N31 - SOLUTIONS

Separation Techniques and Concentration Calculations

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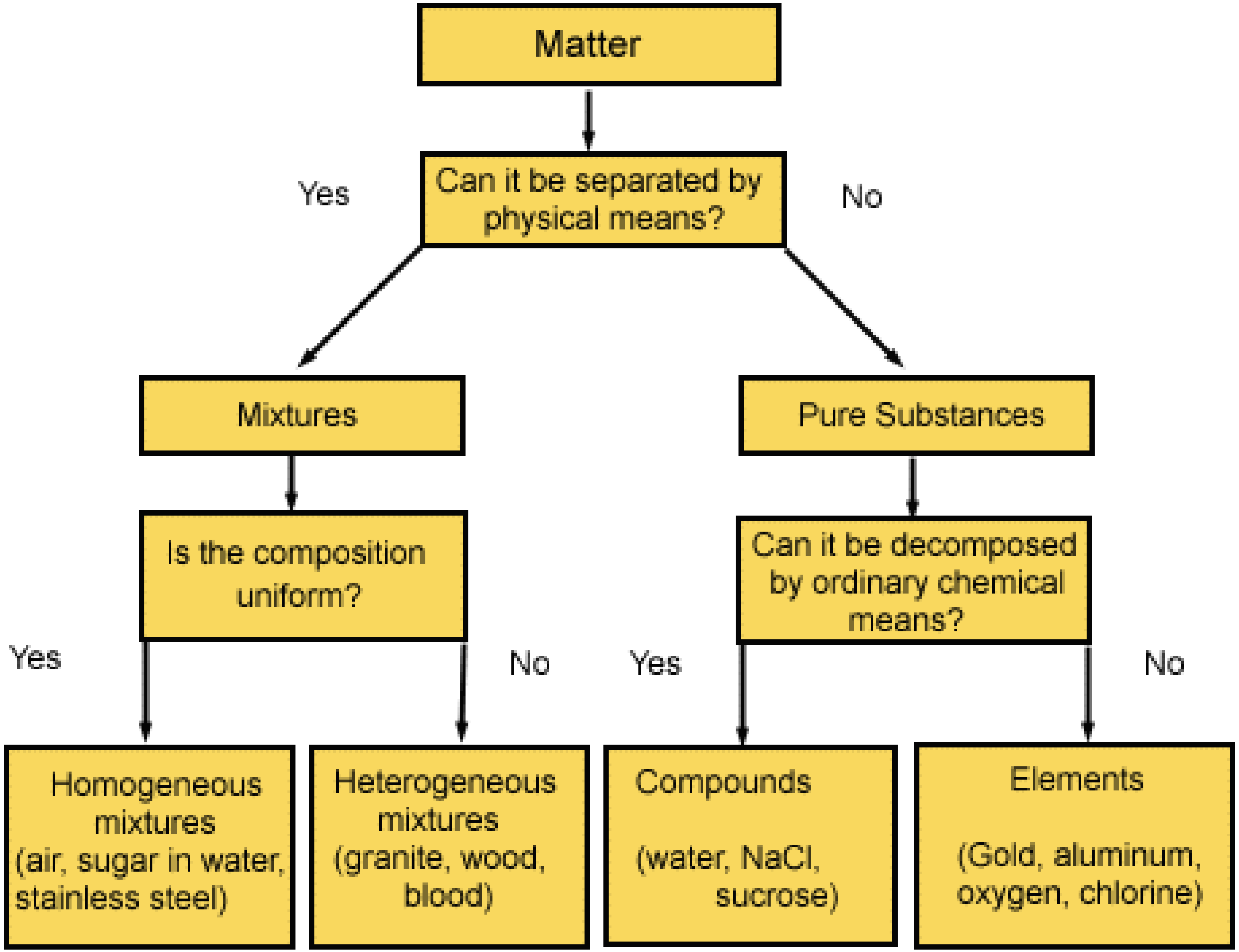
Target: I can describe ways to separate the components in a solution and can perform various concentration related calculations.

Classification of Matter

Solutions are homogeneous mixtures



Classification of Matter

Homogeneous

- “the macroscopic properties do not vary throughout the sample”
- It is “uniformly mixed”

Heterogeneous

- “the macroscopic properties depend on the location in the mixture”
- It is “NOT uniformly mixed”

Solute

A solute is the dissolved substance in a solution.

Salt in salt water

Sugar in soda drinks

Carbon dioxide in soda drinks

Solvent

A solvent is the dissolving medium in a solution.

Water in salt water

Water in soda

Types of Solutions

Solution Phase	Solute Phase	Solvent Phase	Example
Gaseous Solutions	Gas Liquid *Solid**	Gas Gas *Gas**	Air (mostly N_2 and O_2) Humid air (H_2O droplets in air) *Moth balls**
Liquid solutions	Gas Liquid Solid	Liquid Liquid Liquid	Soda (CO_2 in H_2O) Rubbing Alcohol (alcohol in H_2O) Seawater (NaCl in H_2O)
Solid solutions	*Gas** Liquid Solid	*Solid** Solid Solid	*Gas Stove Lighter (H_2 and Pd)** Dental fillings and other Amalgams Brass Alloy (Zn in Cu)

*Combinations in italics and with a * are rare, very few “normal” examples. Most charts leave them off because there are so few examples – they are still possible, just rare*

Separating Components of Mixtures and Solutions

Heterogeneous

Separation techniques take advantage of things such as particle size or location.

Examples:

- Solid + Liquid/Aqueous → **Filtration**
- Two phases that are not miscible → **Decanting**
  (hard to do well...not sure AP would ask you about it?)

Separating Components of Mixtures and Solutions

Homogeneous Solution

Separation techniques take advantage of things such as differences in intermolecular forces.

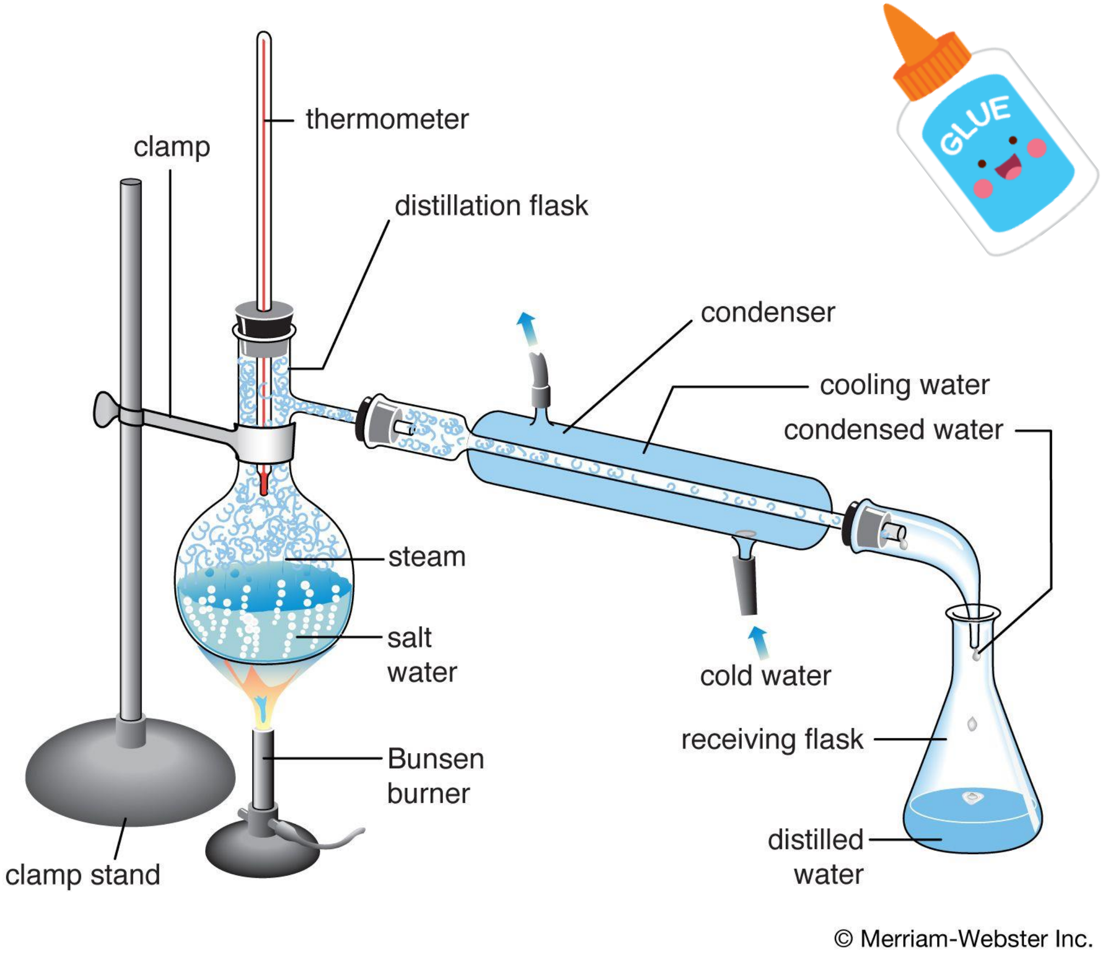
Examples:

- **Distillation** → Differences in Boiling Point
- **Chromatography** → Differences in IMFs btwn mobile/stationary phases

Distillation

Less IMFs

- Higher Vapor Pressure, lower Boiling Point
- Therefore, will boil off sooner, at a lower temp.



More IMFs

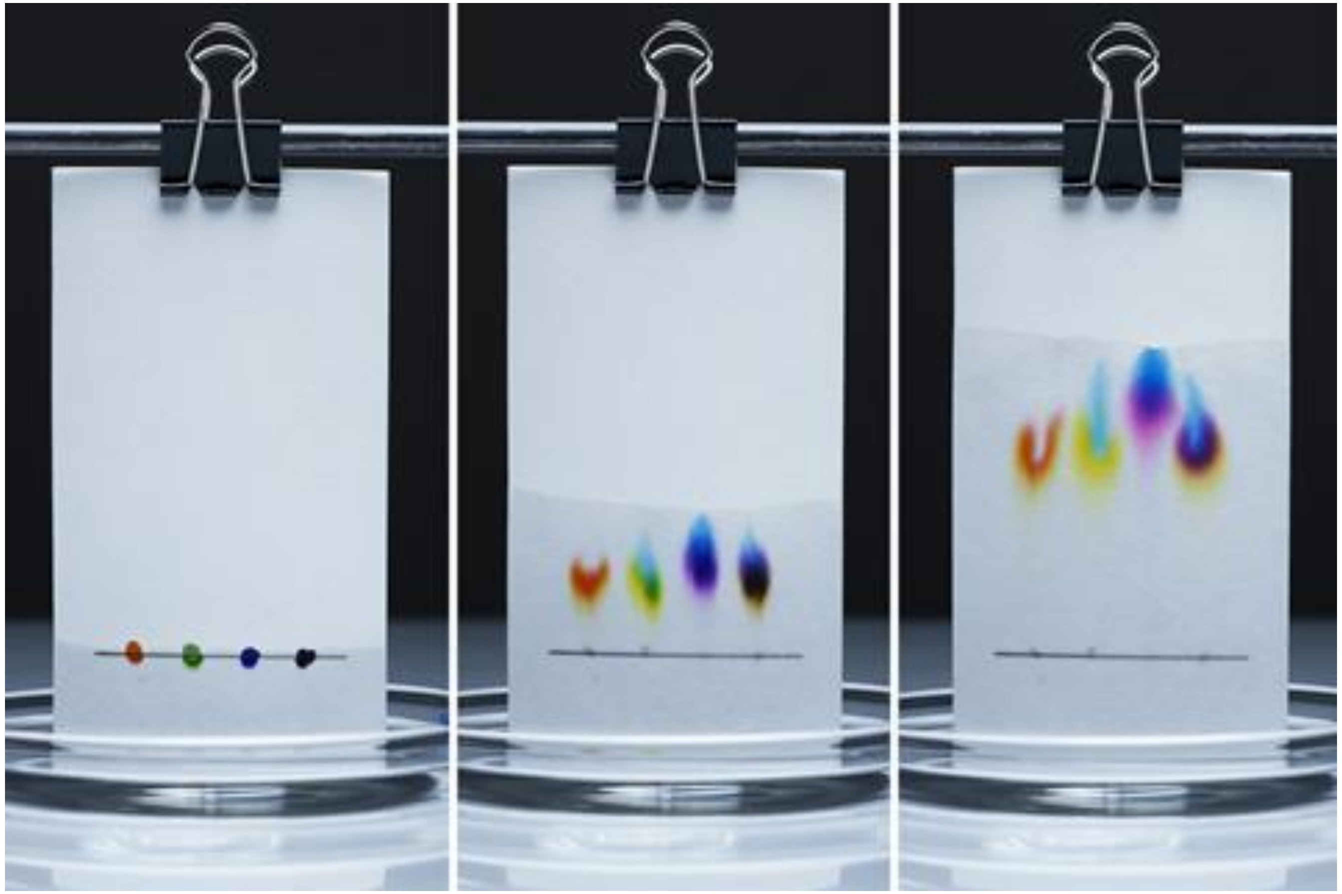
- Lower Vapor Pressure, higher Boiling Point
- Therefore, will boil off later, at a higher temp.

Chromatography

All about the polarity of the two phases

Polar things attracted to polar things.

Less/non-polar things attracted to less/non-polar things.



Chromatography

Stationary phase

Paper Chromatography → Strip of paper
Thin layer (TLC) → glass plate covered in silica
Column Chromatography → column filled with silica gel

Mobile phase

Various solvents that can wick up the stationary phase.

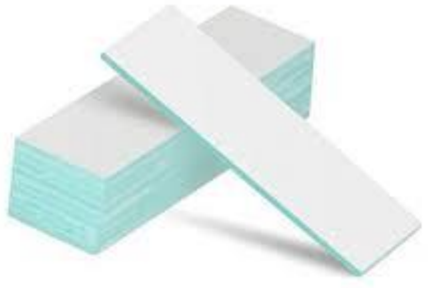
Chromatography

Paper

Good for quick identification/comparison.

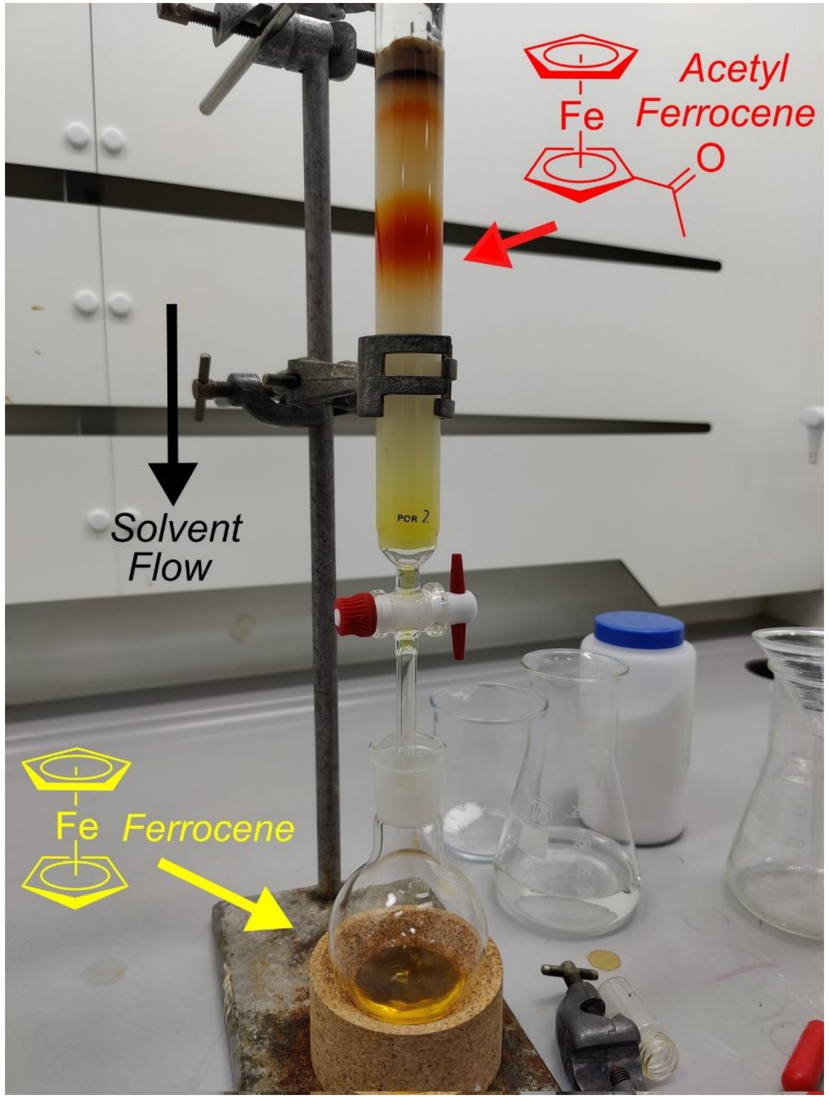
TLC

Tend to get better results, less blurring. Can separate different types of compounds.



Column

Good if you want to collect a component to use for something.



Polarity of the Phases

Stationary Phase

The –OH groups in cellulose (paper) or in silica gel have attraction for H_2O molecule, so surface will be polar.
BUT they could tell you to use a non-polar stationary phase!

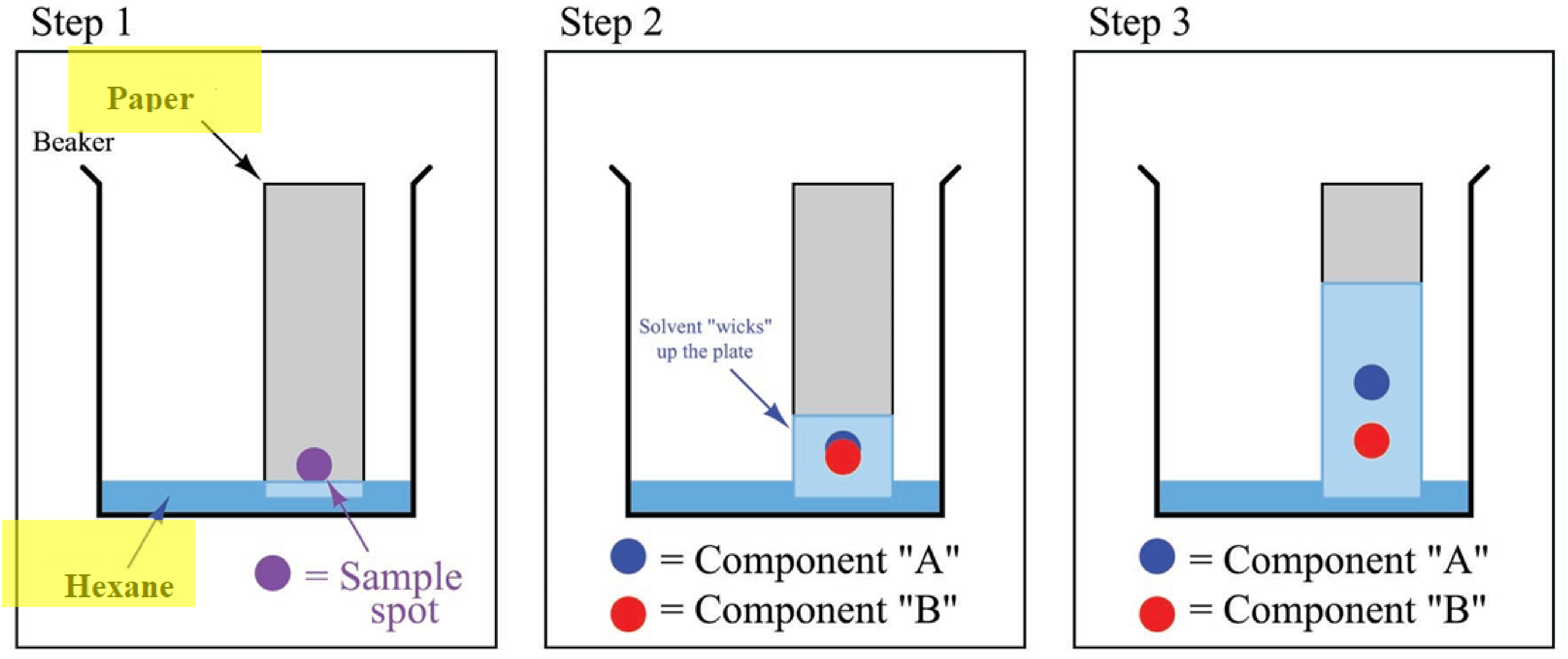
Mobile Phase

Usually a non-polar solvent like hexane, or something like ethanol – still polar, but *less* polar than pure water.
BUT - Could be something like salt water which is more polar than water! So be careful!

Chromatography

Which Component is MORE polar?

B because it traveled less, more attracted to polar stationary phase!

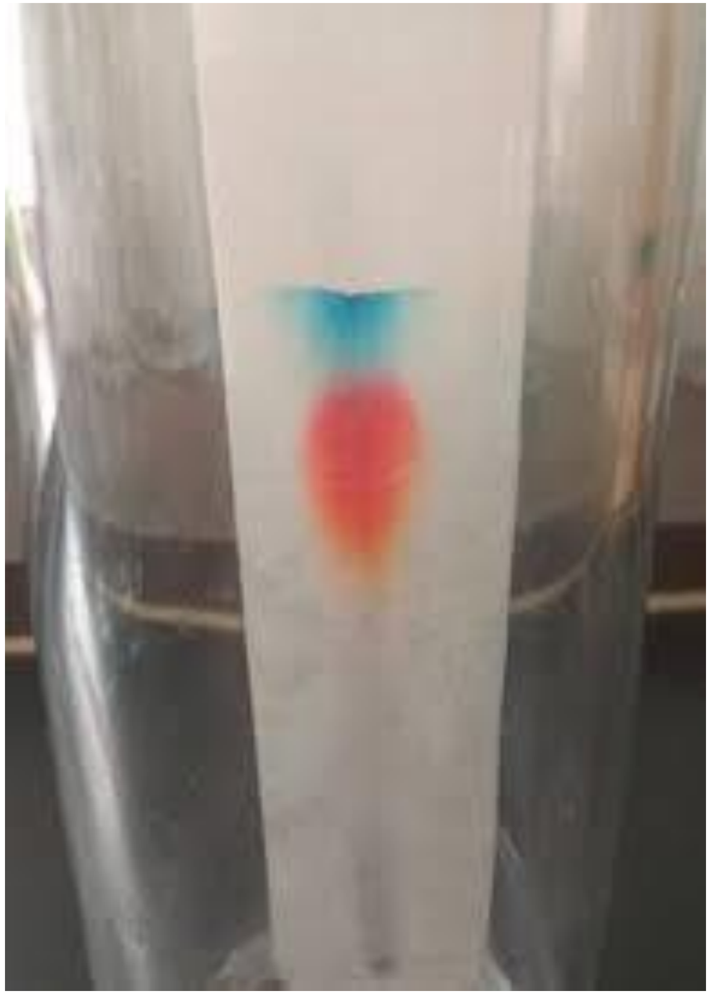


Chromatography

Potential Issues

- Not enough separation between components
- Components all traveled too far up stationary phase

Fix: pretty much always is to change polarity of the solvent!



Calculations

Molarity

Moles of solute per 1 liter of solution - Describes how many molecules of solute in each liter of solution

If a sugar solution concentration is 2.0 M,

- 1 liter of solution contains 2.0 moles of sugar
- 2 liters = 4.0 moles sugar
- 0.5 liters = 1.0 mole sugar

$$\boldsymbol{Molarity, M = \frac{moles\ of\ solute}{Liters\ of\ solution}}$$

Mole Fraction X_A

Mole fraction - the fraction of the moles of one component in the total moles of all the components of the solution.

- Total of all the mole fractions in a solution = 1.
- No units

$$X_A = \frac{n_A}{n_A + nB + \cdots}$$

Mole percentage - the percentage of the moles of one component in the total moles of all the components of the solution.

= mole fraction × 100%

$$X_A = \frac{n_A}{n_A + nB + \cdots} x\ 100$$

Making Dilutions

When you take one more concentrated solution and take a small amount of it and dilute it down by adding more solvent.

$$\boldsymbol{M_1 V_1 = M_2 V_2}$$

Concentrated **Diluted**

Volumetric Flasks

Very accurate marking for a specific volume. You can put a small amount of your concentrated solution into the flask (the V1 amount) and then fill to the line to get the desired diluted solution volume (V2).

Pro: **Very precise**

Con: **Only one volume marking. Can’t use it to measure out various amounts.**

(Use a volumetric pipette, or a graduated cylinder to measure out different volumes. They have lots of markings.

Lots of lab techniques!

- Making solutions
  - Using graduated cylinders
  - sing graduated pipettes
  - Using volumetric pipettes
  - Using volumetric flasks
  - Serial Dilutions

- UV-VIS Spectroscopy
  – Remember Beer's law?! It is back again! ☺

Converting Concentration Units

1. WRITE YOUR UNITS. SERIOUSLY.
2. Write the given concentration as a ratio.
3. Separate the numerator and denominator.
   - Think about each separately
   - Separate into the solute part and solution part
4. Convert the solute part into the required unit.
5. Convert the solution part into the required unit.
6. Use the definitions to calculate the new final concentration units.

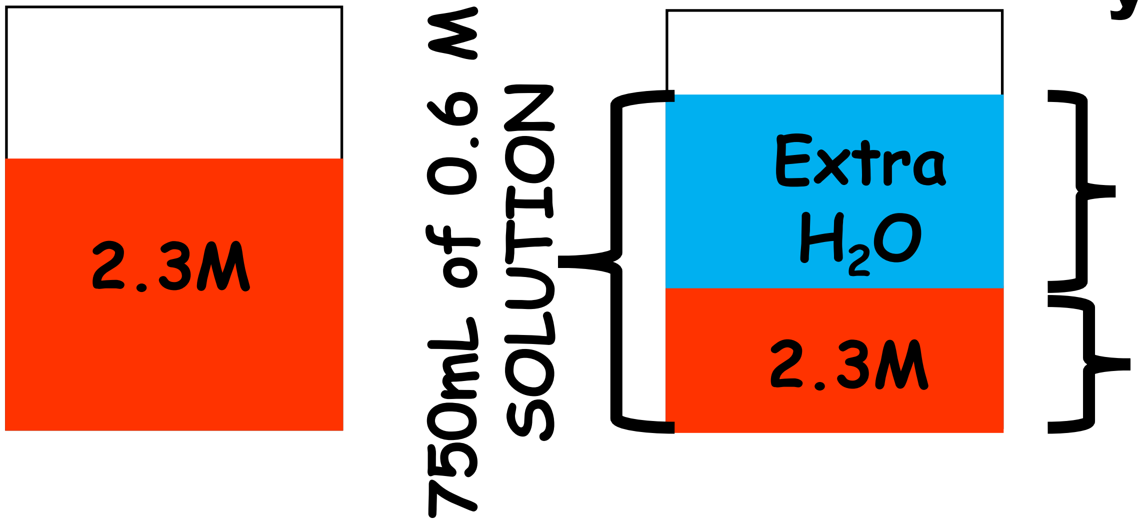
Practice

How much of a 2.3 M solution do you have to use in order to make 750mL of a 0.6 M solution?

$$(2.3M)(V_1) = (0.6M)(750mL)$$

$$V_1 = 195.65\,mL\ of\ the\ 2.3M\ solution\ is\ needed$$

How much water did you add???



750-195.65 =
554.35mL H_2O

195.65mL of the STRONGER STUFF

What is the mole percent of ethanol (C_2H_5OH), which consists of 71.0 g of ethanol for every 14.3 g of water present?

- **A** 66.0%
- **B** 1.94%
- **C** 1.52%
- **D** 83.2%
- **E** 34.0%

$$X_A = \frac{n_A}{n_A + nB + \cdots} x\ 100$$

What is the mole percent of ethanol (C_2H_5OH), which consists of 71.0 g of ethanol for every 14.3 g of water present?

A **66.0%**

B **1.94%**

C **1.52%**

D **83.2%**

E **34.0%**

$$\frac{71.0\text{g}}{} \left| \frac{1\text{mol}}{46.08\text{g}} \right. = \textbf{1.54 mol ethanol}$$

$$\frac{14.3\text{g}}{} \left| \frac{1\text{mol}}{18.02\text{g}} \right. = \textbf{0.794 mol water}$$

$$\frac{1.54\text{mol}}{(1.54\text{mol} + 0.794\text{mol})} \times 100 = \textbf{65.99\%}$$

A solution containing 481.6 g of $Mg(NO_3)_2$ per liter has a density of 1.114 g/ml. The molarity of the solution is:

- A 3.247 M
- B 2.915 M
- C 9.740 M
- D 3.617 M
- E None of these

$$Molarity, M = \frac{moles\ of\ solute}{Liters\ of\ solution}$$

A solution containing 481.6 g of $Mg(NO_3)_2$ per liter has a density of 1.114 g/ml. The molarity of the solution is:

- A **3.247 M**
- B 2.915 M
- C 9.740 M
- D 3.617 M
- E None of these

$$\frac{481.6\text{g}}{} \left| \frac{1\text{mol}}{148.33\text{g}} \right. = 3.247 \text{ mol solute}$$

= 3.247 mol/1L = **3.247 M**

****Density was just extra info! Very common in solutions problems to have more info than you need.****

The next few types of calculations are not “officially” in the class anymore. We are still going to quickly cover them because every once in a while there is some kind of “clever” question that essentially requires these types of calculations. Better safe than sorry!

Molality

Moles of solute per 1 kilogram of solvent

Careful! Defined in terms of amount of solvent, not the solution like most of the other calculations

Does not vary with temperature

– Because based on masses, not volumes

$$Molality, m = \frac{moles\ of\ solute}{kg\ of\ solvent}$$

Parts Solute in Parts Solution

Parts can be measured by mass or volume.

Parts are generally measured in the same units.

- **By mass in grams, kilogram, lbs, etc.**
- **By volume in mL, L, gallons, etc.**
- **Mass and volume combined in grams and mL**

Parts Solute in Parts Solution

Percentage = parts of solute in every 100 parts solution

- If a solution is 0.9% by mass, then there are 0.9 grams of solute in every 100 grams of solution (or 0.9 kg solute in every 100 kg solution).

Parts per million = parts of solute in every 1 million parts solution

- If a solution is 36 ppm by volume, then there are 36 mL of solute in 1 million mL of solution.

Mass Percent

Mass percent - the ratio of mass units of solute to mass units of solution, expressed as a percent

$$mass\ percent = \frac{mass\ of\ solute}{mass\ of\ solution} x100$$

Parts per Million - PPM

Grams of solute per 1,000,000 g of solution

- **mg of solute per 1 kg of solution**
- **1 liter of water = 1 kg of water**

For aqueous solutions we often approximate the kg of the solution as the kg or L of water. For dilute solutions, the difference in density between the solution and pure water is usually negligible.

$$PPM = \frac{amount\ of\ solute}{amount\ of\ solution} x10^6$$

Remember that the density of water is
1g/1mL
Same as 1000g/1L
Same as 1kg/1L

Parts per Billion - PPB

$$PPB = \frac{amount\ of\ solute}{amount\ of\ solution} x10^9$$

$$Parts\ per\ \ldots = \frac{amount\ of\ solute\ (PART)}{amount\ of\ solution\ (WHOLE)} x\ some\ factor$$

% = x 100

ppm = x 1,000,000 = $x10^6$

ppb = x1,000,000,000 = $x10^9$

Find the mass percent of $CuSO_4$ in a solution whose density is 1.30 g/ml and whose molarity is 4.73 M.

A. 41.9%

B. 6.15%

C. 58.1%

D. 6.03%

E. None of these

$$mass\ percent = \frac{mass\ of\ solute}{mass\ of\ solution} x100$$

Find the mass percent of $CuSO_4$ in a solution whose density is 1.30 g/ml and whose molarity is 4.73 M.

- A **41.9%**
- B **6.15%**
- C **58.1%**
- D **6.03%**
- E **None of these**

1 L solution = 4.73 mol $CuSO_4$

$$\frac{4.73\text{mol}}{} \left| \frac{159.62\text{g}}{1\text{mol}} \right. = \mathbf{755g\ solute}$$

$$1\ \text{L} = \frac{1000\text{mL}}{} \left| \frac{1.30\text{g}}{1\text{mL}} \right. = \mathbf{1300g\ solution}$$

$$\frac{755\text{g}}{1300\text{g}} \times 100 = \mathbf{58.15\%}$$

What is the molality of solution of 33.5 g propanol ($CH_3CH_2CH_2OH$) in 152 ml water, if the density of water is 1.00 g/ml?

A. 3.67 m

B. 0.00367 m

C. 0.273 m

D. 0.557 m

E. None of these

$$Molality, m = \frac{moles\ of\ solute}{kg\ of\ solvent}$$

What is the molality of solution of 33.5 g propanol ($CH_3CH_2CH_2OH$) in 152 ml water, if the density of water is 1.00 g/ml?

A **3.67 m**

B 0.00367 m

C 0.273 m

D 0.557 m

E None of these

$$\frac{33.5\text{g}}{} \left| \frac{1\text{mol}}{60.11\text{g}} \right. = \mathbf{0.557\ mol\ solute}$$

$$\frac{0.557\text{mol}}{0.152\text{kg}} = \mathbf{3.67\ m}$$

Link to YouTube Presentation

OLD VERSION! It does not have the separation techniques part, and it covers concentration calculations we won’t do this year. I will redo it if I get time!

https://youtu.be/op8vqy3uxq8