

Part B - 60 marks
Attempt Questions 16 -28
Allow about 1 hour and 45 minutes for this part

Answer the questions in the spaces provided
Show all relevant working in questions involving calculations

MARKS

Question 16 (3 marks)

A 5.00 mL volume of vinegar was found to weigh 4.50 g. The vinegar was placed into a conical flask and diluted with 20.0 mL of distilled water. The concentration of acetic acid (ethanoic acid) in the vinegar was determined by titration with 0.100 mol L⁻¹ sodium hydroxide. At the endpoint, the titre was 23.3 mL.

(a) Calculate the percentage mass of acetic acid in the original undiluted vinegar.

Criteria	Mark
$\text{mole CH}_3\text{COOH} = \text{mole NaOH} = (0.100 \text{ mol L}^{-1} \times 0.0233 \text{ L}) = 2.33 \times 10^{-3} \text{ mol}$ $\text{mass CH}_3\text{COOH} = \text{mole} \times \text{molar mass}$ $= 2.33 \times 10^{-3} \text{ mol} \times [2(12.01) + 2(16.00) + 4(1.008)]$ $= 0.13992 \sim 0.140 \text{ g}$ $\% \text{CH}_3\text{COOH} = (\text{mass/mass}) 100\% = \frac{0.140}{4.50} \times 100 = 3.1\%$	2
Correct calculations	

(b) What is the concentration (mol L⁻¹) of acetic acid in the undiluted vinegar?

Criteria	Mark(s)
$[\text{CH}_3\text{COOH}] = \text{mole CH}_3\text{COOH/vol in L}$ $= 2.33 \times 10^{-3} \text{ mole}/0.005 \text{ L}$ $= 0.466 \text{ mole/L}$	1
Correct calculation	1

Question 17 (3 marks)

(a) (i) Explain why ammonium chloride can form an acidic solution in water and therefore classified as an acidic salt. Use equation(s) in your answer.

Criteria	Mark(s)
<p>The NH_4^+ ion is a better proton donor, ie a stronger acid than water and hence, is able to donate a proton to water to increase H_3O^+ concentration in water.</p> $\text{NH}_4^+ + \text{H}_2\text{O} \rightleftharpoons \text{NH}_3 + \text{H}_3\text{O}^+$	1
any answer with a similar reasoning	1

(ii) Explain why sodium hydrogen carbonate can form a basic solution in water and is therefore classified as a basic salt. Use equation(s) in your answer.

Criteria	Mark(s)
<p>The HCO_3^- ion is amphoteric substance but tends to accept rather than donate protons to water. Abstraction of a proton from water results in a basic solution</p> $\text{HCO}_3^- + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{CO}_3 + \text{OH}^-$ <p>Free OH^- ions in solution make the solution basic</p>	1
any similar reasoning with an equation	1

(b) Name a salt which should form a neutral solution in water.

Criteria	Mark(s)
Sodium chloride	1
any other neutral salt	1

Question 18 (8 marks)

During your course, you determined the heat of neutralisation of an acid. Describe the procedure you followed and justify the appropriateness of the procedure you adopted in order to obtain valid and reliable results.

Criteria	Mark(s)
The heat of neutralisation is the heat released when 1 mole of an acid is neutralised with 1 mole of a base eg $\text{HCl} + \text{NaOH} \rightarrow \text{NaCl} + \text{H}_2\text{O}(\text{l})$ or $\text{H}^+ + \text{OH}^- \rightarrow \text{H}_2\text{O}(\text{l})$ $\Delta H_{\text{neut}} = (-)$ exothermic The experiment was done in the following manner. 50.0mL of 1.00molL ⁻¹ HCl was pipetted into a polystyrene cup and its temperature measured and recorded. 50.0mL of 1.00molL ⁻¹ HCl was placed into a 50.0mL burette and its temperature measured and recorded. The NaOH solution was then added to the HCl solution; stirred (carefully) with the thermometer and the maximum temperature reached noted. The mixture was stirred before recording the temperature to avoid recording localised temperature changes as those of the bulk of the solution. A polystyrene cup (good insulator) is used to prevent heat transfer from the solution to the surrounding. Accurate measurements of volumes, use of pipette and burette is needed for an accurate calculation of mass of solution and number of moles of acid or base. Repeating the experiment several times add to the reliability of the results. The acids and the bases were both accurately known by standardisation so when ΔH is calculated, $\Delta H = (\text{mCg}\Delta T)/n$. the value of n, the number of moles is accurate. The initial temperatures of the NaOH and the HCl may differ hence, the initial temperatures of the HCl and the NaOH were determined and averaged. Assumption of a density of 1g/mL for water incurred little error. Alternatively, a data book could have been consulted for the density of water at specific temperatures. The heat capacity of the solution may not be the same as the heat capacity of water. Use of the actual C_p for NaCl solution may improve the accuracy.	1
Appropriate equations given or heat of neutralisation explained without equations. Detailed procedure is given and with an analysis of each of the steps of the procedure	8

Question 19 (4 marks)

Naturally occurring citric acid has the molecular formula $\text{C}_6\text{H}_8\text{O}_7$. Like all acids, it reacts with carbonate solutions to form carbon dioxide gas. When 1.537 g citric acid was added to a solution containing excess sodium carbonate, 295 mL carbon dioxide (measured at 25°C and 101.3 kPa) was formed.

- (a) Write an equation for the reaction of hydrogen ions with carbonate ions. How many moles of carbon dioxide were formed? 2

Criteria	Mark(s)
$2\text{H}^+ + \text{CO}_3^{2-} \rightarrow \text{H}_2\text{O} + \text{CO}_2(\text{g})$ Moles CO_2 = volume CO_2 /molar volume at SLC = 0.295L/24.47L/mole = 0.0121 moles	1
	1

- (b) Determine the number of moles of hydrogen ions produced by 1.537 g citric acid. 1

Criteria	Mark(s)
Moles H^+ = 2 x moles CO_2 = 2 x 0.0121 = 0.0242 moles Moles of citric acid = 1.537g/(12.01) + 8(1.008) + 7(16.00)g/mole = 8.01 x 10 ⁻³ Moles H^+ = moles H^+ from citric acid?	1

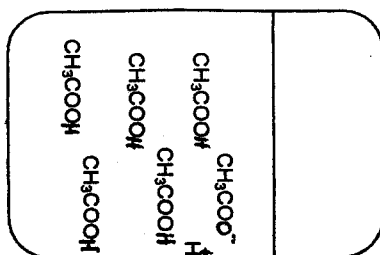
- (c) How many replaceable hydrogens (acidic hydrogens) are there in citric acid? Explain your answer. 1

Criteria	Mark(s)
Moles of H^+ by stoichiometry = 0.0242 while Moles of citric acid = 8.01 x 10 ⁻³ There is 3 times as much H^+ reacting with CO_2 as there are moles of citric acid, therefore, there are 3 replaceable hydrogens in citric acid.	1

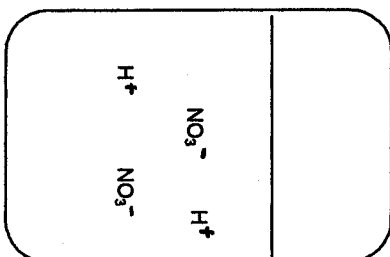
Question 20 (2 marks)

Using ethanoic acid and nitric acid in your answer. Draw diagrams to represent:
(a) a concentrated, weak acid solution. (b) a strong, dilute acid solution

Make sure you use correct formulas in your diagrams.



concentrated weak acid solution



strong, dilute acid solution

Question 21 (6 marks)

(a) Describe the procedure you used to quantitatively analyse a manufactured product

4

Criteria	Mark(s)
Analysis of citric acid in orange juice Citric acid is an acid and can be determined by titration with a standard solution of a base. Exactly 25.00ml. of orange juice was pipetted into a conical flask. The pipette was previously rinsed with orange juice and the conical flask, rinsed with demineralised water. The orange juice was titrated with standard NaOH solution with phenolphthalein as the indicator. The NaOH solution was added until the yellow solution turned orange. The number of moles of citric acid = 3 times the number of moles of NaOH. $\text{H}_3\text{Cit} + 3\text{NaOH} \rightarrow \text{Na}_3\text{Cit} + 3\text{H}_2\text{O}$	4
Complete procedure including equation(s), the principle behind the analysis and the stoichiometry of the reaction	4

(b) Identify one problem you encountered in the procedure.

1

Criteria	Mark(s)
One problem is the difficulty in judging the endpoint of the titration since the orange juice is itself highly coloured	1
any valid problem	1

(c) Propose a solution to this problem.

1

Criteria	Mark(s)
A solution to this problem is the use of a pH glass electrode to monitor the titration. The electrode should be rinsed well after the titration to prevent any orange juice component from fouling the glass membrane	1
any reasonable solution to the analysis problem given in (b)	1

Question 22 (3 marks)

Evaluate the effectiveness of atomic absorption spectrophotometric (AAS) measurements in pollution control.

3

Criteria	Mark(s)
<p>Pollution control requires frequent sampling and continuous testing of the samples over a given time period. Many samples are normally collected and then analysed at the same time. If an abnormally high level of pollutant is detected then measures are put in place to control the pollution. AAS is a very effective tool for pollution control because of its high sensitivity, high selectivity and short analysis time, many samples can be processed quickly. Very low levels of metal ion pollutants can be easily detected with minimum time-consuming sample pre-treatment. Once the instrument is set-up the results can be obtained quickly. The samples are merely aspirated into the AAS instrument and the analysis is done after comparison of the readout with a calibration plot. Interference from other ions is minimal because of the inherent selectivity of the AAS technique which uses a specific hollow cathode lamp for each target ion.</p> <p>A limitation of the technique is its inability to detect non-metallic pollutants such as nitrate, cyanide, phosphate, etc.</p> <p><i>The selectivity, low detection limit, ease of introducing the sample into the instrument and a limitation should be included.</i></p>	3

Question 23. (6 marks)

Describe the test for the biochemical oxygen demand (BOD) and evaluate its importance with respect to the monitoring of the possible eutrophication of waterways.

6

Criteria	Mark(s)
<p>Two identical water samples are collected and analysed for dissolved oxygen by the same technique 5 days apart. After collection both samples are protected from light and oxygen exposure. Dissolved oxygen is analysed with the oxygen electrode or the Winkler titration technique. The difference in the dissolved oxygen level (DO) between the two samples is the biochemical oxygen demand (BOD) of the water sample. BOD is a measure of the concentration of dissolved oxygen needed for the complete breakdown of the organic matter in the water by aerobic bacteria. Breakdown products may be nitrates, phosphate, carbon dioxide, etc. Determination of the BOD shows the level of organic matter content of a water sample and therefore is an indication of the efficiency of pollution control processes in place. High BOD means high organic matter content, (contamination by sewage?). High nutrient level, points to the possibility of algal blooms (where more nutrients are introduced to the water when the algae die. This leads to an even higher BOD, resulting in the depletion of dissolved oxygen, death of other organisms requiring oxygen, ultimate takeover of anaerobic bacteria and the further degradation of the waterway. BOD is a very significant indicator of the factors that lead to eutrophication. However, BOD monitoring alone is not enough to effectively monitor the possible eutrophication of a waterway. Oversupply of nutrients such as phosphate and nitrate from inorganic sources also lead to eutrophication. Hence, if BOD is to be used for monitoring eutrophication, this should be in conjunction with the monitoring of phosphate and nitrate which should be analysed with other techniques.</p> <p><i>Test for BOD described</i></p> <p><i>Role of BOD in eutrophication and importance of monitoring BOD</i></p>	6
	3
	3

Question 24 (5 marks)

Discuss the problems associated with the use of CFCs and the steps taken to alleviate these problems. 5

MARKS

Criteria	Mark(s)
The main problem associated with the use of CFCs is their ability to destroy ozone in the stratosphere. CFCs are broken down in the stratosphere under the influence of UV radiation to produce chlorine free radicals which can destroy ozone. The destruction of the Earth's radiation "shield", the ozone layer, exposes the Earth's surface to dangerous levels of ozone which can cause cell damage in both plants, animals, and humans leading to skin cancers and cataracts. In addition, the CFCs are also greenhouse gases which contribute to global warming leading to global erratic weather patterns.	5
The Montreal Protocol in its various versions aimed to alleviate these problems by halving and later on totally banning the manufacture of CFCs, the encouragement of the use of CFC replacements (such as HCF and HCFC) which are planned to be phased out as well and the setting up of funds to help third world countries phase out CFCs. Research on the development of new sunscreens may help in alleviating the harmful effects of a thinning ozone layer.	3
Problems associated with CFCs	2
Montreal protocol regulations and other initiatives	

Question 25 (5 marks)

(a) A student prepares 250 mL of a 5% (w/v) glucose solution and adds 1 gram of yeast. Write a balanced chemical equation for the fermentation which occurs. 1

MARKS

Criteria	Mark(s)
$C_6H_{12}O_6 \longrightarrow 2 CO_2(g) + 2 C_2H_5OH$	1
<i>Yeast enzymes must be included to obtain the mark</i>	1

(b) Calculate the mass of ethanol produced. 2

Criteria	Mark(s)
mass of glucose = $(0.05 \text{ g/mL}) \times 250 \text{ mL} = 12.5 \text{ g}$	
mole $C_2H_5OH = 2 \times \text{moles } C_6H_{12}O_6$	
$= 2 \times \frac{12.5}{6(12.01) + 12(1.008) + 6(16.00)} = 0.1388 \sim 0.139 \text{ mole}$	1
mass of $C_2H_5OH = \text{mole of } C_2H_5OH \times \text{molar mass} = 0.139 \times [2(12.01) + 6(1.008) + 16.00]$	
$= 6.36 \text{ g}$	1

(c) Describe conditions which promote fermentation. 1

Criteria	Mark(s)
Warm temperature, -37°C and the presence of yeast enzymes promote fermentation	1
<i>At least two conditions should be given to obtain the mark.</i>	1

(d) Relate the structure of the ethanol molecule to its use as a solvent. 1

Criteria	Mark(s)
The ethanol molecule is a good solvent for polar substances because it is a polar molecule. The highly electronegative oxygen depletes the carbon and the hydrogen of electrons making them partially positive and itself, partially negative. It is able, therefore to dissolve polar substances by dipole-dipole interaction or hydroxylated substances by hydrogen bonding. It also has a non-polar part which can dissolve slightly polar substances.	1
<i>any reasonable explanation</i>	1

Question 26 (6 marks)

Using examples of named polymers, compare and contrast addition polymerisation with condensation polymerisation. Make reference to the sources of reactants and the processes used in the manufacture of the reactants.

6

Criteria	Mark(s)
<p><i>Addition polymerisation and condensation polymerisation both involve the combining together of small molecules (monomers) to form one large molecule (polymer). They differ in many respects:</i></p> <ul style="list-style-type: none"> An initiator or a catalyst is used in addition polymerisation. The monomers in <i>addition</i> polymerisation are normally identical, for example for polyethene, ethene is the only monomer used in the manufacture of polyethene: $n\text{CH}_2=\text{CH}_2 + \text{CH}_2=\text{CH}_2 \rightarrow -\text{CH}_2(\text{CH}_2-\text{CH}_2)_n-\text{CH}_2-$ whereas in <i>condensation</i> polymerisation, the monomers may be identical as in nylon, (6-aminohexanoic acid) or different as in the manufacture of polyester from ethylene glycol and terephthalic acid. The repeating unit in an addition polymer always has the same formula as the monomer from which the polymer is formed whereas, the repeating unit in a condensation polymer is smaller than the monomer from which it is made. No other product is formed in <i>addition</i> polymerisation whereas a small molecule, for example, H_2O or HCl is produced in <i>condensation</i> polymerisation. The monomer in an addition polymer has a double bond as the reactive functional group whereas the monomer may utilise functional groups such as acid, alcohol, amino, etc. Reactants (ethene, mainly) in <i>addition</i> polymerisation are obtained from the cracking of petroleum while those of <i>condensation</i> polymerisation may come from the degradation of polymers of biological origins such as cellulose or are industrially synthesised. <p>Summary ADDITION polymerisation</p> <ul style="list-style-type: none"> named polymer description of process must include mention of unsaturated monomer (breaking double bond) alkenes are produced from catalytic cracking of petroleum fractions <p>Condensation polymerization</p> <ul style="list-style-type: none"> named polymer description of process must include elimination of small molecule in the linking mechanism source of reactant and process eg., glucose from photosynthesis 	6
<i>Discussion of similarity</i>	1
<i>Discussion of differences</i>	3
<i>Processes in the manufacture of monomers</i>	2

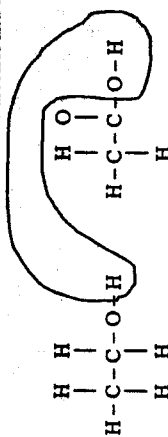
Question 27 (4 marks)

- (a) Give a reason why some nuclei are unstable.

1

Criteria	Mark(s)
proton to neutron ratio is too high or too low or the atom is too heavy ($Z > 83$)	1

- (b) The reaction mechanism for esterification was studied and verified using a tracer. It was proved that water was formed from an H from the alcohol and an OH from the acid.



Identify a named radioisotope which could have been used in this research.

1

Criteria	Mark(s)
oxygen-18, or tritium	1

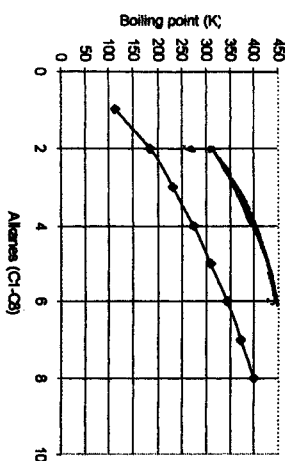
- (c) Cobalt-60 is a multi-purpose commercial radioisotope.

Describe how a non-transuranic isotope like cobalt-60 can be produced in a nuclear reactor and give an equation to illustrate your answer.

2

Criteria	Mark(s)
A non-transuranic isotope such as cobalt-60 can be produced by irradiating a stable isotope such as cobalt-59 with neutrons in a nuclear reactor. $^{59}_{27}\text{Co} + n \rightarrow ^{60}_{27}\text{Co}$	2
Cobalt-60 decays to produce β and γ radiations.	
<i>Description of process equation</i>	1
	1

Question 28 (5 marks)



- The graph shows the boiling points of the alkane series from methane to octane.
- (a) Identify which gaseous alkane (plotted on the graph) would be the easiest to liquefy and give a reason for your answer.

Criteria	Mark(s)
Butane, the gas with the highest boiling point and hence the easiest to liquefy. If all gases were cooled it will be the first to reach its "condensation" temperature which is the same as its boiling point. Among the gaseous hydrocarbons, it exhibits the greatest dispersion forces due to its higher molecular mass.	2
<i>Butane</i>	1
<i>explanation of choice</i>	1

- (b) Sketch a curve on the graph showing the relative boiling points of the alkanic acids from ethanoic acid to hexanoic acid in relation to the corresponding alkanes.

Criteria	Mark(s)
<i>as indicated in the graph</i>	1

- (c) Explain the difference in the boiling points of the alkanes versus the alkanic acids

Criteria	Mark(s)
The alkanes have only weak <i>dispersion forces</i> between molecules and hence require only a small amount of energy to separate them. However, alkanic acids are extensively hydrogen-bonded to each other, hydrogen bonding is a stronger intermolecular force than <i>dispersion forces</i> and hence require more energy to separate the molecules from each other, i.e., higher boiling point.	2
<i>discussion of two forces</i>	2

MARKS

Section II 25 marks

Question 29. (25 marks)

- (a) Describe the work of Davy and Faraday in increasing the understanding of electron transfer reactions.

Criteria	Mark(s)
Davy discovered electrolysis, the use of electricity to break down substances chemically. His contribution includes the electrolysis of sodium and potassium, a technique using electron-transfer processes. He demonstrated these procedures without specifically explaining them.	2
Faraday quantified electrolysis with his laws. He related the mass of substances produced and the amount of electricity passing through.	2

- (b) Various methods can be used to protect the hulls of ships from corrosion. Explain four different methods that are used for protection.

Criteria	Mark(s)
Four different methods used to protect the hulls of ships from corrosion are:	
• Painting the hull of a ship with new polymer paints such as the <i>Rustmaster Pro</i> . This paint forms a smooth impermeable (to oxygen and water) layer on the surface of the hull. It also incorporates additives that react with the surface to form a very insoluble ionic substance <i>pyroxurite</i> . This layer prevents ion migration on the surface and in conjunction with the polymer surface shields the surface from oxygen and water, thus, inhibiting corrosion.	2
• Hulls of ships are bombarded with metal ions such as Ni and Cr in the plasma state. These metal ions form surface alloys on the surface of the hulls to form a "stainless steel" - like finish. The protection is similar to the surface passivation afforded by alloying metals such as Cr and Ni in stainless steel.	2
• Cathodic protection may be employed to protect the hulls of ships. This is done by attaching an active metal i.e. one which has a more negative reduction potential than iron (such as Zn and Mg) to the hull of the ship. These metals, because of their greater reactivity act as sacrificial anodes. The hull becomes the cathode and the active metal becomes the sacrificial anode. The reactions are:	2
$\text{O}_2 + 2\text{H}_2\text{O} + 4\text{e}^- \rightarrow 4\text{OH}^-$ <div style="display: flex; justify-content: space-around;"> <div> $\text{Mg(s)} \rightarrow \text{Mg}^{2+} + 2\text{e}^-$ <p>cathode reaction</p> </div> <div> $\text{Fe(s)} \rightarrow \text{Fe}^{2+} + 2\text{e}^-$ <p>anode reaction</p> </div> </div>	2
• An impressed current may be applied to the hull of the ship with an inert anode and the ship's hull as the cathode. Any Fe^{2+} ions are reduced as well as O_2 (The reduction of oxygen is the main reduction process. The reactions are:	2
$\text{O}_2 + 2\text{H}_2\text{O} + 4\text{e}^- \rightarrow 4\text{OH}^-$ <div style="display: flex; justify-content: space-around;"> <div> $2\text{H}_2\text{O} \rightarrow \text{O}_2 + 4\text{H}^+ + 4\text{e}^-$ <p>cathode reactions</p> </div> <div> $\text{Fe}^{2+} + 2\text{e}^- \rightarrow \text{Fe(s)}$ <p>anode reaction at the inert electrode</p> </div> </div>	2

MARKS

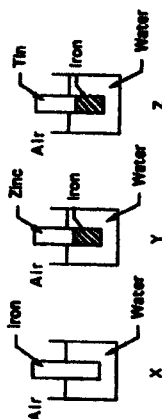
- (c) Describe a passivating metal.

Criteria	Mark(s)
A passivating metal is a reactive metal that readily forms an unreactive surface coating with substances such as O_2 and H_2O	1

- (d) Compare the concentrations of gases normally dissolved in the oceans to their concentrations in the atmosphere. How do the solubilities of these 'soluble' gases vary with ocean depth? Explain.

Criteria	Mark(s)
The concentration of N_2 , O_2 and CO_2 are much greater in the atmosphere than dissolved in seawater. With ocean depth, the solubility of these gases should increase because of the dual positive effect of temperature and pressure on solubility. As depth increases, temperature decreases and hence, in general, gas solubility increases. Similarly an increase in solubility should result from an increase in pressure which results from increased depth. However, actual concentrations of the gases on the surface waters of the ocean are still higher than the bulk of the ocean waters because of immediate contact with the atmosphere, the main source of these gases, and because of the inefficient mixing of surface waters with the bulk of the water of the ocean.	2

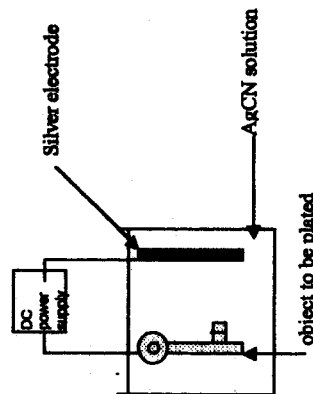
- (e) Three experiments represented in diagrams X, Y, and Z were set up.



In which of these experiments, all at the same temperature, will the iron corrode the most and which will corrode the least? Explain your answer.

Criteria	Mark(s)
Set-up Z will have the iron corroding most. This is because in contact with tin, iron act as the anode and the tin as the cathode. This is due to the greater tendency of iron ($E^{\circ}_{Fe} = -0.44$ v) i.e. more negative reduction potential, to be oxidised compared with Sn, ($E^{\circ}_{Sn} = -0.14$ v). The set-up which will corrode least is Y. Zinc in contact with iron protects the iron from corrosion by acting as the sacrificial anode in the 'corrosion' galvanic cell. This is due to the greater reactivity of zinc ($E^{\circ}_{Zn} = -0.76$ v) compared with iron ($E^{\circ}_{Fe} = -0.44$ v). The reaction in set-up Y is anode: $Zn(s) \rightarrow Zn^{2+} + 2e^{-}$ cathode: $O_2 + H_2O + 4e^{-} \rightarrow 4 OH^{-}$	2

- (f) Silver plated objects are obtained in an electrolytic cell in which the object is one electrode. The other electrode is a block of silver, and silver cyanide solution, $AgCN$, is the electrolyte. The cell is illustrated below:



- (i) Write a balanced equation to represent the oxidation process. At which electrode does this occur?

1

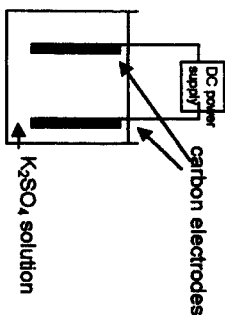
Criteria	Mark(s)
Ag(s) \rightarrow Ag ⁺ + e ⁻ This reaction occurs at the silver electrode, the positive electrode, the anode.	1

- (ii) Write a balanced equation to represent the reduction process. At which electrode does this occur?

1

Criteria	Mark(s)
Ag ⁺ + e ⁻ \rightarrow Ag(s) This reaction occurs at the cathode, the negative electrode, at the "object to be plated"	1

- (g) Consider the electrolysis set-up below:



Describe using half-equations what happens at the anode and the cathode during electrolysis

2

Criteria	Mark(s)
Anode: (positive electrode) H ₂ O \rightarrow 1/2 O ₂ (g) + 2 H ⁺ + 2e ⁻ Cathode: H ₂ O + e ⁻ \rightarrow 1/2 H ₂ (g) + OH ⁻	1 1

End of Question 29

END OF TEST ©

* The actual electrolyte species is Ag(CN)₂⁻.

