# Chemistry
# 6–12

# Section 03

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## 1 Knowledge of the nature of matter

1. Differentiate between pure substances, homogeneous mixtures, and heterogeneous mixtures.
2. Determine the effects of changes in temperature, volume, pressure, or quantity on an ideal gas.
3. Apply units of mass, volume, and moles to determine concentrations and dilutions of solutions.
4. Analyze the effects of physical variables (e.g., pressure, temperature) on solubility and the dissolving process.
5. Analyze problems relating colligative properties to molar mass and solution concentrations.
6. Analyze the effects of forces between chemical species on physical properties (e.g., melting point, boiling point, vapor pressure, solubility, conductivity) of matter.
7. Solve problems involving an intensive property (e.g., density, specific heat) of matter.
8. Differentiate between various physical methods (e.g., chromatography, distillation, filtration) for separating the components of mixtures.
9. Identify the unique physical and chemical properties of water.
10. Differentiate between physical and chemical properties and physical and chemical changes of matter.

## 2 Knowledge of energy and its interaction with matter

1. Distinguish between different forms of energy (e.g., thermal, electrical, nuclear).
2. Relate temperature and heat to the motion of particles (e.g., atoms, molecules) using the kinetic molecular theory.
3. Interpret a phase diagram of a pure substance.
4. Interpret a heating and cooling curve of a substance.
5. Calculate thermal changes associated with chemical reactions, such as heats of reaction, heats of formation, and heats of combustion, from thermochemical data.
6. Analyze entropy changes during solution formation, phase changes, and chemical reactions.
7. Predict spontaneity of a chemical process given either initial and final values of Gibbs free energy or temperature, enthalpy, and entropy.

8. Relate regions of the electromagnetic spectrum to the energy, wavelength, and frequency of photons.

9. Identify the effects of various types of electromagnetic radiation (e.g., ultraviolet, infrared) on the chemical or physical properties of matter.

10. Recognize that energy can be transformed from one form to others and that the total energy in a closed system is conserved.

11. Distinguish between the characteristics of endothermic and exothermic reactions.

**3 Knowledge of bonding and molecular structure**

1. Identify the basic theory and applications of spectroscopy (e.g., infrared, mass spectrometry, nuclear magnetic resonance, ultraviolet, x-ray).

2. Identify types or examples of bonds (e.g., metallic, ionic, polar covalent, nonpolar covalent).

3. Relate electronegativity differences to bond type.

4. Identify properties of simple organic compounds.

5. Given the structural formula for a simple covalent compound, identify the hybridization of the atoms.

6. Identify sigma and pi bonds in a molecule.

7. Interpret the information derived from the following models: Lewis electron dot structures, valence shell electron pair repulsion (VSEPR) theory, and molecular orbital (M/O) theory involving diatomic molecules.

8. Select the most probable Lewis electron dot structure for an ionic or covalent formula (e.g., $CO_2$, $Na_2CO_3$) that follows the octet rule.

9. Predict the geometry (e.g., bent, linear, tetrahedral, trigonal bipyramidal) of simple molecules.

10. Predict the polarity of simple molecules.

11. Predict physical or chemical properties based on the type of bonding involved.

12. Identify the formula for an inorganic chemical compound (e.g., ionic, molecular, acid), given its name.

13. Identify the name of an inorganic chemical compound (e.g., ionic, molecular, acid), given its formula.

14. Identify proper names and formulas for simple organic compounds containing one functional group.

15. Identify common functional groups in an organic molecule.

16. Differentiate between the chemical structures of common biochemical compounds (e.g., lipids, amino acids, peptides, sugars, carbohydrates, nucleic acids).

**4 Knowledge of chemical reactions and stoichiometry**

1. Balance chemical equations.

2. Given common chemical reactants and reaction conditions, predict probable products.

3. Solve mass-mass stoichiometry problems.

4. Solve mass-gas volume stoichiometry problems.

5. Solve solution stoichiometry problems.

6. Solve stoichiometry problems with limiting reactants.

7. Determine empirical and molecular formulas from experimental data.

8. Analyze the effects of concentration, temperature, pressure, surface area, and the presence or absence of catalysts on reaction rate.

9. Predict the effect of a change in concentration, temperature, or pressure on the state of a system initially at equilibrium by applying Le Châtelier's principle.

10. Determine rate laws from concentrations, rate data, or graphs.

11. Determine either the equilibrium constant, *K*, or the concentration of a reaction species at equilibrium.

12. Identify the characteristics of a chemical system in dynamic equilibrium.

13. Identify major characteristics of strong and weak acids or bases.

14. Evaluate the characteristics of buffer systems.

15. Interpret graphical and numerical titration data.

16. Identify oxidation-reduction processes.

17. Balance redox equations in acidic or basic solutions.

18. Determine the spontaneity of a chemical reaction using standard reduction potentials.

19. Identify the characteristics of combustion reactions of simple organic compounds (e.g., sugars, alcohols, simple fossil fuels).

20. Solve problems related to pH or pOH of strong acids or bases.

21. Analyze electrolytic and voltaic cells.

22. Given a balanced chemical equation, identify the common reaction type.

## 5 Knowledge of atomic theory and structure

1. Using the periodic table, determine the number of protons, neutrons, and electrons in an atom or ion of a specific isotope.

2. Using the periodic table, analyze periodic trends in physical properties (e.g., ionic size, atomic size, boiling point, melting point) of the representative elements.

3. Using the periodic table, analyze periodic trends in chemical properties (e.g., electron affinity, ionization energy, electronegativity) of the representative elements.

4. Using the periodic table, determine electron configurations and orbital filling diagrams for elements with atomic numbers 1–56 and their ions.

5. Relate an element's chemical reactivity to its valence-shell electron configuration.

6. Identify the major characteristics of waves and particles, as well as the dual nature of matter.

7. Identify characteristics of unstable nuclei, including the particles and electromagnetic radiation they emit.

8. Given measurable quantities, solve problems involving radioactive decay.

9. Balance simple nuclear equations.

10. Identify the main characteristics of nuclear fission and fusion.

11. Identify electron density distribution diagrams and characteristics for *s*, *p*, and *d* orbitals (e.g., nodes, shapes).

12. Predict the effects of energy quantization at the atomic level.

## 6 Knowledge of the nature of science

1. Identify the characteristics and components of scientific inquiry and how it differs from other areas of learning.

2. Analyze the characteristics (e.g., independent, dependent, and controlled variables; bias; control groups) of a given experimental design.

3. Interpret empirical and graphical data to draw valid conclusions.

4. Analyze the relationship of experimental observations to experimental design, including underlying assumptions, hypotheses, conclusions, models, or theories.

5. Differentiate between the uses of qualitative and quantitative data.

6. Identify how the progressive development of basic science affects applied science, technology, the economy, and society.

7. Identify evidence of the progressive historical development of science.

**7 Knowledge of measurement**

1. Convert between units for one-, two-, and three-dimensional quantities.

2. Determine the units of a given mathematical expression.

3. Apply prefixes (e.g., kilo-, milli-, nano-) used in scientific measurements.

4. Distinguish between accuracy and precision and between systematic and random error.

5. Apply the correct number of significant figures in measurements or calculations.

6. Relate the Celsius, Fahrenheit, and Kelvin temperature scales, including the boiling point and melting point of water.

7. Use scientific notation (e.g., convert between decimal and scientific notation, perform mathematical calculations with numbers written in scientific notation).

8. Solve a multistep problem involving dimensional analysis (e.g., kinetics, solution preparation, thermochemistry).

**8 Knowledge of appropriate laboratory use and procedures**

1. Identify appropriate chemistry laboratory procedures for the safe storage, use, and disposal of materials and equipment.

2. Choose the correct laboratory equipment for a particular procedure.

3. Identify emergency procedures and safety equipment needed in the chemistry laboratory and classroom.

4. Identify the areas of teacher liability and responsibility in chemistry-related activities.

5. Relate knowledge of pertinent guidelines (e.g., from American Chemical Society, Environmental Protection Agency, material safety data sheets, National Science Teachers Association, Americans with Disabilities Act) to laboratory safety, hazardous materials, experimentation, and accommodations for students with special needs.