## PART 3

Answer all questions in Part 3 . The calculations are to be set out in detail in this Question / Answer booklet. Marks will be allocated for correct equations and clear setting out, even if you cannot complete the problem. When the questions are divided into sections, clearly distinguish each section using (a) , (b) ,etc. etc. Express your final numerical answers to three (3) significant figures where appropriate, and provide units where applicable. Information that may be necessary to solve problems is located on the separate Chemistry Data Sheet. Show clear reasoning: if you don't marks will be lost. This part carries 50 marks (25% of the total).

1 A farmer accidentally empties a 5.000kg bag of 75.0% pure zinc nitrate hexahydrate, $Zn(NO_3)_2.6H_2O$, into a water tank containing 6000.0 L of rainwater. In order to remove this he decides to precipitate the zinc ions by using washing soda, sodium carbonate decahydrate, $Na_2CO_3.10H_20$

(a) Write an equation to describe the removal of the zinc ions by precipitation with the sodium carbonate solution. (1)

(b) Calculate the mass of sodium carbonate decahydrate that should be added to exactly remove all the zinc ions. (4)

However, the farmer believes that because 5.000kg of the zinc nitrate hexahydrate was added then an equal mass of $Na_2CO_3.10H_20$ should be added to the tank and so 5.000kg of pure $Na_2CO_3.10H_20$ is added.

(c ) Calculate whether the zinc nitrate or sodium carbonate is in excess. (2)

(d) Calculate the mass of zinc carbonate that is precipitated when the 5.000 kg of the sodium carbonate decahydrate was added. (2)

(e) Calculate the final concentration of $Na^+$ ions in the tank. (2)

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The results page of an experiment to determine the percentage purity of a sample of impure potassium carbonate , by titration against 0.1036 $molL^{-1}$ nitric acid is reproduced below :

| Object | Mass (g) |
|---|---|
| Beaker + impure potassium carbonate | 87.852 |
| Beaker | 85.641 |
| | |

The impure potassium carbonate was dissolved in distilled water and made up to a volume of 500.0mL in a volumetric flask

Volume of potassium carbonate solution pipetted = 20.00mL

**Burette readings** The nitric acid solution was placed in a burette

Concentration of nitric acid solution in burette =0.1036 $molL^{-1}$

| Titration | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Initial volume (mL) | 10.02 | 13.62 | 23.12 | 15.67 | 21.10 |
| Final volume (mL) | 39.65 | 36.04 | 45.66 | 38.15 | 42.10 |
| | | | | | |

(a) Determine the appropriate titration volume of nitric acid solution (2)

(b) Calculate the number of moles of potassium carbonate in the 20.00mL sample (4)

(c) Calculate the % purity of the potassium carbonate sample (4)

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4 Sulfuric acid can be prepared as a by product of the roasting of iron III sulfide as described by the following equations :

$$2Fe_2S_3 + 9O_2 \rightarrow 2Fe_2O_3 + 6\,SO_2$$

$$2SO_2 + O_2 \rightarrow 2SO_3$$

$$SO_3 + H_2O \rightarrow H_2SO_4$$

(a) How many moles of $Fe_2S_3$ is needed to produce 1 mole of $H_2SO_4$ ? (2)

(b) What mass of $Fe_2S_3$ is needed to produce 200.0 kg of 95.5% pure $H_2SO_4$ if the process for making sulfuric acid is only 82.2 % efficient ? (7)

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5 Iron ore consists of $Fe_2O_3$ and granite rock

A 1.500kg sample of crushed iron ore is dissolved in **excess** hydrochloric acid. The total amount of hydrochloric acid added was 2.50 litres, and the concentration of this acid was 4.250 $molL^{-1}$

20.00mL of this resulting acid solution (formed by dissolving the $Fe_2O_3$ ) required 12.74 ml of 0.1242 molL-1 NaOH solution to reach the end point.

(a) Calculate the number of moles of $H^+$ in the 20.00ml lots of the resulting acid solution formed from the iron ore (2)

(b) Calculate the total moles of $H^+$ in the resulting acid solution (1)

(c) Write a balanced equation for the reaction between $Fe_2O_3$ and hydrochloric acid (1)

(d) Calculate the number of moles of $H^+$ originally added to the crushed iron ore sample (1)

(e) Calculate the % $Fe_2O_3$ in the sample. (4)

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3 A swimming pool contains 40,000 litres of water. Unfortunately a bag of caustic soda (NaOH) is added to this pool and as a result the pH of the pool rises to 10.9.

(a) Calculate the concentration of $OH^-$ ions in the pool after the caustic soda was added. (2)

(b) Calculate the mass of sodium hydroxide that was added to the pool (3)

(c) The pool owner purchases a 100 L container of 9.50 mol $L^{-1}$ hydrochloric acid and adds the entire contents to the pool. Calculate :

(i) the final concentration of $H^+$ ions (4)

(ii) the final pH (1)

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2 In the cylinder of a motor car engine at high temperature, nitrogen and oxygen combine to form $NO_2$. This $NO_2$ is a source of environmental pollution.

$$N_{2\ (g)} \quad + \quad 2O_2(g) \quad \Leftarrow\!\Rightarrow \quad 2NO_2(g) \qquad H = +126\ \text{kJmol-1}$$

The source of this mixture of nitrogen and oxygen is the air that is added to the vaporised octane to be ignited by the spark plugs to power the vehicle.

The energy to drive the car is obtained from explosive combustion of a vaporised petrol (octane) / air mixture in the cylinders of the engine.

$$2\ C_8H_{18(g)} \quad + \quad 25\ O_{2(g)} \quad \Leftarrow\!\Rightarrow \quad 16CO_{2(g)} \ + \ 18H_2O(g) \qquad H = -1540\text{kJmol-1}$$

As a chemical engineer use chemical principles to design the engine features that would minimise the **yield** of $NO_2$ emissions- consider the factors such as the size (volume ) of the cylinders, temperature at which the engine operates ( it may vary from 110°C to 195°C) and the amount of air added to the octane for the second reaction. Also discuss how these conditions would affect the **rate of reaction.**

Whatever your recommendations, describe the impact of this design on the **efficiency of the combustion reaction** in terms of the same equilibrium and rate principles

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