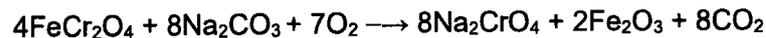


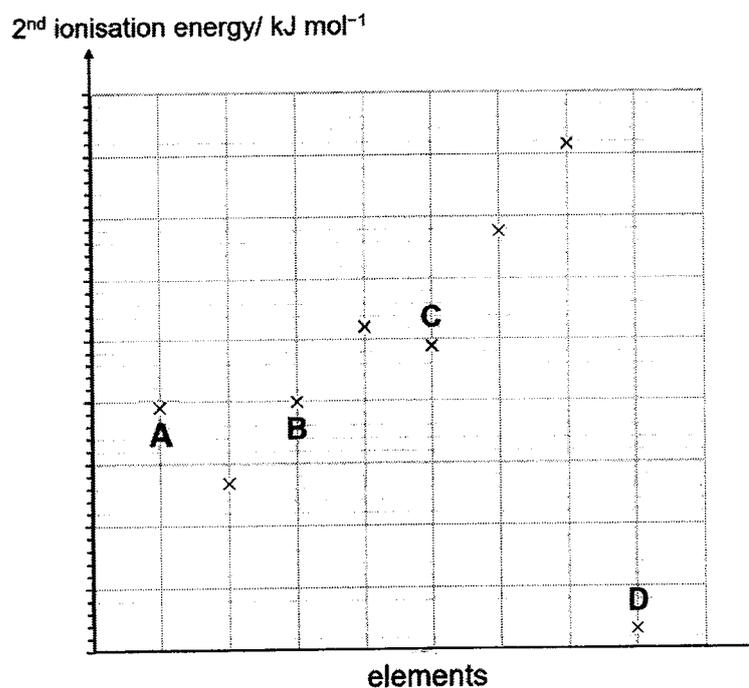
- 1 Sodium chromate(VI), Na_2CrO_4 , is manufactured by heating chromite, FeCr_2O_4 , with sodium carbonate in an oxidising atmosphere. Chromite contains $\text{Cr}_2\text{O}_4^{2-}$ ions.



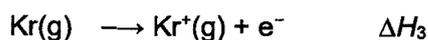
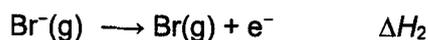
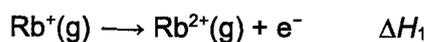
What happens in this reaction?

- A Chromium and iron are the only elements oxidised.
 B Chromium, iron and carbon are oxidised.
 C Only chromium is oxidised.
 D Only iron is oxidised.
- 2 Which species has two unpaired electrons?
 A B^+ B Cu^+ C Mg D S
- 3 The variation in the second ionisation energy of eight consecutive elements in the Periodic Table with atomic numbers ≤ 20 is shown in the graph.

Which element is a Group 13 element?



- 4 What do the ions $^{15}\text{N}^{3-}$ and $^{14}\text{C}^{4-}$ have in common?
- A They have 10 neutrons in their nuclei.
- B They have more electrons than neutrons.
- C They have a valence electronic configuration of $3s^2 3p^6$.
- D They contain the same number of nucleons in their nuclei.
- 5 What is the order of decreasing enthalpy change for the three reactions shown?



- A $\Delta H_1 > \Delta H_2 > \Delta H_3$
- B $\Delta H_1 > \Delta H_3 > \Delta H_2$
- C $\Delta H_2 > \Delta H_1 > \Delta H_3$
- D $\Delta H_2 > \Delta H_3 > \Delta H_1$
- 6 Barium dithionate, $\text{BaS}_2\text{O}_6 \cdot 2\text{H}_2\text{O}$, is soluble in water.

$\text{S}_2\text{O}_6^{2-}$ ions slowly decompose in acidic solution.



3.513 g of $\text{BaS}_2\text{O}_6 \cdot 2\text{H}_2\text{O}$ is dissolved in some water and the solution made up to the mark with $\text{HCl}(\text{aq})$ in a 100 cm^3 volumetric flask.

At time x min, a white precipitate of mass 0.661 g is present in the flask.

What is the concentration of BaS_2O_6 in the volumetric flask at time x min?

[Ar: Ba, 137.3; S, 32.1; O, 16.0; H, 1.0]

- A $0.0077 \text{ mol dm}^{-3}$
- B $0.0090 \text{ mol dm}^{-3}$
- C $0.077 \text{ mol dm}^{-3}$
- D $0.090 \text{ mol dm}^{-3}$

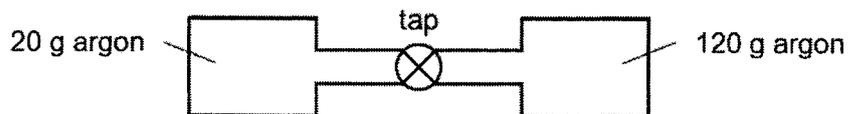
- 7 $\text{NH}_4\text{Fe}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}$ is a hydrated 'double salt'. A student analyses this double salt using the following chemical tests.

Which row gives the correct result for the stated test?

	Test	Results
1	Reaction with cold $\text{NaOH}(\text{aq})$	Green ppt
2	Reaction with $\text{Ba}(\text{NO}_3)_2(\text{aq})$	White ppt
3	Reaction with warm $\text{NaOH}(\text{aq})$	Red-brown ppt and an alkaline gas

- A** 1, 2 and 3 **B** Only 1 and 2 **C** Only 2 and 3 **D** Only 1
- 8 Which statements about BF_3 and NF_3 are correct?
- 1 The shape of BF_3 is trigonal planar while that of NF_3 is trigonal pyramidal.
 - 2 Both BF_3 and NF_3 are polar molecules.
 - 3 BF_3 can act as a Lewis acid because the boron atom has empty low-lying orbitals.
- A** 1 and 2 **B** 2 and 3 **C** 1 and 3 **D** 1, 2 and 3
- 9 Silicon carbide has a similar structure to diamond.
Silicon carbide can be used as
- A** a lubricant.
 - B** a tip for cutting tools.
 - C** a substitute for pencil 'lead'.
 - D** an electrical conductor.
- 10 Which statement is **not** a basic assumption of the kinetic theory of gases?
- A** The atoms or molecules have negligible size in comparison with the space they occupy.
 - B** There are negligible intermolecular forces between the gas particles.
 - C** Collisions between the individual particles and the vessel are perfectly elastic.
 - D** The particles of a given gas have the same kinetic energy at a given temperature.

- 11 The diagram below shows two containers of argon gas connected by a closed tap. Each container has a volume of 500 dm^3 .



The temperature of the system is changed to $250 \text{ }^\circ\text{C}$ and the tap is opened.

What is the pressure of argon within the system at $250 \text{ }^\circ\text{C}$?

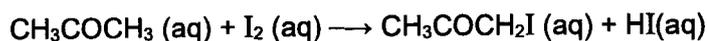
- A 7.29 kPa B 14.6 kPa C 15.3 kPa D 30.5 kPa
- 12 The standard enthalpy change of combustion of but-1-ene, $\text{CH}_2=\text{CHCH}_2\text{CH}_3(\text{g})$, is $x \text{ kJ mol}^{-1}$.
The standard enthalpy change of the reaction $2\text{C}_2\text{H}_4(\text{g}) \longrightarrow \text{CH}_2=\text{CHCH}_2\text{CH}_3(\text{g})$ is $y \text{ kJ mol}^{-1}$.
What is the standard enthalpy change of combustion of ethene, $\text{C}_2\text{H}_4(\text{g})$?

- A $\frac{x}{2} + y \text{ kJ mol}^{-1}$
- B $x + \frac{y}{2} \text{ kJ mol}^{-1}$
- C $\frac{x+y}{2} \text{ kJ mol}^{-1}$
- D $\frac{x y}{2} \text{ kJ mol}^{-1}$

- 13 Which suggested mechanism is consistent with the experimentally-obtained rate equation?

	rate equation	suggested mechanism
A	$\text{rate} = k[\text{N}_2\text{O}][\text{H}_2]$	$2\text{NO} + \text{H}_2 \longrightarrow \text{N}_2\text{O} + \text{H}_2\text{O}$ $\text{N}_2\text{O} + \text{H}_2 \xrightarrow{\text{slow}} \text{N}_2 + \text{H}_2\text{O}$
B	$\text{rate} = k[\text{NO}]^2[\text{H}_2]^2$	$2\text{NO} + \text{H}_2 \longrightarrow \text{N}_2\text{O} + \text{H}_2\text{O}$ $\text{N}_2\text{O} + \text{H}_2 \xrightarrow{\text{slow}} \text{N}_2 + \text{H}_2\text{O}$
C	$\text{rate} = k[\text{H}_2\text{O}_2][\text{I}^-]$	$\text{H}_2\text{O}_2 + \text{I}^- \longrightarrow \text{IO}^- + \text{H}_2\text{O}$ $\text{H}_2\text{O}_2 + \text{IO}^- \xrightarrow{\text{slow}} \text{I}^- + \text{H}_2\text{O} + \text{O}_2$
D	$\text{rate} = k[\text{H}_2\text{O}_2][\text{IO}^-]$	$\text{H}_2\text{O}_2 + \text{I}^- \longrightarrow \text{IO}^- + \text{H}_2\text{O}$ $\text{H}_2\text{O}_2 + \text{IO}^- \xrightarrow{\text{slow}} \text{I}^- + \text{H}_2\text{O} + \text{O}_2$

- 14 Propanone reacts with iodine in the presence of sulfuric acid.



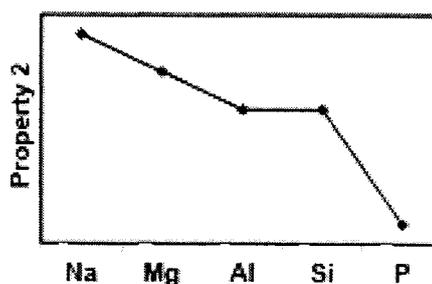
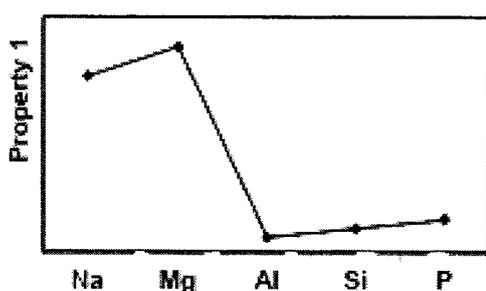
The rate equation for this reaction is: $\text{rate} = k[\text{H}^+][\text{CH}_3\text{COCH}_3]$.

Two experiments were carried out. In both experiments, the initial concentrations of propanone and iodine remained the same but the initial concentration of the sulfuric acid was changed. The initial rate in the first experiment was three times faster than the initial rate in the second experiment. In the first experiment the initial pH was 1.50.

What is the initial pH in the second experiment?

- A** 1.02 **B** 1.98 **C** 2.28 **D** 4.50
- 15 Which factor contributes to $\text{Ba}(\text{NO}_3)_2$ decomposing at a higher temperature than $\text{Mg}(\text{NO}_3)_2$?
- A** The charge density of the Ba^{2+} ion is lower than that of the Mg^{2+} ion.
- B** The standard enthalpy change of formation of BaO is more negative than that of MgO .
- C** The lattice energy of $\text{Ba}(\text{NO}_3)_2$ is less negative than that of $\text{Mg}(\text{NO}_3)_2$.
- D** The melting point of $\text{Ba}(\text{NO}_3)_2$ is higher than that of $\text{Mg}(\text{NO}_3)_2$.

- 16 Which statement explains the trend of decreasing volatility from HCl to HI ?
- A The electronegativity between the bonded atoms increases.
- B The molecules are polar and they have increasingly stronger permanent dipole-permanent dipoles.
- C There are more electrons in iodine atom than in chlorine atom.
- D The bond length decreases from H-Cl to H-I , hence thermal stability increases.
- 17 The graphs below show the variation of two properties of some Period 3 elements and/or their compounds.



Which option correctly describes properties 1 and 2?

	Property 1	Property 2
A	atomic radius of the elements	electrical conductivity of the elements
B	boiling point of the chlorides at the highest oxidation states	pH of the oxides when added to water
C	melting point of the oxides	first ionisation energies of the elements
D	electrical conductivity of elements	pH of the chlorides at the highest oxidation states when added to water

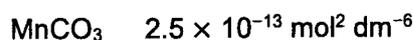
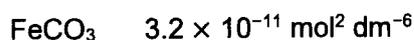
- 18 10.0 cm^3 of $0.100 \text{ mol dm}^{-3}$ of dilute sodium hydroxide was titrated against $0.100 \text{ mol dm}^{-3}$ of dilute ethanoic acid.

What is the volume of dilute ethanoic acid required to produce a buffer with maximum buffering capacity?

- A 5.00 cm^3 B 10.00 cm^3 C 15.00 cm^3 D 20.00 cm^3

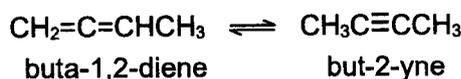
- 19 An acidified solution contains CaCl_2 , FeCl_2 and MnCl_2 , each of concentration 0.10 mol dm^{-3} . Carbon dioxide is blown through the solution until it is saturated with carbon dioxide at 25°C . The concentration of $\text{CO}_3^{2-}(\text{aq})$ in the saturated solution reaches $1 \times 10^{-9} \text{ mol dm}^{-3}$.

The value of the solubility product, K_{sp} , of each of the carbonates at 25°C is given below.



Which statement describes what happens in the solution?

- A Only CaCO_3 and FeCO_3 are precipitated.
 B Only CaCO_3 is precipitated.
 C Only MnCO_3 and FeCO_3 are precipitated.
 D Only MnCO_3 is precipitated.
- 20 Buta-1,2-diene and but-2-yne both have the same molecular formula, C_4H_6 . They exist in equilibrium as shown:



Which bond is present in buta-1,2-diene but **not** present in but-2-yne?

- A a σ bond formed by s – sp overlap
 B a π bond formed by p – p overlap
 C a σ bond formed by sp – sp^2 overlap
 D a σ bond formed by sp^2 – sp^2 overlap
- 21 The chlorofluorocarbon, CCl_2F_2 , can cause the breakdown of ozone in the upper atmosphere. Which initiation step could occur with ultraviolet radiation to catalyse this breakdown?
- A $\text{CCl}_2\text{F}_2 \rightarrow \cdot\text{C} + \cdot\text{Cl}_2\text{F}_2$
 B $\text{CCl}_2\text{F}_2 \rightarrow \cdot\text{F} + \cdot\text{CCl}_2\text{F}$
 C $\text{CCl}_2\text{F}_2 \rightarrow \cdot\text{Cl} + \cdot\text{CClF}_2$
 D $\text{CCl}_2\text{F}_2 \rightarrow \cdot\text{Cl}_2 + \cdot\text{CF}_2$

22 Which hydrocarbons undergo substitution reactions to form only one monochloro-derivative?

- 1 cyclobutane
- 2 2,2-dimethylpropane
- 3 2-methylpropane

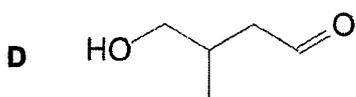
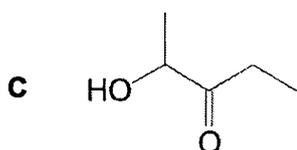
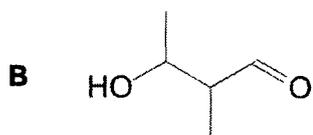
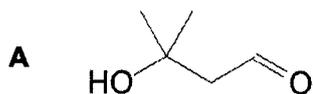
A 1 and 2 only B 2 and 3 only C 1 and 3 only D 1, 2 and 3

23 The alkene 2,4-dimethylpenta-1,3-diene reacts with two moles of HBr to give X as the major product.

What is the structure of X?

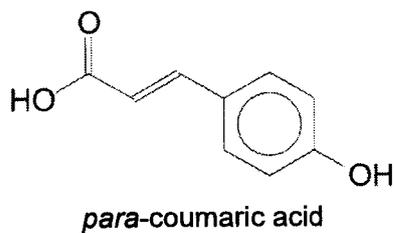
- A $\text{CH}_2\text{BrCH}(\text{CH}_3)\text{CH}_2\text{CBr}(\text{CH}_3)_2$
- B $\text{CH}_2\text{BrCH}(\text{CH}_3)\text{CHBrCH}(\text{CH}_3)_2$
- C $(\text{CH}_3)_2\text{CBrCHBrCH}(\text{CH}_3)_2$
- D $(\text{CH}_3)_2\text{CBrCH}_2\text{CBr}(\text{CH}_3)_2$

24 Which compound can form an organic product with molecular formula $\text{C}_5\text{H}_8\text{O}_2$ when heated with excess acidified potassium dichromate(VI)?



10

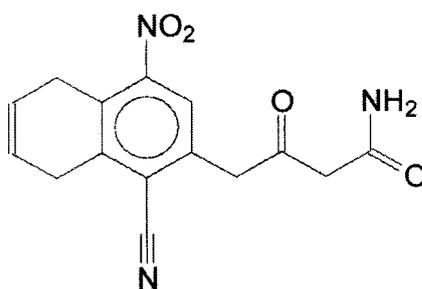
25 *Para*-coumaric acid is an antioxidant in coffee.



When treated with aqueous bromine, what is the maximum number of bromine atoms that can be incorporated into a molecule of *para*-coumaric acid?

- A** 2 **B** 3 **C** 4 **D** 5

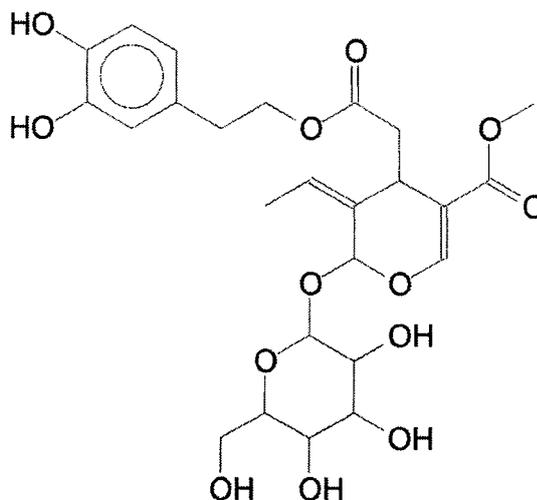
26

**P**

When treated with each of the respective reagents, what is the number of hydrogen atoms that can be incorporated into a molecule of **P**?

	H ₂ , Ni	LiAlH ₄ in dry ether	NaBH ₄ in ethanol
A	6	6	4
B	6	8	4
C	8	6	2
D	8	8	2

- 27 Biophenols derived from olives are used as traditional remedies for a variety of conditions, including inflammatory states and cardiovascular diseases. Oleuropein is the most well-known compound of this family and is present in olive tree leaves. Oleuropein has the following structure:

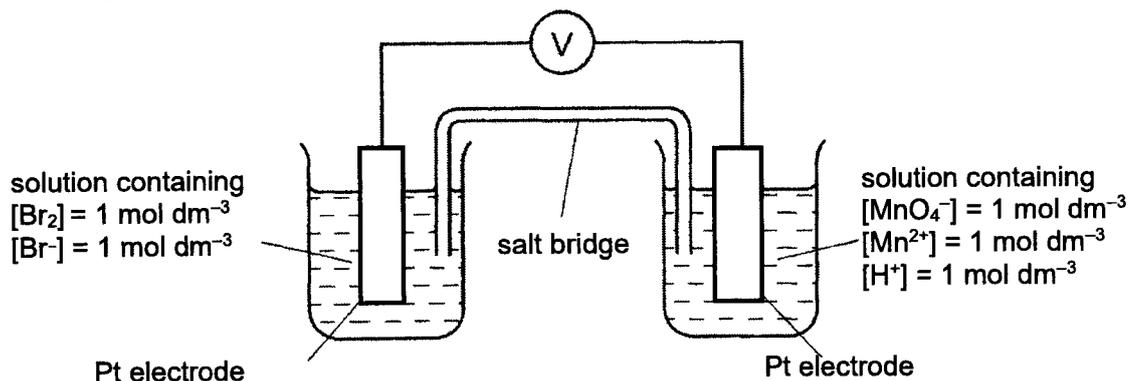


- Which statement about oleuropein is correct?
- A** It does not decolourise cold alkaline KMnO_4 .
- B** It reacts with Na_2CO_3 to liberate CO_2 gas.
- C** A product containing 9 chiral centers is formed when 1 mole of oleuropein reacts with excess H_2 gas in the presence of platinum.
- D** 6 moles of HCl are formed when 1 mole of oleuropein reacts with excess PCl_5 at room temperature.
- 28 Methyl ethanoate, $\text{CH}_3\text{OCOCH}_3$ undergoes acidic hydrolysis in the presence of H_2^{18}O .

Which products are formed?

- 1 $\text{CH}_3^{18}\text{OH}$
- 2 $\text{CH}_3\text{CO}^{18}\text{OH}$
- 3 CH_3OH
- A** 1 and 2 only **B** 1 and 3 only **C** 2 and 3 only **D** 1, 2 and 3

- 29 Use of the Data Booklet is relevant to this question.
The following electrochemical cell was set up at 25 °C.



Which of the following statements are true?

- 1 When silver nitrate crystals are added to the Br_2/Br^- half cell, E_{cell} becomes less positive.
- 2 The ΔG° of the above reaction is -434 kJ mol^{-1} .
- 3 Addition of water to the $\text{MnO}_4^-/\text{Mn}^{2+}$ half-cell has no effect on the E_{cell} of the cell.

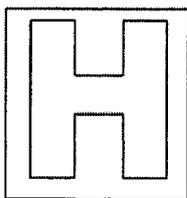
A 1 only B 2 only C 1 and 2 only D 2 and 3 only

- 30 When crystalline potassium chromate(VI), K_2CrO_4 , was dissolved in water, a yellow solution **P** was formed. The addition of dilute sulfuric acid to **P** gave an orange solution **Q**.

When hydrogen sulfide, H_2S , was bubbled through solution **Q**, the solution changed colour and gave a solution **R**, with a yellow solid.

Which process does **not** occur in this sequence?

- A Ligand exchange reaction
- B Acid-base reaction
- C Redox reaction
- D Precipitation reaction



NATIONAL JUNIOR COLLEGE
SH2 PRELIMINARY EXAMINATION
 Higher 2

CANDIDATE
NAME

SUBJECT
CLASS

REGISTRATION
NUMBER

CHEMISTRY

Paper 2 Structured Questions

9729/02

16 September 2025

2 hours

Candidates answer on Question Paper.
 Additional Materials: Data Booklet

READ THE INSTRUCTIONS FIRST

Write your subject class, registration number and name on all the work you hand in.

Write in dark blue or black pen on both sides of the paper. You may use a soft pencil for any diagrams, graphs or rough working.

Do not use paper clips, highlighters, glue or correction fluid.

Answers **all** questions.

The number of marks is given in brackets [] at the end of each question or part question.

For Examiner's Use	
1	/16
2	/14
3	/17
4	/16
5	/12
Paper 2 Total	/75

	Marks	Weightings
Paper 1	/30	15%
Paper 2	/75	30%
Paper 3	/80	35%
Paper 4	/55	20%

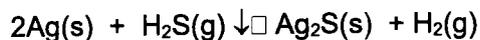
Overall Percentage	
Grade	

This document consists of **19** printed pages.

[Turn over

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

- 1 925 silver, also known as sterling silver, is an alloy that is commonly used to make jewellery. It consists of 92.5% silver and 7.5% other metals, such as copper, by mass. Over time, the alloy can form a tarnish of $\text{Ag}_2\text{S}(\text{s})$ when it reacts with hydrogen sulfide, as represented by the following equation.



- (a) (i) Write the full electronic configuration for copper.

..... [1]

- (ii) State and explain the difference in atomic radii for silver and copper.

.....

 [2]

- (b) The Ag_2S tarnish on sterling silver can be removed until only sterling silver remains. A student weighs a tarnished sterling silver sample both before and after removing the Ag_2S and records the data in Table 1.1.

Table 1.1

mass before tarnish removal /g	54.23
mass after tarnish removal /g	52.34

Assuming that only $\text{Ag}_2\text{S}(\text{s})$ is removed, calculate the amount of silver atoms removed.

[1]

- (c) (i) Suggest and explain the relative magnitudes of the lattice energy of the silver compounds, Ag_2S , Ag_2O and Ag_2Se .

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[2]

- (ii) Using relevant data from the *Data Booklet* and Table 1.2, construct an energy level diagram to calculate the lattice energy of Ag_2O .

Table 1.2

standard enthalpy change of atomisation of silver	+285 kJ mol ⁻¹
1 st electron affinity of oxygen	-141 kJ mol ⁻¹
2 nd electron affinity of oxygen	+798 kJ mol ⁻¹
standard enthalpy change of formation of $\text{Ag}_2\text{O}(\text{s})$	-31 kJ mol ⁻¹

- (d) Rhodium plating is a process used to protect sterling silver from tarnishing. This involves electroplating (depositing) solid rhodium, $\text{Rh}(\text{s})$, onto the surface of the metal from an acidified solution of $\text{Rh}_2(\text{SO}_4)_3(\text{aq})$. Oxygen gas is produced during this process.

[4]

One of the half equations involved in this reaction is



- (i) Write the half equation for the formation of oxygen gas in this reaction and hence, write the balanced ionic equation for the overall reaction.

.....

[2]

- (ii) Calculate the value of E°_{cell} for the overall reaction in (i).

[1]

- (iii) Based on your answer to (ii), explain why this process requires the use of an external power source.

.....

[1]

- (iv) Calculate the current that must be supplied for 3.5 g of Rh to be plated onto a piece of sterling silver in 3 minutes.

[2]

[Total : 16]

- 2 (a) Xenon is a noble gas and forms various fluorides with fluorine. Two of these are xenon difluoride, XeF_2 , and xenon tetrafluoride, XeF_4 , which are crystalline solids with melting points of 140°C and 112°C respectively.

- (i) Draw the dot-and-cross diagrams for XeF_2 and XeF_4 and hence state their molecular shapes.

[3]

- (ii) Even though XeF_4 has more electrons and is hence expected to have greater intermolecular forces than XeF_2 , its melting point is lower. Suggest why XeF_2 has a higher melting point than XeF_4 .

.....

.....

.....

.....

[1]

- (iii) Using your knowledge of covalent bond formation, explain why

- xenon reacts with fluorine but neon does not.

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- xenon reacts with fluorine but not with iodine.

.....

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.....

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[2]

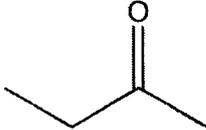
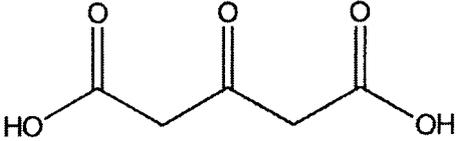
- (b) **P** and **Q** are compounds containing the same functional groups.

Both compounds

- readily decolourise bromine in the dark

- liberate a gas with sodium metal
- do not have O atom bonded to an unsaturated carbon atom
- react with hot acidified potassium manganate(VII) to give the products as shown in Table 2.1.

Table 2.1

compound	products of oxidation
P ($C_6H_{12}O$)	 and CO_2
Q (C_5H_8O)	

- (i) Considering the molecular formulae of the two compounds together with the information given above, name the two functional groups that are present in compounds **P** and **Q**.

..... [2]

- (ii) Suggest the structures of compounds **P** and **Q**.

Compound P	Compound Q

[2]

- (c) Compound **R**, $C_9H_{18}O_2$, has the same two functional groups as **P** and **Q** in (b). Upon strong oxidation by hot acidified $KMnO_4$, compound **S**, $C_6H_{12}O_2$, and compound **T**, $C_3H_4O_3$, are obtained.

The following four reagents were used to test compounds **S** and **T**, and the results are shown in the table below.

test reagent	result of test with	
	compound S	compound T
Na(s)	fizzes	fizzes
$NaHCO_3(aq)$	no reaction	fizzes
$I_2(aq) + OH(aq)$, warm	no reaction	yellow ppt
2,4-DNPH	orange ppt	orange ppt

- (i) By considering the test results with Na(s) and $NaHCO_3(aq)$, name the functional group that is present in **S** and **T**.

Functional group present in **S**:

Functional group present in **T**:

[2]

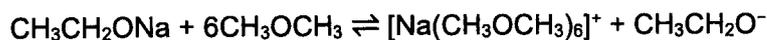
- (ii) Suggest the structures of compounds **S** and **T**.

Compound S	Compound T

[2]

[Total : 14]

- 3 (a) A sodium ethoxide slurry is prepared by dissolving sodium in dry ethanol. When this slurry is transferred into liquid dimethyl ether, CH_3OCH_3 , at 40°C , the following equilibrium is established.



- (i) Write a balanced equation for the reaction of ethanol with sodium.

..... [1]

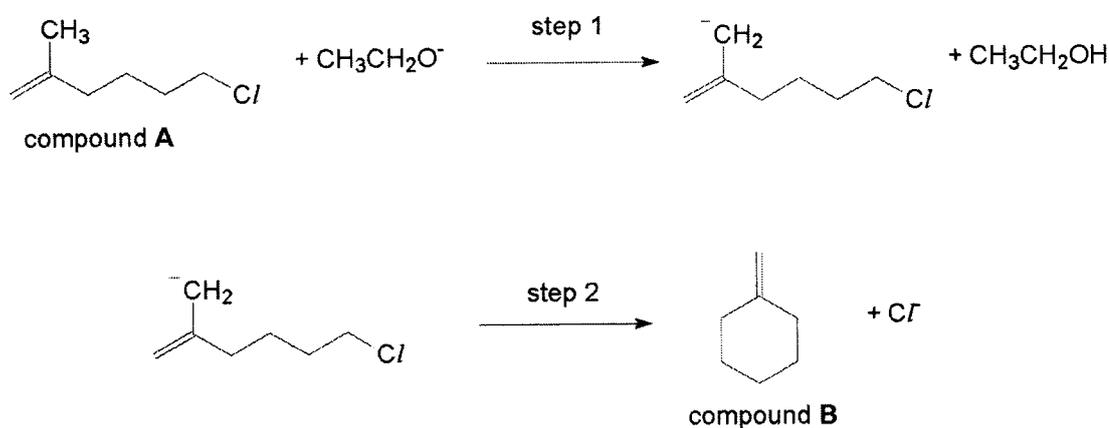
- (ii) Using your knowledge of VSEPR theory, state and explain the bond angle around the oxygen atom in CH_3OCH_3 .

.....

 [2]

- (b) The strongly basic ethoxide ion, $\text{CH}_3\text{CH}_2\text{O}^-$, removes a proton from compound A, giving the anion shown in Fig. 3.1.

Intramolecular attack of the anion on the C–Cl bond forms compound B.



Show the mechanism for step 2 on Fig. 3.1 by adding a lone pair, curly arrows and dipoles.

State the name of the mechanism involved.

..... [2]

- (e) 2-bromobutane can be used to synthesise propanoic acid by the three-step route shown in Fig. 3.2.

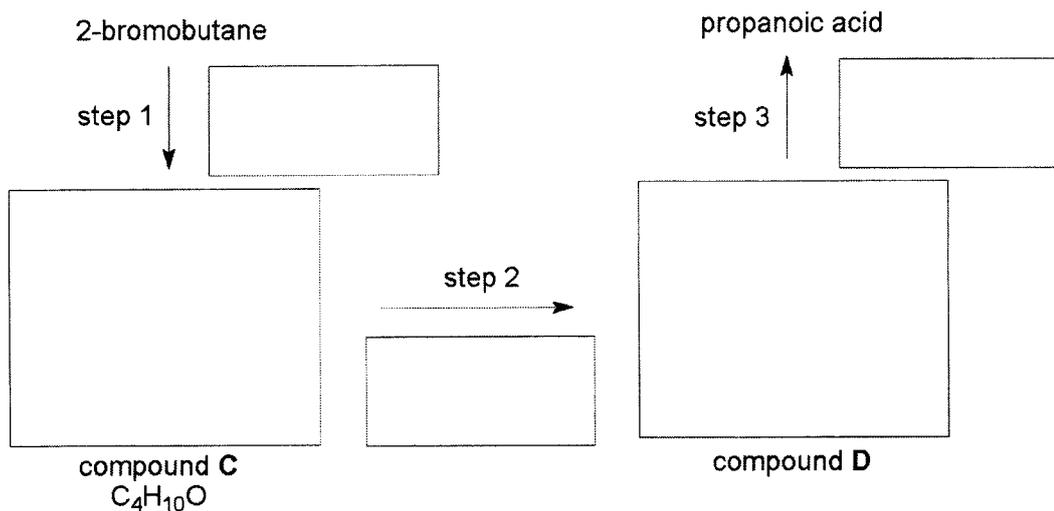


Fig. 3.2

State the reagents and conditions required for each step and suggest structures for the organic compounds, **C** and **D**.

[5]

- (f) The K_b of a secondary amine, $R_1(R_2)NH$, is $5.75 \times 10^{-4} \text{ mol dm}^{-3}$. A 1.50 g sample of the amine is dissolved in water and the solution is made up to 1.00 dm^3 . The pH of the resulting solution is 11.55.

Calculate the relative molecular mass of $R_1(R_2)NH$, and suggest a structural formula for $R_1(R_2)NH$. Show your working clearly.

[3]

[Total : 17]

4 Although carbon monoxide, CO, is a poisonous gas, it is an important starting material in the synthesis of many industrially important compounds.

(a) (i) Draw a dot-and-cross diagram to show the bonding in carbon monoxide.

[1]

(ii) Suggest why carbon monoxide is poisonous.

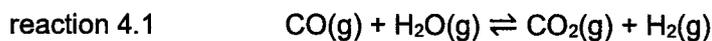
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[1]

Carbon monoxide can undergo water-gas shift reaction. The carbon monoxide gas reacts with steam to produce carbon dioxide gas and hydrogen gas.



(b) Explain the difference in boiling points of CO and of CO₂ in terms of the type and relative strength of the intermolecular forces.

species	boiling point/ °C
CO	-191
CO ₂	-78

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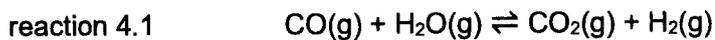
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[2]

- (c) 0.200 mol of carbon monoxide and 0.200 mol of steam was placed in reaction vessel and allowed to react at a temperature of 800 K. The percentage of carbon monoxide reacted was found to be 77.5%.



- (i) Write the expression for the equilibrium constant, K_c , for reaction 4.1.

[1]

- (ii) Calculate the value of the equilibrium constant, K_c , at 800 K.

[2]

- (iii) The Gibbs free energy change of reaction, ΔG_r , for reaction 4.1 is $-18.4 \text{ kJ mol}^{-1}$ at 600 K. The relationship between the equilibrium constant and the Gibbs free energy change of this reaction can be expressed as:

$$\Delta G = -RT \ln K_c$$

Calculate the value of K_c for the reaction 4.1 at 600 K.

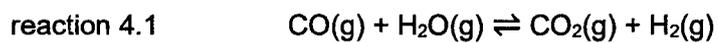
[1]

(d) Table 4.1 gives data relevant to this question.

Table 4.1

$\otimes H_f^\ominus \text{CO(g)}$	$-110.5 \text{ kJ mol}^{-1}$
$\otimes H_f^\ominus \text{CO}_2\text{(g)}$	$-393.5 \text{ kJ mol}^{-1}$
$\otimes H_f^\ominus \text{H}_2\text{O(g)}$	$-241.1 \text{ kJ mol}^{-1}$

Using the data given in Table 4.1, construct an energy cycle to calculate the enthalpy change of reaction for reaction 4.1.



[2]

- (e) William Henry studied the equilibria when an ideal gas dissolves in a liquid. He proposed that the concentration of the gas dissolved in a liquid is proportional to the partial pressure of the gas above the liquid surface. This proportionality factor is called Henry's law constant, K_H .

The Henry's law constant, K_H , can be represented as the equation below.

$$K_H = \frac{\text{maximum concentration of gas dissolved in mol dm}^3}{\text{partial pressure of gas in atm}}$$

Sealed containers of fizzy drinks contain dissolved CO_2 . This dissolved CO_2 is in equilibrium with a very small quantity of gaseous CO_2 at the top of the container.



The Henry's law constant for CO_2 is $3.3 \times 10^{-2} \text{ mol dm}^{-3} \text{ atm}^{-1}$ at 25°C .

- (i) The partial pressure of CO_2 gas in a can of 250 cm^3 fizzy drink is 3.0 atm at 25°C .

Calculate the concentration of CO_2 in the fizzy drink and hence the mass of CO_2 dissolved in the 250 cm^3 of fizzy drink.

[2]

Fig. 4.1 shows the relationship between Henry's law constant and temperature.

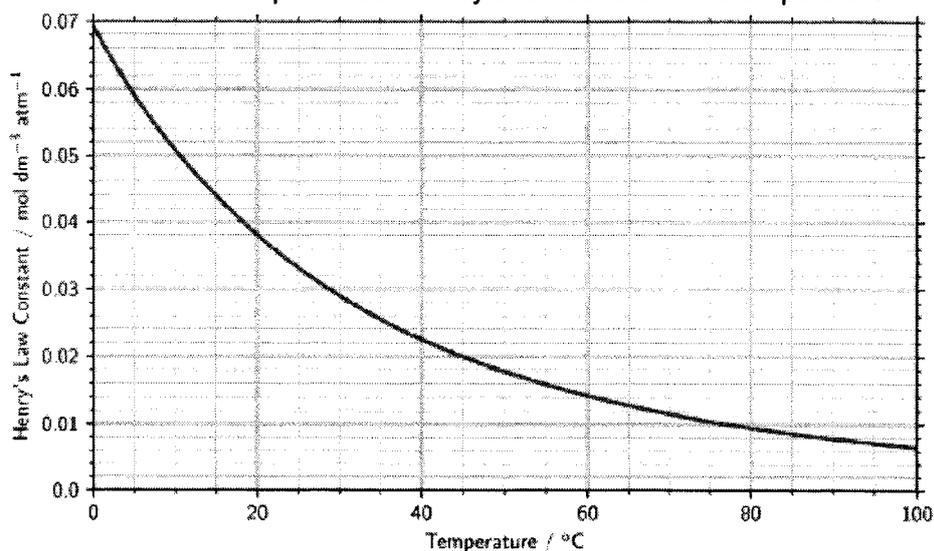


Fig. 4.1

- (ii) The maximum pressure that a fizzy canned drink can withstand is 6.2 atm. Using the concentration of CO₂ in the fizzy drink calculated in (i), calculate the value of K_H at this pressure.

[1]

- (iii) Using Fig. 4.1, determine the maximum temperature at which the fizzy canned drink can be stored safely.

Maximum temperature:

[1]

- (iv) Deduce, with reasoning, the sign of enthalpy change for reaction 4.2.

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[2]

[Total : 16]

- 5 Plastic takeaway containers for food are commonly made of polypropene (PP) which is microwave safe and chemically inert.

Polymerisation is a chemical process where small molecules (monomers) combine to form a large molecule (polymer) through the formation of covalent bonds. Fig 5.1 shows the process of joining many propene monomers to form polypropene. The type of polymerisation is known as addition polymerisation as only 1 single product is formed.

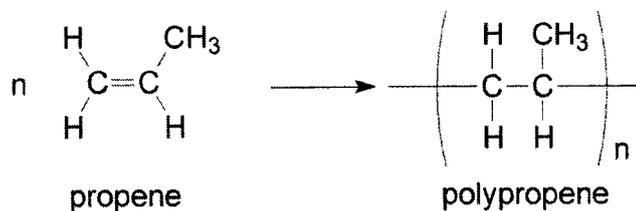


Fig 5.1

- (a) (i) The polymerisation of 1 mole of propene to form polypropene (Fig 5.1) has a standard entropy change of $-110 \text{ J mol}^{-1} \text{ K}^{-1}$.

Account for the negative sign of the standard entropy change for polymerisation.

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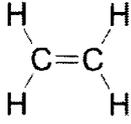
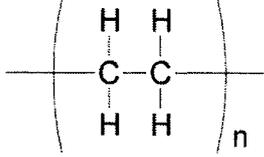
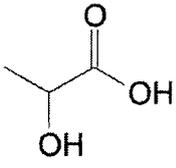
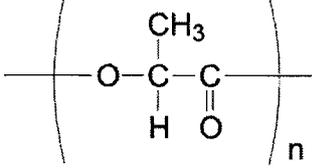
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[2]

- (ii) Given that the standard enthalpy change of polymerisation of polypropene is $-55.0 \text{ kJ mol}^{-1}$, calculate the maximum temperature for the reaction to be spontaneous.

[2]

The increasing environmental concerns over plastic pollution have led to innovations in food packaging design. Many food establishments now use paper-based takeaway containers coated with either polyethene (PE) or polylactic acid (PLA) instead of conventional plastic containers.

monomer	polymer
 <p>ethene</p>	 <p>polyethene (PE)</p>
 <p>lactic acid</p>	 <p>polylactic acid (PLA)</p>

- (b) (i) State the IUPAC name of lactic acid.

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[1]

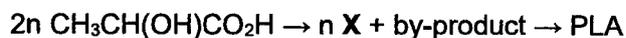
- (ii) Similar to propene, ethene undergoes addition polymerisation to form polyethene. Lactic acid undergoes a different type of polymerisation as a by-product is formed. Identify the by-product and hence state the type of polymerisation undergone by lactic acid to form PLA.

By-product:

Type of polymerisation:

[1]

- (iii) The equation for polymerisation of lactic acid to form PLA is found to be:



X is a cyclic intermediate with the molecular formula of $\text{C}_6\text{H}_8\text{O}_4$.

X does not react with Na.

Draw the skeletal structure of **X**.

[1]

- (c) Tom Yum soup is cooked with Thai bird's eye chillies, lime juice and lemongrass to give the characteristic sour and spicy flavour. A Thai food stall vendor is choosing between takeaway food containers coated with PE or PLA to contain hot Tom Yum soup.

By considering the structures of PE and PLA, and the properties of Tom Yum soup, explain which type of takeaway food container you would recommend to the Thai food stall vendor.

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[2]

- (d) Microplastics are particles with sizes ranging from 1 μm to 5 mm in any dimension (1 mm = 1000 μm).

While PE-coated and PLA-coated paper containers still contain plastic elements, they use significantly less plastic than traditional PP containers, thereby reducing the potential for microplastic generation.

A researcher studied the degradation of samples of PE and PLA in an aqueous condition with a similar salt concentration as seawater and with exposure to UV light after 2 years. He then determined the proportion of particles with various sizes of $\leq 3 \mu\text{m}$, as shown in Fig 5.2.

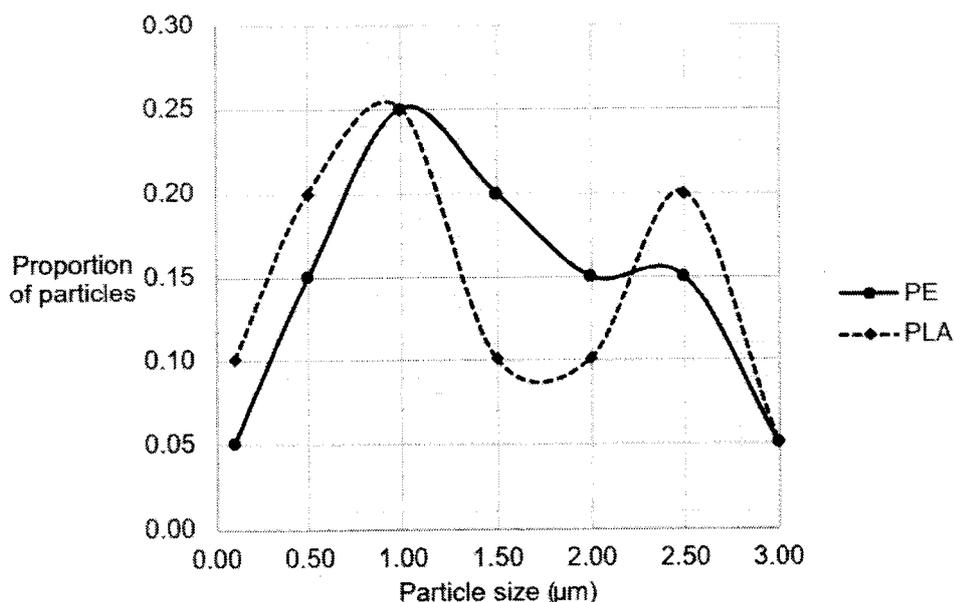


Fig 5.2

- (i) With reference to Fig 5.2, explain whether you would expect PE or PLA to degrade and generate more microplastics in the sea.

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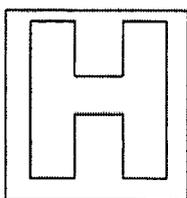
[2]

- (ii) State one other condition for the degradation of PE and PLA in the sea that the researcher should have considered in his investigation.

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[1]

[Total: 12]



NATIONAL JUNIOR COLLEGE
SH2 PRELIMINARY EXAMINATION
 Higher 2

CANDIDATE
NAME

SUBJECT
CLASS

REGISTRATION
NUMBER

CHEMISTRY

Paper 3 Free Response

9729/03

23 September 2025

2 hours

Candidates answer on Question Paper.
 Additional Materials: Data Booklet

READ THE INSTRUCTIONS FIRST

Write your subject class, registration number and name on all the work you hand in.

Write in dark blue or black pen.

You may use a soft pencil for any diagrams or graphs.

Do not use staples, paper clips, glue or correction fluid.

Section A

Answer **all** questions.

Section B

Answer **one** question.

A Data Booklet is provided.

The use of an approved scientific calculator is expected, where appropriate.

The number of marks is given in brackets [] at the end of each question or part question.

For Examiner's Use	
Section A	
1	/19
2	/20
3	/21
Section B (*circle the question you attempted)	
4	/20
5	/20
Paper 3 Total	/80

This document consists of **28** printed pages.

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- (b) The student carried out another experiment by heating equal amounts of carbonates of magnesium, calcium and barium for two minutes using a Bunsen burner. Table 1.1 shows the volume of gas collected.

Table 1.1

Group 2 carbonate	MgCO ₃	CaCO ₃	BaCO ₃
Volume of gas collected / cm ³	80	25	5

Using relevant data from the *Data Booklet*, explain the results obtained by the student. [3]

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- (c) Table 1.2 shows the bond length of various nitrogen-oxygen bonds.

Table 1.2

Bond	N O	N=O	nitrogen-oxygen bond in NO ₃
Bond Length (nm)	0.136	0.115	0.128

Suggest an explanation for the observed NO bond length in nitrate ion. [2]

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- (d) Sodium carbonate, a Group 1 carbonate, can be used to maintain the pH of swimming pool water to the ideal range of 7.0–7.6. If the concentration of sodium carbonate is too high, it will cause skin irritation to swimmers.

The management committee of a public swimming pool hired a chemist to advise them on the need to adjust the pH of pool water. The chemist titrated a 10.0 cm³ sample of pool water (assume it contains only Na₂CO₃) against 0.05 mol dm⁻³ HCl.

20.00 cm³ of the HCl solution was required to turn the phenolphthalein indicator from pink to colourless. When the titration is repeated using methyl orange indicator, 40.00 cm³ of HCl was required to reach the end point.

[The K_{b1} and K_{b2} values of Na₂CO₃ at 25 °C are 2.13×10^{-4} and 2.25×10^{-8} respectively.]

- (i) The pH at the first equivalence point is found to be greater than 7. Write an equation to explain this observed pH. [1]
- (ii) Calculate the concentration of Na₂CO₃ in the pool water sample. [1]
- (iii) Using your answer to (ii), calculate the initial pH of the pool water sample. [2]
- (iv) Sketch the pH volume added curve you would expect to obtain when 50.00 cm³ of the HCl solution is added to 10.0 cm³ of the pool water sample. Label the various key points on the curve. [2]

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- (d) Describe and explain the trend in the thermal stability of the hydrogen halides HCl , HBr and HI . Include an equation for the thermal decomposition reaction in your answer. [3]

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- (e) Three pure solid compounds, labelled **D**, **E** and **F**, are placed on the lab bench. It is known that the compounds are AlCl_3 , Na_2CO_3 or MgSO_4 .

A student performed several tests, and the results are summarised in Table 4.1.

Table 4.1

Compound	pH of the aqueous solution of the compound	results of adding $\text{NaOH}(\text{aq})$ to a solution of the compound	results of adding $\text{HCl}(\text{aq})$ to the solid compound
D	> 7	No observed reaction	Evolution of a gas
E	< 7	White ppt soluble in excess NaOH	No observed reaction
F	< 7	White ppt insoluble in excess NaOH	No observed reaction

- (i) Suggest the identities of the compounds **D**, **E** and **F** based on the observations in Table 4.1. [2]
- (ii) Suggest the formula of the white compound observed when an excess of NaOH is added to a solution of the compound **F**. [1]
- (iii) With the aid of an equation, explain why an aqueous solution of **E** has a $\text{pH} < 7$. [2]

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(f) Beryllium oxide, BeO, has similar chemical properties as Al_2O_3 .

Write the chemical equations when separate samples of BeO are reacted with $HCl(aq)$ and $NaOH(aq)$. [2]

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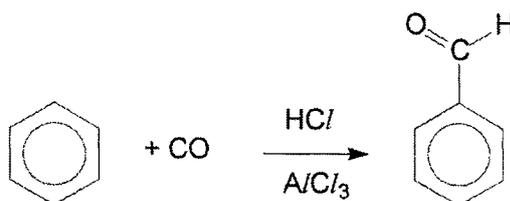
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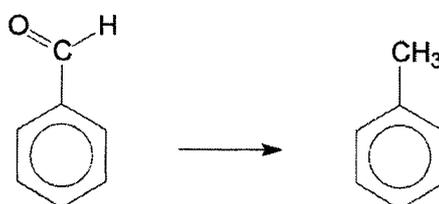
[Total : 20]

- 5 (a) Benzaldehyde, C_6H_5CHO , served as a precursor in the production of various chemicals, including pharmaceuticals and dyes. Benzaldehyde can be synthesised from carbon monoxide and benzene by the Gatterman–Koch reaction in the presence of hydrogen chloride and aluminium chloride. This reaction is an electrophilic substitution reaction.



The following describes the mechanism for the reaction.

- step 1: Carbon monoxide, hydrogen chloride and aluminium chloride react to form the electrophile, $H-C^+=O$, and one other product.
- step 2: The electrophile reacts with benzene to form an intermediate in the rate-determining step.
- step 3: The intermediate loses a H^+ to regenerate hydrogen chloride and aluminium chloride.
- (i) Explain why benzene undergoes substitution reactions rather than addition reaction. [1]
- (ii) Write the equation for the generation of the electrophile in step 1 of the Gatterman–Koch reaction. [1]
- (iii) $AlCl_3$ acts as a *Lewis acid* in step 1 of the reaction. Describe how $AlCl_3$ act as a *Lewis acid* in this step. [1]
- (iv) Draw a reaction mechanism for step 2 and step 3. Include all relevant charges and curly arrows. Include the structure of the organic intermediate. [2]
- (v) Benzaldehyde formed can undergo further reaction to form methylbenzene.



State the type of reaction that benzaldehyde undergoes and explain your answer. [2]

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