

3.5 Gas volumes

Name: _____ Class: _____ Date: _____

Total: 19 marks**KEY WORDS** gas volume

Objective

Use equal-volume-equal-moles and equation ratios for reacting gases. Chemistry only, HT. Original questions for spec statement 4.3.5.

1 Key knowledge and worked examples

At the same temperature and pressure, **equal volumes of gases contain equal numbers of moles** – so the volumes of gases in a reaction stand in the **ratio of the balancing numbers**.

At room temperature and pressure (20 °C, one atmosphere), use 24 dm³/mol. Gas volume = amount × 24 dm³/mol; convert cm³ to dm³ before dividing by 24. This approximation does not apply unchanged under other conditions.

Examples: $2 \text{H}_2 + \text{O}_2 \rightarrow 2 \text{H}_2\text{O}$ – 2 volumes of hydrogen react with 1 volume of oxygen; $\text{H}_2 + \text{Cl}_2 \rightarrow 2 \text{HCl}$ – 1 volume + 1 volume gives 2 volumes of product.

Worked example (3 marks). 60 cm³ of methane burns completely: $\text{CH}_4 + 2 \text{O}_2 \rightarrow \text{CO}_2 + 2 \text{H}_2\text{O}$. What volume of oxygen is needed, and of CO₂ formed (all gases measured alike)?

O₂ volume = $2 \times \text{CH}_4 = 2 \times 60 = 120 \text{ cm}^3$; CO₂ volume = $1 \times \text{CH}_4 = 60 \text{ cm}^3$; volumes follow the equation ratio because equal gas volumes hold equal moles.

2 Practice

2.1 What does 1 cm³ of any two gases at the same temperature and pressure contain equally? [1]

2.2 $\text{N}_2 + 3 \text{H}_2 \rightarrow 2 \text{NH}_3$ – 30 cm³ of nitrogen needs what volume of hydrogen? [1]

2.3 What volume of HCl gas forms from 25 cm³ of H₂ reacting with excess Cl₂? [1]

3 Exam-style questions

3.1 (*HT*) 50 cm³ of propane reacts with oxygen: $\text{C}_3\text{H}_8 + 5 \text{O}_2 \rightarrow 3 \text{CO}_2 + 4 \text{H}_2\text{O}$. Calculate the volume of oxygen needed and the volume of carbon dioxide formed. [4]

3.2 (*HT*) 100 cm³ of hydrogen reacts with 50 cm³ of oxygen. Determine whether either gas is in excess and the theoretical volume of steam formed, assuming complete reaction and all volumes compared at the same temperature and pressure with water remaining gaseous. [4]

3.3 (*HT*) Air is about 20 % oxygen. What volume of air supplies the oxygen for complete combustion of 200 cm³ of butane, $2 \text{C}_4\text{H}_{10} + 13 \text{O}_2 \rightarrow 8 \text{CO}_2 + 10 \text{H}_2\text{O}$? [4]

3.4 At room temperature and pressure, 24 dm³ of gas is one mole. Calculate the volume of 4.4 g CO₂ (C = 12, O = 16), giving dm³ and cm³. State why 24 dm³/mol must not be used unchanged for a gas at a different temperature and pressure. [4]

Solutions

2.1 The same number of moles.

2.2 $3 \times 30 = 90 \text{ cm}^3$.

2.3 50 cm^3 .

3.1 $\text{O}_2 = 5 \times 50 = 250 \text{ cm}^3$; $\text{CO}_2 = 3 \times 50 = 150 \text{ cm}^3$.

3.2 Ratio $\text{H}_2 : \text{O}_2 = 2 : 1$; $100 \text{ cm}^3 \text{ H}_2$ needs $50 \text{ cm}^3 \text{ O}_2$ exactly; neither is in excess / both fully react; steam volume = 100 cm^3 .

3.3 Oxygen needed = $13/2 \times 200 = 1300 \text{ cm}^3$; air is 20 % oxygen; air volume = $1300 \div 0.20 = 6500 \text{ cm}^3$.

3.4 $M(\text{CO}_2) = 12 + 2 \times 16 = 44 \text{ g/mol}$, so $n = 4.4/44 = 0.100 \text{ mol}$. $V = 0.100 \times 24 = 2.40 \text{ dm}^3 = 2400 \text{ cm}^3$. Gas molar volume depends on temperature and pressure; the stated approximation is for room conditions.