GRADE 12

PHYSICAL SCIENCES: CHEMISTRY Paper 2

TRIALS AUGUST 2008

(150 marks; 3 hours)

This question paper consists of 11 pages and an answer sheet for question 1.5

INSTRUCTIONS AND INFORMATION

1. **Answer ALL the questions on the A4 paper provided**
2. **Non-programmable calculators may be used.**
3. **Appropriate mathematical instruments may be used.**
4. **Number the answers correctly according to the numbering system used in this question paper.**

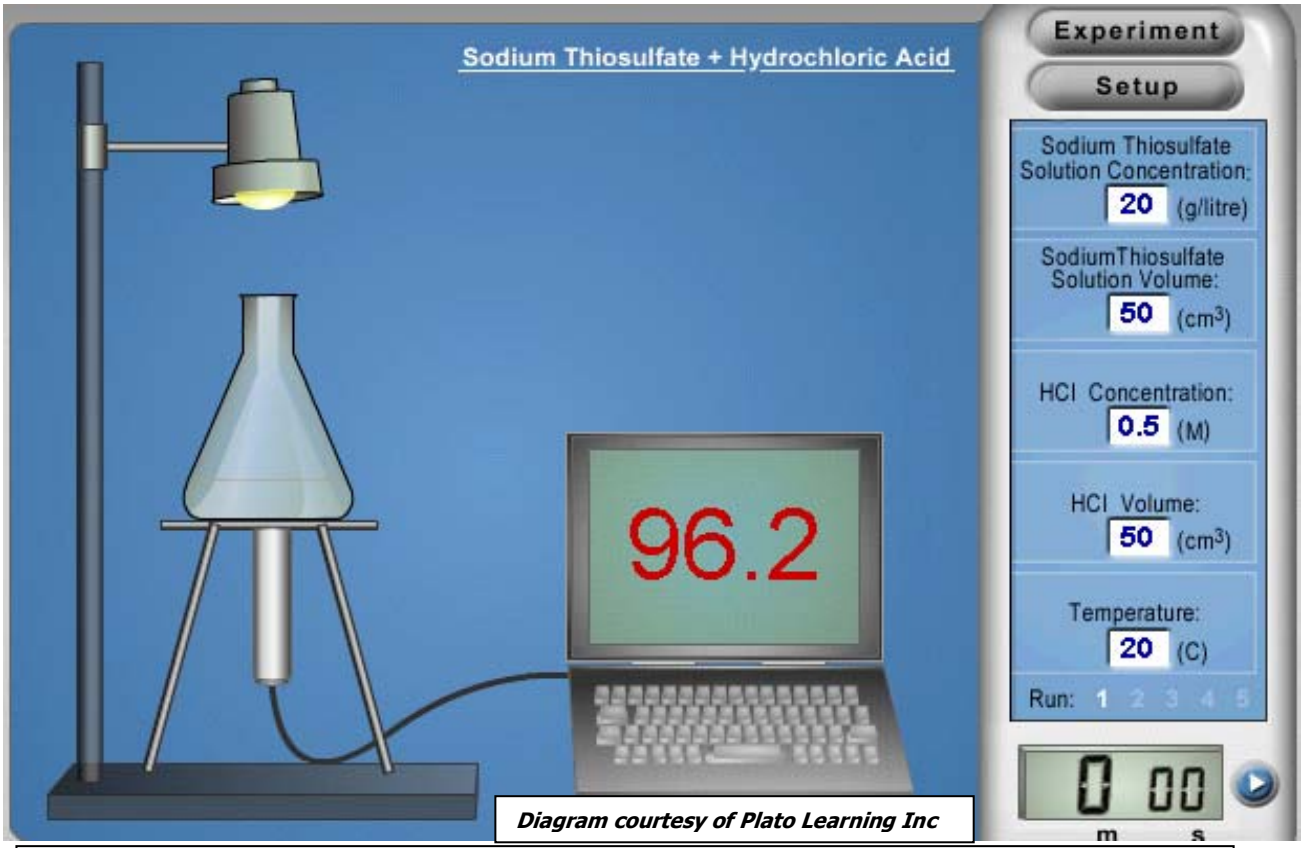
Learning outcomes and levels of difficulty

LO1 Practical Scientific Inquiry and Problem Solving Skills
LO2 Constructing and Applying Scientific Knowledge
LO3 The Nature of Science and its relationship to Technology, Society and the Environment

	LO1	LO2	LO3	Level 1	Level 2	Level 3	Level 4
TOTAL %	26	53	21	10	50	22	18
TARGET %	30	50	20	10	50	20	20

Question 1 Reaction Rate Experiment

When a precipitate (insoluble solid) forms in a reaction the solution becomes more opaque (light cannot pass through it). The reaction rate can be monitored using a light meter which detects the decrease in light intensity passing through the solution which becomes more opaque as the reaction proceeds. The apparatus shown in the diagram below was used to investigate how changing the concentration of hydrochloric acid would affect the rate of its reaction with sodium thiosulphate solution.



Reaction $Na_2S_2O_{3(aq)} + 2HCl_{(aq)} \rightarrow 2NaCl_{(aq)} + SO_{2(g)} + S_{(s)} + H_2O_{(l)}$

The reaction conditions shown in the "Experiment Setup" were kept constant and the light intensity was recorded every minute for a period of 5 minutes. The experiment was then repeated using hydrochloric acid of different concentrations. The results are recorded in the table below.

Concentration of HCl ($mol.dm^{-3}$)	Light intensity (lumens)					
	Start (Time = 0)	1 minute	2 minutes	3 minutes	4 minutes	5 minutes
0,5	96,2	88	80,9	74,1	67,7	62,1
1,0	96,2	77,2	61,6	49,8	40,2	32,2
2,0	96,2	70,9	52,5	38,6	28,5	21,2

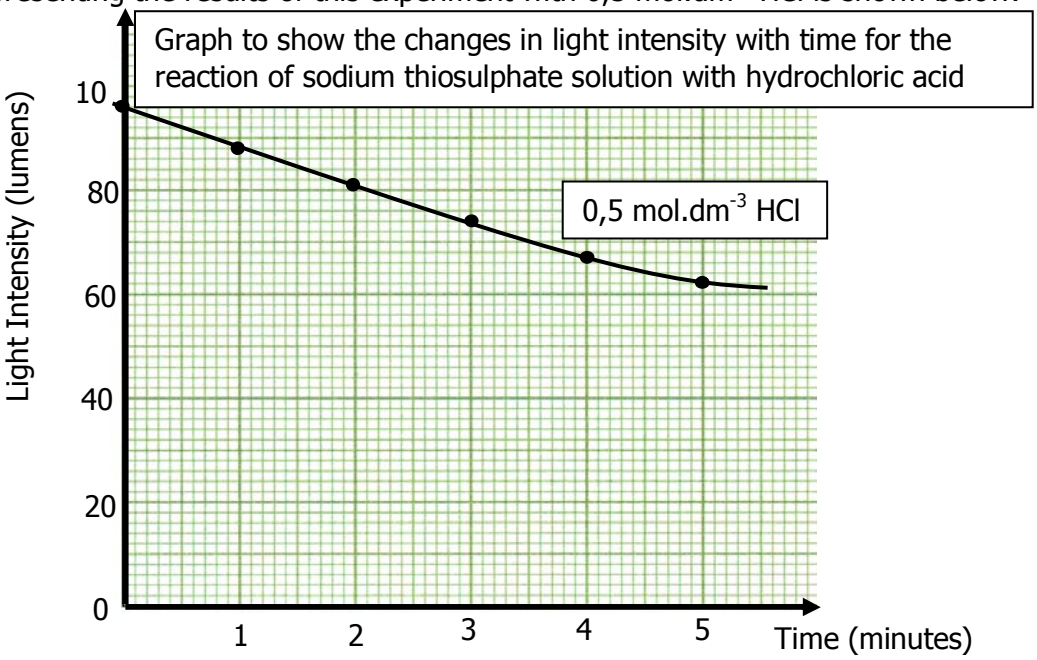
1.1 Consult the equation given for the reaction taking place in the flask and state what substance formed in this reaction is responsible for the solution becoming opaque? (1)

1.2 What is the independent variable in this investigation? (1)

1.3 What is the dependent variable in this investigation? (1)

1.4 Give two variables that were controlled (fixed) in this investigation. (2)

A graph representing the results of this experiment with 0,5 mol.dm^{-3} HCl is shown below.

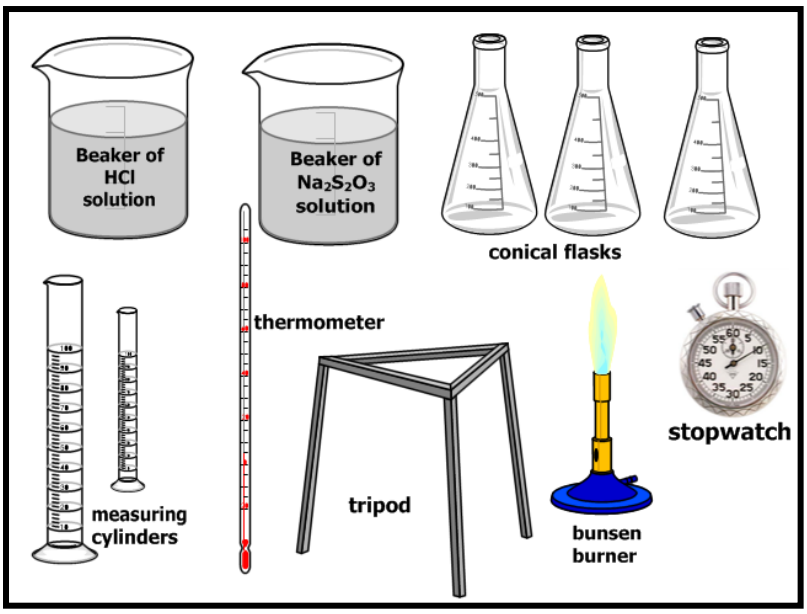


1.5 This graph is shown on your **answer sheet.** On the same axes on your **answer sheet** plot graphs to represent the reactions of 1,0 mol.dm^{-3} HCl and 2,0 mol.dm^{-3} HCl. (4)

1.6 What conclusion can you draw from this experiment regarding the effect of concentration on reaction rate? (2)

1.7 Consider what is happening to the molecules in the solution and explain your conclusion in terms of the collision theory. (2)

1.8 Your teacher sets you the task of investigating the effect of temperature on the rate of this same reaction between sodium thiosulphate and hydrochloric acid. You do NOT have a light meter available. You have access to the apparatus and chemicals: shown opposite.



1.8.1 State your investigative question. (1)

1.8.2 Give a suitable hypothesis for your investigation. (2)

1.8.3 Explain how you will carry out your investigation. Give your method in point form indicating clearly what measurements you will take. Explain how you will keep certain variables constant in order to ensure a fair test. (6)

22 marks

Question 2 Industrial Equilibrium Reactions

In the Haber Process hydrogen gas obtained from the Chlor-Alkali Process is reacted with nitrogen gas to produce ammonia (NH_3). The ammonia gas produced in this process is used as the starting material in the Ostwald Process for the industrial preparation of nitric acid (HNO_3). The steps involved in these reactions are shown below.

Process	Reaction	Conditions
Haber Process	$N_2(g) + 3H_2(g) \leftrightarrows 2NH_3(g)$ $\Delta H < 0$	450 ^oC ; 200 atmospheres ; iron catalyst
Ostwald Process	$4NH_3(g) + 5O_2(g) \leftrightarrows 4NO(g) + 6H_2O(g)$ $\Delta H < 0$ $2NO(g) + O_2(g) \leftrightarrows 2NO_2(g)$ $\Delta H < 0$ $3NO_2(g) + H_2O(l) \leftrightarrows 2HNO_3(aq) + NO(g)$	1 000 ^oC ; platinum catalyst

2.1 What type of reaction is represented by each of these steps? (1)

2.2 State Le Chatelier's Principle. (2)

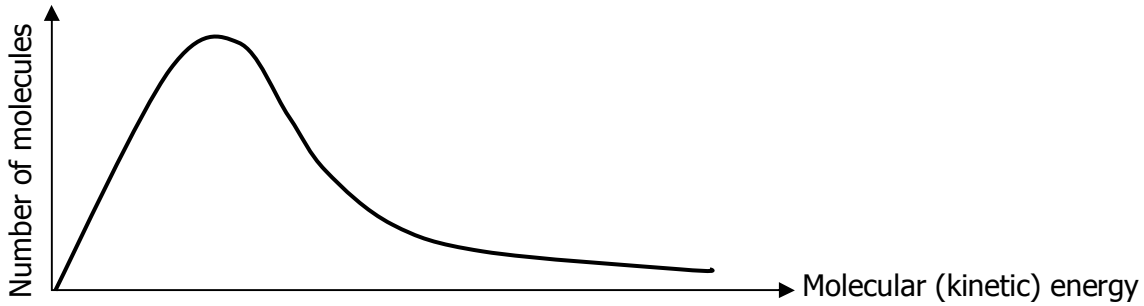
2.3 When considering the effect of each of the following changes answer only ***increase, decrease or no effect.***

2.3.1 What effect does the use of an iron catalyst have on the yield of ammonia in the Haber Process? (1)

2.3.2 What effect does increasing the temperature have on the yield of NO in the first step of the Ostwald Process? (1)

2.3.3 What effect does increasing the pressure have on the solubility of NO_2 in the last step of the Ostwald Process? (1)

Graph to show the distribution of molecular energies at constant temperature



2.4 A platinum catalyst is used in the first step of the Ostwald Process. Copy the above graph into your answer book and use it to explain how the catalyst increases the rate of the reaction. Add suitable labels to your graph to assist in your explanation. (4)

2.5 How will the mass of the platinum catalyst change during the course of the reaction? Explain. (2)

The Haber Process and the Ostwald Process provide important reactants for the manufacture of **nitrogenous fertilisers.** These processes were developed at the start of World War 1.

2.6 What was the main source of nitrogen used in organic fertilisers prior to World War 1? (1)

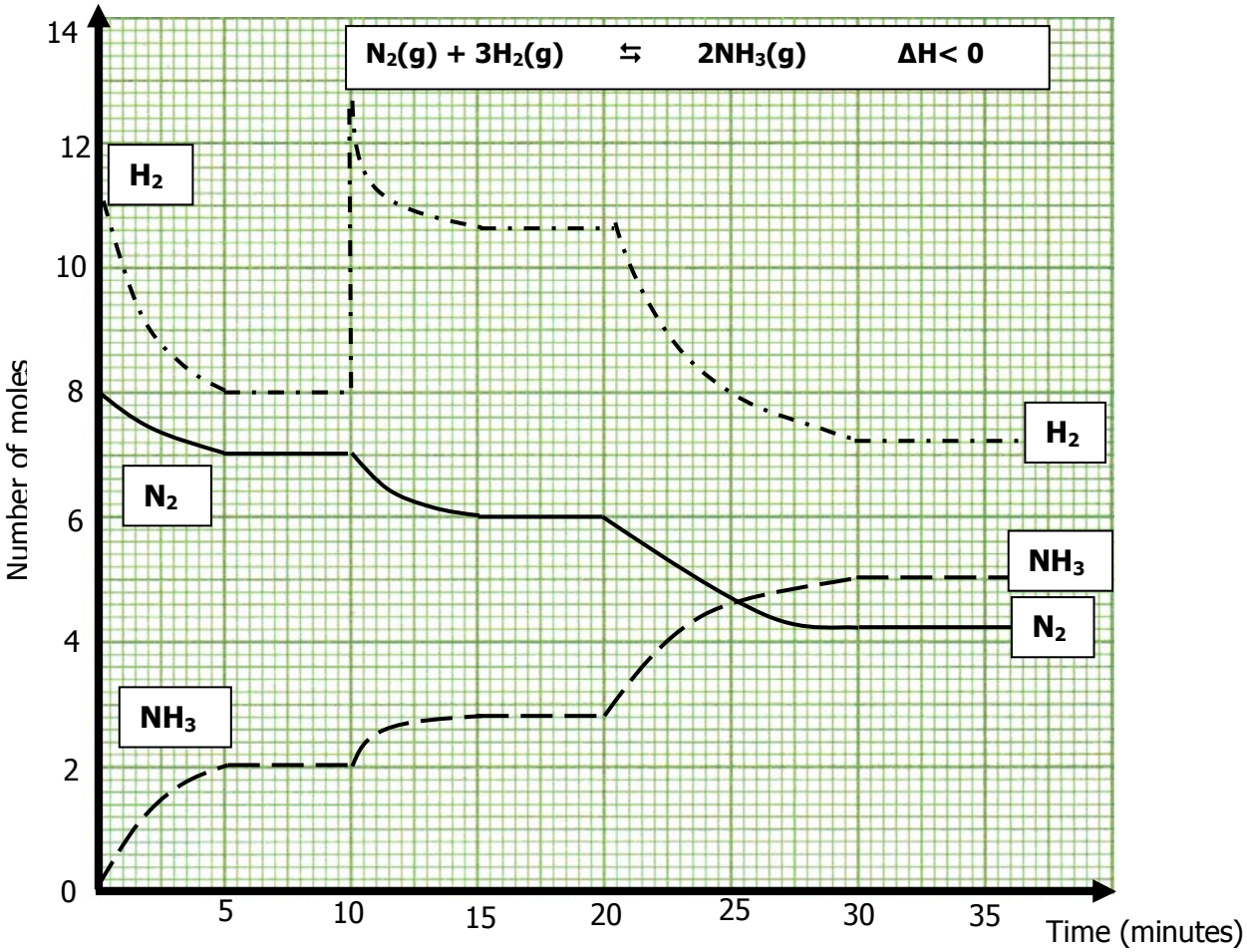
2.7 Use the information given on the label of the 2 kg box of fertiliser shown opposite to determine what percentage of the contents of the box is nitrogen containing compounds. (4)

2.8 Explain how fertilisers can lead to eutrophication of dams. (3)

20 marks

Question 3 Haber Process

In a Haber Process reaction to make ammonia 8 mol of N_2 gas and 11 mol of H_2 gas is introduced into a container of volume 10 dm^3 at a temperature of 450 ^oC. The container is sealed immediately after the gases are added. The graph below represents the changes in the number of moles of the gases in the reaction vessel over a period of 35 minutes.



3.1 Write an expression for the equilibrium constant, K_c for the Haber Process reaction. (2)

3.2 Use figures from the graph to determine the equilibrium **concentrations** of H_2, N_2 and NH_3 at a time of 8 minutes. (3)

3.3 Calculate the equilibrium constant, K_c at 450 ^oC for this reaction at a time of 8 minutes. (2)

3.4 What does your calculated value of K_c indicate about the yield of ammonia at 450 ^oC? (1)

3.5 Give one advantage of performing the process at such a high temperature. (1)

3.6 What change was made to the equilibrium mixture at a time of 10 minutes? (1)

3.7 Explain why the number of moles of the various gases changed as they did after the change at 10 minutes was made. (2)

3.8 At a time of 20 minutes a further change was made to the equilibrium mixture which brought about a permanent change in the equilibrium constant, K_c. **Explain** the change that must have been made and state how this change would have affected the equilibrium constant *(increase or decrease).* You are NOT required to re-calculate K_c. (4)

16 marks

Question 4 Galvanic Cells

4.1 Your teacher gives you a half cell containing an unknown sample of metal, X in a **standard** solution of its salt. This half cell is connected to a **standard** lead half cell.

Cell notation: $X(s)/X^{2+}(aq)$ // $Pb^{2+}(aq)/Pb(s)$ Cell reaction: $X(s) + Pb^{2+}(aq) \rightarrow X^{2+}(aq) + Pb(s)$

4.1.1 What are the **standard** conditions for this cell? (2)

4.1.2 Is metal X the anode or cathode of this cell? (1)

4.1.3 Suggest a suitable electrolyte for use in the lead half cell. (1)

4.1.4 Give the symbol of the reducing agent in this cell. (1)

You are required to determine the Standard Reduction Potential (E^o) of this unknown metal X using the apparatus provided:

Lead half cell; Metal X half cell; Salt bridge containing $KNO_3(aq)$; Voltmeter; Connecting leads

4.1.5 Draw a labelled diagram to show how you would use the above apparatus to set up a galvanic cell between metal X and lead. Indicate the **direction of electron flow** on your diagram. (3)

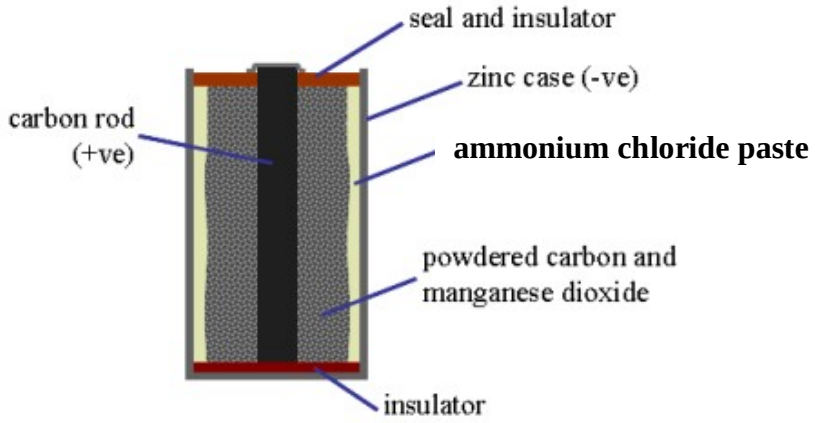
4.1.6 Explain what reading you would take and exactly how you would use it to determine the identity of the unknown metal X. (4)

4.1.7 What happens to the emf of the cell as the reactions taking place in the half cells approach equilibrium? (1)

4.1.8 How will the emf of the cell be affected if the concentration of Pb^{2+} ions is increased by dissolving crystals of a soluble lead salt in the lead half cell? Explain. (3)

[16]

4.2 The Leclanche cell is an example of a **primary** galvanic cell, more commonly known as the zinc-carbon battery. Study the diagram of this cell below before answering the questions that follow.



4.2.1 How does a primary cell differ from a secondary cell? Give one example of a secondary cell. (2)

4.2.2 Name the energy transfers taking place in this cell. (1)

4.2.3 Why does the zinc case corrode when the cell is old? Use a suitable half reaction to support your answer. (2)

4.2.4 How does surrounding the carbon (graphite) rod with **powdered** carbon enable the cell to produce bigger currents? (3)

[8]

4.3 **Alkaline** batteries are comparable to zinc-carbon batteries, but the difference is that alkaline batteries use potassium hydroxide (KOH) as an electrolyte rather than ammonium chloride.
The half-reactions are:

Anode $Zn\ (s) + 2OH^-\ (aq) \rightarrow ZnO\ (s) + H_2O\ (l) + 2e^-$

Cathode $2MnO_2\ (s) + H_2O\ (l) + 2e^- \rightarrow Mn_2O_3\ (s) + 2OH^-\ (aq)$

4.3.1 Write the nett cell reaction for the alkaline battery. (2)

Table to compare the properties of different batteries

Type	Size	Diameter (mm)	Height (mm)	Emf (V)	Capacity (A.h)	Cost (R)
Zinc-carbon	AA	14,5	50,5	1,5	0,8	5,00
Alkaline	AA	14,5	50,5	1,5	2,8	9,50
Alkaline	D	34,2	61,5	1,5	20,5	17,50

4.3.2 Explain why both of the **alkaline** batteries shown in the above table have the same emf even though the D type battery is significantly bigger than the AA type battery. (2)

4.3.3 Give a definition for cell capacity. (2)

4.3.4 Consider the factors that affect cell capacity and suggest why the D type alkaline battery has a larger capacity than the AA type alkaline battery. (2)

4.3.5 Calculate the total amount of energy that the zinc-carbon AA battery should be able to supply if used continuously for 1 hour. (3)

AA size **D size**

4.3.6 Your digital camera uses one AA size battery and requires a current of 0,6 A to operate effectively. You have been asked to take photos of models at a fashion shoot and estimate that you will need to use your camera continuously for a time of 4 hours. What is the most cost effective choice of battery for the job you have to do? Show suitable calculations to justify your answer. (5)

Even if never taken out of the original package, primary batteries can lose 8 to 20 percent of their original charge every year at a temperature of about 20° - 30°C. This is due to non-current-producing "side" chemical reactions, which occur within the cell. The life of a primary battery can be increased if they are stored in a cool place when not in use.

4.3.7 Use your knowledge of reaction rates to explain why storing the batteries in a cool place prolongs their life. (2)

4.3.8 Whilst most AA batteries have to be thrown away once flat it is possible nowadays to purchase rechargeable AA batteries. These batteries can be recharged by passing an electric current through them which reverses the chemical reaction. The products of the reaction during discharge are converted back into the starting materials during recharging. Rechargeable batteries cost R45 each, which is considerably more than their non-rechargeable counterparts but they have less of a negative impact on the health of the environment. Give **3** ways in which the use of rechargeable batteries reduces environmental damage when compared to non-rechargeable batteries. (3)

[21]

45 marks

Question 5 Extraction of Aluminium

Prior to 1886 aluminium was considered as a rare and expensive metal since it could not be extracted from its mineral ore (bauxite). However in 1886 the Hall-Heroult electrolytic method for extracting aluminium from Bauxite was developed. Aluminium is the second most widely used metal in the world and is in high demand due to its special properties.

5.1 Aluminium extraction has impacted significantly on the growth and development of nations. Give **2 properties** of aluminium and **2 uses** of aluminium that relate specifically to each of these properties. (4)

Diagram of an electrolytic cell used for the electrolysis of aluminium oxide

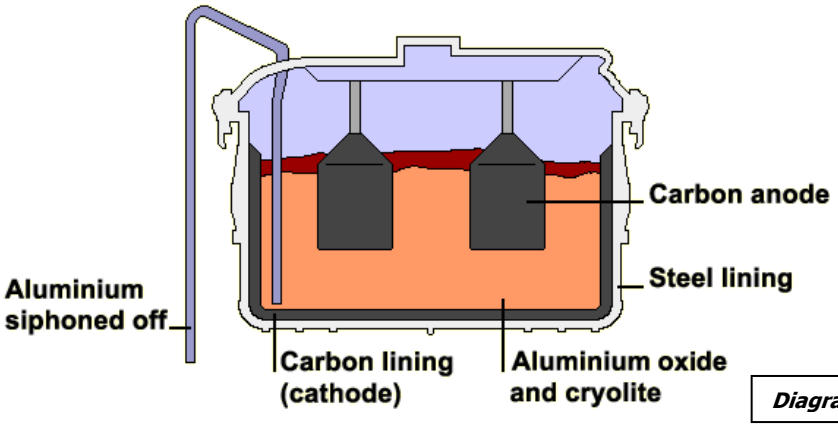


Diagram courtesy of Plato Learning Inc

Consider the above diagram before answering the questions that follow.

5.2 What is the function of the cryolite? (1)

5.3 Give one way in which the use of cryolite in the extraction of aluminium impacts positively on the environment and one way in which it impacts negatively on the environment. (2)

5.4 Oxygen ions are oxidised to form oxygen gas at the carbon anode: $\mathbf{2O^{2-} \rightarrow O_2 + 4e^-}$
The carbon anodes constantly corrode away and have to be replaced. Give a balanced equation to show the reaction responsible for the corrosion of the anodes and explain why this reaction contributes to global warming. (2)

South Africa is one of the world's largest producers of aluminium, which is extremely important to the country's economy. Unfortunately the process consumes enormous quantities of energy which impacts significantly on Eskom's ability to meet the country's electricity demands. The high energy consumption of a smelter means that the recycling of Al products is very important.

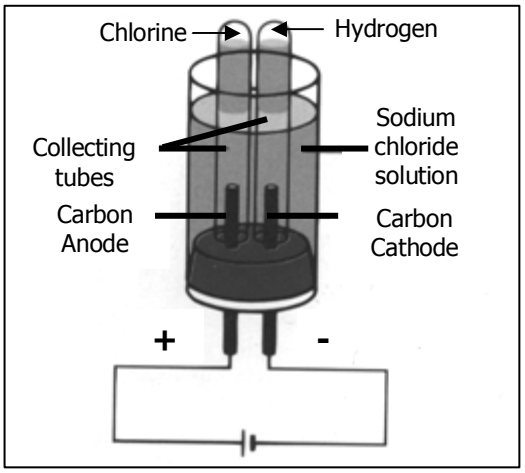
> Recycling used aluminium cans requires only about five percent of the energy needed to produce aluminium from bauxite. Recycling just one can saves enough electricity to light a 100-watt bulb for 3 ½ hours. http://www.wessa-umhlanga.org.za/index.html

5.5 The Headmaster recently attended a conference where an important item on the agenda was "Greening your campus".

Write a report to the Headmaster in which you motivate for the College to become involved in aluminium recycling by having a collection point for aluminium cans on the campus. Consider some of the environmental problems associated with the extraction of aluminium from its ore and how these will be reduced by recycling. Give your report in point form and avoid repetition. (7)

16 marks

Question 6 Electrolysis of Sodium Chloride Solution



Siphiwe and John conduct an experiment to investigate how different factors affect the rate of electrolysis of a solution of sodium chloride (NaCl). They use the apparatus shown in the adjacent diagram and make changes to the electrode size, the concentration of the solution and the distance between the electrodes. They measure the volume of hydrogen gas produced at the cathode in each experiment after 10 minutes.

Their results are tabulated below.

Table to show the volume of hydrogen gas produced during the electrolysis of sodium chloride solution

Experiment	Concentration of NaCl ($mol.dm^{-3}$)	Electrode size	Distance between the electrodes (mm)	Volume of hydrogen in 10 minutes (cm^3)
A	0,75	Medium	50	14,3
B	1,00	Medium	50	18,6
C	1,50	Medium	50	25,2
D	1,00	Small	50	12,8
E	1,00	Large	50	22,4
F	1,00	Medium	25	23,6
G	1,00	Medium	100	11,4
H	1,5	Small	100	13,7

6.1 Which **3** experiments can be used to determine the effect of the concentration of NaCl(aq) on the rate of electrolysis? (1)

6.2 What conclusion can be drawn from the results regarding the effect of concentration of NaCl(aq) on the rate of electrolysis? (2)

6.3 Which **3** experiments can be used to determine the effect of electrode size on the rate of electrolysis? (1)

6.4 What conclusion can be drawn from the results regarding the effect of electrode size on the rate of electrolysis? (2)

6.5 Which **3** experiments can be used to determine the effect of the distance between the electrodes on the rate of electrolysis? (1)

6.6 What conclusion can be drawn from the results regarding the effect of the distance between the electrodes on the rate of electrolysis? (2)

6.7 Explain why it is not possible to draw any valid conclusions from experiment H. (2)

6.8 What is the energy conversion taking place in this electrolytic cell? (1)

6.9 Chlorine gas is produced at the anode. Write a chemical equation representing the half reaction taking place at the **anode.** (1)

Siphiwe and John find that the pH of the solution in their cell increases during electrolysis indicating that they have formed a base (alkali). Their background research reveals that in addition to H_2 gas, OH^- ions are produced during the reaction at the cathode.

6.10 Write a chemical equation representing the half reaction taking place at the **cathode.** (1)

6.11 Write a chemical equation to represent the nett cell reaction. (1)

6.12 Show by means of a suitable calculation using values from the Table of Reduction Potentials that this is a non-spontaneous reaction. (3)

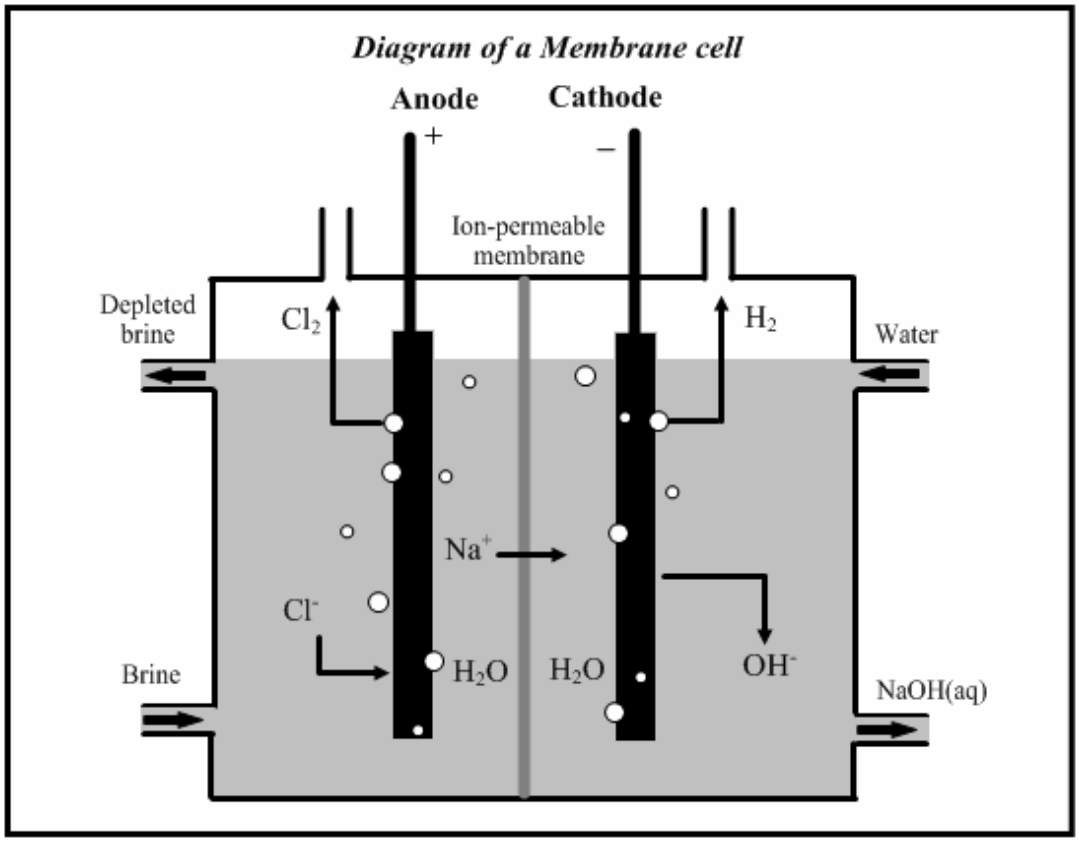
The electrolysis of brine (solution of sodium chloride) is the basis of the chlor-alkali process, a major industry producing hydrogen, chlorine and sodium hydroxide. The right design of the electrolytic cell is crucial to ensure that the products obtained are as pure as possible and do not mix with each other. The design of the **mercury cell** by Hamilton Young Castner in the 1890's solved this problem.

6.13 Give **two advantages** that the mercury cell has over the apparatus used by Siphiwe and John in their experiments. (2)

6.14 Mercury cells have been phased out in many countries due to environmental problems associated with their use. What health problems may workers in a mercury membrane cell factory experience? (1)

6.15 Mercury cells were replaced with asbestos membrane cells but these also caused health problems for the factory workers. What health problems face workers in an asbestos membrane cell factory? (1)

Chemical engineers have now developed safer methods for electrolysing brine. The latest is the membrane cell as shown in the diagram below. The ion-selective membrane between the anode and cathode compartments only lets Na^+ ions and water through. This means that the sodium hydroxide formed in the cathode compartment can't mix and react with the chlorine gas formed in the anode compartment.



6.16 Give one further advantage (beside environmental health and safety) that membrane cells have over mercury cells and asbestos membrane cells. (1)

6.17 Without the chlor-alkali industry life as we know it would be very different because the chemicals produced are used in the manufacturing of a wide variety of products used in day-to-day life. Chlorine and sodium hydroxide are among the top 10 chemicals produced in the world. Give **one** use of **each** of these two products (chlorine and sodium hydroxide) and state how the use you have chosen specifically impacts **your** life on a daily basis. (4)

6.18 Despite the health risks involved there are still countries that continue to use mercury cells and asbestos membrane cells because they allege that they can't afford to replace existing technology with safer membrane cells. These countries need the chemicals produced in order to manufacture much needed products that contribute to the well being of the nation. Do the advantages to the economy and development of the country outweigh the possible health risks to the workers in the cell room? Justify your answer by giving due consideration to the ethics of the situation, the financial implications and the benefit gained by the citizens of the country from the use of the products of this process. (4)

31 marks

TOTAL: 150 MARKS