# Announcements for Monday, 04NOV2024

- Office Hours are **cancelled** today
- Week 9 Homework Assignments available on eLearning
  - Graded and Timed Quiz 9 – “Chemical reaction” due **Tuesday, 05NOV2024, at 6:00 PM (EST)**
- Mid-Semester Survey due **tonight at 11:59 PM (EST)**

**ANY GENERAL QUESTIONS?** Feel free to see me after class!

# Try This On Your Own

What volume of **0.250 M NaCl(aq)** should be added to completely react **421 mL** of **0.236 M $Pb(NO_3)_2$(aq)** to form $PbCl_2$(s) and $NaNO_3$(aq)?

$$\mathbf{2}\ NaCl(aq) + Pb(NO_3)_2(aq) \longrightarrow PbCl_2(s) + \mathbf{2}\ NaNO_3(aq)$$

**from balanced equation**

$$\frac{\mathbf{421\ mL}}{Pb(NO_3)_2(aq)} \times \frac{1\ L}{1000\ mL} \times \frac{0.236\ mol\ Pb(NO_3)_2}{1\ L} \times \frac{\mathbf{2}\ mol\ NaCl}{1\ moL\ Pb(NO_3)_2} \times \frac{1\ L}{0.250\ mol\ NaCl} \times \frac{1000\ mL}{1\ L} = \frac{\mathbf{795\ mL}}{NaCl(aq)}$$

**0.236 M $Pb(NO_3)_2$(aq)**

**0.250 M NaCl(aq)**

# Solution Stoichiometry – Examples

What mass of $Ca_3(PO_4)_2$ will be produced when 25.0 mL of 0.111 M $K_3PO_4$(aq) reacts completely with 35.0 mL of 0.243 M $Ca(NO_3)_2$(aq) according to the unbalanced reaction $K_3PO_4(aq) + Ca(NO_3)_2(aq) \longrightarrow Ca_3(PO_4)_2(s) + KNO_3(aq)$?

0.430 g $Ca_3(PO_4)_2$

1.5 L of 0.25 M $Na_2CO_3$(aq) reacts with 0.55 L of 0.84 M HCl(aq) according to the reaction $Na_2CO_3(aq) + 2\,HCl(aq) \longrightarrow 2\,NaCl(aq) + H_2O(\ell) + CO_2(g)$. Assuming 100% yield, calculate the number of $CO_2$ molecules generated in this reaction.

$1.4\times10^{23}$ $CO_2$ molecules

(challenging) Consider the reaction $NH_3(aq) + HCl(aq) \longrightarrow NH_4Cl(aq)$

500. mL of 1.5 M $NH_3$(aq) is mixed with 250. mL of 1.0 M HCl(aq) and reacts with 100% yield. What is the concentration of $NH_3$ once the reaction finishes?

$$500\text{ mL NH}_3 \times \frac{1\text{ L}}{1000\text{ mL}} \times \frac{1.5\text{ mol NH}_3}{1\text{ L}} = 0.75\text{ molNH}_3 \times \frac{1\text{ mol NH}_4\text{Cl}}{1\text{ mol NH}_3} = 0.75\text{ mol NH}_4\text{Cl}$$

$$250\text{ mL HCl} \times \frac{1\text{ L}}{1000\text{ mL}} \times \frac{1.0\text{ mol HCl}}{1\text{ L}} = 0.25\text{ mol HCl} \times \frac{1\text{ mol NH}_4\text{Cl}}{1\text{ mol HCl}} = 0.25\text{ mol NH}_4\text{Cl} \ldots \mathit{HCl\ is\ limiting}, \mathbf{NH_3\ in\ excess}$$

$$\text{Amount NH}_3\text{ reacted:}\ \ 0.25\text{ mol HCl} \times \frac{1.0\text{ mol HCl}}{1\text{ L}} \times \frac{1\text{ mol NH}_3}{1\text{ mol HCl}} = 0.25\text{ mol NH}_3\text{ reacted;}\ \ 0.75\text{ mol NH}_3\text{ to start}$$

$$\mathbf{Excess\ NH_3} = 0.75\text{ mol} - 0.25\text{ mol} = 0.50\text{ mol} \quad [\text{NH}_3] = \frac{\text{moles NH}_3}{\mathbf{total}\text{ volume}} = \frac{0.50\text{ mol}}{(0.500\text{ L} + 0.250\text{ L})} = \frac{0.50\text{ mol}}{0.750\text{ L}} = \mathbf{0.67\ M\ NH_3}$$

# Try This On Your Own

500.0 mL of 2.00 M $MgCl_2(aq)$ is mixed with 200.0 mL of 0.500 M $Pb(NO_3)_2(aq)$ and allowed to react to completion.

- Which species will be present in the reaction vessel once the reaction completes?

$H_2O$, $PbCl_2(s)$, $NO_3^-(aq)$ (from $Mg(NO_3)_2$), $Mg^{2+}(aq)$ (from $Mg(NO_3)_2$ AND *excess* $MgCl_2$), and $Cl^-(aq)$ (from *excess* $MgCl_2$)

$$MgCl_2(aq) + Pb(NO_3)_2(aq) \rightarrow Mg(NO_3)_2(aq) + PbCl_2(s)$$

excess

$$500\ \text{mL MgCl}_2 \times \frac{1\ \text{L}}{1000\ \text{mL}} \times \frac{2.00\ \text{mol MgCl}_2}{1\ \text{L}} = 1.00\ \text{mol MgCl}_2 \times \frac{1\ \text{mol PbCl}_2}{1\ \text{mol MgCl}_2} = 1.00\ \text{mol PbCl}_2$$

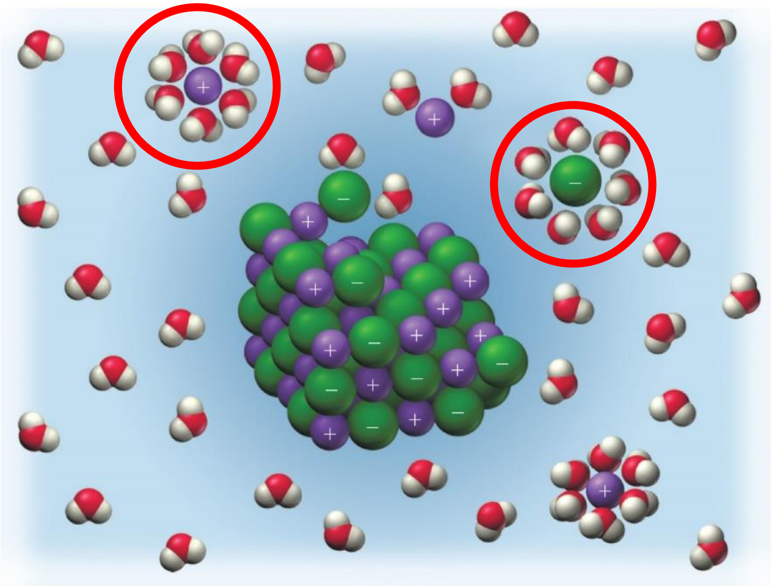
$$200\ \text{mL Pb(NO}_3)_2 \times \frac{1\ \text{L}}{1000\ \text{mL}} \times \frac{0.500\ \text{mol Pb(NO}_3)_2}{1\ \text{L}} = 0.100\ \text{mol Pb(NO}_3)_2 \times \frac{1\ \text{mol PbCl}_2}{1\ \text{mol Pb(NO}_3)_2} = 0.100\ \text{mol PbCl}_2$$

limiting

# The Process of Dissolution in Water

*water molecules surround and envelope the solute particles*

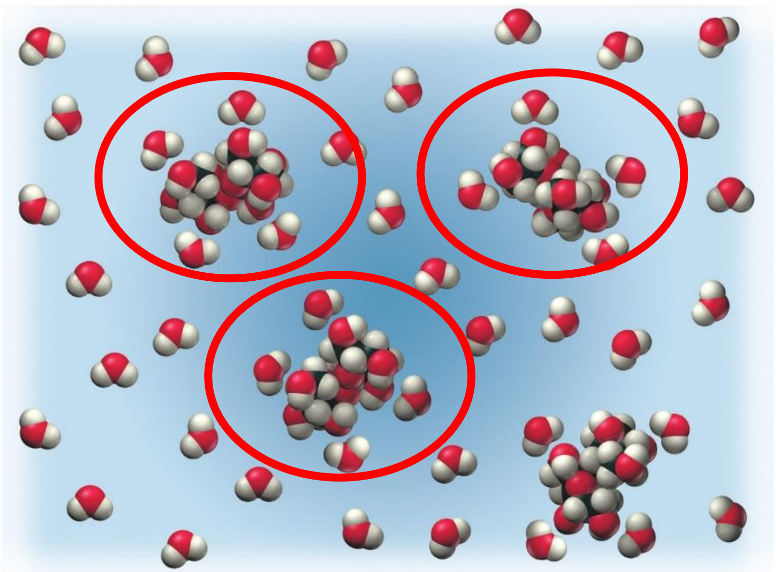
**$NaCl + H_2O$**



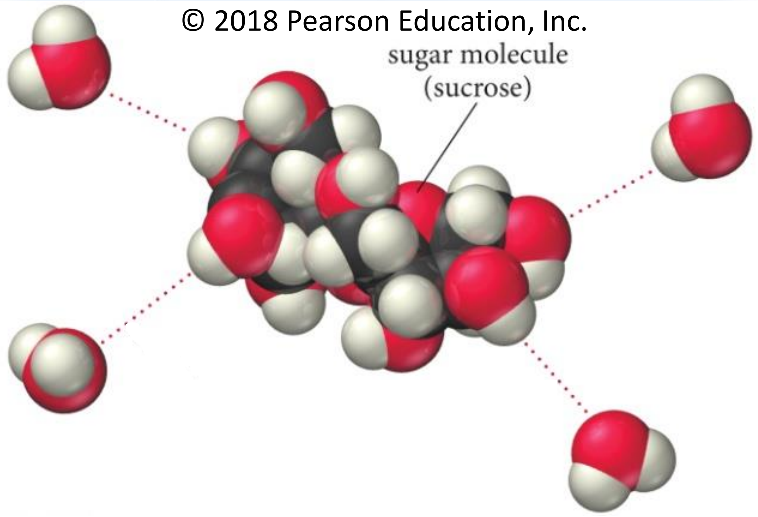



**note how water orients itself differently with the ions**

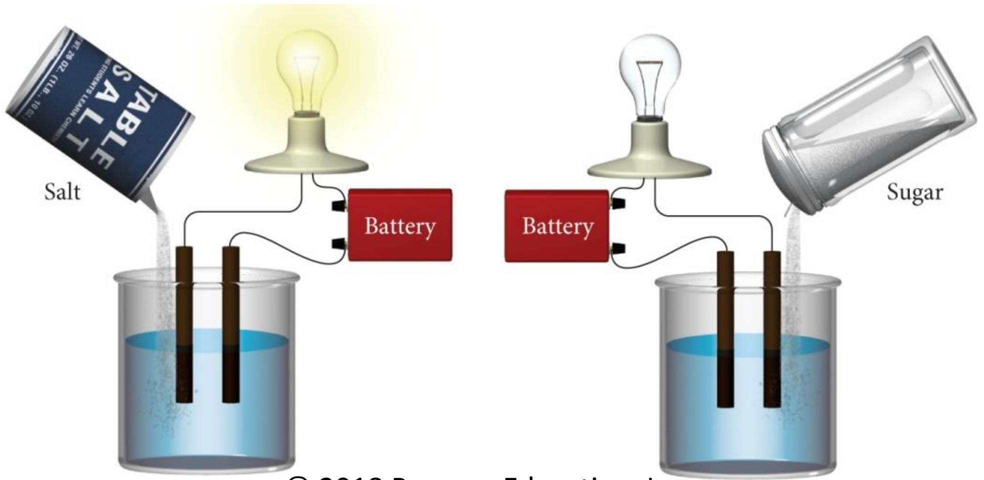
**$C_{12}H_{22}O_{11} + H_2O$**







# Electrolytes





**electrolyte =** a compound that when dissolved in water, allows the water to conduct electricity

- mobile charges are necessary to conduct a current

<u>strong electrolytes</u>

- completely dissociate into ions
  - $HCl(g) + H_2O(\ell) \longrightarrow H^+(aq) + Cl^-(aq)$
- soluble ionic compounds (see solubility rules)
- strong acids

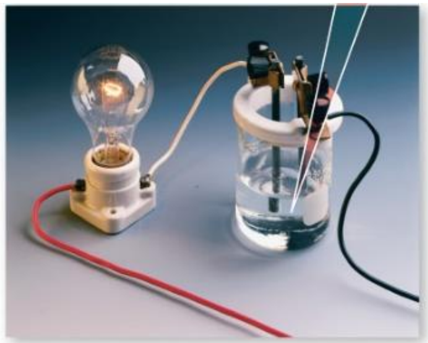
<u>weak electrolytes</u>

- partially dissociate into ions
  - $HF(g) + H_2O(\ell) \rightleftharpoons H^+(aq) + F^-(aq)$
- weak acids, weak bases

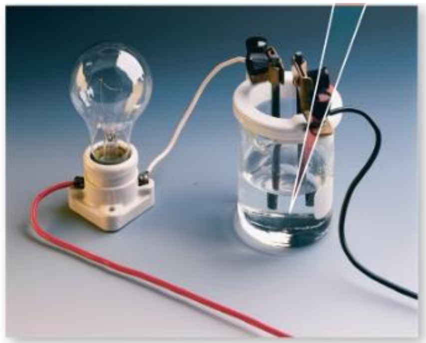
<u>nonelectrolytes</u>

- dissolve and remain as intact molecules
  - $C_{12}H_{22}O_{11}(s) + H_2O(\ell) \longrightarrow C_{12}H_{22}O_{11}(aq)$
- soluble molecular compounds that are **not acids or bases**

Strong electrolyte



Weak electrolyte



Nonelectrolyte

# Solubility Rules – Ionic Compounds in Water

- a set of empirical rules that allow us to determine an ionic compound's water-solubility
  - based on numerous experimental observations
- soluble or insoluble?
  - $Hg_2(NO_3)_2$ (**soluble**)
  - $Ag_2CO_3$ (**insoluble**)
  - LiOH (**soluble**)
- although you don't have to memorize, you should be familiar with some commonly soluble ions ($Na^+$, $NH_4^+$, $NO_3^-$, $C_2H_3O_2^-$/$CH_3COO^-$)

**TABLE 8.1 Solubility Rules for Ionic Compounds in Water**

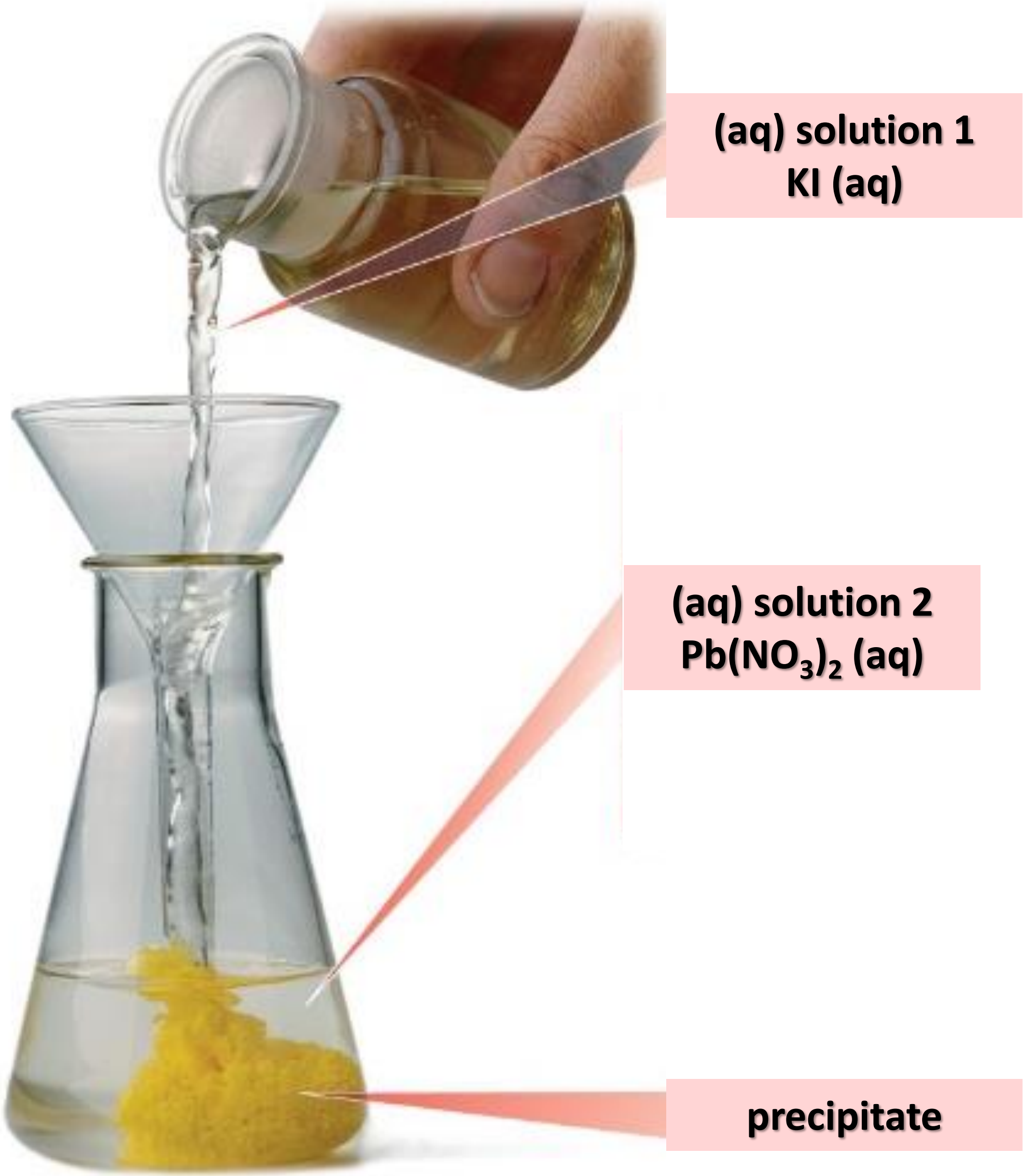
| Compounds Containing the Following Ions Are Generally Soluble | Exceptions |
|---|---|
| $Li^+$, $Na^+$, $K^+$, and $NH_4^+$ | None |
| $NO_3^-$ and $C_2H_3O_2^-$ | None |
| $Cl^-$, $Br^-$, and $I^-$ | When these ions pair with $Ag^+$, $Hg_2^{2+}$, or $Pb^{2+}$, the resulting compounds are insoluble. |
| $SO_4^{2-}$ | When $SO_4^{2-}$ pairs with $Sr^{2+}$, $Ba^{2+}$, $Pb^{2+}$, $Ag^+$, or $Ca^{2+}$, the resulting compound is insoluble. |
| **Compounds Containing the Following Ions Are Generally Insoluble** | **Exceptions** |
| $OH^-$ and $S^{2-}$ | When these ions pair with $Li^+$, $Na^+$, $K^+$, or $NH_4^+$, the resulting compounds are soluble. |
| | When $S^{2-}$ pairs with $Ca^{2+}$, $Sr^{2+}$, or $Ba^{2+}$, the resulting compound is soluble. |
| | When $OH^-$ pairs with $Ca^{2+}$, $Sr^{2+}$, or $Ba^{2+}$, the resulting compound is slightly soluble. |
| $CO_3^{2-}$ and $PO_4^{3-}$ | When these ions pair with $Li^+$, $Na^+$, $K^+$, or $NH_4^+$, the resulting compounds are soluble. |

# Precipitation Reactions

- **precipitation reaction =** an insoluble ionic compound forms upon the mixing of two aqueous solutions of ionic compounds
- predicting products for a precipitation reaction
  - swap ions so that the cation from one compound partners with the anion from the other compound
  - predict precipitates using solubility rules

$2\ KI(aq) + Pb(NO_3)_2(aq) \longrightarrow 2\ KNO_3(aq) + \mathbf{PbI_2(s)}$

net-ionic equation: $Pb^{2+}(aq) + 2\ I^{-}(aq) \longrightarrow PbI_2(s)$



# Ways of Representing Aqueous Reactions

Aqueous solutions of sodium sulfide and magnesium chloride are mixed to form aqueous sodium chloride and a precipitate of magnesium sulfide

$Na^{+}$ $S^{2-}$ $\rightarrow$ $Na_2S$   $Mg^{2+}$ $Cl^{-}$ $\rightarrow$ $MgCl_2$   $NaCl$   $MgS$

1. **<u>molecular equation (a misnomer)</u>**

- balanced reaction with all of the compounds shown associated (i.e., not separated into ions)

$$Na_2S(\mathbf{aq}) \;+\; MgCl_2(\mathbf{aq}) \;\rightarrow\; 2\,NaCl(\mathbf{aq}) \;+\; MgS(\mathbf{s})$$

# Ways of Representing Aqueous Reactions (continued)

Aqueous solutions of sodium sulfide and magnesium chloride are mixed to form aqueous sodium chloride and a precipitate of magnesium sulfide

## 2. <u>complete ionic equation</u>

- species that are strong electrolytes in (aq) solution should be shown as dissociated; weak electrolytes, nonelectrolytes, and undissolved solids should not be dissociated

$$Na_2S(aq) \quad + \quad MgCl_2(aq) \quad \longrightarrow \quad 2\ NaCl(aq) \quad + \quad MgS(s)$$

| $Na_2S(aq)$ | $MgCl_2(aq)$ | $2\ NaCl(aq)$ | $MgS(s)$ |
|---|---|---|---|
| dissociate? | dissociate? | dissociate? | dissociate? |
| YES! | YES! | YES! | NO!! |

$$\boxed{2Na^{+}(aq) + S^{2-}(aq) + Mg^{2+}(aq) + 2Cl^{-}(aq) \longrightarrow 2Na^{+}(aq) + 2Cl^{-}(aq) + MgS(s)}$$

**complete ionic equation**

# Ways of Representing Aqueous Reactions (continued)

Aqueous solutions of sodium sulfide and magnesium chloride are mixed to form aqueous sodium chloride and a precipitate of magnesium sulfide

### 3. <u>net ionic equation</u>

- only species that change during the reaction are shown
- **spectator ions =** ions present on both sides of the equation that don't actually participate in the reaction

$$\cancel{2Na^{+}}(aq) + S^{2-}(aq) + Mg^{2+}(aq) + \cancel{2Cl^{-}}(aq) \longrightarrow \cancel{2Na^{+}}(aq) + \cancel{2Cl^{-}}(aq) + MgS(s)$$

$$\downarrow$$

$$\boxed{Mg^{2+}(aq) + S^{2-}(aq) \longrightarrow MgS(s)}$$

**net ionic equation**

# Writing Net Ionic Equations

## step 1: write balanced overall molecular equation

- be sure to write the correct chemical formulas
- correctly determine the states of the compounds based on the wording of the question
  - species dissolved in water are (aq)
  - precipitates that form are (s)
  - use solubility rules to determine solubility and precipitates

## step 2: write complete ionic equation

- go species by species and dissociate **strong electrolytes** present in (aq) solution
  - soluble ionic compounds in water and strong acids in water get separated
  - weak acids and nonelectrolytes DON'T get separated

## step 3: write net ionic equation

- cancel spectator ions
- make sure balanced coefficients are expressed in lowest whole number

# Try This

- Write a balanced net ionic equations for the reaction that takes place when aqueous mercury(I) nitrate reacts with an aqueous solution of magnesium bromide.

**molecular:** $Hg_2(NO_3)_2(aq) + MgBr_2(aq) \longrightarrow Mg(NO_3)_2(aq) + Hg_2Br_2(s)$

**CIE:** $Hg_2^{2+}(aq) + 2\ NO_3^-(aq) + Mg^{2+}(aq) + 2\ Br^-(aq) \longrightarrow Mg^{2+}(aq) + 2\ NO_3^-(aq) + Hg_2Br_2(s)$

**NIE:** $Hg_2^{2+}(aq) + 2\ Br^-(aq) \longrightarrow Hg_2Br_2(s)$

# Try These On Your Own

- Write a balanced net ionic equation for the reaction that takes place when an aqueous solution of iron(II) nitrate is mixed with an aqueous solution of potassium phosphate.

- Write a balanced net ionic equation for the reaction that takes place when **solid** sodium chloride is added to an aqueous solution of silver acetate.

- Write balanced molecular, complete ionic, and net ionic equations for the reaction that takes place when aqueous copper(II) acetate reacts with an aqueous solution of calcium hydroxide.