

## Exam Choice

### 2008 Chemistry Trial HSC examination. Marking Guidelines and model Answers.

#### Section I A Multiple Choice

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

#### Section I B

16

Marking guidelines	Marks
assesses the accuracy of the statement AND outlining the production of acid rain from two other sources AND includes one correct, relevant chemical equation	3
assesses the accuracy of the statement AND outlines one other means of acid rain production OR outlines one other method of acid rain production AND includes an appropriate, correct equation	2
response contains one correct statement about the production of acid rain other than from S impurities in coal	1

This statement is inaccurate. While it is true that S impurities in coal contribute to acid rain according to the following equations:  $S + O_2 \rightarrow SO_2$ , and  $SO_2 + H_2O \rightarrow H_2SO_3$ , it is not true to say that converting to methane would eliminate acid rain production. This is because high temperature combustion also produces oxides of nitrogen:  $N_2 + O_2 \rightarrow 2NO$ , and  $2NO + O_2 \rightarrow 2NO_2$ . This also contributes to acid rain:  $2NO_2 + H_2O \rightarrow HNO_2 + HNO_3$ .

17

Marking guidelines	Marks
the response: <ul style="list-style-type: none"> <li>- outlines the Arrhenius and Lowry-Bronsted definitions of acids and bases</li> <li>- explains why the Arrhenius definition cannot account for <math>NaHCO_3</math> being a base</li> <li>- identifies that the Arrhenius definition cannot account for <math>NaHCO_3</math> being amphiprotic</li> <li>- explains how the Lowry-Bronsted definition accounts for its amphiprotic behaviour</li> <li>- includes two or more correct, relevant chemical equations</li> </ul>	5
the response contains three or four of the above features	3-4
the response contains one or two correct statements about the Arrhenius and Lowry-Bronsted definitions, relevant to $NaHCO_3$	1-2

The Arrhenius definition of acids/bases is that they ionise in water to give  $H^+$  ions, and bases ionise in water to produce  $OH^-$  ions. This definition does not account for the behaviour of  $NaHCO_3$ :

- it gives basic aqueous solutions even though it does not contain  $OH^-$  ions
- it reacts with both acids and bases

The Lowry-Bronsted definition is that acids are proton donors and that bases are proton acceptors.  $NaHCO_3$  can be classified as an acid or a base using this definition, depending on reaction conditions. Thus, it produces basic aqueous solutions because when it dissolves it ionises to give  $Na^+$  ions and  $HCO_3^-$  ions. The hydrogencarbonate ions accept a proton from water, producing  $OH^-$  ions and hence a pH greater than 7:  $HCO_3^- + H_2O \rightarrow H_2CO_3 + OH^-$ . In this case it is behaving like a Lowry-Bronsted base. However, in solutions of weak bases it can act as an acid, donating a proton:  $HCO_3^- + PO_4^{3-} \rightarrow HPO_4^{2-} + CO_3^{2-}$ . Thus the Lowry-Bronsted definition can account for the basic and amphiprotic behaviour of  $NaHCO_3$ .

18a

Marking guidelines	Marks
correctly identifies X including its atomic and mass numbers	1

X is carbon, Z=6, A=12

18b

Marking guidelines	Marks
correctly identifies Z as a beta particle, or an electron	1

Z = a beta particle

18c

Marking guidelines	Marks
identifies why each process outlined requires a different production method AND identifies the production method required for each AND assesses the statement as inaccurate	3
assesses the statement as inaccurate and provides an incomplete explanation of why	2
makes one correct, relevant statement about either process shown	1

The student is incorrect because only the process shown in (b) can be done using a nuclear reactor. Process (a) requires a particle accelerator because the positive charges on both the target nucleus and the proton produce repulsive forces which must be overcome. Process (b) involves an uncharged particle, hence no repulsive forces need to be overcome, and a nuclear reactor can be used.

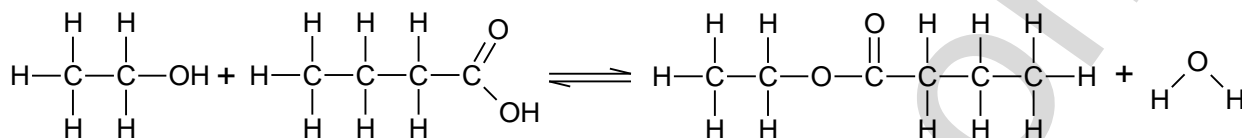
19a

Marking guidelines	Marks
Writes a correct chemical equation for each reaction including states for (1) (conditions not marked)	2
Writes one correct chemical equation (reaction conditions not marked)	1

equation 1:  $\text{C}_6\text{H}_{12}\text{O}_6(\text{aq}) \rightarrow 2\text{CO}_2(\text{g}) + 2\text{C}_2\text{H}_5\text{OH}(\text{aq})$ equation 2:  $\text{C}_2\text{H}_5\text{OH}(\text{g}) \rightarrow \text{C}_2\text{H}_4(\text{g}) + \text{H}_2\text{O}(\text{l})$ 

19b

Marking guidelines	Marks
Writes a correct equation using structural formulas as an equilibrium reaction	2
Equation contains one error	1



19c

Marking guidelines	Marks
Identifies that HDPE is formed using moderate temperatures and pressures, and a Zeigler-Natta catalyst (identity of catalyst not required).	2
Identifies one aspect of the reaction conditions required to make HDPE.	1

Ethylene is converted to polyethylene in an addition polymerisation reaction, involving moderate temperatures and pressures, and a Zeigler-Natta catalyst is used (a titanium chloride/trialkyl aluminium mixed catalyst).

19d

Marking guidelines	Marks
Correctly identifies the reaction conditions for reaction (1) AND assesses their importance (explains <i>why</i> they are important).	3
Correctly identifies the reaction conditions for reactions (1) AND gives a weak assessment OR Identifies some of the reaction conditions AND assesses their importance well.	2
Correctly identifies one correct reaction condition.	1

Reaction (1) is fermentation. This is carried out at 37°C in the presence of yeast, and in anaerobic conditions. These reaction conditions are extremely important. The yeast is important because it contains enzymes which catalyse the reaction, increasing its rate. The temperature is important because too low and the rate is too slow, too high and the enzymes in the yeast are denatured and can not catalyse the reaction. The lack of oxygen is important because in the presence of oxygen, aerobic oxidation, or respiration, would occur, producing only CO<sub>2</sub> and H<sub>2</sub>O instead of ethanol.

20a

Marking guidelines	Marks
identifies the process as reduction and a decrease in oxidation number from +7 to +2	1

The oxidation number of Mn changes from +7 to +2, hence the manganese ion is reduced.

20b

Marking guidelines	Marks
correctly calculates the number of moles of MnO <sub>4</sub> <sup>-</sup> present	1

$$n = C \times V = 0.025 \times 0.02000 = 5 \times 10^{-4} \text{ mol}$$

20c

Marking guidelines	Marks
correctly calculates the mass of Fe <sup>2+</sup> in 100 mL of water, showing working, and to the correct number of significant figures (4)	3
calculates the number of mole of Fe <sup>2+</sup> in 100 mL of tank water	2
calculates the number of mole of Fe <sup>2+</sup> in 32.50 mL of tank water	1

$$n(\text{Fe}^{2+}) = 5 \times n(\text{MnO}_4^-) = 5 \times 5.000 \times 10^{-4} = 2.500 \times 10^{-3}$$

This was contained in 32.50 mL of tank water,

$$\text{so in } 100.0 \text{ mL } n(\text{Fe}^{2+}) = 2.5 \times 10^{-3} \times (100/32.50) = 7.6923 \times 10^{-3} \text{ mol.}$$

$$m(\text{Fe}^{2+}) = n \times \text{MM} = 7.6923 \times 10^{-3} \times 55.845 = 0.4296 \text{ g.}$$

21a

Marking guidelines	Marks
identifies one property of NaOH that makes it unsuitable for use as a primary standard	1

NaOH is unsuitable for use as a primary standard because (for example) it reacts with CO<sub>2</sub> in the atmosphere. Hence its apparent mass is not its actual mass.

21b

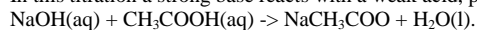
Marking guidelines	Marks
correctly calculates the pH of the solution	1

$$\text{pH} = -\log[\text{H}^+] = -\log(0.1155 \times 0.01) = 2.9$$

21c

Marking guidelines	Marks
explains why phenolphthalein is an appropriate choice, including two equations	3
explains why phenolphthalein is an appropriate choice, but equations are incorrect OR gives a partial explanation of why phenolphthalein is an appropriate choice, and includes correct equations	2
writes one correct, relevant equation OR identifies that the titration produces a basic solution	1

In this titration a strong base reacts with a weak acid, producing a solution of sodium acetate at the equivalence point:



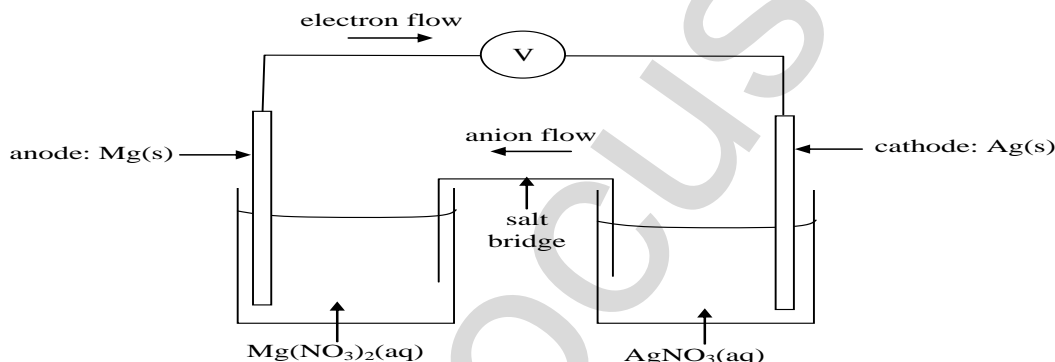
Sodium acetate is ionised in solution:  $\text{NaCH}_3\text{COO} \rightarrow \text{Na}^+(\text{aq}) + \text{CH}_3\text{COO}^-(\text{aq})$

and the acetate ion reacts with water, producing  $\text{OH}^-$  ions, making the solution at the equivalence point basic:  $\text{CH}_3\text{COO}^-(\text{aq}) + \text{H}_2\text{O(l)} \rightleftharpoons \text{CH}_3\text{COOH(aq)} + \text{OH}^-$

Because phenolphthalein changes colour in the basic region, its use assures that the end point will correspond to the equivalence point, and hence it is an appropriate choice.

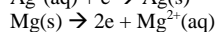
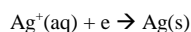
22a

Marking guidelines	Marks
draws a fully labelled diagram	3
diagram is correct but only partially labelled	2
one aspect of the diagram or labelling is correct	1



22b

Marking guidelines	Marks
writes two correct half equations	2
writes half equations for the appropriate species, but has oxidation and reduction reversed	1



22c

Marking guidelines	Marks
correctly calculates cell voltage	1

$$\text{cell voltage is } 2.37 + 0.80 = 3.17 \text{ V}$$

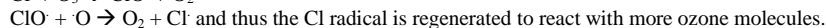
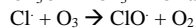
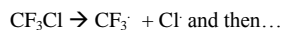
23

Marking guidelines	Marks
outlines the importance of ozone in the stratosphere AND outlines the use of CFCs AND outlines the impact of CFCs on stratospheric ozone including appropriate equations AND outlines the use of technology such as TOMS in measuring ozone concentration AND outlines the use of CFC replacement chemicals AND makes reference to information given in, and the duration of the timeline shown AND provides an overall evaluation	7
response includes most of the above, and makes reference to the timeline given	5-6
response includes an outline of the importance of ozone, the use of CFCs and their impact on ozone concentration	3-4
response includes limited information about ozone and CFCs	1-2

Human activity and technology have had a huge impact on the concentration of ozone in the stratosphere, first unknowingly causing its depletion and later acting to halt ongoing depletion.

As shown in the timeline, in the late 1920s CFCs were discovered to be non-flammable, non-toxic, inert, and to have excellent thermal properties. Thus they were used in a wide range of applications, for example as dry cleaning agents, solvents, propellants, and very widely as refrigerants. However, the use of CFCs in this way resulted in their discharge into the atmosphere. Because they are unreactive and not water soluble, they are not removed from the troposphere by chemical reaction, nor in rain, and hence migrate to the stratosphere where they are responsible for ozone depletion.

Ozone is naturally formed and decayed in the stratosphere in photochemical reactions which absorb UV radiation. As a result, the intensity of UV radiation reaching the earth's surface is reduced. However, when CFCs are present in the stratosphere, they react in the presence of UV radiation to produce chlorine radicals which destroy ozone, and in the process are themselves regenerated. One CFC molecule can destroy thousands of ozone molecules. The process can be represented as:



The effect of CFCs in the stratosphere was detected using a technique called total ozone mapping spectroscopy (TOMS), in which satellite based spectrometers compare the intensity of UV radiation from the sun with that being reflected back from the earth, and then use this to calculate the concentration of ozone in the stratosphere. Between approximately 1978 and 1990 there was a general and very significant reduction in ozone concentration over Antarctica in spring, resulting in a general reduction of global ozone concentration.

Use of the TOMS technology allowed scientists to obtain the data necessary to lead to the Montreal Protocol, shown in the timeline. This international agreement resulted in developed nations eliminating the production and use of CFCs by the mid 1990s. To achieve this, technology was required to produce new chemicals which could replace CFCs, but which did not have their ozone depleting property. Replacement chemicals such as HCFCs, HFCs and more recently hydrocarbons have been used, and as a result ozone mapping has shown that the concentration over Antarctica in spring has stabilised over the last 5 years, and scientists now believe that within the next 50 years the ozone concentration will begin to increase.

Thus human activity and technology over the time period shown in the timeline have had a huge impact on ozone concentration – causing its depletion, and more recently allowing its depletion to be halted.

**24a**

Marking guidelines	Marks
Describes what is meant by the term catchment area	1

A catchment area is the area of land through which rain water flows before entering a storage dam for later use.

**24b**

Marking guidelines	Marks
identifies a possible contaminant and its source AND a test for the contaminant	2
identifies a possible contaminant and its source OR a test for the contaminant	1

Excess nitrate ions can contaminate catchment water from sources such as agricultural run-off, as fertilisers contain high levels of nitrate. Nitrate levels can be measured by colourimetry or via titration.

**24c**

Marking guidelines	Marks
explains the high quality of Sydney's drinking water by describing steps that occur in its sanitation AND explains why each step is required	2-3
Identifies one step in the treatment of water which occurs prior to its consumption	1

Even though the water we drink from a tap was collected from a catchment area with possible sources of contamination, several steps occur in its treatment prior to it being made available to drink. The 'raw' water is first filtered to remove any large debris that may be present. Chemicals may be added to remove dissolved contaminants (eg potassium permanganate can be added to remove  $\text{Fe}^{2+}$  ions). Flocculating agents are added to coagulate undissolved particles, making them easier to trap by filtration, which occurs through layers of sand and gravel. This filtration stage removes most suspended solids. Post-filtration stages include chlorination takes place to kill disease causing bacteria and pH adjustment. Collectively, these steps allow change 'raw' water into potable water by removing the majority of contaminants, making water generally safe to drink.

**25a**

Marking guidelines	Marks
calculates the total volume of $\text{CO}_2$ dissolved in the soft drink, using the data given	3
calculates the volume of $\text{CO}_2$ dissolved based on mass of $\text{CO}_2$ lost over the 12 hour period OR the mass lost when the bottle was opened	2
calculation contains one correct step	1

mass of  $\text{CO}_2$  lost when lid is removed =  $335.8 - 335.2 = 0.6\text{g}$

mass of  $\text{CO}_2$  lost during the 12 hours =  $332.1 - 327.2 = 4.9\text{g}$

total mass of  $\text{CO}_2$  lost =  $5.5\text{g}$

$n(\text{CO}_2 \text{ lost}) = 5.5/44 = 0.125\text{mol}$

$V(\text{CO}_2 \text{ lost}) = n \times MV = 0.125 \times 24.79 = 3.1 \text{ L}$

25b

Marking guidelines	Marks
explains how the pH would change as CO <sub>2</sub> is removed by making reference to the carbonic acid/hydrogen carbonate equilibrium, and includes a correct chemical equation	3
gives a partial explanation of how the pH would change as CO <sub>2</sub> is removed and includes a correct chemical equation OR explains how the pH would change as CO <sub>2</sub> is removed by making reference to the carbonic acid/hydrogen carbonate equilibrium	2
includes an appropriate chemical equation OR identifies that the solution will become less acidic OR identifies that the pH will increase	1

As the CO<sub>2</sub> is liberated from the soft drink the pH would increase. This because CO<sub>2</sub> reacts with H<sub>2</sub>O to produce carbonic acid: CO<sub>2</sub> + H<sub>2</sub>O <-> H<sub>2</sub>CO<sub>3</sub>. This ionises to give H<sup>+</sup> ions: H<sub>2</sub>CO<sub>3</sub> <-> H<sup>+</sup> + HCO<sub>3</sub><sup>-</sup>. As the CO<sub>2</sub> is removed, the concentration of H<sub>2</sub>CO<sub>3</sub> decreases, which in turn decreases the concentration of H<sup>+</sup> ions in solution (according to Le Chatelier's Principle). Thus, the pH increases as the solution becomes less acidic.

25c

Marking guidelines	Marks
explains why a combination of both methods is best by identifying one limitation and one advantage of each method	3
explains why a combination of both methods is best by identifying one limitation or advantage of each method OR identifies one limitation and one advantage of each method	2
identifies one limitation or one advantage of one method	1

A combination of both methods is best because it combines the advantages of each and eliminates their disadvantages. The method the student used has an advantage in that it enables the mass of CO<sub>2</sub> trapped in the headspace of the bottle to be calculated. This is because the bottle is weighed before and after it is first opened. However, this method does not take into account CO<sub>2</sub> that remains in solution, after out-gassing has ceased. Also, the student's results suggest that student did not weigh the bottle to constant mass, which decreases the accuracy of their method further. The second, titration method has the advantage that all the CO<sub>2</sub> in solution is measured, but it is limited in that it does not take into account CO<sub>2</sub> lost when the bottle is first opened. Combining both methods, by weighing the bottle before and after its initial opening, recording the mass loss during out-gassing until a constant mass is reached, then titrating any CO<sub>2</sub> remaining in solution when the constant mass is reached would give the most accurate results.

## Section 2. Options.

### Question 26 – Industrial Chemistry

26 a (i)

Marking guidelines	Marks
identifies both products of the Solvay process as sodium carbonate and calcium chloride	1

26 a (ii)

Marking guidelines	Marks
outlines two criteria used to locate a plant such as a Solvay plant	2
outlines one criteria used to locate a plant such as a Solvay plant	1

Chemical industries, such as a Solvay plant, are located on the basis of a number of criteria, including proximity to raw materials, and to waste disposal sites. One of the raw materials in the Solvay process is brine, and thus it would be sensible to locate a plant near the coast to avoid expensive shipping costs. The process produces calcium chloride as a waste product, and disposal of this into the ocean is the least environmentally damaging method of disposal, and for this reason also it would be advantageous for a Solvay plant to have a coastal location.

26 a (iii)

Marking guidelines	Marks
explains the formation of the products from the Solvay tower and includes a relevant chemical equation	3
identifies that ammoniacal brine is produced in the Solvay tower and includes a relevant chemical equation	2
identifies that ammoniacal brine is produced in the Solvay tower OR writes a relevant chemical equation	1

The products of the Solvay tower are formed in the following way:

- ammonia is dissolved in the brine to produce ammoniacal brine, which contains NH<sub>4</sub>OH
- when CO<sub>2</sub> is bubbled in, it dissolves to produce carbonic acid:  
CO<sub>2</sub> + H<sub>2</sub>O -> H<sub>2</sub>CO<sub>3</sub>
- an acid/base reaction occurs, and overall, the following ions result: NH<sub>4</sub><sup>+</sup>, HCO<sub>3</sub><sup>-</sup>, along with Na<sup>+</sup> and Cl<sup>-</sup> from the brine
- when the reaction mixture is cooled, NaHCO<sub>3</sub> precipitates, because it is less soluble than NH<sub>4</sub>Cl

26 b

Marking guidelines	Marks
describes the chemistry of the mercury, diaphragm and membrane processes for NaOH production AND clearly identifies both similarities and differences AND evaluates their impact on society and the environment	6
outlines the chemistry of the three processes AND evaluates their impact on society and the environment	4-5
response contains limited information about each of the three processes and their impact on society and the environment	2-3
response contains one correct statement about the electrolysis of brine by one method	1

All three processes to produce NaOH(aq) involve electrolysis of brine, saturated NaCl(aq). The mercury process was initially used. In this process, the anode is an inert electrode made of graphite or platinum, and the chloride ions are oxidised at this electrode, to produce chlorine gas:  $2\text{Cl}^- \rightarrow \text{Cl}_2(\text{g}) + 2\text{e}^-$ . Sodium ions are reduced at a flowing mercury cathode,  $\text{Na}^+ + \text{e}^- \rightarrow \text{Na}(\text{s})$  and the Na(s) produced dissolves in the mercury to form an amalgam. The amalgam flows to a separate compartment where it is sprayed into water. The sodium metal in the amalgam reacts with the water to produce NaOH(aq) and  $\text{H}_2(\text{g})$ . Because the amalgam is removed from the brine, the NaOH produced is of very high purity. However, the process had large energy requirements, and mercury also leaked from the plants into the surrounding environment. The impact of this process on society and environment was devastating. Mercury is poisonous, affecting both humans and whole ecosystems, and plants produced a relatively large amount of  $\text{CO}_2$ , which is a greenhouse gas.

This method was superseded by the diaphragm method. The chloride ions in the brine are oxidised at an inert anode (steel mesh) to give chlorine gas, and this is still kept separate from the other product. However, in this case the reduction of water occurs directly at the cathode (also steel mesh), and hydrogen gas is produced:  $2\text{H}_2\text{O} \rightarrow 2\text{OH}^- + \text{H}_2 + 2\text{e}^-$ . The anode and cathode compartments are separated by an asbestos diaphragm. Sodium ions pass through this diaphragm, producing NaOH in the cathode compartment (where  $\text{OH}^-$  ions are produced). Sodium chloride can also pass through this diaphragm, hence the purity of the NaOH is not as high as that of the mercury process. However, because of the absence of mercury, mercury poisoning is eliminated by this process, and since it has lower energy requirements, its greenhouse impact is also lower than the mercury process. As a result, its impact on society and the environment is lower than that of the mercury process. However, because the process uses asbestos, there is a huge associated social impact: asbestosis and lung cancer in workers exposed to asbestos.

The most recent method for NaOH production, and that with by far the lowest social and environmental impact, is the membrane process. Chloride ions are oxidised to chlorine gas, and water reduced to hydrogen gas and hydroxide ions at an inert cathode. However in this case it is a Teflon membrane for example, that separates the two compartments. This is highly selective and only allows  $\text{Na}^+$  ions to pass through, producing NaOH(aq) in the cathode compartment. While all three processes have similarities and differences, the membrane process has by far the lowest social and environmental impact of the three methods, since neither mercury nor asbestos are used. The NaOH produced is of very high purity and thus further separation is not required, also lowering the energy requirements of this process.

#### Question 26 c (i)

Marking guidelines	Marks
describes a method to produce soap AND identifies one risk associated with the procedure AND identifies one method of addressing this risk	3
outlines a limited method to produce soap AND identifies one risk and how it can be addressed OR outlines a method for producing soap AND identifies one associated risk	2
response contains limited information about how the procedure can be carried out OR identifies and minimises one risk associated with the procedure	1

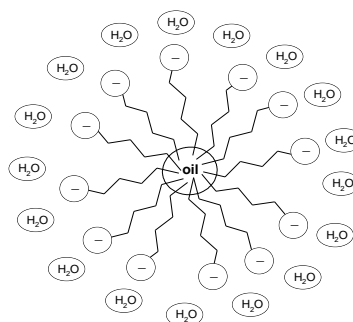
To produce soap in the laboratory we did the following:

- we heated olive oil and 5M NaOH(aq) in an evaporating basin using a Bunsen burner
- once the reaction mixture had cooled we added saturated NaCl(aq)
- we separated the soap from the reaction mixture by filtration and washed it with cold water
- 5M NaOH solution is highly caustic, causing severe burns on skin contact. To avoid skin contact during this procedure we wore gloves.

#### 26 c (ii)

Marking guidelines	Marks
explains the cleaning action of soaps and detergents in terms of micelle formation AND compares the effect of soap and the detergents in hard water AND includes a relevant diagram	4
response contains most of the above criteria	3
response contains a limited explanation of the cleaning action of soaps and detergents OR response contains a limited explanation of the effect of these species in hard water	2
response contains one correct statement about the cleaning action, structure, or effect in hard water of a soap or detergent, or contains a correct, relevant diagram or structure	1

Soaps and detergents act as an emulsifying agent between grease/oil, and water. Soaps and detergents have long, hydrophobic, hydrocarbon 'tails', and polar (or ionic) hydrophilic 'heads'. The tails are non-polar, and dissolve in grease and oil droplets. Agitation causes the whole of the oil droplets to be surrounded by the hydrophobic tails of the soap/detergent particles, leaving the hydrophilic heads surrounded by water molecules. This forms a micelle. In hard water, soap ions precipitate with the  $\text{Mg}^{2+}$  and  $\text{Ca}^{2+}$  ions present, and so lose much of their cleaning activity. On the other hand, synthetic detergents do not lose their cleaning activity in hard water, because they do not precipitate with  $\text{Mg}^{2+}$  and  $\text{Ca}^{2+}$  ions – anionic detergents because their ion pairs are soluble, non-ionic and cationic detergents because they do not interact at all with the cations in hard water.



#### 26 d (i)

Marking guidelines	Marks
correctly calculates K showing working	2
writes a correct expression for K	1

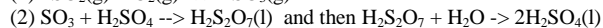
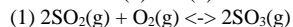
$$K = \frac{[HI]^2}{[H_2][I_2]}$$

$$= \frac{(2.8)^2}{(0.5)(0.45)} = 35$$

26 d (ii)

Marking guidelines	Marks
describes in detail, and justifies the chemistry of steps (1) and (2) and includes two correct chemical equations	4
outlines, and provides a partial justification for the chemistry of steps (1) and (2) and includes two correct chemical equations	3
outlines, and provides a partial justification for the chemistry of steps (1) and (2) OR outlines the chemistry of steps (1) and (2) and gives two correct chemical equations	2
response contains one correct equation or identifies one correct aspect of steps (1) or (2)	1

Conversions (1) and (2) in the diagram correspond to the following reactions:



Reaction (1) is an equilibrium reaction, and is exothermic in the forward direction. As a result conditions are manipulated to maximise both rate and yield. The reaction is carried out at a moderate temperature, to maximise the yield of  $SO_3$ , (because the forward reaction is exothermic) and the catalyst beds increase the rate by providing an alternative mechanism with a lower activation energy than would otherwise be the case. The catalyst used is solid  $V_2O_5$ , present in three separate catalyst beds, each at a successively lower temperature. As the reaction mixture passes over the three beds, the lower temperature shifts the equilibrium position to the right, increasing the yield of  $SO_3$ . Sequence (2) is used to convert  $SO_3$  to  $H_2SO_4$ . The first reaction in the sequence produces oleum, which is then mixed with water to produce concentrated sulfuric acid. This is done because the reaction of  $SO_3$  with water directly is so highly exothermic that it produces a dangerous mist of  $H_2SO_4$ . The reaction to produce oleum, and then to produce sulfuric acid is safer and easier to handle and contain.

#### Question 27 – Shipwrecks, Corrosion and Conservation

27 a (i)

Marking guidelines	Marks
identifies the gas as oxygen	1

27 a (ii)

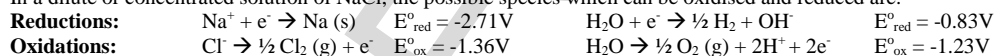
Marking guidelines	Marks
outlines at least THREE factors that affect the rate of electrolysis	2
identifies a factor that affects the rate of electrolysis	1

The rate at which electrolysis of the solution occurs can be increased by increasing the potential difference applied across the electrodes (as long as the potential difference is greater than the minimum voltage required for the reaction). Electrolysis will also occur faster if the electrodes are closer together and if the surface area of the electrodes is increased. If the concentration of the electrolyte is increased, the rate of electrolysis will increase.

27 a (iii)

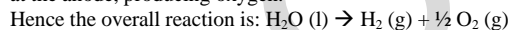
Marking guidelines	Marks
compares the products of electrolysis at low and high salt concentrations AND explains the comparison using balanced half-equations and reduction potential data	2-3
identifies one feature of the storage of glucose as glycogen	1

In a dilute or concentrated solution of NaCl, the possible species which can be oxidised and reduced are:



$Na^+$  is stable and will not be reduced, regardless of the concentration of the solution. Hence the  $H_2O$  is always reduced to hydrogen at the cathode.

The oxidation of water requires less energy input than that of the  $Cl^-$  ion, and thus at low  $Cl^-$  concentrations the oxidation of water will occur at the anode, producing oxygen.



At higher concentrations of  $Cl^-$ , the water is still reduced in preference to  $Na^+$ , hence hydrogen is produced at the cathode. However, because the  $E_{ox}^{\circ}$  are close for  $Cl^-$  and  $H_2O$ , some  $Cl^-$  ions are oxidised to  $Cl_2$  gas at the anode. The gases produced at the anode will therefore be a mixture of oxygen and chlorine. As chloride concentration increases, less oxygen is produced and at very  $Cl^-$  concentrations, no oxygen is produced.



27 b

Marking guidelines	Marks
provides characteristics of the procedures to treat AND restore two artefacts of different compositions (one must be metallic) explains why different procedures are required in the treatment and restoration processes includes relevant equations in the answer	6
provides characteristics of the procedures to treat AND restore a marine artefact of metallic composition AND explains the processes used be relating to the composition of the artefact AND outlines the treatment of ANOTHER artefact of different composition OR provides characteristics of the procedures to treat AND restore a marine artefact of metallic composition AND explains the processes used be relating to the composition of the artefact AND includes relevant equations in the answer	4-5
outlines the treatment and restoration of named types of artefact OR explains the procedures to treat and restore a named type of artefact	2-3
identifies a step in the treatment or restoration of a named type of artefact	1

Copper artefacts (including alloys of copper) are often found in shipwrecks (eg in coins, brass or bronze ornaments and fittings etc).

The treatment and restoration procedures generally involve the following steps:

1. mechanical cleaning to remove encrustation if present. This must be done with care not to damage the artefact
2. chemical treatment in a weak acid solution to dissolve any insoluble carbonate via the reaction  $2\text{H}^+ + \text{CO}_3^{2-} \rightarrow \text{H}_2\text{O} + \text{CO}_2$ .
3. Electrolysis may be required to remove any remaining products of corrosion. In this case, the artefact is immersed into an electrolyte solution and made the cathode. Copper ions present in any solid impurities on the artefact are reduced to metallic copper (eg copper in CuO reduced to Cu):  $\text{Cu}^{2+}(\text{s}) + 2\text{e}^- \rightarrow \text{Cu}(\text{s})$
4. The artefact is then washed thoroughly to remove any remaining chemicals and dried. It may be coated with a lacquer which provides a physical barrier, preventing further corrosion.

This procedure contrasts to that used for the treatment of artefacts of other compositions eg wooden ones. Waterlogged wooden artefacts are treated following main steps:

1. Desalination via soaking in water to remove soluble salts such as chlorides
2. Impregnation with a material such as an inert wax or oil to replace water and support the cellular structure of wood.
3. Very slow controlled drying freeze drying to remove any residual water.

**27 c (i)**

Marking guidelines	Marks
outlines a procedure that could be used to investigate the effect of changing dissolved oxygen levels in water and the rate of corrosion justifies steps in the procedure.	3
response contains most of the above, but one step may be omitted or not justified	2
response contains one correct step of the procedure	1

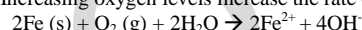
Step	Justification
1. Collect 3 steel nails and clean with emery paper.	Steel nails contain iron. Cleaning is needed to remove any trace of rust. The same type of nail is required to control this variable, to ensure validity.
2. Boil water and place 50mL into a small beaker.	Boiling removes dissolved oxygen from the water.
3. Pour 50mL of tap water into a second beaker.	This will contain more dissolved oxygen than the boiled water.
4. Pour 50mL of tap water into a third beaker. Aerate the water with an aquarium aerator.	This will produce water with the highest oxygen level. Thus steps 2-4 give a suitable range of oxygen level in water, required to make the investigation valid.
5. Add a clean nail to each beaker and cover with a layer of oil.	The oil prevents any oxygen movement between the water and air. Thus any conclusion we draw from the investigation is concerned with only the initial dissolved oxygen levels, and not a result of oxygen from the atmosphere.
6. Observe appearance of nails and look for signs of rusting over several weeks.	

**27 c (ii)**

Marking guidelines	Marks
Describes THREE variables in the aqueous environment that would affect the rate of corrosion of an artefact AND Explains how each factor affects the rate of corrosion of metallic artefacts Included at least one chemical equation	3-4
Outlines how TWO variables in the aqueous environment that would affect the rate of corrosion of a metallic artefact.	2-3
identifies one variable in the aqueous environment that would affect the rate of corrosion of a metallic artefact.	1

Variables in the aqueous environment of a metallic artefact that affect its rate of corrosion include temperature, oxygen levels, salinity, acidity and whether the metal is exposed to sulfate reducing bacteria.

Temperature of the water decreases with an increase in depth. This can slow down the rate of corrosion, although other variables can influence this affect. Increasing oxygen levels increase the rate of corrosion, because oxygen is one reactant in the corrosion process:



Oxygen levels decrease with depth (more aeration occurs near the water's surface) and so corrosion may occur more slowly at greater depths.

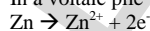
The presence of sulfate-reducing bacteria in acidic microclimates (at great depths) increases the rate of corrosion of metals such as iron in deep sea wrecks. They are able to reduce sulfate ions in the ocean, using electrons removed from metallic iron, thus accelerating the rate at which iron oxidises:



**27 d (i)**

Marking guidelines	Marks
outlines the role of electron movement AND ion migration in the operation of the pile AND provides one equation to show the source or consumption of electrons at either anode or cathode	2
identifies one feature of how the voltaic pile operates	1

In a voltaic pile with Zn and Ag, the Zn is oxidised and loses electrons:



The electrons produced are transferred via an external circuit to the Ag electrode, where water is reduced.

Ions in the brine solution between the two metals migrate (+ve towards the Zn; -ve towards Ag) to complete the circuit.

**29 d (ii)**

Marking guidelines	Marks
describes the work of BOTH scientists in the area of electrochemistry AND analyses HOW their work has improved our understanding of electrochemistry	3-4
outlines the contribution of EITHER scientist to our understanding of electrochemical reactions	2
identifies one contribution of either scientist to our understanding of electrochemical reactions	1



Davy made use of Volta's work in the development of cells via electron-transfer reactions in the area of electrolysis—that is, he used electricity the cells produced to decompose solutions such as alkalis, and then solid samples of potassium and sodium hydroxide, producing metallic potassium and sodium. He therefore isolated pure samples of these elements for the first time. He went on to isolate other metals such as calcium and magnesium. He also did research on the nature of corrosion and found that corrosion on copper could be reduced from contact of the copper with zinc. Thus Davy's work was significant in that it applied electrochemistry to useful applications.

Faraday contributed much of the current electrochemical terminology we use today, including the term electrolyte, anode (site of oxidation) and cathode (site of reduction). He also termed 'anions' for the negatively charged particles which move towards the anode and 'cations' for the positive particles which move towards the cathode. His work emphasised the significance of ion movement to the functioning of electrochemical cells. He also experimentally developed quantitative laws relating to electrolysis.

#### Question 28 – The Biochemistry of movement

##### 28 a (i)

Marking guidelines	Marks
identifies the molecule as glucose	1

##### 28 a (ii)

Marking guidelines	Marks
outlines how the human body makes use of carbohydrates such as glucose in respiration	2
identifies a use of glucose in the human body (eg energy production)	1

Glucose is a carbohydrate used primarily as a source of energy in the human body. It is the starting material needed for both anaerobic and aerobic respiration, both of which produce ATP, an important energy transfer molecule.

##### 28 a (iii)

Marking guidelines	Marks
explains the features of the bonding between glucose molecules in glycogen that occurs as glucose is stored and identifies where it is stored	2-3
identifies one feature of the storage of glucose as glycogen	1

Glucose is stored in the human body in the form of glycogen, which is a condensation polymer of glucose. A condensation reaction occurs between the glucose monomers, in which 2 hydroxyl groups on neighbouring glucose monomers react. A water molecule is eliminated and the monomers become joined by a glycosidic bond (an O atom joins the monomers). Glycogen is stored both in the liver and in muscles.

##### 28 b

Marking guidelines	Marks
provides characteristics of the structure AND function of enzymes explains how models are used to assist our understanding of enzyme structure and function identifies a limitation of the model used to explain enzyme structure and function makes a clear judgment on the importance of models in understanding the structure and function of enzymes	6
provides characteristics of the structure AND function of enzymes explains how models are used to assist our understanding of enzyme structure and function identifies a limitation of the model used to explain enzyme structure and function OR provides characteristics of the structure AND function of enzymes explains how models are used to assist our understanding of enzyme structure and function makes a clear judgment on the importance of models in understanding the structure and function of enzymes	4-5
provides the characteristics of the structure AND the function of enzymes OR describes the use of models in developing our understanding of enzyme structure and/or function	2-3
identifies a feature of the structure and/or function of an enzyme OR a model that has been developed to explain enzyme structure or function	1

Enzymes are proteins which are known to act as biological catalysts—their function is thus to increase the rate of reactions occurring in living systems. Experimentation has shown that enzymes are highly specific—that is, enzymes cannot act on a variety of target molecules (substrates), but only on a specific substrate. The site on the enzyme that interacts with the substrate is called the active site.

A useful model that has been developed to explain the specificity of enzyme action is the 'lock and key' model. This model explains that each enzyme has an active site (a location within its molecular structure) which has specific shape that allows it to fit together with a matching substrate, much like a key fits into a matching lock. If the shape of the active site of the enzyme and the substrate do not match, the model explains it will not be able to function as an enzyme on that substrate.

This model suggests that enzymes first bond with the matching substrate, allowing it to then break down simpler components or to bring about the synthesis of a complex molecule from the substrate. The products can then separate from the enzyme, returning it to its original composition and structure. This enables the enzyme to act on other matching substrate molecules. Like all catalysts, the enzyme molecule is not consumed by the reaction.

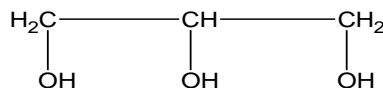
Experimentation has also shown that some substances can interfere with the catalysis of certain processes. The 'lock and key' model is also useful in explaining this observation. It suggests that the interfering molecule (an inhibitor) can block the active site, thus preventing the matching substrate molecule from binding to the enzyme.

The model, like all other models, has limitations. For example, it does not explain the chemical basis for the bonding between the enzyme and substrate. However, it is a simple model that is able to explain some of the observations of enzyme activity and is therefore a widely accepted and useful model.

##### 28 c (i)

Marking guidelines	Marks
draws the structural formula of glycerol AND relates the structure of glycerol to its high viscosity and solubility in water	2-3
draws the structural formula of glycerol OR identifies one feature of the relative viscosity or solubility in water of glycerol	1

The structural formula of glycerol is:



Glycerol is a relatively viscous liquid with a high solubility in water. These observations can be explained in terms of its molecular structure. It is a polar molecule consisting of 3 hydroxy functional groups. The O atoms on one molecule can thus form strong hydrogen bonds to the H atoms in the hydroxy groups on neighbouring molecules. This means there are many opportunities for hydrogen bonding within the sample. The relatively strong forces that therefore exist between glycerol molecules explain its high viscosity (slow rate of flow). Water is likewise a polar molecule which has O atoms directly bonded to H atoms. Hydrogen bonds also form between glycerol and water molecules. This explains why glycerol has a high solubility in water.

**28 c (ii)**

Marking guidelines	Marks
Displays an extensive knowledge of the features of TAG and explains why these features make TAGs important energy storage molecules Explains that TAGs can be converted to and from other energy sources Provides an overall assessment of their importance	4
Describes the body's use of TAGs as an energy store with some explanation given. Displays knowledge of energy comparisons with other energy sources	2-3
identifies the main role of TAGS in the human body (ie for energy storage)	1

TAGS are triesters of glycerol with long chain fatty acids, which contain many carbon atoms in a reduced state. Upon breaking down, the carbon atoms in the fatty acids are oxidised, producing acetyl-CoA molecules. These molecules then enter the reactions in the TCA cycle, where they are oxidised. Hydrogen atoms are also produced by the oxidation of the fatty acids. The energy released from the oxidation of the C atoms in the fatty acids is greater than that released from glucose, because many of the C atoms in glucose are already oxidised. Thus a relatively large amount of ATP is produced from the oxidation of the fatty acids from TAGS. Another reason for their high store of energy is the fact that TAGS can be stored in tissue with smaller volumes of water compared to carbohydrates. This is because of the long hydrophobic hydrocarbon chains of the fatty acids, as opposed to the hydrogen bonds which can form between water and other carbohydrates such as glucose. Therefore TAGS are essential molecules for the storage of energy in the body. When there is excess carbohydrates in the diet, TAGS can be synthesised and stored until such time as energy is required by the body, when TAGS can be broken down as described to release the energy stored in the molecules.

**28 d (i)**

Marking guidelines	Marks
describes the general structure of a skeletal muscle cell	2
identifies one feature of the structure of a skeletal muscle cell	1

Skeletal muscle cells consist of hundreds of contractile units called myofibrils. These are striated in appearance and run parallel to each other along the length of the muscle cell. The dark bands on the myofibril are caused by thick bands of a protein known as myosin. In between the myosin are thin lighter bands of another protein called actin. These are the contractile units in the muscle.

**28 d (ii)**

Marking guidelines	Marks
relates the process of muscle cell contraction to the presence of calcium ions AND describes the cause of muscle cell contraction in terms of bond formation between actin and myosin AND/OR explains the role of ATP in muscle cell contraction	3-4
outlines the process by which muscle cells contract	2
identifies the cause of muscle cell contraction is calcium ions OR identifies ATP is consumed as muscle cells contract	1

Scientists believe that muscle cell contraction is triggered when a nerve impulse brings about the release of calcium ions over the actin and myosin in the muscle fibre. Prior to release of calcium, when the muscle cells are relaxed, the actin and myosin are unable to make contact due to the presence of two regulatory proteins, troponin and tropomyosin found on the actin. Once the calcium ions are released, the tropomyosin protein is thought to move away, allowing a cross-bridge to form between the troponin and myosin. Once this occurs, an enzyme causes the hydrolysis of ATP. The energy released by the hydrolysis of ATP allows the cross-bridge to shorten, thus contracting the muscle cell.

**Question 29 – The Chemistry of Art**

**29 a (i)**

Marking guidelines	Marks
identifies an appropriate pigment	1

iron(III) oxide, or red ochre

**29 a (ii)**

Marking guidelines	Marks
outlines two other uses of pigments by ancient cultures	2
outlines one other use of pigments by ancient cultures	1

Apart from paintings, pigments were also used by ancient cultures as makeup, especially for ceremonial purposes or by wealthy or important members of a culture, and for decorating the dead in rituals designed to promote their well being in the afterlife.

## 29 a (iii)

Marking guidelines	Marks
explains how two properties make a material useful as a pigment	3
identifies two properties important in pigments	2
identifies one property important in a pigment	1

For a material to be useful as a pigment it had to be insoluble in water. This was important so that the artwork was not destroyed by rain or moisture. Another important property is that it had to be chemically stable in order to prevent the art work being destroyed over time by reactions of the pigment with chemicals in the air.

## 29 b

Marking guidelines	Marks
defines first ionisation energy and electronegativity AND identifies the trends in first IE and electronegativity across the periods and down the groups AND explains the trends in terms of effective nuclear charge (use of this specific term not necessary)	6
defines first ionisation energy and electronegativity AND identifies the trends in first IE and electronegativity across the periods OR down the groups AND explains the trends in terms of effective nuclear charge (use of this specific term not necessary) OR defines first ionisation energy and electronegativity AND identifies the trends in first IE OR electronegativity across the periods and down the groups AND explains the trends in terms of effective nuclear charge (use of this specific term not necessary)	4-5
defines first ionisation energy OR electronegativity AND identifies one trend in first ionisation energy OR electronegativity	2-3
defines first ionisation energy OR electronegativity OR identifies one trend in first ionisation energy OR electronegativity	1

First ionisation energy is the energy required to remove an electron from the valence shell of an atom in the gas phase. Electronegativity is the attraction that an atom has for an additional electron. Both are important in determining an element's reactivity and the type of bonds that it forms. The trends in these two properties are as follows:

- across the second and third periods: 1<sup>st</sup> IE generally increases with slight decreases at B and O for period 2, and Al and S. Electronegativity increases across the periods.
- down a group: 1<sup>st</sup> IE and electronegativity decrease.

The reason for these trends is as follows:

- Moving across a period effective nuclear charge increases.
  - o the nucleus is increasingly positive moving across a period as more protons are added
  - o more electrons are also added, but to the same valence shell
  - o the valence shell is shielded from the nucleus to the same extent moving across a period
  - o as a result the attraction between the nucleus and the valence shell increases
  - o this results in more energy being required to remove an electron from the valence shell and hence first ionisation energy generally increases
  - o as the effective nuclear charge increases the attraction of the electron for additional electrons (to complete the valence shell) also increases and hence electronegativity increases across a period
  - o there are slight decreases in 1<sup>st</sup> IE moving across the period as indicated above, because moving from Be to B, and from Mg to Al, the valence electron is using a 2p or 3p orbital, which is less 'penetrating' than the s orbital, and hence the electron is held a little less tightly. Moving from N to O and from P to S the p orbitals are becoming doubly filled, and electron-electron repulsion in these orbitals also decreases slightly the energy required to remove the electron.
- Moving down the groups
  - o although the number of protons and electrons is increasing, the valence shell is increasingly shielded from the nuclear charge by filled electron shells between it and the nucleus
  - o as a result effective nuclear charge decreases moving down a group
  - o thus there is a decrease in the attraction between the nucleus and the valence shell
  - o as a result, both first IE and electronegativity decrease

## 29 c (i)

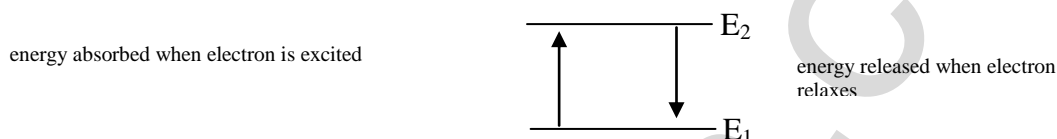
Marking guidelines	Marks
outlines a procedure that could be used to carry out flame tests AND justifies steps in the procedure AND identifies a risk involved in the procedure and justifies the step(s) taken to minimise the risk	3
response contains most of the above	2
response contains one correct step OR identifies one safety issue with a procedure	1

The procedure we used was to take a platinum loop on a glass rod, and dip it into concentrated HCl. The loop was then placed into the hot part of the Bunsen flame. We did this to ensure that the loop was clean. A very small volume of HCl was used, and we wore gloves and safety glasses. This was to avoid skin and eye contact because conc. HCl is very corrosive, and we used a small volume to minimise the risk should a spill occur. After washing the loop we placed it into a salt such as potassium chloride, and collected a small amount of the salt on the end of the loop. This was then placed in the hot part of the Bunsen flame and the flame colour observed. The loop was then cleaned using HCl again, and the other salts tested in the same way.

## 29 c (ii)

Marking guidelines	Marks
outlines the Bohr model of the atom AND outlines the processes of electron excitation and relaxation AND clearly states that the energy required/released in these processes is quantised or discrete or specific AND explains why different flame colours are observed for different elements AND includes an appropriate diagram	4
response includes three of the above points	3
outlines the main features of the Bohr model OR outlines how electrons move between levels and relates to flame colours OR draws a diagram of a general or specific atom showing the features of the Bohr model	2
response contains the notion that electrons orbit the nucleus in shells OR that electrons can be excited	1

The Bohr model of the atom has electrons orbiting the nucleus at fixed radii and with fixed energy, in discrete energy levels. The energy difference between these energy levels is quantised, and electrons can move from a lower energy level to a higher one (become excited) by absorbing the specific energy difference between the two levels. When they relax, or return to the ground state, they release the same amount of energy. The energy required to excite an electron can come from light, or heat, as in a flame test. In the flame test electrons in the sample absorb energy from the flame and become excited. They relax, and release the same amount of energy, but it is released as light of a specific wavelength, observed as the flame colour. The energy required to excite electrons is different for different atoms, because their electron configurations and atomic numbers differ, hence the energies of each orbital are different. This accounts for the different flame colours of different elements.



## 29 d (i)

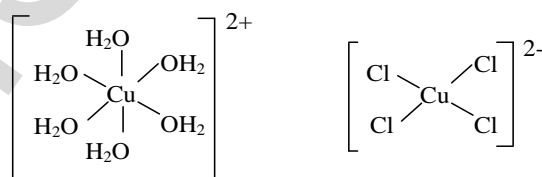
Marking guidelines	Marks
explains why copper is a transition metal in terms of having a partially filled d-set in its common oxidation state	2
states that copper is a transition metal because it has a variable valency	1

Copper is classified as a transition metal because it contains partially filled d-orbitals in its common oxidation state, 2+.

## 29 d (ii)

Marking guidelines	Marks
identifies that the hexaquaquacopper(II) ion is formed when $\text{CuSO}_4$ is dissolved in water using appropriate concepts such as ligand, coordinate covalent bonds, AND explains why this complex appears blue using concepts of excited electrons in split d-orbitals, absorption and transmittance of light of specific wavelengths AND identifies that the tetrachlorocopper(II) ion is formed when conc. HCl is added AND explains why this complex is a different colour in terms of different d-orbital splitting AND draws a Lewis diagram of each complex	4
identifies that different complexes are formed when $\text{CuSO}_4$ is dissolved in water and when conc HCl is added AND states that different colours are observed because the d-orbitals are split to different extents in the two complexes AND draws one correct Lewis diagram	3
identifies that complexes are present in solution and draws one correct Lewis diagram OR explains that the colours are different because different complexes are present which absorb different wavelengths of light (or different energies of visible light)	2
response contains one correct feature	1

When anhydrous copper(II) sulfate is dissolved in water, 6 water molecules surround the copper(II) ion and act as ligands – they donate a non-bonding electron pair on oxygen to form coordinate covalent bonds with the copper(II). This produces the hexaquaquacopper(II) complex ion. In the complex ion copper's d-electrons are split into two sets, and the energy difference between the two sets corresponds to the energy carried by orange light. Photos of orange light are absorbed by the solution as d-electrons in complex ions are excited, and hence the solution transmits what is observed as blue light, and it appears blue. When conc. HCl is added, chloride ions displace the water molecules as ligands, and coordinate to the copper(II) ion. Chloride ions are relatively large, and four fit around the copper(II) ion, producing the tetrachlorocopper(II) complex ion. In this complex the energy difference between the two sets of d-orbitals is different, hence its different colour – the complex absorbs red light and transmits green.



## Question 30 – Forensic Chemistry

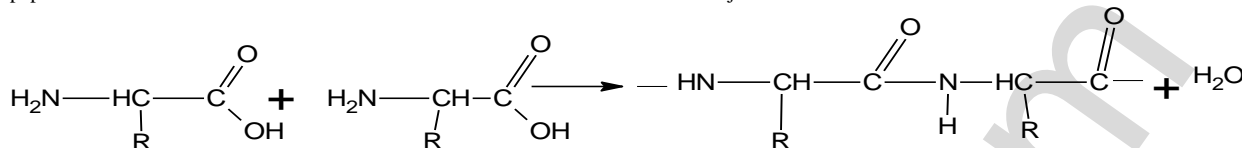
## 30 a (i)

Marking guidelines	Marks
identifies the group to which the chemical belongs as an amino acid	1

30 a (ii)

Marking guidelines	Marks
Provides characteristics of a peptide bond, including an appropriate diagram	2
identifies one feature of a peptide bond, in words or as part of a diagram	1

The peptide bond is formed when amino acid molecules join to form a protein via a condensation reaction. The active sites on the amino acids (eg the NH<sub>2</sub> group on one and the COOH group on a neighbouring molecule) react and the amino acids link by a –N– bond, known as a peptide or amine bond. A water molecule is eliminated as the amino acid molecules join.



30 a (iii)

Marking guidelines	Marks
describes the process of electrophoresis relates the process of electrophoresis to the work of a forensic chemist	3
describes the process of electrophoresis OR relates the process of electrophoresis to forensic investigations	2
identifies a feature of electrophoresis OR describes how electrophoresis can be used in a forensic investigation	1

Electrophoresis is a method used to separate components of a mixture using an applied potential difference. The mixture to be separated is placed onto a surface eg filter paper which contains an electrolyte. A voltage is applied across the surface and any charged particles move towards either the positive or negative electrode depending on the charge they carry. The rate at which particles move depends on variables such as their mass and charge, thus allowing the components of the mixture to be separated. The technique is extremely useful to forensic scientists, allowing them to identify origins of biological samples found at crime scenes (eg proteins). For example, it forms the basis of DNA fingerprinting, a technique which separates components of DNA, leading to the formation of a DNA ‘fingerprint’-a photo showing a band pattern unique for each individual.

30 b

Marking guidelines	Marks
demonstrates extensive knowledge of TWO or more chromatographic techniques AND explains how the described techniques are used by forensic scientists, including specific examples makes a judgement on the significance of the techniques to the work of forensic scientists	5-6
describes TWO or more chromatographic techniques OR describes ONE chromatographic technique AND makes a judgment on the significance of the chromatographic technique to forensic scientists	3-4
describes a chromatographic technique identifies two or more chromatographic techniques	2
identifies a chromatographic technique	1

There are a number of chromatographic techniques and each of them may be used in forensic investigations to separate mixtures found in small quantities. This aids in the isolation of a material from a sample or the identification of a material. All techniques separate components in a mixture based on differences in their relative adsorption in a stationary phase (eg paper or silica) to that in a mobile phase (eg a liquid or gas solvent).

The number of chromatographic techniques available to the forensic scientist have increased and the integration of the basic techniques with technology (eg computers to store data etc) has greatly increased the usefulness of the technique.

Two forms of chromatography are gas-liquid chromatography (GLC) and high performance liquid (HPLC). Both a very sensitive techniques and scientists can work with microsamples (down to 10<sup>-9</sup> g).

GLC is less expensive than HPLC and is commonly used in the detection of a range of substances eg drugs in urine or blood. This technique permits rapid separation of a sample and provides a quantitative determination of each compound in a mixture, assisting greatly in identifying the origin or a sample. HPLC can also be used to detect illicit drugs in urine/blood (in amounts down to 10<sup>-12</sup>g) and is used in the analysis of materials such as cosmetics, herbicides and drinking water. Like GLC, the technique allows for a quantitative determination of the components in a mixture.

Therefore, due to their quantitative nature and high sensitivity, chromatographic techniques play a vital role in the work of forensic scientists.

30 c (i)

Marking guidelines	Marks
outlines a procedure that could be used to carry out flame tests AND justifies steps in the procedure AND identifies a risk involved in the procedure and justifies the step(s) taken to minimise the risk	3
response contains most of the above	2
response contains one correct step OR identifies one safety issue with a procedure	1

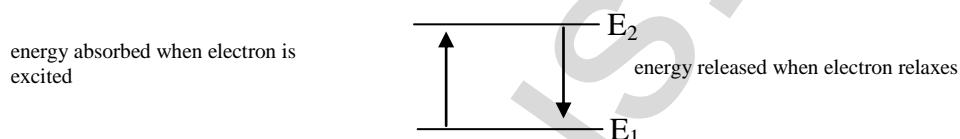
The procedure we used was to take a platinum loop on a glass rod, and dip it into concentrated HCl. The loop was then placed into the hot part of the Bunsen flame. We did this to ensure that the loop was clean. A very small volume of HCl was used, and we wore gloves and safety glasses. This was to avoid skin and eye contact because conc. HCl is very corrosive, and we used a small volume to minimise the risk should a spill occur. After washing the loop we placed it into a salt such as potassium chloride, and collected a small amount of the salt on the end of the loop. This was then placed in the hot part of the Bunsen flame and the flame colour observed. The loop was then cleaned using HCl again, and the other salts tested in the same way.

30 c (ii)

Marking guidelines	Marks
outlines the Bohr model of the atom AND outlines the processes of electron excitation and relaxation AND clearly states that the energy required/released in these processes is quantised or discrete or specific AND uses the above to explain the origin of emission spectra for different elements AND includes an appropriate diagram	4
response includes three of the above points	3
outlines the main features of the Bohr model OR outlines how electrons move between levels OR describes features of the emission spectra of elements and relates partially to the Bohr model draws a diagram of a general or specific atom some features of the Bohr model	2
response contains the notion that electrons orbit the nucleus in shells OR identifies electrons can be excited to higher levels OR identifies a feature of emission spectra	1

The Bohr model of the atom has electrons orbiting the nucleus at fixed radii and with fixed energy, in discrete energy levels. The energy difference between these energy levels is quantised, and electrons can move from a lower energy level to a higher one (become excited) by absorbing the specific energy difference between the two levels. When they relax, or return to the ground state, they release the same amount of energy.

The energy required to excite an electron can come from heat or electric current. When an instrument known as a spectroscope is used to view the radiation the excited samples emits, a line emission spectra is observed-this is a series of coloured lines on a black background, unique for each element. Each line on the spectra corresponds to light of a specific wavelength being released as an excited electron falls back to a lower energy level. The energy required to excite electrons is different for different atoms, because their electron configurations and atomic numbers differ, hence the energies of each orbital are different. This accounts for the different coloured lines making up each element's spectra.



30 d (i)

Marking guidelines	Marks
Describes the structure of DNA and relates this to its use in identifying relationships between individuals	2
Outlines characteristics of the structure of DNA	1

DNA is a biopolymer which makes up the chromosomes of living things. It is composed of nucleotides containing a sugar, phosphate and nitrogen base group. Whilst all DNA is made of these basic groups, the non-coding regions between genes (introns) are unique (apart from identical twins). DNA can be analysed by a process known as DNA fingerprinting. From analysis of DNA fingerprints taken from two individuals (taken from samples such as blood), a forensic scientist is able to determine whether they are related by looking for the degree of similarity/difference observed in the bands in the fingerprint.

30 d (ii)

Marking guidelines	Marks
describes the role of DNA analysis in forensic investigations AND explains issues associated with the use of DNA evidence AND makes a judgement on the impact of DNA analysis on individuals AND society	3-4
outlines the role of DNA analysis in forensic investigations OR explains some issues associated with the use of DNA evidence	2
identifies one positive or negative aspect of forensic DNA analysis on individuals or society.	1

Since the introduction of DNA analysis in forensic investigations, investigators have a reliable and cost effective method of analysing samples of biological material associated with criminal activity. For example, fluids such as blood and semen found at a crime scene can be analysed and DNA it contains 'finger-printed'. The DNA can be used to determine the identity of the source of the fluid. For example, DNA fingerprints of known criminals are stored in databases and these can be used for comparison against DNA found out a crime scene. Alternatively, a sample of DNA can be taken from a suspect and compared to DNA found at a crime scene. This could be used as evidence to suggest the suspect was innocent or guilty. Although there are ethical issues associated with the use of DNA evidence (eg the storage of an individual's DNA fingerprint in DNA data bases), possible contamination of samples at crime scenes or in laboratories, society has largely benefited from its use-many crimes have been solved due to DNA analysis. Likewise, innocent individuals suspected of crimes have been able to demonstrate their innocence with DNA analysis.