Higher Chemistry

Chemistry In Society Unit 3

The Chemical Industry, Mole Calculations, Percentage Yield and Atom Economy

The Chemical Industry Exercise 1

1.) The chemical industry will design a process to
Maximise what?
Minimise what?

2.) Describe the stages in the manufacture of a new product.

3.) What does the term Feedstock mean?

4.) What are the main raw materials used in the chemical industry?

5.) Give examples of capital, fixed and variable costs.

6.) Describe a continuous process, giving advantages and disadvantages.

7.) Describe a batch process, giving advantages and disadvantages.

8.) Along with economic viability suggest other factors that will impact on the location and route used to manufacture a new product.

9.) Aluminium is extracted from its purified oxide by molten electrolysis. Suggest two advantages and disadvantages of siting the aluminium smelters in the Scottish Highlands.

The Chemical Industry Exercise 2 Past Paper Questions

1. Which element is NOT a raw material in the chemical Industry?

A Nitrogen
B Oxygen
C Sodium
D Sulfur

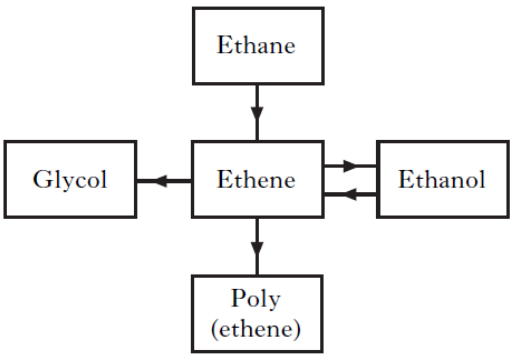
2. The costs involved in the industrial production of a chemical are made up of fixed costs and variable costs.
Which of the following is most likely to be classified as a variable cost?

A The cost of land rental
B The cost of plant construction
C The cost of labour
D The cost of raw materials

3. Which of the following is produced by a batch process?

A Sulfuric acid from sulfur and oxygen
B Aspirin from salicylic acid
C Iron from iron ore
D Ammonia from nitrogen and hydrogen

4 The flow chart summarises some industrial processes involving ethene.

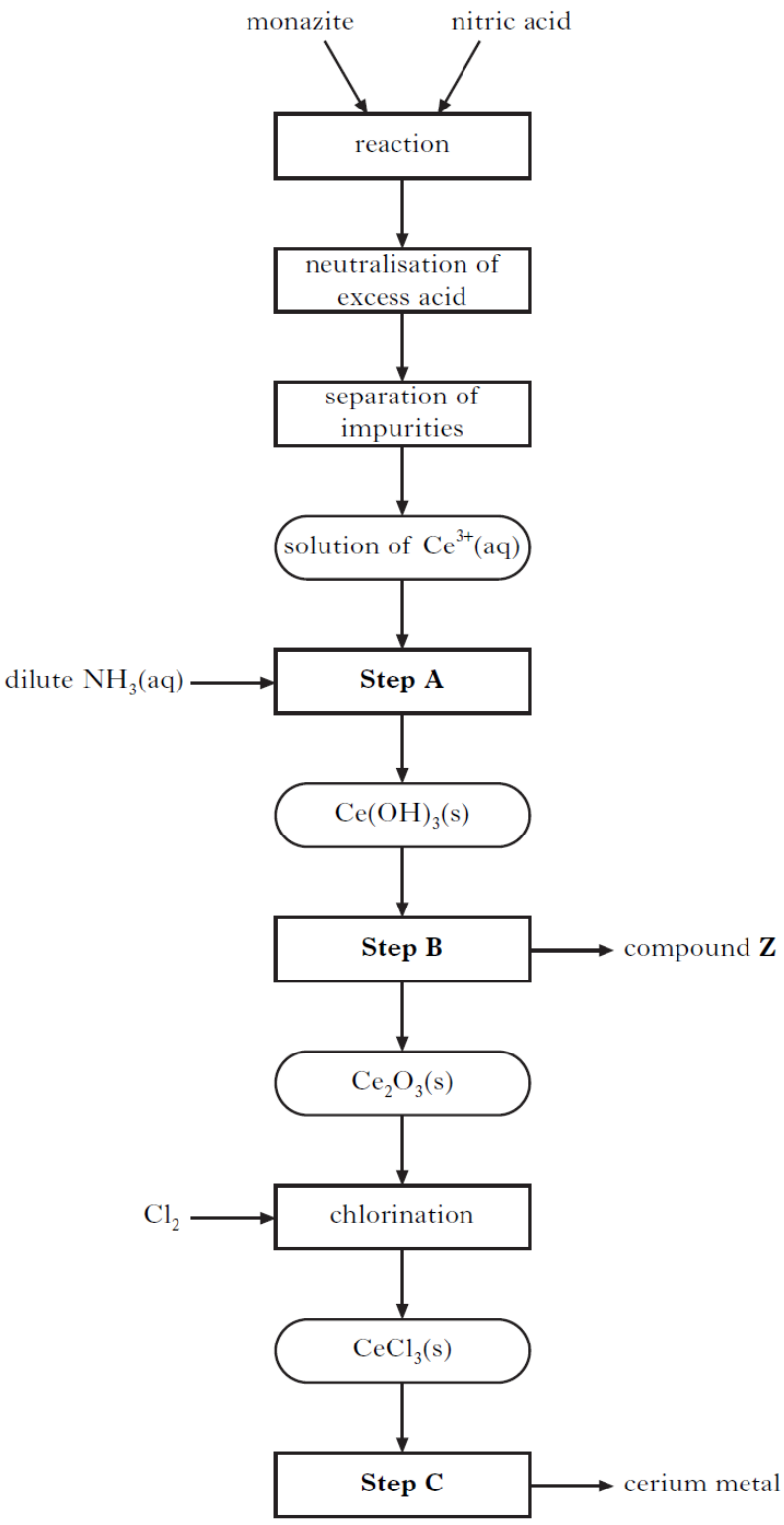


The feedstocks for ethene in these processes are

A ethane and glycol
B ethane and ethanol
C glycol and poly(ethene)
D glycol, poly(ethene) and ethanol.

5. Which of the following compounds is a raw material in the chemical industry?

A Ammonia
B Calcium carbonate
C Hexane
D Nitric acid


monazite
nitric acid
reaction
neutralisation of excess acid
separation of impurities
solution of $Ce^{3+}(aq)$
dilute $NH_3(aq)$
Step A
$Ce(OH)_3(s)$
Step B
compound Z
$Ce_2O_3(s)$
Cl_2
chlorination
$CeCl_3(s)$
Step C
cerium metal

6. Cerium metal is extracted from the mineral monazite. The flow diagram for the extraction of cerium from the mineral is shown on the previous page.

Name the type of chemical reaction taking place in Step A.

In Step B, cerium hydroxide is heated to form cerium oxide, Ce_2O_3, and compound Z.

Name compound Z.

In Step C, cerium metal is obtained by electrolysis

What feature of the electrolysis can be used to reduce the cost of cerium production?

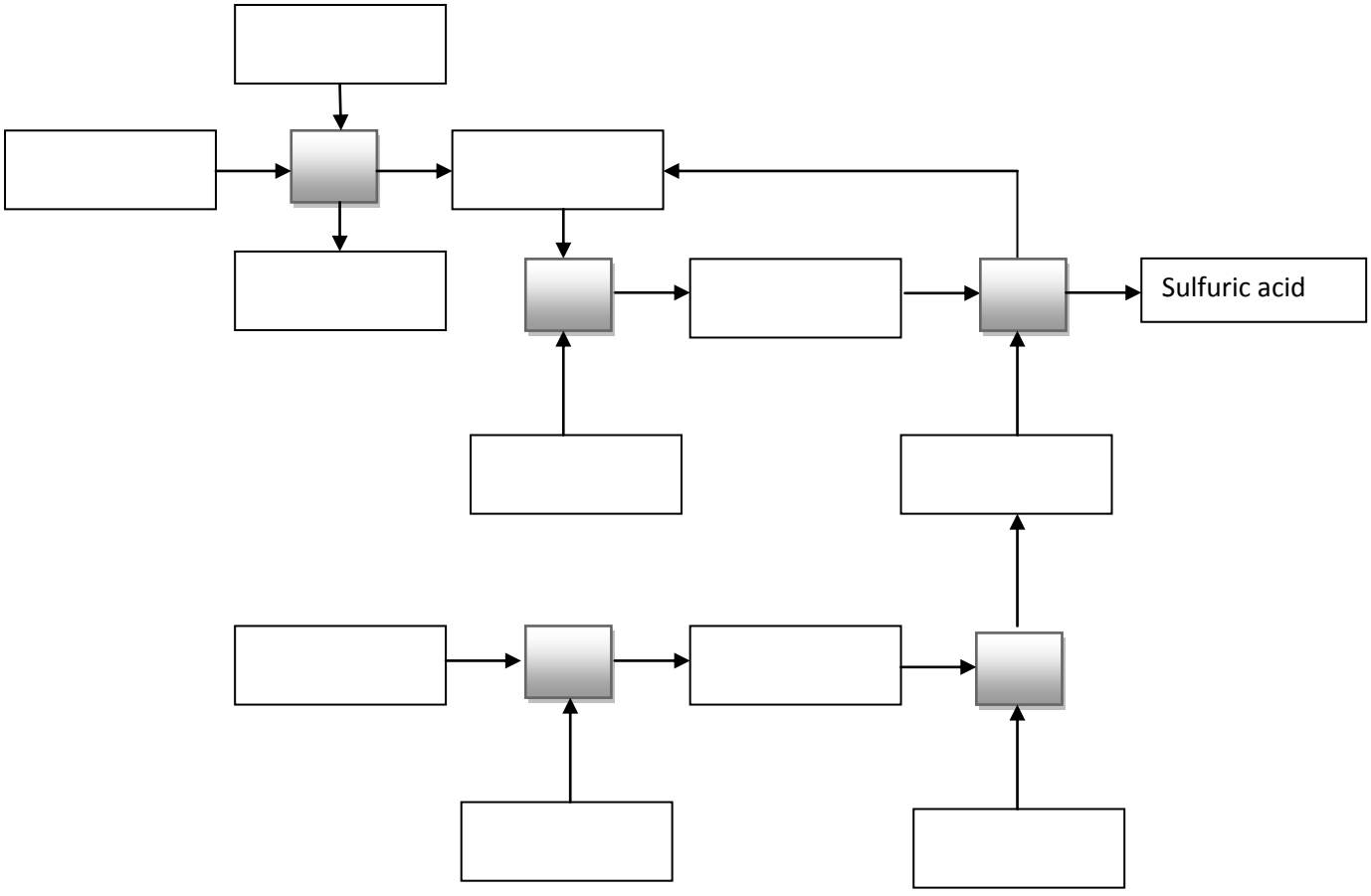
7. About 2.5 million tonnes of sulfuric acid are produced each year in the UK. Sulfuric acid was made industrially by the Chamber Process. The following chemical reactions are involved.

Sulfur is burned to produce sulfur dioxide.
Sulfur dioxide reacts with water to produce sulfurous acid.
Nitric oxide is produced by the catalytic oxidation of ammonia; water is also a product of this reaction.
Nitric oxide reacts with oxygen to form nitrogen dioxide
Nitrogen dioxide reacts with sulfurous acid to form sulfuric acid and regenerate nitric oxide.

Copy and complete the flow diagram below of the Chamber process with the names of the chemicals involved (2 Marks)

To show the name of a chemical

To Show a reaction



The Mole Revision Exercise 3

Moles and mass

1.) Write the formula and then work out the gram formula mass (mass of 1 mole) of:

a) hydrogen sulfide (b) magnesium bromide
c) hydrogen sulfate (d) hydrogen nitrate

2.) What is the mass of the following?

a) 10 moles of calcium carbonate (b) 3 moles of sodium chloride
c) 0.5 moles of lithium fluoride (d) 0.2 moles of methane (CH_4)

3.) How many moles of compound are present in:

a) 14 g of nitrogen gas (b) 400 g of copper(I) oxide
c) 85 g of lithium chloride (d) 117 g of sodium sulfide

Moles and concentration

1) Calculate the number of moles of:
   a) sodium chloride in 1000 cm^3 of 1 mol l^{-1} solution.
   b) sodium chloride in 500 cm^3 of 0.5 mol l^{-1} solution.
   c) potassium nitrate in 250 cm^3 of 0.5 mol l^{-1} solution.

2) What volume of water is required to make:
   a) 3 moles of potassium hydroxide into a 1.5 mol l^{-1} solution?
   b) 0.5 moles of sodium chloride into a 2 mol l^{-1} solution?
   c) 0.1 moles of lithium oxide into a 0.05 mol l^{-1} solution?

3) What concentration of solution is obtained if we dissolve:
   a) 2 moles of sodium hydroxide in 500 ml of water?
   b) 1 mole of lithium chloride in 2 L of water?
   c) 1.5 moles of magnesium bromide in 100 cm^3 of water?

4) What concentration of solution is obtained if we dissolve:

   a) 40 g of sodium hydroxide in 1 litre of water?
   b) 58.5 g of sodium chloride in 100 cm^3 of water?
   c) 585 g of sodium chloride in 10 litres of water?

5) What volume of water is required to make:

a) 56 g of potassium hydroxide into a 1.5 mol l^{-1} solution?
b) 117 g of sodium chloride into a 2 mol l^{-1} solution?
c) 15 g of lithium oxide into a 0.05 mol l^{-1} solution?

6) What mass of substance is required to make:

a) 500 cm^3 of 2 mol l^{-1} aluminium nitrate solution?
b) 2 L of 0.5 mol l^{-1} potassium bromide solution?
c) 100 cm^3 of 3 mol l^{-1} calcium sulfate solution?

<u>Balancing Equations and Calculations from Balanced Equations Revision</u>

1.) Balance the following equations:

a) $N_2 + H_2 \rightarrow NH_3$
b) $N_2 + O_2 \rightarrow NO$
c) $Na + H_2O \rightarrow NaOH + H_2$
d) $CH_4 + O_2 \rightarrow CO_2 + H_2O$

2.) $2Mg + O_2 \rightarrow MgO$

Calculate the mass of oxygen required to burn 6 g of magnesium.

3.) $CaCO_3 \rightarrow CaO + CO_2$

What mass of $CaCO_3$ is required to form 2.8 g of calcium oxide?

4.) $N_2 + 3H_2 \rightarrow 2NH_3$

What mass of ammonia (NH_3) is produced from 7 g of nitrogen?

Excess Calculations Exercise 4

In each of the following reactions calculate which reactant is in excess

1.) a) $Zn(s) + H_2SO_4(aq) \longrightarrow ZnSO_4(aq) + H_2(g)$

6.5 g of Zinc added to 25 cm^3 of dilute sulfuric acid, concentration 2 mol l^{-1}

b) $Mg\ (s) + 2HCl(aq) \longrightarrow MgCl_2(aq) + H_2(g)$

2.4 g of magnesium added to 100 cm^3 of dilute hydrochloric acid, concentration 1 mol l^{-1}

c) $Zn(s) + 2HCl(aq) \longrightarrow ZnCl_2(aq) + H_2(g)$

3.6 g of Zinc added to 50 cm^3 of dilute hydrochloric acid, concentration 0.5 mol l^{-1}

d) $Mg\ (s) + H_2SO_4(aq) \longrightarrow MgSO_4(aq) + H_2(g)$

4.7 g of magnesium added to 25 cm^3 of dilute sulfuric acid, concentration 1 mol l^{-1}

2.) Iron(II) sulfide reacts with hydrochloric acid as follows:

$FeS(s) + 2HCl(aq) \longrightarrow FeCl_2(aq) + H_2S(g)$

If 4.4 g of iron(II) sulfide was added to 160 cm^3 of 0.5 mol l^{-1} hydrochloric acid, show by calculation which substance is in excess.

3.) A student added 0.20 g of silver nitrate, $AgNO_3$, to 25 cm^3 of water. This solution was then added to 20 cm^3 of 0.0010 mol l^{-1} hydrochloric acid. The equation for the reaction is:

$AgNO_3(aq) + HCl(aq) \longrightarrow AgCl(s) + HNO_3(aq)$

Show by calculation which reactant is in excess.

4.) What mass of ammonia gas is produced when 1.32 g of ammonium sulfate is heated with 1 g of sodium hydroxide?

$(NH_4)_2SO_4 + 2NaOH \longrightarrow 2NH_3 + Na_2SO_4 + 2H_2O$

5.) What mass of sulfur dioxide is produced when 1.26 g of sodium sulphite is added to 50cm^3 of dilute hydrochloric acid , concentration 2 mol l^{-1}

$Na_2SO_3 + 2HCl \longrightarrow 2NaCl + H_2O + SO_2$

6.) Calcite is a very pure form of calcium carbonate which reacts with nitric acid as follows:

$CaCO_3(s) + 2HNO_3(aq) \longrightarrow Ca(NO_3)_2(aq) + H_2O(l) + CO_2(g)$

A 2.14 g piece of calcite was added to 50.0 cm^3 of 0.200 mol l^{-1} nitric acid in a beaker. Calculate the mass of calcite, in grams, left unreacted.

7.) Copper(II) oxide reacts with sulfuric acid as follows:

$CuO(s) + H_2SO_4(aq) \longrightarrow CuSO_4(aq) + H_2O(l)$

1.6 g of copper(II) oxide is added to a beaker containing 50 cm^3 of 0.25 mol l^{-1} sulfuric acid. Calculate the mass of copper(II) oxide remaining after the reaction was complete.

8.) Lead reacts with hydrochloric acid as follows:

$Pb(s) + 2HCl(aq) \longrightarrow PbCl_2(aq) + H_2(g)$

If 6.22 g of lead was added to 50 cm^3 of 1 mol l^{-1} hydrochloric acid, calculate the mass of lead left unreacted.

9.) A strip of zinc metal weighing 2.00 g is placed in an aqueous solution containing 10.00 g of silver nitrate. The reaction that occurs is

$$Zn(s) + 2AgNO_3(aq) \longrightarrow 2Ag(s) + Zn(NO_3)_2(aq)$$

(a) Determine which reactant is in excess.

(b) Calculate how many grams of silver will be formed.

10.) A piece of lithium with a mass of 1.50 g is placed in an aqueous solution containing 6.00 g of copper (II) sulfate. The reaction that occurs is:

$$2Li(s) + CuSO_4(aq) \longrightarrow Cu(s) + Li_2SO_4\ (aq)$$

(a) Determine which reactant is in excess.

(b) Calculate how many grams of copper will be formed.

Molar Volume Exercise 5

1.) Decide which has the greater volume, measurements made at the same temperature and pressure

a) 17 g of ammonia or 17 g of methane
b) 20 g of neon or 20 g of nitrogen
c) 4 g of hydrogen or 44 g of carbon dioxide
d) 6.4 g of sulfur dioxide or 8 g of oxygen

2.) The volume of 0.22 g of propene C_3H_6 is 118 cm^3. Calculate the volume of 2 moles of propene at this temperature and pressure .

3.) Calculate the volume of 2.4 g of ethane, C_2H_4. (take the molar volume to be 23.6 litres mol^{-1})

4.) The volume of 1 g of hydrogen is 11.6 litres. Calculate the volume of 4 moles of hydrogen at this temperature and pressure.

5.) 3 g of an alkane occupies a volume of 2.24 litres. What is the molecular formula of the alkane (take the molar volume to be 22.4 litres mol^{-1})

6.) Using the densities in the data booklet calculate the volume of 10 g of

(a) Hydrogen
(b) Argon

7.) Using the densities in the data booklet calculate the mass of 10 litres of

(a) Helium
(b) Nitrogen

8.) From the following data calculate the approximate formula mass of the gas X.

Mass of plastic bottle empty	=	112.30 g
Mass of plastic bottle + Gas X	=	113.52 g
Capacity of plastic bottle	=	1 litre
Molar volume of gas X	=	23.6 litres

9.) A flask, capacity 600 cm3 was used to calculate the molar volume of sulfur dioxide.

The following data was obtained:

Mass of evacuated flask	=	512.97 g
Mass of flask + sulfur dioxide	=	514.57 g

10.) Some of liquid Z is injected into a large syringe and it evaporates. The following results were recorded:

Mass of syringe before injection	=	4.648 g
Mass of syringe after injection	=	4.774 g
Syringe reading before injection	=	0 cm^3
Syringe reading after injection	=	84 cm^3

Calculate the relative formula mass of liquid Z
(Molar volume = 30.6 litre mol^{-1})

Balanced Equations Using Mass and Volumes Exercise 6

Molar volume 24 litres unless stated otherwise

1.) What volume (in l) of carbon dioxide would be produced by completely reacting 60 g of carbon with oxygen?

$C + O_2 \longrightarrow CO_2$

2.) What volume (in l) of hydrogen would be produced by completely reacting 60 cm^3 of hydrochloric acid of concentration 1.2 mol l^{-1} with zinc?

$Zn + 2HCl \longrightarrow ZnCl_2 + H_2$

3.) What volume (in l) of carbon dioxide would be produced by completely reacting 10 g of calcium carbonate with hydrochloric acid?

$CaCO_3 + 2HCl \longrightarrow CaCl_2 + H_2O + CO_2$

4.) $Mg(s) + 2HCl(aq) \longrightarrow MgCl_2(aq) + H_2(g)$

What volume of hydrogen gas is produced when 5 g of magnesium is added to 100 cm^3 of dilute hydrochloric acid concentration 2 mol l^{-1} (Molar volume =23.6 Litres mol^{-1})

5.) What mass of magnesium oxide is obtained when 24 g of magnesium is ignited in 5 litres of oxygen

$Mg(s) + O_2(g) \longrightarrow MgO(s)$

(Molar volume is 22.8 litres mol^{-1})

6) What mass of water is produced when 2 litres of hydrogen is burned in excess oxygen (use the density of hydrogen given in the data book)

7) Calculate the volume of oxygen required for the complete combustion of 1 g of ethane C_2H_4
(Molar volume is 32.2 litres mol^{-1})

8) Chlorine gas can be produced by heating calcium hypochlorite, $Ca(OCl)_2$, in dilute hydrochloric acid.

$$Ca(OCl)_2(s) + 2HCl(aq) \longrightarrow Ca(OH)_2(aq) + 2Cl_2(g)$$

Calculate the mass of calcium hypochlorite that would be needed to produce 0·096 litres of chlorine gas. (Take the molar volume of chlorine gas to be 24 litres mol^{-1}.)

9.) Hydrogen fluoride gas is manufactured by reacting calcium fluoride with concentrated sulfuric acid.

$$CaF_2 + H_2SO_4 \longrightarrow CaSO_4 + 2HF$$

What volume of hydrogen fluoride gas is produced when 1.0 kg of calcium fluoride reacts completely with concentrated sulfuric acid?
(Take the molar volume of hydrogen fluoride gas to be 24 litres mol^{-1}.)

10.) In the lab, nitrogen dioxide gas can be prepared by heating copper(II) nitrate.

$$Cu(NO_3)_{2(s)} \longrightarrow CuO_{(s)} + 2NO_{2(g)} + \tfrac{1}{2}\, O_{2(g)}$$

Calculate the volume of nitrogen dioxide gas produced when 2.0 g of copper(II) nitrate is completely decomposed on heating.
(Take the molar volume of nitrogen dioxide to be 24 litres mol^{-1}.)

Reacting Volumes **Exercise 7**

1.) In each of the following reactions decide the ratio of the volume of product(s) to the volume of reactant(s).

a) $H_2(g) + F_2(g) \longrightarrow 2HF(g)$

b) $N_2(g) + 3H_2(g) \longrightarrow 2NH_3(g)$

c) $2C(s) + O_2(g) \longrightarrow 2CO(g)$

d) $C_2H_4(g) + 3O_2(g) \longrightarrow 2CO_2(g) + 2H_2O(l)$

2.) $N_2(g) + 2O_2(g) \longrightarrow 2NO_2(g)$

What volume of nitrogen dioxide is produced when 100 cm^3 of nitrogen is sparked in excess oxygen?

3.) When the following gases are burned calculate the volume of oxygen required and the volume of carbon dioxide produced

a) 50 cm^3 of methane
b) 200 cm^3 of ethane
c) 250 cm^3 of carbon monoxide

4.) 10 cm^3 of butane gas is mixed with 75 cm^3 of oxygen and the mixture exploded. Calculate the volume and composition of the resulting gas mixture.

$C_4H_{10}(g) + 6.5\ O_2(g) \longrightarrow 4CO_2(g) + 5H_2O(l)$

5.) If 100cm^3 of propene is burned completely with 900 cm^3 of oxygen what will be the volume and composition of the resulting gas mixture?

6) 50 cm^3 of ethyne, C_2H_2 is burned completely in 220 cm^3 of oxygen

a) What will be the volume and composition of the resulting gas mixture?
b) What will be the volume and composition of the resulting gas mixture if the experiment was repeated at 200°C?

7) What volume of oxygen (in litres) would be required for the complete combustion of a gaseous mixture containing 1 litre of carbon monoxide and 3 litres of hydrogen?

8) 20 cm^3 of ammonia gas reacted with an excess of heated copper(II) oxide.

$$3CuO + 2NH_3 \longrightarrow 3Cu + 3H_2O + N_2$$

Assuming all measurements were made at 200 °C, what would be the volume of gaseous products?

9) $2C_2H_2(g) + 5O_2(g) \longrightarrow 4CO_2(g) + 2H_2O(l)$
ethyne

What volume of gas would be produced by the complete combustion of 100 cm^3 of ethyne gas? All volumes were measured at atmospheric pressure and room temperature.

10) The equation for the complete combustion of propane is:

$$C_3H_8(g) + 5O_2(g) \longrightarrow 3CO_2(g) + 4H_2O(l)$$

30 cm^3 of propane is mixed with 200 cm^3 of oxygen and the mixture is ignited. What is the volume of the resulting gas mixture? (All volumes are measured at the same temperature and pressure.)

Percentage Yield and Atom Economy **Exercise 8**

1.) CH_3OH + C_2H_5COOH $\rightleftharpoons$ $C_2H_5COOCH_3$ + H_20
Methanol propanoic acid methyl propanoate

In preparation, 40.4 g of methyl propanoate is obtained from 18.3 g of methanol.

(a) Calculate the percentage yield
(b) Calculate the atom economy in regards to methyl propanoate

2.) C_3H_7OH $\xrightarrow{\text{oxidation}}$ C_2H_5CHO
Propan-1-ol Propanal

In a preparation, 3.2 g of propanal is obtained from 3.9g of propan-1-ol. Calculate the percentage yield.

3.) C_3H_6 + Br_2 $\longrightarrow$ $C_3H_6Br_2$

20.4 g of 1,2-dibromopropane is obtained from 5.2 g of propene.

Calculate the percentage yield

4.) N_2 + $3H_2$ $\rightleftharpoons$ $2NH_3$

Under test conditions, 2 kg of hydrogen reacts with excess nitrogen to produce 1.5 kg of ammonia.

Calculate the percentage yield

5.) $2SO_2$ + O_2 $\rightleftharpoons$ $2SO_3$

Under test conditions, 1 kg of sulfur dioxide reacts with excess oxygen to produce 0.8 kg of sulfur trioxide.

Calculate the percentage yield

6.) $2FeCl_2 + Cl_2 \longrightarrow 2FeCl_3$

5.072 g of iron (II) chloride yields 4.869 g of iron (III) chloride, calculate the percentage yield.

7.) Calculate the atom economy for the production sulfur trioxide assuming that all the reactants are converted into products.

$H_2SO_4 \longrightarrow H_2O + SO_3$

8.) Which reaction below has the highest atom economy for producing water?

$2C_2H_6 + 7O_2 \longrightarrow 4CO_2 + 6H_2O$

$C_3H_6 + 4\frac{1}{2}O_2 \longrightarrow 3CO_2 + 3H_2O$

9.) $4NH_3 + 5O_2 \longrightarrow 4NO + 6H_2O$

a) 1.68×10^3 kg of NO was produced from 1.36×10^3 kg calculate the percentage yield.

b) Calculate the atom economy in terms of the production of NO

10.) $Fe2O3 + 3CO \longrightarrow 2Fe + 3CO2$

6.65 x 104 kg of an iron ore which is impure iron (III) oxide is reacted with an excess of carbon monoxide, producing 2.79 x 104 kg of iron.

a) Calculate the mass of pure iron (III) oxide in the ore. (Assuming that all the iron (III) oxide is reduced to iron and that the impurities do not take part in the reaction)

b) Calculate the percentage by mass, of the iron (III) oxide in the ore.