FINISH CHAPTER 4
START CHAPTER 5: ENERGY!

**Today’s Goals**

Quick review of redox reactions and oxidation numbers

Concentrations of Solutions
  - Molarity; Electrolyte (ion) concentrations; Dilutions
  - Solution Stoichiometry

Titrations (Read text – will be covered in lab lecture)

Chapter 5: Thermochemistry
  - Nature of Energy and the First Law

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**OXIDATION–REDUCTION REACTIONS**

- We say that the element that loses electrons in the reaction is **oxidized**. (Lose Electrons: Oxidation)
- And the substance that gains electrons in the reaction is **reduced**. (Gain Electrons: Reduction)

**LEO goes GER**

- You cannot have one without the other.
- We also define redox in terms of changes in oxidation number
  - Oxidation number increases for element being oxidized;
  - Oxidation number decreases for element being reduced.
REDOX REVIEW

1. Free elements have an oxidation number = 0.
2. Monoatomic ions: oxidation number = ion charge.
3. Sum of oxidation numbers of all atoms/ions in neutral compound = 0; in charged compound; sum = charge
4. Group I metals oxidation number = +1
5. Group II metals oxidation number = +2
6. For nonmetals:
   
<table>
<thead>
<tr>
<th>Nonmetal</th>
<th>Oxidation #</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>-1</td>
<td>CF₄</td>
</tr>
<tr>
<td>H</td>
<td>+1</td>
<td>CH₄</td>
</tr>
<tr>
<td>O</td>
<td>-2</td>
<td>CO₂</td>
</tr>
<tr>
<td>Group 7A</td>
<td>-1</td>
<td>CCl₄</td>
</tr>
<tr>
<td>Group 6A</td>
<td>-2</td>
<td>CS₂</td>
</tr>
<tr>
<td>Group 5A</td>
<td>-3</td>
<td>NH₃</td>
</tr>
</tbody>
</table>

7. Can find oxidation #s in a compound using elements that don’t change (like finding a Type II metal’s charge)

TRY THESE

How are the oxidation numbers changing?

4 Ag(s) + 2 H₂S(g) + O₂(g) → Ag₂S(s) + 2 H₂O(g)

Ag 0       H+1, S-2   O 0      Ag +1, S-2   H+1; O-2
Ag is oxidized; O is reduced

2 Fe(s) + O₂(g) → FeO(s)

Fe 0       O 0      Fe +2, O-2
Fe is oxidized; O is reduced

2 Fe(s) + 3 O₂(g) → Fe₂O₃(s)

Fe 0       O 0      Fe +3, O-2
Fe is oxidized; O is reduced
CONCENTRATIONS OF SOLUTIONS

• Concentration: amount of solute in a given quantity of solvent.

• Amount and quantity can be expressed in many ways
  – Grams per mL or L → mass/volume
  – Moles per mL or L → Molarity
  – Mass percent → mass solute/total mass of solution
  – Volume percent → volume solute/total mass of solution
  – Atoms per gallon
    • Maybe not the most practical

WAYS TO EXPRESS CONCENTRATION

Percentages

– **Mass percent (\% m/m):**
  \[
  \text{Percent by mass} = \left( \frac{\text{Mass of component}}{\text{Mass of solution}} \right) (100\%)
  \]

  Note: mass of the solution = mass of the solute + mass of solvent.

– **Mass to volume (\% m/v) =** g solute in final volume of 100 mL x 100%

– **Volume to volume (\%v/v) =** volume of liquid solute in the total volume of solution x 100 (used for liquid/liquid solutions)
  \[
  \text{Percent by volume} = \left( \frac{\text{Volume of component}}{\text{Volume of component} + \text{Volume of solvent}} \right) (100\%)
  \]

Parts per million (ppm): Just as percent means “out of a hundred”, ppm means “out of a million”. 1 ppm is equivalent to 1 milligram of solute per liter of liquid (mg/l) or per kilogram (mg/kg).
% m/m or mass percent:
Number of grams of solute in 100 g of final solution
Example: 5% mass percent solution
• Weigh 5 g solute
• Weigh 95 g solvent
• Solute + solvent = 100 g total

% m/v: Number of grams of solute in 100 mL of solvent:
Example: 5% m/v solution
• Weigh 5 g solute
• Add solvent to make 100 mL total

For liquid/liquid solutions:
% v/v or % by volume = volume of liquid solute out of a total volume of solute + solvent of 100 mL
Example: 50% v/v
• Add 50 mL solute
• Add 50 mL solvent

Note: Final volume may be less than 100 mL due to interaction of solute and solvent

ETHANOL: A COMMON COLLEGIATE SOLUTE

• Concentration of ethanol on bottles is given in two ways:
  – % alcohol by volume
  – Sometimes % alcohol by weight
  – Proof: One "proof" is equal to one-half percent of alcohol by volume.

Blood alcohol: Liquid in liquid solution
  Measured as the weight of ethanol (g) in 100 mL of blood, or 210 L of breath. Expressed as %.

Breathalyzer: Gas in gas solution
COMPOSITION OF MILK (PER 100 G)

<table>
<thead>
<tr>
<th>Constituents</th>
<th>Unit</th>
<th>Cow</th>
<th>Goat</th>
<th>Sheep</th>
<th>Water Buffalo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>g</td>
<td>87.8</td>
<td>88.9</td>
<td>83.0</td>
<td>81.1</td>
</tr>
<tr>
<td>Protein</td>
<td>g</td>
<td>3.2</td>
<td>3.1</td>
<td>5.4</td>
<td>4.5</td>
</tr>
<tr>
<td>Fat</td>
<td>g</td>
<td>3.9</td>
<td>3.5</td>
<td>6.0</td>
<td>8.0</td>
</tr>
<tr>
<td>Carbohydrate</td>
<td>g</td>
<td>4.8</td>
<td>4.4</td>
<td>5.1</td>
<td>4.9</td>
</tr>
<tr>
<td>Cholesterol</td>
<td>mg</td>
<td>14</td>
<td>10</td>
<td>11</td>
<td>8</td>
</tr>
</tbody>
</table>

**Mass percent:**

\[
\text{Mass percent} = \left( \frac{\text{Mass of component}}{\text{Total mass of solution}} \right) \times 100
\]

**Using Concentrations as Conversion Factors**

- Concentrations show the relationship between the amount of solute and the amount of solvent.
  - 12% by mass sugar (aq) means 12 g sugar \( \equiv \) 100 g solution.
- The concentration can then be used to convert the amount of solute into the amount of solution or visa versa.
**Solutions in the Chemistry World**

- Molarity (M): Number of moles of solute/Liter of solution
- Very commonly used to show reagent concentrations.
- Why? We plan reactions based on mole ratios from balanced equations. If reagent concentrations are in moles, we can easily figure out how much reagent we need. For example:

  \[ 2 \text{X} + 3 \text{Y} \rightarrow \text{X}_2 \text{Y}_3 \]

  Reagent \( \text{X} \) has a concentration of 0.1 moles/L
  Reagent \( \text{Y} \) has a concentration of 0.3 moles/L
  Mole ratio from equation is \( 2 \text{X} : 3 \text{Y} \)

  How many L of Reagent \( \text{X} \) and \( \text{Y} \) do I need to make 0.5 mol of \( \text{X}_2 \text{Y}_3 \)?

  
  \[
  0.5 \text{ mol of } \text{X}_2 \text{Y}_3 \times \frac{2 \text{ mole X}}{1 \text{ mole } \text{X}_2 \text{Y}_3} \times \frac{1 \text{ L X}}{0.1 \text{ mol X}} = 10 \text{ L of 0.1 M X} \\
  0.5 \text{ mol of } \text{X}_2 \text{Y}_3 \times \frac{3 \text{ mole Y}}{1 \text{ mole } \text{X}_2 \text{Y}_3} \times \frac{1 \text{ L Y}}{0.3 \text{ mol Y}} = 5 \text{ L of 0.3 M Y}
  \]

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**PREPARING A 1.00 M NaCl SOLUTION**

Weigh out 1 mole (58.45 g) of NaCl and add it to a 1.00 L volumetric flask.

Add water to dissolve the NaCl, then add water to the mark.

Swirl to mix.

**Step 1**  
**Step 2**  
**Step 3**

*Note: Making molar concentration solutions is the process as making a weight to volume solution*
Calculations: Molarity = moles/liter

• What is the molarity of 2.3 moles of sugar in 765 mL solution?

\[
\text{Molarity} = \frac{2.3 \text{ moles sugar} \times 1000 \text{ mL}}{765 \text{ mL}} = 3.06 \text{ M}
\]

• To make a solution of specific molarity: 0.25 M NaCl
  ▪ Need to know molar mass: 23.0 + 35.5 = 58.5 g/mole
  ▪ Calculate mass per volume:
    \[58.5 \text{ g NaCl/mole} \times 0.25 \text{ mole NaCl/L} = 15 \text{ g NaCl/L}\]
  ▪ Decide on the volume for you need: 200 mL
    For 200 mL, we use 0.200 L x 15 g NaCl/L = 3.00 g NaCl

USING MOLARITIES IN STOICHIOMETRIC CALCULATIONS

(Mole ratios from balanced equation)
How Many Grams of CuSO₄•5 H₂O (MM 249.69) are in 250.0 mL of a 1.00 M Solution?

<table>
<thead>
<tr>
<th>Given:</th>
<th>Find:</th>
</tr>
</thead>
<tbody>
<tr>
<td>250.0 mL solution</td>
<td>mass CuSO₄•5 H₂O, g</td>
</tr>
</tbody>
</table>

**Solution Map:**

<table>
<thead>
<tr>
<th>mL sol’n</th>
<th>L sol’n</th>
<th>mol CuSO₄</th>
<th>g CuSO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.001 L</td>
<td>1.00 mol</td>
<td>249.69 g</td>
<td></td>
</tr>
</tbody>
</table>

1.00 L solution = 1.00 mol; 1 mL = 0.001 L; 1 mol = 249.69 g

**Relationship:**

\[
250.0 \text{ mL sol'n} \times \frac{0.001 \text{ L}}{1 \text{ mL}} \times \frac{1.00 \text{ mol CuSO₄•5H₂O}}{1 \text{ L sol'n}} \times \frac{249.69 \text{ g CuSO₄•5H₂O}}{1 \text{ mol CuSO₄•5H₂O}} = 62.4 \text{ g CuSO₄•5H₂O}
\]

**Check:** The unit is correct, the magnitude seems reasonable as the volume is \(\frac{1}{4}\) of a liter.

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**ION CONCENTRATIONS**

- The molarity refers to the # of moles of the *whole compound*.
- For molecular compounds, their concentration will be the same as the molarity.
- Since ionic compounds dissociate in water, the # of moles of the individual ions in solution will depend on the formula of the compound.
- For example: 1 mole of CaCl₂ will dissociate in water to form 1 mole of Ca⁺ ions and 2 moles of Cl⁻ ions.
Determine the Molarity of the Ions in a 0.150 M Na$_3$PO$_4$($aq$) Solution.

<table>
<thead>
<tr>
<th>Given:</th>
<th>0.150 M Na$_3$PO$_4$($aq$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Find:</td>
<td>concentration of Na$^+$ and PO$_4^{3-}$, $M$</td>
</tr>
</tbody>
</table>

**Relationships:**

Na$_3$PO$_4$($aq$) $\rightarrow$ 3 Na$^+$($aq$) + PO$_4^{3-}$($aq$)

**Solve:**

\[
0.150 \text{ M Na}_3\text{PO}_4 \times \frac{1 \text{ mol PO}_4^{3-}}{1 \text{ mol Na}_3\text{PO}_4} = 0.150 \text{ M PO}_4^{3-}
\]

\[
0.150 \text{ M Na}_3\text{PO}_4 \times \frac{3 \text{ mol Na}^+}{1 \text{ mol Na}_3\text{PO}_4} = 0.450 \text{ M Na}^+
\]

**Check:** The unit is correct, the magnitude seems reasonable as the ion molarities $> \text{ the Na}_3\text{PO}_4$ concentration.

How Many Liters of 0.0623 M Ba(OH)$_2$($aq$) Are Needed to React with 0.438 L of 0.107 M HCl?

Ba(OH)$_2$($aq$) + 2 HCl($aq$) $\rightarrow$ BaCl$_2$($aq$) + 2 H$_2$O($l$)

<table>
<thead>
<tr>
<th>Given:</th>
<th>0.0438 L HCl</th>
</tr>
</thead>
<tbody>
<tr>
<td>Find:</td>
<td>L Ba(OH)$_2$</td>
</tr>
</tbody>
</table>

**Solution Map:**

- L HCl $\rightarrow$ mol HCl $\rightarrow$ mol Ba(OH)$_2$ $\rightarrow$ L Ba(OH)$_2$

- $\frac{0.107 \text{ mol HCl}}{1 \text{ L}} \times \frac{1 \text{ mol Ba(OH)}_2}{2 \text{ mol HCl}} \times \frac{1 \text{ L}}{0.0623 \text{ mol Ba(OH)}_2} = 0.376 \text{ L Ba(OH)}_2$

**Check:** The unit is correct.
Find the Molarity of All Ions in the Given Solutions of Strong Electrolytes.

- $0.25 \text{ M MgBr}_2(aq)$.
- $0.33 \text{ M Na}_2\text{CO}_3(aq)$.
- $0.0750 \text{ M Fe}_2(\text{SO}_4)_3(aq)$.

**Dilutions:** A type of v/v solution

Dilutions: Adding solvent to a known quantity of a concentrated reagent to make a less concentrated solution.

Handy equation: $C_1V_1 = C_2V_2$

Concentration$_\text{initial} \times$ Volume$_\text{initial} = \text{Concentration}_\text{final} \times$ Volume$_\text{final}$

Works whether concentration is % w/v, % v/v or molarity

Set up equation to solve for unknown:

*How many mL of 5.0 M NaCl do I need to make 100 mL of a 0.2 M NaCl solution?*

$5.0 \text{ M NaCl} \times X \text{ mL} \times 5.0 \text{ M NaCl} = 0.2 \text{ M NaCl} \times 100 \text{ mL} \times 0.2 \text{ M NaCl}$

$X \text{ mL} \times 5.0 \text{ M NaCl} = \frac{0.2 \text{ M NaCl} \times 100 \text{ mL} \times 0.2 \text{ M NaCl}}{5.0 \text{ M NaCl}}$

$X = 4 \text{ mL} \times 5.0 \text{ M NaCl}$
DILUTION

• One can also dilute a more concentrated solution by
  – Using a pipet to deliver a volume of the solution to a new volumetric flask, and
  – Adding solvent to the line on the neck of the new flask.

FOR THURSDAY

• Begin reading Chapter 5: Thermochemistry
• Mastering Chemistry due by tomorrow at 11 pm
• Pre-Lab for Molar Mass of Unknown Acid
  – Beware: Read the lab and not just the prelab questions. You need to write a procedure for yourself as part of the prelab
  – I will be checking your procedures as you go into lab lecture on Thursday.
• Solubility Lab due