Volumes of gases

4.3.5 · Quantitative chemistry · revision notes

Equal amounts in moles of different gases occupy the same volume at the same temperature and pressure. At room temperature and pressure, one mole of any gas occupies 24 dm^3. You use this to convert between moles, masses and volumes of gases, and to find the volumes of gases in reactions. This subtopic is in GCSE Chemistry only (not Combined Science) and is Higher tier only.

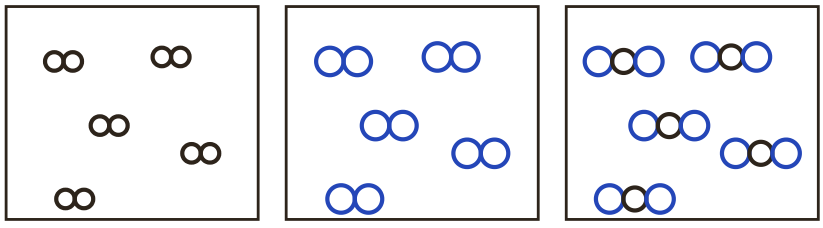
Key facts

- 1 mol of any gas = 24 dm^3 at room temperature and pressure (20 °C, 1 atmosphere)
- volume (dm^3) = moles × 24
- Gas volumes react in the same ratio as the balancing numbers (same temperature and pressure)
- 24 dm^3 = 24 000 cm^3
- moles = volume (dm^3) ÷ 24
- Only use 24 dm^3 for gases, never for solids, liquids or solutions

Notes

The volume of one mole of gas

- Equal amounts in moles of gases occupy the **same volume** under the same conditions of temperature and pressure, whatever the gas.
- At **room temperature and pressure** (20 °C and 1 atmosphere), the volume of 1 mol of any gas is **24 dm^3** (24 000 cm^3).



At room temperature and pressure, 1 mol of any gas has the same number of molecules and the same volume, 24 dm^3.

- volume of gas (dm^3) = moles × 24, so moles = volume (dm^3) ÷ 24.
- For volumes in cm^3, use 24 000 instead of 24.

From mass to volume and back

- Example: volume of 8.0 g of oxygen, O_2, at room temperature and pressure. Moles = 8.0 ÷ 32 = 0.25 mol. Volume = 0.25 × 24 = 6.0 dm^3.
- Example: mass of 600 cm^3 of carbon dioxide at room temperature and pressure. Moles = 600 ÷ 24 000 = 0.025 mol. Mass = 0.025 × 44 = 1.1 g.
- A heavy gas does not take up more room: 1 mol of hydrogen (2 g) and 1 mol of carbon dioxide (44 g) both occupy 24 dm^3.

Gas volumes in equations

- Because 1 mol of every gas has the same volume, the **volumes** of gaseous reactants and products are in the same ratio as the balancing numbers (measured at the same temperature and pressure).
- Example: $2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$. 50 cm^3 of hydrogen reacts with 25 cm^3 of oxygen.
- With a gas in excess, the volume left over = volume added − volume that reacts. The total gas volume after the reaction is this excess plus the gaseous products; leave out any liquid or solid.
- Example: 50 cm^3 of H_2 with 40 cm^3 of O_2: 25 cm^3 of O_2 reacts, so 15 cm^3 of O_2 is left. The water is a liquid, so 15 cm^3 of gas remains.
- This only works for gases. For a solid, liquid or solution in the equation, work with moles and masses instead.
- Mixed example: $CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2$. 5.00 g of $CaCO_3$ = 5.00 ÷ 100 = 0.0500 mol, which makes 0.0500 mol of CO_2. Volume = 0.0500 × 24 = 1.20 dm^3 at room temperature and pressure.

How to answer each type of question

Calculate the volume of a gas from its mass

3 marks | Grade 7

1. Work out the M_r of the gas.
2. Moles = mass ÷ M_r.
3. Volume = moles × 24 dm^3 (or × 24 000 for cm^3).

Example. Calculate the volume of 3.4 g of ammonia gas, NH_3, at room temperature and pressure.
A_r: H = 1; N = 14

The volume of one mole of any gas at room temperature and pressure is 24 dm^3. [3 marks]

Model answer.

M_r = 17, so moles = 3.4 ÷ 17 = 0.20 mol (1)

volume = 0.20 × 24 (1)

= 4.8 dm^3 (1)

Calculate the mass of a volume of gas

3 marks | Grade 8

1. Moles = volume ÷ 24 000 (cm^3) or ÷ 24 (dm^3).
2. Work out the M_r of the gas.
3. Mass = moles × M_r.

Example. A student collected 180 cm^3 of oxygen, O_2, at room temperature and pressure.
Calculate the mass of oxygen collected.
A_r: O = 16

The volume of one mole of any gas at room temperature and pressure is 24 dm^3. [3 marks]

Model answer.

moles = 180 ÷ 24 000 = 0.00750 mol (1)

M_r of O_2 = 32 (1)

mass = 0.00750 × 32 = 0.240 g (1)

Calculate reacting volumes of gases

2 marks | Grade 8

1. Check that the substances are gases, (g), at the same temperature and pressure.
2. Use the balancing numbers as the volume ratio.

Example. Methane burns in oxygen.
$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$

40 cm^3 of methane burns completely. All volumes are measured at the same temperature and pressure.
Calculate the volume of oxygen used and the volume of carbon dioxide produced. [2 marks]

Model answer.

oxygen: 2 × 40 = 80 cm^3 (1)

carbon dioxide: 1 × 40 = 40 cm^3 (1)

Calculate the volume of gas made from a mass of solid

4 marks | Grade 9

1. Moles of the solid = mass ÷ A_r or M_r.
2. Use the balancing numbers to find the moles of gas.
3. Volume = moles × 24 dm^3.
4. Convert to the unit asked for.

Example. Magnesium reacts with hydrochloric acid.
$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$

Calculate the volume of hydrogen, in cm^3, produced when 0.36 g of magnesium reacts with excess acid at room temperature and pressure.
A_r: Mg = 24

The volume of one mole of any gas at room temperature and pressure is 24 dm^3. [4 marks]

Model answer.

moles of Mg = 0.36 ÷ 24 = 0.015 mol (1)

ratio 1 : 1, so 0.015 mol of H_2 (1)

volume = 0.015 × 24 = 0.36 dm^3 (1)

= 360 cm^3 (1)

Don't lose marks

- Using 24 dm^3 for a solid, liquid or solution, e.g. for water or hydrochloric acid in an equation.
- Mixing units: using 24 with a volume in cm^3, or 24 000 with a volume in dm^3.
- Forgetting the balancing numbers when finding volumes of gases in a reaction.
- Using the volume ratio for a solid reactant instead of converting its mass to moles first.
- Dividing by 24 when you should multiply (moles to volume).

More tips

Memory tricks

- 24 for any gas: which gas it is does not matter, only the number of moles.
- For reactions between gases only, skip moles altogether: volumes scale directly with the balancing numbers.
- Answer in cm^3? Use 24 000. Answer in dm^3? Use 24.
- Moles to volume: multiply by 24. Volume to moles: divide by 24.

Exam technique

- Check whether the answer should be in dm^3 or cm^3, and convert at the end.
- Learn that 1 mol of gas occupies 24 dm^3 at room temperature and pressure, in case the value is not given.
- Only apply the 24 dm^3 rule at room temperature and pressure (20 °C and 1 atmosphere).

What each grade needs

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

Grade 6

Recall the volume of one mole of gas

1 mol of any gas occupies 24 dm^3 at room temperature and pressure (20 °C and 1 atmosphere).

Grade 6

Calculate gas volume from moles

Volume (dm^3) = moles × 24.

Grade 7

Calculate gas volume from mass

Find moles = mass ÷ M_r, then multiply by 24.

Grade 7

Calculate moles or mass from gas volume

Moles = volume (dm^3) ÷ 24; mass = moles × M_r.

Grade 8

Find reacting volumes of gases from equations

Gas volumes are in the same ratio as the balancing numbers.

Grade 9

Link masses and gas volumes in reactions

E.g. find the volume of gas made from a given mass of a solid reactant.

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