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**CHEMISTRY**

**UNIT 3**

**2022**

**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 | 73 | 35 |
| Section Three  Extended answer | 5 | 5 | 70 | 85 | 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 (8 marks)**

(a) State the value, including appropriate units, of (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| (i) -100 kJ mol-1 | 1 |
| (ii) accept values in the range 125-135 kJ mol-1 | 1 |
| **Total** | **2** |

(b) Which reaction (A, B or C) is **not** a combustion reaction? Justify your choice. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Reaction A | 1 |
| Any of the following justifications:   * unlike reaction A, combustion reactions are always exothermic * unlike reaction A, combustion of a fuel will release heat energy * reaction A is the only endothermic reaction * in reaction A the value of DH is a positive value * in reaction A the enthalpy of the products is greater than the enthalpy of the reactants | 1 |
| **Total** | **2** |

(c) Which reaction (A, B or C) represents combustion of the fuel with the lowest autoignition point? Justify your choice. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Reaction B | 1 |
| Lowest (forward) activation energy | 1 |
| **Total** | **2** |

(d) Which reaction (A, B or C) is most likely to be reversible? Justify your choice. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Reaction A | 1 |
| Any of the following justifications:   * lowest activation energy in both forward and reverse directions * combustion reactions (i.e. B and C) are not reversible | 1 |
| **Total** | **2** |

**Question 27 (10 marks)**

(a) Explain, in terms of the collision theory, why the batteries are crushed before being mixed with the leach solution. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| This will increase the surface area / state of subdivision (of the solid material), | 1 |
| resulting in an increased frequency of collisions with the leaching solution. | 1 |
| Thus the rate of reaction is increased. | 1 |
| **Total** | **3** |

(b) Calculate the concentration of hydrogen peroxide, in grams per litre, that would be present in the leach solution after 5 hours. (7 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| m(LiCoO2) = (48.6/100) x 5.00  = 2.43 g | 1 |
| n(LiCoO2) = 2.43 / 97.87  = 0.024829 mol | 1 |
| n(H2O2 used) = (3/2) x 0.024829  = 0.037243 mol | 1 |
| n(H2O2 initial) = 0.60 x 0.150  = 0.09 mol | 1 |
| n(H2O2 remaining) = 0.09 – 0.037243  = 0.052757 mol | 1 |
| m(H2O2 remaining) = 0.052757 x 34.016  = 1.79457 g | 1 |
| c(H2O2 remaining) = 1.79457 / 0.15  = 12 g L-1 | 1 |
| **Total** | **7** |

**Question 28 (7 marks)**

(a) Identify the feature of the hydrazine molecule that allows it to behave as a Br**∅**nsted-Lowry base. (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Non-bonding / lone pair of electrons (on the nitrogen atom) | 1 |
| **Total** | **1** |

(b) Amend the Lewis diagram above, to represent the conjugate acid of hydrazine, which is named ‘hydrazinium’. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| H  +  H  +  **or** |  |
| Addition of H on non-bonding electrons of either N atom | 1 |
| Positive charge shown (may be on N atom or outside of square brackets) | 1 |
| **Total** | **2** |

(c) Write a balanced chemical equation showing the reaction between hydrazine and nitric acid, to form the salt hydrazinium nitrate. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| N2H4(aq) + HNO3(aq) → N2H5NO3(aq)  **or**  N2H4(aq) + H+(aq) → N2H5+(aq)  **or**  N2H4(aq) + H3O+(aq) → N2H5+(aq) + H2O(l) |  |
| Correct reactant species | 1 |
| Correct product species | 1 |
| **Total** | **2** |
| Note: state symbols are not required for full marks | |

(d) Predict whether the resulting solution would be acidic, basic or neutral (circle your choice). Use a chemical equation to support your answer. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Acidic (circled) | 1 |
| N2H5+(aq) + H2O(l) ⇌ N2H4(aq) + H3O+(aq) | 1 |
| **Total** | **2** |
| Note: state symbols are not required for full marks | |

**Question 29 (7 marks)**

(a) Select a piece of data that supports the assertion ‘AgBr(s) has a very low aqueous solubility’. Justify your answer. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| The Kc value for equation 1 is very small. | 1 |
| This indicates a very small concentration of each product is present, demonstrating the dissolution of AgBr occurs to a small extent. | 1 |
| **Total** | **2** |

(b) Use Le Chatelier’s principle, to describe how the introduction of thiosulfate ions assists in removing the silver bromide crystals from the photographic film. (5 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| When the concentration of S2O32-(aq) is increased, the system will act to decrease the concentration of S2O32-(aq) ions. | 1 |
| Thus the forward reaction in equation 2 will be favoured.  **or**  Thus the equilibrium in equation 2 will shift to the right. | 1 |
| This will reduce the concentration of Ag+(aq) present, | 1 |
| therefore the forward reaction in equation 1 will also be favoured.  **or**  therefore the equilibrium in equation 1 will also shift to the right. | 1 |
| This decreases the amount of AgBr(s) present (and thus removes it from the photographic film). | 1 |
| **Total** | **5** |

**Question 30 (6 marks)**

(a) Write a balanced equation for this half-reaction, and suggest a value for the associated standard reduction potential. (4 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Half-reaction**  H2SeO4(aq) + 2 H+(aq) + 2 e- ⇌ H2SeO3(aq) + H2O(l)  **or**  SeO42-(aq) + 4 H+(aq) + 2 e- ⇌ H2SeO3(aq) + H2O(l) |  |
| Correct species | 1 |
| Correct balancing | 1 |
| **E0 value**  Any value between (but not including) +1.36 V and +1.51 V |  |
| Value within acceptable range | 1 |
| Correct units | 1 |
| **Total** | **4** |

(b) Justify whether selenic acid could be prepared by reacting acidified sodium dichromate solution with selenous acid, under standard conditions. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| The reduction potential of dichromate (+1.36 V) is lower than that of selenic acid, H2SeO4.  **or**  The reduction potential of selenic acid, H2SeO4,is higher than that of dichromate (+1.36V).  **or**  The oxidation potential of selenous acid is lower than -1.36 V. | 1 |
| Thus dichromate is not a strong enough oxidant to oxidise selenous acid / to produce selenic acid.  **or**  Thus the cell potential will have a negative value, indicating the reaction will not occur. | 1 |
| **Total** | **2** |

**Question 31 (9 marks)**

(a) Explain why a decrease in temperature will decrease the rate of a reaction. Sketch a labelled kinetic energy distribution (Maxwell-Boltzmann) diagram to support your answer.

(6 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| (A decrease in temperature results in) a decrease in the average kinetic energy of particles. | 1 |
| This will decrease the frequency of successful collisions, | 1 |
| in addition to decreasing the proportion of successful collisions. | 1 |
| Kinetic energy  Number of particles  Ea  Low temp  High temp |  |
| Correct shape of high and low temperature curves | 1 |
| Curves labelled to indicate higher / lower temperature | 1 |
| Activation energy indicated | 1 |
| **Total** | **6** |

(b) Use the trend in the data to state the relationship between the variables. (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| As the temperature decreases, the volume of N2O3(l) increases. | 1 |
| **Total** | **1** |

(c) Identify two (2) ways in which the students should improve the graphical representation of their data. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Variables are on the incorrect axes / Axis labels need to be switched | 1 |
| A line of best fit should be used | 1 |
| **Total** | **2** |

**Question 32 (9 marks)**

(a) Write an equation for the buffer solution that would be formed. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| HPO42-(aq) + H2O(l) ⇌ H2PO4-(aq) + OH-(aq)  **or**  HPO42-(aq) + H3O+(aq) ⇌ H2PO4-(aq) + H2O(l) |  |
| Correct species | 1 |
| Double arrow shown in equation | 1 |
| **Total** | **2** |
| Note: state symbols are not required for full marks | |

(b) Which buffer (A, B or C) would demonstrate the highest buffering capacity, if required to interact with both acidic and basic species? Justify your choice. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Buffer B | 1 |
| It has the most similar concentrations of the conjugate acid-base pair, HPO42-(aq)/ H2PO4-(aq). | 1 |
| Therefore will have the greatest ability to maintain pH upon addition of either acid or base. | 1 |
| **Total** | **3** |

(c) Explain why Buffer A has the lowest pH. Use a relevant chemical equation to support your answer. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| H2PO4-(aq) is an acidic species and will hydrolyse in water to produce hydronium ions, H3O+(aq) | 1 |
| H2PO4-(aq) + H2O(l) ⇌ HPO42-(aq) + H3O+(aq) | 1 |
| **Total** | **2** |
| Note: state symbols are not required for full marks | |

(d) Identify the spectator ion present in this buffer, and state why it has no effect on the pH of the buffer. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Potassium ions, K+(aq) | 1 |
| K+(aq) ions do not hydrolyse in water, thus they are neutral. | 1 |
| **Total** | **2** |

**Question 33 (11 marks)**

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

|  |  |
| --- | --- |
| **Description** | **Marks** |
| K = [Br2][F2]5  [BrF5]2 |  |
| Products over reactants | 1 |
| Correct indices | 1 |
| **Total** | **2** |

(b) Complete the following table, by predicting the observations for each time period. Provide a brief explanation for each observation. (9 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Initial |  |
| **Observations**   * Red-brown colour darkens. | 1 |
| **Explanation**   * The concentration of Br2 (and all other gases) has increased (resulting in the colour of Br2 intensifying). | 1 |
| During shift |  |
| **Observations**   * Red-brown colour fades. | 1 |
| **Explanation**   * The reverse reaction rate is increased relative to the forward reaction rate. * Thus the equilibrium shifts left, reducing the concentration of Br2. | 1  1 |
| Final |  |
| **Observations**   * Red-brown colour remains constant. * Colour is darker than original equilibrium. | 1  1 |
| **Explanation**   * The concentration of all species remains constant. * Since the change is only partially counteracted, the final concentration of Br2 will still be higher than original. | 1  1 |
| **Total** | **9** |

**Question 34 (6 marks)**

(a) Briefly describe the principles of cathodic protection. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| The steel/iron is connected to the negative terminal of a power source, ensuring it is the cathode. | 1 |
| An anode (commonly made of, for example, scrap iron metal or coated titanium) is connected and is the site of oxidation. | 1 |
| The current flows to the steel structure, ensuring it is protected / unable to oxidise. | 1 |
| **Total** | **3** |

(b) By providing three (3) justifications, construct an argument that supports this statement. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Any three justifications which identify either advantages of cathodic protection or disadvantages of powder coating. | 3 |
| Advantages of cathodic protection include:   * provides good corrosion protection over long distances * provides good corrosion protection for larger structures * anodes are easily replaced   Disadvantages of powder coating include:   * if the coating was chipped/damaged this would be hard to see * if the coating was chipped/damaged this would be hard to repair * the coating could wear off over time * coating an entire pipeline would be expensive * there may be joins in the pipeline where the coating was not complete |  |
| **Total** | **3** |

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

**Question 35 (19 marks)**

(a) Identify one (1) safety risk associated with this cell and one (1) safety measure to reduce this risk. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Safety risk identified | 1 |
| Safety measure **related to** stated risk | 1 |
| Any of the following safety risks:   * Chlorine gas is toxic * Hydrogen gas is explosive * Sodium hydroxide is caustic * Use of electrical current * Production of acidic / caustic waste streams   Any related safety measure, including:   * Ensure appropriate ventilation / ensure safe storage of chlorine * Ensure chlorine is not inhaled / wear gas mask / perform in fumehood etc * Keep sources of ignition away / ensure safe storage of hydrogen * Prevent contact with sodium hydroxide / wear gloves / wear protective clothing / wear glasses * Check electrical connections / ensure maintenance of electrical apparatus etc * Have a first aid kit and safety plan to treat sodium hydroxide burns * Ensuring appropriate steps are taken to minimise environmental impact of waste streams e.g. recycling waste water, removing acid / alkaline components from waste water etc |  |
| **Total** | **2** |

(b) Complete the table below, regarding the titanium and nickel electrodes in the membrane cell. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| |  |  |  | | --- | --- | --- | |  | Designation of electrode | Polarity | | Titanium | anode | + | | Nickel | cathode | – | |  |
| Both anode and cathode correctly identified | 1 |
| Both polarities correctly identified | 1 |
| **Total** | **2** |
| Note: mark each column individually, no follow through marks are awarded. | |

(c) Provide a justification for the choice of titanium as the electrode material. (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Any of the following justifications:   * It is unreactive and will not be oxidised * It will not corrode whilst submerged in salt solution * It is a metal and allows for the transfer of electrons | 1 |
| **Total** | **1** |

(d) Explain why electrical energy needs to be provided for this cell to function. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| This reaction has a negative cell potential | 1 |
| and is therefore non-spontaneous (thus requiring electrical energy to drive the reaction to take place). | 1 |
| **Total** | **2** |

(e) Calculate the final pH of the solution surrounding the nickel electrode. (5 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| n(Cl2) = (105 x 66.5) / (8.314 x 298.15)  = 2.8169 mol | 1 |
| n(OH-) = 2 x 2.8169  = 5.6337 mol | 1 |
| c(OH-) = 5.6337 / 12  = 0.46948 mol L-1 | 1 |
| [H+] = (1.0 x 10-14) / 0.46948  = 2.130 x 10-14 mol L-1 | 1 |
| pH = -log(2.130 x 10-14)  = 13.7 | 1 |
| **Total** | **5** |

(f) Describe why this O2(g) forms, using a relevant chemical equation to support your answer. Propose a reason why the amount of O2(g) produced decreases, as the concentration of NaCl(aq) increases. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| The O2(g) is formed from the (preferential) oxidation of water. | 1 |
| 2 H2O(l) → O2(g) + 4 H+(aq) + 4 e- | 1 |
| As the concentration of NaCl(aq) increases;  the value of the oxidation potential (for the oxidation of Cl-(aq)) would change and this will affect which species is likely to be oxidised.  **or**  the concentration of chloride increases, and therefore there is more likely to be collisions between the Cl-(aq) ions and the anode. | 1 |
| **Total** | **3** |
| Note: state symbols are not required for full marks | |

(g) Name one (1) product of the Downs process that is the same, and one (1) product that is different, to those produced in the chloralkali process. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Chlorine (gas) | 1 |
| Sodium (metal) | 1 |
| **Total** | **2** |

(h) Suggest two (2) reasons the Downs process requires a greater energy input than the chloralkali process. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| More (heat) energy would be required to maintain the electrolyte in a molten state in the Downs cell. | 1 |
| More (electrical) energy **or** a higher voltage would be required to drive the reaction to occur since the reaction has a more negative cell potential. | 1 |
| **Total** | **2** |

**Question 36 (18 marks)**

(a) Explain, with the use of an equation, how the phosphate ion, PO43-(aq), contributes to the alkalinity of the water. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Phosphate ions hydrolyse in water to produce OH-(aq). | 1 |
| PO43-(aq) + H2O(l) ⇌ HPO42-(aq) + OH-(aq) | 1 |
| Therefore the [OH-] > [H3O+], resulting in an alkaline solution. | 1 |
| **Total** | **3** |
| Note: state symbols are not required for full marks | |

(b) Calculate the ‘total alkalinity’ of the river water sample, if the density of the river water was determined to be 1.024 kg L-1. (5 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| From titration curve,  V(HCl titre) = 13.20 mL | 1 |
| n(HCl in 100 mL) = 0.01565 x 0.01320  = 0.00020658 mol | 1 |
| n(HCl in 1 L) = 10 x 0.00020658  = 0.0020658 mol | 1 |
| n(HCl in 1 kg) = 0.0020658 / 1.024  = 0.002017 mol | 1 |
| total alkalinity = 0.002017 x 1000  = 2.02 mmol | 1 |
| **Total** | **5** |
| Note: accept titre values in the range 13.1-13.3 mL. This results in final values for total alkalinity being in the range 2.00 - 2.03 mmol. | |

(c) Identify three (3) ways the students could increase the validity of their reported total alkalinity value. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Any three appropriate suggestions, including:   * Collect samples from different depths in the river * Collect samples from different locations along the river * Collect samples at different times of the day * Collect samples during different months / seasons | 3 |
| **Total** | **3** |

(d) Explain why bromothymol blue would **not** be an appropriate indicator choice for this titration. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| The equivalence point for this reaction is acidic (occurring at approximately pH 4.2-4.5) | 1 |
| Therefore the end point / colour change of this indicator would occur too early (and lead to lower titre volumes) | 1 |
| **Total** | **2** |

(e) If the students had incorrectly rinsed the burette with water; (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |   8 -    6 -    4 -    2 -  pH  Volume of HCl(aq) added (mL)  l l l l l l l l l l l l l l l l  2.00 4.00 6.00 8.00 10.00 12.00 14.00 16.00 | |
| (i) curve is same shape as original, but indicates higher average titre  (see dashed line above) | 1 |
| (ii) too high (circled) | 1 |
| **Total** | **2** |

(f) Increased atmospheric CO2(g) levels result in sea water having a lower total alkalinity. By referring to the equations above, justify why lower total alkalinity corresponds to a decrease in carbonate ion concentration. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| (A lower total alkalinity) will result in a decreased OH-(aq) concentration. | 1 |
| This will shift the equilibrium position of equation 2 (and 3) to the right. | 1 |
| This will partially counteract the decrease in OH-(aq) concentration whilst lowering the concentration of CO32-(aq). | 1 |
| **Total** | **3** |

**Question 37 (18 marks)**

(a) Explain the difference in gradient between the N2(g) and O2(g) curves, from Time A to B. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| The N2(g) is used up at half the rate of O2(g).  **or**  The O2(g) is used up at twice the rate of the N2(g). | 1 |
| This is because the stoichiometric ratio of N2(g) to O2(g) is 1:2 in the chemical equation. | 1 |
| **Total** | **2** |

(b) Identify the change that occurred at Time C. (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| O2(g) was injected into the system / The concentration of O2(g) in the system was increased. | 1 |
| **Total** | **1** |

(c) At Time E, the temperature of the system was decreased. Is the reaction endothermic or exothermic as written? Justify your answer. (4 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| The graph shows an increase in the concentration of reactants. | 1 |
| Therefore the reverse reaction must be favoured. | 1 |
| A temperature decrease favours the exothermic reaction (in order to produce more heat). | 1 |
| Thus the equation must be endothermic as written. | 1 |
| **Total** | **4** |

(d) On the blank grid on the previous page, sketch a graph illustrating the changes in both the forward and reverse reaction rates that occurred in this system from Time A to G. Use a solid line (–––) to represent the forward reaction rate and a dashed line (- - -) to represent the reverse reaction rate. (8 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |   Reaction rate  Time  l l l l l l l  A B C D E F G | |
| **From A to B**  Correct shape of curves  Correct use of solid/dashed lines (i.e. forward higher than reverse) | 1  1 |
| **From C to D**  Correct shape of curves  Correct use of solid/dashed lines (i.e. forward higher than reverse) | 1  1 |
| **From E to F**  Instantaneous decrease shown for both rates  Correct shape of curves  Correct use of solid/dashed lines (i.e. reverse higher than forward) | 1  1  1 |
| **From B to C, D to E, F to G**  Horizontal lines | 1 |
| **Total** | **8** |

(e) Provide a justification for the lack of reactivity between N2(g) and O2(g) at room temperature, given that the Kc value for this reaction is large. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| The reaction may have a high activation energy. | 1 |
| Therefore at room temperature the reactants do not have enough energy to overcome this barrier and form products. | 1 |
| A large Kc value does not indicate a fast reaction rate, it only indicates the position of equilibrium once established. | 1 |
| **Total** | **3** |

**Question 38 (16 marks)**

(a) Is M(s) the anode or cathode in this cell? Justify your answer. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Anode | 1 |
| Either of the following justifications;   * Electrode M lost mass (to form metallic ions) * Therefore it must have been oxidised   **or**   * The pH of the HCl(aq) electrolyte increased * Therefore indicating reduction of H+(aq) (and therefore the platinum electrode is the cathode) | 2 |
| **Total** | **3** |

(b) Write balanced half-equations for the reactions occurring in this cell. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| anode: M(s) → M2+(aq) + 2 e- | 1 |
| cathode: 2 H+(aq) + 2 e- → H2(g) | 1 |
| **Total** | **2** |
| Note: state symbols are not required for full marks | |

(c) List two (2) quantitative pieces of data, that would allow the hydrogen half-cell to conform to ‘standard conditions’. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Any two of the following:   * The H2(g) is at 100 kPa * The reactants are at 25 °C * The initial concentration of HCl(aq) is 1 mol L-1 | 2 |
| **Total** | **2** |
| Note: accept a pressure of 1 atm / 101.3 kPa, as standard reduction potential tables can differ in this regard. | |

(d) Determine the identity of M(s). Show all workings. (9 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| [H+ initial] = 10-0  = 1 mol L-1 | 1 |
| [H+ final] = 10-0.422  = 0.37844 mol L-1 | 1 |
| n(H+ initial) = 1 x 0.750  = 0.750 mol | 1 |
| n(H+ final) = 0.37844 x 0.750  = 0.28383 mol | 1 |
| n(H+ reacted) = 0.750 – 0.28383  = 0.46617 mol | 1 |
| n(M) = ½ x n(H+)  = 0.23308 mol | 1 |
| m(M lost) = 91.3 – 65.2  = 26.1 g | 1 |
| M(M) = 26.1 / 0.23308  = 111.98 g mol-1 | 1 |
| M is likely to be cadmium | 1 |
| **Total** | **9** |

**Question 39 (14 marks)**

(a) Classify malic acid as strong or weak. Justify your answer. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Weak | 1 |
| Both Ka values are small / much lower than 1, | 1 |
| indicating malic acid undergoes a small degree of ionisation. | 1 |
| **Total** | **3** |

(b) Write an acid dissociation constant expression for the **second** ionisation of malic acid. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Ka2 = [C4H4O52-][H3O+]  [C4H5O5-] |  |
| Correct products | 1 |
| Correct reactants | 1 |
| **Total** | **2** |

(c) Determine the percentage purity of the E296 sample. State your answer to the appropriate number of significant figures. (9 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| n(NaOH initial) = 0.1594 x 0.220  = 0.035068 mol | 1 |
| n(HCl required) = 0.03703 x 0.01712  = 0.00063395 mol | 1 |
| n(xs NaOH in 25 mL) = 0.00063395 mol | 1 |
| n(xs NaOH in 220 mL) = 0.00063395 x (220/25)  = 0.0055788 mol | 1 |
| n(NaOH react with C4H6O5) = 0.035068 – 0.0055788  = 0.029489 mol | 1 |
| n(C4H6O5) = ½ x n(NaOH)  = 0.014745 mol | 1 |
| m(C4H6O5) = 0.014745 x 134.088  = 1.9771 g | 1 |
| % purity of E296 = 1.9771 / 2.015 x 100  = 98.1178 % | 1 |
| = 98.12% (4SF) | 1 |
| **Total** | **9** |