Centre Number

Student Number

CATHOLIC SECONDARY SCHOOLS
ASSOCIATION OF NEW SOUTH WALES

2004
TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION

Chemistry

Afternoon Session
Friday 6 August 2004

Total marks – 100

Section I Pages 3-18

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 21-31

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

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using blue or black pen
- Draw diagrams using pencil
- Board-approved calculators may be used
- Use the Data Sheet and Periodic Table provided
- Use Multiple Choice Answer Sheet provided
- Write your Centre Number and Student Number and the top of this page, page 9 and page 21

EXAMINERS

Anna Davis (convenor)	Casimir Catholic College, Marrickville
Karen Bertinshaw	Gilroy College, Castle Hill
Narelle Lovell	Domremy College, Five Dock
Deborah Vitlin	Presbyterian Ladies College, Croydon
Chris Warren	St Vincent's College, Potts Point

Sources

Diagrams for Question 33 (b) & 33 (d)

James, M et al (2000). *Chemical Connections 2 (2nd Edition)*, John Wiley &Sons Australia Ltd, Milton

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 provided

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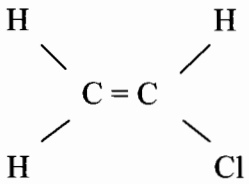
1 The diagram shows a commercially significant monomer, systematically known as chloroethene.



What is the common name of the polymer made from this monomer?

(A) polyethylene

(B) polyvinyl chloride

(C) polyvinyl acetate

(D) polystyrene

2 Which statement is correct concerning the addition of bromine water to cyclohexene?

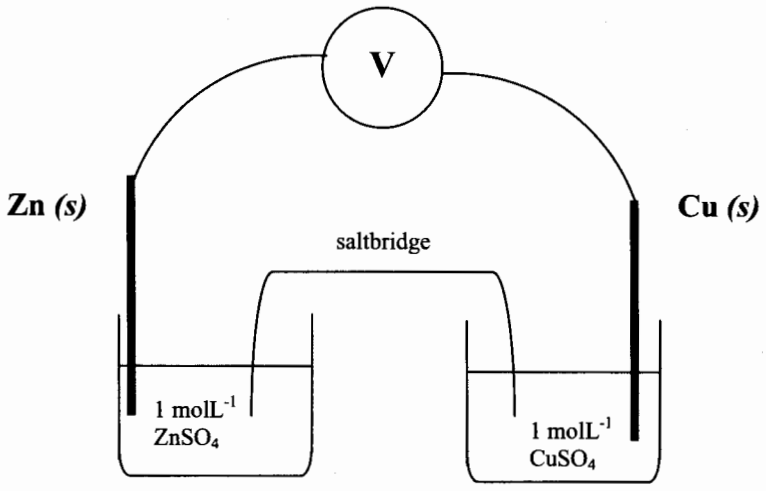
(A) The reaction is rapid and the bromine water changes colour

(B) The reaction is rapid and the cyclohexene changes colour

(C) The reaction is slow and requires light energy to proceed

(D) The reaction is slow and works best in the dark

3 The diagram shows the equipment used to measure the potential difference between two metal electrodes.



Identify the half equation for the reaction taking place at the cathode.

(A) $Zn\ (s) \rightleftharpoons Zn^{2+} + 2e^-$

(B) $Zn^{2+} + 2e^- \rightleftharpoons Zn\ (s)$

(C) $Cu\ (s) \rightleftharpoons Cu^{2+} + 2e^-$

(D) $Cu^{2+} + 2e^- \rightleftharpoons Cu\ (s)$

4 Identify the correct equation for the fermentation of glucose.

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

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

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

(D) $C_6H_{12}O_6\ (s) \rightarrow 2C_2H_5OH\ (l) + 2CO_2\ (g)$

5 Identify the pair of exothermic reactions.

(A) The combustion of ethanol and the fermentation of glucose

(B) The dehydration of ethanol and the combustion of ethanol

(C) The cracking of petroleum and the dehydration of ethanol

(D) The reaction of a galvanic cell and the cracking of petroleum

6 The best indicator to distinguish between rain water and 0.1 $molL^{-1}$ hydrochloric acid is

(A) bromothymol blue

(B) litmus

(C) phenolphthalein

(D) methyl orange

7 When added to water, the oxides of Group I are

(A) acidic

(B) basic

(C) insoluble

(D) amphoteric

8 The pH of a 0.0115 $molL^{-1}$ solution of H_2SO_4 is closest to

(A) 0.9

(B) 1.2

(C) 1.6

(D) 1.9

9 The conjugate acid of HPO_4^{2-} is

(A) H_3O^+

(B) $H_2PO_4^-$

(C) PO_4^{3-}

(D) H_3PO_4

10 The table below shows the boiling points of some compounds.

Compound	Boiling Point (°C)
butanoic acid	163
butanol	120
ethanoic acid	118
ethanol	78
methanoic acid	101
methanol	65

The boiling points, in °C, of propanoic acid and propanol are closest to

	Propanoic acid	*Propanol*
(A)	141	97
(B)	95	130
(C)	188	140
(D)	109	72

11 Incomplete combustion of hydrocarbons may result in the production of undesirable substances. TWO such substances are

(A) water and carbon dioxide

(B) carbon and carbon monoxide

(C) hydrogen and carbon

(D) sulfur dioxide and water

12 Which of the following is NOT a correct statement about ozone?

(A) Ozone is less reactive than normal oxygen

(B) Ozone is a pollutant in the lower atmosphere

(C) Ozone contains a co-ordinate covalent bond

(D) Ozone acts as an upper atmosphere UV radiation shield

13 The purpose of adding chlorine to domestic water supplies is to

(A) clarify the water

(B) reduce the pH of the water

(C) remove heavy metal ions like lead from the water

(D) disinfect the water

14 A student wanted to determine if a water sample was sea water or fresh water. Which of the following tests would most readily distinguish between sea water and fresh water?

(A) Hardness

(B) Turbidity

(C) Total dissolved solids

(D) Dissolved oxygen and biochemical oxygen demand

15 The Haber process is given below

$3\ H_2\ (g) + N_2\ (g) \rightleftharpoons 2\ NH_3\ (g)$

Which of the following will favour the production of ammonia?

(A) Decreasing the concentration of N_2 *(g)*

(B) Decreasing the pressure of the system

(C) Adding Ar *(g)*

(D) Decreasing the volume of the system

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Centre Number

Student Number

Chemistry

Section I (continued)

Part B – 60 marks
Attempt Questions 16-27
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.

Question 16 (3 marks) **Marks**

(a) Identify the substance that must be added to ethylene in order to produce ethanol. **1**

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(b) Explain why ethanol will dissolve both in water and in pentane. **2**

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Question 17 (3 marks)

The following equation shows the nuclear decay of commercially produced radioactive platinum-199.

$$^{199}_{78}Pt \rightarrow ^{199}_{79}Au + X$$

(a) Identify particle X. **1**

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(b) Describe a process that can be used to detect this radiation. **2**

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Question 18 (4 marks) **Marks**

In your studies, you analysed information regarding the development and use of a particular biopolymer. **4**

Assess the impacts that the use of this biopolymer may have on society or the environment.

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Question 19 (3 marks)

For this exam, you have been supplied with a data sheet containing a table showing some standard potentials. You have used this information in your course to calculate the $E^{\varnothing}$ requirement of different electrochemical processes. **3**

Describe the standard conditions under which these values were obtained and explain why they are necessary.

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Question 20 (7 marks) **Marks**

During the course, you performed a first-hand investigation to determine the molar heat of combustion of an alkanol.

(a) Write an equation for the complete combustion of an alkanol. **1**

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(b) Outline a procedure for determining the heat of combustion of an alkanol and justify the procedure you used. **6**

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Question 21 (4 marks) **Marks**

(a) Identify the THREE chemicals required to manufacture ethyl butanoate in a school laboratory. **2**

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(b) Identify an ester and outline the use of this ester. **2**

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Question 22 (3 marks)

Represent the ionisation of acetic acid in water:

(a) using an equation; and **1**

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(b) using a diagram to model the resultant solution. **2**

Question 23 (3 marks) **Marks**

Coal, containing 0.1 % sulfur, is burned in a power station. **3**

Calculate the volume of sulfur dioxide released at 25°C and 100kPa when 10.0 million kg of coal is burned.

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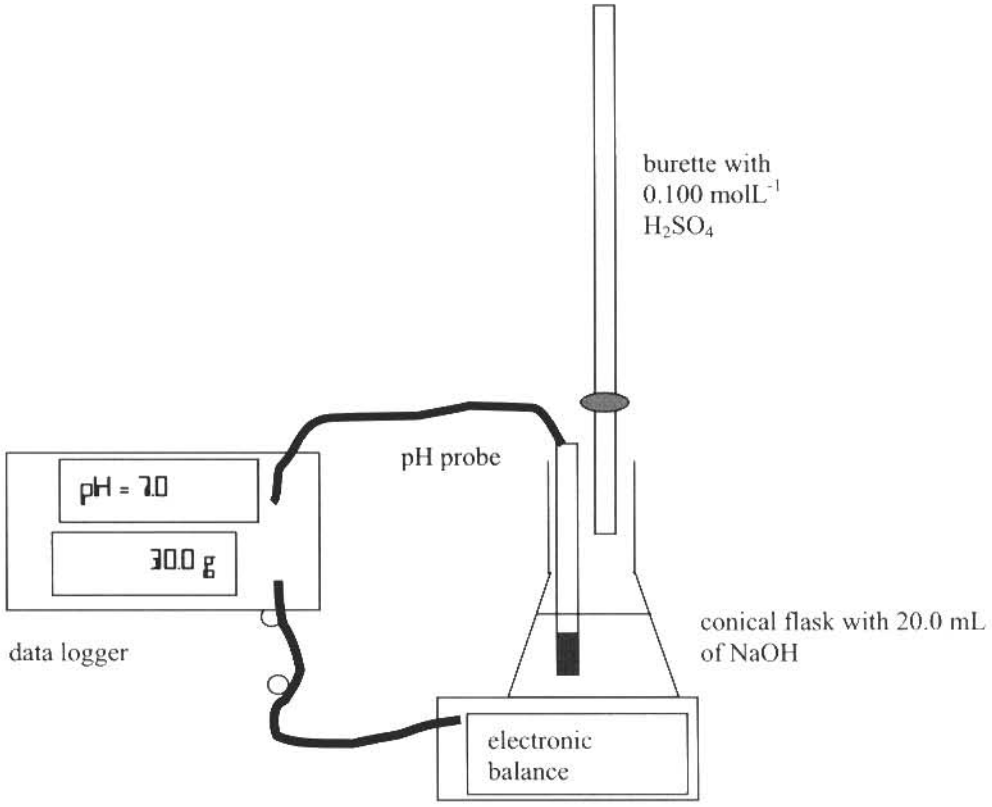
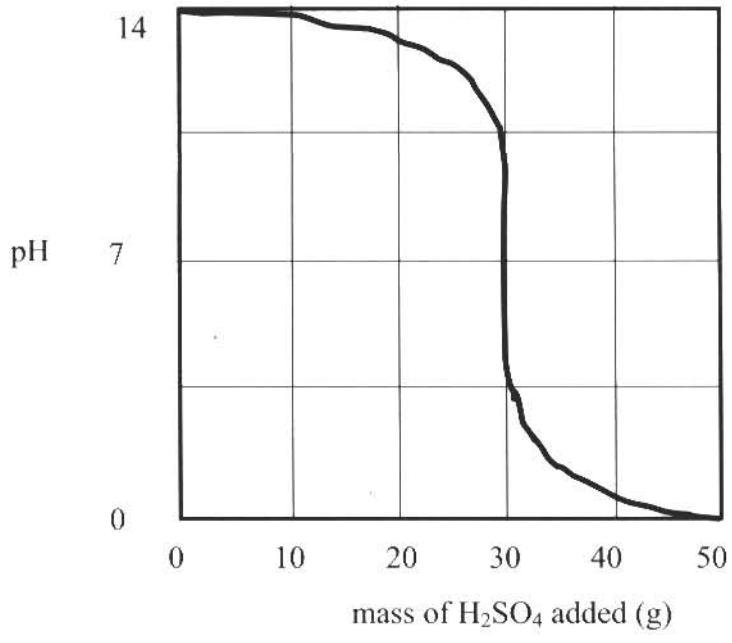
Question 24 (4 marks) **Marks**

A student added 20.0 mL of NaOH solution to a conical flask and placed it on a set of electronic scales, connected to a data logger. The balance was then zeroed. **4**



The NaOH was then titrated with excess 0.100 molL^{-1} H_2SO_4 solution. The data logger was used to monitor the changes in pH and mass in the reaction flask.

The data from the data-logger was printed as a graph.



Question 24 continues on page 15

Marks

Question 24 (continued)

Assuming the solutions have a density of 1 $g.mL^{-1}$, calculate the initial concentration of NaOH in the flask.

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Question 25 (6 marks)

Different theories of acids and bases were developed by Lavoisier, Davy, Arrhenius and Brönsted-Lowry. Sulfuric acid, H_2SO_4 was classified as an acid by all of these scientists.

Explain how each of their theories predict that H_2SO_4 is an acid. Support your answer by using equations where appropriate. **6**

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Question 26 (6 marks) **Marks**

(a) Draw the structure of, and name, an example of a CFC (chlorofluorocarbon). **1**

(b) Identify an alternative used to replace CFCs and account for its use. **2**

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(c) Describe how information about changing atmospheric ozone concentrations is obtained. **3**

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Question 27 (8 marks) **Marks**

The Haber process is used to produce ammonia.

(a) Identify an industrial use of ammonia. **1**

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(b) Is the production of ammonia, using this process, endothermic or exothermic? **1**

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(c) Identify the catalyst used in the Haber process and explain why it is used. **3**

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(d) Why was the work of Haber, in developing the process for the production of ammonia, so significant? **3**

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Question 28 (6 marks) **Marks**

Assess the impact of the use of Atomic Absorption Spectroscopy on society and the environment. **6**

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Centre Number

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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 SEPARATE writing booklet.

Show all relevant working in questions involving calculations.

2801-1

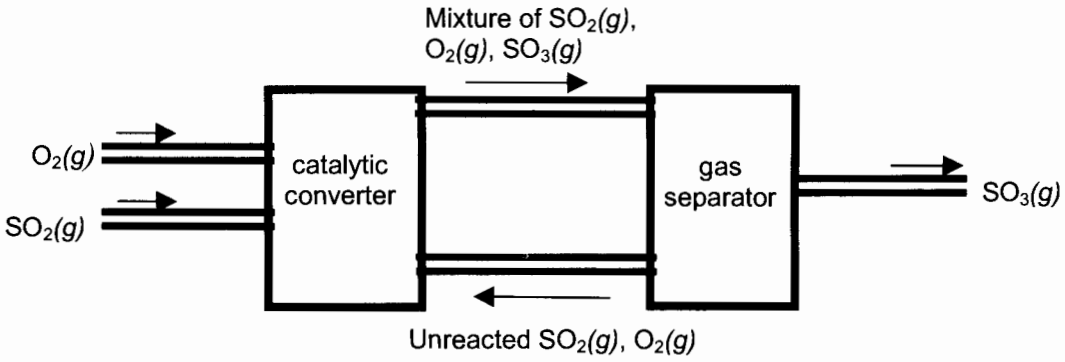
Question 29 – Industrial Chemistry (25 marks) **Marks**

(a) Sodium hydroxide is commercially manufactured from sodium chloride by electrolysis.

(i) Define electrolysis. **1**

(ii) Explain how an advance in technology has led to improvements in the way that sodium hydroxide is made. **3**

(b) One stage in the production of sulfuric acid is shown below.



(i) Write a balanced equation to represent the equilibrium reaction that occurs in the catalytic converter. **1**

(ii) Calculate a value for the equilibrium constant (K) if the equilibrium concentrations of the gases in the catalytic converter are: **2**

$[O_2] = 1.0\ molL^{-1}$
$[SO_2] = 2.0\ molL^{-1}$
$[SO_3] = 4.0\ molL^{-1}$

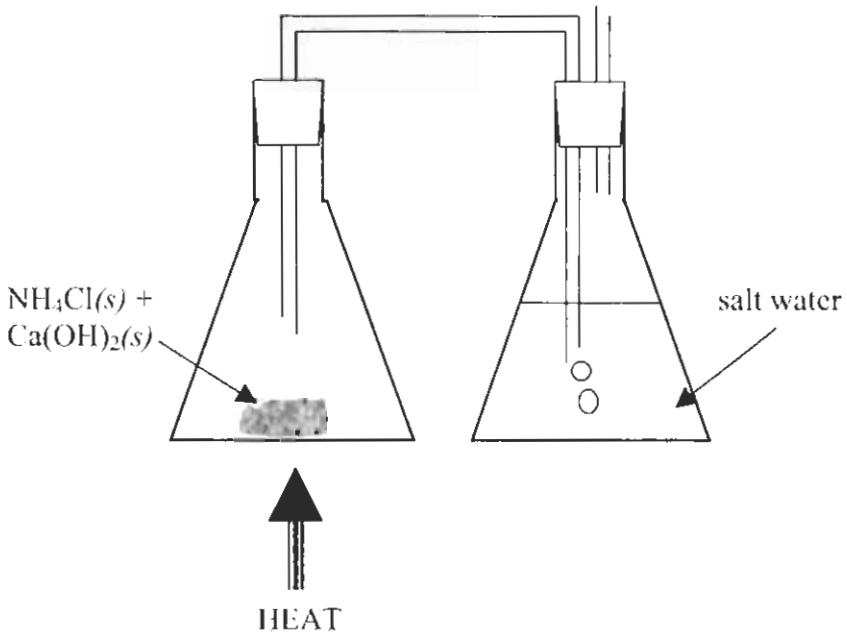
(iii) Explain the safety precautions required when transporting sulfuric acid. **3**

Question 29 continues on page 23

(c) The recovery of ammonia during the Solvay process can be modelled in the laboratory.

A mixture of solid ammonium chloride and calcium hydroxide is heated strongly in a flask. The ammonia produced is bubbled through a solution of salt water.

$$NH_4Cl(s) + Ca(OH)_2(s) \rightarrow NH_3(g) + CaCl_2(s) + H_2O(g)$$



(i) Outline a method for quantitatively measuring the amount of ammonia produced. **2**

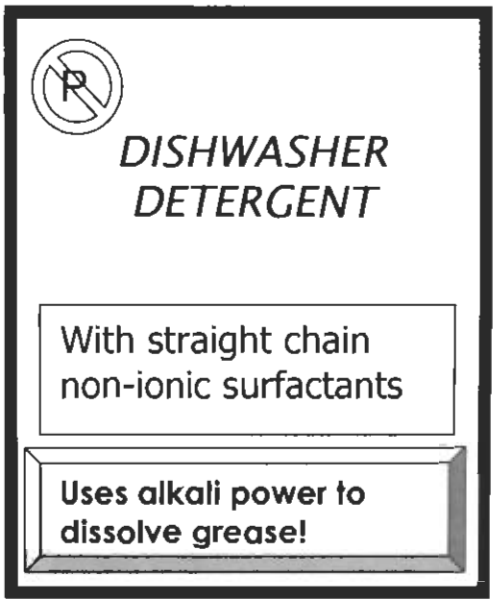
(ii) Account for the colour change observed if several drops of phenolphthalein are added to the salt water. **2**

Question 20 continues on page 24

(d) Two dishwashing detergent packages are shown below.

Detergent A

Detergent B



Recommend the most "environmentally friendly" detergent. Justify your choice. **4**

(c) Modelling is used in chemistry to represent chemical reactions and explain concepts. **7**

Discuss the features of a model you have used to demonstrate the effect of changing concentration on an equilibrium reaction.

End of Question 29

Question 30 – Shipwrecks, Corrosion and Conservation (25 marks) **Marks**

(a) (i) Identify a negative ion that is present in artefacts recovered from ocean shipwrecks. **1**

(ii) Explain why artefacts recovered from long submerged shipwrecks are not dried immediately. **3**

(b) (i) Identify the TWO main elements in steel. **1**

(ii) Explain the process of rusting of steel objects. **2**

(iii) Account for the fact that the composition of steel alloys can determine its properties such as corrosion resistance. **3**

(c) (i) Outline the procedure you used to identify ONE factor that affected the rate of electrolysis. **2**

(ii) Account for your observations. **2**

(d) A student used iron nails that had been painted as one of the samples tested in a first-hand investigation designed to compare the effectiveness of different protections used to coat iron and prevent corrosion. **4**

The student weighed each of the 5 iron nails with the paint coat intact and placed them into 5 identical test tubes containing 10 mL of a 1 $molL^{-1}$ solution of hydrochloric acid. She then used a file to remove a strip of paint from 5 additional iron nails, exposing the bare metal underneath.

These nails were also weighed before placing them into 5 identical test tubes containing 10 mL of a 1 $molL^{-1}$ solution of hydrochloric acid. These samples were then left overnight.

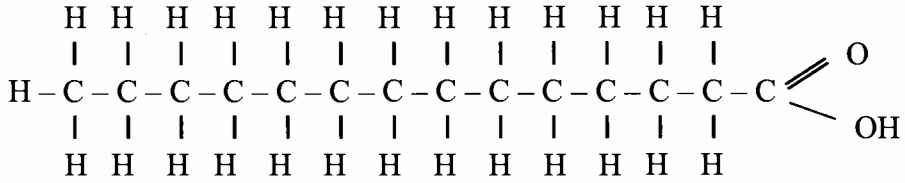
Evaluate the student's procedure.

(e) Discuss the chemistry involved and the impacts on society and the environment of the application of cathodic protection in marine and wet terrestrial environments. **7**

End of Question 30

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

This diagram is needed for part (a) and part (b).



Molecule A

(a) (i) Identify the class of compounds to which molecule A belongs. **1**

(ii) Identify the part of this molecule that mixes with water and explain why this occurs. **3**

(b) Molecule A is stored in human cells as part of a larger molecule called a triacyl glycerol (TAG).

TAGs are produced when molecules such as molecule A form ester linkages with a particular alcohol.

(i) Identify this alcohol. **1**

(ii) Explain, using a diagram if necessary, the process of oxidation of molecule A. **2**

(iii) Compare and assess the importance of TAGs and glycogen in their respective roles as stores of the energy required for human metabolism. **3**

(c) Proteins are important both as structural molecules and as enzymes. During the course, you performed a first-hand investigation to investigate the effect of pH or temperature on the action of an enzyme.

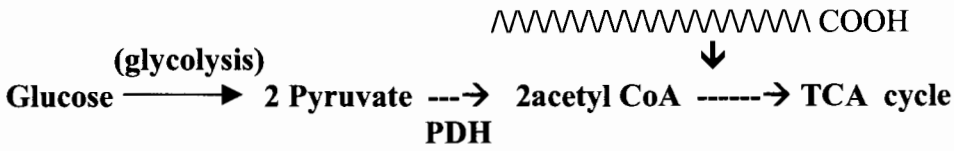
(i) Identify the enzyme used and its substrate. **1**

(ii) Assess the validity and accuracy of your experiment. **3**

Question 31 continues on page 27

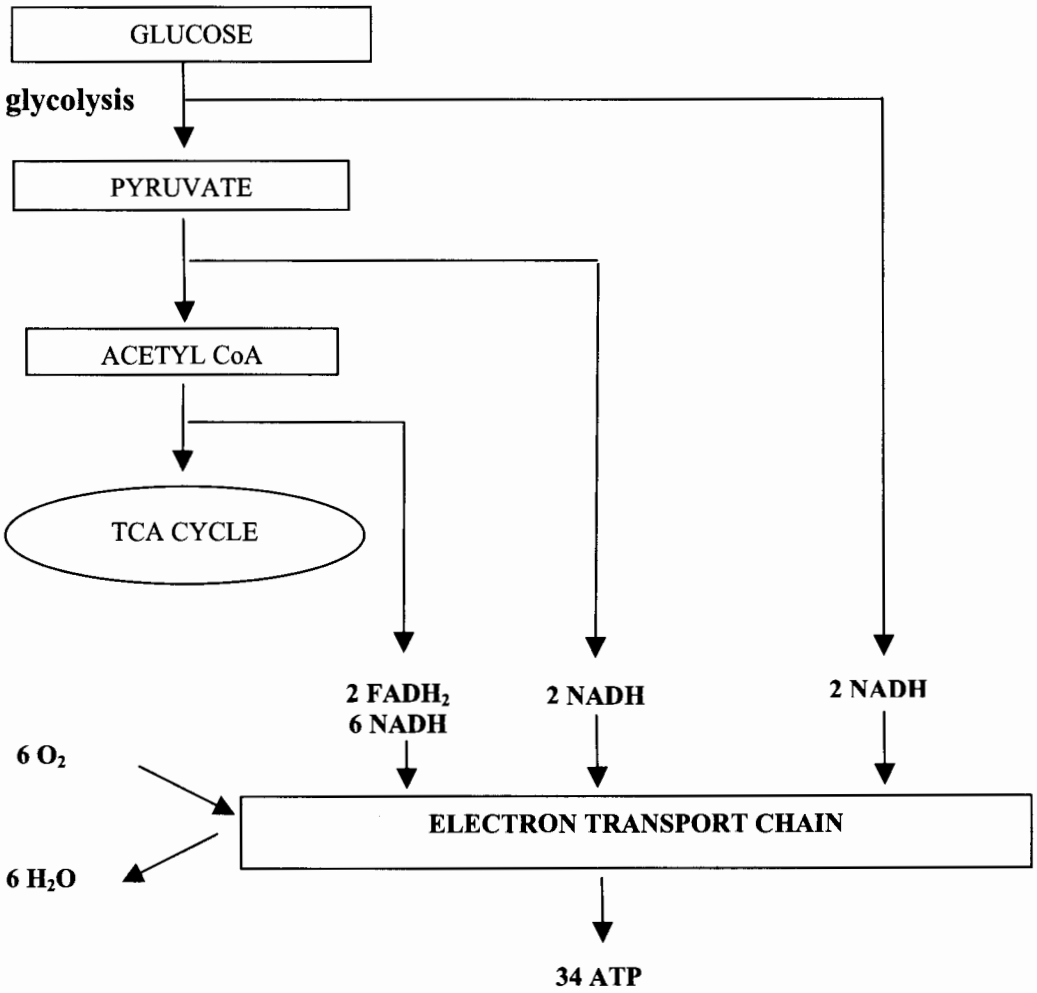
Question 31 (continued) **Marks**

(d) The diagram below shows an important metabolic pathway in the human body.



Discuss the importance of the PDH (Pyruvate dehydrogenase) complex in its inhibition of the conversion of pyruvate to acetyl CoA, relating it to a body's needs in prolonged gentle exercise. **4**

(e) Evaluate the importance of NADH and $FADH_2$ in the human respiratory chain. **7**



End of Question 31

Question 32 – The Chemistry of Art (25 marks) **Marks**

(a) (i) Name a cosmetic pigment used in ancient Egypt or Rome. **1**

(ii) Assess the potential health risk associated with the use of this pigment. **3**

(b) An atom of a certain element has the electronic configuration

$$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^3\ 4s^2$$

(i) What is the name of the element? **1**

(ii) Describe any differences in energy between the 1s, 2s and 2p subshells. **2**

(iii) How does the Pauli exclusion principle and Hund's rule allow you to identify the position of electrons around this atom? **3**

(c) During your practical work you performed a first-hand investigation to observe the colour changes that occur as a transition metal changes its oxidation state.

(i) Name the transition metal you used in this practical work. **1**

(ii) Account for the colour changes you observed as the oxidation state of your metal ion changed. **3**

(d) The diagram for this question is on the next page. **4**

The diagram shows a structure for the oxalate ion and a structure for the coordination complex ion known as the trisoxalatochromate(III) ion.

Describe the bonding that occurs in the coordination complex ion.

(e) In 1914 Niels Bohr published his model of the structure of the atom based on study of the line spectrum of hydrogen. **7**

Assess how useful his model has been.

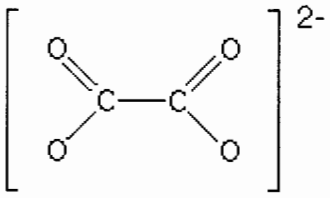
Question 32 continues on page 29

Question 32 (continued)

Diagrams for Question 32 (d)

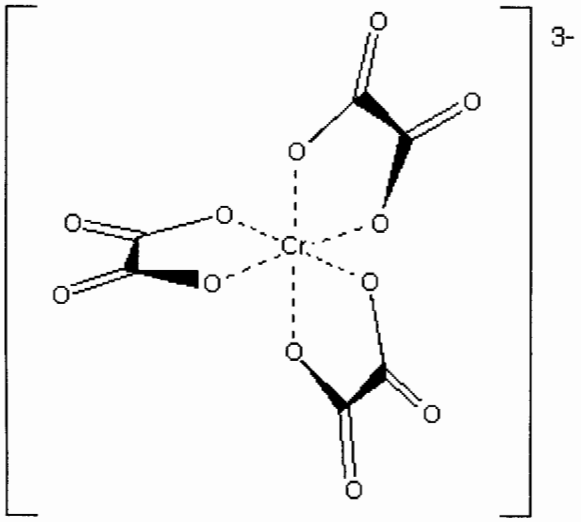
Example of a Bidentate Ligand
A bidentate ligand has two points at which it can attach to the central atom. One example of such a ligand is the:

oxalate ion



The two single-bonded oxygen atoms can each donate electrons to a central atom. Three oxalate ions can coordinate a single central atom, giving an octahedral complex. The result looks like this:

trisoxalatochromate(III) ion or just $[Cr(ox)_3]^{3-}$



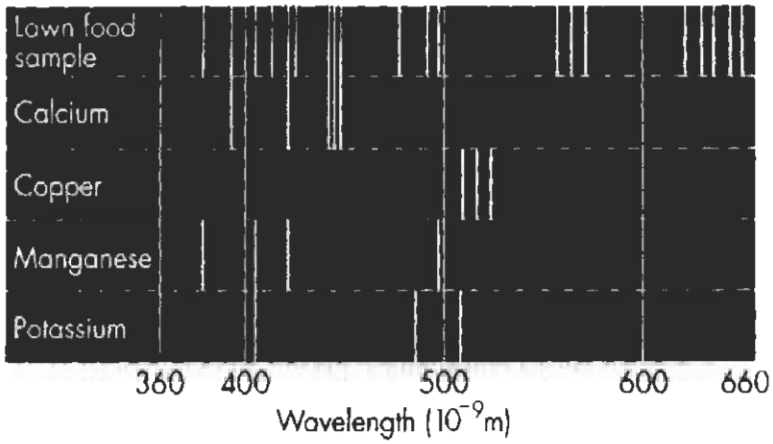
End of Question 32

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

(a) (i) Identify ONE of the major functional groups in an amino acid. **1**

(ii) Explain how proteins are formed from amino acids. **3**

(b) The diagram below shows the spectra of a sample of lawn food. It also shows the spectra of some trace elements that may be present in lawn food.



Spectra of elements in lawn food

(i) Identify ONE trace element that is present in lawn food. **1**

(ii) Describe, using a specific example, the use of line emission spectra by the forensic chemist to identify the presence of elements in chemicals. **2**

(iii) Explain why each element produces its signature emission spectrum. **3**

(c) During the course, you performed chemical tests to distinguish between alkenes and alkanols.

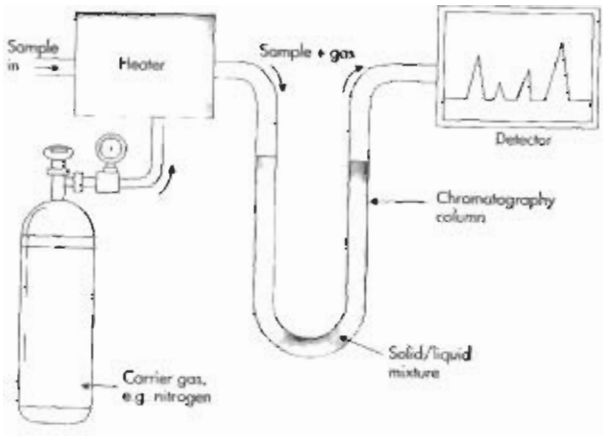
A student tested 1-propanol and cyclohexene with bromine water. The student also tested 1-propanol and cyclohexene with acidified potassium permanganate.

(i) Identify ONE safety precaution that must be taken during this investigation (general answers, eg safety glasses, will not be accepted). **1**

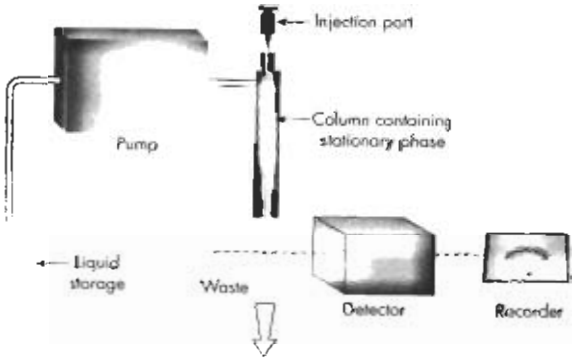
(ii) Account for your observations, including the names of any products formed. **3**

Question 33 continues on page 31

(d) Compare gas chromatography (GC) with high performance liquid chromatography (HPLC). **4**



Gas Chromatography



High Performance Liquid Chromatography

(e) Discuss how the process of electrophoresis assists the forensic chemist in analysing DNA. **7**

End of Question 33

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Centre Number

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CATHOLIC SECONDARY SCHOOLS ASSOCIATION OF NEW SOUTH WALES
YEAR 12 TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION 2004

CHEMISTRY– MULTIPLE CHOICE ANSWER SHEET

Select the alternative A, B, C, or D that best answers the question. Fill in the response oval completely.

Sample 2 + 4 = (A) 2 (B) 6 (C) 8 (D) 9

A○ B● C○ D○

If you think you have made a mistake, put a cross through the incorrect answer and fill in the new answer.

A● B⊗ C○ D○

If you have changed your mind and have crossed out what you consider to be the correct answer, then indicate this by writing the word *correct* and drawing an arrow as follows:

correct

A⊗ B⊗ C○ D○

ATTEMPT ALL QUESTIONS

Question	**1**	A ○	B ○	C ○	D ○
	2	A ○	B ○	C ○	D ○
	3	A ○	B ○	C ○	D ○
	4	A ○	B ○	C ○	D ○
	5	A ○	B ○	C ○	D ○
	6	A ○	B ○	C ○	D ○
	7	A ○	B ○	C ○	D ○
	8	A ○	B ○	C ○	D ○
	9	A ○	B ○	C ○	D ○
	10	A ○	B ○	C ○	D ○
	11	A ○	B ○	C ○	D ○
	12	A ○	B ○	C ○	D ○
	13	A ○	B ○	C ○	D ○
	14	A ○	B ○	C ○	D ○
	15	A ○	B ○	C ○	D ○

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 — Symbol of element
Atomic Weight — 197.0 — Name of element
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 65.39 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 — Ununilium	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