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Viscosity of liquids: Aliphatic nitriles

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Dr M. Frenkel†	— Thermodynamics Research Center, National Institute of Standards & Technology, Boulder, USA
Dr Sumnesh Gupta†	— Dow Chemical, Midland, USA
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Dr K.N. Marsh†	— University of Canterbury, New Zealand
Mrs K.M. de Reuck	— Imperial College of Science, Technology & Medicine, London, UK
Dr C. Tsonopoulos†	— Independent
Mr J.T.R. Watson	— Independent.

* Emeritus Member.

† Corresponding Member.

The technical work involved in the assessment of the available information and the construction and subsequent development of the Data Item was undertaken (under contract to ESDU) by

Dr J.H. Dymond — The University, Glasgow.

The person with overall responsibility for the work in this subject area is Mr S.J. Pugh, Head of Thermofluids Group.

VISCOSITY OF LIQUIDS: ALIPHATIC NITRILES

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Data Sheets for each of the liquids are given in the following order:-

Formula	Name	Alternative Name(s)
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ALKANENITRILES

1. CH_3CN	Ethanenitrile	Acetonitrile	Cyanomethane	Methyl cyanide	7
2. $\text{CH}_3\text{CH}_2\text{CN}$	Propanenitrile	Propionitrile	Cyanoethane	Ethyl cyanide	9
3. $\text{CH}_3[\text{CH}_2]_2\text{CN}$	Butanenitrile	Butyronitrile	1-Cyanopropane	Propyl cyanide	11
4. $\text{CH}_3[\text{CH}_2]_3\text{CN}$	Pentanenitrile	Valeronitrile	1-Cyanobutane	Butyl cyanide	13
5. $\text{CH}_3[\text{CH}_2]_4\text{CN}$	Hexanenitrile	Capronitrile	1-Cyanopentane	Pentyl cyanide	14
6. $\text{CH}_3[\text{CH}_2]_5\text{CN}$	Heptanenitrile	Enanthonitrile	1-Cyanoheptane	Hexyl cyanide	15
7. $\text{CH}_3[\text{CH}_2]_6\text{CN}$	Octanenitrile	Caprylonitrile	1-Cyanoheptane	Heptyl cyanide	16
8. $\text{CH}_3[\text{CH}_2]_7\text{CN}$	Nonanenitrile	Pelargonitrile	1-Cyanooctane	Octyl cyanide	17
9. $\text{CH}_3[\text{CH}_2]_8\text{CN}$	Decanenitrile	Caprinitrile	1-Cyanononane	Nonyl cyanide	18
10. $\text{CH}_3[\text{CH}_2]_9\text{CN}$	Undecanenitrile		1-Cyanodecane	Decyl cyanide	19
11. $\text{CH}_3[\text{CH}_2]_{10}\text{CN}$	Dodecanenitrile	Laurnitrile	1-Cyanoundecane	Undecyl cyanide	20
12. $\text{CH}_3[\text{CH}_2]_{11}\text{CN}$	Tridecanenitrile		1-Cyanododecane	Dodecyl cyanide	21
13. $\text{CH}_3[\text{CH}_2]_{12}\text{CN}$	Tetradecanenitrile	Myristonitrile	1-Cyanotridecane	Tridecyl cyanide	22

Formula	Name	Alternative Name(s)	
14. $\text{CH}_3[\text{CH}_2]_{13}\text{CN}$	Pentadecanenitrile	1-Cyanotetradecane Tetradecyl cyanide	23
15. $\text{CH}_3[\text{CH}_2]_{14}\text{CN}$	Hexadecanenitrile Palmitonitrile	1-Cyanopentadecane Pentadecyl cyanide	24
16. $\text{CH}_3[\text{CH}_2]_{15}\text{CN}$	Heptadecanenitrile Margaritrile	1-Cyanoheptadecane Heptadecyl cyanide	25
17. $\text{CH}_3[\text{CH}_2]_{16}\text{CN}$	Octadecanenitrile Stearonitrile	1-Cyanoheptadecane Heptadecyl cyanide	26

ALKENENITRILES

18. $\text{H}_2\text{C}=\text{CHCN}$	Propenenitrile	Acrylonitrile	Cyanoethene	Vinyl cyanide	27
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VISCOSITY OF LIQUIDS: ALIPHATIC NITRILES

1. INTRODUCTION

This Item presents values for the viscosity at saturation pressure, in tabular form, for liquid aliphatic nitriles. In general the range covered is from just above the melting temperature to about 0.9 times the critical temperature.

The values given are based on data which are believed to be the most reliable available and have been reviewed and suitably extended. In common with other Items, quantities are expressed in SI units and conversion factors to other units are provided in Section 3.

Section 4 gives the procedure used to obtain the values of viscosity presented and indicates the effect of pressure. Section 5 gives an explanation of the Tables and indicates the uncertainties in the values presented.

Appendix A provides a complete bibliography of data sources for this Item. Data sources for individual compounds are listed on the appropriate Data Sheet.

2. NOTATION AND UNITS

The SI unit of dynamic viscosity is the newton second per square metre (N s/m^2). The values presented in the tables are given in millinewton second per square metre (mN s/m^2), a submultiple which is convenient for the magnitudes considered and which is equal to the c.g.s. centipoise (cP).

A, B	dimensionless constants for each liquid in Equation (4.1)	–
C	constant for each liquid in Equation (4.2)	K
D	constant for each liquid in Equation (4.1)	mN s/m^2
p	pressure	N/m^2 (Pa)
T	kelvin temperature	K
t	Celsius temperature, $T - 273.15$	$^{\circ}\text{C}$
α	constant in Equation (4.3)	m^2/N
η	dynamic viscosity	mN s/m^2 (cP)
θ	dimensionless temperature dependent variable in Equation (4.2)	–

Subscripts

c	denotes value at the critical point
p	denotes value at pressure p
r	denotes reduced quantity, <i>e.g.</i> $T_r = T/T_c$.

3. CONVERSION FACTORS

$$\begin{aligned} 1 \text{ mN s/m}^2 &= 1 \text{ centipoise} \\ &= 145.04 \times 10^{-9} \text{ lbf s/in}^2 \\ &= 101.97 \times 10^{-6} \text{ kgf s/m}^2 \\ &= 10^{-3} \text{ kg/m s} \end{aligned}$$

$$\begin{aligned} 10^5 \text{ Pa} &= 1 \text{ bar} \\ &= 14.5038 \text{ lbf/in}^2 \\ &= 1.0197 \text{ kgf/cm}^2 \\ &= 0.9869 \text{ atm} \\ &= 750.062 \text{ mmHg.} \end{aligned}$$

4. LIQUID VISCOSITY

4.1 Viscosity at Saturation Pressure

The two equations most commonly used to describe variations of viscosity with temperature at saturation pressure are:

$$\ln \eta = A' + \frac{B'}{T},$$

and
$$\ln \eta = A'' + \frac{B''}{T - C''}.$$

Both of these can provide adequate representations of viscosity over limited ranges of temperature but are unsatisfactory over the full range. The first form often produces large deviations near the melting temperature or at higher viscosities, and neither is realistic for near-critical temperatures. Several equations are available which use molar volume as an independent variable but these are limited by the need for accurate volumetric data or an equation of state.

The following equation (Reference 1), which has been used for the present work has been found to give a good representation of the data from the melting temperature to $T_r = 0.9$:

$$\ln \frac{\eta}{D} = A(\theta - 1)^{1/3} + B(\theta - 1)^{4/3}, \quad (4.1)$$

where
$$\theta = \frac{T_c - C}{T - C}. \quad (4.2)$$

Relatively few reliable data are available at reduced temperatures greater than 0.9; however, the equation form is consistent with observed trends in that region and produces reasonable estimates close to the critical temperature.

Preliminary values for the constants A , B , C and D were derived from least square percentage deviation fits to the data sets which were considered to be the most accurate. It was found that satisfactory fits could be obtained with C set to $T_c/8$ and with A taken as constant and equal to 2.. The constant C , which has the dimensions of temperature is much lower in value than the melting temperature. Revised values for B and D were then obtained by fitting Equation (4.1) to viscosity data for individual compounds. The constant D is in effect a pseudo-critical viscosity, which is produced by the equation at the critical point. Values for A , B , C and D are given in Table 7.1 and the critical temperatures for these substances have been taken from ESDU 80001 (Reference 2) or estimated from correlations of ESDU values with chemical

structure.

In view of the uncertainties in the experimental data, and the deviations between different data sets for certain compounds, it was found that different sets of B and D values gave equally acceptable data fits in some cases. Values for B and D were chosen so as to give a good correlation with corresponding values for other members of each chemical series, whilst maintaining an acceptable fit to the data for the compound under study. In this way a set of viscosity values was produced, which varied consistently within a given chemical series.

4.2 Effect of Pressure

No accurate general expression is available for estimating the effect of pressure on the viscosity of these liquids. However, the simple expression given for n -alkanes in ESDU 79027 (Reference 1) applies to these liquids under similar conditions and is reproduced here as an approximate guide.

The viscosity of liquids with high viscosity at saturation pressure increases more rapidly with pressure than that of liquids with a low viscosity at saturation pressure. In most cases, the viscosity increases by about 1 per cent for a pressure increase of 1 MPa (10 bar). Below the normal boiling point, the difference between values measured at atmospheric pressure and those at saturation is therefore very small.

For liquids from the melting temperature to about $0.75 T_c$, the following relationship may be used as an approximate guide:

$$\ln \frac{\eta_p}{\eta} = \alpha p, \quad (4.3)$$

where η_p is the viscosity at pressure p , η is the viscosity at saturation pressure, and α is a pressure-viscosity coefficient. The average value for α is $1 \times 10^{-8} \text{ m}^2/\text{N}$ for pressures up to 50 MPa. For liquids in general, the higher the viscosity at saturation pressure, the higher the value of α .

5. EXPLANATION OF TABLES

The values of A , B , C and D to be used in Equations (4.1) and (4.2) are given in Table 7.1 together with the critical temperature and the range of applicability.

Values of the viscosity of individual compounds are given on separate sheets at 10 kelvin intervals with temperatures in K and °C. Extrapolated values are indicated in parenthesis. The sources of data used to derive the correlation are listed.

The highest accuracy band of the tabulated values in this Item is given as $\pm 3\%$, which is usually for temperatures close to ambient and for compounds for which there are experimental data. Outside this range, it is recommended that the user allows for larger uncertainties of between $\pm 5\%$ and $\pm 15\%$ as indicated in the Tables. Some fluids have poor thermal stability, coupled with a high critical temperature. Although values have been tabulated for all liquids up to $T_r = 0.9$, many of these liquids will decompose at elevated temperatures. This decomposition is likely to be rapid at temperatures above 300 °C and uncertainties greater than those quoted may occur.

6. REFERENCES

The references given are recommended sources of information supplementary to that in this Item.

1. ESDU Viscosity of liquids: Aliphatic hydrocarbons Part 1. Alkanes. Data Item 79027, ESDU International plc, London, UK, 1979.
2. ESDU Vapour pressures and critical points of liquids: Aliphatic nitrogen compounds. Data Item 80001, ESDU International plc, London, UK, 1980.

7. TABLES

TABLE 7.1 Constants for Equations (4.1) and (4.2)

Compound	T_c	A	B	C	D	Range of Applicability °C
	K					
1. Ethanenitrile	545.35	2.	0.291	68.17	0.0323	-50 to 220
2. Propanenitrile	561.	2.	0.380	70.12	0.0316	-90 to 240
3. Butanenitrile	581.	2.	0.453	72.62	0.0348	-90 to 250
4. Pentanenitrile	604.	2.	0.495	75.50	0.0362	-80 to 270
5. Hexanenitrile	626.	2.	0.534	78.25	0.0374	-70 to 290
6. Heptanenitrile	646.	2.	0.573	80.75	0.0386	-50 to 310
7. Octanenitrile	664.	2.	0.611	83.00	0.0398	-40 to 330
8. Nonanenitrile	681.	2.	0.643	85.12	0.0410	-30 to 350
9. Decanenitrile	697.	2.	0.671	87.12	0.0421	-20 to 360
10. Undecanenitrile	712.	2.	0.693	89.00	0.0431	-10 to 370
11. Dodecanenitrile	726.	2.	0.712	90.75	0.0440	0 to 380
12. Tridecanenitrile	740.	2.	0.729	92.50	0.0448	10 to 390
13. Tetradecanenitrile	752.	2.	0.744	94.00	0.0455	20 to 400
14. Pentadecanenitrile	764.	2.	0.757	95.50	0.0461	20 to 410
15. Hexadecanenitrile	775.	2.	0.767	96.87	0.0466	30 to 420
16. Heptadecanenitrile	785.	2.	0.776	98.13	0.0471	30 to 430
17. Octadecanenitrile	795.	2.	0.784	99.37	0.0476	40 to 440
18. Propenenitrile	540.	2.	0.112	67.50	0.0392	-80 to 220

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CH₃CN ETHANENITRILE (ACETONITRILE, CYANOMETHANE, METHYL CYANIDE)

$$\ln(\eta/D) = A(\theta - 1)^{1/3} + B(\theta - 1)^{4/3}$$

$$\text{where } \theta = (T_c - C)/(T - C)$$

η = viscosity at saturation pressure (mN s/m²)

$$T_c = 545.35 \text{ K}$$

$$A = 2., \quad B = 0.291, \quad C = 68.17, \quad D = 0.0323$$

T K	η mN s/m ²	Uncert. in η %	T K	η mN s/m ²	Uncert. in η %	t °C	η mN s/m ²	Uncert. in η %	t °C	η mN s/m ²	Uncert. in η %
220	(0.951)	10	360	(0.211)	5	-50	(0.898)	10	90	(0.207)	5
230	(0.797)	10	370	(0.197)	5	-40	(0.757)	10	100	(0.193)	5
240	(0.681)	10	380	(0.185)	5	-30	(0.650)	10	110	(0.181)	5
250	(0.591)	10	390	(0.173)	5	-20	(0.567)	10	120	(0.170)	5
260	(0.519)	10	400	(0.163)	5	-10	(0.500)	10	130	(0.159)	5
270	0.461	5	410	(0.153)	5	0	0.445	5	140	(0.150)	5
280	0.413	5	420	(0.144)	5	10	0.400	5	150	(0.141)	5
290	0.373	3	430	(0.135)	10	20	0.362	3	160	(0.132)	10
300	0.339	3	440	(0.127)	10	30	0.330	3	170	(0.124)	10
310	0.310	3	450	(0.119)	10	40	0.302	3	180	(0.117)	10
320	0.285	3	460	(0.112)	10	50	0.278	3	190	(0.110)	10
330	0.263	3	470	(0.105)	10	60	0.257	3	200	(0.103)	10
340	0.244	5	480	(0.098)	10	70	0.238	5	210	(0.096)	10
350	0.227	5	490	(0.091)	10	80	0.222	5	220	(0.089)	10

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