Essential Question

How do intermolecular forces help us separate a solution?

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Why Not Filtration?

- Filtration only removes **undissolved** solids, like sand in water.
- Dissolved particles, like salt ions or sugar molecules, are far smaller than the holes in filter paper, so they pass right through.
- To separate the parts of a solution, we need methods based on differences in **intermolecular forces (IMFs)**.

The sand grains never dissolved, so they get caught on the filter paper. Everything that dissolved is spread out as individual particles and passes through with the water.

Separation Methods

- For a solution, chromatography separates components by how strongly they are attracted to two different phases, and distillation separates them by boiling point.
- Both come down to differences in IMFs.

Filtration separates by particle size, so it only works on heterogeneous mixtures.

Chromatography Setup

- **Stationary phase:** stays in place. In paper chromatography, this is the paper.
- **Mobile phase:** the solvent, which moves up the paper by capillary action and carries the sample with it.
- **Solvent front:** the line where the solvent stops moving.

Draw the start line in **pencil**, because pen ink would separate too.

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How Chromatography Separates

- More strongly attracted to the **mobile phase** → travels farther
- More strongly attracted to the **stationary phase** → stays near the start
- Different IMF strengths lead to different distances, and that is how the mixture separates.

Every component in the mixture is attracted to both phases, like a tug of war. The mobile phase pulls each component along, and the stationary phase holds it back.

Polarity and Distance

Stationary phase	Mobile phase	Travels farthest
Polar (paper)	Less polar solvent	Least polar component
Nonpolar coating	Polar solvent (water)	Most polar component

Types of Chromatography

- **Paper:** the stationary phase is the paper.
- **Thin-layer (TLC):** a glass or plastic plate coated with a thin layer of solid, usually silica.
- **Column:** a tube packed with solid. Solvent is poured in at the top, and each component can be collected as it comes out the bottom.

Different equipment, same idea: components separate based on their attraction to the stationary phase versus the mobile phase.

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Retention Factor (R_f)

- Measure both distances from the **start line**.
- R_f is always between 0 and 1 and has no units, because the centimeters cancel.
- Higher R_f → more attracted to the mobile phase. Lower R_f → more attracted to the stationary phase.

R_f = distance spot traveled ÷ distance solvent traveled

Distillation

- Separates liquids with different boiling points.
- Heat the mixture: the component with the lower boiling point vaporizes first.
- The condenser, cooled by flowing water, turns the vapor back into a liquid called the distillate.

The thermometer at the top measures the temperature of the vapor that is leaving the flask, so you can tell which component is coming over.

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Distillation and IMFs

- Weaker IMFs → higher vapor pressure → lower boiling point
- The component with the weaker IMFs boils off first.
- Ethanol (78 °C) distills before water (100 °C).

The first distillate is rich in ethanol, but it will not be perfectly pure.

Example: Calculating R_f

Try it first!

In a paper chromatography experiment, the solvent front moved 8.0 cm from the start line. A red dye moved 2.4 cm. What is the R_f value of the red dye?

Example: Reading a Chromatogram

Try it first!

Three dyes were separated on polar paper using a nonpolar solvent. Which dye is the most polar? Justify your answer using intermolecular forces.

Diagram: Chromatogram of three dyes. Dye A traveled farthest, close to the solvent front. Dye C traveled a medium distance. Dye B traveled the shortest distance, closest to the start line.

Example: Predicting Distillation Order

Try it first!

A mixture of pentane (C_5H_{12}) and hexane (C_6H_{14}) is distilled. Which compound collects first in the receiving flask? Justify your answer using intermolecular forces.

Example: Choosing a Method

Try it first!

Choose the best method to separate each mixture, and explain your choice: (a) sand and water, (b) ethanol and water, (c) the dyes in black ink.

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Big Ideas

- Filtration only separates undissolved solids. It cannot separate the parts of a solution.
- Chromatography separates components by their attraction to the stationary phase versus the mobile phase.
- R_f = distance spot traveled ÷ distance solvent traveled, always between 0 and 1.
- In distillation, the component with weaker IMFs has a higher vapor pressure and boils off first.