Newington College

Student Number ☐☐☐☐☐☐☐☐☐

2014
TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION

Chemistry

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black or blue pen
- Draw diagrams using pencil
- Board-approved calculators may be used
- Use the Data Sheet and Periodic Table provided
- Use the Multiple-Choice Answer Sheet provided
- Write your Centre Number and Student Number at the top of this page, page 13 and on the Multiple-Choice Answer Sheet

Total marks – 100

Section I Pages 3-25

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 21-32
- Allow about 1 hour and 40 minutes for this part

Section II Pages 27-32

25 marks
- Attempt ONE question from Questions 33-35
- Allow about 45 minutes for this section

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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 Manganese is a transition metal which forms the following compounds:

Compound 1 MnO_2
Compound 2 $KMnO_4$

The oxidation numbers of manganese in compounds 1 and 2 respectively are

(A) +4, +6

(B) +2, +3

(C) +4, +7

(D) +2, -3

2 A new therapy for killing cancer cells is known as Targeted Alpha Treatment. Some biological molecules can selectively target particular cancer cells; they will find these cells, even if spread around the body, and bind to them. If an alpha-emitting radionuclide (such as bismuth-213) is attached to such a tumour specific carrier, the alpha particle produced during its radioactive decay can kill one or a few targeted cancer cells along its trajectory.

The nuclear reaction is:

$$^{213}_{83}\text{Bi} \rightarrow {}^{4}_{2}\text{He} + {}^{209}_{81}\text{Tl} + \text{energy}$$

Which of the following statements is INCORRECT?

(A) The alpha particles produced are positively charged.

(B) Alpha particles can penetrate the body and be detected by a photographic film.

(C) Alpha particles cause ionisation in the target cells.

(D) Alpha particles have 2 protons and 2 neutrons.

3 The reversible reaction to form ethylene from ethanol is represented:

$$C_2H_6O\,(g) \rightleftharpoons C_2H_4\,(g) + H_2O\,(g) \qquad \Delta H = +45 \text{ kJ mol}^{-1}$$

Identify the CORRECT statement.

(A) The backward reaction is known as dehydration.

(B) The highest yield of ethylene is achieved at high temperature and high pressure.

(C) An excess of water favours the formation of ethylene.

(D) Sulfuric acid acts as a catalyst both for the backward and forward reactions.

4 Ethanol is a good solvent for a range of chemicals. It can dissolve in water but is also blended with petrol as a fuel. It exhibits these properties because of the range of intermolecular forces it can exert on other molecules.

Which of the following lists all the intermolecular forces which ethanol can exert on other molecules?

(A) Covalent bonds, dispersion forces

(B) Dipole-dipole interactions, hydrogen bonds

(C) Covalent bonds, hydrogen bonds, dispersion forces

(D) Dispersion forces, dipole-dipole interactions, hydrogen bonds

5 What mass of ethanol is obtained when 5.68 g of carbon dioxide is produced during fermentation of glucose, at 25°C?

(A) 2.95 g

(B) 5.94 g

(C) 11.5 g

(D) 147.2 g

6 Which of the following is the best oxidising agent?

(A) Bromine

(B) Chloride ion

(C) Potassium ion

(D) Potassium

7 An acidic, pollutant gas formed during high temperature combustion in an internal combustion engine is

(A) Sulfur dioxide.

(B) nitrogen dioxide.

(C) carbon monoxide.

(D) ammonia.

8 The pH of 0.1 mol L^{-1} solutions of acetic, citric and hydrochloric acids was measured.

Which solution has the highest pH?

(A) Acetic acid

(B) Citric acid

(C) Hydrochloric acid

(D) All 3 acids have the same pH as they have the same concentration.

9 Excess zinc is added to a flask containing 50.65 mL of 0.96 mol L^{-1} hydrochloric acid at 25°C and 100 kPa.

What volume of hydrogen gas, expressed to the correct number of significant figures, is produced?

(A) 0.60 L

(B) 0.603 L

(C) 1.2 L

(D) 1.21 L

10 20 mL of 0.08 mol L^{-1} HCl is mixed with 30 mL of 0.05 mol L^{-1} NaOH.

What is the pH of the resultant solution?

(A) 1.1

(B) 2.7

(C) 4.0

(D) 7.0

11 Using the same 0.1 mol L^{-1} hydrochloric acid solution, a student carried out 2 titrations.

Titration 1: 25.0 mL of 0.1 mol L^{-1} sodium hydroxide solution
Titration 2: 25.0 mL of 0.1 mol L^{-1} ammonia solution

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

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

12 The pH of a solution of sodium acetate (CH_3COONa) was measured and found to be 9.05.

Which of the following best explains the pH value?

(A) Sodium ions donate protons to water.

(B) Acetate ions donate protons to water.

(C) Sodium ions accept protons from water.

(D) Acetate ions accept protons from water.

13 Which of the following cations can be identified from a flame test?

(A) Mg^{2+}

(B) Ba^{2+}

(C) Zn^{2+}

(D) Pb^{2+}

14 All the silver ions present in a 50.0 mL solution were precipitated by reaction with excess chloride ions. The mass of the dried precipitate was 0.143 g.

What was the concentration of silver in the original solution?

(A) 0.02 g L^{-1}

(B) 4.3 g L^{-1}

(C) 2.16 g L^{-1}

(D) 2.9 g L^{-1}

15 Which of the following is amphiprotic?

(A) HCl

(B) NH_4^+

(C) HCO_3^-

(D) Al

16 A scientist collected a 100 mL sample of water from one location in a stream. He divided the sample into 5 identical 20 mL samples and then used Atomic Absorption Spectroscopy to determine the concentration of iron in each sample.

The results of the analyses of the 5 identical samples are shown in the table below.

Sample No.	***Absorption***
1	0.282
2	0.287
3	0.202
4	0.285
5	0.283

What value should be used to determine the concentration of iron?

(A) 0.2678

(B) 0.268

(C) 0.28425

(D) 0.284

17 Which of the following chemicals is LEAST LIKELY to cause reduction of atmospheric ozone?

(A) CF_3Cl

(B) $CClF_3$

(C) CF_4

(D) $CHClF_2$

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

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

The samples were gathered from

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

Which of the samples is MOST LIKELY to have been taken from a holding pond near a zinc mine?

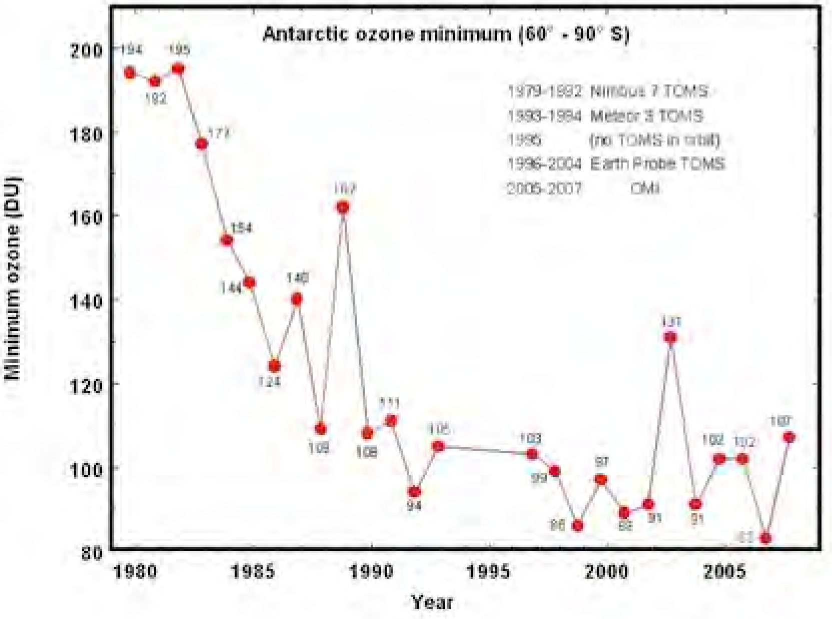
(A) ***A***

(B) ***B***

(C) ***C***

(D) ***D***

19 The graph shows data recording the minimum ozone concentrations over the Antarctic, from October 1979 to October 2012 (the final reading shown on the graph).



Based on these data alone, which of the following is a VALID statement about the minimum Antarctic ozone concentration?

(A) The variation in ozone concentration between 1980 and 2012 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 minimum concentration of ozone will be greater in 2015 than in 1998.

(D) The minimum concentration of ozone was greater in 2012 than in 2006.

20 Which of the following is a description of *turbidity*?

(A) It gives an indication of the dissolved solids in a sample.

(B) It gives an indication of the concentration of suspended solids in a sample.

(C) It gives an indication of the dissolved oxygen concentration in a sample.

(D) It gives an indication of the concentration of dissolved and suspended solids in a sample.

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2014 TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION
Chemistry

Section I (continued)

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

Answer the questions in the spaces provided.

Show all relevant working in questions involving calculations.

Question 21 (4 marks)

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

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

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Question 22 (9 marks)

(a) Outline the features and uses common to all galvanic cells. **4**

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(b) A student carried out experiments to determine the relative activities of 3 metals, ***Q, R*** and ***S***. The results of these experiments are in the table below. **2**

Metal	***Reaction in air***	***Reaction with water***	***Reaction with dilute hydrochloric acid***
Q	Burns to form metallic oxide	Reacts with steam to form hydrogen	Hydrogen is formed
R	Reacts slowly to form metallic oxide	Does not react	Does not react
S	Burns to form metallic oxide	Reacts slowly over a few days	Hydrogen is formed

For each of ***Q***, ***R*** and ***S***, identify ONE example of a metal having the properties listed in the table above.

Q …………………………………………………………………………

R …………………………………………………………………………

S …………………………………………………………………………

Question 22 continues on the next page

Question 22 (continued)

(c) Using the metals you have identified in part (b) above, choose the pair of metals which would produce the greatest cell voltage when used as the electrodes in a galvanic cell. **1**

Metals chosen ……………………………………………………………….

(d) Write half-equations for the half-cell reactions in the galvanic cell formed from the metals chosen in part (c) above and determine the standard cell potential. **2**

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Question 23 (4 marks)

A student was asked to carry out a first-hand investigation using the chemicals, hexane, hex-1-ene and bromine water.

(a) Explain the purpose of the investigation. **1**

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(b) Describe the risks associated with carrying out this experiment and the steps taken to avoid these risks. **2**

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(c) Outline the result you would expect from the investigation. **1**

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Question 24 (4 marks)

Evaluate the strategies that have been used to repair the damage to the ozone layer. **4**

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Question 25 (4 marks)

(a) In the following table classify the salts as forming acidic, basic or neutral solutions. **2**

Salt	**Solution (Acidic, basic or neutral)**
Sodium hydrogencarbonate	
Ammonium nitrate	
Sodium chloride	
Sodium ethanoate	

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(b) From the above table choose a salt that forms an acidic or basic solution and justify its classification. **2**

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Question 26 (3 marks)

With the aid of labelled electron-dot diagrams, compare the bonding in oxygen and ozone molecules, and explain how the differences you describe affect ONE physical property of the gases. **3**

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Question 27 (5 marks)

Methanol is an important chemical that can be produced industrially from carbon monoxide and hydrogen, as shown in the following equation.

$$CO\ (g) + 2H_2\ (g) \leftrightarrow CH_3OH\ (g) \qquad \Delta H = -100.4\ kJ/mol$$

(a) Suggest reaction conditions that would optimise the rate and yield of methanol production. Justify each condition by applying your knowledge of equilibrium and reaction rates. **3**

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(b) The industrial production of ammonia from hydrogen and nitrogen is also an equilibrium reaction. Explain why the choice of 350°C is regarded as a "balanced" temperature for this reaction. **2**

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Question 28 (5 marks)

An antacid tablet is known to contain calcium carbonate ($CaCO_3$). To determine the mass of calcium carbonate in the tablet, the following procedure was used.

- The tablet was crushed and then placed in a beaker.
- A pipette was used to add 25.0 mL of 0.605 mol L^{-1} hydrochloric acid to the crushed tablet in the beaker.
- Once the reaction between the calcium carbonate and hydrochloric acid had stopped, phenolphthalein indicator was added to the reaction mixture.
- A burette was then used to add 0.275 mol L^{-1} sodium hydroxide to the beaker to neutralise the excess hydrochloric acid.
- The phenolphthalein changed from colourless to pink after 13.6 mL of the sodium hydroxide solution had been added.

(a) Write a balanced equation for the reaction that occurred between the calcium carbonate in the tablet and the hydrochloric acid. **1**

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(b) How many moles of hydrochloric acid were added to the crushed tablet in the beaker? **1**

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(c) Calculate the mass of calcium carbonate in the original antacid tablet. **3**

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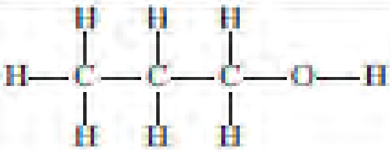
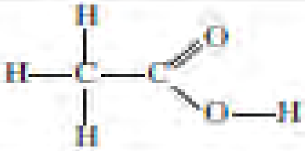
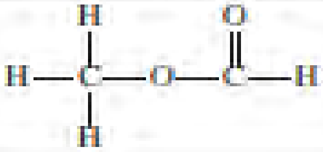
Question 29 (3 marks)

The table shows information about carbon compounds ***X***, ***Y*** and ***Z***.

Compound	*Structural formula*	*Molecular weight*	*Boiling point*
X		60	97°C
Y		60	118°C
Z		60	?

(a) The boiling point of compound ***Z*** is not shown. Would you expect this missing boiling point to be above 118°C, below 97°C or between 97°C and 118°C? Explain your reasoning, with reference to the structure and bonding of the THREE compounds. **2**

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(b) Name the TWO carbon compounds needed to prepare compound ***Z*** in the school laboratory. **1**

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Question 30 (3 marks)

(a) A student placed a quantity of ethanol in a spirit burner. He lit the wick and the energy produced was used to heat 100 g of water in a beaker. **2**

The change in mass of the spirit burner was measured by placing the burner on an electronic balance. The temperature was measured using a probe attached to a data logger.

The student made the following measurements:

Initial mass of burner and ethanol	54.67 g
Final mass of burner and ethanol	54.12 g
Initial temperature water	15°C
Final temperature of water	23°C

Calculate the heat of combustion of ethanol in kJ/mol.

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(b) Write an equation for a combustion reaction which may have occurred in this experiment if oxygen was limiting. **1**

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Question 31 (7 marks)

"Catalysts are essential for a wide range of chemical reactions." **7**

Analyse this statement, referring in your response to the Haber Process and to a range of other catalysed reactions you have studied.

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Question 32 (4 marks)

A scientist tested the water in a lake to predict whether eutrophication was likely to occur. His tests included the dissolved oxygen level (DO), the biochemical oxygen demand (BOD) and the levels of nutrients such as phosphate ions.

(a) Outline the procedure the scientist would use for determining the BOD of the water sample. **1**

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(b) Which of the tests performed by the scientist would give the best indication of the future onset of eutrophication? **3**
Discuss your response, referring to the THREE tests carried out.

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End of Section I – Part B

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Chemistry

Section II
25 marks

Attempt ONE question from Questions 33-35
Allow about 45 minutes for this section

Answer the question in a SEPARATE writing booklet.

Show all relevant working in questions involving calculations.

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Question 33 – Industrial Chemistry (25 marks)

(a) Carbon disulfide reacts with hydrogen to produce methane and hydrogen sulfide as shown by the following equation.

$$CS_{2(g)} + 4H_{2(g)} \leftrightarrow CH_{4(g)} + 2\,H_2S_{(g)}$$

At equilibrium, a 5.0 litre sealed flask contains 0.55 moles methane and 0.125 moles hydrogen sulfide gas, 0.15 moles carbon disulfide and 0.15 moles of hydrogen at 625 ^{0}C.

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

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(ii) Calculate the value for K. Show relevant working. **2**

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(iii) Predict the effect on the reaction direction by increasing the pressure. Explain your answer using Le Chatelier's Principle. **2**

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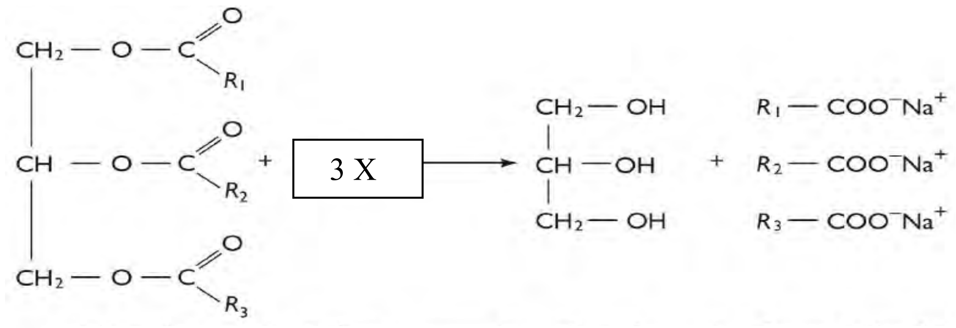
(b) The equation represents a reaction that can be performed in a school laboratory.



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

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

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(iii) Describe how this type of reaction could be carried out in the school laboratory. **2**

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(iv) Describe a use of Product Y and explain how it works. **2**

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(c) Sodium hydroxide is produced by the electrolysis of sodium chloride.

(i) Write a balanced equation for the electrolysis of **molten** sodium chloride **1**

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(ii) The commercial production of sodium hydroxide uses the electrolysis of concentrated sodium chloride **solution** (brine). Identify the two gases which are made during the commercial production of sodium hydroxide. **1**

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(iii) Sodium hydroxide can be produced using a PTFE (polytetrafluoroethene) membrane. Describe two advantages of this method over other methods **2**

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(d) During your study of the Industrial Chemistry Option you modelled a step in the Solvay process

(i) Name the catalyst in the Solvay Process. **1**

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(ii) Describe the step you modelled and write a balanced equation for the step. **2**

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Question 32 continues over page

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(e) In the production of sulfuric acid by the contact process, it is important to monitor the temperature. **7**

Explain this statement with reference to each step in the process and discuss the safety precautions which must be taken when transporting sulfuric acid.

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End of Question 33

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Question 34 – Shipwrecks, Corrosion and Conservation (25 marks)

(a) Describe the significance of the work of Galvani and Volta in the development of our understanding of electron transfer reactions. **3**

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(b) A 1.0 mol L^{-1} solution of copper (II) sulfate was electrolysed using inert graphite electrodes.

(i) Draw a labelled diagram to represent this cell. **1**

(ii) Describe what you would observe at each electrode as electrolysis occurred and write half-equations for these electrode reactions. **3**

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(c) The rate of decay exhibited by a sunken ship is influenced by the final depth of the wreck.

(i) Outline changes in the composition and properties of seawater as the depth of the ocean increases. **2**

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(ii) Explain the significance of the final depth at which an iron artefact from a shipwreck is located on the amount of corrosion it may exhibit. **3**

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Question 33 continues over page

(d) Explain the chemistry involved in the rusting of iron, and in the techniques which reduce or prevent it. **7**

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(e) Steels differ greatly in their properties. **3**
Identify the main constituents of three types of steel and relate the differences in composition to their properties.

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

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

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(ii) Explain why the artefact to be restored is placed at the cathode in an electrolytic cell. **2**

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Question 35 – Forensic Chemistry (25 marks)

(a) (i) Draw a general formula to represent an amino acid. **1**

(ii) Use the structure you have drawn in part (i) above to explain how different amino acids differ in structure. **1**

(iii) Explain how electrophoresis can be used to separate and identify amino acids in a solution formed by hydrolysis of a protein. **4**

(b) You performed a first-hand investigation to distinguish between the following classes of compounds: alkanes, alkenes, alkanols and alkanoic acids.

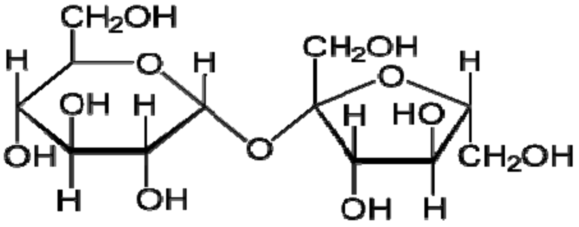
(i) Draw a flow chart to summarise a sequence of tests which can be used to distinguish between these FOUR classes of compounds. **3**

(ii) Identify the alkane, the alkene, the alkanol and the alkanoic acid you used in the investigation and write equations for TWO chemical reactions used to distinguish between these classes of compounds. **3**

(c) During your practical work a first-hand investigation was performed to distinguish between reducing and non-reducing sugars.

(i) Explain how the structural differences between reducing and non-reducing sugars allow them to be distinguished in the laboratory. **2**

(ii) The structural formula below shows a sugar. **2**



Classify this substance as a reducing or non-reducing sugar and justify your classification.

Question 35 continues on the next page

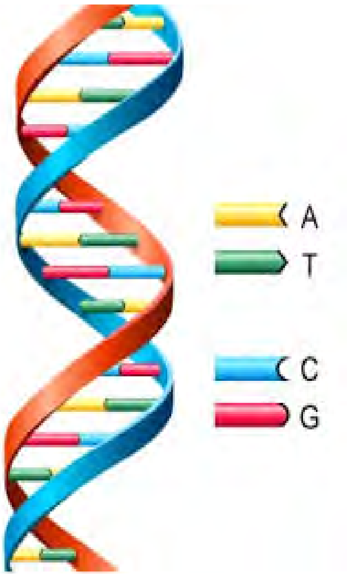
Question 35 (continued)

(d) A scientist decided to use emission spectroscopy to assist in a forensic analysis of a soil sample.

(i) Explain why each element has its own unique emission spectrum. **2**

(ii) Assess the usefulness of a range of instrumental techniques in the identification of the composition of a soil sample by a forensic chemist. **5**

(e) The diagram below shows part of a DNA chain. **2**



Explain why the bases (A, T, C and G) are important in the use of DNA for forensic analysis.

End of paper

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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 ○

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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

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

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.

Student Number

PERIODIC TABLE OF THE ELEMENTS

KEY

Atomic Number	79	Symbol of element
	Au	
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.

2014 TRIAL
HIGHER SCHOOL
CERTIFICATE
EXAMINATION

CHEMISTRY – MARKING GUIDELINES

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

Question	**Correct Response**	**Targeted Performance Bands**
1	C	3-4
2	B	3-4
3	D	2-3
4	D	3-4
5	B	4-5
6	A	3-4
7	B	2-3
8	B	2-3
9	A	4-5
10	B	5-6
11	D	5-6
12	D	4-5
13	B	2-3
14	C	4-5
15	C	3-4
16	D	3-4
17	C	2-3
18	B	2-3
19	D	3-4
20	B	2-3

Section I
Part B – 55 marks
Question 21 (4 marks)
21 (a) (1 mark)
Outcomes Assessed: H6, H13
Targeted Performance Bands: 2-3

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

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

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

Criteria	Marks
• Identifies that transuranic elements are made artificially by bombardment in a nuclear reactor or in an accelerator (cyclotron or linear accelerator) AND • Writes ONE correct nuclear equation for a reactor bombardment with neutrons AND • Writes ONE correct nuclear equation for an accelerator bombardment with a positively charged particle	3
• Both descriptions but without 2 equations	2
• One description	1

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

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

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

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

Question 22 (9 marks)
22 (a) (4 marks)
Outcomes Assessed: H4, H7, H8
Targeted Performance Bands: 2-4

Criteria	**Marks**
• Outlines that all galvanic cells use spontaneous oxidation-reduction reactions to produce a portable source of electrical energy AND • Identifies that all galvanic cells have a separated anode and cathode, where oxidation and reduction reactions (respectively) occur AND • Identifies that all galvanic cells have an electrolyte AND • Identifies that all galvanic cells have a salt bridge/porous partition which allows movement of ions	4
• THREE of the above	3
• TWO of the above	2
• ONE of the above	1

Sample answer (A diagram may be used to convey the same information)
Galvanic cells are designed to provide a portable source of electricity for use in powering torches, clocks, toys etc.
All galvanic cells involve spontaneous oxidation-reduction reactions, occurring at separate electrodes in physically separated compartments. Oxidation occurs at the anode and reduction at the cathode. The 2 compartments are externally connected by a conducting wire which transfers electrons from the anode, through a device which operates because of the electron flow, back to the cathode. Inside the galvanic cell and through a connecting salt bridge or porous partition, electrolytes allow movement of ions to ensure that charge does not build up around the electrodes which would prevent the electron flow through the external circuit.

22 (b) (2 marks)
Outcomes Assessed: H8, H14
Targeted Performance Bands: 2-3

Criteria	**Marks**
• Identifies THREE appropriate metals	2
• Identifies TWO appropriate metals	1

Sample answer

Q Magnesium

R Copper

S Iron

22 (c) (1 mark)

Outcomes Assessed: H8

Targeted Performance Bands: 2-3

Criteria	Mark
• Identifies ***Q*** and ***R*** or the nominated metals from part (b) above (no explanation required)	1

Sample answer

The greatest voltage will result when the most active metal (***Q***) and the least active (***R***) are at the anode and cathode respectively.

22 (d) (2 marks)

Outcomes Assessed: H7, H8, H13

Targeted Performance Bands: 2-4

Criteria	Marks
• Writes 2 correct half-equations for the galvanic cell using the metals nominated in part (b) (states not required) AND • Calculates correctly the standard cell potential	2
• Writes 2 correct half-equations for the galvanic cell using the metals nominated in part (b) OR • Calculates correctly the standard cell potential	1

Sample answer

The anode half-reaction is:

$Mg\ (s) \rightleftharpoons Mg^{2+}\ (aq) + 2e^-$ +2.36 V

The cathode half-reaction is:

$Cu^{2+}\ (aq) + 2e^- \rightleftharpoons Cu\ (s)$ +0.34 V

The overall equation is: $Mg\ (s) + Cu^{2+}\ (aq) \rightleftharpoons Mg^{2+}\ (aq) + Cu\ (s)$ $E^\circ = +2.70$ V

Question 23 (4 marks)

23 (a) (1 mark)

Outcomes Assessed: H11

Targeted Performance Bands: 2-3

Criteria	Mark
• Explains that the purpose of the investigation is to distinguish between hexane and hex-1-ene, alkene and alkane, double bond and single bond OR saturated and unsaturated	1

Sample answer

The purpose of the investigation is to distinguish between hexane and hex-1-ene by reacting them with bromine water.

23 (b) (2 marks)

Outcomes Assessed: H9, H11

Targeted Performance Bands: 2-4

Criteria	Marks
• Describes TWO risks associated with the hydrocarbons and with bromine water AND the steps taken to avoid the risks	2
• Describes ONE risk and the steps taken to avoid the risk with hexane, hex-1-ene OR bromine water	1

Sample answer

Both hexane and hex-1-ene are flammable liquids, and would burn in air if in contact with a flame. The experiment should be done away from any sources of heat, such as Bunsen burners.

Both liquids are volatile and the gases formed can cause respiratory problems if inhaled. Care must be taken to avoid inhaling by carrying out the investigation in a fume cupboard.

Bromine is volatile and the gas is acidic and highly corrosive to soft tissue if inhaled or splashed into eyes or onto skin. Care must be taken not to inhale any vapour or to spill any of the bromine water; use the fume cupboard and wear goggles to avoid these risks.

23 (c) (1 mark)

Outcomes Assessed: H9, H11

Targeted Performance Bands: 2-3

Criteria	Mark
• Outlines the result	1

Sample answer

Hex-1-ene will rapidly decolourise the yellow/brown bromine water (in <30 seconds if the test tube has been shaken), even in a darkened cupboard. Hexane will not react.

Question 24 (4 marks)
Outcomes Assessed: H3, H4, H7, H9
Targeted Performance Bands: 2-6

Criteria	**Marks**
• Evaluates two strategies that have been used to repair the damage to the ozone layer using two criteria which are expanded upon demonstrating a thorough knowledge and understanding • Explains the chemistry of CFC's (and other gases causing ozone depletion) • Uses equations to show ozone formation and/or destruction	4
• Evaluates two strategies that have been used to repair the damage to the ozone layer using two criteria which are expanded upon demonstrating a sound knowledge and understanding • Explains the chemistry of CFC's causing ozone depletion	3
• Explains briefly a strategy used to repair damage to ozone layer without evaluation • Identifies a cause of ozone layer depletion	2
• Explains briefly a strategy used to repair damage to ozone layer without evaluation OR • Identifies a cause of ozone layer depletion	1

Suggested answer

The ozone layer is located in the stratosphere where short wavelength UV causes oxygen molecules to decompose into oxygen free radicals, which then react with other oxygen molecules to form ozone.

$$O_{2(g)} + UV \rightarrow O + O \qquad O + O_2 \rightarrow O_{3(g)}$$

Pollutants which have entered the stratosphere such as CFCs and nitrogen monoxide can cause the destruction of ozone.

$$NO_{(g)} + O_{3(g)} \rightarrow NO_{2(g)} + O_{2(g)}$$
$$CCl_3F \rightarrow CCl_2F + Cl \text{ then } Cl + O_{3(g)} \rightarrow ClO + O_{2(g)}$$

Two strategies that have been used to repair the damage to the ozone layer have been to introduce international agreements in which nations have agreed to phase out the use of CFCs and other ozone depleting chemicals and finding alternative compounds to CFCs.

The effectiveness of these strategies has been mixed. The international agreements were not initially signed by all nations so not all had made reductions in their use of ozone depleting chemicals. Also, the first alternative compounds used to replace CFCs were HCFCs which were shown to still cause ozone destruction but at a reduced rate. So, while the production of CFCs has declined significantly, the rate of reducing the CFCs in the atmosphere has been slow. The amount of ozone in the stratosphere has not, so far, shown any increase. It is estimated that the process of repairing the damage to the ozone layer will take another 50 to 100 years.

Question 25 (4 marks)
25 (a) (2 marks)
Outcomes Assessed: H8
Targeted Performance Bands: 3-4

Criteria	Marks
• All correctly classified	2
• One or 2 correctly classified	1

Sample answer

Salt	**Solution (Acidic, basic or neutral)**
Sodium carbonate	basic
Ammonium nitrate	acidic
Sodium chloride	neutral
Sodium ethanoate	basic

25 (b) (2 marks)
Outcomes Assessed: H8, H11, H13
Targeted Performance Bands: 3-5

Criteria	Marks
• Acidity of salt justified AND • Equation given to support answer	2
• Acidity justified	1

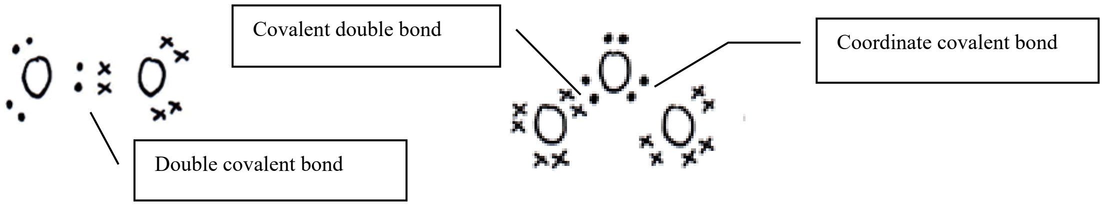
Sample answer
Ammonium nitrate is acidic because the salt dissociates in water to an ammonium ion and a nitrate ion.
$NH_4NO_3 \rightarrow NH_4^+ + NO_3^-$
The nitrate is inert as it is the weak conjugate of a strong acid (nitric acid). The ammonium is a strong conjugate acid of the weak base ammonia. As such it reacts with water donating a proton to become ammonia. Water accepts the proton to become hydronium, an acid.
$NH_4^+ + H_2O \rightarrow NH_3 + H_3O^+$

Question 26 (3 marks)

Outcomes Assessed: H6, H13
Targeted Performance Bands: 3-4

Criteria	Mark
• Draws correct electron-dot formulae for oxygen and ozone gas and labels all bonds • Explain, correctly a physical difference between them	3
• Draws correct electron-dot formulae for oxygen and ozone gas and labels all bonds	2
• Correct dot diagram for oxygen OR ozone OR a physical property difference	1

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



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

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

Question 27 (5 marks)
(a) (3 marks)

Marking Guidelines	Marks
• Explains how at least THREE reaction conditions would maximise the yield of the production of methanol AND • Explains how TWO reaction conditions would increase the rate of the reaction AND • Two conditions increase the yield	**3**
• Explains TWO conditions increasing rate/yield	**2**
• Identifies one reaction condition that would maximise the yield or rate of the production of methanol	**1**

Sample Answer
The reaction should be carried out at high pressures, as this will shift the equilibrium position to the right, which produces fewer moles of gas, and thereby minimises the effect of added pressure. Thus the yield of methanol increases, and higher pressure also increases rate of reaction. As the forward reaction is exothermic, decreasing temperature will increase the yield. However, low temperatures will also lead to a low reaction rate. Thus, a moderate temperature may be used as a compromise so that the yield is relatively high and the rate is also suitable to make the production economically viable. A catalyst may also be added to increase the rate of the reaction, given that higher temperatures cannot be employed due to yield issues. Finally, an excess of either reactant will favour the forward reaction, as would removal of the methanol from the reaction vessel as it is produced.

(b) (2 marks)

Marking Guidelines	Marks
• Explains how moderate temperatures are employed as a compromise	**2**

between rate and yield.	
- Explanation of high temperatures OR low. No real address of "balance"	**1**

Sample Answer
This is an equilibrium reaction and is thus dependent on optimum temperatures to achieve the optimum yield of ammonia at the least cost. At temperatures lower than 400°C the reaction is too slow because molecules have less kinetic energy and above 400°C the reverse reaction is favoured according to Le Chatelier's Principle, as it absorbs heat but this reduces the yield of ammonia. A relatively low temperature of 400°C is possible as a balance with the use of an iron catalyst to reduce the activation energy.

Question 28 (5 marks)
28 (a) (1 mark)
Outcomes Assessed: H13
Targeted Performance Bands: 2-3

Criteria	**Mark**
- Writes a correctly balanced equation with states	1

Sample answer
$CaCO_3\,(s) + 2HCl\,(aq) \rightarrow CaCl_2\,(aq) + CO_2\,(g) + H_2O\,(l)$

28 (b) (1 mark)
Outcomes Assessed: H10
Targeted Performance Bands: 2-3

Criteria	**Mark**
- Correct answer	1

Sample answer
Moles of HCl used initially (to react and dissolve tablet) = c x V
= 0.605 x 0.0250
= 0.015125 mol
= 0.0151 mol (to 3 s.f.)

28 (c) (3 marks)
Outcomes Assessed: H10
Targeted Performance Bands: 3-5

Criteria	**Marks**
- Calculates the mass of calcium carbonate in the tablet	3
- Calculates the moles of calcium carbonate in the tablet	2
- Calculates the moles of hydrochloric acid which reacted with the tablet	1

Sample answer
The excess HCl was titrated with NaOH solution.
$HCl\,(aq) + NaOH\,(aq) \rightarrow H_2O\,(l) + NaCl\,(aq)$

Moles of NaOH used = cV = 0.275 x 0.0136 = 0.00374 mol

Hence excess moles of HCl present = 0.00374 mol (same as moles of NaOH used)

Hence moles of HCl used in reaction with tablet

= moles HCl used initially – moles HCl excess

= (0.015125 – 0.00374) = 0.011385 mol = 0.0114 (to 3 s.f.)

Hence moles of calcium carbonate reacted = ½ x moles HCl reacted = 0.00569 mol

Hence mass of calcium carbonate in tablet = 0.00569 x (40.08 + 12.01 + 48.00) = 0.570 g

Question 29 (3 marks)
29 (a) (2 marks)
Outcomes Assessed: H6, H7, H9
Targeted Performance Bands: 3-5

Criteria	Marks
• Predicts that the boiling point of the ester will be below 97°C AND • Identifies the intermolecular forces as hydrogen bonding in acids and alcohols and dipole-dipole forces in esters	2
• Predicts that the boiling point of the ester will be below 97°C OR • Identifies the intermolecular forces as hydrogen bonding in acids and alcohols and dipole-dipole forces in esters	1

Sample answer
The boiling points of organic compounds of similar mass differ because of the different intermolecular forces which need to be broken for boiling of the liquid to occur. While alcohols and carboxylic acids are held together by strong hydrogen bonds in the liquid state, esters have weaker dipole-dipole interactions, and therefore have lower boiling points. Hence the boiling point of the ester would be expected to be below the boiling points of the alcohol and acid – hence below 97°C.

29 (b) (1 mark)
Outcomes Assessed: H9, H13
Targeted Performance Bands: 2-3

Criteria	Mark
• Names the TWO compounds correctly	1

Sample answer
Methanol and methanoic acid

Question 30 (3 marks)
30 (a) (2 mark)
Outcomes Assessed: H7, H9
Targeted Performance Bands: 2-4

Criteria	Mark
• Correct answer with calculations given	2
• One error made in calculation	1

Sample answer

$\Delta H = - mC\Delta T$
$= - 100 \times 4.18 \times 8$
$= - 3344$ J/0.55g ethanol
$= -6080$J/g ethanol
$= -6080 \times 46.068$
$= - 280093.44$J/mol
$= 280$kJ/mol

30 (b) (1 mark)
Outcomes Assessed: H13
Targeted Performance Bands: 3-4

Criteria	Mark
• Writes a balanced equation for incomplete combustion of ethanol, including carbon or carbon monoxide as a product (several possible answers)	1

Sample answer
$C_2H_6O\ (l) + O_2\ (g) \rightarrow 3H_2O\ (l) + 2C\ (s)$

Question 31 (7 marks)
Outcomes Assessed: H3, H4, H7, H8, H9
Targeted Performance Bands: 2-6

Criteria	Marks
• Analyses the statement • Discusses thoroughly the reasons for the use of a catalyst in terms of reaction rate, reaction pathway and activation energy • Discusses the use of a catalyst to improve efficiency, costs and safety in industrial processes • Relates the analysis to the use of a catalyst in the Haber Process • Relates the analysis to a range of other catalysed reactions	7
• Discusses thoroughly the reasons for the use of a catalyst in terms of reaction rate, reaction pathway and activation energy • Discusses the use of a catalyst to improve efficiency, costs and safety in industrial processes • Relates the analysis to the use of a catalyst in the Haber Process • Relates the analysis to a range of other catalysed reactions	6
• Discusses soundly the reasons for the use of a catalyst in terms of reaction rate, reaction pathway and activation energy • Discusses the use of a catalyst to improve efficiency, costs and safety in industrial processes • Relates the analysis to the use of a catalyst in the Haber Process • Relates the analysis to a range of other catalysed reactions	5
• Discusses soundly the reasons for the use of a catalyst in terms of reaction rate, reaction pathway and activation energy • Relates the analysis to the use of a catalyst in the Haber Process • Relates the analysis to a range of other catalysed reactions	4
• Outlines the reasons for the use of a catalyst in terms of reaction rate, reaction pathway and activation energy • Describes the use of a catalyst in the Haber Process • Describes the use of a catalyst in other catalysed reactions	3
• Outlines the reasons for the use of a catalyst in terms of reaction rate • Describes the use of a catalyst in the Haber Process	2
• Outlines the reasons for the use of a catalyst in terms of reaction rate OR • Describes the use of a catalyst in the Haber Process	1

Sample answer

Catalysts are chemical substances which, when present in a reaction mixture, increase the rate of reaction by lowering the activation energy for the reaction. The presence of the catalyst allows a different reaction mechanism, with lower energy required for the particles to reach the intermediate state. This means the presence of the catalyst ensures that the reaction can proceed at a lower temperature (hence saving energy) and at a faster rate (as a greater proportion of molecules will have the lower required activation energy for the reaction). The catalyst is not consumed.

The Haber Process uses an inert (or surface) catalyst to bring about the following reaction:

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

The catalyst is iron on the surface of magnetite, iron oxide. The surface of the powdered iron oxide is reduced to iron using hydrogen gas. In the presence of this catalyst, less energy is required to break the bonds in nitrogen and hydrogen molecules to form individual atoms than would be required if the catalyst were not present.

Since the formation of ammonia is an exothermic reaction, the yield of ammonia would be higher at low temperatures. However, a low temperature would mean a slow rate of reaction, so scientists monitor and manage the temperature conditions to keep a moderate, compromise temperature (about 400°C) to achieve an optimal yield at an acceptable rate. The rate is further enhanced at this moderate temperature by the use of the inert catalytic surface. The use of the catalyst makes the Haber Process cost and energy efficient.

Esterification uses concentrated sulfuric acid as a catalyst. Esterification is a condensation reaction, with water being formed by the reaction of an alcohol and a carboxylic acid. The sulfuric acid dehydrates these molecules, pulling -H and -OH from the organic molecules. The sulfuric acid is actively involved chemically in the reaction process but is regenerated, so is not used up by the reaction.

The catalytic cracking of long-chain alkanes to produce shorter-chain alkanes and alkenes is a significant step in the production of ethylene from crude oil. The ethylene produced is a reactive chemical which can be converted into a range of essential carbon-based materials for society. The catalyst used in cracking is a zeolite, a solid material which provides an inert porous surface. This surface attracts the electrons in the gaseous molecules and allows the breaking of the covalent bonds more readily than if no catalyst were present. This in turn means a greater rate of reaction and a more efficient and economical industrial process.

Fermentation is a process used to convert glucose to ethanol, essential if biomass is to replace fossil fuels as a source of materials and energy. Fermentation is catalysed by a living enzyme, yeast. Biochemical reactions are catalysed by enzymes, many of which act specifically to break or make a particular bond within the living tissue. Without these enzymes, life would not be possible.

Overall analysis

Catalysts allow reactions to proceed at a faster rate. This means that industrial processes using catalysts can proceed optimally at a lower temperature. Lower temperatures reduce energy costs and can mean greater safety in the industrial environment and increased life of production vessels. Lower temperatures can sometimes produce higher yields (as in the case of the Haber Process). Catalysts can be inert surfaces, can be chemicals which are involved within steps of the reaction but can be regenerated and can be required for biochemical processes. These are examples that support the statement that “catalysts are essential for a wide range of chemical reactions.”

Question 32 (4 marks)

32 (a) (1 mark)

Outcomes Assessed: H3, H4

Targeted Performance Bands: 2-4

Criteria	Mark
• Outlines the procedure for a BOD test	1

Sample answer

Measurement of BOD_5 – biochemical oxygen demand over a 5-day period

This test measures the concentration of dissolved oxygen needed for the complete breakdown of organic matter by aerobic bacteria over a 5-day period. The water sample is collected in a jar and the DO is measured using an oxygen probe. The sample is kept in a dark place for 5 days and the DO re-measured. The BOD_5 is the difference in the readings. The greater the amount of organic wastes in the water, the greater the BOD_5. Organic wastes may be caused by sewage, or wastes from food-processing plants (meat and poultry works), from farming areas, etc.

32 (b) (3 marks)
Outcomes Assessed: H3, H4, H8
Targeted Performance Bands: 2-5

Criteria	Marks
• Indicates that measurement of levels of nutrients would give the best indication of onset of eutrophication AND • Discusses the use of the THREE tests to predict eutrophication	3
• Indicates that measurement of levels of nutrients would give the best indication of onset of eutrophication AND • Discusses the use of TWO tests to predict eutrophication	2
• Indicates that measurement of levels of nutrients would give the best indication of onset of eutrophication OR • Outlines some correct information about the use of ONE test to predict eutrophication	1

Sample answer
Eutrophication is best predicted by testing the water for phosphate and nitrate ions.

Eutrophication is the response of an aquatic ecosystem to the addition of artificial or natural substances, such as nitrates and phosphates, through fertilisers or sewage. One example is the "bloom" or great increase of phytoplankton in a water body as a response to increased levels of nutrients. Negative environmental effects include hypoxia, the depletion of oxygen in the water, which causes a reduction in specific fish and other animals.

It is the nutrients, especially the phosphate ions, which lead to development of algal blooms. The algal bloom prevents sunlight penetrating the surface of the water and leads to low oxygen levels in the water. Photosynthesis cannot occur below the bloom so the combination of lack of sunlight and lack of oxygen leads to a destruction of the food chain. The aerobic organisms die. When the plants eventually die, the river becomes choked with dead and decaying matter. The BOD will increase, resulting in the depletion of all DO.

Once eutrophication has occurred, testing for the DO (dissolved oxygen) would show a very low oxygen concentration and would indicate that the water body had already undergone eutrophication. Testing for BOD would show that there was already a large amount of decaying organic material in the water.

However, neither DO nor BOD tests will predict that eutrophication will occur in the future, as DO levels can be low and BOD high due to high organic material but unrelated to nutrient and algal blooms.

Section II – OPTIONS

Question 33 – Industrial Chemistry (25 marks)

33 (a) (i) (1 mark)

Outcomes Assessed: H8

Targeted Performance Bands: 3-5

Criteria	Marks
- Correctly writes the equilibrium expression	1

Sample answer

$$K = \frac{[H_2S\,(g)]^2\,[CH_4\,(g)]}{[CS_2\,(g)]\;[H_2\,(g)]^4}$$

33 (a) (ii) (2 marks)

Outcomes Assessed: H10

Targeted Performance Bands: 3-5

Criteria	Marks
- Correct answer	2
- Correct equilibrium constant expression OR - Correct calculation of the equilibrium concentrations of all 3 gases	1

Sample answer

	Equilibrium concentration
$[CH_4\,(g)]$	= 0.11 mol/L
$[H_2S\,(g)]$	= 0.025 mol/L
$[CS_2\,(g)]$	= 0.030 mol/L
$[H_2\,(g)]$	= 0.030 mol/L

$$K = \frac{[H_2S\,(g)]^2\,[CH_4\,(g)]}{[CS_2\,(g)]\;[H_2\,(g)]^4} = 2.8 \times 10^2 \quad (2829)$$

33 (a) (iii) (2 marks)

Outcomes Assessed: H10

Targeted Performance Bands: 3-5

Criteria	Marks
- Correct change with correct explanation	2
- Correct change (from left to right) with inadequate explanation	1

Sample answer

The equilibrium will shift from left to right. The equilibrium responds to the increase in pressure by turning 5 moles of gas into 3 moles of gas in an attempt to minimise the disturbance.

33 (b) (i) (1 mark)

Outcomes Assessed: H9, H13

Targeted Performance Bands: 2-3

Criteria	Mark
• Identifies saponification	1

Sample answer

Saponification (hydrolysis of an ester)

33 (b) (ii) (1 mark)

Outcomes Assessed: H9, H13

Targeted Performance Bands: 2-3

Criteria	Mark
• Identifies reactant X	1

Sample answer

Sodium hydroxide

33 (b) (iii) (2 marks)

Outcomes Assessed: H11

Targeted Performance Bands: 2-4

Criteria	Marks
• Describes the two main steps in the laboratory preparation of a soap (reaction with NaOH, precipitation with NaCl)	2
• Describes one of the steps	1

Sample answer

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

33 (b) (iv) (2 marks)

Outcomes Assessed: H4, H9

Targeted Performance Bands: 2-3

Criteria	Mark
• Describes a use of soap AND how it works	2
• Describes a use of soap but not how it works	1

Sample answer

The product formed by the saponification reaction is a soap, which can be used for personal cleaning. The soap emulsifies oil by embedding its non-polar tail in the oil droplet while presenting an ionic head to the aqueous environment so that it can be washed away.

33 (c) (i) (1 mark)
Outcomes Assessed: H4, H8, H13
Targeted Performance Bands: 3-5

Criteria	Mark
- Writes a correct equation	1

Sample answer
$2NaCl\,(l) \rightarrow 2Na\,(l) + Cl_2\,(g)$

33 (c) (ii) (1 mark)
Outcomes Assessed: H4, H8, H13
Targeted Performance Bands: 3-5

Criteria	Mark
- Correctly identifies hydrogen and chlorine	1

Sample answer
Hydrogen and chlorine

33 (c) (iii) (2 marks)
Outcomes Assessed: H4, H8
Targeted Performance Bands: 2-5

Criteria	Marks
- Explains that the membrane is ion-selective, allowing sodium ions to pass through but not chloride ions AND - Explains that the membrane method does not involve the use of toxic or dangerous materials such as asbestos and mercury	2
- Explains that the membrane is ion-selective, allowing sodium ions to pass through but not chloride ions OR - Explains that the membrane method does not involve the use of toxic or dangerous materials such as asbestos and mercury	1

Sample answer
By comparison, in the diaphragm cell, the asbestos membrane allows passage of chloride ions from the anode compartment into the cathode compartment, where hydroxide ions are produced. This means that the product, sodium hydroxide, is contaminated with sodium chloride. Further, the hydroxide ions can migrate into the anode compartment and react with chlorine to produce the strongly oxidising hypochlorite ion, which can also be a contaminant.

Some asbestos fibres could also potentially contaminate the product in the diaphragm method and mercury is lost to the environment during the operation of the mercury cell. Both asbestos and mercury represent considerable hazards to humans and the environment.

33 (d) (i) (1 mark)

Outcomes Assessed: H7, H8, H13

Targeted Performance Bands: 2-5

Criteria	Marks
• Identifies ammonia as the catalyst	1

Sample answer

Ammonia (NH_3)

33 (d) (ii) (2 marks)

Outcomes Assessed: H7, H8, H13

Targeted Performance Bands: 3-5

Criteria	Mark
• Describes a step in the Solvay process AND writes a balanced equation for it	2
• Describes a step in the Solvay process	1

Sample answer

Carbon dioxide was bubbled through ammoniated brine in a measuring cylinder. White crystals formed in the measuring cylinder and heat was given off.

$$CO_2 + H_2O + NH_3 \rightarrow NH_4^+ + HCO_3^-$$

33 (e) (i) (7 marks)

Outcomes Assessed: H4, H8, H14

Targeted Performance Bands: 2-6

Criteria	Marks
• Explains thoroughly the need for temperature control and monitoring during the production of sulfuric acid • Explains thoroughly the need for safety precautions during the transport of sulfuric acid	7
• Explains soundly the need for temperature control and monitoring during the production of sulfuric acid • Explains soundly the need for safety precautions during the transport of sulfuric acid	6
• Explains briefly the need for temperature control and monitoring during the production of sulfuric acid • Explains soundly the need for safety precautions during the transport of sulfuric acid	5
• Identifies at least TWO aspects of temperature monitoring during the production of sulfuric acid • Identifies at least TWO safety precaution in the transport of sulfuric acid	4
• Identifies at least TWO aspects of temperature monitoring during the production of sulfuric acid • Identifies at least ONE safety precaution in the transport of sulfuric acid	3
• Identifies at least ONE aspects of temperature monitoring during the production of sulfuric acid AND • Identifies at least ONE safety precaution in the transport of sulfuric acid	2
• Identifies at least ONE aspects of temperature monitoring during the	1

production of sulfuric acid OR • Identifies at least ONE safety precaution in the transport of sulfuric acid	

Sample answer

The production of sulfuric acid

Sulfur dioxide is obtained from the burning of sulfur or from the roasting of sulfide ores. In either case high temperature is used to create the sulfur dioxide needed for the next step in the process.

The key step in the contact process is the reaction of sulfur dioxide with oxygen to form sulfur trioxide. The reaction is exothermic.

$$2SO_2\ (g) \quad + \quad O_2\ (g) \quad \rightarrow \quad 2SO_3\ (g) \qquad \Delta H = -92\ kJ.mol^{-1}$$

Commercially this reaction is performed in three stages, in each case it occurs over a catalyst bed of vanadium (V) oxide. In the first bed the temperature is 550C to increase the rate of reaction so that equilibrium will be achieved quickly. However, at this temperature only 70% of the SO_2 is converted to SO_3 at equilibrium. The gas mixture is passed to a second catalyst bed at 400C which allows the equilibrium to shift to the left and 97% of the SO_2 is converted. The gas mixture is then passed through oleum ($H_2S_2O_7$) and the SO_3 dissolves and is removed. The remaining SO_2 and O_2 is passed to the third catalyst bed at 400C and the final conversion of 99.7% in total is achieved.

The SO_3 is dissolved in sulfuric acid (H_2SO_4) to form oleum ($H_2S_2O_7$) rather than in water to form sulphuric acid, as the dissolving of SO_3 in water is dangerously exothermic - the sulfuric acid forms as a vapour which presents considerable dangers and difficulties in handling.

Scientists must monitor this second stage, and repeat it if necessary, to ensure that less than 0.2 ppm is released into the atmosphere.

Monitoring of this final stage of production is essential, as concentrated sulfuric acid is a strong oxidant and dehydrating agent and it reacts with many chemicals. Its reaction with water is strongly exothermic.

The transportation of sulfuric acid and safety

Pure sulfuric acid (>98%) is transported in steel tankers. Theoretically the iron in the steel cannot react with the sulfuric acid unless water is added to it and ionisation occurs. However to further protect the tank a phenolic liner (plastic layer) is used to coat the inside of the tank. If the sulfuric acid is dilute it must be transported in glass or durable plastic containers. People handling sulfuric acid must wear eye protection and clothing that is resistant to chemical action. Vehicles transporting sulfuric acid should carry solid sodium hydrogen carbonate which can be deployed in the event of a spill.

Question 34 – Shipwrecks, Corrosion and Conservation (25 marks)
34 (a) (3 marks)
Outcomes Assessed: H1, H2
Targeted Performance Bands: 2-4

Criteria	Marks
• Thorough description of the significance of the work of Galvani and Volta, in the development of our understanding of electron transfer reactions • Must describe Galvani's conclusion (1 mark) • Must describe Volta's conclusion (1 mark) • Must address "significance" (1 mark)	3
• Sound description of the significance of the work of Galvani and Volta, in the development of our understanding of electron transfer reactions	2
• Some correct information about the work of Galvani and Volta	1

Sample answer
At the time of Galvani (1700s), the nature of matter (atoms, molecules, ions, etc) was not known and the only known form of electricity was static electricity (although the causes of static electricity were not understood). Galvani is recognised as the first scientist to generate an electric current (1780). He joined wires of different metals together and placed the unjoined ends into frog muscle. His interpretation (animal electricity) was wrong but his work inspired others including Volta to further develop an understanding of electricity by devising galvanic cells.

Volta showed that the electric current was due to the different metals dipping into an electrolyte solution, not the frog muscle. He created the first galvanic cell, using copper and tin in salt solution. He then developed a stack of these cells (known as Volta's pile) which could produce a larger current than a single cell and he changed the metals to zinc and silver, to produce larger currents. Even though Volta did not understand what was generating the current, he made a significant contribution to the understanding of electricity, by constructing the first useable galvanic cell and by recognising that the differing metals generated the electric current.

The work of Galvani and Volta might not have been significant if their ideas had not been extended by Davy and Faraday. Davy showed that there was a *qualitative* connection between electricity and matter produced or broken down in electrolysis reactions. Faraday extended the work of Davy and established a *quantitativ*e relationship between the amount of matter produced and the amount of electric charge.

Hence the work of Galvani and its interpretation and extension by Volta (and later by Davy and Faraday) led to an understanding of the transfer of electrons during chemical reactions.

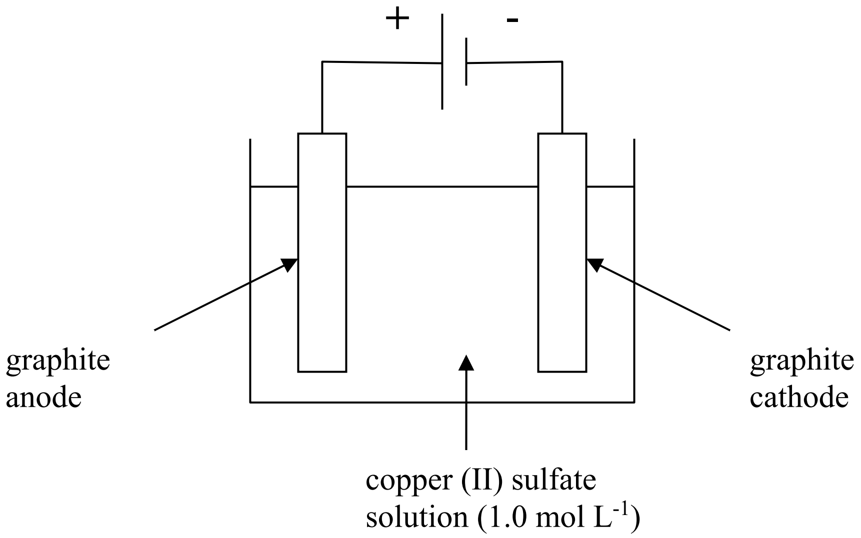
34 (b) (i) (1 mark)

Outcomes Assessed: H8, H13

Targeted Performance Bands: 2-3

Criteria	Mark
• Draws a correctly labelled diagram	1

Sample answer



34 (b) (ii) (3 marks)

Outcomes Assessed: H8, H11, H13

Targeted Performance Bands: 2-4

Criteria	Marks
• Describes observations at BOTH electrodes AND • Writes half-equations for BOTH electrode reactions	3
• Describes observations at BOTH electrodes AND • Writes a half-equation for ONE electrode reaction	2
• Describes observations at BOTH electrodes OR • Writes a half-equation for ONE electrode reaction	1

Sample answer

At the anode:

Water is oxidised to form oxygen, so bubbles of gas would be observed.

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

At the cathode:

Copper ions are reduced to copper metal, so a deposit of metal (copper) building up on the cathode would be observed, associated with a reduction in blue colour of the electrolyte solution around the cathode.

$Cu^{2+}\ (aq) + 2e^- \rightarrow Cu\ (s)$

34 (c) (5 marks)

(i) (2 marks)

Marking Guidelines	Marks
• Outlines changes in the concentration of at least one gas AND one other property of seawater, such as temperature or pressure, as depth increases.	2
• Identifies a trend between either the concentration of a gas OR another property of seawater, and depth.	1

As ocean depth increases, the temperature of the water decreases and the pressure increases. These factors affect the composition of gases in the water. In general, gas concentration in ocean water increases with decreasing temperature and increasing pressure so that the concentration would increase at increasing depth. However O_2 is consumed in the upper ocean by aerobic organisms and it is produced by aquatic plants present near the surface. It also dissolves more readily near the surface due to aeration. Hence its concentration decreases at greater depths. At greater depths CO_2 is more soluble and it is also produced by decay of dead organic material. Hence its concentration increases with increasing depth.

34 (c) (ii) (3 marks)

Marking Guidelines	Marks
• Describes at least two factors related to water depth that may influence the rate of corrosion AND • Explains how each factor affects the rate of corrosion, including at least one relevant equation	3
• Describes at least two factors related to water depth that may influence the rate of corrosion AND • Explains how one of these factors affects the rate of corrosion	2
• Identifies two factors related to water depth that may influence the rate of corrosion AND • Outlines how one of these factors affects the rate of corrosion	1

Variables in the aqueous environment of a metallic artefact that affect its rate of corrosion include temperature, oxygen levels, salinity, acidity and whether the metal is exposed to sulfate reducing bacteria.

Water temperature decreases with increasing depth. This can slow down the rate of corrosion, although other variables can influence this affect. Increasing oxygen levels increase the rate of corrosion, because oxygen is one reactant in the corrosion process:

$2Fe (s) + O_2 (g) + 2H_2O \rightarrow 2Fe^{2+} + 4OH^-$.

Oxygen levels decrease with depth (more aeration occurs near the water's surface) and so corrosion may occur more slowly at greater depths.

The presence of sulfate-reducing bacteria in acidic microclimates (at great depths) increases the rate of corrosion of metals such as iron in deep sea wrecks. They are able to reduce sulfate ions in the ocean, using electrons removed from metallic iron, thus accelerating the rate at which iron oxidises:

$SO_4^{2-} + 10H^+ + 8e^- \rightarrow H_2S + 4H_2O$.

34 (d) (7 marks)

Criteria	Marks
• Explains in detail the process of rusting using equations and describes the conditions under which it occurs • AND • Outlines THREE methods of reducing corrosion of steel ships • Description AND equation for oxidation of Fe and reduction of water and oxygen to hydroxide (1 mark) • Precipitation of iron (II)hydroxide (1 mark) • Further oxidation of iron to iron (III) oxide as rust (1 mark) • Physical barrier with example (1 mark) • Sacrificial anode with equations as evidence (1 mark) • Induced current explained (1 mark) • Surface alloying OR galvanizing explained (1 mark)	7
• Explains the process of rusting and describes the conditions under which it occurs • AND • Outlines TWO methods of reducing corrosion of steel ships	6
• Explains the process of rusting OR • Describes the conditions under which it occurs	5
• 4 of the points above HOLISTIC	4
• 3 of the points above HOLISTIC	3
• 2 of the points above HOLISTIC	2
• Outlines ONE method of reducing corrosion of steel ships	1

Suggested answer

On the moist surface of the iron structure, iron atoms oxidise to form Fe^{2+} in an anodic region of the metal. The electrons travel to another location on the surface usually where a carbon atom is located (the cathode), here dissolved oxygen is reduced to OH^-.

$$\text{Anode: } Fe_{(s)} \rightarrow Fe^{2+}_{(aq)} + 2e^-$$

$$\text{Cathode: } O_{2(g)} + H_2O_{(l)} + 4e^- \rightarrow 4OH^-_{(aq)}$$

Fe^{2+} and OH^- ions migrate towards each other and form insoluble iron (II) hydroxide which is then oxidised to iron (III) oxide (rust).

The corrosion of iron requires both oxygen and water to be present. Impurities within the iron allow cathodic sites to form to allow rusting.

Steel ships can be protected from corrosion by excluding contact with oxygen and water with a protective coating or by cathodic protection. A protective coating such as paint can reduce corrosion by preventing the steel coming in direct contact with oxygen and water. Steel ships can be protected by a surface alloy by bombarding the steel with ions of chromium and nickel using high temperature conditions. Steel ships can also be protected using other metals as sacrificial anodes or by applying a low voltage. Metals such as zinc or magnesium can be attached to the hull to undergo oxidation instead of the steel.

34 (e) (3 marks)

Outcomes Assessed: H3, H4, H8

Targeted Performance Bands: 2-5

Criteria	Marks
• Identifies the main constituents of 3 types of steel AND • Relates the properties of THREE types of steel to the differences in composition	3
• Identifies the main constituents BOTH of stainless steel and soft steel AND • Relates the properties of ONE steel to its composition	2
• Identifies the main constituents BOTH of stainless steel and soft steel OR • Relates the properties of ONE steel to its composition	1

Sample answer

Mild steel contains iron and <0.2% carbon.
Structural steel contains carbon and 0.3 – 0.6% carbon
Tool steel contains iron and 0.6 – 1.5% carbon
Stainless steel contains iron, 10% to 20% chromium and 5% to 20% nickel.

The presence of chromium in stainless steel provides the alloy with passivating properties. The chromium reacts with oxygen to form a transparent hard coating of oxide which protects the steel from corrosion. Stainless steel is hard and has a shiny appearance because of the presence of nickel and chromium.

‘Mild steel’ is soft and malleable because it has only iron and a low percentage of carbon and it corrodes rapidly.
Structural steel with a greater % of carbon is stronger and less malleable.
Tool steel with the highest % of carbon is very hard and brittle.

34 (f) (i) (1 mark)
Outcomes Assessed: H13
Targeted Performance Bands: 2-3

Criteria	Mark
• Writes an appropriate equation for the removal of concretions (with states)	1

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

34 (f) (ii) (2 marks)
Outcomes Assessed: H3, H4, H7, H8
Targeted Performance Bands: 3-5

Criteria	Marks
• Correct explanation of ONE feature of electrolysis to restore the artefact at the cathode. EITHER • One = removes chlorides from cracks • Two = returns the metal ion to the metal by reduction • Three = by making the artefact negative oxidation is prevented	2
• Some correct information about the electrolytic restoration of an artefact	1

Sample answer
Metal artefacts are usually coated with a corrosion product, e.g. iron objects have a coating of $Fe(OH)Cl$ or Fe_2O_3 or $FeCl_2$. The metal artefact is connected to the negative terminal of the power source as the cathode in an electrolytic cell.
At the cathode, reduction of the corrosion product occurs, which releases the chloride ion and restores iron to the surface of the artefact (where the corrosion product would have been attached). Hence the shape and engravings on metals objects can be restored to their original condition.
$Fe^{2+}(s)\,) + 2e^- \rightarrow Fe\,(s)$
$Fe(OH)Cl\,(s) + 2e^- \rightarrow Fe\,(s) + OH^-\,(aq) + Cl^-\,(aq)$

Question 35 – Forensic Chemistry (25 marks)

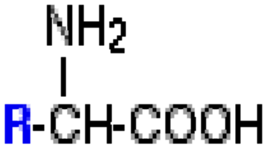
35 (a) (i) (1 mark)

Outcomes Assessed: H9, H13

Targeted Performance Bands: 2-3

Criteria	Mark
• Correct answer	1

Sample answer



$$R\text{-}\underset{}{\overset{\displaystyle NH_2\atop|}{CH}}\text{-}COOH$$

35 (a) (ii) (1 mark)

Outcomes Assessed: H9

Targeted Performance Bands: 2-3

Criteria	Mark
• Correct explanation	1

Sample answer

Different amino acids differ in the structure of R, the side chain. The simplest amino acid, glycine, has R = H (a hydrogen atom). Alanine has R = CH_3 (a methyl group). The differing properties of R determine the properties of different amino acids.

35 (a) (iii) (4 marks)
Outcomes Assessed: H9, H11
Targeted Performance Bands: 2-5

Criteria	Marks
• Explains the process of hydrolysis of proteins to form amino acids • Thoroughly explains how amino acids can be separated by electrophoresis, in terms of the zwitterionic structure of amino acids, and the charge/mass ratio • Describes the method of identification of amino acids	4
• Explains the process of hydrolysis of proteins to form amino acids • Soundly explains how amino acids can be separated by electrophoresis, in terms of the zwitterionic structure of amino acids, and the charge/mass ratio • Describes the method of identification of amino acids	3
• Soundly explains how amino acids can be separated by electrophoresis, in terms of the zwitterionic structure of amino acids, and the charge/mass ratio • Describes the method of identification of amino acids	2
• Some correct explanation about the structure of amino acids which is relevant to the process of electrophoresis OR • Some correct information about the use of electrophoresis for separation and identification of amino acids	1

Sample answer
Proteins are polypeptides containing from hundreds to thousands of amino acids linked together by peptide bonds.
Proteins are hydrolysed in the laboratory to form amino acids by warming them with about 6 mol L^{-1} hydrochloric acid. The resulting solution contains the conjugate acids of the amino acids; eg: the basic $–NH_2$ group accepts a proton to become $–NH_3^+$. In living organisms, the hydrolysis is catalysed by enzymes, with specific enzymes breaking specific peptide bonds.

The zwitterionic form of an amino acid is a dipolar ion formed from the amino acid. This dipolar ion exists in solution in equilibrium with the molecular form. The zwitterionic form results from the reaction of the acidic $–COOH$ group with the basic $–NH_2$ group.
Because amino acids in solution can exist as this zwitterionic form, amino acids will move under the influence of an electric field, with the positively charged $–NH_3^+$ group(s) being attracted to the negative pole and the carboxyl $–COO^-$ group(s) being attracted to the positive pole of an electric field. The speed of movement depends both on the mass of the amino acid and the charge on each molecule (or the charge/mass ratio). Because the amino acids are both acids and bases, and some acids have acidic or basic groups on the side chain, each amino acid has its characteristic strength as an acid or as a base.

Electrophoresis is a method of separating amino acids in a mixture, based on the different charges and different masses of the acids. The technique uses a strip of filter paper soaked in an electrolyte solution containing a suitable buffer. A voltage is applied across the strip of paper and the sample to be separated is placed on a line across the middle of the strip. Positively charged particles migrate one way, negatively charged the other way and neutral particles do not move at all. The amino acids are colourless but their positions can be made visible by spraying the paper with ninhydrin solution, which turns purple when amino acids are present.

The identity of the amino acids in a mixture can be determined by comparing the distance moved of each amino acid in the sample against standards of known amino acids tested under the same conditions.

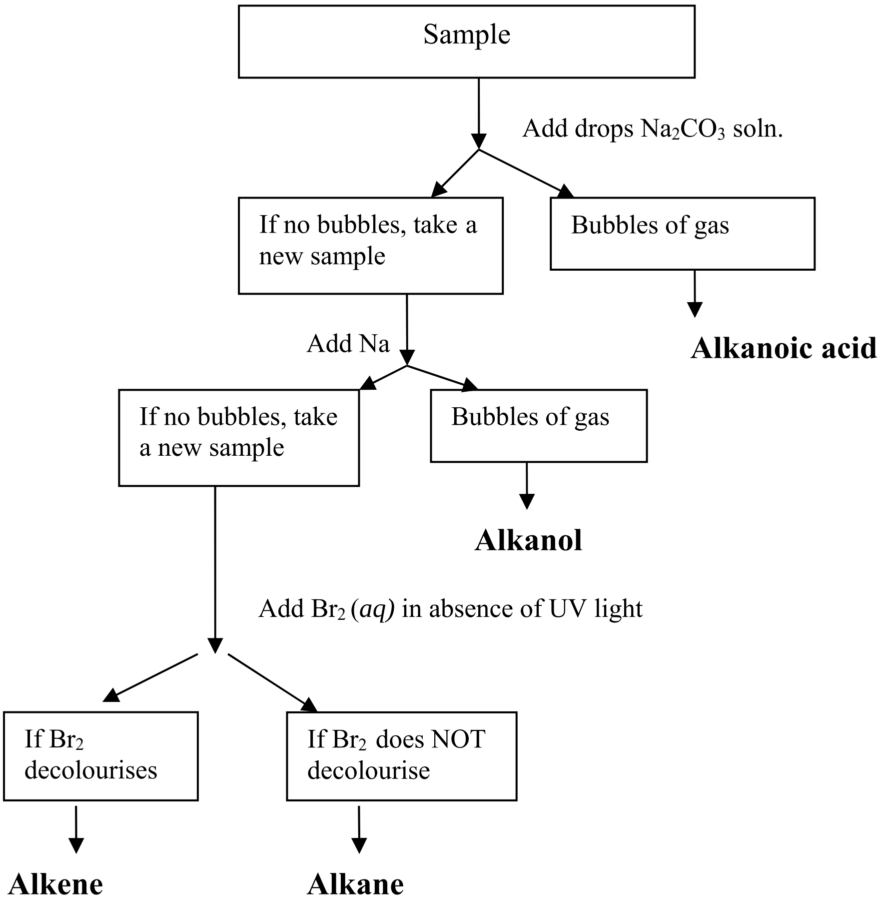
35 (b) (i) (3 marks)

Outcomes Assessed: H9, H11, H12, H13

Targeted Performance Bands: 2-4

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

Sample answer



35 (b) (ii) (3 marks)

Outcomes Assessed: H9, H13

Targeted Performance Bands: 3-5

Criteria	Marks
• Identifies the FOUR compounds used in the investigation • Writes TWO correct equations	3
• Identifies the FOUR compounds used in the investigation AND • Writes ONE correct equation	2
• Identifies the FOUR compounds used in the investigation OR • Writes ONE correct equation	1

Sample answer

hex-1-ene = alkene
hexane = alkane
hexan-1-ol = alkanol
hexanoic acid = alkanoic acid

<u>To identify hexanoic acid</u>

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

<u>To identify hexan-1-ol</u>

$2CH_3CH_2CH_2CH_2\,CH_2CH_2OH\ (l) + 2Na\ (s) \rightarrow H_2\ (g) + 2CH_3CH_2CH_2CH_2\,CH_2CH_2O^-\ Na^+\ (s)$

35 (c) (i) (2 marks)

Outcomes Assessed: H9, H13

Targeted Performance Bands: 3-5

Criteria	Marks
• Explains the structural differences between reducing and non-reducing sugars AND • Relates the structural differences to a different reaction with an appropriate reagent (e.g. Fehling's solution)	2
• Explains the structural differences between reducing and non-reducing sugars OR • Explains that reducing and non-reducing sugars have different reactions with an appropriate reagent (e.g. Fehling's solution)	1

Sample answer

Reducing sugars contain the functional groups -CHO or -CO-CH_2OH in the open chain structure (or a ring O atom and an -OH group attached to the same carbon atom) and thus can be oxidised by Fehling's solution to form the salt of a carboxylic acid, while reducing the copper (II) ions to copper (I) ions in the reddish-brown copper (I) oxide, Cu_2O.

Non-reducing sugars have no -OH on a carbonyl carbon and so do not react with Fehling's solution.

The equation for the reduction process for a reducing sugar (where R represents the rest of the molecule) is:

$$\text{R-CHO}\,(aq) + 2Cu^{2+}\,(aq) + 5OH^-\,(aq) \rightarrow \underset{\text{reddish-brown}}{Cu_2O\,(s)} + \text{R-COO}^-\,(aq) + 3H_2O\,(l)$$

35 (c) (ii) (2 marks)

Outcomes Assessed: H9, H13, H14

Targeted Performance Bands: 3-5

Criteria	Marks
• Classifies the sugar as non-reducing AND • Justifies the classification in terms of the structure	2
• Classifies the sugar as non-reducing	1

Sample answer

The sugar shown (sucrose) is a non-reducing sugar.

Non-reducing sugars have no -OH on a carbonyl carbon. Sucrose is a disaccharide formed from glucose and fructose. The carbonyl carbons join to form the disaccharide and hence cannot open out into an open chain structure. Sucrose only exists as a ring structure and hence there is no terminal -CHO group available to cause reduction of Fehling's solution.

35 (d) (i) (2 marks)

Outcomes Assessed: H6, H7

Targeted Performance Bands: 3-5

Criteria	Marks
• Explains thoroughly the production of a unique emission spectrum for each element	2
• Explains soundly the production of an emission spectrum	1

Sample answer

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

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

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

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

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

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

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

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

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

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

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

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

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

35 (e) (2 marks)

Outcomes Assessed: H4, H9
Targeted Performance Bands: 3-5

Criteria	Marks
• Explains that the sequence of bases (A, T, C and G) along a DNA strand determines the genetic code for that individual AND • Explains that the non-coding portion of DNA has sequences of bases which repeat and the number of repeats is unique for an individual and allows identification of the individual	2
• Explains that the sequence of bases along a DNA strand determines the genetic code for that individual OR • Explains that the non-coding portion of DNA has sequences of bases which repeat and the number of repeats is unique for an individual and allows identification of the individual	1

Sample answer
DNA occurs as two long chains that are connected by hydrogen bonding between base pairs.

The base pairs are:
- adenine and thymine (AT or TA)
- cytosine and guanine (CG or GC).

The chains are twisted in a double helix, consisting of two twisted chains, which resemble a spiral staircase. The base pairs are represented by the steps of the staircase. It is the sequence of these bases along a DNA strand which determines the genetic code for that individual.

DNA carries two forms of information; genetic coding and non-coding information. Non-coding information is often called “junk DNA” as, at present, it has no known function. However, it is the pattern of non-coding information that is used in DNA fingerprinting. It has been estimated that 95-99% of human DNA is non-coding “junk DNA”!
Non-coding information is carried on the series of bases which separate the genetic coding information. This “junk DNA” sequence is unique to an individual. The order of the bases in non-coding information is often repetitive. The repetitive sequences are examined to identify the number of repeating base sequences which is unique for an individual and allows identification of the individual.