NATIONAL SENIOR CERTIFICATE EXAMINATION
MAY 2021

PHYSICAL SCIENCES: PAPER II

Time: 3 hours 200 marks

PLEASE READ THE FOLLOWING INSTRUCTIONS CAREFULLY

1. This question paper consists of 14 pages, a yellow ANSWER SHEET of 1 page (i) and a green DATA SHEET of 3 pages (i–iii). Please check that your question paper is complete.

2. Remove the DATA SHEET and ANSWER SHEET from the middle of this question paper. **Write your examination number on the yellow ANSWER SHEET.**

3. Read all of the questions carefully.

4. ALL of the questions in this paper must be answered.

5. Question 1 consists of 10 multiple-choice questions that must be answered on the answer sheet provided on the inside cover of your Answer Book.

6. **START EACH QUESTION ON A NEW PAGE.**

7. Please ensure that you number your answers as the questions are numbered.

8. Unless instructed otherwise it is NOT necessary to give state symbols (phase indicators) when asked to write a balanced chemical equation.

9. Use the data and formulae whenever necessary.

10. Show all the necessary steps in calculations.

11. Where appropriate, take your answers to 2 decimal places.

12. It is in your own interest to write legibly and to present your work neatly.

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QUESTION 1 MULTIPLE-CHOICE

Answer these questions on the multiple-choice answer sheet on the inside front cover of your Answer Book. Make a cross (X) in the box corresponding to the letter of the option that you consider to be most correct. Every question has only one correct answer.

A	B	C	D

Here the answer C has been marked.

1.1 One mole of CO_2 contains:

A 3 atoms
B $6{,}02 \times 10^{23}$ atoms of oxygen
C 44 molecules of CO_2
D $6{,}02 \times 10^{23}$ molecules of CO_2

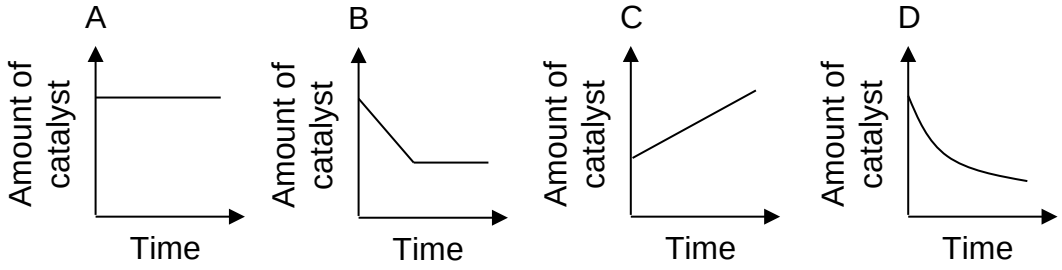
1.2 Which statement is TRUE regarding the substance NF_3?

A It is ionic.
B It has polar covalent bonds and dipole-dipole interactions.
C It has polar covalent bonds and London forces only.
D It has pure covalent bonds and London forces only.

1.3 Consider the reaction represented by the balanced chemical equation below, using rhodium as a catalyst:

$$2CO(g) + 2NO(g) \rightarrow 2CO_2(g) + N_2(g)$$

In a closed system of carbon monoxide, nitrogen monoxide and rhodium, which one of the graphs below best illustrates the change in the amount of rhodium over time?



1.4 Dihydrogen sulfide dissolves in water according to the following chemical equation:

$$H_2S + 2H_2O \rightleftharpoons S^{2-} + 2H_3O^+$$

What is the effect of adding hydrochloric acid to a solution containing dihydrogen sulfide?

A The concentration of sulfide ions increases.
B The concentration of sulfide ions decreases.
C There is no effect on the concentration of sulfide ions.
D The extent of the ionisation of the hydrochloric acid will increase.

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1.5 The hydroxide ion concentration of a 2 mol·dm^{-3} solution of nitric acid is:

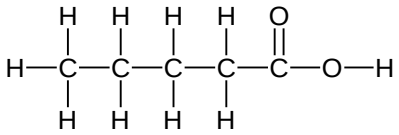
A 2 mol·dm^{-3}
B 5 × 10^{-13} mol·dm^{-3}
C 2 × 10^{-15} mol·dm^{-3}
D 5 × 10^{-15} mol·dm^{-3}

1.6 Which one of the following will produce a basic solution when dissolved in water?

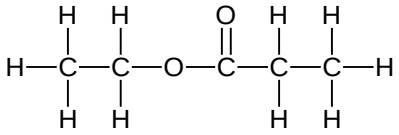
A lithium nitrite
B ammonium bromide
C hydrogen chloride
D potassium nitrate

1.7 Which of the following are STRUCTURAL ISOMERS of ethyl propanoate?

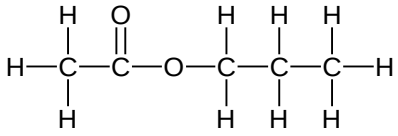
(i)



(ii)



(iii)



A i and ii only
B ii and iii only
C i and iii only
D i, ii and iii

1.8 Consider the reaction represented by the following chemical equation:

$$2C_2H_6(g) + 7O_2 \rightarrow 4CO_2(g) + 6H_2O(g)$$

The reaction is an example of a/an:

A addition reaction.
B dehydration reaction.
C oxidation reaction.
D endothermic reaction.

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1.9 Which statement is correct for the reaction of an UNSATURATED hydrocarbon with bromine (test for unsaturation)?

A The reaction is slow.
B The reaction is a substitution reaction.
C The bromine will decolourise quickly due to an addition reaction.
D Ultraviolet light is needed for this reaction.

1.10 When considering a scientific experiment, the term *precision* refers to:

A not making mistakes.
B getting a result close to an accepted result.
C getting results that have a large range of values.
D getting results that are close to the average.

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QUESTION 2

2.1 Jivan is investigating three unknown solids, **X**, **Y**, and **Z**. He performs some investigations and arrives at the following observations for each solid:

Solid	Melting point (°C)	Conducts electricity at:	
		795 °C	815 °C
X	800	Yes	Yes
Y	805	No	Yes
Z	810	No	No

2.1.1 Define *metallic bond*. (2)

2.1.2 In what phase is:

(a) **X** at 795 °C? (1)

(b) **Y** at 815 °C? (1)

2.1.3 From the information provided, deduce which substance is a metal, and give a reason why it does or does not conduct. (2)

2.1.4 With reference to the type of bonding in **Y**, explain its conductivity at 815 °C, but not at 795 °C. (3)

2.2 2.2.1 Define *intermolecular force*. (2)

2.2.2 Fully explain the difference in melting points between iodine monobromide (IBr) and iodine monofluoride (IF). The melting point of IBr is 42 °C and that of IF is −45 °C. (5)

[16]

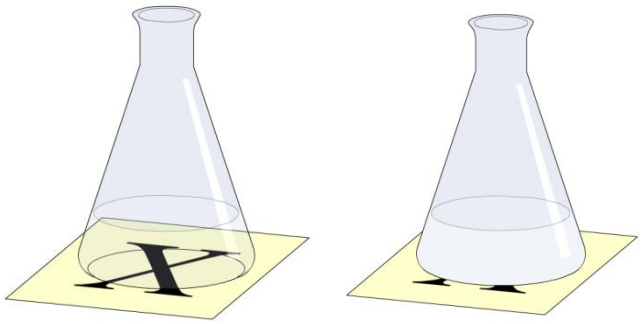
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QUESTION 3

In an investigation into the effect of concentration and temperature on reaction rate, the reaction as shown in the balanced chemical equation below is used:

$$Na_2S_2O_3(aq) + 2HC\ell(aq) \rightarrow 2NaC\ell(aq) + SO_2(g) + H_2O(\ell) + S(s)$$

Thandi places the reaction vessel on a piece of paper that has been marked with an '**X**'. When a sufficient amount of precipitate has formed, the turbidity (cloudiness) of the solution is such that the '**X**' disappears. The figure alongside shows the experimental setup.



Start of reaction **Reaction after some time**

The time taken for the '**X**' to disappear is measured for various reaction conditions as shown in the table below. Note that the **sodium thiosulfate** is the **limiting reagent** in Experiments **1** to **4** and the **hydrochloric acid** is the **limiting reagent** in Experiment **5**.

Experiment	**Volume of $Na_2S_2O_3$ (dm^3)**	**Concentration of $Na_2S_2O_3$ ($mol \cdot dm^{-3}$)**	**Volume of $HC\ell$ (dm^3)**	**Concentration of $HC\ell$ ($mol \cdot dm^{-3}$)**	**Temperature (°C)**
1	0,1	0,05	0,1	0,1	25
2	0,1	0,05	0,1	0,1	35
3	0,1	0,05	0,1	0,2	25
4	0,1	0,05	0,1	0,3	25
5	0,1	0,05	0,1	0,05	25

3.1 Write a chemical equation showing the ionisation of hydrochloric acid in water. (3)

3.2 Write the symbol for the product that is responsible for the precipitate. (1)

3.3 For which experiment will the **'X'** disappear the fastest? (1)

3.4 Consider Experiments **1** and **2**.

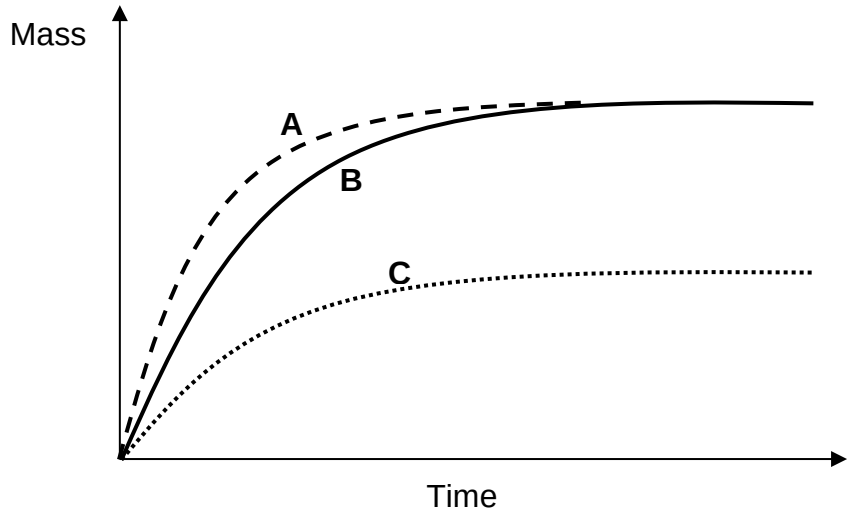
3.4.1 On the ANSWER SHEET, a partially labelled Maxwell-Boltzmann distribution curve for Experiment **1** has been given.

(a) Label the *y*-axis.
(b) Draw the distribution curve for Experiment **2**.
(c) Indicate and label the activation energy. (4)

3.4.2 Using the collision theory, and with reference to the Maxwell-Boltzmann distribution curves in Question 3.4.1, explain fully which experiment would have the higher reaction rate. (4)

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3.5 Consider the graphs below of mass of precipitate formed versus time labelled **A**, **B**, and **C**.



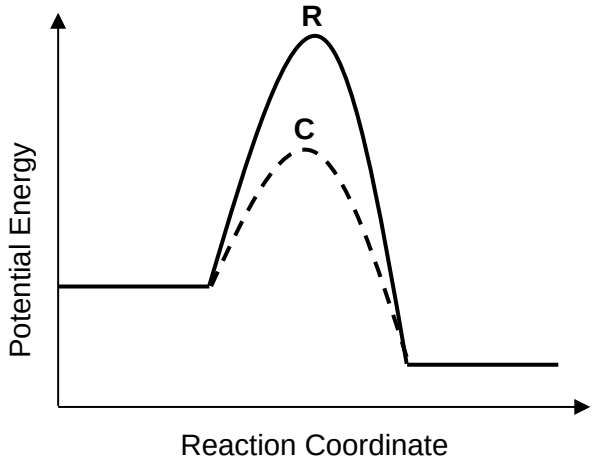
Which graph, **A**, **B**, or **C**, represents:

3.5.1 Experiment **2**? (1)

3.5.2 Experiment **4**? (1)

3.5.3 Experiment **5**? (1)

3.6 Thobeka changes another reaction condition which is represented in the graph below. Curve **R** (solid line) denotes the initial conditions, and curve **C** (dashed line) denotes the changed condition.



3.6.1 Define *activation energy*. (2)

3.6.2 Classify this reaction as EXOTHERMIC or ENDOTHERMIC. (1)

3.6.3 What sign (POSITIVE or NEGATIVE) does the heat of reaction (enthalpy change) have? (1)

3.6.4 Which have stronger bonds: the REACTANTS or the PRODUCTS? (1)

3.6.5 Which reaction condition did Thobeka change? (2)

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QUESTION 4

The oxygen and nitrogen present in air can react in an internal combustion engine at 1 200 °C as follows:

$$N_2(g) + O_2(g) \rightleftharpoons 2NO(g) \qquad \Delta H > 0$$

The equilibrium constant for this reaction at 1 200 °C is $1{,}1 \times 10^{-5}$.

4.1 What does the magnitude of the equilibrium constant for this reaction indicate? (2)

4.2 Fully explain the effect of the high temperature on the YIELD of nitrogen monoxide. (4)

4.3 Internal combustion engines also produce very high pressures. What is the effect of high pressure on the amount of nitrogen monoxide formed? State only INCREASES, DECREASES, or REMAINS THE SAME. (2)

4.4 If oxygen-rich air (air with a higher concentration of oxygen) entered the combustion chamber, how would this affect the amount of nitrogen monoxide formed? State only INCREASE, DECREASE, or REMAIN THE SAME. (2)

4.5 $4{,}5 \times 10^{-3}$ mol each of N_2 and O_2 are added to an empty 0,2 dm^3 container at 1 200 °C, which is then sealed.

4.5.1 Write the expression for the equilibrium constant for this reaction. (2)

4.5.2 Determine the concentration of nitrogen monoxide gas that is present at equilibrium. (6)

When the colourless nitrogen monoxide gas leaves the engine in the exhaust, it reacts reversibly with the oxygen in the air to form the brown gas, NO_2, which is a major contributor to air pollution and smog.

4.6 Write a balanced chemical equation for this reaction. (3)

4.7 Use Le Châtelier's principle to explain the effect of decreasing the pressure of an equilibrium system of nitrogen monoxide, oxygen and nitrogen dioxide. State also any observation that will be made. (4)

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QUESTION 5

Consider the following balanced chemical equations showing some reactions important to acid and base chemistry.

A: $HNO_3 + KOH \rightarrow KNO_3 + H_2O$

B: $2HNO_3 + Na_2CO_3 \rightarrow 2NaNO_3 + CO_2 + H_2O$

C: $H_2SO_3 + H_2O \rightleftharpoons HSO_3^- + H_3O^+$

D: $NH_4C\ell \rightarrow NH_4^+ + C\ell^-$

Below is a table of common indicators, together with the ranges of pH in which the colour change takes place.

Indicator	Colour in lower pH	Colour in higher pH	pH Range
Methyl orange	Red	Yellow	3,1 – 4,4
Bromothymol blue	Yellow	Blue	6,0 – 7,6
Phenolphthalein	Colourless	Pink	8,3 – 10

5.1 Define *acid* in terms of Brønsted and Lowry. (1)

5.2 Consider all of the chemical equations (**A** to **D**) above.

5.2.1 Define *amphoteric substance*. (2)

5.2.2 Write the formula of a chemical species (other than H_2O) that is amphoteric. (1)

5.2.3 Write the formula for the conjugate acid of this species. (2)

5.3 Consider the table of indicators and reaction **A**.

5.3.1 What colour will methyl orange be at pH 5? (1)

5.3.2 What indicator is most suitable for indicating the end point for reaction **A**? (2)

5.4 5.4.1 Define *hydrolysis of a salt*. (2)

5.4.2 Consider reaction **D**. Explain whether a solution of $NH_4C\ell$ would be acidic, basic or neutral. Include any relevant hydrolysis equations in your answer. (5)

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5.5 Consider reactions **A** and **B**, shown below again.

A: $HNO_3 + KOH \rightarrow KNO_3 + H_2O$

B: $2HNO_3 + Na_2CO_3 \rightarrow 2NaNO_3 + CO_2 + H_2O$

A 13 g, **impure** sample of KOH is initially dissolved in 200 cm^3 of a 1,2 $mol \cdot dm^{-3}$ nitric acid solution. The nitric acid was in excess.

50 cm^3 of the resulting solution was then titrated to neutralisation using 23,67 cm^3 of a standard 0,85 $mol \cdot dm^{-3}$ sodium carbonate solution.

5.5.1 Determine the amount (in mol) of nitric acid that was added to the KOH. (4)

5.5.2 Define *standard solution*. (2)

5.5.3 Define *neutralisation point*. (2)

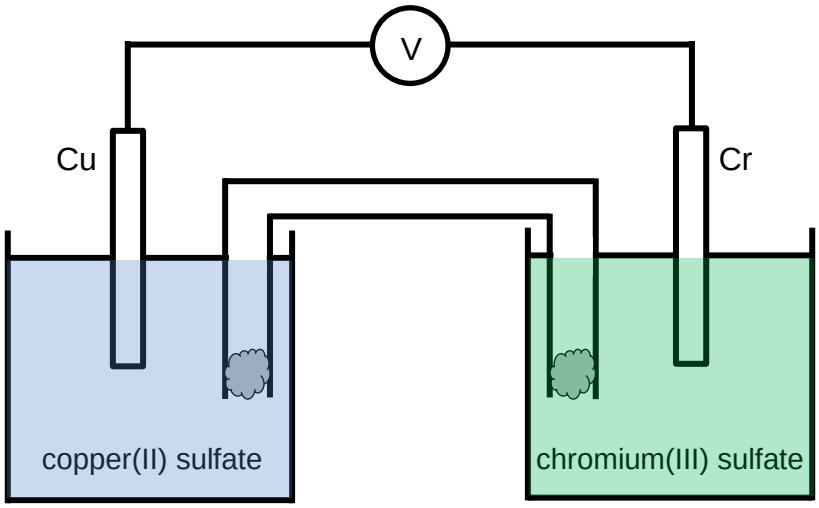
5.5.4 Calculate the percentage purity of the KOH sample. (9)

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QUESTION 6

In the standard cell shown in the diagram below, a copper electrode is placed into a solution of blue copper(II) sulfate, and a chromium electrode is placed into a green chromium(III) sulfate solution. The voltmeter registers a reading.



6.1 Classify this cell as GALVANIC or ELECTROLYTIC. (1)

6.2 Write the formula of chromium(III) sulfate. (2)

6.3 6.3.1 Define *reduction*. (1)

6.3.2 Write the reduction half-reaction. (2)

6.3.3 Define *anode*. (2)

6.3.4 Identify the anode. (1)

6.3.5 Describe TWO observations that can be made in the chromium half-cell after the cell has delivered current for a significant amount of time. (2)

6.4 Write a chemical equation for the net cell reaction that occurs in this cell. (3)

6.5 6.5.1 Determine the initial reading on the voltmeter. (3)

6.5.2 If the initial concentration of copper(II) sulfate used was greater than 1 mol·dm^{-3}, fully explain the effect that this would have on the initial voltmeter reading. (3)

6.6 6.6.1 Write the chemical formula for a suitable reagent that can be used in the salt bridge. (1)

6.6.2 Explain how the salt bridge maintains electrical neutrality in the chromium half-cell. In your answer, refer to the changing ionic conditions as well as the movement of ions. (3)

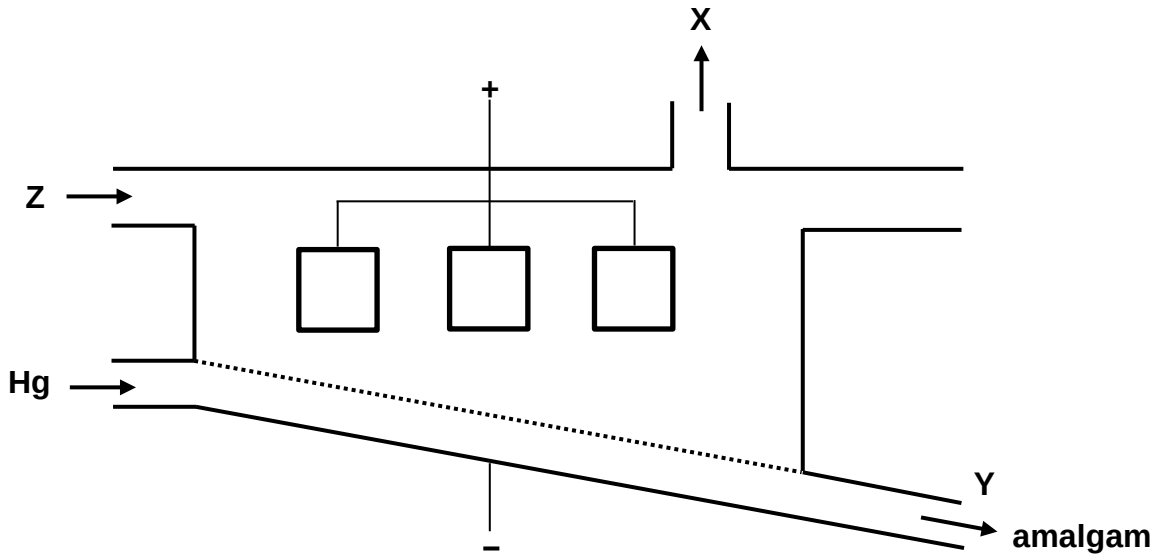
6.7 Write the cell notation for this cell, including conditions and phase indicators. (6)

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QUESTION 7

The diagram below is representative of a mercury cathode cell used in the Chlor-Alkali Industry. Review the process and answer the questions that follow.



The electrolyte **Z** is a saturated sodium chloride solution.

7.1 What name is given to a saturated (concentrated) sodium chloride solution? (2)

7.2 Define *electrolyte*. (2)

7.3 Write the equation for the half-reaction that occurs at the anode. (2)

7.4 NAME the gaseous product collected at **X**. (1)

7.5 Would the same product be collected at **X** if an electrolyte of DILUTE sodium chloride instead of saturated sodium chloride solution is used? Answer YES or NO, and explain FULLY. (3)

7.6 Write the equation for the half-reaction that occurs at the cathode. (2)

7.7 Describe briefly what happens to the amalgam as it leaves this cell (at **Y**) and write the formula for each of the TWO products that result from this next process. (3)

7.8 Explain why metals such as copper are not suitable for use as the anodes in this cell. (2)

7.9 With reference to SAFETY and ECONOMICS, explain why the mercury cell has been phased out and has almost completely been replaced by the membrane cell. (4)

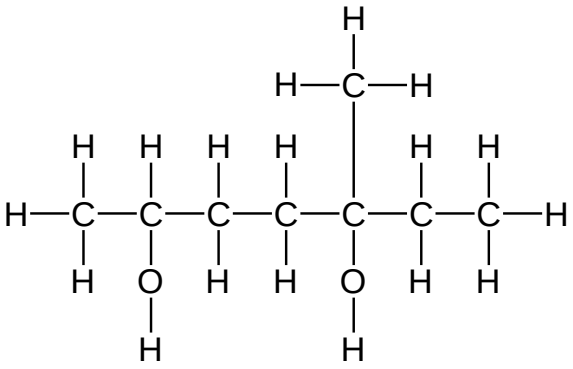
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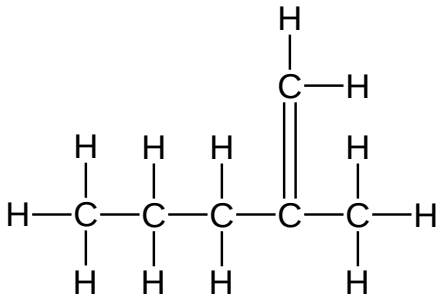
QUESTION 8

Consider the organic compounds **A** to **D** shown below.

A



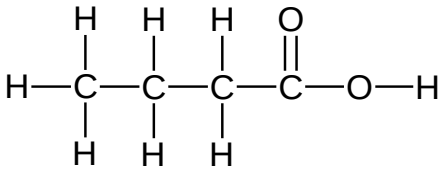
B



C

$CH_3COOC(CH_3)_2CH_3$

D



8.1 Write down the IUPAC name of compound **A**. (4)

8.2 Write down the IUPAC name of compound **B**. (3)

8.3 Draw the structural formula of compound **C**. (2)

8.4 Define *functional group*. (2)

8.5 NAME the functional group present in compound **D**. (1)

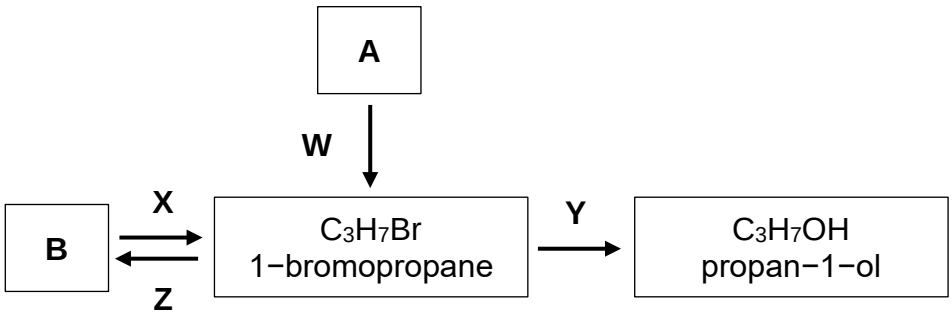
8.6 Draw the structural formula for a FUNCTIONAL ISOMER of compound **D**. (2)

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QUESTION 9

Haloalkanes are important in organic synthesis, for example 1−bromopropane is involved in four organic reactions, **W**, **X**, **Y** and **Z**, as shown in the diagram below. Compounds **A** and **B** are organic compounds.



The reaction conditions for each reaction are given in the table below.

Reaction	Conditions
W	Br_2 and UV light
X	Compound **B** is treated with HBr
Y	1−bromopropane is heated with a dilute, aqueous solution of sodium hydroxide under reflux
Z	1−bromopropane is heated with a concentrated, alcoholic solution of potassium hydroxide

9.1 Write down the GENERAL types of reactions for each of the following:

9.1.1 Reaction **X** (1)

9.1.2 Reaction **Y** (1)

9.1.3 Reaction **Z** (1)

9.2 Write down the SPECIFIC types (NAMES) of each of the following:

9.2.1 Reaction **W** (1)

9.2.2 Reaction **X** (1)

9.2.3 Reaction **Y** (1)

9.2.4 Reaction **Z** (1)

9.3 Identify the homologous series to which compound **A** belongs. (1)

9.4 Use condensed-structural formulae to write a balanced chemical equation for reaction **X**. (4)

9.5 Use structural formulae to write a balanced chemical equation for reaction **Y**. (4)

9.6 Write down the IUPAC name of the organic product produced when propan−1−ol is treated with concentrated sulfuric acid and heated. (2)

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Total: 200 marks

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