Big Ideas

Big Ideas – ACS Exams Anchoring Concepts Content Map (ACCM)

Studies of past ACS Exams have shown that while individual tests vary somewhat in their content, overall the coverage of big ideas in chemistry is fairly broad when looked at with the lens of the ACCM. What is listed below are anchoring concepts or "big ideas" (in **bold**). These are followed by statements which provide more detail on how these big ideas are explained or included in the undergraduate curriculum. These are included in this guide as these big ideas apply to all levels of chemistry in the undergraduate program, and it can be useful to see how the specific chapter or content area you are studying fits into the bigger picture of your undergraduate program. Towards that end, at the beginning of each chapter in this guide, you are provided with the specific big idea covered in that chapter.

I. Atoms

A. Atoms have unique chemical identities based on the number of protons in the nucleus.
B. Electrons play the key role for atoms to bond with other atoms.
C. Atoms display a periodicity in their structures and observable phenomena that depend on that structure.
D. Most information about atoms is inferred from studies on collections of atoms often involving an interaction with electromagnetic radiation.
E. Macroscopic samples of matter contain so many atoms that they are counted in moles.
F. Atoms maintain their identity, except in nuclear reactions.
G. Ions arise when the number of electrons and protons are not equal, and can be formed from atoms.

II. Bonding

A. Because protons and electrons are charged, physical models of bonding are based on electrostatic forces.
B. Because chemical bonds arise from sharing of negatively charged valence electrons between positively charged nuclei, the overall electrostatic interaction is attractive.
C. When chemical bonds form, the overall energy of the bonding atoms is lowered relative to free atoms, and therefore energy is released.
D. To break a chemical bond requires an input of energy.
E. A theoretical construct that describes chemical bonding utilizes the construction of molecular orbitals for the bond based on overlap of atomic orbitals on the constituent atoms.
F. Covalent bonds can be categorized based on the number of electrons (pairs) shared. The most common categories are single, double, and triple bonds.
G. Metallic bonding arises in many solids and fundamentally involves the sharing of valence electrons among many positively charged "cores" over extended distances.

III. Structure and Function

A. Atoms combine to form new compounds that have new properties based on structural and electronic features.
B. Models exist that allow the prediction of the shape of chemicals about any bonding atom in a molecule.
C. Theoretical models are capable of providing detail structure for whole molecules based on energy minimization methods.
D. Symmetry, based on geometry, plays an important role in how atoms interact within molecules and how molecules are observed in many experiments.
E. Three-dimensional structures may give rise to chirality, which can play an important role in observed chemical and physical properties.
F. Reactions of molecules can often be understood in terms of subsets of atoms, called functional groups.
G. Periodic trends among elements can be used to organize the understanding of structure and function for related chemical compounds.
H. Many solid state, extended systems exist, and geometric structures play an important role in understanding the properties of these systems.

IV. Intermolecular Interactions

A. Intermolecular forces are generally weaker, on an individual basis, than chemical bonds, but the presence of many such interactions may lead to overall strong interactions.
B. For large molecules, intermolecular forces may occur between different regions of the molecule. In these cases, they are sometimes termed noncovalent forces.
C. Intermolecular forces can be categorized based on the permanence and structural details of the dipoles involved.
D. For condensed phases that are not structures of extended chemical bonds, the physical properties of the state are strongly influenced by the nature of the intermolecular forces.
E. The energy consequences of chemical reactions that take place in condensed phases (solution) usually must include intermolecular forces to be correctly/completely explained.

V. Chemical Reactions

A. In chemical changes, matter is conserved and this is the basis behind the ability to represent chemical change via a balanced chemical equation.
B. Chemical change involves the breaking or forming of chemical bonds, or typically both.
C. Chemical change can be observed at both the particulate and macroscopic levels, and models exist that allow the translation between these two levels of observation.
D. There are a large number of possible chemical reactions, and categories have been devised to organize understanding of these reaction types.
E. Many chemical properties of elements follow periodic trends that can be used to strategically design reactions to achieve desired outcomes.
F. Chemical change can be controlled by choices of reactants, reaction conditions, or use of catalysts.
G. Controlling chemical reactions is a key requirement in the synthesis of new materials.

VI. Energy and Thermodynamics

A. Most chemical changes are accompanied by a net change of energy of the system.
B. Many chemical reactions require an energy input to be initiated.
C. The type of energy associated with chemical change may be heat, light, or electrical energy.
D. Breaking chemical bonds requires energy; formation of chemical bonds releases energy.
E. The forces that are associated with energy change in chemical processes are electrostatic forces.
F. In accord with thermodynamics, energy is conserved in chemical changes, but the change of form in which the energy is present may be harnessed via natural or human-made devices.
G. Thermodynamics provides a detailed capacity to understand energy change at the macroscopic level.
H. The tendency of nature to disperse, particularly in terms of energy distribution, is embodied in the state function called entropy.
I. Energy changes associated with nuclear chemistry are many orders of magnitude larger than those of classical chemical changes.

VII. Kinetics

A. Chemical change can be measured as a function of time and occurs over a wide range of time scales.
B. Empirically derived rate laws summarize the dependence of reaction rates on concentrations of reactants and temperature.
C. Most chemical reactions take place by a series of more elementary reactions, called the reaction mechanism.
D. An elementary reaction requires that the reactants collide (interact) and have both enough energy and appropriate orientation of colliding particles for the reaction to occur.
E. Catalysis increases the rate of reaction and has important applications in a number of subdisciplines of chemistry.
F. Reaction products can be influenced by controlling whether reaction rate or reaction energy plays the key role in the mechanism.

VIII. Equilibrium

A. Both physical and chemical changes may occur in either direction (e.g., from reactants to products or products to reactants).
B. When opposing processes both occur at the same rate the net change is zero.

C. For chemical reactions, the equilibrium state can be characterized via the equilibrium constant.
D. When the equilibrium constant is very large or small, products or reactants, respectively, are primarily present at equilibrium. Systems with K near 1 have significant amounts of both reactants and products present.
E. If perturbed, a system at equilibrium will respond in the direction that tends to offset the perturbation.
F. Thermodynamics provides mathematical tools to understand equilibrium systems quantitatively.
G. Equilibrium concepts have important applications in several subdisciplines of chemistry.

IX. Experiments, Measurement, and Data

A. Quantitative observation of matter can be made at a wide range of distance scales and/or time scales.
B. Because there are a large number of compounds, a system of naming these compounds is used.
C. Experimental control of reactions plays a key role in the synthesis of new materials and analysis of composition.
D. Chemical measurements are based on mass, charge, or interaction with electrons or photons.
E. Observations are verifiable, so experimental conditions, including considerations of the representativeness of samples, must be considered for experiments.
F. Fidelity of inferences made from data requires appropriate experimental design.
G. Chemistry experiments have risks associated with them, so chemical safety is a key consideration in the design of any experiment.

X. Visualization

A. Many theoretical constructs are constructed at the particulate level, while many empirical observations are made at the macroscopic level.
B. The mole represents the key factor for translating between the macroscopic and particulate levels.
C. Macroscopic properties result from large numbers of particles, so statistical methods provide a useful model for understanding the connections between these levels.
D. Quantitative reasoning within chemistry is often visualized and interpreted graphically.