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| **UNIT** | **ESSENTIAL KNOWLEDGE** | **LEARNING OBJECTIVES** | **Skills/Concepts****(review from HS Chem)** |
| 1: Structure of Matter (~ 2 wks, S1)Textbook:Ch 1-3 | * Molecules are composes of specific combinations of different elements and of combinations of the same elements in differing amounts and proportions
* Chemical analysis provides a method for determining the relative number of atoms in a substance, which can be used to identify the substance or determine its purity
* The mole is the fundamental unit for counting numbers of particles on the macroscopic level and allows quantitative connections to be drawn between laboratory experiences, which occur at the macroscopic level, and chemical processes, which occur at the atomic level
* Conservation of atoms makes it possible to compute the masses of substances involved in physical and chemical processes. Chemical processes result in the formation of new substances, and the amount of these depends on the number and the types and masses of elements in the reactants as well as the efficiency of the transformation
 | * Justify the observation that the ratio of the masses of the constituent elements in any pure sample of that compound is always identical on the basis of atomic molecular theory.
* Select and apply mathematical routines to mass data or identify or infer the composition of pure substances and/or mixtures
* Select and apply mathematical relationships to mass data in order to justify a claim regarding the identity and/or estimated purity of a substance
* Connect the number of particles, moles, mass, and volume of substances to one another, both quantitatively and qualitatively
* Predict properties of substances based on their chemical formulas and provide explanations of their properties based on particle views
 | * Using Sig Figs Correctly
* Metric Conversions & Dimensional Analysis
* Types of Matter Classification
* Basic Techniques to separate Matter
* Law of Conservation of Mass
* Law of Definite Proportions
* Law of Multiple Proportions
* Basic Atomic Structure
* Basic properties of Metals, Metalloids, Nonmetals
* Naming Compounds
* Balancing Equations
* Basic Stoichiometric Calculations (including dilutions)
* % Composition
* Empirical & Molecular Formula
* Limiting Reactants
* % Yield
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| **UNIT** | **ESSENTIAL KNOWLEDGE** | **LEARNING OBJECTIVES** | **Skills/Concepts** |
| 2: Reactions in Solution (~ 5 wks, S1)Textbook:Ch 4 | * Solutions are homogeneous mixtures in which the physical properties are dependent on the concentration of the solute and the strengths of all interactions among the particles of the solutes and solvent
* A chemical change may be represented by a molecular, ionic, or net ionic equation
* Quantitative information can be derived from stoichiometric calculations that utilize the mole ratios from the balanced chemical equations. The role of stoichiometry in real world applications is important to note, so that it does not seem to be simply an exercise done only by chemists
* Synthesis reactions are those in which atoms and/or molecules combine to form a new compound. Decomposition is the reverse of synthesis, a process whereby molecules are decomposed, often by the use of heat
* In a neutralization reaction, protons are transferred from an acid to a base
* In oxidation-reduction (redox) reactions, there is a net transfer of electrons. The species that loses electrons is oxidized, and the species that gains electrons is reduced.
* Product of heat or light, formation of a gas, and formation of a precipitate and/or color change are possible evidences that a chemical change has occurred
* Net changes in energy for a chemical reaction can be endothermic or exothermic
 | * Translate among macroscopic observations of change, chemical equations, and particle views
* Translate an observed chemical change into a balanced chemical equation and justify the choice of equation type (molecular, ionic, or net ionic) in terms of utility for the given circumstance
* Use stoichiometric calculations to predict the results of forming a reaction in the laboratory and/or to analyze deviations from the expected results
* Relate quantities (measured mass of substance, volumes of solutions, or volumes and pressures of gases) to identify stoichiometric relationships for a reaction, including situations involving limiting reactants and situations in which the reaction has not gone to completion
* Design a plan in order to collect data on the synthesis or decomposition of a compound to confirm the conservation of matter and the law of definite proportions
* Identify Bronsted-Lowry acids, bases, and/or conjugate acid-base pairs, using proton transfer reactions to justify the identification
* Draw and/or interpret representations of solutions that show the interactions between solute and solvent
* Identify redox reactions and justify the identification in terms of electron transfer
* Create or interpret representations that connect the concept of molarity with the interactions between solute and solvent
* Design and/or interpret data from an experiment that uses gravimetric analysis to determine the concentration of an analyte in solute
* Design and/or interpret data from experiment that uses titration to determine the concentration of an analyte in solution
* Design or interpret the results of an experiment involving a redox titration
 | * Product Prediction
* Solubility Rules
* Net Ionic Rxn
* Strong vs Weak Electrolytes
* Solute/Solvent Interactions
* Precipitation Reactions
* Gravimetric Analysis
* Acid & Base Reactions
* Bronsted-Lowry Acid Base & Conjugate acid-base pairs
* Titrations with acids and bases (volumetric analysis)
* Standardization of Solutions
* Redox Reactions
* Oxidation numbers
* Reducing agent
* Oxidizing agent
* Redox Titrations
* Balancing Redox Reactions
* Half Reaction
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| **UNIT** | **ESSENTIAL KNOWLEDGE** | **LEARNING OBJECTIVES** | **Skills/Concepts** |
| Unit 3: The Atom & Periodicity (~2 wks, S1)Textbook: Ch 7 | * The atom is composed of negatively charged electrons, which can leave the atom, and a positively charged nucleus that is made of protons and neutrons. The attraction of the electrons to the nucleus is the basis of the structure of the atom. Coulomb’s law is qualitatively useful for understanding the structure of the atom
* The electronic structure of the atom can be described using an electron configuration that reflects the concept of electrons in quantized energy levels or shells; the energetic of the electrons in the atom can be understood by consideration of Coulomb’s law
* Many properties of atoms exhibit periodic trends that are reflective of the periodicity of electronic structure
* The currently accepted best model of the atom is based on the quantum mechanical model
* As is the case with all scientific models, any model of the atom is subject to refinement and change in response to new experimental results. In that sense, an atomic model is not regarded as an exact description of the atom, but rather a theoretical construct that fits a set of experimental data
* An early model of the atom stated that all atoms of an element are identical. Mass spectrometry data demonstrate evidence that contradicts this early model
* The interaction of electromagnetic waves or light with matter is a powerful means to probe the structure of atoms and molecules, and to measure their concentration
* Physical and chemical processes can be depicted symbolically; when this is done, the illustration must conserve all atoms of all types
 | * Explain the distribution of electrons in an atom or ion based upon data
* Analyze data relating to electron energies for patterns and relationships
* Describe the electronic structure of the atom, using PES data, ionization energy data, and/or Coulomb’s law to construct explanations of how the energies of electrons within shells in atoms vary
* Explain the distribution of electrons using Coulomb’s law to analyze measured energies
* Predict and/or justify trends in atomic properties based on location on the periodic table and/or the shell model
* Justify with evidence the arrangement of the periodic table and can apply periodic properties to chemical reactivity
* Analyze data, based on periodicity and the properties of binary compounds, to identify patterns and generate hypotheses related to the molecular design of compounds for which data are not supplied
* Explain why a given set of data suggests, or does not suggest, the need to refine the atomic model from a classical shell model with the quantum mechanical model
* Given information about a particular model of the atom, determine if the model is consistent with specified evidence
* Use data from mass spectroscopy to identify the elements and the masses of individual atoms of a specific element
* Justify the selection of a particular type of spectroscopy to measure properties associated with vibrational or electronic motions of molecules
* Design and/or interpret the results of an experiment regarding the absorption of light to determine the concentration of an absorbing species in a solution
* Predict properties of substances based on their chemical formulas, and provide explanations of their properties based on particle views.
 | * Atomic History
* Atomic Models
* Planck
* Atomic Structure of Hydrogen
* Bohr Model
* Quantum Mechanical Model (Heisenberg, de Broglie, and Schrodinger)
* Photoelectric effect
* Mass Spectroscopy & Photoelectric Spectroscopy
* Orbital shapes
* Electron Configuration
* Periodic table trends (atomic radii, electron affinity, ionization energy, electronegativity)
* Isoelectric periodic table trends
* Activity Series for metals & nonmetals
* Coulomb’s Law
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| **UNIT** | **ESSENTIAL KNOWLEDGE** | **LEARNING OBJECTIVES** | **Skills/Concepts** |
| Unit 4: Bonding and Intermolecular Forces(~6 wks,S1)Textbook:Ch 8, 9, 10 | * The different properties of solids and liquids can be explained by the differences in their structures, both at the particulate level and in their supramolecular structures
* London Dispersion forces are attractive forces present between all atoms and molecules. LDFs are often the strongest net intermolecular force between large molecules
* Dipole forces result from the attraction among the positive ends and negative ends of polar molecules. Hydrogen bonding is a strong type of dipole-dipole force that exists when very electronegative atoms (N, O, F) are involved
* Intermolecular forces play a key role in determining the properties of substances, including biological structures and interactions
* In covalent bonding, electrons are shared between the nuclei of two atoms to form a molecule or polyatomic ion. Electronegativity differences between the two atoms account for the distribution of the shared electrons and the polarity of the bond
* Ionic bonding results from the net attraction between oppositely charged ions, closely packed together in a crystal lattice
* Metallic bonding describes an array of positively charged metal cores surrounded by a sea of mobile valence electrons
* The localized electron bonding model describes and predicts molecular structure using lewis diagrams and the VSEPR model
* Ionic solids have high melting points, are brittle, and conduct electricity when molten or in solution
* Metallic solids are good conductors of heat and electricity, have a wide range of melting points, and are shiny, malleable, ductile, and readily alloyed
* Covalent network solids generally have extremely high melting points, are hard, and are thermal insulators. Some conduct electricity
* Molecular solids with low molecular weight usually have low melting points and are not expected to conduct electricity as solids, in solution, or when molten
* Potential energy is associated with the interaction of molecules; as molecules draw near each other, they experience an attractive force
* At the particulate scale, chemical processes can be distinguished from physical processes because chemical bonds can be distinguished from intermolecular interactions
* Noncovalent and intermolecular interactions play important roles in many biological and polymer systems
 | * Explain the relative strength of acids and bases based on their molecular structure, interparticle forces, and solution equilibrium
* Use aspects of particulate models (i.e. particle spacing, motion, and forces of attraction) to reason about observed differences between solid and liquid phases among solid and liquid materials
* Explain how solutes can be separated by chromatography based on intermolecular interactions
* Draw and/or interpret representations of solutions that show the interactions between the solute and solvent
* Design and/or interpret the results of a separation experiment (filtration, paper chromatography, column chromography, or distillation) in terms of the relative strength of interactions among and between the components
* Explain the trends in properties and/or predict the properties of samples consisting of particles with no permanent dipole on the basis of London Dispersion Forces
* Describe the relationships between the structural features of polar molecules and the forces of attraction between the particles
* Apply Coulomb’s law qualitatively (including using representations) to describe the interactions of ions, and the attractions between ions and solvents to explain the factors that contribute to the solubility of ionic compounds
* Explain observations regarding the solubility of ionic solids and molecules in water and other solvents on the basis of particle views that include intermolecular interactions and entropic effects
* Explain the properties (phase, vapor pressure, viscosity) of small and large molecular compounds in terms of the strengths and types of intermolecular forces
* Predict the type of bonding present between two atoms in a binary compound based on position in the periodic table and the electronegativity of the elements
* Rank and justify the ranking of bond polarity on the basis of the locations of the bonded atoms in the periodic table
* Create visual representations of ionic substances that connect the microscopic structure to macroscopic properties, and/or use representations to connect the microscopic structure to macroscopic properties (boiling point, solubility, hardness, brittleness, low volatility, lack of malleability, ductility, or conductivity)
* Explain how a bonding model involving delocalized electrons is consistent with macroscopic properties of metals (conductivity, malleability, ductility, low volatility) and the shell model of the atom
* Use Lewis diagrams and VSEPR to predict the geometry of molecules, identify hybridization, and make predictions about polarity
* Design or evaluate a plan to collect and/or interpret data needed to deduce the type of bonding in a sample of a solid
* Create a representation of an ionic solid that shows essential characteristics of the structure and interactions present in the substance
* Explain a representation that connects properties of an ionic solid to its structural attributes and to the interactions present at the atomic level
* Compare the properties of metal alloys with their constituent elements to determine if the alloy has formed, identify the type of alloy formed, and explain the differences in properties using particulate level reasoning
* Use the electron sea model of metallic bonding that shows essential characterisitics of the structure and interactions present in the substance
* Explain a representation that connects properties of a metallic solid to its structural attributes and to the interactions present at the atomic level
* Create a representation of a covalent solid that shows essential characteristics of the structure and interactions present in the substance
* Explain a representation that connects the properties of a covalent solid to its structural attributes and to the interactions present
* Create a representation of a molecular solid that shows essential characteristics of the structure and interactions present in the substance
* Explain a representation that connects properties of a molecular solid to its structural attributes and to the interactions present
* Create or use graphical representations in order to connect the dependence of potential energy to the distance between atoms and factors, such as bond order (for covalent interactions) and polarity (for intermolecular attractions), which influence the interaction strength
* Make claims and/or predictions regarding relative magnitudes of the forces acting within collections of interacting molecules based on the distribution of electrons within the molecules and the types of intermolecular forces through which the molecules interact
* Support the claim about whether a process is chemical or physical change (or may be classified as both) based on whether the process involves changes in the intramolecular or intermolecular interactions
* Identify the noncovalent interactions within and between large molecules and/or connect the shape and function of the large molecule to the presence and magnitude of these interactions
 | * Coulomb’s Law
* Types of Chemical Bonds
* Electronegativity
* Bond Polarity
* Dipole Moments
* Ionic Compounds
* Covalent Compounds
* Bond Energies
* Lewis Structures
* Octet Rule & exceptions
* Resonance
* Formal Charge
* VSEPR
* Localized Electron Model
* Atomic Orbitals
* Hybridization
* Molecluar Orbitals
* Diamagnetism
* Paramagnetism
* Combining Orbitals
* Intermolecular Forces
* Dipole-Dipole Forces
* London Dispersion Forces
* Liquids
* Structures of Solids
* Metallic Bonding and Structures
* Network Atomic Structures
* Semiconductors
* Molecular Solids
* Ionic Solids
* Vapor pressure and Changes of State
* Phase Diagrams
* Factors Affecting Solubility
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| **UNIT** | **ESSENTIAL KNOWLEDGE** | **LEARNING OBJECTIVES** | **Skills/Concepts** |
| Unit 5: Gases(~2 wks, S1)Textbook: Ch 5 | * The gaseous state can be effectively modeled with a mathematical equation relating various macroscopic properties. A gas has neither a definite volume or definite shape; because the effects of attractive forces are minimal, we usually assume that the particles move independently
 | * Use KMT and concepts of intermolecular forces to make predictions about the macroscopic properties of gases, including both ideal and non-ideal behavior
* Refine multiple representations of a sample of matter in the gas phase to accurately represent the effect of changes in macroscopic properties on the sample
* Apply mathematical relationships or estimation to determine macroscopic variables for ideal gases
* Qualitatively analyze data regarding real gases to identify deviations from ideal behavior and relate these to molecular interactions
* Relate temperature to the motions of particles, either via particulate representations, such as drawing of particles with arrows indication velocities and/or via representations of average kinetic energy and distribution of kinetic energy and distribution of kinetic energies of the particles, such as plots of the Maxwell-Boltzmann distribution
 | * Pressure
* Gas Laws
* Ideal Gas law
* Gas Stoichiometry
* Dalton’s Law of Partial Pressures
* Kinetic Molecular Theory of Gases
* Root Mean Square Velocity
* Maxwell-Boltzmann Distributions
* Effusion & Diffusion
* Real Gases
* Chemistry in the atmosphere
 |
| **UNIT** | **ESSENTIAL KNOWLEDGE** | **LEARNING OBJECTIVES** | **Skills/Concepts** |
| Unit 6: Kinetics(~3 wks, S2)Textbook:Ch 12  | * The rate of a chemical reaction is influenced by the concentration or pressure of reactants, the phase of reactants or products, and environmental factors such as temperature and solvent
* The rate law shows how the rate depends on reactant concentrations
* The magnitude and temperature dependence of the rate of reaction is contained quantitatively in the rate constant
* Elementary reactions can be unimolecular or involve collisions between two or more molecules
* Not all collisions are successful. To get over the activation energy barrier, the colliding species need sufficient energy. Also, the orientations of the reactant molecules during the collision must allow for the rearrangement of reactant bonds to form product bonds
* A successful collision can be viewed as following a reaction path with an associated energy profile
* The mechanism of a multistep reaction consists of a series of elementary reactions that add up to the overall reaction
* In many reactions, the rate is set by the slowest elementary reaction, or rate-limiting step
* Reaction intermediates, which are formed during the reaction but not present in the overall reaction, play an important role in multistep reactions
* Catalysts function by lowering the activation energy of an elementary step in a reaction mechanism, and by providing a new and faster reaction mechanism
* Important classes in catalysis include acid-base catalysis, surface catalysis, and enzyme catalysis
* A thermodynamically favored process may not occur due to kinetic constraints (kinetic vs thermodynamic control)
 | * Design and/or interpret the results of an experiment regarding the factors (temperature, concentration, surface area) that may influence the rate of a reaction
* Connect the half-life of a reaction to the rate constant for a first order reaction and justify the use of this relation in terms of the reaction being a first order reaction
* Analyze concentration vs time data to determine the rate law for a zero, first, or second order reaction
* Connect the rate law for an elementary reaction to the frequency and success of molecular collisions, including connecting the frequency and success to the order and rate constant, respectively
* Explain the difference between collisions that convert reactants to products and those that do not in terms of energy distributions and molecular orientation.
* Use representations of the energy profile for an elementary reaction (from the reactions, through the transition state, to the products) to make qualitative predictions regarding the relative temperature dependence on reaction rate
* Evaluate alternative explanations, as expressed by reaction mechanisms, to determine which are consistent with data regarding the overall rate of a reaction, and data that can be used to infer the presence of a reaction intermediate
* Translate among reaction energy profile representations, particulate representations, and symbolic representations (chemical equations) of a chemical reaction occurring in the presence and absence of a catalyst
* Explain changes in reaction rates arising from the use of acid-base catalysts, surface catalysts, or enzyme catalysts including selecting appropriate mechanisms with or without the catalyst present
 | * Reaction Rates
* Rate Laws
* Rate order
* Initial Rates
* Integrated Rate Laws
* First order rate laws
* Second order rate laws
* Zero order rate laws
* Reaction mechanisms
* Activation energy
* Arrhenius Equation
* Catalysis
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| **UNIT** | **ESSENTIAL KNOWLEDGE** | **LEARNING OBJECTIVES** | **Skills/Concepts** |
| Unit 7: Equilibrium(~6 wks,S2)Textbook:Ch 13, 14, 15 | * In many classes of reactions, it is important to consider both the forward and reverse reaction
* The current state of a system undergoing a reversible reaction can be characterized by the extent to which reactants have been converted to products. The relative quantities of reaction components are quantitatively described by the reaction quotient, Q
* When a system is at equilibrium, all macroscopic values, such as concentrations, partial pressures, and temperature do not change over time. Equilibrium results from an equality between the rates of the forward and reverse reactions, at which point Q=K
* The magnitude of the equilibrium constant, K, can be used to determine whether the equilibrium lies toward the reactant side or product side
* Systems at equilibrium respond to disturbances by partially countering the effect of the disturbance (Le Chatelier’s principle)
* A disturbance to a system at equilibrium causes Q to differ from K, thereby taking the system out of the original equilibrium state. The system responds by bring Q back to agreement with K, thereby establishing a new equilibrium state
* Chemical equilibrium reasoning can be used to describe the proton-transfer reactions of acid-base chemistry
* The pH is an important characteristic of aqueous solutions that can be controlled with buffers. Comparing pH to pKa allows one to determine the protonation state of a molecule with a labile proton
* The solubility of a substance can be understood in terms of chemical equilibrium
* When the difference in Gibbs free energy between reactants and products, ΔG°, is much larger than the thermal energy, RT, the equilibrium constant is either very small (for ΔG°> 0) or very large (for ΔG° < 0). When ΔG° is comparable to the thermal energy, RT, the equilibrium constant is near 1.
 | * Explain the relative strengths of acids and bases based on molecular structure, interparticle forces, and solution equilibrium
* Use LeChatelier’s principle to make qualitative predictions for systems in which coupled reactions that share a common intermediate drive formation of a product
* Make quantitative predictions for systems involving couple reactions that share a common intermediate, based on the equilibrium constant for the combined reaction
* Explain why a thermodynamically favored reaction may not product large amounts of product (based on consideration of both initial conditions and kinetic effects) or why a thermodynamically unfavored chemical reaction can product large amounts of product for certain sets of initial conditions
* Given a set of experimental observations regarding chemical, physical, biological, or environmental processes that are reversible, construct an explanation that connects the observations to the reversibility of the underlying chemical reactions or processes
* Given a manipulation of a chemical reaction or set of reactions (e.g., reversal of reaction or addition of two reactions), determine the effects of that manipulation on Q or K
* Connect kinetics to equilibrium by using reasoning about equilibrium, such as Le Chatelier’s principle, to infer the relative rates of the forward and reverse reactions
* Given a set of initial conditions (concentrations or partial pressures) and the equilibrium constant, K, use the tendency of A to approach K to predict and justify the prediction s to whether the reaction will proceed toward the products or reactants as equilibrium is approached.
* Given data (tabular, graphical, etc) from which the state of the system at equilibrium can be obtained, calculate the equilibrium constant, K
* Given a set of initial conditions, use stoichiometric relationships and the law of mass action (Q=K at equilibrium) to determine qualitatively and/or quantitatively the conditions at equilibrium for a system involving a single reversible reaction
* For a reversible reaction that has a large or small K, to determine which chemical species will have very large versus very small concentration at equilibrium
* Use Le Chatelier’s principle to predict the direction of the shift resulting from possible stresses on a system at chemical equilibrium. The student is able to use Le Chatelier’s principle to design a set of conditions that will optimize a desired outcome such as a product yield.
* Connect Le Chatelier’s principle to the comparison of Q to K by explaining the effects of stress on Q and K
* Generate or use a particulate representation of an acid (strong or weak or polyprotic) and a strong base to explain the species that will have large versus small concentration at equilibrium
* Reason about the distinction between strong and weak acidic solutions with similar values of pH, including the percent ionization of the acids, the concentrations needed to achieve the same pH, and the amount of based needed to reach the equivalence point in a titration
* Interpret titration data for monoprotic or polyprotic acids involving titration of a weak or strong acid by a strong base (or a weak or strong base by a strong acid) to determine the concentration of the titrant and the pKa for a weak acid or the pKb for a weak base
* Based on the dependence of Kw on temperature, reason that neutrality requires [H+] = [OH-] as opposed to requiring pH=7, including especially the applications to biological systems
* Identify a given solution as containing a mixture of strong acids and/or bases and calculate or estimate the pH (and concentrations of all chemical species) in the resulting solution
* Identify a given solution as being the solution of a monoprotic weak acid or base (including salts in which one ion is a weak acid or base), calculate the pH and concentration of all species in the solution, and/or infer the relative strengths of the weak acids or bases from given equilibrium concentrations
* Given an arbitrary mixture of weak and strong acids and bases (including polyprotic systems), determine which species will react strongly with one another (i.e., K>1) and what species will be present in large concentrations at equilibrium
* Design a buffer solution with a target pH and buffer capacity by selecting an appropriate conjugate acid-base pair and estimating the concentrations needed to achieve the desired capacity
* Relate the predominant form a chemical species involving a labile proton (i.e, protonated/deprotonated form of a weak acid) to the pH of a solution and the pKa associated with the labile proton
* Identify a solution as being a buffer solution and explain the buffer mechanism in terms of the reactions that would occur on addition of acid or base
* Predict the solubility of a salt, or rank the solubility of salts, given the relevant Ksp values
* Interpret data regarding the solubility of salts to determine, or rank, the relevant Ksp
* Interpret data regarding the relative solubility of salts in terms of factors (common ions, pH) that influence the solubility
* Analyze the enthalpic and entropic changes associated with the dissolution of a salt, using particulate level interactions and representations
* Express the equilibrium constant in terms of ΔG° and RT and use this relationship to estimate the magnitude of K and consequently, the thermodynamically favorability of the process.
 | * Equilibrium constant
* Equilibrium expressions with pressures
* Heterogeneous equilibria
* Reaction quotient
* Calculating equilibrium with concentrations and partial pressures
* Solving equilibrium problems
* Le Chatelier’s Principle
* The nature of acids and bases
* Acid strength
* The pH Scale
* Calculating pH of a strong acid solution
* Calculating pH of a weak solutions
* Percent dissocation
* Bases
* Polyprotic acids
* Acid-base properties of salts
* Effect of structure on acid-base properties
* Acid-base properties of oxides
* Solving acid-base problems
* Acid base equilibrium
* Common ion effect
* Buffered solutions
* Buffer capacity
* Titrations and pH curves
* pKa
* Ka
* Acid-base indicators
* Solubility equilibria
* Solubility product
* Selective precipitation
* Qualitative analysis
* Complex ion equilibria
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| **UNIT** | **ESSENTIAL KNOWLEDGE** | **LEARNING OBJECTIVES** | **Skills/Concepts** |
| Unit 8: Chemical Energy & Thermo(~4 wks, S2)Textbook: Ch 6, 16 | * Temperature is a measure of the average kinetic energy of atoms and molecules
* The process of kinetic energy transfer at the particulate state is referred to in this course as heat transfer, and the spontaneous direction of the transfer is always from a hot to a cold body
* Energy is transferred between systems either through heat transfer or through one system doing work on the other system
* When two systems are in contact with each other and are otherwise isolated, the energy that comes out of one system is equal to the energy that goes into the other system. The combined energy of the two systems remains fixed. Energy transfer can occur through either heat exchange or work
* Chemical systems undergo three main processes that change their energy: heating/cooling, phase transitions, and chemical reactions
* Calorimetry is an experimental technique that is used to determine the heat exchanged/transferred in a chemical system
* Potential energy is associated with a particular geometric arrangement of atoms or ions and the electrostatic interactions between them
* The net energy change during a reaction is the sum of the energy required to break the bonds in the reactant molecules and the energy released in forming the bonds of the product molecules. The net change in energy may be positive, for endothermic reactions where energy is required, or negative for exothermic reactions where energy is released
* Entropy is a measure of dispersal of matter and energy
* Some physical or chemical processes involve both a decrease in the internal energy of the components (ΔH°<0) under consideration and an increase in the entropy of those components (ΔS°>0). These processes are necessarily thermodynamically favored (ΔG°<0)
* If a chemical process is not driven by both entropy and enthalpy changes, then the Gibbs free energy change can be used to determine whether the process is thermodynamically favored
* External sources of energy can be used to drive change in cases where the Gibbs free energy change is positive
 | * Interpret observations regarding macroscopic energy changes associated with a reaction or process to generate a relevant symbolic and/or graphical representation of the energy changes
* Generate explanations or make predictions about the transfer of thermal energy between systems based on this transfer being due to a kinetic energy transfer between systems arising from molecular collisions
* Use the conservation of energy to relate the magnitudes of the energy changes occurring in two or more interacting systems, including identification of the systems, the type (heat vs work), or the direction of energy flow
* Use the conservation of energy to relate the magnitudes of the energy changes when two nonreacting systems are mixed or brought into contact with one another
* Use calculations or estimations to relate energy changes associated with heating/cooling a substance to the heat capacity, relate energy changes associated with a phase transition to the enthalpy of fusion/vaporization, relate energy changes associated with chemical reaction to the enthalpy of the reaction, and related energy changes to PΔV work
* Design and/or interpret the results of an experiment in which calorimetry is used to determine the enthalpy change of a chemical process (heating/cooling, phase transition, or chemical reaction) at constant pressure
* Draw qualitative and quantitative connections between the reaction enthalpy and the energies involved in the breaking and formation of chemical bonds
* Use representations and models to predict the sign and relative magnitude of the entropy change associated with chemical or physical processes
* Predict whether or not a physical or chemical process is thermodynamically favored by determination (either quantitatively or qualitatively) the signs of both ΔH° and ΔS° and calculation or estimation of ΔG° when needed
* Determine whether a chemical or physical process is thermodynamically favored by calculating the change is standard Gibbs free energy.
* Explain how the application of external energy sources or the coupling of favorable with unfavorable reactions can be used to cause processes that are not thermodynamically favorable to become favorable
 | Part I: Thermochemistry (Ch 6)* Chemical energy
* Enthalpy
* First Law of Thermodynamics
* Work
* Calorimetry
* Hess’s law
* Standard enthalpies of formation
* Present sources of energy
* New energy sources

Part II: Entropy, Free Energy, and Thermodynamically Favored Processes (Ch 16)* Entropy
* Second Law of Thermodynamics
* Effect of Temperature
* Free Energy
* Third Law of Thermodynamics
* Entropy changes in chemical reactions
* Free energy and chemical reaction
* Dependence of free energy on pressure
* Free energy and equilibrium
* Free energy and work
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| **UNIT** | **ESSENTIAL KNOWLEDGE** | **LEARNING OBJECTIVES** | **Skills/Concepts** |
| Unit 9: Electochem(~1 wk, S2) Textbook:Ch 17 | * Electrochemistry shows the interconversion between chemical and electrical energy in galvanic or electrolytic cells
 | * Make qualitative or quantitative predictions about galvanic or electrolytic reactions based on half-cell reactions and potentials and/or Faraday’s laws
* Analyze data regarding galvanic or electrolytic cells to identify properties of the underlying redox reactions
 | * Galvanic cells
* Cell Potential
* Cell Potential, Electrical Work, and Free energy
* Dependence of Cell potential on concentration
 |