CATHOLIC SECONDARY SCHOOLS ASSOCIATION OF NEW SOUTH WALES

2009 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	H4, H9	3-4
3	B	H6, H8	3-4
4	D	H6	3-4
5	B	H3, H6	3-4
6	C	H8	4-5
7	C	H6, H13	3-4
8	B	H8, H14	4-5
9	A	H8, H10	5-6
10	B	H10	3-4
11	C	H9, H10	5-6
12	D	H4, H8	3-4
13	A	H8, H11	2-3
14	D	H4	2-3
15	A	H8, H13	3-4

Section I
Part B – 60 marks

Question 16 (2 marks)
Outcomes Assessed: H2, H8, H9
Targeted Performance Bands: 2-4

Criteria	Marks
• Describes the steps in the formation of the addition polymer poly(vinyl chloride)	2
• Describes some correct information about the formation of an addition polymer	1

Sample answer:
An initiator splits to form free radicals.
$R-O-O-R \longrightarrow 2R-O\bullet$
These free radicals react with the double bond in the monomer, vinyl chloride (chloroethene) to form a monomer radical.
$R-O\bullet + CH_2{=}CHCl \longrightarrow R-O-CH_2-CHCl\bullet$
The monomer radical reacts with other chloroethene monomers and chain growth occurs.
$R-O-CH_2-CHCl\bullet + n\,(CH_2{=}CHCl) \longrightarrow R-O-(CH_2-CHCl)_n-CH_2-CHCl\bullet$
This produces a long chain of repeating $-(CH_2-CHCl)$ units, which is poly(vinyl chloride).

Question 17 (9 marks)
(a) (2 marks)
Outcomes Assessed: H8, H9
Targeted Performance Bands: 2-4

Criteria	Marks
• Provides a thorough description of the conditions required to produce ethanol by fermentation of glucose	2
• Describes at least TWO correct conditions required to produce ethanol by fermentation of glucose	1

Sample answer:
The conditions for the production of ethanol by fermentation of glucose are:
- an absence of oxygen
- a dilute aqueous solution containing suitable sugar or other carbohydrate
- a temperature of 37°C
- the presence of yeast

(b) (2 marks)
Outcomes Assessed: H9, H10, H13
Targeted Performance Bands: 2-4

Criteria	Marks
• Explains how mass changes can be used to monitor the fermentation reaction AND • Includes a suitable equation	2
• Explains how mass changes can be used to monitor the fermentation reaction OR • Includes a suitable equation	1

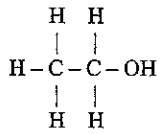
Sample answer:
As ethanol is produced during the fermentation process, $CO_2\,(g)$ is also produced.
$C_6H_{12}O_6\,(aq) \xrightarrow{Yeast/37°C/Anaerobic} 2C_2H_5OH\,(aq) + 2CO_2\,(g)$

If the fermentation is carried out in an open container, the mass of the container will fall as the reaction proceeds because carbon dioxide escapes into the air. Monitoring the loss in mass (and hence the progress of the reaction) can be achieved using a data logger or electronic balance.

(c) (3 marks)
Outcomes Assessed: H6, H9
Targeted Performance Bands: 2-5

Criteria	Marks
• Relates the polar nature of the ethanol molecule to its use as a solvent AND • Relates the presence of the non-polar hydrocarbon chain to the use of ethanol as a solvent AND • Provides a justification	3
• Relates the polar nature of the ethanol molecule to its use as a solvent AND • Relates the presence of the non-polar hydrocarbon chain to the use of ethanol as a solvent	2
• Relates the polar nature of the ethanol molecule to its use as a solvent OR • Relates the presence of the non-polar hydrocarbon chain to the use of ethanol as a solvent	1

Sample answer:
Ethanol is often used as a solvent due to its structure:



It has the alkanol functional group (–OH) on one end which makes it polar and hydrophilic (water-loving) and able to dissolve other polar substances, such as water.
It also has a non-polar (hydrophobic) hydrocarbon chain (CH_3CH_2–) which enables it to dissolve non-polar substances, such as petrol.

Justification
Since ethanol has this "dual nature" due to the two different parts of its structure, it is an ideal solvent for both polar and non-polar chemicals and hence for a wide range of materials. It is especially useful when mixtures of polar and non-polar substances are produced (as in the production of cosmetics and pharmaceutical preparations).

(d) (2 marks)
Outcomes Assessed: H3, H9
Targeted Performance Bands: 2-4

Criteria	Marks
• Identifies a logical sequence of steps including fractional distillation, catalytic cracking and hydration	2
• Identifies a logical sequence including TWO of fractional distillation, catalytic cracking and hydration	1

Sample answer:
Crude oil is separated into its fractions by fractional distillation.
The long-chain fractions are cracked to produce short chains and alkenes, including ethylene.
Ethylene is hydrated to form ethanol, using water and sulfuric acid catalyst.

Question 18 (5 marks)

(a) (2 marks)

Outcomes Assessed: H6, H8

Targeted Performance Bands: 2-4

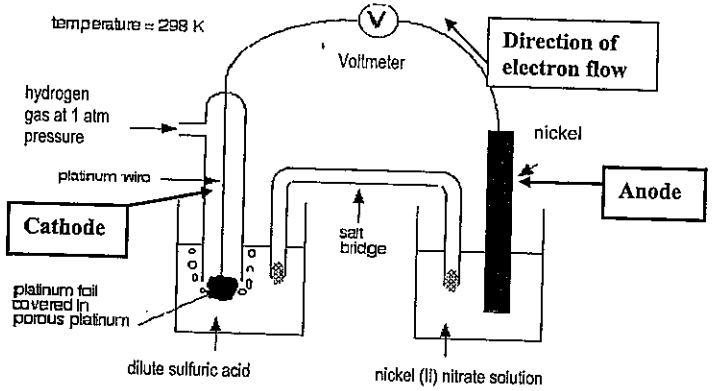
Criteria	Marks
• Writes TWO correct half-equations • Shows the direction of electron flow on the diagram (must be consistent with half-equations)	2
• Writes TWO correct half-equations OR • Shows the direction of electron flow on the diagram	1

Sample answer:

The electrons flow from the anode (the nickel electrode) through the external circuit to the cathode (the platinum electrode), where the hydrogen ions gain the electrons.

At the anode: $Ni\ (s) \rightleftharpoons Ni^{2+}\ (aq) + 2e^-$

At the cathode: $2H^+(aq) + 2e^- \rightleftharpoons H_2\ (g)$



(b) (1 mark)

Outcomes Assessed: H6, H8

Targeted Performance Bands: 2-4

Criteria	Mark
• Labels the anode and cathode	1

Sample answer:

See diagram above.

(c) (2 marks)

Outcomes Assessed: H4

Targeted Performance Bands: 2-3

Criteria	Marks
• Suggests TWO valid reasons	2
• Suggests ONE valid reason	1

Sample answer:

The reaction only produces a voltage of 0.24 V, too small for commercial use.
The hydrogen half-cell has a platinum electrode. This would make the cell very expensive.
(The reaction produces hydrogen gas which would build up pressure inside a sealed commercial cell.)

Question 19 (4 marks)
(a) (2 marks)
Outcomes Assessed: H3, H4, H6, H12
Targeted Performance Bands: 3-5

Criteria	Marks
• Explains the choice of phosphorus-32, in terms both of radiation emitted and half-life	2
• Deduces that the isotope cannot be an alpha emitter OR • Deduces that the isotope has a half-life of 14 days	1

Sample answer:
The radioisotope has to be a beta or gamma emitter because the paper between the rock and the film would have blocked alpha particles.
The time difference for the development of the image of the same intensity (20 minutes versus 5 minutes) means that the scintillation rate had dropped to a quarter of its original value, meaning that two half-lives had passed in the interim 28 days. Thus the half-life of the isotope must be 14 days. The isotope must be a beta emitter or gamma emitter with a half-life of 14 days. The only isotope in the table that has both of these properties is phosphorus-32.

(b) (1 mark)
Outcomes Assessed: H3
Targeted Performance Bands: 2-3

Criteria	Mark
• Identifies ONE instrument or process (other than a photographic film) which can be used to detect radiation	1

Sample answer:
Geiger-Müller counter

(c) (1 mark)
Outcomes Assessed: H6, H13
Targeted Performance Bands: 3-4

Criteria	Mark
• Correct answer	1

Sample answer:
Actinium-227

Question 20 (6 marks)
(a) (1 mark)
Outcomes Assessed: H1
Targeted Performance Bands: 2-3

Criteria	Mark
• Correct answer	1

Sample answer:
Lowry and/or Brønsted

(b) (i) (1 mark)
Outcomes Assessed: H4
Targeted Performance Bands: 2-3

Criteria	Mark
• Correct answer	1

Sample answer:
High temperature combustion of nitrogen and oxygen – as in internal combustion engines or coal-fired power stations

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

Criteria	Marks
• Explains the formation of acid rain AND • Writes a balanced equation with states	2
• Explains the formation of acid rain OR • Writes a balanced equation with states	1

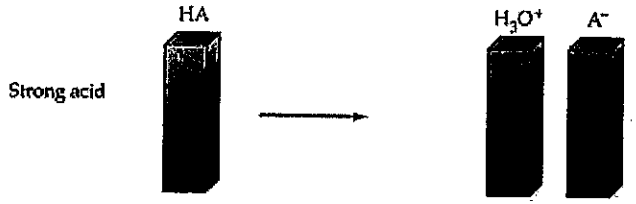
Sample answer:
The acidic oxide, nitrogen dioxide, reacts with water (from rain) to produce a mixture of nitrous and nitric acids.

$2NO_2\,(g) + H_2O\,(l) \rightarrow HNO_2\,(aq) + HNO_3\,(aq)$

(c) (2 marks)
Outcomes Assessed: H14
Targeted Performance Bands: 2-4

Criteria	Marks
• Models the substances and their quantities, correctly showing no HA present, equal quantities of H_3O^+ and A^- and the same amount of H_3O^+ and A^- as the original HA	2
• Models the substances qualitatively showing no HA present and both H_3O^+ and A^-	1

Sample answer:



Question 21 (5 marks)
(a) (2 marks)
Outcomes Assessed: H10
Targeted Performance Bands: 2-4

Criteria	Marks
• Calculates the mass with correct units and THREE significant figures	2
• Calculates the mass	1

Sample answer:
V_{NaOH} = 100.0 mL = 0.1000 L
c_{NaOH} = 0.100 mol L^{-1}
n_{NaOH} = c_{NaOH} x V_{NaOH}
= 0.100 mol L^{-1} x 0.1000 L
= 0.0100 mol
m_{NaOH} = n_{NaOH} x M_{NaOH}
= 0.0100 mol x 39.998 g mol^{-1}
= 0.400 g (3 significant figures)

(b) (3 marks)
Outcomes Assessed: H14
Targeted Performance Bands: 2-6

Criteria	Marks
• Evaluates the appropriateness of THREE aspects of the method, demonstrating a thorough knowledge of primary standards and an understanding of accuracy and titration techniques	3
• Discusses the appropriateness of TWO aspects of the method	2
• Identifies ONE inappropriate or appropriate step in the method	1

Sample answer:
The use of the deionised water and the volumetric flask were appropriate, as both would contribute to the production of a pure solution of accurate concentration.

A primary standard should be solid, extremely pure, stable, with a high molecular weight and high solubility. Sodium hydroxide is a solid having a high solubility. However, it is not stable in air, being hygroscopic (absorbing water) and readily reacting with carbon dioxide from the air. Therefore the sample weighed out was probably impure and would produce a solution of lower concentration than expected, as some of the weight would be water or sodium carbonate, rather than sodium hydroxide. As sodium hydroxide does not have a high molecular weight, the error when weighing will be more significant than with other heavier bases.

Sodium hydroxide is highly corrosive to skin and eyes and releases heat when dissolved in water. The choice of a hazardous chemical, when safer options are available, is inappropriate.

The student's method would have produced a much more accurate result if the sodium hydroxide solution had first been standardised against an acidic primary standard such as oxalic acid or potassium hydrogen phthalate.

Evaluation

Sodium hydroxide as a primary standard is a highly inappropriate choice as it would lead to an inaccurate determination of the concentration of the vinegar. The method introduces hazards (the weighing out of a corrosive solid) and more accurate results would have been obtained if the sodium hydroxide had been standardised against an acidic primary standard prior to titration against the vinegar.

Question 22 (5 marks)
Outcomes Assessed: H8, H14
Targeted Performance Bands: 2-6

Criteria	Marks
• Analyses and explains all concentrations and pH readings, demonstrating a thorough knowledge of pH, equilibrium, acid strength and the related degree of ionisation	5
• Analyses and explains all concentrations and pH readings, demonstrating a sound knowledge of pH, equilibrium, acid strength and the related degree of ionisation	3-4
• Explains some aspects of concentrations AND pH readings	2
• Relates a feature in the table to equilibrium or acid strength	1

Sample answer:

Despite having the same initial pH of 2.4, which indicates the $[H^+]$ in both were equal, the actual concentrations of the acids were very different.

This reflects the different strengths of the two acids. Hydrochloric acid is strong and totally ionises whereas acetic acid is weak and only ionises partially. Therefore, despite the acetic acid having a much higher acid concentration of 1.0 mol L^{-1}, the $[H^+]$ in acetic acid must be only 0.0040 mol L^{-1}.

After addition of the salts the hydrochloric acid pH remained the same whilst the acetic acid pH rose to 2.6 indicating a drop in $[H^+]$.

As acetic acid is a weak acid it only partially ionises according to the following equilibrium:
$CH_3COOH\ (aq) + H_2O\ (l) \rightleftharpoons CH_3COO^-\ (aq) + H_3O^+\ (aq)$

The addition of sodium acetate increases the concentration of acetate ions.

Le Chatelier's Principle states:
If a chemical system at equilibrium experiences a change in concentration, temperature, volume or pressure, then the equilibrium shifts to counteract the imposed change.

According to this principle, the equilibrium shown in the above equation would shift to the left to reduce the concentration of acetate ions.

This would reduce the concentration of H^+ and hence would raise the pH.

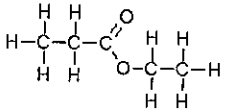
As hydrochloric acid is a strong acid it ionises completely:
$HCl\ (aq) + H_2O\ (l) \rightarrow H_3O^+\ (aq) + Cl^-(aq)$

The addition of sodium chloride ions will produce more chloride ions. As there is no equilibrium, the addition of these ions will have no effect. The pH will remain unchanged.

Question 23 (4 marks)
(a) (2 marks)
Outcomes Assessed: H9, H13
Targeted Performance Bands: 2-4

Criteria	Marks
• Correctly names and writes the structural formulae for X AND Y	2
• Correctly names and writes the structural formula for X OR Y	1

Sample answer:
One of the compounds is ethyl propanoate.



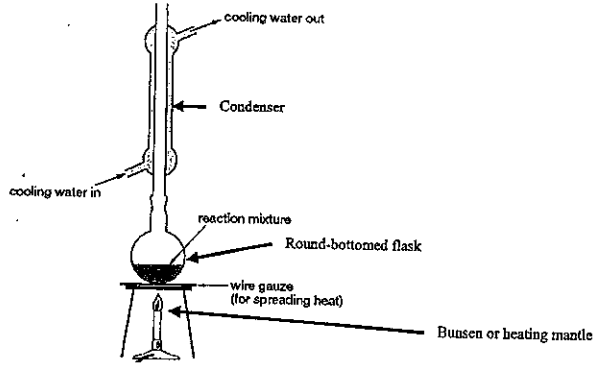
The other compound is water.

H – O – H

(b) (2 marks)
Outcomes Assessed: H9, H11, H13
Targeted Performance Bands: 3-4

Criteria	Marks
• Draws AND labels correctly a reflux apparatus	2
• Partially correct and labelled drawing of a reflux apparatus	1

Sample answer:



Question 24 (4 marks)
Outcomes Assessed: H4, H8
Targeted Performance Bands: 3-6

Criteria	Marks
• Analyses the statement • Recognises that the reaction is exothermic • Recognises that compromises (balancing acts), relating to temperature and use of a catalyst, need to be made to achieve an optimal yield, rather than a high yield or high rate of reaction	4
• Recognises that the reaction is exothermic • Recognises that compromises (balancing acts), relating to temperature and use of a catalyst, need to be made to achieve an optimal yield, rather than a high yield or high rate of reaction	3
• Recognises that compromise conditions are necessary to achieve an optimal yield	2
• Outlines some correct information with respect to the Haber process concerning reaction energy OR reaction rate OR equilibrium	1

Sample answer:
The Haber process is managed to provide the optimal yield of ammonia. In industry an optimal yield is not necessarily the highest yield; it may also reflect the rate of production, the costs of production and the safety of the production method.

Since the enthalpy change (reaction energy) is negative, this means that the overall reaction gives out energy. So, by Le Chatelier's Principle, a low temperature will give a high yield of ammonia but at a slow rate.

A catalyst (iron on the surface of iron oxide) is used to increase the rate of reaction; the catalyst reduces the activation energy for the reaction and hence increases the rate of reaction.

Slow rates are not good for production on an industrial scale, so a compromise (balancing act) is achieved by using a moderate temperature; fast enough to achieve a moderate rate but not so high that the yield is unacceptably low.

The conditions are manipulated (by removing the product as it forms and using high pressure) to compensate for the use of a moderate rather than low temperature.

Question 25 (4 marks)
(a) (1 mark)
Outcomes Assessed: H7, H9, H13
Targeted Performance Bands: 3-4

Criteria	Mark
• Writes an appropriate balanced equation producing CO or C or a mixture	1

Sample answer:
(Many possible answers)
$C_3H_8\ (g) + 3O_2\ (g) \rightarrow C\ (s) + 2CO\ (g) + 4H_2O\ (l)$

(b) (3 marks)
Outcomes Assessed: H4, H7, H9
Targeted Performance Bands: 3-5

Criteria	Marks
• Discusses why incomplete combustion is an issue for society AND • Discusses monitoring and management to achieve a correct oxygen:fuel ratio	3
• Outlines why incomplete combustion is an issue for society AND • Outlines monitoring and management to achieve a correct oxygen:fuel ratio	2
• Outlines why incomplete combustion is an issue for society OR • Outlines monitoring and management to achieve a correct oxygen:fuel ratio	1

Sample answer:
Incomplete combustion results in the formation of poisonous carbon monoxide or soot (carbon) or a combination of both. Less energy is released than for complete combustion, the flame is cooler, so valuable fuel is wasted by inefficient combustion. The air quality (soot and carbon monoxide) is impacted. All these aspects make incomplete combustion an issue for society.

In order to reduce the possibility of incomplete combustion, the oxygen: fuel ratio must be monitored and managed so that excess oxygen is available. With excess oxygen, carbon dioxide rather than carbon monoxide or carbon will be produced and the maximum energy from a given amount of fuel will be released.

Question 26 (5 marks)
(a) (2 marks)
Outcomes Assessed: H1, H3, H4
Targeted Performance Bands: 2-4

Criteria	Marks
• Outlines at least TWO methods used to measure ozone concentration	2
• Outlines ONE method used to measure ozone concentration	1

Sample answer:
Early measurements of atmospheric ozone concentration were made using ground-based Dobson UV spectrometers as well as on air samples collected by high-altitude balloons and aircraft. More recent instruments include the total ozone mapping spectrometer (TOMS) and a solar ultraviolet detector orbiting the Earth in the Nimbus-7 satellite.

(b) (1 mark)
Outcomes Assessed: H1, H3, H4
Targeted Performance Bands: 2-3

Criteria	Mark
• Outlines the international agreements to phase out the use of ozone-destroying chemicals OR identifies a replacement chemical used	1

Sample answer:
Since 1987, there have been international agreements whereby nations have undertaken to phase out the use of CFCs, halons and other ozone-destroying compounds.

Alternate answer: There are now replacements for CFCs that are less damaging molecules, such as HCFCs (most of which are broken down in the troposphere due to less stable bonds) and HFCs (which do not contain any chlorine or bromine atoms).

(c) (2 marks)
Outcomes Assessed: H4, H13
Targeted Performance Bands: 3-5

Criteria	Marks
• Explains, using an equation, the formation of a chlorine free radical AND • Explains, using an equation, the reaction of a free radical with ozone	2
• Explains, using an equation, the formation of a chlorine free radical OR • Explains, using an equation, the reaction of a free radical with ozone	1

Sample answer:
A CFC molecule, such as CCl_3F, is broken down by UV light to form a chlorine radical, $Cl\bullet$.

$$CCl_3F\ (g) \xrightarrow{UV} CCl_2F\bullet\ (g) + Cl\bullet\ (g)$$

The chlorine radical reacts with ozone, reducing the ozone concentration.

$$Cl\bullet\ (g) + O_3\ (g) \rightarrow ClO\bullet\ (g) + O_2\ (g)$$

Question 27 (3 marks)
Outcomes Assessed: H3, H4
Targeted Performance Bands: 2-5

Criteria	Marks
• Discusses at least TWO uses of chemical treatments for mass water supplies AND • Discusses the use of membrane filters for purification of mass water supplies	3
• Discusses at least ONE use of a chemical treatment for mass water supplies AND • Discusses the use of membrane filters for purification of mass water supplies	2
• Discusses at least ONE use of a chemical treatment for mass water supplies OR • Discusses the use of membrane filters for purification of mass water supplies OR • Identifies ONE chemical treatment for mass water supplies AND identifies a use of membrane filters	1

Sample answer:
Drinking water must be purified from its raw state before consumption. Both chemicals and membrane filters are used for purification of water supplies but are used at different stages in the purification processes and when different levels of purity are desired.

Water, for use as drinking water, must be treated by chemicals to precipitate dissolved ions, adjust the pH and flocculate the water to assist in filtration. Chlorination is also used to destroy any disease-carrying bacteria. These methods are relatively cheap and used in treating mass water supplies. They ensure that the purity of the water falls within the parameters allowed by the monitoring body of the local catchment.

Membrane filters increase the level of purity of the water, by removing substances not usually removed in the normal treatment process, such as viruses and even some ions, and are usually only used in the final steps of water treatment. Water is forced under pressure through membranes which have small pores that block the passage of any particles larger than the diameter of the pore. The smaller the pore size of the membrane, the greater the purity of the water. Membrane filters would not be suitable for purifying water directly from a reservoir as the pores would clog quickly. In addition, the cost of the membranes is relatively expensive, thus they are in limited use in treatment of mass water supplies but are used in the production of soft drinks and beer, or treatment of water for medical use. They are used in some community swimming pools to reduce the risk of spread of viruses within a community.

Question 28 (4 marks)
(a) (2 marks)
Outcomes Assessed: H10, H11
Targeted Performance Bands: 3-5

Criteria	Marks
• Calculates the percentage of sulfate in the lawn fertiliser	2
• Calculates the no. of moles of sulfate precipitated	1

Sample answer:

Mass of barium sulfate precipitate = 1.80 g
Moles of barium sulfate precipitate = 1.80/233.40
= 7.712×10^{-3} mol
Hence moles of sulfate ion = 7.712×10^{-3} mol
Mass of sulfate ion = $7.712 \times 10^{-3} \times 96.06$ g
= 0.741 g

% of sulfate in fertiliser = 0.741/1.03 x 100%
= 71.9%

(b) (2 marks)
Outcomes Assessed: H10, H11
Targeted Performance Bands: 3-5

Criteria	Marks
• Explains the impact of incorrect techniques on the accuracy of the result	2
• Identifies sources of inaccuracy in washing and drying the precipitate	1

Sample answer:
The accuracy of the result could be impacted by failure to wash the precipitate completely. More than one wash stage is required to remove the excess barium or chloride ions or other ions from the fertiliser which might remain adsorbed onto the barium sulfate precipitate. This would mean that the final dried solid would have a greater mass and the value for the percentage of sulfate would be too high.

The precipitate might not have been dried completely and water might remain in the sample weighed. This also would result in an error in the mass of sample and a higher than correct calculation of the percentage of sulfate. Repeated drying and weighing stages (drying to constant mass) are needed to ensure that all water has been removed.

Section II – OPTIONS

Question 29 – Industrial Chemistry (25 marks)
(a) (2 marks)
Outcomes Assessed: H1, H3, H4
Targeted Performance Bands: 2-3

Criteria	Marks
• Describes the issues associated with the shrinking world resources of one natural material which is not a fossil fuel AND • Identifies a suitable replacement material	2
• Describes the issues associated with the shrinking world resources of one natural material which is not a fossil fuel	1

Sample Answer:
Many possible answers.

Rubber is a natural product manufactured from the latex obtained from certain varieties of rubber trees. The use of rubber for all aspects of everyday life (hollow tubes, threads for clothing, waterproof shoes and raincoats, balls for tennis and golf, bedding, tyres on bicycles and most significantly, on motor vehicles) continues to grow, and the supplies from rainforests and plantations cannot keep up with the demands.

Synthetic rubbers, based on butadiene from crude oil, have been developed over the past century. In future decades, limitations on the availability of crude oil may force society to seek alternate raw materials for production of synthetic rubber. Research into the use of polymers based on lactic acid derived from crops (wheat, sugar beet) indicates that synthetic rubbers based on biopolymers, rather than on petroleum, may be used in future decades.

(b) (i) (4 marks)

Outcomes Assessed: H10, H12

Targeted Performance Bands: 3-5

Criteria	Marks
• Gives correct answer with working and equations	4
• Gives correct equilibrium moles for gases AND • Gives correct equilibrium expression AND • Gives correct chemical equation	3
• Gives correct equilibrium expression AND • Gives correct chemical equation	2
• Gives correct equilibrium expression OR • Gives correct chemical equation	1

Sample Answer:

	$2SO_2\,(g)$	+ $O_2\,(g)$	$\rightleftharpoons$ $2SO_3\,(g)$
Initially	0.360 mol	0.300 mol	0.000 mol
Change	-0.240 mol	-0.120 mol	+0.240 mol
At equil.	0.120 mol	0.180 mol	0.240 mol

In 1 L vessel:

$$K = \frac{[SO_3\,(g)]^2}{[SO_2\,(g)]^2\,[O_2\,(g)]} = \frac{(0.240)^2}{(0.120)^2\,(0.180)}$$

$$= 22.2$$

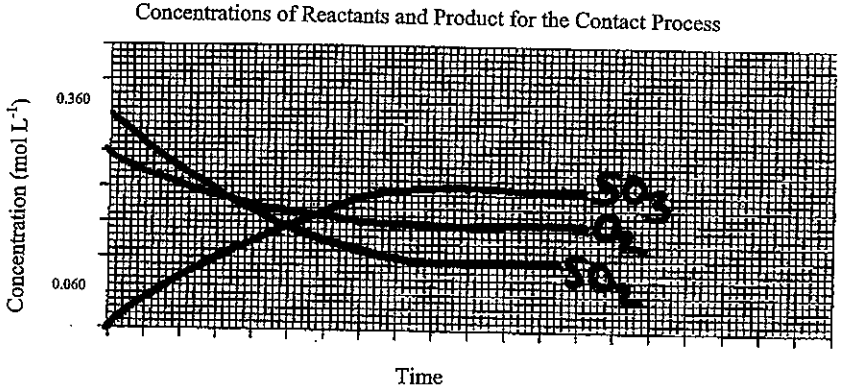
(b) (ii) (2 marks)

Outcomes Assessed: H10, H13

Targeted Performance Bands: 3-5

Criteria	Marks
• Correctly sketches the data on a graph, consistent with part (b) (i) AND • Clearly labels axes and has an appropriate scale	2
• Correctly sketches the data on a graph, consistent with part (b) (i) OR • Clearly labels axes and has an appropriate scale	1

Sample Answer:



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

Criteria	Mark
• Correctly defines saponification	1

Sample Answer:
Saponification is the process of making soap from a base (e.g. NaOH) and a fat or oil (eg. olive oil).

(c) (ii) (3 marks)
Outcomes Assessed: H11, H12
Targeted Performance Bands: 3-5

Criteria	Marks
• Correctly outlines the procedure used AND • Outlines how the product was identified	3
• Correctly outlines the procedure used OR • Partially outlines the procedure used AND outlines how the product was identified	2
• Partially outlines the procedure used	1

Sample Answer:
Approximately 3 g NaOH was dissolved in 15 mL water in a beaker, and 5 mL olive oil added.
The mixture was heated over a Bunsen for 30 minutes and water was slowly added during the heating process to maintain the volume of the solution. The solution was kept simmering and not allowed to boil vigorously.
After 30 minutes, sodium chloride (solid) was added to salt out the soap.
The solid which formed was filtered from the liquid using a Buchner funnel and retained.
The soap precipitate was washed using a small amount of water.

To identify the soap, a small amount of the soap was placed into a test tube with some water. A stopper was placed in the test tube and the test tube shaken. If soap is present, foam will form.

(c) (iii) (3 marks)
Outcomes Assessed: H2, H3, H4, H9
Targeted Performance Bands: 2-5

Criteria	Marks
• Thoroughly accounts for the cleaning action of soap	3
• Identifies water solubility of soaps AND • Identifies polar and non-polar ends of soaps	2
• Identifies water solubility of soaps OR • Identifies polar and non-polar ends of soaps	1

Sample Answer:
Soap is an ionic salt composed of a long hydrocarbon chain with a terminal anionic group and a simple cation such as Na^+ or K^+. It is water soluble.
The hydrocarbon tail is hydrophobic (water-hating) whilst the anionic group (charged head) is hydrophilic (water-loving).
In dilute water solutions these soap anions form a surface layer in which the hydrophobic tails are out of water and the hydrophilic heads are stabilised in the water by ion-dipole attractions. Dirt is usually mixed with grease. The non-ionic hydrocarbon end of the molecule dissolves in the grease and the ionic hydrophilic (water-loving) end dissolves in water. Thus soap molecules help to emulsify the grease, making it into small droplets (called micelles) which can mix with water and be washed away.

(d) (6 marks)

Outcomes Assessed: H1, H2, H3, H4, H7, H8

Targeted Performance Bands: 2-6

Criteria	Marks
• Evaluates the THREE industrial production methods for sodium hydroxide, by considering the chemical reactions and technologies involved and evaluates their relative impacts on society and the environment	6
• Demonstrates a thorough knowledge of the THREE industrial production methods for sodium hydroxide, the chemical reactions and technologies involved and discusses their impacts on society and the environment	5
• Demonstrates a limited knowledge of the THREE industrial production methods for sodium hydroxide, the chemical reactions and technologies involved and outlines their impacts on society and the environment	3-4
• Demonstrates a limited knowledge of the THREE industrial production methods for sodium hydroxide	1-2

Sample answer:

The production of sodium hydroxide has changed over time from the diaphragm and mercury cells (both 1890s) to the membrane cell process.

For the diaphragm cell process, iron is the cathode (iron mesh). The anode is titanium. Brine flows through the cell.

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

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

The chief technical and environmental problem associated with use of this cell was the use of the asbestos membrane. Airborne particles from asbestos can cause major respiratory problems in humans.

The porous asbestos diaphragm allowed the (necessary) migration of sodium ions from the brine into the cathode compartment, but also allowed migration of chloride ions from the anode compartment into the cathode compartment (causing residual sodium chloride in the sodium hydroxide) and migration of hydroxide ions from the cathode compartment into the waste brine (causing the formation of hypochlorite ion (OCl^-) from reaction of hydroxide and chlorine). This hypochlorite ion is a strong oxidant which needs to be removed before discharge of the waste brine into the environment.

Because of these technical and environmental problems, diaphragm cells are no longer built and few are still in use.

For the mercury cell process, mercury is the cathode and it flows on the floor of a tank. The anodes are titanium plates. Brine flows through the tank.

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

Cathode: $Na^+(aq) + e^- \rightarrow Na(\text{amalgam with Hg})(l)$

The sodium from the cathode reaction flows into a second tank where it reacts with water to form sodium hydroxide.

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

The cell uses mercury and requires a very high current. It produces very pure sodium hydroxide. However, it is hard to prevent traces of mercury in the waste brine. Metallic mercury, if released into the environment, is insoluble and sinks to the bottom of waterways. Here some bacteria exist which can convert the mercury into mercury compounds which are poisonous (mercury affects the nervous system and the brain). Compounds of mercury in ocean water can be taken up by organisms and passed along the food chain with biological concentration (bioaccumulation) at each stage. The result is that end consumers (humans eating fish) can receive quite significant doses of mercury. As a result, despite their efficiency, very few mercury cells have been built in recent years.

The membrane cell is like the diaphragm cell but has an improved diaphragm – a membrane which is selective in terms of permeability of ions, producing a higher purity of sodium hydroxide. The availability of new polymers, such as the cation exchange PTFE membrane, overcame the disadvantages of the older diaphragm cell, without introducing further problems. Issues that remain are the high cost of electricity and the need to ensure that the products, chlorine and hydrogen, do not come into contact.

All three industrial processes have the same net equation:

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

Evaluation

Even though the THREE different electrolytic cells used for the industrial production of sodium hydroxide have used the same chemical reaction (and hence the same raw material, brine), the production of sodium hydroxide via the membrane process is the now the preferred method and all new sodium hydroxide plants use this technology.

Whilst the mercury cell is still used in some countries for production of sodium hydroxide and is energy efficient, the purity of the sodium hydroxide from the membrane cell process is far superior and outweighs the extra cost of production.

The membrane cell is also preferred since it does not involve the use of mercury or asbestos, which are hazards to society and the environment. Furthermore, the problems associated with the discharge of the hypochlorite ion with the waste brine have been overcome.

(e) (4 marks)
Outcomes Assessed: H1, H3, H4, H5, H7, H8
Targeted Performance Bands: 2-6

Criteria	Marks
• Critically assesses the THREE sites in relation to their suitability for the Solvay process	4
• Discusses the THREE sites in relation to their suitability for the Solvay process	3
• Discusses correctly some aspects of the criteria for selection of sites for the Solvay process	2
• Outlines some correct information about the Solvay process	1

Sample answer:
The raw materials required for the production of sodium carbonate are limestone and brine and the products are calcium chloride (waste) and sodium carbonate.

Steps in creation of sodium carbonate:
- Brine (NaCl) is purified so that it is suitable for use in the process.
- Sodium hydrogen carbonate ($NaHCO_3$) is formed from the reaction between carbon dioxide (CO_2), water (H_2O), ammonia (NH_3) and sodium chloride (NaCl).
- Sodium hydrogen carbonate ($NaHCO_3$) is heated and turned into sodium carbonate (Na_2CO_3).
- Ammonium chloride (NH_4Cl) formed in the reaction is turned back to ammonia (NH_3) and reused.

The most important factors in determining a site for production include availability of raw materials (brine, limestone), availability of transport, availability of sufficient energy at competitive rates, location of markets for the product (product can be sold), availability of a workforce at reasonable cost, and suitability of nearby sites for disposal of wastes (wastes are excess heat and solid $CaCl_2$). In Australia, most Solvay plants are located on the coastline, so that excess heat can be dissipated directly into the ocean, to minimise the impact of thermal pollution.

Assessment
Site B has the advantage of availability of power at a reasonable cost, as it is so close to the power plant. Site C has the advantage, not only of being on the train line, but also of being close to limestone deposits, close enough to the city to have ready access to the workforce and close enough to a port to be able to have access to brine. However, it does not have ready access to the ocean for direct disposal of the wastes, heat and the calcium chloride.
Site A, inland from a large city, has advantages over the other two sites, in that a workforce is available, the ocean is nearby for the supply of brine, power supplies will be in place for the city and limestone deposits can be transported by rail. However, Site A it is not on the coastline, so disposal of wastes cannot be conveniently achieved.
A better option would be to consider a fourth alternate site, close to A and its port, with the ability to dispose of the wastes directly into the ocean.