Neap

Trial Examination 2023

Question and Response Booklet

QCE Chemistry Units 3&4

Paper 2

Student's Name: ____________________

Teacher's Name: ____________________

Time allowed

- Perusal time – 10 minutes
- Working time – 90 minutes

General instructions

- Answer all questions in this question and response booklet.
- Write using black or blue pen.
- QCAA-approved calculator permitted.
- Planning paper will not be marked.

Section 1 (50 marks)

- 7 short response questions

SECTION 1

Instructions

- If you need more space for a response, use the additional pages at the back of this booklet.
  - On the additional pages, write the question number you are responding to.
  - Cancel any incorrect response by ruling a single diagonal line through your work.
  - Write the page number of your alternative/additional response, i.e. See page …
  - If you do not do this, your original response will be marked.

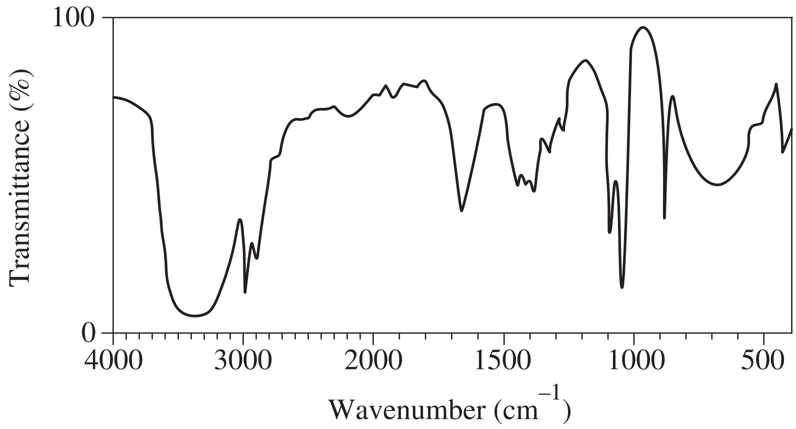
DO NOT WRITE ON THIS PAGE

THIS PAGE WILL NOT BE MARKED

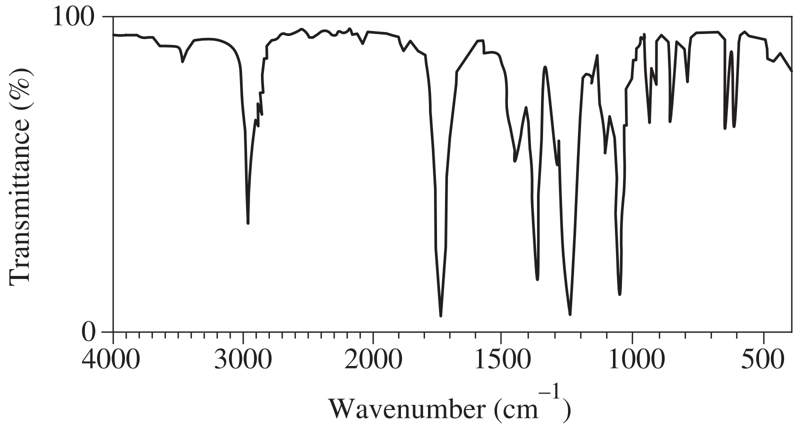
QUESTION 1 (7 marks)

The infrared spectra of an alcohol, an ester and a ketone are as shown.

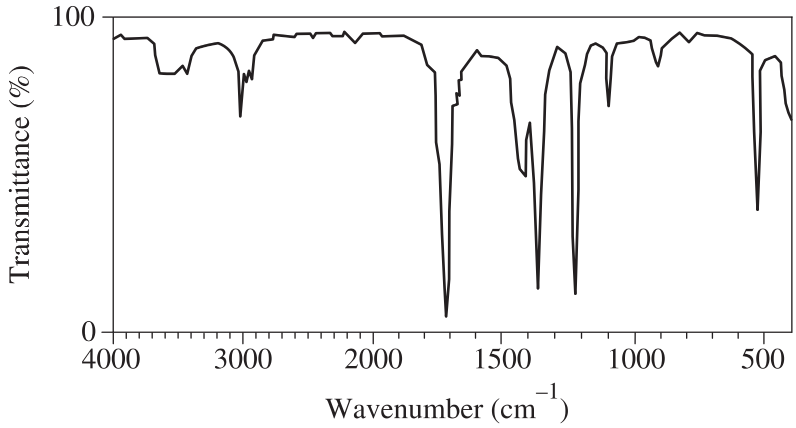
Infrared spectrum 1



Infrared spectrum 2

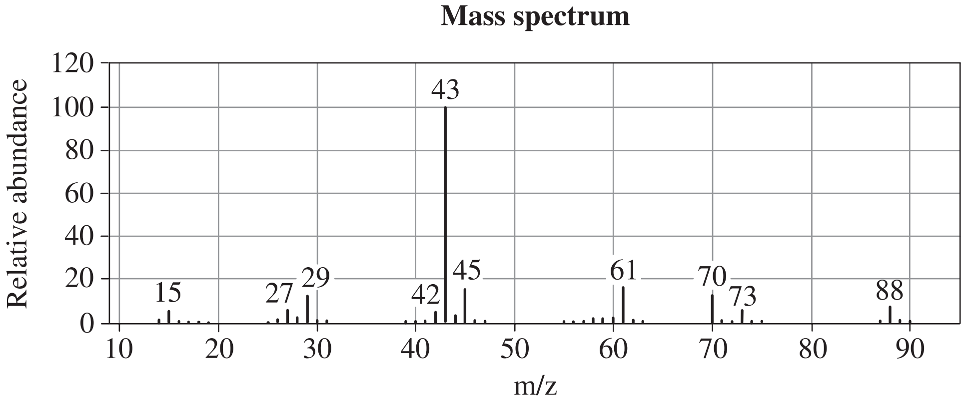


Infrared spectrum 3



a) Deduce which spectrum belongs to the alcohol. Explain your reasoning by referring to one absorption band and one absorption peak. *[3 marks]*

The mass spectrum shown is for a compound produced via the reaction between ethanol and ethanoic acid.



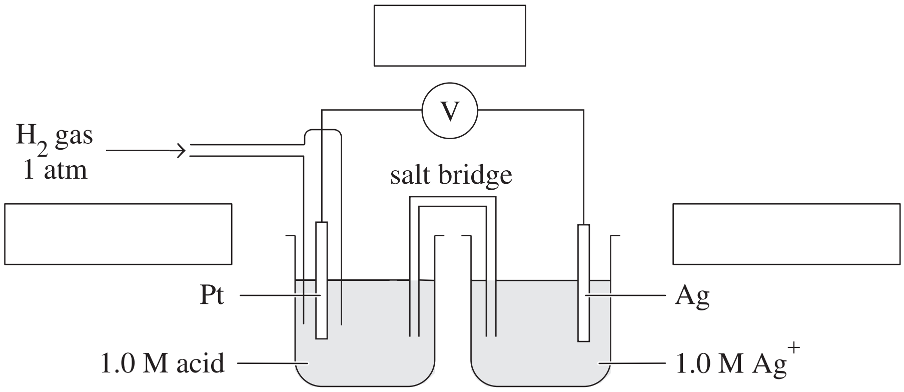
b) Identify two features of the mass spectrum that enable the compound to be identified. *[2 marks]*

c) Draw the structural formula of the compound and deduce its IUPAC name. *[2 marks]*

IUPAC name: ____________________

QUESTION 2 (11 marks)

Consider the galvanic cell shown.



a) On the diagram, label the following:

- the electrode where oxidation occurs
- the electrode where reduction occurs
- the direction of electron flow through the external circuit *[3 marks]*

b) i) Write the balanced half-equations for the reactions at the oxidation and reduction electrodes. *[2 marks]*

Oxidation: ____________________

____

Reduction: ____________________

____

ii) Calculate the cell potential ($E°$). *[2 marks]*

____

____

____

____

$E° =$ ____________________ V (to two decimal places)

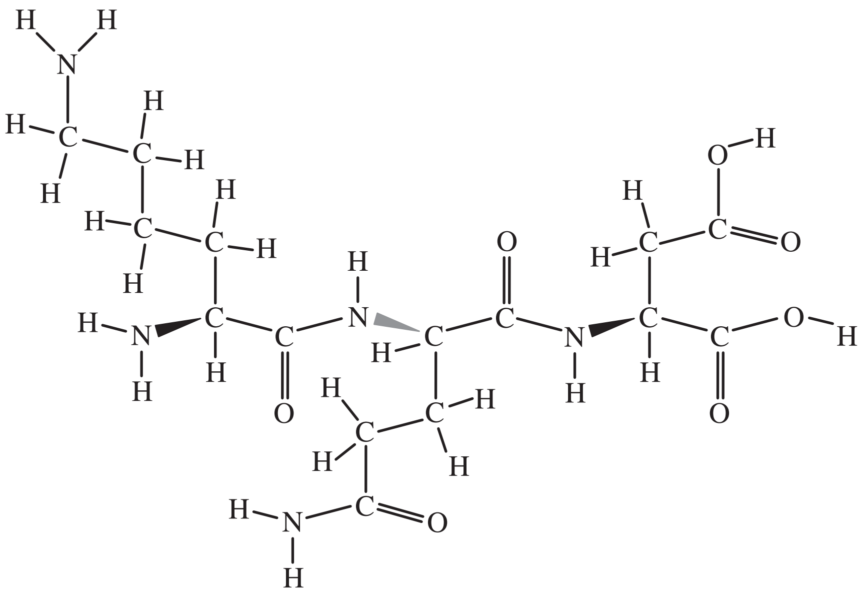
c) Explain why ions move through the salt bridge and the direction(s) in which they move through the salt bridge. *[2 marks]*

d) Silver nitrate solution was used in one of the half-cells.

Determine how the cell potential would change if solid sodium chloride were added to the silver nitrate solution. Explain your reasoning using the balanced redox equation. *[2 marks]*

QUESTION 3 (5 marks)

The structural formula shown is a peptide composed of three amino acids.



a) On the structural formula, circle the bonds between the amino acids. *[1 mark]*

b) Deduce the names of the amino acids in the peptide from left to right.
Explain your reasoning for each amino acid. *[3 marks]*

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c) Identify the peptide using the symbols of the amino acids deduced in 3b). *[1 mark]*

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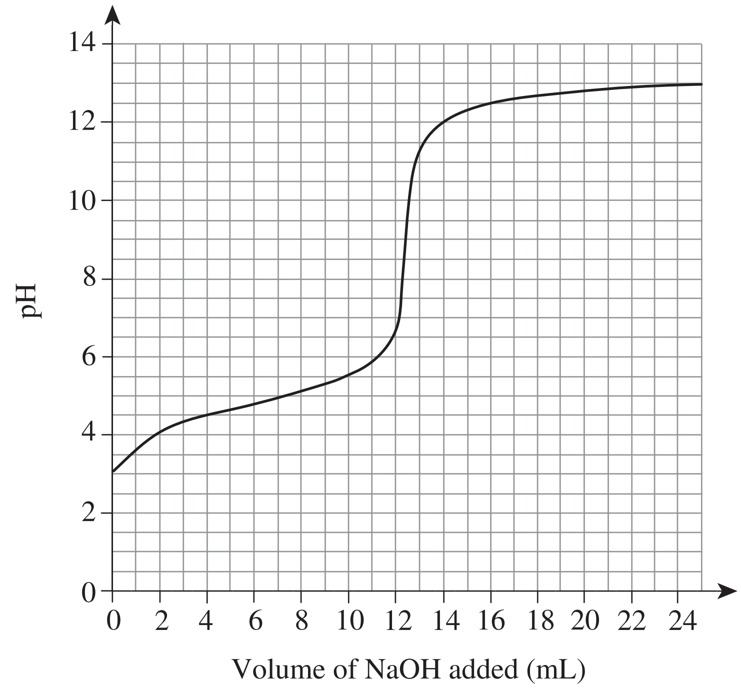
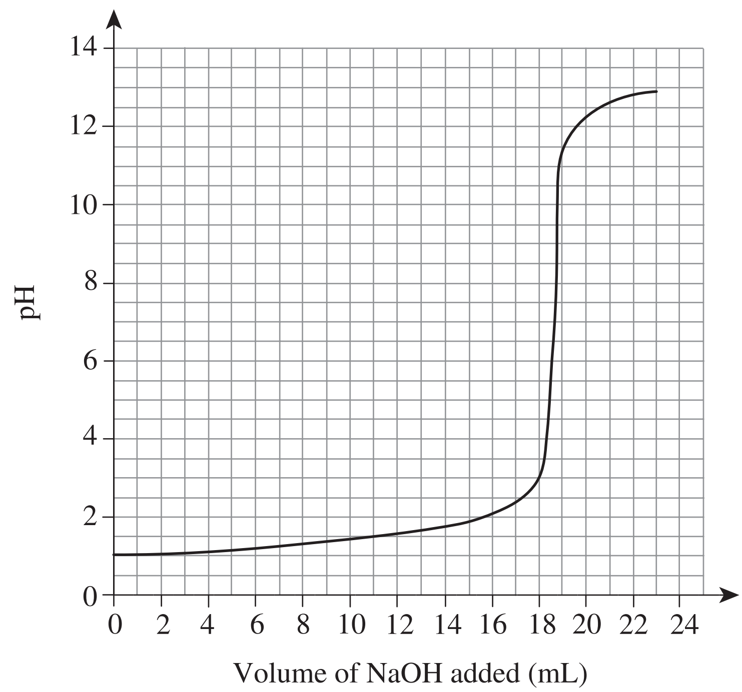
QUESTION 4 (8 marks)

The titration curves shown were produced from two titration experiments. In one experiment, ethanoic acid solution (CH_3COOH) was titrated against 0.1 mol L^{-1} sodium hydroxide solution (NaOH). In the other experiment, hydrochloric acid solution (HCl) was titrated against the same NaOH solution. In both experiments, the NaOH solution was added to the acid solution, which was in a conical flask, via a burette. The pH of each mixture was measured using a pH meter placed in the conical flask.

Titration 1



Titration 2



CH_3COOH has a dissociation constant (K_a) of 1.8×10^{-5}, a pK_a of 4.76 and was considered to be approximately 0.1 mol L^{-1}.

a) Deduce which acid solution was used in used in each titration. Explain your reasoning. *[2 marks]*

Titration 1: ______________________________

____

Titration 2: ______________________________

____

b) The initial pH of the acid solution in titration 1 was 3.0.
Show how this can be determined using calculations. *[3 marks]*

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c) Explain why titration 1 has a greater equivalence point than titration 2. *[2 marks]*

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d) The use of methyl red or phenolphthalein was considered for both titrations. Data about the indicators are shown in the table.

Name	pK_a	pH range of colour change	Colour change (acidic to basic)
Methyl red	5.1	4.4–6.2	pink to yellow
Phenolphthalein	9.6	8.3–10.0	colourless to pink

Explain why phenolphthalein would have been preferred. *[1 mark]*

QUESTION 5 (7 marks)

The ammonia that is used to make fertiliser is manufactured using the Haber process. The process involves the use of a catalyst and is shown by the following equation.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \quad \Delta H = -92 \text{ kJ mol}^{-1}$$

Sulfuric acid is manufactured using the contact process, which is a complex series of reactions represented by the following equations.

Step 1. $S(s) + O_2(g) \rightarrow SO_2(g) \quad \Delta H = -297 \text{ kJ mol}^{-1}$

Step 2. $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \quad \Delta H = -196 \text{ kJ mol}^{-1}$

Step 3. $SO_3(g) + H_2SO_4(l) \rightarrow H_2S_2O_7(l)$

Step 4. $H_2S_2O_7(l) + H_2O(l) \rightarrow 2H_2SO_4(l)$

a) Explain why the highest yield of NH_3 is obtained at 350–550°C, which is very low for an industrial process, and 100–200 atm pressure. *[2 marks]*

b) An iron catalyst, obtained from iron oxide (Fe_3O_4), is used in the Haber process.

i) State why the iron catalyst is finely ground when used in this process. *[1 mark]*

ii) With reference to the equilibrium constant (K_c), explain why, in the Haber process, the gases are recycled and usually passed over four beds of catalyst with cooling at each pass. *[2 marks]*

c) Unlike the Haber process, the contact process has four steps.
In the table, explain the factors of the contact process shown. *[2 marks]*

Factor	Explanation
In step 1 ($S(s) + O_2(g) \rightarrow SO_2(g)$, $\Delta H = -297$ kJ mol^{-1}), excess oxygen is not used. The sulfur to oxygen ratio is kept at 1 : 1.	
Step 2 ($2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$, $\Delta H = -196$ kJ mol^{-1}) is the most crucial step to control.	

QUESTION 6 (6 marks)

In a titration, a 60 mL solution of 0.10 M calcium hydroxide ($Ca(OH)_2$) was mixed with a 50 mL solution of 0.10 M nitric acid (HNO_3). A second titration was then performed where 0.050 M sulfuric acid solution (H_2SO_4) was added to neutralise the mixture.

Determine the volume of H_2SO_4 required to neutralise the mixture during the second titration. In your response, include balanced chemical equations for both reactions.

Volume = ____________________ mL (to three significant figures)

QUESTION 7 (6 marks)

The transition metal vanadium (V) can exist in several oxidation states, as shown in the table.

Oxidation state of vanadium	Formula of ion	Colour of ion
+4	$VO^{2+}(aq)$	blue
+3	$V^{3+}(aq)$	green
+2	$V^{2+}(aq)$	purple

The equations for the ion changes are shown in the table below.

Change	Equation	$E°$
blue to green	$VO^{2+}(aq) + 2H^{+}(aq) + e^{-} \rightarrow V^{3+}(aq) + H_2O(l)$	+0.34
green to purple	$V^{3+}(aq) + e^{-} \rightarrow V^{2+}(aq)$	–0.26

In an experiment, samples of the metals zinc (Zn) and tin (Sn) are each added to an acidified solution containing VO^{2+} ions.

Determine whether each metal would cause the colour of the solution to change from blue to purple. Explain your reasoning for each metal using cell potential ($E°$) values and calculations.

END OF PAPER

ADDITIONAL PAGE FOR STUDENT RESPONSES

Write the question number you are responding to.

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Write the question number you are responding to.

Neap

Trial Examination 2023

Formula and Data Booklet

QCE Chemistry Units 3&4

FORMULAS

Processing of data
Absolute uncertainty of the mean $\Delta\bar{x} = \pm\frac{(x_{max} - x_{min})}{2}$
Percentage uncertainty (%) $= \frac{\text{absolute uncertainty}}{\text{measurement}} \times \frac{100}{1}$
Percentrage error (%) $= \left\lvert \frac{\text{measured value} - \text{true value}}{\text{true value}} \right\rvert \times 100$

Chemical reactions – reactants, products and energy change
$\Delta H = H_{(\text{products})} - H_{(\text{reactants})}$
$\Delta H = \sum(\text{bonds broken}) - \sum(\text{bonds formed})$
$Q = mc\Delta T$
Percentage yield (%) $= \frac{\text{experimental yield}}{\text{theoretical yield}} \times \frac{100}{1}$

Aqueous solutions and acidity
Molarity $= \frac{\text{moles of solute } (n)}{\text{volume of solution } (V)}$

Chemical equilibrium systems
$K_c = \frac{[C]^c [D]^d}{[A]^a [B]^b}$ for the reaction: aA + bB $\rightleftharpoons$ cC + dD
$K_w = [H^+][OH^-]$
$pH = -\log_{10}[H^+]$
$pOH = -\log_{10}[OH^-]$
$K_w = K_a \times K_b$
$K_a = \frac{[H_3O^+][A^-]}{[HA]}$
$K_b = \frac{[BH^+][OH^-]}{[B]}$

PHYSICAL CONSTANTS AND UNIT CONVERSIONS

Physical constants and unit conversions	
Absolute zero	0 K = −273°C
Atomic mass unit	$1\text{ amu} = 1.66 \times 10^{-27}\text{ kg}$
Avogadro's constant	$N_A = 6.02 \times 10^{23}\text{ mol}^{-1}$
Ideal gas constant	$R = 8.31\text{ J mol}^{-1}\text{ K}^{-1}$
Ionic product constant for water (at 298 K)	$K_w = 1.00 \times 10^{-14}\text{ mol}^2\text{ dm}^{-6}$
Molar volume of an ideal gas (at STP)	$2.27 \times 10^{-2}\text{ m}^3\text{ mol}^{-1} = 22.7\text{ dm}^3\text{ mol}^{-1}$
Specific heat capacity of water (at 298 K)	$c_w = 4.18\text{ J g}^{-1}\text{ K}^{-1}$
Standard temperature and pressure (STP)	273 K and 100 kPa
Volume and capacity conversions	$1\text{ dm}^3 = 1 \times 10^{-3}\text{ m}^3 = 1 \times 10^3\text{ cm}^3 = 1\text{ L}$

LIST OF ELEMENTS

Name	Atomic no.	Symbol
Hydrogen	1	H
Helium	2	He
Lithium	3	Li
Beryllium	4	Be
Boron	5	B
Carbon	6	C
Nitrogen	7	N
Oxygen	8	O
Fluorine	9	F
Neon	10	Ne
Sodium	11	Na
Magnesium	12	Mg
Aluminium	13	Al
Silicon	14	Si
Phosphorus	15	P
Sulfur	16	S
Chlorine	17	Cl
Argon	18	Ar
Potassium	19	K
Calcium	20	Ca
Scandium	21	Sc
Titanium	22	Ti
Vanadium	23	V
Chromium	24	Cr
Manganese	25	Mn
Iron	26	Fe
Cobalt	27	Co
Nickel	28	Ni
Copper	29	Cu
Zinc	30	Zn
Gallium	31	Ga
Germanium	32	Ge
Arsenic	33	As
Selenium	34	Se
Bromine	35	Br

Name	Atomic no.	Symbol
Krypton	36	Kr
Rubidium	37	Rb
Strontium	38	Sr
Yttrium	39	Y
Zirconium	40	Zr
Niobium	41	Nb
Molybdenum	42	Mo
Technetium	43	Tc
Ruthenium	44	Ru
Rhodium	45	Rh
Palladium	46	Pd
Silver	47	Ag
Cadmium	48	Cd
Indium	49	In
Tin	50	Sn
Antimony	51	Sb
Tellerium	52	Te
Iodine	53	I
Xenon	54	Xe
Cesium	55	Cs
Barium	56	Ba
Lanthanum	57	La
Cerium	58	Ce
Praseodymium	59	Pr
Neodymium	60	Nd
Promethium	61	Pm
Samarium	62	Sm
Europium	63	Eu
Gadolinium	64	Gd
Terbium	65	Tb
Dysprosium	66	Dy
Holmium	67	Ho
Erbium	68	Er
Thulium	69	Tm
Ytterbium	70	Yb

LIST OF ELEMENTS (CONTINUED)

Name	Atomic no.	Symbol
Lutetium	71	Lu
Hafnium	72	Hf
Tantalum	73	Ta
Tungsten	74	W
Rhenium	75	Re
Osmium	76	Os
Iridium	77	Ir
Platinum	78	Pt
Gold	79	Au
Mercury	80	Hg
Thallium	81	Tl
Lead	82	Pb
Bismuth	83	Bi
Polonium	84	Po
Astatine	85	At
Radon	86	Rn
Francium	87	Fr
Radium	88	Ra
Actinium	89	Ac
Thorium	90	Th
Protactinium	91	Pa
Uranium	92	U
Neptunium	93	Np
Plutonium	94	Pu

Name	Atomic no.	Symbol
Americium	95	Am
Curium	96	Cm
Berkelium	97	Bk
Californium	98	Cf
Einsteinium	99	Es
Fermium	100	Fm
Mendelevium	101	Md
Nobelium	102	No
Lawrencium	103	Lr
Rutherfordium	104	Rf
Dubnium	105	Db
Seaborgium	106	Sg
Bohrium	107	Bh
Hassium	108	Hs
Meitnerium	109	Mt
Darmstadtium	110	Ds
Roentgenium	111	Rg
Copernicium	112	Cn
Nihonium	113	Nh
Flerovium	114	Fl
Moscovium	115	Mc
Livermorium	116	Lv
Tennessine	117	Ts
Oganesson	118	Og

PERIODIC TABLE OF THE ELEMENTS

KEY

atomic number	symbol	relative atomic mass*
1	H	1.01

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 **H** 1.01																	2 **He** 4.00
3 **Li** 6.94	4 **Be** 9.01											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
11 **Na** 22.99	12 **Mg** 24.31											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.06	17 **Cl** 35.45	18 **Ar** 39.95
19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.87	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.69	29 **Cu** 63.55	30 **Zn** 65.38	31 **Ga** 69.72	32 **Ge** 72.63	33 **As** 74.92	34 **Se** 78.97	35 **Br** 79.90	36 **Kr** 83.80
37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.95	43 **Tc** (98.91)	44 **Ru** 101.07	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.71	51 **Sb** 121.76	52 **Te** 127.60	53 **I** 126.90	54 **Xe** 131.29
55 **Cs** 132.91	56 **Ba** 137.33	57–71 Lanthanoids	72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.84	75 **Re** 186.21	76 **Os** 190.23	77 **Ir** 192.22	78 **Pt** 195.08	79 **Au** 196.97	80 **Hg** 200.59	81 **Tl** 204.38	82 **Pb** 207.2	83 **Bi** 208.98	84 **Po** (210.0)	85 **At** (210.0)	86 **Rn** (222.0)
87 **Fr** (223.0)	88 **Ra** (226.1)	89–103 Actinoids	104 **Rf** (261.1)	105 **Db** (262.1)	106 **Sg** (263.1)	107 **Bh** (264.1)	108 **Hs** (265.1)	109 **Mt** (268)	110 **Ds** (281)	111 **Rg** (272)	112 **Cn** (285)	113 **Nh** (284)	114 **Fl** (289)	115 **Mc** (288)	116 **Lv** (293)	117 **Ts** (294)	118 **Og** (294)

Lanthanoids

57 **La** 138.91	58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** (146.9)	62 **Sm** 150.36	63 **Eu** 151.96	64 **Gd** 157.25	65 **Tb** 158.93	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.93	70 **Yb** 173.05	71 **Lu** 174.97

Actinoids

89 **Ac** (227.0)	90 **Th** 232.0	91 **Pa** 231.0	92 **U** 238.0	93 **Np** (237.0)	94 **Pu** (239.1)	95 **Am** (241.1)	96 **Cm** (244.1)	97 **Bk** (249.1)	98 **Cf** (252.1)	99 **Es** (252.1)	100 **Fm** (252.1)	101 **Md** (258.1)	102 **No** (259.1)	103 **Lr** (262.1)

Groups are numbered according to IUPAC convention 1–18.
*Values in brackets are for the isotope with the longest half-life.

ATOMIC AND IONIC RADII OF SELECTED ELEMENTS

KEY

Key	
3	atomic number
Li	symbol
130	atomic radius (10^{-12} m)
76 (1+)	ionic radius (10^{-12} m), charge of ion

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 **H** 32 208 (1−)																	2 **He** 37
3 **Li** 130 76 (1+)	4 **Be** 99 45 (2+)											5 **B** 84 27 (3+)	6 **C** 75 16 (4+)	7 **N** 71 146 (3−)	8 **O** 64 140 (2−)	9 **F** 60 133 (1−)	10 **Ne** 62
11 **Na** 160 102 (1+)	12 **Mg** 140 72 (2+)											13 **Al** 124 53 (3+)	14 **Si** 114 40 (4+)	15 **P** 109 38 (5+)	16 **S** 104 184 (2−)	17 **Cl** 100 181 (1−)	18 **Ar** 101
19 **K** 200 138 (1+)	20 **Ca** 174 100 (2+)	21 **Sc** 159 75 (3+)	22 **Ti** 148 86 (2+) 61 (4+)	23 **V** 144 79 (2+) 54 (5+)	24 **Cr** 130 62 (3+) 44 (6+)	25 **Mn** 129 83 (2+) 64 (3+)	26 **Fe** 124 78 (2+) 64 (3+)	27 **Co** 118 74 (2+) 61 (3+)	28 **Ni** 117 69 (2+) 60 (3+)	29 **Cu** 122 77 (1+) 73 (2+)	30 **Zn** 120 74 (2+)	31 **Ga** 123 62 (3+)	32 **Ge** 120 53 (4+) 272 (4−)	33 **As** 120 58 (3+) 46 (5+)	34 **Se** 118 198 (2−)	35 **Br** 117 196 (1−)	36 **Kr** 116
37 **Rb** 215 152 (1+)	38 **Sr** 190 118 (2+)	39 **Y** 176 90 (3+)	40 **Zr** 164 72 (4+)	41 **Nb** 156 64 (5+)	42 **Mo** 148 65 (4+)	43 **Tc** 138 65 (4+)	44 **Ru** 136 62 (4+)	45 **Rh** 134 67 (3+)	46 **Pd** 130 86 (2+)	47 **Ag** 136 115 (1+)	48 **Cd** 140 95 (2+)	49 **In** 142 80 (3+)	50 **Sn** 140 69 (4+)	51 **Sb** 140 76 (3+)	52 **Te** 137 221 (2−)	53 **I** 136 220 (1−)	54 **Xe** 136
55 **Cs** 238 167 (1+)	56 **Ba** 206 135 (2+)																

Groups are numbered according to IUPAC convention 1–18.

ELECTRONEGATIVITIES AND FIRST IONISATION ENERGIES OF SELECTED ELEMENTS

KEY

1	atomic number
H	symbol
2.2	electronegativity
1318	first ionisation enthalpies (kJ mol^{-1})

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 **H** 2.2 1318																	2 **He** 2379
3 **Li** 1.0 526	4 **Be** 1.6 906											5 **B** 2.0 807	6 **C** 2.6 1093	7 **N** 3.0 1407	8 **O** 3.4 1320	9 **F** 4.0 1687	10 **Ne** 2087
11 **Na** 0.9 502	12 **Mg** 1.3 744											13 **Al** 1.6 584	14 **Si** 1.9 793	15 **P** 2.2 1018	16 **S** 2.6 1006	17 **Cl** 3.2 1257	18 **Ar** 1527
19 **K** 0.8 425	20 **Ca** 1.0 596	21 **Sc** 1.4 637	22 **Ti** 1.5 664	23 **V** 1.6 656	24 **Cr** 1.7 659	25 **Mn** 1.6 724	26 **Fe** 1.8 766	27 **Co** 1.9 765	28 **Ni** 1.9 743	29 **Cu** 1.9 752	30 **Zn** 1.7 913	31 **Ga** 1.8 585	32 **Ge** 2.0 768	33 **As** 2.2 953	34 **Se** 2.6 947	35 **Br** 3.0 1146	36 **Kr** 2.9 1357
37 **Rb** 0.8 409	38 **Sr** 1.0 556	39 **Y** 1.2 606	40 **Zr** 1.3 666	41 **Nb** 1.6 670	42 **Mo** 2.2 691	43 **Tc** 1.9 708	44 **Ru** 2.2 717	45 **Rh** 2.3 726	46 **Pd** 2.2 811	47 **Ag** 1.9 737	48 **Cd** 1.7 874	49 **In** 1.8 565	50 **Sn** 2.0 715	51 **Sb** 2.1 840	52 **Te** 2.1 876	53 **I** 2.7 1015	54 **Xe** 2.6 1177
55 **Cs** 0.8 382	56 **Ba** 0.9 509																

Groups are numbered according to IUPAC convention 1–18.

SOLUBILITY OF SELECTED COMPOUNDS AT 298 K

	bromide	carbonate	chloride	hydroxide	iodide	nitrate	oxide	phosphate	sulfate
aluminium	s	–	s	i	s	s	i	i	s
ammonium	s	s	s	s	s	s	–	s	s
barium	s	i	s	s	s	s	s	i	i
calcium	s	i	s	p	s	s	p	i	p
cobalt(II)	s	i	s	i	s	s	i	i	s
copper(II)	s	–	s	i	i	s	i	i	s
iron(II)	s	i	s	i	s	s	i	i	s
iron(III)	s	–	s	i	s	s	i	i	s
lead(II)	p	i	s	i	i	s	i	i	i
lithium	s	s	s	s	s	s	s	–	s
magnesium	s	i	s	i	s	s	i	p	s
manganese(II)	s	i	s	i	s	s	i	p	s
potassium	s	s	s	s	s	s	s	s	s
silver	i	i	i	i	i	s	i	i	p
sodium	s	s	s	s	s	s	s	s	s
zinc	s	i	s	i	s	s	i	i	s

Key

Abbreviation	Explanation
s	soluble in water (solubility greater than 10 g L^{-1})
p	partially soluble in water (solubility between 1 and 10 g L^{-1})
i	insoluble in water (solubility less than 1 g L^{-1})
–	no data

AVERAGE BOND ENTHALPIES AT 298 K

Single bonds

	ΔH (kJ mol^{-1})								
	H	**C**	**N**	**O**	**F**	**S**	**Cl**	**Br**	**I**
H	436								
C	414	346							
N	391	286	158						
O	463	358	214	144					
F	567	492	278	191	159				
S	364	289			327	266			
Cl	431	324	192	206	255	271	242		
Br	366	285		201	249	218	219	193	
I	298	228		201	280		211	178	151

Multiple bonds

Bond	ΔH (kJ mol^{-1})
C=C	614
C≡C	839
C=N	615
C≡N	890
C=O	804
N=N	470
N≡N	945
O=O	498

REACTIVITY SERIES OF METALS

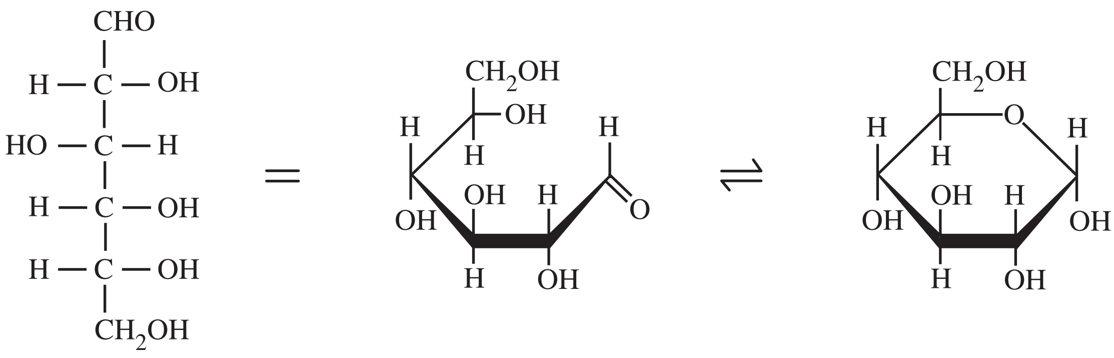
Element	Reactivity
K	most reactive ↑
Na	
Li	
Ba	
Sr	
Ca	
Mg	
Al	
C*	
Mn	
Zn	
Cr	
Fe	
Cd	
Co	
Ni	
Sn	
Pb	
H_2*	
Sb	
Bi	
Cu	
Hg	
Ag	
Au	
Pt	least reactive

* Carbon (C) and hydrogen gas (H_2) added for comparison

STANDARD ELECTRODE POTENTIALS AT 298 K

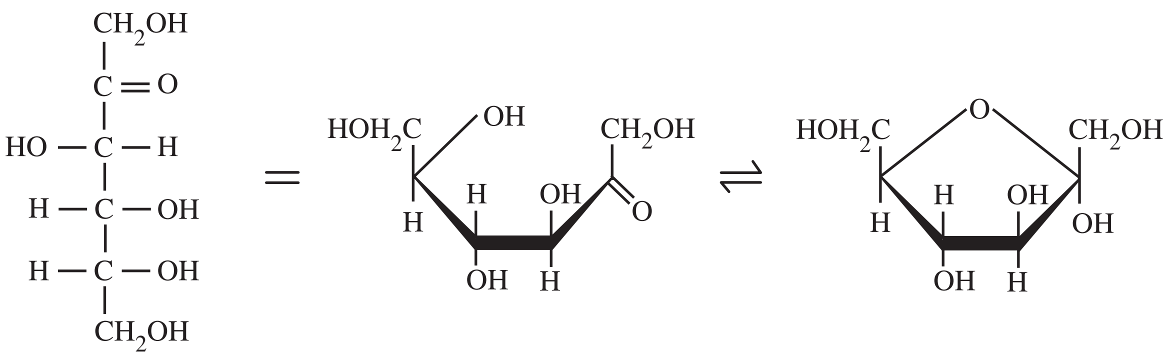
Oxidised species $\rightleftharpoons$ Reduced species	$E°$ (V)
$Li^+(aq) + e^- \rightleftharpoons Li(s)$	–3.04
$K^+(aq) + e^- \rightleftharpoons K(s)$	–2.94
$Ba^{2+}(aq) + 2e^- \rightleftharpoons Ba(s)$	–2.91
$Ca^{2+}(aq) + 2e^- \rightleftharpoons Ca(s)$	–2.87
$Na^+(aq) + e^- \rightleftharpoons Na(s)$	–2.71
$Mg^{2+}(aq) + 2e^- \rightleftharpoons Mg(s)$	–2.36
$Al^{3+}(aq) + 3e^- \rightleftharpoons Al(s)$	–1.68
$Mn^{2+}(aq) + 2e^- \rightleftharpoons Mn(s)$	–1.18
$2H_2O(l) + 2e^- \rightleftharpoons H_2(g) + 2OH^-(aq)$	–0.83
$Zn^{2+}(aq) + 2e^- \rightleftharpoons Zn(s)$	–0.76
$Fe^{2+}(aq) + 2e^- \rightleftharpoons Fe(s)$	–0.44
$Ni^{2+}(aq) + 2e^- \rightleftharpoons Ni(s)$	–0.24
$Sn^{2+}(aq) + 2e^- \rightleftharpoons Sn(s)$	–0.14
$Pb^{2+}(aq) + 2e^- \rightleftharpoons Pb(s)$	–0.13
$2H^+(aq) + 2e^- \rightleftharpoons H_2(g)$	0.00
$Cu^{2+}(aq) + e^- \rightleftharpoons Cu^+(aq)$	+0.16
$SO_4^{2-}(aq) + 4H^+(aq) + 2e^- \rightleftharpoons SO_2(aq) + 2H_2O(l)$	+0.16
$Cu^{2+}(aq) + 2e^- \rightleftharpoons Cu(s)$	+0.34
$O_2(g) + 2H_2O(l) + 4e^- \rightleftharpoons 4OH^-(aq)$	+0.40
$Cu^+(aq) + e^- \rightleftharpoons Cu(s)$	+0.52
$I_2(s) + 2e^- \rightleftharpoons 2I^-(aq)$	+0.54
$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq)$	+0.77
$Ag^+(aq) + e^- \rightleftharpoons Ag(s)$	+0.80
$Br_2(l) + 2e^- \rightleftharpoons 2Br^-(aq)$	+1.08
$O_2(g) + 4H^+(aq) + 4e^- \rightleftharpoons 2H_2O(l)$	+1.23
$Cl_2(g) + 2e^- \rightleftharpoons 2Cl^-(aq)$	+1.36
$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightleftharpoons 2Cr^{3+}(aq) + 7H_2O(l)$	+1.36
$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightleftharpoons Mn^{2+}(aq) + 4H_2O(l)$	+1.51
$F_2(g) + 2e^- \rightleftharpoons 2F^-(aq)$	+2.89

GLUCOSE AND FRUCTOSE: STRAIGHT CHAIN AND α-RING FORMS



straight chain D-glucose

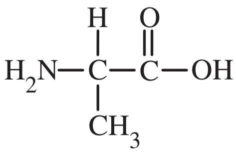
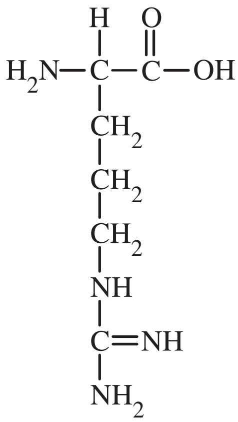
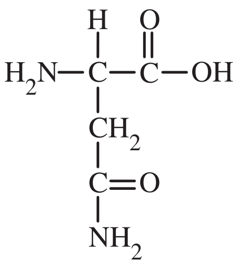
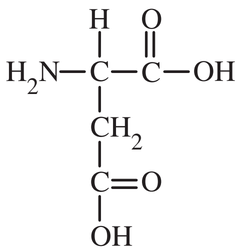
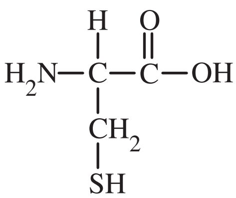
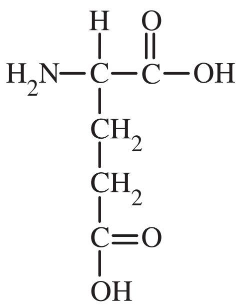
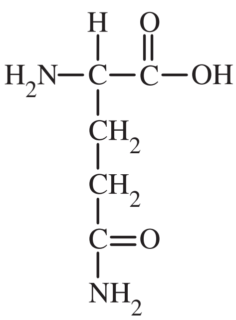
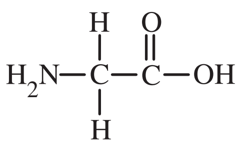
α-D-glucose



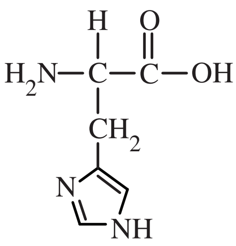
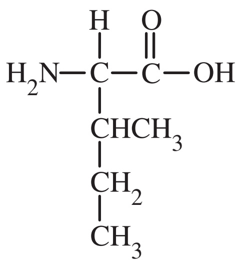
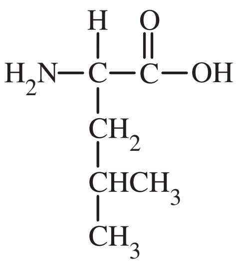
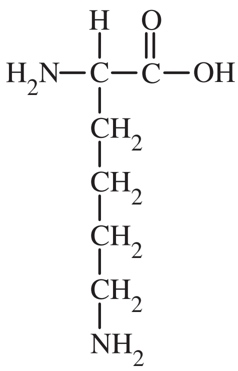
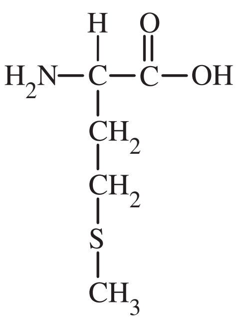
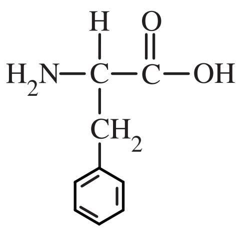
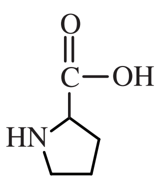
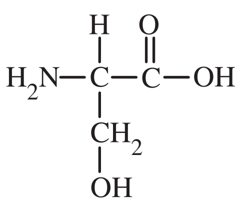
straight chain D-fructose

α-D-fructose

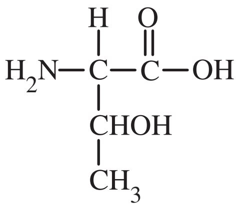
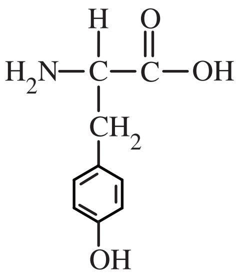
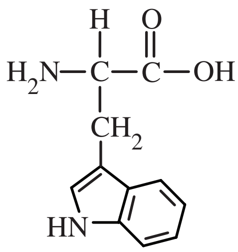
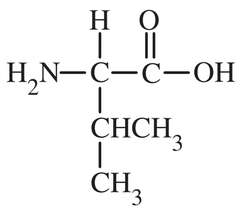
COMMON AMINO ACIDS

Common name (symbol)	Structural formula	pH of isoelectric point	Common name (symbol)	Structural formula	pH of isoelectric point
Alanine (Ala)		6.1	Arginine (Arg)		10.7
Asparagine (Asn)		5.4	Aspartic acid (Asp)		3.0
Cysteine (Cys)		5.1	Glutamic acid (Glu)		3.2
Glutamine (Gln)		5.7	Glycine (Gly)		6.1

COMMON AMINO ACIDS (continued)

Common name (symbol)	Structural formula	pH of isoelectric point	Common name (symbol)	Structural formula	pH of isoelectric point
Histidine (His)		7.6	Isoleucine (Ile)		6.0
Leucine (Leu)		6.0	Lysine (Lys)		9.7
Methionine (Met)		5.7	Phenylalanine (Phe)		5.7
Proline (Pro)		6.3	Serine (Ser)		5.7

COMMON AMINO ACIDS (continued)

Common name (symbol)	Structural formula	pH of isoelectric point
Threonine (Thr)		5.6
Tyrosine (Tyr)		5.7
Tryptophan (Trp)		5.9
Valine (Val)		6.0

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ACID–BASE INDICATORS

Name	pK_a	pH range of colour change	Colour change (acidic to basic)
Methyl orange	3.7	3.1–4.4	red to yellow
Bromophenol blue	4.2	3.0–4.6	yellow to blue
Bromocresol green	4.7	3.8–5.4	yellow to blue
Methyl red	5.1	4.4–6.2	pink to yellow
Bromothymol blue	7.0	6.0–7.6	yellow to blue
Phenol red	7.9	6.8–8.4	yellow to red
Phenolphthalein	9.6	8.3–10.0	colourless to pink

INFRARED DATA

The table below shows the characteristic range of infrared absorption due to stretching in organic molecules.

Bond	Organic molecules	Wavelength (cm^{-1})
C–I	iodoalkanes	490–620
C–Br	bromoalkanes	500–600
C–Cl	chloroalkanes	600–800
C–F	fluoroalkanes	1000–1400
C–O	alcohol, ester	1050–1410
C=C	alkenes	1620–1680
C=O	aldehydes, carboxylic acid, ester, ketones	1700–1750
C≡C	alkynes	2100–2260
O–H	carboxylic acids (hydrogen-bonded)	2500–3000
C–H	alkanes, alkenes, alkynes, aldehydes, amides	2720–3100
O–H	alcohol (hydrogen-bonded)	3200–3600
N–H	amines	3300–3500

FORMULAS AND CHARGES FOR COMMON POLYATOMIC IONS

Anions	
acetate (ethanoate)	CH_3COO^- or $C_2H_3O_2^-$
carbonate	CO_3^{2-}
chlorate	ClO_3^-
chlorite	ClO_2^-
chromate	CrO_4^{2-}
citrate	$C_6H_5O_7^{3-}$
cyanide	CN^-
dichromate	$Cr_2O_7^{2-}$
dihydrogen phosphate	$H_2PO_4^-$
hypochlorite	ClO^-
hydrogen carbonate	HCO_3^-
hydrogen sulfate	HSO_4^-
hydrogen phosphate	HPO_4^{2-}
hydroxide	OH^-
nitrate	NO_3^-
nitrite	NO_2^-
perchlorate	ClO_4^-
permanganate	MnO_4^-
peroxide	O_2^{2-}
phosphate	PO_4^{3-}
sulfate	SO_4^{2-}
sulfite	SO_3^{2-}
thiosulfate	$S_2O_3^{2-}$

Cations	
ammonium	NH_4^+
hydronium	H_3O^+

REFERENCES

Aylward, G and Findlay, T 2008, *SI Chemical Data*, 5th ed, John Wiley & Sons, Brisbane.

Haynes, WM (ed) 2016, *CRC Handbook of Chemistry and Physics*, 97th ed, CRC Press, Boca Raton, US.