

**General Chemistry II
(Chem 1412/LSC - Tomball)**

Chapter 12: Chemistry of Solutions

I. Types of Solutions

- A. Definition of Solutions**
- B. Components of A Solution**
- C. Types of Solutions**
- D. Character of Solutions**

II. Solubility and the Solution Process

- A. Factors Affecting Solubility**
- B. Molecular Solutions**
- C. Ionic Solutions**

III. Colligative Properties

- A. Concentration Expressions**
- B. Vapor Pressure Of Solutions**
- C. Boiling - Point Elevation and Freezing - Point Depression**
- D. Osmosis**
- E. Colligative Properties of Ionic Solutions**

IV. Stoichiometry & Quantitative Relations in Chemical Equations

- A. Mole Interpretation of an Equation**
- B. Stoichiometry of a Chemical Reaction**
- C. Limiting Reactant Problems**
- D. Theoretical & %Yields**

V. Calculations Involving Solutions

- A. Expressing Concentration Of Solution**
- B. Dilution Process & the Dilution Equation**
- C. Stoichiometry of Solution Reactions**

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Chapter 13: Chemical Kinetics

I. Concept of Chemical Kinetics

- A. Describing Rates of Reaction
- B. Factors Affecting Rate of Reaction
- C. Measurement of Reaction Rate

II. Rate Laws

- A. Rate Factors
 - 1. Concentration
 - 2. Surface Area
 - 3. Nature of Reacting Compounds
 - 4. Temperature
 - 5. Catalyst
- B. Rate Laws and Concentration Effects
 - 1. Rate as a function of Rxn Coefficients
 - 2. Rate Averaging
 - 3. Rate as a function of experimental observations
 - 4. Rate as a function of concentration and time
- C. Rxn Rate and the Kinetic Molecular Theory
 - 1. Collision Theory & Reactivity
 - 2. Transition State Theory
 - 3. Arrhenius Equation
- D. Catalysts
 - 1. Effect of Catalyst on Activation Energy of Rxns

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CHAPTER 14: CHEMICAL EQUILIBRIUM

INTRODUCTION TO EQUILIBRIUM

- I. THE LAW OF MASS ACTION
 - A. EQUILIBRIUM EQUATIONS
 - B. EQUILIBRIUM CONSTANTS (K_C & K_P - VALUES)
 - C. MEANING OF EQUILIBRIUM CONSTANTS
 - D. RELATIONSHIP BETWEEN K_C & K_P - VALUES
 - E. SUMMATION OF REACTIONS
 - F. CALCULATION OF K_C - VALUES

- II. HETEROGENEOUS EQUILIBRIA
 - A. CONCEPT OF PURE CONDENSED PHASES

- III. Le CHATLIER'S PRINCIPLE
 - A. PREDICTING THE DIRECTION OF A REACTION
 - B. FACTORS AFFECTING EQUILIBRIUM

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LE CHATELIER'S PRINCIPLE:

If a system in dynamic equilibrium is subjected to a disturbance that upsets the equilibrium, the system changes in such a way as to reduce the disturbance and, if possible, return the system to equilibrium.

Factors affecting chemical equilibria:

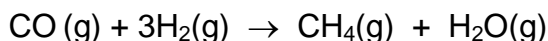
- Concentration
- Temperature
- Pressure
- Volume

NOTE:

Addition of an *inert gas* or *catalyst* to a reaction system at equilibrium does not affect the existing equilibrium.

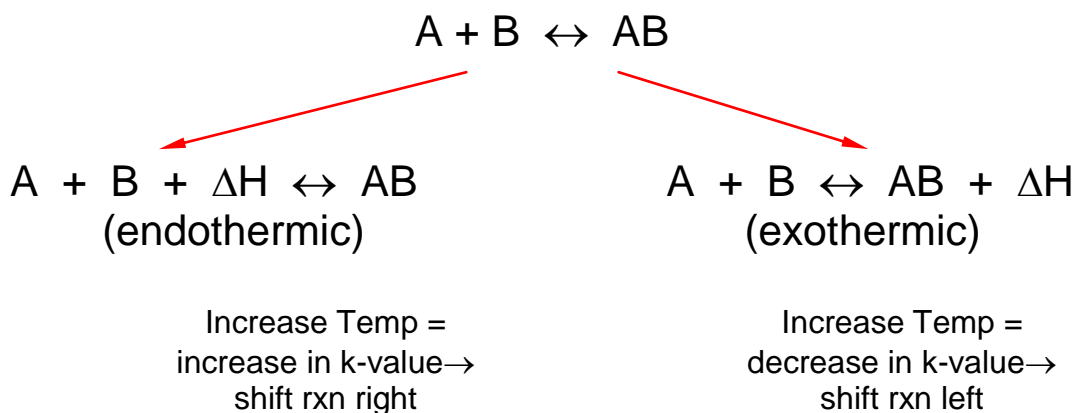
EFFECT OF CONCENTRATION ON EQUILIBRIUM

Consider the following reaction:



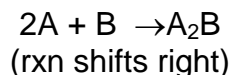
If 1 mole of $\text{CO}_2\text{(g)}$ & 3 moles $\text{H}_2\text{(g)}$ are placed into a 1 liter reaction flask and allowed to react. At equilibrium the concentrations of $\text{CO}_2\text{(g)}$ & $\text{H}_2\text{(g)}$ are 0.613M and 1.839M respectively. What are the equilibrium concentrations of methane and water at equilibrium and, what is the effect of removing all of the water from the system after the equilibrium is established? (New Equilibrium for CO(g) = 0.491M)

EFFECT OF TEMPERATURE ON EQUILIBRIUM

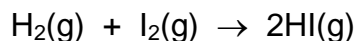


EFFECT OF PRESSURE-VOLUME CHANGES

Decrease in volume (increase pressure) shifts reaction to side having the smaller number moles of gas



If moles of gas on reactant and product sides are equal then no shift in equilibrium will occur



CHAPTER 15: ACIDS AND BASES

I. INTRODUCTION

- A. REACTIONS IN SOLUTION
- B. ELECTROLYTES
- C. CHARACTER OF ACIDS & BASES

II. THEORIES OF ACIDS & BASES

- A. ARRHENIUS THEORY
- B. BRONSTED-LOWRY THEORY
- C. LEWIS THEORY

III. ACID AND BASE STRENGTHS

- A. RELATIVE STRENGTHS OF ACIDS AND BASES
- B. MOLECULAR STRUCTURE AND ACID STRENGTH

IV. SELF-IONIZATION OF WATER AND pH

- A. SELF-IONIZATION OF WATER
- B. SOLUTIONS OF A STRONG ACID OR BASE
- C. THE pH OF A SOLUTION

CHAPTER 16: ACID - BASE EQUILIBRIUM

I. SOLUTIONS OF WEAK ACID OR WEAK BASE

- A. ACID IONIZATION EQUILIBRIA
- B. POLYPROTIC ACIDS
- C. BASE IONIZATION EQUILIBRIA
- D. HYDROLYSIS OF SALTS

II. SOLUTIONS OF MIXED SOLUTES

- A. COMMON ION EFFECT
- B. BUFFERS
- C. ACID - BASE TITRATION CURVES

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CHAPTER 17: SOLUBILITY & COMPLEX-ION EQUILIBRIA

I. SOLUBILITY PRODUCT CONSTANT (K_{SP})

A. THEORETICAL CONCEPTS

1. K_{SP} FROM SOLUBILITY DATA
2. MOLAR SOLUBILITY FROM K_{SP}

B. POTENTIAL FOR PRECIPITATION

1. CONDITIONS
2. CALCULATIONS

C. pH EFFECTS

II. COMMON ION EFFECT & SOLUBILITY

A. SOLUBILITY OF A SALT IN A SOLUTION CONTAINING A COMMON ION

III. COMPLEX-ION EQUILIBRIA

A. SOLUBILITY OF A SALT IN THE PRESENCE OF A COMPLEXING AGENT

CHAPTER 18: CHEMICAL THERMODYNAMICS

I. INTRODUCTION TO CHEMICAL THERMODYNAMICS

- A. STUDY OF REACTIONS (Kinetics, Equilibrium & Thermodynamics)
- B. DEFINITION AND PURPOSE OF THERMODYNAMICS
- C. CHEMICAL REACTIONS & THERMODYNAMICS

II. THE FIRST LAW OF THERMODYNAMICS

- A. THE CONCEPT OF ENERGY
 - 1. DEFINITION & TYPES OF ENERGY
 - 2. CLASSIFICATION (KE, PE, IE)
 - 3. LAW OF CONSERVATION OF ENERGY
- B. ENERGY FLOW
 - 1. ENERGY OF CHEMICAL REACTIONS (Heat of Rxn)
 - 2. SYSTEM AND SURROUNDINGS
- C. ANALYSIS OF ENERGY CHANGES USING 1st LAW
 - 1. CLOSED SYSTEM vs. OPEN SYSTEM
 - 2. HESS'S LAW AND CHEMICAL REACTIONS
 - 3. BOND ENERGY CALCULATIONS

III. THE SECOND LAW OF THERMODYNAMICS

- A. DEFINITION & CONCEPT
- B. ENTROPY vs. CHANGE IN ENTROPY
- C. THE THIRD LAW OF THERMODYNAMICS

IV. FREE ENERGY AND THE CONCEPT OF SPONTANEITY

- A. STANDARD FREE ENERGY CHANGES
- B. EQUATION OF FREE ENERGY
- C. FREE ENERGY & USEFUL WORK

V. THERMODYNAMIC CALCULATIONS

- A. STOICHIOMETRY OF EQUATIONS
- B. REACTION COUPLING
- C. HESS'S LAW
- D. CALCULATION OF FREE ENERGY AND FEASIBILITY OF REACTION
- E. EQUILIBRIUM CONSTANTS FROM THERMODYNAMIC EQUATIONS

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The following is from both Chapters 4 & 19.
OXIDATION-REDUCTION REACTIONS

I. TERMINOLOGY & DESCRIPTION OF REDOX REACTIONS

- A. PROCESS & DEFINITIONS**
- B. ASSIGNING OXIDATION NUMBERS**

II. BALANCING REDOX REACTIONS

- A. THE OXIDATION-NUMBER METHOD**
- B. HALF-REACTION METHOD**

IV. SOLUTION STOICHIOMETRY

- A. MOLES & MOLARITY**
- B. EQUIVALENT WEIGHTS & NORMALITY**
- E. ANALYSIS OF SOLUTION REACTIONS**

BALANCING REDOX REACTIONS:

BALANCING BY THE OXIDATION-NUMBER METHOD

1. ASSIGN OXIDATION NUMBERS
2. NOTE ATOMS UNDERGOING CHANGES IN OXIDATION STATE
3. DETERMINE CHANGE PER ATOM
4. DETERMINE CHANGE PER FORMULA UNIT
5. BALANCE TOTAL CHARGE TRANSFER
(Σ electrons lost = Σ electrons gained)
6. BALANCE ELEMENTS UNDERGOING CHARGE TRANSFER.
7. BALANCE ELEMENTS OTHER THAN OXYGEN & HYDROGEN.
8. BALANCE OXYGEN:
 - A. ACIDIC OR NEUTRAL: Add H_2O to side needing oxygen.
 - B. BASIC: Add 2OH^- per oxygen (O) to side needing oxygen
then, add $1 \text{H}_2\text{O}$ per oxygen (O) to other side.
9. BALANCE HYDROGEN:
 - A. ACIDIC OR NEUTRAL: Add hydrogen ions (H^+) to side
needing hydrogen.
 - B. BASIC: Add $1 \text{H}_2\text{O}$ per H^+ needed to side needing hydrogen
then, add 1OH^- per H_2O added to other side.
10. SIMPLIFY H^+ , OH^- & H_2O

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CHAPTER 19: ELECTROCHEMISTRY

- I. THE STUDY OF ELECTROCHEMISTRY**
- A. ELECTROLYTIC CELLS**
 - B. GALVANIC CELLS**
 - C. CONDUCTIVITY (METALLIC VS. SOLUTION)**
 - D. SPONTANEITY IN ELECTROCHEMICAL PROCESS**
- II. ELECTROLYTIC CELLS:**
- A. GENERAL CONCEPTS**
 - **CELL STRUCTURE**
 - **CELL CHEMISTRY**
 - **CELL ANALYSIS**
 - B. TYPES OF ELECTROLYSIS (MELT VS AQUEOUS)**
 - MELT: KBr(l)**
 - AQUEOUS: (KBr(aq), CuSO₄(aq), CuBr(aq), Na₂SO₄(aq))**
 - C. QUANTITATIVE ASPECTS OF ELECTROLYSIS**
(**FARADAY'S LAW: 1F = 96,500 amp•sec = 1 mole e⁻ = 96,500 Coulombs**)
 - D. APPLICATIONS OF ELECTROLYTIC CELLS**
- III. GALVANIC CELLS**
- B. GENERAL CONCEPTS**
 - **CELL STRUCTURE**
 - **CELL CHEMISTRY**
 - **CELL ANALYSIS**
 - B. CELL POTENTIALS AND REDUCTION POTENTIALS**
 - C. SPONTANEITY OF GALVANIC PROCESS**
 - D. THERMODYNAMIC PROCESS IN GALVANIC CELLS**
 - 1. **Calculation of Equilibrium Constants**
 - 2. **Standard Cell Potentials**
 - 3. **The Nernst Equation**
 - 4. **Standard Electrochemical Potential (E°) and Work**
 - 5. **Concentration Cells**
 - 6. **Solubility Product**
 - E. APPLICATIONS OF GALVANIC CELLS**

ELECTROCHEMISTRY :

TABLE OF STANDARD ELECTRODE REDUCTION POTENTIALS

(E_0 volts)

| | |
|---|-------|
| $\text{Li}^+(\text{aq}) + \text{e}^- \longrightarrow \text{Li}(\text{s})$ | -3.04 |
| $\text{K}^+(\text{aq}) + \text{e}^- \longrightarrow \text{K}(\text{s})$ | -2.92 |
| $\text{Na}^+(\text{aq}) + \text{e}^- \longrightarrow \text{Na}(\text{s})$ | -2.71 |
| $\text{Mg}^{2+}(\text{aq}) + 2\text{e}^- \longrightarrow \text{Mg}(\text{s})$ | -2.38 |
| $\text{Al}^{3+}(\text{aq}) + 3\text{e}^- \longrightarrow \text{Al}(\text{s})$ | -1.66 |
| $\text{Mn}^{2+}(\text{aq}) + 2\text{e}^- \longrightarrow \text{Mn}(\text{s})$ | -1.03 |
| $2\text{H}_2\text{O}(\text{l}) + 2\text{e}^- \longrightarrow \text{H}_2(\text{g}) + 2\text{OH}^-(\text{aq})$ | -0.83 |
| $\text{Zn}^{2+}(\text{aq}) + 2\text{e}^- \longrightarrow \text{Zn}(\text{s})$ | -0.76 |
| $\text{Cr}^{3+}(\text{aq}) + 3\text{e}^- \longrightarrow \text{Cr}(\text{s})$ | -0.74 |
| $\text{Fe}^{2+}(\text{aq}) + 2\text{e}^- \longrightarrow \text{Fe}(\text{s})$ | -0.41 |
| $\text{Cd}^{2+}(\text{aq}) + 2\text{e}^- \longrightarrow \text{Cd}(\text{s})$ | -0.40 |
| $\text{PbSO}_4(\text{s}) + 2\text{e}^- \longrightarrow \text{Pb}(\text{s}) + \text{SO}_4^{2-}(\text{aq})$ | -0.36 |
| $\text{Co}^{2+}(\text{aq}) + 2\text{e}^- \longrightarrow \text{Co}(\text{s})$ | -0.28 |
| $\text{Ni}^{2+}(\text{aq}) + 2\text{e}^- \longrightarrow \text{Ni}(\text{s})$ | -0.23 |
| $\text{Sn}^{2+}(\text{aq}) + 2\text{e}^- \longrightarrow \text{Sn}(\text{s})$ | -0.14 |
| $\text{Pb}^{2+}(\text{aq}) + 2\text{e}^- \longrightarrow \text{Pb}(\text{s})$ | -0.13 |
| $2\text{H}^+(\text{aq}) + 2\text{e}^- \longrightarrow \text{H}_2(\text{g})$ | 0.00 |
| $\text{Cu}^{2+}(\text{aq}) + 2\text{e}^- \longrightarrow \text{Cu}(\text{s})$ | +0.34 |
| $\text{O}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l}) + 4\text{e}^- \longrightarrow 4\text{OH}^-(\text{aq})$ | +0.40 |
| $\text{I}_2(\text{s}) + 2\text{e}^- \longrightarrow 2\text{I}^-(\text{aq})$ | +0.54 |
| $\text{O}_2(\text{g}) + 2\text{H}^+(\text{aq}) + 2\text{e}^- \longrightarrow \text{H}_2\text{O}_2(\text{aq})$ | +0.68 |
| $\text{Fe}^{3+}(\text{aq}) + \text{e}^- \longrightarrow \text{Fe}^{2+}(\text{aq})$ | +0.77 |
| $\text{Ag}^+(\text{aq}) + \text{e}^- \longrightarrow \text{Ag}(\text{s})$ | +0.80 |
| $\text{Hg}^{2+}(\text{aq}) + 2\text{e}^- \longrightarrow \text{Hg}(\text{l})$ | +0.85 |
| $\text{NO}_3^-(\text{aq}) + 4\text{H}^+(\text{aq}) + 3\text{e}^- \longrightarrow \text{NO}(\text{g}) + \text{H}_2\text{O}(\text{l})$ | +0.96 |
| $\text{Br}_2(\text{l}) + 2\text{e}^- \longrightarrow 2\text{Br}^-(\text{aq})$ | +1.07 |
| $\text{O}_2(\text{g}) + 4\text{H}^+(\text{aq}) + 4\text{e}^- \longrightarrow 2\text{H}_2\text{O}(\text{l})$ | +1.23 |
| $\text{Cl}_2(\text{g}) + 2\text{e}^- \longrightarrow 2\text{Cl}^-(\text{aq})$ | +1.36 |
| $\text{Au}^{3+}(\text{aq}) + 3\text{e}^- \longrightarrow \text{Au}(\text{s})$ | +1.48 |
| $\text{MnO}_4^-(\text{aq}) + 8\text{H}^+(\text{aq}) + 5\text{e}^- \longrightarrow \text{Mn}^{2+}(\text{aq}) + 4\text{H}_2\text{O}(\text{l})$ | +1.49 |
| $\text{PbO}_2(\text{s}) + 4\text{H}^+(\text{aq}) + \text{SO}_4^{2-}(\text{aq}) + 2\text{e}^- \longrightarrow \text{PbSO}_4(\text{s}) + 2\text{H}_2\text{O}(\text{l})$ | +1.69 |
| $\text{H}_2\text{O}_2(\text{aq}) + 2\text{H}^+(\text{aq}) + 2\text{e}^- \longrightarrow 2\text{H}_2\text{O}(\text{l})$ | +1.78 |
| $\text{Co}^{3+}(\text{aq}) + \text{e}^- \longrightarrow \text{Co}^{2+}(\text{aq})$ | +1.84 |
| $\text{F}_2(\text{g}) + 2\text{e}^- \longrightarrow 2\text{F}^-(\text{aq})$ | +2.87 |

CHAPTER 20: NUCLEAR CHEMISTRY

I. RADIOACTIVITY & NUCLEAR REACTIONS

A. Radioactivity

1. Types of Radioactivity
2. Nuclear Equations
3. Nuclear Stability
4. Radioactive Decay

B. Nuclear Bombardment Reactions

1. Transmutation of Elements
2. Particle Accelerators
3. Trans-Uranium Elements

C. Measurement of Radioactivity

1. Radiation Counters
2. Biological Effects of Radioactivity

II. KINETICS OF RADIOACTIVE DECAY

A. Radioactive Decay and Half-Life

B. Radioactive Dating per C-14 Decay and K-40 Decay

III. NUCLEAR ENERGY

A. Mass - Energy Transformations

1. Mass Defect
2. Nuclear Binding Energy

B. Nuclear Energy

1. Nuclear Fission
2. Nuclear Fusion

TERMS USED IN RADIOACTIVE DECAY PROCESS

Radiation –

Alpha (${}^4_2\alpha$) - Helium Nuclei

Beta (${}^0_{-1}\beta$) - High energy electron

Gamma (${}^0_0\gamma$) – High energy EMR

Electron Capture (EC) - Gain of Beta Particle

Positron Emission (${}^0_{+1}\beta$) - Loss of 'positive' electron

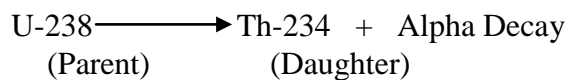
Nuclide - Refers to the nucleus of a particular isotope.

Radionuclide – Radioactive nucleus

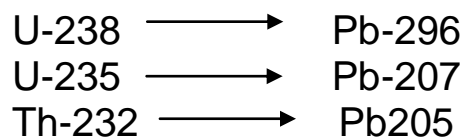
Radioisotopes – Elements that are radioactive

Parent Isotope – The primary isotope undergoing decay

Daughter Isotope – The isotope formed from decay of parent isotope



Radioactive Decay Series – Series of spontaneous decay reactions leading to a stable (non-radioactive) isotope.



NUCLEAR STABILITY

All elements above atomic number 83 (Bismuth) are radioactive and possess no known stable isotopes.

Most elements with atomic numbers less than 83 have one or more stable radio-isotopes.

FACTORS AFFECTING NUCLEAR STABILITY:

As the number of protons increase, there must be more neutrons present to help overcome the strong repulsive forces between protons.

Elements with greatest stability lie in the “Band of Stability” region of the Neutron-# vs, Proton-# plot.

Nuclei that lie outside the “Band of Stability” are unstable and decay to a stable n^0/p^+ ratio. The position of the radioisotope relative to the “Band of Stability” dictates the type of radiation emitted.

Isotopes above the “Band of Stability” must decrease n^0/p^+ ratio by increasing atomic number by Beta emission. – ($n^0 \rightarrow p^+ + e^-$).

Isotopes below the “Band of Stability” must increase the n^0/p^+ ratio by decreasing atomic number by positron emission or electron capture. ($p^+ + e^- \rightarrow n^0$) or , Electron Capture by neutron ($n^0 + e^- \rightarrow p^+$).

NATURAL RADIOACTIVE DECAY SERIES

U-238 =>Pb-206 $t_{1/2} = 4.47 \times 10^9 \text{ yrs } (\infty)$

U-235 => Pb-207 $t_{1/2} = 7.04 \times 10^8 \text{ yrs } (\infty)$

Th-232 => Pb-208 $t_{1/2} = 1.40 \times 10^{10} \text{ yrs } (\infty)$

QUANTITATIVE NUCLEAR ENERGY:

$m_{p^+} = 1.0072770 \text{ amu}$

$m_{e^-} = 0.0005486 \text{ amu}$

$m_n^0 = 1.008665 \text{ amu}$

Theoretical Atomic Mass = $\sum m_{p^+} + \sum m_{e^-} + \sum m_n^0$

Actual Atomic Mass < Theoretical Atomic Mass by Mass Defect
(Mass Defect \equiv Nuclear Binding Energy)

Energy – Mass relationships:

Nuclear energy:

- electron volts (eV) = 1.602×10^{-19} joules
- Million electron volts (MeV) = 1.602×10^{-13} joules
= 1.602×10^{-16} Kilojoules
- Per-particle nuclear energy:
1amu = 931 MeV