Mole calculations: formulas and practice

Every formula you need for Topic 3 (stoichiometry), the steps that earn method marks, and 12 practice questions with worked answers at the end.

To find	Formula	Units
moles from mass	**moles = mass ÷ M_r**	mass in g, M_r in g/mol
moles of a gas	**moles = volume ÷ 24**	volume in dm^3 at r.t.p.
moles in a solution	**moles = concentration × volume**	mol/dm^3 × dm^3
concentration in g/dm^3	**concentration = mass ÷ volume**	g ÷ dm^3
number of particles	**particles = moles × 6.02×10^{23}**	Avogadro constant
percentage yield	**actual ÷ theoretical × 100**	%
percentage purity	**mass of pure product ÷ mass of sample × 100**	%
percentage by mass of an element	**(A_r × number of atoms) ÷ M_r × 100**	%

Reacting-mass method (4 steps)

1. Write the balanced equation.
2. Work out the moles of the substance you know.
3. Use the equation ratio to get the moles of the substance you want.
4. Change moles back to mass, volume or concentration.

Empirical formula method

1. Write the mass (or %) of each element.
2. Divide each by its A_r.
3. Divide every answer by the smallest one.
4. Round to whole numbers (×2 if you get .5).

Units to watch: 1 dm^3 = 1000 cm^3, so divide cm^3 by 1000 to get dm^3. 1 kg = 1000 g. Only round the final answer, and give it to the same number of significant figures as the data. Molar gas volume 24 dm^3 is given on the Periodic Table page of the paper; calculators are allowed in every paper.

Practice questions

1. How many moles are in 4.4 g of carbon dioxide, CO_2? (C = 12, O = 16)
2. What is the mass of 0.25 mol of sodium hydroxide, NaOH? (Na = 23, O = 16, H = 1)
3. What volume does 0.50 mol of oxygen gas take up at r.t.p.?
4. How many moles of HCl are in 25.0 cm^3 of 0.100 mol/dm^3 hydrochloric acid?

5. $CaCO_3 \rightarrow CaO + CO_2$. What mass of calcium oxide forms from 50 g of calcium carbonate? (Ca = 40, C = 12, O = 16)
6. A compound contains 2.4 g of carbon and 0.6 g of hydrogen. Find its empirical formula. (C = 12, H = 1)
7. The theoretical yield is 28 g but only 21 g is made. What is the percentage yield?
8. $Mg + 2HCl \rightarrow MgCl_2 + H_2$. What volume of hydrogen at r.t.p. forms from 0.48 g of magnesium? (Mg = 24)
9. Balance: $Al + O_2 \rightarrow Al_2O_3$
10. How many molecules are in 0.50 mol of water? (Avogadro constant = 6.02×10^{23})
11. 20.0 cm^3 of 0.100 mol/dm^3 NaOH exactly neutralises 25.0 cm^3 of HCl. $NaOH + HCl \rightarrow NaCl + H_2O$. Find the concentration of the HCl.
12. What is the percentage by mass of nitrogen in ammonium nitrate, NH_4NO_3? (N = 14, H = 1, O = 16)

Answers with working

1. How many moles are in 4.4 g of carbon dioxide, CO_2? (C = 12, O = 16)
   M_r = 44; 4.4 ÷ 44 = **0.10 mol**
2. What is the mass of 0.25 mol of sodium hydroxide, NaOH? (Na = 23, O = 16, H = 1)
   M_r = 40; 0.25 × 40 = **10 g**
3. What volume does 0.50 mol of oxygen gas take up at r.t.p.?
   0.50 × 24 = **12 dm³**
4. How many moles of HCl are in 25.0 cm³ of 0.100 mol/dm³ hydrochloric acid?
   25.0 ÷ 1000 = 0.0250 dm³; 0.100 × 0.0250 = **0.00250 mol**
5. $CaCO_3 \rightarrow CaO + CO_2$. What mass of calcium oxide forms from 50 g of calcium carbonate? (Ca = 40, C = 12, O = 16)
   moles $CaCO_3$ = 50 ÷ 100 = 0.50; ratio 1 : 1, so 0.50 mol CaO; 0.50 × 56 = **28 g**
6. A compound contains 2.4 g of carbon and 0.6 g of hydrogen. Find its empirical formula. (C = 12, H = 1)
   C: 2.4 ÷ 12 = 0.20; H: 0.6 ÷ 1 = 0.60; ratio 1 : 3 → **CH_3**
7. The theoretical yield is 28 g but only 21 g is made. What is the percentage yield?
   21 ÷ 28 × 100 = **75%**
8. $Mg + 2HCl \rightarrow MgCl_2 + H_2$. What volume of hydrogen at r.t.p. forms from 0.48 g of magnesium? (Mg = 24)
   moles Mg = 0.48 ÷ 24 = 0.020; ratio 1 : 1; 0.020 × 24 = **0.48 dm³**
9. Balance: $Al + O_2 \rightarrow Al_2O_3$
   $4Al + 3O_2 \rightarrow 2Al_2O_3$
10. How many molecules are in 0.50 mol of water? (Avogadro constant = 6.02×10^{23})
    $0.50 \times 6.02 \times 10^{23}$ = **3.01×10^{23} molecules**
11. 20.0 cm³ of 0.100 mol/dm³ NaOH exactly neutralises 25.0 cm³ of HCl. $NaOH + HCl \rightarrow NaCl + H_2O$. Find the concentration of the HCl.
    moles NaOH = 0.100 × 0.0200 = 0.00200; ratio 1 : 1; 0.00200 ÷ 0.0250 = **0.0800 mol/dm³**
12. What is the percentage by mass of nitrogen in ammonium nitrate, NH_4NO_3? (N = 14, H = 1, O = 16)
    M_r = 80; nitrogen = 2 × 14 = 28; 28 ÷ 80 × 100 = **35%**