Neap

Trial Examination 2020

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.
- QCAA formula and data booklet provided.

Section 1 (65 marks)
- 8 short response questions

Students are advised that this is a trial examination only and cannot in any way guarantee the content or the format of the 2020 QCE Chemistry examination.

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SECTION 1

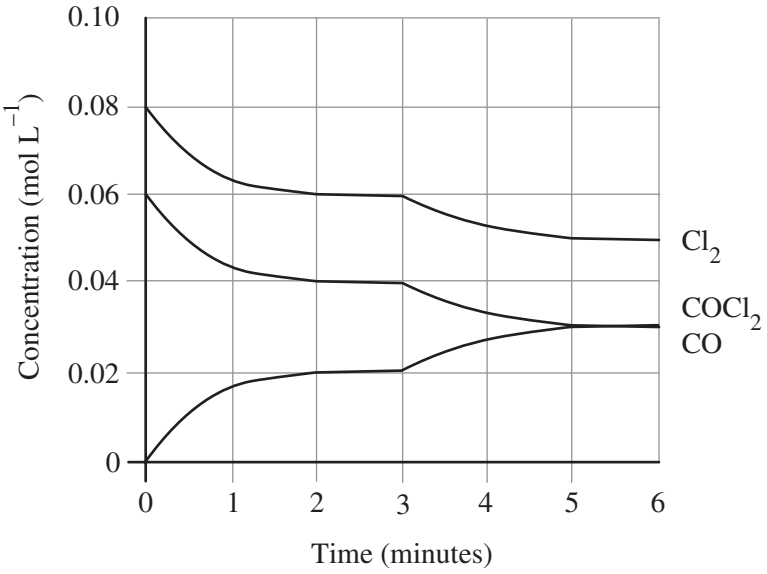
Instructions

- 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.

QUESTION 1 (6 marks)

The graph below shows the variation in the concentration of gases over time for the following equilibrium system.

$$Cl_2(g) + CO(g) \rightleftharpoons COCl_2(g)$$



a) Calculate the value of the equilibrium constant (K_c) at 2.5 minutes. Show your working. *[2 marks]*

_____

_____

_____

_____

K_c = _____ M^{-1}

b) At 3 minutes, the reaction mixture was cooled.

What evidence indicates that the formation of $COCl_2$ is exothermic?
Show your reasoning. *[2 marks]*

_____

_____

_____

_____

c) Without calculation, explain whether the value of K_c at 5.5 minutes is higher, lower or equal to the value at 2.5 minutes. *[2 marks]*

_____

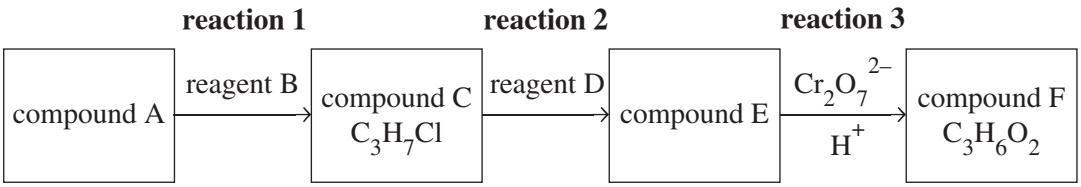
_____

_____

_____

QUESTION 2 (9 marks)

The flowchart below shows the synthesis of compound F from compound A. Compound A is an unsaturated hydrocarbon of molar mass 42 g mol^{-1}.



a) Describe a simple laboratory test that could be performed to show that compound A is unsaturated. *[2 marks]*

_____

_____

_____

_____

b) Give the formulas of reagents B and D. *[2 marks]*

B: _____

D: _____

c) Deduce the following. *[2 marks]*

Functional group of compound E: _____

Class of organic compound (or homologous series) of compound F: _____

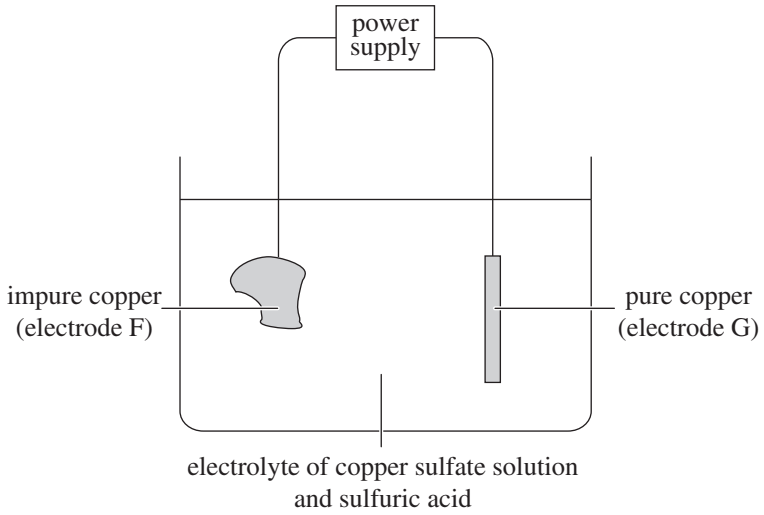
d) Complete the table below by stating the general reaction types for reactions 1, 2 and 3. *[3 marks]*

Reaction 1	Reaction 2	Reaction 3

QUESTION 3 (7 marks)

Copper ore is heated in air to produce copper metal of about 95% purity. Impurities in the copper metal often include the elements gold, silver, zinc and nickel.

An electrolytic cell can be used to produce copper of purity above 99%. The diagram below shows the design of this type of cell.



a) Explain why an electrolytic cell usually has both electrodes in one container, whereas a galvanic cell uses separate half-cells. *[2 marks]*

_____

_____

_____

_____

b) Electrode F contains copper as well as other metals. The voltage in the electrolytic cell is adjusted so that only copper and stronger reductants than copper are converted to ions.

In the table below, identify electrode F and its polarity by writing the half-equation for the reaction that occurs at the electrode in the appropriate space. *[2 marks]*

	Anode	**Cathode**
Positive		
Negative		

c) Metals such as gold are not converted to ions at electrode F and fall to the base of the cell as a sludge.

Identify a metal other than gold that might also be present in the sludge. *[1 mark]*

_____

d) Only copper metal is deposited at electrode G even though the electrolyte contains other metal ions such as $Ni^{2+}(aq)$.

Explain why nickel metal is not deposited at electrode G. *[2 marks]*

_____

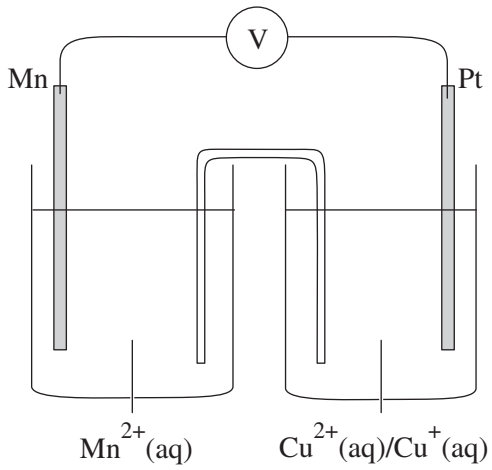
_____

_____

_____

QUESTION 4 (7 marks)

The galvanic cell below was set up under standard conditions.



a) On the diagram above, identify the direction of the flow of electrons by drawing an arrow with the label 'electrons' above the relevant conductor. *[1 mark]*

b) On the diagram above, identify the direction of the movement of positive ions between the half-cells by drawing an arrow with the label '+ ions' above the relevant conductor. *[1 mark]*

c) Calculate the cell potential. Show your working. *[2 marks]*

_____

_____

Cell potential = _____ V

d) Write the half-equation for the reaction that occurs at the cathode. Include state symbols. *[1 mark]*

_____

e) Write the equation for the overall cell reaction. Include state symbols. *[2 marks]*

_____

QUESTION 5 (10 marks)

a) A secondary alcohol containing three carbon atoms per molecule is oxidised.

Draw the structural formulas of the secondary alcohol and the product, and name both compounds using IUPAC rules. *[4 marks]*

Structural formula of the secondary alcohol	**Structural formula of the product**
IUPAC name:	**IUPAC name:**

b) When methanoic acid reacts with methanamine, an amide is the organic product.

Using condensed structural formulas, write a balanced chemical equation for this synthesis reaction. *[2 marks]*

_____

c) Explain how 1-propanamine can be produced from an alkane. Include reagents, conditions and any intermediate products in the reaction pathway in your response. *[4 marks]*

_____

_____

_____

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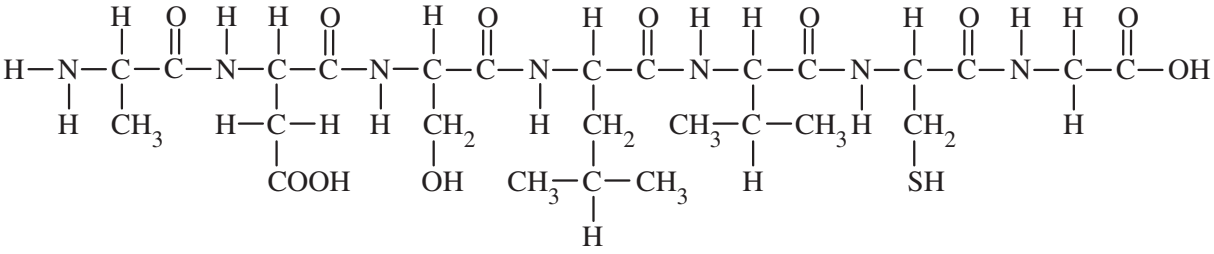
_____

_____

_____

QUESTION 6 (10 marks)

The diagram below shows the structure of a polypeptide.



a) State the number of amino acids used to produce this polypeptide. *[1 mark]*

_____

b) Draw a circle around a peptide bond in the diagram above. *[1 mark]*

c) Apply the IUPAC rules to name the amino acid in the polypeptide that has the lowest molar mass. *[1 mark]*

_____

d) The polypeptide can be hydrolysed, and the amino acids that would be produced can be analysed using chromatography.

Explain how the process of chromatography separates the components of a mixture. *[3 marks]*

_____

_____

_____

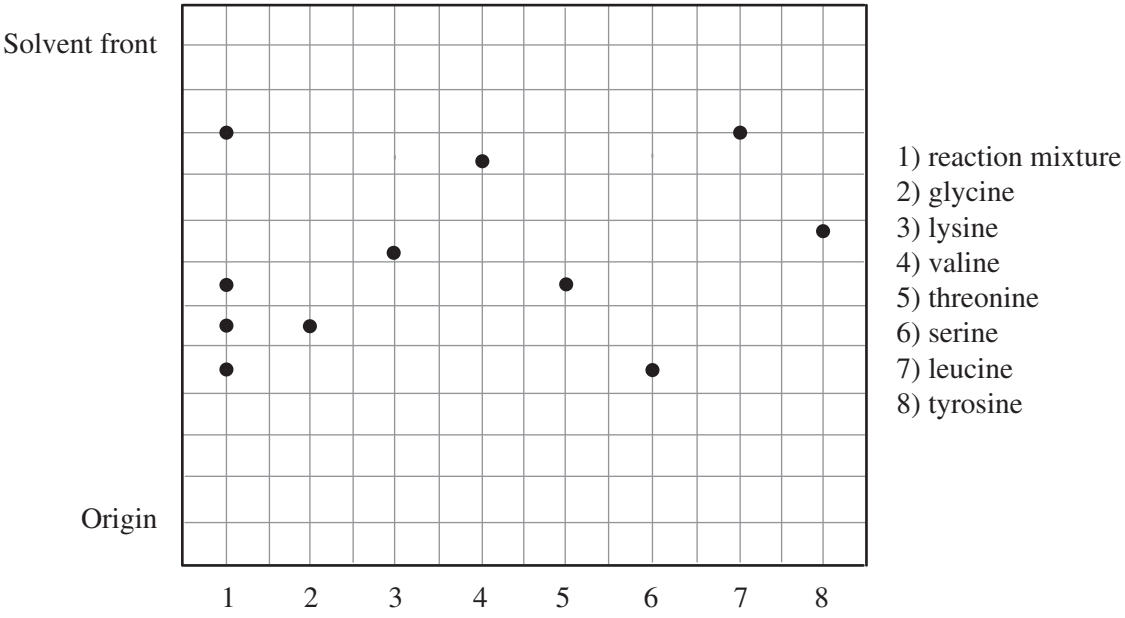
_____

_____

_____

e) One type of chromatography is thin-layer chromatography (TLC), which uses an absorbent solid layer on a glass plate. The mixture being analysed is spotted onto the absorbent layer, and then the glass plate is held vertically with the bottom edge dipped in a solvent. The solvent rises up the absorbent layer and causes separation of the mixture's components.

The results of a TLC analysis of a polypeptide (different to the polypeptide in the diagram on page 9) is shown below. Known standard amino acids were spotted onto the origin line for lanes 2 to 8.



Choose one of the standard amino acids used in this analysis and explain whether it was or was not present in the polypeptide. *[2 marks]*

_____

_____

_____

_____

f) Electrophoresis is another technique used to analyse proteins.

Briefly explain how the separation of a mixture of proteins is achieved through electrophoresis. *[2 marks]*

_____

_____

_____

_____

QUESTION 7 (9 marks)

Enzymes are proteins that can be used as catalysts for the synthesis of chemicals on an industrial scale.

a) The tertiary structure of an enzyme is crucial to its function as a catalyst.

Describe the tertiary structure of a protein and explain the role of the tertiary structure in an enzyme's function. *[5 marks]*

b) Using a balanced chemical equation, describe the production of ethanol from fermentation. *[4 marks]*

QUESTION 8 (7 marks)

Dimethyl ether is manufactured industrially from methanol through the chemical reaction shown by the following equation.

$$2CH_3OH(g) \rightleftharpoons CH_3OCH_3(g) + H_2O(g) \quad K_c = 5.74 \text{ at } 350^oC$$

Methanol gas was injected into an empty 10 L reaction vessel, and equilibrium was established at 350ºC.

a) Calculate the equilibrium concentration of all the gases present if there was 0.186 mol of methanol at equilibrium. Show your working. *[4 marks]*

b) Calculate the mass of methanol injected into the vessel. Show your working. *[3 marks]*

$m(CH_3OH)$: _____

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 2020

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 (%) = $\frac{\text{absolute uncertainty}}{\text{measurement}} \times \frac{100}{1}$
Percentage error (%) = $\left\lvert\frac{\text{measured value} - \text{true value}}{\text{true value}}\right\rvert \times 100$

Chemical reactions – reactants, products and energy change
$\Delta H = H_{(\text{products})} - H_{(\text{reactants})}$
$\Delta H = \Sigma(\text{bonds broken}) - \Sigma(\text{bonds formed})$
$Q = mc\Delta T$
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 amu = 1.66×10^{-27} kg
Avogadro's constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}
Ideal gas constant	$R = 8.31$ J mol^{-1} K^{-1}
Ionic product constant for water (at 298 K)	$K_w = 1.00 \times 10^{-14}$ mol^2 dm^{-6}
Molar volume of an ideal gas (at STP)	2.27×10^{-2} m^3 mol^{-1} = 22.7 dm^3 mol^{-1}
Specific heat capacity of water (at 298 K)	$c_w = 4.18$ J g^{-1} K^{-1}
Standard temperature and pressure (STP)	273 K and 100 kPa
Volume and capacity conversions	1 dm^3 = 1×10^{-3} m^3 = 1×10^3 cm^3 = 1 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: 1 H 1.01 — atomic number, symbol, relative atomic mass*

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

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

ionic radius (10^{-12} m)

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

Groups are numbered according to IUPAC convention 1–18.

ELECTRONEGATIVITIES AND FIRST IONISATION ENERGIES OF SELECTED ELEMENTS

KEY

H 1
2.2
1318

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

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

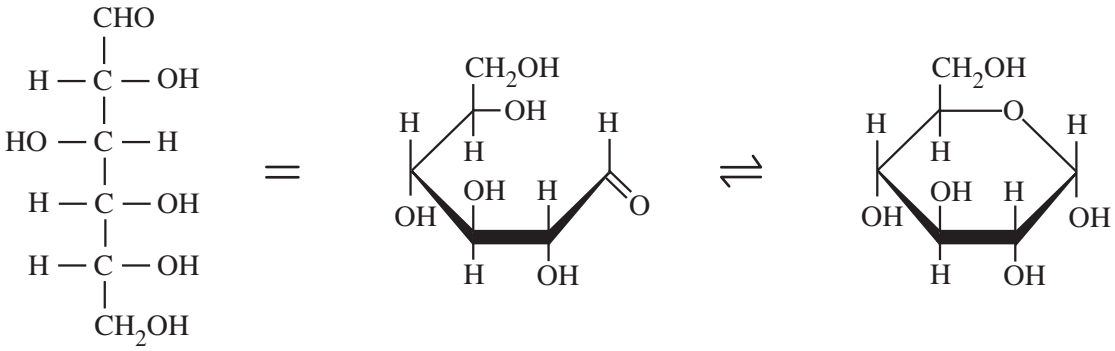
Element	Reactivity
K	most reactive
Na	
Li	
Ba	
Sr	
Ca	
Mg	
Al	
C*	
Mn	
Zn	
Cr	
Fe	
Cd	
Co	
Ni	
Sn	
Pb	
H_2*	
Sb	
Bi	
Cu	
Hg	
Ag	
Au	
Pt	least reactive

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

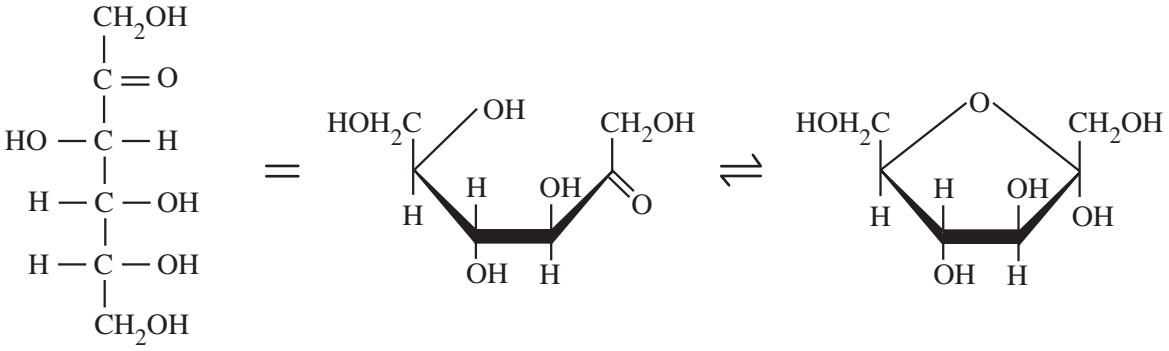
STANDARD ELECTRODE POTENTIALS AT 298 K

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

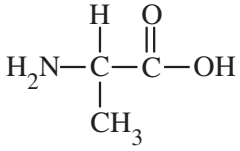
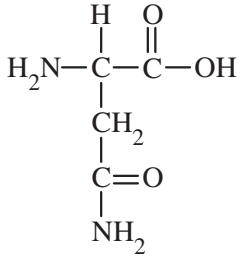
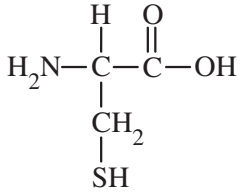
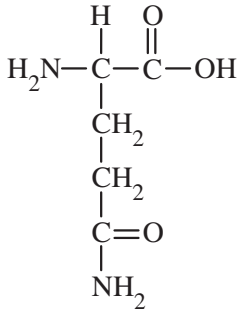


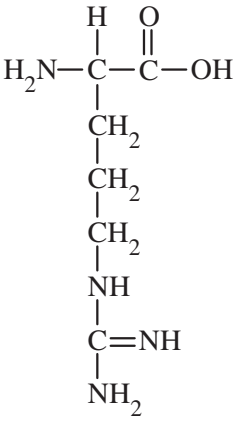
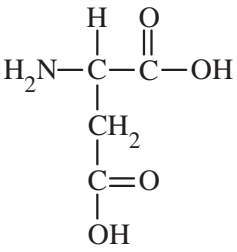
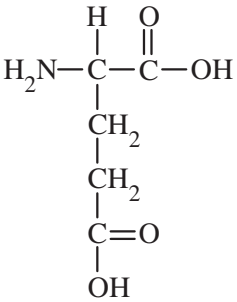
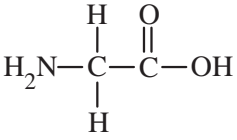
straight chain D-glucose α-D-glucose



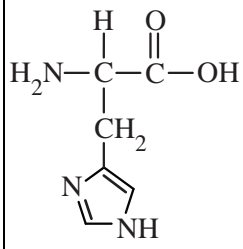
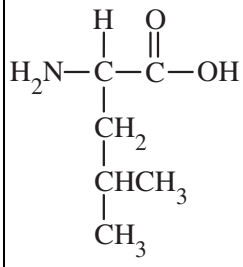
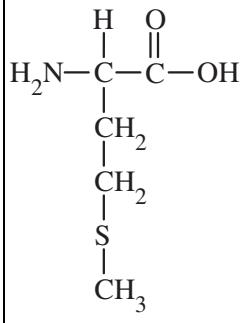
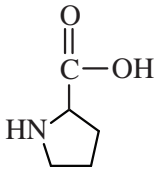
straight chain D-fructose α-D-fructose

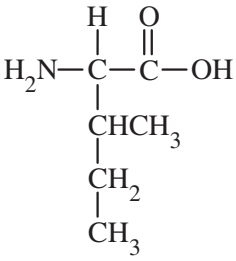
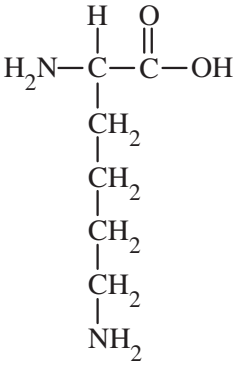
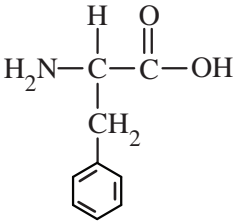
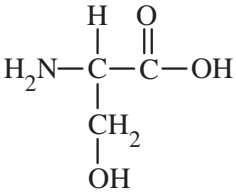
COMMON AMINO ACIDS

Common name (symbol)	Structural formula	pH of isoelectric point
Alanine (Ala)		6.1
Asparagine (Asn)		5.4
Cysteine (Cys)		5.1
Glutamine (Gln)		5.7

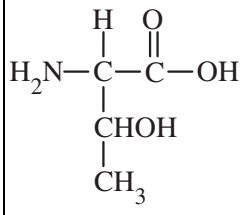
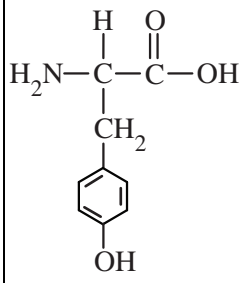
Common name (symbol)	Structural formula	pH of isoelectric point
Arginine (Arg)		10.7
Aspartic acid (Asp)		3.0
Glutamic acid (Glu)		3.2
Glycine (Gly)		6.1

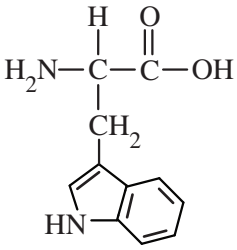
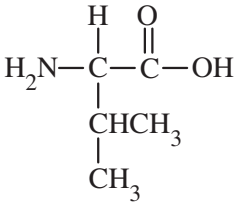
COMMON AMINO ACIDS (continued)

Common name (symbol)	Structural formula	pH of isoelectric point
Histidine (His)		7.6
Leucine (Leu)		6.0
Methionine (Met)		5.7
Proline (Pro)		6.3

Common name (symbol)	Structural formula	pH of isoelectric point
Isoleucine (Ile)		6.0
Lysine (Lys)		9.7
Phenylalanine (Phe)		5.7
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

Common name (symbol)	Structural formula	pH of isoelectric point
Tryptophan (Trp)		5.9
Valine (Val)		6.0

ACID–BASE INDICATORS

Name	pKa	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, Gordon & Findlay, Tristan (2008) *SI Chemical Data*, 6th ed, John Wiley & Sons, Brisbane.

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