NATIONAL SENIOR CERTIFICATE EXAMINATION
EXEMPLAR 2008

PHYSICAL SCIENCES: PAPER II

Time: 3 hours 150 marks

PLEASE READ THE FOLLOWING INSTRUCTIONS CAREFULLY

1. This paper consists of:
   - a question paper of 16 pages
   - a data and formula booklet of 3 pages (i – iii)

   Make sure that your question paper is complete.

2. Remove the pages of data and formulae from the middle of this question paper.

3. Use the data and formulae whenever necessary.

4. Read the questions carefully.

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

6. Questions 1, 2, 3, 4, 6 and 7 are compulsory for all candidates. Questions 5 and 8 contain options.

   In Question 5, answer either 5A or 5B.
   In Question 8, answer either 8A or 8B.

QUESTION 1

Consider the organic compounds below, represented by their condensed/ molecular formulae:

C_3H_8	$C_2H_5COOCH_3$		$CH_3CH(CH_3)CH_2CH_3$
C_2H_5OH	C_4H_6	$CH_3C\ell$	CH_3COCH_3

1.1 Select one compound that contains a double bond between two carbon atoms. (1)

1.2 Select one compound that is an ester and draw its structural formula. (2)

1.3 Select an alkane with less than five carbon atoms and write down an equation for a substitution reaction of this alkane with HCℓ. (2)

Propanone reacts with Iodine in the presence of an acid catalyst according to the following chemical equation:

$CH_3COCH_3(aq) + I_2(aq) \rightarrow CH_3COCH_2I(aq) + HI(aq)$

1.4 Explain why this can be referred to as a substitution reaction. (1)

The rate at which this reaction takes place can be measured by finding the time taken for the iodine colour to disappear. You can follow the rate of the reaction using a colorimeter.
A colorimeter is an instrument which **compares** the amount of light passing through a solution with the amount which can pass through a sample of pure solvent.

Digital Colorimeter

This amount will be recorded as: **'% of light transmitted'** in this experiment.
The propanone and iodine are mixed with the acid catalyst in a small container which is immediately placed in the colorimeter. Initially the solution is very dark but as time passes the solution gradually clears and the % of light transmitted increases and is displayed on the digital colorimeter and **recorded** every 15 seconds.

This process is carried out four times with four different concentrations of iodine solution in an effort to determine the effect of changing the concentration of iodine on the reaction rate.
The results of this process have been recorded in the following four tables.

Colorimeter results for the reaction between propanone and iodine:

Table 1 $[I_2] = 0{,}01\ mol \cdot dm^{-3}$	
Time (s)	**% of light transmitted**
0	3
15	23
30	39
45	52
60	65
75	75
90	80
105	80
120	80
135	80
150	80

Table 2 $[I_2] = 0{,}015\ mol \cdot dm^{-3}$	
Time (s)	**% of light transmitted**
0	3
15	27
30	45
45	61
60	73
75	80
90	80
105	80
120	80
135	80
150	80

Table 3 $[I_2] = 0{,}02\ mol \cdot dm^{-3}$	
Time (s)	**% of light transmitted**
0	3
15	33
30	55
45	70
60	80
75	80
90	80
105	80
120	80
135	80
150	80

Table 4 $[I_2] = 0{,}025\ mol \cdot dm^{-3}$	
Time (s)	**% of light transmitted**
0	3
15	44
30	66
45	80
60	80
75	80
90	80
105	80
120	80
135	80
150	80

1.5 Write down a suitable investigative question from what has been described. (1)

1.6 Care must be taken to control certain variables. Explain why the temperature must be kept constant. (1)

1.7 Name another variable that must be kept constant. (1)

1.8 On the **same system of axes** plot a graph of '% of light transmitted' versus time for each table. Join the points for each set of results and label each line clearly. (8)

1.9 Explain why all the graphs eventually become **horizontal**. (1)

1.10 Copy the following table into your book and fill in the appropriate values:

Time taken to reach 80% transparency (s)	**Concentration of Iodine ($mol.dm^{-3}$)**	**Rate** $\frac{[I_2]}{t}$ **(s^{-1})**

(4)

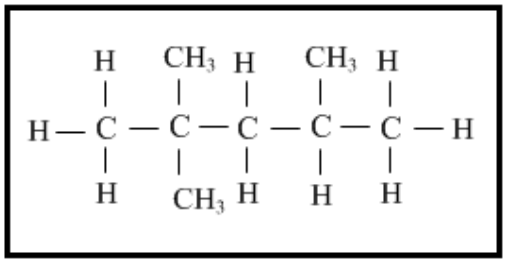
1.11 According to the values in your table, describe the relationship between the reaction rate and the concentration of the iodine. (1)

1.12 Explain the trend you described in 1.11 by referring to the behaviour of the reacting molecules in the solution. (3)

[26]

QUESTION 2

Petrol with an octane rating of 98 is made up of 98% 2,2,4 – trimethylpentane.
The structural formula of 2,2,4 – trimethylpentane is given below.



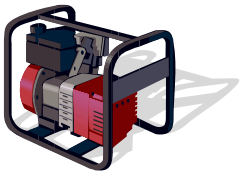
2.1 Explain why 2,2,4 – trimethylpentane is called a **saturated** hydrocarbon. (1)

2.2 It is given that 2,2,4 – Trimethylpentane is an **isomer** of octane.

2.2.1 Explain what is meant by the term isomer. (1)

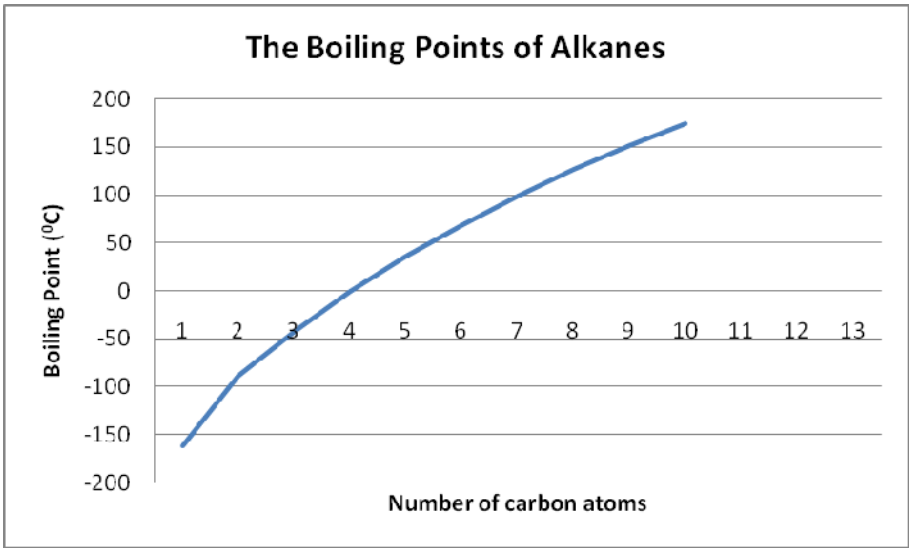
2.2.2 Write down the condensed formula for another **branched** isomer of octane and give its IUPAC name. (2)

The graph relates the boiling points of alkanes to the number of carbon atoms in the chain.



Businesses have lost a lot of money due to the recent unexpected power outages in South Africa. Investing in alternative power supplies such as generators is important to avoid similar losses in the future.

The preferred fuel for generators is **diesel** rather than petrol because diesel produces more power per litre than petrol does. Diesel is composed of heavy hydrocarbons, with at least **12 carbon atoms** per molecule.



2.3 Referring to the graph above, describe the relationship between the boiling point and the number of carbon atoms in molecules of the alkanes. (1)

2.4 Read off the approximate boiling point of **petrol** and use the graph to estimate the value for the boiling point of **diesel**. (2)

2.5 Explain fully the above trend in terms of the relative strength of the intermolecular forces between the molecules. (3)

[10]

This question has two options. DO EITHER 3A OR 3B. DO NOT answer both questions.

QUESTION 3A

Polyethylene is an addition polymer, and is formed by the process of the joining of monomers to create a very long chain.

3.1 Draw the structural formula of the monomer of polyethylene. (1)

3.2 In the formation of polyethylene, the process is initiated by a free radical.
Explain what is meant by a free radical. (1)

3.3 Use a diagram to explain how a free radical adds to the double bond of a monomer to create a free radical with a longer chain during the propagation step of this reaction. (2)

3.4 Explain **in words**, one way in which this process can be terminated. (2)

High density polyethylene (HDPE) is often used to make the casing for lead acid batteries.

> Lead acid batteries are made up of sheets of lead immersed in a 'bath' of sulphuric acid. Usually the whole assembly is contained in a robust plastic case made of **polypropylene** or **polyethylene**.

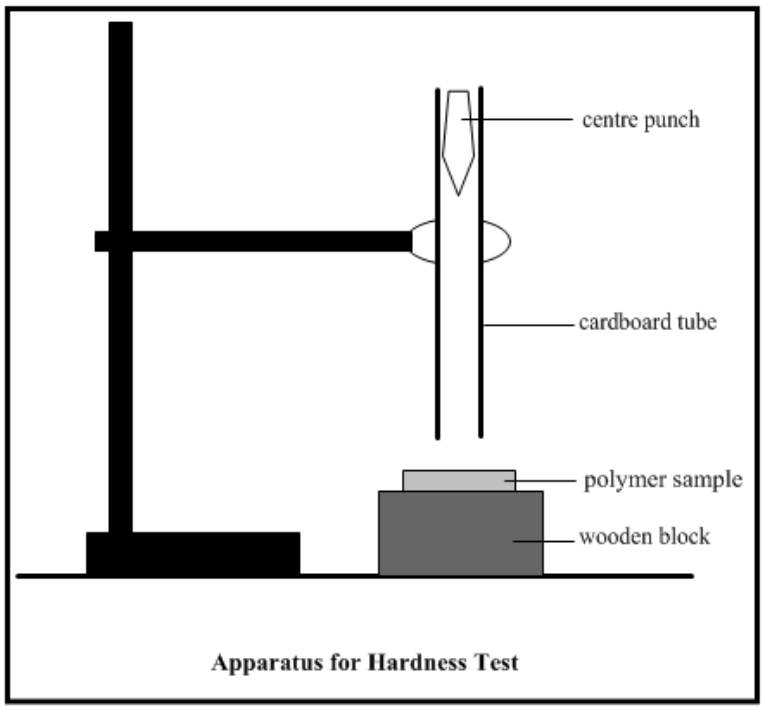
3.5 HDPE is a thermoplastic. Describe two properties of thermoplastics that make HDPE a suitable material for the case of a lead acid battery. (2)

3.6 HDPE is used rather than LDPE(low density polyethylene), which is too soft and has a low melting point. Describe the difference in their chain structures and how this difference explains these properties. (2)

3.7 Give two reasons why an **iron** casing would not be suitable for the lead acid battery. (2)

A **battery case** must be hard and resistant to corrosion by sulphuric acid.
LDPE, HDPE, polypropylene (PP) and polyvinylchloride (PVC) are all addition polymers that are resistant to the sulphuric acid used in lead acid batteries.

The following apparatus is used to compare the hardness of samples of these different polymers. The centre punch is allowed to fall down the cardboard tube and make an indentation in the polymer sample. The results of the investigation are recorded in the table.



Apparatus for Hardness Test

Name of Polymer	**Part 1 Depth of indentation (mm) at 20 ^{o}C**	**Part 2 Depth of indentation (mm) at 40 ^{o}C**
Low density Polyethylene (LDPE)	4	7,1
High density Polyethylene (HDPE)	2,4	4,8
Polyvinylchloride (PVC)	2,3	2,5
Polypropylene (PP)	1,9	2,1

3.8 State a suitable hypothesis for:

3.8.1 **Part 1** of this experiment. (1)

3.8.2 **Part 2** of this experiment (1)

3.9 State, giving a reason for your answer, whether or not the results in the table support your hypothesis to:

3.9.1 **Part 1** of this experiment. (1)

3.9.2 **Part 2** of this experiment (1)

3.10 Identify two factors other than temperature that should be kept constant throughout this investigation. (2)

3.11 What can you deduce about the hardness of these addition polymers by comparing the results to Part 1 and Part 2? (1)

3.12 Why should the case of a car battery be tested at different temperatures? (1)

[20]

OR

QUESTION 3B

Carbohydrates include sugars and their polymers.

3.1 Name the process in which plant cells use sunlight to produce carbohydrates from carbon dioxide and water. (1)

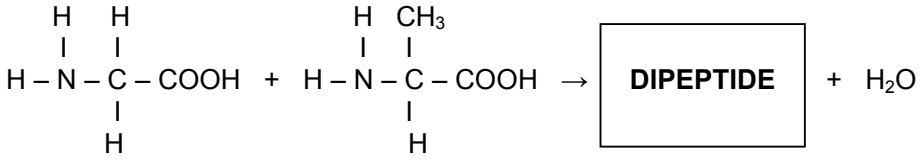
3.2 Glucose ($C_6H_{12}O_6$), is a common monosaccharide. Draw one of the possible ring structural formulae of glucose. (2)

3.3 Glucose is a monomer of larger polysaccharide molecules.
Write down the **name** and **function** of one of the polysaccharide molecules of which glucose is monomer. (2)

Proteins are biological polymers.

3.4 What are the monomers of proteins called? (1)

3.5 Below is an incomplete chemical equation. On the left hand side are two protein monomers that combine to form a dipeptide and water:



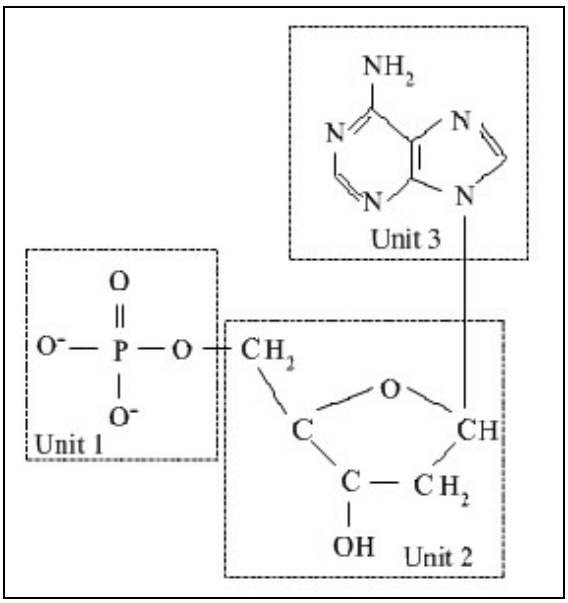
3.5.1 Name the two monomers on the left hand side. (2)

3.5.2 Draw the structural formula of the dipeptide, labelling the **peptide bond** clearly. (3)

3.5.3 Where are the two monomers most likely be to be found in the tertiary structure of the protein?
Explain your answer by referring to the structure of each monomer. (3)

DNA is a polymer belonging to the nucleic acids. The monomers that make up the nucleic acids are called nucleotides.

3.6 Identify the units labelled (1), (2) and (3) in the nucleotide below: (3)

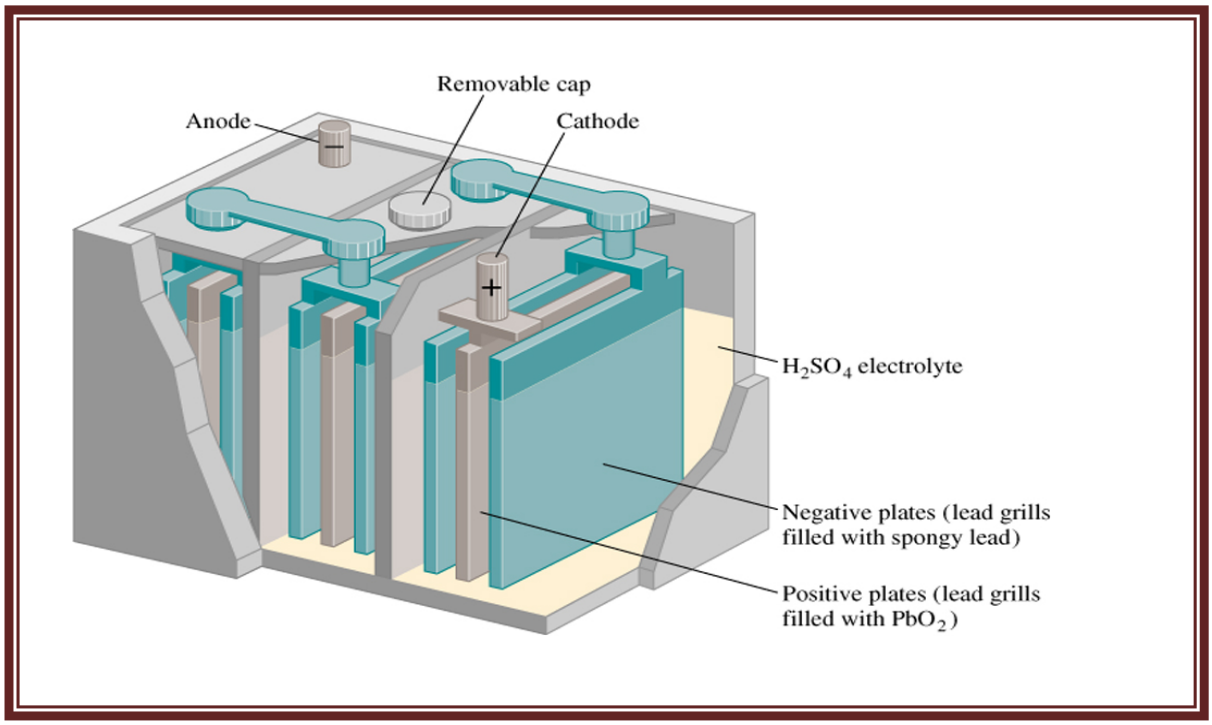


3.7 Briefly explain the **function** of DNA in the human body. (3)

[20]

QUESTION 4

Diagram 1



Study the above diagram of a lead acid battery and answer the questions that follow:

4.1 What is meant by the term oxidation and where does it occur in the above diagram? (2)

4.2 Describe the role of the electrolyte in the above battery. (1)

4.3 Describe one function of the removable cap. (1)

Below are the two half reactions that take place in each cell of the battery during discharge:

$$Pb(s) + SO_4^{2-}(aq) \rightarrow PbSO_4(s) + 2e^- \qquad E^{\Theta} = -0,36V$$
$$PbO_2(s) + SO_4^{2-}(aq) + 4H^+(aq) + 2e^- \rightarrow PbSO_4(s) + 2H_2O(\ell) \qquad E^{\Theta} = 1,69V$$

4.4 Write down the net cell reaction using the above half reactions. Include the phase of each substance in your equation. (2)

4.5 Calculate E^{θ}_{cell}, for one cell in the lead acid battery. Write down an appropriate equation and show your working. (3)

4.6 What is the total emf of the battery in Diagram 1? Explain your answer. (2)

A lead acid battery is a secondary cell.

4.7 Explain why it is called a secondary cell and describe what happens when it is recharged. (3)

4.8 Why is the density of the electrolyte an indication of the state of the cell? (2)

Although lead acid batteries may be charged and re-charged many times, each cycle places small stresses on the lead plates, which eventually distort. This causes short circuits within the battery so that the battery is unable to hold stored energy for a prolonged period and the battery needs to be replaced.

Used lead acid batteries contain mostly lead, acid and plastic.

4.9 Write a short paragraph explaining why these components are harmful to the environment and how this is addressed by recycling. (6)

Batteries come in many different forms and types and have had an undeniable impact on our lives.

4.10 Describe four examples of the positive impact of batteries on humans. In each case name the type of battery and explain how it has benefited us. (4)

[26]

QUESTION 5

Below are values obtained in an investigation into the relationship between the temperature and the internal resistance of a lead acid battery.

Lead acid battery:

Internal resistance vs Temperature

Temperature (°C)	Internal Resistance (Ohms)
-10	2,5
-5	2,4
0	2,3
5	2,2
10	2,1
15	2
20	1,9
25	1,8
30	1,7
35	1,6
40	1,5

5.1 Write down a suitable hypothesis for this investigation. (2)

5.2 Identify the independent variable. (1)

5.3 Plot a graph of temperature vs internal resistance that illustrates the trend in this investigation (6)

5.4 Write down a suitable conclusion based on the data analysed. (2)

People living in cold climates sometimes have trouble starting their cars because the battery has 'gone dead.'

5.5 Use the results of the investigation to explain why this is so. (2)

5.6 Describe two **other** factors that can affect the rate of the chemical reaction that takes place in a lead acid battery. (2)

5.7 The reserve capacity of a battery gives the time in minutes that the battery would continue to supply 25 A of current should the alternator of the vehicle fail.

Consider a 12 V, 50 Ah battery that has a reserve capacity of 100 minutes. Calculate

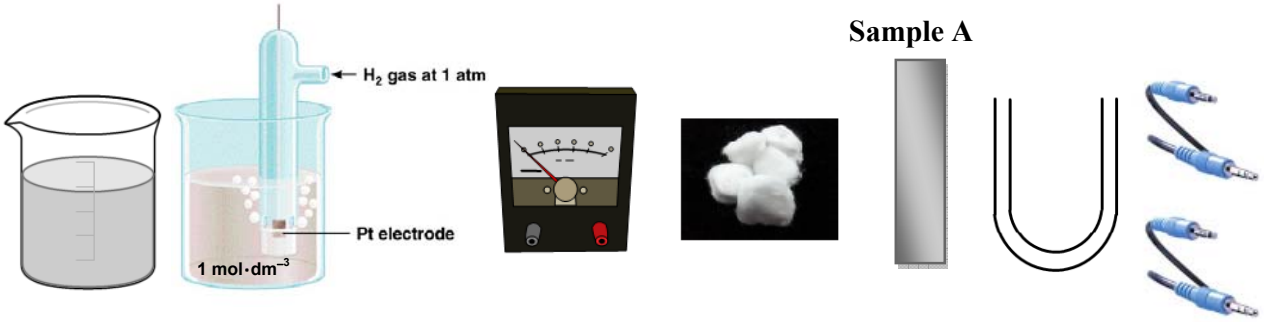
5.7.1 the charge this battery can produce in this time. (2)

5.7.2 the energy that will be delivered to the circuit in this time. (2)

[19]

QUESTION 6

Your teacher gives you an unknown sample of metal, **Sample A**. The Standard Reduction Potential of this metal needs to be determined using the apparatus provided.



6.1 Draw a labelled experimental **setup** for measuring the Standard Reduction Potential of this metal. (4)

6.2 Describe three **measurements** you need to make before you can connect the voltmeter in the circuit. (3)

6.3 You obtain a voltmeter reading of 2,37 V. What metal is sample A made of? (1)

6.4 Read the article entitled '**Alternative Power Sources for South African Business**' and answer the question that follows:

Alternative Power Sources for South African Business:

In recent months South Africa has experienced regular load shedding and many businesses have lost a lot of money due to the power outages.

Investing in alternative power supplies such as diesel generators and/ or battery systems (called a UPS or uninterrupted power supply) has become a priority to avoid such losses in the future.

Diesel generators require the lowest initial capital outlay, but because of the high cost of the diesel fuel, they are more expensive to run than grid power or UPS.

The UPS is made up of three components. The first component is the batteries themselves. The inverter is the second component that converts the d.c. that the batteries supply to a.c. that can be used in the business during outages. The third component is the charger that uses grid power to charge the batteries.

The UPS is expensive to install, but because it charges from the grid, it has much lower running costs than a diesel generator. UPS has the added advantage that the batteries can also be charged by wind turbines or solar panels.

You have a choice between a diesel generator and a system of lead – acid batteries as a back up power supply for your business.

Write a **6 point** recommendation to your business partners justifying your choice in terms of cost effectiveness and its effect on the environment.

Remember to **address the weaknesses** of your choice too. (11)

[19]

QUESTION 7

7.1 A lead acid battery is a galvanic cell. How does a galvanic cell differ from an electrolytic cell? (2)

There are three different industrial processes that use electrolytic cells to produce chlorine from brine (salt water). These processes are known as the diaphragm process, the mercury cathode process and the membrane process.

Below is a diagram of a membrane cell.

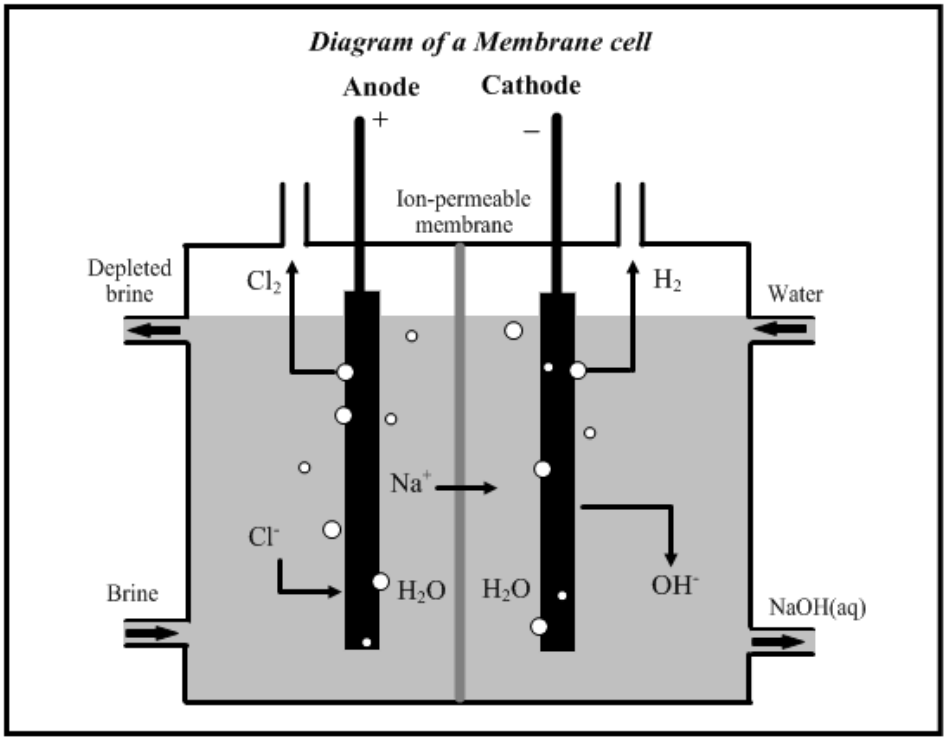


Diagram 2

7.2 Use **equations** from the Table of Reduction Potentials to write down the half-reactions taking place at the:

7.2.1 anode and the (1)

7.2.2 cathode (1)

7.3 Use **values** from the Table of Reduction Potentials to show that this reaction is **not** spontaneous. (3)

7.4 Use Diagram 2 to identify the **names** of the three useful products of this cell and write down a use of each one. (3)

7.5 The mercury cathode process and the diaphragm process are currently being phased out. Explain why these two processes are both harmful to the environment. (2)

[12]

This question has two options. DO EITHER 8A OR 8B. DO NOT answer both questions.

QUESTION 8A

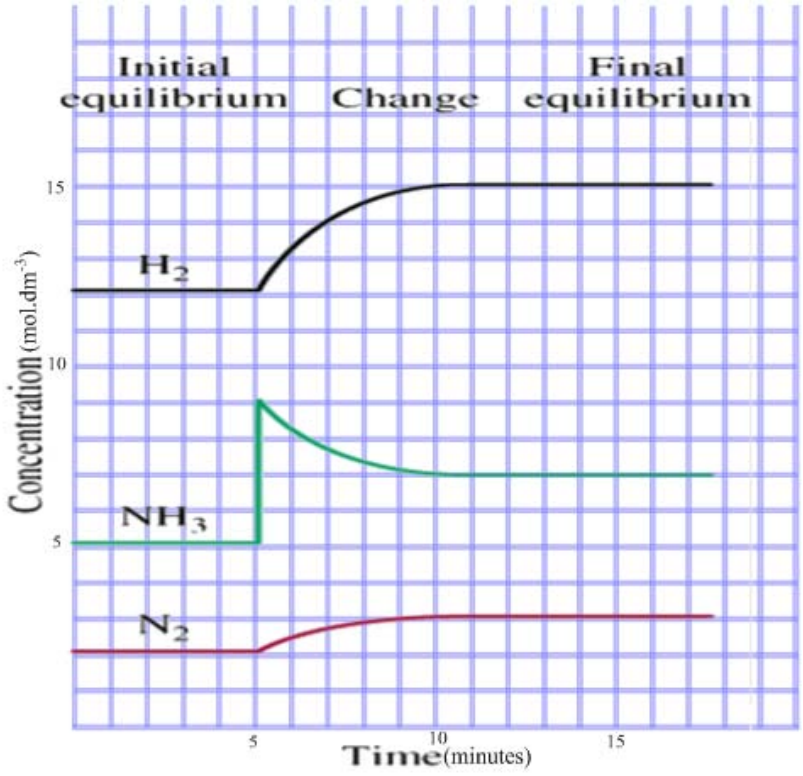
The Haber process was developed near the beginning of the twentieth century to produce ammonia gas. In this process nitrogen and hydrogen gas react according to the following equation:

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

The following graph illustrates the change in concentration of nitrogen, hydrogen and ammonia over a period of time for the Harber Process:

Concentration versus time graph for the reaction

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$



The initial equilibrium of the system was disturbed after 5 minutes by **adding ammonia gas** to the sealed container.

8.1 Explain why the concentration of nitrogen and hydrogen started to increase after 5 minutes. (2)

8.2 After what time was the final equilibrium established? (1)

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

8.4 Calculate the value of the equilibrium constant for the final equilibrium. (2)

8.5 Without doing any calculations, write down the value of the equilibrium constant during the first 5 minutes. Explain how you got to your answer. (2)

The ammonia produced in the Haber process is used to make ammonium nitrate.

8.6 Write down the **chemical formula** of ammonium nitrate. (1)

The ammonium nitrate is used to make fertilizers because it is readily soluble in water and contains a high percentage of nitrogen.

8.7 Calculate the percentage of nitrogen by mass in ammonium nitrate. (2)

8.8 Evaluate the positive and negative environmental impacts of the use of nitrogen fertilizer. (4)

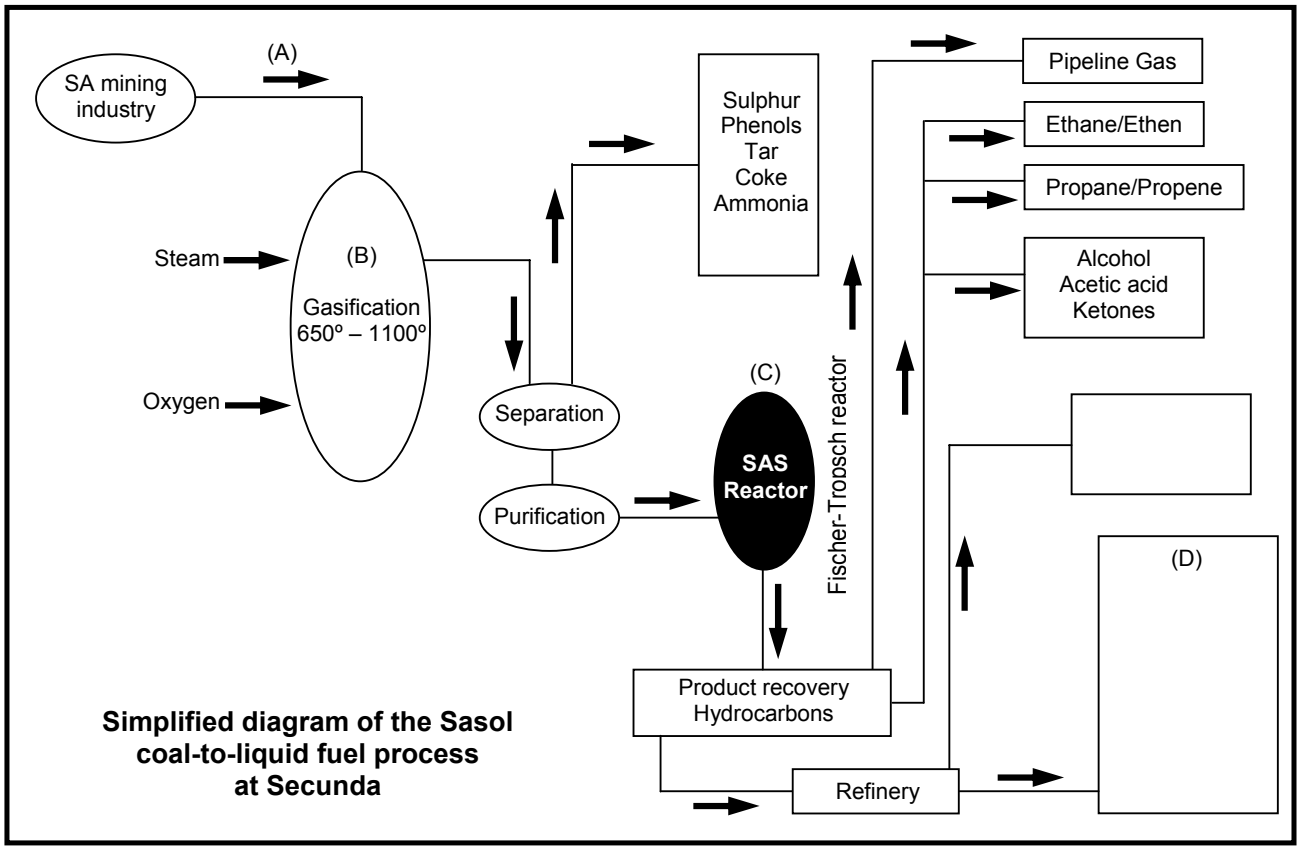
8.9 Discuss briefly what can be done to prevent eutrophication. (2)

[18]

OR

QUESTION 8B

Sasol is the major producer of chemicals in South Africa. It employs 31 000 people and has an annual turnover of 41 billion rand.
Study the diagram below of the Sasol plant in Secunda and answer the questions that follow.



Simplified diagram of the Sasol coal-to-liquid fuel process at Secunda

8.1 What is the name of the raw material for this plant that enters the process at **(A)** in the diagram. (1)

8.2 Write down the formulae of the reactants in the gasification process at **(B)** (3)

8.3 Synthesis gas is a mixture of CO and H_2 which is converted to hydrocarbons in the SAS reactor **(C)**, according to the general equation:

$$nCO + (2n+1)H_2 \rightarrow C_nH_{2n+2} + nH_2O$$

Write down the Fischer-Tropsch synthesis reaction for the production of **butane** from CO an H_2. (2)

8.4 The fuels at **(D)** are separated by a physical process.

8.4.1 Name this process. (1)

8.4.2 Describe the physical property of these fuels that makes the process possible. (2)

8.5 At **(E)** ethane is steam cracked in a high temperature furnace to produce ethene.

8.5.1 Explain why ethene is an important feedstock for the polymer industry. (1)

8.5.2 Identify **another** monomer in the diagram that is also an important feedstock for the polymer industry. (1)

8.6 Post-gasification streams contain sulphur as a pollutant in the form of $SO_2(g)$ and $H_2S(g)$ which can be released into the atmosphere.

8.6.1 Where does the sulphur come from in this process? (1)

8.6.2 Why must the $H_2S(g)$ be removed before the synthesis gas reaches the SAS reactor at **(C)**? (1)

8.6.3 Balance the equation below and use it to explain one way $H_2S(g)$ can be removed from the post-gasification streams.

$$SO_2(g) + H_2S(g) \rightarrow S(s) + H_2O(\ell)$$

(3)

8.6.4 Describe one **health and safety** hazard that Sasol's Fischer-Tropsch process poses for *some* of its 31 000 employees and what precautions could be taken to cope with it. (2)

[18]

TOTAL FOR THIS PAPER: 150 MARKS