CHEM 115
Review for Exam 1

Lecture 9
Prof. Sevian

Agenda

- More practice with writing net ionic equations
- Rules about test taking in Chem 115
  - Read the info on the website
  - Sit every other seat, every other row
  - You should bring a calculator and pencil (not pen)
  - Scratch paper will be provided
  - The exam is from 2:00-3:15
  - The exam ends at 3:15
- Review for Exam 1, which is this Thursday
What is a net ionic equation?

Fe$_2$(SO$_4$)$_3$ (aq) + 6 LiOH (aq) → 2 Fe(OH)$_3$ (s) + 3 Li$_2$SO$_4$ (aq)

Practice writing another net ionic equation

- What is the net ionic equation that occurs when a solution of sodium sulfide is combined with a solution of silver nitrate?

Na$_2$S (aq) + AgNO$_3$ (aq)
Review for Exam 1

- Classifying matter
- Density as an example of an intensive property
  - Calculating density
  - Significant figures
- Conversions
  - Dimensional analysis as a technique for solving problems
  - Types of conversions we have used:
    - Using density to convert between g and cm³ (or mL)
    - Using molar mass to convert between g and mol
    - Using Avogadro’s number to convert between moles and molecules (or atoms or units of ionic formula)
    - Using stoichiometric coefficient ratios to convert between one kind of chemical and another
Density = A measure of concentration

Which is more dense, the solid or the gas?

Density measures how many particles (how much “stuff”) are in a given volume (space). To compare two samples, you can either:

- Compare equal volumes and then see which one has more particles (stuff) in that same volume (space)
- Compare equal amounts of particles (stuff) and see which one takes up more volume (space)

Example: Density Problem

Mercury has a density of 13.534 g/mL. What is the mass of 24 mL of mercury?

Start

24 mL

End

13.534 g

320 g

Mass units are grams
Using Molar Mass as a Conversion

What is the mass of 0.00497 mol of CH₃COOH?

Molar mass = 60.05 g/mol

\[ 0.00497 \text{ mol CH}_3\text{COOH} \times \frac{60.05 \text{ g}}{1 \text{ mol}} = 0.298 \text{ g CH}_3\text{COOH} \]

How Many Molecules?

Too many to count!

How many molecules of water are in a 2.00-L bottle that is filled with water? Water has a density of 1.000 g/mL.

\[ \frac{2.00 \text{ L H}_2\text{O}}{1 \text{ L}} \times \frac{1000 \text{ mL}}{1 \text{ L}} \times \frac{1.000 \text{ g}}{1 \text{ mL}} \times \frac{1 \text{ mol}}{18.02 \text{ g}} \times \frac{6.022 \times 10^{23} \text{ molecules}}{1 \text{ mol}} = 6.68 \times 10^{25} \text{ molecules of H}_2\text{O} \]
Clicker question #1

Each container has the same volume of gas at the same temperature and pressure. However, each container has a different gas in it.

Which flask has the gas with the greatest density?
A) I.
B) II.
C) III.
D) They are all the same density.

Stoichiometry problem for the reaction: \( \text{N}_2 + 3 \text{H}_2 \rightarrow 2 \text{NH}_3 \)

<table>
<thead>
<tr>
<th></th>
<th>( \text{N}_2 )</th>
<th>( \text{H}_2 )</th>
<th>( \text{NH}_3 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before</td>
<td>2.06 g ( \text{N}_2 )</td>
<td>excess</td>
<td>none</td>
</tr>
<tr>
<td></td>
<td>( 2.06 \text{ g N}_2 \times \frac{1 \text{ mol N}_2}{28.02 \text{ g N}_2} = 0.0735 \text{ mol N}_2 )</td>
<td>excess</td>
<td>none</td>
</tr>
<tr>
<td>Change</td>
<td>-0.0735 mol ( \text{N}_2 )</td>
<td>you could figure out how much if you wanted to</td>
<td>0.0735 mol ( \text{N}_2 \times \frac{2 \text{ mol NH}_3}{1 \text{ mol N}_2} = 0.147 \text{ mol NH}_3 )</td>
</tr>
<tr>
<td>After</td>
<td>none</td>
<td>some</td>
<td>0.147 mol ( \text{NH}_3 \times \frac{17.03 \text{ g NH}_3}{1 \text{ mol NH}_3} = 2.50 \text{ g NH}_3 )</td>
</tr>
</tbody>
</table>
Clicker question #2

A flask is prepared with 15.0 g of NO and 16.0 g of O₂. If the following reaction were to occur,

\[
2 \text{NO} + \text{O}_2 \rightarrow 2 \text{NO}_2
\]

which reactant would be the limiting one?

<table>
<thead>
<tr>
<th>Compound</th>
<th>NO</th>
<th>O₂</th>
<th>NO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molar mass (g·mol⁻¹)</td>
<td>30.0</td>
<td>32.0</td>
<td>46.0</td>
</tr>
</tbody>
</table>

A) NO would be the limiting reactant  
B) O₂ would be the limiting reactant  
C) NO₂ would be the limiting reactant  
D) Neither reactant would be limiting  
E) Both reactants would be limiting

Review for Exam 1

- How can atoms of the same element vary?  
  - Isotopes have different quantities of neutrons, but they have the same quantities of protons and electrons  
  - How to write an isotope symbol  
  - What the numbers inside the boxes on the periodic table mean
- Most of chemistry is about electrons  
  - When a neutral atom gains electrons, it becomes negatively charged  
    - Nonmetals do this (and you can figure out the charge from the Pd Table)  
    - There are lots of negatively charged nonmetal polyatomic ions  
    - There are some negatively charged polyatomic ions which have metal inners with oxygen bonded (e.g. Cr₂O₇²⁻, MnO₄⁻)  
  - When a neutral atom loses electrons, it becomes positively charged  
    - Metals do this (and for non-transition metals you can figure out the charge from the Pd Table)  
    - Many transition metals can lose different amounts of electrons  
    - Occasionally you have positively charged polyatomic ions (e.g., NH₄⁺)
- Chemical nomenclature  
  - First figure out if a compound is ionic, molecular or acid  
  - Then use naming rules for that kind of compound
How Can the Nucleus Vary?

Three different isotopes of carbon atoms
(Note: Bohr model is incorrect, but very useful)

<table>
<thead>
<tr>
<th>Same</th>
<th>All have 6 electrons</th>
<th>All have 6 protons</th>
<th>All neutral</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Different</td>
<td>6 neutrons</td>
<td>7 neutrons</td>
<td>8 neutrons</td>
<td></td>
</tr>
<tr>
<td>Symbol</td>
<td>$^{12}\text{C}_6$</td>
<td>$^{13}\text{C}_6$</td>
<td>$^{14}\text{C}_6$</td>
<td></td>
</tr>
</tbody>
</table>

Reading the Periodic Table

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Atomic number</th>
<th>Atomic weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{12}\text{Mg}$</td>
<td>12</td>
<td>24.31</td>
</tr>
</tbody>
</table>

- A neutral isotope of magnesium
- A $+2$ charged ion of the magnesium-25 isotope
- A different neutral isotope of magnesium
- A $+2$ charged ion of magnesium (with no information about which isotope, so you have to conclude that it is a common sample of magnesium ions and all isotopes are present in their naturally occurring abundances)
Clicker question #3

Which is correct for a +2 charged ion of $^{89}_{38} \text{Sr}$?

<table>
<thead>
<tr>
<th></th>
<th>protons</th>
<th>neutrons</th>
<th>electrons</th>
</tr>
</thead>
<tbody>
<tr>
<td>A)</td>
<td>38</td>
<td>89</td>
<td>38</td>
</tr>
<tr>
<td>B)</td>
<td>38</td>
<td>51</td>
<td>38</td>
</tr>
<tr>
<td>C)</td>
<td>38</td>
<td>51</td>
<td>36</td>
</tr>
<tr>
<td>D)</td>
<td>38</td>
<td>51</td>
<td>40</td>
</tr>
<tr>
<td>E)</td>
<td>Not enough information to tell</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Overview of chemical nomenclature (1)

- Given the formula, to figure out the name
  - First figure out if it's ionic, molecular, or an acid, then name according to one of the following rules:

1. Ionic
   - Distinguish the two ions – this will usually involve figuring out their charges
   - First name = positive ion, Last name = negative ion
     - Transition metals need ionic charge given as part of name (you have to say which one since they can take more than one possible charge)

2. Molecular
   - Primarily you will need to know water, ammonia and the first 10 alkanes
   - Otherwise, First name = (prefix)element, Last name = (prefix)element-ide

3. Acid
   - Break down as if it were an ionic compound, H$^+$ is always the positive ion
   - First name = derived from negative ion, Last name = acid
Overview of chemical nomenclature (2)

- Given the name, to figure out the formula
  - First figure out if it's ionic, molecular, or an acid, then determine the formula according to one of the following methods:

1. Ionic
   - First name = positive ion, Last name = negative ion
   - Figure out what the formulas of the ions and their charges are
   - Determine the smallest ratio of ions to make a neutral compound

2. Molecular
   - Primarily you will need to know water, ammonia and the first 10 alkanes

3. Acid
   - First name = derived from negative ion, Last name = acid (means H+)
   - Figure out the formula and charge on the negative ion is
   - Determine the ratio of H+ and the negative ion to make a neutral compound

If the compound is neutral, do not write charges in the chemical formula

Clicker question #4
Which answer has the correct classifications for knowing which naming rules to use for the compounds?

<table>
<thead>
<tr>
<th></th>
<th>H₂CO₃</th>
<th>Na₂CO₃</th>
<th>C₂H₅OH</th>
</tr>
</thead>
<tbody>
<tr>
<td>A)</td>
<td>Acid</td>
<td>Ionic</td>
<td>Molecular</td>
</tr>
<tr>
<td>B)</td>
<td>Ionic</td>
<td>Molecular</td>
<td>Acid</td>
</tr>
<tr>
<td>C)</td>
<td>Molecular</td>
<td>Acid</td>
<td>Ionic</td>
</tr>
<tr>
<td>D)</td>
<td>Not enough information to tell</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Review for Exam 1

- Chemical formulas
  - Calculating molar mass
  - Mass ↔ moles conversions
- Composition is percent (parts of 100) by mass
  - Elements in a compound (C, H and O in acetic acid, CH₃COOH)
  - Compounds in a hydrated ionic compound (e.g., CuSO₄•5H₂O)
  - Compounds in a mixture (ingredients in baking powder)
- Determining empirical formula (smallest integer ratio of moles in a formula)
  - Simplifying a formula (e.g., C₆H₁₂O₆ has empirical formula CH₂O)
  - Starting with percent composition (or mass composition)
- Determining molecular formula
  - Must be given enough information to get two things:
    - Empirical formula (can be given or can get from mass %)
    - Molecular mass (need to compare this to empirical mass)

Hydrated Ionic Compounds

How many moles are in 5.55 g of BaCl₂•2H₂O?

One unit of ionic formula consists of:

- One Ba²⁺ ion = 137.3
- Two Cl⁻ ions = 2 × 35.45
- Two H₂O molecules = 2 × 18.02

Formula weight = 244.2 g/mol

\[
5.55 \text{ g } \text{BaCl}_2 \cdot 2\text{H}_2\text{O} \times \frac{1 \text{ mol}}{244.2 \text{ g}} = 0.0227 \text{ mol } \text{BaCl}_2 \cdot 2\text{H}_2\text{O}
\]
Composition of a Compound

What is the composition by mass of acetic acid (CH₃COOH)?

\[
\begin{align*}
\%C &= \frac{24.02}{60.05} \times 100\% = 40.00\% \\
\%H &= \frac{4.032}{60.05} \times 100\% = 6.714\% \\
\%O &= \frac{32.00}{60.05} \times 100\% = 53.29\%
\end{align*}
\]

Check: \(40.00 + 6.714 + 53.29 = 100.00\%\)

Recall from earlier:
Molar mass = 60.05 g/mol

Composition of a Hydrated Compound

Heating barium chloride dihydrate (BaCl₂•2H₂O) drives off the water, leaving the anhydrous compound (BaCl₂). The chemical reaction is

\[
\text{BaCl}_2\cdot2\text{H}_2\text{O} \, (s) \rightarrow \text{BaCl}_2 \, (s) + 2 \, \text{H}_2\text{O} \, (g)
\]

If you begin with a 10.0 g sample of the hydrated compound, what mass of water will be lost?

\[
\%\text{H}_2\text{O} = \frac{2 \times 18.02}{244.2} \times 100\% = 7.379\%
\]

mass of \(\text{H}_2\text{O}\) in sample = 7.379% of 10.0 g

= \(0.07379 \times 10.0\) g

= 0.738 g

Formula weight = 244.2 g/mol
Composition of a Mixture

Baking powder is a mixture of ingredients. A sample of baking powder contains 3.50 g of calcium hydrogen phosphate (CaHPO$_4$), 1.50 g of sodium bicarbonate (NaHCO$_3$), and 1.00 g of silicon dioxide (SiO$_2$). Calculate the percent composition by mass.

$$\%\text{CaHPO}_4 = \frac{3.50\text{g}}{3.50+1.50+1.00\text{g}} \times 100\% = 58.3\%$$

$$\%\text{NaHCO}_3 = \frac{1.50\text{g}}{6.00\text{g}} \times 100\% = 25.0\%$$

$$\%\text{SiO}_2 = 100 - (58.3 + 25.0)\% = 16.7\%$$

Molecular Formula to Empirical Formula

- What are the empirical formulas of these compounds?

- All three of these compounds have 85.63% carbon, and 14.37% hydrogen by mass
Empirical Formula to Molecular Formula

To do this, you must be given two pieces of information:
1) Information that will get you to the empirical formula
2) The molecular mass

Empirical Unit CH₂
Mass is 12.01 + 2(1.008) = 14.03 g/mol

C₂H₄
2 × (CH₂) = 2 × (14.03) = 28.06 g/mol

C₄H₈
4 × (CH₂) = 4 × (14.03) = 56.12 g/mol

C₆H₁₂
6 × (CH₂) = 6 × (14.03) = 84.18 g/mol

Clicker question #5

A student solved the following problem and made a critical mistake. What is the mistake?

Problem:
Analysis of 0.500 g of an unknown chemical revealed that it contained 0.200 g of carbon, 0.034 g of hydrogen, and the rest oxygen. What is the empirical formula?

Student's work:
Empirical formula is C \left( \frac{0.200}{0.034} \right) H \left( \frac{0.034}{0.034} \right) O \left( \frac{0.266}{0.034} \right)
Simplifies to: C₆H₁₀O₈

A) The student calculated the amount of oxygen incorrectly.
B) The student rounded improperly on the subscripts.
C) The student made a ratio of mass instead of moles.
D) The student should have divided all the numbers by 0.500 first.
Review for Exam 1

- Chemical reactions
  - Types of reactions: combustion, precipitation, and others
  - Predicting products: need to first figure out what kind of reaction it is
    - If it is an exchange reaction, then reactant ionic compounds switch partners
      - Remember to write the positive ion first in ionic compounds
      - Remember to make neutral compounds
  - Balance a chemical equation by conservation of matter
    - You can only do stoichiometry calculations with balanced reactions
- Stoichiometry calculations
  - When you are told (sometimes implicitly) that one reactant is in excess
  - When you are given both reactants and have to figure out which one is limiting

Chemical Equations

- Represent a chemical change of matter
- Reactants (starting materials) on left
- Products (ending materials) on right

Reactants → Products

- What goes in must come out, just connected (bonded) differently
Combustion of propane

\[ \text{H}_3\text{C}-\text{C}-\text{C}+5\text{O}_2 \rightarrow 3\text{CO}_2 + 4\text{H}_2\text{O} \]

1. Balance the Carbons
2. Balance the Hydrogens
3. Balance the Oxygens
4. Is it balanced?

Balanced chemical equation:

\[ \text{C}_3\text{H}_8 + 5\text{O}_2 \rightarrow 3\text{CO}_2 + 4\text{H}_2\text{O} \]

Another reason why it’s important to know how to name chemicals: so you can identify the ions to balance reactions that involve ions.

When the balancing units are ions, not atoms

\[ \text{CuSO}_4 + 3\text{Na}_3\text{PO}_4 \rightarrow \text{Cu}_3(\text{PO}_4)_2 + 3\text{Na}_2\text{SO}_4 \]

\[ 3\text{CuSO}_4 + 2\text{Na}_3\text{PO}_4 \rightarrow \text{Cu}_3(\text{PO}_4)_2 + 3\text{Na}_2\text{SO}_4 \]
General Strategy for Simple Stoichiometry Problems

Stoichiometry (counting atoms) of $N_2 + 3H_2 \rightarrow 2NH_3$

<table>
<thead>
<tr>
<th></th>
<th>N$_2$</th>
<th>H$_2$</th>
<th>NH$_3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before</td>
<td>4 mol</td>
<td>9 mol</td>
<td>0 mol</td>
</tr>
<tr>
<td>Change</td>
<td>-3 mol</td>
<td>-9 mol</td>
<td>+6 mol</td>
</tr>
<tr>
<td>After</td>
<td>1 mol</td>
<td>0 mol</td>
<td>6 mol</td>
</tr>
</tbody>
</table>
Review for Exam 1

- Precipitation reactions
  - These are exchange reactions
  - When predicting the products that result from mixing two solutions containing ionic compounds, key is to figure out whether one (or both) product is insoluble, and hence precipitates out of solution
  - Don’t forget to form neutral compounds on the product side
- Writing net ionic equations
  - Shows the “net” of what is reacting
    - Spectator ions are omitted because they do not participate
    - Ok to write ions because it is understood that these are ions dissolved water
    - Only ionic compounds that are soluble break into ions, everything else remains whole (i.e., precipitates, gases, reactants that start as solids)
  - You’re learning how to write these for precipitation reactions, but you will also need to write them for other kinds of reactions soon

Solubility guidelines

How to read this table:
If one ion from the “Soluble Compounds” list is in an ionic compound, then a lot of the ionic compound can dissolve in water.
Likewise, if one ion from the “Insoluble Compounds” list is in an ionic compound, then the ionic compound will not dissolve very much in water.

| TABLE 4.1 Solubility Guidelines for Common Ionic Compounds in Water |
|---------------------------------|---------------------------------------------|
| **Soluble Ionic Compounds**     | **Important Exceptions**                    |
| Compounds containing           |                                             |
| $\text{NO}_3^-$                  | None                                        |
| $\text{C}_2\text{H}_5\text{O}_2^-$ | None                                        |
| $\text{Cl}^-$                    | Compounds of $\text{Ag}^{+}$, $\text{Hg}_2^{2+}$, and $\text{Pb}^{2+}$ |
| $\text{Br}^-$                    | Compounds of $\text{Ag}^{+}$, $\text{Hg}_2^{2+}$, and $\text{Pb}^{2+}$ |
| $\text{I}^-$                     | Compounds of $\text{Ag}^{+}$, $\text{Hg}_2^{2+}$, and $\text{Pb}^{2+}$ |
| $\text{SO}_4^{2-}$               | Compounds of $\text{Sr}^{2+}$, $\text{Ba}^{2+}$, $\text{Hg}_2^{2+}$, and $\text{Pb}^{2+}$ |

| **Insoluble Ionic Compounds**    | **Important Exceptions**                    |
| Compounds containing           |                                             |
| $\text{S}^{2-}$                 | Compounds of $\text{NH}_4^+$, the alkali metal cations, and $\text{Ca}^{2+}$, $\text{Sr}^{2+}$, and $\text{Ba}^{2+}$ |
| $\text{CO}_3^{2-}$              | Compounds of $\text{NH}_4^+$ and the alkali metal cations |
| $\text{PO}_4^{3-}$              | Compounds of $\text{NH}_4^+$ and the alkali metal cations |
| $\text{OH}^-$                   | Compounds of the alkali metal cations, and $\text{NH}_3$, $\text{Ca}^{2+}$, $\text{Sr}^{2+}$, and $\text{Ba}^{2+}$ |

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Clicker question #6

Which of the following salts would be least soluble in water?

A) CaCO₃  
B) Na₂CO₃  
C) CaBr₂  
D) AgBr  
E) AgNO₃

Clicker question #7

What would be the products if you mixed a solution of Pb(C₂H₃O₂)₂ with a solution of KOH?

A) PbK (s) and C₂H₃O₂OH (aq)  
B) KC₂H₃O₂ (aq) and Pb(OH)₂ (s)  
C) PbOH (s) and KC₂H₃O₂ (aq)  
D) HC₂H₃O₂ (aq) and KOPb (s)  
E) No reaction would occur