BOARD OF STUDIES
NEW SOUTH WALES

2008

HIGHER SCHOOL CERTIFICATE EXAMINATION

Chemistry

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black or blue pen
- Draw diagrams using pencil
- Board-approved calculators may be used
- 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, 15, 17 and 21

Total marks – 100

Section I Pages 2–23

75 marks

This section has two parts, Part A and Part B

Part A – 15 marks

- Attempt Questions 1–15
- Allow about 30 minutes for this part

Part B – 60 marks

- Attempt Questions 16–28
- Allow about 1 hour and 45 minutes for this part

Section II Pages 25–35

25 marks

- Attempt ONE question from Questions 29–33
- Allow about 45 minutes for this section

Section I
75 marks

Part A – 15 marks
Attempt Questions 1–15
Allow about 30 minutes for this part

Use the multiple-choice answer sheet for Questions 1–15.

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1 Which of the following radiations is measured with a Geiger counter?

(A) Beta

(B) Infrared

(C) Microwave

(D) Ultraviolet

2 What are the volumes of one mole of argon, Ar, and one mole of fluorine, F_2, at 0°C and 100 kPa?

	Volume (litres)	
	Ar	F_2
(A)	12.40	24.79
(B)	22.71	22.71
(C)	22.71	45.42
(D)	24.79	24.79

3 Which term describes the relationship between oxygen and ozone?

(A) Allotropes

(B) Conjugates

(C) Isomers

(D) Isotopes

4 What is the main constituent of the atmosphere at ground level?

(A) Water

(B) Oxygen

(C) Nitrogen

(D) Carbon dioxide

5 Why is ethanol used in preference to water as the main ingredient of perfume?

(A) Ethanol is cheaper to produce.

(B) Ethanol has no detectable odour.

(C) Ethanol dissolves esters more readily.

(D) Ethanol has a significantly lower density.

6 What is the specific heat of a compound?

(A) The quantity of heat required to boil 1 g of the compound

(B) The quantity of heat required to melt 1 g of the compound

(C) The quantity of heat required to increase the temperature of the compound by 1°C

(D) The quantity of heat required to increase the temperature of 1 g of the compound by 1°C

7 Which of the following changes will always shift this equilibrium reaction to the right?

$$2HI(g) \rightleftharpoons H_2(g) + I_2(g) \qquad \Delta H = -52 \text{ kJ}$$

(A) Adding a catalyst

(B) Increasing the pressure

(C) Increasing the temperature

(D) Adding more of the reactant

8 According to the Arrhenius theory of acids and bases, an acid is a substance that

(A) tastes sour.

(B) is capable of donating a hydrogen ion.

(C) can accept a pair of electrons to form a co-ordinate covalent bond.

(D) increases the concentration of hydrogen ions in an aqueous solution.

9 Which of the following lower atmosphere pollutant gases is produced directly by the smelting of mineral ores?

(A) Carbon monoxide

(B) Nitrogen dioxide

(C) Ozone

(D) Sulfur dioxide

10 The molar heat of combustion of ethanol is 1367 kJ mol^{-1}.

What quantity of ethanol must be combusted to raise the temperature of 1.0 kg water from 50°C to boiling point at sea level (assuming no loss of heat to the surroundings)?

(A) 6.5 g

(B) 7.0 g

(C) 209 g

(D) 300 g

11 In which of the following alternatives are the three compounds listed in order of increasing boiling point?

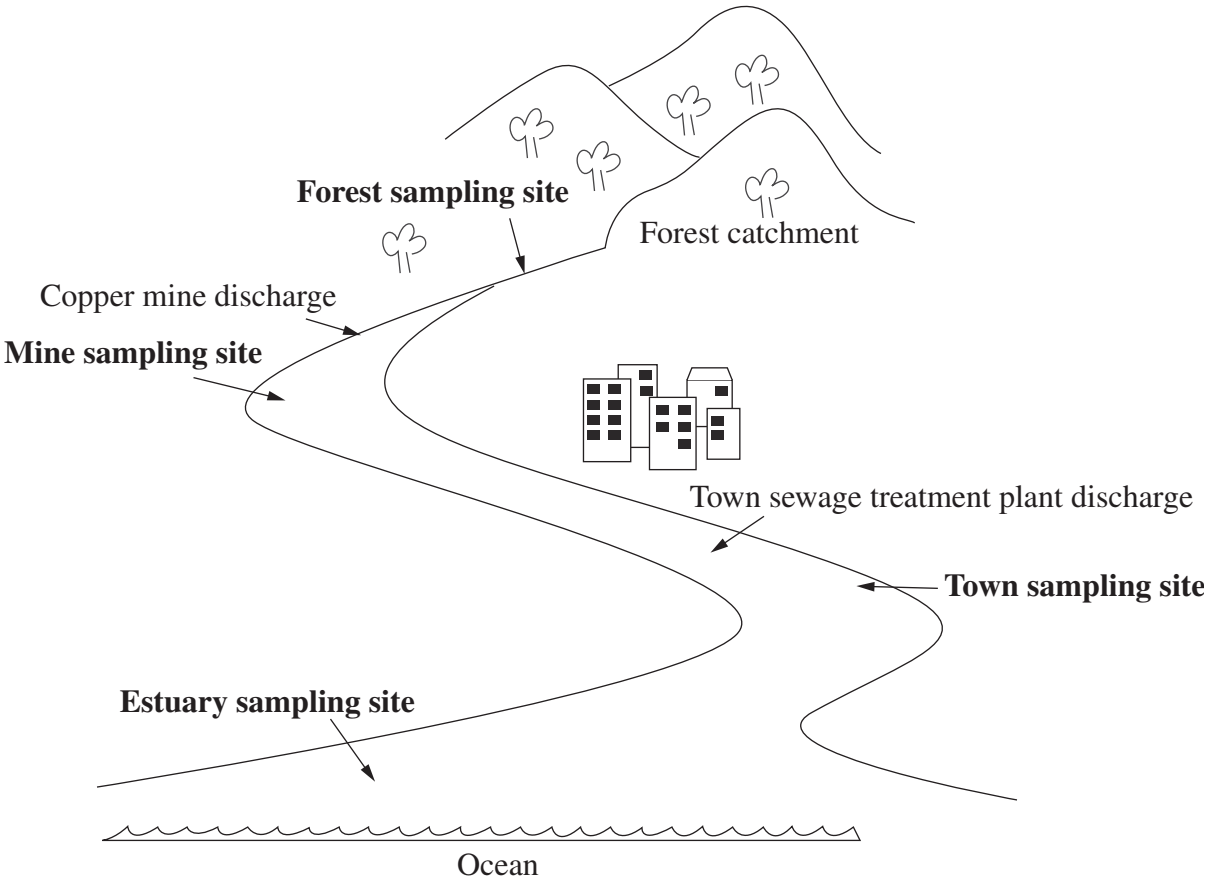
(A) Pentane, butan-1-ol, propanoic acid

(B) Propanoic acid, butan-1-ol, pentane

(C) Propanoic acid, pentane, butan-1-ol

(D) Butan-1-ol, propanoic acid, pentane

12 Samples of water were collected from a river at four different sites: forest, mine, town and estuary.



The results of various analyses of the water samples are shown.

	Site 1	*Site 2*	*Site 3*	*Site 4*
pH	6.8	6.8	7.8	5.9
Total Dissolved Solids (mg/L)	305	85	7600	290
Biochemical Oxygen Demand (mg/L)	32	2	2	3
E. coli (CFU/100 mL)	18	2	2	2

Using the data from the table above identify each of the sampling sites.

	Site 1	*Site 2*	*Site 3*	*Site 4*
(A)	Town	Forest	Estuary	Mine
(B)	Estuary	Forest	Town	Mine
(C)	Mine	Town	Forest	Estuary
(D)	Town	Mine	Estuary	Forest

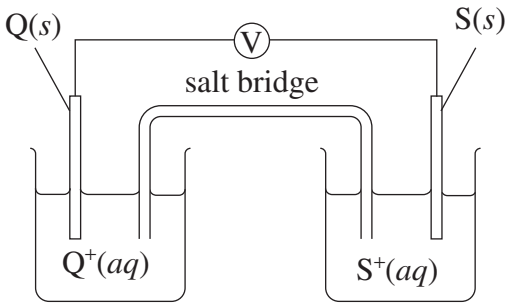
13 Some reactions of the metals Q, R and S are given below.

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

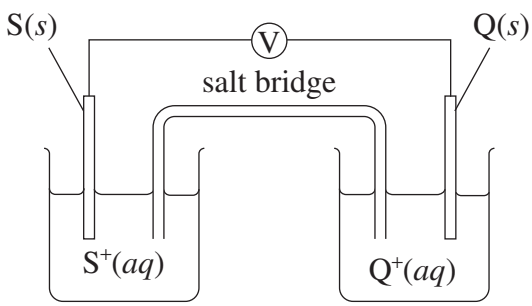
In a galvanic cell, Q^+, R^+ and S^+ would represent cations of these metals.

Which galvanic cell will produce the greatest voltage?

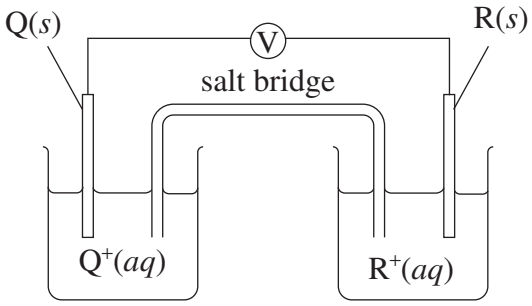
(A)



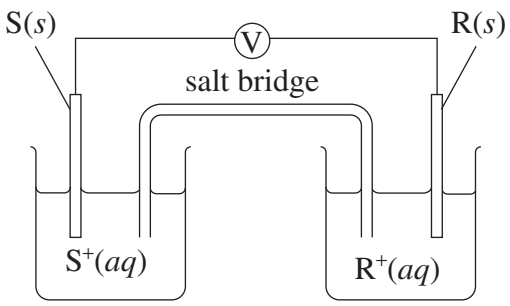
(B)



(C)



(D)



14 20 mL of 0.08 mol L^{-1} HCl is mixed with 30 mL of 0.05 mol L^{-1} NaOH.

What is the pH of the resultant solution?

(A) 1.1

(B) 2.7

(C) 4.0

(D) 7.0

15 A 2.45 g sample of lawn fertiliser was analysed for its sulfate content. After filtration and drying, 2.18 g of barium sulfate was recovered.

What is the % w/w of sulfate in the lawn fertiliser?

(A) 16.8

(B) 36.6

(C) 46.2

(D) 89.0

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Chemistry

Centre Number

Student Number

Section I (continued)

Part B – 60 marks
Attempt Questions 16–28
Allow about 1 hour and 45 minutes for this part

Answer the questions in the spaces provided.

Show all relevant working in questions involving calculations.

Marks

Question 16 (5 marks)

The process of fractional distillation is used to separate crude oil into different fractions. One of the compounds obtained from fractional distillation is $C_{10}H_{22}$.

This compound undergoes catalytic cracking as follows:

$$C_{10}H_{22} \rightarrow C_8H_{18} + C_2H_4$$

(a) Complete the table below to identify the products and the homologous series to which they belong. **2**

	C_8H_{18}	C_2H_4
Name of compound		
Name of series		

(b) Using examples from your first-hand investigation, explain how you distinguished between these two series of compounds. Include a relevant equation in your answer. **3**

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Marks

Question 17 (5 marks)

Using TWO examples, analyse how the features of catchment areas will determine the water treatment necessary to make the water safe to drink. **5**

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Centre Number

Student Number

Section I (continued)

Marks

Question 18 (5 marks)

(a) Draw Lewis electron dot structures for oxygen and ozone. **2**

(b) Account for the differences in the properties of oxygen and ozone on the basis of their molecular structure and bonding. **3**

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Marks

Question 19 (5 marks)

A laboratory assesses the amount of zinc in dietary supplement tablets.

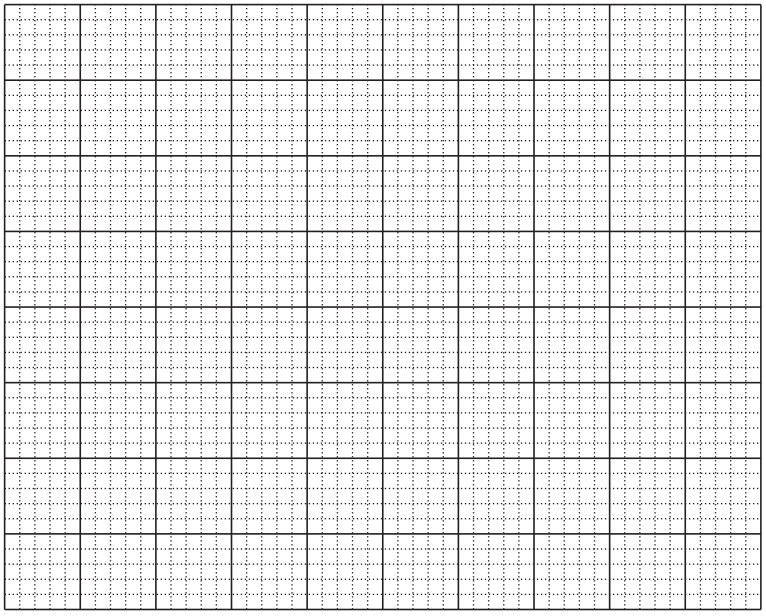
A chemist prepared 4 tablet samples for analysis by dissolving the tablets individually in 10% nitric acid. Each tablet solution was made up to a final volume of 100 mL. Five standard solutions of zinc were also prepared.

The absorbances of the standard and sample solutions were determined by atomic absorption spectroscopy at 213.9 nm.

The results are presented in the table.

Standard zinc solutions (mg L^{-1})	*Absorbance*
0.00	0.000
1.00	0.170
2.00	0.330
3.00	0.503
4.00	0.680
Tablet samples: mean absorbance	0.280

(a) Plot a calibration curve for the standard zinc solutions on the grid. **3**



Question 19 continues on page 13

Question 19 (continued)

(b) Using the mean absorbance of the tablet samples, calculate the mean amount of zinc per tablet in mg. **2**

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End of Question 19

Question 20 (3 marks)

1.22 g of an unknown gas has a volume of 15.0 L at 100 kPa and 25°C.

(a) Calculate the molar mass of the gas. **2**

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(b) Identify the gas. **1**

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Chemistry

Centre Number

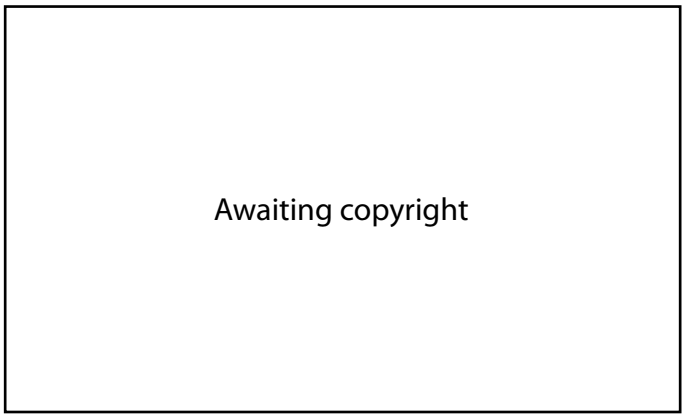
Section I (continued)

Student Number

Marks

Question 21 (4 marks)

The graph shows the concentration of CCl_3F known as CFC-11, as measured at the Cape Grim Baseline Air Pollution Station, in north-western Tasmania.



(a) Explain the changes in concentration of CFC-11 as illustrated by the graph. **2**

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(b) Why is it important to monitor the concentration of CFC-11? **2**

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Marks

Question 22 (5 marks)

The following extract was taken from the website of a leading car manufacturer. **5**

Critically evaluate the extract with reference to ethanol being a 'carbon-neutral' fuel. Support your answer with relevant chemical equations.

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Centre Number

Student Number

Section I (continued)

Marks

Question 23 (4 marks)

Using Le Chatelier's principle, justify the choice of temperature and pressure conditions used to optimise the yield in the Haber process. **4**

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Marks

Question 24 (5 marks)

The table shows four fuels and their various properties.

Property	*Petrol*	*Kerosene*	*Hydrogen*	*Ethanol*
Heat of combustion (kJ mol^{-1})	5460	10 000	285	1370
Boiling point (°C)	126	300	–253	78
Density (g mL^{-1})	0.69	0.78	n/a	0.78
Average molar mass (g mol^{-1})	114	210	2	46

(a) Which fuel provides the greatest amount of energy per gram? **1**

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(b) A car has an 80 L petrol tank. Calculate the energy released by the complete combustion of one full tank of petrol. **2**

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(c) How many litres of hydrogen gas at 25°C and 100 kPa would be needed to supply the same amount of energy as 80 L of petrol? **2**

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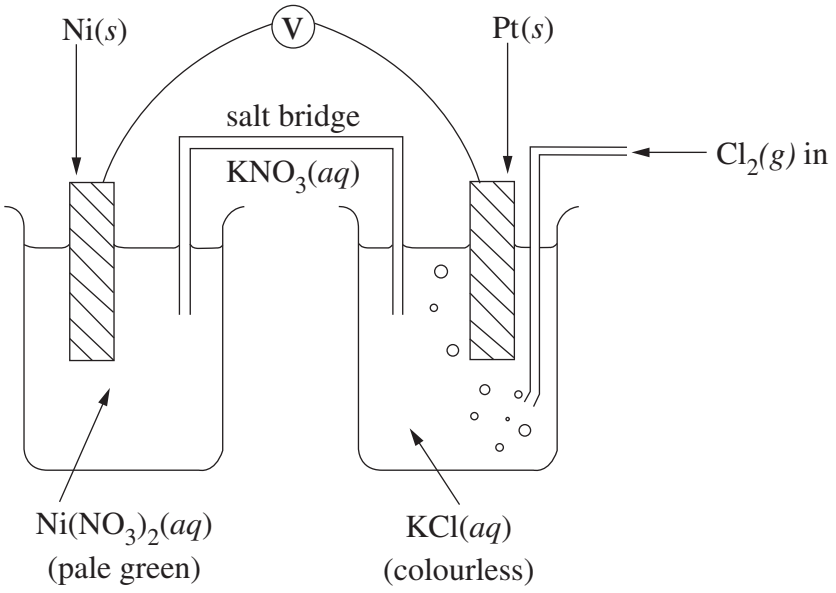
Marks

Question 25 (5 marks)

A galvanic cell under standard conditions is represented below.



(a) On the diagram, clearly label the anode, the cathode and the direction of electron flow. **1**

(b) Write a balanced net ionic equation for the overall cell reaction. **1**

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(c) Calculate the standard cell potential ($E^{\ominus}$). **1**

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(d) Explain any colour changes observed in this cell as the reaction proceeds. **2**

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Centre Number

Student Number

Section I (continued)

Marks

Question 26 (4 marks)

Explain how a buffer works with reference to a specific example in a natural system. **4**

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Marks

Question 27 (4 marks)

(a) Classify these salts as forming acidic, basic or neutral solutions. **2**

Salt	*Classification of solution*
Ammonium chloride	
Sodium ethanoate	
Sodium chloride	
Ammonium nitrate	

(b) From the table, choose a salt that forms an acidic or basic solution, and justify its classification. Include an equation to illustrate your answer. **2**

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Marks

Question 28 (6 marks)

A standard solution was prepared by dissolving 1.314 g of sodium carbonate in water. The solution was made up to a final volume of 250.0 mL.

(a) Calculate the concentration of the sodium carbonate solution. **2**

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This solution was used to determine the concentration of a solution of hydrochloric acid. Four 25.00 mL samples of the acid were titrated with the sodium carbonate solution. The average titration volume required to reach the end point was 23.45 mL.

(b) Write a balanced equation for the titration reaction. **1**

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(c) Calculate the concentration of the hydrochloric acid solution. **3**

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Chemistry

Section II

25 marks
Attempt ONE question from Questions 29–33
Allow about 45 minutes for this section

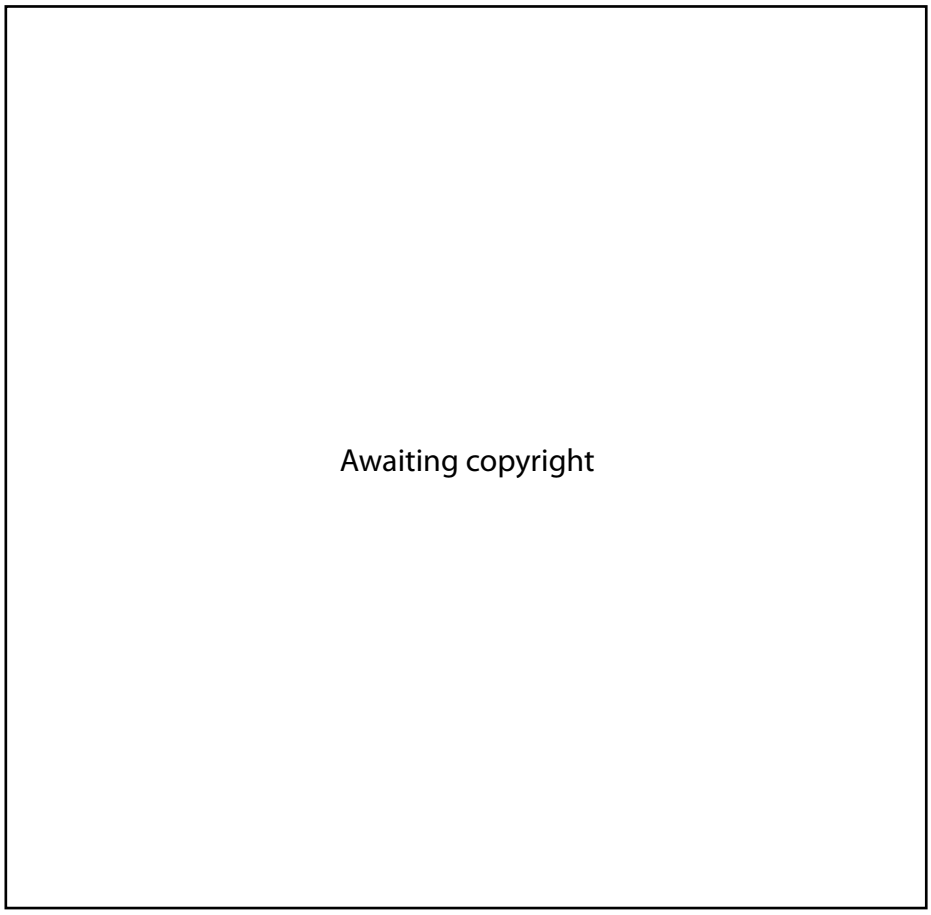
Answer the question in a writing booklet. Extra writing booklets are available.

Show all relevant working in questions involving calculations.

Marks

Question 29 — Industrial Chemistry (25 marks)

(a) The following diagram illustrates the process used to extract sulfur from underground deposits.



(i) Copy and complete this table in your writing booklet to identify which fluid is pumped through each pipe. **2**

Pipe	*Fluid*
Pipe 1	
Pipe 2	
Pipe 3	

Do NOT write your answers here.

(ii) Explain why this process can be used to extract sulfur. **2**

(iii) What possible environmental issues are associated with this process? **2**

Question 29 continues on page 27

Question 29 (continued)

(b) A first-hand investigation was performed to observe the electrolysis of sodium chloride.

(i) Describe an appropriate procedure. **3**

(ii) Identify the reactions that occur at the anode and at the cathode and give equations for these reactions. **2**

(iii) What condition would need to be changed to produce sodium metal as a product? **1**

(c) Consider the following mixture of gases in a closed 5.0 L vessel at 730°C.

Gas	*Quantity* (mol)
CH_4	2.00
H_2O	1.25
CO	0.75
H_2	0.75

The following reaction occurs:

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g) \qquad \Delta H = +206 \text{ kJ}$$

The equilibrium constant, K, is 0.26 at 730°C.

(i) Determine whether the system is at equilibrium. **3**

(ii) Explain how conditions in this reaction could be adjusted to increase the quantity of products. **3**

(d) Synthetic detergents have been developed over the past 60 years. **7**

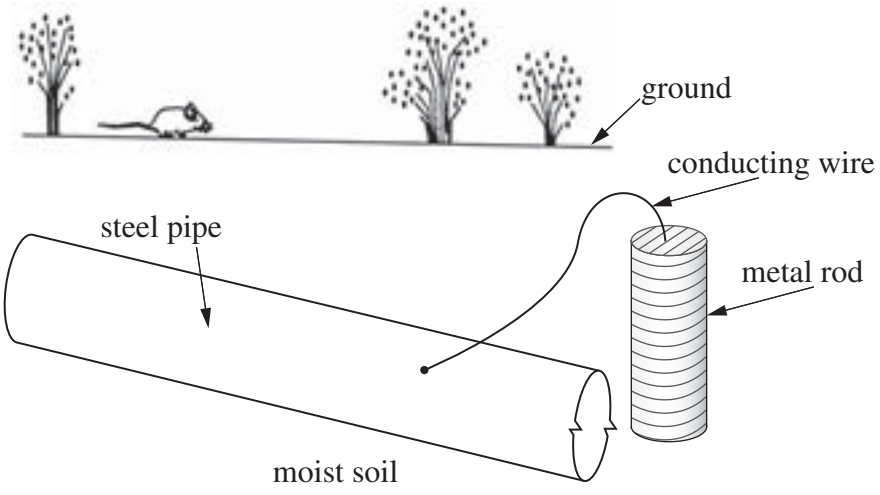
Compare anionic, cationic and non-ionic synthetic detergents in terms of their use and chemical composition and the impact that these detergents have had on the environment.

End of Question 29

Marks

Question 30 — Shipwrecks, Corrosion and Conservation (25 marks)

(a) Underground gas pipelines are often made of steel. To prevent the pipe from rusting it is connected at regular intervals to metal rods.



(i) Identify a suitable metal for the rod and explain how this prevents corrosion of the pipe. Support your answer with relevant chemical equations. **3**

(ii) Suggest TWO other methods that could be used to protect the pipe from corrosion and explain how each of these methods is effective. **3**

(b) A first-hand investigation was performed to compare the rate of corrosion of iron and a named steel.

(i) Describe an appropriate procedure. **3**

(ii) Explain the results obtained using relevant equations. **2**

(iii) How can steel composition be modified to increase corrosion resistance? **1**

Question 30 continues on page 29

Question 30 (continued)

(c) A 1.0 mol L^{-1} solution of silver nitrate was electrolysed using platinum electrodes.

Silver was produced at one electrode and a gas was produced at the other.

(i) Draw a labelled diagram to represent this cell. **2**

(ii) Identify the reactions that occur at the anode and the cathode and give equations for these reactions. **2**

(iii) Identify FOUR factors that affect the rate of deposition of silver. **2**

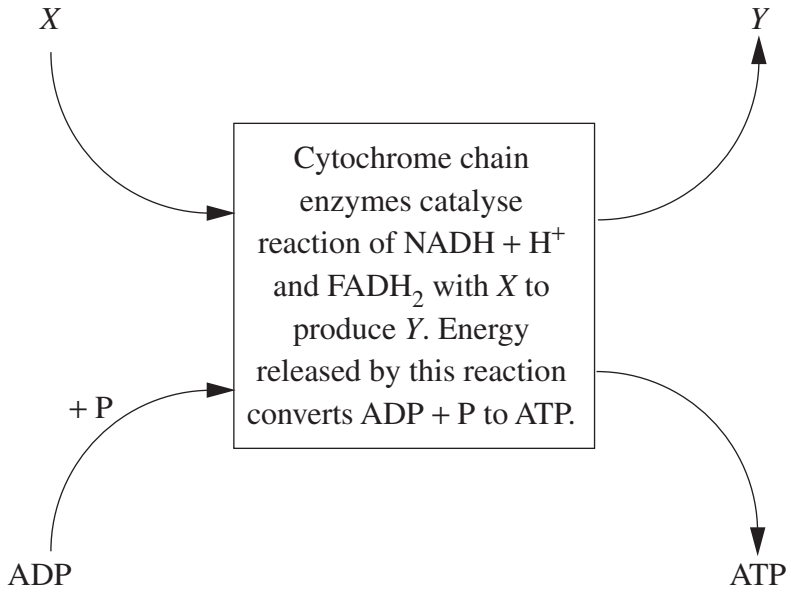
(d) Several maritime archaeological projects exist around Australia. Compare the conservation and restoration techniques used in TWO of these projects with reference to the chemistry applied. **7**

End of Question 30

Marks

Question 31 — The Biochemistry of Movement (25 marks)

(a) The following flowchart outlines a specific section of an important biochemical process.



(i) Identify *X* and *Y* in your writing booklet. **1**

(ii) Identify this biochemical process and the specific section outlined by the flowchart. **2**

(iii) With reference to *X* and *Y* explain the role of the co-factors NADH and $FADH_2$. Include equations in your answer. **3**

(b) A first-hand investigation was performed to observe the effects of changes in temperature on the reaction of a named enzyme.

(i) Describe an appropriate procedure. **3**

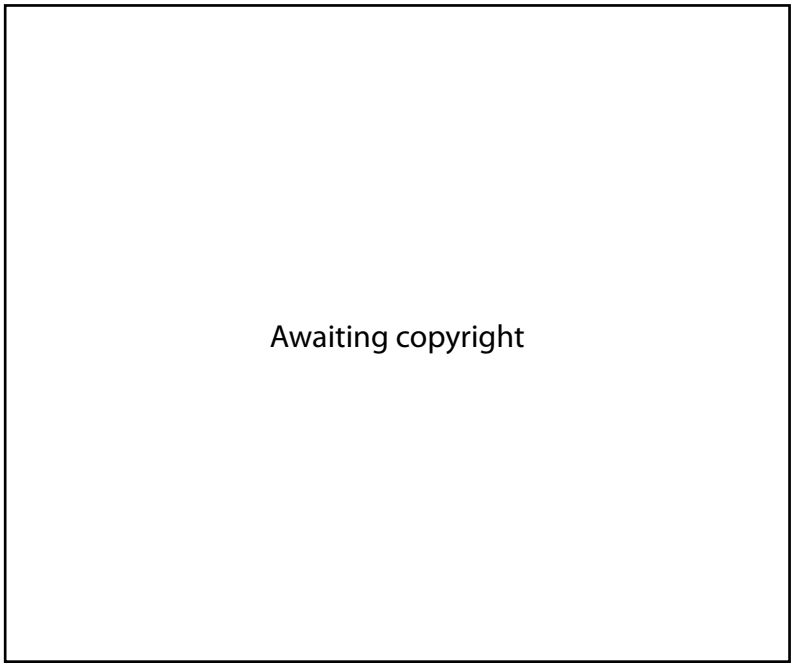
(ii) Sketch an appropriate graph to represent the results. **2**

(iii) Identify the group of biochemical compounds to which this enzyme belongs. **1**

Question 31 continues on page 31

Question 31 (continued)

(c) The nutrition information below appeared on the packaging of a food item.



(i) Identify THREE major nutrient groups listed in the panel that are required for human cellular metabolic processes. **1**

(ii) Quantitatively compare the total energy of the contents of this package with the suggested average daily adult intake. **2**

(iii) Explain how the contents of this package could meet the metabolic requirements of human Type 1 skeletal muscle fibres. **3**

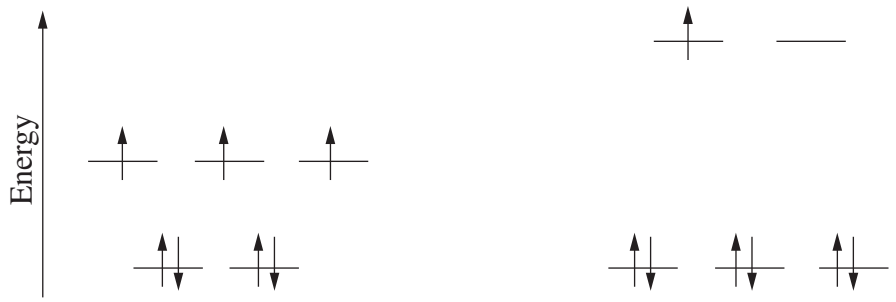
(d) With reference to the body's metabolic processes, analyse how modern athletes might modify their diet over time to cope with a change in focus from less strenuous exercise to sprinting. **7**

End of Question 31

Marks

Question 32 — The Chemistry of Art (25 marks)

(a) The diagram below shows the ground state electron configuration of two complexes of cobalt in aqueous solution.



$[CoCl_4]^{2-}$
blue solution

$[Co(H_2O)_6]^{2+}$
red solution

(i) Identify the block in the periodic table to which cobalt belongs and write the electron configuration of cobalt metal in its ground state. **2**

(ii) Explain the difference in the colour of the two complexes. **3**

(iii) Why are solutions of zinc complexes colourless? **1**

(b) A first-hand investigation was performed to demonstrate the oxidising strength of potassium permanganate.

(i) Describe an appropriate procedure. **3**

(ii) Explain the results obtained with the use of half equations. **2**

(iii) A solution of potassium permanganate was added to solutions of the following three compounds: potassium iodide, potassium bromide and potassium fluoride. **1**

Identify which of these solutions would react with the potassium permanganate.

Question 32 continues on page 33

Question 32 (continued)

(c) An acidified solution of $VO_2^+(aq)$ is poured into a flask containing zinc metal. When the flask is swirled the following sequence of colour changes is observed.

yellow	⟶	green	⟶	blue	⟶	violet
$VO_2^+(aq)$		$VO^{2+}(aq)$		$V^{3+}(aq)$		$V^{2+}(aq)$

(i) Sketch the expected absorption spectrum for the violet $V^{2+}(aq)$ solution and justify the shape of the curve you have drawn. **3**

(ii) Use the following unbalanced half equations to give the overall equation for the colour change from yellow to violet. **2**

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

$$VO_2^+(aq) + H^+(aq) + e^- \rightarrow V^{2+}(aq) + H_2O(l)$$

(iii) Identify the class of reaction to which the reactions in part (ii) belong. **1**

(d) A painting is discovered in a disused storeroom of a local museum. The style suggests the painting is approximately 500 years old. **7**

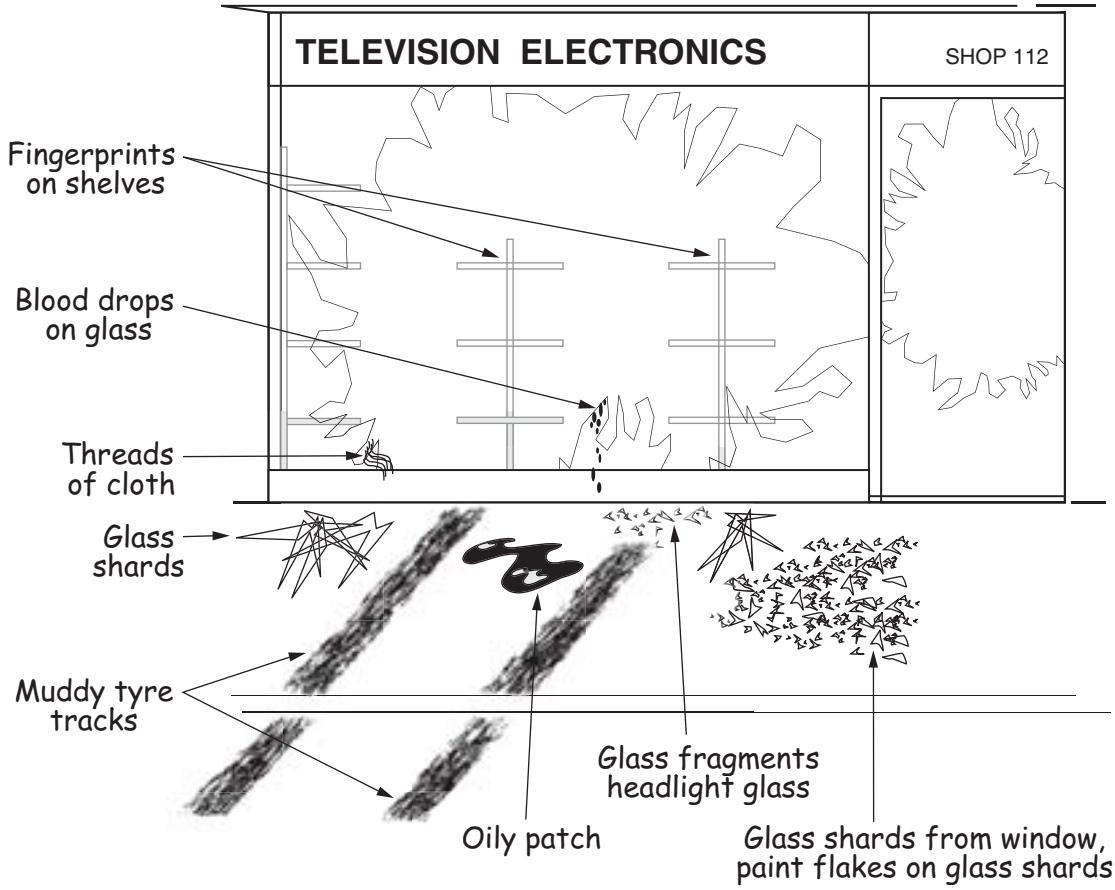
Describe some methods a chemist would use to identify pigments in the painting and to check the estimated age of the painting.

End of Question 32

Marks

Question 33 — Forensic Chemistry (25 marks)

(a) At a crime scene secured by police, it appears a motor vehicle has been driven into a plate glass window. Display cases inside the window are empty and the vehicle is gone. The forensic examiner made the following annotated sketch.



(i) Identify FOUR pieces of evidence that could be collected to help solve the crime. **2**

(ii) Identify TWO instrumental techniques and explain how each could be used to analyse the evidence collected from this crime scene. **4**

Question 33 continues on page 35

Question 33 (continued)

(b) A first-hand investigation was performed to identify reducing and non-reducing sugars.

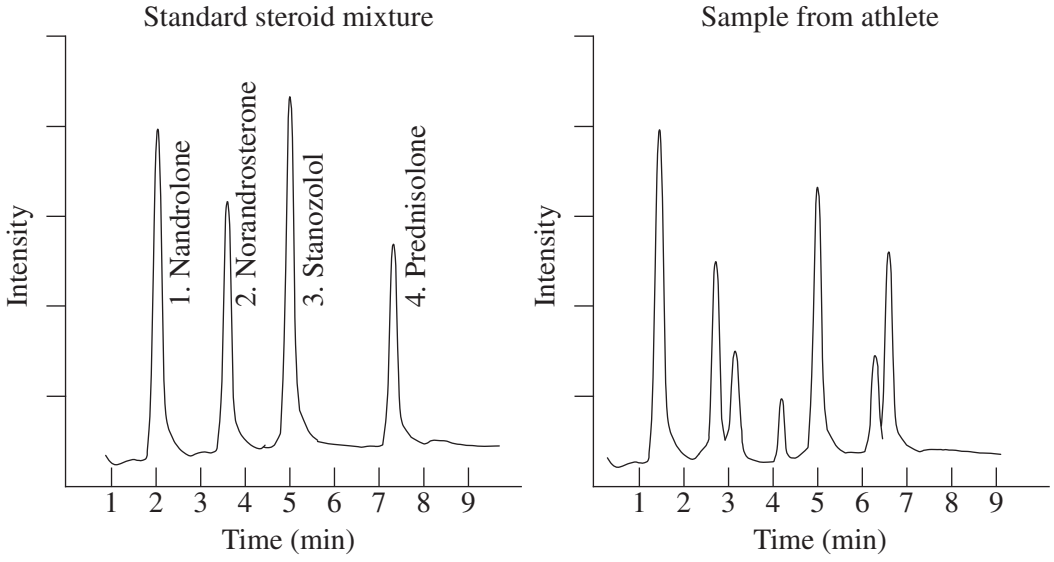
(i) Describe an appropriate procedure. **3**

(ii) Account for the results obtained in terms of the chemical differences between reducing and non-reducing sugars. **2**

(iii) Suggest an instrumental method for identifying different sugars. **1**

(c) An athlete provided a urine sample to be tested for steroids. The sample and the steroid standards were treated and then analysed by gas chromatography with mass spectrometric detection.

Below are chromatograms of a standard mixture containing four different steroids, and the sample from the athlete.



(i) Identify which steroid, if any, the athlete has taken. **1**

(ii) What properties of compounds would lead a forensic chemist to use high pressure liquid chromatography over gas chromatography? **2**

(iii) Describe the principle of operation of the mass spectrometer. Include a diagram in your answer. **3**

(d) With reference to a named example, explain the theory behind emission spectra and how such information could be useful in determining the origins of a mixture. **7**

End of paper

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Chemistry

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

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

Some standard potentials

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

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

PERIODIC TABLE OF THE ELEMENTS

KEY

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

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

Lanthanoids

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

Actinoids

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

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

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