BOARD OF STUDIES
NEW SOUTH WALES

PRESIDING OFFICER'S COPY

# 2011

## 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, 15, 17, 19 and 21

**Total marks – 100**

**Section I** Pages 2–22

**75 marks**

This section has two parts, Part A and Part B

Part A – 20 marks

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

Part B – 55 marks

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

**Section II** Pages 23–33

**25 marks**

- Attempt ONE question from Questions 33–37
- 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 industrial processes is used to produce ethanol from ethylene?

(A) Hydration

(B) Dehydration

(C) Addition polymerisation

(D) Condensation polymerisation

**2** Which of the following shows two products that result from the fermentation of glucose?

(A) Cellulose and water

(B) Ethanol and oxygen

(C) Carbon dioxide and water

(D) Ethanol and carbon dioxide

**3** Which of the following lists contains ONLY basic substances?

(A) Oven cleaner, urine, vinegar

(B) Lemonade, drain cleaner, blood

(C) Baking soda, ammonia, sea water

(D) Antacid, dishwashing detergent, lemon juice

**4** Which of the following gases can cause major depletion of the ozone layer?

(A) $O_2$

(B) $NO_2$

(C) $CO_2$

(D) $CCl_3F$

5 Iron (III) chloride and aluminium sulphate are two chemicals that can be used in the purification of town water supplies. What is the role of these chemicals?

(A) To disinfect water by removing bacteria

(B) To remove particulate material by flocculation

(C) To control the concentration of total dissolved solids

(D) To control the pH of the water within the required range

6 Which property would be most useful in distinguishing between butan-1-ol and propan-1-ol?

(A) Boiling point

(B) Colour

(C) Conductivity

(D) Density

7 Which of the following lists contains ONLY unstable isotopes?

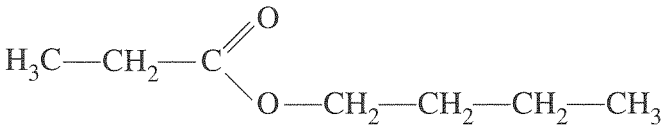
(A) $^{207}_{82}Pb$, $^{99}_{43}Tc$, $^{12}_{7}N$

(B) $^{214}_{82}Pb$, $^{46}_{20}Ca$, $^{99}_{43}Tc$

(C) $^{238}_{92}U$, $^{40}_{20}Ca$, $^{12}_{7}N$

(D) $^{238}_{92}U$, $^{40}_{20}Ca$, $^{99}_{43}Tc$

8 What is the systematic name of the molecule shown?



(A) Butyl butanoate

(B) Propyl butanoate

(C) Butyl propanoate

(D) Propyl propanoate

**9** What property of $O_3$ makes it more soluble in water than $O_2$ in water?

(A) $O_3$ is a polar molecule.

(B) $O_3$ has a resonance structure.

(C) $O_3$ is a highly reactive molecule.

(D) $O_3$ has a coordinate covalent bond.

**10** An aqueous sample containing the following anions is analysed.

$Cl^-$ $CO_3^{2-}$ $SO_4^{2-}$

In which order should the reagents be added to determine the amount of chloride in the sample?

| | *Reagent 1* | *Reagent 2* | *Reagent 3* |
|---|---|---|---|
| (A) | $AgNO_3$ | $H_2SO_4$ | $BaSO_4$ |
| (B) | HCl | $Pb(NO_3)_2$ | $AgNO_3$ |
| (C) | $HNO_3$ | $Ba(NO_3)_2$ | $AgNO_3$ |
| (D) | $Ba(NO_3)_2$ | $AgNO_3$ | $CH_3COOH$ |

**11** Which compound can form when bromine water reacts with propene?

(A) 1-bromopropane

(B) 2-bromopropane

(C) 1,1-dibromopropane

(D) 1,2-dibromopropane

12 A table of redox couples and their standard reduction potentials is shown.

| Redox couple | $E^{\ominus}$ |
|---|---|
| $Ag^+/Ag$ | 0.80 V |
| $Cd^{2+}/Cd$ | −0.40 V |
| $Pd^{2+}/Pd$ | 0.92 V |
| $Ni^{2+}/Ni$ | −0.24 V |

Which of the following ranks the metals in decreasing order of their electrochemical activity?

(A) Ni > Cd > Ag > Pd

(B) Pd > Ag > Cd > Ni

(C) Pd > Ag > Ni > Cd

(D) Cd > Ni > Ag > Pd

13 When chloride ions are added to a solution containing $Co(H_2O)_6^{2+}(aq)$, the following equilibrium is established.

$$\underset{\text{Pink}}{Co(H_2O)_6^{2+}(aq)} + 4Cl^-(aq) \rightleftharpoons \underset{\text{Blue}}{CoCl_4^{2-}(aq)} + 6H_2O(\ell)$$

Which of the following statements about the colour of the solution is true?

(A) Diluting the solution with water will make it turn blue.

(B) If the reaction is exothermic, heating the solution will make it turn blue.

(C) If the reaction is endothermic, cooling the solution will make it turn pink.

(D) Adding a large amount of solid potassium chloride to the solution will make it turn pink.

14 How many isomers are there for $C_3H_6BrCl$?

(A) 3

(B) 4

(C) 5

(D) 6

Use the information provided to answer Questions 15 and 16.

> Using 0.100 mol $L^{-1}$ NaOH, a student titrated 25.0 mL of a 0.100 mol $L^{-1}$ weak monoprotic acid, and separately titrated 25.0 mL of a 0.100 mol $L^{-1}$ strong monoprotic acid.

**15** Which statement about the volume of base required to reach the equivalence point is correct?

(A) The weak acid will require the same volume of base as the strong acid.

(B) The weak acid will require a larger volume of base than the strong acid.

(C) The weak acid will require a smaller volume of base than the strong acid.

(D) The volume of base required will depend on the molar mass of the acid used.

**16** Which statement correctly describes the pH at each titration equivalence point?

(A) The pH of both solutions will be the same.

(B) One of the solutions will be neutral while the other will have a pH higher than 7.

(C) One of the solutions will be neutral while the other will have a pH lower than 7.

(D) One of the solutions will have a pH higher than 7 while the other will have a pH lower than 7.

**17** The molar heat of combustion of pentan-1-ol is 2800 kJ $mol^{-1}$. A quantity of pentan-1-ol was combusted, generating 108 kJ of heat.

What mass of pentan-1-ol was combusted?

(A) 2.29 g

(B) 2.86 g

(C) 3.32 g

(D) 3.40 g

**18** A household cleaning agent contains a weak base with the formula NaX. 1.00 g of this compound was dissolved in water to give 100.0 mL of solution. A 20.0 mL sample of the solution was titrated with 0.100 mol $L^{-1}$ hydrochloric acid, and required 24.4 mL of the acid for neutralisation.

What is the molar mass of the weak base?

(A) 82.0 g

(B) 84.0 g

(C) 122 g

(D) 410 g

**19** All of the carbon dioxide in a soft drink with an initial mass of 381.04 g was carefully extracted and collected as a gas. The final mass of the drink was 380.41 g.

What volume would the carbon dioxide occupy at 100 kPa and 25°C?

(A) 0.33 L

(B) 0.35 L

(C) 0.56 L

(D) 0.63 L

**20** When charcoal reacts in the presence of oxygen, carbon monoxide and carbon dioxide are produced according to the following chemical reactions.

$$C(s) + \frac{1}{2}O_2(g) \rightarrow CO(g)$$

$$C(s) + O_2(g) \rightarrow CO_2(g)$$

What would be the total mass of gas produced when 400 g of charcoal is reacted, assuming equal amounts are consumed in each reaction?

(A) 0.93 kg

(B) 1.2 kg

(C) 1.5 kg

(D) 2.5 kg

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# Chemistry

Centre Number

Student Number

## Section I (continued)

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

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

Show all relevant working in questions involving calculations.

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**Question 21** (4 marks)

What features of the molecular structure of ethanol account for its extensive use as a solvent? Include a diagram in your answer. **4**

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**Question 22** (4 marks)

(a) Use chemical equations to show how ozone is depleted in the stratosphere. **2**

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(b) Outline ONE method used to monitor stratospheric ozone. **2**

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Centre Number

Student Number

**Section I – Part B (continued)**

**Question 23** (3 marks)

(a) Element 112 was first synthesised in 1996 and officially named in 2009 as copernicium, Cn. **1**

Explain why the transuranic isotope $^{278}_{112}Cn$ is unstable.

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(b) Describe a method by which transuranic elements can be synthesised. **2**

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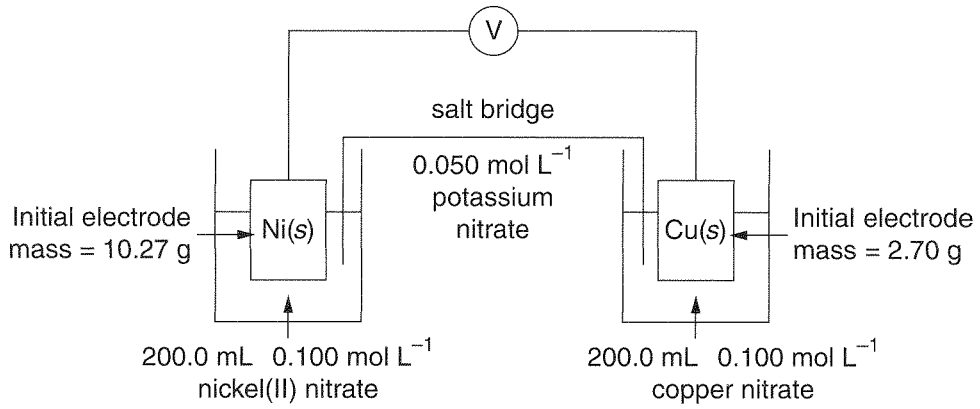
**Question 24** (7 marks)

A galvanic cell was constructed as shown in the diagram.




(a) Calculate the standard cell potential ($E^{\ominus}$). In your answer, include a net ionic equation for the overall cell reaction. **2**

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(b) After a period of time, a solid deposit that had formed on the copper electrode was removed and dried. The deposit had a mass of 0.395 g. **3**

(i) Calculate the final mass of the nickel electrode.

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(ii) Calculate the final concentration of the nickel(II) nitrate solution. **2**

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Centre Number

Student Number

**Section I – Part B (continued)**

**Question 25** (3 marks)

Explain the role of the conjugate acid/base pair, $H_2PO_4^-/HPO_4^{2-}$, in maintaining the pH of living cells. Include chemical equations in your answer. **3**

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**Question 26** (6 marks)

A manufacturer makes lemon cordial by mixing flavouring, sugar syrup and citric acid. The concentration of the citric acid is determined by titration with NaOH.

The sodium hydroxide solution is prepared by dissolving 4.000 g of NaOH pellets in water to give 1.000 L of solution. This solution is standardised by titrating 25.00 mL with a 0.1011 mol $L^{-1}$ standardised solution of HCl. The average titration volume is found to be 24.10 mL.

To analyse the lemon cordial 50.00 mL of the cordial is diluted to 500.0 mL. Then 25.00 mL of the diluted solution is titrated with the NaOH solution to the phenolphthalein endpoint.

The following data were collected during one of the analysis runs of the lemon cordial.

| | |
|---|---|
| Titration #1 volume | 26.55 mL |
| Titration #2 volume | 27.25 mL |
| Titration #3 volume | 27.30 mL |
| Titration #4 volume | 27.20 mL |

(a) Why is the calculated concentration of the standardised NaOH solution different from the concentration calculated using the mass given, assuming no human error occurred? **2**

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(b) Determine the concentration of citric acid in the lemon cordial. **4**

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Centre Number

Student Number

**Section I – Part B (continued)**

**Question 27** (5 marks)

The following extract was taken from a blog about environmental issues. **5**

> ... the use of long-lasting polymers for short-lived applications can cause problems for the preservation of living systems ... Plastic debris has a costly impact on waste management for municipalities.

Assess the uses of polystyrene and a named biopolymer in terms of their properties, with reference to the statements made in this blog.

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Centre Number

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**Section I – Part B (continued)**

**Question 28** (4 marks)

A student investigating the water quality of stormwater in a drain near the school collected samples for testing in the school laboratory. The student conducted the following tests to measure the quality of the stormwater. **4**

- Hardness
- Phosphate level
- Biochemical oxygen demand
- Total dissolved solids
- Turbidity
- Nitrate level

For TWO of these tests, outline the chemical or physical principle involved and the procedure followed in a school laboratory.

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**Question 29** (4 marks)

(a) Justify the continued use of the Arrhenius definition of acids and bases, despite the development of the more sophisticated Brönsted–Lowry definition. **3**

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(b) Why does the neutralisation of any strong acid in an aqueous solution by any strong base always result in a heat of reaction of approximately –57 kJ $mol^{-1}$? **1**

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**Question 30** (6 marks)

**Please turn over**

**Question 30** (6 marks)

The flowchart outlines the sequence of steps in the Ostwald process for the manufacture of nitric acid. **6**

Step 1 $4NH_3(g) + 5O_2(g) \overset{900°C}{\rightleftharpoons} 4NO(g) + 6H_2O(g) \quad \Delta H = -950 \text{ kJ}$

↓

Step 2 $2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g) \quad \Delta H = -114 \text{ kJ}$

↓

Step 3 $3NO_2(g) + H_2O(\ell) \rightarrow 2HNO_3(aq) + NO(g) \quad \Delta H = -117 \text{ kJ}$

Explain the reaction conditions required at each step of the Ostwald process to maximise the yield and production rate of nitric acid.

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**Question 31** (4 marks)

A council monitors the water quality of a local river daily. The records for six days are shown in the table. During this period contamination from unknown sources was detected. **4**

| | *Mon* | *Tue* | *Wed* | *Thu* | *Fri* | *Sat* |
|---|---|---|---|---|---|---|
| pH | 7.2 | 7.3 | 7.2 | 7.0 | 7.2 | 7.3 |
| Turbidity (NTU) | 5 | 67 | 5 | 25 | 10 | 8 |
| Total dissolved solids (ppm) | 340 | 436 | 342 | 380 | 370 | 360 |
| Temperature (°C) | 15.6 | 16.0 | 15.8 | 15.8 | 16.0 | 16.2 |
| Dissolved oxygen (ppm) | 9.7 | 9.6 | 9.7 | 4.2 | 4.3 | 8.0 |
| Biochemical oxygen demand (ppm) | 2.6 | 4.0 | 3.2 | 52 | 20 | 7.8 |
| Faecal coliforms (cfu/100 mL) | 10 | 10 | 12 | 514 | 60 | 18 |

Propose possible sources of the contamination, justifying your answer with reference to the data provided.

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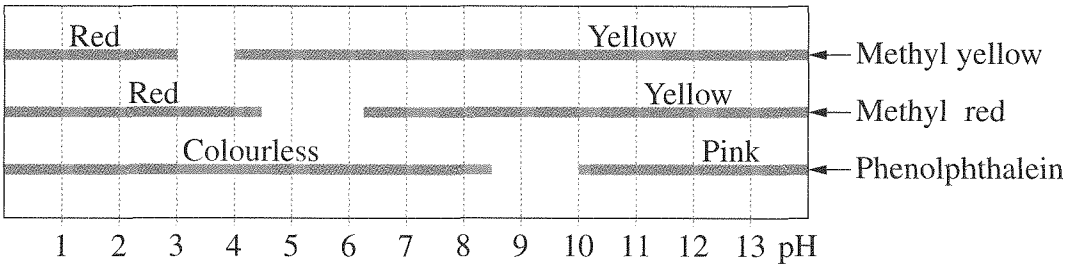
**Question 32** (5 marks)

To determine the pH of garden soil, a sample was first saturated with distilled water in a petri dish. Barium sulfate powder was added to the surface of the sample, and drops of the three indicators listed below were added to separate parts of the sample. The colours observed are shown in the table.

**Experimental results**

| *Indicator* | Methyl yellow | Methyl red | Phenolphthalein |
|---|---|---|---|
| *Colour observed* | Yellow | Red | Colourless |

**Indicator colour ranges**




**Plant response**

| *Plant* | *soil pH range for optimal growth* |
|---|---|
| Carrot | 5.5 – 6.8 |
| Chrysanthemum | 6.0 – 6.3 |
| Hydrangea Blue | 4.0 – 5.0 |
| Hydrangea White | 6.5 – 8.0 |
| Potato | 5.0 – 5.7 |

(a) Why is barium sulfate powder added when testing soil pH? **1**

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(b) Using the information given, select the plant that will grow well at the current soil pH, and justify your selection. **2**

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(c) Outline the method you would use to test a natural indicator that has been prepared in the school laboratory. **2**

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2011 HIGHER SCHOOL CERTIFICATE EXAMINATION

# Chemistry

## Section II

**25 marks**
**Attempt ONE question from Questions 33–37**
**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.

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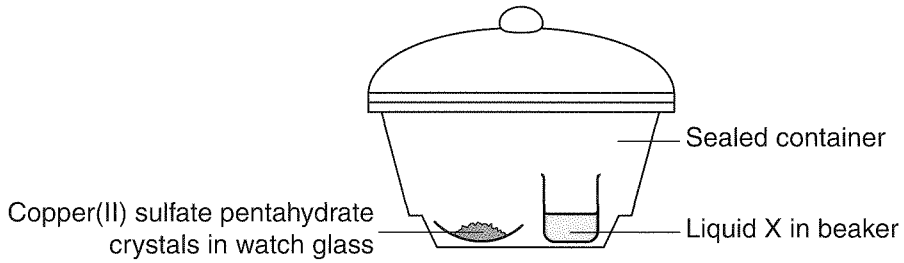
**Question 33 — Industrial Chemistry** (25 marks)

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

(a) A student set up the following experiment to model a process and observed the colour change of the crystals. **3**




Identify liquid X and explain the colour change of the crystals. Include a chemical equation in your answer.

(b) (i) Why are the large volumes of $CO_2(g)$ produced during the Solvay process of little environmental concern? Include chemical equations in your answer. **3**

(ii) Calcium chloride is also produced during the Solvay process. Calculate the mass of calcium chloride produced per tonne of sodium chloride used in the Solvay process. **2**

(c) A 0.05 mol $L^{-1}$ solution of sodium chloride was electrolysed using graphite electrodes. Separate pieces of litmus paper were dipped into the solution next to each electrode.

The following observations were made.

| *Polarity of electrode* | *Observation* | *Colour of litmus paper* |
|---|---|---|
| Positive | Bubbles | Red |
| Negative | Bubbles | Blue |

(i) Account for the observations at the anode and cathode. Include relevant chemical equations in your answer. **3**

(ii) What is the difference between the electrolytic cell described above and a galvanic cell, in terms of energy requirements? **2**

**Question 33 continues on page 25**

Question 33 (continued)

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

(d) (i) Models are often used to help explain complex concepts. Outline a first-hand investigation that can model an equilibrium reaction. **2**

(ii) Assess the validity of the information that could be collected in this investigation. **3**

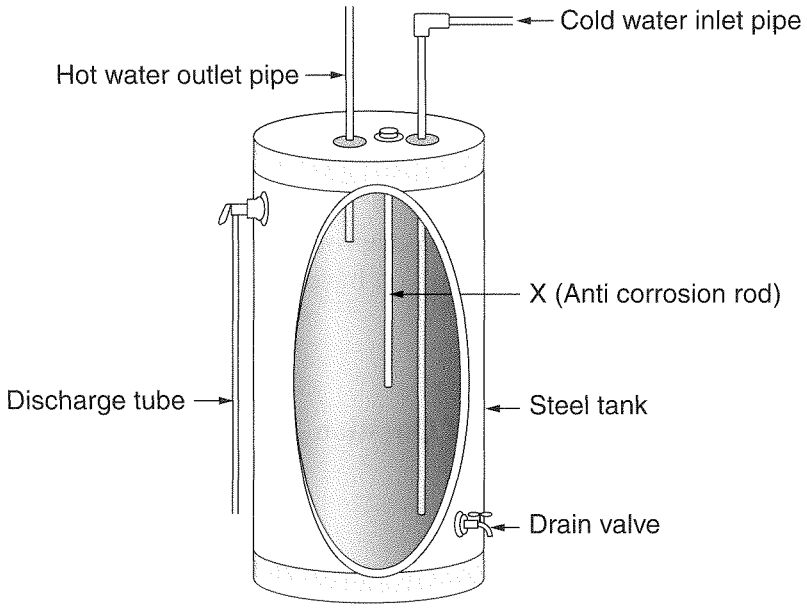
(e) Evaluate the impact on society of the environmental issues associated with THREE of the industrial processes that you have studied in this option. **7**

**End of Question 33**

**Question 34 — Shipwrecks, Corrosion and Conservation** (25 marks)

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

(a) The diagram shows a hot water tank. **3**




Name an appropriate material from which X can be made, and justify your choice.

(b) There are two common household methods to remove the tarnish on silver cutlery: polishing with a soft cloth and toothpaste or placing the cutlery into an aluminium tray filled with warm sodium hydrogen carbonate solution and leaving it overnight.

(i) Explain, with the use of equations, the chemistry involved in the aluminium tray method. **4**

(ii) Identify an advantage of the aluminium tray method. **1**

**Question 34 continues on page 27**

Question 34 (continued)

(c) A dilute solution of potassium sulfate was electrolysed using graphite electrodes. Separate pieces of litmus paper were dipped into the solution next to each electrode.

The following observations were made.

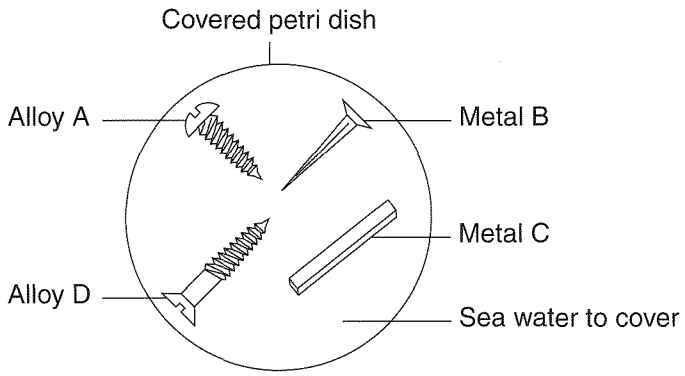
| *Polarity of electrode* | *Observation* | *Colour of litmus paper* |
|---|---|---|
| Positive | Bubbles | Red |
| Negative | Bubbles | Blue |

(i) Draw and label a diagram to represent this cell. **3**

(ii) Identify the products formed at the anode and cathode by writing the equations for each of these reactions. **2**

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

(d) A student set up the following investigation to compare the rate of corrosion of a variety of metals and alloys, in order to identify those best suited for use in marine vessels. Photos were taken of the experiment on a daily basis for several weeks.




(i) Explain the method the student should have used to prepare the samples for the investigation. **2**

(ii) Assess the validity of the data collected in this experiment. **3**

(e) 'Corrosion at great depth in the ocean was predicted to be slow.' **7**

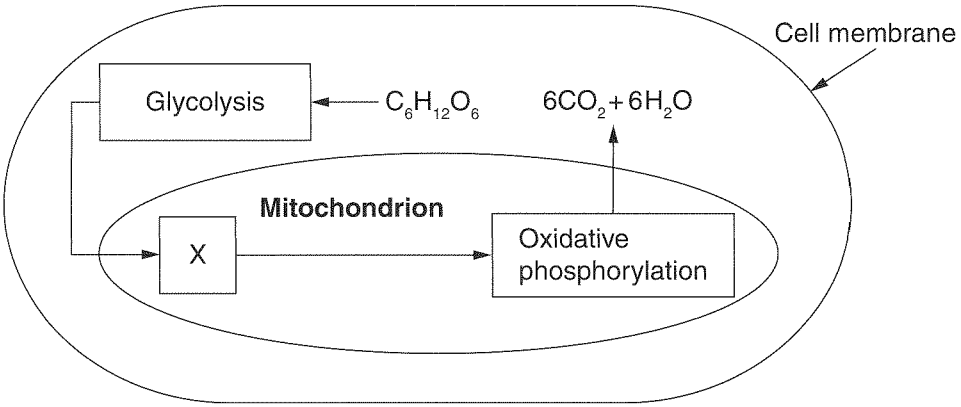
Evaluate this statement with reference to recent maritime investigations. Include chemical equations in your answer.

**End of Question 34**

**Question 35 — The Biochemistry of Movement** (25 marks)

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

(a) The main steps in cellular respiration are shown in the diagram of the cell. **3**




Identify the process represented by X, and explain the difference in oxygen requirements of glycolysis and the chemical processes in mitochondria.

(b) (i) Using the general formula for an amino acid, write an equation to show the formation of a dipeptide. **2**

(ii) Explain the effect of an increase in temperature and a change in pH on the molecular structure of a protein. **3**

(c) The table shows the percentage of each muscle cell type used for particular activities.

| *Activity* | *% of Type 1 muscle cells* | *% of Type 2 muscle cells* |
|---|---|---|
| Sedentary activity | 40 | 15 |
| Sprinting | 25 | 50 |
| Marathon running | 75 | 10 |

(i) The use of muscle cell type changes as the nature of the activity changes. Give reasons for this. **3**

(ii) Use an equation to show how ATP is regenerated during muscle contraction. **2**

**Question 35 continues on page 29**

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

(d) A student wants to test the effects of temperature on enzyme function. A piece of calf liver is placed in a test tube with hydrogen peroxide. The test tube is then placed in a water bath. As the reaction occurs, the rate is monitored by measuring the time taken for the reaction to stop producing oxygen.

(i) Account for the fact that there is an optimal temperature for enzyme function. **2**

(ii) Assess the validity of the data collected in this experiment. **3**

(e) 'A knowledge of the availability of energy from fats and carbohydrates has improved society's understanding of nutrition.' **7**

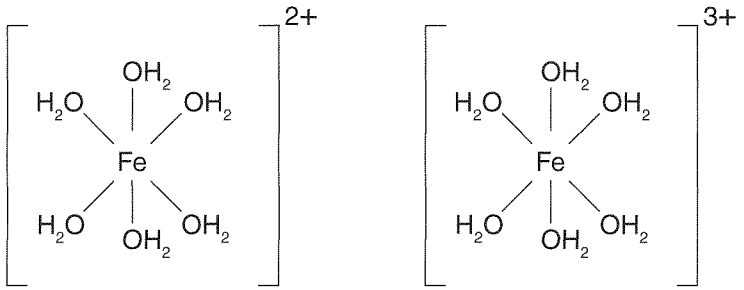
Analyse this statement with reference to metabolic pathways.

**End of Question 35**

**Question 36 — The Chemistry of Art** (25 marks)

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

(a) The structures of two aqueous iron complexes are represented in the diagram. **3**




Green Yellow-brown

Account for the different colours of the complexes.

(b) (i) Identify ONE cation and ONE anion that can be represented by the electron configuration $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$. **2**

(ii) Explain the fact that Group I and Group II metal ions have one oxidation state while the transition metals often have multiple oxidation states. **3**

(c) The emission lines for an element are listed in the table.

| *Line number* | *Wavelength (nm)* |
|---|---|
| 1 | 656 |
| 2 | 486 |
| 3 | 434 |
| 4 | 419 |

(i) Describe a method by which the values in the table may have been obtained. **2**

(ii) Draw an energy level diagram that corresponds to the data given. Assume a common final energy level for each transition. **3**

**Question 36 continues on page 31**

Question 36 (continued)

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

(d) (i) Describe an experiment that can be performed in the school laboratory to illustrate the emission colour of Group II metals. **2**

(ii) Assess the validity of the data collected in this experiment. **3**

(e) To what extent has our understanding of the pigments used in medieval painting increased with the use of a range of technologies? **7**

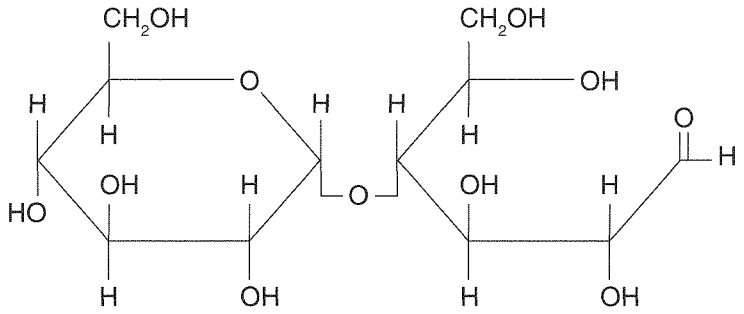
In your answer, refer to THREE spectroscopic techniques.

**End of Question 36**

**Question 37 — Forensic Chemistry** (25 marks)

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

(a) Identify the structure shown, and justify your answer. **3**




(b) (i) Using the general formula of an amino acid, write an equation to show the formation of a dipeptide. **2**

(ii) Explain the principles of paper chromatography, with reference to the separation of amino acids. **3**

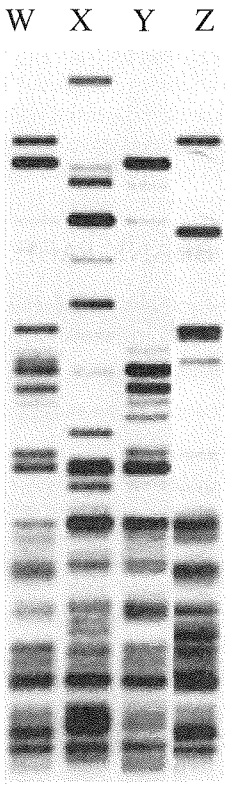
**Question 37 continues on page 33**

Question 37 (continued)

(c) (i) Describe the technique by which DNA is analysed and then used to identify relationships between people. **4**

(ii) The diagram shows the DNA fingerprints (W, X, Y and Z) from a child, the child's biological parents and a family friend. **1**

Identify the DNA fingerprint of the child.




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

(d) A student has four unlabelled bottles all containing white crystals. The four substances are known to be sucrose, potassium chloride, glycine (amino acid) and acetylsalicylic acid (aspirin).

(i) Explain a method the student could use in the school laboratory to identify the contents of the four unlabelled bottles. **4**

(ii) Identify ONE destructive and ONE non-destructive test the student may have used. **1**

(e) Select THREE instrumental techniques you have studied in this option. Evaluate the optimal use of each technique with reference to the analysis of forensic samples. **7**

**End of paper**

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## DATA SHEET

Avogadro constant, $N_A$ ..... $6.022 \times 10^{23}$ 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), $K_w$ ..... $1.0 \times 10^{-14}$

Specific heat capacity of water ..... $4.18 \times 10^3$ 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.