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**CHEMISTRY**

**UNIT 3**

**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 | 8 | 8 | 60 | 75 | 35 |
| Section Three  Extended answer | 5 | 5 | 70 | 89 | 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% (75 marks)**

**Question 26 (11 marks)**

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

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Progress of reaction  Enthalpy (kJ mol-1)  Ea  DH  H2(g) + Br2(g)  2 HBr(g) |  |
| Shape of curve is exothermic | 1 |
| Reactants and products labelled | 1 |
| Activation energy and enthalpy change correctly labelled | 1 |
| **Total** | **3** |

(b) Explain, in terms of collision theory, how platinum increases the rate of this reaction.

(2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| A catalyst provides an alternate reaction pathway with a lower activation energy. | 1 |
| This results in a greater proportion of particles with Ek > Ea. | 1 |
| **Total** | **2** |

(c) Complete the tables below by;

* identifying two (2) changes that could be imposed on this system, which would result in a darker red-brown appearance, and
* justifying why this colour change occurs. (6 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Imposed change 1**   * Increase in temperature. | 1 |
| **Justification**   * The endothermic / reverse reaction would be favoured. * This would result in an increased concentration of Br2(g) (and thus result in a darker colour). | 1  1 |
| **Imposed change 2**   * Decrease in volume. | 1 |
| **Justification**   * The gas particles would be forced into a smaller space. * This would result in an increased concentration of Br2(g) (and thus result in a darker colour). | 1  1 |
| **Total** | **6** |

**Question 27 (10 marks)**

(a) Write an equation for this process that illustrates each the Arrhenius and Bronsted-Lowry behaviours of an acid. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Arrhenius**  HMnO4(aq) → H+(aq) + MnO4-(aq) | 1 |
| **Bronsted-Lowry**  HMnO4(aq) + H2O(l) → H3O+(aq) + MnO4-(aq) | 1 |
| Both equations use a single arrow. | 1 |
| **Total** | **3** |
| Note: state symbols are not required for full marks. | |

(b) Demonstrate, with the use of oxidation numbers, that permanganic acid is both the oxidising and reducing agent in this reaction. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Mn atoms are reduced, oxidation number changes from (+7) to (+4). | 1 |
| O atoms are oxidised, oxidation number changes from (–2) to (0) / (–1). | 1 |
| **Total** | **2** |

(c) Explain, in terms of collision theory, how adding heat or other acids can speed up this decomposition reaction. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Addition of heat**   * The average kinetic energy of particles is increased. * This results in a higher frequency of collisions and a greater proportion of successful collisions. | 1  1 |
| **Addition of other acids**   * An increased concentration of H+(aq) / H3O+(aq) results in a higher frequency of reactant collisions (i.e. between H+(aq) and MnO4-(aq)). | 1 |
| **Total** | **3** |

(d) What is the likely pH of sodium permanganate solution, NaMnO4(aq)? Circle your choice below and justify your answer. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| 7 (circled) | 1 |
| The conjugate base of a strong acid is neutral.  **or**  The salt formed from a strong acid and strong base is neutral.  **or**  Neither Na+(aq) or MnO4-(aq) undergo hydrolysis. | 1 |
| **Total** | **2** |

**Question 28 (9 marks)**

(a) Calculate the concentration of hydrochloric acid (in mol L-1) in the freshly prepared aqua regia sample. (6 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| n(NaOH) = 0.1778 x 0.01728  = 0.0030724 mol | 1 |
| n(H+ in 15 mL) = 0.0030724 mol | 1 |
| n(H+ in 250 mL) = 0.0030724 x (250 / 15)  = 0.0512064 mol | 1 |
| = n(H+ in 5 mL of aqua regia) | 1 |
| n(H+ from HCl) = (3 / 4) x 0.0512064  = 0.0384048 mol | 1 |
| c(HCl) = 0.0384048 / 0.005  = 7.681 mol L-1 | 1 |
| **Total** | **6** |

(b) Describe why the concentration of hydrochloric acid calculated is likely to be lower than that used to prepare the original aqua regia solution. (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| As decomposition of aqua regia occurs, the concentration of hydrochloric (and nitric) acid will fall. | 1 |
| **Total** | **1** |

(c) Identify two (2) safety risks the chemist should consider when performing this analysis. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Any two (2) of the following:   * Acids (HCl / HNO3) are corrosive * Toxic vapours are produced during the decomposition * Bases (NaOH) are caustic | 2 |
| **Total** | **2** |

**Question 29 (9 marks)**

(a) Write a balanced ionic equation for the reaction that would occur when 1.0 mol L-1 nitric acid is poured over powdered iron(III) carbonate. Include state symbols in your answer. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Fe2(CO3)3(s) + 6 H+(aq) → 2 Fe3+(aq) + 3 CO2(g) + 3 H2O(l) |  |
| Correct species | 1 |
| Correct balancing | 1 |
| Correct state symbols | 1 |
| **Total** | **3** |

(b) Write observations for the reaction that would take place when chlorine gas is bubbled through sodium bromide solution. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| A green-yellow gas dissolves in a colourless solution. | 1 |
| An orange solution is formed. | 1 |
| **Total** | **2** |

(c) Write balanced oxidation and reduction half-equations for the reaction that would occur when a several pieces of chromium are placed in a tin(II) nitrate solution. (2 marks)

|  |  |  |
| --- | --- | --- |
| **Description** | | **Marks** |
| Oxidation | Cr(s) → Cr3+(aq) + 3 e- | 1 |
| Reduction | Sn2+(aq) + 2 e- → Sn(s) | 1 |
| **Total** | | **2** |
| Note: state symbols are not required for full marks. | | |

(d) Prove whether the reaction below would occur spontaneously, under standard conditions.

(2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Fe2+(aq) → Fe3+(aq) + e- – 0.77 V  O2(g) + 2 H+(aq) + 2 e- → H2O2(aq) + 0.70 V | 1 |
| EMF is negative / less than zero / – 0.07 V (therefore reaction would not occur spontaneously). | 1 |
| **Total** | **2** |

**Question 30 (9 marks)**

Complete the table, by stating the effect of each change on the;

* position of equilibrium
* rate of the reverse reaction, and
* concentration of O2(g).

|  |  |
| --- | --- |
| **Description** | **Marks** |
| |  |  |  |  | | --- | --- | --- | --- | |  | Position of equilibrium | Rate of reverse reaction | Concentration of O2(g) | | Addition of H2O(g) at constant volume | **left** | **increased** | **decreased** | | Removal of NH3(g) at constant volume | **left** | **decreased** | **decreased** | | Decrease total volume of system | **right** | **increased** | **increased** | | 9 |
| **Total** | **9** |

**Question 31 (10 marks)**

Calculate the pH of the filtered water sample. You may assume the original pH of the untreated water was 7.

|  |  |
| --- | --- |
| **Description** | **Marks** |
| m(Mn2+ in sample) = 0.120 x 455  = 54.6 mg | 1 |
| = 0.0546 g | 1 |
| n(Mn2+) = 0.0546 / 54.94  = 0.0009938 mol | 1 |
| n(MnO(OH)2) = 0.0009938 mol | 1 |
| m(MnO(OH)2) = 0.0009938 x 104.956  = 0.1043 g | 1 |
| m(Fe(OH)3) = 0.487 – 0.1043  = 0.3827 g | 1 |
| n(Fe(OH)3) = 0.3827 / 106.874  = 0.003581 mol | 1 |
| n(H+ total) = 2 x n(Fe(OH)3) + 2 x n(MnO(OH)2)  = 0.009149 mol | 1 |
| c(H+) = 0.009149 / 455  = 2.011 x 10-5 mol L-1 | 1 |
| pH = – log (2.011 x 10-5)  = 4.697 | 1 |
| **Total** | **10** |

**Question 32 (8 marks)**

(a) On the equation above, label and link the conjugate acid-base pairs. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| H2PO4-(aq) + CO32-(aq) ⇌ HCO3-(aq) + HPO42-(aq)  **acid base acid base** |  |
| Acidic and basic species correctly labelled | 1 |
| Pairs correctly linked | 1 |
| **Total** | **2** |

(b) Identify one (1) solution above that would have a pH below 7, and support your choice with an appropriate chemical equation. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| NaH2PO4 | 1 |
| H2PO4-(aq) + H2O(l) ⇌ HPO42-(aq) + H3O+(aq) | 1 |
| **Total** | **2** |
| Note: state symbols are not required for full marks. | |

(c) Identify one (1) solution above that would have a pH above 7, and support your choice with an appropriate chemical equation. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Na2CO3  **or**  NaHCO3  **or**  Na2HPO4 | 1 |
| CO32-(aq) + H2O(l) ⇌ HCO3-(aq) + OH-(aq)  **or**  HCO3-(aq) + H2O(l) ⇌ H2CO3(aq) + OH-(aq)  **or**  HPO42-(aq) + H2O(l) ⇌ H2PO4-(aq) + OH-(aq) | 1 |
| **Total** | **2** |
| Note: state symbols are not required for full marks. | |

(d) Define the term ‘polyprotic’ and name one (1) different polyprotic acid. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Donates more than one proton / H+ per molecule.  **or**  Contains more than one acidic / ionisable hydrogen per molecule. | 1 |
| Many possible answers, including;   * sulfuric acid * sulfurous acid * oxalic acid | 1 |
| **Total** | **2** |

**Question 33 (9 marks)**

(a) Write balanced half-equations for the reactions occurring at each electrode. (3 marks)

|  |  |  |
| --- | --- | --- |
| **Description** | | **Marks** |
| Cathode | Cl2(g) + 2 e- → 2 Cl-(aq) | 1 |
| Anode | Co(s) → Co2+(aq) + 2 e- | 1 |
| Half-equations matched to correct electrode | | 1 |
| **Total** | | **3** |
| Note: state symbols are not required for full marks. | | |

(b) Complete the following table. (3 marks)

|  |  |  |
| --- | --- | --- |
| **Description** | | **Marks** |
| Concentration of Co2+(aq) | 1 mol L-1 | 1 |
| Pressure of Cl2(g) | 100 kPa **or** 101.3 kPa | 1 |
| EMF | +1.64 V | 1 |
| **Total** | | **3** |
| Note: correct units are required for full marks. | | |

(c) Complete the following table, for this version of the cell. (3 marks)

|  |  |  |
| --- | --- | --- |
| **Description** | | **Marks** |
| Polarity of C(s) | positive | 1 |
| Observations at C(s) | colourless (odourless) gas produced | 1 |
| EMF | +0.28 V | 1 |
| **Total** | | **3** |

**Section Three: Extended answer 40% (89 marks)**

**Question 34 (16 marks)**

(a) On the axes below, sketch a titration curve for this investigation. Label the equivalence point. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Volume of HCl(aq)  pH 7 –  ← equivalence point |  |
| Initial and final pH approximated correctly | 1 |
| Shape of curve sketched correctly | 1 |
| Equivalence point labelled correctly | 1 |
| **Total** | **3** |

(b) Calculate the average titre using the professor’s data. (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| 22.37 mL | 1 |
| **Total** | **1** |

(c) Which student obtained the most precise results? Justify your answer. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Student A | 1 |
| Data set has the smallest range. | 1 |
| **Total** | **2** |

(d) Which student used phenolphthalein indicator (end point pH 8.8 - 10.1) in their titration? Justify your answer. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Student C | 1 |
| A basic end point would occur before the equivalence point, resulting in titres volumes being lower than the true value. | 1 |
| **Total** | **2** |

(e) Suggest two (2) sources of random error that may have affected the professor’s results. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Any two (2) of the following:   * Slight errors in reading glassware volumes * Judgement of end point colour * Drops of solution remaining inside pipette / on sides of conical flask * Small bubbles of air trapped in burette tap | 2 |
| **Total** | **2** |

(f) Calculate the concentration of the hydrochloric acid solution, using the professor’s results. State your answer to the appropriate number of significant figures. (6 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| n(Na2B4O7.10H2O) = 11.06 / 381.38  = 0.02890 mol | 1 |
| c(B4O72-) = 0.02890 / 0.5  = 0.0580 mol L-1 | 1 |
| n(B4O72- in 20 mL) = 0.0580 x 0.02  = 0.001160 mol | 1 |
| n(H+ total) = 2 x n(B4O72-)  = 0.002320 mol | 1 |
| c(H+) = 0.002320 / 0.02237  = 0.10371 mol L-1 | 1 |
| = 0.1037 mol L-1 (4 SF) | 1 |
| **Total** | **6** |

**Question 35 (16 marks)**

(a) Write the equilibrium expression for this reaction when it is in equilibrium. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| or  p(N2)p(O2)2  p(NO2)2  K =  [N2][O2]2  [NO2]2  K = | 2 |
| One superscript incorrect or missing. | 1 |
| **Total** | **2** |

(b) Assuming all other conditions remain constant, what happens to the equilibrium constant after the pressure of the system, is lowered and equilibrium is re-established? (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| No change in K | 1 |
| **Total** | **1** |

(c) (i) On the axes below, draw the forward ( \_\_\_\_ ) and reverse (- - -) reaction rates, starting at the moment the oxygen and nitrogen gases begin to react with each other until after equilibrium has been established at time A. Continue the graph until time B. (3 marks) A diagram of a temperature

Description automatically generated with low confidence

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Both curves have the correct shape & orientation | 1 |
| Both curves meeting at point A | 1 |
| Straight line between point A and B | 1 |
| **Total** | **3** |

(ii) On the same axes above, draw and clearly label the effect of conducting the same reaction at a higher temperature. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| The added curves show: |  |
| Equilibrium reached sooner | 1 |
| Reaction rates are higher | 1 |
| **Total** | **2** |

(d) On the axes below, draw separate curves to show how the concentrations of the three gases change with time, starting at the moment the oxygen and nitrogen gases begin to react with each other until the system reaches equilibrium at Time E1. Continue the graph from Time E1 to Time E2. Assume that the initial concentrations of oxygen and nitrogen are identical.

Label clearly the line for each gas. (5 marks)

A picture containing line, diagram, plot, slope

Description automatically generated

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Correct shape and orientation for curves depicting N­2(aq) and O2(g) | 1 |
| Correct shape and orientation for curve depicting NO2(g) | 1 |
| Curve for NO2(g) starting at zero | 1 |
| Ratio of change 2:1 for O2(g) compared with N2(g) | 1 |
| Straight horizontal lines between E1 and E2 | 1 |
| **Total** | **5** |

(e) At Time E2 shown on the axis, the reaction vessel is doubled in volume, and the systemis then again allowed to reach equilibrium at Time E3. On the same graph above, showhow the concentrations of the three gases would change in response to the change in

volume, from Time E2 until equilibrium is re-established at Time E3. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Immediate reduction (halving) of concentration for all gases | 1 |
| Correct shape and orientation for curve for N2(g) and O2(g) | 1 |
| Correct shape and orientation for curve for NO2(g) | 1 |
| **Total** | **3** |

**Question 36 (20 marks)**

(a) Classify these equilibria as ‘homogeneous’ or ‘heterogeneous’, and write the equilibrium constant expression for each. (4 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Equilibrium 1** |  |
| Heterogeneous | 1 |
| [Cu2+] [OH-]2  1  K = | 1 |
| **Equilibrium 2** |  |
| Homogeneous | 1 |
| [Cu2+] [NH3]4  [Cu(NH3)42+]  K = | 1 |
| **Total** | **4** |

(b) Describe any observations that would have been made as equilibrium was established. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Blue solution fades. | 1 |
| Blue solid forms. | 1 |
| **Total** | **2** |

(c) On the graph above, add a curve showing the concentration changes for OH-(aq) ions, from Time 0 to E1. Continue your curve from Time E1 to T1. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
|  |  |
| Correct initial (0.11 mol L-1) and final (0.03 mol L-1) concentration of OH-(aq) | 1 |
| Correctly sketched shape of curve from Time 0 to E1 | 1 |
| Horizontal from E1 to T1 | 1 |
| **Total** | **3** |

(d) Explain why no curve can be plotted for Cu(OH)2(s). (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Solids do not have a measurable concentration / can be considered to have a fixed concentration. | 1 |
| **Total** | **1** |

(e) Explain, in terms of collision theory, what is happening to the rate of the forward reaction from Time 0 to Time E1. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Concentration of reactant particles / Cu2+(aq) and OH-(aq) is decreasing. | 1 |
| Thus, less frequent collisions are occurring. | 1 |
| The forward reaction rate is therefore decreasing. | 1 |
| **Total** | **3** |

(f) On the same graph above, sketch a curve using a dotted line, showing the change in concentration for NH3(aq) from Time T1 until equilibrium is established at Time E2. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Chart, line chart  Description automatically generated |  |
| Vertical line at T1 showing addition of NH3(aq) | 1 |
| Correctly sketched shape of curve from Time T1 to E2 (no particular gradient or estimation of concentration values are necessary) | 1 |
| **Total** | **2** |
| Note: no particular gradient or estimation of initial / final concentration values are necessary in this question; marks should be allocated for a curve that matches the shape of that above. | |

(g) Explain this observation, in terms of collision theory and reaction rates. (5 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Addition of NH3 decreased the concentration of Cu2+(aq) (present in Equilibrium 1). | 1 |
| This resulted in a decrease in the frequency of reactant collisions. | 1 |
| The forward and reverse reaction rates were both decreased, but the forward rate decreased by more.  **or**  The forward and reverse reaction rates were both decreased, but the reverse rate decreased by less.  **or**  Therefore the reverse reaction rate was occurring faster than the forward reaction rate. | 1 |
| This resulted in the reverse reaction being favoured.  **or**  This resulted in a shift to the left. | 1 |
| Thus Cu(OH)2(s) was consumed (decreasing the mass present). | 1 |
| **Total** | **5** |

**Question 37 (19 marks)**

(a) Write a series of two (2) balanced chemical equations, showing how the production of CO2(aq) by the fish, results in a lowered water pH. (2 marks)

|  |  |  |
| --- | --- | --- |
| **Description** | | **Marks** |
| 1. | CO2(aq) + H2O(l) ⇌ H2CO3(aq) | 1 |
| 2. | H2CO3(aq) + H2O(l) ⇌ H3O+(aq) + HCO3-(aq)  **or**  H2CO3(aq) ⇌ H+(aq) + HCO3-(aq) | 1 |
| **Total** | | **2** |
| Note: state symbols are not required for full marks. | | |

(b) Describe how this results in the formation of an ‘open system’. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| In an open system matter and energy can be exchanged. | 1 |
| (Opening the bag results in) CO2(g) is able to leave the system / air is able to enter the system. | 1 |
| **Total** | **2** |

(c) Write a chemical equation showing how CaCO3(s) can result in an increased water pH. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| CO32-(aq) + H2O(l) ⇌ HCO3-(aq) + OH-(aq)  **or**  CaCO3(s) + 2 H+(aq) → Ca2+(aq) + CO2(aq) + H2O(l)  **or**  CaCO3(s) + 2 H3O+(aq) → Ca2+(aq) + CO2(aq) + 3 H2O(l) |  |
| Correct species | **1** |
| Correct balancing | **1** |
| **Total** | **2** |
| Note: state symbols are not required for full marks. | |

(d) Explain how this buffer allows the pH of aquarium water to be maintained, as acids are produced. Use a chemical equation to support your answer. (4 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Production of acids will increase the concentration of H3O+(aq). | 1 |
| This will react with the conjugate base component / CO32-(aq) in the buffer. | 1 |
| H3O+(aq) + CO32-(aq) ⇌ HCO3-(aq) + H2O(l) | 1 |
| The concentration of H3O+(aq) is thus relatively unaltered, maintaining pH. | 1 |
| **Total** | **4** |

(e) Write balanced half-equations, in acidic conditions, representing both processes performed by the nitrifying bacteria. (4 marks)

|  |  |  |
| --- | --- | --- |
| **Description** | | **Marks** |
| Ammonia to nitrite ions | NH3(aq) + 2 H2O(l) → NO2-(aq) + 7 H+(aq) + 6 e- | 1 |
| Nitrite ions to nitrate ions | NO2-(aq) + H2O(l) → NO3-(aq) + 2 H+(aq) + 2 e- | 1 |
| **Total** | | **2** |
| Note: state symbols are not required for full marks. | | |

(f) Describe how the student could prepare a full tank of water with a pH of 8.6. Support your answer with appropriate calculations. (5 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| [H+ desired] = 10-8.6  = 2.5119 x 10-9 mol L-1 | 1 |
| [OH- desired] = (1.0 x 10-14) / (2.5119 x 10-9)  = 3.9811 x 10-6 mol L-1 | 1 |
| n(OH- required) = 3.9811 x 10-6 x 75  = 2.9858 x 10-4 mol | 1 |
| V(NaOH required) = 2.9858 x 10-4 / 0.02717  = 0.01099 L | 1 |
| Place 11 mL of NaOH in the tank, and make up to 75 L with distilled water. | 1 |
| **Total** | **5** |
| Alternate working for final two steps of calculation:  V(NaOH required) = c2V2 / c1  = (3.9811 x 10-6 x 75) / 0.02717  = 0.01099 L | |

**Question 38 (18 marks)**

A diagram of a salt bridge

Description automatically generated with medium confidence

Negative ions

Positive ions

Cathode

Anode

(a) Draw an arrow between points A and B to show the direction of electron flow. (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Arrow pointing from B to A | 1 |
| **Total** | **1** |

(b) On the diagram above label the anode and cathode, and show the direction of ion flow through the salt bridge. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Labels the copper electrode as the anode | 1 |
| Labels the chlorine component as the cathode | 1 |
| Shows arrows representing ion movement | 1 |
| **Total** | **3** |

(c) Provide two reasons for why a salt bridge is necessary in this cell. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Maintain the flow of charge | 1 |
| Prevent build-up of negative charge at the cathode | 1 |
| **Total** | **2** |

(d) Complete the table below, writing the half-equations occurring at each electrode, and then the overall redox reaction for this cell. (4 marks)

|  |  |  |
| --- | --- | --- |
| **Description** | | **Marks** |
| Correctly places half-equations | | 1 |
| Correct Cl2 half-equation | | 1 |
| Correct Cu half-equation | | 1 |
| Correct total equation | | 1 |
| **Total** | | **4** |
| Reduction | Cl2 + 2e- 🡪 2Cl- | |
| Oxidation | Cu 🡪 Cu2+ + 2e- | |
| Overall Redox | Cl2 + Cu 🡪 Cu2+ + 2Cl- | |

(e) State the observation that you would expect to see in the Cl2/NaCl half-cell. (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| A greenish-yellow gas will decolourise | 1 |
| **Total** | **1** |

(f) Predict a metal/metal ion cell that could be used in place of the Cu/Cu2+ cell to give a higher emf (volts). (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Any of: Pb/Pb2+, Sn/Sn2+, Ni/Ni2+, Co/Co2+, Cd/Cd2+, Fe/Fe2+, Cr/Cr3+, Zn/Zn2+, Mn/Mn2+, Al/Al3+, Mg/Mg2+, Na/Na+, Ca/Ca2+, Sr/Sr2+, Ba/Ba2+, K/K+ | 1 |
| **Total** | **1** |

(g) The mass of the copper electrode submerged in the Cu(NO3)2 solution was 12.6g, 0.4L of Cl2(g) at STP was also available. Determine the limiting reagent in this cell. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| n(Cu) = 12.6 / 63.55  = 0.198 mol | 1 |
| n(Cl2) = 0.4 / 22.71  = 0.0176 mol | 1 |
| The limiting reagent is the chlorine gas. | 1 |
| **Total** | **3** |

(h) The cell is allowed to react until the limiting reagent is used up. Determine the mass of the excess reagent remaining once the cell has stopped functioning. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| n(Cu reacted) = n(Cl2)  = 0.0176 mol | 1 |
| m(Cu reacted) = 0.0176 x 63.55  = 1.12 g | 1 |
| m(Cu leftover) = 12.6 – 1.12  = 11.5 g | 1 |
| **Total** | **3** |