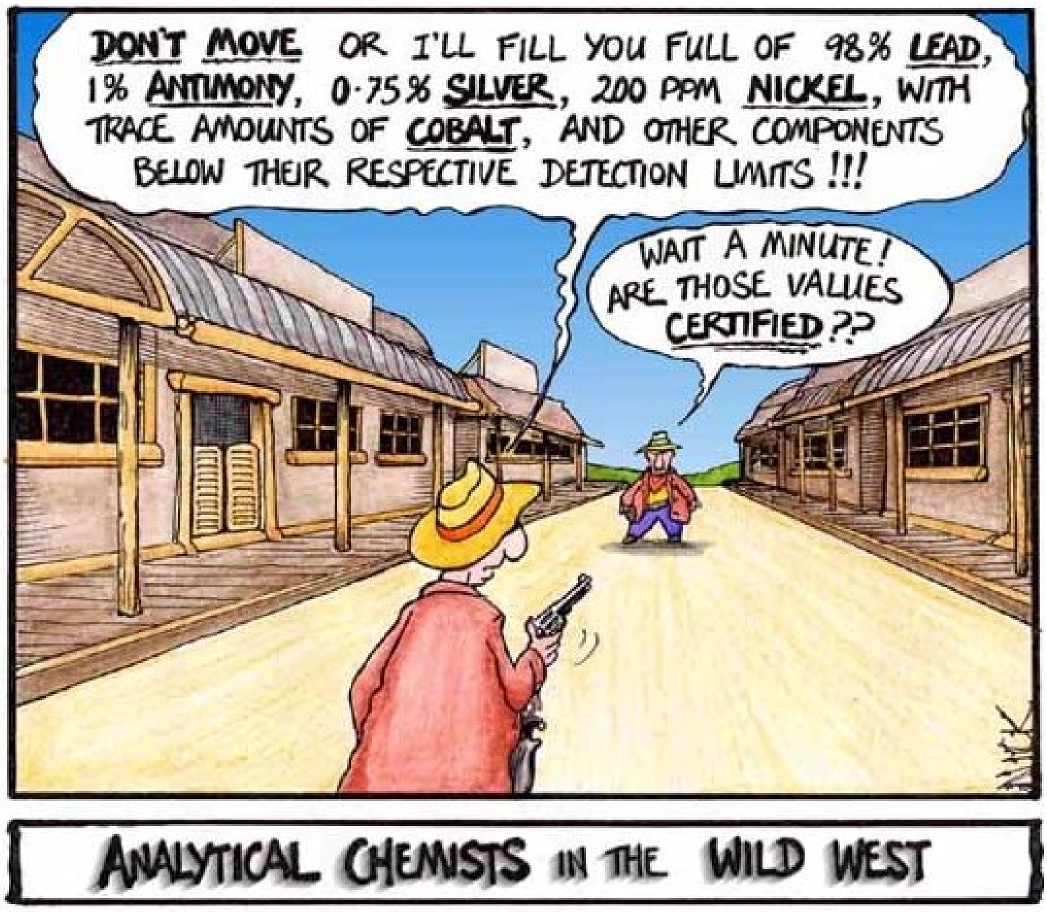
3AB Chemistry

Matter
Solutions &
reactions



http://www.siraze.net/chemistry/sezennur/subjects/comics/comics19.htm

Tyson

Macroscopic properties of matter

- Interpret observations, such as the colour changes of physical and chemical systems at equilibrium
- Use observable properties, such as the colour of ions, to help predict and explain the formation of products in chemical processes (see data sheet)
- Use the Kinetic Theory to explain the concept of absolute zero

Solutions

- Apply the solubility rules to predict if a precipitate will form when two dilute ionic solutions are mixed (see data sheet)
- Perform concentration calculations (mol L^{-1}, g L^{-1} ppm, percentage composition)
- Calculate the concentration of ions in solution for strong electrolytes
- Perform the calculation of concentration and volume involved in the dilution of solutions and the addition of solutions

Chemical Reactions

Reactions, equations and stoichiometry

- Describe, write equations for and interpret observations for the following reaction types:
  - Precipitation
  - Solvation of ions in aqueous solution
  - Physical and chemical equilibrium
- Write ionic equations appropriate to the chosen context using ions in appendix 1.
- Perform calculations involving
  - Conversion between Celcius and Kelvin temperature scales
  - Mass, molar mass, number of moles of solute, concentration and volume of solution and gas volume using PV=nRT
  - Percentage purity of reactants or percentage yield in industrial processes
  - A limiting reagent, including:
    - Identification of limiting reagents
    - Calculation of excess reagents

Applied Chemistry

- Write the chemical formulae for molecular compounds based on the number of atoms of each element present as inferred from the systematic names
- Write the molecular formulae of commonly encountered molecules that have non-systematic names

Macroscopic properties of matter

What is the difference between a physical equilibrium system and a chemical equilibrium system?

Name two solutions that could be combined to form a blue precipitate

What are the assumptions of kinetic theory?

What is absolute zero?

Solutions ref page 93 of textbook
(note we will not cover the issue of polarity of solutes and solvents until after we have studied bonding)
When two substances are mixed together and a homogeneous mixture forms it can be said that one substance has dissolved in the other to form a solution.

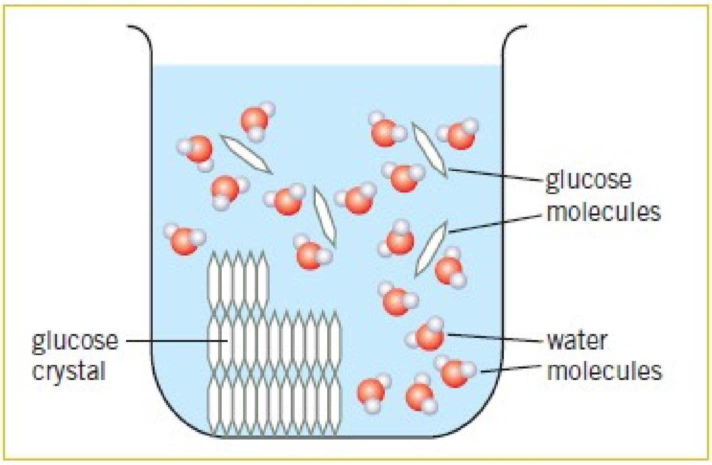


Figure 4.1 A model for glucose dissolving in water

Ref Lewis, C.& Lewis P. (2009). Chemistry for WA 2. Pearson Heinemann, Australia p93

The words solute and solvent are often used when referring to the preparation of a solution. The substance present in the larger amount is usually referred to as the solvent.
Some examples of solutions are given in the table below

Type of solution	Examples
Solid in solid	'Silver' coins (nickel in copper), bronze (tin in copper), stainless steel (carbon, chromium in iron)
Solid in liquid	Cordial (sugar in water), seawater (sodium chloride and other salts in water)
Liquid in liquid	Beer and wine (alcohol in water), vinegar (acetic acid in water), perfumes (liquid fragrant compounds in ethanol)
Gas in liquid	Cloudy ammonia (ammonia gas in water), hydrochloric acid (hydrogen chloride in water), effervescent drinks (carbon dioxide in water)
Gas in gas	Air (nitrogen, oxygen, carbon dioxide and other gases)

Ref Lewis, C.& Lewis P. (2009). Chemistry for WA 2. Pearson Heinemann, Australia p94

Reviewing terms related to solutions

Concentrated solution

Dilute solution

Saturated solution

Unsaturated solution

Supersaturated solution

The mole concept ref page 103 textbook (revision from year 11)

The mole is just a number (sometimes called avogadro's number)
The number is 6.02×10^{23}
What's so special about this number? Well if you take this number of hydrogen atoms they weigh one gram and this makes the calculation of molar mass (the mass of one mole of a substance very easy)

$\boxed{n = \text{mass}/\text{mass of 1 mole}}$

where n is the number of moles

Review exercise 4.3 page 107 textbook

1. a) What is the mass of 5.03×10^{22} molecules of carbon dioxide?
   b) What is the amount, in mol, of sulfur in 18.5g of aluminium sulfate?
   c) What mass of oxygen would be in 0.624g of calcium carbonate?
   d) What is the relative atomic mass of a particular metal if 4.86×10^{-3} mol of the metal has a mass of 524mg?

Year 10 revision

1. In one mole of H_2O

   (i) How many moles of hydrogen are there? (2mol)
   (ii) How many moles of oxygen are there? (1mol)

2. In one mole of calcium carbonate

   (i) How many moles of calcium are there? (1mol)
   (ii) How many moles of carbon are there? (1mol)
   (iii) How many moles of oxygen are there? (3mol)

3. In one mole of $H_2C_2O_4.2H_2O$

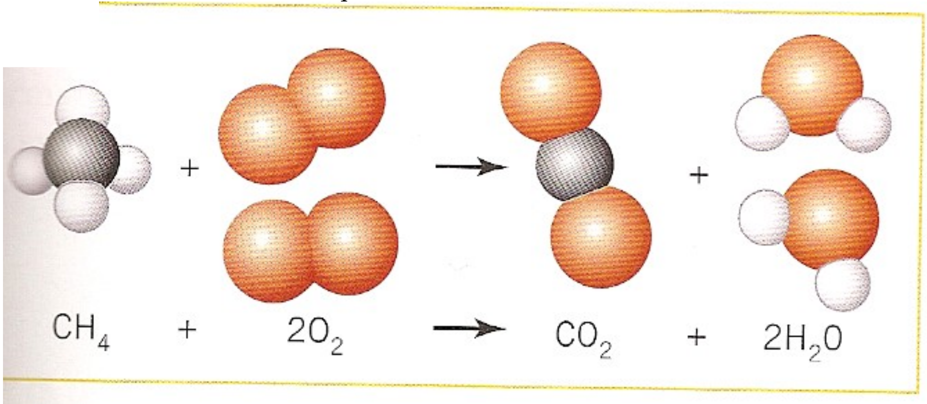
   (i) How many moles of hydrogen are there? (6mol)
   (ii) How many moles of carbon are there? (2mol)
   (iii) How many moles of oxygen are there? (6mol)

4. In 2 moles of $Mg(OH)_2$

   (i) How many moles of magnesium are there? (2mol)
   (ii) How many moles of oxygen are there? (4mol)
   (iii) How many moles of hydrogen are there? (4mol)

The mole and chemical equations year 10 revision

What do balanced chemical equations tell us?



Ref Lewis, C.& Lewis P. (2009). Chemistry for WA 2. Pearson Heinemann, Australia

If I have 1 mole of CH_4 how many moles of water will be produced?

CH_4 + $2O_2$ → CO_2 + $2H_2O$
1mole x mole

n H_2O = 2/1 x n CH_4 = 2/1 x 1 = 2 mol

Some for you to try

1. Nitrogen gas reacts with hydrogen gas according to the following equation

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

a) If you have 3 moles of nitrogen gas how many moles of NH_3 will be produced?
b) If you have 2 moles of hydrogen gas how many moles of NH_3 will form?

2. Methane gas burns in the presence of oxygen gas according to the following equation

$$\mathbf{CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O}$$

If you have 0.6moles of methane gas how many moles of oxygen gas will be required to react with it?

Mass to mass calculations year 11 revision

Questions to try

1. The equation for the decomposition of magnesium carbonate is as follows:
   $MgCO_3 \rightarrow MgO + CO_2$
   What mass of carbon dioxide will be produced if 42g of magnesium carbonate is decomposed?
   (22g)
2. How many grams of potassium chlorate must be heated to obtain 3.5g of oxygen gas?
   $2KClO_3 \rightarrow 2KCl + 3O_2$
   (8.9g)
3. Methane burns in oxygen to produce carbon dioxide and water
   $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$
   When 4g of methane burn what is the number of grams of carbon dioxide produced?
   (11g)
4. What mass of zinc chloride will be produced if 0.2 mole of hydrochloric acid is reacted with zinc oxide?
   $ZnO + 2HCl \rightarrow H_2O + ZnCl_2$
   (13.6g)
5. In the production of nitric acid ammonia is reacted initially with oxygen to form nitric oxide, NO, and water according to the following equation
   $4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$
   If 17g of ammonia is reacted with oxygen, what mass of nitric oxide will be produced?
   (30.0g)

Limiting reagent

Example 1

A mixture of 4 mole of hydrogen and 3 mole of oxygen react to form water according to the equation

$2H_2 + O_2 \rightarrow 2H_2O$
4mol 3mol

Which is the limiting reagent?

Need ratio $\frac{H_2}{O_2} = \frac{2}{1}$ Given ratio $\frac{H_2}{O_2} = \frac{4}{3} = \frac{1.33}{1}$

Therefore H_2 is limiting reagent

Example 2

If 4.18mole of aluminium is burnt with 5.92 mole of chlorine to form aluminium chloride, which is the limiting reagent?

$2Al + 3Cl_2 \rightarrow 2AlCl_3$
4.18mol 5.92mol

Need $\frac{Al}{Cl_2} = \frac{2}{3} = \frac{0.66}{1}$ Given $\frac{Al}{Cl_2} = \frac{4.18}{5.92} = \frac{0.71}{1}$

Therefore Cl_2 is limiting

Example 3

Silicon carbide is an important ceramic material that is made by heating a mixture of sand (silicon dioxide) with powdered carbon at a very high temperature. Carbon monoxide is also formed.

$SiO_2 + 3C \rightarrow SiC + 2CO$
102g 98.3g x gram

Calculate the mass of carbon monoxide formed when 102g of silicon dioxide is reacted with 98.3g of carbon according to the equation above.

n SiO_2 = 102/ 28.09 + (2x16) = 102/60.09 = 1.697mol

n C = 98.3/12.01 = 8.18mol

Need $\frac{SiO_2}{C} = \frac{1}{3} = \frac{0.33}{1}$ Given $\frac{SiO_2}{C} = \frac{1.697}{8.18} = \frac{0.207}{1}$

Therefore LR is SiO_2

n CO = 2/1 x n SiO_2 = 2/1 x 1.697 = 3.394 mol

mass CO = 3.394 x (12.01 + 16) = 3.394 x 28.01 = 95.1g

How do we calculate the mass of the excess reagent that is left over after the reaction?

Year 11 Limiting Reagent Calculations Practice

1. Sodium peroxide reacts with water according to the following equation
   $2Na_2O_{2(s)} + 2H_2O_{(l)} \rightarrow 4NaOH_{(aq)} + O_{2(g)}$
   If 25.0g of Na_2O_2 are reacted with 10g of water calculate

   a) the mass of sodium hydroxide produced.
   b) the mass of oxygen gas evolved.

2. Calcium metal reacts with hydrochloric acid to produce calcium chloride and hydrogen gas
   a) Write a balanced equation for this reaction
   b) If 4g of hydrochloric acid is added to 4g of calcium metal
      i) which reactant will be completely used up?
      ii) what mass of hydrogen gas will be produced?

3. A mixture made up of 4g of ethyne gas (C_2H_2) and 5g of oxygen gas is sparked in a combustion chamber. The following reaction occurs:
   $2C_2H_{2(g)} + 5O_{2(g)} \rightarrow 4CO_{2(g)} + 2H_2O_{(l)}$

   Determine:
   a) the number of moles of each of the reacting gases before the reaction
   b) the number of moles of carbon dioxide gas formed
   c) the mass of water formed
   d) the mass of excess reagent left after the reaction

4. Molten iron is produced in a blast furnace according to the following reaction
   $Fe_2O_{3(s)} + 3CO_{(g)} \rightarrow 2Fe_{(l)} + 3CO_{2(g)}$

   If 1 tonne (1000kg) of iron is produced by this reaction determine the mass of iron III oxide used.

5. Ammonia gas can be produced according to the following reaction
   $N_{2(g)} + 3H_{2(g)} \rightarrow 2NH_{3(g)}$

   If 20g of nitrogen gas is mixed with 20g of hydrogen gas how many grams of ammonia gas will be formed?

Answers

1. $2Na_2O_{2(s)}$ + $2H_2O_{(l)} \rightarrow 4NaOH_{(aq)} + O_{2(g)}$

   25g 10g

n= 25/(2x23 + 2x16)= 0.3205mol n= 10/ 2 + 16 = 0.556mol

need Na_2O_2/ H_2O = 2/2 =1/1

given Na_2O_2/ H_2O = 0.3205/0.556 = 0.576/1

therefore Na_2O_2 is limiting reagent

a) moles NaOH = 4/2 x moles Na_2O_2 = 2 x 0.3205 = 0.641mol
   mass NaOH = 0.641 x (23 + 16 + 1) = 25.64g

b) moles of O_2 = ½ x moles of Na_2O_2 = ½ x 0.3205 = 0.160mol
   mass of O_2 = 0.160 x 32 = 5.13g

2. a) Ca + 2HCl → H_2 + $CaCl_2$

b) 4g 4g

n= 4/40 = 0.1 n= 4/36.5=0.11

need Ca/HCl = ½ = 0.5/1

given Ca/HCl = 0.1/0.11 = 0.91/1

therefore HCl is limiting reagent

moles of H_2 = ½ x moles HCl = ½ x 0.11 = 0.055mol
mass of H_2 = 0.055 x 2 = 0.11g

3. $2C_2H_{2(g)}$ + $5O_{2(g)} \rightarrow 4CO_{2(g)} + 2H_2O_{(l)}$

a) 4g 5g

n= 4/(2x12 + 2x1)=0.154 n= 5/32=0.156

b) need C_2H_2/O_2 = 2/5 =0.4/1

given C_2H_2/O_2 = 0.154/0.156 = 0.987/1

therefore O_2 is limiting reagent

moles CO_2 = 4/5 x moles O_2 = 4/5 x 0.156 = 0.1248mol
mass CO_2 = 0.1248 x 44 = 5.49g

c) $2C_2H_{2(g)}$ + $5O_{2(g)} \rightarrow 4CO_{2(g)} + 2H_2O_{(l)}$

moles H_2O = 2/5 x moles O_2 = 2/5 x 0.156 = 0.4 x 0.156 = 0.0624mol

mass H_2O = 0.0624 x 18 = 1.12g

d) to find the mass of excess reagent leftover we need to find how much of it is used first

moles C_2H_2 used = 2/5 x moles O_2 = 2/5 x 0.156 = 0.0624

mass C_2H_2 used = 0.0624 x (2 x 12 + 2) = 1.62g

mass C_2H_2 leftover = 4-1.62 = 2.38g

4. $Fe_2O_{3(s)}$ + $3CO_{(g)} \rightarrow 2Fe_{(l)}$ + $3CO_{2(g)}$
1000kg
n= 1000 000/56 = 17857.1

moles Fe_2O_3 = ½ x moles Fe = ½ x 17857.1= 8928.6mol
mass Fe_2O_3 = 8928.6 x (2 x 56 + 3 x 16) = 1428 576g = 1428.6kg

no this was not a limiting reagent calculation !

5. $N_{2(g)}$ + $3H_{2(g)} \rightarrow 2NH_{3(g)}$
20g 20g
n= 20/2x14 = 0.714 n= 20/2 = 10

need N_2/H_2 = 1/3 = 0.33/1

given N_2/H_2 = 0.714/10 =0.0714/1

therefore the limiting reagent is N_2

moles NH_3 = 2/1 x moles N_2 = 2 x 0.714 = 1.43mol
mass NH_3 = 1.43 x (14 + 3x1) = 24.3g

Solution concentrations ref page 108 textbook (revision from year 11)

The concentration of a solution refers to the quantity of solute dissolved in a particular quantity of solution. The mass or volume of the solution includes the mass or volume of both the solute and the solvent.

Four methods commonly used to express solution concentrations are:

- Moles per litre, mol L^{-1}
- Grams per litre, g L^{-1}
- Parts per million, ppm
- Percentage composition by mass

Concentration in moles per litre, mol L^{-1} (molarity)

This method shows the amount in mole of solute dissolved in a litre of solution. For example, a 2.00 mol L^{-1} hydrochloric acid solution (or 2.00 M HCl) contains 2.00 moles of HCl molecules dissolved in every 1.00 L of solution.

Concentration, in mol L^{-1}, can be calculated using the formula:

$$\text{concentration (mol L}^{-1}\text{)} = \frac{\text{moles of solute}}{\text{volume of solution in L}}$$

or $c = \frac{n}{v}$ where v is in litres.

Example

Examples for you to do on your own

Example 1

Hydrogen peroxide solution used for hair bleaching is sold as solutions containing 5.00g of H_2O_2 dissolved in 120mL of solution. What is the concentration, in $molL^{-1}$, of this hair bleaching solution? (1.22M)

Example 2

Phenobarbital, $C_{12}H_{12}N_2O_3$, is a sedative used to relieve anxiety and for short term treatment of insomnia. It may be taken as an elixir with 5.00mL being the dose. If the concentration of the Phenobarbital solution is $0.0170molL^{-1}$, what mass of the drug is present in one dose? (0.0197g)

Concentration in grams per litre ($g\ L^{-1}$)

$$\text{Concentration } (gL^{-1}) = \frac{\text{mass solute in g}}{\text{volume of solution in L}}$$

Example

Example for you to try

Example 1
A 300mL can of lemon-flavoured mineral water contains 5.10mg of sulfate ions.
Calculate the concentration, in gL^{-1} , of sulfate ions in the mineral water.
($0.0170 gL^{-1}$)

Concentration in parts per million ref page 111 textbook
When very small quantities of solute are dissolved to form a solution the concentration is often measured in parts per million (ppm).

$$\text{Concentration in ppm} = \frac{\text{mass solute in mg}}{\text{mass of solution in kg}}$$

OR

$$\text{Concentration in ppm} = \frac{\text{mass solute in g}}{\text{mass solution in g}} \times 10^6$$

Note: sometimes it is necessary to calculate the mass of a solution from its volume. To do this you will need to use the formula for density

$$\text{Density of solution} = \frac{\text{mass of solution}}{\text{volume of solution}}$$

Example

Concentration expressed as percentage composition

Concentration expressed as a percentage composition is referring to the percentage of solute in a particular solution. This may be on a mass (m) or volume (v) basis and leads to notations such as 10% (m/m), 5% (m/v) or 15% (v/v). The percentage composition of a solution provides information about the mass or volume of a solute dissolved in 100 'masses' or volumes of the solution. For example, a 1.5% (m/m) NaCl solution is one in which 1.5 g of sodium chloride is dissolved in 100g of the solution; or in a wine with an alcohol content of 12% (v/v), there is 12mL of alcohol (ethanol) dissolved in 100mL of the wine.

To calculate the percentage composition of a solution in the different units, the following equations can be used:

$$\text{percentage composition by mass (\% m/m)} = \frac{\text{mass of solute in g}}{\text{mass of solution in g}} \times 100$$

$$\text{percentage composition by volume (\% v/v)} = \frac{\text{volume of solute in mL}}{\text{volume of solution in mL}} \times 100$$

$$\text{percentage composition by mass/volume (\% m/v)} = \frac{\text{mass of solute in g}}{\text{volume of solution in mL}} \times 100$$

Example 4.13 page 112 textbook

Calculate the amount, in mole, of sodium ions present in 650mL of a 2.00% (g/mL) sodium carbonate solution.

Solution

This problem has three steps:
volume of solution → mass of Na_2CO_3 → mole of Na_2CO_3 → mole of Na^+

Step 1 mass of sodium carbonate in 650mL of the 2% solution = 2% of 650

$$= \frac{2.00}{100} \times 650 = 13.0\text{g}$$

Step 2 mole of $Na_2CO_3 = \frac{\text{mass of } Na_2CO_3}{\text{molar mass of } Na_2CO_3}$

molar mass of Na_2CO_3 = (2 x 22.99) + 12.01 + (3 x 16.00) = 105.99 g mol^{-1}

mole of $Na_2CO_3 = \frac{13.0}{105.99} = 0.1227$ mol

Step 3 $Na_2CO_3 \rightarrow 2Na^+ + CO_3^{2-}$

1 mol of Na_2CO_3 will form 2 mol of Na^+

so 0.1227 mol of Na_2CO_3 will form 2 x 0.1227 = 0.245 mol Na^+

Examples for you to try

Example 1
Determine the percentage composition by mass of a 125g salt solution that contains 20g of NaCl.

$$\% \text{ by mass} = \frac{\text{mass NaCl}}{\text{mass of solution}} \times 100$$

=

Example 2
A 4g sugar cube ($C_{12}H_{22}O_{11}$) is dissolved in a 350mL teacup that is completely full. (Assume the mass of the tea solution ,that has the sugar in it, in the cup is 1 gram per mL)

What is the percentage composition by mass of sugar in the tea?

1. What is the concentration of a solution in grams/Litre when 80 grams of sodium chloride, NaCl, is dissolved in 2 litres of solution?

2. A solution of sugar contains 35 grams of sucrose, $C_{12}H_{22}O_{11}$ in 100 mL of solution. What is the concentration of the solution in grams/Litre?

3. What is the molarity (moles per litre) of a solution in which 80 grams of sodium hydroxide, NaOH, is dissolved in 1 litre of solution?

4. Calculate the molarity of a solution of potassium fluoride, KF, in which 58 grams of the compound are dissolved in 4 litres of solution

5. If 0.500 grams of glucose, $C_6H_{12}O_6$ is dissolved in enough water to make 0.750 litres of solution what is the concentration of the solution in $molL^{-1}$?

6. If 250 grams of KNO_3 is dissolved in 10^2 litres of water what is the percentage composition by mass of potassium nitrate in the solution. (Assume the solution has a density of 1 gram per mL)

7. Sodium chloride is added to many foods. The label on a bottle of tomato puree indicates that there is 400mg of sodium in a 200g serving of the tomato puree. What is the percentage by mass of sodium in the tomato puree?

8. If household bleach is 5.25% NaOCl by mass what mass of NaOCl is present in 200g of the bleach solution?

<u>concentration calculations</u> ANSWERS

1. NaCl
Mass = 80 g
v = 2 L
c = ? gL^{-1}

concentration = $\frac{80}{2}$ = 40 gL^{-1}

2. $C_{12}H_{22}O_{11}$ sugar
Mass = 35 g
v = 100 mL
c = ? gL^{-1}

concentration = $\frac{35}{0.1}$ = 350 gL^{-1}

3. NaOH

Mass = 80

v = 1L
c = ? mol L^{-1}

$n = \frac{\textbf{mass}}{\textbf{molar mass}}$

$= \frac{80}{22.99 + 16 + 1.008}$

$= \frac{80}{39.998} = 2$ mol

$c = \frac{n}{v} = \frac{2}{1} = \underline{2M}$

4. KF
Mass = 58 g
v = 4L
c = ? mol L^{-1} (molarity means concentration in moles per litre)

$n = \frac{\textbf{mass}}{\textbf{molar mass}} = \frac{58}{39.1 + 19} = \frac{58}{58.1} = 1$ mol

$c = \frac{n}{v} = \frac{1}{4} = 0.25$ M

5. $C_6H_{10}O_6$ glucose

Mass = 0.5g

v = 0.75L
c = ? mol L^{-1}

$n = \frac{\textbf{mass}}{\textbf{molar mass}}$

$= \frac{0.5}{6 \times 12.01 + 12 \times 1.008 + 6 \times 16}$

$= \frac{0.5}{180}$

= 0.00278 mol

$c = \frac{n}{v} = \frac{0.00278}{0.75}$
= 0.0037 M

6. KNO_3

Mass = 250 g
v = 100 L = 100 000 mL
c = ? % by mass

% $KNO_3 = \frac{250}{100\ 000} \times 100$
= 0.25%

7. Na

Mass = 400 mg = $\frac{400}{1000\ g}$ = 0.4 g
Mass of solution = 200 g

% Na = $\frac{0.4}{200} \times 100 = 0.02\%$

8. NaOCl

Mass NaOCl = $\frac{5.25}{100}$ x 200 = 10.5 g

Review exercise 4.4 page 113 textbook

1. Calculate the concentration (in mol L^{-1}) of chloride ions if 0.581g of aluminium chloride is dissolved in sufficient water to make 250mL of solution.

2. Sodium hydrogensulfite is added to wine as a preservative.

   a) If the recommended concentration is 0.010 mol L^{-1} sodium hydrogensulfite, what mass of sodium hydrogensulfite would need to be added to a 450 L barrel of wine to achieve this concentration?

   b) What assumption did you make in this calculation?

3. A sample of tap water was found to contain 0.0472g of NaCl per 250g of solution. Calculate the concentration, in ppm, of NaCl in the tap water.

4. The label on a bottle of hospital-grade disinfectant states that the disinfectant contains 49.9g L^{-1} of sodium hypochlorite (NaClO) and 12.0g L^{-1} of sodium hydroxide. If these are the only two sources of sodium ions, calculate the concentration, in mol L^{-1}, of sodium ions in this disinfectant.

5. The water supply of many cities is fluoridates, giving 1.00 ppm of F^-. Express this concentration as mol of F^- per L of solution, assuming 1.00 mL of solution has a mass of 1.00g.

6. The concentration of calcium in milk is 0.114% (m/m) and the recommended daily amount of calcium consumed by a teenager is 1300mg. How many glasses of milk would need to be consumed to achieve this recommended daily amount? Assume the volume of the glass is 250mL and that 100mL of milk has a mass of 103g.

4.5 Diluting and mixing solutions

When more solvent is added to a solution, the concentration of the solution decreases. In this dilution process, the volume of the solution is increased, but the amount of solute remains constant. That is:

mole of solute in concentrated solution = mole of solute in dilute solution

A method sometimes used to calculate the new concentration of a diluted solution is based on this statement.

If mole of solute in the initial concentration solution
= mole of solute in the final diluted solution
and because
mole of solute = concentrations of solution x volume of solution
then it follows that:
concentration of initial solution x initial volume = concentration of final solution x final volume
or

$$\boxed{c_1v_1 = c_2v_2}$$

where c_1 and v_1 refer to the concentrated solution before dilution and c_2 and v_2 refer to the diluted solution.

When mixing two solutions, it is sometimes not possible to use $c_1v_1 = c_2v_2$ in the calculation because the amount in mole of the solute changes because of the addition. The method will therefore probably involve calculating the relevant amount in mole of solute present in the mixture, and then the concentration or volume of the new mixture, whatever is asked in the question.

Example 4.15 ref page 115 textbook

1.20 L of 1.36 mol L^{-1} $MgCl_2$ solution is added to 0.932 L of 1.26 mol L^{-1} NaCl solution. Calculate the concentration, in mol L^{-1}, of chloride ions in the resulting solution.

Solution

The steps in this calculation are:

$\frac{\text{concentration of } MgCl_2(aq)}{\text{volume of } MaCl_2(aq)}$ → mole of $MgCl_2$ → mole of Cl^- (A)

total mole of Cl^- → concentration of Cl^- (B)

$\frac{\text{concentration of NaCl (aq)}}{\text{volume of NaCl (aq)}}$ → mole of NaCl → mole of Cl^-

Then (A) + (B) = total mole Cl^- → concentration Cl^-

Step 1 Find the amount in mole of $MgCl_2$ solution.

concentration of $MgCl_2$ solution = $\frac{\text{mole of } MgCl_2}{\text{volume of } MgCl_2 \text{ solution}}$

$1.36 = \frac{\text{mole of } MgCl_2}{1.20}$

mole of $MgCl_2$ = 1.36 x 1.20 = 1.632 mol

Step 2 Find the amount in mole of Cl^- from $MgCl_2$.

$MgCl_2 \rightarrow Mg^{2+} + 2Cl^-$

1 mol of $MgCl_2$ will form 2 mol of Cl^-

so 1.632 mol of $MgCl_2$ will form 2 x 1.632 = 3.264 mol of Cl^-

Step 3 Find the amount in mole of NaCl solution.

concentration of NaCl solution = $\frac{\text{mole of NaCl}}{\text{volume of NaCl solution}}$

$1.27 = \frac{\text{mole of NaCl}}{0.932}$

mole of NaCl = 1.27 x 0.932 – 1.184 mol

Step 4 Find the amount in mole of Cl^- from NaCl.

$NaCl \rightarrow Na^+ + Cl^-$

1 mol of NaCl will form 1 mol of Cl^-

Step 5 Find the total mole of Cl^-.

total mole of Cl^- = 3.264 + 1.184 = 4.448

Step 6 Find the concentration of Cl^- in new solution.

new volume = 1.20 + 0.932 = 2.132 L

concentration of Cl^- in new solution = $\frac{\text{mole of } Cl^2}{\text{volume of solution}}$

$$= \frac{4.448}{2.132} = 2.09 \text{ mol L}^{-1}$$

Review exercise 4.5 page 116 textbook

(Assume that the volumes are additive in the following problems.)

1. 116mL of water is added to 22.0mL of a 3.72g L^{-1} sodium carbonate solution. Calculate the concentration, in mol L^{-1}, of the dilutes sodium carbonate solution.

2. When fully charged, a car battery contains 33.5% (m/m) H_2SO_4 solution. The concentration of concentrated sulfuric acid is 98.0% (m/m). To make up 250g of the battery acid, what mass of water and concentrated acid need to be mixed together?

3. 500mL of distilled water was added to 320mL of 5.33 mol L^{-1} sodium hydroxide solution. What amount, in mole, of hydroxide ions would be present in 20.0 mL of this diluted solution?

4. 50.0mL of 0.126 mol L^{-1} nitric acid is mixed with 70.0mL of 0.429 mol L-1 nitric acid. Calculate the concentration of the resulting solution of nitric acid, in g L-1.

5. Concentrated hydrochloric acid has a density of 1.16 g mL^{-1} and contains 32.0% by mass of hydrogen chloride. What volumes of this concentrated acid and of water would need to be mixed together to prepare 500mL of a 2.00 mol L^{-1} HCl solution?

Rules for writing ionic equations

All strong electrolytes are to be written in ionic form.
All other substances to be written in molecular form
(note – solids, liquids and gases will always be written in molecular form)

How do you know what are strong electrolytes?

Review exercise 5.1 ref page 126 textbook

1. Write balanced chemical equations for the following reactions.

   a) When heated at about 250°C, calcium nitrate decomposes to form calcium oxide, nitrogen dioxide and oxygen.
   b) One of the most important minerals from which copper is extracted is chalcopyrites, $CuFeS_2$. In the first stage of the extraction process, chalcopyrites is roasted in air to produce copper(I) sulfide, iron(II) oxide and sulfur dioxide. During this roasting process, the copper mineral reacts with oxygen in the air.
   c) Group 1 oxides can be prepared by reducing a nitrate with the metal; for example, potassium oxide can be formed when potassium is heated strongly with sodium nitrate. Nitrogen is also formed in this reaction.
   d) Ammonia gas will not burn in air; however, it burns in pure oxygen, with a pale yellow-green flame. The products formed (at normal atmospheric conditions) are nitrogen and water vapour.

2. Give observations for the following reactions.

   a) If chlorine is bubbled through a solution of sodium bromide, the following reaction occurs:
   $$Cl_2(g) + 2Br^-(aq) \rightarrow Br_2(aq) + 2Cl^-(aq)$$

   b) When a strip of zinc is added to a dilute solution of copper sulfate, the copper ions are reduced according to the equation:
   $$Cu^{2+}(aq) + Zn(s) \rightarrow Cu(s) + Zn^{2+}(aq)$$

3. Write ionic equations and give observation for the following reactions.

   a) A solution of aluminium sulfate and water are formed when 2 mol L^{-1} sulfuric acid is added to solid aluminium oxide.
   b) If hydrogen sulfide is bubbled into a chlorine solution, the products formed are sulfur and hydrochloric acid.
   c) The products formed when solution of acetic acid and potassium hydrogencarbonate are mixed are carbon dioxide, water and a solution of potassium acetate.
   d) When 3 mol L^{-1} nitric acid is added to copper, a solution of copper nitrate, water and the colourless gas nitrogen monoxide form.

Review exercise 5.2 ref page 130 textbook

1. Name and give the formula of the precipitate formed when the following substances are mixed.

   a) solution of silver nitrate + solution of potassium bromide
   b) solution of potassium phosphate + solution of calcium nitrate
   c) potassium hydroxide solution + barium nitrate solution

2. Write an ionic equation for any reaction that may occur when the following solution are mixed. Also give the observations.

   a) solution of potassium chloride + solution of sodium hydroxide
   b) sodium hydroxide solution + copper nitrate solution
   c) solution of cobalt chloride + solution of sodium carbonate
   d) lead nitrate solution + hydrochloric acid solution

3. Identify the mistake in each of the following.

   a) The equation for the reaction that occurs when a solution of barium chloride is mixed with a solution of ammonium sulfate is
   $NH_4^+(aq) + Cl^-(aq) \rightarrow NH_4Cl(s)$

   b) The equation for the reaction that occurs when a solution of nickel(II) nitrate is mixed with a solution of sodium hydroxide is
   $Ni^{2+}(aq) + OH^-(aq) \rightarrow Ni(OH)_2(s)$

   c) The equation for the reaction that occurs when a solution of copper iodide is mixed with a solution of sodium sulfate is
   $Cu^{2+}(aq) + SO_4^{2-}(aq) \rightarrow CuSO_4(s)$

   d) When a solution of silver nitrate is mixed with hydrochloric acid solution, no reaction occurs because acids do not react with nitrates.

Review exercise 5.3 Stoichiometry ref page 131 textbook

1. a) When aluminium is heated strongly with iodine, the following reaction occurs:

$$2Al(s) + 3I_2(s) \rightarrow 2AlI_3(s)$$

What mass of iodine would be required to form 128g of aluminium iodide?

b) Acid reacts with marble chips according to the equation:

$$CaCO_3(s) + 2H^+(aq) \rightarrow Ca^{2+}(aq) + CO_2(g) + H_2O(l)$$

What volume of 2.17 mol L^{-1} hydrochloric acid would be required to react with 10.5g of marble chips (calcium carbonate)?

2. Students in Year 12 are to prepare hydrogen sulfide by reacting iron(II) sulfide with acid according to the equation:

$$FeS(s) + 2H^+(aq) \rightarrow Fe^{2+}(aq) + H_2S(g)$$

Health authorities recommend that exposure to hydrogen sulfide be limited to concentrations less than 14.0mg m^{-3} of air.

What mass of iron(II) sulfide should the teacher make available to the class so that the average concentration in a 250m^3 classroom will not exceed the recommended level?

3. Hydrogen peroxide, usually purchased as a 6% (mass) solution, is used as a bleach for dyeing hair and as a disinfectant. The concentration of a hydrogen peroxide solution can be accurately determined by reacting the solution with potassium permanganate in the presence of acid:

$$2MnO_4^-(aq) + 6H^+(aq) + 5H_2O_2(aq) \rightarrow 2Mn^{2+}(aq) + 5O_2(g) + 8H_2O(l)$$

10.00g of the hydrogen peroxide solution was first diluted with water to a volume of 250.0mL. It was then found that 25.00mL of this diluted solution reacted with exactly 18.49mL of 0.0128 mol L^{-1} $KMnO_4$ solution. Calculate the percentage by mass of the original hydrogen peroxide solution.

4. Sulfuric acid can be manufactured by the following series of reactions:

$$4FeS_2(s) + 11O_2(g) \rightarrow 2Fe_2O_3(s) + 8SO_2(g)$$
$$2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$$
$$SO_3(g) + H_2O(l) \rightarrow H_2SO_4(aq)$$

Calculate the mass of sulfuric acid that can be produced from 3.70 tonnes of iron pyrites (FeS_2).

5. To determine the solubility of magnesium hydroxide in water at 25°C, a saturated solution was prepared by adding an excess of powdered magnesium hydroxide to 100mL of water at 25°C. The mixture was filtered to remove the undissolved magnesium hydroxide.

a) Write equations for the dissolving of magnesium hydroxide in water and for the reaction of the dissolved magnesium hydroxide with nitric acid.
b) Calculate the solubility, in mol dissolved per litre of solution, of magnesium hydroxide in water at 25°C.
c) How could you make sure the mixture obtained in the first step was a saturated solution?
d) Why was the mixture filtered before the reaction with nitric acid, i.e. why was the nitric acid not just added to the original mixture produced?

6. A 0.782g strip of pure magnesium was added to 50.0mL of 1.54 mol L^{-1} HCl solution. What volume of 0.285 mol L^{-1} NaOH solution would be required to neutralise the hydrochloric acid left over from the reaction with magnesium?

$$Mg(s) + 2H^+(aq) \rightarrow Mg^{2+}(aq) + H_2(g)$$
$$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$$

If we are working with gases how do we convert between moles and volume?

$$n = \frac{V}{22.4}$$ at STP standard temperature and pressure

Standard temp is ________________________

Standard pressure is _____________________

The **molar volume** of a gas at STP is 22.41 litres

What does the term molar volume mean?

____

Example 1
What volume will 2.5 moles of oxygen gas (O_2) occupy at STP?

Example 2
What volume will 2.5 moles of argon gas (Ar) occupy at STP?

Example 3
What volume will 2.5 moles of carbon dioxide (CO_2) occupy at STP?

What did you learn from the 3 examples above?

____

____

Ideal gas law

$PV = nRT$

Example

Exercise 5.4 Gases and stoichiometry ref page 135 textbook

1. If 4.63g of methane, CH_4, is introduced into an evacuated 2.00L container at a temperature of 35.0°C, what is the pressure in the container?

2. What mass of zinc will react with excess hydrochloric acid to produce 592mL of hydrogen at 20.0°C and 834 mmHg pressure?

$$Zn(s) + 2H^+(aq) \rightarrow H_2(g) + Zn^{2+}(aq)$$

3. In a laboratory, 56.4mL of dry sulfur dioxide gas at a temperature of T°C and 98.0 kPa pressure was dissolved in a hydrogen peroxide solution to convert all the sulfur dioxide to sulfate ions:

$$SO_2(g) + H_2O_2(aq) \rightarrow SO_4^{2-}(aq) + 2H^+(aq)$$

Addition of excess barium chloride solution to the resultant solution gave 0.521g of barium silfate precipitate. What was the temperature, T, of the laboratory?

4. When 3.4L of propane burns in an excess of air, what volume of carbon dioxide will be formed, assuming the volumes are measured at the same temperature and pressure?

5. To remove the carbon dioxide from the exhaust gases emerging from a factory, the exhaust gas is forced through a solution of calcium hydroxide. The reaction that occurs is:

$$CO_2(g) + 2OH^-(aq) + Ca^{2+}(aq) \rightarrow CaCO_3(s) + H_2O(l)$$

If 15.0kL, measured at 29.5°C and 108 kPa, of exhaust gas containing 3.10% of carbon dioxide by mass was passed through a solution of 0.486 mol L^{-1} calcium hydroxide, what volume of this calcium hydroxide solution would be required to remove all the carbon dioxide?

6. Acrylonitrile is a colourless liquid that is used in the production of many acrylic fibred. It is produced by the ammoxidation of propene, in which a mixture of propene, ammonia and air is passed over a catalyst:

$$2CH_2 = CH\text{-}CH_3(g) + 2NH_3(g) + 3O_2(g) \rightarrow 2CH_2 = CH\text{-}CN(l) + 6H_2O(l)$$

a) What minimum volume of ammonia and of air would be required to react with 236 L of propene, assuming air is 20.8% (by volume) oxygen and the volumes are measured at the same temperature and pressure?

b) Assuming the reaction is 100% complete, is it possible to calculate the amount of acrylonitrile produced in this reaction? If not, what additional information would be required for this calculation?

Review exercise 5.5 Limiting reagent ref page 142 textbook

1. The Space Shuttle Orbiter uses methylhydrazine, $CH_3N_2H_3$, as a fuel. This substance is oxidised by dinitrogen tetraoxide to provide energy for propulsion. These two liquid propellants ignite spontaneously on contact with one another to form carbon dioxide, nitrogen and gaseous water. During one mission, when the Orbiter was manoeuvred into orbit, a mixture of 1250kg of methylhydrazine and 1350kg of dinitrogen tetraoxide was reacted to produce the required energy.

   a) Write a balanced equation for the reaction of methylhydrazine with dinitrogen tetraoxide.

   b) Calculate the total amount, in mole, of gas produced in the reaction required to put the Orbiter into orbit.

2. 0.120g of aluminium is added to 6.38mL of 2.03 mol L^{-1} HCl and the evolved gas is collected at 24°C and 1.00 x 10^5 Pa. What volume of hydrogen will be produced?

$$2Al(s) + 6H^+(aq) \rightarrow 2Al^{3+}(aq) + 3H_2(g)$$

3. In the production of nitric acid, one stage involves the catalytic oxidation of ammonia at 900°C:

$$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$$

   a) What volume of the gas nitrogen monoxide (NO) will be produced by the complete oxidation of 4.00 L of ammonia?
   b) Assuming 12.0 L of ammonia and 20.0 L of oxygen are mixed and reacted as completely as possible, what is the overall change (in L) in volume?

4. A precipitation reaction occurs when 23.9 mL of 0.175 mol L^{-1} $CuCl_2$ solution is added to 42.6 mL of 0.251 mol L^{-1} NaPO4 solution. Calculate:

   a) the mass of precipitate formed
   b) the concentration of each of the ions remaining in the solution after the reaction.

5. 0.700 g of potassium hydroxide was dissolved in 50.0 mL of 0.800 mol L^{-1} sulfuric acid. Calculate the concentration of sulfuric acid in the mixture after the rection. (Assume no volume change occurred.)

Stoichiometry and percentages ref page 143 textbook

Often problems either give information concerning the percentage purity of a particular substance or the percentage yield of a reaction, or they ask for percentages such as these to be calculated.

The percentage purity, by mass, of a substance can be calculated using the formula:

$$\text{percentage purity of the material} = \frac{\textbf{mass of pure substance}}{\textbf{mass of impure substance}} \times 100$$

The percentage yield of a reaction is a measure of how much product was actually produced compared to the theoretical amount expected to be produced. This theoretical amount can be calculated using the stoichiometric ratio given in the balanced chemical equation. One equation that can be used to determine the percentage yield of a reaction is:

$$\text{percentage yield of a reaction} = \frac{\textbf{mass of product actually obtained}}{\textbf{theoretical mass of product expected}} \times 100$$

The amount in mole of the product formed, compared to the theoretical amount in mole, can be used to determine the percentage yield, as can the actual and theoretical volumes (measured at the same temperature and pressure) of a gaseous product.

→ **Example 5.16**

Calculation of the percentage purity of a substance

Aluminium reacts with iron oxide according to the equation:

$$8Al(s) + 3Fe_3O_4(s) \rightarrow 4Al_2O_3(s) + 9Fe(s)$$

When 24.0 g of an impure sample of aluminium was reacted with iron oxide, 45.7 g of iron was formed. Calculate the percentage purity of the sample of impure aluminium.

→ **Solution**

This is a four-step problem:

mass of Fe → mole of Fe → mole of Al → mass of Al → % purity of Al samples

Step 1 $n(\text{Fe}) = \frac{m(\text{Fe})}{M(\text{Fe})}$ $M(\text{Fe}) = 55.85$ g mol^{-1}

$= \frac{45.7}{55.85} = 0.8183$ mol

Step 2 From the balanced equation:

9 mol of Fe are formed from 8 mol of Al

or 1 mol of Fe is formed from $\frac{8}{9}$ mole of Al

so 0.8183 mol of Fe are formed from $\frac{8}{9}$ x 0.8183 = 0.7274 mol of Al

Step 3 $n(\text{Al}) = \frac{m(\text{Al})}{M(\text{Al})}$ $M(\text{Al}) = 26.98$ g mol^{-1}

$0.7274 = \frac{m(\text{Al})}{26.98}$

$m(\text{Al}) = 0.7274 \times 26.98 = 19.63$ g

Step 4 Percentage purity of the Al sample = $\frac{\text{mass of pure Al}}{\text{mass of impure sample}} \times 100$

$= \frac{19.63}{24.0} \times 100 = 81.8\%$

→ **Example 5.17**

Calculation of a percentage yield of a reaction

Sodium tripolyphosphate (NaTPP) is used as a builder in detergent. Its function is to react with calcium ions that may be present in any 'hard' water. It does, however, contribute in a major way to the overgrowth of algae in rivers and lakes. NaTPP is produced by heating a mixture of the NaH_2PO_4 and Na_2HPO_4 salts:

$$NaH_2PO_4(s) + 2Na_2HPO_4(s) \rightarrow Na_5P_3O_{10}(s) + 2H_2O(g)$$

If 2.50 tonnes of Na_2HPO_4 is heated with a stoichiometric amount of $NaHPO_4$, 3.08 tonnes of NaTPP is produced. What is the percentage yield of the process?

→ **Solution**

The steps are:

mass of Na_2HPO_4 → mole of Na_2HPO_4 → mole of $Na_5P_3O_{10}$ → mass of $Na_5P_3O_{10}$

calculation of theoretical mass of $Na_5P_3O_{10}$ → percentage yield

Step 1 $\quad n(Na_2HPO_4) = \dfrac{m(Na_2HPO_4)}{M(Na_2HPO_4)}$

$M(Na_2HPO_4) = (2 \times 22.99) + 1.008 + 30.97 + (4 \times 16.00) = 141.958 \text{ g mol}^{-1}$

$n(Na_2HPO_4) = \dfrac{2.50.10^6}{141.958} = 1.761 \times 10^4$ mol

Step 2 From balanced equation:

2 mol of Na_2HPO_4 will form 1 mol of $Na_5P_3O_{10}$

or 1 mol of Na_2HPO_4 will form ½ mol of $Na_5P_3O_{10}$

so 1.761×10^4 mol of Na_2HPO_4 will form $\frac{1}{2} \times 1.761 \times 10^4$

$= 8.805 \times 10^3$ mol of $Na_5P_3O_{10}$

Step 3 $\quad n(Na_5P_3O_{10}) = \dfrac{m(Na_5P_3O_{10})}{M(Na_5P_3O_{10})}$

$M(Na_5P_3O_{10}) = (5 \times 22.99) + (3 \times 30.97) + (10 \times 16.00) = 367.86 \text{ g mol}^{-}$

1

$8.805 \times 10^3 = \dfrac{m(Na_5P_3O_{10})}{367}.86$

$m(Na_5P_3O_{10}) = 8.805 \times 10^3 \times 367.86 = 3.239 \times 10^6 \text{ g} = 3.239$ tonnes

Step 4 From 2.50 tonnes of Na_2PO_4 you would expect to form 3.239 tonnes of $Na_5P_3O_{10}$, but only 3.08 tonnes actually formed.

$$\text{percentage yield} = \frac{\text{mass of } Na_5P_3O_{10} \text{ actually formed}}{\text{theoretical mass of } Na_5P_3O_{10}} \times 100$$

$$= \frac{3.08}{3.239} \times 100 = 95.1\%$$

→ **Example 5.18**

Calculation of a percentage yield of a reaction

One of the first methods used to produce nitrogen monoxide, a substance from which nitric acid is produced, involved heating a mixture of nitrogen from which nitric acid is produced, involved heating a mixture of nitrogen and oxygen to about 3000°C using the electric discharge of a carbon arc:

$$N_2(g) + O_2(g) \rightarrow 2NO(g)$$

This reaction was not very efficient, as shown in the figures below and was replaced by the more economical oxidation of ammonia.

In a trial experiment of the direct oxidation of nitrogen process, 2.00 L of nitrogen was reacted with a slight excess of oxygen and 0.0675 L of nitrogen monoxide was produced. Assuming the volumes were measured at the same temperature and pressure, calculate the percentage yield of this reaction.

→ **Solution**

The steps are $\underbrace{\text{volume of } N_2 \rightarrow \text{volume of NO}}_{\text{Calculation of theoretical volume of NO}} \rightarrow$ percentage yield of reaction

Step 1 From balanced equation: 1 L of N_2 would form 2 L of NO

so 2.00 L of N_2 would form 4.00 L of NO

Step 2 The theoretical (or predicted) volume of NO formed is 4.00 L; however, only 0.0675 L was formed.

$$\text{percentage yield} = \frac{\text{volume of product actually obtained}}{\text{theoretical volume of product}} \times 100$$

$$= \frac{0.0675}{4.00} \times 100 = 1.69\%$$

→ **Example 5.19**

Calculation involving the determination of the amount of product, using the percentage yield of the reaction

White phosphorus is prepared commercially according to the overall reaction:

$$2Ca_3(PO_4)_2(s) + 6SiO_2(s) + 10C(s) \rightarrow 6CaSiO_3(s) + 10CO(g) + P_4(l)$$

What mass of silicon dioxide is needed to produce 1.0kg of phosphorus if the process is only 90% efficient?

→ **Solution**

The steps are

mass of P_4 → mole of P_4 → mole of SiO_2 (for 100% yield) → mass of SiO_2 (for 100% yield) → actual mass of SiO_2 required

Step 1 $n(P_4) = \frac{m(P_4)}{M(P_4)}$ $M(P_4) = 4 \times 30.97 = 123.88 \text{ g mol}^{-1}$

$= \frac{1.0.10^3}{123.88} = 8.07 \text{ mol}$

Step 2 From the balanced equation:

1 mol of P_4 would form from 6 mol of SiO_2

so 8.07 mol of P_4 would form from 6 x 8.07 = 48.4 mol of SiO_2

Step 3 $n(SiO_2) = \frac{m(SiO_2)}{M(SiO_2)}$

$M(SiO_2) = 28.09 + (2 \times 16.00) = 60.09 \text{ g mol}^{-1}$

$48.4 = \frac{m(SiO_2)}{60.09}$

$m(SiO_2) = 48.4 \times 60.09 = 2910 \text{ g}$

Step 4 2910 g of SiO_2 is required to form 1.00 kg of phosphorus if the reaction yield is 100%. However, during the reaction only 90% of the available mass of SiO_2 actually produces P_4. As a result, more than 2910 g of SiO_2 needs to be used in the reaction.

90% of the available mass of SiO_2 = 2910 g

$\frac{90}{100}$ x available mass of SiO_2 = 2910

available mass of $SiO_2 = 2910 \times \frac{100}{90} = 3230$ g

That is, 3200g or 3.2 kg of SiO_2 is required to produce 1.0 kg of P_4

Review exercise 5.6 Stoichiometry and percentages ref page 146 textbook

1. A sample of potassium chlorate to be used as a weed killer has been contaminated with sand (SiO_2). When heated, the chlorate decomposes according to the equation:

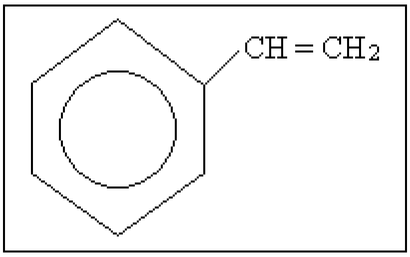
$$2KClO_3(s) \rightarrow 2KCl(s) + 3O_2(g)$$

The sand resists decomposition. If 20.0g of the sample yields 387 mL of oxygen at 77°C and 714 mmHg pressure, what is the percentage purity of the potassium chlorate sample?

2. When coal is burnt, any sulfur present will also burn to form sulfur dioxide, which is a major contributor to acid rain. To remove the sulfur dioxide from the exhaust gases produced in a coal-powered power plant, it can be reacted with calcium oxide. Calcium sulphite is formed in this reaction.

   a) Write equation for the combustion of sulfur and the reaction of sulfur dioxide
   b) A particular power station burns 2500 tonnes of coal per day. If the coal contains 2.4%, by mass, of sulfur, what mass of calcium sulphite would be produced daily in the purification process?

3. Styrene, $C_6H_5CH{=}CH_2$, is used extensively in the production of synthetic rubber and plastics such as polystyrene foam. Its structural formula is shown below:



   a) Industrially, styrene is produced by the catalytic dehydrogenation of ethylbenzene:
   $$C_6H_5\text{-}CH_2CH_3(g) \rightarrow C_6H_5\text{-}CH{=}CH_2(g) + H_2(g)$$
   Pure ethylbenzene is heated to around 630°C and passed over a metal oxide catalyst to form styrene. If 34.8 kg of ethylbenzene flows into the catalyst chamber, and 12.9 kg of styrene is produced, what is the percentage yield of this reaction?
   b) The mixture that emerges from the catalyst chamber is separated to produce pure styrene, unreacted ethylbenzene and hydrogen. What do you think is done with the unreacted ethylbenzene?

4. Zinc is a widely used metal in society; for instance, it is used to galvanise iron to prevent corrosion of the iron. Zinc is extracted from its sulfide ore in a multistep procedure that initially involves concentration of the ore by froth flotation followed by roasting. Zinc sulfide is converted into zinc oxide in the roasting process. At this stage, the zinc oxide mixture still contains impurities. Sulfuric acid is used to leach (dissolve) the zinc from the oxide mixture, forming a solution of zinc sulfate:

$$H_2SO_4(aq) + ZnO(s) \rightarrow ZnSO_4(aq) + H_2O(l)$$

Electrolysis of the zinc sulfate solution is then undertaken to produce zinc that is 99.995% pure:

$$2ZnSO_4(aq) + 2H_2O(l) \rightarrow 2Zn(s) + 2H_2SO_4(aq) + O_2(g)$$

Calculate the mass of zinc obtained, after the leaching and electrolysis processes of a particular batch of zinc oxide mixture, given the data below:
mass of zinc oxide mixture used 4.1×10^6g
percentage by mass of zinc oxide in this mixture 51%
percentage yield of the leaching reaction 76%
percentage yield of the electrolysis reaction 92%

5. 19.4g of marble (impure calcium carbonate) was dissolved in 50.0mL of 1.29 mol L^{-1} HCl.

$$CaCO_3(s) + 2H^+(aq) \rightarrow Ca^{2+}(aq) + CO_2(g) + H_2O(l)$$

The unreacted acid was exactly neutralised by 27.5 mL of 1.05 mol L^{-1}:

$$OH^-(aq) + H^+(aq) \rightarrow H_2O(l)$$

Calculate the percentage, by mass, of calcium carbonate in the marble.

QUESTIONS ref page 148 textbook

1. Figure 5.8 shows the result of adding a solution of sodium chromate to a solution of silver nitrate.

   a) **Describe** and **explain** what happened when the two solutions are mixed.
   b) Write an ionic equation for the reaction that occurred in the test tube.

2. Write ionic equations for the following reactions, and give the observations.

   a) A solution of aluminium chloride is mixed with a solution of sodium sulfide.
   b) Hydrochloric acid is mixed with a solution of lead nitrate.
   c) Sulfur dioxide, water and a solution of potassium chloride are formed when hydrochloric acid is added to a solid potassium sulphite.
   d) Solutions of sulfuric acid and lithium hydroxide are mixed.
   e) A solution of nickel nitrate is added to a solution of sodium hydroxide.
   f) Copper oxide is added to a solution of 2 mol L^{-1} acetic acid and the mixture is heated. A solution of copper acetate and water is formed.

3. One type of fire extinguisher depends on the reaction of sodium hydrogencarbonate with sulfuric acid to produce carbon dioxide. The equation for the reaction is:

   $2NaHCO_3(s) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$

   If a fire extinguisher is designed to hold 5.00×10^2 g of sodium hydrogencarbonate calculate:

   a) the volume of 12.0 mol L^{-1} sulfuric acid that would be required to react completely with the sodium hydrogencarbonate
   b) the volume of carbon dioxide produced at a temperature of 23°C and 99.4 kPa pressure.

4. The cathode ray tube of a television set has a volume of about 5.00 L. The pressure inside it is typically 0.100 Pa at 25.0°C. Estimate the number of molecules it contains.

5. Cement is a mixture of calcium and aluminium silicates, formed by heating limestone, $CaCO_3$, with clay at a temperature of around 1400°C. An equation that can be used to represent this complex reaction is:

$$4CaCO_3(s) + Al_2Si_2O_7(s) \rightarrow \underbrace{2CaSiO_3(s) + Ca_2Al_2O_5(s)}_{\text{cement}} + 4CO_2(g)$$

a) Calculate the mass of limestone required to make a 25 kg bag of cement.
b) After water, concrete is the second-most used resource globally. Cement is the key ingredient of concrete. However, there are concerns that the cement-production process cannot be regarded as being ‘environmentally friendly’. Suggest some of the reasons for these concerns.

6. Chlorine gas can be produced in the laboratory by reacting hydrochloric acid with manganese dioxide. If 23.6g of MnO_2 is added to 35.7 mL of 4.11 mol L^{-1} HCl, what volume of Cl_2 at kPa and 28°C will be formed? ($MnCl_2$ and H_2O are also formed in the reaction.)

7. During city travel, a Holden Commodore consumes on average 1.0 L of petrol every 11km travelled. In one year the car travels 12 000 km.

a) Assuming petrol is 100% octane (density of 0.70 g mL^{-1}) and that its combustion in the car engine yields only carbon dioxide and water, calculate the volume of carbon dioxide, at 25°C and 100 kPa pressure, produced by the car in one year.
b) In Perth there are approximately 1.1 million cars. Estimate the appropriate volume of carbon dioxide produced by the cars in Perth in one year if they all have the characteristics similar to a Holden Commodore.

8. A 0.387g sample of iron tablets, composed of mainly hydrated iron(II) sulfate, was ground to a powder and dissolved in a dilute solution of sulfuric acid. It was found that 19.86 mL of 0.01040 mol L^{-1} $KMnO_4$ solution was required to react with all of the iron(II) ions in the sample.

a) What was the percentage, by mass, of iron in the tablets, assuming it was present as iron(II) ions.
(The two half-equations for the redox reaction are:

$$Fe^{2+}(aq) \rightarrow Fe^{3+}(aq) + e^-$$

$$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l)$$)

b) In this redox reaction, which reactant has acted as the reductant and which as the oxidant?
c) What observations would you expect for the reaction of Fe^{2+} and MnO_4^-?
d) The label on the bottle containing the iron tablets stated that a 0.50g tablet contains 5.0mg of iron. Does your figure obtained in part a, agree with the amount? If not, propose a reason for why the values may be different.

11. Boron trichloride hydrolyses readily according to the reaction:

$$BCl_3(g) + 3H_2O(l) \rightarrow H_3BO_3(aq) + 3HCl(aq)$$

If the boric acid produced in the reaction is triprotic, what volume of 6.82 mol L^{-1} potassium hydroxide is required to neutralise the acid solution resulting from the hydrolysis of 6.77g of boron trichloride?

(Hint: The neutralising reactions are:

$3OH + H_3BO_3 \rightarrow$

$BO_3^{3} + 2H_2O$ and $H^2 + OH \rightarrow H_2O$)

12. 2.40g of a metallic oxide of type MO was dissolved in 100mL 1.00 mol L^{-1} hydrochloric acid. The resulting liquid was made up to 500mL with distilled water. 50.0mL of the diluted solution then required 20.2 mL of 0.204 mol L^{-1} sodium hydroxide for neutralisation. Calculate the atomic mass of the element M.

13. An average adult female breathes in about 12kg of air a day. Inhaled air contains about 21% by volume of oxygen and exhaled air about 16% by volume of oxygen.

a) Assuming the density of air is 1.2g L^{-1}, calculate the volume of oxygen used by an average adult female in a day.
b) If the volume of the oxygen is measured at 20°C and 100 kPa, how many molecules of oxygen are used each day?
c) Why does the oxygen content of the ait decrease when inhaled into the body?
d) The reaction between oxygen and glucose can be represented by the following equation:

$$C_6H_{12}O_6(aq) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l); \quad DH = -2810 \text{ kJ}$$

(i) What volume of carbon dioxide, at 20°C and 100 kPa, would be formed from the oxygen used by the female adult in a day?
(ii) How much heat would be generated daily by the reaction of the oxygen with glucose in the respiration process?

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Year 11 Chemistry

Mastery Test : Ionic Equations for Precipitation Reactions

Name: ___________________ Date: ______________________________

Write ionic equations and give observations for the following reactions. If there is no reaction then write ‘no reaction’ for the equation and ‘no observable change’ for the observation.

1. A solution of copper II chloride is added to a solution of silver nitrate

Equation: ____

Observation: ____

2. A solution of sodium hydroxide is added to aqueous magnesium chloride

Equation: ____

Observation: ____

3. A solution of potassium chloride is added to aqueous ammonium nitrate

Equation ____

Observation ____

4. A solution of calcium nitrate is added to aqueous potassium chloride

Equation ____

Observation ____

5. A solution of sodium hydroxide is added to aqueous cobalt II chloride

Equation ____

Observation ____

Answers

1. $Ag^{+}_{(aq)}$ + $Cl^{-}_{(aq)}$ $\rightarrow$ $AgCl_{(s)}$
Observation: a colourless solution and a blue solution are mixed and a white precipitate is formed

2. $Mg^{2+}_{(aq)} + 2OH^{-}_{(aq)} \rightarrow Mg(OH)_{2(s)}$
Observation: two colourless solutions are mixed and a white precipitate is formed.

3. no reaction
Observation: no visible change

4. no reaction
Observation: no visible change

5. $Co^{2+}_{(aq)}$ + $2OH^{-}_{(aq)} \rightarrow$ $Co(OH)_{2(s)}$
Observation: a pale pink solution is mixed with a colourless solution and a pale pink precipitate is formed.

Year 11 Chemistry Mastery Test: Precipitation Reactions

Name: __________________ Date: ____________________

1. Write balanced ionic equations for the reactions that occur when the following solutions are mixed.

   a) magnesium nitrate and sodium hydroxide

   ____

   b) aluminium chloride and sodium carbonate

   ____

   c) ammonium chloride and silver nitrate

   ____

   d) barium hydroxide and sodium sulfide

   ____

   e) copper II nitrate and potassium hydroxide

   ____

   f) calcium nitrate and potassium phosphate

   ____

Answers

1.

a) $Mg^{2+}_{(aq)} + 2OH^-_{(aq)} \rightarrow Mg(OH)_{2(s)}$

b) $2Al^{3+}_{(aq)} + 3CO_3^{2-}{}_{(aq)} \rightarrow Al_2(CO_3)_{3(s)}$

c) $Ag^+_{(aq)} + Cl^-_{(aq)} \rightarrow AgCl_{(s)}$

d) $Ba^{2+}_{(aq)} + S^{2-}_{(aq)} \rightarrow BaS_{(s)}$

e) $Cu^{2+}_{(aq)} + 2OH^-_{(aq)} \rightarrow Cu(OH)_{2(s)}$

f) $3Ca^{2+}_{(aq)} + 2PO_4^{3-}{}_{(aq)} \rightarrow Ca_3(PO_4)_{2(s)}$