Newington College

IN FIDE SCIENTIAM

Student Number

2012
TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION

Chemistry

Total marks – 100

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, page 13 and on the Multiple-Choice Answer Sheet

Section I Pages 3-26

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 21-30
- Allow about 1 hour and 40 minutes for this part

Section II Pages 29-34

25 marks
- Attempt ONE question from Questions 31-35
- Allow about 45 minutes for this section

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 Ethanol would be a good solvent for

(A) pentan-1-ol.

(B) petrol.

(C) water.

(D) all of the above.

2 Uranium is the principal element used in nuclear reactors. One example of a nuclear fission reaction is:

$$^{235}_{92}\text{U} + ^{1}_{0}\text{n} \rightarrow ^{92}_{36}\text{A} + {}_{56}\text{B} + 2\,^{1}_{0}\text{n}$$

The isotopes A and B respectively are

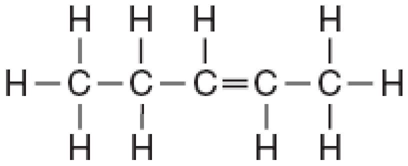
(A) uranium-92 and barium-142.

(B) krypton-36 and barium-56.

(C) krypton-92 and barium-143.

(D) krypton-92 and barium-142.

3 A student was asked to compare the reactions with bromine water of alkanes and alkenes. She decided to use the compound below as one of the two hydrocarbons being investigated.



The other hydrocarbon investigated should be

(A) pent-1-ene.

(B) pentane.

(C) hexane.

(D) cyclohexane.

4 When powdered zinc is warmed with a purple solution containing permanganate ions (MnO_4^-), the solution changes colour due to the formation of almost colourless Mn^{2+}.

During this reaction

(A) manganese has lost electrons and has reached a lower oxidation state.

(B) manganese has gained electrons and has reached a lower oxidation state.

(C) manganese has lost electrons and has reached a higher oxidation state.

(D) manganese has gained electrons and has reached a higher oxidation state.

5 The molar heat of combustion of pentan-1-ol is 2800 kJ mol^{-1}. A quantity of pentan-1-ol was combusted, generating 79.5 kJ of heat energy.

What mass of pentan-1-ol was combusted?

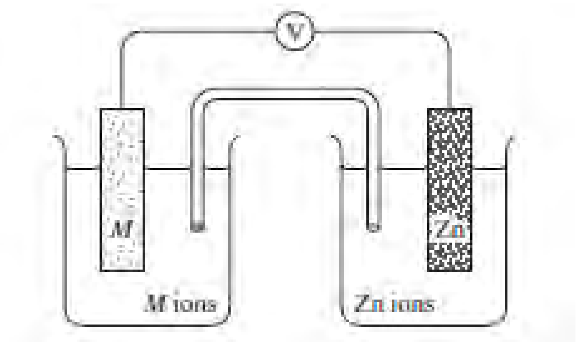
(A) 17.2 g

(B) 2.15 g

(C) 2.50 g

(D) 2.55 g

6 The diagram shows a galvanic cell set up with zinc and another metal (*M*) as electrodes.



Which of the following metals would you place as *M* to produce the highest theoretical voltage under standard conditions for this cell?

(A) Silver

(B) Iron

(C) Magnesium

(D) Lead

7 Which of the following species has the highest boiling point?

(A) Ethylene

(B) Ethanol

(C) Ethane

(D) Ethanoic acid

8 In the following equation

$HPO_4^{2-}\,(aq) + H_2O\,(l) \rightleftharpoons H_2PO_4^{-}\,(aq) + OH^{-}\,(aq)$

(A)	HPO_4^{2-} is acting as an acid	OH^- is acting as its conjugate base
(B)	HPO_4^{2-} is acting as an acid	$H_2PO_4^-$ is acting as its conjugate base
(C)	HPO_4^{2-} is acting as a base	OH^- is acting as its conjugate acid
(D)	HPO_4^{2-} is acting as a base	$H_2PO_4^-$ is acting as its conjugate acid

9 An aqueous solution was tested in the laboratory with various indicators, producing the following results.

Indicator	***Colour***
Phenolphthalein	Colourless
Methyl orange	Yellow
Bromothymol blue	Blue

The solution tested could be

(A) hydrochloric acid.

(B) sodium hydroxide.

(C) seawater.

(D) carbonic acid.

10 Sulfur trioxide is classified as

(A) an acidic oxide, because it reacts with acids to form salts.

(B) a basic oxide, because it produces hydroxide ions in aqueous solution.

(C) an acidic oxide, because it reacts with bases to form salts.

(D) a basic oxide, because it is neutralised by acids.

11 The volume of gas produced when 6.54 g zinc reacts with 50.0 mL of 1.00 mol L^{-1} hydrochloric acid at 0°C and 100 kPa pressure is closest to

(A) 0.568 L

(B) 0.620 L

(C) 2.27 L

(D) 2.48 L

12 What is the pH of the resulting solution when 50.0 mL of 0.15 mol L^{-1} potassium hydroxide solution and 150 mL of 0.10 mol L^{-1} sulfuric acid are mixed?

(A) 0.95

(B) 2.12

(C) 1.4

(D) 1.65

13 A 1.0×10^{-6} mol L^{-1} solution of an acid HX was found to have a pH of 6.00. This solution would best be described as a

(A) concentrated solution of a weak acid.

(B) dilute solution of a strong acid.

(C) dilute solution of a weak acid.

(D) concentrated solution of a strong acid.

14 The pH of a solution of sodium propanoate (CH_3CH_2COONa) was measured to be 8.75.

Which of the following statements best explains the recorded pH?

(A) Sodium ions donate protons to water.

(B) Propanoate ions and sodium ions donate protons to water.

(C) Sodium ions accept protons from water.

(D) Propanoate ions accept protons from water.

15 A student analysed a 250 mL sample of water taken from a local pond. Data collected during his analysis are shown below. Steps in his analysis included filtration and evaporation of the filtrate to dryness.

Mass of filter paper	0.23 g
Mass of filter paper and solid	0.47 g
Mass of evaporating basin	43.53 g
Mass of basin and solid remaining	44.67 g

The percentage of total dissolved solids in the pond water sample was

(A) 0.096%

(B) 0.456%

(C) 0.552%

(D) 17.6%

16 A student wished to identify the cation and anion present in a colourless aqueous solution. He performed the following tests.

	Test	***Observation***
1	Nitric acid was added to a sample of the solution.	No bubbles of gas formed.
2	Sulfuric acid was added to another sample of the solution.	A white precipitate formed.
3	A flame test was carried out on another sample of the solution.	No distinctive coloured flame was produced.
4	Silver nitrate solution was added to another sample of the solution.	No precipitate formed.
5	Hydrochloric acid was added to another sample of the solution.	A white precipitate formed.

These results are consistent with the presence, in the solution, of

(A) sodium ions and nitrate ions.

(B) sodium ions and chloride ions.

(C) lead (II) ions and nitrate ions.

(D) lead (II) ions and chloride ions.

17 A student performed a sampling technique as part of a first-hand investigation on water quality and repeated the sampling technique several times.

What aspect of the experiment was improved by repeating the procedure?

(A) Reliability

(B) Accuracy

(C) Validity

(D) All of the above

18 Consider the following reaction at equilibrium:

$2NO\,(g) + O_2\,(g) \rightleftharpoons 2NO_2\,(g) \qquad \Delta H = -114$ kJ

What would be the effect on the equilibrium of an increase in temperature of the reaction container?

(A) The concentrations of nitrogen monoxide and oxygen will both increase.

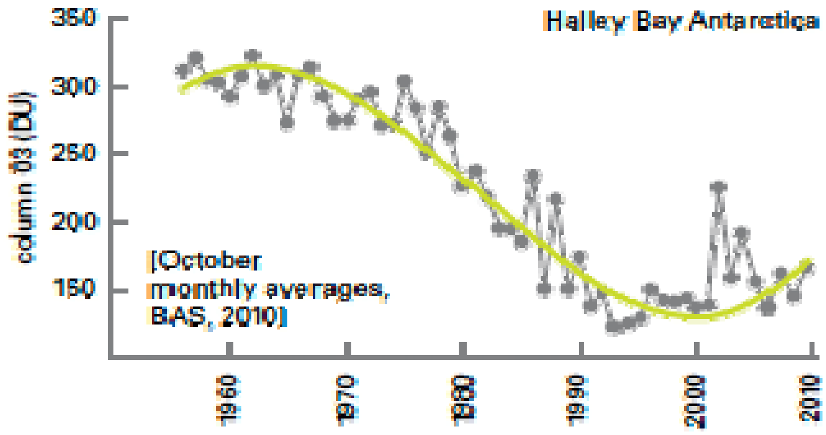
(B) The equilibrium will shift to the right.

(C) The concentration of $NO_2\,(g)$ will increase.

(D) The rate of the reverse reaction will be less than the rate of the forward reaction.

19 The graph shows October ozone concentrations above Halley Bay in Antarctica between 1956 and 2010.

Halley Bay Antarctica (CSIRO 2009)



Based on these data alone, which of the following is a valid statement about the concentration of ozone above Halley Bay?

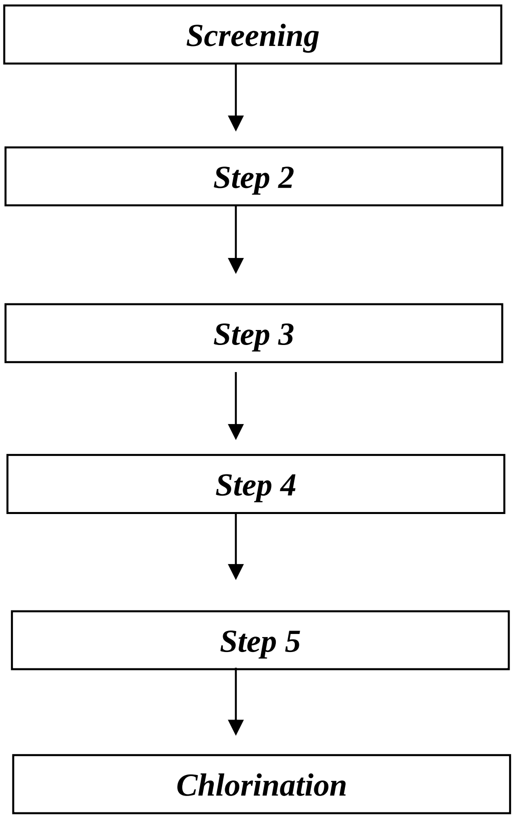
(A) The variation in ozone concentration between 1960 and 1980 was due to changes in atmospheric CFC concentrations.

(B) The variation in ozone concentration from one year to the next is due only to changes in atmospheric CFC concentrations.

(C) The concentration of ozone will be greater in 2012 than in 1998.

(D) The concentration of ozone was greater in 2008 than in 2000.

20 The diagram shows steps in the purification of water for drinking.



Which sequence represents the correct order of ***Steps 2***, ***3***, ***4*** and ***5***?

	Step 2	***Step 3***	***Step 4***	***Step 5***
(A)	pH adjustment	Sedimentation	Flocculation	Filtration
(B)	pH adjustment	Flocculation	Sedimentation	Filtration
(C)	Filtration	Sedimentation	pH adjustment	Flocculation
(D)	Filtration	Flocculation	Sedimentation	pH adjustment

BLANK PAGE

2012 TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION

Chemistry

Student Number

Section I (continued)

Part B – 55 marks
Attempt Questions 21-30
Allow about 1 hour and 40 minutes for this part

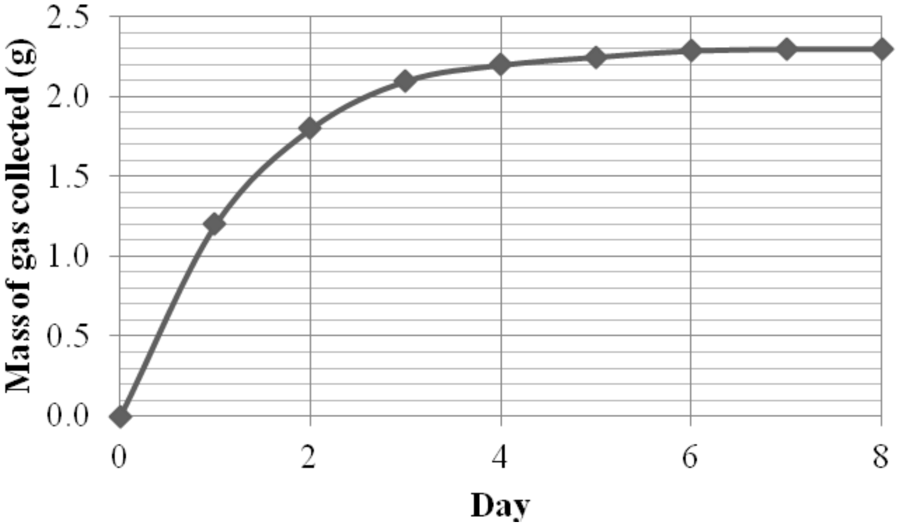
Answer the questions in the spaces provided.

Show all relevant working in questions involving calculations.

Question 21 (4 marks)

A student made a solution by dissolving 5.0 g of glucose in water in a flask and added yeast and a suitable yeast nutrient. The flask was connected via a delivery tube to a syringe. The syringe was weighed at regular intervals over an 8-day period in order to calculate the mass of gas which had been collected in the syringe.

The graph shows the mass of gas collected over the 8-day period. The reaction was conducted at 25°C and 100 kPa.



(a) Identify the gas produced. **1**

……………………………………………………………………………………..

(b) Calculate the volume of gas which would have been in the syringe. **1**

……………………………………………………………………………………..

……………………………………………………………………………………..

……………………………………………………………………………………..

(c) Calculate the mass of glucose which had fermented during the 8-day period. **2**

……………………………………………………………………………………..

……………………………………………………………………………………..

……………………………………………………………………………………..

Question 22 (8 marks)

"The twentieth century saw an explosion in the use of traditional materials and in research for development of a wider range of materials to satisfy the needs of society. This explosion has had, and will continue to have, wide implications for society, for the environment and for future research and development in chemistry." **8**

Analyse this statement, using a range of examples you have studied relating to the production of materials.

Extra space for your response is available (if needed) on the next page.

Question 22 (continued)

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

Question 23 (6 marks)

During your study of oxidation-reduction reactions, you have carried out an investigation of the chemistry and structure EITHER of a dry cell OR a lead-acid cell.

(a) Identify which cell you have investigated. **3**

....

Draw a labelled diagram to show the structure of the cell. Ensure that you have identified the anode, cathode and electrolyte.

(b) Write half-equations for the half-cell reactions. **2**

………………………………………………………………………………………..

………………………………………………………………………………………..

(c) Identify ONE benefit and ONE problem associated with the use of this cell. **1**

………………………………………………………………………………………..

………………………………………………………………………………………..

………………………………………………………………………………………..

………………………………………………………………………………………..

………………………………………………………………………………………..

Question 24 (5 marks)

All Lowry-Bronsted acid-base reactions involve the formation of a co-ordinate covalent bond.

(a) Define acids and bases according to the Lowry-Bronsted theory. **1**

……………………………………………………………………………………..

……………………………………………………………………………………..

……………………………………………………………………………………..

(b) The hydronium ion (H_3O^+) acts as an acid in aqueous solution. By using electron-dot formulae for the reactants and the products, show the formation of a co-ordinate covalent bond when hydronium ion reacts with ammonia (NH_3). **2**

(c) Explain what is meant by a co-ordinate covalent bond. Indicate, on your equation in part (b) above, the bond formed during the reaction which is classified as a co-ordinate covalent bond. **2**

……………………………………………………………………………………..

……………………………………………………………………………………..

……………………………………………………………………………………..

……………………………………………………………………………………..

……………………………………………………………………………………..

……………………………………………………………………………………..

Question 25 (6 marks)

A manufacturer made a lemon drink by mixing flavouring, sugar syrup and citric acid.

A chemist determined the concentration of the citric acid by titration with NaOH.

The sodium hydroxide solution was prepared by dissolving 4.176 g of NaOH pellets in water to give 1.000 L of solution. This solution was standardised by titrating 25.00 mL with a 0.1024 mol L^{-1} standardised solution of HCl. The average titration volume was found to be 25.10 mL.

To analyse the citric acid concentration, 50.00 mL of the lemon drink was diluted to 500.0 mL. 25.00 mL of the diluted solution was then titrated with the NaOH solution to the phenolphthalein endpoint.

The following data were collected during the titration of the diluted lemon drink with the standardised sodium hydroxide solution.

Titration 1	28.30 mL
Titration 2	27.50 mL
Titration 3	27.45 mL
Titration 4	27.55 mL

(a) Why was the concentration of the standardised NaOH solution (as calculated using the titration data) different from the concentration of NaOH as calculated using the mass of pellets dissolved? Assume that no human error occurred. **2**

…………………………………………………………………………………………..

…………………………………………………………………………………………..

…………………………………………………………………………………………..

…………………………………………………………………………………………..

…………………………………………………………………………………………..

…………………………………………………………………………………………..

…………………………………………………………………………………………..

Question 25 continues on the next page

Question 25 (continued)

(b) Calculate the concentration of the citric acid in the manufactured lemon drink. **4**

…………………………………………………………………………………………..

…………………………………………………………………………………………..

…………………………………………………………………………………………..

…………………………………………………………………………………………..

…………………………………………………………………………………………..

…………………………………………………………………………………………..

…………………………………………………………………………………………..

…………………………………………………………………………………………..

…………………………………………………………………………………………..

…………………………………………………………………………………………..

…………………………………………………………………………………………..

Question 26 (3 marks)

Carbon dioxide is an acidic oxide and the acid it forms is classified as weak.

(a) Write an equation to show the formation of an acid from the reaction of carbon dioxide gas with water. Show correct states in your equation, assuming the reaction occurs at 25ºC. **1**

………………………………………………………………………………………..

(b) Explain why a solution of sodium hydrogen carbonate has a pH greater than 7. Use an equation in your response. **2**

………………………………………………………………………………………..

………………………………………………………………………………………..

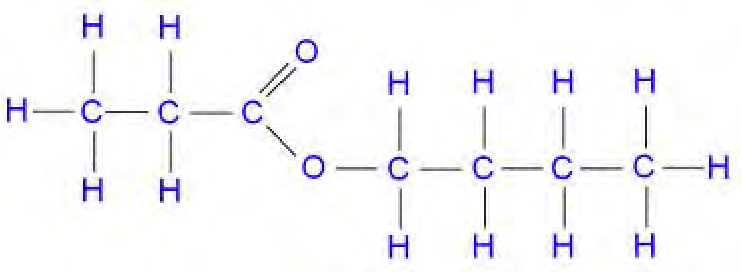
………………………………………………………………………………………..

………………………………………………………………………………………..

………………………………………………………………………………………..

Question 27 (4 marks)

The compound shown below was prepared in a school laboratory by refluxing TWO carbon compounds with concentrated sulfuric acid.



(a) Draw the expanded structural formulae for the TWO carbon compounds and name these compounds. **2**

(b) Explain the roles of sulfuric acid in the formation of this compound. **2**

………………………………………………………………………………..

………………………………………………………………………………..

………………………………………………………………………………..

………………………………………………………………………………..

………………………………………………………………………………..

………………………………………………………………………………..

………………………………………………………………………………..

………………………………………………………………………………..

………………………………………………………………………………..

………………………………………………………………………………..

Question 28 (6 marks)

(a) Write a balanced equation for the reaction to form ammonia during the Haber process, showing the energy term in your equation. **1**

…………………………………………………………………………………......

(b) Explain why the yield of ammonia is reduced at high temperatures. **1**

…………………………………………………………………………………......

…………………………………………………………………………………......

…………………………………………………………………………………......

…………………………………………………………………………………......

(c) Identify a catalyst used for the Haber process. **1**

…………………………………………………………………………………......

Question 28 continues on the next page

Question 28 (continued)

(d) Discuss the need for the monitoring by chemists of the pressure and the temperature of the reaction vessel during the Haber process. **3**

……………………………………………………………………………….......

……………………………………………………………………………….......

……………………………………………………………………………….......

……………………………………………………………………………….......

……………………………………………………………………………….......

……………………………………………………………………………….......

……………………………………………………………………………….......

……………………………………………………………………………….......

……………………………………………………………………………….......

……………………………………………………………………………….......

……………………………………………………………………………….......

……………………………………………………………………………….......

……………………………………………………………………………….......

Question 29 (8 marks)

A scientist monitoring the impact of effluent on a river system used AAS to compare the lead ion concentration above and below the effluent discharge point in the river.

The table below shows the absorbance values for the water samples and also those for a range of standard solutions.

Solution	***[Pb^{2+}] (mg/L)***	***Absorbance %***
Standard	0.1	15
Standard	0.2	32
Standard	0.4	63
Standard	0.6	97
River sample 1		1
River sample 2		2
River sample 3		53
River sample 4		48

(a) Use the grid below to plot the absorbance for the standards. **2**

(b) Complete the data in the table for the [Pb^{2+}]. **2**

Question 29 continues on the next page

Question 29 (continued)

(c) Assess the quality of the river water for freshwater organisms, above and below the entry point of the effluent, given that the maximum acceptable level for [Pb^{2+}] is 0.05 ppm. **1**

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

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

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

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

(d) Outline a chemical procedure for determining the lead ion concentration in a river. Include an equation for the reaction(s) you describe. **3**

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

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

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

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

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

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

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

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

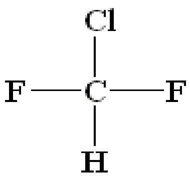
………………………………………………………………………………….......

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

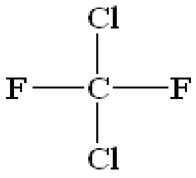
………………………………………………………………………………….......

Question 30 (5 marks)

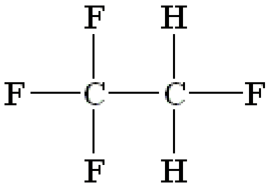
The structural formulae of three haloalkanes are shown below.



Compound 1



Compound 2



Compound 3

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

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

(b) Evaluate the impacts of these haloalkanes on depletion of ozone in the stratosphere. Include an equation for the depletion of ozone in your response. **4**

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

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

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

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

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

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

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

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

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

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

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

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

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

End of Section I – Part B

BLANK PAGE

2012 TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION
Chemistry

Section II
25 marks

Attempt ONE question from Questions 31-35
Allow about 45 minutes for this section

Show all relevant working in questions involving calculations.

Question 31 – Industrial Chemistry (25 marks)

(a) Outline TWO reasons why an identified natural substance (that is not a fossil fuel) has been or is being replaced by an identified synthetic material. **2**

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

(b) Sulfuric acid is produced commercially using the Contact process and this process may be modelled in the school laboratory. One important step is the production of sulfur trioxide gas from sulfur dioxide gas.

(i) Write a balanced equation for the production of one mole of sulfur trioxide from sulfur dioxide. **1**

……………………………………………………………………………

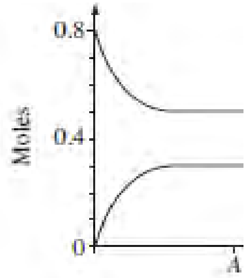
(ii) Write an equilibrium constant expression for this reaction. **1**

……………………………………………………………………………

……………………………………………………………………………

Question 31 (continued)

(b) (iii) At room temperature, 0.80 moles of sulfur dioxide and 0.40 moles of oxygen were added to a sealed 10 L vessel and allowed to come to equilibrium. The graph below shows changes in the moles of two of the reacting species as the reaction proceeds. **2**



Calculate the equilibrium constant for the reaction (as shown in your balanced equation) at time *A*.

………………………………………………………………………..........

………………………………………………………………………..........

………………………………………………………………………..........

………………………………………………………………………..........

(iv) Identify the sources of sulfur dioxide gas for this industrial process, both in Australia and elsewhere. Include appropriate equations in your response. **3**

………………………………………………………………………..........

………………………………………………………………………..........

………………………………………………………………………..........

………………………………………………………………………..........

………………………………………………………………………..........

………………………………………………………………………..........

………………………………………………………………………..........

………………………………………………………………………..........

………………………………………………………………………..........

………………………………………………………………………..........

Question 31 (continued)

(c) (i) Explain the role of surfactants in the production of emulsions. Use examples and diagrams in your response. **3**

……………………………………………………………………….........

……………………………………………………………………….........

……………………………………………………………………….........

……………………………………………………………………….........

……………………………………………………………………….........

……………………………………………………………………….........

……………………………………………………………………….........

……………………………………………………………………….........

……………………………………………………………………….........

……………………………………………………………………….........

……………………………………………………………………….........

……………………………………………………………………….........

(ii) Compare and explain the effectiveness of the use of soaps and synthetic detergents in hard water. **2**

……………………………………………………………………….........

……………………………………………………………………….........

……………………………………………………………………….........

……………………………………………………………………….........

……………………………………………………………………….........

……………………………………………………………………….........

Question 31 continues on the next page

(c) (iii) Outline the cleaning action of soap, and include a labelled diagram of a micelle in your answer **3**

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

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

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

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

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

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

(iv) Describe the structure and properties of ONE type of synthetic detergent that have been developed to meet the increasing demand for soaps. **2**

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

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

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

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

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

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

(d) Sodium hydroxide is an important base.

(i) Write a balanced equation for the overall reaction which occurs in the electrolytic production of sodium hydroxide using a membrane cell. **1**

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

Question 31 (continued)

(d) (ii) Explain why the industrial production of sodium hydroxide uses concentrated sodium chloride solution (brine) as its raw material rather than a dilute solution or molten sodium chloride. Use half-equations for the cell reactions in your response. **5**

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

End of Question 31

Question 32 – Shipwrecks, Corrosion and Conservation (25 marks)

(a) (i) Our understanding of electron transfer reactions and their potential applications developed as a result of the contributions by a number of scientists.
Identify the scientist who formulated two significant laws relating to the quantitative aspects of electrolysis. **1**

....

(ii) A student wished to apply the process of electrolysis to produce a sample of chlorine gas, starting with a solid sample of sodium chloride.
Describe some of the factors that the student must consider in order to carry out this task. **2**

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

…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

(iii) In 1807, Sir Humphrey Davy used the recently invented voltaic pile to isolate a pure sample of sodium from sodium hydroxide via electrolysis.
Calculate the minimum voltage required to operate an electrolytic cell for the isolation of sodium, including relevant half-equations and the net ionic equation that occurs as it operates. **2**

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

…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

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

…………………………………………………………………………………

…………………………………………………………………………………

(b) Aluminium and chromium are classified as “passivating metals”.

(i) Predict and explain the different rates of corrosion of passivating metals and iron in a moist aerobic environment. Use appropriate equations or half-equations in your response. **4**

……………………………………………………………………….....

……………………………………………………………………..

……………………………………………………………………..

……………………………………………………………………..

……………………………………………………………………...

………………………………………………………………………

………………………………………………………………………

……………………………………………………………………….....

……………………………………………………………………..

……………………………………………………………………..

……………………………………………………………………..

……………………………………………………………………...

………………………………………………………………………

………………………………………………………………………

……………………………………………………………………….....

……………………………………………………………………..

……………………………………………………………………..

……………………………………………………………………..

(ii) Compare the effectiveness of the use of the variety of metals used for construction purposes in a marine environment. **4**

…………………………………………………………………………...

……………………………………………………………………………

……………………………………………………………………………

…………………………………………………………………………...

……………………………………………………………………………

……………………………………………………………………………

…………………………………………………………………………...

……………………………………………………………………………

……………………………………………………………………………

…………………………………………………………………………...

……………………………………………………………………………

……………………………………………………………………………

…………………………………………………………………………...

……………………………………………………………………………

……………………………………………………………………………

…………………………………………………………………………...

……………………………………………………………………………

……………………………………………………………………………

(c) During your study of corrosion of shipwrecks, you performed a first-hand investigation to identify a factor which affects the rate of an electrolysis reaction.

(i) Identify the factor. **1**

………………………………………………………………………...

(ii) Describe how you set up this experiment. A diagram may be used in your response. **2**

……………………………………………………………………………

……………………………………………………………………………

……………………………………………………………………………

……………………………………………………………………………

……………………………………………………………………………

……………………………………………………………………………

……………………………………………………………………………

……………………………………………………………………………

(iii) Explain the results you achieved and the conclusions you made, using half-equations for the reactions which occurred. **3**

……………………………………………………………………………

……………………………………………………………………………

……………………………………………………………………………

……………………………………………………………………………

……………………………………………………………………………

……………………………………………………………………………

……………………………………………………………………………

……………………………………………………………………………

(d) (i) Outline the changes in solubility of oxygen in water as the pressure increases. **1**

……………………………………………………………………………

……………………………………………………………………………

(ii) Describe how the concentration of oxygen in seawater changes with depth. **1**

……………………………………………………………………………

……………………………………………………………………………

(iii) By discussing your responses to parts (i) and (ii) above, justify the expectation that corrosion of shipwrecks would be expected to be minimal at depth in the oceans. **4**

……………………………………………………………………………

……………………………………………………………………………

……………………………………………………………………………

……………………………………………………………………………

……………………………………………………………………………

……………………………………………………………………………

……………………………………………………………………………

……………………………………………………………………………

……………………………………………………………………………

……………………………………………………………………………

End of Question 32

Marks

Question 33 - The Biochemistry of Movement (25 marks)

(a) (i) Identify the two locations of glycogen storage in humans. **1**

(ii) Identify the structure of glycogen and outline how glycogen is formed. **2**

(iii) Account for the different solubility in water of glycerol and TAGs, supporting your answer with the structural formula of glycerol. **3**

(b) Assess the importance of the structure of proteins and describe how this can be disrupted. Illustrate your answer with the results of your own first-hand investigation into enzyme activity. **6**

(c) Carbohydrates and fats are important biological molecules with a number of functions, including being fuels for cells.

(i) Describe how muscle cells contract and identify the role of ATP in this process. **3**

(ii) Describe the aerobic metabolism of glucose and its role in ATP production. **4**

(d) Gentle exercise and sprinting are different in terms of energy requirements, and metabolic products such as lactic acid.

(i) Lactic acid is also known by two other names.

Identify these two names. **2**

(ii) Compare and contrast Type 1 and 2 muscle cells and the way in which their energy requirements are met, and explain why muscle cramps can result from high-intensity exercise. **4**

Marks

Question 34 - The Chemistry of Art (25 marks)

(a) The copper based pigment malachite contains combined copper in the form $CuCO_3$ and $Cu(OH)_2$.

(i) Write the electron configuration of copper as it would occur in both $CuCO_3$ and $Cu(OH)_2$. **1**

(ii) Apart from the metal ion present, explain how TWO other variables may affect the colour of a mineral. **2**

(iii) Cu^{2+} ions form a complex ion with chloride ions as represented by the following equation:

$$Cu^{2+} + 4Cl^{-} \rightarrow [CuCl_4]^{2-}$$

Describe the bonding between the copper and chloride ions in the complex ion. Include a Lewis diagram to assist in your description. **3**

(b) You have investigated the phenomena of flame colours for various metal ions, one of which was sodium.

Describe the procedure you followed in your investigation and account for the flame colour observed for sodium using an appropriate atomic model and an energy level diagram. **6**

(c) For thousands of years, humans have used naturally occurring minerals to depict various images in works of art.

(i) Describe the properties of some named minerals that make them useful for this purpose. **3**

(ii) Explain some factors that have resulted in changes in the type of substances used as pigments in art works over the past 200 years, using specific examples with your answer. **4**

(d) The current atomic model can be used to explain many trends in the properties of elements as they are placed in the periodic table.

(i) Define the term electronegativity and outline the trend in electronegativity down a group. **2**

(ii) Using elements in Period 2 as examples, analyse the relationship between trends in first ionization energy and electronegativity across the period, and account for the trends described at the atomic level. **4**

Marks

Question 35 - Forensic Chemistry (25 marks)

(a) Carbohydrates are a vital group of compounds which are equally important in the animal and plant kingdom.

1

(i) Carbohydrates can be represented by the general formula $C_x(H_2O)_y$. Write the formula for sucrose using this format.

2

(ii) Identify the roles of cellulose, starch and glycogen in living systems.

3

(iii) Describe the chemical difference between reducing and non-reducing sugars and illustrate your answer with the results of your own first-hand investigation to distinguish between these two types of sugars.

6

(b) A range of spectroscopic techniques is available to forensic chemists. Explain how line emission spectra and mass spectra are obtained including the underlying chemistry, and assess their usefulness to a forensic chemist.

(c) Forensic chemists use the analysis of various types of inorganic and organic material to aid in the investigation of crimes.

(i) A laboratory technician finds that the labels have fallen off four bottles of colourless liquids in their storeroom. The labels that they find on the shelf are shown below.

0.1 M Na_2CO_3

1-octene

1-octanol

octane

3

Design a series of chemical tests that would allow these liquids to be distinguished in the school laboratory, and identify the underlying chemistry.

4

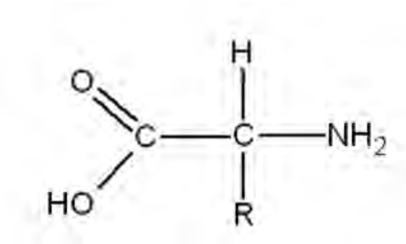
(ii) Describe the structure and composition of DNA, and explain why DNA analysis is so useful to a forensic chemist.

Question 34 continues on page 31. **Marks**

Question 34 (continued)

2

(d) (i) Identify the type of compound shown below. Draw and label the major functional groups it contains.



4

(ii) With reference to the compound shown in d(i), describe the structure of proteins, and explain how their origins may be determined using electrophoresis.

End of Paper

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 ○

BLANK PAGE

DATA SHEET

Avogadro constant, N_A .... 6.022×10^{23} mol^{-1}

Volume of 1 mole ideal gas: at 100 kPa and
at 0°C (273.15 K) .... 22.71 L
at 25°C (298.15 K) .... 24.79 L

Ionisation constant for water at 25°C (298.15 K), K_w .... 1.0×10^{-14}

Specific heat capacity of water .... 4.18×10^{3} J kg^{-1} K^{-1}

Some useful formulae

$\text{pH} = -\log_{10}[\text{H}^+]$ $\Delta H = -m\,C\,\Delta T$

Some standard potentials

$K^+ + e^-$	$\rightleftharpoons$	$K(s)$	–2.94 V
$Ba^{2+} + 2e^-$	$\rightleftharpoons$	$Ba(s)$	–2.91 V
$Ca^{2+} + 2e^-$	$\rightleftharpoons$	$Ca(s)$	–2.87 V
$Na^+ + e^-$	$\rightleftharpoons$	$Na(s)$	–2.71 V
$Mg^{2+} + 2e^-$	$\rightleftharpoons$	$Mg(s)$	–2.36 V
$Al^{3+} + 3e^-$	$\rightleftharpoons$	$Al(s)$	–1.68 V
$Mn^{2+} + 2e^-$	$\rightleftharpoons$	$Mn(s)$	–1.18 V
$H_2O + e^-$	$\rightleftharpoons$	$\frac{1}{2}H_2(g) + OH^-$	–0.83 V
$Zn^{2+} + 2e^-$	$\rightleftharpoons$	$Zn(s)$	–0.76 V
$Fe^{2+} + 2e^-$	$\rightleftharpoons$	$Fe(s)$	–0.44 V
$Ni^{2+} + 2e^-$	$\rightleftharpoons$	$Ni(s)$	–0.24 V
$Sn^{2+} + 2e^-$	$\rightleftharpoons$	$Sn(s)$	–0.14 V
$Pb^{2+} + 2e^-$	$\rightleftharpoons$	$Pb(s)$	–0.13 V
$H^+ + e^-$	$\rightleftharpoons$	$\frac{1}{2}H_2(g)$	0.00 V
$SO_4^{2-} + 4H^+ + 2e^-$	$\rightleftharpoons$	$SO_2(aq) + 2H_2O$	0.16 V
$Cu^{2+} + 2e^-$	$\rightleftharpoons$	$Cu(s)$	0.34 V
$\frac{1}{2}O_2(g) + H_2O + 2e^-$	$\rightleftharpoons$	$2OH^-$	0.40 V
$Cu^+ + e^-$	$\rightleftharpoons$	$Cu(s)$	0.52 V
$\frac{1}{2}I_2(s) + e^-$	$\rightleftharpoons$	I^-	0.54 V
$\frac{1}{2}I_2(aq) + e^-$	$\rightleftharpoons$	I^-	0.62 V
$Fe^{3+} + e^-$	$\rightleftharpoons$	Fe^{2+}	0.77 V
$Ag^+ + e^-$	$\rightleftharpoons$	$Ag(s)$	0.80 V
$\frac{1}{2}Br_2(l) + e^-$	$\rightleftharpoons$	Br^-	1.08 V
$\frac{1}{2}Br_2(aq) + e^-$	$\rightleftharpoons$	Br^-	1.10 V
$\frac{1}{2}O_2(g) + 2H^+ + 2e^-$	$\rightleftharpoons$	H_2O	1.23 V
$\frac{1}{2}Cl_2(g) + e^-$	$\rightleftharpoons$	Cl^-	1.36 V
$\frac{1}{2}Cr_2O_7^{2-} + 7H^+ + 3e^-$	$\rightleftharpoons$	$Cr^{3+} + \frac{7}{2}H_2O$	1.36 V
$\frac{1}{2}Cl_2(aq) + e^-$	$\rightleftharpoons$	Cl^-	1.40 V
$MnO_4^- + 8H^+ + 5e^-$	$\rightleftharpoons$	$Mn^{2+} + 4H_2O$	1.51 V
$\frac{1}{2}F_2(g) + e^-$	$\rightleftharpoons$	F^-	2.89 V

Aylward and Findlay, *SI Chemical Data* (5th Edition) is the principal source of data for this examination paper. Some data may have been modified for examination purposes.

PERIODIC TABLE OF THE ELEMENTS

KEY

Atomic Number	79	
	Au	Symbol of element
Atomic Weight	197.0	
	Gold	Name of element

1 H 1.008 Hydrogen																	2 He 4.003 Helium
3 Li 6.941 Lithium	4 Be 9.012 Beryllium											5 B 10.81 Boron	6 C 12.01 Carbon	7 N 14.01 Nitrogen	8 O 16.00 Oxygen	9 F 19.00 Fluorine	10 Ne 20.18 Neon
11 Na 22.99 Sodium	12 Mg 24.31 Magnesium											13 Al 26.98 Aluminium	14 Si 28.09 Silicon	15 P 30.97 Phosphorus	16 S 32.07 Sulfur	17 Cl 35.45 Chlorine	18 Ar 39.95 Argon
19 K 39.10 Potassium	20 Ca 40.08 Calcium	21 Sc 44.96 Scandium	22 Ti 47.87 Titanium	23 V 50.94 Vanadium	24 Cr 52.00 Chromium	25 Mn 54.94 Manganese	26 Fe 55.85 Iron	27 Co 58.93 Cobalt	28 Ni 58.69 Nickel	29 Cu 63.55 Copper	30 Zn 65.41 Zinc	31 Ga 69.72 Gallium	32 Ge 72.64 Germanium	33 As 74.92 Arsenic	34 Se 78.96 Selenium	35 Br 79.90 Bromine	36 Kr 83.80 Krypton
37 Rb 85.47 Rubidium	38 Sr 87.62 Strontium	39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.94 Molybdenum	43 Tc [97.91] Technetium	44 Ru 101.1 Ruthenium	45 Rh 102.9 Rhodium	46 Pd 106.4 Palladium	47 Ag 107.9 Silver	48 Cd 112.4 Cadmium	49 In 114.8 Indium	50 Sn 118.7 Tin	51 Sb 121.8 Antimony	52 Te 127.6 Tellurium	53 I 126.9 Iodine	54 Xe 131.3 Xenon
55 Cs 132.9 Caesium	56 Ba 137.3 Barium	57–71 Lanthanoids	72 Hf 178.5 Hafnium	73 Ta 180.9 Tantalum	74 W 183.8 Tungsten	75 Re 186.2 Rhenium	76 Os 190.2 Osmium	77 Ir 192.2 Iridium	78 Pt 195.1 Platinum	79 Au 197.0 Gold	80 Hg 200.6 Mercury	81 Tl 204.4 Thallium	82 Pb 207.2 Lead	83 Bi 209.0 Bismuth	84 Po [209.0] Polonium	85 At [210.0] Astatine	86 Rn [222.0] Radon
87 Fr [223] Francium	88 Ra [226] Radium	89–103 Actinoids	104 Rf [261] Rutherfordium	105 Db [262] Dubnium	106 Sg [266] Seaborgium	107 Bh [264] Bohrium	108 Hs [277] Hassium	109 Mt [268] Meitnerium	110 Ds [271] Darmstadtium	111 Rg [272] Roentgenium							

Lanthanoids

57 La 138.9 Lanthanum	58 Ce 140.1 Cerium	59 Pr 140.9 Praseodymium	60 Nd 144.2 Neodymium	61 Pm [145] Promethium	62 Sm 150.4 Samarium	63 Eu 152.0 Europium	64 Gd 157.3 Gadolinium	65 Tb 158.9 Terbium	66 Dy 162.5 Dysprosium	67 Ho 164.9 Holmium	68 Er 167.3 Erbium	69 Tm 168.9 Thulium	70 Yb 173.0 Ytterbium	71 Lu 175.0 Lutetium

Actinoids

89 Ac [227] Actinium	90 Th 232.0 Thorium	91 Pa 231.0 Protactinium	92 U 238.0 Uranium	93 Np [237] Neptunium	94 Pu [244] Plutonium	95 Am [243] Americium	96 Cm [247] Curium	97 Bk [247] Berkelium	98 Cf [251] Californium	99 Es [252] Einsteinium	100 Fm [257] Fermium	101 Md [258] Mendelevium	102 No [259] Nobelium	103 Lr [262] Lawrencium

For elements that have no stable or long-lived nuclides, the mass number of the nuclide with the longest confirmed half-life is listed between square brackets.

The International Union of Pure and Applied Chemistry Periodic Table of the Elements (October 2005 version) is the principal source of data. Some data may have been modified.

CHEMISTRY
TRIAL 2012

MARKING
GUIDE

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

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

Section I

Part B – 55 marks

Question 21 (4 marks)

21 (a) (1 mark)

Outcomes Assessed: H9

Targeted Performance Bands: 2-3

Criteria	**Mark**
• Identifies carbon dioxide	1

Sample answer

Carbon dioxide

21 (b) (1 mark)

Outcomes Assessed: H10

Targeted Performance Bands: 2-3

Criteria	**Mark**
• Correct answer	1

Sample answer

Mass of gas collected = 2.3 g
Moles carbon dioxide collected = 2.3/44.01 = 0.0523 mol
Volume of gas at 25ºC and 100 kPa = 0.0523 x 24.79 = 1.3 L

21 (c) (2 marks)

Outcomes Assessed: H10

Targeted Performance Bands: 2-4

Criteria	**Marks**
• Correct answer	2
• Calculates correct number of moles of glucose fermented	1

Sample answer

Moles carbon dioxide produced = 0.052 mol
Since 1 mole glucose ferments to form 2 moles carbon dioxide (from balanced equation)
Moles glucose fermented = ½ x 0.052 = 0.026 mol
Mass glucose fermented = 0.026 x 180.1 = 4.7 g

Question 22 (8 marks)
Outcomes Assessed: H1, H3, H4, H5
Targeted Performance Bands: 2-6

Criteria	Marks
• Analyses the statement • Discusses thoroughly the "explosion in the use of traditional materials" • Discusses thoroughly the "development of a wider range of materials to satisfy the needs of society" • Discusses thoroughly the implications of these explosions • Uses a range of examples including most of the following: fossil fuels, polymers from fossil fuels, biomass fuels, biopolymers, ethanol, energy from oxidation-reduction reactions and radioisotopes	8
• Discusses thoroughly the "explosion in the use of traditional materials" • Discusses thoroughly the "development of a wider range of materials to satisfy the needs of society" • Discusses thoroughly the implications of these explosions • Uses a range of examples including most of the following: fossil fuels, polymers from fossil fuels, biomass fuels, biopolymers, ethanol, energy from oxidation-reduction reactions and radioisotopes	6-7
• Discusses soundly the "explosion in the use of traditional materials" • Discusses soundly the "development of a wider range of materials to satisfy the needs of society" • Discusses soundly the implications of these explosions • Uses a range of examples including some of the following: fossil fuels, polymers from fossil fuels, biomass fuels, biopolymers, ethanol, energy from oxidation-reduction reactions and radioisotopes	4-5
• Outlines some changes in the use of materials in the twentieth century AND • Outlines some implications of these changes AND • Uses a range of examples	2-3
• Outlines some changes in the use of materials in the twentieth century OR • Outlines some implications of these changes OR • Uses a range of examples	1

Sample answer

"The twentieth century saw an explosion in the use of traditional materials …"

During the twentieth century, the world population increased significantly. With this increase in population came increased demands for the traditional materials such as fuels for transport, industry and heating, materials for construction to replace and supplement timber and iron, fibres for clothing and household goods and chemicals to improve medical care.

For a large part of this century, the demands were satisfied by fossil fuels. Coal provided a major source of energy for transport, for industry, for domestic heating. Coal gas also provided energy for cooking and heating. As the demands for liquid fuels for transport increased, crude oil production increased, and petroleum provided not only petrol, diesel and aviation fuel but also chemicals such as ethylene. Chemical industries based around fossil fuels developed.

"…the research for development of a wider range of materials to satisfy the needs of society."
The development of petrochemicals, based around the production of ethylene from long-chain hydrocarbons by cracking, led to the manufacture of a range of carbon-based chemicals. These included polymers, such as polyethylene, PVC and polystyrene as well as synthetically produced materials including esters, acids, alcohols, nylon, polyesters, synthetic rubber, adhesives, resins, medications, etc. These chemicals, based on the petroleum industry, changed the lifestyles of society but many of these had negative impacts on the environment, due to lack of biodegradability.

" … This explosion has had, and will continue to have, wide implications for society …"

The explosion in the use of petroleum led to dwindling supplies and high costs of this non-renewable fossil fuel and by the 1970s it became evident that traditional materials needed to be supplemented or replaced by others derived from renewable resources. In the decades since the 1970s, the use of biomass as a source of carbon-based chemicals for energy and for manufacturing has grown but has been limited to a large extent by the difficulty of converting cellulose into short-chain hydrocarbons and by the inefficiency of fermentation processes needed to convert sugars, starch and cellulose from plants into ethanol. Ethanol now supplies a significant proportion of liquid fuel for transport, to the detriment of world food supplies.

Electrical energy, once largely provided by the burning of fossil fuels such as coal in power stations, is now supplemented by the use of batteries. A wide range of new batteries (using transfer of electrons between reductants and oxidants) has been developed in recent decades. This is vital for use in new technologies such as computers, mobile phones, etc.

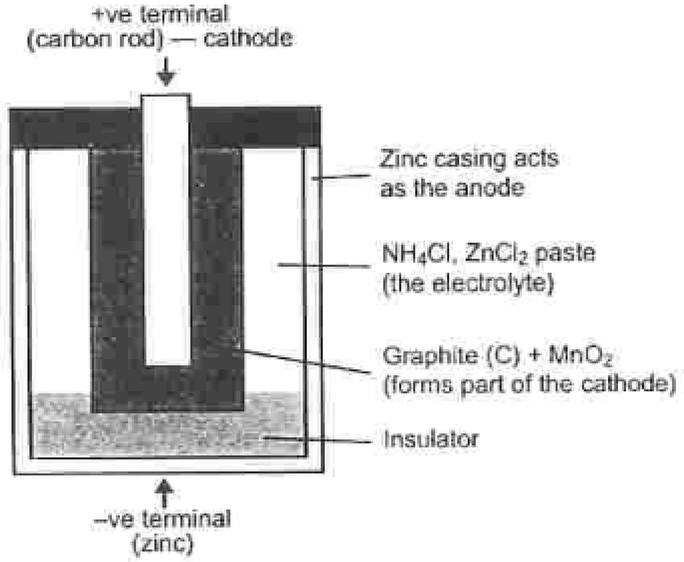
The development of materials used in medicine has been driven by improvements in understanding of health issues and research into new techniques. Synthetic biopolymers, which are biodegradable, have been developed and are being used to a large extent in medicine. Radioisotopes produced by nuclear industry (in reactors and in accelerators) allow diagnosis and treatment of medical conditions. The development of radioisotopes has benefitted research and industry.

This explosion has had, and will continue to have, wide implications … for the environment and for future research and development in chemistry."
As the world population continues to increase, as food supplies dwindle and as the demands for high quality health care, housing, transport and new technologies grow, there will be continued problems for the environment associated with these changes. Issues associated with climate change related to the use of carbon-based fuels will need resolution in years to come, as will the decreasing supplies of the non-renewable resources upon which chemical industry is still dependant. The use of renewable solar, wind, wave and geothermal power sources will become more significant, with the possibility of nuclear energy being harnessed safely for future generations. New sources of raw chemicals for the new technologies and industries of the future will need to be developed and these will continue to need further research and development of chemistry.

Question 23 (6 marks)
23 (a) (3 marks)
Outcomes Assessed: H4, H13
Targeted Performance Bands: 2-4

Criteria	Marks
• Draws a correct labelled diagram for either a dry cell or a lead-acid cell AND • Correctly identifies the chemicals used at the anode, cathode and electrolyte	3
• Draws a partially correct labelled diagram for either a dry cell or a lead-acid cell AND • Correctly identifies the chemicals used at the anode, cathode and electrolyte	2
• Correctly identifies TWO of the chemicals used at the anode, cathode and electrolyte	1

Sample answer (if dry cell identified)



23 (b) (2 marks)
Outcomes Assessed: H8, H13
Targeted Performance Bands: 2-4

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

Sample answer
Anode: $Zn\ (s) \rightleftharpoons Zn^{2+}\ (aq) + 2e^-$
Cathode: $NH_4^+\ (aq) + MnO_2\ (s) + H_2O\ (l) + e^- \rightleftharpoons Mn(OH)_3\ (s) + NH_3\ (aq)$

23 (c) (1 mark)

Outcomes Assessed: H4

Targeted Performance Bands: 2-3

Criteria	Mark
• Describes ONE significant benefit and ONE significant problem	1

Sample answer

Benefit:	The dry cell is cheap, light weight and portable.
Problem:	The voltage fluctuates as the cell is easily polarised (build-up of charge around electrodes).

Question 24 (5 marks)
24 (a) (1 mark)
Outcomes Assessed: H8
Targeted Performance Bands: 2-4

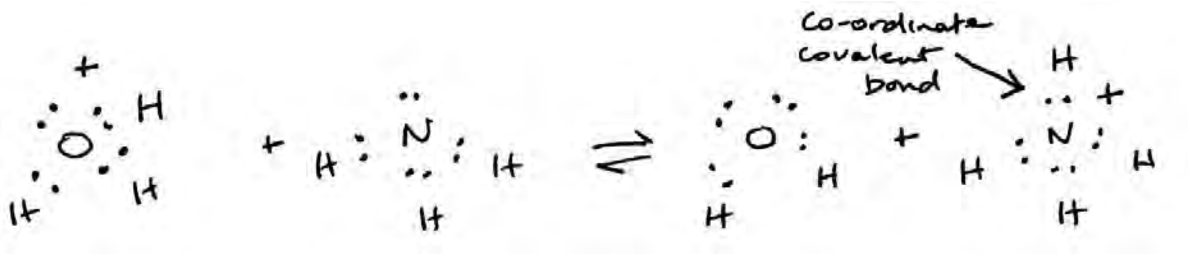
Criteria	Mark
• Correct answer	1

Sample answer
Acids are defined as proton donors and bases are proton acceptors according to the Lowry-Bronsted theory.

24 (b) (2 marks)
Outcomes Assessed: H6, H8, H13
Targeted Performance Bands: 2-5

Criteria	Marks
• Correct equation showing correct electron dot formulae for reactants and products	2
• Correct electron dot formulae for TWO of the species involved	1

Sample answer



24 (c) (2 marks)
Outcomes Assessed: H8
Targeted Performance Bands: 2-4

Criteria	Marks
• Explains what is meant by a co-ordinate covalent bond AND • Indicates the co-ordinate covalent bond on the equation in (b) above	2
• Explains what is meant by a co-ordinate covalent bond OR • Indicates the co-ordinate covalent bond on the equation in (b) above	1

Sample answer
A co-ordinate covalent bond joins atoms by sharing of electrons. The bonding method differs from a "normal" covalent bond in that, in the co-ordinate bond, the electrons are contributed unevenly to the bond. Here the nitrogen of the ammonia molecule donates both electrons into the bond. The hydrogen ion, from the hydronium ion, bonds with the nitrogen atom but does not contribute any electrons into the bond formation.

Question 25 (6 marks)
25 (a) (2 marks)
Outcomes Assessed: H11
Targeted Performance Bands: 2-4

	Marks
• Explains why sodium hydroxide is not suitable as a primary standard to determine the concentration of the citric acid	2
• Identifies that sodium hydroxide is not a primary standard / is not pure	1

Sample answer
Sodium hydroxide is not a primary standard since it cannot be accurately weighed out as it absorbs water and carbon dioxide from the air and hence its concentration cannot be accurately determined from the mass weighed out. It must be standardised (i.e. its concentration accurately determined) by titration against the HCl of known concentration prior to use in the titration with citric acid.

25 (b) (4 marks)
Outcomes Assessed: H10
Targeted Performance Bands: 3-6

	Marks
• Correctly calculates the concentration of the citric acid in the lemon drink (to 4 sig. figures)	4
• Correctly calculates the concentration of the citric acid in the lemon drink (to the wrong number of sig. figures)	3
• Correctly calculates the concentration of citric acid in the diluted lemon drink OR • Calculates the concentration of the citric acid in the full strength lemon drink using the wrong sodium hydroxide concentration	2
• Calculates the concentration of the sodium hydroxide solution against the standardised hydrochloric acid solution	1

Sample answer
Moles of HCl in average titration volume = n = cV = 0.1024 x 25.10/1000 = 0.00257024 mol
Hence moles of NaOH in a 25.00 mL aliquot = 0.00257024 mol
Concentration NaOH = n/V = 0.00257024/0.02500 = **0.1028096 mol L^{-1}**

Moles NaOH in the average titration volume of 27.50 ml (the rough initial reading was not included in calculation of the average titre) = cV = 0.1028096 x 0.02750 = 0.0028273 mol

Since NaOH and citric acid react in a 3: 1 mole ratio
Moles diluted citric acid in 25.00 mL of diluted lemon drink = 0.0028273/3 = 0.00094242 mol
Hence conc. of the dilute lemon drink = n/V = 0.00094242 / 0.02500 = **0.0376968 mol L^{-1}**

Since the original lemon drink was diluted by a factor of 10 (50.00 mL was diluted to 500.0 mL)

Concentration of original lemon drink = 0.0376968 x 10 = **0.3770 mol L^{-1}** (to 4 sig fig)

Question 26 (3 marks)
26 (a) (1 mark)
Outcomes Assessed: H8, H13

Targeted Performance Bands: 2-3

Criteria	Mark
- Correct answer	1

Sample answer

$CO_2\,(g) + H_2O\,(l) \rightleftharpoons H_2CO_3\,(aq)$

26 (b) (2 marks)

Outcomes Assessed: H8, H13

Targeted Performance Bands: 3-5

Criteria	Marks
- Explains why a solution of sodium hydrogen carbonate has a pH > 7 AND - Writes an equation to show the formation of hydroxide ions	2
- Explains why a solution of sodium hydrogen carbonate has a pH > 7 OR - Writes an equation to show the formation of hydroxide ions	1

Sample answer

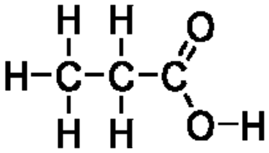
The hydrogen carbonate ion is a base and reacts with water, accepting a proton from water. Water forms hydroxide ions. As a result, $[OH^-] > [H_3O^+]$ and the pH >7.

$HCO_3^-\,(aq) + H_2O\,(l) \rightleftharpoons H_2CO_3\,(aq) + OH^-\,(aq)$

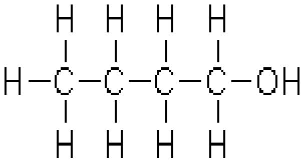
Question 27 (4 marks)
27 (a) (2 marks)
Outcomes Assessed: H9, H13
Targeted Performance Bands: 2-4

Criteria	Marks
• Draws TWO correct expanded structural formulae AND • Correctly names the TWO compounds	2
• Draws TWO correct expanded structural formulae OR • Correctly names the TWO compounds OR • Draws ONE correct expanded formula and correctly names this compound	1

Sample answer



Propanoic acid



Butan-1-ol (or 1-butanol)

27 (b) (2 marks)
Outcomes Assessed: H9, H11
Targeted Performance Bands: 3-5

Criteria	Marks
• Explains the roles of sulfuric acid as a catalyst AND dehydrating agent	2
• Explains the role of sulfuric acid as a catalyst OR as a dehydrating agent	1

Sample answer
Sulfuric acid acts as a catalyst, to increase the rate of reaction, by providing a reaction pathway of lower activation energy. It also acts as a dehydrating agent, removing water from the equilibrium mixture and hence driving the equilibrium reaction towards the right and increasing the yield of the ester.

Question 28 (6 marks)

28 (a) (1 mark)

Outcomes Assessed: H13

Targeted Performance Bands: 2-3

Criteria	Mark
- Writes a balanced equation for the Haber process, showing an exothermic reaction	1

Sample answer

$N_2\,(g) + 3H_2\,(g) \rightleftharpoons 2NH_3\,(g) \qquad \Delta H = -92 \text{ kJ mol}^{-1}$

28 (b) (1 mark)

Outcomes Assessed: H8

Targeted Performance Bands: 2-3

Criteria	Mark
- Outlines an appropriate reason	1

Sample answer

According to Le Chatelier’s Principle, the endothermic reaction (which absorbs added energy) is favoured by an increase in temperature. Hence, as temperature increases the yield of reactants increases and the yield of products (ammonia) decreases.

28 (c) (1 mark)

Outcomes Assessed: H4

Targeted Performance Bands: 2-3

Criteria	Mark
- Identifies iron or magnetite or iron oxide as the catalyst	1

Sample answer

Iron on the surface of iron oxide (magnetite) is the catalyst.

28 (d) (3 marks)

Outcomes Assessed: H3, H4, H7, H8

Targeted Performance Bands: 2-5

Criteria	**Marks**
• Discusses thoroughly the need for monitoring the catalyst AND • Discusses thoroughly the need for monitoring the temperature of the reaction vessel	3
• Outlines reasons for monitoring the catalyst AND • Outlines reasons for monitoring the temperature of the reaction vessel	2
• Outlines reasons for monitoring the catalyst OR • Outlines reasons for monitoring the temperature of the reaction vessel	1

Sample answer

The role of the catalyst in the Haber process is to allow the gaseous equilibrium reaction to occur on its surface so that the reaction can occur at a faster rate than if no catalyst were present. The condition of the catalyst must be monitored by industrial chemists, to ensure that its surface has not become deactivated. This can occur if sulfur compounds, carbon monoxide or carbon dioxide are present in the gases entering the catalytic chamber.

The catalyst lowers the activation energy for both the forward and backward reactions and so the rate of production of ammonia at a given temperature is greater. Since the greatest yield of ammonia is produced at low temperature, an efficient catalyst is essential to ensure the highest rate of reaction.

Since the production of ammonia is an exothermic process, a low temperature gives the greatest yield of ammonia. However, at higher temperatures, the rate of production of ammonia is greater. A compromise moderate temperature gives an optimal yield at an acceptable rate.

Hence chemists must monitor both the temperature and the condition of the catalyst to ensure an economically viable yield of ammonia.

Question 29 (8 marks)

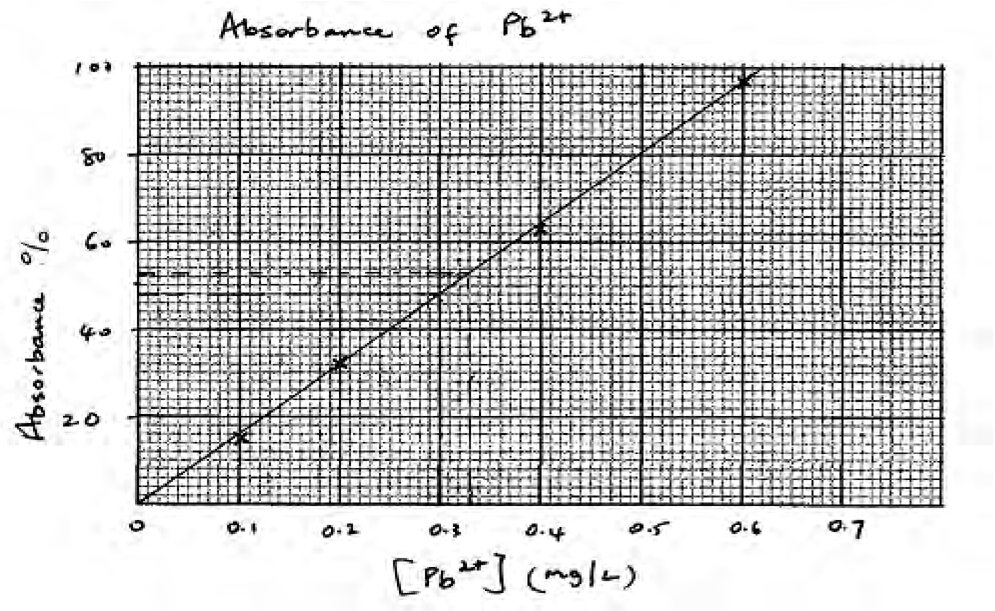
29 (a) (2 marks)

Outcomes Assessed: H13

Targeted Performance Bands: 2-4

Criteria	Marks
• Plots 4 points correctly, selects axes correctly, uses appropriate scale, joins points	2
• Some points plotted correctly, selects axes correctly, uses appropriate scale, joins points	1

Sample answer



29 (b) (2 marks)

Outcomes Assessed: H10, H14

Targeted Performance Bands: 2-4

Criteria	Marks
• Completes the data in table – all 4 samples	2
• Completes the data in table – at least 2 samples	1

Sample answer

Solution	***$[Pb^{2+}]$ (mg/L)***	***Absorbance %***
Standard	0.1	15
Standard	0.2	32
Standard	0.4	63
Standard	0.6	97
River sample 1	0.006	1
River sample 2	0.012	2
River sample 3	0.33	53
River sample 4	0.30	48

Note: values for samples 1 and 2 can only be determined by calculation, not from the graph.

29 (c) (1 mark)

Outcomes Assessed: H14

Targeted Performance Bands: 3-4

Criteria	Mark
• Correct answer	1

Sample answer
The point of effluent entry must be between sampling points 2 and 3. Before the entry of effluent the [Pb^{2+}] is < 0.05ppm (mg/L), so the water is suitable for freshwater organisms. After the entry point, the water is not suitable as the [Pb^{2+}] is > 0.05ppm (mg/L).

29 (d) (3 marks)
Outcomes Assessed: H11, H13
Targeted Performance Bands: 2-5

Criteria	Marks
• Outlines, in a logical sequence, a suitable procedure for determining the lead ion concentration AND • Writes a correct equation	3
• Outlines a partially correct procedure AND • Writes a correct equation OR • Outlines, in a logical sequence, a suitable procedure for determining the lead ion concentration	2
• Outlines a partially correct procedure OR • Writes a correct equation	1

Sample answer
Three 100 mL samples of river water were collected and sealed into previously cleaned and labelled bottles and were taken to the laboratory for testing.

Excess hydrochloric acid was added to the sample and the precipitate was filtered through a previously weighed filter paper and left to dry. The mass of the residue, lead chloride, was calculated and hence the concentration of lead ions determined.

The procedure was repeated 3 times and the result averaged to determine the [Pb^{2+}].

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

Question 30 (5 marks)

30 (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.

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

Criteria	Marks
• Evaluates the different impacts of the THREE haloalkanes AND • Correctly identifies the impact of each haloalkane AND • Includes an equation to show destruction of ozone	4
• Correctly outlines the impact of 2 of the 3 haloalkanes AND • Includes an equation to show destruction of ozone	3
• Correctly identifies the impact of 1of the haloalkanes AND • Includes an equation to show destruction of ozone	2
• Correctly identifies the impact of 1of the 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, compound 2 (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 31 – Industrial Chemistry (25 marks)
31 (a) (2 marks)
Outcomes Assessed: H4, H5
Targeted Performance Bands: 2-3

Criteria	**Marks**
• Outlines TWO significant reasons	2
• Outlines ONE significant reason	1

Sample answer
Natural rubber has been replaced by synthetic rubber.

The demand for rubber (shoes, tyres for vehicles including military vehicles, elastic materials) had grown to a point where the natural supplies could not keep up with demand.

The supply of natural rubber decreased, as much of the rubber was sourced from South American rainforests, which were cleared as intensive agriculture demands grew for an increasing population.

31 (b) (i) (1 mark)
Outcomes Assessed: H13
Targeted Performance Bands: 2-3

Criteria	Mark
• Writes a balanced equation for the production of 1 mole of sulfur trioxide	1

Sample answer

$SO_2\,(g) + \frac{1}{2}O_2\,(g) \rightleftharpoons SO_3\,(g) \quad \Delta H = -99 \text{ kJ mol}^{-1}$

31 (b) (ii) (1 mark)
Outcomes Assessed: H13
Targeted Performance Bands: 2-3

Criteria	Mark
• Writes the equilibrium constant expression for this reaction	1

Sample answer

$$K = \frac{[SO_3(g)]}{[O_2(g)]^{\frac{1}{2}}\,[SO_2(g)]}$$

31 (b) (iii) (2 marks)
Outcomes Assessed: H10
Targeted Performance Bands: 3-5

Criteria	Marks
• Correct answer (no units required)	2
• Correct determination of concentrations of the THREE species at equilibrium	1

Sample answer

Initially:
$[SO_3(g)]$ = 0.00 mol/L
$[SO_2(g)]$ = 0.80 mol / 10 L = 0.08 mol/L
$[O_2(g)]$ = 0.40 mol / 10 L = 0.04 mol/L

Since 1 mole SO_3 is formed from ½ mole O_2
Then 0.3 mole SO_3 is formed from 0.15 mole O_2
Hence moles O_2 remaining at equilibrium = 0.40 – 0.15 = 0.25 mol (in 10 L)

At equilibrium, in the 10 L flask
$[SO_3(g)]$ = 0.30 mol / 10 L = 0.03 mol/L
$[SO_2(g)]$ = 0.50 mol / 10 L = 0.05 mol/L
$[O_2(g)]$ = 0.25 mol / 10 L = 0.025 mol/L

$$K = \frac{[SO_3(g)]}{[O_2(g)]^{\frac{1}{2}}\,[SO_2(g)]}$$

$$= \frac{0.03}{(0.025)^{\frac{1}{2}}\,(0.05)} = 3.8$$

31 (b) (iv) (3 marks)
Outcomes Assessed: H4, H8, H13
Targeted Performance Bands: 2-4

Criteria	Marks
- Correctly identifies TWO sources of sulfur dioxide gas for this process AND - Writes TWO equations for these processes	3
- Correctly identifies TWO sources of sulfur dioxide gas for this process AND - Writes ONE equation for one of these processes	2
- Correctly identifies TWO sources of sulfur dioxide gas for this process	1

Sample answer
Sulfur dioxide can be sourced from the element sulfur (obtained from underground solid sulfur by the Frasch process) or as a by-product from the smelting of sulfide ores in industry.

Method 1
Liquefied sulfur is sprayed into an excess of dry air to form sulfur dioxide:

$S\,(l) + O_2\,(g) \rightarrow SO_2\,(g)$

Method 2
From smelting of zinc or copper sulfides (the normal method used in Australia)

$2ZnS\,(s) + 3O_2\,(g) \rightarrow 2SO_2\,(g) + 2ZnO\,(s)$

31 (c) (i) (3 marks)

Outcomes Assessed: H3, H4, H9

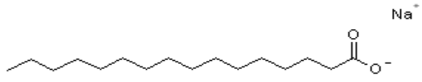
Targeted Performance Bands: 2-5

Criteria	Marks
• Explains the role of surfactants in the production of emulsions AND • Describes the structures of surfactants and emulsions AND • Uses examples and/or diagrams	3
• Explains the role of surfactants in the production of emulsions AND • Describes the structures of surfactants and emulsions	2
• Explains the role of surfactants in the production of emulsions OR • Describes the structures of surfactants and emulsions	1

Sample answer

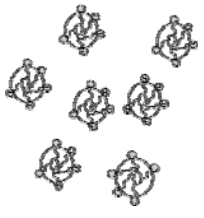
A surfactant is a substance which disperses other substances such as dirt and grease as small particles throughout water. An emulsion is the mixture formed.

All surfactants have a similar structure; a hydrophobic tail which is attracted to the oily substance, and a charged or polar head attracted to water.
Soap (below) is a surfactant.



Surfactants decrease the surface tension of water (they get between the water particles and reduce the force of attraction between them). This reduction in surface tension allows the water particles to wet (spread out over) the surface of a dirty object rather than stay together as a drop of water. Surfactants separate large drops of an oily substance into small droplets called micelles.

The emulsion is the mixture formed by the surfactant, oil and water. In this emulsion, the small droplets of the insoluble oily material can remain dispersed through the water or aqueous solution, separated from the water by the action of the surfactant.



31 (c) (ii) (2 marks)
Outcomes Assessed: H3, H4, H9
Targeted Performance Bands: 4-6

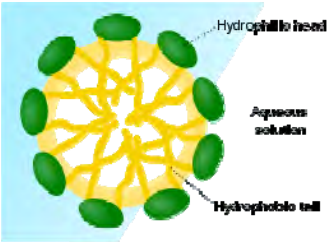
Criteria	**Marks**
• Compares the effectiveness of soaps and synthetic detergents in hard water AND • Explains the difference in effectiveness	2
• Compares the effectiveness of soaps and synthetic detergents in hard water	1

Sample answer
Synthetic detergents are more effective as surfactants and cleaning agents in hard water than are soaps. Cationic and non-ionic detergents are more efficient than anionic detergents in hard water.

Hard water contains high concentrations of calcium and magnesium ions. Soaps form insoluble compounds with calcium and magnesium ions. This removes the soap from the solution as a precipitate and hence the soap is not effective in its cleaning action. Synthetic detergents are either not affected by hard water (this applies to cationic and non-ionic detergents) or form soluble complexes with the calcium and magnesium ions. This uses up some of the anionic detergent, so anionic detergents are less effective in hard water than in soft.

31 (c) (iii) (3 marks)
Outline the cleaning action of soap, and include a labelled diagram of a micelle in your answer

Criteria	**Marks**
• Outlines the cleaning action relating to properties AND • Includes a clear, labelled diagram	3
• Compares the effectiveness of soaps and synthetic detergents in hard water AND • Labelled diagram	2
• Poor description of action OR • Unlabelled diagram	1



Soaps are amphipathic/amphiphilic. This means they are both hydrophilic and hydrophobic parts. This allows them to interact with both polar and non-polar substances e.g. Water **and** lipids. The tails can become buried (dissolved) in grease stains. Attraction of the heads to water molecules, coupled with agitation, helps break up the grease into smaller droplets that are washed away.

31 (c) (iv) (2 marks)

Describe the structure and properties of ONE type of synthetic detergent that have been developed to meet the increasing demand for soaps.

Criteria	Marks
• Names a specific group of synthetic detergents and outlines its structure AND • Relates the property of the detergent to its use	2
• Names a specific group of synthetic detergents and outlines its structure OR • Relates the property of the detergent to its use	1

31 (d) (i) (1 mark)

Outcomes Assessed: H4, H8, H13

Targeted Performance Bands: 3-4

Criteria	Mark
• Correct answer	1

Sample answer

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

32 (d) (ii) (5 marks)

Outcomes Assessed: H3, H4, H8, H13

Targeted Performance Bands: 2-5

Criteria	Marks
• Explains thoroughly why concentrated brine rather than dilute sodium chloride or molten sodium chloride is used in the production of sodium hydroxide AND • Writes half-equations for all cell reactions described	5
• Explains soundly why concentrated brine rather than dilute sodium chloride or molten sodium chloride is used in the production of sodium hydroxide AND • Writes half-equations for all cell reactions described	4
• Identifies the products of electrolysis of brine, dilute sodium chloride and molten sodium chloride AND • Writes half-equations for all cell reactions described	3
• Identifies the products of electrolysis of TWO of brine, dilute sodium chloride and molten sodium chloride AND • Writes half-equations for the cell reactions described	2
• Identifies the products of electrolysis of ONE of brine, dilute sodium chloride and molten sodium chloride AND • Writes half-equations for the cell reactions described	1

Sample answer

The industrial production of sodium hydroxide requires the production of hydroxide ions in solution.

If concentrated sodium chloride (brine) is used, the electrolysis yields the products $H_2(g)$ and $Cl_2(g)$, with hydroxide ions and sodium ions remaining in solution. On evaporation these form solid sodium hydroxide.

Cathode: $H_2O\,(l) + e^- \rightleftharpoons \frac{1}{2} H_2\,(g) + OH^-\,(aq)$ -0.83 V

Anode: $2Cl^-\,(l) \rightleftharpoons Cl_2\,(g) + 2e^-$ -1.36 V

If dilute NaCl solution were used, $H_2(g)$ and $O_2(g)$ rather than hydrogen and chlorine would be formed and sodium hydroxide could still be formed. However, this is not as useful for the chloralkali industry, as chlorine is a significant by-product.

Cathode: $H_2O\,(l) + e^- \rightleftharpoons \frac{1}{2} H_2\,(g) + OH^-\,(aq)$ -0.83 V

Anode: $H_2O\,(l) \rightleftharpoons \frac{1}{2} O_2\,(g) + 2H^+\,(aq) + 2e^-$ -1.23 V

Furthermore, the voltages predicted by the equations only apply for 1 mol/L solutions. If more concentrated solutions are used, the voltage required is not as great. Hence, there is a cost benefit in ensuring that the brine is concentrated, to achieve the production of pure chlorine at the lowest cost rather than a mixture of chlorine and oxygen, in conjunction with the production of sodium hydroxide.

If molten sodium chloride were used, then the products would be sodium and chlorine and sodium hydroxide could not be produced directly.

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

Question 32 – Shipwrecks, Corrosion and Conservation (25 marks)

a.i.

Marking Guidelines	Marks
• Identifies Faraday as the scientist	**1**

a.ii.

Marking Guidelines	Marks
• Describes TWO relevant factors that need to be considered and a safety aspect.	**2**
• Identifies ONE relevant factor that needs to be considered.	**1**

The student will need to consider the concentration of the solution they make from the solid NaCl. If it is too dilute, only hydrogen and oxygen would be produced. They will need to consider the type of electrode used. In this case they need it to be inert so that it doesn't react with chlorine or other possible products. Graphite would be a good choice. They need to carry the reaction out in a fume cupboard because chlorine gas is highly toxic.

a.iii.

Marking Guidelines	Marks
• Provides half-equations, net ionic equation and calculates the minimum voltage required to operate the cell.	**3**
• Response contains two of the above points.	**2**
• Provides half-equations OR the net ionic equation OR calculates the minimum voltage required to operate the cell.	**1**

The NaOH must be molten, and in the melt, the only ions are Na^+ and OH^- . The Na^+ will be reduced at the cathode:

$Na^+ + e^- \rightarrow Na$ $EMF^o_{red} = -2.71V$

The OH^- will be oxidised at the anode:

$2OH^- \rightarrow \frac{1}{2} O_2 + H_2O + 2e^-$ $EMF^o_{ox} = -0.40V$

The overall cell reaction is:

$2Na^+ + 2e^- \rightarrow 2Na$

$2OH^- \rightarrow \frac{1}{2} O_2 + H_2O + 2e^-$

$2Na^+ + 2OH^- \rightarrow 2Na + \frac{1}{2} O_2 + H_2O$

$EMF^o_{cell} = -2.71 - 0.40 = -3.11V$

Thu 3.11V is needed to operate the cell as an electrolytic cell.

32 (b) (i) (4 marks)

Outcomes Assessed: H8, H13

Targeted Performance Bands: 2-6

Criteria	Marks
• Predicts and explains the different rates of corrosion of passivating metals and iron AND • Discusses thoroughly the properties of passivating metals, using an appropriate example AND • Discusses thoroughly the corrosion of iron in a moist aerobic environment AND • Writes half-equations or equations for the corrosion of iron	4
• Predicts and explains the different rates of corrosion of passivating metals	3

and iron AND • Discusses soundly the properties of passivating metals, using an appropriate example AND • Discusses soundly the corrosion of iron in a moist aerobic environment AND • Writes half-equations or equations for the corrosion of iron	
• Outlines some correct information about the difference in corrosion of an identified passivating metal and iron AND • Writes half-equations or equations for the corrosion of iron	2
• Outlines some correct information about the difference in corrosion of an identified passivating metal and iron OR • Writes half-equations or equations for the corrosion of iron	1

Sample answer

Iron corrodes at a much faster rate than passivating metals, such as aluminium and chromium. Passivating metals are reactive metals that readily form an unreactive surface coating with substances such as oxygen, water and carbon dioxide. This coating protects the passivating metals from further corrosion. Aluminium forms a transparent oxide coating, which is strong and impervious and prevents further corrosion of the aluminium metal.

Iron does not form a passivating layer. It readily reacts with water and oxygen to form iron (II) hydroxide, which in turn oxidises to form iron (III) oxide or rust. The rust layer is porous and permeable and is not strongly bonded to the underlying iron. The rust flakes off the iron and the corrosion process continues.

At the anode: $Fe\,(s) \rightleftharpoons Fe^{2+}\,(aq) + 2e^-$ E° = +0.44 V

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

The overall equation is:
$2Fe\,(s) + O_2\,(g) + 2H_2O\,(l) \rightleftharpoons 4OH^-\,(aq) + 2Fe^{2+}\,(aq)$

The iron (II) hydroxide is then oxidised to iron (III) oxide (rust):
$4Fe(OH)_2\,(s) + O_2\,(g) \rightarrow 2(Fe_2O_3.H_2O)\,(s) + 2H_2O\,(l)$

The passivating oxide layer on aluminium can be destroyed by chloride ions. This occurs if the aluminium is exposed to hydrochloric acid or to salt spray. This breakdown occurs slowly, so even in a marine environment the rate of corrosion of aluminium is much slower than that of iron, even though aluminium is a more active metal, with greater tendency to be oxidised and lose electrons than iron.

$Al\,(s) \rightleftharpoons Al^{3+}\,(aq) + 3e^-$ $\qquad E° = +1.68$ V

32 (b) (ii) (4 marks)
Outcomes Assessed: H4, H5, H8, H13
Targeted Performance Bands: 2-6

Criteria	Marks
• Compares the effectiveness of the use of stainless steel and galvanised iron for construction in marine environments AND • Discusses the corrosion resistant properties of stainless steel AND • Discusses the corrosion resistant properties of galvanised iron	4
• Discusses the corrosion resistant properties of stainless steel AND • Discusses the corrosion resistant properties of galvanised iron	3
• Outlines some correct information about the corrosion resistant properties of stainless steel AND • Outlines some correct information about the corrosion resistant properties of galvanised iron	2
• Outlines some correct information about the corrosion resistant properties of stainless steel OR • Outlines some correct information about the corrosion resistant properties of galvanised iron	1

Sample answer

Stainless steel is an alloy of iron containing 10% to 20% chromium and 5% to 10% nickel. Chromium forms a passivating transparent layer which protects the whole alloy surface from corrosion. Stainless steel is particularly useful in marine environments, as the chromium oxide layer is not destroyed by chloride ions. The chromium in the alloy gives it a shiny surface, which makes it attractive as well as useful as a building material. Stainless steel is expensive, which restricts its use for large scale construction. In marine environments, stainless steel is normally used for fixtures and fittings associated with boats. Galvanised iron is a less expensive substitute but its corrosion resistance is relatively short-lived.

Galvanised iron is iron which has been protected by coating it with zinc. The zinc corrodes preferentially and hence the iron acts as the inert cathode (i.e. it is an example of cathodic protection).

At the anode: $Zn\,(s) \rightleftharpoons Zn^{2+}(aq) + 2e^-$ +0.76 V
At the inert iron cathode: $O_2\,(g) + 2H_2O\,(l) + 4e^- \rightleftharpoons 4OH^-(aq)$ +0.40 V

Galvanised iron is used extensively in construction. The iron is protected while any zinc remains, even if the surface is damaged or cut, so the iron is protected for many years in a dry environment. It is less expensive than stainless steel, so has wide applications. It develops a white coating of zinc carbonate and zinc oxide. This coating has some passivating properties but it is not as strongly bound as the impervious coating of aluminium oxide or chromium oxide. The coating is NOT transparent, so the galvanised surface changes appearance as it corrodes. The galvanised surface is often coated with paint to enhance the corrosion resistance.

Iron can be protected by galvanising if the zinc anode is replaced at regular intervals. Zinc ingots in electrical contact with the steel hulls of ships can protect the iron from corrosion until all the zinc is oxidised. Alternatively, new zinc coatings can be applied to iron by painting the iron with a paint that includes particles of zinc or dipping the iron object into molten zinc.

Hence both stainless steel and galvanised iron are effective for construction in marine environments. Both are corrosion resistant; with stainless steel retaining its effectiveness for a longer time as the chromium oxide layer is passivating and impermeable. Galvanising is less expensive and is used in situations where the iron can be recoated with zinc to restore the corrosion resistance at a later time.

32 (c) (i) (1 mark)
Outcomes Assessed: H8
Targeted Performance Bands: 2-3

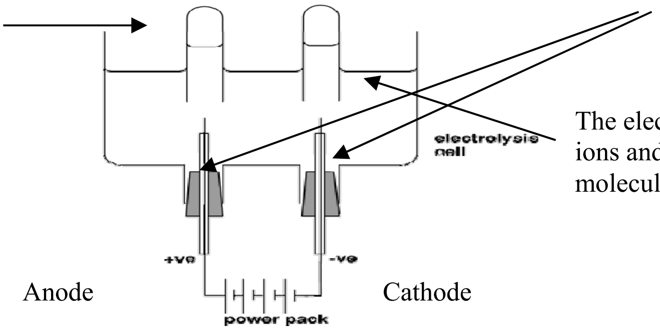
Criteria	Mark
• Identifies a factor which affects the rate of electrolysis	1

Sample answer
The voltage applied (or the concentration of the electrolyte or the distance between the electrodes or the surface area of the electrodes).

32 (c) (ii) (2 marks)
Outcomes Assessed: H11
Targeted Performance Bands: 2-4

Criteria	Marks
• Describes, in a logical sequence or by using a diagram, how a controlled experiment was set up	2
• Outlines some correct details of the experimental set-up	1

Sample answer
Two electrolytic cells were set up as shown below, to show how the change in applied voltage affected the rate of the electrolysis of sulfuric acid solution.



The products of electrolysis of sulfuric acid solution were gases and were collected in the test tubes placed above the electrodes. **The rate of production of gases was used to measure the rate of electrolysis.**

Electrodes – inert

The electrolyte contains hydrogen ions and sulfate ions and H_2O molecules.

The voltage of the power pack was varied from 2 to 4 volts

A voltage of 2 volts was applied to 1 cell, while a voltage of 4 volts was applied to the other. The rate of production of gases was used as the measure of the different rates of reaction.

32 (c) (iii) (3 marks)
Outcomes Assessed: H8, H11, H13
Targeted Performance Bands: 2-5

Criteria	Marks
• Explains the results and conclusions made AND • Writes half-equations for the reactions which occurred	3
• Outlines the results and conclusions made AND • Writes half-equations for the reactions which occurred	2
• Outlines the results and conclusions made OR • Writes half-equations for the reactions which occurred	1

Sample answer
Gases were produced at both electrodes.

The rate of production of these gases (as measured by the rate of bubble formation and the rate of displacement of water in the test tubes) increased as the voltage increased.

Increased voltage means that there is a greater force on electrons to move through the circuit, a greater current flow and a greater rate of oxidation and reduction reactions at the electrodes.

At the anode:
$2H_2O\ (l) \rightleftharpoons O_2\ (g) + 4H^+\ (aq) + 4e^-$

At the cathode:
$2H^+\ (aq) + 2e^- \rightleftharpoons H_2\ (g)$

32 (d) (i) (1 mark)

Outcomes Assessed: H8

Targeted Performance Bands: 2-3

Criteria	Mark
• Outlines an increase in solubility of oxygen in water as pressure increases	1

Sample answer

As the pressure increases, the solubility of oxygen in water increases.

32 (d) (ii) (1 mark)

Outcomes Assessed: H8

Targeted Performance Bands: 3-4

Criteria	Mark
• Describes a decrease in oxygen concentration as depth increases	1

Sample answer

The sources of oxygen in sea water are atmospheric oxygen, at the surface, and oxygen generated by photosynthesis. As depth increases, in general, the oxygen concentration decreases, as aerobic organisms remove oxygen from the water, photosynthesis decreases (as it is dependent on light from the surface) and there are few convection currents to take surface oxygen to greater depths.

32 (d) (iii) (4 marks)

Outcomes Assessed: H8

Targeted Performance Bands: 3-6

Criteria	Marks
• Justifies the expectation that corrosion of shipwrecks would be expected to be minimal at depth • Discusses the responses to parts (i) and (ii) • Relates the rate of reaction to oxygen concentration • Relates the rate of corrosion to temperature and to the electrolyte present	4
• Discusses the responses to parts (i) and (ii) • Relates the rate of reaction to oxygen concentration • Relates the rate of corrosion to temperature and to the electrolyte present	3
• Discusses the responses to parts (i) and (ii) AND • Relates the rate of reaction to oxygen concentration OR • Relates the rate of corrosion to temperature and to the electrolyte present	2
• Discusses the responses to parts (i) and (ii) OR • Relates the rate of reaction to oxygen concentration OR • Relates the rate of corrosion to temperature and to the electrolyte present	1

Sample answer

Aerobic 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 by this aerobic process depends on the concentration of oxygen present, then the rate of corrosion of shipwrecks would be expected to decrease as the concentration of oxygen decreases.
The increase in solubility of oxygen as the pressure increases is relevant to the amount of oxygen dissolving in water when there is a constant amount of oxygen present (as in a diver's tank); more oxygen dissolves at depth as the pressure on the diver increases. However, it is not relevant to the rate of corrosion of shipwrecks, as the oxygen supply diminishes as depth increases as the oxygen is removed from the water by aerobic organisms and is not replenished.

Hence only the concentration of oxygen at a particular depth, not the pressure, determines the rate and extent of corrosion reactions.

Factors other than the oxygen concentration also impact on the rate and extent or corrosion of shipwreck.

Reactions occur at a faster rate at high temperature than at low temperature. As depth increases, the temperature and hence the rate of reaction decrease.

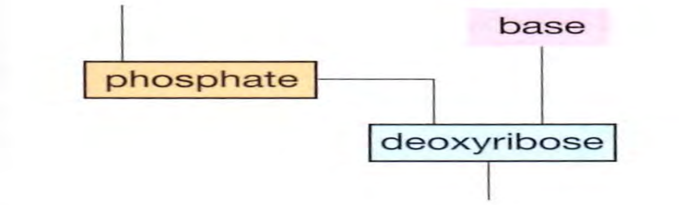
Galvanic reactions require an electrolyte so that transfer of electrons from anode to cathode is not hampered by a build-up of charge around the electrodes. The ocean is an electrolyte but the concentration of ions remains almost constant as depth increases in the ocean.

Hence, the expectation that the rate of corrosion should decrease as depth increases is justified when only aerobic corrosion is considered. This is due to the decrease in oxygen concentration and the decrease in temperature rather than due to any effects of pressure.

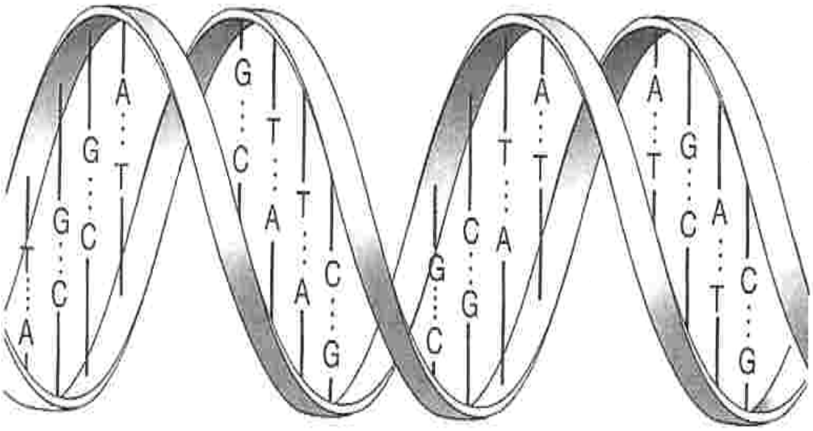
Question 33 – Forensic Chemistry (25 marks)
33 (a) (i) (3 marks)
Outcomes Assessed: H9, H13
Targeted Performance Bands: 3-5

Criteria	Marks
• Identifies the parts of a nucleotide, by reference to a diagram AND • Identifies that the sequence of nucleotides determines the unique structure of DNA AND • Identifies that DNA is a polymer consisting of a double chain of nucleotides linked by hydrogen bonding between specific bases	3
• TWO of the above	2
• ONE of the above	

Sample answer
The repeating unit of DNA is a nucleotide. Each nucleotide consists of a sugar, a phosphate group and a base.



DNA is formed when nucleotides link together (via the phosphate and sugar groups). The bases can be of 4 different types: thymine (T), adenine (A), cytosine (C) and guanine (G). The long strands of nucleotides form a double chain (a double helix) with the bases linkng the chains together by hydrogen bonding. Guanine and cytosine form one pairing and adenine and thymine the other. The phosphate-sugar-phosphate chain forms the backbone of the DNA double helix.



33 (a) (ii) (2 marks)
Outcomes Assessed: H4, H9
Targeted Performance Bands: 3-4

Criteria	Marks
• Explains why DNA analysis allows identification of individuals	2
• Outlines that each person (apart from identical twins) has a unique sequence of bases in his/her DNA	1

Sample answer
The sections of the DNA that do not code for essential proteins (non-coding regions) are unique for individuals; i.e. each person (apart from an identical twin) has a unique pattern of non-coding DNA (intron) sequences which can be used to identify that person. The techniques used to perform DNA analysis are extremely accurate in identifying the source of the sample (<1 in 10 billion chance of inaccuracy). Furthermore, the testing is extremely sensitive, with only a minute sample required to perform the test. The regions of non-coding DNA can be separated and mapped by a process called DNA fingerprinting, which allows for identification of individuals by comparing samples to determine whether the samples are from the same person, related people or unrelated individuals.

33 (b) (i) (1 mark)

Outcomes Assessed: H9

Targeted Performance Bands: 2-3

Criteria	Mark
• Identifies the monomer	1

Sample answer

The monomer is α-glucose.

33 (b) (ii) (2 marks)

Outcomes Assessed: H4, H9

Targeted Performance Bands: 2-4

Criteria	Marks
• Identifies starch and cellulose as being sourced from plant material and glycogen as being sourced from animal material AND • Identifies that the polysaccharides can be distinguished by chemical testing in forensic investigations	2
• Identifies starch and cellulose as being sourced from plant material and glycogen as being sourced from animal material OR • Identifies that the polysaccharides can be distinguished by chemical testing in forensic investigations	1

Sample answer

The polysaccharides found in plants are starch and cellulose. Both of these are only found in plant material. Glycogen is only found in animal material. Hence testing a sample to determine which carbohydrate is present can distinguish between plant and animal material.

Starch is partially soluble in water and can be identified by the addition of iodine solution that will form a blue-black complex.

Cellulose is not soluble in water, and its presence can be indicated by the addition of Shultz reagent or treatment with 60% sulfuric acid and iodine solution to form a brown colour.

Glycogen is soluble in water and will form a brown/pink colour when iodine solution is added to it.

33 (c) (i) (3 marks)

Outcomes Assessed: H9

Targeted Performance Bands: 2-5

Criteria	Marks
• Compares the structure AND properties of proteins used for structural purposes and proteins used for the metabolism of organisms AND • Uses appropriate examples of BOTH types	3
• Identifies some differences in the structure AND properties of proteins used for structural purposes and proteins used for the metabolism of organisms AND • Uses appropriate examples of BOTH types	2
• Identifies some differences in the structure OR properties of proteins used for structural purposes and proteins used for the metabolism of organisms AND • Uses at least ONE appropriate example of EITHER type of protein	1

Sample answer

Structural proteins are fibrous, stringy and tough, burn with a characteristic smell and are insoluble in water. They make up the structural materials in organisms, such as keratin in skin, fingernails, horns, wool and feathers and collagen in tendons, cartilage and hides.

Proteins used in the metabolic functioning of organisms are globular in shape and are soluble in water. They include insulin (controlling glucose metabolism), haemoglobin (for oxygen transport in the blood), myoglobin (for storage of oxygen), antibodies (to fight disease) and enzymes (as biological catalysts).

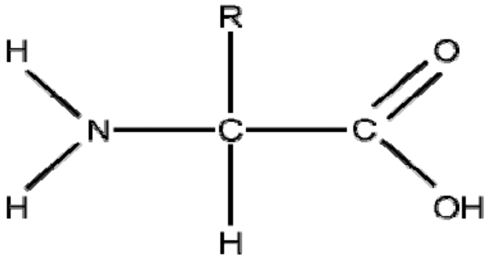
33 (c) (ii) (1 mark)

Outcomes Assessed: H9, H13

Targeted Performance Bands: 2-3

Criteria	Mark
• Draws a diagram to represent the general formula of an amino acid	1

Sample answer



33 (c) (iii) (3 marks)

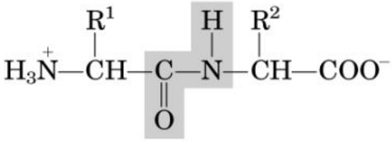
Outcomes Assessed: H9, H13

Targeted Performance Bands: 2-5

Criteria	Marks
• Describes the linking of amino acids to form peptide bonds and polypeptides • Describes a protein in terms of its primary, secondary and tertiary structures	3
• Describes the linking of amino acids to form peptide bonds and polypeptides AND • Outlines some details of protein structure	2
• Describes the linking of amino acids to form peptide bonds and polypeptides OR • Outlines some details of protein structure	1

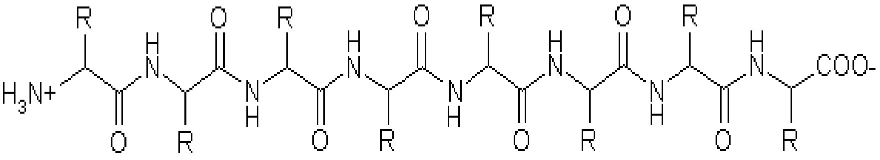
Sample answer

Amino acids link together to form a peptide bond. Different amino acids have different structures in the groups represented as –R in the diagrams.



$$H_3\overset{+}{N}-\overset{R^1}{\overset{|}{C}H}-\underset{\underset{O}{\|}}{C}-\overset{H}{\overset{|}{N}}-\overset{R^2}{\overset{|}{C}H}-COO^-$$

This process can be repeated until a polypeptide is formed with a unique sequence of amino acids for a particular protein.



The structure of a protein consists of the primary structure (the identity of the amino acids, their relative amounts and their sequence), the secondary structure (the structure of the segments, the way the molecule is curled or folded) and the tertiary structure (the arrangement, shape of the whole molecule).

33 (c) (iv) (3 marks)

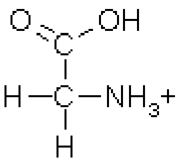
Outcomes Assessed: H9, H11

Targeted Performance Bands: 3-5

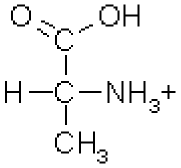
Criteria	Marks
• Explains the method of electrophoresis for separation and identification of amino acids AND • Identifies that glycine and alanine have different masses but the same charge, so will move at different rates	3
• Outlines some aspects of the method of electrophoresis for separation and identification of amino acids AND • Identifies that glycine and alanine have different masses but the same charge, so will move at different rates	2
• Outlines some aspects of the method of electrophoresis for separation and identification of amino acids OR • Identifies that glycine and alanine have different masses but the same charge, so will move at different rates	1

Sample answer

At low pH the amino acids will have the structures below.



glycine



alanine

At low pH, both glycine and alanine exist as positive ions, with the positive charge being on the $-NH_3^+$ group. Hence both amino acids have a +1 charge at low pH.

In electrophoresis, the speed of movement of the amino acids between the charged electrodes depends both on the charge and the mass. Since both these amino acids have the same charge at low pH, the heavier molecule (alanine) will move towards the negative electrode more slowly than the lower mass molecule (glycine).

The amino acids separate from each other and the position of each on the electrophoresis paper can be identified by using ninhydrin dye to show up both amino acids. The position of each amino acid can be compared with standards of known amino acids to reconfirm the above prediction.

33 (d) (i) (2 marks)

Outcomes Assessed: H11

Targeted Performance Bands: 2-4

Criteria	Marks
• Describes a chemical test to distinguish between organic and inorganic compounds AND • Outlines the results of the test	2
• Describes a chemical test to distinguish between organic and inorganic compounds OR • Outlines the results of the test	1

Sample answer

Place a small sample of the compound to be tested in a combustion tube fitted with a cork and delivery tube. The delivery tube should deliver gases released into a beaker containing limewater. Heat the sample strongly.

Organic compounds undergo combustion in excess oxygen to produce carbon dioxide which can be identified using the limewater test. The limewater develops a white precipitate of calcium carbonate.

Inorganic compounds do not undergo combustion to produce carbon dioxide and water.

33 (d) (ii) (5 marks)
Outcomes Assessed: H3, H4, H6, H7
Targeted Performance Bands: 2-6

Criteria	Marks
• Assesses the usefulness of emission spectroscopy and another identified instrumental technique for forensic analysis of this sample • Discusses thoroughly the usefulness of emission spectroscopy for forensic analysis • Discusses thoroughly the usefulness of another identified instrumental t technique for forensic analysis	5
• Discusses thoroughly the usefulness of emission spectroscopy for forensic analysis • Discusses thoroughly the usefulness of another identified instrumental technique for forensic analysis	4
• Discusses soundly the usefulness of emission spectroscopy for forensic analysis • Discusses soundly the usefulness of another identified instrumental technique for forensic analysis	3
• Identifies a use AND a limitation of emission spectroscopy for forensic analysis AND • Identifies a use AND a limitation of another identified instrumental technique for forensic analysis	2
• Identifies a use AND a limitation of emission spectroscopy for forensic analysis OR • Identifies a use AND a limitation of another identified instrumental technique for forensic analysis	1

Sample answer
When a sample contains both inorganic and organic components, it may require analysis using more than one instrumental technique.

Emission spectroscopy has had extensive use in investigation of the origins of mixtures, in both 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).

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. Since different atoms have different sets of energy levels and each atom has its own unique set, then when emission of light energy occurs from a particular element the light is always of the same frequencies. 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 the whole mixture, 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.

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 the organic compound another instrumental technique, such as mass spectrometry, 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.

Hence mass spectrometry is useful for identifying organic compounds in forensic 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.

Assessment
Both emission spectroscopy and mass spectrometry can play significant roles in the identification of a forensic sample. Both can produce unique fingerprints of the components in the mixture and hence analysis to match forensic samples can be effectively achieved. Both techniques only require extremely small samples.

However, both techniques are destructive. Emission spectroscopy cannot identify a specific compound. It can only identify the atoms present in that compound and, to a limited extent, give a quantitative measure of the amount of that element present. Mass spectrometry breaks the compounds into fragments and mixtures of compounds produce spectra complicated by the presence of many different fragments from different compounds.