Barker College

2004
TRIAL HIGHER SCHOOL CERTIFICATE

Chemistry

Staff Involved:

- KHW*
- RJP
- ASM

AM FRIDAY 13 AUGUST

110 copies

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using blue or black pen
- Board-approved calculators may be used
- Draw diagrams using pencil
- A Data Sheet and Periodic Table are provided at the back of this paper
- Write your Barker Student Number at the top of the Part A answer sheet and at the top of ALL answer pages in Part B and Section II

Total marks – 100

Section I Pages 2 - 22

Total – 90 marks

This section has two parts, Part A and Part B

Part A

15 marks
- Indicate all answers on the Answer Sheet provided
- Allow about 30 minutes for this part

Part B

75 marks
- Attempt Questions 16 – 29
- Indicate all answers in the spaces provided on the paper
- Allow about 2 hours for this part

Section II Pages 23 – 26

10 marks
- Attempt EITHER Question 30 OR Question 31
- Indicate all answers in the spaces provided on paper
- Allow about 30 minutes for this section

Section I

Total marks – 90

Part A

15 marks

Attempt Questions 1–15
Allow about 30 minutes for this part

Use the multiple-choice answer sheet

Select the alternative A, B, C or D that best answers the question. Fill in the response oval completely.

Sample 2 + 4 = (A) 2 (B) 6 (C) 8 (D) 9

(A) ○ (B) ● (C) ○ (D) ○

If you think you have made a mistake, put a cross through the incorrect answer and fill in the new answer.

(A) ● (B) ⊗ (C) ○ (D) ○

If you change your mind and have crossed out what you consider to be the correct answer, then indicate this by writing the word *correct* and drawing an arrow as follows.

correct ←

(A) ⊗ (B) ⊗ (C) ○ (D) ○

1. What is the purpose of cracking during the refining of petroleum?

   (A) To convert natural gas into petrol and other fuels.
   (B) To increase the yields of heavy oils and tars.
   (C) To obtain a higher yield of petrol and other fuels from crude oil.
   (D) To lower the temperature at which crude oil is distilled.

2. Identify the products of the anaerobic fermentation of sugars.

   (A) Ethanol and carbon dioxide.
   (B) Glucose and water.
   (C) Yeast and carbon dioxide.
   (D) Ethanol and water.

3. What is the meaning of this statement?
   "The molar heat of combustion of ethanol is 1367 kJ".

   (A) 1367 kJ of energy is needed to completely burn one mole of ethanol.
   (B) 1367 kJ is used up when 46.1 g ethanol undergoes complete combustion.
   (C) Chemical energy is decreased by 1367 kJ when one mole of ethanol is converted to carbon dioxide and water.
   (D) There is a transfer of 1367 kJ from the environment to ethanol during the complete combustion of one mole of ethanol.

4. Which of the following could be classed as an acid by the Lowry-Bronsted theory, but not by Lavoisier's theory?

   (A) CO_2
   (B) HCl
   (C) HNO_3
   (D) CH_3COOH

5. A solution of barium hydroxide has a concentration of .005 mol L^{-1}.
   What is its pH at 25°C?

   (A) 2.3
   (B) 11.7
   (C) 2
   (D) 12

6. Which list only contains acidic oxides?

   (A) NO, CO, CO_2, SO_2
   (B) MgO, BaO, CO, NO
   (C) SO_2, SO_3, NO_2, CO_2
   (D) CO, SO_2, SO_3, NO

7. 0.1 mol/L citric acid is neutralised by a solution of 0.1 mol/L sodium hydroxide. Choose the best indicator for this titration.

(A) Methyl orange.
(B) Phenolphthalein.
(C) Bromothymol blue.
(D) Universal.

8. Which statement is true?
In a galvanic cell:

(A) oxidation occurs at the cathode
(B) cations flow from the anode half-cell to the cathode half-cell through the salt bridge
(C) electrical energy is used to bring about a chemical change
(D) the cathode is assigned a negative charge

9. Consider the following electron transfer reaction.

$$MnO_2 + 4HCl \rightleftharpoons MnCl_2 + 2H_2O + Cl_2$$

Which statement is incorrect?

(A) The oxidation state of manganese in $MnCl_2$ is +2.
(B) The oxidation state of manganese in MnO_2 is +4.
(C) The oxidation state of chlorine in Cl_2 is 0.
(D) The oxidation state of oxygen in water is 0.

10. The following equation represents the nuclear decay of radium-88.

$$^{228}_{88}Ra \rightarrow {}^{228}_{89}Ac + X$$

Identify the species marked X.

(A) An alpha particle.
(B) A beta paricle.
(C) A neutron.
(D) A proton.

11. What is Biological Oxygen Demand (BOD)?

(A) A measure of the number of aerobic organisms in a sample of water.
(B) A measure of organic wastes that can be broken down by organisms in a body of water.
(C) A measure of inorganic wastes that can be broken down by anaerobic organisms.
(D) The quantity of oxygen needed to respire organic wastes in a body of water.

12. Consider the four chloroalkanes.

I 2,4-dichloropentane
II 2,4-dichlorohexane
III 2,3-dichlorohexane
IV 2,2,3,3-tetrachloropentane

Which of the above chloroalkanes are isomers?

(A) I and II
(B) I and IV
(C) II and III
(D) III and IV

13. Which of the following is a list of the atmospheric gases in decreasing order of abundance?

(A) Oxygen; carbon dioxide; neon; methane.
(B) Oxygen; argon; helium; carbon dioxide.
(C) Nitrogen; oxygen; argon; carbon dioxide.
(D) Oxygen; nitrogen; argon; carbon dioxide.

14. Which gaseous molecule contains a coordinate covalent bond?

(A) Carbon dioxide.
(B) Water vapour.
(C) Ozone.
(D) Oxygen.

15. Choose the equation which correctly describes the incomplete combustion of octane.

(A) $C_8H_{18} + \frac{9}{2}O_2 \rightarrow 8C + 9H_2O$
(B) $C_8H_8 + 10O_2 \rightarrow 8CO_2 + 4H_2O$
(C) $C_8H_{18} + \frac{25}{2}O_2 \rightarrow 8CO_2 + 9H_2O$
(D) $C_8H_8 + 2O_2 \rightarrow 8C + 4H_2O$

End of Part A

Student No. .....

Section I (continued)
Part B – 75 marks
Attempt ALL questions
Allow about 2 hours for this part

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Marks

Question 16 (7 marks)

During your Chemistry course you carried out a first-hand investigation to compare the reactivity of alkanes and alkenes.

(a) Name the alkane and alkene you compared and draw structural formulae to represent both compounds. **2**

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(b) Describe the method used to compare the reactivity of the two hydrocarbons. **2**

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Question 16 continues on page 7

Question 16 (continued)

Marks

(c) Describe the results of your investigation including any relevant chemical equations. **3**

Question 17 (5 marks)

(a) Draw a structural formula to represent the compound which is commerically known as vinyl chloride. **1**

(b) Give the systematic name for this compound. **1**

(c) Vinyl chloride forms an addition polymer.

(i) What is meant by an "addition" polymer? **1**

Question 17 continues on page 8

Question 17 (c) (continued)

Marks

(ii) Draw a section of the polymer formed from vinyl chloride showing three repeating units. **1**

(iii) Identify a use for this polymer. **1**

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Question 18 (3 marks)

Describe and account for the many uses of ethanol as a solvent for both polar and non-polar substances. **3**

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Student No. .....

Marks

Question 19 (2 marks)

The transuranic element, americium-241, is made by bombarding plutonium-239 with neutrons; a small particle is emitted in the process.

(a) What are transuranic elements? **1**

(b) Write a nuclear equation for the process described above. **1**

Question 20 (4 marks)

By referring to the table of reduction potentials provided, discuss the relationship between the displacement of metal ions in solution by other metals and the relative activity of metals. Use relevant equations or half-equations in your answer. **4**

Student No. .....

Marks

Question 21 (2 marks)

When limestone is strongly heated it decomposes to form calcium oxide and carbon dioxide according to the equation:

$$CaCO_{3(s)} \rightarrow CaO_{(s)} + CO_{2(g)}$$

What is the maximum volume of carbon dioxide, measured at 25°C and 100 kPa pressure, that can be produced when 3.7 g of calcium carbonate decomposes? **2**

Question 22 (3 marks)

Describe the use of Atomic Absorption Spectroscopy and assess its impact on scientific understanding of the effects of trace elements. Refer to a least **ONE** trace element in your answer. **3**

Student No. .....

Marks

Question 23 (4 marks)

The pH values of two monoprotic acids (represented as HX and HY) of the same concentration are shown in the table below.

Acid	Concentration (mol L^{-1})	pH
HX	0.1	5.1
HY	0.1	1.0

(a) Explain why the two acids have different pH values. **2**

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(b) Write an equation for the reaction of HX with water. **1**

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(c) Calculate the $[H^+]$ of a solution of HY. **1**

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Student No. .....

Marks

Question 24 (6 marks)

A student wishing to determine the concentration of a sodium hydroxide solution by titration found that 38.4 mL of 0.15 mol L^{-1} sulfuric acid solution was needed to react with 25.0 mL of the sodium hydroxide solution.

(a) Calculate the concentration of the sodium hydroxide solution, in mol L^{-1}. **2**

(b) Explain how the student would know when the two solutions had reacted completely. **1**

(c) List **THREE** items of laboratory glassware that are used during titrations and describe how each is rinsed prior to carrying out the titration. **3**

Student No. .....

Marks

Question 25 (4 marks)

(a) Qualitatively describe the effect of buffers with reference to a specific example in a natural system. **2**

(b) Identify a specific chemical which can be used to minimise damage in a chemical spill and explain why it is effective. **2**

Student No. .....

Marks

Question 26 (10 marks)

The Haber process was developed in 1908 as a method of synthesising ammonia and was converted into a successful industrial process during the following decade.

(a) Evaluate the significance of the Haber process at that time in world history. **2**

(b) Identify **TWO** reasons for ammonia synthesis continuing to be significant today. **2**

(c) (i) Write an equation that describes the Haber process. **1**

(ii) Is the synthesis of ammonia an exothermic or endothermic reaction? **1**

Question 26 continues on page 15

Question 26 (continued)

Marks

(d) By analysing the factors affecting ammonia synthesis, explain why the Haber process requires a compromise between these factors. **4**

End of Question 26

Student No. .....

Marks

Question 27 (8 marks)

(a) Explain why the presence of ozone in the upper atmosphere is beneficial to life on earth. **2**

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(b) CFCs can lower the concentration of ozone in the upper atmosphere.

(i) Which element in the molecules of CFCs causes the destruction of the ozone molecule? **1**

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(ii) Write an equation which shows how ozone is destroyed by this element. **1**

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(c) (i) Using electron dot diagrams (Lewis diagrams), draw and label the oxygen molecule and the ozone molecule. **2**

(ii) Referring to their structure and bonding, compare oxygen and ozone over one property. **2**

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Marks

Question 28 (12 marks)

Many working chemists are involved in monitoring the Earth's atmosphere, or the Earth's hydrosphere.

(a) In the atmosphere, changes in ozone concentration have been reported over the last twenty years, and these changes have been attributed to CFCs.

Analyse the evidence that indicates these changes have occurred and explain how the information is obtained. **3**

(b) The CFC-113 was used as a solvent and has the systematic name:

2, 2, 2 - trichloro -1, 1, 1 - trifluoroethane

(i) Draw the structural formula of this CFC. **1**

Question 28 continues on page 18

Question 28 (b) (continued) **Marks**

(ii) Draw an isomer of CFC-113 and name it systematically. **2**

(c) In city water supplies many undesirable impurities are present.

(i) Describe the physical and chemical processes used to purify and sanitise your local water supply. You may use a clearly and thoroughly labelled diagram if you wish. **3**

Question 28 continues on page 19

Question 28 (c) (continued) **Marks**

(ii) Assess the effectiveness of this process. **1**

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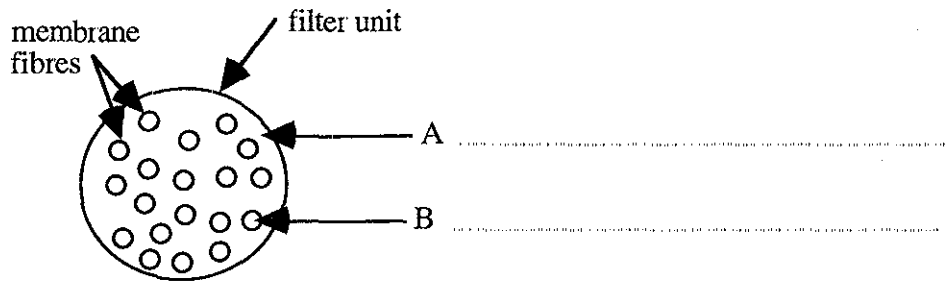
Question 28 continues on page 20

Question 28 (continued) **Marks**

(d) (i) Purification of recycled water may include microscopic membrane filtration. The cross-sectional diagram below shows a bundle of membrane fibres in the filter unit.

Correctly label A and B as "dirty water flow" and "clean water flow".



1

(ii) Describe **ONE** advantage of microscopic membrane filtration over traditional sand and gravel filtration. **1**

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End of Question 28

Student No. .....

Marks

Question 29 (5 marks)

Some Year 12 students carried out a first-hand investigation to determine the presence of anions in a sample of water. They were given the following information:

- All chlorides are soluble except silver and lead
- All sulfates are soluble except silver, lead, barium, calcium and strontium
- Carbonates neutralise acids
- Phosphates will form a bright yellow precipitate with oxyanions of molybdenum

Their procedure and results are summarised in the following table.

Procedure	Observations
1. Addition of excess HNO_3	Vigorous bubbling and fizzing
2. Addition of excess barium nitrate	No visible reaction
3. Addition of excess silver nitrate	A white precipitate formed
4. The precipitate was filtered off	
5. Ammonium molybdate was added	No visible reaction

(a) Which **TWO** ions have been identified as being in the sample by this procedure? **2**

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(b) Write a net ionic equation to describe the reaction in (3) of the procedure. **1**

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Question 29 continues on page 22

Question 29 (continued) **Marks**

(c) Is this analysis qualitative or quantitative? **1**

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(d) Explain why the order in which the tests were carried out is important, referring to the error that would be caused by adding silver nitrate before barium nitrate. **1**

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End of Question 29

End of Section I

Student No. .....

Section II

10 marks
Attempt EITHER Question 30 OR Question 31
Allow about 30 minutes for this section

Use the spaces provided on the paper.

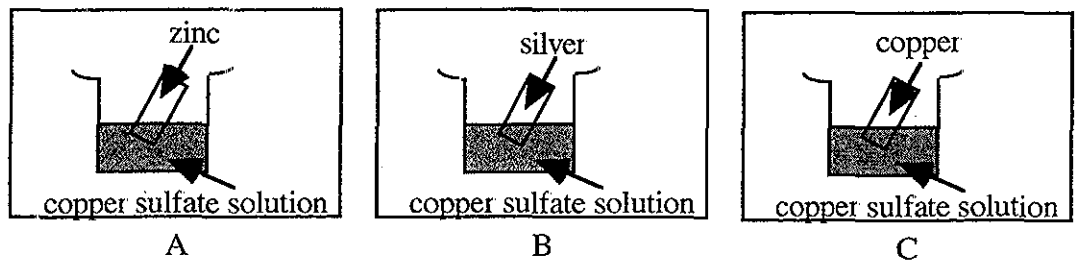
Marks

EITHER

Shipwrecks, Corrosion and Conservation

Question 30 (10 marks)

(a) From your knowledge of electron transfer and metal reactivity, circle the diagram below which illustrates the conditions necessary for a reaction to occur. **1**



(b) Identify the sources of the salts dissolved in the ocean. **2**

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Question 30 continues on page 24

Question 30 (continued)

Marks

(c) (i) Explain why steel has been the most popular material for ship building since the mid 19th century. **2**

(ii) Describe the conditions under which rusting occurs and explain the process of rusting, using relevant equations where appropriate. **5**

OR

Student No. .....

Marks

Forensic Chemistry

Question 31 (10 marks)

(a) (i) Use the words organic or inorganic to describe the following chemicals. **2**

Potassium cyanide .....

Methane .....

Glucose .....

Calcium carbonate .....

(ii) Describe a test that could be done in the laboratory to distinguish between an alcohol and an alkanoic acid. **1**

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(iii) Explain how the inorganic chemical properties of soil may be useful evidence in a forensic examination. **2**

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Question 31 continues on page 26

Question 30 (continued)

Marks

(b) Discuss, using a recent example, how progress in analytical chemistry and changes in technology can alter the outome of a forensic investigation. **5**

End of Paper

Student No. SOLUTIONS

Barker College

29/07/04

2004
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Chemistry

ANSWER SHEET

Staff Involved:

- KHW*
- RJP
- ASM

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110 copies

Section I
Part A – Multiple Choice
Choose the best response and fill in the response oval completely

1.	A	B	●	D
2.	●	B	C	D
3.	A	B	●	D
4.	A	●	C	D
5.	A	B	C	●
6.	A	B	●	D
7.	A	●	C	D
8.	A	●	C	D
9.	A	B	C	●
10.	A	●	C	D
11.	A	B	C	●
12.	A	B	●	D
13.	A	B	●	D
14.	A	B	●	D
15.	●	B	C	D

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Total marks – 100

Section I Pages 2 - 22

Total – 90 marks

This section has two parts, Part A and Part B

Part A

15 marks
- Indicate all answers on the Answer Sheet provided
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Part B
75 marks
- Attempt Questions 16 – 29
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Section II Pages 23 – 26

10 marks
- Attempt EITHER Question 30 OR Question 31
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Section I

Total marks – 90

Part A

15 marks

Attempt Questions 1–15
Allow about 30 minutes for this part

Use the multiple-choice answer sheet

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Sample 2 + 4 = (A) 2 (B) 6 (C) 8 (D) 9

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correct ←

(A) ⊗ (B) ⊗ (C) ○ (D) ○

1. What is the purpose of cracking during the refining of petroleum?

   (A) To convert natural gas into petrol and other fuels.
   (B) To increase the yields of heavy oils and tars.
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   (B) MgO, BaO, CO, NO
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(D) The oxidation state of oxygen in water is 0.

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IV 2,2,3,3-tetrachloropentane

Which of the above chloroalkanes are isomers?

(A) I and II
(B) I and IV
(C) II and III
(D) III and IV

13. Which of the following is a list of the atmospheric gases in decreasing order of abundance?

(A) Oxygen; carbon dioxide; neon; methane.
(B) Oxygen; argon; helium; carbon dioxide.
(C) Nitrogen; oxygen; argon; carbon dioxide.
(D) Oxygen; nitrogen; argon; carbon dioxide.

14. Which gaseous molecule contains a coordinate covalent bond?

(A) Carbon dioxide.
(B) Water vapour.
(C) Ozone.
(D) Oxygen.

15. Choose the equation which correctly describes the incomplete combustion of octane.

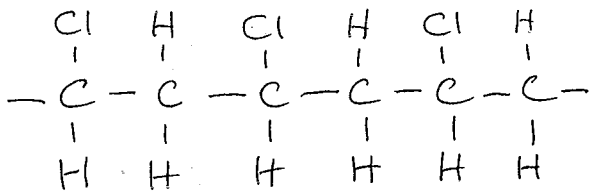
(A) $C_8H_{18} + \frac{9}{2}O_2 \rightarrow 8C + 9H_2O$
(B) $C_8H_8 + 10O_2 \rightarrow 8CO_2 + 4H_2O$
(C) $C_8H_{18} + \frac{25}{2}O_2 \rightarrow 8CO_2 + 9H_2O$
(D) $C_8H_8 + 2O_2 \rightarrow 8C + 4H_2O$

End of Part A

Question 17 (c) (continued)

Marks

(ii) Draw a section of the polymer formed from vinyl chloride showing three repeating units. 1



(iii) Identify a use for this polymer. 1

Sewage + drainage pipes / garden hoses / insulation around electrical wires / downpipes + guttering

Question 18 (3 marks)

Describe and account for the many uses of ethanol as a solvent for both polar and non-polar substances. 3

Ethanol is a good solvent for short chain hydrocarbons, which are non-polar molecules, and other carbon compounds which have short hydrocarbon chains.
It is also a good solvent for polar molecules, some ionic substances and for water and substances in aqueous solution.
Molecules of ethanol have a dual nature. The end of the molecule is an –OH group which forms hydrogen bonds with water and is attracted to polar molecules. This part of alcohol molecules is described as hydrophilic (water loving).
The hydrocarbon chain is non-polar (hydrophobic – water hating) as carbon and hydrogen atoms have almost identical electronegativity. This non-polar part of the molecule is not repelled by other non-polar molecules and allows the alcohol to mix with these non-polar molecules.

One mark for discussion of dual nature of molecule.

One mark for discussion of hydrogen bonding or polar interactions.

One mark for discussion of non-polar interactions. 3

Marks

Question 19 (2 marks)

The transuranic element, americium-241, is made by bombarding plutonium-239 with neutrons; a small particle is emitted in the process.

(a) What are transuranic elements? 1

Elements with Atomic Number > 92

Transuranic elements are those elements with atomic numbers greater than 92. They are artificially produced and are found in the periodic table after uranium. They are produced by bombardment of other nuclei with neutrons or high speed positive particles such as helium or carbon nuclei.

(b) Write a nuclear equation for the process described above. 1

$^{239}_{94}Pu + 2\,^{1}_{0}n \rightarrow {}^{241}_{95}Am + {}^{0}_{-1}e$

Question 20 (4 marks)

By referring to the table of reduction potentials provided, discuss the relationship between the displacement of metal ions in solution by other metals and the relative activity of metals. Use relevant equations or half-equations in your answer. 4

(1) mark for identifying more and less reactive metals from the table of reduction potentials

(1) mark for actually describing a displacement reaction using equations

(1) mark for calculating the cell potential of this displacement

(1) mark for correctly identifying that a positive potential means the displacement will spontaneously occur

Section I (continued)
Part B – 75 marks
Attempt ALL questions
Allow about 2 hours for this part

Student No. .....

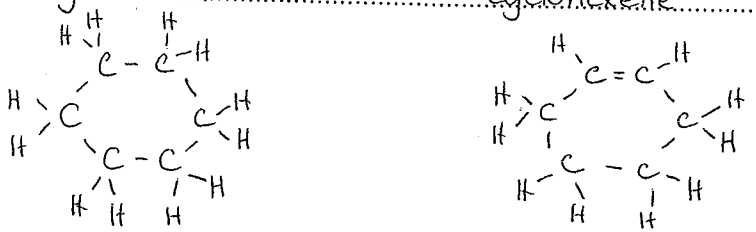
Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Question 16 (7 marks) — Marks

During your Chemistry course you carried out a first-hand investigation to compare the reactivity of alkanes and alkenes.

(a) Name the alkane and alkene you compared and draw structural formulae to represent both compounds. **2**

cyclohexane ..... cyclohexene .....



1 each - name matching correct structural formula

(a)
alkane - hexane
$CH_3CH_2CH_2CH_2CH_2CH_3$
alkene – 1-hexene
$CH_2 = CHCH_2CH_2CH_2CH_3$

(a)
One mark for suitable choice compounds.
One mark for formulae.

(b) Describe the method used to compare the reactivity of the two hydrocarbons. **2**

- 2 mL of each hydrocarbon were placed separately into 2 identical test tubes in a darkened cupboard
- Several drops of Br_2 water were added to each test tube and the test tubes were stoppered and shaken. Colour changes were recorded. The test tubes were left in the dark for 10-20 min
- The above steps were repeated but the test tubes were left in strong UV light for 10-20 minutes.
- After 20 min both sets of test tubes were observed and colour changes compared and noted

One mark for controlling the experiment.

One mark for addition of bromine and observation of colour

Question 16 continues on page 7

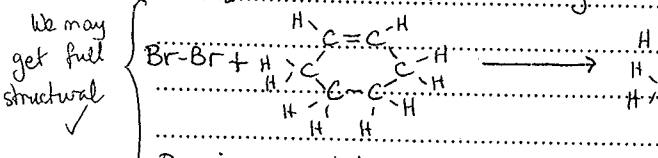
Alkenes react rapidly with bromine. An addition reaction occurs and no HBr (g) is formed. Bromine is rapidly decolourised even in the absence of UV light.
C_6H_{12} (g) + Br_2 (g) → $C_6H_{12}Br_2$ (l)
red → colourless

Alkanes do not react with bromine unless UV light is present.
When alkanes do react, they do so by a substitution reaction. A bromine atom replaces a hydrogen atom in the alkane molecule.
C_6H_{14} (g) + Br_2 (g) → $C_6H_{13}Br$ (l) + HBr (g)
red → colourless

(c) Describe the results of your investigation including any relevant chemical equations. **3** — Marks

- Cyclohexene in the dark and in the light immediately decolourised the Br_2 water which went from orange to colourless

We may get full structural ✓



Bromine + cyclohexene → 1,2-dibromocyclohexane

One mark for each equation. (2)
One mark for observed results. (1)

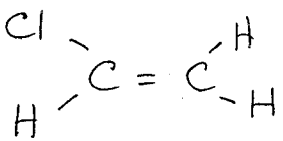
- Cyclohexane in the dark had no reaction with Br_2 water
- Cyclohexane in strong UV light decolourised Br_2 water after 20 min

$C_6H_{12} + Br_2 \xrightarrow{U.V.} C_6H_{11}Br + HBr$

cyclohexane + bromine $\xrightarrow{U.V.}$ bromocyclohexane + hydrogen bromide

Question 17 (5 marks)

(a) Draw a structural formula to represent the compound which is commercially known as vinyl chloride. **1**



(b) Give the systematic name for this compound. **1**

chloroethene

An addition polymer is formed by the linking together of monomer units into a long chain. The monomer units have a double bond joining 2 carbon atoms. Hydrogen or other atoms are attached as side groups to the carbon atoms. As the monomers link together, electrons from each of the double bonds of the neighbouring molecules join together to form a single covalent bond which holds the neighbouring units together.

(c) Vinyl chloride forms an addition polymer.

(i) What is meant by an "addition" polymer? **1**

The double bond in each monomer unit opens out so that another monomer unit can add on to it. In this way many monomers add together to form a polymer with no loss of any atoms

One mark if both the concept of "addition" and the concept of

Question 17 continues on page 8

Question 20.

Active metals are those which are good reducing agents and readily give up electrons (are oxidised). They are found high, on the right-hand side of the table of reduction potentials.

Metals will displace other metals which are less active (i.e. lower down the table on the right-hand side) from a solution containing ions of the less active metal.

The most active metals are recognised by their ability to react with water and acids to form hydrogen gas.

For example, calcium metal, high on the right-hand side of the table, reacts vigorously with water and hydrochloric acid to produce hydrogen gas:

$Ca(s) \rightleftharpoons Ca^{2+} + 2e^-$ $E^*_{oxid} = +2.87V$

$2H_2O + 2e^- \rightleftharpoons H_2(g) + 2OH^-$ $E^*_{red} = -0.83V$

Overall equation

$Ca(s) + 2H_2O \rightleftharpoons H_2(g) + 2OH^- + Ca^{2+}$

$E^*_{overall} = +2.04V$

$Ca(s) \rightleftharpoons Ca^{2+} + 2e^-$ $E^*_{oxid} = +2.87V$

$2H+ + 2e- \rightleftharpoons H_2(g)$ $E^*_{red} = -0.00V$

Overall equation

$Ca(s) + 2H^+ \rightleftharpoons H_2(g) + Ca2^+$

$E^*_{overall} = +2.87V$

The positive values of the electromotive force, calculated using the values from the table, indicate that these reactions occur spontaneously.

A less active metal, such as lead, will not react with water (as shown by the negative overall E^* value) and will only react very slowly with acid (as shown by the small overall E^* value).

$Pb(s) \rightleftharpoons Pb^{2+} + 2e^-$ $E^*_{oxid} = +0.13V$

$2H_2O + 2e^- \rightleftharpoons H_2(g) + 2OH^-$

$E^*_{red} = -0.83V$

Overall equation

$Pb(s) + 2H_2O \rightleftharpoons H_2(g) + 2OH^- + Pb^{2+}$

$E^*_{overall} = -0.70V$

$Pb(s) \rightleftharpoons Pb^{2+} + 2e^-$ $E^*_{oxid} = +0.13V$

$2H^+ + 2e^- \rightleftharpoons H_2(g)$ $E^*_{red} = -0.00V$

Overall equation

$Pb(s) + 2H^+ \rightleftharpoons H_2(g) + Pb^{2+}$ $E^*_{overall} = +0.13V$

Active metals will displace less active metals from solutions containing ions of the less active metal, as shown by the following example.

$Ca(s) \rightleftharpoons Ca^{2+} + 2e^-$ $E^*_{oxid} = +2.87V$

$Pb^{2+} + 2e^- \rightleftharpoons Pb(s)$ $E^*_{red} = -0.13V$

Overall equation

$Ca(s) + Pb^{2+} \rightleftharpoons Ca^{2+} + Pb(s)$ $E^*_{overall} = +2.74V$

The positive value for the overall E^* value shows the reaction will occur spontaneously.

The less active metal, lead, will not displace calcium from a solution containing calcium ions:

$Pb(s) \rightleftharpoons Pb^{2+} + 2e^-$ $E^*_{oxid} = +0.13V$

$Ca^{2+} + 2e^- \rightleftharpoons Ca(s)$ $E^*_{red} = -2.87V$

Overall equation

$Pb(s) + Ca^{2+} \rightleftharpoons Pb^{2+} + Ca(s)$ $E^*_{overall} = -2.74V$

The negative value for the overall E^0 value shows the reaction will not occur spontaneously.

One mark for identification of position of active versus less active metals on the table or correctly identifying examples of more and less active metals.

One mark for use of E^* values to identify active versus less active metals.

One mark for demonstration of understanding of displacement reactions.

One mark for correct equations used to demonstrate at least one displacement reaction. 4

- An active metal will give up electrons readily (oxidise)
- The more active a metal is, the higher it is on the table of reduction potentials provided, and the more negative is its standard reduction potential value as published on the table provided.

→ 1 (Can ID more & less reactive from the table)

- A more reactive metal will displace the ions of a less active metal from aqueous solution, and in so doing generate a positive emf

eg $Zn_{(s)} \rightarrow Zn^{2+}_{(aq)} + 2\bar{e}$ (oxidation of more reactive metal) The solid zinc goes into solution

$Cu^{2+}_{(aq)} + 2\bar{e} \rightarrow Cu_{(s)}$ (reduction of the less reactive metal) The aqueous Cu^{2+} ions come out of solution and hence Cu^{2+} has been displaced by zinc.

→ 1 (Can ID a displacement reaction & describe with equations)

- The total emf of the displacement is $0.76V$ $(Zn \rightarrow Zn^{2+} + 2e)$ + $0.34V$ $(Cu^{2+} + 2\bar{e} \rightarrow Cu)$ = $1.10V$

→ 1 (Or give example using table emf.)

- If solid copper was placed in a zinc ion solution, no displacement would occur because copper is less reactive than zinc and the total emf = $-1.10V$ which which will not spontaneously occur.

→ 1

Student No. .....

Marks

Question 21 (2 marks)

When limestone is strongly heated it decomposes to form calcium oxide and carbon dioxide according to the equation:

$$CaCO_{3(s)} \rightarrow CaO_{(s)} + CO_{2(g)}$$

$M_{CaCO_3} = 40.08 + 12.01 + 48 = 100.09$

What is the maximum volume of carbon dioxide, measured at 25°C and 100 kPa pressure, that can be produced when 3.7 g of calcium carbonate decomposes? 2

Moles CO_2 = moles $CaCO_3$ = $3.7/100.09 = 0.0369$ mol – 1 mark

Vol $CO_2 = 0.0369 \times 24.79 = 0.9147$ L

$= 0.91$ L (Correct to 2 sig. figs) 1 mark

Question 22 (3 marks)

Describe the use of Atomic Absorption Spectroscopy and assess its impact on scientific understanding of the effects of trace elements. Refer to a least **ONE** trace element in your answer. 3

(1) Uses – To monitor very small concentrations of ions in the environment, especially pollutants;

– To measure concentrations of micronutrients in soil, contaminants in food, medicine & manufactured goods;

– To measure trace elements in living things

(1) Impact – Prior to AAS, very small quantities of elements could not be detected, so trace elements and their essential function for normal growth and development of plants and animals were unknown.

(1) One example – Animal enzyme function depends on Zn, Co, Cu, Ni, Mo and I in trace amounts.

– Plant growth requires trace amounts of Mn, Cu, B, Mo, Zn.

Because AAS can detect a dark, trace elements can be added to the soil

Student No. .....

Marks

Question 23 (4 marks)

The pH values of two monoprotic acids (represented as HX and HY) of the same concentration are shown in the table below.

Acid	Concentration (mol L^{-1})	pH
HX	0.1	5.1
HY	0.1	1.0

(a) Explain why the two acids have different pH values. 2

HY is a strong acid because it ionises completely ($[HY] = [H^+]$) 1

HX is a weak acid because it only partially ionises ($[H^+] < [HX]$) 1

(b) Write an equation for the reaction of HX with water. 1

$HX + H_2O \rightleftharpoons H_3O^+ + X^-$

Must have equilibrium arrows

(c) Calculate the $[H^+]$ of a solution of HY. 1

Either $[H^+] = [HY] = 0.1 \text{ mol } L^{-1}$

Or $[H^+] = 10^{-pH} = 10^{-1} = 0.1 \text{ mol } L^{-1}$

Must have correct units

Sample answers	Marking Guide
Question 23. **(a)** The acids have different pH values because one is strong (HY) and the other is weak (HX). HY ionises completely in water: $HY + H_2O \rightarrow H_3O^+ + Y^-$ HX ionises partially in water and hence produces fewer hydrogen ions (and a higher pH) than HY at the same concentration: $HX + H_2O \rightleftharpoons H_3O^+ + X^-$ **(b)** $HX + H_2O \rightleftharpoons H_3O^+ + X^-$ **(c)** $[H^+] = 10^{-pH}$ $= 10^{-1.0}$ $= 0.1 \text{ mol } L^{-1}$	**(a)** **One mark** for identification of HY as a strong acid and HX as a weak acid. **One mark** for explanation in terms of degree of ionisation or correct equations showing complete reaction for HY and an equilibrium for HX **(b)** **One mark.** Equation must show equilibrium arrows. **(c)** **One mark** if both value and units correct. 4

Question 24.	
(a) $2NaOH + H_2SO_4 \rightleftharpoons Na_2SO_4 + 2H_2O$ 2 moles + 1 mole No. of moles H_2SO_4 reacted = (38.4/1000) x 0.15 $= 5.76 \times 10^{-3}$ Hence no. moles NaOH present = $2 \times 5.76 \times 10^{-3}$ Concentration sodium hydroxide solution $= 2 \times 5.76 \times 10^{-3} / 25 \times 10^{-3}$ $= 0.461 \text{ mol } L^{-1}$	**(a)** **One mark** calculation of moles of NaOH or recognition of 2:1 ratio of moles NaOH: moles H_2SO_4 **One mark** calculation concentration of NaOH.
(b) Indicators or pH meters are used during titration reactions to show the end point (when the 2 solutions have reacted in the correct stoichiometric proportions, as determined by the equation). Since this is a strong acid/strong base reaction, then the pH should be close to 7 at the end point, with the pH changing from very high to very low over a one drop range. An indicator such as phenolphthalein is suitable; initially the colour in the flask will be pink/purple which will change to colourless at the end point. Other indicators (litmus, bromothymol blue, methyl orange, but not universal) could also be used.	**(b)** **One mark** if correct explanation given (cannot just be a statement).
(c) Burette: rinsed with the solution to be placed in it. Conical flask: rinsed with distilled water. Pipette: rinsed with the solution being delivered from it.	**(c)** **One mark** for **each piece** of equipment only if washing technique correct.

Student No. .....

Marks

Question 24 (6 marks)

A student wishing to determine the concentration of a sodium hydroxide solution by titration found that 38.4 mL of 0.15 mol L^{-1} sulfuric acid solution was needed to react with 25.0 mL of the sodium hydroxide solution.

(a) Calculate the concentration of the sodium hydroxide solution, in mol L^{-1} 2

$2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$

2 mole : 1 mole

Moles $H_2SO_4 = 0.0384\,L \times 0.15\,mol\,L^{-1} = 5.76 \times 10^{-3}$

$\therefore$ Moles $NaOH = 2 \times 5.76 \times 10^{-3} = 11.52 \times 10^{-3}$ - (1)

$C_{NaOH} = \frac{11.52 \times 10^{-3}}{0.025} = 0.461\,mol\,L^{-1}$ - (1)

(b) Explain how the student would know when the two solutions had reacted completely. 1

The acid-base indicator would permanently change colour. (As this is a strong acid/strong base titration the endpoint would be at pH 7 and with only one drop more of acid the phenolphthalein would change from pink to colourless.)

(c) List **THREE** items of laboratory glassware that are used during titrations and describe how each is rinsed prior to carrying out the titration. 3

Burette - rinsed with the solution it will deliver to the titration -(1)

Conical flask - rinsed with distilled water -(1)

Pipette - rinsed with the solution it will deliver to the conical flask -(1)

Student No. .....

Marks

Question 25 (4 marks)

(a) Qualitatively describe the effect of buffers with reference to a specific example in a natural system. 2

- A buffer solution contains considerable amounts of a weak acid and its conjugate base in equilibrium, so that it can maintain a constant pH even when significant amounts of strong acid or strong base are added to it. (1)
- Haemoglobin acts as a buffer in blood. (1)

(b) Identify a specific chemical which can be used to minimise damage in a chemical spill and explain why it is effective. 2

Sodium hydrogen carbonate can be used cheaply and with no damage to the environment. It is also effective on both acidic and basic spills because of its amphiprotic nature. (1)

In acid spills $HCO_3^- + H^+ \rightarrow H_2O + CO_2$

In basic spills $HCO_3^- + OH^- \rightarrow H_2O + CO_3^{2-}$ (1)

(Some students may identify one chemical for an acid spill - Na_2CO_3 - and one for a basic spill - HCl or H_2SO_4.)

Student No. .....

Marks

Question 26 (10 marks)

The Haber process was developed in 1908 as a method of synthesising ammonia and was converted into a successful industrial process during the following decade.

(a) Evaluate the significance of the Haber process at that time in world history. 2

(a)
The manufacture of ammonia was important early in the twentieth century because of:
- a growing need to produce fertilisers to grow crops for an increasing world population. The supplies of the other chemical fertilisers (e.g. sodium nitrate) were diminishing.
- the need to produce explosives in pre-World War I Europe.

The Haber process enabled Germany to continue its production of fertilizer & explosives after Britain had cut off its supply of nitrates from Chile & therefore enabled Germany to go to war.

(b) Identify **TWO** reasons for ammonia synthesis continuing to be significant today. 2

The production of ammonia is important today as it is a source of:
- fertilisers
- cleaning agents and detergents
- fibres and plastics
- nitric acid and explosives.

1 mark each for any two

(c) (i) Write an equation that describes the Haber process. 1

$N_{2(g)} + 3H_{2(g)} \rightleftharpoons NH_{3(g)}$

(ii) Is the synthesis of ammonia an exothermic or endothermic reaction? 1

Exothermic

Question 26 continues on page 15

Marks

(d) By analysing the factors affecting ammonia synthesis, explain why the Haber process requires a compromise between these factors. 4

- The factors affecting ammonia synthesis are temperature, pressure, concentrations of reactants and products, and use of a catalyst.

Why a compromise is required

- Because ammonia synthesis is an equilibrium reaction and each of these factors affects the equilibrium differently, there must be a compromise between these factors to get a good yield of ammonia.

Analysis of factors

- Temperature must be high enough to achieve a good rate, but not too high because energy input favours formation of reactants. (Optimal temperature ~ 300-400°C)
- Pressure is best as high as possible as increased pressure shifts the equilibrium towards product formation. The strength and expense of reaction vessels is a consideration. (~300atm)
- Concentrations of reactants and products also affect the position of the equilibrium so the ratio of N_2 : H_2 must be maintained at 1:3 and NH_3 must be removed as it is formed so the equilibrium favours NH_3 formation
- A catalyst does not affect the position of the equilibrium but by enabling a good rate of reaction it reduces the requirement for high temperatures.

End of Question 26

Student No. .....

Question 27 (8 marks)

Marks

(a) Explain why the presence of ozone in the upper atmosphere is beneficial to life on earth. 2

Question 27.
(a)
Ozone in upper atmosphere (stratosphere) is a benefit to life on earth. In the upper atmosphere the ozone acts to protect the earth from radiation by absorbing the high energy UV radiation, while allowing the low energy UV radiation to reach the earth. This high energy UV radiation would cause cancerous tissues (skin cancer) if it reached the earth. A region where there is a decrease in amount of ozone is known as the ozone hole.

(a)
One mark for description of selective UV absorption and transmission.

One mark for problem if UV radiation reaches earth.

(b) CFCs can lower the concentration of ozone in the upper atmosphere.

(i) Which element in the molecules of CFCs causes the destruction of the ozone molecule? 1

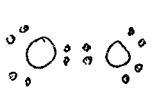
Chlorine

(ii) Write an equation which shows how ozone is destroyed by this element. 1

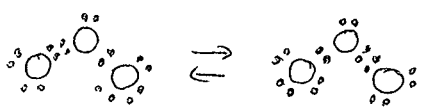
$Cl + O_3 \rightarrow ClO + O_2$

(c) (i) Using electron dot diagrams (Lewis diagrams), draw and label the oxygen molecule and the ozone molecule. 2

Oxygen



Ozone



Must be bent

(ii) Referring to their structure and bonding, compare oxygen and ozone over one property. 2

Properties - B.P., Solubility, Reactivity

B.P. $O_2 < O_3$ O_3 has more $\bar{e}$'s, more dispersion forces

Solubility $O_3 > O_2$ O_3 is bent, polar so more attracted to H_2O

Reactivity $O_2 < O_3$ O_2 has to break double bond to react so requires more energy to react. O_3 reacts at single bond

1 mark for suitable property 1 mark for explanation

Student No. .....

Marks

Question 28 (12 marks)

Many working chemists are involved in monitoring the Earth's atmosphere, or the Earth's hydrosphere.

(a) In the atmosphere, changes in ozone concentration have been reported over the last twenty years, and these changes have been attributed to CFCs.

Analyse the evidence that indicates these changes have occurred and explain how the information is obtained. 3

Evidence

- Measurements of total amount of O_3 in a column of the atmosphere have been made since 1957 and in 1970's a dramatic decline in springtime O_3 occurred over the entire Antarctic region
- By 1980's a hole with no O_3 occurred over Antarctica with 30% - 50% depletion outside the hole. Present readings indicate springtime O_3 depletion over Antarctica at > 50%

1

- Investigations in the 1970's showed that CFC's were the most significant depleter of O_3 in the stratosphere. They had been widely used since the 1950's

1

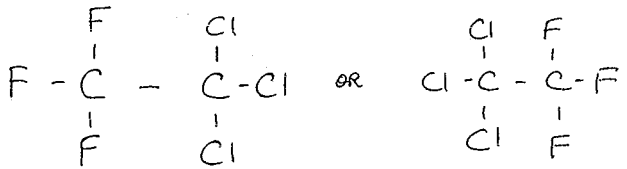
- O_3 levels in the atmosphere are using
  - UV spectrophotometers pointing straight up into the atmosphere
  - UV spectrophotometers pointing down from the balloons
  - Satellite carried spectrophotometers which gave a global picture of changes in O_3 ie Total Ozone Mapping Spectrophotometer (TOMS)

1

(b) The CFC-113 was used as a solvent and has the systematic name:

2, 2, 2 - trichloro -1, 1, 1 - trifluoroethane

(i) Draw the structural formula of this CFC. 1



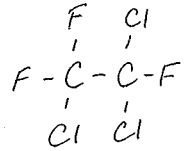
OR

Question 28 continues on page 18

Student No. .....

Question 28 (b) (continued) Marks

(ii) Draw an isomer of CFC-113 and name it systematically. 2



1

2,2,1- trichloro- 1,1,2- trifluoroethane 1

(c) In city water supplies many undesirable impurities are present.

(i) Describe the physical and chemical processes used to purify and sanitise your local water supply. You may use a clearly and thoroughly labelled diagram if you wish. 3

Step1 Clarification by Flocculation - the pH of the water is made basic by adding lime or NaOH, then Fe^{3+} or Al^{3+} compounds are added. These ions precipitate as hydroxides. Fine clay suspensions stick to the hydroxides forming heavier particles which then sink to the bottom. The tank sludge is periodically removed

Step2 Filtration The clarified water passes through a bed of sand (and gravel, or sand and anthracite) and any remaining flocculation precipitates & organic matter are filtered out. The water is clear, colourless and odourless after this step.

Step3 Sanitation (sterilisation) Gaseous chlorine is added to kill bacteria and some viruses. [Cl_2] must stay above 1ppm until the water reaches the user.

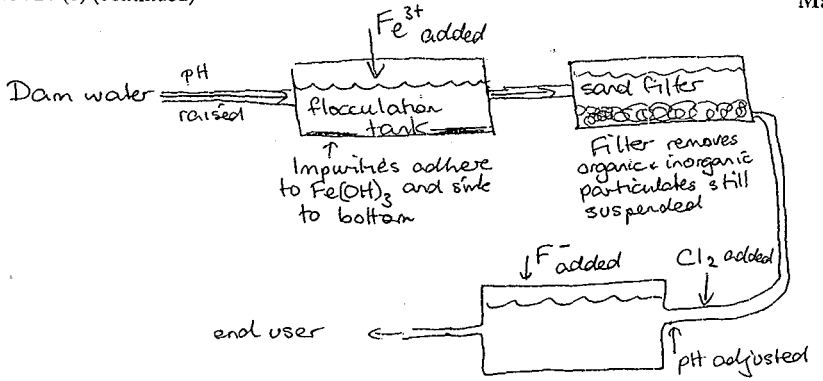
Step 4 Fluoridation - Sodium fluoride is added to strengthen tooth enamel in growing children.

Throughout the process water quality is tested and the quality monitored to meet set criteria

Question 28 continues on page 19

Student No. .....

Question 28 (c) (continued) Marks



1 mark for flocculation

1 mark for filtering

1 mark for adding Cl_2 & F^-

Must be in right order

Must have explanatory labels

Must be neat, clear & easy to follow

(ii) Assess the effectiveness of this process. 1

Water treatment is a balance between cost and quality. The above process failed in 1998 when levels of Giardia & Cryptosporidium were too high in the Prospect Reservoir. Not all viruses can be killed with Cl_2. Better methods would include micromembrane filtration or ozone sterilisation, both of which would add significant costs to the consumer. Most of the time the above method is sufficient & cost effective.

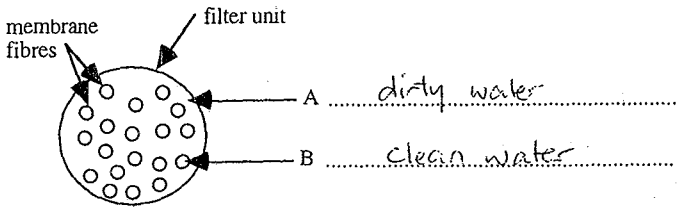
Question 28 continues on page 20

Student No. .....

Question 28 (continued) Marks

(d) (i) Purification of recycled water may include microscopic membrane filtration. The cross-sectional diagram below shows a bundle of membrane fibres in the filter unit.

Correctly label A and B as "dirty water flow" and "clean water flow".



1

(ii) Describe **ONE** advantage of microscopic membrane filtration over traditional sand and gravel filtration. 1

- Can filter out much smaller particles
- Filters out virtually 100% of particles larger than pore size
- Are very thin so water flows through rapidly
- Can withstand pressure differences of 3-5 atm
- Can be easily cleaned by back flushing with air or water & then used again

End of Question 28

Student No. .....

Marks

Question 29 (5 marks)

Some Year 12 students carried out a first-hand investigation to determine the presence of anions in a sample of water. They were given the following information:

- All chlorides are soluble except silver and lead
- All sulfates are soluble except silver, lead, barium, calcium and strontium
- Carbonates neutralise acids
- Phosphates will form a bright yellow precipitate with oxyanions of molybdenum

Their procedure and results are summarised in the following table.

Procedure	Observations
1. Addition of excess HNO_3	Vigorous bubbling and fizzing
2. Addition of excess barium nitrate	No visible reaction
3. Addition of excess silver nitrate	A white precipitate formed
4. The precipitate was filtered off	
5. Ammonium molybdate was added	No visible reaction

(a) Which **TWO** ions have been identified as being in the sample by this procedure? 2

Carbonate and chloride (or CO_3^{2-} & Cl^-)

1 1

(b) Write a net ionic equation to describe the reaction in (3) of the procedure. 1

$Ag^+_{(aq)} + Cl^-_{(aq)} \rightarrow AgCl_{(s)}$

Question 29 continues on page 22

Student No. .....

Question 29 (continued) Marks

(c) Is this analysis qualitative or quantitative? 1

Qualitative

(d) Explain why the order in which the tests were carried out is important, referring to the error that would be caused by adding silver nitrate before barium nitrate. 1

If the steps are out of order different results will be obtained eg if silver nitrate is added first the precipitate formed could be Cl^-, SO_4^{2-} which would then be filtered off, specific identification being impossible. When the $Ba(NO_3)_2$ was added there would be no sulfates left to identify, so it cannot be concluded that sulfates are present or not present.

End of Question 29

End of Section I

Student No. .....

Section II

10 marks
Attempt EITHER Question 30 OR Question 31
Allow about 30 minutes for this section

Use the spaces provided on the paper.

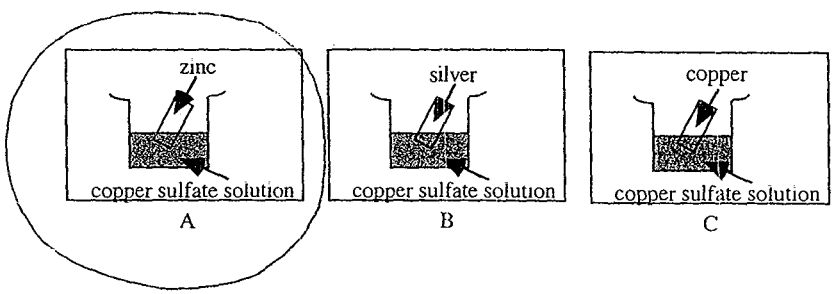
Marks

EITHER

Shipwrecks, Corrosion and Conservation

Question 30 (10 marks)

(a) From your knowledge of electron transfer and metal reactivity, circle the diagram below which illustrates the conditions necessary for a reaction to occur. 1



(b) Identify the sources of the salts dissolved in the ocean. 2

Sodium, magnesium, calcium, chloride & sulfate ions dissolve from rocks & soils in rainwater & percolate through the ground to streams & rivers into the ocean. Underground water at lower pH also dissolves carbonates to give hydrogen carbonate ions. Small amounts of nitrates & phosphates dissolve from organic matter decaying in waterways. 1

Seawater percolating down into fissures in mid ocean ridges is superheated & is forced back up into the ocean as hydrothermal vents - the super hot water ~~does~~ carries dissolved sulfides & sulfates of metals. As the water cools Fe^{2+}, Cu^{2+} Zn^{2+} + Ag^+ crystalise out but K^+, Mg^{2+} Ca^{2+}, Na^+, Cl^- + SO_4^{2-} stay dissolved. 1

Question 30 continues on page 22

Acceptable

1. Leaching of ions from rocks & soil by rain and ground water which eventually runs to ocean → 1
2. Water (ocean) passes through [illegible]

The oceans contain a greater concentration of salts than fresh water. The oceans act as electrolytes because they are solutions of dissolved salts. These dissolved salts contain ions.

The sources of these ions are

- the salts which make up the rocks of the earth's crust and
- the chemicals making up the magma in mid-ocean ridges between the terrestrial plates.

Water dissolves/leaches the salts from the terrestrial environments. These salts run into the rivers and streams until they reach the oceans. There they can precipitate and settle or can stay dissolved in the water. The ocean currents ensure that the ions are moved from place to place and are fairly evenly distributed in the earth's oceans.

As corrosion is a galvanic process then the presence of electrolytes promotes the corrosion reaction.

Fresh water, containing fewer ions, does not allow the current to flow to the same extent in a galvanic cell.

Student No. .....

Marks

(c) (i) Explain why steel has been the most popular material for ship building since the mid 19th century. 2

Steel has the advantages of

- hardness
- mechanical strength
- malleability (can be rolled into sheets then pressed into desired shapes)
- sheets can be welded so they fuse into one solid

($\frac{1}{2}$ each)

(ii) Describe the conditions under which rusting occurs and explain the process of rusting, using relevant equations where appropriate. 5

Conditions (Essential)

- Rusting is the corrosion of iron to form a porous, flaky iron oxide
- Rusting occurs when both oxygen and water are present → 1
- Salt accelerates rusting / impurities, stress points + the presence of a less reactive metal will the iron also accelerate rusting.

Process

- At a point of stress on the surface of the iron, iron atoms lose electrons & are oxidised $Fe_{(s)} \rightarrow Fe^{2+}_{(aq)} + 2\bar{e}$ (anode) → 1
- The electrons move to another point on the surface where they reduce the oxygen that is dissolved in the water at that surface point $\frac{1}{2}O_2 + 2H_2O + 2\bar{e} \rightarrow 2OH^-$ (cathode) ($O_2 + 4H_2O + 4\bar{e} \rightarrow 4OH^-$) → 1
- The Fe^{2+} ions at the anodic site + the OH^- ions at the cathodic site migrate through the water to form the $Fe(OH)_2$ precipitate $Fe^{2+}_{(aq)} + 2OH^-_{(aq)} \rightarrow Fe(OH)_{2(s)}$ → 1
- In the presence of dissolved oxygen, further oxidation of Fe^{2+} occurs to form Fe^{3+}, the red flaky powder solid we know as rust.

$4Fe(OH)_2 + O_2 \rightarrow 2Fe_2O_3 \cdot H_2O + 2H_2O$ → 1

* If no equations but accurate descriptions of each step → marks OR