CRANBROOK
SCHOOL

Centre Number

Student Number

2014
HSC Trial Examination
Assessment Task 4
Task Weighting 35%

# Chemistry

**General Instructions**

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black or blue pen
- Draw diagrams using pencil
- Board-approved calculators may be used
- Use the Data Sheet and Periodic Table provided
- Use the Multiple-Choice Answer Sheet provided
- Write your Centre Number and Student Number at the top of this page, on the Multiple-Choice Answer Sheet, and on the booklet(s) used for the Option.

**Total marks – 100**

**Additional Materials Needed**

- Multiple Choice Answer Sheet
- One writing booklet for the Option

**Section I** Pages 3-22

**75 marks**
This section has two parts, Part A and Part B

Part A – 20 marks
- Attempt Questions 1-20
- Allow about 35 minutes for this part

Part B – 55 marks
- Attempt Questions 21-31
- Allow about 1 hour and 40 minutes for this part

**Section II** Pages 23-28

**25 marks**
- Attempt ONE question from Questions 32-34
- Allow about 45 minutes for this section

This paper must not be removed from the examination room

**BLANK PAGE**

## Section I
**75 marks**

### Part A – 20 marks
**Attempt Questions 1-20**
**Allow about 35 minutes for this part**

Use the multiple-choice answer sheet provided for Questions 1-20.

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 have changed 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:

A ☒ B ☒ ← *correct* C ○ D ○

**1** In a first-hand investigation in a school laboratory, students were asked to distinguish between alkanes and alkenes, by reaction with bromine water.

The most suitable pair of chemicals to use in this experiment would be

(A) propane and ethane.

(B) cyclohexene and hexane.

(C) hex-3-ene and hexane.

(D) hex-1-ene and hex-2-ene.

**2** Boron neutron capture therapy is now being trialled for destruction of cancers such as brain tumours. The therapy is based on the nuclear capture and fission reactions that occur when non-radioactive boron-10 is irradiated with neutrons of the appropriate energy to yield high energy alpha particles and high energy lithium-7 nuclei. The therapy is highly selective and can target the tumour at the cellular level without causing radiation damage to the adjacent normal cells and tissues.

The nuclear reaction is:

$$^{10}_{5}\text{B} + {}^{1}_{0}\text{n} \rightarrow {}^{11}_{5}\text{B} \rightarrow {}^{4}_{2}\text{He} + {}^{7}_{3}\text{Li} + \text{energy}$$

Which of the following statements about this method of treatment is INCORRECT?

(A) The products of the breakdown of boron-11 have a short range and will not penetrate surrounding cells.

(B) The products of breakdown of boron-11 are positively charged and have ionising potential.

(C) The neutrons used to irradiate the boron-10 can be produced in a nuclear reactor.

(D) Boron-10 is bombarded with positively charged particles.

**3** Membrane technology is not used to sanitise water for mass consumption.

Which of the following would be implications if such technology were to be used in the future?

(A) The efficiency of water supply would increase, but so would the cost.

(B) The cost of water would increase, but it would be safer to drink.

(C) The water would be safer to drink and the efficiency of supply would increase.

(D) The cost of water would increase, but with no change to its safety.

**4** The following results were obtained by a student performing titrations.

| *Titration no.* | *Initial burette reading (mL)* | *Final burette reading (mL)* |
|---|---|---|
| 1 | 0.00 | 23.40 |
| 2 | 24.00 | 46.75 |
| 3 | 0.00 | 22.70 |
| 4 | 0.00 | 22.75 |

Which value should the student use as the solution volume in the calculation?

(A) 22.70mL

(B) 22.73 mL

(C) 22.90mL

(D) 23.40mL

**5** The molar heat of combustion of propan-1-ol is 2020 kJ $mol^{-1}$. A quantity of propan-1-ol was combusted, generating 40.4 kJ of heat energy.

What mass of water would be formed, assuming complete combustion?

(A) 1.44 g

(B) 0.36 g

(C) 0.08 g

(D) 0.02 g

**6** Which of the following reactions will occur spontaneously?

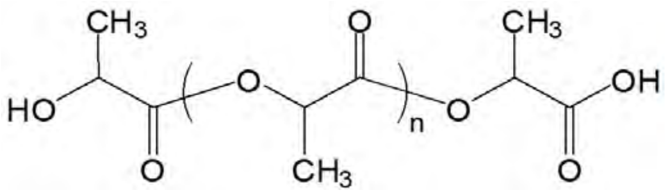
(A) $Zn\,(s) + Br_2\,(l) \rightarrow 2Br^-\,(aq) + Zn^{2+}\,(aq)$

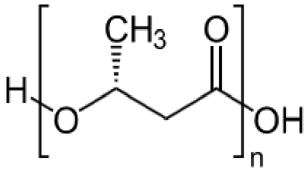
(B) $Zn\,(s) + 2Cl^-\,(aq) \rightarrow Cl_2\,(g) + Zn^{2+}\,(aq)$

(C) $Br_2\,(l) + 2Cl^-\,(aq) \rightarrow Cl_2\,(g) + 2Br^-\,(aq)$

(D) $Cl_2\,(g) + Br_2\,(l) \rightarrow 2Cl^-\,(aq) + 2Br^-\,(aq)$

**7** Which of the following best describes the TWO structures shown?





(A) Polyesters

(B) Condensation polymers

(C) Molecules

(D) All of the above.

**8** Sodium reacts with water to produce hydrogen gas and sodium hydroxide. What mass of sodium would be required to produce 4.5 L of hydrogen at 0ºC and 100 kPa?

(A) 0.2 g

(B) 0.4 g

(C) 4.5 g

(D) 9.1 g

**9** The following equilibrium was set up in a sealed reaction vessel:

$N_2O_4\,(g) \rightleftharpoons 2NO_2\ (g) \qquad \Delta H = +54.8 \text{ kJ mol}^{-1}$

Which of the following would DECREASE the yield of nitrogen dioxide?

(A) Adding the gas, argon, to the reaction vessel.

(B) Decreasing the volume of the reaction vessel.

(C) Raising the temperature of the reaction vessel.

(D) Adding a catalyst to the reaction vessel.

**10** Which substance shows the CORRECT indicator colour?

| | *Substance* | *Indicator* | *Colour* |
|---|---|---|---|
| (A) | Stomach acid | Phenolphthalein | Pink |
| (B) | Soda water (carbonated water) | Bromothymol blue | Yellow |
| (C) | Vinegar | Litmus solution | Blue |
| (D) | Caustic soda | Methyl orange | Red |

**11** Which of the following statements is INCORRECT?

(A) Carbon dioxide is classified as an acidic oxide as it reacts with water to form an acid.

(B) Zinc oxide is classified as an amphoteric oxide as it reacts both with hydrochloric acid and sodium hydroxide to form water.

(C) Sodium oxide is classified as a basic oxide as it reacts with water to form a solution with pH <7.

(D) Nitrogen dioxide is classified as an acidic oxide as it reacts with water to form an acidic solution.

**12** Using the same 0.100 mol $L^{-1}$ sodium hydroxide solution, a student carried out 2 titrations.

Titration 1: 25.0 mL of 0.100 mol $L^{-1}$ acetic acid
Titration 2: 25.0 mL of 0.100 mol $L^{-1}$ hydrochloric acid

Which of the following summarises the CORRECT information about these TWO titrations?

| | ***Titration 1*** | | ***Titration 2*** | |
|---|---|---|---|---|
| | ***Volume of sodium hydroxide required to reach equivalence point*** | ***pH at equivalence point*** | ***Volume of sodium hydroxide required to reach equivalence point*** | ***pH at equivalence point*** |
| (A) | 25 mL | >7 | 25 mL | 7 |
| (B) | >25 mL | >7 | <25 mL | <7 |
| (C) | 25 mL | <7 | 25 mL | 7 |
| (D) | <25 mL | 7 | >25 mL | >7 |

13 Iron (III) chloride and aluminium sulfate are two chemicals used in the purification of town water supplies.

What is the role of these chemicals?

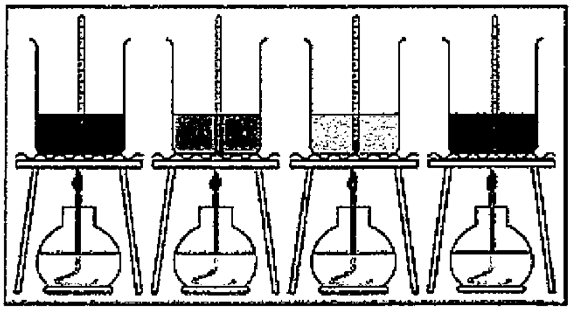
(A) To disinfect water by killing bacteria.

(B) To remove particulate material by coagulation and flocculation.

(C) To reduce the concentration of heavy metals.

(D) To maintain the pH of the water within the required range.

14 A *first-hand investigation* was performed to determine the molar heats of combustion for four alkanols.



Which of the following correctly classifies two variables?

| | *Independent variable* | *Dependent variable* |
|---|---|---|
| (A) | Temperature increase | Mass water in beaker |
| (B) | Mass alkanol used | Identity of alkanol used |
| (C) | Mass water in beaker | Time interval |
| (D) | Identity of alkanol used | Temperature increase |

15 A haloalkane has a molecular formula of $C_3H_6Cl_2$.
How many different isomers are there of this haloalkane?

(A) 1

(B) 2

(C) 3

(D) 4

**16** Many scientists have furthered our understanding of *acids.*

Which option correctly links a scientist to the main concept which they proposed?

(A) Lavoisier- acids contain oxygen.

(B) Davy- acids are proton donors.

(C) Arrhenius- acids are sour and change litmus to red.

(D) Bronsted and Lowry- acids are electron pair acceptors.

**17** Which gases are most likely to be produced by the *combustion of petrol* in a motor car?

(A) Ozone and methane

(B) Sulfur dioxide and chlorofluorocarbons

(C) Carbon dioxide and argon

(D) Nitrogen dioxide and carbon monoxide

**18** The onset of eutrophication of water bodies results from

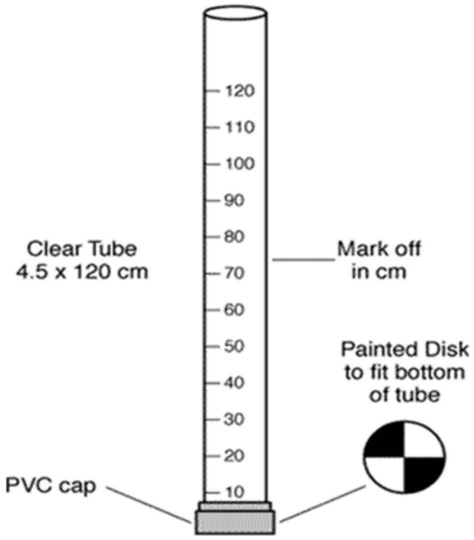
(A) an increase in the supply of nutrients such as phosphate and nitrate ions.

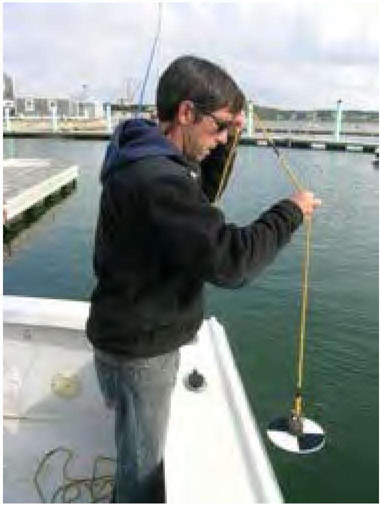
(B) an increase in the temperature.

(C) deposition of silt and organic wastes.

(D) a decrease in the concentration of oxygen in the water.

**19** The diagram and photograph show the use of equipment to measure a property of water supplies.





Which of the following properties of water is tested using this equipment?

(A) Oxygen concentration

(B) Turbidity

(C) pH

(D) TDS

**20** Some measurements were made on various water samples and the results tabulated:

| **Sample** | ***A*** | ***B*** | ***C*** | ***D*** |
|---|---|---|---|---|
| **DO (ppm)** | 5.5 | 7.5 | 8.7 | 5.6 |
| **TDS (ppm)** | 350 | 600 | 45 | 800 |
| **Turbidity (NTU)** | 100 | 60 | 5 | 10 |
| **pH** | 6.5 | 3.5 | 6.5 | 7.5 |
| **Coliforms (CFU/100 mL)** | 30 | 0 | 0 | 0 |

The samples were gathered from

- A dam in a farming community
- A river flowing through a national park in a mountainous area
- A holding pond near a zinc mine
- An underground supply of bore water

Which of the samples is most likely to be taken from an underground bore water supply?

(A) ***A***

(B) ***B***

(C) ***C***

(D) ***D***

☐☐☐☐☐

Centre Number

## Section I (continued)

☐☐☐☐☐☐☐☐☐

Student Number

**Part B – 55 marks**
**Attempt Questions 21-32**
**Allow about 1 hour and 40 minutes for this part**

Answer the questions in the spaces provided.

Show all relevant working in questions involving calculations.

---

**Question 21** (5 marks) **Marks**

“GRO-FAST” is a brand of fertiliser that claims to be pure ammonium sulfate.

**GRO-FAST**

**100% ammonium sulfate**
**LAWN FERTILISER**

(a) Write a balanced equation for an acid-base reaction that could produce this fertiliser. **1**

.......................................................................................................................

(b) Calculate the % sulfate that you would expect to be present in this fertiliser. **1**

.......................................................................................................................

.......................................................................................................................

(c) Design a valid experimental procedure you could use in the laboratory to verify the sulfate content in "GRO-FAST". (Calculation steps are not required.) **3**

.......................................................................................................................

.......................................................................................................................

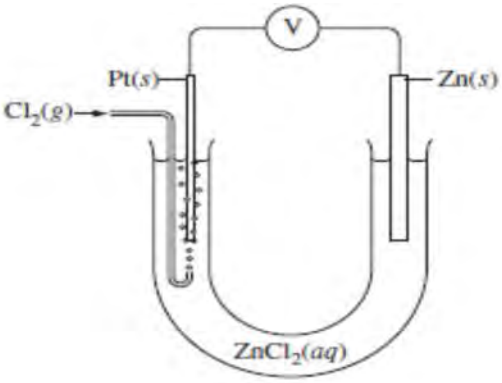
.......................................................................................................................

.......................................................................................................................

.......................................................................................................................

**Question 22** (5 marks) **Marks**

A galvanic cell was set up as shown in the diagram.



(a) Identify the electrode at which reduction occurs. **1**

………………………………………………………………………………………..

(b) Write an overall equation for the cell reaction and calculate the standard cell potential. **2**

………………………………………………………………………………………..

………………………………………………………………………………………..

(c) Explain why the process occurring in the cell can be described as "galvanic". **2**

………………………………………………………………………………………..

………………………………………………………………………………………..

………………………………………………………………………………………..

………………………………………………………………………………………..

………………………………………………………………………………………..

………………………………………………………………………………………..

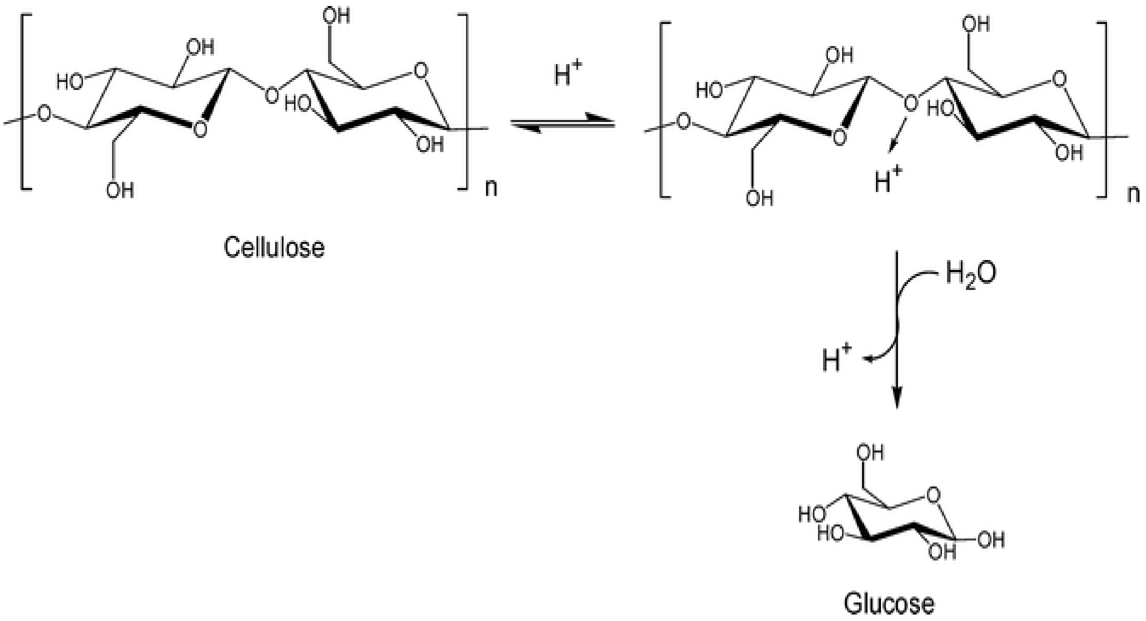
………………………………………………………………………………………..

………………………………………………………………………………………..

………………………………………………………………………………………..

**Question 23** (6 marks) **Marks**

Consider the following chemical reactions:



Critically evaluate the significance of these reactions as an industrial source of raw materials and energy for future generations. **6**

………………………………………………………………………………………..

………………………………………………………………………………………..

………………………………………………………………………………………..

………………………………………………………………………………………..

………………………………………………………………………………………..

………………………………………………………………………………………..

………………………………………………………………………………………..

………………………………………………………………………………………..

………………………………………………………………………………………..

**Extra space for your response is provided on the next page**

Question 23 (continued)

…………………………………………………………………………………………..

…………………………………………………………………………………………..

…………………………………………………………………………………………..

…………………………………………………………………………………………..

…………………………………………………………………………………………..

…………………………………………………………………………………………..

…………………………………………………………………………………………..

…………………………………………………………………………………………..

…………………………………………………………………………………………..

…………………………………………………………………………………………..

…………………………………………………………………………………………..

…………………………………………………………………………………………..

…………………………………………………………………………………………..

…………………………………………………………………………………………..

…………………………………………………………………………………………..

…………………………………………………………………………………………..

…………………………………………………………………………………………..

…………………………………………………………………………………………..

**Question 24** (6 marks) **Marks**

Three chemicals bottles are missing their labels. It is known that one is 1-heptene, another is hexane and the other is ethanol.

(a) Using only water and bromine water as your reagents, design a *first-hand Investigation* to correctly identify each of the THREE chemicals. Include the *method* and expected *results.* **4**

……………………………………………………………………………………..

……………………………………………………………………………………..

……………………………………………………………………………………..

……………………………………………………………………………………..

……………………………………………………………………………………..

……………………………………………………………………………………..

……………………………………………………………………………………..

……………………………………………………………………………………..

(b) Identify ONE *hazard* in this investigation AND suggest a safety measure that could be used to minimise the risk. **2**

……………………………………………………………………………………..

……………………………………………………………………………………..

……………………………………………………………………………………..

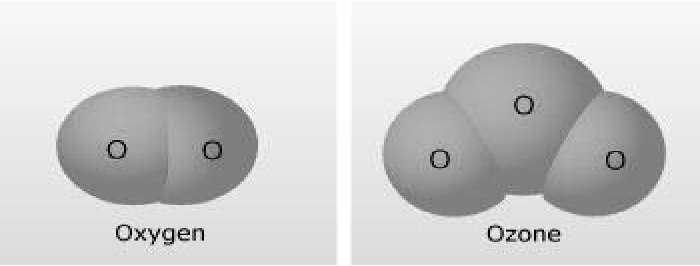
……………………………………………………………………………………..

……………………………………………………………………………………..

**Marks**

**Question 25** (7 marks)

Elemental oxygen has two allotropes, as shown below.



(a) A 51.6L (measured at 25°C and 100kPa) sample of a pure allotrope of oxygen has a mass of 100.0g.

Show, by calculation, which allotrope of oxygen is present in the sample. **2**

.....................................................................................................................

.....................................................................................................................

.....................................................................................................................

(b) Explain the difference in the way oxygen atoms are bonded in diatomic oxygen and ozone, including electron-dot diagrams with your answer. **3**

.....................................................................................................................

.....................................................................................................................

.....................................................................................................................

**2**

(c) Which allotrope would you expect to have a higher boiling point?

Justify your answer.

.....................................................................................................................

.....................................................................................................................

.....................................................................................................................

.....................................................................................................................

**Question 26** (5 marks) **Marks**

(a) Using expanded structural formulae, write an equation to show the formation of the ester, 1-propyl methanoate, from an alcohol and an acid. **2**

(b) Use a labelled diagram to explain why this experiment should be carried out using reflux apparatus. **3**

**Question 27** (4 marks) **Marks**

A green solution was made containing a weak acid, HA (which is a yellow molecule) and its conjugate base, $A^-$ (which is blue).

(a) Write an equation for the reaction which occurs when a strong base such as sodium hydroxide is added to this solution. **1**

……………………………………………………………………………….........

(b) Write an equation for the reaction which occurs when a strong acid such as hydrochloric acid is added to this solution. **1**

……………………………………………………………………………….........

(c) Use your equations to explain why this solution can act as an indicator. **2**

……………………………………………………………………………….........

……………………………………………………………………………….........

……………………………………………………………………………….........

……………………………………………………………………………….........

**Question 28** (4 marks)

(a) Which elements are classified as "transuranic"? **1**

...........................................................................................................................

...........................................................................................................................

(b) Describe TWO different methods of production of transuranic elements. Include an appropriate equation for each method you describe. **3**

……………………………………………………………………………..

...........................................................................................................................

...........................................................................................................................

...........................................................................................................................

...........................................................................................................................

**Question 29** (3 marks) **Marks**

Scientists use atomic absorption spectroscopy (AAS) for many different analyses.
In one experiment, solutions containing zinc ions were analysed. A standard solution of 5 ppm zinc was found to have an absorbance of 0.360. A second solution containing zinc ions of unknown concentration was analysed and found to have an absorbance of 0.540.

(a) Determine the concentration of zinc in the second (unknown) solution. **1**

……………………………………………………………………………………..

………………………………………………………………………………………

………………………………………………………………………………………

(b) 250 mL of the second (unknown) solution was reacted with excess sodium carbonate solution. A precipitate of zinc carbonate formed. This precipitate was filtered, dried and weighed. **2**

Calculate the mass, in grams, of the precipitate formed.

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

**Question 30** (6 marks) **Marks**

A student was asked to carry out a sequence of precipitation reactions to separate and identify cations present in a solution containing a mixture of the nitrate salts of these cations: **$Pb^{2+}$, $Ca^{2+}$ and $Fe^{2+}$.**

(a) Draw a flowchart to summarise the method used to separate and identify the cations. **3**

(b) Write equations for the THREE precipitation reactions which occurred. **3**

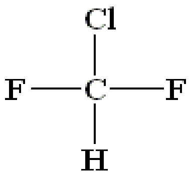
……………………………………………………………………………………….........

……………………………………………………………………………………….........

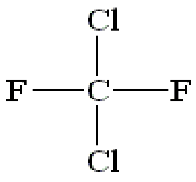
……………………………………………………………………………………….........

**Question 31** (4 marks) **Marks**

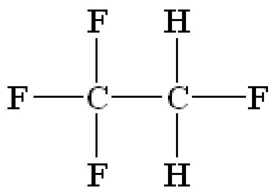
The structural formulae of three haloalkanes are shown below.



***Compound 1***



***Compound 2***



***Compound 3***

(a) Give the correct systematic (IUPAC) name for ***Compound 3***. **1**

…………………………………………………………………………………………..........

(b) Assess the impacts of these haloalkanes on depletion of ozone in the stratosphere. **3**

…………………………………………………………………………………………..........

…………………………………………………………………………………………..........

…………………………………………………………………………………………..........

…………………………………………………………………………………………..........

…………………………………………………………………………………………..........

…………………………………………………………………………………………..........

…………………………………………………………………………………………..........

…………………………………………………………………………………………..........

…………………………………………………………………………………………..........

…………………………………………………………………………………………..........

…………………………………………………………………………………………..........

…………………………………………………………………………………………..........

…………………………………………………………………………………………..........

**End of Section I – Part B**

## Section II

**25 marks**

**Attempt ONE question from Questions 32–34**

**Allow about 45 minutes for this section**

Answer parts (a)–(c) of the question in Section II Answer Booklet 1. Answer parts (d)–(e) of the question in Section II Answer Booklet 2. Extra writing booklets are available.

Show all relevant working in questions involving calculations.

**Question 32 – Industrial Chemistry** (25 marks) **Marks**

(a) (i) "The method of extraction of sulfur by the Frasch process is only possible because of the physical properties of the element sulfur." Assess this statement. **4**

(ii) During the industrial production of sulfuric acid, the conversion of sulfur dioxide to sulfur trioxide occurs in steps. Outline these steps and explain why they are necessary. **4**

(b) Gaseous hydrogen bromide partially decomposes to form hydrogen and bromine according to the equation:

$$2HBr\,(g) \rightleftharpoons H_2\,(g) + Br_2\,(g)$$

At 450 K, the equilibrium constant for the decomposition reaction is 0.0575.

Some hydrogen bromide gas was placed in an evacuated 3.00 L vessel and heated to 450 K. When the system had reached equilibrium, the equilibrium concentration of hydrogen was found to be $9.50 \times 10^{-4}$ mol $L^{-1}$.

(i) Write the equilibrium constant expression for the decomposition reaction. **1**

(ii) Calculate the concentration of gaseous bromine in the equilibrium mixture at 450 K. **1**

(iii) Calculate the concentration of gaseous hydrogen bromide in the equilibrium mixture at 450 K. **1**

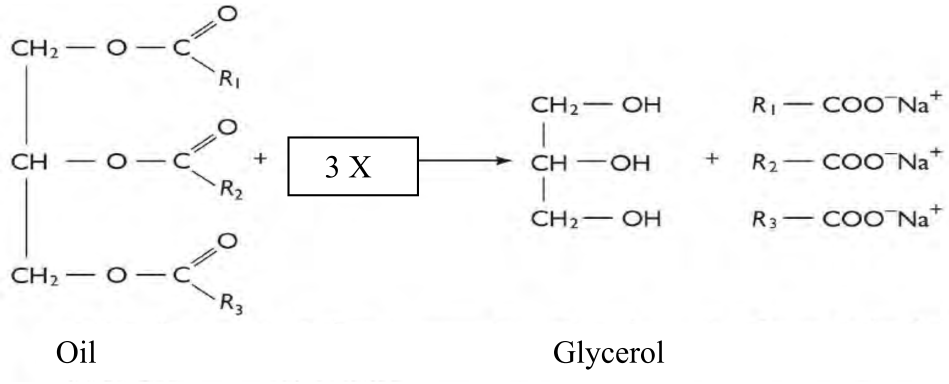
(c) (i) Using appropriate half-equations, explain why the reaction products of electrolysis of molten sodium chloride differ from the products of electrolysis of concentrated brine solution. **4**

(ii) "The use of a membrane cell in the industrial production of sodium hydroxide is preferable to earlier electrolytic methods."
Assess this statement. **4**

**Question 32 continues on the next page**

Question 32 (continued)

(d) The equation represents a reaction that can be performed in a school laboratory.



(i) Identify the term used to describe this type of reaction. **1**

(ii) Identify the reactant X. **1**

(iii) Describe how this type of reaction could be carried out in the school laboratory. Include appropriate safety precautions in your response and explain the reasons for these precautions. **3**

(iv) Describe a use of the product other than glycerol formed by this reaction. **1**

**End of Question 32**

**Question 33 – Shipwrecks, Corrosion and Conservation** (25 marks) **Marks**

(a) You have studied the historical contributions of 4 scientists, **Davy, Faraday, Galvani and Volta,** to the development of our understanding of the electrical nature of matter. **5**

Draw up a table to summarise the main contributions of each of these 4 scientists. Ensure that you list the scientists in the table in chronological order.

(b) "As the temperature of water decreases and as the pressure increases, the concentration of oxygen dissolved in sea water would be expected to increase." **6**

"Hence the corrosion of shipwrecks at depth might be expected to be greater than at the surface."

Assess these statements.

(c) The position of aluminium on the Table of Reduction Potentials indicates that aluminium is a reactive metal. However, aluminium is used in building construction and as an alloy in aircraft. **2**

Explain this apparent anomaly.

(d) There are several different ways of protecting iron from corrosion.

(i) Design a laboratory experiment to compare the effectiveness of several different methods of protection of iron. Include relevant labelled diagrams. **3**

(ii) Outline the results of your experiment. **2**

(iii) Explain how one of these methods is used in the protection of ocean-going ships. Use an equation (or half-equations) in your response. **2**

(e) Metal artefacts which are recovered from shipwrecks are often coated in concretions which must be removed before electrolysis is used to assist in restoration.

(i) Write an appropriate equation for a chemical reaction which can assist in the removal of the concretions. **1**

(ii) Discuss the process of restoration of a metal artefact by electrolysis. Include a diagram to represent the electrolytic cell used and equations (or half-equations) in your response. **4**

**End of Question 33**

**Question 34 – Forensic Chemistry** (25 marks) **Marks**

(a) "The analysis of DNA is now an extremely valuable tool for forensic investigations." **3**

Provide evidence to support this statement.

(b) The table below shows information about 3 polysaccharides.

| | ***A*** | ***B*** | ***C*** |
|---|---|---|---|
| Source | Plant | Animal | Plant |
| Structure | Contains branched and linear chains | Contains highly branched chains | Contains linear chains only |

(i) Outline THREE common structural properties of the polysaccharides ***A***, ***B*** and ***C***. **2**

(ii) What is the main function of polysaccharide ***B***? **1**

(iii) Explain how the structure of ***C*** is related to its function in plants. **2**

(c) (i) Clarify the meaning of the terms *organic compounds* and *inorganic compounds.* **1**

(ii) Describe how you distinguish, using a laboratory test, between an organic and an inorganic compound. **2**

(iii) Draw a flowchart to show the sequence of laboratory reactions to identify and distinguish between the compounds:
hex-1-ene, hexane, hexan-1-ol and hexanoic acid. **3**

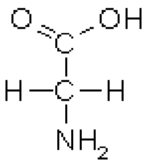
(iv) Write balanced equations for TWO of the identifying reactions included in your flowchart in (iii) above. **2**

(d) A scientist decided to use instrumental techniques to assist in a forensic analysis of a soil sample taken from a crime scene. Evaluate the use of at least THREE different instrumental techniques for this analysis. **6**

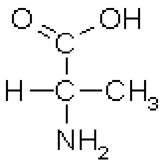
**Question 34 continues on the next page**

Question 34 (continued) **Marks**

(e) Two amino acids are represented by the structures below:



glycine



alanine

(i) Explain why they are both classified as amino acids. **1**

(ii) Use a diagram to show how these 2 amino acids would link together to form a dipeptide. **1**

(iii) Identify a method used to separate and distinguish between the two amino acids. **1**

**End of Paper**

☐☐☐☐☐
Centre Number

☐☐☐☐☐☐☐☐☐
Student Number

**CHEMISTRY – MULTIPLE-CHOICE ANSWER SHEET**

**ATTEMPT ALL QUESTIONS**

**Question** **1** A ○ B ○ C ○ D ○
**2** A ○ B ○ C ○ D ○
**3** A ○ B ○ C ○ D ○
**4** A ○ B ○ C ○ D ○
**5** A ○ B ○ C ○ D ○
**6** A ○ B ○ C ○ D ○
**7** A ○ B ○ C ○ D ○
**8** A ○ B ○ C ○ D ○
**9** A ○ B ○ C ○ D ○
**10** A ○ B ○ C ○ D ○
**11** A ○ B ○ C ○ D ○
**12** A ○ B ○ C ○ D ○
**13** A ○ B ○ C ○ D ○
**14** A ○ B ○ C ○ D ○
**15** A ○ B ○ C ○ D ○
**16** A ○ B ○ C ○ D ○
**17** A ○ B ○ C ○ D ○
**18** A ○ B ○ C ○ D ○
**19** A ○ B ○ C ○ D ○
**20** A ○ B ○ C ○ D ○

# Cranbrook 2014 HSC TRIAL EXAMINATION

# CHEMISTRY – MAPPING GRID

| Exam Section | Question | Marks | Syllabus/Course Outcomes | Content | Targeted Performance Bands | Answer |
|---|---|---|---|---|---|---|
| Section I: Part A: Multiple Choice | 1 | 1 | H9, H13 | 9.2.1 | 2-3 | C |
| | 2 | 1 | H6, H13 | 9.2.5 | 2-3 | D |
| | 3 | 1 | H6, H13 | 9.2.4 | 3-4 | B |
| | 4 | 1 | H9, H13, H14 | 9.2.3 | 3-4 | B |
| | 5 | 1 | H7, H9, H10, H13 | 9.2.3 | 4-5 | A |
| | 6 | 1 | H8 | 9.2.4 | 3-4 | A |
| | 7 | 1 | H9 | 9.2.2 | 2-3 | D |
| | 8 | 1 | H8, H10 | 9.3.2 | 5-6 | D |
| | 9 | 1 | H8 | 9.3.2 | 4-5 | B |
| | 10 | 1 | H8 | 9.3.1 | 3-4 | B |
| | 11 | 1 | H8, H13 | 9.3.2 | 2-3 | C |
| | 12 | 1 | H8, H10 | 9.3.4 | 5-6 | A |
| | 13 | 1 | H4, H8 | 9.4.5 | 2-3 | B |
| | 14 | 1 | H9 | 9.3.5 | 3-4 | D |
| | 15 | 1 | H9, H13 | 9.4.4 | 4-5 | D |
| | 16 | 1 | H8, H11 | 9.4.3 | 3-4 | A |
| | 17 | 1 | H6, H8 | 9.4.4 | 3-4 | D |
| | 18 | 1 | H4 | 9.4.5 | 2-3 | A |
| | 19 | 1 | H4 | 9.4.5 | 2-3 | B |
| | 20 | 1 | H4 | 9.4.5 | 3-4 | D |
| Section I: Part B: Free Response | 21 | 3 | H4, H6 | 9.2.5 | 3-6 | |
| | 22 | 5 | H7, H8, H13 | 9.2.4 | 2-5 | |
| | 23 | 6 | H3, H4, H7, H9 | 9.2.2 | 2-6 | |
| | 24 | 5 | H10, H11, H12, H14 | 9.2.3 | 2-5 | |
| | 25 | 4 | H8, H14 | 9.3.2 | 2-5 | |
| | 26 | 6 | H9, H11, H12, H13 | 9.3.5 | 2-5 | |
| | 27 | 3 | H10 | 9.3.3 | 3-5 | |
| | 28 | 4 | H8, H13 | 9.3.1, 9.3.3, 9.3.4 | 3-5 | |
| | 29 | 5 | H3, H4, H8 | 9.4.2 | 2-6 | |
| | 30 | 3 | H10 | 9.4.3 | 2-5 | |
| | 31 | 6 | H8, H11, H13 | 9.4.3 | 2-4 | |
| | 32 | 5 | H3, H4, H8, H13 | 9.4.4 | 2-6 | |

**Disclaimer**

| | | | | | | |
|---|---|---|---|---|---|---|
| Section II: Option: Industrial Chemistry | 33 (a) | 8 | H3, H4, H8, H13 | 9.5.3 | 2-6 | |
| | 33 (b) | 3 | H10 | 9.5.2 | 2-5 | |
| | 33 (c) | 8 | H1, H3, H4, H7, H8, H13 | 9.5.4 | 2-6 | |
| | 33 (d) | 4 | H3, H4, H9 | 9.5.5 | 2-5 | |
| | 33 (e) | 2 | H4, H5 | 9.5.6 | 3-5 | |
| Section II: Option: Shipwrecks, Corrosion and Conservation | 34 (a) | 5 | H1, H2, H13 | 9.6.1 | 2-5 | |
| | 34 (b) | 6 | H4, H8, H14 | 9.6.5, 9.6.6 | 2-6 | |
| | 34 (c) | 2 | H3, H4, H7, H8 | 9.6.2 | 2-4 | |
| | 34 (d) | 7 | H4, H8, H11, H12, H13 | 9.6.4 | 2-5 | |
| | 34 (e) | 5 | H4, H7, H8, H13 | 9.6.3, 9.6.5 | 2-5 | |
| Section II: Option: Forensic Chemistry | 35 (a) | 3 | H3, H4 | 9.9.1, 9.9.4 | 3-5 | |
| | 35 (b) | 5 | H9 | 9.9.2 | 2-5 | |
| | 35 (c) | 8 | H9, H11, H12, H13 | 9.9.1 | 2-5 | |
| | 35 (d) | 6 | H3, H4, H6, H7 | 9.9.1, 9.9.5, 9.9.6 | 2-6 | |
| | 35 (e) | 3 | H4, H9, H13 | 9.9.3 | 2-5 | |

# 2014 HSC TRIAL EXAMINATION

# CHEMISTRY – MARKING GUIDELINES

**Section I**
**Part A – 20 marks**
**Questions 1-20** (1 mark each)

| Question | Correct Response | Outcomes Assessed | Targeted Performance Bands |
|---|---|---|---|
| 1 | C | H9, H13 | 2-3 |
| 2 | D | H6, H13 | 2-3 |
| 3 | B | H6, H13 | 3-4 |
| 4 | B | H9, H13, H14 | 3-4 |
| 5 | A | H7, H9, H10, H13 | 4-5 |
| 6 | A | H8 | 3-4 |
| 7 | D | H9 | 2-3 |
| 8 | D | H8, H10 | 5-6 |
| 9 | B | H8 | 4-5 |
| 10 | B | H8 | 3-4 |
| 11 | C | H8, H13 | 2-3 |
| 12 | A | H8, H10 | 5-6 |
| 13 | B | H4, H8 | 2-3 |
| 14 | D | H9 | 3-4 |
| 15 | D | H9, H13 | 4-5 |
| 16 | A | H8, H11 | 3-4 |
| 17 | D | H6, H8 | 3-4 |
| 18 | A | H4 | 2-3 |
| 19 | B | H4 | 2-3 |
| 20 | D | H4 | 3-4 |

## Section I
## Part B – 55 marks

### Question 21 (5 marks)

**21.a**

| Marking Guidelines | Marks |
|---|---|
| • Writes a balanced chemical equation for the reaction that produces ammonium sulphate ( no states necessary, but incorrect states marked wrong) | **1** |

$2NH_3\ (aq) + H_2SO_4\ (aq) \rightarrow (NH_4)_2SO_4\ (aq)$

**21.b**

| Marking Guidelines | Marks |
|---|---|
| • Calculates the % sulfate in ammonium sulfate. | **1** |

$\%\ (SO_4^{2-}) = MM\ (SO_4^{2-})\ /\ MM\ ((NH_4)_2SO_4) \times 100 = 96.07\ /\ 132.184 \times 100 = 72.7\%$

**21.c**

| Marking Guidelines | Marks |
|---|---|
| • Describes a valid procedure for precipitating out the sulfate in the fertiliser and using gravimetric analysis to determine the % by mass of sulfate in the fertliliser. Must include excess barium, and dry & weigh. | **3** |
| • Outlines a basic procedure for determining the % by mass of sulfate in the fertiliser, with insufficient detail or a major step omitted. | **2** |
| • Identifies one step in the procedure (eg addition of barium nitrate). | **1** |

1. **Weigh** a small sample of 'GRO-FAST' on an electronic balance.
2. Dissolve the sample in distilled water, heating gently if needed to ensure sample dissolves.
3. Add **excess** 2M barium nitrate to the solution to precipitate out the sulfate. Add slowly and apply gentle heat to promote large particle size for the barium sulfate.
4. Weigh the filter paper
5. Filter the mixture, **dry** the residue and re-weigh on an electronic balance.

### Question 22 (5 marks)

22 (a) (1 mark)

***Outcomes Assessed: H8***

***Targeted Performance Bands: 2-3***

| Criteria | Mark |
|---|---|
| • Identifies the platinum electrode as the site of reduction | 1 |

**Sample answer**

The platinum electrode is where chlorine is reduced.

22 (b) (2 marks)

***Outcomes Assessed: H7, H8, H13***

***Targeted Performance Bands: 2-4***

| Criteria | Marks |
|---|---|
| • Writes a correctly balanced overall equation AND calculates the standard cell potential (including states where not (aq)) | 2 |
| • Writes a correctly balanced overall equation OR calculates the standard cell potential (or 2 marks w/o states where not (aq)) | 1 |

**Sample answer**

$$\begin{array}{llll} Zn\,(s) & \rightleftharpoons & Zn^{2+}\,(aq) + 2e^- & 0.76\ V \\ \underline{Cl_2\,(g) + 2e^-} & \underline{\rightleftharpoons} & \underline{2Cl^-\,(aq)} & \underline{1.36\ V} \\ Zn\,(s) + Cl_2\,(g) & \rightarrow & Zn^{2+}(aq) + 2Cl^-\,(aq) & 2.12\ V \end{array}$$

Standard cell potential = 2.12 V

22 (c) (2 marks)

***Outcomes Assessed: H7, H8***

***Targeted Performance Bands: 3-5***

| **Criteria** | **Marks** |
|---|---|
| - Explains that a galvanic process involves a spontaneous transfer of electrons from an anode to a cathode because of the differing potentials of the metal electrodes in the presence of an electrolyte | 2 |
| - Explains that the process is spontaneous OR explains that the process involves transfer of electrons between anode and cathode OR explains that the process involves the movement of ions in an electrolyte | 1 |

**Sample answer**

Galvanic processes occur when spontaneous oxidation-reduction reactions occur, for example, when dissimilar metals are in electrical contact. The metals have different abilities to lose electrons (different oxidation potentials). The transfer of electrons in this cell occurs because the zinc at the anode loses electrons to the conducting wire and inert cathode; the electrons are picked up by the chlorine gas at the cathode and ions move in the electrolyte to maintain electrical neutrality in the solution.

**Question 23** (6 marks)
***Outcomes Assessed: H3, H4, H7, H9***
***Targeted Performance Bands: 2-6***

| Criteria | Marks |
|---|---|
| • Critically evaluates the significance of the reactions for future generations<br>• Identifies the reactions as 2 steps in the acidic hydrolysis of cellulose to glucose<br>• Discusses thoroughly benefits of cellulose as an industrial source of raw materials<br>• Discusses thoroughly benefits of cellulose as an industrial source of energy<br>• Discusses thoroughly problems associated with the use of cellulose because of the stability of its structure<br>• Discusses thoroughly problems associated with the fermentation of glucose for industry | 6 |
| • Identifies the reactions as 2 steps in the acidic hydrolysis of cellulose to glucose<br>• Discusses thoroughly benefits of cellulose as an industrial source of raw materials<br>• Discusses thoroughly benefits of cellulose as an industrial source of energy<br>• Discusses thoroughly problems associated with the use of cellulose because of the stability of its structure<br>• Discusses thoroughly problems associated with the fermentation of glucose for industry | 5 |
| • Identifies the reactions as 2 steps in the acidic hydrolysis of cellulose to glucose<br>• Discusses soundly benefits of cellulose as an industrial source of raw materials<br>• Discusses soundly benefits of cellulose as an industrial source of energy<br>• Discusses soundly problems associated with the use of cellulose for industry | 4 |
| • Discusses soundly benefits of cellulose as an industrial source of raw materials<br>• Discusses soundly benefits of cellulose as an industrial source of energy<br>• Discusses soundly problems associated with the use of cellulose for industry | 3 |
| • Identifies some benefits of cellulose as an industrial source of raw materials and energy<br>• Identifies some problems associated with the use of cellulose for industry | 2 |
| • Identifies some benefits of cellulose as an industrial source of raw materials and energy OR identifies some problems associated with the use of cellulose for industry | 1 |

**Sample answer**
The equations show 2 steps in the acid-catalysed hydrolysis of cellulose to glucose.

Cellulose is the chief component of biomass and hence is available for future generations as a source of materials for the production of energy and of other compounds which can be the starting products for chemical industry. Cellulose is renewable and its products are biodegradable and hence its use as a source of materials and energy would not cause environmental problems into the future. It is present in the cell wall of every plant cell and hence is not limited by climate to the same extent as sugar cane or other carbohydrate-rich crops.

However, cellulose has a very stable structure because of its long linear polymer chains which have strong covalent bonds within the chain and strong hydrogen bonding between neighbouring chains. This stable structure has meant that the use of cellulose as a source of glucose has been limited until the past decade. Cellulose does break down in the presence of enzymes and in an acidic environment but the hydrolysis reaction is slow and hence is not as efficient or cost effective as the hydrolysis of crops which contain starch or sugar.

Once the cellulose is broken down into glucose, low temperature fermentation, using yeast, is used to convert the glucose into ethanol. Ethanol can then be converted into a broad range of other chemical compounds or can be burnt as a fuel.

Unfortunately the fermentation process is very inefficient. The aqueous solutions of glucose which are fermented must be dilute and the temperature low (37ºC). Much energy is wasted in the separation of the ethanol from water after the fermentation. Large areas of land must be cultivated and cleared; this requires large input of energy.

Evaluation

The reactions referred to in the question are significant at the present time and will continue to be so for future generations. It is inevitable that, as supplies of fossil fuels such as petroleum and coal dwindle and as economic and political influences direct change, renewable sources of fuels and materials will be developed to the point where industry will be forced to establish large scale efficient manufacturing plants using biomass to supply the needs of society. In parallel, sources of energy (such as solar, nuclear, geothermal) which are alternate both to the use of fossil fuels and the use of biomass will need to develop to overcome the limitations of our current industrial processes.

**Question 24(a)**

| Criteria | Mark |
|---|---|
| • Logical method, results given and *all* THREE unknowns identified with both reagents | 4 |
| • Method given for identification of TWO unknowns with both reagents used | 3 |
| • Method given for identification of ONE unknown | 2 |
| • ONE relevant piece of information | 1 |

*Answer may include:* Place 1–2 mL of each unknown substance separately into 3 marked test-tubes. Add 1-2 drops of water to each and **shake** gently. The water is fully miscible only with ethanol, which is now identified. Label the ethanol bottle.

Add about 10 drops of bromine water to the two tubes in which water remains undissolved. **Shake** and observe. Results: 1-heptene decolourises bromine water, hexane does not. Label the remaining bottles

**Question 24(b)**

| Criteria | Mark |
|---|---|
| • Risk AND safety measure | 2 |
| • Risk OR safety measure | 1 |

*Answer may include:* Bromine water – bromine vapour fumes should not be inhaled. Fume cupboard used. Also, flammability of all three unknowns, no naked flames.

## Question 25 (4 marks)

**25.a**

| Marking Guidelines | Marks |
|---|---|
| • Calculates the molar mass of the oxygen allotrope in the sample and uses this to identify the correct allotrope. | 2 |
| • Calculates the number of moles of the oxygen allotrope in the sample. | 1 |

$n = V/V_m = 51.6/24.79 = 2.08$ mol

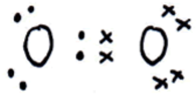
MM = m/n = 100/2.08 = 48.0 g/mol

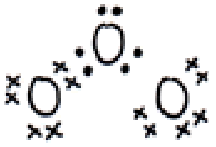
Thus the allotrope must be $O_3$, which has a molar mass of 48 g/mol.

**25.b**

| Marking Guidelines | Marks |
|---|---|
| • Draws the correct electron-dot diagrams of oxygen and ozone and explains in text the difference in bonding in the two allotropes-must refer to coordinate covalent bonding in ozone. | 3 |
| • Draws at least ONE correct electron-dot diagrams for oxygen or ozone and explains in text the difference in bonding in the two allotropes. | 2 |
| • Draws one correct electron-dot diagram OR<br>• Identifies a feature of bonding in either allotrope. | 1 |

In oxygen ($O_2$), the two oxygen atoms are bonded by two pairs of bonding electrons (ie a double covalent bond). Each oxygen also has 2 pairs of non-bonding electrons.





In ozone ($O_3$), two of the atoms are bound by a double covalent bond, but there is a single coordinate covalent bond between the central oxygen atom and the other oxygen. This other atom is using none of its electrons to form the bond-it thus has 3 non-bonding pairs of electrons around it.

**25.c**

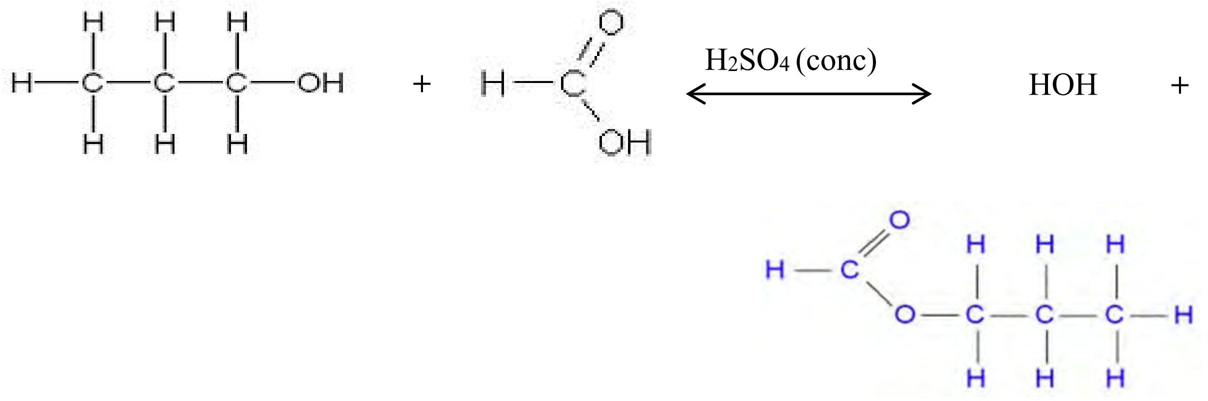
| Marking Guidelines | Marks |
|---|---|
| • Identifies that ozone will have the higher BP and explains this using intermolecular forces. | 2 |
| • Identifies that ozone will have the higher BP and partially explains this. | 1 |

Ozone has a higher boiling point than oxygen. It has a greater molecular mass, thus stronger dispersion forces, but because it is a bent molecule with an asymmetrical electron distribution, it has a degree of polarity and also has dipole-dipole interactions. Thus it has stronger intermolecular forces than oxygen gas (dispersion forces only), resulting in a higher boiling point.

**Question 26** (6 marks)
26 (a) (2 marks)
***Outcomes Assessed: H9, H13***
***Targeted Performance Bands: 3-5***

| Criteria | Marks |
|---|---|
| • Writes a complete correct equation (including the catalyst & arrow) for the reaction | 2 |
| • Writes TWO correct structural formulae for TWO of the alcohol, acid and ester & has water present in the equation. | 1 |

**Sample answer**



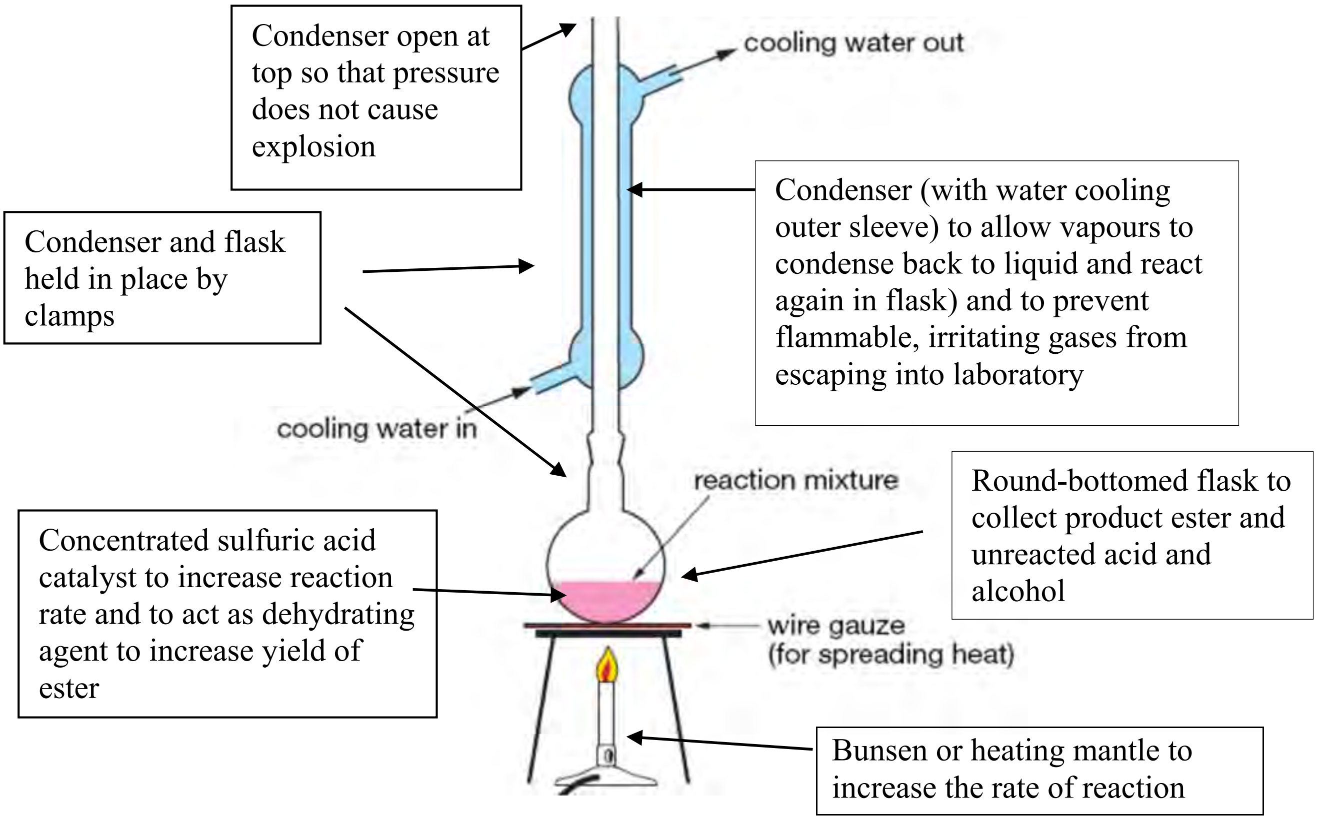
26 (b) (4 marks)

***Outcomes Assessed: H9, H11, H12, H13***

***Targeted Performance Bands: 2-5***

| Criteria | Marks |
|---|---|
| • Draws a fully labelled, correct diagram of reflux apparatus<br>• Explains thoroughly why the condenser is used<br>• Explains thoroughly why the Bunsen is used | 3 |
| • Draws a partially correct labelled diagram<br>• Explains soundly why the condenser is used<br>• Explains soundly why the Bunsen is used | 2.5 |
| • Draws a partially correct labelled diagram<br>• Explains a reason why the condenser is used<br>• Explains a reason why the Bunsen is used | 2 |
| • Draws a partially correct labelled diagram OR explains a reason why the condenser is used OR explains a reason why the Bunsen is used | 1 |

**Sample answer**



Condenser open at top so that pressure does not cause explosion

Condenser (with water cooling outer sleeve) to allow vapours to condense back to liquid and react again in flask) and to prevent flammable, irritating gases from escaping into laboratory

Condenser and flask held in place by clamps

Round-bottomed flask to collect product ester and unreacted acid and alcohol

Concentrated sulfuric acid catalyst to increase reaction rate and to act as dehydrating agent to increase yield of ester

Bunsen or heating mantle to increase the rate of reaction

**Question 27** (3 marks)
28 (a) (1 mark)
***Outcomes Assessed: H8, H13***
***Targeted Performance Bands: 3-4***

| Criteria | Mark |
|---|---|
| • Writes correct equation | 1 |

**Sample answer**

$OH^{-}\,(aq) + HA\,(aq) \rightarrow H_2O\,(l) + \underset{\text{blue}}{A^{-}}\,(aq)$

28 (b) (1 mark)
***Outcomes Assessed: H8, H13***
***Targeted Performance Bands: 3-4***

| Criteria | Mark |
|---|---|
| • Writes correct equation | 1 |

**Sample answer**

$H_3O^{+}\,(aq) + A^{-}\,(aq) \rightarrow H_2O\,(l) + \underset{\text{yellow}}{HA}\,(aq)$

28 (c) (2 marks)
***Outcomes Assessed: H8, H13***
***Targeted Performance Bands: 3-5***

| Criteria | Marks |
|---|---|
| • Explains why the solution can act as an indicator, as the colour changes with changes in pH / changes in concentration of $H_3O^+$<br>• Refers to the reactions in parts (a) and (b) | 2 |
| • Explains why the solution can act as an indicator as the colour changes with pH changes/concentration of $H_3O^+$ changes | 1 |

**Sample answer**

The solution is a green equilibrium mixture of HA (yellow) and $A^-$ (blue).

The equilibrium in the solution can be represented:

$$\underset{\text{yellow}}{HA}\,(aq) + H_2O\,(l) \rightleftharpoons \underset{\text{blue}}{A^{-}}\,(aq) + H_3O^{+}\,(aq)$$

When a strong base is added, the reaction in 28 (a) occurs and the indicator solution turns blue. Considering the equilibrium reaction above, the green solution turns blue, as the concentration of $H_3O^+$ decreases and the indicator equilibrium shifts to the right.

When a strong acid is added, the reaction in 28 (b) occurs. Considering the equilibrium reaction above, the green solution turns yellow, as the equilibrium shifts to the left as the concentration of $H_3O^+$ increases.

Hence the green solution can act as an indicator as it is a different colour in acidic and basic solutions; i.e. in solutions of different pH.

**Question 28** (4 marks)
28 (a) (1 mark)
***Outcomes Assessed: H6, H13***
***Targeted Performance Bands: 2-3***

| Criteria | Mark |
|---|---|
| - Identifies transuranic elements as those with Atomic No. > 92, after Uranium | 1 |

**Sample answer**
Transuranic elements are those after uranium in the Periodic Table; i.e. they have Z > 92.

28 (b) (3 marks)
***Outcomes Assessed: H6, H8, H13***
***Targeted Performance Bands: 2-4***

| Criteria | Marks |
|---|---|
| - Identifies that transuranic elements are made artificially by bombardment in a nuclear reactor or in an accelerator (cyclotron or linear accelerator)<br>- AND<br>- Writes ONE correct nuclear equation for a reactor bombardment with neutrons<br>- AND<br>- Writes ONE correct nuclear equation for an accelerator bombardment with a positively charged particle | 3 |
| - TWO of the above | 2 |
| - ONE of the above | 1 |

**Sample answer**
Some transuranic elements are made artificially by bombardment in a nuclear reactor by neutrons.

$$^{238}_{92}\text{U} + {}^{1}_{0}\text{n} \rightarrow {}^{239}_{92}\text{U} \rightarrow {}^{0}_{-1}\text{e} + {}^{239}_{93}\text{Np}$$

Transuranic elements are also produced by bombardment of nuclei by high speed positive particles such as helium (alpha particles), protons or nuclei of other atoms, such as carbon, in linear accelerators or in cyclotrons.

$$^{242}_{96}\text{Cm} + {}^{4}_{2}\text{He} \rightarrow {}^{245}_{98}\text{Cf} + {}^{1}_{0}\text{n}$$

**Question 29** (5 marks)
30 (a) (1 mark)
***Outcomes Assessed: H10***
***Targeted Performance Bands: 2-3***

| Criteria | Mark |
|---|---|
| - Correct answer | 1 |

**Sample answer**
During AAS analysis, the absorbance is proportional to the concentration of ions being analysed.
Since a standard solution of $Zn^{2+}$ of 5 ppm has an absorbance of 0.360, the concentration of the solution of $Zn^{2+}$ with an absorbance of 0.540 must be (0.540/0.360) x 5 = 7.5 ppm.

30 (b) (2 marks)

***Outcomes Assessed: H10***

***Targeted Performance Bands: 3-5***

| Criteria | Marks |
|---|---|
| • Correct answer | 2 |
| • Determines the mass of zinc ion in the 250 mL sample | 1 |

**Sample answer**

The unknown solution of $Zn^{2+}$ has a concentration of 7.5 ppm = 7.5 mg $L^{-1}$
A 250 mL sample contains 0.250 x 7.5 mg = 1.875 mg

In the precipitation reaction:

$Zn^{2+}$ *(aq)* + $CO_3^{2-}$ *(aq)* $\rightarrow$ $ZnCO_3$ *(s)*

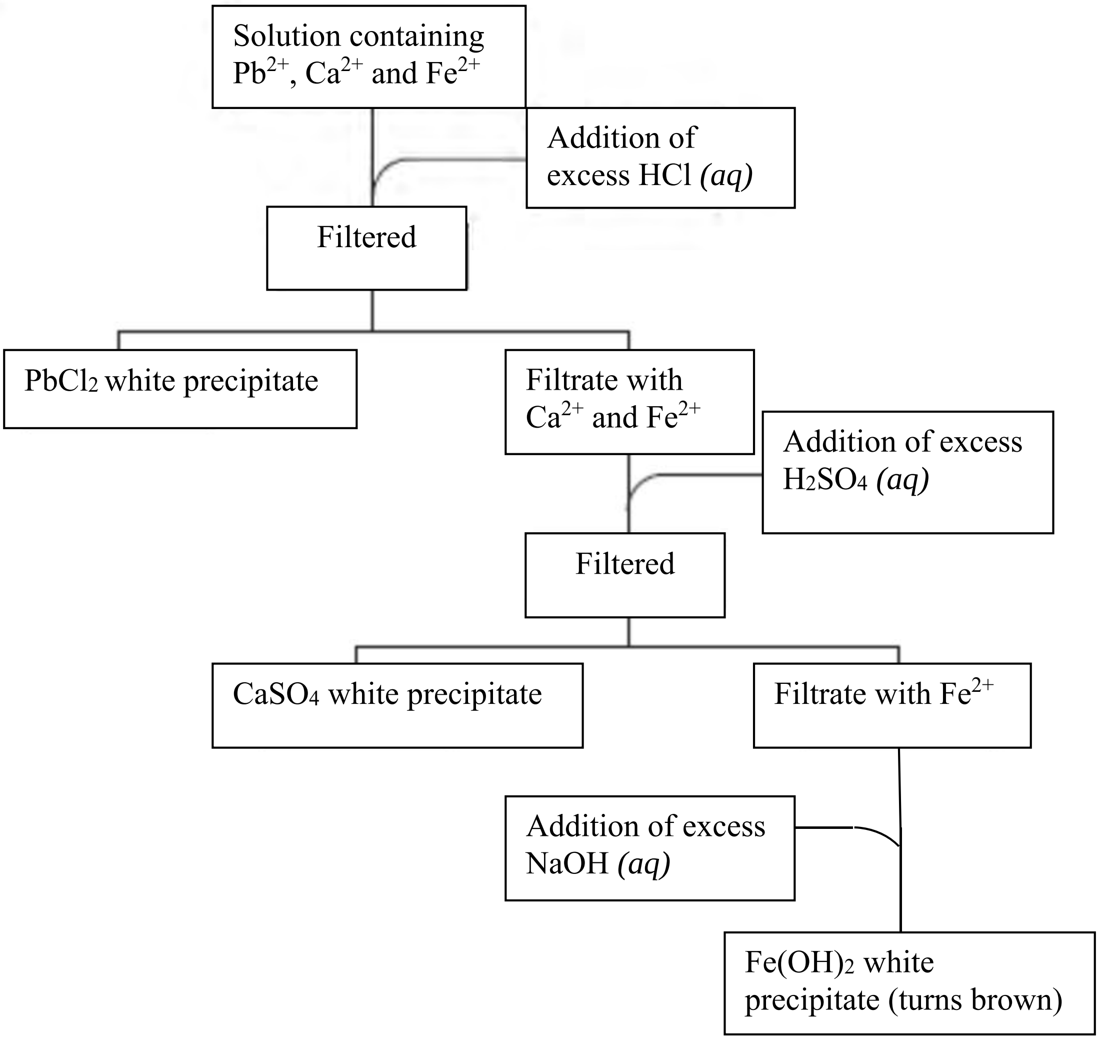
| | |
|---|---|
| 1 mol | 1mol |
| 65.39 g | 125.4 g |

Hence 1.875 mg $Zn^{2+}$ forms (125.4/65.39) x 1.875 mg $ZnCO_3$ = 3.6 mg = $3.6 \times 10^{-3}$ g $ZnCO_3$

**Question 30** (3 marks)
31 (a) (3 marks)
***Outcomes Assessed: H8, H11, H13***
***Targeted Performance Bands: 2-4***

| Criteria | Marks |
|---|---|
| • Draws a flowchart showing method of identification & separation of the THREE cations | 3 |
| • Draws a flowchart showing method of identification of TWO cations | 2 |
| • Draws a flowchart showing method of identification of ONE cation | 1 |

**Sample answer**



31 (b) (3 marks)

***Outcomes Assessed: H8, H13***

***Targeted Performance Bands: 2-3***

| Criteria | Marks |
|---|---|
| • Writes THREE correct precipitation equations | 3 |
| • Writes TWO correct precipitation equations | 2 |
| • Writes ONE correct precipitation equation | 1 |

**Sample answer**

$Pb^{2+}(aq) + 2Cl^{-}(aq) \rightarrow PbCl_2(s)$

$Ca^{2+}(aq) + SO_4^{2-}(aq) \rightarrow CaSO_4(s)$

$Fe^{2+}(aq) + 2OH^{-}(aq) \rightarrow Fe(OH)_2(s)$

**Question 31** (6 marks)
31 (a) (1 mark)
***Outcomes Assessed: H13***
***Targeted Performance Bands: 2-3***

| Criteria | Mark |
|---|---|
| • Correct answer | 1 |

**Sample answer**
Compound 3 is 1,1,1,2-tetrafluoroethane.

31 (b) (4 marks)
***Outcomes Assessed: H3, H4, H8, H13***
***Targeted Performance Bands: 3-6***

| Criteria | Marks |
|---|---|
| • Assesses the different impacts of the THREE haloalkanes AND correctly identifies the impact of each haloalkane AND includes an equation to show destruction of ozone | 3 |
| • Correctly outlines the impact of 2 of the 3 haloalkanes AND includes an equation to show destruction of ozone | 2.5 |
| • Correctly identifies the impact of 1 of the 3 haloalkanes AND includes an equation to show destruction of ozone | 2 |
| • Correctly identifies the impact of 1of the 3 haloalkanes OR includes an equation/equations to show destruction of ozone | 1 |

**Sample answer**
Compound 1 is a HCFC – containing hydrogen, chlorine, fluorine and carbon atoms.
Compound 2 is a CFC – containing chlorine, fluorine and carbon atoms.
Compound 3 is a HFC – containing hydrogen, fluorine and carbon atoms.

The haloalkanes which have greatest impact on the ozone levels are those containing chlorine and bromine atoms. Fluorine does not cause ozone depletion.

Of these 3 compounds, <u>compound 2</u> (the only CFC) will cause the greatest depletion of ozone. It has chlorine atoms and no hydrogen atoms. The compound is extremely stable in the troposphere and slowly diffuses over many years into the stratosphere. Here the high energy UV radiation causes it to lose chlorine atoms (free radicals).

$CF_2Cl_2\,(g) \rightarrow CF_2Cl\bullet + Cl\bullet$

The free radical Cl• reacts with ozone, removing it from the stratosphere. The chlorine free radical is then regenerated, by reaction with available oxygen free radicals (from ozone or oxygen in UV light) as shown below.

$Cl\bullet + O_3 \rightarrow ClO\bullet + O_2$
$ClO\bullet + O\bullet \rightarrow Cl\bullet + O_2$

Compounds such as compound 2 have been the cause of ozone depletion over the last 50 years and some molecules released prior to worldwide banning of their use in the 1990s still persist in the troposphere.

Compound 1, a HCFC, is still capable of depleting ozone as it contains chlorine atoms. The carbon-chlorine bonds break in the stratosphere. However, the presence of hydrogen atoms makes the compound less stable as it diffuses through the troposphere and only a small percentage of HCFCs reach the stratosphere to cause ozone depletion.

Compound 3 is a HFC. It contains carbon-hydrogen bonds so is likely to be destroyed in the troposphere and does not contain chlorine, so does not cause ozone depletion.

Hence the order of ozone depletion ability (least to greatest) is:
Compound 3, compound 1, compound 2.

## Section II – OPTIONS

**Question 32 – Industrial Chemistry** (25 marks)

32 (a) (i) (4 marks)

***Outcomes Assessed: H4, H8***

***Targeted Performance Bands: 2-5***

| Criteria | Marks |
|---|---|
| • Assessment of the statement AND thorough discussion of the method of extraction of sulfur by the Frasch process, relating the process to specific physical properties of sulfur (must include m.p. & preferably density) | 4 |
| • Assessment of the statement AND sound discussion of the method of extraction of sulfur by the Frasch process, relating the process to physical properties of sulfur | 3 |
| • Describes the method of extraction of sulfur by the Frasch process AND describes some physical properties of sulfur | 2 |
| • Describes the method of extraction of sulfur by the Frasch process OR describes some physical properties of sulfur | 1 |

**Sample answer**

In the Frasch process, superheated water at 160°C is forced down the outer of 3 concentric pipes into the sulfur deposit. This melts the sulfur (because sulfur has a low melting point at 113°C) and forms an emulsion of sulfur and water.

Compressed air is blown down the inner pipe and the sulfur-water mixture is forced up the middle pipe to the surface.

The low melting point of sulfur, its low density of 2.07g/mL (which means that the compressed air can push it to the surface) and its insolubility in water (which means it can be easily separated from the water once it has been collected at the surface) are all physical properties of sulfur which permit this method of extraction.

Assessment

The statement is correct, as it is only possible to use this method of extraction because of the physical properties of sulfur - its insolubility in water, its low density and its low melting point.

32 (a) (ii) (4 marks)

***Outcomes Assessed: H3, H4, H8, H13***

***Targeted Performance Bands: 2-6***

| Criteria | Marks |
|---|---|
| • Outlines the steps in conversion of sulfur dioxide to sulfur trioxide<br>• Includes an equation for the equilibrium process AND explains thoroughly the reasons why these steps are necessary, discussing<br>  • achieving an optimal yield of sulfur trioxide<br>  • the catalyst used<br>  • the temperature and pressure conditions | 4 |
| • Outlines the steps in conversion of sulfur dioxide to sulfur trioxide<br>• Includes an equation for the equilibrium process AND explains soundly the reasons why these steps are necessary, discussing TWO of the following<br>  • achieving an optimal yield of sulfur trioxide<br>  • the catalyst used<br>  • the temperature and pressure conditions | 3 |
| • Outlines the steps in conversion of sulfur dioxide to sulfur trioxide AND outlines some reasons why these steps are necessary, discussing at least TWO of the following<br>  • achieving an optimal yield of sulfur trioxide<br>  • the catalyst used<br>  • the temperature and pressure conditions | 2 |
| • Outlines the steps in conversion of sulfur dioxide to sulfur trioxide OR outlines some reasons why these steps are necessary | 1 |

**Sample answer**

Conversion of sulfur dioxide to sulfur trioxide occurs in steps, to ensure the optimal yield (the best balance of yield and rate) of sulfur trioxide and to ensure that only trace amounts of sulfur dioxide are released into the atmosphere.

$2SO_2\,(g) + O_2\,(g) \rightleftharpoons 2SO_3\,(g) \quad \Delta H = -198\ \text{kJ mol}^{-1}$

When the pressure is increased, by Le Chatelier's Principle, the equilibrium shifts to compensate by moving to the right (the side of the equilibrium with fewer moles of gas molecules).

When the temperature is reduced, the equilibrium shifts to compensate, by shifting to the right to release more heat energy, as the forward equilibrium reaction is exothermic.

Hence the conditions of high pressure and low temperature would favour the production of the greatest yield of sulfur trioxide.

However, the rate of this reaction at low temperature would be too slow for an industrial process, so a compromise is reached.

Thus the conversion of sulfur dioxide to sulfur trioxide is done in steps using a vanadium (V) oxide on silica catalyst, with an excess of oxygen (from air, as using pure oxygen is not cost-effective and can be a safety risk) and at above atmospheric pressure (but not at very high pressure as this is not cost-effective):

Step 1 - A fast but low yield stage at 550°C

This step ensures that a small yield of sulfur trioxide is produced rapidly. This is removed from the equilibrium and the equilibrium mixture is passed to step 2.

Step 2 - A slower but high yield stage at 400°C

This step ensures a higher yield of sulfur trioxide but at a slower rate. At the lower temperature, the equilibrium shifts to the right to achieve a higher yield of sulfur trioxide, which is then removed from the equilibrium mixture.

Step 3 - To reduce the waste sulfur dioxide, at 400°C

The first 2 steps only achieve about 97% conversion to sulfur trioxide and the residue of 3% $SO_2$ is not acceptable as a waste into the atmosphere. The remaining equilibrium mixture after step 2 is recycled back over the same catalyst at 400°C to convert more sulfur dioxide to sulfur trioxide until only a trace (0.3%) remains to be exhausted into the atmosphere.

33 (b) (i) (1 mark)

***Outcomes Assessed: H10***

***Targeted Performance Bands: 2-3***

| Criteria | Mark |
|---|---|
| • Correct answer | 1 |

**Sample answer**

$$K = \frac{[H_2\,(g)]\ [Br_2\,(g)]}{[HBr\,(g)]^2}$$

32 (b) (ii) (1 mark)

***Outcomes Assessed: H10***

***Targeted Performance Bands: 3-4***

| Criteria | Mark |
|---|---|
| • Correct answer | 1 |

**Sample answer**

The concentration of bromine, $[Br_2\,(g)] = [H_2\,(g)] = 9.50 \times 10^{-4}$ mol $L^{-1}$

32 (b) (iii) (1 mark)

***Outcomes Assessed: H10***

***Targeted Performance Bands: 3-5***

| Criteria | Mark |
|---|---|
| • Correct answer | 1 |

**Sample answer**

$$K = \frac{[H_2\,(g)]\ [Br_2\,(g)]}{[HBr\,(g)]^2} = \frac{(9.50 \times 10^{-4})\ (9.50 \times 10^{-4})}{[HBr\,(g)]^2} = 0.0575$$

$$\text{Hence } [HBr\,(g)]^2 = \frac{(9.50 \times 10^{-4})\ (9.50 \times 10^{-4})}{0.0575} = \frac{9.025 \times 10^{-7}}{0.0575} = 1.569 \times 10^{-5}$$

$[HBr] = 3.96 \times 10^{-3}$ mol $L^{-1}$

32 (c) (i) (4 marks)

***Outcomes Assessed: H7, H8, H13***

***Targeted Performance Bands: 2-5***

| Criteria | Marks |
|---|---|
| • Thorough explanation of why the products of electrolysis of molten sodium chloride differ from the products of electrolysis of concentrated brine solution, including half-equations for both processes | 4 |
| • Sound explanation of why the products of electrolysis of molten sodium chloride differ from the products of electrolysis of concentrated brine solution, including half-equations for both processes | 3 |
| • Sound explanation of why the products of electrolysis of molten sodium chloride differ from the products of electrolysis of concentrated brine solution OR correct half-equations to show the products of BOTH processes | 2 |
| • Some correct information about electrolysis of molten sodium chloride OR of concentrated brine OR correct half-equations to show the products of electrolysis of molten sodium chloride OR of concentrated brine | 1 |

**Sample answer**

When molten sodium chloride is electrolysed using inert electrodes, since no water is present, hydrogen and oxygen cannot be formed. Sodium and chlorine are produced. A voltage of >4.07 V must be applied.

At the anode: $2Cl^-(l) \rightleftharpoons Cl_2(g) + 2e^-$ -1.36 V

At the cathode: $Na^+(l) + e^- \rightleftharpoons Na(l)$ -2.71 V

Overall: $2Na^+(l) + 2Cl^-(l) \rightleftharpoons 2Na(l) + Cl_2(g)$ -4.07 V

When concentrated brine solution is electrolysed, the electrolyte contains sodium chloride in aqueous solution: $Na^+$, $Cl^-$ ions and $H_2O$ molecules.

The water molecules are reduced in preference to the $Na^+$:

At the cathode: $2H_2O(l) + 2e^- \rightleftharpoons H_2(g) + 2OH^-(aq)$ -0.83 V

Possible reactions at the anode are:

$2Cl^-(aq) \rightleftharpoons Cl_2(g) + 2e^-$ -1.36 V

$2H_2O(l) \rightleftharpoons O_2(g) + 4H^+(aq) + 4e^-$ -1.23 V

When the concentration of chloride ion is greater than 1 mol $L^{-1}$ (standard concentration), chlorine is produced as well as oxygen. The higher the chloride ion concentration, the greater the proportion of chlorine produced (in preference to oxygen).

Hence when electrolysis of molten sodium chloride is compared with electrolysis of concentrated brine solution, the processes differ in that the electrolytes differ (water vs. no water) and hence the products formed differ (sodium and chlorine vs hydrogen and chlorine or oxygen).

32 (c) (ii) (4 marks)

***Outcomes Assessed: H1, H3, H4***

***Targeted Performance Bands: 3-6***

| Criteria | Marks |
|---|---|
| • Assessment of statement<br>• Thorough discussion of the benefits of the membrane cell over identified earlier methods for the industrial production of sodium hydroxide | 4 |
| • Thorough discussion of the benefits of the membrane cell over identified earlier methods for the industrial production of sodium hydroxide | 3 |
| • Sound discussion of the benefits of the membrane cell over identified earlier methods for the industrial production of sodium hydroxide | 2 |
| • Some correct information about a problem arising from an earlier production method | 1 |

**Sample answer**

The industrial production of sodium hydroxide has used 3 different methods over time but has involved the same overall electrolysis reaction:

$2NaCl\ (aq) + 2H_2O\ (l) \rightarrow H_2\ (g) + Cl_2\ (g) + 2NaOH\ (aq)$

The diaphragm cell used a barrier made from asbestos to separate the anode and cathode compartments. The diaphragm cell allowed some movement of ions between the anode and cathode half-cells, which reduced the purity of the final product and allowed the formation of the hypochlorite ion ($OCl^-$), a strong oxidant, which can kill useful micro-organisms and cause adverse chemical changes if discharged into the environment.

The mercury cell used mercury as the cathode and did not require a barrier to separate the half-cells. This method was able to produce sodium hydroxide of greater purity than could be achieved in the diaphragm cell and no hypochlorite ion was released to damage the environment. However, some traces of waste mercury were released into water courses with the spent brine. This mercury was eventually broken down by the action of bacteria to release poisonous mercury ions into the food chain, causing potential death or health risks to a variety of organisms.

The membrane cell used new technologies to incorporate anionic groups into a membrane made from the polymer PTFE. This membrane does not allow the mixing of hydroxide and chloride ions, so the hypochlorite ion ($OCl^-$) is not formed.

The recognition of health risks associated with the use of an asbestos diaphragm in the diaphragm cell and with the use of a mercury cathode in the mercury cell led to the development of a membrane cell, which overcame the environmental risks associated with the earlier production methods.

Assessment

The statement is correct, as the membrane cell for the production of sodium hydroxide has largely replaced the earlier diaphragm and mercury cells, and is preferable to earlier cells as it eliminates the environmental concerns associated with the use of asbestos, the release of mercury and the production of the harmful hypochlorite ion. The membrane cell also produces a purer product than the earlier diaphragm cell.

32 (d) (i) (1 mark)

***Outcomes Assessed: H9, H13***

***Targeted Performance Bands: 2-3***

| Criteria | Mark |
|---|---|
| • Identifies saponification | 1 |

**Sample answer**

Saponification

32 (d) (ii) (1 mark)

***Outcomes Assessed: H9, H13***

***Targeted Performance Bands: 2-3***

| Criteria | Mark |
|---|---|
| • Identifies reactant X | 1 |

**Sample answer**

Sodium hydroxide

32 (d) (iii) (3 marks)

***Outcomes Assessed: H11***

***Targeted Performance Bands: 2-4***

| Criteria | Marks |
|---|---|
| • Describes the steps in the laboratory preparation of a soap<br>• Describes appropriate safety precautions<br>• Explains the reasons for these safety precautions | 3 |
| • TWO of the above | 2 |
| • ONE of the above | 1 |

**Sample answer**

The production of soap in the school laboratory involves the heating of an ester (such as the oil, glyceryl tripalmitate) with concentrated sodium hydroxide solution. After prolonged heating, the ester dissolves. The mixture is cooled and poured into an open beaker and saturated with brine (nearly saturated NaCl solution). The mixture separates into 2 layers – a semi-solid soap on top and glycerol underneath. The soap is skimmed off and washed to remove the salt and alkali.

Because the ester is an oil which is volatile and flammable, for safety reasons refluxing is normally used in a school laboratory, to reduce the risks of fires, burns or inhaling the vapours.

The production of soap requires the use of concentrated sodium hydroxide, which is caustic. It dissolves in water, releasing a large amount of energy, and reacts with skin and fatty tissues. If it gets in the eyes, it can cause permanent eye damage. Safe work practices to reduce the risks include use of goggles, wearing of protective clothing, having water available to dilute any spills and a substance available to neutralise the alkali (such as sodium hydrogen carbonate).

32 (d) (iv) (1 mark)

***Outcomes Assessed: H4, H9***

***Targeted Performance Bands: 2-3***

| **Criteria** | **Mark** |
|---|---|
| • Describes a use of soap | 1 |

**Sample answer**

The product formed by the saponification reaction is a soap, which can be used for personal cleaning.

**Question 33 – Shipwrecks, Corrosion and Conservation** (25 marks)

33 (a) (5 marks)

***Outcomes Assessed: H1, H2, H13***

***Targeted Performance Bands: 2-5***

| Criteria | Marks |
|---|---|
| • Draws up a table showing the 4 scientists in chronological order AND outlines the work of the FOUR scientists | 5 |
| • Outlines the work of the FOUR scientists | 4 |
| • Outlines the work of THREE scientists | 3 |
| • Outlines the work of TWO scientists | 2 |
| • Outlines the work of ONE scientist | 1 |

**Sample answer**

| ***Scientist*** | ***Main Contributions*** |
|---|---|
| Galvani<br>(1737-1798) | Galvani is recognised as the first scientist to generate an electric current (1780). He joined wires of different metals together and placed the unjoined ends into frog muscle. His interpretation (animal electricity) was wrong but his work inspired others including Volta to further develop an understanding of electricity by devising galvanic cells. |
| Volta<br>(1745-1827) | Volta showed that the electric current was due to the different metals dipping into an electrolyte solution, not the frog muscle. He created the first galvanic cell, using copper and tin in salt solution. He then developed a stack of these cells (known as Volta's pile) which could produce a larger current than a single cell and he changed the metals to zinc and silver, to produce larger currents. Even though Volta did not understand what was generating the current, he made a significant contribution to the understanding of electricity, by constructing the first useable galvanic cell and by recognising that the differing metals generated the electric current. |
| Davy<br>(1778-1829) | Davy used Volta's piles to cause electrolysis reactions. This led to the understanding of the differences in elements and compounds and the discovery of new elements. Davy showed that there was a *qualitative* connection between electricity and matter produced or broken down in electrolysis reactions. He used electrolysis to perform decomposition reactions such as the electrolysis of water. He prepared samples of active metals and could distinguish between elements and compounds. |
| Faraday<br>(1791-1867) | Faraday (a research assistant to Davy) continued and extended Davy's electrolysis experiments. He invented a device for measuring the amount of electric charge that flowed during electrolysis and showed a *quantitative* relationship between electricity and matter produced. He proposed Laws of Electrolysis which led to an understanding of the relationship between electricity, moles of a substance and valency. He is renowned for his work on electromagnetism and the generation of electricity. |

33 (b) (6 marks)
***Outcomes Assessed: H4, H8, H14***
***Targeted Performance Bands: 2-6***

| **Criteria** | **Marks** |
|---|---|
| - Assessment of both statements<br>- Thorough explanation of concentration trends in relation BOTH to temperature and pressure<br>- Thorough explanation of the effect of depth on corrosion both in aerobic and anaerobic conditions | 6 |
| - Thorough explanation of concentration trends in relation BOTH to temperature and pressure<br>- Thorough explanation of the effect of depth on corrosion both in aerobic and anaerobic conditions | 5 |
| - Sound explanation of concentration trends in relation BOTH to temperature and pressure<br>- Sound explanation of the effect of depth on corrosion both in aerobic and anaerobic conditions | 4 |
| - Sound explanation of concentration trends in relation BOTH to temperature and pressure<br>- Sound explanation of the effect of depth on corrosion in aerobic conditions | 3 |
| - Some correct information about the concentration trends relating to EITHER temperature OR pressure AND explanation of some effects of depth on corrosion | 2 |
| - Some correct information about the concentration trends relating to EITHER temperature OR pressure OR explanation of some effects of depth on corrosion | 1 |

**Sample answer**
As the temperature of water increases, according to Le Chatelier's Principle, the equilibrium
$O_2(g) \rightleftharpoons O_2(aq) \quad \Delta H = \text{-ve}$

will move to the left, so the concentration of oxygen dissolved in water will decrease. Conversely, as the temperature of water decreases, oxygen will become more soluble.

Also according to Le Chatelier's Principle, as the pressure increases, the solubility of oxygen should increase, as the equilibrium will shift to the right, to reduce the number of gaseous molecules.

**Hence the statement:** "As the temperature of water decreases and as the pressure increases, the concentration of oxygen dissolved in sea water would be expected to increase" is correct, if there were an ample supply of oxygen gas, and would explain the differential solubility close to the **surface** of hot and cold water or if there were different atmospheric pressure conditions.

At depth, the pressure is greater, and if an excess of oxygen gas were present, the solubility would be greater.
At depth, the temperature is lower, as convection currents would bring warmer water to the surface, where it is warmed anyway by the radiant heat from the sun. Oxygen has a greater solubility in cold water than in warm water.

Corrosion of iron in sea water is a galvanic process, involving oxygen in the reduction reaction.

$Fe\,(s) \rightleftharpoons Fe^{2+}\,(aq) + 2e^-$ (oxidation)

$O_2\,(g) + 2H_2O\,(l) + 4e^- \rightleftharpoons 4OH^-\,(aq)$ (reduction)

Since the rate of corrosion depends on the concentration of oxygen present, then the rate of corrosion of shipwrecks will depend on the concentration of oxygen dissolved in the water.

However, the second statement ONLY APPLIES if there is an ample supply of oxygen present. Only then would more dissolve at lower temperatures and higher pressures.
In the ocean, the oxygen is removed from the water by aerobic organisms. Photosynthesis only produces oxygen where sunlight penetrates, so oxygen is not replenished as it is used up. The rate of diffusion of oxygen downwards is slow, as there is little mixing of warm surface water and cooler water below. Hence the corrosion of shipwrecks IS NOT GREATER at depth than at the surface because inadequate oxygen is available (despite the optimum conditions for high solubility of oxygen, i.e. high pressure and low temperature).

Corrosion at depth does occur but that is not due to the presence of oxygen. Shipwrecks at great depths are corroded by electrochemical (oxidation and reduction) reactions in the presence of anaerobic bacteria. The bacteria are sulfur-reducing species whose wastes catalyse the reduction of sulfate ions in the water to hydrogen sulphide ions.

$SO_4^{2-}\,(aq) + 5H_2O\,(l) + 8e^- \rightleftharpoons HS^-\,(aq) + 9OH^-\,(aq)$

$4Fe\,(s) \rightleftharpoons 4Fe^{2+}\,(aq) + 8e^-$

The overall reaction which occurs at depth is:

$4Fe\,(s) + SO_4^{2-}\,(aq) + 5H_2O\,(l) \rightleftharpoons FeS\,(s) + 3Fe(OH)_2\,(s) + H_2O\,(l) + 2OH^-\,(aq)$

Black iron (II) sulfide forms on the steel as well as white iron (II) hydroxide. This is NOT oxidised to rust because of the absence of oxygen.

Acidic environments (found at depth) accelerate corrosion in non-passivating metals.
In slightly acidic environments, the hydroxide ions produced by the reduction reaction react and are removed from the equilibrium reaction by the hydrogen ions.

33 (c) (2 marks)

***Outcomes Assessed: H3, H4, H7, H8***

***Targeted Performance Bands: 2-4***

| Criteria | Marks |
|---|---|
| • Explains the relationship between activity of a metal and the Table of Reduction Potentials AND links the use of aluminium in building and aircraft with its passivating nature | 2 |
| • Explains the relationship between activity of a metal and the Table of Reduction Potentials OR links the use of aluminium in building and aircraft with its passivating nature | 1 |

**Sample answer**

The supplied Table of Reduction Potentials shows that aluminium is the 6th most reactive metal of those listed, with only potassium, barium, calcium, sodium and magnesium losing electrons more readily. Loss of electrons (oxidation) is a measure of the reactivity of a metal. On this basis, it would not be expected that aluminium should be used in building or in aircraft manufacture, as the aluminium would be expected to react/corrode readily in air, acid, etc.

However, aluminium **is** suitable for these uses. This apparent anomaly is explained by the fact that aluminium forms an unreactive, hard, impermeable and strongly bonded transparent aluminium oxide layer (a passivating layer) on exposure to oxygen. This passivating layer protects the aluminium from further corrosion (unless chloride ions are present, which destroy the passivating layer).

At the anode: $Al\,(s) \rightleftharpoons Al^{3+}\,(aq) + 3e^-$

At the cathode: $O_2\,(g) + 4e^- \rightleftharpoons 2O^{2-}\,(aq)$

$Al_2O_3\,(s)$, an impermeable transparent solid, forms on the surface of the aluminium.

33 (d) (i) (3 marks)

***Outcomes Assessed: H11, H12, H13***

***Targeted Performance Bands: 2-5***

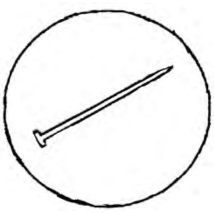
| Criteria | Marks |
|---|---|
| • Designs an appropriate experiment with a valid method and includes a control<br>• Draws clear labelled diagrams<br>• Includes at least 3 different methods of protection of iron | 3 |
| • Designs an appropriate experiment with a valid method and includes a control AND includes fewer than 3 methods of protection OR draws partially correct labelled diagrams | 2 |
| • Designs an appropriate experiment with a valid method OR draws partially correct labelled diagrams | 1 |

**Sample answer (other possible methods)**

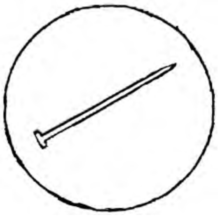
Five identical petri dishes were set up containing cleaned iron nails. Each dish was half-filled with an agar gel which contained an indicator to show hydroxide ions, an indicator to show iron (II) ions and salt water.

- Dish 1 – left as a control
- Dish 2 – the iron nail had been previously painted with a galvanising paint containing zinc
- Dish 3 – the iron nail had been coated with oil before placing in the dish
- Dish 4 – the iron nail had been wrapped in magnesium wire before placing in the dish
- Dish 5 – the iron nail had been wrapped in copper wire before placing in the dish

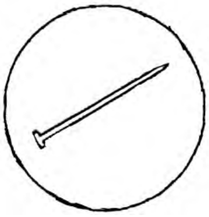
Diagrams of petri dishes initially



Dish 1 – salt water, agar, indicators, no protection



Dish 2 – salt water, agar, indicators, painted coating on nail



Dish 3 – salt water, agar, indicators, oil coating on nail

Dish 4 – salt water, agar, indicators, Mg wire wrapped around nail as protection

Dish 5 – salt water, agar, indicators, Cu wire wrapped around nail as protection

33 (d) (ii) (2 marks)

***Outcomes Assessed: H8, H11***

***Targeted Performance Bands: 2-4***

| Criteria | Marks |
|---|---|
| • Results correctly and thoroughly outlined | 2 |
| • Some correct results outlined | 1 |

**Sample answer**

After one day, a blue colour, indicating corrosion of the iron nail, and a pink colour indicating formation of hydroxide ions, had developed in the agar gel in dishes 1 and 5.

After 2 days, the blue and pink colours had intensified and spread in dishes 1 and 5 and had started to develop in dish 3.

After four days, a slight pink colour was seen near the head of the painted nail in dish 2.
No blue colour had developed in dish 4 but there were faint patches of pink and white.

33 (d) (iii) (2 marks)

***Outcomes Assessed: H4, H8, H13***

***Targeted Performance Bands: 2-4***

| Criteria | Marks |
|---|---|
| • Explains how one of the protection methods is used in ocean-going ships AND writes a correct equation or half-equations | 2 |
| • Explains how one of the protection methods is used in ocean-going ships OR writes a correct equation or half-equations | 1 |

**Sample answer**

Ocean going ships are protected by attaching ingots of magnesium to the metal hull of the ship. These corrode preferentially (since magnesium is oxidised more readily than iron in the marine environment). Hence the iron ship is protected (it acts as an inert cathode; the magnesium ingot acts as a sacrificial anode).

At the anode: $Mg\,(s) \rightleftharpoons Mg^{2+}\,(aq) + 2e^-$ E° = +2.36 V
At the cathode: $O_2\,(g) + 2H_2O\,(l) + 4e^- \rightleftharpoons 4OH^-\,(aq)$ E° = +0.40 V

33 (e) (i) (1 mark)

***Outcomes Assessed: H8, H13***

***Targeted Performance Bands: 2-4***

| Criteria | Mark |
|---|---|
| • Writes a correct, appropriate equation | 1 |

**Sample answer**

Concretions are deposits of calcium carbonate, which can be removed by reaction with a very dilute acid solution.

$CaCO_3\,(s) + 2H^+\,(aq) \rightarrow Ca^{2+}\,(aq) + CO_2\,(g) + H_2O\,(l)$

33 (e) (ii) (4 marks)

***Outcomes Assessed: H4, H7, H8, H13***

***Targeted Performance Bands: 2-5***

| Criteria | Marks |
|---|---|
| • Discusses thoroughly the process of restoration of a metal artefact by electrolysis<br>• Draws a correct diagram for an electrolytic cell showing the artefact at the cathode<br>• Writes appropriate equations or half-equations for the electrolysis reaction | 4 |
| • Outlines the process of restoration of a metal artefact by electrolysis<br>• Draws a correct diagram for an electrolytic cell showing the artefact at the cathode<br>• Writes appropriate equations or half-equations for the electrolysis reaction | 3 |
| • TWO of<br>• Outlines the process of restoration of a metal artefact by electrolysis<br>• Draws a correct diagram for an electrolytic cell showing the artefact at the cathode<br>• Writes appropriate equations or half-equations for the electrolysis reaction | 2 |
| • ONE of<br>• Outlines the process of restoration of a metal artefact by electrolysis<br>• Draws a correct diagram for an electrolytic cell showing the artefact at the cathode<br>• Writes appropriate equations or half-equations for the electrolysis reaction | 1 |

**Sample answer**

The aim of the process is to convert the corrosion product which is still adhering to the object back to the original metal. Iron objects have a coating of $Fe(OH)Cl$. The corrosion product on the surface of the copper artefact is usually copper hydroxyl chloride ($Cu(OH)Cl$).

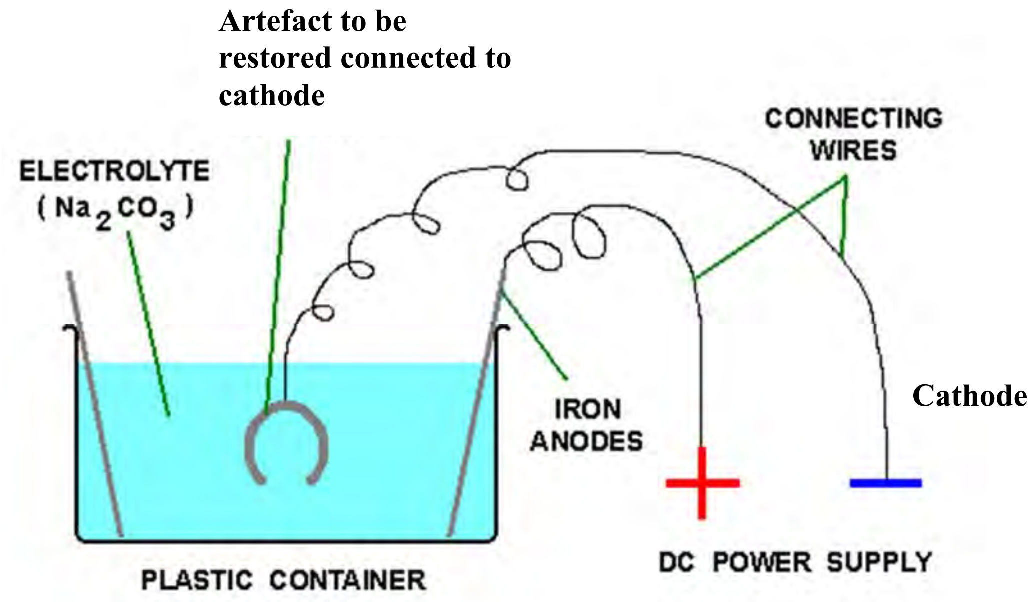
The metal artefact is connected to the negative terminal of the power source as the cathode in an electrolytic cell.

At the cathode, reduction of the corrosion product occurs, which releases the chloride ion and restores the original metal to the surface of the artefact (where the corrosion product would have been attached). Hence the shape and engravings on metals objects can be restored to their original condition.
Hence the artefact is both conserved and restored by the electrolysis process.

If the metal is iron, the half-equation for the cathode reaction is
$Fe(OH)Cl\,(s) + 2e^- \rightarrow Fe\,(s) + OH^-\,(aq) + Cl^-\,(aq)$

If the metal is copper, the half-equation is
$Cu(OH)Cl\,(s) + 2e^- \rightarrow Cu\,(s) + OH^-\,(aq) + Cl^-\,(aq)$

The anode reaction, if an inert electrode is used, is
$4OH^-\,(aq) \rightarrow O_2\,(g) + 2H_2O\,(l) + 4e^-$



To prevent further corrosion, the metallic object should then be preserved by coating with a clear acrylic lacquer.

**Question 34 – Forensic Chemistry** (25 marks)
34 (a) (3 marks)
***Outcomes Assessed: H3, H4***
***Targeted Performance Bands: 3-5***

| Criteria | Marks |
|---|---|
| • Provides AT LEAST 3 examples of evidence to support the statement and explains why the evidence is valuable for forensic investigations | 3 |
| • Provides TWO examples of evidence to support the statement and explains why the evidence is valuable for forensic investigations | 2 |
| • Provides ONE example of evidence to support the statement and explains why the evidence is valuable for forensic investigations | 1 |

**Sample answer**
DNA analysis is extremely accurate in identifying the source of the sample. The techniques used to perform DNA analysis have <1 in 10 billion chance of inaccuracy. Each person (apart from identical twins) has a unique pattern of non-coding DNA (intron) sequences.

Example: Identification of the victims of natural disasters, such as the earthquakes in New Zealand and Chile and the tsunamis associated with earthquakes in Indonesia and Japan, have been made in recent years on the basis of DNA technology.

DNA testing is extremely sensitive with only a minute sample required to perform the test. This makes the technique valuable for forensic investigations when only small samples are available. A single hair or drop of blood can link a person to a crime scene.

Example: In recent years, a murder conviction in the case of the missing tourist, Peter Falconio, was made on the basis of the accused murderer's blood found on the shirt of the victim's girlfriend.

DNA analysis allows identification of paternity, maternity and family relations. Closely related people have a high proportion of their introns in common. As a result, DNA analysis can be regarded as an extremely accurate test of the relationship between people and hence its use for this purpose is justified. The DNA of a relative can give evidence supporting the identification of a body even centuries after the death of a person.

Example: The skeletal remains of the English king, Richard III, who was killed in battle in 1485, were verified after a DNA match between the descendants of the king and that extracted from the burial site under a car park in Leicester.

34 (b) (i) (2 marks)

***Outcomes Assessed: H9***

***Targeted Performance Bands: 2-4***

| Criteria | Marks |
|---|---|
| • Outlines THREE common structural properties of ***A***, ***B*** and ***C*** | 2 |
| • Outlines TWO common structural properties of ***A***, ***B*** and ***C*** | 1 |

**Sample answer**

All 3 polysaccharides are

- polymers
- formed by linkage of glucose monomers
- classified as carbohydrates, since they contain only carbon, hydrogen and oxygen atoms and have the general formula $C_x(H_2O)_y$.

34 (b) (ii) (1 mark)

***Outcomes Assessed: H9***

***Targeted Performance Bands: 3-4***

| Criteria | Mark |
|---|---|
| • Identifies the main function of glycogen | 1 |

**Sample answer**

Glycogen is the main storage carbohydrate in animals. It is stored in the liver and muscle. Glycogen supplies glucose when energy demands are required, such as during exercises. It also provides a reserve supply of glucose so that blood glucose concentration can be kept at a sufficient level to supply the brain.

34 (b) (iii) (2 marks)

***Outcomes Assessed: H9***

***Targeted Performance Bands: 3-5***

| Criteria | Marks |
|---|---|
| • Identifies cellulose and outlines its structure<br>AND<br>• Explains how the structure of ***C*** is related to its function in plants | 2 |
| • Identifies cellulose and outlines its structure<br>OR<br>• Explains how the structure of ***C*** is related to its function in plants | 1 |

**Sample answer**

***C*** is cellulose. It has long polymer straight chains of β-glucose monomers which are able to be closely held together by hydrogen bonds to form strong multi-chain strands. These form the structural cell wall of plant cells, which give the cell rigidity and determine the rectangular shape characteristic of plant cells. The strength and upright stance of most plants are due to the cellulose and the water within the cells.

34 (c) (i) (1 mark)

***Outcomes Assessed: H13***

***Targeted Performance Bands: 2-3***

| Criteria | Mark |
|---|---|
| • Clarifies the meaning of the terms "organic compounds" and "inorganic compounds" | 1 |

**Sample answer**

Organic compounds are molecules containing carbon and (by default) this means that inorganic chemistry deals with compounds lacking carbon. The definition is clarified in that compounds containing carbon as part of an ion, such as carbonates, hydrogen carbonates and cyanides or derived from an ion (carbon dioxide gas) are classified as inorganic. Inorganic compounds are traditionally viewed as being synthesised by the agency of geological systems. In contrast, organic compounds are found in or derived from biological systems.

34 (c) (ii) (2 marks)

***Outcomes Assessed: H9, H11***

***Targeted Performance Bands: 2-4***

| Criteria | Marks |
|---|---|
| • Describes the procedure for a controlled laboratory test<br>AND<br>• Describes and explains the results | 2 |
| • Describes the procedure for a controlled laboratory test<br>OR<br>• Describes and explains the results | 1 |

**Sample answer**

Two samples, one known to be an organic compound (sugar, a compound containing carbon) and one known to be inorganic (sodium chloride) were placed in identical test tubes and strongly heated. The test tubes were observed to determine whether a black residue formed, which disappeared on continued strong heating. The gas collected as the black solid was strongly heated was tested by passing it into limewater.

Result

The organic compound, when heated, decomposed and left a black residue, carbon. The black residue, when heated strongly, formed a gas which turned limewater milky.

The inorganic compound did not decompose on heating. No black residue was observed.

Hence organic compounds are identified by the production of carbon as a decomposition residue which, on strong heating, forms carbon dioxide. This is identified by the positive limewater test. Inorganic compounds do not form a black residue, as they do not contain carbon.

(Equations not necessary)
$C_{12}H_{22}O_{11}\ (s) \rightarrow 12C\ (s) + 11H_2O\ (l)$
$C\ (s) + O_2\ (g) \rightarrow CO_2\ (g)$
$CO_2\ (g) + Ca(OH)_2\ (aq) \rightarrow CaCO_3\ (s) + H_2O\ (l)$

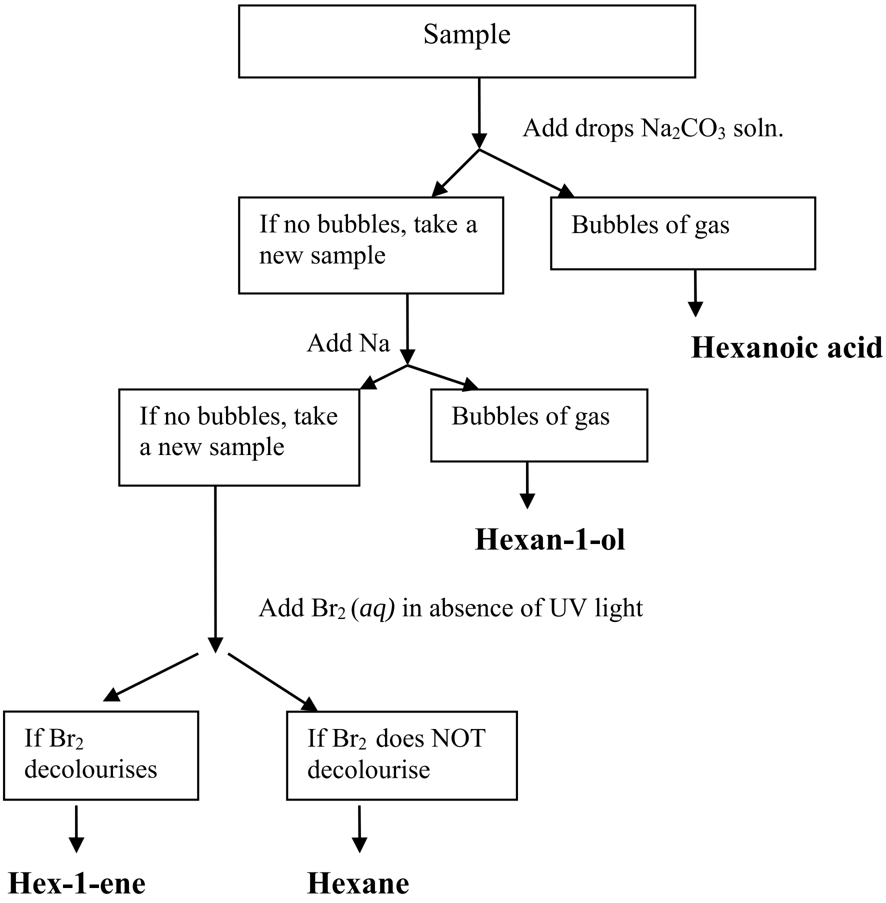
34 (c) (iii) (3 marks)

***Outcomes Assessed: H9, H11, H12, H13***

***Targeted Performance Bands: 2-5***

| Criteria | Marks |
|---|---|
| • Draws a flowchart showing a correct series of tests to distinguish between the FOUR samples | 3 |
| • Draws a partially correct flowchart showing a correct series of tests to distinguish between THREE of the samples | 2 |
| • Draws a partially correct flowchart showing a correct test to identify TWO of the samples | 1 |

**Sample answer**



34 (c) (iv) (2 marks)
***Outcomes Assessed: H9, H13***
***Targeted Performance Bands: 3-5***

| Criteria | Marks |
|---|---|
| • Writes TWO correct equations | 2 |
| • Writes ONE correct equation | 1 |

**Sample answer**

To identify hexanoic acid

$2CH_3CH_2CH_2CH_2CH_2COOH\ (aq) + CO_3^{2-}\ (aq) \rightarrow CO_2\ (g) + H_2O\ (l) + 2CH_3CH_2CH_2CH_2CH_2COO^-\ (aq)$

To identify hexan-1-ol

$2CH_3CH_2CH_2CH_2CH_2CH_2OH\ (l) + 2Na\ (s) \rightarrow H_2\ (g) + 2CH_3CH_2CH_2CH_2CH_2CH_2O^-\ Na^+\ (s)$

34 (d) (6 marks)
***Outcomes Assessed: H3, H4, H6, H7***
***Targeted Performance Bands: 2-6***

| Criteria | Marks |
|---|---|
| • Evaluates the use of AT LEAST THREE instrumental techniques for analysis of soil samples<br>• Identifies the likely components of a soil sample<br>• Compares thoroughly the applicability of AT LEAST THREE instrumental techniques for analysis of soil samples | 6 |
| • Identifies the likely components of a soil sample<br>• Compares thoroughly the applicability of AT LEAST THREE instrumental techniques for analysis of soil samples | 5 |
| • Identifies the likely components of a soil sample<br>• Compares soundly the applicability of AT LEAST THREE instrumental techniques for analysis of soil samples | 4 |
| • Compares thoroughly the applicability of TWO instrumental techniques for analysis of soil samples | 3 |
| • Compares soundly the applicability of TWO instrumental techniques for analysis of soil samples | 2 |
| • Discusses soundly the usefulness of ONE instrumental technique for analysis of soil samples<br>OR<br>• Identifies TWO or more instrumental techniques for analysis of soil samples | 1 |

**Sample answer (answers will vary according to the instrumental techniques evaluated)**

Soil contains inorganic chemicals (from the weathering of rocks) and organic matter. When a sample contains both inorganic and organic components, it will require analysis using more than one instrumental technique.

Instrumental techniques commonly used with soil samples are: emission spectroscopy, mass spectrometry, gas chromatography and atomic absorption spectroscopy.

In **emission spectroscopy**, atoms, when excited, absorb heat or electrical energy and their electrons move from their stable energy levels into higher energy levels. The electrons then fall back from higher to lower energy levels, emitting the energy they had absorbed as light of definite frequencies and hence definite colours. Analysis of this light by a spectroscope produces a record of the exact frequencies emitted by each different element. Hence a database can be set up to identify each element from its emission spectrum.

Emission spectroscopy can produce a fingerprint of a whole mixture of atoms, with the spectrum showing emission lines for all elements present in the sample. This fingerprint spectrum is compared with other samples to determine the origin of the sample requiring forensic investigation.

Evaluation
Hence **emission spectroscopy** is useful in investigation of the origins of the inorganic mixtures in soil, both in qualitative analysis (the element is/is not present) and to some limited extent in quantitative analysis (how much is present, as estimated by the intensity of the emission lines). The chief limitation of emission spectroscopy is that the measuring process destroys the compounds present in the tested sample, as the compounds are converted into gaseous atoms during the testing process. Hence emission spectroscopy only identifies the elements, but not the compounds, present and hence is of little use in identification of the organic materials in a mixture.

To identify each organic compound in a soil sample, other instrumental techniques, such as mass spectrometry and gas chromatography, must be employed.

When an element or a compound is ionised in a **mass spectrometer**, it breaks into its charged fragments (either ions consisting of several atoms or groups of atoms) in a characteristic way. As molecules of organic compounds become more complex, the pattern of fragments becomes more complicated. However, families of compounds, with different functional groups, have consistent fragments. Molecules of more than 8 to 10 atoms have unique mass spectra and hence the mass spectrum can be used to identify the compound in a sample being analysed. Libraries of mass spectra are available to forensic scientists to make positive identification of compounds in samples (or to rule out the possibility of a compound being present). Computer technology can be used to match samples with library records.

Evaluation
Hence **mass spectrometry** is useful for identifying organic compounds in soil samples. However, there are limitations in the use of mass spectrometry in that the technique breaks the samples into fragments and cannot differentiate between fragments that come from different components in a mixture.

**Chromatography** can also be used in analysis of the organic components of soil and can identify the compounds themselves, not just the elements making up the compounds. Gas-liquid chromatography (GLC) can measure quantities of the organic compounds in parts per million or billion. GLC separates substances on the basis of their different solubilities in the stationary liquid phase coating the walls of the chromatography column. The different components vaporise in the hot column and the different gases move through the column at different rates. The gases leaving the end of the column are detected by an electric current which flows when the component of the mixture ionises in a hot flame as it leaves the column. Compounds are identified by the time taken after injection to reach the detector. GLC is restricted in that it cannot identify compounds that decompose below 250ºC or those that do not vaporise by that temperature. High Pressure Liquid Chromatography (HPLC) allows the components of mixtures to be separated on the basis of their different solubilities in two liquids, one stationary and one moving. High pressure is needed to force the solvent through the tightly packed column. The retention times of the organic components are compared with retention times of known materials under identical conditions. It is more flexible than GLC, in that it can operate at room temperature and mixtures do not need to be vaporised. This means that samples which are non-volatile or which would be destroyed at high temperatures can be analysed.

Evaluation
Organic compounds present in the soil sample can be separated and identified against known standards by the use of **chromatography**.

Overall evaluation and comparison
Since soil is a mixture of inorganic and organic components, more than one instrumental method is necessary to determine the soil's composition. Emission spectroscopy and mass spectrometry can play significant roles in the identification of a forensic sample and both can produce unique fingerprints of the components in the mixture and allow soil samples to be matched. However, chromatography is needed for analyses to determine the organic compounds present in the sample.

34 (e) (i) (1 mark)
***Outcomes Assessed: H9, H13***
***Targeted Performance Bands: 2-3***

| Criteria | Mark |
|---|---|
| • Correct answer | 1 |

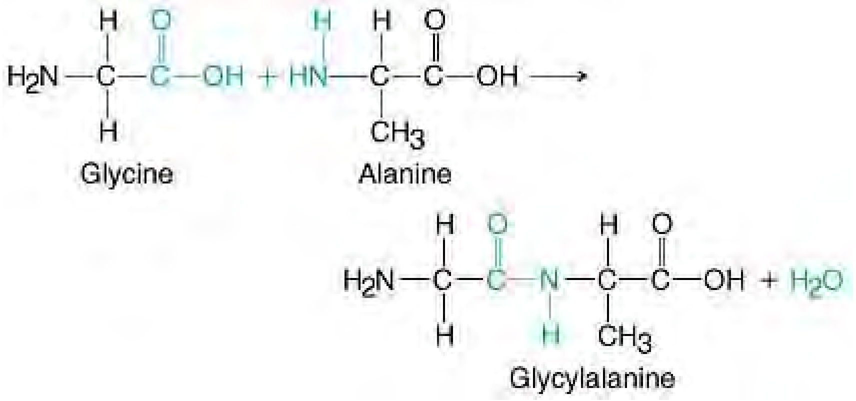
**Sample answer**
Glycine and alanine are classified as amino acids as they contain the 2 characteristic functional groups of amino acids.

- amine group: $-NH_2$
- carboxylic acid group: $-COOH$

34 (e) (ii) (1 mark)
***Outcomes Assessed: H9, H13***
***Targeted Performance Bands: 3-5***

| Criteria | Mark |
|---|---|
| • Correct answer | 1 |

**Sample answer**



34 (e) (iii) (1 mark)

***Outcomes Assessed: H4***

***Targeted Performance Bands: 2-3***

| Criteria | Mark |
|---|---|
| • Chromatography or electrophoresis | 1 |

**Sample answer**

Chromatography or electrophoresis could be used.