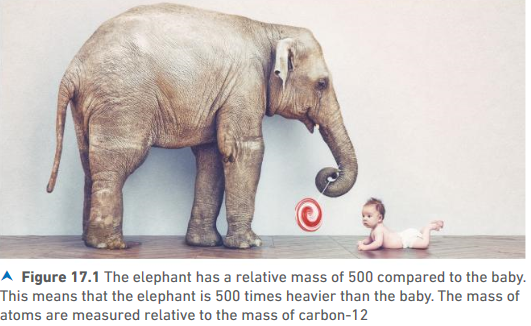
**Chemistry Unit C1: Structures, Trends, Chemical Reactions, Quantitative Chemistry and Analysis**

**C1.7 Quantitative chemistry**

|  |  |  |  |
| --- | --- | --- | --- |
| **Content - CCEA Double Award Chemistry 1 – Fort Hill Integrated College** | Got it | Nearly | Haven’t a clue |
| **C1.7 Quantitative chemistry** | | | |
| **Formula mass** |  |  |  |
| Can you recall that the relative atomic mass (Ar) of an atom is the mass of the atom compared with that of the carbon-12 isotope, which has a mass of exactly 12, and demonstrate knowledge and understanding that Ar is a weighted mean of the mass numbers; |  |  |  |
| Can you calculate the relative formula mass (Mr) (relative molecular mass) of a compound and the percentage of an element, by mass, in a compound; |  |  |  |
| **The mole** |  |  |  |
| Can you demonstrate knowledge and understanding that chemical amounts are measured in moles and that the mass of one mole of a substance in grams is numerically equal to the relative formula mass; |  |  |  |
| Can you convert the given mass of a substance to the amount of the substance in moles (and vice versa) by using the relative atomic or formula mass; |  |  |  |
| **Can you** **calculate the reacting masses of reactants or products, given a balanced symbol equation and using moles and simple ratio, including examples where there is a limiting reactant;** |  |  |  |
| **Percentage yield** |  |  |  |
| **Can you** **calculate the theoretical yield and the percentage yield of a chemical reaction given the actual yield;** |  |  |  |
| **Can you** **recognise possible reasons why the percentage yield of a product is less than 100%, including loss of product in separation from the reaction mixture, as a result of side reactions or because the reaction is reversible and may not go to completion.** |  |  |  |

**Quantitative Chemistry**

**Relative Atomic mass (Ar)**

Atoms have a tiny mass e.g. C-12 atom is 2.0x10-24g – too small to measure. Chemists measure the mass of atoms **RELATIVE** to each other.

In **Chemistry we compare the mass of an atom with the mass of a carbon-12 isotope which has a mass of exactly 12.** The mass of an atom is the MEAN mass of its Isotopes. (see atomic structure chapter).

To find the Ar of an Element, simply look at your periodic table and take the mass number (larger).

**Relative Formula Mass (Mr)**

The formula mass of a compound is the Ar of all the elements present. Be careful as sometimes there are more than one of the same atom!

|  |  |
| --- | --- |
| Example: MgCl2 | Example: H2SO4 |
| (1 x Mg) + 2 (Cl) | (2xH) + (S) + (4xO) |
| 1x24 + 2(35) | (2x1) + 32 + (4x16) |
| = 24 + 70 = **94** | = 2 + 32 + 64 = **98** |

Find the Mr of these compounds:

|  |  |
| --- | --- |
| 1. NaCl | 1. SiO2 |
|  |  |
|  |  |
| 1. Cl2 | 1. Li2O |
|  |  |
|  |  |
| 1. CaCO3 | 1. CCl4 |
|  |  |
|  |  |
| 1. HCN | 1. H2PO4 |
|  |  |
|  |  |
| 1. Mg(OH)2 | 1. Al2(CO3)3 |
|  |  |
|  |  |

**Percentage of an element in a compound**

To find the percentage of an element, by mass, in a compound;

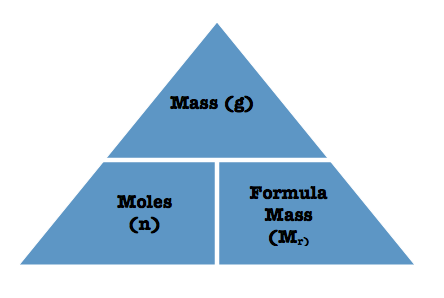
|  |  |
| --- | --- |
| % of Ca in CaCO3 | % Al in Al2(CO3)3 |
| **Mr** ofCaCO3 = 100 | **Mr** ofAl2(CO3)3 = 234 |
| **Ar** of Ca = 40 | **Ar** ofAl x 2= (27 x 2) = 54 |
| 40/100 x 100 = 40% | 54/234 x 100 = 23.08% |

[](http://www.google.co.uk/url?sa=i&rct=j&q=&esrc=s&source=images&cd=&cad=rja&uact=8&ved=&url=/url?sa%3Di%26rct%3Dj%26q%3D%26esrc%3Ds%26source%3Dimages%26cd%3D%26ved%3D%26url%3Dhttps://www.partyrama.co.uk/danger-mouse-penfold-lifesize-cardboard-cutout-94cm/%26psig%3DAOvVaw1MqHQ9GcdS2O7o4qO1Ktkj%26ust%3D1561467986296920&psig=AOvVaw1MqHQ9GcdS2O7o4qO1Ktkj&ust=1561467986296920)**The Mole**

Even a very small amount of substance such as a pinhead is made of millions of atoms – a much bigger “number” is needed! A more convenient measure called a Mole is used.

The number is often referred to as the Avogadro constant. It is just a word to describe this really massive number like dozen, couple, score.

**A mole of atoms contains 6 x 1023 atoms.**

There is a formula that can be used to convert moles, masses and Mr:

[](http://www.google.co.uk/url?sa=i&rct=j&q=&esrc=s&source=images&cd=&ved=2ahUKEwjhwOikoZXgAhXhqHEKHTUdAlUQjRx6BAgBEAU&url=/url?sa%3Di%26rct%3Dj%26q%3D%26esrc%3Ds%26source%3Dimages%26cd%3D%26ved%3D%26url%3Dhttps://www.pinterest.com/pin/415105290624952105/%26psig%3DAOvVaw12Hj-dAg8LJUutQgw9fQ9j%26ust%3D1548929243323471&psig=AOvVaw12Hj-dAg8LJUutQgw9fQ9j&ust=1548929243323471)**1 mole of a substance has a mass of its Mr in grams.**

**Example 1:** Calculate the number of moles in 4.9g of H2SO4

Find Mr H2SO4 first = (2x1) + (32) + (4x16) = 98

Moles = Mass (g) / Mr = 4.9/98 = 0.05 mol

**Example 2:** Find the mass of 20 moles of CO2

Mr CO2 = (12) + (2x16) = 12 + 32 = 44

Mass = Mr x moles = 44 x 20 = 880g

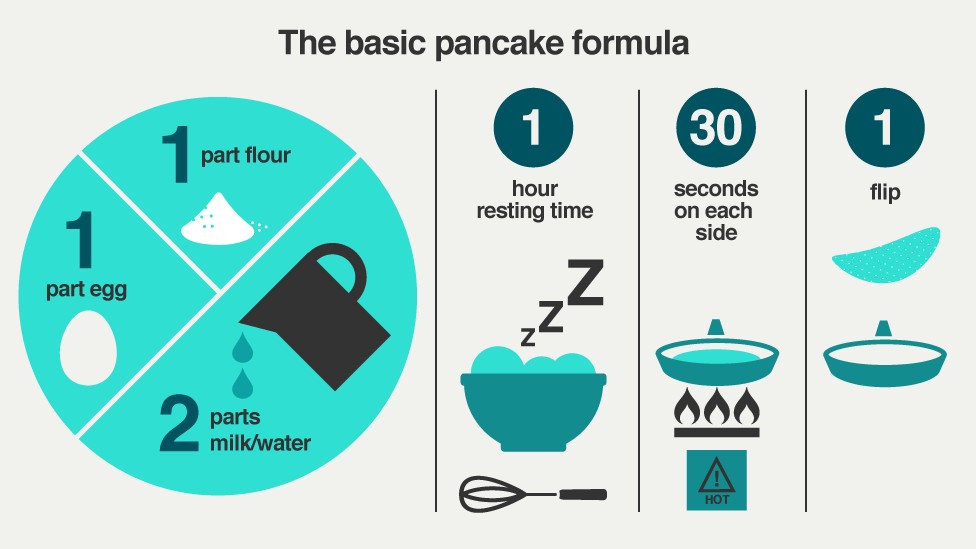
Test yourself

1. What is the mass of one of mole of the following?

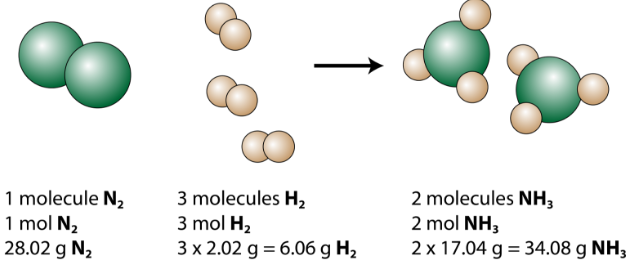
mass = mole x Mr

* 1. NaCl mass = 1 x (23+35) = 58g
  2. Ca
  3. H2SO4
  4. Mg(NO3)2
  5. (NH4)2SO4

1. Calculate the number of moles in:
   1. 12g of H2SO4
   2. 16g of Mg(OH)2
   3. 50g of CaCO3
   4. 54g of Al2(SO4)3
   5. 4g of O2
   6. 5.6g of Ca(OH)2
2. Calculate the mass in grams of:
   1. 0.5 mole of FeSO4
   2. 0.1 mole of MgO
   3. 0.125 mole of CuO
   4. 2 moles of Ca(OH)2
   5. 4 moles of Na2CO3

[](http://www.google.co.uk/url?sa=i&rct=j&q=&esrc=s&source=images&cd=&ved=2ahUKEwjfpLOFqoLjAhUtXhUIHUPoBZAQjRx6BAgBEAU&url=http://www.bbc.co.uk/guides/zy73gk7&psig=AOvVaw1JAkmAvIfgpPeU0k4amfeq&ust=1561472899236264)**Mole ratios - HIGHER**

A ratio is a way to compare the quantities of something e.g. mixing cement or cooking rice. In a balanced symbol equation, the substances are in ratio. The balancing numbers give the ratio of moles that react together.

[](https://www.google.co.uk/url?sa=i&rct=j&q=&esrc=s&source=images&cd=&ved=2ahUKEwjIp8K9ooLjAhUqQRUIHcjhCF8QjRx6BAgBEAU&url=https://chem.libretexts.org/Bookshelves/Introductory_Chemistry/Book:_Introductory_Chemistry_(CK-12)/12:_Stoichiometry/12.2:_Mole_Ratios&psig=AOvVaw1z0SvPR4cBcW6m5TxfEstr&ust=1561470824539397)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| N2 | + | 3H2 | 🡪 | 2NH3 |
| 1 mole N2 | Reacts with | 3 moles of H2 | To form | 2 moles of NH3 |
| Ratio: | 1 mole N2: 3 moles H2: 2 moles NH3 | | | |

Examples

1. **2Mg + O2 🡪 2MgO**

The ratio of Mg: O2 is 2:1

So if I have 6 moles of Magnesium I will need 3 mole of oxygen to react with it.

1. **4Al + 3O2 🡪 2Al2O3**

How many moles of aluminium are needed to produce 0.76 moles?

of Aluminium oxide?

Al: Al2O3  = 4:2 = 2:1

So always twice as many Aluminium moles required as aluminium oxide produced.

So 0.76 mole of Aluminium oxide requires 2 x 0.76 = 1.52 mole

**Test yourself**

1. In the reaction shown the copper nitrate is heated until it has all decomposed.

**2Cu(NO3)2 🡪 2CuO + 4NO2 + O2**

1. How many moles of O2 are produced from 4 moles of Cu(NO3)2?
2. How many moles of NO2 are produced from 0.6 moles of Cu(NO3)2?
3. In the reaction

**CaO + 3C 🡪 CaC2 + CO**

1. How many moles of carbon are needed to completely react with 0.33 moles of CaO?
2. How many moles of CO are produced when 3.3 moles of carbon react completely?
3. In the reaction

**2H2 + O2 🡪 2H2O**

1. How many moles of H2O are produced if 0.5 moles of hydrogen completely react?
2. How many moles of water are produced if 0.1 moles of oxygen completely react?
3. How many moles of hydrogen react if 0.4 moles of oxygen completely react?
4. How many moles of oxygen react if 10 moles of hydrogen completely react?
5. In the reaction

**3Pb + 2O2 🡪 Pb3O4**

* 1. How many moles of oxygen are needed to completely react with 0.66 moles of lead?
  2. How many moles of Pb3O4 are produced when 2.2 moles of oxygen completely react?
  3. How many moles of Pb3O4 are produced when 0.33 moles of lead completely react?

1. Potassium chlorate (KClO3) decomposes to form potassium chloride and oxygen, as shown in the equation:

**2KClO3 🡪 2KCl + 3O2**

* 1. How many moles of potassium chloride are formed when 10 moles of potassium chlorate completely decompose?
  2. How many moles of oxygen are formed when 4 moles of potassium chlorate completely decompose?
  3. How many moles of potassium chloride are formed when 0.5 moles of potassium chlorate completely decompose?

**Calculating reacting masses of reactants and products (Higher)**

Chemists need to be able to calculate how much of each reactant to use in a chemical reaction.

To do this we need to combine the last two steps:

* Underline the 2 substances you are dealing with in the equation
* Calculate Mr of the substance you have information about and calculate the number of moles
* Use the ratio from the balanced equation to calculate the number of moles of the substance you need to find the mass of
* Calculate the mass = moles x Mr

**Example**

What mass of magnesium carbonate reacts with 3.62g of HCl?

MgCO3 + 2HCl 🡪 MgCl2 + H2O + CO2

3.62g

Mr (HCl) = 1 + 35.5 = 36.5

moles HCl = mass/ Mr = 3.65/36.5 = 0.1mol

ratio – 2HCl : 1MgCO3

* 1. : ?
  2. : 0.1/ 2
  3. : 0.05

Mr of MgCO3 = 24 + 12 + (16x3) = 84

mass MgCO3 = moles x Mr

= 0.05 x 84 = **4.2g**

**Test yourself**

1. What mass of oxygen is needed to completely react with 10g of hydrogen?

2H2 + O2 🡪 2H2O

1. What mass of calcium oxide is formed from complete decomposition of 25g of calcium carbonate?

CaCO3 🡪 CaO + CO2

1. What mass of magnesium oxide would be made from complete reaction of 3g of magnesium with oxygen?

2Mg + O2 🡪 2MgO

1. Lithium reacts with water as shown in the equation below. What mass of hydrogen would be produced from complete reaction of 1.4g of lithium?

2Li + 2H2O 🡪 2LiOH + H2

1. What mass of calcium carbonate is needed to completely react with 3.65g of HCl?

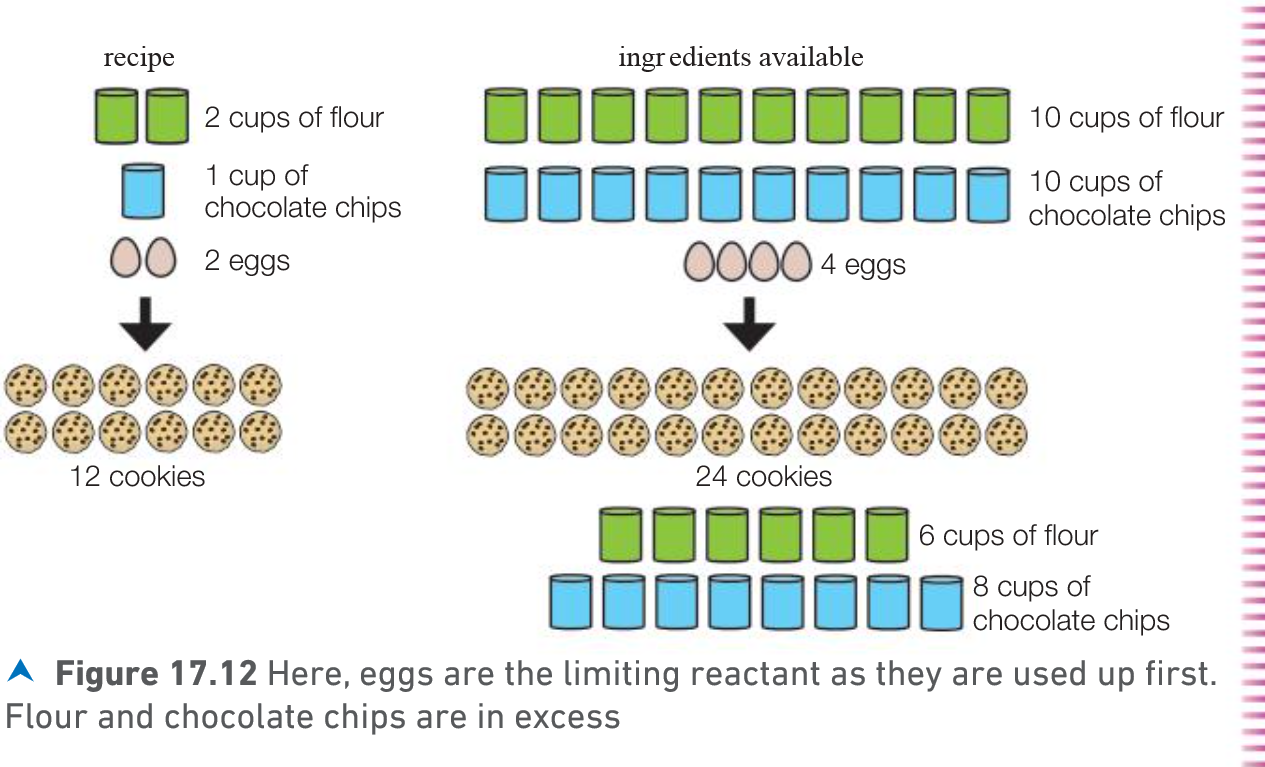
CaCO3 + 2HCl 🡪 CaCl2 + H2O + CO2

1. What mass of NO2 is obtained from complete decomposition of 33.1g of lead nitrate?

2Pb(NO3)2 🡪 2PBO + 4NO2 + O2

[](http://www.google.co.uk/url?sa=i&rct=j&q=&esrc=s&source=images&cd=&ved=2ahUKEwiFmvbaiYfjAhW_QxUIHVeBBawQjRx6BAgBEAU&url=http://destinationgippsland.com.au/marketing-limited-wander-campaigns/&psig=AOvVaw2UE3AZ74Jbpk9W7SPvVl1c&ust=1561636002472340)**Limiting reactant (Higher)**

In a chemical reaction the reactant that \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ is the limiting reactant. This is best illustrated in Baking!



If one reactant is in excess this means \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.

We use this knowledge if one of the reactants in the production of chemicals is very expensive. The cheaper reactant will be added in excess to ensure \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.

When fuels are burned an excess of \_\_\_\_\_\_\_\_\_\_\_ is used as fuels are expensive and in limited supply.

**Example:**

5 moles of Zn are added to 7 moles of H2SO4. One of the reagents is in excess.

Zn + H2SO4 🡪 ZnSO4 + H2

1. Which reactant is in excess?
2. Calculate the number of zinc sulfate and hydrogen formed.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | Zn | + | H2SO4 | 🡪 | ZnSO4 | + | H2 |
| Reacting ratio from the equation | 1 mole of Zn | *Reacts with* | 1 mole of H2SO4 | To make | 1 mole of ZnSO4 | and | 1 mole of H2 |
| Amount provided | 5 moles of Zn  ***Limiting reactant*** |  | 7 moles of H2SO4  **In excess so it does not all react** |  |  |  |  |
| Reaction that takes place | 5 moles of Zn | Reacts with | 7 moles of H2SO4 | To make | 5 mole of ZnSO4 | and | 5 mole of H2 |

Test yourself

1. Copper (II) oxide reacts with hydrogen according to the equation;

CuO + H2 🡪 Cu + H2O

How many moles of copper would be made if;

1. 10 moles of copper (II) oxide were reacted with 15 moles of hydrogen
2. 3 moles of copper (II) oxide were reacted with 3 moles of hydrogen
3. 0.6 moles of copper (II) oxide were reacted with 0.3 moles of hydrogen
4. Copper (II) oxide reacts with methane as shown below;

4CuO + CH4 🡪 4Cu + 2H2O + CO2

How many moles of copper would be made if;

* 1. 4 moles of copper (II) oxide were reacted with 4 moles of methane
  2. 3 moles of copper (II) oxide were reacted with 1 moles of methane
  3. 6 moles of copper (II) oxide were reacted with 2 moles of methane

1. What mass of calcium sulphide can be made when 6g of calcium reacts with 8g of sulphur?

Ca + S 🡪 CaS

1. What mass of calcium chloride is obtained from 20g of ammonium chloride and 50g of calcium oxide? Give your answer to two decimal places.

2NH4Cl + CaO 🡪 CaCl2 + H2O + 2NH3

[](https://www.google.co.uk/url?sa=i&rct=j&q=&esrc=s&source=images&cd=&ved=2ahUKEwjq75eInYfjAhVrRhUIHXSuBkQQjRx6BAgBEAU&url=https://www.greenhouseecocleaning.com/unpopped-popcorn/&psig=AOvVaw2BA-bg6QSoXvrFXr9PkJiP&ust=1561641203959812)**Percentage yield (P192)**

**Theoretical yield** is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Actual Yield** is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

The actual yield is LESS than the theoretical yield because:

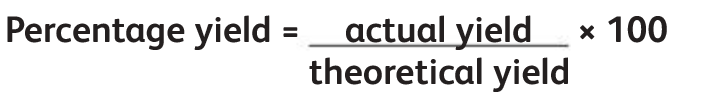
* Some of the product \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

* Side reactions may occur – this means that some of the

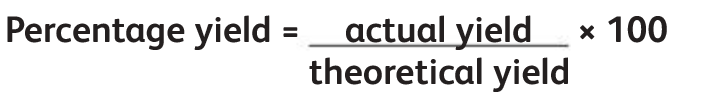
\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

* Some reactions do not go to completion. This means they do not \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_



Example

In a reaction to produce aspirin, the theoretical yield was 40g but the mass of aspirin produced was 5g. Calculate the percentage yield of aspirin.

= 5/40 x 100 = 12.5%

A higher percentage yield industry means more P\_\_\_\_\_\_\_ is formed and more P\_\_\_\_\_\_\_\_\_ is made.

**Test yourself**

1. In a reaction to produce paracetamol, the theoretical yield was 200g but the yield was actually 150g
   1. Calculate the percentage yield
   2. Give three possible reasons for the percentage yield being less than 100%.
2. In the reaction of hydrogen with oxygen, 0.85 moles of water were produced/ The theoretical yield for the reaction is 0.95 moles. Calculate the percentage yield of this reaction.
3. 1. What is the maximum mass of ammonium chloride that could be formed when 7.3g of HCl is neutralised by ammonia?

NH3 + HCl 🡪 NH4Cl

* 1. This experiment produced only 8.3g of ammonium chloride. What is the percentage yield?

1. Phenol is converted to a trichlorophenol according to the equation below.

C6H5OH + 3Cl2 🡪 C6H2Cl3OH + 3HCl

phenol trichlorophenol

1. Calculate the theoretical yield of trichlorophenol from 47g of phenol.
2. If 90.6g of trichlorophenol were actually produced, calculate the percentage yield.