U.S. AIR FORCE Project RAND

PHYSICAL PROPERTIES AND THERMODYNAMIC FUNCTIONS OF FUELS, OXIDIZERS, AND PRODUCTS OF COMBUSTION

I FUELS

CHEMICAL RESEARCH DIVISION STAFF
BATTELLE MEMORIAL INSTITUTE • COLUMBUS, OHIO

January 1949

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I FUELS

INTRODUCTION

This report is one of a series of technical survey reports which have been prepared by Battelle Memorial Institute on a subcontract under Prime Contract No. W33-038 ac-14105, Project RAND, between The RAND Corporation and the United States Air Force.

This collection of the physical and thermodynamic properties of a diverse variety of compounds which may be of interest as rocket or jet fuels was compiled in the course of Battelle's exploratory work for Project RAND. In many instances, the data were not readily obtainable, but were scattered throughout the physical and chemical literature. To make the data available to others working in the rocket or ramjet fields, they are being published as RAND reports.

This is the first volume of three related compendia of physical properties and thermodynamic functions of rocket and ramjet propellant substances. The three volumes are entitled: I, Fuels; II, Oxidizers; and III, Products of Combustion.

The information contained in this report was compiled during the period October 1, 1946, to August 15, 1948.

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CONTENTS

SUMMARY

A compilation of the physical properties and thermodynamic functions of thirty-four chemical elements and compounds which may be of interest as fuels for rocket-propelled vehicles has been prepared. In preparing this compilation, all available sources of information were studied, and it is believed that the data presented herein represent the best available at this time.

All the data pertaining to each fuel have been grouped together and are arranged in the following order:

1. Molecular formula.
2. Molecular weight.
3. Melting or freezing point.
4. Boiling point and/or sublimation temperature.
5. Density (vapor; liquid; solid).
6. Vapor pressure.
7. Triple point.
8. Viscosity (vapor; liquid).
9. Surface tension.
10. Coefficient of thermal expansion.
11. Coefficient of thermal conductivity.
12. Dipole moment.
13. Heat of fusion.
14. Heat of vaporization and/or sublimation.
15. Heat of formation.
16. Heat of combustion.
17. Critical data.
18. Equation of state.
19. Compressibility.
20. Heat capacity of vapor, C_p and C_v.
21. Ratio of specific heats.
22. Heat capacity of liquid and solid.
23. Free energy of formation.
24. Free-energy function.
25. Heat-content function.
26. Entropy.

In some cases there are gaps in the available data. Where this is true, the entry "no information" has been made under the appropriate heading in the data sheets.

For convenience of reference, the sources of the data cited have been included as a part of each data sheet. In addition, a detailed bibliography of all sources consulted, whether the results reported were used or not, is appended to the report. These bibliographies will serve as nuclei for further research on specific compounds and will also indicate the degree of exhaustiveness of search for data made in any given case.

PHYSICAL PROPERTIES AND THERMODYNAMIC FUNCTIONS OF FUELS, OXIDIZERS, AND PRODUCTS OF COMBUSTION

I FUELS

INTRODUCTION

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ACETONE

MOLECULAR FORMULA

CH_3COCH_3; C_3H_6O

MOLECULAR WEIGHT

58.078

Ref. *International Atomic Weights*, 1947.

MELTING POINT

Melting point = −94.6°C

Ref. Guttmann, *J. Am. Chem. Soc.*, Vol.29 (1907), p.347.

BOILING POINT

Boiling point = 56.5°C

Ref. Guttmann, *J. Am. Chem. Soc.*, Vol.29 (1907), p.347.

DENSITY

Vapor and Liquid (in Equilibrium)

Temperature (°C)	Density (gm/cc)	
	Liquid	Vapor
60	0.746	0.003
70	0.734	0.003
80	0.719	0.004
90	0.706	0.005
100	0.693	0.007
110	0.679	0.009
120	0.665	0.011
130	0.650	0.013
140	0.634	0.016
150	0.618	0.020
160	0.601	0.024
170	0.588	0.030
180	0.568	0.039
190	0.540	0.050
200	0.514	0.065

Vapor and Liquid (in Equilibrium) *Cont'd*

Temperature (°C)	Density (gm/cc)	
	Liquid	Vapor
210	0.482	0.085
220	0.443	0.110
230	0.393	0.152
235	0.268	0.268 (Critical)

Ref. *International Critical Tables*, Vol.3 (1928), p.239.

Liquid

Temperature (°C)	Density (gm/cc)
−90	0.91065
−80	0.90015
−70	0.88961
−60	0.87899
−50	0.86830
−40	0.85756
−30	0.84675
−20	0.83587
−10	0.82493
−6	0.82053
0	0.81392
+10	0.80285
20	0.79171
30	0.78051
40	0.76925
50	0.75792

Ref. Felsing and Durban, *J. Am. Chem. Soc.*, Vol.48 (1926), p. 2885.

Solid

d = 0.9686 gm/cc at −99°C

Ref. *International Critical Tables*, Vol.3 (1928), p.45.

VAPOR PRESSURE

Temp (°C)	Press. (mm Hg)	Temp (°C)	Press. (atm)
−59.4	1	56.5	1
−40.5	5	78.6	2
−31.1	10	113.0	5
−20.8	20	144.5	10
−9.4	40	181.0	20
−2.0	60	205.0	30
+7.7	100	214.5	40
22.7	200	–	–
39.5	400	–	–
56.5	760	–	–

Ref. Stull, *Ind. Eng. Chem.*, Vol.39 (1947), p.517.

TRIPLE POINT

No information.

VISCOSITY

Vapor

Temperature (°C)	η (poises)
100	0.0000931
212.5	0.000124

Ref. *International Critical Tables*, Vol.5 (1929), p.3.

Liquid

Temp (°C)	η (poises)	Temp (°C)	η (poises)
−89.7	0.02051	15.24	0.003376
−79.7	0.01505	19.02	0.003258
−69.7	0.01200	23.01	0.003131
−59.7	0.00981	27.22	0.003007
−49.9	0.00818	32.43	0.002863
−40.0	0.00713	36.0	0.002772
−30.3	0.00613	40.04	0.002675
−20.4	0.00516	44.12	0.002584
−10.6	0.00451	47.62	0.002503
±0.0	0.00389	52.20	0.002405
+7.86	0.003638	53.86	0.002377
11.72	0.003495	–	–

Ref. *International Critical Tables*, Vol.7 (1930), p.214.

SURFACE TENSION

Temperature (°C)	γ (dynes/cm)
0	26.21
20	23.70
40	21.16
60	18.61
80	16.2

Ref. *International Critical Tables*, Vol.4 (1928), p.450.

COEFFICIENT OF THERMAL EXPANSION

$$V_t = V_0 (1 + at + bt^2 + ct^3)$$

where

V_t = volume at temperature t°C

V_0 = volume at 0°C

$a = 1.3240 \times 10^{-3}$

$b = 3.8090 \times 10^{-6}$

$c = -0.87983 \times 10^{-8}$

Ref. Perry, *Chemical Engineers' Handbook*, second edition, 1941, p.485.

COEFFICIENT OF THERMAL CONDUCTIVITY (VAPOR)

Temperature (°C)	$k \times 10^5$ (cal/cm sec deg)
0	2.3
46	3.1
100	4.1
184	6.1

Above values measured relative to air having a k value of 5.682×10^{-5} at 0°C.

Ref. Moser, "Dissertation" (Berlin, 1913); Perry, *Chemical Engineers' Handbook*, second edition, 1941, p.961.

DIPOLE MOMENT $\mu = 2.85$ debye, for the vapor

Ref. Hobbs, *J. Chem. Phys.*, Vol.7 (1939), pp.849-50.

HEAT OF FUSION

ΔH_f = 19.6 cal/gm at −94.6°C

Ref. Maass and Waldbauer, *J. Am. Chem. Soc.*, Vol.47 (1925), p.7.

HEAT OF VAPORIZATION

Temperature (°C)	ΔH_v (cal/gm)
0	134.74
20	131.87
40	128.05
56.1	124.44
60	123.51
80	118.26
100	112.76
235	0

Ref. *International Critical Tables*, Vol.5 (1929), p.138.

HEAT OF FORMATION

$\Delta H^\circ_{298.1}$ = −57,200 cal/mole

Ref. Parks and Kelley, *J. Am. Chem. Soc.*, Vol.47 (1925), p.2089.

HEAT OF COMBUSTION

ΔH_c = −430,800 cal/mole

Ref. Kharasch, *J. Research Nat. Bur. Standards*, Vol.2 (1929), p.359.

CRITICAL DATA

t_c = 235°C
d_c = 0.268 gm/cc
p_c = 47.0 atm

Ref. *International Critical Tables*, Vol.3 (1928), p.239.

EQUATION OF STATE

$$\left(P + \frac{n^2 a}{V^2}\right)(V - nb) = nRT$$

where

P = absolute pressure in atmospheres
T = absolute temperature, °K
V = volume in liters/mole
R = gas constant = 0.08207 liter atm/mole deg
n = number of moles
a = 13.91 atm liters^2/mole^2
b = 0.0994 liter/mole

Ref. Lange, *Handbook of Chemistry*, sixth edition, 1946, p.1472.

COMPRESSIBILITY

$$\beta_t = \frac{1}{V_1}\left(\frac{V_1 - V_2}{P_2 - P_1}\right)$$

where

V_1 = volume of a liquid under a pressure of P_1 at t°C
V_2 = volume of the liquid at some other pressure, P_2, at the same temperature

Temperature (°C)	Pressure Range (atm)	$\beta_t \times 10^6$
14.2	8.90-36.51	111
0	100-500	82
0	500-1000	59
0	1000-1500	47
0	1500-2000	40
25	82.5	111.8

Ref. Lange, *Handbook of Chemistry*, sixth edition, 1946, p.1584.

HEAT CAPACITY OF GAS, C_p AND C_v

Temperature (°K)	C_p (cal/mole deg)
298.1	18.38
300	18.47
400	22.69
500	26.56
600	29.93
700	32.79
800	35.27
900	37.44
1000	39.04
1100	40.81
1200	42.29
1300	43.60
1400	44.44
1500	45.35

Ref. Godnev, Payukhina, and Sverdlin, *J. Phys. Chem.* (U.S.S.R.), Vol. 14, No.3 (1940), p.374.

RATIO OF SPECIFIC HEATS — No information.

HEAT CAPACITY OF LIQUID AND SOLID

Liquid

$C_p = 29.6 + 4.64 \times 10^{-2}(t - 15)$ where t = °C

C_p = 29.0 cal/mole deg from 0 – 20°C

Ref. Landolt-Börnstein, *Physikalisch-Chemische Tabellen*, 3rd Suppl., 1936, p.2292. .

Solid

Temperature (°C)	C_p (cal/gm deg)
−100	0.40
−120	0.36
−140	0.31
−160	0.28
−180	0.21

Ref. Maass and Waldbauer, *J. Am. Chem. Soc.*, Vol.47 (1925), p.7.

FREE ENERGY OF FORMATION $\Delta F_{298.1} = 0$, by definition

FREE-ENERGY FUNCTION

Temperature (°K)	$-(F^\circ - E_o^\circ)/T$, cal/mole deg
298.1	57.53
300	57.62
400	61.67
500	65.20
600	68.55
700	71.53
800	74.40
900	77.23
1000	79.72
1100	82.18
1200	84.61
1300	86.84
1400	88.93
1500	91.10

Ref. Godnev, Payukhina, and Sverdlin, *J. Phys. Chem.* (U.S.S.R.), Vol. 14, No.3 (1940), pp.374-79.

HEAT-CONTENT FUNCTION No information.

ENTROPY

Temperature (°K)	S° (cal/mole deg)
298.1	70.72
300	70.83
400	76.67
500	82.19
600	87.32
700	92.13
800	96.49
900	101.20
1000	105.03
1100	108.81
1200	112.51
1300	115.83
1400	119.10
1500	122.22

Ref. Godnev, Payukhina, and Sverdlin, *J. Phys. Chem.* (U.S.S.R.), Vol. 14, No.3 (1940), pp.374-79.

ACETYLENE

MOLECULAR FORMULA

C_2H_2; CHCH

MOLECULAR WEIGHT

26.036

Ref. *International Atomic Weights*, 1947.

MELTING POINT

Melting point = −81. °C

Ref. American Petroleum Institute, Research Project No.44, *Collection, Analysis, and Calculation of Data on the Properties of Hydrocarbons*, 1945.

SUBLIMATION POINT

Sublimation point = −84. °C at 760 mm

Ref. American Petroleum Institute, Research Project No.44, *Collection, Analysis, and Calculation of Data on the Properties of Hydrocarbons*, 1945.

DENSITY

Vapor

d = 1.1708 gm/l, at 0°C and 760 mm Hg

Ref. Landolt-Börnstein, *Physikalisch-Chemische Tabellen*, 1st Suppl., 1927, p.161.

Liquid

d = 0.6181 gm/cc at −81.8°C

Ref. Maass and Wright, *J. Am. Chem. Soc.*, Vol.43 (1921), pp.1098-1111.

Solid

$d = 0.6208$ gm/cc at -84°C

Ref. Perry, *Chemical Engineers' Handbook*, second edition, 1941, p. 411.

VAPOR PRESSURE

Temp (°C)	Press. (atm)	Density (gm/cc)	
		Liquid	Vapor
−84	1.00		
−81.5	1.20	0.618	0.0021
−70	2.20	0.601	0.0036
−60	3.48	0.585	0.0056
−50	5.3	0.568	0.0085
−40	7.7	0.551	0.012
−30	10.9	0.532	0.017
−20	14.9	0.512	0.024
−10	20.0	0.490	0.033
0	26.3	0.464	0.045
+10	33.9	0.435	0.060
20	43.1	0.400	0.082
30	54.1	0.346	0.122
36	61.7	0.230	0.230 (Critical Point)

Ref. *International Critical Tables*, Vol.3 (1928), p.230.

TRIPLE POINT

Temperature at triple point = −81.5°C

Pressure at triple point = 1.20 atm

Ref. *International Critical Tables*, Vol.3 (1928), p.230.

VISCOSITY

Gas

Temperature (°C)	$\eta \times 10^7$ (poises)
20	1022
30	1055
40	1085

VISCOSITY (*Cont'd*)

Gas (*Cont'd*)

Temperature (°C)	$\eta \times 10^7$ (poises)
50	1114
60	1146
70	1180
80	1208
90	1246
100	1274

Ref. Adzumi, *Bull. Chem. Soc., Japan*, Vol.12 (1937), pp.199-226.

Liquid — No information.

SURFACE TENSION

Temperature (°C)	γ (dynes/cm)
−81.8	19.28
−80.3	18.92
−79.15	18.76
−76.15	18.09
−70.85	17.16
−66.35	16.30
−62.5	15.45
−56.0	14.31

Ref. Maass and Wright, *J. Am. Chem. Soc.*, Vol.43 (1921), pp.1098-1111.

COEFFICIENT OF THERMAL EXPANSION

$$\alpha = \frac{V - V_0}{tV_0}$$

where

V = volume at temperature t °C
V_0 = volume at 0 °C
t = temperature °C
$\alpha = 0.003771$ at 0 °C
$\alpha = 0.003738$ at 0°-100 °C

Ref. *International Critical Tables*, Vol.3 (1928), p.16.

COEFFICIENT OF THERMAL CONDUCTIVITY

Temperature (°C)	$k \times 10^5$ (cal/sec cm deg)
−75	2.8
0	4.5
+50	5.8
100	7.1

Above values relative to air having a k value of 5.682×10^{-5} at 0°C

Ref. Eucken, *Physik. Z.*, Vol.12 (1911), p.1101; Vol.14 (1913), p 324; Perry, *Chemical Engineers' Handbook*, second edition, 1941, p.390.

DIPOLE MOMENT

$\mu = 0$ debye, for the vapor between −80° to 25°C

Ref. Watson, Rao, and Ramaswamy, *Proc. Roy. Soc.*, London, Vol.143 (1934), p.558.

HEAT OF FUSION

$\Delta H_f = 0.60$ kcal/mole at −81.5°C

Ref. McIntosh, *J. Phys. Chem.*, Vol.11 (1907), p.306.

HEAT OF VAPORIZATION

$\Delta H_v = 5.74$ kcal/mole at −81.5°C and 1.2 atm

Ref. McIntosh, *J. Phys. Chem.*, Vol.11 (1907), p.306.

HEAT OF FORMATION

$$2C(\text{solid, graphite}) + H_2(\text{gas}) = C_2H_2(\text{gas})$$

Temperature (°K)	ΔH_f°, kcal/mole
0	54.329
298.16	54.194
300	54.193
400	54.134
500	54.049
600	53.931
700	53.787
800	53.627
900	53.462
1000	53.304
1100	53.151
1200	53.003
1300	52.851
1400	52.698
1500	52.548

Ref. Wagman, *et al.*, *J. Research Nat. Bur. Standards*, Vol.35 (1946), pp.467-96.

HEAT OF COMBUSTION

$$C_2H_2(\text{gas}) + 2.5\ O_2(\text{gas}) \longrightarrow H_2O(\text{liquid}) + 2\,CO_2(\text{gas})$$

$$\Delta H_c = -310.615 \text{ kcal/mole at } 25\,^\circ\text{C}$$

$$C_2H_2(\text{gas}) + 2.5\ O_2(\text{gas}) \longrightarrow H_2O(\text{gas}) + 2\,CO_2(\text{gas})$$

$$\Delta H_c = -300.096 \text{ kcal/mole at } 25\,^\circ\text{C}$$

Ref. American Petroleum Institute, Research Project No.44, *Collection, Analysis, and Calculation of Data on the Properties of Hydrocarbons*, Table 12-n, 1945.

CRITICAL DATA

$t_c = 36.0\,^\circ\text{C}$

$p_c = 62.0$ atm

$d_c = 0.231$ gm/cc

Ref. *International Critical Tables*, Vol.3 (1928), p.230.

EQUATION OF STATE

$$\left(P + \frac{n^2 a}{V^2}\right)(V - nb) = nRT$$

where

P = pressure, absolute atmospheres
V = volume, liters
R = 0.08206 liter atm/mole deg
T = temperature, °K
n = number of moles
a = 4.390 liters^2 atm/mole^2
b = 0.05136 liter/mole

Ref. Lange, *Handbook of Chemistry*, sixth edition, 1946, p.1472.

COMPRESSIBILITY

PV = 1.000 at 0°C and 1 atm

Pressure (atm)	PV	
	0°C	25°C
0.5	1.0057	1.0989
1.0	1.0000	1.0937
2.0	0.9891	1.0841
4.0	0.9708	1.0684
6.0	0.9530	1.0531
8.0	0.9360	1.0385
10.0	0.9194	1.0255
12.0	0.9026	1.0139

Ref. Landolt-Börnstein, *Physikalisch-Chemische Tabellen*, 2nd Suppl., 1931, p.61.

HEAT CAPACITY OF VAPOR, C_p AND C_v

Temperature (°K)	$C_p°$ (cal/deg mole)
0	0
298.16	10.499
300	10.532
400	11.973
500	12.967
600	13.728

HEAT CAPACITY OF VAPOR, C_p AND C_v (*Cont'd*)

Temperature (°K)	$C_p°$ (cal/deg mole)
700	14.366
800	14.933
900	15.449
1000	15.922
1100	16.353
1200	16.744
1300	17.099
1400	17.418
1500	17.704

Ref. Wagman, *et al.*, *J. Research Nat. Bur. Standards*, Vol.35 (1946), pp.467-96.

RATIO OF SPECIFIC HEATS — No information

HEAT CAPACITY OF LIQUID AND SOLID

Liquid — No information

Solid

C_p = 7.86 cal/mole deg

Ref. Justi, *Spezifische Wärme, Enthalpie, Entropie und Dissoziation technischer Gase*, 1938, p.108.

FREE ENERGY OF FORMATION

Temperature (°K)	$\Delta F_f°$ (kcal/mole)
0	54.329
298.16	50.000
300	49.975
400	48.577
500	47.196
600	45.835
700	44.498
800	43.178
900	41.882
1000	40.604
1100	39.339

Temperature (°K)	ΔF_f° (kcal/mole)
1200	38.089
1300	36.854
1400	35.624
1500	34.410

Ref. Wagman, *et al.*, *J. Research Nat. Bur. Standards*, Vol.35 (1946), pp.467-96.

FREE-ENERGY FUNCTION

Temperature (°K)	$-(F^\circ - H_o^\circ)/T$ (cal/mole deg)
0	0
298.16	39.976
300	40.025
400	42.451
500	44.508
600	46.313
700	47.930
800	49.400
900	50.752
1000	52.005
1100	53.175
1200	54.275
1300	55.313
1400	56.296
1500	57.231

Ref. Wagman, *et al.*, *J. Research Nat. Bur. Standards*, Vol.35 (1946), pp.467-96.

HEAT-CONTENT FUNCTION

Temperature (°K)	$(H^\circ - H_o^\circ)/T$ (cal/mole deg)
0	0
298.16	8.021
300	8.036
400	8.853
500	9.582
600	10.212
700	10.762
800	11.249
900	11.689
1000	12.090

HEAT-CONTENT FUNCTION (*Cont'd*)

Temperature (°K)	$(H^\circ - H_o^\circ)/T$(cal/mole deg)
1100	12.460
1200	12.802
1300	13.119
1400	13.416
1500	13.694

Ref. Wagman, *et al.*, *J. Research Nat. Bur. Standards*, Vol.35 (1946), pp.467-96.

ENTROPY

Temperature (°K)	S° (cal/mole deg)
0	0
298.16	47.997
300	48.061
400	51.304
500	54.090
600	56.525
700	58.692
800	60.649
900	62.441
1000	64.095
1100	65.635
1200	67.077
1300	68.432
1400	69.712
1500	70.925

Ref. Wagman, *et al.*, *J. Research Nat. Bur. Standards*, Vol.35 (1946), pp.467-96.

ALUMINUM

MOLECULAR (ATOMIC) FORMULA

Al

MOLECULAR (ATOMIC) WEIGHT

26.97

Ref. *International Atomic Weights*, 1947.

MELTING POINT

Melting point = 658.6°C

Ref. Kelley, *U.S. Bur. Mines Bull. 393* (1936).

BOILING POINT

Boiling point = 2057°C

Ref. Kelley, *U.S. Bur. Mines Bull. 383* (1935).

DENSITY

Vapor — No information

Liquid

Temperature (°C)	Density (gm/cc)
700	2.382
800	2.353
900	2.325
1000	2.298

Ref. Landolt-Börnstein, *Physikalisch-Chemische Tabellen*, 2nd Suppl., p.209.

Solid

Cast – 99.75% pure, d = 2.703 gm/cc at 20°C
Cold rolled–99.75% pure, d = 2.699 gm/cc at 20°C

Ref. *International Critical Tables*, Vol.2, p.456.

VAPOR PRESSURE

Temperature (°C)	Pressure (mm Hg)
1284	1
1421	5
1487	10
1555	20
1635	40
1684	60
1749	100
1844	200
1947	400
2056	760

Ref. Stull, *Ind. Eng. Chem.*, Vol.39 (1947), pp.540-50.

TRIPLE POINT — No information

VISCOSITY

Vapor — No information

Liquid

Temperature (°C)	η (poises)
670	0.06350
690	0.03733
700	0.02890
720	0.02310
730	0.02114
765	0.01850
800	0.01392

Ref. Polyak and Sergeev, *Compt. rend. acac. sci.*, (*U.R.S.S.*), Vol.30 (1941), pp.137-9.

SURFACE TENSION

γ = 520 dynes/cm at 750°C

Ref. *International Critical Tables*, Vol.1, p.103; Smith, *J. Inst. Metals*, Vol.12 (1914), pp. 168-209.

COEFFICIENT OF THERMAL EXPANSION

Temperature Range (°C)	Average Coefficient of Expansion per °C ($\times 10^6$)
20-100	23.86
20-200	24.58
20-300	25.45
20-400	26.49
20-500	27.68

Ref. Taylor, *et al.*, *Metals and Alloys*, Vol.9 (1938), pp.189-192.

COEFFICIENT OF THERMAL CONDUCTIVITY

Temperature (°C)	k (cal/sec cm deg)
0	0.48
100	0.49
200	0.51
300	0.55
400	0.59
500	0.64

Ref. Perry, *Chemical Engineers' Handbook*, second edition, 1941, p.949.

DIPOLE MOMENT

$\mu = 0$

Ref. Branch and Calvin, *The Theory of Organic Chemistry*, 1941.

HEAT OF FUSION

ΔH_f = 2,550 cal/gm atom at 660°C

Ref. Kelley, *U.S. Bur. Mines Bull. 393* (1936).

HEAT OF SUBLIMATION

ΔH_s = 67,497 cal/gm atom at 298.1 °K

Ref. Kelley, *U.S. Bur. Mines Bull. 383* (1935), p.15.

HEAT OF VAPORIZATION

ΔH_v = 65,084 cal/gm atom at 298.1°K
ΔH_v = 61,022 cal/gm atom at 2330°K

Ref. Kelley, *U.S. Bur. Mines Bull. 383* (1935), p.15.

HEAT OF FORMATION

ΔH_{solid} = 0, by definition
ΔH_{liquid} = 55 kcal/mole

Ref. Bichowsky and Rossini, *The Thermochemistry of Chemical Substances*, 1936, p.106.

HEAT OF COMBUSTION

ΔH_c = −380.000 cal/mole

Ref. Budgen, *Aluminum and Its Alloys*, 1933, p.62.

CRITICAL DATA — No information

EQUATION OF STATE — No information

COMPRESSIBILITY

$$\beta = \frac{-1}{V^\circ}\frac{\partial V}{\partial P} = \text{cubic compressibility}$$

Temperature (°C)	Pressure (atm)	$\beta \times 10^6$
20	0-9,870	1.34
20	99-493	1.49
30	0	1.384
30	11,600	1.298

Ref. *International Critical Tables*, Vol.3 (1928), p.46.

HEAT CAPACITY OF VAPOR, C_p AND C_v

C_p = 5.00 cal/deg mole (average value for temperature range 298.1°-3000°K) accuracy ± 1%

Ref. Kelley, *U.S. Bur. Mines Bull. 383* (1935), p.15.

RATIO OF SPECIFIC HEATS

No information

HEAT CAPACITY OF LIQUID AND SOLID

Liquid

C_p = 7.00 cal/deg mole (931°-1273°K) accuracy ± 5%

Ref. Kelley, *U.S. Bur. Mines Bull. 371* (1934), p.8.

Solid

Temp (°K)	Cal/Deg Atom C_p	Cal/Deg Atom C_v	Temp (°K)	Cal/Deg Atom C_p	Cal/Deg Atom C_v
15	0.022	0.022	170	4.776	4.690
20	0.054	0.054	180	4.920	4.823
30	0.203	0.203	190	5.045	4.938
40	0.500	0.500	200	5.158	5.039
50	0.913	0.912	210	5.251	5.122
60	1.378	1.375	220	5.338	5.198
70	1.851	1.846	230	5.418	5.268
80	2.307	2.298	240	5.490	5.329
90	2.729	2.714	250	5.557	5.383
100	3.116	3.094	260	5.619	5.436
110	3.451	3.422	270	5.677	5.483
120	3.741	3.704	280	5.728	5.523
130	3.989	3.943	290	5.778	5.562
140	4.221	4.165	298.1	5.817	5.592
150	4.427	4.361	300	5.826	5.599
160	4.612	4.536			

Ref. Giauque and Meade, *J. Am. Chem. Soc.*, Vol.63 (1941), p.1897.

FREE ENERGY OF FORMATION

Solid

$$\Delta F^{\circ}_{298.1} = 0, \text{ by definition}$$

Vapor

Temp (°K)	$\Delta F_t^{\circ}/T$ (cal/deg atom)	Temp (°K)	$\Delta F_t^{\circ}/T$ (cal/deg atom)
298.1	193.85	1300	21.16
400	136.20	1400	17.70
500	102.53	1500	14.70
600	80.12	1600	12.09
700	64.16	2000	4.34
800	52.23	2100	2.87
900	42.98	2200	1.55
1000	35.79	2300	0.34
1100	30.01	2400	−0.76
1200	25.21		

Ref. Kelley, *U.S. Bur. Mines Bull. 383* (1935).

FREE-ENERGY FUNCTION

Solid

Temp (°K)	$-(F-H^{\circ}_{o})/T$ (cal/deg atom)	Temp (°K)	$-(F-H^{\circ}_{o})/T$ (cal/deg atom)
15	0.002	170	1.421
20	0.004	180	1.559
30	0.015	190	1.695
40	0.037	200	1.832
50	0.077	210	1.968
60	0.132	220	2.105
70	0.205	230	2.239
80	0.293	240	2.371
90	0.393	250	2.502
100	0.503	260	2.633
110	0.622	270	2.755
120	0.749	280	2.887
130	0.876	290	3.011
140	1.010	298.1	3.101
150	1.145	300	3.134
160	1.383		

Ref. Giauque and Meade, *J. Am. Chem. Soc.*, Vol.63 (1941), p.1897.

HEAT-CONTENT FUNCTION

Temp (°K)	$(H-H_0^\circ)/T$ (cal/deg atom)	Temp (°K)	$(H-H_0^\circ)/T$ (cal/deg atom)
15	0.005	170	2.344
20	0.013	180	2.484
30	0.048	190	2.616
40	0.121	200	2.740
50	0.236	210	2.858
60	0.388	220	2.968
70	0.563	230	3.073
80	0.753	240	3.173
90	0.949	250	3.267
100	1.147	260	3.356
110	1.342	270	3.447
120	1.530	280	3.522
130	1.710	290	3.599
140	1.881	298.1	3.668
150	2.044	300	3.672
16[illegible]	2.198		

Ref. Giauque and Meade, *J. Am. Chem. Soc.*, Vol.63 (1941), p.1897.

ENTROPY

Temp (°K)	S_t (cal/deg atom)	Temp (°K)	S_t (cal/deg atom)
15	0.007	170	3.765
20	0.017	180	4.043
30	0.063	190	4.311
40	0.158	200	4.572
50	0.313	210	4.826
60	0.520	220	5.073
70	0.768	230	5.312
80	1.046	240	5.544
90	1.342	250	5.769
100	1.650	260	.989
110	1.964	270	6.202
120	2.279	280	6.409
130	2.586	290	6.610
140	2.891	298.1	6.769
150	3.189	300	6.806
160	3.481		

Above values do not include entropy due to nuclear spin and isotropic mixing.

Ref. Giauque and Meade, *J. Am. Chem. Soc.*, Vol.63 (1941), p.1897.

ALUMINUM BOROHYDRIDE

MOLECULAR FORMULA

$Al(BH_4)_3$

MOLECULAR WEIGHT

71.53

Ref. *International Atomic Weights*, 1947.

MELTING POINT

Melting point = −64.5°C ± 0.5°

Ref. Schlesinger, Sanderson, and Burg, *J. Am. Chem. Soc.*, Vol. 62 (1940), p. 3421.

BOILING POINT

Boiling point = 44.5°C

Ref. Schlesinger and Burg, *Chem. Rev.*, Vol. 31 (1942), p. 1.

DENSITY

No information

VAPOR PRESSURE

Temperature (°C)	Pressure (mm Hg)
−41.9	11.0
−34.1	18.0
−28.5	25.3
−18.4	46.1
−11.9	65.5
−8.4	80.0
−4.7	95.0
−2.0	108.6
0.0	119.5
7.6	171.
9.9	190.
11.5	203.
13.5	220.
14.1	226.
16.9	257.

Ref. Schlesinger, Sanderson, and Burg, *J. Am. Chem. Soc.*, Vol. 62, (1940), p. 3421.

TRIPLE POINT VISCOSITY SURFACE TENSION COEFFICIENT OF THERMAL EXPANSION COEFFICIENT OF THERMAL CONDUCTIVITY DIPOLE MOMENT HEAT OF FUSION	No information
HEAT OF VAPORIZATION ΔH_v = 7,160 cal/mole (calculated) Ref. Schlesinger, Sanderson, and Burg, *J. Am. Chem. Soc.*, Vol.62 (1940), p.3421.	
HEAT OF FORMATION HEAT OF COMBUSTION CRITICAL DATA EQUATION OF STATE COMPRESSIBILITY HEAT CAPACITY OF GAS, C_p OR C_v RATIO OF SPECIFIC HEAT HEAT CAPACITY OF LIQUID AND SOLID FREE ENERGY OF FORMATION FREE-ENERGY FUNCTION HEAT-CONTENT FUNCTION ENTROPY	No information

AMMONIA

MOLECULAR FORMULA	NH_3
MOLECULAR WEIGHT 17.0320 Ref. *International Atomic Weights*, 1947.	

MELTING POINT

Melting point = −77.74°C at 45.58 mm Hg

Ref. Overstreet and Giauque, *J. Am. Chem. Soc.*, Vol.59 (1937), p.254.

BOILING POINT

Boiling point = −33.42°C

Ref. Overstreet and Giauque, *J. Am. Chem. Soc.*, Vol.59 (1937), p.133.

DENSITY

Gas

d = 0.7710 gm/liter, at 0°C and 1 atm

Ref. *International Critical Tables*, Vol.3 (1928), p.3.

Liquid

Temperature (°C)	Density (gm/cc)
−70	0.7253
−50	0.7020
−30	0.6777
−10	0.6520
0	0.6386
+20	0.6103

Ref. Yost and Russell, *Systematic Inorganic Chemistry*, 1944, p.134.

Solid

d = 0.817 gm/cc, at −79°C

Ref. *International Critical Tables*, Vol.1 (1926), p.108.

VAPOR PRESSURE

Temp (°C)	Press. (mm Hg)	Temp (°C)	Press. (mm Hg)
−70	81.9	+10	4612.0
−60	164.2	20	6428.5
−50	306.6	30	8749.0
−40	538.3	40	11658.0
−30	896.7	50	15245.0
−20	1426.8	60	19606.0
−10	2181.4	70	24842.0
0	3221.0		

Ref. Cragoe, Meyers, and Taylor, *J. Am. Chem. Soc.*, Vol.42 (1920), p.206.

TRIPLE POINT

Temperature (°C) = −77.74

Pressure (mm Hg) = 45.58

Ref. Overstreet and Giauque, *J. Am. Chem. Soc.*, Vol.59 (1937), p.254.

VISCOSITY

Gas — No information

Liquid

Temperature (°C)	$\eta \times 10^3$ (poises)	Reference
25	1.350	(1)
15	1.457	(1)
5	1.618	(1)
−33.5	2.60	(2)

Refs. (1) Plank and Hunt, *J. Am. Chem. Soc.*, Vol.61 (1939), p.3590.

(2) Elsey, *J. Am. Chem. Soc.*, Vol.42 (1920), p.2454.

SURFACE TENSION

Temperature (°C)	γ (dynes/cm)	Reference
−56.0	39.15	(1)
−51.7	38.30	(1)
−39.0	35.56	(1)
−34.0	34.39	(1)
−33.0	34.06	(1)
+11.1	23.4 ± 2	(2)
+34.1	18.1 ± 2	(2)
+59.0	13.0 ± 2	(2)

Refs. (1) Durrant, Pearson, and Robinson, *J, Am. Chem. Soc.*, 1934, p.734.

(2) *International Critical Tables*, Vol.4 (1928), p.442.

COEFFICIENT OF THERMAL EXPANSION

Gas

$\alpha = (V - V_0)\, tV_0$ = change in volume per unit volume per degree centigrade

At 0°C, $100\alpha = 0.3857$

0°-100°C, $100\alpha = 0.3797$

Ref. *International Critical Tables*, Vol.3 (1928), p.16.

Liquid

Temperature (°C)	$\beta \times 10^3$
−40	1.74
−30	1.80
−20	1.85
−10	1.94
0	2.04
+10	2.17
20	2.34
30	2.57
40	2.85
50	3.13
60	3.38

Liquid (*Cont'd*)

Temperature (°C)	$\beta \times 10^3$
70	3.80
80	4.28
90	4.91
100	5.72

The coefficient β represents the increase in volume per unit volume per degree centigrade.

Ref. Mellor, *Comprehensive Treatise on Inorganic and Theoretical Chemistry*, Vol.8, p.175.

COEFFICIENT OF THERMAL CONDUCTIVITY

Vapor

Temperature (°C)	$k \times 10^5$ (cal/sec cm deg)
−60	3.9
0	5.3
+50	6.5
100	7.6

Above values relative to air having k value of 5.682×10^{-5}.

Ref. Eucken, *Physik. Z.*, Vol.12 (1911), p.1101; Vol.14 (1913), p.324.

DIPOLE MOMENT

$\mu = 1.466$ debye

Ref. de Bruyne and Smythe, *J. Am. Chem. Soc.*, Vol.57 (1935), p.1203.

HEAT OF FUSION

$H_f = 1351.6 \pm 0.2$ cal/mole

Ref. Overstreet and Giauque, *J. Am. Chem. Soc.*, Vol.59 (1937), p.254.

HEAT OF VAPORIZATION

ΔH_v = 5581 cal/mole, at −33.42°C

Ref. Overstreet and Giauque, *J. Am. Chem. Soc.*, Vol.59 (1937), p.254.

HEAT OF FORMATION

Reaction:

$$\frac{1}{2} N_2(g) + \frac{3}{2} H_2(g) = NH_3(g)$$

$\Delta H^\circ_{298.1} = -11{,}040$ cal/mole

Ref. Stevenson and McMahon, *J. Am. Chem. Soc.*, Vol.61 (1939), p.437.

HEAT OF COMBUSTION

Reaction:

$$\frac{5}{4} O_2(g) + NH_3(g) = NO(g) + \frac{3}{2} H_2O(g)$$

$\Delta H_c = -55{,}010$ cal/mole

Ref. Stevenson and McMahon, *J. Am. Chem. Soc.*, Vol.61 (1939), p.437.

CRITICAL DATA

t_c = 132.4°C

P_c = 111.5 atm

d_c = 0.235 gm/cc

Ref. Pickering, *Nat. Bur. Standards (U.S.), Sci. Tech. Paper S-541*, Vol.21 (1926-7), p.604.

EQUATION OF STATE

Beattie-Bridgeman Equation of State

$$p = \frac{RT\left(1 - \frac{c}{VT^3}\right)}{V^2}\left[V + B_0\left(1 - \frac{b}{V}\right)\right] - \frac{A_0}{V^2}\left(1 - \frac{a}{V}\right)$$

where

P = pressure, atm
R = gas constant, 0.08206 liter atm/deg mole
A_0 = 2.3930
a = 0.17031
B_0 = 0.03415
b = 0.19112
c = 476.87 × 10^4
V = volume, liters/mole
T = temp, °C

Maximum deviation is 0.155% from data of Meyers and Jessup in the range of specific volumes of 1300 to 20 cc/gm and temperature range of 75-325°C.

Ref. Beattie and Lawrence, *J. Am. Chem. Soc.*, Vol.52 (1930), pp.6-14.

COMPRESSIBILITY

PV = 1.0000 AT 1 ATMOSPHERE AND 0 °C

Pressure (atm)	0°C	25°C	50°C	100°C	132.9°C	150°C	200°C	250°C	300°C
1	1.000	1.095	1.191	1.379	1.503	1.567	1.754	1.940	2.126
2	0.986	1.085	1.182	1.373	1.498	1.563	1.750	1.937	2.124
5		1.049	1.153	1.354	1.483	1.549	1.740	1.930	2.119
10			1.103	1.321	1.457	1.526	1.724	1.917	2.109
20			0.988	1.252	1.404	1.479	1.690	1.892	2.089
30				1.176	1.349	1.430	1.656	1.867	2.071
40				1.090	1.290	1.378	1.621	1.840	2.051
50				0.995	1.227	1.326	1.586	1.816	2.032
60					1.160	1.272	1.551	1.791	2.013
80						1.157	1.479	1.740	1.976
100							1.408	1.690	1.938
120									1.903

COMPRESSIBILITY (*Cont'd*)

PV = 1.0000 AT 1 ATMOSPHERE AND 0 °C

Pressure (atm)	0 °C*	10 °C	20 °C	30 °C	40 °C	50 °C	60 °C	70 °C	80 °C	90 °C	100 °C
100	0.1196	0.1223	0.1250	0.1279	0.1305	0.1334	0.1373	0.1417	0.1465	0.1535	0.1606
200	0.2437	0.2457	0.2484	0.2526	0.2570	0.2628	0.2693	0.2769	0.2859	0.2963	0.3081
300	0.3533	0.3594	0.3657	0.3722	0.3796	0.3886	0.3980	0.4082	0.4190	0.4309	0.4441
400	0.4720	0.4777	0.4843	0.4913	0.4998	0.5094	0.5206	0.5322	0.5449	0.5593	0.5705
500	0.5839	0.5914	0.5995	0.6084	0.6186	0.6300	0.6419	0.6552	0.6696	0.6853	0.7019
600	0.6942	0.7027	0.7113	0.7213	0.7321	0.7443	0.7576	0.7728	0.7898	0.8076	0.8261
700	0.8060	0.8137	0.8222	0.8330	0.8453	0.8608	0.8754	0.8916	0.9094	0.9279	0.9472
800	0.9171	0.9256	0.9340	0.9441	0.9564	0.9711	0.9873	1.0050	1.0243	1.0443	1.0659
900	1.0281	1.0351	1.0436	1.0544	1.0659	1.0814	1.0976	1.1168	1.1361	1.1577	1.1801
1000	1.1431	1.1489	1.1562	1.1654	1.1770	1.1917	1.2086	1.2279	1.2495	1.2719	1.2942
1100	1.2557	1.2603	1.2672	1.2757	1.2873	1.3012	1.3182	1.3382	1.3606	1.3829	1.4069

*Data at 0 °C were extrapolated graphically.

PV = 1.0000 AT 1 ATMOSPHERE AND 0 °C

Pressure (atm)	110 °C	120 °C	130 °C	140 °C	150 °C	160 °C	170 °C	180 °C	190 °C	200 °C	210 °C
100	0.1724										
200	0.3209	0.3363	0.3563	0.3845	0.4273	0.4921	0.5769	0.6841	0.8137	0.9680	
300	0.4588	0.4760	0.4963	0.5199	0.5479	0.5798	0.6209	0.6703	0.7327	0.8114	
400	0.5917	0.6097	0.6308	0.6541	0.6801	0.7090	0.7421	0.7790	0.8237	0.8700	
500	0.7204	0.7404	0.7622	0.7852	0.8099	0.8369	0.8669	0.8797	0.9387	0.9788	
600	0.8469	0.8677	0.8901	0.9132	0.9379	0.9634	0.9927	1.0243	1.0567	1.0922	
700	0.9680	0.9896	1.0127	1.0366	1.0613	1.0875	1.1153	1.1423	1.1708	1.2001	
800	1.0875	1.1107	1.1346	1.1585	1.1839	1.2102	1.2372	1.2665	1.2958	1.3266	
900	1.2032	1.2271	1.2518	1.2773	1.3035	1.3297	1.3583	1.3868	1.4161	1.4477	1.4817
1000	1.3189	1.3436	1.3698	1.3961	1.4223	1.4493	1.4778	1.5056	1.5364	1.5673	1.5989
1100	1.4323	1.4585	1.4855	1.5118	1.5395	1.5673	1.5958	1.6259	1.6560	1.6861	1.7161

Ref. Perry, *Chemical Engineers' Handbook*, second edition, p.490.

HEAT CAPACITY OF GAS, C_p AND C_v

Temp (°C)	C_v (cal/deg mole)	C_p (cal/deg mole)	Temp (°C)	C_v (cal/deg mole)	C_p (cal/deg mole)
0	6.37	8.355	1100	13.33	15.31
25	6.545	8.525	1200	13.72	15.71
100	6.99	8.975	1300	14.07	16.06
200	7.73	9.72	1400	14.40	16.38
300	8.48	10.47	1500	14.67	16.67
400	9.14	11.13	1750	15.27	17.26
500	9.94	11.93	2000	15.73	17.71
600	10.62	12.61	2250	16.07	18.06
700	11.26	13.24	2500	16.34	18.33
800	11.85	13.83	2750	16.56	18.55
900	12.39	14.38	3000	16.74	18.72
1000	12.89	14.87			

Ref. Justi, *Spezifische Wärme, Enthalpie, Entropie und Dissoziation technischer Gase* (Berlin), 1938, p.149.

RATIO OF SPECIFIC HEATS

Can be calculated from data given in preceding table, C_p/C_v.

HEAT CAPACITY OF LIQUID AND SOLID

Liquid

Temperature (°K)	C_p (cal/mole deg)
200	17.58
210	17.75
220	17.90
230	18.03
240	18.12

Above values taken from smooth curve through observations.

Ref. Overstreet and Giauque, *J. Am. Chem. Soc.*, Vol.59 (1937), p.254.

HEAT CAPACITY OF LIQUID AND SOLID (*Cont'd*)

Solid

Temperature (°K)	C_p (cal/mole deg)
20	0.368
30	1.033
40	1.841
50	2.663
60	3.474
70	4.232
80	4.954
90	5.612
100	6.246
110	5.877
120	7.497
130	8.102
140	8.699
150	9.272
160	9.846
170	10.42
180	11.03
190	11.71

Ref. Overstreet and Giauque, *J. Am. Chem. Soc.*, Vol.59 (1937), p.254.

FREE ENERGY OF FORMATION

Reaction:

$$\tfrac{1}{2}N_2(g) + \tfrac{3}{2}H_2(g) = NH_3(g)$$

$$\Delta F^\circ_{298.1} = -3972 \text{ cal/mole}$$

Ref. Stephenson and McMahon, *J. Am. Chem. Soc.*, Vol.61 (1939), p.437.

FREE-ENERGY FUNCTION

Temperature (°K)	$-(F^\circ - H_\circ^\circ)/T$, (cal/mole deg)	Temperature (°K)	$-(F^\circ - H_\circ^\circ)/T$, (cal/mole deg)
298.1	37.989	1200	50.535
300	38.040	1300	51.408
400	40.380	1400	52.239
500	42.249	1500	53.033
600	43.826	1600	53.792
700	45.209	1700	54.522
800	46.250	1800	55.224
900	47.585	1900	55.914
1000	48.634	2000	56.559
1100	49.614		

Ref. Stephenson and McMahon, *J. Am. Chem. Soc.*, Vol. 61 (1939), pp. 437-440.

HEAT-CONTENT FUNCTION

No information on function, but following data indicate molar heat content of ammonia in ideal gas state relative to 0°C.

Temp(°C)	$\Delta H_\circ^t$, kcal/mole	Temp(°C)	$\Delta H_\circ^t$, kcal/mole
0	0.000	1100	13.42
25	0.211	1200	15.02
100	0.867	1300	16.64
200	1.798	1400	18.29
300	2.848	1500	19.97
400	3.930	1750	21.67
500	5.086	2000	23.42
600	6.310	2250	25.21
700	7.610	2500	27.03
800	8.953	2750	28.88
900	10.364	3000	30.74
1000	11.87		

Ref. Justi, *Spezifische Wärme, Enthalpie, Entropie und Dissoziation technischer Gase* (Berlin), 1938, p. 149.

ENTROPY

Temperature (°K)	S_t° (cal/mole deg)
298.1	46.034
300	46.089
400	48.628
500	50.761
600	52.602
700	54.346
800	55.915
900	57.378
1000	58.757
1100	60.059
1200	61.296
1300	62.473
1400	63.598
1500	64.673
1600	65.704
1700	66.692
1800	67.641
1900	68.554
2000	69.434

Ref. Stephenson and McMahon, *J. Am. Chem. Soc.*, Vol.61 (1939), p.437.

ANILINE

MOLECULAR FORMULA

$C_6H_5NH_2$

MOLECULAR WEIGHT

93.125

Ref. *International Atomic Weights*, 1947.

MELTING POINT

Melting point = −6.24°C

Ref. Knowles, *Ind. Eng. Chem.*, Vol. 12 (1920), p.881.

BOILING POINT

Boiling point = 184.32°-184.39° at 760 mm Hg

Ref. Knowles, *Ind. Eng. Chem.*, Vol. 12 (1920), p.881.

DENSITY

Vapor — No information.

Liquid

The following values for the density of liquid aniline have been calculated from the data for specific volume in this reference.

Temperature (°C)	Density (gm/cc)
0.0	1.0389
5.25	1.0344
21.89	1.0200
30.63	1.0124
41.65	1.0029
50.12	0.9955
62.35	0.9849
79.04	0.9702
98.95	0.9524

Ref. Tyrer, *J. Chem. Soc.*, Vol.105 (1914), p.2534.

Solid — No information.

VAPOR PRESSURE

Temperature (°C)	Pressure (mm Hg)
43.1	1
47.9	2
51.8	3
55.0	4
57.9	5
69.2	10
77.2	15
82.8	20
87.2	25
90.9	30
94.0	35
96.9	40
99.5	45

VAPOR PRESSURE (*Cont'd*)

Temperature (°C)	Pressure (mm Hg)
101.9	50
111.9	75
119.4	100

Ref. Kahlbaum, *Z. physik. Chem.*, Vol. 26 (1898), p.603.

Temperature (°C)	Pressure (mm Hg)
131.5	150
139.6	200
146.5	250
152.1	300
157.0	350
161.4	400
165.3	450
169.3	500
172.5	550
175.6	600
178.5	650
181.2	700
184.3	760

Ref.. Beckmann and Liesche, *Z.physik. Chem.*, Vol.89 (1915), p.111.

TRIPLE POINT — No information

VISCOSITY

Vapor — No information

Liquid

Temperature (°C)	η (centipoises)
20	4.400
25	3.770
30	3.218
35	2.783
40	2.432
45	2.150
50	1.919
55	1.726
60	1.557

Liquid (*Cont'd*)

Temperature (°C)	η (centipoises)
65	1.415
70	1.296
75	1.190
80	1.098
85	1.018
90	0.9455
95	0.8817
98	0.840
100	0.8284

These values are accurate within ±0.20-0.30%

Ref. Steiner, *Ind. Eng. Chem.*, Anal. Ed., Vol.10 (1938), pp.582-584.

SURFACE TENSION

Temperature (°C)	γ (dynes/cm)
10	44.0
20	42.9
50	39.4
100	33.7
150	27.9
180	24.4

Ref. *International Critical Tables*, Vol.4 (1929), p.454.

COEFFICIENT OF THERMAL EXPANSION

The thermal expansion of aniline may be calculated by means of the following equation:

$$V_t = V_0 (1 + at + bt^2)$$

Temp Range (°C)	$a \times 10^4$	$b \times 10^7$
0-141	8.235	8.408
7-154	8.173	9.191

Ref. Landolt-Börnstein, *Physikalisch-Chemische Tabellen*, 2nd Suppl., p.1234.

COEFFICIENT OF THERMAL CONDUCTIVITY

Liquid

k = 0.000413 cal/sec cm deg at 0-20°C

Ref. Kaye and Higgins, *Proc. Roy. Soc. (London)*, Vol.A117 (1928), p.459.

Solid

k = 0.167 cal/sec cm deg at −40°C

Ref. *International Critical Tables*, Vol.5 (1929), p.216.

DIPOLE MOMENT

μ = 1.6 debye

Ref. Debye, *Dipole Moment and Chemical Structure*, 1931, p.29.

HEAT OF FUSION

ΔH_f = 27.09 cal/gm at −6.3°C

= 2,522 cal/mole at −6.3°C

Ref. Parks, Huffman, and Barmore, *J. Am. Chem. Soc.*, Vol.55 (1933), p.2733.

HEAT OF VAPORIZATION

ΔH_v = 104.3 cal/gm at 184.25°C

Ref. Luginin, *Ann. chim. et phys.* (7), Vol.27 (1902), pp.121 ff.

HEAT OF FORMATION

ΔH_{298} = 7,340 cal/mole

Ref. Parks and Huffman, *Free Energies of Some Organic Compounds*, 1932, p.39.

HEAT OF COMBUSTION

$\Delta H_c = -811{,}860$ cal/mole

Ref. Parks, Huffman, and Barmore, *J. Am. Chem. Soc.*, Vol.55 (1933), p.2733.

CRITICAL DATA

$t_c = 425.65°K$

$p_c = 52.35$ atm

Ref. Guye and Mallet, *Arch. sci. phys. et nat.*, Vol.134 (1902), p.168.

EQUATION OF STATE — No information

COMPRESSIBILITY

$$\beta t = \frac{1}{V_1} \cdot \frac{V_1 - V_2}{P_2 - P_1}$$

Where

V_1 = volume at t°C and pressure P_1

V_2 = volume at 2°C and pressure P_2

Temperature (°C)	Pressure (atm)	$\beta t \times 10^6$
25	85.5	43.2
25	181.5	40.5
25	281.5	38.3
25	390	36.1

Ref. Landolt-Börnstein, *Physikalisch-Chemische Tabellen*, 1st Suppl., p.95.

HEAT CAPACITY OF VAPOR, C_p AND C_v

RATIO OF SPECIFIC HEATS

} No information

HEAT CAPACITY OF LIQUID AND SOLID

Liquid

Temperature (°K)	C_p (cal/gm deg)
275.7	0.481
285.8	0.482
298.2	0.490

Ref. Parks, Huffman, and Barmore, *J. Am. Chem. Soc.*, Vol.55 (1933), p.2733.

Solid

Temperature (°K)	C_p (cal/gm deg)
93.5	0.128
99.8	0.133
107.7	0.141
118.6	0.152
139.5	0.172
159.9	0.195
180.3	0.219
200.2	0.245
211.3	0.260
220.2	0.270
229.1	0.282
236.3	0.293

Ref. Parks, Huffman, and Barmore, *J. Am. Chem. Soc.*, Vol.55 (1933), p.2733.

FREE ENERGY OF FORMATION

Liquid

$\Delta F^{\circ}_{298.1}$ = +35,400 cal/mole

Ref. Parks, Huffman, and Barmore, *J. Am. Chem. Soc.*, Vol.55 (1933), p.2733.

FREE-ENERGY FUNCTION

HEAT-CONTENT FUNCTION

No information

ENTROPY

$S_{298.1}$ = 45.8 cal/mole deg

$\Delta S_{298.1}$ = 94.2 cal/mole deg

Ref. Parks, Huffman, and Barmore, *J. Am. Chem. Soc.*, Vol.55 (1933), p.2733.

CARBON DISULFIDE

MOLECULAR FORMULA

CS_2

MOLECULAR WEIGHT

76.14

Ref. *International Atomic Weights*, 1947.

MELTING POINT

Melting point = −111.99 ± 0.05°C

Ref. Brown and Manov, *J. Am. Chem. Soc.*, Vol.59 (1937), p.500.

BOILING POINT

Boiling point = 46.262°C

Ref. Zmaczynski, *J. chim. phys.* (U.S.S.R.), Vol.27 (1930), p.503.

DENSITY

Vapor

Temp (°C)	Density (gm/ml)	Ref.	Temp (°C)	Density (gm/ml)	Ref.
−29.34	0.00004882	(1)	−14.01	0.00030710	(1)
−23.41	0.00014639	(1)	−3.06	0.0005103	(1)

DENSITY (*Cont'd*)

Vapor (*Cont'd*)

Temp (°C)	Density (gm/ml)	Ref.	Temp (°C)	Density (gm/ml)	Ref.
+8.26	0.0007992	(1)	99.24	0.011671	(1)
16.37	0.0010964	(1)	130.48	0.02166	(1)
22.44	0.0013642	(1)	159.10	0.03484	(1)
45.38	0.002934	(2)	171.52	0.04185	(1)
52.17	0.003559	(2)	183.40	0.05846	(1)
53.53	0.003709	(2)	193.05	0.07309	(1)
57.08	0.0040642	(1)	209.32	0.09907	(1)
59.94	0.004452	(2)	217.35	0.11627	(1)
64.24	0.005000	(2)	229.46	0.14205	(1)
66.96	0.005376	(2)	262.8	0.25700	(1)
70.10	0.005797	(2)	271.6	0.3215	(1)
75.55	0.006658	(2)	273.0	0.3679	(1)
78.82	0.007288	(1)	273.05	0.3772	(1)
85.03	0.008361	(2)			

Refs. (1) Battelli, *Mem. Tor.* (2), Vol.41 (1890), p.1; Vol.42 (1891), p.1.

(2) Wullner, and Grotrian *Wied. Ann.*, Vol.11 (1880), p.556.

Liquid

Temperature (°C)	Density (gm/ml)
13.45	1.27348
22.6	1.25983
33.95	1.24283

Ref. Schwers, *J. Chem. Soc.*, Vol.101 (1912), p.1889.

Temperature (°C)	Density (gm/ml)
−90	1.4363

Ref. Mazur, *Nature*, Vol.128 (1931), p.673.

Solid

d = 1.67367 gm/cc at −273°C (extrapolated value)

Ref. Timmermans, *Bull. soc. chim. Belg.*, Vol.32. (1923), p.299.

VAPOR PRESSURE

Temp (°C)	Press. (mm Hg)	Temp (°C)	Press. (mm Hg)
−70	1.6	−30	26.2
−60	3.5	−20	46.5
−50	7.1	−10	78.8
−40	14.0	0	127.3

Ref. *International Critical Tables*, Vol.3 (1928), p.23.

Temp (°C)	Press. (mm Hg)	Temp (°C)	Press. (mm Hg)
10	198.01	150	9,095
20	296.48	160	10,963
30	432.76	170	12,449
40	616.75	180	17,095
50	859.49	190	20,317
60	1,172.9	200	23,813
70	1,569.6	210	27,555
80	2,062.1	220	31,519
90	2,662.8	230	35,675
100	3,383.4	240	39,994
110	4,234.4	250	44,445
120	5,225.	260	48,997
130	6,362	270	53,622
140	7,652.	273.05	55,380

Ref. Battelli, *Atti. accad., nazl. Lincei*, (5), Vol.16, I (1907). p.243.

TRIPLE POINT

No information

VISCOSITY

Vapor Temperature (°C)	$\eta \times 10^7$ (poises)	Reference
0	911	(1)
14.2	964	(1)
114.3	1303	(2)
152.8	1434	(2)
190.2	1561	(2)
228.2	1692	(2)
267.3	1830	(2)
309.8	1966	(2)

Refs.(1) Suhrmann, *Z. Physik*, Vol. 14 (1923), p.56.

Refs.(2) Titani, *Bull. Chem. Soc. Japan*, Vol.8 (1933), p.255.

VISCOSITY (*Cont'd*)

Liquid

Temperature (°C)	$\eta \times 10^4$ (poises)
0.40	43.62
4.88	41.3
9.45	39.7
10.8	38.39
14.91	39.01
19.94	37.63
25.34	36.56
30.30	34.2
35.51	32.8
40.60	31.7
45.96	31.67

Ref. Thorpe and Rodger, *Phil. Trans.*, Vol.185A (1894), p.397.

SURFACE TENSION (WITH AIR INTERFACE)

Temperature (°C)	γ (dynes/cm)	Reference
0	35.28	(1)
10	33.81	(1)
21	32.2	(2)
25	29.33	(3)
45	28.66	(1)
60	26.45	(1)

Refs.(1) *International Critical Tables*, Vol.4 (1928), p.447.

(2) *Ibid.*, 475.

(3) Worthington, *Phil.Mag.*(5)., Vol.20 (1885), p.66.

COEFFICIENT OF THERMAL EXPANSION

$$V_t = V_0(1 + \alpha t)$$

Temp (°C)	α	Reference
−105	0.00105	(1)
−100	0.001037	(2)
−80	0.001026	(1)
−60	0.00103	(1)

Temp (°C)	α	Reference
−50	0.001048	(2)
−40	0.00105	(1)
−20	0.00109	(1)
0	0.001132	(2)
+15	0.00122	(1)

Refs. (1) Mazur, *Nature*, Vol. 144 (1939), p. 328.

(2) Seitz, Alterthum, and Lechner, *Ann. Physik*, Vol. 49 (1916), p. 85.

COEFFICIENT OF THERMAL CONDUCTIVITY

Temperature (°C)	k (cal/cm sec deg)	Reference
0	0.0003879	(1)
30	0.000380	(2)
75	0.000362	(2)

Refs. (1) Goldschmidt, *Physik. Z.*, Vol. 12 (1911), p. 417.

(2) Bridgman, *Proc. Am. Acad. Arts Sci.*, Vol. 59 (1923), p. 141.

Conductivity at higher pressures:

The ratios of thermal conductivity of liquid carbon disulfide at pressure P, in kg/cm^2, and t, °C, to that at a pressure of 1 atmosphere and the same temperature are tabulated in Table 11 of the Bridgman reference.

Press., kg/cm^2	2,000	4,000	6,000	8,000	10,000	12,000
Ratio at 30°C	1.310	1.512	1.663	1.783	1.880	1.962
Ratio at 75°C	1.366	1.607	1.789	1.935	2.054	2.154

Ref. Bridgman, *Proc. Am. Acad. Arts Sci.*, Vol. 59 (1923), p. 141.

DIPOLE MOMENT

$\mu = 0$ debye

Ref. Schwingel and Williams, *Phys. Rev.*, Vol. 35 (1930), p. 855.

HEAT OF FUSION

ΔH_f = 1049 ± 3 cal/mole at −111.99°C

Ref. Brown and Manov, *J. Am. Chem. Soc.*, Vol.59 (1937), p.500.

HEAT OF VAPORIZATION

Temperature (°C)	ΔH_v (cal/gm)
0	89.4
20	87.5
40	85.1
46.25	84.1 ± 0.3%
60	82.2
80	79.1
100	75.5
120	71.7
140	67.3

Ref. *International Critical Tables*, Vol.5 (1929), p.138.

HEAT OF FORMATION

$C(\beta\text{-graphite}) + 2S(rh) = CS_2(l)$

$\Delta H_{298.1}$ = 20,900 cal/mole

$C(\beta\text{-graphite}) + 2S(rh) = CS_2(g)$

$\Delta H_{298.1}$ = 27,580 cal/mole

Ref. Kelley, *U.S. Bur. Mines Bull. 406* (1937).

HEAT OF COMBUSTION

$CS_2(l) + 3O_2 = 2SO_2(g) + CO_2(g)$ (18°C and 1 atm)

ΔH_c = −246.6 kcal/mole

Ref. Kharasch, *J. Research Nat. Bur. Standards*, Vol.2 (1929), p.359.

CRITICAL DATA

t_c = 273.05°C

p_c = 72.868 atm

Ref. Battelli, *Atti. accad. nazl. Lincei* (5), Vol.16, I (1907), p.243.

EQUATION OF STATE

$$\left(P + \frac{n^2 a}{V^2}\right)(V - nb) = nRT$$

where

P = pressure, atm
V = volume, liters/mole
T = temp, °K
R = gas constant, 0.08207 liter atm/mole deg
n = number of moles
a = 11.62 liters^{2}atm/moles^2
b = 0.07685 liters/mole

Ref. Battelli, *Atti. accad. nazl. Lincei* (5), Vol.16, I (1907), p.243.

COMPRESSIBILITY

Temperature (°C)	Pressure (atm)	$\beta \times 10^6$, atm^{-1}
-104.7	0	40.5
-104.7	484	35.2
-49.94	0	57.4
-49.94	484	45.3
-49.94	967	40.1

Ref. Seitz and Lechner, *Ann. Phys.* (4), Vol.49 (1916), p.93.

Temperature (°C)	Pressure (atm)	$\beta \times 10^6$, atm^{-1}
0	1-500	66
0	500-1,000	53
0	1,000-1,500	43
0	1,500-2,000	37
0	2,000-2,500	33
0	2,500-3,000	29
49.15	1,000-1,500	51
49.15	1,500-2,000	44
49.15	2,000-2,500	38

Ref. Amagat, *Ann. chim. et phys.* (6), Vol.29 (1893), pp.68 and 505.

COMPRESSIBILITY (Cont'd)

Temperature (°C)	Pressure (atm)	$\beta \times 10^6$, atm^{-1}
20	107	77.2
20	262.5	69.6
20	441.5	60.1
20	679.5	51.0

Ref. Ritzel, *Z. physik. Chem.*, Vol.60 (1907), p.319.

Relative Volumes at

Pressure kg/cm^2	20°C	30°C	40°C	50°C	60°C	70°C	80°C
1	1.0235	1.0357	1.0490	1.0630	1.0775	1.0928	1.0992
1,000	0.9586	0.9671	0.9752	0.9829	0.9907	0.9991	1.0093
2,000	0.9173	0.9240	0.9302	0.9362	0.9423	0.9485	0.9552
4,000	0.8647	0.8688	0.8732	0.8770	0.8823	0.8855	0.8902
6,000	0.8295	0.8329	0.8367	0.8406	0.8442	0.8472	0.8501
8,000	0.8022	0.8061	0.8100	0.8131	0.8162	0.8191	0.8220
10,000	0.7805	0.7844	0.7879	0.7910	0.7940	0.7969	0.7997
12,000	0.7638	0.7658	0.7682	0.7710	0.7743	0.7772	0.7795

Ref. Bridgman, *Proc. Am. Acad. Arts Sci.*, Vol.49 (1913), p.4.

HEAT CAPACITY OF GAS, C_p, AND C_v

Temp (°K)	C_p (cal/mole deg)	Temp (°K)	C_p (cal/mole deg)
298.1	10.91	1100	14.15
400	11.85	1200	14.26
500	12.52	1300	14.35
600	13.00	1400	14.42
700	13.37	1500	14.48
800	13.65	1600	14.53
900	13.86	1700	14.57
1000	14.02	1800	14.61

0°C = 273.1°K

Ref. Cross, *J. Chem. Phys.*, Vol.3 (1935), p.825.

RATIO OF SPECIFIC HEATS

Temperature (°C)	C_p/C_v
0	1.536
10	1.544
20	1.556
30	1.574
40	1.603
50	1.636

Ref. Freyer, Hubbard, and Andrews, *J. Am. Chem. Soc.*, Vol.51 (1929), p.759.

HEAT CAPACITY OF LIQUID AND SOLID

Liquid

Temp (°K)	C_p (cal/mole deg)	Temp (°K)	C_p (cal/mole deg)
161.11	Melting Point	219.31	17.95
163.93	18.10	227.34	17.93
169.51	17.97	235.80	18.00
176.17	17.91	244.25	18.00
183.04	17.94	253.06	17.88
189.64	17.99	261.66	18.10
192.30	17.91	269.69	18.08
198.44	17.90	278.22	18.06
205.28	18.00	297.43	18.17
211.83	18.02		

0°C = 273.1°K

Ref. Brown and Manov, *J. Am. Chem. Soc.*, Vol.59 (1937), p.500.

Temperature (°C)	C_v (cal/gm deg)
0	0.160
−20	0.139
−50	0.121
−70	0.114
−90	0.110

Ref. Zakrzewski, *Anz. Akad. Wiss.*, Krakau (A), 1917, pp.86-101.

HEAT CAPACITY OF LIQUID AND SOLID (*Cont'd*)

Solid

Temp (°K)	C_p (cal/mole deg)	Temp (°K)	C_p (cal/mole deg)
15.05	1.65	94.21	10.76
17.50	2.22	99.00	10.98
20.15	2.87	104.00	11.31
23.06	3.48	108.17	11.48
26.19	4.18	108.93	11.59
29.76	4.96	114.03	11.82
33.68	5.64	119.36	12.04
37.67	6.32	119.91	12.07
42.22	6.97	126.03	12.39
47.39	7.53	131.54	12.58
52.25	7.91	137.38	12.81
57.52	8.50	144.31	13.05
63.47	8.92	150.47	13.26
69.96	9.36	152.23	13.34
75.54	9.57	155.63	13.50
81.19	9.86	156.83	13.53
87.21	10.31	158.74	14.46
89.37	10.31	161.11	Melting Point
94.17	10.61		

Ref. Brown and Manov, *J. Am. Chem Soc.*, Vol.59 (1937), p.500.

FREE ENERGY OF FORMATION

$$C(\text{graphite}) + 2S(rh) = CS_2(l)$$

$$\Delta F^\circ_{298.1} = 15{,}160 \text{ cal/mole}$$

Ref. Kelley, *U.S. Bur. Mines Bull. 406* (1937).

$$C(\text{graphite}) + 2S(rh) = CS_2(g)$$

Temperature (°K)	ΔF_f° (cal/mole)
298.1	15,600
400	11,550
500	7,660
600	3,860
700	140
800	−3,470
900	−6,990

Temperature (°K)	ΔF_f° (cal/mole)
1000	−10,400
1100	−13,700
1200	−16,890

Ref. Thacker, Folkins and Miller, *Ind. Eng. Chem.*, Vol.33 (1941), p.584.

FREE ENERGY FUNCTION

$$C(\text{graphite}) + S_2(g) = CS_2(g)$$

Temp (°K)	$-(F^\circ - E_o^\circ)/T$ (cal/mole deg)	Temp (°K)	$-(F^\circ - E_o^\circ)/T$ (cal/mole deg)
298.1	48.28	1100	61.63
400	50.90	1200	62.67
500	53.04	1300	63.65
600	54.89	1400	64.57
700	56.51	1500	65.44
800	57.97	1600	66.25
900	59.30	1700	67.02
1000	60.51	1800	67.75

Ref. Cross, *J. Chem. Phys.*, Vol.3 (1935), p.825.

HEAT-CONTENT FUNCTION No information

ENTROPY

$$C(\text{graphite}) + S_2(g) = CS_2(g)$$

Temp (°K)	S_t° (cal/mole deg)	Temp (°K)	S_t° (cal/mole deg)
298.1	56.84	1100	73.50
400	60.19	1200	74.74
500	62.91	1300	75.89
600	65.24	1400	76.96
700	67.27	1500	77.97
800	69.08	1600	78.91
900	70.70	1700	79.79
1000	72.16	1800	80.61

Ref. Cross, *J. Chem. Phys.*, Vol.3 (1935), p.825.

For $CS_2(l)$ $S^\circ_{298.1} = 36.10$ cal/mole

Ref. Brown and Manov, *J. Am. Chem. Soc.*, Vol.59 (1937), p.500.

CARBON MONOXIDE

MOLECULAR FORMULA

CO

MOLECULAR WEIGHT

28.01

Ref. *International Atomic Weights*, 1947.

MELTING POINT

Melting point = −205.07°C

Ref. Clayton and Giauque, *J. Am. Chem. Soc.*, Vol.54 (1932), p.2610.

BOILING POINT

Boiling point = −191.48°C at 760 mm Hg

Ref. Clusius and Teske, *Z. physik. Chem.* B, Vol.6 (1929), p.148.

DENSITY

Gas and Liquid in Equilibrium With Each Other

Temperature (°C)	Density (gm/ml)	
	Liquid	Gas
−150	0.5580	0.0880
−146	0.5230	0.1104
−143	0.4807	0.1479
−140	0.4258	0.2016
−138.7	0.3110	0.3110 (Critical Point)

Ref. Cardozo, *J. chim. phys.*, Vol.13 (1915), p.312.

Liquid

Temperature (°C)	Density (gm/ml)
−205	0.8558
−200	0.8348
−195	0.8138
−190	0.7929
−185	0.7718
−184	0.7676

Ref. Baly and Donnan, *J. Chem. Soc.*, Vol.81 (1902), p.911.

VAPOR PRESSURE

Temperature (°K)	Pressure (atm)
56.86	0.009493 (Solid)
62.68	0.048003
64.96	0.079931
67.14	0.12866
68.10	0.15146 (Melting Point)
73.85	0.37198 (Liquid)
77.96	0.64566
81.45	0.98131
81.61	1.000
87.61	1.8833
94.34	3.473
103.48	6.922
112.20	12.072
125.96	25.014
131.82	32.911
132.88	34.529 (Critical Point)

Ref. Crommelin, Bijleveld, and Brown, *Proc. Acad. Sci. (Amsterdam)*, Vol.34 (1931), p.1314.

TRIPLE POINT

Temperature (°C) = −204.99

Pressure (atm) = 0.15146

Ref. Crommelin, Bijleveld, and Brown, *Proc. Acad. Sci. (Amsterdam)*, Vol.34 (1931), p.1314.

VISCOSITY

Temp (°C)	$\eta \times 10^7$ (poises)	Temp (°C)	$\eta \times 10^7$ (poises)
−191.6	565	+15.1	1730
−149.2	868.5	17.1	1731
−78.4	1280	55.9	1903
−78.2	1286.6	100.4	2086
−37.7	1477	101.3	2090
−35.5	1489	151.0	2283
0.0	1630	200.2	2467
		250.0	2635

Ref. Landolt-Börnstein, *Physikalisch-Chemische Tabellen* (Berlin), Vol.1, p.173; 1st Suppl., p.143; 2nd Suppl., p.138.

SURFACE TENSION

Temperature (°C)	γ (dynes/cm)
−188	8.7
−193	9.8
−203	12.1

Above values for liquid interface in contact with its vapor.

Ref. Lange, *Handbook of Chemistry*, fourth edition, 1937.

COEFFICIENT OF THERMAL EXPANSION

$\alpha = 0.003673$ between 0° and 100°C

This value represents the change in volume per unit volume per degree centigrade.

Ref. Perry, *Chemical Engineer's Handbook*, second edition, p.486.

COEFFICIENT OF THERMAL CONDUCTIVITY

Gas

Temperature (°C)	$k \times 10^5$ (cal/cm sec deg)
−191	1.7
−181	1.9
0	5.6

Ref. Perry, *Chemical Engineer's Handbook*, second edition, p.959.

DIPOLE MOMENT

$\mu = 0.12$ debye

Ref. Getman and Daniels, *Outlines of Theoretical Chemistry*, sixth edition, p.100.

HEAT OF FUSION

$\Delta H_f = 7.132$ cal/gm at 68.09°K

Ref. Clayton and Giauque, *J. Am. Chem. Soc.*, Vol.54 (1932), p.2610.

HEAT OF VAPORIZATION

$\Delta H_v = 51.60$ cal/gm at 760 mm Hg

Ref. Clusius and Teske, *Z. physik. Chem.*, B, Vol.6 (1929), p.148.

HEAT OF FORMATION

$$C(\text{graphite}) + \tfrac{1}{2} O_2 = CO_2(\text{gas})$$

Temperature (°K)	$\Delta H_t°$(kcal/mole)
0	−27.2019
298.16	−26.4157
300	−26.4131
400	−26.317
500	−26.295
600	−26.330
700	−26.407
800	−26.511
900	−26.635
1000	−26.768
1100	−26.909
1200	−27.056
1300	−27.212
1400	−27.376
1500	−27.545

Ref. Wagman, *et al.*, *J. Research Nat. Bur. Standards*, Vol.34 (1945), p.143.

HEAT OF COMBUSTION

$H_c = 67,636.1 \pm 28.7$ cal/mole

Ref. Rossini, *J. Research Nat. Bur. Standards*, Vol.22 (1939), p.407.

CRITICAL DATA

$t_c = -138.7°C$

$p_c = 34.60$ atm

$d_c = 0.3110$ gm/ml

Ref. Cardozo, *J. chim. phys.*, Vol.13 (1915), p.312.

EQUATION OF STATE

$$\left(P + \frac{n^2 a}{V^2}\right)(V - nb) = nRT$$

where

P = pressure, atm
V = volume, liters/mole
T = absolute temperature, °K
R = gas constant = 0.08207 liter atm/mole deg
n = number of moles
a = 1.4844 liters^2 atm/mole^2
b = 0.03987 liter/mole

Ref. Dodge, *Chemical Engineering Thermodynamics*, p.662.

COMPRESSIBILITY

PV = 1.000 AT 1 ATMOSPHERE AND 0°C

Pressure (atm)	-70°C	-50°C	-25°C	0°C	25°C	50°C	100°C	150°C	200°C
1	0.7427	0.8162	0.9082	1.0000	1.0918	1.1836	1.3671	1.5504	1.7336
10	0.7275	0.8061	0.9025	0.9960	1.0885	1.1830	1.3700	1.5565	1.7423
20	0.7115	0.7947	0.8960	0.9912	1.0858	1.1827	1.3735	1.5630	1.7510
30	0.6950	0.7840	0.8895	0.9868	1.0836	1.1820	1.3769	1.5695	1.7595
40	0.6792	0.7730	0.8833	0.9825	1.0820	1.1821	1.3800	1.5755	1.7683
50	0.6636	0.7622	0.8768	0.9780	1.0814	1.1826	1.3837	1.5823	1.7758
60	0.6495	0.7530	0.8712	0.9755	1.0810	1.1842	1.3878	1.5880	1.7833
80	0.6274	0.7355	0.8620	0.9718	1.0820	1.1893	1.3967	1.6008	1.7985
100	0.6147	0.7264	0.8592	0.9725	1.0851	1.1955	1.4062	1.6151	1.8146
200	0.6631	0.7656	0.9022	1.0200	1.1415	1.2561	1.4794	1.6987	1.9090
300	0.7955	0.8872	1.0087	1.1211	1.2408	1.3521	1.5798	1.8054	2.0183
400	0.9434	1.0285	1.1403	1.2487	1.3625	1.4716	1.6963	1.9178	2.1380
500	1.0920	1.1755	1.2831	1.3843	1.4940	1.6023	1.8235	2.0450	2.2627
600	1.2386	1.3225	1.4282	1.5256	1.6317	1.7378	1.9557	2.1757	2.3923
800	1.5236	1.6100	1.7153	1.8064	1.9115	2.0144	2.2244	2.4442	2.6702
1000	1.7992	1.8871	1.9935	2.0827	2.1857	2.2879	2.4935	2.7142	2.9264

Ref. Perry, *Chemical Engineers' Handbook*, second edition, p.491.

HEAT CAPACITY OF THE GAS, C_p AND C_v

Temp (°C)	C_p° (cal/ mole deg)	Temp (°C)	C_p° (cal/ mole deg)
200	6.956	1200	8.167
250	6.958	1250	8.218
298.16	6.965	1300	8.265
300	6.965	1400	8.349
400	7.013	1500	8.419
500	7.120	1750	8.561
600	7.276	2000	8.665
700	7.451	2500	8.806
800	7.624	3000	8.899
900	7.787	3500	8.963
1000	7.932	4000	9.015
1100	8.058	4500	9.059
		5000	9.099

Ref. Wagman, *et al., J. Research Nat. Bur. Standards*, Vol.34 (1945), pp.143-61.

Temp (°C)	C_v (cal/ mole deg)	Temp (°C)	C_v (cal/ mole deg)
0	4.97	1100	6.34
25	4.99	1200	6.42
100	5.01	1300	6.485
200	5.10	1400	6.54
300	5.25	1500	6.59
400	5.40	1750	6.69
500	5.58	2000	6.77
600	5.76	2250	6.83
700	5.91	2500	6.88
800	6.04	2750	6.92
900	6.16	3000	6.94
1000	6.26		

Ref. Justi, *Spezifische Wärme, Enthalpie, Entropie und Dissoziation technischer Gase*, 1938, p.108.

RATIO OF SPECIFIC HEATS No information

HEAT CAPACITY OF LIQUID AND SOLID

Temperature (°K)	C_p (cal/gm deg)
11.89	0.0433 (Solid)
16.19	0.0823
23.9	0.1537
47.6	0.3086
57.0	0.457
63.2	0.4339
66.3	0.439
70.1	0.551 (Liquid)
81.3	0.567

Ref. Clusius, *Z. physik. Chem.*, B, Vol.3 (1929), p.41.

FREE ENERGY OF FORMATION

$$C(\text{graphite}) + \tfrac{1}{2}\,O_2(\text{gas}) = CO(\text{gas})$$

Temperature (°K)	ΔF_f° (kcal/mole)
0	−27.2019
298.16	−32.8079
300	−32.8464
400	−35.007
500	−37.184
600	−39.358
700	−41.526
800	−43.677
900	−45.816
1000	−47.942
1100	−50.053
1200	−52.153
1300	−54.235
1400	−56.308
1500	58.370

Ref. Wagman, *et al.*, *J. Research Nat. Bur. Standards*, Vol.34 (1945), pp.143-61.

FREE-ENERGY FUNCTION

Temp (°K)	$-(F^\circ - H_o^\circ)/T$ (cal/mole deg)	Temp (°K)	$-(F^\circ - H_o^\circ)/T$ (cal/mole deg)
200	37.574	1250	50.497
250	39.124	1300	50.789
298.16	40.350	1400	51.345
300	40.391	1500	51.884
400	42.393	1750	53.041
500	43.947	2000	54.078
600	45.222	2500	55.842
700	46.308	3000	57.314
800	47.254	3500	58.578
900	48.097	4000	59.688
1000	48.860	4500	60.676
1100	49.554	5000	61.566
1200	50.196		

Ref. Wagman, *et al.*, *J. Research Nat. Bur. Standards*, Vol.34 (1945), pp.143-61.

HEAT CONTENT FUNCTION

Temp (°K)	$(H^\circ - H_o^\circ)/T$ (cal/mole deg)	Temp (°K)	$(H^\circ - H_o^\circ)/T$ (cal/mole deg)
200	6.9470	1250	7.4221
250	6.9495	1300	7.4538
298.16	6.9514	1400	7.5149
300	6.9515	1500	7.5725
400	6.9594	1750	7.7033
500	6.9799	2000	7.8182
600	7.0159	2500	8.0028
700	7.0654	3000	8.1448
800	7.1247	3500	8.2572
900	7.1895	4000	8.3487
1000	7.2565	4500	8.4238
1100	7.3238	5000	8.4905
1200	7.3898		

Ref. Wagman, *et al.*, *J. Research Nat. Bur. Standards*, Vol.34 (1945), pp.143-61.

ENTROPY

Temp (°K)	S_t° (cal/mole deg)	Temp (°K)	S_t° (cal/mole deg)
200	44.251	1250	57.919
250	46.074	1300	58.243
298.16	47.301	1400	58.860
300	49.342	1500	59.436
400	49.352	1750	60.744
500	50.927	2000	61.896
600	52.238	2500	63.845
700	53.373	3000	65.459
800	54.379	3500	66.835
900	55.287	4000	68.037
1000	56.116	4500	69.100
1100	56.878	5000	70.056
1200	57.586		

Ref. Wagman, *et al.*, *J. Research Nat. Bur. Standards*, Vol.34 (1945), pp.143-61.

CYANOGEN

MOLECULAR FORMULA

$N \equiv C - C \equiv N$; C_2N_2

MOLECULAR WEIGHT

52.036

Ref. *International Atomic Weights*, 1947.

MELTING POINT

Melting Point = −27.83°C

Ref. Ruehrwein and Giauque, *J. Am. Chem. Soc.*, Vol.61 (1939), p.2940.

BOILING POINT

Boiling Point = −21.15°C

Ref. Ruehrwein and Giauque, *J. Am. Chem. Soc.*, Vol.61 (1939), p.2940.

DENSITY

Gas — No information

Liquid

d = 0.866 at 17°C

Ref. *International Critical Tables*, Vol.3 (1928), p.231.

Solid — No information

VAPOR PRESSURE

Temperature (°K)	Pressure (mm Hg)
179.94	1.7 (Solid)
190.7	5.65
191.25	6.48
199.05	12.79
203.86	22.29
212.41	47.53
224.08	123.2
230.27	196.7
237.82	336.4
239.92	390.9
240.79	412.9
245.93	572.6 (Liquid)
247.91	629.8
251.77	754.0
255.35	886.4
258.26	1007.4
260.03	1086.4
261.82	1171.5
263.40	1250.7
265.97	1387.4

(0°C = 273.1°K)

Ref. Perry and Bardwell, *J. Am. Chem. Soc.*, Vol.47 (1925), p.2629.

TRIPLE POINT

Temperature (°C) = −27.83

Pressure (mm Hg) = 553.6

Ref. Ruehrwein and Giauque, *J. Am. Chem. Soc.*, Vol.61 (1939), p.2940.

VISCOSITY

Gas

Temperature (°C)	$\eta \times 10^6$ (poises)
0	92.8
17	98.7
100	127.1

Ref. *International Critical Tables*, Vol.5 (1929), p.3.

Liquid — No information

SURFACE TENSION — No information

COEFFICIENT OF THERMAL EXPANSION

α(constant pressure) = 0.00396 at 0°C

0.00387 at 0-100°C

Ref. *International Critical Tables*, Vol.3 (1928), p.16.

COEFFICIENT OF THERMAL CONDUCTIVITY — No information

DIPOLE MOMENT

μ = 0.3 debye

Ref. Braune and *Asche, Z. physik Chem., B*, Vol.14 (1931), pp.18-26.

HEAT OF FUSION

ΔH_f = 1938 ± 1 cal/mole

Ref. Ruehrwein and Giauque, *J. Am. Chem. Soc.*, Vol.61 (1939), p.2940.

HEAT OF VAPORIZATION

ΔH_v = 5576 ± 5 cal/mole at −21.15°C

Ref. Ruehrwein and Giauque, *J. Am. Chem. Soc.*, Vol.61 (1939), p.2940.

HEAT OF FORMATION (GAS)

ΔH_{298} = +72,800 ± 200 cal/mole

Ref. Wartenberg and Schutla, *Z. physik. Chem.*, A, Vol.164 (1933), p.386.

HEAT OF COMBUSTION

ΔH_c = −261,300 ± 200 cal/mole

Ref. Wartenberg and Schutla, *Z. physik. Chem.*, A, Vol.164 (1933), p.386.

CRITICAL DATA

t_c = 128.3°C

P_c = 59.75 atm

Ref. Cardozo and Baume, *J. chim. phys.*, Vol.10 (1912), pp.470-511.

EQUATION OF STATE

COMPRESSIBILITY

} No information

HEAT CAPACITY OF GAS, C_p AND C_v

Temperature (°K)	C_p (cal/mole deg)
250	12.79
300	13.60
350	14.25
400	14.78
450	15.22
500	15.67

Ref. Stevenson, *J. Chem. phys.*, Vol.7 (1939), p.171.

Temperature (°K)	C_v (cal/mole deg)
294.1	12.04
320.4	12.29

Ref. Stitt, *J. Chem. Phys.*, Vol.7 (1939), p.1115.

RATIO OF SPECIFIC HEATS, C_p/C_v

$C_p/C_v = 1.256$ at 15°C

Ref. *International Critical Tables*, Vol.5 (1929), p.80.

HEAT CAPACITY OF LIQUID AND SOLID

Temp (°K)	C_p (cal/mole deg)	Temp (°K)	C_p (cal/mole deg)
15	0.86	110	12.08
20	1.76	120	12.73
25	2.82	130	13.35
30	3.78	140	13.91
35	4.74	150	14.47
40	5.57	160	15.02
45	6.33	170	15.58
50	7.02	180	16.20
60	8.20	190	16.82
70	9.13	200	17.45
80	9.97	210	18.11
90	10.71	220	18.82
100	11.41	230	19.54

Temp (°K)	C_p (cal/ mole deg)	Temp (°K)	C_p (cal/ mole deg)
240	20.27	251.95	Boiling Point
245.27	Melting Point	255	25.27
250	25.17		

$0°C = 273.10°K$

Data above obtained from smooth curve through experimental points.

Ref. Ruehrwein and Giauque, *J. Am. Chem. Soc.*, Vol.61 (1939), p.2940.

FREE ENERGY OF FORMATION

$\Delta F_{298.1} = 69,100$ cal/mole

Ref. Stevenson, *J. Chem. Phys.*, Vol.7 (1939), p.171.

FREE ENERGY FUNCTION

Temperature (°K)	$-(F° - E_o°)/T$ (cal/mole deg)
250	45.98
298.1	47.70
350	49.40
400	50.87

Ref. Stevenson, *J. Chem. Phys.*, Vol.7 (1939), p.171.

HEAT CONTENT FUNCTION

Temperature (°K)	$-(H° - E_o°)/T$ (cal/mole deg)
250	2.40
291.1	2.90
298.1	3.03
350	3.75
400	4.48

Ref. Stevenson, *J. Chem. Phys.*, Vol.7 (1939), p.171.

ENTROPY

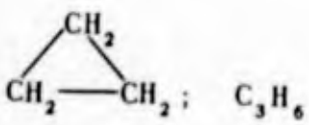
Temperature (°K)	S_t° (cal/mole deg)
291.16	57.58
298.16	57.91
300	57.98
350	60.13
400	62.17
450	63.84
500	65.49
600	68.39
700	70.94
800	73.20
900	75.32
1,000	77.22

From spectrographic measurements of translational, rotational, and vibrational levels.

Ref. Thompson, *Trans. Faraday Soc.*, Vol.37 (1941), p.344.

CYCLOPROPANE

MOLECULAR FORMULA



C_3H_6

MOLECULAR WEIGHT

42.08

Ref. *International Atomic Weights*, 1947.

MELTING POINT

Melting point = −127.6°C

Ref. Ruehrwein and Powell, *J. Am. Chem. Soc.*, Vol.68 (1946), p. 1063.

BOILING POINT

Boiling point = −32.8°C at 760 mm Hg

Ref. Ruehrwein and Powell, *J. Am. Chem. Soc.*, Vol.68 (1946), p.1063.

DENSITY

Gas

d = 1.7463 ± 0.0009 gm/liter at 35°C and 1 atm

Ref. Ruehrwein and Powell, *J. Am. Chem, Soc.*, Vol.68 (1946), p.1063.

Liquid

Temperature (°C)	Density (gm/ml)
−30	0.6769
−40	0.6886
−50	0.7002
−60	0.7119
−70	0.7235
−80	0.7352
at normal boiling point	0.6807

Ref. Grosse and Linn, *J. Am. Chem. Soc.*, Vol.61 (1939), p.752.

Solid — No information

VAPOR PRESSURE

Temperature (°K)	Pressure (mm Hg)
183.13	26.3
191.35	49.0
195.70	66.7
199.86	88.2
204.94	122.0
209.93	164.9
215.05	220.9
220.05	289.6
225.13	375.9
229.88	473.9
235.18	606.9
238.35	698.4
241.08	785.6

Ref. Ruehrwein and Powell, *J. Am. Chem. Soc.*, Vol.68 (1946), p.1063.

TRIPLE POINT — No information

VISCOSITY

Gas

Temperature (°C)	$\eta \times 10^7$ (poises)
0	807
20	876
40	923

Ref. Titani, *Bull. Chem. Soc., Japan*, Vol.5 (1930), p.98.

Liquid — No information

SURFACE TENSION
COEFFICIENT OF THERMAL EXPANSION
COEFFICIENT OF THERMAL CONDUCTIVITY
DIPOLE MOMENT
} No information

HEAT OF FUSION

ΔH_f = 1,301 cal/mole at 127.62°C

Ref. Ruehrwein and Powell, *J. Am. Chem. Soc.*, Vol.68 (1946), p.1063.

HEAT OF VAPORIZATION

ΔH_v = 4,793 cal/mole at −32.86°C

Ref. Ruehrwein and Powell, *J. Am. Chem. Soc.*, Vol.68 (1946), p.1063.

HEAT OF FORMATION

No reliable reference quoted. Using heat of combustion of cyclopropane as −496,800 and heat of formation of CO_2 and H_2O as −94,052 and −68,317, respectively, the calculated heat of formation of cyclopropane would be

+9,690 cal/mole

HEAT OF COMBUSTION

$\Delta H_c = -496{,}800$ cal/mole

Ref. Kharasch, *J. Research Nat. Bur. Standards*, Vol.2 (1929), p.373.

CRITICAL DATA

$t_c = 124.6°C$

$p_c = 54.22$ atm

Ref. Doss, *Physical Constants of the Principal Hydrocarbons*, fourth edition, 1943, p.106.

EQUATION OF STATE
COMPRESSIBILITY } No information

HEAT CAPACITY OF GAS, C_p AND C_v

Temperature (°K)	C_p° (cal/mole deg)
100	7.96
150	8.25
200	9.30
250	11.14
300	13.44
350	15.88
400	18.33
500	22.64
600	26.14
700	29.04
800	31.45
900	33.57
1000	35.37

Ref. Kistiakowsky and Rice, *J. Chem. Phys.*, Vol.8 (1940), p.610.

RATIO OF SPECIFIC HEATS No information

HEAT CAPACITY OF LIQUID AND SOLID

Liquid

Temperature (°K)	C_p (cal/mole deg)
150	18.12
160	17.97
170	17.95
180	18.00
190	18.11
200	18.26
210	18.45
220	18.69
230	19.01
240	19.44
240.30	Boiling point

Solid

Temperature (°K)	C_p (cal/mole deg)
15	0.68
20	1.34
25	2.27
30	3.31
35	4.42
40	5.41
45	6.28
50	7.11
60	8.59
70	9.71
80	10.62
90	11.49
100	12.27
110	12.94
120	13.62
130	14.39
140	15.18
145.4	Melting point

Ref. Ruehrwein and Powell, *J. Am. Chem. Soc.*, Vol.68 (1946), p.1063.

FREE ENERGY OF FORMATION

No reliable information quoted from literature. It can be calculated, using the following data

	Entropy, $S^\circ_{298.1}$	$\Delta H^\circ_{298.1}$
Cyclopropane (gas)	56.84	9,690
Hydrogen (gas)	31.211	
Carbon (graphite)	1.3609	

to obtain a value:

$$\Delta F_{298.1} = 21{,}880 \text{ cal/mole.}$$

FREE-ENERGY FUNCTION

Temperature (°K)	$-(F - E_o^\circ)/T$ (cal/mole deg)
100	38.71
150	41.93
200	44.25
250	46.11
300	47.73
350	49.21
400	50.60
500	53.22
600	55.72
700	58.15
800	60.47
900	62.71
1000	64.90

Ref. Kistiakowsky and Rice, *J. Chem. Phys.*, Vol.8 (1940), p.610.

HEAT-CONTENT FUNCTION

No information

ENTROPY

Temperature (°K)	S° (cal/mole deg)
100	46.66
150	49.92
200	52.43
250	54.69

ENTROPY (*Cont'd*)

Temperature (°K)	S_t° (cal/mole deg)
300	56.92
350	59.18
400	61.46
500	66.03
600	70.47
700	74.73
800	78.78
900	82.61
1000	86.24

Ref. Linnett, *J. Chem. Phys.*, Vol.6 (1938), p.692; Kistiakowsky and Rice, *J. Chem. Phys.*, Vol.8 (1940), p.610.

$S^\circ_{298.1}$ = 56.84 cal/mole deg, based on molecular data and ignoring entropy of nuclear spin.

Ref. Ruehrwein and Powell, *J. Am. Chem. Soc.*, Vol.68 (1946), p.1036.

DIBORANE

MOLECULAR FORMULA

B_2H_6

MOLECULAR WEIGHT

27.69

Ref. *International Atomic Weights*, 1947.

MELTING POINT

Melting point = −165.5°C

Ref. Stock and Kuss, *Ber.*, Vol.56 (1923), p.789.

BOILING POINT

Boiling point = −92.5°C at 760 mm Hg

Ref. Stock and Kuss, *Ber.*, Vol.56 (1923), p.789.

DENSITY

Gas — No information

Liquid

Temperature (°C)	Density (gm/ml)
−129.5	0.4818
−120.3	0.4698
−115.6	0.4640
−112.5	0.4600
−108.2	0.4542

Ref. Laubengayer, *et al.*, *J. Am. Chem. Soc.*, Vol.63 (1941), p.559.

Temperature (°C)	Density (gm/ml)
−110.0	0.4547
−109.5	0.4541
−107.8	0.4525
−105.6	0.4503
−102.7	0.4472
−100.9	0.4454
−98.1	0.4425
−96.7	0.4414
−94.5	0.4393
−92.6	0.4371

Ref. Stock and Kuss, *Ber.*, Vol.56 (1923), p.789.

Solid

Temperature (°C)	Density (gm/ml)
−183.	0.577
−195.8	0.580

Ref. Stock, *Hydrides of Boron and Silicon*, 1933, p.54.

VAPOR PRESSURE

Temp (°C)	Pressure (mm Hg)	Temp (°C)	Pressure (mm Hg)
−148.3	6.0	−115.2	187
−144.8	11.3	−109.2	272
−139.0	20.3	−104.5	361
−134.9	30.7	−99.3	521
−130.5	48	−96.4	608
−129.5	52	−95.5	637
−124.5	83	−93.8	701
−119.9	122	−92.75	748
		−92.5	760

Ref. Stock and Kuss, *Ber.*, Vol.56 (1923), p.789.

TRIPLE POINT
VISCOSITY } No information

SURFACE TENSION

Temperature (°C)	γ (dynes/cm)
−108.2	16.12
−112.5	16.95
−115.6	17.51
−120.3	18.32
−129.5	19.94

Ref. Laubengayer, *et al.*, *J. Am. Chem. Soc.*, Vol.63 (1941), p.559.

Temperature (°C)	γ (dynes/cm)
−119.0	17.16
−118.6	17.26
−117.2	16.98
−116.0	16.88
−112.3	16.30
−111.8	16.36
−108.3	15.82
−108.1	15.67
−105.9	15.48
−102.8	14.84
−94.8	13.78
−94.5	13.70
−92.1	13.41

Ref. Stock and Kuss, *Ber.*, Vol.56 (1923), p.789.

COEFFICIENT OF THERMAL EXPANSION
COEFFICIENT OF THERMAL CONDUCTIVITY } No information

DIPOLE MOMENT

$\mu = 0$ debye

Ref. Ramaswamy, *Proc. Indian Acad. Sci.*, Vol.2A (1935), pp.364 and 630.

HEAT OF FUSION No information

HEAT OF VAPORIZATION

$\Delta H_v = 3.685$ cal/mole

(calculated from vapor pressure data)

Ref. Kelley, *U.S. Bur. Mines Bull. 383* (1935).

HEAT OF FORMATION

$\Delta H^\circ_{298.1} = -44 \pm 3$ kcal/mole

Ref. Roth and Borger, *Ber.*, Vol.70B (1937), p.48.

HEAT OF COMBUSTION

$$B_2H_6(g) + 3O_2(g) = 2H_3BO_3$$

$\Delta H_c = -528$ kcal/mole at 303°K

Ref. *Heat of Combustion of Diborane*, Nat. Bur. Standards Report to Bur. Aeronautics, Navy Dept. (No date).

CRITICAL DATA

$t_c = 16.7 \pm 0.2$°C

$p_c = 581 \pm 5$ psia

Ref. Newkirk, A.E., *J. Am. Chem. Soc.*, Vol.70 (1948), p.1978.

EQUATION OF STATE
COMPRESSIBILITY } No information

HEAT CAPACITY OF GAS, C_p AND C_v

Temperature (°K)	C_v cal/mole deg
324.0	12.47
288.0	11.22
250.3	9.79
219.7	8.76
185.2	7.74

Ref. Stitt, *J. Chem. Phys.*, Vol.8 (1940), p.981.

RATIO OF SPECIFIC HEATS No information

HEAT CAPACITY OF LIQUID AND SOLID

Liquid

C_v = 6.92 cal/mole deg at 152.5°K

Ref. Stitt, *J. Chem. Phys.*, Vol.8 (1940), p.981.

Solid

C_v = 6.35 ± 0.20 cal/mole deg at 95°K

Ref. Stitt, *J. Chem. Phys.*, Vol.8 (1940), p.981.

FREE ENERGY OF FORMATION
FREE-ENERGY FUNCTION
HEAT-CONTENT FUNCTION } No information

ENTROPY

$S^\circ_{298.1}$ = 55.35 ± 0.2 cal/mole deg

Ref. Pitzer, *J. Am. Chem. Soc.*, Vol.69 (1947), p.184.

ETHANE

MOLECULAR FORMULA

CH_3CH_3; C_2H_6

MOLECULAR WEIGHT

30.07

Ref. *International Atomic Weights*, 1947.

MELTING POINT

Melting point = −183.23°C

Ref. American Petroleum Institute, Research Project No.44, *Collection, Analysis, and Calculation of Data on Properties of Hydrocarbons*, 1945, Table z1.

BOILING POINT

Boiling point = −88.63°C

Ref. American Petroleum Institute, Research Project No.44, *Collection, Analysis, and Calculation of Data on Properties of Hydrocarbons*, 1945, Table a1.

DENSITY

Gas

d = 1.3566 gm/liter, at 0°C and 1 atm

Ref. *International Critical Tables*, Vol.3 (1927), p.3.

DENSITY (*Cont'd*)

Liquid

d = 0.5612 gm/ml, at −100°C

Ref. *International Critical Tables*, Vol.3 (1927), p.28.

Vapor and Liquid in Equilibrium With Each Other

Temp (°C)	Press. (atm)	Density (gm/cc)	
		Liquid	Vapor
−88.62	1.000	0.546	0.00206
−80	1.556	0.535	0.00311
−70	2.471	0.522	0.00478
−60	3.743	0.509	0.00707
−50	5.449	0.496	0.0101
−40	7.672	0.482	0.0141
−30	10.50	0.468	0.0193
−20	14.02	0.453	0.0260
−10	18.34	0.435	0.0348
0	23.56	0.416	0.0463
10	29.83	0.393	0.0619
20	37.28	0.363	0.085
30	46.1	0.30	0.14

Ref. *International Critical Tables*, Vol.3 (1927), p.28.

Temperature (°C)	Density (gm/cc)
−74	0.5272
−78.8	.5338
−83.1	.5392
−88.1	.5458
−88.6	.5459
−88.3	.5469
−89.05	.5472
−95.3	.5549
−98.2	.5589
−97.7	.5608
−105.8	.5685
−108.2	.5719

Ref. Egloff, *Physical Constants of Hydrocarbons*, Vol.1 (1939), p.28.

Solid	No information

VAPOR PRESSURE

Press. (mm Hg)	Temp (°C)	Press. (mm Hg)	Temp (°C)
10	−142.88	700	−90.14
20	−136.69	710	−89.88
30	−132.74	720	−89.63
40	−129.78	730	−89.37
50	−127.39	740	−89.12
60	−125.36	750	−88.88
80	−122.03	760	−88.63
100	−119.33	770	−88.39
150	−114.12	780	−88.15
200	−110.19	790	−87.91
250	−106.98	800	−87.67
300	−104.25	900	−85.44
400	−99.74	1000	−83.38
500	−96.05	1200	−79.71
600	−92.90	1500	−75.00

Ref. American Petroleum Institute, Research Project No.44, *Collection, Analysis, and Calculation of Data on Properties of Hydrocarbons*, 1945, Table 1K.

TRIPLE POINT

Pressure, 1 atm

Temperature, −183.23°C

Ref. American Petroleum Institute, Research Project No.44, *Collection, Analysis, and Calculation of Data on Properties of Hydrocarbons*, 1945, Table 1z.

VISCOSITY

Gas

Temperature (°C)	$\eta \times 10^6$ (poises)
−78.5	63.4
0	84.8

Ref. *International Critical Tables*, Vol.5 (1927), p.3.

VISCOSITY (*Cont'd*)

Liquid

Temperature (°C)	$\eta \times 10^7$ (poises)
17.2	901
50.8	1001
100.4	1143
149.9	1278
200.3	1409
250.0	1526

Ref. Trautz and Sorg, *Ann. Physik*, Vol.10 (1931), p.81.

Temperature (°C)	$\eta \times 10^5$ (poises)
−175	985
−170	805
−165	673
−160	574
−155	500
−150	442
−145	396
−140	359
−135	328
−130	301
−125	278
−120	257
−115	238
−110	222
−105	207
−100	195
−95	183
−90	172
−85*	162

*For the liquid above the normal boiling point, at saturation pressure.

Ref. American Petroleum Institute, Research Project No.44, *Collection, Analysis, and Calculation of Data on Properties of Hydrocarbons*, 1945, Table 20c (Part 1).

SURFACE TENSION

γ = 16.05 dynes/cm, at −88.3°C

Ref. Krautzoff, *Annual Tables of Constants and Numerical Data*, Vol.13 (27), 1939, p.3.

COEFFICIENT OF THERMAL EXPANSION No information

COEFFICIENT OF THERMAL CONDUCTIVITY

Temperature (°C)	$k \times 10^5$ (cal/cm sec deg)
10.2	4.648
8.02	4.597
6.02	4.540
4.01	4.478
3.02	4.440
2.02	4.417
0	4.360

Ref. Brouty, *Annual Tables of Constants and Numerical Data*, Vol.12 (4), 1937, p.2.

DIPOLE MOMENT

μ = 0 debye, for the gas from −80 to 25°C

Ref. Sidgwick, *Trans. Faraday Soc.* (II), Vol.30 (1934), p.904.

HEAT OF FUSION

ΔH_f = 0.6829 kcal/mole, at −183.23°C

Ref. American Petroleum Institute, Research Project No.44, *Collection, Analysis, and Calculation of Data on Properties of Hydrocarbons*, 1945, Table 1z.

HEAT OF VAPORIZATION

ΔH_v° = 3.514 kcal/mole, at −89.63°C or 116.97 cal/gm

Ref. American Petroleum Institute, Research Project No.44, *Collection, Analysis, and Calculation of Data on Properties of Hydrocarbons*, 1945, Table 1m.

HEAT OF FORMATION

Gas

Temperature (°K)	ΔH_f° (kcal/mole)
0	−16.517
298.16	−20.236
300	−20.258
400	−21.419
500	−22.437
600	−23.28
700	−23.98
800	−24.53
900	−24.97
1000	−25.28
1100	−25.50
1200	−25.64
1300	−25.72
1400	−25.75
1500	−25.73

Ref. Prosen, Pitzer, and Rossini, *J. Research Nat. Bur. Standards*, Vol.34 (1945), p.403.

HEAT OF COMBUSTION

At 26°C and constant pressure, to form H_2O (liquid) and CO_2 (gas)

ΔH_c° = −372.820 kcal/mole

Ref. Prosen and Rossini, *J. Research Nat. Bur. Standards*, Vol.34 (1945), p.263.

CRITICAL DATA

$t_c = 32.27 \pm 0.01°C$

$P_c = 48.20 \pm 0.02$ atm

$d_c = 0.203$ gm/ml; uncertainty of 1%

Ref. Beattie, Su, and Simard, *J. Am. Chem. Soc.*, Vol.61 (1939), p.924.

EQUATION OF STATE

$$\left(P + \frac{n^2 a}{V^2}\right)(V - nb) = nRT$$

where

P = atmospheres (absolute)

V = liters/mole

R = 0.08207 liter atm/mole degree

T = degrees K

n = number of moles

$a = 5.419$ liters^2 atm/mole^2

$b = 0.06415$ liters/mole

Ref. Dodge, *Chemical Engineering Thermodynamics*, pp.172, 662-63.

COMPRESSIBILITY

Density (moles/liter)	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
Temperature (°C)	Pressure (absolute atmospheres)									
25	11.11	20.14	27.34	32.84	36.88	39.66	41.35			
50	12.24	22.58	31.24	38.41	44.27	49.02	52.87	55.97	58.49	60.56
75	13.34	24.95	35.08	43.80	51.37	57.98	63.78	68.89	73.52	77.79
100	14.43	27.28	38.79	49.03	58.29	66.68	74.36	81.50	88.25	94.73
125	15.52	29.64	42.49	54.25	65.13	75.26	84.81	93.91	102.73	111.46
150	16.60	31.89	46.08	59.31	71.78	83.61	94.99	106.06	117.0	127.98
175	17.67	34.17	49.66	64.36	78.40	91.93	105.13	118.16	131.20	144.41
200	18.71	36.44	53.25	69.38	84.97	100.19	115.20	130.18	145.30	160.77
225	19.80	38.64	56.73	74.27	91.38	108.24	125.02	141.90	159.08	176.73
250	20.89	40.87	60.23	79.16	97.81	116.30	138.84	153.59	172.87	192.77

Ref. Beattie, Hadlock, and Poffenberger, *J. Chem. Phys.*, Vol.3 (1935), p.93.

HEAT CAPACITY OF GAS, C_p AND C_v

Temperature (°K)	C_p° (cal/mole deg)
0	0
298.16	12.585
300	12.648
400	15.68
500	18.66
600	21.35
700	23.72
800	25.83
900	27.69
1000	29.33
1100	30.77
1200	32.02
1300	33.11
1400	34.07
1500	34.90

Ref. American Petroleum Institute, Research Project No.44, *Collection, Analysis, and Calculation of Data on Properties of Hydrocarbons*, 1945, Table 1v.

RATIO OF SPECIFIC HEATS

Pressure (atm)	Temperature (°C)	(C_p/C_v)
1	50	1.21
1	100	1.19

Ref. *International Critical Tables*, Vol.5 (1927), p.80.

HEAT CAPACITY OF LIQUID AND SOLID

Temperature (°K)	C_p (cal/mole deg)
15	0.655 (Solid)
20	1.535
25	2.470
30	3.590
35	4.785
40	4.944
50	7.810
60	9.450

Temperature (°K)	C_p (cal/mole deg)
70	11.09
80	12.72
90	16.30 (Liquid)
100	16.38
110	16.47
120	16.55
130	16.61
140	16.69
150	16.79
160	19.93
170	17.08
180	17.26

Ref. Witt and Kemp, *J. Am. Chem. Soc.*, Vol.59 (1937), pp.273-76.

FREE ENERGY OF FORMATION

Temperature (°K)	ΔF_t° (kcal/mole)
0	−16.517
298.16	−7.860
300	−7.785
400	−3.447
500	+1.168
600	5.97
700	10.90
800	15.92
900	21.00
1000	26.13
1100	31.28
1200	36.45
1300	41.62
1400	46.79
1500	51.99

Ref. Prosen, Pitzer, and Rossini, *J. Research Nat. Bur. Standards*, Vol.34 (1945), p.263.

FREE-ENERGY FUNCTION

Temperature (°K)	$-(F^\circ - H_0^\circ)/T$ (cal/mole deg)
0	0
298.16	45.27
300	45.33
400	48.24
500	50.77
600	53.08
700	55.25
800	57.29
900	59.24
1000	61.11
1100	62.90
1200	64.63
1300	66.30
1400	67.91
1500	69.46

Ref. American Petroleum Institute, Research Project No.44, *Collection, Analysis, and Calculation of Data on Properties of Hydrocarbons*, 1945, Table 1s.

HEAT-CONTENT FUNCTION

Temperature (°K)	$(H^\circ - H_0^\circ)/T$ (cal/mole deg)
0	0
298.16	9.578
300	9.596
400	10.74
500	12.02
600	13.36
700	14.68
800	15.95
900	17.15
1000	18.28
1100	19.35
1200	20.35
1300	21.29
1400	22.17
1500	23.00

Ref. American Petroleum Institute, Research Project No.44, *Collection, Analysis, and Calculation of Data on Properties of Hydrocarbons*, 1945, Table 1r.

ENTROPY

Temperature (°K)	$S°$ (cal/mole deg)
0	0
298.16	54.85
300	54.93
400	58.98
500	62.79
600	66.44
700	69.93
800	73.24
900	76.39
1000	79.39
1100	82.25
1200	84.98
1300	87.59
1400	90.08
1500	92.46

Ref. American Petroleum Institute, Research Project No.44, *Collection, Analysis, and Calculation of Data on Properties of Hydrocarbons*, 1945, Table 1t.

ETHANOL

MOLECULAR FORMULA

C_2H_5OH

MOLECULAR WEIGHT

46.07

Ref. *International Atomic Weights*, 1947.

MELTING POINT

Melting point = −114.6°C (158.5°K)

Ref. Kelley, *J. Am. Chem. Soc.*, Vol.51 (1929), p.779.

BOILING POINT

Boiling Point = 78.319°C

Ref. Swietoslawski, *et al.*, *Compt. rend.*, Vol.194 (1932), p.357.

DENSITY

Vapor and Liquid in Equilibrium

Temperature (°C)	Density (gm/ml)	
	Liquid	Vapor
0	0.80625	0.000033
10	0.7979	0.000062
20	0.7894	0.000111
30	0.7810	0.000191
40	0.7722	0.000315
50	0.7633	0.000506
60	0.7541	0.000790
70	0.7446	0.00119
78.3	0.7365	0.00165
80	0.7348	0.00174
90	0.7251	0.00250
100	0.7157	0.00351
110	0.7057	0.00486
120	0.6925	0.00658
130	0.6789	0.00877
140	0.6631	0.01152
150	0.6489	0.01488
160	0.6329	0.01916
170	0.6165	0.02446
180	0.5984	0.03115
190	0.5782	0.0397
200	0.5568	0.0508
210	0.5291	0.0655
220	0.4958	0.0854
230	0.4550	0.1135
240	0.3825	0.1715
243.1	0.2755	(critical point)

Ref. Young, *Dublin Pro.*, Vol.12 (1910), p.374.

Solid — No information

VAPOR PRESSURE

Liquid

Temp (°C)	Press (mm Hg)	Temp (°C)	Press (mm Hg)
−65	0.021	15	32.2
−60	0.045	20	43.9
−55	0.087	25	59.0
−50	0.12	30	78.8
−45	0.24	35	103.7
−40	0.39	40	135.3
−35	0.63	45	174.0
−30	1.04	50	222.2
−25	1.63	55	280.6
−20	2.5	60	352.7
−15	3.65	65	448.8
−10	5.6	70	542.5
−5	8.3	75	666.1
0	12.2	80	812.6
5	17.3	85	986.3
10	23.6	90	1187.

Ref. *International Critical Tables*, Vol.3 (1928), p.217.

Temp (°C)	Press (atm)	Temp (°C)	Press (atm)
78.3	1.000	170	15.61
80	1.069	180	19.44
90	1.562	190	23.94
100	2.228	200	29.20
110	3.107	210	35.31
120	4.243	220	42.38
130	5.685	230	50.53
140	7.486	240	59.92
150	9.700	243.1	63.11(Critical)
160	12.39		

Ref. Young, *Dublin Proc.*, Vol.12 (1910), p.374.

Solid — No information

TRIPLE POINT — No information

VISCOSITY

Vapor

Temperature (°C)	$\eta \times 10^7$ (poises)	Reference
0	827	(1)
16.8	885	(1)
100	1090	(2)
130.2	1173	(3)
170.7	1293	(3)
191.8	1355	(3)
212.5	1417	(2)
217.5	1421	(3)
251.7	1519	(3)
278.2	1585	(3)
308.7	1670	(3)

Refs. (1) Puluj, *Wien. Ber.*, Vol.78 (2), 1878, p.279.

(2) Rappenecker, Diss. Freiburg, 1909, *Z. physik. Chem.*, Vol.72 (1910), p.695.

(3) Titani, *Bull. Chem. Soc., Japan*, Vol.8 (1933), p.255.

Liquid

Temperature (°C)	η (poises)
-98.11	0.440
-96.54	0.390
-89.80	0.284
-83.03	0.204
-74.22	0.148
-71.50	0.132
-63.98	0.100
-59.42	0.0841
-56.58	0.0788
-52.58	0.0687
-37.65	0.0444
-32.01	0.0384
-26.56	0.0333
-17.59	0.0268
-0.30	0.0180

Ref. Mitsukuri and Tonomura, *Proc. Imp. Acad. (Tokyo)*, Vol.5 (1929), p.23; ref. Landolt-Börnstein, *Physikalisch-Chemische Tabellen*, Suppl. 2a (1931), p.98.

Liquid (*Cont'd*)

Temperature (°C)	γ (poises)
30	0.00991
40	0.00825
50	0.00701
60	0.00591
70	0.00503
78.27	0.00446
80	0.00435
90	0.00376
100	0.00325
110	0.00283
120	0.00248
130	0.00217
140	0.00191
150	0.00166

Ref. Titani, *Bull. Chem. Soc., Japan*, Vol.2 (1927), pp.95, 161, 196, and 225.

Viscosity as a function of temperature for the range 0-309°C

$$\mu = aT^n, \text{ or}$$

$$\log \mu = \log a + n \log T$$

T = °K

$a \times 10^6 = 0.449$

$n = 0.930$

Ref. Licht and Stechert, *J. Phys. Chem.*, Vol.48 (1944), pp.23-47.

SURFACE TENSION

Temperature (°C)	γ (dynes/cm)
30.00	21.14
20.00	22.00
−12.16	25.30
−22.02	26.10
−31.49	27.15
−43.21	28.11
−52.83	29.12
−62.49	30.17
−69.75	30.90
−74.73	31.54

SURFACE TENSION (*Cont'd*)

Temperature (°C)	γ (dynes/cm)
−80.52	32.21
−89.09	33.12
−93.03	33.64

Ref. Tonomura and Ishihara, *Bull. Chem. Soc., Japan*, Vol.9 (1934), pp.439-41.

COEFFICIENT OF THERMAL EXPANSION

Pressure (kg/cm²)	Volume at °C					
	−100	−80	−60	−40	−20	0
1	0.9021	0.9212	0.9403	0.9597	0.9794	1.0000
100	0.8976	0.9159	0.9342	0.9526	0.9714	0.9908
200	0.8933	0.9110	0.9287	0.9463	0.9643	0.9827
300	0.8891	0.9063	0.9235	0.9405	0.9577	0.9752
400	0.8852	0.9019	0.9185	0.9350	0.9515	0.9684
500	0.8815	0.8977	0.9138	0.9298	0.9458	0.9620
600	0.8780	0.8938	0.9093	0.9249	0.9404	0.9560
800	0.8714	0.8864	0.9011	0.9158	0.9305	0.9453
1000	0.8652	0.8793	0.8935	0.9076	0.9216	0.9356

Ref. Seitz and Lechner, *Ann. Physik* (4), Vol.49 (1916), p.93.

COEFFICIENT OF THERMAL CONDUCTIVITY

Vapor — No information

Liquid

Temperature (°C)	$k \times 10^3$ (cal/cm sec deg)
0	0.4455
5.2	0.487
11	0.46
25	0.43
51	0.369

Ref. Landolt-Börnstein, *Physikalisch-Chemische Tabellen*, Vol.2 (1923), p.1302.

DIPOLE MOMENT

μ = 1.72 debye, for the gas

Ref. Hojendahl, "Studies of Dipole Moment," 1928, calculated from experiments of Port, *Ann. Physik.*, Vol.42 (1913), p.569.

HEAT OF FUSION

ΔH_f = 26.06 cal/gm
= 1.200 kcal/mole

Ref. Kelley, *J. Am. Chem. Soc.*, Vol.51 (1929), p.779.

HEAT OF VAPORIZATION

ΔH_v = 219.8 cal/gm at 25°C

Ref. Rossini, *J. Research Nat. Bur. Standards*, Vol.13 (1934), p.192 (critical selection of reported values).

ΔH_v = 204.3 cal/gm at 78.3°C

Ref. *International Critical Tables*, Vol.5 (1929), p.137.

HEAT OF FORMATION

Liquid

$\Delta H^\circ_{298.1}$ = −66,750 cal/mole

Vapor

$\Delta H^\circ_{298.1}$ = −56,630 cal/mole

Ref. Schumann and Aston, *J. Chem. Phys.*, Vol.6 (1938), p.480.

HEAT OF COMBUSTION

Liquid

$\Delta H_c = -326.66 \pm 0.1$ kcal/mole at 25°C

Vapor

$\Delta H_c = -336.78 \pm 0.1$ kcal/mole at 25°C

Ref. Rossini, *J. Research Nat. Bur. Standards*, Vol.8 (1932), p.119.

CRITICAL DATA

$t_c = 243.1$°C
$P_c = 63.11$ atm
$d_c = 0.2755$ gm/ml

Ref. Young, *Dublin Proc.*, Vol.12 (1910), p.374.

EQUATION OF STATE

$$\left(P + \frac{n^2 a}{V^2}\right)(V - nb) = nRT$$

P = atm
V = liters/mole
R = 0.08207 liter atm/mole deg
T = °K
n = number of moles
a = 12.02 liters^2 atm/mole^2
b = 0.08407 liter/mole

Ref. Lange, *Handbook of Chemistry*, sixth edition, 1946, p.1472.

COMPRESSIBILITY

Pressure (atm)	Temperature (°C)			
	20	40	60	80
1	1.0212	1.0438	1.0679	1.0934
500	0.9782	0.9943	1.0121	1.0319
1.000	0.9479	0.9608	0.9760	0.9922
1.500	0.9247	0.9358	0.9482	0.9615
2.000	0.9059	0.9159	0.9266	0.9380
2.500	0.8899	0.8991	0.9088	0.9187
3.000	0.8760	0.8848	0.8935	0.9025
3.500	0.8634	0.8718	0.8800	0.8884
4.000	0.8517	0.8599	0.8678	0.8756
4.500	0.8410	0.8491	0.8567	0.8640
5.000	0.8314	0.8394	0.8467	0.8536
6.000	0.8149	0.8225	0.8291	0.8354
7.000	0.8009	0.8080	0.8139	0.8196
8.000	0.7888	0.7953	0.8005	0.8061
9.000	0.7776	0.7836	0.7884	0.7940
10.000	0.7671	0.7726	0.7776	0.7830
11.000	0.7574	0.7626	0.7682	0.7734
12.000	0.7485	0.7535	0.7600	0.7648

Ref. *International Critical Tables*, Vol.3 (1927), p.41.

HEAT CAPACITY OF GAS, C_p , C_v No information

RATIO OF SPECIFIC HEATS

$$\frac{C_p}{C_v} = 1.13, \text{ at } 90°C \text{ and } 1 \text{ atm}$$

Ref. Dixon and Greenwood, *Proc. Royal Soc. (London)*, A,Vol. 105 (1924), p.199.

HEAT CAPACITY OF LIQUID AND SOLID

Solid

Crystals		Glass	
Temperature (°K)	C_p (cal/mole deg)	Temperature (°K)	C_p (cal/mole deg)
18.57	1.458	18.19	1.830
21.40	1.906	23.11	2.728
24.87	2.619	27.19	3.655
30.43	3.632	33.12	4.542
36.49	4.567	40.75	5.790
40.05	5.098	44.27	6.451
46.73	6.368	51.63	7.680
54.26	7.317	60.14	8.703
66.21	8.657	70.76	9.96
73.15	9.241	79.07	10.92
85.53	10.25	85.83	11.90
96.20	11.01	90.47	12.73
113.56	12.28	100.78	19.14
132.55	13.48	108.21	19.26

Ref. Kelley, *J. Am. Chem. Soc.*, Vol.51 (1929), p.779.

Liquid

Temperature (°K)	C_p (cal/mole deg)
163.51	20.74
181.23	21.16
217.64	22.23
260.56	23.77
271.02	24.41
288.95	25.91
294.31	26.26

Ref. Kelley, *J. Am. Chem. Soc.*, Vol.51 (1929), p.779.

FREE ENERGY OF FORMATION

$\Delta F^{\circ}_{298.1} = -42,200$ cal/mole (liquid)

Ref. Parks and Huffman, *Free Energies of Some Organic Compounds*, 1932, p.109.

FREE-ENERGY FUNCTION

Temperature (°K)	$-(F^\circ - E_0^\circ)/T$* (cal/mole deg)
400	58.97
450	60.58
500	62.10
550	63.58
600	65.04

*On basis of hindered rotation; ICT critical constants used.

Ref. Schumann and Aston, *J. Chem. Physics*, Vol.6 (1938), p.480.

HEAT CONTENT FUNCTION No information

ENTROPY

S°_{298} = 38.4 cal/mole deg

Ref. Kelley, *J. Am. Chem. Soc.*, Vol.51 (1929), p.779.

ΔS°_{298} = −82.4 cal/mole deg

Ref. Parks and Huffman, *Free Energies of Some Organic Compounds*, 1932, p.109.

ETHYLENE

MOLECULAR FORMULA

C_2H_4 ; CH_2CH_2

MOLECULAR WEIGHT

28.052

Ref. *International Atomic Weights*, 1947.

MELTING POINT

Melting point = −169.15°C

Ref. American Petroleum Institute, Research Project No.44, *Collection, Analysis, and Calculation of Data on the Properties of Hydrocarbons*, 1945, Table 28.

BOILING POINT

Boiling point = −103.71°C at 760 mm Hg

Ref. American Petroleum Institute, Research Project No.44, *Collection, Analysis, and Calculation of Data on the Properties of Hydrocarbons*, 1945, Table 8a (Part I).

DENSITY

Gas

d = 1.2604 gm/liter at 0°C and 1 atm press.

Ref. *International Critical Tables*, Vol.3 (1928), p.3.

Liquid

Temp (°C)	Density (gm/cc)	Temp (°C)	Density (gm/cc)
9.5	0.2159	−84.05	0.5400
7.98	0.28726	−89.4	0.5482
6.50	0.30342	−99.05	0.5630
6.2	0.306	−99.4	0.5631
5.84	0.30840	−103.01	0.56740
4.3	0.332	−103.3	0.5657
−3.7	0.353	−103.7	0.5696
−7.70	0.37721	−103.9	0.5699
−10.93	0.38818	−105.0	0.5669
−14.18	0.39855	−105.9	0.5674
−19.205	0.41313	−107.7	0.5696
−21.0	0.414	−108.7	0.5762
−24.33	0.42655	−114.2	0.5752
−37.13	0.45610	−114.69	0.58380
−48.15	0.47822	−129.90	0.60449
−69.45	0.5172	−145.07	0.62465
		−169	0.6585

Ref. Egloff, *Physical Constants of Hydrocarbons*, Vol.1 (1939), p.162.

Solid

$d = 0.6585$ gm/ml at −169°C

Ref. Ladenburg and Kruger, *Ber.*, Vol.32 (1899), p.46.

VAPOR PRESSURE

Liquid

Temp (°C)	Pressure (mm Hg)	Temp (°C)	Pressure (mm Hg)
−153.22	10	−104.62	720
−147.59	20	−104.39	730
−144.00	30	−104.16	740
−141.31	40	−103.93	750
−139.13	50	−103.71	760
−137.28	60	−103.49	770
−134.24	80	−103.27	780
−131.78	100	−103.05	790
−127.03	150	−102.83	800
−123.44	200	−100.78	900
−120.51	250	−98.90	1000
−118.01	300	−95.53	1200
−113.88	400	−91.20	1500
−110.51	500		
−107.62	600		
−105.09	700		
−104.86	710		

Ref. American Petroleum Institute, Research Project No.44, *Collection, Analysis, and Calculation of Data on the Properties of Hydrocarbons*, 1945, Table 8K (Part I).

Solid — No information

TRIPLE POINT

No information

VISCOSITY

Gas

Temperature (°C)	$\eta \times 10^7$ (poises)
−79.3	716
−40.7	816
−1.8	940
+14.0	990
16.1	996
18.2	1008
21.9	1018
51.0	1109
100.6	1264
154.7	1434
197.6	1543
252.0	1681

Ref. *Annual Tables of Constants and Numerical Data*, Vol.9 (1931), p.37.

Liquid

Temperature (°K)	η (poises)
168.7	0.00178
168.3	0.00181
160.0	0.00207
155.0	0.00215
141.2	0.00281
134.1	0.00333
128.1	0.00369
128.2	0.00388
126.0	0.00402
110.5	0.00522

Ref. Rudenko and Shubnikov, *Physik Z. Sowjetunion*, Vol.8 (1935), pp.179-84.

SURFACE TENSION

γ = 16.50 dynes/cm at −103.9°C

Ref. *Annual Tables of Constants and Numerical Data*, Vol.2 (27), 1939, p.3.

Liquid-saturated vapor interface:

Temperature (°C)	γ (dynes/cm)
−107.0	17.66
−106.4	17.45
−99.3	16.10
−96.3	15.47
−91.9	14.93

Ref. *Annual Tables of Constants and Numerical Data*, Vol. 2 (24), 1937, p.4.

COEFFICIENT OF THERMAL EXPANSION

At constant pressure, for temperatures from 0°C to 100°C

$$\alpha_v = \frac{1}{V_0}\left[\frac{dv}{dt}\right]_p$$

Pressure (mm Hg) = 760

$$10^6 \alpha_v = 3735$$

Ref. Coppock, *Phil. Mag.*, Vol.19 (1935), p.446.

COEFFICIENT OF THERMAL CONDUCTIVITY

Gas

$$k_0 = 3.92 \times 10^{-5} \text{ (cal/cm sec deg)}$$

Temperature (°C)	k_t/k_0
−71.1	0.636
−50	0.739
0	1.0
50	1.29
100	1.60

Ref. *International Critical Tables*, Vol.5 (1927), p.214.

Liquid — No information

DIPOLE MOMENT

$\mu = 0$ debye from 25° to 80°C

Ref. *Annual Tables of Constants and Numerical Data*, Vol. 2 (1), 1939, p. 41

HEAT OF FUSION

$\Delta H_f = 0.8008$ kcal/mole at −169.15°C

Ref. American Petroleum Institute, Research Project No. 44, *Collection, Analysis, and Calculation of Data on the Properties of Hydrocarbons*, 1945, Table 8 (Part I).

HEAT OF VAPORIZATION

$\Delta H_v = 3.237$ kcal/mole at −103.71°C

Ref. American Petroleum Institute, Research Project No. 44, *Collection, Analysis, and Calculation of Data on the Properties of Hydrocarbons*, 1945, Table m-8.

HEAT OF FORMATION

Temperature (°K)	ΔH_f°, kcal/mole
0	14.522
298.16	12.496
300	12.482
400	11.766
500	11.138
600	10.600
700	10.142
800	9.760
900	9.448
1000	9.205
1100	9.02
1200	8.88

Temperature (°K)	ΔH_f°, kcal/mole
1300	8.76
1400	8.67
1500	8.61

Ref. American Petroleum Institute, Research Project No.44, *Collection, Analysis, and Calculation of Data on the Properties of Hydrocarbons*, 1945, Table w8 (Part I).

HEAT OF COMBUSTION

At 25°C and constant pressure, to form

H_2O (l) and CO_2 (g)

$\Delta H_c = -337.234$ kcal/mole

H_2O (g) and CO_2 (g)

$\Delta H_c = -316.195$ kcal/mole

Ref. American Petroleum Institute, Research Project No.44, *Collection, Analysis, and Calculation of Data on the Properties of Hydrocarbons*, 1945, Table n8 (Part I).

CRITICAL DATA

$t_c = 9.50°C \pm 0.1°$

$P_c = 50.65$ atm $\pm$ 0.1 atm

Ref. Cardozo and Arni, *J. chim. phys.*, Vol.10 (1912), p.504.

$d_c = 0.22$ gm/ml

Ref. Perry, *Chemical Engineers' Handbook*, second edition, 1941, p.475.

EQUATION OF STATE

Van der Waal's Equation:

$$\left(P + \frac{n^2 a}{V^2}\right)(V - nb) = nRT$$

where

P = atm
V = liters/mole
R = 0.08207 liter atm/mole deg
T = °K
n = number of moles
a = 4.48 liters^2 atm/mole^2
b = 0.05719 liters/mole

Ref. Dodge, *Chemical Engineering Thermodynamics*, 1944, pp. 172, 662-3.

COMPRESSIBILITY

Pressure (atm)	Temperature (°C)					
	0	20	40	60	80	100
1	1.000					
50	0.1755	0.6290	0.8140	0.9535	1.0770	1.1920
100	0.3100	0.3600	0.4705	0.6680	0.8465	1.0050
150	0.4405	0.4850	0.5505	0.6490	0.7760	0.9240
200	0.5650	0.6095	0.6690	0.7440	0.8380	0.9460
300	0.8055	0.8520	0.9075	0.9720	1.0475	1.1330
500	1.2555	1.3075	1.3670	1.4310	1.5000	1.5775
1000	2.2890	2.3535	2.4215	2.4925	2.5660	2.6425

Ref. Perry, *Chemical Engineers' Handbook*, second edition, 1941, p. 487.

HEAT CAPACITY OF GAS, C_p AND C_v

Temperature (°K)	C_p° (cal/mole deg)
0	0
298.16	10.41
300	10.45
400	12.90
500	15.16
600	17.10
700	18.76
800	20.20
900	21.46
1000	22.57
1100	23.54
1200	24.39
1300	25.14
1400	25.79
1500	26.36

Ref. American Petroleum Institute, Research Project No.44, *Collection, Analysis, and Calculation of Data on the Properties of Hydrocarbons*, 1945, Table v8 (Part I).

RATIO OF SPECIFIC HEATS

Temperature (°C)	γ (C_p/C_v)
−91	1.35
−36	1.29
0	1.24
18	1.25
100	1.19
at 0.5 atm, 20°C	1.27
at 3 atm, 20°C	1.32

HEAT CAPACITY OF LIQUID AND SOLID — No information

FREE ENERGY OF FORMATION

Temperature (°K)	ΔF_f° (kcal/mole)
0	14.522
298.16	16.282
300	16.305
400	17.675
500	19.245
600	20.918
700	22.676
800	24.490
900	26.354
1000	28.249
1100	30.16
1200	32.09
1300	34.03
1400	35.97
1500	37.92

Ref. American Petroleum Institute, Research Project No.44, *Collection, Analysis, and Calculation of Data on the Properties of Hydrocarbons*, 1945, Table x8 (Part I).

FREE-ENERGY FUNCTION

Temperature (°K)	$-(F^\circ - H_0^\circ)/T$ (cal/mole deg)
0	0
298.16	43.98
300	44.03
400	46.61
500	48.74
600	50.70
700	52.50
800	54.19
900	55.78
1000	57.29
1100	58.74
1200	60.12
1300	61.44
1400	62.71
1500	63.94

Ref. American Petroleum Institute, Research Project No.44, *Collection, Analysis, and Calculation of Data on the Properties of Hydrocarbons*, 1945, Table s8 (Part I).

HEAT-CONTENT FUNCTION

Temperature (°K)	$(H^\circ - H_o^\circ)/T$ (cal/mole deg)
0	0
298.16	8.47
300	8.48
400	9.28
500	10.23
600	11.22
700	12.18
800	13.10
900	13.96
1000	14.76
1100	15.52
1200	16.22
1300	16.88
1400	17.50
1500	18.07

Ref. American Petroleum Institute, Research Project No.44, *Collection, Analysis, and Calculation of Data on the Properties of Hydrocarbons*, 1945, Table n8 (Part I).

ENTROPY

Temperature (°K)	S_t^c (cal/mole deg)
0	0
298.16	52.45
300	52.51
400	55.89
500	58.98
600	61.92
700	64.68
800	67.28
900	69.74
1000	72.06
1100	74.26
1200	76.34
1300	78.32
1400	80.21
1500	82.01

Ref. American Petroleum Institute, Research Project No.44, *Collection, Analysis, and Calculation of Data on the Properties of Hydrocarbons*, 1945, Table t8 (Part I).

ETHYL ETHER

MOLECULAR FORMULA

$C_2H_5OC_2H_5$; $C_4H_{10}O$

MOLECULAR WEIGHT

74.12

Ref. *International Atomic Weights*, 1947.

MELTING POINT

Melting point, stable form α, = −116.3°C

Melting point, unstable form β, = −123.3°C

Ref. Skau, *J. Phys. Chem.*, Vol.37 (1933), p.609.

BOILING POINT

Boiling point = 34.6°C, at 760 mm Hg

Ref. Timmermans and Martin, *J. chim. phys.*, Vol.25 (1928), p.411.

DENSITY

Vapor, Liquid (In Equilibrium)

Temperature (°C)	Density (gm/cc)	
	Liquid	Vapor
0	0.7362	0.000827
10	0.7248	0.001264
20	0.7135	0.001870
30	0.7019	0.002677
40	0.6894	0.003731
50	0.6764	0.005079
60	0.6658	0.006771
70	0.6532	0.00892
80	0.6402	0.01155
90	0.6250	0.01477
100	0.6105	0.01867
110	0.5942	0.02349

Vapor, Liquid (In Equilibrium) (*Cont'd*)

Temperature (°C)	Density (gm/cc) Liquid	Vapor
120	0.5764	0.02934
130	0.5580	0.03638
140	0.5385	0.04488
150	0.5179	0.05551
160	0.4947	0.06911
170	0.4658	0.08731
180	0.4268	0.1135
185	0.4018	0.1320
190	0.3663	0.1620
193	0.3300	0.2012
193.8	0.2625	0.2625 (Critical Point)

Ref. Young, *Dublin Proc*, Vol.12 (1910), p. 374; Landolt-Börnstein, *Physikalisch-Chemische Tabellen*, Vol.1 (1923), p.285.

Liquid

Temperature (°C)	Density (gm/cc)
−109.8	0.8521
−99.8	0.8418
−92.2	0.8343
−84.4	0.8262
−75.4	0.8170
−64.5	0.8055
−53.9	0.7944
−43.0	0.7829
−32.1	0.7712
−30.1	0.7691
−20.2	0.7584
−10.2	0.7475
0.0	0.7363

Ref. Archibald and Ure, *J. Chem. Soc.*, 1927, p.610.

Solid

d = 0.9212 gm/ml, at −117.6°C

Ref. Korber, *Ann. Physik.*, Vol.37 (1912), p.1014.

VAPOR PRESSURE

Liquid

Temp (°C)	Press. (mm Hg)	Temp (°C)	Press. (mm Hg)
−119.8	0.0027	−80.3	0.582
−117.3	0.0065	−75.8	0.953
−104.7	0.020	−64.4	2.77
−101.6	0.044	−57.3	5.12
−97.4	0.073	−56.7	5.34
−96.4	0.085	−53.5	7.01
−85.2	0.330	−44.2	14.17
−81.0	0.540	−32.4	31.93

Ref. Landolt-Börnstein, *Physikalisch-Chemische Tabellen*, Vol.2 (1923), p.1364.

Temp (°C)	Press. (mm Hg)	Temp (°C)	Press. (mm Hg)
−60.8	3.95	−16.6	80.7
−55.7	5.93	−11.6	104.8
−50.9	8.77	−6.7	134.8
−46.0	12.62	0.01	186.1
−41.1	17.78	5.0	233.7
−36.2	24.77	9.9	290.6
−31.3	34.03	14.9	358.2
−26.4	45.8	19.9	437.7
−21.5	61.3		

Ref. Taylor and Smith, *J. Am. Chem. Soc.*, Vol.44 (1922), p.2457.

Temp (°C)	Press. (mm Hg)	Temp (°C)	Press. (mm Hg)
−20	63.0	100	4,859
−10	111.8	110	6,070
0	184.9	120	7,496
10	291.8	130	9,157
20	442.4	140	11,078
30	647.9	150	13,281
40	921.2	160	15,788
50	1,276.	170	18,622
60	1,728.	180	21,804
70	2,294.	190	25,355
80	2,991.	193.8*	27,060
90	3,840.		

*Critical point

Ref. Ramsey and Young, *Phil. Trans.* (A), Vol.178 (1887), p.57.

Solid	No information
TRIPLE POINT	No information

VISCOSITY

Vapor

Temperature (°C)	$\eta \times 10^7$ (poises)	Reference
0	689	(1)
7.2	712	(1)
10.0	716	(2)
18.9	735	(2)
25.8	755	(2)
31.4	771	(2)
36.5	793	(2)
100	942	(3)
100	967	(4)
212.5	1234	(4)

Refs.(1) Puluj, *Wien. Ber.*, Vol.78 (2), 1878, p.279.

(2) Landolt-Börnstein, *Physikalisch-Chemische Tabellen*, Vol.1 (1923), p.171.

(3) Petersen, *Phys. Rev.*, Vol.25 (1907), p.225.

(4) Rappenecker, *Diss. Freiburg*, 1909; *Z. physik Chem.*, Vol.72 (1910), p.695.

Liquid

Temperature (°C)	η (poises)
−109.8	0.02514
−99.8	0.01708
−92.2	0.01334
−84.4	0.010747
−75.4	0.008664
−64.5	0.00693
−53.9	0.00574
−43.0	0.00485
−32.1	0.00420
−30.1	0.004109
−20.2	0.003636
−10.2	0.003239
0	0.002903

Ref. Archibald and Ure, *J. Chem. Soc.*, 1927, p.610.

VISCOSITY (*Cont'd*)

Liquid (*Cont'd*)

Temperature (°C)	η (poises)
15	0.00279
30	0.00247

Ref. Timmermans and Martin, *J. chim. phys.*, Vol.25 (1928), p.411.

SURFACE TENSION

Temperature (°C)	γ (dynes/cm)
20	17.01
50	13.47
100	7.97
150	3.12
190	0.15

Ref. *International Critical Tables*, Vol.4 (1928), p.451.

COEFFICIENT OF THERMAL EXPANSION (CUBICAL)

$\alpha = 0.001445$ from $-78.5°$ to 0°C

Ref. Klemm, *Z. anorg. Chem.*, Vol.207 (1932), p.161.

$\alpha = 0.00162$ from $0°$ to 30°C

Ref. Timmermans and Martin, *J. chim. phys.*, Vol.25 (1928), p.411.

In both instances:

$$\alpha = \frac{1}{V_0}\frac{dV}{dt}$$

COEFFICIENT OF THERMAL CONDUCTIVITY

Vapor

$k_0 = 2.89 \times 10^{-5}$ cal/cm sec deg, at 0°C

Temperature (°C)	k_t/k_0
0	1.0
46	1.29
100	1.70
184	2.45
212.5	2.71

Ref. *International Critical Tables*, Vol.5 (1927), pp.214-15.

Liquid — No information

DIPOLE MOMENT

$\mu = 1.18$ debye

Ref. Groves and Sugden, *J. Chem. Soc.*, 1937, p.1779.

HEAT OF FUSION

ΔH_f, stable form α at −116.4°C, = 24.3 cal/gm
ΔH_f, unstable form β at −123.4°C, = 22.9 cal/gm

Ref. Saphir, *Bull. soc. chim. Belg.*, Vol.38 (1929), p.392.

HEAT OF VAPORIZATION

$\Delta H_v = 84.5$ cal/gm at 34.83°C

Ref. Ramsey and Young, *Phil. Trans.* (A), Vol.178 (1887), p.90.

HEAT OF FORMATION

$\Delta H^{\circ}_{298} = -67,300$ cal/mole (liquid)

Ref. Parks, Kelley, and Huffman, *J. Am. Chem. Soc.*, Vol.51 (1929), p.1969.

HEAT OF COMBUSTION

$\Delta H_c = -651,400$ cal/mole (liquid)

Ref. Parks, Kelley, and Huffman, *J. Am. Chem. Soc.*, Vol.51 (1929), p.1969.

CRITICAL DATA

$t_c = 193.8\,^{\circ}C$

$P_c = 35.50$ atm

$d_c = 0.2625$ gm/ml

Ref. Young, *Dublin Proc.*, Vol.12 (1910), p.374.

EQUATION OF STATE

Vapor

$$P = \left(\frac{1.1074}{V-a}\right)T - \frac{5709}{(V+0.734)^2}$$

where

$T = {}^{\circ}K$

V = specific volume, cc/gm

P = pressure, atm

$\log_{10} a = 0.77325 - 2.4240/V$

Ref. Beattie, *J. Am. Chem. Soc.*, Vol.46 (1924), p.342.

COMPRESSIBILITY

Pressure (atm)	20°C	40°C	60°C	80°C
1	1.0315	1.0669	–	–
500	0.9668	0.9884	1.0123	1.0369
1,000	0.9337	0.9498	0.9683	0.9484
2,000	0.8850	0.8952	0.9069	0.9189
2,500	0.8663	0.8756	0.8860	0.8962
3,000	0.8503	0.8594	0.8688	0.8776
3,500	0.8366	0.8454	0.8539	0.8620
4,000	0.8246	0.8329	0.8407	0.8481
4,500	0.8139	0.8218	0.8292	0.8360
5,000	0.8044	0.8121	0.8189	0.8252
6,000	0.7883	0.7953	0.8017	0.8070
7,000	0.7743	0.7806	0.7865	0.7917
8,000	0.7613	0.7670	0.7725	0.7779
9,000	0.7492	0.7545	0.7597	0.7652
10,000	0.7380	0.7431	0.7482	0.7535
11,000	0.7275	0.7325	0.7377	0.7427
12,000	0.7178	0.7225	0.7280	0.7326

Above values relative to volume of 1.0000 at 0°C and 1 atm

Ref. Bridgman, *Proc. Am. Acad. Arts Sci.*, Vol.49 (1913), p.3.

HEAT CAPACITY OF VAPOR, LIQUID AND SOLID

Solid

Temperature (°K)	C_p (cal/gm deg)
79.5	0.205
91.6	0.231
105.5	0.251
128.5	0.283
137.2	0.300

Liquid

159.3	0.475
193.3	0.502
237.8	0.522
255.5	0.532

Ref. Aoyama and Kanda, *Science Repts, Tohoku Imp. Univ.* (1), Vol.24 (1935), p.119.

HEAT CAPACITY OF VAPOR, LIQUID AND SOLID (*Cont'd*)

Liquid

Temperature (°C)	C_p (cal/gm deg)
30	0.547
80	0.690
120	0.803
140	0.822
180	1.041

Vapor

35	0.445
27-189	0.462
69-224	0.48
200-300	0.533

Ref. *International Critical Tables*, Vol.5 (1929), pp.81,108.

[Stable Form]

Solid

Temperature (°K)	C_p (cal/gm deg)
76.1	0.201
82.5	0.212
89.1	0.222
93.4	0.227
95.5	0.233
96.7	0.233
98.3	0.236
103.4	0.244
103.7	0.244
110.5	0.254
110.8	0.255
112.0	0.256
114.5	0.259
123.3	0.271
131.1	0.283
135.2	0.287

Liquid

Temperature (°K)	C_p (cal/gm deg)
164.4	0.475
186.1	0.490
195.6	0.498
201.6	0.501
205.5	0.505
213.5	0.507
275.2	0.544
280.2	0.547
286.0	0.549
290.0	0.551

Ref. Parks and Huffman, *J. Am. Chem. Soc.*, Vol.48 (1926), p.2788.

RATIO OF SPECIFIC HEATS No information

HEAT CAPACITY OF LIQUID AND SOLID

(See "Heat Capacity of Vapor, Liquid, and Solid")

FREE ENERGY OF FORMATION

$\Delta F^{\circ}_{298.1} = -32,300$ cal/mole

Ref. Parks, Kelley, and Huffman, *J. Am. Chem. Soc.*, Vol.51 (1929), p.1969.

FREE-ENERGY FUNCTION
HEAT-CONTENT FUNCTION } No information

ENTROPY

$S^{\circ}_{298} = 60.4$ cal/mole deg (based on MW = 74.08)
$\Delta S^{\circ}_{298} = -117.3$ cal/mole deg (based on MW = 74.08)

Ref. Parks, Kelley, and Huffman, *J. Am. Chem. Soc.*, Vol.51 (1929), p.1969.

FORMALDEHYDE

MOLECULAR FORMULA

HCHO; CH_2O

MOLECULAR WEIGHT

30.026

Ref. *International Atomic Weights*, 1947.

MELTING POINT

Melting point = −118.0°C

Ref. Spence and Wild, *J. Chem. Soc.*, 1935, p.506.

BOILING POINT

Boiling point = −19.2°C

Ref. Spence and Wild, *J. Chem. Soc.*, 1935, p.506.

DENSITY

Liquid

Temperature (°C)	Density (gm/ml)
−80	0.9151
−20	0.8153

Ref. Kekulé, *Ber.*, Vol.25 (1892), p.2435.

Vapor and Solid No information

VAPOR PRESSURE

Temp (°C)	Press. (mm Hg)	Temp (°C)	Press. (mm Hg)
−109.4	0.95	−64.6	61.65
−104.4	1.85	−63.7	65.20
−98.3	3.60	−55.8	111.0
−95.2	4.85	−54.0	124.7
−89.1	8.68	−49.3	163.1
−85.6	12.25	−40.6	266.6
−78.9	21.02	−39.1	290.6
−78.3	22.11	−34.3	368.9
−71.9	35.40	−28.4	496.6
−68.5	46.43	−22.3	664.3
−65.3	58.95	−19.2	760.0

Ref. Spence and Wild, *J. Chem. Soc.*, 1935, p.506.

TRIPLE POINT No information

VISCOSITY (Of Commercial Aqueous Formaldehyde Solutions)

Formaldehyde (%)	Methanol (%)	Degrees Engler (at 20°C)
37.2	0.0	1.156
36.9	8.3	1.166
36.5	10.0	1.175
37.0	11.9	1.194

Ref. Walker, *Formaldehyde*, 1944, p.42.

SURFACE TENSION No information

COEFFICIENT OF THERMAL EXPANSION

.00283 ml/gm deg between −20° and −80°C

Ref. Walker, *Formaldehyde*, 1944, p.23.

COEFFICIENT OF THERMAL CONDUCTIVITY
DIPOLE MOMENT
HEAT OF FUSION
} No information

HEAT OF VAPORIZATION

ΔH_v = 5570 cal/mole at −19.2°C

Ref. Spence and Wild, *J. Chem. Soc.*, 1935, p.506.

HEAT OF FORMATION

$\Delta H_{291.1}$ = −28.48 kcal/mole

Ref. Thompson, *Trans. Faraday Soc.*, Vol.37 (1941), p.249.

HEAT OF COMBUSTION

ΔH_c = −134.1 kcal/mole at 18°C for the monomer

Ref. Wartenberg and Lerner-Steinberg, *Z. angew. Chem.*, Vol.38 (1925), p.591.

CRITICAL DATA

t_c = 141°C

p_c = 65 atm

Above are assumed values

Ref. Walker, *Formaldehyde*, 1944, p.20.

EQUATION OF STATE
COMPRESSIBILITY } No information

HEAT CAPACITY OF GAS, C_p AND C_v

Gas

Temperature (°K)	C_p° (cal/mole deg*)
291.16	8.40
298.16	8.45
300	8.47

*Calculated

Gas (*Cont'd*)

Temperature (°K)	C_p° (cal/mole deg*)
350	8.88
400	9.37
450	9.90
500	10.44
550	10.98
600	11.50
650	12.07
700	12.48
800	13.36
900	14.13
1000	14.80
1100	15.38
1200	15.92
1300	16.31
1400	16.68
1500	17.00

*Calculated

Ref. Thompson, *Trans. Faraday Soc.*, Vol.37 (1941), p.249.

RATIO OF SPECIFIC HEATS
HEAT CAPACITY OF LIQUID AND SOLID } No information

FREE ENERGY OF FORMATION

Gas

Temp (°K)	F_t° (kcal/mole)	Temp (°K)	F_t° (kcal/mole)
298.16	−27.17	700	−24.4
300	−27.16	800	−23.6
350	−26.9	900	−22.7
400	−26.6	1000	−21.9
450	−26.3	1100	−21.0
500	−26.0	1200	−20.15
550	−25.6	1300	−19.2
600	−25.2	1400	−18.25
650	−24.8	1500	−17.3

Ref. Thompson, *Trans. Faraday Soc.*, Vol.37 (1941), p.249.

FREE-ENERGY FUNCTION

Temperature (°K)	$-(F^\circ - E_o^\circ)/T$ (cal/mole deg)
291.16	44.064
298.16	44.254
300	44.304
350	45.549
400	46.642
450	47.621
500	48.539
550	49.342
600	50.115
650	50.846
700	51.531
800	52.813
900	54.004
1000	55.111
1100	56.145
1200	57.179
1300	58.062
1400	58.953
1500	59.807

Ref. Thompson, *Trans. Faraday Soc.*, Vol.37 (1941), p.249.

HEAT-CONTENT FUNCTION

Temperature (°K)	$(H^\circ - E_o^\circ)/T$ (cal/mole deg)
291.16	8.020
298.16	8.026
300	8.033
350	8.117
400	8.248
450	8.400
500	8.578
550	8.805
600	8.977
650	9.108
700	9.410
800	8.845
900	10.287
1000	10.707
1100	10.092
1200	9.606
1300	9.104
1400	8.692
1500	8.320

Ref. Thompson, *Trans. Faraday Soc.*, Vol.37 (1941), p.249.

ENTROPY

Temperature (°K)	S_t° (cal/mole deg*)
291.16	52.084
298.16	52.284
300	52.337
350	53.672
400	54.889
450	56.021
500	57.117
550	58.112
600	59.093
650	60.053
700	60.942
800	62.658
900	64.294
1000	65.819
1100	67.683
1200	68.706
1300	69.896
1400	71.121
1500	72.287

*Does not include nuclear spin.

Ref. Thompson, *Trans. Faraday Soc.*, Vol.37 (1941), p.249.

HYDRAZINE

MOLECULAR FORMULA

N_2H_4; $H_2N - NH_2$

MOLECULAR WEIGHT

32.048

Ref. *International Atomic Weights*, 1947.

MELTING POINT

Melting point = 1.4°C

Ref. *International Critical Tables*, Vol.1 (1926), p.108.

BOILING POINT

Boiling point = 113.5°C at 760 mm Hg

Ref. Yost and Russell, *Systematic Inorganic Chemistry*, 1944, p.116.

DENSITY

Vapor — No information

Liquid

d = 1.011 gm/cc at 15°C

Ref. *International Critical Tables*, Vol.1 (1926), p.108.

Solid

d = 1.146 gm/cc at −5°C

Ref. Beck, *Wien. Chem. Z.*, Vol.46 (1943), p.18.

VAPOR PRESSURE

Liquid

Temp (°C)	Press. (mm Hg)	Temp (°C)	Press. (mm Hg)
20.21	10.4	65.63	114.0
20.60	10.7	67.82	127.3
23.73	12.6	70.04	141.7
26.02	14.6	76.01	184.2
28.84	15.1	85.38	271.0
29.85	18.3	88.20	308.8
37.89	28.2	96.43	417.1
43.32	38.1	107.85	615.9
48.48	50.3	111.33	696.2
48.60	50.8	114.15	760.0
57.41	78.1		

Ref. Hieber and Woerner, *Z. Elektrochem.*, Vol.40 (1934), p.252.

Temperature (°C)	Pressure (atm)
113.5	1.0
140	2.3
170	5.0
200	10.0
250	26.0
300	56.0
350	104.0
380	145.0 (Critical Pressure)

Ref. *International Critical Tables*, Vol.3 (1928), p.229.

Solid — No information

TRIPLE POINT

VISCOSITY: VAPOR LIQUID } No information

SURFACE TENSION

γ = 62.32 dynes/cm at 35°C

Ref. Barrick, Drake, and Lochte, *J. Am. Chem. Soc.*, Vol.58 (1936), p.160.

COEFFICIENT OF THERMAL EXPANSION

COEFFICIENT OF THERMAL CONDUCTIVITY: Vapor, Liquid

No information

DIPOLE MOMENT

μ = 1.83 debye

Ref. Audrieth, Nespital, and Ulich, *J. Am. Chem. Soc.*, Vol.55 (1933), p.673.

HEAT OF FUSION

ΔH_f = 1.02 kcal/mole

Ref. Hieber and Woerner, *Z. Elektrochem.*, Vol.40 (1934), p.252.

HEAT OF VAPORIZATION

ΔH_v = 10.2 kcal/mole at 23.1°C
= 9.67 kcal/mole at 101°C

Ref. Hieber and Woerner, *Z. Elektrochem.*, Vol.40 (1934), pp.252-6.

HEAT OF FORMATION

$\Delta H^\circ_{298.1}$ = 12.05 kcal/mole for N_2H_4 liquid

Ref. Hughes, Corruccini, and Gilbert, *J. Am. Chem. Soc.*, Vol.61 (1939), p.2639.

HEAT OF COMBUSTION

$\Delta H_c = -148.63 \pm 0.03$ kcal/mole

Ref. Hughes, Corruccini, and Gilbert, *J. Am. Chem. Soc.*, Vol. 61 (1939), p. 2639.

CRITICAL DATA

$t_c = 380°C$

$p_c = 145$ atm

Ref. Yost and Russell, *Systematic Inorganic Chemistry*, 1944, p. 116.

EQUATION OF STATE
COMPRESSIBILITY
HEAT CAPACITY OF VAPOR
RATIO OF SPECIFIC HEATS
HEAT CAPACITY OF LIQUID AND SOLID
FREE ENERGY OF FORMATION
FREE-ENERGY FUNCTION
HEAT-CONTENT FUNCTION
ENTROPY

No information

HYDROGEN

MOLECULAR FORMULA

H_2

MOLECULAR WEIGHT

2.016

Ref. *International Atomic Weights*, 1947.

MELTING POINT

Melting point = 13.95°K

Ref. Giauque, *J. Am. Chem. Soc.*, Vol.52 (1930), p.4816.

BOILING POINT

Boiling point = −252.780 ± 0.001°C at 760 mm Hg

Ref. Heuse and Otto, *Ann. Physik* (5), Vol.9 (1931), p.486.

DENSITY

Gas

d = 0.08987 gm/liter at 0°C and 760 mm Hg

Ref. *International Critical Tables*, Vol.1 (1926), p.102.

Liquid

d = 0.0709 gm/cc at −252.7°C

Ref. *International Critical Tables*, Vol.1 (1926), p.104.

Solid

d = 0.0808 gm/cc at −262.0°C

Ref. *International Critical Tables*, Vol.1 (1926), p.104.

VAPOR PRESSURE

Liquid

Temperature (°C)	Pressure (mm Hg)	Pressure (atm)
−259.14	51.4	–
−258.46	79.9	–
−256.61	191.9	–
−254.73	397.6	–
−252.74	760.0	1.000
−252.45	823.7	1.084
−248.50	2199.2	2.8937
−245.68	–	5.0566
−240.49	–	11.752
−239.91 (C^P)	–	12.80

Ref. Kelley, *U.S. Bur. Mines Bull. 383* (1935), p.50.

Solid

Temperature (°C)	Pressure (atm)
−266.1	1.84×10^{-5}
−265.6	5.28×10^{-5}
−265.1	1.34×10^{-4}
−264.6	3.07×10^{-4}
−264.1	6.45×10^{-4}
−263.6	1.26×10^{-3}
−263.1	2.33×10^{-3}
−262.6	0.00407
−262.1	0.00679
−261.6	0.0109
−261.1	0.0169
−260.6	0.0254
−260.1	0.0370
−259.6	0.0528
−259.16	0.0708

Ref. Kelley, *U.S. Bur. Mines Bull. 383* (1935), p.50.

TRIPLE POINT

Temperature (°C) = −259.24

Pressure (mm Hg) = 54.

Ref. Scott, *et al.*, *J. Chem. Phys.*, Vol.2 (1934), p.454.

VISCOSITY

Gas

$$\eta = bT\left(T_r^{\frac{3}{4}} + T_r^{-\frac{3}{4}}\right)^{-d}$$

Where

η = coefficient of viscosity, in poises
b = a constant
T = absolute temperature, °K
T_r = reduced temperature = T/T_c
d = a constant

For the temperature range −258° to 825°C,

$b \times 10^6 = 0.653$ $\quad d = 0.464$

Average error = 1.2%

Ref. Licht and Stechert, *J. Phys. Chem.*, Vol.48 (1944), pp.23-47.

Liquid

Temperature (°K)	$\eta \times 10^5$ (poises)
14.83	215
15.39	200
16.40	182
17.06	172
17.74	159
18.38	151
18.95	143
19.66	139
20.00	139

Ref. H.C. Brinkman, *Physica*, Vol.7 (1940), pp.447-48.

SURFACE TENSION

γ = 1.91 dyne/cm at −252.7°C(−422.86°F)

Ref. *International Critical Tables*, Vol.1 (1926), p.103.

COEFFICIENT OF THERMAL EXPANSION

Gas

$$\alpha_{0,t} = \frac{v - v_0}{t v_0} = \text{coefficient of expansion at constant pressure } p_0 \text{ between } 0° \text{ and } t°C$$

$\alpha \times 10^6$

p_0 (atm)	0° to 100°C	0° to 20°C	0° to −77°C	0° to −104°C	0° to −147°C	0° to −183°C	0° to −190°C	0° to −205°C	0° to −212°C
1	3661	–	–	–	–	–	–	–	–
5	3665	3655	3658	3661	3666	3674	3678	3685	3691
10	3646	3647	3652	3656	3667	3680	3685	3701	3711
15	3637	3639	3646	3652	3668	3688	3696	3717	3732
20	3629	3631	3640	3648	3669	3697	3707	3734	3754
25	3620	3623	3635	3644	3670	3704	3716	3751	3774
30	3611	3615	3629	3640	3670	3710	3724	3766	3792
35	3602	3608	3623	3635	3669	3715	3731	3779	3808
40	3594	3601	3618	3631	3668	3721	3738	3789	3821
45	3585	3593	3613	3626	3666	3724	3742	3796	3830
50	3576	3586	3608	3621	3663	3727	3746	3802	3835
55	3567	3578	3602	3616	3659	3728	3748	3806	3838
60	3558	3571	3596	3611	3654	3728	3749	3808	3841

Ref. Witkowski, *Anz. Akad. Wiss.*, Krakau, 1905, p.305; Landolt-Bőrnstein, *Physikalisch-Chemische Tabellen*, Vol.1, p.115; *International Critical Tables*, Vol.3, pp.5-6.

Liquid

$$\frac{10^3}{V}\left(\frac{\Delta V}{\Delta t}\right)_{p=p} = 12.6 \text{ between } T_K = 13.99° \text{ and } T_K = 20.39°$$

Ref. Onnes and Crommelin, *Communs. Phys. Lab.*, Univ. Leiden, No.137a; *International Critical Tables*, Vol.3, p.20.

COEFFICIENT OF THERMAL CONDUCTIVITY

Gas

Temperature (°K)	$k \times 10^5$ (cal/cm sec deg)
84.70	13.90
93.99	15.41
125.60	19.91
142.23	22.46
158.70	24.89
175.95	27.19
192.28	29.38
200.40	30.68
207.66	31.62
218.18	33.09
236.56	35.56
254.38	37.68
274.02	39.75
277.69	40.05
293.28	41.64
324.28	44.53
341.27	45.97
357.31	47.51
374.25	49.10

Average deviation from smooth curve = ±0.194%

Ref. Johnston and Grilly, *J. Chem. Phys.*, Vol.14 (1946), pp.233-38.

Liquid — No information

DIPOLE MOMENT

$\mu = 0$ debye

Ref. Branch and Calvin, *The Theory of Organic Chemistry*, 1941, p.129.

HEAT OF FUSION

$\Delta H_f = 28$ cal/mole at 13.95°K

Ref. Giauque, *J. Am. Chem. Soc.*, Vol.52 (1930), pp.4816.

HEAT OF VAPORIZATION

ΔH_v = 108 cal/gm atom at 760 mm Hg
109.2 cal/gm atom at 600 mm Hg
110.8 cal/gm atom at 400 mm Hg
112.2 cal/gm atom at 200 mm Hg

Ref. *International Critical Tables*, Vol.5 (1929), p.135.

HEAT OF FORMATION

$\Delta H^{\circ}_{298.1} = 0$, by definition

HEAT OF COMBUSTION

$\Delta H_c = -68{,}317$ cal/mole, to form $H_2O(l)$

Ref. Rossini, *et al.*, *J. Research Nat. Bur. Standards*, Vol.34 (1945), p.143.

CRITICAL DATA

$t_c = -239.9°C$
$P_c = 12.8$ atm
$d_c = 0.0310$ gm/cc

Ref. *International Critical Tables*, Vol.1, p.102.

EQUATION OF STATE

Van der Waals' Equation: $\left(P + \frac{n^2 a}{V^2}\right)(V - nb) = nRT$

where

P = pressure, atm.
V = molal volume, liters/mole
n = number of moles

EQUATION OF STATE (*Cont'd*)

R = universal gas constant, 0.08206 liter atm/mole deg
T = temperature, °K
a = 0.2447 liter^2 atm/mole^2
b = 0.02658 liter/mole

Ref. Dodge, *Chemical Engineering Thermodynamics*, 1944, pp.172, 662-63.

COMPRESSIBILITY

PV = 1.0000 AT 0°C AND 1 ATMOSPHERE

Pressure (atm)	-207.9	-183	-150	-100	-70	-50	-25	0	20	50	100	200	300
1	0.2380	0.3297	0.4508	0.6340	0.7438	0.8170	0.9085	1.0000	1.0732	1.1830	1.3660	1.7317	2.0974
10	0.2308	0.3279	0.4520	0.6377	0.7482	0.8219	0.9138	1.0057	1.0791	1.1891	1.3723	1.7380	2.1037
20	0.2239	0.3265	0.4541	0.6421	0.7535	0.8275	0.9187	1.0120	1.0855	1.1957	1.3792	1.7450	2.1108
30	0.2183	0.3260	0.4564	0.6466	0.7583	0.8331	0.9257	1.0183	1.0920	1.2027	1.3862	1.7520	2.1178
40	0.2144	0.3262	0.4591	0.6513	0.7642	0.8389	0.9318	1.0247	1.0985	1.2094	1.3931	1.7590	2.1249
50	0.2166	0.3271	0.4623	0.6562	0.7695	0.8447	0.9378	1.0309	1.1051	1.2162	1.4001	1.7660	2.1319
60	0.2127	0.3289	0.4658	0.6613	0.7752	0.8506	0.9441	1.0376	1.1116	1.2230	1.4070	1.7731	2.1392
80	0.2187	0.3346	0.4740	0.6720	0.7870	0.8628	0.9567	1.0507	1.1249	1.2365	1.4209	1.7871	2.1530
100	0.2301	0.3434	0.4839	0.6834	0.8003	0.8754	0.9700	1.0639	1.1388	1.2510	1.4356	1.8042	2.1733
200					0.8640	0.9411	1.0383	1.1336	1.2066	1.3203	1.5071	1.8756	2.2393
300					0.9340	1.0112	1.1093	1.2045	1.2799	1.3915	1.5790	-	-
400					1.0075	1.0832	1.1803	1.2775	1.3511	1.4635	1.6513	2.0206	2.3826
500					1.0804	1.1568	1.2542	1.3500	1.4240	1.5357	1.7235	-	-
600					1.1555	1.2301	1.3272	1.4226	1.4958	1.6081	1.7955	2.1628	2.5246
800					1.3018	1.3755	1.4717	1.5665	1.6391	1.7512	1.9380	2.3043	2.6653
1000					1.4443	1.5184	1.6139	1.7101	1.7795	1.8917	2.0784	2.4568	2.8026

Ref. Perry, *Chemical Engineers' Handbook*, second edition, 1941, p.488.

HEAT CAPACITY OF GAS, C_p AND C_v

Temperature (°C)	C_p	C_v
−181	22.3	14.0
−76	26.6	18.3
+15	28.58	20.27

The above values for C_p and C_v are expressed in joules/gram mole/°C. To convert to gram calories/gram mole/°C, multiply by 0.2389.

Ref. *International Critical Tables*, Vol.5 (1929), p.80.

Temp (°K)	C_p° (cal/mole deg)	Temp (°K)	C_p° (cal/mole deg)
250	6.769	1250	7.454
298.16	6.892	1300	7.505
300	6.895	1400	7.610
400	6.974	1500	7.713
500	6.993	1750	7.957
600	7.008	2000	8.175
700	7.035	2500	8.526
800	7.078	3000	8.791
900	7.139	3500	8.993
1000	7.217	4000	9.151
1100	7.308	4500	9.282
1200	7.404	5000	9.389

Ref. Wagman, *et al.*, *J. Research Nat. Bur. Standards*, Vol.34 (1945), pp.143-161.

Temp (°C)	C_v^∞ (cal/mole deg)	Temp (°C)	C_v^∞ (cal/mole deg)
0	4.88	1100	5.60
25	4.92	1200	5.71
100	4.98	1300	5.81
200	5.00	1400	5.91
300	5.02	1500	6.00
400	5.04	1750	6.22
500	5.08	2000	6.40
600	5.14	2250	6.56
700	5.21	2500	6.69
800	5.30	2750	6.82
900	5.39	3000	6.94
1000	5.50		

Ref. Justi, *Spezifische Wärme, Enthalpie, Entropie und Dissoziation technischer Gase* (Berlin), 1938, p.143.

RATIO OF SPECIFIC HEATS

Temperature (°C)	γ (C_p/C_v)
−181	1.597
−76	1.453
+15	1.410

Ref. *International Critical Tables*, Vol.5, p.80.

HEAT CAPACITY OF LIQUID AND SOLID

Liquid

Temperature (°C)	C_p (cal/mole deg)
−260.5	1.28
−256	3.86
−255.7	3.95
−251.9	4.70

Ref. Landolt-Börnstein, *Physikalisch-Chemische Tabellen*, Auflage II, p.1278.

Solid (para-)

Temperature (°K)	C_p (cal/mole deg)
4.98	0.0869
5.11	0.0730
5.68	0.1025
5.95	0.128
7.53	0.252
8.075	0.320
8.57	0.405
9.87	0.557

Ref. Landolt-Börnstein, *Physikalisch-Chemische Tabellen*, 3rd. Suppl., p.2319; Mendelsohn, Ruhemann, and Simon, *Z. physik. Chem.*, B, Vol.15 (1931), p.121.

Solid (para-ortho-; 1:1)

Temperature (°K)	C_p (cal/mole deg)
2.74	0.41
4.02	0.342
5.34	0.331
6.17	0.369
7.94	0.409
9.08	0.521
10.55	0.705
11.47	0.85

Ref. Landolt-Börnstein, *Physikalisch-Chemische Tabellen*, 3rd Suppl., p.2319; Mendelsohn, Ruhemann, and Simon, *Z. physik. Chem.*, B, Vol.15 (1931), p.121.

FREE ENERGY OF FORMATION

$\Delta F^{\circ}_{298.1} = 0$, by definition

FREE-ENERGY FUNCTION

Temp (°K)	$-(F^{\circ} - H^{\circ}_{o})/T$ (cal/mole deg)	Temp (°K)	$-(F^{\circ} - H^{\circ}_{o})/T$ (cal/mole deg)
250	23.331	1250	34.305
298.16	24.423	1300	34.576
300	24.465	1400	35.098
400	26.422	1500	35.590
500	27.950	1750	36.696
600	29.203	2000	37.669
700	30.265	2500	39.328
800	31.186	3000	40.719
900	32.004	3500	41.922
1000	32.738	4000	42.988
1100	33.402	4500	43.942
1200	34.012	5000	44.809

Ref. Wagman, *et al.*, *J. Research Nat. Bur. Standards*, Vol.34 (1945), pp.143-161.

HEAT-CONTENT FUNCTION

Temp (°K)	$-(H^\circ - H_o^\circ)/T$ (cal/mole deg)	Temp (°K)	$-(H^\circ - H_o^\circ)/T$ (cal/mole deg)
250	6.7771	1250	7.0387
298.16	6.7877	1300	7.0563
300	6.7882	1400	7.0919
400	6.8275	1500	7.1295
500	6.8590	1750	7.2307
600	6.8810	2000	7.3358
700	6.9022	2500	7.5402
800	6.9218	3000	7.7286
900	6.9423	3500	7.8963
1000	6.9658	4000	8.0420
1100	6.9927	4500	8.1733
1200	7.0230	5000	8.2898

Ref. Wagman, *et al.*, *J. Research Nat. Bur. Standards*, Vol.34 (1945), pp.143-161.

ENTROPY

Temp (°K)	S_t° (cal/mole deg)	Temp (°K)	S_t° (cal/mole deg)
250	30.108	1250	41.344
298.16	31.211	1300	41.632
300	31.253	1400	42.190
400	33.250	1500	42.720
500	34.809	1750	43.928
600	36.084	2000	45.005
700	37.167	2500	46.868
800	38.108	3000	48.448
900	38.946	3500	49.818
1000	39.704	4000	51.030
1100	40.395	4500	52.115
1200	41.035	5000	53.099

Ref. Wagman, *et al.*, *J. Research Nat. Bur. Standards*, Vol.34 (1945), pp.143-161.

LITHIUM

MOLECULAR FORMULA

Li

MOLECULAR (ATOMIC) WEIGHT

6.940

Ref. *International Atomic Weights*, 1947.

MELTING POINT

Melting point = 186°C

Ref. *International Critical Tables*, Vol.1 (1926), p.104.

BOILING POINT

Boiling point = 1372°C

Ref. Kelley, *U.S. Bur. Mines Bull. 383* (1935)(Selected Value).

DENSITY

Vapor, Liquid } No information

Solid

d = 0.53 gm/ml at 20°C

Ref. *International Critical Tables*, Vol.2 (1927), p.456.

VAPOR PRESSURE

Liquid

Temperature (°C)	Pressure (mm Hg)
723	1
828	5
881	10
940	20
1003	40
1042	60
1097	100
1178	200
1273	400
1372	760

Ref. Stull, *Ind. Eng. Chem.*, Vol.39 (1947), p.540.

Temperature °K	Temperature °C	Pressure (atm)
865	592	0.0001
980	707	0.001
1131	858	0.01
1337	1064	0.1
1444	1171	0.25
1539	1266	0.5
1645	1372	1.0

Ref. Kelley, *U.S. Bur. Mines Bull. 383* (1935)(Selected Value).

Solid — No information

TRIPLE POINT
VISCOSITY (VAPOR, LIQUID)
SURFACE TENSION
} No information

COEFFICIENT OF THERMAL EXPANSION

Linear Expansion

$$L_t = L_0(1 + \alpha T + \beta T^2 + \cdots)$$

For solid lithium in temperature range 0°-178°C

$$10^6 \times \alpha = 51.2$$
$$10^9 \times \beta = 31$$

Cubical Expansion

$$V_t = V_0(1 + At + Bt^2)$$

For solid lithium in the temperature range 0°-178°C

$$10^6 \times A = 153.5$$
$$10^9 \times B = 92$$

For liquid lithium in the temperature range 182°-235°C

$$10^6 \times A = 174.3$$
$$10^9 \times B = 106$$

Ref. Bernini and Cantoni, *Nuovo cimento*, Vol.8 (1914), pp.241-60.

COEFFICIENT OF THERMAL CONDUCTIVITY

Vapor, Liquid } No information

Solid

Temperature (°C)	k (cal/cm sec deg)
−250	1.00
−200	0.218
−175	0.207
−150	0.200
−125	0.192
−100	0.185

COEFFICIENT OF THERMAL CONDUCTIVITY (*Cont'd*)

Solid (*Cont'd*)

Temperature (°C)	k (cal/cm sec deg)
−75	0.177
−50	0.170
−25	0.163
0	0.155
+20	0.149
50	0.153
75	0.161
100	0.166
125	0.169
150	0.170

Ref. Landolt-Börnstein, *Physikalisch-Chemische Tabellen*, 2nd Suppl., p.1260; Bidwell, *Phys. Rev.* (2), Vol.28 (1926), p.584.

DIPOLE MOMENT

$\mu = 0$ debye

Ref. Branch & Calvin, *The Theory of Organic Chemistry*, 1941, p.129.

HEAT OF FUSION

$\Delta H_f = 0.836$ kcal/gm atom

Ref. *International Critical Tables*, Vol.1 (1926), p.104.

HEAT OF VAPORIZATION

$\Delta H_v = 35.656$ kcal/gm atom, at 298.1°K

The heat of vaporization at any temperature may be calculated by means of the expression

$$\Delta H_{v_t} = (36,410 - 2.53T) \text{ cal/gm atom}$$

where

$T = K°$

Using this formula, the heat of vaporization of lithium at its normal boiling point of 1372°C (1645°K) is

$$\Delta H_v = 32,248 \text{ cal/gm atom}$$

Ref. Kelley, *U.S. Bur. Mines Bull. 383* (1935), p.63.

HEAT OF FORMATION

Vapor

$$\Delta H^\circ_{298.1} = 36,439 \text{ cal/gm atom}$$

Solid

$$\Delta H^\circ = 0 \text{ by convention}$$

Ref. Kelley, *U.S. Bur. Mines Bull. 383* (1935).

HEAT OF COMBUSTION

$$\Delta H_t^\circ \text{ Li}_2\text{O} = -142.3 \text{ kcal/mole}$$

Therefore, ΔH_c° Li $= -142.3$ kcal/mole

Ref. Bichowsky and Rossini, *Thermochemistry of Chemical Substances*, 1936, p.131.

CRITICAL DATA
EQUATION OF STATE } No information

COMPRESSIBILITY

$$\beta = \frac{1}{V_0} \cdot \frac{\partial v}{\partial p} = \text{cubical compressibility}$$

Temperature (°C)	Pressure (atm)	$\beta \times 10^6$
30	0	8.979
30	11,600	6.566
20	99-493	9.1

Ref. *International Critical Tables*, Vol.3 (1923), p.47.

HEAT CAPACITY OF VAPOR, C_p AND C_v

Temp (°K)	C_p° (cal/mole deg)	Temp (°K)	C_p° (cal/mole deg)	Temp (°K)	C_p° (cal/mole deg)
298.1	4.967	2700	5.104	4400	6.035
1000	4.967	2800	5.136	4500	6.101
1100	4.967	2900	5.171	4600	6.166
1200	4.967	3000	5.211	4700	6.229
1300	4.967	3100	5.252	4800	6.291
1400	4.967	3200	5.301	4900	6.352
1500	4.967	3300	5.349	5000	6.411
1600	4.967	3400	5.404	5100	6.470
1700	4.970	3500	5.461	5200	6.526
1800	4.973	3600	5.520	5300	6.605
1900	4.976	3700	5.581	5400	6.632
2000	4.983	3800	5.643	5500	6.681
2100	4.990	3900	5.707	5600	6.729
2200	5.001	4000	5.771	5700	6.775
2300	5.014	4100	5.837	5800	6.818
2400	5.031	4200	5.902	5900	6.858
2500	5.054	4300	5.969	6000	6.897
2600	5.076				

Ref. Sachsel and Mantis, Unpublished Calculations, Battelle Memorial Institute, 1947.

RATIO OF SPECIFIC HEATS — No information

HEAT CAPACITY OF LIQUID AND SOLID

Liquid

$C_p = 7.50$ cal/deg gm atom

Ref. Kelley, *U.S. Bur. Mines Bull. 383* (1935), p.63.

Temperature Range C_p { 453°-700°K: 8.5; 700°-1000°K: 7.5; 1000°-1500°K: 7.0

Ref. Beutler and Levi, *Z. physik. Chem.* (B), Vol.24 (1934), p.278.

Solid

Temperature (°K)	C_p (cal/deg gm atom)
10	(0.03)
25	0.16
50	0.99
100	3.07
150	4.26
200	4.94
298.1	5.65

Ref. Kelley, *U.S. Bur. Mines Bull. 434* (1948), p.87.

FREE ENERGY OF FORMATION

Vapor

Solid = gas

$\Delta F^\circ_{298.1}$ = 28,807 cal/mole

Solid

$\Delta F^\circ_{298.1}$ = 0 by definition

Ref. Kelley, *U.S. Bur. Mines Bull. 383* (1935), p.63.

FREE-ENERGY FUNCTION

Temp (°K)	$-(F^\circ - E^\circ_o)/T$ (cal/mole deg)	Temp (°K)	$-(F^\circ - E^\circ_o)/T$ (cal/mole deg)
298.1	28.184*	2200	38.113
1000	34.197	2400	38.546
1100	34.670	2500	38.749
1200	35.066	2600	38.945
1300	35.500	2800	39.314
1400	35.868	3000	39.659
1500	36.211	3500	40.432
1600	36.531	4000	41.112
1700	36.832	4500	41.720
1800	37.116	5000	42.273
1900	37.585	5500	42.785
2000	37.640	6000	43.263

*Value obtained from Kelley, *U.S. Bur. Mines Bull. 383* (1935), p.63.

Ref. Sachsel, Goodrich, and Mantis, Unpublished Calculations, Battelle Memorial Institute, 1947.

HEAT-CONTENT FUNCTION

Temp (°K)	$(H^\circ - H_o^\circ)/T$ (cal/deg mole)	Temp (°K)	$(H^\circ - H_o^\circ)/T$ (cal/deg mole)
298.1	4.968	2200	4.970
1000	4.967	2400	4.974
1100	4.967	2500	4.978
1200	4.967	2600	4.980
1300	4.967	2800	4.989
1400	4.967	3000	5.001
1500	4.967	3500	5.048
1600	4.967	4000	5.118
1700	4.967	4500	5.210
1800	4.968	5000	5.315
1900	4.968	5500	5.427
2000	4.968	6000	5.541

Ref. Sachsel, Goodrich, and Mantis, Unpublished Calculations, Battelle Memorial Institute, 1947.

ENTROPY

Gas

Temp (°K)	S_t° (cal/mole deg)	Temp (°K)	S_t° (cal/mole deg)
298.16	33.15*	2200	43.084
1000	39.164	2400	43.520
1100	39.637	2500	43.727
1200	40.069	2600	43.925
1300	40.467	2800	44.303
1400	40.835	3000	44.660
1500	41.178	3500	45.480
1600	41.498	4000	46.230
1700	41.799	4500	46.930
1800	42.084	5000	47.588
1900	42.353	5500	48.212
2000	42.607	6000	48.804

These entropy values do not include contributions due to nuclear spin, and are the virtual entropies at $P = 1$ atm.

*Value obtained from Kelley, *U.S. Bur. Mines Bull. 383* (1935), p. 63.

Ref. Sachsel, Goodrich, and Mantis, Unpublished Calculations, Battelle Memorial Institute, 1947.

Liquid	No information
Solid	$S^{\circ}_{298.1} = 6.70 \pm 0.06$ cal/mole deg Ref. Kelley, *U.S. Bur. Mines Bull.* 434 (1948).

LITHIUM HYDRIDE

MOLECULAR FORMULA	LiH
MOLECULAR WEIGHT	7.95 Ref. *International Atomic Weights*, 1947.
MELTING POINT	Melting point = 680°C Ref. Guntz, *Compt. rend.*, Vol.122 (1896), p.244.
BOILING POINT	No information
DENSITY Vapor Liquid	No information

DENSITY (*Cont'd*)

Solid

$d = 0.76 \pm 0.01$ gm/cc at 20°C

Ref. Tronstad and Wergeland, *Kgl. Norske Videnskab. Selskabs*, Forh. 10, No. 10 (1937), p. 36 (Pub. 1938).

VAPOR PRESSURE

Dissociation pressure = 27 mm at 680°C (melting point)

Ref. Guntz, *Compt. rend.*, Vol. 122 (1896), p. 244.

TRIPLE POINT
VISCOSITY: VAPOR, LIQUID
SURFACE TENSION
COEFFICIENT OF THERMAL EXPANSION
COEFFICIENT OF THERMAL CONDUCTIVITY: VAPOR, LIQUID
DIPOLE MOMENT
HEAT OF FUSION
HEAT OF VAPORIZATION

} No information

HEAT OF FORMATION

$$Li(s) + \tfrac{1}{2} H_2(g) = LiH(s)$$

$$\Delta H^\circ_{298.1} = -22.9 \text{ kcal/mole}$$

Ref. Kapustinskii, Shamovskii, and Bayushkina, *J. Phys. Chem.* (U.S.S.R.), Vol. 10 (1937), p. 620.

HEAT OF COMBUSTION
CRITICAL DATA
EQUATION OF STATE
COMPRESSIBILITY

} No information

HEAT CAPACITY OF THE GAS, C_p AND C_v

Temperature (°K)	C_v (cal/mole deg)	C_p (cal/mole deg)
0	2.9804	4.9673
10	5.1326	7.1195
20	4.990	6.977
50	4.97	6.96
100	4.97	6.96
150	4.98	6.97
200	5.00	6.98
250	5.04	7.03
298.1	5.12	7.11
300	5.12	7.11
350	5.24	7.23
400	5.38	7.37
500	5.67	7.66
600	5.94	7.93
700	6.17	8.15
800	6.35	8.34
900	6.50	8.49
1000	6.63	8.62
1250	6.87	8.86
1500	7.04	9.03

Ref. Greenlee and Johnston, Ohio State University, Unpublished Data, 1940.

RATIO OF SPECIFIC HEATS

Temperature (°K)	$\gamma = C_p/C_v$
0	1.667
10	1.387
20	1.398
50	1.400
100	1.400
150	1.400
200	1.396
250	1.395
298.1	1.389
300	1.389
350	1.380
400	1.370
500	1.351
600	1.335
700	1.321

RATIO OF SPECIFIC HEATS (*Cont'd*)

Temperature (°K)	$\gamma = C_p/C_v$
800	1.313
900	1.306
1000	1.300
1250	1.290
1500	1.283

Ref. Greenlee and Johnston, Ohio State University, Unpublished Data, 1940.

HEAT CAPACITY OF THE LIQUID AND SOLID

Liquid — No information

Solid

Temperature (°C)	C_p (cal/mole deg)
−223.1	0.20
−200	0.65
−180	1.27
−173.1	1.50
−160	2.24
−123.1	3.50
−80	5.81
−23.1	7.24
0	7.79
+19.6	8.19
25	8.24
50	8.51

Ref. Günther, *Ann. Physik.*, Vol.63 (1920), p.476.

FREE ENERGY OF FORMATION

$\Delta H^\circ_{298.1} = -17,900$ cal/mole for equation

$$Li(s) + \tfrac{1}{2} H_2(g) = LiH(s)$$

Above value calculated using following thermodynamic values;

$S^\circ_{298.1} = 6.70$ cal/mole deg for $Li(s)$

$S^\circ_{298.1} = 15.60$ cal/mole deg for $\tfrac{1}{2} H_2(g)$

$S^\circ_{298.1} = 5.63$ cal/mole deg for $LiH(s)$

$\Delta S^\circ_{298.1} = 22,900$ cal/mole for $LiH(s)$

FREE-ENERGY FUNCTION

LiH gas

Temperature (°K)	$-(F^\circ - E_o^\circ)/T$ (cal/mole deg)
10	10.969
20	15.408
50	21.564
100	26.315
150	29.114
200	31.104
250	32.652
298.1	33.875
300	33.920
350	34.995
400	35.931
500	37.510
600	38.820
700	39.944
800	40.934
900	41.819
1000	42.622
1250	44.358
1500	45.811
2000	48.171
2500	50.056

Ref. Greenlee and Johnston, Ohio State University, Unpublished Data, 1940.

HEAT-CONTENT FUNCTION No information

ENTROPY

Gas

Temperature (°K)	S_t° (cal/mole deg)
298.1	40.839
300	40.884
400	42.962
500	44.638
600	46.059
700	47.298
800	48.399
900	49.390
1000	50.292
1500	53.874
2000	56.511

Ref. Greenlee and Johnston, Ohio State University, Unpublished Data, 1940.

ENTROPY (*Cont'd*)

Solid

Temperature (°K)	S_t° (cal/mole deg)
0	0
50	0.06
100	0.50
150	1.48
200	2.79
250	4.21
273.1	4.89
298.1	5.63

Ref. Günther, *Ann. Physik.*, Vol.63 (1920), pp.476-80.

MAGNESIUM

MOLECULAR FORMULA

Mg

MOLECULAR WEIGHT

24.32

Ref. *International Atomic Weights*, 1947.

MELTING POINT

Melting point = 650°C

Ref. Zalesinski and Zulinski, *Bull. intern. acad. polon. sci., Classe sci. math. nat.* (in German), 1928A, p.479.

BOILING POINT

Boiling point = 1107°C at 760 mm Hg

Ref. Baur and Brunner, *Helv. Chim. Acta*, Vol.17 (1934), p.958.

DENSITY

Vapor — No information

Liquid

Temperature (°C)	Density (gm/ml)	Reference
650	1.601	(1)
700	1.536	(1)
750	1.470	(1)
780	1.545	(2)
765-850	1.584-0.00018 (t-675)	(3)

Refs. (1) Arndt and Ploetz, *Z. physik. Chem.*, vol.130 (1927), p.184.

(2) Sauerwald, *Z. Metallkunde*, Vol.14 (1922), p.461.

(3) Gothe and Mangelsdorff, *Z. Metallkunde*, Vol.29 (1937), p.352.

Solid

Temperature (°C)	Density (gm/ml)	Reference
0	1.7407	(1)
25	1.7373	(1)
400	1.692	(2)
500	1.676	(2)
600	1.622	(2)
700	1.575	(2)
800	1.555	(2)

Refs. (1) Batecas and Casado, *Z. physik. Chem.*, Vol.A181 (1937), p.197.

(2) Pelzel, *Z. Metallkunde*, Vol.32 (1940), p.7.

VAPOR PRESSURE

	Temperature (°C)	Pressure mm Hg
Solid:	516	0.076
	608	0.76
Liquid:	725	7.6
	886	76.
	963	190.
	1030	380.
	1107	760.

Ref. Kelley, *U.S. Bur. Mines Bull. 383* (1935).

TRIPLE POINT
VISCOSITY } No information

SURFACE TENSION

In atmosphere of argon:

Temperature (°C)	γ (dynes/cm)
681	563
894	502

Ref. Alico, *Introduction to Magnesium and its Alloys*, 1945, p.30.

COEFFICIENT OF THERMAL EXPANSION

(Linear)

Temperature Range (°C)	$\beta \times 10^6$	Reference
−190 to 0	20.8	(1)
0 to 100	26.1	(1)
20 to 300	27.9	(2)
20 to 500	29.8	(2)
20 to 650	30.3	(3)

Refs. (1) Ebert, *Z. Physik.*, Vol.47 (1928), p.712.

(2) Hidnert and Sweeney, *J. Research Nat. Bur. Standards*, Vol.1 (1928), p.771.

(3) Endo, *Bull. Chem. Soc. Japan*, Vol.2 (1927), p.131.

COEFFICIENT OF THERMAL CONDUCTIVITY

Vapor
Liquid } No information

Solid

Temperature (°C)	Kcal/sec cm deg
100	0.33
200	0.32
300	0.31
400	0.31
500	0.32

Ref. Schofield, *Proc. Royal soc. (London)*, Vol.107 (1925), p.206.

DIPOLE MOMENT

$\mu = 0$ debye

Ref. Branch and Calvin, *Theory of Organic Chemistry* 1941, p.129.

HEAT OF FUSION

$\Delta H_f = 2{,}160$ cal/mole

Ref. Perry, *Chemical Engineers' Handbook*, second edition, 1941, p.499.

HEAT OF VAPORIZATION

$\Delta H_v = 32.517$ kcal/gm atom at 1107°C and 760 mm Hg

Ref. Baur and Brunner, *Helv.Chim. Acta*, Vol.17 (1934), p.958.

HEAT OF FORMATION

$\Delta H^\circ_{298.1}$ (Vapor) $= -35{,}907$ cal/mole

$\Delta H^\circ_{298.1}$ (Solid) $= 0$

Ref. Kelley, *U.S. Bur. Mines Bull. 383* (1935).

HEAT OF COMBUSTION

$\Delta H_c = -146{,}100$ cal/mole

Ref. Franck and Hockwald, *Z. Elektrochem*, Vol.31 (1925), p.581.

CRITICAL DATA

$t_c = 2100°C$ (approx)

Ref. Ruff and Hartman, *Z. anorg. u. allgem. Chem.*, Vol.133 (1924), p.29.

EQUATION OF STATE
COMPRESSIBILITY } No information

HEAT CAPACITY OF VAPOR, C_p AND C_v

$C_{p,298.1} = 4.97$ cal/mole deg (calculated)

Ref. Kelley, *U.S. Bur. Mines Bull. 383* (1935).

RATIO OF SPECIFIC HEATS No information

HEAT CAPACITY OF LIQUID AND SOLID

Liquid No information

Solid

Temperature (°K)	C_p (cal/mole deg)
20	0.12
30	0.44
40	0.86
50	1.47
60	2.05
70	2.62
80	3.14
90	3.61
100	3.97
150	5.13

Solid *(Cont'd)*

Temperature (°K)	C_v (cal/mole deg)
200	5.58
250	5.83
300	6.03

Ref. *International Critical Tables*, Vol. 5 (1929), p. 85.

$C_p = 6.20 + 0.00133T - 67800/T^2$ cal/mole/deg K

Ref. Kelley, *U.S. Bur. Mines Bull. 371* (1934).

FREE ENERGY OF FORMATION

$\Delta F^\circ_{298.1}$ (Gas) = 27,640 cal/mole

$\Delta F^\circ_{298.1}$ (Solid) = 0

Ref. Kelley, *U.S. Bur. Mines Bull. 371* (1934).

FREE-ENERGY FUNCTION

Vapor

Temperature (°K)	$-(F^\circ - E^\circ_o)/T$ (cal/mole deg)
298.1	30.545
400	32.005
500	33.114
600	34.019
700	34.785
800	35.448
900	36.033
1000	36.557
1100	37.030
1200	37.462
1300	37.860
1400	38.228
1500	38.571

Ref. Kelley, *U.S. Bur. Mines Bull. 371* (1934).

HEAT-CONTENT FUNCTION No information

ENTROPY

$S^{\circ}_{298.1}$ (Gas) = 35.51 ± nil cal/mole deg

$S^{\circ}_{298.1}$ (Solid) = 7.8 ± 0.1 cal/mole deg

Ref. Kelley, *U.S. Bur. Mines Bull. 350* (1932).

METHANE

MOLECULAR FORMULA

CH_4

MOLECULAR WEIGHT

16.04

Ref. *International Atomic Weights*, 1947.

MELTING POINT

Melting point = −182.48 °C

Ref. American Petroleum Institute, Research Project No.44, *Collection, Analysis, and Calculation of Data on the Properties of Hydrocarbons*, 1945, Table a, 1.

BOILING POINT

Boiling point = −161.49 °C at 760 mm Hg

Ref. American Petroleum Institute, Research Project No.44, *Collection, Analysis, and Calculation of Data on the Properties of Hydrocarbons*, 1945, Table a, 1.

DENSITY

Gas (in equilibrium with liquid)

Temperature (°C)	Density (gm/ml)
−161.5	0.0018
−160	0.0020
−150	0.0039
−140	0.0068
−130	0.0112
−120	0.0175
−110	0.0269
−100	0.0413
−90	0.0665

Ref. *International Critical Tables*, Vol.3 (1928), p.3.

Liquid

Temperature (°C)	Density (gm/ml)
−173.1	0.4417
−168.1	0.4335
−163.1	0.4263
−161.58	0.4241
−158.1	0.4190
−153.1	0.4117
−148.1	0.4043
−143.1	0.3967
−138.1	0.3888
−133.1	0.3804
−128.1	0.3712
−123.1	0.3612
−118.1	0.3505
−113.1	0.3391
−108.1	0.3279
−103.1	0.3137
−98.1	0.2988
−93.1	0.2812
−88.1	0.2573
−82.1	0.1613 (Critical)

Ref. Keyes, Taylor, and Smith, *J. Math. Phys.*, Vol.1 (1922), p.211; Egloff, *Physical Constants of Hydrocarbons*, Vol.1 (1939), p.26.

DENSITY (*Cont'd*)

Solid — No information

VAPOR PRESSURE

Liquid

Temp (°C)	Press. (mm Hg)	Temp (°C)	Press. (mm Hg)
−195.51	10	−162.48	700
−191.77	20	−162.31	710
−189.41	30	−162.14	720
−187.66	40	−161.98	730
−186.25	50	−161.81	740
−185.06	60	−161.65	750
−183.12	80	−161.49	760
−181.45	100	−161.33	770
−178.09	150	−161.17	780
−175.55	200	−161.02	790
−173.47	250	−160.86	800
−171.69	300	−159.39	900
−168.76	400	−158.04	1000
−166.35	500	−155.6	1200
−164.29	600	−152.5	1500

Ref. American Petroleum Institute, Research Project No.44, *Collection, Analysis, and Calculation of Data on the Properties of Hydrocarbons*, 1945, Table 2K.

Solid

Temperature (°C)	Pressure (mm Hg)
−182.47	87.67
−188.49	35.13
−194.16	13.04
−199.70	4.24
−208.02	0.506

Ref. Freeth and Verschoyle, *Proc. Roy. Soc. (London)*, A, Vol.130 (1931), p.453.

TRIPLE POINT

Temperature = −182.48 °C

Pressure = 87.7 mm Hg

Ref. American Petroleum Institute, Research Project No.44, *Collection, Analysis, and Calculation of Data on the Properties of Hydrocarbons*, 1945, Table k1.

VISCOSITY

Gas

Pressure (atm)	$\eta \times 10^6$ (poises)			
	30 °C	50 °C	70 °C	95 °C
1.00	110.8	117.1	125.6	133.7
4.40	112.2	118.1	126.3	134.9
28.2	115.7	121.5	129.5	136.9
41.8	119.8	124.8	132.2	139.7
55.4	123.7	128.3	135.1	142.3
69.0	128.1	132.8	138.4	145.3
82.7	132.7	137.1	142.1	147.8
96.3	138.6	142.9	146.7	151.2
116.8	147.3	150.9	153.3	156.3
137.0	158.1	159.0	160.6	161.8
171.0				173.5

Ref. Comings, Mayland, and Egly, *Univ. Illinois Eng. Expt. Sta. Bull.*, Series No.354 (1944), p.27.

Temperature (°C)	$\eta \times 10^7$ (poises)
20	1087
57.6	1205
100	1331
150	1471
200.5	1605
250.0	1725

Ref. Trautz and Sorg, *Ann. Physik* (5), Vol.10 (1931), p.81.

VISCOSITY (*Cont'd*)

Gas (*Cont'd*)

Temperature (°C)	$\eta \times 10^7$ (poises)
284	1813
380	2026
499	2264

Ref. Trautz and Sorg, *Ann. Physik* (5), Vol.7 (1930), p.427.

Liquid

Temperature (°K)	$\eta \times 10^5$ (poises)
90.1	210
93.5	188
94.6	179
110.6	100
111.2	98

Ref. Taylor and Murray, *Annual Tables of Constants and Numerical Data*, Vol.12 (23), 1937, p.4.

SURFACE TENSION No information

COEFFICIENT OF THERMAL EXPANSION

Coefficient at constant pressure for temperature range 0-100°C

$$\alpha_v = \frac{1}{V_0}\left(\frac{dv}{dt}\right)_p ;$$

at 760 mm Hg, $\alpha_v \times 10^6 = 3,682$

Ref. Coppock, *Phil. Mag.* (7), Vol.19 (1935), p.446.

COEFFICIENT OF THERMAL CONDUCTIVITY

Gas

Press. (mm Hg)	Temp (°C)	k × 10^5 (cal/cm sec deg)
500.0	0	7.205
185-740	10.03	7.568
"	8.03	7.498
"	6.02	7.428
"	4.02	7.374
"	3.03	7.318
"	2.03	7.285
"	0	7.21

Ref. Brouty, *Annual Tables of Constants and Numerical Data*, Vol.12 (4), 1937, p.2.

DIPOLE MOMENT

$\mu = 0$ debye, $-80°$ to 100°C

Ref. Sidgwick, *Trans. Faraday Soc.*, Vol.30 (II), 1934, p.904.

HEAT OF FUSION

$\Delta H_f = 0.225$ kcal/mole

Ref. American Petroleum Institute, Research Project No.44, *Collection, Analysis, and Calculation of Data on the Properties of Hydrocarbons*, 1945, Table z1.

HEAT OF VAPORIZATION

$\Delta H_v = 1.955$ kcal/mole

Ref. American Petroleum Institute, Research Project No.44, *Collection, Analysis, and Calculation of Data on the Properties of Hydrocarbons*, 1945, Table m1.

HEAT OF FORMATION

Temperature (°K)	ΔH_f° (kcal/mole)
0	−15.987
298.16	−17.889
300	−17.903
400	−18.629
500	−19.302
600	−19.893
700	−20.401
800	−20.823
900	−21.166
1000	−21.43
1100	−21.65
1200	−21.79
1300	−21.92
1400	−22.00
1500	−22.06

Ref. Wagman, *et al.*, *J. Research Nat. Bur. Standards*, Vol.34 (1945), p.143.

HEAT OF COMBUSTION

At 25°C and constant pressure, to form

H_2O (l) and CO_2 (g)

$\Delta H_c^\circ = -212.798$ kcal/mole

H_2O (g) and CO_2 (g)

$\Delta H_c^\circ = -191.759$ kcal/mole

Ref. American Petroleum Institute, Research Project No.44, *Collection, Analysis, and Calculation of Data on the Properties of Hydrocarbons*, 1945, Table 1n.

CRITICAL DATA

$t_c = -82.25\,^{\circ}C$

$p_c = 45.60$ atm

$d_c = 0.1623$ gm/cc

Ref. Cardozo, *J. chim. Phys.*, Vol.13 (1915), p.312.

EQUATION OF STATE

$$\left(P + \frac{n^2 a}{V^2}\right)(V - nb) = nRT$$

P = atmospheres

V = liters/mole

R = 0.08207 liter atm/mole deg

T = °K

n = number of moles

a = 2.264 liter^2 atm/mole^2

b = 0.04278 liter/mole

Ref. Dodge, *Chemical Engineering Thermodynamics*, pp.173, 662-63.

COMPRESSIBILITY

Volume	Pressure (atm)				
(cc/gm)	0°C	50°C	100°C	150°C	200°C
40	32.297	39.418	46.474	53.486	60.486
35	36.514	44.760	52.935	61.040	69.158
30	42.003	51.809	61.510	71.139	80.752
25	49.441	61.504	73.445	85.260	97.050
20	60.129	75.980	91.240	106.540	121.806
15	76.879	99.004	120.854	142.426	163.973
12	92.689	121.949	150.883	179.407	207.951
10	107.950	145.076	181.840	218.122	254.266

Ref. Keyes and Burks, *J. Am. Chem. Soc.*, Vol.49 (1927), p.1403.

HEAT CAPACITY OF GAS, C_p AND C_v

Temperature (°K)	C_p° (cal/mole deg)
0	0
298.16	8.536
300	8.552
400	9.736
500	11.133
600	12.546
700	13.88
800	15.10
900	16.21
1000	17.21
1100	18.09
1200	18.88
1300	19.57
1400	20.18
1500	20.71

Ref. Wagman, *et al.*, *J. Research Nat. Bur. Standards*, Vol.34 (1945), p.143.

RATIO OF SPECIFIC HEATS

Temp (°C)	Press. (atm)	γ $(=C_p/C_v)$
--115	1	1.41
−74	1	1.35
+15	1	1.31

Ref. Lange, *Handbook of Chemistry*, sixth edition, 1946, p.1477.

HEAT CAPACITY OF LIQUID AND SOLID No information

FREE ENERGY OF FORMATION

$$C \text{ (graphite)} + 2H_2(g) = CH_4(g)$$

Temperature (°K)	ΔF_f° (kcal/mole)
0	−15.987
298.16	−12.140
300	−12.104
400	−10.048
500	−7.840
600	−5.49
700	−3.05
800	−0.55
900	+2.01
1000	4.61
1100	7.22
1200	9.85
1300	12.50
1400	15.14
1500	17.80

Ref. Wagman, *et al.*, *J. Research Nat. Bur. Standards*, Vol.34 (1945), p.143.

FREE-ENERGY FUNCTION

Temperature (°K)	$-(F^\circ - H_\circ^\circ)/T$ (cal/mole deg)
0	0
298.16	36.46
300	36.51
400	36.86
500	40.75
600	42.39
700	43.86
800	45.21
900	46.47
1000	47.65
1100	48.78
1200	49.86
1300	50.89
1400	51.88
1500	52.84

Ref. Wagman, *et al.*, *J. Research Nat. Bur. Standards*, Vol.34 (1945), p.143.

HEAT-CONTENT FUNCTION

Temperature (°K)	$(H^\circ - H_\circ^\circ)/T$ (cal/mole deg)
0	0
298.16	8.039
300	8.042
400	8.307
500	8.730
600	9.249
700	9.816
800	10.401
900	10.985
1000	11.56
1100	12.11
1200	12.65
1300	13.15
1400	13.63
1500	14.09

Ref. Wagman, *et al.*, *J. Research Nat. Bur. Standards*, Vol.34 (1945), p.143.

ENTROPY

Temperature (°K)	S_t° (cal/mole deg)
0	0
298.16	44.50
300	44.55
400	47.17
500	49.48
600	51.64
700	53.68
800	55.61
900	57.45
1000	59.21
1100	60.89
1200	62.50
1300	64.04
1400	65.51
1500	66.93

Ref. Wagman, *et al.*, *J. Research Nat. Bur. Standards*, Vol.34 (1945) p.143.

METHANOL

MOLECULAR FORMULA

CH_3OH

MOLECULAR WEIGHT

32.04

Ref. *International Atomic Weights*, 1947.

MELTING POINT

Melting point = 175.22°K

= -97.94°C

Ref. Kelley, *J. Am. Chem. Soc.*, Vol. 51 (1929), p.180.

BOILING POINT

boiling point = 64.65°C

Ref. Timmermans, *et al.*, *J. chim. phys.*, Vol.27 (1930), p.401.

DENSITY

Vapor, Liquid (in Equilibrium)

Temperature (°C)	Density (gm/ml)	
	Liquid	Vapor
0	0.8100	0.0000562
10	0.8008	0.0000996
20	0.7915	0.0001695
30	0.7825	0.0002772
40	0.7740	0.0004394
50	0.7650	0.0006739
60	0.7555	0.001006
70	0.7460	0.001465
80	0.7355	0.002084
90	0.7250	0.002907
100	0.7140	0.003984
110	0.7020	0.005376
120	0.6900	0.007142
130	0.6770	0.009379
140	0.6640	0.01216
150	0.6495	0.01562
160	0.6340	0.01994
170	0.6160	0.02526
180	0.5980	0.03186
190	0.5770	0.04010
200	0.5530	0.05075
210	0.5255	0.06521
220	0.4900	0.08635
225	0.4675	0.1003
230	0.4410	0.1187
232	0.4295	0.1277
234	0.4145	0.1381
236	0.3955	0.1505
238	0.3705	0.1681
239	–	0.1878
240	0.2722	0.2722 (Critical)

Ref. Young, *Dublin Proc.*, Vol.12 (1910), p.374.

Solid

$d = 0.9673$, at -94.9°C

Ref. *International Critical Tables*, Vol.3 (1927), p.45.

VAPOR PRESSURE

Liquid

Temp (°C)	Press. (atm)	Temp (°C)	Press. (atm)
0	0.0389	70	1.219
10	0.0713	80	1.764
20	0.1251	90	2.493
25	0.1632	100	3.451
30	0.2109	110	4.686
40	0.3427	120	6.252
50	0.5388	130	8.209
60	0.8255		

Ref. Fiock, Guinings, and Holton, *J. Research Nat. Bur. Standards*, Vol.6 (1931), p.895.

Temp (°C)	Press. (atm)	Temp (°C)	Press. (atm)
140	10.63	210	47.03
150	13.57	220	56.18
160	17.11	225	61.25
170	21.34	230	66.67
180	26.35	235	72.47
190	32.23	240.0	78.67 (Critical)
200	39.08		

Ref. Young, *Dublin Proc.*, Vol.12 (1910), p.374.

Solid

No information

TRIPLE POINT

No information

VISCOSITY

Vapor

Temperature (°C)	$\eta \times 10^7$ (poises)
111.3	1259
153.9	1408
188.8	1527
217.5	1620
250.0	1725
277.6	1815
311.5	1921

Ref. Titani, *Bull. Chem. Soc. Japan*, Vol.8 (1933), p.255.

VISCOSITY (*Cont'd*)

Liquid

Temperature (°C)	η (poises)
−98.30	0.139
−86.78	0.0764
−84.23	0.0680
−77.94	0.0531
−72.55	0.0436
−58.62	0.0282
−44.53	0.0198
−33.34	0.0153
−22.29	0.0122
0	0.0082

Ref. Tonomura, *Science Repts. Tohoku Imp. Univ.* (1) Vol.22 (1933), p.104.

Temperature (°C)	η (poises)
15	0.00623
30	0.00510

Ref. Timmermans and Hennaut-Roland, *J. chim. phys.*, Vol.27 (1930), p.27.

SURFACE TENSION (ALCOHOL-AIR INTERFACE)

Temperature (°C)	γ (dynes/cm)
0	24.49
20	22.61
30	21.75
50	20.14
70	18.51
100	15.67
150	10.42
200	4.41
235	0.34

Ref. *International Critical Tables*, Vol.4 (1927), p.448.

COEFFICIENT OF THERMAL EXPANSION (CUBICAL)

Temperature (°C)	a
−90	0.001143
−50	0.001105
0	0.001153

Where

$$V_t = V_0(1 + at)$$

Ref. Seitz, Altertum, and Lechner, *Ann. Phys.*, Vol.49(1916), p.85.

COEFFICIENT OF THERMAL CONDUCTIVITY

$k_0 = 3.15 \times 10^{-5}$ cal/cm sec deg, at 0°C

Ref. *International Critical Tables*, Vol.5 (1927), p.214.

DIPOLE MOMENT

$\mu = 1.66$ debye

Ref. Branch and Calvin, *Theory of Organic Chemistry*, 1941, p.131.

HEAT OF FUSION

$\Delta H_f = 757$ cal/mole, at 175.22°K

Ref. Kelley, *J. Am. Chem. Soc.*, Vol.51 (1929), p.180.

HEAT OF VAPORIZATION

$\Delta H_v = 284$ cal/gm, at 20°C

Ref. Wolfe, Pahlke, and Wehage, *Z. physik. Chem.*, B Vol.28 (1935), p.1.

HEAT OF VAPORIZATION (*Cont'd*)

ΔH_v = 279.1 cal/gm, at 25°C

Ref. Rossini, *J. Research Nat. Bur. Standards*, Vol.13 (1934) (Selected value), p.192.

ΔH_v = 263.6 cal/gm, at 64.59°C

Ref. Tyrer, *J. Chem. Soc.*, Vol.101 (1912), p.84.

HEAT OF FORMATION

Gas

Temperature (°K)	ΔH_f° (cal/mole)
298	−48.490
300	−48.500
400	−49.330
500	−50.040
600	−50.660
700	−51.190
800	−51.590
900	−51.920
1000	−52.180

Ref. Smith, *Chemical Eng. Progress*, Vol.44 (1948), p.521.

HEAT OF COMBUSTION

State	Temperature (°C)	ΔH_c (kcal/mole)
Vapor	25	−182.58 ± 0.05
Liquid	25	−173.64 ± 0.05

Ref. Rossini, *J. Research Nat. Bur. Standards*, Vol.13 (1934)(Selected Values), p.192.

CRITICAL DATA

t_c = 240.0°C

p_c = 78.67 atm

d_c = 0.2722 gm/ml

Ref. Young, *Dublin Proc.*, Vol.12 (1910), p.374.

EQUATION OF STATE

$$P(V - V_1) = RT\left(1 - \frac{P}{P_c}\right)$$

Where

P = pressure, atm

P_c = critical pressure, atm

T = absolute temperature, °K

V = molecular volume of gas, liters

V_1 = molecular volume of liquid, liters

R = gas constant, 0.08206

Temperature range, 0-190°C

Pressure range up to 80-90 percent of absolute critical pressure

Reported accuracy of at least 7 percent

Ref. Herz, *Z. Elektrochem*, Vol.30 (1924), p.604.

COMPRESSIBILITY

$$B_t = \frac{1}{V_1}\left(\frac{V_1 - V_2}{P_2 - P_1}\right)$$

Where

V_1 = volume of a liquid under pressure of P_1 at t°C, and V_2 = volume at pressure P_2 and at same temperature

t°C	Pressure range (atm)	$B_t \times 10^6$
0	1-500	79
0	500-1000	58
0	1000-1500	47
0	1500-2000	40
0	2500-3000	29

Ref. Amagat, *Ann. chim. et phys.* (5), Vol.11 (1877), p.520.

COMPRESSIBILITY (*Cont'd*)

Pressure (atm)	Temperature (°C)					
	−100	−80	−60	−40	−20	0
1	.8939	.9145	.9352	.9561	.9775	1.0000
500	.8727	.8904	.9076	.9245	.9418	.9595
1000	.8556	.8713	.8865	.9011	.9159	.9308

Ref. Seitz and Lechner, *Ann. Physik*, Vol.49 (1916), p.93.

Pressure (atm)	Temperature (°C)			
	20	40	60	80
1	1.0238	1.0483	1.0737	1.1005
500	0.9811	0.9987	1.0187	1.0400
1,000	0.9494	0.9651	0.9808	0.9993
1,500	0.9256	0.9393	0.9526	0.9672
2,000	0.9064	0.9189	0.9306	0.9429
2,500	0.8906	0.9019	0.9124	0.9231
3,000	0.8763	0.8870	0.8966	0.9065
3,500	0.8636	0.8733	0.8824	0.8915
4,000	0.8523	0.8613	0.8700	0.8782
4,500	0.8420	0.8505	0.8587	0.8663
5,000	0.8325	0.8407	0.8487	0.8559
6,000	0.8163	0.8240	0.8314	0.8381
7,000	0.8023	0.8099	0.8163	0.8231
8,000	0.7907	0.7973	0.8039	0.8102
9,000	0.7797	0.7859	0.7920	0.7981
10,000	0.7696	0.7756	0.7816	0.7875
11,000	0.7605	0.7664	0.7728	0.7785
12,000	0.7527	0.7587	0.7652	0.7709

Relative volumes based on volume at 0° and 1 atm.

Ref. Bridgman, *Proc. Am. Acad. Arts Sci.*, Vol.49 (1913), p.3.

HEAT CAPACITY OF VAPOR, C_p AND C_v

RATIO OF SPECIFIC HEATS

No information

HEAT CAPACITY OF LIQUID AND SOLID

Solid

Temp (°K)	C_p (cal/mole deg)	Temp (°K)	C_p (cal/mole deg)
18.80	1.109	97.22	10.23
21.55	1.512	111.14	11.23
24.43	1.959	114.82	11.48
27.25	2.292	117.97	11.64
30.72	2.829	118.79	11.64
34.33	3.437	121.44	11.75
37.64	3.962	125.37	12.18
40.87	4.427	129.38	12.28
43.93	4.840	133.71	12.64
48.07	5.404	147.86	12.97
56.03	6.425	152.29	13.69
59.53	6.845	153.98	14.12
63.29	7.252	157.08	92.5
69.95	8.001	157.46	283.4
73.95	8.392	159.58	17.92
77.61	8.735	163.94	11.36
81.48	9.001	164.14	11.29
85.52	9.295	166.23	11.63
89.29	9.693	167.65	11.68
93.18	9.939		

Liquid

Temp (°K)	C_p (cal/mole deg)	Temp (°K)	C_p (cal/mole deg)
181.09	16.77	235.84	17.41
185.10	16.67	256.34	17.70
189.06	16.77	267.01	18.13
192.97	16.79	273.58	18.30
196.77	16.78	277.81	18.46
210.34	16.97	285.15	18.70
221.69	17.08	292.01	19.11

Ref. Kelley, *J. Am. Chem. Soc.*, Vol.51 (1929), p.180.

FREE ENERGY OF FORMATION

Vapor

Temperature (°K)	F_f° (cal/mole)
298	−39,060
300	−39,000
400	−35,800
500	−32,160
600	−28,560
700	−24,840
800	−21,080
900	−17,230
1000	−13,380

Ref. Smith, *Chemical Eng. Progress*, Vol. 44 (1948), p. 521.

FREE-ENERGY FUNCTION
HEAT-CONTENT FUNCTION
} No information

ENTROPY

Vapor

Temperature (°K)	S_f° (cal/mole deg)
298	56.7
300	56.7
400	60.0
500	63.1
600	66.0
700	68.6
800	71.0
900	73.3
1000	75.5

Ref. Smith, *Chemical Eng. Progress*, Vol. 44 (1948), p. 521.

Liquid

S_{298}° = 31.0 cal/mole deg

Ref. Parks, Kelley, and Huffman, *J. Am. Chem. Soc.*, Vol. 51 (1929), p. 1969.

METHYLAMINE

MOLECULAR FORMULA

CH_3NH_2 ; CH_5N

MOLECULAR WEIGHT

31.058

Ref. *International Atomic Weights*, 1947.

MELTING POINT

Melting point = −93.46°C

Ref. Aston, Siller, and Messerly, *J. Am. Chem. Soc.*, Vol.59 (1937), p.1743.

BOILING POINT

Boiling point = −6.32°C at 760 mm Hg

Ref. Aston, Siller, and Messerly, *J. Am. Chem. Soc.*, Vol.59 (1937), p.1743.

DENSITY

Gas

Temperature (°C)	Density (gm/ml)
−6.79	0.69572
−6.30	0.69423
1.86	0.68447
10.99	0.67335
17.21	0.66575
19.78	0.66277

Ref. Felsing and Thomas, *Ind. Eng. Chem.*, Vol.21 (1929), p.1269.

DENSITY (*Cont'd*)

Liquid

Temperature (°C)	Density (gm/ml)
−82.58	0.77787
−74.19	0.76903
−64.25	0.75850
−55.52	0.74931
−44.31	0.73719
−36.37	0.72884
−20.94	0.71124
−13.60	0.70273
−11.00	0.6992
−10.80	0.699

Ref. Felsing and Thomas, *Ind. Eng. Chem.*, Vol.21 (1929), p.1269.

Solid

$d = 0.823 \pm 0.005$ gm/ml at −92.5°C

Ref. Mehl, Beihefte, *Z. ges. Kalte-Ind.* (1), Vol.3, (1933), p.5.

VAPOR PRESSURE

Liquid

Temperature (°K)	Pressure (mm Hg)
190.01	4.06
198.90	9.59
206.93	19.19
214.27	34.75
221.98	60.67
228.48	94.29
236.46	155.86
244.40	247.20
249.54	326.65
255.60	446.09
260.60	569.33
264.79	693.03
266.88	761.55

Ref. Aston, Siller, and Messerly, *J. Am. Chem. Soc.*, Vol.59 (1937), p.1743.

Solid — No information

TRIPLE POINT No information

VISCOSITY

Gas

$\eta = 0.00236$ poises at 0°C

Ref. Fitzgerald, *J. Phys. Chem.*, Vol.16 (1912), p.621.

Liquid No information

SURFACE TENSION

Temperature (°C)	γ (dyne/cm)
−70	29.2
−49	27.0
−20	23.6
−18	23.1
−12	22.2

Ref. Jaeger, *Z. anorg. u. allgem. Chem.*, Vol.101 (1917), p.1.

Temperature (°C)	γ (dyne/cm)
15	20.60
25	19.19
35	17.65

Ref. Swift and Calkins, *J. Am. Chem. Soc.*, Vol.65 (1943), p.2415.

COEFFICIENT OF THERMAL EXPANSION

$\alpha = 3898 \times 10^{-6}$

Ref. Leduc, *Compt. rend.*, Vol.148, (1909), p.1173.

COEFFICIENT OF THERMAL CONDUCTIVITY

Gas

3.823×10^{-5} cal/cm sec deg at 6.5°C

Ref. Hofker, *Jahresber. Progymn. Wattenscheid*, 1893.

Liquid — No information

DIPOLE MOMENT

$\mu = 0.99$ debye

Ref. Ghosh and Chatterjee, *Phys. Rev.*, Vol.37 (1931), p.427.

HEAT OF FUSION

$\Delta H_f = 1465.8 \pm 2.0$ cal/mole

Ref. Aston, Siller, and Messerly, *J. Am. Chem. Soc.*, Vol.59 (1937), p.1743.

HEAT OF VAPORIZATION

$\Delta H_v = 6169 \pm 30$ cal/mole at 263.76°K

Ref. Aston, Siller, and Messerly, *J. Am. Chem. Soc.*, Vol.59 (1937) p.1743.

HEAT OF FORMATION

$\Delta H^\circ_{298.1} = -7,100$ cal/mole

Ref. Anderson, Beyer, and Watson, *Nat. Petroleum News*, Vol.36 (1944), p.476.

HEAT OF COMBUSTION

ΔH_c (Gas) = −256,960 cal/mole

ΔH_c (Liquid) = −256,100 cal/mole

Ref. Kharasch, *J. Research Nat. Bur. Standards*, Vol.2 (1929), p.359.

CRITICAL DATA

t_c = 156.9°C

P_c = 73.6 atm

Ref. Berthoud, *J. chim. phys.*, Vol.15 (1917), p.3.

EQUATION OF STATE

$$\left(P + \frac{n^2 a}{V^2}\right)(V - nb) = nRT$$

P = pressure, atm

V = volume, liters/mole

T = temp., °K

R = gas constant, 0.08207

n = number of moles

a = 7.130 liters^2 atm/mole^2

b = 0.05992 liter/mole

Ref. Lange, *Handbook of Chemistry*, sixth edition, 1946, p.1472.

COMPRESSIBILITY No information

HEAT CAPACITY OF GAS, C_p AND C_v

Temperature (°C)	C_p (cal/mole deg)
0	11.45
25	12.71
50	13.63

Ref. Aston and Doty, *J. Chem. Phys.*, Vol.8 (1940), p.743.

RATIO OF SPECIFIC HEATS

$$\frac{C_p}{C_v} = 1.202 \text{ at } 25°C$$

Ref. Felsing and Jessen, *J. Am. Chem. Soc.*, Vol.55 (1933), p.4418.

HEAT CAPACITY OF LIQUID AND SOLID

Liquid

Temperature (°K)	C_p (cal/mole deg)
186.61	23.68
200.90	23.86
212.47	24.07
224.28	24.08
233.92	24.32
252.48	24.18

Other intermediate values were reported.

Ref. Aston, Siller, and Messerly, *J. Am. Chem. Soc.*, Vol.59 (1937), p.1743.

Solid

Temperature (°K)	C_p (cal/mole deg)
14.76	0.435
49.05	5.199
101.83	10.80
149.56	12.78
174.76	14.61

Other intermediate values were reported.

Ref. Aston, Siller, and Messerly, *J. Am. Chem. Soc.*, Vol.59 (1937), p.1743.

FREE ENERGY OF FORMATION FREE-ENERGY FUNCTION HEAT-CONTENT FUNCTION	No information
ENTROPY Gas $S^{\circ}_{298.1} = 57.73$ cal/mole deg Ref. Aston, Siller, and Messerly, *J. Am. Chem. Soc.*, Vol.59 (1937), p.1743.	

METHYL NITRATE

MOLECULAR FORMULA CH_3NO_3
MOLECULAR WEIGHT 77.04 Ref. *International Atomic Weights*, 1947.
MELTING POINT Melting point — Explodes
BOILING POINT Boiling point = 66.5°C Ref. Thompson and Purkis, *Trans. Faraday Soc.*, Vol.32 (1936), p.674.

DENSITY

Vapor — No information

Liquid

Temperature (°C)	Density (gm/ml)
5	1.2322
10	1.2241
15	1.2167
20	1.2096
25	1.2032

Ref. Perkin, *J. Chem. Soc.*, Vol.55 (1889), p.682.

Solid — No information

VAPOR PRESSURE (LIQUID, SOLID)
TRIPLE POINT
VISCOSITY (VAPOR, LIQUID)
SURFACE TENSION
COEFFICIENT OF THERMAL EXPANSION
COEFFICIENT OF THERMAL CONDUCTIVITY (VAPOR,LIQUID)
— No information

DIPOLE MOMENT

μ = 2.85 debye, at 20°C (measured in benzene)

Ref. Cowley and Partington, *J. Chem. Soc.*, 1933, p.1252.

HEAT OF FUSION — No information

HEAT OF VAPORIZATION

ΔH_v = 7,800 cal/mole

Ref. Thompson and Purkis, *Trans. Faraday Soc.*, Vol.32 (1936), p.674.

HEAT OF FORMATION
HEAT OF COMBUSTION
CRITICAL DATA
EQUATION OF STATE
COMPRESSIBILITY
HEAT CAPACITY OF VAPOR
RATIO OF SPECIFIC HEATS
HEAT CAPACITY OF LIQUID AND SOLID
FREE ENERGY OF FORMATION
FREE-ENERGY FUNCTION
HEAT-CONTENT FUNCTION
ENTROPY

No information

MONOETHYLANILINE

MOLECULAR FORMULA

$C_6H_5NHC_2H_5$; $C_8H_{11}N$

MOLECULAR WEIGHT

121.18

Ref. *International Atomic Weights*, 1947.

MELTING POINT

Melting point = −63.5°C

Ref. *Bull. soc. chim. Belg.*, Vol.27 (1913), p.234.

BOILING POINT

Boiling point = 204.72°C

Ref. Nelson and Wales, *J. Am. Chem. Soc.*, Vol.47 (1925), p.867.

DENSITY

Vapor No information

Liquid

$d_4^{20} = 0.9625$

$d_4^{4} = 0.9727$

$d_{15}^{15} = 0.9643$

$d_{25}^{25} = 0.9583$

Ref. Beilstein, *Handbook of Organic Chemistry* (Berlin), Vol.12 (1929), p.159.

Solid No information

VAPOR PRESSURE

Liquid

Temp (°C)	Press. (mm Hg)	Temp (°C)	Press. (mm Hg)
50	2.4	156.34	194.0
60	4.0	159.26	215.2
70	6.1	162.66	235.7
81	10.3	169.97	295.8
91.55	16.9	172.67	319.9
101.52	24.2	182.41	424.3
107.42	32.0	184.08	439.8
110.66	38.5	189.06	509.0
116.58	46.5	190.3	521.9
122.99	60.2	194.6	586.1
128.88	74.6	197.0	624.0
134.42	91.9	200.69	685.5
135.08	92.5	200.90	688.8
143.47	126.7	203.85	745.7
146.58	141.6	205.20	769.3
152.11	167.5	206.70	795.8

Ref. Nelson and Wales, *J. Am. Chem. Soc.*, Vol.47 (1925), p.867.

Solid No information

TRIPLE POINT — No information

VISCOSITY

Vapor — No information

Liquid

at 25°C = 2.32 centistokes

Ref. Noll and Bolz, *Papier-Fabr.*, Vol.33 (Tech. Teil), 1935, p.193.

SURFACE TENSION
COEFFICIENT OF THERMAL EXPANSION
COEFFICIENT OF THERMAL CONDUCTIVITY (VAPOR, LIQUID)
DIPOLE MOMENT
HEAT OF FUSION
} No information

HEAT OF VAPORIZATION

ΔH_v = 94.0 cal/gm, or 11.38 kcal/mole at 204.72°C

Above value calculated from equation:

$\Delta H_v = 13.248 - .0039T$, where T = °K

Ref. Nelson and Wales, *J. Am. Chem. Soc.*, Vol.47 (1925), p.867.

HEAT OF FORMATION — No information

HEAT OF COMBUSTION

ΔH_c = -1126.88 kcal/mole, at constant pressure

Ref. Beilstein, *Handbook of Organic Chemistry* (Berlin), Vol.12 (1929), p.159.

CRITICAL DATA

$t_c = 425.4°C$

Above value questionable as to accuracy

Ref. Radice, These de doctorat, Geneve 1899; cit. *Arch. sci. phys.*, Vol.13 (1902), p.40.

EQUATION OF STATE — No information

COMPRESSIBILITY

$\beta = 45.89 \times 10^{-6}$

Ref. Richards and Mathews, *Z. physik. chem.*, Vol.61 (1908), p.452.

HEAT CAPACITY OF VAPOR
RATIO OF SPECIFIC HEATS
HEAT CAPACITY OF LIQUID AND SOLID
FREE ENERGY OF FORMATION
FREE-ENERGY FUNCTION
HEAT-CONTENT FUNCTION
ENTROPY

No information

NITROETHANE

MOLECULAR FORMULA

$C_2H_5NO_2$

MOLECULAR WEIGHT

75.07

Ref. *International Atomic Weights*, 1947.

MELTING POINT

Melting point = −90°C

Ref. Gabriel, *Chem. Ind.*, Vol.45 (1939), p.664.

BOILING POINT

Boiling point = 114.9°C

Ref. Buhmann and Fuchs, *Z. physik Chem.*, Vol.18 (1895), p.49..

DENSITY

Vapor — No information

Liquid

d = 1.03819 gm/cc at 25°C

Ref. Boyd and Copeland, *J. Am. Chem. Soc.*, Vol.64 (1942), p.2540.

Solid — No information

VAPOR PRESSURE

Liquid

$$\log P = \frac{A}{T} + B \log T + C$$

where

P = mm Hg

T = °K

A = −3249.5

B = −8.3188

C = 32.803

equation valid in range 0-160°C

Ref. Hodge, *Ind. Eng. Chem.*, Vol.32 (1940), p.748.

Solid — No information

TRIPLE POINT — No information

VISCOSITY

(Compared with water under identical conditions.)

Liquid

Temperature (°C)	Specific Viscosity
10	45
15	42
20	40
25	38
30	36
40	32
50	29

Ref. Pribram and Handl, *Wien Ber.*, Vol.84 (2), 1881, p.717.

SURFACE TENSION

Temperature (°C)	γ (dynes/cm)
10	33.4
20	32.2
50	28.5
100	22.5
110	21.2

Ref. *International Critical Tables*, Vol.4 (1928), p.449.

COEFFICIENT OF THERMAL EXPANSION
COEFFICIENT OF THERMAL CONDUCTIVITY (VAPOR, LIQUID) } No information

DIPOLE MOMENT

Vapor

$\mu = 4.03$ debye at 20°C

Ref. Sidgwick, *Trans. Faraday Soc.*, Vol.30 Pt.2 (1934), p.904.

Liquid μ = 3.58 debye Ref. Wiswall and Smyth, *J. Chem. Phys.*, Vol.9 (1941), p.358.
HEAT OF FUSION — No information
HEAT OF VAPORIZATION ΔH_v = 9,075 cal/mole at 0°C Ref. Goodeve, *Trans. Faraday Soc.*, Vol.30 (1934), p.501.
HEAT OF FORMATION — No information
HEAT OF COMBUSTION ΔH_c = 322.2 kcal/mole at 20°C and constant pressure Ref. Kharasch, *J. Research Nat. Bur. Standards*, Vol.2 (1929), p.359.
CRITICAL DATA t_c = 388.7°C Ref. Boyd and Copeland, *J. Am. Chem. Soc.*, Vol.64 (1942), p.2540.
EQUATION OF STATE COMPRESSIBILITY HEAT CAPACITY OF VAPOR RATIO OF SPECIFIC HEATS HEAT CAPACITY OF LIQUID AND SOLID FREE ENERGY OF FORMATION FREE-ENERGY FUNCTION HEAT-CONTENT FUNCTION ENTROPY — No information

NITROMETHANE

MOLECULAR FORMULA

CH_3NO_2

MOLECULAR WEIGHT

61.04

Ref. *International Atomic Weights*, 1947.

MELTING POINT

Melting point = −28.37

Ref. Jones and Giauque, *J. Am. Chem. Soc.*, Vol.69 (1947), p.983.

BOILING POINT

Boiling point = 101.25°C at 760 mm Hg

Ref. Timmermans and Hennaut-Roland, *J. chim. phys.*, Vol.29 (1932), p.529.

DENSITY

Vapor

d = 0.001972 gm/ml at 108.7°C

Ref. Williams, *J. Am. Chem. Soc.*, Vol.47 (1925), p.2644.

Liquid

d_4^{25} = 1.13118

Ref. Boyd and Copeland, *J. Am. Chem. Soc.*, Vol.64 (1942), p.2542.

VAPOR PRESSURE

Liquid

Temperature (°C)	Pressure (mm Hg)
25	38.0
30	48.0
40	76.0
50	121.0
60	177
70	263
80	397
85	450
90	531
95	623.5
100	744.5

Ref. Halban, *Z. phys. Chem.*, Vol.84 (1913), p.129.

Solid — No information

TRIPLE POINT — No information

VISCOSITY

Vapor — No information

Liquid

Temperature (°C)	η (poises)
0	0.00843
25	0.00631
40	0.00526
55	0.00450
70	0.00392
85	0.00342

Ref. *International Critical Tables*, Vol.7 (1930), p.213.

SURFACE TENSION

Temperature (°C)	γ (dynes/cm)
0	39.8
20	36.8
45	33.4
100	26.1

Ref. *International Critical Tables*, Vol.4 (1928), p.448.

COEFFICIENT OF THERMAL EXPANSION

$$\alpha = \frac{1}{V_0}\frac{dV}{dt};$$

$\alpha = 0.00119$ over range 0-30°C

Ref. Timmermans, *et al.*, *J. chim. phys.*, Vol.29 (1932), p.529.

COEFFICIENT OF THERMAL CONDUCTIVITY

Vapor — No information

Liquid

Temperature (°C)	k (cal/cm sec deg)
30	515×10^{-6}
60	495×10^{-6}

Ref. Smith, *Trans. Am. Soc. Mech. Engrs.*, Vol.58 (1936), p.719.

DIPOLE MOMENT

$\mu = 3.50$ debye

Ref. Wiswall and Smyth, *J. Chem. Phys.*, Vol.9 (1940), p.358.

HEAT OF FUSION

$\Delta H_f = 2,319 \pm 3$ cal/mole

Ref. Jones and Giauque, *J. Am. Chem. Soc.*, Vol.69 (1947), p.983.

HEAT OF VAPORIZATION

$\Delta H_v = 134.94 \pm 0.35$ cal/gm at 99.9°C

Ref. Mathews, Ramsdell and Thompson, *J. Am. Chem. Soc.*, Vol.48 (1926), p.562.

$\Delta \bar{H}_v = 9,147$ cal/mole at 25°C and 760 mm Hg

Ref. Jones and Giauque, *J. Am. Chem. Soc.*, Vol.69 (1947), p.983.

HEAT OF FORMATION

ΔH°_{291} (Gas) = −18.6 kcal/mole[1]

ΔH°_{291} (Liquid) = −27.2 kcal/mole[2], [4]

−27.6 kcal/mole[3], [4]

Refs. (1) Bichowsky and Rossini, *Thermochemistry of Chemical Substances*, 1936, p.51.

(2) Swietoslawski, *Z. phys. Chem.*, Vol.72 (1910), p.49.

(3) Berthelot and Matignon, *Ann. chim. et phys.* (6), Vol.28 (1893), p.565.

(4) Bichowsky and Rossini, *Thermochemistry of Chemical Substances*, 1936, p.248.

HEAT OF COMBUSTION

ΔH_c = −169.4 kcal/mole at 20°C

Ref. Kharasch, *J. Research Nat. Bur. Standards*, Vol.2 (1929), p.359.

CRITICAL DATA

t_c = 349.6°C

Ref. Boyd and Copeland, *J. Am. Chem. Soc.*, Vol.64 (1942), p.2542.

EQUATION OF STATE No information

COMPRESSIBILITY

Temperature (°C)	Pressure limits (atm)	$\beta \times 10^{-6}$
18.36	0-8	69.4
24.85	0-8	71.6

Ref. Hebeisen, *Ann. Phys.* (4) Vol.77 (1925), p.216.

HEAT CAPACITY OF VAPOR, C_p AND C_v

Pressure atm	C_p (cal/mole deg)				
	105°C	115°C	130°C	145°C	161°C
.98	18.71	18.63	18.79	18.96	19.11
.50	17.52	17.58	17.82		
.25	16.84	16.97	17.27		
.00	16.22	16.45	16.81		

Ref. DeVries and Collins, *J. Am. Chem. Soc.*, Vol.64 (1942), p.1225.

RATIO OF SPECIFIC HEATS

No information

HEAT CAPACITY OF LIQUID AND SOLID

Temp (°K)	C_p (cal/mole deg)	Temp (°K)	C_p (cal/mole deg)
15	0.89	170	15.75
20	2.07	180	16.19
30	4.59	190	16.63
40	6.90	200	17.08
50	8.53	210	17.53
60	9.76	220	17.98
70	10.70	230	18.43
80	11.47	240	18.88
90	12.10	244.73	Melting Point
100	12.62	250	24.96
110	13.10	260	25.01
120	13.56	270	25.08
130	14.01	280	25.17
140	14.45	290	25.26
150	14.88	300	25.35
160	15.31		

Ref. Jones and Giauque, *J. Am. Chem. Soc.*, Vol.69 (1947), p.983.

FREE ENERGY OF FORMATION

No information, but can be calculated from existing entropy values and equation $\Delta F = \Delta H - T\Delta S$.

FREE-ENERGY FUNCTION

No information

HEAT-CONTENT FUNCTION No information

ENTROPY

Gas

$S^{\circ}_{298.1} = 65.73$ cal/mole deg

Ref. Jones and Giauque, *J. Am. Chem. Soc.*, Vol.69 (1947), p.983.

n-OCTANE

MOLECULAR FORMULA

C_8H_{18}

MOLECULAR WEIGHT

114.224

Ref. *International Atomic Weights*, 1947.

MELTING POINT

Melting point = −56.806°C

Ref. Forziati, *et al.*, *J. Research Nat. Bur. Standards*, Vol.36 (1946), p.129.

BOILING POINT

Boiling point = 125.665°C

Ref. Forziati, *et al.*, *J. Research Nat. Bur. Standards*, Vol.36 (1946), p.129

DENSITY

Liquid and Vapor (in Equilibrium)

Temperature (°C)	Density (gm/ml) Liquid	Vapor
0	0.71848	–
20	0.7022	0.0001
40	0.6860	0.0002
50	0.6778	0.0003
60	0.6694	0.0004
70	0.6611	0.0006
80	0.6525	0.0009
90	0.6438	0.0013
100	0.6351	0.0017
110	0.6260	0.0023
120	0.6168	0.003247
130	0.6071	0.004219
140	0.5973	0.005405
150	0.5875	0.006863
160	0.5772	0.008591
170	0.5667	0.01071
180	0.5556	0.01316
190	0.5441	0.01613
200	0.5317	0.01965
210	0.5189	0.02364
220	0.5053	0.02874
230	0.4901	0.03484
240	0.4732	0.04237
250	0.4554	0.05118
260	0.4364	0.06223
270	0.4123	0.07716
280	0.3818	0.09833
290	0.3365	0.1346
296.2	0.2327	0.2327 (Critical)

Ref. Young, *Dublin Proc.*, Vol.12 (1910), p.374.

Solid — No information

VAPOR PRESSURE

Liquid

Temp (°C)	Press (mm Hg)	Temp (°C)	Press (mm Hg)
−35	0.17	60	77.55
−30	0.28	70	117.9
−20	0.64	80	174.8
−10	1.39	90	253.4
0	2.94	100	353.6
+10	5.62	110	481.9
20	10.45	120	646.4
30	18.40	130	859.
40	30.85	140	1114
50	49.35	150	1425

Ref. *International Critical Tables*, Vol.3 (1928), p.225.

Temperature (°C)	Pressure (mm Hg)
160	1,807
170	2,255
180	2,775
190	3,385
200	4,100
210	4,925
220	5,875
230	6,950
240	8,200
250	9,600
260	11,180
270	12,980
280	15,000
290	17,150
296.2	18,700

Ref. Young, *Dublin Proc.*, Vol.12 (1910), p.374.

Solid — No information

TRIPLE POINT — No information

VISCOSITY

Vapor — No information

Liquid

Temp (°C)	η (centipoises)	Temp (°C)	η (centipoises)
−60	1.53	40	0.4329
−55	1.44	45	0.4102
−50	1.37	50	0.3888
−45	1.29	55	0.3691
−40	1.22	60	0.3509
−35	1.15	65	0.3342
−30	1.086	70	0.3185
−25	1.020	75	0.3042
−20	0.955	80	0.2906
−15	0.892	85	0.2780
−10	0.828	90	0.2662
−5	0.768	95	0.2552
0	0.7142	100	0.2446
+5	0.6651	105	0.235
10	0.6213	110	0.225
15	0.5816	115	0.216
20	0.5458	120	0.208
25	0.5136	125	0.200
30	0.4845	130	0.192
35	0.4578		

Ref. American Petroleum Institute, Research Project No.44, *Collection, Analysis, and Calculation of Data on the Properties of Hydrocarbons*, 1945, Table 20c (Part II).

SURFACE TENSION

Temperature (°C)	γ (dynes/cm)
20	21.78
30	20.74
40	19.85
50	18.83

(maximum bubble pressure method)

Ref. Quayle, Day, and Brown, *J. Am. Chem. Soc.*, Vol.66 (1944), p.938.

COEFFICIENT OF THERMAL EXPANSION

$$V_t = V_0(1 + \alpha t)$$

$\alpha = 0.116 \times 10^{-2}$, at 0°-30°C

Ref. Timmermans and Martin, *J. chim. phys.*, Vol.25 (1928), p.411.

COEFFICIENT OF THERMAL CONDUCTIVITY

Vapor — No information

Liquid

Temperature (°C)	k (cal/cm sec deg)
30	0.000342
60	0.000333
100	0.000309

Ref. Smith, *Trans. Am. Soc. Mech. Engrs.*, Vol.58 (1936), p.719.

DIPOLE MOMENT

$\mu = 0$ debye, at −50°C to boiling point

Ref. Dornte and Smyth, *J. Am. Chem. Soc.*, Vol.52 (1930), p.3546.

HEAT OF FUSION

$\Delta H_f = 4.931$ kcal/mole, at −56.798°C

Ref. American Petroleum Institute, Research Project No.44, *Collection, Analysis, and Calculation of Data on the Properties of Hydrocarbons*, 1945, Table 3z.

HEAT OF VAPORIZATION

At 25°C:

$\Delta H_v = 9.915$ kcal/mole (saturation pressure)

Ref. American Petroleum Institute, Research Project No.44, *Collection, Analysis, and Calculation of Data on the Properties of Hydrocarbons*, 1945, Table 3m.

HEAT OF VAPORIZATION (*Cont'd*)

At 125.66°C:

ΔH_v = 8.360 kcal/mole, at 1 atm

Ref. American Petroleum Institute, Research Project No.44, *Collection, Analysis, and Calculation of Data on the Properties of Hydrocarbons*, 1945, Table 1p.

HEAT OF FORMATION

$$8C\ (\text{graphite}) + 9H_2\ (\text{gas}) = C_8H_{18}\ (\text{liquid})$$

$\Delta H_{298.1}$ = 59,740 cal/mole

Ref. American Petroleum Institute, Research Project No.44, *Collection, Analysis, and Calculation of Data on the Properties of Hydrocarbons*, 1945, Table 1p.

$$8C\ (\text{graphite}) + 9H_2\ (\text{gas}) = C_8H_{18}\ (\text{gas})$$

Temperature (°K)	ΔH_f° (kcal/mole)
0	−38.33
298.16	−49.82
300	−49.88
400	−52.83
500	−55.30
600	−57.23
700	−58.71
800	−59.81
900	−60.57
1000	−60.96
1100	−61.08
1200	−60.97
1300	−60.71
1400	−60.31
1500	−59.86

Ref. American Petroleum Institute, Research Project No.44, *Collection, Analysis, and Calculation of Data on the Properties of Hydrocarbons*, 1945, Table 1a.

HEAT OF COMBUSTION

State of Octane	ΔH_c, at 20°C and constant pressure to form: H_2O (l) + CO_2 (g) (kcal/mole)	H_2O (g) + CO_2 (g) (kcal/mole)
Vapor	−1317.45	−1222.77
Liquid	−1307.53	−1212.85

Ref. American Petroleum Institute, Research Project No.44, *Collection, Analysis, and Calculation of Data on the Properties of Hydrocarbons*, 1945, Table 3w.

CRITICAL DATA

t_c = 296.2°C

p_c = 18,730 mm Hg

d_c = 0.2327 gm/ml

Ref. Young, *Dublin Proc.*, Vol.12 (1910), p.374.

EQUATION OF STATE

$$\left(P + \frac{n^2 a}{V^2}\right)(V - nb) = nRT$$

where

P = pressure, atm

V = volume, liters/mole

T = temperature, °K

R = gas constant 0.08207 liter atm/mole deg

n = number of moles

a = 37.32 liter^2 atm/mole^2

b = 0.2368 liter/mole

Ref. Young, *Dublin Proc.*, Vol.12 (1910), p.374.

COMPRESSIBILITY

Temperature (°C)	Specific Volume (cc/gm at various pressures)			
	5 atm	20 atm	100 atm	300 atm
100	1.569	1.559	1.530	1.477
125	1.629	1.617	1.580	1.516
150	1.697	1.681	1.634	1.554
175	1.780	1.759	1.697	1.596
200	–	1.849	1.760	1.640
225	–	1.971	1.836	1.686
250	–	2.149	1.928	1.743
275	–	2.484	2.033	1.795

Ref. Felsing and Watson, *J. Am. Chem. Soc.*, Vol.64 (1942), p.1822.

HEAT CAPACITY OF VAPOR, C_p AND C_v

Temperature (°K)	C_p (cal/mole deg)
0	0
298.16	46.58
300	46.94
400	58.31
500	69.27
600	78.28
700	86.08
800	92.79
900	98.59
1000	103.68
1100	108.04
1200	111.88
1300	115.23
1400	118.10
1500	120.52

Ref. American Petroleum Institute, Research Project No.44, *Collection, Analysis, and Calculation of Data on the Properties of Hydrocarbons*, 1945, Table 3v.

RATIO OF SPECIFIC HEATS

$\gamma = 1.040$

Ref. Anon., *Oil Gas J.*, Vol.44 (1945), p.115.

HEAT CAPACITY OF LIQUID AND SOLID

Liquid

Temperature (°K)	C_p (cal/gm deg)
223.0	0.482
232.7	0.483
244.8	0.487
255.7	0.493
275.3	0.504
279.3	0.508
284.8	0.513
293.7	0.518

0°C = 273.1°K

Ref. Parks, Huffman, and Thomas, *J. Am. Chem. Soc.*, Vol.52 (1930), p.1032.

Solid

Temperature (°K)	C_p (cal/gm deg)	Temperature (°K)	C_p (cal/gm deg)
85.5	0.188	146.6	0.274
90.8	0.196	152.7	0.282
96.9	0.209	161.2	0.292
103.0	0.219	171.6	0.308
109.5	0.227	176.9	0.317
122.2	0.244	181.6	0.326
128.7	0.252	186.4	0.338
134.8	0.258	195.9	0.372

0°C = 273.1°K

Ref. Parks, Huffman, and Thomas, *J. Am. Chem. Soc.*, Vol.52 (1930), p.1032.

FREE ENERGY OF FORMATION

$$8C\ (\text{graphite}) + 9H_2(\text{gas}) = C_8H_{18}(\text{gas})$$

Temperature (°K)	ΔF_f° (kcal/mole)
0	−38.3?
298.16	+4.14
300	4.47
400	23.06

FREE ENERGY OF FORMATION (*Cont'd*)

Temperature (°K)	ΔF_f° (kcal/mole)
500	42.32
600	62.03
700	82.03
800	102.17
900	122.45
1000	142.79
1100	163.14
1200	183.51
1300	203.90
1400	224.26
1500	244.71

Ref. American Petroleum Institute, Research Project No.44. *Collection, Analysis, and Calculation of Data on the Properties of Hydrocarbons*, 1945, Table 3x.

FREE-ENERGY FUNCTION

Temperature (°K)	$-(F^\circ - H_o^\circ)/T$ (cal/mole deg)
0	0
298.16	81.52
300	81.70
400	90.93
500	99.42
600	107.37
700	114.92
800	122.14
900	129.06
1000	135.69
1100	142.05
1200	148.16
1300	154.03
1400	159.67
1500	165.06

Ref. American Petroleum Institute, Research Project No.44, *Collection, Analysis, and Calculation of Data on the Properties of Hydrocarbons*, 1945, Table 3s.

HEAT-CONTENT FUNCTION

Temperature (°K)	$(H^\circ - H^\circ_0)/T$ (cal/mole deg)
0	0
298.16	29.30
300	29.41
400	35.25
500	40.93
600	46.40
700	51.54
800	56.26
900	60.61
1000	64.66
1100	68.40
1200	71.87
1300	75.09
1400	78.08
1500	80.82

Ref. American Petroleum Institute, Research Project No.44, *Collection, Analysis, and Calculation of Data on the Properties of Hydrocarbons*, 1945, Table 3n.

ENTROPY

$$8C\ (\text{graphite}) + 9H_2(\text{gas}) = C_8H_{18}(\text{gas})$$

Temperature (°K)	S°_t (cal/mole deg)
0	0
298.16	110.82
300	111.11
400	126.18
500	140.35
600	153.77
700	166.46
800	178.40
900	189.67
1000	200.35
1100	210.45
1200	220.03
1300	229.12
1400	237.75
1500	245.88

Ref. American Petroleum Institute, Research Project No.44, *Collection, Analysis, and Calculation of Data on the Properties of Hydrocarbons*, 1945, Table 3t.

PENTABORANE

MOLECULAR FORMULA

B_5H_9

MOLECULAR WEIGHT

63.17

Ref. *International Atomic Weights*, 1947.

MELTING POINT

Melting point = −46.6°C

Ref. Stock and Siecke, *Ber.*, Vol.57 (1924), p.562.

BOILING POINT

Boiling point = 48. °C

Ref. Schlesinger and Burg, *Chem. Rev.*, Vol.31 (1942), p.1.

DENSITY

Vapor

d = 2.88 mg/cc at 0°C and 760 mm pressure

Ref. Stock and Kuss, *Ber.*, Vol.56B (1923), p.789.

Liquid

d = 0.61 gm/cc at 0°C

Ref. Stock and Kuss, *Ber.*, Vol.56B (1923), p.789.

VAPOR PRESSURE

Temperature (°C)	Pressure (mm Hg)
−41.3	4.8
−35.6	7.4
−28.9	12.
−25.1	15.1
−20.0	21.1
−14.9	28.5
−9.9	37.8
−5.0	49.0
0.0	65.
+6.0	84.
11.2	111.
15.1	131.

Ref. Stock and Kuss, *Ber.*, Vol.56B (1923), p.789.

TRIPLE POINT
VISCOSITY
SURFACE TENSION
COEFFICIENT OF THERMAL EXPANSION
COEFFICIENT OF THERMAL CONDUCTIVITY
DIPOLE MOMENT
HEAT OF FUSION
HEAT OF VAPORIZATION
HEAT OF FORMATION
HEAT OF COMBUSTION
CRITICAL DATA
EQUATION OF STATE
COMPRESSIBILITY
HEAT CAPACITY OF GAS, C_p OR C_v
RATIO OF SPECIFIC HEATS
HEAT CAPACITY OF LIQUID AND SOLID
FREE ENERGY OF FORMATION
FREE-ENERGY FUNCTION
HEAT-CONTENT FUNCTION
ENTROPY

} No information

SODIUM

MOLECULAR FORMULA

Na (*s*); Na and Na_2 (*g*)

MOLECULAR WEIGHT

22.997

Ref. *International Atomic Weights*, 1947.

MELTING POINT

Melting point = 97.7°C

Ref. Edmondson and Egerton, *Proc. Roy. Soc. (London)*, Vol.A113 (1927), p.520.

BOILING POINT

Boiling point = 889°C at 760 mm Hg

Ref. Gordon, *J. Chem. Phys.*, Vol.4 (1936), p.100.

DENSITY

Vapor — No information

Liquid

Temperature (°C)	Density (gm/ml)
Melting point	0.9287
Boiling point	0.7414

Ref. Gmelin, *Handbuch der Anorganische Chemie*, eighth edition, Vol.21, p.70.

Solid

Temperature (°C)	Density (gm/ml)	Reference
−273	1.045 to 1.124	(2)
−188	1.0066	(1)
0	0.9721 to 0.9725	(2)
10	0.9743	(2)
15	0.9720 to 0.9722	(2)
20	0.9710 to 0.9723	(2)
Melting Point	0.9515	(3)

Refs. (1) Dewar, B., *Chem. News*, Vol.85 (1902), p.277.

(2) Gmelin, *Handbuch der Anorganische Chemie*, eighth edition, Vol.21, p.69.

(3) Hagen, *Wied. Ann*, Vol.19 (1883), p.442.

VAPOR PRESSURE

Liquid — No information

Solid

Temperature (°K)	Pressure (atm)
622	0.0001
702	0.001
807	0.01
952	0.10
1027	0.25
1092	0.50
1165	1.00

Ref. Kelley, *U.S. Bur. Mines Bull. 393* (1936).

TRIPLE POINT — No information

VISCOSITY

Vapor — No information

VISCOSITY (*Cont'd*)

Liquid

Temperature (°C)	η (poises)
98.0	0.007264
99.6	0.007142
102.4	0.006856
120.4	0.006170
154.5	0.005314
155.0	0.005322
159.1	0.005225
173.7	0.004942
183.4	0.004760
206.7	0.004431
218.0	0.004239
289.0	0.003506
355.0	0.003015

Ref. Chiong, *Proc. Roy. Soc. (London)*, Vol.A157 (1936), p.264.

SURFACE TENSION

Temperature (°C)	Gas	Method	γ (dynes/cm)	Ref.
Melting point	CO_2	Drop weight	293.6	(1)
100	High vac.	Drop shape	222.	(2)
250	High vac.	Mod. flat drop	211.	(2)

Refs. (1) Gmelin, *Handbuch der Anorganische Chemie*, eighth edition, Vol.21, p.71.

(2) Poindexter, *Phys. Rev.*, Vol.27 (1926), p.820.

COEFFICIENT OF THERMAL EXPANSION

Linear

Temperature (°K)	% Expansion*
80	−1.155
90	−1.114
100	−1.071

*Based on length at 273°K.

Linear (*Cont'd*)

Temperature (°K)	% Expansion*
110	−1.022
120	−0.970
130	−0.917
140	−0.860
150	−0.801
160	−0.742
170	−0.682
180	−0.621
190	−0.557
200	−0.493
210	−0.428
220	−0.361
230	−0.294
240	−0.226
250	−0.158
260	−0.090
270	−0.022
280	+0.047
290	+0.116

*Based on length at 273°K.

Ref. Siegel and Quimby, *Phys. Rev.*, Vol.54 (1938), p.76.

COEFFICIENT OF THERMAL CONDUCTIVITY

Vapor — No information

Liquid

$$k_t = 0.860[1 - 0.338 \times 10^{-3}(t - 100) - 2.6 \times 10^{-6}(t - 100)^2]$$

where

k_t = thermal conductivity at t°C watts/cm deg from 100°C to 210°C

Ref. Hall, *Phys. Rev.*, Vol.53 (1938), p.1004.

COEFFICIENT OF THERMAL CONDUCTIVITY (*Cont'd*)

Solid

Temperature (°K)	k (cal/cm sec deg)
348	0.270
323	0.290
293	0.300
273	0.335
223	0.280
198	0.288
173	0.305
148	0.324
123	0.340
98	0.360
73	0.377
33	0.403

Ref. Bidwell, *Phys. Rev.*, Vol.28 (1926), p.584.

DIPOLE MOMENT

$\mu = 0$ debye

Ref. Clark, *Proc. Roy. Soc. (London)*, Vol.124 (1929), p.689.

HEAT OF FUSION

$\Delta H_f = 635$ cal/gm atom

Ref. Kelley, *U.S. Bur. Mines Bull. 393* (1936).

HEAT OF VAPORIZATION

$\Delta H_v = 23.12$ kcal/mole at 1187°K

Ref. Kelley, *U.S. Bur. Mines Bull. 383* (1935).

HEAT OF FORMATION

State	$\Delta H^\circ_{298.1}$
Solid	0 (by definition)
Vapor	−25,949 cal/mole

Ref. Kelley, *U.S. Bur. Mines Bull. 383* (1935).

HEAT OF COMBUSTION — No information

CRITICAL DATA

t_c = 2000°C

p_c = 343 atm

Ref. Gmelin, *Handbuch der Anorganische Chemie*, eighth edition, Vol.21, p.71.

EQUATION OF STATE — No information

COMPRESSIBILITY

Pressure (kg/cm²)	Compressibility ($\Delta V/V_0$ at 23°C)
10,000	0.117
20,000	0.182
30,000	0.232
40,000	0.273
50,000	0.310
60,000	0.343
70,000	0.372
80,000	0.397
90,000	0.419
100,000	0.440

Ref. Bridgman, *Phys. Rev.*, Vol.60 (1941), p.351.

Press. (kg/cm²)	$\Delta V/V_0$ at 30°C	$\Delta V/V_0$ at 75°C
1,000	0.0153	0.0166
2,000	0.0299	0.0321
3,000	0.0437	0.0466
6,000	0.0819	0.0856
9,000	0.1159	0.1106
12,000	0.1465	0.1528

Ref. Gmelin, *Handbuch der Anorganische Chemie*, eighth edition, Vol.21, p.71.

HEAT CAPACITY OF VAPOR, C_p AND C_v

C_p = 4.97 cal/gm atom deg (theoretical)

Ref. Kelley, *U.S. Bur. Mines Bull. 371* (1934).

RATIO OF SPECIFIC HEATS

$\frac{C_p}{C_v}$ = 1.68 from 750°-920°C

Ref. Marburg, *Ann. Physik*, Vol.38 (1912), p.1027.

HEAT CAPACITY OF LIQUID AND SOLID

Liquid

C_p = 7.50 cal/gm atom deg, from 371° to 451°K, 2% accuracy

Ref. Kelley, *U.S. Bur. Mines Bull. 371* (1934).

Solid

Temperature (°K)	C_p (cal/mole deg)
10	0.116
20	0.837
40	2.99
60	4.36
80	5.02
100	5.42
120	5.66
140	5.84
160	6.00
180	6.13
200	6.24
220	6.36
240	6.47
260	6.59
280	6.71
300	6.83
320	6.94
340	7.10
360	7.35
371	7.55

Ref. Simon and Zeidler, *Z. physik Chem.*, Vol.123 (1926), p.383.

FREE ENERGY OF FORMATION

$\Delta F^\circ_{298.1}$(Solid) = 0

$\Delta F^\circ_{298.1}$(Vapor) = −18,639 cal/mole

Ref. Kelley, *U.S. Bur. Mines Bull. 383* (1935).

FREE-ENERGY FUNCTION

Monatomic Vapor

Temp (°K)	$-(F^\circ - E^\circ_o)/T$ (cal/mole deg)	Temp (°K)	$-(F^\circ - E^\circ_o)/T$ (cal/mole deg)
298.1	31.756	1700	40.404
300	31.787	1800	40.678
400	33.216	1900	40.956
500	34.325	2000	41.211
600	35.230	2100	41.453
700	35.996	2200	41.684
800	36.659	2300	41.905
900	37.244	2400	42.116
1000	37.768	2500	42.320
1100	38.241	2600	42.515
1200	38.673	2700	42.702
1300	39.071	2800	42.883
1400	39.439	2900	43.059
1500	39.782	3000	43.227
1600	40.102		

Ref. Overstreet, "Calculation of Free Energy from Spectroscopic Data," Master's Thesis, University of California, Berkeley, California (1930).

Diatomic Vapor

Temp (°K)	$-(F^\circ - E^\circ_o)/T$ (cal/mole deg)
298.1	46.685
300	46.738
400	49.163
500	51.077
600	52.659

FREE-ENERGY FUNCTION (*Cont'd*)

Diatomic Vapor (*Cont'd*)

Temp (°K)	$-(F^\circ - E_o^\circ)/T$ (cal/mole deg)
700	54.009
800	55.188
900	56.235
1000	57.178
1200	58.83
1400	60.24
1600	61.47
1800	62.58
2000	63.58

Ref. Gordon, *J. Chem. Phys.*, Vol.4 (1936), p.100.

HEAT-CONTENT FUNCTION No information

ENTROPY

N_2 Vapor

$S^\circ_{298.1} = 36.72$ cal/mole deg, based on Sackur equation

Ref. Kelley, *U.S. Bur. Mines Bull. 434* (1941).

Na_2 Vapor

$S^\circ_{298.1} = 54.9 \pm 0.3$ cal/mole deg, based on spectroscopic data

Ref. Allen and Longair, *Phil. Mag.*, Vol.19 (1935), p.1032.

TETRANITROMETHANE

MOLECULAR FORMULA $C(NO_2)_4$

MOLECULAR WEIGHT

196.04

Ref. *International Atomic Weights*, 1947.

MELTING POINT

Melting point = 13. °C

Ref. Schischow, *Ann. chim.*, Vol.119 (1861), p.248.

BOILING POINT

Boiling point = 126. °C

Ref. Schischow, *Ann. chim.*, Vol.119 (1861), p.248.

DENSITY

Vapor — No information

Liquid

Temperature (°C)	Density (gm/ml)
20	1.638
25	1.629
30	1.620
35	1.614
50	1.584

Ref. *Annual Tables of Constants and Numerical Data*, Vol.11 (1), 1937, p.10.

Solid

d = 1.6377 gm/ml, at 12.2°C

Ref. Auwers and Harres, *Ber.*, Vol.62B (1929), p.2287.

VAPOR PRESSURE

Liquid

Temperature (°C)	Pressure (mm Hg)
40	22.6
50	44.2
60	70.6
70	109.0
80	164.0
90	239.
100	339.
110	470.
120	640.

Ref. *International Critical Tables*, Vol.3 (1928), p.215.

Solid — No information

TRIPLE POINT
VISCOSITY (VAPOR, LIQUID) — No information

SURFACE TENSION

Temperature (°C)	γ (dynes/cm)
20	30.47
25	29.44
30	28.98
35	28.74
50	26.45

Ref. *Annual Tables of Constants and Numerical Data*, Vol.11 (7), 1937, p.3.

COEFFICIENT OF THERMAL EXPANSION
COEFFICIENT OF THERMAL CONDUCTIVITY (VAPOR, LIQUID) — No information

DIPOLE MOMENT

μ = 0.19 debye at 25°C, in carbon tetrachloride
0.48 debye at 25°C, in benzene

Ref. Sidgwick, *Trans. Faraday Soc.*, Vol.30 (Part II), 1934, p.904.

HEAT OF FUSION HEAT OF VAPORIZATION	No information

HEAT OF FORMATION

$\Delta H^{\circ}_{298.1} = -8.9$ kcal/mole

Ref. Roth and Isecke, *Ber.*, Vol.77B (1934), p.537.

HEAT OF COMBUSTION

$\Delta H_c = -102.9$ kcal/mole

Ref. Roth and Isecke, *Ber.*, Vol.77B (1934), p.537.

CRITICAL DATA EQUATION OF STATE COMPRESSIBILITY HEAT CAPACITY OF VAPOR RATIO OF SPECIFIC HEATS HEAT CAPACITY OF LIQUID AND SOLID FREE ENERGY OF FORMATION FREE-ENERGY FUNCTION HEAT-CONTENT FUNCTION ENTROPY	No information

TRIBORINETRIAMINE (BORAZOLE)

MOLECULAR FORMULA $B_3N_3H_6$

MOLECULAR WEIGHT

80.53

Ref. *International Atomic Weights*, (1947).

MELTING POINT

Melting point = −58.0°C

Ref. Wiberg and Bolz, *Ber.*, Vol.73 (1940), p.209.

BOILING POINT

Boiling point = 55.0°C

Ref. Wiberg and Bolz, *Ber.*, Vol.73 (1940), p.209.

DENSITY

Gas

Temperature (°C)	Density (mg/ml)	Pressure (mm Hg)
20.5	0.2694	61.2
22.0	0.0926	21.2

Ref. Wiberg and Bolz, *Ber.*, Vol.73 (1940), p.209.

Liquid

Temp (°C)	gm/ml	Temp (°C)	gm/ml
−36.0	0.8966	−11.0	0.8722
−32.0	0.8917	−5.7	0.8671
−26.2	0.8873	+0.5	0.8614
−20.7	0.8807	5.0	0.8561
−16.0	0.8762	9.7	0.8519

Ref. Wiberg and Bolz, *Ber.*, Vol.73 (1940), p.209.

Solid

d = 1.00 gm/ml at −65°C

Ref. Stock and Pohland, *Ber.*, Vol.59 (1926), p.2215.

VAPOR PRESSURE

Temp (°C)	Press (mm Hg)	Temp (°C)	Press (mm Hg)
−54.0	2.2	25.4	259.2
−33.0	11.6	30.7	319.0
−20.0	29.0	34.9	374.3
−13.5	43.0	40.2	456.2
0.0	85.1	45.1	542.3
10.5	139.0	48.8	617.0
20.0	210.0	51.2	670.9
		55.0	760.0

Ref. Wiberg and Bolz, *Ber.*, Vol.73 (1940), p.209.

TRIPLE POINT
VISCOSITY
} No information

SURFACE TENSION

Temp (°C)	γ (dynes/cm)	Temp (°C)	γ (dynes/cm)
−36.0	28.56	−15.2	26.18
−31.0	27.94	−10.0	25.42
−25.0	27.34	−3.0	24.66
−20.0	26.94	+3.0	24.24

Ref. Wiberg and Bolz, *Ber.*, Vol.73 (1940), p.209.

COEFFICIENT OF THERMAL EXPANSION
COEFFICIENT OF THERMAL CONDUCTIVITY
} No information

DIPOLE MOMENT

$\mu = 0.67$ debye

Ref. Ramaswamy, *Proc. Indian Acad. Sci.*, Vol.2A (1935), p.364.

HEAT OF FUSION No information

HEAT OF VAPORIZATION

ΔH_v = 7,034 cal/mole, calculated from vapor pressure data

Ref. Wiberg and Bolz, *Ber.*, Vol.73 (1940), p.209.

HEAT OF FORMATION
HEAT OF COMBUSTION } No information

CRITICAL DATA

t_c = 252°C calculated from surface-energy data

EQUATION OF STATE
COMPRESSIBILITY } No information

HEAT CAPACITY OF GAS AND LIQUID

Temperature (°K)	C_p° (cal/mole deg)
298.1	23.3 (Liquid)
326	25.3 (Boiling Point)
350	27.1 (Gas)
400	30.4
500	36.0
600	40.5
700	44.2
800	47.2
900	49.6
1000	51.8

Above values calculated using following data of Crawford and Edsall, *J. Chem. Phys.*, Vol.7 (1939), p.223:

S°_{298} (l) = 51.0 E.U.

S°_{326} (l) = 53.4 E.U.

$[(F^\circ - E^\circ_o)/T]_{298}$ (l) = −62.5 cal/mole

Ref. Bauer, *Chem. Revs.*, Vol.31 (1942), p.43.

RATIO OF SPECIFIC HEATS
HEAT CAPACITY OF SOLID
FREE ENERGY OF FORMATION } No information

FREE-ENERGY FUNCTION

Temperature (°K)	$-(F^\circ - E_o^\circ)/T$ (cal/mole deg)
298.1	60.4 (Liquid)
326	61.5 (Boiling Point)
350	62.6
400	64.8
500	68.7
600	72.6
700	76.6
800	80.2
900	83.6
1000	87.0

Above values calculated from vapor-pressure data and following values of Crawford and Edsall, *J. Chem. Phys.*, Vol.7 (1939), p.223:

$$S^\circ_{298}\ (l) = 51.0$$

$$S^\circ_{326}\ (l) = 53.4$$

$$[(F^\circ - E_o^\circ)/T]_{298}\ (l) = -62.5 \text{ cal/mole}$$

Ref. Bauer, *Chem. Revs.*, Vol.31 (1942), p.43.

HEAT-CONTENT FUNCTION No information

ENTROPY

Temperature (°K)	S° (cal/mole deg)
298.1	73.7
326	75.8
350	77.7
400	81.5
500	88.9
600	95.9
700	102.5
800	108.5
900	114.2
1000	119.6

Above values calculated from vapor-pressure data and following values of Crawford and Edsall, *J. Chem. Phys.*, Vol.7 (1939), p.223:

ENTROPY (*Cont'd*)

$S^{\circ}_{293}\,(l) = 51.0$

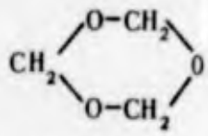
$S^{\circ}_{326}\,(l) = 53.4$

$[(F^{\circ} - E^{\circ}_{o})/T]_{298}\,(l) = -62.5$ cal/mole

Ref. Bauer, *Chem. Revs.*, Vol.31 (1942), p.43.

TRIOXANE

MOLECULAR FORMULA



1, 3, 5 Trioxane

(Other polymers not included)

MOLECULAR WEIGHT

90.078

Ref. *International Atomic Weights*, 1947.

MELTING POINT

Melting Point = 61. °C

Ref. Maryott and Acree, *J. Research Nat. Bur. Standards*, Vol.33 (1944), p.71.

BOILING POINT

Boiling Point = 114.5 °C, at 759 mm Hg

Ref. Auerbach and Barschall, *Chem. Zentral.*, II (1907), p.1735.

DENSITY

Vapor — No information

Liquid

d = 1.17 gm/cc, at 65. °C

Ref. Walker and Carlisle, *Chem. Eng. News*, Vol.21 (1943), p.1250.

Solid — No information

VAPOR PRESSURE

Liquid Solid

Temperature (°C)	Pressure (mm Hg)	Reference
25	13	(1)
37.5	31	(1)
86	283	(2)
87	296	(2)
90	330	(2)
114.5	759	(1)
129	1214	(1)

Refs.(1) Auerbach and Barschall, *Studien uber Formaldehyd–Die festen Polymeren des Formaldehyds*, pp.38-45.

(2) C.E. Frank, duPont.

TRIPLE POINT
VISCOSITY OF VAPOR AND LIQUID
SURFACE TENSION
COEFFICIENT OF THERMAL EXPANSION
COEFFICIENT OF THERMAL CONDUCTIVITY

No information

DIPOLE MOMENT

μ = 2.18 debye, in benzene

Ref. Maryott and Acree, *J. Research Nat. Bur. Standards*, Vol.33 (1944), p.71.

HEAT OF FUSION — No information

HEAT OF VAPORIZATION

ΔH_v = 3.2 kcal/CH_2O unit at the boiling point, calculated from its vapor pressure values

Ref. Walker and Carlisle, *Chem. Eng. News*, Vol.21 (1943), p.1250.

HEAT OF FORMATION

$$C(\text{graphite}) + H_2(g) + \tfrac{1}{2}O_2(g) = \tfrac{1}{3}(CH_2O)_3(s)$$

$\Delta H_{291°K}$ = 43. kcal/CH_2O unit

Calculated using Rossini's values of ΔH_{291} of water and carbon dioxide as 68.3 and 94.0 kcal/mole respectively.

Ref. Walker and Carlisle, *Chem. Eng. News*, Vol.21 (1943), p.1250.

HEAT OF COMBUSTION

ΔH_c = 118.9 kcal/CH_2O unit, at 23°C

Ref. Walker and Carlisle, *Chem. Eng. News*, Vol.21 (1943), p.1250.

CRITICAL DATA
EQUATION OF STATE
COMPRESSIBILITY
HEAT CAPACITY OF VAPOR
RATIO OF SPECIFIC HEATS
HEAT CAPACITY OF LIQUID AND SOLID
FREE ENERGY OF FORMATION
FREE-ENERGY FUNCTION
HEAT-CONTENT FUNCTION
ENTROPY

No information

REFERENCES

Arrangement

Bibliographical references are grouped under the various fuels considered, except for those to books, which often cover several materials and are grouped separately. References to the literature from which values have been taken for inclusion in these data sheets are denoted by an asterisk; others usually contain physical or thermodynamic data which have been included in later, summary publications or have been superseded by values judged to be more reliable. Many of the less readily accessible references were consulted only in abstract form when the abstract showed that it was probably not worth while to have recourse to the original.

These references are given by page in the table of contents in the front of the report.

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