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GRADE 12
Physical Science: Paper 2 (Chemistry)
2021

Time: 3 hours
Examiner: K van Schoor

Marks: 200
Moderator: K McNeil

PLEASE READ THE FOLLOWING INSTRUCTIONS CAREFULLY:

1. This paper consists of 16 pages, make sure that your paper is complete.
2. Answer ALL the questions in the answer book and answer sheet provided.
3. Question 1 consists of 10 multiple-choice questions. Answer these on the inside cover of your answer book.
4. Read the questions carefully.
5. START EACH QUESTION ON A NEW PAGE.
6. Use the data and formulae provided whenever necessary.
7. Show all the necessary steps in calculations.
8. Units need not be included in the working of calculations, but you must show appropriate units in the answer.
9. Unless instructed otherwise, you do NOT have to give the state symbols when asked to write a balanced chemical equation.
10. Where appropriate, express answers as decimal places and not as fractions. The use of scientific notation is encouraged.
11. It is in your own interest to write legibly and to present your work neatly.

Acknowledgements – some questions and pictures were adapted from the following sources:
IEB 2021/2020/2016, IEBT 2017, CIE, Alpha 2002, SJC 2021, BC grade 11 2021.

Question 1: Multiple Choice Questions**[20]**

Answer these questions on the multiple-choice grid in the front flap of your answer book. Place a cross over the correct letter on the grid.

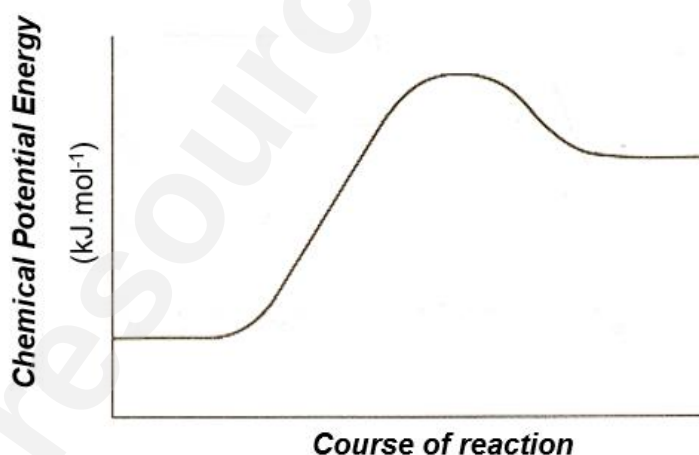
1.1. Identify the bonding in pure iron hydroxide.

- A Hydrogen bonding
 - B Ionic bonding
 - C Covalent bonding
 - D Metallic bonding
- (2)

1.2. Which one of the following contains covalent bonds that are the most polar?

- A HF
 - B CH₄
 - C SO₂
 - D Si₂
- (2)

1.3. The following diagram shows the energy profile as a chemical reaction proceeds.



Which one of the following combinations are correct?

	Type of reaction	Substance with the strongest bonds
A	Exothermic	Products
B	Exothermic	Reactants
C	Endothermic	Products
D	Endothermic	Reactants

(2)

- 1.4. 2 moles of PCl_5 gas are heated in a closed container. 50% of the PCl_5 gas decomposes to set up the equilibrium represented by the balanced chemical equation below.



How many moles of gas are present in the container at equilibrium?

- A 1
- B 2
- C 3
- D 4

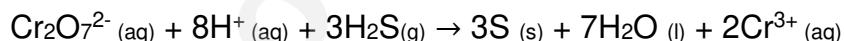
(2)

- 1.5. A titration between **DOH** and **HZ** produces the salt **DZ** as one of the products. The K_b value for **DOH** is $1,8 \times 10^{-5}$ at 25°C and the K_a value for **HZ** is $2,4 \times 10^{-1}$ at 25°C . What is the approximate pH of the solution at the endpoint of the titration?

- A 13
- B 7
- C 5
- D 1

(2)

- 1.6. When potassium dichromate reacts with hydrogen sulphide in the presence of an acid, the solution changes from orange to cloudy green in colour. This indicates that a redox reaction has taken place. The balanced ionic chemical equation for the reaction is:



The oxidising and reducing agents in the forward reaction are:

	Oxidising agent	Reducing agent
A	$\text{Cr}_2\text{O}_7^{2-}$	H_2S
B	H_2S	$\text{Cr}_2\text{O}_7^{2-}$
C	2Cr^{3+}	H_2S
D	$\text{Cr}_2\text{O}_7^{2-}$	H^+

(2)

- 1.7. Which one of the following reactions is not a **redox** reaction?

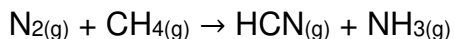
- A Zinc reacts with dilute hydrochloric acid.
- B Magnesium ribbon burns in a jar of chlorine.
- C A zinc spoon erodes when left in a solution of copper sulphate.
- D Concentrated hydrochloric acid is added to a saturated solution of sodium chloride.

(2)

- 1.8. The emf in a galvanic cell can be increased by:
- A Using electrodes with larger surface areas.
 - B Changing the concentration of the ions in the cells.
 - C Replace the salt bridge with a shorter, wider one.
 - D Using a better conducting wire to connect the anode and the cathode.
- (2)
- 1.9. Which one of the following organic compounds is an unsaturated hydrocarbon?
- A C_3H_8
 - B C_4H_8
 - C CH_3COOH
 - D CH_4
- (2)
- 1.10. Which one of the following organic compounds is a functional isomer of hexanoic acid?
- A methyl hexanoate
 - B 2,2-dimethylbutan-1-ol
 - C 1-hexanol
 - D methyl pentanoate
- (2)

Question 2:**[16]**

Chemicals found by the Cassini Huygens probe on Titan, a moon of Saturn, suggested the following basic chemical reaction is taking place:



- 2.1. Define an *intramolecular bond*. (2)
- 2.2. Name the specific type of intramolecular bonding in methane. (2)
- 2.3. Define *intermolecular force*. (2)
- 2.4. Nitrogen gas and methane gas have the same type of intermolecular forces.
 - 2.4.1. Name and explain the origin of the intermolecular forces present in nitrogen and methane gas. (4)
 - 2.4.2. State which one will have the highest boiling point? (1)
- 2.5. As the two products, hydrogen cyanide and ammonia, reach the surface of Titan, they condense.
 - 2.5.1. Which one of the products will become a liquid first? (1)
 - 2.5.2. Provide a detailed explanation for your answer in 2.5.1. (4)

Question 3:**[32]**

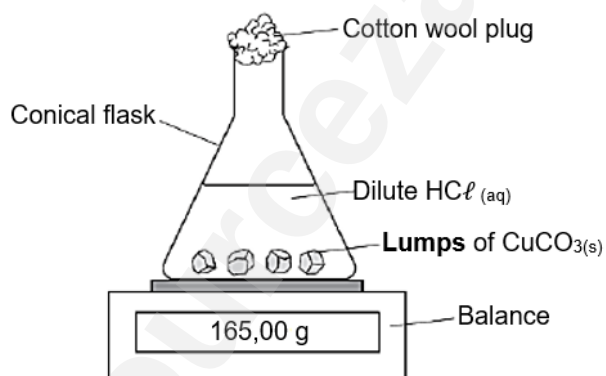
2 g of impure copper (II) carbonate reacts with an excess of hydrochloric acid. The balanced chemical equation for the reaction that takes place is:



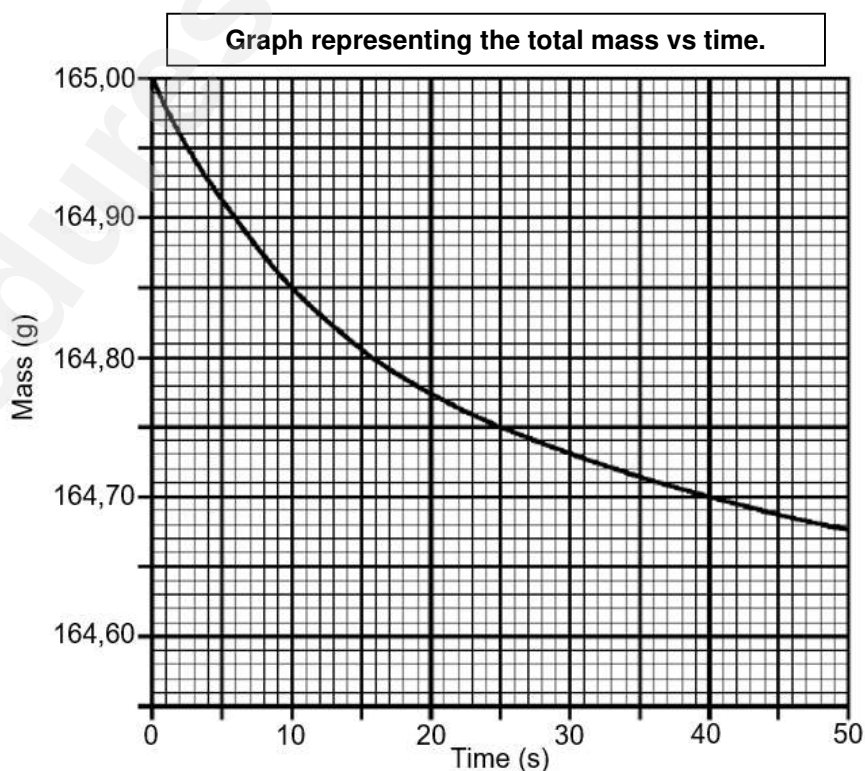
160 cm³ of carbon dioxide gas was collected at STP.

- 3.1. Define *molar mass*. (2)
- 3.2. Determine the amount (in moles) of CO₂ that was produced. (3)
- 3.3. Determine the percentage purity of the copper (II) carbonate. (5)

To determine the rate of the reaction, Karli used the apparatus shown below:



The graph below shows her results for the first 50 seconds.



3.4. Kiara suggests to Karli that the reaction has gone to completion after 50 s.

3.4.1. Define the *rate of the reaction*. (2)

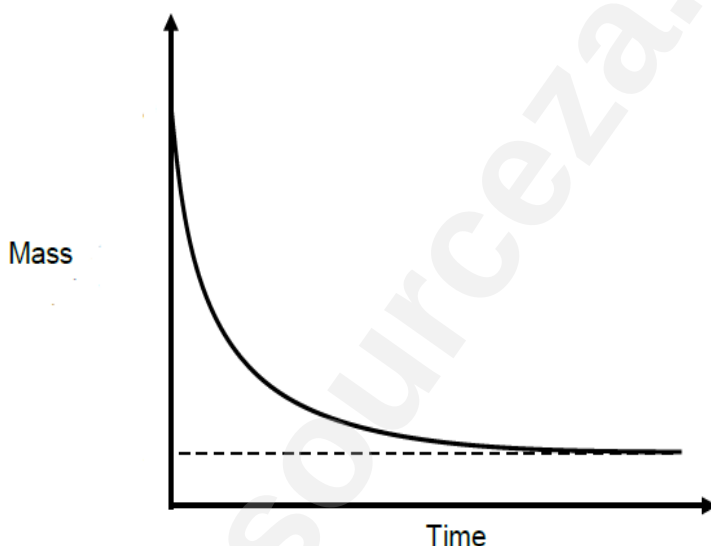
3.4.2. Is Kiara correct? (1)

3.4.3. Refer to the graph to explain your answer for 3.4.2. (2)

3.4.4. Calculate the average rate of the reaction in g.s^{-1} :
 a) During the first 10 s
 b) Between 20 s and 40 s. (4)

3.4.5. Explain the difference in your answers between (a) and (b) above. (4)

A sketch graph for the reaction is shown below as well as on your answer sheet.



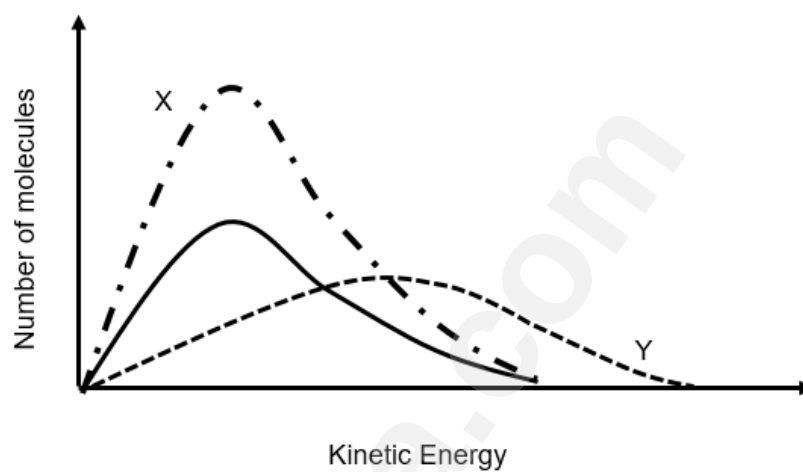
3.5. On the copy of this sketch graph on your answer sheet, draw two more curves for the following reaction conditions. Label the lines clearly as **A** and **B**.

A: 2 g of powdered copper (II) carbonate is used. (2)

B: The concentration of the acid was halved. (2)

3.6. Use the collision theory to explain how the change in scenario **A** affected the rate of this reaction. (3)

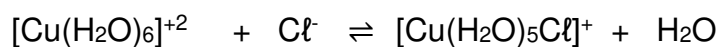
- 3.7. The Maxwell-Boltzmann distribution for the original reaction done by Karli is shown below using the solid line.



Which of the other two lines indicates the same reaction, taking place at a higher temperature. Write only X or Y. (2)

Question 4:**[31]**

4.1. Consider the following equilibrium reaction for ions dissolved in ethanol.



(light blue)

(green)

The equilibrium mixture is initially blue-green.

4.1.1. The container is not sealed. Why can this system still be considered a *closed system*? (2)

4.1.2. Hydrochloric acid is added to the mixture.

a) What colour change will be observed in the container after some time? (1)

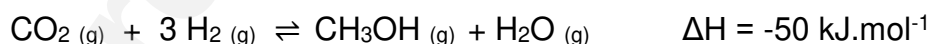
b) Explain this observation with reference to the **rate** of the **forward reaction only**. (2)

4.1.3. Sulphuric acid, known for its dehydrating properties, is added to the equilibrium mixture.

a) State *Le Chatelier's Principle*. (2)

b) Use Le Chatelier's Principle to explain why the solution turns more green when the sulphuric acid is added. (3)

4.2. A step in the manufacturing of methanol is the reaction between carbon dioxide and hydrogen.



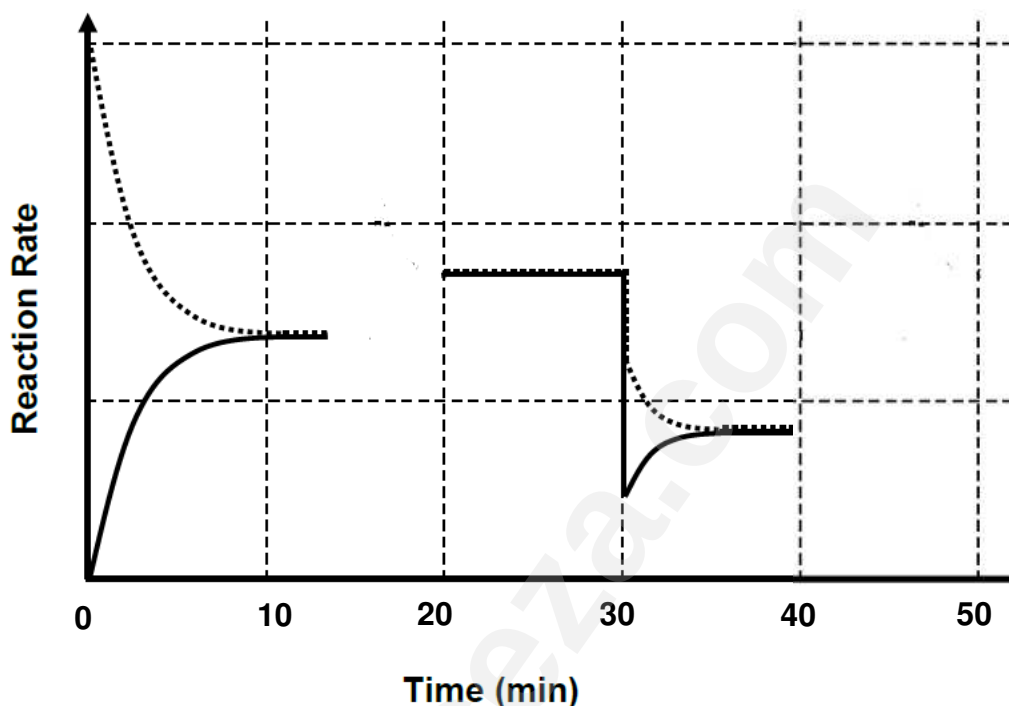
To investigate this reaction, Wayne heated 4,4 mol of carbon dioxide gas and 6,5 mol of hydrogen gas in a 750 ml container. When equilibrium is reached at 400 °C, there was 2,1 mol of water vapour present.

4.2.1. How does the negative value of ΔH prove that the forward reaction is *exothermic*? (2)

4.2.2. Write an expression for the equilibrium constant for this reaction. (2)

4.2.3. Determine the value of the equilibrium constant for this reaction at 400 °C. (5)

- 4.3. Wayne monitored the rate of the forward and the reverse reactions and obtained the following graph:



- 4.3.1. How did Wayne know that the equilibrium was reached after 10 minutes? (2)
- 4.3.2. Just after 10 minutes the pressure of the container was increased. Wayne accidentally erased the part of the graph showing the effect of this change.
- What effect will the increase in pressure have on the amount of water vapour in the sealed container once the equilibrium is re-established? (1)
 - On the copy of this graph on your answer sheet, complete the part of the graph that Wayne erased between 10 and 20 minutes. (2)
- 4.3.3. At 30 minutes, a change was made to the temperature.
- From the graph, determine and write down which reaction (forward or reverse) was initially favoured after the change in temperature. (1)
 - Why does this process in the industry take place at high temperatures? (2)
- 4.3.4. At 40 minutes a catalyst was added to the reaction.
- Define a *catalyst*. (2)
 - On the copy of the graph on your answer sheet, complete the rate vs time sketch graph to show the effect of the addition of the catalyst. (2)

Question 5:**[28]**

5.1. Carla makes 60 cm³ of a 0,19 mol.dm⁻³ standard solution of lithium hydroxide. She uses all of this solution in a titration against 25 cm³ of a solution of sulphuric acid

5.1.1. Define *standard solution*. (1)

5.1.2. Calculate the mass of lithium hydroxide needed to make the standard solution. (4)

5.1.3. Write the dissociation reaction for the lithium hydroxide in water. Include phase symbols. (3)

5.1.4. Write a balanced equation for the reaction of lithium hydroxide and sulphuric acid. (3)

5.1.5. Name of the conjugate acid of lithium hydroxide. (2)

5.1.6. Calculate the concentration of the sulphuric acid. (4)

5.2. Consider the salt sodium ethanoate.

5.2.1. Write the chemical formulae of the acid and base that could react to produce this salt. (2)

5.2.2. Would the acid or the base be a better conductor of electricity, assuming the same concentration? (1)

5.2.3. Explain your answer in 5.2.2. (3)

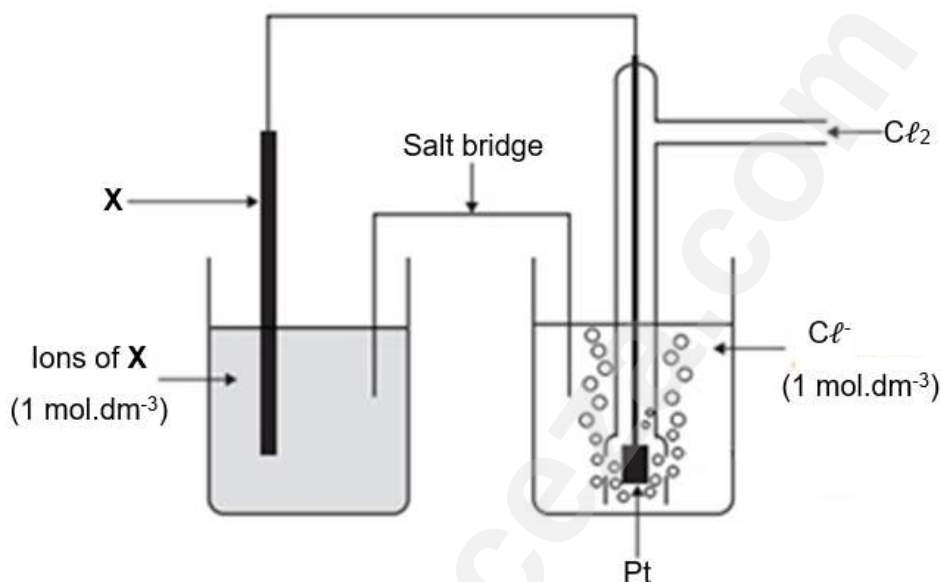
5.2.4. Define *hydrolysis of a salt*. (2)

5.2.5. Use a hydrolysis equation to show that this sodium ethanoate could be considered a **basic** salt. (3)

Question 6:

[18]

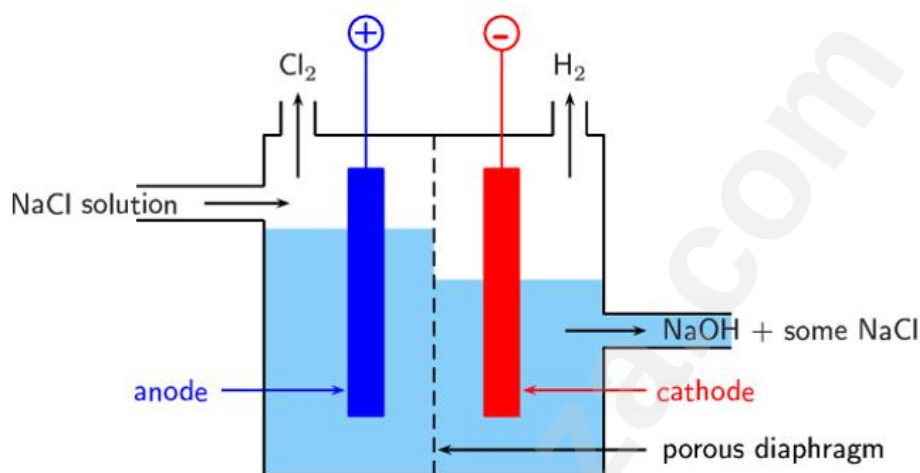
The galvanic cell shown below was set up using Cl_2/Cl^- cathode half-cell and a half-cell made from an unknown metal **X** electrode and a solution of the same metal ions.



- 6.1. Define a *redox reaction*. (2)
- 6.2. State one reason for the choice of platinum as the cathode. (2)
- 6.3. A charge of 9409 C of electricity was passed through the wire.
0,0325 mol of metal **X** was lost from the electrode made of metal **X**.
 - 6.3.1. Calculate the number of moles of electrons that were transferred between the electrodes. (3)
 - 6.3.2. Use your answer in 6.3.1. to determine the charge on the ions of metal **X**. (3)
 - 6.3.3. Write the cell notation for this cell including phase indicators. (4)
- 6.4. Pulkit wants to use a standard hydrogen electrode to determine the standard electrode potential of the half-cell containing metal **X** and its ions. Describe the standard hydrogen electrode and briefly explain its role as the reference electrode. (4)

Question 7:**[16]**

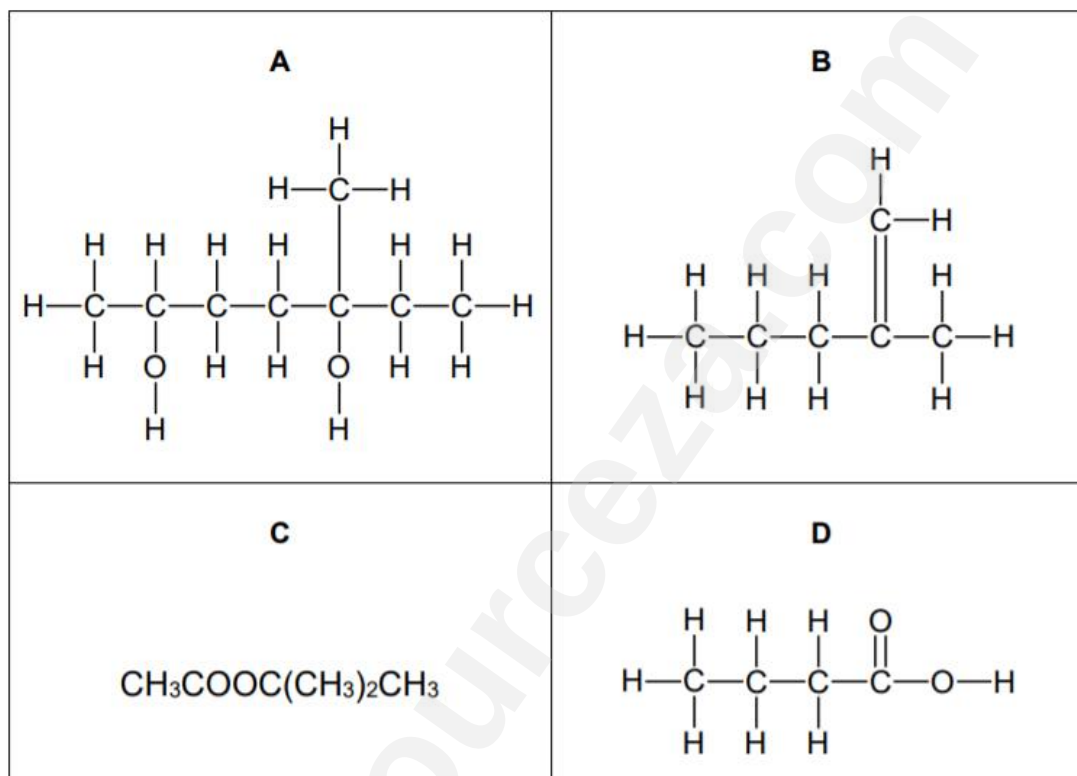
The diagram below is a simplified illustration of the industrial production of chlorine by means of a diaphragm cell.



- 7.1. State the energy conversion taking place in this cell. (2)
- 7.2. Explain why alternating current cannot be used during this process. (2)
- 7.3. Write the equation for the oxidation half-reaction. (2)
- 7.4. With reference to the redox table, explain why sodium ions do not get reduced at the cathode. (3)
- 7.5. Write the net ionic equation for this cell. (3)
- 7.6. Give the chemical symbol for the reducing agent. (1)
- 7.7. Due to the toxic material the diaphragm is made of, this cell is being phased out.
 - 7.7.1. Name the material that the diaphragm is made of. (1)
 - 7.7.2. Give the name of a better alternative cell which could be used? (1)
 - 7.7.3. Give one **other** (besides being non-toxic) advantage of the cell mentioned in 7.7.2. (1)

Question 8:**[18]**

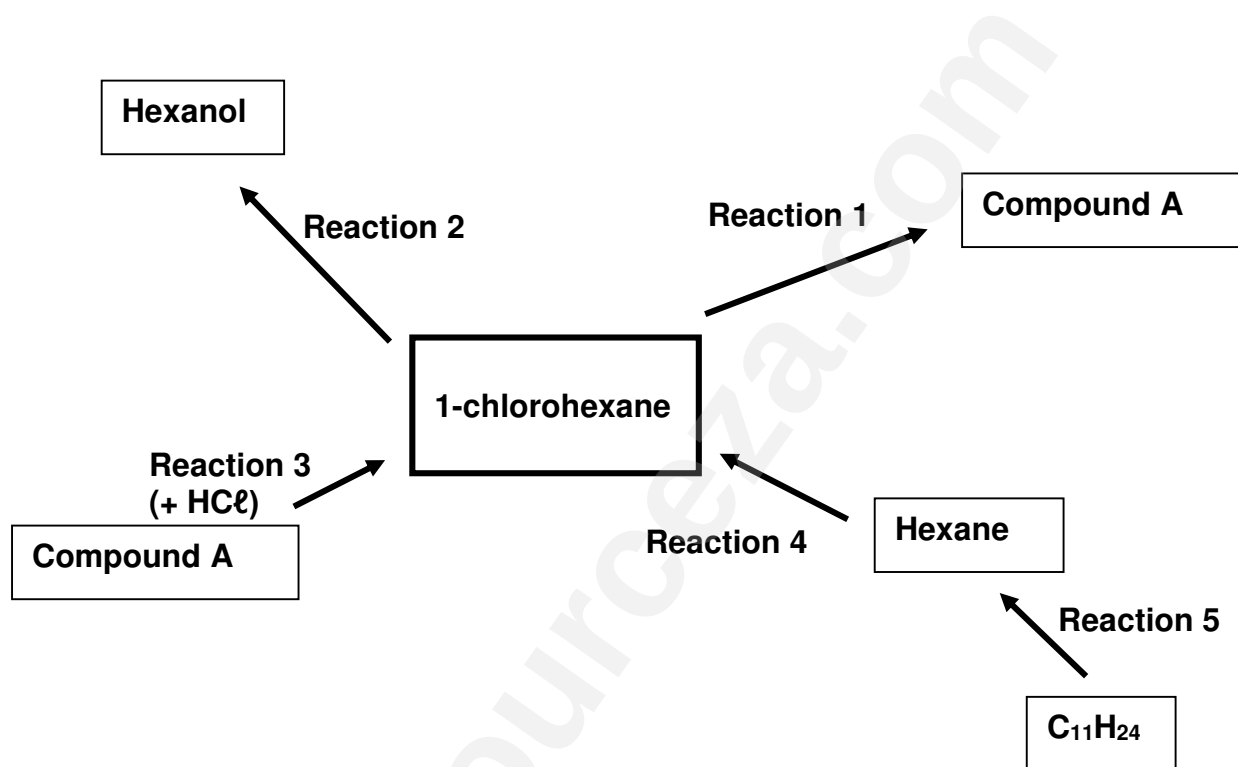
Consider the organic compounds A to D shown below



- 8.1. Write down the IUPAC name of compounds **A** and **B**. (5)
- 8.2. Draw the structural formula of compound **C**. (2)
- 8.3. Define a *homologous series*. (2)
- 8.4. Name the homologous series that compound **D** belongs to. (1)
- 8.5. Give the condensed structural formula for a positional isomer of compound **B**. (2)
- 8.6. A structural isomer of compound **C** would be pentanoic acid.
 - 8.6.1. What type of structural isomer would this be? (2)
 - 8.6.2. Which of the two isomers will have the highest boiling point? (1)
 - 8.6.3. Explain your answer in 8.6.2 by referring to the intermolecular forces present in these substances. (3)

Question 9:**[21]**

The diagram below shows a range of chemical reactions centered around 1-chlorohexane.



9.1. **Reaction 1** takes place in an alcoholic solution of potassium hydroxide.

9.1.1. Give the specific name for this reaction. (1)

9.1.2. Write the balanced chemical equation using molecular formulae to represent this reaction. (3)

9.2. Give the specific name for **Reaction 2**. (1)

9.3. **Reaction 3** takes place spontaneously where **Reaction 4** needs UV light to occur.

9.3.1. Give the general name for reaction 3. (1)

9.3.2. Give the reason for the difference in the reactivity of hexane and compound **A**. (2)

9.4. Write a balanced molecular equation for the combustion of hexane. (3)

9.5. Reaction 5 represents the thermal cracking of $C_{11}H_{24}$.

9.5.1. Name the general type of reaction of which cracking is an example. (1)

9.5.2. Give the molecular formula of the other organic product besides hexane that is formed during this reaction. (2)

9.6. Hexanol can be used to produce hexyl ethanoate.

9.6.1. State the reaction conditions needed for this reaction. (2)

9.6.2. Give the specific name for this type of reaction. (1)

9.6.3. Use structural formula to show the chemical reaction for the formation of hexyl ethanoate using hexanol and another organic compound. (4)

The End