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Examination number:

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ST ANNE'S DIOCESAN COLLEGE

TRIAL EXAMINATION

PHYSICAL SCIENCES

PAPER 2 CHEMISTRY

August 2021

Time: 3 hours

200 Marks

Examiner: J FORREST

Moderator: K SANDERS

The use of other IEB teachers' questions, in whole or in part, is gratefully acknowledged.

READ THE FOLLOWING INSTRUCTIONS CAREFULLY

1. This paper consists of:
 - p2-21 Questions 1 to 10
 - p23-25 Chemistry Data Sheets
 - p27 ANSWER SHEET Question 1

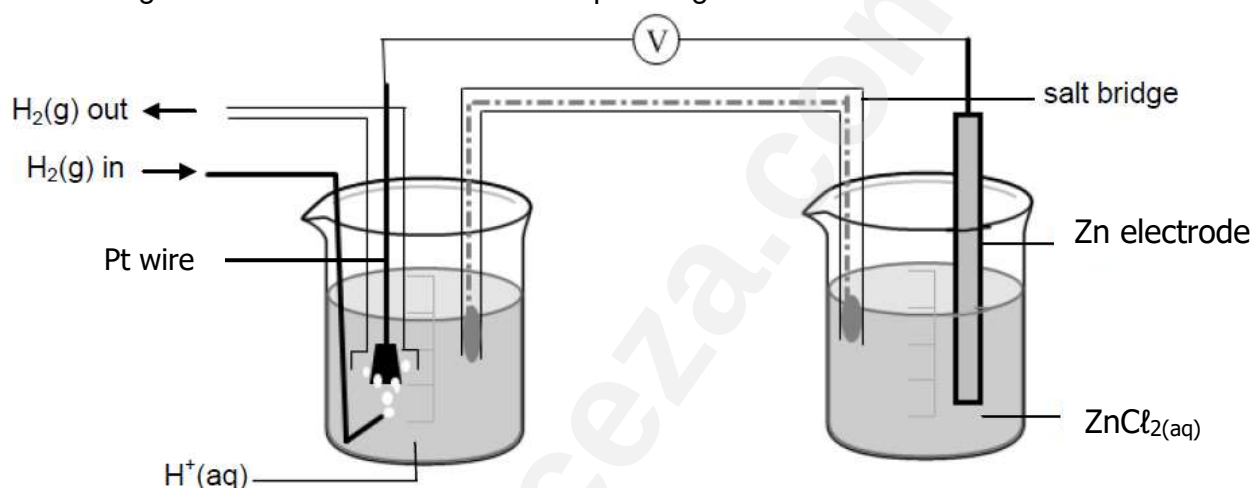
Please make sure that your question paper is complete.

2. The data sheets may be detached if necessary.
 3. Read the questions carefully and answer in any order, with clear numbering.
 4. Show your working in all calculations, including equations used.
 5. Units need not be included in the working of calculations, but appropriate units must be shown in the answer.
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QUESTION 1 MULTIPLE CHOICE QUESTIONS
(Record answers on the ANSWER SHEET on page 27)

Four options are provided as possible answers to the following questions.
 Each question has only ONE correct answer.

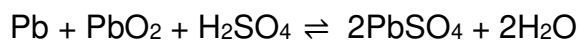
- 1.1 Consider the electrochemical cell that is shown in the diagram below. The cell consists of a standard hydrogen half-cell that is joined to a standard zinc half-cell by a salt bridge. The electrochemical cell is operating under standard conditions.



Which one of the following gives the most suitable electrolyte for use in the hydrogen half-cell and the electrode which acts as the anode in the spontaneous reaction that takes place in this electrochemical cell?

	Electrolyte for hydrogen half-cell	Anode
A	1 mol.dm ⁻³ H ₂ SO ₄	Zn
B	1 mol.dm ⁻³ HCl	Pt
C	1 mol.dm ⁻³ HCl	Zn
D	1 mol.dm ⁻³ H ₂ SO ₄	Pt

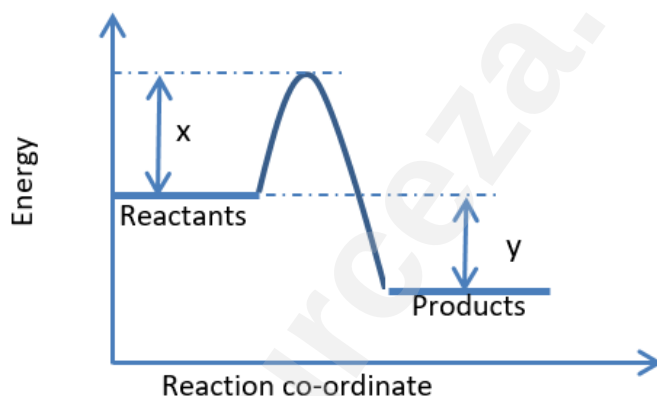
1.2 Given the lead-acid battery reaction:



Name the oxidising agent for the forward reaction.

- A Pb
- B PbO₂
- C H₂SO₄
- D H₂O

1.3 What is the activation energy of the reverse reaction as shown in the given energy profile diagram?



- A $X + Y$
- B Y
- C X
- D $X - Y$

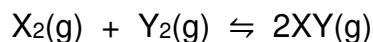
1.4 The following two changes were carried out on each of the systems listed below:

- I. Pressure was decreased at a constant temperature
- II. Temperature was increased at a constant pressure

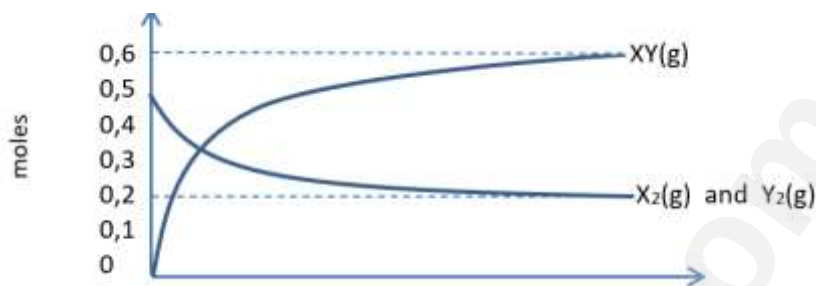
Which system would give an increase in the proportion of products in both these changes?

- | | | |
|---|--|---------------------------------------|
| A | $\text{H}_2(\text{g}) + \text{I}_2(\text{g}) \rightleftharpoons 2\text{HI}(\text{g})$ | $\Delta H = +53 \text{ kJ.mol}^{-1}$ |
| B | $4\text{NH}_3(\text{g}) + 5 \text{O}_2(\text{g}) \rightleftharpoons 4\text{NO}(\text{g}) + 6 \text{H}_2\text{O}(\text{g})$ | $\Delta H = -950 \text{ kJ.mol}^{-1}$ |
| C | $\text{N}_2(\text{g}) + 3 \text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g})$ | $\Delta H = -92 \text{ kJ.mol}^{-1}$ |
| D | $\text{N}_2\text{O}_4(\text{g}) \rightleftharpoons 2\text{NO}_2(\text{g})$ | $\Delta H = +57 \text{ kJ.mol}^{-1}$ |

1.5 Consider the reaction:



The graph shows how the number of moles of each gas changes when a mixture containing 0,5 mol each of $\text{X}_2(\text{g})$ and $\text{Y}_2(\text{g})$ is heated in a closed container.



What is the value of the equilibrium constant, K_c , for this reaction?

- A 18
- B 9
- C 3
- D 1,5

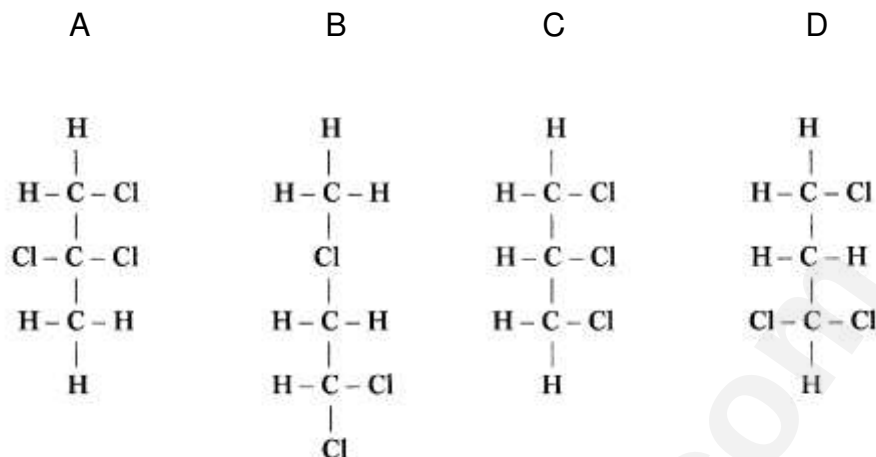
1.6 Aluminium metal is produced commercially by electrolysis of a mixture of bauxite, Al_2O_3 and cryolite, Na_3AlF_6 . What is the main function of the cryolite?

- A Al_2O_3 is covalent and AlF_6^{3-} ions interact with it to produce Al^{3+} ions which can be discharged at the cathode.
- B Cryolite is a base, forming NaAlO_2 with bauxite, enabling aluminium to be discharged at the anode.
- C Cryolite minimises the release of O^{2-} ions at the graphite anodes, which otherwise burn away to CO.
- D Cryolite reduces the melting point of bauxite.

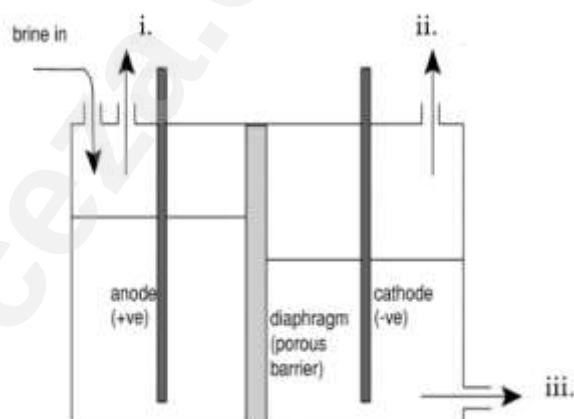
1.7 Which one of the following bond polarities is **not** correct?

- A $\overset{\delta+}{\text{C}} - \overset{\delta-}{\text{H}}$ in ethane
- B $\overset{\delta+}{\text{C}} - \overset{\delta-}{\text{Br}}$ in bromoethane
- C $\overset{\delta+}{\text{C}} - \overset{\delta-}{\text{O}}$ in ethanol
- D $\overset{\delta+}{\text{C}} = \overset{\delta-}{\text{O}}$ in ethanoic acid

1.8 Which is the correct structure for 1,2,2 tri-chloropropane?



Consider the schematic diagram for the electrolysis of brine on an industrial scale using a diaphragm cell and then answer questions 1.9 and 1.10



1.9 Which combination for the chemicals produced at i, ii and iii is correct.

	i	ii	iii
A	hydrogen	chlorine	oxygen
B	hydrogen	oxygen	sodium hydroxide
C	chlorine	hydrogen	sodium hydroxide
D	hydrogen	chlorine	sodium hydroxide

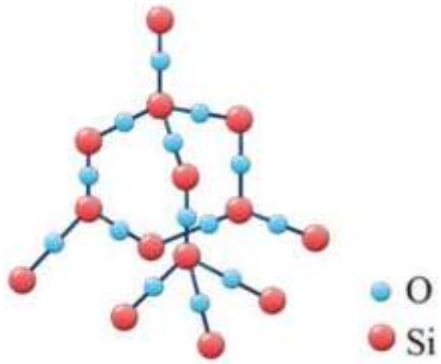
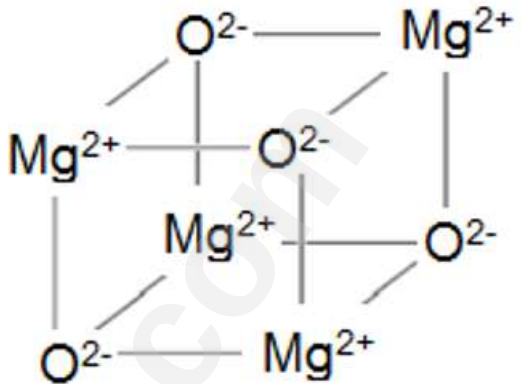
1.10 The main impurity found at (iii) is sodium chloride. Which statement about this impurity and the product produced at (iii) is **false**?

- A the impurity is as a result of brine passing through the membrane
- B the impurity can easily be separated from the desired product and does not affect the efficiency of the process.
- C the impurity can be minimised by changing the design of the cell which replaces the diaphragm with a selective membrane.
- D the impurity is neutral in pH and is ionic in nature. The desired product can be used to make soap.

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QUESTION 2 BONDING

2.1 The structures below show two different lattices (not to scale):

Compound A	Compound B
	

2.1.1 Give the chemical name for:

a) Compound A (1)

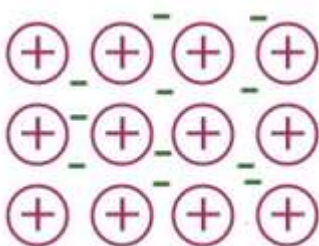
b) Compound B (1)

2.1.2 Define an **ionic bond**. (2)

2.1.3 Do both compounds have ionic bonds? Explain your answer. (3)

2.1.4 Are both these compounds able to conduct electricity? Explain briefly. (3)

2.2 Consider the following diagram.



2.2.1 What type of bonding is represented by the diagram? (1)

2.2.2 Give an example of a substance that would have this type of bonding. (1)

2.3 Consider the methanol molecule which has molecular formula CH_4O .

2.3.1 Define **electronegativity**. (2)

2.3.2 Draw the Lewis structure for this molecule, clearly indicating to which atom the electrons come from. (2)

2.3.3 State the molecular geometry around the carbon and oxygen atom as being either:

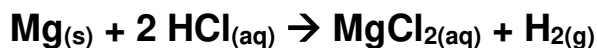
pyramidal ; tetrahedral or angular

(a) the carbon atom

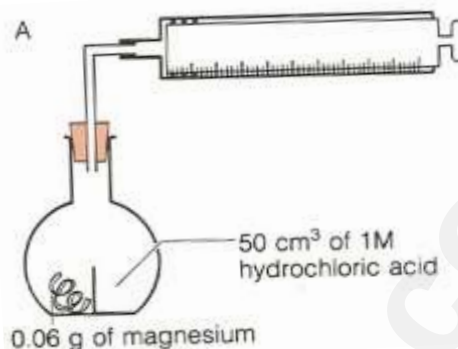
(b) the oxygen atom (2)

2.3.4 Label the most polar bond within the molecule in 2.3.2. (1)

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QUESTION 3 RATES OF REACTION

An experiment to investigate the rate of the above reaction was carried out as shown in the diagram below.

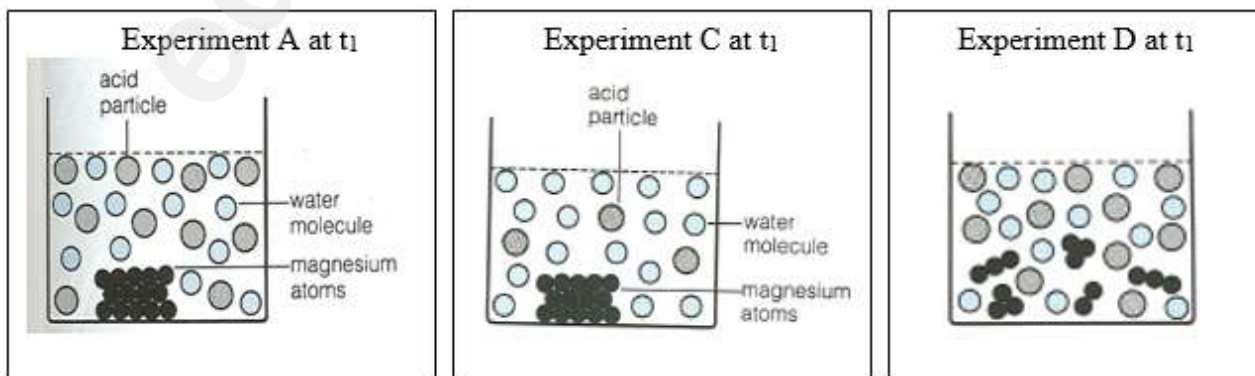


- A divided flask was used to keep the reactants apart initially.
- The stop-watch was started once the flask was tipped up to mix the chemicals.
- The volume of $\text{H}_2(\text{g})$ collected was measured as a function of time.
- The temperature was kept constant for all experiments.
- The molar gas volume at the temperature used is $24 \text{ dm}^3 \cdot \text{mol}^{-1}$.

The data collected was recorded in the Table below:

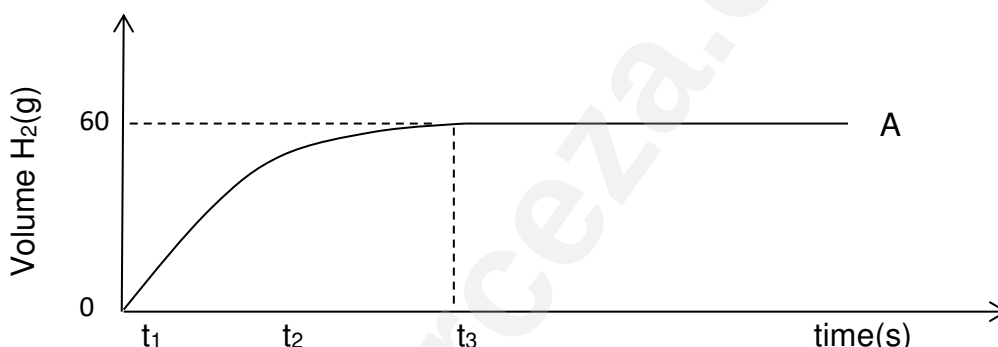
Experiment	Mass Mg (g)	Volume HCl (cm^3)	[HCl] ($\text{mol} \cdot \text{dm}^{-3}$)
A	0.06	50	1
B	0.03	50	1
C	See diagram below		
D	See diagram below		

Molecular diagrams of the initial reaction mixture for Experiments A, C and D are shown below.



- 3.1 Define: **reaction rate** (2)
- 3.2 Using the diagram of Experiment A as a reference, state what factor is being investigated in:
- 3.2.1 Experiment C; and
- 3.2.2 Experiment D (2)
- 3.3 Use the data provided for Experiment A to determine which reactant was in excess and hence prove that 60 cm^3 of $\text{H}_2(\text{g})$ would be collected at this temperature as shown in the graph below. (6)

Refer to the graph below and answer the questions which follow.



- 3.4 What does the gradient of this graph represent? (1)
- 3.5 Name and explain two possible reasons why the gradient of the graph is less steep at t_2 compared to t_1 . You should refer to the collision theory in your answer. (4)

The rate of this reaction could also be investigated by measuring the mass loss of an open flask as a function of time.

- 3.6 It is a law of nature that “matter is conserved” i.e. mass cannot be lost in a chemical reaction. Why would the mass of an open flask decrease as this reaction proceeds? (1)
- 3.7 Calculate the mass of $\text{H}_2(\text{g})$ that would be produced in Experiment A. (2)
- 3.8 Comment on which of the two experimental techniques is preferable in this case (measuring volume produced or measuring mass loss). Justify your answer. (2)

[20]

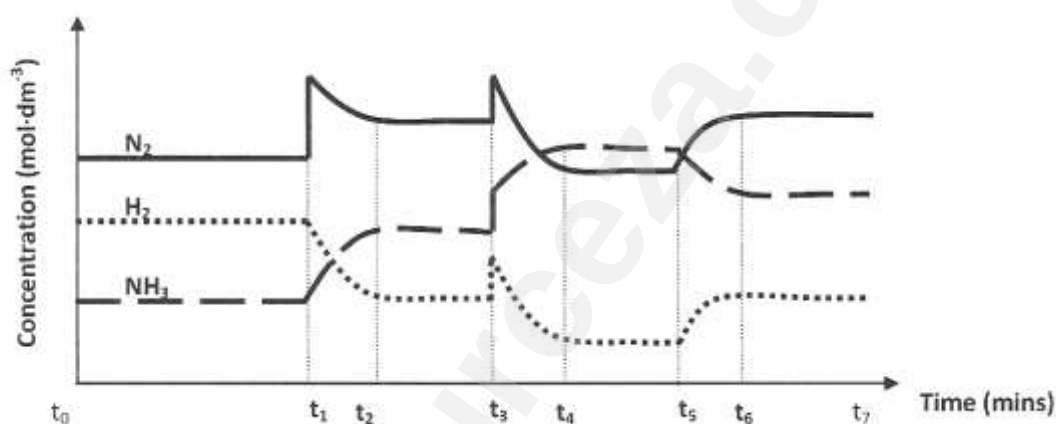
QUESTION 4 EQUILIBRIUM

A fertiliser company produces ammonia on a large scale at a temperature of 450°C. The balanced equation below represents the reaction that takes place in a sealed 2 dm³ container.



To meet an increased demand for fertiliser, the management of the company instructs their engineers to make the necessary adjustments to the dynamic chemical equilibrium of the reaction to increase the yield of ammonia.

In a trial run on a small scale in the laboratory, an engineer makes adjustments to the equilibrium mixture. The graphs below represent the results obtained.



- 4.1 Explain what is meant by the term “dynamic chemical equilibrium”. (2)
- 4.2 Give one time interval during which the reaction would have been in dynamic chemical equilibrium. (1)
- 4.3 Using le Chatelier’s Principle, identify and explain the changes made to the equilibrium mixture and state the effect on the equilibrium between each of the following times:
- 4.3.1 t_1 and t_2 (3)
- 4.3.2 t_5 and t_6 (3)
- 4.4 At t_3 , both the reactants and product showed a sudden increase in concentration.
- 4.4.1 What do you think happened at this point to cause the increase in concentration? (1)
- 4.4.2 Using le Chatelier’s Principle, explain how the equilibrium now re-establishes itself between t_3 and t_4 . (3)

4.5 At t_7 , the following amounts of reactant and product were present at equilibrium at a temperature of 450°C :

- 1,28 mol of H_2 ,
- 49,6 g of N_2
- $12,31 \text{ dm}^3$ of NH_3 gas at STP

The volume of the reaction container is 2 dm^3

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

4.5.2 Calculate the value of K_c for this reaction at 450°C . (7)

4.5.3 What would happen to the value of the equilibrium constant (K_c) calculated above, under the following conditions ?

(Simply answer INCREASE, DECREASE or STAY THE SAME)

- a) $\text{N}_2 (\text{g})$ is removed from the system.
- b) The temperature is decreased to 350°C .
- c) The size of the reaction vessel is increased. (3)

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QUESTION 5 ORGANIC

The letters A to D below each refer to a specific organic compound or series of compounds:

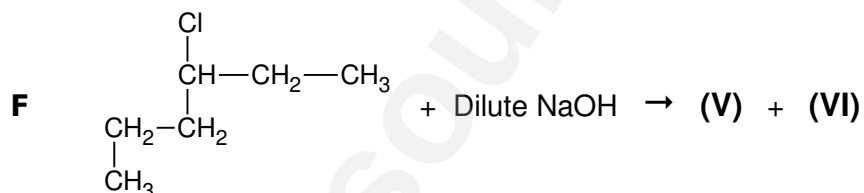
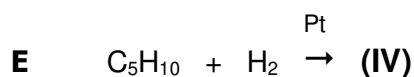
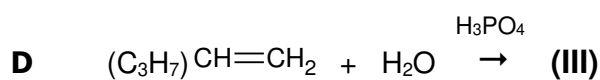
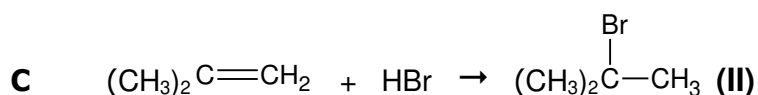
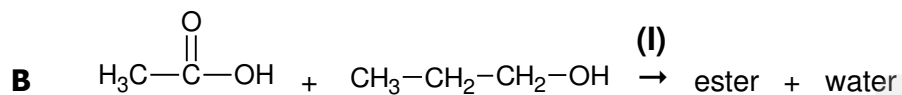
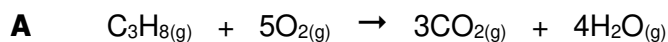
A	C_nH_{2n+2}
B	$ \begin{array}{c} \text{Cl} \quad \quad \text{Cl} \\ \diagdown \quad \diagup \\ \text{C} = \text{C} \\ \diagup \quad \diagdown \\ \text{H} \quad \quad \text{CH}_2\text{—CH}_3 \end{array} $
C	Pentanoic acid
D	Propanol

- 5.1. Write down an important use of the series of compound with general formula A. (1)
- 5.2. Name compound B. (2)
- 5.3. Define: **homologous series**. (2)
- 5.4. Name the homologous series of the compound that is the product of the reaction between compounds C and D. (1)
- 5.5. Name the compound formed in the reaction specified in 5.4. above. (2)
- 5.6. Explain which of compounds C or D would have the higher boiling point. (5)
- 5.7. Would you expect compound B to be soluble in water? Explain your answer. (3)
- 5.8. Define the term **isomer**. (2)
- 5.9. Draw the structural formula of one of the functional isomers of compound C. (2)

[20]

QUESTION 6 ORGANIC REACTIONS

The questions that follow all refer to the following reaction equations, representing some basic reactions of organic compounds:



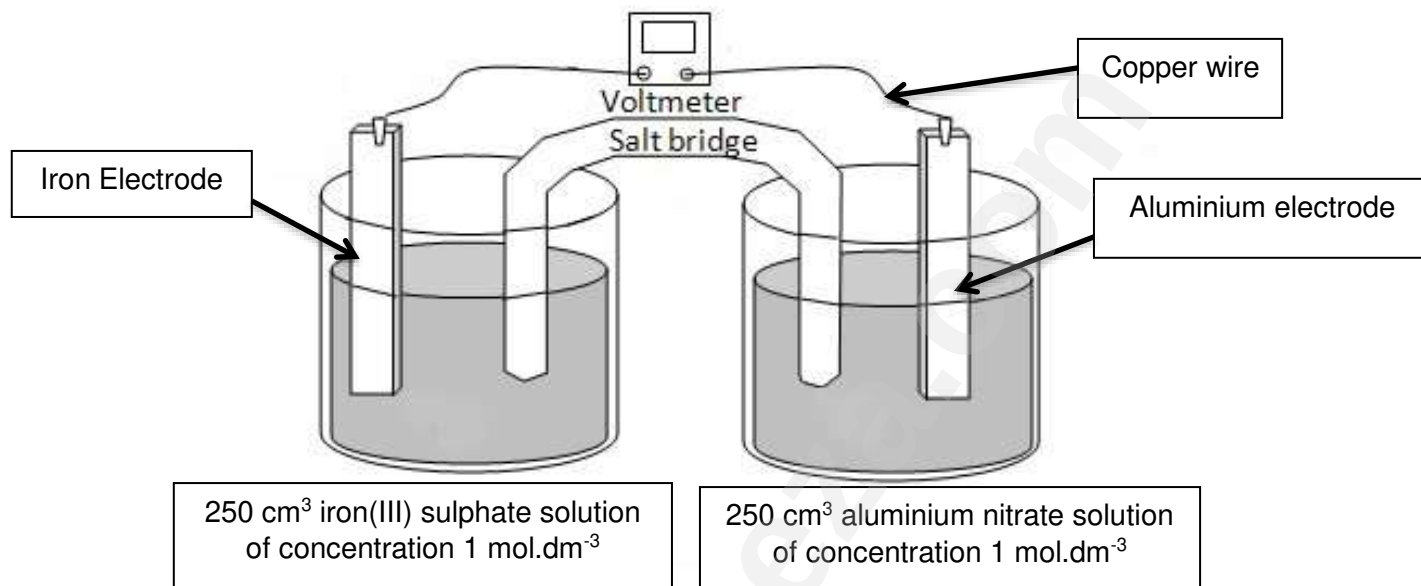
- 6.1. Identify the general type of reaction in A, C and F. (3)
- 6.2. Name the specific reaction type for B, D, and F. (3)
- 6.3. Name compound (II). (2)
- 6.4. Draw the structural formula of compound (III), which is the product of reaction D. (3)
- 6.5. Name compounds (V) and (VI) in reaction F. (3)

- 6.6. What is the name for the process being represented in reaction G? (1)
- 6.7. Explain the significance of this process (reaction G) in terms of industry. (3)
- 6.8. Hydrogenation of vegetable oils has been used in the food industry to make the well-known butter substitute, margarine.
- 6.8.1 Explain in detail why liquid plant oils become solids when they are hydrogenated. (3)
- 6.8.2 To which homologous series does compound (IV) belong? (1)
- 6.9. Esters, such as the product in reaction B, are used in the food industry as flavourings.
- 6.9.1 Write the IUPAC name of the carboxylic acid used in reaction B. (1)
- 6.9.2 Write the formulae for compound (I) and state its function in reaction B. (2)
- 6.10. Outline a procedure in which the hydrocarbon reactant in reaction C could be tested for unsaturation. (4)

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QUESTION 7 GALVANIC CELL

Consider the diagram below of a cell set up in a lab by Katlo and Megan. The temperature in the lab is **20°C**. The mass of the aluminium electrode at the start of the experiment was 24.5g and the iron electrode was 36.1g.



- 7.1 State the energy conversion that takes place in this type of cell. (1)
- 7.2 Is this cell a standard cell? Give a reason for your answer. (2)
- 7.3 What mass of iron(III) sulphate was weighed out to prepare the solution used here? (3)
- 7.4 Write down the half-reaction that occurs at the cathode in this cell. (2)
- 7.5 What would you observe in the half cell where oxidation is taking place? (2)
- 7.6 After the cell was operating for a while, the electrolyte around the aluminium electrode was analysed and found to contain sulphate ions. Explain how and why this is possible. (2)
- 7.7 If the cell was performing under standard conditions, calculate the emf produced by this electrochemical cell. (3)
- 7.8 After 60 minutes, the cell was disconnected and the electrodes dried and weighed. It was found that the iron electrode now had a mass of 36.85g. Calculate the current that must have been flowing in the wire. (6)

7.9 The current created in this cell depends on two factors, namely, the **rate of the reaction** and the **internal resistance** of the cell. Other than changing the standard conditions of a cell, name **one** thing that could be done to the cell in order to...

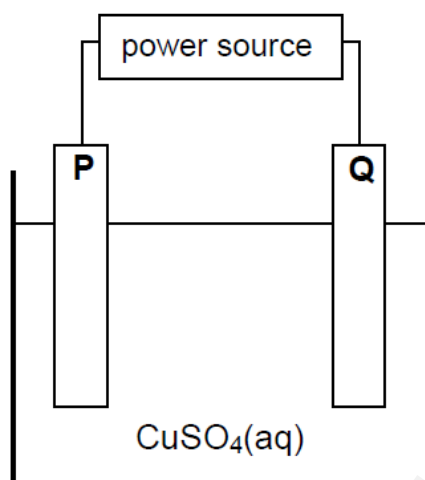
7.9.1 increase the rate of the reaction (1)

7.9.2 decrease the internal resistance of the cell (1)

[23]

QUESTION 8 ELECTROLYSIS

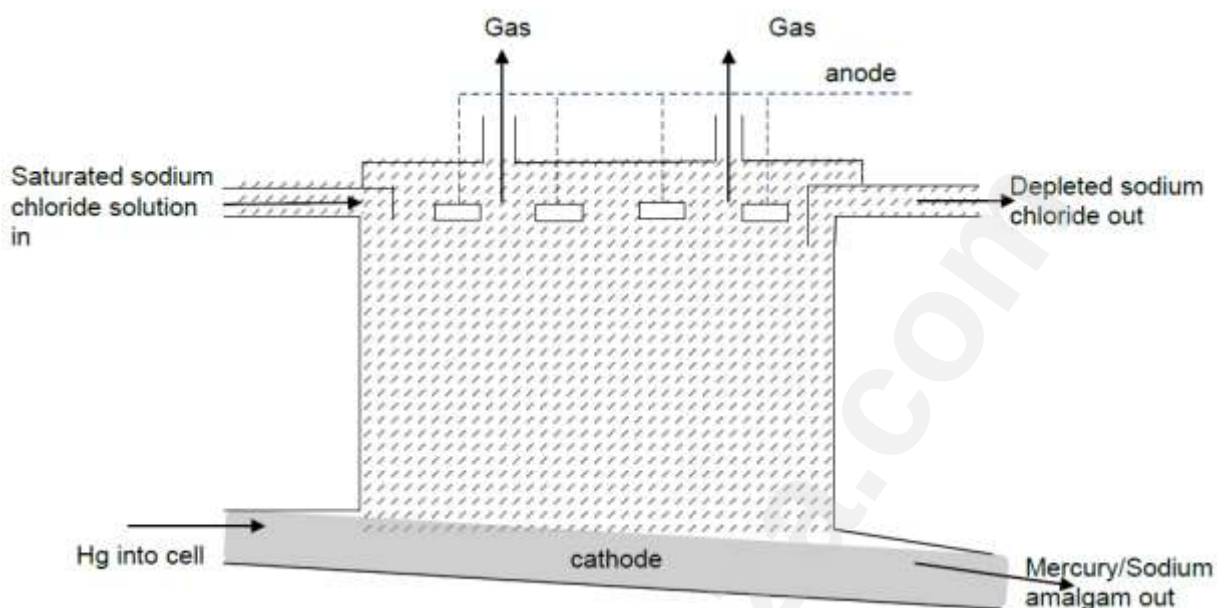
- 8.1 The simplified diagram represents a cell used in the electrorefining of copper. One of the electrodes consists of impure copper and the other one of pure copper.



When an electric current passes through the solution, **electrode P becomes coated with copper.**

- 8.1.1 Is electrode P the cathode or the anode? Support your answer by writing the half-reaction that takes place at electrode P. (2)
- 8.1.2 It is found that the impure copper plate contains impurities of nickel and gold. The gold forms part of the residue at the bottom of the container during electrolysis. (3)
- a) Refer to the relative strengths of reducing agents to explain why gold forms part of the residue at the bottom of the container. (3)
- b) Refer to the relative strengths of oxidizing and reducing agents to explain what happens to the nickel impurities in the impure copper plate. (3)

8.2 The diagram below shows a simplified Mercury cell used in the Chlor-Alkali process.



8.2.1 Give the common name for the raw material of this process. (1)

8.2.2 What substance is formed at the positive electrode? (1)

8.2.3 The Na(Hg) amalgam is reacted with water in a separate container to produce two of the products of this process. Write a balanced chemical equation to represent this reaction. (2)

8.2.4 Name one advantage of this type of cell. (1)

8.2.5 Why is the use of this cell being phased out? (1)

8.2.6 Name the type of cell which is replacing this cell. (1)

[15]

QUESTION 9 ACIDS AND BASES

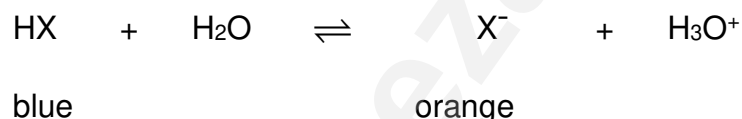
Oxalic acid, $\text{H}_2\text{C}_2\text{O}_4$, is both a weak diprotic acid and a reducing agent. Because it is a pure and stable crystalline compound, it can be used to prepare a standard solution. This standard oxalic acid solution can then be used to standardize solutions of sodium hydroxide (by acid-base titration) and potassium permanganate (by redox titration).

9.1 Define:

9.1.1 **weak acid.** (2)

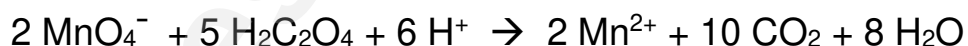
9.1.2 **standard solution.** (2)

9.2 Indicators are actually weak acids. Suppose indicator HX reacts as follows:



A few drops of this indicator are added to some water. Some NaOH is then added. Use Le Chatelier's principle to explain what colour the solution will be. (4)

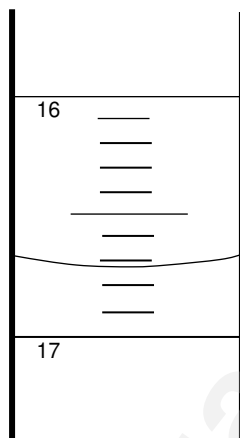
9.3 When oxalic acid is used to standardize a permanganate solution, the overall reaction equation is as follows:



9.3.1 Write down the formula of the oxidizing agent. (1)

9.3.2 What colour change would you expect to see in this titration? (1)

- 9.4 25,0 cm³ of a 0,0434 mol.dm⁻³ standard oxalic acid solution is pipetted into a conical flask. The burette is filled with the permanganate solution. The permanganate solution is titrated into the oxalic acid solution until the end point volume (in cm³) shown in the diagram below is obtained.

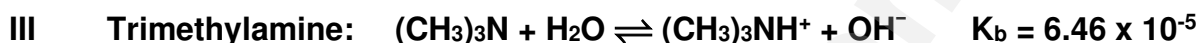
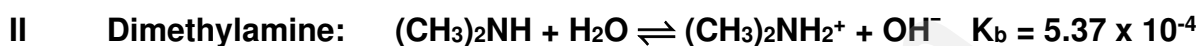


- 9.4.1 Write down the end-point volume. (1)
- 9.4.2 Calculate the concentration of the permanganate solution. (4)
Report your answer to the correct number of significant figures.

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QUESTION 10 ACIDS AND BASES

10.1 Consider the following equations representing the ionization reactions of three bases:



10.1.1 Are these bases strong or weak bases? Justify your answer. (2)

10.1.2 A 0.1 mol.dm^{-3} solution of each of the three bases is prepared.

Which solution will have the **lowest** pH? Explain your answer. (3)

10.2 Water is amphiprotic and can auto-ionize.

10.2.1 Define: **amphiprotic**? (2)

10.2.2 Write the equation which represents the auto-ionization of water. (2)

10.2.3 Show how you would calculate the hydronium ion concentration in a neutral aqueous solution at 25°C . (2)

10.2.4 In another solution at 25°C , the **hydroxide ion** concentration is $3.2 \times 10^{-10} \text{ mol.dm}^{-3}$. Determine whether this solution is acidic, basic or neutral. Explain your reasoning. (3)

[14]

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**EXAMINATION DATA SHEET FOR THE PHYSICAL SCIENCES
(CHEMISTRY)**

TABLE 1 PHYSICAL CONSTANTS

NAME	SYMBOL	VALUE
Magnitude of charge on electron	e	$1,6 \times 10^{-19} \text{ C}$
Mass of an electron	m_e	$9,1 \times 10^{-31} \text{ kg}$
Standard pressure	p^θ	$1,01 \times 10^5 \text{ Pa}$
Molar gas volume at STP	V_m	$22,4 \text{ dm}^3 \cdot \text{mol}^{-1}$
Standard temperature	T^θ	273 K
Avogadro's constant	N_A	$6,02 \times 10^{23} \text{ mol}^{-1}$
Faraday's constant	F	$96\,500 \text{ C} \cdot \text{mol}^{-1}$

TABLE 2 CHEMISTRY FORMULAE

$n = \frac{m}{M}$	$n = \frac{N}{N_A}$	$n = \frac{V}{V_m}$
$c = \frac{n}{V}$ OR $c = \frac{m}{MV}$	$K_w = [H_3O^+] \cdot [OH^-] = 1 \times 10^{-14}$ at 25 °C (298 K)	
$q = It$ $q = nF$	$E_{\text{cell}}^\theta = E_{\text{cathode}}^\theta - E_{\text{anode}}^\theta$ $E_{\text{cell}}^\theta = E_{\text{oxidising agent}}^\theta - E_{\text{reducing agent}}^\theta$	

TABLE 3 PERIODIC TABLE

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	12,1 H						12,1 H											2 He
2	31,0 Li	41,5 Be											52,0 B	62,5 C	73,0 N	83,5 O	94,0 F	10 Ne
3	110,9 Na	121,2 Mg											131,5 Al	141,8 Si	152,1 P	162,5 S	173,0 Cl	18 Ar
													23 Na	24,3 Mg	27 Al	28 Si	31 P	32 S
4	190,8 K	201,0 Ca	211,3 Sc	221,5 Ti	231,6 V	241,6 Cr	251,5 Mn	261,8 Fe	271,8 Co	281,8 Ni	291,9 Cu	301,6 Zn	311,6 Ga	321,8 Ge	332,0 As	342,4 Se	352,8 Br	36 Kr
5	370,8 Rb	381,0 Sr	391,2 Y	401,4 Zr	411,6 Nb	421,8 Mo	431,9 Tc	442,2 Ru	452,2 Rh	462,2 Pd	471,9 Ag	481,7 Cd	491,7 In	501,8 Sn	511,9 Sb	522,1 Te	532,5 I	54 Xe
6	55 Cs	56 Ba		72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra		178,5 Hf	181 Ta	184 W	186 Re	190 Os	192 Ir	195 Pt	197 Au	200,6 Hg	204,4 Tl	207 Pb	209 Bi	209 Po	209 At	209 Rn

TABLE 4 STANDARD ELECTRODE POTENTIALS

Half-reaction			E°/volt
$\text{Li}^+ + \text{e}^- \rightleftharpoons \text{Li}$			-3,05
$\text{K}^+ + \text{e}^- \rightleftharpoons \text{K}$			-2,93
$\text{Cs}^+ + \text{e}^- \rightleftharpoons \text{Cs}$			-2,92
$\text{Ba}^{2+} + 2\text{e}^- \rightleftharpoons \text{Ba}$			-2,90
$\text{Sr}^{2+} + 2\text{e}^- \rightleftharpoons \text{Sr}$			-2,89
$\text{Ca}^{2+} + 2\text{e}^- \rightleftharpoons \text{Ca}$			-2,87
$\text{Na}^+ + \text{e}^- \rightleftharpoons \text{Na}$			-2,71
$\text{Mg}^{2+} + 2\text{e}^- \rightleftharpoons \text{Mg}$			-2,37
$\text{Al}^{3+} + 3\text{e}^- \rightleftharpoons \text{Al}$			-1,66
$\text{Mn}^{2+} + 2\text{e}^- \rightleftharpoons \text{Mn}$			-1,18
$2\text{H}_2\text{O} + 2\text{e}^- \rightleftharpoons \text{H}_2(\text{g}) + 2\text{OH}^-$			-0,83
$\text{Zn}^{2+} + 2\text{e}^- \rightleftharpoons \text{Zn}$			-0,76
$\text{Cr}^{3+} + 3\text{e}^- \rightleftharpoons \text{Cr}$			-0,74
$\text{Fe}^{2+} + 2\text{e}^- \rightleftharpoons \text{Fe}$			-0,44
$\text{Cd}^{2+} + 2\text{e}^- \rightleftharpoons \text{Cd}$			-0,40
$\text{Co}^{2+} + 2\text{e}^- \rightleftharpoons \text{Co}$			-0,28
$\text{Ni}^{2+} + 2\text{e}^- \rightleftharpoons \text{Ni}$			-0,25
$\text{Sn}^{2+} + 2\text{e}^- \rightleftharpoons \text{Sn}$			-0,14
$\text{Pb}^{2+} + 2\text{e}^- \rightleftharpoons \text{Pb}$			-0,13
$\text{Fe}^{3+} + 3\text{e}^- \rightleftharpoons \text{Fe}$			-0,04
$2\text{H}^+ + 2\text{e}^- \rightleftharpoons \text{H}_2(\text{g})$			0,00
$\text{S} + 2\text{H}^+ + 2\text{e}^- \rightleftharpoons \text{H}_2\text{S}(\text{g})$			+0,14
$\text{Sn}^{4+} + 2\text{e}^- \rightleftharpoons \text{Sn}^{2+}$			+0,15
$\text{SO}_4^{2-} + 4\text{H}^+ + 2\text{e}^- \rightleftharpoons \text{SO}_2(\text{g}) + 2\text{H}_2\text{O}$			+0,17
$\text{Cu}^{2+} + 2\text{e}^- \rightleftharpoons \text{Cu}$			+0,34
$2\text{H}_2\text{O} + \text{O}_2 + 4\text{e}^- \rightleftharpoons 4\text{OH}^-$			+0,40
$\text{SO}_2 + 4\text{H}^+ + 4\text{e}^- \rightleftharpoons \text{S} + 2\text{H}_2\text{O}$			+0,45
$\text{I}_2 + 2\text{e}^- \rightleftharpoons 2\text{I}^-$			+0,54
$\text{O}_2(\text{g}) + 2\text{H}^+ + 2\text{e}^- \rightleftharpoons \text{H}_2\text{O}_2$			+0,68
$\text{Fe}^{3+} + \text{e}^- \rightleftharpoons \text{Fe}^{2+}$			+0,77
$\text{Hg}^{2+} + 2\text{e}^- \rightleftharpoons \text{Hg}$			+0,79
$\text{NO}_3^- + 2\text{H}^+ + \text{e}^- \rightleftharpoons \text{NO}_2(\text{g}) + \text{H}_2\text{O}$			+0,80
$\text{Ag}^+ + \text{e}^- \rightleftharpoons \text{Ag}$			+0,80
$\text{NO}_3^- + 4\text{H}^+ + 3\text{e}^- \rightleftharpoons \text{NO}(\text{g}) + 2\text{H}_2\text{O}$			+0,96
$\text{Br}_2 + 2\text{e}^- \rightleftharpoons 2\text{Br}^-$			+1,09
$\text{Pt}^{2+} + 2\text{e}^- \rightleftharpoons \text{Pt}$			+1,20
$\text{MnO}_2 + 4\text{H}^+ + 2\text{e}^- \rightleftharpoons \text{Mn}^{2+} + 2\text{H}_2\text{O}$			+1,21
$\text{O}_2 + 4\text{H}^+ + 4\text{e}^- \rightleftharpoons 2\text{H}_2\text{O}$			+1,23
$\text{Cr}_2\text{O}_7^{2-} + 14\text{H}^+ + 6\text{e}^- \rightleftharpoons 2\text{Cr}^{3+} + 7\text{H}_2\text{O}$			+1,33
$\text{Cl}_2(\text{g}) + 2\text{e}^- \rightleftharpoons 2\text{Cl}^-$			+1,36
$\text{Au}^{3+} + 3\text{e}^- \rightleftharpoons \text{Au}$			+1,42
$\text{MnO}_4^- + 8\text{H}^+ + 5\text{e}^- \rightleftharpoons \text{Mn}^{2+} + 4\text{H}_2\text{O}$			+1,51
$\text{H}_2\text{O}_2 + 2\text{H}^+ + 2\text{e}^- \rightleftharpoons 2\text{H}_2\text{O}$			+1,77
$\text{F}_2(\text{g}) + 2\text{e}^- \rightleftharpoons 2\text{F}^-$			+2,87

Increasing oxidising ability

Increasing reducing ability

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APPENDIX A

Exam number :

QUESTION 1**MULTIPLE CHOICE ANSWER GRID****MARK ONLY THE CORRECT ANSWER WITH A CROSS.**

eg.	A	~~B~~	C	D
-----	---	--------------	---	---

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

For marking purposes only:

Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	TOTAL
/20	/19	/20	/25	/20	/29	/23	/15	/15	/14	/200

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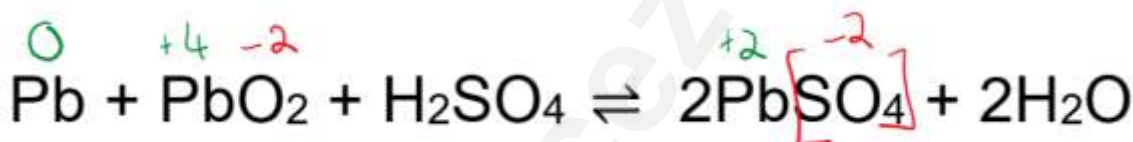
MCQ explanations

- 1.1. The electrolyte needs to be a solution that provides $[H^+] = 1 \text{ mol.dm}^{-3}$,
Any strong acid will be a suitable source of H^+ ions
Sulphuric acid is diprotic, so 1 mol.dm^{-3} of H_2SO_4 gives $[H^+] = 2 \text{ mol.dm}^{-3}$,
HCl is monoprotic so 1 mol.dm^{-3} of HCl gives $[H^+] = 1 \text{ mol.dm}^{-3}$

The question also asks for the anode in the **spontaneous reaction**. (i.e. not considering that hydrogen is always connected to the voltmeter as if it is the anode)
Looking at the redox table, this is the chemical that is highest on the left hand side which is Zn

- 1.2. To find the oxidizing agent we need to find which substance is reduced. The easiest method to do this is to use oxidation numbers.

Pb is by itself (O.N = 0) in one of the reactants and is in compounds in the products so its oxidation number will definitely change. We will start here:



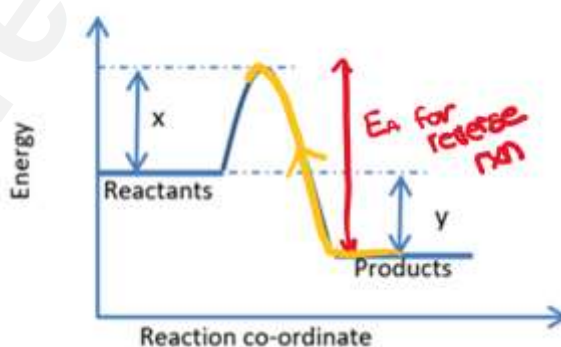
lead is both oxidized and reduced, I do not need to bother working out the O.N of the other compounds.

Lead in the form of Pb is oxidized

Lead in the form of PbO_2 is reduced

So the oxidizing agent is PbO_2

- 1.3. For the reverse reaction, we are going from products to reactants. To start the reaction we need to get from the products (where we start) to the activated complex. This energy is $Y + X$



- 1.4. The stress is a decrease in pressure
The system counteracts this by increasing pressure
By shifting to the side with more moles of gas
We know the change favoured the forward reaction
Therefore the forward reaction creates **more moles of gas**

The second stress is an increase in temperature

The system counteracts this by decreasing the temperature

By favouring the endothermic reaction

We know that the forward reaction was favoured

Therefore the forward reaction **must be endothermic**

Reaction	Moles of gas in reactants	Moles of gas in products	Fwd rxn
$\text{H}_2(\text{g}) + \text{I}_2(\text{g}) \rightleftharpoons 2\text{HI}(\text{g})$	2	2	Endo
$4\text{NH}_3(\text{g}) + 5\text{O}_2(\text{g}) \rightleftharpoons 4\text{NO}(\text{g}) + 6\text{H}_2\text{O}(\text{g})$	9	10	Exo
$\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g})$	4	2	Exo
$\text{N}_2\text{O}_4(\text{g}) \rightleftharpoons 2\text{NO}_2(\text{g})$	1	2	Endo

1.5. For this reaction

$$k_c = \frac{[\text{XY}]^2}{[\text{Y}]^1[\text{X}]^1}$$

$$k_c = \frac{(0,6)^2}{(0,2)(0,2)}$$

$$K_c = 9$$

1.6. Factual content from theory

1.7. To determine bond polarities we must consider electronegativities.
 C (2,5) is more electronegative than H (2,1) bond polarity NOT correct
 C (2,5) is less electronegative than Br (2,8) bond polarity correct
 C (2,5) is less electronegative than O (3,5) bond polarity correct
 C (2,5) is less electronegative than O (3,5) bond polarity correct

Note, the bond polarity depends on which two atoms are bonding

It does not depend on which other atoms are in the molecule

It does not depend on if there is a single, double or triple bond

1.8. The correct structure has two chlorines attached to a middle carbon and one chlorine attached to an end carbon.

1.9. Factual content from theory

1.10. Factual content from theory

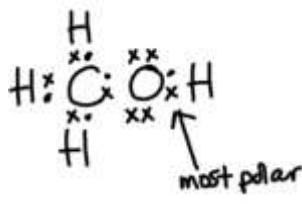
QUESTION 1

- 1.1 C
- 1.2 B
- 1.3 A
- 1.4 D
- 1.5 B

- 1.6 D
- 1.7 A
- 1.8 A
- 1.9 C
- 1.10 B

[20]

QUESTION 2

- 2.1.1 a) Silicon dioxide (1)
b) Magnesium oxide (1)
- 2.1.2 A transfer of electrons and subsequent electrostatic attraction✓✓ (2)
- 2.1.3 Compound A: giant covalent lattice✓ with polar covalent bonding between all particles ✓
and Compound B: metal + non-metal therefore ionic bonding. ✓ (3)
- 2.1.4 Compound A does not conduct no free ions or electrons✓
Compound B When molten✓ (dissolved in water -1 MgO insoluble); ions are free to move ✓ (3)
- 2.2.1 metallic bonding✓ (1)
- 2.2.2 any metal✓ (1)
- 2.3.1 A measure of the tendency of an atom to attract a bonding pair of electrons✓✓ (2)
- 2.3.2
- 
- (2)
- 2.3.3 (a) tetrahedral✓ (b) bent/angular✓ (2)
- 2.3.4 The O-H bond (1)

[19]**QUESTION 3**

- 3.1 Reaction rate as the change in concentration per unit time of either a reactant or product. ✓✓ (2)
- 3.2.1 effect of concentration✓ (1)
- 3.2.2 effect of surface area✓ (1)
- 3.3 moles Mg = m/M
= $0.06/24,3$
= 0.0025 mol ✓
- moles HCl = $c \times V$
= 1×0.05
= 0.05 mol ✓

0.0025mol Mg requires 0.005 mol HCl✓

∴ HCl is in excess✓ and Mg is LR

0.0025 mol Mg produces 0.0025mol H₂ (1:1)✓

Volume H₂ = nV_m

$$= 0.0025 \times 22,4$$

$$= 0.06 \text{ dm}^3 \checkmark$$

$$= 60 \text{ cm}^3$$

(6)

3.4 rate of the reaction✓

(1)

3.5 Concentration of HCl or Surface area of Magnesium✓

As the surface area decreases there will be fewer effective collisions✓ in the same time period✓

Lower rate therefore less steep gradient. ✓

(4)

3.6 H₂(g) is escaping✓

(1)

3.7 m = nM

$$= 0.0025 \times 2 \checkmark$$

$$= 0.005 \text{ g H}_2 \checkmark$$

(2)

3.8 Measuring volume is better✓ because mass loss is too small and thus difficult to measure.✓

(2)

[20]

QUESTION 4

4.1 When the forward reaction continues to proceed at an equal rate to the reverse reaction✓ ✓

(2)

4.2 t₂ – t₃ ✓ OR t₄ – t₅ OR t₆ – t₇ OR t₀ – t₁

(1)

4.3.1 Change: Conc of N₂ was increased / more N₂ added ✓. (no coe within question)

Response: Forward reaction favoured ✓

Reason: to use up N₂ ∴ [N₂] and [H₂] decreases and [NH₃] increases ✓.

(3)

OR

The stress is an increase in [N₂]

The system counteracts this by decreasing [N₂]

By favoring the reaction which uses N₂

The forward reaction is then favored

Which causes [N₂] and [H₂] to decrease and [NH₃] to increase

(3)

4.3.2 Change: Increase in temp ✓. (no coe within question)

Response: Reverse reaction has been favoured ✓ OR (endothermic)

Reason: to remove heat from the system, and [NH₃] decreased, and more N₂ and H₂ are formed ✓.

OR

The stress is an increase in temperature

The system counteracts this by decreasing the temperature

The system favors the endothermic reaction

The system favors the reverse reaction

Answer: This causes [N₂] and [H₂] to increase and [NH₃] to decrease

(3)

4.4.1 Increase in pressure ✓ (decrease volume) (1)

4.4.2 Change: Increase in pressure (no coe)

Response : forward reaction is favoured ✓

Reason: favours the reaction which leads to fewer ✓ moles of gas, leading to more NH_3 being formed ✓ or less N_2 and H_2

OR

The stress is an increase in pressure

The system counteracts this by decreasing the pressure

The system favors the reaction which produces fewer moles of gas

The forward reaction is favored

Answer: This causes $[\text{N}_2]$ and $[\text{H}_2]$ to decrease and $[\text{NH}_3]$ to increase (3)

4.5.1 $K_c = \frac{[\text{NH}_3]^2}{[\text{N}_2][\text{H}_2]^3}$ ✓✓ (2)

4.5.2 Before we can calculate k_c we need to find the concentrations

For hydrogen	For nitrogen	For ammonia
$C_{\text{H}_2} = \frac{n}{v}$ $= \frac{1,28}{2}$ $= 0,64 \text{ mol. dm}^{-3} \checkmark$	$n_{\text{H}_2} = \frac{49,6}{28}$ $= 1,77 \text{ mol} \checkmark$ $C_{\text{N}_2} = \frac{n}{v}$ $= \frac{1,77}{2}$ $= 0,89 \text{ mol. dm}^{-3} \checkmark$	$n_{\text{NH}_3} = \frac{V}{V_0}$ $= \frac{12,31}{22,4}$ $= 0,55 \text{ mol} \checkmark$ $C_{\text{NH}_3} = \frac{n}{v}$ $= \frac{0,55}{2}$ $= 0,28 \text{ mol. dm}^{-3} \checkmark$

$K_c = \frac{(0,28)^2}{0,89 \cdot (0,64)^3} = 0,34$ ✓✓ accept 0,33 (7)

4.5.3 a) stay the same ✓

b) increase ✓

c) stay the same ✓

(3)

[25]

QUESTION 5

5.1. Fuel ✓ (1)

5.2. 1,2-dichlorobut-1-ene ✓✓ (2)

5.3. Homologous series is a series of similar compounds which have the same functional group and the same general formula, in which each member differs from the previous by a single CH_2 unit. (2)

5.4. Ester ✓ (1)

5.5. Propyl✓ pentanoate ✓ (2)

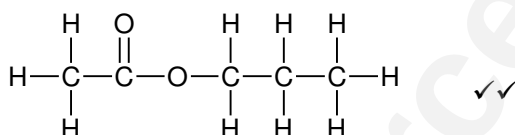
5.6.

- Pentanoic acid (C) and propanol (D) both exhibit hydrogen bonding ✓
- pentanoic acid is also longer than propanol ✓
- thus resulting in more surface interactions and stronger London forces ✓
- Thus, the intermolecular forces between pentanoic acid molecules are stronger ✓
- More energy is therefore needed to overcome imf's between pentanoic acid molecules ✓
- Resulting in a higher boiling point for pentanoic acid (5)

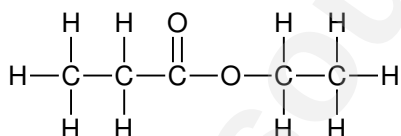
5.7. Yes ✓ C-Cl bond is polar and molecule dipole and water is polar and molecule is a dipole✓
and therefore like dissolves like. ✓
(Accept Hydrogen bonds too strong to overcome and therefore only slightly soluble) (3)

5.8. Compound with the same molecular formula (i.e. composition of atoms) but different structural formula (i.e. structure). ✓✓ (2)

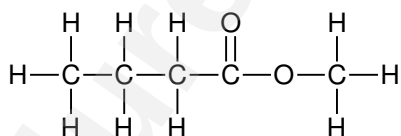
5.9



OR



OR



(2)

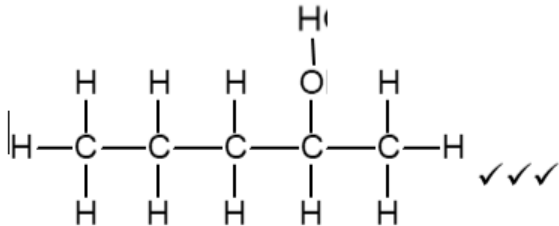
[20]

QUESTION 6

6.1. A – Combustion ✓
C – Addition ✓
F – Substitution ✓ (3)

6.2. B – Esterification ✓
D – Hydration ✓
F – Hydrolysis ✓ (3)

6.3. 2-bromo-2-methylpropane ✓✓ (-1 for each mistake) (2)

- 6.4.  ✓✓✓ (-1 for each mistake) (3)
- 6.5. Hexan-3-ol ✓✓
Sodium chloride ✓ (3)
- 6.6. Cracking ✓ (1)
- 6.7. - Many long-chain hydrocarbons extracted from crude oil are not very valuable ✓
- Cracking breaks down these long-chain hydrocarbons into smaller chain hydrocarbons ✓
- which can be used in petrol, etc. and so are much more valuable ✓ (3)
- 6.8.1 - Hydrogenation results in the hydrocarbon becoming more saturated ✓
- more London forces between the molecules and therefore overall intermolecular strength greater ✓
- resulting in a higher melting point ✓ (3)
- 6.8.2 Alkanes ✓ (1)
- 6.9.1 Ethanoic acid ✓ (1)
- 6.9.2 H_2SO_4 ✓ it acts as an acid catalyst ✓ OR dehydrating agent. (2)
- 6.10
- The reactant is placed into a test tube
 - Bromine water is added to the test tube ✓
 - The mixture is agitated and placed in an area away from sunlight ✓
 - If the bromine water decolourises, then the reactant is unsaturated ✓
 - If the bromine water doesn't decolourise, then it is saturated ✓
- (4)

[29]

QUESTION 7

- 7.1 chemical to electrical ✓ (1)
- 7.2 No ✓, temp is 20°C ✓ not 25°C (2)
- 7.3 $m = c \times V \times M_r$
 $= 1 \times 0.25 \times 400$ ✓
 $= 100 \text{ g Fe}_2(\text{SO}_4)_3$ ✓ (3)
- 7.4 $\text{Fe}^{3+} + 3\text{e}^- \rightarrow \text{Fe}$ ✓✓ (2)
- 7.5 The Al electrode erodes or loses mass ✓✓ (2)
- 7.6 Sulphate anions move through the salt bridge ✓ into the anode solution because there is an excess of positive charge there ✓ due to the oxidation of Aluminium. (2)

$$\begin{aligned}
 7.7 \quad E^\circ_{\text{cell}} &= E^\circ_{\text{c}} - E^\circ_{\text{a}} \\
 &= -0.04 - (-1.66) \checkmark \\
 &= 1.62 \text{ V} \checkmark
 \end{aligned}
 \tag{3}$$

$$\begin{aligned}
 7.8 \quad \text{Mass Fe gained} &= 36.85 - 36.1 \\
 &= 0.75 \text{ g} \checkmark
 \end{aligned}$$

$$\begin{aligned}
 \therefore n(\text{Fe}) &= m/M \\
 &= 0.75 / 56 \\
 &= 0.0134 \text{ mol} \checkmark
 \end{aligned}$$

$$\begin{aligned}
 n(e^-) &= 0.0134 \times 3 & (\text{ratio iron to electrons 1:3}) \quad \text{Fe}^{3+} + 3e^- \rightarrow \text{Fe} \\
 &= 0.04 \text{ mol } e^- \checkmark
 \end{aligned}$$

$$\begin{aligned}
 Q &= n_{\text{electrons}} F \\
 &= 0.04 \times 96500 \\
 &= 3877.2 \text{ C} \checkmark
 \end{aligned}$$

$$\begin{aligned}
 I &= Q/t \\
 &= 3877.2 / (60 \times 60) \checkmark \\
 &= 1.08 \text{ A} \checkmark
 \end{aligned}$$

(6)

7.9.1 Use electrodes with larger surface area ✓ (1)

7.9.2 Use a shorter, wider salt bridge ✓ (1)

[23]**QUESTION 8**

8.1 cathode ✓; $\text{Cu}^{2+} + 2e^- \rightarrow \text{Cu}$ ✓ (2)

8.1.2 a) Au is weaker RA than Cu ✓
so does not get oxidised ✓ – falls to the bottom as the electrode breaks up ✓ (3)

b) Ni is stronger RA than Cu so gets oxidised to Ni^{2+} . ✓
 Cu^{2+} is stronger OA than Ni^{2+} ✓ so gets
reduced preferentially ✓ (3)

8.2.1 brine ✓ (1)

8.2.2 chlorine gas or Cl_2 ✓ (1)

8.2.3 $2\text{Na(Hg)} + 2\text{H}_2\text{O} \rightarrow 2\text{NaOH} + \text{H}_2 + 2\text{Hg}$ ✓✓ (-1 for each mistake) (accept without Hg) (2)

8.2.4 NaOH not contaminated with NaCl ✓ (1)

8.2.5 Hg gets into environment – it is a toxic heavy metal ✓ (1)

8.2.6 membrane cell ✓ (1)

[15]

QUESTION 9

9.1.1 Weak acid – an acid that only partially ionises in an aqueous solution✓✓ (2)

9.1.2 Standard solution is a solution of known concentration.✓✓ (2)

9.2 Change : The OH^- reacts with the H_3O^+ and lowers its concentration.✓

Response: forward is favoured.✓

Reason: The reaction which makes more H_3O^+ ✓ Thus more of the orange X^- is formed.✓ (4)

OR

Stress is a decrease in $[\text{H}_3\text{O}^+]$ (this is because the OH^- reacts with H_3O^+)

Note: you have to link the stress directly to a reactant or product in the equilibrium reaction

The system counteracts this by increasing $[\text{H}_3\text{O}^+]$

The system does this by making more $[\text{H}_3\text{O}^+]$

Therefore the forward reaction is favoured

Answer: the colour changes to orange

9.3.1 Mn^{7+} ✓ or MnO_4^- (1)

9.3.2 purple to colourless✓ (1)

9.4.1 16.72 cm^3 ✓ (range 16.7 to 16.75) (1)

9.4.2 $n(\text{oxalic acid}) = c \times V$
 $= 0.0434 \times 0.0250$ ✓
 $= 0.00109 \text{ mol}$

Or use titration formula

$n(\text{MnO}_4^-) = 0.00109 / 5 \times 2$ (mol ratio 5:2)
 $= 0.000436$ ✓

$C(\text{MnO}_4^-) = n / V$
 $= 0.000436 / 0.01672$
 $= 0.0260 \text{ mol.dm}^{-3}$ ✓ 3 sf✓ coe (4)

[15]

QUESTION 10

10.1.1 Weak✓ – low K_b values ✓ or only ionise partially double arrow (2)

10.1.2 III✓ : weakest base ✓ $\therefore$ has lowest $[\text{OH}^-]$ ✓

$\therefore$ has highest $[\text{H}_3\text{O}^+]$ $\therefore$ has lowest pH or lowest K_b value (3)

10.2.1 Amphoteric is a substance that can act as acid or base✓ (2)

10.2.2 $\text{H}_2\text{O} + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{OH}^-$ ✓✓ ($\rightarrow$ - 1 mark) (2)

10.2.3 neutral means $[\text{OH}^-] = [\text{H}_3\text{O}^+]$ ✓

$$= \sqrt{1 \times 10^{-14}}$$

$$= 1 \times 10^{-7} \text{ mol.dm}^{-3}$$
✓ (2)

$$10.2.4 \quad [\text{H}_3\text{O}^+] = 1 \times 10^{-14} / 3.2 \times 10^{-10} \\ = 3.1 \times 10^{-5} \text{ mol.dm}^{-3} \checkmark$$

$$3.1 \times 10^{-5} \text{ mol.dm}^{-3} \checkmark > 1 \times 10^{-7} \checkmark \\ \therefore \text{acidic} \checkmark$$

Or explain qualitatively $[\text{H}_3\text{O}^+] > [\text{OH}^-]$

(3)

[14]