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 **This booklet is to be used to aid revision in study periods and at home. You should work through all the exercises during the course of the unit. Your teacher may decide to set some of the work as homework.**

Some of the questions in the booklet may be in the Extension test and prelim!

****Getting the most from reactants

**1.** Aluminium is extracted from its purified oxide by molten electrolysis. Suggest two advantages and two disadvantages of locating aluminium smelters in the Scottish Highlands.

**2.** Write down 5 factors which will affect the design of a chemical process.

**3.** A reaction in a chemical plant is exothermic.

 (a) Explain what is meant by an exothermic reaction.

 (b) How does the exothermic reaction help the chemical plant make a profit?

**4.** By-products are usually created in industrial chemical processes.

 (a) Explain what is meant by a by-product.

 (b) How can by-products be

 (i) profit making?

 (ii) profit losing?

**5.** As well as transportation, what other reasons could there be for siting chemical works close to rivers?

**6.** What are the four stages in the manufacture of a new product? Write a sentence or two to explain each stage.

**7.** Imagine you were researching a method for converting benzene to a long chain alkylbenzene for detergent manufacture. What amounts of reagents would you use?

A milligrams

B grams

C kilograms

D metric tonnes (1000 kg)

**8.** Give three ways that the operators of chemical plants can minimize the effect of the processes on the environment.

**9.** The Haber process is used to make ammonia. For this process list

 (a) the feedstocks

 (b) the raw materials

**10.** The cost of energy is of major importance to the chemical industry. State one way by which energy costs can be kept down.

**11.** State three factors which can influence the location of a chemical plant.

**12.** Give two examples of steps taken by the chemical industry to reduce environmental damage.

**13.** Give one advantage and one disadvantage of using a “continuous” method of manufacturing a product.

**14.** About 21 million tonnes of sulphuric acid are produced each year in the UK.

Sulphuric acid can be prepared in industry by the Chamber Process. The following chemical reactions are involved.

Sulphur is burned to produce sulphur dioxide.

Sulphur dioxide reacts with water to provide sulphurous 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 sulphurous acid to form sulphuric acid and regenerate nitric oxide.

Complete the flow diagram of the Chamber Process with the names of the chemicals involved in the reactions.

**15.** Titanium is a very useful metal. It has many uses, from components of spacecraft to spectacle frames. The diagram shows steps in the manufacture of titanium.



**(a)** In this diagram, sodium is recycled. Add a labelled arrow to the diagram to show how another chemical is recycled.

**(b)** TiCl4, can be separated from impurities by fractional distillation because it is volatile.

What does this suggest about the type of bonding in TiCl4?

**(c)** During the distillation step, care must be taken to ensure that no water enters the reaction chamber. What type of reaction is this designed to prevent?

**(d)** Give another name for the redox reaction to produce titanium.

# Balancing Equations (revision Nat 5)



**1.** Find the values of a, b, c and d such that the following equation would be balanced:

*a*Al2S3  + *b*H2O → *c*Al(OH)3 + *d*H2S

**2.** Christian Schoenbein discovered ozone, O3, in 1839.

 Ozone in air can be detected using paper strips that have been soaked in a mixture of starch and potassium iodide solution. The paper changes colour when ozone is present.

 Ozone reacts with potassium iodide and water to form iodine, oxygen and potassium hydroxide.

 Write the balanced chemical equation for this reaction.

**3.** In many bathroom cleaning products, the bleaching agent is the hypochlorite ion, ClO–(aq).

 Hypochlorite bleaches can be made by reacting sodium hydroxide with chlorine. Sodium hypochlorite, sodium chloride and water are formed.

 Write a balanced equation for the reaction.

**4.** Hydrogen has been named as a ‘fuel for the future’. In a recent article researchers reported success in making hydrogen from glycerol:

C3H8O3(l) → CO2(g) + CH4(g) + H2(g)

Balance this equation.

**5.** Methane is produced in the reaction of aluminium carbide with water.

Al4C3 + H2O → Al(OH)3 + CH4

Balance the above equation.

**6.** Carbon monoxide can be produced in many ways.

One method involves the reaction of carbon with an oxide of boron.

B2O3 + C → B4C + CO

Balance this equation.

**7.** Nitrogen dioxide gas can be prepared in different ways.

It is manufactured industrially as part of the Ostwald process. In the first stage of the process, nitrogen monoxide is produced by passing ammonia and oxygen over a platinum catalyst.

NH3(g) + O2(g) → NO(g) + H2O(g)

Balance the above equation.

**8.** When exploded, glycerol trinitrate decomposes to give nitrogen, water, carbon dioxide and oxygen.

Balance the equation for this reaction.

C3H5N3O9(l) → N2(g) + H2O(g) + CO2(g) + O2(g)

**9.** Acid-base reactions are common in chemistry.

Write the balanced equation for the reaction between copper(I1) oxide and nitric acid.

# Level 2The mole (revision)

**1.** What is the mass of

a) 1 mole of H2O

b) 5 moles of CO2

c) 20 moles of NH3

d) 0.1 moles of C2H5OH

e) 0.05 moles of C2H4?

**2.** How many moles are in

 a) 1.8g of H2O

 b) 8.8g of CO2

c) 1.755kg of NaCl

d) 40kg of MgO

e) 0.12g of NaOH

**3.** What is the concentration of a solution containing:

a) 5 moles of NaCl dissolved in 5 l of water

b) 0.3 moles of NaCl dissolved in 0.5 l of water

c) 2 moles of NaCl dissolved in 250 ml of water

d) 175.5g of NaCl dissolved in 500 ml of water

e) 11.7g of NaCl dissolved in 10 l of water

**4.** Calculate the number of moles of solute required to prepare 250cm3 of a 0.100 mol l-1 solution of oxalic acid.

**5.** What mass of copper(II) sulphate crystals (CuSO4) should be dissolved to produce 100cm3 of a 2.5 mol l-1 solution ?

**6.** Find the mass of :-

a) sodium chloride in 100 ml of 0.2 moll-1 sodium chloride solution (NaCl)

b) glucose in 250ml of 0.05 moll-1 glucose solution (C6H12O6).

**7.** Find the concentration of:-

a) a 400 ml solution of potassium chloride containing 0.2 moles of potassium chloride. (KCl)

b) a 2 litre solution of sodium carbonate containing 10.6g of sodium carbonate. (Na2CO3)

# Calculations from Equations



**1.** How many grams of magnesium oxide would be produced by reacting completely 4.0 g of magnesium with oxygen?

2Mg + O2 🡪 2MgO

**2.** Oxygen can be converted into ozone (O3) by passing an elecrical discharge through it. Calculate the number of ozone molecules that would be formed if 16g of oxygen were completely converted into ozone.

 3O2 🡪 2O3

**3.** Ammonia reduces copper(II) oxide to copper. The other products of the reaction are water and nitrogen.

2NH3 + 3CuO 🡪 3Cu + H2O + N2

Calculate the mass of copper produced and the mass of ammonia consumed when 56.4g of copper(II) oxide are reduced in this way.

**4.** What mass of aluminium will be needed to react with 10 g of CuO, and what mass of Al2O3 will be produced?

3CuO + 2Al 🡪 Al2O3 + 3Cu

**5.** In a reaction magnesium carbonate powder is used to neutralise 250 cm3 of 2 mol l-1 dilute hydrochloric acid. Calculate the mass of magnesium carbonate required to neutralise the dilute hydrochloric acid.

MgCO3 + 2HCl 🡪 MgCl2 + H2O+ CO2

**6.** In a reaction sodium carbonate powder is used to neutralise 200 cm3 of 2 mol l-1 dilute sulphuric acid. Calculate the mass of sodium carbonate required to neutralise the dilute sulphuric acid.

Na2CO3 + H2SO4 🡪 Na2SO4 + H2O +CO2

**7.** 20 cm3 of a solution of NaOH is exactly neutralised by 25 cm3 of a solution of HCl of concentration 0.5 mol l–1.

 HCl + NaOH → NaCl + H2O

Calculate the concentration of the NaOH solution in mol l –1.

**8.** 100 cm3 of a solution of KOH is exactly neutralised by 150 cm3 of a solution of H2SO4 of concentration 0.25 mol l–1.

 H2SO4 + 2KOH → K2SO4 + 2H2O

Calculate the concentration of the KOH solution in mol l –1.

**9.** 50 cm3 of a solution of HCl is exactly neutralised by 20 cm3 of a solution of Ca(OH)2 of concentration 2.0 mol l–1.

2HCl + Ca(OH)2 → CaCl2 + 2H2O

Calculate the concentration of the HCl solution in mol l –1.

**10.** 2.5 l of a solution of NaOH is exactly neutralised by 1.5 lof a solution of HCl of concentration 1.0 mol l–1.

HCl + NaOH → NaCl + H2O

Calculate the concentration of the NaOH solution in mol l –1.

# Avogadro and the mole



**1.** Which of the following has the greatest number of molecules?

A 0.1g of hydrogen gas

B 0.16g of methane

C 0.34g of ammonia

D 0.14g of nitrogen

**2.** How many moles of ions are present in 0.2 moles of alumnium sulphate

A 0.2 moles

B 0.4 moles

C 0.6 moles

D 1 mole

**3.** A mixture of magnesium bromide and magnesium sulfate is known to contain 3 mol of magnesium and 4 mol of bromide ions. How many moles of sulfate ions are present?

A 1

B 2

C 3

D 4

**4.** Find the number of atoms in ;-

a) 2 moles magnesium

b) 100g of calcium

**5.** Find the number of molecules in 4.6g of nitrogen dioxide.

**6.** The mass of 1 mol of sodium is 23 g. What is the approximate mass of one sodium atom?

**A** 6 × 1023g

**B** 6 × 10–23g

**C** 3.8 × 10–23g

**D** 3.8 × 10–24g

**7.** The Avogadro Constant is the same as the number of

**A** ions in 1 mol of NaCl

**B** atoms in 1 mol of hydrogen gas

**C** electrons in 1 mol of helium gas

**D** molecules in 1 mol of oxygen gas.

**8.** The Avogadro Constant is the same as

**A** the number of molecules in 16g Oxygen

**B** the number of ions in 1 litre of sodium chloride solution, concentration 1 mol-l

**C** the number of atoms in24g of carbon

**D** the number of molecules in 2g of Hydrogen

**9.** In which of the following pairs do the gases contain the same number of oxygen atoms?

**A** 1 mol of oxygen and 1 mol of carbon monoxide

**B** 1 mol of oxygen and 0.5 mol of carbon dioxide

**C** 0.5 mol of oxygen and 1 mol of carbon dioxide

**D** 1 mol of oxygen and 1 mol of carbon dioxide

**10.** The Avogadro Constant is the same as the number of

**A** molecules in 16 g of oxygen

**B** ions in 1 litre of sodium chloride solution, concentration 1 mol l–1

**C** atoms in 24 g of carbon

**D** molecules in 2 g of hydrogen.

#

# Level 2Molar gas volume

**1.** Which of the following has the largest volume under the same conditions of temperature and pressure?

**A** 1 g hydrogen

 **B** 14 g nitrogen

**C** 20·2 g neon

**D** 35·5 g chlorine

**2.** 20cm3 of butane is burned in 150 cm3 of oxygen.

C4H10(g) +6 O2(g) → 4CO2(g) + 5H2O(g)

What is the total volume of gas present after complete combustion of the butane?

**A** 80cm3

**B** 100cm3

**C** 180cm3

**D** 200cm3

**3.** In which reaction is the volume of the products equal to the volume of the reactants?

**A** 2H2(g) + O2(g) → 2H2O(g)

**B** 3H2(g) + N2(g) → 2NH3(g)

**C** N2(g) + O2(g ) → 2NO(g)

**D** 2SO2(g) + O2(g) → 2SO3(g)

**The molar volume of any gas is 24 litres at s.t.p.**

**4.** What volume would the following amounts of gas occupy?

 a) 2 moles of helium

 b) 0.1 moles of oxygen

 c) 5.5 moles of nitrogen

d) 2.4 g of ozone

e) 0.88 g of carbon dioxide

**5.** 2NO(g) + O2(g) → 2NO2(g)

How many litres of nitrogen dioxide gas would be produced in a reaction, starting with a mixture of 5 litres of nitrogen monoxide gas and 2 litres of oxygen gas?

(All volumes are measured under the same conditions of temperature and pressure.)

**A** 2

**B** 3

**C** 4

**D** 5

**6.** Which of the following gas samples has the same volume as 7 g of carbon monoxide? (All volumes are measured at the same temperature and pressure.)

**A** 1 g of hydrogen

**B** 3.5 g of nitrogen

**C** 10 g of argon

**D** 35. 5 g of chlorine

**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? (All volumes are measured at the same temperature and pressure.)

**A** 1

**B** 2

**C** 3

**D** 4

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

C + O2 🡪 CO2

**9.** What volume (in l) of hydrogen would be produced by completely reacting 60 cm3 of hydrochloric acid of concentration 1.2 mol l–1 with zinc?

 Zn + 2HCl 🡪 ZnCl2 + H2

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

 CaCO3 + 2HCl 🡪 CaCl2 + H2O + CO2

**11.** What volume (in l) of hydrogen would be produced by completely reacting 60 cm3 of hydrochloric acid of concentration 1.2 mol l–1 with zinc?

 Zn + 2HCl 🡪 ZnCl2 + H2

**12.** In the reaction of lithium with water, what mass of lithium (in grams) would be required to produce 600 cm3 of hydrogen?

2Li + 2H2O 🡪 2LiOH + H2

**13.** Calculate the volume of oxygen that would be required to react completely with 1.0 *l* of methane.

 CH4 + 2O2 🡪 CO2 +2H2O

**14.** Calculate the volume of oxygen that would be required to react completely with 5.0 *l* of ethane.

 C2H4 + 3O2 🡪 2CO2 +2H2O

**15.** Chlorine gas can be produced by heating calcium hypochlorite, Ca(OCl)2, in dilute hydrochloric acid.

 Ca(OCl)2(s) + 2HCl(aq) → Ca(OH)2(aq) + 2Cl2(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.)

**16.** A student bubbled 240 cm3 of carbon dioxide into 400 cm3 of 0·10 mol ℓ –1 lithium hydroxide solution.

The equation for the reaction is:

 2LiOH(aq) + CO2(g) → Li2CO3(aq) + H2O(*ℓ* )

Calculate the number of moles of lithium hydroxide that would **not** have reacted.

(Take the molar volume of carbon dioxide to be 24 litres mol–1.)

# Reagent in excess



**1.** Iron(II) sulphide reacts with hydrochloric acid as follows:

 FeS(s) + 2HCl(aq) 🡪 FeCl2(aq) + H2S(g)

If 4.4g of iron(II) sulphide was added to 160cm3 of 0.5 mol l-1 hydrochloric acid, show by calculation which substance is in excess.

**2.** A student added 0.20g of silver nitrate, AgNO3, to 25 cm3 of water. This solution was then added to 20cm3 of 0.0010 mol l-1 hydrochloric acid. The equation for the reaction is:

AgNO3(aq) + HCl(aq) 🡪 AgCl(s) + HNO3(aq)

Show by calculation which reactant is in excess.

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

 CaCO3(s) + 2HNO3(aq) 🡪 Ca(NO3)2(aq) + H2O(l) + CO2(g)

 A 2.14g piece of calcite was added to 50.0cm3 of 0.200 mol l-1 nitric acid in a beaker.

Calculate the mass of calcite, in grams, left unreacted.

**4.** Copper(II) oxide reacts with sulphuric acid as follows:

 CuO(s) + H2SO4(aq) 🡪 CuSO4(aq) + H2O(l)

1.6 g of copper(II) oxide is added to a beaker containing 50cm3 of 0.25 mol l-1 sulphuric acid.

Calculate the mass of copper(II) oxide remaining after the reaction was complete.

**5.** Lead reacts with hydrochloric acid as follows:

 Pb(s) + 2HCl(aq) 🡪 PbCl2(aq) + H2(g)

If 6.22g of lead was added to 50cm3 of 1 mol l-1 hydrochloric acid, calculate the mass of lead left unreacted.

**6.** 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) + 2AgNO3(aq) 🡪 2Ag(s) + Zn(NO3)2(aq)

(a) Determine which reactant is in excess.

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

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

2Li(s) + CuSO4(aq) 🡪 Cu + Li2SO4 (aq)

(a) Determine which reactant is in excess.

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

# Equilibrium



**1.** The reaction between SO2 and O2 may be described as

2SO2(g) + O2(g)  2SO3(g)ΔH = -196 kJ mol-1

Select the two conditions that will favour a high yield of SO3.

A Removal of SO2

B Lower the pressure

C Lower the temperature

D Use a catalyst

E Addition of more O2

**2.** A chemical reaction has reached dynamic equilibrium at a certain temperature. Which one of following statements is **incorrect**?

A The reaction has stopped completely

B The concentrations of the reactants remains constant

C Products are continuously being formed

D The rate of the forward reaction is equal to the rate of the reverse reaction

**3.** Three moles of ethanol and three moles of ethanoic acid were reacted together according to the equation

 C2H5OH + CH3COOH  CH3COOC2H5 + H2O

At equilibrium, there was 2 moles each of ethyl ethanoate and water formed. What is the equilibrium constant for this reaction?

A 4

B 2

C 0.25

D 0.44

**4.** In which of the following would a change in pressure not affect the yield of product

****

**5.** A catalyst is added to a chemical reaction at equilibrium. Which statement about catalysts is correct?



**6.** Nitrogen dioxide can be produced in a number of ways but industrially it is produced using the Ostwald process. Inthe first stage of this process nitrogen monoxide is produced by passing over a hot catalyst.

In the second stage of this process the nitrogen monoxide combines with oxygen in an exothermic reaction to produce nitrogen dioxide.



What happens to the yield of nitrogen dioxide if the reaction mixture in stage 2 is cooled?

**7.** One method used to produce methanol requires synthesis gas. The following equation shows the production of methanol from synthesis gas.



Which line in the table shows the conditions that would cause the greatest increase in the amount of methanol produced?



**8.** If the yield of ammonia at equilibrium is 15% then the equilibrium position lies…

**A** well to the right

**B** well to the left

**C** almost centrally

**D** equally to each side

**9.** Equilibrium is reached when the rate of the forward reaction…………

**A** reaches zero

**B** reaches its minimum

**C** equals the back reaction rate

**D** is twice the back reaction rate

**10.** If the equilibrium position for a reaction lies well to the right, then the equilibrium mixture will contain…

**A** more products than reactants

**B** more reactants than products

**C** only reactants

**D** only products

**11.** Starting with NH3 rather than N2 and H2 , would give an equilibrium mixture with..

**A** a greater proportion of ammonia

**B** less nitrogen

**C** the same proportions of all three gases

**D** less ammonia than before

**12.** Which conditions would give the best yield of Hydrogen at equilibrium in this reaction?

 CH4(g) + H­O(g)↔CO(g) + 3H2(g) Δ= +210kJ

**A** High temperature and low pressure

**B** High temperature and high pressure

**C** Low temperature and low pressure

**D** Low temperature and high pressure

**13.** In which reaction below will a change in pressure have no effect on the composition of the equilibrium mixture?

**A** 4NH3(g) + 5O2(g) ↔ 4NO2(g) + 6H2O(l)

**B** 2SO2 (g) + O2(g) ↔ 2SO3(g)

**C** CO(g) + H2O(g) ↔ CO2(g) + H2O(g)

**D** C2H4(g) + H2O(g) ↔ C2H5OH(g)

**14.** Ammonia gas dissolves in water to form an alkaline solution.

NH3(g) + H2O(l) ↔ NH4 + (aq) + OH- (aq) ΔH = -31kJ

How would each of the following changes affect the position of equilibrium?

**a)** Increasing the temperature.

**b)** Increasing the pressure**.**

**c)** Adding ammonium chloride.

**15.** The diagram shows the concentrations of hydrogen, iodine and hydrogen iodide for the reaction between hydrogen and iodine.



Which of the following statements is **incorrect**?

A the equilibrium lies predominantly to the left

B at point A on the time axis, the concentration of all three gases is zero

C The reaction between the gases reaches equilibrium at point B.

D Adding more hydrogen at point D will alter the shape of the graph.

E At point C, the system is in a state of dynamic equilibrium.

**16.** Consider the following equilibrium reaction
 
Which one of the following will cause a yellow colour to predominate?

A Addition of sodium hydroxide (NaOH)

B Addition of sodium chromate (Na2CrO4)

C Addition of hydrochloric acid (HCl)

D Removal of water

**17.** Which one of the following equilibrium reactions is **not** affected by a change in pressure?

 A

 B

 C

 D

**18.** What does it mean to say that a chemical reaction has reached equilibrium?

**19.** The forward reaction of the equilibrium system below is endothermic. Dilute HCl is added and the colour changes to blue. What colour change occurs when the mixture is cooled?

 

**20.** The reaction of nitrogen dioxide (NO2) forming dinitrogen tetroxide (N2O4) is exothermic in the forward direction.

 

State **two** conditions will cause the equilibrium mixture to go dark brown?

**21.** Ammonia is formed in the Haber process according to the following balanced equation.

N2 + 3H2  2NH3



The table shows the percentages of ammonia present at equilibrium under different conditions of temperature T and pressure P when hydrogen and nitrogen gases were mixed in a 3:1 molar ratio. Is this an endothermic or exothermic reaction? Give a reason for your answer.

**22.** The following equilibrium involves two compounds of phosphorus.

PCl3(g) + 3NH3 (g) ****** P(NH2)3(g) + 3HCl(g)

(a) An increase in temperature moves the equilibrium to the left. What does this indicate about the enthalpy change for the forward reaction?

(b) What effect, if any, will an increase in pressure have on the equilibrium?

**23.** The balanced equation for a reaction at equilibrium is:

 **aA + bB ** cC + dD**

(a) For this reaction, the equilibrium constant, K, can be defined as:

 

where [A] represents the concentration of A, etc and a represents the number of moles of A,etc.

(i) Write down the expression for the equilibrium constant for the following equilibrium.

 N2(g) + 3H2(g) ****** 2NH3(g)

(ii) What will happen to the position of the equilibrium if the reaction is carried out over a catalyst?

(b) In industry, the reaction of nitrogen with hydrogen to produce ammonia by the Haber Process does not attain equilibrium.

Give one feature of the operating conditions which leads to the Haber Process not reaching equilibrium

**24.** When a yellow solution of iron (III) chloride (FeCl3)and a colourless solution of potassium thiocyanate (KCNS) were mixed in a test tube, a red colour appeared and the following equilibrium was established:

 Fe3+(aq) + CNS-(aq)   Fe(CNS)2+(aq)

 yellow red

Explain:

(a) the effect on the Fe3+ ion concentration of adding KCNS to the equilibrium mixture

(b) why changing the pressure has no effect on this reaction.

**25.** Consider the following equilibrium reaction at room temperature used to dissolve iodine (I2) crystals in an aqueous solution of iodide ions (I-).

I2(aq) + I -(aq)  I3-(aq)

State and explain the effect on the equilibrium concentration of triiodide ions of adding a substance that reacts with iodine, eg. starch.

**26.** Iodine monochloride and chlorine gas react together to establish the following equilibrium in a closed system.



Which line in the table shows the conditions that would cause the greatest increase in the amount of ICl3 produced in this reaction.



# Percentage Yield and Atom Economy



**1.** 20 g of lithium hydroxide was reacted with potassium chloride:

 LiOH + KCl 🡪 LiCl + KOH

(a) What is the theoretical yield of lithium chloride?

(b) If 6 g of lithium chloride was actually produced, what is the percentage yield?

**2.** The equation below shows the combustion of propanol:

 C3H8 + 5 O2 🡪 3 CO2 + 4 H2O

a) If you start with 5 grams of C3H8, what is the theoretical yield of water?

b) If the percentage yield was 75%, how many grams of water will actually be made?

**3.** In the reaction below, the theoretical yield was 10.7 g but the actual yield was 4.5 g.

Calculate the percentage yield.

Be + 2 HCl 🡪 BeCl2 + H2

**4.** What is the theoretical yield of sodium oxide if you start with 20 grams of calcium oxide?

2 NaCl + CaO 🡪 CaCl2 + Na2O

**5.** In the reaction below:

 FeBr2 + 2 KCl 🡪 FeCl2 + 2 KBr

a) What is the theoretical yield of iron (II) chloride if you start with 340 g of iron (II) bromide?

b) What is my percentage yield of iron (II) chloride if my actual yield is 40 g?

**6.** In the reaction below:

TiS + H2O 🡪 H2S + TiO

What is the percentage yield of titanium (II) oxide if you start with 20 g of titanium (II) sulfide and the actual yield of titanium (II) oxide is 22 g?

**7.** In the reaction below:

U + 3 Br2 🡪 UBr6

What is the actual yield of uranium hexabromide if you start with 100 g of uranium and get a percentage yield of 83% ?

**8.** In the reaction below:

 H2SO4 🡪 H2O + SO3

If you start with 89 kg of sulfuric acid and produce 71 kg of water, what is the percentage yield?

**9.** If, in the reaction below 32 kg of C2H6 produces 44 kg of CO2, what is the % yield?

 2C2H6 + 7O2 🡪 4CO2 + 6H2O

**10.** If, in the reaction below, 80 g of Cl2 produces 38 g of CCl4 what is the % yield?

CS2 + 3Cl2 🡪 CCl4 + S2Cl2

**11.** If, in the reaction below, 49 g of Fe3O4 produces a 78.25 % yield of Fe. How many grams are produced?

 **Fe3O4 + 4H2 🡪 3Fe + 4H2O**

**12.** If, in the reaction below, 40 tonnes of H2O produces 6.7 tonnes of HF what is the % yield?

CH3COF + H2O 🡪 CH3COOH + HF

**13.** Calculate the atom economy for the production of lithium chloride assuming that all the reactants are converted into products.

LiOH + KCl 🡪 LiCl + KOH

**14.** Calculate the atom economy for the production of titanium oxide assuming that all the reactants are converted into products.

 TiS + H2O 🡪 H2S + TiO

**15.** Calculate the atom economy for the production sulphur trioxide assuming that all thereactants are converted into products.

H2SO4 🡪 H2O + SO3

**16.** Which reaction below has the highest atom economy for producing water?

2C2H6 + 7O2 🡪 4CO2 + 6H2O

C3H6 + 4½O2 🡪 3CO2 + 3H2O

**17.** Sulphur trioxide can be prepared in the laboratory by the reaction of sulphur dioxide with oxygen.

2SO2(g) + O2(g) 2SO3(g)

The sulphur dioxide and oxygen gases are dried by bubbling them through concentrated sulphuric acid. The reaction mixture is passed over heated vanadium(V) oxide.

Sulphur trioxide has a melting point of 17 °C. It is collected as a white crystalline solid.

Under certain conditions, 43·2 tonnes of sulphur trioxide are produced in the reaction of 51·2 tonnes of sulphur dioxide with excess oxygen.

Calculate the percentage yield of sulphur trioxide.

**18.** From the 1990s, ibuprofen has been synthesised by a three step process. The equation below shows the fi nal step of the synthesis.



What is the atom economy of this step?

**19.** Ethane-1,2-diol is produced in industry by reacting glycerol with hydrogen. Excess hydrogen reacts with 27·6 kg of glycerol to produce 13·4 kg of ethane-1,2-diol.



Calculate the percentage yield of ethane-1,2-diol.

# Enthalpy of Solution



**1.** When a substance is dissolved in 200 cm3 of water, the temperature rose from 18 oC to 23 oC. What is the energy change for this reaction?

**2.** When a substance was dissolved in 150 cm3 of water, the temperature fell from 22.5 oC to 18.1oC. What was the energy change for this reaction?

**3.** A substance dissolved in 500 cm3 water and the temperature fell from 20.3 oC to 16.9oC. What was the energy change for this reaction?

**4.** 0.01 moles of a substance was dissolved in 200 cm3 of water and the temperature dropped form 19 oC to 17 oC. What is the enthalpy of solution of this substance?

**5.** 0.025 moles of a salt dissolved in 400 cm3 of water and the temperature of the solution rose from 20 oC to 25 oC. What is the enthalpy of solution of this salt?

**6.** 0.05 moles of a compound dissolved in 500 cm3 of water, causing the temperature of the water to fall from 21 oC to 19.3 oC. What is the enthalpy of solution of the compound?

**7.** 5.3g of sodium carbonate (Na2CO3) was dissolved in 100 cm3 of water. The temperature of the water rose from 20.5 oC to 25.3 oC. What is the enthalpy of solution of this compound?

**8.** 14.92g of potassium chloride (KCl) dissolved in 250 cm3 of water causing the temperature of the water to change form 20.5 oC to 18.9 oC. What is the enthalpy of solution of potassium chloride?

**9.** 2.022g of potassium nitrate (KNO3) is dissolved in 100 cm3 of water. The temperature of the water changed from 23.5 oC to 21.2 oC. What is the enthalpy of solution of potassium nitrate?

**10.** 8g of ammonium nitrate (NH4NO3) is dissolved in 200 cm3 of water causing the temperature to change from 17 oC to 14 oC. What is the enthalpy of solution of ammonium nitrate?

**11.** 4g of sodium hydroxide (NaOH) dissolved in 250 cm3 of water causing a temperature change from 19 oC to 23.3 oC. What is the enthalpy of solution of sodium hydroxide?

**12.** When 11.9g of potassium bromide (KBr) was dissolved in 300 cm3 of water the temperature changed from 24.8 oC to 21.2 oC. What was the enthalpy of solution?

**13.** A student found that 1·08kJ of energy was **released** when 1·2 g of potassium hydroxide was dissolved completely in water.

Calculate the enthalpy of solution of potassium hydroxide.

**14.** Calculate the enthalpy change for each of the following experiments.

(a) When 1 g of potassium carbonate dissolved in 10 cm3 of water the temperature increased by 5.60C.

(b) When 1 g of sodium nitrate dissolved in 10 cm3 of water the temperature fell by 5.60C.

**15.** From the results of question 14 calculate the **enthalpy of solution** for

 a) potassium carbonate (14a)

 b) sodium nitrate (14b)

**16.** The enthalpy change when 1 mole of sodium carbonate dissolves in water is 24.6 kJ mol-1. Calculate the mass of sodium carbonate which would produce a temperature rise of 9.20C when added to 25cm3 of water.

**17.** 2g of sodium hydroxide, NaOH, is dissolved in 0.125 kg of water causing the temperature to rise from 19oC to 23oC. Calculate the enthalpy of solution of sodium hydroxide.

**18.** 14.9g of potassium chloride, KCl, is dissolved in 200cm3 of water causing the temperature to fall from 19.5oC to 15.5oC. Calculate the enthalpy of solution of potassium chloride.

# Enthalpy of Combustion



**1.** When a substance was burned, it raised the temperature of 200 cm3 of water from 21 oC to 25.5 oC. What quantity of heat that was released by this reaction?

**2.** A Bunsen Burner is used to heat 0.5 kg of water from 20.5 oC to 39.5 oC. How much heat energy has been produced?

**3.** An alcohol is burned to heat up 100 cm3 of water from 10 oC to 18 oC. How much heat energy has been released?

**4.** If 0.1 moles of a substance burns to produce enough heat to raise the temperature of 500 cm3 of water from 25 oC to 50oC, calculate the enthalpy of combustion of this substance.

**5.** 0.05 moles of a fuel was burned and it raised the temperature of 100 cm3 of water from 18.2 oC to 24.5 oC. What is the enthalpy of combustion of this fuel?

**6.** When 1g of ethanol (C2H5OH) was burned, the heat produced warmed 5 litres of water from 18oC to 18.5oC. What is the enthalpy of combustion of ethanol?

**7.** When 1g of Sulphur was burned, the heat produced warmed 110g of water from 180C to 18.5oC. What is the enthalpy of combustion of Sulphur?

**8.** 0.32g of methanol (CH3OH) was burned and it heated up 200 cm3 of water from 19.5 oC to 27.5 oC. Calculate the enthalpy of combustion of methanol.

**9.** 0.2g of methane (CH4) was burned and it heated up 250 cm3 of water from 18.5 oC to 28.5 oC. Calculate the enthalpy of combustion of methane.

**10.** 0.22g of propane (C3H8) was burned and it heated up 150 cm3 of water from 21 oC to 31 oC. Calculate the enthalpy of combustion of propane.

**11.** Butane (C4H10) is used to heat 175 cm3 of water from 22.2 oC to 31.7 oC. What is the enthalpy of combustion of butane if 3g of the gas had been used?

**12.** Ethanol, C2H5OH, can be used as a fuel in some camping stoves.



The enthalpy of combustion of ethanol is −1367 kJ mol−1. Using this value, calculate the number of moles of ethanol required to raise the temperature of 500 g of water from 18 °C to 100 °C.

**Show your working clearly.**

**13.** A value for the enthalpy of combustion of butan-2-ol, C4H9OH, can be determined experimentally using the apparatus shown.



Mass of butan-2-ol burned = 1·0 g

Temperature rise of water = 40 °C

Use these results to calculate the enthalpy of combustion of butan-2-ol, in kJ mol–1.

**14.** Diborane can be used to manufacture pentaborane (B5H9).

Pentaborane was also considered for use as a rocket fuel because its enthalpy of combustion is − 9037 kJ mol−1.

Calculate the energy released, in kJ, when 1 kilogram of pentaborane is completely burned.

**15.** A pupil found the enthalpy of combustion of propan-1-ol using the following apparatus.



(a) In addition to the initial and final temperatures of the water, what other measurements would the pupil have made.

(b) Describe a change that could be made to the experimental procedure in order to achieve more accurate results.

(c) The table shows the enthalpies of combustion of three alcohols.

|  |  |
| --- | --- |
| Alcohol | Enthalpy of combustion/kJ mol-1 |
| methanol | -715 |
| ethanol | -1371 |
| propan-1-ol | -2010 |

Why is there a **regular** increase in enthalpies of combustion from methanol to ethanol to propan-1-ol?

# Level 2 Enthalpy of Neutralisation

The enthalpy of neutralisation is defined as the amount of energy released when one mole of water is produced during the reaction of an acid and alkali. The enthalpy of neutralisation is a constant -57.3KJ mol l-1

**1.** What is the amount of heat produced when 25 cm3 NaOH (1 moll-1) is neutralised by 25 cm3 HCl (1 moll-1) and the temperature rose by 5.3 oC ?

**2.** What is the amount of heat produced when 50 cm3 NaOH 1 (moll-1) is neutralised by 25 cm3 HCl (1 moll-1) and the temperature rose by 3.3 oC ?

**3.** What is the amount of heat produced when 50 cm3 NaOH (1 moll-1) is neutralised by 50 cm3 HCl (1 moll-1) and the temperature rose by 7.8 oC ?

**4.** 100 cm3 of 0.5 moll-l nitric acid (HNO3) and 100 cm3 0.5 moll-l potassium hydroxide (KOH) took part in a neutralisation resulting in a temperature rise of 3.5oC. What is the enthalpy of neutralisation of the KOH for this reaction?

KOH + HNO3 → KNO3 + H2O

**5.** 25 cm3 of 0.5 moll-l sulphuric acid (H2SO4) and 50 cm3 0.5 moll-l sodium hydroxide (NaOH) took part in a neutralisation resulting in a temperature rise of 3. 5oC. What is the enthalpy of neutralisation of NaOH for this reaction?

2NaOH + H2SO4 → Na2SO4 + 2H2O

**6.** A pupil added 50cm3 of NaOH(aq) to 50cm3 HCl(aq). Each solution had a concentration of 2.0 mol l-1. The temperature rise was 13.5oC. Calculate the enthalpy of neutralisation.

**7.** 40cm3 of 1 mol l-1 of nitric acid, HNO3, and 40cm3 of 1 mol l-1 sodium hydroxide, NaOH, both at room temperature of 19oC were mixed and the temperature increased to 25.8oC. Calculate the enthalpy of neutralisation.

# Chemical Energy Hess’s Law



1. What is the relationship between a, b, c and d? Answer in the form a =

 S(s) + H2(g) → H2S(g) ΔH = a

 H2(g) + ½ O2 (g) → H2O(l) ΔH = b

 S(s) + O2(g) → SO2(g) ΔH = c

 H2S(g) + 1 ½ O2(g) → H2O(l) +SO2(g) ΔH = d

**2.** The enthalpy changes for the formation of one mole of aluminium oxide and one mole of iron(III) oxide are shown below.

 2Al(s) + 1½O2(g) 🡪 Al2O3(s) ΔH = -1676 kJ mol-1

 2Fe(s) + 1½O2(g) 🡪 Fe2O3(s) ΔH = -825 kJ mol-1

 Use the above information to calculate the enthalpy change for the reaction:

 2Al(s) + Fe2O3(s) 🡪 Al2O3(s) + 2Fe(s)

**3.** The equation for the enthalpy of formation of propanone is:

 3C(s) + 3H2(g) + ½O2(g) C3H6O(l)

Use the following information on enthalpies of combustion to calculate the enthalpy of formation of propanone.

 C(s) + O2(g) CO2(g) H = -394 kJmol-1

 H2(g) + ½O2(g) H2O(l) H = -286 kJmol-1

 C3H6O(l) + 4O2(g) 3CO2(g) + 3H2O(l)H = -1804 kJmol-1

**4.** The equation below represents the hydrogenation of ethene to ethane.

 C2H4(g) + H2(g) → C2H6(g)

Use the enthalpies of combustion of ethene, hydrogen and ethane from page 9 of the data booklet to calculate the enthalpy change for the above reaction.

**5.** Calculate a value for the enthalpy change involved in the formation of one mole of hydrogen peroxide from water (ΔH3). The enthalpy change when hydrogen forms hydrogen peroxide is -188 kJ mol-1 and the enthalpy of combustion of hydrogen to form water is -286 kJ mol-1.

**6.** Calculate a value for the enthalpy change involved in the decomposition of nitrogen dioxide to nitrogen monoxide given the following information.

 Equation (a) N2(g) + O2(g) 🡪 2NO(g) ΔH = +181 kJ

 Equation (b) N2(g) + 2O2(g) 🡪 2NO2(g) ΔH = +68 kJ

**7.** The sulphur-iodine cycle is an industrial process used to manufacture hydrogen. There are three steps in the sulphur-iodine cycle.

**Step 1:** I2 + SO2 + 2H2O → 2HI + H2SO4

**Step 2:** 2HI → I2 + H2

**Step 3:** H2SO4 → SO2 + H2O + ½O2

**(i)** Why does step 3 help to reduce the cost of manufacturing hydrogen?

**(ii)** What is the overall equation for the sulphur-iodine cycle?

#

**8.** The enthalpy of formation of glycerol is the enthalpy change for the reaction:

3C(s) + 4H2(g) + 1½O2(g) → C3H8O3(ℓ)

 (graphite)

Calculate the enthalpy of formation of glycerol, in kJ mol–1, using information from the data booklet and the following data.

C3H8O3(ℓ) + 3½O2(g) → 3CO2(g) + 4H2O(ℓ) ΔH = – 1654 kJ mol–1

Using the data above, calculate the enthalpy change, in kJ mol–1, for the production of butan-2-ol by hydration of but-2-ene.

**9.** Enthalpy changes can also be calculated using Hess’s Law.

The enthalpy of formation for pentan-1-ol is shown below.

5C(s) + 6H2(g) + O2(g) → C5H11OH( ℓ ) ΔH = –354 kJ mol–1

Using this value, and the enthalpies of combustion of carbon and hydrogen from the data booklet, calculate the enthalpy of combustion of pentan-1-ol, in kJ mol–1.

**10.** Given that



The enthalphy change for the reaction



will be



**11.** The three equations shown below all involve displacement reactions of metals and metal oxides



What is the relationship between A, B and C according to Hess’s Law



**12.** Given the equations



then according to Hess’sLaw



**13.** The equation for the enthapy of formation of ethyne is



Use the values for the enthalphy of combustion of ethyne, carbon and hydrogen given in the data booklet to calculate the enthalphy of formation of ethyne.

# Bond Enthalpies



**1.** In the presence of bright light, hydrogen and bromine react. One step in the reaction is shown

 below.

 ***H2(g) + Br(g) → HBr(g) + H(g)***

 The enthalpy change for this step can be represented as

 A (H-H bond enthalpy) + (Br-Br bond enthalpy)

 B (H-H bond enthalpy) − (Br-Br bond enthalpy)

 C (H-H bond enthalpy) + (H-Br bond enthalpy)

 D (H-H bond enthalpy) − (H-Br bond enthalpy).

**2.** Use the information in the table to calculate the enthalpy change for the following reaction:

H2(g) + Cl2(g) 🡪 2HCl(g)

|  |  |
| --- | --- |
| Bonds | ΔH to break bond (kJ mol-1) |
| H-H | 432 |
| Cl-Cl | 243 |
| H-Cl | 428 |

**3.** Using the bond enthalpy values from your data booklet, calculate the enthalpy changes for the

 following reactions:

 (a) CH4(g) + 2O2(g) 🡪 CO2(g) + 2H2O(g)

 (b) C3H8(g) + 5O2(g) 🡪 3CO2(g) + 4H2O(g)

 (c) C3H6(g) + H2(g) 🡪 C3H8(g)

 (d) N2(g) + 2O2(g) 🡪 2NO2(g)

**4.** The production of hydrogen chloride from hydrogen and chlorine is exothermic.

H2(g) + Cl2(g) → 2HCl(g)

Using bond enthalpy values, calculate the enthalpy change, in kJ mol-1, for this reaction.

**5.** Chloromethane can be produced by the reaction of methane with chlorine.

CH4(g) + Cl2(g) → CH3Cl(g) + HCl(g)

Using bond enthalpies from the data booklet, calculate the enthalpy change, in

kJ mol−1, for this reaction.Oxidising and Reducing Agents

****

**1.** Write a half equation for each of the changes shown below and state whether they are oxidation or reduction half-equations.

a) Hg → Hg2+

b) Cr3+ → Cr

c) I2 → I-

d) F- → F

e) Fe2+ → Fe3+

f) Sn2+ → Sn4+

g) Fe2O4 -→ Fe3+

h) Cl2 → ClO3-

i) O2 → H2O2

j) I2 → IO3-

**2.** In each of the following examples write:

i) the ion-electron half equation for the oxidation and reduction process

ii) the overall REDOX equation for the reaction

iii) the names of the oxidising and reducing agent

a) A displacement reaction between zinc and silver (II) nitrate

b) A reaction where calcium is added to dilute hydrochloric acid

c) The reaction of acidified potassium permanganate solution with sodium bromide solution

**3.** Which of the following is a redox reaction?

A NaOH + HCl → NaCl + H2O

B Zn + 2HCl → ZnCl2 + H2

C NiO + 2HCl → NiCl2  + H2O

D CuCO3 + 2HCl → CuCl2 + H2O + CO2

**4.** During a redox process in acid solution, iodate ions, IO3- (aq) , are converted into iodine, I2 (aq).

 IO3- (aq) → I2 (aq)

The numbers of H+ (aq) and H2O(l) required to balance the ion-electron equation for the formation of 1 mol of I2(aq) are, respectively

A 6 and 3

B 3 and 6

C 12 and 6

D 6 and 12

**5.** Iodide ions can be oxidised using acidified potassium permanganate solution. The equations are:

 2I-(aq) → I2(aq) + 2e-

 MnO4-(aq) + 8H+(aq) + 5e- →Mn2+(aq) + 4H2O(l)

How many moles of iodide ions are oxidised by one mole of permanganate ions?

A 1.0

B 2.0

C 2.5

D 5.0

**6.** Stanic chloride (SnCl4) was used in World War 1 as a chemical weapon due to its corrosive and toxic properties. It can be produced by the reaction shown.



What ion is oxidized in the above reaction?

**7.** In which of the following reactions is hydrogen acting as an oxidising agent?



**8.** During a redox process, chlorate ions are converted into chlorine.



The reaction is carried out in acidic conditions to provide H+ ions. How many H+ ions would be required to balance this ion-electron equation?

A 12

B 10

C 8

D 6

**9.** The ion electron equations for the oxidation and reduction reactions that take place in a methanol fuel cell are:



Combine the two ion-electron equations to give the equation for the overall redox reaction.

**10.** Acrylonitrile can be reduced to form CH3CH2CN. Complete and balance the ion-electron equation for the reduction reaction.



The ion electron equation for the oxidation of copper by nitric acid are shown



How many moles of copper ions are oxidised by 1 mole of nitrate ions?

A 0.33

B 0.67

C 1.50

D 3.00

**11.** What is the significance of the acronym ‘OILRIG’ when explaining a redox process.

**12.** What is meant by a spectator ion?

**13.**  For the following displacement reactions write down the relevant ion-electron equations and use them to work out the redox equation. Do not include the spectator ions.

(a) copper metal reacts with silver(I) nitrate solution to form copper (II) nitrate solution and silver.

(b) chromium metal reacts with nickel (II) sulphate solution to form chromium (III) sulphate solution and nickel.

(c) magnesium metal displaces aluminium from aluminium (III) oxide.

(d) copper is displaced from a solution of copper (II) sulphate by sodium metal.

**14.** Give the names of two strong oxidising agents and give two uses of each.

**15.** The ion-electron equations below represent the reduction and oxidation reactions which take place when an acidified solution of dichromate ions react with sulphite ions.

 Cr2O72-(aq) + 14H+(aq) + 6e- 2Cr3+(aq) + 7H2O(l)

 SO32-(aq) + H2O(l) SO42-(aq) + 2H+(aq) + 2e-

Write the REDOX equation for this reaction.

**16.** Sulphur dioxide is added to wine as a preservative. A mass of 20 to 40 mg of sulphur dioxide per litre of wine will safeguard the wine without affecting its taste.

(a) Describe clearly, with full experimental detail, how 0.05 mol l-1 iodine solution would be diluted to give 250 cm3 of 0.005 mol l-1 solution.

(b) The equation for the reaction which takes place is:

 SO2(aq) + I2(aq) + 2H2O(l) → 4H+(aq) + SO42-(aq) + 2I-(aq)

(i) The indicator used in this reaction causes a change from blue to colourless at the end point. Name a substance which could be used as this indicator.

(ii) Write the ion-electron equation for the reduction reaction taking place.

****Chromatography



**1.** Use the diagram showing a paper chromatography experiment to define the following terms:

 (a) mobile phase

 (b) stationary phase

 (c) Rf value

**2.** Compare and explain the speed at which the following move up the paper in paper chromatography.

 (a) Large molecules compared with small molecules.

 (b) A polar solvent compared with a non-polar solvent.

**3.** An organic chemist is attempting to synthesise a fragrance compound by the following chemical reaction.

 *compound X + compound Y → fragrance compound*

After one hour, a sample is removed and compared with pure samples of compounds X and Y using thin-layer chromatography. Which of the following chromatograms shows that the reaction has produced a pure sample of the fragrance compound?



**4.** Describe how chromatography can be used to identify the amino acids that make up a protein.

**5.** Label the parts A – F on the gas chromatography equipment below:

Labels

sample inlet

oven

gas (mobile phase)

detector

coil

chromatogram

**6.** In terms of gas liquid chromatography

 (a) what is the mobile phase?

 (b) what is the stationary phase?

 (c) why is the injection port heated?

 (d) explain what is meant by retention time.

**7.**  Give 3 different uses of gas liquid chromatography.

**8.**  (a) Which gases are usually used as carrier gases in gas chromatography?

 (b) Explain why these particular gases are used.

**9.** If the stationary phase in gas chromatography is non-polar, how would the retention times of polar and non-polar samples in the column compare to each other?

**10.** A technician analyses a mixture of hydrocarbons using gas chromatography. She first calibrates the equipment using standard hydrocarbons. The retention times of these hydrocarbons are shown in the table.

|  |  |  |
| --- | --- | --- |
| hydrocarbon | formula | retention time in minutes |
| methane | CH4 | 1.7 |
| ethane | C2H6 | 2.2 |
| propane | C3H8 | 3.5 |
| butane | C4H10 | 4.0 |
| pentane | C5H12 | 7.4 |

The technician then analyses the mixture of hydrocarbons. The recorder print out from this analysis is shown below.



(a) How does the recorder print out show that butane has the highest concentration?

(b) Use data in the table to draw a conclusion relating the formula of each hydrocarbon to its retention time.

# Volumetric Analysis



**1.** 25 cm3 of a solution of sodium hydroxide was added to a flask and titrated with a 0.2 mol l-1 solution of hydrochloric acid.

***HCl + NaOH → NaCl + H2O***

The experiment was carried out three times and the volumes of HCl titrated in each experiment are shown in the table.

|  |  |
| --- | --- |
| Titration | Volume of 0.2 mol l-1 solution of HCl (cm3) |
| 1 | 11.3 |
| 2 | 10.4 |
| 3 | 10.6 |

Calculate the concentration of the NaOH solution in mol l –1.

**2.** 20 cm3 of a solution of potassium hydroxide was added to a flask and titrated with a 0.1 mol l-1 solution of hydrochloric acid.

 HCl + KOH → KCl + H2O

The experiment was carried out three times and the volumes of HCl titrated in each experiment are shown in the table.

|  |  |
| --- | --- |
| Titration | Volume of 0.2 mol l-1 solution of HCl (cm3) |
| 1 | 20.6 |
| 2 | 19.9 |
| 3 | 20.0 |

Calculate the concentration of the KOH solution in mol l –1.

**3.** 10 cm3 of a solution of KOH was added to a flask and titrated with a 0.05 mol l-1 solution of H2SO4.

 H2SO4 + 2KOH → K2SO4 + 2H2O

The experiment was carried out three times and the volumes of HCl titrated in each experiment are shown in the table.

|  |  |
| --- | --- |
| Titration | Volume of 0.2 mol l-1 solution of HCl (cm3) |
| 1 | 15.9 |
| 2 | 15.2 |
| 3 | 15.3 |

Calculate the concentration of the KOH solution in mol l –1.

**4.** Rhubarb leaves contain oxalic acid, (COOH)2. A pupil found that it required 17 cm3 of 0.001 mol l-1 of sodium hydroxide to neutralise 25 cm3 of a solution made from rhubarb leaves. Calculate the concentration of oxalic acid in the solution given that the equation for the reaction is:

 (COOH)2 + 2NaOH 🡪 Na2(COO)2 + 2H2O

**5.** Acidified potassium permanganate can be used to determine the concentration of hydrogen peroxide solution; the solutions react in the ratio of

 **2 mol of potassium permanganate: 5mol of hydrogen peroxide.**

In an analysis it is found that 16.8 cm3 of 0.025 mol l-1 potassium permanganate reacts exactly with a 50 cm3 sample of hydrogen peroxide solution. What is the concentration, in mol l-1 of the hydrogen peroxide solution?

**6.** Iodine reacts with thiosulphate ions as follows:

 I2(aq) + 2S2O32-(aq) 2I -(aq) + S4O62-(aq)

In an experiment it was found that 1.2 x 10-5 mol of iodine reacted with 3.0 cm3 of the sodium thiosulphate solution. Use this information to calculate the concentration of the thiosulphate solution in mol l-1.

**7.** Vitamin C, C6H8O6, is a powerful reducing agent. The concentration of vitamin C in a solutioncan be found by titrating it with a standard solution of iodine, using starch as an indicator. The equation for the reaction is:

 C6H8O6(aq) + I2(aq) C6H6O6(aq) + 2H+(aq) + 2I-(aq)

A vitamin C tablet was crushed and dissolved in some water. The solution was then transferred to a standard 250 cm3 flask and made up to the 250 cm3 mark with distilled water.

In one investigation it was found that an average of 29.5 cm3 of 0.02 mol l-1 iodine solution was required to react completely with 25.0 cm3 of vitamin C solution.

Use this result to calculate the mass, in grams, of vitamin C in the tablet.

**8.** Hydrogen sulfide, H2S, can cause an unpleasant smell in water supplies. The concentration of hydrogen sulfide can be measured by titrating with a chlorine standard solution. The equation for the reaction taking place is

 4Cl2(aq)  + H2S(aq) + 4H2O(l) → SO42−(aq) + 10H+(aq) + 8Cl−(aq)

50·0 cm3 samples of water were titrated using a 0∙010 mol l−1 chlorine solution.

(a) Name an appropriate piece of apparatus which could be used to measure out the water samples.

(b) What is meant by the term standard solution?

(c) An average of 29·4 cm3 of 0∙010 mol l−1 chlorine solution was required to react completely with a 50·0 cm3 sample of water. Calculate the hydrogen sulfide concentration, in mol l−1, present in the water sample. Show your working clearly.

**9.** A compound known as ethylenediaminetetraacetic acid (EDTA) is useful for measuring the quantities of certain metal ions in solution. For example, Ca2+ ions and EDTA react in a 1 mol:1 mol ratio.

It is found that 14.6 cm3 of 0.1 mol l-1 EDTA reacts exactly with a 25cm3 sample of a solution containing Ca2+ ions.

Calculate the concentration, in mol l-1, of the calcium ion solution.

**10.** Trichloromethane , is insoluble in water. When ammonia is added to the beaker containing water and trichloromethane, the ammonia dissolves in bith solvents giving different concentrations.



is called the partition coefficient.

This can be found by titrating the ammnia in each layer against diluute hydrochloric acid.

(a) How could the end points of the titrations be observed?

(b) The concentration of ammonia in water was calculated from three titrations.

The titre volumes were as follows

1st 24.7 cm3

2nd 24.0 cm3

3rd 23.9 cm3

(c) What volume of dilute hydrochloric acid would be used to calculate the concentration of water in ammonia?

(d) The concentration of ammonia in water was found to be 1.7 mol ℓ-1. For the ammonia in terachloromethane, it was found that 18.4 cm3 of dilute hydrochloric acid, concentration 0.050 mol ℓ-1 was required to neutralise 20 cm3 of the ammonia solution.

(e) Calculate the value for the partition coefficient of ammonia between water and trichloromethane.

**11.** A 50·0cm3 sample of contaminated water containing chromate ions was titrated and found t require 27·4 cm3 of 0·0200 mol ℓ –1 iron(II) sulphate solution to reach the end-point.

The redox equation for the reaction is:

 3Fe2+(aq) + CrO42–(aq) + 8H+(aq) → 3Fe3+(aq) + Cr3+(aq) + 4H2O(ℓ )

Calculate the chromate ion concentration, in mol l–1, present in the sample of water.

**12.** An average of 21·6cm3 of 0·0150 mol ℓ –1 acidified permanganate solution was required to react completely with the nitrite ions in a 25·0 cm3 sample of river water.

The equation for the reaction taking place is:

2MnO4–(aq) + 5NO2–(aq) + 6H+(aq) → 2Mn2+(aq) + 5NO3–(aq) + 3H2O(ℓ)

Calculate the nitrite ion concentration, in mol l–1, in the river water.