Section I
75 marks

Catholic trial 2008.

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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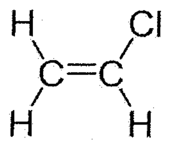
1 Which of the following correctly identifies this monomer?



	Systematic name	*Common name*
(A)	chloroethene	vinyl chloride
(B)	styrene	chloroethene
(C)	chloroethene	styrene
(D)	vinyl chloride	chloroethene

2 The following table gives the heats of combustion of three liquid alkanols in kJ/g.

Alkanol	*Heat of combustion (kJ/g)*
methanol	22.7
ethanol	29.7
1-butanol	36.1

Which of the following is the best approximation for the molar heat of combustion of 1-propanol?

	Molar heat of combustion (kJ/mol)
(A)	34
(B)	43
(C)	2000
(D)	3200

3 Most of the world's ethylene is currently produced from the

(A) dehydration of ethanol.

(B) fermentation of sugars.

(C) treatment of biomass.

(D) cracking of crude oil.

4 Which part of a galvanic cell is responsible for maintaining electrical neutrality?

(A) The anode

(B) The cathode

(C) The electrolyte solution surrounding the electrodes

(D) The electrolyte solution in the salt bridge

5 Americium-241 is produced according to the reaction

$$^{239}_{94}\mathrm{Pu} + 2X \rightarrow {}^{241}_{95}\mathrm{Am} + {}^{0}_{-1}\mathrm{e}$$

What is the identity of X?

(A) A neutron

(B) A proton

(C) A beta particle

(D) An alpha particle

6 An unknown chemical was removed from the surface of a food storage cupboard being checked for contamination. One of the first tests performed by the chemist was to determine the pH of the chemical by using indicators.

The results are shown in the table below.

Indicator	*Colour*
Phenolphthalein	Colourless
Methyl orange	Yellow
Bromothymol blue	Yellow

How should the chemist classify the chemical?

(A) Strongly acidic

(B) Slightly acidic

(C) Neutral

(D) Slightly alkaline

7 The conjugate base of HNO_2 is

(A) OH^-

(B) NO_2^-

(C) NO_3^-

(D) H_3O^+

8 Which action would result in an increase of TWO pH units of the solution?

(A) Diluting 10 mL of 0.01 mol L^{-1} HCl *(aq)* to 40 mL

(B) Diluting 10 mL of 0.01 mol L^{-1} NaOH *(aq)* to 40 mL

(C) Diluting 10 mL of 0.01 mol L^{-1} HCl *(aq)* to 1000 mL

(D) Diluting 10 mL of 0.01 mol L^{-1} NaOH *(aq)* to 1000 mL

9 A naturally occurring, moderately weak, triprotic acid is represented by the formula

(A) $C_6H_8O_7$

(B) $CH_3(CH_2)_6COOH$

(C) CH_3COOH

(D) H_3O^+

10 During the esterification process, a reflux system is often set up. The refluxing

(A) allows the reaction to proceed at a lower temperature.

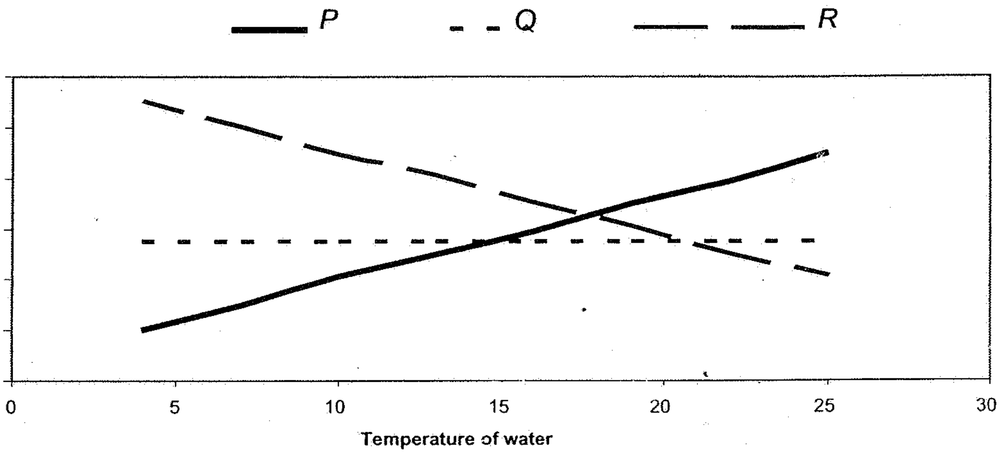
(B) prevents the very volatile concentrated sulfuric acid from evaporating.

(C) allows the reactants to react efficiently at a higher temperature.

(D) prevents the alcohol from boiling in the flask.

11 A river that begins at the foot of a glacier was tested for water quality at several places along its course as the water moves downstream through uninhabited forest reserve. The temperature of the water increases as the water moves downstream. THREE different tests (labelled *P*, *Q* and *R* in the graph's legend) were conducted at EACH location.

The data plotted to represent the results of the three tests (*P*, *Q* and *R*) is shown below.



Identify the THREE tests carried out.

	Test P	*Test Q*	*Test R*
(A)	Total dissolved solids	Acidity	Dissolved oxygen
(B)	Turbidity	Total dissolved solids	Hardness
(C)	Acidity	Hardness	Turbidity
(D)	Dissolved oxygen	Turbidity	Total dissolved solids

12 Which of the following species does not contain a co-ordinate covalent bond?

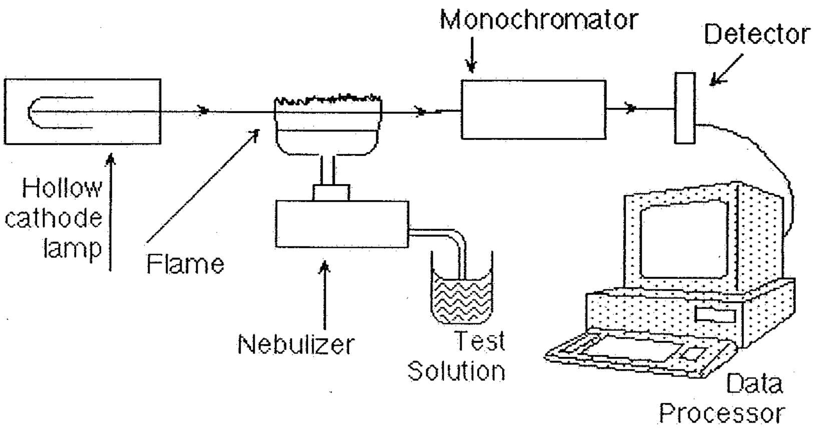
(A) O_3

(B) CO

(C) NH_4^+

(D) CH_4

13 The diagram below shows an Atomic Absorption Spectrometer being used to test for the presence of lead.



http://www.chemistry.nmsu.edu/Instrumentation/AAS1.html

If the test solution contains lead, then the light picked up by the detector will be at a

(A) higher intensity than the light produced by the hollow cathode lamp.

(B) lower intensity than the light produced by the hollow cathode lamp.

(C) higher frequency than the light produced by the hollow cathode lamp.

(D) lower frequency than the light produced by the hollow cathode lamp.

14 In the Haber process, which of the following conditions would result in the most industrially efficient method of increasing the yield of ammonia?

(A) Increasing the temperature of the reaction vessel

(B) Increasing the amount of N_2 *(g)*

(C) Increasing the amount of H_2 *(g)*

(D) Removing the NH_3 *(g)* as it forms

15 A student was given a pure sample of an unknown salt and asked to determine the cation and anion present. She carried out the following reactions.

	Method	*Result*
Test 1	Dilute nitric acid was added to a portion of the sample.	Bubbles of gas were observed. The solid sample dissolved, forming a solution. No precipitate formed.
Test 2	Dilute hydrochloric acid was added to another portion of the sample.	Bubbles of gas were observed. The solid sample dissolved, forming a solution. No precipitate formed.
Test 3	Dilute sulfuric acid was added to another portion of the sample.	Bubbles of gas were observed. The solid sample dissolved, forming a solution. No precipitate formed.
Test 4	Excess sodium hydroxide solution was added to the solution resulting from Test 1.	A white precipitate formed which turned brown on standing.
Test 5	A flame test was carried out on a fresh portion of the sample.	No distinctive flame colour was observed.

The student's results are consistent with the unknown salt being

(A) calcium carbonate.

(B) calcium nitrate.

(C) iron (II) carbonate.

(D) iron (II) nitrate.

Centre Number

Student Number

Chemistry

Section I (continued)

Part B – 60 marks
Attempt Questions 16-30
Allow about 1 hour and 45 minutes for this part

Answer the questions in the spaces provided.

Show all relevant working in questions involving calculations.

Marks

Question 16 (4 marks)

In your course you conducted a first-hand investigation to compare the reactivities, in bromine water, of an appropriate alkene and its corresponding alkane.

(a) Identify the dependent variable in your investigation. **1**

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(b) Name and draw the structural formula for the alkene used in your investigation. **1**

(c) Justify the selection of this alkene. **2**

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3501-1

Marks

Question 17 (5 marks)

Tincture of iodine is an antiseptic often found in medical kits. It is a solution of iodine (I_2) in ethanol. Ethanol is used as the solvent as iodine is relatively insoluble in water. When an aqueous solution of iodine is required, iodide ions are added to iodine to form the triiodide ion (I_3^-) which is more soluble in water.

$$I_2\,(s) + I^-\,(aq) \rightarrow I_3^-\,(aq)$$

(a) Draw an electron dot structure for the iodide ion. **1**

(b) Draw a labelled diagram to explain the solubility of iodine (I_2) in ethanol. **2**

(c) Explain why the triiodide ion (I_3^-) is more soluble in water than is iodine (I_2). **2**

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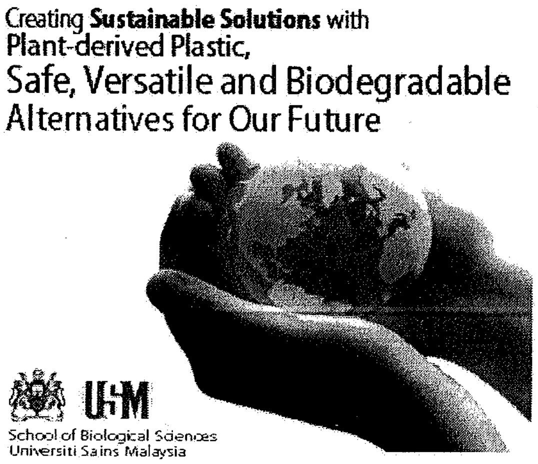
Marks

Question 18 (5 marks)

The following image was found during an investigation about biopolymers. 5



http://www.ecobiomaterial.com/research-002.php

Assess the validity of the claims made in this source, by referring BOTH to a recently developed biopolymer and to a petroleum-based polymer.

Marks

Question 19 (3 marks)

A student was asked to construct a galvanic cell using lead and magnesium electrodes and lead (II) nitrate and magnesium nitrate as electrolyte solutions.

(a) Calculate the maximum cell voltage that could be produced from this galvanic cell at standard conditions, showing the reduction and oxidation half-equations and all relevant working. **2**

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(b) The cell voltage measured by the student was less than the calculated E° value. Suggest a possible reason for this difference. **1**

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Marks

Question 20 (3 marks)

Radioisotopes are used both in medicine and industry. 3

Identify a radioisotope used EITHER in industry OR medicine.
Describe its use and explain how the properties of the identified radioisotope make it appropriate for the use you have described.

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Marks

Question 21 (2 marks)

As part of your course work, you prepared an indicator from a natural material.

(a) Outline the procedure that you followed. **1**

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(b) Outline how you determined whether the indicator you produced was appropriate to test the acidity of a substance. **1**

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Marks

Question 22 (4 marks)

One equilibrium reaction occurring in soft drinks involves carbon dioxide dissolving in water. The dissolution reaction is exothermic.

(a) Use Le Chatelier's Principle to predict the effect on the solubility of carbon dioxide in water as the temperature is increased. **2**

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(b) Using an equilibrium equation, explain why a solution of carbon dioxide in water is acidic. **2**

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Marks

Question 23 (6 marks)

A titration was carried out to determine the concentration of an acetic acid solution, using previously standardised 0.105 mol L^{-1} sodium hydroxide solution.

(a) Outline the method used to standardise the sodium hydroxide solution. **2**

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(b) Calculate the concentration of the acetic acid solution, if 25.0 mL of this solution reacted completely with 17.6 mL of the sodium hydroxide solution. **2**

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(c) Methyl orange is NOT a suitable indicator for use in this titration. Justify this statement. **2**

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Marks

Question 24 (4 marks)

When sodium burns in oxygen it forms sodium oxide, Na_2O.
Sodium also reacts with water to form sodium hydroxide and hydrogen gas.
A small sample of sodium was reacted with 100.0 mL water in a beaker and the resulting sodium hydroxide solution was found to have a concentration of 3.16×10^{-2} mol L^{-1}.

(a) Explain why sodium oxide is classified as a basic oxide. **1**

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(b) Write a balanced equation for the reaction of sodium with water. **1**

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(c) Determine the mass of sodium which must have reacted with the water in the beaker. **2**

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Marks

Question 25 (4 marks)

A student mixed 1-butanol and ethanoic acid together and heated them under reflux with concentrated sulfuric acid.

(a) Name the ester which was produced in this reaction. **1**

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(b) Draw the structural formula for this ester. **1**

(c) Outline TWO purposes for the addition of concentrated sulfuric acid. **2**

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Marks

Question 26 (3 marks)

In the combustion chamber of a petrol-burning car, the majority of the fuel burnt is octane.

(a) Write the balanced equation for the complete combustion of octane. **1**

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(b) Calculate the volume of carbon dioxide which would be produced by the complete combustion of 1.000 kg of octane (measured at 25°C and 100 kPa pressure). **2**

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Marks

Question 27 (6 marks)

A student was given a water sample and asked to determine whether the water should be classified as hard or soft and whether calcium ions were present in the sample.

The steps he took were as follows:

	Method	*Observations*
Step 1	The student added soap solution to a portion of the sample in a test tube and shook the test tube.	Bubbles formed.
Step 2	The student added sodium carbonate solution to a portion of the sample in a test tube and shook the test tube. The student filtered off the precipitate, discarded the precipitate and retained the filtrate for Step 3.	A white precipitate formed.
Step 3	The student heated the filtrate from Step 2 in an evaporating basin until the water had evaporated and a dry solid remained. He then carried out a flame test on the dry solid.	A yellow flame was produced.

The student concluded that:

- the water sample he tested should be classified as soft, as bubbles had formed in Step 1.
- calcium ions were present in the sample, as a white solid had been precipitated in Step 2 and a yellow flame had been observed in Step 3.

The teacher told the student that his conclusions were not valid.

(a) Explain the difference between an invalid experiment and an unreliable experiment. **2**

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Question 27 continues on page 21

Marks

Question 27 (continued)

(b) Evaluate the validity of the conclusions that the student reached. **4**

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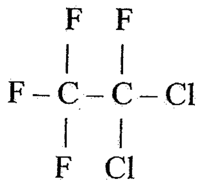
End of Question 27

Marks

Question 28 (4 marks)

(a) Use systematic naming to identify this isomer of $C_2Cl_2F_4$. **1**



(b) Use appropriate chemical equations to show how the release of ONE $C_2Cl_2F_4$ molecule into the atmosphere can result in the destruction of many ozone molecules. **3**

Marks

Question 29 (3 marks)

The catalyst used in the Haber process is iron on the surface of magnetite. 3
By referring to the role of the catalyst, explain why it is essential for industrial chemists to monitor the condition of the catalyst used in this process.

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Question 30 (4 marks) **Marks**

The water supply of large cities needs to be purified and sanitised before it is acceptable for human consumption. **4**
Outline the methods used to purify the supply PRIOR to its chlorination, and discuss the need for purification of the water supply.

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Question 31 – Industrial Chemistry (25 marks)

(a) Sulfuric acid is one of the world's most produced chemicals.

(i) Identify ONE safety precaution you need to take when handling sulfuric acid. **1**

(ii) The first step in the production of sulfuric acid is the extraction of elemental sulfur from mineral deposits. **4**
Describe the Frasch process used to extract sulfur, relating the method to the properties of elemental sulfur which allow its extraction.
Describe potential environmental issues that may be associated with this extraction process.

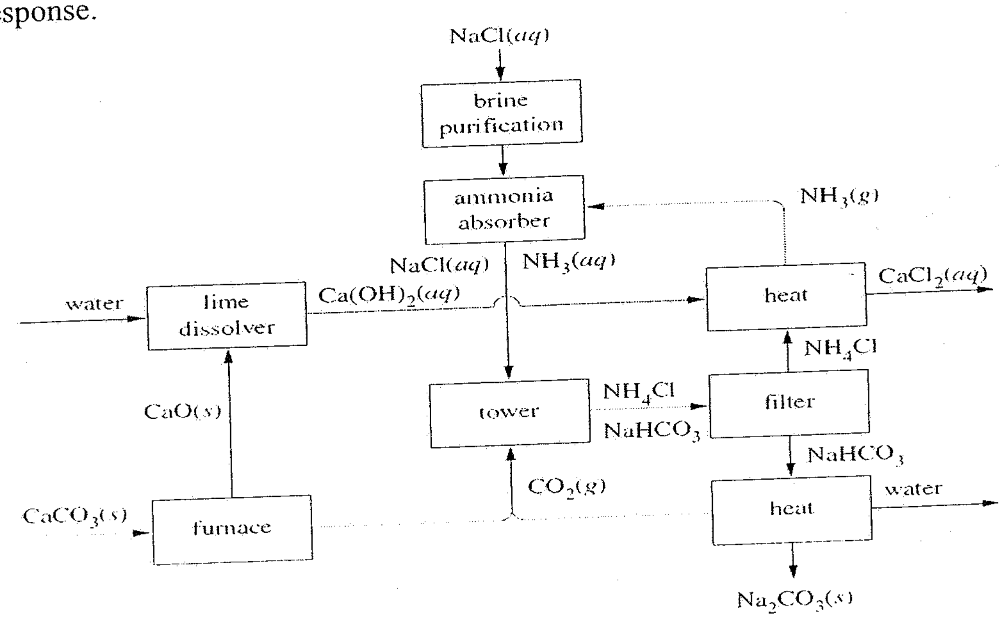
(b) In order to convert sulfur dioxide into sulfur trioxide, a chemist mixed 4.325×10^3 mol of sulfur dioxide with 2.132×10^3 mol of oxygen in a 10.00 L reaction vessel. At equilibrium, he noted that 3.762×10^3 mol of sulfur trioxide had been produced.

(i) Write a balanced equation for this reaction. **1**

(ii) Write an expression for the equilibrium constant for this reaction. **1**

(iii) Calculate the equilibrium constant for the reaction at this temperature. **3**

(c) The flow chart summarises the steps involved in the Solvay process. **4**
Describe the chemistry involved in the stage of the Solvay Process which involves formation of a hydrogen carbonate compound. Include balanced equations in your response.



Question 31 continues on page 27

Marks

Question 31 (continued)

(d) The production of sodium hydroxide can be carried out industrially using different electrolytic processes. **7**
Describe the diaphragm process and products.
Compare the environmental issues and the technical considerations in the diaphragm process with those associated with the mercury-cell process.

(e) During the course of your studies you performed a first-hand investigation to carry out saponification and test the product. **4**
Outline your procedure, including any safety considerations, describe your results and describe how you tested the product.

End of Question 31

CATHOLIC SECONDARY SCHOOLS ASSOCIATION OF NEW SOUTH WALES

2008 TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION

CHEMISTRY – MARKING GUIDELINES

The sample answers include features that should be found in a response that receives full marks. For the extended response questions, a set of guidelines is included with a sample answer.

Section I
Part A – 15 marks

Questions 1-15 (1 mark each)

Question	Correct Response	Outcomes Assessed	Targeted Performance Bands
1	A	H9	2-3
2	C	H9, H10	4-5
3	D	H3, H9	3-4
4	D	H8	2-3
5	A	H6, H13	3-4
6	B	H14	4-5
7	B	H6, H13	3-4
8	C	H10	5-6
9	A	H8, H13	3-4
10	C	H9, H11	3-4
11	A	H14	4-5
12	D	H4, H8	2-3
13	B	H3, H6, H7	3-4
14	D	H3	3-4
15	C	H8, H11	4-5

Section I
Part B – 60 marks

Question 16 (4 marks)
(a) (1 mark)
Outcomes Assessed: H9, H11
Targeted Performance Bands: 2–3

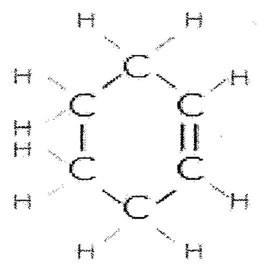
Criteria	Mark
• Identifies the dependent variable	1

Sample answer:
The colour or lack of colour of the bromine water

(b) (1 mark)
Outcomes Assessed: H9, H13
Targeted Performance Bands: 3-4

Criteria	Mark
• Names and draws an appropriate alkene	1

Sample answer:
cyclohexene



(c) (2 marks)
Outcomes Assessed: H9, H11
Targeted Performance Bands: 2-4

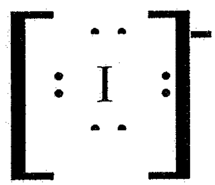
Criteria	Marks
• Justifies in terms of toxicity AND state at SLC, explaining the importance of BOTH features	2
• Justifies in terms of toxicity OR state at SLC	1

Sample answer:
Cyclohexene is a liquid at room temperature. It can therefore be easily mixed with bromine water in a test tube. The smaller chained alkenes are gases which would make the reaction impractical. Whilst cyclohexene is toxic and highly flammable, it can be handled in small quantities in a fume hood by senior students wearing skin and eye protection.

Question 17 (5 marks)
(a) (1 mark)
Outcomes Assessed: H6, H13
Targeted Performance Bands: 3-4

Criteria	Mark
• Draws an electron dot structure	1

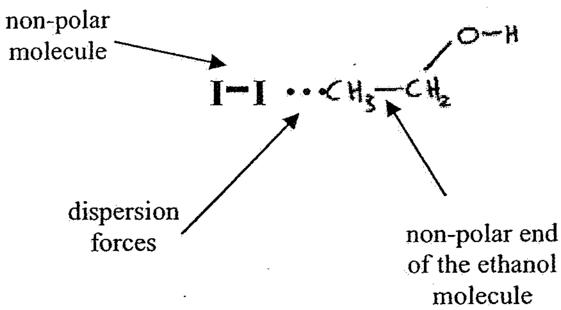
Sample answer:



(b) (2 marks)
Outcomes Assessed: H6, H13
Targeted Performance Bands: 3-5

Criteria	Marks
• Explains the solubility using a labelled diagram that shows the attraction between the non-polar end of the ethanol molecule and the non-polar iodine molecule	2
• Explains with a correctly drawn diagram without appropriate labelling OR • Explains with appropriate labels on a diagram with minor errors	1

Sample answer:



(c) (2 marks)

Outcomes Assessed: H6

Targeted Performance Bands: 2-4

Criteria	Marks
• Explains that triiodide ions are attracted to the positive end of the polar water molecule, unlike iodine molecules which are non-polar	2
• Explains that triiodide ions are attracted to the positive end of the polar water molecule OR • Explains that iodine molecules are non-polar and therefore not attracted to polar water molecules	1

Sample answer:

Water is a polar molecule. The triiodide ion is negatively charged and will be attracted to the positive end of the polar water molecules, hence increasing its solubility above that of the iodine molecule which is non-polar and will only experience weak dispersion forces with water.

Question 18 (5 marks)
Outcomes Assessed: H14
Targeted Performance Bands: 2-6

Criteria	Marks
• Assesses the validity of the claims, referring to safety, versatility (range of uses), biodegradability and renewability of polymers AND • Refers BOTH to a recently developed biopolymer AND to a petroleum-based polymer	5
• Assesses the validity of some of the claims made in the source AND • Refers BOTH to a recently developed biopolymer AND to a petroleum-based polymer	3-4
• Assesses validity of ONE claim made in the source OR • Describes features of a recently developed biopolymer	2
• Identifies a recently developed biopolymer OR • Identifies general characteristics of biopolymers	1

Sample answer:
Biopol (PHB) is an example of a recently discovered biopolymer. It is a renewable resource as it is produced by the fermentation of glucose by the bacterium *Alcaligenes eutrophus*. In the face of dwindling fossil fuel reserves, Biopol could provide a sustainable alternative to petroleum-based plastics such as polyethylene.
Biopol is a safe, versatile, biodegradable and renewable alternative to polyethylene. The biopolymer is safe for human consumption. Unlike polyethylene, its biocompatibility makes it useful for dissolving sutures and the administration of slow-release drugs. Polyethylene remains as an almost permanent environmental pollutant. In contrast, Biopol is biodegradable, decaying quite rapidly to carbon dioxide and water when exposed to microbes in landfill, sewage or the ocean. Biopol's versatility enables it to be used not only for medical purposes but for disposable razors, shampoo bottles, plastic films and coatings.

<u>Assessment.</u>
When considering the qualities of Biopol, the claims made in the source appear to be quite valid. It is a safe, versatile and biodegradable alternative to polyethylene. However, its importance in our future and as a competitor to polyethylene will depend on the ability of researchers to solve the problems associated with large-scale production and its considerable expense in comparison to petroleum-based alternatives.

Question 19 (3 marks)
(a) (2 marks)
Outcomes Assessed: H7, H10
Targeted Performance Bands: 3-4

Criteria	Marks
• Provides correct oxidation and reduction half-equations AND • Calculates correct cell voltage	2
• Correct oxidation and reduction half-equations only OR • Cell voltage consistent with incorrect half-equations	1

Sample answer:

Oxidation:	$Mg\ (s) \rightarrow Mg^{2+}\ (aq) + 2e^-$	+2.36 V
Reduction:	$Pb^{2+}\ (aq) + 2e^- \rightarrow Pb\ (s)$	-0.13 V
Overall reaction:	$Mg\ (s) + Pb^{2+}\ (aq) \rightarrow Mg^{2+}\ (aq) + Pb\ (s)$	+2.23 V
Overall cell voltage (E°):		+2.23 V

(b) (1 mark)
Outcomes Assessed: H8
Targeted Performance Bands: 3-4

Criteria	Mark
• Provides appropriate explanation	1

Sample answer:
The cell voltage was not measured under standard conditions; e.g. the concentration of electrolyte solutions was not 1.0 mol L^{-1} or the temperature varied from 25°C.

Question 20 (3 marks)
Outcomes Assessed: H1, H4
Targeted Performance Bands: 3-5

Criteria	Marks
• Identifies a radioisotope • Provides a correct example of its use in industry or medicine • Identifies some appropriate physical or chemical properties of the named isotope • Links these properties to the identified uses	3
• Identifies a radioisotope • Provides a correct example of its use in industry or medicine • Identifies some appropriate physical or chemical properties of the named isotope	2
• Identifies a radioisotope AND provides a correct example of its use in industry or medicine OR • Identifies a radioisotope AND identifies some appropriate physical or chemical properties of the named isotope	1

***Sample answer* : (choosing cobalt-60)**
Cobalt-60 is used in industry to sterilise surgical instruments, in thickness gauges, and for irradiation of some foods (limited in Australia). It is used in medicine for the radiation treatment of some cancers.
Cobalt-60 is a non-reactive element, has low-energy gamma emissions and a moderately long half-life of about 5½ years. Thus, in industry it will not react with gases or moisture in the air and its moderately long half-life means that it does not need to be replaced very often. The low-energy emissions mean that stringent safety precautions are not necessary.

Question 21 (2 marks)
(a) (1 mark)
Outcomes Assessed: H11
Targeted Performance Bands: 2-3

Criteria	Mark
• Outlines a valid procedure	1

Sample answer:
Red cabbage leaves were collected and cut into small pieces. The pieces were placed into a beaker and covered with water, which was then heated over a Bunsen burner until the water became purple/blue because of the colour leaching from the leaves. The coloured water and leaves were separated by straining and the leaves were discarded.

(b) (1 mark)
Outcomes Assessed: H11
Targeted Performance Bands: 2-3

Criteria	Mark
• Outlines an appropriate procedure	1

Sample answer:
Small samples of the indicator solution prepared were added to each of THREE test tubes containing an acid (hydrochloric), a base (sodium hydroxide) and a neutral solution (water). The indicator would be appropriate for use to test the acidity of a substance, if it had different colours in acid and in base.

Question 22 (4 marks)
(a) (2 marks)
Outcomes Assessed: H8
Targeted Performance Bands: 3-4

Criteria	Marks
• Uses Le Chatelier's Principle to predict the effect on solubility of an increase in temperature	2
• Predicts the effect on solubility of an increase in temperature	1

Sample answer:
At high temperature, since the dissolution reaction ($CO_2\ (g) \rightleftharpoons CO_2\ (aq)$) is exothermic, the backward reaction is favoured because that is the direction that absorbs heat and so, according to Le Chatelier, tends to counteract the temperature increase. The solubility of carbon dioxide decreases and bubbles of carbon dioxide gas are produced.

(b) (2 marks)
Outcomes Assessed: H8, H13
Targeted Performance Bands: 3-4

Criteria	Marks
• Explains why a solution of carbon dioxide in water is acidic AND • Writes an appropriate equilibrium equation	2
• Explains why a solution of carbon dioxide in water is acidic OR • Writes an appropriate equilibrium equation	1

Sample answer:

$$CO_2\ (aq) + H_2O\ (l) \rightleftharpoons H_2CO_3\ (aq)$$

OR

$$CO_2\ (aq) + 2H_2O\ (l) \rightleftharpoons H_3O^+\ (aq) + HCO_3^-\ (aq)$$

The solution is acidic since carbonic acid is formed, which is a weak acid. It partially ionises to produce hydronium ions.

Question 23 (6 marks)
(a) (2 marks)
Outcomes Assessed: H11
Targeted Performance Bands: 3–5

Criteria	Marks
• Outlines, in logical order, the steps needed to standardise the sodium hydroxide solution, starting from a primary standard	2
• Outlines a step which reacts the sodium hydroxide with an acid of known concentration	1

Sample answer:
The sodium hydroxide solution must be standardised by titrating it with an acid of exactly known concentration. This can be a primary standard (can be accurately weighed out) such as oxalic acid or a solution of (say) hydrochloric acid which has been previously standardised against a primary standard such as anhydrous sodium carbonate.

(b) (2 marks)
Outcomes Assessed: H10, H11
Targeted Performance Bands: 3-4

Criteria	Marks
• Calculates the concentration of acetic acid	2
• Calculates the correct number of moles of sodium hydroxide	1

Sample answer:
Moles NaOH = $n = cV = 0.105 \times 17.6/1000 = 0.00185$ mol

Moles CH_3COOH = moles NaOH = 0.00185 mol

$\therefore$ $[CH_3COOH] = n/V = 0.00185/0.0250 = 0.0739 \text{ mol L}^{-1}$

(c) (2 marks)
Outcomes Assessed: H11
Targeted Performance Bands: 3–4

Criteria	Marks
• Justifies why methyl orange is unsuitable for use in this titration in terms of BOTH the pH at the equivalence point AND the colour change range for methyl orange	2
• Outlines some correct information about the indicator colour change OR the pH at the equivalence point of the titration	1

Sample answer:
The titration involves a weak acid and a strong base. As a result, at the equivalence point, the pH will be >7 (in the alkaline range).
Hence methyl orange is NOT a suitable indicator since it changes colour at acidic pH values, between pH 3 and 5. It would not change colour at the equivalence point. At the commencement of this titration, the acetic acid is in the flask and the methyl orange will already be orange/yellow in colour. It will not change colour as sodium hydroxide is added to the flask. Hence a valid end point cannot be achieved.

Question 24 (4 marks)
(a) (1 mark)
Outcomes Assessed: H6, H8
Targeted Performance Bands: 2-3

Criteria	Mark
• Explains classification of sodium oxide as a basic oxide	1

Sample answer:
Sodium oxide is a basic oxide as it is an oxide of an active metal, sodium. It reacts with water to form hydroxide ions and hence an alkaline solution and is neutralised by acids.

(b) (1 mark)
Outcomes Assessed: H6, H8
Targeted Performance Bands: 2-3

Criteria	Mark
• Writes a balanced equation for the reaction of sodium with water	1

Sample answer:
$2Na\ (s) + 2H_2O\ (l) \rightarrow 2NaOH\ (aq) + H_2\ (g)$

(c) (2 marks)
Outcomes Assessed: H10
Targeted Performance Bands: 3-5

Criteria	Marks
• Calculates the mass of sodium reacted	2
• Calculates the number of moles of sodium hydroxide (per 100 mL water)	1

Sample answer:
$[NaOH] = 3.16 \times 10^{-2}$ mol L^{-1}

Since the volume of the solution was 100.0 mL
$\therefore$ moles of NaOH present in 100 mL solution = 3.16×10^{-3} mol

Hence moles Na reacted must have been the same (3.16×10^{-3} mol)
$\therefore$ mass of sodium reacted $= 3.16 \times 10^{-3} \times 22.99$ g
$= 7.26 \times 10^{-2}$ g

Question 25 (4 marks)
(a) (1 mark)
Outcomes Assessed: H9, H11
Targeted Performance Bands: 2–3

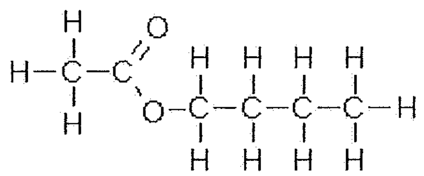
Criteria	Mark
• Correct answer	1

Sample answer:
1-butyl ethanoate

(b) (1 mark)
Outcomes Assessed: H9, H13
Targeted Performance Bands: 3–4

Criteria	Mark
• Correct answer	1

Sample answer:



(c) (2 marks)
Outcomes Assessed: H8, H10, H13
Targeted Performance Bands: 2-4

Criteria	Marks
• Correctly outlines TWO purposes for the use of concentrated sulfuric acid	2
• Correctly outlines ONE purpose for the use of concentrated sulfuric acid	1

Sample answer:
Concentrated sulfuric acid

- is used as a catalyst to speed up the rate of reaction, and
- acts as a dehydrating agent and absorbs water, which helps prevent the equilibrium reaction (1-butanol + ethanoic acid $\rightleftharpoons$ 1-butyl ethanoate + water) from shifting back to the left.

Question 26 (3 marks)
(a) (1 mark)
Outcomes Assessed: H9, H13
Targeted Performance Bands: 2-3

Criteria	Mark
• Correct answer	1

Sample answer:
$C_8H_{18}\,(l) + {}^{25}\!/_{2}\,O_2\,(g) \rightarrow 8CO_2\,(g) + 9H_2O\,(l)$

(b) (2 marks)
Outcomes Assessed: H10
Targeted Performance Bands: 2-4

Criteria	Marks
• Correct answer (to 4 significant figures) OR • Answer consistent with incorrect equation in (a) (to 4 significant figures)	2
• Correct answer (but to incorrect number of significant figures) OR • Correct moles of carbon dioxide OR • Moles of carbon dioxide consistent with incorrect equation in (a)	1

Sample answer:
Molar mass of octane = 114.26 g
Moles of octane = 1000.0/114.26
= 8.7520 mol
Hence moles of carbon dioxide = 8 x 8.7520 mol = 70.016 mol

Volume carbon dioxide = 70.016 x 24.79 L = 1736 L

Question 27 (6 marks)
(a) (2 marks)
Outcomes Assessed: H11, H13
Targeted Performance Bands: 2–3

Criteria	Marks
• Explains the difference between an invalid experiment and an unreliable experiment	2
• Explains what is meant by an invalid experiment OR • Explains what is meant by an unreliable experiment	1

Sample answer:
An invalid experiment cannot achieve a valid result because the method of the experiment is incorrect or partially incorrect.
An unreliable experiment is one that does not give the same result when repeated many times, using the same method.

(b) (4 marks)
Outcomes Assessed: H11, H12, H14
Targeted Performance Bands: 3-6

Criteria	Marks
• Evaluates thoroughly the validity of the conclusions	4
• Explains why some aspects of the experimental method are invalid and hence the conclusions are invalid	2-3
• Outlines some invalid aspect of the method or conclusions	1

Sample answer:
The experimental method needs to be designed to determine whether
- the water is hard or soft, and
- calcium ions are present.

Step 1. This would be a valid qualitative method for classifying the water as hard or soft, if comparison test tubes, using deionised water and water known to be hard, had been used. Since no controls were used for comparison, the conclusion is not valid.

Step 2. This would be a valid method for quantitatively determining the hardness of the water, if the mass of precipitate per given volume of solution had been determined and the precipitate had been identified as calcium or magnesium carbonate. Hardness is expressed quantitatively in milligrams of $CaCO_3$ per litre. As the method retained the filtrate (not the precipitate) and did not include determining quantitatively the mass of precipitate, it cannot be considered valid for determination of hardness. The precipitate could also have been one of many white insoluble carbonates (not necessary calcium or magnesium carbonates, which cause hardness of water).

Step 3. A flame test can be used to identify the presence of calcium ions – but the student used the filtrate, rather than the residue, to carry out the flame test. If calcium ions were present, they would have been precipitated out (to a great extent) as calcium carbonate. Minimal calcium ions would remain in the filtrate. The yellow colour of the flame would indicate sodium ions, not calcium ions, remaining in the filtrate.

Hence overall, the method used was inadequate and therefore invalid for determining whether the water was hard or soft and hence the conclusion that the water was soft is invalid.
The conclusion that the water contained calcium ions is also invalid, as the filtrate (instead of the residue) was used to carry out the flame test. Since the method is invalid, then a correct or valid conclusion cannot be drawn.

Question 28 (4 marks)
(a) (1 mark)
Outcomes Assessed: H9, H13
Targeted Performance Bands: 3-4

Criteria	Mark
• Identifies isomer using correct systematic name	1

Sample answer:
2, 2-dichloro-1,1,1,2-tetrafluoroethane

(b) (3 marks)
Outcomes Assessed: H4, H9
Targeted Performance Bands: 3–5

Criteria	Marks
• Explains THREE chemical reactions • Writes THREE correct equations for these reactions • Explains that a chain reaction can occur	3
• Explains TWO chemical reactions • Writes TWO correct equations for these reactions	2
• Explains ONE chemical reaction AND • Writes ONE correct equation for this reaction	1

Sample answer:
Reaction 1:
$C_2Cl_2F_4$ is a CFC.
UV light splits a chlorine free radical from a CFC.

$$C_2Cl_2F_4 \xrightarrow{UV} C_2ClF_4\bullet + Cl\bullet$$

Reaction 2:
The chlorine free radical destroys an ozone molecule.

$$Cl\bullet + O_3 \rightarrow ClO\bullet + O_2$$

Reaction 3:
The ClO• free radical reacts with an oxygen free radical (produced by breakdown of either ozone or oxygen by UV light), to produce an oxygen molecule and to free up the Cl• again.

$$ClO\bullet + O\bullet \rightarrow O_2 + Cl\bullet$$

Thus the Cl• free radical can repeat steps 2 and 3, to destroy many ozone molecules (i.e. a chain reaction can occur).

Question 29 (3 marks)
Outcomes Assessed: H3, H4, H8
Targeted Performance Bands: 2-5

Criteria	Marks
• Explains the role of the catalyst in the Haber process • Recognises the particular requirement for an efficient catalyst to increase the rate of reaction when only moderate temperature conditions apply • Explains some aspects of the monitoring of the catalyst by industrial chemists to ensure that the catalyst has not become deactivated	3
• Explains the role of the catalyst in the Haber process • Explains some aspects of the monitoring of the catalyst by industrial chemists to ensure that the catalyst has not become deactivated	2
• Explains the role of the catalyst in the Haber process OR • Explains some aspects of the monitoring of the catalyst by industrial chemists to ensure that the catalyst has not become deactivated	1

Sample answer:
The role of the catalyst in the Haber process is to allow the gaseous equilibrium reaction to occur on its surface so that the reaction can occur at a faster rate than if no catalyst were present. The catalyst lowers the activation energy for both the forward and backward reactions and so the rate of production of ammonia at a given temperature is greater. Since the greatest yield of ammonia is produced at low temperature, an efficient catalyst is essential to ensure the highest rate of reaction.
The condition of the catalyst must be monitored by industrial chemists to ensure that its surface has not become deactivated. This can occur if sulfur compounds, carbon monoxide or carbon dioxide are present in the gases entering the catalytic chamber. The catalytic surface is most effective when it is granular and porous, to provide the biggest surface area. The catalyst must be monitored and replaced if the efficiency of the catalytic process is endangered.

Question 30 (4 marks)
Outcomes Assessed: H3, H4, H8
Targeted Performance Bands: 2-5

Criteria	Marks
• Outlines thoroughly all the steps used to purify water supplies prior to chlorination AND discusses the need for purification of the water supply	4
• Outlines some of the steps used to purify water supplies prior to chlorination AND discusses the need for purification of the water supply	2-3
• Some correct information about the need to purify water supplies OR • Some correct information about the steps used for purification	1

Sample answer:
Water flowing in a river or water that is held in reservoirs contains both chemicals and living things that can be potentially harmful to human beings. The source of the water, the geology of the area and the extent of human activity in the catchment area can affect the purity of the water supply.

Prior to the sanitisation of water (by addition of chlorine to destroy the microbes which could cause disease and death), the dissolved oxygen content is increased and the water is clarified to remove sediments, inorganic matter which could be damaging to health and coloured organic material.

The water is aerated by spraying it into the air or by allowing it to fall from a dam into holding tanks. This increases the dissolved oxygen content and assists in oxidising sulfur compounds (to sulfate ions) and iron salts (to iron (III) oxides) which are later removed. The increased oxygen concentration assists in the oxidation of organic materials which are broken down by aerobic bacteria in the water supply.

The clarity of the water is increased by removal of small suspended particles. These are separated out by a process called flocculation. Chemicals such as alum or iron (III) salts are added to the water to produce a gelatinous precipitate of aluminium or iron (III) hydroxide. This traps other suspended particles, including iron oxides and some microbes. The precipitate is then left to sediment out and the purified water is drawn from above the level of the sludge and passed through a series of filters made from sand and gravel. If the water passing out of the filter contains coloured organic matter, the water is further clarified by passing it through charcoal filters that adsorb the coloured matter onto the charcoal surface. Membrane filters can remove finer sediment (and some microbes), if the clarity of the water does not meet the required level of purity prior to the subsequent sanitisation step.

Section II – OPTIONS

Question 31 – Industrial Chemistry (25 marks)
(a) (i) (1 mark)
Outcomes Assessed: H11
Targeted Performance Bands: 2-3

Criteria	Mark
• Identifies ONE safety precaution	1

Sample answer:
When diluting always add acid to water.

(a) (ii) (4 marks)

Outcomes Assessed: H4, H8.

Targeted Performance Bands: 2-5

Criteria	Marks
• Describes the Frasch process AND • Relates the method of extraction to the properties of sulfur which allow its extraction AND • Describes at least TWO environmental issues associated with the Frasch process	4
• Describes the Frasch process AND • Relates the method of extraction to the properties of sulfur which allow its extraction OR • Describes the Frasch process AND • Identifies relevant physical properties of sulfur AND • Describes at least TWO environmental issues associated with the Frasch process	3
• Describes the Frasch process AND • Identifies relevant physical properties of sulfur OR • Describes the Frasch process AND • Describes at least TWO environmental issues associated with the Frasch process	2
• Describes the Frasch process OR • Identifies relevant physical properties of sulfur OR • Describes an environmental issue associated with the Frasch process	1

Sample answer:

In the Frasch process, superheated water (160°C) is forced down the outermost of three concentric pipes into the sulfur deposit. This melts the sulfur (mp 113°C) and forms an emulsion. Compressed air is forced down the innermost pipe. This forces the water-sulfur emulsion up the middle pipe into the collection vessel. The sulfur then solidifies, separating itself from the water; it is 99.9% pure at this point.

Sulfur has a <u>low melting point</u> (113°C) and <u>low density</u> (2.07 g/ml). Thus it easily melts and its low density allows compressed air to easily lift it to the surface through the middle pipe. Sulfur is also <u>insoluble</u> in water so it is easily separated from water.

Sulfur is non-volatile and odourless, thus it does not escape into the atmosphere. It is, however, easily oxidised to sulfur dioxide or reduced to hydrogen sulfide, both being air pollutants. Therefore it is vital that neither oxidation nor reduction occur in the Frasch process. The water should be reused since other impurities, which may be harmful to the environment, may have dissolved from the ore into the water. It is also very difficult to backfill underground caverns left by extraction, since sulfur beds are deep under clay, quicksand, sand and limestone deposits.

earth Subsidence hole.

(b) (i) (1 mark)
Outcomes Assessed: H13
Targeted Performance Bands: 2-3

Criteria	Mark
• Writes a correctly balanced equation	1

Sample answer:
$2SO_2\,(g) + O_2\,(g) \rightleftharpoons 2SO_3\,(g)$

(b) (ii) (1 mark)
Outcomes Assessed: H10
Targeted Performance Bands: 2-3

Criteria	Mark
• Writes a correct expression for the equilibrium constant	1

Sample answer:

$$K = \frac{[SO_3(g)]^2}{[SO_2(g)]^2[O_2(g)]}$$

(b) (iii) (3 marks)
Outcomes Assessed: H10
Targeted Performance Bands: 3-6

Criteria	Marks
• Correctly calculates the equilibrium constant	3
• Correctly substitutes CONCENTRATION into equilibrium expression OR • Calculates equilibrium constant using number of moles	2
• Correctly calculates the number of moles at equilibrium	1

Sample answer:

	$2SO_2\,(g)$	$+\ O_2\,(g)$	$\rightleftharpoons\ 2SO_3\,(g)$
Initial moles	4.325×10^3	2.132×10^3	0
Change in moles	-3.762×10^3	-1.881×10^3	$+3.762 \times 10^3$
At equilibrium	0.563×10^3	0.251×10^3	3.762×10^3

	SO_2	O_2	SO_3
mole ratio	2	1	2
Initial mol	4.325×10^3	2.132×10^3	0
Reacted mol	-3.762×10^3	1.881×10^3	$+3.762 \times 10^3$
Eqm mol	0.563×10^3	0.251×10^3	3.762×10^3
Eqm conc.	0.563×10^2	0.251×10^2	3.762×10^2
$C = \frac{n}{V} = \frac{}{10L}$			

Change moles to concentration by dividing by 10.00 L
Concentration at equilibrium

	0.563×10^2	0.251×10^2	3.762×10^2

$$K = \frac{[SO_3(g)]^2}{[SO_2(g)]^2[O_2(g)]}$$

$$= \frac{(3.762 \times 10^2)^2}{(0.563 \times 10^2)^2 \times (0.251 \times 10^2)} \qquad = \frac{14.15 \times 10^4}{0.07956 \times 10^6}$$

$$= \quad 1.779$$

(c) (4 marks)

Outcomes Assessed: H4, H13, H14

Targeted Performance Bands: 2-5

Criteria	Marks
• Describes all steps in the stage AND writes TWO relevant balanced equations	4
• Describes all steps in the stage AND writes ONE relevant balanced equation OR • Identifies all steps in the stage AND writes TWO relevant balanced equations OR • Describes all steps in the stage ONLY	3
• Identifies a step in the stage AND writes a relevant balanced equation OR • Identifies all steps in the stage OR • Writes TWO relevant balanced equations ONLY	2
• Writes a relevant balanced equation OR • Identifies a step in the stage	1

Sample answer:

Calcium carbonate is heated in a kiln to form carbon dioxide and calcium oxide

$CaCO_3\,(s) \xrightarrow{heat} CO_2\,(g) + CaO\,(s)$

The calcium oxide is removed, to be used in ammonia recovery.

Coke is also present in the kiln, producing more carbon dioxide when heated, as well as providing heat to decompose the calcium carbonate.

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

Ammonia is dissolved in the purified brine (NaCl) and carbon dioxide is dissolved in this solution.

$NaCl\,(aq) + NH_3\,(g) + H_2O\,(l) + CO_2\,(g) \rightarrow NH_4Cl\,(aq) + NaHCO_3\,(aq)$

This reaction is carried out at a low temperature (0°C) so that sodium hydrogen carbonate, which is relatively insoluble at low temperatures, precipitates out. The mixture is filtered. Sodium hydrogen carbonate is washed, dried and used to make sodium carbonate.

(d) (7 marks)

Outcomes Assessed: H3, H4, H8

Targeted Performance Bands: 2-6

Criteria	Marks
• Describes thoroughly the diaphragm process and products • Compares the environmental issues and technical considerations in the diaphragm process with those associated with the mercury-cell process	7
• Describes thoroughly the diaphragm process and products • Describes thoroughly the environmental issues and technical considerations of the diaphragm cell and of the mercury-cell process	5-6
• Describes soundly the diaphragm process and products • Describes soundly the environmental issues and technical considerations of the diaphragm cell and of the mercury-cell process	3-4
• Identifies some correct information about the diaphragm cell • Identifies some correct information about the environmental issues and technical considerations in the diaphragm OR the mercury-cell process	1-2

Sample answer:

The diaphragm process is one method that has been used in the production of sodium hydroxide. The main products of the process are sodium hydroxide, chlorine gas and hydrogen gas.

An iron mesh cathode is used (due to no reaction with OH^-).

$2H_2O\ (l) + 2e^- \rightarrow H_2\ (g) + 2OH^-\ (aq)$

A titanium anode is used (so as not to react with Cl^-).

$2Cl^-\ (aq) \rightarrow Cl_2\ (g) + 2e^-$

Brine flows through the cell which is separated into two chambers by an asbestos diaphragm which completes the flow of electricity by letting Na^+ ions through.

Net ionic equation: $2Cl^-\ (aq) + 2H_2O\ (l) \rightarrow Cl_2\ (g) + H_2\ (g) + 2OH^-\ (aq)$

Full equation: $2NaCl\ (aq) + 2H_2O\ (l) \rightarrow Cl_2\ (g) + H_2\ (g) + 2NaOH\ (aq)$

Environmental issues to consider include the asbestos diaphragm (which, if the particles become airborne are extremely harmful when breathed in) and any ClO^- (a strong oxidant) in the waste brine. The release of chlorine gas into the environment is another issue as it is a poisonous gas and there are regulations controlling permitted levels in the atmosphere. NaOH itself is corrosive and must be stored in plastic containers. Hydrogen gas and chlorine gas react explosively; therefore leaks, sparks and flames must be avoided. There is a need to minimise the effect of the general running of the plant (noise, light, emissions, etc) and of transport operations on the surrounding population.

By comparison, the mercury-cell does not use a diaphragm, so there are no health problems associated with asbestos. ClO^- is not produced in a mercury-cell as the chloride ions do not come into contact with the product (NaOH). However, traces of mercury do escape into the environment when spent brine is returned to the ocean. The mercury sinks but in the anaerobic conditions at depth special bacteria convert mercury metal into mercury ions, which are then taken into the food chain. These ions cannot be easily excreted by animals and hence bio-accumulate up the food chain. Mercury ions cause damage to the nervous system and can cause serious illness or death.

Technical considerations in the diaphragm process include availability of transport facilities, workforce (and appropriate accommodation for them) and proximity to electric power (a major issue) and raw materials. The staff needs to be skilled in the handling and disposal of toxic substances (chlorine, sodium hydroxide) and explosive substances (hydrogen). A very high level of plant safety must be maintained and constantly monitored.
There is a need to keep Cl_2 gas and H_2 gas separate as they react explosively when together. OH^- and Cl^- need to be separated as well, as unwanted ClO^- may form. To maximise purity of NaOH, it is necessary to remove as much Cl^- as possible.

By comparison, the mercury-cell produces almost pure NaOH because there is no opportunity for the NaOH to be contaminated with NaCl (as NaOH is formed in a separate chamber from the reaction of the amalgamated sodium with water). The mercury-cell process separates the chlorine and hydrogen (released in separated tanks) and no unwanted ClO^- can form. The mercury process is more energy-efficient and the electrolysis units can be much larger than in the diaphragm process.

However, both mercury-cells and diaphragm cells are being replaced (because of their environmental and technical limitations) by membrane cells. The cation exchange membrane (which prevents mixing of chloride and hydroxide ions) overcomes a shortcoming of the diaphragm cell. The membrane cell does not use either asbestos or mercury and so has little impact on the environment.

(e) (4 marks)
Outcomes Assessed: H4, H8, H9, H11
Targeted Performance Bands: 2-5

Criteria	Marks
• Outlines the procedure • Identifies safety considerations • Describes the results • Describes how the product was tested	4
• THREE of the above	3
• TWO of the above	2
• ONE of the above	1

Sample answer:
Procedure
Pour 100 mL warm water into a 200 mL beaker and add 10 g sodium hydroxide. Add 25 mL olive oil and heat in a water bath for 30 minutes. Add concentrated NaCl solution to precipitate the soap, filter and wash with a small amount of water.

Safety considerations
NaOH is an alkaline solution, about pH 12, so you must wear safety goggles and work near a tap so that a supply of running water is available. If alkali is splashed on the skin, wash it off immediately and continue washing for 15 minutes.

Results
The NaOH reacts with the ester in the olive oil to produce soap and glycerol. After NaCl has been added, soap will precipitate as a white solid which is then separated from the solution.

Testing procedure
To test the product you can either shake the solid with water to see if it suds (forms bubbles/foam) or add it to water and oil and see if it forms an emulsion. Soap, water and oil form an emulsion. In such mixtures, soap acts as the emulsifier (the substance which causes large droplets of oil to break up into very small droplets that can remain dispersed through the water almost indefinitely).