**PART 1 (60 marks = 30% of paper)**

Answer ALL questions in Part 1 on the separate Multiple Choice Answer Sheet provided. Each question in this part is worth 2 marks.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 1 | [A] | [B] | [C] | **X** |  | 16 | [A] | [B] | **X** | [D] |
| 2 | **X** | [B] | [C] | [D] |  | 17 | **X** | [B] | [C] | [D] |
| 3 | [A] | [B] | [C] | **X** |  | 18 | [A] | **X** | [C] | [D] |
| 4 | [A] | [B] | [C] | **X** |  | 19 | [A] | [B] | [C] | **X** |
| 5 | **X** | [B] | [C] | [D] |  | 20 | [A] | **X** | [C] | [D] |
| 6 | [A] | [B] | [C] | **X** |  | 21 | **X** | [B] | [C] | [D] |
| 7 | [A] | [B] | [C] | **X** |  | 22 | [A] | **X** | [C] | [D] |
| 8 | [A] | **X** | [C] | [D] |  | 23 | [A] | [B] | [C] | **X** |
| 9 | [A] | **X** | [C] | [D] |  | 24 | [A] | **X** | [C] | [D] |
| 10 | [A] | [B] | [C] | **X** |  | 25 | [A] | **X** | [C] | [D] |
| 11 | [A] | [B] | **X** | [D] |  | 26 | [A] | [B] | **X** | [D] |
| 12 | [A] | [B] | [C] | **X** |  | 27 | [A] | [B] | [C] | **X** |
| 13 | [A] | [B] | [C] | **X** |  | 28 | **X** | [B] | [C] | [D] |
| 14 | [A] | [B] | **X** | [D] |  | 29 | **X** | [B] | [C] | [D] |
| 15 | [A] | [B] | [C] | **X** |  | 30 | [A] | [B] | **X** | [D] |

**PART 2 (70 marks = 35% of paper)**

Answer ALL questions in Part 2 in the spaces provided below.

1. Write equations for any reactions that occur in the following procedures. If no reaction occurs, then write ‘no reaction’.

In each case describe in full what you would observe, including any: colours; odours; precipitates (give the colour); or gases evolved (give the colour or

describe as colourless). If a reaction occurs but the change is not visible, then

you should state this.

a) Propane is bubbled through bromine water while exposed to sunlight.

Equation **C3H8 + Br2 C3H7Br + HBr**

Observation **Red-orange colour of solution slowly fades. (or NVR)**

b) Solutions of barium hydroxide and propanoic acid are mixed.

Equation **CH3CH2COOH + OH– CH3CH2COO– + H2O**

Observation **NVR**

c) Excess ammonia solution is added to solid zinc hydroxide.

Equation **Zn(OH)2 + 4 NH3 Zn(NH3)42+ + 2 OH–**

Observation **White solid dissolves forming a colourless solution.**

d) 1.0 mol L–1 sodium chloride in acid is added to 1.0 mol L–1 sodium

permanganate

Equation **2 MnO4– + 10 C– + 16 H+ 2 Mn2+ + 5 C2 + 8 H2O**

Observation **Purple solution fades to colourless**

**(and a yellow-green gas evolves)**

[3 x 3 = 12 marks]

2. Draw electron dot diagrams for the following, showing all valence electrons as either ‥ or – .

|  |  |  |
| --- | --- | --- |
| a) NH4CN  Picture 1 | [ C ≡ N ]– | b) H2SO4 molecule |

[4 marks]

3. Consider the following graph, which depicts the boiling points (in Kelvin) of the group VII hydrides.

Briefly account for the shape of the graph.

**HI > HBr > HC due to increasing dispersion forces with increasing**

**molar mass.**

**HF > HC due to hydrogen bonding between HF molecules.**

[2 marks]

4. Complete the following table using the list of substances below. Whilst there

may be more than one possible answer, only one answer per box is required.

You may use the same substance more than once.

HCHO H2O2 HCN SiO2 SO3 O3 CO2 CH4 NC3

|  |  |
| --- | --- |
| a) a polar linear molecule | **HCN** |
| b) a substance with hydrogen bonds  between its molecules | **H2O2** |
| c) a substance with only dispersion forces  between its molecules | **CH4, SO3, CO2** |
| d) a polar trigonal planar molecule | **HCHO** |
| e) a polar molecule with non-polar bonds | **H2O2, O3** |
| f) a non-polar molecule with polar bonds | **CO2, SO3** |

**each** [6 marks]

5. Ammonium acetate (ethanoate) is soluble in water. Explain, with the aid of equations, why it would be difficult to predict whether a 0.100 mol L–1 solution

of ammonium acetate is acidic or basic.

**NH4+ is acidic NH4+ + H2O ⇄ NH3 + H3O+**

**CH3COO– is basic CH3COO– + H2O ⇄ CH3COOH + OH–**

**One cannot predict whether the solution will be acidic or basic without knowing the position of the equilibria.**

[4 marks]

6. Water self-ionises as follows:

H2O(l) ⇄ H**+**(aq) + OH**–**(aq)

The value of Kw varies with temperature as follows:

25ºC Kw = 1.0 x 10–14

50ºC Kw = 5.5 x 10–14

Use the above information to answer and explain the following:

a) In the self-ionisation of water, is the forward reaction endothermic or exothermic? Explain your answer.

**As T increases, Kw increases**

**Since Kw = [H+].[OH–], [H+] and [OH–] increases**

**This is a shift to the right so, applying LCP, forward reaction**

**must be endothermic.**

b) Calculate the pH of water at 50ºC.

**[H+] = √ 5.5 x 10–4 = 2.345 x 10–4 mol L–1**

**pH = – log [H+] = – log (2.345 x 10–4) = 6.63**

(3,2 = 5 marks)

7. The decomposition of carbonyl bromide is given by the following equation:

COBr2(g) ⇄ CO(g) + Br2(g) ΔH = +63 kJ

a) Write the equilibrium law expression for this reaction.

**K = [CO].[Br2] / [COBr2]**

[1 mark]

b) Complete the following table:

|  |  |  |  |
| --- | --- | --- | --- |
| Change in  equilibrium system | Effect on the rate of the forward reaction when equilibrium is reestablished  (increase, decrease or  no change) | Effect on the number of moles  of COBr2  (increase, decrease, or no change) | Effect on the equilibrium constant, K  (increase, decrease, or no change) |
| a) carbon monoxide is added to the reaction vessel at constant volume and temperature | **increase** | **increase** | **no change** |
| b) the temperature is increased at constant  volume | **increase** | **decrease** | **increase** |
| c) argon is added at constant pressure and temperature | **decrease** | **decrease** | **no change** |
| d) ethene is introduced to the flask at constant volume and temperature  **Note - ethene reacts with Br2** | **decrease** | **decrease** | **no change** |

**each** [12 marks]

8. For the following pairs of chemicals, give a simple test and observation by which you can distinguish between them.

a) two colourless liquids: 3-methyl-2-butanol and 2-methyl-2-butanol

Test:  **add H+/MnO4– or H+/Cr2O72–**

Observations:

3-methyl-2-butanol **purple to c/less or orange to green**

2-methyl-2-butanol **NVR**

b) two colourless liquids: hydrogen peroxide solution and water

Test: **add a catalyst (e.g. MnO2) or a suitable oxidant (e.g. C2) or**

**reductant (e.g. I–)**

Observations: **depends on test, but for most:**

H2O2(aq) **c/less, o/less gas evolved**

H2O(l) **NVR**

[6 marks]

9. Write the anode and cathode reactions for the following cells:

a) electrolysis of AgNO3(aq) using a Pt anode and Ag cathode

anode **2 H2O O2 + 4 H+ + 4 e–**

cathode **Ag+ + e– Ag**

b) the H2/O2 fuel cell in acidic conditions

anode **H2 2 H+ + 2 e–**

cathode **O2 + 4 H+ + 4 e– 2 H2O**

c) recharging the lead-acid accumulator (car battery)

anode **PbSO4 + 2 H2O PbO2 + SO42–  + 4 H+ + 2 e–**

cathode **PbSO4 + 2 e­– Pb + SO42–**

[6 marks]

10. a) Use one or more of the following molecules to sketch a section of the appropriate polymer. Your sketch should show at least two repeating units.

* cis-2-butene
* HOCH2CH2CH2OH
* HOOCCOOH

|  |
| --- |
| Addition polymer  **CH3 CH3 CH3 CH3**  **I I I I**  **––––– C –– C –– C –– C –––––**  **I I I I**  **H H H H** |

|  |
| --- |
| Condensation polymer  **O O O O**  **II II II II**  **––– C – C ­– O – CH2CH2CH2 – O – C – C – O – CH2CH2CH2 – O ––** |

b) Sketch the monomer/s that would be used to make the polymer whose structure is shown below.

O O O O

ll ll ll ll

– C – O– (CH2)4 – C – O – (CH2)4 – C – O – (CH2)4 –C –

|  |
| --- |
| **HO(CH2)4COOH** |

[2,2,2 = 6 marks]

11. There are several isomers with molecular formula C4H8O. Draw full structural formula(e) of isomer(s) that fit the following descriptions;

|  |  |
| --- | --- |
| Description | Structural Formula(e) |
| a) the product of oxidising 2-butanol using acidified sodium dichromate | **CH3COCH2CH3** |
| b) it can be oxidised to  2-methylpropanoic acid using acidified potassium permanganate | **(CH3)2CHCHO** |
| c) a saturated primary alcohol |  |
| d) a saturated secondary alcohol |  |
| e) a pair of geometric isomers | **H CH2OH H3C CH2OH**  **\ / \ /**  **C = C and C = C**  **/ \ / \**  **H3C H H H**  **or**  **HO CH3 H3C CH3**  **\ / \ /**  **C = C and C = C**  **/ \ / \**  **H3C H HO H**  **or**  **HO H HO CH2CH3**  **\ / \ /**  **C = C and C = C**  **/ \ / \**  **H CH2CH3 H H** |

[6 marks]

**END OF PART 2**

**PART 3 (50 marks = 25% of paper)**

1. a)

|  |  |  |
| --- | --- | --- |
| **P**  **m(P) = 2 x 30.97 x 0.562**  **222.56**  **= 0.1564 g**  **% (P) = 0.1564 X 100**  **0.847**  **= 18.47 %** | **C**  **n(Ag+) = n(C–)**  **= 0.5 x 0.0225**  **= 0.01125 mol**  **m(C) = 0.01125 x 35.45**  **= 0.3988 g**  **%(C) = 0.3988 x 100**  **0.639**  **= 62.41 %** | **S**  **%(S) = 100 – [%P + % C]**    **= 19.12 %** |
| **n(P) = 18.47/30.97**  **= 0.5964**  **ratio : 1**  **(/0.5962)** | **n(C) = 62.41/35.25**  **= 1.760**  **3** | **n(S) = 19.12/32.06**  **= 0.5964**  **1** |

**EF : PSC3**

b) **n(compound) = PV/RT = 41.33 x 0 .3 = 0.002851 mol**

**8.315 x 523.1**

**M(compound) = m/n = 0.482/0.002851 =** **169.1 g mol–1**

c) **M(PSC3) x n = 169.1**

**169.4 x n = 169 .1 n = 1**

**MF : PSC3**

2. **n(Br2)total = c.V = 0.3 x 0.020 = 0.006000 mol**

**n(Na2S2O3)reacted = c.V = 0.0314 x 0.01742 = 0.0005470 mol**

**n(Br2)excess = 4 x n(Na2S2O3) = 4 x 0.000547 = 0.002188 mol**

**n(Br2)reacted = 0.006000 – 0.002188 = 0.003812 mol**

**n(C2H4) = n(Br2) = 0.003812 mol**

**V(C2H4) = nRT/P = 0.003812 x 8.315 x 298.1 = 0.09573 L**

**98.7**

**%(C2H4) by volume = 0.09573 x 100 = 9.57 %**

**1.00**

3 a)

|  |  |  |
| --- | --- | --- |
| **Solution X**  **[H2SO4] = 0.210 x 50/250**  **= 0.0420 mol L–1** | **Solution Y**  **n(HC) = V/22.41**  **= 0.585/22.41**  **= 0.0261 mol**  **[HC] = n/V**  **= 0.0261/0.50**  **= 0.0522 mol L–1** | **Solution Z**  **n(NaOH) = c.V**  **= 0.557/39.998**  **= 0.01393 mol**  **[NaOH] = n/V**  **= 0.01393/0.100**  **= 0.139 mol L–1** |

b) **H+ + OH– H2O**

**n(H+) from H2SO4  = 2 x 0.03 x 0.0420 = 0.002520 mol**

**n(H+) from HC = 0.03 x 0.0522 = 0.001566 mol**

**n(H+)total = 0.001566 + 0.00252 = 0.004086 mol**

**n(OH–) = 0.03 x 0.1393 = 0.004170 mol**

**n(OH–)excess = 0.004170 – 0.004086 = 0.00008400 mol**

**[OH-] = 0.00008400 / 0.0900 = 0.0009333 mol L–1**

**pOH = – log[OH–] = 3.02**

**pH = 14 – pOH = 11.0**

4. a) **n(H2C2O4) = 4.277/90.036 = 0.04750 mol**

**[H2C2O4] = n/v = 0.04750 x 20//250 = 0.003800 mol L–1**

**n(Cr2O72–) = 1/3 x 0.003800 = 0.001267 mol**

**[Cr2O72–] = n/v = 0.001267/0.02555 = 0.0496 mol L–1**

b) **n(Cr2O72–) = c x v = 0.0496 x 0.03546 = 0.001758 mol**

**n(CH3CH2OH) = 3/2 x 0.001758 = 0.002637 mol**

**m(CH3CH2OH) = 0.002637 x 46.068 = 0.1215 g**

**% (alcohol) by mass = 0.1215 x 100 = 0.486 %**

**25**

5. a) **n(Au) = 0.124/197.0 = 0.0006294 mol**

**n(e) = n(Au) = 0.0006294 mol**

**since cathode reaction is Au(CN)2– + e– Au + 2 CN–**

**Q = n(e) x 96490 = 0.0006294 x 96490 = 60.73 C**

**With % efficiency Q = 100/68.1 x 60.73 = 89.18 C**

**t = Q/I = 89.18/5.20 = 17.1 seconds**

b) **Hg22+ + 2 e– 2 Hg**

**Q = 34.30 x 5.20 = 178.37 C**

**n(e-) = 178.37/96490 = 0.001848 mol**

**n(Hg) = n(e-) = 0.001848 mol**

**m(Hg) = 0.001848 x 200.6 = 0.3708 g**

**true m(Hg) obtained = 0.813 x .3708 = 0.301 g**

**End of Part 3**

**PART 4 (20 marks = 10% of paper)**

*There is no single correct response to this question.*

*In order to achieve high marks, responses would need to:*

*- be relevant to the topic/s referred to in the question*

*- make specific reference to the material/information presented*

*- provide equations where appropriate*

*- link evidence to theory*

*- contain no errors*

*Listed below are some points that could have been addressed.*

Zinc is a metallic solid. Its structure is that of Zn2+ ions in a sea of delocalised electrons (sketch diagram). The metallic bond is the electrostatic attraction between cations and surrounding delocalised electrons. These bonds are strong, so zinc has moderately high melting and boiling points (420ºC and 907ºC respectively). The non-directional nature of the bonds accounts for its malleability and ductility. The delocalised valance electrons provide the mobile charged particles required for electrical conductivity.

Zinc oxide is an ionic solid. Its structure is that of a three-dimensional network of alternate Zn2+ and O2– ions (again, include a diagram). The ionic bond is the electrostatic attraction between oppositely charged ions. The bond is very strong, so zinc oxide has a high melting point (1975ºC).

Zinc, zinc oxide and zinc hydroxide are amphoteric, which means that these substances can react with both acids and bases. This is demonstrated by the equations below, which show the reaction of each with H+ and OH–:

Zn(s) + 2 H+(aq)  Zn2+(aq) + H2(g)

Zn(s) + 2 OH–(aq)  + 2 H2O(l) Zn(OH)42–(aq) + H2(g)

ZnO(s) + 2 H+(aq)  Zn2+(aq) + H2O(g)

ZnO(s) + 2 OH–(aq)  + H2O(l) Zn(OH)42–(aq)

Zn(OH)2(s) + 2 H+(aq)  Zn2+(aq) + 2 H2O(g)

Zn(OH)2(s) + 2 OH–(aq)  Zn(OH)42–(aq)

In the extraction of zinc, the sphalerite is heated strongly in air. The sulfide is oxidised to SO2, with ZnS converted to ZnO. The zinc is recovered from zinc oxide by carbon reduction. This is similar to the recover of iron from iron(III) oxide via carbon reduction, except that the reducing agent in the latter is CO rather than C.

In the alternative method for the extraction of zinc from zinc oxide, the zinc oxide is dissolved in sulfuric acid:

ZnO(s) + 2 H+(aq)  Zn2+(aq) + H2O(g)

and the zinc recovered by electrolytic reduction of the solution (sketch a diagram):

Zn2+ + 2 e– Zn

In electrolysis, electrical energy is used to drive a non-spontaneous chemical reaction. Reduction occurs at the negative electrode (connected to negative terminal of external power source) and oxidation at the positive electrode (connected to the positive terminal). The flow of charge through the solution is via movement of ions - anions towards anode, cations towards cathode.

Under standard conditions, the reduction of zinc ions would not occur because water is a stronger oxidant, as demonstrated by their standard reduction potentials

2 H2O + 2 e– H2 + 2 OH­– [1.00 x 10–7 mol L­–1] Eº = – 0.41 V

Zn2+ + 2 e– Zn Eº = – 0.76 V

However, at sufficiently high concentration the reduction of Zn2+ becomes more likely.

In ores containing cadmium, cadmium ions are removed from solution by displacement with powdered zinc. This reaction can occur because zinc is a more reactive metal than cadmium:

Cd2+ + 2 e– Cd Eº = – 0.40 V

Zn2+ + 2 e– Zn Eº = – 0.76 V

Cd2+ + Zn Cd + Zn2+

The zinc that goes into solution can be recovered via the subsequent electrolytic reduction.

A similar reaction occurs in the use of powdered zinc to recover gold from the aurocyanide complex:

2 Au(CN)2–(aq) + Zn(s) → Zn(CN)42–(aq) + 2 Au(s)

Many other uses of zinc rely on its ability to act as a reductant, such as the use of zinc in dry cells. The dry cell is an electrochemical cell or battery, in which a spontaneous reaction occurs. Since the oxidant and reductant are physically separated, the reaction will only occur if the battery is connected via an external circuit. This allows the flow of electrons to be utilised. The flow of charge within the battery is via ions; anions flow towards the anode and cations towards the cathode. Note that in the electrochemical cell the polarities of the anode and cathode are negative and positive respectively.

The dry cell has an outer zinc casing, which contains an NH4Cl / MnO2 paste and a carbon rod (sketch a diagram). The zinc serves as the anode and is oxidised:

Zn Zn2+ + 2 e–

The carbon rod serves as the cathode, at which manganese is reduced:

2 MnO2 + 2 H+ + 2 e– → Mn2O3 + H2O

The hydrogen ions are supplied by the hydrolysis of ammonium ions, which are weakly acidic:

NH4+ + H2O ⇄ NH3 + H3O+

The dry cell is a primary cell - meaning that it cannot be recharged - and typically generates an EMF of approximately 1.5 V.

Zinc is also used to prevent the corrosion of iron (rusting). The first stage of rusting involves the oxidation of iron by oxygen in the presence of water:

Fe Fe2+ + 2 e–

O2 + H2O + 4 e– 4 OH–

Fe(OH)2 forms, which is further oxidised to Fe(OH)3, which is dehydrated forming the familiar reddish-brown Fe2O3. Unlike the oxides of many other metals (e.g. zinc, aluminium), the oxidised layer at the surface of the iron affords no protection to the underlying metal.

Corrosion prevention targets the initial oxidation of iron.

If zinc is physically connected, either directly or indirectly (by an electrical conductor), to an iron/steel structure an electrochemical cell is established (sketch a diagram). Since zinc is a stronger reductant, it will undergo oxidation:

Zn Zn2+ + 2 e–

The iron/steel structure acts as the cathode where a reduction reaction occurs, possibly:

O2 + H2O + 4 e– 4 OH–

Since the zinc is consumed, it is referred to a sacrificial anode.

Zinc is used to galvanise iron/steel objects. This involves coating the object in a layer of zinc by electroplating or by immersion in a bath of molten zinc. The layer of zinc serves as a physical barrier, preventing the underlying iron/steel from contact with O2 and H2O. If scratched, the iron/steel continues to be protected because the zinc in the stronger reductant and is preferentially oxidised, making the exposed iron cathodic.

Zinc is a transition metal. Like many transition metals it forms complex ions - Zn(CN)42–, Zn(OH)42–, Zn(NH3)42+. However, unlike many transition metals it is colourless in solution.

**END OF EXAMINATION**