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**TOTAL MARKS**

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Preliminary Examination 2023

Physical Sciences: Paper II

Time: 3 hours**200 marks**

NAME: _____

PLEASE READ THE FOLLOWING INSTRUCTIONS CAREFULLY

1. This question paper consists of 37 pages and a DATA SHEET of 3 pages (i–iii). Please make sure that your question paper is complete.
2. Answer ALL the questions on the question paper.
3. Read the questions carefully.
4. Use the data and formulae whenever necessary.
5. Unless instructed otherwise, it is NOT necessary to give state symbols (phase indicators) when asked to write a balanced chemical equation.
6. Show all the necessary steps in calculations.
7. Where appropriate, express final answers correct to TWO decimal places.
8. It is in your interest to write legibly and to present your work neatly.
9. Two blank pages (pages 36 and 37) are included at the end of the exam paper. If you run out of space for an answer, use these pages. If you use the extra space, make sure that you indicate this clearly at the question to ensure that your answer is marked in full.

FOR MARKER TO ENTER MARKS

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9
Mark									
Moderated mark									
Question total	20	28	18	19	31	30	14	22	18

QUESTION 1 MULTIPLE CHOICE

Answer these questions on the multiple-choice answer grid below. Make a clear cross (X) in the box corresponding to the letter that you consider to be correct. Every question has only one correct answer.

A	B	~~C~~	D
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Here the option C has been marked as an example.

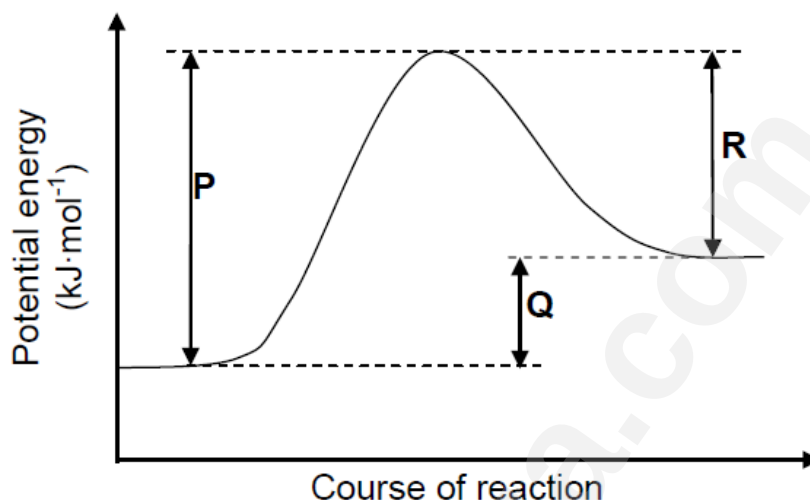
1.1	A	B	C	D
1.2	A	B	C	D
1.3	A	B	C	D
1.4	A	B	C	D
1.5	A	B	C	D
1.6	A	B	C	D
1.7	A	B	C	D
1.8	A	B	C	D
1.9	A	B	C	D
1.10	A	B	C	D

1.1 Which of the following is the correct formula for ammonium thiosulphate?

- A NH_3SO_3
- B $(\text{NH}_4)_2\text{SO}_4$
- C $\text{NH}_3\text{S}_2\text{O}_3$
- D $(\text{NH}_4)_2\text{S}_2\text{O}_3$

- 1.2 The energy changes represented by **P**, **Q** and **R** on the potential energy graph below take place during a reversible chemical reaction.

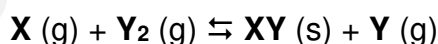
(Adapted from Hilton College Preliminary Paper 2, 2019)



Which ONE of the following best describes the effect that the removal of a catalyst will have on **P**, **Q**, **R**?

	P	Q	R
A	increases	stays the same	increases
B	decreases	stays the same	decreases
C	decreases	decreases	decreases
D	increases	increases	increases

- 1.3 1 mol of **X** and 1 mol of **Y₂** are placed in an evacuated container with a volume of 1 dm³. **X** and **Y₂** react according to the equation represented below:



The equilibrium constant, K_c , is determined at a specific temperature.

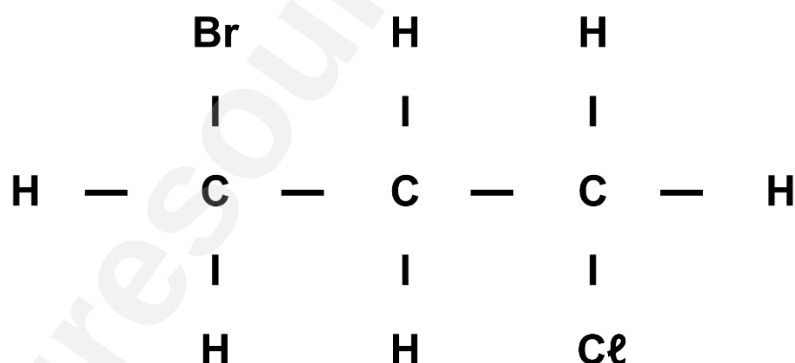
If $K_c = 0,5$, then which of the following concerning the concentrations of the substances at equilibrium is true?

- A $[\text{X}] = [\text{Y}]$
- B $[\text{XY}] = [\text{Y}]$
- C $2[\text{Y}] = [\text{X}][\text{Y}_2]$
- D $[\text{X}][\text{Y}_2] = 0,5[\text{Y}]$

- 1.8 Cryolite, sodium aluminium fluoride, is used in the electrolytic extraction of aluminium. Which of the following statements regarding cryolite is NOT true?

Cryolite

- A lowers the melting point of the alumina.
 - B increases the electrical conductivity of the molten alumina.
 - C increases the activation energy of the aluminum oxide.
 - D consists of ions that are strong reducing agents.
- 1.9 The complete combustion of 2 mol of propene results in the formation of
- A 6 moles of CO₂ and 6 moles of H₂O
 - B 3 moles of CO₂ and 4 moles of H₂O
 - C 2 moles of CO₂ and 9 moles of H₂O
 - D 1 mole of CO₂ and 5 moles of H₂O
- 1.10 Given the organic compound below:



The IUPAC name of a positional isomer would be:

- A 1-bromo-3-chloropropane
- B 1-chloro-3-bromopropane
- C 2-bromo-3-chloropropane
- D 2-bromo-1-chloropropane

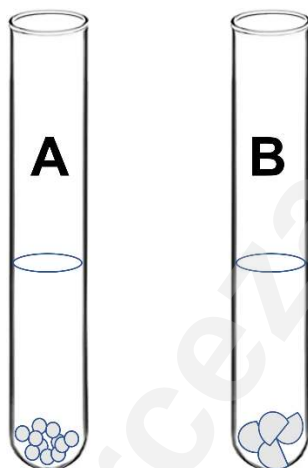
[20]

QUESTION TWO

Two students, Thabo and Mikayla, carry out the following investigation:

Two test-tubes, **A** and **B**, each containing 60 cm^3 of a $0,5 \text{ mol} \cdot \text{dm}^{-3}$ solution of hydrochloric acid are prepared.

0,8 g of calcium carbonate powder is added to test-tube **A** and 0,8 g of calcium carbonate chips are added to test-tube **B**.



The chemical equation for the reaction that takes place in the two test-tubes is:



2.1 Identify the independent variable in this investigation.

(1)

2.2 Describe one difference in the observations that Thabo and Mikayla will record for the reactions occurring in test-tubes **A** and **B**.

(2)

- 2.3 Explain the difference in the observation indicated in question 2.2 in terms of the collision theory.

(3)

- 2.4 Determine which reagent, CaCO_3 or HCl , is the limiting reagent in the reactions that occur in test-tubes **A** and **B**. Show all working.

(6)

- 2.5 State whether the following INCREASE, DECREASE or REMAIN THE SAME during the chemical reactions that take place in test-tubes **A** and **B**.

2.5.1 The concentration of the calcium ions.

(1)

2.5.2 The concentration of the hydronium ions.

(1)

2.5.3 The pH of the solution.

(1)

Thabo and Mikayla decide to repeat the investigation by adding 0,8 g of calcium carbonate powder to 120 cm³ of a 0,5 mol·dm⁻³ solution of hydrochloric acid in a test-tube labelled **C**.

2.6 How does the rate of production of carbon dioxide gas, and the final amount of carbon dioxide gas that is produced on completion of the reactions, compare between test-tube **C** and test-tube **A**.

Write only INCREASE, DECREASE or REMAIN THE SAME in the table below.

RATE OF PRODUCTION OF CO _{2(g)}	FINAL AMOUNT OF CO _{2(g)} PRODUCED

(2)

2.7 Define *intramolecular bonding*.

(2)

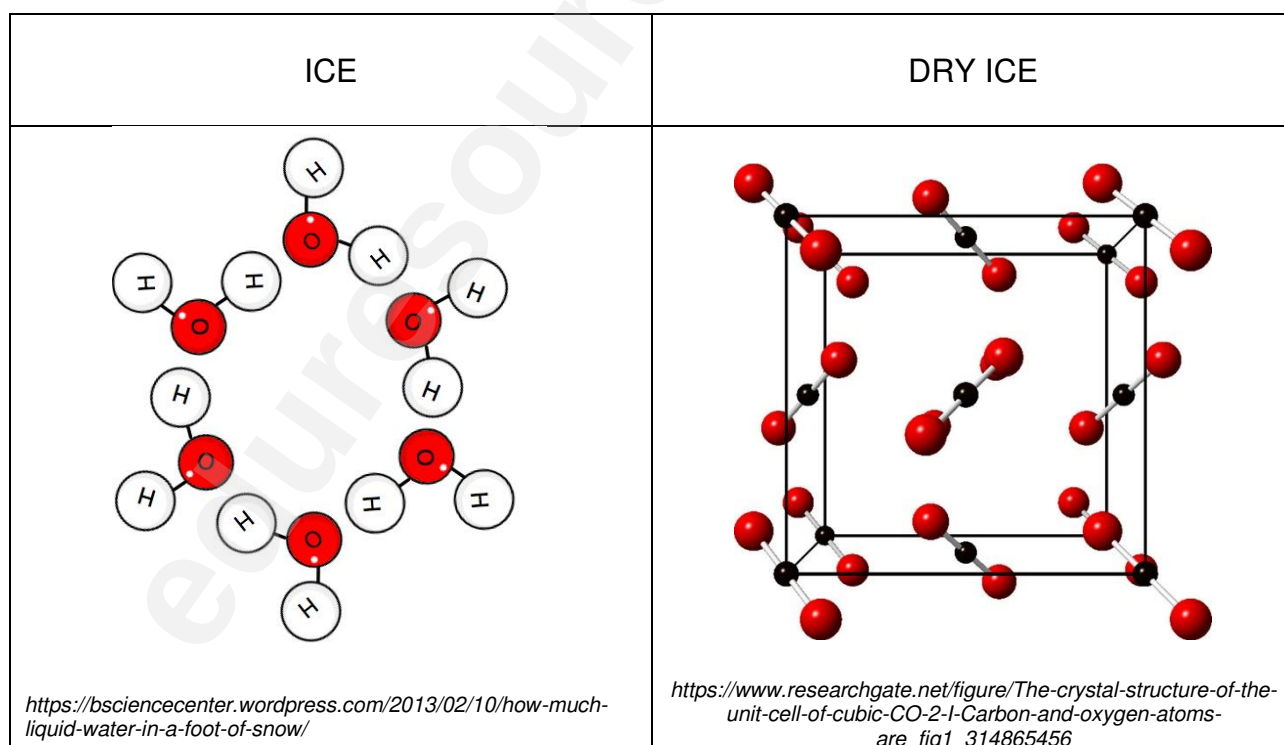
2.8 Name the product of the reaction between calcium carbonate and hydrochloric acid that consists of cations and anions.

(1)

2.9 Name the specific type of intramolecular bond that is found in carbon dioxide. Support your answer with a calculation.

(3)

The diagrams below show the arrangement of water and carbon dioxide molecules, in crystals of ice and dry ice, respectively.



2.10 Why does dry ice sublime at $-78,5^{\circ}\text{C}$ and ice melt at $0,0^{\circ}\text{C}$?

Refer to the nature of the intermolecular forces and the arrangement of the molecules in solid water and solid carbon dioxide to explain this difference.

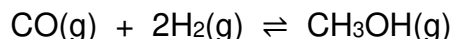
This image shows a blank sheet of white paper with horizontal ruling lines. A diagonal watermark with the text "rceza.com" is visible across the page. The watermark is light gray and oriented from the bottom-left towards the top-right. There are ten horizontal lines spaced evenly down the page.

(5)

[28]

QUESTION THREE

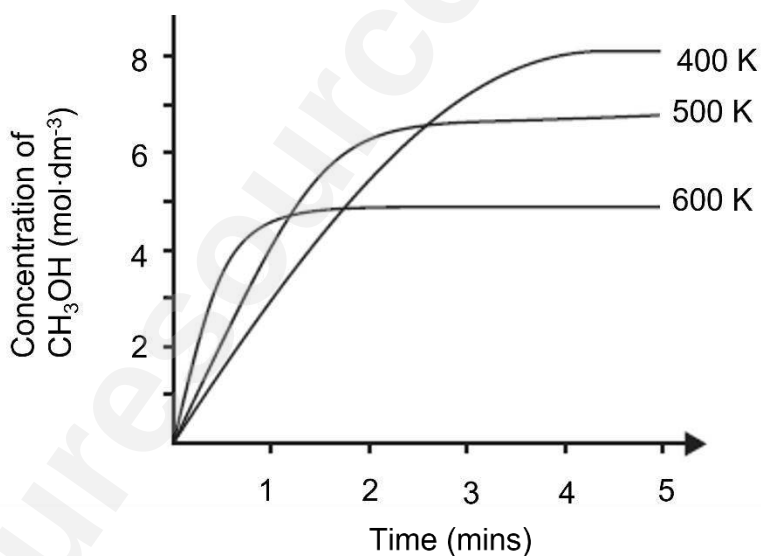
Methanol (CH_3OH) is an important chemical that is used in fuel mixtures. It is produced on an industrial scale by the catalytic conversion of a mixture of hydrogen (H_2) and carbon monoxide (CO) gases at a temperature of 520 K and a pressure of 5000 to 10 000 kPa. The chemical equation for the reversible reaction that occurs is represented below.



3.1 Explain what is meant by a *reversible reaction*.

(2)

CO and H_2 gases are mixed in a closed system. The graph below shows how the concentration of methanol changes with time at three different temperatures. The pressure is the same at each temperature.



3.2 Define a *closed system*.

(2)

- 3.3 Calculate the average rate of production of methanol during the first four minutes at 400 K.

(3)

- 3.4 Give one piece of evidence from the graph that indicates that the initial average rate of production of ethanol is higher at 600 K than at 400 K.

(1)

- 3.5 Describe one effect, other than rate of reaction, of an increase in temperature on the production of methanol.

(2)

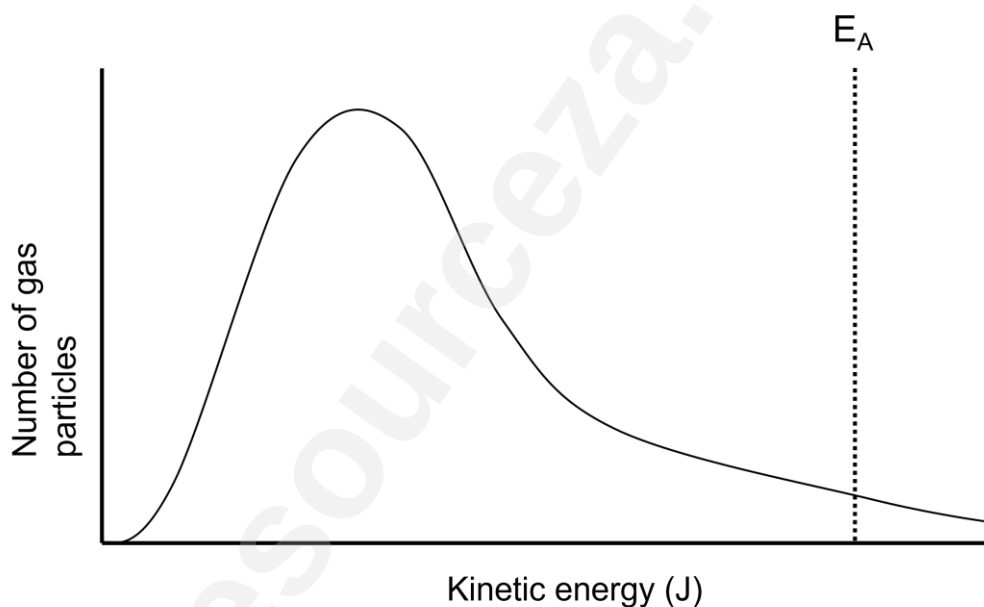
- 3.6 Is the forward reaction exothermic or endothermic? Explain your answer.

(3)

- 3.7 Why is the industrial production of methanol carried out at 520 K rather than at 400 K or 600 K?

(2)

The Boltzmann-distribution curve below represents the number of hydrogen and carbon monoxide gas particles versus kinetic energy. The dashed line represents the activation energy, E_A .



A catalyst consisting of a mixture of Cu, Zn and Al is added to the reaction vessel.

- 3.8 Show the effect of a catalyst on the above Maxwell-Boltzmann distribution curve.

(2)

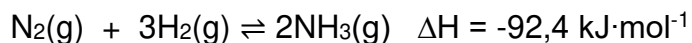
- 3.9 Shade in the number of particles that can undergo effective collisions, in the presence of the catalyst, on the above Boltzmann distribution curve.

(1)

[18]

QUESTION FOUR

The Haber process is a reversible chemical reaction used in the production of ammonia, NH_3 , from nitrogen, N_2 , and hydrogen, H_2 , gases. The balanced chemical equation for the reaction is:



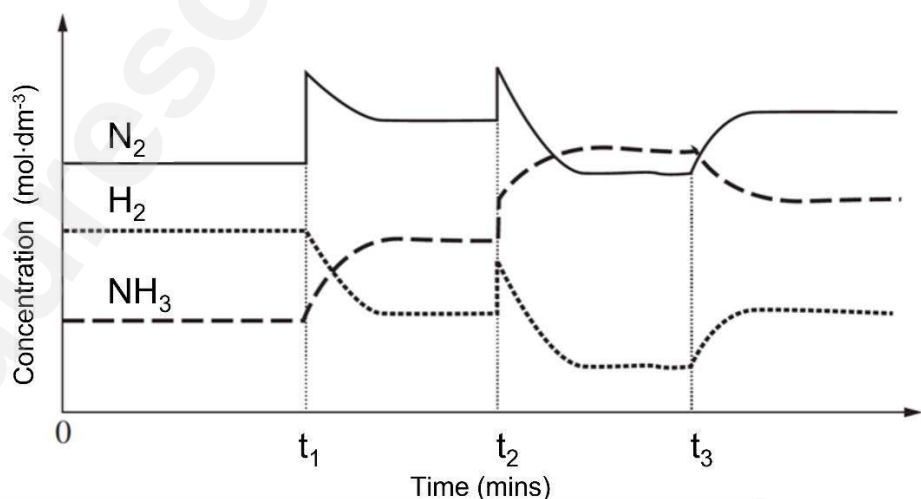
4.1 Explain what is meant by *heat of reaction*.

(2)

4.2 What is the heat of reaction for the reverse reaction?

(1)

The graph below represents the changes in the concentrations of the gases in a closed reaction vessel over time. The graph is not drawn to scale.



<https://scienceready.com.au/pages/le-chateliers-principle>

4.3 Compare the rates of the forward and reverse reactions at:

4.3.1 Time = 0 minutes

(1)

4.3.2 A time just after t_1

(1)

4.4 What change occurred at t_2 ?

(1)

4.5 How does the change at t_2 affect the yield of ammonia at equilibrium? Explain your answer with reference to the graph.

(5)

A group of investigators place **X** moles of nitrogen gas and 20 g of hydrogen gas into an empty 10 dm³ container at 400 K.

At equilibrium the concentration of ammonia is $0,2 \text{ mol}\cdot\text{dm}^{-3}$.

4.6 Write an expression for the equilibrium constant for the Haber process.

(2)

4.7 The equilibrium constant for the Haber process at 400 K is 6,04. Determine the value of **X**.

(6)

[19]

QUESTION FIVE

Three different acid solutions **P**, **Q** and **R**, are prepared as shown in the table below:

P	0,08 mol·dm ⁻³ H ₂ SO ₄
Q	0,10 mol·dm ⁻³ HNO ₃
R	0,06 mol·dm ⁻³ CH ₃ COOH

5.1 Which of the solutions, **P**, **Q** or **R**.....

5.1.1 Is classified as a strong, diprotic acid?

(1)

5.1.2 Will have the highest pH?

(1)

5.1.3 Will have the highest electrical conductivity?

(1)

5.1.4 Explain your answer to question 5.1.3 by comparing the three different acid solutions to one another.

(3)

5.2 Write an equation to show the ionisation of ethanoic acid in water.

(2)

5.3 Write the formula for the conjugate base of CH_3COOH .

(1)

5.4 Write an expression for the ionisation constant for ethanoic acid.

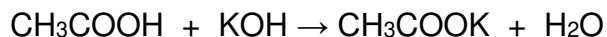
(2)

5.5 Will ethanoic acid have a high or a low ionisation constant? Explain your answer by referring to the expression in question 5.4

(2)

Kayla is given 250 cm³ of solution **R**. She performs a titration using **R**, to determine the concentration of a solution of potassium hydroxide.

The equation for the reaction that occurs during the titration is given below.



- 5.6 Which indicator from the list of acid-base indicators shown below, would be the most suitable for Kayla to choose for this titration?

(1)

INDICATOR	APPROXIMATE pH RANGE FOR COLOUR CHANGE	COLOUR CHANGE
Methyl orange	3,2-4,4	Red to yellow
Bromothymol blue	6,0-7,6	Yellow to blue
Phenolphthalein	8,2-10,0	Colourless to pink
Bromocresol green	3,8-5,4	Yellow to blue

- 5.7 Explain your choice in question 5.6 in terms of the hydrolysis of the salt formed in the titration.

(4)

Kayla set up her apparatus for the titration: she placed 30 cm³ of the KOH into a clean conical flask: added a few drops of her chosen indicator to the contents of the flask, and then began to titrate the acid against the base.

5.8 State ONE advantage of using a conical flask during a titration,

(2)

5.9 Describe the colour change that will take place during this titration, using the indicator named in question 5.6.

(1)

Kayla obtains the following results for three runs of the titration:

Table to show the volume of acid titrated against 30 cm³ base solution used for each run of the titration.

Run number	1	2	3
Start volume (cm ³)	4,51	4,15	6,80
End volume (cm ³)	44,39	43,25	49,31
Volume delivered to flask (cm ³)			

5.10 Complete the table above and determine the average volume of acid delivered to the conical flask during the titration. Use all the runs when calculating the average. Fill this value into the space provided.

Average volume delivered (cm³)

(4)

5.11 Calculate the concentration of the hydronium ions in the original potassium hydroxide solution at 25°C. Show all working

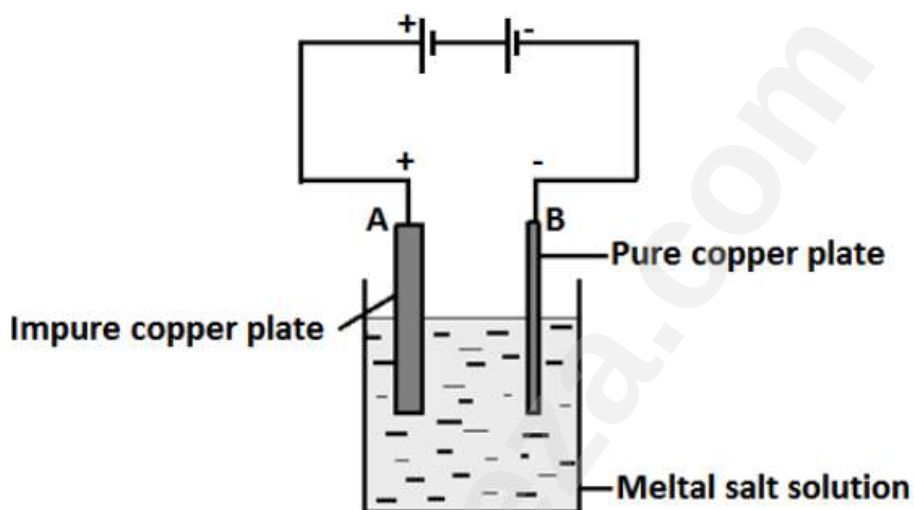
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(6)

[31]

QUESTION SIX

The copper metal that is used in electric cables must be pure if it is to be an efficient current carrier. An electrolytic cell is set up, as shown below, to purify copper.



<https://www.vedantu.com/question-answer/the-diagram-shows-the-process-of-purification-of-class-11-physics-cbse-5ff521d75845d9326062a851>

6.1 Define *electrolyte*.

(2)

6.2 Is the cathode of the above electrolytic cell, the pure copper plate, or the impure copper plate?

(1)

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- 6.3 Mg and Pt are two impurities found in the impure copper. Explain why there would be magnesium ions in the electrolyte and platinum metal in the anode sludge.

(4)

A laboratory technician is tasked to determine the relationship between current strength and the time taken to deposit a specific mass, **m**, of pure copper at electrode **B**. The technician's results are represented in the table below.

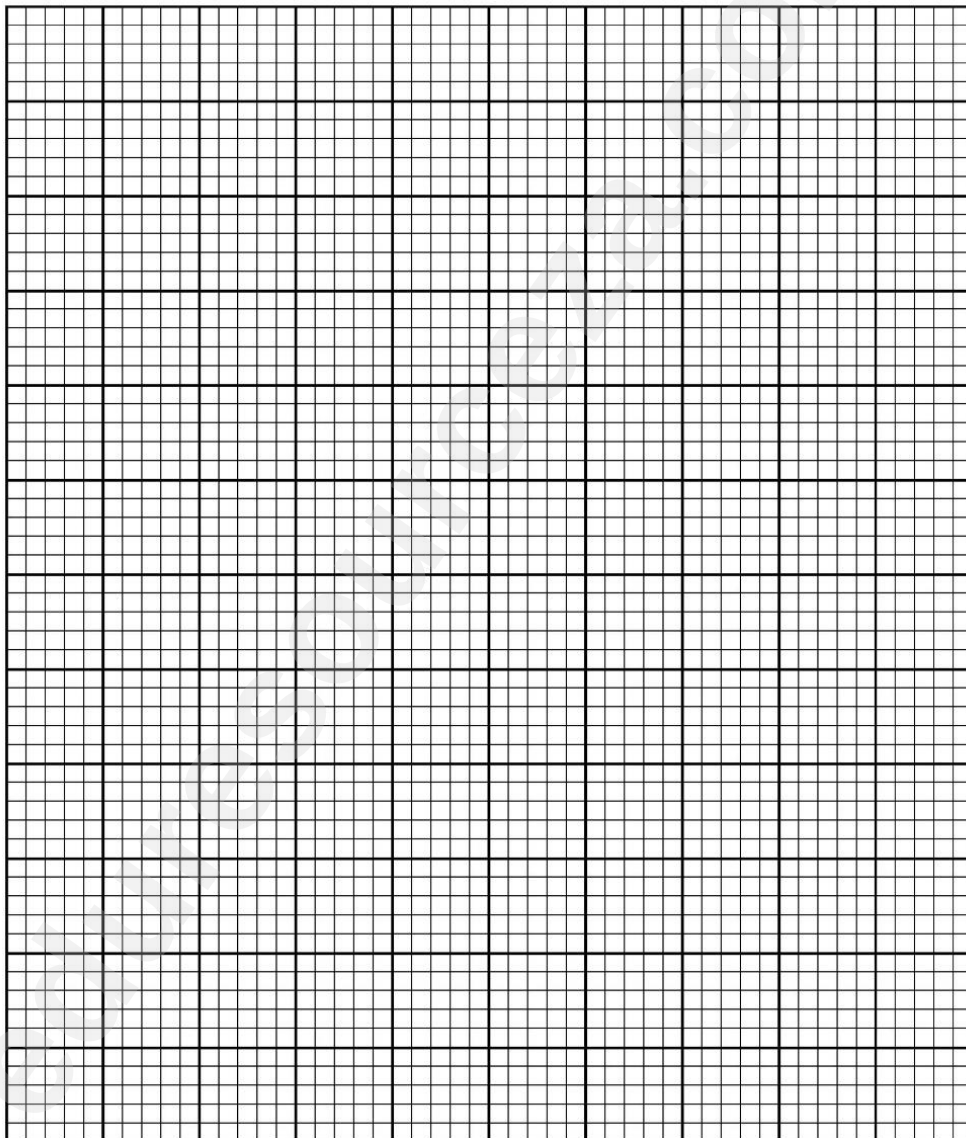
time (s)	$\frac{1}{\text{time}} \text{ (s}^{-1}\text{)}(\times 10^{-3})$	current (A)
60	16,6	50
120	8,3	24
180		17
240	4,2	12
300	3,3	9

- 6.4 Complete the table above by filling in the missing value.

(2)

- 6.5 Plot a line of best-fit for the graph of current (y-axis) vs $1/\text{time}$ (x-axis), on the graph sheet provided.

(6)



- 6.6 Calculate the gradient of the graph. The points you use must be clearly indicated on the graph plotted in question 6.5.

(3)

- 6.7 Using the gradient and relevant equations, determine:

- 6.7.1 The number of moles of electrons transferred in this cell, when mass, **m**, of copper is deposited at electrode **B**.

(4)

6.7.2 The mass, **m**, of Cu deposited at the electrode **B**.

(3)

6.8 In another electrolytic cell, a tin (Sn) medallion is being coated with gold metal (Au).

Complete the table by writing in the name or formulae for the **chemical species** that fits the following descriptions in this new electrolytic cell:

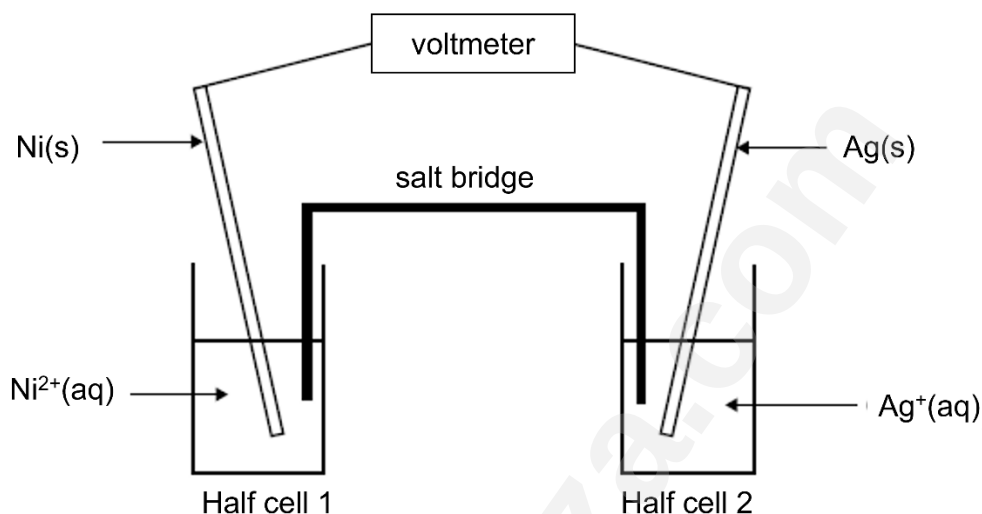
DESCRIPTION	CHEMICAL SPECIES
Anode	
Cathode	
Positive ions in electrolyte	
Oxidizing agent	
Reducing agent	

(5)

[30]

QUESTION SEVEN

A galvanic cell is set up, under standard conditions, using a nickel (Ni) electrode and a silver (Ag) electrode.



7.1 Define *anode*.

(2)

7.2 A grade 12 student makes the following statement:

The anode in this cell is the nickel electrode.

Explain, in terms of reducing agents, why this statement is correct.

(3)

- 7.3 Write the cell notation for the above galvanic cell, including phase indicators and standard conditions.

(5)

- 7.4 Calculate the emf of this cell under standard conditions.

(3)

- 7.5 Will the emf INCREASE, DECREASE or REMAIN THE SAME if the temperature was increased to 40°C?

(1)

[14]

QUESTION EIGHT

The table below consists of organic compounds **A** to **E**. Refer to this table when answering the questions below.

A	B	C
$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$	ethyl pentanoate	C_2H_4
D	E	
$ \begin{array}{ccccccc} & & \text{H} & & & & \\ & & & & \text{H} & & \text{H} & & \text{H} \\ & & \text{O} & & & & & & \\ & & & & \text{I} & & \text{I} & & \text{I} \\ \text{H} & - & \text{C} & - & \text{C} & - & \text{C} & - & \text{C} & - & \text{H} \\ & & & & & & & & \\ & & \text{O} & & \text{H} & & \text{H} & & \text{H} \\ & & & & & & & & \\ & & \text{H} & & & & & & \end{array} $	2-methylhexanoic acid	

8.1 Define *homologous series*.

(3)

8.2 Name the homologous series which compound **C** belongs to.

(1)

8.3 Will compound **A** or compound **C** rapidly decolourise bromine water?

(1)

8.4 Give the IUPAC name for compound **D**.

(3)

8.5 Name the functional group of compound **D**.

(1)

8.6 Draw the complete structural formula for compound **E**.

(3)

8.7 Write the IUPAC name for a functional isomer of compound **E**.

(2)

8.8 Write the general formula for the homologous series that compound **A** belongs to.

(1)

8.9 Give the IUPAC names of the two reactants that are required to produce compound **B**.

Reactant 1: _____

Reactant 2: _____

(2)

8.10 Explain, in terms of energy and intermolecular forces, why compound **D** has a higher boiling point than compound **A**.

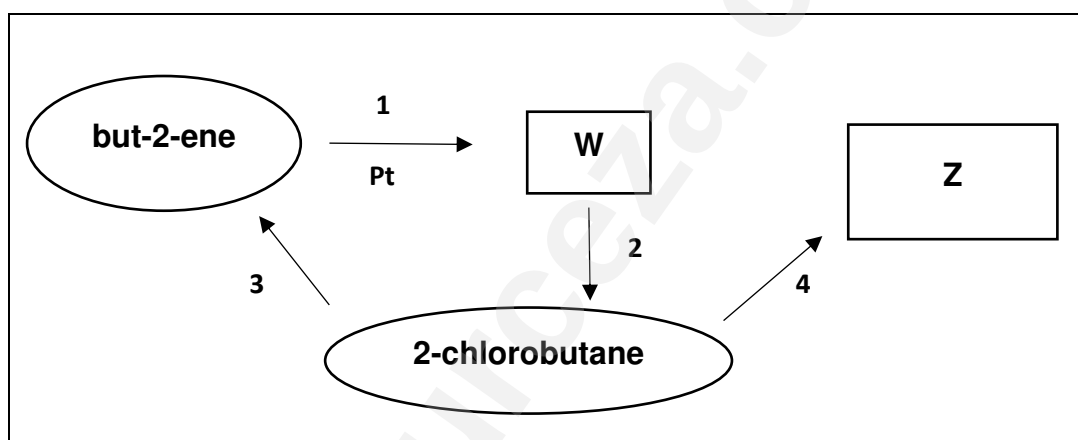
(5)

[22]

QUESTION NINE

- 9.1 The flow diagram below shows reactions **1- 5** and organic compounds **W** and **Z**. The table shows the reaction conditions for reactions **1,2** and **4**.

Reaction **1** takes place in the presence of hydrogen gas and a platinum catalyst.
 Reaction **2** needs UV light.
 Reaction **4** needs aqueous potassium hydroxide and heat



- 9.1.1 Write the IUPAC name for compound **W**.

(2)

- 9.1.2 Is reaction **1** an ADDITION, SUBSTITUTION, or ELIMINATION reaction?

(1)

9.1.3 Name the SPECIFIC type of reaction for reaction 2.

(1)

9.1.4 List THREE reaction conditions needed for reaction 3 to occur.

(3)

9.1.5 Write a balanced chemical equation, using condensed structural formulae for reaction 4.

(3)

9.1.6 Selvin says:

Pent-2-ene and but-2-ene would have the same boiling point because they both have the same functional group.

Critically evaluate Selvin's statement.

(3)

9.2 A hydrocarbon $C_{10}H_{22}$ undergoes the following process.



p is an integer.

9.2.1 Define *hydrocarbon*.

(2)

9.2.2 What type of chemical reaction is represented by the chemical equation shown above.

(1)

9.2.3 Explain how we know that the value of p is 8.

(2)

[18]

ADDITIONAL SPACE (ALL QUESTIONS)

**REMEMBER TO CLEARLY INDICATE AT THE QUESTION THAT YOU USED THE
ADDITIONAL SPACE TO ENSURE THAT ALL ANSWERS ARE MARKED.**

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