



**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		4		79		5		6		7		8		9		2	
H	Be	Au	Fe	Ni	Cu	N	B	C	O	F	Ne	Al	Si	P	Cl	He	
1.0 Hydrogen	9.0 Beryllium	197.0 Gold	55.8 Iron	58.7 Nickel	63.5 Copper	14.0 Nitrogen	10.8 Boron	12.0 Carbon	16.0 Oxygen	19.0 Fluorine	20.2 Neon	27.0 Aluminium	28.1 Silicon	31.0 Phosphorus	35.5 Chlorine	4.0 Helium	
Li	Mg	Co	Mn	Ni	Cu	N	B	C	O	F	Ne	Al	Si	P	Cl	He	
6.9 Lithium	24.3 Magnesium	58.9 Cobalt	54.9 Manganese	58.7 Nickel	63.5 Copper	14.0 Nitrogen	10.8 Boron	12.0 Carbon	16.0 Oxygen	19.0 Fluorine	20.2 Neon	27.0 Aluminium	28.1 Silicon	31.0 Phosphorus	35.5 Chlorine	4.0 Helium	
Na	Mg	Co	Mn	Ni	Cu	N	B	C	O	F	Ne	Al	Si	P	Cl	He	
23.0 Sodium	24.3 Magnesium	58.9 Cobalt	54.9 Manganese	58.7 Nickel	63.5 Copper	14.0 Nitrogen	10.8 Boron	12.0 Carbon	16.0 Oxygen	19.0 Fluorine	20.2 Neon	27.0 Aluminium	28.1 Silicon	31.0 Phosphorus	35.5 Chlorine	4.0 Helium	
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr	
39.1 Potassium	40.1 Calcium	45.0 Scandium	47.9 Titanium	50.9 Vanadium	52.0 Chromium	54.9 Manganese	55.8 Iron	58.7 Nickel	63.5 Copper	65.4 Zinc	69.7 Gallium	72.6 Germanium	74.9 Arsenic	79.0 Selenium	79.9 Bromine	83.8 Krypton	
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Cd	In	Sn	Sb	Te	I	Xe	
85.5 Rubidium	87.6 Strontium	88.9 Yttrium	91.2 Zirconium	92.9 Niobium	96.0 Molybdenum	(98) Technetium	101.1 Ruthenium	102.9 Rhodium	106.4 Palladium	112.4 Cadmium	114.8 Indium	118.7 Tin	121.8 Antimony	127.6 Tellurium	126.9 Iodine	131.3 Xenon	
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Hg	Tl	Pb	Bi	Po	At	Rn	
132.9 Caesium	137.3 Barium	138.9 Lanthanum	178.5 Hafnium	180.9 Tantalum	183.8 Tungsten	186.2 Rhenium	190.2 Osmium	192.2 Iridium	195.1 Platinum	200.6 Mercury	204.4 Thallium	207.2 Lead	209.0 Bismuth	(210) Polonium	(222) Astatine	(222) Radon	
Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	Ds	Cn	Uut	Uuq	Uup	Uuh	Uus	Uuo	
(223) Francium	(226) Radium	(227) Actinium	(261) Rutherfordium	(262) Dubnium	(266) Seaborgium	(264) Bohrium	(267) Hassium	(268) Meitnerium	(271) Darmstadtium	(285) Copernicium	(284) Uut	(289) Uuq	(288) Uup	(293) Uuh	(294) Uus	(294) Uuo	
87	88	89	104	105	106	107	108	109	110	111	112	114	115	116	117	118	
(223) Francium	(226) Radium	(227) Actinium	(261) Rutherfordium	(262) Dubnium	(266) Seaborgium	(264) Bohrium	(267) Hassium	(268) Meitnerium	(271) Darmstadtium	(272) Roentgenium	(285) Copernicium	(289) Uuq	(288) Uup	(293) Uuh	(294) Uus	(294) Uuo	
68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	
167.3 Erbium	168.9 Thulium	173.1 Ytterbium	175.0 Lutetium	157.3 Gadolinium	158.9 Terbium	159.8 Dysprosium	162.5 Holmium	164.9 Erbium	167.3 Thulium	173.1 Ytterbium	175.0 Lutetium	178.5 Hafnium	180.9 Tantalum	183.8 Tungsten	186.2 Rhenium	189.8 Osmium	
99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	
(252) Einsteinium	(257) Fermium	(258) Mendelevium	(259) Nobelium	(262) Lawrencium	(263) Tennessine	(264) Oganesson	(265) Livermorium	(266) Tennessine	(267) Oganesson	(268) Tennessine	(269) Oganesson	(270) Tennessine	(271) Oganesson	(272) Tennessine	(273) Tennessine	(274) Tennessine	
90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	
232.0 Thorium	231.0 Protactinium	238.0 Uranium	(237) Neptunium	(244) Plutonium	(243) Americium	(247) Curium	(247) Berkelium	(251) Californium	(252) Einsteinium	(257) Fermium	(258) Mendelevium	(259) Nobelium	(262) Lawrencium	(263) Tennessine	(264) Oganesson	(265) Livermorium	

The value in brackets indicates the mass number of the longest-lived isotope.

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

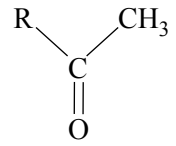
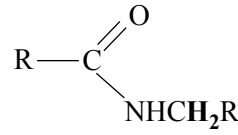
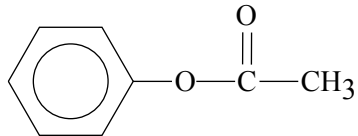
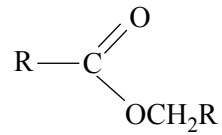
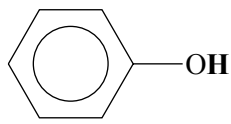
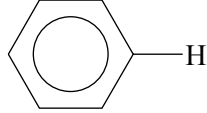
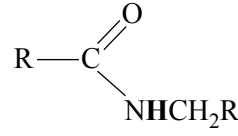
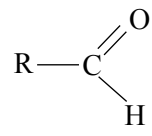
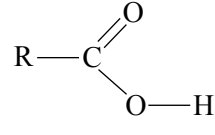
SI prefix	Symbol	Value
giga	G	10^9
mega	M	10^6
kilo	k	10^3
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}

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	0.8–1.0
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

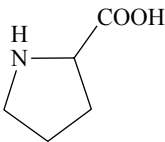
7. Infrared absorption data

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)

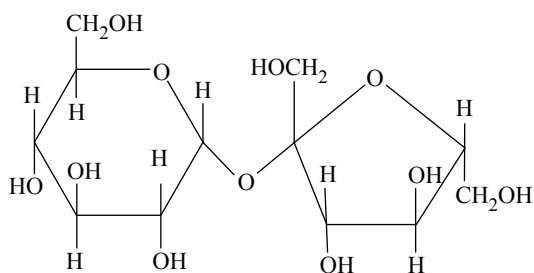
Name	Symbol	Structure
alanine	Ala	$\begin{array}{c} \text{CH}_3 \\ \\ \text{H}_2\text{N}-\text{CH}-\text{COOH} \end{array}$
arginine	Arg	$\begin{array}{c} \text{NH} \\ \\ \text{CH}_2-\text{CH}_2-\text{CH}_2-\text{NH}-\text{C}-\text{NH}_2 \\ \\ \text{H}_2\text{N}-\text{CH}-\text{COOH} \end{array}$
asparagine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

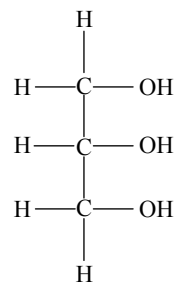
9. Formulas of some fatty acids

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	$C_{19}H_{31}COOH$

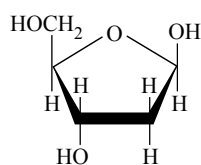
10. Structural formulas of some important biomolecules



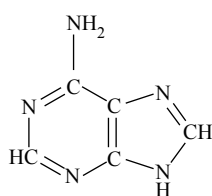
sucrose



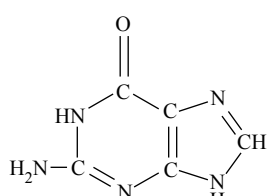
glycerol



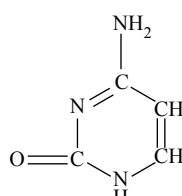
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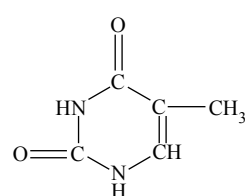
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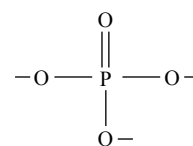
guanine



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