SOLUTIONS

- a SOLUTION is a HOMOGENEOUS MIXTURE.

Uniform properties throughout!

- parts of a solution:

① SOLUTE(S)

- component(s) of a solution present in small amounts.

② SOLVENT

- the component of a solution present in the GREATEST amount

- in solutions involving a solid or gas mixed with a LIQUID, the liquid is typically considered the solvent.

- solutions are usually the same phase as the pure solvent. For example, at room temperature salt water is a liquid similar to pure water.

SOLVENTS

- We traditionally think of solutions as involving gases or solids dissolved in liquid solvents. But ANY of the three phases may act as a solvent!

① GAS SOLVENTS

- Gases are MISCIBLE, meaning that they will mix together in any proportion.
- This makes sense, since under moderate conditions the molecules of a gas don't interact wth each other.
- Gas solvents will only dissolve other gases.

② LIQUID SOLVENTS

- Can dissolve solutes that are in any phase: gas, liquid, or solid.
- Whether a potential solute will dissolve in a liquid depends on how compatible the forces are between the liquid solvent and the solute.

③ SOLID SOLVENTS

- Solids can dissolve other solids, and occasionally - liquids.
- Solid-solid solutions are called ALLOYS. Brass (15% zinc dissolved in copper) is a good example.
- AMALGAM is a solution resulting from dissolving mercury into another metal.

CONCENTRATION

- When you discuss a solution, you need to be aware of:
  - what materials are in the solution
  - how much of each material is in the solution

- CONCENTRATION is the amount of one substance compared to the others in a solution. This sounds vague, but that's because there are many different ways to specify concentration!

- We will discuss four different concentration units in CHM 111:

① MASS PERCENTAGE

$$= \frac{\text{mass solute}}{\text{mass solution}} \times 100\% \qquad \%\ ,\ \%\ ^{w}/_{w}$$

② MOLARITY

$$= \frac{\text{moles solute}}{\text{L solution}} \qquad M \text{ or } \underline{M}$$

③ MOLALITY

$$= \frac{\text{moles solute}}{\text{kg solvent}} \qquad m$$

④ MOLE FRACTION

$$= \frac{\text{moles component A}}{\text{moles solution}} \qquad X_A$$

57 How would you prepare 455 grams of an aqueous solution that is 6.50% sodium sulfate by mass?

$$\underset{\uparrow\ 6.50\%}{\text{mass \%}} = \frac{\text{mass solute}}{\underset{\uparrow\ 455\,g}{\text{mass solution}}} \times 100\%$$

We know everything in this definition EXCEPT the mass of sodium sulfate we need, so we calculate the mass of sodium sulfate using basic algebra.

$$6.50 = \frac{\text{mass solute}}{455\,g} \times 100$$

① $\times\ 455\,g$

② $\div\ 100$

$$\frac{6.50 \times 455\,g}{100} = 29.575\,g = \boxed{29.6\,g\ Na_2SO_4}$$

How much water? Subtract the mass of sodium sulfate from the total mass,

$$455\,g\ \text{solution} - 29.6\,g\ Na_2SO_4 = 425.4\,g = \boxed{425\,g\ \text{water}}$$

What's the MOLALITY and MOLE FRACTION OF SOLUTE of the previous solution?

29, 6 g Na_2SO_4, 425 g water ← previous solution

$$m = \frac{\text{mol solute } (Na_2SO_4) \text{ ①}}{\text{Kg solvent (water) ②}}$$

① Convert mass sodium sulfate to moles using formula weight of sodium sulfate.

② Convert the 425 g of water to kg

Na_2SO_4: Na : 2 × 22.99

S : 1 × 32.07

O : 4 × 16.00

$142.05 \text{ g } Na_2SO_4 = \text{mol } Na_2SO_4$

$$29.6 \text{ g } Na_2SO_4 \times \frac{\text{mol } Na_2SO_4}{142.05 \text{ g } Na_2SO_4} = 0.2083773319 \text{ mol } Na_2SO_4 \text{ ①}$$

$\text{Kg} = 10^3 \text{ g}$

$$425 \text{ g} \times \frac{\text{Kg}}{10^3 \text{ g}} = 0{,}425 \text{ kg water ②}$$

$$m = \frac{0.2083773319 \text{ mol } Na_2SO_4}{0{,}425 \text{ kg water}} = \boxed{0.490 \text{ m } Na_2SO_4}$$

29.6 g Na_2SO_4, 425 g water ← previous solution

$$X_{Na_2SO_4} = \frac{\text{mol solute } (Na_2SO_4) \quad \textcircled{1}}{\text{mol solution (mol water + mol } Na_2SO_4) \quad \textcircled{2}}$$

① Calculate moles sodium sulfate from the mass using formula weight. (We've already done this!)

② Calculate moles water by converting mass water to moles, then add in the moles sodium sulfate to get total moles.

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① 0.2083773319 mol Na_2SO_4 (See previous page for calculation)

H_2O: H: 2 × 1.008

O: 1 × 16.00

18.016 g H_2O = mol H_2O

$$425 \text{ g } H_2O \times \frac{\text{mol } H_2O}{18.016 \text{ g } H_2O} = 23.5901421 \text{ mol } H_2O$$

$$\text{mol solution} = 23.5901421 \text{ mol } H_2O + 0.2083773319 \text{ mol } Na_2SO_4$$

$$= 23.79851943 \text{ mol}$$

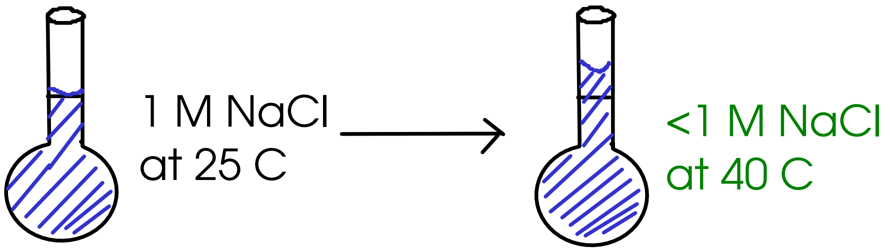
$$X_{Na_2SO_4} = \frac{0.2083773319 \text{ mol } Na_2SO_4}{23.79851943 \text{ mol}} = \boxed{0.00876}$$

MOLARITY

- In the previous example, we converted between three of the four units that we discussed: mass percent, molality, and mole fraction.

- We didn't do MOLARITY, because the information given in the previous problem was not sufficient to determine molarity!

$$\underline{M} = \frac{\text{moles solute}}{\underline{\text{L solution}}}$$



Molarity is based on VOLUME, while the other three units are based on MASS. (moles and mass can be directly converted)

Volume depends on TEMPERATURE!

- If you HEAT a solution, what happens to CONCENTRATION?

ex: $\underline{5.00 \text{ mol } Na_2SO_4}$ in $\underline{1 \text{ L solution}}$

constant when heated

increases. (thermal expansion)

... the MOLAR CONCENTRATION decreases. (But the concentration in the other three units we discussed stays the same.)

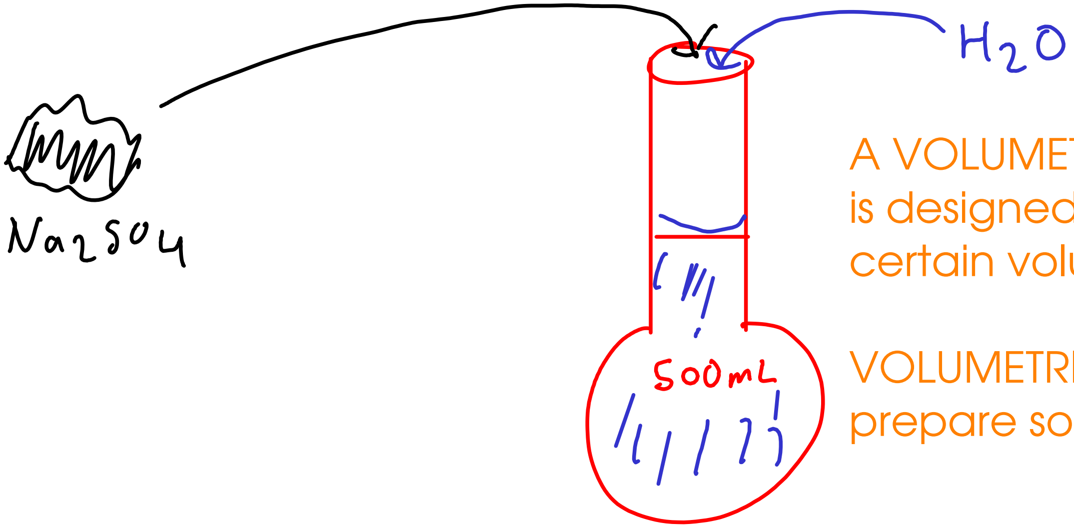
- If you COOL a solution, the MOLAR CONCENTRATION increases. (The other three units stay the same!)

... we use MOLARITY so much because it's easy to work with. It is easier to measure the VOLUME of a liquid solution than it is to measure mass.

Example: How would we prepare 500. mL of 0.500 M sodium sulfate in water?

Na_2SO_4: /mol

Dissolve the appropriate amount of sodium sulfate into enough water to make 500. mL of solution.



volumetric flask

A VOLUMETRIC FLASK is a flask that is designed to precisely contain a certain volume of liquid.

VOLUMETRIC FLASKS are used to prepare solutions.

$$M = \frac{\text{mol } Na_2SO_4}{\text{L solution}} \; ; \quad 0.500\text{ M} = \frac{\text{mol } Na_2SO_4}{0.500\text{ L}}$$

$$\text{mol } Na_2SO_4 = (0.500\text{ M})(0.500\text{ L}) = 0.250\text{ mol } Na_2SO_4$$

$$0.250\text{ mol } Na_2SO_4 \times \frac{142.05\text{ g } Na_2SO_4}{\text{mol } Na_2SO_4} = \boxed{35.5\text{ g } Na_2SO_4}$$

Dissolve 35.5 grams of sodium sulfate in enough water to make 500. mL of solution. The concentration will be 0.500 M.

More on MOLARITY

To prepare a solution of a given molarity, you generally have two options:

① Weigh out the appropriate amount of solute, then dilute to the desired volume with solvent (usually water)"

"stock solution"

② Take a previously prepared solution of known concentration and DILUTE it with solvent to form a new solution

- Use DILUTION EQUATION

The dilution equation is easy to derive with simple algebra.

$$M \times V$$

$$\frac{mol}{L} \times L = \text{moles solute}$$

... but when you dilute a solution, the number of moles of solute REMAINS CONSTANT. (After all, you're adding only SOLVENT)

$$M_1V_1 = M_2V_2$$

Since the number of moles of solute stays the same, this equality must be true!

before
diution

after
dilution

$M_1V_1 = M_2V_2$ ... the "DILUTION EQUATION"

M_1 = molarity of concentrated solution

V_1 = volume of concentrated solution

M_2 = molarity of dilute solution

V_2 = volume of dilute solution ←(TOTAL VOLUME, NOT the volume water added!)

The volumes don't HAVE to be in liters, as long as you use the same volume UNIT for both V_1 and V_2

Example: Take the 0.500 M sodium sulfate we discussed in the previous example and dilute it to make 150. mL of 0.333 M solution. How many mL of the original solution will we need to dilute?

$$M_1V_1 = M_2V_2$$

$$(0.500\ M)\ V_1 = (0.333\ M)(150.\ mL)$$

$$V_1 = \boxed{99.9\ mL\ \text{of}\ 0.500\ M}$$

Take 99.9 mL of 0.500 M sodium sulfate, and add water until the TOTAL VOLUME OF THE SOLUTION is 150. mL