

FRIDAY, 21 JUNE 2024 – MORNING

CHEMISTRY – A level component 3

Data Booklet

Avogadro constant	$N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$
molar gas constant	$R = 8.31 \text{ J mol}^{-1} \text{ K}^{-1}$
molar gas volume at 273 K and 1 atm	$V_m = 22.4 \text{ dm}^3 \text{ mol}^{-1}$
molar gas volume at 298 K and 1 atm	$V_m = 24.5 \text{ dm}^3 \text{ mol}^{-1}$
Planck constant	$h = 6.63 \times 10^{-34} \text{ J s}$
speed of light	$c = 3.00 \times 10^8 \text{ m s}^{-1}$
density of water	$d = 1.00 \text{ g cm}^{-3}$
specific heat capacity of water	$c = 4.18 \text{ J g}^{-1} \text{ K}^{-1}$
ionic product of water at 298 K	$K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$
fundamental electronic charge	$e = 1.60 \times 10^{-19} \text{ C}$

temperature (K) = temperature (°C) + 273

$1 \text{ dm}^3 = 1000 \text{ cm}^3$

$1 \text{ m}^3 = 1000 \text{ dm}^3$

1 tonne = 1000 kg

$1 \text{ atm} = 1.01 \times 10^5 \text{ Pa}$

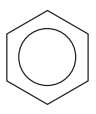
Multiple	Prefix	Symbol
10^{-9}	nano	n
10^{-6}	micro	μ
10^{-3}	milli	m

Multiple	Prefix	Symbol
10^3	kilo	k
10^6	mega	M
10^9	giga	G

Infrared absorption values

Bond	Wavenumber / cm^{-1}
C — Br	500 to 600
C — Cl	650 to 800
C — O	1000 to 1300
C = C	1620 to 1670
C = O	1650 to 1750
C $\equiv$ N	2100 to 2250
C — H	2800 to 3100
O — H (carboxylic acid)	2500 to 3200 (very broad)
O — H (alcohol / phenol)	3200 to 3550 (broad)
N — H	3300 to 3500

¹³C NMR chemical shifts relative to TMS = 0

Type of carbon	Chemical shift, δ (ppm)
$\begin{array}{c} \quad \\ -\text{C}-\text{C}- \\ \quad \end{array}$	5 to 40
$\begin{array}{c} \\ \text{R}-\text{C}-\text{Cl or Br} \\ \end{array}$	10 to 70
$\begin{array}{c} \\ \text{R}-\text{C}-\text{C}- \\ \quad \\ \text{O} \end{array}$	20 to 50
$\begin{array}{c} \\ \text{R}-\text{C}-\text{N} \diagup \diagdown \\ \end{array}$	25 to 60
$\begin{array}{c} \\ -\text{C}-\text{O}- \\ \end{array}$	50 to 90
$\begin{array}{c} \diagdown \quad \diagup \\ \text{C}=\text{C} \\ \diagup \quad \diagdown \end{array}$	90 to 150
$\text{R}-\text{C} \equiv \text{N}$	110 to 125
	110 to 160
$\begin{array}{c} \text{R}-\text{C}- \text{ (carboxylic acid / ester)} \\ \\ \text{O} \end{array}$	160 to 185
$\begin{array}{c} \text{R}-\text{C}- \text{ (aldehyde / ketone)} \\ \\ \text{O} \end{array}$	190 to 220

^1H NMR chemical shifts relative to TMS = 0

Type of proton	Chemical shift, δ (ppm)
$-\text{CH}_3$	0.1 to 2.0
$\text{R}-\text{CH}_3$	0.9
$\text{R}-\text{CH}_2-\text{R}$	1.3
$\text{CH}_3-\text{C}\equiv\text{N}$	2.0
$\text{CH}_3-\text{C}(=\text{O})$	2.0 to 2.5
$-\text{CH}_2-\text{C}(=\text{O})$	2.0 to 3.0
 - CH_3	2.2 to 2.3
$\text{HC}-\text{Cl}$ or $\text{HC}-\text{Br}$	3.1 to 4.3
$\text{HC}-\text{O}$	3.3 to 4.3
$\text{R}-\text{OH}$	4.5 *
$-\text{C}=\text{CH}$	4.5 to 6.3
$-\text{C}=\text{CH}-\text{CO}$	5.8 to 6.5
 - $\text{CH}=\text{C}$	6.5 to 7.5
 - H	6.5 to 8.0
 - OH	7.0 *
$\text{R}-\text{C}(=\text{O})\text{H}$	9.8 *
$\text{R}-\text{C}(=\text{O})\text{OH}$	11.0 *

*variable figure dependent on concentration and solvent

THE PERIODIC TABLE

Period **1** **2** **3** **4** **5** **6** **7** **0**

Group

s block		p block					
1	2						
1.01 H Hydrogen 1		10.8 B Boron 5	12.0 C Carbon 6	14.0 N Nitrogen 7	16.0 O Oxygen 8	19.0 F Fluorine 9	20.2 Ne Neon 10
6.94 Li Lithium 3	9.01 Be Beryllium 4	27.0 Al Aluminium 13	28.1 Si Silicon 14	31.0 P Phosphorus 15	32.1 S Sulfur 16	35.5 Cl Chlorine 17	40.0 Ar Argon 18
23.0 Na Sodium 11	24.3 Mg Magnesium 12	69.7 Ga Gallium 31	72.6 Ge Germanium 32	74.9 As Arsenic 33	79.0 Se Selenium 34	79.9 Br Bromine 35	83.8 Kr Krypton 36
39.1 K Potassium 19	87.6 Sr Strontium 38	65.4 Zn Zinc 30	63.5 Cu Copper 29	58.7 Ni Nickel 28	58.9 Co Cobalt 27	58.7 Ni Nickel 28	58.9 Co Cobalt 27
85.5 Rb Rubidium 37	137 Ba Barium 56	112 Cd Cadmium 48	108 Ag Silver 47	106 Pd Palladium 46	103 Rh Rhodium 45	106 Pd Palladium 46	103 Rh Rhodium 45
133 Cs Caesium 55	(226) Fr Francium 87	115 In Indium 49	197 Au Gold 79	195 Pt Platinum 78	192 Ir Iridium 77	195 Pt Platinum 78	192 Ir Iridium 77
(223) Fr Francium 87	(226) Ra Radium 88	201 Hg Mercury 80	204 Tl Thallium 81	207 Pb Lead 82	209 Bi Bismuth 83	207 Pb Lead 82	209 Bi Bismuth 83
(227) Ac Actinium 89	(227) Ac Actinium 89	208 Po Polonium 84	210 At Astatine 85	210 Po Polonium 84	210 Po Polonium 84	210 Po Polonium 84	210 Po Polonium 84
Lanthanoid elements		f block					
140 Ce Cerium 58	141 Pr Praseodymium 59	144 Nd Neodymium 60	147 Pm Promethium 61	150 Sm Samarium 62	153 Eu Europium 63	157 Gd Gadolinium 64	159 Tb Terbium 65
162 Dy Dysprosium 66	163 Ho Holmium 67	167 Er Erbium 68	169 Tm Thulium 69	173 Yb Ytterbium 70	175 Lu Lutetium 71	173 Yb Ytterbium 70	175 Lu Lutetium 71
232 Th Thorium 90	(231) Pa Protactinium 91	238 U Uranium 92	(237) Np Neptunium 93	(242) Pu Plutonium 94	(243) Am Americium 95	(247) Cm Curium 96	(245) Bk Berkelium 97
Actinoid elements							
253 Fm Fermium 100	(253) Fm Fermium 100	(254) Es Einsteinium 99	(255) Md Mendelevium 101	(256) No Nobelium 102	(257) Lr Lawrencium 103	(254) Es Einsteinium 99	(255) Md Mendelevium 101

Key

Ar

Symbol

Name

Z

relative atomic mass

atomic number