Centre Number

Student Number

CATHOLIC SECONDARY SCHOOLS
ASSOCIATION OF NEW SOUTH WALES

2001
TRIAL HIGHER SCHOOLCERTIFICATE EXAMINATION

Chemistry

Morning Session
Wednesday 15 August 2001

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Board-approved calculators may be used
- Write using a blue or black pen
- Draw diagrams using pencil
- Use the Multiple Choice Answer Sheet provided
- Write your answers for Part B in the spaces provided
- Section II – write your answers in the Answer Book provided
- A Data Sheet and Periodic Table are provided separately

Section I Pages 3 – 19

Total marks **(75)**
This section has two parts, Part A and Part B

Part A
Total marks **(15)**
- Attempt Questions 1 – 15
- Allow about 30 minutes for this part

Part B
Total marks **(60)**
- Attempt Questions 16 – 28
- Allow about 1 hour 45 minutes for this part.

Section II Pages 21 – 31

Total marks **(25)**
- Attempt ONE question from Questions 29 – 33
- Allow about 45 minutes for this section

EXAMINERS

P R Luke (convenor)	
A M Hanson	St Francis Xavier's College, Hamilton
A J L Gray	St Francis Xavier's College, Hamilton

Section I

Total marks (75)

Part A

Total marks (15)
Attempt Questions 1 – 15
Allow about 30 minutes for Part A

Use the Multiple Choice Answer Sheet provided.

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1 When long chain hydrocarbons in crude oil are catalytically cracked to produce smaller molecules, the following reaction can occur:

$$C_{11}H_{24} \rightarrow C_9H_{20} + X$$

What is the name of molecule X?

(A) ethane
(B) propane
(C) ethene
(D) propene

2 A certain liquid hydrocarbon decolorizes bromine water quickly in the dark. Which of the following could have been this hydrocarbon?

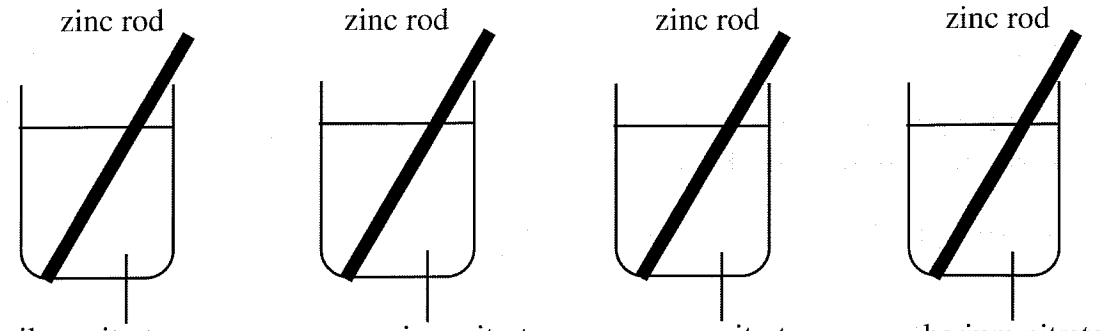
(A) cyclohexene
(B) hexane
(C) 1–propanol
(D) octane

3 In an experiment in a particle accelerator with the isotope sodium–24, a neutron is captured by the Na–24 nucleus, forming a new isotope of sodium. This new isotope decays by alpha-particle emission, producing a daughter nucleus.

The daughter nucleus is:

(A) aluminium–28
(B) fluorine–20
(C) neon–20
(D) fluorine–21

4 A zinc rod is placed in four different solutions, as shown in the diagrams below.



Beaker 1 **Beaker 2** **Beaker 3** **Beaker 4**

You would notice a displacement reaction in beakers

(A) **1** and **2**
(B) **1** and **3**
(C) **1** and **4**
(D) **2** and **3**

5 Ethanol is widely used as a solvent in cosmetics, food flavorings and medicines. What possible intermolecular forces can ethanol exert on other molecules?

(A) covalent bonds, dispersion forces
(B) dipole/dipole interactions, dispersion forces
(C) covalent bonds, hydrogen bonds, dispersion forces
(D) dispersion forces, dipole/dipole interactions, hydrogen bonds

6 Naturally colored compounds which occur in some flowers can be used as a test for

(A) the presence of electrolytes in soil
(B) chemical indicators in soil
(C) the acidity and basicity of soil
(D) the color range of compounds in soil

7 Sulphur dioxide is a toxic, colorless, non-flammable gas. It can be detected in air by its pungent odor. Sulphur dioxide can be formed by reacting

(A) water and sulphuric acid
(B) acetic acid and sulphuric acid
(C) sodium sulphite and oxygen
(D) copper sulphide and oxygen

8 Lavoisier, in 1780, thought that acids contained oxygen (among other things). Which of these acids shows this idea is false?

(A) nitric acid
(B) hydrochloric acid
(C) sulphuric acid
(D) phosphoric acid

9 Which one of the following species can be amphiprotic in water?

(A) HCO_3^-

(B) HCl

(C) NH_3

(D) PO_4^{3-}

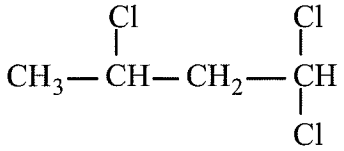
10 The pH of four acids of the same concentration is shown in this table:

ACID	CONCENTRATION (mol L^{-1})	pH
W	0.1	5.1
X	0.1	2.9
Y	0.1	2.1
Z	0.1	1.0

The acid with the greatest degree of ionisation is

(A) *W*
(B) *X*
(C) *Y*
(D) *Z*

11 A compound has the structural formula



Its systematic name is

(A) trichlorobutane
(B) 1,3-trichlorobutane
(C) 2,4,4-trichlorobutane
(D) 1,1,3-trichlorobutane

12 Which method would best remove the turbidity in water for human consumption?

(A) filtration
(B) treatment with a flocculating agent, followed by filtration
(C) treatment with chlorine, followed by filtration
(D) treatment with a water softener, followed by filtration

13 Which one of the following, if present in water in high concentration, would *NOT* be classed as "heavy metal pollution"?

(A) sodium ion
(B) mercury ion
(C) lead ion
(D) copper ion

14 A chemist has a solution containing 180 ppm of phosphate ions. He takes 10 mL of this solution, and adds 90 mL of distilled water to it. The phosphate ion concentration in this 100 mL solution is

(A) 18 ppm
(B) 20 ppm
(C) 160 ppm
(D) 200 ppm

15 The pH of water solutions of oxygen gas (O_2) and oxide ion (O^{2-}) are compared. Which line in the table below gives the correct comparison?

	O_2 DISSOLVED IN WATER	O^{2-} DISSOLVED IN WATER
(A)	pH < 7	pH < 7
(B)	pH = 7	pH > 7
(C)	pH > 7	pH > 7
(D)	pH = 7	pH = 7

Section I
Part B
Total marks (60)
Attempt Questions 16 – 28
Allow about 1 hour and 45 minutes for Part B

Answer the questions in the spaces provided.

Show all relevant working in questions involving calculations.

Question 16 (3 marks) **Marks**

Alkenes, and their derivatives, are important substances in the production of addition polymers. Polystyrene is an *addition polymer*.

(a) (i) Draw the structural formula of the monomer from which polystyrene is formed. **1**

(ii) Give the systematic name of this monomer. **1**

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(b) Explain the meaning of the term *addition polymer*. **1**

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Question 17 (3 marks) **Marks**

Cellulose may be used in the future as the raw material for what we now call *petrochemicals*.

(a) Give one reason why we need alternative sources for the compounds presently obtained from the petrochemical industry. **1**

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(b) Why would cellulose be a good raw material to build petrochemicals? **1**

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(c) Cellulose is a *condensation polymer* of glucose. Explain the meaning of the term *condensation polymer*. **1**

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Question 18 (3 marks) **Marks**

Ethanol has been suggested as an alternative to petrol as a fuel.

(a) (i) Ethanol can be made industrially by the fermentation of glucose. What is the other product obtained from the fermentation of glucose? **1**

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(ii) Another method of making ethanol industrially is by reaction of ethene with water. Name the catalyst used in this industrial process. **1**

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(b) Give one advantage, *OR* one disadvantage, of using ethanol as an alternative fuel. **1**

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Question 19 (7 marks)

A student wished to find the heat of combustion of ethanol, C_2H_5OH.

He used a spirit burner (containing ethanol) to heat 250 g of water in a beaker. The water temperature rose from 15°C to 31°C. During this combustion, the burner lost 0.90 g in mass, due to ethanol burning.

(a) Calculate the heat of combustion of ethanol, in kJ mol^{-1}. **6**

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(b) A databook gives the heat of combustion as –1360 kJ mol^{-1}. Give one reason to account for the discrepancy between this value and the one you calculated in (a). **1**

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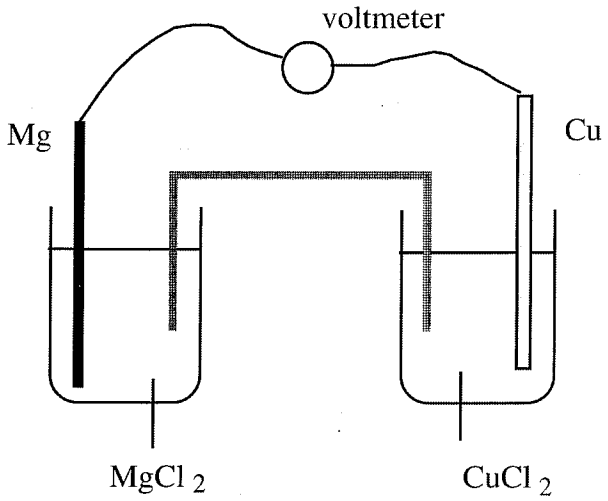
Marks

Question 20 (4 marks)

The diagram shows an electrochemical cell. The concentrations of the two solutions are 1 mol L^{-1}.



(a) Apart from a reading on the meter, give one observation you could make that would show a reaction is taking place. **1**

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(b) Calculate the reading on the voltmeter under standard conditions. **3**

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Question 21 (3 marks) **Marks**

(a) Name the ester formed between the reaction of ethanol and propanoic acid. **1**

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(b) If you carry out this reaction in the laboratory, you will have to heat the reaction mixture to speed up the reaction. This heating is best done under reflux. Give *TWO* reasons why refluxing the reaction mixture is good technique. **2**

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Question 22 (7 marks) **Marks**

This table gives the solubility of carbon dioxide in water at various temperatures.

TEMPERATURE/°C	SOLUBILITY/g of CO_2 per 100 g of water
0	0.33
10	0.23
20	0.17
30	0.13
40	0.097

(a) Describe the trend in the solubility of carbon dioxide with change in temperature. **1**

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(b) The dissolving of carbon dioxide in water involves an equilibrium process. Write a balanced equation for a reversible reaction of carbon dioxide with water. **2**

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(c) One test for carbon dioxide is to bubble the gas through a solution of calcium hydroxide, when a white precipitate of calcium carbonate is formed. **4**

$$Ca(OH)_2(aq) + CO_2(g) \rightarrow CaCO_3(s) + H_2O(l)$$

Calculate the volume of carbon dioxide gas, measured at 25°C and 101.3 kPa, needed to produce 0.50 g of calcium carbonate by the reaction.

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Question 23 (4 marks) **Marks**

Ammonia is a weak base in water solution. It reacts with water according to the equation

$$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$$

(a) (i) Why is ammonia classed as a *base* in this reaction? **1**

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(ii) Why is ammonia classed as a *weak* base in this reaction? **1**

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(b) What is the hydrogen ion concentration (mol L^{-1}) in a solution of pH 8.50? **1**

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(c) Give the formula of the conjugate acid of the hydroxide ion, OH^-. **1**

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Question 24 (6 marks) **Marks**

In a titration, a student finds that 30.0 mL of a 0.300 mol L^{-1} sulphuric acid solution is needed to react with 25.0 mL of a sodium hydroxide solution.

The equation for the titration reaction is

$$2NaOH(aq) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$$

(a) Calculate the concentration of the sodium hydroxide solution, in mol L^{-1}. **3**

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(b) Describe the correct technique for conducting titrations. **3**

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Question 25 (5 marks) **Marks**

This is a description of a test to identify the presence of chloride ions (Cl^-) in a water sample—

- acidify the sample with dilute nitric acid
- add a solution of silver nitrate ($AgNO_3$), when the appearance of a white precipitate shows the presence of Cl^-.

(a) The white precipitate is silver chloride, AgCl. Write a balanced equation for its formation in this test. Include states in your equation. **2**

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(b) The dilute nitric acid is added to remove carbonate ions from the water. This is necessary because white silver carbonate may precipitate when silver nitrate is added. How does the nitric acid remove carbonate ions from the water? **1**

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(c) Select either an anion or a cation from the list below. Describe a chemical test that would identify the ion you selected. **2**

ANIONS	CATIONS
carbonate	barium
sulphate	lead

Cation or anion selected .....

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Question 26 (8 marks) **Marks**

The equation below shows the synthesis of ammonia from its elements. ΔH for the reaction is also given, showing that the forward reaction is exothermic—

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -92 \text{ kJ mol}^{-1}$$

The Haber process uses this reaction, carried out in the presence of a catalyst, at a moderate temperature and high pressure.

(a) Identify ONE industrial use for ammonia. **1**

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(b) Identify a catalyst used in the Haber process. **1**

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(c) (i) Cooler reaction temperatures will increase the yield of ammonia. Explain. **1**

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(ii) Cooler reaction temperatures will slow down the formation of ammonia. Explain. **1**

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Question 26 continued on page 18

Question 26 (continued) **Marks**

(d) Analyse the impact of increased pressure on the reaction system above. **4**

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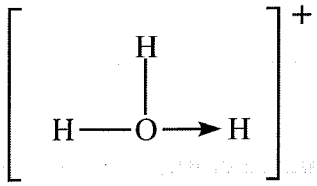
Question 27 (2 marks)

The H_3O^+ ion contains a coordinate covalent bond. The structural formula of the ion can be written like this—



Using dots (•) to represent electrons from oxygen, and crosses (×) to represent electrons from hydrogen, draw the Lewis diagram of the H_3O^+ ion. **2**

Question 28 (5 marks) **Marks**

Ozone (O_3) and oxygen (O_2) are allotropes of the element oxygen. Ozone is present in the upper atmosphere where it acts as a "shield" to incoming ultraviolet radiation.

(a) (i) Chlorofluorocarbons (CFCs) can lower the concentration of ozone in the upper atmosphere. Name the element present in CFCs that is directly responsible for the destruction of ozone molecules in the upper atmosphere. **1**

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(ii) Identify one source of CFCs in the upper atmosphere. **1**

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(iii) The CFC "Freon–12" is dichlorodifluoromethane. Draw the structural formula of this compound. **1**

(b) The table below shows some properties of oxygen and ozone. **2**

	DENSITY OF LIQUID/g mL^{-1}	MELTING POINT/°C	BOILING POINT/°C
Oxygen, O_2	1.15	–219	–183
Ozone, O_3	1.61	–193	–111

Select one of these properties. Account for the difference in this property between O_2 and O_3 in terms of their molecular structure and/or bonding.

Property selected.....

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Section II – Options

Total marks (25)
Attempt ONE question from Questions 29 – 33
Allow about 45 minutes for Section II

Answer the question you select in the Answer Book provided.

Show all relevant working in questions involving calculations.

Question 29 – Industrial Chemistry (25 marks) **Marks**

(a) Industrial processes can sometimes supply replacements for natural products.

(i) Name ONE natural product associated with shrinking world resources. **1**

(ii) Name its replacement, as made by industrial processes. **1**

(b) Phosgene gas, $COCl_2$, an important industrial chemical, partially decomposes at 1250°C:

$$COCl_2(g) \rightleftharpoons CO(g) + Cl_2(g)$$

(i) In one experiment, 1.00 mol of pure phosgene is placed in a 10.0 L sealed flask. When equilibrium is established at 1250°C, 0.20 mol of phosgene are in the flask.

1 How many mol of CO, and of Cl_2, are in the flask at equilibrium? **3**

2 Calculate the value for the equilibrium constant for the reaction, as written. **2**

(ii) In another experiment, 1.00 mol of pure phosgene is placed in a 2.0 L sealed flask. Equilibrium is established at 1250°C. How would the value of the equilibrium constant compare with the value you calculated in (i)? Explain. **1**

(c) The electrolysis of sodium chloride solution produces two important industrial chemicals: sodium hydroxide and chlorine. The *mercury cell*, and the *diaphragm cell*, are two different cells carrying out this electrolysis reaction.

(i) Describe *each* of these TWO cells. **6**

(ii) Analyse an environmental difficulty associated with ONE of these cells. **2**

(d) The Solvay process manufactures sodium carbonate.

(i) Give one use for sodium carbonate. **1**

(ii) Describe the chemistry involved in EITHER sodium hydrogencarbonate formation OR ammonia recovery. **2**

(iii) The physical location of an industrial plant is very important. What criteria should be kept in mind when locating a plant to carry out the Solvay process? **2**

Question 29 continues on page 23

Question 29 (continues) **Marks**

(e) Sulphuric acid is one of the most important industrial chemicals.

(i) Give one industrial use of sulphuric acid. **1**

(ii) Describe a reaction you have carried out to observe sulphuric acid acting as an oxidizing agent. In your description, mention any *special* safety precaution you needed to take because of the nature of sulphuric acid. **2**

(iii) In the manufacture of sulphuric acid, one step involves the conversion of sulphur dioxide to sulphur trioxide. State one reaction condition necessary for this conversion. **1**

End of Question 29

Question 30 – Shipwrecks and Salvage (25 marks) **Marks**

(a) Iron as produced in a blast furnace contains about 4% carbon. Steels contain up to 1.5% carbon. Compare the suitability of iron to steels for ship construction. Explain. **2**

(b) A steel ship in marine conditions is subjected to ideal conditions for corrosion. Outline one method for corrosion protection of the ship in marine conditions. **2**

(c) Explain why aluminium and not sodium is a passivating metal. **2**

(d) In 1976 it was believed that the Titanic was at such a great depth of water that the rate and extent of corrosion would be greatly retarded because: **5**

I. water temperature was approximately 0°C
II. very little dissolved oxygen was available
III. no damaging sea life was present
IV. low solubility of salts at such conditions
V. pH of sea water would be the normal value of pH 7–8

Yet in 1986 photographs taken by a submersible showed that the Titanic had *vast and extensive* corrosion, surprising for a ship that had only been submerged for several decades.

After much research and analysis the overall equation for the corrosion of the iron was found to be:

$$4Fe(s) + SO_4^{2-}(aq) + 5H_2O(l) \rightleftharpoons FeS(s) + 3Fe(OH)_2(s) + H_2O(l) + 2OH^-(aq)$$

Address points I–V and give the actual conditions to which the Titanic was subjected in order to account for the rate and extent of corrosion.

Question 30 continues on page 25

Question 30 (continues) **Marks**

(e) A small wooden trinket box was obtained from the Titanic site.

(i) Explain why the wooden box must not be allowed to dry out when it reaches the surface **1**

(ii) State and explain a conservation method that could be applied to the wooden box. **3**

(f) Luigi Galvani first generated an electric current by using two different metal wires placed separately on a freshly extracted frog muscle. **2**

List two chemical conditions which enabled the generation of the electric current.

(g) (i) Draw a labelled diagram of the apparatus used to electrolyze a copper nitrate solution using platinum electrodes. **4**

Your labelling should include

- electrolyte
- power supply
- anode and cathode
- an ammeter to measure the current

(ii) Write the half-equations for the oxidation and reduction half-reactions that occur in this electrolysis. **2**

(iii) How would you use the apparatus you drew in (i) to test the truth of Faraday's first law of electrolysis? **2**

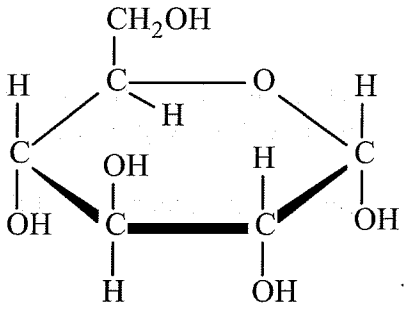
End of Question 30

Question 31 – Biochemistry of Movement (25 marks) **Marks**

(a) Draw up a table which, for each of TWO properties, compares Type 1 and Type 2 muscle cells. **2**

(b) The following structural formulas show various biomolecules. **4**

(J)



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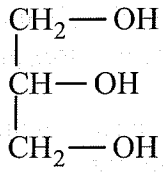

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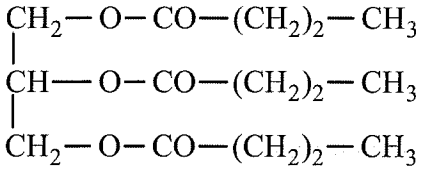
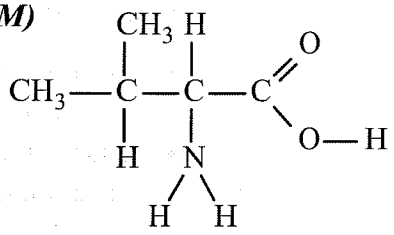


(M)



Indicate what class or family each molecule belongs to. Choose from this list—

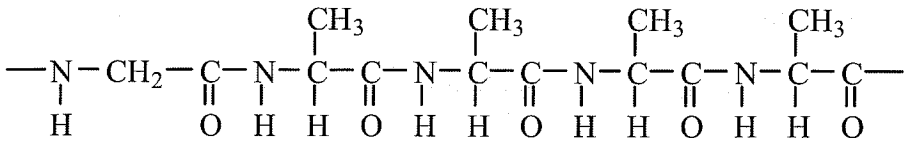
alcohol, amino acid, fatty acid, fat, protein, carbohydrate, enzyme

Question 31 continues on page 27

Question 31 (continued) **Marks**

(c) The primary structure of a protein is the sequence of amino acids in the protein.

The structural formula below shows part of the primary structure of a certain protein.



(i) Write the structural formula of ONE of the amino acids in this protein. **1**

(ii) The secondary and tertiary structures of this protein refer to its three-dimensional shape, which happens to be a helix. **2**

Name two forces involved in holding this helix together (apart from the bonds involved in the primary structure).

(d) The process of aerobic respiration in a muscle cell can be broken down into three main parts—

- glycolysis
- TCA cycle (Krebs cycle)
- cytochrome chain

(i) Where in a muscle cell does glycolysis occur? **1**

(ii) Compare quantitatively the net ATP output of *glycolysis* with that of the *TCA cycle plus cytochrome chain*. Base your comparison on one mole of glucose. **2**

(iii) A runner sprinting hard over 200 m produces a high concentration of lactic acid in those muscle cells she is using.

1 Explain the formation of lactic acid in these circumstances. **1**

2 Describe ONE way in which the runner's body removes the lactic acid. **1**

Question 31 continues on page 28

Marks

(e) During your study of this Option, you performed an investigation to observe the effect of changes of temperature on a named enzyme reaction.

(i) State the enzyme reaction you investigated. **1**

(ii) Describe how you carried out your investigation. Include details of the apparatus you used. **4**

(iii) Summarise the results you obtained in a graph. **3**

(iv) Explain the shape of your graph, over the complete range of temperatures you investigated. **3**

End of Question 31

Question 32 — Chemistry of Art (25 marks) **Marks**

(a) Iron(III) oxide powder, $Fe_2O_3(s)$, has been used as a red/brown pigment for thousands of years. Many other early pigments are like iron(III) oxide in that they are compounds of transition metals.

(i) Why do compounds of transition metals tend to make good pigments? **1**

(ii) How might you convert iron(III) oxide into a paint? **1**

(iii) Outline one way in which modern paints are superior to paints of even just a few hundred years ago. **1**

(b) The ground state electron configuration of vanadium, in terms of shells, is 2.8.11.2.

(i) Explain why vanadium is classed as a *d–block* element. **1**

(ii) Write the ground state electron configuration of vanadium in terms of SUBSHELLS. **2**

(c) When ammonia is added to a solution containing pale-blue hydrated copper(II) ions, the deep-blue tetramminecopper(II) ion is formed—

$$\underset{\text{pale-blue}}{Cu(H_2O)_4^{2+}} + 4NH_3 \rightarrow \underset{\text{deep-blue}}{Cu(NH_3)_4^{2+}} + 4H_2O(l)$$

(i) The attachment of the ammonia ligands to the Cu^{2+} ion shows ammonia acting as a Lewis base. Explain. **1**

(ii) If ammonia is replaced by Cl^-, the green-blue complex ion $CuCl_4^{2-}$ is formed.

1 Show that the oxidation number of copper in $CuCl_4^{2-}$, $Cu(NH_3)_4^{2+}$, and $Cu(H_2O)_4^{2+}$ is +2. **2**

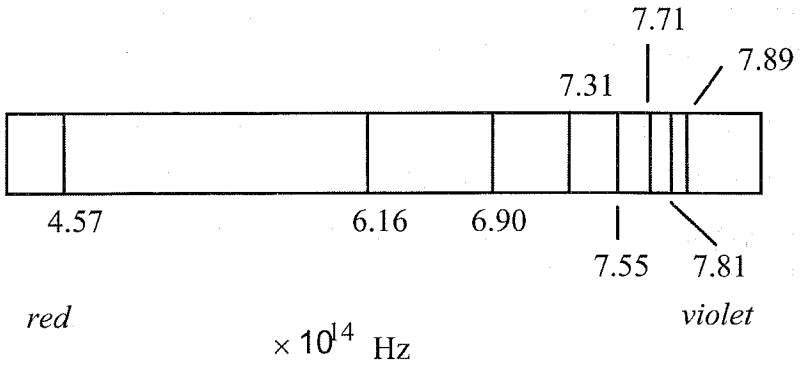
2 Suggest a reason why the color of these three complex ions is slightly different, even though copper has the same oxidation number in all of them. **1**

(iii) The ion $Cu(H_2O)_4^{2+}$ can function as an oxidizing agent. **2**
Use the reaction of this ion with $Mg(s)$ to form Mg^{2+} and $Cu(s)$ to explain this statement.

Question 32 continued on page 30

 Marks

(d) The diagram shows part of the emission spectrum of H*(g)*.



Line spectrum of H
Frequencies of lines in the visible region

The Bohr model of the atom attempted to explain such line spectra.

(i) Describe the Bohr model of the atom. **3**

(ii) How did this model of the atom explain the spectrum of H*(g)*? **3**

(e) Describe how data about successive ionization energies of an element can give information about the number of electrons in the valence shell, and valence subshells, of atoms of the element. **7**

In your answer, consider

- an *s-block* element
- a *p-block* element
- a *d-block* element

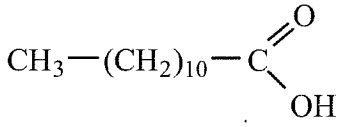
End of Question 32

Question 33 — Forensic Chemistry (25 marks) **Marks**

(a) You are required to distinguish between a sample of a reducing sugar, and a sample of a non-reducing sugar. How would you do this in the lab? Answer this question by stating the equipment you would use, the reagents you would use, any special reaction conditions, and the result you would expect in each case. **4**

(b) Describe one way in which plant and animal carbohydrates are similar, and one way in which they can differ. **2**

(c) Lauric acid has the structural formula



With glycerol, it forms the triglyceride fat present in coconut oil.

s(i) Draw the structural formula of the triglyceride formed between glycerol and lauric acid. **2**

(ii) People frequently say that fats and water don't mix. In fact, fat molecules have a water-soluble end, and a water-insoluble end. Show on your structural formula the water-insoluble end of the fat. **1**

(d) The amino acid composition of a protein can be determined by first reacting the protein with hot 6 mol L^{-1} hydrochloric acid for a suitable time, and then performing a chromatography separation on the reaction mixture.

(i) Draw the general structural formula of an amino acid. **2**
(ii) Amino acids join by the formation of a peptide bond. Show the structure of a peptide bond. **2**
(iii) What is happening to the protein during the reaction with the hot acid? **1**
(iv) Describe how you would carry out the chromatography separation. **3**

(e) (i) Outline how a mass spectroscope can give evidence about the relative molecular mass of a substance in a forensic sample. **3**

(ii) Name one other characteristic of a forensic sample that can be discovered using a mass spectroscope. **1**

(f) List some issues associated with a government maintaining a database of the DNA of individuals in society. **4**

End of Question 33

CATHOLIC SECONDARY SCHOOLS ASSOCIATION
CHEMISTRY DATA SHEET

Avogadro's constant, N_A ..... 6.022×10^{23} mol^{-1}
Volume of 1 mole ideal gas: at 100 kPa and
at 0°C (273 K) ..... 22.71 L
at 25°C (298 K) ..... 24.79 L
Ionisation constant for water at 25°C (298.15 K), K_w ..... 1.0×10^{-14}
Specific heat capacity of water ..... 4.18×10^3 J kg^{-1} K^{-1}

Some useful formulae

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

Some standard potentials

$K^+ + e^-$	$\rightleftharpoons$	$K_{(s)}$	–2.94 V
$Ba^{2+} + 2e^-$	$\rightleftharpoons$	$Ba_{(s)}$	–2.91 V
$Ca^{2+} + 2e^-$	$\rightleftharpoons$	$Ca_{(s)}$	–2.87 V
$Na^+ + e^-$	$\rightleftharpoons$	$Na_{(s)}$	–2.71 V
$Mg^{2+} + 2e^-$	$\rightleftharpoons$	$Mg_{(s)}$	–2.36 V
$Al^{3+} + 3e^-$	$\rightleftharpoons$	$Al_{(s)}$	–1.68 V
$Mn^{2+} + 2e^-$	$\rightleftharpoons$	$Mn_{(s)}$	–1.18 V
$H_2O + e^-$	$\rightleftharpoons$	$\frac{1}{2} H_{2(g)} + OH^-$	–0.83 V
$Zn^{2+} + 2e^-$	$\rightleftharpoons$	$Zn_{(s)}$	–0.76 V
$Fe^{2+} + 2e^-$	$\rightleftharpoons$	$Fe_{(s)}$	–0.44 V
$Ni^{2+} + 2e^-$	$\rightleftharpoons$	$Ni_{(s)}$	–0.24 V
$Sn^{2+} + 2e^-$	$\rightleftharpoons$	$Sn_{(s)}$	–0.14 V
$Pb^{2+} + 2e^-$	$\rightleftharpoons$	$Pb_{(s)}$	–0.13 V
$H^+ + e^-$	$\rightleftharpoons$	$\frac{1}{2} H_{2(g)}$	0.00 V
$SO_4^{2-} + 4H^+ + 2e^-$	$\rightleftharpoons$	$SO_{2(aq)} + 2H_2O$	0.16 V
$Cu^{2+} + 2e^-$	$\rightleftharpoons$	$Cu_{(s)}$	0.34 V
$\frac{1}{2} O_{2(g)} + H_2O + 2e^-$	$\rightleftharpoons$	$2OH^-$	0.40 V
$Cu^+ + e^-$	$\rightleftharpoons$	$Cu_{(s)}$	0.52 V
$\frac{1}{2} I_{2(s)} + e^-$	$\rightleftharpoons$	I^-	0.54 V
$\frac{1}{2} I_{2(aq)} + e^-$	$\rightleftharpoons$	I^-	0.62 V
$Fe^{3+} + e^-$	$\rightleftharpoons$	Fe^{2+}	0.77 V
$Ag^+ + e^-$	$\rightleftharpoons$	$Ag_{(s)}$	0.80 V
$\frac{1}{2} Br_{2(l)} + e^-$	$\rightleftharpoons$	Br^-	1.08 V
$\frac{1}{2} Br_{2(aq)} + e^-$	$\rightleftharpoons$	Br^-	1.10 V
$\frac{1}{2} O_{2(g)} + 2H^+ + 2e^-$	$\rightleftharpoons$	H_2O	1.23 V
$\frac{1}{2} Cl_{2(g)} + e^-$	$\rightleftharpoons$	Cl^-	1.36 V
$\frac{1}{2} Cr_2O_7^{2-} + 7H^+ + 3e^-$	$\rightleftharpoons$	$Cr^{3+} + \frac{7}{2} H_2O$	1.36 V
$\frac{1}{2} Cl_{2(aq)} + e^-$	$\rightleftharpoons$	Cl^-	1.40 V
$MnO_4^- + 8H^+ + 5e^-$	$\rightleftharpoons$	$Mn^{2+} + 4H_2O$	1.51 V
$\frac{1}{2} F_{2(g)} + e^-$	$\rightleftharpoons$	F^-	2.89 V

THE PERIODIC TABLE

KEY

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

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 65.39 Zinc	31 Ga 69.72 Gallium	32 Ge 72.61 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 [98.91] 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 Lanthanides	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 [210.0] Polonium	85 At [210.0] Astatine	86 Rn [222.0] Radon
87 Fr [223.0] Francium	88 Ra [226.0] Radium	89–103 Actinides	104 Rf [261.1] Rutherfordium	105 Db [262.1] Dubnium	106 Sg [263.1] Seaborgium	107 Bh [264.1] Bohrium	108 Hs [265.1] Hassium	109 Mt [268] Meitnerium	110 Uun — Ununnilium	111 Uuu — Unununium	112 Uub — Ununbium	113	114 Uuq — Ununquadium	115	116 Uuh — Ununhexium	117	118 Uuo — Ununoctium

Lanthanides

57 La 138.9 Lanthanum	58 Ce 140.1 Cerium	59 Pr 140.9 Praseodymium	60 Nd 144.2 Neodymium	61 Pm [146.9] 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

Actinides

89 Ac [227.0] Actinium	90 Th 232.0 Thorium	91 Pa 231.0 Protactinium	92 U 238.0 Uranium	93 Np [237.0] Neptunium	94 Pu [239.1] Plutonium	95 Am [241.1] Americium	96 Cm [244.1] Curium	97 Bk [249.1] Berkelium	98 Cf [252.1] Californium	99 Es [252.1] Einsteinium	100 Fm [257.1] Fermium	101 Md [258.1] Mendelevium	102 No [259.1] Nobelium	103 Lr [262.1] Lawrencium