Using moles to balance equations (HT only)

5.3.2.3 · Chemistry · revision notes

If you know the masses of the reactants and products in a reaction, you can work out the balancing numbers in its equation. Convert each mass to moles, then find the simplest whole-number ratio. This subtopic is Higher tier only.

Key facts

- moles = mass ÷ M_r
- ×2 if you get a .5; ×3 if you get .33 or .67
- Gaseous elements: O_2, H_2, N_2, Cl_2
- Divide all the mole values by the smallest one
- Whole-number mole ratio = balancing numbers
- Missing mass: total mass of reactants = total mass of products

Notes

The method

- Step 1: write the formula of each reactant and product and work out each M_r.
- Step 2: moles of each substance = mass ÷ M_r.
- Step 3: divide every number of moles by the smallest of them.
- Step 4: if any answer is not a whole number, multiply them all by the same number (e.g. a 1.5 means multiply everything by 2).
- Step 5: use the whole numbers as the balancing numbers, then check that the atoms balance.

Worked example

- 4.8 g of magnesium reacts with 3.2 g of oxygen, O_2, to make 8.0 g of magnesium oxide, MgO.
- Moles: Mg = 4.8 ÷ 24 = 0.20; O_2 = 3.2 ÷ 32 = 0.10; MgO = 8.0 ÷ 40 = 0.20.
- Divide by the smallest (0.10): Mg 2, O_2 1, MgO 2.
- Equation: 2Mg + O_2 → 2MgO. Check: 2 Mg atoms and 2 O atoms on each side.



0.20 mol Mg ÷ 0.10 → 2 | 0.10 mol O_2 ÷ 0.10 → 1 | 0.20 mol MgO ÷ 0.10 → 2

$2Mg + O_2 \rightarrow 2MgO$

The mole ratio 0.20 : 0.10 : 0.20 is the same as 2 : 1 : 2, the numbers of particles that react.

Useful points

- Use the formula of the gas as it exists: oxygen gas is O_2 (M_r 32), not O (16).
- The masses obey conservation of mass (here 4.8 + 3.2 = 8.0 g), so you can use this to find a missing mass.
- You may need to rearrange moles = mass ÷ M_r to find a mass or an M_r.
- A ratio very close to a whole number (e.g. 2.01 : 1) comes from rounding: treat it as 2 : 1.
- Given only the moles of the reactants, use their ratio, then balance the atoms to find the product's formula: 0.30 mol of Fe with 0.20 mol of O_2 gives $3Fe + 2O_2 \rightarrow Fe_3O_4$.

How to answer each type of question

Balance an equation from reacting masses 3 to 4 marks **Grade 7**

1. Work out the moles of every substance: mass ÷ M_r.
2. Divide by the smallest number of moles.
3. Multiply up if you need whole numbers.
4. Write the balanced equation.

Example. A student reacted 5.6 g of iron with 10.65 g of chlorine, Cl_2. 16.25 g of iron chloride, $FeCl_3$, formed.
Use these masses to balance the equation.
....Fe + ...Cl_2 → ....$FeCl_3$
A_r: Cl = 35.5; Fe = 56 [4 marks]

Model answer.

moles of Fe = 5.6 ÷ 56 = 0.10	(1)
moles of Cl_2 = 10.65 ÷ 71 = 0.15 and moles of $FeCl_3$ = 16.25 ÷ 162.5 = 0.10	(1)
ratio 0.10 : 0.15 : 0.10 = 1 : 1.5 : 1 = 2 : 3 : 2	(1)
$2Fe + 3Cl_2 \rightarrow 2FeCl_3$	(1)

Find a missing mass, then balance

4 marks | Grade 8

1. Use conservation of mass to find the missing mass.
2. Convert every mass to moles.
3. Divide by the smallest and write the balanced equation.

Example. 2.8 g of nitrogen, N_2, reacted with hydrogen, H_2, to make 3.4 g of ammonia, NH_3.
Use these masses to balance the equation.
$....N_2 + ...H_2 \rightleftharpoons ....NH_3$
A_r: H = 1; N = 14 [4 marks]

Model answer.

mass of H_2 = 3.4 − 2.8 = 0.6 g	(1)
moles: N_2 = 2.8 ÷ 28 = 0.10; H_2 = 0.6 ÷ 2 = 0.30; NH_3 = 3.4 ÷ 17 = 0.20	(1)
dividing by 0.10 gives 1 : 3 : 2	(1)
$N_2 + 3H_2 \rightleftharpoons 2NH_3$	(1)

Balance a combustion equation from masses

4 marks | Grade 9

1. Find the moles of the fuel, oxygen and each product.
2. Divide by the smallest number of moles.
3. Double everything if you get a .5, then write the equation.

Example. When 1.16 g of butane, C_4H_{10}, burns completely, it reacts with 4.16 g of oxygen, O_2, and produces 3.52 g of carbon dioxide and 1.80 g of water.
Use these masses to write a balanced equation for the reaction.
A_r: H = 1; C = 12; O = 16 [4 marks]

Model answer.

moles: C_4H_{10} = 1.16 ÷ 58 = 0.020; O_2 = 4.16 ÷ 32 = 0.13	(1)
CO_2 = 3.52 ÷ 44 = 0.080; H_2O = 1.80 ÷ 18 = 0.10	(1)
dividing by 0.020 gives 1 : 6.5 : 4 : 5, so doubling gives 2 : 13 : 8 : 10	(1)
$2C_4H_{10} + 13O_2 \rightarrow 8CO_2 + 10H_2O$	(1)

Don’t lose marks

- Using the A_r of O (16) for oxygen gas instead of the M_r of O_2 (32).
- Dividing by the largest number of moles instead of the smallest.
- Rounding 1.5 up to 2 instead of doubling every value.
- Using the masses themselves as the ratio instead of converting them to moles.
- Multiplying only some of the values when scaling to whole numbers.

More tips

Memory tricks

- Use a table: substance | mass | M_r | moles | ÷ smallest | whole number. It keeps every step tidy.
- Conservation check: the reactant masses add up to the product masses. If one mass is missing, find it this way first.
- Decimals to spot: .5 → ×2; .33 or .67 → ×3; .25 or .75 → ×4.
- Always finish by counting atoms: if they balance, your ratio is right.

Exam technique

- Show the moles of every substance: each is often a separate mark.
- Write the final balanced equation in full, not just the ratio.
- Keep 2 or 3 significant figures in the moles so the ratio is clear.

What each grade needs

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

Grade 6 — **Convert each reacting mass into moles**
Divide each mass by its M_r, using O_2, H_2, Cl_2 or N_2 for gaseous elements.

Grade 7 — **Find the simplest whole-number mole ratio**
Divide every number of moles by the smallest one.

Grade 7 — **Write the balanced equation from the ratio**
The whole numbers are the balancing numbers in front of each formula.

Grade 8 — **Turn a non-whole ratio into whole numbers**
If you get 1 : 1.5, multiply every number by 2 to get 2 : 3.

Grade 9 — **Find a missing mass, then balance**
Use conservation of mass to find the unknown mass before converting all masses to moles.

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