**ATAR course examination, Semester 1, 2021**

**Answer Key**

**Section One: Multiple–choice (25 Marks)**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **1** | **A** |  | **14** | **B** |  | **A = 5** |
| **2** | **C** |  | **15** | **D** |  | **B = 8** |
| **3** | **B** |  | **16** | **C** |  | **C = 5** |
| **4** | **D** |  | **17** | **A** |  | **D = 7** |
| **5** | **D** |  | **18** | **B** |  |  |
| **6** | **B** |  | **19** | **D** |  |  |
| **7** | **B** |  | **20** | **D** |  |  |
| **8** | **B** |  | **21** | **D** |  |  |
| **9** | **C** |  | **22** | **B** |  |  |
| **10** | **A** |  | **23** | **C** |  |  |
| **11** | **B** |  | **24** | **D** |  |  |
| **12** | **A** |  | **25** | **A** |  |  |
| **13** | **C** |  |  |  |  |  |

**Section Two: Short answer (80 Marks)**

**Question 26 (7 marks)**

(a) Sketch energy profile diagrams for each of these reactions. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Phosphorus reaction correct exothermic shape | **1** |
| Potassium chlorate reaction correct exothermic shape | **1** |
| Phosphorus reaction has much lower activation energy that potassium chlorate reaction | **1** |
| **Total** | **3** |

(b) Write a balanced equation for the decomposition of potassium chlorate including the heat of reaction and state symbols. ΔH = – 98.56 kJ (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Equation correctly balanced: 2 KCℓO3(s) → 2 KCℓ(s) + 3 O2(g) + 98.56 kJ | **1** |
| State symbols correct | **1** |
| Heat on rhs | **1** |
| **Total** | **3** |

(c) State one reason why the experimental value obtained is lower than the theoretical value. (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Loss of heat to the surroundings | **1** |
| **Total** | **1** |

**Question 27 (4 marks)**

Using ethanoic acid as an example, distinguish between the definition of the term 'acid' in the Davy and the Brønsted–Lowry models. Include relevant equations in your answer.

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Davy** |  |
| an acid contains replaceable hydrogen | **1** |
| 2 CH3COOH(aq) + Mg(s) → H2(g) + Mg(CH3COO)2 (aq) | **1** |
| **Brønsted-Lowry** |  |
| An acid donates hydrogen ions/protons | **1** |
| CH3COOH(aq) + H2O(ℓ) → H3O+(aq) + CH3COO–(aq) | **1** |
| **Total** | **4** |

**Question 28 (8 marks)**

Write four (4) half-equations representing the steps in the sulfur cycle described above, assuming acidic conditions. Classify each step as a reduction (R) or oxidation (O) process.

|  |  |
| --- | --- |
| Description | Marks |
| Step 1: 8 H2S → S8 + 16 H+ + 16 e- |  |
| Correct half-equation | 1 |
| Oxidation (O) | 1 |
| Step 2: S8 + 32 H2O → 8 SO42- + 64 H+ + 48 e- |  |
| Correct half-equation | 1 |
| Oxidation (O) | 1 |
| Step 3: SO42- + 2 H+ + 2 e- → SO32- + H2O |  |
| Correct half-equation | 1 |
| Reduction (R) | 1 |
| Step 4: SO32- + 8 H+ + 6 e- → H2S + 3 H2O |  |
| Correct half-equation | 1 |
| Reduction (R) | 1 |
| Total | 8 |

**Question 29 (15 marks)**

An investigation into the oxidising strength of various metals was set up as shown below initially comparing copper and magnesium.

(a) Label the anode and cathode. (1 mark)

|  |  |
| --- | --- |
| **Description** | Marks |
| Mg = anode and Cu = cathode | 1 |
| **Total** | 1 |

(b) Write the overall redox equation and calculate the cell voltage under standard conditions. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Cu2+(aq) + Mg(s) → Cu(s) + Mg2+(aq) | **1** |
| Cell voltage = + 2.70 V | **1** |
| **Total** | **2** |

(c) Name suitable electrolyte solutions for each beaker. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Magnesium: magnesium nitrate/sulfate | **1** |
| Copper: copper nitrate/sulfate | **1** |
| **Total** | **2** |

The voltage measured was initially higher than predicted then slowly decreased.

(d) Explain this observation. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Higher: was greater than 1 mol L–1 Cu2+ | **1** |
| Decreased: concentration of Cu2+ decreased so voltage decreases | **1** |
| **Total** | **2** |

(e) State two observations for the copper half–cell as the reaction proceeds. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Solution: became less blue | **1** |
| Electrode: became larger | **1** |
| **Total** | **2** |

As part of the experiment the student weighed both electrodes before and after the experiment and found one electrode increased by 0.253 g.

(f) Calculate the mass change in the other electrode. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Identifies Cu electrode increases by 0.253 g | **1** |
| n(Cu) = 0.253 ÷ 63.55 = 0.00398 = n(Mg) | **1** |
| m(Mg) electrode change = 0.00398 × 24.31 = 0.096 g decrease (must state decrease) | **1** |
| **Total** | **3** |

The equipment shown above compares the oxidising strength of copper and magnesium.

(g) How could the oxidising strength of zinc be determined using this equipment? (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Replace Mg with zinc and measure cell voltage | **1** |
| If voltage +ve then zinc is more readily oxidised than copper | **1** |
| Use size of voltage to compare oxidising strength to magnesium | **1** |
| **Total** | **3** |

**Question 30 (6 marks)**

Write balanced equation for reactions occurring between the following substances and describe observations during the reaction and the contents of the flask at the end of the reaction.

(a) A small amount of aqueous chlorine is added to some potassium iodide solution. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Equation**  Cℓ2(aq) + 2 I–(aq) → I2(aq) + 2 Cℓ–(aq) | **1** |
| **Observation(s) during the reaction**  Pale yellow solution added to a colourless solution; solution becomes brown | **1** |
| **Contents of flask when reaction has finished**  Light brown solution | **1** |
| **Total** | **3** |

(b) A large volume of sodium hydroxide solution is added to a small volume of sulfuric acid containing a few drops of phenolphthalein. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Equation**  OH–(aq) + H+(aq) → H2O(ℓ) | **1** |
| **Observation(s) during the reaction**  2 colourless solutions mixed; solution turns pink | **1** |
| **Contents of flask when reaction has finished**  Pink solution | **1** |
| **Total** | **3** |

**Question 31 (15 marks)**

(a) Determine by calculation if this sample of rock should be considered limestone. (8 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| n(NaOH) = 2.004 × 0.0300 = 0.06012 mol | **1** |
| n(HCℓ) excess = n(NaOH) = 0.06012 | **1** |
| n(HCℓ) added = 0.5030 × 0.2000 = 0.1006 | **1** |
| n(HCℓ) reacting with CaCO3 = 0.1006 – 0.06012 = 0.04048 mol | **1** |
| n(CaCO3) = ½ × n(HCℓ) = 0.02024 mol | **1** |
| m(CaCO3) = 0.02024 × 100.09 = 2.02582 g | **1** |
| %CaCO3 = 2.0258/3.75 × 100 = 54.02 % | **1** |
| Yes limestone as sample is more than 50% CaCO3 | **1** |
| **Total** | **8** |

(b) Explain how this reaction will behave differently if it is carried out in an open container compared with a closed container. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| In an open container bubbles of CO2 gas will escape and all the solid CaCO3 will convert to CaO. | **1** |
| In a closed container CO2 gas can recombine with CaO and the reverse reaction can occur | **1** |
| **Total** | **2** |

(c) Write the equilibrium expression for this reaction. (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| K = [CO2] | **1** |
| **Total** | **1** |

(d) Compare the relative amounts of products and reactants at equilibrium. (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Reactants ˃ products | **1** |
| **Total** | **1** |

(e) Predict the effect on K of reducing the temperature. Justify your answer. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| K decreases | **1** |
| Temp decrease favours exothermic reverse reaction | **1** |
| Reducing [CO2] (and therefore reducing K) | **1** |
| **Total** | **3** |

**Question 32 (7 marks)**

(a) Write the equation for the reaction of the dihydrogen phosphate ion with water. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| H2PO4–(aq) + H2O(ℓ) ⇌ HPO42−(aq) + H3O+(aq) | **2** |
| One minor error or no ⇌ | **1** |
| **Total** | **2** |

(b) Which one of the following reactions will be more likely to take place? Explain your answer by referring to the relative strength of the conjugate acids and bases present. (5 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Equation #1 | **1** |
| Ka for 3rd ionisation (removal of 3rd H) = 4.8 × 10–13 | **1** |
| Kw for water is 1 × 10-14 | **1** |
| HPO42–(aq) is therefore a slightly stronger acid than H2O(ℓ) | **1** |
| So HPO42–(aq) will donate a proton to H2O(ℓ) (as shown in equation 1) | **1** |
| **Total** | **5** |

**Question 33 (10 marks)**

(a) Describe the initial effect of lactic acid on the pH of blood. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Increases [H+] | **1** |
| Decreases pH | **1** |
| **Total** | **2** |

(b) Explain, using collision theory, how the buffer acts to reduce the impact of lactic acid. (4 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Increased [H+/lactic acid] increases rate of collisions between reacting particles | **1** |
| This increases the rate of the forward reaction relative to the reverse rate | **1** |
| This reduces the [H+] as it is used up in the forward reaction | **1** |
| Returning the [H+] close to its original value so maintaining pH of the buffer | **1** |
| **Total** | **4** |

(c) Explain how both these processes can help maintain normal pH. (4 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Lungs  xs [CO2] causes reverse reaction to be favoured increasing [H+] and decreasing pH | **1** |
| Removing CO2 reverses this - maintaining pH | **1** |
| Kidneys  xs [HCO3–] causes forward reaction to be decreasing [H+] and increasing pH | **1** |
| Removing HCO3– reverses this - maintaining pH | **1** |
| **Total** | **4** |

**Question 34 (8 marks)**

(a) Calculate the mass of barium hydroxide solid required to neutralise 45.0 mL of a hydrochloric acid solution at pH = 1.52. (6 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **H+** |  |
| [H+] = –10–1.52 = 3.019951 × 10–2 | **1** |
| n(H+) = 0.0450 x 3.019951 × 10–2 = 1.358 × 10–3 mol | **1** |
| **OH-** |  |
| H+ + OH– → H2O or states stoichiometry  n(H+) = n(OH-)= 1.358 × 10–3 mol | **1** |
| ∴ n(Ba(OH)2) = 1.358 × 10–3 ÷ 2 = 6.79489 × 10–4 mol | **1** |
| M(Ba(OH)2) = 171.34 | **1** |
| m(Ba(OH)2) = 171.34 × 6.79489 × 10–4 = 0.116 g | **1** |
| **Total** | **6** |

(b) Discuss the effect, if any, on the mass of barium hydroxide required if the original solutionwere sulfuric acid. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| pH = 1.52 or [H+] = 0.0302 mol L-1 for either acid | **1** |
| So irrespective of what acid the same mass of base is required | **1** |
| **Total** | **2** |

**End of section two**

**Section Three: Extended answer (88 Marks)**

(a) Determine the concentration of FeSCN2+(aq) present at equilibrium. (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **0.002 mol L-1** | **1** |
| **Total** | **1** |

(b) Sketch a graph, including all relevant species, showing the establishment of equilibrium, from Time 0 where the reactants were mixed, to Time E1, where equilibrium was established and maintained. (5 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Fe3+(aq) concentration decreases from 0.01 to 0.008 mol L-1** | **1** |
| **SCN-(aq) concentration decreases from 0.006 to 0.004 mol L-1** | **1** |
| **FeSCN2+(aq) concentration increases from 0 to 0.002 mol L-1** | **1** |
| **Horizontal lines from E1 onwards** | **1** |
| **Labels on each of the three curves** | **1** |
| **Total** | **5** |
| **Example of a five mark response**   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |   l l  0 E1 Time  Concentration (mol L-1)  0.010 –  0.009 –  0.008 –  0.007 –  0.006 –  0.005 –  0.004 –  0.003 –  0.002 –  0.001 –  Fe3+(aq)  SCN-(aq)  FeSCN2+(aq) | |

(c) Justify these results by using Le Chatelier’s principle and making reference to any appropriate equations provided. (6 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Addition of H3O+:** |  |
| **The H3O+(aq) added will react with SCN-(aq) as shown in equation (ii)** | **1** |
| **The SCN-(aq) concentration will therefore be lowered** | **1** |
| **The original equilibrium will therefore shift left to increase the concentration of SCN-(aq)** | **1** |
| **Addition of OH-:** |  |
| **The OH-(aq) added will react with Fe3+(aq) as shown in equation (iii)** | **1** |
| **The Fe3+(aq) concentration will therefore be lowered** | **1** |
| **The original equilibrium will therefore shift left to increase the concentration of Fe3+(aq)** | **1** |
| **Total** | **6** |

(d) Describe the observation that would have distinguished between the addition of acid and base to the equilibrium system. (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Addition of OH-(aq) would cause a pale brown precipitate to form | 1 |
| **Total** | **1** |

(e) Explain, in terms of reaction rates, the effect this would have on the equilibrium position. (4 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Adding KF(aq) would (increase the concentration of F-(aq) which will react with, and) lower the concentration of Fe3+(aq) | 1 |
| This would decrease both the forward and reverse reaction rates (due to a decreased frequency of collisions) | 1 |
| The reverse reaction rate would not decrease by as much as the forward reaction rate  **or**  The forward reaction rate would decrease more, relative to the reverse reaction rate | 1 |
| This would result in a shift to the left / the reverse reaction being favoured | 1 |
| **Total** | **4** |

**Question 36 (14 marks)**

1. Explain why the pH at the first equivalence point is acidic, whilst the pH at the second equivalence point is basic. Include relevant chemical equations in your answer.

(4 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **At the first equivalence point:** |  |
| **The salt produced (NaH2PO4) is acidic due to the presence / hydrolysis of H2PO4-(aq) ions (which results in an excess of H3O+ ions)** | **1** |
| **H2PO4-(aq) + H2O(l) → HPO42-(aq) + H3O+(aq)** | **1** |
| **At the second equivalence point:** |  |
| **The salt produced (Na2HPO4) is basic due to the presence / hydrolysis of HPO42-(aq) ions (which results in an excess of OH- ions)** | **1** |
| **HPO42-(aq) + H2O(l) → H2PO4-(aq) + OH-(aq)** | **1** |
| **Total** | **4** |

(b) Suggest one practical reason a pH meter is used to detect the equivalence point, instead of the indicator phenolphthalein. (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **The colour of the Coca-Cola would obscure the indicator colour** | **1** |
| **Total** | **1** |

(c) Calculate the milligrams of phosphorus present in a 375 mL can of Coca-Cola. (6 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **n(NaOH) = 0.1005 x 0.01665**  **= 0.0016733 mol** | **1** |
| **n(H3PO4) = 0.0016733 / 2**  **= 0.00083666 mol**  **= n(H3PO4 in 150 mL Coca-Cola)** | **1** |
| **= n(P in 150 mL Coca-Cola)** | **1** |
| **n(P in 375 mL can) = 0.00083666 x (375 / 150)**  **= 0.00209165 mol** | **1** |
| **m(P) = 0.00209165 x 30.97**  **= 0.064778 g** | **1** |
| **= 64.78 mg** | **1** |
| **Total** | **6** |

(d) Classify this error as random or systematic. Justify your choice and state the likely effect this would have on the students’ calculated phosphorus content. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Systematic** | **1** |
| **This error would result in consistently higher titre values** | **1** |
| **The calculated concentration of P would be greater than the true value** | **1** |
| **Total** | **3** |

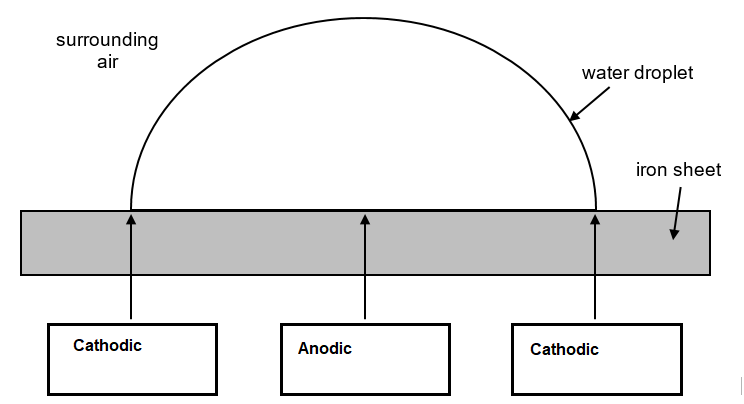
**Question 37 (18 marks)**

Iron is used widely in modern society, in structures such as bridges and buildings, in reinforced concrete as well as piping, and to manufacture cars and ships. The corrosion of iron to form rust is a costly and potentially dangerous problem, and a great deal of money is spent trying to prevent, reduce and repair the damage caused by the corrosion of iron.

The corrosion of iron to form rust involves a sequence of reactions. The process generally begins when iron comes into contact with water and oxygen. The overall equation for the initial redox reaction involved in the corrosion of iron can be represented by the following chemical equation.

2 Fe(s) + O2(g) + H2O(l) → 4 OH-(aq) + 2 Fe2+(aq)

(a) The diagram below shows a close-up view of a water droplet on a sheet of iron.



|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Cation (Fe2+ label and direction)** | **1** |
| **Anion (OH- label and direction)** | **1** |
| **Total** | **2** |
| **Example of a two mark response**  Fe2+(aq)  OH-(aq)  OH-(aq)  **Note: if ion flow is only labelled on one ‘side’ of the water droplet, allocate full marks** | |

(b) Demonstrate that this reaction is a redox process, using oxidation numbers to support your answer. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Oxidation of iron atoms from (0) in Fe to (+2) in Fe2+** | **1** |
| **Reduction of oxygen atoms from (0) in O2 to (-2) in OH-** | **1** |
| **Total** | **2** |

Consider the following statement made by a student in response to a question on corrosion.

*‘Corrosion of iron is a very slow process so the reaction will have a small equilibrium constant.’*

(c) Comment on this statement by discussing both rate of reaction and equilibrium. (4 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **As corrosion is a slow process its rate of reaction can be said to be low** | **1** |
| **This means it will take a long time to come to equilibrium** | **1** |
| **(The equilibrium constant is [products]/[reactants]) a small K implies the reactants are favoured** | **1** |
| **This is not necessarily the case as the forward reaction (forming rust) may be largely favoured giving a large value for K** | **1** |
| **Total** | **4** |

The next step in the reaction sequence to form rust, involves the formation of a precipitate.

(d) Write a balanced ionic equation for this step. (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Fe2+(aq) + 2 OH-(aq) → Fe(OH)2(s)** | **1** |
| **Total** | **1** |

The product of this precipitation reaction is further oxidised to solid iron(III) hydroxide, which then dehydrates to form orange-brown rust, Fe2O3.H­2O(s). This is illustrated in the chemical equation below.

2 Fe(OH)3(s) → Fe2O3.H­2O(s) + 2 H2O(l)

The mass of a sample of iron sheet was recorded. After a period of time, rust formed on the surface of the iron. All traces of the rust were then scraped off, and the new mass of the iron sheet was recorded. The results are shown in the table below.

|  |  |
| --- | --- |
| Initial mass of iron (g) | 84.2 g |
| Final mass of iron (g) | 77.1 g |

(e) Calculate the volume of O2(g) that would have reacted to produce this rust. The partial pressure of O2(g) in air is 21.2 kPa and the temperature of the air was 19.3 °C. State your answer to the appropriate number of significant figures. (5 marks)

|  |  |
| --- | --- |
| Description | Marks |
| m(Fe reacted) = 84.2 – 77.1  = 7.1 g | 1 |
| n(Fe) = 7.1 / 55.85  = 0.12713 mol | 1 |
| n(O2) = 0.12713 / 2  = 0.063563 mol | 1 |
| V(O2) = (0.063563 x 8.314 x 292.45) / 21.2  = 7.29006 L | 1 |
| = 7.29 L (3 SF) | 1 |
| Total | 5 |

(f) Calculate the maximum mass of rust, Fe2O3.H2O(s), that would have formed from this corrosion. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **n(Fe2O3.H2O) = 0.12713 / 2**  **= 0.063563 mol** | **1** |
| **m(Fe2O3.H2O) = 0.063563 x 177.716**  **= 11.3 g** | **1** |
| **Total** | **2** |

This experiment was repeated with a galvanised iron sheet (i.e. an iron sheet coated in zinc), which was exposed to identical conditions, for the same period of time. The galvanised iron sheet showed no signs of rust.

(g) Explain these observations. (2 marks)

|  |  |
| --- | --- |
| Description | Marks |
| The zinc coating acts as a sacrificial anode | 1 |
| This is because zinc has a higher oxidation potential / is more reactive than iron | 1 |
| Therefore the zinc coating will be preferentially oxidised | 1 |
| The iron is thus protected, and no evidence of corrosion is seen (until all of the Zn coating has been oxidised) | 1 |
| ***Any two*** Total | 2 |

**Question 38 (20 marks)**

The buffering capacity of seawater results from the presence of hydrogencarbonate, HCO3-(aq) and carbonate, CO32-(aq) ions. The chemical equation for this buffer is given below.

HCO3-(aq) + H2O(l) ⇌ CO32-(aq) + H3O+(aq)

(a) Define a buffer. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **A solution containing a weak conjugate acid-base pair,** | **1** |
| **that can resist a change in pH when small amounts of acid or base are added to it** | **1** |
| **Total** | **2** |

(b) Describe how the large increase in atmospheric CO2(g) caused by human activity, results in a higher H3O+(aq) concentration in seawater. (Note: chemical equations are **not** required in your answer). (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Some of the excess atmospheric CO2(g) dissolves into seawater,** | **1** |
| **which then forms carbonic acid** | **1** |
| **Carbonic acid then hydrolyses / ionises to produce H3O+(aq)** | **1** |
| **Total** | **3** |

(c) Justify, using Le Chatelier’s principle, how the hydrogencarbonate / carbonate buffer system in seawater responds to this increase in H3O+(aq). (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **The increase in H3O+(aq) shifts the equilibrium to the left** | **1** |
| **This will partially counteract the change by decreasing the H3O+(aq) concentration / using up some of the extra H3O+(aq)** | **1** |
| **Total** | **2** |

(d) Plot this data on the same set of axes, using the grid below. (5 marks)

|  |  |
| --- | --- |
| Description | Marks |
| x-axis label and scale | 1 |
| y-axis label and scale | 1 |
| Points and curve for addition of HCl(aq) | 1 |
| Points and curve for addition of NaOH(aq) | 1 |
| Labels on each curve | 1 |
| Total | 5 |
| Example of a five mark response   |  |  |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |   11 –  10 –  9 –  8 –  7 –  pH 6 –  5 –  4 –  3 –  2 –  1 –  l l l l l l l l l l l l l  1 2 3 4 5 6 7 8 9 10 11 12 13  Volume added (mL)  addition of NaOH(aq)  addition of HCl(aq)  x  x  x  x  x  x  x  x  x  x  x  x  x  x  x  x  x  x  x  x | |

(e) Does seawater contain a higher concentration of HCO3-(aq) or CO32-(aq)? Justify your answer, by referring to the data collected in this investigation. (4 marks)

|  |  |
| --- | --- |
| Description | **Marks** |
| Higher concentration of HCO3-(aq) | 1 |
| The seawater has a higher buffering capacity for the addition of OH-(aq) | 1 |
| This is shown by the seawater resisting a pH change upon addition of a greater amount of OH-(aq) | 1 |
| Therefore there must be a higher concentration of the conjugate acid species present (relative to the conjugate base species) | 1 |
| Total | **4** |

(f) State two (2) negative consequences associated with the cuttlefish not being able to form its internal calcium carbonate shell. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Any **two** of the following (or other relevant answers): |  |
| * may disrupt the food web * species may be unable to reproduce * species may become endangered / extinct * reduced biodiversity of ecosystem (if endangered / extinct) | 2 |
| **Total** | **2** |

(g) Suggest two (2) ways humans can reduce their production of CO2(g). (2 marks)

|  |  |
| --- | --- |
| Description | Marks |
| Any two of the following (or other relevant answers): |  |
| * reduce reliance on fossil fuels * reduce car use / take public transport / ride bikes * decrease use of electricity * reduce consumption of meat * reduce deforestation * increase use of biofuels / renewable sources of energy | 2 |
| Total | 2 |

**Question 40 (19 marks)**

Gold is a precious metal that humankind has used for thousands of years. Over the centuries there have been many methods used to extract gold from its ore. Whilst it is a relatively unreactive metal, it does dissolve in alkaline solutions of cyanide. This discovery, in 1783, lead to the development of the ‘gold cyanidation’ process, which is widely used today.

In the extraction of gold, the ore is first ground and crushed. Water and sodium cyanide solution, NaCN(aq), are then added to form a slurry. This mixture is then left for 16 - 48 hours with a stream of oxygen gas passing through the mixture. During this time ‘gold leaching’ occurs. This process results in the gold being oxidised to the (+1) oxidation state and dissolving into solution to form the aurocyanide ion.

This process can be represented by the ‘Elsner equation’.

4 Au(s) + 8 CN-(aq) + O2(g) + 2 H2O(l) → 4 Au(CN)2-(aq) + 4 OH-(aq)

A sample of gold-bearing ore was crushed and placed in a tank, along with 25 kL of leaching solution. The initial concentration of NaCN(aq) in the leach solution was 0.478 g L-1. After 48 hours, this had fallen to 0.083 g L-1.

Calculate the mass of gold that was leached into solution. (6 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **m(NaCN initial) = 0.478 x 25000**  **= 11950 g** | **1** |
| **m(NaCN final) = 0.083 x 25000**  **= 2075 g** | **1** |
| **m(NaCN reacted) = 11950 - 2075**  **= 9875 g** | **1** |
| **n(NaCN) = 9875 / 49.01**  **= 201.4895 mol** | **1** |
| **n(Au) = (1/2) x 201.4895**  **= 100.7447 mol** | **1** |
| **m(Au) = 100.7447 x 197**  **= 19847 g (2.0 x 104 g)** | **1** |
| **Total** | **6** |

(b) Calculate the final pH of the leaching solution. (You may assume that only the OH-(aq) ions produced are contributing to pH). (4 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **n(OH-) = 100.7447 mol** | **1** |
| **c(OH-) = 100.7447 / 25000**  **= 0.0040298 mol L-1** | **1** |
| **[H+] = (1.0 x 10-14) / 0.0040298**  **= 2.4815 x 10-12 mol L-1** | **1** |
| **pH = - log (2.4815 x 10-12)**  **= 11.6 (12)** | **1** |
| **Total** | **4** |
| **Alternate working:**  **pOH = - log (0.0040298)**  **= 2.3947**  **pH = 14 - 2.3947**  **= 11.6 (12)** | |

(c) State the oxidant and the reductant in this process. (2 marks)

|  |  |
| --- | --- |
| Description | Marks |
| Oxidant: Au(CN)2- | 1 |
| Reductant: Zn | 1 |
| Total | 2 |

(d) Explain, in terms of the collision theory, why zinc **dust** is used to precipitate the gold out of solution. (3 marks)

|  |  |
| --- | --- |
| Description | Marks |
| The dust has a high surface area / high state of subdivision | 1 |
| This results in an increased frequency of collision, | 1 |
| and therefore a faster reaction rate | 1 |
| Total | 3 |

(e) Explain how this would allow separation of the two metals to occur. Use data from your standard reduction potential table to support your answer. (4 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **The cell potential / EMF for the reaction between Zn and H+ is positive**  **(+ 0.76 V)** | **1** |
| **The cell potential / EMF for the reaction between Au and H+ is negative**  **(- 1.50 V)** | **1** |
| **Therefore the reaction between Zn and the acid is spontaneous / the reaction between Au and the acid is non-spontaneous** | **1** |
| **This will result in the Zn dissolving in the acid, leaving behind solid Au (which can thus be separated)** | **1** |
| **Total** | **4** |

**End of questions**