29.6 g Na_2SO_4, 425.4 g water ← previous solution

$$\frac{\text{mol } Na_2SO_4 \; (1)}{\text{mol solution} \; (2)}$$

mole fraction (definition)

1 - Convert 29.6 grams sodium sulfate to moles. We already did this to find molality, so we can re-use the number.

2 - This is the total moles of both sodium sulfate and water. We need to find the moles of water. Convert 425.4 grams water to moles using FORMULA WEIGHT.

(1) 0.2083773319 mol Na_2SO_4

(2) H_2O: H - 2 × 1.008
O - 1 × 16.00

18.016 g H_2O = mol H_2O

$$425.4 \text{ g } H_2O \times \frac{\text{mol } H_2O}{18.016 \text{ g } H_2O} = 23.61234458 \text{ mol } H_2O$$

$$\text{mol solution} = 0.2083773319 \text{ mol } Na_2SO_4 + 23.61234458 \text{ mol } H_2O$$

$$= 23.82072191 \text{ mol solution}$$

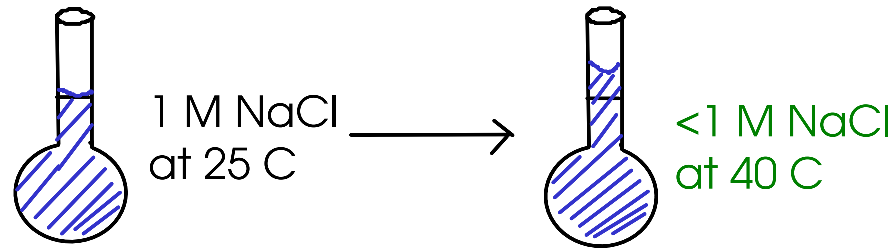
$$X_{Na_2SO_4} = \frac{0.2083773319 \text{ mol } Na_2SO_4}{23.82072191 \text{ mol solution}} \simeq \boxed{0.00875}$$

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!

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



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: 5.00 mol Na_2SO_4 in 1 L solution

5.00 mol Na_2SO_4 — constant when heated

1 L solution — increases (thermal expansion)

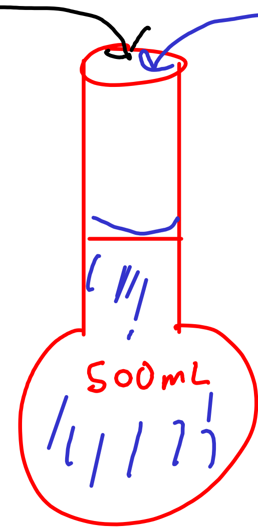
... the MOLAR CONCENTRATION decreases. (But the concentration in the other three units we discussed stays the same.)

- 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. Na_2SO_4: (142.05 g/mol)

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

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



H_2O

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

VOLUMETRIC FLASKS are used to prepare solutions.

$$\overset{(0.500\,M)}{M} = \frac{\text{mol } Na_2SO_4}{\underset{(0.500\,L)}{\text{L solution}}}$$

molarity (definition)

volumetric flask

$*500\,mL = 0.500\,L$

We already know the desired molarity (0.500 M) and we know the volume of solution (500 mL, or 0.500 L). We simply need to find the mass of sodium sulfate to dissolve.

$$0.500\,M = \frac{\text{mol } Na_2SO_4}{0.500\,L} \;;\; 0.250\,\text{mol} = \text{mol } Na_2SO_4$$

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

Add 35.5 grams sodium sulfate to 500 mL volumetric flask and dilute to the mark with deionized or distilled water.

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?

$$M_1V_1 = M_2V_2$$

$M_1 = 0.500\,M$ $M_2 = 0.333\,M$

$V_1 = ?$ $V_2 = 150.\,mL$

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

$$V_1 = \boxed{99.9\text{ mL of } 0.500\,M\ Na_2SO_4}$$

Measure out 99.9 mL of 0.500 M sodium sulfate, then add enough water to make a total volume of 150. mL ...

MOLARITY and the other concentration units

- To convert between molarity and the other three concentration units we've studied, you have to know more about the solution. For example:

molarity $\rightarrow$ molality

$$\frac{\text{moles A}}{\text{L solution}} \longrightarrow \frac{\text{moles A}}{\text{kg solvent}}$$

* To perform this conversion, you can assume a liter of solution, which will give you the number of moles present. But you've then got to have a way to convert the volume of SOLUTION to the mass of the SOLVENT. How?

* You need DENSITY (which depends on temperature). The density of the solution will allow you to find the total mass of the solution.

* If you subtract out the mass of the SOLUTE, then what you have left is the mass of the SOLVENT. Express that in kilograms, and you have all the information you need to find molality!

* You'll run into the same situation when you use any of the other mass or mole based units. DENSITY is required to go back and forth between MOLARITY and these units.

Example: If a solution is 0.688 m citric acid, what is the molar concentration (M) of the solution? The density of the solution is 1.049 g/mL

$H_3C_6H_5O_7$: 192.125 g/mol "CA"

$$\frac{0.688 \text{ mol CA}}{\text{Kg solvent}} \longrightarrow \frac{? \text{ mol CA}}{\text{L solution}}$$

molality (definition) molarity (definition)

ASSUME A BASIS of 1 kg SOLVENT. This means that we have 0.688 moles CA (because of the molal concentration we were given). Now we just need to find the volume of solution. To do that, we need to find the MASS of CA (from 0.688 mol) and add it to the kilogram of solvent. Then we can convert this mass to volume using density.

192.125 g CA = mol CA

$$0.688 \text{ mol CA} \times \frac{192.125 \text{ g CA}}{\text{mol CA}} = 132.182 \text{ g CA}$$

Add mass CA to mass solvent

$$1000 \text{ g solvent} + 132.182 \text{ g CA} = 1132.182 \text{ g solution}$$

Now find volume...

1.049 g solution = mL

$$1132.182 \text{ g solution} \times \frac{\text{mL}}{1.049 \text{ g solution}} = 1079.296473 \text{ mL} = 1.079296473 \text{ L}$$

Find molarity

$$M = \frac{0.688 \text{ mol CA}}{1.079296473 \text{ L}} = \boxed{0.637 \text{ M CA}}$$

An aqueous solution is 8.50% ammonium chloride by mass. The density of the solution is 1.024 g/mL
Find: molality and molarity.

NH_4Cl : 53.491 g/mol H_2O: 18.016 g/mol

$$\frac{8.50\,g\ NH_4Cl}{100\,g\ solution} \longrightarrow \frac{mol\ NH_4Cl}{kg\ H_2O}$$

mass percent (definition) molality (definition)

Let's ASSUME A BASIS of 100 g solution. That means we have 8.50 grams ammonium chloride. Then, convert mass ammonium chloride to moles. Find the mass of water by subtracting the amount of ammonium chloride from the mass of solution we assumed.

$$53.491\,g\ NH_4Cl = mol\ NH_4Cl$$

$$8.50\,g\ NH_4Cl \times \frac{mol\ NH_4Cl}{53.491\,g\ NH_4Cl} \simeq 0.1589052364\ mol\ NH_4Cl$$

Now find mass water...

$$100\,g\ solution - 8.50\,g\ NH_4Cl = 91.5\,g\ H_2O = 0.0915\,kg\ H_2O$$

Molaity is ...

$$m = \frac{0.1589052364\ mol\ NH_4Cl}{0.0915\ kg\ H_2O} = \boxed{1.74\ m\ NH_4Cl}$$

An aqueous solution is 8.50% ammonium chloride by mass. The density of the solution is 1.024 g/mL
Find: molality and molarity.

NH_4Cl : 53.491 g/mol H_2O: 18.016 g/mol

$$\frac{8.50\,g\ NH_4Cl}{100\,g\ solution} \longrightarrow \frac{mol\ NH_4Cl}{L\ solution}$$

mass percent (definition)   molarity (definition)

We'll keep the basis of 100 grams solution. We can use the calculated moles ammonium chloride from our previous calculation since the basis is the same. We then need to convert 100 grams solution to volume using the density.

$0.1589052364\ mol\ NH_4Cl$

Find volume

$1.024\ g\ solution = mL$

$$100\,g\ solution \times \frac{mL}{1.024\,g\ solution} = 97.65625\ mL = 0.09765625\ L$$

Find molarity

$$M = \frac{0.1589052364\ mol\ NH_4Cl}{0.09765625\ L} = \boxed{1.63\ M\ NH_4Cl}$$

COLLIGATIVE PROPERTIES

- properties unique to solutions.

- depend only on the CONCENTRATION of a solution and not the IDENTITY of the solute**

**ionic solutes: Remember that they dissociate into MULTIPLE IONS!

1. Freezing point depression
   - The freezing temperature of a SOLUTION gets lower as the CONCENTRATION of a solution increases.

2. Vapor pressure lowering
   - The vapor pressure of a solution (pressure of sovent vapor over a liquid surface) goes DOWN as solution concentration goes UP

3. Boiling point elevation
   - The boiling temperature of a solution increases as the concentration of the solution increases.

4. Osmotic pressure
   - The pressure required to PREVENT the process of osmosis