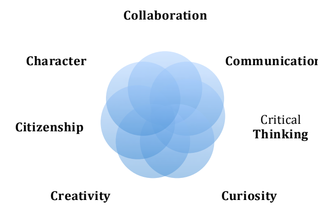
Content Area: Science	Course: AP Chemistry	Grade Level: 11-12
	**R14 The Seven Cs of Learning** 	

Unit Titles	Length of Unit
• The Structure of Matter	• 2 weeks
• Stoichiometry and Reactions in Solution	• 4 weeks
• Chemical Energy and Thermochemistry	• 3 weeks
• Atomic Structure and Periodicity	• 2 weeks
• Bonding	• 3-4 weeks
• States of Matter and Intermolecular Forces	• 3-4 weeks
• Rates of Chemical Reactions	• 2-3 weeks
• Equilibrium	• 6 weeks
• Entropy and Free Energy	• 2 weeks
• Electrochemistry	• 2 weeks

Region 14 Schools
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Strands	Course Level Expectations
Big Idea 1	• Students will understand the chemical elements are fundamental building materials of matter, and all matter can be understood in terms of arrangements of atoms. These atoms retain their identity in chemical reactions.
Big Idea 2	• Students will understand chemical and physical properties of materials can be explained by the structure and the arrangement of atoms, ions, or molecules and the forces between them.
Big Idea 3	• Students will understand changes in matter involve the rearrangement and/or reorganization of atoms and/or the transfer of electrons.
Big Idea 4	• Students will understand rates of chemical reactions are determined by details of the molecular collisions.
Big Idea 5	• Students will understand the laws of thermodynamics describe the essential role of energy and explain and predict the direction of changes in matter.

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Unit Title	The Structure of Matter	Length of Unit	2 weeks

Inquiry Questions **(Engaging & Debatable)**	• Knowing that error is unavoidable in experimentation, what margins of error are acceptable for experimental results to be considered reliable? • How do the bonding structures between atoms and molecules influence how materials appear and behave at the macroscopic level? • How can we calculate the amount of matter in a substance?
Standards*	**Big Idea** 1 **Learning Objectives**: 1.1, 1.2, 1.3, 1.13, 1.14
Unit Strands & Concepts	• Classification of matter, properties of matter, atomic theory of matter, • Modern view of atomic structure, • Molecules and molecular compounds, ions and ionic compounds
Key Vocabulary	Proton, neutron, electron, physical property/change, chemical property/change, ionic, covalent, ion, the mole, molar mass, average atomic mass, error, significant figures, atom, ion, molecule

*Standards based on College Board AP Chemistry Course and Exam Description
For more information visit: https://apcentral.collegeboard.org/pdf/ap-chemistry-course-and-exam-description.pdf?course=ap-chemistry

Unit Title	The Structure of Matter	Length of Unit	2 weeks

Critical Content: My students will **Know**…	**Key Skills:** My students will be able to **(Do)**…
• ionic compounds are the combination of cations and anions. • ionic compounds are a repeating array of positively charged ions attracted to negatively charged ions. • covalent compounds are formed between nonmetals. • particles vibrate in place in the solid phase, but are free to move in the liquid phase. • mixtures can be separated by their physical properties. • average atomic mass of an element can be calculated using mass spectrometry data. • scientists use the mole concept to define and calculate the amount of a substance being used.	• predict the type of bonding between two types of atoms in binary compounds based on position on the periodic table and the electronegativity of the elements. • name binary covalent compounds and ionic compounds. • create visual representations of ionic substances that connect the microscopic structure to macroscopic properties. • use aspects of particulate models to reason about observed differences between the solid and liquid phase. • connect the number of particles, moles, mass, and volume of substances to one another, both qualitatively and quantitatively. • design and/or interpret the results of a separation experiment (filtration, paper chromatography, column chromatography, or distillation) in terms of the relative strength of interactions among and between the components. • use data from mass spectrometry to identify the elements and the masses of individual atoms of a specific element.

Assessments:	• Summative Assessment, Lab Reports
Teacher Resources:	Flinn Scientific: Investigation 7: Green Chemistry Analysis of a Mixture, How many atoms thick is a sheet of Al foil?, POGIL: Classification of Matter, POGIL: Average Atomic Mass, POGIL: Fundamentals of Experimental Design, POGIL: Organizing Data, Brown & Lemay: Chemistry: The Central Science: Chapters 1 + 2 Relevant podcasts

Unit Title	Stoichiometry and Reactions in Solution	Length of Unit	4 weeks

Inquiry Questions **(Engaging & Debatable)**	• How do we know if a sample is pure? • How can we test a solution through chemical reactions to determine the amount of a material present in a mixture? • Why don't all single and double replacement reactions occur?
Standards*	**Big Ideas**: 1 and 3 **Learning Objectives:** 1.4, 1.18, 1.19, 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.8, 3.10
Unit Strands & Concepts	• Calculating formula weights, calculating the empirical formula of a compound, • Simple patterns of chemical reactivity, • Quantitative information from balanced equations, limiting reactants, properties of aqueous solutions, predicting the products of precipitation reactions, acid/base reactions, oxidation-reduction reactions, calculating the concentration of solutions
Key Vocabulary	Molar mass, mole ratio, activity series, precipitation reaction, stoichiometry, empirical formula, solubility, products, reactants, coefficients, limiting reactant, percent yield

Unit Title	Stoichiometry and Reactions in Solution	Length of Unit	weeks

Critical Content: **My students will Know…**	**Key Skills:** **My students will be able to (Do)…**
• only some mixtures of compounds and elements result in a chemical reaction. • Molarity = Moles solute/Liters solution • the amount of reactant necessary or amount of product can be predicted using stoichiometry. • solubility of compounds is relations to solute and solvent attractions. • the activity series can be used to predict i a single replacement reaction will occur. • ionic compounds dissociate into ions when they dissolve • oxidation involves the loss of electrons; reduction involves the gaining of electrons • matter is neither created nor destroyed in a chemical or physical process.	• 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 the atomic molecular theory. • use stoichiometric calculations to predict the results of performing reaction in the laboratory and/or to analyze deviations from the expected results. • relate quantities (measured mass of substances, 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 and/or interpret data from an experiment that uses gravimetric analysis to determine the concentration of an analyte in a solution. • predict the products and states of matter of a chemical reaction. • draw and/or interpret representations of solutions that show the interactions between the solute and solvent. • create or interpret representations that link the concept of molarity with particle views of solutions • 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

Assessments:	• Summative Assessment, Lab Reports

Teacher Resources:	Flinn Scientific: Investigation 3: Gravimetric Analysis of Calcium and Hard Water Flinn Scientific: Investigation 1: Analysis of Food Dye in Beverages, Flinn Scientific: Investigation 2: % Cu in Brass, Chem Olympiad 2008: Identify 7 Unknown Solutions Using Solubility Rules, POGIL: Solubility Rules and Net Ionic Equations, POGIL: Limiting and Excess Reactants, Solubility curve activity, Brown & Lemay: Chemistry: The Central Science: Chapters 3 + 4 Relevant podcasts:

Unit Title	**Chemical Energy and Thermochemistry**	**Length of Unit**	3 weeks

Inquiry Questions **(Engaging & Debatable)**	• How do we get energy out of chemical reactions? • How is energy related to phase changes and interparticle interactions?
Standards*	**Big Ideas:** 3 and 5 **Learning Objectives:** 3.11, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8
Unit Strands & Concepts	• The First Law of Thermodynamics, • Enthalpies of reaction or physical change, • Calorimetry
Key Vocabulary	enthalpy, endothermic, exothermic, heat of fusion, heat of vaporization, Hess's Law, heat of formation, calormietry, specific heat

Unit Title	Chemical Energy and Thermochemistry	Length of Unit	weeks

Critical Content: My students will Know…	Key Skills: My students will be able to (Do)…
• endothermic processes require energy; exothermic processes release energy. • the energy of the universe is constant, it only changes forms. • temperature does not change during a phase change because the added or released heat goes to breaking or forming intermolecular forces. • heat flows from warmer objects to colder objects. • energy is independent of the pathway it reached that state. • specific heat describes how much heat something can absorb before it changes temperature. • ΔH can be calculated using: ○ Hess's Law ○ $\Delta H = mC\Delta T$ ○ $\Delta H = mH_{fus}$ ○ $\Delta H = mH_{vap}$ ○ $\Delta H = \Sigma\Delta H_f^\circ$ products – $\Sigma\Delta H_f^\circ$ reactants ○ $\Delta H = \Sigma\ n\ \Delta H$ (bond enthalpies) reactants – $\Sigma\ m\ \Delta H$(bond enthalpies)	• relate the temperature of particles to their movement. • explain or make predictions about the transfer of thermal energy between systems. • use conservation of energy to relate the magnitude of the energy changes occurring in two or more interacting systems. • design and/or interpret the results of an experiment in which calorimetry is used to determine the change in enthalpy of a chemical process (heating/cooling, phase transition, or chemical reaction) at constant pressure. • use calculations and estimations to relate energy changes associated with heating/cooling substance to its specific heat capacity, enthalpy of fusion or enthalpy of vaporization. • draw qualitative and quantitative connections between the reaction enthalpy and the energies involved in the break and formation of chemical bonds.

Assessments:	• Summative Assessment, Lab Reporting
Teacher Resources:	POGIL: Calorimetry, Flinn Scientific: Investigation 12: Designing a Hand Warmer, Brown & Lemay: Chemistry: The Central Science: Chapter 5, Relevant podcasts:

Unit Title	Atomic Structure an Periodicity	Length of Unit	2 weeks

Inquiry Questions **(Engaging & Debatable)**	• Why do elements and compounds produce different colors when ignited? • How is an elements' properties related to its position on the periodic table? • How does modern experimental evidence like PES, ionization energy, and mass spectroscopy both support and show the limitations of the shell model of the atom?
Standards*	**Big Idea:** 1 **Learning Objectives:** 1.5, 1.6, 1.7, 1.8, 1.9, 1.10, 1.12
Unit Strands & Concepts	• Quantized energy and photons, • Quantum mechanics and atomic orbitals, representation of orbitals, • Electron configurations, correlation between electron configuration and the periodic table, • Effective nuclear charge, periodic trends for sizes of ions and atoms, ionization energy, and electronegativity, • Metallic vs. nonmetallic character of elements
Key Vocabulary	flame test, electron configuration, ionization energy, electronegativity, electron affinity, atomic orbital, wavelength, frequency, emission spectra, alkali metal, alkali earth metal, transition metal, halogen, noble gas

Unit Title	Atomic Structure an Periodicity	Length of Unit	2 weeks

Critical Content: **My students will Know…**	**Key Skills:** **My students will be able to (Do)…**
• the energy of light can be calculated using $E = hv$. • the wavelength and frequency of light can be calculated using $c = \lambda\nu$. • every element and compound produces characteristic light when ignited that can be used to identify that element or compound. • the rules that govern where electrons exist in an atom. (2 electrons per orbital; electrons fill orbitals lowest in energy first; electrons sharing the same orbital will have opposite spins; electrons will fill separate orbitals before pairing) • periodic trends are all a result of the attraction between the nucleus and valence electrons.	• predict physical and chemical properties of elements based on their position of the periodic table. • justify with evidence the arrangement of the periodic table and apply periodic properties to chemical reactivity. • 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 • use flame tests as a way of identifying elements.

Assessments:	• Teacher designed summative assessments, Lab reports
Teacher Resources:	Lab: What is Mystical Fire?, College Board Handout: Photoelectron Spectroscopy ChemActivity 6 – Atomic Size, ChemActivity 5 – Ionization Energy, ChemActivity 7 - Light Calculations and Electromagnetic Radiation, POGIL: Advanced Periodic Trend, Brown & Lemay: Chemistry: The Central Science: Chapters 6 + 7, Relevant podcasts: https://sites.google.com/a/ctreg14.org/mrs-yard-s-science-site/ap-chemistry/podcasts.

Unit Title	Bonding	Length of Unit	3-4 weeks

Inquiry Questions **(Engaging & Debatable)**	• How does electronegativity relate to bond type? • How do intermolecular forces relate to macroscopic properties? • What do ionic, metallic and covalent compounds look like on a microscopic level?
Standards*	**Big Idea**: 2 **Learning Objectives**: 2.1, 2.17, 2.18, 2.21, 2.22 - 2.32
Unit Strands & Concepts	• Lewis symbols and the octet rule, • Ionic bonding, covalent bonding, bond polarity and electronegativity, • Drawing Lewis structures, • Resonance structures, exceptions to the octet rule, strengths of covalent bonds, • Molecular shapes and bond angles, the VSEPR model, molecular shape and polarity, hybrid orbitals, classification of solids, structure of solids, metallic solids, metallic bonding, ionic solids, molecular solids, covalent network solids, separation of a mixture using chromatography
Key Vocabulary	Lewis dot structure, resonance, bond order, molecular orbital theory, intermolecular forces, polarity, chromatography, hybrid orbitals, sigma bonds, pi bond, lattice energy, the octet rule, formal charge

Unit Title	Bonding	Length of Unit	weeks

Critical Content: My students will Know...	Key Skills: My students will be able to (Do)...
• bonding electrons arrange themselves in 3D space to minimize repulsion between them. • electronegativity differences and average electronegativity values determine if bonds are nonpolar, polar, metallic or ionic. • the strength of ionic bonds is related to the size of the ions and their charge. • hybrid orbitals form sigma bonds; unhybridized orbitals for pi bonds. • chromatography separates a mixture based on that mixtures attraction to the mobile vs. stationary phases. • electrons are transferred to form ionic bonds; electrons and shared to form covalent bonds; electrons are shared in a "sea of electrons" to form metallic bonds. • most bonds form so that atoms will have 8 electrons in their valence shell. • when multiple Lewis dot structures can be drawn for a covalent compound, the most accurate model is the one that minimizes formal charge.	• 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. • use Lewis diagrams and VSEPR theory to predict the geometry of molecules, identify hybridization, and make predictions about polarity. • describe the relationships between the structural features of polar molecules and the forces of attraction between the particles. • explain how solutes can be separated by chromatography based on intermolecular interactions. • design and/or interpret the results of a separation experiment (filtration, paper chromatography, column chromatography, or distillation) in terms of the relative strength of interactions among and between the components. • use molecular orbital theory to predict the bonding in covalent compounds. • Compare the properties of metal alloys with their constituent elements to determine if an alloy has formed, identify the type of alloy formed, and explain the differences in • properties using particulate level reasoning.

Assessments:	• Summative Assessment, Lab Reports
Teacher Resources:	ChemActivity 26: The Bond Type Triangle, ChemActivity 24: Ionic Bonding, ChemActivity 25: Metallic Bonding Flinn Scientific: Investigation 6: Qualitative Analysis of Chemical Bonding, Flinn Scientific: Investigation 5: Separation of a Dye Mixture Using Chromatography Brown & Lemay: Chemistry: The Central Science: Chapters 8, 9 + 12 Relevant podcasts

Unit Title	**States of Matter and Intermolecular Forces**	**Length of Unit**	3-4 weeks

Inquiry Questions (Engaging & Debatable)	• Since gases cannot be easily studied with mass data, how else can we measure and study gas particles? • How can London Dispersion Forces be stronger than hydrogen bonding? • How can the properties of a liquid be altered?
Standards*	**Big Ideas**: 2 and 5 **Learning Objectives**: 2.4, 2.5, 2.7 - 16, 5.9, 5.10, 5.11
Unit Strands & Concepts	• Pressure, the gas laws, the ideal gas equation, applications of the ideal gas law, gas mixtures and partial pressure, the kinetic molecular theory of gases, • Deviations from ideal behavior, molecular comparison of solids, liquids and gases, properties of liquids, phase changes, • Relationship between temperature, pressure and volume in gases, types of intermolecular forces, strength of intermolecular forces
Key Vocabulary	London dispersion forces, dipole-dipole forces, ion-dipole forces, hydrogen bonding, colligative property

Unit Title	States of Matter and Intermolecular Forces	Length of Unit	3-4 weeks

Critical Content: My students will Know…	Key Skills: My students will be able to (Do)…
• the pressure of a gas can be changed by changing the volume of the container or by changing the temperature. • Pressure, volume, moles and temperature of a gas are related using the ideal gas law: PV = nRT. • the strength of London Dispersion forces increases with an increased number of electrons. • solutes lower the freezing point and raise the boiling point of solvents. • the total pressure of a mixture of gases equals the sum of the pressures that each would exert if it were present alone. • molecular motion is directly related to temperature. • molecular speed and molecular mass are indirectly related. • stronger intermolecular forces result in compounds with higher freezing points, higher boiling points, lower vapor pressures, higher viscosities and higher surface tensions. • phase changes are dependent upon both pressure and temperature.	• apply mathematical relationships or estimation to determine macroscopic variables for ideal gases. • apply mathematical relationships or estimation to determine macroscopic variables for ideal gases. • explain the trends in properties and/or predict 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. • explain the properties (phase, vapor pressure, viscosity, etc.) of small and large molecular compounds in terms of the strengths and types of intermolecular forces. • 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. • 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.

Assessments:	• Summative Assessment, Lab Reports
Teacher Resources:	POGIL - How does the strength of IMFs relate to physical properties? POGIL - Gas Variables ChemActivity 33 – The Ideal Gas Law ChemActivity 27 – Intermolecular Forces, Gas Law lab activity – Molar Mass of Volatile Liquids, Molar Mass by Freezing Point Depression Lab Activity Brown & Lemay: Chemistry: The Central Science: Chapters 10, 11, + 13 Phase diagram activity, Relevant podcasts

Unit Title	Rates of Chemical Reactions	Length of Unit	2-3 weeks

Inquiry Questions **(Engaging & Debatable)**	• How can experimental controls be used to regulate the rate at which a chemical reaction will proceed? • What are the industrial and environmental benefits of catalysts? • Why don't all reaction rates depend on concentration?
Standards*	**Big Idea**: 4 **Learning Objectives**: 4.1 - 4.9
Unit Strands & Concepts	• Factors that affect reaction rates, reaction rates, • Concentration and rate laws, • The change of concentration with time, temperature and rate, reaction mechanisms, catalysts
Key Vocabulary	rate law, kinetics, reaction order, rate law constant, rate determining step, catalyst, activation energy, reaction coordinate diagram, activated complex, Maxwell-Boltzmann distribution, elementary step

Unit Title	Rates of Chemical Reactions	Length of Unit	2-3 weeks

Critical Content: **My students will Know…**	**Key Skills:** **My students will be able to (Do)…**
• molecules must collide with the correct orientation and with enough energy to cause bond breakage and formation. • increased temperature, decreased particle size, increased concentration and catalysts can speed up chemical reactions. • the rates of various components of a chemical reaction are dependent upon their coefficients in the balanced equation. • rate laws show the relationship between the reaction rate and concentrations of the reactants. • concentrations of reactants in a first order process can be calculated using: ln [A]t − ln [A]0 = − kt • concentrations of reactants in a second order process can be calculated using: 1/[A]t – 1/[A]0 = kt • half life is a first order process and can be calculated using: $t_{1/2}$ = .693/k. • reaction mechanisms describe how a reaction occurs.	• design and/or interpret the results of an experiment regarding the factors (i.e., • temperature, concentration, surface area) that may influence the rate of a reaction. • analyze concentration vs. time data to determine the rate law for a zeroth-, first-, or second-order reaction. • connect the half-life of a reaction to the rate constant of a first-order reaction and justify the use of this relation in terms of the reaction being a first-order reaction. • explain the difference between collisions that convert reactants to products and those that do not in terms of energy distributions and molecular orientation. • evaluate alternative explanations, as expressed by reaction mechanisms, to determine which are consistent with data regarding the overall rate of a reaction, an • 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.

Assessments:	• Summative Assessment, Lab Reports
Teacher Resources:	Flinn Scientific: Investigation 10: Determining the Rate of Decomposition of $CaCO_3$ Flinn Scientific: Investigation 11: Kinetics of Crystal Violet Fading Factors that Affect Reaction Rates PHeT Online Simulation Mechanisms of a Chemical Reaction Online Simulation POGIL: Collision Theory Brown Lemay: Chemistry: The Central Science: Chapter 14 Relevan podcasts:

Unit Title	**Equilibrium**	**Length of Unit**	6 weeks

Inquiry Questions **(Engaging & Debatable)**	• How do reactions respond to disturbances to the equilibrium mixture? • How is equilibrium established? • What does an equilibrium constant reveal about an equilibrium mixture?
Standards*	**Big Idea:** 5 and 6 **Learning Objectives**: 2.2, 3.7, 5.16, 6.1 - 6.25,
Unit Strands & Concepts	• The concept of equilibrium, the equilibrium constant, • Understand and working with equilibrium constants, calculating equilibrium constants, • Applications of equilibrium constants, • Le Chatelier's Principle, Bronsted-Lowry acids and bases, • The autoionization of water, the pH scale, strong acids and bases, weak acids, weak bases, relationship between Ka and Kb, acid-base properties of salt solutions, acid-base behavior and chemical structure, • The common-ion effect, buffered solutions, acid-base titrations, solubility equilibria, factors that affect solubility
Key Vocabulary	equilibrium, Le Chatelier's principle, acid, base, buffer, solubility product, equilibrium constant, reaction quotient, conjugate acid/base pair, titration, titration curve

Unit Title	Equilibrium	Length of Unit	weeks

Critical Content: My students will Know…	Key Skills: My students will be able to (Do)…
• chemical equilibrium occurs when a reaction and its reverse reaction proceed at the same rate. • once equilibrium is achieved, the amount of each reactant and product remains constant, even though the reaction continues. • the equilibrium constant can be calculated in terms of concentration using: $Kc = [C]^c[D]^d/[A]^a[B]^b$, where the exponents represent the coefficients from the balanced equation. • the equilibrium constant can be calculated in terms of pressure using: $Kp = (P_C^c)(P_D^d)/ (P_A^a)(P_B^b)$, where the exponents represent the coefficients from the balanced equation. • values are calculated to determine if a system is at equilibrium and which direction it will shift it is not at equilibrium. • if K is greater than 1, products predominate at equilibrium; if K is less than 1, reactants predominate at equilibrium. • solids and liquids do not appear in equilibrium expressions. • i a system at equilibrium is disturbed by a change in temperature, pressure, or the concentration of one of the components, the system will shift its equilibrium position	• given a set of experimental observations regarding physical, chemical, 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 set of initial conditions (concentrations or partial pressures) and the equilibrium constant, K, use the tendency of Q to approach K to predict and justify the • prediction as to whether the reaction will proceed toward products or reactants as equilibrium is approached. • given data (tabular, graphical, etc.) from which the state of a system at equilibrium can be obtained, calculate the equilibrium constant, K. • connect kinetics to equilibrium by using reasoning about equilibrium, such as LeChatelier's principle, to infer the relative rates of the forward and reverse reactions. • use LeChatelier's principle to predict the direction of the shift resulting from various possible stresses on a system at chemical equilibrium. • Use LeChatelier's principle to design a set of conditions that will optimize a desired outcome, such as product yield. • connect LeChatelier's principle to the comparison of Q to K by explaining the effects of the stress on Q and K. • identify compounds as Brønsted-Lowry acids, bases, and/or conjugate acid-base pairs, using proton-transfer reactions to justify the identification.

so as to counteract the effect of the disturbance.

- strong acids/bases completely dissociate in water; weak acids/bases only partially dissociate.
- the seven strong acids are HCl, HBr, HI, HNO_3 H_2SO_4 $HClO_3$ and $HClO_4$.
- strong bases are alkali metal hydroxides and heavier alkali earth hydroxides.
- the equilibria of weak acids is described using:
- $K_a = [H^+][A^-]/[HA]$
- the equilibria of weak bases is described using:
- K_b $[HB][OH^-]/[B^-]$
- the pH of salts can be predicted using the following: the anion that is a conjugate base of a strong base is neutral; the cation that is the conjugate acid of a strong acid is neutral; the anion that is the conjugate base of a weak base is basic; the cation that is the conjugate acid of a weak acid is acid; conjugates of weak acids and bases are dependent upon the K_a and K_b values.
- the more polar the H-X bond and/or the weaker the H-X bond, the more acidic the compound.
- buffers are mixtures of weak acids and their conjugate bases or weak bases and their conjugate acids.
- buffer resist change in pH.
- the shape, initial pH, and pH at the equivalence point are dependent upon the strength of the acid and base that were mixed.
- the pH at the half equivalence point of a titration curve equals the pKa or pKb of the reacted acid or base.
- K_{sp} values indicate the solubility of ionic compounds.

- reason about the distinction between strong and weak acid 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 base needed to reach the equivalence point in a titration.
- 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.
- explain the relative strengths of acids and bases based on molecular structure, interparticle forces, and solution equilibrium.
- for a reversible reaction that has a large or small K, determine which chemical species will have very large versus very small concentrations at equilibrium.
- 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.
- 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.
- 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.
- Predict the solubility of a salt, or rank the solubility of salts, given the relevant
- Ksp values.
- 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.

Assessments:	• Summative Assessment, Lab Reports
Teacher Resources:	Lab Investigation: Understanding Le Chateleir's Principle Lab Investigation: Determining an Equilibrium Constant Lab Investigation: Determining the Ka of a Weak Acid Inquiry Activity: Reaction Quotient Flinn Scientific: Investigation 14: Acid/Base Titrations ChemActivity 43: Acid Strength, ChemActivity 44: Weak Acid/Base Dissociation, ChemActivity 45: pH POGIL: Equilibrium,POGIL: Acids and Bases, POGIL: Strong vs. Weak Acids Online Simulation: Equilirium , Online Simultaion: Le Chateliers Principle Acid/Base Online Simulation Lab Investigation: Introduction to Buffers: Is it or is it not? That is the Question Flinn Scientific: Investigation 15: Buffers in Household Products Flinn Scientific: Investigation 16: Properties of Buffered Solutions Brown Lemay: Chemistry: The Central Science: Chapters 15-17, Relevan podcasts

Unit Title	Entropy and Free Energy	Length of Unit	2 weeks

Inquiry Questions **(Engaging & Debatable)**	• What are the driving forces of chemical reactions? • How can a non-spontaneous process be forced to occur? • How can a spontaneous process be prevented?
Standards*	**Big Ideas:** 3 and 5 **Learning Objectives:** 3.9, 3.12, 3.13, 5.12, 5.13, 5.14, 5.15, 5,17, 5,18
Unit Strands & Concepts	• Spontaneous processes, • Entropy and the second law of thermodynamics, • Molecular interpretation of entropy, • Entropy change in chemical reactions, • Gibbs free energy, free energy and temperature, • Free energy and the equilibrium constant
Key Vocabulary	Gibbs free energy, entropy, enthalpy, spontaneous process, non-spontaneous process

Unit Title	Entropy and Free Energy	Length of Unit	2 weeks

Critical Content: My students will Know...	Key Skills: My students will be able to (Do)...
• spontaneous processes occur without outside intervention. • processes that are spontaneous in one direction are non-spontaneous in the opposite direction. • spontaneity can be temperature dependent. • entropy is the measure of the disorder of a system. • Gibbs free energy is released during a spontaneous process; Gibbs free energy is required for a non-spontaneous process. • Gibbs free energy can be calculated using: ○ $\Delta G° = \Delta H° - T\Delta S°$. • spontaneous processes have equilibrium constants greater than 1; non-spontaneous processes have equilibrium constants less than 1. • Gibbs free energy is related to the equilibrium constant using the following equation: $\Delta G° = -RT\ln K$	• predict whether or not a physical or chemical process is thermodynamically favored by determination of (either quantitatively or qualitatively) the signs of both $\Delta H°$ • and $\Delta S°$ and calculation or estimation of $\Delta G°$ when needed. • determine whether a chemical or physical process is thermodynamically favorable by calculating the change in standard Gibbs free energy. • explain why a thermodynamically favored chemical reaction may not produce large amounts of product (based on consideration of both initial conditions and kinetic effects), or why a thermodynamically unfavored chemical reaction can produce large amounts of product for certain sets of initial conditions. • relate the sign of Gibbs free energy to the equilibrium constant.

Assessments:	• Summative Assessment, Lab Reports
Teacher Resources:	Flinn Scientific: Investigation 8: Analysis of H_2O_2, Investigation of the thermodynamic favorability of extracting metal ores Brown Lemay: Chemistry: The Central Science: Chapter 19, Relevant podcasts

Unit Title	Electrochemistry	Length of Unit	2 weeks

Inquiry Questions **(Engaging & Debatable)**	• What drives redox reactions and how are they used in batteries? • How do rechargeable batteries work?
Standards*	**Big Ideas:** 3 and 5 **Learning Objectives**: 3.9, 3.12, 3.13, 5.12, 5.13, 5.14, 5.15, 5,17, 5,18
Unit Strands & Concepts	• Oxidation and reduction reactions, • Voltaic cells, cell potential under standard conditions, • Free energy and redox reactions, • Cell potential under nonstandard conditions, • Electrolysis, voltage and the equilibrium constant
Key Vocabulary	activity series, oxidation, reduction, voltage, cell potential, electrolysis, anode, cathode, reducing agent, oxidizing agent, concentration cell

Unit Title	Electrochemistry	Length of Unit	weeks

Critical Content: My students will Know…	Key Skills: My students will be able to (Do)…
• a species is oxidized when it loses electrons; a species is reduced when it gains electrons. • the species that is reduced is the oxidizing agent; the species that is oxidized is the reducing agent. • reduction happens at the cathode of a voltaic cell; oxidation happens at the anode of a voltaic cell. • electrons are transferred from the anode to the cathode. • the voltage of a battery can be calculated using: $E_{cell} = E_{red}(\text{cathode}) - E_{red}(\text{anode})$ • electrons are spontaneously transferred in a voltaic cell and result in a positive voltage; electron transfer is forced to occur in an electrolytic cell and result in a negative voltage. • Gibbs free energy can be calculated for any cell using: $\Delta G = -nFE$. • a concentration cell can create voltage when the voltage of the solution in the cathode is higher than the concentration of the same solution in the anode.	• analyze data regarding galvanic or electrolytic cells to identify properties of the underlying redox reactions. • identify redox reactions and justify the identification in terms of electron transfer. • make qualitative or quantitative predictions about galvanic or electrolytic reactions based on half-cell reactions and potentials and/or Faraday's Laws. • 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. • predict the spontaneous direction of electron transfer given a standard reduction potential table.

Assessments:	• Summative Assessment, Lab Reports
Teacher Resources:	POGIL: Batteries, Experiment 10-2: Which Metal is Appropriate for Food + Beverage Storage?, Experiment 11-1: Which Metal Provides the Best Voltage? Brown Lemay: Chemistry: The Central Science: Chapter 20 Relevan podcasts