BOARD OF STUDIES
NEW SOUTH WALES

2012

HIGHER SCHOOL CERTIFICATE EXAMINATION

Chemistry

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black or blue pen
  Black pen is preferred
- 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
- Write your Centre Number and Student Number at the top of pages 9, 11, 13, 17, 19 and 23

Total marks – 100

Section I Pages 2–25

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 21–33
- Allow about 1 hour and 40 minutes for this part

Section II Pages 27–38

25 marks

- Attempt ONE question from Questions 34–38
- 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 Which of the following is a measure of the clarity of water?

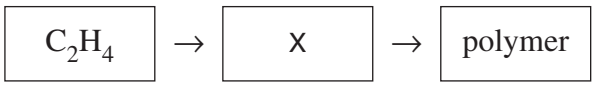
(A) Hardness

(B) Turbidity

(C) Total dissolved solids

(D) Biochemical oxygen demand

2



Which of the following compounds is represented by X in the flowchart?

(A) Cellulose

(B) Ethanol

(C) Glucose

(D) Styrene

3 What effect does a catalyst have on a reaction?

(A) It increases the rate.

(B) It increases the yield.

(C) It increases the heat of reaction.

(D) It increases the activation energy.

4 Which pieces of glassware should be used when preparing a primary standard solution?

(A) Pipette, burette and conical flask

(B) Dropper, watch glass and pipette

(C) Beaker, filter funnel and volumetric flask

(D) Measuring cylinder, stirring rod and conical flask

5 Which of the following is a balanced equation representing the fermentation of glucose?

(A) $C_6H_{12}O_6(aq) \rightarrow 2C_3H_6O_3(aq)$

(B) $C_6H_{12}O_6(aq) \rightarrow 2C_2H_5OH(aq) + 2CO_2(g)$

(C) $C_6H_{12}O_6(aq) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l)$

(D) $C_6H_{12}O_6(aq) + 3O_2(g) \rightarrow C_2H_5OH(aq) + 4CO_2(g) + 3H_2O(l)$

6 Cobalt-60 is produced according to the equation:

$$^{59}_{27}\text{Co} + ^{1}_{0}\text{n} \rightarrow ^{60}_{27}\text{Co}$$

Where would a commercial quantity of cobalt-60 be produced?

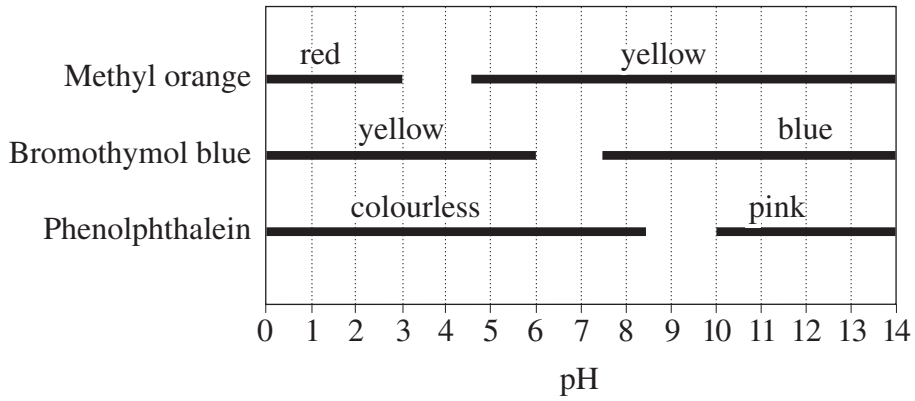
(A) Cyclotron

(B) Scintillator

(C) Nuclear reactor

(D) Particle accelerator

7 Methyl orange, bromothymol blue and phenolphthalein indicators were mixed together to form a solution.



Over what pH range would the solution be yellow?

(A) 0 – 14

(B) 3 – 4.5

(C) 3 – 7.5

(D) 4.5 – 6

8 Which acid / base pair could act as a buffer?

(A) H_3O^+ / H_2O

(B) H_2O / OH^-

(C) HNO_3 / NO_3^-

(D) $H_2PO_4^- / HPO_4^{2-}$

9 Which of the following contains a coordinate covalent bond?

(A) NH_3

(B) NH_4^+

(C) H_2O

(D) OH^-

10 Samples of a solution of barium nitrate were independently tested with chloride ions, with sulfate ions and also for flame colour.

Which row of the following table would represent the results?

	Chloride	*Sulfate*	*Flame test*
(A)	No precipitate	No precipitate	Red
(B)	No precipitate	Precipitate	Green
(C)	Precipitate	Precipitate	Green
(D)	Precipitate	No precipitate	Red

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

Which solution has the highest pH?

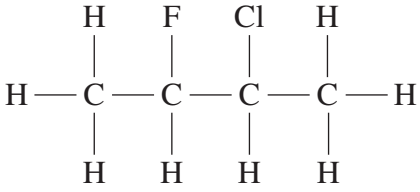
(A) Citric acid

(B) Acetic acid

(C) Hydrochloric acid

(D) The pH of the three solutions is the same.

12 What is the correct IUPAC name for the following compound?



(A) 2-chloro-2-fluorobutane

(B) 2-fluoro-3-chlorobutane

(C) 3-fluoro-2-chlorobutane

(D) 3-chloro-2-fluorobutane

Use the information provided to answer Questions 13 and 14.

This equation represents a common redox reaction.

$$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6Fe^{2+}(aq) \rightarrow 2Cr^{3+}(aq) + 6Fe^{3+}(aq) + 7H_2O(l)$$

13 What is the oxidising agent in the reaction?

(A) H^+

(B) Cr^{3+}

(C) Fe^{2+}

(D) $Cr_2O_7^{2-}$

14 What is the value of $E^{\ominus}_{cell}$ for the reaction?

(A) 0.59 V

(B) 0.92 V

(C) 1.90 V

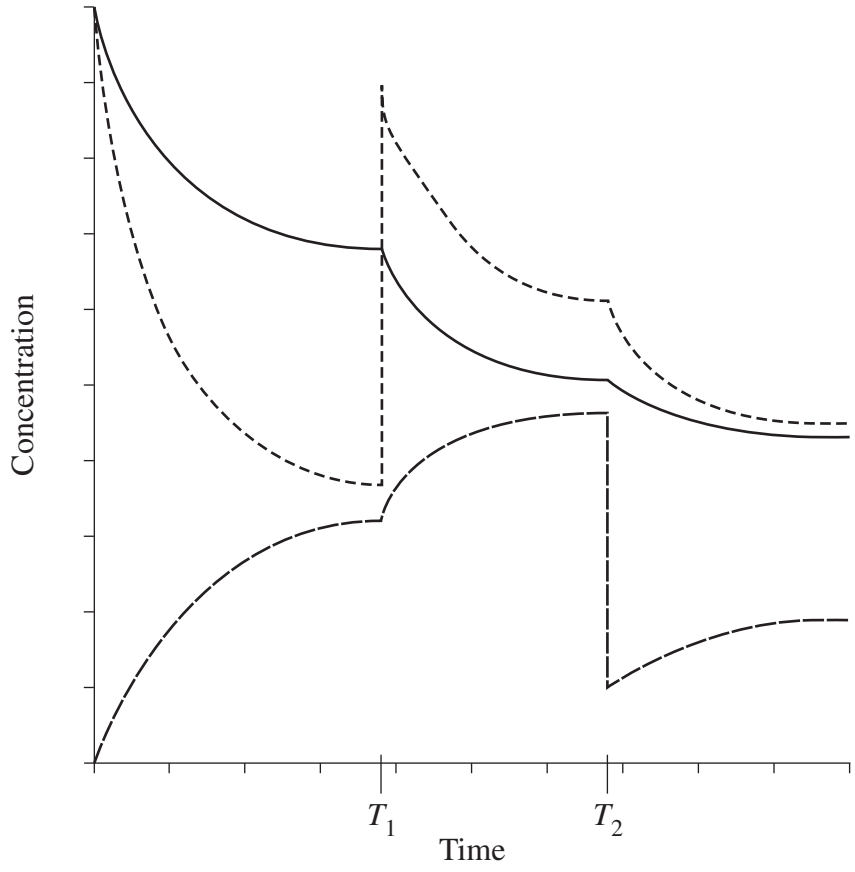
(D) 2.13 V

15 In which row of the following table are the listed oxides correctly classified?

	Acidic	*Basic*	*Neutral*	*Amphoteric*
(A)	CO_2	Na_2O	SO_3	Al_2O_3
(B)	Na_2O	CO_2	H_2O	Al_2O_3
(C)	CO_2	MgO	H_2O	ZnO
(D)	SO_2	K_2O	CO	CO_2

16 The graph shows the concentrations over time for the system:

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



What has happened at times T_1 and T_2?

	T_1	T_2
(A)	H_2 added	CH_3OH removed
(B)	CO added	CH_3OH removed
(C)	H_2 added	CO removed
(D)	CO added	CO and H_2 removed

17 The heat of combustion of propan-1-ol is 2021 kJ mol^{-1}. Combustion takes place according to the equation:

$$2C_3H_7OH(l) + 9O_2(g) \rightarrow 6CO_2(g) + 8H_2O(l)$$

What mass of water is formed when 1530 kJ of energy is released?

(A) 3.4 g

(B) 14 g

(C) 55 g

(D) 144 g

18 Which of the following changes take place when 50 mL of water is added to 50 mL of 0.1 mol L^{-1} acetic acid?

	pH	*Degree of ionisation*
(A)	Increase	Decrease
(B)	Decrease	Increase
(C)	Increase	Increase
(D)	Decrease	Decrease

19 What mass of anhydrous sodium carbonate is required to neutralise 100.0 mL of 0.500 mol L^{-1} acetic acid?

(A) 2.65 g

(B) 5.30 g

(C) 10.6 g

(D) 53.0 g

20 All the lead ions present in a 50.0 mL solution were precipitated by reaction with excess chloride ions. The mass of the dried precipitate was 0.595 g.

What was the concentration of lead in the original solution?

(A) 8.87 g L^{-1}

(B) 10.2 g L^{-1}

(C) 11.9 g L^{-1}

(D) 16.0 g L^{-1}

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Chemistry

Centre Number

Student Number

Section I (continued)

Part B – 55 marks
Attempt Questions 21–33
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.

Question 21 (4 marks)

(a) Write a balanced chemical equation, using structural formulae, for the formation of ethyl butanoate. **2**

(b) Common safety precautions in school laboratories include the use of safety glasses, gloves and lab coats. Justify the use of another safety precaution specifically required to safely make ethyl butanoate. **2**

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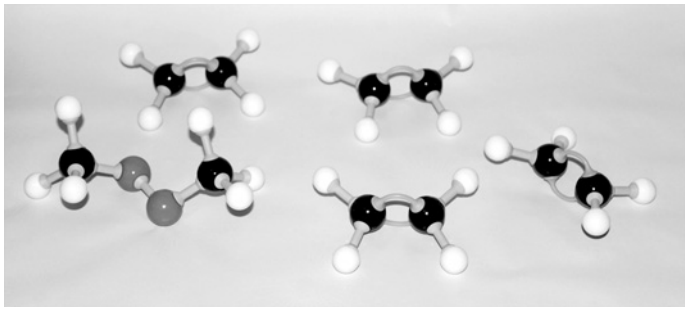
Question 22 (3 marks)

A student created the following models to demonstrate a chemical process.

I



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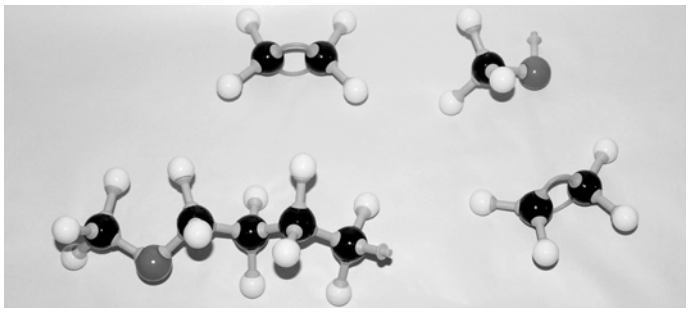

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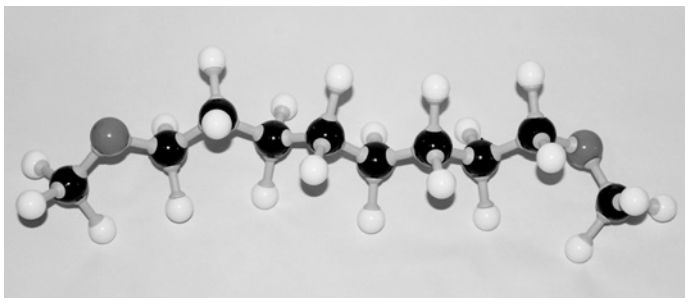

(a) What is the chemical process being modelled? **1**

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(b) Why are models such as these useful? **2**

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Centre Number

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Section I – Part B (continued)

Question 23 (3 marks)

Explain the impact of an increase in pressure and an increase in temperature on the solubility of carbon dioxide in water. Include a relevant equation in your answer. **3**

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Question 24 (3 marks)

Explain why ammonia is such an important raw material in industry today. **3**

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Section I – Part B (continued)

Question 25 (3 marks)

Describe the process of monitoring waterways for eutrophication. **3**

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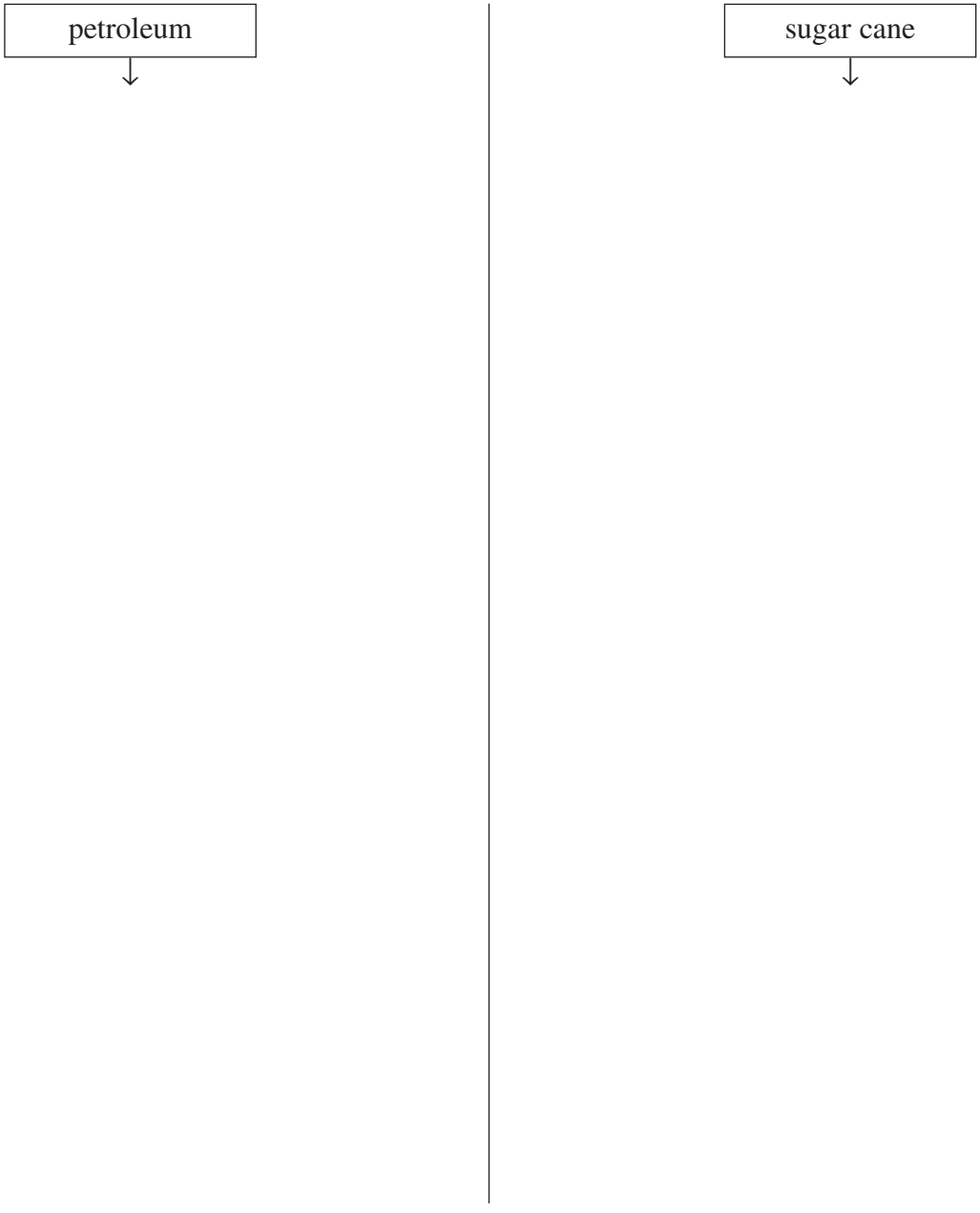
Question 26 (8 marks)

Petroleum and sugar cane are both raw materials used for the production of ethanol.

(a) Construct separate flow diagrams for the production of ethanol from each raw material. **5**



Question 26 continues on page 15

(b) Compare the environmental sustainability of producing ethanol from these two raw materials. **3**

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End of Question 26

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Question 27 (3 marks)

Iodine-131 decays through both beta and gamma emission. Iodine-123 decays through gamma emission only.

(a) Iodine-131 is used for diagnosis and therapy whereas Iodine-123 is used only for diagnosis. **2**

	beta emission	gamma emission
Emitted particle	electron	gamma-ray
Ability to pass through biological tissue	low	high

With reference to the information and the table, justify the different uses of these two radioisotopes.

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(b) Write the equation representing the decay of Iodine-131 by beta emission. **1**

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Question 28 (3 marks)

A solution was made by mixing 75.00 mL of 0.120 mol L^{-1} hydrochloric acid with 25.00 mL of 0.200 mol L^{-1} sodium hydroxide. **3**

What is the pH of the solution?

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Centre Number

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Section I – Part B (continued)

Question 29 (5 marks)

Draw a labelled diagram to show the layered structure of the atmosphere. In your diagram include: **5**

- the names of TWO atmospheric pollutants, positioned in the layers where the detrimental impact occurs
- the names of the sources of the two pollutants identified.

Question 30 (6 marks)

A chemist analysed aspirin tablets for quality control. The initial step of the analysis was the standardisation of a NaOH solution. Three 25.00 mL samples of a 0.1034 mol L^{-1} solution of standardised HCl were titrated with the NaOH solution. The average volume required for neutralisation was 25.75 mL.

(a) Calculate the molarity of the NaOH solution. **2**

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Three flasks were prepared each containing a mixture of 25 mL of water and 10 mL of ethanol. An aspirin tablet was dissolved in each flask. The aspirin in each solution was titrated with the standardised NaOH solution according to the following equation:

$$C_9H_8O_4(aq) + NaOH(aq) \rightarrow C_9H_7O_4Na(aq) + H_2O(l)$$

The following titration results were obtained.

Tablet	*Volume* (mL)
1	16.60
2	16.50
3	16.55

(b) (i) Calculate the average mass (mg) of aspirin per tablet. **3**

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(ii) Why was it necessary to include the ethanol in the mixture? **1**

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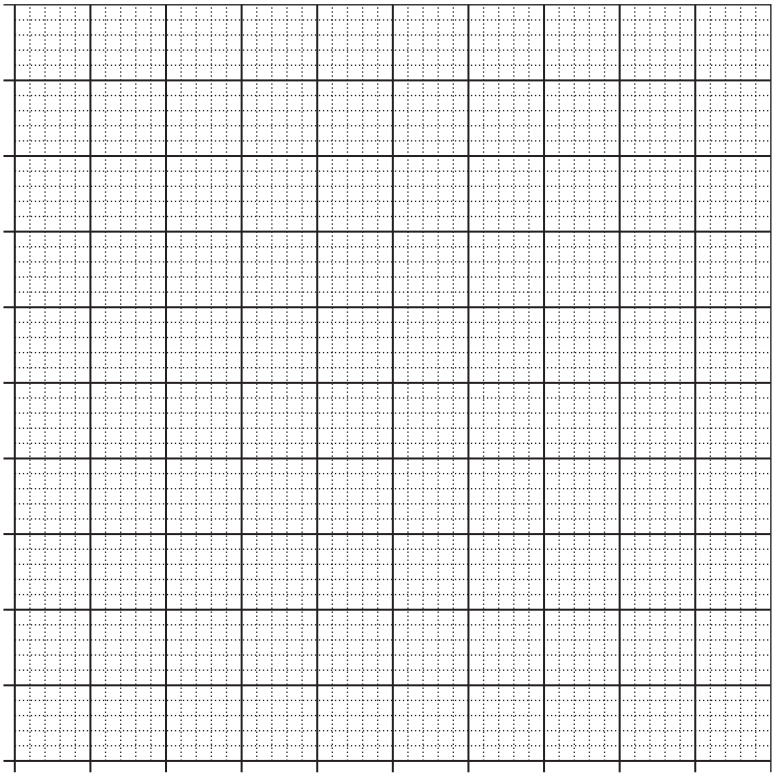
Question 31 (5 marks)

The boiling points of some alkanols are given in the table.

Alkanol	*Boiling point* (°C)
Methanol	65
Ethanol	79
Propan-1-ol	97
Pentan-1-ol	138
Hexan-1-ol	157
Heptan-1-ol	176

(a) Using the data provided, construct a graph that shows the relationship between carbon chain length and boiling point. **3**



(b) Using the graph, predict the boiling point of butan-1-ol. **1**

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(c) What is the intermolecular force responsible for the trend shown in the graph? **1**

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Centre Number

Student Number

Section I – Part B (continued)

Question 32 (3 marks)

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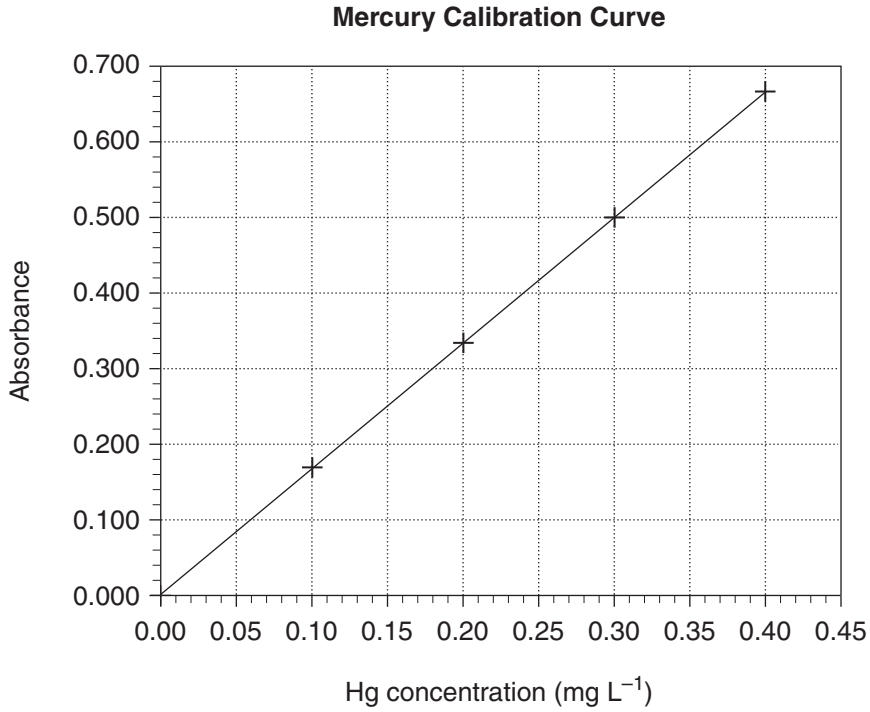
Question 32 (3 marks)

The mercury concentration of a certain fish species was determined by atomic absorption spectroscopy. The sample data are: **3**

Mass of fish (g)	18.6
Final sample volume (mL)	25.0
Absorbance (mean)	0.280



A consumer wants to avoid eating fish with a mercury concentration greater than 0.5 mg/kg of fish.

Calculate the concentration of mercury in the fish sample and state whether the consumer can eat this fish species.

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Question 33 (6 marks)

Chemists can assist in reversing or minimising the environmental problems caused by technology and the human demand for products and services. **6**

With reference to this statement, assess the need for chemists to collaborate when monitoring the environmental impact of a named electrochemical cell.

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Chemistry

Section II

25 marks
Attempt ONE question from Questions 34–38
Allow about 45 minutes for this section

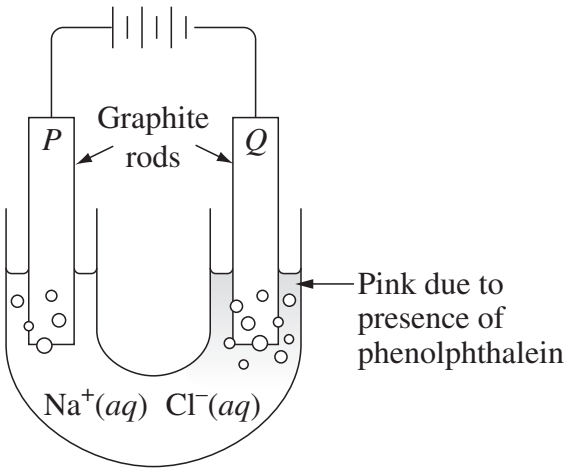
Answer parts (a)–(c) of the question in Section II Answer Booklet 1.
Answer parts (d)–(e) of the question in Section II Answer Booklet 2.
Extra writing booklets are available.

Show all relevant working in questions involving calculations.

Question 34 — Industrial Chemistry (25 marks)

Answer parts (a)–(c) in Section II Answer Booklet 1.

(a) The following equipment was set up and the reaction allowed to proceed. Gases were produced at both electrodes. **3**



Name this process and identify the gas at each electrode.

(b) The equilibrium constant expression for a gaseous reaction is as follows:

$$K = \frac{[N_2][O_2]}{[NO]^2}$$

(i) Write the equation for this reaction. **1**

(ii) 0.400 moles of NO was placed in a 1.00 L vessel at 2000°C. The equilibrium concentration of N_2 was found to be 0.198 mol L^{-1}. **3**

Calculate the equilibrium constant for this reaction and use this value to describe the position of the equilibrium.

(iii) What could be changed that would result in a different value of K for this equilibrium? **1**

Question 34 continues on page 29

Question 34 (continued)

(c) The production of sulfuric acid is shown.

$$S(s) \longrightarrow SO_2(g) \longrightarrow SO_3(g) \longrightarrow \boxed{\text{oleum}} \longrightarrow H_2SO_4(l)$$

(i) Describe the production of oleum and its conversion to concentrated sulfuric acid. Include chemical equations in your answer. **3**

(ii) SO_3 can react with water to produce a solution of H_2SO_4. **2**

Why is it essential to convert SO_3 to oleum before the formation of H_2SO_4?

Answer parts (d)–(e) in Section II Answer Booklet 2.

(d) (i) Outline how one of the steps involved in the Solvay process can be chemically modelled in the school laboratory. Include a balanced chemical equation in your answer. **3**

(ii) Identify ONE risk factor and ONE difficulty associated with the laboratory modelling of the step. **2**

(e) Initially soap was the only product of the surfactant industry. Due to societal pressures and chemical developments, production in this industry has evolved to include a wide range of products. **7**

Account for these changes over time with reference to the structure and uses of surfactants.

End of Question 34

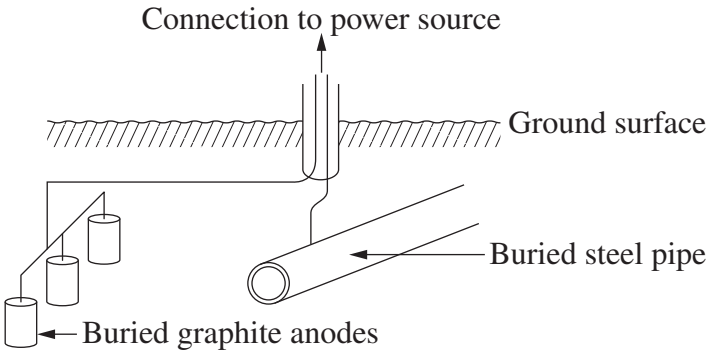
Question 35 — Shipwrecks, Corrosion and Conservation (25 marks)

Answer parts (a)–(c) in Section II Answer Booklet 1.

(a) A sealed container transporting a recently recovered artefact is damaged, allowing seawater to escape while appearing to leave the artefact intact. **3**

Why would the loss of seawater be of concern to the maritime archaeologists receiving the artefact?

(b) The diagram illustrates one method of protecting a steel pipe.



(i) Explain how this method works. **3**

(ii) Suggest an alternative way the pipe can be chemically protected. Use half-equations to support your answer. **2**

Question 35 continues on page 31

(c) Corrosion in some wrecks can be represented in part by the following half-equation.

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

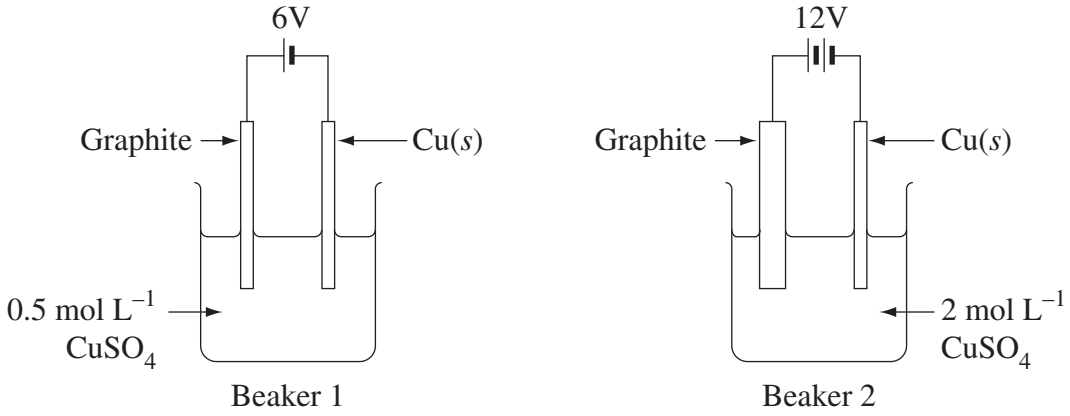
(i) Under what conditions would this process occur naturally? **2**

(ii) These conditions were simulated in a laboratory by placing a piece of steel in an appropriate solution. The amount of hydrogen sulfide produced was monitored over time. **3**

Calculate the loss of iron, in grams, from the piece of steel if 0.76 g of hydrogen sulfide was produced. Include a balanced equation in your answer.

Answer parts (d)–(e) in Section II Answer Booklet 2.

(d) A student set up the following two beakers to investigate factors affecting electrolysis.



(i) Why is this investigation not valid? **1**

(ii) Draw diagrams to show how this investigation should be carried out to accurately identify TWO factors affecting electrolysis. Indicate the expected results on your diagrams. **4**

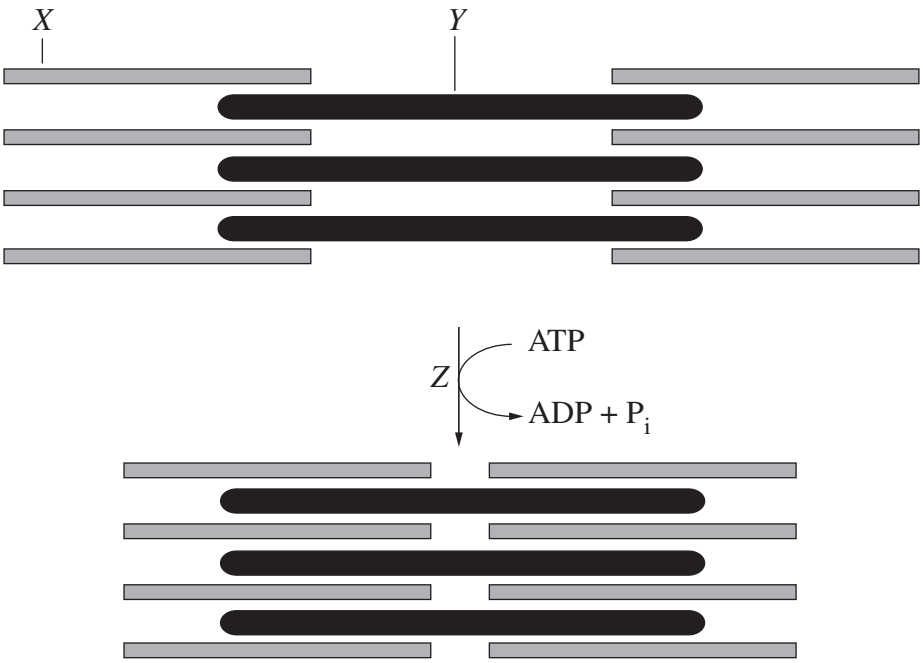
(e) Critically evaluate the continued use of steel in ship building with reference to the history of ocean-going vessels, the composition of steel and ways in which its interaction with the environment can be controlled. **7**

End of Question 35

Question 36 — The Biochemistry of Movement (25 marks)

Answer parts (a)–(c) in Section II Answer Booklet 1.

(a) The diagram illustrates schematically the current model of muscle contraction. **3**



Name protein *X*, protein *Y* and metal ion *Z*.

(b) (i) Provide the general formula for a fatty acid. **1**

(ii) Provide the structural formula for glycerol. **1**

(iii) Account for the difference in the aqueous solubility of glycerol compared to that of fatty acids and triacylglycerols (TAGs). **3**

Question 36 continues on page 33

Question 36 (continued)

(c) (i) Why do fats have a greater energy density than carbohydrates? **1**

(ii) Carbohydrates and fats have parts of their oxidative metabolic pathways in common. **4**

Use a flow diagram to outline the main stages of the aerobic metabolism of fats and carbohydrates.

In your diagram clearly identify:

- separate pathways
- common pathway
- stage where most of the ATP is produced
- stage where most of the carbon dioxide is released.

Answer parts (d)–(e) in Section II Answer Booklet 2.

(d) (i) Compare the forces and bonds that determine the level of structure in proteins. **3**

(ii) How is the secondary structure of proteins affected by changes in pH? **2**

(e) Compare and contrast the aerobic and anaerobic metabolism of glucose within the context of muscle function during different forms of exercise and the relative amounts of energy released. **7**

End of Question 36

Question 37 — The Chemistry of Art (25 marks)

Answer parts (a)–(c) in Section II Answer Booklet 1.

(a) The formulae of three coordination complexes are shown.

$[Mn(H_2O)_6]^{2+}$

$[Mn(NH_3)_2(H_2O)_3OH]^{2+}$

$[Mn(CO)_4NO]$

(i) What is the oxidation state of manganese in $[Mn(NH_3)_2(H_2O)_3OH]^{2+}$? **1**

(ii) Draw a Lewis structure of ONE of these coordination complexes, and describe the bonding in this molecule. **2**

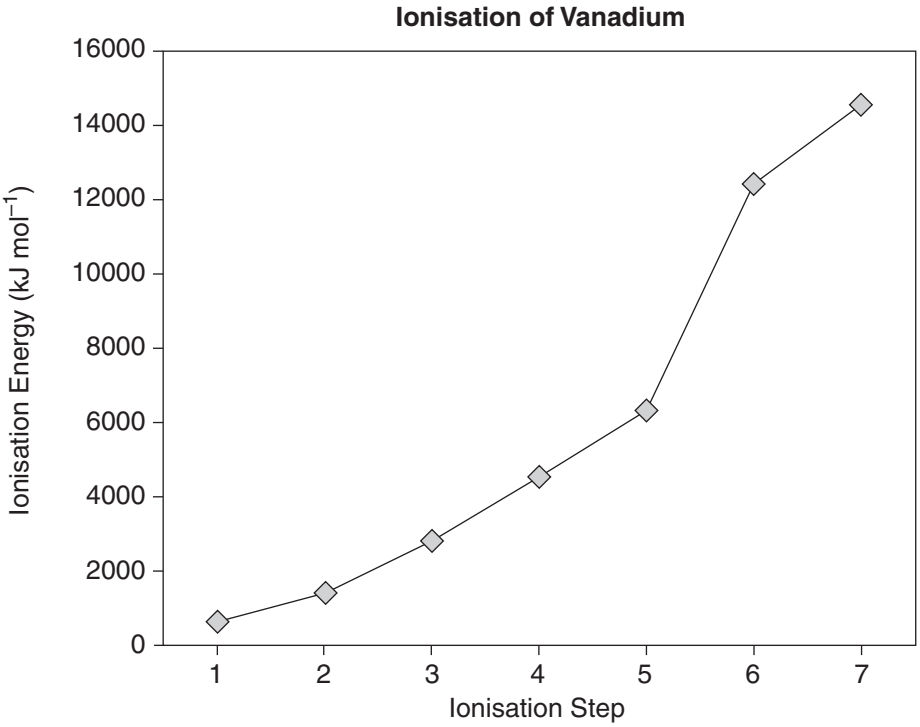
(b) (i) Why has copper sulfate pentahydrate ($CuSO_4 \cdot 5H_2O$), with its strong blue colour, not been used as a pigment? **2**

(ii) Describe a named process that can be used to attach pigments to surfaces. **3**

Question 37 continues on page 35

Question 37 (continued)

(c) The ionisation energies of vanadium are shown in the graph.



Explain the relationship between ionisation energy and the arrangement of electrons in the vanadium atom. **5**

Answer parts (d)–(e) in Section II Answer Booklet 2.

(d) (i) Describe an experiment that could be performed to relate the colour of iron solutions to the electronic configuration of iron ions, if the supplied salt is iron(II) chloride crystals. **3**

(ii) Write the electronic configuration of Fe^{2+} and Fe^{3+}. **2**

(e) Evaluate the contribution of the Bohr model to the development of our understanding of the structure of the atom. **7**

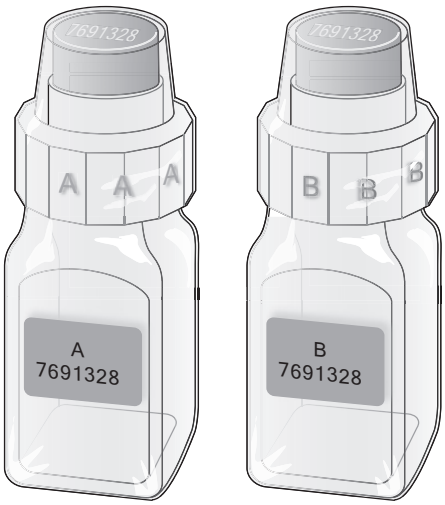
End of Question 37

Question 38 — Forensic Chemistry (25 marks)

Answer parts (a)–(c) in Section II Answer Booklet 1.

(a) Describe how the different characteristics of a soil sample would allow forensic chemists to trace its origin. **3**

(b) An athlete is required to give two urine samples. Sample A is tested for evidence of substances on the banned substance list. If a banned substance is detected in Sample A then Sample B is tested. If both samples are positive for a banned substance then the athlete is asked to explain the findings at a court hearing.



(i) Describe what precautions should be undertaken to ensure that the evidence collected for this purpose is accepted by the court. **3**

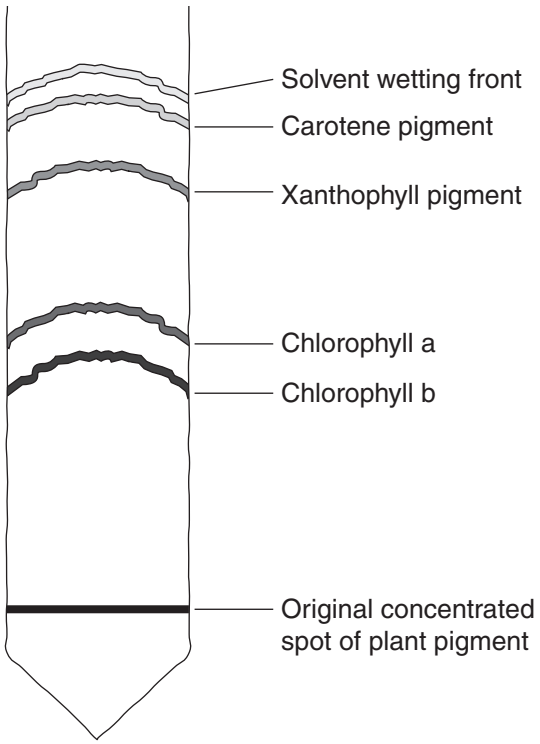
(ii) New technology is constantly required in forensic chemistry to keep up with drug cheats or improve the outcomes of a criminal investigation. **2**

Outline how recent advances in technology could have altered the outcome of a specific case.

Question 38 continues on page 37

Question 38 (continued)

(c) The diagram shows the separation of plant pigments by chromatography using hexane as a solvent.



(i) State which of the pigments is the least polar and justify your choice. **2**

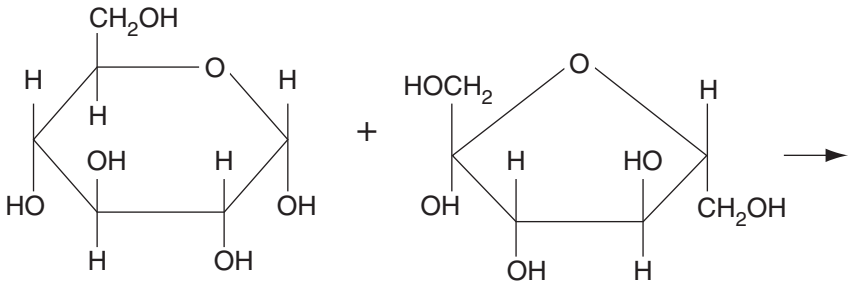
(ii) Explain how changing the solvent would affect the separation process. **3**

Question 38 continues on page 38

Question 38 (continued)

Answer parts (d)–(e) in Section II Answer Booklet 2.

(d) Sucrose is a carbohydrate composed of fructose and glucose.



α-glucose β-fructose

(i) Complete the structural equation for the formation of sucrose. **2**

(ii) Outline a chemical test that could be performed to distinguish between sucrose and the monomers fructose and glucose. Include a chemical equation in your answer. **3**

(e) Analyse how modern techniques utilise the features of DNA and manipulate it to successfully generate an individual's DNA profile. **7**

End of paper

DATA SHEET

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

Volume of 1 mole ideal gas: at 100 kPa and

at 0°C (273.15 K) ..... 22.71 L

at 25°C (298.15 K) ..... 24.79 L

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

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

Some useful formulae

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

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.