Conservation of Mass
Conservation of Mass

- Mass of atoms and molecules
  - Balancing equations
  - Changing mass
  - Analysing data
  - Summary activities
What is a chemical reaction?

A chemical reaction is a change that takes place when one or more substances (called reactants) form one or more new substances (called products).

For example:

\[ \text{carbon} + \text{oxygen} \rightarrow \text{carbon dioxide} \]

It is often difficult to reverse a chemical reaction and change the products back into the reactants.
Does mass change during a reaction?

During a reaction, the total mass of the substances involved remains constant.

Press "play" to see what happens when copper sulfate and sodium hydroxide react.
Why doesn’t the mass change?

In a chemical reaction, no atoms are made or destroyed.

The reaction just changes how the atoms are bonded together.

The total mass of reactants at the start of a reaction is equal to the total mass of the products at the end. This is called the **principle of conservation of mass**.
Weighing atoms

What is the mass of an atom?

Would it be sensible to measure its mass in grams?

Scientists use a unit of measurement called relative atomic mass. It can be abbreviated to ‘r.a.m.’ or ‘A_r’.

The relative atomic mass of an atom is its mass relative to the mass of 1/12\(^{th}\) of an atom of carbon-12.
What is relative atomic mass?
Where are RAM values found?

The values of relative atomic mass (r.a.m.) are usually given in a data book or found in the periodic table. So you don’t have to work them out or remember them all!

When looking up relative atomic mass in the periodic table, remember that it is always the larger of the two numbers given.

What is the other number?
How is relative formula mass calculated?

To find the **relative formula mass (Mr)** of a compound, add up the relative atomic masses of all the atoms in its formula.

**Step 1:** Write down the formula of the molecule.

**Step 2:** Find the r.a.m. of each type of atom in the molecule.

**Step 3:** Multiply each r.a.m. by the number of atoms of that element and add these values together.

What is the relative formula mass of water?

- **Step 1:** formula of water is H₂O
- **Step 2:** r.a.m. values: hydrogen = 1, oxygen = 16
- **Step 3:** relative formula mass = \((2 \times 1) + (1 \times 16) = 18\)
We can use relative formula masses with symbol equations to show that mass is conserved during a reaction.

The Mr of a compound is the total of the relative atomic masses (r.a.m) of all the atoms in its formula.

For example: \[4\text{Na(s)} + \text{O}_2(g) \rightarrow 2\text{Na}_2\text{O}(s)\]

Na r.a.m. = 23
4Na Mr = 92

O r.a.m. = 16
\(\text{O}_2\) Mr = 32

Total Mr of products
2\(\text{Na}_2\text{O}\) Mr = 124

We can see that the total Mr on both sides of the equation are the same, so no mass has been lost.
What is the relative formula mass?
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What is a symbol equation?

A symbol equation uses the formulae of the reactants and products to show what happens in a chemical reaction.

A symbol equation must be balanced to give the correct ratio of reactants and products.

\[ \text{S(s)} + \text{O}_2(\text{g}) \rightarrow \text{SO}_2(\text{g}) \]

This equation shows that one atom of sulfur (S) reacts with one molecule of oxygen (O$_2$) to make one molecule of sulfur dioxide (SO$_2$).
Balanced equations

A symbol equation must be balanced because mass is conserved. The atoms of each element in the reactants must be the same as the number of atoms of each element in the products.

**Multipliers** are used in the equation to balance the reactants and products.

Can you balance this equation?

\[

cu(s) + o_2(g) \rightarrow cuO(s)
\]

\[
2cu(s) + o_2(g) \rightarrow 2cuO(s)
\]

In this equation, the multiplier in front of the copper in the reactants balances the copper atoms. The multiplier in front of the product balances the oxygen atoms.
Balancing ionic equations

Equations involving ions must also be balanced.

For example, magnesium hydroxide (Mg(OH)₂) is formed from magnesium chloride (MgCl₂) and potassium hydroxide (KOH).

The ionic equation for the formation of Mg(OH)₂ is:

\[ \text{Mg}^{2+} (aq) + \text{OH}^- (aq) \rightarrow \text{Mg(OH)}_2 (s) \]

Is this equation balanced?

\[ \text{Mg}^{2+} (aq) + 2\text{OH}^- (aq) \rightarrow \text{Mg(OH)}_2 (s) \]

There are now an equal number ions on both sides of the equation.
Calculating mass (1)

If you know the mass a reactant then you can use a balanced equation to calculate the mass of products produced.

For example, if 6 grams of copper react with oxygen, what is the mass of copper oxide produced?

**Step 1.** Write out the balanced equation.

\[ 2\text{Cu}(s) + \text{O}_2(g) \rightarrow 2\text{CuO}(s) \]

**Step 2.** Calculate the moles of reactant.

Energy balance the equation: moles = \( \frac{\text{mass}}{\text{Mr}} \)

\[ \text{Mr Cu} = \text{r.a.m. Cu} = 63.5 \]

\[ \text{moles} = \frac{6}{63.5} = 0.094 \text{ moles of Cu} \]
Step 3. Write out the mole relationship of the reactants and products in the equation.

This is equal to the multipliers in the equation.

\[ 2\text{Cu(s)} + 1\text{O}_2 \rightarrow 2\text{CuO(s)} \]

2 moles of Cu + 1 of mole O\(_2\) \rightarrow 2 moles of CuO

Step 4. Calculate the number of moles of CuO produced in the reaction.

\[ 2\text{ moles Cu} \rightarrow 2\text{ moles CuO} \]

0.094 moles Cu \rightarrow 0.094 moles CuO

Step 5. Calculate the mass of CuO produced in the reaction.

\[ \text{mass} = \text{moles} \times \text{Mr} \]

mass CuO = 0.094 \times 79.5 = 7.5g
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What happens to the mass?

What happens to mass during this reaction?

How does the mass of the substance change during this reaction?

Click "play" to find out.
In the reaction between magnesium and oxygen, the mass increased.

What is the balanced symbol equation for this reaction?

\[ 2\text{Mg}_\text{(s)} + \text{O}_2\text{(g)} \rightarrow 2\text{MgO}_\text{(s)} \]

The balanced symbol equation shows that gaseous oxygen atoms from the air joined up with the magnesium atoms to create solid magnesium oxide.

The mass of oxygen was not taken into account at the start, and so the addition of oxygen has resulted in an increase in mass.
What happens to the mass?

How does the mass of the substance change during this reaction?

Click "play" to find out.
After heating 40g of copper carbonate, the mass decreased to 30g.

\[ \text{CuCO}_3(s) \rightarrow \text{CuO}(s) + \text{CO}_2(g) \]

Why did the mass decrease?

The reaction took place in an open system. This means the carbon dioxide gas could escape into the surrounding air.

The mass of carbon dioxide was therefore not taken into account, and so a decrease in mass was observed.

Can you calculate the mass of carbon dioxide that was produced in the reaction?
Reactions involving open systems

In an open system, changes in mass can be observed during or after a chemical reaction.

This is often because the mass of gases released or used up in the reaction are not taken into account.

When the reaction occurs, the mass of the particles doesn’t change, however the state of the particles do.

The change in mass can be explained by the particle model.
The particle model and changing mass

According to the particle model, all particles are in constant motion, and the amount a particle can move depends on the state the compound is in; solid, liquid, or gas.

**Solid particles** are strongly bonded to each other, and so cannot move out or their regular arrangement.

**Gas particles** are not bonded to each other, and so can move far apart in random directions.

In an open system gas particles can spread through the test tube and exit into the environment.

A decrease in mass is therefore observed.
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Results obtained from experiments always have some degree of uncertainty.

**What is an accurate result?**

The accuracy of a measurement is how close it is to the true value.

**What is a precise result?**

The precision of a measurement is dependent on the amount of random errors. Precise measurements are very close to the mean value.
The break down of 40 grams of copper carbonate to copper oxide and carbon dioxide gas was carried out five times. The final mass of the reaction for each repeat was recorded in the table below.

<table>
<thead>
<tr>
<th>repeat number</th>
<th>mass following decomposition (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>30</td>
</tr>
<tr>
<td>2</td>
<td>29</td>
</tr>
<tr>
<td>3</td>
<td>31</td>
</tr>
<tr>
<td>4</td>
<td>30</td>
</tr>
<tr>
<td>5</td>
<td>38</td>
</tr>
</tbody>
</table>

How reliable is the data?
Did you spot any outliers in the data?

<table>
<thead>
<tr>
<th>sample number</th>
<th>mass of system following decomposition (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>30</td>
</tr>
<tr>
<td>2</td>
<td>29</td>
</tr>
<tr>
<td>3</td>
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</tr>
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<td>30</td>
</tr>
<tr>
<td>5</td>
<td><strong>38</strong></td>
</tr>
</tbody>
</table>

The mass of repeat 5 varies greatly from repeat 1 to 4. This could be due to equipment malfunction or human error.
Calculating the mean

The **mean** is the sum of all the samples divided by the total number of samples.

Ignoring the outlier, can you calculate the mean for the data?

\[
\frac{30 + 29 + 31 + 30}{4} = 30 \text{ grams}
\]

What does this tell you?

The mean gives the best estimate for the final mass of the decomposition of 40g of copper carbonate.
Calculating the range

The **range** of a set of data is the highest value minus the lowest value. The smaller the range, the less variation in the data.

Ignoring the outlier, can you calculate the range for the data?

You first need to order the data from lowest to highest:

29, 30, 30, 31

range: 31 – 29 grams = 2

Comparing this with the mean, how accurate do you think the estimate for the final mass of the reaction is?
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