

Moles, formulae, gas volumes and atom economy

Chemistry grades 11-12 (A Level · IB · Class 11-12) · Worksheet answers

Each answer shows the formula, the substitution with units and the result in bold. Small differences in the last digit may come from rounding of intermediate values, so keep at least one extra figure until the end.

Level: Chemistry grades 11-12 (A Level · IB · Class 11-12) · **Curriculum:** A Level 3.1.2

Problem 1 Moles of salt

1. $n = 117 \div 58.5 = \mathbf{2.00 \text{ mol}}$.
2. $N = 2.00 \times 6.02 \times 10^{23} = \mathbf{1.20 \times 10^{24}}$ formula units.
3. $m = 0.250 \times 58.5 = \mathbf{14.6 \text{ g}}$.

Problem 2 Sodium hydroxide solution

1. $n = c \times V = 0.400 \times 0.250 = \mathbf{0.100 \text{ mol}}$.
2. $m = 0.100 \times 40.0 = \mathbf{4.00 \text{ g}}$.

Problem 3 Unit conversions

1. $250 \times 10^{-6} = \mathbf{2.50 \times 10^{-4} \text{ m}^3}$.
2. $101 \times 10^3 = \mathbf{1.01 \times 10^5 \text{ Pa}}$.
3. $27 + 273 = \mathbf{300 \text{ K}}$.
4. $2.40 \times 10^{-3} = \mathbf{2.40 \times 10^{-3} \text{ m}^3}$.

Problem 4 Formula of an iron oxide

1. $n(\text{Fe}) = 5.60 \div 56.0 = 0.100 \text{ mol}$; $n(\text{O}) = 2.40 \div 16.0 = 0.150 \text{ mol}$.
2. Ratio Fe : O = $0.100 : 0.150 = 2 : 3$.
3. The formula is **Fe₂O₃**.

Problem 5 Vitamin C in a tablet

1. $M = 6 \times 12.0 + 8 \times 1.0 + 6 \times 16.0 = 72.0 + 8.0 + 96.0 = \mathbf{176.0 \text{ g mol}^{-1}}$.
2. $n = 0.500 \text{ g} \div 176.0 \text{ g mol}^{-1} = \mathbf{2.84 \times 10^{-3} \text{ mol}}$.

Problem 6 Why is atom economy 100 %?

1. Atom economy = **100 %**.

2. There is only one product, so every reactant atom ends up in the ethanol. The mass of the desired product equals the total mass of products.

Problem 7 Formula of sodium sulfate

- $n(\text{Na}) = 32.4 \div 23.0 = 1.41 \text{ mol}$; $n(\text{S}) = 22.6 \div 32.1 = 0.704 \text{ mol}$; $n(\text{O}) = 45.0 \div 16.0 = 2.81 \text{ mol}$.
- Dividing by 0.704: 2.00 : 1.00 : 4.00. The empirical formula is **Na₂SO₄**.

Problem 8 Carbon dioxide at room conditions

$T = 298 \text{ K}$ and $p = 1.00 \times 10^5 \text{ Pa}$. $V = nRT \div p = (0.0800 \times 8.31 \times 298) \div 100\,000 = 1.98 \times 10^{-3} \text{ m}^3 = \mathbf{1.98 \text{ dm}^3}$.

Problem 9 Gas in a cylinder

- $T = 293 \text{ K}$; $V = 2.40 \times 10^{-3} \text{ m}^3$. $n = pV \div RT = (1.50 \times 10^5 \times 2.40 \times 10^{-3}) \div (8.31 \times 293) = 360 \div 2435 = \mathbf{0.148 \text{ mol}}$.
- $m = 0.1479 \times 32.0 = \mathbf{4.73 \text{ g}}$.

Problem 10 Molar mass of a volatile liquid

- $V = 62.0 \times 10^{-6} = 6.20 \times 10^{-5} \text{ m}^3$; $p = 1.01 \times 10^5 \text{ Pa}$; $T = 373 \text{ K}$.
- $n = pV \div RT = (1.01 \times 10^5 \times 6.20 \times 10^{-5}) \div (8.31 \times 373) = 6.262 \div 3099.6 = \mathbf{2.02 \times 10^{-3} \text{ mol}}$.
- $M = m \div n = 0.150 \div 0.00202 = \mathbf{74 \text{ g mol}^{-1}}$.

Problem 11 Phosphorus oxide

- $2 \times 31.0 + 5 \times 16.0 = 62.0 + 80.0 = \mathbf{142.0}$.
- $284 \div 142.0 = 2$, so the molecular formula is **P₄O₁₀**.

Problem 12 Burning an organic liquid

- $n(\text{CO}_2) = 1.76 \div 44.0 = 0.0400 \text{ mol}$, so $n(\text{C}) = \mathbf{0.0400 \text{ mol}}$. $n(\text{H}_2\text{O}) = 0.900 \div 18.0 = 0.0500 \text{ mol}$, so $n(\text{H}) = \mathbf{0.100 \text{ mol}}$.
- $m(\text{C}) = 0.0400 \times 12.0 = 0.480 \text{ g}$; $m(\text{H}) = 0.100 \times 1.0 = 0.100 \text{ g}$; $m(\text{O}) = 0.740 - 0.480 - 0.100 = \mathbf{0.160 \text{ g}}$, so $n(\text{O}) = 0.0100 \text{ mol}$.
- $\text{C} : \text{H} : \text{O} = 0.0400 : 0.100 : 0.0100 = 4 : 10 : 1$. The empirical formula is **C₄H₁₀O** (mass 74.0), and $M = 74.0$, so the molecular formula is **C₄H₁₀O**.

Problem 13 Atom economy in iron making

- $2 \times 55.8 = 111.6$; $3 \times 44.0 = 132.0$; total = 243.6.
- Atom economy = $111.6 \div 243.6 \times 100 = \mathbf{45.8 \%}$.

Problem 14 Percentage yield of ethyl ethanoate

1. $n(\text{ethanol}) = 4.60 \div 46.0 = 0.100 \text{ mol}$, so the maximum mass = $0.100 \times 88.0 = \mathbf{8.80 \text{ g}}$.
2. $\text{Yield} = 3.10 \div 8.80 \times 100 = \mathbf{35.2 \%}$.

Problem 15 Hydrated copper sulfate

1. $m(\text{H}_2\text{O}) = 2.50 - 1.60 = 0.90 \text{ g}$; $n = 0.90 \div 18.0 = \mathbf{0.0500 \text{ mol}}$.
2. $n(\text{CuSO}_4) = 1.60 \div 159.6 = \mathbf{0.0100 \text{ mol}}$.
3. $0.0500 \div 0.0100 = \mathbf{x = 5}$.

Problem 16 Reading a pressure graph

1. $\text{Gradient} = 150 \div 2.0 = \mathbf{75 \text{ kPa dm}^3}$. Since $p = nRT \times (1/V)$, the slope is nRT ; $1 \text{ kPa} \times 1 \text{ dm}^3 = 10^3 \text{ Pa} \times 10^{-3} \text{ m}^3 = 1 \text{ J}$, so it is 75 J .
2. $n = 75 \div (8.31 \times 300) = 75 \div 2493 = \mathbf{0.0301 \text{ mol}}$.
3. The gradient **increases** to $nR \times 350 = 87.5 \text{ J}$ (it is proportional to T).

Problem 17 Identifying a gas from density

1. From $pV = nRT$ with $n = m/M$ and $\rho = m/V$: $pV = (m/M)RT$, so $M = pRT / p$.
2. $\rho = 1.94 \text{ g dm}^{-3} = 1940 \text{ g m}^{-3}$. $M = (1940 \times 8.31 \times 298) \div 100\,000 = \mathbf{48.0 \text{ g mol}^{-1}}$.
3. O_2 is 32.0, O_3 is 48.0 and N_2O is 44.0. The gas is **ozone, O_3** .

Problem 18 Gas from baking soda

1. $n(\text{NaHCO}_3) = 4.20 \div 84.0 = \mathbf{0.0500 \text{ mol}}$.
2. 2 mol NaHCO_3 give 1 mol H_2O and 1 mol CO_2 , so 0.0500 mol gives $0.0250 + 0.0250 = \mathbf{0.0500 \text{ mol gas}}$.
3. $T = 473 \text{ K}$. $V = nRT \div p = (0.0500 \times 8.31 \times 473) \div 100\,000 = 1.97 \times 10^{-3} \text{ m}^3 = \mathbf{1.97 \text{ dm}^3}$.

Problem 19 Two routes to hydrogen

1. Route A: $3 \times 2.0 = 6.0$; total products = $28.0 + 6.0 = 34.0$; economy = $6.0 \div 34.0 \times 100 = \mathbf{17.6 \%}$. Route B: $4 \times 2.0 = 8.0$; total = $44.0 + 8.0 = 52.0$; economy = $8.0 \div 52.0 \times 100 = \mathbf{15.4 \%}$.
2. Route A has the higher atom economy because the waste product CO is lighter than CO_2 . Atom economy ignores the yield, energy use, rate and the hazard of the by-products, so the better route also depends on those.

Problem 20 Hydrocarbon from gas data

1. $n = pV \div RT = (1.00 \times 10^5 \times 1.55 \times 10^{-4}) \div (8.31 \times 373) = 5.00 \times 10^{-3} \text{ mol}$; $M = 0.280 \div 0.00500 = \mathbf{56 \text{ g mol}^{-1}}$.

2. In 100 g: $C = 85.7 \div 12.0 = 7.14$ mol; $H = 14.3 \div 1.0 = 14.3$ mol. Ratio 1 : 2, so the empirical formula is **CH₂** (14.0).

3. $56.0 \div 14.0 = 4$, so the molecular formula is **C₄H₈**.