CHM 123	Work • Derived units, sign conventions • Mechanical advantage • Work Kinetic Energy Theorem Energy • Kinetic Energy: KE = ½ mv^2; units • Potential Energy o PE = mgh (gravitational, local) o PE = ½ kx^2(spring) • Conservation of energy • Conservative forces • Power, units Gas Phase • Absolute temperature, (K) Kelvin Scale • Pressure, simple mercury barometer • Molar volume at 0°C and 1 atm = 22.4 L/mol • Ideal gas o Definition o Ideal Gas Law: $PV = nRT$ o Boyle's Law: PV = constant o Charles' Law: V/T = constant o Avogadro's Law: V/n = constant • Kinetic Molecular Theory of Gases o Heat capacity at constant volume and at constant pressure o Boltzmann's Constant • Deviation of real gas behavior from Ideal Gas Law o Qualitative o Quantitative (Van der Waals' Equation) • Partial pressure, mole fraction • Dalton's Law relating partial pressure to composition Light, Electromagnetic Radiation • Concept of Interference; Young Double-slit Experiment • Thin films, diffraction grating, single-slit diffraction • Other diffraction phenomena, X-ray diffraction • Polarization of light • Circular polarization • Properties of electromagnetic radiation o Velocity equals constant c, *in vacuo* o Electromagnetic radiation consists of perpendicularly oscillating electric and magnetic o fields; direction of propagation is perpendicular to both • Classification of electromagnetic spectrum, photon energy $E = (hf)$ • Visual spectrum, color Atomic Nucleus • Atomic number, atomic weight • Neutrons, protons, isotopes • Nuclear forces, binding energy

	• Radioactive decay
	  o α, β, γ decay
	  o Half-life, exponential decay, semi-log plots
	• Mass spectrometer
	Electronic Structure
	• Orbital structure of hydrogen atom, principal quantum number n, number of electrons per orbital
	• Ground state, excited states
	• Absorption and emission line spectra
	• Use of Pauli Exclusion Principle
	• Paramagnetism and diamagnetism
	• Conventional notation for electronic structure
	• Bohr atom
	• Heisenberg Uncertainty Principle
	• Effective nuclear charge
	• Photoelectric effect
	The Periodic Table - Classification of Elements into Groups by Electronic Structure
	• Alkali metals
	• Alkaline earth metals: their chemical characteristics
	• Halogens: their chemical characteristics
	• Noble gases: their physical and chemical characteristics
	• Transition metals
	• Representative elements
	• Metals and non-metals
	• Oxygen group
	The Periodic Table - Variations of Chemical Properties with Group and Row
	• Valence electrons
	• First and second ionization energy
	  o Definition
	  o Prediction from electronic structure for elements in different groups or rows
	• Electron affinity
	  o Definition
	  o Variation with group and row
	• Electronegativity
	  o Definition
	  o Comparative values for some representative elements and important groups
	• Electron shells and the sizes of atoms
	• Electron shells and the sizes of ions
	Stoichiometry
	• Molecular weight
	• Empirical versus molecular formula
	• Metric units commonly used in the context of chemistry
	• Description of composition by percent mass
	• Mole concept, Avogadro's number NA

- Definition of density
- Oxidation number
  - Common oxidizing and reducing agents
  - Disproportionation reactions
- Description of reactions by chemical equations
  - Conventions for writing chemical equations
  - Balancing equations, including redox equations
  - Limiting reactants
- Theoretical yields

Ions in Solutions

- Anion, cation: common names, formulas and charges for familiar ions (e.g., NH_4^+ ammonium, PO_4^{3-} phosphate, SO_4^{2-} sulfate)
- Hydration, the hydronium ion

Titration

- Indicators
- Neutralization
- Interpretation of the titration curves
- Redox titration

Covalent Bond

- Lewis Electron Dot formulas
  - Resonance structures
  - Formal charge
  - Lewis acids and bases
- Partial ionic character
  - Role of electronegativity in determining charge distribution
  - Dipole Moment
- σ and π bonds
  - Hybrid orbitals: sp^3, sp^2, sp and respective geometries
  - Valence shell electron pair repulsion and the prediction of shapes of molecules (e.g., NH3, H2O, CO2)
  - Structural formulas for molecules involving H, C, N, O, F, S, P, Si, Cl
  - Delocalized electrons and resonance in ions and molecules
- Multiple bonding
  - Affect on bond length and bond energies
  - Rigidity in molecular structure
- Stereochemistry of covalently bonded molecules
  - Isomers
    - Structural isomers
    - Stereoisomers (e.g., diastereomers, enantiomers, cis/trans isomers)
    - Conformational isomers
  - Polarization of light, specific rotation
  - Absolute and relative configuration
    - Conventions for writing R and S forms
  - Conventions for writing E and Z forms

Energy Changes in Chemical Reactions - Thermochemistry, Thermodynamics

- Thermodynamic system – state function

	▪ Zeroth Law – concept of temperature ▪ First Law: ΔE = Q – W (conservation of energy) ▪ Second Law – concept of entropy o Entropy as a measure of "disorder" o Relative entropy for gas, liquid, and crystal states ▪ Measurement of heat changes (calorimetry), heat capacity, specific heat ▪ Heat transfer – conduction, convection, radiation ▪ Endothermic/exothermic reactions o Enthalpy, H, and standard heats of reaction and formation o Hess' Law of Heat Summation ▪ Bond dissociation energy as related to heats of formation ▪ Free energy: G ▪ Spontaneous reactions and ΔG° ▪ Coefficient of expansion ▪ Heat of fusion, heat of vaporization • Phase diagram: pressure and temperature
CHM 124	Plasma Membrane • General function in cell containment • Composition of membranes o Lipid components ▪ Phospholipids (and phosphatids) ▪ Steroids ▪ Waxes o Protein components o Fluid mosaic model • Membrane dynamics • Solute transport across membranes o Thermodynamic considerations o Osmosis ▪ Colligative properties, osmotic pressure o Passive transport o Active transport ▪ Sodium/potassium pump • Membrane channels • Membrane potential • Membrane receptors • Exocytosis and endocytosis • Intercellular junctions o Gap junctions o Tight junctions o Desmosomes Electrochemistry o Concentration cell: direction of electron flow, Nernst equation Equilibrium • Concept of force, units • Analysis of forces acting on an object • Newton's First Law of Motion, inertia

	• Torques, lever arms Electrochemistry • Electrolytic cell o Electrolysis o Anode, cathode o Electrolyte o Faraday's Law relating amount of elements deposited (or gas liberated) at an electrode to o current o Electron flow, oxidation, and reduction at the electrodes • Galvanic or Voltaic cells o Half-reactions o Reduction potentials, cell potential o Direction of electron flow • Concentration cell • Batteries o Electromotive force, Voltage o Lead-storage batteries o Nickel-cadmium batteries Acid/Base Equilibria • Bronsted-Lowry definition of acid, base • Ionization of water o K_w, its approximate value ($K_w = [H^+][OH^-] = 10^{-14}$ at 25°C, 1 atm) o Definition of pH: pH of pure water • Conjugate acids and bases (e.g., NH_4^+ and NH_3) • Strong acids and bases (e.g., nitric, sulfuric) • Weak acids and bases (e.g., acetic, benzoic) o Dissociation of weak acids and bases with or without added salt o Hydrolysis of salts of weak acids or bases o Calculation of pH of solutions of salts of weak acids or bases • Equilibrium constants K_a and K_b: pK_a, pK_b • Buffers o Definition and concepts (common buffer systems) o Influence on titration curves Solubility • Units of concentration (e.g., molarity) • Solubility product constant; the equilibrium expression Ksp • Common-ion effect, its use in laboratory separations o Complex ion formation o Complex ions and solubility o Solubility and pH Titration • Indicators • Neutralization • Interpretation of the titration curves • Redox titration Liquid Phase - Intermolecular Forces

	• Hydrogen bonding • Dipole Interactions • Van der Waals' Forces (London dispersion forces) Energy Changes in Chemical Reactions - Thermochemistry, Thermodynamics • Thermodynamic system – state function • Zeroth Law – concept of temperature • First Law: $\Delta E = Q - W$ (conservation of energy) • Second Law – concept of entropy o Entropy as a measure of "disorder" o Relative entropy for gas, liquid, and crystal states • Measurement of heat changes (calorimetry), heat capacity, specific heat • Heat transfer – conduction, convection, radiation • Endothermic/exothermic reactions o Enthalpy, H, and standard heats of reaction and formation o Hess' Law of Heat Summation • Bond dissociation energy as related to heats of formation • Free energy: G • Spontaneous reactions and $\Delta G°$ • Coefficient of expansion • Heat of fusion, heat of vaporization • Phase diagram: pressure and temperature Rate Processes in Chemical Reactions - Kinetics and Equilibrium • Reaction rate • Dependence of reaction rate upon concentration of reactants o Rate law, rate constant o Reaction order • Rate-determining step • Dependence of reaction rate upon temperature o Activation energy ▪ Activated complex or transition state ▪ Interpretation of energy profiles showing energies of reactants, products, activation energy, and ΔH for the reaction o Use of the Arrhenius Equation • Kinetic control versus thermodynamic control of a reaction • Catalysts • Equilibrium in reversible chemical reactions o Law of Mass Action o Equilibrium Constant o Application of Le Châtelier's Principle • Relationship of the equilibrium constant and $\Delta G°$
CHM 313	Molecular Structure and Absorption Spectra • Infrared region o Intramolecular vibrations and rotations o Recognizing common characteristic group absorptions, fingerprint region • Visible region

- Absorption in visible region gives complementary color (e.g., carotene)
- Effect of structural changes on absorption (e.g., indicators)

- Ultraviolet region
  - π-electron and non-bonding electron transitions
  - Conjugated systems
- NMR spectroscopy
  - Protons in a magnetic field; equivalent protons
  - Spin-spin splitting

Covalent Bond

- Lewis Electron Dot formulas
  - Resonance structures
  - Formal charge
  - Lewis acids and bases
- Partial ionic character
  - Role of electronegativity in determining charge distribution
  - Dipole Moment
- σ and π bonds
  - Hybrid orbitals: sp^3, sp^2, sp and respective geometries
  - Valence shell electron pair repulsion and the prediction of shapes of molecules (e.g., NH3, H2O, CO2)
  - Structural formulas for molecules involving H, C, N, O, F, S, P, Si, Cl
  - Delocalized electrons and resonance in ions and molecules
- Multiple bonding
  - Effect on bond length and bond energies
  - Rigidity in molecular structure
- Stereochemistry of covalently bonded molecules (OC)
  - Isomers
    - Structural isomers
    - Stereoisomers (e.g., diastereomers, enantiomers, cis/trans isomers)
    - Conformational isomers
  - Polarization of light, specific rotation
  - Absolute and relative configuration
    - Conventions for writing R and S forms
  - Conventions for writing E and Z forms

Separations and Purifications

- Extraction: distribution of solute between two immiscible solvents
- Distillation
- Chromatography
  - Basic principles involved in separation process
    - Column chromatography, gas-liquid chromatography
    - High pressure liquid chromatography
  - Paper chromatography
  - Thin-layer chromatography
- Separation and purification of peptides and proteins
  - Electrophoresis

	○ Quantitative analysis ○ Chromatography ▪ Size-exclusion ▪ Ion-exchange ▪ Affinity ○ Racemic mixtures, separation of enantiomers Alcohols • Description ○ Nomenclature ○ Physical properties (acidity, hydrogen bonding) • Important reactions ○ Oxidation ○ Protection of alcohol ○ Preparation of mesylates and tosylates
CHM 314	Amino Acids • Description ○ Absolute configuration at the α position ○ Amino acids as dipolar ions ○ Classifications ▪ Acidic or basic ▪ Hydrophobic or hydrophilic • Reactions ○ Sulfur linkage for cysteine and cysteine ○ Peptide linkage: polypeptides and proteins ○ Hydrolysis Nucleic Acid Structure and Function • Description • Nucleotides and nucleosides ○ Sugar phosphate backbone ○ Pyrimidine, purine residues • Deoxyribonucleic acid (DNA): double helix, Watson–Crick model of DNA structure • Base pairing specificity: A with T, G with C • Function in transmission of genetic information ○ DNA denaturation, reannealing, hybridization Carbohydrates • Description ○ Nomenclature and classification, common names ○ Absolute configuration ○ Cyclic structure and conformations of hexoses ○ Epimers and anomers • Hydrolysis of the glycoside linkage • Monosaccharides • Disaccharides • Polysaccharides Nucleotides and Nucleic Acids

	• Nucleotides and nucleosides: composition
	  o Sugar phosphate backbone
	  o Pyrimidine, purine residues
	• Deoxyribonucleic acid: DNA, double helix
	• Chemistry
	• Other functions
	Amino Acids, Peptides, Proteins
	• Amino acids: description
	  o Absolute configuration at the α position
	  o Dipolar ions
	  o Classification
	  ▪ Acidic or basic
	  ▪ Hydrophilic or hydrophobic
	  o Synthesis of α-amino acids
	  ▪ Strecker Synthesis
	  ▪ Gabriel Synthesis
	• Peptides and proteins: reactions
	  o Sulfur linkage for cysteine and cystine
	  o Peptide linkage: polypeptides and proteins
	  o Hydrolysis
	• General Principles
	  o 1° structure of proteins
	  o 2° structure of proteins
	  o 3° structure of proteins
	  o o Isoelectric point
	Carbohydrates
	• Description
	  o Nomenclature and classification, common names
	  o Absolute configuration
	  o Cyclic structure and conformations of hexoses
	  o Epimers and anomers
	• Hydrolysis of the glycoside linkage
	• Keto-enol tautomerism of monosaccharides
	• Disaccharides
	• Polysaccharides
	Aldehydes and Ketones
	• Description
	  o Nomenclature
	  o Physical properties
	• Important reactions
	  o Nucleophilic addition reactions at C=O bond
	  ▪ Acetal, hemiacetal
	  ▪ Imine, enamine
	  ▪ Hydride reagents
	  ▪ Cyanohydrin
	  o Oxidation of aldehydes
	  o Reactions at adjacent positions: enolate chemistry

	▪ Keto-enol tautomerism (α-racemization) ▪ Aldol condensation, retro-aldol ▪ Kinetic versus thermodynamic enolate • General principles o Effect of substituents on reactivity of C=O; steric hindrance • o Acidity of α-H; carbanions Carboxylic Acids • Description o Nomenclature o Physical properties • Important reactions o Carboxyl group reactions ▪ Amides (and lactam), esters (and lactone), anhydride formation ▪ Reduction ▪ Decarboxylation • Reactions at 2-position, substitution Acid Derivatives (Anhydrides, Amides, Esters) • Description o Nomenclature o Physical properties • Important reactions o Nucleophilic substitution o Transesterification o Hydrolysis of amides • General principles o Relative reactivity of acid derivatives o Steric effects o Electronic effects • Strain (e.g., β-lactams) Phenols • Oxidation and reduction (e.g., hydroquinones), ubiquinones: biological $2e^-$ redox centers Polycyclic and Heterocyclic Aromatic Compounds • Biological aromatic heterocycles Phosphorus Compounds • Description, structure of phosphoric acids
CHM 420	Amino Acids • Description o Absolute configuration at the α position o Amino acids as dipolar ions o Classifications ▪ Acidic or basic ▪ Hydrophobic or hydrophilic • Reactions o Sulfur linkage for cysteine and cysteine o Peptide linkage: polypeptides and proteins

	o Hydrolysis Protein Structure • Structure o 1° structure of proteins o 2° structure of proteins o 3° structure of proteins; role of proline, cystine, hydrophobic bonding o 4° structure of proteins • Conformational stability o Denaturing and folding o Hydrophobic interactions o Solvation layer (entropy) • Separation techniques o Isoelectric point o Electrophoresis Non-Enzymatic Protein Function • Binding • Immune system • Motors Enzyme Structure and Function • Function of enzymes in catalyzing biological reactions • Enzyme classification by reaction type • Reduction of activation energy • Substrates and enzyme specificity • Active Site Model • Induced-fit Model • Mechanism of catalysis o Cofactors o Coenzymes o Water-soluble vitamins • Effects of local conditions on enzyme activity Control of Enzyme Activity • Kinetics o General (catalysis) o Michaelis-Menten o Cooperativity • Feedback regulation • Inhibition – types o Competitive o Non-competitive o Mixed o Uncompetitive • Regulatory enzymes o Allosteric enzymes o Covalently-modified enzymes • Zymogen Nucleic Acid Structure and Function

	• Description
	• Nucleotides and nucleosides
	  o Sugar phosphate backbone
	  o Pyrimidine, purine residues
	• Deoxyribonucleic acid (DNA): double helix, Watson–Crick model of DNA structure
	• Base pairing specificity: A with T, G with C
	• Function in transmission of genetic information
	• DNA denaturation, reannealing, hybridization
	Evidence that DNA is Genetic Material
	Principles of Bioenergetics
	• Bioenergetics/thermodynamics
	  o Free energy/Keq
	  ▪ Equilibrium constant
	  ▪ Relationship of the equilibrium constant and ΔG°
	  o Concentration
	  ▪ Le Châtelier's Principle
	  o Endothermic/exothermic reactions
	  o Free energy: G
	  o Spontaneous reactions and ΔG°
	• Phosphoryl group transfers and ATP
	  o ATP hydrolysis ΔG << 0
	  o ATP group transfers
	• Biological oxidation-reduction
	  o Half-reactions
	  o Soluble electron carriers
	  o Flavoproteins
	Carbohydrates
	• Description
	  o Nomenclature and classification, common names
	  o Absolute configuration
	  o Cyclic structure and conformations of hexoses
	  o Epimers and anomers
	• Hydrolysis of the glycoside linkage
	• Monosaccharides
	• Disaccharides
	• Polysaccharides
	Glycolysis, Gluconeogenesis, and the Pentose Phosphate Pathway
	• Glycolysis (aerobic), substrates and products
	  o Feeder pathways: glycogen, starch metabolism
	• Fermentation (anaerobic glycolysis)
	• Gluconeogenesis
	• Pentose phosphate pathway
	• Net molecular and energetic results of respiration processes
	Principles of Metabolic Regulation
	• Regulation of metabolic pathways
	  o Maintenance of a dynamic steady state

	• Regulation of glycolysis and gluconeogenesis
	• Metabolism of glycogen
	• Regulation of glycogen synthesis and breakdown
	  o Allosteric and hormonal control
	• Analysis of metabolic control
	Citric Acid Cycle
	• Acetyl-CoA production
	• Reactions of the cycle, substrates and products
	• Regulation of the cycle
	• Net molecular and energetic results of respiration processes
	Metabolism of Fatty Acids and Proteins
	• Description of fatty acids
	• Digestion, mobilization, and transport of fats
	• Oxidation of fatty acids
	  o Saturated fats
	  o Unsaturated fats
	• Ketone bodies
	• Anabolism of fats
	• Non-template synthesis: biosynthesis of lipids and polysaccharides
	• Metabolism of proteins
	Oxidative Phosphorylation
	• Electron transport chain and oxidative phosphorylation, substrates and products, general features of the pathway
	• Electron transfer in mitochondria
	  o NADH, NADPH
	  o Flavoproteins
	  o Cytochromes
	• ATP synthase, chemiosmotic coupling
	  o Proton motive force
	• Net molecular and energetic results of respiration processes
	• Regulation of oxidative phosphorylation
	• Mitochondria, apoptosis, oxidative stress
	Hormonal Regulation and Integration of Metabolism
	• Higher level integration of hormone structure and function
	• Tissue specific metabolism
	• Hormonal regulation of fuel metabolism
	• Obesity and regulation of body mass
	Plasma Membrane
	• General function in cell containment
	• Composition of membranes
	  o Lipid components
	  ▪ Phospholipids (and phosphatids)
	  ▪ Steroids
	  ▪ Waxes
	  o Protein components
	  o Fluid mosaic model

	• Membrane dynamics
	• Solute transport across membranes
	  o Thermodynamic considerations
	  o Osmosis
	  ▪ Colligative properties, osmotic pressure
	  o Passive transport
	  o Active transport
	  ▪ Sodium/potassium pump
	• Membrane channels
	• Membrane potential
	• Membrane receptors
	• Exocytosis and endocytosis
	• Intercellular junctions
	  o Gap junctions
	  o Tight junctions
	  o Desmosomes
	Membrane-Bound Organelles and Defining Characteristics of Eukaryotic Cells
	• Defining characteristics of eukaryotic cells: membrane bound nucleus, presence of organelles,
	• mitotic division
	• Nucleus
	  o Compartmentalization, storage of genetic information
	  o Nucleolus: location and function
	  o Nuclear envelope, nuclear pores
	• Mitochondria
	  o Site of ATP production
	  o Inner and outer membrane structure
	  o Self-replication
	• Lysosomes: membrane-bound vesicles containing hydrolytic enzymes
	• Endoplasmic reticulum
	  o Rough and smooth components
	  o Rough endoplasmic reticulum site of ribosomes
	  o Double membrane structure
	  o Role in membrane biosynthesis
	  o Role in biosynthesis of secreted proteins
	• Golgi apparatus: general structure and role in packaging and secretion
	• Peroxisomes: organelles that collect peroxides
	Electrochemistry
	• Concentration cell: direction of electron flow, Nernst equation
	Biosignalling
	• Gated ion channels
	  o Voltage gated
	  o Ligand gated
	• Receptor enzymes
	• G protein-coupled receptors
	Lipids
	• Description; structure

- Steroids
- Terpenes and terpenoids

Equilibrium

- Concept of force, units
- Analysis of forces acting on an object
- Newton's First Law of Motion, inertia
- Torques, lever arms

Electrochemistry

- Electrolytic cell
  - Electrolysis
  - Anode, cathode
  - Electrolyte
  - Faraday's Law relating amount of elements deposited (or gas liberated) at an electrode to
  - current
  - Electron flow, oxidation, and reduction at the electrodes
- Galvanic or Voltaic cells
  - Half-reactions
  - Reduction potentials, cell potential
  - Direction of electron flow
- Concentration cell
- Batteries
  - Electromotive force, Voltage
  - Lead-storage batteries
- Nickel-cadmium batteries

Acid/Base Equilibria

- Bronsted-Lowry definition of acid, base
- Ionization of water
  - K_w, its approximate value ($K_w = [H^+][OH^-] = 10^{-14}$ at 25°C, 1 atm)
  - Definition of pH: pH of pure water
- Conjugate acids and bases (e.g., NH_4^+ and NH_3)
- Strong acids and bases (e.g., nitric, sulfuric)
- Weak acids and bases (e.g., acetic, benzoic)
  - Dissociation of weak acids and bases with or without added salt
  - Hydrolysis of salts of weak acids or bases
  - Calculation of pH of solutions of salts of weak acids or bases
- Equilibrium constants K_a and K_b: pK_a, pK_b
- Buffers
  - Definition and concepts (common buffer systems)
  - Influence on titration curves

Titration

- Indicators
- Neutralization
- Interpretation of the titration curves
- Redox titration

Separations and Purifications

- Extraction: distribution of solute between two immiscible solvents

	• Distillation
	• Chromatography
	  o Basic principles involved in separation process
	  ▪ Column chromatography, gas-liquid chromatography
	  ▪ High pressure liquid chromatography
	  o Paper chromatography
	  o Thin-layer chromatography
	• Separation and purification of peptides and proteins
	  o Electrophoresis
	  o Quantitative analysis
	  o Chromatography
	  ▪ Size-exclusion
	  ▪ Ion-exchange
	  ▪ Affinity
	• Racemic mixtures, separation of enantiomers
	Nucleotides and Nucleic Acids
	• Nucleotides and nucleosides: composition
	  o Sugar phosphate backbone
	  o Pyrimidine, purine residues
	• Deoxyribonucleic acid: DNA, double helix
	• Chemistry
	• Other functions
	Amino Acids, Peptides, Proteins
	• Amino acids: description
	  o Absolute configuration at the α position
	  o Dipolar ions
	  o Classification
	  ▪ Acidic or basic
	  ▪ Hydrophilic or hydrophobic
	  o Synthesis of α-amino acids
	  ▪ Strecker Synthesis
	  ▪ Gabriel Synthesis
	• Peptides and proteins: reactions
	  o Sulfur linkage for cysteine and cystine
	  o Peptide linkage: polypeptides and proteins
	  o Hydrolysis
	• General Principles
	  o 1° structure of proteins
	  o 2° structure of proteins
	  o 3° structure of proteins
	  o o Isoelectric point
	The Three-Dimensional Protein Structure
	• Conformational stability
	  o Hydrophobic interactions
	  o Solvation layer (entropy)
	• 4° quaternary structure
	• Denaturing and Folding

Non-Enzymatic Protein Function
- Binding
- Immune system
- Motor

Lipids
- Types
  - Storage
    - Triacyl glycerols
    - Free fatty acids: saponification
  - Structural
    - Phospholipids and phosphatids
    - Sphingolipids
    - Waxes
  - Signals/cofactors
    - Fat-soluble vitamins
    - Steroids
    - Prostaglandins

Carbohydrates
- Description
  - Nomenclature and classification, common names
  - Absolute configuration
  - Cyclic structure and conformations of hexoses
  - Epimers and anomers
- Hydrolysis of the glycoside linkage
- Keto-enol tautomerism of monosaccharides
- Disaccharides
- Polysaccharides

Phenols
- Oxidation and reduction (e.g., hydroquinones), ubiquinones: biological $2e^-$ redox centers

Enzymes
- Classification by reaction type
- Mechanism
  - Substrates and enzyme specificity
  - Active site model
  - Induced-fit model
  - Cofactors, coenzymes and vitamins
- Kinetics
  - General (catalysis)
  - Michaelis-Menten
  - Cooperativity
  - Effects of local conditions on enzyme activity
- Inhibition
- Regulatory enzymes
  - Allosteric
  - Covalently modified

Principles of Bioenergetics

	• Bioenergetics/thermodynamics
	  o Free energy/K_{eq}
	  o Concentration
	• Phosphorylation/ATP
	  o ATP hydrolysis ΔG << 0
	  o ATP group transfers
	• Biological oxidation–reduction
	  o Half-reactions
	  o Soluble electron carriers
	  o Flavoproteins

CHM 451	Amino Acids
	• Description
	  o Absolute configuration at the α position
	  o Amino acids as dipolar ions
	  o Classifications
	  ▪ Acidic or basic
	  ▪ Hydrophobic or hydrophilic
	• Reactions
	  o Sulfur linkage for cysteine and cysteine
	  o Peptide linkage: polypeptides and proteins
	  o Hydrolysis
	Protein Structure
	• Structure
	  o 1° structure of proteins
	  o 2° structure of proteins
	  o 3° structure of proteins; role of proline, cystine, hydrophobic bonding
	  o 4° structure of proteins
	• Conformational stability
	  o Denaturing and folding
	  o Hydrophobic interactions
	  o Solvation layer (entropy)
	• Separation techniques
	  o Isoelectric point
	  o Electrophoresis
	Non-Enzymatic Protein Function
	• Binding
	• Immune system
	• Motors
	Enzyme Structure and Function
	• Function of enzymes in catalyzing biological reactions
	• Enzyme classification by reaction type
	• Reduction of activation energy
	• Substrates and enzyme specificity
	• Active Site Model
	• Induced-fit Model
	• Mechanism of catalysis

	○ Cofactors ○ Coenzymes ○ Water-soluble vitamins • Effects of local conditions on enzyme activity Control of Enzyme Activity • Kinetics ○ General (catalysis) ○ Michaelis-Menten ○ Cooperativity • Feedback regulation • Inhibition – types ○ Competitive ○ Non-competitive ○ Mixed ○ Uncompetitive • Regulatory enzymes ○ Allosteric enzymes ○ Covalently-modified enzymes • Zymogen Nucleic Acid Structure and Function • Description • Nucleotides and nucleosides ○ Sugar phosphate backbone ○ Pyrimidine, purine residues • Deoxyribonucleic acid (DNA): double helix, Watson–Crick model of DNA structure • Base pairing specificity: A with T, G with C • Function in transmission of genetic information • DNA denaturation, reannealing, hybridization Evidence that DNA is Genetic Material Principles of Bioenergetics • Bioenergetics/thermodynamics ○ Free energy/Keq ▪ Equilibrium constant ▪ Relationship of the equilibrium constant and ΔG° ○ Concentration ▪ Le Châtelier's Principle ○ Endothermic/exothermic reactions ○ Free energy: G ○ Spontaneous reactions and ΔG° • Phosphoryl group transfers and ATP ○ ATP hydrolysis ΔG << 0 ○ ATP group transfers • Biological oxidation-reduction ○ Half-reactions ○ Soluble electron carriers ○ Flavoproteins

	Carbohydrates
	• Description
	  o Nomenclature and classification, common names
	  o Absolute configuration
	  o Cyclic structure and conformations of hexoses
	  o Epimers and anomers
	• Hydrolysis of the glycoside linkage
	• Monosaccharides
	• Disaccharides
	• Polysaccharides
	Glycolysis, Gluconeogenesis, and the Pentose Phosphate Pathway
	• Glycolysis (aerobic), substrates and products
	  o Feeder pathways: glycogen, starch metabolism
	• Fermentation (anaerobic glycolysis)
	• Gluconeogenesis
	• Pentose phosphate pathway
	• Net molecular and energetic results of respiration processes
	Principles of Metabolic Regulation
	• Regulation of metabolic pathways
	  o Maintenance of a dynamic steady state
	• Regulation of glycolysis and gluconeogenesis
	• Metabolism of glycogen
	• Regulation of glycogen synthesis and breakdown
	  o Allosteric and hormonal control
	• Analysis of metabolic control
	Plasma Membrane
	• General function in cell containment
	• Composition of membranes
	  o Lipid components
	  ▪ Phospholipids (and phosphatids)
	  ▪ Steroids
	  ▪ Waxes
	  o Protein components
	  o Fluid mosaic model
	• Membrane dynamics
	• Solute transport across membranes
	  o Thermodynamic considerations
	  o Osmosis
	  ▪ Colligative properties, osmotic pressure
	  o Passive transport
	  o Active transport
	  ▪ Sodium/potassium pump
	• Membrane channels
	• Membrane potential
	• Membrane receptors
	• Exocytosis and endocytosis
	• Intercellular junctions

	o Gap junctions o Tight junctions o Desmosomes Membrane-Bound Organelles and Defining Characteristics of Eukaryotic Cells • Defining characteristics of eukaryotic cells: membrane bound nucleus, presence of organelles, • mitotic division • Nucleus o Compartmentalization, storage of genetic information o Nucleolus: location and function o Nuclear envelope, nuclear pores • Mitochondria o Site of ATP production o Inner and outer membrane structure o Self-replication • Lysosomes: membrane-bound vesicles containing hydrolytic enzymes • Endoplasmic reticulum o Rough and smooth components o Rough endoplasmic reticulum site of ribosomes o Double membrane structure o Role in membrane biosynthesis o Role in biosynthesis of secreted proteins • Golgi apparatus: general structure and role in packaging and secretion • Peroxisomes: organelles that collect peroxides Electrochemistry • Concentration cell: direction of electron flow, Nernst equation Biosignalling • Gated ion channels o Voltage gated o Ligand gated • Receptor enzymes • G protein-coupled receptors Lipids • Description; structure o Steroids • Terpenes and terpenoids Equilibrium • Concept of force, units • Analysis of forces acting on an object • Newton's First Law of Motion, inertia • Torques, lever arms Electrochemistry • Electrolytic cell o Electrolysis o Anode, cathode o Electrolyte o Faraday's Law relating amount of elements deposited (or gas

liberated) at an electrode to
    - current
    - Electron flow, oxidation, and reduction at the electrodes
- Galvanic or Voltaic cells
    - Half-reactions
    - Reduction potentials, cell potential
    - Direction of electron flow
- Concentration cell
- Batteries
    - Electromotive force, Voltage
    - Lead-storage batteries
- Nickel-cadmium batteries

Acid/Base Equilibria

- Bronsted-Lowry definition of acid, base
- Ionization of water
    - K_w, its approximate value ($K_w = [H^+][OH^-] = 10^{-14}$ at 25°C, 1 atm)
    - Definition of pH: pH of pure water
- Conjugate acids and bases (e.g., NH_4^+ and NH_3)
- Strong acids and bases (e.g., nitric, sulfuric)
- Weak acids and bases (e.g., acetic, benzoic)
    - Dissociation of weak acids and bases with or without added salt
    - Hydrolysis of salts of weak acids or bases
    - Calculation of pH of solutions of salts of weak acids or bases
- Equilibrium constants K_a and K_b: pK_a, pK_b
- Buffers
    - Definition and concepts (common buffer systems)
    - Influence on titration curves

Titration

- Indicators
- Neutralization
- Interpretation of the titration curves
- Redox titration

Separations and Purifications

- Extraction: distribution of solute between two immiscible solvents
- Distillation
- Chromatography
    - Basic principles involved in separation process
        - Column chromatography, gas-liquid chromatography
        - High pressure liquid chromatography
    - Paper chromatography
    - Thin-layer chromatography
- Separation and purification of peptides and proteins
    - Electrophoresis
    - Quantitative analysis
    - Chromatography
        - Size-exclusion
        - Ion-exchange

	▪ Affinity • Racemic mixtures, separation of enantiomers Nucleotides and Nucleic Acids • Nucleotides and nucleosides: composition o Sugar phosphate backbone o Pyrimidine, purine residues • Deoxyribonucleic acid: DNA, double helix • Chemistry • Other functions Amino Acids, Peptides, Proteins • Amino acids: description o Absolute configuration at the α position o Dipolar ions o Classification ▪ Acidic or basic ▪ Hydrophilic or hydrophobic o Synthesis of α-amino acids ▪ Strecker Synthesis ▪ Gabriel Synthesis • Peptides and proteins: reactions o Sulfur linkage for cysteine and cystine o Peptide linkage: polypeptides and proteins o Hydrolysis • General Principles o 1° structure of proteins o 2° structure of proteins o 3° structure of proteins o o Isoelectric point The Three-Dimensional Protein Structure • Conformational stability o Hydrophobic interactions o Solvation layer (entropy) • 4° quaternary structure • Denaturing and Folding Non-Enzymatic Protein Function • Binding • Immune system • Motor Lipids • Types o Storage ▪ Triacyl glycerols ▪ Free fatty acids: saponification o Structural ▪ Phospholipids and phosphatids ▪ Sphingolipids ▪ Waxes

	○ Signals/cofactors ▪ Fat-soluble vitamins ▪ Steroids ▪ Prostaglandins Carbohydrates • Description ○ Nomenclature and classification, common names ○ Absolute configuration ○ Cyclic structure and conformations of hexoses ○ Epimers and anomers • Hydrolysis of the glycoside linkage • Keto-enol tautomerism of monosaccharides • Disaccharides • Polysaccharides Enzymes • Classification by reaction type • Mechanism ○ Substrates and enzyme specificity ○ Active site model ○ Induced-fit model ○ Cofactors, coenzymes and vitamins • Kinetics ○ General (catalysis) ○ Michaelis-Menten ○ Cooperativity ○ Effects of local conditions on enzyme activity • Inhibition • Regulatory enzymes ○ Allosteric ○ Covalently modified Principles of Bioenergetics • Bioenergetics/thermodynamics ○ Free energy/K_{eq} ○ Concentration • Phosphorylation/ATP ○ ATP hydrolysis $\Delta G << 0$ ○ ATP group transfers • Biological oxidation–reduction ○ Half-reactions ○ Soluble electron carriers ○ Flavoproteins
CHM 452	Non-Enzymatic Protein Function • Binding • Immune system • Motors Enzyme Structure and Function • Function of enzymes in catalyzing biological reactions

	• Enzyme classification by reaction type
	• Reduction of activation energy
	• Substrates and enzyme specificity
	• Active Site Model
	• Induced-fit Model
	• Mechanism of catalysis
	  o Cofactors
	  o Coenzymes
	  o Water-soluble vitamins
	• Effects of local conditions on enzyme activity
	Control of Enzyme Activity
	• Kinetics
	  o General (catalysis)
	  o Michaelis-Menten
	  o Cooperativity
	• Feedback regulation
	• Inhibition – types
	  o Competitive
	  o Non-competitive
	  o Mixed
	  o Uncompetitive
	• Regulatory enzymes
	  o Allosteric enzymes
	  o Covalently-modified enzymes
	• Zymogen
	Nucleic Acid Structure and Function
	• Description
	• Nucleotides and nucleosides
	  o Sugar phosphate backbone
	  o Pyrimidine, purine residues
	• Deoxyribonucleic acid (DNA): double helix, Watson–Crick model of DNA structure
	• Base pairing specificity: A with T, G with C
	• Function in transmission of genetic information
	• DNA denaturation, reannealing, hybridization
	DNA Replication
	• Mechanism of replication: separation of strands, specific coupling of free nucleic acids
	• Semi-conservative nature of replication
	• Specific enzymes involved in replication
	• Origins of replication, multiple origins in eukaryotes
	• Replicating the ends of DNA molecules
	Repair of DNA
	• Repair during replication
	• Repair of mutations
	Genetic Code
	• Central Dogma: DNA → RNA → protein

	• The triplet code
	• Codon-anticodon relationship
	• Degenerate code, wobble pairing
	• Missense, nonsense codons
	• Initiation, termination codons
	• Messenger RNA (mRNA)
	Transcription
	• Transfer RNA (tRNA); ribosomal RNA (rRNA)
	• Mechanism of transcription
	• mRNA processing in eukaryotes, introns, exons
	• Ribozymes, spliceosomes, small nuclear ribonucleoproteins (snRNPs), small nuclear RNA (snRNAs)
	Translation
	• Roles of mRNA, tRNA, rRNA
	• Role and structure of ribosomes
	• Initiation, termination co-factors
	• Post-translational modification of proteins
	Eukaryotic Chromosome Organization
	• Chromosomal proteins
	• Single copy vs. repetitive DNA
	• Supercoiling
	• Heterochromatin vs. euchromatin
	• Telomeres, centromeres
	Evidence that DNA is Genetic Material
	Principles of Metabolic Regulation
	• Regulation of metabolic pathways
	  o Maintenance of a dynamic steady state
	• Regulation of glycolysis and gluconeogenesis
	• Metabolism of glycogen
	• Regulation of glycogen synthesis and breakdown
	  o Allosteric and hormonal control
	• Analysis of metabolic control
	Citric Acid Cycle
	• Acetyl-CoA production
	• Reactions of the cycle, substrates and products
	• Regulation of the cycle
	• Net molecular and energetic results of respiration processes
	Metabolism of Fatty Acids and Proteins
	• Description of fatty acids
	• Digestion, mobilization, and transport of fats
	• Oxidation of fatty acids
	  o Saturated fats
	  o Unsaturated fats
	• Ketone bodies
	• Anabolism of fats

	• Non-template synthesis: biosynthesis of lipids and polysaccharides • Metabolism of proteins Oxidative Phosphorylation • Electron transport chain and oxidative phosphorylation, substrates and products, general features of the pathway • Electron transfer in mitochondria o NADH, NADPH o Flavoproteins o Cytochromes • ATP synthase, chemiosmotic coupling o Proton motive force • Net molecular and energetic results of respiration processes • Regulation of oxidative phosphorylation • Mitochondria, apoptosis, oxidative stress Hormonal Regulation and Integration of Metabolism • Higher level integration of hormone structure and function • Tissue specific metabolism • Hormonal regulation of fuel metabolism • Obesity and regulation of body mass Lipids • Description; structure o Steroids • Terpenes and terpenoids Nucleotides and Nucleic Acids • Nucleotides and nucleosides: composition o Sugar phosphate backbone o Pyrimidine, purine residues • Deoxyribonucleic acid: DNA, double helix • Chemistry • Other functions Lipids • Types o Storage ▪ Triacyl glycerols ▪ Free fatty acids: saponification o Structural ▪ Phospholipids and phosphatids ▪ Sphingolipids ▪ Waxes o Signals/cofactors ▪ Fat-soluble vitamins ▪ Steroids ▪ Prostaglandins Phenols • Oxidation and reduction (e.g., hydroquinones), ubiquinones: biological $2e^-$ redox centers Enzymes

	• Classification by reaction type
	• Mechanism
	  o Substrates and enzyme specificity
	  o Active site model
	  o Induced-fit model
	  o Cofactors, coenzymes and vitamins
	• Kinetics
	  o General (catalysis)
	  o Michaelis-Menten
	  o Cooperativity
	  o Effects of local conditions on enzyme activity
	• Inhibition
	• Regulatory enzymes
	  o Allosteric
	  o Covalently modified

CHM 462L	Protein Structure
	• Structure
	  o 1° structure of proteins
	  o 2° structure of proteins
	  o 3° structure of proteins; role of proline, cystine, hydrophobic bonding
	  o 4° structure of proteins
	• Conformational stability
	  o Denaturing and folding
	  o Hydrophobic interactions
	  o Solvation layer (entropy)
	• Separation techniques
	  o Isoelectric point
	  o Electrophoresis
	Enzyme Structure and Function
	• Function of enzymes in catalyzing biological reactions
	• Enzyme classification by reaction type
	• Reduction of activation energy
	• Substrates and enzyme specificity
	• Active Site Model
	• Induced-fit Model
	• Mechanism of catalysis
	  o Cofactors
	  o Coenzymes
	  o Water-soluble vitamins
	• Effects of local conditions on enzyme activity
	Genetic Code
	• Central Dogma: DNA → RNA → protein
	• The triplet code
	• Codon-anticodon relationship
	• Degenerate code, wobble pairing

	• Missense, nonsense codons • Initiation, termination codons • Messenger RNA (mRNA) Recombinant DNA and Biotechnology • Gene cloning • Restriction enzymes • DNA libraries • Generation of cDNA • Hybridization • Expressing cloned genes • Polymerase Chain Reaction • Gel Electrophoresis and Southern Blotting • DNA sequencing • Analyzing gene expression • Determining gene function • Stem cells • Practical applications of DNA technology: medical applications, human gene therapy, pharmaceuticals, forensic evidence, environmental cleanup, agriculture • Safety and ethics of DNA technology Separations and Purifications • Extraction: distribution of solute between two immiscible solvents • Distillation • Chromatography o Basic principles involved in separation process ▪ Column chromatography, gas-liquid chromatography ▪ High pressure liquid chromatography o Paper chromatography o Thin-layer chromatography • Separation and purification of peptides and proteins o Electrophoresis o Quantitative analysis o Chromatography ▪ Size-exclusion ▪ Ion-exchange ▪ Affinity • Racemic mixtures, separation of enantiomers • Enzymes • Classification by reaction type • Mechanism o Substrates and enzyme specificity o Active site model o Induced-fit model o Cofactors, coenzymes and vitamins • Kinetics o General (catalysis)

	○ Michaelis-Menten ○ Cooperativity ○ Effects of local conditions on enzyme activity • Inhibition • Regulatory enzymes ○ Allosteric • Covalently modified