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**CHEMISTRY**

**UNITS 3 & 4**

**2023**

**MARKING GUIDE**

***TIME ALLOWED FOR THIS PAPER***

Reading time before commencing work: Ten minutes

Working time for the paper: Three hours

***MATERIALS REQUIRED/RECOMMENDED FOR THIS PAPER***

**To be provided by the supervisor:**

This Question/Answer Booklet

Multiple-choice Answer Sheet

Chemistry Data Book

**To be provided by the candidate:**

Standard items: pens, pencils, eraser or correction fluid, ruler, highlighter.

Special items: calculators satisfying the conditions set by the SCSA for this subject.

***IMPORTANT NOTE TO CANDIDATES***

No other items may be taken into the examination room. It is **your** responsibility to ensure that you do not have any unauthorised notes or other items of a non-personal nature in the examination room. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

**Structure of this paper**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Section | Number of questions available | Number of questions to be answered | Suggested working time  (minutes) | Marks available | Percentage of exam |
| Section One  Multiple-choice | 25 | 25 | 50 | 25 | 25 |
| Section Two  Short answer | 9 | 9 | 60 | 78 | 35 |
| Section Three  Extended answer | 5 | 5 | 70 | 86 | 40 |
|  |  |  |  | **Total** | 100 |

**Section One: Multiple-choice 25% (25 marks)**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 1 | a □ b □ c ■ d □ |  | 6 | a □ b □ c ■ d □ |  | 11 | a □ b ■ c □ d □ |
| 2 | a ■ b □ c □ d □ |  | 7 | a □ b □ c ■ d □ |  | 12 | a □ b □ c ■ d □ |
| 3 | a ■ b □ c □ d □ |  | 8 | a □ b □ c □ d ■ |  | 13 | a □ b □ c □ d ■ |
| 4 | a □ b ■ c □ d □ |  | 9 | a ■ b □ c □ d □ |  | 14 | a ■ b □ c □ d □ |
| 5 | a □ b ■ c □ d □ |  | 10 | a □ b ■ c □ d □ |  | 15 | a □ b □ c ■ d □ |

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 16 | a □ b ■ c □ d □ |  | 21 | a □ b □ c □ d ■ |  |  |  |
| 17 | a □ b ■ c □ d □ |  | 22 | a □ b □ c ■ d □ |  |  |  |
| 18 | a □ b ■ c □ d □ |  | 23 | a □ b □ c □ d ■ |  |  |  |
| 19 | a □ b □ c ■ d □ |  | 24 | a ■ b □ c □ d □ |  |  |  |
| 20 | a ■ b □ c □ d □ |  | 25 | a □ b ■ c □ d □ |  |  |  |

**Section Two: Short answer 35% (73 marks)**

**Question 26 (10 marks)**

(a) Identify the change that was imposed on the system at Time T1. (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Decrease in volume.  **or**  Volume of system was halved. | 1 |
| **Total** | **1** |
| Note: accept ‘an additional amount of each gas was injected simultaneously’ | |

(b) State and explain what happened to the **forward** reaction rate during each of the following time periods;

1. instantaneously, at Time T1. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| The forward reaction rate increased. | 1 |
| There are a greater number of gas particles per unit volume. | 1 |
| Therefore the frequency of (reactant) collisions would increase. | 1 |
| **Total** | **3** |

1. between Time T1 and T2. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| The forward reaction rate increased. | 1 |
| As the position of equilibrium shifts to the left, reactants are produced at a faster rate than they are consumed. | 1 |
| Therefore the frequency of (reactant) collisions would increase. | 1 |
| **Total** | **3** |

(c) On the graph on the previous page, continue the curves from Time T3 until equilibrium was re-established at Time T4. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |   l l l l  T1 T2 T3 T4  Time  Partial pressure (kPa)  Cl2(g)  O2(g)  Cl2O(g) | |
| Correct ‘direction’ (i.e. increase or decrease) of curves | 1 |
| Correct stoichiometric ratio shown in gradient of curves | 1 |
| Horizontal lines at T4 and beyond | 1 |
| **Total** | **3** |

**Question 27 (6 marks)**

(a) Identify the type of redox reaction occurring. (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| (Metal) displacement. | 1 |
| **Total** | **1** |

(b) Justify this is a redox reaction, by describing the process of electron transfer taking place. (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Electrons are transferred from copper metal to gold ions. | 1 |
| **Total** | **1** |

(c) Justify this is a spontaneous redox reaction, by referring to standard reduction potential data. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Au3+(aq) + 3 e- → Au(s) +1.50 V  Cu(s) → Cu2+(aq) + 2 e- - 0.34 V  +1.16 V | 1 |
| Since EMF > 0 reaction is spontaneous. | 1 |
| **Total** | **2** |
| Note: accept written answers that refer specifically to standard reduction potential data.  e.g. ‘For a reaction to be spontaneous, the EMF must be a positive value. Thus because the reduction potential for Au3+(aq) to Au(s) is +1.50 V, the oxidation potential of Cu(s) to Cu2+(aq) would have to be greater than -1.50 V. Since the oxidation potential of Cu(s) to Cu2+(aq) is -0.34 V, the reaction is spontaneous.’ | |

(d) Describe the observations that would be associated with this reaction. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Any two of the following:   * salmon pink metal dissolves * colourless solution becomes blue * yellow solid formed | 2 |
| **Total** | **2** |

**Question 28 (9 marks)**

(a) Write a balanced ionic equation for the reaction that would take place. Include state symbols in your answer. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Mg(s) + 2 H+(aq) → Mg2+(aq) + H2(g) | |
| Correct species and correctly balanced equation | 1 |
| Correct state symbols | 1 |
| **Total** | **2** |

(b) Calculate the original pH of the hydrochloric acid solution. (7 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| [H+ final] = 10-3.03  = 0.00093325 mol L-1 | 1 |
| n(H+ final) = 0.00093325 x 0.175  = 0.00016332 mol | 1 |
| n(Mg) = 1.074 / 24.31  = 0.044179 mol | 1 |
| n(H+ reacted) = 2 x n(Mg)  = 0.088359 mol | 1 |
| n(H+ initial) = 0.088359 + 0.00016332  = 0.088522 mol | 1 |
| [H+] = 0.088522 / 0.175  = 0.50584 mol L-1 | 1 |
| pH = -log(0.50584)  = 0.296 | 1 |
| **Total** | **7** |

**Question 29 (9 marks)**

(a) Complete the following table by;

* drawing structural diagrams for the organic substances named, and
* stating the expected observations for the distinguishing test described. (6 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| |  |  | | --- | --- | | Structural diagram: | Structural diagram: | | Distinguishing observation:  **white solid dissolves,**  **colourless (odourless) gas produced** | Distinguishing observation:  **no visible reaction** | | |
| Correct structural diagram of 2-methylpropanoic acid | 2 |
| Correct structural diagram of 3,3,4-trifluorobutanal | 2 |
| Correct distinguishing observation for 2-methylpropanoic acid | 1 |
| Correct distinguishing observation for 3,3,4-trifluorobutanal | 1 |
| **Total** | **6** |
| Note: one mark may be allocated per structural diagram for a minor error such as a ‘missing H atom’ etc. | |

(b) Complete the following table by;

* + stating the correct IUPAC name for the organic substances drawn, and
  + identifying the chemical(s) which could be used to produce the distinguishing observations given. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| |  |  | | --- | --- | | IUPAC name:  **2-bromo-4-methylhexan-3-one** | IUPAC name:  **3,5-dichloropentan-2-ol** | | A few drops of  **acidified dichromate solution OR H+/Cr2O72-(aq)**  is added and warmed. | | | |
| Correct IUPAC name of 2-bromo-4-methylhexan-3-one | 1 |
| Correct IUPAC name of 3,5-dichloropentan-2-ol | 1 |
| Correct identification of distinguishing reagent | 1 |
| **Total** | **3** |

**Question 30 (8 marks)**

(a) Suggest a reason that ‘redox flow batteries’ are classified as a type of fuel cell. (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| There is a continual flow of reactants through the cell. | 1 |
| **Total** | **1** |

(b) Classify the zinc-cerium battery as a primary or secondary cell. (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Secondary | 1 |
| **Total** | **1** |

(c) Consider the chemical processes occurring at the electrode in the zinc half-cell during **discharge**, and complete the following table. (3 marks)

|  |  |  |
| --- | --- | --- |
| **Description** | | **Marks** |
| Classify this electrode as the  ‘anode’ or ‘cathode’. | anode | 1 |
| Classify the polarity of this electrode  as ‘positive’ or ‘negative’. | negative | 1 |
| Identify whether cations would move  ‘toward’ or ‘away from’ this electrode. | away from | 1 |
| **Total** | | **3** |

(d) Calculate the maximum voltage produced by the zinc-cerium cell, under standard conditions. (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| +2.48 V | 1 |
| **Total** | **1** |

(e) Write a balanced chemical equation for the overall reaction that occurs during **recharge** of the zinc-cerium battery. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| 2 Ce3+(aq) + Zn2+(aq) → 2 Ce4+(aq) + Zn(s) |  |
| Correct species | 1 |
| Correct balancing | 1 |
| **Total** | **2** |
| Note: state symbols are not required for full marks | |

**Question 31 (10 marks)**

(a) Determine the empirical formula of the compound. (4 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| |  |  |  |  | | --- | --- | --- | --- | |  | **C** | **H** | **N** | | mass (g) | (39.9/100) x 1.839  = 0.73376 | 1.839 – 0.857 – 0.73376  = 0.24824 | 0.857 | | moles (mol) | 0.73376 / 12.01  = 0.061096 | 0.24824 / 1.008  = 0.24627 | 0.857 / 14.01  = 0.061171 | | ratio | 0.061096 / 0.061096  = 1 | 0.24627 / 0.061096  = 4 | 0.061171 / 0.061096  = 1 |   Empirical formula is CH4N | |
| Calculating mass of C | 1 |
| Calculating mass of H | 1 |
| Calculating moles of C/H/N | 1 |
| Determining simplest ratio and writing empirical formula as CH4N | 1 |
| **Total** | **4** |

(b) Determine the molecular formula of the compound. (4 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| n(HNO3) = 0.7406 x 0.02844  = 0.021063 mol | 1 |
| n(base) = ½ x n(HNO3)  = 0.010531 mol | 1 |
| M(base) = 0.633 / 0.010531  = 60.1063 g mol-1 | 1 |
| M / M(EF) = 60.1063 / 30.052  = 2  Therefore molecular formula is C2H8N2 | 1 |
| **Total** | **4** |

(c) Suggest a possible identity for this compound by drawing a structural diagram and stating the corresponding IUPAC name. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
|  | 1 |
| ethane-1,2-diamine **or** ethane-1,1-diamine | 1 |
| **Total** | **2** |

**Question 32 (9 marks)**

(a) Write the equilibrium constant expression (K) for this reaction. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| K = [I2][ H5IO6]5  [IO3-]7[H+]7 |  |
| Products over reactants | 1 |
| Correct indices | 1 |
| **Total** | **2** |

(b) Complete this table by stating how each of the changes would affect;

(i) the rate of the forward reaction once equilibrium is re-established, and

(ii) the position of equilibrium. (4 marks)

|  |  |  |  |
| --- | --- | --- | --- |
| **Description** | | | **Marks** |
| A few drops of starch solution  was added. | decreased | right | 2 |
| A 100 mL aliquot of distilled  water was added. | decreased | left | 2 |
| **Total** | | | **4** |

(c) On the axes below, sketch an energy profile diagram for this reaction. Label the activation energy and enthalpy change. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Progress of reaction  Enthalpy (kJ mol-1)  Ea  DH | |
| Exothermic shape of curve | 1 |
| Correctly labelled activation energy | 1 |
| Correctly labelled enthalpy change | 1 |
| **Total** | **3** |

**Question 33 (8 marks)**

(a) Identify the number of peptide bonds that would be formed during synthesis of the entire beta casein protein. (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| 208 | 1 |
| **Total** | **1** |

(b) Identify whether the diagram above represents the primary, secondary or tertiary structure of the beta casein protein. (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Primary | 1 |
| **Total** | **1** |

(c) Draw a full structural diagram of the **A2 variant** of the beta casein protein, showing only the amino acid residues from position 66 to 68. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
|  | |
| Three amino acids (Ile – Pro – Asn) drawn correctly | 1 |
| Both peptide links drawn correctly | 1 |
| Non-terminating ends | 1 |
| **Total** | **3** |

(d) Explain how an amino acid change can result in alteration of the shape of a protein.

(3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Changes to amino acids (in the primary structure) will incorporate different side chains. | 1 |
| Side chains determine the secondary and tertiary structures of a protein. | 1 |
| Secondary and tertiary structures determine the shape (and therefore function) of a protein. | 1 |
| **Total** | **3** |

**Question 34 (9 marks)**

(a) Explain, in terms of collision theory and reaction rates, why a ‘compromise’ temperature of around 300 °C is used for this industrial process. (6 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Explanation of effect of temperature on rate, for example:   * A high temperature will increase the average kinetic energy of particles. * This will increase the frequency of collisions and proportion of successful collisions. * Thus resulting in a faster reaction rate.   **or**   * A low temperature will decrease the average kinetic energy of particles. * This will decrease the frequency of collisions and proportion of successful collisions. * Thus resulting in a slower reaction rate. | 3 |
| Explanation of effect of temperature on yield, for example:   * A high temperature will result in a lower yield. * Since the reverse reaction rate will be increased relative to the forward reaction rate / the reverse reaction rate will be increased more than the forward reaction rate.   **or**   * A low temperature will result in a higher yield. * Since the reverse reaction rate will be decreased relative to the forward reaction rate / the reverse reaction rate will be decreased more than the forward reaction rate. | 2 |
| Statement addressing ‘compromise’, for example:   * A compromise temperature achieves a reasonable yield whilst maintaining a reasonable rate of reaction .   **or**   * a compromise temperature aims to simultaneously address the opposing requirements for high rate and yield. | 1 |
| **Total** | **6** |

(b) Explain why a much lower temperature of 25-35 °C is used for the production of ethanol by the fermentation method. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| The fermentation method uses an enzyme catalyst. | 1 |
| Enzymes are proteins which only function due to their shape. | 1 |
| The shape of an enzyme is maintained within an optimal temperature range.  **or**  A higher temperature would denature/destroy the shape (secondary and tertiary structures) of a protein/enzyme. | 1 |
| **Total** | **3** |

**Section Three: Extended answer 40% (85 marks)**

**Question 35 (20 marks)**

(a) State the systematic IUPAC name for oxalic acid. (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Ethanedioic acid | 1 |
| **Total** | **1** |

(b) Explain why oxalic acid is highly soluble in water. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| The predominant intermolecular forces in both water and oxalic acid are hydrogen bonds. | 1 |
| When these substances are mixed, new hydrogen bonds (and dipole-dipole and dispersion forces) are able to form between water and oxalic acid. | 1 |
| The formation of these new forces releases sufficient energy to overcome the original intermolecular forces within water and within oxalic acid.  **or**  The strength of these new forces are sufficient to overcome the original intermolecular forces within water and within oxalic acid. | 1 |
| **Total** | **3** |

(c) Explain why phenolphthalein, which has an end point of approximately pH 8.3 - 10, is an appropriate indicator choice for this titration. Use a chemical equation to support your answer. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Phenolphthalein has a basic end point which is chosen to coincide with the basic equivalence point in the titration. | 1 |
| The oxalate ions formed in this titration (hydrolyse with water to) produce an excess of hydroxide ions.  **or**  The oxalate ions produced in this titration result in [OH-] > [H3O+]. | 1 |
| C2O42-(aq) + H2O(l) ⇌ HC2O4-(aq) + OH-(aq) | 1 |
| **Total** | **3** |

(d) Calculate the percentage by mass of oxalic acid in the rhubarb leaves. State your answer to the appropriate number of significant figures. (7 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| n(NaOH initial) = 0.1014 x 0.02000  = 0.002028 mol | 1 |
| n(oxalic in 19.54 mL) = ½ x n(NaOH)  = 0.001014 mol | 1 |
| n(oxalic in 100.0 mL) = 0.001014 x (100/19.54)  = 0.005189 mol | 1 |
| n(oxalic in leaves) = 0.005189 mol | 1 |
| m(oxalic) = 0.005189 x 90.036  = 0.467229 g | 1 |
| % oxalic in leaves = (0.467229 / 73.82) x 100  = 0.63293 % | 1 |
| = 0.6329 % (4SF) | 1 |
| **Total** | **7** |

(e) Calculate the mass of rhubarb leaves that would need to be ingested by an average 70 kg person, to result in a lethal dose of oxalic acid being consumed. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| m(oxalic required for lethal dose) = (375/1000) x 70  = 26.25 g | 1 |
| m(leaves required for lethal dose) = 26.25 x (100/0.6329)  = 4148 g | 1 |
| **Total** | **2** |

(f) Identify which suggested improvement would increase the reliability and which would increase the validity. (2 marks)

|  |  |  |
| --- | --- | --- |
| **Description** | | **Marks** |
| Sampling leaves from different rhubarb plants  grown in different geographical regions. | validity | 1 |
| Repeating the volumetric analysis several times  to obtain an average titre. | reliability | 1 |
| **Total** | | **2** |

(g) State and explain the effect of this error on the calculated percentage by mass of oxalic acid in the rhubarb leaves. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| This error would dilute the rhubarb extract / increase the titre volume required. | 1 |
| Thus the calculated oxalic acid concentration would be lower. | 1 |
| **Total** | **2** |

**Question 36 (17 marks)**

(a) Explain how the total mass of hydroxyapatite in teeth can remain constant, despite the processes of demineralisation and mineralisation continually occurring. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Equilibrium has been established in this system. | 1 |
| The rate of forward reaction is equal to the rate of reverse reaction  **or**  The rate of demineralisation is equal to the rate of remineralisation | 1 |
| Thus there is a constant mass of hydroxyapatite. | 1 |
| **Total** | **3** |

(b) Justify, with reference to Le Chatelier’s principle, how consuming acidic foods can result in tooth decay. (4 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Acidic foods will (increase the concentration of H3O+ which will) decrease the concentration of OH- in the mouth. | 1 |
| (Le Chatelier’s principle predicts that) the system will therefore act to increase the concentration of OH-. | 1 |
| This will result in the forward reaction being favoured. | 1 |
| Thus the mass of hydroxyapatite/tooth enamel is decreased (leading to tooth decay).  **or**  Thus demineralisation of the teeth occurs faster than remineralisation (leading to tooth decay). | 1 |
| **Total** | **4** |

(c) Write a balanced chemical equation, illustrating how lactic acid lowers the pH inside the mouth. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **or** | |
| Correct species | 1 |
| Double arrow | 1 |
| **Total** | **2** |

(d) Explain, in terms of reaction rates, how this buffer system counteracts the lowered pH associated with consuming food. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| An increase in the concentration of H+ will increase the rate of both forward and reverse reactions (due to an increased frequency of collisions). | 1 |
| However the reverse reaction rate will be increased relative to the forward reaction rate / the reverse reaction rate will be increased more than the forward reaction rate. | 1 |
| Thus the buffer system favours the reverse reaction, lowering the concentration of H+ and maintaining the pH in the mouth. | 1 |
| **Total** | **3** |

(e) State and explain the effect this has on the buffering capacity of saliva. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Increased buffering capacity. | 1 |
| The concentration of the conjugate base species/component of the buffer has been increased. | 1 |
| Therefore a greater amount of H+/acidic food can be neutralised  (HCO3-(aq) + H3O+(aq) ⇌ H2O(l) + H2CO3(aq) ) | 1 |
| **Total** | **3** |

(f) By referring to the Kc values provided, justify why the presence of fluorapatite in teeth protects against tooth decay. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| The lower Kc value shows that fluorapatite is less soluble / less likely to undergo demineralisation. | 1 |
| Thus the tooth enamel is stronger / won’t be broken down as easily (conferring protection against tooth decay). | 1 |
| **Total** | **2** |

**Question 37 (15 marks)**

(a) Calculate the concentration of Mg2+(aq), in mg L-1, in the hard water sample. (7 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| n(Ca2+) = 0.004117 x 0.385  = 0.001585 mol | 1 |
| n(Ca(C15H31COO)2) = 0.001585 mol | 1 |
| m(Ca(C15H31COO)2) = 0.001585 x 550.896  = 0.87319 g | 1 |
| m(Mg(C15H31COO)2) = 1.636 – 0.87319  = 0.76281 g | 1 |
| n(Mg(C15H31COO)2) = 0.76281 / 535.126  = 0.0014255 mol  = n(Mg2+) | 1 |
| m(Mg2+) = 0.0014255 x 24.31 x 1000  = 34.653 mg | 1 |
| c(Mg2+) = 34.653 / 0.385  = 90.01 mg L-1 | 1 |
| **Total** | **7** |
| Alternate working (for final three marks):  m(Mg2+) = (24.31/535.126) x 0.76281  = 0.034653 g  = 34.653 mg  c(Mg2+) = 34.653 / 0.385  = 90.01 mg L-1 | |

(b) Calculate the minimum mass of sodium palmitate, C15H31COONa(s) (M = 278.398 g mol-1), required to ensure precipitation of all the Ca2+(aq) and Mg2+(aq) ions. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| n(C15H31COO- required) = 2 x n(Ca2+) + 2 x n(Mg2+)  = 2 x 0.001585 + 2 x 0.0014255  = 0.0060209 mol | 1 |
| n(C15H31COONa) = 0.0060209 mol | 1 |
| m(C15H31COONa) = 0.0060209 x 278.398  = 1.676 g | 1 |
| **Total** | **3** |

(c) Write a balanced chemical equation showing how the soap sodium palmitate can be produced. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **or**    **or** | |
| Correct reactants | 1 |
| Correct products | 1 |
| Correct balancing | 1 |
| **Total** | **3** |

(d) Explain why the detergent would be a more effective choice. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| No scum would be formed when using detergent.  **or**  The detergent surfactant won’t precipitate in hard water. | 1 |
| Therefore the surfactant ion remains dissolved/suspended/in a micelle and is able to clean (more effectively than soap). | 1 |
| **Total** | **2** |

**Question 38 (20 marks)**

(a) Complete the table below by;

(i) identifying the other reactant required to convert ethene to ethylene dichloride, and (ii) naming the type of reaction occurring in this step. (2 marks)

|  |  |  |
| --- | --- | --- |
| **Description** | | **Marks** |
| Identity of other reactant required | chlorine / Cl2 | 1 |
| Type of reaction occurring | addition / halogenation | 1 |
| **Total** | | **2** |

(b) Identify the type(s) of intermolecular force(s) that would exist within a sample of PVC. (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Dipole-dipole and dispersion forces. | 1 |
| **Total** | **1** |

(c) Draw a structural diagram showing three (3) repeating units of polystyrene. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
|  | |
| Correct structure of repeating unit shown | 1 |
| Three repeating units shown | 1 |
| **Total** | **2** |

(d) Name the co-monomer used in the production of LLDPE. (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Hex-1-ene | 1 |
| **Total** | **1** |

(e) State the effect this would have on the melting point of the LLDPE, and justify your answer by referring to the role of intermolecular forces present in the polymer. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| The melting point would decrease. | 1 |
| More branches on the polymer would disrupt the ability of the polymer chains to pack together / decrease the contact surface area between adjacent polymer chains. | 1 |
| This would result in weaker dispersion forces. | 1 |
| **Total** | **3** |

(f) Complete the table below by;

(i) drawing the structure of the other monomer required, and

(ii) naming the type of polymerisation reaction occurring to produce PET. (2 marks)

|  |  |  |
| --- | --- | --- |
| **Description** | | **Marks** |
| Structural diagram of other  monomer required |  | 1 |
| Type of polymerisation  reaction occurring | condensation | 1 |
| **Total** | | **2** |

(g) Determine the limiting reagent. Show all workings. (6 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| V(O2 present) = (95/100) x 13.6 x 1000  = 12920 L | 1 |
| n(O2 present) = (2500 x 12920) / (8.314 x 533.15)  = 7286.9 mol | 1 |
| m(CH2CH2 present) = 228 x 1000  = 228000 g | 1 |
| n(CH2CH2 present) = 228000 / 28.052  = 8127.8 mol | 1 |
| n(O2 required) = (6/7) x 8127.8  = 6966.7 mol  **or**  n(CH2CH2 required) = (7/6) x 7286.9  = 8501.4 mol | 1 |
| Since n(CH2CH2 present) < n(CH2CH2 required) **ethene** is the limiting reagent.  **or**  Since n(O2 present) > n(O2 required) **ethene** is the limiting reagent. | 1 |
| **Total** | **6** |

(h) Calculate the percent yield of this process. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| n(theoretical CH2CH2O) = (6/7) x n(CH2CH2)  = 6966.7 mol | 1 |
| m(theoretical CH2CH2O) = 6966.7 x 44.052  = 306895 g  = 306.895 kg | 1 |
| % yield = (279 / 306.895) x 100  = 90.91 % | 1 |
| **Total** | **3** |

**Question 39 (14 marks)**

(a) Write balanced half-equations for the **initial** reactions that occur during the electrochemical process of corrosion. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| anodic region: Fe(s) → Fe2+(aq) + 2 e-  cathodic region: O2(g) + 2 H2O(l) + 4 e- → 4 OH-(aq) | |
| Correct oxidation half-equation | 1 |
| Correct reduction half-equation | 1 |
| Half-equations assigned to correct electrode region | 1 |
| **Total** | **3** |

(b) On the diagram above, label the direction of electron flow. (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Diagram  Description automatically generated | |
| Labelled arrow shown correctly on diagram | 1 |
| **Total** | **1** |

(c) Explain how these aluminium blocks are able to reduce the rate of corrosion. Support your answer with an appropriate half-equation. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| The aluminium is preferentially oxidised in place of the iron. | 1 |
| Al(s) → Al3+(aq) + 3 e- | 1 |
| This is because it has a higher oxidation potential than iron / is more easily oxidised than iron / has an oxidation potential greater than +0.44 V / has an oxidation potential of +1.68 V. | 1 |
| **Total** | **3** |

(d) On the diagram above, label the polarity (sign) of the power supply terminals. (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Diagram, shape  Description automatically generated | |
| Polarities shown correctly on diagram | 1 |
| **Total** | **1** |

(e) Write balanced half-equations representing each of the possible reactions that could occur at the inert electrode. (4 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| regular seawater: 2 Cl-(aq) → Cl2(g) + 2 e- | |
| Correct species | 1 |
| Correct balancing | 1 |
| low saline seawater: 2 H2O(l) → O2(g) + 4 H+(aq) + 4 e- | |
| Correct species | 1 |
| Correct balancing | 1 |
| **Total** | **4** |

(f) Describe why ‘sacrificial anode cathodic protection’ is considered a galvanic process, but ‘impressed current cathodic protection’ is considered an electrolytic process. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Sacrificial anode cathodic protection is a spontaneous redox reaction. | 1 |
| Impressed current cathodic protection is a non-spontaneous redox reaction. | 1 |
| **Total** | **2** |