Rewarding Learning

Centre Number

Candidate Number

ADVANCED
General Certificate of Education
2023

Chemistry

Assessment Unit A2 2

assessing

Analytical, Transition Metals, Electrochemistry and Further Organic Chemistry

[ACH24]

ACH24

MONDAY 12 JUNE, MORNING

TIME

2 hours.

INSTRUCTIONS TO CANDIDATES

Write your Centre Number and Candidate Number in the spaces provided at the top of this page.
Answer **all fifteen** questions in **Sections A and B**.
You must answer the questions in the spaces provided.
Do not write outside the boxed area on each page or on blank pages.
Complete in black ink only. **Do not write with a gel pen or a pencil.**

INFORMATION FOR CANDIDATES

The total mark for this paper is 110.
Quality of written communication will be assessed in Questions **13(c)** and **14(f)(iii)**.
The figures in brackets printed down the right-hand side of pages indicate the marks awarded to each question or part question.
A Periodic Table of Elements, containing some data, is included with this question paper.

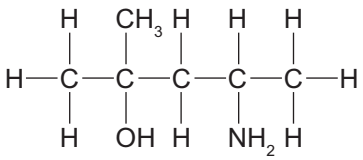
Section A

For each of the following questions, only **one** of the lettered responses (A–D) is correct.

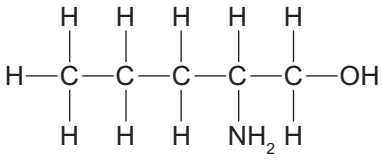
Select the correct response for each question and write the appropriate letter in the space provided.

1 Which one of the following compounds is a tertiary alcohol and a secondary amine?

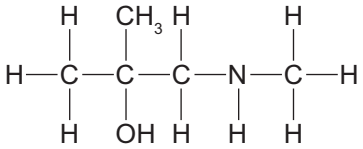
A



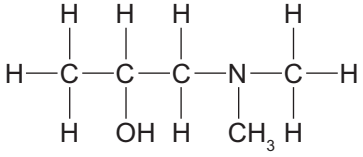
B



C



D



Answer _____ [1]

2 Which one of the following does **not** give the correct colour change when the reaction occurs in solution?

	Reaction	**Colour change**
A	Excess KI(aq) added to acidified KIO_3(aq)	colourless to brown
B	Excess $FeSO_4$(aq) added to acidified $KMnO_4$(aq)	colourless to pink
C	Excess NH_3(aq) added to $CuSO_4$(aq)	blue to deep blue
D	Excess HCl(aq) added to NaOH(aq) containing methyl orange	yellow to red

Answer _____ [1]

3 Which one of the following shows the correct formula of the compound and one of its uses?

	Compound	**Formula**	**Use**
A	calcium carbonate	$CaCO_3$	painkiller
B	cisplatin	$[Pt(NH_3)_2Cl_2]^{2+}$	cancer treatment
C	salicylic acid	$C_7H_6O_3$	wart treatment
D	silver nitrate	$AgNO_3$	antacid

Answer _____ [1]

[Turn over

4 Which one of the following is the electronic configuration of a copper(I) ion?

A $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^1$

B $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}$

C $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^9\ 4s^1$

D $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2$

Answer _____ [1]

5 Which one of the following can only act as a monodentate ligand?

A 1,2-diaminoethane

B ethanedioate ions

C edta

D hydroxide ions

Answer _____ [1]

6 Which one of the following shows only two singlets on its high resolution ^1H nmr spectrum?

A ethane

B methyl ethanoate

C propanone

D pentan-2-one

Answer _____ [1]

7 Which one of the following is the correct IUPAC name and molecular formula for the organic compound formed when butylamine reacts with propanoyl chloride?

	IUPAC name	Molecular formula
A	N-butylpropanamide	$C_7H_{15}NO$
B	N-butylpropanamide	$C_7H_{17}NO_2$
C	N-propylbutanamide	$C_7H_{15}NO$
D	N-propylbutanamide	$C_7H_{17}NO_2$

Answer _____ [1]

8 Which one of the following is the volume of 0.0525 mol dm^{-3} potassium manganate(VII) solution required to react with 25.0 cm^3 of 0.105 mol dm^{-3} iron(II) sulfate solution made up in sulfuric acid?

A 2 cm^3

B 10 cm^3

C 50 cm^3

D 250 cm^3

Answer _____ [1]

9 Which one of the following compounds is the strongest base?

A $(CH_3CH_2)_2NH$

B CH_3CONH_2

C $CH_3CH_2NH_2$

D $C_6H_5NH_2$

Answer _____ [1]

[Turn over

10 Which one of the following is the formula of copper(II) arsenate(V)?

A $CuAsO_4$

B Cu_2AsO_4

C $Cu(AsO_4)_2$

D $Cu_3(AsO_4)_2$

Answer _____ [1]

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(Questions continue overleaf)

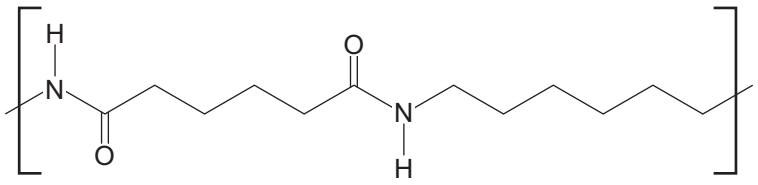
[Turn over

Section B

Answer **all five** questions in the spaces provided.

11 Small molecules which combine to form a polymer are called monomers.

(a) The repeating unit of a polymer called nylon-6,6 is shown below.



nylon-6,6

(i) State the IUPAC names of two monomers used to form this polymer.

_____

_____ [2]

(ii) State two different terms which may be used to describe the type of polymer shown.

_____

_____ [2]

(iii) Explain why the polymer is referred to as nylon-**6,6**.

_____

_____ [1]

(iv) A section of nylon-6,6 contains 240 of the repeating unit shown above. Calculate the relative formula mass of this section of polymer.

Answer _____ [1]

(v) Nylon is a biodegradable polymer. Define the term **biodegradable** and explain why nylon is biodegradable.

_____

_____

_____ [2]

(vi) Explain why nylon-6,6 melts at a higher temperature than a polymer such as polythene.

_____

_____

_____ [2]

(b) Hydroxyethanoic acid can form a polymer.

(i) Draw the structural formula of the organic molecule formed from the polymerisation of three hydroxyethanoic acid molecules in acidic conditions.

[2]

(ii) Name the functional group formed when hydroxyethanoic acid undergoes polymerisation.

_____ [1]

[Turn over

12 Many inorganic reactions involve the production of a gas or the formation of a precipitate.

(a) A series of reactions occurs when a piece of solid barium is added to a solution containing copper(II) sulfate. Bubbles of hydrogen gas are formed in the solution. A white precipitate and a blue precipitate are both produced.

(i) Write an equation for barium reacting with water in the solution.

_____ [1]

(ii) Write ionic equations for the reactions which occur to produce both precipitates. Identify the white precipitate and the blue precipitate.

_____

_____

_____

_____

_____ [4]

(b) The following tests were carried out on solutions labelled **A**, **B** and **C** and the results recorded in the table.

Test \ Solution	A	B	C
Add silver nitrate solution	**white precipitate**	yellow precipitate	no change
Add hydrochloric acid	no effervescence	no effervescence	**effervescence**
Add ammonia solution	**green precipitate** which dissolved in excess ammonia solution to form a blue solution	blue precipitate which dissolved in excess ammonia solution to form a **yellow solution**	no observable change

(i) Write the formulae for the following which are highlighted in bold in the table.

White precipitate _____

Gas which causes effervescence _____

Green precipitate _____

Yellow solution _____ [4]

(ii) Identify **A** and **B**.

A _____

B _____ [2]

(iii) **C** cannot be fully identified from the tests carried out. Suggest one possible identity for **C** and describe another test which could be carried out to identify it more fully.

_____

_____

_____ [2]

[Turn over

13 Some standard electrode potentials are given below.

Half-equation for standard electrode potential	**$E^{\ominus}$ /V**
$V^{3+}(aq) + e^- \rightleftharpoons V^{2+}(aq)$	–0.26
$SO_4^{2-}(aq) + 4H^+(aq) + 2e^- \rightleftharpoons SO_2(g) + 2H_2O(l)$	+0.17
$VO^{2+}(aq) + 2H^+(aq) + e^- \rightleftharpoons V^{3+}(aq) + H_2O(l)$	+0.32
$Cu^{2+}(aq) + 2e^- \rightleftharpoons Cu(s)$	+0.34
$I_2(aq) + 2e^- \rightleftharpoons 2I^-(aq)$	+0.54
$VO_2^+(aq) + 2H^+(aq) + e^- \rightleftharpoons VO^{2+}(aq) + H_2O(l)$	+1.00
$Cl_2(g) + 2e^- \rightleftharpoons 2Cl^-(aq)$	+1.36

(a) VO_2^+ in acidic solution can be reduced to VO^{2+} by iodide ions.

(i) Write an ionic equation for the reaction.

_____

_____ [2]

(ii) Calculate the emf for the reaction in **(a)(i)**.

Answer _____ [1]

(b) A solution containing 131 mg of $(VO_2)_2SO_4$ is acidified using an excess of sulfuric acid and mixed with a solution containing 441 mg of VSO_4. The following reaction occurs.

$$(VO_2)_2SO_4(aq) + 4H_2SO_4(aq) + 4VSO_4(aq) \longrightarrow 3V_2(SO_4)_3(aq) + 4H_2O(l)$$

(i) Complete the table, giving the colour of the vanadium compounds in solution.

Vanadium compound	Colour
$(VO_2)_2SO_4(aq)$	
$VSO_4(aq)$	
$V_2(SO_4)_3(aq)$	

[3]

(ii) Calculate the mass, in mg, of $V_2(SO_4)_3$ which will be present in the solution when the reaction is complete.

Answer _____ mg [4]

(iii) Identify an oxidising agent from the table of standard electrode potentials which would oxidise vanadium from the +2 to the +4 oxidation state but not to the +5 oxidation state.

_____ [1]

[Turn over

(c) Describe how the standard electrode potential of the Cu^{2+}/Cu half-cell could be measured using a standard hydrogen electrode. State the conditions needed.

In this question you will be assessed on your written communication skills including the use of specialist scientific terms.

[6]

(d) A hydrogen-oxygen fuel cell may operate in acidic or alkaline conditions.

The standard electrode potentials involved in the alkaline hydrogen-oxygen fuel cell are:

		$E^{\ominus}$ / V
Electrode 1:	$2H_2O(l) + 2e^- \rightleftharpoons H_2(g) + 2OH^-(aq)$	–0.83
Electrode 2:	$O_2(g) + 2H_2O(l) + 4e^- \rightleftharpoons 4OH^-(aq)$	+0.40

(i) State and explain which electrode (1 or 2) would be the negative electrode.

_____

_____ [1]

(ii) Calculate the emf of the alkaline hydrogen-oxygen fuel cell.

Answer _____ [1]

(iii) Write an overall equation for the reaction occurring in the cell.

_____ [1]

(iv) Complete the conventional cell representation of the alkaline hydrogen-oxygen fuel cell.

Pt(s) $H_2(g)$ $OH^-(aq)$ $H_2O(l)$ $O_2(g)$ $H_2O(l)$ $OH^-(aq)$ Pt(s)

[2]

(v) State one environmental advantage of using a hydrogen-oxygen fuel cell.

_____

_____ [1]

[Turn over

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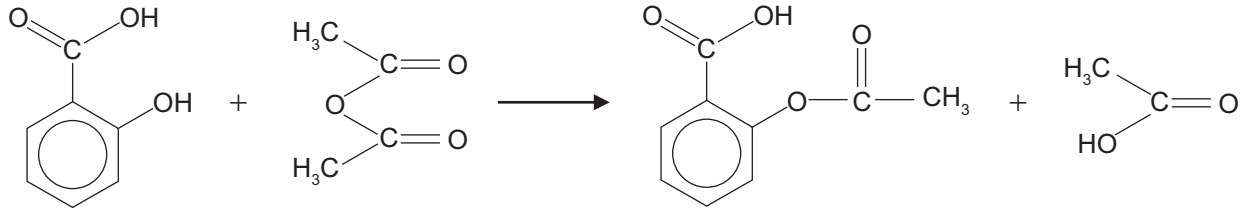
(Questions continue overleaf)

14 Aspirin, $C_9H_8O_4$, may be synthesised in the laboratory using the reaction of salicylic acid with **excess** ethanoic anhydride. The equation for the reaction is given below.



salicylic acid ethanoic anhydride aspirin ethanoic acid

(a) State the IUPAC name for salicylic acid.

_____ [1]

(b) State the IUPAC name and draw the structural formula of another compound which will react with salicylic acid to form aspirin. Explain why ethanoic anhydride is used in preference to this compound.

_____

_____

_____ [3]

(c) Identify the ion which causes the peak at an m/z ratio of 43 in the mass spectrum of ethanoic anhydride.

_____ [1]

[Turn over

(d) State the approximate chemical shifts, peak integration and any splitting patterns observed in the ^{1}H nmr spectrum of ethanoic acid.

chemical shift: _____

_____

peak integration: _____

_____

splitting pattern: _____

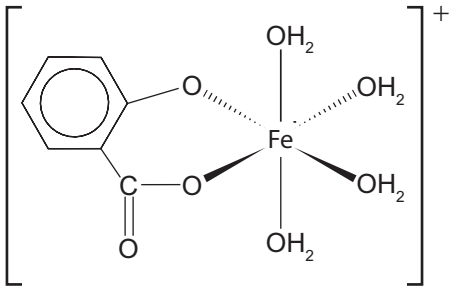
_____ [3]

(e) Both the –COOH group and the –OH group in salicylic acid can ionise in solution.

(i) Write an equation for the ionisation of salicylic acid in which both of these groups are ionised.

_____ [1]

(ii) The synthesis of aspirin may be monitored using iron(III) chloride solution. The iron(III) ion forms a purple complex with the completely ionised salicylic acid. This complex is shown below.



Write an ionic equation for the formation of the complex from an aqueous solution of iron(III) ions and the ionised salicylic acid.

_____ [1]

(iii) State the co-ordination number and shape of the complex in **(e)(ii)**.

co-ordination number _____

shape _____ [2]

[Turn over

(f) Thin-layer chromatography (TLC) may also be used to monitor the progress of the synthesis of aspirin in the laboratory. The solvent used is ethyl ethanoate.

The chromatogram is dried thoroughly and developed using an alkaline solution of potassium manganate(VII) which stains the TLC plate purple. After strong heating of the TLC plate, most organic compounds show as a yellow/brown spot due to the presence of a mixture of green manganate(VI) ions, MnO_4^{2-}, and black manganese(IV) oxide.

The R_f values for the reactants and products are shown below.

	R_f
salicylic acid	0.315
aspirin	0.800
ethanoic anhydride	0.545
ethanoic acid	0.380

(i) Write a half-equation for the conversion of manganate(VII) to manganate(VI).

_____ [1]

(ii) Suggest the type of reaction which organic compounds undergo in the presence of alkaline potassium manganate(VII).

_____ [1]

(iii) Describe, giving experimental details, how TLC can be carried out on a sample of the reaction mixture and the R_f values calculated and used to determine if the reaction is complete.

In this question you will be assessed on your written communication skills including the use of specialist scientific terms.

[6]

[Turn over

(g) 4.50 g of a sample of impure solid aspirin were mixed with an excess of sodium hydroxide in solution (40.0 cm^3 of 1.25 mol dm^{-3}). The mixture was heated and diluted to 250.0 cm^3 using deionised water in a volumetric flask. A 25.0 cm^3 sample of the solution was titrated against 0.140 mol dm^{-3} hydrochloric acid using phenolphthalein indicator. 14.3 cm^3 of hydrochloric acid were required.

Aspirin reacts with sodium hydroxide according to the equation:

$$C_9H_8O_4 + 2NaOH \longrightarrow C_7H_5O_3Na + CH_3COONa + H_2O$$

(i) State the colour change observed at the end point of the titration.

_____ [1]

(ii) Name the two types of reaction occurring when sodium hydroxide reacts with aspirin.

_____

_____ [2]

(iii) Calculate the mass of aspirin in the sample. Give your answer to 3 significant figures.

Answer _____ g [5]

(iv) The manufacturer's given value for the percentage of aspirin in the sample was 65%. Calculate the percentage of aspirin in the sample from the titration.

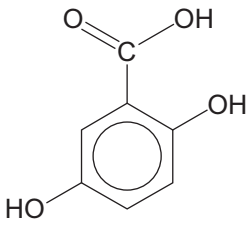
Answer _____% [1]

(v) Suggest why the value calculated in **(g)(iv)** may be different to the manufacturer's given value.

_____

_____ [1]

(h) Aspirin is metabolised in the liver to form gentisic acid which is excreted by the kidneys in urine as it is more soluble in water than aspirin.



gentisic acid

(i) Suggest the IUPAC name of gentisic acid.

_____ [1]

(ii) Explain why gentisic acid is more soluble in water than aspirin.

_____

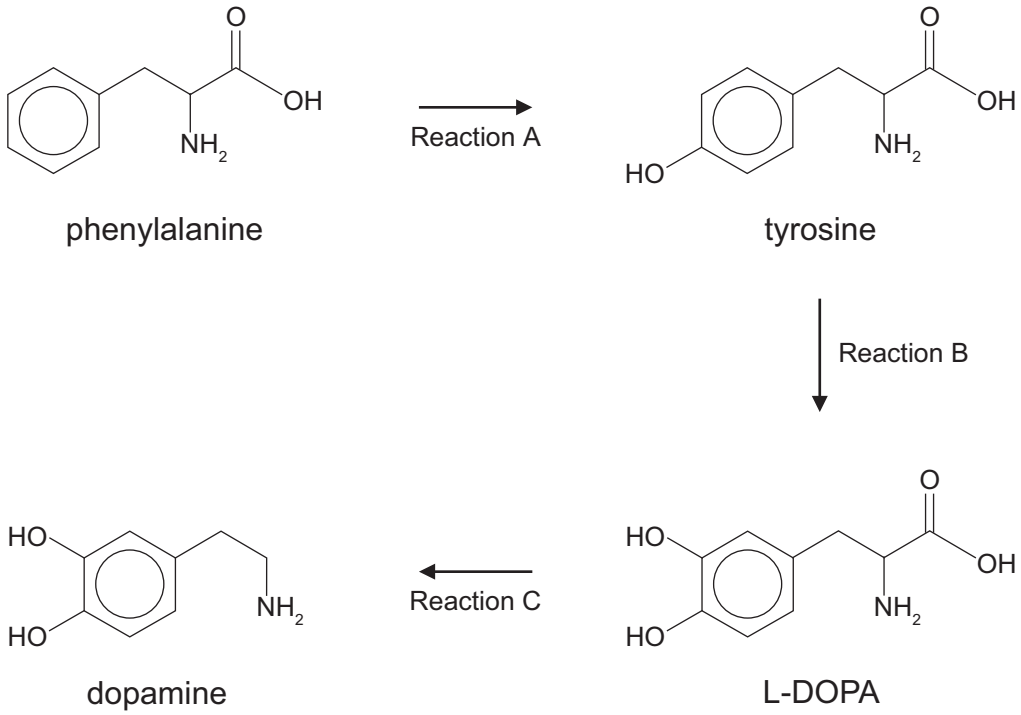
_____

_____

_____ [2]

[Turn over

15 Dopamine is a neurotransmitter in the human body. It is synthesised from the amino acid phenylalanine via another amino acid, tyrosine, and L-DOPA.



phenylalanine tyrosine

dopamine L-DOPA

(a) Suggest the IUPAC name for phenylalanine.

_____ [2]

(b) Draw the structure of a dipeptide formed between phenylalanine and glycine. Circle the peptide group.

[3]

(c) Phenylalanine reacts with nitrous acid.

(i) Name the reagents used to prepare nitrous acid.

_____

_____ [1]

(ii) Write an equation for the reaction of nitrous acid with phenylalanine.

_____ [2]

(iii) What is observed during the reaction of nitrous acid with phenylalanine?

_____

_____ [1]

(d) Reaction **C** is a decarboxylation reaction.

(i) Suggest what is meant by decarboxylation.

_____

_____ [1]

(ii) Suggest the name of the inorganic product of this reaction.

_____ [1]

(e) **(i)** Explain why dopamine is not optically active.

_____

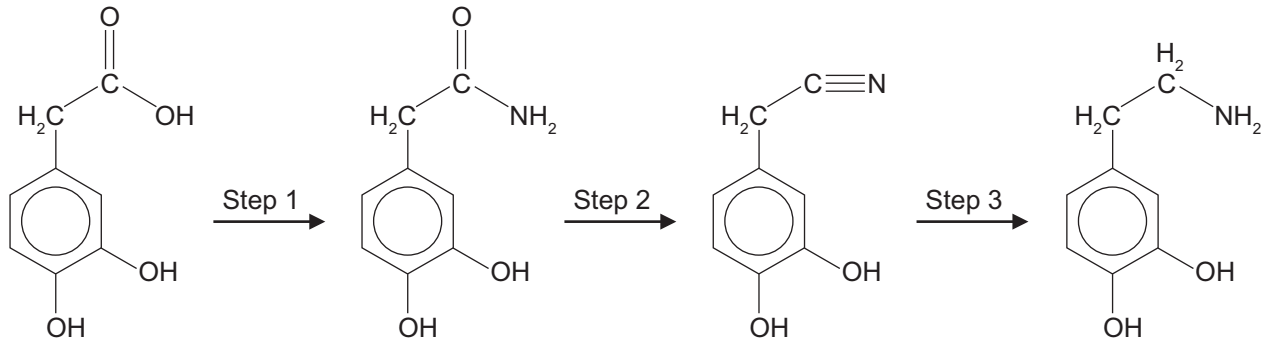
_____ [1]

[Turn over

(ii) Write an equation for the reaction of excess dopamine with sulfuric acid.

[2]

(f) Dopamine may be synthesised in the laboratory from (3,4-dihydroxyphenyl)ethanoic acid.



Complete the table below to give the reagents and type of reaction for Steps 2 and 3.

Step	Reagent(s)	Type of reaction
2		
3		

[4]

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General Information

1 tonne = 10^6 g
1 metre = 10^9 nm
One mole of any gas at 293 K and a pressure of 1 atmosphere (10^5 Pa) occupies a volume of 24 dm^3
Avogadro Constant = 6.02×10^{23} mol^{-1}
Planck Constant = 6.63×10^{-34} J s
Specific Heat Capacity of water = 4.2 J g^{-1} K^{-1}
Speed of Light = 3×10^8 m s^{-1}

Characteristic absorptions in IR spectroscopy

Wavenumber/cm^{-1}	Bond	Compound
550–850	C–X (X = Cl, Br, I)	Haloalkanes
750–1100	C–C	Alkanes, alkyl groups
1000–1300	C–O	Alcohols, esters, carboxylic acids
1450–1650	C=C	Arenes
1600–1700	C=C	Alkenes
1650–1800	C=O	Carboxylic acids, esters, aldehydes, ketones, amides, acyl chlorides
2200–2300	C≡N	Nitriles
2500–3200	O–H	Carboxylic acids
2750–2850	C–H	Aldehydes
2850–3000	C–H	Alkanes, alkyl groups, alkenes, arenes
3200–3600	O–H	Alcohols
3300–3500	N–H	Amines, amides

Proton Chemical Shifts in Nuclear Magnetic Resonance Spectroscopy (relative to TMS)

Chemical Shift	Structure	
0.5–2.0	–C**H**	Saturated alkanes
0.5–5.5	–O**H**	Alcohols
1.0–3.0	–N**H**	Amines
2.0–3.0	–CO–C**H**	Ketones
	–N–C**H**	Amines
	C_6H_5–C**H**	Arene (aliphatic on ring)
2.0–4.0	X–C**H**	X = Cl or Br (3.0–4.0)
		X = I (2.0–3.0)
4.5–6.0	–C=C**H**	Alkenes
5.5–8.5	RCON**H**	Amides
6.0–8.0	–C_6**H**$_5$	Arenes (on ring)
9.0–10.0	–C**H**O	Aldehydes
10.0–12.0	–COO**H**	Carboxylic acids

These chemical shifts are concentration and temperature dependent and may be outside the ranges indicated above.

COUNCIL FOR THE **CURRICULUM, EXAMINATIONS** AND **ASSESSMENT**
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Data Leaflet

Including the Periodic Table of the Elements

For the use of candidates taking
Advanced Subsidiary and
Advanced Level Examinations

Copies must be free from notes or additions of any kind. No other type of data booklet or information sheet is authorised for use in the examinations

gce a/as examinations

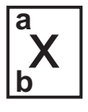
chemistry

THE PERIODIC TABLE OF ELEMENTS

I	II											III	IV	V	VI	VII	0
Group																	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H Hydrogen 1																	4 He Helium 2
7 Li Lithium 3	9 Be Beryllium 4											11 B Boron 5	12 C Carbon 6	14 N Nitrogen 7	16 O Oxygen 8	19 F Fluorine 9	20 Ne Neon 10
23 Na Sodium 11	24 Mg Magnesium 12											27 Al Aluminium 13	28 Si Silicon 14	31 P Phosphorus 15	32 S Sulfur 16	35.5 Cl Chlorine 17	40 Ar Argon 18
39 K Potassium 19	40 Ca Calcium 20	45 Sc Scandium 21	48 Ti Titanium 22	51 V Vanadium 23	52 Cr Chromium 24	55 Mn Manganese 25	56 Fe Iron 26	59 Co Cobalt 27	59 Ni Nickel 28	64 Cu Copper 29	65 Zn Zinc 30	70 Ga Gallium 31	73 Ge Germanium 32	75 As Arsenic 33	79 Se Selenium 34	80 Br Bromine 35	84 Kr Krypton 36
85 Rb Rubidium 37	88 Sr Strontium 38	89 Y Yttrium 39	91 Zr Zirconium 40	93 Nb Niobium 41	96 Mo Molybdenum 42	98 Tc Technetium 43	101 Ru Ruthenium 44	103 Rh Rhodium 45	106 Pd Palladium 46	108 Ag Silver 47	112 Cd Cadmium 48	115 In Indium 49	119 Sn Tin 50	122 Sb Antimony 51	128 Te Tellurium 52	127 I Iodine 53	131 Xe Xenon 54
133 Cs Caesium 55	137 Ba Barium 56	139 La* Lanthanum 57	178 Hf Hafnium 72	181 Ta Tantalum 73	184 W Tungsten 74	186 Re Rhenium 75	190 Os Osmium 76	192 Ir Iridium 77	195 Pt Platinum 78	197 Au Gold 79	201 Hg Mercury 80	204 Tl Thallium 81	207 Pb Lead 82	209 Bi Bismuth 83	210 Po Polonium 84	210 At Astatine 85	222 Rn Radon 86
223 Fr Francium 87	226 Ra Radium 88	227 Ac† Actinium 89	261 Rf Rutherfordium 104	262 Db Dubnium 105	266 Sg Seaborgium 106	264 Bh Bohrium 107	277 Hs Hassium 108	268 Mt Meitnerium 109	271 Ds Darmstadtium 110	272 Rg Roentgenium 111	285 Cn Copernicium 112						

140 Ce Cerium 58	141 Pr Praseodymium 59	144 Nd Neodymium 60	145 Pm Promethium 61	150 Sm Samarium 62	152 Eu Europium 63	157 Gd Gadolinium 64	159 Tb Terbium 65	162 Dy Dysprosium 66	165 Ho Holmium 67	167 Er Erbium 68	169 Tm Thulium 69	173 Yb Ytterbium 70	175 Lu Lutetium 71
232 Th Thorium 90	231 Pa Protactinium 91	238 U Uranium 92	237 Np Neptunium 93	242 Pu Plutonium 94	243 Am Americium 95	247 Cm Curium 96	245 Bk Berkelium 97	251 Cf Californium 98	254 Es Einsteinium 99	253 Fm Fermium 100	256 Md Mendelevium 101	254 No Nobelium 102	257 Lr Lawrencium 103

* 58 – 71 Lanthanum series
† 90 – 103 Actinium series



a = relative atomic mass (approx)
x = atomic symbol
b = atomic number

11331.03