BOSTES BOARD OF STUDIES TEACHING & EDUCATIONAL STANDARDS NSW

2015 HIGHER SCHOOL CERTIFICATE EXAMINATION

Chemistry

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black pen
- Draw diagrams using pencil
- Board-approved calculators may be used
- A data sheet and a Periodic Table are provided at the back of this paper

Total marks – 100

Section I Pages 2–28

75 marks

This section has two parts, Part A and Part B

Part A – 20 marks

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

Part B – 55 marks

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

Section II Pages 29–39

25 marks

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

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 for Questions 1–20.

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1 In which layer of the atmosphere does ozone absorb the most UV radiation?

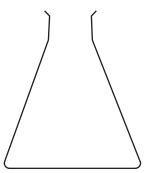
(A) Mesosphere

(B) Stratosphere

(C) Thermosphere

(D) Troposphere

2 Which type of glassware is used in a titration to deliver an accurate volume of a solution to a known volume of another solution?

(A) 

(B) 

(C) 

(D) 

3 What flame colour do copper ions produce when heated?

(A) Brick red

(B) Blue-green

(C) Pale purple

(D) Yellow-orange

4 What happens to Fe^{2+} in the following reaction?

$$Sn^{4+} + Fe^{2+} \longrightarrow Sn^{3+} + Fe^{3+}$$

(A) It undergoes oxidation and gains electrons.

(B) It undergoes reduction and gains electrons.

(C) It undergoes oxidation and loses electrons.

(D) It undergoes reduction and loses electrons.

5 The oxides CaO, CO_2, Na_2O and N_2O_4 are placed in water to form four separate solutions.

Which row of the table correctly indicates the solutions with pH less than 7 and the solutions with pH greater than 7?

	Solutions			
	pH less than 7		*pH greater than 7*	
(A)	CO_2	N_2O_4	CaO	Na_2O
(B)	CaO	N_2O_4	CO_2	Na_2O
(C)	CaO	Na_2O	CO_2	N_2O_4
(D)	CO_2	Na_2O	CaO	N_2O_4

6 Which of the following is the most suitable replacement for CFCs in terms of reducing their environmental impact?

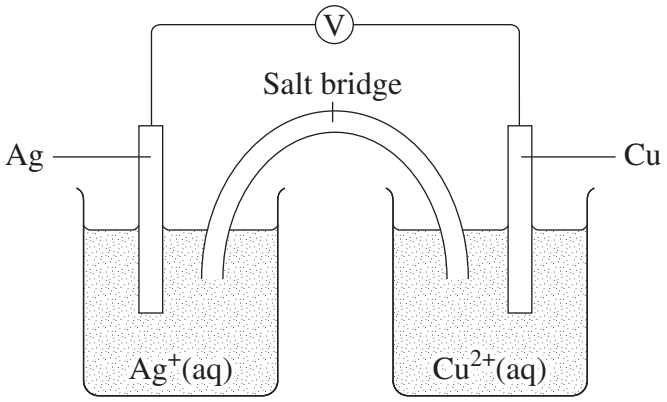
(A) CH_4

(B) CH_2F_2

(C) CH_2ClF

(D) $CHCl_2CCl_2F$

7 A diagram of a simple cell is shown.



Which of the following occurs when the cell is in operation?

(A) Silver ions are formed in solution.

(B) The copper electrode loses electrons.

(C) Electrons travel through the electrolyte.

(D) The copper electrode increases in mass.

8 Which of the following statements best explains the solubility of ethanol in octane?

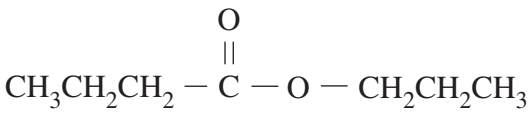
(A) Ethanol and octane are both non-polar.

(B) Ethanol forms hydrogen bonds with octane.

(C) Ethanol forms dispersion forces with octane.

(D) Ethanol forms dipole-dipole bonds with octane.

9 What are the reactants used to make this compound?



(A) Butan-1-ol and butanoic acid

(B) Butan-1-ol and propanoic acid

(C) Propan-1-ol and butanoic acid

(D) Propan-1-ol and propanoic acid

10 Which of the equations correctly describes incomplete combustion?

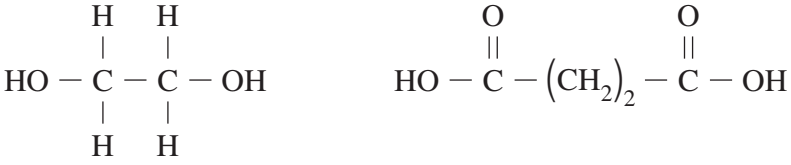
(A) $C_2H_5OH(l) + 2O_2(g) \longrightarrow 2CO(g) + 3H_2O(l)$

(B) $C_2H_5OH(l) + \frac{7}{2}O_2(g) \longrightarrow 2CO_2(g) + 3H_2O(l)$

(C) $C_2H_5OH(l) + 3O_2(g) \longrightarrow 2CO_2(g) + 3H_2O(l)$

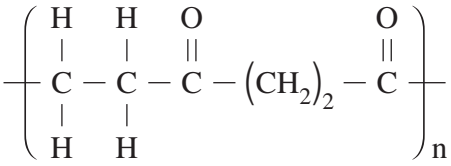
(D) $C_2H_5OH(l) + 2O_2(g) \longrightarrow C(s) + CO(g) + 3H_2O(l)$

11 Two monomers are shown.



Which of the following shows a condensation polymer that could be formed from the monomers?

(A)



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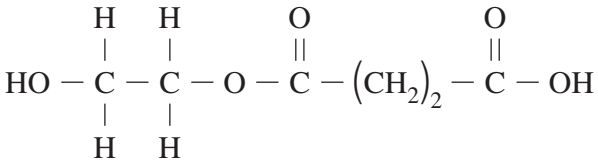
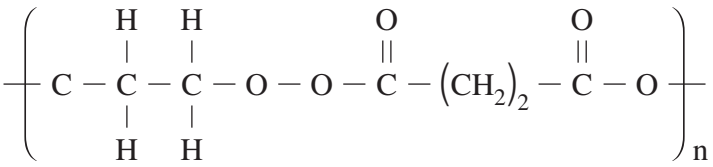
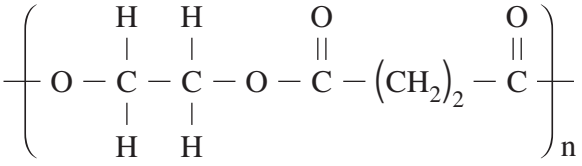


(C)



(D)



12 A transuranic element can be produced in a nuclear reactor according to this equation:

$$^{239}_{94}\text{Pu} + 2\text{X} \longrightarrow {}^{241}_{94}\text{Pu} \longrightarrow {}^{241}_{95}\text{Am} + \text{Y}$$

Which row of the table correctly identifies X and Y?

	X	Y
(A)	Neutron	Electron
(B)	Proton	Neutron
(C)	Neutron	Proton
(D)	Proton	Electron

13 Which of the following solutions has the highest pH?

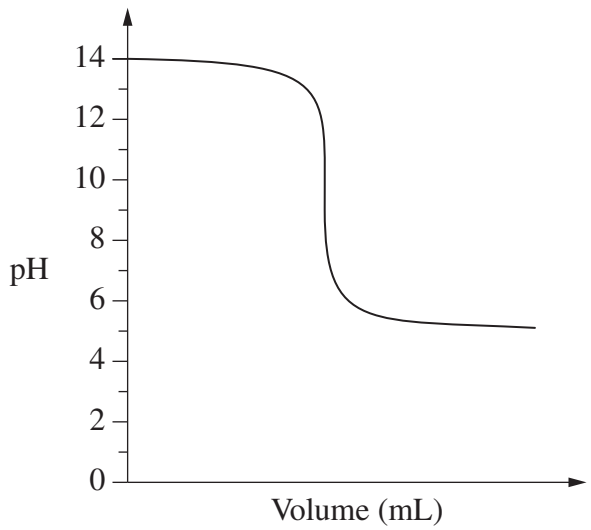
(A) 1.0 mol L^{-1} acetic acid

(B) 0.10 mol L^{-1} acetic acid

(C) 1.0 mol L^{-1} hydrochloric acid

(D) 0.10 mol L^{-1} hydrochloric acid

14 The graph shows the changes in pH during a titration.



Which pH range should an indicator have to be used in this titration?

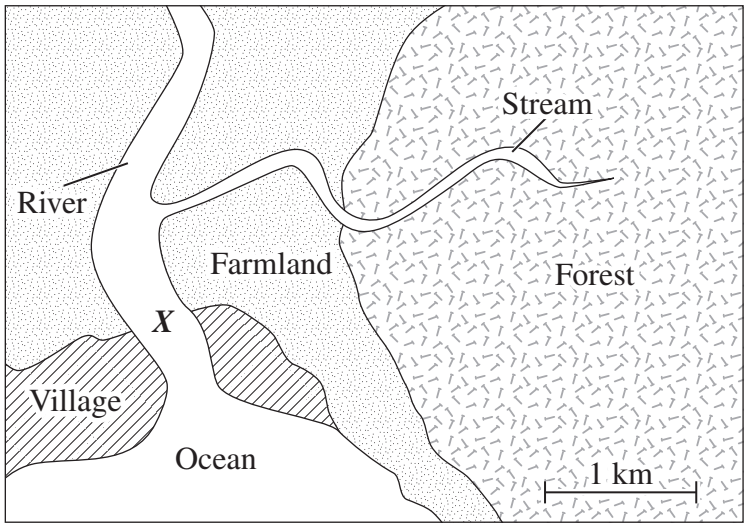
(A) 3.1–4.4

(B) 5.0–8.0

(C) 6.0–7.6

(D) 8.3–10.0

15 Part of a water catchment is shown in the diagram.



A sample of river water taken from point ***X*** is analysed.

Which row of the table shows the most likely results?

	Results of water analysis at ***X***			
	Turbidity (NTU)	*BOD* (ppm)	*pH*	*Total dissolved solids* (ppm)
(A)	400	18	6.5	22 000
(B)	22	3	8.5	17
(C)	5	18	6.5	22 000
(D)	400	3	8.5	17

16 The equation describes an equilibrium reaction occurring in a closed system.

$$X(g) + Y(g) \rightleftharpoons 4Z(g) \qquad \Delta H = +58 \text{ kJ}$$

Under which set of conditions would the highest yield of $Z(g)$ be obtained?

	Temperature (°C)	*Pressure* (kPa)
(A)	50	100
(B)	50	200
(C)	300	100
(D)	300	200

17 What volume of carbon dioxide will be produced if 10.3 g of glucose is fermented at 25°C and 100 kPa?

(A) 1.30 L

(B) 1.42 L

(C) 2.57 L

(D) 2.83 L

Use this information to answer Questions 18–19.

A sample of pond water from a contaminated site was analysed to determine the concentration of lead ions using the following procedure.

- A measuring cylinder was used to collect a 50 mL sample from the pond.
- The sample was placed in a clean dry beaker.
- 25.0 mL of 0.200 mol L^{-1} sodium chloride solution was added to the sample.
- The precipitate of lead(II) chloride that formed was filtered, dried and weighed. It had a mass of 0.13 g.

18 How could the reliability of the analysis of the pond water be improved?

(A) Analyse more samples from the same pond

(B) Use 50 mL of distilled water as a control sample

(C) Analyse samples from different ponds on the site

(D) Remove other contaminants from the sample before the analysis

19 What was the concentration of lead ions in the sample?

(A) 5.0×10^{-3} mol L^{-1}

(B) 5.8×10^{-3} mol L^{-1}

(C) 9.3×10^{-3} mol L^{-1}

(D) 10.7×10^{-3} mol L^{-1}

20 The table shows the heat of combustion of four straight chain alkanols.

Number of C atoms in straight chain alkanol	*Heat of combustion* (kJ mol^{-1})
1	726
3	2021
5	3331
7	4638

What is the mass of water that could be heated from 20°C to 45°C by the complete combustion of 1.0 g of heptan-1-ol?

(A) 0.032 kg

(B) 0.044 kg

(C) 0.36 kg

(D) 0.38 kg

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Chemistry

Centre Number

Student Number

Section I (continued)

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

Answer the questions in the spaces provided. These spaces provide guidance for the expected length of response.

Show all relevant working in questions involving calculations.

Extra writing space is provided on pages 27 and 28. If you use this space, clearly indicate which question you are answering.

Write your Centre Number and Student Number at the top of this page.

Please turn over

Question 21 (4 marks)

(a) Outline a suitable method to prepare a natural indicator. **2**

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(b) How could a natural indicator be tested? **2**

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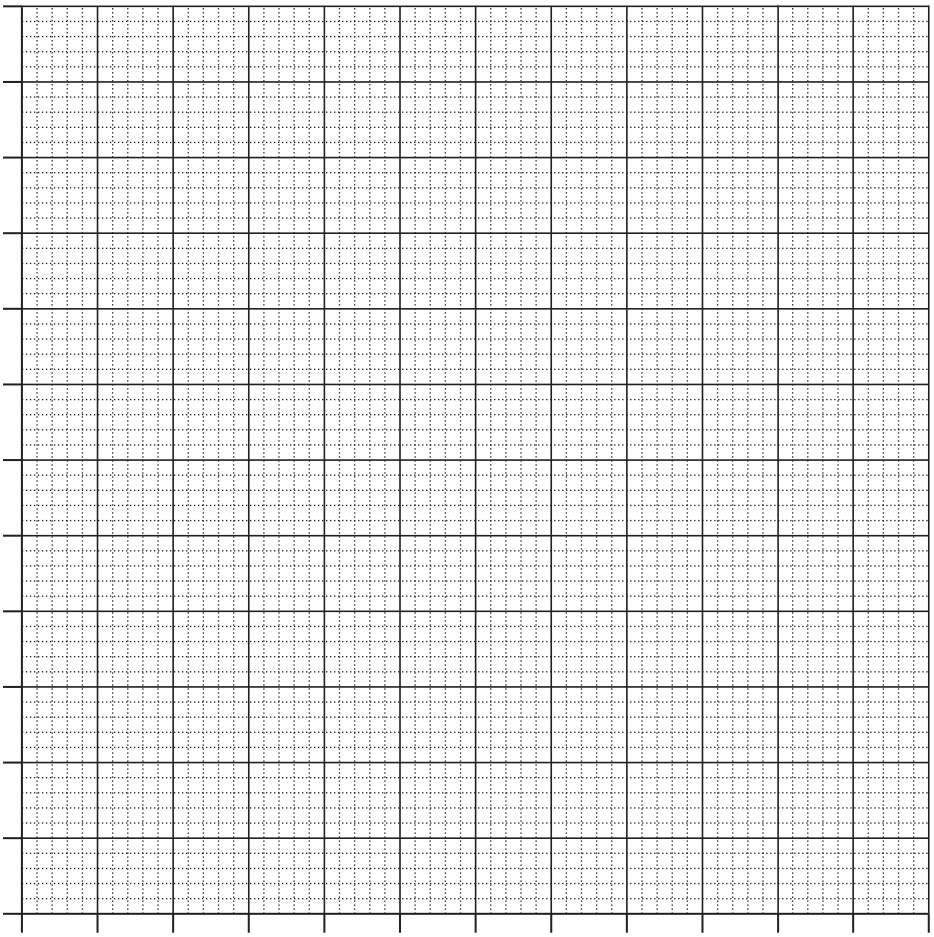
Question 22 (7 marks)

The table shows data for ozone concentrations over 50 years in the upper atmosphere above Antarctica.

Year	*Ozone Concentration* (Dobson Units)
1955	320
1960	300
1970	300
1980	260
1995	130
2000	130
2005	150

(a) Draw a line graph of the data on the grid provided. **4**



Question 22 continues on page 16

Question 22 (continued)

(b) Describe a method by which this data could have been measured. **3**

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End of Question 22

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Question 23 (4 marks)

Explain how the structure and chemistry of ONE of the following cells determines its cost and practicality. **4**

- button cell
- fuel cell
- vanadium redox cell
- lithium cell
- liquid junction photovoltaic device (eg the Gratzel cell)

Name of cell: .....

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Question 24 (5 marks)

(a) Explain why the salt, sodium acetate, forms a basic solution when dissolved in water. Include an equation in your answer. **2**

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(b) A solution is prepared by using equal volumes and concentrations of acetic acid and sodium acetate. **3**

Explain how the pH of this solution would be affected by the addition of a small amount of sodium hydroxide solution. Include an equation in your answer.

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Question 25 (7 marks)

(a) Describe the steps involved in the process of *addition polymerisation*. **3**

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(b) Explain the uses of polyethylene and polystyrene in terms of their structures and properties. **4**

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Question 26 (7 marks)

A sodium hydroxide solution was titrated against citric acid ($C_6H_8O_7$) which is triprotic.

(a) Draw the structural formula of citric acid (2–hydroxypropane–1,2,3–tricarboxylic acid). **1**

(b) How could a computer-based technology be used to identify the equivalence point of this titration? **2**

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Question 26 continues on page 21

Question 26 (continued)

(c) The sodium hydroxide solution was titrated against 25.0 mL samples of 0.100 mol L^{-1} citric acid. The average volume of sodium hydroxide used was 41.50 mL. **4**

Calculate the concentration of the sodium hydroxide solution.

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End of Question 26

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Question 27 (5 marks)

Name a radioisotope used in a non-medical industry and discuss its use in that industry in terms of its properties. **5**

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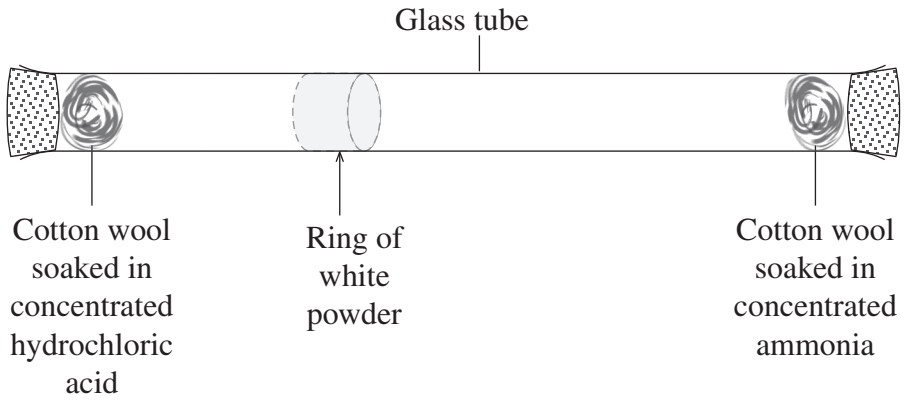
Question 28 (3 marks)

The equipment shown is set up. After some time a ring of white powder is seen to form on the inside of the glass tube.



(a) Why would this NOT be an acid–base reaction according to Arrhenius? **1**

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(b) Explain why this would be considered a Brönsted–Lowry acid–base reaction. Include an equation in your answer. **2**

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Question 29 (7 marks)

The procedure of a first-hand investigation conducted in a school laboratory to determine the percentage of sulfate in a lawn fertiliser is shown.

- 2.00 g of a sample of fertiliser was ground up and placed in a beaker.
- It was dissolved in about 200 mL of 0.1 mol L^{-1} hydrochloric acid, stirred and filtered.
- Excess barium chloride solution was quickly added to this beaker and a precipitate formed.
- The precipitate was then allowed to settle, filtered using filter paper and the residue collected.
- The residue was dried and weighed and had a mass of 2.23 g.

(a) Suggest modifications that could be made to the procedure to improve the results of this investigation. Justify your suggestions. **4**

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Question 29 continues on page 25

Question 29 (continued)

(b) Calculate the percentage of sulfate in the original fertiliser sample. **3**

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End of Question 29

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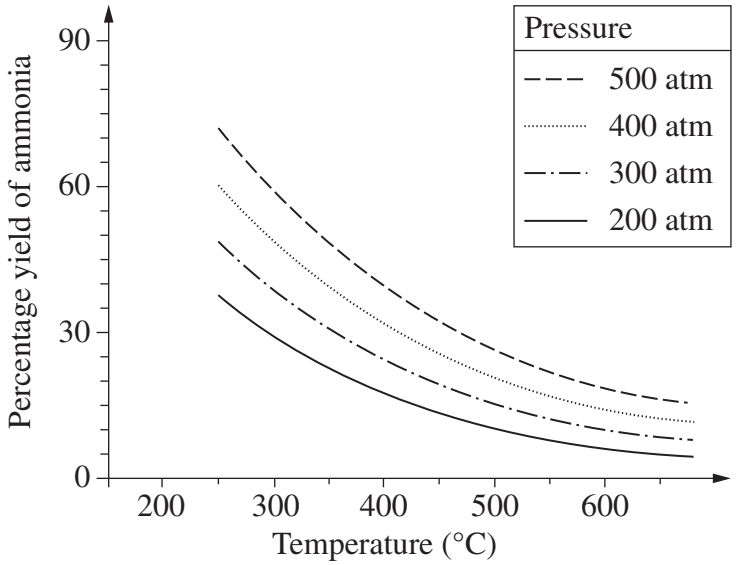
Question 30 (6 marks)

The graph shows the percentage yield of ammonia produced from nitrogen and hydrogen at different temperatures and pressures. **6**



The Haber process is the main industrial procedure for the production of ammonia. Explain the conditions used in the Haber process with reference to the graph.

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Section I Part B extra writing space

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Office Use Only – Do NOT write anything, or make any marks below this line.

Chemistry

Section II

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

Answer parts (a)–(d) of one question in the Section II Writing Booklet. Extra writing booklets are available.

Show all relevant working in questions involving calculations.

Question 31 — Industrial Chemistry (25 marks)

Answer parts (a) and (b) of the question on pages 2–4 of the Section II Writing Booklet. Start each part of the question on a new page.

(a) At temperatures above 100°C, hydrogen and carbon monoxide react to form methanol gas in this reversible reaction.

$$2H_2(g) + CO(g) \rightleftharpoons CH_3OH(g)$$

A mixture of hydrogen, carbon monoxide and methanol is placed in a container with a volume that can be changed. The mixture is allowed to reach equilibrium.

(i) The initial volume of the container is 1.00 L. **2**

Account for any changes in the concentration of hydrogen gas when the volume of the container is rapidly increased to 2.00 L.

(ii) The initial mixture placed in the container had 0.50 mol of hydrogen, 1.00 mol of carbon monoxide and 2.50 mol of methanol. Once the volume of the container had been increased to 2.00 L and equilibrium had been re-established, the number of moles of hydrogen in the mixture had changed by 0.36 mol. **3**

Calculate the equilibrium constant for this reaction.

(b) (i) Describe how saponification can be safely carried out as part of a first-hand investigation. **3**

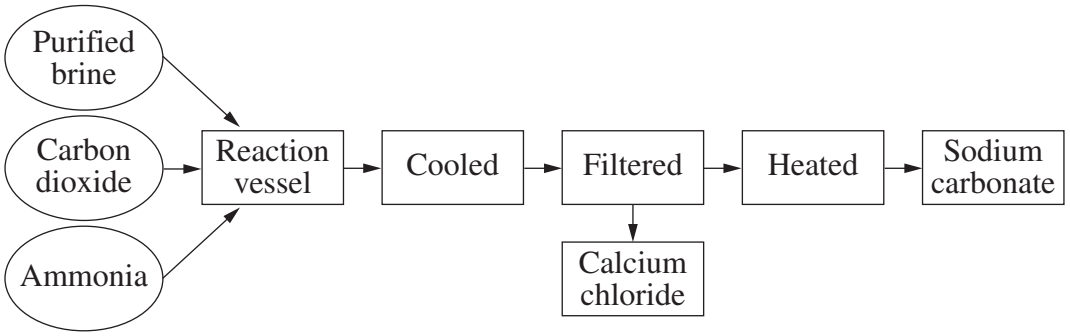
(ii) Explain the chemistry related to the cleaning properties of the product of saponification. **4**

Question 31 continues on page 31

Question 31 (continued)

Answer parts (c) and (d) of the question on pages 5–8 of the Section II Writing Booklet. Start each part of the question on a new page.

(c) The diagram shows part of the Solvay process for producing sodium carbonate.



(i) Outline the chemistry of the production of sodium carbonate in the process shown. Include equations in your answer. **3**

(ii) By making specific reference to the diagram, justify the requirements for the location of a Solvay process plant. **3**

(d) Compare the membrane cell method with ONE other method used in the industrial production of sodium hydroxide in terms of technical and environmental issues. **7**

End of Question 31

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

Answer parts (a) and (b) of the question on pages 2–4 of the Section II Writing Booklet. Start each part of the question on a new page.

(a) (i) Outline the limitations of using paint to protect ships that are in constant use. **2**

(ii) Explain the chemical principles involved in the use of a sacrificial anode. Include relevant chemical equations in your answer. **3**

(b) (i) Describe a valid and reliable first-hand investigation that can be used to compare the rates of corrosion of iron with ONE named form of steel. **3**

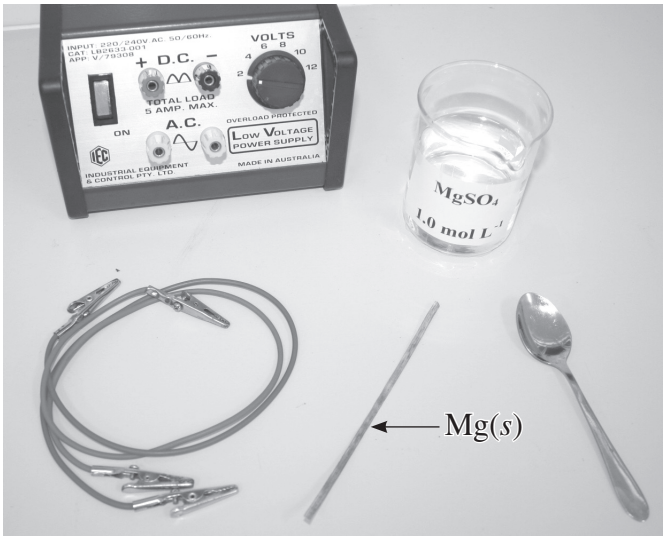
(ii) Explain how the percentage composition of steel can determine its properties, with reference to TWO types of steel. **4**

Question 32 continues on page 33

Question 32 (continued)

Answer parts (c) and (d) of the question on pages 5–8 of the Section II Writing Booklet. Start each part of the question on a new page.

(c) (i) The equipment in the photograph was used in an attempt to plate a metal spoon with magnesium using an electrolytic cell containing a solution of magnesium sulfate. **3**



Draw a labelled scientific diagram of the electrolytic cell. Include the cathode, anode, direction of electron flow and polarity of the electrodes.

(ii) Explain how Davy's work increased our understanding of electron transfer reactions. **3**

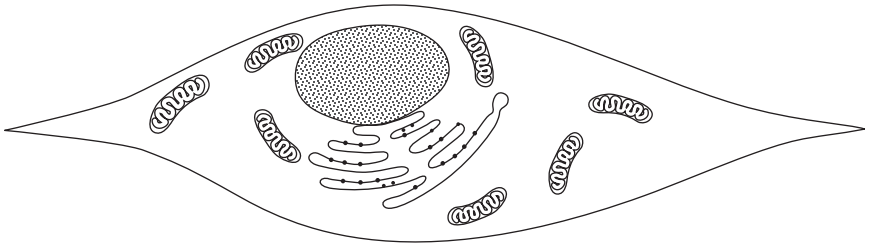
(d) Two identical ships are sunk in seawater. One is sunk in shallow water (60 m) and the other in deep water (4000 m). Explain how the rusting processes differ in these two ships. Include equations in your answer. **7**

End of Question 32

Question 33 — The Biochemistry of Movement (25 marks)

Answer parts (a) and (b) of the question on pages 2–4 of the Section II Writing Booklet. Start each part of the question on a new page.

(a) (i) A simplified diagram of a muscle cell is shown. **2**



Identify the TWO components of the cell that are involved in respiration AND the type of respiration that occurs in each.

(ii) Explain the biological significance of adenosine triphosphate (ATP) with reference to its structure. **3**

(b) (i) Describe a reliable and valid procedure that can be carried out to demonstrate the effect of changing temperature on enzyme function. **3**

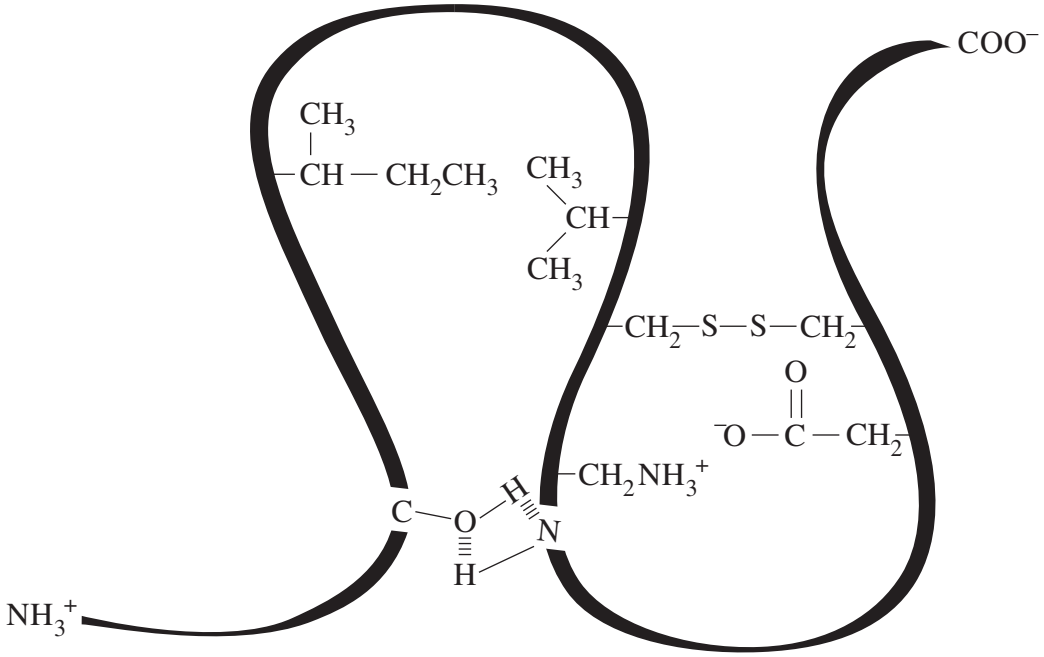
(ii) Discuss the use of models in understanding how enzymes function in living systems. **4**

Question 33 continues on page 35

Question 33 (continued)

Answer parts (c) and (d) of the question on pages 5–8 of the Section II Writing Booklet. Start each part of the question on a new page.

(c) A section of a protein is shown.



(i) Using TWO examples from the diagram, explain how bonding between sections of the protein chain influences its shape. **3**

(ii) With reference to the diagram, account for ways in which this protein may be denatured. **3**

(d) Compare the metabolic pathways involved in sprinting with those involved when walking at a gentle pace. **7**

End of Question 33

Question 34 — The Chemistry of Art (25 marks)

Answer parts (a) and (b) of the question on pages 2–4 of the Section II Writing Booklet. Start each part of the question on a new page.

(a) (i) Identify the chemical composition of a cosmetic used in an ancient culture and identify the potential health risk associated with the use of the cosmetic. **2**

(ii) Explain why $Cr^{2+}(aq)$ is coloured whereas $Zn^{2+}(aq)$ is not coloured. **3**

(b) An investigation is to be conducted to observe the flame colour of some metal ions.

(i) Describe a safe and valid procedure that can be used to carry out this investigation, identifying the specific metal ions observed. **3**

(ii) Explain why only certain metal ions can be identified using flame colours, naming ONE metal ion that cannot be identified using flame colours. **4**

Question 34 continues on page 37

Question 34 (continued)

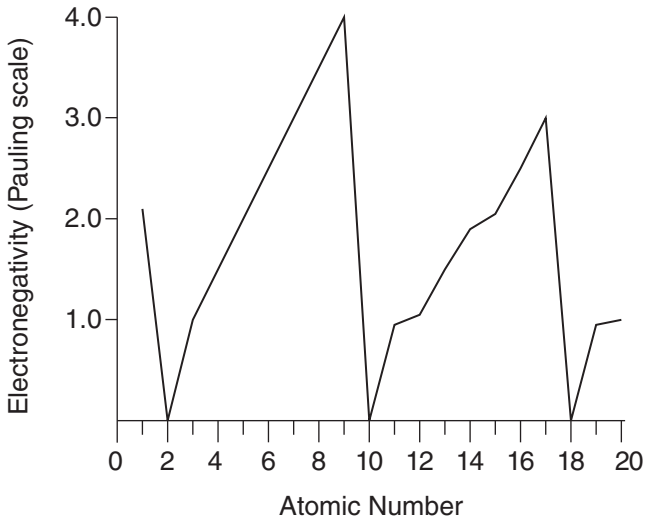
Answer parts (c) and (d) of the question on pages 5–8 of the Section II Writing Booklet. Start each part of the question on a new page.

(c) (i) The first ionisation energy of each of the elements in the third row of the Periodic Table is given. **3**

Element	Na	Mg	Al	Si	P	S	Cl	Ar
First ionisation energy ($kJ\ mol^{-1}$)	494	736	577	786	1060	1000	1260	1520

Use the data in the table to explain how the first ionisation energy of these elements can provide evidence for the existence of sub-shells in atoms.

(ii) The graph shows the electronegativity values for elements in Periods 1, 2 and 3 of the Periodic Table.



Use the graph to explain the relationship between the arrangement of electrons in an element and its electronegativity. **3**

(d) Assess how the Bohr model of the atom has contributed to our understanding of atomic structure, making reference to emission spectra. **7**

End of Question 34

Question 35 — Forensic Chemistry (25 marks)

Answer parts (a) and (b) of the question on pages 2–4 of the Section II Writing Booklet. Start each part of the question on a new page.

(a) (i) Compare the composition of glycogen with that of cellulose. **2**

(ii) Relate the differences in composition of glycogen and cellulose to their different structures. **3**

(b) (i) Identify the structure of amino acids and describe the relationship between amino acids and proteins. **3**

(ii) Describe a safe and valid procedure that can be used to show the presence of protein in egg white. Include expected results. **4**

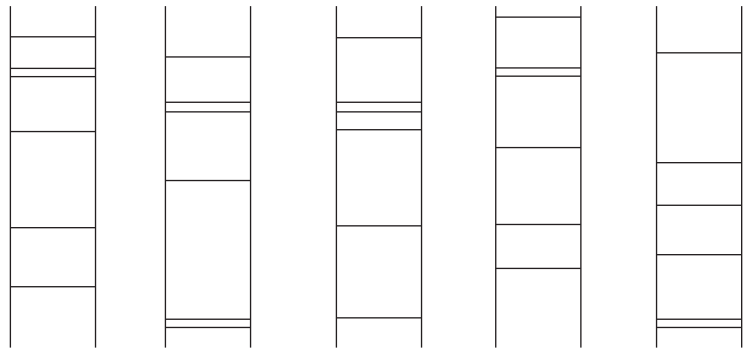
Question 35 continues on page 39

Question 35 (continued)

Answer parts (c) and (d) of the question on pages 5–8 of the Section II Writing Booklet. Start each part of the question on a new page.

(c) (i) George and Linda have one child together. Each of them also has one child from a previous relationship. A schematic representation of their DNA profiles is shown below. **3**

DNA profiles obtained from George, Linda and the three children



Use the information in the DNA profiles to identify the relationships of Child A, Child B and Child C to George and Linda. Justify your answer.

(ii) Describe the benefits of maintaining DNA data banks. **3**

(d) Name ONE chromatography technique and assess its use in the analysis of forensic evidence. **7**

End of paper

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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

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

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

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

PERIODIC TABLE OF THE ELEMENTS

KEY

Atomic Number	79
Symbol	Au
Standard Atomic Weight	197.0
Name	Gold

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 65.38 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 87.61 Strontium	39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.96 Molybdenum	43 Tc 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 183.9 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 Polonium	85 At Astatine	86 Rn Radon
87 Fr Francium	88 Ra Radium	89–103 Actinoids	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Ds Darmstadtium	111 Rg Roentgenium	112 Cn Copernicium						

Lanthanoids

57 La 138.9 Lanthanum	58 Ce 140.1 Cerium	59 Pr 140.9 Praseodymium	60 Nd 144.2 Neodymium	61 Pm 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 173.1 Ytterbium	71 Lu 175.0 Lutetium

Actinoids

89 Ac Actinium	90 Th 232.0 Thorium	91 Pa 231.0 Protactinium	92 U 238.0 Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium

Elements with atomic numbers 113 and above have been reported but not fully authenticated.

Standard atomic weights are abridged to four significant figures.

Elements with no reported values in the table have no stable nuclides.

The International Union of Pure and Applied Chemistry Periodic Table of the Elements (February 2010 version) is the principal source of data. Some data may have been modified.