alcohol	0.5 to 85	13.797 to 0.573	13.36	1502.01	336.75
Benzyl alcohol	20 to 50	5.582 to 2.574	16.11	1087.98	367.21
2 - Phenyl ethanol	25 to 50	7.610 to 3.200	15.72	1450.09	363.27
Phenol	18.3 to 90	12.70 to 1.306	16.40	1405.48	370.07
o - Chloro phenol	0 to 150	10.70 to 0.540	15.67	982.38	362.76
m - Chloro phenol	25 to 50	11.50 to 4.000	15.59	1775.58	361.94

<i>Compound</i>	<i>Temp. Range, °C</i>	<i>Viscosity Range, cP</i>	<i>NE</i>	<i>B</i>	<i>T₀, K</i>
p – Chloro phenol	45 to 50	6.150 to 5.000	16.07	1862.01	366.81
o – Cresol	0 to 110	39.70 to 0.890	15.95	1533.41	365.61
m – Cresol	0 to 110	84.40 to 1.020	16.47	1785.57	370.75
p – Cresol	0 to 110	98.40 to 1.080	16.67	1826.92	372.68
o – Nitro phenol	40 to 80	2.750 to 1.350	16.59	839.02	371.91
Allyl alcohol	0 to 95.2	2.145 to 0.379	11.19	793.52	307.26
Hexa hydro cresol	20 to 90	21.80 to 1.260	16.09	1864.02	367.01
Ethylene glycol	20 to 100	19.90 to 1.990	20.07	1364.99	402.41
Propylene glycol	40 to 180	19.45 to 0.783	23.05	1404.20	426.74
Formic acid	7.6 to 100	2.385 to 0.549	12.50	729.35	325.72
Acetic acid	30.9 to 112.6	1.025 to 0.406	11.12	600.94	306.21
Propionic acid	4.7 to 137	1.404 to 0.329	10.67	535.04	299.32
Butyric acid	0 to 155.8	2.286 to 0.327	12.16	640.42	321.13
Valeric acid	16.5 to 90	2.410 to 0.753	13.72	729.09	341.13
Caproic acid	16.1 to 90	3.56 to 0.980	15.36	793.55	359.54
Heptanoic acid	17.5 to 90	4.600 to 1.190	16.77	856.73	373.63
Octanoic acid	20 to 90	5.748 to 1.300	17.13	979.13	377.02
Nonanoic acid	20 to 90	8.080 to 1.730	19.05	1026.92	393.97
Decanoic acid	50 to 70	4.340 to 2.880	20.60	987.89	406.82
Do decanoic acid	50 to 90	7.300 to 2.990	22.90	1135.68	425.51
Tetra decanoic acid	60 to 90	7.222 to 3.691	24.65	1174.64	439.80
Hexa decanoic acid	70 to 95	7.800 to 4.470	26.67	1209.47	456.29
Stearic acid	70 to 98	11.6 to 5.18	25.92	1449.71	450.16
Oleic acid	20 to 180	36.56 to 1.336	28.01	1198.58	467.22
Iso butyric acid	3.7 to 147.5	1.761 to 0.323	11.46	588.65	311.24
Benzoic acid	122.5 to 130.0	1.670 to 1.260	20.74	2617.62	407.88
Phenyl acetic acid	77 to 130	3.540 to 1.400	22.79	1073.11	424.62
3 - Phenyl propionic acid	49.7 to 130.0	9.800 to 1.720	24.03	1224.95	434.74
Methyl formate	0.6 to 29.3	0.426 to 0.319	6.15	363.19	212.70
Methyl acetate	0 to 54.3	0.484 to 0.273	6.65	408.62	224.03
Methyl propionate	0.4 to 68.5	0.579 to 0.281	7.23	482.74	236.58
Methyl butyrate	0.3 to 98.3	0.755 to 0.259	8.12	479.35	254.66
Methyl laurate	25 to 50	3.080 to 1.850	15.28	853.20	358.70
Ethyl formate	0.5 to 52	0.502 to 0.294	6.75	400.91	226.23
Ethyl acetate	0 to 75	0.582 to 0.283	7.20	427.38	235.94
Ethyl propionate	0.4 to 89.7	0.689 to 0.263	7.82	463.31	248.72

<i>Compound</i>	<i>Temp. Range, °C</i>	<i>Viscosity Range, cP</i>	<i>NE</i>	<i>B</i>	<i>T₀, K</i>
Ethyl butyrate	15 to 70	0.711 to 0.381	8.62	489.95	264.22
Ethyl valerate	20 to 50	0.836 to 0.536	9.56	602.07	281.10
Ethyl caprylate	25 to 50	1.380 to 0.943	11.93	642.67	317.95
Ethyl pelargonate	25 to 50	1.690 to 1.110	12.76	703.62	329.14
Ethyl palmitate	25 to 50	5.76 to 3.14	17.77	1015.54	382.86
Propyl formate	0.3 to 77.5	0.665 to 0.286	7.69	452.97	246.09
Propyl acetate	0.4 to 96.9	0.765 to 0.260	8.18	489.53	255.83
Propyl butyrate	20 to 50	0.829 to 0.551	9.51	560.29	280.24
Amyl acetate	11 to 25	1.580 to 0.811	10.25	1752.25	292.64
n - Butyl acetate	0 to 40	1.004 to 0.563	9.06	537.58	272.30
Methyl isobutyrate	0.3 to 88.8	0.669 to 0.259	7.69	451.21	246.09
Iso butyl acetate	19.9 to 99.4	0.724 to 0.287	8.96	533.99	270.49
Phthalic acid diethyl ester	25 to 55	10.10 to 4.182	19.24	1131.83	395.56
Ethyl benzoate	20 to 70	2.238 to 0.950	13.50	746.50	338.47
Benzyl benzoate	5 to 100	19.28 to 1.655	19.24	1131.83	395.56
Acetone	- 80 to 60	1.487 to 0.226	6.02	367.25	209.68
Methyl ethyl ketone	0.3 to 76.3	0.536 to 0.246	7.00	423.84	231.67
Methyl propyl ketone	0.4 to 98.8	0.640 to 0.240	7.54	437.94	243.03
Diethyl ketone	0.5 to 98.8	0.591 to 0.227	7.28	425.53	237.63
Methyl - n - butyl ketone	20 to 25	0.626 to 0.584	8.52	528.91	262.34
Aceto phenone	11.9 to 95.0	2.280 to 0.653	13.02	648.82	332.49
Benzo phenone	25 to 120	13.61 to 1.38	20.01	1253.51	401.92
Methyl propyl ether	0.3 to 35.1	0.306 to 0.218	5.39	353.90	194.55
Di ethyl ether	- 80 to 100	0.958 to 0.118	5.23	353.14	190.58
Ethyl propyl ether	0.3 to 60.2	0.395 to 0.215	6.18	399.87	213.39
Ethyl hexyl ether	25 to 50	0.929 to 0.653	10.24	590.07	292.47
Di propyl ether	0.6 to 88	0.535 to 0.215	7.10	445.84	233.82
Methyl iso butyl ether	0.4 to 55.2	0.379 to 0.219	6.04	389.66	210.14
Ethyl iso butyl ether	0.4 to 77.5	0.480 to 0.214	6.77	433.54	226.67
Anisole	0 to 60	1.780 to 0.970	12.51	388.84	325.85
Phenetole	0 to 80	1.860 to 0.550	11.10	646.88	305.91
Methyl chloride	0 to 120	0.221 to 0.072	5.35	426.45	193.56
Ethyl chloride	- 20 to 40	0.392 to 0.224	5.24	320.94	190.83
Propyl chloride	0.4 to 44.7	0.432 to 0.278	6.25	374.77	215.00

<i>Compound</i>	<i>Temp. Range, °C</i>	<i>Viscosity Range, cP</i>	<i>NE</i>	<i>B</i>	<i>T₀, K</i>
Iso propyl chloride	0.3 to 33.0	0.400 to 0.282	6.13	306.25	212.24
Iso butyl chloride	0.3 to 65.3	0.582 to 0.267	7.27	437.19	237.42
Bromo ethane	- 100 to 30	2.890 to 0.348	6.50	369.80	22.68
Propyl bromide	0.4 to 67.9	0.641 to 0.332	7.43	395.31	240.76
n - Butyl bromide	0 to 100	0.820 to 0.331	8.31	426.90	258.34
n - Amyl bromide	0 to 100	1.057 to 0.370	9.26	464.92	275.87
n - Hexyl bromide	0 to 100	1.362 to 0.432	10.27	509.06	292.26
n - Heptyl bromide	0 to 100	1.820 to 0.513	11.44	560.71	310.95
n - Octyl bromide	0 to 100	2.415 to 0.601	12.56	613.34	326.52
n - Nonyl bromide	0 to 100	3.155 to 0.692	13.52	666.45	338.71
n - Decyl bromide	0 to 100	4.115 to 0.797	14.38	712.69	348.83
Iso butyl bromide	0.3 to 87.9	0.820 to 0.323	8.35	451.38	259.11
Iodo methane	0 to 40	0.593 to 0.409	6.92	336.19	229.95
Iodo ethane	0.3 to 70	0.716 to 0.391	7.70	370.85	246.30
1 – Iodo propane	0.3 to 98.9	0.934 to 0.362	8.88	434.09	269.03
2 – Iodo propane	0.3 to 88.7	0.875 to 0.361	8.55	427.38	262.91
Iso butyl iodide	0.4 to 116.1	1.154 to 0.349	9.62	472.80	282.13
Iodo benzene	4.6 to 137.6	2.207 to 0.448	12.92	565.72	331.21
Bromo benzene	0.1 to 142.3	1.573 to 0.351	10.87	508.18	302.42
Chloro benzene	0 to 119.6	1.053 to 0.307	9.28	477.76	276.22
Fluoro benzene	9.3 to 100.0	0.647 to 0.275	8.03	452.06	252.89
Ethylene fluoride	0 to 60	0.289 to 0.180	5.07	319.27	186.56
Methylene chloride	0.5 to 37.5	0.532 to 0.370	6.70	359.55	225.13
Chloroform	- 13 to 60	0.855 to 0.389	7.71	394.81	246.50
Carbon tetrachloride	0 to 100	1.369 to 0.384	10.14	540.15	290.84
Ethylidene chloride	7.1 to 54.5	0.569 to 0.348	7.35	412.27	239.10
Ethylene chloride	0 to 100	0.417 to 1.123	9.38	473.95	277.98
1,1,2,2 - Tetra chloro ethane	0 to 80	2.656 to 0.760	12.88	647.05	330.69
Methylene bromide	15 to 30	1.090 to 0.920	10.37	428.91	294.57
Bromoform	6.4 to 76.5	2.381 to 1.009	14.57	519.07	350.97
Allyl bromide	0.3 to 68.7	0.616 to 0.319	7.26	389.59	237.21
Allyl iodide	0.3 to 98.4	0.926 to 0.358	8.75	425.52	266.64
Di ethyl amine	- 33.5 to 35	0.823 to 0.279	6.89	473.89	229.29
Aniline	0 to 120	10.20 to 0.653	15.14	1074.61	357.21
o – Toludine	0.3 to 100	10.105 to 0.831	15.07	1085.11	356.46
m – Toludine	25 to 130	3.310 to 0.500	14.85	928.12	354.07

<i>Compound</i>	<i>Temp. Range, °C</i>	<i>Viscosity Range, cP</i>	<i>NE</i>	<i>B</i>	<i>T₀, K</i>
p – Toludine	39.9 to 175	2.080 to 0.420	15.03	738.90	356.02
3 – Chloro aniline	25 to 55	3.500 to 1.760	15.11	973.87	356.89
Benzyl amine	25 to 130	1.590 to 0.442	12.70	636.49	328.46
n - Methyl aniline	0.3 to 70	4.265 to 0.886	13.04	915.12	332.74
n - Ethyl aniline	0.3 to 100	4.123 to 0.603	13.28	843.72	335.76
Di phenyl amine	55 to 130	4.660 to 1.040	20.23	1162.20	403.72
Benzyl phenyl amine	55 to 130	5.390 to 1.200	21.38	1150.84	413.11
n – Methyl di phenyl amine	9.8 to 130	11.00 to 0.810	17.86	1054.41	383.67
n,n – Di ethyl aniline	0.5 to 98	3.840 to 0.630	13.26	812.59	335.51
n,n – Di methyl aniline	0 to 177	2.020 to 0.341	12.08	553.02	320.03
Nitro methane	0 to 85	0.843 to 0.343	8.46	452.50	261.21
Nitro benzene	0.3 to 207.6	3.83 to 0.324	13.69	642.85	340.77
o – Nitro toluene	0 to 60	3.830 to 1.210	13.92	759.86	343.51
m – Nitro toluene	20 to 100	2.330 to 0.564	13.28	870.01	335.76
2 – Nitro butane	30 to 60	0.812 to 0.585	9.82	478.08	285.13
2-Nitro-2 -pentane	30 to 60	0.871 to 0.619	10.17	498.20	291.34
3-Nitro-2- pentane	30 to 60	0.925 to 0.646	10.47	523.53	296.17
2-Nitro-2- hexane	30 to 60	1.144 to 0.780	11.51	558.55	311.97
3-Nitro-2- hexene	30 to 60	1.091 to 0.737	11.26	571.84	308.30
3-Nitro-3- hexene	30 to 60	0.996 to 0.690	10.83	535.10	301.80
2-Nitro-2- heptene	30 to 60	1.336 to 0.888	12.28	595.27	322.77
3-Nitro-2- heptene	30 to 60	1.355 to 0.877	12.26	634.53	322.50
3-Nitr -3- heptene	30 to 60	1.292 to 0.849	12.06	612.54	319.75
4-Nitro-3- heptene	30 to 60	1.235 to 0.821	11.86	595.72	316.97
2-Nitro-2- octene	30 to 60	1.680 to 1.064	13.36	666.11	336.75
3-Nitro- 2- octene	30 to 60	1.673 to 1.040	13.21	693.02	334.88
3-Nitro- 3- octene	30 to 60	1.536 to 0.984	12.90	649.02	330.95
4-Nitro-3- octene	30 to 60	1.499 to 0.955	12.74	657.30	328.88

<i>Compound</i>	<i>Temp. Range, °C</i>	<i>Viscosity Range, cP</i>	<i>NE</i>	<i>B</i>	<i>T₀, K</i>
4-Nitro-4 - octene	30 to 60	1.603 to 1.005	13.02	680.49	332.49
2-Nitro-2- nonene	30 to 60	2.019 to 1.241	14.27	709.17	347.58
3-Nitro-2- nonene	30 to 60	2.038 to 1.215	14.06	753.73	345.15
3-Nitro-3- nonene	30 to 60	1.915 to 1.168	13.87	721.02	342.92
4-Nitro-3- nonene	30 to 60	1.899 to 1.151	13.77	729.81	341.73
4-Nitro-4 - nonene	30 to 60	1.872 to 1.146	13.76	715.41	341.61
5-Nitro-4 - nonene	30 to 60	1.927 to 1.162	13.82	737.09	342.32
Tri fluoro methyl cyclo hexane	20 to 60	0.951 to 0.575	10.02	531.75	288.87
Tri fluoro toluene	20 to 60	0.573 to 0.387	7.85	417.84	249.32
Tri fluoro - 2 - propanol	15 to 55	3.668 to 0.994	12.56	1352.82	326.52
Tri fluoro iso butanol	25 to 55	3.320 to 1.190	13.00	1455.54	332.23
Tri fluoro acetic acid	20 to 65	0.873 to 0.473	9.72	585.54	283.84
Tri fluoro ethanoic acid, 2-propyl ester	20 to 60	0.724 to 0.425	9.05	564.92	272.12
Tri fluoro acetone	8 to 15	0.358 to 0.328	6.36	442.45	217.52
Tri fluoro tri chloro ethane	20 to 45	0.698 to 0.516	8.77	489.18	267.01

Combining Eq. 4.58 and Eq. 4.59, we finally get

$$B = (1/n)(\Delta H_V - RT) \quad (4.60)$$

As a first approximation, the heat of vaporization at the normal boiling point ΔH_{VB} can be substituted for ΔH_V . Fishtine³⁵ method can be used to estimate the value of ΔH_{VB} according to the equation

$$\Delta H_{VB} = K_F T_B (8.75 + R \ln T_B) \quad (4.61)$$

where R is the universal gas constant (1.987 cal/mol K) and K_F is the Fishtine constant. From a consideration of the dipole moments of several compounds, Fishtine presented the values of K_F , shown in Table 4.24, in relation to the structure of the molecule.

Important notes for the calculation of K_F

- Consider any phenyl group as a single carbon atom.
- K_F factors are the same for all aliphatic isomers of a given compound. For example, $K_F=1.31$ for n-butylalcohol, iso-butylalcohol, tert-butylalcohol and sec-butylalcohol.
- In organometallic compounds, consider any metallic atom as a carbon atom.
- For compounds not included in the above table, assume $K_F = 1.06$.

Combining the equations given above, we obtain

$$B = (1/n)[K_F T_B (8.75 + R \ln T_B) - RT] \quad (4.62)$$

The value of n depends on the type of compound and is given in Table 4.25.

Table 4.24. K_F factors for aliphatic and alicyclic organic compounds for calculation of parameters B in Eq. 4.61.

Type of Substance	Number of Carbons											
	1	2	3	4	5	6	7	8	9	10	11	12 – 20
Hydrocarbons												
Alkane Isomers	-	-	-	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
Mono- & Diole-fins & Isomers	-	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.00
Cyclic Saturated Hydro-Carbons	-	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Alkyl Derivatives of Cyclic Saturated Hydrocarbons	-	-	-	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
Halides (Saturated & Unsaturated)												
Monochlorides	1.05	1.04	1.03	1.03	1.03	1.03	1.03	1.03	1.02	1.02	1.02	1.01
Monobromides	1.04	1.03	1.03	1.03	1.03	1.03	1.02	1.02	1.02	1.01	1.01	1.01
Monoiodides	1.03	1.02	1.02	1.02	1.02	1.02	1.01	1.01	1.01	1.01	1.01	1.01
Polyhalides (not entirely halogenated)	1.05	1.05	1.05	1.04	1.04	1.04	1.03	1.03	1.03	1.02	1.02	1.01
Mixed halides (completely halogenated)	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
Perfluoro carbons	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Compound Containing the Keto Group												
Esters	-	1.14	1.09	1.08	1.07	1.06	1.05	1.04	1.04	1.03	1.02	1.01
Ketones	-	-	1.08	1.07	1.06	1.06	1.05	1.04	1.04	1.03	1.02	1.01
Aldehydes	-	1.09	1.08	1.08	1.07	1.06	1.05	1.04	1.04	1.03	1.02	1.01
Nitrogen Compounds												
Primary Amines	1.16	1.13	1.12	1.11	1.10	1.10	1.09	1.09	1.08	1.07	1.06	1.05 ^b
Secondary Amines	-	1.09	1.08	1.08	1.07	1.07	1.06	1.05	1.05	1.04	1.04	1.03 ^b

Type of Substance	Number of Carbons											
	1	2	3	4	5	6	7	8	9	10	11	12 – 20
Tertiary Amines	-	-	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
Nitriles	-	1.05	1.07	1.06	1.06	1.05	1.05	1.04	1.04	1.03	1.02	1.01
Nitro Compounds	1.07	1.07	1.07	1.06	1.06	1.05	1.05	1.04	1.04	1.03	1.02	1.01
Sulfur Compounds												
Mercaptans	1.05	1.03	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
Sulfides	-	1.03	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
Alcohols												
Single OH group	1.22	1.31	1.31	1.31	1.31	1.30	1.29	1.28	1.27	1.26	1.24	1.24 ^b
Diols (Glycols or Condensed Glycols)	-	1.33	1.33	1.33	1.33	1.33	1.33	1.33				
Triols (Glycerol, etc.)	-	-	1.38	1.38	1.38							
Cyclohexanol, Cyclohexyl methyl alcohol, etc.						1.20	1.20	1.21	1.24	1.26		
Miscellaneous Compounds												
Ethers (Aliphatic)	-	1.03	1.03	1.02	1.02	1.02	1.01	1.01	1.01	1.01	1.01	1.01
Oxides (Cyclic Ethers)	-	1.08	1.07	1.06	1.05	1.05	1.04	1.03	1.02	1.01	1.01	1.01

^a Carboxylic or heterocyclic compounds having aliphatic properties.

^b For N = 12 only; no prediction for K_F where N > 12.

Table 4.25. Values of n for different types of compounds.

Compound Type	Value of n
Aliphatic Hydrocarbons	8
Ketones(Aliphatic and Aromatic)	7
All Other Organic Compounds	5

The following basic steps are recommended for the estimation of liquid viscosity by the Grain method.

- Obtain η_B from Table 4.1.
- Obtain the Fishtine constant K_F from Table 4.24
- Obtain the value of n from Table 4.25
- Calculate B from Eq. 4.62
- Calculate $\ln \eta$ at the temperature T from Eq. 4.57.

4.3.2.1.2 Viscosity Correlations Based on Density

Density is one of the properties which can be measured accurately and with greater ease. We will outline in this section, some of the important methods relating viscosity to density.

4.3.2.1.2.a Bachinskii's Formula

Bachinskii's equation³⁶ is one of the first relationships developed between the viscosity and density of liquids. He proposed a linear dependency of fluidity (reciprocal of viscosity) on the specific volume (reciprocal of density) as

$$(1/\eta) = (A/\rho) - B \quad (4.63)$$

where A and B are constants characteristic of the substance.

The equation is often presented in the form:

$$V = \omega + C\varphi \quad (4.64)$$

where C is a constant characteristic of the substance,
 V is the specific volume [$V = (1 / \rho)$],
 φ is the fluidity [$\varphi = (1/\eta)$], and
 ω is a constant related to the critical volume V_C by the approximate relation given by Eq. 4.65.

$$\omega = 0.307V_C \quad (4.65)$$

Bachinskii's formula is not obeyed by alcohols, organic acids, halo-compounds like ethylene dichloride, water and mercury. With the exception of water, the compounds give convex curves instead of straight lines. The curve for water is concave.

Another popular form of the viscosity dependence on density is

$$\eta V^x = A \exp \left[\frac{B}{V^y T} \right] \quad (4.66)$$

where V is the molar volume, A and B are constants, and the values of both x and y are in the range between zero and unity. The constants x and y are calculated from the experimental viscosity-temperature data of the substance. This equation as well as Batschinskii's formula are of historic importance.

4.3.2.1.2.b Przezdziecki and Sridhar Method

Przezdziecki and Sridhar³⁷ used the Hildebrand modification of the Batschinskii equation and obtained the following expression:

$$\eta = \frac{V_0}{E(V - V_0)} \quad (4.67)$$

where η is the liquid viscosity in cP and V is the liquid molar volume in cm³/mol. The parameters E and V_0 are defined as follows.

$$E = -1.12 + \frac{V_C}{12.94 + 0.10M - 0.23P_C + 0.0424T_F - 11.58(T_F/T_C)} \quad (4.68)$$

$$V_0 = 0.0085\omega T_C - 2.02 + \frac{V_{mF}}{0.342(T_F/T_C) + 0.894} \quad (4.69)$$

where, T_C is the critical temperature in K,
 P_C is the critical pressure in bar,
 V_C is the critical volume in cm³/mol,
 M is the molecular weight in g/mol,
 T_F is the freezing point in K,

ω is the acentric factor, and
 V_{mF} is the liquid molar volume at T_F in cm^3/mol .

For the application of this method, one requires the values of T_C , P_C , V_C , T_F , V_{mF} and ω in addition to the liquid molar volume at the temperature of interest. Data on V and V_{mF} are often not available. Even if they are available, the authors recommend the Gunn-Yamada method³⁸ to be used for the estimation of V and V_{mF} from T and T_F .

Application of the Gunn-Yamada method requires the knowledge of the accurate value of the molar volume V^R at T^R . At any other temperature

$$V(T) = V^R \left[f(T)/f(T^R) \right] \quad (4.70)$$

$$\text{where, } f(T) = H_1(1 - \omega H_2) \quad (4.71)$$

$$H_1 = 0.33593 - 0.33953T_R + 1.51941T_R^2 - 2.02512T_R^3 + 1.11422T_R^4 \quad (4.72)$$

$$H_2 = 0.29607 - 0.09045T_R - 0.04842T_R^2 \quad (4.73)$$

Careful comparison of the method revealed that large errors resulted for alcohols and for other substances at low temperatures. Luckas and Lucas³⁹ suggested that the method should not be used below a reduced temperature of about 0.55.

4.3.2.1.3 Viscosity Correlations Based on Surface Tension

Surface tension is a characteristic property of liquid which indicates the forces determining the formation of different kinds of interfaces (particularly the liquid-vapor) while viscosity is characteristically a measure of capacity of the liquid to flow. It is reasonable to determine the relationships between the two characteristic physical properties, for use in estimations.

4.3.2.1.3.a Pelofsky equation

Pelofsky⁴⁰ proposed an empirical equation relating the liquid viscosity to the surface tension in the form:

$$\gamma = Ae^{(B/\eta)} \quad (4.74)$$

where A and B are dimensional constants. Based on a study of 32 liquids, both organic and inorganic, including water, benzene and toluene, B is shown to be a function of (Mk/R) where M is the molecular mass, k is the thermal conductivity and R is the gas constant.

The relationship can also be written in the form

$$\ln \gamma = (B/\eta) + \ln A \quad (4.75)$$

where B is the slope and $\ln A$ is the intercept of a plot of $\ln \gamma$ versus $(1/\eta)$. The slopes are found to be directly proportional to the molecular mass of the substance while the intercept is probably indicative of the substance's solid phase, since $A = \gamma$ when the viscosity approaches infinity.

In terms of a non-dimensional constant C (which can be related to the Rheochor) the equation can be written as

$$\gamma = A' \exp \left[\frac{CMk}{R\eta} \right] \quad (4.76)$$

where M is the molecular mass (g/mol), k is the thermal conductivity (cal/sec. cm²), R is the universal gas constant (1.986 cal/mol K) and A' is an empirical constant.

4.3.2.1.3.b Schonhorn method

Schonhorn⁴¹ extended the ideas of Pelfosky and proposed a relation between the absolute viscosity and surface tension in the form

$$\gamma = \gamma_N \exp \left[- \frac{B}{(\eta_L - \eta_V)} \right] \quad (4.77)$$

where γ_N is the surface tension at temperature T_N (the temperature at which the viscosity becomes infinite), and η_L and η_V are the viscosity of liquid and vapor, respectively. T_N is related to the temperature of homogeneous nucleation. Schonhorn described the application of the methodology to 11 substances.

4.3.2.2 Viscosity Dependence on Molecular Properties

The viscosity of a liquid can be expected to depend on the properties of the molecules of which it is composed. A priori one can expect that molecular properties such as molar volume V_m , shape factor ϕ , molecular mass M , polarizability α and dipole moment μ should all have influence on liquid viscosity. Lutskii⁴² studied the problem by comparing the viscosities of groups of substances which differ only in one molecular property.

4.3.2.2.1 Dependence of Viscosity on Molecular Weight

Comparison of the viscosities of isotopic compounds, the molecules of which differ only in mass (like liquefied methane and deuteriomethane) shows that the viscosities are proportional to $\sqrt[3]{M}$ and can be expressed as

$$(\eta)_{P,T,\phi,\mu,\alpha} = A\sqrt[3]{M} \quad (4.78)$$

where A is a constant.

4.3.2.2.2 Viscosity Dependence on Molar Refraction

Lutskii⁴² considered the relationship between the quantity $(\eta/\sqrt[3]{M})_{P,T,\phi,\mu}$ and molar refraction, R_D , and showed that ;

$$\left(\frac{\eta}{\sqrt[3]{M}} \right)_{P,T,\phi,\mu} = A R_D^{(3/2)} \quad (4.79)$$

where A is a constant. When the relationship between the quantities $R_D^{(3/2)}$ and $(\eta/\sqrt[3]{M})$ is plotted, the points corresponding to compounds with similar shape factors fall on a straight line.

4.3.2.2.3 Dependence of Viscosity on Dipole Moment

In an analogous manner, Lutskii⁴² also examined the relationship between liquid viscosity and dipole moment, μ , for compounds with similar molecular mass, similar molecular shapes, and similar values of R_D resulting in a linear equation

$$\eta = A\mu + B \quad (4.80)$$

where constants A and B are obtained by regressing the experimental data.

4.3.2.2.4 Viscosity Dependence on Shape Factor

An investigation on the dependence of the liquid viscosity η on the shape factor ϕ of the molecules showed that at 25°C the viscosities of tertiary compounds are 10 to 20% greater than those of compounds with straight chain molecules. The viscosities of compounds with cyclic molecules are 2 to 4 times as great as those of corresponding liquids with chain molecules. The ratio increases as the number of carbon atoms in the molecule increases.

4.3.2.2.5 Effect of Bonds, and Cyclic Structures on Viscosity

The observed regularities may be associated with the presence or absence of bonds, which permit free rotation in the molecule. Polycyclic molecules are comparatively rigid having a fixed shape with no mobile elements. Liquids composed of this type of molecules have high viscosities. On the other hand, the viscosities of liquids made up of molecules with a straight chain structure (in particular, normal aliphatic hydrocarbons) are low. In the latter case, the presence of a considerable number of bonds, permitting rotation of one part of the molecule with respect to the other, may enable the molecules to arrange and fit themselves so as to facilitate the process of flow.

4.3.2.2.6 Viscosity-Molecular Property Relation for Substances with Similar Shape Factors

It follows from Lutskii's analysis⁴² that for molecules with similar shape factors ϕ , the following relationship can exist

$$\left[\frac{\eta}{(\sqrt{M} R_D^{(3/2)})} \right]_{P,T,\phi} = A + B \mu \quad (4.81)$$

where A and B are constants. This relationship is valid for the series of compounds which can be represented by the general formula C_6H_5X , where X denotes: $-CH_3$, $-OCH_3$, $-F$, $-Br$, $-Cl$, $-I$, $-N(CH_3)_2$, $-COOC_2H_5$, $-COCH_3$, $-CN$, $-NC$, $-NO_2$, $-NH_2$, $-OH$. While the deviations from the expected linear behavior are reasonable for most of the compounds, it should be noted that the compounds containing $-OH$, $-COOH$, and $-NH_2$ show large deviations. Lutskii explains the deviations from the rules just mentioned as due to the formation of intermolecular or intramolecular hydrogen bonds in associated liquids. For such liquids, the observed values of viscosity may be as much as five to ten times as great as those calculated

on the basis of isologous series. Discrepancies caused by the shape factor ϕ are lower.

4.3.2.3 Generalized Relationships for Liquid Viscosity

Generalized methods for the estimation of liquid viscosity can be broadly described under the main categories of those based on additive principles (called group contribution methods) and those based on the theorem of corresponding states (denoted as corresponding states methods). There is a close relationship among all of them, in the sense that, often there is an element of interrelations between molecular properties in the so-called purely empirical methods and the characteristic properties used in the corresponding states methods can be estimated fairly reliably from constitutive and additive contributions.

4.3.2.3.1 Group Contribution Methods

Several methods have been proposed for the estimation of liquid viscosity from the observed dependence of viscosity on some physical property and the relation of the constants of the resulting equation found to be dependent on the constitution and structure of the molecule (which can be calculated from the atomic/group/structural contributions). A few commonly used methods are described in this section.

4.3.2.3.1.a Souders Method

Souders⁴³ found that the viscosity coefficient (I) in the following equation relating the density (ρ) and molecular mass (M) to the liquid viscosity (η) can be calculated additively by summing up the contributions corresponding to the respective groups and bonds present in the molecules.

$$\log(\log 10 \eta) = [(I/M)\rho] - 2.9 \quad (4.82)$$

The contributions of different groups and bonds to the viscosity constant (I) are given in Table 4.26.

Table 4.26. Contributions of different groups, structures and bonds for the calculation of the viscosity constant I of the Souders equation, Eq. (4.82): $\log(\log 10 \eta) = [(I/M)\rho] - 2.9$.

Atom/Group/Bond	Contribution
H	2.7
O	29.7
C	50.2
N	37.0
Cl	60.0
Br	79.0
I	110.0
Double bond	- 15.5
5-Member ring	- 24.0
6-Member ring	- 21.0
Side Groups on a 6- Member ring	
Molecular weight < 17	- 9.0
Molecular weight > 16	- 17.0
<i>Ortho</i> – or <i>para</i> – position	3.0
<i>Meta</i> – position	- 1.0
$\begin{array}{c} \text{R} \quad \quad \text{R} \\ \diagdown \quad \diagup \\ \text{CH} - \text{CH} \\ \diagup \quad \diagdown \\ \text{R} \quad \quad \text{R} \end{array}$	8.0
$\begin{array}{c} \text{R} \quad \text{R} \\ \diagdown \quad \diagup \\ \text{C} \\ \diagup \quad \diagdown \\ \text{R} \quad \text{R} \end{array}$	10.0
-CH ₂ -	55.6
$\begin{array}{c} \text{H} - \text{C} - \text{R} \\ \\ \text{O} \end{array}$	10.0
- CH = CH – CH ₂ – X*	4.0
$\begin{array}{c} \text{R} \\ \diagdown \\ \text{CH} - \text{X}^* \\ \diagup \\ \text{R} \end{array}$	6.0
- OH	57.1
COO	90.0
COOH	104.4
NO ₂	80.0

R: Hydrocarbon group; X*: Halide group

This method is applicable to aromatic and alicyclic compounds, giving an average deviation of about 10%. Satisfactory results are also obtained for the viscosity of esters. The viscosities calculated for unsaturated or branched chain hydrocarbons are less accurate with an average error of about 20%. Calculated viscosities for alcohols and compounds containing several halogen atoms in the molecule are usually too high while those for acids are too low.

Dutt *et al.*⁴⁴ extended the application of the Souders method to phosphorous containing compounds, by proposing a contribution of 67.1 for each phosphorous atom to the structural constant (*I*). When applied to 16 phosphorous containing compounds at 91 data points, the method gives an overall average absolute deviation of about 23%, comparable to the other group contribution methods.

4.3.2.3.1.b Thomas Method

Thomas⁴⁵ proposed the equation

$$\log\left(8.569\frac{\eta}{\rho^{0.5}}\right) = \theta\left[\frac{1}{T_R} - 1\right] \quad (4.83)$$

where η is the viscosity in cP, ρ is the density in g/mL, T_R is the reduced temperature ($= T/T_C$), where T and T_C are respectively the temperature of interest and the critical temperature in K, and θ is a coefficient which is related to the atoms, groups and bonds present in the molecule. The equation is applicable to the temperature region of $T_R < 0.7$. Contributions of atoms/groups/bonds to be used are given in Table 4.27.

Table 4.27. Contributions of atoms/bonds/groups for the calculation of the coefficient θ in the Thomas equation, Eq. (4.83): $\log(8.569\eta/\rho^{0.5}) = \theta[(1/T_R) - 1]$.

Atom/Group/Bond	Contribution to θ
C	- 0.462
H	0.249
O	0.054
Cl	0.340
Br	0.326
I	0.335
Double Bond	0.487
C ₆ H ₅	0.385
S	0.043
CO(Ketones, Esters)	0.105
CN(Cyanides)	0.381

For a large number of liquids, the method gives an average deviation of about 5%, with the exception of compounds like benzene and haloalkenes. Other investigations in the application of the method gave an average deviation of about 15%, with the exception of alcohols and acids. Thomas and co-workers published several other papers⁴⁶⁻⁵⁰ with the main theme of proposing predictive methods for liquid viscosity and understanding the theoretical implications.

Thomas^{46,47} proposed the following relationships between the liquid viscosity (η), molar volume (V) and saturated vapor pressure (P_v)

$$\ln(\eta\sqrt{V}) = A - (B/T) \quad (4.84)$$

$$\text{and } \ln(\eta\sqrt{V}) = \alpha - \beta \ln P_v \quad (4.85)$$

where A , B , α and β are constants and T is the temperature in Kelvin. These equations, when plotted as $\ln(\eta\sqrt{V})$ versus $(1/T)$ and $\ln(\eta\sqrt{V})$ versus $\ln(P_v)$, have been found to exhibit linearity in the case of non-associated liquids. The equations have been thoroughly examined by Thomas⁴⁷ in his subsequent work where no significant departures were found for non-associated compounds even at temperatures when the plot of $\ln(\eta\sqrt{V})$ versus $(1/T)$ is manifestly non-linear.

Differentiation of Eqs (4.84) and (4.85) with respect to $(1/T)$ give

$$\frac{d \ln(\eta\sqrt{V})}{d(1/T)} = -B = -\beta \frac{d \ln P_v}{d(1/T)} \quad (4.86)$$

At the temperatures where the vapor behaves ideally, we may utilize the thermodynamic relation

$$\frac{d \ln P_v}{d(1/T)} = -\frac{L}{R} \quad (4.87)$$

in which L is the molar latent heat of vaporization (energy of vaporization).

$$\text{Hence, } B = \beta L/R \quad (4.88)$$

$$\text{or } \beta = R B/L \quad (4.89)$$

Although put forward on purely empirical grounds, Eq. (4.89) is intuitively attractive on the premise that the constant β is equal to the ratio of the viscous energy to the energy of vaporization. For compounds with molecules closely approaching spherical shape, β is sensibly constant at about 0.220 for all non-associated liquids and appears to be independent of size, polarity or the presence or otherwise of flexible bonds.

Thomas⁴⁹ proposed the vapor pressure equation

$$\ln P_v = \ln \psi - (I/T^\theta) \quad (4.90)$$

where ψ is shown to be a universal constant for non-associated liquids of diverse types and I and θ are constant for each substance. Combining this vapor pressure equation with Eq. (4.85) one easily gets

$$\ln(\eta\sqrt{V}) = \alpha - \beta \ln \psi + \beta(I/T^\theta) \quad (4.91)$$

Or, in terms of base 10 logarithms

$$\log(\eta\sqrt{V}) = \{(\alpha/2.303) - \beta \log \psi\} + \{\beta(I/2.303T^\theta)\} = \alpha' + (\beta'/T^\theta) \quad (4.92)$$

in which α' and β' are independent of temperature. This equation is similar to the Eyring-type equation except that an additional constant θ has been introduced.

The interesting aspect of the series of papers published by Thomas is the interrelations among various physical properties. Such an interrelationship allows one to use some of the equations judiciously to predict the viscosity for substances for which data is totally unavailable.

Dutt and Venugopal⁵¹ extended the application of Thomas method to fluorinated hydrocarbons by proposing a contribution of 0.336 for each fluorine atom to the structural parameter, θ . The extension has been applied to 16 fluorinated hydrocarbons at 117 data points and is shown to predict the viscosity with an average absolute deviation of 16.6%.

4.3.2.3.1.c Morris Method

Morris⁵² suggested the relation

$$\log(\eta/\eta^+) = J[(1/T_R) - 1] \quad (4.93)$$

the parameter η^+ is a constant for each compound class (given in Table 4.28), T_R is the reduced temperature ($= T/T_C$) and J is a function of the molecular structure to be calculated from

$$J = \left[0.0577 + \sum_i (b_i n_i) \right]^{(1/2)} \quad (4.94)$$

The values of b_i for several commonly occurring groups are listed in Table 4.29.

Table 4.28. Pseudocritical viscosity η^+ (in cP) of different classes of compounds for use in the Morris Method, Eq. (4.93): $\log(\eta/\eta^+) = J[(1/T_R) - 1]$.

<i>Class of Compound</i>	<i>Pseudocritical Viscosity (η^+)</i>
Hydrocarbons	0.0875
Halogenated Hydrocarbons	0.148
Benzene Derivatives	0.0895
Halogenated Benzene Derivatives	0.123
Alcohols	0.0819
Organic Acids	0.117
Ethers, Ketones, Aldehydes, Acetates	0.096
Phenols	0.0126
Miscellaneous	0.100

Table 4.29. Structural contributions to J for use in the Morris Method, Eq. (4.94):

$$J = \left[0.0577 + \sum_i (b_i n_i) \right]^{(1/2)} .$$

<i>Group</i>	<i>b_i</i>
CH ₃ , CH ₂ and CH	0.0825
Halogen Substituted CH ₃	0.0
Halogen Substituted CH ₂	0.0893
Halogen Substituted CH	0.0667
Halogen Substituted C	0.0
Br	0.2058
Cl	0.1470
F	0.1344
I	0.1908
Double Bond	-0.0742
C ₆ H ₄ Benzene Ring	0.3558
Additional H in the Ring	0.1446
CH ₂ as Saturated Ring Member	0.1707
CH ₃ , CH ₂ and CH Adjoining Ring	0.0520
NO ₂ , Adjoining Ring	0.4170
NH ₂ , Adjoining Ring	0.7645
F, Cl Adjoining Ring	0.0
OH for Alcohols	2.0446

Group	b_i
COOH for Acids	0.8896
C = O for Ketones	0.3217
C = O – O for Acetates	0.4369
OH for Phenols	3.4420
- O – for Ethers	0.1090

4.3.2.3.1.d Orrick and Erbar Method

Orrick and Erbar⁵³ proposed group contribution methodology for the parameters A and B of the equation

$$\ln \left[\frac{\eta}{\rho M} \right] = A + \left(\frac{B}{T} \right) \quad (4.95)$$

where η is the liquid viscosity in cP
 ρ is the density at 20 °C in g/cm³
 M is the molecular mass, and
 T is the absolute temperature in K

The group contributions for estimating A and B are noted in Table 4.30. For liquids whose freezing point is above 20°C, the density of liquid at the melting point should be used in the calculations.

Table 4.30. Group contributions to A and B of Orrick and Erbar Method.

Group	Contribution to A	Contribution to B
Carbon Atoms(n excluding those present in the groups shown below)	- (6.95 + 0.21 n)	275 + 99 n
$\begin{array}{c} \\ \text{R}-\text{C}-\text{R} \\ \\ \text{R} \end{array}$	- 0.15	35
$\begin{array}{c} \text{R} \quad \text{R} \\ \diagdown \quad \diagup \\ \text{C} \\ \diagup \quad \diagdown \\ \text{R} \quad \text{R} \end{array}$	- 1.20	400
Double Bond	0.24	- 90

Group	Contribution to A	Contribution to B
Five Membered Ring	0.10	32
Six Membered Ring	- 0.45	250
Aromatic Ring	0	20
Ortho Substitution	- 0.12	100
Meta Substituion	0.05	- 34
Para Substitution	- 0.01	- 5
Chlorine	- 0.61	220
Bromine	- 1.25	365
Iodine	- 1.75	400
- OH	- 3.00	1600
- COO -	- 1.00	420
- O -	- 0.38	140
- C = O -	- 0.50	350
- COOH	- 0.90	770

4.3.2.3.1.e Rheochor Method¹

Viscosities of liquids at the normal boiling point (η_B) can be calculated from values of molecular weight (M), liquid density at the normal boiling point (ρ_B), the density of the saturated vapor at the normal boiling temperature (ρ_{VB}) and the Rheochor (R_{Ch}), which can be estimated from the atomic and group contributions given in Table 4.31. The equation for the calculation of viscosity is

$$(10\eta_B)^{0.125} = R_{Ch} \frac{(\rho_{VB} + 2\rho_B)}{M} \quad (4.96)$$

Table 4.31. Atomic and group contributions to Rheochor (R_{Ch}).

Atom / Atomic Group	Contribution
C	12.8
H (in C – H)	5.5
H (in O – H)	10.0
O (in Ethers)	10.0
O (in Alcohols)	13.0
O (in Aldehydes, Ketones)	13.2
Cl	27.3
Br	37.8
N	6.6
NH ₂	20.6
NH	13.6
ONO	39.3
NO ₂	38.9
CN	33.0
COO(in Acids and Esters)	36.0
C ₆ H ₅	101.7

4.3.2.3.1.f Group Contribution Method of Sastri and Rao

Based on the concept of linearity between vapor pressure and viscosity, Sastri and Rao¹⁰ proposed a group contribution method using the relation

$$\eta = \eta_B P^{-N} \quad (4.97)$$

where η_B is viscosity at the normal boiling point, P is the vapor pressure, and N is a constant.

Practical application of Eq. (4.97) needs the not so readily available properties and parameters – vapor pressure, η_B (viscosity at the normal boiling point) and the exponential constant (N). The difficulty has been circumvented by proposing appropriate estimation equations for P (the vapor pressure) and group contributions for the estimation of η_B and N .

Grain¹¹ equation is recommended for calculation of the vapor pressure below the normal boiling point and is given by:

$$\ln P = \frac{H_V}{\Delta Z_R R T_B} \left[1 - \frac{(3 - 2T/T_B)^{0.19}}{T/T_B} - 0.38(3 - 2T/T_B)^{-0.81} \ln \left(\frac{T}{T_B} \right) \right] \quad (4.98)$$

Substituting for H_V by Kistiakowsky equation and taking $Z_B = 0.97$ as recommended by Miller⁵⁴, we can obtain

$$\ln P = (4.5398 - 1.0309 \ln T_B) \left[1 - \frac{(3 - 2T/T_B)^{0.19}}{T/T_B} - 0.38(3 - 2T/T_B)^{-0.81} \ln \left(\frac{T}{T_B} \right) \right] \quad (4.99)$$

For P above the normal boiling point we can use

$$\ln P = a - (b/T) \quad (4.100)$$

$$\text{Where, } a = \ln P_C (T_C / (T_C - T_B)) \quad (4.101)$$

$$\text{and } b = (a/T_B) \quad (4.102)$$

The final correlation becomes same as Eq. (4.97)

$$\eta = \eta_B P^{-N}$$

The value of P can be calculated as indicated above applying Eqs. (4.98)–(4.102) and the viscosity η can be calculated from Eq. (4.97) by substituting the values of η_B and N according to the following recommendations.

$$\eta_B = \sum \Delta\eta_B + \sum \Delta\eta_{Bcor} \quad (4.103)$$

The value of N can be obtained according to the following equations.

Below the normal boiling point:

$$N = 0.2 + \sum \Delta N + \sum \Delta N_{cor} \text{ (for all substances)} \quad (4.104)$$

Above the normal boiling point:

$$N = 0.375 \text{ for hydrocarbons, otherwise} \quad (4.105)$$

$$N = 0.35, \text{ but for low temperature region } N = 0.3. \quad (4.106)$$

The contributions of different hydrocarbon functional groups for calculating η_B and N , for application below the normal boiling point are given in Tables 4.32 to 4.39.

Table 4.32. Contributions of hydrocarbon groups and structures for Sastri and Rao method.

Functional Group/ Structure	$\Delta\eta_B$	ΔN	Remarks
Non-ring			
- CH ₃	0.105	0.000	For n - alkanes C > 8, $\Delta N = 0.050$
>CH ₂	0.000	0.000	
>CH -	- 0.110	0.050	If both groups are present $\Delta N = 0.05$ only. ΔN values applicable in the case of aliphatic hydrocarbons and halogen derivatives of aliphatic compounds. Other cases, $\Delta N = 0$
> C <	- 0.180	0.100	
= CH ₂	0.085	0.000	For n-alkenes C > 8, $\Delta N = 0.050$
= CH -	- 0.005	0.000	
= C <	- 0.100	0.000	
HC $\equiv$ C -	0.190	0.000	For n-alkynes C > 8, $\Delta N = 0.050$
Ring			
>CH ₂	0.060	0.000	
>CH -	- 0.085	0.000	
> C <	- 0.180	0.000	
= CH - (Alicyclic)	0.040	0.000	
= CH - (Others)	0.050	0.000	
= C < (Alicyclic)	- 0.100	0.000	
= C < (Others)	- 0.120	0.000	

Table 4.33. Contributions of ring structures/chain length to ΔN .

Group	Contribution to ΔN	Remarks
Monocyclic and saturated polycyclic hydrocarbon rings (unsubstituted)	0.100	
Methyl-substituted compounds of the above	0.050	
Monocyclic mono-alkyl hydrocarbons (alicyclic)		
1 < C _{br} ≤ 5	0.025	
C _{br} > 5	0.050	
Monocyclic multisubstituted alkyl Alicyclic hydrocarbons	0.025	
Monoalkylbenzenes C _{br} > 1	0.025	
Bicyclic hydrocarbons partly or fully unsaturated	0.050	
Unsaturated triacyclic hydrocarbons	0.100	

Group	Contribution to ΔN	Remarks
Position correction for multiple substitution in aromatics by hydrocarbon/ nitro groups or combinations of these		
Ortho	0.050	
Meta or Para	0.000	
1,3,5	0.100	
1,2,4	0.050	
1,2,6	0.125	Contributions of other functional groups to be neglected
$\Delta\eta_{\text{Bcor}}$ for multiple substitutions in aromatics by hydrocarbon groups is 0.070.		

Some general observations about the contributions are:

The contributions of the functional groups to η_B and N below the normal boiling point are in general found to be cumulative. However, if the compound contains more than one identical functional group, its contribution to N should be taken only once unless otherwise mentioned. The chain length has only marginal effect on η_B and ΔN as indicated, except in the case of hydroxyl ion in aliphatic alcohols. It has also been observed that contribution of aliphatic hydrocarbon functional groups to ΔN is limited to aliphatic hydrocarbons and their halogen derivatives. The contribution of non-hydrocarbon functional groups (other than halogen and hydroxyl groups) attached to the side chain in aromatic compounds are found to be the same as the corresponding ones for aliphatic compounds. In several cases where more than one functional group is present, special values or corrections are required and these are mentioned at appropriate places. The authors compared their method with the group contribution method of van Velzen *et al.*²⁹ and the corresponding states method of Letsou and Stiel⁵⁵ and found that the method produces results comparable in accuracy to the method of van Velzen *et al.* for the low temperature region and the method of Letsou and Stiel for the high temperature region.

In a personal communication Sastri^{10a} recommends the use of the equation (developed using additionally the corresponding states theory)

$$\ln \eta = \left[\left(\frac{\ln \eta_B}{\ln(\alpha \eta_B)} \right)^\phi \right] \ln(\alpha \eta_B) \quad (4.107)$$

for the calculation of liquid viscosity from a reduced temperature of 0.7 to near the critical temperature. In Eq. (4.107), α is equal to 0.1175 for alcohols and 0.248 for the other compounds and η_B is the viscosity (mPa.s) at the normal boiling point to be calculated from the group contributions given in Tables 4.32 to 4.39. For reduced temperatures above 0.9, average deviations of about 10% are to be expected.

Table 4.34. Contribution of halogen groups.

Functional group/structure	$\Delta\eta_{\text{H}}$, halogen attached to					ΔN^b in		
	$-\text{CH}_3$ or $>\text{CH}_2^a$	$>\text{CH}-$	$>\text{C}<^d$	$=\text{CH}-$	$=\text{C}<$	Aliphatics	Alicyclics	Aromatics
- F ^c	0.185	0.155	0.115	n.d.	n.d.	0.000	0.075	0.025
- Cl ^a	0.185	0.185	0.170	0.180	0.150	0.000	0.075	0.025
- Br	0.240	0.240	0.210	0.240	0.210	0.000	0.075	0.025
- I	0.260	0.260	n.d.	n.d.	n.d.	0.000	0.075	0.025

^aSpecial configurations/function group structure

(1) X – (CH₂)_n – X where X is halogen, $\Delta N_{\text{cor}} = 0.050$

(2) Cl – C – Cl ring, $\Delta N_{\text{cor}} = 0.050$ for each group.

^bPresence of non-hydrocarbon group in cyclic compounds functional group/structure combinations

(1) Halogen attached to ring carbon in compounds containing

(i) – NH₂, $\Delta N_{\text{cor}} = -0.100$

(ii) other functional groups, $\Delta N_{\text{cor}} = -0.050$

(2) Halogen attached to non-hydrocarbon functional group, $\Delta N_{\text{cor}} = -0.050$

^cGroup contributions to the fluorine groups of perfluoro compounds are given in Table 4.34.

Table 4.35. Contributions of fluorine groups in perfluoro-compounds.

Group	ΔH_B	ΔN
Non-ring		
- CF ₃	0.210	0.150 for all perfluoro n-compounds
>CF ₃	0.000	
>CF -	- 0.080	0.200 for all iso - compounds
Ring		
- CF ₂ -	0.120	0.200 for all cyclic compounds
- CF -	0.170	

Table 4.36. Contributions of oxygen groups.

Functional group/ structure	Location	$\Delta\eta_B$	ΔN	Remarks
- O -	Non-ring, attached to ring	0.020	0.050	In compounds containing-NH ₂ group attached to ring carbon special values $\Delta\eta_B = 0.150$, $\Delta N = 0.200$ for the combination
- O -	Ring	0.140	0.050	In compounds containing >CO group special value $\Delta N = 0.125$ for the combination
- O -	Others	0.000	0.050	In aliphatic compounds containing -OH special value of $\Delta N = 0.100$ for the combination In cyclic compounds >CO group (with or without other functional groups) special value $\Delta N = 0.125$ for the combination
>CO	Non-ring attached to ring carbon	0.030	0.050	In cyclic compounds containing -O- group (with or without other functional groups) special value $\Delta N = 0.125$ for combination In cyclic compounds >NH group $\Delta\eta_{Bcor} = 0.100$
>CO	Ring	0.055	0.100	In cyclic compounds containing >NH group $\Delta\eta_{Bcor} = 0.100$ In compounds containing -O- group special value $\Delta N = 0.125$ for the combination For aliphatic compounds containing-NH ₂ groups $\Delta\eta_{Bcor} = 0.100$
>CO	Others	0.030	0.025	For cyclic compounds containing >NH groups $\Delta\eta_{Bcor} = 0.100$ In aliphatic compounds containing -OH special value $\Delta N = 0.125$ for the combination
O(CO -) ₂	Anhydride	0.060	0.050	
-CHO		0.140	0.050	In compounds containing -OH (phenolic) special value $\Delta N = 0.125$ for the combination
-COO -		0.040	0.050	ΔN value for each -COO- group For -H in formates $\Delta\eta_B = 0.165$
-COOH	In aliphatics Saturated	0.220	0.100	For C = 3 or 4
-COOH	Unsaturated	0.250	0.100	$\Delta N = 0.050$
-COOH	In aromatics	0.195	0.175	

Table 4.37. Contributions of hydroxyl groups.

Functional group/ structure	$A\eta_B$	ΔN	Remarks
- OH in aliphatics saturated primary - n	$0.615 - 0.092 C + 0.004 C^2 - 10^{-0.58C}$ for $C \leq 10$ and 0.200 for $C > 10$	0.3 for $2 < C < 12$ 0.15 for others	In compounds containing - O - group special value $\Delta N = 0.100$ for the combination In compounds containing >NH groups special value $\Delta N = 0.300$ for the combination
Branched	$0.615 - 0.092 C + 0.004 C^2 - 10^{-0.58C}$	0.375	
Secondary saturated chain	$0.67 - 0.092 C + 0.004 C^2 - 10^{-0.58C}$	0.425 for $C \leq 5$ 0.300 for $C > 5$	
Secondary branched	$0.67 - 0.092 C + 0.004 C^2 - 10^{-0.58C}$	0.425 for $C \leq 10$ 0.300 for $C > 10$	
Tertiary	$0.615 - 0.092 C + 0.004 C^2 - 10^{-0.58C}$	0.650	In compounds containing >CO / - O - groups special value $\Delta N = 0.125$ for the combination
Unsaturated	0.300	0.200	
In cyclic alcohols	0.270	0.150	
Phenolic	0.210	0.275	In compounds containing - NO ₂ / - CHO groups special value $\Delta N = 0.125$ for the combination

Table 4.38. Contributions of nitrogen groups.

Functional group/ structure	Location	$\Delta\eta_B^a$	ΔN	Remarks
-NH ₂	Aliphatic n-amines	0.170	0.100	$\Delta\eta_B = 0.220$ in NH ₂ -(CH ₂) _n -NH ₂ In compounds containing >CO, $\Delta\eta_{Bcor} = 0.100$
-NH ₂	Aliphatic isoamines attached to >CH	0.200	0.100	
-NH ₂	Monocyclic compounds attached to side chain	0.170	0.100	
-NH ₂	Monocyclic compounds attached to ring carbon	0.150	0.200	$\Delta\eta_{Bcor}$ for com-pounds containing halogens according to the earlier table
-NH ₂	Other aromatics	0.150	0.100	
>NH	Aliphatics	0.020	0.075	
>NH	Aromatic compounds attached to side chain	0.020	0.075	
>NH	Aromatic compounds attached to ring carbon	0.020	0.010	In cyclic compounds containing >CO, $\Delta\eta_{Bcor} = 0.100$
>NH	Ring	0.200	0.050	In cyclic compounds containing >CO, $\Delta\eta_{Bcor} = 0.100$
>N -	Aliphatics	-0.115	0.050	
>N -	Aromatic compounds attached to side chain	-0.115	0.050	
>N -	Aromatic compounds attached to ring carbon	-0.060	0.050	
>N -	Ring	0.100	0.050	
-NO ₂	Aliphatics	0.180	0.050	
-NO ₂	Aromatics	0.160	0.050	For multiple presence, $\Delta N = 0.100$ For multiple presence, $\Delta N = 0.100$ Position correction to be applied as indicated in the first table In compounds containing -OH (phenolic) special value $\Delta N = 0.125$ for combination $\Delta\eta_B = 0.135$ in CN- (CH ₂) _n -CN
-CN		0.110	0.050	

^a $\Delta\eta_B = 0.080$ for (-H) in compounds containing hydrocarbon functional groups like formamide.

Table 4.39. Contributions of sulfur groups.

<i>Functional Group/Structure</i>	$\Delta\eta_B$	ΔN
- S - Non-ring	0.045	0.000
- S - Ring	0.150	0.050
- SH	0.150	0.025

4.3.2.3.1.g Lucas and Lucas Method

Lucas and Lucas³⁹ proposed a liquid viscosity estimation method, combining both the activation energy type expression and the free volume type expression with the concepts of additivity, applicable to the entire practical range for the alkanes.

The simple activation type expression originally proposed by Andrade⁵⁶ can be written in the form modified by van Velzen *et al.*²⁹ as

$$\log \eta = B \left[\frac{1}{T} - \frac{1}{T_0} \right] \quad (4.108)$$

where T_0 is the temperature at which $\eta = 1$ cP.

In an analogous manner the simple free volume type expression, originally proposed by Batschinskii³⁶, can be written in the modified form as

$$\eta = \frac{V_R - V_0}{V - V_0} \quad (4.109)$$

where V_R represents the molar volume corresponding to the viscosity of 1 cP and V_0 is another volume parameter. Comparisons with the experimental information show that the activation energy type expression is obeyed better in the reduced temperature range of 0.4 to 0.6 while the free volume type expression is better obeyed in the reduced temperature range of 0.55 to 0.97. Figures 4.11 and 4.12 show the parameters of Eqs. (4.108) and (4.109) respectively, as a function of number of carbon atoms for alkanes.

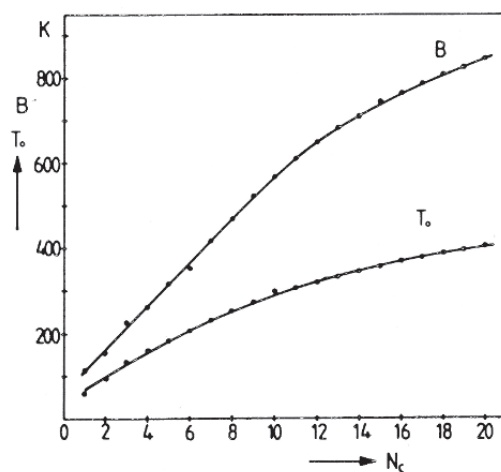


Figure 4.11. Parameters of Eq. (4.108) as a function of the number of carbon atoms for the alkanes (Adopted from M. Lucas and K. Lucas, Viscosity of liquids: An equation with parameters correlating with structural groups, *AIChE J.* **32**(1), 139-141, 1986).

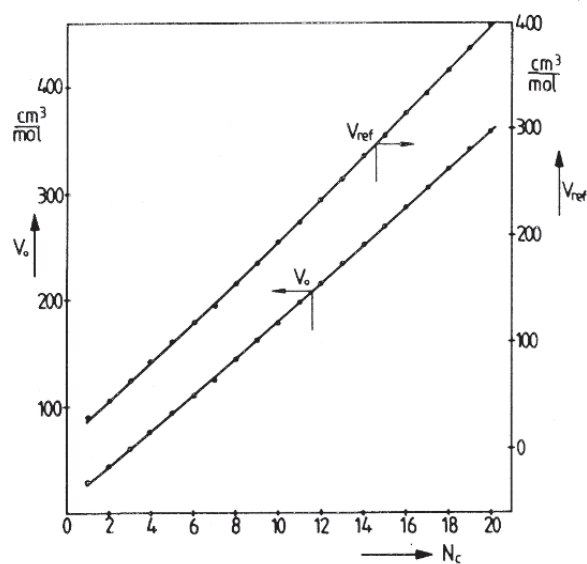


Figure 4.12. Parameters of Eq. (4.109) as a function of the number of carbon atoms for alkanes (Adopted from M. Lucas and K. Lucas, Viscosity of liquids: An equation with parameters correlating with structural groups, *AIChE J.* **32**(1), 139-141, 1986).

The final equation for the entire temperature range is

$$\eta = x_{TV} \eta_T + (1 - x_{TV}) \eta_V \quad (4.110)$$

$$\text{where, } \log \eta_T = B[(1/T) - (1/T_0)] \quad (4.111)$$

$$\eta_V = [(V_R - V_0)/(V - V_0)]^{1.15}, \text{ and} \quad (4.112)$$

$$x_{TV} = \frac{10^3 \exp[-0.5T_C \{(T/T_C) - 0.55\}]}{[1 + 10^3 \exp\{-0.5T_C \{(T/T_C) - 0.55\}\}]} \quad (4.113)$$

The parameter, x_{TV} , defined by Eq. (4.113) is a switching function which dampens the activation energy term for the reduced temperature >0.55 and the free volume term for the reduced temperature <0.55 . Eq. (4.110) therefore reduces to the activation energy equation at low temperatures and to the free volume equation at high temperatures. This is a physically wrong situation. However the use of free volume equation at high temperatures in a viscosity correlation is practically undesirable, because the calculation of viscosity then becomes significantly dependent on the accuracy with which the volume (or density) is known or can be calculated. Volume (or density) in Eq. (4.112) can be eliminated, in favor of temperature by the methods such as that of Gunn and Yamada³⁸ and avoid the ambiguity of density determination. For lower temperatures, in the reduced temperature range of 0.3 to 0.4, Lucas and Lucas proposed the use of the following equation, Eq. (4.114)

$$\eta = \eta_T \left[\frac{0.4}{T/T_C} \right]^n \quad (4.114)$$

which contains an additional parameter n as a power. Five adjustable parameters have been used to cover the entire temperature range. However, it is worth noting that these are not fitted simultaneously. Only the first set of two parameters is fitted for the reduced temperature range between 0.4 and 0.6, another set of two parameters are fitted in the reduced temperature range of 0.55 and 0.97, where as the parameter n is only occasionally needed.

4.3.2.3.2 Corresponding States Method

According to the principle of corresponding states, a dimensionless property of one substance is equal to that of another reference substance if both are evaluated at the same reduced conditions. In the two parameter corresponding states, each fluid is characterized by an energy parameter (ε/k) and a shape distance parameter (σ). If the two fluids are in corresponding states (or are conformal), the reduced viscosity of the fluid i can be expressed in terms of the reference fluid o in the form:

$$\eta_{Ri}(V_{Ri}, T_{Ri}) = \eta_{Ro}(V_{Ro}, T_{Ro}) \quad (4.115)$$

At the same reduced conditions, $V_{Ri} = V_{Ro}$ and $T_{Ri} = T_{Ro}$, the above equation can be written as

$$\frac{\eta_i}{\eta_i^*} \left[\frac{V}{\sigma_i^3}, \frac{T}{\varepsilon_i/k} \right] = \frac{\eta_o}{\eta_o^*} \left[\frac{V}{\sigma_o^3}, \frac{T}{\varepsilon_o/k} \right] \quad (4.116)$$

where η^* is defined from simple kinetic theory for dilute gases as

$$\eta^* = \frac{R^{0.5} T_C^{0.5} M^{0.5}}{N_A^{0.333} V_V^{0.667}} = \frac{P_C^{0.667} M^{0.5}}{R^{0.167} N_A^{0.333} T_C^{0.167}} \quad (4.117)$$

where, R is the universal gas constant,
 T_C is the critical pressure,
 M is the molecular weight,
 N_A is the Avogadro's number,
 V_C is the critical volume, and
 P_C is critical pressure.

By describing viscosity in terms of density (ρ) and temperature (T), we get

$$\eta_i \left[\frac{\rho}{\rho_{Ci}}, \frac{T}{T_{Ci}} \right] = \eta_o \left[\frac{\rho}{\rho_{Co}}, \frac{T}{T_{Co}} \right] \left[\frac{M_i}{M_o} \right]^{0.5} \left[\frac{\rho_{Ci}}{\rho_{Co}} \right]^{0.667} \left[\frac{T_{Ci}}{T_{Co}} \right]^{0.5} \quad (4.118)$$

where, i is any fluid of interest and o is the reference fluid.

4.3.2.3.2.a Shape Factor Corrections

Eq. (4.118) is applicable to the fluids which conform to the two parameter corresponding states and is therefore not really applicable for polyatomic fluids (or mixtures). Hanley⁵⁷ integrated the shape factor approach which preserves the two parameter corresponding states form thorough the definition of the reducing parameters as follows

$$h_{io} = (V_{Ci}/V_{Co})\varphi_{io} = (\rho_{Co}/\rho_{Ci})\varphi_{io} \quad (4.119)$$

$$f_{io} = (T_{Ci}/T_{Co})\theta_{io} \quad (4.120)$$

where, θ_{io} and φ_{io} are the shape factors determined from the empirical expressions given in the paper of Ely and Hanley⁶¹. The final expression given for viscosity is

$$\eta_i(\rho, T) = \eta_o(h_{io}, T/f_{io})(M_i/M_o)^{0.5} h_{io}^{-0.667} f_{io}^{0.5} \quad (4.121)$$

This approach, described in detail in References 57, 60 and 61 needs information on the values of the acentric factor and critical compressibility factor of the reference liquid and the liquid of interest, besides an accurate equation of state for the reference fluid for its application.

4.3.2.3.2.b Extension to Heavier Molecules

Hanley⁵⁷ suggested that the predicted viscosity be multiplied by a correction term, which should be unity if fluids i and o follow simple corresponding states, otherwise should be a strong function of density and weak function of temperature. The correction term should also approach unity as density approaches zero. Hanley presented an empirical correction which resulted in significantly improved viscosity predictions for nitrogen, C₂, C₃ hydrocarbons and CO₂. Rowlinson and Watson⁵⁸ suggested that the shape factors of a fluid of interest (i) with respect to a reference fluid (o) could be determined exactly for any pure fluid by the simultaneous solution of the conformal equations

$$Z_i(V_i, T_i) = Z_o(V/h_{io}, T/f_{io}), \text{ and} \quad (4.122)$$

$$A_i(V, T) = f_{io} A_o(V/h_{io}, T/f_{io}) - RT \ln(h_{io}) \quad (4.123)$$

where, Z , V , T are respectively, the compressibility factor, volume, and temperature, h is the volume reducing ratio, f is the temperature reducing ratio.

Leach⁵⁹ solved similar equations for C_1 to C_{15} paraffin's with methane as the reference fluid and generalized the results with the following empirical expressions:

$$\theta_{io} = 1 + (\omega_i - \omega_o) [a_1 + b_1 \ln T_{Ri} + (c_1 + d_1/T_{Ri})(V_{Ri} - 0.5)] \quad (4.124)$$

$$\varphi_o = [1 + (\omega_i - \omega_o) (a_2(V_{Ri} + b_2) + c_2(V_{Ri} + d_2) \ln T_{Ri})] (Z_{Co}/Z_{Ci}) \quad (4.125)$$

where, if $V_{Ri} \geq 2$, $V_{Ri} = 2.0$ and if $V_{Ri} \leq 0.5$, $V_{Ri} = 0.5$ and a similar constraint was imposed on T_{Ri} , and a_1 , b_1 , c_1 , d_1 , a_2 , b_2 , c_2 , and d_2 are constants.

Ely⁶⁰ modified the Ely and Hanley⁶¹ model to partially correct for non-correspondence between the reference fluid and pure high molar mass fluids and for size and mass differences in mixtures. The non-correspondence has been addressed by changing the reference fluid from methane to propane, since the non-correspondence in viscosity between propane and methane is the same as the one between n-C₂₀ and methane, and since propane has the lowest reduced triple point amongst paraffin's. The low temperature data of Diller⁶² made it possible to use propane as the reference fluid. A 32-term BWR type equation of state is used for density (which reproduces densities within 0.3%). Viscosity predictions using propane reference were much the same as in the case of the previous work using methane as the reference fluid, except for components lighter than propane – methane, ethane and ethylene - for which the results are slightly poorer. A correction factor for non-correspondence of pure fluids is no longer needed with the propane reference fluid.

Baltatu⁶³ applied the extended corresponding states model to petroleum fractions with the required critical properties and acentric factor obtained using a simple characterization. For the crude oil data of Amin and Maddox⁶⁴ the reported average deviations are about 6.5%, although maximum deviations are as high as 32.7%.

Haile *et al.*⁶⁵ defined fluid i to be in corresponding state with fluid o if the two following conformal equations are satisfied

$$Z_i(P, T) = Z_o(P/q_{io}, T/f_{io}) \quad (4.126)$$

$$\eta_i(P, T) = \eta_o(P/q_{io}, T/f_{io}) (M_i/M_o)^{0.5} f_{io}^{-0.167} q_{io}^{0.667} \quad (4.127)$$

where, $f_{i,o}$ is defined as

$$f_{io} = (T_{Ci}/T_{Co})\theta_{io}, \text{ and} \quad (4.128)$$

$$q_{io} = (P_{Ci}/P_{Co})\psi_{io} \quad (4.129)$$

The above functional representation for compressibility factor ensured that the reduced PVT surfaces would be the same for any two substances while the functional representation of viscosity ensured that the reduced viscosity surfaces would be the same. The shape factors have been determined by solving the two functional representations simultaneously for f_{io} and q_{io} .

Haile *et al.* found that these shape factors would not usually have the same values as those found for thermodynamic properties where the residual Helmholtz free energy is used as the second conformal equation instead of viscosity.

Hwang and Whiting⁶⁶ also emphasized that the shape factors may have different values if different properties have been used in conformal solution equations. Even though equating residual Helmholtz free energies ensures that the free energy surface will be the same in reduced form for two substances, it does not ensure that the transport property surfaces will be the same. This observation is made by simply changing the second conformal equation from equating residual Helmholtz free energies to equating viscosities. Viscosity shape factors are then compared with thermodynamic shape factors and it is shown that the deviation between viscosity and thermodynamic shape factors is significant except for non-polar straight chain hydrocarbons (which are the most conformal). They modified the Ely-Hanley method by expressing the temperature (or energy shape factor) as

$$\theta_{i,o} = 1 + (\omega_i^\eta - \omega_o^\eta)f(T_{r,i}, V_{r,i}) + k/T_{r,i} \quad (4.130)$$

where ω^η is the viscosity acentric factor and k is the associating parameter. The form k/T_r has been used because of its ability to meet the theoretical limit at high temperatures where the hydrogen bond loses its dominance. The viscosity acentric factor apparently characterized the effects of molecular shape, orientation, internal degrees of freedom and intermolecular forces besides the hydrogen bond. The generalized correlations and coefficients of the Leach shape factors are retained, but the viscosity acentric factor is allowed to vary for polar fluids. The density (or size) shape factor correlation of the earlier model is retained. Hwang and Whiting modified the temperature (or energy) shape factor $\theta_{i,o}$, with the density (or size) shape

factor $\phi_{i,o}$ unchanged because $\theta_{i,o}$ seems to have a stronger effect than $\phi_{i,o}$ on the calculation of viscosity. They retained the Leach functional form because the function $f(T_{r,i}, V_{r,i})$ in the expression for $\theta_{i,o}$ satisfies the essential temperature behavior for viscosity that the viscosity of gas increases with temperature while the viscosity of a liquid decreases with temperature. They presented optimum values of viscosity ω^n and k for 38 compounds. The modified method showed significant improvement over the method of Ely and Hanley for highly branched alkanes, naphthalenes, some aromatics and various polar associating compounds with overall average absolute deviations of 5.3% and 17.6% for the modified and original methods respectively.

Monnery *et al.*⁶⁷ also concluded that viscosity prediction is more sensitive to the shape factor θ and modified the extended corresponding states method. With their generalized correlations, viscosities of 46 common hydrocarbons have been predicted with an average absolute deviation of about 6 %. Details of the method are given in Section 4.3.2.5d.

4.3.2.3.2.c Tham and Gubbins Approach

Based on the time correlation function theory, Tham and Gubbins derived a corresponding states method for the calculation of viscosity for pure monoatomic dense fluids⁶⁸ and for nonpolar polyatomic dense fluids⁶⁹. Although the time correlation function is difficult to solve for dense fluids, it may be used as a basis for rigorous derivation of the corresponding states principle for viscosity. Such a derivation is presented by Helfand and Rice⁷⁰ based on the following assumptions:

1. the intramolecular degrees of freedom (rotation, vibration) are independent of translational degrees of freedom and density,
2. intermolecular potentials are pair wise additive, and
3. the potential energy of a pair of molecules has the form

$$\phi = \varepsilon f(r/\sigma) \quad (4.131)$$

where, ε and σ are respectively the energy and distance parameters of the potential function, r is the distance and f is a universal function of the reduced distance.

The resulting generalized relationship is

$$\eta^*(T^*, V^*) = \frac{\eta \sigma^2}{(M\varepsilon)^{0.5}} \quad (4.132)$$

where, $T^* = (kT/\varepsilon)$, $V^* = V/(N_0 \sigma^3)$ and M is the molecular mass, k is the Boltzmann constant, and N_0 is the Avogadro's number. The essential simplification for monoatomic as opposed to polyatomic fluids is that the assumption (1) given above is satisfied. Tham and Gubbins⁶⁸ compared correspondence behavior of monoatomic fluids to provide some insight and validity of this assumption. The potential parameters ε and σ are determined by fitting the values reported by different researchers from gas phase viscosity data to empirical function of the acentric factor. Good agreement over the entire temperature and density range is obtained for reduced viscosity with the data for Ne, Ar, Kr and Xe at a given pressure. Reduced viscosities at a constant reduced pressure have been fitted to the following equation with an average absolute deviation of 6 %.

$$\ln \eta^* = a_0 + \frac{a_1}{(T^*)^2} + \frac{a_3}{(T^*)^3} + \frac{a_4}{(T^*)^4} \quad (4.133)$$

Tham and Gubbins concluded that correspondence principle for transport properties is obeyed by inert gases over the entire range of temperature and pressure for which experimental data are available. Good agreement at the highest densities shows that errors introduced by assuming additivity pair potentials are within the limits of experimental errors.

After establishing that the simple corresponding states are obeyed by monatomic molecules over the entire range of temperature and pressure, Tham and Gubbins⁶⁹ reported that the same situation is not true for polyatomic fluids at high density. This has been demonstrated by a plot of reduced viscosity η^* computed from Eq. (4.132) as a function of $(1/T^*)$ at $P^* \cong 0$, using the molecular parameters defined by Tham and Gubbins⁶⁹, where $T^* = k T/\alpha \varepsilon$, k being the Boltzmann constant, T is the absolute temperature and ε the energy parameter. According to Tham and Gubbins, parameter α may be thought of as a rotational coupling coefficient. When hindered rotation is absent, as in dilute gases and monatomic fluids at all densities, $\alpha \approx 1$, while for polyatomic fluids $\alpha > 1$. Ultimately, α is a third parameter in this application of corresponding states to transport properties. The parameter α has been treated as adjustable and assumed to be approximately constant at high fluid densities. The coefficient for polyatomic fluids has been determined by fitting experimental values of saturated liquid density to the reduced viscosity for the inert gases.

$$\ln \eta^* = a_0 + \frac{a_1}{(T^*)^2} + \frac{a_3}{(T^*)^3} + \frac{a_4}{(T^*)^4} \quad (4.134)$$

The values of α have been reported by Tham and Gubbins⁶⁹ for 25 pure fluids, including inert gas fluids, some simple diatomic molecules, paraffin's upto n- C₉, benzene, cyclopentane and cyclohexane and found that its density dependence is only small. Average absolute deviations ranged from 6 to 10 % for the 25 fluids. A plot of η^* from the equation

$$\eta^*(T^*, V^*) = \frac{(\eta \sigma^2)}{\alpha (M \epsilon)^{0.5}} \quad (4.135)$$

versus $(1/T^*)$ for the polyatomic fluids shows that all the values of η^* fall on a single curve.

4.3.2.3.2.d Pedersen *et al.* Relations

Pedersen *et al.*⁷¹ proposed a corresponding states approach, similar to the Ely and Hanley⁶¹ model, for the calculation of the viscosity of hydrocarbons and crude oils, based on the method of Tham and Gubbins⁶⁹ which can be applied to both the fluid of interest (subscript x) and the reference fluid (subscript 0) and is written in terms of pressure as:

$$\eta_x(P, T) = \left(\frac{T_{Cx}}{T_{C0}} \right)^{-0.167} \left(\frac{P_{Cx}}{P_{C0}} \right)^{0.667} \left(\frac{M_x}{M_0} \right)^{0.5} \left(\frac{\alpha T_{Gx}}{\alpha T_{G0}} \right)^{-0.167} \eta_0(P_0^*, T_0^*) \quad (4.136)$$

$$\text{where } T_0^* = T(T_{C0}/T_{Cx})(\alpha_{TG0}/\alpha_{TGx}) \quad (4.137)$$

$$P_0^* = P(P_{C0}/P_{Cx})(\alpha_{TG0}/\alpha_{TGx}) \quad (4.138)$$

and α_{TG} is the Tham-Gubbins rotational coupling coefficient.

Pedersen *et al.*⁷¹ described the complete details of the method and applied the methodology to the prediction of viscosity of 15 pure substances at 67 data points (for a variety of substances including carbon dioxide, normal hydrocarbons upto C₇, cyclohexane and selected aromatic hydrocarbons upto C₁₅), 12 binary mixtures (formed by variety of hydrocarbons including normal and straight chain aliphatics and benzene) at 52 data points, and several crude oils (at 111 data points) covering a viscosity values beyond 2 cP. The average absolute deviations are generally less than the other

generalized methods available in the literature and are about 12%, 8% and 5%, respectively for pure fluids, binary mixtures and crude oils.

4.3.2.3.2.e Onnes Method

Onnes⁷² postulated that the group

$$\left[T_C / (M^3 P_C^4) \right]^{(1/6)} \quad (4.139)$$

should have the same value for all the substances when in corresponding states. As a result of their empirical study, Smith and Brown⁷³ found that the equation:

$$\frac{\eta}{\sqrt{M}} = f(T_R, P_R) \quad (4.140)$$

provides a good representation of the viscosity data for liquid normal paraffins. The function f is the same for all paraffins. For homologous series of associated liquids, such as ethers, acids and alcohols, Smith and Brown⁷³ find it necessary to modify their relationship by replacing the molecular mass M by the viscosity constant I from Souder's equation⁴³ as

$$\frac{\eta}{\sqrt{I}} = f(T_R, P_R) \quad (4.141)$$

Smith and Brown⁷³ found that the form of the function f depends on the homologous series considered. If, for example, $(\eta/\sqrt{I})$ is plotted as a function of the reduced temperature T_R , a set of separate curves, one for each series of compounds is obtained. These curves can be used to estimate the viscosity of any compound from the knowledge of the viscosity of one of the compounds belonging to the homologous series. Generality is shown in the plots of the reduced viscosity defined as (η/η_M) where η_M refers to the viscosity at the melting temperature and $\theta = (T - T_M)/(T_C - T_M)$ for the compounds with odd and even number of carbon atoms separately even when they belong to the same series.

4.3.2.3.2.f Stiel and Thodos Method

Stiel and Thodos⁷⁴ proposed corresponding states based correlation in the form

$$\eta\xi = f(Z_C, T_R) \quad (4.142)$$

where

- η is viscosity in cP,
- T_R is reduced temperature ($=T / T_C$),
- T_C is critical temperature in Kelvin's,
- Z_C is critical compressibility factor,
- ξ is $T_C^{(1/6)} / M^{(1/2)} P_C^{(2/3)}$,
- M is molecular mass, and
- P_C is critical pressure in atmospheres.

The relationship is graphically represented in Fig.4.13 and is useful for rapid estimation of saturated liquid viscosities in the temperatures between the normal boiling and critical temperatures.

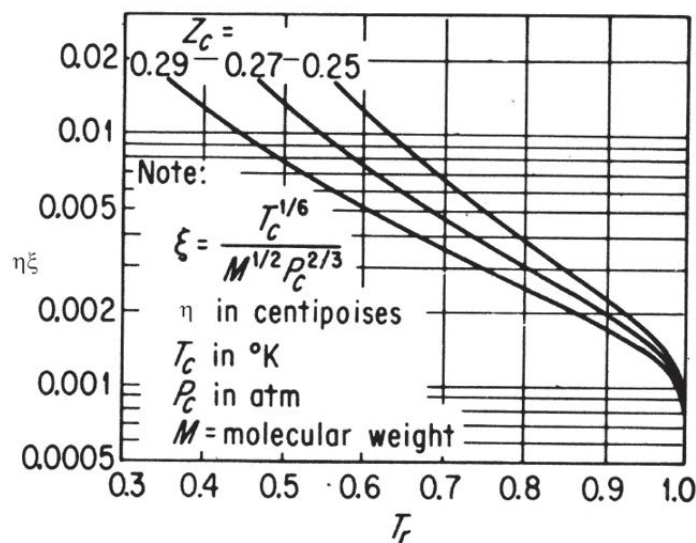


Figure 4.13. Reduced viscosity ($\eta\xi$) as a function of T_R and Z_C (Adopted from R. C. Reid, J. M. Prausnitz, and T. K. Sherwood, *The Properties of Gases and Liquids*, McGraw-Hill, New York, 3rd Ed., 1977).

4.3.2.3.2.g Sastri and Rao Method

Sastri and Rao⁷⁵ proposed a generalized method relating liquid viscosity to the saturated vapor pressure. The relations presented by them are

$$\eta_{\xi} = 0.0272P^{0.2} \text{ for } T < T_B \quad (4.143)$$

and

$$\eta_{\xi} = 0.1025P^{0.4} \text{ for } T > T_B \quad (4.144)$$

where P is the vapor pressure at the temperature of interest and ξ is defined by Eq. (4.142). The method requires good vapor pressure data and the errors in the predicted values are often about $\pm 20\%$.

The general form the equation can be written as:

$$\eta = AP^{-N} \quad (4.145)$$

with a sharp change at the normal boiling point. The equation at the normal boiling point is same as that of Eq. (4.97).

$$\eta = \eta_B P^{-N} \quad (4.104)$$

The values of η_B and N are found to be nearly constant for the liquids of similar nature like the members of a homologous series. This suggested a new direction for relating liquid viscosity to chemical structure. Sastri and Rao¹⁰ proposed a group contribution method based on these ideas. The details of the group contribution method are presented earlier in this book in Section 4.3.2.3.1f.

4.3.2.3.2.h Letsou and Stiel Method

Letsou and Stiel⁷⁶ correlated the liquid viscosity data of argon, nitrogen, carbon dioxide, and ten hydrocarbons and proposed the equation

$$(\eta_{\xi}) = (\eta_{\xi})^{(0)} + \omega(\eta_{\xi})^{(1)} \quad (4.146)$$

$$\text{where } (\eta_{\xi})^{(0)} = 10^{-4} (151.78 - 213.51T_R + 75.03T_R^2) \quad (4.147)$$

and $(\eta_{\xi})^{(1)} = 10^{-4} (425.59 - 767.50T_R + 340.07T_R^2)$ (4.148)

where $\xi = \frac{T_C^{(1/6)}}{M^{(1/2)}P_C^{(2/3)}}$ (4.149)

T_C is the critical temperature in Kelvin, P_C the critical pressure in atmosphere, M is the molecular mass and ω is the acentric factor.

4.3.2.3.2.i Two Fluid Approach of Teja and Rice

Based on the two fluid approach, Teja and Rice⁷⁷ proposed the relation:

$$\ln(\eta_{\xi_{TR}}) = \ln(\eta_{\xi_{TR}})^{r_1} + \left[\frac{(\omega - \omega^{r_1})}{(\omega^{r_2} - \omega^{r_1})} \right] \left[(\ln \eta_{\xi_{TR}})^{r_2} - (\ln \eta_{\xi_{TR}})^{r_1} \right] \quad (4.150)$$

where $\xi_{TR} = \frac{V_C^{(2/3)}}{(MT_C)^{(1/2)}}$ (4.151)

They correlated the reference fluid viscosities with an Andrade type equation

$$\ln(\eta_{\xi}) = A + (B/T_R) \quad (4.152)$$

Teja *et al.*⁷⁸ restated the Teja-Rice method in terms of P_C instead of V_C with the reducing parameter described as

$$\xi_{TR} = \frac{T_C^{0.167}}{(M^{0.5} P_C^{0.667})} \quad (4.104)$$

Aasberg-Petersen *et al.*⁷⁹ proposed a method based on the Teja-Rice approach, using molar mass (instead of the acentric factor) as the third parameter.

4.3.2.3.2.j Okeson and Rowley Method

The extended Lee-Kesler method, proposed by Okeson and Rowley⁸⁰ can be viewed as a perturbation about a spherically symmetric reference fluid in terms of a size/shape parameter (α) and a polar parameter (β) resulting in a four parameter corresponding state method. Okeson and Rowley⁸⁰ based ‘ α ’

on the radius of gyration ' r ' to avoid inclusion of polar contributions. However, in view of the success of acentric factor in correlating non-polar fluid properties, ' α ' has been chosen as ' ω ' for non-polar fluids, which has been accomplished by correlating the acentric factor for eighty non-polar fluids as a function of ' α '.

The equation is given by:

$$\alpha = 7.7706 \times 10^{-4} + 0.0330r + 0.01506r^2 - 9.997 \times 10^{-4}r^3 \quad (4.153)$$

The equation correlates α for all fluids, but gives values of α equal to ω only for non-polar fluids. For polar fluids α and ω may differ considerably. According to the authors, liquid density is a good indicator of polarity interactions. Values of β are calculated from a single density value in terms of the compressibility factor Z to give

$$\beta = \frac{[(Z - Z_o) - \alpha(Z_1 - Z_o)/\alpha_1]}{(Z_2 - Z_2^*)} \quad (4.154)$$

$$\text{where, } Z_2^* = \frac{Z_o + \alpha_2(Z_1 - Z_o)}{\alpha_1} \quad (4.155)$$

Values of α and β for many fluids have been tabulated by Wilding and Rowley⁸¹.

The final expression for viscosity is

$$(\eta_\xi) = (\eta_\xi)^{(0)} + \alpha(\eta_\xi)^{(1)} + \beta(\eta_\xi)^{(2)} \quad (4.156)$$

where η_ξ is the reduced viscosity and ξ is equal to $(1/\eta^*)$ wherein η^* is to be calculated from an appropriate equation.

4.3.2.3.2.k Application of Molar Polarization and Additional Parameter

Prabhakar *et al.*⁸² proposed a simple generalized correlation for liquid viscosity based on the use of the constituents of molar polarization at the critical temperature, which are R_M (molar refraction, an additive and constitutive property) and $P_P (= 4\pi N\mu^2/9kT_c)$ as the characteristic parameters. This provided an approximate equation for estimation of liquid viscosity.

$$\log \eta_R = 0.01R_M + 0.005P_P - 0.63 - 2.8T_R \quad (4.157)$$

In this equation,

- R_M is the molar refraction (which can be calculated from the atomic and structural contributions available in the literature),
- η_R is the reduced viscosity $\left(= \eta / \left(P_C^{0.667} M^{0.5} / T_C^{0.167} \right) \right)$,
- P_P is the polar contribution to molar polarization $(= 4\pi N \mu^2 / 9kT_C)$,
- μ is the dipole moment in Debyes,
- T_R is the reduced temperature $(= T / T_C)$,
- T is the temperature of interest in K,
- T_C is the critical temperature in K,
- P_C is the critical pressure in atm,
- M is the molecular mass,
- N is the Avogadro's number, and
- k is the Boltzmann constant.

The method has been shown to represent the liquid viscosity of several substances to about the same average absolute deviation as the methods of the same complexity available in the literature.

4.3.2.3.2.1 Yucel and Ozdogan Relation

Yucel and Ozdogan⁸³ proposed a semi-theoretical method based on Enskog's hard sphere theory for dense fluids and the principle of corresponding states. Viscosities of a total of 75 organic liquids (37 acyclic and 38 cyclic hydrocarbons) could be represented to good accuracy in the reduced temperature range of 0.45 to 0.8.

Based on the van der Waals model of real fluid and Enskog's hard sphere theory the dynamic viscosity of monoatomic liquid can be written as

$$\eta_m = 4y\eta_0 \left[\frac{1}{Z-1} + 0.8 + 0.761(Z-1) \right] \quad (4.158)$$

where Z is the hard sphere compressibility factor, η_0 is the viscosity of the dilute mono-atomic gas (Pa.s), $y = (\pi N_0 \sigma^3 \rho / 6)$, with N_0 as the Avogadro's number, σ as the hard sphere diameter (m) and ρ as the molar density (kmol/m^3).

The parameters Z , η_0 , and σ are given by the following expressions.

$$Z = \frac{(1 + y + y^2 + y^3)}{(1 - y)^3} \quad (4.159)$$

$$\eta_0 = \frac{2.6693 \times 10^{-5} (MT)^{(0.5)}}{\sigma^2} \quad (4.160)$$

$$\sigma = \left(\frac{6V_C}{\pi N_0} \right)^{(1/3)} (0.549058 - 0.010827T_R) \quad (4.161)$$

where T is the absolute temperature (K), M is the molar mass (kg/kmol), V_C is the critical volume (m³/kmol), and T_R is the reduced temperature (T/T_C). For simple mono-atomic liquids, dynamic viscosities at any temperature and pressure can be calculated from the above equations from the knowledge of the critical properties, molar mass and molar density.

The method can be extended to the dynamic viscosity of polyatomic liquids through the equation

$$\eta^*(T_R, P_R, \alpha) = \eta_m^*(T_R, P_R) + \eta_f^*(T_R, P_R, \alpha) \quad (4.162)$$

in which η_m^* is the reduced dynamic viscosity of a hypothetical simple monoatomic liquid and η_f^* is a correction term which employs a third parameter α to account for the factors effecting viscosity of polyatomic liquids.

Neglecting the effect of pressure on dynamic viscosity, for conditions near atmospheric pressure, Eq. (4.162) can be written as

$$\eta^*(T_R, \alpha) = \eta_m^*(T_R) + \eta_f^*(T_R, \alpha) \quad (4.163)$$

$$\text{where } \eta_m^* = 10^{-9} [6.7994 - 8.7599T_R + 2.8158T_R^2] \quad (4.164)$$

The dynamic viscosity data of the 75 selected organic compounds belonging to the four classes: alkanes, alkenes, aromatics and cycloalkanes are separately represented in the form

$$\log \eta^* = \log \left[\frac{\eta T_C^{0.167}}{M^{0.5} P_C^{0.667}} \right] = -A + \left(\frac{B}{T_R} \right) \quad (4.165)$$

which reproduced the experimental data well. The constants A and B for the selected compounds are given in Table 4.40.

Table 4.40. Constants of the reduced dynamic viscosity equation for selected liquids given by Eq. (4.165): $\log \eta^* = \log [\eta T_C^{0.167} / M^{0.5} P_C^{0.667}] = -A + (B/T_R)$.

Substance	Temperature Range, K	A	B
Alkanes			
n - Butane	183.15 to 268.15	5.1420	0.6264
n - Pentane	148.15 to 308.15	5.2168	0.6715
2 - Methyl butane	223.15 to 298.15	5.3925	0.7907
2 - Methyl pentane	178.15 to 338.15	5.2549	0.7214
3 - Methyl pentane	273.75 to 313.15	5.3343	0.7727
n - Heptane	183.15 to 368.15	5.3609	0.8058
2 - Methylhexane	273.15 to 361.55	5.3460	0.7870
n - Octane	218.15 to 398.15	5.3601	0.8285
n - Nonane	223.15 to 423.15	5.4240	0.8859
n - Decane	248.15 to 443.15	5.4234	0.9070
n - Un decane	248.15 to 468.15	5.4668	0.9480
n - Do decane	268.15 to 488.15	5.4566	0.9585
n - Tri decane	268.15 to 508.15	5.4829	0.9871
n - Tetra decane	283.15 to 523.15	5.4755	0.9932
n - Penta decane	283.15 to 543.15	5.4885	1.0167
n - Hexa decane	293.15 to 558.15	5.4769	1.0250
n - Hepta decane	298.15 to 573.15	5.4692	1.0349
n - Octa decane	303.15 to 588.15	5.4653	1.0411
n - Nona decane	308.15 to 598.15	5.4497	1.0494
n - Eicosane	313.15 to 613.15	5.4508	1.0573
Alkenes			
But - 1 - ene	158.15 to 238.15	5.1782	0.6108
Pent - 1 - ene	183.15 to 273.15	5.2436	0.6568
Hex - 1 - ene	218.15 to 333.15	5.3066	0.7092
Hept - 1 - ene	273.15 to 363.15	5.2165	0.6867
Oct - 1 - ene	273.15 to 388.15	5.2632	0.7394
Non - 1 - ene	273.15 to 388.15	5.3091	0.7927
Dec - 1 - ene	273.15 to 388.15	5.3576	0.8418
Un dec - 1 - ene	273.15 to 388.15	5.4050	0.8893
Do dec - 1 - ene	273.15 to 388.15	5.4625	0.9356
Tri dec - 1 - ene	273.15 to 388.15	5.4954	0.9725
Tetra dec - 1 - ene	273.15 to 388.15	5.5304	1.0099
Penta dec - 1 - ene	273.15 to 388.15	5.5768	1.0483
2 - Methyl butyl - 2 - ene	273.15 to 305.75	5.2755	0.6866
2 - Methyl butyl - 1,3 - diene	273.15 to 303.15	5.3113	0.6794
Hexa dec - 1 - ene	278.15 to 388.15	5.5820	1.0689
Octa dec - 1 - ene	293.15 to 388.15	5.5804	1.1040
Aromatics			
Benzene	283.15 to 353.15	5.6385	0.9586
Toluene	248.15 to 383.15	5.4259	0.7949
Ethyl benzene	248.15 to 353.15	5.3664	0.7684
1,2 - Di methyl benzene	268.15 to 413.15	5.4288	0.8133
1,3 - Di methyl benzene	273.15 to 408.15	5.3346	0.7363
1,4 - Di methyl benzene	288.15 to 408.15	5.3774	0.7669
n - Propyl benzene	248.15 to 423.15	5.4303	0.8252

<i>Substance</i>	<i>Temperature Range, K</i>	<i>A</i>	<i>B</i>
Iso propyl benzene	273.15 to 333.15	5.4391	0.8193
n - Butyl benzene	248.15 to 423.15	5.4612	0.8530
n - Pentyl benzene	253.15 to 423.15	5.5685	0.9337
n - Hexyl benzene	253.15 to 423.15	5.6224	0.9791
n - Heptyl benzene	253.15 to 423.15	5.6654	1.0166
n - Octyl benzene	253.15 to 423.15	5.7249	1.0605
n - Nonyl benzene	253.15 to 423.15	5.7824	1.1027
n - Decyl benzene	258.15 to 423.15	5.7961	1.1211
n - Undecyl benzene	263.15 to 423.15	5.8135	1.1422
n - Do decyl benzene	273.15 to 423.15	5.7994	1.1470
n - Tri decyl benzene	278.15 to 423.15	5.8235	1.1681
n - Tetra decyl benzene	288.15 to 423.15	5.8183	1.1777
n - Penta decyl benzene	293.15 to 423.15	5.8421	1.1988
n - Hexa decyl benzene	303.15 to 423.15	5.8406	1.2068
Cyclo alkanes			
Cyclo pentane	248.15 to 318.15	5.3179	0.7950
Methyl cyclo pentane	248.15 to 318.15	5.3564	0.8260
Ethyl cyclo pentane	253.15 to 373.15	5.2837	0.7618
n - Propyl cyclo pentane	253.15 to 383.15	5.2566	0.7543
n - Hexyl cyclo pentane	253.15 to 383.15	5.4265	0.9287
n - Heptyl cyclo pentane	253.15 to 383.15	5.4525	0.9622
n - Octyl cyclo pentane	253.15 to 383.15	5.4899	1.0007
n - Nonyl cyclo pentane	253.15 to 383.15	5.5262	1.0329
n - Decyl cyclo pentane	253.15 to 383.15	5.5571	1.0647
n - Do decyl cyclo pentane	268.15 to 383.15	5.6536	1.1374
n - Tri decyl cyclo pentane	278.15 to 383.15	5.7001	1.1713
Cyclo hexane	283.15 to 353.15	5.8156	1.1815
Methyl cyclo hexane	248.15 to 373.15	5.5030	0.9261
Ethyl cyclo hexane	248.15 to 383.15	3.3405	0.8320
n - Propyl cyclo hexane	248.15 to 383.15	5.4061	0.8589
n - Butyl cyclo hexane	253.15 to 383.15	5.5111	0.8956
n - Decyl cyclo hexane	273.15 to 383.15	5.8822	1.2329

In order to use Eq. (4.163), the values of η_f^* are obtained using the available experimental data for the different groups of substances and the relation

$$\eta_f^* = \eta^* - \eta_m^* \quad (4.166)$$

The values of η_f^* , thus obtained are correlated with reduced temperature T_R or reduced normal boiling temperature T_{BR} . The resulting relations are

$$\frac{\eta_f^*(T_R, \alpha_i)}{\eta_f^*(0.5, \alpha_i)} = f(T_R) \quad (4.167)$$

$$\eta_f^* \text{ can be expressed as } \eta_f^*(T_R, \alpha) = \eta'_f(T_R) \eta''_f f(\alpha) \quad (4.168)$$

The reduced normal boiling temperature (T_{BR}) has been found to be a good characterizing parameter. Finally the following empirical equations resulted.

For normal and iso-alkanes:

$$\eta'_f(T_R) = 0.0271 T_R^{-5.2846} \quad (4.169)$$

$$\eta''_f(T_{BR}) = 10^{-9} [-130.53 + 720.48 T_{BR} - 1329 T_{BR}^2 + 825.06 T_{BR}^3] \quad (4.170)$$

For alkanes and alkadienes :

$$\eta'_f(T_R) = 0.02051 T_R^{-5.6132} \quad (4.171)$$

$$\eta''_f(T_{BR}) = 10^{-9} [17.929 + 136.36 T_{BR} - 573.47 T_{BR}^2 + 502.25 T_{BR}^3] \quad (4.172)$$

For cyclic hydrocarbons:

$$\eta'_f(T_R) = 0.0103 T_R^{-6.5398} \quad (4.173)$$

$$\eta''_f(T_{BR}) = 10^{-9} [268.53 - 1064.5 T_{BR} + 1349 T_{BR}^2 - 522.17 T_{BR}^3] \quad (4.174)$$

For cycloalkanes:

$$\eta'_f(T_R) = 0.0205 T_R^{-5.6472} \quad (4.175)$$

$$\eta''_f(T_{BR}) = 10^{-9} [883.63 - 3469.6 T_{BR} + 4445.2 T_{BR}^2 - 1823.7 T_{BR}^3] \quad (4.176)$$

The methodology described gave good results for the groups of compounds mentioned subject to the availability of the input data needed for the application of the relevant equations.

4.3.2.3.2.m Lee and Wei Approach

Lee and Wei⁸⁴ proposed a corresponding states model applicable to the calculation of the viscosity of liquids using oxygen (r1), octane (r2) and water (r3) as three reference fluids. The corresponding states model based on three reference fluids can be written as:

$$\eta_R(T_R, P_R) = \eta_R^{r1} + \frac{\alpha - \alpha^{r1}}{\alpha - \alpha^{r2}} [\eta_R^{r2} - \eta_R^{r1}] + \beta^* \left[\eta_R^{r3} - \left(\eta_R^{r1} + \frac{\alpha - \alpha^{r1}}{\alpha - \alpha^{r2}} (\eta_R^{r2} - \eta_R^{r1}) \right) \right] \quad (4.177)$$

$$\text{with } \eta_R = \ln \left(\frac{\eta}{\eta^*} + 1 \right); \eta^* = \frac{M^{(1/2)} P_C^{(2/3)}}{(RT_C)^{(1/6)} N^{(1/3)}} \quad (4.178)$$

$$T_R = T/(T_C \theta); P_R = (P/P_C); \beta^* = (\beta/\beta^{r3}) \quad (4.179)$$

where N is the Avagadro's number and the parameters are: α (radius of gyration), θ (energy correction factor) and β^* (an empirical dimensionless polar/association parameter relative to water) that characterize the size/shape and polar/hydrogen-bonding effects.

As already mentioned, the reference fluids selected are : oxygen, octane, and water. The reduced viscosity of the chosen reference fluids can be expressed as :

$$\eta_R^{(i)} = A_0 + (A_1/T_R) + A_2 T_R + A_3 T_R^2 + A_4 P_R + A_5 P_R^{0.5} + A_6 T_R P_R \quad (4.180)$$

with the value of the parameter θ as unity. The coefficients of the equation for the reference fluids (chosen) are listed in Table 4.41.

Table 4.41. Coefficients of the reduced viscosity equation (Eq. 4.180) for the selected reference fluids, Eq. (4.180): $\eta_R^{(i)} = A_0 + (A_1/T_R) + A_2T_R + A_3T_R^2 + A_4P_R + A_5P_R^{0.5} + A_6T_RP_R$.

Substance	Oxygen	Octane	Water
A ₀	- 6.6572	- 5.1080	- 44.7450
A ₁	2.6327	2.72726	10.4698
A ₂	11.4927	9.1402	75.4262
A ₃	- 6.4140	- 5.5270	- 43.846
A ₄	0.00392	- 0.03138	- 0.05814
A ₅	0.0092	0.0144	0.0013
A ₆	0.0910	0.0883	0.1203

The method provides for the calculation of the dynamic viscosity from a knowledge of the model parameters (T_C , P_C , α , θ and β^*). While θ can be estimated from the following equation with the coefficients given for each class of compounds, β^* has to be calculated from a knowledge of the viscosity of the fluid at one known temperature and pressure.

$$\theta = B_0 + (B_1/Z_C) + B_2T_C^{0.5} \quad (4.181)$$

where Z_C is the critical compressibility factor and T_C is the critical temperature in K. The coefficients of Eq. (4.181) for different classes of organic compounds are given in Table 4.42.

Table 4.42. Coefficients of the generalized equation (Eq. 4.181) for θ for different classes of substances, Eq. (4.181): $\theta = B_0 + (B_1/Z_C) + B_2T_C^{0.5}$.

Substance Class	B_0	B_1	B_2
Alkanes	1.1403	- 0.1163	0.01366
Alkenes	0.6985	0.10294	- 0.00513
Alicyclics	3.2093	- 0.47549	- 0.01465
Alkylbenzenes	2.2787	- 0.34340	-
Alkylhalides	0.4126	-	0.03202
Alcohols	5.2358	- 0.30248	- 0.11702
Ethers	0.6162	0.10376	-
Ketones	0.8327	0.04327	-
Carboxylic acids	1.1199	0.00584	-
Esters	1.5208	- 0.11563	-
Nitriles, Amines, etc.	2.2758	- 0.00428	- 0.04924
Benzene derivatives	0.2938	0.18358	-

Pure liquid viscosities are predicted with an average absolute deviation of about 5 to 7%, depending on the types of substances and the temperature and pressure conditions.

4.3.2.4 Gas Viscosity Estimation Methods Recommended for Liquids

The following are some other corresponding states based methods for gas viscosities recommended for liquid viscosity estimation within the density limits of applicability.

4.3.2.4.1 Golubev Approach

Golubev⁸⁵ proposed the following equations for the estimation of gas viscosity

$$\eta = \eta_C^* T_R^{0.965} \quad \text{for } T_R < 1 \quad (4.182)$$

$$\eta = \eta_C^* T_R^{[0.71 + (0.29/T_R)]}, \text{ otherwise} \quad (4.183)$$

$$\eta_C^* = 3.5 [M^{(1/2)} P_C^{(2/3)} / T_C^{(1/6)}] \quad (4.184)$$

4.3.2.4.2 Thodos *et al.* Equations

Thodos and coworkers⁸⁶⁻⁸⁸ proposed the following expressions for calculating liquid viscosities that were based on gas viscosity models, and are presented below.

For Nonpolar Gases:

$$\eta \xi = 4.610 T_R^{0.618} - 2.04 e^{-0.449 T_R} + 1.94 e^{-4.058 T_R} + 0.1 \quad (4.185)$$

For Hydrogen Bonded Type Polar Gases:

$$\eta \xi = (0.755 T_R - 0.055) Z_C^{-5.4} \quad \text{for } T_R < 2.0 \quad (4.186)$$

For Non-hydrogen Bonded Type Polar Gases:

$$\eta \xi = (1.90 T_R - 0.29)^{4.5} Z_C^{-2.3} \quad \text{for } T_R < 2.5 \quad (4.187)$$

$$\text{where } \xi = T_C^{(1/6)} M^{(-1/2)} P_C^{(-2/3)}, \text{ and} \quad (4.188)$$

Z_C is the critical compressibility factor.

4.3.2.4.3 Reichenberg Method

Reichenberg⁸⁹ method involved correction of the dilute gas viscosity (low pressure viscosity) for the effect of pressure at the same temperature by relating the ratio of the viscosity of the dense gas to the viscosity of the dilute gas at the same temperature to a function of pressure and temperature. The resulting equation was:

$$\frac{\eta}{\eta_0} = f(P_R, T_R) = 1 + \frac{Q(AP_R^{1.5})}{BP_R + (1 + CP_R^D)^{-1}} \quad (4.189)$$

where

$$A = \left(\frac{1.9824 \times 10^{-3}}{T_R} \right) \exp(5.2683T_R^{-0.5767}) \quad (4.190)$$

$$B = A(1.6552T_R - 1.2760) \quad (4.191)$$

$$C = (0.1319 / T_R) \exp(3.7035T_R - 79.8678) \quad (4.192)$$

$$D = (2.9496 / T_R) \exp(2.9190T_R^{-16.6169}) \quad (4.193)$$

$$Q = 1 - 1.5665\mu_R, \text{ and} \quad (4.194)$$

$$\mu_R = 52.46\mu^2(P_C / T_C^2) \quad (4.195)$$

where μ is the dipole moment in debyes, P_C is the critical pressure in bars and T_C is the critical temperature in Kelvin.

4.3.2.4.4 Jossi *et al.* Relation

Based on the dimensional analysis, Jossi *et al.*⁹⁰ derived the following relationship for calculating viscosity.

$$[\eta(P, T) - \eta_0(T)]_{\xi_T} = f(\rho_R) \quad (4.196)$$

where ξ_T has the same meaning as that for dilute gases. They noted that the experimental data ranging from the dense gas to the liquid phase for 11 relatively non-polar substances fell essentially on a single curve, which has been fitted to the following equation for $0.1 < \rho_R < 3.0$

$$\begin{aligned} [(\eta - \eta_0)_{\xi} + 10^{-4}]^{0.25} = & 0.10230 + 0.023364\rho_R + 0.058533\rho_R^2 \\ & - 0.040758\rho_R^3 + 0.009332\rho_R^4 \end{aligned} \quad (4.197)$$

In an extension of the approach to polar substances, Stiel and Thodos⁹¹ regressed the experimental data for 14 fluids and obtained the following equations

$$(\eta - \eta_0)_{\xi_T} = 16.56 \times 10^{-5} \rho_R^{1.111} \quad \text{for } \rho_R \leq 0.10 \quad (4.198)$$

$$(\eta - \eta_0)_{\xi_T} = 0.607 \times 10^{-5} [9.045\rho_R + 0.63]^{1.739} \quad \text{for } \rho_R \leq 0.90 \quad (4.199)$$

$$\begin{aligned} \log[-\log\{(\eta - \eta_0)_{\xi_T}\}] = & 0.6439 - 0.1005\rho_R - \Delta \\ & \text{for } 0.90 \leq \rho_R \leq 2.6 \end{aligned} \quad (4.200)$$

where

$$\Delta = 0 \quad \text{for } 0.9 \leq \rho_R \leq 2.2 \quad (4.201)$$

$$\Delta = 4.75 \times 10^{-4} [\rho_R^3 - 10.65]^2 \quad \text{for } 2.2 \leq \rho_R \leq 2.6 \quad (4.202)$$

4.3.2.5 Potential Parameter Approaches

Several investigators developed methods for the estimation of viscosity of liquids based on potential parameters. Some of them are described in the following sections.

4.3.2.5a Bondi's Approach

From the considerations of the molecular theory, Bondi⁹² suggested the relationship:

$$\eta^* \sim \exp(1/T^*) = \eta r_0^2 / (m\varepsilon)^{1/2} \quad (4.203)$$

with $T^* = kT/\varepsilon$, r_0 is the inter molecular distance in cm at which the intermolecular potential is a minimum, ε is the minimum value of the potential energy in ergs and $m (= M/N)$ is the mass of the molecule in grams. The representation is valid for several series of compounds including n-paraffinic, iso-paraffinic, naphthalenic and aromatic hydrocarbons, and ethers.

4.3.2.5b Malek and Stiel Relation

Malek and Stiel⁹³ proposed the following alternate forms for $\eta^*\xi$ for polar gases in terms of acentric factor ω and the Stiel's polar factor X .

The viscosity of a polar gas represented by the Stockmayer potential model can be written as

$$\eta^* = 2.669 \times 10^{-3} \frac{\sqrt{MT}}{\sigma^2 \Omega^{(2,2)*}(T^*, \Delta^*)} \quad (4.204)$$

where $T^* = (kT/\varepsilon)$ and $\Delta^* = 0.5(\mu^2/\varepsilon\sigma^3)$. Tables of $\Omega^{(2,2)*}$ as a function of T^* and Δ^* are available⁹⁴. For polar fluids, the dimensionless parameters can be related to the macroscopic parameters ω and X through vapor pressure by the following equations

$$\omega = -1.0 - \log P_R \Big|_{T_R=0.7} \quad (4.205)$$

$$X = 1.552 + 1.70\omega + \log P_R \Big|_{T_R=0.6} \quad (4.206)$$

$\eta^*\xi$ is a function of T_R , ω and X , where η^* is the viscosity of gas at atmospheric pressure in cP, $\xi = T_C^{(1/6)} / [M^{(1/2)} P_C^{(2/3)}]$, $T_R = (T / T_C)$, T is the temperature of interest, and T_C is the critical temperature in K, P_C is the critical pressure in atmospheres, M is the molecular mass, ω the acentric factor and X is Stiel's polar factor.

The Stockmayer force constants (ε/k) and σ can be related to ω and X in the form

$$\sigma^* = \sigma(P_C / T_C)^{1/3} = 2.3454 + 0.2972\omega - 40.4271X + 61.7657\omega X - 15.8248X^2 - 0.9706\omega^2 \quad (4.207)$$

$$U^* = (\varepsilon / kT_C) = 0.8082 - 0.04504\omega - 27.3866X^2 - 48.9402\omega X - 48.7293X^2 + 0.8784\omega^2 \quad (4.208)$$

$$\Delta^* = 0.5(\mu^2 / \varepsilon\sigma^3) = 86.0405X + 131.6080\omega X + 90.8009X^2 \quad (4.209)$$

4.3.2.5c Chung *et al.* Method

Chung *et al.*⁹⁵ presented generalized correlations in terms of potential parameters for the estimation of dilute gas viscosity as well as for the dense fluids (applicable for liquids as well). Their starting point was the Chapman and Enskog theory, written as:

$$\eta_0 = (26.69 \times 10^{-6}) \left[\frac{(MT)^{0.5}}{\sigma^2 \Omega^*} \right] \quad (4.210)$$

where η_0 is the viscosity in poise, M is the molecular mass in g/mol, T is the absolute temperature in Kelvin, σ is the potential distance parameter in Angstroms and Ω^* is the reduced collision integral which depends on the chosen intermolecular potential. They used

$$(\varepsilon / k) = (T_C / 1.2593) \quad (4.211)$$

$$\sigma = 0.809V_C^{(1/3)} \quad (4.212)$$

where (ε/k) and T_C are in Kelvin, σ in Angstroms, and V_C in cm^3/mol . Combining these equations with the Lennard-Jones Potential Energy function,

$$\psi(r) = 4\varepsilon \left[\left(\sigma/r \right)^{12} - \left(\sigma/r \right)^6 \right], \text{ and} \quad (4.213)$$

$$T^* = 1.2593T_R \quad (4.214)$$

The final expression proposed by Chung *et al.*⁹⁵ became,

$$\eta = 40.785 \times 10^{-5} F_C \frac{(MT)^{1/2}}{V_C^{(2/3)} \Omega^*} \quad (4.215)$$

where η is viscosity in μP
 M is molecular weight in g/mol
 T is temperature in K
 V_C is critical volume, cc/mol, and
 Ω_V is viscosity collision integral from the Neufeld *et al.*⁹⁶ equation, which is given by

$$\Omega^* = \frac{A}{T^{*B}} + \frac{C}{\exp(DT^*)} + \frac{E}{\exp(FT^*)} + GT^{*B} \sin(ST^{*W} - H) \quad (4.216)$$

where $A=1.16145$, $B=0.14874$, $C=0.52487$, $D=0.77320$, $E=2.16178$, $F=2.43787$, $G=-6.435 \times 10^{-4}$, $H=7.27371$, $S=18.0323$ and $W=-0.76830$. The dimensionless temperature T^* is related to the potential energy parameter (ε) and Boltzmann's constant (k) by

$$T^* = kT/\varepsilon \quad (4.217)$$

with

$$T^* = 1.2593T_R, \text{ and} \quad (4.218)$$

$$F_C = 1 - 0.2756 \omega + 0.059035 \mu_R^4 + \kappa \quad (4.219)$$

where ω is the acentric factor and κ is a correction factor for hydrogen bonding effect of associating substances such as alcohols, acids and water. The values of the factor κ for some important substances are noted in Table 4.43.

Table 4.43. The parameter (κ) for some important substances.

Compound	κ	Compound	κ
Methanol	0.215175	1-Pentanol	0.121555
Ethanol	0.174823	1-Hexanol	0.114230
1 - Propanol	0.143453	1-Heptanol	0.108674
2 - Propanol	0.143453	Acetic acid	0.091549
1 - Butanol	0.131671	Water	0.075908
2 - Methyl - 1 - propanol	0.131671		

The term μ_R is a dimensionless dipole moment defined as:

$$\mu_R = 131.3 \frac{\mu}{(V_C T_C)^{1/2}} \quad (4.220)$$

The above equations are applicable only to simple molecular gases such as argon and methane. To extend to polyatomic molecular gases, the viscosity calculated from the above equation has to be multiplied by a factor F_C to account for the molecular structure and polar effects. The following equations are also useful in the application of this method.

$$\sigma = 0.809 V_C^{(1/3)} \quad (4.221)$$

$$(\varepsilon/k) = (T_C / 1.2593) \quad (4.222)$$

where (ε/k) and the critical temperature T_C are in Kelvin, σ is in Angstrom, and the critical volume (V_C) is in cm^3/mol .

For dense fluids, the equation is extended to account for the effects of temperature and pressure by developing an empirically correlated function of density and temperature as shown below.

$$\eta = \eta_K + \eta_P \quad (4.223)$$

The viscosity is expressed in Poise.

$$\eta_K = \eta_0 \left[\frac{1}{G_2} + A_6 Y \right] \quad (4.224)$$

$$\eta_P = \left[36.344 \times 10^{-6} - \frac{(MT_C)^{(1/2)}}{(V_C)^{(2/3)}} \right] A_7 Y^2 G_2 \exp \left[A_8 + \frac{A_9}{T^*} + \frac{A_{10}}{T^{*2}} \right] \quad (4.225)$$

$$\text{where, } Y = \rho V_C / 6; \quad G_1 = \frac{(1.0 - 0.5Y)}{(1 - Y)^3} \quad (4.226)$$

$$G_1 = \frac{\left[\frac{A_1}{y} [1 - \exp(-A_4 Y)] + A_2 G_1 \exp(A_4 Y) + A_3 G_1 \right]}{(A_1 A_4 + A_2 + A_3)} \quad (4.227)$$

η_0 is the viscosity of the low-pressure gas given by Eq. 4.210 which accounts for the associating effects of hydrogen bonding. The constants A_1 to A_{10} are linear functions of the acentric factor (ω), the reduced dipole moment (μ_R) and the association factor (κ) in the form:

$$A_i = a_0(i) + a_1(i)\omega + a_2(i)\mu_R + a_3(i)\kappa \quad i = 1 \text{ to } 10 \quad (4.228)$$

The values of a_0 , a_1 , a_2 and a_3 are given in Table 4.44. The constants a_0 and a_1 are determined from the viscosity data on non-polar fluids, while a_2 and a_3 are determined from the viscosity data on polar and associating fluids by regression. The first two terms are included for non-polar fluids while the third term is included for polar fluids and the fourth term is needed for hydrogen bonding substances.

Table 4.44. Constants to be used for the generalized viscosity equation proposed by Chung et al., Eq. (4.228): $A_i = a_0(i) + a_1(i)\omega + a_2(i)\mu_R + a_3(i)\kappa$ $i = 1$ to 10 .

(i)	$a_0(i)$	$a_1(i)$	$a_2(i)$	$a_3(i)$
1	6.32402	50.41190	- 51.68010	1189.02
2	0.0012102	0.0011536	- 0.0062571	0.0037283
3	5.28346	254.2090	- 168.481	3898.27
4	6.62263	38.09570	- 8.46414	31.4178
5	19.7454	7.63034	- 14.35440	31.52670
6	- 1.89992	- 12.53670	4.98529	- 18.15070
7	24.2745	3.44945	- 11.29130	69.34660
8	0.79716	1.11764	0.012348	- 4.11661
9	- 0.23816	0.067695	- 0.81630	4.02528
10	0.068629	0.34793	0.59256	- 0.72663

G_2 approaches unity as density approaches zero and sharply increases with density at higher values. At the limiting value of low density, the η_P term is negligible while at extremely high density, η_K is small and η_P is the major contributor. The viscosity equation proposed by Chung *et al.*⁹⁵ is applicable to the entire PVT region.

A modified form of the Chung *et al.* equation is proposed by Brule and Starling⁹⁷ expressing viscosity as follows.

$$\eta = \text{viscosity} = \left[26.693 \sqrt{\{M(\varepsilon/k)\}/\sigma^2} \right] \eta^* \text{ in micropoise} \quad (4.229)$$

$$\eta^* = \text{reduced viscosity} = \eta_K^* + \eta_\Phi^* \quad (4.230)$$

$$\begin{aligned} \eta_K^* &= \text{kinetic contribution to reduced viscosity} \\ &= \eta_0^* \left[E_6 y + \frac{1}{G_n(y)} \right] \end{aligned} \quad (4.231)$$

$$\begin{aligned} \eta_\Phi^* &= \text{potential contribution to reduced viscosity} \\ &= E_7 y_2 [G_n(y)] \exp \left[E_8 + (E_9/T^*) + \left(\frac{E_{10}}{T^{*2}} \right) \right] \end{aligned} \quad (4.232)$$

$$\begin{aligned}\eta_0^* &= \text{dilute gas contribution to reduced viscosity} \\ &= E_0 \eta_{CE}^*\end{aligned}\quad (4.233)$$

$$\begin{aligned}\eta_{CE}^* &= \text{Chapman-Enskog relation for dilute gases} \\ &= \sqrt{(T^*)} / \Omega^{(2,2)*}\end{aligned}\quad (4.234)$$

$$G_n(y) = \frac{\left[\frac{E_1}{y} [1 - \exp(-E_4 y)] + E_2 G \exp(E_5 y) + E_3 G \right]}{[E_1 E_4 + E_2 + E_3]} \quad (4.235)$$

where y is the reduced density number defined as

$$y = \left(\frac{\pi}{6} \right) \rho^* = 0.318 \frac{\pi}{6} \frac{\rho}{\rho_C} \quad (4.236)$$

ρ is the molar density calculated from for example modified BWR equation of state, and ρ_C is the critical density.

The viscosity correlation parameter E_i is calculated as a function of the orientation parameter γ using the relation:

$$E_i = a_i + b_i \gamma_i \quad (4.237)$$

and the universal constants a_i and b_i given in Table 4.45.

Table 4.45. Universal Constants a_i and b_i for obtaining the parameters E_i for the Brule and Starling viscosity correlation, Eq. (4.237): $E_i = a_i + b_i \gamma_i$.

(i)	a_i	b_i
0	1.0	- 0.2756
1	17.4499	34.0631
2	- 0.000961125	0.00723450
3	51.0431	169.460
4	- 0.605917	71.1743
5	21.3818	- 2.11014
6	4.66798	- 39.9408
7	3.76241	56.6234
8	1.00377	3.13962
9	- 0.0777423	- 3.58446

The collision integral $\Omega^{(2,2)}$ is evaluated as a function of temperature using an empirical expression that was developed based on the Lennard-Jones intermolecular potential model and is given below.

$$\Omega^{(2,2)} = \frac{A}{T^{*B}} + \frac{C}{\exp(DT^*)} + \frac{E}{\exp(FT^{*2})} + RT^{*B} \sin(ST^{*W} - P) \quad (4.238)$$

Using the coefficients given in Table 4.46.

Table 4.46. Coefficients for calculating the transport collision integrals for the Lennard-Jones (12-6) potential, Eq. (2.238): $\Omega^{(2,2)} = (A/T^{*B}) + C/\exp(DT^*) + E/\exp(FT^{*2}) + RT^{*B} \sin(ST^{*W} - P)$.

Coefficient	Value
A	1.16145
B	0.14874
C	0.52487
D	0.77320
E	2.16178
F	2.43787
R	-0.0006435
S	18.0323
W	-0.7683
P	7.27371

The proposed model of Chung-Lee-Starling is capable of predicting the viscosities of high molecular weight paraffins, typical of petroleum and polycyclic aromatic hydrocarbons preponderant in fossil fluids derived from petroleum residue, shale oil and coal. The viscosities of light gases and petroleum and coal liquids can be predicted over wide ranges of temperature and pressure.

4.3.2.5d Monnery *et al.* Approach for Non-polar Substances

Monnery *et al.*⁶⁷ described and discussed the evaluation and application of shape factors in the potential parameter based corresponding state method of Ely and Hanley for the prediction of the viscosities of liquid hydrocarbons. In this approach, the reduced viscosity of a fluid is written as:

$$\eta_R = (\eta / \eta_C) = f(T_R, \rho_R) \quad (4.239)$$

The critical viscosity η_C is defined from the kinetic theory as:

$$\eta_c = C \frac{(MT_c)^{(1/2)}}{(V_c)^{(2/3)}} \quad (4.240)$$

where C is a constant. According to the corresponding states theory, the functional form of the above equation should be the same for all conformal fluids and enable the expression of the viscosity of any fluid i in terms of the reference fluid o in the form

$$\eta_i(\rho, T) = \eta_o \left[\rho \left(\frac{\sigma_i}{\sigma_o} \right)^3, T \left(\frac{\epsilon_o}{\epsilon_i} \right) \right] \left(\frac{M_i}{M_o} \right)^{(1/2)} \left(\frac{\sigma_o}{\sigma_i} \right)^2 \left(\frac{\epsilon_i}{\epsilon_o} \right)^{(1/2)} \quad (4.241)$$

Since (ϵ/k) is proportional to T_c and σ^3 is proportional to $(1/\rho_c)$ the expression can be rearranged as

$$\eta_i(\rho, T) = \eta_o \left[\rho \left(\frac{\rho_{Ci}}{\rho_{Co}} \right)^3, T \left(\frac{T_{Co}}{T_{Ci}} \right) \right] \left(\frac{M_i}{M_o} \right)^{(1/2)} \left(\frac{\rho_{Ci}}{\rho_{Co}} \right)^{2/3} \left(\frac{T_{Ci}}{T_{Co}} \right)^{(1/2)} \quad (4.242)$$

These expressions are applicable to conformal fluids only. For non-conformal fluids, the extended corresponding states method where the shape factors, θ and Φ , are introduced to account for the non-conformity of the molecules can be used. The reducing ratios f (for temperature) and h (for volume) are defined as

$$f_{i,o} = (T_{Ci} / T_{Co}) \theta_{i,o} \quad (4.243)$$

$$h_{i,o} = (\rho_{Co} / \rho_{Ci}) \Phi_{i,o} \quad (4.244)$$

On introduction of the reducing ratios, the equation for viscosity becomes:

$$\eta_i(\rho, T) = \eta_o \left[\rho h_{i,o}, T / f_{i,o} \right] (M_i, M_o)^{(1/2)} h_{i,o}^{-(2/3)} f_{i,o}^{(1/2)} \quad (4.245)$$

which can be rewritten as:

$$\eta_i(\rho, T) = \eta_o(\rho_o, T_o) (M_i, M_o)^{(1/2)} h_{i,o}^{-(2/3)} f_{i,o}^{(1/2)} \quad (4.246)$$

$$\text{where } \rho_o = \rho h_{i,o} \text{ and } T_o = T / f_{i,o} \quad (4.247)$$

$\theta_{i,o}$ and $\Phi_{i,o}$ can be determined from the following density independent shape factor relations proposed by Ely⁹⁸

$$\theta_{i,o} = [1 + (\omega_i - \omega_o)(a + b \ln T_R)] \quad (4.248)$$

$$\text{and } \Phi_{i,o} = [1 - (\omega_i - \omega_o)(c + d \ln T_R)](Z_{Ci} / Z_{Co}) \quad (4.249)$$

Generalized shape factor functions have been represented by the equation

$$f = A + B \ln T_R + C (\ln T_R)^2 \quad (4.250)$$

The coefficients A , B and C for different types of hydrocarbons are related to the ratio of the normal boiling point (T_B) of the substance and the normal boiling point of the reference substance (T_{Bo}); propane in the present case. The coefficients of the equations have the following form.

$$A = A_1 + A_2 (T_B / T_{Bo}) + A_3 (T_B / T_{Bo})^2 \quad (4.251)$$

$$B = B_1 + B_2 (T_B / T_{Bo}) + B_3 (T_B / T_{Bo})^2 \quad (4.252)$$

$$C = C_1 + C_2 (T_B / T_{Bo}) + C_3 (T_B / T_{Bo})^2 \quad (4.253)$$

The values of the coefficients are provided for different series of compounds in Table 4.47.

Table 4.47. Coefficients of the generalized shape factor functions.

Series	Paraffins $M > 100$	Paraffins $M < 100$	Olefins	Cyclo- pentanes	Cyclo- hexanes	Aromatics
A ₁	0.26272	0.13215	0.11160	0.99771	0.27932	0.88181
A ₂	0.75213	0.85844	0.79508	0.13439	0.67150	0.23520
A ₃	-	-	-	0.11630	0.03507	0.07400
B ₁	0.45977	-0.27418	0.0649	-1.25286	-11.1327	-7.6852
B ₂	-0.39881	0.55865	-0.1001	1.40528	11.4363	8.8326
B ₃	-	-0.29932	-0.0405	-0.49602	-3.0526	-2.5330

<i>Series</i>	<i>Paraffins M > 100</i>	<i>Paraffins M < 100</i>	<i>Olefins</i>	<i>Cyclo- pentanes</i>	<i>Cyclo- hexanes</i>	<i>Aromatics</i>
C ₁	- 1.25725	0.04500	- 0.0002	0.28865	7.3664	1.18301
C ₂	1.18289	- 0.08811	- 0.0010	- 0.40786	- 8.4463	- 1.36990
C ₃	0.23304	0.04298	0.0065	0.14878	2.4357	0.39911

4.3.2.5e Monnery *et al.* Method Using Square-Well Potential Function

Monnery *et al.*⁹⁹ proposed a model based on statistical mechanics, for simultaneous calculation of liquid and gas viscosities. They employed the square well intermolecular potential for non-polar compounds. Employing theoretical results along with the modifications to correct the model for molecular chaos assumption and the inadequacy of the square well potential, final expressions have been proposed. Perturbation theory has been used to obtain the radial distribution function values. The model parameters are determined from liquid and gas viscosity data and generalized in terms of group contributions. The methodology described in detail by Monnery *et al.*⁹⁹ produces estimates of a variety of non-polar compounds within 8%.

4.3.2.5f Monnery *et al.* Approach for Polar and Associated Substances

Monnery *et al.*¹⁰⁰ modified a statistical mechanical model based on the square well inter-molecular potential for calculating both liquid and gas phase viscosities of polar and associated compounds. Corrections have been incorporated into the original theory for the assumptions of only two body interactions and molecular chaos for velocities and the inadequacy of the square well potential. Further modifications have been carried out in such a manner that a consistent low density limit is approached and improved dilute gas temperature dependence results. The three model parameters appearing in the final expression are determined from gas and liquid viscosity data and generalized group contributions for the model are proposed. The scheme, discussed in detail by Monnery *et al.*¹⁰⁰ is shown to provide estimated values of gas and liquid viscosities of over 100 polar and hydrogen bonding substances with average deviations of 2.1% for gas and 6.8% for liquid.

4.3.2.6 Artificial Neural Net Approaches

In the recent past artificial neural net (ANN) has emerged as a powerful tool in representing the data difficult to be formulated and predicted by means of a well defined dependence on the variables known to be responsible. It is therefore no surprise that some recent efforts on the representation of liquid viscosity used the ANN approach.

4.3.2.6a Homer *et al.* Method for Liquid Viscosity and Other Physical Properties

Homer *et al.*¹⁰¹ described an ANN and equilibrium property based predictive method for the viscosity, density, heat of vaporization, boiling point and Pitzer's acentric factor for pure organic liquid hydrocarbons applicable to the wide range of reduced temperatures between 0.45 and 0.7. This model, *COMMITTEE* ANN has been trained, using ten physicochemical and structural properties, along with absolute temperature as inputs, to correlate and predict viscosity. A set of 281 compounds, of diverse structure have been arbitrarily pooled into two sub sets, the first sub set of 200 compounds which have been used to train the *COMMITTEE* ANN, and a second sub set of 81 compounds which have been used to test the predictive performance of the *COMMITTEE* ANN. The viscosity and input data for each individual compound is compiled (on the average) at forty different temperatures, ranging from melting point to boiling point, for each of the chosen compounds. The mean average absolute deviation in viscosity predicted by the *COMMITTEE* ANN is 7.9% which reduces to 6.5% when the correlated data is also included in the comparison.

ANN's used for the prediction of physicochemical properties, have generally been multi-layered, feed forward and non-linear, trained via the back propagation rule to perform a function approximation. After evaluating a considerable number of differently structured neural networks, an ANN, consisting of ten ANNs, organized into a *COMMITTEE* by Homer *et al.* Each of the ten ANNs has a single hidden layer with seven neurons and an output layer with one neuron. The hidden layer has a *tansig* transfer function and the output layer has a *purelin* transfer function. Each ANN in the committee has been trained to different local minima of the error function.

The pool of compounds in this study consisted of an original set of 16 classifications of a total of 281 pure hydrocarbons as shown in Table 4.48.

Table 4.48. Details of the family classes and number of compound used in the work of Homer *et al.*

<i>Class</i>	<i>Family name</i>	<i>Number of compounds</i>
1	n-Alkanes	30
2	Methylalkanes	16
3	Dimethylalkanes	21
4	Other alkanes	20
5	Cycloalkanes	6
6	Alkylcyclopentanes	11
7	Alkylcyclohexanes	13
8	Alk-1-enes	19
9	Alk-2,3,4-enes	18

<i>Class</i>	<i>Family name</i>	<i>Number of compounds</i>
10	Methylalkenes	16
11	Ethyl and Higher alkenes	11
12	Cycloalkenes	7
13	Dialkenes	24
14	Alkynes	16
15	n-Alkylbenzenes	19
16	Other alkylbenzenes	34
	Total	281

Experimental viscosity values noted from the DIPPR data base every 5 K temperature difference, ranging from the melting point to the boiling point amounting to about 40 data points (as a function of temperature) for each compound have been used.

The inputs to the *COMMITTEE* ANN are: the absolute temperature, five physical properties and five structural indicators. The physical properties are molecular mass, Pitzer's acentric factor, normal boiling point, the temperature dependent density, and latent heat of vaporization. The structural inputs are the number of cyclic rings, the number of double bonds, the number of double bonds in the cyclic ring, the number of triple bonds, the number of triple bonds in the cyclic ring and the number of benzene rings in the compound. For each compound, the temperature dependent properties at the temperatures at which viscosities have been chosen are used. The method, as indicated, uses a large amount of input data and is quite complex, finally giving results better than the generalized methods based on a minimum amount of input data and can probably be effectively used if all the required input data are available.

4.3.2.6b Dutt *et al.* Approach

As ANNs gained importance over the last few years as nonlinear modeling tools in several applications, Dutt *et al.*¹⁵, employing ANN as a model, predicted the viscosity of 100 compounds. A typical feed forward network with one input layer consisting of the independent variables, one hidden layer and one output layer with a single neuron for viscosity has been chosen. The input layer performs the task of scaling the inputs to a range of -5 to +5 according to

$$x_i = \left\{ \frac{Inp_i - Inp_{i,min}}{Inp_{i,max} - Inp_{i,min}} \times 10 \right\} - 5 \quad i = 1, \dots, n \quad (4.254)$$

where $Inp_{i,max}$ and $Inp_{i,min}$ are the maximum and minimum values of the i^{th} input variable Inp_i which are defined on the basis of the data considered for

the model development. The task of each neuron in the hidden layer is summarized as follows:

$$h_j = f\left(\sum_{i=1}^n w_{ij}x_i + w_{0j}\right) \quad j = 1, \dots, m \quad (4.255)$$

where

$$f(x) = \frac{1}{1 + \exp(-x)} \quad (4.256)$$

The function $f(x)$ represents the sigmoid activation function, n is the number of input nodes other than a bias node, m is the number of neurons in the hidden layer (excluding bias node), h_j is the output of the j^{th} neuron in the hidden layer, and w_{ij} represent the weights connecting the input layer and the hidden layer. The output, y is calculated according to the following equation;

$$y = f\left(\sum_{j=1}^m v_j h_j + v_0\right) \quad (4.257)$$

where v_j represent the weights connecting the hidden layer to the single output and $f(x)$ is the sigmoid activation function. The output is then scaled back from 0 to 1 to the range of viscosities considered in the study as:

$$\eta = \eta_{\min} + y(\eta_{\max} - \eta_{\min}) \quad (4.258)$$

where $\eta_{\min}$ and $\eta_{\max}$ are the minimum and maximum values of the viscosity in the data considered for model development. The method used for training is the combined design and training algorithm (CDTA) based on back propagation with an adaptive learning rate and a constant acceleration factor¹⁰². The data on 100 compounds is divided into two parts – training data consisting of 90 compounds, and testing data consisting of 10 compounds. The training data is employed to update the weights, whereas the testing data is used for checking the convergence. Several input combinations including temperature, boiling point, dipole moment, acentric factor, critical temperature, density, and freezing temperature were explored, and for each combination, the number of neurons in the hidden layer was determined using the training algorithm. The ANN model resulting in minimum % absolute deviation had a configuration of 5 – 19 – 1 (i.e., 5 inputs, 19 neurons in the hidden layer, and 1 output) and resulted in an

overall absolute deviation of 13.86 % (training data: 13.20 %, testing data: 19.86 %). The inputs of the network were found to be temperature, boiling point, dipole moment, acentric factor and density. The weights of the resulting network are reported in Table 4.49. The % average absolute deviation values for all the 100 compounds are reported in the section on comparison of the prediction methods.

In view of lesser complexity and need for the requirement of density, boiling point, acentric factor and dipole moment as the only inputs, the method can be considered to be a good estimation method.

Table 4.49. Weights of the ANN model for prediction of viscosity.

Weights from input to hidden layer, w_{ij}							Weights from hidden to output layer, v_j	
Input - > Hidden Node No. (i)	Temp.	Boiling Point	Dipole Moment	Acentric Factor	Density	Bias	Hidden Node No. (j)	Viscosity
1	-1.71	-1.00	0.71	0.17	1.25	-1.21	1	-1.45
2	-3.72	0.96	1.70	-1.64	3.27	-0.78	2	2.74
3	-0.88	0.18	1.36	-2.92	3.13	-0.32	3	-2.75
4	1.77	0.16	0.00	-1.17	-0.81	1.27	4	-2.45
5	5.71	-1.42	-1.00	-1.97	-3.49	4.03	5	-1.69
6	-1.17	-3.03	-0.70	4.40	4.27	0.80	6	-1.33
7	0.01	-0.04	2.37	-2.46	-1.22	-2.49	7	-2.15
8	0.82	-2.53	2.38	-3.82	-4.40	0.88	8	-1.31
9	1.57	-2.02	0.01	-0.06	0.12	-0.69	9	-1.46
10	-1.67	-1.57	-0.39	-1.98	-1.62	1.16	10	-0.88
11	-1.97	-2.84	1.01	-0.67	0.63	1.11	11	-1.26
12	0.39	-1.58	0.46	-0.72	1.69	1.39	12	2.53
13	-1.40	-0.78	1.18	0.08	1.39	-0.97	13	-1.56
14	-0.67	0.38	0.34	1.90	4.15	0.71	14	-2.54
15	0.49	-0.93	0.68	-0.01	1.90	0.46	15	0.67
16	-0.83	0.81	0.20	-2.00	-0.36	0.87	16	1.13
17	1.23	0.05	0.37	-0.06	0.48	-0.50	17	-1.21
18	-0.90	0.18	0.61	-1.57	0.15	0.12	18	2.19
19	0.24	1.25	-6.97	1.81	2.43	0.18	19	-1.89
							Bias	2.88

4.3.2.7 Dedicated Equations for Selected Substances and Groups of Substances

4.3.2.7a Ammonia, Hydrogen and Water

Jossi *et al.*⁹⁰ in their attempt to develop generalized relations for dense gas and liquid phases of pure substances found that ammonia, hydrogen and water do not conform to the generalized pattern viscosity behavior of other substances and proposed the following dedicated equations for these substances.

Ammonia:

$$\left[(\eta - \eta^*) \xi + 10^{-4} \right]^{0.25} = 0.1067 + 0.022655 \rho_R + 0.034749 \rho_R^2 + 0.032153 \rho_R^3 + 0.0089998 \rho_R^4 \quad (4.259)$$

Hydrogen:

$$\left[(\eta - \eta^*) \xi + 10^{-4} \right]^{0.25} = 0.10616 - 0.042426 \rho_R + 0.17553 \rho_R^2 + 0.12295 \rho_R^3 + 0.028149 \rho_R^4 \quad (4.260)$$

Water:

$$\left[(\eta - \eta^*) \xi + 10^{-4} \right]^{0.25} = 0.10721 - 0.040646 \rho_R + 0.0026282 \rho_R^2 + 0.005443 \rho_R^3 + 0.0017979 \rho_R^4 \quad (4.261)$$

where η and η^* are the viscosities in cP at the conditions of interest (temperature in Kelvins and pressure in atmospheres) and at the same temperature and normal pressure of 1 atmosphere, respectively, ξ is the viscosity parameter $[=T_C^{(1/6)}/M^{(1/2)}P_C^{(2/3)}]$, $\rho_R [= (\rho/\rho_C)]$ is the reduced density, and ρ_C is the density at the critical point in g/cm³.

4.3.2.7b Liquid Hydrocarbons

Abbott and Kaufman¹⁰³ proposed the following generalized form for the kinematic viscosity of liquid *n*-alkanes.

$$\ln \nu_R = \ln \left(\frac{\nu}{\nu_C} \right) = A(\rho_R - 1) + B(\rho_R - 1)^{7/2} + \sum_{j=1}^5 C_j \left[\exp(\rho_R - 1)^{j+1} - 1 \right] \quad (4.262)$$

and established the following set of coefficients for n-alkanes

$$A = 0.51593\omega - 0.14696\omega^2 \quad (4.263)$$

$$B = 6.31284 \times 10^{-2} + 9.5999 \times 10^{-2} \omega \quad (4.264)$$

$$C_1 = 0.15976 \quad (4.265)$$

$$C_2 = 0.0 \quad (4.266)$$

$$C_3 = 2.60128 \times 10^{-3} \quad (4.267)$$

$$C_4 = 5.09402 \times 10^{-4} - 1.16879 \times 10^{-3} \omega + 6.19878 \times 10^{-4} \omega^2 \quad (4.268)$$

$$C_5 = 0.0 \quad (4.269)$$

The input data required for applying the method are: the critical properties (T_C and P_C), the normal boiling temperature (T_B), the acentric factor (ω) and the molecular mass (M) of the hydrocarbon of interest. The method gives an average absolute deviation of 2.7% for C_1 to C_{12} hydrocarbons at 522 data points that were used for comparison and can be considered a good estimation method for n-alkanes.

Dutt¹⁰⁴ proposed that the three constant equation for viscosity similar in form to the Antoine equation for vapor pressure can be applied successfully to hydrocarbons and correlated the constants of the equation to the normal boiling point for each homologous series. The equation proposed for the kinematic viscosity, ν , in cSt as a function of the temperature (t) in °C is

$$\ln \nu = A + \frac{(m + nt_B)}{(t + 239 - 0.19t_B)} \quad (4.270)$$

where t_B is the normal boiling point in °C. The values of A , m and n for the homologous series of hydrocarbons studied are given in Table 4.50.

Table 4.50. Constants to be used in Eq. (4.268) for the estimation of the kinematic viscosity (ν) in centi stokes from the temperature (t) in °C for different classes of hydrocarbons.

S.No.	Series	A	m	N
1	Alkanes(normal) C ₂ to C ₂₀	- 2.873	416.43	1.6139
2	Mono-Olefins(normal) C ₂ to C ₂₀	- 2.927	396.67	1.6977
3	Alkylcyclohexanes(normal) C ₆ to C ₂₂	- 3.252	372.62	2.1821
4	Alkanes(normal) C ₁ to C ₅	- 2.7315	404.06	1.5183
5	Alkylbenzenes(normal) C ₁ to C ₈	- 3.0967	593.71	0.5802
6	Cyclopentanes(normal) C ₅ to C ₂₁	- 2.8558	497.96	1.4250
7	Alkylbenzenes(normal) C ₆ to C ₂₂	- 3.1779	548.24	1.3072

The method gives results with an overall average absolute deviation of about 6% and can be considered as a dependable estimation method for viscosity of liquid hydrocarbons.

Allan and Teja¹⁰⁵ proposed a method based on the effective carbon number for the correlation and prediction of the viscosity of liquid hydrocarbons. Viscosity is expressed as:

$$\ln \eta = A \left[-\frac{1}{B} + \frac{1}{T + C} \right] \quad (4.271)$$

The constants A , B and C for n-alkanes (ethane to eicosane) are related to the number of carbon atoms (n) as:

$$A = 145.73 + 99.01n + 0.83n^2 - 0.125n^3 \quad (4.272)$$

$$B = 30.48 + 34.01n + 1.23n^2 - 0.017n^3 \quad (4.273)$$

$$C = -3.07 - 1.99n \quad (4.274)$$

The average absolute deviation for hydrocarbons is 3% with a maximum deviation of about 10%.

From the knowledge of one liquid viscosity data point, it is possible to extend the methodology to other pure hydrocarbons, through the definition of the effective carbon number (ECN). The known liquid viscosity at one temperature and the constants A , B and C can be used in these equations to arrive at a value for ECN which can subsequently be used to determine liquid viscosity at the other temperatures. As the expressions can give three roots for n (ECN), it is recommended that the root giving the value closest to the actual number of carbon atoms be chosen as the correct value. By testing well over 50 hydrocarbons, the method is found to predict the viscosity to an average absolute deviation of about 2.5%.

Kerps and Druin¹⁰⁶ developed a method for the prediction of the viscosity of liquid hydrocarbons and gave an empirical equation for each of the four series of homologous hydrocarbons studied by them: n-paraffins, n-1-alkenes, n-alkylcyclohexanes and n-alkylbenzenes.

The steps involved in developing the expression for viscosity is discussed below. The viscosity of a monatomic gas from the kinetic theory of gases can be written as:

$$\eta = \frac{1}{3} U \rho \lambda \quad (4.275)$$

where U is the mean molecular speed of the molecules (cm/sec), ρ is the density (g/cc), λ is the mean free path, cm. Adopting a similar approach to liquids with the assumption that the liquid molecules are arranged in a cubic lattice, with center-to-center spacing is given by

$$\Delta = (V / N)^{(1/3)} \quad (4.276)$$

It is assumed that the momentum is transferred from one lattice plane to an adjacent plane at the sonic velocity (V_s) for the liquid. (Similar model for energy transport, with a cubic lattice similar to that of the solid state has been proposed earlier by Bridgman¹⁰⁷ for the thermal conductivity of pure liquids). Bridgman assumed that the energy transfer takes place from plane to plane at the sonic velocity by collisions arising out of molecular vibrations about the equilibrium lattice positions. Bridgman's equation for thermal conductivity can be written as

$$K = 3(N / V)^{(2/3)} k V_s \quad (4.277)$$

where N is the Avogadro number, V is the molar volume (cm³/gmol), k is the Boltzman constant and V_s is the velocity of sound in the fluid.

Momentum transfer takes place by molecules reaching a given plane which have on the average suffered their last collision at a distance ' Δ ' and can be expressed by:

$$\Delta = (2/3)\lambda = (V/N)^{(1/3)} \quad (4.278)$$

Mean molecular speed is given by;

$$U = 2|U_y| \quad (4.279)$$

In the above equation, ' $|U_y|$ ' is the absolute value of the y component of the mean molecular velocity. Similar relations apply to the velocity components in the x and z directions. Combining the above equations and replacing ' $|U_y|$ ' by the sonic velocity results in the following expression for viscosity.

$$\eta = \rho V_s \left(\frac{V}{N} \right)^{(1/8)} \quad (4.280)$$

The velocity of sound in a liquid can be calculated from

$$V_s = (\beta \rho / M)^3 \quad (4.281)$$

β being an empirical factor accounting for structural effects. Substituting the value of β and the other information, the equation for viscosity can be written as

$$\eta = \frac{\rho^{(11/3)} \beta^3}{M^{(8/3)} N^{(1/3)}} \quad (4.282)$$

It can be shown that the ratio of the thermal conductivity (K in calories per second per centimeter per degree K) and viscosity (η in Poise) is given by

$$M(K/\eta) = 6 \quad (4.283)$$

where M is the molecular mass.

The velocity of sound in liquids is generally five to ten times greater than the mean free speed of the molecules. In terms of the intermolecular distances one can write,

$$V_s = V'_s \left(V / NV_f \right)^{(1/3)} \quad (4.284)$$

The mean molecular speed of the liquid molecules, from the speed of sound arguments becomes

$$U_1 = U \left(\frac{V}{NV_f} \right)^{(1/3)} = \left(\frac{8kT}{m\pi} \right)^{(1/2)} \left(\frac{V}{N} \right)^{(1/3)} \quad (4.285)$$

Viscosity of a monoatomic liquid can be written as

$$\eta = 0.5\rho \left(\frac{V}{N} \right)^{(1/3)} \left(\frac{8kT}{m\pi} \right)^{(1/2)} \left(\frac{V}{NV_f} \right)^{(1/3)} \quad (4.286)$$

On eliminating the free volume V_f from the analysis, and writing γ for specific heat ratio, we get

$$V'_s = (\gamma kT / m)^{(1/2)} \quad (4.287)$$

For liquids, γ is nearly unity except near the critical point. The viscosity of the monoatomic liquid can be finally written as:

$$\eta = 0.8\rho (V / N)^{(1/3)} \quad (4.288)$$

This relation is the same as the one derived from the kinetic theory approach, except for the constant appearing 0.8 instead of 1.0 for the kinetic theory approach.

The equation for viscosity derived from the kinetic theory is given by:

$$\eta = \frac{\rho^{(11/3)} \beta^3}{M^{(8/3)} N^{(1/3)}} \quad (4.289)$$

When this equation is used for the calculation of the viscosity of normal paraffins, 1-alkanes, monoalkyl-cyclohexanes and monoalkylbenzenes over the ranges of the temperature of the available experimental data, average deviations ranging from 30 to 40 % have been reported. However, when the individual point deviations ($Z = \eta/\eta_R$) are plotted against the reduced temperatures with respect to the normal boiling point ($T_{RB} = T/T_B$) on log - log coordinates, it has been noticed that the predicted viscosities for each homologous series differed from the experimental values in a regular manner. For each series, a family of curves, parametric in the number of carbon atoms, may be drawn through the Z points. The Z function approaches a limiting value at about 20 carbon atoms.

For each series of homologous series, the parametric curves, may be approximated by a single line of best fit having the form;

$$Z = \exp \left[a + b \ln(T_{RB}) + c \{ \ln(T_{RB}) \}^2 \right] \quad (4.290)$$

The coefficients of the equation for the homologous series of hydrocarbons are given in Table 4.51.

Table 4.51. The coefficients to be used in Eq. (4.290) for different series of hydrocarbons.

Series	A	B	C
n-Paraffins, C ₅ to C ₂₀	0.323	0.239	- 3.56
n-1-Alkanes, C ₅ to C ₂₀	0.552	0.405	- 3.88
Mono-n-alkylcyclohexanes, C ₈ to C ₂₂	0.337	0.842	- 3.20
Mono-n-alkylbenzenes, C ₇ to C ₂₂	0.442	- 0.270	- 4.60

Incorporating the above correction factor, the equation for viscosity becomes

$$\eta = \rho^{(11/3)} \beta^3 / \{ M^{(8/3)} N^{(1/3)} Z \} \quad (4.291)$$

which generally predicts viscosities with average errors of about 5 to 10%.

The constants of the equation for Z have been further improved through the introduction of another variable, the number of carbon atoms (N equal to the total number of carbon atoms in the case of n-Paraffins and n-1-Alkenes and number of carbon atoms in the alkyl side chain in the case of mono-n-alkylcyclohexanes and mono-n-alkylbenzenes). The variables, a , b , and c of the equation for Z are expressed as follows:

$$a = a_1 + a_2N + a_3N^2 \quad (4.292)$$

$$b = b_1 + b_2N + b_3N^2 \quad (4.293)$$

$$c = c_1 + c_2N + c_3N^2 \quad (4.294)$$

The coefficients for different series studied are noted in Table 4.52.

Table 4.52. Coefficients to be used in Eqs. (4.292)-(4.294) for different Series of hydrocarbons.

Series	<i>n</i> -Paraffins	<i>n</i> -1-Alkenes	Mono- <i>n</i> -alkyl cyclohexanes	Mono- <i>n</i> - alkylbenzenes
a ₁	0.496	1.01	0.573	1.32
a ₂	- 0.0147	- 0.0642	- 0.141	- 0.240
a ₃	0.0	0.0	0.0	0.0103
b ₁	- 0.279	1.94	2.00	3.76
b ₂	0.0978	- 0.213	- 0.705	- 1.08
b ₃	- 0.00498	0.0	0.0406	0.0472
c ₁	- 3.15	0.950	- 2.26	- 0.0534
c ₂	- 0.0573	- 0.634	- 0.810	- 1.22
c ₃	0.0	0.0144	0.0449	0.0564

The improvement resulted in the prediction of viscosities of the hydrocarbons with average absolute deviations ranging from 1.5 to 5%.

Orbey and Sandler¹⁰⁸ presented empirical models for calculating the viscosity of hydrocarbons over wide ranges of temperature and pressure, choosing propane as the reference fluid. The viscosity of saturated liquid propane at atmospheric pressure is represented as:

$$\ln \eta_R = \ln(\eta / \eta_{ref}) = -1.6866 + 1.4010(T_B / T) + 0.2406(T_B / T)^2 \quad (4.295)$$

The reduced viscosity of the other hydrocarbons can be written as:

$$\ln(\eta / \eta_{ref}) = k \ln \eta_R \quad (4.296)$$

where k is a parameter, specific to each compound.

The parameter k is related to the normal boiling temperature (T_B) by the form :

$$k = 0.143 + 0.00463T_B - 0.00000405T_B^2 \quad (4.297)$$

On setting $\mu_{ref} = 0.225$ mPa.s, the methodology becomes totally predictive for pure hydrocarbons and found to give an average absolute deviation of less than 3%. The effect of pressure could be well represented by:

$$\left[\eta(P) / \eta(P^{sat}) = \exp \left[m \cdot (P - P^{sat}) \right] \right] \approx m \cdot P \quad (4.298)$$

where $m = 0.98 \times 10^{-5} \text{ (kPa)}^{-1}$.

Monnery *et al.*⁶⁷ described and discussed the evaluation and application of shape factors in the potential parameter based corresponding state method of Ely and Hanley for the prediction of the viscosities of liquid hydrocarbons. This approach is described in detail in Section 4.3.2.5d. Using the methodology discussed, the viscosities of the hydrocarbons could be generally predicted with an average absolute deviation of less than 5%.

4.3.2.7c Liquid Halogenated Hydrocarbons

Hovrath¹⁰⁹ presented correlations for the viscosities of liquid halogenated hydrocarbons from their normal boiling points (capable of predicting within 5 to 10 % of their true values) for applications in engineering design calculations. Table 4.53 gives the normal boiling points and the viscosities of several halogenated hydrocarbons at their normal boiling temperature.

Table 4.53. Normal boiling points and viscosity at the normal boiling point for several halogenated hydrocarbons.

No.	Name	Formula	Boiling Point, °C	Viscosity at the Normal Boiling Point, cP
1	Fluoromethane	CH ₃ F	- 78.4	0.28
2	Difluoromethane	CH ₂ F ₂	- 51.6	0.38
3	Trifluoromethane	CHF ₃	- 82.0	0.38
4	Tetrafluoromethane	CF ₄	- 128.0	0.39
5	Chloromethane	CH ₃ Cl	- 24.22	0.32
6	Dichloromethane	CH ₂ Cl ₂	40.7	0.38
7	Trichloromethane	CHCl ₃	61.3	0.38
8	Tetrachloromethane	CCl ₄	76.5	0.48
9	Chlorofluoromethane	CH ₂ ClF	- 9.1	0.37
10	Dichlorofluoromethane	CHCl ₂ F	8.9	0.38
11	Chlorodifluoromethane	CHClF ₂	- 40.8	0.37
12	Chlorotrifluoromethane	CClF ₃	- 82.0	0.39
13	Dichlorodifluoromethane	CCl ₂ F ₂	- 29.5	0.38

No.	Name	Formula	Boiling Point, °C	Viscosity at the Normal Boiling Point, cP
14	Trichlorofluoromethane	CCl ₃ F	24.0	0.38
15	Fluoromethane	CH ₃ F	- 78.4	0.28
16	Fluoroethane	C ₂ H ₅ F	- 37.7	0.25
17	Fluoro-n-propane	C ₃ H ₇ F	2.5	0.24
18	Fluoro-n-butane	C ₄ H ₉ F	32.5	0.24
19	Fluoro-n-pentane	C ₅ H ₁₁ F	62.8	0.24
20	Fluoro-n-hexane	C ₆ H ₁₃ F	91.5	0.24
21	Fluoro-n-heptane	C ₇ H ₁₅ F	117.9	0.25
22	Fluoro-n-octane	C ₈ H ₁₇ F	142.5	0.24
23	Fluoro-n-nonane	C ₉ H ₁₉ F	166.0	0.24
24	Fluoro-n-decane	C ₁₀ H ₂₁ F	186.2	0.24
25	Chloromethane	CH ₃ Cl	- 24.22	0.32
26	Chloroethane	C ₂ H ₅ Cl	12.27	0.29
27	Chloro-n-propane	C ₃ H ₇ Cl	46.6	0.28
28	Chloro-n-butane	C ₄ H ₉ Cl	78.44	0.28
29	Chloro-n-pentane	C ₅ H ₁₁ Cl	107.8	0.28
30	Chloro-n-hexane	C ₆ H ₁₃ Cl	134.5	0.27
31	Chloro-n-heptane	C ₇ H ₁₅ Cl	159.0	0.29
32	Chloro-n-octane	C ₈ H ₁₇ Cl	182.0	0.28
33	Chloro-n-nonane	C ₉ H ₁₉ Cl	203.4	0.28
34	Chloro-n-decane	C ₁₀ H ₂₁ Cl	223.4	0.28
35	Bromomethane	CH ₃ Br	3.56	0.37
36	Bromoethane	C ₂ H ₅ Br	38.4	0.33
37	Bromo-n-propane	C ₃ H ₈ Br	71.0	0.33
38	Bromo-n-butane	C ₄ H ₉ Br	101.6	0.33
39	Bromo-n-pentane	C ₅ H ₁₁ Br	129.6	0.32
40	Bromo-n-hexane	C ₆ H ₁₃ Br	155.3	0.32
41	Bromo-n-heptane	C ₇ H ₁₅ Br	178.9	0.33
42	Bromo-n-octane	C ₈ H ₁₇ Br	200.8	0.33
43	Bromo-n-nonane	C ₉ H ₁₉ Br	221.0	0.33
44	Bromo-n-decane	C ₁₀ H ₂₁ Br	240.6	0.33
45	Iodomethane	CH ₃ I	42.4	0.40
46	Iodoethane	C ₂ H ₅ I	72.3	0.37
47	Iodo-n-propane	C ₃ H ₇ I	102.45	0.37
48	Iodo-n-butane	C ₄ H ₉ I	130.53	0.37
49	Iodo-n-pentane	C ₅ H ₁₁ I	157.0	0.37
50	Iodo-n-hexane	C ₆ H ₁₃ I	181.33	0.37
51	Iodo-n-heptane	C ₇ H ₁₅ I	204.0	0.36
52	Iodo-n-octane	C ₈ H ₁₇ I	225.5	0.37
53	Iodo-n-nonane	C ₉ H ₁₉ I	246.0	0.39
54	Iodo-n-decane	C ₁₀ H ₂₁ I	265.0	0.37

Viscosity (η) at any other temperature (T) can be estimated from the normal boiling temperature (T_B) and the viscosity at the normal boiling point (η_B) from the equation:

$$\eta = \eta_B (T / T_B)^n \quad (4.299)$$

where the constant n needs to be determined from the known viscosity-temperature data of the particular substance.

4.3.2.7d Isomeric Substituted Benzenes

Thomas *et al.*¹¹⁰ presented a systematic study on the temperature dependence of viscosity and of isomeric substituted benzenes and found that abnormal increase in viscosity is not necessarily because of proximity to the freezing point. Disk shaped condensed ring aromatics are found to behave as normal fluids, in contrast, compounds containing 'crowned' benzene rings linked through flexible bonds appearing associated in the liquid state, also produce abnormal increase in viscosity. Experimental data on several substances has been presented and discussed.

Viscosity of a liquid can be represented in the form

$$\log \left[\eta V^{(1/2)} \right] = \alpha + (\beta / T^\theta) \quad (4.300)$$

where V is the specific volume and α , β and θ are constants. In terms of the same parameter θ , vapor pressure P of the liquid as a function of the temperature T can be written as

$$\log P = \log \psi - (I / T^\theta) \quad (4.301)$$

Ψ is a universal constant ($= 1.9 \times 10^6$ mm) and I is a constant characteristic of each substance.

Differentiating Eq. (4.301) and introducing the thermodynamic relation, vapor pressure P can be eliminated.

$$L = RT^2 \left[\frac{d(\ln P)}{dT} \right], \text{ and} \quad (4.302)$$

$$L = 2.303 RI\theta / T^{(\theta-1)} \quad (4.303)$$

At any chosen pressure, θ is equal to the molar entropy of vaporization ΔS multiplied by a numerical constant, having the same value for all the non-

associated liquids. For example, at 100 mmHg where the vapor can be assumed to behave ideally, one can write;

$$\theta = 0.05110 \Delta S \quad (4.304)$$

When the vapor pressure data are not available, ΔS can readily be estimated from an aspherical factor A (which has additive properties) and the number of flexible bonds (n) appearing in the molecule.

Thomas¹¹¹ presented a detailed discussion of the method of calculation of ΔS from from aspherical factor A and the number of flexible bonds (n). A summary of the method of estimating ΔS for different classes of compounds is presented here.

For a Variety of Non-Associating Substances:

$$\Delta S = \frac{Z}{(0.03675Z + 0.0905)} \quad (4.305)$$

In this equation, Z represents the molecular number (equal to the sum of the atomic numbers) Equation 4.305 predicts the molar entropy of boiling at 100 mmHg (ΔS) of 41 compounds, including: SiH_4 , eight tetrahalides, five tetramethyls, four hexafluorides, six tetrahalides of N, P and B, three mixed perhalides of methane, C_2Me_6 , C_2F_6 , four phosphoryl and triphosphoryl halides, and low molecular weight diatomic gases like: oxygen, nitrogen, carbonmonoxide and fluorine (all of which have ΔS values in the range of 23 to 27) with an average absolute deviation of 0.8%.

For Inert Gases:

$$\Delta S = Z / (0.03675Z + 0.150) \quad (4.306)$$

can be applied to determine ΔS at 100 mmHg for argon, krypton, and xenon with good accuracy.

For Non-globular Inflexible Molecules:

$$\Delta S = Z / (0.03675Z + 0.0905 - A) \quad (4.307)$$

A is the Aspherical factor and can be used to calculate ΔS at 100 mmHg with good accuracy.

For Flexible Molecules:

$$\Delta S = \left[Z / (0.03675Z + 0.150) \right] + 0.26n \quad (4.308)$$

where n is the number of flexible bonds. Table 4.54 provides the value of group contributions to A .

Additionally,

For paraffins the Me_3C group reduces n by 0.5 unit, and the CMe_2 reduces n by 0.5 unit on each side of the chain, except when attached to another such group, when no reduction should be applied to the $\text{Me}_2\text{C}-\text{CMe}_2$ bond.

For compounds like $\text{CH}_3-\text{CH}_2-\text{CH}_2-\text{CH}_2-\text{CH}_3$, it is expected that the conformation corresponds to a stretching-out of the molecule in two planes at right angles and the value of $n = 3$ is recommended to be used.

For homologues containing methyl groups, the n values are to be calculated by adding 1 for each methyl group.

For ethyl and methoxy- derivatives, each group increases n by 1.5 units instead of 1.

The methodology described provides the values of ΔS in good agreement with the observed data as shown in Table 4.55.

The limitations of the method have also been described in detail by Thomas¹¹¹.

Table 4.54. Aspherical factors for different groups for the application of group contribution method to calculate *A*.

Group	Location	<i>A</i>
CH ₃	Inflexible molecule in which the atoms, other than hydrogen, are arranged in non-branching sequence like in ethane, propane, methyl and ethyl halides and cyanides, dimethyl ether, acetaldehyde, propene, but-2-ene, methyl acetylene	0.015
CH ₃	Other cases like flexible molecules and branched molecules like isobutane, CH ₂ :CMe ₂ , nitromethane, where the CH ₃ does not lead to lengthening of the molecule	0
CH ₂	Inflexible molecules	0
CH ₂	Flexible molecules	0.004
H	In hydrohalides, HCN, H ₂ S, in the SH group of CH ₂ SH, C ₂ H ₅ SH, HCH= group of ethene, propene, allene, vinyl chloride, etc.	0.015
H	For branched compounds like CH ₂ :CCl ₂	0
CH ₂	In the ring	0
Three Membered Ring		0.045
Four Membered Ring		0.036
Five Membered Ring		0.036
Six Membered Ring		0.030
Seven Membered Ring		0.050
Eight Membered Ring		0.050
Halogen Atom		0
Benzene Ring	Perfluorohydrocarbon	0.087
o-,m-,p- distributed benzenes		0
Aromatic Double Bond		0.019
Double Bond in Alkanes, Dienes, Acetylenes		0
Double Bonds in Conjugated dienes, allenes, cycloalkanes		0.019
Carbon-Carbon Triple Bond		0.050

<i>Group</i>	<i>Location</i>	<i>A</i>
Fluorine		0.050
Chlorine		0.045
Bromine		0.040
Iodine		0.040
Fluorine	Attached to Benzene or Ethylene Molecule	0.022
Chlorine	Attached to Benzene or Ethylene Molecule	0.032
-S-		0.040
-O-		0.040
-S-S-		0.050
-CO-		0.090
-CN		0.080
-NO ₂		0.120
-O-NO ₂		0.125
>B-		0.015
>N-		0.030
-N≡	In nitrogen Aromatics	0.060

Table 4.55. Prediction capabilities of the group contribution method proposed by Thomas¹¹¹ for the estimation of ΔS at 100 mmHg for different classes of compounds.

<i>Compound Class or Type</i>	<i>No. of Compounds</i>	<i>% Average Absolute Deviation</i>
Set of Compounds containing substances like SiH ₄ , tetrahalides, tetraethyls, hexafluorides, tetrahalides of N, P, B, mixed perhalides of methane, C ₂ Me ₆ , C ₃ F ₆ , phosphoryl and thiophosphoryl halides, lower diatomic gases	41	0.8
n-Paraffins from Ethane	19	0.3
Branched chain Paraffins	70	0.4
Cycloalkanes with 3,4,5,6,7 & 8-membered rings	40	0.4
Alkylbenzenes	37	0.3
Polycyclic aromatic hydrocarbons	9	0.7
Alkenes	46	0.5
Cyclopentenes & Cyclohexenes	12	0.7
Dienes & Allenes	12	0.7
Alkyl halides, HCl, HBr and HI	30	0.6
Saturated Aliphatic Poly halides	17	0.8
Halogenobenzenes	19	0.5
Vinyl type halides	8	0.3
Alkane thiols, Alkyl sulfides, Thia cyclopentanes, Cyclobutanes	40	0.4
Disulfides	7	0.3
Aliphatic ethers, Acetals, Tetrahydrofuran, Dioxan	15	0.9
Aliphatic Esters	17	0.5
Aliphatic aldehydes & Ketones	11	0.3
Cyanides including C ₂ N ₂ , HCH and Vinyl type compounds	14	0.5
Nitrates	5	0.3
Nitro compounds	9	0.3
Alkylborates, Alkyl borines & Alkoxychloroborines	12	0.6
Tertiary amines & Tetramethylhydrazine	4	0.7
Silicon compounds	26	1.5
Furan, Thiophene, 2- and 3- Methylthiophene	4	0.6
Pyridine compounds	8	0.3
Vinylbenzenes, Aromatics containing CN, CO, NO ₂ , etc,	50	1.0

Combining Eqs. (4.300) and (4.301) one can write:

$$-\left[\frac{d \log \left(\eta V^{(1/2)} \right)}{d \log P} \right] = (\beta / I) = \alpha \quad (4.309)$$

The parameter α (the ratio of the activation energy for viscous flow to the energy of vaporization) is equal to 0.220 for all non-associated liquids. Associated liquids have larger values of α due to additional contributions to

ΔS arising out of the rupture of intermolecular complexes on vaporization, as described in the foregoing paragraphs. The parameters of the equations for viscosity and vapor pressure, Eqs. (4.300) and (4.301), as well as some physical properties of selected substances are given in Table 4.56.

Entries of Table 4.56 indicate that the criteria of both entropies of vaporization, and the ratios of energy of viscous flow to energy of vaporization, lead to the conclusion that condensed ring compounds and compounds with open benzene rings behave as normal fluids when the temperature approaches the freezing point.

The bottom part of Table 4.56 presents the behavior of eight polyphenyl compounds in which the benzene rings are in crowned positions. With the single exception of o-terphenyl, vapor pressures have been measured at temperatures far removed from those of the viscosity measurements. ' β ' being a variable for such materials (increasing rapidly with falling temperature), evaluation of α in the manner similar to non-associated materials is not correct. The value of α quoted for o-terphenyl in the table has been obtained by numerical differentiation of the $\log [\eta V^{(1/2)}]$ versus $\log P$ data. Its value is 0.5 at 90°C and about 0.6 at 80°C, considerably larger than the normal value of 0.22 for non-associated liquids. Therefore it can be concluded that o-terphenyl is associated in the liquid state. The degree of association for associated compounds can be written as:

$$\gamma = \frac{\beta' T^{(\theta-1)}}{0.220 L \theta'} \quad (4.310)$$

where β' refers to the hypothetical monomer. Degrees of association for some associating compounds as a function of temperature are given in Table 4.57.

In view of the non-availability of the data on such typical compounds, the measured values of the kinematic viscosity reported by Thomas *et al.*¹¹⁰ are given in Table 4.58.

Marked difference in the behavior has to be noticed for the case of closely related isomeric compounds with similar boiling temperatures but significantly different melting points, if proximity to the melting point has any effect on the viscosity of liquid. *Ortho*-, *meta*-, and *para*-substituted benzenes are examples of such a set. The *para*-isomer generally possesses the highest melting point. Table 4.59 summarizes the information for eight sets of such isomers, whose data are represented with an overall average absolute deviation of about 1.5%.

Table 4.56. Parameters for use in Eqs. (4.300) and (4.301) and some important physical properties of isomeric substituted benzenes.

Compound	Boiling Point, °C	Freezing Point, °C	Aspherical Factor	Flexible Bonds	θ Calc. from A & n	θ Calc. from Vapor Pressure	I	-a	B	A
Diphenyl	256	70	0.174	1	1.44	1.4555	31257.4	0.3792	6914	0.22
Diphenyl ether	259	27	0.214	2	1.47	1.4673	33965.8	0.5882	9391.9	0.28
Diphenyl methane	266	26	0.178	2	1.45	1.4576	32543.4	0.2850	7190.9	0.22
Naphthalene	218	80	0.155	0	1.43	1.4228	22914.9	-	-	-
Triphenylene	432	199	0.291	0	1.46	-	-	0.3498	11799	0.24
Acenaphthene	278	93	0.191	0	1.44	1.4310	28459.0	0.3803	7313	0.26
Fluorene	298	114	0.291	0	1.44	1.4410	31865.6	0.2536	7045.3	0.22
Anthracene	340	216	0.223	0	1.44	1.4317	33411.0	-	-	0.26
Phenanthrene	339	100	0.223	0	1.44	1.4269	32198.1	0.2599	7246.5	0.27
Fluoranthene	379	110	0.278	0	1.46	1.4339	38297.0	0.3090	9837.4	0.20
Pyrene	395	150	0.272	0	1.46	1.4552	43686.7	0.4874	11557	-
Triphenyl phosphate	414	50	0.590	6	1.59	-	-	0.4831	22445	-
Triphenyl Amine	127	80	0.291	3	1.49	1.4755	47232.2	-	-	-
Triphenyl	80	80	0.291	3	1.49	1.4725	48752.4	-	-	-
Phosphine										
Triphenyl	61	61	0.291	3	1.48	1.5483	78991.7	-	-	-
Arsine										
Triphenyl	55	55	0.291	3	1.48	1.6000	-	-	-	-
Stibine										
Triphenyl methane	93	93	0.291	3	1.48	1.4300	-	-	-	-
Triphenyl tin Chloride	106	106	0.306	3	1.47	-	-	-	-	-
o-Terphenyl	55	55	0.261	2	1.47	1.5333	63521.3	-	-	0.50

Table 4.57. Degree of association of polyphenyl compounds as a function of temperature.

Temp, °C	Tri-phenyl Amine	Tri-phenyl Phosphine	Tri-Phenyl arsine	Tri-phenyl stebine	o-Ter-phenyl	m-Ter-phenyl	Tri-Phenyl methane	Tri-phenyl tin chloride
60			2.03	2.02	3.12			
70			1.83	1.78	2.64			
80			1.69	1.60	2.29			
90		1.60	1.56	1.44	2.06	1.48		
100		1.46	1.46	1.35	1.86	1.36	1.70	
110		1.39	1.35	1.27	1.72	1.27	1.60	
120		1.34	1.27	1.20	1.60	1.19	1.51	1.30
130	1.58	1.28	1.20	1.15	1.52	1.14	1.43	1.23
140	1.47	1.24	1.17	1.09	1.46	1.10	1.38	1.19
150	1.39	1.20	1.10	1.06	1.42		1.33	1.15
160	1.32	1.15		1.03	1.38		1.30	1.12
180	1.25	1.09		1.00	1.32		1.25	1.09
200	1.22				1.26		1.21	1.05
220					1.21			1.03
240					1.17			1.01
260					1.14			

Table 4.58. Measured Values of the kinematic viscosity(ν) in millistokes as a function of temperature(t) in $^{\circ}\text{C}$.

Substance	$t, ^{\circ}\text{C}$	ν , millistokes	Substance	$t, ^{\circ}\text{C}$	ν , millistokes	Substance	$t, ^{\circ}\text{C}$	ν , millistokes
p-Chloro-toluene	2.3	10.73	o-Chloro-toluene	-10.1	15.13	p-Nitro-toluene	52.7	11.90
	7.7	9.93		-0.5	12.77		60.0	10.78
	18.1	8.61					69.1	9.67
m-Dichloro-robenzene	28.2	7.75	o-Dichloro-robenzene	-17.5	21.27	N,N-Dime-thylaniline	79.8	8.56
	-17.5	15.54					3.0	20.19
	-11.8	13.87		-11.9	18.71		9.7	17.74
Diphenyl-methane	-1.0	11.48	Triphenyl-methane	-1.1	15.10	Triphenyl tin chloride	30.4	12.67
	18.1	34.6		103.3	34.6		40.8	10.98
	21.7	31.8					55.2	9.21
	23.8	30.4	Triphenyl-methane				69.7	7.88
	27.7	28.0		108.0	31.2		112.9	26.6
	29.8	26.8		114.2	27.6		120.5	23.2
	34.8	24.2		118.7	25.2		129.8	19.28
	44.5	20.3		128.3	21.4		139.6	17.24
	54.2	17.32		134.8	19.27		150.8	14.78
	66.0	14.62		144.1	16.82		160.5	13.18
	73.9	13.31		150.9	15.28		169.6	11.85
	86.9	11.19		159.7	13.69		179.8	10.65
	95.4	10.25		169.2	12.22		187.1	9.90
	104.0	9.41		184.2	10.40		201.8	8.63
	110.1	8.88		200.0	8.91		209.9	7.99
				219.5	7.56		220.6	7.34
							231.0	6.78

Substance	$t, ^\circ\text{C}$	ν , milliStokes	Substance	$t, ^\circ\text{C}$	ν , milliStokes	Substance	$t, ^\circ\text{C}$	ν , milliStokes
Triphenyl amine	115.3	8.46	Triphenyl phosphine	82.6	66.30	Triphenyl arsine	45.8	255.9
	123.7	7.86						
	129.4	25.70						
	136.0	22.70						
	143.3	20.00						
	150.5	17.89						
	158.3	16.00						
	166.6	14.30						
	175.1	12.77						
	184.2	11.55						
	195.1	10.24						
	203.1	9.44						
Triphenyl stibine	213.4	8.59	Triphenyl stibine	138.8	15.97		140.7	16.78
	54.8	136.1						
	59.6	110.9						
	64.4	89.2						
	69.3	76.0						
	74.4	64.2						
	79.4	54.4						
	84.4	45.7						
	94.5	35.4						
	104.2	28.9						
	114.4	23.8						
	124.9	19.79						

Table 4.59. Parameters of the Equation : $\log \{ \eta V (1/2) \} = \alpha + \beta / T$ [Units : Viscosity (η) in millipoise; Specific Volume(V) in cm^3/g ; Temperature(T) in Kelvin.

Compound	Temperature Range, °C	Melting Point, °C	Θ	- α	B
o-Xylene	- 5 to 130	- 25	1.415	0.2957	3882
m-Xylene	0 to 135	- 47	1.415	0.2546	3332
p-Xylene	15 to 130	13	1.415	0.2902	3509
o-Chlorotoluene	- 10 to 153	- 35	1.430	0.2338	4164
m-Chlorotoluene	0 to 150	- 48	1.430	0.2140	3846
p-Chlorotoluene	2 to 152	7	1.430	0.2453	3993
o-Dichlorobenzene	- 17 to 130	- 18	1.435	0.1683	4404
m-Dichlorobenzene	- 17 to 157	- 25	1.435	0.2053	4150
p-Dichlorobenzene	60 to 160	53	1.435	0.2205	4316
o-Methoxytoluene	15 to 165		1.440	0.3801	5458
m-Methoxytoluene	18 to 167		1.440	0.3496	5145
p-Methoxytoluene	17 to 165		1.440	0.3663	5278
o-Bromotoluene	0 to 100	- 26	1.420	0.2900	5145
m-Bromotoluene	0 to 100	- 40	1.420	0.2140	5278
p-Bromotoluene	30 to 100	28	1.420	0.2096	4450
o-Dimethoxybenzene	53 to 195	21	1.470	0.4608	8211
m-Dimethoxybenzene	40 to 201	- 52	1.470	0.3785	7323
p-Dimethoxybenzene	62 to 200	56	1.470	0.3593	7147
o-Cyanotoluene	20 to 140	- 14	1.450	0.2734	5706
m-Cyanotoluene	20 to 140	- 23	1.450	0.2896	5673
p-Cyanotoluene	30 to 140	29	1.450	0.2639	5641
o-Nitrotoluene	20 to 191	- 4	1.480	0.2470	7073
m-Nitrotoluene	20 to 100	16	1.480	0.2667	7145
p-Nitrotoluene	52 to 216	52	1.480	0.2166	6897
N,N-Dimethylaniline	3 to 189	2	1.430	0.2793	4887
n-Heptadecane	22 to 300	22	1.570	0.2114	14080
n-Octadecane	62 to 300	61	1.725	0.0155	41244

4.3.2.7e Fatty Esters and Vegetable Oils

An Andrade type equation for liquid viscosity (η) as a function of molecular mass (M) and temperature (T in K) was developed by Dutt *et al.*¹¹² and is given below.

$$\ln \left[\eta (M)^{1.5} \right] = -10.97 + (1037/T) \quad (4.311)$$

For fatty esters, the equation predicted values with an average absolute deviation of 9.1% for 28 substances at 95 data points.

Krishnakumari *et al.*¹¹³ developed an equation for calculating viscosity (η , cP) as a function of temperature (T in K) for vegetable oils.

$$\ln \eta = -6.667 + (3189/T) \quad (4.312)$$

The equation provided an average absolute deviation of 13.3% when the data on 43 vegetable oils at 139 data points were tested.

Expressing the constants of Andrade model developed in terms of the cubic functions of the ratio of the iodine value (*IV*) to the saponification value (*SV*), the liquid viscosity of 21 vegetable oils at 85 data points could be represented with an average absolute deviation of 8.8% by the following equation

$$\ln \eta = \left[6.684 - 1.527 \left(\frac{IV}{SV} \right) + 1.146 \left(\frac{IV}{SV} \right)^2 + 1.1942 \left(\frac{IV}{SV} \right)^3 \right] + \left[\frac{3084 + 1302 \left(\frac{IV}{SV} \right) + 1710 \left(\frac{IV}{SV} \right)^2 + 88.59 \left(\frac{IV}{SV} \right)^3}{N} \right] \quad (4.313)$$

4.4 COMPARISON OF SELECTED PREDICTION METHODS

4.4.1 COMPARISON OF PREDICTION CAPABILITIES OF SELECTED METHODS

In this section, ten methods have been selected for comparison of their relative prediction capabilities. These ten methods were selected based on their superior estimation capabilities compared to other methods described in this chapter. A summary of the results of comparison for 100 randomly selected representative compounds is shown in Tables 4.60 and 4.61.

Table 4.60. Summary of comparison of the prediction capabilities of Orrick and Erbar, Prabhakar *et al.*, Przedzicki and Sridhar, Dutt *et al.* and Souders methods.

Substance (No. of Data Points)	Percentage Average Absolute Deviation				
	Orrick and Erbar	Prabhakar <i>et al.</i>	Przedzicki and Sridhar	Dutt <i>et al.</i>	Souders
Acetaldehyde(6)	56.21	154.48	10.61	10.00	30.39
Acetic acid(7)	11.93	42.91	5.73	30.14	35.24
Acetone(7)	40.05	171.77	2.75	5.77	36.11
Acetophenone(6)	6.71	191.89	3.87	2.28	46.67
Allyl alcohol(6)	22.11	50.58	-	11.08	64.37
Amyl alcohol(5)	7.21	63.49	78.62	21.65	12.07
Aniline(7)		30.30	51.98	52.07	19.32
Benzene(6)	22.85	12.56	18.31	15.80	-
n-Butane(8)	18.92	17.84	7.34	7.94	9.30
Butanoic acid(5)	13.34	34.29	16.80	26.77	8.31
1-Butene(6)	20.53	28.16	-	13.85	29.10
n-Butyl alcohol(7)	1.21	59.53	73.48	20.73	10.04
Butyl amine(8)	-	16.94	28.06	35.02	22.07
Butyl benzene(6)	44.37	50.78	35.41	12.45	6.68
Carbontetrachloride(7)	-	18.50	9.53	10.58	59.84
Chlorobenzene(7)	2.12	80.00	3.82	11.24	7.55
Chloroform(6)	-	25.97	9.67	16.63	86.59
m-Cresol(6)	10.49	45.56	63.25	17.44	20.96
o-Cresol(6)	49.20	15.27	32.32	16.58	123.29
Cyclohexane(7)	41.64	35.29	25.24	51.78	2.92
Cyclopentane(5)	321.14	15.81	32.51	32.39	2.63
Decane(6)	2.84	21.30	31.26	1.08	3.48
1,1-Dichloroethane(6)	0.63	68.16	19.76	3.62	2.69
Dichloromethane(6)	27.35	53.84	25.47	14.50	68.88
Diethyl amine(6)	-	6.71	5.64	10.34	7.49
Diethyl carbonate(6)	26.37	13.73	3.25	7.94	15.74
Diethyl ketone(5)	21.43	170.93	8.42	8.20	11.33
Diethyl sulfide(5)	-	75.91	13.88	7.60	-
Dimethyl carbonate(6)	24.20	6.26	28.87	6.49	21.87
N,N-Dimethyl formamide(7)	-	5.28	14.70	9.76	4.59
2,2-Dimethylpropane(6)	18.91	15.28	25.81	37.91	23.41
Dimethylsulfide(6)	-	60.70	7.42	4.20	-
1,4-Dioxane(5)	44.06	41.64	14.95	44.50	88.46
Diphenyl ether(6)	25.37	32.80	24.95	7.56	-
Diphenyl methane(6)	56.77	48.15	25.00	4.75	78.92
Dipropyl amine(5)	-	16.21	20.24	6.81	4.51
Dodecane(5)	3.83	23.09	44.00	4.66	9.52
Ethane(6)	40.13	18.23	11.83	9.77	34.35
Ethanethiol(5)	-	64.61	22.81	0.32	-
Ethyl acetate(7)	43.42	28.05	7.66	7.70	11.46
Ethyl alcohol(6)	16.55	60.38	79.52	25.61	14.55
Ethyl benzene(8)	1.09	38.14	20.73	9.21	2.39

<i>Substance (No. of Data Points)</i>	<i>Percentage Average Absolute Deviation</i>				
	<i>Orrick and Erbar</i>	<i>Prabhakar et al.</i>	<i>Przedzicki and Sridhar</i>	<i>Dutt et al.</i>	<i>Souders</i>
Ethyl bromide(7)	33.55	142.33	17.56	41.47	17.51
Ethylene(6)	-	16.94	15.74	2.49	51.96
Ethylene bromide(7)	21.60	7.65	20.39	14.13	92.42
Ethylene chloride(6)	33.35	34.39	12.12	15.18	24.56
Ethyl ether(5)	3.50	21.49	5.06	8.50	7.22
Ethyl formate(5)	18.17	40.28	10.07	3.85	25.37
Ethyl propionate(5)	55.33	36.05	13.43	3.88	2.24
Formic acid(7)	47.00	64.97	26.66	47.33	52.23
Furan(6)	20.80	6.43	34.13	16.05	24.73
Heptadecane(6)	11.50	38.75	57.96	3.64	21.43
Heptane(7)	4.28	18.66	16.12	3.40	6.93
Hexadecane(6)	3.44	33.13	58.08	2.37	17.27
Hexane(6)	4.22	18.66	5.21	4.93	1.68
1-Hexene(5)	5.75	36.64	5.14	15.68	4.99
1-Hexyne(5)	-	16.98	20.97	5.50	-
Isoamyl alcohol(6)	11.84	61.84	80.69	24.80	7.57
Isobutane(7)	28.79	17.27	27.61	25.32	30.09
Isobutyl acetate(7)	57.05	39.14	39.36	8.92	11.52
Isobutyric acid(5)	28.09	39.65	34.33	23.80	10.79
Isopropyl alcohol(6)	14.67	76.46	81.04	54.07	35.52
Isopropyl amine(5)	-	4.32	24.96	31.00	31.86
Methane(6)	-	26.41	1.99	13.30	24.77
Methyl acetate(6)	26.42	26.61	10.56	4.75	2.89
Methyl alcohol(6)	14.67	76.46	100.00	24.93	43.67
Methyl amine(6)	-	6.08	76.84	23.20	16.92
Methyl-n-amylketone(7)	52.92	242.28	17.30	26.48	36.60
2-Methylbutane(6)	9.11	7.31	17.86	8.64	6.93
2-Methyl-2-butene(6)	5.35	20.38	0.57	13.67	9.19
Methylbutanone(5)	3.67	30.16	19.98	2.59	16.56
Methyl cyclopentane(6)	40.59	10.36	44.02	29.48	23.94
Methyl formate(7)	3.45	28.38	26.36	3.27	26.18
Methyl isobutyrate(6)	12.85	53.08	17.99	1.88	19.14
Methyl propionate(6)	57.99	32.09	11.25	4.17	15.32
Methyl-n-propylketone(5)	13.87	122.89	3.77	1.66	2.01
Niromethane(6)	-	133.71	-	5.36	54.94
Nonane(5)	0.97	19.14	29.40	0.90	0.99
Octane(5)	1.93	17.92	17.07	0.87	1.07
Octadecane(6)	1.71	39.79	63.53	0.47	19.08
Pentadecane(5)	2.67	29.37	56.40	2.56	14.47
Pentane(6)	5.89	15.63	6.74	12.85	35.39
1-Penene(6)	5.19	35.20	5.13	12.92	7.39
Phenol(6)	35.86	44.37	47.59	26.41	52.00
Propane(6)	20.64	20.61	21.60	22.46	49.49
Propionic acid(5)	27.95	28.76	7.01	14.01	9.59
n-Propyl acetate(5)	2.80	28.26	24.15	3.20	4.12

Substance (No. of Data Points)	Percentage Average Absolute Deviation				
	Orrick and Erbar	Prabhakar et al.	Przedzicki and Sridhar	Dutt et al.	Souders
n-Propyl alcohol(5)	8.03	72.50	84.13	39.36	13.82
Propyl formate(6)	10.92	36.33	21.35	6.24	4.75
Pyridine(7)	0.90	48.23	27.97	23.26	7.53
Pyrrole(7)	-	11.72	17.20	37.87	43.36
Quinoline(6)	-	40.18	42.31	19.00	28.32
Teradecane(7)	4.87	23.87	56.56	5.30	14.21
Tetrahydrofuran(5)	28.37	35.28	31.38	17.55	36.87
Toluene(7)	11.81	26.40	19.24	1.69	2.34
Trichlorofluoromethane (7)	-	20.46	16.47	5.58	-
Tridecane(5)	4.32	24.00	49.58	4.69	11.96
Triethyl amine(5)	-	49.06	10.39	11.16	24.62
m-Xylene(7)	0.90	48.23	4.70	19.11	3.97
o-Xylene(7)	3.91	33.49	2.94	1.39	3.34

Table 4.61. Summary of comparisons of the prediction capabilities of Sastri and Rao, Morris, Thomas, van Velzen *et al.* and Dutt *et al.* ANN methods.

Substance (Number of Data Points)	Percentage Average Absolute Deviation				
	Sastri and Rao	Morris	Thomas	van Velzen et al.	ANN Method
Acetaldehyde(6)	9.17	8.36	3.94	-	3.41
Acetic acid(7)	27.84	2.92	45.62	25.81	24.16
Acetone(7)	22.90	38.90	7.93	3.64	26.24
Acetophenone(6)	13.40	11.02	9.50	5.80	13.11
Allyl alcohol(6)	10.87	17.99	43.76	44.75	15.28
Amyl alcohol(6)	21.72	14.27	76.20	7.31	2.79
Aniline(7)	23.95	42.62	-	16.71	5.75
Benzene(6)	7.89	11.55	19.06	21.16	10.24
n-Butane(8)	7.48	5.46	2.05	6.91	13.51
Butanoic acid(5)	17.84	15.88	45.69	3.09	6.82
1-Butene(6)	10.86	10.88	16.28	4.06	11.89
n-Butyl alcohol(7)	33.80	14.11	71.42	2.84	6.63
Butyl amine(8)	15.47	-	-	8.77	24.58
Butyl benzene(6)	18.65	15.00	1.56	3.20	20.87
Carbontetrachloride(7)	4.36	15.52	3.27	4.79	13.64
Chlorobenzene(7)	5.42	19.53	3.54	6.35	14.41
Chloroform(6)	2.60	10.77	18.20	7.19	19.32
m-Cresol(6)	71.85	23.60	4.68	41.79	3.02
o-Cresol(6)	105.94	29.67	54.54	10.04	5.93
Cyclohexane(7)	22.20	21.73	76.99	33.20	16.67
Cyclopentane(5)	8.56	5.99	69.75	32.16	15.60
Decane(6)	7.76	3.58	3.63	3.09	9.79

<i>Substance</i> <i>(Number of Data Points)</i>	<i>Percentage Average Absolute Deviation</i>				
	<i>Sastri and Rao</i>	<i>Morris</i>	<i>Thomas</i>	<i>van Velzen et al.</i>	<i>ANN Method</i>
1,1-Dichloroethane(7)	6.35	12.03	0.39	0.54	12.04
Dichloromethane(6)	1.26	4.15	8.07	11.03	14.39
Diethyl amine(6)	3.03	-	-	8.77	6.87
Diethyl carbonate(6)	19.52	18.66	11.18	39.63	20.59
Diethyl ketone(5)	3.64	17.91	7.32	3.36	16.33
Diethyl sulfide(5)	4.89	-	0.61	-	34.83
Dimethyl carbonate(6)	18.97	23.60	4.68	41.79	11.10
n,n-Dimethyl formamide(7)	11.14	-	-	79.03	17.58
2,2-Dimethylpropane(6)	20.43	34.26	31.72	13.43	22.91
Dimethyl sulfide(6)	7.42	-	1.39	-	24.05
1,4-Dioxane(5)	7.24	34.02	78.94	209.80	14.81
Diphenyl ether(6)	11.55	40.31	20.24	363.99	3.41
Diphenyl methane(6)	42.30	15.07	15.96	25.94	6.16
Dipropyl amine(5)	4.61	-	-	59.31	38.86
Dodecane(5)	13.70	6.68	3.54	1.89	12.30
Ethane(6)	22.09	4.64	31.93	9.39	9.66
Ethanethiol(5)	5.04	-	4.13	-	9.21
Ethyl acetate(7)	7.47	9.53	7.23	10.97	17.51
Ethyl alcohol(6)	15.19	4.93	71.13	52.55	18.00
Ethyl benzene(8)	9.33	3.79	2.78	3.21	10.33
Ethyl bromide(7)	11.14	12.31	9.57	11.36	48.02
Ethylene(6)	9.15	23.86	24.06	41.14	14.18
Ethylene bromide(7)	15.88	15.14	3.51	10.18	6.67
Ethylene chloride(6)	17.13	14.17	10.20	4.03	19.26
Ethyl ether(5)	7.75	18.45	9.65	4.24	8.90
Ethyl formate(5)	5.33	32.65	9.36	1.66	14.42
Ethyl propionate(5)	2.42	12.24	4.14	6.91	9.19
Formic acid(7)	53.58	35.16	60.79	56.31	10.60
Furan(6)	2.76	-	-	1311.18	2.75
Heptadecane(6)	11.90	21.33	13.01	2.57	9.09
Heptane(7)	16.98	4.31	4.84	4.26	17.51
Hexadecane(6)	16.82	28.77	13.64	1.78	6.40
Hexane(6)	6.12	2.91	2.77	3.33	7.34
1-Hexene(6)	5.86	4.43	15.13	7.51	50.48
1-Hexyne(5)	22.05	-	-	-	5.72
Isoamyl alcohol(6)	30.02	23.80	76.04	3.38	7.16
Isobutane(7)	22.14	24.25	17.27	4.90	10.40
Isobutyl acetate(7)	11.37	1.57	14.68	8.57	16.45
Isobutyric acid(5)	13.55	14.52	44.33	10.20	9.40
Isopropyl alcohol(6)	12.60	48.87	82.18	1.65	9.70
Isopropyl amine(5)	9.66	-	-	22.71	21.94
Methane(6)	16.22	23.77	52.00	110.64	7.88
Methyl acetate(6)	10.02	1.63	0.84	3.68	7.09
Methyl alcohol(6)	8.08	90.55	60.97	160.35	23.31
Methyl amine(6)	7.02	-	-	16.66	4.87

<i>Substance</i> <i>(Number of Data Points)</i>	<i>Percentage Average Absolute Deviation</i>				
	<i>Sastri and Rao</i>	<i>Morris</i>	<i>Thomas</i>	<i>van Velzen et al.</i>	<i>ANN Method</i>
Methyl-n-amylketone(7)	22.26	50.30	27.70	20.83	4.29
2-Methyl butane(6)	7.78	7.86	2.57	1.96	16.56
2-Methyl-2-butene(6)	1.11	0.82	11.59	5.28	4.12
Methyl butanoate(6)	6.02	10.37	6.01	0.66	14.97
Methyl cyclopentane(6)	29.36	14.68	72.83	23.11	7.16
Methyl formate(7)	22.60	40.51	4.62	4.49	5.10
Methylisobutyrate(6)	6.36	11.41	5.08	2.13	17.58
Methylpropionate(5)	11.25	8.66	2.16	3.71	2.83
Methyl-n-propylketone(6)	4.63	11.22	1.04	2.46	15.53
Nitromethane(6)	13.40	-	-	1.60	16.77
Nonane(5)	3.45	1.51	2.79	1.03	16.51
Octane(5)	11.14	1.06	28.78	2.79	12.73
Octadecane(6)	18.80	45.74	28.78	2.79	3.52
Pentadecane(5)	16.23	23.38	8.82	2.69	5.76
Pentane(6)	7.78	3.11	7.35	3.56	16.73
1-Pentene(6)	6.97	1.38	14.98	6.40	18.85
Phenol(6)	31.30	30.00	72.18	7.23	16.40
Propane(6)	10.88	18.28	9.34	13.00	9.13
Propionic acid(5)	10.27	21.54	37.89	3.87	7.00
n-Propyl acetate(5)	7.12	2.45	9.16	0.57	12.26
n-Propyl alcohol(5)	15.72	29.75	80.74	4.52	14.54
Propyl formate(6)	14.93	1.44	11.03	7.61	7.67
Pyridine(7)	9.97	-	-	-	9.97
Pyrrole(7)	14.95	-	-	62.74	24.05
Quinoline(6)	50.01			41.52	9.04
Tetradecane(7)	18.00	8.41	3.58	3.17	3.78
Tetrahydrofuran(5)	2.76	5.28	68.70	966.90	17.98
Toluene(7)	6.34	5.34	9.87	10.71	16.96
Trichlorofluoromethane(7)	9.39	4.90	-	86.32	26.88
Tridecane(5)	15.98	10.22	2.00	2.66	5.76
Triethylamine(5)	1.29	-	-	99.52	15.12
m-Xylene(7)	10.58	8.97	4.94	4.91	12.55
o-Xylene(7)	7.87	22.30	9.67	14.81	18.84

4.4.2 INPUT REQUIREMENTS AND OTHER DETAILS OF THE SELECTED PREDICTION METHODS

Table 4.62 summarizes the input data requirements and prediction capabilities of the methods compared in the previous section.

Table 4.62. Details of estimation methods considered for comparison.

<i>Methods</i>	<i>Inputs other than temperature</i>	<i>Eq. No. in text</i>	<i>No. of compounds</i>	<i>Average absolute deviation (%)</i>
Orrick & Erbar	Density at 20°C (ρ_{20}) Molecular weight (M) A & B by Group Contribution	4.95	79	20.13
Prabhakar <i>et al.</i>	Molecular weight (M) Critical Temperature (T_c) Critical Pressure (P_c) Dipole moment (μ) Molar refraction (R_M)	4.157	100	42.91
Przedzicki & Sridhar	Molecular weight (M) Critical Volume (V_c) Critical Temperature (T_c) Critical Pressure (P_c) Freezing point (T_F) Acentric factor (ω) liquid molar volume at T_F (V_{MF})	4.66 to 4.72	97	26.63
Dutt <i>et al.</i>	Boiling point in °C (t_B) Acentric factor (ω) Reference temperature (T^{Ref}) Density at T^{Ref} (ρ^{Ref}) Dipole moment (μ)	4.23 to 4.26	100	14.63
Souders	Molecular weight (M) Density (ρ_L) Viscosity coefficient (I) by Group Contribution	4.82	93	23.69
Sastri & Rao	Vapor pressure at T (P) Viscosity at normal boiling point (η_B) & N by Group Contribution	4.97 to 4.106	100	14.83
Morris	Critical Temperature (T_c) Pseudo critical viscosity (η^+) & b_i by Group Contribution	4.93 & 4.94	84	17.11
Thomas	Density (ρ) Critical Temperature (T_c) Coefficient θ by Group Contribution	4.83	86	23.91
Van Velzen <i>et al.</i>	Temperature at which viscosity becomes one (T_0) & parameter (B) by Group Contribution	4.48 to 4.54	94	46.94
Artificial Neural Networks	Boiling point (T_B) Acentric factor (ω) Density (ρ) Dipole moment (μ)	4.252 to 4.256	100	13.86

From the information presented in Tables 4.61 and 4.62, it is clear that the methodologies for the prediction of liquid viscosity proposed by Dutt (Section 4.3.2.1.2d) and Sastri and Rao (Section 4.3.2.3.1f) and Artificial Neural Networks (Section 4.3.2.6b) provide the best estimates on an overall basis for the 100 substances considered here. The choice among the methods is to be decided on the availability of the required input data mentioned in Table 4.62.

Prabhakar *et al.* method (Section 4.3.2.3.2k), applicable to all the 100 substances, can be considered as a method capable of providing a rough estimate, when the input data required for more precise methods are not available, but those for Prabhakar *et al.* method are either available or can be estimated.

Orrick and Erbar (Section 4.3.2.3.1d), Morris (Section 4.3.2.3.1c) and Thomas (Section 4.3.2.3.1b) methods could be applied to lesser number of compounds: 79, 84 and 86 respectively, due the lack of necessary information, but give good design estimates of liquid viscosity. It is worth noting that the fairly complex group contribution method of van Velzen *et al.* (Section 4.3.2.1.1d) gives results quite similar to the Prabhakar *et al.*

When applied with limitations in mind, the methods proposed by Thomas (Section 4.3.2.3.1b), Souders (Section 4.3.2.3.1a) and Przedzicki and Sridhar (Section 4.3.2.1.2b) can provide reasonable design estimates of liquid viscosity. It should be noted that the choice of the best estimation method has to be based mainly on the availability of dependable values of the required input data.

4.5 SUMMARY

This chapter presented most of the methods available in the literature for the correlation and estimation of liquid viscosity. The initial sections are devoted to the general discussion of the variation of liquid viscosity of organic liquids as a function of pressure at high pressures (noting that the effect of pressure on liquid viscosity is negligible at pressures upto a few atmospheres). A few methods for the estimation of the effect of pressure have also been mentioned.

The major effort is related to the more important aspect (from the industrial point of view) of the variation of liquid viscosity with temperature. The subject matter has been described under two broad sections – correlation and estimation methods. The correlation methods section is sub-divided into two-constant, three-constant and multi-constant equations, which essentially present the information available in the literature about the forms of equations describing the temperature dependence of liquid viscosity and the

coefficients of the different forms of the equations given in the literature. Some of the important generalized forms have also been included in these subsections, while bulk of the effort in the development of generalized methods has been presented under the estimation methods section at appropriate places. The constants (or coefficients) of different equations have also been tabulated to facilitate direct and quick estimation. Some methods have also been included which provide thoughts towards the development of the prediction methods for specific applications.

In the section on estimation methods, the material has been presented under the broad classification of relationships with: physical or molecular properties and generalized relationships based on group contributions, the corresponding states theory, potential parameters, followed by artificial neural net approaches. A mention is also made about dedicated equations developed for selected sets or classes of substances.

Based on the analysis of various methods, the following general remarks are in order.

- (i) The prediction accuracies generally improve with the amount of input data being used.
- (ii) The choice of the best prediction method depends on the amount of reliable input data available.
- (iii) Generalized methods based on group contributions or corresponding states theories are to be used only when no experimental viscosity data are available.
- (iv) If the substance of interest is listed in any of the tables under correlation methods, the information should be used to predict the liquid viscosity in preference to any estimation method in the order of preference indicated by the complexity of the equation suggested and the conditions of interest.

It is suggested that if the coefficients of any correlating equation or under dedicated equations section are available, these methods should be used to get a design estimate of the liquid viscosity. A three constant or multi-constant equation is to be given preference to the simpler two constant equations, if the constants are available.

In the absence of constants of any correlation equation for the substance of interest, an estimation method depending on the availability of physical and molecular properties has to be selected and applied. The type of accuracies mentioned in the original papers are to be expected out of the prediction using any particular method.

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