Announcements for Thursday, 31OCT2024

- Mid-Semester Survey due **Monday, 04NOV2024, at 11:59 PM (EST)**

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

Try This On Your Own

When heated, calcium carbonate can decompose into calcium oxide and carbon dioxide according to the balanced equation

$$CaCO_3(s) \longrightarrow CaO(s) + CO_2(g)$$

actual yield

What mass of $CaCO_3$ ($\mathcal{M}$ = 100.09 g/mol) must undergo decomposition to generate 10.0 g CO_2 ($\mathcal{M}$ = 44.01 g/mol) if the above reaction only has a yield of 75.0 %? **30.3 g $CaCO_3(s)$**

percent yield

approach 1

"75.0% of what is 10.0 g?" ⟶ 0.750 × ? = 10.0 g

$$? = \frac{10.0\ \mathrm{g}}{0.750} = 13.33\ \mathrm{g\ CO_2}$$

approach 2

$$\%\ \text{yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100\%$$

$$75.0\% = \frac{10.0\ \mathrm{g\ CO_2}}{\text{theoretical yield of } \mathrm{CO_2}} \times 100\%$$

$$\text{theoretical yield of } \mathrm{CO_2} = \frac{10.0\ \mathrm{g\ CO_2}}{0.750} = 13.33\ \mathrm{g\ CO_2}$$

$$13.33\ \mathrm{g\ CO_2} \times \frac{1\ \mathrm{mol\ CO_2}}{44.01\ \mathrm{g\ CO_2}} \times \frac{1\ \mathrm{mol\ CaCO_3}}{1\ \mathrm{mol\ CO_2}} \times \frac{100.09\ \mathrm{g\ CaCO_3}}{1\ \mathrm{mol\ CaCO_3}} = 30.3\ \mathrm{g\ CaCO_3}$$

More Reaction Stoichiometry – Try These On Your Own

Consider the reaction $Cl_2(g) + 3\ F_2(g) \longrightarrow 2\ ClF_3(g)$. What mass of $ClF_3(g)$ was produced from the reaction of 80.0 g $Cl_2(g)$ with 106 g $F_2(g)$? Assume 100% yield.

$$80.0\ \mathrm{g\ Cl_2} \times \frac{1\ \mathrm{mol\ Cl_2}}{70.90\ \mathrm{g}} \times \frac{2\ \mathrm{mol\ ClF_3}}{1\ \mathrm{mol\ Cl_2}} \times \frac{92.45\ \mathrm{g}}{1\ \mathrm{mol\ ClF_3}} = 208.6\ \approx 209\ \mathrm{g\ ClF_3}$$

$$106\ \mathrm{g\ F_2} \times \frac{1\ \mathrm{mol\ F_2}}{38.00\ \mathrm{g}} \times \frac{2\ \mathrm{mol\ ClF_3}}{3\ \mathrm{mol\ F_2}} \times \frac{92.45\ \mathrm{g}}{1\ \mathrm{mol\ ClF_3}} = 171.9 \approx 172\ \mathrm{g\ ClF_3}\ \text{(theoretical yield)}$$

Consider the reaction $2\ N_2(g) + 5\ O_2(g) \longrightarrow 2\ N_2O_5(g)$ in which 20.0 g N_2 is combined with 50.0 g O_2. What mass of excess reagent is left over once the reaction goes to completion?

$$20.0\ \mathrm{g\ N_2} \times \frac{1\ \mathrm{mol\ N_2}}{28.02\ \mathrm{g}} \times \frac{5\ \mathrm{mol\ O_2}}{2\ \mathrm{mol\ N_2}} \times \frac{32.00\ \mathrm{g}}{1\ \mathrm{mol\ O_2}} = 57.1\ \mathrm{g\ O_2}\ \text{needed but only have } 50.0\mathrm{g};\ \mathrm{O_2}\ \text{is limiting}$$

$$50.0\ \mathrm{g\ O_2} \times \frac{1\ \mathrm{mol\ N_2}}{32.00\ \mathrm{g}} \times \frac{2\ \mathrm{mol\ N_2}}{5\ \mathrm{mol\ O_2}} \times \frac{28.02\ \mathrm{g}}{1\ \mathrm{mol\ N_2}} = 17.5\ \mathrm{g\ N_2};\ \text{excess} = 20.0 - 17.5 = 2.5\ \mathrm{g\ excess\ N_2}$$

10. g H_2 reacted with 40. g O_2 to produce water in 80.% yield. How many moles of water was actually produced?

$$10\ \mathrm{g\ H_2} \times \frac{1\ \mathrm{mol\ H_2}}{2.016\ \mathrm{g}} \times \frac{2\ \mathrm{mol\ H_2O}}{2\ \mathrm{mol\ H_2}} = 5.0\ \mathrm{mol\ H_2O} \quad \%\ \text{yield} = 80\% = \frac{\text{actual}}{2.5\ \mathrm{mol}} \times 100\%;\ \text{actual} = 2.0\ \mathrm{mol\ H_2O}$$

$$40\ \mathrm{g\ O_2} \times \frac{1\ \mathrm{mol\ O_2}}{32.00\ \mathrm{g}} \times \frac{2\ \mathrm{mol\ H_2O}}{1\ \mathrm{mol\ O_2}} = 2.5\ \mathrm{mol\ H_2O}\ \text{(theoretical yield)}$$

Chapter 8: Introduction to Solutions and Aqueous Reactions

Some questions we'll try to answer

- How do we numerically express the compositions of solutions?
- What happens to a solution during the process of dilution?
- What are the different ways we represent chemical reactions taking place in an aqueous environment?
- What are electrolytes and how can we characterize compounds based on their electrolytic behavior?
- How do we determine the solubility of a compound and how do we identify a precipitation reaction ?
- What are acids and bases and how do we identify neutralization reactions?
- What are oxidation and reduction and how do we identify redox reactions?

Aqueous Solutions

- recall from Chapter 1: **homogeneous mixture**
  - composed of two or more compounds
  - can be separated by physical methods
  - composition is not fixed or definite
  - properties uniform throughout sample
- **solution =** homogeneous mixture in which a ***solute*** (solid, liquid, or gas) is dissolved in a ***solvent*** (which is usually a liquid)
  - solvent is usually the component present in the larger amount
- **aqueous solution =** solvent is water
  - many important and relevant reactions take place in aqueous environments
- the composition of a solution is numerically expressed using **concentration**

$$\text{concentration} = \frac{\text{solute (mass, moles, volume ...)}}{\text{solvent or solution (mass, moles, volume ...)}}$$

  - lots of concentration units possible

Molarity/Molar Concentration (M)

- amount of solute (in moles) per Liter of solution
  - $\text{Molarity} = \dfrac{\text{amount solute (mol)}}{\text{volume of } \textbf{solution} \text{ (L)}}$

- a new conversion factor!
  - molarity can convert **volume of solution** $\leftrightarrow$ **moles of *solute***

- a species within brackets means "the molar concentration of that species"
  - $[C_6H_{12}O_6]$ = "molarity of a glucose solution"

How many grams of NH_3 (17.03 g/mol) are in 65 mL of 9.9 M ammonia solution? **11 g**

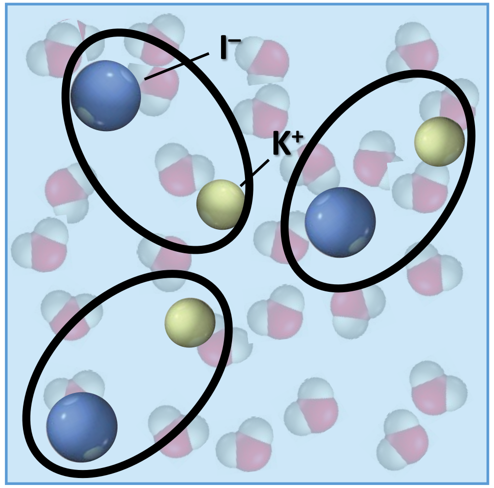
Concentration *of Ions* within Solution

- soluble ionic compounds **dissociate** (i.e., break apart) into ions when they dissolve in water
  - they are **electrolytes (?!?)** (more next lecture)

example: $KI\ (s) + H_2O\ (\ell) \longrightarrow KI\ (aq) \longrightarrow K^+(aq) + I^-(aq)$

1 mole of KI produces 1 mole K^+ and 1 mole I^-

$[KI] = [K^+] = [I^-]$



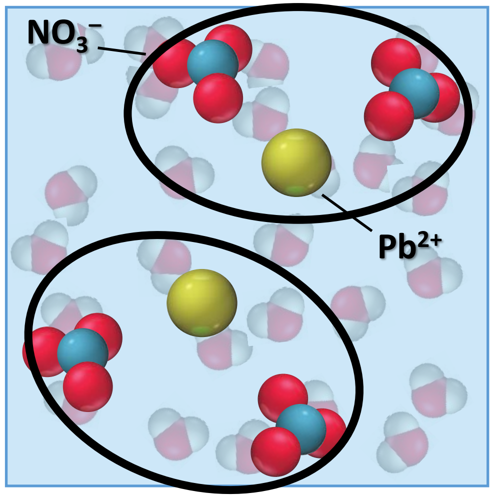
1 K^+ : 1 I^-

but what about an aqueous solution of $Pb(NO_3)_2$?

$Pb(NO_3)_2(s) + H_2O(\ell) \longrightarrow Pb(NO_3)_2(aq) \longrightarrow Pb^{2+}(aq) + \mathbf{2}\ NO_3^-(aq)$

$[Pb(NO_3)_2] = [Pb^{2+}]$ BUT! $[Pb^{2+}] \neq [NO_3^-]$

$[NO_3^-] = \mathbf{2} \times [Pb^{2+}]$!



1 Pb^{2+} : 2 NO_3^-

properly identifying a solute as an electrolyte is very important

- many solution properties are impacted (more in Ch 13)

What mass of lithium phosphate (MM= 115.79 g/mol) should be added to enough water to give 25.0 mL of a solution with $[Li^+]$ = 0.300 M? **0.289 g**

The Process of Dilution

add 29 g NaCl (0.50 mole)

enough water to form 1.0 L of solution

0.50 mole NaCl in 1.0 L solution

[NaCl] = 0.50 mol/L = 0.50 M

remove a 0.120-L aliquot

add 0.200 L water

volume? ↑↓ NC

amount solute? ↑↓ NC

concentration? ↑↓ **NC**

0.120 L solution

[NaCl] = 0.50 M

$$0.120\ \mathrm{L} \times \frac{0.50\ \mathrm{mol\ NaCl}}{1.0\ \mathrm{L}} = 0.060\ \mathrm{mol\ NaCl}$$

volume and moles of solute decreases

molarity does not change

dilution

volume? ↑↓ NC

amount solute? ↑↓ **NC**

concentration? ↑↓ NC

0.320 L solution

0.060 moles NaCl

$$[NaCl] = \frac{0.060\ \mathrm{mol\ NaCl}}{0.320\ \mathrm{L}} = 0.19\ \mathrm{M}$$

volume increases

molarity decreases

moles of solute does not change

Dilution Calculations

dilution = adding solvent to a volume of solution causing a decrease in concentration

- amount of solute doesn't change but volume and concentration do
- $M_1V_1 = M_2V_2$
  - M_1 and V_1 = initial concentration and initial volume
  - M_2 and V_2 = final concentration and final volume
  - doesn't always have to be adding solvent; solvent can also be removed to make a solution more concentrated

★ USE $M_1V_1=M_2V_2$ ONLY FOR DILUTION PROBLEMS (scenarios where the amount of solvent of a solution is being changed…a **physical** process)

- NOT FOR STOICHIOMETRY (where a reaction is taking place…a **chemical** process)

Try on you own: To what volume should 50.0 mL of 1.30 M NaCl(aq) be diluted to give a concentration of 0.450 M? **144 mL**

Solution Stoichiometry

- an extension of what we learned in Chapter 7
  - still need a balanced reaction and still need to convert into moles to utilize the molar relationships within the balanced reaction
- quantities of reactants and products given as volumes and concentrations rather than masses
  - use molarity and volume to get moles
- concepts of limiting reactant, excess reactant, theoretical yield, etc. still apply

Try This

How many moles of AgCl(s) will form when 500. mL of 2.0 M $AgNO_3(aq)$ is mixed with 500. mL of 2.0 M $MgCl_2(aq)$? Assume 100% yield. **1.0 mol**

$$2\ AgNO_3(aq) + MgCl_2(aq) \rightarrow 2\ AgCl(s) + Mg(NO_3)_2(aq)$$

$$\frac{\textbf{500. mL}}{AgNO_3(aq)} \times \frac{1\ L}{1000\ mL} \times \frac{2.0\ mol\ AgNO_3}{1\ L} \times \frac{2\ mol\ AgCl}{2\ moL\ AgNO_3} = \textbf{1.0 mol}\ AgCl(s)$$

limiting reactant

theoretical yield

$$\frac{\textbf{500. mL}}{MgCl_2(aq)} \times \frac{1\ L}{1000\ mL} \times \frac{2.0\ mol\ MgCl_2}{1\ L} \times \frac{2\ mol\ AgCl}{1\ moL\ MgCl_2} = 2.0\ mol\ AgCl(s)$$

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)?

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 $K_3PO_4(aq) + Ca(NO_3)_2(aq) \rightarrow Ca_3(PO_4)_2(s) + KNO_3(aq)$?

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 $Na_2CO_3(aq) + 2\ HCl(aq) \rightarrow 2\ NaCl(aq) + H_2O(\ell) + CO_2(g)$. Assuming 100% yield, calculate the number of CO_2 molecules generated in this reaction.

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

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?

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?