2011 Chemistry HSC Examination
'Sample Answers'

When examination committees develop questions for the examination, they may write 'sample answers' or, in the case of some questions, 'answers could include'. The committees do this to ensure that the questions will effectively assess students' knowledge and skills.

This material is also provided to the Supervisor of Marking, to give some guidance about the nature and scope of the responses the committee expected students would produce. How sample answers are used at marking centres varies. Sample answers may be used extensively and even modified at the marking centre OR they may be considered only briefly at the beginning of marking. In a few cases, the sample answers may not be used at all at marking.

The Board publishes this information to assist in understanding how the marking guidelines were implemented.
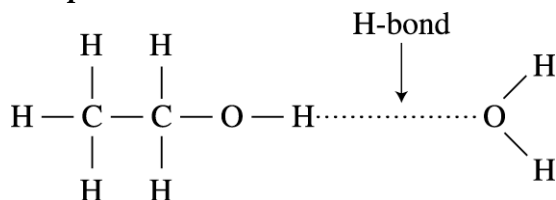
The 'sample answers' or similar advice contained in this document are not intended to be exemplary or even complete answers or responses. As they are part of the examination committee's 'working document', they may contain typographical errors, omissions, or only some of the possible correct answers.

Section I
Part B
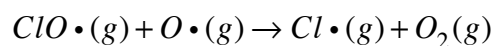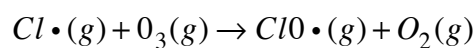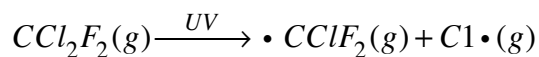
Question 21

Sample answer:

Ethanol is widely used as a solvent due to its structure. Ethanol can act as a solvent for both polar and non-polar substances. The ethanol molecule has a polar OH end and a non-polar end (where the $-CH_3$ is). It is also a small molecule. The polar end dissolves polar substances by H–bonds or dipole-dipole interactions. The non-polar end can dissolve non-polar substances by dispersion forces.

Any other appropriate diagram demonstrating ethanol as a solvent.

Question 22 (a)

Sample answer:

$$CCl_2F_2(g) \xrightarrow{UV} \bullet CClF_2(g) + Cl \bullet (g)$$
$$Cl \bullet (g) + O_3(g) \rightarrow ClO \bullet (g) + O_2(g)$$
$$ClO \bullet (g) + O \bullet (g) \rightarrow Cl \bullet (g) + O_2(g)$$

Question 22 (b)

Sample answer:

Ozone can be measured by spectrometry from the earth's surface. Ozone has specific absorption lines. Ultraviolet light from the sun that is absorbed at these wavelengths is measured and is proportional to the concentration of ozone.
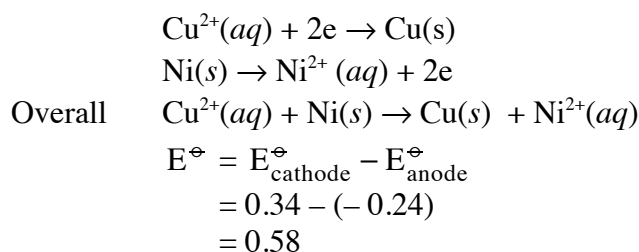
Question 23 (a)

Sample answer:

Isotopes such as copernicium-278 are unstable because they are heavy nuclei with high neutron:proton ratios, eg Cn-278 = 166:112.

Question 23 (b)

Sample answer:

Transuranic elements can be synthesised in a particle accelerator (positive ion accelerator). There are three types of accelerators: linear accelerators, cyclotrons and synchrotrons. Each uses alternating electric and magnetic fields to accelerate particles at high speed to penetrate a target nucleus.

Answers could include:

Bombardment with neutrons, which occurs in a nuclear reactor, as no acceleration is necessary for neutrons to be absorbed by a target nucleus.

Question 24 (a)

Sample answer:

$$Cu^{2+}(aq) + 2e \rightarrow Cu(s)$$
$$Ni(s) \rightarrow Ni^{2+}(aq) + 2e$$

Overall $\quad Cu^{2+}(aq) + Ni(s) \rightarrow Cu(s) + Ni^{2+}(aq)$

$$E^{\ominus} = E^{\ominus}_{cathode} - E^{\ominus}_{anode}$$
$$= 0.34 - (-0.24)$$
$$= 0.58$$

Question 24 (b) (i)

Sample answer:

Mass $Cu(s) = 0.395$

$\text{Moles} = \dfrac{m}{f.m} = \dfrac{0.395}{63.55} = 6.22 \times 10^{-3}$

Moles Ni lost = moles Cu deposited
$$= 6.22 \times 10^{-3}$$

Mass Ni lost $\quad = (6.22 \times 10^{-3}) \times 58.69$
$$= 0.3648 \, g$$

Final mass Ni electrode $\quad = 10.27 - 0.3648$
$$= 9.9052 \, g$$

Question 24 (b) (ii)

Sample answer:

Initial moles of Ni in solution $= 0.200 \times 0.100$
$$= 0.0200$$

Additional moles $\quad = 6.22 \times 10^{-3}$

Final moles $\quad = 0.02622$

Final concentration $\quad = \dfrac{0.02622}{0.200}$
$$= 0.1311 \text{ mol L}^{-1}$$

Question 25

Sample answer:

$H_2PO_4^-/HPO_4^{2-}$ is a buffer system in the cell. This means it can neutralise both an acid or a base in the cell, therefore maintaining the pH.

$$HPO_4^{2-} + H_3O^+ \rightarrow H_2PO_4^- + H_2O$$

$$H_2PO_4^- + H_2O \rightarrow HPO_4^{2-} + H_3O^+$$
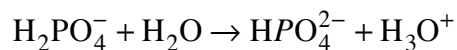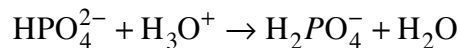
Question 26 (a)

Sample answer:

$$\frac{moles}{volume} = \frac{4.000}{40} \div 1.000 \text{ L}$$

Concentration of NaOH from mass given

$$= 0.1000 \text{ mol L}^{-1}$$

Concentration of NaOH from titration:

$$\text{moles } HCl = MV$$
$$= 0.1011 \times 0.02410$$
$$= 2.437 \times 10^{-3}$$
$$= \text{moles NaOH}$$

$$\text{concentration NaOH} = \frac{moles}{V}$$
$$= \frac{2.437 \times 10^{-3}}{0.025}$$
$$= 0.09746 \text{ molL}^{-1}$$

The difference in concentration is due to the NaOH being impure. NaOH is hydroscopic and absorbs H_2O easily. The mass of the NaOH probably contained H_2O.

Question 26 (b)

Sample answer:

Average volume NaOH $\quad= 27.25$ ml

moles NaOH used $= MV = 0.09746 \times 0.02725$

$$= 2.656 \times 10^{-3}$$

moles of citric acid $= \dfrac{\text{moles of NaOH}}{3}$

$$= 8.853 \times 10^{-4}$$

concentration of dilute solution $= \dfrac{\text{moles}}{\text{volume}}$

$$= \dfrac{8.853 \times 10^{-4}}{0.025}$$

$$= 0.0354 \text{ mol L}^{-1}$$

concentration of original solution $= M_1 V_1 = M_2 V_2$

$$= M_1 \times 50 = 500 \times 0.03541$$

$$= 0.354 \text{ mol L}^{-1}$$

Question 27

Sample answer:

Long-lasting, non-biodegradable polymers such as polystyrene greatly affect the environment, as microorganisms cannot break them down. Polystyrene is lightweight and can be made into a solidifying foam to be used in insulating cups. It can also be manufactured into a clear, hard and brittle plastic for drinking cups. These properties make polystyrene a useful polymer. However, due to its inability to biodegrade and most of its uses being short-lived, polystyrene debris builds up in the environment.

Polylactic acid (PLA) is an alternative to traditional polymers. PLA is classed as a biopolymer as it is biodegradable. It is used for short-lived applications such as cold/warm drinking cups and plastic bags. As PLA is made from the waste products of corn crops, which are converted by bacteria into lactic acid and then reacted to form PLA, it is easily broken down by microorganisms once it has been disposed of.

Therefore, biopolymers such as PLA should be used instead of traditional polymers, such as polystyrene, as biopolymers break down in the environment and do not accumulate as debris.

Answers could include:

Biopol
PHB
Other biopolymers

Question 28

Sample answer:

- Hardness: The test for hardness uses the chemical principle that calcium and magnesium ions form stable complexes with EDTA. As hard water contains high concentrations of calcium and magnesium ions, hardness can be tested by the volumetric analysis (titration) of a water sample with EDTA. Hardness is measured in mg L^{-1} or ppm.

- Total dissolved solids (TDS): The test for TDS uses the physical principle that ionic salts conduct electricity. As pure water does not conduct electricity, the amount of ionic salts or TDS in a sample can be measured by performing a conductivity test. Results are then compared with a set of standards to determine the TDS. TDS are measured in mg L^{-1} or ppm.

Answers could include:

Correct chemical or physical principles and procedures for the tests listed.

Question 29 (a)

Sample answer:

Arrhenius defines an acid as a substance that ionises in water to produce hydrogen ions (H^+). He defines a base as a substance that ionises in water to produce hydroxide ions (OH^-). Alternatively, Brönsted-Lowry defines the acid-base reaction as a transfer of a proton. They define acids as proton donors and bases as proton acceptors. The Arrhenius definition continues to be used despite the fact it only applies to aqueous solutions. This is because Arrhenius's theory is encompassed by the Brönsted-Lowry definition, most acid-base reactions occur in aqueous solutions, and the theory demonstrates the formation of salt and water during neutralisation reactions.

Question 29 (b)

Sample answer:

There is the same net ionic equation for neutralisation of strong acid and strong base:
$$H^+(aq) + OH^-(aq) \rightarrow H_2O$$
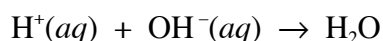
The heat of reaction is the same for these neutralisation reactions because the spectator ions do not influence the heat of reaction, and strong acids and bases completely dissociate into their H^+/OH^- ions respectively.

Question 30

Sample answer:

Step 1 in the process is very exothermic as increasing the temperature will force the reaction in the reverse direction. However, as indicated, the reaction occurs at 900°C. This high temperature is necessary to keep up the rate of reaction. To compensate for the high temperature, it would be appropriate to decrease the pressure. This would force the reaction in the forward direction, as there are more moles of product than moles of reactants. Removing NO as it forms would speed up the reaction. Catalysts should be used in all steps to also speed up the rate of reaction.

In Step 2, the temperature isn't as critical as the ΔH is only -114 kJ. NO_2 is more stable than NO in the presence of O_2. For this reaction, an increase in pressure is necessary in order to force the reaction to the product side, producing more NO_2. NO_2 should also be removed as it forms to keep the reaction proceeding in the forward direction.

Step 3 is not an equilibrium reaction; therefore, increasing the temperature will increase the rate of reaction, producing more HNO_3 despite it also being exothermic reaction.

Question 31

Sample answer:

Two contamination events occurred. They have difference characteristics:

Tuesday — elevated turbidity indicates increased suspended solids, approximately 10×
— slight increase in total dissolved solids indicating more ions present
— not biologically degradable material as BOD and dissolved oxygen unchanged
— no impact on pH, temperature or coliforms.

Possible sources: suspended solids of soil, rock origin (eg land slip), land disturbance, silt retention pond failure (in a construction zone).

Thursday — elevated turbidity, less than Tuesday
— material is biologically degradable, as shown by BOD and dissolved oxygen
— material is contaminated by faecal coliforms.

Possible sources: sewage spill, broken sewage pipe, sewage treatment plant spill, animal feedlot spill or discharge.

Question 32 (a)

Sample answer:

Barium sulfate is an insoluble white powder that absorbs the soil moisture and therefore will show the indicator colour.

Question 32 (b)

Sample answer:

From the data provided, the soil pH is observed to be between 4 – 4.5. The only plants that will grow optimally at this pH would be blue hydrangeas.

Question 32 (c)

Sample answer:

Test the small amount of the natural indicator made with several solutions of known pH covering the range from 1–14 and note the colour; for example, various concentrations of HC*l* and NaOH, acetic acid, Na_2CO_3 solution, ammonia solution and water.
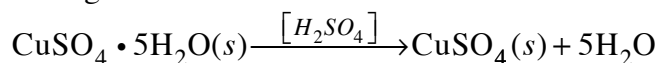
Section II

Question 33 (a)

Sample answer:

Liquid X is **concentrated** sulfuric acid (H_2SO_4).

Concentrated sulfuric acid has a very strong affinity to water.

It acts as an absorbent in the container, removing water from the blue copper sulfate and turning it white.

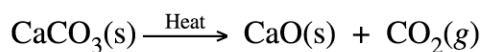$$CuSO_4 \cdot 5H_2O(s) \xrightarrow{\left[H_2SO_4\right]} CuSO_4(s) + 5H_2O$$

(blue)   (white)   (in solution with H_2SO_4)

Question 33 (b) (i)

Sample answer:
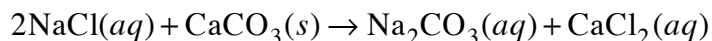
Despite large volumes of $CO_2(g)$ being produced during the Solvay process, most, if not all, $CO_2(g)$ is piped to the carbonator and used to carbonate the ammoniacal brine.

$$2NaHCO_3(s) \longrightarrow Na_2CO_3(s) + H_2O(g) + CO_2(g)$$

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

Returned to the carbonate where
$$CO_2(g) + H_2O(g) \rightleftharpoons H_2CO_3(aq)$$

Question 33 (b) (ii)

Sample answer:

$$2\text{NaCl}(aq) + \text{CaCO}_3(s) \rightarrow \text{Na}_2\text{CO}_3(aq) + \text{CaCl}_2(aq)$$

$$M_{\text{NaCl}} = 1 \text{ tonne} = 1000 \text{ kg} = 1.0 \times 10^6 \, g$$

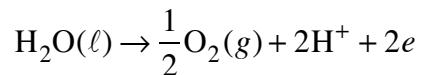$$N_{\text{NaCl}} = \frac{1.0 \times 10^6}{(22.99 + 35.45)} = \frac{1.0 \times 10^6}{58.44} = 17111.56 \text{ mol}$$

$$N_{CaCl_2} \quad \therefore {}^n\text{CaCl}_2 = \frac{1}{2}(17111.56 \text{ mol})$$

$$= 8555.78 \text{ mol}$$

$$M_{\text{CaCl}_2} = \left[8555.78 \times \left[40.08 + 2(35.45) \right] \right]$$

$$= 949521 \text{ g}$$
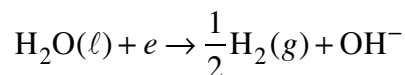
$$= 949.521 \text{ kg}$$

$$= 950 \text{ kg}$$

Question 33 (c) (i)

Sample answer:

At low concentration of sodium chloride, water is preferentially oxidised and reduced. This produces oxygen gas (bubbles) and hydrogen ions (red litmus) at the positive anode.

$$\text{H}_2\text{O}(\ell) \rightarrow \frac{1}{2}\text{O}_2(g) + 2\text{H}^+ + 2e$$

Hydrogen gas (bubbles) and hydroxide ions (blue litmus) are formed at the negative cathode.

$$\text{H}_2\text{O}(\ell) + e \rightarrow \frac{1}{2}\text{H}_2(g) + \text{OH}^-$$

Question 33 (c) (ii)

Sample answer:

The electrochemical (electrolytic) cell requires a power source and converts electricity energy into chemical energy.

A galvanic cell operates spontaneously and converts chemical energy into electrical energy.

Question 33 (d) (i)

Sample answer:

Two identical measuring cylinders are filled with different volumes of water. Water is transferred backwards and forwards from each cylinder using two differently sized pipettes until the volume of water in each cylinder remains constant (but at different levels).

- There are many models that could 'physically' model equilibrium in a closed system (that are 'non-chemical')
- Diagrams can be included

Question 33 (d) (ii)

Sample answer:

The information collected while physically modelling equilibrium is valid to a point, in that it reflects many of the characteristics of a closed chemical system at equilibrium. These characteristics include initial macroscopic changes in concentrations (volumes of water) of both 'reactants', and 'products' that continue during the transfer of water backwards and forwards until there is no macroscopic change in water levels. This is despite the dynamic nature of the continued movement of water from one cylinder to another. However, the limitations of any model in reflecting all characteristics of an actual chemical equilibrium system does compromise its validity.

Question 33 (e)

Sample answers:

The origins of elemental sulfur that is required to produce sulfuric acid include natural deposits, extraction from minerals containing sulfide and sulfates, and extraction from coal, crude oil and natural gas.

Elemental deposits have been marginalised in the 21st century because of legislation to prevent acid rain via emission of $SO_2(g)$ into the environment. However, the Frasch process is still used and thus has environmental effects that need to be addressed. While sulfur itself is odourless and non-toxic, if it is **not** cooled quickly, it has the potential to oxidise.

$$S + O_2(g) \rightarrow SO_2(g)$$
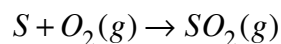
The superheated water, once recovered, also needs to be cooled to avoid thermal pollution. Sizeable underground cavens can result in ground subsidence and can be difficult to backfill. There are three industrial processes that have been used historically to produce sodium hydroxide:

$$2NaCl(aq) + 2H_2O(l) \rightarrow Cl_2(g)$$
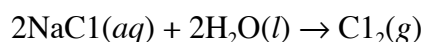
Each process has its own specific environmental concerns. The legislative banning of the original asbestos diaphragm was necessary due to the carcinogenic nature of asbestos. This led to the more recent synthetic 'inert' polymer membrane technology. The brine waste from the diaphragm cell may also have been contaminated with hypochlorite ions, which is a disinfectant and therefore must be removed before it is discharged into the environment.

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

The mercury cell was designed to keep the explosive mixture of $H_2(g)$ and $Cl_2(g)$ apart. Although the mercury is recycled, there is a mechanical loss of mercury to the environment and thus the potential for biomagnification and bioaccumulation, which leads to toxic health concerns. The high energy needs of the chloro-alkali industry results in significant combustion of fossil fuels, which is a contemporary environmental issue in regard to global warming.

Original soaps produced from natural oils and fats had specific technical problems in that they did not lather in hard and/or acidic water. Synthetic detergents were developed to overcome these problems. The early highly branched anionic detergents were non-biodegradable and led to the significant foaming of waterways. Non-branching detergents were developed to promote biodegradability.

Phosphate-builders that are added to detergents to promote cleansing power can find their way into natural waterways and lead to algal blooms and eutrophication. Other compounds, such as zeolites, promote cleansing power without the problem of eutrophication, and are now starting to replace phosphate-builders in detergents.

Some cationic detergents have biocidal properties and if ejected as wastewater into natural waterways, can upset the balance of bacterial decomposition.

An environmental issue associated with the Solvay Process is the disposal of the slurry waste product calcium chloride (which also contains some NaCI, $Ca(OH)_2$ and suspended $CaCO_3$). Some $CaCl_2$ can be recovered, purified and sold overseas where there is a market, but in Australia it is discharged safely into the ocean. It becomes an environmental problem where access to the ocean is limited, as its discharge into fresh water can significantly raise its salinity levels and the salinity levels of soil and groundwater. The use of cooling towers significantly reduces the potential problem of thermal pollution, and industrial techniques are so efficient that virtually no ammonia, which could contaminate the environment, is lost during recycling.

Answers could include:

Any three of the above and appropriate equations.

Question 34 (a)

Sample answer:

X must be a metal like Mg, $E^{\ominus} = -2.36$ V compared with Fe, $E^{\ominus} = -0.44$ V, because it acts as a sacrificial anode. X prevents the steel tank from corroding because it is preferentially oxidised.
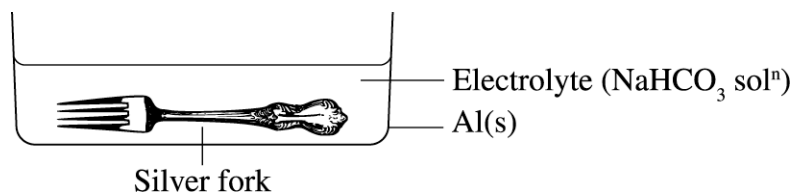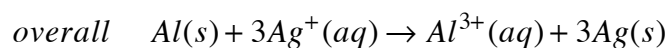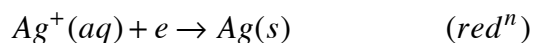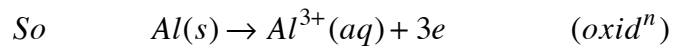
Answers could include:
Zn is X.
X must be a more active metal than iron.

Question 34 (b) (i)

Sample answer:

Aluminium is a more reactive metal than silver. Both metals in contact in the electrolyte (ie $NaHCO_3$) solution form a galvanic cell. The tarnish on the cutlery is a silver compound.

$$So \qquad Al(s) \rightarrow Al^{3+}(aq) + 3e \qquad (oxid^n)$$

$$Ag^+(aq) + e \rightarrow Ag(s) \qquad (red^n)$$

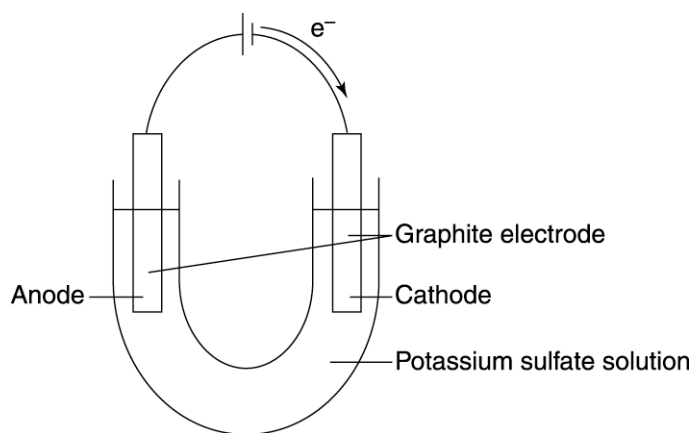$$overall \quad Al(s) + 3Ag^+(aq) \rightarrow Al^{3+}(aq) + 3Ag(s)$$
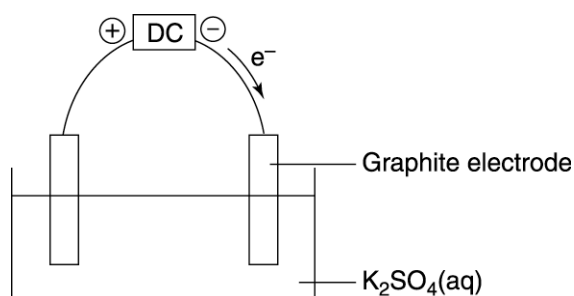

Question 34 (b) (ii)

Sample answer:

The toothpaste/cloth method is abrasive and would wear away the silver surface.
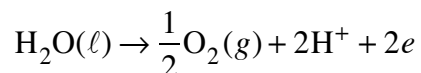
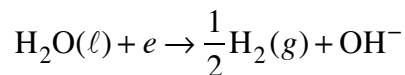**Question 34 (c) (i)**

Sample answer:

Answers could include:

Question 34 (c) (ii)

Sample answer:

At the positive electrode (anode)

$$H_2O(\ell) \rightarrow \frac{1}{2}O_2(g) + 2H^+ + 2e$$

At the negative electrode (cathode)

$$H_2O(\ell) + e \rightarrow \frac{1}{2}H_2(g) + OH^-$$

Question 34 (d) (i)

Sample answer:

Each sample should be cleaned by rubbing with steel wool or fine sandpaper to expose the metal surface.

Answers could include:

Clean the samples (by abrasion) to remove grease, tarnish or coating from the surface.

Question 34 (d) (ii)

Sample answer:

The experimental design is limited due to the student's inability to control variables.

The independent variable is the type of metal (alloy), so each sample should have the same size and shape (and extent of mechanical stress due to machining/manufacture) – in this experiment, they don't. In addition, the extent of corrosion over time is measured by making subjective, qualitative observations of photos since the quantitative observations would be too difficult to do.

Answers could include:

There has been an attempt to control the variable in the experiment. The same electrolyte has been used. The comparisons have been made regularly over an appropriate time period.

Question 34 (e)

Sample answer:

Before the *Titanic* was found, slow corrosion of the ship was predicted because of the very cold temperature (slow rate of reaction) and low oxygen (O_2). At great ocean depths, oxygen diffusion from the surface is limited, there are no photosynthetic organisms, and dissolved oxygen has been used up by aerobic organisms. For iron to rust, water and oxygen were (thought to be) necessary.

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

$$O_2(g) + 2H_2O(\ell) + 4e \rightarrow 4OH^-(aq)$$

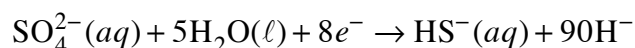and $Fe^{2+}(aq) + 2OH^-(aq) \rightarrow Fe(OH)_2(s)$
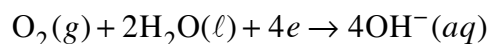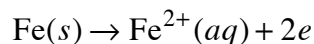
and further oxidation to Fe(III)!

The badly corroded hull of the *Titanic* indicated another agent was acting in the process of corrosion. The original prediction that the corrosion process would be slow because of the great depth proved to be incorrect. Sulfate-reducing bacteria play a role in corrosion.

$$SO_4^{2-}(aq) + 5H_2O(\ell) + 8e^- \rightarrow HS^-(aq) + 90H^-$$

So Fe^{2+} reacts with HS^- and OH^- to form

$Fe(s)$ and $Fe(OH)_2$ without the need for O_2.

As the sulfate ion is abundant in the ocean at all depths and the anaerobic bacteria that is also present accelerates the reduction of sulfate, a better explanation of the corrosion of shipwrecks that lie at great depth has emerged.

Question 35 (a)

Sample answer:

Process X is the TCA cycle. The oxygen requirements for glycolysis are nil, as this process is anaerobic and therefore does not require oxygen. The chemical processes in the mitochondria, however, are aerobic and require oxygen.

Question 35 (b) (i)

Sample answer:
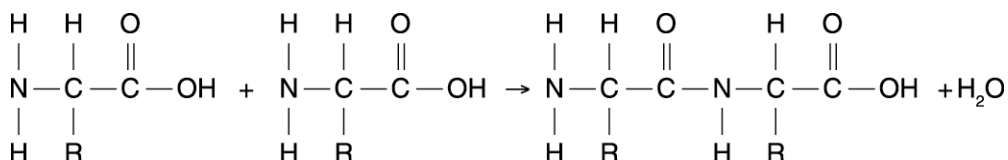
Question 35 (b) (ii)

Sample answer:

An increase in temperature and a change in pH can change the structure of a protein through a process called protein denaturation. Denaturation disrupts the forces and bonds that determine secondary, tertiary and, if relevant, quaternary structure of a protein.

Increases in temperature therefore increase the thermal motion that may disrupt the forces in the protein arrangement, thus altering its shape, eg when egg white is cooked. Changes in pH can disrupt electrostatic forces, hydrogen bonds and disulfide bonds, therefore destabilising the protein structure and changing its shape, eg when milk curdles.

Question 35 (c) (i)

Sample answer

Type 1 and 2 muscle cells are used by the body for different activities. This is because each type functions differently. Type 1 undergo aerobic respiration. Type 2 muscle cells contract rapidly and are blood (and oxygen) poor, so they carry out anaerobic respiration.

A marathon runner will use mostly Type 1 muscle cells because running is a form of aerobic exercise and requires cells to contract slowly but for a sustained period of time. Sprinters, on the other hand, use mostly Type 2 muscle cells because sprinting is a form of anaerobic exercise and requires cells to contract rapidly for a short period of time. People who undertake sedentary activity will use much less Type 1 and 2 muscle cells compared to either of these types of runners – their muscles won't need to contract as much since they are not working them as hard.

Question 35 (c) (ii)

Sample answer:

Energy + ADP + Pi $\rightarrow$ ATP

Question 35 (d) (i)

Sample answer:

An optimal temperature is necessary for enzyme function as there needs to be a high enough temperature to ensure the reaction occurs at a reasonable rate. The temperature must be maintained so that it does not denature the protein in the enzyme. The optimal temperature for enzymes in humans is 37°C.

Question 35 (d) (ii)

Sample answer:

The validity of the experimental design is compromised due to the mismatch between the aim and the independent variable. The student's aim is to see the effect of change in temperature on enzyme activity, yet only uses one water bath instead of a number of baths with a range of different temperatures containing separate identical samples.

Should a number of water baths at different temperatures have been used, it would be important to keep the mass of the calf liver the same in each water bath. It may even be better to increase the surface area:volume ratio by blending a piece of calf liver and then measuring out equal portions into the different water baths. The volume of hydrogen peroxide also needs to be the same. In addition, collecting results by the described method may be subjective. If the occasional bubble is still being produced, has the reaction 'stopped'? This experimental design would need some modification to provide valid results to achieve the stated aim.

Question 35 (e)

Sample answer:

Foods provide the chemical compounds that are involved in metabolic pathways. Carbohydrates and fats are the MAIN sources of energy in humans. Carbohydrates are hydrolysed into glucose, which is then oxidised via glycolysis and the Krebs Cycle to release energy. This is the preferential metabolic pathway for the production of energy in a resting or sedentary human being, providing at least 60% of daily energy requirements in the form of ATP. Fats are stored in cells as triglycerides and can be hydrolysed into long chain fatty acids that are then oxidised via the Krebs Cycle.

Glucose is stored as glycogen in the liver and muscle and can meet energy requirements for up to 12 hours. Fats stored in the cells, however, can provide energy for up to 12 weeks. Fats provide approximately 9 kJ g^{-1}, whereas carbohydrates provide approximately half that amount.

This knowledge of energy availability has improved our understanding of nutrition. It has shown that fats are stored for long-term use while glycogen from carbohydrates is used for short-term energy requirements. This means that health professionals can create awareness about the issues related to nutrition and the consumption of fats and carbohydrates.

Question 36 (a)

Sample answer:

The different colours arise because the Fe ions have different oxidation states.

This means that the electronic configurations of the ions are different, and therefore the energy required to cause an electronic transition is different. Thus, photons of different wavelengths in the visible part of the electromagnetic spectrum are absorbed by the complexes.

Question 36 (b) (i)

Sample answer:

K^+, Cl^-

Answers could include:

Ca^{2+}, S^{2-}
Sc^{3+}, P^{3-}
Any combination of one cation and one anion

Question 36 (b) (ii)

Sample answer:

Group I and II metals lose one or two 's' valence shell electrons easily to acquire a noble gas electron configuration. Removal of further electrons is difficult. Thus Group I metals lose one electron and Group II metals lose two electrons to form +1 and +2 cations respectively. Transitions elements lose 'd' shell electrons, to obtain a variety of oxidation states.

Answers could include:

Explicit discussion of unfilled 'd' shell electrons. Transition elements all have a common +2 oxidation state, as well as other oxidation states.

Question 36 (c) (i)

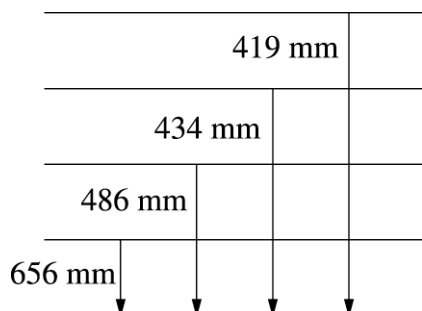*Sample answer:*

An instrument such as a spectroscope would have been used to display the light emitted by a sample of the element as lines or peaks against a wavelength scale. The element may have been heated in a flame or had an electrical discharge passed through it.

Answers could include:

The terms spectroscope or spectrometer are interchangeable.

Question 36 (c) (ii)

Sample answer:

Question 36 (d) (i)

Sample answer:

A typical method would be the flame test. A Bunsen burner is set up to burn with the blue low-luminosity flame. A platinum wire loop, perhaps dampened, is dipped into a sample of the Group II metal salt and then placed in the flame. The colour of the flame is recorded, either crudely by looking at the flame with the eye, or more accurately by using a spectroscope to measure the emission spectrum.

Answers could include:

Other methods would include using aqueous solutions of the salts rather than solids.

Question 36 (d) (ii)

Sample answer:

Confidence in this experiment relies primarily on being sure that the metal salt is not contaminated, either in the original sample or in the portion taken by the platinum loop. Contamination by sodium salts is a particular problem because of the intense colour of the sodium emission. Also of concern is the subjective judgement of colour.

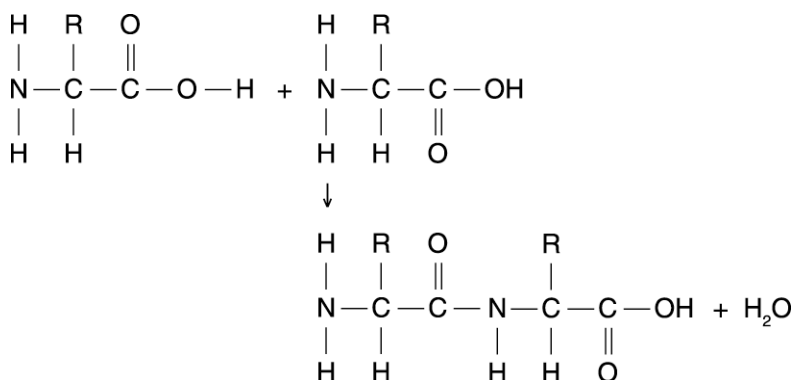**Question 36 (e)**

Answers could include:

- Reflectance spectroscopy is based on the principle that a sample may absorb some photons and reflect others of different wavelengths. The reflected light is collected and measured as intensity as a function of wavelength. A plot is produced showing reflectance against wavelength. Many of the natural pigments used in medieval paintings contain transition metal elements that give rise to the colour of the pigment, eg Cu, Fe, Zn and Co. The oxidation state of the element and the ligands bound to it determine the colour of the pigment. Reflective spectroscopy is useful as it does not require the extraction of a sample of the painting. Thus, it is a non-destructive technique.

- Infrared reflectography is a specific form of reflectance spectroscopy. It uses infrared radiation (wavelength range of ~700 nm – 1 mm). The technique is particularly sensitive to any underlying drawing in graphite, charcoal or black ink, thus giving clues to the artistic process. Infrared radiation is also useful in identifying copper-containing green pigments and therefore helps to detect the presence of these pigments.

- Ultraviolet-visible spectroscopy, which uses wavelengths in the range of 200–700 nm, operates on the same principle. Identification of pigments can be made by comparison of the obtained spectrum to those from known standards.

- Laser microspectral analysis uses a high-energy pulse of laser light to vaporise a small portion of the painting. This vapour is electrically excited, resulting in the sample emitting radiation that is collected as an emission spectrum. The ability of spectroscopic techniques to determine what pigments were used by medieval artists in their paintings has greatly helped our understanding of the artistic process, as well as the economic, political and geographical factors that have influenced this process through elucidating choices and restrictions on pigment.

Question 37 (a)

Sample answer:

A reducing sugar – disaccharide

It is a reducing sugar because it can be oxidised by an oxidising agent.

For example, Benedict's solution, due to the free carbonyl group.

Question 37 (b) (i)

Sample answer:

```
H   R   O            H   R
|   |   ||           |   |
N — C — C — O — H  + N — C — C — OH
|   |                |   |   ||
H   H                H   H   O

              ↓

        H   R   O           R
        |   |   ||          |
        N — C — C — N — C — C — OH  + H₂O
        |   |       |   |   ||
        H   H       H   H   O
```

Question 37 (b) (ii)

Sample answer:

Paper chromatography is a process that is used to separate substances based on their structure. There are two phases: the stationary phase, which is the paper; and the moving phase, which is usually a mixture of liquids.

The substances, eg amino acids, will travel up the paper, carried by the moving phase at different rates. The speed at which they travel will depend on their size and their polarity. These two factors will be determined by the nature of their side chains.

After the chromatographic separation, the final positions of the amino acids are determined by reacting them to form visible coloured compounds. The distance travelled is characteristic of a particular amino acid under those conditions.

Question 37 (c) (i)

Sample answer:

The analysis of DNA is a multi-step process. Initially, the DNA needs to be separated from the sample. The DNA is then cut into segments. Each segment is copied multiple times using a process called polymerisation chain reaction (PCR). These segments then undergo electrophoresis, a process by which the different segments are separated based on mass and charge. The separated bands are radioactively labelled and then detected by X-ray.

The resulting profile or fingerprint of DNA segments for a sample can be compared to others for identification or matching purposes.

Question 37 (c) (ii)

Sample answer:

Strip W

Question 37 (d) (i)

Sample answer:

1. Test for solubility
    *   aspirin soluble
2. Test for conductivity
    *   sucrose – nil conductivity
    *   glycine and aspirin – minor conductivity
    *   KCI – highly conductive
3. Heat
    *   KCI won't melt on a Bunsen burner
    *   others are organic and therefore won't combust
4. Biuret test
    *   identifies glycine
5. Add acid
    *   reacts with aspirin and glycine
6. Add acid, then heat, then add Benedict's solution to identify sucrose.

Question 37 (d) (ii)

Sample answer:

Destructive test – combusting one of the organic compounds
Non–destructive test – dissolution of KCl

Question 37 (e)

Sample answer:

Technique	Principle	Characteristics that best support forensic analysis
Atomic emission spectroscopy (AAS not acceptable)	Identification of elements based on emission lines	• small fragments of metals or other materials can be analysed • non-destructive • multiple elements identifiable from one test • one test can 'fingerprint' soils, metal alloys • semi-quantitative
Mass spectrometry (MS)	Separation based on mass:charge ratio; electronic detection (especially powerful when proceeded by GC/HPLC)	• highly sensitive, especially useful for organic compounds as identity can be established by comparison to library of mass spectra • quantitative • can distinguish samples based on isotopic ratios
Gas chromatography (GC)	Chromatographic separation technique based on gas mobile phase	• accommodates a very small sample size • highly sensitive, especially when coupled with MS, which gives identity of components • can accommodate complex samples yielding peaks, giving useful 'fingerprint' chromatograms • can pyrolyse small samples then perform GC, leading to characteristics pyrolysis fingerprint
High performance liquid chromatography (HPLC)	Chromatographic separation based on liquid mobile phase under high pressure	• for use in separation of non-volatile and heat-sensitive compounds • especially suited to analysis of drugs and protein mixtures • can be coupled to MS as well as other detectors
Electrophoresis	Separation based on migration of ions in an electric field (migration also dependent on molecular size) Detection via 'attached' labels – radioactive or luminescent	• for use in identification of proteins and DNA in body fluids • are bio-compounds that carry surface charge, depending on solution pH • characteristic fingerprint used for comparison purposes