Neap:

HSC Trial Examination 2010

Chemistry

This paper must be kept under strict security and may only be used on or after the morning of Thursday 5 August, 2010 as specified in the Neap Examination Timetable.

General Instructions

Reading time – 5 minutes

Working time – 3 hours

Write using blue or black pen

Draw diagrams using pencil

Board-approved calculators may be used

A data sheet and Periodic Table are provided at the back of this paper

Total Marks 100
Section I Pages 2–16

75 marks

This section has two parts, Part A and Part B

Part A – 20 marks
Attempt Questions 1–20
Allow about 40 minutes for this part

Part B – 55 marks
Attempt Questions 21–31
Allow about 1 hour and 35 minutes for this part

Section II Pages 17–23

25 marks

Attempt ONE question from Questions 32–35
Allow about 45 minutes for this section

No Biochemistry of Movement Option is included.

Students are advised that this is a trial examination only and cannot in any way guarantee the content or the format of the 2010 HSC Chemistry Examination.

Section I

75 marks

Part A – 20 marks
Attempt Questions 1–20
Allow about 40 minutes for this part

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

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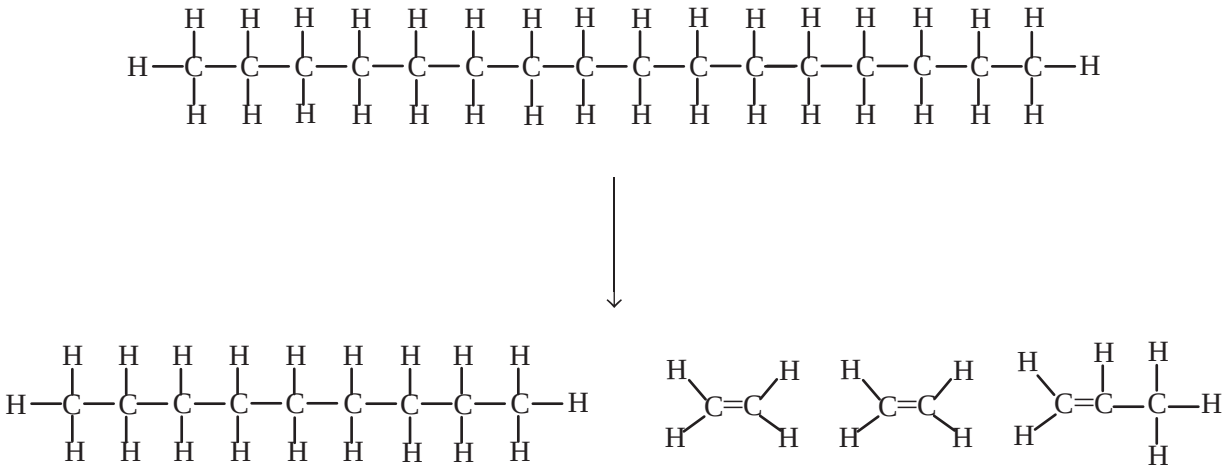
1. Which characteristic of ethylene makes it so easily transformed into other products?

(A) gaseous nature at STP
(B) carbon–carbon double bond present
(C) low molecular weight
(D) carbon–hydrogen single bonds present

2. Identify the process shown in the diagram



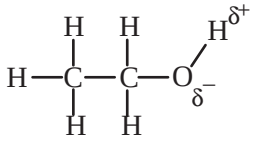
(A) cracking
(B) polymerisation
(C) condensation
(D) esterification

3. Which of the following shows the reaction conditions that would most favour the reaction shown?

$$C_2H_5OH \xrightarrow{\text{reaction conditions}} C_2H_4 + H_2O$$

(A) heat, vanadium catalyst
(B) water, concentrated phosphoric acid
(C) heat, concentrated sulfuric acid
(D) heat, concentrated sodium hydroxide solution

4. The diagram below shows the structure of ethanol.



This structure helps to explain which physical property of ethanol?

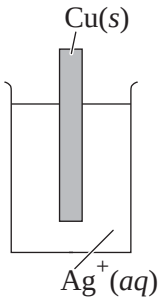
(A) ability to dissolve polar and non-polar substances
(B) flammability
(C) high molar heat of combustion
(D) relatively low boiling point compared to similar alkanes

5. Propanol has the formula C_3H_7OH. A student carried out an experiment to calculate the heat of combustion per mole of propanol. She found that 1.47 g of this alkanol yielded 36.4 kJ of heat energy. According to these figures, which is the molar heat of combustion of propanol?

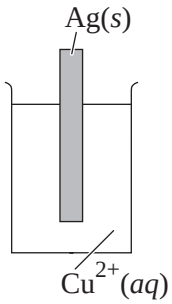
(A) –27.76 kJ
(B) –53.51 kJ
(C) –1444 kJ
(D) –1487 kJ

6. The diagrams below show four solid metal strips dipped in aqueous solutions of metal ions. Which combination would result in copper being deposited on the metal strip?

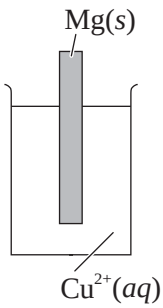
(A)



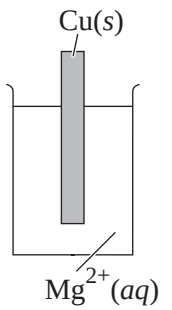
(B)



(C)



(D)



7. Which set of elements contains **only** unstable nuclei?

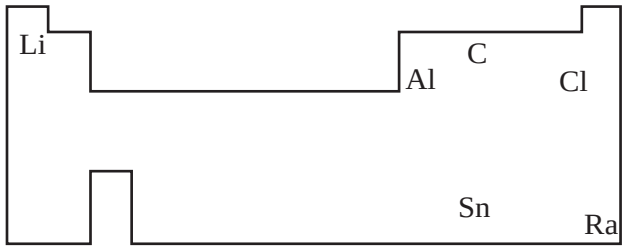
(A) $^{14}_{6}C$ $^{238}_{92}U$ $^{241}_{95}Am$

(B) $^{1}_{1}H$ $^{12}_{6}C$ $^{18}_{8}O$

(C) $^{2}_{1}H$ $^{35}_{17}Cl$ $^{16}_{8}O$

(D) $^{37}_{17}Cl$ $^{52}_{24}Cr$ $^{31}_{15}P$

8. The diagram below is a representation of the Periodic Table. The positions of six different elements are shown.



The oxides of which of these elements react only with acids, only with bases or with acids and with bases?

	Oxide reacts with acid	*Oxide reacts with base*	*Oxide reacts with acid and with base*
(A)	Cl	Li	C
(B)	Li	C	Sn
(C)	Ra	Sn	Cl
(D)	C	Cl	Ra

9. Concentrated nitric acid and copper react according to the equation:

$$3Cu(s) + 8HNO_3(aq) \rightarrow 3Cu(NO_3)_2(aq) + 2NO(g) + 4H_2O(l)$$

In a particular experiment, 0.100 mol of copper was consumed and nitrogen monoxide was the only gas produced. The gas was collected at room temperature and pressure (298 K and 100 kPa.)

The volume of gas collected was

(A) 1.52 L

(B) 1.65 L

(C) 2.48 L

(D) 3.68 L

10. A solution of concentrated hydrochloric acid is to be titrated against a standard sodium carbonate solution. The list below outlines the steps involved in this titration:

- 25.00 mL of the concentrated hydrochloric acid solution was pipetted into a 250.0 mL volumetric flask and the solution diluted to the volumetric mark.
- 25.00 mL of this diluted hydrochloric acid solution was pipetted into a clean 250.0 mL conical flask. Three drops of an indicator solution was added to this flask.
- A burette was used to measure the volume of standard sodium carbonate solution that was needed to be added to the conical flask to observe a colour change.

Which of the following procedures is incorrect?

(A) The conical flask was rinsed with the dilute hydrochloric acid solution before pipetting the dilute hydrochloric acid solution into it.

(B) The volumetric flask (also called a standard flask) was rinsed with distilled water immediately before pipetting the concentrated hydrochloric acid solution into it.

(C) The pipette was rinsed with dilute hydrochloric acid solution immediately before using it to measure 25.00 mL of dilute hydrochloric acid solution into the conical flask.

(D) The burette was rinsed with some of the standard sodium carbonate solution immediately before using it to measure the volume of sodium carbonate solution needed to observe a colour change.

11. Which of the following mixtures would form a buffer solution?

(A) 100.0 mL of 0.1 mol L^{-1} NH_4Cl mixed with 100.0 mL of 0.1 mol L^{-1} NH_4OH

(B) 200 mL of 0.1 mol L^{-1} NaOH mixed with 100 mL of 0.1 mol L^{-1} NaCl

(C) 100 ml of 0.1 mol L^{-1} H_2SO_4 mixed with 200 mL of 0.1 mol L^{-1} NaOH

(D) 50.0 mL of 0.1 mol L^{-1} HCl mixed with 50.0 mL of 0.1 mol L^{-1} NaOH

12. A solution is prepared by mixing 100.0 mL of 0.100 mol L^{-1} of $NaNO_3$ with 200.0 mL of 0.100 mol L^{-1} HCl and then adding sufficient water to give a final volume of 500.0 mL.

What is the pH of the solution?

(A) 1.00

(B) 1.12

(C) 1.40

(D) 1.70

13. In the following reaction a proton is transferred:

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

The proton transfer is from

(A) $H_2CO_3(aq)$ to $H_2CO_3^-(aq)$.

(B) $OH^-(aq)$ to $H_2O(l)$.

(C) $H_2CO_3\ (aq)$ to $H_2O(l)$.

(D) $H_2CO_3\ (aq)$ to $OH^-(aq)$.

14. The following excerpt is taken from the Sydney Morning Herald describing the work of Sam Fonti in his preparation of fireworks for Sydney's 2010 New Year's Eve celebrations.

> *It may look like trial and error, but it is really rocket science. Mr Fonti is trying to devise a new firework colour – aquamarine, a "clean, shiny, natural blue" – to join the lime, magenta and peach he has previously perfected.*
>
> John Huxley, 28 December 2009

Which of the following chemicals is most likely to be used by Mr Fonti to produce a natural blue-coloured firework?

(A) lead (II) oxide

(B) barium oxide

(C) copper (II) oxide

(D) calcium oxide

15. In 1918 Fritz Haber was awarded a Nobel Prize in Chemistry.

Which of the following best describes why this prize was awarded?

(A) He designed an industrial plant to synthesise ammonia.

(B) He manufactured synthetic fertilisers to feed growing world populations.

(C) He developed reaction conditions to economically produce ammonia.

(D) He was the first chemist to synthesise ammonia from its elements.

16. There are two allotropes of oxygen.
Which of the following alternatives correctly compares features of these allotropes?

	Similar features	*Different features*
(A)	• Appearance at room temperature • Volume that 1 mole of allotrope occupies at standard conditions	• Melting and boiling points • Toxicity towards living things
(B)	• Chemical reactivity • Odour	• Physical state at room temperature • Density
(C)	• Appearance at room temperature • Molecular shape	• Volume that 1 mole of allotrope occupies at standard conditions • Melting and boiling points
(D)	• Physical state at room temperature • Molar mass	• Chemical reactivity • Odour

17. The following data relates to the reaction between two gases, A and B, to produce C, an important industrial gas. The table shows the percentage yield of C at various temperatures and pressures.

	Percentage yield of gas (%)	
Temperature (°C)	*Pressure = 200 atm*	*Pressure = 300 atm*
300	23.5	26.0
400	36.9	41.4
500	54.2	57.3
600	61.5	65.7

Which of the following equations producing gas C is consistent with the data shown in the table?

(A) $2A(g) + B(g) \rightleftharpoons 2C(g)$ $\Delta H = -130 \text{ kJ mol}^{-1}$

(B) $A(g) + B(g) \rightleftharpoons 4C(g)$ $\Delta H = -210 \text{ kJ mol}^{-1}$

(C) $A(g) + 2B(g) \rightleftharpoons C(g)$ $\Delta H = +60 \text{ kJ mol}^{-1}$

(D) $2A(g) + 3B(g) \rightleftharpoons 6C(g)$ $\Delta H = +110 \text{ kJ mol}^{-1}$

18. This question relates to the four sets of reactants shown below I to IV.

I. ethene + bromine $\rightarrow$

II. carbon + oxygen $\rightarrow$

III. 1-butene + water $\rightarrow$

IV. methane + oxygen $\rightarrow$

Which of the following alternatives identifies the set(s) of reactants that could produce more than one product upon their reaction?

(A) II and III only
(B) II, III and IV only
(C) IV only
(D) II and IV only

19. In which of the following processes would a coordinate covalent bond be formed?

(A) carbon reacts with oxygen to form carbon dioxide
(B) ammonia gas reacts with hydrogen chloride to ammonium chloride
(C) methane reacts with chlorine gas, forming chloromethane and hydrogen chloride
(D) propene reacts with bromine forming 1,2-dibromopropane

20. Which of the following forms of pollution can be detected and assessed effectively by atomic absorption spectroscopy?

(A) eutrophication due to increased phosphate levels in water
(B) photochemical smog in tropospheric air
(C) lead contamination in soil surrounding a lead smelter
(D) increased levels of acidity in a lake next to an industrial plant

Section I (continued)

Part B – 55 marks
Attempt Questions 21–31
Allow about 1 hour and 35 minutes for this part

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

Marks

Question 21 (5 marks)

As part of your course you will have carried out an investigation to compare the reactivities of alkanes with the corresponding alkenes in bromine water.

(a) Describe how you carried out the investigation including how you ensured that the procedure was safe for you and others. **3**

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(b) Outline the results of your investigation. **1**

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(c) Write a balanced equation for a reaction that took place. **1**

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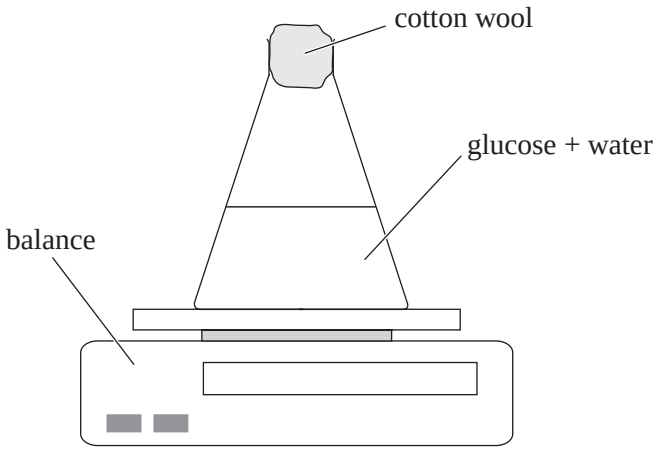
Marks

Question 22 (4 marks)

A student was carrying out an investigation into the fermentation of glucose. The diagram was part of his report.



(a) Explain what would happen to the mass of the flask and its contents as the fermentation proceeded. **2**

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(b) What would be needed as well as glucose and water for fermentation to occur? **1**

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(c) Write a balanced equation for the fermentation of glucose. **1**

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Marks

Question 23 (4 marks)

The questions refer to the following reaction, which takes place when a zinc–carbon cell (battery) is producing electricity.

$$Zn(s) + 2NH_4^+(aq) + 2MnO_2(s) \rightarrow Zn^{2+}(aq) + Mn_2O_3(s) + 2NH_3(aq) + H_2O(l)$$

(a) What is the polarity of the zinc electrode? Justify your answer. **2**

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(b) Assuming that the reaction went to completion, calculate the mass of water that would be produced by 2.2 g of zinc. **2**

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Question 24 (5 marks)

Radioactive isotopes (radioisotopes) are widely used in industry and in medicine. As well as having benefits, there are also problems associated with the use of these isotopes.

Discuss how radioisotopes are utilised in industry and medicine and the impact they have made. Include specific radioisotopes in your answer. **5**

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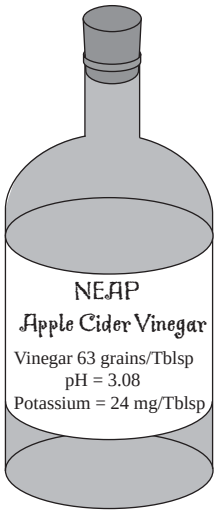
Marks

Question 25 (8 marks)

Vinegar is a dilute form of acetic (ethanoic) acid and can be made from fermented apples.



A student performed a first-hand investigation to determine the concentration of acetic (ethanoic) acid in a sample of apple cider. She performed the following steps:

1. 50.00 mL sample of the apple cider vinegar was first diluted with water to make 500.00 mL of dilute vinegar solution.
2. 25.00 mL aliquots of the diluted apple cider vinegar were then titrated against a 0.105 mol L^{-1} sodium hydroxide solution.

The results are shown in Table 1.

Titration	*Volume of 0.105 mol L^{-1} NaOH (mL)*
1	28.60
2	26.10
3	25.90
4	27.50
5	26.00

(a) Calculate the concentration, in moles per litre, of acetic acid in the apple cider vinegar. **5**

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(b) Using appropriate equations, compare the ionisation in water of ethanoic acid with that of nitric acid. **3**

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Question 26 (4 marks)

The ester methyl butanoate, used as a food flavouring, is to be prepared in the school laboratory. A student decided that a few drops of concentrated phosphoric acid would be needed as a catalyst and that the reaction mixture would need to be heated under reflux.

(a) Draw the structural formula for methyl butanoate. **1**

(b) Name two other chemicals needed for the preparation of methyl butanoate. **1**

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(c) Justify the student's decision to use an acid catalyst and to heat the reaction mixture under reflux. **2**

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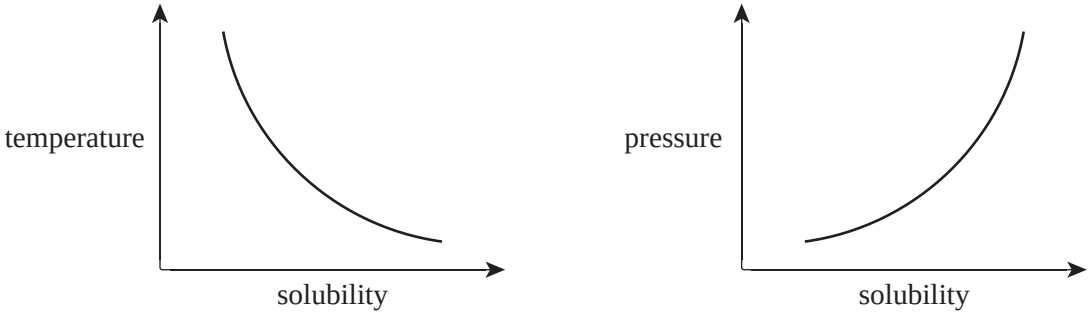
Marks

Question 27 (7 marks)

Carbon dioxide can be dissolved in water. It forms carbonic acid (H_2CO_3) on dissolving in an equilibrium reaction. Many soft drinks are 'carbonated', i.e. contain dissolved carbon dioxide to generate bubbles. The figure below indicates the relationship between the solubility of carbon dioxide in water with changes in temperature and pressure.



(a) Describe the relationship between the solubility of carbon dioxide in water and changes in temperature and pressure. **1**

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(b) Write an equation for carbon dioxide dissolving in water. **1**

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(c) Le Chatelier's principle can be used to predict the effect of changing conditions of equilibrium reactions.

(i) State Le Chatelier's principle. **1**

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(ii) Explain the relationship between temperature and solubility of carbon dioxide in water using Le Chatelier's principle. **2**

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(d) Outline how you could find the mass of dissolved carbon dioxide in a soft drink. **2**

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Marks

Question 28 (3 marks)

A student was given a sample of water thought to contain higher than usual levels of sulfate ions. Aqueous barium nitrate was also supplied.

Describe the procedure the student should follow to find the concentration of sulfate ions present. **3**

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Question 29 (6 marks)

Evaluate the role that chemical monitoring and treatment play in the production of Sydney's drinking water. **6**

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Question 30 (3 marks)

People suffering from low blood iron can take supplementary iron tablets.

An analytical chemistry student was given the role of determining the concentration of iron in a brand of iron tablet.

The student made use of the fact that iron (present as Fe^{2+}) in the dissolved tablet will react with the permanganate ion (MnO_4^-) in a redox reaction, as indicated by the ionic equation:

$$5Fe^{2+}(aq) + MnO_4^-(aq) + 8H^+(aq) \rightarrow 5Fe^{3+}(aq) + Mn^{2+}(aq) + 4H_2O(l)$$

The student carried out the following basic procedure:

1. A tablet was weighed on an electronic balance and found to have a mass of 500 mg.
2. A tablet was crushed and dissolved in a small quantity of dilute sulfuric acid.
3. The filtrate was titrated against a 0.0104 M solution of potassium permanganate ($KMnO_4$).
4. After three accurate trials, an average of 25.10 mL of the permanganate solution was required to react the end-point with the iron in the tablet.

(a) Calculate the average moles of iron (as Fe^{2+}) required to reach the end-point with the standard permanganate solution. **2**

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(b) Use your answer to (a) to determine the percentage (w/w) of iron in an average tablet. **1**

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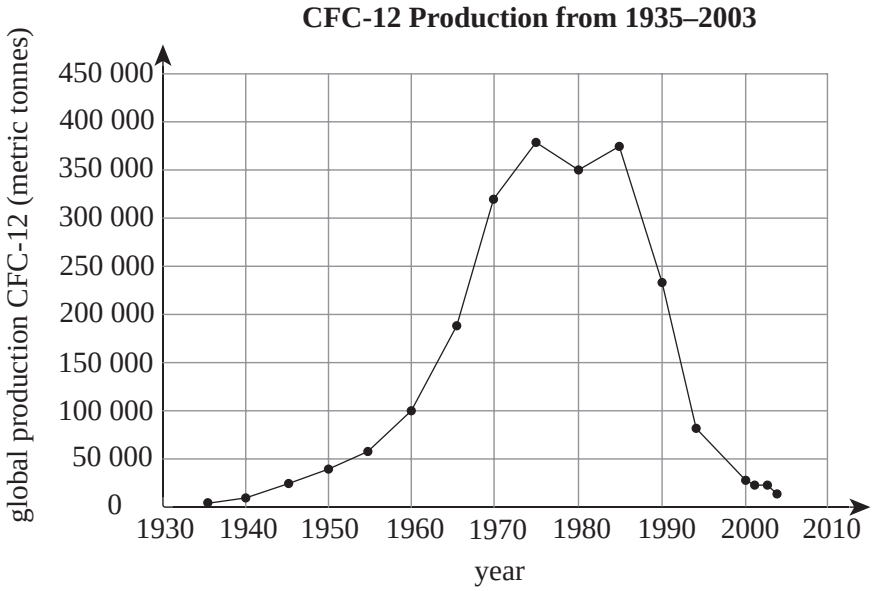
Question 31 (6 marks)

CFC-12 (also referred to as Freon-12) has the IUPAC name dichlorodifluoromethane.

(a) Give the structural formula for this molecule. **1**

(b) The graph below shows the global production of this gas from 1935 to 2003. **5**



Use your knowledge of the uses and environmental effects of molecules such as CFC-12 to account for general trends in its production as shown in this graph. Support your answer with appropriate chemical equations.

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End of Section I

Section II

25 marks
Attempt ONE question from Questions 32–35
Allow about 45 minutes for this section

Answer the question in a writing booklet. Extra writing booklets are available.
Show all relevant working in questions involving calculations.

Pages

Marks

Question 32 — Industrial Chemistry (25 marks)

(a) (i) Identify ONE key difference between galvanic and electrolytic cells. **1**

(ii) Explain why different products are obtained in the electrolysis of molten and dilute aqueous sodium chloride. **2**

(iii) Describe the mercury process for producing sodium hydroxide. Include relevant chemical equations in your answer. **3**

(b) (i) The reaction of water with red-hot carbon is endothermic and is represented by the following equation:

$$H_2O(g) + C(s) \rightleftharpoons CO(g) + H_2(g) \quad \Delta H = 131 \text{ kJ mol}^{-1}$$

Calculate the equilibrium constant (K) for a reaction system at equilibrium, which contains 2.5 mol of steam, 3 mol of carbon, 1.5 mol of carbon monoxide and 0.96 mol of hydrogen, in a 1 L flask. **2**

(ii) Outline the effect of decreasing the temperature of this system on the value of K. **1**

(c) Describe the procedure you used to safely carry out a saponification reaction in the laboratory, identifying the reactants and products of your procedure. **3**

(d) (i) Calculate the mass of sodium hydrogen carbonate which must be produced in the Solvay process, in order to produce 135 kg of sodium carbonate. **2**

(ii) Explain the importance of the use, and regeneration of ammonia in the Solvay process, illustrating your answer with chemical equations. **4**

(e) Explain the chemistry of sulfuric acid production from elemental sulfur, and analyse the relationship between rate and yield in this process. **7**

End of Question 32

Marks

Question 33 — Shipwrecks, Corrosion and Conservation (25 marks)

(a) During your practical work you performed a first-hand investigation to compare the corrosion rates of different metals or alloys. This investigation would have involved an electrolyte, such as salt.

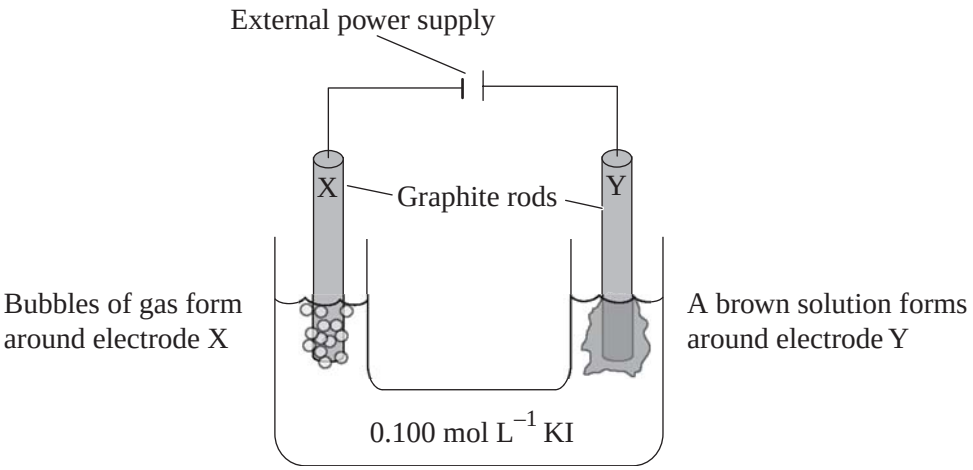
(i) Identify the origins of the minerals, such as salt, in the Earth's oceans. **1**

(ii) Describe a procedure that could be used to compare the corrosion rates of iron, steel and zinc. Indicate the data that should be recorded during the experiment. **5**

(b) Shipwrecks at great depth were expected to show little sign of corrosion. The discovery of the wreck of the Titanic showed that this expectation was incorrect. The wreck of the Titanic was covered by black and red coloured corrosion deposits. It is believed that sulfate reducing bacteria are responsible for much of the corrosion that was observed on the wreck of the Titanic.

With the aid of equations, explain how sulfate reducing bacteria contribute to the corrosion of iron. **3**

(c) The diagram below shows an electrolytic cell.



Describe, with the use of half equations, the processes that occur at the anode and at the cathode. **3**

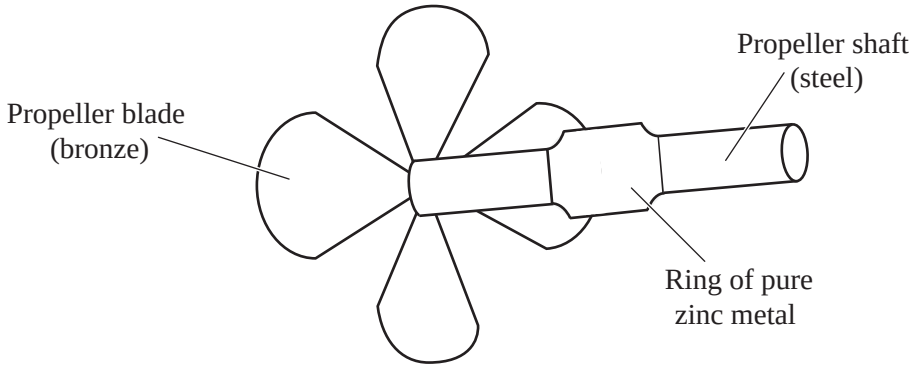
Question 33 continues on page 20

Question 33 (continued)

(d) (i) Reactive metals such chromium and aluminium form a strongly adhering oxide coating as a result of reaction with atmospheric oxygen.

What name is given to these types of reactive metals? **1**

(ii) A ship designer has proposed a method of protecting the ship's propeller from corrosion. The propeller blade is made from bronze (an alloy of copper and tin) and the propeller shaft is made from steel. A ring of zinc metal is attached to the propeller shaft, as shown in the following diagram:



Describe, including equations, how this design works to protect the ship's propeller (both blade and shaft) from corrosion. **3**

(iii) A student suggests the propeller could be better protected using an impressed current.

Describe, using half equations, what happens at the propeller when it is the cathode of the electrolytic cell that is used in the impressed current system of cathodic protection. **2**

(e) The preservation and restoration of artefacts recovered from marine environments presents several challenges. **7**

Discuss the challenges, and the techniques associated with recovering small wooden artefacts from a shipwreck with those associated with recovering small iron artefacts from the same shipwreck.

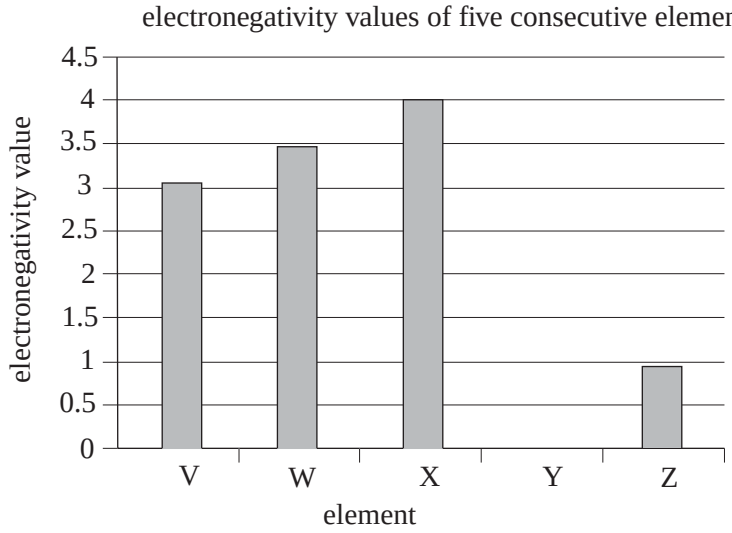
End of Question 33

Marks

Question 34 — The Chemistry of Art (25 marks)

(a) (i) Define the term 'electronegativity'. **1**

(ii) The letters V to Z are used to represent five real elements which are consecutive in the Periodic Table. The following chart shows the electronegativity values of these elements. (No value for electronegativity is assigned for element Y.)



Identify the element (by letter) which would have the highest first ionisation energy. Explain fully how you arrived at your answer. **2**

(iii) Explain the relationship between the electron configuration and the electronegativity values for the elements shown in the graph. **3**

(b) (i) Describe an example of a technology used to analyse materials in artworks for authentication or conservation purposes. **2**

(ii) Classify the technique you described above as destructive or non-destructive, justifying your answer. **1**

(c) Using specific examples to illustrate your answer, explain the implications of the use of naturally occurring minerals as cosmetics on the health of members of a named ancient culture. **3**

Question 34 continues on page 22

Marks

Question 34 (continued)

(d) (i) A student recorded the following results after adding a few drops of acidified potassium permanganate to each halide solution shown in the table.

Halide solution tested	*NaF*	*NaCl*	*NaBr*	*NaI*
Colour change observed	No change	Purple colour of MnO_4^-	Purple colour of MnO_4^- fades	Purple colour of MnO_4^- fades

Write separate half equations and a net ionic equation for the reaction that results in the observed colour change when potassium permanganate is added to sodium bromide solution. **2**

(ii) The student concluded that the permanganate ion was a strong oxidising agent.

Explain how these results relate to the student's conclusion and account for the strong oxidising strength of ions such as permanganate. **4**

(e) A chemistry student made the following observations during a series of experiments involving copper(II) sulfate:

- Copper(II) sulfate forms a blue solution when added to water.
- When this solution is sprayed into a Bunsen burner flame, a blue-green flame is observed.
- When the emission from the flame is observed using a spectroscope, a series of coloured lines – mainly green and blue – appear on a black background.
- When concentrated hydrochloric acid is added to a solution of copper(II) sulfate, a colour change from blue to green is observed.

Apply your knowledge of atomic structure and electron arrangement to account for the above observations. **7**

End of Question 34

Marks

Question 35 — Forensic Chemistry (25 marks)

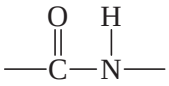
(a) We can categorise compounds into either organic or inorganic compounds.

(i) State the major structural difference between these two types of compounds. **1**

(ii) When analysing unknown compounds, the first step is often to determine whether they are organic or inorganic. **5**

Describe a sequence of tests that could be used to distinguish between two named organic and inorganic compounds.

(b) (i) The diagram below shows a peptide bond.



What is formed when many amino acids are joined by peptide bonds? **1**

(ii) Describe how the large molecules formed by peptide bonds can be broken down. **2**

(c) Both animals and plants contain carbohydrates.

Compare the compositions and structures of the carbohydrates from these two sources. **3**

(d) In 2001, the CrimTrac Agency launched the National Criminal Investigation DNA Database (NCIDD) to allow the eight State and Territory legal systems and the Federal legal system to match DNA profiles. Though the database has been endorsed by law enforcement agencies, some lawyers have voiced concerns about the ethics of maintaining data banks of DNA.

(i) Explain the uses of DNA analysis in forensic chemistry. **4**

(ii) Outline the critical issues raised by maintaining data banks of DNA. **2**

(e) Chromatography was first used over a hundred years ago, and the number of chromatographic techniques and uses have increased since then. **7**

Discuss how the development of chromatographic methods has advanced forensic science.

End of paper

DATA SHEET

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

Volume of 1 mole of 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

$$pH = -\log_{10}[H^+] \qquad \Delta H = mC\Delta T$$

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

PERIODIC TABLE OF THE ELEMENTS

KEY

Atomic number

Atomic weight

Symbol of element

Name of element

1 **H** 1.008 Hydrogen																	2 **He** 4.003 Helium
3 **Li** 6.941 Lithium	4 **Be** 9.012 Beryllium							79 **Au** 197.0 Gold				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.