

AP Chemistry Standards and Benchmarks

Standard: Understands and applies the principles of Scientific Inquiry

Benchmark 1: Scientific Reasoning

Course Level Benchmarks	Vocabulary	Knowledge	Skills	Classroom Resources
A. Formulates and revises scientific explanations and models	<ul style="list-style-type: none"> scientific explanation scientific model data 	<ul style="list-style-type: none"> Knows scientific explanations and models are based on data. Know new data may lead to the modification of scientific explanations and models. 	<ul style="list-style-type: none"> Analyzes data with respect to scientific explanations and models. Adjusts scientific explanations and models based on data. 	
B. Understands how scientific knowledge changes with new evidence	<ul style="list-style-type: none"> scientific knowledge evidence influence ethics 	<ul style="list-style-type: none"> Knows examples of scientific knowledge that has changed when new evidence was presented. Knows that science is an ongoing process and is never finished. 	<ul style="list-style-type: none"> Describes how chemistry concepts have evolved with the discovery of new evidence Hypothesizes how current chemistry concepts and practices will influence future societies 	
C. Uses technology and mathematics to perform scientific investigations and communications	<ul style="list-style-type: none"> technology mathematics accuracy scientific investigations scientific communication spreadsheet and graphs 	<ul style="list-style-type: none"> Knows how technology can help scientific investigations and communications. Knows mathematical computations and formulas are essential to scientific investigations. 	<ul style="list-style-type: none"> Determines tools most appropriate to use given a particular situation Uses the necessary mathematics for a particular situation Calculates results with a given degree of accuracy Uses metric units and significant figures correctly Formulates graphic representation of data 	<u>Technology:</u> use of science to solve everyday problems
D. Demonstrates safe handling procedures	<ul style="list-style-type: none"> OSHA EPA MSDS Right to Know hazardous safety procedures 	<ul style="list-style-type: none"> Knows appropriate safety procedures for a given situation Knows where safety devices are located in the classroom Understands the process of waste disposal 	<ul style="list-style-type: none"> Follows required safety procedures Recognizes, reports, and corrects safety problems Follows waste disposal procedures 	

AP Chemistry Standards and Benchmarks

Standard: Understands and applies the basic concepts of Physical Science

Benchmark 1: Structure of Matter

Course Level Benchmarks	Vocabulary	Knowledge	Skills	Classroom Resources
A. Understands the atomic theory and structure	<ul style="list-style-type: none">• atomic theory• atomic mass• atomic number• mole• Avogadro's number• molar mass	<ul style="list-style-type: none">• Knows how protons, neutrons, and electrons are referenced in the periodic table• Knows the reasoning for the organization of the periodic table• Knows one mole always contains the same number of particles, no matter what the substance	<ul style="list-style-type: none">• Describes atomic structure, atomic numbers, and mass number• Calculates atomic weight from isotopic masses and abundances• Explains the concept of the mole• Uses molar mass in calculations	

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<p>B. Understands chemical bonding</p>	<ul style="list-style-type: none"> • chemical bond • molecular formula • condensed formulas • structural formula • molecular models • binding forces • ionic • covalent • metallic • hydrogen bonding • van der Waals • polarity • Lewis structures • valence bond • orbitals • sigma bonds • pi bonds • VSEPR • electronegativity • molecules • ions • isomerism • dipole moments 	<ul style="list-style-type: none"> • Understands the difference between elements, atoms, compounds, and molecules • Knows how to name compounds • Understands the difference between ionic and covalent bonds • Understands the properties of covalent bonds and their influence on molecular structure • Knows how to use molar mass in calculations • Understands what resonance means and knows how and when to use this means of representing bonding • Understands why some molecules are polar and others are nonpolar • Understands the differences between valence bond theory and molecular orbital theory • Understands the differences between bonding and antibonding molecular orbitals • Understands how molecules having double bonds can have isomeric forms 	<ul style="list-style-type: none"> • Interprets, predicts, and writes formulas for ionic and molecular compounds • Calculates percent composition for a compound • Derives formulas from experimental data • Uses VSEPR to predict the shapes of molecules and ions • Uses electronegativities to predict the charge distribution in molecules and ions to define polarity of bonds • Draws Lewis structures for molecular compounds and ions • Applies the octet rule and recognizes exceptions to the octet rule • Calculates formal charges for atoms in a molecule based on Lewis structures • Predicts the polarity of a molecule • Predicts trends in bond order, bond length, and bond dissociation • Identifies the hybridization of an atom in a molecule or ion • Writes the molecular orbital configuration for simple diatomic molecules • Distinguishes how sigma and pi bonds arise • Uses molecular orbital theory to explain the properties of O₂ and other diatomic molecules 	
<p>C. Understands nuclear chemistry</p>	<ul style="list-style-type: none"> • nuclear equations • half-lives • radioactivity 	<ul style="list-style-type: none"> • Understands rates of radioactive decay • Understands health and safety with respect to radioactivity 	<ul style="list-style-type: none"> • Identifies radioactive elements • Describes natural and artificial nuclear reactions 	

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Standard 2: Understands and applies the basic concepts of physical science				
Benchmark 2: States of Matter				
Course Level Benchmarks	Vocabulary	Knowledge	Skills	Classroom Resources
A. Understands gases	<ul style="list-style-type: none"> equation of state gas laws ideal gas partial pressures diffusion effusion 	<ul style="list-style-type: none"> Understands the basis of gas laws and how to use those laws (Boyle's law, Charles's law, Avogadro's hypothesis, Dalton's law) Understands kinetic-molecular theory as it applies to gases, especially the distribution of molecular speed Understands the phenomena of diffusion and effusion 	<ul style="list-style-type: none"> Applies the gas laws to stoichiometric calculations Recognizes why real gases do not behave like ideal gas laws 	
B. Understands Kinetic-molecular theory	<ul style="list-style-type: none"> Avogadro's hypothesis kinetic energy Ideal gas laws 		<ul style="list-style-type: none"> Applies the kinetic-molecular theory to the properties of matter 	

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<p>C. Understands liquids and solids</p>	<ul style="list-style-type: none">• liquid• solid• phase diagram• changes of state• critical points• triple points• structure of solids• lattice energies	<ul style="list-style-type: none">• Understands the importance of hydrogen bonding• Understands the properties of liquids• Understands the properties of solids• Understands the nature of phase diagrams• Recognizes the different points and regions of a phase diagram	<ul style="list-style-type: none">• Describes the various intermolecular forces found in liquids and solids• Tells when two molecules can interact through a dipole-dipole attraction and when hydrogen bonding may occur• Explains the processes of evaporation and condensation• Uses the enthalpy of vaporization in calculations• Defines the equilibrium vapor pressure of a liquid• Explains the relationship between the vapor pressure and boiling point of a liquid• Characterizes different types of solids: metallic, ionic, molecular, network, amorphous• Defines the enthalpy of fusion and uses it in calculations• Uses a phase diagram to evaluate the vapor pressure of a liquid and the relative densities of a liquid and a solid	
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D. Understands solutions	<ul style="list-style-type: none">• solution• solubility• concentration• Raoult's law• colligative properties• solutes• osmosis• molarity• mole fraction• weight percent• parts per million• precipitation reaction	<ul style="list-style-type: none">• Understands the nature of ionic substances dissolved in water• Recognizes common acids and bases and understands their behavior in aqueous solutions• Understands the solution process• Understands the colligative properties of solutions• Knows the factors that affect solutions	<ul style="list-style-type: none">• Categorizes acids and bases as strong or weak• Writes equations for reactions in aqueous solutions• Writes net ionic equations• Predicts the products of acid-base reactions• Predicts the solubility of ionic compounds in water• Calculates the concentration of a solute in a solution in units of moles per liter• Uses concentrations in calculations• Prepares a solution of a given molarity from the solute and a solvent or by dilution• Defines the terms solution, solvent, solute, and colligative properties• Describes the process of dissolving a solute in a solvent, including energy changes that may occur• Describes the effect of pressure and temperature on the solubility of solute	
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AP Chemistry Standards and Benchmarks

Standard 2: Understands and applies the basic concepts of physical science				
Benchmark 3: Reactions				
Course Level Benchmarks	Vocabulary	Knowledge	Skills	Classroom Resources
A. Understands reaction types	<ul style="list-style-type: none"> acid-base reactions Arrhenius Brønsted-Lowry Lewis amphoterism precipitation reactions oxidation-reduction reactions electrochemistry 	<ul style="list-style-type: none"> Knows oxidation numbers of elements represent the charge an atom Knows the influence of structure and bonding on acid-base reactions Knows the Brønsted-Lowry and Lewis theories of acids and bases 	<ul style="list-style-type: none"> Identifies oxidation-reduction reactions and the oxidizing and reducing agents Uses the Brønsted concept of acids and bases Writes balanced equations for monoprotic and polyprotic acids and bases in water Writes equilibrium constant expressions for weak acids and bases Calculates pK_a from K_a and understands how pK_a is correlated with acid strength Writes equations for acid-base reactions and decides whether they are product- or reactant-favored Uses the equilibrium constant to calculate the pH of a solution of a salt of weak acid or weak base Recognizes the type of acid-base reaction and describes its result Characterizes a compound as a Lewis base or Lewis acid 	

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<p>B. Understands stoichiometry</p>	<ul style="list-style-type: none"> • stoichiometry • net ionic equations • chemical systems • balancing equations • redox reactions • mass/volume relations • mole concept • empirical formulas • limiting reactants 	<ul style="list-style-type: none"> • Understands how a reaction can be depicted in an equation • Understands the information conveyed by a balanced reaction • Understands the principle of the law of conservation of matter • Understands the impact of a limiting reactant on a chemical equation • Explains the difference between actual yield, theoretical yield, and percent yield 	<ul style="list-style-type: none"> • Balances equations for chemical reactions • Performs stoichiometry calculations using balanced chemical equation • Calculates the theoretical and percent yields of a chemical reactions • Uses stoichiometry to analyze a mixture of compounds • Finds the empirical formula of an unknown compound using stoichiometry 	
<p>C. Understands equilibrium</p>	<ul style="list-style-type: none"> • dynamic equilibrium • Le Chatelier's principle • equilibrium constants • quantitative treatment • common ion effect • buffers • hydrolysis 	<ul style="list-style-type: none"> • Understands the nature and characteristics of chemical equilibria • Understands the significance of the equilibrium constant, K, and the reaction quotient Q • Understands how to use K in quantitative studies of chemical equilibria • Understands chemical reactions are reversible and equilibria are dynamic • Recognizes the concentration of solids, pure liquids, and solvents are not included in the equilibrium constant expression 	<ul style="list-style-type: none"> • Writes the reaction quotient, Q, for a chemical reaction • Uses the reaction quotient, Q, to decide whether a reaction is at equilibrium or if there will be a net conversion of reactants to products or reactants to reactants to attain equilibrium • Calculates an equilibrium constant given the reactant and product concentrations at equilibrium and vice versa • Predicts, using Le Chatelier's principle, the effect of a disturbance on an equilibrium on a chemical equilibrium 	

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<p>D. Understands kinetics</p>	<ul style="list-style-type: none">• kinetic• rate of reaction• reactant order• rate constants• reaction rate laws• energy of activation• catalysts• rate-determining step• reaction mechanism• collision theory	<ul style="list-style-type: none">• Understands rates of reactions and the conditions affecting rates• Understands collision theory of reaction rates and the role of activation energy	<ul style="list-style-type: none">• Describes the rate equation, rate constant, and reaction order from experimental data• Describes the factors that affect reaction rate• Uses the relationships between reactant concentration and time for zero-order, first-order, and second-order reactions• Applies graphical methods for determining reaction order and the rate constant• Relates the activation energy (E_a) to the rate of thermodynamics of a reaction• Uses collision theory to describe the reactant concentration on reaction rate• Describes the function of a catalyst and its effect on the activation energy and mechanism of a reaction• Describes the elementary steps of a mechanism• Defines the rate-determining step in a mechanism and identifies any reaction intermediates	
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<p>E. Understands thermodynamics</p>	<ul style="list-style-type: none"> • thermodynamics • state functions • enthalpy • heat of formation • heat of reaction • Hess's law • heats of vaporization • fusion • calorimetry • entropy • free energy 	<ul style="list-style-type: none"> • Understands heat trans associated with changes in temperature and changes of state • Understands the state functions enthalpy and internal energy • Knows the language of thermodynamics: the system and its surroundings; exothermic and endothermic • Understands the sign conventions of thermodynamics 	<ul style="list-style-type: none"> • Calculates energy changes in chemical reactions • Measures energy changes in chemical reactions • Applies Hess's law to find the enthalpy change for a reaction • Interprets energy level diagrams 	
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Descriptive Chemistry

These descriptive facts, including chemistry involved in environmental and societal issues, should not be isolated from the principles being studied but should be taught throughout the course to illustrate and illuminate the principles. The following areas should be covered:

- chemical reactivity and products of chemical reactions
- relationships in the periodic table: horizontal, vertical and diagonal (with examples from alkali metals, alkaline earth metals, halogens, the first series of transition elements)
- introduction to organic chemistry: hydrocarbons and functional groups (structure, nomenclature, chemical properties)
 - Classifies organic compounds based on formula and structure
 - Draws structures of common organic compounds
 - Understands the factors that contribute to the large numbers of organic compounds and the wide array of structures
 - Names simple compounds, including alkanes, alkenes, alkynes, and aromatic compounds
 - Identifies possible isomers for a given formula
 - Names and draws structures of carbonyl compounds – aldehydes, ketones, acids, esters, and amides
 - Recognizes the connection between the structures and properties of alcohols
 - Relates properties of polymers to their structures

Laboratory

The AP Chemistry Examination includes some questions based on experiences and skill student acquire in the laboratory:

- making observations of chemical reactions and substances
- recording data

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- calculating and interpreting results based on the quantitative data obtained
- communicating effectively the results of experimental work

Chemical Calculations

Attention should be given to significant figures, precision of measured values, and the use of logarithmic and exponential relationships.

Critical analysis of the reasonableness of results is to be encouraged:

- percentage composition
- empirical and molecular formulas from experimental data
- molar masses from gas density, freezing-point, and boiling-point measurements
- Gas laws, including the ideal gas law, Dalton's law, and Graham's law
- Stoichiometric relations using the concept of the mole, titration calculations
- Mole fractions; mole and molal solutions
- Faraday's law of electrolysis
- Equilibrium constants and their applications, including their use for simultaneous equilibria
- Standard electrode potentials and their use; Nernst equation
- Thermodynamic and thermochemical calculations
- Kinetics calculations