**2.1 Chemical change**

Whenever new chemical substances are formed a chemical change has taken place.

If your eyes were strong enough to actually see what happens during a chemical change you would see that bonds in the reactants are broken and new bonds form to create the new products.

**Reactants**: these are the particles (elements and compounds) present at the start of the reaction. So they are the starting materials of a chemical reaction.

**Products**: these are the particles (elements and compounds) produced as a result of the chemical reaction.

Some examples of chemical changes that you are already aware of are as follows:

* The rusting of iron
* The burning of fuels
* Digestion of food
* Cooking food
* Rotting materials

In order to work with chemical reactions you need a way to write them. This requires an understanding of several things:

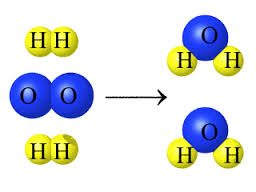
* An understanding of the Law of Constant Composition.
* An understanding of the Law of Conservation of Matter.
* The chemical formulae of all the reactants and all the products.
* The physical state in which the reactants and products exist.
* The amounts and ratios of reactants required for a complete reaction to take place and the amounts and ratios of the products formed.

**Law of Constant Composition**

The law: All samples of a particular chemical compound have the same elemental **composition** by mass regardless of how the compound was made or where it is found.

For example, water is always made from 2 atoms of hydrogen (H) bound to 1 atom of oxygen (O) and the mass ratio of H to O is always 11%:89%.

This is always true for water. If the proportions change the substance has changed and is no longer water.



Similar diagram for H2O2

H2O H2O2

+ +

H2O → H2O2

+

O2

It is possible for H and O to combine in a different ratio, namely H2O2. This is no longer water, but a different compound called hydrogen peroxide.

Why is this useful?

If you can measure the mass of each element present in a compound, you can determine the chemical formula of that compound.

Activity: Answer the following questions

1. In carbon dioxide (CO2) the ratio of mass of C:O is always 3:8. If 6.0 g of carbon is completely converted into carbon dioxide, how much oxygen (in grams) is required?
2. The mass ratio of H:O in water is 1:8. In a sample of water that has a mass of 36 g what is the mass of H and O?

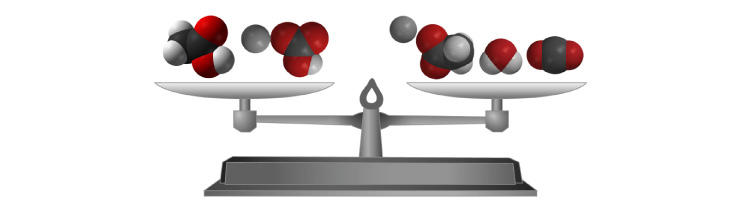
Answers:

1. 16 g
2. H is 1/9 of the total mass: 1/9 x 36 g = 4 g and O is 8/9 of the total mass: 8/9 x 36 = 32 g.

**Law of Conservation of Matter**

The law: Mass in a closed system is neither created nor destroyed by chemical reactions or physical changes. Therefore, according to the law of conservation of mass, the **mass of the products** in a chemical reaction must **equal** the **mass of the** **reactants**.

A simpler way of saying this is that mass is never lost or gained during a chemical reaction, it simply changes its form (form reactants to products).



Note: These measurements have to be made in a closed system to make sure that no reactants or products escape from the reaction vessel. If that happened the masses would appear to be different.

Why is this useful?

It means that if you can measure the masses of the reactants before a reaction starts and the mass of one of the products, you can calculate the mass of the other product without having to measure it.

It also means that you can measure the information you need to write down chemical equations that describe exactly what the reactants and products in a reaction are, what the mass ratios are.

Activity: Answer the following questions

1. In a chemical reaction, 300 grams of reactant A are combined with 100 grams of reactant B. Both A and B react to completion so no A or B is left over. How much will the total product weigh?
2. In a reaction, 25 grams of reactant AB breaks down completely into 10 grams of product A and an unknown amount of product B. How much does product B weigh?
3. Consider the following reaction:  
    CaCl2 + Na2CO3 → NaCl + CaCO3  
   If 2.12 g of CaCl2 reacts completely with 2.20 g of Na2CO3 and 2.90 g of calcium carbonate is formed, what amount of NaCl is produced?
4. In an experiment you react 40.0 g of calcium with 16.0 g of oxygen. At the end of the reaction you have calcium oxide. What would the mass of the product be?
5. If 24.0 g of magnesium reacts with oxygen to form 40.0 g of magnesium oxide, how much oxygen was used up in the reaction?

Answers:

1. 400 g
2. 15 g
3. 1.42 g
4. 56.0 g
5. 16.0 g

**State symbols**

State symbols allow you to show the physical state in whcich the recatants and products are present during a chemical reaction.

The state symbols are as follows:

* g for gas
* s for solid
* l for liquid
* aq for aqueous solution ( a solution in water)

State symbols are shown in brackets after the chemical formula. For example water, a liquid, is shown as H2O(l), copper, a solid is shown as Cu(s), nitrogen, a gas, is shown as N2(g) and a solution of sodium chloride in water is shown as NaCl(aq)

**Representing chemical reactions**

Chemical reactions are represented by chemical equations.

* Chemical equations can be **word equations**. For example:

Carbon reacts with oxygen to form carbon dioxide

* In chemistry, **symbol equations** are usually preferred as they contain more useful information. In a symbol equation the word equation given above becomes:  
    
   C(s) + O2(g) → CO2(g)  
    
  As you can see there is now information about the atoms making up the reactants and the products, the ratios in which they combine and the state in which each component is when the reaction takes place. You will also learn more about the importance of equations of this type as you go along.

**Balancing chemical equations**

The total number of atoms of each element present in the reactants must always be equal to the total number of the same elements in the products, regardless of how they are arranged into compounds. This is to obey the Law of Conservation of Mass. No atoms can disappear during the reaction, nor can additional atoms be produced.

Consider the chemical equation for the reaction that forms water.

To form water you know that you need hydrogen gas and oxygen gas to react together to form the water. You also know the formula of these molecules: H2(g), O2(g) and H2O(l).

The chemical equation for the formation of water is therefore:

H2(g) + O2(g) …… H2O(l)

But wait a minute, does this obey the Law of Conservation of Mass?

On the left hand side there are 2 H atoms and 2 O atoms.

On the right hand side there are 2H atoms but only 1 O atom, so something appears to have been lost during the reaction. This cannot be according to the law.

So the equation is *not balanced* and you have to do something about that.

A water molecule has two H atoms for every O atom, so the ratio is 2:1 for H:O. Therefore, on the left hand side the ration also has to be 2:1.

Now the chemical equation looks like this:

2H2(g) + O2(g) …… H2O(l)

Let’s check if this now works:

On the left: 4 H atoms and 2 O atoms

On the right: 2H atoms and 1 O atom.

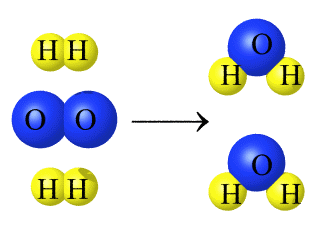
Still wrong.

To balance the equation correctly the number of atoms of both H and O on the right must be doubled.

Now the chemical equation looks like this:

2H2(g) + O2(g) …… 2H2O(l)

Diagramatically this reaction can be represented as follows:



Let’s check if this now works:

On the left: 4 H atoms and 2 O atoms

On the right: 4H atoms and 2 O atoms.

We have a balanced equation for the reaction!

In order to balance equations in this way remember that only the numbers in front of the formula can be changed. These are called *stoichiometric coefficients.*

*NB: If you change the numbers after the element symbols (the subscripts) you will be changing the nature of the substance and this is not allowed.*

Activity: Write *word equations* and *balance* the following equations:

(Remember that ions such as NO3-, OH-, HCO3- and CO3- move as complete units).

1. C2H6(g)  +  O2(g)  →  CO2(g)  +  H2O(g)
2. AgNO3(aq)  +  NaCl(aq)  →  AgCl(s)  +  NaNO3(aq)
3. Na(s) + H2O(l) → NaOH(aq) + H2(g)
4. NH3(g) → N2(g) + H2(g)
5. NaHCO3(s) → Na2CO3(s) + CO2(g) + H2O(g)

Answers:

1. Ethane gas reacts with oxygen to form carbon dioxide gas and water vapour.  
   For balancing:
   1. C2H6(g)  +  O2(g)  →  CO2(g)  +  H2O(g)  
      LHS: 2C, 6H, 2O RHS: 1C, 2H, 3O
   2. C2H6(g)  +  O2(g)  →  2CO2(g)  +  H2O(g)   
      LHS: 2C, 6H, 2O RHS: 2C, 2H, 5O
   3. C2H6(g)  +  5O2(g)  →  2CO2(g)  +  H2O(g)  
      LHS: 2C, 6H, 10O RHS: 2C, 6H, 5O
2. Silver nitrate reacts with aqueous sodium chloride to form solid silver chloride and aqueous sodium nitrate  
   For balancing:
   1. AgNO3(aq)  +  NaCl(aq)  →  AgCl(s)  +  NaNO3(aq)  
      LHS: 1Ag, 1NO3-, 1Na, 1Cl RHS: 1Ag, 1NO3-, 1Na, 1Cl

The equation is balanced.

1. Solid sodium reacts with water to form aqueous sodium hydroxide and hydrogen gas.

For balancing:

1. Na(s) + H2O(l) → NaOH(aq) + H2(g)  
   LHS: 1Na, 2H, 1O RHS: 1Na, 1OH, 2H
2. Na(s) + 3H2O(l) → NaOH(aq) + 3H2(g)  
   LHS: 1Na, 6H, 3O RHS: 1Na, 6H, 1O
3. Na(s) + 3H2O(l) → 3NaOH(aq) + 3H2(g)  
   LHS: 1Na, 6H, 3O RHS: 3Na, 6H, 1O