CHAPTER 9

Tables

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by Michael de Podesta.

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- G. W. C. Kaye and T. H. Laby, *Tables of Physical and Chemical Constants*: 14th, 15th and 16th Editions, published by Longman (Harlow) in the UK and Wiley (New York) in the USA. This is referred to as *Kaye & Laby* in the text.
- Weast *CRC Handbook of Chemistry and Physics:* 65th *Edition* [also known as the 'Rubber Bible'], published by Chemical Rubber Publishing Company (Chicago, Ill)
- John Emsley, *The Elements*, published by Clarendon Press / Oxford University Press (Oxford).

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Table 9.1 The density of some elements at their melting temperatures in the liquid state. Also given is the ratio of the liquid density to the density of the solid at 25 °C (Table 7.2). The four elements which contract on melting: (silicon, gallium, germanium and bismuth) are shaded.

Z	Element	A	Liquid density (kg m^{-3})	Ratio of liquid/solid density
3	Lithium	6.941	516	0.968
5	Boron	10.81	2080	0.843
11	Sodium	22.99	930	0.962
12	Magnesium	24.31	1580	0.909
13	Aluminium	26.98	2400	0.889
14	Silicon	28.09	2525	1.080
16	Sulphur	32.06	1819	0.872
19	Potassium	39.10	824	0.955
20	Calcium	40.08	1365	0.892
22	Titanium	47.90	4130	0.916
23	Vanadium	50.94	5550	0.878
25	Manganese	54.94	6430	0.860
26	Iron	55.85	7100	0.901
28	Nickel	58.70	7800	0.875
29	Copper	63.55	8000	0.895
30	Zinc	65.38	6600	0.925
31	Gallium	69.72	6113.6	1.035
32	Germanium	72.59	5530	1.038
34	Selenium	78.96	4000	0.832
37	Rubidium	85.47	1470	0.959
40	Zirconium	91.22	5800	0.891
41	Niobium	92.91	7830	0.913
42	Molybdenum	95.94	9350	0.915
44	Ruthenium	101.1	10900	0.889
45	Rhodium	102.9	10850	0.874
46	Palladium	106.4	10700	0.892
47	Silver	107.9	9300	0.886
48	Cadmium	112.4	8020	0.927
50	Tin	118.7	6980	0.958
51	Antimony	121.7	6490	0.970
52	Tellurium	127.6	5770	0.924
55	Caesium	132.9	1845	0.971
56	Barium	137.3	3323	0.925
72	Hafnium	178.5	12000	0.904
73	Tantalum	180.9	15000	0.900
74	Tungsten	183.9	17600	0.914
75	Rhenium	186.2	18800	0.894
76	Osmium	190.2	20100	0.890
77	Iridium	192.2	20000	0.887
78	Platinum	195.1	19700	0.918
79	Gold	197.0	17320	0.898
81	Thallium	204.4	11290	0.951
82	Lead	207.2	10690	0.942
83	Bismuth	209.0	10050	1.025
92	Uranium	238.0	17907	0.940

Table 9.2 The density of substances that are liquids at room temperature. The table gives the name of the substance, the chemical formula for its molecules, the relative molecular mass of each molecule, the density and the temperature of the density measurement. Only the last three entries in the table are *inorganic*.

Liquid and chemical formula		MW	Density (kg m^{-3})	
Organic liquids				
Methanol	CH_3OH	32	791	@20°C
Ethanol	C_2H_5OH	46	789	@20°C
Propan-1-ol	C_3H_7OH	60	804	@20°C
Propan-2-ol	C_3H_7OH	60	786	@20°C
2 Methyl-propan-1-ol	C_4H_9OH	74	817	@20°C
2 Methyl-propan-2-ol	C_4H_9OH	74	789	@20°C
Butan-1-ol	C_4H_9OH	74	810	@20°C
Butan-2-ol	C_4H_9OH	74	808	@20°C
2 Methyl-butan-1-ol	$C_5H_{11}OH$	88	816	@20°C
2 Methyl-butan-2-ol	$C_5H_{11}OH$	88	809	@20°C
Pentanol	$C_5H_{11}OH$	88	813	@20°C
Octanol	$C_8H_{17}OH$	130	827	@20°C
Aniline	C_6H_7N	86	1026	@15°C
Acetone	C_3H_6O	58	787	@25°C
Benzene	C_6H_6	78	879	@20°C
Inorganic liquids				
Carbon disulphide	CS_2	76	1293	@0 °C
Carbon tetrachloride	CCl_4	154	1632	@0 °C
Water (see Table 9.3)	H_2O	18	1000	@0 °C

Table 9.3 The density of water (H_2O) and heavy water (D_2O) as a function of temperature at atmospheric pressure.

T (°C)	H_2O	D_2O	T (°C)	H_2O	D_2O
0	999.84	—	40	992.22	1100.0
2	999.94	—	45	—	1097.9
4	999.97	—	50	988.04	1095.7
5	—	1105.6	55	—	1093.3
6	999.94	—	60	983.20	1090.6
8	999.85	—	65	—	1087.8
10	999.70	1106.0	70	977.77	1084.8
15	—	1105.9	75	—	1081.6
20	998.20	1105.3	80	971.79	1078.2
25	—	1104.4	85	—	1074.7
30	995.65	1103.2	90	965.31	1071.1
35	—	1101.7	95	—	1067.4
			100	958.36	1063.5

Table 9.4 The bulk modulus of some liquids at the pressure and temperature shown. The pressure is shown in units of atmospheres, where one atmosphere is approximately 0.1 MPa.

Liquid and formula	***P*** **(Atm)**	***B*** **(GPa)**	***T*** **(°C)**
Organic liquids			
Methanol, CH_3OH	37	0.97	14.7
Ethanol, C_2H_5OH	1	1.32	0
Propan-1-ol, C_3H_7OH	8	1.04	17.7
Propan-2-ol, C_3H_7OH	8	0.983	17.8
Butan-1-ol, C_4H_9OH	8	1.13	17.4
Butan-2-ol, C_4H_9OH	8	1.03	17.9
Ether	1	0.689	0
Ether	1000	1.56	0
Benzene, C_6H_6	8	1.10	17.9
Inorganic liquids			
Carbon disulphide, CS_2	8	1.16	15.6
Carbon tetrachloride, CCl_4	1	1.12	20
Water, H_2O	1	2.05	15
Water, H_2O	1000	2.75	15
Water, H_2O	2500	3.88.	14.2

Table 9.5 The coefficient of volume expansivity β for various liquids at temperatures around room temperature. The shaded column shows the value of the volume expansivity of the corresponding solid substance. N/A indicates that data is not available.

Substance		MW	*T* (°C)	β (°C^{-1}) Liquid	β (°C^{-1}) Solid
Organic liquids					
Acetic acid	CH_3COOH	60	20	107×10^{-5}	N/A
Acetone	CH_3COCH_3	58	20	143×10^{-5}	N/A
Methanol	CH_3OH	46	20	119×10^{-5}	N/A
Ethanol	C_2H_5OH	32	20	108×10^{-5}	N/A
Aniline	C_6H_7N	86	20	85×10^{-5}	N/A
Benzene	C_6H_6	78	20	121×10^{-5}	N/A
Toluene	$C_6H_5CH_3$	92	20	107×10^{-5}	N/A
Inorganic liquids					
Carbon Disulphide	CS_2	76	20	119×10^{-5}	N/A
Carbon Tetrachloride	CCl_4	154	20	122×10^{-5}	N/A
Water	H_2O	18	20	21×10^{-5}	N/A
Metals					
Lithium	Li	23	400-1125	19×10^{-5}	16.8×10^{-5} @ 20 °C
Sodium	Na	39	96.5	25×10^{-5}	21.2×10^{-5} @ 20 °C
Potassium	K	85.5	64 - 1400	29×10^{-5}	24.9×10^{-5} @ 20 °C
Rubidium	Rb	133	39	30×10^{-5}	27.0×10^{-5} @ 20 °C
Copper	Cu	63.6	1084	10×10^{-5}	4.95×10^{-5} @ 20 °C
Copper	Cu	63.6	1084	10×10^{-5}	6.09×10^{-5} @ 527 °C
Mercury	Hg	200.6	0 - 100	18.1×10^{-5}	N/A

Table 9.6 The speed of sound in liquids showing c_L, the speed of longitudinal waves. For the elements, where possible, the data for the solid state (taken from Table 7.12) is also included, in the shaded column, for comparison. Data for ice is also included.

Substance	T (°C)	c_L (ms^{-1})	Substance	T (°C)	c_L (ms^{-1})	Substance	T (°C)	c_L (ms^{-1})	c_L (ms^{-1})
Organic Liquids			***Elements***			***Elements***			
Acetic acid	20	1173	Hydrogen, H_2	–258	1242	Cadmium, Cd	360	2150	2780
Acetone	20	1190	Helium, He	–269	211	Copper,Cu	1350	3350	4759
Methanol	20	1121	Nitrogen, N_2	–189	745	Gallium, Ga	50	2740	
Ethanol	20	1162	Oxygen, O_2	–186	950	Mercury,Hg	20	1454	
Propanol	20	1223	Sodium, Na	110	2520	Silver, Ag	1150	2630	3704
Butanol	20	1258	Potassium, K	80	1869	Tin, Sn	240	2470	3380
iso-Pentanol	20	1255	Rubidium, Rb	50	1427	Zinc, Zn	450	2700	4187
Hexanol	20	1331	Caesium, Cs	40	980				
Hexanol	20	1331							
Heptanol	20	1343							
Water	0	1402							
Ice	–20	3840							

Table 9.7 The viscosity η of various substance in their liquid state in units of mPa s as a function of the temperature in °C. To obtain the viscosity in units of Pa s, multiply the entries in this table by 10^{-3}. For example, the viscosity of mercury at 25 °C is 1.528×10^{-3} Pa s.

	Temperature (°C)												
Substance	**–100**	**–50**	**0**	**25**	**30**	**50**	**75**	**100**	**400**	**600**	**700**	**800**	**1100**
Acetic acid	—	—	—	1.116	1.037	0.792	0.591	0.457	—	—	—	—	—
Acetone	—	—	0.402	0.310	0.295	0.247	0.200	0.165	—	—	—	—	—
Benzene	—	—	—	0.603	0.562	0.436	0.332	0.263	—	—	—	—	—
Carbon disulphide	2.132	0.796	0.445	0.357	0.343	—	—	—	—	—	—	—	—
Methanol	—	2.258	0.797	0.543	0.507	0.392	0.294	0.227	—	—	—	—	—
Ethanol	98.96	8.318	1.873	1.084	0.983	0.684	0.459	0.323	—	—	—	—	—
Sodium	—	—	—	—	—	—	—	0.680	0.286	0.215	0.192	0.174	—
Potassium	—	—	—	—	—	—	—	0.458	0.224	0.172	0.155	0.141	—
Mercury	—	—	1.616	1.528	1.497	1.401	1.322	1.255	—	—	—	—	—
Tin	—	—	—	—	—	—	—	—	1.33	1.04	0.950	0.890	0.780

Table 9.8 Analysis of the slopes found in Figures 9.13 and 9.14 in terms of Equation 9.20.

Substance	Slope (K)	ΔE_h (J)	ΔE_h (meV)
Acetone	907	12.52×10^{-21}	78.1
CS_2	736	10.16×10^{-21}	63.4
Methanol	1271	17.55×10^{-21}	109.5
Ethanol	1845	25.47×10^{-21}	159.0
Sodium	769	10.62×10^{-21}	66.3
Potassium	661	9.126×10^{-21}	57.0
Tin	688	9.50×10^{-21}	59.3
Water	1862	25.7×10^{-21}	160

Table 9.9 The surface energy or surface tension of various substances in their liquid state (10^{-3} N m^{-1}) at a given temperature in °C. For example, the surface tension of benzene is 28.88×10^{-3} N m^{-1}.

Substance	Temperature (°C)	γ (mN m^{-1})
Acetic acid	20	27.59
Acetone	20	23.46
Benzene	20	28.88
Carbon disulphide	20	32.32
Methanol	20	22.50
Ethanol	20	22.39
Water	20	72.75
Sodium	100	209.9
Potassium	65	110.9
Mercury	25	485.5
Lead	350	444.5
Aluminium	700	900
Gold	1100	1120

Table 9.10 The value of ΔE_S (evaluated according to Equation 9.25) deduced from surface tension data on various substances in their liquid state (Table 9.9).

Substance		MW	ρ (kg m^{-3})	T (°C)	γ (mN m^{-1})	ΔE_S (meV)
Acetic acid	CH_3COOH	60	1049	20	27.59	35.9
Acetone	CH_3COCH_3	58	790	20	23.46	36.0
Benzene	C_6H_6	78	877	20	28.88	50.4
Carbon disulphide	CS_2	76	1293	20	32.32	42.8
Methanol	CH_3OH	32	791	20	22.50	23.2
Ethanol	C_2H_5OH	46	789	20	22.39	29.5
Water	H_2O	18	1000	20	72.75	43.7
Sodium	Na	23	930	100	209.9	156
Potassium	K	39	824	65	110.9	127
Mercury	Hg	201	13600	25	485.5	256
Lead	Pb	207	10690	350	444.5	281
Aluminium	Al	27	2400	700	900	396
Gold	Au	197	17320	1100	1120	496

Table 9.11 Analysis of the slopes found in Figures 9.23 and 9.24 in terms of Equation 9.36.

		ΔE_e	
Substance	**Slope (K)**	**(J)**	**(eV)**
Copper	–35209	486×10^{-21}	3.04
Silver	–29191	403×10^{-21}	2.52
Gold	–37355	516×10^{-21}	3.22
Aluminium	–34380	474×10^{-21}	2.96
Tin	–31616	436×10^{-21}	2.72
Helium	–9.51	0.13×10^{-21}	0.00082
Neon	–234	3.23×10^{-21}	0.020
Argon	–781	10.8×10^{-21}	0.067
Krypton	–1247	17.2×10^{-21}	0.107
Xenon	–1767	24.4×10^{-21}	0.152

Table 9.12 Collated value of ΔE_e, ΔE_S and ΔE_h (in units of milli electron volts) from Tables 9.8, 9.10 and 9.11. Also shown are the values of ΔE_S and ΔE_h normalised for each liquid. The small table at the foot of the main table presents a summary of the data from each category.

Substance		**ΔE_e (meV)**	**ΔE_s (meV)**	**ΔE_h (meV)**	**$\Delta E_e/\Delta E_e$**	**$\Delta E_s/\Delta E_e$**	**$\Delta E_h/\Delta E_e$**
Acetic acid	CH_3COOH	391	36	114	1	0.092	0.292
Acetone	CH_3COCH_3	319	36	78	1	0.113	0.245
Benzene	C_6H_6	373	50	106	1	0.134	0.284
Carbon disulphide	CS_2	—	43	63	1	—	—
Methanol	CH_3OH	379	23	110	1	0.061	0.290
Ethanol	C_2H_5OH	423	30	159	1	0.071	0.376
Water	H_2O	405	44	160	1	0.109	0.395
Sodium	Na	954	156	66	1	0.164	0.0692
Potassium	K	786	127	57	1	0.162	0.0725
Mercury	Hg	579	256	23	1	0.442	0.0397
Tin	Sn	2720	—	59	1	—	0.0217
Lead	Pb	1742	281	98	1	0.161	0.0563
Aluminium	Al	2790	396	96	1	0.142	0.0344
Gold	Au	3220	496	175	1	0.154	0.0543
Copper	Cu	3030	—	—	1	—	—
Silver	Ag	2520	—	—	1	—	—

Summary

Substance	$\Delta E_e/\Delta E_e$	$\Delta E_s/\Delta E_e$	$\Delta E_h/\Delta E_e$
Organic	1	$\approx \frac{1}{10}$	$\approx \frac{1}{3}$
Metallic	1	$\approx \frac{1}{6}$	$\approx \frac{1}{20}$

Table 9.13 The heat capacities at constant pressure C_P for a selection of substances that are liquids at around room temperature. The table records the substance name and chemical formula, the relative molecular mass of its constituent molecules, the number of atoms per molecule, and the temperature at which the measurement is made. The molar heat capacity is then recorded as in J K^{-1} and as a multiple of the gas constant R.

					C_P	
Substance		***MW***	***N***	***T* (°C)**	**(J K^{-1} mol^{-1})**	**(*R*)**
Organic liquids						
Methanol	CH_3OH	32	6	12	80.64	9.7
Ethanol	C_2H_5OH	46	9	0	105.3	12.7
Ethanol	C_2H_5OH	46	9	20	113.4	13.6
Ethanol	C_2H_5OH	46	9	40	124.7	15.0
Propanol	C_3H_7OH	60	12	18	138.0	16.6
Acetic acid	$C_2H_4O_2$	60	8	20	124.3	15.0
Acetone	C_3H_6O	58	10	20	124.7	15.0
Aniline	C_6H_7N	93	14	15	199.9	24.0
Benzene	C_6H_6	78	12	10	110.8	13.3
Benzene	C_6H_6	78	12	40	138.1	16.6
Bromoethane	C_2H_5Br	109	8	20	100.8	12.1
Chloroform	$CHCl_3$	120	5	20	113.8	13.7
Cyclohexane	C_6H_{10}	82	16	20	156.5	18.8
1,2 Dichloroethane	$C_2H_4Cl_2$	98	8	20	129.3	15.6
Dichloromethane	$C_2H_2Cl_2$	96	6	20	100.0	12.0
Ethanadiol	$C_2H_6O_2$	62	10	20	149.8	18.0
Ethyl acetate	$C_4H_8O_2$	82	8	20	170.1	20.5
Ethyl nitrate	$C_2H_5O_3N$	91	11	20	170.3	20.5
Formamide	CH_3ON	45	6	20	107.6	12.9
Formic acid	CH_2O_2	46	5	20	99.0	11.9
Nitromethane	CH_3O_2N	61	7	20	106.0	12.7
Nitroethane	$C_2H_5O_2N$	75	10	20	134.2	16.1
Toluene	C_7H_8	92	15	18	153.6	18.5
Inorganic liquids						
Arsenic trifluoride	AsF_3	132	4	20	126.6	15.2
Boron trichloride	BCl_3	118	4	20	106.7	12.8
Bromine	Br_2	160	2	20	75.7	9.11
Carbon disulphide	CS_2	76	3	20	75.7	9.11
Hydrogen cyanide	HCN	27	3	20	70.6	8.49
Water	H_2O	18	3	0	75.9	9.13
Heavy water	D_2O	20	3	0	84.3	10.1
Mercury	Hg	201	1	20	28.0	3.37
Hydrazine	N_2H_4	32	6	20	98.9	11.9
Silicon tetrachloride	$SiCl_4$	170	5	20	145.3	17.5
Tin tetrachloride	$SnCl_4$	261	5	20	165.3	19.9
Titanium tetrachloride	$TiCl_4$	190	5	20	145.2	17.5

Table 9.14 Thermal conductivity of miscellaneous non-metallic liquids in units of $WK^{-1}\,m^{-1}$. The data is given at two temperatures T_1 and T_2, and varies roughly linearly between these two temperatures. (Figure 9.32 (a)).

Liquid	T_1	T_2	K_1	K_2
Acetone	193	333	0.198	0.146
Aniline	293		0.172	
Benzene	293	323	0.147	0.137
Methanol	233	333	0.223	0.186
Ethanol	233	353	0.189	0.150
N-butanol	213	353	0.167	0.106
N-propanol	233	353	0.168	0.148
Toluene	193	353	0.159	0.119
Carbon tetrachloride	253	333	0.115	0.102
Water	273	353	0.561	0.673
Xenon	173	223	0.07	0.05

Table 9.15 Thermal conductivity (W K^{-1} m^{-1}) of elemental metals in their liquid state. Shaded entries refer to the solid state. The data are graphed in Figure 9.33.

Liquid		**173 K**	**273 K**	**373 K**	**573 K**	**973 K**	K_L/K_S**(%)**
Lithium	Li	98	86	82	47	59	57
Sodium	Na	141	142	88	78	60	62
Potassium	K	105	104	53	45	32	51
Rubidium	Rb	59	58	32	29	22	55
Caesium	Cs	37	36	20	20.6	17.7	56
Mercury	Hg	29.5	7.8	9.4	11.7	—	26
Aluminium	Al	241	236	240	233	92	39
Bismuth	Bi	11	8.2	7.2	13	17	181
Gallium	Ga	43	41	33	45	—	80
Tin	Sn	76	68	63	32	40	51

Table 9.16 Thermal conductivity ($WK^{-1}\ m^{-1}$) and electrical resistivity (Ω m) of elemental metals in their liquid state. Also evaluated is the quantity $\rho\kappa/T$ known as the *Lorentz number* and has theoretical value of 2.45×10^{-8} ($W\ \Omega\ K^{-2}$).

	373 K			573 K			973 K		
Liquid	ρ	κ	$\rho\kappa/T$	ρ	κ	$\rho\kappa/T$	ρ	κ	$\rho\kappa/T$
Sodium	9.7×10^{-8}	88	2.3×10^{-8}	16.8×10^{-8}	78	2.3×10^{-8}	39.2×10^{-8}	60	2.4×10^{-8}
Potassium	17.5×10^{-8}	53	2.5×10^{-8}	28.2×10^{-8}	45	2.2×10^{-8}	66.4×10^{-8}	32	2.2×10^{-8}
Rubidium	27.5×10^{-8}	32	2.4×10^{-8}	48×10^{-8}	29	2.4×10^{-8}	99×10^{-8}	22	2.2×10^{-8}
Caesium	43.5×10^{-8}	20	2.3×10^{-8}	67×10^{-8}	20.6	2.4×10^{-8}	134×10^{-8}	17.7	2.4×10^{-8}
Mercury	103.5×10^{-8}	9.4	2.6×10^{-8}	128×10^{-8}	11.7	2.6×10^{-8}	214×10^{-8}	—	—

Table 9.17 The resistivity ($\times 10^{-8}\ \Omega$ m) of elemental metals with low melting points. The shaded data above the line in the table refers to the metals in the solid state and data below line refer to data in the liquid state. The last row of the table shows the ratio of the resistivities in the solid and liquid states. The figure is derived from the ratio of the last datum in the solid region to the first datum in the liquid region.

T(K)	Na	K	Rb	Cs	Hg
0	0	0	0	0	0
78.2	0.76	1.30	2.59	4.1	5.8
273.2	4.33	6.49	11.5	18.8	94.1
373.2	9.51	15.8	27.3	44.5	103.5
573.2	17.4	27.7	45.1	67.3	128
973.2	38.9	64.7	93	128	214
1473.2	88	165	250	338	630
ρ_S/ρ_L (%)	46	41	42	42	6

Table 9.19 The results of calculations of the molecular polarisability of non-polar molecules based on dielectric constant data for both liquid and gaseous states. The value of on Equation 9.51 $\alpha/\varepsilon_o = (\varepsilon - 1)/n$ with n estimated by either Equation 9.49 or 9.50 as appropriate. The data for the densities of liquid hydrogen, nitrogen and oxygen are estimates based on a 10% decrease of the density of the solid. See Table 5.16 for gas data and Table 9.18 for liquid data. The gas data refer to atmospheric pressure (1.013×10^5 Pa). Notice that the inferred value of α is quite similar in liquid and gaseous states.

		Liquid				Gas			
Substance		ρ (kg m^{-3})	ε–1	n ($\times 10^{28}$ m^3)	α/ε_o ($\times 10^{-30}$)	ρ (kg m^{-3})	ε–1	n ($\times 10^{28}$ m^3)	α/ε_o ($\times 10^{-30}$)
Argon	40	1410	0.53	2.12	25	293	5.16	2.50	21
Helium	4	120	0.048	1.81	2.65	293	0.65	2.50	2.6
Hydrogen	2	≈80	0.228	2.41	9.5	293	2.54	2.50	10.2
Nitrogen	28	≈930	0.45	2.00	22.5	293	5.47	2.50	21.9
Oxygen	32	≈1300	0.507	2.45	20.5	293	4.94	2.50	19.8

Table 9.20 The results of the calculations of the permanent molecular dipole moment (in C m) of polar molecules according to Equation 9.53. The gas data refer to atmospheric pressure (1.013×10^5 Pa).

		Liquid					Gas			
Substance	**M**	***T*** **(K)**	***ρ*** **(kg m^{-3})**	***ε*****–1**	***n*** **(×10^{28} m^3)**	**p (×10^{-30})**	***T*** **(K)**	***ε*****–1**	***n*** **(×10^{28} m^3)**	**p (×10^{-30})**
Methanol	32	298	791	31.6	1.49	15.2	373	57	1.97	6.29
Ethanol	46	298	789	23.3	1.03	15.7	373	61 or 78	1.97	6.5 or 7.4
Water	18	293	1000	79.4	3.35	16.0	373	60	1.97	6.45

Table 9.18 The relative dielectric permittivity ε of various insulating liquids. The relative permittivity of vacuum is exactly 1.

Substance	**MW**	***T***	**ε – 1**	**ε**
Argon, Ar	40	82 K	0.53	1.53
Helium, He	4	4.19 K	0.048	1.048
Hydrogen, H_2	2	20.4 K	0.228	1.228
Nitrogen, N_2	28	70 K	0.45	1.45
Oxygen, O_2	32	80 K	0.507	1.507
Methanol, CH_3OH	32	25 °C	31.6	32.6
Ethanol, C_2H_5OH	46	25 °C	23.3	24.3
Propanol, C_3H_7OH	60	25 °C	19.1	20.1
Butanol, C_4H_9OH	74	20 °C	16.8	17.8
Pentanol, $C_5H_{11}OH$	88	25 °C	12.9	13.9
Hexanol, $C_6H_{13}OH$	102	25 °C	12.3	13.3
Aniline, C_6H_7N	86	20 °C	5.90	6.90
Acetone, C_3H_6O	58	25 °C	19.7	20.7
Carbon disulphide, CS_2	76	20 °C	1.64	2.64
Water, H_2O	18	20 °C	79.4	80.4

Table 9.19 The results of calculations of the molecular polarisability of non-polar molecules based on dielectric constant data for both liquid and gaseous states. The value of on Equation 9.51 $\alpha/\varepsilon_o = (\varepsilon - 1)/n$ with n estimated by either Equation 9.49 or 9.50 as appropriate. The data for the densities of liquid hydrogen, nitrogen and oxygen are estimates based on a 10% decrease of the density of the solid. See Table 5.16 for gas data and Table 9.18 for liquid data. The gas data refer to atmospheric pressure (1.013×10^5 Pa). Notice that the inferred value of α is quite similar in liquid and gaseous states.

		Liquid				Gas			
Substance		ρ (kg m^{-3})	ε–1	n ($\times 10^{28}$ m^3)	α/ε_o ($\times 10^{-30}$)	ρ (kg m^{-3})	ε–1	n ($\times 10^{28}$ m^3)	α/ε_o ($\times 10^{-30}$)
Argon	40	1410	0.53	2.12	25	293	5.16	2.50	21
Helium	4	120	0.048	1.81	2.65	293	0.65	2.50	2.6
Hydrogen	2	≈80	0.228	2.41	9.5	293	2.54	2.50	10.2
Nitrogen	28	≈930	0.45	2.00	22.5	293	5.47	2.50	21.9
Oxygen	32	≈1300	0.507	2.45	20.5	293	4.94	2.50	19.8

Table 9.20 The results of the calculations of the permanent molecular dipole moment (in C m) of polar molecules according to Equation 9.53. The gas data refer to atmospheric pressure (1.013×10^5 Pa).

		Liquid					Gas			
Substance	**M**	***T*** **(K)**	***ρ*** **(kg m^{-3})**	***ε*****–1**	***n*** **(×10^{28} m^3)**	**p (×10^{-30})**	***T*** **(K)**	***ε*****–1**	***n*** **(×10^{28} m^3)**	**p (×10^{-30})**
Methanol	32	298	791	31.6	1.49	15.2	373	57	1.97	6.29
Ethanol	46	298	789	23.3	1.03	15.7	373	61 or 78	1.97	6.5 or 7.4
Water	18	293	1000	79.4	3.35	16.0	373	60	1.97	6.45

Table 9.21 The refractive index of various liquids for yellow light.

Substance and chemical formula	**MW**	n_{light}
Water, H_2O	18	1.33
Carbon tetrachloride, CCl_4	152	1.405
Toluene, C_7H_8	92	1.497
Methanol, CH_3OH	32	1.329
Ethanol, C_2H_5OH	44	1.3614
Propan-1-ol, C_3H_7OH	56	1.3852
Propan-2-ol, $C_2H_5OHCH_2$	56	1.3742
Acetic acid, CH_3COOH		1.3716
Benzene, C_6H_6	78	1.501
Aniline, C_6H_7N	86	1.586
Hydrogen disulphide, HS_2	65	1.885

Table 9.22 Calculation of the refractive indices of liquid water, methanol and benzene from the data on the refractive index of their vapours (Table 5.18). The predictions for $n_{light}-1$ are 20 to 25% below the experimental values. The method of calculation is described in Equations 9.55 to 9.61.

			Gas			Liquid			
Substance		**MW**	**Number density (m^{-3})**	**n_{light}**	**Molecular polarisability α ($F^{-1}m^4$)**	**Density (kg m^{-3})**	**Number density (m^{-3})**	**Prediction $n_{light}-1$**	**Actual $n_{light}-1$**
Water	H_2O	18	2.689×10^{25}	1.000254	1.647×10^{-40}	1000	3.346×10^{28}	0.27	0.33
Methanol	CH_3OH	32	2.689×10^{25}	1.000586	3.860×10^{-40}	791	1.489×10^{28}	0.284	0.329
Benzene	C_6H_6	78	2.689×10^{25}	1.001762	11.61×10^{-40}	879	6.786×10^{27}	0.375	0.501