# 1e - Chemical formulae, equations and calculations

## Edexcel IGCSE Chemistry Revision Notes



### How to use these notes

These notes cover everything you need to know for this part of the specification. They have been written in question-answer format to make them easier for you to study from.

In order to study successfully, I recommend you do the following for each question and answer:

- Read it carefully and make sure you **understand** it.
- **Memorise** the answer.
- **Practice** applying your understanding to past exam questions.

A good way to memorise information is to use **retrieval practice**. This is when you practise retrieving information from your memory. You could do this by making a flashcard for each question with the question on one side and the answer on the other. Or you could use a flashcard app. Alternatively, use a sheet of paper to cover up the answer so you can only see the question. Try to answer the question and then check how you did.

You should practise retrieving each answer from your memory until you can do it perfectly. Even once you can retrieve the answer perfectly, your ability to retrieve it will probably fade as time passes without practising. Therefore you will need to keep going back to the questions that you have previously mastered and practising them again. However, each time you re-learn the answer, the memory will be stronger and will last longer than the time before.

*1.25*

**What is a chemical reaction?**
A chemical reaction is when one set of chemical substances turns into another set of chemical substances.

**What are reactants?**
Reactants are the substances present at the start of a chemical reaction. They react to form products.

**What are products?**
Products are the substances that the reactants turn into in a chemical reaction.

**What is a chemical formula?**
A chemical formula is a symbol or series of symbols that represents a particular chemical substance.

**How do you write the chemical formula for an atom?**
To write the chemical formula for an atom, simply write the chemical symbol of its element.

**How do you write the chemical formula for a molecule or compound?**
To write the chemical formula for a molecule or compound, write out the chemical symbols of all of the elements in it with no spaces between them. If the molecule or compound contains more than one of a particular element, show this by putting a number to the right of that element's symbol.

**How do you write the chemical formula for an ion?**
To write the chemical formula for an ion, follow the same steps you would for an atom, molecule or compound but then write the charge to the upper right of the formula. In the formula of an ion, you write the sign of the charge after the number (e.g. 2+, rather than +2), and if the number is 1, you leave it out and just write + or -.

**Examples of chemical formulae**

The chemical formula of a chlorine atom is:

$Cl$

The chemical formula of an oxygen atom is:

$O$

The chemical formula of a water molecule is:

$H_2O$

This shows that a water molecule contains two hydrogen atoms and one oxygen atom.

The chemical formula of a magnesium ion with a charge of +2 is:

$Mg^{2+}$

The chemical formula of a fluoride ion with a charge of -1 is:

$F^-$

The chemical formula of a sulfate ion with a charge of -2 is:

$SO_4^{2-}$

This shows that a sulfate ion contains one sulfur atom and four oxygen atoms and has a charge of -2.

**What is a chemical equation?**
A chemical equation is a written representation of a chemical reaction.

**How do you write a chemical equation?**
To write a chemical equation, start by writing out the reactants on the left. Put plus signs (+) between the reactants. Then draw an arrow from the reactants pointing to the right. Then write out the products to the right of the arrow. Put plus signs between the products.

**What is a word equation?**
A word equation is a chemical equation in which the reactants and products are represented by their names written out in words.

**What is a symbol equation?**
A symbol equation is a chemical equation in which each reactant and each product is represented by its chemical formula.

**How can the ratios of the reactants and products be represented in a chemical equation?**
The ratios of the reactants and products can be represented in a chemical equation by writing numbers before the formulae of the reactants and products.

**What is a balanced chemical equation?**
A balanced chemical equation is a symbol equation in which the amount of each element is the same in the reactants and the products.

## *1.26*

**How do you calculate the relative formula mass of a molecule or compound?**
To calculate the relative formula mass of a molecule or compound, you first need to know its chemical formula. Then, multiply the relative atomic mass of each element that is present by the number that is after its symbol in the chemical formula (if there is no number then this represents a 1). Finally, add all of these numbers together to get the relative formula mass.

**Example: Calculating the relative formula mass of magnesium chloride**

Magnesium chloride has the formula $MgCl_2$.

The relative atomic mass of magnesium is 24.

Because there is no number after Mg in $MgCl_2$, we do not need to multiply 24 by anything (or, in other words, we need to multiply it by 1).

The relative atomic mass of chlorine is 35.5.

Because there is a 2 after Cl in $MgCl_2$, we need to multiply 35.5 by 2. This gives 71.

We now add the 24 and the 71 together which gives 95. Therefore the relative formula mass of magnesium chloride is 95.

This whole calculation can be summarised as:

Relative formula mass of $MgCl_2$ = 24 + (35.5 x 2) = 95

## *1.27*

**What is the unit for the amount of a substance? What is it abbreviated to?**
The unit for the amount of a substance is a mole. It is abbreviated to mol.

## *1.28*

**When carrying out calculations involving amounts and masses of substances, when should you use relative atomic mass and when should you use relative formula mass?**
If you are carrying out a calculation about individual atoms of an element (e.g. O, Ne, C) you should use relative atomic mass.

If you are carrying out a calculation about a molecule or compound (e.g. $O_2$, $CH_4$, NaCl) you should use relative formula mass.

**What is the formula that links the amount of a substance, its mass, and its relative atomic mass or relative formula mass?**
Amount of a substance, mass and relative atomic mass or relative formula mass are linked by the following formulae:

For individual atoms:

$$Mass\ (g)\ =\ Amount\ (mol)\ \times\ Relative\ atomic\ mass\ (g/mol)$$

For a molecule or compound:

$$Mass\ (g)\ =\ Amount\ (mol)\ \times\ Relative\ formula\ mass\ (g/mol)$$

## *1.29*

**If you are told the mass of one substance involved in a reaction, how can you work out the mass of another substance involved in the reaction?**
If you are told the mass of one substance involved in a reaction, you can work out the mass of another substance involved in the reaction by using the following steps:

- First, work out the relative atomic mass or relative formula mass of the substance that you have been told the mass of.
- Then use this, along with the substance's mass, to calculate the amount in moles of the substance that is involved in the reaction.
- Then, use the balanced symbol equation to work out the ratio of the amount of the substance you have been given the mass of to the amount of the substance you are trying to find the mass of.
- Use this ratio, along with the amount in moles of the substance you have been given the mass of, to work out the amount in moles of the substance you are trying to find the mass of.
- Work out the relative atomic mass or relative formula mass of the substance you are trying to find the mass of.
- Use this, along with the amount in moles of the substance, to work out its mass.

**Example: Calculating reacting masses**

Here is an example reacting masses question:

> *Sodium reacts with water to form sodium hydroxide and hydrogen, as shown in the balanced equation below.*
>
> $2Na + 2H_2O \rightarrow 2NaOH + H_2$
>
> *What mass of sodium must be reacted in order to produce 10g of hydrogen?*

Here is how to solve it:

STEP 1

First we need to identify which substances the question is about.

This type of question will always give you the mass of one substance and ask you to find the mass of another. The substances could both be reactants, or they could both be products, or one could be a reactant and the other a product. This makes absolutely no difference to the method!

In this case, the substance we have been given the mass of is hydrogen ($H_2$), which is one of the products.

The substance we have been asked to find the mass of is sodium (Na), which is one of the reactants.

If you are working on paper, it could be helpful at this point to circle the two important substances in the equation in the question.

STEP 2

We have been told that the mass of hydrogen ($H_2$) is 10g. We need to work out what amount this is in moles.

To do this we first need to know hydrogen's relative formula mass. We use relative formula mass (rather than relative atomic mass) whenever there is more than one element in the substance's formula or one of the elements has a number after it. In hydrogen's case, the H has a 2 after it, so we need to use relative formula mass.

Since the formula of hydrogen is $H_2$, we calculate its relative formula mass by looking up the relative atomic mass of the element hydrogen (H), which is 1, and then multiplying it by 2:

Relative formula mass of $H_2$ = 1 x 2 = 2

STEP 3

We can now work out the amount, in moles, of hydrogen.

We know that the formula that links mass, amount and relative formula mass is:

$$Mass\ (g)\ =\ Amount\ (mol)\ \times\ Relative\ formula\ mass\ (g/mol)$$

Substituting in the things we know gives us:

$$10g\ =\ Amount\ (mol)\ \times\ 2g/mol$$

Rearranging to make amount the subject gives:

$$Amount\ (mol)\ =\ 10g \div 2g/mol\ =\ 5\ mol$$

Therefore, the amount of hydrogen is 5 mol.

STEP 4

We now need to work out the ratio of the amount of sodium to the amount of hydrogen and use this to work out the amount of sodium in moles.

In the balanced equation, sodium (Na) has a 2 before it, and hydrogen ($H_2$) does not have any number before it, which implies a 1. Therefore, the ratio of the amount of sodium to the amount of hydrogen is 2:1.

Note that this is the ratio of the amounts (in moles) of the two substances. It is **not** the ratio of their masses! This is why we had to convert the mass of hydrogen (10g) to the amount of hydrogen (5 mol) before we could apply the ratio.

Since the ratio of amount of sodium to amount of hydrogen is 2:1, we know that there are twice as many moles of sodium as there are of hydrogen. Since there are 5 mol of hydrogen, there must be twice this many moles of sodium:

Amount of sodium = 5 mol x 2 = 10 mol

STEP 5

Now we know that there are 10 moles of sodium, all that remains is to convert this to mass.

Sodium's formula is Na, which is just a single element with no number after it. Therefore, we use relative atomic mass (rather than relative formula mass) for sodium.

The relative atomic mass of sodium is 23.

VERY IMPORTANT NOTE:

The 2 in front of sodium in the equation (2Na + ...) is **NOT** part of sodium's formula!

It is just there to show the ratio of the amount of sodium to the amounts of the other substances.

You should ignore any numbers before a substance's formula when working out its relative atomic mass or relative formula mass.

Including these numbers is a very common mistake, which is why I have written this in big font!

Since we know that there 10 moles of sodium, and sodium's relative atomic mass is 23, we can finally work out the mass of sodium:

$$Mass\ (g)\ =\ Amount\ (mol)\ \times\ Relative\ atomic\ mass\ (g/mol)$$

$$Mass\ (g)\ =\ 10\ mol\ \times\ 23\ g/mol\ =\ 230g$$

So this gives us the answer: 230g of sodium are needed.

**Using a table to do reacting masses questions**

Some students find it helpful to draw a table when doing these types of questions. We start by drawing a table as shown below. RAM stands for relative atomic mass and RFM stands for relative formula mass.

| | Sodium (Na) | Hydrogen ($H_2$) |
|---|---|---|
| Ratio: | | |
| Mass (g): | | |
| RAM or RFM (g/mol): | | |
| Amount (mol): | | |

We then fill in all the information we have been given in the question, as shown below. We can also identify which cell in the table we are ultimately aiming to fill in. In this case, we are trying to find out the mass of sodium, so I have shaded the cell for sodium's mass in grey to show that it is our target. If you are working on paper, you could circle the target cell.

| | Sodium (Na) | Hydrogen ($H_2$) |
|---|---|---|
| Ratio: | 2 : 1 | |
| Mass (g): | | 10 |
| RAM or RFM (g/mol): | | |
| Amount (mol): | | |

Next we work out hydrogen's relative formula mass and add it to the table:

| | Sodium (Na) | Hydrogen ($H_2$) |
|---|---|---|
| Ratio: | 2 : 1 | |
| Mass (g): | | 10 |
| RAM or RFM (g/mol): | | 2 |
| Amount (mol): | | |

Next we calculate the amount in moles of hydrogen and add it to the table:

| | Sodium (Na) | Hydrogen ($H_2$) |
|---|---|---|
| Ratio: | 2 : 1 | |
| Mass (g): | | 10 |
| RAM or RFM (g/mol): | | 2 |
| Amount (mol): | | 5 |

Next we use the ratio, along with the amount of hydrogen, to work out he amount of sodium:

| | Sodium (Na) | Hydrogen ($H_2$) |
|---|---|---|
| Ratio: | 2 : 1 | |
| Mass (g): | | 10 |
| RAM or RFM (g/mol): | | 2 |
| Amount (mol): | 10 | 5 |

Next we work out sodium's relative atomic mass:

| | Sodium (Na) | Hydrogen ($H_2$) |
|---|---|---|
| Ratio: | 2 : 1 | |
| Mass (g): | | 10 |
| RAM or RFM (g/mol): | 23 | 2 |
| Amount (mol): | 10 | 5 |

Finally, we calculate the mass of sodium:

| | Sodium (Na) | Hydrogen ($H_2$) |
|---|---|---|
| Ratio: | 2 : 1 | |
| Mass (g): | 230 | 10 |
| RAM or RFM (g/mol): | 23 | 2 |
| Amount (mol): | 10 | 5 |

## *1.30*

**What is theoretical yield?**
Theoretical yield is the amount of a particular product that we would expect to get from a reaction if 100% of the reactants were converted into products. We work it out by doing a calculation based on the amounts of reactants used.

**What is actual yield?**
Actual yield is the amount of a particular product that is actually produced when we carry out a reaction. We find it out by making a real-world measurement.

**How do we calculate the percentage yield of a reaction?**
We calculate the percentage yield of a reaction using the following formula:

$$Percentage\ yield\ (\%) = \frac{Actual\ yield}{Theoretical\ yield} \times 100\%$$

The actual yield and the theoretical yield must be in the same units.

## *1.31*

**How can the formula of a metal oxide be worked out experimentally?**
To work out the formula of a metal oxide experimentally, do the following steps:

- Start with a pure sample of the metal that is found in the metal oxide (e.g. if the metal oxide is magnesium oxide, then start with pure magnesium).
- Weigh the metal and record its mass.
- Heat the metal in air so that it reacts with oxygen to form the metal oxide. Continue until all of the metal has reacted.
- Weigh the metal oxide that has been formed and record its mass.
- Subtract the mass of the original metal from the mass of the metal oxide to find the mass of oxygen atoms that were incorporated into the metal oxide.
- Use the metal's relative atomic mass to work out the amount in moles of metal atoms that went into the metal oxide.
- Do the same for the oxygen atoms.
- Find the ratio of the amount in moles of the metal atoms to the amount in moles of oxygen atoms. This will tell you the formula of the metal oxide (e.g. for magnesium oxide, you would find that there is a 1:1 ratio of magnesium atoms to oxygen atoms, so the formula is MgO).

**What is water of crystallisation?**
Solid ionic compounds exist as crystals. Each crystal is a giant ionic lattice made up of huge numbers of ions arranged in a regular pattern. In some ionic compounds, water molecules ($H_2O$) can enter the lattice and take up positions between the ions. This is called 'water of crystallisation'.

**How do we describe a compound that contains water of crystallisation?**
A compound that contains water of crystallisation is described as 'hydrated' (e.g. Calcium chloride containing water of crystallisation is called 'hydrated calcium chloride').

**How do we describe a compound that does not contain water of crystallisation?**
A compound that does not contain water of crystallisation is described as 'anhydrous' (e.g. Calcium chloride without water of crystallisation is called 'anhydrous calcium chloride).

**How do you write the formula of a hydrated compound?**
To write the formula of a hydrated compound, first write the formula of the compound, then put a dot, then write the number of moles of water molecules that are present per mole of the compound, then write '$H_2O$' (e.g. '$MgSO_4 \cdot 7H_2O$' is the formula for magnesium sulfate with 7 moles of water of crystallisation for every 1 mole of magnesium sulfate).

**How can the formula of a hydrated compound be worked out experimentally?**
The formula of a hydrated compound can be worked out experimentally by following the steps below. Note that you need to already know the formula of the anhydrous version of the compound.

- Weigh a sample of the hydrated compound and record its mass.
- Heat this sample in a crucible to evaporate the water of crystallisation out of it. Continue until all of the water of crystallisation has been removed (when the mass stops changing).
- Weigh the anhydrous compound that has been formed and record its mass.
- Subtract the mass of the anhydrous compound from the mass of the original hydrated compound to work out what mass of water molecules was in the original hydrated compound.
- Use the relative formula mass of the anhydrous compound to work out what amount, in moles, of the anhydrous compound was left at the end.
- Use the relative formula mass of water (which is 18) to work out what amount, in moles, of water molecules were in the original hydrated compound.
- Find the ratio of the amount of the hydrated compound to the amount of water molecules and use this to write the formula (e.g. if you found that there were 3 mol of calcium chloride and 12 mol of water molecules, this would be a 1:4 ratio, so the formula would be $CaCl_2 \cdot 4H_2O$).

**How do you write the molecular formula of a molecule?**
To write a molecular formula of a molecule, write out the chemical symbols of all the elements in the molecule and write a number after each one to show how many atoms of that element are in the molecule. If only one atom of that element is in the molecule then do not write a number.

**Example: Writing a molecular formula**

The molecule propene contains 3 carbon atoms and 6 hydrogen atoms.

Therefore, its molecular formula is $C_3H_6$.

**How do you write the empirical formula of a molecule?**
To write the empirical formula of a molecule, follow the same process as you would to write a molecular formula, but instead of showing the actual number of atoms of each element in the molecule, show the simplest whole number ratio of the numbers of atoms of each element.

**Example: Writing an empirical formula**

In propene there are 3 carbon atoms and 6 hydrogen atoms.

Therefore, the ratio of carbon atoms to hydrogen atoms is 3:6.

The simplest whole-number version of this ratio is 1:2.
(To get the simplest whole number version of this ratio, we first identify the highest common factor of 3 and 6, which is 3. Then we divide both of the numbers in the ratio by this amount).

Therefore, the empirical formula of propene is $CH_2$.

**Note: For compounds with giant structures there is no difference between molecular formula and empirical formula.**

Some compounds have giant structures. This includes all ionic compounds - which have giant ionic structures - as well as the compound silicon dioxide, which has a giant covalent structure.

These compounds are made up of huge numbers of ions or atoms bonded together in a fixed ratio in either a giant ionic lattice or a giant covalent lattice.

These giant structures are not made up of molecules.

For example, calcium chloride is an ionic compound. A single crystal of calcium chloride is made up of huge numbers of calcium ions ($Ca^{2+}$) and chloride ions ($Cl^-$) bonded together in a giant ionic lattice.

Although we say that calcium chloride has a ‘molecular formula’ of $CaCl_2$, this is actually

misleading. There are no molecules in calcium chloride. When we say that its 'molecular formula' is $CaCl_2$, we don't actually mean that it is made up of molecules containing 1 calcium ion and 2 chloride ions. What we really mean is that there is a 1:2 ratio of calcium ions to chloride ions in the giant ionic lattice. The actual numbers of ions are massive and will vary from one calcium chloride crystal to the next (but they will always be in a 1:2 ratio).

Therefore, what we call the 'molecular formula' of calcium chloride is really an empirical formula - it shows the ratio of the numbers of ions. Therefore, for compounds with giant structures, molecular formula and empirical formula are the same thing.

## *1.33*

**How do you work out the empirical formula of a compound if you are told the mass of atoms of each element in a sample of the compound?**
If you are given the mass of atoms of each element in a sample of a compound, you can work out the compound's empirical formula by doing the following:

- First divide the mass of atoms of each element by the element's relative atomic mass to find the amount, in moles, of atoms of each element. Write this as a ratio.
- Divide all of the numbers by the smallest number to simplify the ratio.
- Do any further simplifying needed to get the ratio in its smallest whole-number form (you may need to do some rounding).
- Use this ratio to write the empirical formula.

**How do you work out the empirical formula of a compound if you are told what percentage of its mass is made up of each type of element?**
If you are told what percentage of an element's mass is made up of each type of element, you can work out what mass of atoms of each element would be present in a 100g sample of the compound - this is just the percentage but without the '%' sign (e.g. if 15% of the compound's mass is oxygen atoms, then there would be 15g of oxygen atoms in a 100g sample of the compound). You can then work out the empirical formula based on the masses (see above).

**How do you work out the molecular formula of a compound if you know its empirical formula and its relative formula mass?**
If you know a compound's empirical formula and relative formula mass, you can work out its molecular formula by doing the following:

- First, work out what the relative formula mass would be if the empirical formula was the molecular formula (e.g. if the empirical formula is $CH_2$, then the relative formula mass of this would be 12 + (1 x 2) = 14).
- Divide the relative formula mass by the number that you just calculated. The answer should be a whole number (e.g. if the empirical formula is $CH_2$ and the relative formula mass is 42, then you would do 42 ÷ 14 = 3).

- Multiply every number in the empirical formula by this number that you have just calculated. This will give you the molecular formula (e.g. in our example, we would multiply every number in $CH_2$ by 3, which would give $C_3H_6$).

## *1.34C*

**How many $cm^3$ are equal to $1dm^3$?**
$1000cm^3 = 1dm^3$

**What is the formula linking amount of solute, volume of solution, and concentration?**
The formula linking amount of solute, volume of solution, and concentration is:

$$Concentration\ (mol/dm^3) = \frac{Amount\ of\ solute\ (mol)}{Volume\ of\ solution\ (dm^3)}$$

## *1.35C*

**What is the volume of 1 mole of gas in $dm^3$ at room temperature and pressure?**
The volume of 1 mole of gas at room temperature and pressure is $24dm^3$.

**What is the volume of 1 mole of gas in $cm^3$ at room temperature and pressure?**
The volume of 1 mole of gas at room temperature and pressure is $24{,}000cm^3$.