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

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

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

Need to calculate mass of solute (sodium sulfate)

$$\text{mass}\ \% = \frac{\text{mass solute}}{\text{mass solution}} \times 100\ \%$$

6.50 %

455 g

We know everything in this definition EXCEPT the mass of the solute (sodium sulfate). So, we can calculate the mass of sodium sulfate we need by solving for the unknown:

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

① × 455 g

② ÷ 100

$$\frac{6.50 \times 455\ \text{g}}{100} = \text{mass solute} = \boxed{29.6\ \text{g}\ Na_2SO_4}$$

How much water? Since we know the total mass of the solution, we can find the amount of water to use by subtraction:

$$455\ \text{g total} - 29.6\ \text{g}\ Na_2SO_4 = \boxed{425\ \text{g}\ H_2O}$$

Mix 29.6 g of sodium sulfate with 425 g water to prepare the solution.

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

29.6 g Na_2SO_4, 425 g water ← previous solution

$$m = \frac{\text{mol solute} \ ①}{\text{kg solvent} \ ②}$$

① Convert mass of solute to moles using the formula weight of sodium sulfate

② Convert mass solvent (mass of water) from grams to kilograms

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① Na_2SO_4: Na : 2 × 22.99

S : 1 × 32.07

O : 4 × 16.00

142.05 g Na_2SO_4 = mol Na_2SO_4

$$29.6 \text{ g } Na_2SO_4 \times \frac{\text{mol } Na_2SO_4}{142.05 \text{ g } Na_2SO_4} = 0.208377 \text{ mol } Na_2SO_4$$

10^3 g = kg

② $$425 \text{ g } H_2O \times \frac{\text{kg}}{10^3 \text{ g}} = 0.425 \text{ kg } H_2O$$

$$m = \frac{\text{mol solute}}{\text{kg solvent}} = \frac{0.208377 \text{ mol } Na_2SO_4}{0.425 \text{ kg } H_2O} = \boxed{0.490 \text{ m } Na_2SO_4}$$

29 6 g Na_2SO_4 , 425 g water ← previous solution

$$X_{Na_2SO_4} = \frac{\text{mol } Na_2SO_4 \text{ ①}}{\text{total mol solution ②}}$$

① Calculate mol sodium sulfate (but we already did that to find molality)

② Find mol water by converting the mass of water (425 g) to moles, then add moles of sodium sulfate.

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① 0.208377 mol Na_2SO_4 (see previous page)

② H_2O: H : 2 x 1.008
O : 1 x 16.00

$18.016 \text{ g } H_2O = \text{mol } H_2O$

$$425 \text{ g } H_2O \times \frac{\text{mol } H_2O}{18.016 \text{ g } H_2O} = 23.5901 \text{ mol } H_2O$$

total = 23.5901 mol H_2O + 0.208377 mol Na_2SO_4 = 23.7985 mol

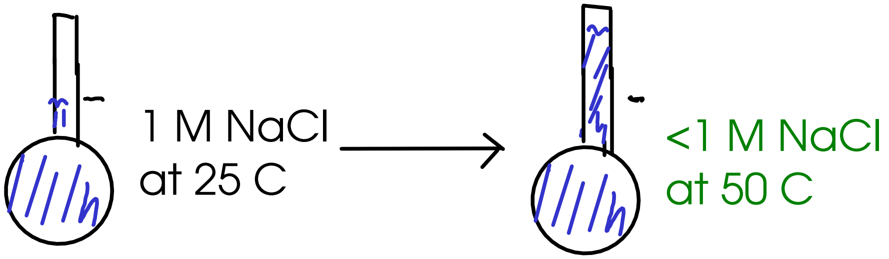
$$X_{Na_2SO_4} = \frac{\text{mol } Na_2SO_4}{\text{total mol solution}} = \frac{0.208377 \text{ mol } Na_2SO_4}{23.7985 \text{ mol}} = \boxed{0.00876}$$

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!

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



1 M NaCl
at 25 C

<1 M NaCl
at 50 C

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: $\underbrace{5.00 \text{ mol } Na_2SO_4}_{\text{constant when heated}}$ in $\underbrace{1 L \text{ solution}}_{\text{increases. (thermal expansion)}}$

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

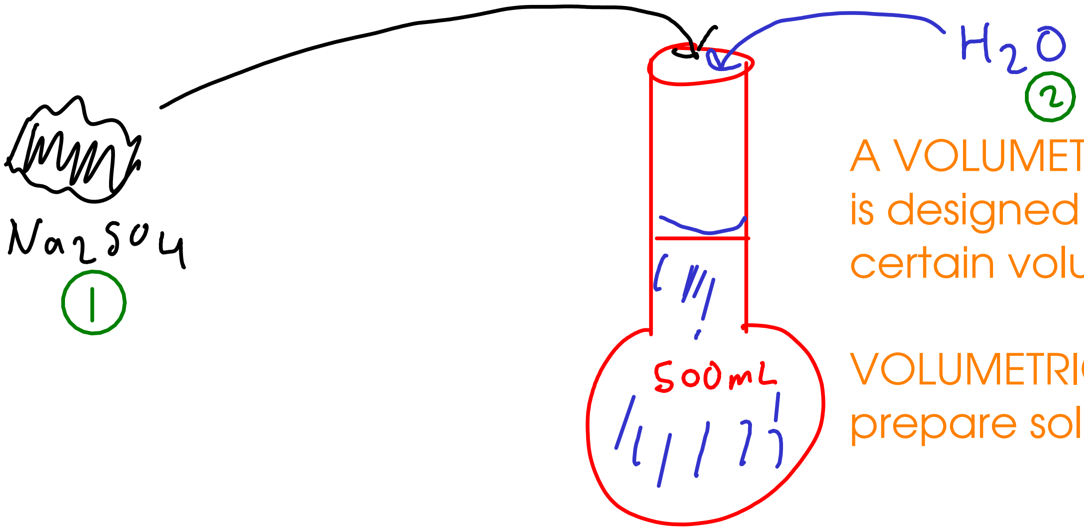
- If you COOL a solution, the MOLAR CONCENTRATION increases. (The other three units stay the same!)

... 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 : 142.05 g/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.

Calculate the mass of sodium sulfate to put in the flask.

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

$$mol\ Na_2SO_4 = (0.500\ mol/L)(0.500\ L) = 0.250\ mol\ Na_2SO_4$$

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

Dissolve 35.5 g of sodium sulfate in enough water to make 500. mL solution

① ②