



Rewarding Learning

ADVANCED
General Certificate of Education
2025

Centre Number

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Candidate Number

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Chemistry

StemUp Model Solution

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.

14555

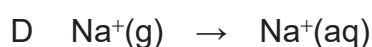
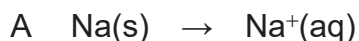


Section A

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: D 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 **A** B C D [1]



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

- A 25.0 cm³ of 0.1 M CH₃COOH(aq) + 15.0 cm³ of 0.2 M NaOH(aq)
- B 25.0 cm³ of 0.1 M H₂SO₄(aq) + 15.0 cm³ of 0.2 M NaOH(aq)
- C 25.0 cm³ of 0.1 M CH₃COOH(aq) + 10.0 cm³ of 0.15 M NaOH(aq)
- D 25.0 cm³ of 0.1 M H₂SO₄(aq) + 25.0 cm³ of 0.2 M NaOH(aq)

Answer: C A B C D [1]

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

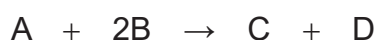
- A butanal
- B ethanal
- C propanoic acid
- D propanone

Answer: D A B C D [1]

[Turn over]



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

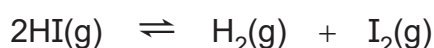


Which one of the following statements is **not** true?

- 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 dm^3 were allowed to reach equilibrium at 450 K. Which one of the following is the concentration of hydrogen iodide, in 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: ☒ D ☐ 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: ☒ C ☐ A ☐ B ☐ C ☐ D [1]

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

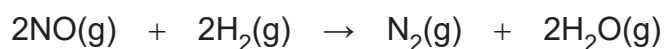
- A decrease in temperature
B increase in concentration of a reactant
C increase in temperature
D decrease in activation energy

Answer: ☒ B ☐ 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 ⁻³	[H ₂] /mol dm ⁻³	Rate /mol dm ⁻³ s ⁻¹
1	0.02	0.05	4.00×10^{-6}
2	0.05	0.05	2.50×10^{-5}
3	0.04	0.08	2.56×10^{-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:

C

A

B

C

D

[1]





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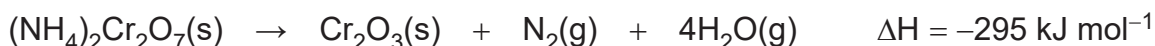
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Section B

Answer all **seven** questions in this section.

- 11 Ammonium dichromate(VI) decomposes on gentle heating according to the equation below.



- (a) Define the terms entropy (S) and free energy change (ΔG). Explain why the decomposition of ammonium dichromate(VI) is feasible at all temperatures and why the reaction requires heating at room temperature.

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

Entropy (S) is a measure of the disorder (randomness) of a system:

the more disordered the particles, the greater the entropy.

The free energy change is $\Delta G = \Delta H - T\Delta S$; a reaction is feasible

when ΔG is negative (or zero).

In this decomposition one mole of solid forms one mole of solid and

five moles of gas, so disorder increases and ΔS is positive ($\Delta S > 0$).

ΔH is negative (-295 kJ mol^{-1}), so the reaction is exothermic.

As $\Delta H < 0$ and $\Delta S > 0$, the term $-T\Delta S$ is always negative, so ΔG is

negative at all temperatures and the reaction is feasible at all

temperatures.

However, the reaction has a high activation energy, so at room

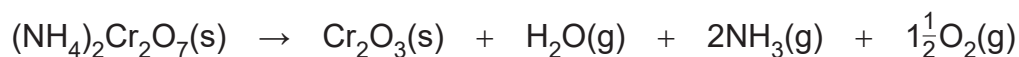
temperature heat is needed to provide the energy to initiate the

reaction.

[6]



- (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 ⁻¹	Entropy /J K ⁻¹ mol ⁻¹
(NH ₄) ₂ Cr ₂ O ₇ (s)	-1801	114
Cr ₂ O ₃ (s)	-1128	82
H ₂ O(g)	-242	189
NH ₃ (g)	-46	193
O ₂ (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.



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

$$\begin{aligned} \Delta S &= [82 + 189 + 2(193) + 1.5(205)] - 114 \\ &= +850.5 \text{ J K}^{-1} \text{ mol}^{-1} = +0.8505 \text{ kJ K}^{-1} \text{ mol}^{-1} \end{aligned}$$

$$\begin{aligned} \Delta H &= [-1128 + (-242) + 2(-46) + 0] - (-1801) \\ &= +339 \text{ kJ mol}^{-1} \end{aligned}$$

$$\text{feasible when } \Delta G = \Delta H - T\Delta S = 0, \text{ so } T = \Delta H \div \Delta S$$

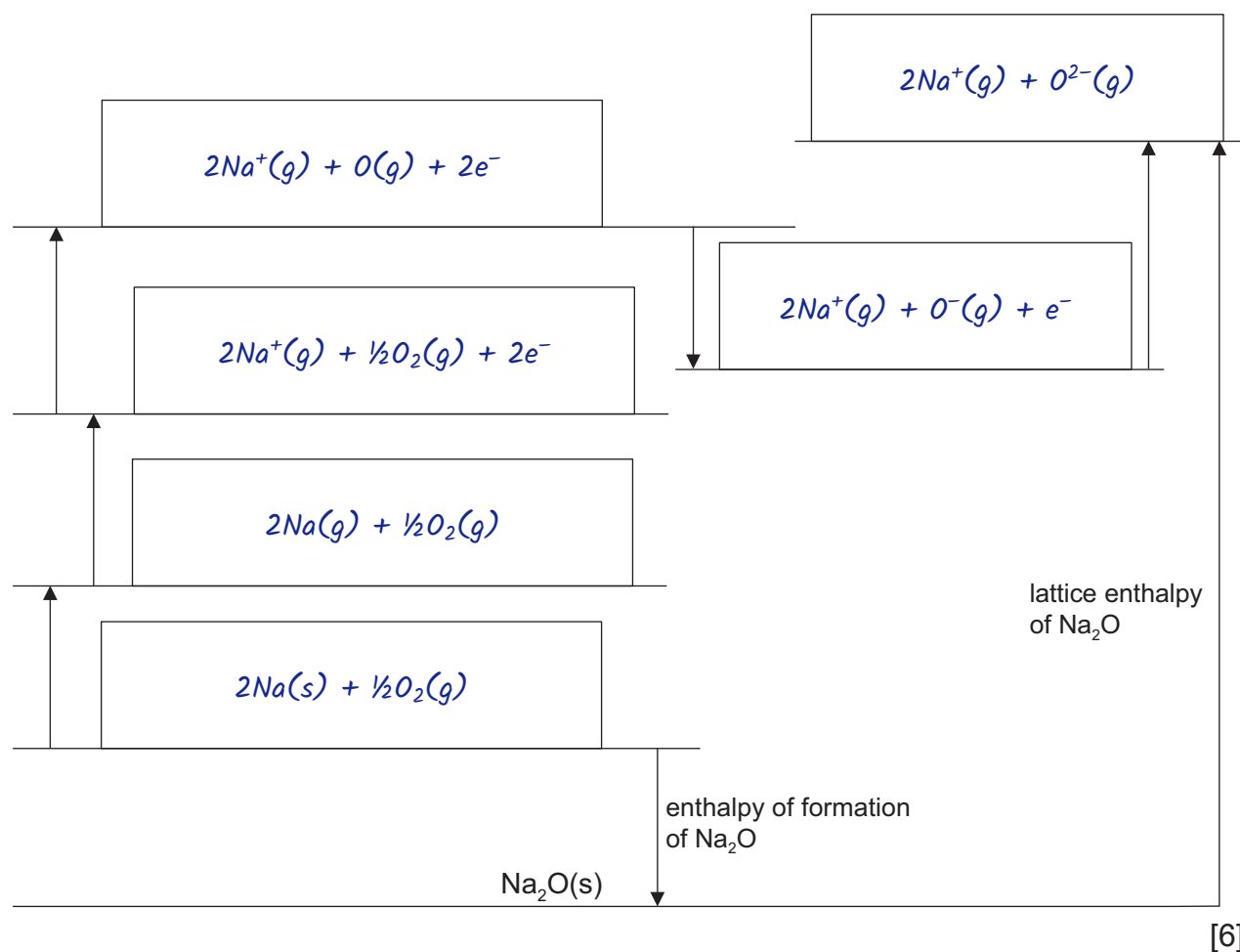
$$T = 339 \div 0.8505 = 398.6 \text{ K}$$

Answer 398.6 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.



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

Enthalpy change	$\Delta H^\ominus / \text{kJ mol}^{-1}$
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

$$\begin{aligned}\text{lattice enthalpy} &= -\Delta H_f + 2\Delta H_{at}(\text{Na}) + 2IE_1(\text{Na}) \\ &\quad + \Delta H_{at}(\text{O}) + EA_1(\text{O}) + EA_2(\text{O}) \\ &= -(-416) + 2(+108) + 2(+500) + 249 + (-141) + 791 \\ &= +2531 \text{ kJ mol}^{-1}\end{aligned}$$

Answer +2531 kJ mol⁻¹ [3]

[Turn over



- (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 H_2O

Brønsted–Lowry base O^{2-}

Explanation H_2O donates a proton (H^+) to O^{2-} , so H_2O is the acid;

O^{2-} accepts the proton, so O^{2-} is the base.

[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	<i>iron(III) bromide</i>
with ethanoyl chloride	<i>phenylethanone</i>	<i>aluminium chloride</i>

[3]

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



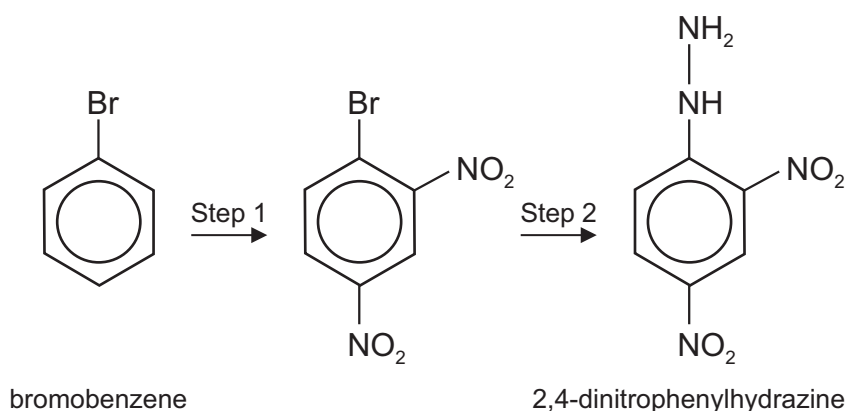
(iii) Name the mechanism by which benzene reacts with bromine and with ethanoyl chloride.

electrophilic substitution [1]

[Turn over]



- (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.

concentrated sulfuric acid

concentrated nitric acid

[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]



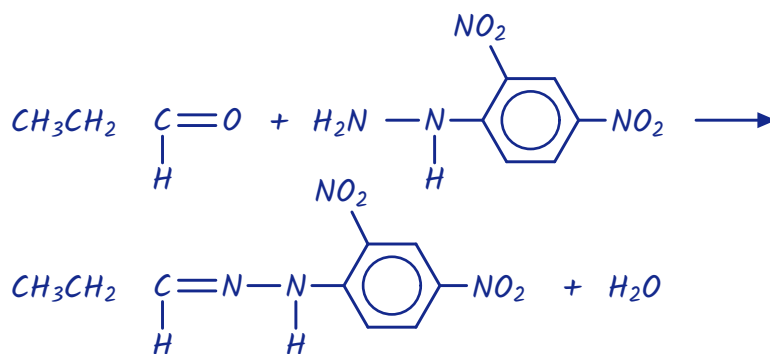
(iv) Suggest the formula for hydrazine.



[1]

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

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



product: propanal 2,4-dinitrophenylhydrazone (orange precipitate)

[2]

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

condensation (addition-elimination)

[1]

[Turn over]



- 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 ³	pH of solution
nitric acid	HNO ₃	0.49	125	
sodium ethanoate	CH ₃ COONa	2.50	100	8.62
sodium hydroxide	NaOH	1.76		13.74
2-chloropropanoic acid	CH ₃ CHClCOOH	2.19	500	2.11

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

$$\text{moles HNO}_3 = 0.49 \div 63 = 7.78 \times 10^{-3} \text{ mol}$$

$$[H^+] = [HNO_3] = 7.78 \times 10^{-3} \div 0.125 = 0.0622 \text{ mol dm}^{-3}$$

$$\text{pH} = -\log_{10}(0.0622) = 1.21$$

Answer 1.21 [3]

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

It is the salt of a strong base and a weak acid; ethanoate ions

react with water: $\text{CH}_3\text{COO}^- + \text{H}_2\text{O} \rightleftharpoons \text{CH}_3\text{COOH} + \text{OH}^-$ [1]



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

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

$$[H^+] = 10^{-13.74} = 1.82 \times 10^{-14} \text{ mol dm}^{-3}$$

$$\begin{aligned} [OH^-] &= K_w \div [H^+] = 1.00 \times 10^{-14} \div 1.82 \times 10^{-14} \\ &= 0.55 \text{ mol dm}^{-3} \end{aligned}$$

$$\text{moles NaOH} = 1.76 \div 40 = 0.044 \text{ mol}$$

$$\text{volume} = 0.044 \div 0.55 \times 1000 = 80 \text{ cm}^3$$

Answer 80 cm³ [4]

(iv) Calculate the pK_a of 2-chloropropanoic acid. Give your answer to 2 decimal places.

$$[H^+] = 10^{-2.11} = 7.76 \times 10^{-3} \text{ mol dm}^{-3}$$

$$M_r = 108.5; \text{ moles acid} = 2.19 \div 108.5 = 0.0202 \text{ mol}$$

$$[\text{acid}] = 0.0202 \div 0.500 = 0.0404 \text{ mol dm}^{-3}$$

$$\begin{aligned} K_a &= [H^+]^2 \div [HA] = (7.76 \times 10^{-3})^2 \div 0.0404 \\ &= 1.49 \times 10^{-3} \text{ mol dm}^{-3} \end{aligned}$$

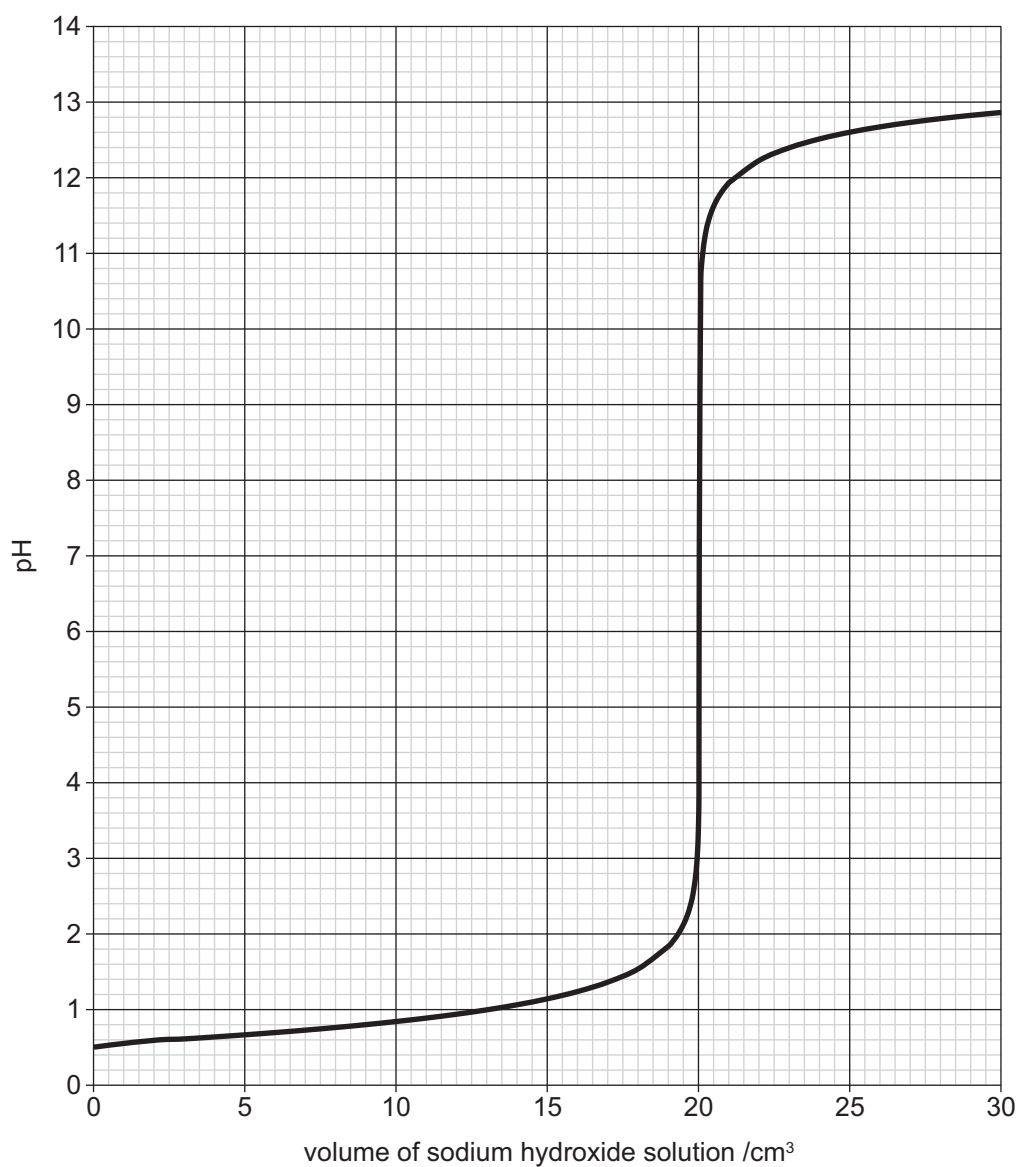
$$pK_a = -\log_{10}(1.49 \times 10^{-3}) = 2.83$$

Answer 2.83 [4]

[Turn over]



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



- (i) Describe, giving practical details, how an experiment was carried out to obtain the pH results needed to draw this titration curve.

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

Using a pipette and pipette filler, transfer 25.0 cm³ of the sulfuric acid into a conical flask (or beaker) containing a magnetic stirrer bar.

Calibrate a pH meter using buffer solutions, place the probe in the acid and record the initial pH.

Fill a burette with the sodium hydroxide solution and record the initial burette reading.

Add the sodium hydroxide from the burette in 5 cm³ portions, stirring (magnetic stirrer) after each addition, and record the pH after each addition.

As the end point approaches (about 15 to 25 cm³), add the sodium hydroxide in 1 cm³ portions (or dropwise), recording the pH each time.

Continue adding until about 30 cm³ has been added, then plot pH against volume of sodium hydroxide.

[6]

- (ii) What volume of sodium hydroxide solution was required to neutralise the sulfuric acid?

Answer 20 cm³ [1]

[Turn over]



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

Answer 0.5 [1]

(iv) Calculate the concentration of the sulfuric acid in mol dm^{-3} . Give your answer to 3 significant figures.

$$[H^+] = 10^{-0.5} = 0.316 \text{ mol dm}^{-3}$$

$$H_2SO_4 \text{ is diprotic: } [H_2SO_4] = 0.316 \div 2 = 0.158$$

Answer 0.158 mol dm^{-3} [2]

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

Indicator phenolphthalein

From colourless to pink [2]





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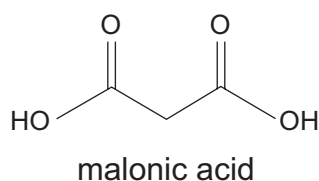
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15 Malonic acid is found in fruit and vegetables.



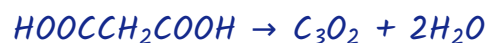
(a) State the IUPAC name for malonic acid.

propanedioic 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.

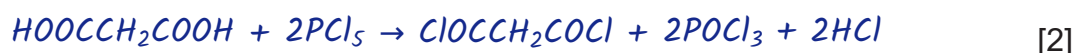


[1]



(c) Malonic acid reacts with phosphorus pentachloride.

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



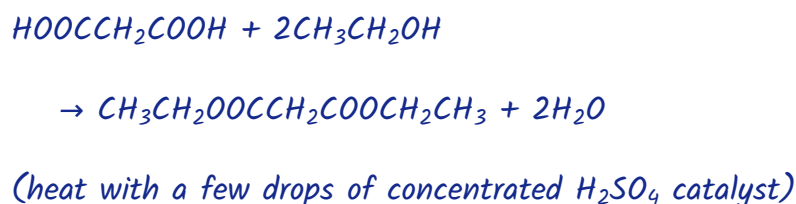
- (ii) Suggest a name for the organic product.

propanedioyl dichloride

 [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.

Between diethyl malonate molecules there are only van der Waals

forces and permanent dipole-dipole attractions.

Malonic acid molecules form stronger hydrogen bonds between

them, which need more energy to break.

 [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).

reduction

[1]

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



[2]





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[Turn over



- 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?

glycerol

[1]

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

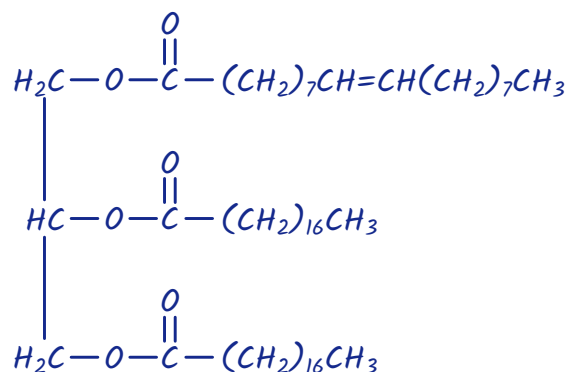
They all contain a chain of 18 carbon atoms (octadec = 18 carbons).

[1]

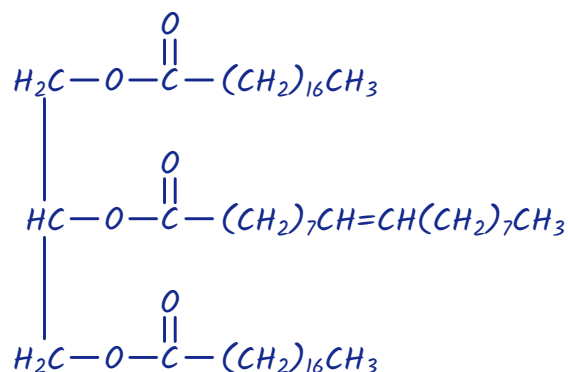


- (c) Draw the structure of the two fat molecules which may be formed when one molecule of propane-1,2,3-triol reacts with two molecules of fatty acid A and one molecule of fatty acid B.

Fat molecule 1:



Fat molecule 2:



[2]

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

Saturated A

Unsaturated B, C and D [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.

nickel [1]

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

$C_{57}H_{94}O_6 + 8H_2 \rightarrow C_{57}H_{110}O_6$ [2]

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

two molecules of C and one molecule of D

_____ [1]

(iv) Define **transesterification**.

A reaction in which the alkyl group of an ester is exchanged
with the alkyl group of an alcohol, forming a new ester and a
new alcohol. [2]

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

making biodiesel (fuel) [1]





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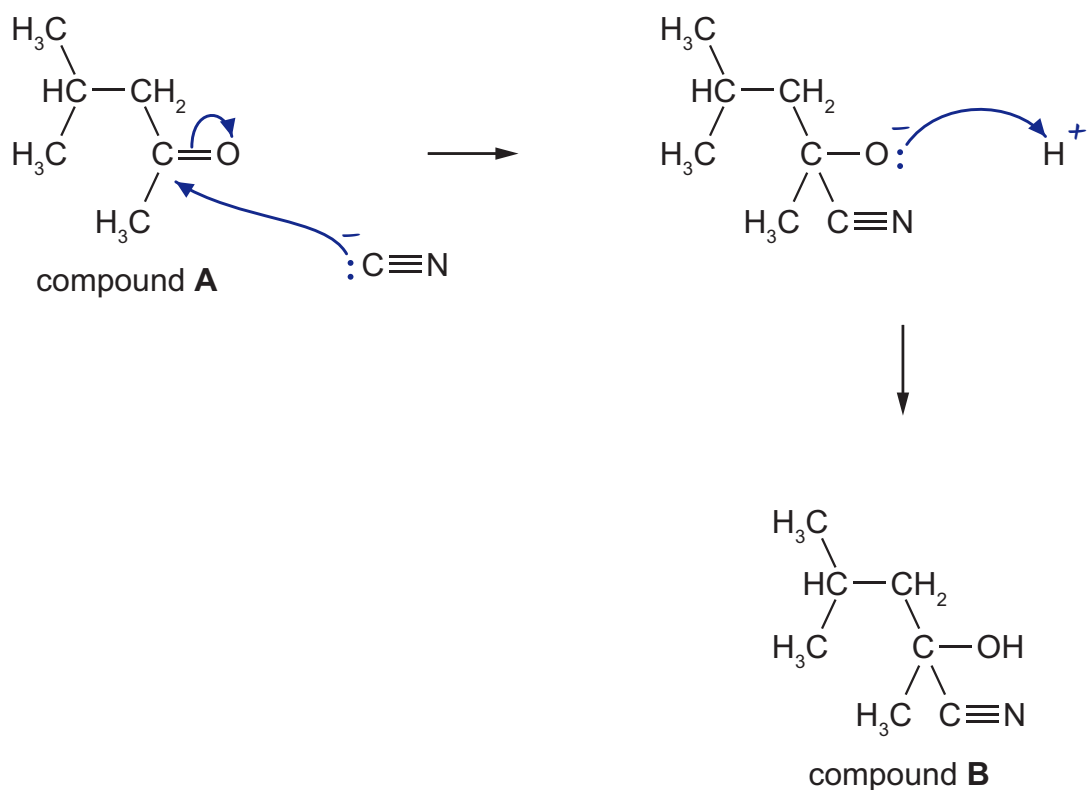
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[Turn over



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.

nucleophilic addition

[1]

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

4-methylpentan-2-one

[1]



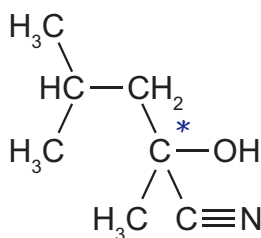
(b) Compound **B** formed in (a)(i) has an asymmetric centre.

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

A carbon atom with four different atoms or groups attached to it.

[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.

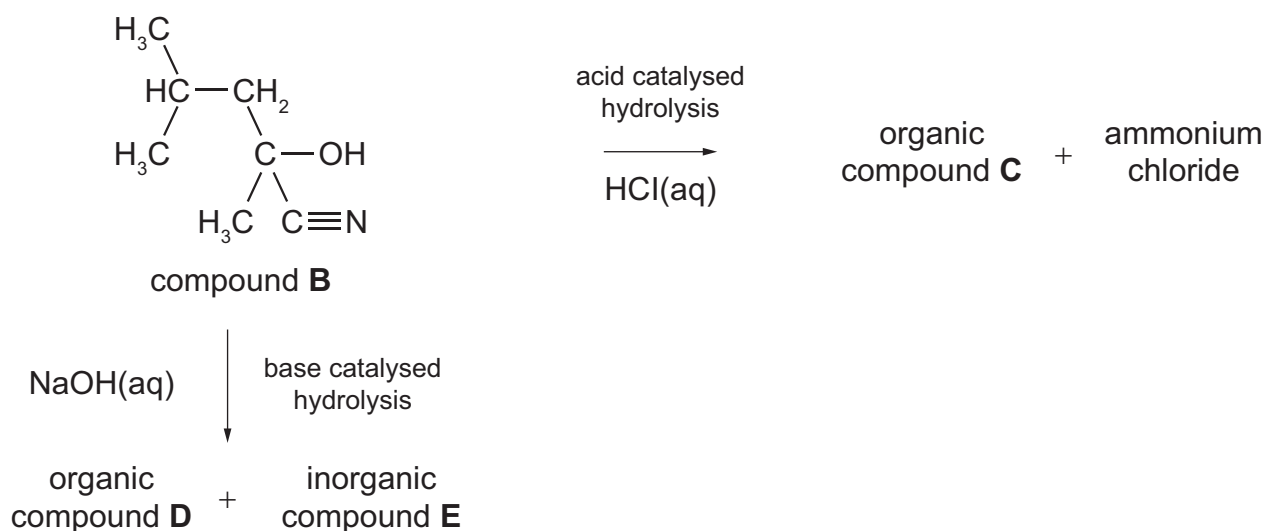
The planar C=O group is attacked by CN⁻ equally from above and below, so equal amounts of both optical isomers form: a racemic mixture, whose effects on plane-polarised light cancel.

[1]

[Turn over]



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



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

2-hydroxy-2,4-dimethylpentanoic acid

[2]

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

ammonia

[1]

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

ethanal

[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 dm³

Avogadro Constant = 6.02×10^{23} mol⁻¹

Planck Constant = 6.63×10^{-34} Js

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

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



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	–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 ₆ H ₅ –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 ₆ H ₅	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

THE PERIODIC TABLE OF ELEMENTS																			
I	II	Group												III	IV	V	VI	VII	0
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18		
1 H Hydrogen																	4 He Helium		
7 Li Lithium	9 Be Beryllium											11 B Boron	12 C Carbon	14 N Nitrogen	16 O Oxygen	19 F Fluorine	20 Ne Neon		
23 Na Sodium	24 Mg Magnesium											27 Al Aluminium	28 Si Silicon	31 P Phosphorus	32 S Sulfur	35.5 Cl Chlorine	40 Ar Argon		
39 K Potassium	40 Ca Calcium	45 Sc Scandium	48 Ti Titanium	51 V Vanadium	52 Cr Chromium	55 Mn Manganese	56 Fe Iron	59 Co Cobalt	59 Ni Nickel	64 Cu Copper	65 Zn Zinc	70 Ga Gallium	73 Ge Germanium	75 As Arsenic	79 Se Selenium	80 Br Bromine	84 Kr Krypton		
85 Rb Rubidium	88 Sr Strontium	89 Y Yttrium	91 Zr Zirconium	93 Nb Niobium	96 Mo Molybdenum	98 Tc Technetium	101 Ru Ruthenium	103 Rh Rhodium	106 Pd Palladium	108 Ag Silver	112 Cd Cadmium	115 In Indium	119 Sn Tin	122 Sb Antimony	128 Te Tellurium	127 I Iodine	131 Xe Xenon		
133 Cs Caesium	137 Ba Barium	139 La [*] Lanthanum	178 Hf Hafnium	181 Ta Tantalum	184 W Tungsten	186 Re Rhenium	190 Os Osmium	192 Ir Iridium	195 Pt Platinum	197 Au Gold	201 Hg Mercury	204 Tl Thallium	207 Pb Lead	209 Bi Bismuth	210 Po Polonium	210 At Astatine	222 Rn Radon		
223 Fr Francium	226 Ra Radium	227 Ac [†] Actinium	261 Rf Rutherfordium	262 Db Dubnium	266 Sg Seaborgium	264 Bh Bohrium	277 Hs Hassium	268 Mt Meitnerium	271 Ds Darmstadtium	272 Rg Roentgenium	285 Cn Copernicium								
			140 Ce Cerium	141 Pr Praseodymium	144 Nd Neodymium	145 Pm Promethium	150 Sm Samarium	152 Eu Europium	157 Gd Gadolinium	159 Tb Terbium	162 Dy Dysprosium	165 Ho Holmium	167 Er Erbium	169 Tm Thulium	173 Yb Ytterbium	175 Lu Lutetium			
			232 Th Thorium	231 Pa Protactinium	238 U Uranium	237 Np Neptunium	242 Pu Plutonium	243 Am Americium	247 Cm Curium	245 Bk Berkelium	251 Cf Californium	254 Es Einsteinium	253 Fm Fermium	256 Md Mendelevium	254 No Nobelium	257 Lr Lawrencium			

a

X

b

a = relative atomic mass (approx)

x = atomic symbol

b = atomic number

* 58 – 71 Lanthanum series

† 90 – 103 Actinium series

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

a

X

b

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