Ch. 4.2 & 4.5: Precipitation Reactions, Net Ionic Reactions; Concentrations of Solutions

A. Concentrations of Solutions

- Molarity: *moles of solute per liter of solution*, Molar (*M*)
- Molarity is conversion factor between moles of solute and volume of solution.
- What is the concentration of a solution containing 0.0450 mol $ZnCl_2$ in a 250. mL solution?

$$? \text{ M } ZnCl_2 = \frac{0.0450 \text{ mol } ZnCl_2}{250. \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = \frac{0.180 \text{ mol } ZnCl_2}{1 \text{ L}} = 0.180 \text{ M } ZnCl_2$$

- To make a solution, need to add a specific amount of solid to correct volumetric flask, make ~3/4 full with solvent to dissolve solid, fill nearly to the calibration mark then use dropper to dilute to mark with solvent.
  - What mass of $AlCl_3$ is needed to make 0.100 L of a 0.250 M solution of $AlCl_3$?

$$? \text{ g } AlCl_3 = 0.100 \text{ L} \times \frac{0.250 \text{ mol } AlCl_3}{1 \text{ L}} \times \frac{133.33 \text{ g } AlCl_3}{1 \text{ mol } AlCl_3} = 3.33 \text{ g } AlCl_3$$

B. Dilutions of Solutions

- Basic concept: moles of solute do not change when a solution is diluted:
  - $\text{moles solute} = \frac{\text{moles solute}}{\text{L solution}} \times \text{L solution} = MV$

    Since moles solute for concentrated solution = moles solute for dilute solution,

$$M_{conc}V_{conc} = M_{dil}V_{dil}$$

- Volume & Concentration Indirectly proportional—as volume increases, concentration decreases
- To make a dilution, need to add a specific *volume* of a concentrated *stock solution* to a volumetric flask of the right volume and add enough solvent to dilute to the volume mark.
  - For acids, must always add concentrated acid to water before final dilution
    - Mixing is highly exothermic and can splatter concentrated acid if water added to acid.
  - What volume of a 3.00 M solution of HCl would be required to make 250. mL of 0.0500 M HCl? [don't need to convert to L since mL cancel!]

$$3.00 \text{ M} \times V_{conc} = 0.0500 \text{ M} \times 250. \text{ mL so } V_{conc} = 250. \text{ mL} \times \frac{0.0500 \text{ M}}{3.00 \text{ M}} = 4.17 \text{ mL } 3.00 \text{ M HCl}$$

C. Finding Concentration of ions when mix two solutions (no precipitate forms)

- Find total moles then divide by total volume:
  - If one mixes 35.0 mL of 2.0M $CaCl_2$ and 15.0 mL of 5.0M NaCl, what is the concentration of the chloride ions in the resulting solution?

<u>Step 1</u>: Find moles of Cl^- ions in the $CaCl_2$ solution

$$\text{Mol } Cl^- = 35.0 \text{ mL} \times \frac{2.0 \text{ mol } CaCl_2}{1000 \text{ mL}} \times \frac{2 \text{ mol } Cl^-}{1 \text{ mol } CaCl_2} = 0.14 \text{ mol } Cl^-$$

<u>Step 2</u>: Find moles of Cl^- ions in the NaCl solution

$$\text{mol } Cl^- = 15.0 \text{ mL} \times \frac{5.0 \text{ mol NaCl}}{1000 \text{ mL}} \times \frac{1 \text{ mol } Cl^-}{1 \text{ mol NaCl}} = 0.075 \text{ mol } Cl^-$$

<u>Step 3</u>: Calculate molarity of final solution

$$[Cl^-] = \frac{0.14 \text{ mol} + 0.075 \text{ mol}}{35.0 \text{ mL} + 15.0 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = \frac{0.215 \text{ mol } Cl^-}{0.050 \text{ L}} = \boxed{4.3 \text{ M}}$$

D. Precipitation Reactions

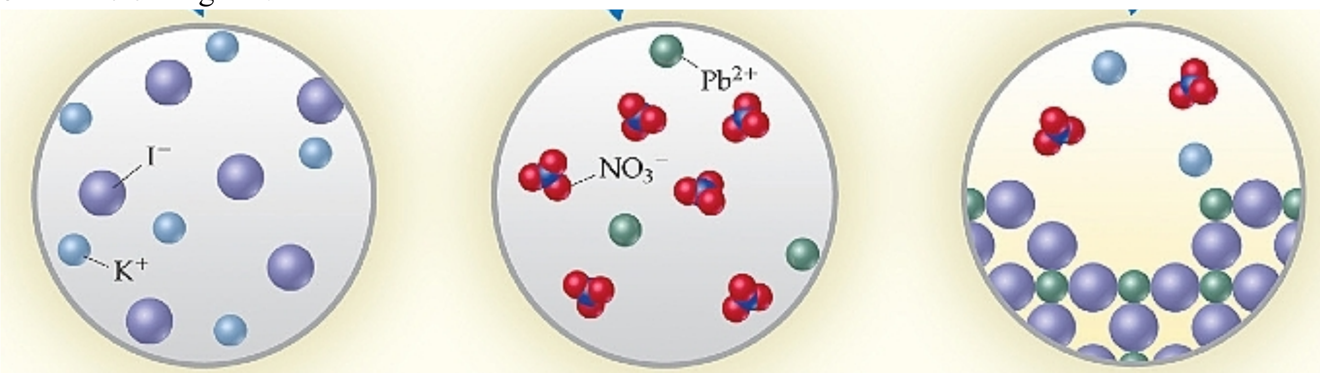
- When two solutions are brought together, an **insoluble** combination of ions may form:
  - e.g. $Pb(NO_3)_2$ (aq) + K_2CrO_4 (aq) → $PbCrO_4$ (s) + 2 KNO_3 (aq)
  - Reaction example: Determine the products and indicate which product is soluble and which is not:

    $Pb(NO_3)_2$ (aq) + Na_2SO_4 (aq) → **$PbSO_4$ (s) + 2 $NaNO_3$ (aq)**

- Above reaction written as a <u>molecular equation</u> (all species in molecular form):
  - NOT a realistic picture of reaction.
- In aqueous solution, soluble ionic compounds & strong acids dissociate, so write in dissociated form for <u>complete ionic equation (CIE)</u>:

  Pb^{2+} (aq) + 2 NO_3^- (aq) + 2 K^+ (aq) + CrO_4^{2-} (aq) → **$PbCrO_4$ (s) + 2 K^+ (aq) + NO_3^- (aq)**
  - Solids, liquids, gases, weak acids and insoluble ionics must be written as compounds—not dissociated!
- Actual reaction only involves species that *change*!
  - K^+ and NO_3^- remain in solution—*spectator ions*, don't participate in reaction
    - Cancel out spectator ions from equation to form <u>net ionic equation (NIE):</u>

      Pb^{2+} (aq) + CrO_4^{2-} (aq) → $PbCrO_4$ (s)
- Particle Diagram:



2 KI(*aq*) The addition of a colorless solution of potassium iodide (KI) + $Pb(NO_3)_2$(*aq*) to a colorless solution of lead nitrate ⟶ PbI_2(*s*) + 2 KNO_3(*aq*) produces a yellow precipitate of lead iodide (PbI_2) that slowly settles to the bottom of the beaker.

E. Determining how to separate ions in a solution by forming a precipitate.

Ex: Suggest a method for how one could separate Na^+ ions from Sr^{2+} ions.

Hint: What ion could be added to make one of the ions become part of an insoluble solid?

1. Mix with SO_4^{2-} solution: Sr^{2+} (aq) + SO_4^{2-} (aq) → $SrSO_4$ (s)
   - Solid $SrSO_4$ precipitate collected on filter, Na^+ ions stay dissolved (Na_2SO_4 is soluble) and go through
2. Add F^- solution: Sr^{2+} (aq) + F^- (aq) → SrF_2 (s)
   - NaF is soluble