Summary sheet: Writing formulae

Writing formulae

Compounds should have no overall charges, so the positive and negative charges should cancel each other out.

Apart from working out the charges on ions made up of one element, you need to know the following compound ions and their charges.

Name	Formula	Charge
hydroxide	OH^-	1–
nitrate	NO_3^-	1–
sulfate	SO_4^{2-}	2–
carbonate	CO_3^{2-}	2–
ammonium	NH_4^+	1+

Follow these steps.

Write the name of the compound	Magnesium bromide	Sodium sulfate
Work out the charge of your positive ion = group number, or 1+ for ammonium.	Mg^{2+}	Na^+
Work out the charge of your negative ion = group number – 8 *or* known charge for a compound ion.	Br^-	SO_4^{2-}
Rewrite the symbols; put a bracket around any compound ion.	Mg^{2+} Br^- Mg Br	Na^+ SO_4^{2-} Na (SO_4)
Swap the numbers of the charges and drop them to the opposite ion.	$MgBr_2$	$Na_2(SO_4)$

Writing ionic equations

- Make sure all state symbols are included.
- Identify the species that are aqueous, using the rules of solubility.

1 Look at the cation – is it Group 1 or ammonium? If so → soluble.

2 Look at the anion – is it a nitrate? If so → soluble.

- Proceed only if you have ruled out 1 and 2.

1 Is the anion a halide (chloride, bromide or iodide)?

2 If so, look at the metal – lead or silver? If so → insoluble.

3 Is the anion a sulfate?

4 If so, look at the metal – barium, calcium, lead? If so → insoluble.

5 Is the anion a hydroxide?

6 If so, look at the metal – transition metal or Group 2 (after Ca)? If so → insoluble.

- Split all the soluble salts into their aqueous ions on both sides – remember to write the numbers in front of the ions for multiples.

- Cancel out the ions that appear on both sides – again pay attention to numbers.
- Write your final equation (always keep the state symbols unless specifically told not to!).

Reacting masses

To work out masses of reactants and products from equations, follow these steps.

Steps to follow	**Example**	**Example**
	5 g of Ca reacted with excess chlorine. What mass of $CaCl_2$ is formed?	When $MgCO_3$ was heated strongly, 4 g of MgO was formed. What is the mass of $MgCO_3$ that was heated?
Write the balanced equation.	$Ca + Cl_2 \rightarrow CaCl_2$	$MgCO_3 \rightarrow MgO + CO_{2(g)}$
Write the masses given.	5 g (excess) **?**	**?** 4 g
Find the A_r or M_r.	40 111	84 40
Divide by the atomic or molecular mass (step 2 ÷ step 3).	$\frac{5}{40} : \frac{?}{111}$	$\frac{?}{84} : \frac{4}{40}$
Treat these like ratios, rearrange to find the unknown (**?**).	Mass of $CaCl_2$ = (5 × 111) ÷ 40 = 13.9 g	Mass of $MgCO_3$ = (4 × 84) ÷ 40 = 8.4 g

Note: if you are told something is in excess, do not use it in the calculation!

Percentage yield

The calculations above dealt with the masses you get or use if the reaction is 100% complete.

Most reactions are not 100% complete for the following reasons:

- not all the reactant reacts
- some is lost in the glassware as you transfer the reactants and the products
- some other products might be formed that you do not want.

This is a problem in industry. Less of the desired product has been made, so there is less to use or sell, and the waste has to be disposed of. Waste products can be harmful to the environment, e.g. the one above produces the greenhouse gas CO_2. Industries try to choose reactions that minimise waste and do not produce harmful products. They also try to make the rate of reaction high enough to make the reaction turnover fast so they can increase production and make money.

To work out % yield: use the balanced equation to work out how much of the given product you should get if the reaction is 100% efficient – this is the theoretical yield.

Then: $\%\ \text{yield} = \frac{\text{actual yield} \times 100}{\text{theoretical yield}}$

Worked examples: Calculations

The example exam questions in the shaded sections are followed by working out and hints on answering the questions.

Empirical formulae

1 Sulfamic acid is a white solid used by plumbers as a limescale remover.

a Sulfamic acid contains 14.42% by mass of nitrogen, 3.09% hydrogen and 33.06% sulfur. The remainder is oxygen.

i Calculate the empirical formula of sulfamic acid. **(3)**

Interpreting the question

- 'The remainder is oxygen.' So you need to calculate the percentage of oxygen.
- 'Calculate the empirical formula of sulfamic acid.' This is the main question.

Answering the question

What you do	Calculation				Common mistakes
Write the symbols of the elements.	N	H	S	O	Remember you can check the symbols in the Periodic Table.
Note the % underneath.	14.42	3.09	33.06	100 – (14.42 + 3.09 + 33.06) = 49.43	Check sum of % = 100%. Make sure you transfer the correct % for the correct element.
Write the A_r.	14.01	1	32.06	16	Remember to use the Periodic Table correctly!
Divide % by A_r for ratio.	1.03	3.09	1.03	3.09	Do not round up at this stage.
Divide by smallest number for simplest ratio.	1	3	1	3	These numbers give you the number of each atom in the empirical formula.
Write the empirical formula.	NH_3SO_3				Make sure you actually write this formula out – don't leave the answer at the ratio stage.

ii The molar mass of sulfamic acid is 97.1 g mol^{-1}. Use this information to deduce the molecular formula of sulfamic acid.

Answering the question

Work out empirical mass first, then use this to work out the molecular formula.

1 1 × N = 14; 3 × H= 3; 1 × S = 32; 3 × O = 16 × 3 = 48

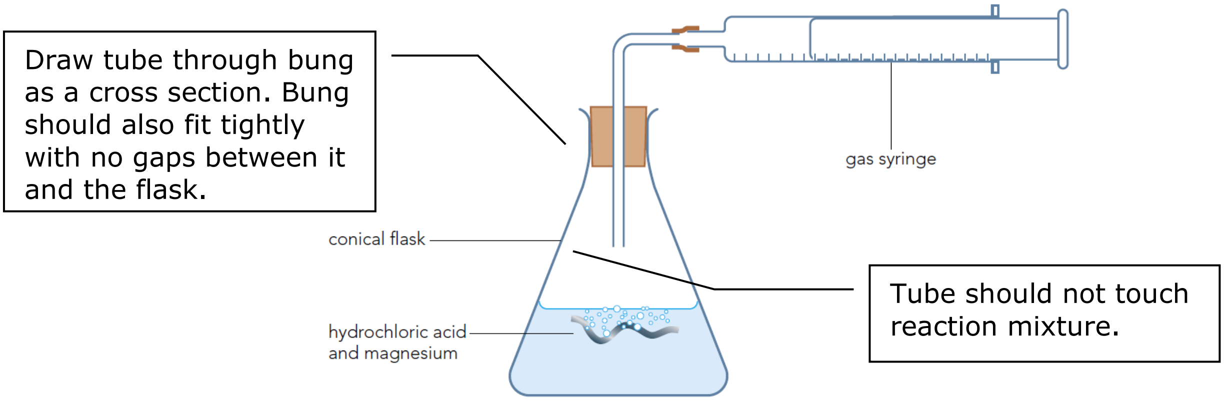
2 Empirical mass =14 + 3 + 32 + 48 = 97

3 Divide molar mass by empirical mass: 97.01/97 = 1, therefore molecular formula = empirical formula.

b Sulfamic acid reacts with magnesium to produce hydrogen gas. In an experiment, a solution containing 5.5×10^{-3} moles of sulfamic acid reacted with excess magnesium. The volume of hydrogen produced was 66 cm^3, measured at room temperature and pressure.

i Draw a labelled diagram of the apparatus you would use to carry out this experiment, showing how you would collect the hydrogen produced and measure its volume.

Answering the question



ii Calculate the number of moles of hydrogen, H_2, produced in this reaction.

The molar volume of a gas is 24 $dm^3\,mol^{-1}$ at room temperature and pressure.

Interpreting the question

- *Excess magnesium* means that you cannot use this substance in the calculation.
- The molar volume is given in dm^3 but the volume of hydrogen is given in cm^3.

Answering the question

1 The molar volume of a gas is 24 $dm^3\,mol^{-1}$ at room temperature and pressure.

2 Number of moles of a gas = volume/molar volume.

3 Number of moles of H_2 = 66/24 000 = 2.75×10^{-3} mol.

iii Show that the data confirms that two moles of sulfamic acid produces one mole of hydrogen gas, and hence write an equation for the reaction between sulfamic acid and magnesium, using $H[H_2NSO_3]$ to represent the sulfamic acid.

Interpreting the question

This question is asking you to compare the number of moles.

- sulfamic acid = 5.5×10^{-3} mol.
- hydrogen molecules = 2.75×10^{-3} mol (answer from part **ii**).

Answering the question

1 5.5×10^{-3} mol of sulfamic acid produce 2.75×10^{-3} mol of H_2, so

2 2 mol of sulfamic acid produce 1 mol of H_2

3 $2\ H[H_2NSO_3] + Mg \rightarrow Mg(H_2NSO_3)_2 + H_2$

Molar gas volumes and the Avogadro constant

2 Airbags, used as safety features in cars, contain sodium azide, NaN_3. An airbag requires a large volume of gas produced in a few milliseconds. The gas is produced in this reaction:

$$2NaN_3(s) \rightarrow 2Na(s) + 3N_2(g) \qquad \Delta H \text{ is positive}$$

When the airbag is fully inflated, it contains 50 dm^3 of nitrogen gas.

a Calculate the number of molecules in 50 dm^3 of nitrogen gas under these conditions.

[The Avogadro constant = 6.02×10^{23} mol^{-1}. The molar volume of nitrogen gas under the conditions in the airbag is 24 $dm^3\ mol^{-1}$.]

Interpreting the question

- The Avogadro constant is used when you need to work out the number of particles.
- When you are given the molar volume, you will need to calculate the number of moles.

Answering the question

1 Use molar volume to convert 50 dm^3 to moles of N_2.

Number of moles of N_2 = 50/24 = 2.08 mol

2 Use the Avogadro constant to work out the number of molecules in 2.08 mol.

$6.02 \times 10^{23} \times 2.08 = 1.25 \times 10^{24}$ molecules

b Calculate the mass of sodium azide, NaN_3, that would produce 50 dm^3 of nitrogen gas.

Answering the question

1 Molar ratios: $2NaN_3 \rightarrow 2Na + 3N_2$

2 Number of moles: ? ? 2.08

The question asks us to relate sodium azide to nitrogen gas. Using the equation, you can see that every 2 mol of sodium azide (NaN_3) gives 3 mol of nitrogen (N_2). Therefore the number of moles of sodium azide is always two-thirds that of nitrogen.

3 Using ratios: number of moles of sodium azide = ⅔ × 2.08 = 1.39 mol.

4 Convert moles to mass:

- Molar mass of sodium azide = 23 + (14 × 3) = 65 $g\,mol^{-1}$
- Use equation: Number of moles = mass/molar mass
  so mass = number of moles × molar mass = 65 $g\,mol^{-1}$ × 1.39 mol = 90.4 g