Rewarding Learning

Centre Number

Candidate Number

ADVANCED
General Certificate of Education
2022

Chemistry

Assessment Unit A2 1
assessing
Further Physical and
Organic Chemistry

ACH14

[ACH14]
MONDAY 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 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 **11(b)** and **14(b)(ii)**.
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.

13108

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 is true for the combustion of propanone as shown below?

$$CH_3COCH_3(l) + 4O_2(g) \rightarrow 3CO_2(g) + 3H_2O(g)$$

A ΔS is negative and ΔH is negative

B ΔS is negative and ΔH is positive

C ΔS is positive and ΔH is negative

D ΔS is positive and ΔH is positive

Answer _____ [1]

2 Which one of the following 0.1 mol dm^{-3} solutions has a pH greater than 7?

A ammonium chloride

B ammonium nitrate

C sodium citrate

D sodium sulfate

Answer _____ [1]

3 What volume of water must be added to 10 cm^3 of a 0.2 mol dm^{-3} solution of hydrogen peroxide to make a 0.05 mol dm^{-3} solution of hydrogen peroxide?

A 20 cm^3

B 30 cm^3

C 40 cm^3

D 50 cm^3

Answer _____ [1]

4 Which one of the following compounds has the greatest lattice enthalpy?

A calcium chloride

B calcium oxide

C magnesium chloride

D magnesium oxide

Answer _____ [1]

5 Complete combustion of 40 cm^3 of a gaseous hydrocarbon requires 240 cm^3 of oxygen. 160 cm^3 of carbon dioxide are formed at room temperature and pressure. The formula of the hydrocarbon is:

A C_4H_8

B C_4H_{10}

C C_6H_{12}

D C_6H_{14}

Answer _____ [1]

[Turn over

6 Which one of the following gives the correct mechanisms for the reactions shown?

	Reaction of cyanide ions with halogenoalkanes	**Reaction of hydrogen cyanide with carbonyl compounds**
A	electrophilic substitution	electrophilic addition
B	electrophilic substitution	nucleophilic addition
C	nucleophilic substitution	electrophilic addition
D	nucleophilic substitution	nucleophilic addition

Answer _____ [1]

7 0.15 mol of a fat which is a triester, required 10.8 dm^3 of hydrogen gas at room temperature and pressure for complete hydrogenation. The average number of C═C double bonds in each fatty acid chain of the fat is:

A 1

B 2

C 3

D 4

Answer _____ [1]

8 What is the percentage by mass of oxygen in methyl 3-nitrobenzoate?

A 17.6 %

B 26.5 %

C 35.4 %

D 44.2 %

Answer _____ [1]

9 Which one of the following alcohols can form the ester $HCOOCH(CH_3)_2$?

A methanol

B 2-methylpropan-2-ol

C propan-1-ol

D propan-2-ol

Answer _____ [1]

10 Fluoride ions react with water in the following equilibrium:

$$F^-(aq) + H_2O(l) \rightleftharpoons HF(aq) + OH^-(aq)$$

Which one of the following shows the Brønsted–Lowry bases in this equilibrium?

A F^- and HF

B F^- and OH^-

C H_2O and HF

D H_2O and OH^-

Answer _____ [1]

[Turn over

Section B

Answer **all five** questions in this section

11 Hydrogen peroxide reacts with iodide ions according to the equation:

$$H_2O_2(aq) + 2H^+(aq) + 2I^-(aq) \rightarrow 2H_2O(l) + I_2(aq)$$

(a) The table shows data obtained from experiments investigating the initial rate of this reaction.

Experiment number	$[H_2O_2]$ /mol dm^{-3}	$[H^+]$ /mol dm^{-3}	$[I^-]$ /mol dm^{-3}	Initial rate of reaction /mol dm^{-3} s^{-1}
1	0.050	0.050	0.050	1.24×10^{-6}
2	0.100	0.100	0.100	
3	0.100	0.200		3.72×10^{-6}
4	0.500	0.100		1.55×10^{-6}

The rate equation for the reaction is:

$$\text{rate} = k[H_2O_2][I^-]$$

(i) Calculate a value for the rate constant using the results of experiment 1. State the units. Give your answer to 3 significant figures.

_____

_____

_____ [2]

(ii) Complete the table by inserting the missing values. [3]

(b) Describe how the initial rate of this reaction in mol dm^{-3} s^{-1} could be measured using colorimetry.

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

[6]

[Turn over

(c) A mechanism for the reaction is shown below in 4 steps:

Step 1: $H_2O_2 + I^- \rightarrow IO^- + H_2O$

Step 2: $IO^- + H^+ \rightarrow HIO$

Step 3: $HIO + I^- \rightarrow I_2 + OH^-$

Step 4: $OH^- + H^+ \rightarrow H_2O$

(i) Explain, using the rate equation, why Step 1 is the rate determining step in this mechanism.

_____

_____

_____ [1]

(ii) Suggest why Step 2 and Step 4 are faster than Steps 1 and 3.

_____

_____ [1]

(iii) What is the systematic name for the IO^- ion?

_____ [1]

12 Magnesium oxide is formed from its elements as follows:

$$Mg(s) + \tfrac{1}{2}O_2(g) \rightarrow MgO(s) \qquad \Delta_f H^{\ominus} = -602\,kJ\,mol^{-1}$$

(a) (i) Use the values in the table to calculate the entropy change for the reaction.

Substance	MgO(s)	$O_2(g)$	Mg(s)
Entropy /J K^{-1} mol^{-1}	26.9	205	32.7

[2]

(ii) Write the equation for **free energy change**.

[1]

(iii) Calculate the free energy change for the formation of magnesium oxide at 298 K. State the units. Give your answer to 3 significant figures.

[3]

(iv) Explain why this reaction is feasible at 298 K.

[1]

[Turn over

(b) The following enthalpy changes can be used to calculate the lattice enthalpy of magnesium oxide.

$Mg(s) \rightarrow Mg(g)$	$+ 148\,kJ\,mol^{-1}$
$Mg(g) \rightarrow Mg^{2+}(g) + 2e^-$	$+ 2189\,kJ\,mol^{-1}$
$O_2(g) \rightarrow 2O(g)$	$+ 498\,kJ\,mol^{-1}$
$O(g) + 2e^- \rightarrow O^{2-}(g)$	$+ 657\,kJ\,mol^{-1}$
$Mg(s) + \frac{1}{2}O_2(g) \rightarrow MgO(s)$	$- 602\,kJ\,mol^{-1}$

(i) Define **lattice enthalpy**.

[2]

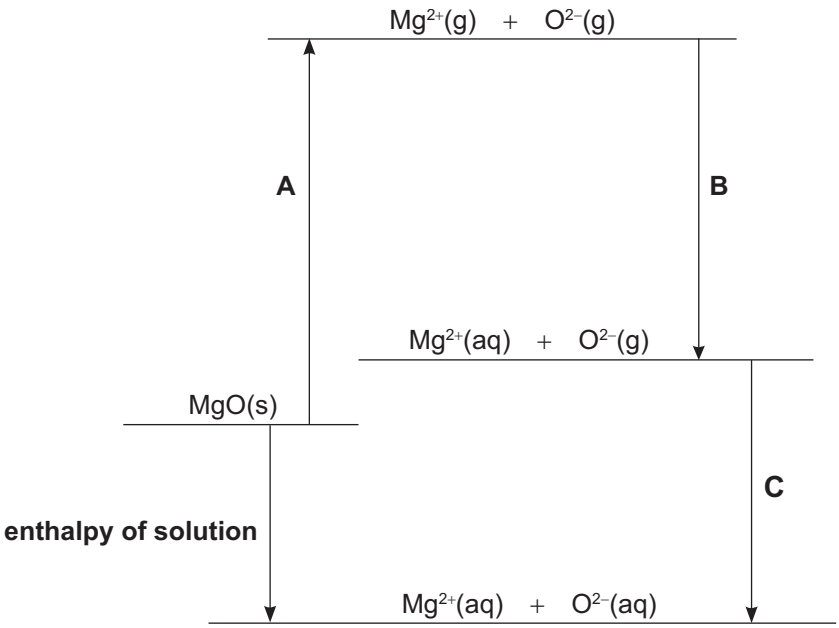
(ii) Calculate the lattice enthalpy of magnesium oxide.

[2]

(iii) Write an equation for the second electron affinity of oxygen. Explain whether this process is exothermic or endothermic.

[2]

(c) A theoretical value for the enthalpy of solution of magnesium oxide may be calculated using a Hess's Law diagram.



(i) Name the enthalpy changes labelled **A** and **B**.

A _____

B _____ [2]

(ii) Suggest why an actual value for the enthalpy of solution of magnesium oxide is not found in any data books.

_____

_____ [1]

[Turn over

13 Benzene was first isolated by Faraday in 1825.

(a) Both benzene and propene will react with bromine but in different ways.

(i) Write equations for the reactions of bromine with benzene and bromine with propene.

benzene: _____

propene: _____ [2]

(ii) Complete the table below.

	Reaction of bromine with benzene	**Reaction of bromine with propene**
Name of mechanism		
IUPAC name of product		

[4]

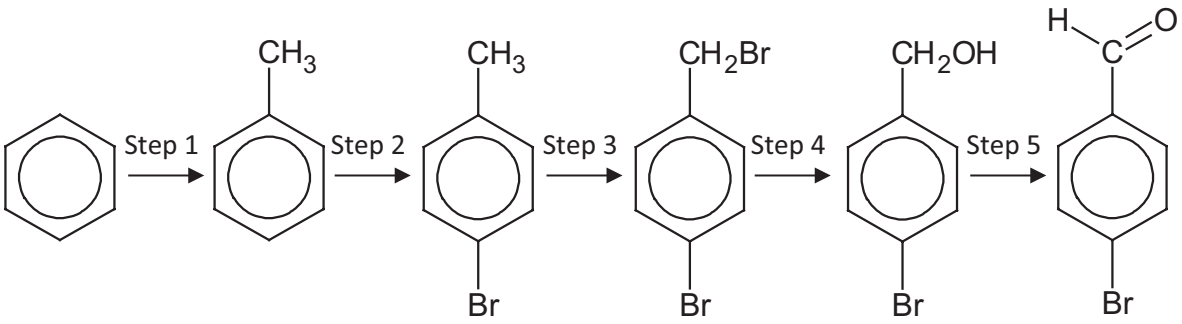
(iii) Explain why the mechanisms for the reactions in **(a)(ii)** are different.

_____

_____

_____ [2]

(b) (4-bromophenyl)methanal can be formed by the sequence of reactions shown below.



(i) Name the reagent and catalyst used in the formation of methylbenzene in Step 1.

reagent: _____

catalyst: _____ [2]

(ii) Methylbenzene reacts with bromine in Step 2 in the same way that benzene reacts with bromine. Including any appropriate equations, outline the mechanism for the catalysed reaction of methylbenzene and bromine in Step 2, using curly arrows.

[5]

[Turn over

(iii) Suggest the name for the reaction mechanism which occurs during Step 3 of the reaction sequence.

_____ [1]

(iv) Name the reagent and the reaction conditions needed to carry out Step 5.

reagent: _____

conditions: _____ [2]

(v) The sample of (4-bromophenyl)methanal obtained contains an organic impurity. The relative molecular mass of the impurity was determined to be 201.

Draw the structure of this organic impurity and state its IUPAC name.

IUPAC name _____ [2]

(c) (i) (4-bromophenyl)methanal reacts with 2,4-dinitrophenylhydrazine. Write an equation for this reaction.

[2]

(ii) State how the purified organic product formed from the reaction in **c(i)** could be used to confirm the identity of (4-bromophenyl)methanal.

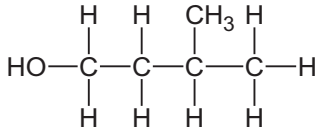
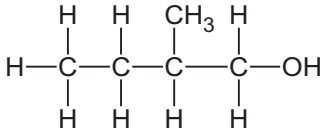
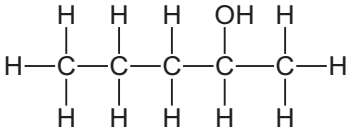
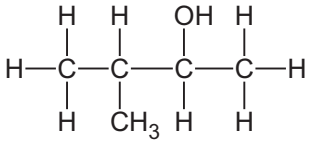
_____

_____ [2]

[Turn over

14 3-methylbutan-1-ol is one of eight alcohols with the molecular formula $C_5H_{12}O$.

(a) (i) Complete the table below for some of the isomers of $C_5H_{12}O$.

Structural formula	Classification	IUPAC name
	primary	3-methylbutan-1-ol
	primary	
		pentan-2-ol
	tertiary	
	secondary	

[5]

(ii) Some of the alcohol isomers are optically active. Define the term **optically active**.

_____

_____ [2]

(iii) Name the alcohols shown in the table in **(a)(i)** which exhibit optical activity.

_____

_____ [2]

(iv) Name the alcohol shown in the table in **(a)(i)** which can be oxidised to produce an optically active compound. Draw the structural formula of the optically active compound.

Name: _____ [2]

[Turn over

(b) 3-methylbutan-1-ol undergoes an esterification reaction with ethanoic acid to form 'banana oil' which is used as a food flavouring.

(i) Write an equation for this esterification reaction.

[2]

(ii) An impure sample of 'banana oil' was obtained in a round-bottomed flask by reacting 3-methylbutan-1-ol with ethanoic acid in the presence of a concentrated sulfuric acid catalyst. The impure sample of the 'banana oil' was collected by distillation. Describe how the sample could be further purified by removing acidic impurities and water.

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

[6]

(c) Coconut oil contains a large proportion of the triglyceride, glyceryl trilaurate. The fatty acid in this triglyceride is lauric acid, $CH_3(CH_2)_{10}COOH$.

(i) Draw the structure of glyceryl trilaurate.

[1]

(ii) Explain why glyceryl trilaurate is a solid at room temperature.

_____

_____

_____ [2]

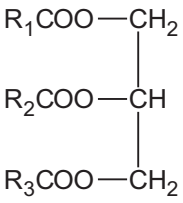
(iii) Biodiesel can be produced from oils such as coconut oil by a transesterification reaction. Define the term **transesterification**.

_____

_____ [2]

[Turn over

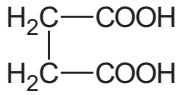
(iv) An oil, with the general formula shown below, can be used in the formation of biodiesel.



Write the equation for the formation of biodiesel by heating the oil with an excess of ethanol in the presence of a catalyst.

[2]

15 Succinic acid is a dicarboxylic acid. It is a white solid at room temperature and melts at 184 °C. It has a solubility in water of 0.0580 kg dm^{-3} at 20 °C.



succinic acid

(a) (i) Explain why succinic acid has a relatively high melting point.

_____

_____

_____ [2]

(ii) Calculate the molarity of a saturated solution of succinic acid at 20 °C. Give your answer to 3 significant figures.

_____

_____

_____

_____ [2]

[Turn over

(b) Succinic acid undergoes two successive acid ionisation reactions with $pK_a1 = 4.30$ and $pK_a2 = 5.60$.

(i) Write an expression for the first acid dissociation constant for succinic acid.

[1]

(ii) Using the pK_a1 value, calculate the pH of a 0.100 mol dm^{-3} solution of succinic acid. Give your answer to 2 decimal places.

[3]

(c) Dimethyl succinate ($C_6H_{10}O_4$) is a fruit-flavoured additive for ice-cream and chewing gum. It can be hydrolysed to form succinic acid and methanol.

$$C_6H_{10}O_4 + 2H_2O \rightleftharpoons C_4H_6O_4 + 2CH_3OH$$

A mixture of 2.0 moles of dimethyl succinate in 5.0 moles of water is left to reach equilibrium in the presence of an acid catalyst at 50 °C. At equilibrium 1.4 moles of dimethyl succinate are present. Calculate the value for K_c in this equilibrium at 50 °C. Give your answer to 2 significant figures.

[4]

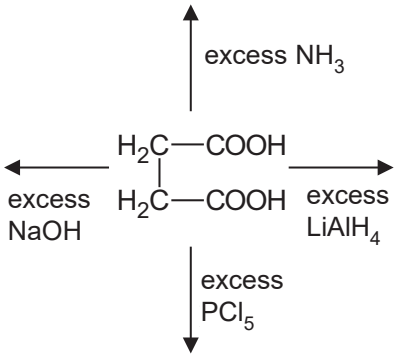
[Turn over

(d) Sodium ethanoate, used in the production of dimethyl succinate, can also be used in buffer solutions. Solid sodium ethanoate (relative formula mass = 82) is added to 250 cm^3 of a 0.1 mol dm^{-3} solution of ethanoic acid to form a buffer with pH 4.80. The K_a of ethanoic acid is 1.74×10^{-5} mol dm^{-3}.

Calculate the mass of sodium ethanoate required and give your answer to 3 significant figures.

[4]

(e) Give the structures of the organic products for the reaction of succinic acid with an excess of each reagent.



[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.

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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

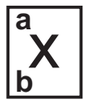
chemistry

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

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