

Moles, formulae, gas volumes and atom economy

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

Name: _____ Date: _____ Class: _____

These problems train the core tools of quantitative chemistry: converting between mass, moles, particles, solutions and gases, finding empirical and molecular formulae from masses or combustion data, and using $pV = nRT$ with the correct units.

They suit A Level, IB Chemistry SL and CBSE Class 11-12. The early problems are single steps, and the last five combine several ideas and need careful units.

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

Problem 1 Moles of salt (easy)

Chiamaka in Lagos weighs 117 g of sodium chloride ($M = 58.5 \text{ g mol}^{-1}$).

1. Calculate the amount of NaCl in mol.
2. Calculate the number of formula units, using $6.02 \times 10^{23} \text{ mol}^{-1}$.
3. Calculate the mass of 0.250 mol of NaCl.

Problem 2 Sodium hydroxide solution (easy)

A student in Leeds makes 0.250 dm^3 of sodium hydroxide solution of concentration $0.400 \text{ mol dm}^{-3}$.

1. Calculate the amount of NaOH dissolved.
2. Calculate the mass of NaOH needed ($M = 40.0 \text{ g mol}^{-1}$).

Problem 3 Unit conversions (easy)

Convert each value to the unit needed for $pV = nRT$.

1. 250 cm^3 to m^3
2. 101 kPa to Pa
3. 27°C to K
4. 2.40 dm^3 to m^3

Problem 4 Formula of an iron oxide (easy)

A sample contains 5.60 g of iron and 2.40 g of oxygen (Ar: Fe 56.0, O 16.0).

1. Calculate the amount of each element.
2. Find the simplest whole-number ratio.
3. Write the empirical formula.

Problem 5 Vitamin C in a tablet (easy)

Vitamin C is $\text{C}_6\text{H}_8\text{O}_6$ (Ar: C 12.0, H 1.0, O 16.0). A tablet contains 500 mg.

1. Calculate the molar mass.
2. Calculate the amount in mol in one tablet.

Problem 6 Why is atom economy 100 %? (easy)

Ethene reacts with steam: $\text{C}_2\text{H}_4 + \text{H}_2\text{O} \rightarrow \text{C}_2\text{H}_5\text{OH}$.

1. State the atom economy for making ethanol this way.
2. Explain why it takes this value.

Problem 7 Formula of sodium sulfate (medium)

A compound contains 32.4 % sodium, 22.6 % sulfur and 45.0 % oxygen by mass (Ar: Na 23.0, S 32.1, O 16.0).

1. Calculate the amount of each element in 100 g.
2. Deduce the empirical formula.

Problem 8 Carbon dioxide at room conditions (medium)

Take $R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$.

1. Calculate the volume in dm^3 of 0.0800 mol of carbon dioxide at 25 °C and 100 kPa.

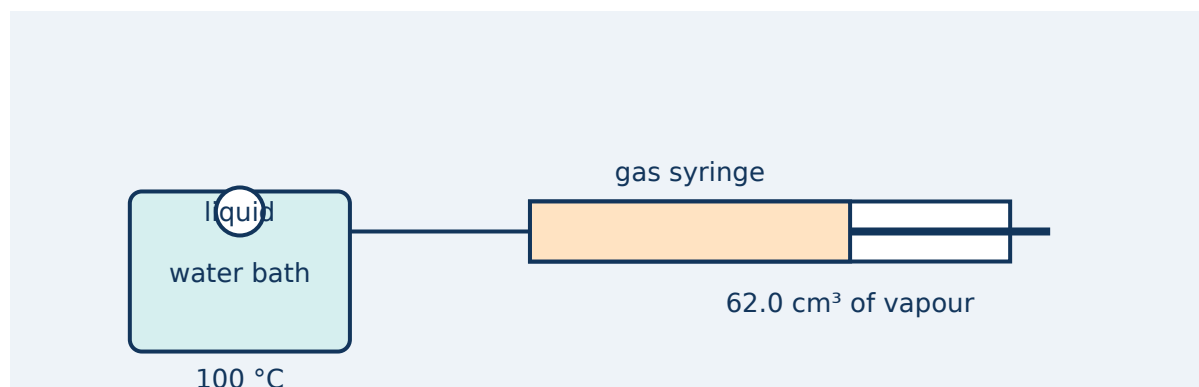
Problem 9 Gas in a cylinder (medium)

A cylinder of volume 2.40 dm^3 holds oxygen at $1.50 \times 10^5 \text{ Pa}$ and 20 °C.

1. Calculate the amount of oxygen in mol.
2. Calculate its mass ($M = 32.0 \text{ g mol}^{-1}$).

Problem 10 Molar mass of a volatile liquid (medium)

A student injects 0.150 g of a volatile liquid into the heated gas syringe. It becomes 62.0 cm^3 of vapour at 100 °C and 101 kPa.



A weighed sample is vaporised in a heated gas syringe and the volume of vapour is read.

1. Convert the data to SI units.
2. Calculate the amount of vapour.
3. Calculate the molar mass of the liquid.

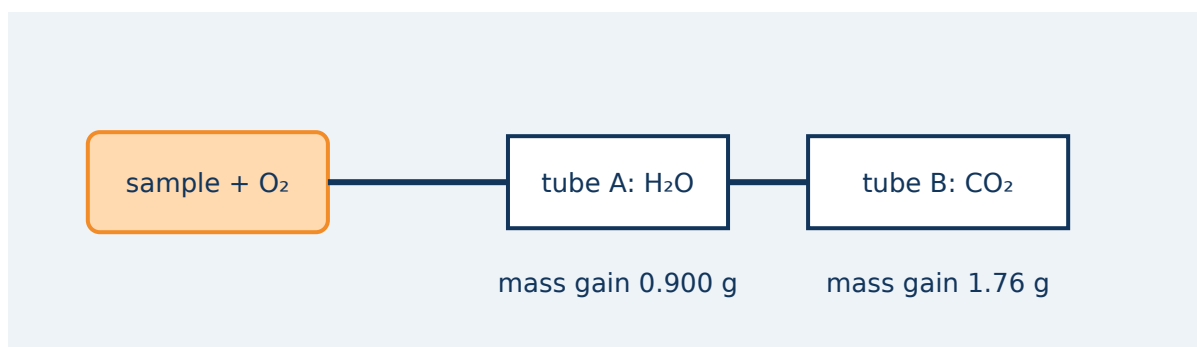
Problem 11 Phosphorus oxide (medium)

An oxide of phosphorus has empirical formula P_2O_5 and molar mass 284 g mol^{-1} (Ar: P 31.0, O 16.0).

1. Calculate the mass of the empirical formula unit.
2. Deduce the molecular formula.

Problem 12 Burning an organic liquid (medium)

A compound of carbon, hydrogen and oxygen (0.740 g , $M = 74.0 \text{ g mol}^{-1}$) burns completely. The absorbers gain 0.900 g of water and 1.76 g of carbon dioxide.



The mass gain of each absorber gives the amount of H₂O and CO₂ formed.

1. Calculate the amount of C in the CO₂ and the amount of H in the water.
2. Calculate the mass of oxygen in the sample by difference.
3. Deduce the empirical and molecular formulae.

Problem 13 Atom economy in iron making (medium)

Iron is made in the reaction $Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$ (Ar of Fe = 55.8; Mr of CO₂ = 44.0).

1. Calculate the total mass of products per mole of equation.
2. Calculate the atom economy for iron.

Problem 14 Percentage yield of ethyl ethanoate (medium)

Emma in Leeds heats 4.60 g of ethanol ($M = 46.0$) with excess ethanoic acid and obtains 3.10 g of ethyl ethanoate ($M = 88.0$). The equation is 1 : 1.

1. Calculate the maximum mass of ester.
2. Calculate the percentage yield.

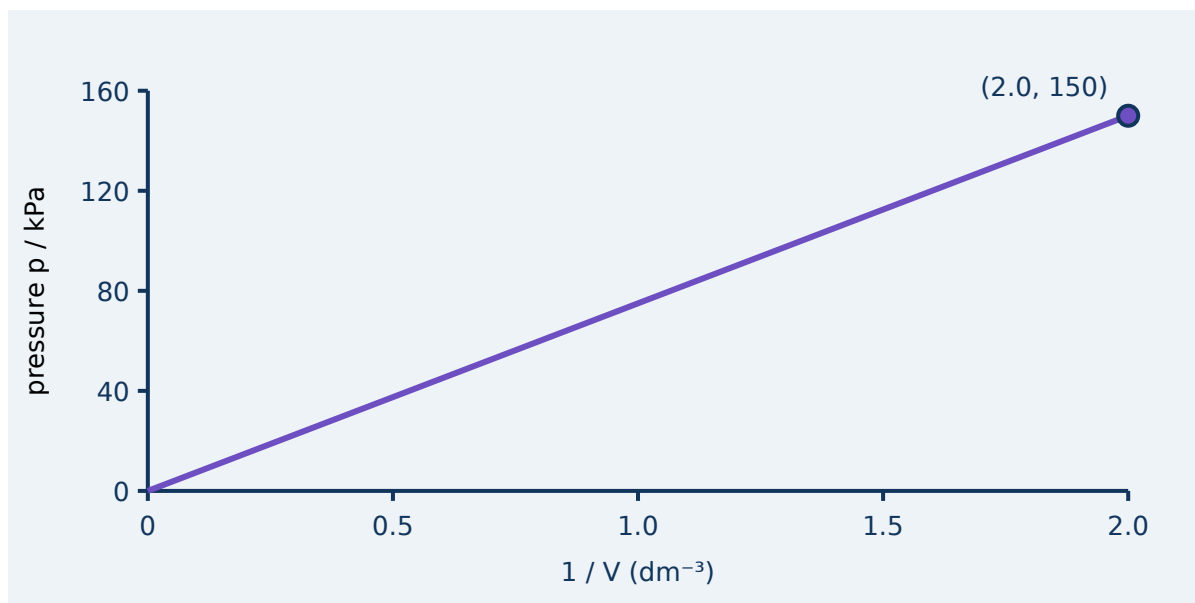
Problem 15 Hydrated copper sulfate (medium)

Heating 2.50 g of $CuSO_4 \cdot xH_2O$ leaves 1.60 g of anhydrous $CuSO_4$ ($M = 159.6$; $H_2O = 18.0$).

1. Calculate the mass and the amount of water lost.
2. Calculate the amount of CuSO_4 .
3. Deduce the value of x .

Problem 16 Reading a pressure graph (hard)

The graph is for a fixed amount of gas at 300 K, with V in dm^3 .



Pressure of a fixed sample of gas at 300 K against $1/V$.

1. Calculate the gradient in kPa dm^3 and explain why it equals nRT in joules.
2. Calculate n .
3. State what happens to the gradient if the temperature rises to 350 K.

Problem 17 Identifying a gas from density (hard)

A gas has density 1.94 g dm^{-3} at 25°C and 100 kPa .

1. Show that $M = \rho RT / p$, where ρ is the density.
2. Calculate the molar mass.
3. Suggest the gas from O_2 , O_3 and N_2O (Ar: N 14.0, O 16.0).

Problem 18 Gas from baking soda (hard)

Sodium hydrogencarbonate decomposes on heating: $2\text{NaHCO}_3(\text{s}) \rightarrow \text{Na}_2\text{CO}_3(\text{s}) + \text{H}_2\text{O}(\text{g}) + \text{CO}_2(\text{g})$. A baker heats 4.20 g ($M = 84.0$) to 200°C at 100 kPa .

1. Calculate the amount of NaHCO_3 .
2. Calculate the total amount of gas formed, counting steam and CO_2 .
3. Calculate the volume of gas in dm^3 .

Problem 19 Two routes to hydrogen (hard)

Route A: $\text{CH}_4 + \text{H}_2\text{O} \rightarrow \text{CO} + 3\text{H}_2$. Route B: $\text{CH}_4 + 2\text{H}_2\text{O} \rightarrow \text{CO}_2 + 4\text{H}_2$. (Mr: CO 28.0, CO_2 44.0,

H₂ 2.0.)

1. Calculate the atom economy for hydrogen in each route.
2. Compare them and give one reason atom economy alone cannot decide the better route.

Problem 20 Hydrocarbon from gas data (hard)

A hydrocarbon contains 85.7 % carbon by mass. A 0.280 g sample forms 155 cm³ of vapour at 100 °C and 100 kPa.

1. Calculate the amount of vapour and the molar mass.
2. Find the empirical formula.
3. Deduce the molecular formula.