Rewarding Learning

ADVANCED
General Certificate of Education
2023

Centre Number

Candidate Number

Chemistry

Assessment Unit A2 1
assessing
Further Physical and
Organic Chemistry

ACH14

[ACH14]
TUESDAY 30 MAY, 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 sixteen** 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 **12(a)** and **13(b)(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.

13616.08**RRR**

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 does **not** contain an asymmetric centre?

A 3-hydroxypentanal

B 3-hydroxypentan-2-one

C 2-methylbutanoic acid

D 3-methylbutanoic acid

Answer _____ [1]

2 A 0.1 M solution of an organic acid has a pH of 4.40. What is the pK_a of this acid?

A 3.4

B 4.4

C 7.8

D 8.8

Answer _____ [1]

3 Which redox reaction represents the largest change in the oxidation state of sulfur?

A $H_2SO_4 + 8HI \rightarrow H_2S + 4I_2 + 4H_2O$

B $S + O_2 \rightarrow SO_2$

C $S_2O_3^{2-} + 2H^+ \rightarrow SO_2 + S + H_2O$

D $S + 6HNO_3 \rightarrow H_2SO_4 + 6NO_2 + 2H_2O$

Answer _____ [1]

4 Which one of the following is the conjugate base of methanol?

A $CH_3OH_2^+$

B CH_3O^-

C H_3O^+

D OH^-

Answer _____ [1]

5 Which one of the following is the ester formed from propan-1-ol and methanoyl chloride?

A $CH_3CH_2COOCH_3$

B $CH_3COOCH_2CH_2CH_3$

C $HCOOCH(CH_3)_2$

D $HCOOCH_2CH_2CH_3$

Answer _____ [1]

6 Which indicator would be suitable for a titration between 1 M solutions of hydrochloric acid and ammonia?

	Indicator	**pH range**
A	chlorophenol red	4.8 – 6.4
B	indigo carmine	11.4 – 13.0
C	methyl violet	0.0 – 1.6
D	thymolphthalein	9.3 – 10.5

Answer _____ [1]

[Turn over

7 Which one of the following compounds reacts with both acidified potassium dichromate(VI) and 2,4-dinitrophenylhydrazine?

A $CH_3CH_2CH_2OH$

B CH_3COCH_3

C $CH_3CH(OH)CH_3$

D CH_3CH_2CHO

Answer _____ [1]

8 Which one of the following gives the units of K_w?

A $mol^{-1}\ dm^3$

B $mol^{-2}\ dm^6$

C $mol\ dm^{-3}$

D $mol^2\ dm^{-6}$

Answer _____ [1]

9 The table below shows some enthalpy change of formation data.

Compound	$TiCl_4(l)$	$H_2O(l)$	$TiO_2(s)$	$HCl(g)$
$\Delta_f H^{\ominus}$ **/kJ mol^{-1}**	–804	–286	–945	–92

What is the value of the enthalpy change of reaction for the following reaction?

$$TiCl_4(l) + 2H_2O(l) \rightarrow TiO_2(s) + 4HCl(g)$$

A $-63\,kJ\,mol^{-1}$

B $-53\,kJ\,mol^{-1}$

C $+53\,kJ\,mol^{-1}$

D $+63\,kJ\,mol^{-1}$

Answer _____ [1]

10 Which one of the following salts would produce a neutral solution when dissolved in water?

A ammonium iodide

B lithium chloride

C potassium ethanoate

D sodium carbonate

Answer _____ [1]

[Turn over

Section B

Answer all **six** questions in this section

11 (a) The oxidation of nitric oxide (NO) in air is one of the reactions that contributes to the formation of acid rain.

$$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$$

Initial rate data for this reaction are shown in the table below.

Experiment	[NO] /mol dm^{-3}	[O_2] /mol dm^{-3}	Initial rate /mol dm^{-3} s^{-1}
1	0.015	0.015	0.048
2	0.030	0.015	0.192
3	0.015	0.030	0.096
4	0.030	0.030	0.384

(i) State the order of the reaction with respect to NO.

_____ [1]

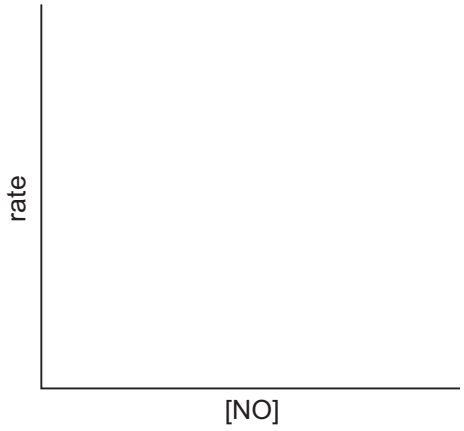
(ii) State the order of the reaction with respect to O_2.

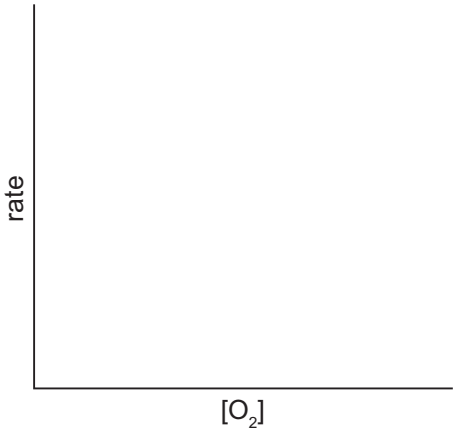
_____ [1]

(iii) Write the rate equation for the reaction.

_____ [1]

(iv) Sketch graphs on the axes below to show how the initial rate of this reaction changes with increasing concentration of the reactants.





[2]

(v) Define the term **rate constant**.

_____

_____

_____ [1]

(vi) Using the results from **Experiment 1** in the table, calculate the value of the rate constant and state its units. Give your answer to 2 significant figures.

Answer _____ [3]

[Turn over

(b) The formation of nitrogen dioxide from nitric oxide involves an entropy change.

$$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$$

The following table gives some entropy values.

Substance	$S^{\ominus}$ /J K^{-1} mol^{-1}
NO	210.5
O_2	205.2
NO_2	240.0

(i) Define the term **entropy**.

_____ [1]

(ii) Calculate the entropy change for this reaction.

Answer _____ J K^{-1} mol^{-1} [1]

(c) Nitrogen dioxide can react to form dinitrogen tetroxide.

$2NO_2(g) \rightarrow N_2O_4(g)$ $\quad \Delta H^{\ominus} = -57\,kJ\,mol^{-1}$ $\quad \Delta S^{\ominus} = -176\,J\,K^{-1}\,mol^{-1}$

(i) Calculate the value of the free energy change for this reaction at 400 K. State the units.

Answer _____ [2]

(ii) Explain if this reaction is feasible at 400 K.

_____

_____ [1]

(iii) Calculate the temperature at which $\Delta G = 0$ for this reaction.

Answer _____ [2]

(d) A mixture of nitric oxide and oxygen, in a closed system, can reach equilibrium.

$$2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$$

The value of the equilibrium constant (K_c) is 8.54 mol^{-1} dm^3 at 500 °C. The equilibrium concentration of NO is 0.42 mol dm^{-3} and that of O_2 is 1.70 mol dm^{-3}.

(i) Write an expression for K_c for this equilibrium.

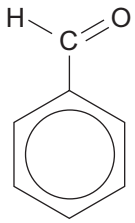
_____ [1]

(ii) Calculate the equilibrium concentration of NO_2 at 500 °C.

Answer _____ [2]

[Turn over

12 Benzaldehyde is an aromatic aldehyde with an almond odour. It can be obtained from natural sources and is widely used in the preparation of dyes, perfumes and flavourings.



benzaldehyde

(a) Describe how you would practically carry out the reaction of a solution of benzaldehyde with Tollens' reagent and with acidified potassium dichromate(VI) solution and state all observations which occur. Write an equation for the oxidation of benzaldehyde and half equations for the reduction of each reagent.

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

[6]

(b) (i) Benzaldehyde undergoes an addition reaction with hydrogen cyanide to form a hydroxynitrile called mandelonitrile. Outline the mechanism for this reaction. Include an equation for the formation of the nucleophile from hydrogen cyanide.

[4]

(ii) The addition of cyanide ions to a carbonyl group is carried out at a pH of 4 – 5. Suggest why a very low pH is not used.

_____

_____ [1]

(iii) Explain why the mandelonitrile formed from the reaction in **(b)(i)** is optically inactive.

_____

_____

_____

_____ [2]

[Turn over

(c) The hydrolysis of mandelonitrile forms mandelic acid $C_6H_5CH(OH)COOH$. This is a weak acid with a K_a value of 3.88×10^{-4} mol dm^{-3}.

Excess mandelic acid reacts with sodium hydroxide to form a buffer solution.

(i) Write an equation for the reaction of mandelic acid with sodium hydroxide.

_____ [1]

(ii) Define the term **buffer solution**.

_____

_____

_____ [1]

(iii) Calculate the pH of the buffer formed on mixing 35.0 cm^3 of 0.125 mol dm^{-3} mandelic acid with 15.0 cm^3 of 0.175 mol dm^{-3} sodium hydroxide solution. Give your answer to 2 decimal places.

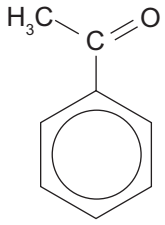
Answer _____ [4]

BLANK PAGE

DO NOT WRITE ON THIS PAGE

(Questions continue overleaf)

13 Phenylethanone is used as a fragrance in perfumes and soaps.



phenylethanone

It is prepared by the reaction of benzene with ethanoyl chloride in the presence of an aluminium chloride catalyst.

(a) (i) Outline a mechanism for the acylation of benzene to form phenylethanone. The mechanism should include equations to show the formation of the electrophile and the regeneration of the catalyst.

[5]

(ii) Define the term **electrophile**.

_____

_____ [1]

(b) Phenylethanone can be nitrated to form (3-nitrophenyl)ethanone which is a solid at room temperature.

(i) State the reagents required for this nitration.

_____

_____ [2]

(ii) Write an equation for the nitration of phenylethanone to form (3-nitrophenyl)ethanone.

_____ [1]

(iii) Describe how the melting point of a solid sample of (3-nitrophenyl)ethanone could be determined. State two effects that the presence of impurities would have on the melting point.

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

_____

_____

_____

_____

_____

_____

_____

_____

_____ [6]

[Turn over

(c) Phenylethanone reacts with 2,4-dinitrophenylhydrazine.

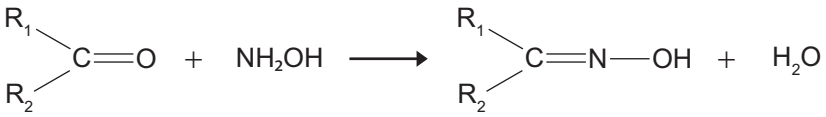
(i) Write an equation for the reaction of phenylethanone with 2,4-dinitrophenylhydrazine.

_____ [2]

(ii) Calculate the volume of phenylethanone needed to form 5.00 g of the 2,4-dinitrophenylhydrazone assuming a 90.0% yield. The density of phenylethanone is 1.03 g cm^{-3}. Give your answer to 3 significant figures.

Answer _____ [4]

(d) Ketones react with hydroxylamine to form an oxime as shown by the general equation below.



ketone oxime

When 0.8764 g of a ketone was treated with excess hydroxylamine it produced 1.103 g of an oxime. Calculate the relative molecular mass of the ketone.

Answer _____ [2]

[Turn over

14 The table shows the names and boiling points of four carboxylic acids with molecular formula $C_5H_{10}O_2$. They are structural isomers.

Name	Boiling point /°C
2,2-dimethylpropanoic acid	164
2-methylbutanoic acid	176
3-methylbutanoic acid	177
pentanoic acid	186

(a) (i) Define the term **structural isomers**.

_____

_____ [1]

(ii) Explain the difference in the boiling point of 2,2-dimethylpropanoic acid and pentanoic acid.

_____

_____

_____

_____ [2]

(b) Pentanoic acid may be formed by the acid catalysed hydrolysis of methyl pentanoate.

(i) Write the equation for this reversible reaction.

_____ [1]

(ii) A different product is formed if the hydrolysis of methyl pentanoate is carried out using dilute sodium hydroxide solution. Name the different product formed and state an advantage of the base catalysed hydrolysis of an ester rather than acid catalysed hydrolysis.

_____

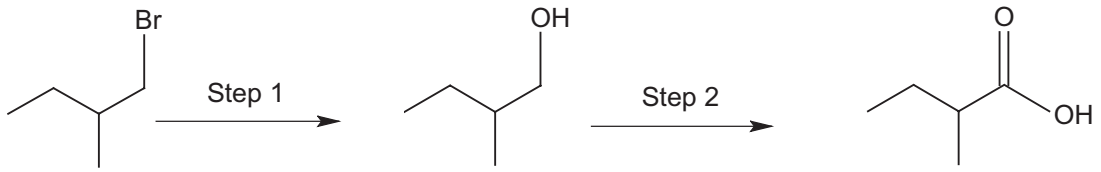
_____

_____

_____ [2]

[Turn over

(c) 2-methylbutanoic acid can be prepared in a two-step synthesis.



1-bromo-2-methylbutane 2-methylbutan-1-ol 2-methylbutanoic acid

(i) State the name of the reagent and the reaction conditions required to carry out Step **1** of the synthesis.

_____

_____

_____ [2]

(ii) State the type of reaction occurring in Step **2**.

_____ [1]

(iii) 2-methylbutanoic acid is reduced using excess lithium tetrahydridoaluminate(III). Write the equation for this reaction.

_____ [2]

(d) 2,2-dimethylpropanoic acid reacts with phosphorus(V) chloride to form the acyl chloride, pivaloyl chloride. This acyl chloride is used in the manufacture of insecticides and pesticides.

(i) Write the equation for this reaction.

_____ [1]

(ii) State two observations for the reaction between phosphorus(V) chloride and 2,2-dimethylpropanoic acid.

_____

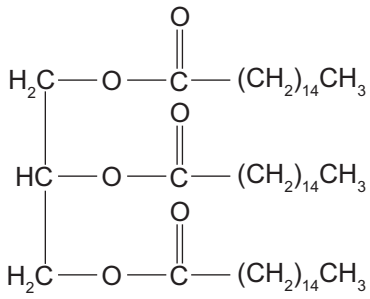
_____

_____ [2]

[Turn over

15 Palm oil is used in many food products and cosmetics.

(a) The fat molecule below is found in palm oil. The fatty acid in this fat is palmitic acid.



(i) Write an equation for the complete combustion of one mole of this fat molecule.

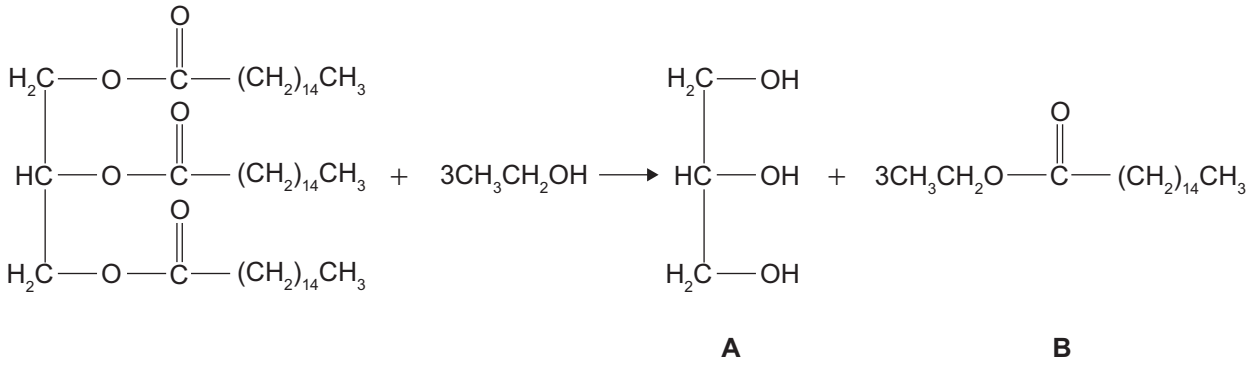
_____ [2]

(ii) Explain whether the fat is saturated or unsaturated based on the structure.

_____

_____ [1]

(b) The fat undergoes the reaction below with ethanol. The products are labelled **A** and **B**.



A **B**

(i) State the IUPAC name for product **A**.

_____ [1]

(ii) Name the process occurring in this reaction.

_____ [1]

(iii) State one use for product **B**.

_____ [1]

(iv) The IUPAC name for palmitic acid is hexadecanoic acid. State the IUPAC name for product **B**.

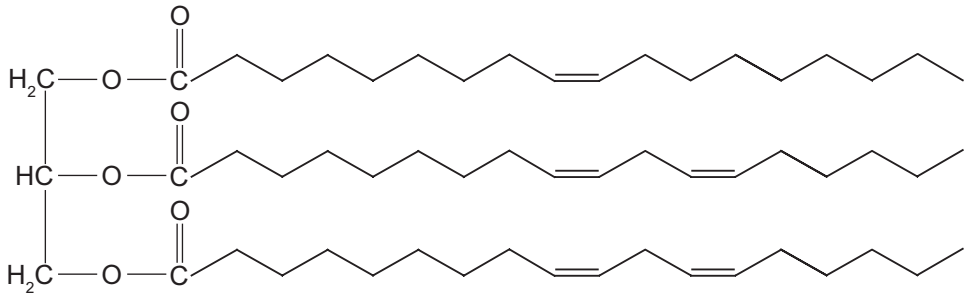
_____ [1]

(v) Calculate the mass of product **B** produced when 125 g of the fat reacts with 30.0 g of ethanol.

Answer _____ g [4]

[Turn over

(c) A second fat found in palm oil is shown below. This fat may be catalytically hydrogenated.



(i) Name the catalyst used in catalytic hydrogenation.

_____ [1]

(ii) Explain why fats such as this are hydrogenated.

_____

_____

_____ [1]

BLANK PAGE

DO NOT WRITE ON THIS PAGE

(Questions continue overleaf)

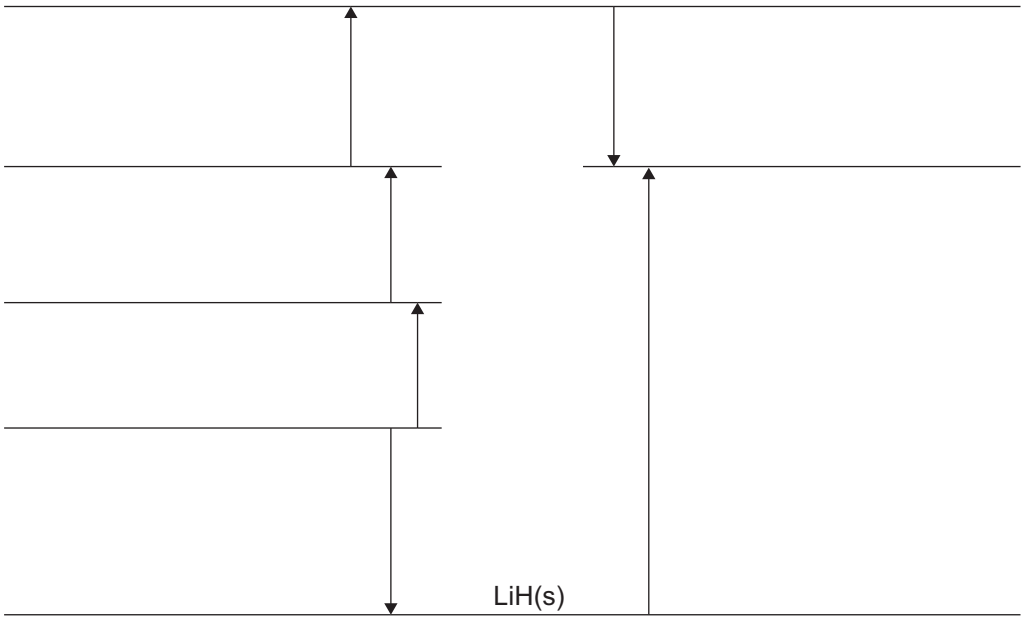
[Turn over

16 Lithium tetrahydridoaluminate(III) may be prepared by the reaction of lithium hydride with aluminium hydride.

(a) Write an equation for this reaction.

_____ [1]

(b) The incomplete Born–Haber cycle diagram below is for lithium hydride.



(i) Complete the diagram. [5]

(ii) Using the values in the table below, calculate the bond enthalpy of hydrogen.

Enthalpy change	**$\Delta H^{\ominus}$ /kJ mol^{-1}**
Enthalpy of formation of lithium hydride	–91
Enthalpy of atomisation of lithium	+159
First ionisation energy of lithium	+520
First electron affinity of hydrogen	–72
Lattice enthalpy of lithium hydride	+916

Answer _____ kJ mol^{-1} [3]

[Turn over

(c) Lithium hydride reacts vigorously with water producing lithium hydroxide and hydrogen gas. The equation for the reaction is:

$$LiH + H_2O \rightarrow LiOH + H_2$$

The reaction is an acid-base reaction.

(i) Write an ionic equation for this reaction.

_____ [1]

(ii) State and explain the role of water in the reaction in terms of the Brønsted–Lowry theory of acids and bases.

_____

_____

_____ [2]

THIS IS THE END OF THE QUESTION PAPER

BLANK PAGE

DO NOT WRITE ON THIS PAGE

BLANK PAGE

DO NOT WRITE ON THIS PAGE

BLANK PAGE

DO NOT WRITE ON THIS PAGE

DO NOT WRITE ON THIS PAGE

ACH14/10
278229

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**
29 Clarendon Road, Clarendon Dock, Belfast BT1 3BG
Tel: +44 (0)28 9026 1200 Fax: +44 (0)28 9026 1234
Email: info@ccea.org.uk Web: www.ccea.org.uk

Rewarding Learning

11331.03

Rewarding Learning

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

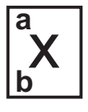
chemistry

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