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TOTAL MARKS

NATIONAL SENIOR CERTIFICATE EXAMINATION
MAY 2025

PHYSICAL SCIENCES: PAPER II

EXAMINATION NUMBER

Time: 3 hours 200 marks

PLEASE READ THE FOLLOWING INSTRUCTIONS CAREFULLY

1. This question paper consists of 29 pages as well as a Data Sheet of 3 pages (i–iii). Please make sure that your question paper is complete.
2. Read the questions carefully.
3. **Answer ALL the questions on the question paper and hand it in at the end of the examination. Remember to write your examination number in the space provided.**
4. Unless instructed otherwise, you do NOT have to give state symbols (phase indicators) when asked to write a balanced chemical equation.
5. Use the data and formulae whenever necessary.
6. Show all the necessary steps in calculations.
7. Where appropriate, take your answers to two decimal places.
8. It is in your own interest to write legibly and to present your work neatly.
9. One blank page (page 28–29) is included at the end of the examination paper. If you run out of space for an answer, use this page. Clearly indicate the number of your answer should you use this extra space.

FOR OFFICE USE ONLY: MARKERS TO ENTER MARKS

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Total
Mark									
Marker Initial									
Moderated Mark									
Moderator Initial									
Question Total	**20**	**18**	**26**	**25**	**24**	**32**	**18**	**37**	**200**
Re-mark									
Initial									
Code									

N12PHSC-2-E

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QUESTION 1 MULTIPLE CHOICE

Every question has only one correct answer. You may use the space provided to solve the questions BUT YOU MUST INDICATE YOUR CHOSEN ANSWER FOR EACH QUESTION IN THE GRID BELOW. Make a clear cross (X) in the box corresponding to the letter that you consider to be correct.

A	B	C	D

Here, 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 Electronegativity is defined as a measure of the tendency of …

A a δ^+ atom to attract lone pairs of electrons on atoms in another molecule
B an atom to attract a bonding pair of electrons
C electrons to have negative charge
D molecules to attract electrons

1.2 Which one of the following name and formula combinations is INCORRECT?

	Name	Formula
A	sodium sulfite	$Na_2S_2O_3$
B	strontium phosphate	$Sr_3(PO_4)_2$
C	iron(II) chlorate	$Fe(C\ell O_3)_2$
D	manganese(IV) oxide	MnO_2

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1.3 In a car airbag, sodium azide (NaN_3) decomposes to form sodium metal and nitrogen gas.

$2NaN_3(s) \rightarrow 2Na(s) + 3N_2(g)$ Reaction (i)

The sodium metal then reacts with excess potassium nitrate to produce more nitrogen gas.

$10Na(s) + 2KNO_3(s) \rightarrow N_2(g) + 5Na_2O(s) + K_2O(s)$ Reaction (ii)

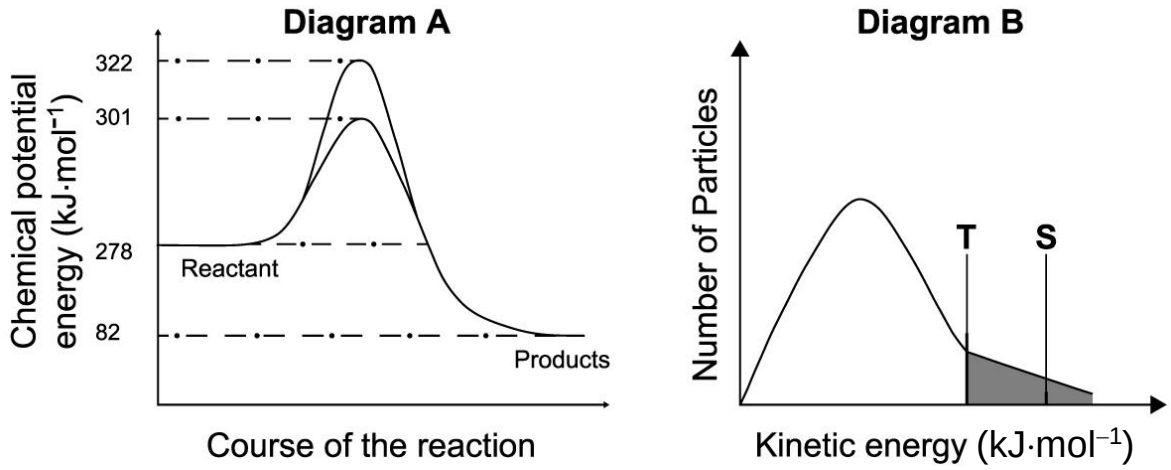
1,00 mol of sodium azide reacts in the airbag. Reaction (i) goes to completion but the % yield of Reaction (ii) is 80%. What is the total number of moles of nitrogen gas that will be formed?

A 4,00 mol
B 2,50 mol
C 1,60 mol
D 1,58 mol

1.4 0,2 mol of $Au(NO_3)_3$ is dissolved in water to prepare a solution of volume 500 cm^3. What is the concentration of ions in the solution, in $mol \cdot dm^{-3}$?

A $4 \times N_A$
B 0,40
C 1,60
D 2,00

1.5 The diagrams below show A, the energy profile graph, and B, the Maxwell-Boltzmann distribution, for the same chemical reaction. The effect of a catalyst is indicated as it normally is.



The value represented by the letter S, in $kJ \cdot mol^{-1}$, is …

A 322 – 278
B 301 – 278
C 322
D 301

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1.6 Study the following two-step decomposition reaction:

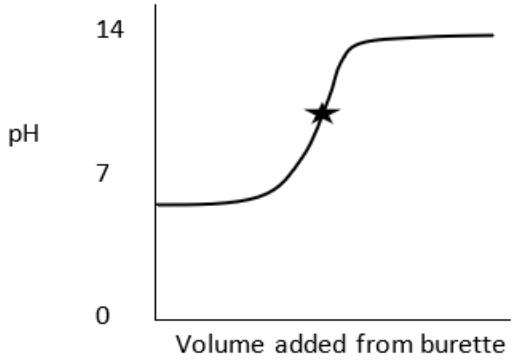
Step 1: $2NO(g) + 2N_2O(g) \longrightarrow 2NO_2(g) + 2N_2(g)$

Step 2: $2NO_2(g) \longrightarrow 2NO(g) + O_2(g)$

Identify the substance decomposed and the catalyst in this reaction.

	Substance decomposed	Catalyst
A	NO	NO_2
B	N_2O	NO
C	NO_2	N_2O
D	NO	N_2O

1.7 During an acid-base titration, the pH of the solution in the flask was recorded as a function of the volume added from the burette. The graph below was obtained. The star on the curve marks the equivalence point of the titration.



Which aqueous solutions (of equal concentration) were most likely to have been in the flask and in the burette?

	Solution in flask	Solution in burette
A	HNO_3	NaOH
B	HCℓ	NH_3
C	NaOH	HF
D	H_2SO_3	KOH

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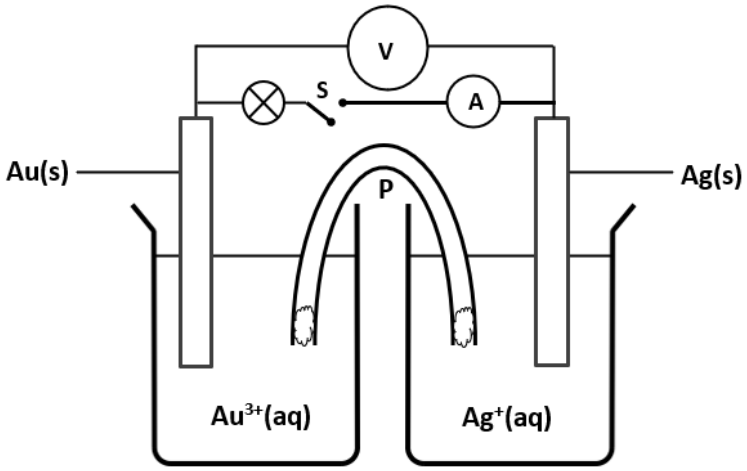
1.8 Consider the galvanic cell represented below:



Which one of the following changes to the electrolyte concentration and salt bridge, P, will increase both the emf of the cell and the current delivered by the cell when S is closed?

	Increase emf by increasing …	**Increase current by making P…**
A	$[Au^{3+}]$	longer
B	$[Ag^{+}]$	wider
C	$[Au^{3+}]$	shorter
D	$[Ag^{+}]$	narrower

1.9 Complete the sentence:

A homologous series is a series of similar compounds which have the same **P** and the same **Q**, in which each member differs from the previous one by a single CH_2 unit.

	P	**Q**
A	molecular formula	functional group
B	structural formula	chemical properties
C	functional group	general formula
D	general formula	physical properties

1.10 Chlorine gas is bubbled through liquid hex-3-ene. What is the organic product of the reaction?

A 3-chlorohexane
B 3-chlorohex-3-ene
C 2,4-dichlorohexane
D 3,4-dichlorohexane

[20]

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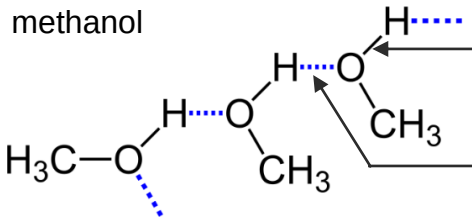
QUESTION 2

2.1 Supply the specific names for the **type of bonding** or **intermolecular forces** indicated.

2.1.1 methanol

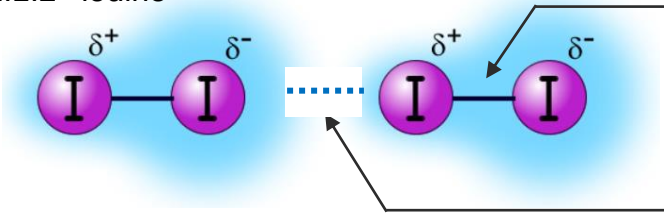


[<https://commons.wikimedia.org/>]

(a) (2)

(b) (1)

2.1.2 iodine



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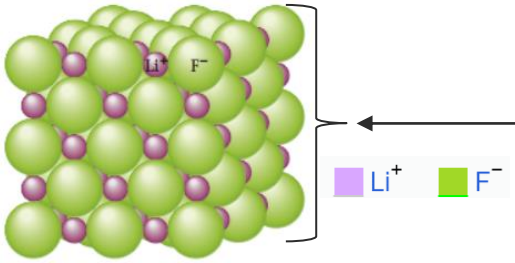
(a) (2)

(b) (1)

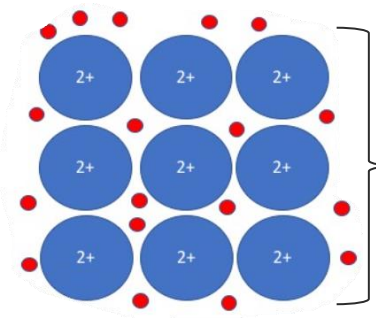
2.1.3 lithium fluoride



[<http://chemistrysaanguyen.weebly.com>]

(1)

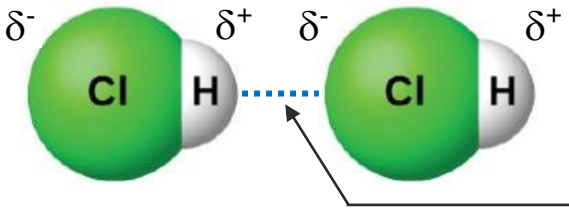
2.1.4 iron



[<https://thescienceteacher.co.uk/>]

(1)

2.1.5 hydrogen chloride



(1)

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2.2 Consider the uneven distribution of the electron cloud (resulting in the δ^+ and δ^-) shown for I_2 (in Question 2.1.2) and that shown for HCℓ (in Question 2.1.5).

In each case, circle the correct word in the table:

2.2.1 In I_2, the electron cloud is unevenly distributed.

PERMANENTLY	TEMPORARILY

(1)

2.2.2 In HCℓ, the electron cloud is unevenly distributed.

PERMANENTLY	TEMPORARILY

(1)

2.3 State which one of the substances in Question 2.1 can conduct electricity **both when solid and when molten**. Identify the charged particles that can move, resulting in a current. (2)

Substance: _____

Charged particles that can move: _____

2.4 At 200 kPa, iodine has a higher melting point and boiling point than methanol.

2.4.1 Name the force or bond responsible for the higher melting point of iodine. (1)

_____

2.4.2 Explain why iodine has the higher melting point. (4)

_____

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[18]

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QUESTION 3

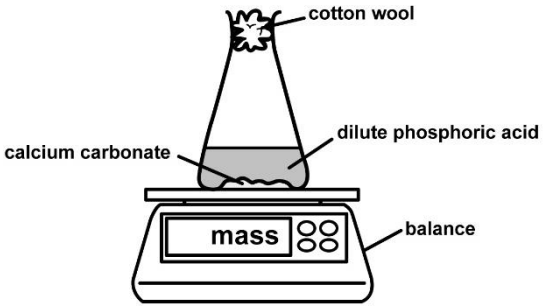
Calcium carbonate and phosphoric acid react exothermically. The reaction is represented by the following balanced equation:

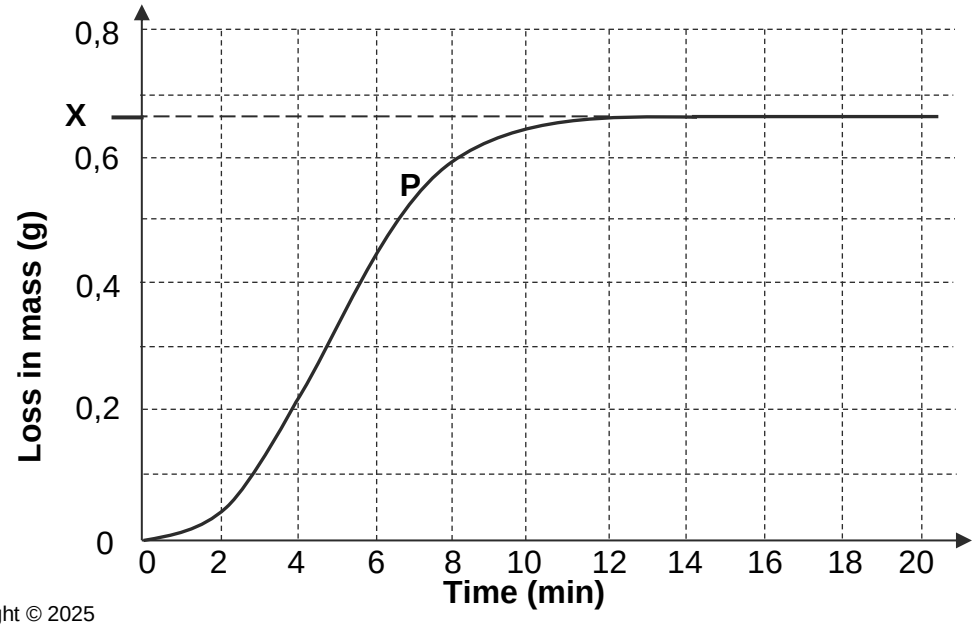
$$3CaCO_3(s) + 2H_3PO_4(aq) \longrightarrow Ca_3(PO_4)_2(aq) + 3CO_2(g) + 3H_2O(\ell) \qquad \Delta H < 0$$

3.1 Define *heat of reaction*, ΔH. (2)

3.2 Explain why ΔH is negative for an exothermic reaction. (2)

1,5 g of $CaCO_3$ was placed in a conical flask on a balance. 20 cm^3 of a 2 $mol \cdot dm^{-3}$ phosphoric acid solution at 20°C was added. Cotton wool was placed in the neck of the flask. The initial mass of the flask and contents was recorded. As the reaction took place, the mass was recorded at two-minute intervals. The loss in mass was plotted to obtain graph **P** shown below.





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3.3 What is the function of the cotton wool in the neck of the flask? (2)

3.4 Consider the amounts of $CaCO_3$ and H_3PO_4 used.

3.4.1 Prove by calculation that the amount of phosphoric acid was in excess. (5)

3.4.2 Calculate the value of **X** on the y-axis of the graph. (3)

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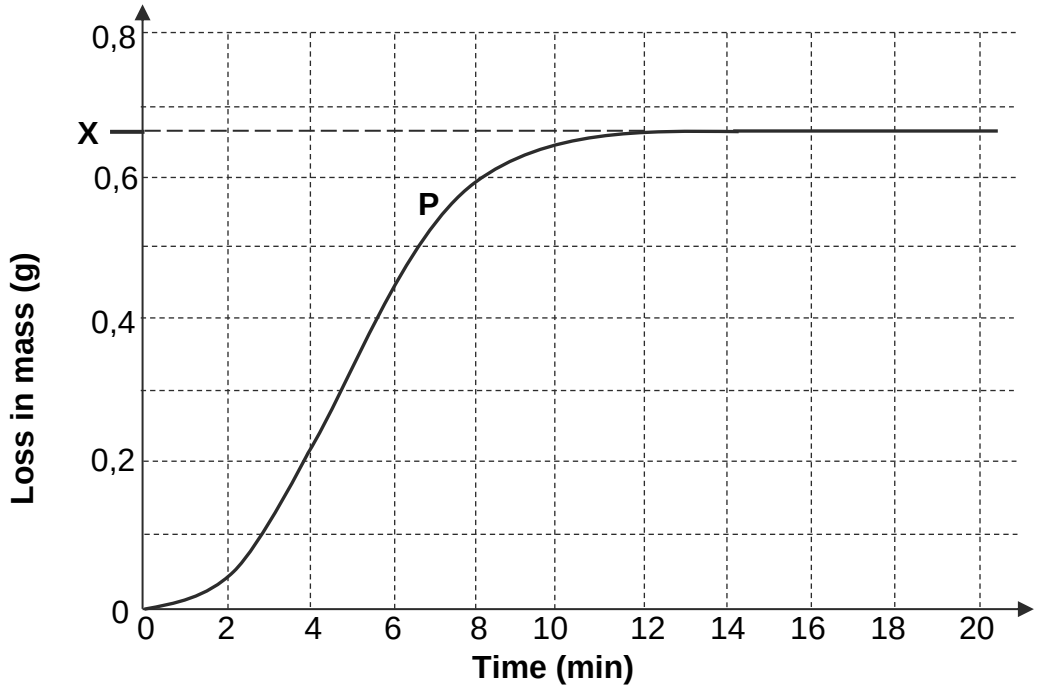
The graph is repeated here for ease of reference:



3.5 Calculate the average rate with respect to CO_2 (in $g \cdot min^{-1}$) in the time interval of **6 to 12 minutes**. Write your answer correct to three decimal places. (3)

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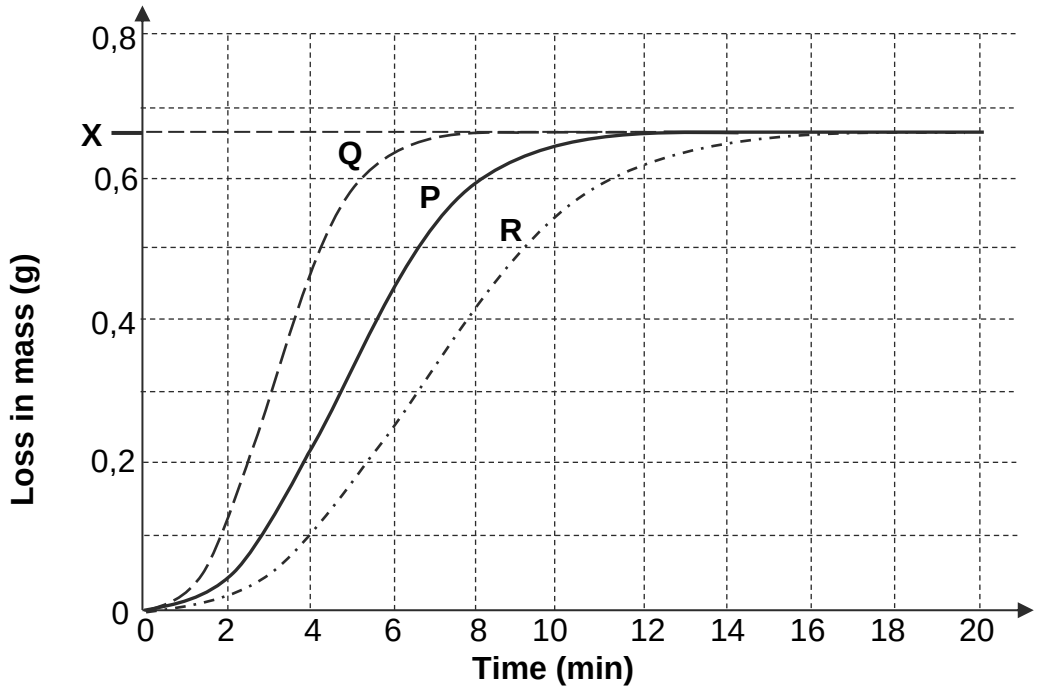
3.6 The reaction rate changes during the course of the reaction. For the reaction resulting in Graph **P**, choose the correct word or phrase to describe the rate for the different time intervals. Also state the predominant factor affecting the rate. (6)

Stage	Time interval (min)	The reaction rate (increases / decreases / remains constant / is zero)	Predominant factor affecting the rate
I	0–4		
II	6–12		
III	12–20		

3.7 The experiment is repeated under various different conditions. Three of the graphs obtained are shown below.



Which graph, **P**, **Q**, or **R**, is most likely to be obtained when the following changes are made to the system?

3.7.1 The initial temperature of the H_3PO_4 is increased from 20°C to 30°C. ☐

3.7.2 The volume of phosphoric acid is increased from 20 cm^3 to 30 cm^3. ☐

Write your answers in the boxes provided. (3)

[26]

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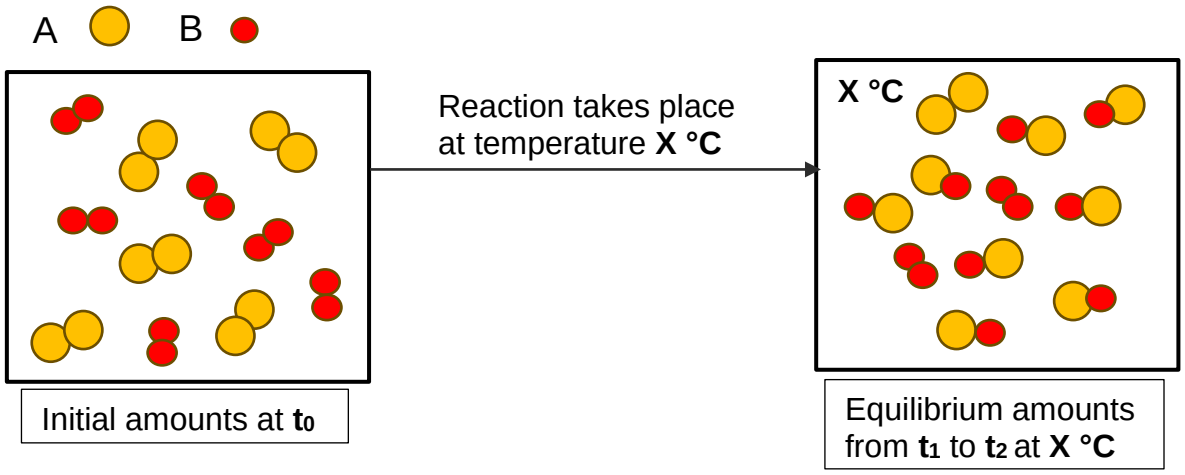
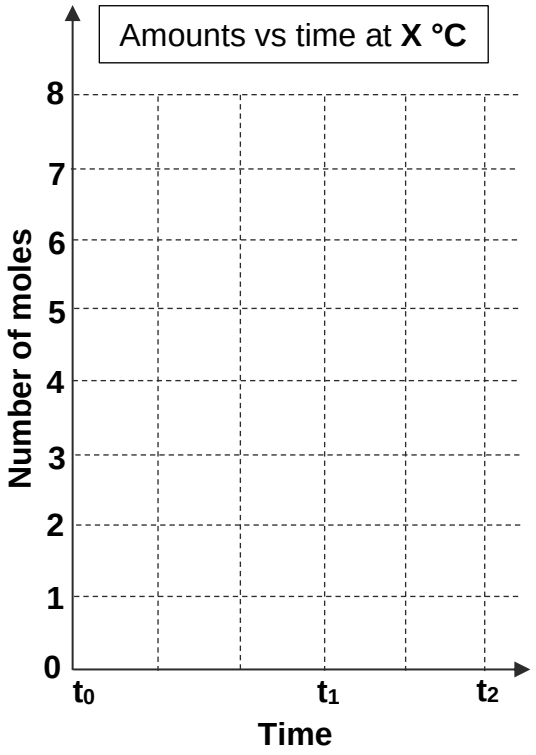
QUESTION 4

The following equilibrium reaction takes place in a sealed **4 dm^3** container:

$$A_2(g) + B_2(g) \rightleftharpoons 2AB(g) \quad \Delta H < 0$$

The number of moles of each substance in the 4 dm^3 container is represented below. Each molecule represents a mole of that substance. Starting with the **same initial amounts**, the reaction is carried out at **two different temperatures**. Equilibrium is established at time **t_1** and maintained until time **t_2**.





4.1 For the reaction occurring at **X °C**, plot the number of moles of A_2, B_2, and AB from **t_0** to **t_2** on the axes provided above. Label the three lines clearly. (5)

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4.2 When the same reaction takes place at **Y °C**, the equilibrium amounts in the 4 dm^3 container are as follows:

- 4 mol A_2
- 5 mol B_2
- 2 mol AB

Reaction equation:

$A_2(g) + B_2(g) \rightleftharpoons 2AB(g)$

4.2.1 Write down the K_c expression for the reaction. (2)

4.2.2 Calculate K_c at **X °C**. (2)

4.2.3 Calculate K_c at **Y °C**. (2)

4.3 Which of **X °C** or **Y °C** is the higher temperature? Explain the answer by applying Le Châtelier's Principle. (5)

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The reaction equation is repeated here for ease of reference.

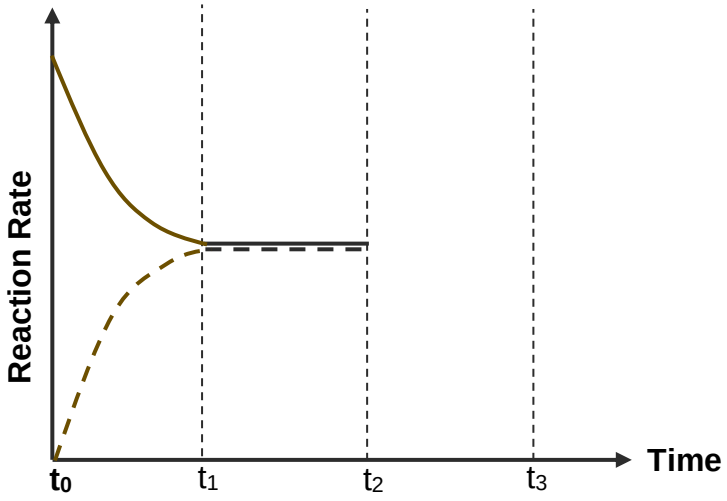
$$A_2(g) + B_2(g) \rightleftharpoons 2AB(g) \quad \Delta H < 0$$

4.4 Consider the reaction taking place at **X °C**. At **t_2**, the volume of the container is decreased at constant temperature. Explain the effect (if any) of the decrease in the volume on …

4.4.1 the reaction rates (refer to the collision theory). (3)

4.4.2 the amounts of each substance in the container (refer to Le Châtelier's Principle). (3)

4.5 In another experiment involving the same reaction at **X °C**, some $B_2(g)$ is removed from the equilibrium mixture at **t_2**. Equilibrium is reestablished before **t_3**. On the axes below, show how the reaction rates will be affected between **t_2** and **t_3**. (3)



[25]

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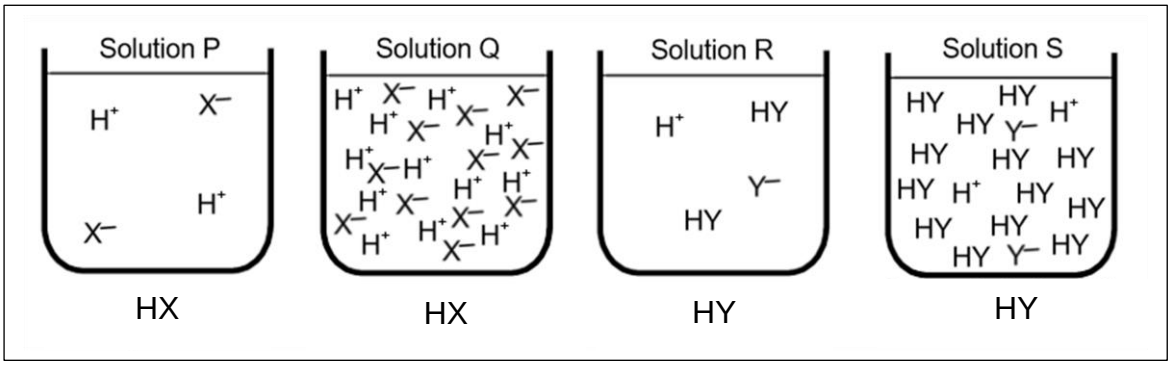
QUESTION 5

5.1 Consider the aqueous solutions **P**, **Q**, **R** and **S**, of two acids, HX and HY, represented below. The solvent H_2O molecules are not shown. Each symbol shown in solution represents 0,1 mole of that substance. The solutions all have the same total volume.

Answer the questions that follow, using the appropriate letter/s where necessary.



5.1.1 Define an *acid* in terms of the Lowry-Brønsted model. (1)

5.1.2 Name the ions that form when H^+ combines with water. (1)

5.1.3 Choose one of the above solutions, that is dilute. Explain your answer. (2)

5.1.4 Which solution will have the highest pH? Give a reason. (2)

5.1.5 Which two solutions will have the same pH? Explain the answer. (2)

5.1.6 Which acid, HX or HY, is a weak acid? Explain the answer. (2)

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5.1.7 The weak acid identified in Question 5.1.6 reacts with KOH to form a salt and water. Circle the correct word in the table:

The salt is	ACIDIC	BASIC	NEUTRAL

(1)

Write the equation for the hydrolysis reaction that supports your answer. (2)

5.2 Refer to the table of K_W values for water at different temperatures.

Temperature (°C)	K_W	Neutral pH
15	$0,457 \times 10^{-14}$	7,17
25	$1,008 \times 10^{-14}$	7,00
35	$2,089 \times 10^{-14}$	6,84
45	$4,074 \times 10^{-14}$	6,69

5.2.1 Water can undergo autoprotolysis. Explain the meaning of this term. (2)

5.2.2 What do the K_W values indicate about the electrical conductivity of water? Explain the answer. (2)

5.2.3 Circle the correct word in the table: (1)

The auto-ionisation reaction of water is	EXOTHERMIC	ENDOTHERMIC

5.2.4 Briefly explain how you deduced the answer in Question 5.2.3. (2)

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The table is repeated here for ease of reference.

Temperature (°C)	K_w	Neutral pH
15	$0{,}457 \times 10^{-14}$	7,17
25	$1{,}008 \times 10^{-14}$	7,00
35	$2{,}089 \times 10^{-14}$	6,84
45	$4{,}074 \times 10^{-14}$	6,69

5.2.5 At 45 °C, the pH of water is 6,69. Why is this a pH-neutral solution? (1)

5.2.6 Calculate the hydroxide ion concentration in water at 45 °C. (3)

[24]

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QUESTION 6

6.1 Chlorine gas is highly reactive and is a strong oxidising agent.

6.1.1 Define *oxidising agent*. (2)

6.1.2 Give a reason why chlorine is a **strong** oxidising agent. (2)

6.1.3 Chlorine gas is bubbled through an aqueous solution of iron(II) sulfate.

(a) Identify the spectator ion in this reaction. (1)

(b) Write equations for:

(i) the reduction half-reaction (1)

(ii) the oxidation half-reaction (1)

(iii) the net ionic reaction (2)

(c) Prove by calculation that this reaction is spontaneous at standard conditions. (4)

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6.1.4 Using the table of standard electrode potentials, refer to the relative strengths of the **oxidising agents** at standard conditions to explain:

(a) whether chlorine will oxidise manganese to manganese(II). (2)

(b) whether chlorine will further oxidise the manganese(II) to permanganate. (2)

6.2 A standard hydrogen electrode is connected to a half-cell containing an acidified solution of dichromate ions and chromium(III) ions, also at standard conditions.

6.2.1 What metal should the electrode in the dichromate/chromium(III) half-cell be made of? (1)

6.2.2 What is the function of the standard hydrogen electrode? (2)

6.2.3 List the **specific** conditions needed for the standard hydrogen electrode. (3)

6.2.4 When this particular cell operates, state whether OXIDATION or REDUCTION will occur at the standard hydrogen electrode. Give a reason. (3)

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6.2.5 Why does the electrolyte in the dichromate half-cell need to be acidified? (1)

6.2.6 The aqueous electrolyte solutions used in this cell are as follows:

- potassium dichromate
- chromium(III) sulfate
- hydrochloric acid
- potassium nitrate for the salt bridge

(a) Write the chemical formulae of:

potassium dichromate _____ (1)

chromium(III) sulfate _____ (1)

(b) One of the reasons potassium nitrate is used for the salt bridge is that it is extremely soluble in water. Explain the significance of this property with regard to the operation of the cell. (2)

(c) Hydrochloric acid is used in the hydrogen half-cell. The pH of the solution changes as the cell operates. (1)

Circle the correct answer: The pH will | INCREASE | DECREASE |

[32]

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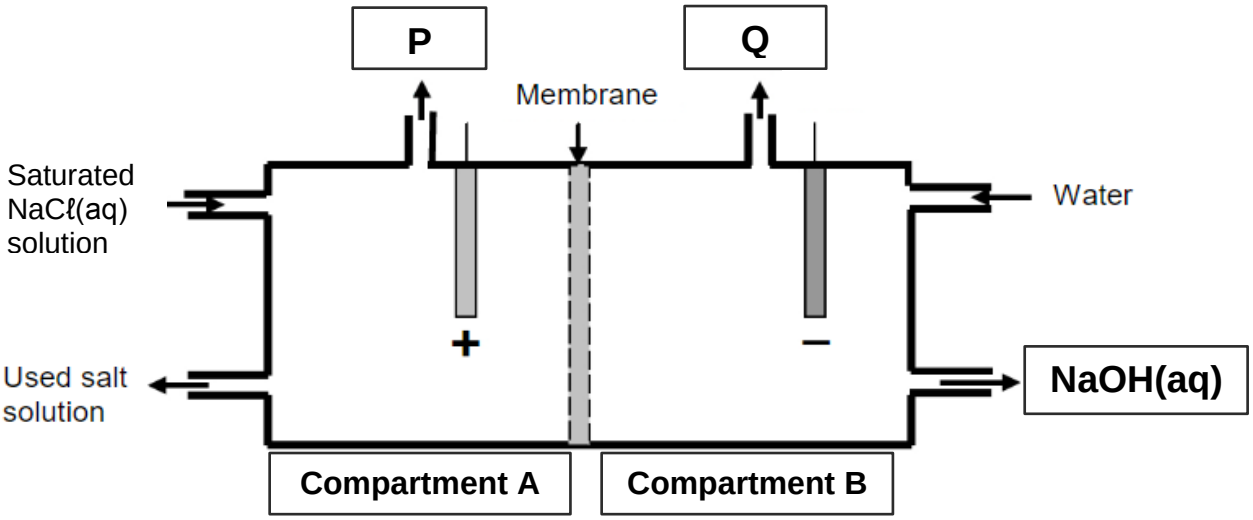
QUESTION 7

The diagram below represents the membrane cell used in the Chlor-Alkali process.



7.1 State the energy conversion that takes place in this process. (2)

_____

7.2 Circle the correct answer in the table:

In the diagram, the **cathode** is in	Compartment **A**	Compartment **B**

(1)

7.3 Identify **P** and **Q**, the gaseous products. (2)

P _____

Q _____

7.4 Write down the complete balanced equation for the overall reaction of the process. (3)

_____

_____

_____

7.5 Why is it necessary for the NaCℓ solution to be **saturated**? (4)

_____

_____

_____

_____

_____

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7.6 In this simplified version of the process, only water is fed into Compartment **B**. Refer to the electrolysis half-reaction to explain how NaOH solution forms in this compartment. (3)

7.7 Hydroxide ions can react as follows to produce contaminant oxygen gas:

$$4OH^- \longrightarrow 2H_2O + O_2 + 4e^-$$

7.7.1 Circle the correct option in the table:

This half-reaction would occur at the	ANODE	CATHODE

(1)

7.7.2 How is this half-reaction prevented in the membrane cell? (2)

[18]

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QUESTION 8

Consider equations **A** to **E** below, representing various organic reactions:

A $C_4H_8 + O_2 \longrightarrow CO_2 + H_2O$ (*unbalanced*)

B $CH_3OH + CH_3CH_2CH_2COOH \xrightarrow{\text{catalyst}} CH_3CH_2CH_2COOCH_3 + H_2O$

C $CH_4 + 2Br_2 \xrightarrow{\text{ultraviolet light}} CH_2Br_2 + 2HBr$

D $CH_3CHC\ell(CH_2)_3CH_3 \xrightarrow{\text{hot NaOH in ethanol}} CH_3CH{=}CH(CH_2)_2CH_3 + HC\ell$

E $CH_3CH_2CH{=}CHCH{=}CHCH_3 + 2H_2 \xrightarrow{Pt} C_7H_{16}$

8.1 Give the reaction type for reactions **A** and **B**. (2)

8.1.1 **A** _____

8.1.2 **B** _____

8.2 Give the SPECIFIC reaction type for reactions **C**, **D,** and **E**. (3)

8.2.1 **C** _____

8.2.2 **D** _____

8.2.3 **E** _____

8.3 Consider equation **A**:

8.3.1 Copy down and balance the given equation. (2)

_____

8.3.2 Define *structural isomers*. (2)

_____

_____

_____

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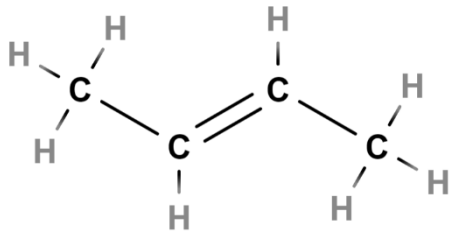
8.3.3 The compound shown below is one possible isomer of C_4H_8.



(a) Write the **condensed structural** formula of a POSITIONAL isomer of the given compound. (2)

(b) Draw the **structural** formula of a CHAIN isomer of the given compound. (2)

8.3.4 Give the IUPAC name of the isomer in Question 8.3.3 that is likely to have the **lowest** boiling point. (2)

8.4 Consider equation **B**:

8.4.1 Identify a suitable catalyst for this reaction. (1)

8.4.2 Name the homologous series to which $CH_3CH_2CH_2COOH$ belongs. (1)

8.4.3 Give the IUPAC name of the organic product of the reaction. (2)

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Equations **C**, **D** and **E** are repeated here for ease of reference:

C $CH_4 + 2Br_2 \xrightarrow{\text{ultraviolet light}} CH_2Br_2 + 2HBr$

D $CH_3CHC\ell(CH_2)_3CH_3 \xrightarrow{\text{hot NaOH in ethanol}} CH_3CH{=}CH(CH_2)_2CH_3 + HC\ell$

E $CH_3CH_2CH{=}CHCH{=}CHCH_3 + 2H_2 \xrightarrow{Pt} C_7H_{16}$

8.5 Consider equation **C**:

8.5.1 Why is ultraviolet light necessary? (1)

8.5.2 Give the IUPAC name of the organic product of the reaction. (2)

8.6 Consider equation **D**:

8.6.1 Give the IUPAC name of the organic product of the reaction. (2)

8.6.2 When the reactant is heated under reflux in dilute aqueous NaOH, a different organic product forms.

(a) Give the IUPAC name of this different organic product. (2)

(b) Name the SPECIFIC type of reaction that occurs under these conditions. (1)

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8.7 Consider equation **E**:

8.7.1 Choose the correct option in the table and give an explanation: (3)

The organic	REACTANT	PRODUCT	is **saturated** because …

8.7.2 Name the reagent used in the standard laboratory test to distinguish between saturated and unsaturated compounds. (1)

8.7.3 Name the homologous series to which the product of reaction **E** belongs. (1)

8.7.4 Give the IUPAC name of the organic reactant. (3)

8.7.5 The product (C_7H_{16}) is a linear compound. What does this mean? (2)

[37]

Total: 200 marks

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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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