Amounts of substances in equations

4.3.2.2 · Quantitative chemistry · revision notes

The balancing numbers in an equation tell you the ratio of the numbers of moles that react and form. Using this, you can calculate the mass of a product from the mass of a reactant, or the mass of reactant needed to make a product. This subtopic is Higher tier only.

Key facts

- Balancing numbers = mole ratio
- moles wanted = moles known × (balancing number of wanted ÷ balancing number of known)
- Masses in an equation = balancing number × M_r
- moles = mass ÷ M_r
- mass = moles × M_r
- Mass ratios work in g, kg or tonnes if the unit stays the same

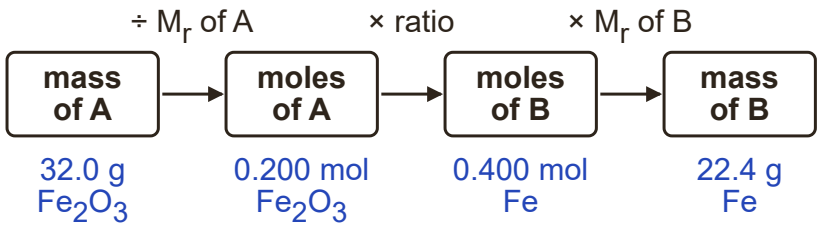
Notes

Equations in moles

- The balancing numbers in a symbol equation give the **ratio of moles** of each substance.
- $Mg + 2HCl \rightarrow MgCl_2 + H_2$ means 1 mol of Mg reacts with 2 mol of HCl to produce 1 mol of $MgCl_2$ and 1 mol of H_2.
- A formula with no number in front counts as 1.
- Masses in an equation: multiply each M_r by its balancing number. For $2Mg + O_2 \rightarrow 2MgO$, 48 g of Mg reacts with 32 g of O_2 to make 80 g of MgO.

The three-step method

- Step 1: moles of the substance you know = mass ÷ M_r.
- Step 2: use the ratio of the balancing numbers to find the moles of the substance you want.
- Step 3: mass of the substance you want = moles × M_r.



The three steps, with the worked example in blue (ratio Fe_2O_3 : Fe = 1 : 2).

- Worked example: what mass of iron forms from 32.0 g of iron(III) oxide? $Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$. Moles of Fe_2O_3 = 32.0 ÷ 160 = 0.200 mol. The ratio is 1 : 2, so moles of Fe = 0.400 mol. Mass of Fe = 0.400 × 56 = 22.4 g.

The ratio (scaling) method

- Work out the masses in the equation (balancing number × M_r), then scale them up or down.
- Example: 160 g of Fe_2O_3 gives 2 × 56 = 112 g of Fe, so 32.0 g gives 112 × 32.0 ÷ 160 = 22.4 g.
- This works in any mass unit: 160 tonnes of Fe_2O_3 gives 112 tonnes of Fe.
- Both methods give the same answer. Use the one you find more reliable.

How to answer each type of question

Use an equation to find amounts in moles 1 to 2 marks **Grade 5**

1. Read the balancing numbers as numbers of moles.
2. Scale the ratio to the amount given.

Example. $N_2 + 3H_2 \rightleftharpoons 2NH_3$

(a) How many moles of hydrogen react with 1 mol of nitrogen? [1 mark]

(b) What is the maximum amount of ammonia that can be made from 6 mol of hydrogen and excess nitrogen? [1 mark]

Model answer.

(a) 3 mol (1)

(b) 6 × 2 ÷ 3 = 4 mol (1)

Calculate the mass of a product 3 to 4 marks **Grade 7**

1. Moles of the known substance = mass ÷ M_r.
2. Use the balancing numbers to find the moles of the product.
3. Mass of product = moles × M_r.

Example. Hydrogen peroxide decomposes:

$2H_2O_2 \rightarrow 2H_2O + O_2$

Calculate the mass of oxygen produced from 3.40 g of hydrogen peroxide.

A_r: H = 1; O = 16 [4 marks]

Model answer.

M_r of H_2O_2 = 34, so moles = 3.40 ÷ 34 = 0.100 mol (1)

ratio 2 : 1, so moles of O_2 = 0.0500 mol (1)

mass of O_2 = 0.0500 × 32 (1)

= 1.60 g (1)

Calculate the mass of reactant needed

3 to 4 marks | Grade 8

1. Work out the M_r values you need.
2. Either find the moles of product and work back through the ratio, or scale the equation masses.
3. Keep the unit the question uses (g, kg or tonnes).

Example. Aluminium is extracted from aluminium oxide by electrolysis.
$2Al_2O_3 \rightarrow 4Al + 3O_2$
Calculate the mass of aluminium oxide needed to produce 54 kg of aluminium.
A_r: O = 16; Al = 27 [4 marks]

Model answer.

M_r of Al_2O_3 = (2 × 27) + (3 × 16) = 102 (1)

2 × 102 = 204 kg of Al_2O_3 gives 4 × 27 = 108 kg of Al (1)

mass needed = 204 × 54 ÷ 108 (1)

= 102 kg (1)

(Or: moles of Al = 54 000 ÷ 27 = 2000 mol; moles of Al_2O_3 = 1000 mol; mass = 1000 × 102 = 102 000 g = 102 kg.)

Don't lose marks

- Ignoring the balancing numbers and assuming a 1 : 1 ratio.
- Multiplying the M_r by the balancing number AND using the mole ratio, so the ratio is counted twice.
- Applying the mole ratio straight to masses in grams, without converting to moles first.
- Forgetting to change kg to g when using moles = mass ÷ M_r.
- Rounding the moles too early.

More tips

Memory tricks

- Mass → moles → ratio → moles → mass. Write the chain at the top of your working.
- Ratio check: if the substance you want has the bigger balancing number, it should have more moles.
- The scaling method saves converting kg or tonnes into grams.
- Check with conservation of mass: the total mass reacting equals the total mass produced.

Exam technique

- Label each line of working (moles of X = ..., moles of Y = ...) so each method mark can be given.
- Use M_r values given in the question; they are there to save you time.
- If you get stuck on one step, carry on with your value: marks for later steps can still be awarded.
- Check that your answer has the unit asked for (g, kg or tonnes) and the right number of significant figures.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 5

Read mole ratios from a balanced equation

The balancing numbers give moles, e.g. $2H_2 + O_2 \rightarrow 2H_2O$ means 2 mol of H_2 react with 1 mol of O_2.

Grade 6

Calculate the masses shown in an equation

For each substance, mass = balancing number × M_r, e.g. $2H_2O$ is 36 g.

Grade 7

Calculate product mass from reactant mass

Moles of known substance → mole ratio → moles of wanted substance → mass.

Grade 8

Calculate the reactant mass needed

Start from the mass of product you want and work back through the mole ratio.

Grade 9

Scale reacting masses in kilograms or tonnes

Mass ratios work in any unit as long as you use the same unit throughout.

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