NATIONAL SENIOR CERTIFICATE EXAMINATION
NOVEMBER 2013

PHYSICAL SCIENCES: PAPER II

Time: 3 hours | 200 marks

PLEASE READ THE FOLLOWING INSTRUCTIONS CAREFULLY

1. This question paper consists of 15 pages, an Answer Sheet (Graph Paper) of 1 page and a Data Booklet of 4 pages (i – iv) with data and formulae. Please remove the Data Booklet and Answer Sheet 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. Question 1 consists of 10 multiple-choice questions. There is only one correct answer to each question. The questions are answered on the inside front cover of your Answer Book. The letter that corresponds with your choice of the correct answer must be marked with a cross as shown in the example below:

A	B	~~C~~ (X)	D

Here the answer C has been marked.

5. **START EACH QUESTION ON A NEW PAGE.**

6. Read the questions carefully.

7. Use the data and formulae whenever necessary.

8. Express ALL answers correct to TWO decimal places.

9. An approved calculator (non-programmable, non-graphical) may be used.

10. Show all the necessary steps in calculations.

11. It is in your own interest to write legibly and to set your work out neatly.

QUESTION 1

Answer these questions on the inside front cover of your Answer Book. Make a cross (X) on the letter of the response which you consider to be the most correct.

1.1 The general formula for the alkynes is …

A C_nH_{2n+2}
B C_nH_{2n-2}
C C_nH_{2n}
D C_nH_{n-2}

1.2 Which one of the following pairs of organic molecules contains members of the same homologous series?

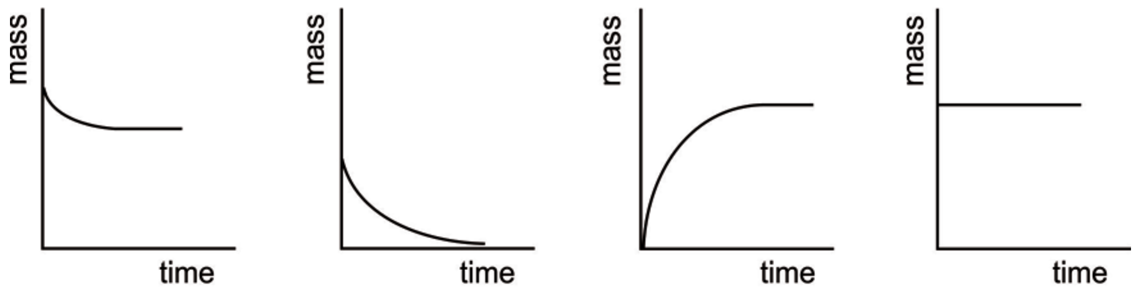
A CH_2CH_2 and $CH_3CH_2CH_3$
B CH_2CHCH_3 and $CHCCH_2CH_3$
C CH_3OH and CH_3COOH
D CH_3COOH and CH_3CH_2COOH

1.3 Which one of the following possible combinations of monomer units could be used in the formation of condensation polymers such as polyesters?

Note:  represents a chain of carbon atoms in the organic compound.

	Monomer unit 1	Monomer unit 2
A	HOOC –  – COOH	 – OH
B	$CH_3 – CH = CH_2$	HO –  – OH
C	HOOC – 	 – OH
D	HOOC –  – COOH	HO –  – OH

1.4 Which one of the following graphs shows the change in mass of a catalyst during a chemical reaction?



A B C D

1.5 Which one of the following statements below regarding the reversible reaction taking place in a closed container is **true**?

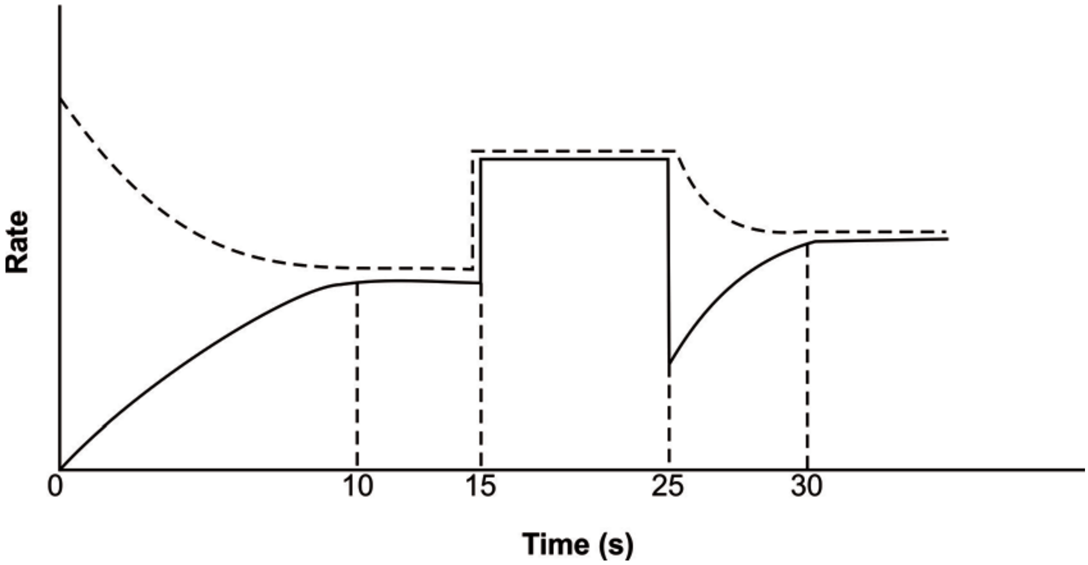
$$2H_2\,(g) + O_2\,(g) \rightleftharpoons 2H_2O\,(g) \qquad \Delta H < 0$$

A Chemical equilibrium is reached when the concentrations of the product and reactants remain constant.
B Chemical equilibrium is reached when the concentration of the products is equal to the concentrations of the reactants.
C When chemical equilibrium is reached the value of K_c is zero.
D Chemical equilibrium is reached when the forward reaction stops.

1.6 A hypothetical chemical reaction in a closed container is represented by the following chemical equation:

$$aA(s) + bB(aq) \rightleftharpoons cC(aq) + dD(g) \qquad \Delta H < 0$$

The graph below represents the rates of the forward and reverse reactions plotted as a function of time. Which one of the following could describe the change in the rates of the reactions at t = 15 s and t = 25 s respectively?



	Disturbance at t = 15 s	Disturbance at t = 25 s
A	Surface area of A was increased	The pressure in the system was increased
B	A catalyst was added	The temperature of the system was decreased
C	The temperature of the system was increased	The surface area of A was decreased
D	The pressure of the system was decreased	The temperature of the system was increased

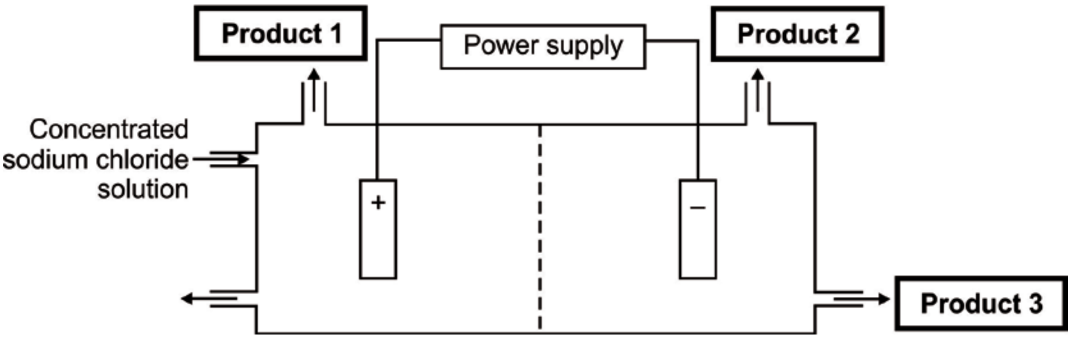
1.7 Consider the list of metals below. Using your Standard Electrode Potential Table, identify which metal will be able to reduce Cd^{2+}(aq) to Cd(s) but will not reduce Mn^{2+}(aq) to Mn(s).

A Zinc
B Magnesium
C Nickel
D Silver

1.8 Pure copper is purified from impure copper using an electrolytic technique. What name is given to this technique?

A Electropurification
B Electroplating
C Electrorefining
D Electrorendering

1.9 A typical membrane cell which is used in the chlor-alkali industry in South Africa is illustrated below.



What are the **three** major products formed in a membrane cell?

	Product 1	**Product 2**	**Product 3**
A	H_2(g)	Cℓ(g)	NaOH(aq)
B	$Cℓ_2$(g)	H_2(g)	Na(s)
C	$Cℓ_2$(g)	H_2(g)	NaCℓ(aq)
D	$Cℓ_2$(g)	H_2(g)	NaOH(aq)

1.10 A lead storage battery which is used in motor cars, involves two half-cell reactions as illustrated below:

	Standard Reduction Potential E^θ (volts)
$PbO_2(s) + HSO_4^-(aq) + 3H^+ + 2e^- \rightleftharpoons PbSO_4(s) + 2H_2O(\ell)$	+ 1,69
$PbSO_4(s) + H^+(aq) + 2e^- \rightleftharpoons Pb(s) + HSO_4^-(aq)$	– 0,36

Using this information, for a cell that involves these reactions under standard conditions, what is the overall reaction and the cell emf (in volts) when the cell is discharging?

	OVERALL CELL REACTION	**emf (volts)**
A	$PbO_2 + 4H^+ \longrightarrow Pb + 2H_2O$	+1,33
B	$PbO_2 + Pb + 2SO_4^{2-} \longrightarrow 2PbSO_4 + 2H_2O$	+2,05
C	$Pb + PbO_2 + 2HSO_4^- + 2H^+ \longrightarrow 2PbSO_4 + 2H_2O$	+ 2,05
D	$2PbSO_4 + 2H_2O \longrightarrow PbO_2 + Pb + 2HSO_4^- + 2H^+$	– 2,05

[20]

QUESTION 2

An experiment was conducted to investigate the decomposition of hydrogen peroxide:

$$2H_2O_2(g) \longrightarrow 2H_2O(g) + O_2(g)$$

Different substances, A and B, were used as catalysts in two separate experiments involving the same volume and concentration of hydrogen peroxide solution. The table below shows the volumes of oxygen collected in the two experiments:

Time (minutes)	**Catalyst A Volume of O_2 collected (dm^3)**	**Catalyst B Volume of O_2 collected (dm^3)**
0	0	0
1	2,0	1,0
2	2,8	1,5
3	3,3	2,0
4	3,8	2,3
5	4,1	2,7
6	4,2	2,9
7	4,2	3,1

2.1 All scientific practical experimentation starts off by providing a hypothesis and an investigative question for the experiment. State:

2.1.1 a hypothesis and

2.1.2 an investigative question for the above experiment. (4)

2.2 What is meant by the term 'independent variable' in a scientific experiment? (2)

2.3 Why will the volume of oxygen that is released be considered the dependent variable in this experiment? (2)

2.4 Using the same set of axes, use the data in the table to plot graphs of ***volume of oxygen*** vs ***time*** for both catalyst A and catalyst B and drawing in lines of best fit. Use the graph paper provided to answer this question. (7)

2.5 Using the graph, calculate the average rate of the reaction (in $dm^3 \cdot min^{-1}$) when using catalyst B over the time interval t = 0 minutes to t = 1,5 minutes. (3)

2.6 What volume of oxygen gas would eventually be produced when using catalyst B? Give a reason for your answer. (3)

[21]

QUESTION 3

3.1 Explain fully what is meant by the following terms:

3.1.1 Alkyl substituents (2)

3.1.2 Saturated hydrocarbons (2)

3.2 Draw organic structures for the following organic compounds:

3.2.1 3-methylpent-2-ene (condensed structural formula) (2)

3.2.2 2,3 – dichlorobutane (full structural formula) (2)

3.3 Several organic compounds are listed below either by their molecular or condensed structural formulae as represented by the letters A to G.

A	CH_3CHO	B	$CH_3CH(CH_3)CH_2CH_3$	C	$CH_3CH_2CH_2C\ell$
D	C_5H_{10}	E	CH_3COOH	F	CH_3COCH_3
G	C_2H_2				

From the list and using letters only, select the compounds that answer the questions below.

3.3.1 Which compound or compounds are saturated hydrocarbons? (2)

3.3.2 Which compound or compounds are unsaturated hydrocarbons? (2)

3.3.3 Identify two compounds which contain a carbonyl group. (2)

3.3.4 To what homologous series does compound C belong? (1)

3.3.5 Using condensed structural formulae, draw and give IUPAC names for TWO isomers of compound B. (4)

3.3.6 The table below compares the boiling points of compounds A and E from the organic compounds listed above.

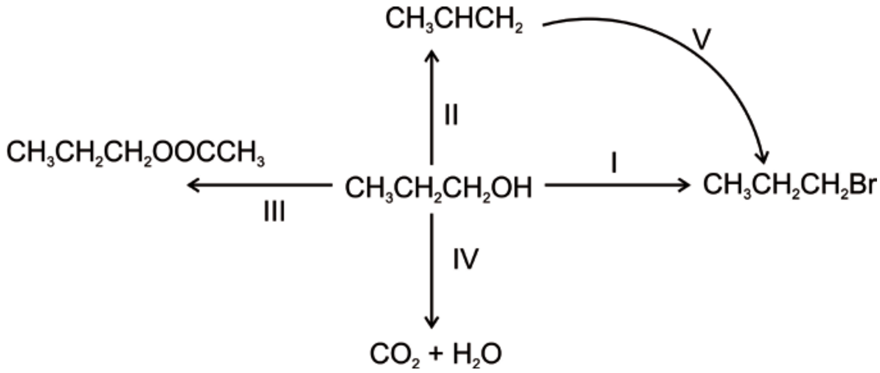
Organic compound	**Structure**	**Boiling point (°C)**
A	CH_3CHO	20
E	CH_3COOH	118

Explain why compound E has a higher boiling point than compound A. (4)

[23]

QUESTION 4

4.1 The organic compound propan-1-ol belongs to the homologous series known as alcohols. It can undergo a number of organic reactions as illustrated by the reactions labelled I – V below.



4.1.1 Identify the type of reaction represented by numerals I – IV respectively. (4)

4.1.2 Consider reaction III.

(a) Give the IUPAC name of the product $CH_3CH_2CH_2OOCCH_3$ formed in this reaction. (2)

(b) Give the IUPAC name of the organic compound that reacts with propan-1-ol in this reaction. (2)

(c) Concentrated sulphuric acid is used in this reaction. Based on its specific functions in the reaction, **explain** why sulphuric acid must be used in the concentrated form. (4)

(d) One possible isomer of $CH_3CH_2CH_2OOCCH_3$ is a member of another homologous series. Give the IUPAC name of this isomer. (2)

4.2 Propene, formed in reaction II, is used as the monomer in the formation of the polymer polypropene (polypropylene). It is a polymer used in a wide variety of applications including packaging, textiles – especially in the production of fishing nets and artificial grass surfaces (astroturf), containers of various types and polymer banknotes. Polypropylene is a non-biodegradable polymer.

4.2.1 What is meant by the term 'monomer' in the context of the polymer chain? (2)

4.2.2 What type of polymerisation will these monomers undergo? (1)

4.2.3 Name the three steps that take place in this type of polymerisation. (3)

4.2.4 Using one monomer only, show how step I in the polymerisation process occurs. (3)

4.2.5 Suggest ONE advantage and ONE disadvantage of the non-biodegradable nature of polypropylene. (2)

4.2.6 Suggest TWO environmental problems caused by the disposal of polypropylene products. (4)

[29]

QUESTION 5

Hydrogen iodide (HI) is formed when hydrogen gas (H_2) and iodine gas (I_2) react in a closed 1,5 dm^3 container reaching dynamic chemical equilibrium at 300 °C in the presence of a catalyst according to the following balanced chemical equation.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g) \qquad \Delta H > 0$$

Initially 3,5 g of H_2 gas and 635 g of I_2 gas were placed in the container and then heated. Once equilibrium had been established, it was found that 1,45 mol of I_2 remained unreacted while 2,1 mol of HI gas was produced.

5.1 Define the term 'dynamic chemical equilibrium'. (3)

5.2 Calculate the amount (in mol) of H_2 and I_2 that were added to the container, before the container was heated to 300 °C. (4)

5.3 How much (in mol) I_2 (g) was thus used up in the reaction? (2)

5.4 Using the stoichiometric (balancing number) ratio in the equation, calculate:

5.4.1 the amount (in mol) of H_2 used up in the reaction. (2)

5.4.2 the amount (in mol) of H_2 left at equilibrium. (2)

5.5 Calculate the equilibrium concentrations of H_2, I_2 and HI. (4)

5.6 Calculate the equilibrium constant (K_c) for the reaction. (3)

5.7 The temperature of the system is increased to 500 °C. Explain how the increase in temperature will affect the value of the equilibrium constant for this reaction. (3)

5.8 Consider the following statement:

The volume of the reaction vessel was increased to 3 dm^3 whilst keeping the temperature constant. This causes the rate of the reverse reaction to increase to re-establish equilibrium within the system.

Analyse this statement and comment on its accuracy. (3)

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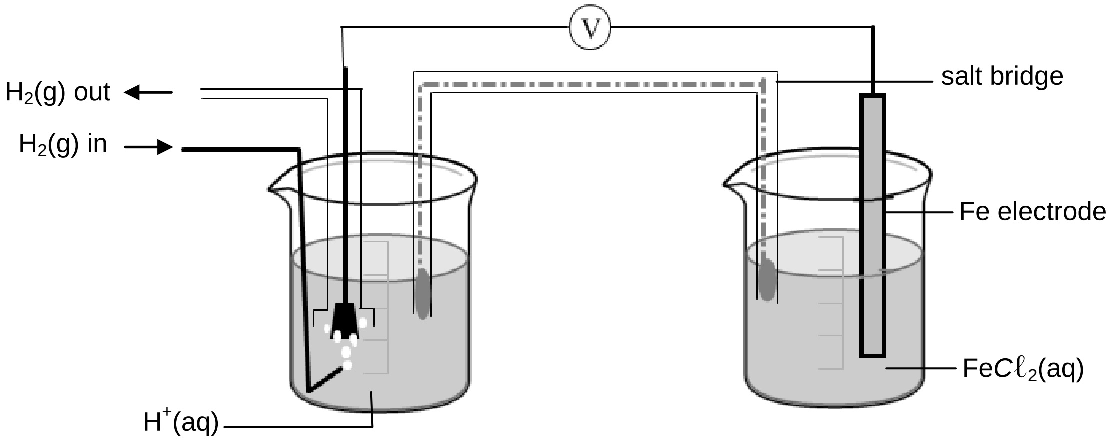
QUESTION 6

6.1 Consider the electrochemical cell that is shown in the diagram below. The cell consists of a standard H_2/H^+ half-cell that is joined to an Fe/Fe^{2+} half-cell by a salt bridge. The electrochemical cell is operating under standard conditions.



6.1.1 Describe what is meant by 'standard conditions', with particular reference to the conditions in the standard hydrogen electrode. (3)

6.1.2 What is the significance of the standard hydrogen electrode being assigned the electrode potential of 0,00 V? (2)

6.1.3 Hydrogen gas is bubbled through the electrolyte in the H_2/H^+ half-cell.

(a) What metal is usually used as the electrode and why is this metal chosen? (2)

(b) Will the hydrogen electrode be the anode or the cathode in this electrochemical cell? Explain your answer. (3)

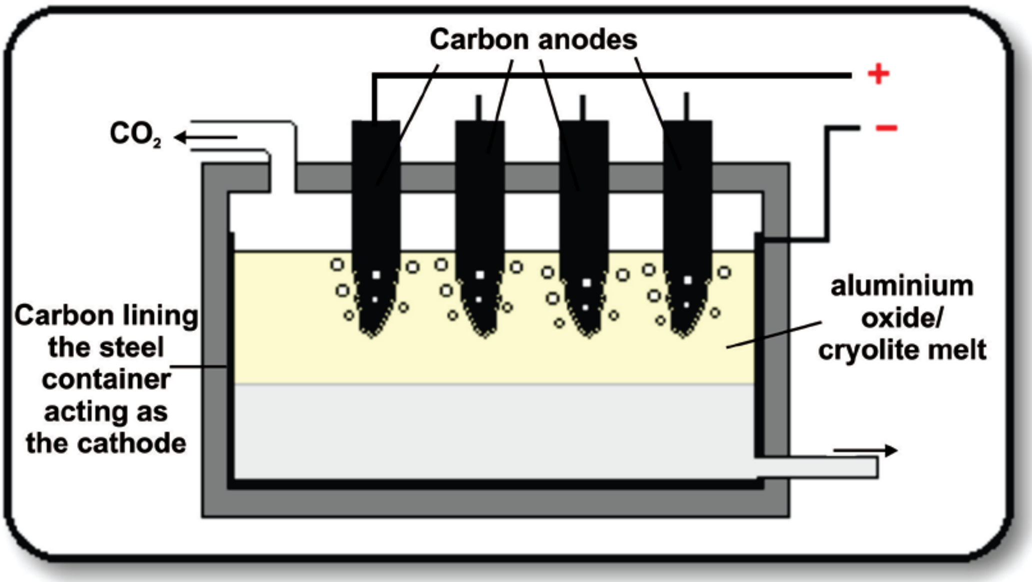
6.1.4 One of the functions of the salt bridge is to maintain half-cell neutrality. With reference to the changing ionic conditions within each half cell, explain how the salt bridge performs this task. (3)

[13]

QUESTION 7

Impure aluminium (bauxite) ore is imported into South Africa from Australia and contains approximately 65% aluminium oxide. The extraction of aluminium is done through an electrolytic technique which involves a three step process:

1. Extraction of the aluminium oxide from the mineral bauxite.
2. Mixing the molten aluminium oxide with a substance called cryolite.
3. Electrolysing the molten aluminium oxide/cryolite mixture to extract aluminium metal.



South Africa has four aluminium smelters situated in the coastal cities of Port Elizabeth and Richards Bay. The smelters contain giant electrolytic cells where carbon electrodes (anodes) are placed directly into the cell while carbon lining the steel casing of the cell is made the cathode.

7.1 What alternate name is given to the aluminium oxide present in the bauxite? (1)

7.2 What is the importance of mixing the aluminium oxide with cryolite and how would this be beneficial to the environment? (3)

7.3 Write down an equation for the half reaction taking place at the cathode. (2)

7.4 Carbon dioxide is one of the waste products produced by this process. How is carbon dioxide formed during this process? (2)

7.5 To produce aluminium, a considerable amount of electrical energy is needed. The average electricity consumed to produce 1 tonne (1 000 kg) of aluminium metal is 17 000 kilowatt-hours (kWh).

7.5.1 Calculate the energy needed to produce 1 tonne of aluminium metal. Express your answer in megajoules (MJ).

(1 kWh = 3 600 000 J 1 MJ = 1 000 000 J). (3)

7.5.2 The overall reaction taking place in the cell is represented by the equation:

$$2A\ell_2O_3 + 3C \longrightarrow 4A\ell + 3CO_2$$

The mass of carbon consumed in the carbon anodes to produce one tonne of aluminium metal is 225 kg.

(a) Determine how many moles of carbon are consumed. (3)

(b) Using the overall reaction, calculate the mass of Al produced. Express your answer in tonnes.

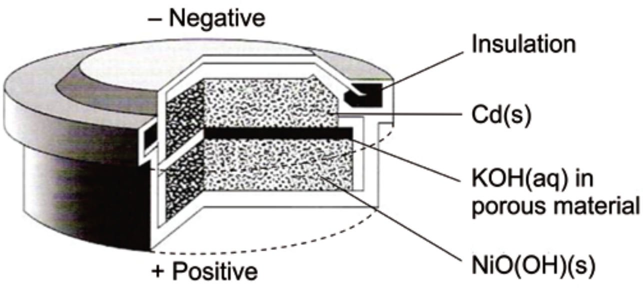
(1 tonne = 1 000 kg) (4)

7.6 State **two** advantages of having the aluminium smelters situated at the coast. (2)

[20]

QUESTION 8

The Nickel-Cadmium cell (Ni-Cd) is an example of the small and lightweight secondary cells that were widely used at one stage in portable equipment such as laptop computers and cellular phones. They were extremely durable and could have a lifespan of several years, far outliving the corresponding primary cell equivalents. A schematic drawing of the cell is shown below:



The half reactions for the nickel-cadmium cell are:

$$2NiO(OH) + 2H_2O + 2e^- \rightleftharpoons 2Ni(OH)_2 + 2OH^- \qquad E^\theta = +0{,}52V$$

$$Cd(OH)_2 + 2e^- \rightleftharpoons Cd + 2OH^- \qquad E^\theta = -0{,}81V$$

The cell delivers a potential difference of 1,25 V (not under standard conditions).

8.1 What is the difference between a primary and a secondary cell? (2)

8.2 Using the half reactions above, identify which substance will act as the anode and which will act as the cathode. Explain your choice. (4)

8.3 Write down the overall reaction for the cell when it is discharging. (2)

8.4 The Ni-Cd cell is a galvanic (voltaic) cell. How is this type of cell different to an electrolytic cell? (2)

8.5 A Ni-Cd cell which has an emf of 1,25 V can store a total amount of energy of 256 250 J when fully charged. It takes an average of 28 hours to discharge completely when in use before having to be recharged.

8.5.1 Define 'cell capacity'. (2)

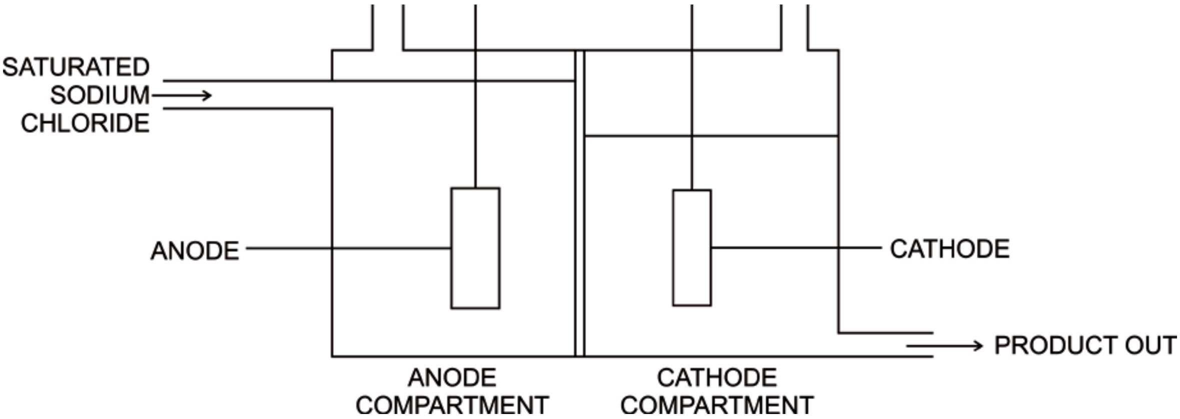
8.5.2 Calculate the average current it is able to deliver whilst discharging. (4)

8.6 Besides the obvious benefits of nickel-cadmium cells mentioned earlier, there are several disadvantages associated with these cells being used as batteries. Suggest TWO possible disadvantages that could be associated with these cells. (2)

[18]

QUESTION 9

The diagram below shows a diaphragm cell which is used in the chlor-alkali industry. Saturated sodium chloride solution flows into the anode compartment filling up both the anode and cathode compartments simultaneously. The cathode compartment, however, is kept at three-quarters that of the volume of the anode compartment. Chlorine gas is produced at the anode while the two compartments are separated by a diaphragm.



9.1 What alternative name is given to the saturated sodium chloride solution? (1)

9.2 What material is most commonly used as the diaphragm in this cell? (1)

9.3 Describe the energy conversion that takes place in this cell. (2)

9.4 Write down equations to represent the following reactions for this cell:

9.4.1 anode half reaction (2)

9.4.2 cathode half reaction (2)

9.4.3 nett cell reaction (2)

9.5 Explain the significance of having the cathode compartment only three-quarters filled with water in this cell. (3)

9.6 Sodium ions (Na^+) are found in the cathode compartment of the cell.
With reference to the Table of Standard Electrode Potentials, explain why sodium metal does not form at the cathode. (2)

9.7 The diaphragm cell has slowly been phased out of the chlor-alkali industry and has been replaced with the more modern membrane cell which has a fluoro polymer membrane which separates the two compartments.

9.7.1 What is the difference in the functioning of the fluoro polymer membrane when compared to the diaphragm cell? (2)

9.7.2 Environmentally, the membrane cell is preferred to the diaphragm cell. Give TWO reasons as to why this is so. (4)

9.8 The following data was obtained from a study comparing the efficiency of the diaphragm and membrane cells within the chlor-alkali industry.

	Diaphragm cell	**Membrane cell**
Purity of NaOH produced (%)	15	35
Amount of energy consumed by cell per 1 000 tons of $C\ell_2$ produced (kWh)	31,75	29,33
Amount of water used per cell per 1 000 tons of $C\ell_2$ produced (litres)	4 200	1 550

Using the data above, draw a conclusion as to which cell would be more cost effective for the chlor-alkali industry. Explain your answer. (3)

9.9 A chemical engineer wishes to produce 11 000 dm^3 of chlorine gas at STP by running the diaphragm cell for a total of 17,5 hours. Calculate the average current that needs to be delivered to this cell in order to produce this volume of gas in the allotted time. (6)

(The charge required to transfer one mole of electrons (Faraday) = 96 500 $C{\cdot}mol^{-1}$, Avogadro constant = $6,02 \times 10^{23}$ mol^{-1})

[30]

Total: 200 marks