Q1.(a) Sodium hydrogencarbonate ($NaHCO_3$) can also be used to neutralise ethanoic acid spillages. The equation for this reaction is shown below.

$$CH_3COOH + NaHCO_3 \longrightarrow CH_3COONa + H_2O + CO_2$$

State the ideal gas equation.

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(1)

(b) There are several methods by which ethanoic acid is synthesised on an industrial scale. One method is the oxidation of butane in the presence of metal ion catalysts. Balance the equation given below which summarises this reaction.

$$.....C_4H_{10} + ...O_2 \longrightarrow .....CH_3COOH + ...H_2O$$

(1)

(c) A second method by which ethanoic acid is synthesised involves the oxidative fermentation of ethanol in the presence of bacteria. The equation representing this reaction is given below.

$$C_2H_5OH + O_2 \longrightarrow CH_3COOH + H_2O$$

In a small scale experiment using this second method it was found that 23.0 g of ethanol produced only 4.54 g of ethanoic acid. Calculate the percentage yield for this experiment.

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(2)
(Total 4 marks)

Q2. Ammonium sulfate reacts with sodium hydroxide to form ammonia, sodium sulfate and water as shown in the equation below.

$$(NH_4)_2SO_4(s) + 2NaOH(aq) \rightarrow 2NH_3(g) + Na_2SO_4(aq) + 2H_2O(l)$$

(a) A 3.14 g sample of ammonium sulfate reacted completely with 39.30 cm^3 of a sodium hydroxide solution.

(i) Calculate the amount, in moles, of $(NH_4)_2SO_4$ in 3.14 g of ammonium sulfate.

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(2)

(ii) Hence calculate the amount, in moles, of sodium hydroxide which reacted.

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(1)

(iii) Calculate the concentration, in mol dm^{-3}, of the sodium hydroxide solution used.

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(1)

(b) Calculate the percentage atom economy for the production of ammonia in the reaction between ammonium sulfate and sodium hydroxide.

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(2)

(c) Ammonia is manufactured by the Haber Process.

$$N_2 + 3H_2 \rightleftharpoons 2NH_3$$

Calculate the percentage atom economy for the production of ammonia in this process.

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(1)

(d) A sample of ammonia gas occupied a volume of 1.53×10^{-2} m^3 at 37 °C and a

pressure of 100 kPa.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

Calculate the amount, in moles, of ammonia in this sample.

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(3)

(e) Glauber's salt is a form of hydrated sodium sulfate that contains 44.1% by mass of sodium sulfate. Hydrated sodium sulfate can be represented by the formula $Na_2SO_4.xH_2O$ where x is an integer. Calculate the value of x.

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(3)
(Total 13 marks)

Q3. Under suitable conditions magnesium will react with dilute nitric acid according to the following equation.

$$Mg(s) + 2HNO_3(aq) \rightarrow Mg(NO_3)_2(aq) + H_2(g)$$

A 0.0732 g sample of magnesium was added to 36.4 cm^3 of 0.265 mol dm^{-3} nitric acid. The acid was in excess.

(a) (i) Calculate the amount, in moles, of magnesium in the 0.0732 g sample.

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(1)

(ii) Hence calculate the amount, in moles, of nitric acid needed to react

completely with this sample of magnesium.

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(1)

(iii) Calculate the amount, in moles, of nitric acid originally added to this sample of magnesium.

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(1)

(iv) Hence calculate the amount, in moles, of nitric acid that remains unreacted.

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(1)

(b) In a second experiment, 0.512 mol of hydrogen gas was produced when another sample of magnesium reacted with dilute nitric acid. Calculate the volume that this gas would occupy at 298 K and 96 kPa. Include units in your final answer.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

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(3)

(c) Concentrated nitric acid reacts with magnesium to form an oxide of nitrogen which contains 30.4% by mass of nitrogen.

Calculate the empirical formula of this oxide of nitrogen. Show your working.

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(3)
(Total 10 marks)

Q4. (a) Nitromethane, CH_3NO_2, is used as an 'energy rich' fuel for motor-racing. It burns in oxygen forming three gases.

$$2CH_3NO_2(l) + 1\tfrac{1}{2}O_2(g) \rightarrow 2CO_2(g) + 3H_2O(g) + N_2(g)$$

(i) A 1.00 mol sample of nitromethane was burned in oxygen forming the products shown in the equation above. Calculate the total volume of gases produced at 298 K and 100 kPa (assume that the water is gaseous).

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(ii) This combustion reaction is very exothermic and reaches a temperature of 1000 K. Determine the total volume of gases when the temperature is raised to 1000 K at a constant pressure.

(If you have been unable to determine a volume in your answer to part (a)(i), you may assume it to be 8.61×10^{-4} m^3 but this is not the correct answer).

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(5)

(b) It has been suggested that, instead of releasing it into the atmosphere, the carbon dioxide gas evolved during a combustion reaction can be absorbed by sodium

hydroxide solution, as shown by the following equation.

$$2NaOH(aq) + CO_2(g) \rightarrow Na_2CO_3(aq) + H_2O(l)$$

(i) Give two reasons why this reaction might not be suitable for the removal of carbon dioxide from the exhaust gases of an engine.

Reason 1 .....

Reason 2 .....

(ii) The sodium hydroxide solution for this reaction can be made on an industrial scale, together with chlorine gas and hydrogen gas, by electrolysis of a dilute solution of sodium chloride. Suggest one commercial advantage and one environmental disadvantage of this industrial process.

Commercial advantage .....

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Environmental disadvantage .....

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(4)

(c) Nitrogen forms several different oxides. Calculate the empirical formula of an oxide of nitrogen which contains 26% of nitrogen by mass.

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(3)

(d) Another oxide of nitrogen, N_2O, decomposes on warming to produce nitrogen and oxygen. Write an equation for the decomposition reaction.

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(1)

(e) Internal combustion engines burn fuels in air. Suggest one advantage of using air mixed with N_2O for this purpose.

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(1)
(Total 14 marks)

Q5. Nitroglycerine, $C_3H_5N_3O_9$, is an explosive which, on detonation, decomposes rapidly to form a large number of gaseous molecules. The equation for this decomposition is given below.

$$4C_3H_5N_3O_9(l) \rightarrow 12CO_2(g) + 10H_2O(g) + 6N_2(g) + O_2(g)$$

(a) A sample of nitroglycerine was detonated and produced 0.350 g of oxygen gas.

(i) State what is meant by the term *one mole* of molecules.

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(ii) Calculate the number of moles of oxygen gas produced in this reaction, and hence deduce the total number of moles of gas formed.

Moles of oxygen gas .....

Total moles of gas .....

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(iii) Calculate the number of moles, and the mass, of nitroglycerine detonated.

Moles of nitroglycerine .....

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Mass of nitroglycerine .....

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(7)

(b) A second sample of nitroglycerine was placed in a strong sealed container and detonated. The volume of this container was 1.00×10^{-3} m^3. The resulting decomposition produced a total of 0.873 mol of gaseous products at a temperature of 1100 K.

State the ideal gas equation and use it to calculate the pressure in the container after detonation.

(The gas constant R = 8.31 J $K^{-1}mol^{-1}$)

Ideal gas equation .....

Pressure .....

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(4)
(Total 11 marks)