

Concentration, separation and absorbance

AP Chemistry · Lesson

Quick answer: Molarity is moles of solute per litre of solution, and dilution follows $M_1V_1 = M_2V_2$. Chromatography separates mixtures by how strongly components bind to a stationary phase, measured by R_f . The Beer-Lambert law, $A = \epsilon bc$, shows that absorbance is proportional to concentration, so a calibration line gives the concentration of an unknown.

Level: AP Chemistry · **Curriculum:** AP Chem Unit 3

How do you measure the concentration of a solution?

Definition

Molarity (M) is the amount of solute in moles per litre of solution: $M = n/V$. A solution of 0.400 M NaCl contains 0.400 mol of NaCl in every litre of solution, not of solvent.

Quantity	Definition	Unit
Molarity, M	moles of solute / litres of solution	mol/L
Mass percent	mass of solute / mass of solution $\times 100$	%
Parts per million	milligrams of solute per litre of dilute aqueous solution	ppm (mg/L)
Mole fraction, x	moles of one component / total moles	no unit

Worked example 1

Aarav in Pune dissolves 5.85 g of NaCl (58.44 g/mol) in water and makes up the solution to 250.0 mL. Find the molarity.

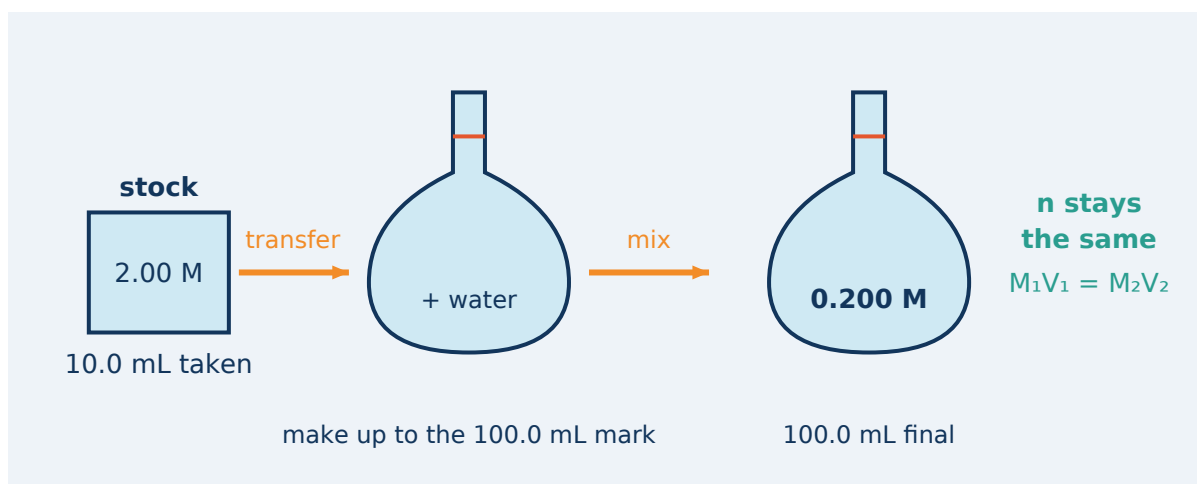
$$n = 5.85 / 58.44 = 0.1001 \text{ mol}$$

$$V = 0.2500 \text{ L}$$

$$M = 0.1001 / 0.2500 = \mathbf{0.400 \text{ mol/L}}$$

How do you dilute a solution?

Adding solvent changes the volume but not the amount of solute. Because $n = MV$ is the same before and after, $M_1V_1 = M_2V_2$. Always add the stock to water, then dilute to the mark of a volumetric flask, since the final volume is what counts, not the volume of water added.



Dilution keeps the amount of solute constant while the volume grows tenfold.

Worked example 2

How much 2.00 M stock is needed to make 100.0 mL of 0.200 M solution?

$$V_1 = M_2V_2 / M_1 = (0.200 \times 100.0) / 2.00 = \mathbf{10.0 \text{ mL}}$$

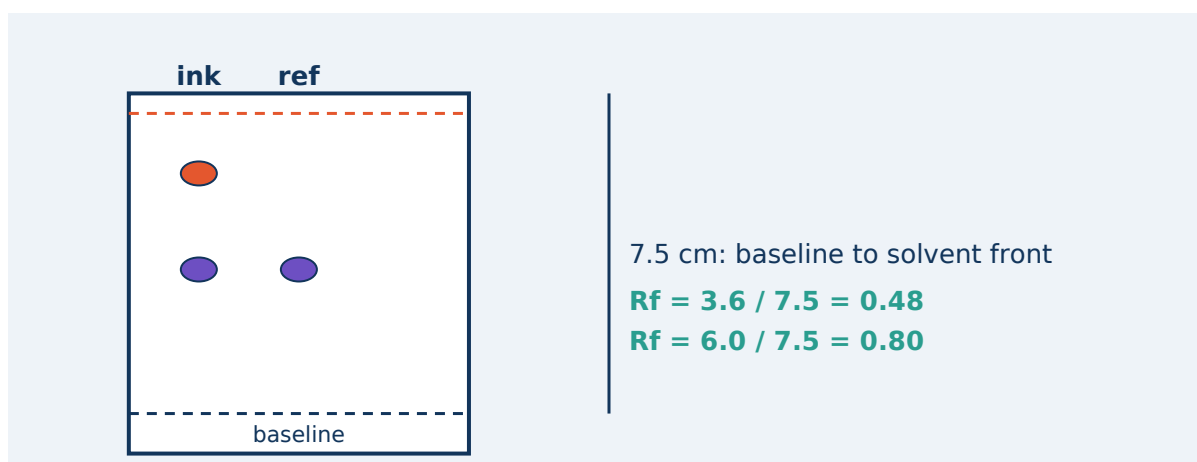
How does chromatography separate a mixture?

In chromatography a mixture is carried by a **mobile phase** (the solvent) over a **stationary phase** (paper or a silica layer). Each component keeps swapping between the two phases. A component that is attracted more strongly to the stationary phase spends less time in the moving solvent and travels less. On silica, polar molecules stick more strongly, so they move less than nonpolar ones in a nonpolar solvent.

Formula

R_f = distance moved by the spot / distance moved by the solvent front

Both distances are measured from the baseline in the same unit. R_f is a number between 0 and 1 with no unit.



A TLC plate: the ink contains the reference dye (same R_f) and a second, less polar dye.

The mixture is separated; the spot with $R_f = 0.48$ matches the reference dye. Other separation methods exploit different properties: filtration separates a solid from a liquid, simple distillation

separates a solvent from a dissolved solid, and fractional distillation separates liquids with different boiling points.

What is the Beer-Lambert law?

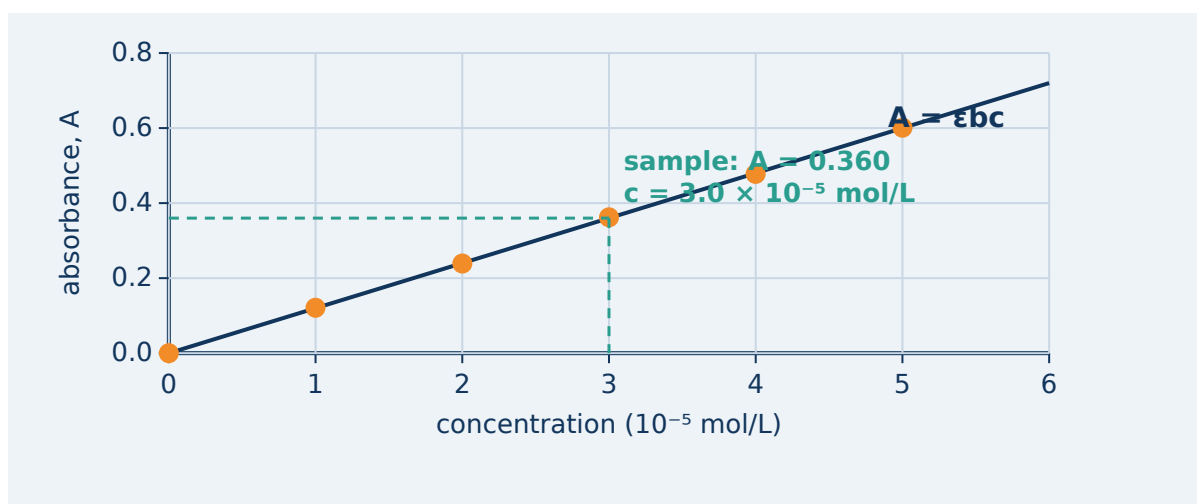
A coloured solution absorbs some wavelengths of light. A spectrophotometer sends light of one wavelength through a cuvette and compares the transmitted intensity I with the intensity I_0 through a blank. The transmittance is $T = I/I_0$ and the absorbance is $A = -\log T$.

Key law

Beer-Lambert law: $A = \epsilon bc$

A = absorbance (no unit), ϵ = molar absorptivity ($\text{L}/(\text{mol}\cdot\text{cm})$), b = path length of the cuvette (cm), c = concentration (mol/L). At fixed wavelength and path length, A is proportional to c .

Choose the wavelength of maximum absorbance, λ_{max} , where the line is steepest and the measurement is most sensitive. Measure a set of standard solutions, plot absorbance against concentration, and read the unknown from the line.



A calibration line: absorbance is proportional to concentration.

Worked example 3

A dye solution in a 1.00 cm cuvette has $A = 0.600$. For this dye $\epsilon = 1.20 \times 10^4 \text{ L}/(\text{mol}\cdot\text{cm})$. Find c .

$$c = A/(\epsilon b) = 0.600 / (1.20 \times 10^4 \times 1.00)$$

$$\mathbf{c = 5.00 \times 10^{-5} \text{ mol/L}}$$

Transmittance T	Percentage T	Absorbance A = $-\log T$
1.00	100 %	0
0.50	50 %	0.301
0.25	25 %	0.602
0.10	10 %	1.000

Common mistake

Do not subtract the volume of the stock from the final volume when diluting, and do not use a calibration line beyond the highest standard. At high absorbance (above about 1.5) the line bends because too little light reaches the detector, so dilute the sample instead.

Lina's tip

For any dilution, ask what stays the same: the moles. Write $n = MV$ for the stock, set it equal to $n = MV$ for the final solution, and solve for the unknown.

Key points to remember

- Molarity $M = n/V$ in mol/L; dilution: $M_1V_1 = M_2V_2$ (moles of solute stay constant).
- R_f = distance moved by spot / distance moved by solvent front, between 0 and 1.
- Beer-Lambert law: $A = \epsilon bc$, with ϵ in $L/(\text{mol} \cdot \text{cm})$, b in cm and c in mol/L.
- $A = -\log T$; $T = 50\%$ gives $A = 0.301$ and $T = 10\%$ gives $A = 1.000$.
- Use λ_{max} and a calibration line; dilute samples with A above about 1.5.

Concentration, separation and absorbance: frequently asked questions

What is the difference between molarity and molality?

Molarity is moles of solute per litre of solution and changes slightly with temperature. Molality is moles of solute per kilogram of solvent and does not depend on temperature.

Why does the flask have a mark and not a mass of water to add?

The final volume of the solution is not the same as the sum of the volumes mixed, because solute and solvent occupy space together. A volumetric flask fills the solution to a calibrated mark so the volume is exact.

Why do we measure absorbance at λ_{max} ?

At the wavelength of maximum absorbance, the absorbance changes most for a given change in concentration, so the calibration line is steepest and small differences in concentration are detected more reliably.

What does a blank do in spectrophotometry?

The blank is the solvent and cuvette without the dye. Setting it to $A = 0$ removes the absorption and reflection of the cuvette and solvent, so the reading depends only on the dye.

Can two different compounds have the same R_f value?

Yes, in one solvent two compounds can have similar R_f values. Matching R_f in several solvents, or using a different technique, gives stronger evidence that two spots are the same compound.