CHEMICAL Reactions happen in solution. We cannot determine the mass of solutes!

* need to be able to determine moles from information about a solution *

Concentration = $\frac{\text{amount of solute}}{\text{amount of solvent}}$

For us, the REALLY important unit of concentration is Molarity

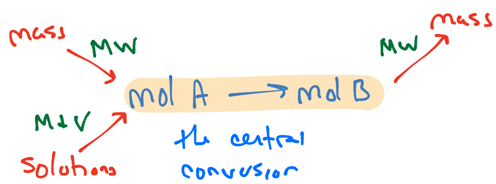
$M \equiv$ Molarity = $\frac{\text{moles of solvent}}{\text{Volume of solvent}}$ ← ALWAYS in Liters

* [X] ≡ concentration of X *

$M = \frac{mol}{L}$ $mM = \frac{mmol}{L}$ $\mu M = \frac{\mu mol}{L}$

Prefixes refer to the mol term
ALWAYS Liters

So we can use molarity as an avenue to determine moles of reactants / products in chemical reactions



- I have 14 mol NaCl dissolved in 2 L. what is the concentration? $\frac{14 \text{ mol}}{2} = 7M$

- 4 L of 3.8 M Na_2O. how many moles of O + Na?

$$\frac{4\text{ L}}{} \left| \frac{3.8 \text{ mol } Na_2O}{L} \right. = \frac{19.2 \text{ mol } Na_2O}{} \left| \frac{1 \text{ mol O}}{1 \text{ mol } Na_2O} \right. = 19.2 \text{ mol O}$$

$$\frac{19.2 \text{ mol } Na_2O}{} \left| \frac{2 \text{ mol Na}}{1 \text{ mol } Na_2O} \right. = 38.4 \text{ mol Na}$$

$$(NH_4)_2SO_{4(aq)} + BaCl_{2(aq)} \longrightarrow BaSO_{4(s)} + 2\,NH_4Cl_{(aq)}$$

Starting with 0.4 L of 0.502 M $(NH_4)_2SO_4$ and excess $BaCl_{2(aq)}$

Sample questions:

1. What mass of $BaCl_{2(aq)}$ will react completely with $(NH_4)_2SO_4$?
2. How much solid will form (in g)
3. What if there is a 78% yield
4. What concentration of NH_4Cl will form? Assume 100% yield.

① central: moles $(NH_4)_2SO_4$ → moles $BaCl_2$ → mass $BaCl_2$

we know V + M

$$\frac{0.4\ L\ (NH_4)_2SO_4}{} \left| \frac{0.502\ mol}{1\ L} \right| \frac{1\ mol\ BaCl_2}{1\ mol\ (NH_4)_2SO_4} = 0.2008\ mol\ BaCl_2 \left| \frac{208.28\ g}{mol} \right.$$

41.81 g

② Only one solid → $BaSO_4$ — 233.4 g/mol

$$\frac{0.4\ L\ (NH_4)_2SO_4}{} \left| \frac{0.502\ mol}{1\ L} \right| \frac{1\ mol\ BaSO_4}{1\ mol\ (NH_4)_2SO_4} \left| \frac{233.4\ g}{1\ mol} \right. = 46.87\ g\ BaSO_4$$

③ $$\frac{46.87\ g}{} \left| \frac{78}{100} \right. = 36.56\ g\ BaSO_4$$

④ $$\frac{0.4\ L\ (NH_4)_2SO_4}{} \left| \frac{0.502\ mol}{L} \right| \frac{2\ mol\ NH_4Cl}{1\ mol\ (NH_4)_2SO_4} = \frac{0.402\ mol\ NH_4Cl}{0.4\ L} = 1.04\ M$$

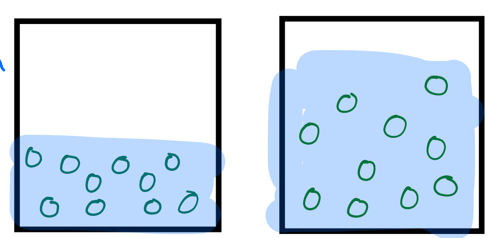
OR

$$\frac{0.502\ mol\ (NH_4)_2SO_4}{L} \left| \frac{2\ mol\ NH_4Cl}{1\ mol\ (NH_4)_2SO_4} \right. = \frac{1.04\ mol}{L} = 1.04\ M$$

What happens to concentrations if we change the volume of solvent?

$$\frac{10\ moles}{1\ L} = 10\ M$$

O = 1 mole of solute



Still 10 moles

$$\frac{10\ mol}{2\ L} = 5\ M$$

* moles of solute stays the same, but volume changes *

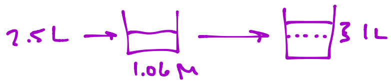
Before change | After change

$$M_1 = \frac{mol}{V_1} \neq \frac{mol}{V_2} = M_2$$

$$M_1V_1 = mol\ solute = M_2V_2$$

* if moles remain constant, $M_1V_1 = M_2V_2$ *

If I have 2.5 L of 1.06 M NaCl and add 1 L of H_2O, what is the [NaCl]



$V_2 = 2.5 + 1 = 3.5L$

$1.06M(2.5L) = M_2(3.5L)$

$M_2 = 0.757\ M = [NaCl]$

This idea is also relevant for chemical reactions:

500 mL of 1.5 M NaCl is mixed with 500 mL of 0.75 M $AgNO_3$.
- predict how much AgCl(s) is formed and determine the concentration of any reactants left over once the reaction is complete.

$AgNO_3(aq) + NaCl(aq) \rightarrow NaNO_3(aq) + AgCl(s)$

① mass of AgCl

→ from NaCl $\frac{0.5L}{} \left| \frac{1.5\ mol\ NaCl}{L} \right| \frac{1\ mol\ AgCl}{1\ mol\ NaCl} \left| \frac{143.32g}{1\ mol} \right. = 107.5g\ AgCl$

→ from $AgNO_3$ $\frac{0.5L}{} \left| \frac{0.75\ mol\ AgNO_3}{L} \right| \frac{1\ mol\ AgCl}{1\ mol\ AgNO_3} \left| \frac{143.32g}{mol} \right. = 53.75g$

② [NaCl] left over $\frac{0.5L}{} \left| \frac{0.75\ mol\ AgNO_3}{L} \right| \frac{1\ mol\ NaCl}{1\ mol\ AgNO_3} = 0.375\ mol\ NaCl$ used

$0.5\ L\left(\frac{1.5\ mol}{L}\right) = 0.75\ mol\ NaCl$ start $- 0.375$ used $= \frac{0.375\ mol\ NaCl}{0.5L + 0.5\ L} = 0.375M$

two solutions mixed together

sample problems:

- Determine [Cl^-] when 1.2 L of 0.86 M NaCl is mixed with 654 mL of 462 mM iron (III) chloride.

① determine total moles Cl^- $\frac{1.2\ L}{} \left| \frac{0.86\ mol\ NaCl}{L} \right| \frac{1\ mol\ Cl^-}{1\ mol\ NaCl} = 1.032\ mol$

$\frac{654\ mL}{} \left| \frac{10^{-3}L}{1\ mL} \right| \frac{462\ mmol\ FeCl_3}{L} \left| \frac{10^{-3}\ mol}{1\ mmol} \right| \frac{3\ mol\ Cl^-}{1\ mol\ FeCl_3} = 0.906\ mol$

② $\frac{\text{total mol}}{\text{total volume}} = \frac{1.032 + 0.906}{1.2 + 0.654} = 1.05\ M = [Cl^-]$

1.2 L of 250 mM $FeCl_3$ is combined with 1.6 L of 500 mM $Ag(C_2H_3O_2)$.
Determine the mass of any solid that forms and the concentration of all
IONS left after the reaction

$$FeCl_3(aq) + 3Ag(C_2H_3O_2)(aq) \longrightarrow Fe(C_2H_3O_2)_3(aq) + 3AgCl(s)$$

① Determine L.R.

$$\frac{1.2\text{ L}}{} \Big| \frac{250\text{ mmol }FeCl_3}{1\text{ L}} \Big| \frac{10^{-3}\text{ mol}}{1\text{ mmol}} \Big| \frac{3\text{ mol }AgCl}{1\text{ mol }FeCl_3} = 0.9\text{ mol }AgCl$$

$$\frac{1.6\text{ L}}{} \Big| \frac{500\text{ mmol }Ag(C_2H_3O_2)}{\text{L}} \Big| \frac{3\text{ mol }AgCl}{3\text{ mol }Ag(C_2H_3O_2)} = 0.8\text{ mol }AgCl \Big| \frac{143.32\text{ g}}{\text{mol}} = 114.7\text{ g }AgCl$$

② Easy ions: Fe^{3+} + $C_2H_3O_2^-$

Ⓐ find moles

Ⓑ divide by new volume

Fe^{3+}: $$\frac{1.2\text{ L}}{} \Big| \frac{250\text{ mmol }FeCl_3}{\text{L}} \Big| \frac{10^{-3}\text{ mol}}{1\text{ mmol}} \Big| \frac{1\text{ mol }Fe}{1\text{ mol }FeCl_3}$$

$$\frac{0.3\text{ mol }Fe^{3+}}{1.2\text{ L} + 1.6\text{ L}} = 0.107\text{ M }Fe^{3+}$$

$C_2H_3O_2^-$: $$\frac{1.6\text{ L}}{} \Big| \frac{500\text{ mmol }Ag(C_2H_3O_2)}{\text{L}} \Big| \frac{10^{-3}\text{ mol}}{1\text{ mmol}} \Big| \frac{1\text{ mol }C_2H_3O_2^-}{1\text{ mol }Ag(C_2H_3O_2)}$$

$$\frac{0.8\text{ mol }C_2H_3O_2^-}{1.2\text{ L} + 1.6\text{ L}} = 0.286\text{ M}$$

A little bit harder = Cl^-. $FeCl_3$ was not the L.R., so some of the Cl^- ended up in AgCl, but the rest is still aqueous

$$\frac{0.8\text{ mol }AgCl\text{ made}}{} \Big| \frac{1\text{ mol }Cl^-}{1\text{ mol }AgCl} = 0.8\text{ mol }Cl^-\text{ used}$$

$$\frac{1.2\text{ L}}{} \Big| \frac{250\text{ mmol }FeCl_3}{\text{L}} \Big| \frac{10^{-3}\text{ mol}}{1\text{ mmol}} \Big| \frac{3\text{ mol }Cl^-}{1\text{ mol }FeCl_3} = 0.9\text{ mol }Cl^-\text{ start}$$

$$0.9 - 0.8 = \frac{0.1\text{ mol }Cl^-\text{ remaining}}{1.2\text{ L} + 1.6\text{ L}} = 0.0357\text{ M }Cl^-$$