**SECTION 1: 25 multiple choice questions (25 marks 25 %)**

Answer ALL questions in Part 1 on the Separate Multiple Choice Answer Sheet provided, using a 2B pencil. Each question in this part is worth 1 mark.

**1b, 2c, 3c, 4b, 5b, 6a, 7a, 8d, 9c, 10c, 11a, 12d, 13b, 14c,**

**15d, 16b, 17d, 18a, 19a, 20a, 21c, 22d, 23c, 24b, 25d.**

**SECTION 2 13 questions (80 marks 40 %)**

Answer ALLquestions in Section 2 in the spaces provided below.

1. Write equations for the reaction that occurs in each of the following procedures.

 If no reaction occurs, write ‘no reaction'.

In each case describe what you would observe, including any

\* colour change

**Subscripts not required**

\* odour

\* precipitate (give the colour)

\* gas evolutions (state the colour or describe as colourless)

If a reaction occurs but the change is not observable, you should state this.

(a) Oxygen gas is bubbled through an acidified solution of iron (II) sulfate.

**Equation** **O2 + 4 H+ + 4 Fe2+ 🡪 2 H2O + 4 Fe3+**

**Observation** **Pale green solution turns red/yellow/brown** **Oxygen dissolves**

 (3marks)

**Equation ionic = 2 full = 1 One observation = 1**

(b) Ethene gas is bubbled through bromine water (aqueous solution of bromine).

**Equation** **C2H4 + Br2 🡪 C2H4Br2**

**Observation** **Brown colour of solution disappears / turns colourless**

 (3marks)

**Equation = 2 Observation = 1**

2. For each of the following sets of observations:

 (i) write a description of any **one** reaction that matches the observations, and

 (ii) give an appropriate equation for **that** reaction.

**e.g**. A brown solution is added to a colourless solution, producing a brown precipitate.

**Reaction** *iron (III) nitrate solution is mixed with sodium hydroxide solution.*

**Equation** *Fe3+ + 3 OH− → Fe(OH)3*

a) A purple solution is mixed with a colourless solution, producing a colourless solution and a colourless gas

**Reaction** **Refer to the Data Sheet Eo Table**

 **Acidified permanganate + oxalic acid 🡪 CO2**

 **Acidified permanganate + hydrogen peroxide 🡪 O2**

**Equation**

 **2 MnO4− + 6 H+ + 5 H2C2O4 🡪 2 Mn2+ + 8 H2O + 10 CO2**

 **2 MnO4− + 6 H+ + 5 H2O2 🡪 2 Mn2+ + 8 H2O + 5 O2**

 (3 marks)

b) A metal strip is placed in a green solution. Silvery-white crystals form on the strip and the green colour fades.

**Reaction**

 **Ni2+ / Fe2+ / Cr3+ salt + more reactive metal Zn / Mg / Al / Mn [not Na or lower]**

**Equation**  **examples**

 **Fe2+ + Zn 🡪 Fe + Zn2+ accept Fe as shiny white**

 **Fe2+ + Mg 🡪 Fe + Mg2+**

 **Ni2+ + Zn 🡪 Ni + Zn2+**

 **3 Ni2+ + 2 Al 🡪 3 Ni + 2 Al3+**

**Metal must be below metal ion on Eo table**

 **2 Cr3+ + 3 Mg 🡪 2 Cr + 3 Mg2+**

 **Cr3+ + Al 🡪 Cr + Al3+**

**Equation = 2 Reaction = 1**

(3 marks)

3. Draw electron-dot diagrams showing the arrangement of all valence electrons in the following chemical species.

 Describe the shape of each (eg: linear/bent/etc)

**OSCl2 (2 possible) OPCl3**

**P**

**Cl**

**Cl**

**Cl**

**O**

**S**

**O**

**Cl**

**Cl**

**Deduct 1 mark per error**

 Shape **triangular planar**  Shape **tetrahedral**

**O**

**Cl**

**Cl**

**S**

 Shape **pyramidal**

 (6 marks)

4. Methane reacts with fluorine to form four different fluorinated compounds.

 Write the names and formulas of all the fluorinated methanes that are polar.

**Fluoromethane CH3F**

**3 = 4 marks**

**2 = 2 marks**

**1 = 1 mark**

**4 = 3 marks**

**Difluoromethane CH2F2**

**Trifluoromethane CHF3**

(4 marks)

5. The following table shows the solubilities of two amines in water.

|  |  |  |
| --- | --- | --- |
| Amine | Methyl amineCH3NH2 | Dodecyl amineCH3(CH2)11NH2 |
| Solubility (g/100 mL) | 108 | 0.05 |

**2 well-explained reasons = 4 marks**

**diagram = 2 marks**

Explain why their solubilities are so different.

Include a labelled diagram.

* **New solute-solvent bonds should be at least as strong as original solute-solute and solvent-solvent bonds**
* **Both can hydrogen-bond, BUT dodecyl isomer has a long non-polar chain that can only interact with H2O by dispersion force attraction,**
* **The new forces of attraction would be much weaker than the bonds broken between water molecules**

**N**

**H**

**H**

**CH3 -------------------- CH2**

**O**

**H**

**H**

**O**

**H**

**H**

**O**

**H**

**H**

**O**

**H**

**H**

**O**

**H**

**H**

**O**

**H**

**H**

**O**

**H**

**H**

**O**

**H**

**H**

**Strong H-bonds replacing strong H-bonding between H2O molecules and NH2 groups**

**Only weak dispersion forces replacing strong H-bonding between H2O molecules**

 (6 marks)

6. Three unlabelled beakers each contain the same volume of 1 mol L−1 solution. The three solutions are:

* sodium hydrogensulfate (NaHSO4)
* sulfuric acid (H2SO4), and
* phosphoric acid (H3PO4).

 The student is asked to identify the solutions. He is also given a bottle of sodium hydroxide (NaOH) solution, a choice of indicators and is allowed to use any other item of laboratory glassware. The student was successful.

 How did the student correctly identify the acids?

 Include equations to support your answer.

**Add measured amount/volumes of NaOH solution to each**

**1**

 **(burette / graduated cylinder)**

**NaHSO4 is monoprotic acid – will need 1 volume**

**2**

**HSO4− + OH− 🡪 SO42− + H2O**

**H2SO4 is diprotic acid – will need 2 volumes**

**2**

**H2SO4 + 2 OH− 🡪 SO42− + H2O**

**H3PO4 is triprotic acid – will need 3 volumes**

**2**

**H3PO4 + 3 OH− 🡪 PO43− + 3 H2O**

 (7 marks)

7. Quaternary ammonium salts can be represented by the following structural formula.



Cl−

H

H

H

If the alkyl group (**R**) is long then the salt acts like a soap or detergent. If it is short the salt has no cleaning properties.

Explain these two differences in properties.

Include a labelled diagram.

**2 well-explained reasons = 3 or 4 marks**

**diagram = 2 or 3 marks**

* **Grease is non-polar**
* **Cleaning agent needs a long non-polar tail to stick deep into the layer of grease so that when the water is agitated and pulls at the polar head sticking out of the grease layer the tail will remain bonded in the grease**
* **A short tail will not provide sufficient dispersion interaction**
* ***Causing the grease to break up into micelles/globules that can be rinsed away (not required)***

**+**

**+**

**+**

**+**

**+**

**+**

**+**

**+**

**+**

**+**

**+**

**+**

**Non-polar grease droplet**

***The exposed negative charges keep micelles from rejoining***

**Italicised parts not required**

**Positive**

**Cationic**

**head**

**Non-polar hydrocarbon tail**

 (6 marks)

8. An electrochemical cell contains the two half cells separated by a porous membrane, which allows ions to migrate through. Each half cell has a metal rod placed in a solution of its nitrate.

Assume the solutions are 1 mol L─1

Porous barrier allows ions to pass through

Pb(NO3)2 solution

Cr(NO3)3 solution

Cr

# Pb

(a) Write the two half reactions that occur, their standard reduction potentials and state whether each is oxidation, or reduction,

**Pb2+ + 2e 🡪 Pb Reduction** Eº = **− 0.13 V**

**Cr 🡪 Cr3+ + 3e Oxidation** Eº = **+ 0.74 V**

 (4 marks)

(b) Write the equation for the net redox equation.

 **3 Pb2+ + 2 Cr 🡪 3 Pb + 2 Cr3+** (2 mark)

(c) What is the emf (electromotive force, or voltage) of the cell?

 **0.61 V** (1 mark)

(d) Draw an arrow in the top box to show the direction of current (electron flow) in the wire connecting the two electrodes.

(1 mark)

(e) What change (or changes) will be observed in the cell?

**Lead rod becomes thicker *(accept shiny crystals form)***

**Chromium rod becomes thinner**

**Chromium solution colour deepens (more green)**

(3 marks)

9. A student is asked to identify four organic liquids, contained in four separate flasks.

* Octene
* Hexan-3-ol (3-hexanol)
* Hexan-3-one (3-hexanone)
* Butanoic acid

The student has access to any chemicals and glassware required.

Describe the tests that should be carried out, and the observations, that enable the liquids to be identified.

Include equations to justify the choice of tests.

**2 marks for each test**

**May be in different order**

**Mix each with bromine water**

**Octene will decolorise it**

**C8H16 + Br2 🡪 C8H16Br2**

**Mix the remaining three with sodium carbonate solution**

**Butanoic acid will produce bubbling**

**2 C3H7COOH + Na2CO3 🡪 2 C3H7COONa + H2O + CO2**

**Mix the remaining two with acidified potassium permanganate (or potassium dichromate) solution**

**Hexanol will turn purple permanganate (or green dichromate) colourless**

**5 C6H14O + 2 MnO4− + 6 H+ 🡪 5 C6H12O + H2O**

 **3-hexanone**

**Hexanone will not decolorise the solutions as ketones are not oxidised with acidified potassium permanganate (or potassium dichromate)**

**Some students may state that octene reacts with acidified permanganate – but so does hexanol**

 (8 marks)

10. The following table gives information about two substances. Use the information to determine whether each substance is acting as an oxidising agent (oxidant), or reducing agent (reductant) and provide a brief explanation to justify your answer.

|  |  |  |
| --- | --- | --- |
| **Substance** | **Information** | **Oxidant, or reductant?** |
| Concentrated sulfuric acidH2SO4 | Reacts with copper to produce sulfur dioxide. | **Oxidant****1****S changes from +6 to +4** **1****is reduced so must be an oxidant** |
| Hydrogen peroxideH2O2 | Reacts with chlorine to produce chloride ion. | **Reductant****1****Cl changes from 0 to −1** **1****is reduced so H2O2 must be a reductant** |

 (4 marks)

11. A student pours pours some silver nitrate solution into a bronze (copper-tin alloy) container.

Is this wise?

Explain why, or why not. Include an equation.

**NO**

**1**

**Both copper and tin *are more reactive than Ag and* react with silver ion**

**The container will dissolve (how much depends on the moles of Ag+ present) and contaminate the solution**

**1**

**2 Ag+ + Cu 🡪 2 Ag + Cu2+**

**1**

**2 Ag+ + Sn 🡪 2 Ag + Sn2+**

(3 marks)

12. Vinegar is about 4% by mass acetic acid and is safe to consume in foods. The same strength sulfuric acid is not safe to consume. Explain why. Include equations.

**Sulfuric acid a strong acid and ionizes completely**

**1**

**1**

**H2SO4 🡪 H+ + HSO4−**

**then H2SO4−** ⇌ **H+ + SO42−**

**Acetic acid (in vinegar) is a weak acid and ionizes to only a small extent *(about 1%)***

**1**

**CH3COOH** ⇌ **H+ + CH3COO−**

**1**

**Sulfuric acid has a much higher hydrogen ion concentration**

(4 marks)

13. Name, and draw structural diagrams for, the following organic compounds.

|  |  |  |
| --- | --- | --- |
| Compound | Structural diagram | Name |
| An isomer of dibromobutane**2 + 1** | **H****H****H****H****C****C****C****C****H****H****H****H****Br** **Br****C****C****C****C****H****H****H****H****H****H****Br****H****Br** **H****C****C****C****C****H****H****Br****H****H** **H****Br****H****H** **H****C****C****C****C****H****H****H****H****H****H****H****Br****Br** **H****C****C****C****C****H****H****H****H****H** **Br****Br****H****H** **H****C****C****C****C****H****H****H****H****H****Br****H****H****Br** **H** | **1,1 – dibromobutane****1,2 - dibromobutane****2,2 - dibromobutane****2,3 - dibromobutane****1,3 - dibromobutane****1,4 - dibromobutane** |
| An ester containing 4 carbon atoms**2 + 1****H****O****H****H****C****C****C****H****H** **H****C****C****O****H****H****OCH2CH3** **H****C****O****OCH2CH2CH3** **H****C****C****C****O****H****H****H****H****OCH3** **H** |  | **methyl propanoate****ethyl ethanoate****propyl methanoate** |
| The ketone with the least number of carbon atoms**2 + 1** |  | **propanone** **acetone** |

(9 marks)

**SECTION 3 5 questions (70 marks 35 %)**

Extended answers

Answer ALLquestions in Section 3 in the spaces provided.

1. **Treatment of waste by-products in chemical industry 16 marks**

 In a chemical industries complex one production plant produces a waste caustic soda (NaOH) solution, which it stores in a large pond. Another production plant produces waste carbon dioxide. The chemical engineers decide to combine both wastes to produce the environmentally friendly by-product, sodium carbonate, by bubbling the carbon dioxide through the caustic soda solution.

 2 NaOH + CO2 🡪 Na2CO3 + H2O

The caustic soda pond contains 500 kL and has a hydroxide (OH−) concentration of 1.00 x 10−2 mol L−1.

(a) What is the pH of the solution?

**1**

**[H+][OH−] = 10−14**

**1**

**[H+] = 10−14 / [OH−] = 10−14 / 10−2 = 10−12**

**1**

**pH = − log [H+] = − log [10−12] = 12**

(3 marks)

(b) What is mass of sodium hydroxide in the caustic soda pond?

**1**

**n = c V = (0.01)(500 000) = 5 000**

**2**

**m = n M = (5 000)(39.998) = 200 000 g (200 kg)**

(3 marks)

(c) What mass of carbon dioxide is needed to completely react with sodium hydroxide?

 ***If you did not answer Part (b) above, use a mass of 100 kg* sodium hydroxide**

**2 NaOH + CO2 2 : 1 mol ration**

**2**

**n (CO2) = ½ n (NaOH) = (0.5)(5 000) = 2 500**

**1**

**m (CO2) = n M = (2 500)(44.01) = 110 025 g (110 kg)**

 **55 kg for 100 kg NaOH**

 (4 marks)

 (d) The carbon dioxide is first cooled to 10oC and is pumped at a pressure of 200 kPa, delivering 150 L per minute.

How long does it take to complete the reaction?

**PV = nRT**

**2**

**V = nRT / P = (2 500)(8.315)(273.1+10) / (200) = 29425 L**

**2**

**Time = volume (L) / volume per minute (L−min)**

**1**

 **= 29425 / 150 = 196 minutes**

 **98 minutes for 100 kg NaOH**

 (5 marks)

 (e) (i) The pond solution is still found to be alkaline (pH of about 9).

 Assuming all the carbon dioxide has reacted suggest a reason why is it still
 alkaline.

**1**

**Sodium carbonate is a basic salt**

**Carbonate ion hydrolyses to produce hydroxide ion**

**1**

**CO32− + H2O ⇌ HCO3− + OH−**

 (2 marks)

2. **Production of phosphorus from fluoroapatite 16 marks**

The mineral fluoroapatite [Ca10(PO4)6F2] is mixed with sand [SiO2] and powdered carbon in a high temperature furnace. The phosphorus is produced as a gas [P4], along with carbon monoxide. The reaction actually produces calcium oxide [CaO], which has a very high melting point. This would make the mixture difficult to control. So, as the calcium oxide is produced it reacts with the sand to form a low melting point slag, calcium silicate [CaSiO3]. This liquid slag is easily separated from the furnace.

The reaction occurring is:

 2Ca10(PO4)6 F2 (s) + 18 SiO2 (s) + 30 C (s) 🡪

 3 P4 (g) + 30 CO (g) + 18 CaSiO3 (l) + 2CaF2 (s)

**1**

(a) Is this reaction exothermic, or endothermic? **Endothermic**

 Give a reason for your choice.

**Passage states reaction is carried out in a furnace, so reactants must require continuous heating**

**1**

(2 marks)

 (b) The main reaction can be represented by the two half reactions:

* phosphate ion producing phosphorus (P4) and oxide ions (O2−), and
* carbon reacting with oxide ion producing carbon monoxide

**1**

Which element, phosphorus or carbon, is being oxidised?  **Carbon**

Justify your answer by referring to oxidation numbers.

**1**

**ON of C = 0 ON of C in CO = +2 *increased***

**ON of P in PO43− = +5 ON of P in P4 = 0 *decreased***

**1**

(c) List three elements whose oxidation states are not changing.

 **calcium oxygen silicon fluorine**

**3**

(6 marks)

(d) Some of the oxide ions produced in Part (b) becomes part of the liquid slag by reacting with calcium ions and sand.
Write the equation for the formation of the slag.

**Ca2+ + SiO2 + O2−** **🡪 CaSiO3**

 (2 marks)

(d) In a laboratory trial a 155 g sample of fluoroapatite (molar mass = 1008.62) is heated with excess sand and 25.0 g of carbon.

 What mass of phosphorus would be produced?

**2Ca10(PO4)6 F2 (s) + 30 C (s) 🡪 3 P4 (g)**

**M = 1008.62 M = 12.01 M = 61.94**

**1**

 **2 mol 30 mol 3 mol**

**Given**

**n = m / M**

**= 25 / 12.01**

**= 2.0816**

**Given**

**n = m / M**

**= 155 / 1008.62**

**= 0.15368**

**2**

**0.15368 mol fluoroapatite needs 30/2 x 0.15368 = 2.305 mol carbon**

**1**

**not enough carbon; carbon is limiting reactant**

**1**

**mol P4 produced 3/30 x mol (C) = (0.1)(2.0816) = 0.20816**

**m (P4) = n M = (0.20816)(4 x 30.97)**

**1**

 **= (0.20816)(123.88) = 25.8 g**

 (6 marks)

3. **Analysing an organic compound 13 marks**

 A certain organic compound is known to contain only carbon, hydrogen and oxygen.

The compound was analysed as follows.

* A 2.149 g sample was burned and the carbon dioxide produced was bubbled through a barium hydroxide solution, producing 11.27 g of barium carbonate (BaCO3).
 CO2 + Ba(OH)2 🡪 BaCO3 + H2O
* The mass of water produced by burning of the sample was 0.7721 g
* The compound was found to have a molecular weight of 150.1

a) What is the empirical formula of the compound? (10 marks)

 [*You may do this by finding the masses of carbon, hydrogen and oxygen in the sample*]

b) What is the molecular formula of the compound? (2 marks)

c) The compound is also known to be a carboxylic acid; that is, containing one COOH group.

 Write the molecular formula in the form of CXHY OZ COOH (giving values for X, Y and Z).

 (1 mark)

**CPHQOR**

**2.149 g**

**11.27 g BaCO3**

**n(C) = n (BaCO3)**

**= 11.27 / 197.31**

**= 0.057118**

**M (C) = n M**

**= (0.057118)(12.01) = 0.68599 g**

**carbon**

**hydrogen**

**0.7721 g H2O**

**n(H) = 2 n (H2O)**

**= 2 x 0.7721 / 18.016**

**= 0.085713**

**m (H) = n M**

**= (0.085713)(1.008) = 0.086399 g**

**m (O) = sample ­− m (C+H)**

**= 2.149 – (0.68599 + 0.086399)**

**= 1.3766**

**n (O) = m / M**

**= 1.3766 / 16.00**

**= 0.08604 mol**

**2**

**3**

**3**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **C** | **H** | **O** |
| **mol** | **0.057118** | **0.085713** | **0.08604** |
| **ratio****÷ 0.057118** | **1****2** | **1.51****3** | **1.51****3** |
| **Empirical formula is C2H3O3** |

**1**

**1**

**b) Empirical formula mass = 24 + 3 + 48 = 75**

**1**

**Molecular weight = 150.1 = 2 x empirical formula mass**

**So molecular formula is C4H6O6**

**1**

**c) Taking COOH out of the formula leaves C3H5O4**

**1**

**formula is C3H5O4 COOH**

4. **Production of benzene 14 marks**

Benzene (C6H6) can be produced by the dehydrogenation of cyclohexane (C6H12) gas. The reaction has a high activation energy (880 kJ mol−1), is also endothermic and reversible. The cyclohexane (C6H12) passes through a special reaction tower where hydrogen is chemically removed. The benzene/cyclohexane/hydrogen mixture then passes through a compressor, where the benzene is liquefied. A special membrane in the compressor allows the small hydrogen molecules to pass through, and out. The unreacted cyclohexane (C6H12) gas is then returned to the reaction tower.

C6H12 (g) + 120 kJ ⇌ C6H6 (g) + 3 H2 (g)

C6H12

C6H6 + C6H12 + H2

Reaction

tower

Compressor

Unreacted

C6H12

returned

Liquid benzene

C6H6

Hydrogen gas

H2

Hydrogen passes through membrane

a) Draw a labelled energy profile diagram for the reaction.

Reaction progress

Potential energy

**C6H12**

**C6H6 + 3H2**

**H = + 120 kJ**

**EACT = + 880 kJ**

**shape 1**

**EACT and H values indicated 1**

**reactant/products 1**

(3 marks)

b) Write an equilibrium constant expression for the reaction.

**[H2O]3**

**K =**

**[C6H6]**

**[C6H12]**

 (2 marks)

c) Under what conditions will the rate of the forward reaction be greatest?

**High temperature**

**High pressure**

**Adding a catalyst**

 (3 marks)

d) For a mixture of all three gases at equilibrium in a sealed container, what conditions will produce the maximum yield of benzene?

**High temperature**

**Low pressure**

 (2 marks)

e) Suggest conditions that would be used for the commercial production of benzene using this process.

 Explain why you chose these conditions.

**High temperature**

**1**

 **Favours shift right and increases reaction rate**

**Compromise pressure**

**High pressure increases reaction rate but favours shift left**

**2**

 **Low pressure decreases reaction rate but favours shift right**

 **Catalyst**

**Increases reaction rate (of forward and reverse) so does not favour shift but allows product to form more quickly**

**1**

 (4 marks)

5. **Determining concentration of cerium (II) sulfate solution by titration 10 marks**

 Cerium (II) ion can be converted to cerium (III) ion by hydrogen peroxide.

H2O2 + 2 H+  + 2 Ce2+ 🡪 2 H2O + 2 Ce3+ cerium is element 58

A solution of cerium (II) sulfate was analysed by the following steps:

1. 50.00 mL of the solution was diluted to 500.0 mL in a volumetric flask
2. 20.00 mL of this diluted solution was pipetted into a conical flask
3. About 20 mL of dilute sulfuric acid was added to the flask
4. Standardised hydrogen peroxide solution of concentration 0.05145 mol L−1 was delivered from a burette
5. 35.45 mL of the hydrogen peroxide was required for complete reaction

What was the concentration in moles per litre (mol L−1) and in grams per litre (g L−1) of the original undiluted cerium sulfate solution?

**n (H2O2) used in titration = c V**

**= (0.05145)(0.03545)**

**= 0.0018239**

**n (Ce2+) consumed = 2 x n (H2O2)**

**2**

**2**

**= (2)(0.0018239)**

**= 0.0036478**

 **present in 20.00 mL aliquot taken from the 500 ml vol flask**

**n (Ce2+) in 500 mL flask**

**2**

**= (500 / 20)(0.0036478)**

**= 0.091195**

 **this was in the original undiluted 50.00 mL solution**

**original concentration = n / V**

**= 0.091195 / 0.05000**

**2**

**= 1.824 mol L−1**

**1**

**= nM grams per litre CeSO4 = 236.16**

**1**

**= (1.8239)(218.16) = 431 g L−1**