



Rewarding Learning

**ADVANCED**  
**General Certificate of Education**  
**2025**

Centre Number

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Candidate Number

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# Chemistry

Assessment Unit A2 1

*assessing*

Further Physical and  
Organic Chemistry



**[ACH14]**

\*ACH14\*

**TUESDAY 27 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.

In **Section A**, answer each question by circling the appropriate letter below the question.

In **Section 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 questions in black ink only and use a dark HB pencil for drawings and graphs.

**Do not write with a gel pen.**

Answer **all seventeen** questions.

## INFORMATION FOR CANDIDATES

The total mark for this paper is 110.

Figures in brackets printed down the right-hand side of pages indicate the marks awarded to each question or part question.

You may use a scientific calculator.

Quality of written communication will be assessed in Questions **11(a)** and **14(b)(i)**.

A Data Leaflet, which includes a Periodic Table of the Elements, is included in this question paper.

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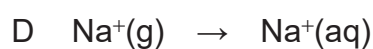
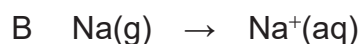
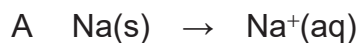
\*36ACH1401\*

## 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 by circling the appropriate letter below the question.**

**1** Which one of the following represents the enthalpy of hydration of sodium ions?



Answer:                    A                    B                    C                    D                    [1]

**2** Which one of the following shows the correct observations for the reactions?

		Reaction with Tollens' reagent	Reaction with sodium carbonate solution	Reaction with acidified potassium dichromate(VI) solution
A	propanal	silver mirror	no reaction	orange to green
B	propanone	silver mirror	no reaction	orange to green
C	propan-1-ol	no reaction	effervescence	no reaction
D	propanoic acid	silver mirror	effervescence	no reaction

Answer:                    A                    B                    C                    D                    [1]



3 Which one of the following mixtures would form a buffer solution?

- A 25.0 cm<sup>3</sup> of 0.1 M CH<sub>3</sub>COOH(aq) + 15.0 cm<sup>3</sup> of 0.2 M NaOH(aq)
- B 25.0 cm<sup>3</sup> of 0.1 M H<sub>2</sub>SO<sub>4</sub>(aq) + 15.0 cm<sup>3</sup> of 0.2 M NaOH(aq)
- C 25.0 cm<sup>3</sup> of 0.1 M CH<sub>3</sub>COOH(aq) + 10.0 cm<sup>3</sup> of 0.15 M NaOH(aq)
- D 25.0 cm<sup>3</sup> of 0.1 M H<sub>2</sub>SO<sub>4</sub>(aq) + 25.0 cm<sup>3</sup> of 0.2 M NaOH(aq)

Answer:                    A                    B                    C                    D                    [1]

4 Which one of the following **cannot** be reduced to form a primary alcohol?

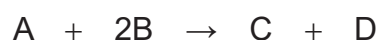
- A butanal
- B ethanal
- C propanoic acid
- D propanone

Answer:                    A                    B                    C                    D                    [1]

[Turn over



5 For the reaction below, the rate equation is  $\text{rate} = k[\text{A}]^2$ .

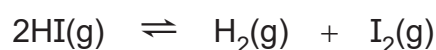


Which one of the following statements is **not** true?

- A The rate of disappearance of B is twice the rate of disappearance of A
- B The reaction is second order with respect to A
- C The reaction is zero order with respect to B
- D The units of the rate constant are  $\text{mol}^{-2} \text{dm}^6 \text{s}^{-1}$

Answer:                    A                    B                    C                    D                    [1]

6 For the reaction:



$K_c = 0.0625$  at 450 K.

3 moles of hydrogen iodide in a container of volume  $10 \text{ dm}^3$  were allowed to reach equilibrium at 450 K. Which one of the following is the concentration of hydrogen iodide, in  $\text{mol dm}^{-3}$ , in the equilibrium mixture?

- A 0.05
- B 0.2
- C 0.25
- D 2

Answer:                    A                    B                    C                    D                    [1]



- 7 Which one of the following shows the correct IUPAC name of the ester formed from the reaction between compounds 1 and 2?

	Compound 1	Compound 2	IUPAC name of ester
A	butanoyl chloride	ethanol	butyl ethanoate
B	ethanoyl chloride	methanol	ethyl methanoate
C	ethanoic acid	propan-1-ol	ethyl propanoate
D	propanoic acid	ethanol	ethyl propanoate

Answer:                    A                    B                    C                    D                    [1]

- 8 How many esters exist with the molecular formula  $C_4H_8O_2$ ?

- A 2  
B 3  
C 4  
D 5

Answer:                    A                    B                    C                    D                    [1]

- 9 Which one of the following does **not** affect the value of the rate constant?

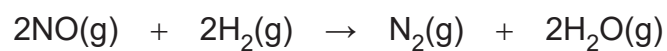
- A decrease in temperature  
B increase in concentration of a reactant  
C increase in temperature  
D decrease in activation energy

Answer:                    A                    B                    C                    D                    [1]

[Turn over



10 The equation for the reaction between nitrogen(II) oxide and hydrogen is:



The table below shows some rate data for this reaction.

Experiment	[NO] /mol dm <sup>-3</sup>	[H <sub>2</sub> ] /mol dm <sup>-3</sup>	Rate /mol dm <sup>-3</sup> s <sup>-1</sup>
1	0.02	0.05	$4.00 \times 10^{-6}$
2	0.05	0.05	$2.50 \times 10^{-5}$
3	0.04	0.08	$2.56 \times 10^{-5}$

Which one of the following is the rate equation for this reaction?

- A rate =  $k[\text{NO}]^2$
- B rate =  $k[\text{NO}][\text{H}_2]$
- C rate =  $k[\text{NO}]^2[\text{H}_2]$
- D rate =  $k[\text{NO}][\text{H}_2]^2$

Answer:                    A                    B                    C                    D                    [1]





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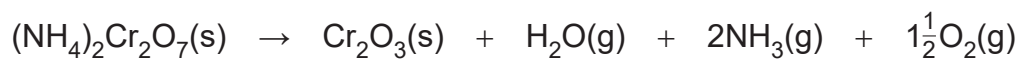
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**\*36ACH1407\***



- (b) With stronger heating, the ammonium dichromate(VI) forms different products as shown by the equation below.



The table below gives some enthalpy and entropy data for the reaction above.

Substance	Enthalpy of formation /kJ mol <sup>-1</sup>	Entropy /J K <sup>-1</sup> mol <sup>-1</sup>
(NH <sub>4</sub> ) <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> (s)	-1801	114
Cr <sub>2</sub> O <sub>3</sub> (s)	-1128	82
H <sub>2</sub> O(g)	-242	189
NH <sub>3</sub> (g)	-46	193
O <sub>2</sub> (g)	0	205

- (i) It was suggested that the nitrogen and water vapour from the initial reaction in (a), react to form ammonia and oxygen. Write an equation for the reaction between nitrogen and water vapour to form ammonia and oxygen.

\_\_\_\_\_ [2]

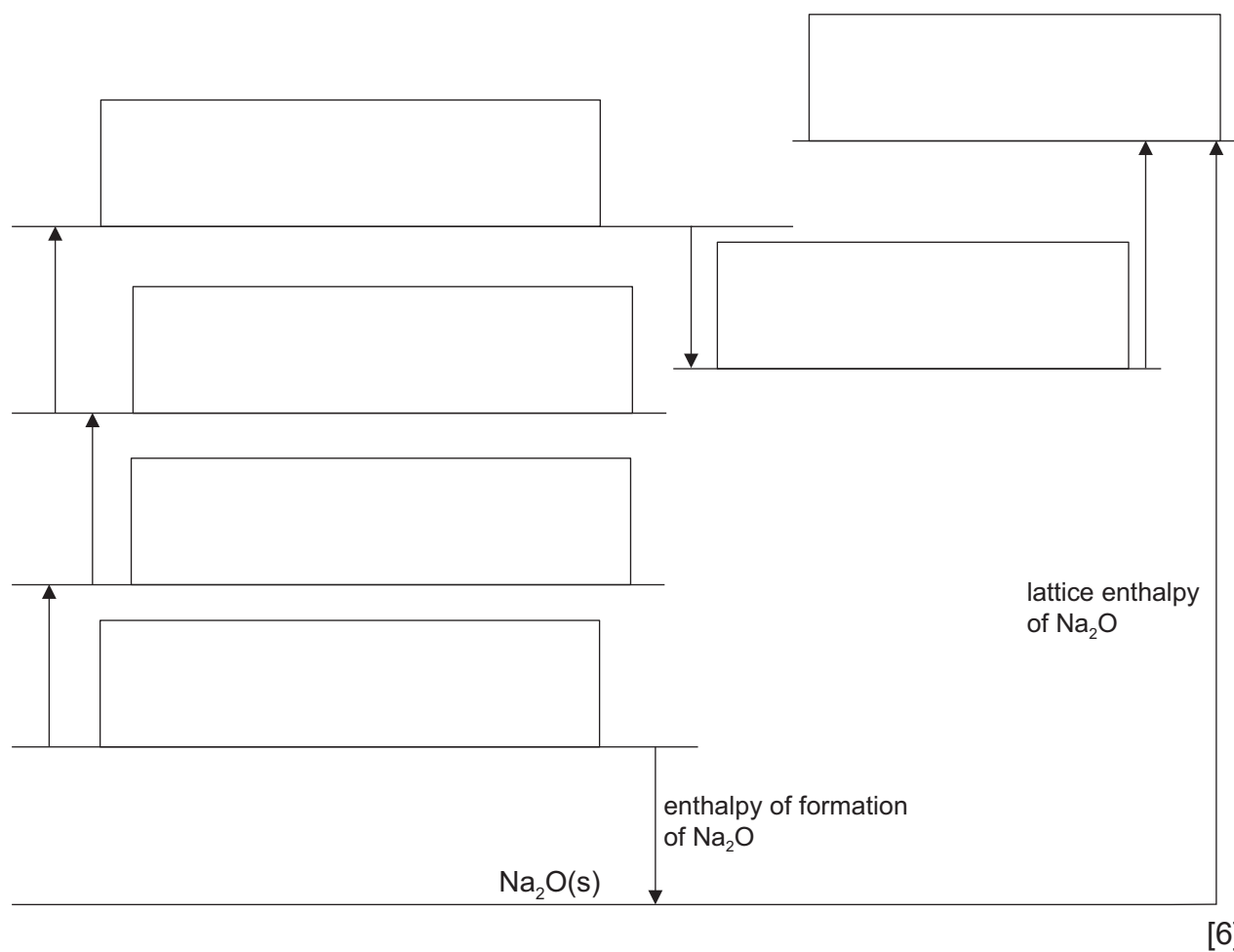
- (ii) Calculate the temperature at which the reaction in (b) becomes feasible.

Answer \_\_\_\_\_ K [4]

[Turn over



12 (a) (i) Complete the Born–Haber cycle below for sodium oxide,  $\text{Na}_2\text{O}(\text{s})$ , by filling in the boxes.



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\*36ACH1410\*

(ii) Calculate the lattice enthalpy of sodium oxide using the information in the table below.

Enthalpy change	$\Delta H^\ominus$ /kJ mol <sup>-1</sup>
Enthalpy of formation of sodium oxide	-416
Enthalpy of atomisation of sodium	+108
First ionisation energy of sodium	+500
Enthalpy of atomisation of oxygen	+249
First electron affinity of oxygen	-141
Second electron affinity of oxygen	+791

Answer \_\_\_\_\_ kJ mol<sup>-1</sup> [3]

[Turn over

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\*36ACH1411\*

(b) The ionic equation below shows the reaction occurring when sodium oxide reacts with water.



Identify the Brønsted–Lowry acid and Brønsted–Lowry base from the ionic equation and explain your answer.

Brønsted–Lowry acid \_\_\_\_\_

Brønsted–Lowry base \_\_\_\_\_

Explanation \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_ [3]



**13** Benzene reacts with bromine and with ethanoyl chloride. Both reactions require a catalyst.

**(a) (i)** Complete the table below.

Reaction of benzene	Name of organic product	Name of catalyst
with bromine	bromobenzene	
with ethanoyl chloride		

[3]

**(ii)** Write an equation for the reaction of benzene with bromine to form bromobenzene.

\_\_\_\_\_ [1]

**(iii)** Name the mechanism by which benzene reacts with bromine and with ethanoyl chloride.

\_\_\_\_\_ [1]

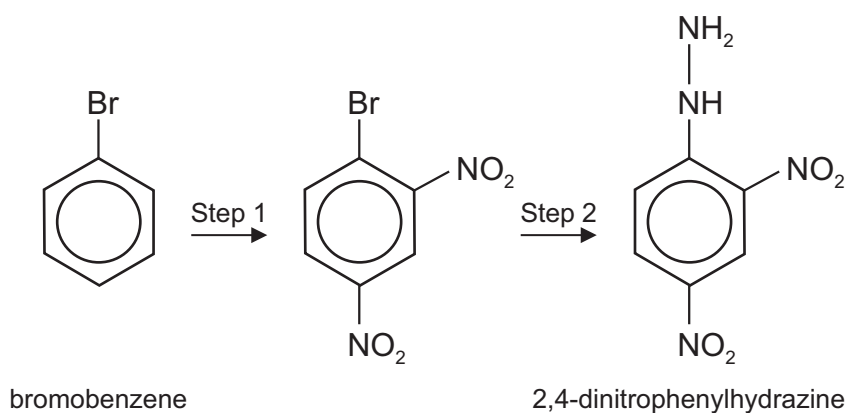
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\*36ACH1413\*

- (b) 2,4-dinitrophenylhydrazine can be synthesised from bromobenzene as shown below. The mechanism for Step 1 involves the reaction of bromobenzene with nitronium ions formed in a nitrating mixture. The nitrated product, formed in Step 1, reacts with hydrazine in Step 2 to form 2,4-dinitrophenylhydrazine.



- (i) In Step 1, name the two reagents in the nitrating mixture.

\_\_\_\_\_ [2]

- (ii) Write an equation for the formation of the nitronium ion in the nitrating mixture.

\_\_\_\_\_ [2]

- (iii) Write an equation for Step 1.

\_\_\_\_\_ [1]



(iv) Suggest the formula for hydrazine.

\_\_\_\_\_ [1]

(c) 2,4-dinitrophenylhydrazine reacts with aldehydes and with ketones.

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

\_\_\_\_\_ [2]

(ii) Name the type of reaction which occurs between 2,4-dinitrophenylhydrazine and propanal.

\_\_\_\_\_ [1]



14 (a) The table below gives details of four different substances dissolved in deionised water. Some data is missing.

Substance	Formula	Mass /g	Volume of solution /cm <sup>3</sup>	pH of solution
nitric acid	HNO <sub>3</sub>	0.49	125	
sodium ethanoate	CH <sub>3</sub> COONa	2.50	100	8.62
sodium hydroxide	NaOH	1.76		13.74
2-chloropropanoic acid	CH <sub>3</sub> CHClCOOH	2.19	500	2.11

(i) Calculate the pH of the solution of nitric acid. Give your answer to 2 decimal places.

Answer \_\_\_\_\_ [3]

(ii) Explain why the solution of sodium ethanoate is alkaline.

\_\_\_\_\_  
\_\_\_\_\_ [1]



(iii) Calculate the volume of solution for sodium hydroxide.

$$K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}.$$

Answer \_\_\_\_\_  $\text{cm}^3$  [4]

(iv) Calculate the  $\text{p}K_a$  of 2-chloropropanoic acid. Give your answer to 2 decimal places.

Answer \_\_\_\_\_ [4]

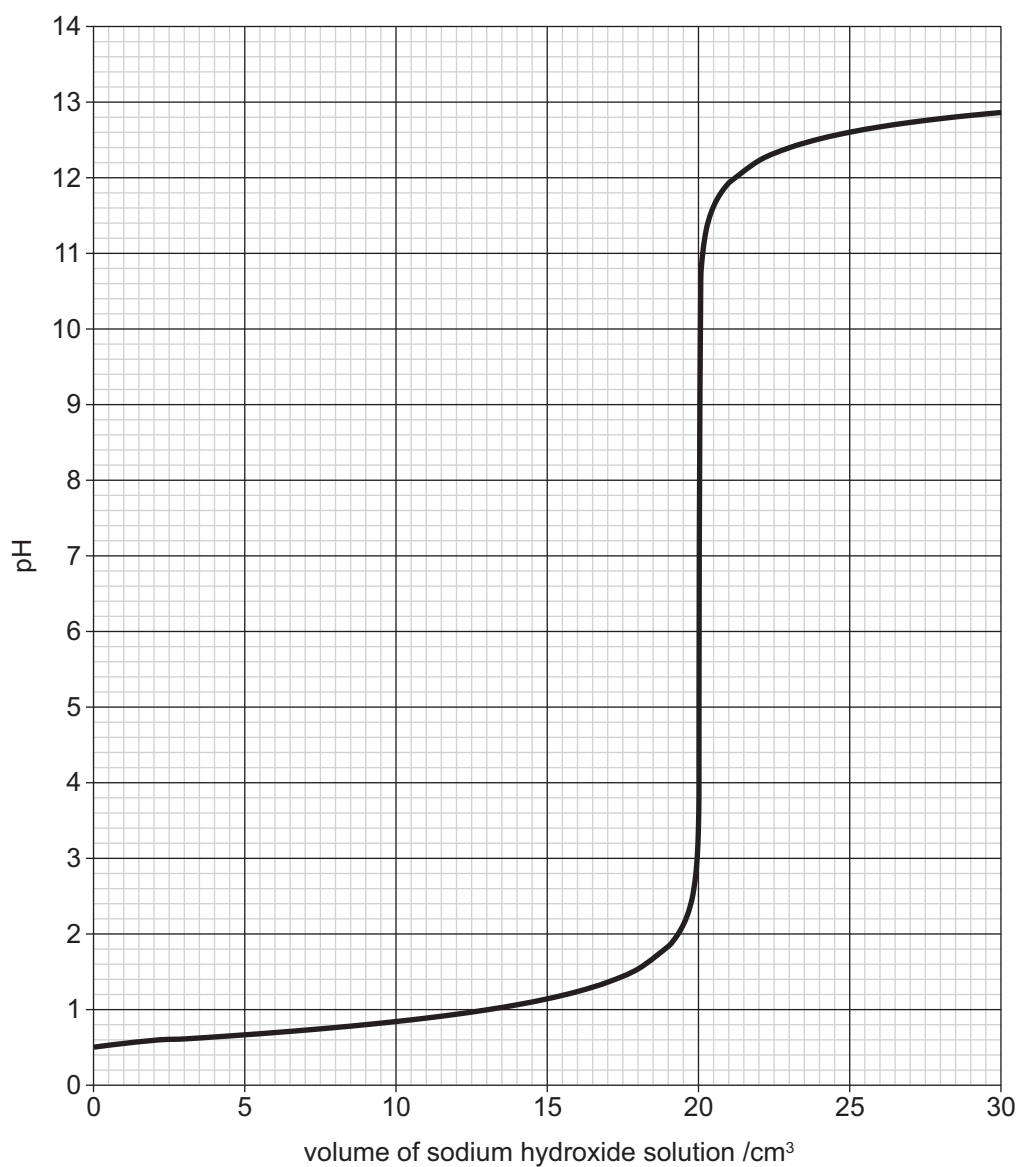
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\*36ACH1417\*

(b) A sample of  $25.0\text{ cm}^3$  of a solution of sulfuric acid was titrated against a solution of sodium hydroxide. The titration curve obtained is shown below.



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\*36ACH1418\*



(iii) State the initial pH of the sulfuric acid.

Answer \_\_\_\_\_ [1]

(iv) Calculate the concentration of the sulfuric acid in mol dm<sup>-3</sup>. Give your answer to 3 significant figures.

Answer \_\_\_\_\_ mol dm<sup>-3</sup> [2]

(v) Suggest the name of a suitable indicator for this titration and state the colour change at the end point.

Indicator \_\_\_\_\_

From \_\_\_\_\_ to \_\_\_\_\_ [2]





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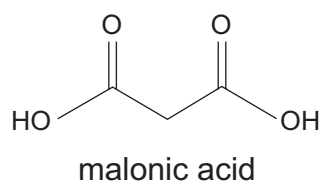
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\*36ACH1421\*

15 Malonic acid is found in fruit and vegetables.



(a) State the IUPAC name for malonic acid.

\_\_\_\_\_ [1]

(b) Malonic acid may be dehydrated to form tricarbon dioxide,  $C_3O_2$ .

(i) Write an equation for this dehydration.

\_\_\_\_\_ [1]

(ii) Suggest a structural formula for tricarbon dioxide.

[1]



(c) Malonic acid reacts with phosphorus pentachloride.

(i) Write an equation for the reaction of malonic acid with excess phosphorus pentachloride.

\_\_\_\_\_ [2]

(ii) Suggest a name for the organic product.

\_\_\_\_\_ [1]

(d) The diester diethyl malonate is found in grapes and strawberries.

(i) Write an equation for the formation of diethyl malonate from malonic acid.

[2]

(ii) Explain why diethyl malonate is a liquid at room temperature whereas malonic acid is a solid.

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_ [2]

[Turn over



(e) Malonic acid reacts with excess lithium tetrahydridoaluminate(III) to form a diol.

(i) Write the formula of lithium tetrahydridoaluminate(III).

\_\_\_\_\_ [1]

(ii) Name the type of reaction which occurs between malonic acid and lithium tetrahydridoaluminate(III).

\_\_\_\_\_ [1]

(iii) Write an equation for the reaction of malonic acid with lithium tetrahydridoaluminate(III).

\_\_\_\_\_ [2]





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**[Turn over**



\*36ACH1425\*

- 16 Fats are formed from propane-1,2,3-triol and fatty acids. Fatty acids can be described as saturated or unsaturated. The table below shows four fatty acids labelled A, B, C and D.

Fatty acid	Structure	IUPAC name
A	$\text{CH}_3(\text{CH}_2)_{16}\text{COOH}$	octadecanoic acid
B	$\text{CH}_3(\text{CH}_2)_7\text{CH}=\text{CH}(\text{CH}_2)_7\text{COOH}$	octadec-9-enoic acid
C	$\text{CH}_3\text{CH}_2\text{CH}=\text{CHCH}_2\text{CH}=\text{CHCH}_2\text{CH}=\text{CH}(\text{CH}_2)_7\text{COOH}$	octadec-9,12,15-trienoic acid
D	$\text{CH}_3(\text{CH}_2)_4\text{CH}=\text{CHCH}_2\text{CH}=\text{CH}(\text{CH}_2)_7\text{COOH}$	octadec-9,12-dienoic acid

- (a) What is the common name of propane-1,2,3-triol?

\_\_\_\_\_ [1]

- (b) Suggest why all the fatty acids (A, B, C and D) have “octadec” in their IUPAC names.

\_\_\_\_\_  
\_\_\_\_\_ [1]



(c) Draw the structure of the two fat molecules which may be formed when one molecule of propane-1,2,3-triol reacts with two molecules of fatty acid A and one molecule of fatty acid B.

Fat molecule 1:

Fat molecule 2:

[2]

(d) Classify each of the fatty acids (A, B, C and D) as saturated or unsaturated.

Saturated \_\_\_\_\_

Unsaturated \_\_\_\_\_ [1]

[Turn over



(e) A fat molecule, which has the molecular formula  $C_{57}H_{94}O_6$ , is formed from propane-1,2,3-triol and fatty acid molecules from the table. The fat can undergo hydrogenation and transesterification reactions.

(i) Name the catalyst used in the hydrogenation of fats.

\_\_\_\_\_ [1]

(ii) Write an equation for the complete hydrogenation of the fat,  $C_{57}H_{94}O_6$ .

\_\_\_\_\_ [2]

(iii) Suggest which fatty acid molecules (A, B, C, D) were used to form the fat molecule.

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_ [1]

(iv) Define **transesterification**.

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_ [2]

(v) State one use of the products of a transesterification reaction.

\_\_\_\_\_ [1]





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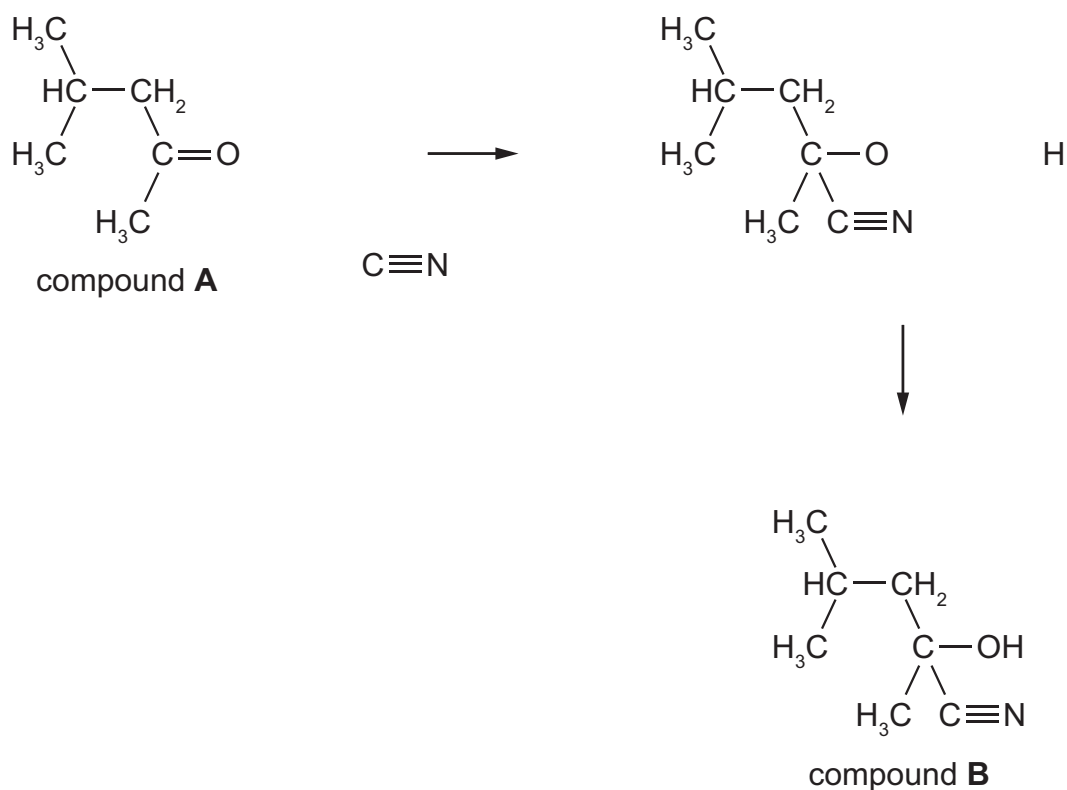
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\*36ACH1429\*

17 Aldehydes and ketones react with hydrogen cyanide.

- (a) (i) Complete the mechanism below for the reaction of compound **A** with hydrogen cyanide by adding relevant charges, lone pairs and curly arrows.



[3]

- (ii) Name the mechanism.

\_\_\_\_\_ [1]

- (iii) State the IUPAC name for compound **A**.

\_\_\_\_\_ [1]



(b) Compound **B** formed in (a)(i) has an asymmetric centre.

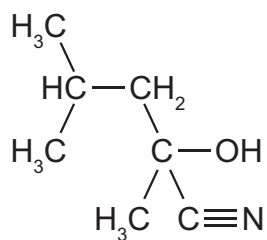
(i) Define the term **asymmetric centre**.

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[1]

(ii) Label the asymmetric centre using an asterisk (\*) on the structure of compound **B** below.



[1]

(iii) Explain why the mixture formed from the reaction of compound **A** with hydrogen cyanide does not show any optical activity.

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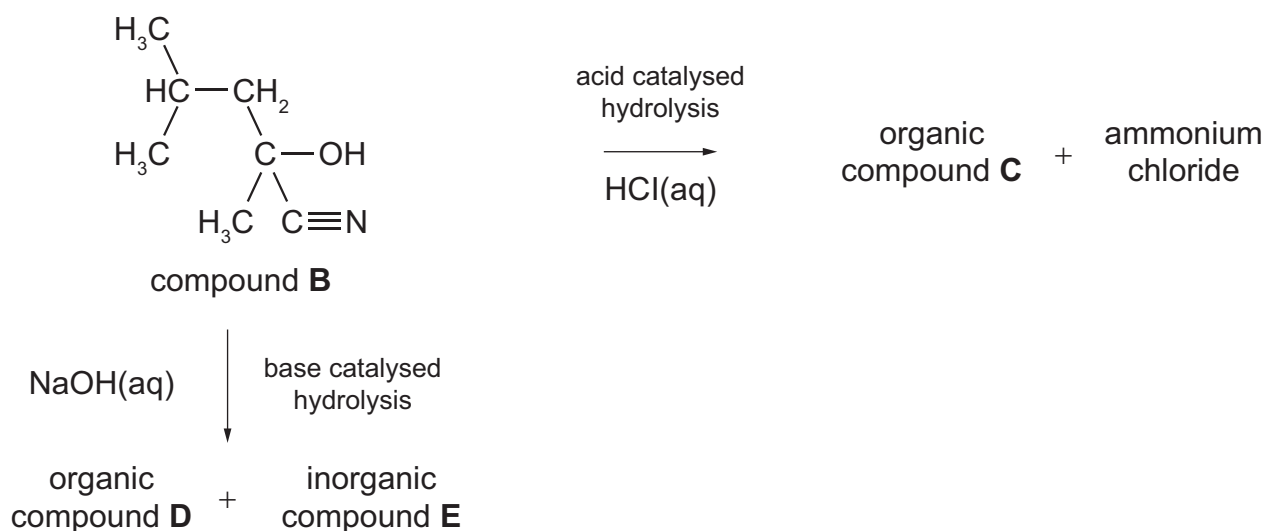
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[1]

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(c) The scheme below details the hydrolysis reactions of compound **B**.



(i) State the IUPAC name for organic compound **C**.

\_\_\_\_\_ [2]

(ii) Name inorganic compound **E**.

\_\_\_\_\_ [1]

(iii) Name the aldehyde or ketone which reacts with hydrogen cyanide to form a compound which undergoes acid hydrolysis to form lactic acid,  $\text{CH}_3\text{CH}(\text{OH})\text{COOH}$ .

\_\_\_\_\_ [1]





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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<sup>3</sup>

Avogadro Constant =  $6.02 \times 10^{23}$  mol<sup>-1</sup>

Planck Constant =  $6.63 \times 10^{-34}$  Js

Specific Heat Capacity of water =  $4.2 \text{ J g}^{-1} \text{ K}^{-1}$

Speed of Light =  $3 \times 10^8 \text{ ms}^{-1}$



## Characteristic absorptions in IR spectroscopy

Wavenumber/cm <sup>-1</sup>	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	–CH	Saturated alkanes
0.5–5.5	–OH	Alcohols
1.0–3.0	–NH	Amines
2.0–3.0	–CO–CH	Ketones
	–N–CH	Amines
	C <sub>6</sub> H <sub>5</sub> –CH	Arene (aliphatic on ring)
2.0–4.0	X–CH	X = Cl or Br (3.0–4.0) X = I (2.0–3.0)
4.5–6.0	–C=CH	Alkenes
5.5–8.5	RCONH	Amides
6.0–8.0	–C <sub>6</sub> H <sub>5</sub>	Arenes (on ring)
9.0–10.0	–CHO	Aldehydes
10.0–12.0	–COOH	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

