NATIONAL SENIOR CERTIFICATE EXAMINATION
NOVEMBER 2011

PHYSICAL SCIENCES: PAPER II

Time: 3 hours 200 marks

PLEASE READ THE FOLLOWING INSTRUCTIONS CAREFULLY

1. This question paper consists of 17 pages, an Answer Sheet (Graph Paper) of 1 page and an Insert of 4 pages (i – iv) with data and formulae. Please remove the Insert from the middle of your paper.
2. Please check that your question paper is complete.
3. ALL the questions in this paper must be answered.
4. **START EACH QUESTION ON A NEW PAGE.**
5. Read the questions carefully.
6. Use the data and formulae whenever necessary.
7. It is in your own interest to write legibly and to set your work out neatly.
8. Express ALL answers correct to TWO decimal places.
9. Show all the necessary steps in calculations.
10. N.B. Question 6.5 is to be answered on the graph paper provided.

Answer this question on the grid provided on the inside front cover of the Answer Book. Place a cross in the appropriate block for each question.

QUESTION 1 MIXED MULTIPLE CHOICE

1.1 Water dissociates according to the following equation:

$2H_2O(\ell) \rightleftharpoons H_3O^+(aq) + OH^-(aq) \qquad K_c = 1 \times 10^{-14}$

This equation implies that …

A the number of H_3O^+ ions formed is equal to the number of water molecules that dissociate.
B H_2O molecules dissociate easily.
C the number of H_3O^+ ions present is less than 1 ion in 100 million molecules.
D the number of H_3O^+ ions present is equal to the number of hydroxide ions present. (2)

1.2 The value of the equilibrium constant for the chemical reaction represented by the following equation is 0,75 at 500 °C and it is 0,83 at a temperature of 600 °C:

$A(s) + B(g) \rightleftharpoons C(s) + D(g)$

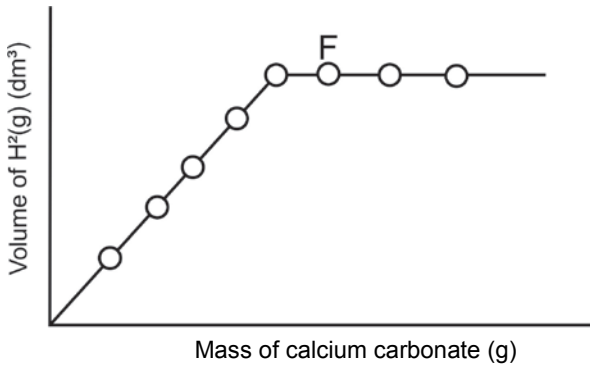
From this information it may be concluded that the forward reaction is …

A exothermic.
B endothermic.
C fast.
D slow. (2)

1.3 Calcium carbonate reacts with hydrochloric acid according to the following chemical equation:

$CaCO_3(s) + 2HC\ell(aq) \rightarrow CaC\ell_2(aq) + CO_2(g) + H_2O(\ell)$

In an investigation, varying masses of calcium carbonate are added to equal amounts of $HC\ell$ and the gas released is collected. The following graph is produced from the results:



From point F it may be deduced that there is …

A an excess of $HC\ell$.
B an excess of $CaCO_3$.
C an excess of either $HC\ell$ or $CaCO_3$.
D an excess of neither reactant. (2)

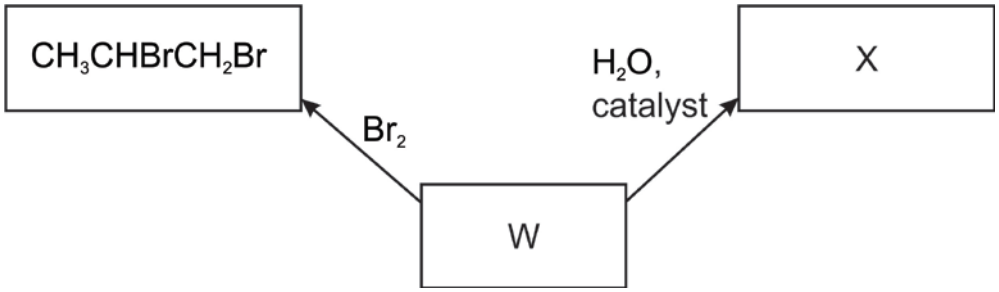
1.4 Hydrogen bromide decomposes according to the following equation:

$2HBr(g) \rightleftharpoons H_2(g) + Br_2(g)$ $K_c = 0{,}006$ at 420 K

2 mol of each of HBr, H_2 and Br_2 were placed in a container and heated to 420 K. When equilibrium is established …

A the number of moles of Br_2 would have decreased.
B the number of moles of HBr would be unchanged.
C the value of K_c would have increased to 1.
D the number of moles of gas would have decreased. (2)

Question 1.5 refers to the following diagram:



1.5 The compounds W and X may be respectively:

A CH_3CHCH_2 and CH_3COCH_3
B $CH_3CH_2CH_2Br$ and $HOCH_2CH_2CH_2OH$
C CH_3CHCH_2 and $CH_3CH_2CH_2OH$
D $CH_3CH_2CH_2Br$ and $HOCH_2CH_2OCH_3$ (2)

1.6 Consider the reaction:

$CH_3 - CH = CH_2 + HC\ell \rightarrow CH_3 - CH_2 - CH_2C\ell$

A The product is an isomer of chloropropane.
B The reaction is a substitution reaction.
C The reaction is slow and needs UV light.
D The product is an ester. (2)

1.7 Copper ions gain 2 electrons to form copper metal. This process is called …

A oxidation.
B hydrogenation.
C catalysis.
D reduction. (2)

1.8 Methanol can be prepared commercially from CO(g) and $H_2(g)$.

$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$ $\Delta H = -92\ kJ \cdot mol^{-1}$

The yield of methanol can be increased by …

A increasing the pressure of the system.
B raising the temperature of the system.
C adding a catalyst.
D changing the initial ratio of the reactants. (2)

1.9 A free radical is best described as …

A a molecular fragment with a non-bonding pair of electrons.
B a molecular fragment with a missing bond.
C a molecular fragment with an unpaired electron.
D a molecular fragment that has bonded to an initiator. (2)

1.10 In the cell to produce aluminium from alumina, the carbon anode …

A gains mass.
B reacts to form CO_2.
C is the site where $Al^{3+} \rightarrow Al$.
D does not conduct electricity. (2)

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QUESTION 2 ORGANIC MOLECULES

Crude oil and other fossil fuels are very important to the world economy. One major use of these fuels is in transportation.

Petrol is a mixture which contains alkenes, alkanes, alcohol and a number of other substances. Compounds containing 8 – 12 carbon atoms form the bulk of those found in petrol.

2.1 Draw the structural formula of the most branched molecules of C_8H_{18}. (2)

2.2 Write down a balanced chemical equation for the combustion of this compound (Question 2.1) in air. (4)

One of the processes used in the refining of crude oil is called 'cracking'. In this process longer chain hydrocarbons are heated to a high temperature in the presence of a catalyst and they are broken into two smaller molecules, one of which is an alkane and the other an alkene. An example of such a longer chain hydrocarbon might be octane:

$CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_3$

An example of a reaction that could occur during the 'cracking' of octane is

$C_8H_{18} \rightarrow C_5H_{12} + A$

2.3 Write down the formula of compound A. (1)

2.4 When compound A reacts with bromine, will the reaction be fast or slow? (1)

2.5 When compound A reacts with bromine, will it be by an addition or substitution reaction? Explain your answer. (3)

2.6 Suggest another possible use for compound A, other than as a fuel. (1)

2.7 The compound $CH_2CHCH(CH_3)CH_3$ can be used to make a number of useful organic products.

2.7.1 Name the compound. (3)

2.7.2 Draw the structural formula of the product that results when this compound reacts with steam. (3)

2.7.3 Name the homologous series to which the new compound (Question 2.7.2) belongs. (1)

2.8 Alcohols have much higher boiling points than those of alkanes of similar chain length. The table below compares the boiling points of straight chain alkanes and straight chain alcohols.

Number of carbon atoms	**Boiling points of alkanes (°C)**	**Boiling points of alcohols (°C)**
1	-162	64
2	-89	78
3	-42	98
4	-0,5	118

2.8.1 Explain why alcohols have a higher boiling point than the equivalent alkanes. (4)

2.8.2 Explain why the boiling points of the alkanes increase with increasing chain length. (3)

2.9 2.9.1 What is meant by the term 'isomers'? (2)

2.9.2 Draw the **condensed formulae** of all the possible isomers of butane and name them. (9)

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QUESTION 3 POLYMERS

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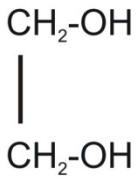
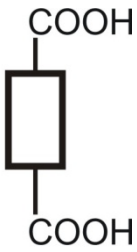
Simple polyesters are produced to make artificial fibres. These fibres can be spun into cloth and are used in the textile industry.

One of the most common polyesters is Terylene. The polymer is made from the following monomers:



A



B

The monomers used are ethan – 1,2– diol (A) and a dicarboxylic acid (B). The block in B represents a complex organic structure.

3.1 Draw the polymer structure containing 2 repeat units. (4)

3.2 Name the type of polymerisation reaction that occurs. (2)

3.3 Esters are generally volatile and produce a smell. Would the product of this reaction be volatile? Explain your answer. (2)

Terylene fibres can be weakened by the addition of dilute acids.

3.4 Suggest a reason why this weakening occurs. (2)

3.5 Explain how the process of making Terylene fibres is brought to an end, i.e. how it is terminated. (2)

Polymers can be divided into two main classes. These are thermoset and thermoplastic polymers.

3.6 Explain the difference between the two types of polymers in terms of:

3.6.1 the effect of heating (2)

3.6.2 the ease of recycling (2)

3.6.3 the degree of cross-linking (2)

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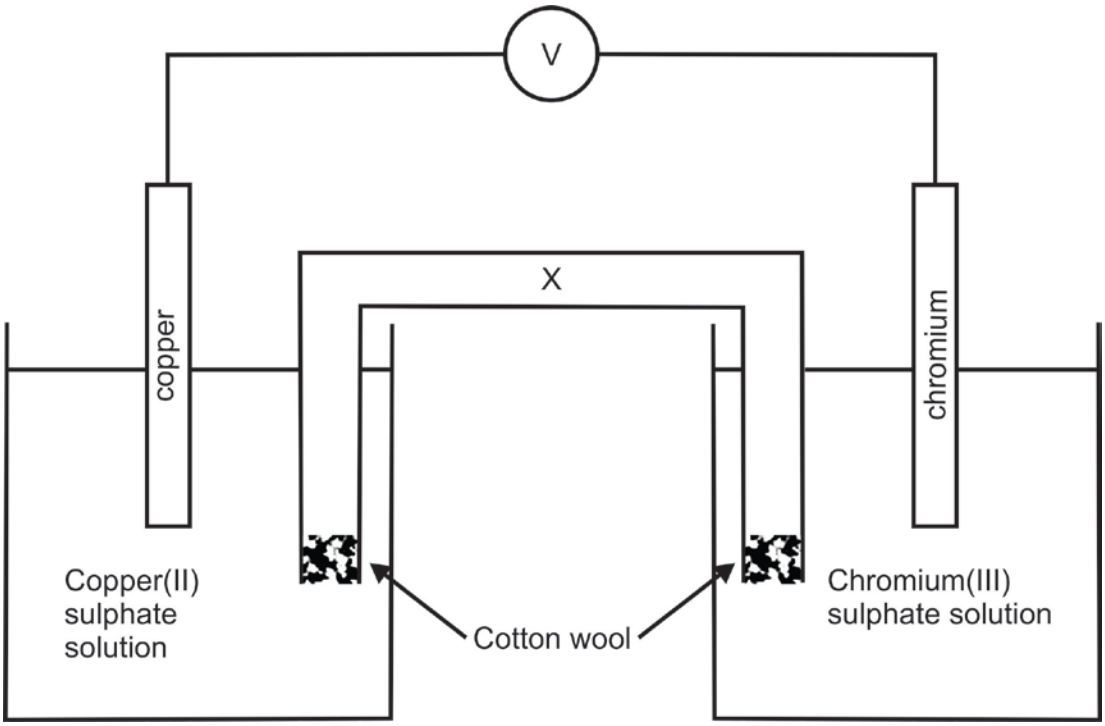
QUESTION 4 GALVANIC CELLS

Start this question on a new page.



The copper electrode is placed in copper(II) sulphate solution. The chromium electrode is placed in a solution of chromium(III) sulphate.

4.1 Write down the formula of copper(II) sulphate. (1)

4.2 Explain why the two electrodes must be placed in solutions of their salts. (2)

4.3 Define the term oxidation. (2)

4.4 4.4.1 Write down the chemical equation for the oxidation half-reaction that occurs in this cell. (2)

4.4.2 Write down the chemical equation for the reduction half-reaction that occurs in this cell. (2)

4.5 Which electrode is the anode? (Write down only Cu or Cr.) (2)

4.6 Write down the equation for the net ionic reaction that occurs in this cell. (3)

4.7 Use the table of standard reduction potentials to determine the initial emf for this cell. (3)

4.8 Is the reaction that occurs in this cell spontaneous? Explain your answer by referring to your calculation in Question 4.7. (2)

4.9 Often the actual cell potential is different from the calculated value. Explain why this might occur. **Be specific** about the factors that may cause this value to change. (4)

4.10 Consider the component X in the diagram.

4.10.1 Name the component X. (1)

4.10.2 Suggest a suitable reagent that might be used in X. (2)

4.10.3 Give 2 possible functions of X. (2)

The half-reaction for zinc is written as follows in the table of reduction potentials:

$Zn^{2+} + 2e^- \rightleftharpoons Zn$ **−0,76 V**

4.11 Explain the meaning of:

4.11.1 $Zn^{2+} + 2e^- \rightleftharpoons Zn$ (1)

4.11.2 −0,76 V (3)

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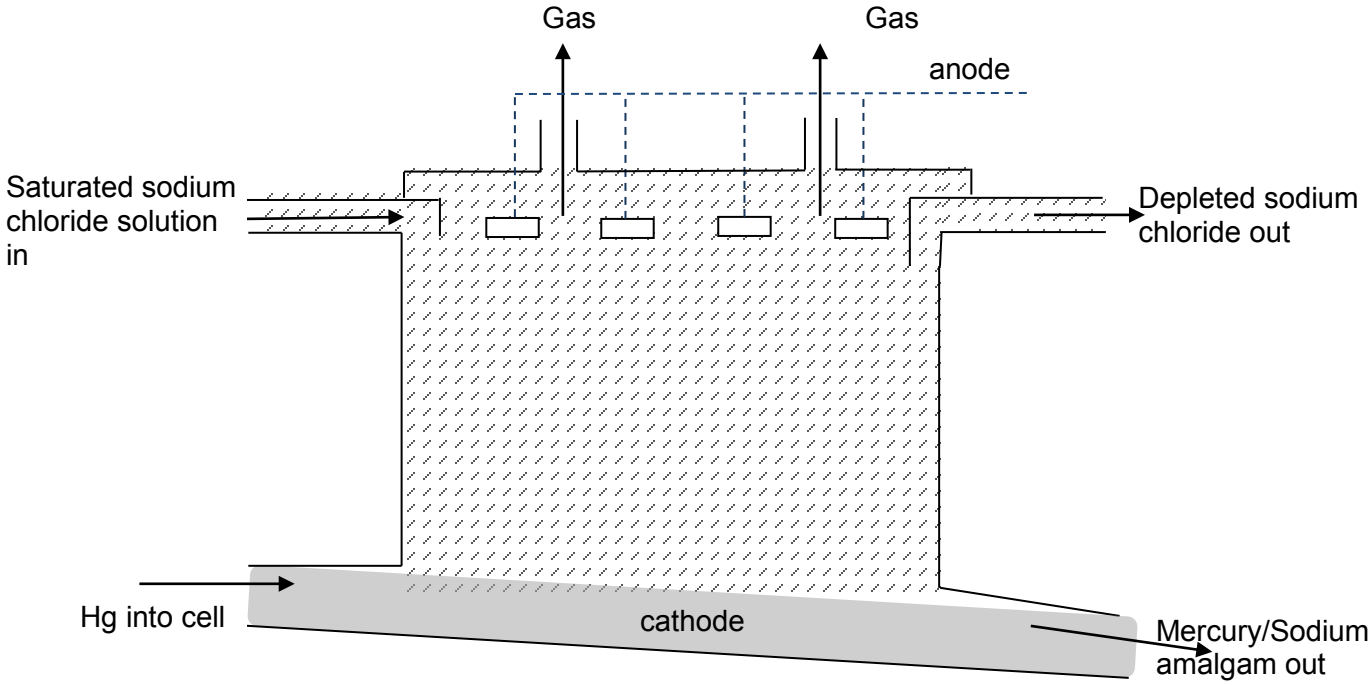
QUESTION 5 THE CHLOR-ALKALI PROCESS

Start this question on a new page.



The diagram illustrates the electrolysis of sodium chloride solution using the mercury cathode cell.

5.1 Give 2 possible reasons why mercury is used as the cathode for this cell. (2)

5.2 Write down the chemical equation for the half-reaction that occurs at the cathode of this cell. (2)

5.3 5.3.1 What happens to the amalgam once it has left the electrolysis chamber? (1)

5.3.2 What chemical reaction occurs in your answer to Question 5.3.1? (No equation required) (1)

5.3.3 State what products are formed during the reaction mentioned in Question 5.3.2. (2)

5.4 Write down the equation for the half-reaction that occurs at the anode of the mercury cathode cell. (2)

The anodes are often made from titanium.

5.5 Suggest a reason for the anodes being made of titanium rather than iron. (2)

The European Chlorine industry is expected to convert all mercury production of chlorine to membrane technology by 2020. The table provides information about the different methods used to produce chlorine. NaOH is sold at a strength of 50%.

	Mercury	**Diaphragm**	**Membrane**
Cell voltage (V)	3,9 – 4,2	2,9 – 3,5	3,0 – 3,6
NaOH strength (wt%)	50	12	33 – 35
Energy consumption (kWh per megatonne of $C\ell_2$) at a current density of (kA/m^2)	3360 (10)	2820 (1,7)	2650 (5)
Steam consumption (kWh per megatonne of $C\ell_2$) for concentration to 50% NaOH	0	610	180

5.6 From the table identify 2 advantages of running the mercury cathode cell over the diaphragm cell. (4)

5.7 From the table identify one advantage of running the mercury cathode cell over the membrane cell. (2)

5.8 Using the data provided, comment on whether it makes sense for the mercury cathode cell to be phased out by 2020 in Europe. (3)

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QUESTION 6 CLOCK EXPERIMENT

Start this question on a new page.

A clock experiment is one where a clear and **immediate** colour change takes place after a specific period of time indicating that a reaction has taken place. In this case the solution changes from colourless to blue.

Matt and Florence are working as a pair on the experiment.

The instructions for the practical state the following:

Aim: To determine the relationship between the temperature of the reactants and the time taken for a reaction to be completed.

Instructions:

- Add 5 cm^3 of solution A to a conical flask.
- Add 2 cm^3 of starch solution to the conical flask.
- Warm 5 identical samples of solution B to the required temperature i.e. 30 °C, 40 °C, 50 °C, 60 °C and 70 °C respectively.
- Add the first sample of solution B to the conical flask. Start the stopwatch **immediately**.
- Time how long it takes for the blue colour to appear.
- Repeat the process for each of the other 4 samples of solution B.

6.1 Write a suitable hypothesis for this investigation. (2)

6.2 Identify:

6.2.1 the independent variable (1)

6.2.2 the dependent variable (1)

6.2.3 2 **suitable and appropriate** control variables for this investigation (2)

6.3 Consider the data from the experiment:

Temp. (°C)	Time – sample 1 (s)	Time – sample 2 (s)	Time – sample 3 (s)	Average time (s)
30	184	179	186	183
40	141	147	143	144
50	118	112	116	115
60	97	100	94	97
70	77	81	80	79

Is this data reliable? Explain your answer. (3)

Matt suggests that there is an inverse relationship (proportionality) between the variables. He wants to plot a graph of temperature vs 1/t.

6.4 What type of graph would Matt have to obtain to confirm that the relationship is one of inverse proportionality? (2)

6.5 Plot a graph, **on the graph paper provided**, of temperature vs 1/t. (7)

6.6 Write a suitable conclusion for this investigation. (3)
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QUESTION 7 RATES AND EQUILIBRIUM

Start this question on a new page.

In the Haber process, the manufacture of ammonia occurs according to the following chemical equation:

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ $\Delta H < 0$

In the Haber process, the product is removed as quickly as it forms.

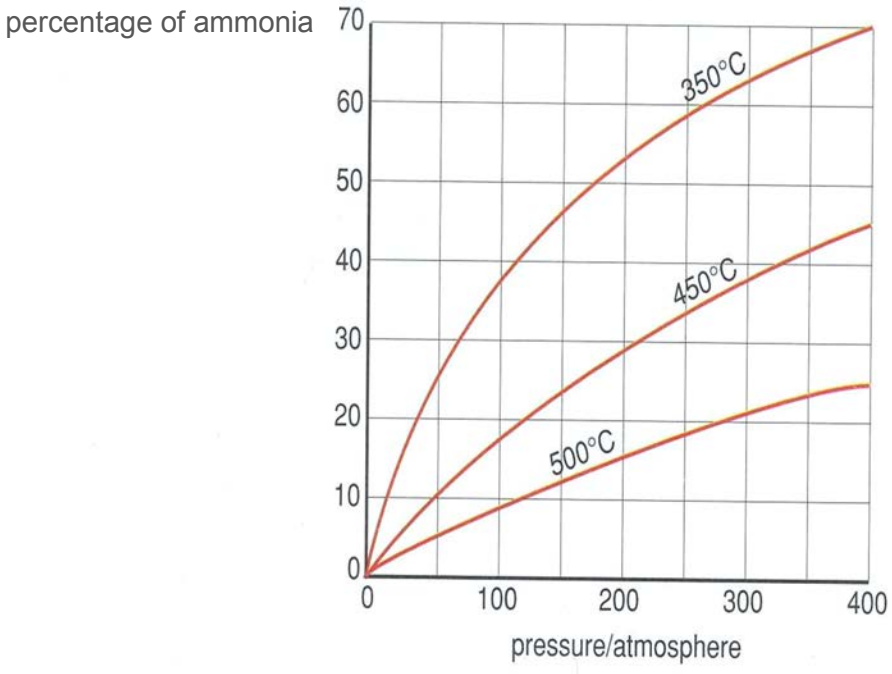
7.1 Does this reaction ever reach equilibrium? Explain your answer. (3)

7.2 Explain why ammonia is removed from the reaction vessel. (2)

7.3 Sketch a potential energy diagram for this reaction. Plot $E_{potential}$ on the y-axis and reaction co-ordinate on the x-axis. (3)

7.4 List three factors that could speed up the rate of this reaction. (3)

The graph shows the percentage of ammonia produced for varying conditions of temperature and pressure.



Consider the data presented in the graph. The Haber process typically operates at about 400 °C, and at a pressure of 200 atmospheres.

7.5 What is the term used to describe the percentage of ammonia produced? (2)

7.6 Discuss why the conditions mentioned are chosen when lower temperatures and higher pressures would ensure a higher yield of product. (4)

7.7 In a laboratory, a simulation of the Haber Process is set up and an equilibrium is established at 400 °C and a pressure of 150 atm. The following concentrations were measured at equilibrium:

$[NH_3] = 0,4 \text{ mol·dm}^{-3}$
$[N_2] = 0,7 \text{ mol·dm}^{-3}$
$[H_2] = 0,3 \text{ mol·dm}^{-3}$

7.7.1 Write down an expression for the equilibrium constant (K_c) for this reaction. (3)

7.7.2 Calculate the value of the constant under these conditions. (2)

7.7.3 How would this value change when equilibrium has been re-established after …

(Write only INCREASES; DECREASES or REMAINS THE SAME)

(a) the temperature has been increased? (2)

(b) a catalyst is added? (2)

(c) more N_2 has been pumped into the container? (2)

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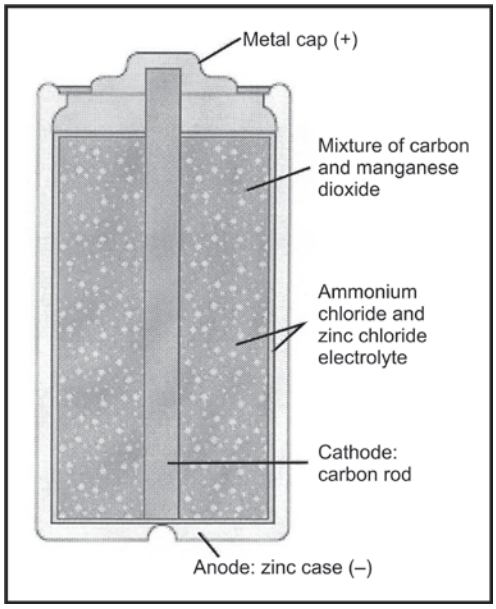
QUESTION 8 THE LECLANCHÉ CELL – COMMON USES OF CELL TECHNOLOGY

Start this question on a new page.

The reaction that takes place at the cathode is:

$2MnO_2(s) + 2NH_4^+(aq) + 2e^- \rightarrow Mn_2O_3(s) + 2NH_3(aq) + H_2O(\ell)$

The Leclanché cell was first developed in 1866. The zinc – carbon **dry cell** is an example of a **primary cell** which works best to deliver a low current for short periods of time. Unfortunately zinc-carbon cells have a problem in that they leak after extended use.



8.1 Explain the terms:

8.1.1 dry cell (1)

8.1.2 primary cell (2)

8.2 Explain why these cell types are prone to leaking. Use a suitable half-reaction to support your argument. (3)

8.3 The Leclanché cell is best used for short periods of time.

Explain why there is a build-up of charge in this cell. (2)

8.4 One of the earliest rechargeable cells was the nickel-cadmium cell. It is preferred over Leclanché cells because it can be recharged well over 1 000 times.

One problem of cadmium is that it is a heavy metal.

The half-reactions for the cell are given below with their half-cell potentials:

$Cd(OH)_2(s) + 2\ e^- \rightleftharpoons Cd(s) + 2OH^-(aq)$ -0,81 V

$NiOOH(s) + H_2O(\ell) + e^- \rightleftharpoons Ni(OH)_2(s) + OH^-(aq)$ 0,53 V

8.4.1 Calculate the amount of charge that would be required to totally recharge a Ni-Cd cell if it has a rated capacity of 2 000 mAh. (3)

8.4.2 Calculate the number of moles of electrons that would be transferred by this amount of charge. (Hint: 1 mol e^- = 96 500 C) (2)

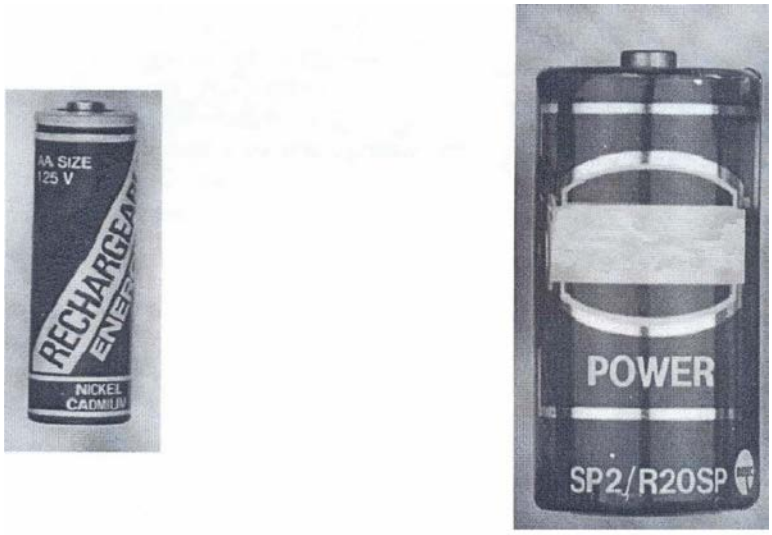
8.4.3 Calculate the number of moles of cadmium that would reform on the electrode when the cell recharges. (1)

8.4.4 Calculate the mass of cadmium that would be replated on the electrode during the recharge cycle. (2)

8.4.5 Suggest 1 disadvantage of using Nickel-cadmium cells. (1)

8.4.6 Suggest 2 reasons why being re-chargeable is an advantage for using Nickel-cadmium cells. (2)

Consider Nickel-cadmium cells of different sizes.



AA-size cell C-size cell

8.4.7 Would you expect the voltages to differ? Explain your answer. (2)

8.4.8 Would you expect the internal resistances of the cells to differ? Explain your answer. (2)

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Total: 200 marks