



**Victorian Certificate of Education
2012**

CHEMISTRY
Written examination

Day Date 2012

Reading time: *.*.* to *.*.* (15 minutes)

Writing time: *.*.* to *.*.* (1 hour 30 minutes)

DATA BOOK

Directions to students

- A question and answer book is provided with this data book.

Students are NOT permitted to bring mobile phones and/or any other unauthorised electronic devices into the examination room.

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1. Periodic table of the elements

1 H 1.0 Hydrogen		4 Be 9.0 Beryllium		79 Au 197.0 Gold		5 B 10.8 Boron		6 C 12.0 Carbon		7 N 14.0 Nitrogen		8 O 16.0 Oxygen		9 F 19.0 Fluorine		2 He 4.0 Helium	
3 Li 6.9 Lithium		12 Mg 24.3 Magnesium		27 Co 58.9 Cobalt		29 Cu 63.5 Copper		30 Zn 65.4 Zinc		33 As 74.9 Arsenic		34 Se 79.0 Selenium		35 Br 79.9 Bromine		10 Ne 20.2 Neon	
11 Na 23.0 Sodium		20 Ca 40.1 Calcium		26 Fe 55.8 Iron		28 Ni 58.7 Nickel		31 Ga 69.7 Gallium		32 Ge 72.6 Germanium		35 Cl 35.5 Chlorine		36 Kr 83.8 Krypton		18 Ar 39.9 Argon	
19 K 39.1 Potassium		38 Sr 87.6 Strontium		44 Ru 101.1 Ruthenium		46 Pd 106.4 Palladium		48 Cd 112.4 Cadmium		50 Sn 118.7 Tin		52 Te 127.6 Tellurium		53 I 126.9 Iodine		54 Xe 131.3 Xenon	
37 Rb 85.5 Rubidium		56 Ba 137.3 Barium		76 Os 190.2 Osmium		78 Pt 195.1 Platinum		80 Hg 200.6 Mercury		82 Pb 207.2 Lead		84 Po (210) Polonium		85 At (210) Astatine		86 Rn (222) Radon	
55 Cs 132.9 Caesium		88 Ra (226) Radium		108 Hs (267) Hassium		110 Ds (271) Darmstadtium		112 Cn (285) Copernicium		114 Uuq (289) Ununquadium		116 Uuh (293) Ununhexium		117 Uus (294) Ununseptium		118 Uuo (294) Ununoctium	
87 Fr (223) Francium		89 Ac (227) Actinium		109 Mt (268) Meitnerium		111 Rg (272) Roentgenium		113 Uut (284) Ununtrium		115 Uup (288) Ununpentium		118 Uuo (294) Ununoctium		119 Uuq (294) Ununquadium		120 Uuo (294) Ununoctium	
21 Sc 45.0 Scandium		39 Y 88.9 Yttrium		45 Rh 102.9 Rhodium		47 Ag 107.9 Silver		49 In 114.8 Indium		51 Sb 121.8 Antimony		53 Bi 209.0 Bismuth		55 At (210) Astatine		56 Rn (222) Radon	
22 Ti 47.9 Titanium		40 Zr 91.2 Zirconium		46 Pd 106.4 Palladium		48 Cd 112.4 Cadmium		50 Sn 118.7 Tin		52 Te 127.6 Tellurium		54 Xe 131.3 Xenon		56 Rn (222) Radon		57 La 138.9 Lanthanum	
23 V 50.9 Vanadium		41 Nb 92.9 Niobium		47 Rh 102.9 Rhodium		49 In 114.8 Indium		51 Sb 121.8 Antimony		53 Bi 209.0 Bismuth		55 At (210) Astatine		57 La 138.9 Lanthanum		58 Ce 140.1 Cerium	
24 Cr 52.0 Chromium		42 Mo 96.0 Molybdenum		48 Cd 112.4 Cadmium		50 Sn 118.7 Tin		52 Te 127.6 Tellurium		54 Xe 131.3 Xenon		56 Rn (222) Radon		58 Ce 140.1 Cerium		59 Pr 140.9 Praseodymium	
25 Mn 54.9 Manganese		43 Tc (98) Technetium		49 In 114.8 Indium		51 Sb 121.8 Antimony		53 Bi 209.0 Bismuth		55 At (210) Astatine		57 La 138.9 Lanthanum		59 Pr 140.9 Praseodymium		60 Nd 144.2 Neodymium	
26 Fe 55.8 Iron		44 Ru 101.1 Ruthenium		50 Sn 118.7 Tin		52 Te 127.6 Tellurium		54 Xe 131.3 Xenon		56 Rn (222) Radon		58 Ce 140.1 Cerium		60 Nd 144.2 Neodymium		61 Pm (145) Promethium	
27 Co 58.9 Cobalt		45 Rh 102.9 Rhodium		51 Sb 121.8 Antimony		53 Bi 209.0 Bismuth		55 At (210) Astatine		57 La 138.9 Lanthanum		59 Pr 140.9 Praseodymium		61 Pm (145) Promethium		62 Sm 150.4 Samarium	
28 Ni 58.7 Nickel		46 Pd 106.4 Palladium		52 Te 127.6 Tellurium		54 Xe 131.3 Xenon		56 Rn (222) Radon		58 Ce 140.1 Cerium		60 Nd 144.2 Neodymium		62 Sm 150.4 Samarium		63 Eu 152.0 Europium	
29 Cu 63.5 Copper		47 Ag 107.9 Silver		53 Bi 209.0 Bismuth		55 At (210) Astatine		57 La 138.9 Lanthanum		59 Pr 140.9 Praseodymium		61 Pm (145) Promethium		63 Eu 152.0 Europium		64 Gd 157.3 Gadolinium	
30 Zn 65.4 Zinc		48 Cd 112.4 Cadmium		54 Xe 131.3 Xenon		56 Rn (222) Radon		58 Ce 140.1 Cerium		60 Nd 144.2 Neodymium		62 Sm 150.4 Samarium		64 Gd 157.3 Gadolinium		65 Tb 158.9 Terbium	
31 Ga 69.7 Gallium		49 In 114.8 Indium		55 At (210) Astatine		57 La 138.9 Lanthanum		59 Pr 140.9 Praseodymium		61 Pm (145) Promethium		63 Eu 152.0 Europium		65 Tb 158.9 Terbium		66 Dy 162.5 Dysprosium	
32 Ge 72.6 Germanium		50 Sn 118.7 Tin		56 Rn (222) Radon		58 Ce 140.1 Cerium		60 Nd 144.2 Neodymium		62 Sm 150.4 Samarium		64 Gd 157.3 Gadolinium		66 Dy 162.5 Dysprosium		67 Ho 164.9 Holmium	
33 As 74.9 Arsenic		51 Sb 121.8 Antimony		57 La 138.9 Lanthanum		59 Pr 140.9 Praseodymium		61 Pm (145) Promethium		63 Eu 152.0 Europium		65 Tb 158.9 Terbium		67 Ho 164.9 Holmium		68 Er 167.3 Erbium	
34 Se 79.0 Selenium		52 Te 127.6 Tellurium		58 Ce 140.1 Cerium		60 Nd 144.2 Neodymium		62 Sm 150.4 Samarium		64 Gd 157.3 Gadolinium		66 Dy 162.5 Dysprosium		68 Er 167.3 Erbium		69 Tm 168.9 Thulium	
35 Br 79.9 Bromine		53 I 126.9 Iodine		60 Nd 144.2 Neodymium		62 Sm 150.4 Samarium		64 Gd 157.3 Gadolinium		66 Dy 162.5 Dysprosium		68 Er 167.3 Erbium		70 Yb 173.1 Ytterbium		71 Lu 175.0 Lutetium	
36 Kr 83.8 Krypton		54 Xe 131.3 Xenon		61 Pm (145) Promethium		63 Eu 152.0 Europium		65 Tb 158.9 Terbium		67 Ho 164.9 Holmium		69 Tm 168.9 Thulium		71 Lu 175.0 Lutetium		72 Hf 178.5 Hafnium	
37 Rb 85.5 Rubidium		55 At (210) Astatine		62 Sm 150.4 Samarium		64 Gd 157.3 Gadolinium		66 Dy 162.5 Dysprosium		68 Er 167.3 Erbium		70 Yb 173.1 Ytterbium		72 Hf 178.5 Hafnium		73 Ta 180.9 Tantalum	
38 Sr 87.6 Strontium		56 Rn (222) Radon		63 Eu 152.0 Europium		65 Tb 158.9 Terbium		67 Ho 164.9 Holmium		69 Tm 168.9 Thulium		71 Lu 175.0 Lutetium		73 Ta 180.9 Tantalum		74 W 183.8 Tungsten	
39 Y 88.9 Yttrium		57 La 138.9 Lanthanum		64 Gd 157.3 Gadolinium		66 Dy 162.5 Dysprosium		68 Er 167.3 Erbium		70 Yb 173.1 Ytterbium		72 Hf 178.5 Hafnium		74 W 183.8 Tungsten		75 Re 186.2 Rhenium	
40 Zr 91.2 Zirconium		58 Ce 140.1 Cerium		65 Tb 158.9 Terbium		67 Ho 164.9 Holmium		69 Tm 168.9 Thulium		71 Lu 175.0 Lutetium		73 Ta 180.9 Tantalum		75 Re 186.2 Rhenium		76 Os 190.2 Osmium	
41 Nb 92.9 Niobium		59 Pr 140.9 Praseodymium		66 Dy 162.5 Dysprosium		68 Er 167.3 Erbium		70 Yb 173.1 Ytterbium		72 Hf 178.5 Hafnium		74 W 183.8 Tungsten		76 Os 190.2 Osmium		77 Ir 192.2 Iridium	
42 Mo 96.0 Molybdenum		60 Nd 144.2 Neodymium		67 Ho 164.9 Holmium		69 Tm 168.9 Thulium		71 Lu 175.0 Lutetium		73 Ta 180.9 Tantalum		75 Re 186.2 Rhenium		77 Ir 192.2 Iridium		78 Pt 195.1 Platinum	
43 Tc (98) Technetium		61 Pm (145) Promethium		68 Er 167.3 Erbium		70 Yb 173.1 Ytterbium		72 Hf 178.5 Hafnium		74 W 183.8 Tungsten		76 Os 190.2 Osmium		78 Pt 195.1 Platinum		79 Au 197.0 Gold	
44 Ru 101.1 Ruthenium		62 Sm 150.4 Samarium		69 Tm 168.9 Thulium		71 Lu 175.0 Lutetium		73 Ta 180.9 Tantalum		75 Re 186.2 Rhenium		77 Ir 192.2 Iridium		79 Au 197.0 Gold		80 Hg 200.6 Mercury	
45 Rh 102.9 Rhodium		63 Eu 152.0 Europium		70 Yb 173.1 Ytterbium		72 Hf 178.5 Hafnium		74 W 183.8 Tungsten		76 Os 190.2 Osmium		78 Pt 195.1 Platinum		80 Hg 200.6 Mercury		81 Tl 204.4 Thallium	
46 Pd 106.4 Palladium		64 Gd 157.3 Gadolinium		71 Lu 175.0 Lutetium		73 Ta 180.9 Tantalum		75 Re 186.2 Rhenium		77 Ir 192.2 Iridium		79 Au 197.0 Gold		81 Tl 204.4 Thallium		82 Pb 207.2 Lead	
47 Ag 107.9 Silver		65 Tb 158.9 Terbium		72 Hf 178.5 Hafnium		74 W 183.8 Tungsten		76 Os 190.2 Osmium		78 Pt 195.1 Platinum		80 Hg 200.6 Mercury		82 Pb 207.2 Lead		83 Bi 209.0 Bismuth	
48 Cd 112.4 Cadmium		66 Dy 162.5 Dysprosium		73 Ta 180.9 Tantalum		75 Re 186.2 Rhenium		77 Ir 192.2 Iridium		79 Au 197.0 Gold		81 Tl 204.4 Thallium		83 Bi 209.0 Bismuth		84 Po (210) Polonium	
49 In 114.8 Indium		67 Ho 164.9 Holmium		74 W 183.8 Tungsten		76 Os 190.2 Osmium		78 Pt 195.1 Platinum		80 Hg 200.6 Mercury		82 Pb 207.2 Lead		84 Po (210) Polonium		85 At (210) Astatine	
50 Sn 118.7 Tin		68 Er 167.3 Erbium		75 Re 186.2 Rhenium		77 Ir 192.2 Iridium		79 Au 197.0 Gold		81 Tl 204.4 Thallium		83 Bi 209.0 Bismuth		85 At (210) Astatine		86 Rn (222) Radon	
51 Sb 121.8 Antimony		69 Tm 168.9 Thulium		76 Os 190.2 Osmium		78 Pt 195.1 Platinum		80 Hg 200.6 Mercury		82 Pb 207.2 Lead		84 Po (210) Polonium		86 Rn (222) Radon		87 Fr (223) Francium	
52 Te 127.6 Tellurium		70 Yb 173.1 Ytterbium		79 Au 197.0 Gold		81 Tl 204.4 Thallium		83 Bi 209.0 Bismuth		85 At (210) Astatine		87 Fr (223) Francium		88 Ra (226) Radium		89 Ac (227) Actinium	
53 I 126.9 Iodine		71 Lu 175.0 Lutetium		80 Hg 200.6 Mercury		82 Pb 207.2 Lead		84 Po (210) Polonium		86 Rn (222) Radon		88 Ra (226) Radium		90 Th 232.0 Thorium		91 Pa 231.0 Protactinium	
54 Xe 131.3 Xenon		72 Hf 178.5 Hafnium		81 Tl 204.4 Thallium		83 Bi 209.0 Bismuth		85 At (210) Astatine		87 Fr (223) Francium		89 Ac (227) Actinium		91 Pa 231.0 Protactinium		92 U 238.0 Uranium	
55 At (210) Astatine		73 Ta 180.9 Tantalum		82 Pb 207.2 Lead		84 Po (210) Polonium		86 Rn (222) Radon		88 Ra (226) Radium		90 Th 232.0 Thorium		92 U 238.0 Uranium		93 Np (237) Neptunium	
56 Rn (222) Radon		74 W 183.8 Tungsten		83 Bi 209.0 Bismuth		85 At (210) Astatine		87 Fr (223) Francium		89 Ac (227) Actinium		91 Pa 231.0 Protactinium		93 Np (237) Neptunium		94 Pu (244) Plutonium	
57 La 138.9 Lanthanum		75 Re 186.2 Rhenium		84 Po (2													

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

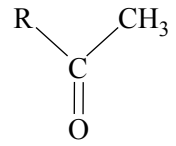
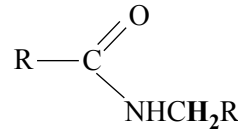
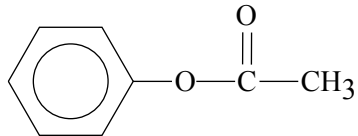
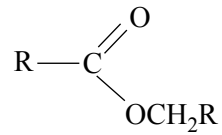
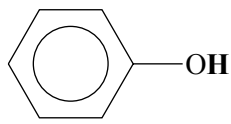
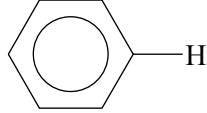
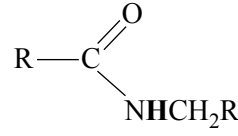
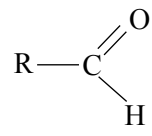
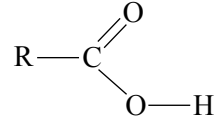
SI prefix	Symbol	Value
giga	G	10^9
mega	M	10^6
kilo	k	10^3
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}

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	0.8–1.0
R-CH ₂ -R	1.2–1.4
RCH = CH- CH₃	1.6–1.9
R ₃ -CH	1.4–1.7
$\text{CH}_3-\text{C} \begin{array}{l} \text{// O} \\ \text{OR} \end{array}$ or $\text{CH}_3-\text{C} \begin{array}{l} \text{// O} \\ \text{NHR} \end{array}$	2.0

Type of proton	Chemical shift (ppm)
	2.1–2.7
R-CH ₂ -X (X = F, Cl, Br or I)	3.0–4.5
R-CH ₂ -OH, R ₂ -CH-OH	3.3–4.5
	3.2
R-O-CH ₃ or R-O-CH ₂ R	3.3
	2.3
	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
	8.1
	9–10
	9–13

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
R ₃ C-NH ₂	35–70
R-CH ₂ -OH	50–90
RC≡CR	75–95
R ₂ C=CR ₂	110–150
RCOOH	160–185

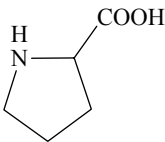
7. Infrared absorption data

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

8. 2-amino acids (α -amino acids)

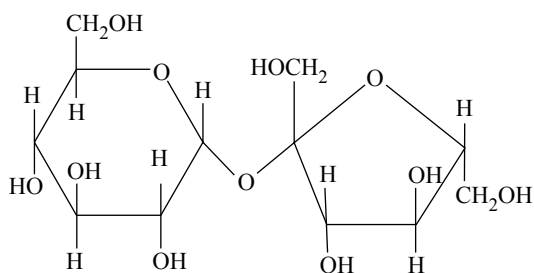
Name	Symbol	Structure
alanine	Ala	$\begin{array}{c} \text{CH}_3 \\ \\ \text{H}_2\text{N}-\text{CH}-\text{COOH} \end{array}$
arginine	Arg	$\begin{array}{c} \text{NH} \\ \\ \text{CH}_2-\text{CH}_2-\text{CH}_2-\text{NH}-\text{C}-\text{NH}_2 \\ \\ \text{H}_2\text{N}-\text{CH}-\text{COOH} \end{array}$
asparagine	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	$\begin{array}{c} \text{N} \\ // \quad \backslash \\ \text{CH}_2-\text{C} \quad \text{N} \\ \quad \backslash \quad / \\ \text{H}_2\text{N}-\text{CH}-\text{COOH} \quad \text{H} \end{array}$
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	$\begin{array}{c} \text{CH}_2 - \text{C}_8\text{H}_6\text{N}_2 \\ \\ \text{H}_2\text{N} - \text{CH} - \text{COOH} \end{array}$
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	$\begin{array}{c} \text{CH}_3 - \text{CH} - \text{CH}_3 \\ \\ \text{H}_2\text{N} - \text{CH} - \text{COOH} \end{array}$

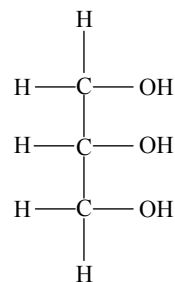
9. Formulas of some fatty acids

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	$C_{19}H_{31}COOH$

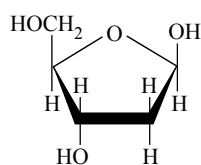
10. Structural formulas of some important biomolecules



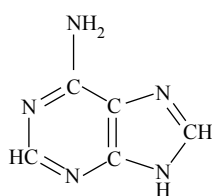
sucrose



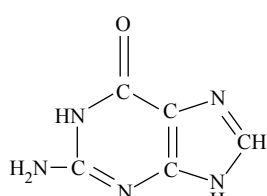
glycerol



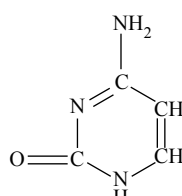
deoxyribose



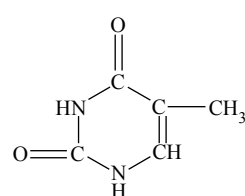
adenine



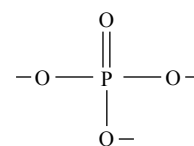
guanine



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 at 25°C

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 combustion 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