NATIONAL SENIOR CERTIFICATE EXAMINATION
NOVEMBER 2009

PHYSICAL SCIENCES: PAPER II

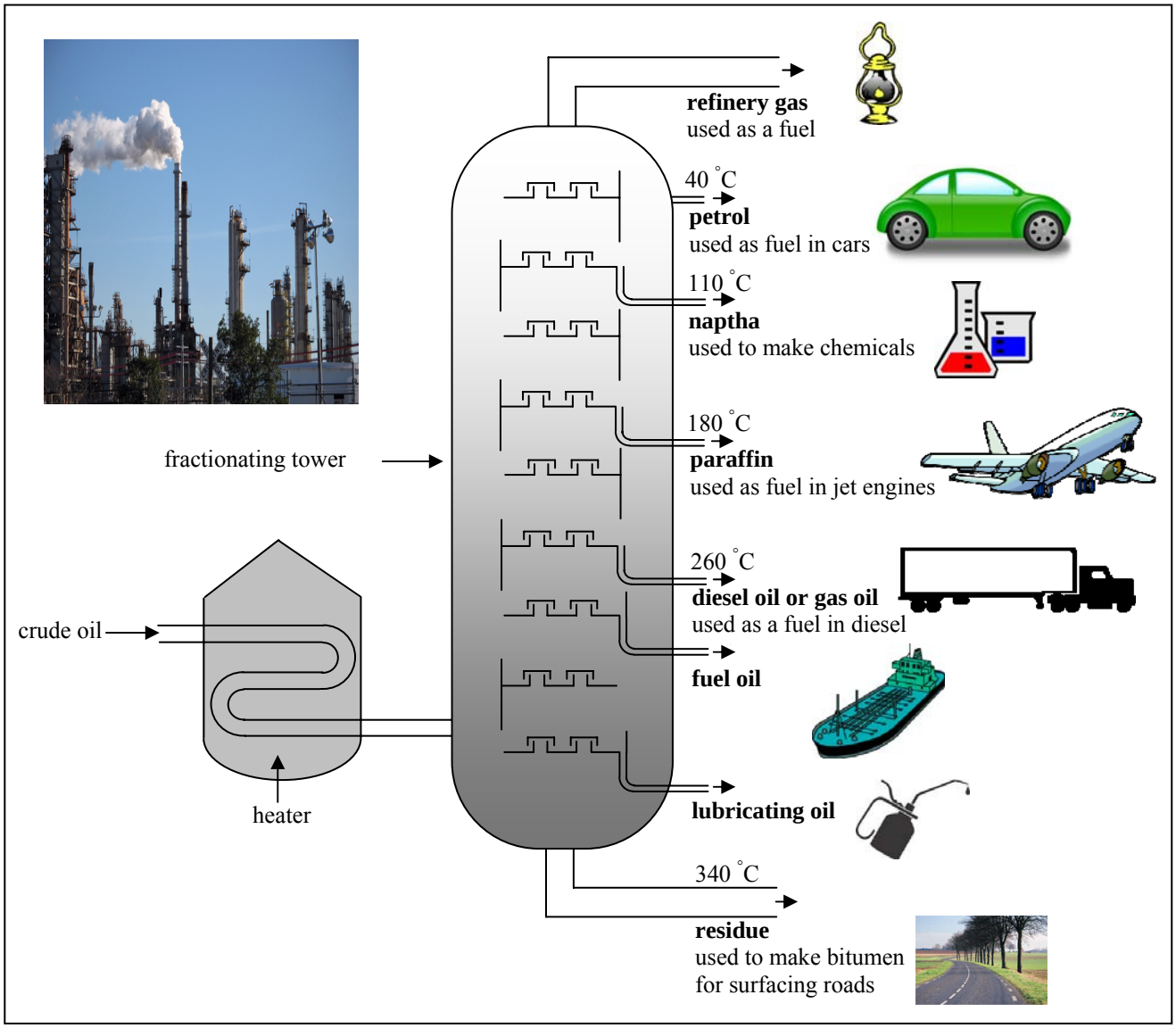
Time: 3 hours 200 marks

PLEASE READ THE FOLLOWING INSTRUCTIONS CAREFULLY

1. This paper consists of a question paper of 14 pages and a four page green insert 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.

QUESTION 1 CRUDE OIL

1.1 Crude oil is a mixture of hydrocarbons. The crude oil is separated into its main fractions in a fractionating tower by a process called fractional distillation. The fractions that are produced are illustrated below:



[Based on Earl, B. & Wilford, L. 1995 *GCSE Chemistry.* John Murray London]

A large proportion of the hydrocarbons in crude oil are alkanes. A number of alkanes are given in the table below:

Alkane	Boiling Point (°C)
Methane	–164
Ethane	–87
Propane	–42
Butane	0
Pentane	36
Hexane	69

1.1.1 Is ethane a solid, liquid or gas at room temperature? (1)

1.1.2 Name the forces that exist between the hexane molecules at room temperature. (2)

1.1.3 Describe the trend in boiling point that is evident from the data. (2)

1.1.4 Explain why this trend occurs in this type of molecule. (5)

1.2 Pentane is a compound that can be extracted from crude oil. It is used as a raw material to make other chemicals. It can, for example, undergo a reaction to form a halopentane which can be used in fire extinguishers.

Pentane can react with chlorine by a free radical mechanism to form a mixture of trichloropentanes.

A simple reaction might be:

$$C_5H_{12} + C\ell_2 \rightarrow C_5H_9C\ell_3 + HC\ell$$

1.2.1 Draw the structural formula for 1,2,2-trichloropentane. (3)

1.2.2 What type of reaction has taken place to form 1,2,2-trichloropentane? Explain your answer. (3)

1.2.3 Balance the equation. (4)

1.2.4 Explain the meaning of the phrase 'free radical'. (2)

1.2.5 Is this reaction spontaneous? Explain. (2)

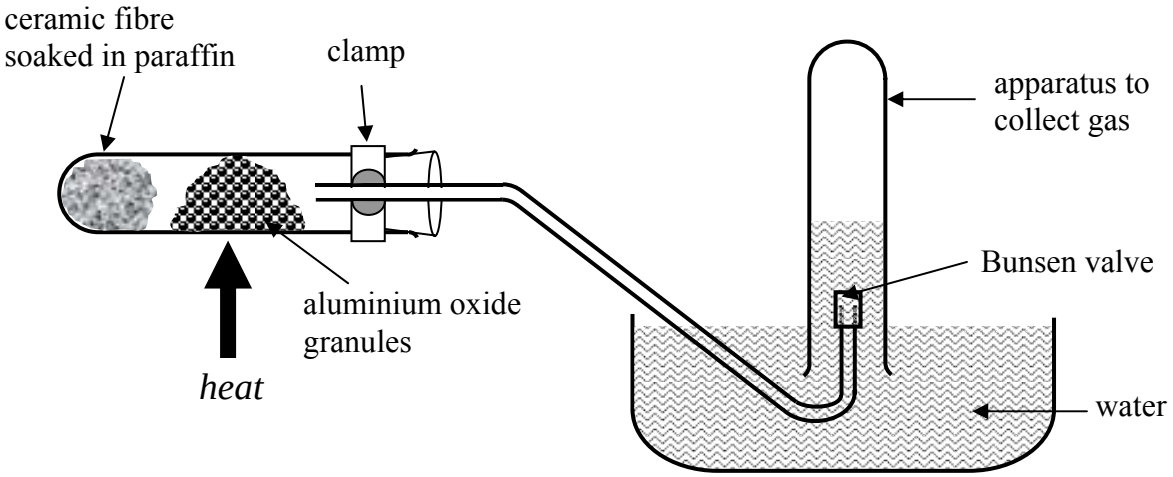
1.2.6 (a) When pentane undergoes combustion it reacts with oxygen to form carbon dioxide and water.
Can the combustion of pentane be classified as a redox reaction? (1)

(b) Explain the reasoning for your answer in 1.2.6 (a). (2)

1.3 The petroleum industry takes long chain molecules and subjects them to a process called 'cracking'. The process breaks these longer chain molecules into shorter chains. This process can be demonstrated in the laboratory by using the apparatus shown below. Paraffin, which is the reactant, is a mixture of alkanes.

The apparatus is used to 'crack' the alkanes in the paraffin using aluminium oxide as a catalyst.

Apparatus for the catalytic cracking of an alkane



1.3.1 Is the gas produced soluble in water? Explain your answer. (2)

1.3.2 (a) Can we use the term saturated when referring to an alkane? (1)
(b) Explain your answer to 1.3.2 (a). (2)

1.3.3 Are the forces between the molecules of the product likely to be weaker or stronger than the forces between the molecules of the reactant (paraffin)? Explain your answer. (3)

1.3.4 The gas produced is collected and a sample of the gas is bubbled through a dilute solution of bromine.

(a) Describe what you would observe when this occurs. (2)
(b) This test can be used to find out about the structure of a molecule. What does it tell the chemist about the molecule's structure? (2)
(c) Explain how the chemist is able to deduce this [1.3.4 (b)] about the structure. (4)

43 marks

QUESTION 2 ORGANIC REACTIONS – ETHANOL

Large volumes of alcohol are produced annually worldwide. Some of this production comes from fermentation processes and a portion of this alcohol is used for alcoholic beverages. Most alcohol is produced from other sources like natural gas and from petroleum. Ethanol production from this source is not legally allowed to be sold for purposes of making alcoholic beverages.

2.1 State two possible reasons why industrial alcohol is mainly produced from natural gas and petroleum. (2)

2.2 Is the ethanol produced by fermentation different from the ethanol produced industrially? Explain your answer. (3)

Brazil is a model country for the production of alcohol from renewable sugar cane. Most of the cars and trucks on the roads of Brazil run on ethanol and not on petrol or diesel. People are divided as to whether the ethanol from sugar cane is really a better option for the environment than using petrol.

2.3 Argue, using scientific principles that ethanol from sugar cane is a better fuel source than petrol for the environment. (4)

2.4 Ethanol can be used in a number of industries. One potential use of ethanol is in the manufacture of fragrances by making esters.

During a science practical one of the tasks is the preparation of an ester. You are expected to choose appropriate chemicals that may be used with ethanol in a reaction to make the ester.

The chemicals you may choose from are:

concentrated sulphuric acid, propanone, propanoic acid and propanal.

For the following question, write down the letter that corresponds to the correct answer:

2.4.1 The function of the sulphuric acid in this reaction is to …

A oxidise the ethanol to form the free radical.
B reduce the ethanol to form the free radical.
C dehydrate the ethanol.
D catalyse the reaction. (2)

For the following question, write down the letter that corresponds to the correct answer:

2.4.2 The process involves …

A the ethanol losing –H and gaining propanone.
B the ethanol losing –H and gaining propanal.
C the formation of water.
D propanoic acid losing a CH_3 fragment. (2)

2.4.3 What would you observe at the end of this experiment? (2)

2.4.4 Would you classify the ester as volatile at room temperature? Explain your answer. (2)

17 marks

QUESTION 3 HYDROGEN PEROXIDE

Hydrogen peroxide (H_2O_2) undergoes decomposition to form water and oxygen gas. Usually this is a slow process, but the reaction can be catalysed by using one of a number of substances.

Michael and Thembi are working on a school project to evaluate 3 different catalysts to see how effectively they work to bring about this decomposition. They have been asked to rank the 3 catalysts in terms of how quickly they bring about the decomposition.

The catalysts that they have been asked to evaluate are MnO_2, PbO_2 and Fe_2O_3 powders.

For the following question, write down the letter that corresponds to the correct answer:

3.1 Which one of the following statements could be a suitable hypothesis for this task?

A Fe_2O_3 catalyses the reaction faster than PbO_2 whilst MnO_2 is the worst catalyst for this reaction.
B The powders act to speed up the reaction.
C The powders act to speed up the reaction relative to the uncatalysed reaction.
D Iron oxide powder is the best catalyst. (2)

3.2 Suggest a suitable physical quantity that Michael and Thembi are going to measure in order to carry out the experiment. (2)

3.3 Write down a suitable method for Michael and Thembi to follow. (Use point form) (6)

3.4 List the key apparatus that they will need. (2)

Michael suggests that they add the catalyst to the peroxide and time the experiment once for each catalyst. Thembi says that they will need to repeat the experiment at least 3 times for each catalyst. Michael argues that it is a simple experiment and that doing the experiment once will be sufficient and not be a waste of time and chemicals. Thembi argues that there must be a better reason to repeat the experiment from a scientific point of view.

For the following question, write down the letter that corresponds to the correct answer:

3.5 A valid scientific experiment with a high level of precision requires that the person doing the experiment:

A works carefully and accurately.
B repeats the experiment at least 5 times.
C gets results that are similar to each other when the experiment is repeated.
D gets data with values closest to the published figures. (2)

After repeating the experiment, they get the following results:

MnO_2	1 st reading	4,8 seconds;	PbO_2	1st reading	7,2 seconds;
Fe_2O_3	1st reading	11,3 seconds;	MnO_2	2nd reading	5,2 seconds;
PbO_2	2nd reading	6,9 seconds;	Fe_2O_3	2nd reading	11,7 seconds;
MnO_2	3rd reading	5,4 seconds;	PbO_2	3rd reading	7,1 seconds;
Fe_2O_3	3rd reading	11,5 seconds			

3.6 Draw up a table of results using this data. (5)

3.7 What observation would Thembi and Michael correctly make when adding each catalyst to the peroxide? (2)

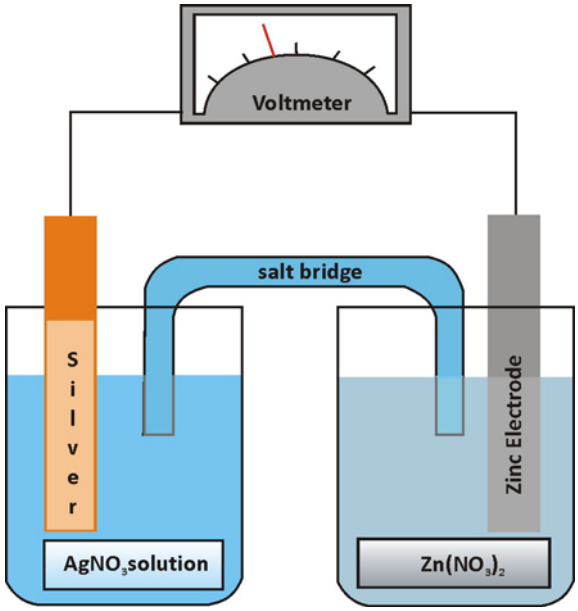
3.8 Write a suitable conclusion for this experiment. (3)

24 marks

QUESTION 4 REDOX CHEMISTRY

Given: $N_A = 6,02 \times 10^{23}\ mol^{-1}$

4.1 Two students Alexis and Khanyiso set up a simple cell in the lab – as shown below. They used zinc and silver as the electrodes.



4.1.1 Is this cell a Galvanic or electrolytic cell? Explain your answer. (3)

4.1.2 Write down the reduction half-reaction that occurs in this cell. (2)

4.1.3 Write down the oxidation half-reaction that occurs in this cell. (2)

4.1.4 Determine the overall cell reaction. Show how you used the answers to 4.1.2 and 4.1.3 to arrive at this. (4)

4.2 Alexis says that the silver electrode will dissolve.

4.2.1 Is she correct? (1)

4.2.2 Explain your answer to 4.2.1. (2)

4.3 Khanyiso says that as the reaction progresses the zinc ions will move through the salt bridge and will coat the silver electrode with zinc.

4.3.1 Is Khanyiso correct? (1)

4.3.2 Explain your answer to 4.3.1. (4)

4.3.3 Explain the function of the salt bridge. (3)

4.4 Rechargeable batteries have become commonplace and are very useful for a wide range of applications. A typical rechargeable battery (AA or penlight size) is marked 1,2 V NiMH; 2 500 mAh. This refers to a modern rechargeable battery of the nickel-metal hydride type. These batteries can be recharged hundreds of times.

These batteries have largely replaced nickel-cadmium batteries (which are also rechargeable). NiMH batteries have approximately the same specifications as non-rechargeable alkali batteries that are commonly on sale today but they have some advantages over them.

4.4.1 Give two possible reasons why nickel-cadmium batteries are being replaced. (2)

4.4.2 Give two possible advantages, related to their effect on the environment, of NiMH batteries over alkaline batteries. (2)

4.4.3 What are the terms used to describe **rechargeable** and **non-rechargeable** batteries respectively? (2)

4.4.4 What property of the battery does the value 2 500 mAh refer to? (1)

4.4.5 If the battery described above is fitted to a device that draws a current of 0,1 A, calculate how long the battery will last, **in hours**, before it needs to be recharged. (4)

4.4.6 The internal resistance of such a battery is typically 0,05 Ω. This is a very low value. Give a possible explanation as to why the internal resistance is low. (2)

4.4.7 The half-reactions occurring in the battery, while it delivers current are:

Anode: $MH + OH^- \rightarrow H_2O + M + e^-$

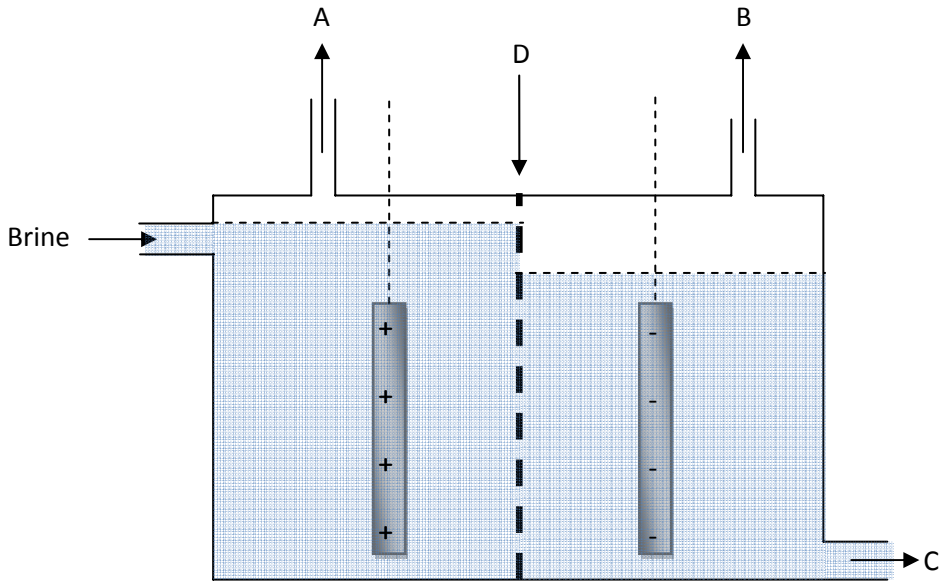
Cathode: $NiO(OH) + H_2O + e^- \rightarrow Ni(OH)_2 + OH^-$

Write down a balanced chemical equation for the overall reaction when the battery is **being recharged**. (3)

38 marks

QUESTION 5 INDUSTRIAL PROCESSING

The diagram below is of a DIAPHRAGM cell which is used for the production of chlorine gas.



5.1 What is brine? (1)

5.2 Write down the products at A, B and C. (3)

5.3 The diaphragm is labelled D. Give three functions of the diaphragm. (3)

5.4 Explain why the water level on the inlet side of the diaphragm is higher than the water level on the outlet side of the diaphragm. (2)

5.5 Is the reaction in this cell spontaneous? (1)

5.6 Write down the half-reaction taking place at the cathode. (2)

5.7 Explain why sodium cannot be produced from this cell. (2)

The process of manufacture of chlorine contains a number of risks.

The edited extract below was reported in *The Mercury* (a Durban newspaper) by Tony Carnie 14 September 2000.

> At least 27 people, including several schoolchildren, were rushed to hospital or treated by ambulance staff on Thursday afternoon after another chlorine gas leak at Umbogintwini, south of Durban.
>
> The leak, which was reported 30 km away in Glenwood, emanated from the same factory responsible for the gassing of more than 100 schoolchildren in Isipingo four months ago.
>
> The latest gas leak from Sasol Polymers (formerly Polifin) happened just after noon and affected several people close to the factory as well as residents and children in Lotus Park, Isipingo, about 2,5 km away.
>
> Kim Fraser, general manager of the company's chemical division, said the cause of the leak was not clear, although it seemed to have come from a loading area where chlorine cylinders are filled for water-purification purposes.
>
> Fraser apologised for the incident and said his company would pay for all medical costs.
>
> A spokesperson for Kingsway Hospital at Amanzimtoti confirmed that 25 people were treated at the hospital and four were expected to remain overnight for observation.

[<http://www.iol.co.za >]

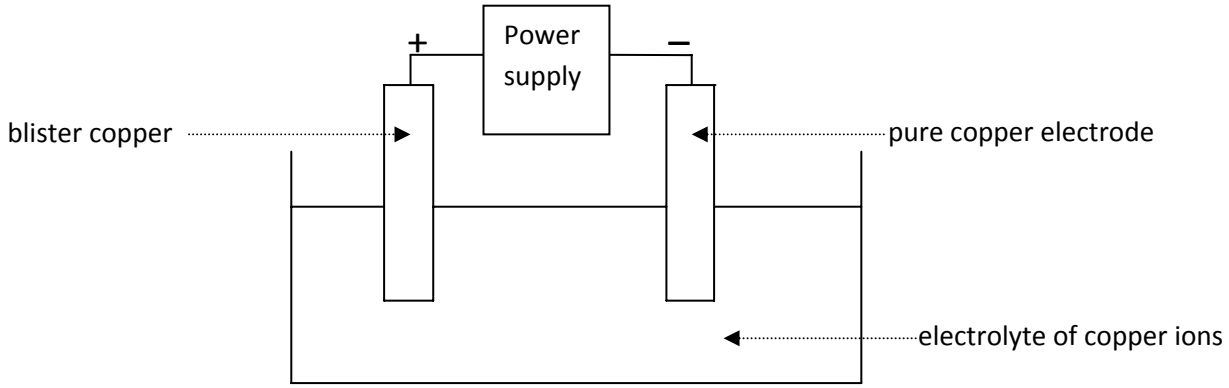
5.8 State 2 risks associated with the manufacture of chlorine gas. (2)

5.9 Discuss critically whether chlorine gas should be manufactured near a city. (4)

20 marks

QUESTION 6 PURIFICATION OF COPPER

6.1 Blister copper has a number of impurities. It is purified by electrolytic means as shown in the diagram below.



6.1.1 Write down the half-reaction taking place at the blister copper. (2)

6.1.2 Is this an oxidation process? (1)

6.2 Impurities in the blister copper include metals such as gold and silver.

6.2.1 What happens to the blister copper as the reaction proceeds? (2)

6.2.2 Explain what happens to the impurities from the blister copper. (2)

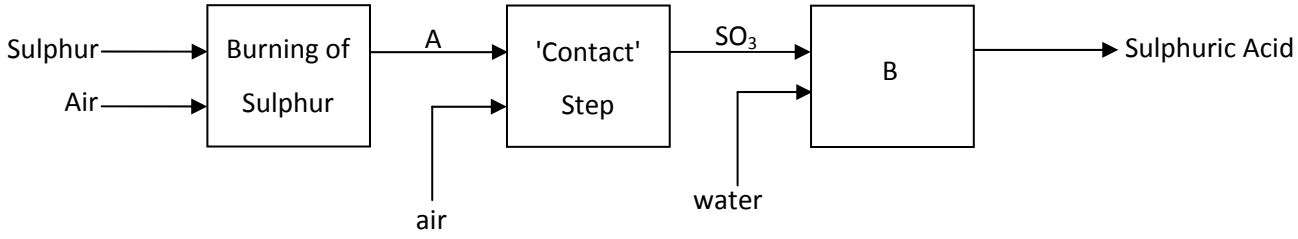
6.2.3 Explain why these impurities do not react. (2)

9 marks

QUESTION 7 FERTILISER AND SULPHURIC ACID

The manufacture of sulphuric acid is a key industrial process. Sulphuric acid is used to make a huge number of other chemicals, including fertiliser.

The process for manufacturing sulphuric acid is called the Contact Process. The flow diagram below represents the Contract process.



7.1 **Name** the product of the burning of sulphur (at A). (1)

7.2 The Contact step can be represented by the equation:

$$2SO_2(g) + O_2(g) \rightleftarrows 2\ SO_3(g) \qquad \Delta H = -197\ kJ$$

Can the Contact step be considered to ever reach equilibrium in this non-closed system? (1)

7.3 If the Contact step is carried out at 450 ºC and 1 atmosphere and it reaches equilibrium:

7.3.1 Write down an expression for the equilibrium constant, (K_c) at 450 ºC. (3)

7.3.2 What would a value of $K_c = 0,1$ indicate about this reaction at equilibrium? (2)

7.3.3 How could this value be increased for this reaction system? (3)

7.3.4 If the engineer monitoring the Contact step was trying to make the reaction occur more quickly, state 3 conditions that she might change. (5)

The engineer is able to get immediate feedback data about the concentration of the gases in the system at equilibrium. For a 10 m^3 reaction vessel, the **concentrations** of the gases are:

$$[SO_2] = 3,1\ mol{\cdot}dm^{-3} \qquad [SO_3] = 5,0\ mol{\cdot}dm^{-3} \qquad [O_2] = 1,9\ mol{\cdot}dm^{-3}$$

7.3.5 Calculate the number of moles of SO_3 in the container at equilibrium. (4)

7.4 The final stage of the Contact Process (Step B) actually consists of two steps. The first step is the addition of SO_3 to concentrated sulphuric acid. The second step is the addition of water to the product.

7.4.1 **Name** the product that forms when SO_3 is added to sulphuric acid. (2)

7.4.2 Why is SO_3 generally not added directly to water? (2)

7.5 The fertiliser superphosphate is made by treating calcium phosphate from rock with sulphuric acid. Calcium phosphate rock is found in North Africa where it is cheap and freely available.

7.5.1 Write down the formula for calcium phosphate. (3)

7.5.2 Write down the formulae of the products of the reaction. (2)

7.5.3 Is calcium phosphate a mineral which is soluble in water? (1)

7.6 Farmers have been using increasing amounts of inorganic fertiliser worldwide over the past 30 years.

7.6.1 Why do we need to use fertiliser for planting and growing crops? (2)

7.6.2 List two possible risks which farmers encounter when using inorganic fertiliser. (2)

7.6.3 How should farmers manage these risks? (2)

7.7 Many waterways in South Africa are threatened by eutrophication. Your teacher has given you the task of analysing some proposals to solve this problem. The key ideas are as follows:

Proposal 1: Ban inorganic fertiliser.

Proposal 2: Triple the cost of inorganic fertiliser by imposing a tax.

7.7.1 What is eutrophication? (4)

7.7.2 What is the cause of eutrophication? (2)

7.7.3 Consider how the banning of inorganic fertiliser would affect farmers' ability to produce food on a large scale and critically analyse how effective proposal 1 would be as a solution to the problem of eutrophication. (4)

7.7.4 How might proposal 2 force farmers to reduce the impact of eutrophication and hence, critically analyse proposal 2 as a solution to the problem of eutrophication. (4)

49 marks

Total: 200 marks