CATHOLIC SECONDARY SCHOOLS ASSOCIATION OF NEW SOUTH WALES

2007 TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION

CHEMISTRY – MARKING GUIDELINES

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

Section I
Part A – 15 marks
Questions 1-15 (1 mark each)

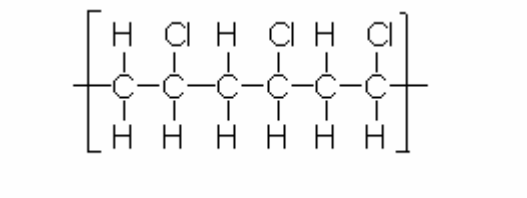
Question	Correct Response	Outcomes Assessed	Targeted Performance Bands
1	A	H9	2–3
2	D	H9, H10	4–5
3	B	H8, H14	3–4
4	C	H6, H8, H14	3–4
5	C	H6, H13	4–5
6	A	H11	2–3
7	B	H12	3–4
8	D	H10	4–5
9	A	H8, H14	3–4
10	B	H6, H9, H13	4–5
11	C	H3, H8	4–5
12	B	H4, H6, H8	5–6
13	C	H4	3–4
14	D	H6	4–5
15	D	H4, H12, H14	5–6

Section I
Part B – 60 marks

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

Criteria	Mark
• Draws section of polymer chain of poly(vinyl chloride) with THREE repeating units	1

Sample answer



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

Criteria	Mark
• Describes ONE use of PVC in terms of ONE property	1

Sample answer
PVC can be used in drainage pipes because it is rigid.

Question 17 (5 marks)

(a) (1 mark)

Outcomes Assessed: H9, H13

Targeted Performance Bands: 2–3

Criteria	Mark
• Writes a correctly balanced equation	1

Sample answer

$$CH_2{=}\ CH_2(g) + H_2O(g) \xrightarrow{H_2SO_4} CH_3\text{-}CH_2\text{-}OH(g)$$

(b) (1 mark)

Outcomes Assessed: H9, H13

Targeted Performance Bands: 2–3

Criteria	Mark
• Writes a correctly balanced equation	1

Sample answer

$$C_6H_{12}O_6(aq) \xrightarrow{\text{yeast}} 2CH_3\text{-}CH_2\text{-}OH(aq) + 2CO_2(g)$$

(c) (3 marks)
Outcomes Assessed: H3, H4, H5, H9, H14
Targeted Performance Bands: 4–6

Criteria	Marks
• Justifies the increased production of ethanol by fermentation by discussing the advantages and/or disadvantages by comparing with alternative production methods	3
• Discusses advantages and/or disadvantages of fermentation	2
• Describes ONE advantage of fermentation	1

Sample answer
Ethanol is a significant industrial chemical which can be used as a fuel, as a raw material in industry, as a solvent, for consumption and as a source of ethylene to produce other ethylene-based products.
Currently, the source of ethanol for these uses, other than for human consumption, is mainly by the hydration of ethylene.
Ethanol produced from fermentation is said to be *renewable* as it is produced from carbohydrate-rich crops such as sugarcane and thus does not depend on a supply of crude oil. Supplies of crude oil are limited, because it is a fossil fuel, and are increasingly expensive.
Production of ethanol from fermentation is said to be more *greenhouse neutral* than production from crude oil. Although the agricultural, transport and refining processes associated with fermentation of glucose to produce ethanol release carbon dioxide into the atmosphere, the process of photosynthesis to produce the carbohydrate-rich crops takes carbon dioxide out of the atmosphere.

The burning of ethanol made from ethylene, which has been derived from crude oil, is releasing into the atmosphere carbon dioxide, which was taken in by plants millions of years ago. Hence the nett effect on the current atmosphere is much greater when fossil fuels, or products derived from fossil fuels, are burnt.

Thus it is important that ethanol from fermentation is available to replace ethanol from crude oil.

However, alternative methods of ethanol production from fermentation which present less environmental impact and are more efficient should be developed to make fermentation a truly viable source of ethanol.

Question 18 (4 marks)
Outcomes Assessed: H1, H4, H5
Targeted Performance Bands: 2–4

Criteria	Marks
• Identifies the raw material and process or organism from which a recently developed biopolymer is produced • Discusses the benefits of the biopolymer by comparing the properties of the biopolymer with alternate polymers derived from crude oil	3–4
• Identifies the raw material and process or organism from which a recently developed biopolymer is produced OR • Identifies advantages of an identified, recently developed biopolymer	2
• Identifies a recently developed biopolymer OR • Identifies the raw material or organism from which a recent biopolymer is produced OR • Identifies an advantage of a recently developed biopolymer	1

Sample answer
Many possible alternatives, check sources. For example:

PHAs (polyβ-hydroxy-alkanoates) are a group of biopolymers, the simplest of which is PHB (polyβ-hydroxybutanoate). PHB is produced by placing *Alcaligenes eutrophus* in a medium in which it can multiply. A nutrient is then restricted and the micro-organism no longer multiplies but produces the biopolymer to be stored and used for an energy source in the future. The organism and the biopolymer are then separated.
PHB has physical properties similar to polypropylene (strong, water-resistant, etc). However, PHB is biodegradable whereas polypropylene is not biodegradable. Thus, it is useful for purposes such as disposable nappies, plastic bottles and bags and wrapping film, and packaging for medical and hospital supplies.

Question 19 (5 marks)
(a) (1 mark)
Outcomes Assessed: H4
Targeted Performance Bands: 2–3

Criteria	Mark
• Identifies a radioisotope used in medicine	1

Sample answer
Technetium-99m

(b) (1 mark)
Outcomes Assessed: H4
Targeted Performance Bands: 3–4

Criteria	Mark
• Identifies a use of the named radioisotope AND explains use in terms of a *chemical* property	1

Sample answer
Tc-99m is used for diagnosing tumours and irregularities throughout the body. Tc-99m can be combined chemically with a tin compound. This binds to red blood cells and can therefore be used to map circulatory system disorders.

(c) (3 marks)
Outcomes Assessed: H4, H14
Targeted Performance Bands: 3–5

Criteria	Marks
• Assesses the potential of the THREE isotopes by considering the type of emission AND half-life	3
• Assesses the potential of TWO isotopes by considering the type of emission AND half-life OR • Assesses the potential of the THREE isotopes by considering the type of emission OR half-life	2
• Assesses the potential of ONE isotope by considering the type of emission and half-life OR • Explains the relevance of the type of emission or half-life	1

Sample answer
Elements X and Y would be suitable for medical purposes as they produce gamma radiation which can pass through human tissue. Element Z would be unsuitable as alpha particles cannot travel through even thin layers of skin.
As it has a short half-life, element X would be suitable for injection into the human body for diagnostic purposes. Element Y would remain an active source of gamma radiation for many years due to its relatively long half-life. Therefore Y would be inappropriate for injection but appropriate as a source of gamma radiation for therapy.

Question 20 (4 marks)
(a) (1 mark)
Outcomes Assessed: H7, H8
Targeted Performance Bands: 2–3

Criteria	Mark
• Defines the term correctly	1

Sample answer
An electrolyte is a substance which in solution or when molten conducts electricity.

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

Criteria	Mark
• Identifies either electrolyte correctly	1

Sample answer
Dry Cell: ammonium chloride paste, including zinc chloride and manganese dioxide
Lead-Acid Cell: sulfuric acid

(c) (2 marks)
Outcomes Assessed: H4
Targeted Performance Bands: 3–4

Criteria	Marks
• Compares cost AND practicality, making TWO clear comparisons	2
• Compares cost OR practicality, making ONE clear comparison	1

Sample answer
(Note: TWO only from the following comparisons needed)

Dry cell	Lithium cell (lithium ion type)
• Cheaper to purchase	• More expensive to purchase
• Low voltage	• Higher voltage
• Good for low current appliances	• Suitable for high current appliances
• Non-rechargeable – one use only	• Rechargeable – multiple use which offsets the high initial cost
• Can leak causing corrosion of electrical components	• Can become very hot and explode • Must incorporate many safety measures
• Robust, easy to store and use	• Loses capacity to store charge with age • Heat sensitive
• Disposal causes minimal harm to the environment	• Disposal should be to a recycling centre to avoid explosion and damage to the environment
• Heavy mass in comparison to electricity output	• Light mass in comparison to electricity output

Question 21 (5 marks)
Outcomes Assessed: H8
Targeted Performance Bands: 3–5

Criteria	Marks
• Writes an appropriate equation to show $H_2PO_4^-$ acting as an acid • Writes an appropriate equation to show $H_2PO_4^-$ acting as a base • Explains the term amphiprotic • Explains that $H_2PO_4^-$ ions release OH^- ions by reacting with water • Relates a pH >7 to basicity	5
• FOUR of the above	4
• THREE of the above	3
• TWO of the above	2
• ONE of the above	1

Sample answer
The dihydrogen phosphate ion ($H_2PO_4^-$) is able to donate a proton to a stronger base (OH^-) and hence act as an acid, or accept a proton from a stronger acid (H_3O^+) and hence act as a base.
Thus it is termed amphiprotic.

<u>As an acid</u>:

$$H_2PO_4^-(aq) + OH^-(aq) \rightarrow H_2O(l) + HPO_4^{2-}(aq)$$

<u>As a base</u>:

$$H_2PO_4^-(aq) + H_3O^+(aq) \rightarrow H_2O(l) + H_3PO_4(aq)$$

A solution of KH_2PO_4 contains $H_2PO_4^-$, which is a stronger base than water, and will accept a proton from water producing OH^-. The formation of hydroxide ions in the water makes the solution <u>basic</u> and hence the pH will be >7.

$$H_2PO_4^-(aq) + H_2O(l) \rightleftharpoons OH^-(aq) + H_3PO_4(aq)$$

Question 22 (3 marks)
Outcomes Assessed: H4, H13
Targeted Performance Bands: 2–4

Criteria	Marks
• Writes an equation and describes the industrial production of an oxide of sulfur • Writes an equation and describes the formation of sulfurous or sulfuric acids from the appropriate oxide of sulfur • Links the presence of H_2SO_3 or H_2SO_4 with the formation of acid rain and hence to a decrease in the pH of waterways	3
• TWO of the 3 above	2
• ONE of the 3 above	1

Sample answer
The industrial production of oxides of sulfur may result from an intentional step in the production of sulfuric acid, or as an unwanted waste from the smelting of metal ores.

$S(s) + O_2(g) \rightarrow SO_2(g)$ OR

$2ZnS(s) + 3O_2(g) \rightarrow SO_2(g) + 2ZnO(s)$

Sulfur dioxide, SO_2, released into the atmosphere can react with water falling as rain, according to the following equation:

$SO_2(g) + H_2O(l) \rightarrow H_2SO_3(aq)$

SO_2 is also oxidised in air:

$SO_2(g) + O_2(g) \rightarrow SO_3(g)$

The resulting sulfur trioxide can also react with water falling as rain:

$SO_3(g) + H_2O(l) \rightarrow H_2SO_4(aq)$

As both H_2SO_3 and H_2SO_4 are acids, the rainwater is now acidic. The groundwater may become acidic as a result of the rain, and hence the pH will fall.

Question 23 (4 marks)
(a) (2 marks)
Outcomes Assessed: H10, H12
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 = 0.125 x 18.7/1000 = 0.00234 mol

Moles CH_3COOH = moles NaOH = 0.00234 mol

$\therefore$ Concentration CH_3COOH = n/V = 0.00234 / 0.025 = 0.0936 mol L^{-1}

(b) (2 marks)
Outcomes Assessed: H10, H11, H12, H14
Targeted Performance Bands: 3–4

Criteria	Marks
• Describes that the pipette should be rinsed with acetic acid instead of distilled water • Explains the resultant dilution of acetic acid results in a lower concentration	2
• Describes that the pipette should be rinsed with acetic acid instead of distilled water OR • Explains the resultant dilution of acetic acid results in a lower concentration	1

Sample Answer
The pipette should be rinsed with the acetic acid solution to ensure that the correct number of moles of acid is transferred to the conical flask. If the pipette is rinsed with distilled water directly before pipetting acetic acid, the solution will be diluted within the pipette.

This will result in an error in calculation of the acetic acid concentration; i.e. the value calculated will be too low.

Question 24 (8 marks)
(a) (i) (2 marks)
Outcomes Assessed: H12, H14
Targeted Performance Bands: 2–3

Criteria	Marks
• Describes TWO trends or relationships	2
• Describes ONE trend or relationship	1

Sample answer
The boiling points of both alkanoic acids and alkanols increase as the molecular weight increases.
The boiling points of alkanoic acids are higher than the boiling points of alkanols of similar molecular weights.

(a) (ii) (2 marks)
Outcomes Assessed: H6, H14
Targeted Performance Bands: 3–5

Criteria	Marks
• Explains ONE trend or relationship in terms of intermolecular forces, including the type of intermolecular force(s) involved	2
• Explains ONE trend or relationship in terms of intermolecular forces only (without correctly identifying the type of intermolecular force(s) involved)	1

Sample answer (Note: other answers apply if other trends/relationships selected)
The boiling points of the alkanols increase as the molecular weight increases.
This is due to the greater mass, greater number of atoms and electrons and longer chain length as the molecular weight increases. As a result, there are greater interactions between the hydrocarbon chains for long-chain alkanols than for short-chain alkanols. These increasing interactions are increasing dispersion forces. (The effect of hydrogen bonding does **not** increase as the molecular weight increases.)

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

Criteria	Mark
• Identifies the water condenser (Liebig condenser)	1

Sample answer
Water condenser

(b) (ii) (3 marks)
Outcomes Assessed: H8, H14
Targeted Performance Bands: 3–5

Criteria	Marks
• Evaluates the appropriateness of using this method AND explains at least TWO reasons for heating under reflux	3
• Explains TWO reasons for heating under reflux	2
• Explains ONE reason for heating under reflux	1

Sample answer
Heating under reflux is appropriate because the refluxing apparatus prevents the volatile reactants escaping before the reaction has reached equilibrium. Refluxing also prevents the flammable, toxic organic reactants escaping into the laboratory.
The volatile reactants are continually cooled and returned to the reaction flask allowing the reaction to take place at higher temperatures.
The reaction rate is faster and the yield of ester is higher at higher temperatures, since the equilibrium reaction is endothermic.

Evaluation
Without the use of reflux, the experiment would be unsuccessful (as little or no ester would be produced or retained in the flask), and would be potentially dangerous, as volatile, irritating and flammable materials would escape into the laboratory.

Question 25 (4 marks)
(a) (1 mark)
Outcomes Assessed: H11, H13
Targeted Performance Bands: 2–3

Criteria	Mark
• Writes a suitable hypothesis which is able to be tested in an experiment (hypothesis does not need to be correct)	1

Sample answer
The molar heat of combustion of 1-butanol is greater than the molar heat of combustion of ethanol.

(b) (1 mark)
Outcomes Assessed: H11
Targeted Performance Bands: 3–4

Criteria	Mark
• Identifies TWO variables which should be controlled	1

Sample answer
The mass (volume) of water, the distance of the beaker from the flame, length of wick, the air turbulence, the equipment used (beakers, the spirit burners, gauze, tripod, thermometer) should be identical.

(c) (2 marks)
Outcomes Assessed: H4, H9
Targeted Performance Bands: 3–4

Criteria	Marks
• Identifies ONE problem • Outlines ONE way the reaction can be managed	2
• Identifies ONE problem OR • Outlines ONE way the reaction can be managed	1

Sample answer
Carbon monoxide and/or carbon (soot) are formed during incomplete combustion of carbon based fuels. A person inhaling carbon monoxide may die of asphyxiation.
The problem can be managed by ensuring an excess supply of oxygen during combustion (increasing the oxygen:fuel ratio).

Question 26 (3 marks)
Outcomes Assessed: H8, H14
Targeted Performance Bands: 4–6

Criteria	Marks
• Justifies the need for monitoring in order to achieve a compromise between yield and rate of production by explaining the impact of changing temperature on both the yield and rate of production of ammonia	3
• Explains the impact of changing temperature on the yield of ammonia • Explains the impact of changing temperature on the rate of production of ammonia	2
• Identifies an impact of changing temperature on the equilibrium	1

Sample answer
As this is an equilibrium reaction, using Le Chatelier's Principle, we can predict that increasing the temperature would push the reaction to the left, toward the reactants, as the forward reaction is exothermic. Thus low temperature produces the highest **yield** of ammonia.
Increasing the temperature increases the **rate** of reaction. Increasing the temperature means more successful collisions as the particles are moving faster. Hence, high temperature produces the fastest **rate of production** of ammonia.

Therefore, the reaction vessel must be monitored to ensure a moderate temperature as a compromise between the highest yield and the fastest rate of production of ammonia.

Question 27 (4 marks)
(a) (2 marks)
Outcomes Assessed: H11, H12
Targeted Performance Bands: 2–3

Criteria	Marks
• Correctly identifies TWO procedures	2
• Correctly identifies ONE procedure	1

Sample answer
Wash the precipitate with distilled water to remove any soluble ions.
Dry the precipitate thoroughly to remove any water. (Both procedures will ensure that the mass is solely due to the $Ca_2P_2O_7(s)$.)

(b) (2 marks)
Outcomes Assessed: H10, H12
Targeted Performance Bands: 3–5

Criteria	Marks
• Correctly calculates the %P in the detergent	2
• Correctly calculates the number of moles of P present	1

Sample answer
Moles of $Ca_2P_2O_7(s) = 0.232/ (40.08x2 + 30.97x2 + 16.00x7) = 9.13x10^{-4}$ mol
Moles of P = 2 x moles $Ca_2P_2O_7 = 0.00183$ mol
Mass P in detergent = 0.00183x30.97 = 0.0566 g
%P in detergent = 0.0566 x 100/4.42 = 1.28%

Question 28 (3 marks)
(a) (1 mark)
Outcomes Assessed: H6
Targeted Performance Bands: 2–3

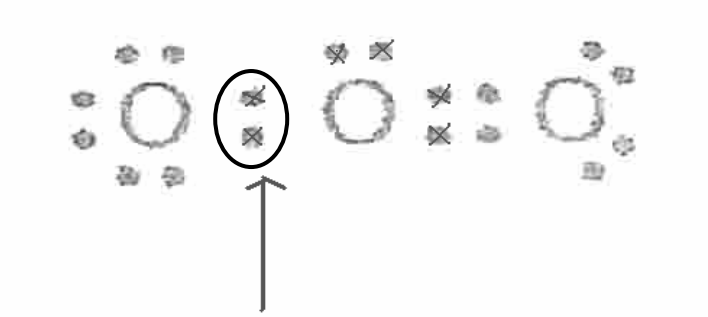
Criteria	Mark
• Defines *allotropes*	1

Sample answer
Allotropes are different physical forms of the same element.

(b) (2 marks)
Outcomes Assessed: H6, H13
Targeted Performance Bands: 3–4

Criteria	Marks
• Draws correct Lewis diagram for ozone AND • Identifies the co-ordinate covalent bond	2
• Draws partially correct Lewis diagram for ozone but identifies correctly the co-ordinate covalent bond OR • Draws correct Lewis diagram for ozone	1

Sample answer



The bond indicated is the co-ordinate covalent bond**.**

Question 29 (6 marks)
Outcomes Assessed: H4, H11, H14
Targeted Performance Bands: 2–6

Criteria	Marks
• Evaluates the use of BOD with respect to the monitoring of the possible eutrophication of waterways • Describes the test for BOD AND describes the role of BOD in eutrophication AND the importance of monitoring BOD	6
• Describes the test for BOD AND describes the role of BOD in eutrophication AND the importance of monitoring BOD	5
• Describes the test for BOD AND identifies the role of BOD in eutrophication AND identifies the importance of monitoring BOD OR • Identifies components of the test for BOD AND describes the role of BOD in eutrophication AND describes the importance of monitoring BOD	4
• Describes the test for BOD OR • Describes the role of BOD in eutrophication AND importance of monitoring BOD	3
• Identifies components of the test for BOD AND identifies a role of BOD in eutrophication	2
• Identifies components of the test for BOD OR • Identifies a role of BOD in eutrophication	1

Sample answer
Collect two identical samples of water from the source to be tested.
One is tested for dissolved oxygen (DO) immediately and the other is tested 5 days later, after being kept in the dark at 25^{o}C.
DO is determined by either the Winkler method or using an oxygen-selective electrode.
The difference in DO between the two samples is the biochemical oxygen demand (BOD) of the water sample.
BOD is a measure of the demand for oxygen by bacteria in the water as they break down organic matter which may release nitrates, phosphates and carbon dioxide as by-products.
A high BOD indicates a high level of organic matter and thus a high nutrient level. A high nutrient level encourages the growth of algae which may lead to an algal bloom. When the algae eventually die, the organic content of the waterway will increase and thus the BOD will increase (more aerobic bacteria) resulting in the depletion of all DO.
Organisms depending on oxygen in the waterway will die and eventually anaerobic bacteria will take over the system. This degradation of the waterway is called eutrophication.

Whilst BOD is a significant indicator of the factors that lead to eutrophication of waterways, it is not effective enough on its own. Determination of the nitrate and phosphate content is an additional valuable tool in the monitoring of the possible eutrophication of waterways.
Therefore the use of BOD in the monitoring of the possible eutrophication of waterways should be analysed in conjunction with other techniques (such as nitrate and phosphate content).

Section II - OPTIONS

Question 30 - Industrial Chemistry (25 marks)

(a) (i) (1 mark)

Outcomes Assessed: H9

Targeted Performance Bands: 2–3

Criteria	Mark
• Identifies the TWO reactants	1

Sample Answer

Sodium hydroxide and glyceryl tristearate

(a) (ii) (4 marks)

Outcomes Assessed: H3, H4, H9

Targeted Performance Bands: 3–4

Criteria	Marks
• Explains how a cationic detergent is chemically different to soap • Relates ONE use of a cationic detergent	4
• Explains how a cationic detergent is different to soap AND • States ONE use of a cationic detergent OR • Partially correctly explains how a cationic detergent is different to soap AND correctly describes ONE use of a cationic detergent	3
• Partially correctly explains how a cationic detergent is different to soap AND correctly states ONE use of a cationic detergent OR • Explains how a cationic detergent is different to soap OR • Correctly describes ONE use of a cationic detergent	2
• States ONE property of a cationic detergent OR • States ONE use of a cationic detergent	1

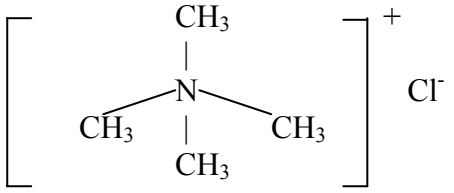
Sample Answer

While soap has a negatively charged head, a cationic detergent has a positively charged head and both have a long carbon chain tail.

Both heads are hydrophilic while both have hydrophobic tails.

The positively charged head of the cationic detergent is related to NH_4Cl except the four hydrogen atoms are replaced with alkyl groups.

e.g.



The positively charged head is attracted to the negatively charged surface of objects, creating a "coating" and hence they are used as fabric softeners and hair conditioners.

(b) (i) (1 mark)
Outcomes Assessed: H10
Targeted Performance Bands: 2–3

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

Sample Answer

$$K = \frac{[CH_3OH(g)]}{[CO(g)][H_2(g)]^2}$$

(b) (ii) (1 mark)
Outcomes Assessed: H10
Targeted Performance Bands: 3–4

Criteria	Mark
• Calculates the equilibrium constant	1

Sample Answer

$$K = \frac{[0.4]}{[2.0][1.6]^2} = 0.078$$

(b) (iii) (1 mark)
Outcomes Assessed: H7, H8
Targeted Performance Bands: 3–4

Criteria	Mark
• Identifies that K would increase	1

Sample Answer
As the reaction is exothermic, a decrease in temperature would shift the equilibrium to the right, thus increasing the concentration of CH_3OH*(g)* at equilibrium and increasing K.

(c) (i) (1 mark)
Outcomes Assessed: H8, H13
Targeted Performance Bands: 2–3

Criteria	Mark
• Writes an equation for the reaction	1

Sample Answer

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

(c) (ii) (2 marks)
Outcomes Assessed: H7, H8
Targeted Performance Bands: 2–3

Criteria	Marks
• Identifies TWO conditions	2
• Identifies ONE condition	1

Sample Answer
Any TWO of:
Increase the oxygen concentration, lower the temperature, increase the pressure, etc.

(c) (iii) (3 marks)
Outcomes Assessed: H7, H8, H11
Targeted Performance Bands: 4–5

Criteria	Marks
• Justifies at least TWO safety precautions in terms of range of properties of sulfuric acid • Explains method of dilution of concentrated sulfuric acid in terms of exothermic nature of the process	3
• Justifies at least TWO safety precautions in terms of range of properties of sulfuric acid OR • Explains method of dilution of concentrated sulfuric acid in terms of exothermic nature of the process	2
• Identifies some safety precaution when diluting sulfuric acid	1

Sample Answer
Sulfuric acid is a very strong acid, oxidising agent and dehydrating agent and can cause severe damage to eyes, skin, clothing, etc, if contacted.
The acid must be handled with protective clothing, safety glasses and gloves.
Dilution must be carried out by very slowly adding acid to water as the reaction is highly exothermic. The reverse (water to acid) is a safety hazard because of the possibility of boiling concentrated acid.

(d) (6 marks)
Outcomes Assessed: H3, H4, H7
Targeted Performance Bands: 2–6

Criteria	Marks
• Describes thoroughly the mercury cell process and products • Evaluates the environmental issues and technical considerations	6
• Describes thoroughly the mercury cell process and products • Describes thoroughly the environmental issues • Describes thoroughly the technical considerations	5
• Describes soundly the mercury cell process and products AND environmental issues AND technical considerations OR • Describes thoroughly TWO of: the mercury cell process and products OR environmental issues OR technical considerations	4
• Identifies limited components of the mercury cell process and products AND environmental issues AND technical considerations OR • Describes soundly TWO of: the mercury cell process and products OR environmental issues OR technical considerations	3
• Identifies limited components of TWO of: the mercury cell process and products OR environmental issues OR technical considerations	2
• Identifies limited components of the mercury cell process and products OR environmental issues OR technical considerations	1

Sample answer:
The mercury cell is one method used in the production of sodium hydroxide. The main products of the process are sodium hydroxide, chlorine gas and hydrogen gas.

The mercury cell uses an electrolysis reaction with an inert (platinum) anode ($2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$) in a solution of sodium chloride, and a mercury *(l)* cathode ($Na^+(aq) + 2e^- \rightarrow Na(l)$) into which sodium metal dissolves forming an amalgam.

The Na/Hg*(l)* amalgam passes through a decomposer (graphite/water) where sodium hydroxide is produced.

$2Na/Hg(l) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g) + 2Hg(l)$.

Overall nett reaction is:

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

Environmental issues to consider include the safe use or safe disposal of mercury (vapours are toxic if inhaled, it can be absorbed through the skin, in waterways it is a poisonous heavy metal which bioaccumulates, it affects the nervous system causing brain damage).

Most of the mercury is recycled or converted into $Hg_2S(s)$ and disposed of in cement in landfill.

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 transport operations on the surrounding population.

Technical considerations 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, mercury, sodium hydroxide) and explosive substances (hydrogen). A very high level of plant safety must be maintained and constantly monitored.

Most plants are located in areas which meet these technical considerations and as long as the appropriate safety standards are maintained the process is a viable option for the production of sodium hydroxide, especially as the mercury cell produces high quality sodium hydroxide.

However, the use of the membrane cell is a better method, as it requires less energy and does not involve the use of toxic mercury. Very few mercury cell plants have been constructed in recent years and many of the older plants have been phased out and replaced by plants using membrane cells.

(e) (5 marks)
Outcomes Assessed: H2, H6, H11
Targeted Performance Bands: 2–5

Criteria	Marks
• Describes the procedure used • Identifies the difficulties associated with the modelling of the step • Describes the risk factors involved in the modelling of the step	4–5
• Any TWO of: describes the procedure OR identifies the difficulties associated with the modelling of the step OR describes the risk factors involved in the modelling of the step OR • Describes the procedure AND identifies some difficulties associated with the modelling of the step AND identifies risk factors involved in the modelling of the step	2–3
• Describes procedure OR • Identifes difficulties associated with the modelling of the step OR • Identifies a risk factor involved in the modelling of the step	1

Sample answer
Many possible answers.

e.g. Ammonia recovery.

$2NH_4Cl(aq) + Ca(OH)_2(aq) \rightarrow CaCl_2(s) + NH_3(g) + H_2O(l)$

Equal volumes of ammonium chloride and saturated calcium hydroxide (lime water) solutions were mixed in a conical flask inside a fume cupboard. Moist red litmus paper was held above the mouth of the flask (the litmus paper turned blue) to indicate the presence of $NH_3(g)$.

The difficulties associated with the modelling of this step include the fact that we were unable to qualitatively identify the recovery of ammonia in the laboratory fume cupboard. We were only able to identify the production of a basic gas. We were also unable to collect the gas generated. In the industrial process, this is done in a closed system with no loss of product, hence the $NH_3(g)$ is able to be re-used.

Ammonia gas is toxic by all routes of exposure. It is a highly lung, eye and skin irritant and is corrosive. Any experiment involving ammonia gas needs to be conducted in a fume cupboard with the use of eye and skin protection (goggles, gloves, lab coat, etc). Care must be taken to avoid any contact of ammonia with halogens as they form an explosive mixture. The risk factors involved in this experiment are minimal if these precautions are taken.

Question 31 – Shipwrecks, Corrosion and Conservation (25 marks)
(a) (3 marks)
Outcomes Assessed: H6, H14
Targeted Performance Bands: 2–4

Criteria	Marks
• Discusses factors that influence the solubility of oxygen in the oceans	3
• Discusses factors that influence solubility of oxygen	2
• Identifies an appropriate factor	1

Sample answer
As temperature decreases the solubility of oxygen increases.
As pressure increases the solubility of oxygen increases.
These two factors would predict a rise in $[O_2]$ with ocean depth but lack of available oxygen at depth prevents this predicted rise in $[O_2]$.
Salinity also affects the solubility of oxygen, with solubility peaking at a salinity of about 4% (w/w) which is approximately the average salinity of the ocean.

The concentration of oxygen in the oceans is affected by all the above factors as well as the rates of photosynthesis and respiration and the amount of wave action and turbulence and the pattern of ocean currents. These four factors vary with depth from the surface, resulting in a peak in O_2 concentration in shallow waters except where cold ocean currents bring oxygen rich waters to great depths.

Hence, the varying concentration of oxygen involves a complex relationship between temperature, pressure, salinity, available oxygen, rates of photosynthesis and respiration, ocean currents and wave action.

(b) (i) (2 marks)
Outcomes Assessed: H2, H11, H12
Targeted Performance Bands: 2–4

Criteria	Marks
• Outlines observable changes and the recording technique	2
• Outlines either observable changes or the recording technique	1

Sample answer
Iron nails placed in saline agar jelly (also containing potassium hexacyanoferrate indicator) of varying pH were inspected daily for five days. The amount of blue resulting from the colour change of the indicator was recorded photographically.

(b) (ii) (3 marks)
Outcomes Assessed: H14
Targeted Performance Bands: 4–5

Criteria	Marks
• Evaluates the appropriateness of the type of data collected AND the method of data collection	3
• Evaluates the appropriateness of the type of data collected OR the method of data collection	2
• Explains an aspect of the data collection	1

Sample answer
In acidic conditions the oxidation of iron will not result in the production of orange rust due to an absence of hydroxide ions. The use of the indicator was appropriate as it produced an intense blue colour in the presence of Fe^{2+} ions.
Using the sequence of photographs of the nails and the blue indicator, the relative rate of oxidation at various pH levels can be determined. Photography was appropriate for the comparison of qualitative data over the five days as it showed a clear sequence of colour change.

(c) (4 marks)
Outcomes Assessed: H1
Targeted Performance Bands: 2–6

Criteria	Marks
• Describes the work of Galvani and Volta in relation to electron transfer reactions • Relates the work of Volta to the work of Galvani • Explains the implications of Volta's work	4
• Describes the work of Galvani and Volta in relation to electron transfer reactions • Relates the work of Volta to the work of Galvani	3
• Describes features of the work on electron transfer reactions carried out by Galvani or Volta	2
• Identifies a feature of the work on electron transfer reactions carried out by Galvani or Volta.	1

Sample answer
Galvani observed that animal tissue, when touched by two different metals, was capable of producing electricity which could stimulate muscle movement. He concluded that the tissue contained "animal electricity" which activated the nerves.
Volta was not convinced and developed an alternative explanation for the observed muscle twitching. He believed the metals were responsible, not the animal tissue. He succeeded in demonstrating this hypothesis by making electricity using two different metals in moist contact. Thus he demonstrated the correctness of "metallic electricity" rather than Galvani's "animal electricity".
Volta's success enabled him to produce the first direct current battery using a combination of metal disks interleaved with cloth soaked in a salt solution. Whilst Galvani's work laid the foundation for biologists to investigate the physiology of nerves and muscles, Volta's work had enormous impact on the scientific community, encouraging scientists to explore the interactions of metals and solutions in their investigations of "electricity". The phenomenon was shown to stem from chemical reactions rather than from biological systems.

(d) (i) (1 mark)
Outcomes Assessed: H3
Targeted Performance Bands: 2–3

Criteria	Mark
• Identifies the composition	1

Sample answer
Steel is composed of iron and carbon and possibly a range of other elements.

(d) (ii) (1 mark)
Outcomes Assessed: H8
Targeted Performance Bands: 3–4

Criteria	Mark
• Writes a correct equation	1

Sample answer
$Fe(s) \rightarrow Fe^{2+}(aq) + 2e^-$

(d) (iii) (4 marks)
Outcomes Assessed: H3, H8
Targeted Performance Bands: 2–5

Criteria	Marks
• Predicts the relative rates of corrosion correctly • Justifies the relative corrosion rates, demonstrating a thorough knowledge of the chemistry involved	4
• Predicts the relative rates of corrosion correctly • Attempts to justify the relative corrosion rates	3
• Successfully justifies the different corrosion rates between TWO of the metals	2
• Predicts the relative rates of corrosion correctly OR • Identifies a reason for slower or faster corrosion in ONE of the samples	1

Sample answer
Ranked in order from the slowest rate of corrosion to the fastest, the steels are Z, X, Y.
Sample Y will corrode rapidly as the steel surface has been scratched, disturbing the metallic lattice structure and producing an oxygenation differential. The iron at the base of the crack will be an anodic site whilst the iron at the top will be a cathodic site due to the greater supply of oxygen.
The steel in Sample Z will be protected from oxidation by the presence of zinc. Zinc is a stronger reductant than iron and will therefore oxidise preferentially instead of the iron. Consequently the iron in the steel will be protected from corrosion.
The rate of corrosion of the steel in Sample X will be slower than Sample Y as there is no disturbance to the metallic lattice and no scratch setting up an oxygen differential. However, Sample X, without the cathodic protection of the zinc layer, will corrode faster than Sample Z.

(e) (i) (1 mark)
Outcomes Assessed: H12
Targeted Performance Bands: 2–3

Criteria	Mark
• Identifies the products	1

Sample answer
Chlorine and hydrogen gases

(e) (ii) (1 mark)
Outcomes Assessed: H8, H12
Targeted Performance Bands: 2–3

Criteria	Mark
• Identifies an appropriate method	1

Sample answer
Moving the electrodes closer together OR increasing the size of the submerged electrodes

(e) (iii) (1 mark)
Outcomes Assessed: H8
Targeted Performance Bands: 3–4

Criteria	Mark
• Writes a correct half-equation	1

Sample answer
$H_2O(l) + e^- \rightarrow \frac{1}{2} H_2(g) + OH^-(aq)$

(e) (iv) (2 marks)
Outcomes Assessed: H8
Targeted Performance Bands: 3–4

Criteria	Marks
• Describes a new reaction occurring at the cathode only	2
• Identifies a reaction involving sodium ions	1

Sample answer
Instead of the reduction of water, sodium ions would be reduced at the cathode to form sodium metal.

$Na^+(l) + e^- \rightarrow Na(l)$

The anode reaction would be the same (production of chlorine).

(e) (v) (2 marks)
Outcomes Assessed: H3
Targeted Performance Bands: 3–4

Criteria	Marks
• Outlines TWO appropriate uses of electrolysis	2
• Outlines ONE appropriate use of electrolysis	1

Sample answer
Serious problems can result from chloride ions remaining in the pores and cracks of metal artefacts recovered from marine wrecks. The chemical process of electrolysis can be used to remove these chloride ions by drawing them out of the cathodic artefact towards the stainless steel anode.
Electrolysis is also used to restore artefacts by placing the artefact at the cathode; e.g. silver artefacts are restored by reducing silver sulfides back to metallic silver.

Question 32 – The Biochemistry of Movement (25 marks)

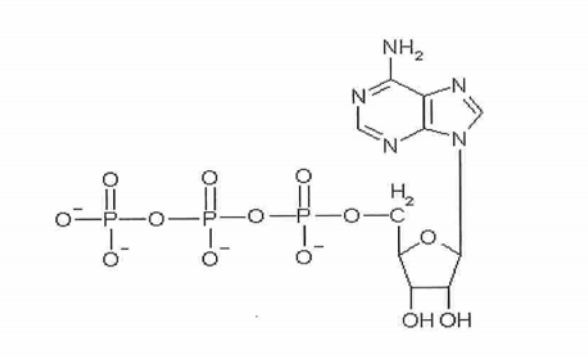
(a) (1 mark)

Outcomes Assessed: H9, H13

Targeted Performance Bands: 3–4

Criteria	Mark
• Correct answer	1

Sample answer



(b) (i) (1 mark)

Outcomes Assessed: H9, H13

Targeted Performance Bands: 2–3

Criteria	Mark
• Correct answer	1

Sample answer

Glycolysis

(b) (ii) (2 marks)

Outcomes Assessed: H13

Targeted Performance Bands: 3–5

Criteria	Marks
• Identifies pyruvic acid (pyruvate) • Describes that lactic acid (lactate ion) is formed under anaerobic conditions	2
• Identifies pyruvic acid (pyruvate) OR • Describes that lactic acid (lactate ion) is formed under anaerobic conditions	1

Sample answer

The pyruvic acid (pyruvate ion) can be converted to lactic acid (lactate ion) during vigorous activity, when oxygen levels are too depleted to allow complete aerobic oxidation to CO_2 and H_2O.

(b) (iii) (2 marks)
Outcomes Assessed: H13
Targeted Performance Bands: 3–5

Criteria	Marks
• Outlines significance of ATP as the energy source for metabolic processes • Outlines the relationship of cellular respiration and ATP	2
• Outlines significance of ATP as the energy source for metabolic processes OR • Outlines the relationship of cellular respiration and ATP	1

Sample answer
ATP is the currency of energy production in most organisms in that ATP is the energy source for almost all metabolic processes.
Cellular respiration is the process by which most of the foods that an organism consumes are broken down, releasing energy. This energy is stored in the ATP.

(c) (i) (1 mark)
Outcomes Assessed: H6, H9, H13
Targeted Performance Bands: 2–3

Criteria	Mark
• Correct answer	1

Sample answer
1, 2, 3-propanetriol

(c) (ii) (2 marks)
Outcomes Assessed: H6, H9, H13
Targeted Performance Bands: 3–4

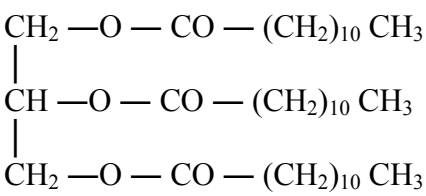
Criteria	Marks
• Recognises the high viscosity of glycerol as its resistance to flow • Relates the viscosity to the strong H-bonding between adjacent molecules because of THREE OH groups in each molecule	2
• Recognises the high viscosity of glycerol as its resistance to flow OR • Relates the viscosity to the strong H-bonding between adjacent molecules because of THREE OH groups in each molecule	1

Sample answer
The viscosity of a liquid is a measure of its resistance to flow. Glycerol has high viscosity because there are strong intermolecular forces between neighbouring molecules, due to the presence of THREE – OH groups on each molecule.

(c) (iii) (1 mark)
Outcomes Assessed: H6, H9, H13
Targeted Performance Bands: 3–4

Criteria	Mark
• Correct formula	1

Sample answer



(c) (iv) (2 marks)
Outcomes Assessed: H6, H8, H9
Targeted Performance Bands: 2–4

Criteria	Marks
• Identifies TAG as predominantly hydrophobic but with THREE hydrophilic ester groups per molecule • Links predominant hydrophobic nature to insolubility in water	2
• Identifies TAG as predominantly hydrophobic but with THREE hydrophilic ester groups per molecule OR • Links predominant hydrophobic nature to insolubility in water	1

Sample answer
The TAG is a tri-ester. Since the molecules do not contain any -OH groups, hydrogen bonding is not possible with water. The ester linkage makes the molecule polar, but the hydrophilic ester linkage is surrounded by long hydrophobic hydrocarbon chains. Hence the overall molecule has a nett hydrophobic effect and does not dissolve in water.

(c) (v) (3 marks)
Outcomes Assessed: H4, H8, H9
Targeted Performance Bands: 3–6

Criteria	Marks
• Assesses the importance of TAGS for humans • Explains why TAGs are needed in terms of energy production • Explains why TAGs are needed as long term energy stores	3
• Assesses the importance of TAGS for humans AND • Explains why TAGs are needed in terms of energy production OR • Assesses the importance of TAGS for humans AND • Explains why TAGs are needed as long term energy stores	2
• Explains why TAGs are needed in terms of energy production OR • Explains why TAGs are needed as long term energy stores	1

Sample answer
About 25-30% of our daily energy needs should come from fatty acids - the rest of our dietary fat intake is stored.

TAGs are stored in the cytoplasm of cells of fat tissue and when required each TAG can be hydrolysed by enzymes to give three fatty acids. These are transported around the body and each fatty acid is able to be broken down to CO_2 and H_2O, releasing energy which is used to make ATP in the mitochondria.

In resting muscle cells TAGs supply most of the energy, whereas during exercise carbohydrates are the main source of energy. An average person of weight 75 kg should carry about 12 kg of fat, ie. about one sixth of body weight. This varies a great deal from person to person, but generally enough fat is stored to last as an energy source for about 2 months.

Hence TAGS are extremely important to humans as they provide the long term store of energy needed.

(d) (i) (2 marks)
Outcomes Assessed: H6, H8, H9
Targeted Performance Bands: 3–5

Criteria	Marks
• Explains the function of a substrate specific binding site on a particular enzyme	2
• Identifies some correct information about the "lock and key model" of enzyme action	1

Sample answer
Enzymes are a special class of proteins which possess a binding site that is specific for a particular substrate. Enzymes have a particular area called an active site that can bind the substrate by means of intermolecular forces (known as the "lock and key model"). Only substrates that match or fit the active site will react. These substrates must be able to form bonds with the active site. Therefore enzymes are substrate specific. No other substrate will fit into the site, so no other substrate can be broken down using this enzyme.

For example, the enzyme sucrase has a binding site specific to the sugar sucrose. Only when sucrose fits into this site on the sucrase are the bonds in sucrose weakened, allowing it to be hydrolysed into glucose and fructose. This functioning of an enzyme can be modeled by the lock and key.

(d) (ii) (4 marks)
Outcomes Assessed: H4, H9, H11
Targeted Performance Bands: 2–5

Criteria	Marks
• Describes a suitable method, with controlled variables and only ONE variable (temperature) changed • Identifies enzyme AND the enzyme is appropriate for the method used • Explains how changes in temperature affected the results, including denaturing of enzyme	4
• Describes a suitable method, with controlled variables and only ONE variable (temperature) changed • Identifies enzyme AND the enzyme is appropriate for the method used • Describes results	3
• Describes a suitable method, with controlled variables and only ONE variable (temperature) changed AND • Identifies enzyme AND the enzyme is appropriate for the method used OR • Describes a suitable method, with controlled variables and only ONE variable (temperature) changed AND • Describes results	2
• Identifies some correct information relating to the first-hand investigation	1

Sample answer

Method of experiment

- The experiment was set up using rennin (junket tablets) as the enzyme and milk as the substrate.
- 6 identical test tubes were set up using 10 mL milk and 10 mL of a solution made from 1 finely crushed junket tablet.
- 6 control test tubes, containing milk but no junket tablets, were set up.
- 6 beakers were set up as water baths, ranging in temperature from 0°C to 50°C.
- The 12 test tubes were simultaneously placed in the 6 water baths. (One control and the test tube containing the enzyme were placed in each water bath.)
- The test tubes were observed, to note when the milk coagulated as a measure of the functionality of the enzyme.
- The results were photographed to record the rate of coagulation.

Results and Explanation

- The rate of coagulation increased as the temperature of the water increased from 0°C to 30°C. At 40°C, some coagulation was evident within a few minutes. At 50°C, the milk did not coagulate.

- As is typical of most reactions, the rate of reaction increased as the temperature rose from 0°C to 30°C. The rate declined at 40°C and no reaction (no coagulation) was observed at 50°C.

- This is because the enzyme (a protein) has been denatured by the high temperature. This denaturation has either broken down the protein chain or has changed the secondary or tertiary structures of the protein, affecting the shape of the active site, the binding site for the substrate. Hence no enzyme catalysed reaction can occur.

(e) (4 marks)
Outcomes Assessed: H4, H8, H9
Targeted Performance Bands: 3–6

Criteria	Marks
• Demonstrates an understanding of the different types of metabolism exhibited by Type 1 and Type 2 muscle contractions • Explains clearly the role and significance of glycogen in both cases • Assesses the worth of carb loading in each case	4
• Demonstrates an understanding of the different types of metabolism exhibited by Type 1 and Type 2 muscle contractions • Explains clearly the role and significance of glycogen in both cases	3
• Demonstrates an understanding of the different types of metabolism exhibited by Type 1 and Type 2 muscle contractions	2
• Describes the types of exercise to which Type 1 and Type 2 muscle contractions contribute	1

Sample answer
In explosive exercise, which makes use of Type 2 or "fast twitching" muscle cells, the first source of energy is the glucose present in the blood. This store lasts only a few minutes, after which the main source of energy changes to anaerobic respiration fuelled by glycogen stores within the cell. As glycogen is metabolised from carbohydrates, a diet plan that increases carbohydrate intake, and hence stored glycogen levels, will have a noticeable benefit during explosive, powerful exercise such as sprinting or weight lifting.

More gentle exercise makes use of Type 1 or "slow twitching" muscles. These provide energy predominantly through aerobic processes which make use of glucose in the blood, which lasts only a few minutes, then stored glycogen in the muscle cells. When the stored glycogen is depleted, metabolism of fat and even amino acids will take over as the main source of energy. Extra stores of carbohydrate would delay, or reduce the extent of, the switch to fat metabolism and hence provide slightly greater endurance for the athlete who needs it.

The benefits of carbohydrate loading, therefore, can be enjoyed by athletes participating in all types of exercise, but will be more significant for those needing the explosive power provided anaerobically by Type 2 muscle contraction.

Question 33 – The Chemistry of Art (25 marks)
(a) (1 mark)
Outcomes Assessed: H6
Targeted Performance Bands: 2–3

Criteria	Mark
• Correct answer	1

Sample answer
$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^5$

(b) (i) (1 mark)
Outcomes Assessed: H6, H7
Targeted Performance Bands: 2–3

Criteria	Mark
• Defines correctly, in terms of the periodic table and atomic structure	1

Sample answer
A transition element has incompletely filled inner electron d-subshells and is found in the block between the groups 2 and 3 of the periodic table.

(b) (ii) (2 marks)
Outcomes Assessed: H6, H7
Targeted Performance Bands: 3–5

Criteria	Marks
• Explains in terms of loss of electrons from both s and d subshells because of closeness of energy levels • Explains that different oxidation states result from different numbers of electrons lost	2
• Explains in terms of loss of electrons from both s and d subshells because of closeness of energy levels OR • Explains that different oxidation states result from different numbers of electrons lost	1

Sample answer
The oxidation state refers to the number of electrons gained or lost by an atom or ion (compared with the atom in the elemental form).
When a transition metal atom becomes an ion, electrons can be lost from the outer s subshell, but also from the inner d subshell. As the s and d subshell electrons are so close in energy, transition elements can involve all or most of these s and d electrons in bonding.

Therefore, transition metals can form different oxidation states in different compounds by giving up different numbers of electrons.

(c) (i) (4 marks)
Outcomes Assessed: H1, H11
Targeted Performance Bands: 2–5

Criteria	Marks
• Identifies a suitable metal ion • Outlines all steps in the method • Assesses the risks	3–4
• Identifies a suitable metal ion • Outlines some correct details of the method used OR • Assesses the risks	2
• Identifies a suitable metal ion OR • Outlines some correct details of the method used OR • Outlines some risks	1

Sample answer

Method – testing sodium ion

To clean the platinum wire, it was dipped into the test tube of concentrated HCl and then heated in the hottest part of the flame until no colour was noted.

When the platinum wire was clean, it was dipped into a sample of the solid (NaCl) to be tested or dipped into a test tube containing a 0.5 mol/L solution of NaCl and held in the hottest part of the flame.

The colour of the flame was recorded.

The platinum wire was cleaned and the test repeated.

Risk assessment

As concentrated acid is used, which can cause damage to skin, eyes and clothing, and the metal wire is heated strongly in the hottest part of a Bunsen flame, safety precautions should include wearing of protective clothing, gloves and safety glasses. A shower and sodium hydrogen carbonate should be available to dilute acid spills, as should heat mats and fire safety equipment.

(c) (ii) (2 marks)
Outcomes assessed: H6, H7
Targeted Performance Bands: 3–4

Criteria	Marks
• Explains specific flame colour with correct reference to energy levels	2
• Explains partially but with little or no reference to energy levels	1

Sample answer
Sodium produces its specific yellow flame colour because when electrons in the ion become excited by receiving energy, they move to higher energy levels. As these electrons move back to lower energy levels, their excess energy is emitted as visible light with a characteristic wavelength. This emitted energy is always of the same frequency (that of yellow light) because of the fixed difference in energy levels in the sodium ion.

(c) (iii) (1 mark)
Outcomes Assessed: H6, H7
Targeted Performance Bands: 3–4

Criteria	Mark
• Describes a valid method to identify the selected ion	1

Sample answer
The metal ion could be identified by using a spectrometer to view the emission spectrum of the ion. The observed spectrum should be compared with a database (chart) showing the unique spectrum for each ion.

(d) (5 marks)
Outcomes Assessed: H3, H4
Targeted Performance Bands: 2–6

Criteria	Marks
• Uses an appropriate example • Describes thoroughly the methodology • Assesses the importance of the technique	4–5
• Uses an appropriate example • Describes soundly the methodology • Describes the importance of the technique	2–3
• Identifies correct information concerning the analysis or its importance	1

Sample answer
Many possible answers.
A powerful pulsed laser is focused onto a surface, causing a small amount of the surface material to be vaporised. Through photon absorption this surface material heats up and ionises.
This laser-induced vapour is a source of light that can be analysed by a spectrometer.
The emission spectrum obtained consists of lines corresponding to the elements evaporated from the sample surface.
Comparison of the spectral lines with those recorded for each element can be used to identify the elements present in a sample.

Assessment of importance
This technique is important for determining trace elements in solid and liquid samples.
It is a very sensitive, non-destructive technique that requires minimal surface preparation.
Alternate methods require larger samples and destruction of the sample.

Laser microspectral analysis is used to analyse the composition of pigments to be used in restoring paintings. A laser is used to vaporise a microscopic amount of a colour of the painting. Atomic emission spectroscopy is then used to identify and measure the amounts of each element present in the colour sample. From the analysis, a substitute for this colour can be prepared.

Analysis of the elements present in the pigments can also be used to identify the validity of an art work, as the use of pigments has changed over time and can be characteristic of a particular country and of a particular time in history.

(e) (3 marks)
Outcomes Assessed: H4, H13
Targeted Performance Bands: 2–4

Criteria	Marks
• Outlines thoroughly the processes and chemistry and pigment used in a named artwork	3
• Outlines soundly some of the processes and chemistry and pigment used in a named artwork	2
• Outlines some correct information about a process OR the chemistry OR the pigment used in a named artwork	1

Sample answer
The blue pigment ultramarine is extracted from the stone lapis lazuli.

An extraction method for this pigment was developed in the 13th century. Firstly, the lapis lazuli stone was mixed with melted wax, resins and oils. This mixture was then wrapped in cloth and kneaded under a dilute lye solution of potassium carbonate. The blue particles of ultramarine formed a precipitate which was applied as a paste to the surface of the artwork and the impurities were collected in the wax, resin and oil.

This method was used by medieval European artists for the blue tones of the Virgin's cloak, as seen in Leonardo da Vinci's "The Virgin of the Rocks".

(f) (2 marks)
Outcomes Assessed: H3, H4, H13
Targeted Performance Bands: 2–4

Criteria	Marks
• Outlines the chemical composition of an identified cosmetic • Assesses the potential health risk associated with its use	2
• Outlines the chemical composition of an identified cosmetic OR • Assesses some correct information about any health risks associated with the use of pigments as cosmetics	1

Sample answer
Cinnabar and vermilion were used as the red pigments in cosmetics, such as rouge and lipstick, in ancient Egypt. The chemical composition of these was mercury (II) sulfide, HgS.

The potential health risks associated with the use of this chemical were extreme because it was highly toxic if ingested or inhaled. Mercury accumulates in the food chain, so even small quantities of mercury compounds can be highly dangerous. It was harmful when used directly on the skin because the accumulation of the poisonous chemical over time caused serious damage to the central nervous system and the kidneys.

(g) (i) (1 mark)
Outcomes Assessed: H6, H13
Targeted Performance Bands: 2–3

Criteria	Mark
• Correct answer	1

Sample answer
$Cu(OH_2)_4^{2+}$

(g) (ii) (1 mark)
Outcomes Assessed: H6, H13
Targeted Performance Bands: 2–3

Criteria	Mark
• Correct answer	1

Sample answer
The chelated ligand is the oxalate ion, $^{-}OOC—OOC^{-}$.

(g) (iii) (2 marks)
Outcomes Assessed: H6, H13
Targeted Performance Bands: 3–4

Criteria	Marks
• Explains the difference in bonding of ligands and chelated ligands, using appropriate examples	2
• Outlines some correct information about the bonding of ligands	1

Sample answer
A ligand is the molecule or ion attached by a pair or pairs of electrons to the central metal atom in a complex ion. All 3 species nominated in the question have ligands (water, ammonia and the oxalate ion) attached to the central metal atom. A non-bonding pair of electrons on the ligand forms a covalent bond with the metal ion, resulting in a complex ion.

A chelated ligand is one attached to the central metal ion by more than 1 pair of electrons. In the nominated species, only the oxalate ion is classified as a chelated ligand, as it is attached to the central metal ion by **TWO** non-bonding pairs (on the oxygen atoms at each end of the ion).

Question 34 – Forensic Chemistry (25 marks)
(a) (i) (1 mark)
Outcomes Assessed: H9
Targeted Performance Bands: 2–3

Criteria	Mark
• Identifies a monomer	1

Sample answer
Glucose

(a) (ii) (2 marks)
Outcomes Assessed: H9
Targeted Performance Bands: 2–3

Criteria	Marks
• Identifies a polysaccharide in plants AND identifies a polysaccharide in animals	2
• Identifies a polysaccharide in plants OR • Identifies a polysaccharide in animals	1

Sample answer
Plant: starch (amylase and amylopectin) or cellulose
Animal: glycogen

(a) (iii) (1 mark)
Outcomes Assessed: H9
Targeted Performance Bands: 3–4

Criteria	Mark
• Outlines a correct procedure that will distinguish the named polysaccharide in plants from the named polysaccharide in animals	1

Sample answer
Plant: Starch is partially soluble in water and can be identified by the addition of iodine solution that will form a blue-black complex. Cellulose is not soluble in water, and its presence can be indicated by the addition of Shultz reagent or treatment with 60% sulfuric acid and iodine solution to form a brown colour.

Animal: Glycogen is soluble in water and will form a pale pink colour when starch solution is added to it.

(b) (5 marks)

Outcomes Assessed: H11, H13

Targeted Performance Bands: 2–5

Criteria	Marks
• Indicates mixture to be separated • Identifies and describes appropriate method for separating the mixture that can be performed in the school laboratory • Identifies the properties of the mixture that allow it to be separated using that method (may be implied in method for maximum 4) • Identifies at least ONE safety precaution • Identifies variables	4–5
• Indicates mixture to be separated AND • Identifies and describes appropriate method for separating the mixture that can be performed in the school laboratory • Identifies at least ONE safety precaution OR identifies variables	2–3
• Indicates mixture to be separated OR • Identifies and describes an appropriate method for separating a mixture that can be performed in the school laboratory	1

Sample answer

Different compounds of chlorophyll can be easily separated using paper chromatography. The chlorophyll is extracted from the leaf by dissolving in water or ethanol (or some other liquid solvent) and dots of this mixture are placed onto the chromatography paper (stationary phase). The paper is then suspended in a suitable liquid (mobile phase) which moves up the paper. As the liquid moves up the paper, the chlorophyll mixture moves with it and the different components move at different rates depending on their different solubilities with the liquids involved. Components in the mixture that have higher solubility in the mobile phase move further up the paper in the allotted time, whereas components of the mixture with higher solubility in the stationary phase will move more slowly. Therefore, the mixture is separated based on the different solubilities of the components of the mixture between the mobile and stationary phases.

Other examples may include food dyes or proteins, and electrophoresis may also be the method used.

(c) (i) (3 mark)
Outcomes Assessed: H4
Targeted Performance Bands: 3–5

Criteria	Marks
• Indicates steps in correct order used to obtain DNA fingerprint • Identifies that sections of DNA used for analysis are non-coding regions • Identifies use of restriction enzymes to cut DNA into fragments	3
• Indicates steps in correct order used to obtain DNA fingerprint AND • Identifies that sections of DNA used for analysis are non-coding regions OR • Indicates steps in correct order used to obtain DNA fingerprint AND • Identifies use of restriction enzymes to cut DNA into fragments	2
• Indicates steps in correct order used to obtain DNA fingerprint	1

Sample answer
DNA is extracted from a biological sample such as hair root, blood, semen or other body tissue. It is then cut into fragments using restriction enzymes that cut the DNA at specific regions of nucleotide sequence. The fragments that are analysed for DNA fingerprinting are ones found in the non-coding region of the DNA (ie. in sections that do not code for proteins) and are known as introns. If there is enough DNA in the sample, the fragments will be separated. If there is not enough DNA, the numbers of fragments may be increased by polymerase chain reaction (PCR). The fragments are then separated by gel electrophoresis, where the fragments move through the gel on the basis of their size. The DNA band pattern is then transferred to a nylon membrane, where a radioactive 'probe' binds onto the DNA. The nylon membrane is then placed onto an X-ray film, which will indicate the position of the bands when it is exposed. The DNA fingerprint is then compared with others for analysis.

(c) (ii) (2 marks)
Outcomes Assessed: H4
Targeted Performance Bands: 3–4

Criteria	Marks
• Suggests that possible father is biological parent • Clearly explains that the introns used in a DNA fingerprint are inherited from the parents and, thus, can be used to show relationships	2
• Suggests that possible father is biological parent • Explains that the introns used in DNA fingerprint are inherited from the parents	1

Sample answer
The test indicates that the possible father is probably the biological parent of the child. Each individual receives approximately half of its DNA fingerprint from each parent. The origin of each band of the child can be identified as having originated from either the introns of the mother or the introns of the possible father in this case.

(d) (i) (1 mark)
Outcomes Assessed: H9
Targeted Performance Bands: 2–3

Criteria	Mark
• Identifies structure	1

Sample answer
Peptide link, peptide bond

(d) (ii) (2 marks)
Outcomes Assessed: H3, H4
Targeted Performance Bands: 3–4

Criteria	Marks
• Identifies that peptide bonds are links formed between amino acids in proteins AND • Indicates that these bonds must be broken to determine the sequence of amino acids in protein	2
• Identifies that peptide bonds are links formed between amino acids in protein OR • Indicates that these bonds must be broken to determine the sequence of amino acids in protein	1

Sample answer
Peptide bonds are formed when amino acids undergo condensation polymerisation to form the primary structure of a protein. They can be broken down by hydrolysis or restriction enzymes, and the amino acids, or protein fragments, can be separated by chromatography or electrophoresis and sequenced.

(e) (2 marks)
Outcomes Assessed: H2
Targeted Performance Bands: 3–4

Criteria	Marks
• Describes how electrons emit energy when they drop from a higher energy level to a lower energy level • Indicates that the electrons in each element have slightly different energy values, so the light emitted is at different wavelengths	2
• Describes how electrons emit energy when they drop from a higher energy level to a lower energy level	1

Sample answer
When a sample of an element is provided with energy, the electrons becomes 'excited' and move from their ground state into a higher energy level, known as an 'excited state'. When an electron falls from an excited state back to a lower energy level it emits energy at a certain wavelength. The energy levels for different atoms are slightly different, so unique frequency patterns are emitted for each atom.

(f) (6 marks)
Outcomes Assessed: H1, H2, H3, H4
Targeted Performance Bands: 2–6

Criteria	Marks
• Describes the 'chain of custody' • Defines analytical chemistry • Provides at least one recent example where either 'chain of custody' or changes in technology have changed the outcome of a forensic investigation • Provides examples of changes in technology, including techniques previously used and current/developing techniques • Provides examples of advantages and/or disadvantages in the changes in technology • Provides evaluation statement	5–6
• Describes the 'chain of custody' • Provides at least one recent example where either 'chain of custody' or changes in technology have changed the outcome of a forensic investigation • Provides examples of changes in technology, including techniques previously used and current/developing techniques • Provides examples of advantages and/or disadvantages in the changes in technology	3–4
TWO of: • Describes the 'chain of custody' • Provides at least one recent example where either 'chain of custody' or changes in technology have changed the outcome of a forensic investigation • Provides examples of changes in technology, including techniques previously used and current/developing techniques • Provides examples of advantages and/or disadvantages in the changes in technology	2
ONE of: • Describes the 'chain of custody' • Provides at least one recent example where either 'chain of custody' or changes in technology have changed the outcome of a forensic investigation • Provides examples of changes in technology, including techniques previously used and current/developing techniques • Provides examples of advantages and/or disadvantages in the changes in technology	1

Sample Answer
'Chain of custody' refers to the strict regulations that control the collection, handling and transport of specimens to be tested. The forensic scientist must verify that no contamination may have occurred at each step in the investigation, from the site of collection to the laboratory where testing is performed.

An example where 'chain of custody' issues effected the outcome of the case was in the OJ Simpson trial in 1997 where lawyers convinced the jury that evidence may have been mishandled, therefore creating 'reasonable doubt' and no conviction. Another example is the

Azaria Chamberlain case (1980s) where Lindy Chamberlain was jailed on the claim that there was foetal blood in the car which was later refuted by tests showing that it was adult blood mixed with rust. As a result, Lindy was then released.

Analytical chemistry refers to the practice of determining what and how much of a substance is in a sample.

There are many different examples of changes in technology that include:
- development of spectroscopic techniques (now allows for fast and extremely accurate analysis of samples)
- development of microscopic techniques (from the magnifying glass to light microscope to electron and scanning microscopy)
- evolving from fingerprinting to ABO blood-typing to DNA fingerprinting and protein analysis.

Advantages of these technologies include:
- more accurate analysis
- faster analysis
- fewer people wrongly convicted
- people who were wrongly convicted being proven innocent and released
- smaller samples being required for analysis
- some testing being non-destructive.

Disadvantages include:
- high cost of testing
- people being wrongly released on technicalities such as claims of mishandled evidence
- people being wrongly convicted due to the possibility of 'planted' evidence

The 'chain of custody' and progress in analytical chemistry are both extremely important in forensic cases. They allow accurate analysis of samples with reduced possibility of mishandling and contamination.