Overview

Quantitative chemistry

Chemical measurements

- Balanced chemical equations
- Conservation of mass
- Relative formula mass

Use of amount of substance (HT)

- Amounts of substances in equations (HT)
- Quantities in equations (HT)
- Using moles to balance equations (HT)
- Limiting reactants (HT)
- Concentrations of solutions

Quantities (chemistry only)

- Percentage yield
- Atom economy
- Moles of solutions and gases (HT)

LearnIT!
KnowIT!

Chemical Measurements PART 1

- Balanced chemical equations
- Conservation of mass

Chemical equations can be very useful.
The law of conservation states that **no atoms** are **lost** or **made** during a chemical reaction so the **mass of the product equals the mass of the reactants**.
Chemical reactions can be represented by **symbol equations** which are **balanced** in terms of the numbers of atoms of each element involved on both sides of the equation.

State symbols **s, l, g** and **aq** are used in symbol equations.

When hydrogen molecules react with chlorine molecules, they make hydrogen chloride molecules:

$$\mathbf{H_2 + Cl_2 \rightarrow HCl}$$

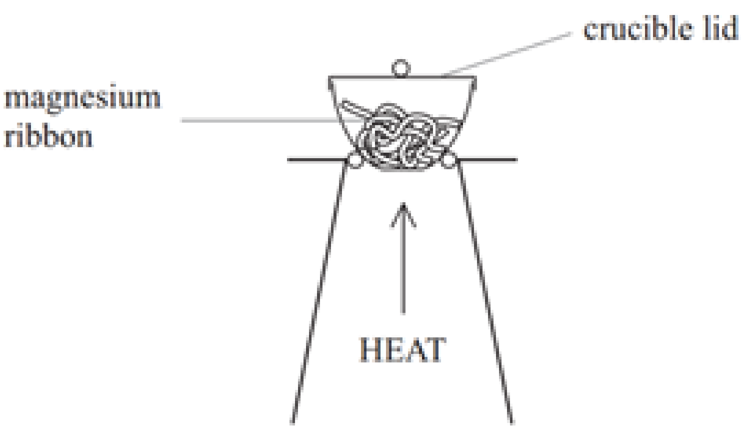
This equation shows the reactants and products, but it is not balanced.

$$\mathbf{H_2 + Cl_2 \rightarrow 2HCl}$$

This balanced equation shows that **one** hydrogen molecules reacts with **one** chlorine molecule to form **two** molecules of hydrochloric acid.

Chemical measurements - PART 1

When magnesium is heated in a crucible it reacts with oxygen and forms magnesium oxide:



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

This equation shows that **two** magnesium atoms react with **one** oxygen molecule to form **two** magnesium oxide compounds.

Here are the results from the reaction:

	Mass in g
Mass of crucible at the start of the reaction	0.23
Mass of crucible at end of reaction	0.41

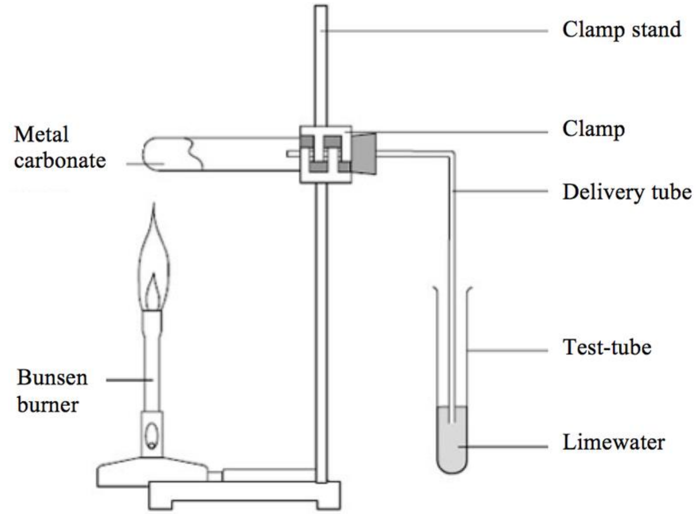
Some reactions may appear to involve a **change in mass** but this can be explained because a **reactant** or **product** is usually a **gas** and its mass has not been taken into account. In this example, the mass of the **magnesium oxide** produced is **greater** than the mass of the original **metal**.

Chemical measurements - PART 1

When calcium carbonate thermally decomposes it forms calcium oxide and carbon dioxide:

$$CaCO_3 \rightarrow CaO + CO_2$$

This equation shows that **one** calcium carbonate compound (made from one calcium, one carbon and three oxygen atoms) forms **one** calcium oxide compound and **one** carbon dioxide molecule.



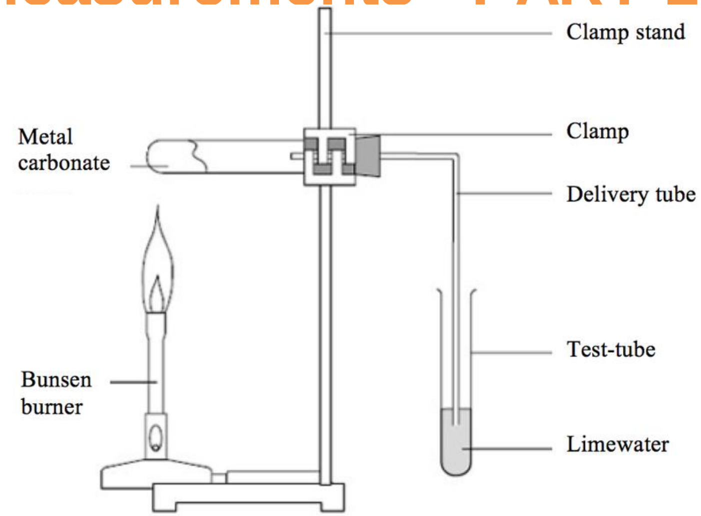
Here are the results from the reaction:

	Mass in g
Mass of metal carbonate at the start of the reaction	0.54
Mass of metal carbonate at end of reaction	0.36

In **thermal decomposition** of metal carbonates, **carbon dioxide** is produced and **escapes** into the **atmosphere** leaving the metal oxide as the only **solid** product.
In this example, the mass of the **calcium oxide** produced is **less** than the mass of the **metal carbonate** formed.

Whenever a measurement is taken, there is always some **uncertainty** about the **result** obtained that may have come from a variety of sources within the investigation. It is useful to determine whether the **mean** value falls within the **range** of uncertainty of the result.

Chemical measurements - PART 1



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This equation shows that **one** calcium carbonate compound (made from one calcium, one carbon and three oxygen atoms) forms **one** calcium oxide compound and **one** carbon dioxide molecule.

Here are the results from the reaction:

	Mass in g
Mass of metal carbonate at the start of the reaction	0.54
Mass of metal carbonate at end of reaction	0.36

In **thermal decomposition** of metal carbonates, **carbon dioxide** is produced and **escapes** into the **atmosphere** leaving the metal oxide as the only **solid** product.

In this example, the mass of the **calcium oxide** produced is **less** than the mass of the **metal carbonate** formed.

Whenever a measurement is taken, there is always some **uncertainty** about the **result** obtained that may have come from a variety of sources within the investigation. It is useful to determine whether the **mean** value falls within the **range** of uncertainty of the result.

QuestionIT!

Chemical Measurements
PART 1

- Balanced chemical equations
- Conservation of mass

1. What is the law of conservation of mass?

2. Why might some reactions appear to show a change in mass?

3. Give two examples of a reaction where a change in mass may appear to take place.

4. Balance the following equations:
   a) $H_2 + O_2 \rightarrow H_2O$
   b) $Ca + HCl \rightarrow CaCl_2 + H_2$
   c) $Li + H_2O \rightarrow LiOH + H_2$
   d) $NH_3 + O_2 \rightarrow NO + H_2O$
   e) $K + O_2 \rightarrow K_2O$

5. How many atoms and elements are in the compound sodium aluminate, $NaAl(OH)_4$?

6. What do the following formulae tell you?
   a) $2HCl$
   b) Cl_2

7. An aqueous solution of hydrogen peroxide (H_2O_2) decomposes to form water and oxygen.
   a) Write a balanced symbol equation for this reaction. Include the state symbols.
   b) Why does the water, produced during the reaction, have a lower mass than the original hydrogen peroxide?

AnswerIT!

Chemical Measurements PART 1

- Balanced chemical equations
- Conservation of mass

1. What is the law of conservation of mass?
   Mass of reactants = mass products.
2. Why might some reactions appear to show a change in mass?
   A reactant or a product is a gas.
3. Give two examples of a reaction where a change in mass may appear to take place.
   Metal reacting with oxygen or an acid. Thermal decomposition.
4. Balance the following equations:
   a) $2H_2 + O_2 \rightarrow 2H_2O$
   b) $Ca + 2HCl \rightarrow CaCl_2 + H_2$
   c) $2Li + 2H_2O \rightarrow 2LiOH + H_2$
   d) $4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$
   e) $4K + O_2 \rightarrow 2K_2O$

1. How many atoms and elements are in the compound sodium aluminate, $NaAl(OH)_4$?

   Four elements and ten atoms.

2. What do the following formulae tell you?

   a) 2HCl

   Two molecules of hydrogen chloride. Each molecule contains one hydrogen atom and one chlorine atom

   b) Cl_2

   One molecule of chlorine made of two atoms.

3. An aqueous solution of hydrogen peroxide (H_2O_2) decomposes to form water and oxygen.

   a) Write a balanced symbol equation for this reaction. Include the state symbols.

   $2H_2O_2 (aq) \rightarrow 2H_2O (l) + O_2(g)$

b) Why does the water, produced during the reaction, have a lower mass than the original hydrogen peroxide?

Because the oxygen gas produced during the reaction escaped into the atmosphere.

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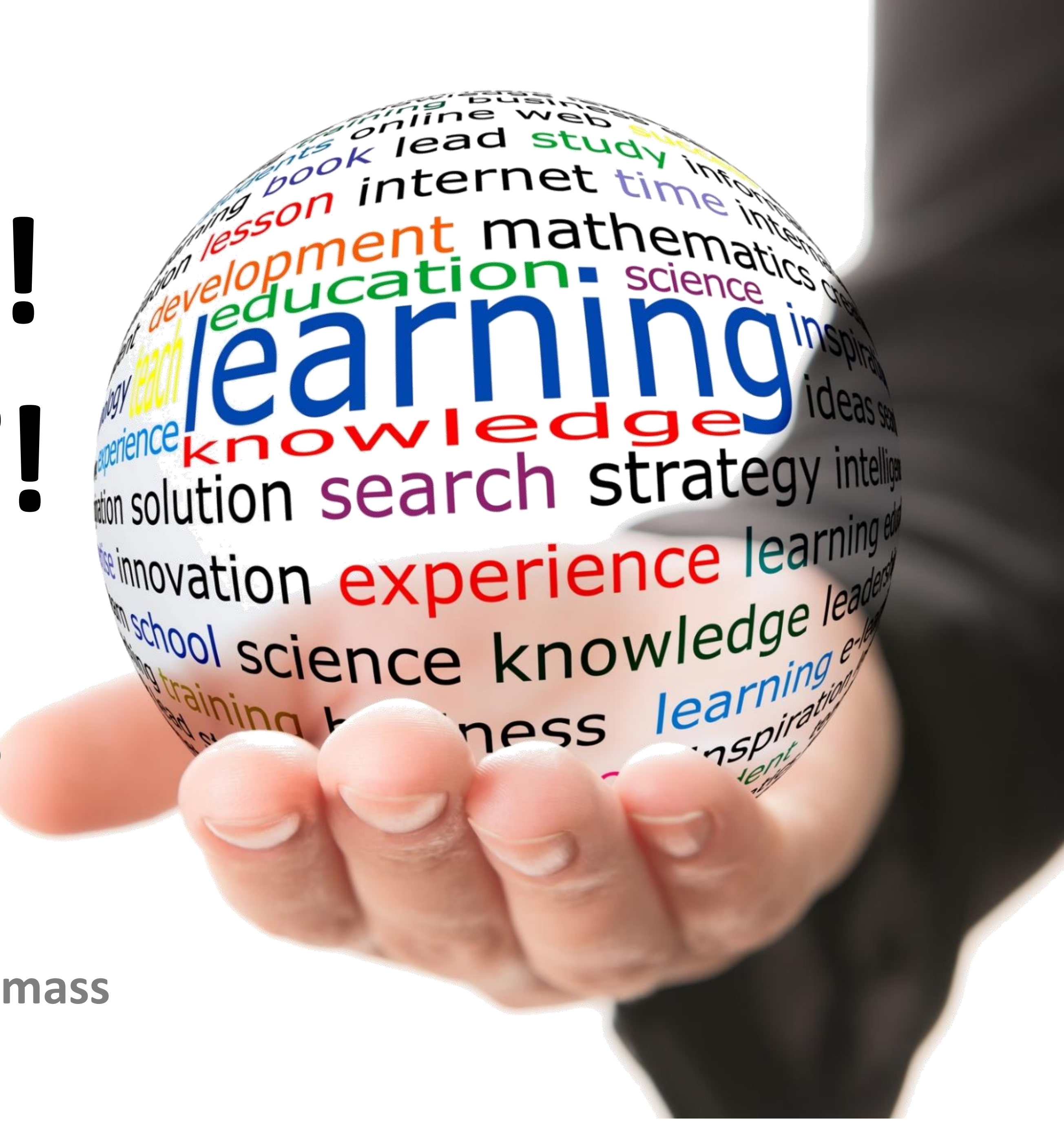
Chemical Measurements PART 2

- Relative formula mass



Chemical measurements - PART 2

Relative formula mass (M_r) of a compound is the **sum** of the **relative atomic masses** of the atoms in the numbers shown in the **formula**.

<u>**The relative atomic masses can be found in the periodic table**</u>

NaCl

(1 x Na + 1 x Cl)

A_r: Na (23) Cl (35.5)

M_r = 23 + 35.5 = 58.5

H_2O

(2 x H + 1 x O)

A_r: H (1) O (16)

M_r = (1 x 2) + 16 = 18

H_2SO_4

(2 x H + 1 x S + 4 x O)

A_r: H (1) S (32) O (16)

M_r = (1x2) + 32 + (16x4) = 98

$Al_2(SO_4)_3$

(2 x Al + 3 x S + 12 x O)

A_r: Al (27) S (32) O (16)

M_r = (27x2) + (32x3) + (16x12) = 342

In a balanced chemical equation, the **sum** of the relative formula masses of the **reactants equals** the **sum** of the relative formula masses of the **products**.

For example:

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

$$(2x24) + (2x16) \rightarrow 2 \times (24+16)$$

$$80 \rightarrow 80$$

QuestionIT!

Chemical Measurements PART 2

- Relative formula mass

1. What is the relative formula mass of a compound?

2. What is the relative formula mass of:
   a) $MgCl_2$
   b) $C_6H_{12}O_6$

3. What can be said about the sum of the relative formula masses of the reactants and products of a reaction?

4. Why can you have relative atomic masses which are not whole numbers e.g. chlorine is 35.5?

AnswerIT!

Chemical Measurements PART 2

- Relative formula mass

1. What is the relative formula mass of a compound?
   Sum of the relative atomic masses of the atoms in the numbers shown in the formula.
2. What is the relative formula mass of:
   a) $MgCl_2$ **95**
   b) $C_6H_{12}O_6$ **180**
3. What can be said about the sum of the relative formula masses of the reactants and products of a reaction?
   In a balanced chemical equation – the sum of the relative formula masses of the reactants in the quantities shown = sum of the relative formula masses of the products in the quantities shown.

4. Why can you have relative atomic masses which are not whole numbers e.g. chlorine is 35.5?
   Isotopes.

LearnIT!
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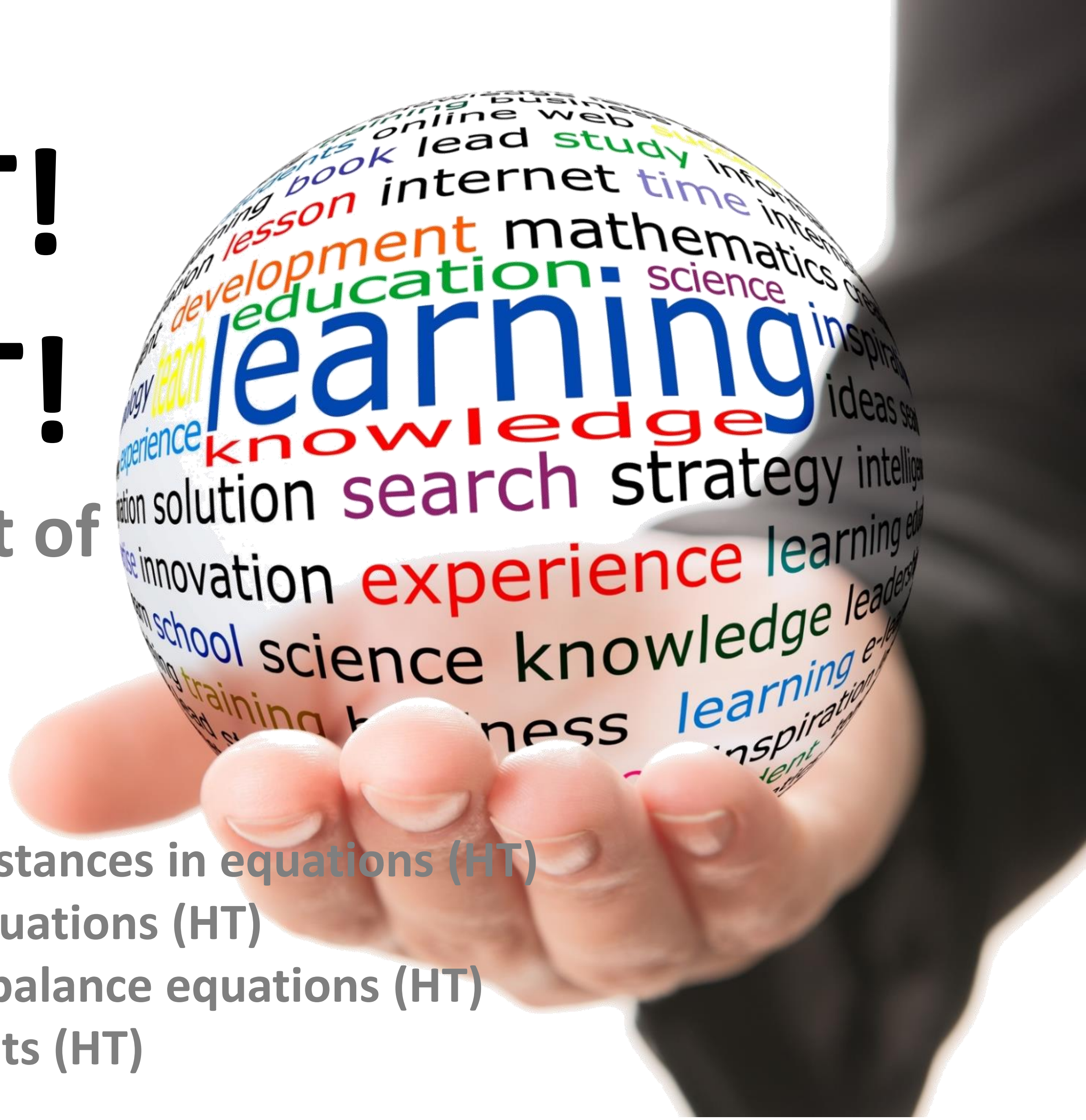
Use of amount of substance
PART 1

- Moles (HT)
- Amounts of substances in equations (HT)
- Quantities in equations (HT)
- Using moles to balance equations (HT)
- Limiting reactants (HT)



Use of amount of substance - PART 1

Chemical amounts are measured in **moles**. The symbol for the unit mole is **mol**.

The mass of **one mole** of a substance **in grams** is numerically **equal** to its **relative formula mass**. **One mole of a substance contains the same number of the stated particles, atoms, molecules or ions as one mole of any other substance**.

The **number** of atoms, molecules or ions in a mole of a given substance is the **Avogadro constant**. The value of the Avogadro constant is **6.02×10^{23} per mole**.

Number of moles = $\frac{\text{mass (g)}}{A_r}$ or $\frac{\text{mass (g)}}{M_r}$	Mass (g) = number of moles x A_r **or** number of moles x M_r
How many moles of sulfuric acid molecules are there in 4.7g of sulfuric acid (H_2SO_4)? Give your answer to 1 significant figure. **$\frac{4.7}{98}$ = 0.05 mol**	*What is the mass of 7.2×10^{-3} moles of aluminium sulfate ($Al_2(SO_4)_3$)? Give your answer to 1 decimal place.* **$7.2 \times 10^{-3} \times 342$ = 2.5g**

Use of amount of substance - PART 1

HIGHER TIER

The **masses** of **reactants** and **products** can be calculated from **balanced symbol equations**.

Chemical equations can be interpreted in terms of **moles**. Example:

$$H_2 + Cl_2 \rightarrow 2HCl$$

This equation shows that **one** mole of **hydrogen** reacts with **one** mole of **chlorine** to form **two** moles of **hydrochloric acid**.

The balanced equation is useful because it can be used to calculate what mass of hydrogen and chlorine react together and how much hydrogen chloride is made.

A_r: H (1)	**so mass of 1 mole of H_2**	**= 2 x 1 = 2g**
A_r: Cl (35.5)	**so mass of 1 mole of Cl_2**	**= 35.5 x2 = 71g**
M_r : HCl (1 + 35.5)	**so mass of 1 mole of HCl**	**= 36.5g**

The balanced equation tells us that one mole of hydrogen reacts with one mole of chlorine to give two moles of hydrogen chloride molecules, so turning this to masses:

1 mole of hydrogen	**= 1 x 2**	**= 2g**
1 mole of chlorine	**= 1 x 71**	**= 71g**
2 moles of hydrochloric acid	**= 2 x 36.5**	**= 73g**

Use of amount of substance - PART 1

HIGHER TIER

Sodium hydroxide reacts with chlorine to make bleach:

$$2NaOH + Cl_2 \rightarrow NaOCl + NaCl + H_2O$$

If you have a solution containing 100.0g of sodium hydroxide, what mass of chlorine gas do you need to convert it to bleach?

M_r : NaOH (23 + 16 + 1) **so mass of 1 mole of NaOH = 40g**
M_r : Cl_2 (35.5 x 2) **so mass of 1 mole of Cl_2 = 71g**

So 100.0g of sodium hydroxide is **100/40 = 2.5 moles**

The balanced symbol equation tells us that for every two moles of sodium hydroxide, you need one mole of chlorine to react with it.
So you need **2.5/2 = 1.25 moles** of chlorine
One mole of chlorine is 71g, so you will need **1.25 x 71g = 88.75g** of chlorine to react with 100.0g of sodium hydroxide.

The **balancing numbers** in a **symbol** equation can be calculated from the **masses** of **reactants** and **products** by **converting** the **masses in grams** to **amounts in moles** and converting the number of moles to **simple whole number ratios**.

8.5g of sodium nitrate ($NaNO_3$) is heated until its mass is constant.
6.9g of sodium nitrite ($NaNO_2$) and 1.6g of oxygen gas (O_2) is produced.

$$NaNO_3 \rightarrow NaNO_2 + O_2$$

M_r: $NaNO_3$ = 23 + 14 + (16x3) = 85
M_r: $NaNO_2$ = 23 + 14 + (16x2) = 69
M_r: O_2 = 16x2 = 32

Number of moles = $\dfrac{\text{mass (g)}}{M_r}$

Then to convert masses to moles use:

Moles of $NaNO_3$ = 8.5/85 = 0.1 mol
Moles of $NaNO_2$ = 6.9/69 = 0.1 mol
Moles of O_2 = 1.6/32 = 0.05 mol

$NaNO_3$	:	$NaNO_2$	:	O_2
0.01	:	0.01	:	0.05

Dividing the ratio by the smallest number gives 2:2:1 $2NaNO_3 \rightarrow 2NaNO_2 + O_2$

Use of amount of substance - PART 1
HIGHER TIER

In a chemical reaction involving **two** reactants, it is common to use an **excess** of one of the reactants to ensure that all the reactant is **used up**. The reactant that is completely used up is called the **limiting reactant** because it **limits** the **amount** of **products**.

4.8g of magnesium ribbon reacts with 7.3g of HCl.
Which is the limiting reactant?

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

A_r: Mg (24) and A_r: Cl (35.5)
4.8g of Mg = 4.8/24 moles = 0.2 mol
7.3g of HCl = 7.3/36.5 moles = 0.2 mol
From the balanced equation:
1 mole of Mg reacts with 2 moles of HCl,
therefore **0.2 mol of Mg will need 0.4 mol of HCl** to react completely, there is only 0.2 mol of HCl, so the HCl is the limiting reactant.

QuestionIT!

Use of amount of substance
PART 1

- Moles (HT)
- Amounts of substances in equations (HT)
- Quantities in equations (HT)
- Using moles to balance equations (HT)
- Limiting reactants (HT)

1. What is meant by the term ‘mole’?
2. What is the symbol for the unit mole?
3. What does ‘Avogadro’s constant’ tell us?
4. What is the value for Avogadro’s constant?
5. How many atoms in 1 mole of carbon?

6. How many atoms in 1 mole of chlorine gas, Cl_2?

7. What can the following equation tell us about the number of moles of each substance?

$$Mg + 2HCl \rightarrow MgCl_2 + H_2$$

8. What is meant by the term ‘limiting reactant’?

9. How many moles of helium atoms are there in 0.04g of helium?

10. What is the mass of 20 moles of calcium carbonate $CaCO_3$?
    Answer in kg.

11. Calcium carbonate decomposes to calcium oxide in a kiln in the following reaction: **$CaCO_3 \rightarrow CaO + CO_2$**
    Calculate the mass of calcium oxide that can be produced when 300 tonnes of calcium carbonate is heated.

12. 0.10g of hydrogen reacts with 3.55g of chlorine to produce 3.65g of hydrogen chloride. Use this information to work out the balancing numbers for hydrogen chloride.

$$H_2 + Cl_2 \rightarrow \_\_\_HCl$$

13. If 4.95 g of ethene (C_2H_4) are combusted with 3.25 g of oxygen, what is the limiting reactant?

$$C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$$

AnswerIT!

Use of amount of substance
PART 1

- Moles (HT)
- Amounts of substances in equations (HT)
- Quantities in equations (HT)
- Using moles to balance equations (HT)
- Limiting reactants (HT)

1. What is meant by the term ‘mole’?
   A measure of the chemical amount of a substance.
2. What is the symbol for the unit mole?
   mol
3. What does ‘Avogadro’s constant’ tell us?
   Number of atoms, molecules or ions in a mole of a substance.
4. What is the value for Avogadro’s constant?
   6.02×10^{23} per mol
5. How many atoms in 1 mole of carbon?
   6.02×10^{23}

6. How many atoms in 1 mole of chlorine gas, Cl_2?

   6.02×10^{23}

7. What can the following equation tell us about the number of moles of each substance?

$$Mg + 2HCl \rightarrow MgCl_2 + H_2$$

   1 mole of magnesium reacts with 2 moles of hydrochloric acid to form 1 mole of magnesium chloride and 1 mole of hydrogen.

8. What is meant by the term ‘limiting reactant’?

   A reactant in a reaction which is completely used up when the other reactant is in excess.

9. How many moles of helium atoms are there in 0.04g of helium?
   0.04/4 = 0.01mol

10. What is the mass of 20 moles of calcium carbonate $CaCO_3$?
    Answer in kg.
    40+12+(16x3) = 100
    100 x 20 = 2,000g = 2kg.

11. Calcium carbonate decomposes to calcium oxide in a kiln in the following reaction: $\mathbf{CaCO_3 \rightarrow CaO + CO_2}$
    Calculate the mass of calcium oxide that can be produced when 300 tonnes of calcium carbonate is heated.
    Relative formula mass of calcium carbonate = 100 = 100g
    Relative formula mass of calcium oxide = 56 = 56g
    100 tonnes of calcium carbonate makes 56 tonnes of calcium oxide
    so 300 tonnes make 168 tonnes

12. 0.10g of hydrogen reacts with 3.55g of chlorine to produce 3.65g of hydrogen chloride. Use this information to work out the balancing numbers for hydrogen chloride.

$$H_2 + Cl_2 \rightarrow \_\_\_HCl$$

M_r: H_2 = 1 x 2 = 2
M_r: Cl_2 = 35.5 x 2 = 71
M_r: HCl = 1 + 35.5 = 36.5

Then to convert masses to moles use:
Moles of H_2 = 0.10/2 = 0.05 mol
Moles of Cl_2 = 3.55/71 = 0.05 mol
Moles of HCl = 3.65/36.5 = 0.1 mol
Dividing the ratio by the smallest number gives 1:1:2
$H_2 + Cl_2 \rightarrow 2HCl$

13. If 4.95 g of ethene (C_2H_4) are combusted with 3.25 g of oxygen, what is the limiting reactant?

$$C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$$

M_r: C_2H_4 = 28
M_r: O_2 = 32

4.95/28 = 0.177 mol
3.25/32 = 0.102 mol

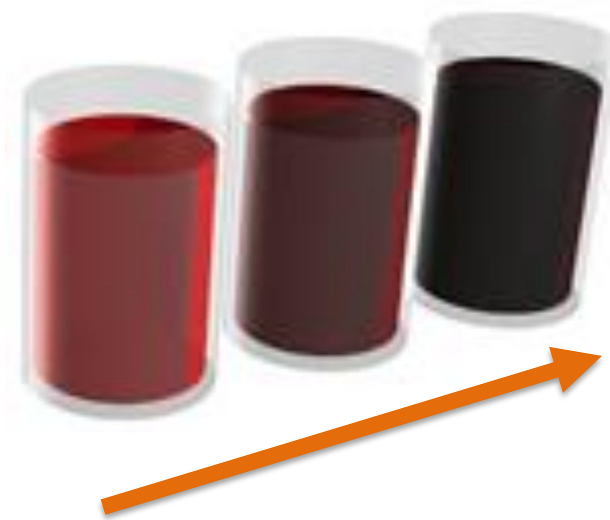
From the equation: 1 mole of ethene reacts with 3 moles of oxygen. In this case 0.177 mol of ethene will need 0.53 mol of oxygen to react, which we do not have, so oxygen is the limiting factor.

LearnIT!
KnowIT!

Use of amount of substance
PART 2

- Concentration of solutions

Calculations - PART 2



Chemists quote the amount of substance (solute) dissolved in a certain volume of the solution. The units used to express the concentration can be grams per decimetre cubed **(g/dm^3)**. **A decimetre ($1dm^3$) cubed is equal to $1000cm^3$.**

The blackcurrant juice is getting more concentrated – the darker colour indicates more squash is in the same volume of its solution

If you know the mass of the solute dissolved in a certain volume of solution, you can work out the concentration using:

$$\textbf{Concentration } (g/dm^3) = \frac{\textbf{amount of solute (g)}}{\textbf{Volume of solution } (dm^3)}$$

Remember if you are using cm^3 to multiply the volume by 1000 to covert to dm^3

Example 1:

50g of sodium hydroxide is dissolved in water to make up $200cm^3$.

What is the concentration in dm^3?

$50g/200cm^3 = 0.25g/cm^3$
$0.25g/cm^3 \times 1000 = 250g/dm^3$

Calculations - PART 2

Example 2:

A solution of sodium chloride has a concentration of $200 g/dm^3$.

What is the mass of sodium chloride in $700 cm^3$ of solution?

Convert $700 cm^3$ into dm^3

$700/1000 = 0.7\ dm^3$

Then rearrange the equation

amount of solute = concentration x volume of solution

(g) (g/dm^3) (dm^3)

$200 g/dm^3 \times 0.7\ dm^3 = 140 g$

HIGHER:

You can increase the concentration of an aqueous solution by:

- Adding more solute and dissolving it in the same volume of its solution.
- Evaporating off some of the water from the solution so you have the same mass of solute in a smaller volume of solution.

QuestionIT!

Use of amount of substance
PART 2

- Concentration of solutions

1. What units can be used for the concentration of a solution?

2. What does dm^3 mean?

3. Give the equation for calculating concentration from the mass of substance and volume of solution.

4. HT Only: How can you increase the concentration of an aqueous solution?

5. Calculate the concentration in g/dm^3 for 50g of sodium chloride in 2.5 dm^3 of water.

6. Calculate the concentration in g/dm^3 of 1.4g of potassium carbonate in $855cm^3$ of water.

7. A teacher has a solution of lithium fluoride with a concentration of $72.6g/dm^3$. Calculate the mass of lithium fluoride dissolved in $25.0cm^3$ of solution.

AnswerIT!

Use of amount of substance
PART 2

- Concentration of solutions

1. What units can be used for the concentration of a solution?
   g/dm^3
2. What does dm^3 mean?
   $1000cm^3$
3. Give the equation for calculating concentration from the mass of substance and volume of solution.
   Concentration = mass ÷ volume
4. HT Only: How can you increase the concentration of an aqueous solution?
   Add more solute and dissolve in the same volume of water; evaporate off some of the water/decrease the volume of water

5. Calculate the concentration in g/dm^3 for 50g of sodium chloride in $2.5dm^3$ of water.
   $50/2.5 = 20g/dm^3$

6. Calculate the concentration in g/dm^3 of 1.4g of potassium carbonate in $855cm^3$ of water.
   $(1.4/855) \times 1000 = 1.64\ g/dm^3$

7. A teacher has a solution of lithium fluoride with a concentration of $72.6g/dm^3$. Calculate the mass of lithium fluoride dissolved in $25.0cm^3$ of solution.
   $25cm^3 = 0.025dm^3$
   $72.6 \times 0.025 = 1.8g$

LearnIT! KnowIT!

Yield and atom economy *CHEMISTRY ONLY*

- Percentage yield
- Atomy economy

Yield and atom economy - CHEMISTRY ONLY

Even though **no atoms** are **gained** or **lost** in a chemical reaction, it is not always possible to obtain the calculated **amount** of **product** because:

- The **reaction may not go to completion** because it is **reversible**
- Some of the **product may be lost** when it is separated from the reaction mixture
- Some of the **reactants may react in ways different to the expected** reactions

The amount of **product** obtained is known as the **yield**.

The **theoretical yield** is the **maximum** calculated amount of a **product** that could be formed from a **given amount** of **reactants**.

The **actual yield** is the **actual** amount of **product** obtained from a **chemical** reaction.

Yield and atom economy - CHEMISTRY ONLY

When **compared** with the **maximum theoretical** amount as a **percentage**, it is called the **percentage yield** and is calculated as:

$$\text{Percentage yield} = \frac{\text{mass of product actually made}}{\text{maximum theoretical mass of product}} \times 100$$

A piece of sodium metal is heated in chlorine gas. A maximum theoretical mass of 10g for sodium chloride was calculated, but the actual yield was only 8g.

Calculate the percentage yield.

Percentage yield = 8/10 x 100

= 80%

This means the percentage yield is 80%

HIGHER:

200g of calcium carbonate is heated. It decomposes to make calcium oxide and carbon dioxide. *Calculate the theoretical mass of calcium oxide made.*

$$CaCO_3 \rightarrow CaO + CO_2$$

M_r of $CaCO_3$ = 40 + 12 + (16x3) = 100

M_r of CaO = 40 + 16 = 56

100g of $CaCO_3$ would make 56 g of CaO

So 200g would make 112g

Yield and atom economy - CHEMISTRY ONLY

The **atom economy (atom utilisation)** is a measure of the **amount** of **starting materials** that end up as **useful products**. It is important for **sustainable development** and for **economic reasons** to use reactions with **high atom economy**. The percentage atom economy is calculated using a **balanced equation** for the reaction as follows:

Example: $$\frac{\text{Relative formula mass of desired product from equation}}{\text{Sum of relative formula mass of all reactants from equation}} \times 100$$

Calculate the atom economy for making hydrogen by reacting zinc with hydrochloric acid:

$Zn + 2HCl \rightarrow ZnCl_2 + H_2$

M_r of H_2 = 1 + 1 = 2

M_r of $ZnCl_2$ = 65 + 35.5 + 35.5 = 136

Atom economy = $\frac{2}{136 + 2} \times 100$

$= \frac{2}{138} \times 100 = 1.45\%$

This method is unlikely to be chosen as it has a low atom economy.

The less waste there is, the higher the atom economy, the less materials are wasted, less energy used, so making the process more economic, 'greener' and sustainable.

QuestionIT!

Yield and atom economy PART 1 *CHEMISTRY ONLY*

- Percentage yield
- Atomy economy

Yield and atom economy (Chemistry only) – QuestionIT

1. What is meant by the term ‘yield’?

2. What is the equation for calculating percentage yield?

3. Give 2 reasons why it is not always possible to obtain the expected amount of product from a reaction.

4. What is meant by the term ‘atom economy’?

5. Why is it important to use reactions with high atom economy?

6. What is the equation for calculating the percentage atom economy from a balanced chemical equation?

7. Magnesium is heated in air to make magnesium oxide. Suggest why the actual yield might be less than the maximum theoretical yield.

8. In the neutralisation of sulfuric acid with sodium hydroxide, the theoretical yield from 13.8g of sulfuric acid is 20g. In a synthesis, the actual yield is 17.4g. What is the percentage yield for this synthesis?

9. Calculate the atom economy for making hydrogen from methane and steam.

$$CH_4 + 2H_2O \rightarrow CO_2 + 4H_2$$

AnswerIT!

Yield and
atom economy
PART 1
CHEMISTRY ONLY

- Percentage yield
- Atomy economy

Yield and atom economy (Chemistry only) – QuestionIT

1. What is meant by the term ‘yield’?

   Amount of product obtained.

2. What is the equation for calculating percentage yield?

   $$\% \text{ yield} = \frac{\text{mass of product actually made}}{\text{Maximum theoretical mass of product}} \times 100$$

3. Give 2 reasons why it is not always possible to obtain the expected amount of product from a reaction.

   Reaction may not go to completion as it is reversible; some product may be lost; some reactants may react differently to expected.

4. What is meant by the term ‘atom economy’?

   Measure of the amount of starting materials that end up as useful products.

5. Why is it important to use reactions with high atom economy?
   Sustainable development; less waste products produced; economically viable; cheaper.

6. What is the equation for calculating the percentage atom economy from a balanced chemical equation?
   Atom economy = $\dfrac{\textbf{RFM of desired product}}{\textbf{Sum of RFM of all reactants}} \times 100$

7. Magnesium is heated in air to make magnesium oxide. Suggest why the actual yield might be less than the maximum theoretical mass.

   Magnesium nitride is formed as well as the magnesium oxide expected/some of the oxide might escape as smoke/not all the magnesium reacts.

8. In the neutralisation of sulfuric acid with sodium hydroxide, the theoretical mass from 13.8g of sodium sulfate is 20g. In a synthesis, the actual yield is 17.4g. What is the percentage yield for this synthesis?

   Percentage yield = (actual yield ÷ theoretical mass) × 100

   Percentage yield = (17.4 ÷ 20) x 100 = 87%

9. Calculate the atom economy for making hydrogen from methane and steam.

$$CH_4 + 2H_2O \rightarrow CO_2 + 4H_2$$

M_r of H_2O = (1 x 2) + 16 = 18

18 x 2 = 36

M_r of CH_4 = 12 + (1 x 4) = 16

Atom economy = $^{4 \times 2}/_{36 + 16} \times 100$

= $^{8}/_{52} \times 100$ = 15.4%

LearnIT!
KnowIT!

Quantities
CHEMISTRY ONLY

- Moles of solution and gases (HT)

The **concentration** of a **solution** is the amount of **solute per volume of solution**.

Chemists measure concentration in moles per cubic decimetre **(mol/dm^3)**.

$$\textbf{Concentration (mol/dm}^3\textbf{)} = \frac{\textbf{amount (mol)}}{\textbf{volume (dm}^3\textbf{)}}$$

Example 1:

What is the concentration of a solution that has 35.0g of solute in 0.5dm^3 of solution?

35/0.5 = 70 g/dm^3

Example 2:

Calculate the mass of magnesium chloride ($MgCl_2$) if there is 1 dm^3 of a 1mol/ dm^3 solution.

Mass of 1 mole of magnesium chloride = 24 + (35.5 × 2) = 95 g

So there are 95 g of magnesium chloride in 1 dm^3 of a 1 mol/dm^3 solution.

Quantities - CHEMISTRY ONLY
Higher

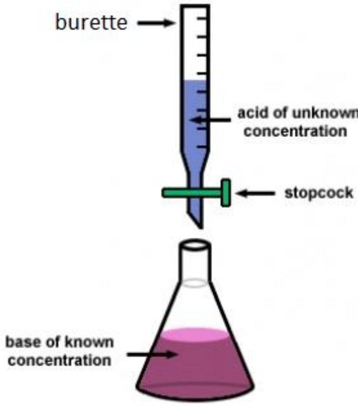
If the volumes of two solutions that react completely are known and the concentrations of one solution is known, the concentration of the other solution can be calculated.

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

It takes $12.20cm^3$ of sulfuric acid to neutralise $24.00cm^3$ of sodium hydroxide solution, which has a concentration of $0.50mol/dm^3$.

Calculate the concentration of the sulfuric acid in g/dm^3

$0.5\ mol/dm^3 \times (24/1000)\ dm^3 = 0.012$ mol of NaOH



The equation shows that 2 mol of NaOH reacts with 1 mol of H_2SO_4, so the number of moles in $12.20cm^3$ of sulfuric acid is **$(0.012/2) = 0.006$ mol of sulfuric acid**

Calculate the concentration of sulfuric acid in mol/dm^3

$0.006\ mol \times (1000/12.2)\ dm^3 = 0.49mol/dm^3$

Calculate the concentration of sulfuric acid in g/dm^3

$H_2SO_4 = (2x1) + 32 + (4x16) = 98g$

$0.49 \times 98g = 48.2g/dm^3$

Equal amounts of moles or gases occupy the same volume under the same conditions of temperature and pressure. The **volume** of **one mole** of any **gas** at **room temperature and pressure (rtp)** (**20°C and 1 atmospheric pressure**) is **24 dm^3**.

You can calculate the **volume** of a gas at room temperature and pressure from its **mass** and **relative formula mass** using the equation:

$$\textbf{Number of moles} = \frac{\textbf{mass}}{\textbf{relative formula mass}}$$

Volume of gas at rtp = moles x 24

You can calculate the **volumes** of gaseous **reactants** and **products** from a **balanced equation** and a given **volume** of a gaseous **reactant or product** using the following equation:

$$\textbf{Volume of gas at rtp} = \frac{\textbf{number of moles} \times \textbf{molar mass}}{\textbf{volume (24 } dm^3\textbf{)}}$$

Quantities - CHEMISTRY ONLY Higher

What is the volume of 3.5g of hydrogen?

A_r : H (1)

M_r : H_2 = 2

1 mole in g = 2g

3.5/2 = 1.75 mol

volume H_2 = 1.75 x 24 = 42 dm^3

6g of a hydrocarbon gas had a volume of 4.8 dm^3. Calculate its molecular mass.

1 mole = 24 dm^3, so 4.8/24 = 0.2 mol

M_r = 6 / 0.2 = 30

if 6g = 0.2 mol, 1 mol equals 30 g

What is the volume of 11.6 g of butane (C_4H_{10}) gas at RTP?

M_r : (4 x 12) + (10 x 1) = 58

11.6/58 = 0.20 mol

volume = 0.20 x 24 = 4.8 dm^3

What mass of magnesium carbonate is needed to make 6 dm^3 of carbon dioxide?

$$MgCO_{3(s)} + H_2SO_{4(aq)} \rightarrow MgSO_{4(aq)} + H_2O_{(l)} + CO_{2(g)}$$

1 mole = 24 dm^3, 6 dm^3 is equal to 6/24 = 0.25 mol of gas

From the equation, 1 mole of $MgCO_3$ produces 1 mole of CO_2, which occupies a volume of 24 dm^3.

so 0.25 moles of $MgCO_3$ is needed to make 0.25 mol of CO_2

M_r : $MgCO_3$ = 24 + 12 + (3 x 16) = 84,

Mass of $MgCO_3$ = 0.25 x 84 = 21g

QuestionIT!

Quantities
CHEMISTRY ONLY

- **Moles of solution and gases (HT)**

1. What are the units for concentration?

2. What is the equation for the calculation of concentration from the moles and volume of solution?

3. What can be said about equal amounts of moles of gases and the volume they occupy?

4. What is meant by RTP?

5. What are the values for RTP?

6. What is the concentration, in g/ dm^3, of a solution that has 40g of solute in $2dm^3$ of solution?

7. Calculate the concentration in mol/dm^3 of a solution that has 0.75 mol of an acid in $3dm^3$ of solution.

8. It takes 28.0cm^3 of potassium hydroxide to neutralise 25.00cm^3 of nitric acid at a concentration of 0.50 mol/dm^3.

$$HNO_3 + KOH \rightarrow KNO_3 + H_2O$$

9. Calculate the concentration of the potassium hydroxide. What is the volume of 4.5g of oxygen?

10. Calculate the number of moles of hydrogen that occupy 6dm^3 at RTP.

AnswerIT!

Quantities
CHEMISTRY ONLY

- **Moles of solution and gases (HT)**

1. What are the units for concentration?
   mol/dm^3 (g/dm^3)
2. What is the equation for the calculation of concentration from the moles and volume of solution?
   Concentration = $\frac{\textbf{Moles}}{\textbf{Volume}}$
3. What can be said about equal amounts of moles of gases and the volume they occupy?
   Equal amounts of moles of gases occupy the same volume under the same conditions of temperature and pressure.

4. What is meant by RTP?

   Room temperature and pressure

5. What are the values for RTP?

   20^{o}C ; 1 atmosphere pressure

6. What is the concentration, in g/ dm^3, of a solution that has 40g of solute in $2dm^3$ of solution?
   Concentration = mass ÷ volume = 40 g ÷ 2 dm^3 = 20 g/dm^3

7. Calculate the concentration in mol/dm^3 of a solution that has 0.75 mol of an acid in $3dm^3$ of solution
   0.75 mol/3 dm^3 = 0.25 mol/dm^3

8. It takes 28.0cm^3 of potassium hydroxide to neutralise 25.00cm^3 of nitric acid at a concentration of 0.50 mol/dm^3.

$$\mathbf{HNO_3 + KOH \rightarrow KNO_3 + H_2O}$$

Calculate the concentration of the potassium hydroxide.

Number of moles of nitric acid = concentration × volume
= 0.5 mol/dm^3 × (25 ÷ 1000) dm^3 = 0.0125 mol
The equation for the reaction shows that 1 mole of potassium hydroxide reacts with 1 mole of nitric acid. So there is 0.0125 mol of KOH in 28 cm^3 of solution.
So the concentration of KOH in mol/dm^3 = number of moles ÷ volume = 0.0125 mol ÷ (28 ÷ 1000) dm^3 = 0.45 mol/dm^3

9. What is the volume of 4.5g of oxygen?

A_r : O (16)
M_r : O_2 = 32
1 mole in g = 32g
4.5/32 = 0.14 mol
Volume O_2 = 0.14 x 24 = 3.38 dm^3

10. Calculate the number of moles of hydrogen that occupy $6dm^3$ at RTP.

Number of moles = 6 ÷ 24 = 0.25 mol