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Physical Sciences Preliminary Examination

Paper II – Chemistry

Monday 20 September 2021

Form V

Marks: 200

Examiner: M-J. Blair

Time: 3 hours

Examination number: _____

PLEASE READ THE FOLLOWING INSTRUCTIONS CAREFULLY

1. This question paper consists of 16 pages, a yellow answer sheet of 2 pages (i-ii) and a green data sheet of 3 pages (i-iii). Please make sure that your question paper is complete.
2. Remove the data and answer sheets from inside this question paper. **Write your examination number on the answer sheet and question paper.**
3. **Please complete the multiple choice question on your answer sheet:**
There is only one correct answer for each of the multiple choice questions. The letter corresponding to the answer you think is correct should be marked with a cross, thus:

A	B	C	D
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Here, C is the answer

4. Start each question on a new page, but please write on both sides of the paper.
5. Use the data and formulae whenever necessary.
6. Show all of the necessary steps in calculations.
7. Where appropriate, take your answers to 2 decimal places, unless instructed otherwise. Units need not be included in the working of calculations, but appropriate units should be shown in the answer.
8. It is in your own interest to write legibly and to present your work neatly. Please ensure that you number your answers as the questions are numbered.
9. When you hand in your exam, place the yellow answer sheet in the **front** of your answer book and your question paper booklet and green data sheets at the **back** of your answer book.

QUESTION 1**MULTIPLE CHOICE**

Answer questions 1.1 – 1.10 on the grid provided on your ANSWER SHEET. There is only one correct answer for each of the multiple choice questions. Place a cross over the letter that represents the most correct answer.

1.1 A molecule is;

- A a group of atoms bonded by ionic bonds
- B a group of atoms bonded by covalent bonds
- C a group of ions bonded by covalent bonds
- D a group of atoms bonded by metallic bonds

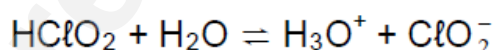
1.2 Which of the following is a polar substance?

- A CO₂
- B Br₂
- C NH₃
- D O₂

1.3 How many moles of electrons are required to oxidise 1 g of aluminium to its ions?

- A 1
- B 3
- C 0,111
- D 0,012

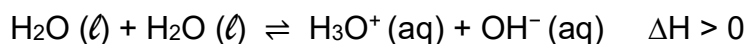
1.4 Consider the reaction represented below:



Which of the following is a conjugate acid-base pair in the above reaction?

- A HClO₂ and ClO₂⁻
- B HClO₂ and H₂O
- C ClO₂⁻ and H₃O⁺
- D HClO₂ and H₃O⁺

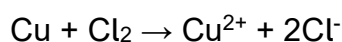
- 1.5 The formation of hydronium ions and hydroxide ions from water is an endothermic process.



Which of the following K_w and temperature combinations is most likely to be correct?

	Temperature (°C)	K_w
A	100	$51,0 \times 10^{-14}$
B	25	$1,5 \times 10^{-14}$
C	50	$0,56 \times 10^{-15}$
D	10	$1,00 \times 10^{-14}$

- 1.6 Consider this reaction from a galvanic cell:



How would replacing the salt bridge with one that is shorter and which contains a more concentrated solution affect the voltage of the cell when compared with the calculated $E^\ominus_{\text{cell}}$ value?

- A Increase
- B Decrease
- C No Effect
- D Increase first then decrease

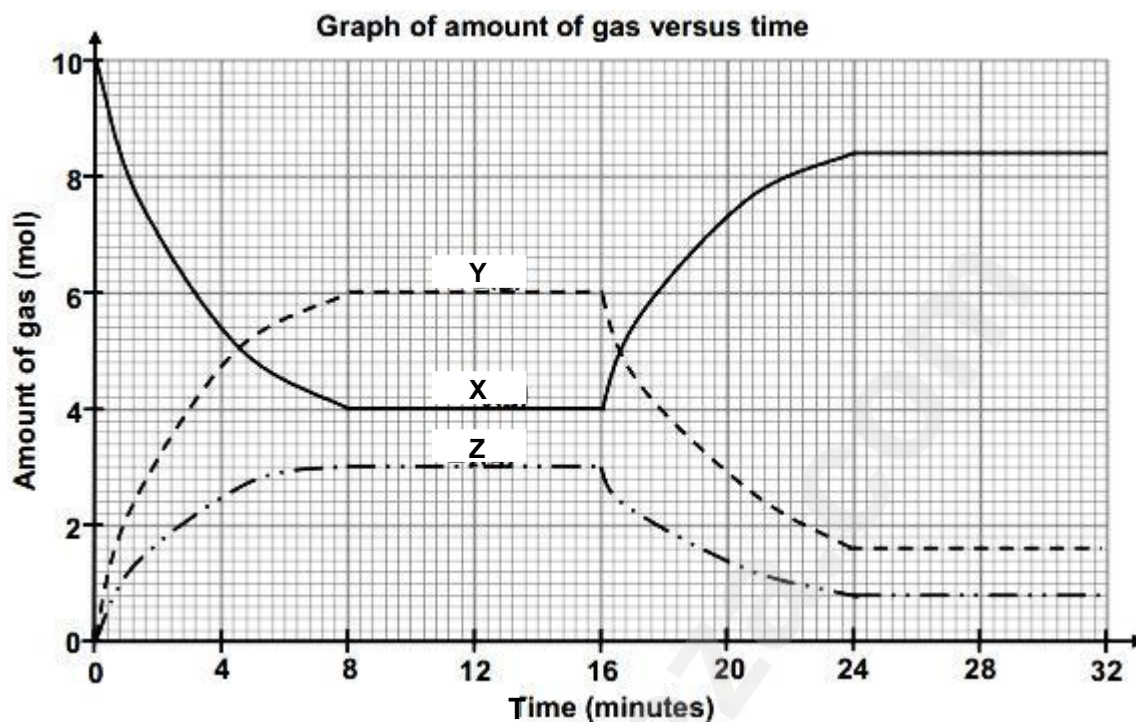
- 1.7 When ammonium sulphate, $(\text{NH}_4)_2\text{SO}_4$, is dissolved in water, the pH of the solution is approximately 6,5. Which of the following equations offers the best explanation for this?

- A $(\text{NH}_4)_2\text{SO}_4 \rightleftharpoons 2\text{NH}_4^+ + \text{SO}_4^{2-}$
- B $\text{NH}_4^+ + \text{H}_2\text{O} \rightleftharpoons \text{NH}_3 + \text{H}_3\text{O}^+$
- C $2\text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{OH}^-$
- D $\text{SO}_4^{2-} + 2\text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{SO}_4 + 2\text{OH}^-$

- 1.8 In which one of the following reactions will an increase in pressure have no effect on the equilibrium?

- A $\text{H}_2 (\text{g}) + \text{Cl}_2 (\text{g}) \rightleftharpoons 2 \text{HCl} (\text{g})$
- B $4 \text{HCl} (\text{g}) + \text{O}_2 (\text{g}) \rightleftharpoons 2 \text{Cl}_2 (\text{g}) + 2 \text{H}_2\text{O} (\text{g})$
- C $4 \text{Na} (\text{s}) + \text{O}_2 (\text{g}) \rightleftharpoons 2 \text{Na}_2\text{O} (\text{s})$
- D $\text{PCl}_5 (\text{g}) \rightleftharpoons \text{PCl}_3 (\text{g}) + \text{Cl}_2 (\text{g})$

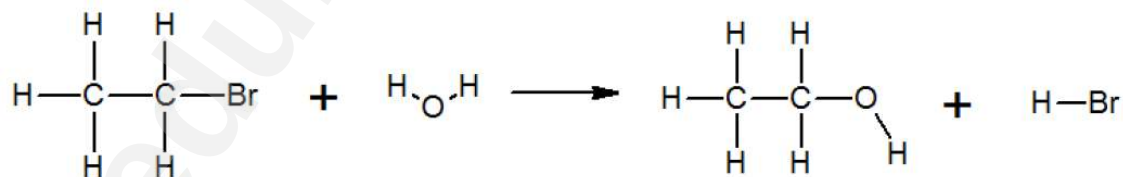
- 1.9 For the graph given below, X is a reactant that exists in equilibrium with products Y and Z. On the graph, the equilibrium is disturbed at 16 minutes and re-establishes at 24 minutes.



Based on the changes shown on the graph, what is the most likely balanced chemical equation for this reaction?

- A $X \rightleftharpoons Y + Z$
- B $2X \rightleftharpoons 2Y + Z$
- C $2X \rightleftharpoons Y + 2Z$
- D $X + Y \rightleftharpoons Z$

- 1.10 Consider the following reaction:



This reaction is an example of

- A hydrolysis
- B hydration
- C hydrogenation
- D hydrohalogenation

[2 x 10 = 20]

- 2.1 Epsom Salts are a white crystalline substance. They help stabilise mood and relieve stress, anxiety and depression and help to relax muscles and relieve pain in the shoulders, neck, back and skull. The chemical formula for Epsom Salts is MgSO_4 .



- 2.1.1 Name and describe the forces which hold MgSO_4 together when the MgSO_4 occurs as a solid. (3)
- 2.1.2 MgSO_4 is the salt produced when sulphuric acid is reacted with magnesium hydroxide. Write and balance the chemical reaction between sulphuric acid and magnesium hydroxide. Phase labels are not required. (4)



- 2.2 Fluorine is an element that is a pale yellow-green gas at room temperature. Fluorine is very reactive and combines with many other elements to form more stable compounds. It is mainly used in industry as **hydrogen fluoride**, which is more stable than **fluorine gas**.

Consider fluorine gas.

- 2.2.1 What type of solid would fluorine form if cooled sufficiently? (1)
- 2.2.2 Name the specific intermolecular forces which are found in solid fluorine. (1)

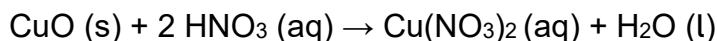
Consider hydrogen fluoride.

- 2.2.3 Name the type of intermolecular force found within solid hydrogen fluoride. (1)
- 2.2.4 The boiling points of fluorine and hydrogen fluoride are -188°C and $19,5^\circ\text{C}$ respectively. Account for the difference in these respective boiling points. (3)

Consider the liquid BrF_3 .

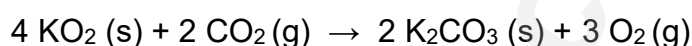
- 2.2.5 Name the type of bond found in BrF_3 . (1)
- 2.2.6 Give the name for the compound BrF_3 . (2)

- 2.3 In an experiment to make crystals of hydrated copper nitrate, a sample of 5,6 g of copper (II) oxide was added to 0,05 dm³ of 2,5 mol.dm⁻³ nitric acid. The following (balanced) reaction occurred:



Calculate the number of moles of each reactant present in order to show that copper (II) oxide is in excess. (7)

- 2.4 Consider the balanced chemical reaction:

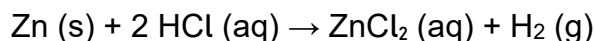


2.4.1 Define the term *yield*. (2)

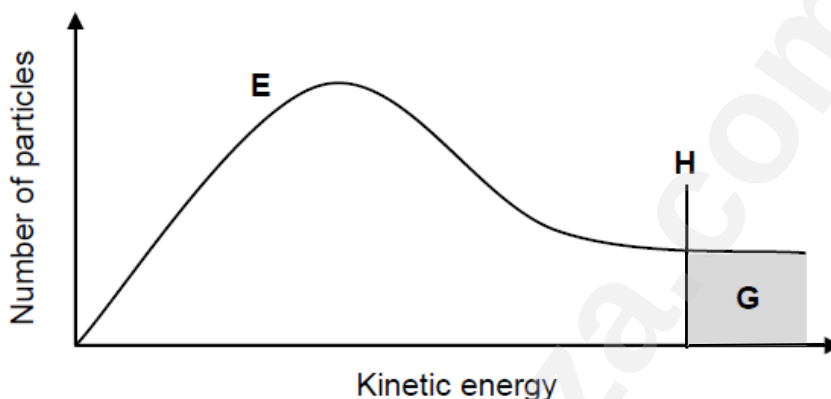
2.4.2 If the reaction has a percentage yield of 59,3 %, what mass of K₂CO₃ (s) can be produced with 30 g of KO₂ (s)? The molar mass of K₂CO₃ is 138 g.mol⁻¹. (7)

[32]

Pupils perform an experiment to allow excess zinc to react with a 30 cm³ hydrochloric acid solution at 25 °C according to the following balanced equation:

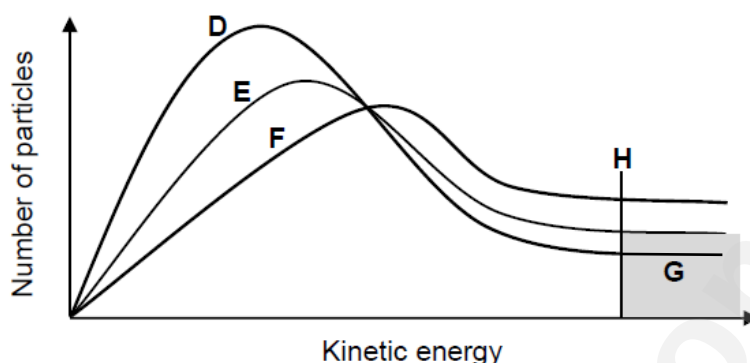


They draw the Maxwell-Boltzmann distribution curve, represented by graph **E** below, for the reaction at these conditions. Line **H** represents the activation energy for the reaction.

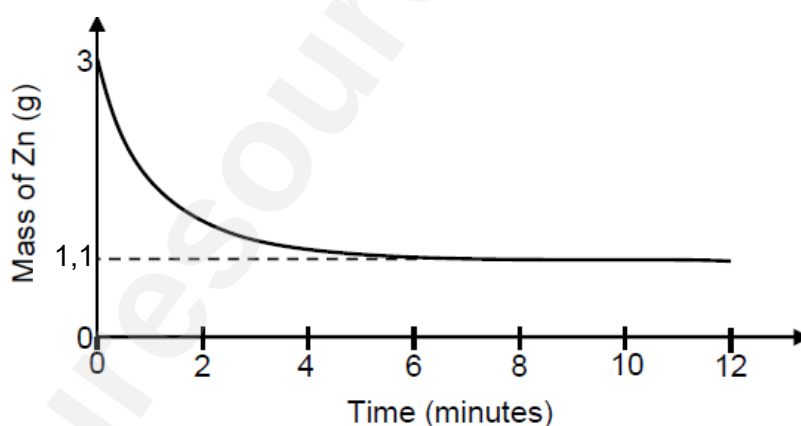


- 3.1 Define the term *activation energy*. (2)
- 3.2 Consider the shaded area **G** to the right of line H on the above graph.
- 3.2.1 What does area **G** represent? (1)
- 3.2.2 How will the addition of a catalyst to the reaction mixture influence area **G**? Write down only INCREASES, DECREASES or NO EFFECT. (1)
- 3.2.3 Fully explain your answer to Q 3.2.2. (2)
- 3.3 The pupils now repeat the experiment at 25°C, but use HCl (aq) of a LOWER CONCENTRATION.
- 3.3.1 The above graph has been reproduced on your ANSWER SHEET. On the same set of axes, sketch the graph that will be obtained at the lower concentration of HCl (aq) and label it as **S**. (2)
- 3.3.2 How will lower HCl (aq) concentration affect the rate of the reaction? Write down only INCREASES, DECREASES or NO EFFECT. (1)

- 3.4 The pupils now repeat the experiment a third time. They use the original acid concentration at **15 °C**. On the same set of axes of graph **E** overleaf, they draw two other graphs and label them as **D** and **F** as shown below.



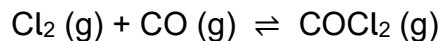
- 3.4.1 Which ONE of the two graphs, **D** or **F**, represents the distribution curve at this new temperature? (1)
- 3.4.2 Fully explain, by referring to the collision theory, how this change in temperature influences the rate of the reaction. (5)
- 3.5 The following mass-versus time graph (not drawn to scale) was obtained for the reaction of zinc with 0,1 dm³ of HCl (aq).



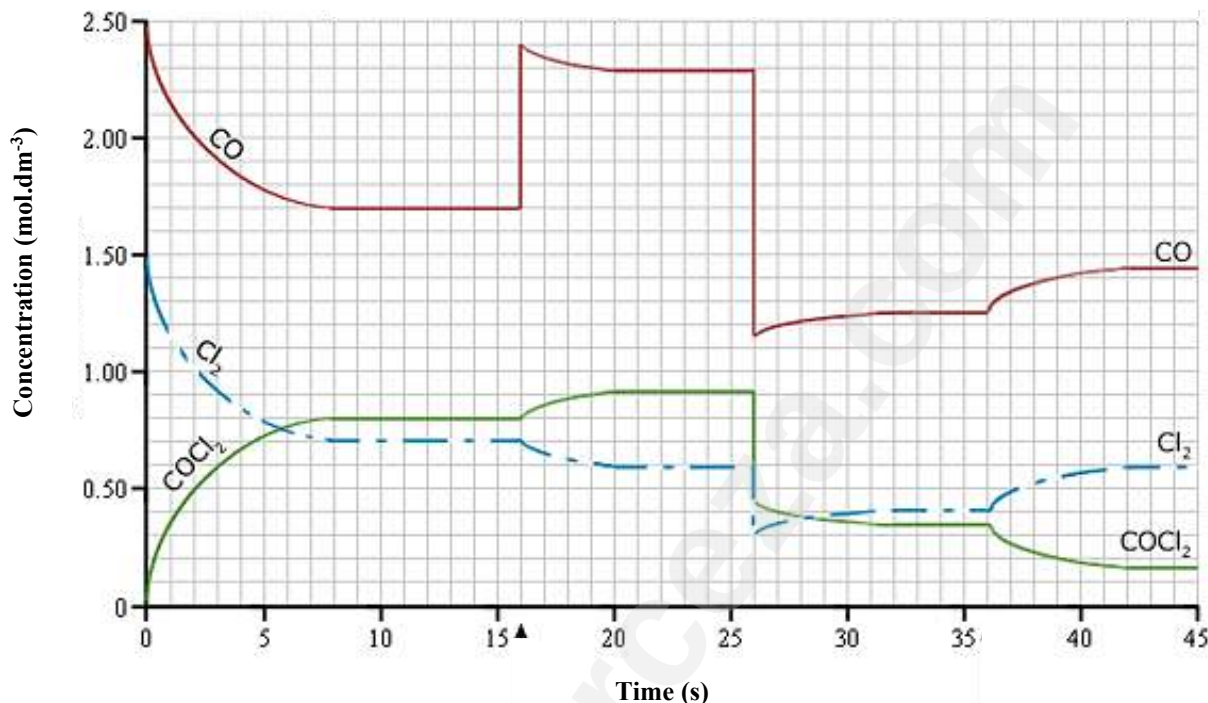
- 3.5.1 How long did it take for the reaction to reach completion? (1)
- 3.5.2 After 1,8 minutes it is found that half of the zinc has reacted. Calculate the average rate in g.s⁻¹ of this reaction in the first 1,8 minutes. (3)
- 3.5.3 Calculate the concentration of HCl (aq) that was used. (5)

[24]

Consider the following equilibrium reaction:



The graph shows a series of disturbances of this equilibrium.



- 4.1 Explain what is meant by 'dynamic chemical equilibrium'. (2)
- 4.2 Consider the **first** time that equilibrium is reached above. (1)
- 4.2.1 At what time is this first equilibrium established on the graph? (1)
- 4.2.2 How can you tell from this graph that equilibrium has been reached at this time? (2)
- 4.3 Consider the disturbances at $t = 16 \text{ s}$ and $t = 26 \text{ s}$. Which one of these was caused by a change in pressure? (1)
- 4.4 Describe how the relative rates of the reaction change from $t = 16 \text{ s}$ to $t = 25 \text{ s}$. (4)
- 4.5 At $t = 36 \text{ s}$, the temperature of the reaction vessel was **increased**. (1)
- 4.5.1 The K_c value for the reaction at $t = 24 \text{ s}$ is 0,67. Based on the changes seen on the graph, how will the K_c of the reaction at 44 s compare to this value? Write GREATER, LESS or THE SAME. (1)
- 4.5.2 Thus, which reaction, forward or reverse, is exothermic? (2)

[13]

- 5.1 Define the term *ionisation*. (2)
- 5.2 When 0,0415 moles of ethanoic acid is dissolved in 1 dm³ of water, the concentration of ethanoic acid molecules in the solution at equilibrium is 0,0410 mol.dm⁻³. Use a table to calculate the K_a value of ethanoic acid. (6)
- 5.3 A pupil carried out a titration by adding an aqueous solution of sodium hydroxide from a burette to a different aqueous solution of ethanoic acid. The end-point was reached when 22,6 cm³ of the sodium hydroxide solution had been added to 25 cm³ of the 0,41 mol.dm⁻³ ethanoic acid solution.
- 5.3.1 Write an equation for the reaction between sodium hydroxide and ethanoic acid (phase labels are not required). (2)
- 5.3.2 The number of moles of ethanoic acid is 0,0103 mol in the 25 cm³, 0,41 mol.dm⁻³ solution. Calculate the concentration of the sodium hydroxide solution used. (4)
- 5.3.3 Calculate the concentration of hydronium ions in the sodium hydroxide solution at 25°C. (2)
- 5.3.4 Would the ethanoic acid or the sodium hydroxide solution be a better conductor of electricity? Substantiate your answer. (3)

The aqueous solution of the basic salt produced during this titration dissociates as follows:



- 5.4 Use the concept of hydrolysis to explain why this salt is basic by referring to chemical reactions to substantiate your answer. (4)

- 5.5 **P** and **Q** are acids. **X** and **Y** are bases. The table shows the strength of each acid and base.

Acids		Bases	
strong	weak	strong	weak
P	Q	X	Y

Each acid was titrated separately with each base using;

- (a) methyl orange as indicator (pH range 3.1 – 4.4), then repeated,
- (b) using phenolphthalein as indicator (pH range 8.3 – 10.0).

For each of the following titrations, decide which indicator, or both or neither, would give a precise end-point.

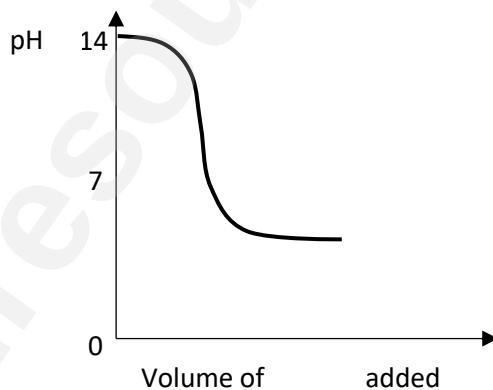
5.5.1 Acid **Q** with base **X**

5.5.2 Acid **P** with base **X**

5.5.3 Acid **P** with base **Y**

(3)

The following axes show a titration curve that would be plotted if one of the acids was titrated with one of the bases.



5.5.4 Provide the missing word in the x-axis label by writing down either ACID or BASE.

(1)

5.5.5 Which of the acids (**P** or **Q**) would have been titrated against which of the bases (**X** or **Y**) to create the graph depicted above?

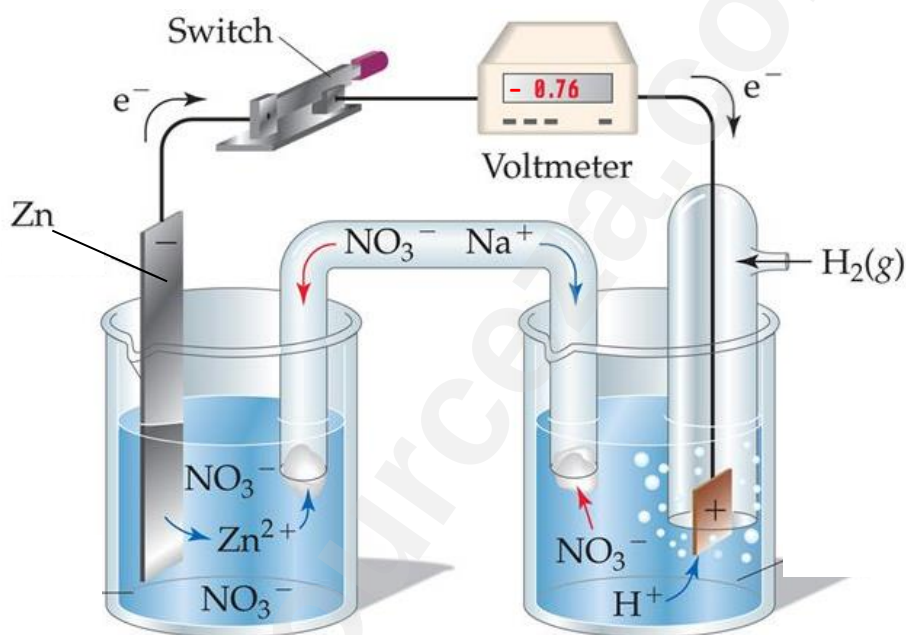
(1)

[28]

Question Six**10 marks**

The standard hydrogen electrode (the SHE) is a redox electrode which forms the basis of the scale of oxidation-reduction potentials ($E^\ominus$ values). The SHE has an electrode potential of 0,00 V.

- 6.1 Write down the half reaction for the SHE electrode from your table of standard electrode potentials showing H^+ ions being reduced. (1)
- 6.2 The SHE with a platinum electrode is connected as a reference electrode to a zinc electrode as shown below:

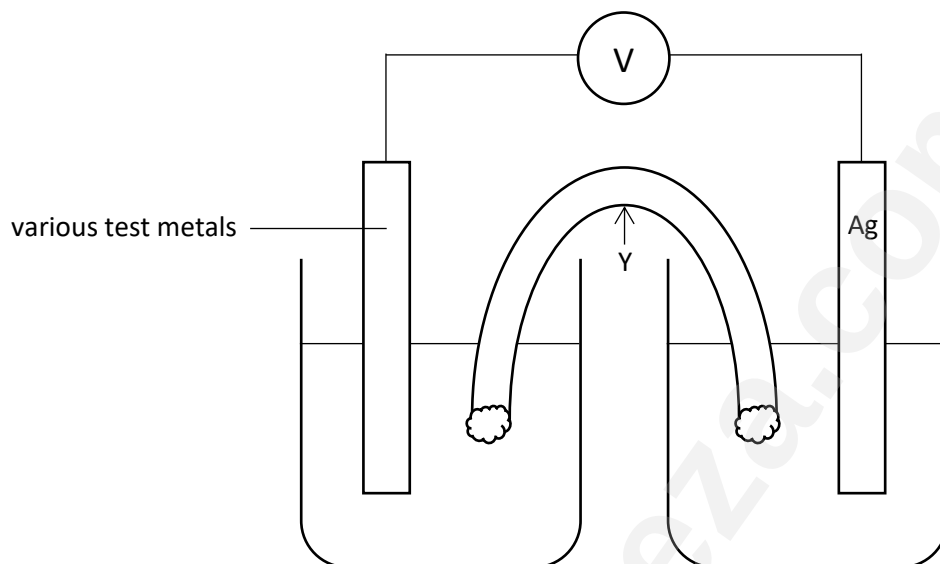


- 6.2.1 Write down the full cell notation for the setup above. Include phase labels and standard conditions. (5)
- 6.2.2 Discuss why a platinum electrode is used in this cell. (2)
- 6.2.3 Provide a reason as to why it is that water is not reduced at the cathode in this cell. (2)

[10]

Khansi wants to conduct an experiment to rank three metals based on their ability to act as reducing agents. She will do this by measuring the emf when each metal half-cell is connected to a silver half-cell. She plans to do the experiment under standard conditions.

The cell that Khansi has constructed is as follows:



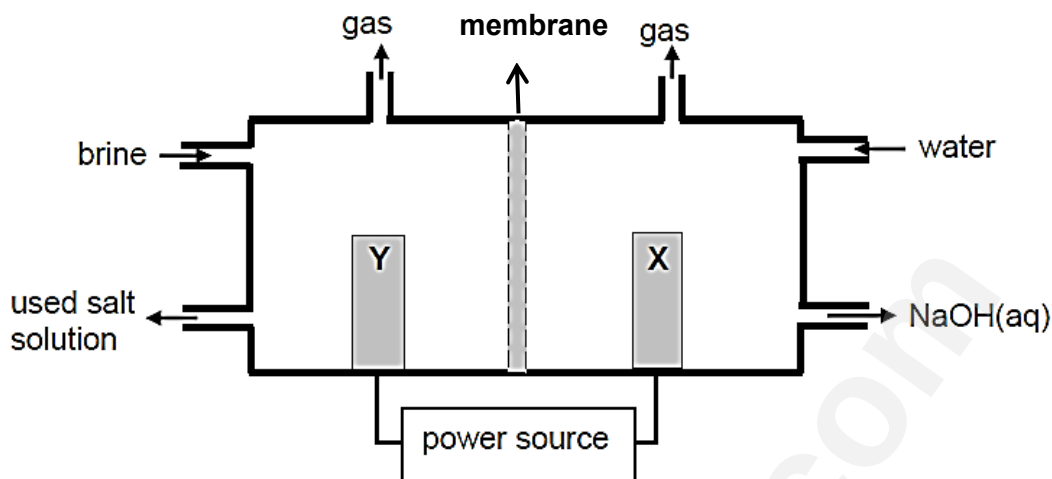
Khansi connects up different metals and she obtains the following results:

Metal connected to silver	$E^\ominus$ (V)
Iron	1,20
X	0,94
Zinc	1,45

- 7.1 Suggest a suitable solution to put into component Y for this experiment. (1)
- 7.2 State a suitable hypothesis that Khansi might make for this experiment. (2)
- 7.3 How could Khansi improve the reliability of her results? (2)
- 7.4 Metal X is an unknown metal that acts as a reducing agent. Use the $E^\ominus_{\text{cell}}$ equation and the information above to work out which metal is X. NAME this metal. (5)

[10]

8.1 The simplified diagram of a cell used in the chlor-alkali industry is shown below.



8.1.1 At which electrode, X or Y, is chlorine gas formed? (1)

8.1.2 Fully describe the type of bond present in the chlorine molecule and explain why the bond is described as such by referring to polarity of the bond. (3)

8.1.3 Use the relative strengths of the oxidising agents present to explain why sodium metal is NOT produced at the cathode in the membrane cell. (2)

8.1.4 A constant current of 4 000 A is passed through a chlor-alkali cell for 2,5 minutes. Calculate the volume of chlorine gas produced, at STP, at the anode during this period of time. (8)

8.1.5 The purity of the sodium hydroxide produced in the chlor-alkali industry varies based on the process used to make the products. Briefly describe how sodium hydroxide's purity is ensured in this membrane cell. (2)

8.2 In a trial done using a mercury cell, the effect of current on the mass of sodium produced at the cathode was measured. The current was passed through the brine for 10 minutes each time. The results are tabulated below.

Table 1: Data for electrolysis of brine trial	
Current	Mass Na
1 Amp	0.16 g
4 Amp	0.57 g
7 Amp	1.00 g
12 Amp	1.68 g
15 Amp	2.15 g

8.2.1 State one error in the format of the table. (1)

- 8.2.2 Plot a graph of the data with mass on the y-axis and current on the x-axis on the graph paper provided on your ANSWER SHEET and draw a line of best fit through the points. (6)
- 8.2.3 Calculate the gradient of your graph. Show the points you used on your graph. (4)
- 8.2.4 Considering that mass is on the y-axis and current is on the x-axis of your graph, put the equation $Q = It$ together with $Q = nF$ and generate an equation in the format of $y = mx + c$ for this graph. Show that your value for ' m ' (the gradient) in your equation is the same as your answer calculated in 8.2.3. (4)

[31]

Question Nine

20 marks

- 9.1 Study the organic compounds labelled A – H below and answer the questions which follow.

A	$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$	B	CH_2CH_2
C	$\text{CH}_3\text{CH}(\text{CH}_3)\text{CH}_3$	D	CH_3OH
E	$\text{CH}_3\text{CH}(\text{Cl})\text{CH}_3$	F	$\text{CH}_3\text{CH}_2\text{CH}_2\text{Cl}$
G	$\text{C}_2\text{H}_5\text{COOH}$	H	$\text{CH}_3\text{OCOCH}_2\text{CH}_3$

- 9.1.1 Identify the homologous series of the organic compounds **B** and **D** above, respectively. (2)
- 9.1.2 Name the organic compounds **C** and **F** above. (4)
- 9.1.3 Draw the functional group of compound **A**. (1)

Consider compound **F**.

- 9.1.4 Write down the LETTER that represents a structural isomer of compound **F**. (1)
- 9.1.5 Name the specific type of isomerism referred to in Q 9.1.4. (1)

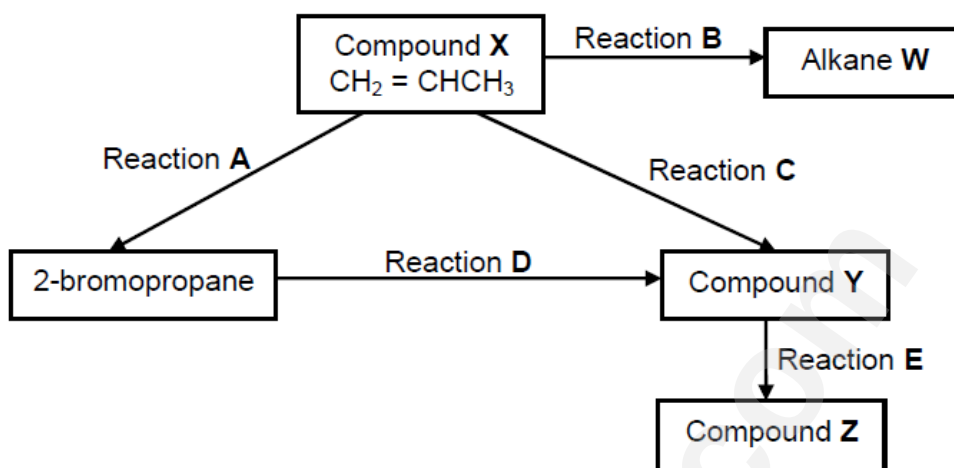
Water is one of the products formed when compounds **D** and **G** are heated in the presence of a catalyst. Write down the:

- 9.1.6 NAME of the functional group of compound **D**. (1)
- 9.1.7 IUPAC name of the organic product formed (compound **H**). (2)
- 9.1.8 Type of reaction that takes place. (1)
- 9.1.9 NAME of the catalyst needed. (1)
- 9.1.10 NAME of two structural isomers of compound **H**. (2)

- 9.2 Draw the structural formula of 1,2-dibromo-3-methylbut-2-ene. (4)

[20]

The flow diagram below shows how different organic compounds can be prepared using compound **X** as the starting material.



- 10.1 Is compound **X** SATURATED or UNSATURATED? (1)
- 10.2 Compound **X** reacts with hydrogen (H_2) during reaction **B** to form alkane **W**. Write down the type of addition reaction that takes place. (1)
- 10.3 During reaction **A**, compound **X** is converted to 2-bromopropane. For this reaction, write down the:
- 10.3.1 NAME or FORMULA of the inorganic reactant needed. (1)
- 10.3.2 Type of reaction that takes place. (1)
- 10.4 Compound **X** reacts with water during reaction **C** to form compound **Y**. Using structural formulae, write down a balanced equation for the reaction. (3)
- 10.5 Consider reaction **D**. Write down the:
- 10.5.1 Reaction conditions. (2)
- 10.5.2 Type of reaction that takes place. (1)
- 10.6 Reaction **E** is an elimination reaction. For this reaction, write down the:
- 10.6.1 IUPAC name of compound **Z**. (1)
- 10.6.2 Type of elimination reaction that takes place. (1)

[12]**TOTAL = 200 marks****Sources: Acknowledgements and Thanks:**

Question 1: 1.1 and 1.2 curve from: <http://www.entropy-book.com/maxwell-boltzmann-distribution/>
 Question 2: 2.1 & 2.2: Adapted from St Mary's Waverley Form III exam 2013. Images: <https://www.onecrazymom.com/16-alternative-uses-for-epsom-salt/> and <https://studiousguy.com/fluorine-uses/>.
 2.3: Adapted from Edexcel Chemistry A level 2018
 Question 3: Free State Province Grade 12 June Chemistry exam 2015
 Question 4: Adapted from St Mary's Waverley FV standardised test June 2015
 Question 5: Adapted from St Mary's Waverley FV standardised test 2016
 Question 6 Adapted from St Mary's Waverley FV standardised test 2016
 Question 7: Adapted from St Mary's Waverley FV standardised test 2013
 Question 8: Adapted from St Mary's DSG prelim P2 2015
 Question 10: Adapted from Free State Province Grade 12 Prelim Chemistry exam 2015