AP CHEMISTRY

UNIT 1: Atomic Structure and Properties

ESSENTIAL QUESTIONS	BIG IDEAS
Why are eggs sold in a dozen? How can the same element be used in nuclear fuel rods and fake diamonds?	• Students understand that the mole allows different units to be compared. • Students understand that formulas identify substances by their unique combination of atoms. • Students understand that atoms and molecules can be identified by their electron distribution and energy. • Students understand that the periodic table shows patterns in electronic structure and trends in atomic properties.

GUIDING QUESTIONS

AP Chemistry course and exam description

Content

- How do you calculate quantities of a substance or its relative number of particles using dimensional analysis and the mole concept?
- How do you explain the quantitative relationship between the mass spectrum of an element and the masses of the element's isotopes?
- How do you explain the quantitative relationship between the elemental composition by mass and the empirical formula of a pure substance?
- How do you explain the quantitative relationship between the elemental composition by mass and the composition of substances in a mixture?
- How do you represent the electron configuration of an element or ions of an element using the Aufbau principle?
- How do you explain the relationship between the photoelectron spectrum of an atom or ion and electron configuration?
- How do you explain the relationship between trends in atomic properties of elements and electronic structure and periodicity?
- How do you explain how the periodic table shows patterns in electronic structure and trends in atomic properties?

Process

- How do you identify an appropriate theory, definition, or mathematical relationship to solve a problem?
- How do you identify information presented graphically to solve a problem?
- How do you identify a testable scientific question based on an observation, data, or a model.
- How do you identify quantities needed to solve a problem from given information (e.g., text, mathematical expressions, graphs or tables)?

- How do you describe the components of and quantitative information from models and representations that illustrate particulate-level properties?
- How do you explain whether a model is consistent with chemical theories?
- How do you explain chemical properties or phenomena using given chemical theories, models and representations?
- How do you explain the connection between particulate-level and macroscopic properties of a substance using models and representations?

Reflective

- Why do we wear a lead apron when we get an x-ray?
- If you were Mendeleev, how would you organize the elements?
- Think about each family of the periodic table, do you agree with the name? Why or why not?

FOCUS STANDARDS

- Next Generation Science Standards Overview linked here.
    - Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms. HS-PS1-1

UNIT 2: Molecular and Ionic Compound Structures

ESSENTIAL QUESTIONS	BIG IDEAS
How has the discovery of DNA changed the world? How are molecular compounds arranged?	• Students understand that atoms or ions bond due to interactions between them, forming compounds. • Students understand that molecular compounds are arranged based on Lewis structures & VSEPR theory.

GUIDING QUESTIONS

AP Chemistry course and exam description

Content

- How do you explain the relationship between the type of bonding and the properties of the elements participating in the bond?
- How do you represent the relationship between potential energy and distance between atoms, based on factors that influence the interaction strength?
- How do you represent an ionic solid with a particulate model that is consistent with Coulomb's law and the properties of the constituent ions?
- How do you represent a metallic solid and/or alloy using a model to show essential characteristics of the structure and interactions present in the substance?
- How do you represent a molecule or ion using a Lewis diagram?
- How do you represent a molecule with a Lewis diagram that accounts for resonance between equivalent structures or that uses formal charge to select between nonequivalent structures?
- How do you represent a molecule with a Lewis diagram that accounts for resonance between equivalent structures or that uses formal charge to select between nonequivalent structures?

Process

- How do you represent chemical phenomena using appropriate graphing techniques, including scale and units?
- How do you represent chemical substances or phenomena with appropriate diagrams or models (e.g. electron configuration)?
- How do you explain the connection between particulate and macroscopic properties using models and representations?
- How do you make a scientific claim?
- How do you support a claim with evidence from scientific data?
- How do you support a claim with evidence from representations or models at the particulate level, such as the structure of atoms and/or molecules?

Reflective

- How do the bonds in an item you can't live without relate to its importance?
- How do manufacturers choose the material they use for new products?
- How would our world be different if electrons were positively charged?

- Which is more important: metallic, ionic, or covalent bonds?

FOCUS STANDARDS

- Next Generation Science Standards Overview linked here.
    - Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties. HS-PS1-2.

UNIT 3: Intermolecular Forces and Properties

ESSENTIAL QUESTIONS	BIG IDEAS
How do interactions between particles influence mixtures? Why does the smell of perfume only last a short time? Why can you swim in water but you cannot walk through a wall? How are the properties of gases described? How can you determine the structure and concentration of a chemical species in a mixture?	• Students understand that intermolecular forces can explain the physical properties of a material. • Students understand that matter exists in three states: solid, liquid, and gas, and their differences are influenced by variances in spacing and motion of the molecules. • Students understand that gas properties are explained macroscopically—using the relationships among pressure, volume, temperature, moles, gas constant—and molecularly by the motion of the gas. • Students understand that interactions between intermolecular forces influence the solubility and separation of mixtures. • Students understand that spectroscopy can determine the structure and concentration in a mixture of a chemical species.

GUIDING QUESTIONS

AP Chemistry course and exam description

Content

- How do you explain the relationship between the chemical structures of molecules and the relative strength of their intermolecular forces when, 1) the molecules are of the same chemical species and 2) the molecules are of two different chemical species?
- How do you explain the relationship among the macroscopic properties of a substance, the particulate-level structure of the substance, and the interactions between these particles?
- How do you represent differences between solid, liquid and gas phases using a particulate-level model?
- How do you explain the relationship between the macroscopic properties of a sample of gas or mixture of gases using the ideal gas law?
- How do you explain the relationship between the motion of particles and macroscopic properties of gases, the KMT, a particulate model, or a graphical representation?
- How do you explain the relationship among non-ideal behaviors of gases, interparticle forces and/or volume?
- How do you calculate the number of solute particles, volume, or molarity of solutions?
- How do you use particulate models for mixtures and represent the interactions between components and their concentrations?
- How can you separate the components of a liquid solution that cannot be separated by filtration by using processes that take advantage of differences in the IMFs?
- How do you explain the relationship between the solubility of ionic and molecular compounds in aqueous and non-aqueous solvents, and

the IMFs between particles?

Process

- How do you explain the degree to which a model or representation describes the connection between particulate-level properties and macroscopic properties?
- How do you explain the connection between particulate- level and macroscopic properties of a substance using models and representations?
- How do you represent visually the relationship between the structures and interactions across multiple levels or scales (e.g., particulate to macroscopic)?
- How do you explain the relationship between variables within an equation when one variable changes?
- How do you provide reasoning to justify a claim using connections between particulate and macroscopic scales or levels?
- How do you visually represent the relationship between the structures and interactions across multiple levels or scales (e.g., particulate to macroscopic)?
- How do you identify experimental procedures that are aligned to the question (which may include a sketch of a lab setup)?
- How do you explain the degree to which a model or representation describes the connection between particulate-level properties and macroscopic properties?

Reflective

- How do pollutants affect our water supply?
- Could your cell phone work without intermolecular forces?
- Why is it better to drink milk than water when eating spicy food?
- What could we have done to make this unit more “Green” (environmentally friendly)? This could be a question for any unit and forces students to think about what we did and why.
- What evidence do we have that particles have interactions?

FOCUS STANDARDS

- Next Generation Science Standards Overview linked here..
    - Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles. HS-PS1-3.

UNIT 4: Chemical Reactions

ESSENTIAL QUESTIONS

What makes fireworks explode?
Why is the mass of a raw egg different from a boiled egg?
What are the processes related to changes in a substance?

BIG IDEAS

- Students understand that a substance that changes its properties, or that changes into a different substance, can be represented by chemical equations.
- Students understand that when a substance changes into a new substance, or when its properties change, no mass is lost or gained.
- Students understand that a substance can change into another substance through different processes, and the change itself can be classified by the sort of processes that produced it.

GUIDING QUESTIONS

AP Chemistry course and exam description

Content

- How do you identify evidence of chemical and physical changes in matter?
- How do you represent changes in matter with a balanced chemical or net ionic equation?
- How do you represent a given chemical reaction or physical process with a consistent particulate model?
- How do you explain the relationship between macroscopic characteristics and bond interactions for chemical and physical processes?
- How do you explain changes in the amounts of reactants and products based on the balanced reaction equation for a chemical process?
- How do you identify the equivalence point in a titration based on the amounts of the titrant and analyte, assuming the titration reaction goes to completion?
- How do you identify a reaction as acid- base, oxidation-reduction, or precipitation?
- How do you identify species as Brønsted- Lowry acids, bases, and/or conjugate acid-base pairs, based on proton-transfer involving those species?
- How do you represent a balanced redox reaction equation using half-reactions?

Process

- How do you formulate a hypothesis or predict the results of an experiment?
- How do you determine a balanced chemical equation for a given chemical phenomena?
- How do you represent chemical substances or phenomena with appropriate diagrams or models (e.g., electron configuration)?
- How do you represent chemical phenomena using appropriate graphing techniques, including correct scale and units?
- How do you describe the components of and quantitative information from models and representations that illustrate both particulate- level and macroscopic-level properties?

Reflective

- What chemical processes allow our body to function?

- Could using too much fertilizer in the midwest be the reason that fish are dying in the ocean?
- Why do chemists use the unit “mole”?
- How would a business use the concept of stoichiometric relationships/percent yield when creating a product?

FOCUS STANDARDS

- Next Generation Science Standards Overview linked here.
    - Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties. HS-PS1-2.
    - Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction. HS-PS1-7.

UNIT 5: Kinetics

ESSENTIAL QUESTIONS	BIG IDEAS
Why are some reactions faster than other reactions? How long will a marble statue last? How can a sports drink cure a headache? Why does bread rise?	• Students understand that some reactions happen quickly, while others happen more slowly and depend on reactant concentrations and temperature. • Students understand that there is a relationship between the speed of a reaction and the collision frequency of particle collisions. • Students understand that many chemical reactions occur through a series of elementary reactions. These elementary reactions when combined form a chemical equation. • Students understand that the speed at which a reaction occurs can be influenced by a catalyst.

GUIDING QUESTIONS

AP Chemistry course and exam description

Content

- How do you explain the relationship between the rate of a chemical reaction and experimental parameters?
- How do you represent experimental data with a consistent rate law expression?
- How do you identify the rate law expression of a chemical reaction using data that show how the concentrations of reaction species change over time?
- How do you represent an elementary reaction as a rate law expression using stoichiometry?
- How do you explain the relationship between the rate of an elementary reaction and the frequency, energy, and orientation of molecular collisions?
- How do you represent the activation energy and overall energy change in an elementary reaction using a reaction energy profile?
- How do you identify the components of a reaction mechanism?
- How do you identify the rate law for a reaction from a mechanism in which the first step is rate limiting?
- How do you identify the rate law for a reaction from a mechanism in which the first step is not rate limiting?
- How do you represent the activation energy and overall energy change in a multistep reaction with a reaction energy profile?
- How do you explain the relationship between the effect of a catalyst on a reaction and changes in the reaction mechanism?

Process

- How do you provide reasoning to justify a claim using connections between particulate and macroscopic scales or levels?
- How do you explain the relationship between variables within an equation when one variable changes?
- How do you identify an appropriate theory, definition, or mathematical relationship to solve a problem?

- How do you determine a balanced chemical equation for a given chemical phenomena?
- How do you represent chemical substances or phenomena with appropriate diagrams or models (e.g., electron configuration)?
- How do you describe the components of and quantitative information from models and representations that illustrate both particulate- level and macroscopic-level properties?

Reflective

- How can the speed of a reaction be manipulated in our everyday life?

FOCUS STANDARDS

- Next Generation Science Standards Overview linked here.
    - Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs. HS-PS1-5.

UNIT 6: Thermodynamics

ESSENTIAL QUESTIONS	BIG IDEAS
Why is energy released when water becomes an ice cube? How are chemical transformations that require bonds to break and form influenced by energy?	• Students understand that changes in a substance's properties or change into a different substance requires an exchange of energy. • Students understand that the energy exchanged in a chemical transformation is required to break and form bonds.

GUIDING QUESTIONS

AP Chemistry course and exam description

Content

- How do you explain the relationship between experimental observations and energy changes associated with a chemical or physical transformation?
- How do you represent a chemical or physical transformation with an energy diagram?
- How do you explain the relationship between the transfer of thermal energy and molecular collisions?
- How do you calculate the heat (q) absorbed or released by a system undergoing heating/ cooling based on the amount of the substance, the heat capacity, and the change in temperature?
- How do you explain changes in the heat (q) absorbed or released by a system undergoing a phase transition based on the amount of the substance in moles and the molar enthalpy of the phase transition?
- How do you calculate the heat (q) absorbed or released by a system undergoing a chemical reaction in relationship to the amount of the reacting substance in moles and the molar enthalpy of reaction?
- How do you calculate the enthalpy change of a reaction based on the average bond energies of bonds broken and formed in the reaction?
- How do you calculate the enthalpy change for a chemical or physical process based on the standard enthalpies of formation?
- How do you represent a chemical or physical process as a sequence of steps?

Process

- How do you provide reasoning to justify a claim using chemical principles or laws, or using mathematical justification?
- How do you represent chemical phenomena using appropriate graphing techniques, including correct scale and units?
- How do you provide reasoning to justify a claim using connections between particulate and macroscopic scales or levels?
- How do you make observations or collect data from representations of laboratory setups or results, while attending to precision where appropriate?
- How do you describe the components of and quantitative information from models and representations that illustrate both particulate- level and macroscopic-level properties?
- How do you explain the connection between particulate- level and macroscopic properties of a substance using models and representation?
- How do you calculate, estimate, or predict an unknown quantity from known quantities by selecting and following a logical computational pathway and attending to precision (e.g., performing dimensional analysis and attending to significant figures)?
- How do you identify quantities needed to solve a problem from given information (e.g., text, mathematical expressions, graphs, or tables)?

Reflective

- Does the food you eat provide the right amount of energy for your day?
- How does natural gas provide heat for your home?

FOCUS STANDARDS

- Next Generation Science Standards Overview linked here.
    - Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy. HS-PS1-4.
    - Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, sultural, and environmental impacts. HS-ETS1-3.

UNIT 7: Equilibrium

ESSENTIAL QUESTIONS	BIG IDEAS
Why is a waterfall considered a spontaneous reaction? How can reactions occur in more than one direction? How is caffeine removed from coffee? Why is food stored in a refrigerator?	• Students understand that some reactions can occur in both forward and reverse directions, sometimes proceeding in each direction simultaneously. • Students understand that a system at equilibrium depends on the relationships between concentrations, partial pressures of chemical species, and equilibrium constant *K*. • Students understand that systems at equilibrium respond to external stresses to offset the effect of the stress. • Students understand that the dissolution of a salt is a reversible process that can be influenced by environmental factors such as pH or other dissolved ions.

GUIDING QUESTIONS

AP Chemistry course and exam description

Content

- How do you explain the relationship between the occurrence of a reversible chemical or physical process, and the establishment of equilibrium, to experimental observations?
- How do you explain the relationship between the direction in which a reversible reaction proceeds and the relative rates of the forward and reverse reactions?
- How do you represent the reaction quotient *Qc* or *Qp*, for a reversible reaction, and the corresponding equilibrium expressions *Kc* = *Qc* or *Kp* = *Qp*?
- How do you calculate *Kc* or *Kp* based on experimental observations of concentrations or pressures at equilibrium?
- How do you explain the relationship between very large or very small values of *K* and the relative concentrations of chemical species at equilibrium?
- How do you represent a multistep process with an overall equilibrium expression, using the constituent *K* expressions for each individual reaction?
- How do you identify the concentrations or partial pressures of chemical species at equilibrium based on the initial conditions and the equilibrium constant?
- How do you represent a system undergoing a reversible reaction with a particulate model?
- How do you identify the response of a system at equilibrium to an external stress, using Le Chatelier's principle?
- How do you explain the relationships between *Q*, *K*, and the direction in which a reversible reaction will proceed to reach equilibrium?
- How do you calculate the solubility of a salt based on the value of *Ksp* for the salt?
- How do you identify the solubility of a salt, and/or the value of *Ksp* for the salt, based on the concentration of a common ion already present in solution?

- How do you identify the qualitative effect of changes in pH on the solubility of a salt?
- How do you explain the relationship between the solubility of a salt and changes in the enthalpy and entropy that occur in the dissolution process?

Process

- How do you provide reasoning to justify a claim using chemical principles or laws, or using mathematical justification?
- How do you explain the degree to which a model or representation describes the connection between particulate-level properties and macroscopic properties?
- How do you represent chemical phenomena using appropriate graphing techniques, including correct scale and units?
- How do you explain the relationship between variables within an equation when one variable changes?
- How do you identify quantities needed to solve a problem from given information (e.g., text, mathematical expressions, graphs, or tables)?
- How do you represent visually the relationship between the structures and interactions across multiple levels or scales (e.g., particulate to macroscopic)?
- How do you explain the connection between experimental results and chemical concepts, processes, or theories?
- How do you calculate, estimate, or predict an unknown quantity from known quantities by selecting and following a logical computational pathway and attending to precision (e.g., performing dimensional analysis and attending to significant figures)?

Reflective

- How can the direction of a reaction be manipulated in our everyday life?

FOCUS STANDARDS

- Next Generation Science Standards Overview linked here.
    - Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium. HS-PS1-6.

UNIT 8: Acids and Bases

ESSENTIAL QUESTIONS	BIG IDEAS
How are reactions involving acids and bases related to pH? How does your body maintain pH balance?	• Students understand that the chemistry of acids and bases involves reversible proton-transfer reactions, with equilibrium concentrations being related to the strength of the acids and bases involved. • Students understand that a buffered solution resists changes to its pH when small amounts of acid or base are added.

GUIDING QUESTIONS

AP Chemistry course and exam description

Content

- How do you calculate the values of pH and pOH, based on *Kw* and the concentration of all species present in a neutral solution of water?
- How do you calculate pH and pOH based on concentrations of all species in a solution of a strong acid or a strong base?
- How do you explain the relationship among pH, pOH, and concentrations of all species in a solution of a monoprotic weak acid or weak base?
- How do you explain the relationship among the concentrations of major species in a mixture of weak and strong acids and bases?
- How do you explain results from the titration of a mono- or polyprotic acid or base solution, in relation to the properties of the solution and its components?
- How do you explain the relationship between the strength of an acid or base and the structure of the molecule or ion?
- How do you explain the relationship between the predominant form of a weak acid or base in solution at a given pH and the p*Ka* of the conjugate acid or the p*Kb* of the conjugate base?
- How do you explain the relationship between the ability of a buffer to stabilize pH and the reactions that occur when an acid or a base is added to a buffered solution?
- How do you identify the pH of a buffer solution based on the identity and concentrations of the conjugate acid-base pair used to create the buffer?
- How do you explain the relationship between the buffer capacity of a solution and the relative concentrations of the conjugate acid and conjugate base components of the solution?

Process

- How do you identify an appropriate theory, definition, or mathematical relationship to solve a problem?
- How do you explain the relationship between variables within an equation when one variable changes?
- How do you calculate, estimate, or predict an unknown quantity from known quantities by selecting and following a logical computational pathway and attending to precision (e.g., performing dimensional analysis and attending to significant figures)?
- How do you identify information presented graphically to solve a problem?
- How do you support a claim with evidence from representations or models at the particulate level, such as the structure of atoms and/or molecules?
- How do you make observations or collect data from representations of laboratory setups or results, while attending to precision where

appropriate?
- How do you provide reasoning to justify a claim using chemical principles or laws, or using mathematical justification?
- How do you explain how potential sources of experimental error may affect the experimental results?

Reflective
- Why is acid rain a problem?
- How can titrations be used in the real world?
- Why do we take antacid tablets? How do they work?

FOCUS STANDARDS

- Next Generation Science Standards Overview linked here.
    - Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs. HS-PS1-5.
    - Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.* HS-PS1-6.

UNIT 9: Applications of Thermodynamics

ESSENTIAL QUESTIONS	BIG IDEAS
How does water flow uphill? How is the favorability of a chemical or physical transformation determined? How is electrical energy generated using chemical reactions?	• Students understand that some chemical or physical processes cannot occur without intervention. • Students understand that the relationship between ΔG° and K can be used to determine favorability of a chemical or physical transformation. • Students understand that electrical energy can be generated by chemical reactions. • Students understand that • • 10 pt. Proxima Nova font

GUIDING QUESTIONS

[AP Chemistry course and exam description]

Content

- How do you identify the sign and relative magnitude of the entropy change associated with chemical or physical processes?
- How do you calculate the entropy change for a chemical or physical process based on the absolute entropies of the species involved in the process?
- How do you explain whether a physical or chemical process is thermodynamically favored based on an evaluation of ΔG°?
- How do you explain, in terms of kinetics, why a thermodynamically favored reaction might not occur at a measurable rate?
- How do you explain whether a process is thermodynamically favored using the relationships between K, ΔG°, and T?
- How do you explain the relationship between external sources of energy or coupled reactions and their ability to drive thermodynamically unfavorable processes?
- How do you explain the relationship between the physical components of an electrochemical cell and the overall operational principles of the cell?
- How do you explain whether an electrochemical cell is thermodynamically favored, based on its standard cell potential and the constituent half-reactions within the cell?
- How do you explain the relationship between deviations from standard cell conditions and changes in the cell potential?
- How do you calculate the amount of charge flow based on changes in the amounts of reactants and products in an electrochemical cell?

Process

- How do you support a claim with evidence from representations or models at the particulate level, such as the structure of atoms and/or molecules?
- How do you calculate, estimate, or predict an unknown quantity from known quantities by selecting and following a logical computational pathway and attending to precision (e.g., performing dimensional analysis and attending to significant figures)?
- How do you provide reasoning to justify a claim using connections between particulate and macroscopic scales or levels?
- How do you provide reasoning to justify a claim using chemical principles or laws, or using mathematical justification?

- How do you explain the degree to which model or representation describes the connection between particulate-level properties and macroscopic properties?
- How do you explain how modifications to an experimental procedure will alter results?
- How do you identify an appropriate theory, definition, or mathematical relationship to solve a problem?

Reflective

- Why do you have to change batteries in your calculator? What does it mean when a battery is “dead”?
- How do rechargeable batteries work?

FOCUS STANDARDS

- Next Generation Science Standards Overview linked here.
    - Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms. HS-PS1-1
    - Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties. HS-PS1-2.