

Appendix: AP Chemistry Concepts at a Glance

Big Idea 1: 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.

<p>Enduring understanding 1.A: All matter is made of atoms. There are a limited number of types of atoms; these are the elements.</p>	<p>Essential knowledge 1.A.1: Molecules are composed of specific combinations of atoms; different molecules are composed of combinations of different elements and of combinations of the same elements in differing amounts and proportions.</p>
	<p>Essential knowledge 1.A.2: 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.</p>
	<p>Essential knowledge 1.A.3: The mole is the fundamental unit for counting numbers of particles on the macroscopic level and allows quantitative connections to be drawn between laboratory experiments, which occur at the macroscopic level, and chemical processes, which occur at the atomic level.</p>
<p>Enduring understanding 1.B: The atoms of each element have unique structures arising from interactions between electrons and nuclei.</p>	<p>Essential knowledge 1.B.1: 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.</p>
	<p>Essential knowledge 1.B.2: 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 energetics of the electrons in the atom can be understood by consideration of Coulomb's law.</p>
<p>Enduring understanding 1.C: Elements display periodicity in their properties when the elements are organized according to increasing atomic number. This periodicity can be explained by the regular variations that occur in the electronic structures of atoms. Periodicity is a useful principle for understanding properties and predicting trends in properties. Its modern-day uses range from examining the composition of materials to generating ideas for designing new materials.</p>	<p>Essential knowledge 1.C.1: Many properties of atoms exhibit periodic trends that are reflective of the periodicity of electronic structure.</p>
	<p>Essential knowledge 1.C.2: The currently accepted best model of the atom is based on the quantum mechanical model.</p>

<p>Enduring understanding 1.D: Atoms are so small that they are difficult to study directly; atomic models are constructed to explain experimental data on collections of atoms.</p>	<p>Essential knowledge 1.D.1: 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.</p>
	<p>Essential knowledge 1.D.2: 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.</p>
	<p>Essential knowledge 1.D.3: 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.</p>
<p>Enduring understanding 1.E: Atoms are conserved in physical and chemical processes.</p>	<p>Essential knowledge 1.E.1: Physical and chemical processes can be depicted symbolically; when this is done, the illustration must conserve all atoms of all types.</p>
	<p>Essential knowledge 1.E.2: 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.</p>

Big Idea 2: 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.

<p>Enduring understanding 2.A: Matter can be described by its physical properties. The physical properties of a substance generally depend on the spacing between the particles (atoms, molecules, ions) that make up the substance and the forces of attraction among them.</p>	<p>Essential knowledge 2.A.1: The different properties of solids and liquids can be explained by differences in their structures, both at the particulate level and in their supramolecular structures.</p>
	<p>Essential knowledge 2.A.2: The gaseous state can be effectively modeled with a mathematical equation relating various macroscopic properties. A gas has neither a definite volume nor a definite shape; because the effects of attractive forces are minimal, we usually assume that the particles move independently.</p>
	<p>Essential knowledge 2.A.3: Solutions are homogenous 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.</p>
<p>Enduring understanding 2.B: Forces of attraction between particles (including the noble gases and also different parts of some large molecules) are important in determining many macroscopic properties of a substance, including how the observable physical state changes with temperature.</p>	<p>Essential knowledge 2.B.1: London dispersion forces are attractive forces present between all atoms and molecules. London dispersion forces are often the strongest net intermolecular force between large molecules.</p>
	<p>Essential knowledge 2.B.2: 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, and F) are involved.</p>
	<p>Essential knowledge 2.B.3: Intermolecular forces play a key role in determining the properties of substances, including biological structures and interactions.</p>
<p>Enduring understanding 2.C: The strong electrostatic forces of attraction holding atoms together in a unit are called chemical bonds.</p>	<p>Essential knowledge 2.C.1: 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.</p>
	<p>Essential knowledge 2.C.2: Ionic bonding results from the net attraction between oppositely charged ions, closely packed together in a crystal lattice.</p>
	<p>Essential knowledge 2.C.3: Metallic bonding describes an array of positively charged metal cores surrounded by a sea of mobile valence electrons.</p>
	<p>Essential knowledge 2.C.4: The localized electron bonding model describes and predicts molecular geometry using Lewis diagrams and the VSEPR model.</p>

Enduring understanding 2.D: The type of bonding in the solid state can be deduced from the properties of the solid state.	Essential knowledge 2.D.1: Ionic solids have high melting points, are brittle, and conduct electricity only when molten or in solution.
	Essential knowledge 2.D.2: Metallic solids are good conductors of heat and electricity, have a wide range of melting points, and are shiny, malleable, ductile, and readily alloyed.
	Essential knowledge 2.D.3: Covalent network solids have properties that reflect their underlying 2-D or 3-D networks of covalent bonds. Covalent network solids generally have extremely high melting points and are hard.
	Essential knowledge 2.D.4: 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.

Big Idea 3: Changes in matter involve the rearrangement and/or reorganization of atoms and/or the transfer of electrons.

<p>Enduring understanding 3.A: Chemical changes are represented by a balanced chemical equation that identifies the ratios with which reactants react and products form.</p>	<p>Essential knowledge 3.A.1: A chemical change may be represented by a molecular, ionic, or net ionic equation.</p>
	<p>Essential knowledge 3.A.2: 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.</p>
<p>Enduring understanding 3.B: Chemical reactions can be classified by considering what the reactants are, what the products are, or how they change from one into the other. Classes of chemical reactions include synthesis, decomposition, acid-base, and oxidation-reduction reactions.</p>	<p>Essential knowledge 3.B.1: 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.</p>
	<p>Essential knowledge 3.B.2: In a neutralization reaction, protons are transferred from an acid to a base.</p>
	<p>Essential knowledge 3.B.3: 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.</p>
<p>Enduring understanding 3.C: Chemical and physical transformations may be observed in several ways and typically involve a change in energy.</p>	<p>Essential knowledge 3.C.1: Production of heat or light, formation of a gas, and formation of a precipitate and/or a color change are possible evidences that a chemical change has occurred.</p>
	<p>Essential knowledge 3.C.2: Net changes in energy for a chemical reaction can be endothermic or exothermic.</p>
	<p>Essential knowledge 3.C.3: Electrochemistry shows the interconversion between chemical and electrical energy in galvanic and electrolytic cells.</p>

Big Idea 4: Rates of chemical reactions are determined by details of the molecular collisions.

<p>Enduring understanding 4.A: Reaction rates that depend on temperature and other environmental factors are determined by measuring changes in concentrations of reactants or products over time.</p>	<p>Essential knowledge 4.A.1: The rate of a reaction is influenced by the concentration or pressure of reactants, the phase of the reactants and products, and environmental factors such as temperature and solvent.</p>
	<p>Essential knowledge 4.A.2: The rate law shows how the rate depends on reactant concentrations.</p>
	<p>Essential knowledge 4.A.3: The magnitude and temperature dependence of the rate of reaction is contained quantitatively in the rate constant.</p>
<p>Enduring understanding 4.B: Elementary reactions are mediated by collisions between molecules. Only collisions having sufficient energy and proper relative orientation of reactants lead to products.</p>	<p>Essential knowledge 4.B.1: Elementary reactions can be unimolecular or involve collisions between two or more molecules.</p>
	<p>Essential knowledge 4.B.2: 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.</p>
	<p>Essential knowledge 4.B.3: A successful collision can be viewed as following a reaction path with an associated energy profile.</p>
<p>Enduring understanding 4.C: Many reactions proceed via a series of elementary reactions.</p>	<p>Essential knowledge 4.C.1: The mechanism of a multistep reaction consists of a series of elementary reactions that add up to the overall reaction.</p>
	<p>Essential knowledge 4.C.2: In many reactions, the rate is set by the slowest elementary reaction, or rate-limiting step.</p>
	<p>Essential knowledge 4.C.3: Reaction intermediates, which are formed during the reaction but not present in the overall reaction, play an important role in multistep reactions.</p>
<p>Enduring understanding 4.D: Reaction rates may be increased by the presence of a catalyst.</p>	<p>Essential knowledge 4.D.1: Catalysts function by lowering the activation energy of an elementary step in a reaction mechanism, and by providing a new and faster reaction mechanism.</p>
	<p>Essential knowledge 4.D.2: Important classes in catalysis include acid-base catalysis, surface catalysis, and enzyme catalysis.</p>

Big Idea 5: The laws of thermodynamics describe the essential role of energy and explain and predict the direction of changes in matter.

<p>Enduring understanding 5.A: Two systems with different temperatures that are in thermal contact will exchange energy. The quantity of thermal energy transferred from one system to another is called heat.</p>	<p>Essential knowledge 5.A.1: Temperature is a measure of the average kinetic energy of atoms and molecules.</p>
	<p>Essential knowledge 5.A.2: The process of kinetic energy transfer at the particulate scale 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.</p>
<p>Enduring understanding 5.B: Energy is neither created nor destroyed, but only transformed from one form to another.</p>	<p>Essential knowledge 5.B.1: Energy is transferred between systems either through heat transfer or through one system doing work on the other system.</p>
	<p>Essential knowledge 5.B.2: 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.</p>
	<p>Essential knowledge 5.B.3: Chemical systems undergo three main processes that change their energy: heating/cooling, phase transitions, and chemical reactions.</p>
	<p>Essential knowledge 5.B.4: Calorimetry is an experimental technique that is used to determine the heat exchanged/transferred in a chemical system.</p>
<p>Enduring understanding 5.C: Breaking bonds requires energy, and making bonds releases energy.</p>	<p>Essential knowledge 5.C.1: Potential energy is associated with a particular geometric arrangement of atoms or ions and the electrostatic interactions between them.</p>
	<p>Essential knowledge 5.C.2: 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.</p>

<p>Enduring understanding 5.D: Electrostatic forces exist between molecules as well as between atoms or ions, and breaking the resultant intermolecular interactions requires energy.</p>	<p>Essential knowledge 5.D.1: Potential energy is associated with the interaction of molecules; as molecules draw near each other, they experience an attractive force.</p>
	<p>Essential knowledge 5.D.2: At the particulate scale, chemical processes can be distinguished from physical processes because chemical bonds can be distinguished from intermolecular interactions.</p>
	<p>Essential knowledge 5.D.3: Noncovalent and intermolecular interactions play important roles in many biological and polymer systems.</p>
<p>Enduring understanding 5.E: Chemical or physical processes are driven by a decrease in enthalpy or an increase in entropy, or both.</p>	<p>Essential knowledge 5.E.1: Entropy is a measure of the dispersal of matter and energy.</p>
	<p>Essential knowledge 5.E.2: Some physical or chemical processes involve <i>both</i> a decrease in the internal energy of the components ($\Delta H^\circ < 0$) under consideration <i>and</i> an increase in the entropy of those components ($\Delta S^\circ > 0$). These processes are necessarily “thermodynamically favored” ($\Delta G^\circ < 0$).</p>
	<p>Essential knowledge 5.E.3: If a chemical or physical process is not driven by <i>both</i> entropy and enthalpy changes, then the Gibbs free energy change can be used to determine whether the process is thermodynamically favored.</p>
	<p>Essential knowledge 5.E.4: External sources of energy can be used to drive change in cases where the Gibbs free energy change is positive.</p>
	<p>Essential knowledge 5.E.5: A thermodynamically favored process may not occur due to kinetic constraints (kinetic vs. thermodynamic control).</p>

Big Idea 6: Any bond or intermolecular attraction that can be formed can be broken. These two processes are in a dynamic competition, sensitive to initial conditions and external perturbations.

<p>Enduring understanding 6.A: Chemical equilibrium is a dynamic, reversible state in which rates of opposing processes are equal.</p>	<p>Essential knowledge 6.A.1: In many classes of reactions, it is important to consider both the forward and reverse reaction.</p>
	<p>Essential knowledge 6.A.2: 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.</p>
	<p>Essential knowledge 6.A.3: When a system is at equilibrium, all macroscopic variables, 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 $Q=K$.</p>
	<p>Essential knowledge 6.A.4: The magnitude of the equilibrium constant, K, can be used to determine whether the equilibrium lies toward the reactant side or product side.</p>
<p>Enduring understanding 6.B: Systems at equilibrium are responsive to external perturbations, with the response leading to a change in the composition of the system.</p>	<p>Essential knowledge 6.B.1: Systems at equilibrium respond to disturbances by partially countering the effect of the disturbance (Le Chatelier's principle).</p>
	<p>Essential knowledge 6.B.2: 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 bringing Q back into agreement with K, thereby establishing a new equilibrium state.</p>
<p>Enduring understanding 6.C: Chemical equilibrium plays an important role in acid-base chemistry and in solubility.</p>	<p>Essential knowledge 6.C.1: Chemical equilibrium reasoning can be used to describe the proton-transfer reactions of acid-base chemistry.</p>
	<p>Essential knowledge 6.C.2: The pH is an important characteristic of aqueous solutions that can be controlled with buffers. Comparing pH to pK_a allows one to determine the protonation state of a molecule with a labile proton.</p>
	<p>Essential knowledge 6.C.3: The solubility of a substance can be understood in terms of chemical equilibrium.</p>

Enduring understanding 6.D: The equilibrium constant is related to temperature and the difference in Gibbs free energy between reactants and products.

Essential knowledge 6.D.1: 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 $\Delta G^\circ > 0$) or very large (for $\Delta G^\circ < 0$). When ΔG° is comparable to the thermal energy (RT), the equilibrium constant is near 1.