

CHEMISTRY

Written examination 2

DATA BOOK

Directions to students

This data book is provided as a reference.

Make sure that you remove this data book from the question and answer book during reading time.

Any writings, jottings, notes or drawings made on this data book will **not** be considered in the marking.

At the end of the examination, ensure that you do **not** leave the data book in the question and answer book.

You may keep this data book.

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1. Periodic table of the elements

1 H Hydrogen 1.0		2 He Helium 4.0	
3 Li Lithium 6.9		4 Be Beryllium 9.0	
11 Na Sodium 23.0		12 Mg Magnesium 24.3	
19 K Potassium 39.1		20 Ca Calcium 40.1	
37 Rb Rubidium 85.5		38 Sr Strontium 87.6	
55 Cs Caesium 132.9		56 Ba Barium 137.3	
87 Fr Francium (223)		88 Ra Radium (226)	
21 Sc Scandium 44.9		22 Ti Titanium 47.9	
23 V Vanadium 50.9		24 Cr Chromium 52.0	
25 Mn Manganese 54.9		26 Fe Iron 55.9	
27 Co Cobalt 58.9		28 Ni Nickel 58.7	
29 Cu Copper 63.6		30 Zn Zinc 65.4	
31 Ga Gallium 69.7		32 Ge Germanium 72.6	
33 As Arsenic 74.9		34 Se Selenium 79.0	
35 Br Bromine 79.9		36 Kr Krypton 83.8	
37 Y Yttrium 88.9		38 Zr Zirconium 91.2	
39 Y Yttrium 88.9		40 Zr Zirconium 91.2	
41 Nb Niobium 92.9		42 Mo Molybdenum 95.9	
43 Tc Technetium 98.1		44 Ru Ruthenium 101.1	
45 Rh Rhodium 102.9		46 Pd Palladium 106.4	
47 Ag Silver 107.9		48 Cd Cadmium 112.4	
49 In Indium 114.8		50 Sn Tin 118.7	
51 Sb Antimony 121.8		52 Te Tellurium 127.6	
53 I Iodine 126.9		54 Xe Xenon 131.3	
55 Cs Caesium 132.9		56 Ba Barium 137.3	
57 La Lanthanum 138.9		58 Ac Actinium 140.1	
71 Lu Lutetium 175.0		72 Hf Hafnium 178.5	
73 Ta Tantalum 180.9		74 W Tungsten 183.8	
75 Re Rhenium 186.2		76 Os Osmium 190.2	
77 Ir Iridium 192.2		78 Pt Platinum 195.1	
79 Au Gold 197.0		80 Hg Mercury 200.6	
81 Tl Thallium 204.4		82 Pb Lead 207.2	
83 Bi Bismuth 209.0		84 Po Polonium (209)	
85 At Astatine (210)		86 Rn Radon (222)	
87 Fr Francium (223)		88 Ra Radium (226)	
89 Ac Actinium (227)		90 Th Thorium 232.0	
91 Pa Protactinium 231.0		92 U Uranium 238.0	
93 Np Neptunium (237.1)		94 Pu Plutonium (244)	
95 Am Americium (243)		96 Cm Curium (247)	
97 Bk Berkelium (247)		98 Cf Californium (251)	
99 Es Einsteinium (252)		100 Fm Fermium (257)	
101 Md Mendelevium (258)		102 No Nobelium (259)	
103 Lr Lawrencium (262)		104 Rf Rutherfordium (261)	
105 Db Dubnium (262)		106 Sg Seaborgium (266)	
107 Bh Bohrium (264)		108 Hs Hassium (277)	
109 Mt Meitnerium (268)		110 Ds Darmstadtium (271)	
111 Rg Roentgenium (272)		112 Unb Unbinilium (272)	
113 Nh Nihonium (284)		114 Uuq Ununquadium (285)	
115 Mc Moscovium (288)		116 Uuh Ununhexium (288)	
117 Tl Tennessine (289)		118 Uuo Ununoctium (289)	

58 Ce Cerium 140.1	59 Pr Praseodymium 140.9	60 Nd Neodymium 144.2	61 Pm Promethium (145)	62 Sm Samarium 150.3	63 Eu Europium 152.0	64 Gd Gadolinium 157.2	65 Tb Terbium 158.9	66 Dy Dysprosium 162.5	67 Ho Holmium 164.9	68 Er Erbium 167.3	69 Tm Thulium 168.9	70 Yb Ytterbium 173.0	71 Lu Lutetium 175.0
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90 Th Thorium 232.0	91 Pa Protactinium 231.0	92 U Uranium 238.0	93 Np Neptunium (237.1)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (262)
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TURN OVER

2. The electrochemical series

	E° in volt
$\text{F}_2(\text{g}) + 2\text{e}^- \rightleftharpoons 2\text{F}^-(\text{aq})$	+2.87
$\text{H}_2\text{O}_2(\text{aq}) + 2\text{H}^+(\text{aq}) + 2\text{e}^- \rightleftharpoons 2\text{H}_2\text{O}(\text{l})$	+1.77
$\text{Au}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{Au}(\text{s})$	+1.68
$\text{Cl}_2(\text{g}) + 2\text{e}^- \rightleftharpoons 2\text{Cl}^-(\text{aq})$	+1.36
$\text{O}_2(\text{g}) + 4\text{H}^+(\text{aq}) + 4\text{e}^- \rightleftharpoons 2\text{H}_2\text{O}(\text{l})$	+1.23
$\text{Br}_2(\text{l}) + 2\text{e}^- \rightleftharpoons 2\text{Br}^-(\text{aq})$	+1.09
$\text{Ag}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{Ag}(\text{s})$	+0.80
$\text{Fe}^{3+}(\text{aq}) + \text{e}^- \rightleftharpoons \text{Fe}^{2+}(\text{aq})$	+0.77
$\text{O}_2(\text{g}) + 2\text{H}^+(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{H}_2\text{O}_2(\text{aq})$	+0.68
$\text{I}_2(\text{s}) + 2\text{e}^- \rightleftharpoons 2\text{I}^-(\text{aq})$	+0.54
$\text{O}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l}) + 4\text{e}^- \rightleftharpoons 4\text{OH}^-(\text{aq})$	+0.40
$\text{Cu}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Cu}(\text{s})$	+0.34
$\text{Sn}^{4+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Sn}^{2+}(\text{aq})$	+0.15
$\text{S}(\text{s}) + 2\text{H}^+(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{H}_2\text{S}(\text{g})$	+0.14
$2\text{H}^+(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{H}_2(\text{g})$	0.00
$\text{Pb}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Pb}(\text{s})$	-0.13
$\text{Sn}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Sn}(\text{s})$	-0.14
$\text{Ni}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Ni}(\text{s})$	-0.23
$\text{Co}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Co}(\text{s})$	-0.28
$\text{Fe}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Fe}(\text{s})$	-0.44
$\text{Zn}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Zn}(\text{s})$	-0.76
$2\text{H}_2\text{O}(\text{l}) + 2\text{e}^- \rightleftharpoons \text{H}_2(\text{g}) + 2\text{OH}^-(\text{aq})$	-0.83
$\text{Mn}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Mn}(\text{s})$	-1.03
$\text{Al}^{3+}(\text{aq}) + 3\text{e}^- \rightleftharpoons \text{Al}(\text{s})$	-1.67
$\text{Mg}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Mg}(\text{s})$	-2.34
$\text{Na}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{Na}(\text{s})$	-2.71
$\text{Ca}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Ca}(\text{s})$	-2.87
$\text{K}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{K}(\text{s})$	-2.93
$\text{Li}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{Li}(\text{s})$	-3.02

3. Physical constants

Avogadro's constant (N_A) = $6.02 \times 10^{23} \text{ mol}^{-1}$

Charge on one electron = $-1.60 \times 10^{-19} \text{ C}$

Faraday constant (F) = $96\,500 \text{ C mol}^{-1}$

Gas constant (R) = $8.31 \text{ J K}^{-1} \text{ mol}^{-1}$

Ionic product for water (K_w) = $1.00 \times 10^{-14} \text{ mol}^2 \text{ L}^{-2}$ at 298 K
(Self ionisation constant)

Molar volume (V_m) of an ideal gas at 273 K, 101.3 kPa (STP) = 22.4 L mol^{-1}

Molar volume (V_m) of an ideal gas at 298 K, 101.3 kPa (SLC) = 24.5 L mol^{-1}

Specific heat capacity (c) of water = $4.18 \text{ J g}^{-1} \text{ K}^{-1}$

Density (d) of water at 25°C = 1.00 g mL^{-1}

1 atm = 101.3 kPa = 760 mm Hg

0°C = 273 K

4. SI prefixes, their symbols and values

SI prefix	Symbol	Value
giga	G	10^9
mega	M	10^6
kilo	k	10^3
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}

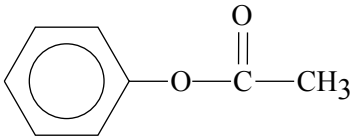
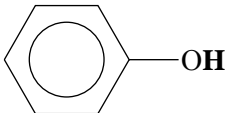
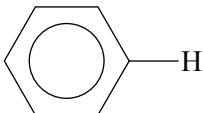
5. ^1H NMR data

Typical proton shift values relative to TMS = 0

These can differ slightly in different solvents. Where more than one proton environment is shown in the formula, the shift refers to the ones in bold letters.

Type of proton	Chemical shift (ppm)
R-CH ₃	0.9
R-CH ₂ -R	1.3
RCH = CH- CH₃	1.7
R ₃ -CH	2.0
$\text{CH}_3-\text{C} \begin{array}{l} \text{O} \\ \parallel \\ \text{OR} \end{array}$ or $\text{CH}_3-\text{C} \begin{array}{l} \text{O} \\ \parallel \\ \text{NHR} \end{array}$	2.0

TURN OVER

Type of proton	Chemical shift (ppm)
$\begin{array}{c} \text{R} \quad \text{CH}_3 \\ \quad \diagdown \quad / \\ \quad \text{C} \\ \quad \\ \quad \text{O} \end{array}$	2.1
R-CH ₂ -X (X = F, Cl, Br or I)	3-4
R-CH ₂ -OH	3.6
$\begin{array}{c} \quad \text{O} \\ \quad // \\ \text{R}-\text{C} \\ \quad \backslash \\ \quad \text{NHCH}_2\text{R} \end{array}$	3.2
R-O-CH ₃ or R-O-CH ₂ R	3.3
	4.1
$\begin{array}{c} \quad \text{O} \\ \quad // \\ \text{R}-\text{C} \\ \quad \backslash \\ \quad \text{OCH}_2\text{R} \end{array}$	4.1
R-O-H	1-6 (varies considerably under different conditions)
R-NH ₂	1-5
RHC = CH ₂	4.6-6.0
	7.0
	7.3
$\begin{array}{c} \quad \text{O} \\ \quad // \\ \text{R}-\text{C} \\ \quad \backslash \\ \quad \text{NHCH}_2\text{R} \end{array}$	8.1
$\begin{array}{c} \quad \text{O} \\ \quad // \\ \text{R}-\text{C} \\ \quad \backslash \\ \quad \text{H} \end{array}$	9-10
$\begin{array}{c} \quad \text{O} \\ \quad // \\ \text{R}-\text{C} \\ \quad \backslash \\ \quad \text{O}-\text{H} \end{array}$	11.5

6. ^{13}C NMR data

Type of carbon	Chemical shift (ppm)
R-CH ₃	8–25
R-CH ₂ -R	20–45
R ₃ -CH	40–60
R ₄ -C	36–45
R-CH ₂ -X	15–80
RC-NH ₂	35–70
R-CH ₂ -OH	50–90
RC≡CR	75–95
RC=CR	110–150
RCOOH	160–185

7. Infrared absorption data

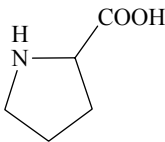
Characteristic range for infrared absorption

Bond	Wave number (cm ⁻¹)
C-Cl	700–800
C-C	750–1100
C-O	1000–1300
C=C	1610–1680
C=O	1670–1750
O-H (acids)	2500–3300
C-H	2850–3300
O-H (alcohols)	3200–3550
N-H (primary amines)	3350–3500

TURN OVER

8. 2-amino acids (α -amino acids)

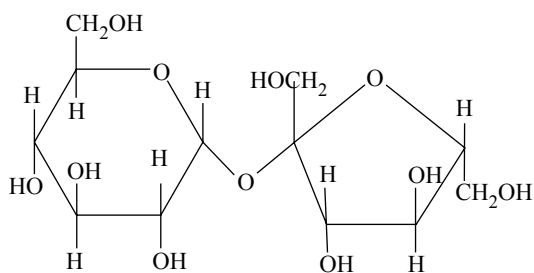
Name	Symbol	Structure
alanine	Ala	$\begin{array}{c} \text{CH}_3 \\ \\ \text{H}_2\text{N}-\text{CH}-\text{COOH} \end{array}$
arginine	Arg	$\begin{array}{c} \text{NH} \\ \\ \text{CH}_2-\text{CH}_2-\text{CH}_2-\text{NH}-\text{C}-\text{NH}_2 \\ \\ \text{H}_2\text{N}-\text{CH}-\text{COOH} \end{array}$
asparagine	Asn	$\begin{array}{c} \text{O} \\ \\ \text{CH}_2-\text{C}-\text{NH}_2 \\ \\ \text{H}_2\text{N}-\text{CH}-\text{COOH} \end{array}$
aspartic acid	Asp	$\begin{array}{c} \text{CH}_2-\text{COOH} \\ \\ \text{H}_2\text{N}-\text{CH}-\text{COOH} \end{array}$
cysteine	Cys	$\begin{array}{c} \text{CH}_2-\text{SH} \\ \\ \text{H}_2\text{N}-\text{CH}-\text{COOH} \end{array}$
glutamine	Gln	$\begin{array}{c} \text{O} \\ \\ \text{CH}_2-\text{CH}_2-\text{C}-\text{NH}_2 \\ \\ \text{H}_2\text{N}-\text{CH}-\text{COOH} \end{array}$
glutamic acid	Glu	$\begin{array}{c} \text{CH}_2-\text{CH}_2-\text{COOH} \\ \\ \text{H}_2\text{N}-\text{CH}-\text{COOH} \end{array}$
glycine	Gly	$\text{H}_2\text{N}-\text{CH}_2-\text{COOH}$
histidine	His	$\begin{array}{c} \text{N} \\ // \quad \backslash \\ \text{CH}_2-\text{C} \quad \text{N}-\text{H} \\ \\ \text{H}_2\text{N}-\text{CH}-\text{COOH} \end{array}$
isoleucine	Ile	$\begin{array}{c} \text{CH}_3-\text{CH}-\text{CH}_2-\text{CH}_3 \\ \\ \text{H}_2\text{N}-\text{CH}-\text{COOH} \end{array}$

Name	Symbol	Structure
leucine	Leu	$\begin{array}{c} \text{CH}_3 - \text{CH} - \text{CH}_3 \\ \\ \text{CH}_2 \\ \\ \text{H}_2\text{N} - \text{CH} - \text{COOH} \end{array}$
lysine	Lys	$\begin{array}{c} \text{CH}_2 - \text{CH}_2 - \text{CH}_2 - \text{CH}_2 - \text{NH}_2 \\ \\ \text{H}_2\text{N} - \text{CH} - \text{COOH} \end{array}$
methionine	Met	$\begin{array}{c} \text{CH}_2 - \text{CH}_2 - \text{S} - \text{CH}_3 \\ \\ \text{H}_2\text{N} - \text{CH} - \text{COOH} \end{array}$
phenylalanine	Phe	$\begin{array}{c} \text{CH}_2 - \text{C}_6\text{H}_5 \\ \\ \text{H}_2\text{N} - \text{CH} - \text{COOH} \end{array}$
proline	Pro	
serine	Ser	$\begin{array}{c} \text{CH}_2 - \text{OH} \\ \\ \text{H}_2\text{N} - \text{CH} - \text{COOH} \end{array}$
threonine	Thr	$\begin{array}{c} \text{CH}_3 - \text{CH} - \text{OH} \\ \\ \text{H}_2\text{N} - \text{CH} - \text{COOH} \end{array}$
tryptophan	Trp	$\begin{array}{c} \text{H} \\ \\ \text{CH}_2 - \text{C}_8\text{H}_6\text{N}_2 \\ \\ \text{H}_2\text{N} - \text{CH} - \text{COOH} \end{array}$
tyrosine	Tyr	$\begin{array}{c} \text{CH}_2 - \text{C}_6\text{H}_4 - \text{OH} \\ \\ \text{H}_2\text{N} - \text{CH} - \text{COOH} \end{array}$
valine	Val	$\begin{array}{c} \text{CH}_3 - \text{CH} - \text{CH}_3 \\ \\ \text{H}_2\text{N} - \text{CH} - \text{COOH} \end{array}$

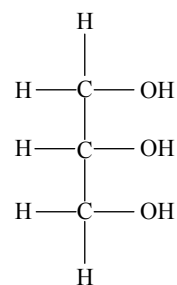
9. Formulas of some fatty acids

Name	Formula
Lauric	$C_{11}H_{23}COOH$
Myristic	$C_{13}H_{27}COOH$
Palmitic	$C_{15}H_{31}COOH$
Palmitoleic	$C_{15}H_{29}COOH$
Stearic	$C_{17}H_{35}COOH$
Oleic	$C_{17}H_{33}COOH$
Linoleic	$C_{17}H_{31}COOH$
Linolenic	$C_{17}H_{29}COOH$
Arachidic	$C_{19}H_{39}COOH$
Arachidonic	$C_{19}H_{31}COOH$

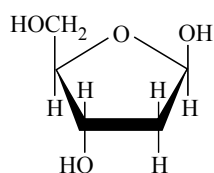
10. Structural formulas of some important biomolecules



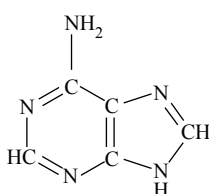
sucrose



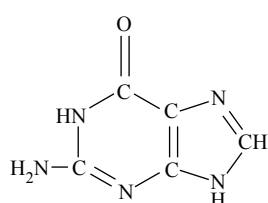
glycerol



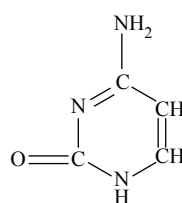
deoxyribose



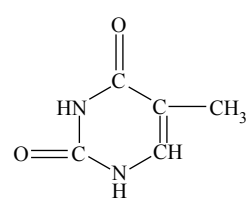
adenine



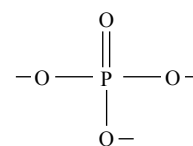
guanine



cytosine



thymine



phosphate

11. Acid-base indicators

Name	pH range	Colour change		K_a
		Acid	Base	
Thymol blue	1.2–2.8	red	yellow	2×10^{-2}
Methyl orange	3.1–4.4	red	yellow	2×10^{-4}
Bromophenol blue	3.0–4.6	yellow	blue	6×10^{-5}
Methyl red	4.2–6.3	red	yellow	8×10^{-6}
Bromothymol blue	6.0–7.6	yellow	blue	1×10^{-7}
Phenol red	6.8–8.4	yellow	red	1×10^{-8}
Phenolphthalein	8.3–10.0	colourless	red	5×10^{-10}

12. Acidity constants, K_a , of some weak acids

Name	Formula	K_a
Ammonium ion	NH_4^+	5.6×10^{-10}
Benzoic	$\text{C}_6\text{H}_5\text{COOH}$	6.4×10^{-5}
Boric	H_3BO_3	5.8×10^{-10}
Ethanoic	CH_3COOH	1.7×10^{-5}
Hydrocyanic	HCN	6.3×10^{-10}
Hydrofluoric	HF	7.6×10^{-4}
Hypobromous	HOBr	2.4×10^{-9}
Hypochlorous	HOCl	2.9×10^{-8}
Lactic	$\text{HC}_3\text{H}_5\text{O}_3$	1.4×10^{-4}
Methanoic	HCOOH	1.8×10^{-4}
Nitrous	HNO_2	7.2×10^{-4}
Propanoic	$\text{C}_2\text{H}_5\text{COOH}$	1.3×10^{-5}

13. Values of molar enthalpy of combustions of some common fuels at 298 K and 101.3 kPa

Substance	Formula	State	ΔH_c (kJ mol ⁻¹)
hydrogen	H_2	g	-286
carbon(graphite)	C	s	-394
methane	CH_4	g	-889
ethane	C_2H_6	g	-1557
propane	C_3H_8	g	-2217
butane	C_4H_{10}	g	-2874
pentane	C_5H_{12}	l	-3509
hexane	C_6H_{14}	l	-4158
octane	C_8H_{18}	l	-5464
ethene	C_2H_4	g	-1409
methanol	CH_3OH	l	-725
ethanol	$\text{C}_2\text{H}_5\text{OH}$	l	-1364
1-propanol	$\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$	l	-2016
2-propanol	$\text{CH}_3\text{CHOHCH}_3$	l	-2003
glucose	$\text{C}_6\text{H}_{12}\text{O}_6$	s	-2816