NATIONAL SENIOR CERTIFICATE EXAMINATION
NOVEMBER 2021

PHYSICAL SCIENCES: PAPER II

Time: 3 hours 200 marks

PLEASE READ THE FOLLOWING INSTRUCTIONS CAREFULLY

1. This question paper consists of 16 pages, a yellow ANSWER SHEET of 1 page (i) and a green DATA SHEET of 3 pages (i–iii). Please make sure that your question paper is complete.
2. Remove the DATA SHEET from the middle of this question paper.
3. Read the questions carefully.
4. ALL 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 front cover of your Answer Book.
6. **START EACH QUESTION ON A NEW PAGE.**
7. Please 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 two decimal places.
12. It is in your interest to write legibly and to present your work neatly.

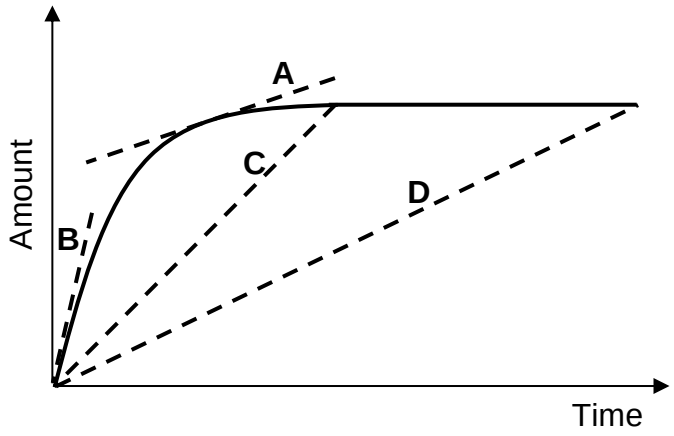
QUESTION 1 MULTIPLE CHOICE

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 The following is a graph of amount of product versus time for a reaction.



Which one of the dashed lines, A, B, C or D, has a gradient that represents the AVERAGE rate of reaction?

1.2 Which one of the following is FALSE regarding a reaction that is at chemical equilibrium?

A The concentration of reactants is always equal to the concentration of products.
B The amount of reactants and products always remains constant.
C The rate of the forward reaction is always equal to the rate of the reverse reaction.
D It can only occur in a closed system.

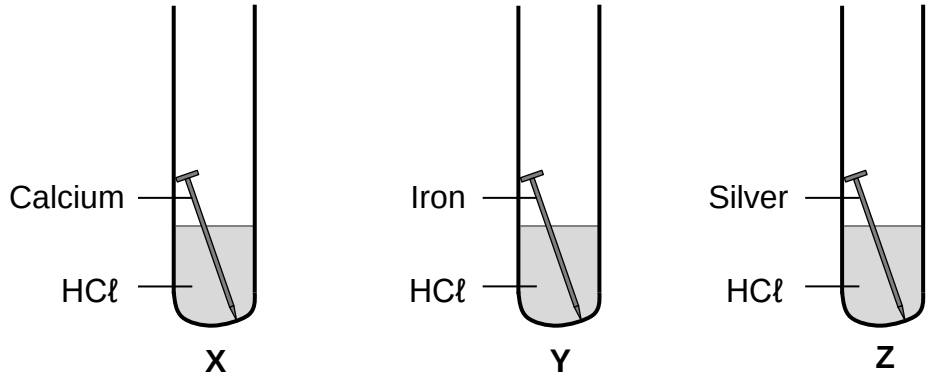
1.3 The following reaction reaches equilibrium in a sealed container:

$$2NOC\ell(g) \rightleftharpoons 2NO(g) + C\ell_2(g) \qquad \Delta H < 0$$

Which one of the following changes will NOT affect the equilibrium amount of nitrogen monoxide (NO)?

A An increase in temperature.
B The addition of inert argon gas.
C The removal of $C\ell_2$.
D A decrease in the volume of the container.

1.4 Kaitlynn puts three nails made of different metals into separate tubes, **X**, **Y**, and **Z**, that each contains 1 mol·dm^{-3} hydrochloric acid at 25 °C.



In which tubes will hydrogen gas be produced?

A **X** and **Y** only
B **X** and **Z** only
C **Y** and **Z** only
D **X**, **Y** and **Z**

1.5 Which one of the following methods will increase the pH of a solution of nitric acid, $HNO_3(aq)$, from pH 4 to pH 6?

A Adding water (diluting the solution)
B Removing water (concentrating the solution)
C Adding $NaNO_3$ crystals to the solution
D Adding $NH_4C\ell$ crystals to the solution

1.6 Consider the proton transfer reaction below.

$$CH_3CH_2NH_2 + HF \rightleftharpoons CH_3CH_2NH_3^+ + F^-$$

Which one of the following correctly identifies an acid–base conjugate pair?

	Conjugate Acid	**Conjugate Base**
A	$CH_3CH_2NH_2$	$CH_3CH_2NH_3^+$
B	$CH_3CH_2NH_2$	F^-
C	HF	$CH_3CH_2NH_3^+$
D	HF	F^-

1.7 A galvanic cell is constructed using Cu and Zn electrodes. The electrons flow from the:

A Cu half-cell to the Zn half-cell through the salt bridge
B Zn half-cell to the Cu half-cell through the salt bridge
C Cu half-cell to the Zn half-cell through the wire
D Zn half-cell to the Cu half-cell through the wire

1.8 Which one of the following is the strongest oxidising agent under standard conditions?

A Fe^{3+}
B Fe
C H_2O_2
D I_2

1.9 A compound with the general formula C_nH_{2n} is a/an:

A alkane
B alkene
C alcohol
D carboxylic acid

1.10 The complete combustion of ONE MOLE of butan−1−ol needs at least:

A 6 mol of O_2
B 7,5 mol of O_2
C 11 mol of O_2
D 12 mol of O_2

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QUESTION 2

Diethyl zinc reacts spontaneously with water to form ethyl zinc hydroxide and ethane according to the following balanced chemical equation:

$$(C_2H_5)_2Zn(\ell) + H_2O(\ell) \rightarrow C_2H_5ZnOH(\ell) + C_2H_6(g)$$

2.1 Consider the heat of reaction.

2.1.1 Define *heat of reaction*. (2)

2.1.2 Define *endothermic reaction*. (2)

2.1.3 In the reaction above, more energy is released than is absorbed. Classify the reaction as ENDOTHERMIC or EXOTHERMIC. (1)

2.1.4 In order for the reaction above to proceed, some bonds must be broken and others must be formed. Is bond breaking an ENDOTHERMIC or EXOTHERMIC process? (1)

2.2 Consider the intermolecular forces in ethane.

2.2.1 Define *intermolecular force*. (2)

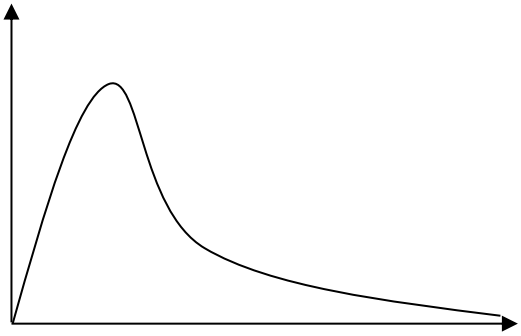
2.2.2 Identify the predominant intermolecular force in ethane. (1)

2.2.3 Hence, explain why ethane is a gas at room temperature. (2)

2.3 Consider rate of reaction.

2.3.1 Define *rate of reaction*. (2)

2.3.2 The following graph shows the Maxwell-Boltzmann distribution curve for the reaction at room temperature (25 °C).



Kinetic energy

This graph has been provided on your ANSWER SHEET. On the graph on the ANSWER SHEET, draw the curve that would be obtained at 50 °C.

Indicate the following on your graph:

- The Y-axis label.
- **E_A**, the activation energy.
- **P**, a shaded area representing the proportion of particles with sufficient kinetic energy to react. (4)

2.3.3 Fully explain how an increase in temperature affects the rate of this reaction. In your answer, refer to the collision theory and to the Maxwell-Botlzmann distribution curves from Question 2.3.2. (4)

2.3.4 How could the rate of this reaction be measured in practice? In your answer, specify what equipment should be used and which quantities should be measured. (3)

2.4 Sarah reacts 50 g of diethyl zinc with 40 g of water.

2.4.1 Use suitable calculations to determine the limiting reagent. (3)

2.4.2 Hence, determine the maximum volume of ethane that Sarah can collect at STP. (4)

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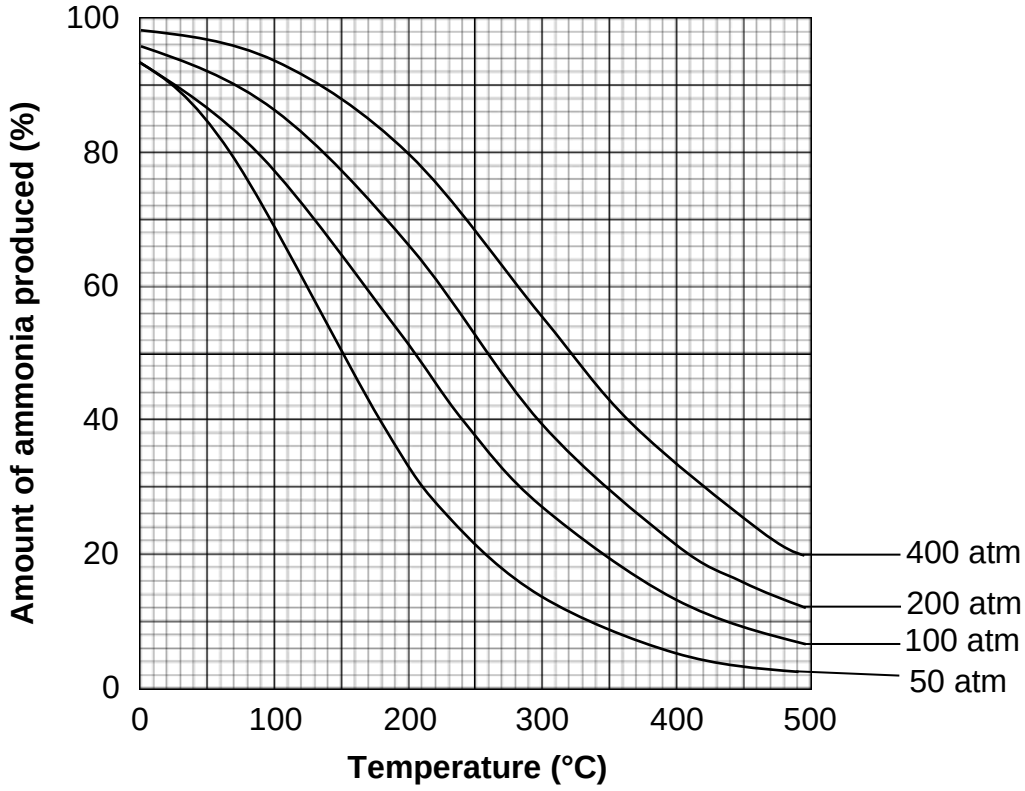
QUESTION 3

The Haber process uses nitrogen and hydrogen gases to produce ammonia gas, represented in the reversible reaction below.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

Bongani researches the Haber process. He finds a graph (below) showing how the percentage yield of ammonia is affected by changes in temperature and pressure.



In industry, the Haber process is typically operated at a **temperature of 450 °C** and a **pressure of 200 atmospheres (200 atm)**.

3.1 Is the forward reaction in the Haber process EXOTHERMIC or ENDOTHERMIC? (1)

3.2 Explain the answer to Question 3.1 in terms of Le Châtelier's principle and by making reference to the graph. (4)

3.3 What is the percentage yield of ammonia at 450 °C and 200 atmospheres? (1)

The Haber process reaction is repeated below:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

3.4 Will high pressures favour the production of ammonia? State only YES or NO. (1)

3.5 From the graph, it can be seen that at 0 °C the yield of ammonia is in excess of 90%. In industry, however, much higher temperatures are used. Fully explain why this is so. (3)

3.6 An iron catalyst is used in industry. How will this affect the percentage yield of ammonia? State only INCREASE, DECREASE, or NO EFFECT. (2)

3.7 Bongani looks up the equilibrium constant for the Haber process from a reputable source but only finds a constant measured at 472 °C and 300 atmospheres.

Can Bongani still use this value for the conditions used in industry? Explain. (3)

3.8 Define *open system* in chemistry. (2)

3.9 The ammonia can be continuously removed from the reaction chamber by dissolving it in solution. With reference to REACTION RATE, explain how this will affect the yield of ammonia. (3)

[20]

QUESTION 4

Propanoic acid, CH_3CH_2COOH, is a weak organic acid. It ionises in water to form the propanoate ion and hydronium ion as shown:

$CH_3CH_2COOH(aq) + H_2O(\ell) \rightleftharpoons CH_3CH_2COO^-(aq) + H_3O^+(aq)$ $K_a = 1,34 \times 10^{-5}$

A 0,32 $mol \cdot dm^{-3}$ standard solution of propanoic acid is prepared in a 500 cm^3 volumetric flask at 25 °C.

4.1 Define *concentration*. (2)

4.2 What mass of propanoic acid was needed to prepare the standard solution? (4)

4.3 Why is propanoic acid considered to be a WEAK acid? (1)

4.4 Write an expression for the acid ionisation constant, K_a. (2)

4.5 Show that the hydronium ion concentration in the above solution is $2,06 \times 10^{-3}$ $mol \cdot dm^{-3}$. (4)

4.6 Hence, determine the concentration of hydroxide ions in the propanoic acid solution. (3)

4.7 Define *covalent bond*. (2)

4.8 Define *electronegativity*. (2)

4.9 Name the specific type of covalent bond present in the H_2O molecules. (1)

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QUESTION 5

Sonali attempted to determine the concentration of a barium hydroxide solution. She used the same propanoic acid solution from Question 4, with a concentration of 0,32 mol·dm^{-3}.

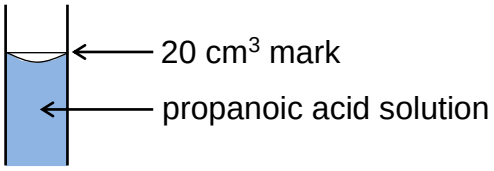
Propanoic acid, CH_3CH_2COOH, is a weak organic acid and barium hydroxide, $Ba(OH)_2$, is a **STRONG** base.

The following steps were performed.

Step 1: A conical flask was rinsed with distilled water.

Step 2: A 20 cm^3 pipette was rinsed with distilled water.

Step 3: Sonali filled the pipette with the 0,32 mol·dm^{-3} standard solution of propanoic acid to the level shown in the diagram below.



Step 4: Sonali transferred the propanoic acid solution from the pipette to the conical flask.

Step 5: Three drops of an appropriate indicator were added to the conical flask.

Step 6: A burette was rinsed with some of the barium hydroxide solution and then filled with the barium hydroxide solution to the mark.

Step 7: Sonali then carried out a titration to determine the concentration of the barium hydroxide solution.

5.1 In steps **2** and **3** above, Sonali did not follow appropriate procedures.

5.1.1 Identify the mistake in EITHER step **2** OR step **3**. (1)

5.1.2 Explain how the mistake identified in Question 5.1.1 would affect the calculated concentration of barium hydroxide. (3)

5.2 Sonali records the following data from her titration. Assume that all previous mistakes were rectified.

Concentration of propanoic acid used: 0,32 mol·dm^{-3}
Volume of propanoic acid used: 0,020 dm^3

Volume of barium hydroxide dispensed (dm^3):			
Run 1	Run 2	Run 3	Average
0,01691	0,01896	0,02095	0,01894

5.2.1 Define *neutralisation*. (2)

5.2.2 Write a balanced chemical equation for the neutralisation reaction in this titration. (3)

5.2.3 Estimate the pH of the solution at its end point. (2)

5.2.4 Using these results, Sonali calculated the concentration of the barium hydroxide solution to be 0,17 mol·dm^{-3}. Show how Sonali calculated this concentration. (5)

5.2.5 The ACTUAL concentration of the barium hydroxide is 0,18 mol·dm^{-3}.

(a) Is Sonali's data PRECISE or IMPRECISE? Give a reason which shows your understanding of the term *precise*. (2)

(b) Is Sonali's data ACCURATE or INACCURATE? Give a reason which shows your understanding of the term *accurate*. (2)

[20]

QUESTION 6

Consider the galvanic cell, represented by the cell notation below.

$$Pt(s) \mid H_2(g) \mid H^+(aq) \parallel Ni^{2+}(aq) \mid Ni(s) \text{ at } 25\ °C$$

This cell was set up to determine the standard electrode potential of the $Ni^{2+} \mid Ni$ half-cell.

6.1 Consider the standard hydrogen electrode used in this cell.

6.1.1 Besides the temperature of 25 °C, state the standard condition associated with the gaseous H_2 in the above cell. (1)

6.1.2 Besides the temperature of 25 °C, state the standard condition associated with the aqueous H^+ in the above cell. (1)

6.1.3 Which terminal of the voltmeter should be connected to the standard hydrogen electrode? State only POSITIVE or NEGATIVE. (1)

6.1.4 Calculate the initial reading on the voltmeter. Show all working. (4)

6.2 The voltmeter is replaced with a resistor, resulting in an average current of 2,25 A being drawn from the cell for 4 hours.

6.2.1 Write down the balanced chemical equation for the SPONTANEOUS reduction half-reaction that occurs. (2)

6.2.2 Calculate the change in mass of the nickel electrode. (8)

6.2.3 The salt bridge maintains electrical neutrality. Describe, with reasons, the movement of ions INTO and OUT OF the salt bridge in the NICKEL half-cell. (3)

6.3 The platinum electrode in the hydrogen half-cell is usually quite small due to it being expensive. If a larger electrode is used, how would this affect the following? (State only INCREASE, DECREASE or NO EFFECT.)

6.3.1 The maximum current produced in the cell. (2)

6.3.2 The initial emf of this cell. (2)

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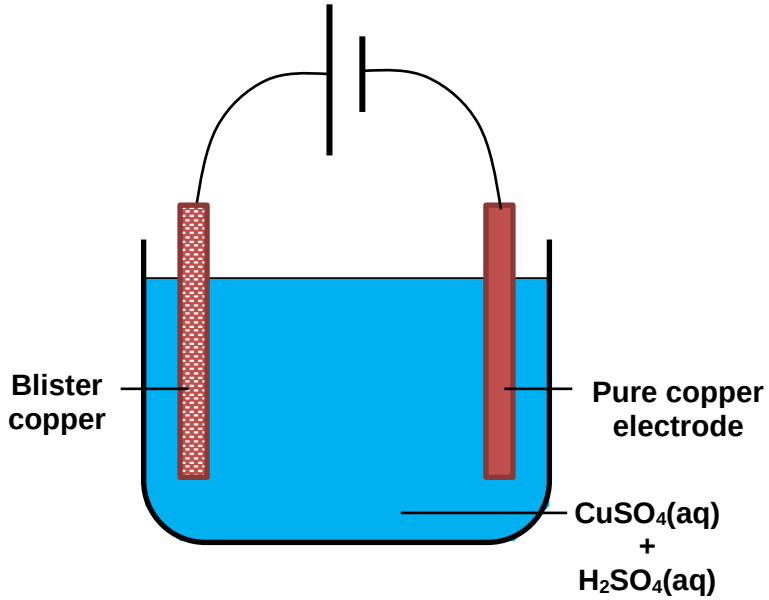
QUESTION 7

The electrochemical cell below is constructed to refine a piece of blister copper (impure copper). In addition to copper metal, the blister copper electrode contains zinc, cobalt, silver and gold.



7.1 Copper is mainly used as a conductor in electrical circuits. Why, then, is it important that the copper used be PURE? (1)

7.2 What energy conversion occurs in this cell? (2)

7.3 The $CuSO_4$ electrolyte is dissolved in solution.

7.3.1 Explain why it is necessary to dissolve the $CuSO_4$ in solution. (2)

7.3.2 What is the purpose of the H_2SO_4? (1)

7.4 Is the blister copper electrode the POSITIVE or NEGATIVE electrode? (1)

7.5 Consider the change occurring at the cathode.

7.5.1 What observation can be made at the **cathode** after some time has passed? (1)

7.5.2 Give a half-reaction to support this observation. (2)

7.6 The zinc and cobalt impurities in the blister copper electrode are oxidised in addition to the copper. The silver and gold impurities are not oxidised.

7.6.1 Define *oxidation*. (1)

7.6.2 Write an equation for the half-reaction for the oxidation of copper. (2)

7.6.3 A sludge accumulates below the blister copper electrode. Which impurities are present in this sludge? (2)

7.6.4 Fully explain why the zinc is oxidised but the silver is not. (3)

7.7 Explain how the concentration of the Cu^{2+} ions in the electrolyte changes over time. (3)

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QUESTION 8

8.1 Consider the following two compounds:

W methyl hexanoate

X 3,3−dimethylpentan−1−ol

8.1.1 Define *functional group*. (2)

8.1.2 Name the functional group found in compound **X**. (1)

8.1.3 Draw the condensed-structural formula for compound **W**. (2)

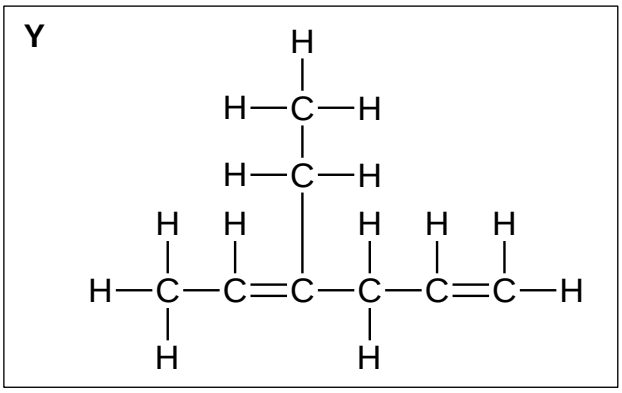
8.1.4 Draw the structural formula for compound **X**. (3)

8.1.5 Define *structural isomers*. (2)

8.1.6 Give the IUPAC name of the FUNCTIONAL isomer of compound **W**. (2)

8.2 Consider the following two compounds:

Y



Z $CHBr_2CHC\ell CH_3$

8.2.1 Write down the IUPAC name for compound **Y**. (4)

8.2.2 Write down the IUPAC name for compound **Z**. (4)

8.2.3 Compound **Y** is a hydrocarbon.

(a) Define *hydrocarbon*. (2)

(b) Classify compound **Y** as SATURATED or UNSATURATED. (1)

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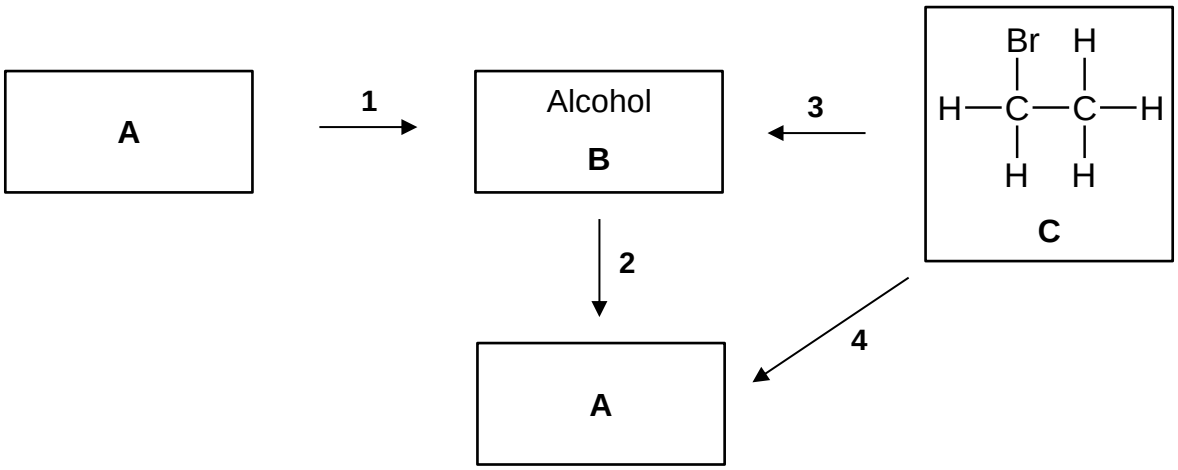
QUESTION 9

The following sequence of reactions involves organic compounds **A**, **B** and **C** in organic reactions **1**, **2, 3** and **4**.



The following conditions were used for each reaction:
- Reaction **1**: Steam and diluted H_3PO_4
- Reaction **2**: Heat with excess concentrated H_2SO_4
- Reaction **3**: Reflux in diluted aqueous KOH

9.1 Define *homologous series*. (2)

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

9.3 Identify the GENERAL TYPE of reaction represented in reaction **1**. (1)

9.4 Identify the GENERAL TYPE of reaction represented in reaction **4**. (1)

9.5 Identify the SPECIFIC TYPE of reaction represented in reaction **2**. (1)

9.6 Identify the SPECIFIC TYPE of reaction represented in reaction **3**. (1)

9.7 Write down the IUPAC name for compound **B**. (3)

9.8 Write down the IUPAC name for compound **C**. (3)

9.9 Which one of the compounds **B** and **C** would have the higher boiling point? Fully explain. (5)

9.10 Alcohol **B** is again heated with a few drops of concentrated H_2SO_4 but with the addition of a carboxylic acid. Identify the homologous series of the product that results. (2)

[20]

Total: 200 marks