1. **50 multiple choice questions (2 pts each)**
   - 30 questions from “old” material
     - ten from test 1, ten from test 2, ten from test 3
     - 20 questions from “new” material
   - 15 nomenclature questions (1 pt each)

   Key to final exam will be posted in glass case outside room 100 after exam is over

---

**WHAT TO STUDY?**

At the end of each chapter
- Strategies in Chemistry
- Summary & Key Terms
  - Also
- Old Exams
- Web problems & Exams

---

**Chem 1412 Final has 115 points (similar to others)**

**CHAP 10: Gases (Ideal & Real)**

**Ideal Gas**

\[ PV = nRT \]

**Real Gas**

\[ P = \frac{nRT}{V - nb} \]

Corrects for molecular volume
Corrects for molecular attraction

---

**GAS PRESSURE**

(force per unit area)

\[ P = \frac{F}{A} \]

- **Pressure Measured with**
  Barometers & Manometers (Open & Closed)
- **Standard Conditions (STP)**
  - Standard temperature 0°C (= 273.15 K)
  - Standard pressure 1 atm
  - “Standard amount” 1 mole
  - “Standard volume” 22.4 Liters

---

**THE IDEAL GAS**

\[ PV = nRT \]

**and its APPLICATIONS**

- **Gas Density:**
  \[ \text{Density} = \frac{\text{grams}}{\text{volume}} = \frac{P \text{ M/V}}{R \ T} \]
- **Molecular Weight:**
  \[ \text{MW} = \frac{\text{grams}}{\text{mole}} = \frac{gRT}{VP} \]
- **Partial Pressures:**
  \[ \frac{P_i}{P_{\text{total}}} = \frac{n_i}{n_t} \quad \text{or} \quad P_i = X_i P_{\text{total}} \]

where \( X_i = \frac{n_i}{n_{\text{total}}} \) is the mole fraction
Collecting Gas over Water & Dalton’s Law

\[ P_{\text{Total}} = (P_{\text{gas}} + P_{\text{water}}) = (n_{\text{gas}} + n_{\text{water}}) \cdot R \cdot T \]

(Gas pressures are additive)

Gas Volumes and Avogadro’s Law

1 \( N_2 \) (gas) + 3 \( H_2 \) (gas) = 2 \( NH_3 \) (gas)

1 volume reacts with 3 volumes to produce 2 volumes

(Volume directly proportional to amount (moles))

Chapter 11 Liquids & Solids

INTER & INTRA MOLECULAR FORCES

- INTRA molecular forces are Chemical Bonds which are formed between elements
- INTER molecular forces are the attractive forces between molecules and ions that determine bulk properties of matter

Types of Intermolecular Forces

1. Ion–dipole
2. Dipole–dipole
3. London Forces \( \Rightarrow \) Instantaneous induced–dipole (dispersion forces)
4. Hydrogen “bonds.”

Some Properties of Liquids

Vapor Pressure
Boiling Point
Viscosity
Surface Tension

Features of a Phase Diagram

- **Triple point**: temperature and pressure at which all three phases are in equilibrium.
- **Vapor-pressure curve**: generally as pressure increases, temperature increases.
- **Critical point**: critical temperature and pressure
- **Melting point curve**: as pressure increases, the solid phase is favored if the solid is more dense than liquid
- **Normal melting point**: melting point at 1 atm.
- **Supercritical Fluid**: A state of matter beyond the critical point that is neither liquid nor gas
CHAP 12: Properties of Solutions

- **SOLUBILITY RULES** – Chapter 4
- **SOLUBILITY** – factors that affect
  - Pressure (HENRY’S LAW)
  - Temperature
- **CONCENTRATION** – Molecular weight
- **COLLIGATIVE PROPERTIES** – Molecular solutions
  - Ionic solutions
- **COLLOIDS**

---

**CONCENTRATION**

is either based on weight or volume

1. **ppm** (parts per million) (based on weight)
2. **ppb** (parts per billion) (based on weight)
3. **Mole Fraction** (based on weight)
4. **Molarity** (based on volume)
5. **Molality** (based on weight)

---

**COLLIGATIVE PROPERTIES**

(determination of molecular weight)

- **of non Electrolytes**
  - Vapor Pressure LOWERING \( \Delta P = x_i P^o_j \)
  - Boiling Point ELEVATION \( \Delta T_b = K_b m \)
  - Freezing Point LOWERING \( \Delta T_f = K_f m \)
  - Osmotic Pressure \( \pi = MRT \)

---

**COLLIGATIVE PROPERTIES**

(determination of molecular weight and/or van’t Hoff i facror)

- **of Electrolytes**
  - Vapor Pressure LOWERING \( \Delta P = i x_i P^o_j \)
  - Boiling Point ELEVATION \( \Delta T_b = i K_b m \)
  - Freezing Point LOWERING \( \Delta T_f = i K_f m \)
  - Osmotic Pressure \( \pi = i MRT \)

---

Chap 14: **CHEMICAL KINETICS**

CHEMICAL KINETICS DEALS WITH

1. How **FAST** (Speed like miles per hour)
2. By what **MECHANISM** Does a Reaction Take Place?
Part I:  
The Rates of Reaction Depends On

1. **Nature of Reactants** \{fixed\}  
2. **Concentration of Reactants** \{variable\}  
3. **Temperature** \{variable\}  
4. **Etc.** \{variable\}  
   - **Catalysts**  
   - **Particle Size**  
   - **Photochemical**

Determine the rate law for  

$$\text{2NO}(g) + \text{2H}_2(g) \rightarrow \text{N}_2(g) + \text{2H}_2\text{O}(g)$$

<table>
<thead>
<tr>
<th>Experiment Number</th>
<th>Initial NO (M)</th>
<th>Initial H₂ (M)</th>
<th>Initial Rate (M/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.10</td>
<td>0.10</td>
<td>1.25 \times 10^{-3}</td>
</tr>
<tr>
<td>2</td>
<td>0.10</td>
<td>0.20</td>
<td>2.46 \times 10^{-3}</td>
</tr>
<tr>
<td>3</td>
<td>0.20</td>
<td>0.10</td>
<td>4.92 \times 10^{-3}</td>
</tr>
</tbody>
</table>

**Half-life** \{t₁/₂\}

is defined as the time required for one-half of a reactant to react

For \( A \rightarrow B \)

at \( t₁/₂ \),

the concentration of \( A \) is one-half the initial concentration of \( A \)

**TEMPERATURE AND RATE**

**AS TEMPERATURE INCREASES, SO DOES THE REACTION RATE.**

THIS IS BECAUSE \( k \) IS TEMPERATURE DEPENDENT.

Part II  
Reaction mechanism.

- Reactions occur through several discrete steps
- Each of these is known as an elementary reaction or elementary process
- The molecularity of a process tells how many molecules are involved in the process

*The Collision Model*

Molecules can only react if they collide

**EQUILIBRIUM**  
Chapters 15 - 17

<table>
<thead>
<tr>
<th>Molecular</th>
<th>Chap 15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ionic (Weak Acid / Base)</td>
<td>Chap 16</td>
</tr>
<tr>
<td>Ionic (“Insoluble” Salts)</td>
<td>Chap 17</td>
</tr>
</tbody>
</table>

- Homogeneous Equilibrium
- Heterogeneous Equilibrium
- Equilibrium Calculations
- Le Châtelier’s Principle
The equilibrium-constant expression depends only on the stoichiometry not on the mechanism:

\[ K = \frac{[\text{Products}]^p}{[\text{Reactants}]^q} \]

Pure Solids and Liquids do not have a concentration so they do not appear in the equilibrium expression.

\[ K_{eq} = \frac{[SO_3]^2}{[SO_2]^3[O_2]} = \frac{(0.925)^2}{(0.075)^2(0.537)} = 2.8 \times 10^2 \]

Catalysts increase the rate of both the forward and reverse reactions:

- Equilibrium is achieved faster, but the equilibrium composition remains unaltered.
- Therefore Catalysts have No effect on the equilibrium concentrations.

Endothermic processes are favored with increase.
Exothermic processes are favored with decrease.

Chapter 16 is a continuation of chapter 15
For WEAK Acids & WEAK Bases

- What is an Acid?
- What is a Base?

1. ARRHENIUS Acid / Base
2. BRONSTED-LOWRY Acid / Base
3. LEWIS Acid / Base

pH and the ion product constant of water:

\[ \text{pH} = -\log [H^+] \]
\[ pOH = -\log [OH^-] \]
\[ pK_a = -\log K_a \]

\[ K_a = [H^+][OH^-] = 1.0 \times 10^{-14} \]
\[ pK_a = pK_b = 14 \]

When \([H^+] = [OH^-]\) have a “neutral” solution and \(pH = pOH = 7\).
pH of some common fluids
- Gastric juice in stomach: 1.0 – 2.0
- Lemon juice: 2.4
- Vinegar: 3.0
- Grapefruit juice: 3.2
- Orange juice: 3.5
- Urine: 4.8 – 7.5
- Saliva: 6.4 – 6.9
- Milk: 6.5
- Blood: 7.35 – 7.45
- Tears: 7.4
- Milk of Magnesia: 10.6
- Household Ammonia: 11.5

**Relationship between $K_a$ and $K_b$**

$$K_a \times K_b = K_w$$

<table>
<thead>
<tr>
<th>ACID</th>
<th>$K_a$</th>
<th>CONJ. BASE</th>
<th>$K_w$</th>
</tr>
</thead>
<tbody>
<tr>
<td>HF</td>
<td>$7.1 \times 10^{-4}$</td>
<td>F-</td>
<td>$1.4 \times 10^{-11}$</td>
</tr>
<tr>
<td>HNO$_2$</td>
<td>$4.5 \times 10^{-4}$</td>
<td>NO$_2^-$</td>
<td>$2.2 \times 10^{-11}$</td>
</tr>
<tr>
<td>HCO$_2$H (formic)</td>
<td>$1.7 \times 10^{-4}$</td>
<td>HCO$_2^-$</td>
<td>$5.9 \times 10^{-11}$</td>
</tr>
<tr>
<td>CH$_3$CO$_2$H (acetic)</td>
<td>$1.8 \times 10^{-5}$</td>
<td>CH$_3$CO$_2^-$</td>
<td>$5.6 \times 10^{-10}$</td>
</tr>
<tr>
<td>HCN</td>
<td>$4.9 \times 10^{-10}$</td>
<td>CN-</td>
<td>$2.0 \times 10^{-6}$</td>
</tr>
</tbody>
</table>

### Acid–Base Properties of Salts

**SALTS IN WATER EITHER FORM**

- **neutral** solutions
- **basic** solutions
- or **acidic** solutions

### Buffer Solution:

**Buffer Solution** is a solution of

- a **Weak** acid
  - or
- a **Weak** base
  - and
- **its salt**

**BOTH ACID (OR BASE) & SALT MUST BE PRESENT**

Will a precipitate form when 50 mL of 1.0 x 10$^{-3}$ M Barium Nitrate is added to 50 mL of 1.0 x 10$^{-4}$ M Sodium Sulfate?

The answer is Yes if the $K_{sp}$ is exceeded

If $[Ba^{2+}][SO_4^{2-}] > K_{sp}$

Moles $Ba^{2+} = 0.0010M \times 0.050L = 5 \times 10^{-5}$

Moles $SO_4^{2-} = 0.00010M \times 0.050L = 5 \times 10^{-6}$

$[Ba^{2+}] = (5 \times 10^{-4}) \text{ (100mL of solution)}$

$[SO_4^{2-}] = (5 \times 10^{-5}) \text{ (100mL of solution)}$

$K_{sp} = [Ba^{2+}][SO_4^{2-}] = 1.1 \times 10^{-10}$

For this case $M_{Ba^{2+}} = (5 \times 10^{-4})$ $M_{SO_4^{2-}} = (5 \times 10^{-5})$

So $[Ba^{2+}][SO_4^{2-}] = (5 \times 10^{-4})(5 \times 10^{-5}) = 2.5 \times 10^{-8}$

Since the ion product $(2.5 \times 10^{-8})$

is greater than the $K_{sp}$ $(1.1 \times 10^{-10})$

a precipitate of barium sulfate is expected
The concentration of calcium ion in the blood plasma is $2.5 \times 10^{-3}$ M. If the concentration of oxalate ion is $1.0 \times 10^{-7}$ M do you expect calcium oxalate to precipitate?

$$\text{Ca}^{2+} + \text{C}_2\text{O}_4^{2-} \rightarrow \text{CaC}_2\text{O}_4$$

$$K_{sp} = [\text{Ca}^{2+}][\text{C}_2\text{O}_4^{2-}] = 2.3 \times 10^{-9}$$

$$M_{\text{Ca}^{2+}} = (2.5 \times 10^{-3}) \text{ and } M_{\text{C}_2\text{O}_4^{2-}} = (1 \times 10^{-7})$$

$$[\text{Ca}^{2+}][\text{C}_2\text{O}_4^{2-}] = (0.0025)(1.0 \times 10^{-7}) = 2.5 \times 10^{-10}$$

Since the ion product ($2.5 \times 10^{-10}$) is smaller than $K_{sp}$, $(2.3 \times 10^{-9})$ do NOT expect precipitation to occur.

Chap 20 ELECTROCHEMISTRY

“Ordinary” Chemical Reactions produce Heat

$$\text{Zn(s) + HCl(aq)} \rightarrow \text{H}_2(g) + \text{ZnCl}_2(aq) + \text{HEAT}$$

Electrochemical Reactions produce Voltage

$$\text{Zn(s) + HCl(aq)} \rightarrow \text{H}_2(g) + \text{ZnCl}_2(aq) + \text{VOLTS}$$

Two Parts To ELECTROCHEMISTRY

**Part 1 SPONTANEOUS Process**
A Chemical Reaction Produces Voltage

BATTERYS

**Part 2 NONSpontaneous Process**
Voltage causes a Chemical Reaction

ELECTROLYSIS

Two (2) electrolytes with a Salt Bridge

<table>
<thead>
<tr>
<th>Electrode</th>
<th>Reaction</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Anode</strong></td>
<td>Zn$^2+$ $\rightarrow$ Zn(s) + 2e$^-$</td>
</tr>
<tr>
<td><strong>Cathode</strong></td>
<td>H$_2$(aq) $\rightarrow$ 2H$^+$ + 2e$^-$</td>
</tr>
</tbody>
</table>

The overall electrochemical reaction

$$\text{Zn(s) + 2 H}^+(aq) \rightarrow \text{Zn}^{2+}(aq) + \text{H}_2(g)$$
**ANODE**  Pb  (the negative electrode)  
\[
Pb (s) + SO_4^{2-} (aq) \rightarrow PbSO_4 (s) + 2e^- 
\]

**CATHODE**  PbO_2 (lead IV oxide)  (positive electrode)  
\[
PbO_2(s) + SO_4^{2-}(aq) + 4H^+(aq) + 2e^- \rightarrow PbSO_4(s) + 2H_2O(l) 
\]

*The overall electrochemical reaction*  
\[
PbO_2(s) + Pb (s) + 2 SO_4^{2-}(aq) + 4 H^+(aq) \rightarrow 2 PbSO_4(s) + 2 H_2O(l) 
\]

**One (1) Electrolyte:**  Sulfuric Acid  
*No need for a salt bridge*

---

**External force causes chemical reactions**  

1 Faraday = 96,500 coulombs  
Coulombs = Amp- seconds  
\[
Q = I \text{ (amps)} \times t \text{ (sec)} 
\]

Two (2) Faradays would produce 1 mole (58.71grams) so one (1) Faraday would produce \( \frac{1}{2} \) mole (29.36 gms)

---

**How Much Ni would be electroplated if 1 Faraday was passed through cell?**  
1 Ni\(^{2+} \rightleftharpoons 2e^- \rightarrow 1 Ni\]

---

**How long would it take for 29.36 grams to be deposited?**  

1 Faraday = 96,500 coulombs  
Coulombs = Amp- seconds  
\[
Q = I \text{ (amps)} \times t \text{ (sec)} 
\]

96,500 coulombs = 2 (amps) x 2 (sec)  
Time = \( \frac{1}{2} \) (96,500) = 48,250 sec  
= 804 minutes  
= 13.4 hours

---

**Will Fe\(^{2+}\)(aq) oxidize Al(s)?**  
*Or......will the following reaction occur?*  
3 Fe\(^{2+}\)(aq) + 2 Al (s) \rightarrow 3 Fe (s) + 2 Al\(^{3+}\)(aq)  

In order to answer that question, calculate \( \varepsilon_{cell} \)  
\[
2e^- + Fe^{2+}(aq) \rightarrow Fe (s) \quad \varepsilon_{red} = -0.44 \\
Al (s) \rightarrow Al^{3+}(aq) + 3e^- \quad \varepsilon_{oxid} = + 1.66 \\
\varepsilon_{cell} = \varepsilon_{oxid} + \varepsilon_{red} = + 
\]

Since \( \varepsilon_{cell} \) is positive, YES the reaction will occur

---

*End Review*
Balancing Oxidation-Reduction Reactions

**In Acidic Solution**
1. Write ion half reactions
2. Balance atoms
3. Add water (if needed)
4. Add electrons

**In Basic Solution**  *one more step is added*
5. OH⁻ is added to equation

---

**Example of Balancing Oxidation-Reduction Reaction:**

\[
\text{NO}_2^-(aq) + \text{Al}(s) \rightarrow \text{NH}_3(g) + \text{Al(OH)}_4^-(aq)
\]

**in Acidic Solution**

The two half reactions are:

\[
\text{NO}_2^-(aq) \rightarrow \text{NH}_3(g) \\
\text{Al}(s) \rightarrow \text{Al(OH)}_4^-(aq)
\]

Adding water:

\[
\text{NO}_2^-(aq) \rightarrow \text{NH}_3(g) + 2 \text{H}_2\text{O} \\
4 \text{H}_2\text{O} + \text{Al}(s) \rightarrow 4 \text{H}^+(aq) + \text{Al(OH)}_4^-(aq)
\]

Adding H⁺:

\[
7 \text{H}^+(aq) + \text{NO}_2^-(aq) \rightarrow \text{NH}_3(g) + 2 \text{H}_2\text{O} \\
4 \text{H}_2\text{O} + \text{Al}(s) \rightarrow 4 \text{H}^+(aq) + \text{Al(OH)}_4^-(aq)
\]

Adding electrons:

\[
6e + 7 \text{H}^+(aq) + \text{NO}_2^-(aq) \rightarrow \text{NH}_3(g) + 2 \text{H}_2\text{O} \\
4 \text{H}_2\text{O} + \text{Al}(s) \rightarrow 4 \text{H}^+(aq) + 3 \text{e} \\
8 \text{H}_2\text{O} + 2 \text{Al}(s) \rightarrow 2 \text{Al(OH)}_4^-(aq) + 8 \text{H}^+(aq) + 6 \text{e}
\]

---

**Balancing Oxidation-Reduction Reactions in Basic Solution**

\[
6\text{H}_2\text{O} + \text{NO}_2^- + 2\text{Al} \rightarrow \text{NH}_3 + 2\text{Al(OH)}_4^- + \text{H}^+
\]

**Add OH⁻(aq) to BOTH sides**

\[
\text{OH}^-(aq) \rightarrow \text{OH}(aq)
\]

\[
\text{OH}^- + 5 \text{H}_2\text{O} + \text{NO}_2^- + 2\text{Al} \rightarrow \text{NH}_3 + 2 \text{Al(OH)}_4^- 
\]
OH\(^{-}\)(aq) + 5H\(_2\)O + NO\(_2\)^{-} (aq) + 2Al(s) \rightarrow
NH\(_3\) (gas) + 2Al(OH\(_4\))^{-} (aq)

The equation is now balanced in basic solution
Are you sure?
Count elements on both sides of reaction