# Grades 9-12 Chemistry

## Metrics, Measuring and Mathematics of Chemistry

1. The accurate use of conversion factors in dimensional analysis is a necessary and fundamental skill in chemistry. As a basis for understanding this concept, students know:
   a. how to solve a variety of unit conversion problems using dimensional analysis using the metric system and the English system.
   b. how to solve a variety of unit conversion problems using dimensional analysis crossing between the metric system and the English system.
   c. how to solve volume conversion problems: from cubic units to other cubic units. how to solve volume conversion problems: from cubic units to a liquid volume measure.
2. Many problems in chemistry demand an understanding of significant digits (figures). As a basis for understanding this concept, students know:
   a. how to make measurements to the proper number of significant figures.
   b. how to identify the number of significant digits in a measurement.
   c. how to solve multiplication and division problems to the proper number of significant figures.
   d. how to solve addition and subtraction problems to the proper number of significant figures.
3. There are several basic units of measure in the metric system and many common metric prefixes. As a basis for understanding this concept, students know:
   a. how to distinguish between the different quantities measured in science: length, mass, volume, temperature, and time.
   b. how to identify the relationship between the common metric prefixes (nano, micro, milli, centi, milli, and kilo)
   c. how to state the common instruments used to measure the quantities listed above.
   d. how to measure the volumes of solids using the displacement method.
   e. how to perform a lab in which they measure length, mass, volume, temperature, and time, and convert those measurements to different metric units.
4. The density of objects can be found by dividing its mass by its volume. As a basis for understanding this concept, students know:
   a. how to solve problems to determine the density of objects.
   b. how to solve problems where they use the density to convert between mass and volume.
   c. how to perform a lab to determine the densities of both solids and liquids.
   d. by comparing densities, how to predict which objects will sink or float.
5. There is a key distinction between the concepts of heat and temperature. As a basis for understanding this concept, students know:
   a. how to distinguish between heat and temperature using specific heat.
   b. how to calculate an unknown quantity for a heat change, given any three of the following: heat loss or gain, mass of substance, specific heat of a substance, or the temperature change of the substance.

## Matter and Energy

6. There are three physical states for matter. As a basis for understanding this concept, students know:
   a. how to distinguish between the three physical states of matter in terms of their shape, volume, and compressibility.

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## Matter and Energy (6. continued)

b. students know the terms that describe the phase changes.
c. how to distinguish between the three states of matter in terms of the strength of attraction between the particles.

7. Matter can be classified many ways. As a basis for understanding this concept, students know:
   a. how to classify a sample as homogeneous or heterogeneous.
   b. how to classify a sample of matter as an element, compounds, or a mixture.
   c. how to distinguish between elements, compounds and mixtures.
   d. how to classify an element as a metal, semimetal (metalloid), or nonmetal.
   e. how to distinguish between metals, semimetals and nonmetals on the basis of their characteristic properties.
8. Matter undergoes many chemical and physical changes. As a basis for understanding this concept, students know:
   a. how to classify a property as being a chemical property or a physical property.
   b. how to classify a change as being a chemical change or a physical change.
   c. how to distinguish between elements, compounds and mixtures in terms of separation by either chemical or physical changes.
   d. how to state the four experimental observations that provide evidence for a chemical reaction.
   e. how to perform a lab where they observe a change and identify whether the change is a chemical change or a physical change.
9. Chemical reactions obey the law of conservation of mass and the law of conservation of energy. As a basis for understanding this concept, students know:
   a. that given the mass of one reactant and the mass of product in a combination reaction, the mass of the other reactant.
   b. how to measure the specific heat of a metal using calorimetry and the law of conservation of energy.

## Atoms and Electrons

10. There is historical evidence for the existence of atoms and the structure of atoms. As a basis for understanding this concept, students know:
    a. the five postulates of Dalton's Atomic Theory.
    b. the law of conservation of mass and the law of constant composition to the postulates of Dalton's Atomic Theory.
    c. how to describe the atom in terms of the Thomson model.
    d. how to describe the experiment that proved the existence of electrons.
    e. how to describe the experiment that proved the existence of the nucleus.
    f. how to draw a diagram of the nuclear atom.
    g. how to state the relative charge and approximate mass (amu) of the proton, neutron and electron.
11. Atoms are composed of protons, neutrons, and electrons. As a basis for understanding this concept, students know:
    a. how to identify the number of protons, neutrons and electrons in a neutral atom of a given element.
    b. the difference between atomic number, mass number, and atomic mass.
    c. how to define and illustrate an isotope in terms of its constituents.

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## **Atoms and Electrons** (11. continued)

d. how to calculate the average atomic mass of an element given the abundance of each naturally occurring isotope.

12. Electrons move about the atom in a cloud of quantized energy levels. As a basis for understanding this concept, students know:

a. how to explain the significance of flame tests in terms of energy levels.
b. how to describe the electron cloud in terms of energy levels, sublevels, and orbitals.
c. how to draw an s-orbital, a p-orbital, and a p-sublevel.
d. the ground-state electron configurations for atoms.
e. the core configurations for atoms.
f. how to identify the number of valence electrons in an atom.
g. how to draw electron dot structures for valence electrons.
h. the octet rule by correctly predicting the charge on an ion (s and p - block elements).
i. the significance of the each of the four quantum numbers.
j. how to write a set of four quantum numbers to describe an electron.

## **Periodic Table**

13. The arrangement of the elements in the periodic table allows prediction of the properties of the elements as well as the structure of atoms and molecules. As a basis for understanding this concept, students know:

a. how to distinguish between groups (families) and periods (series)
b. how to identify an element as being a member of the alkali metals, the alkaline earth metals, the halogens, the noble gases, or the transition elements.
c. how to correlate the s, p, d, and f sublevels with the positions of the elements in the periodic table.
d. the last notation in the electron configuration for an element by its position on the periodic table.
e. how to predict the trend in atomic size for groups and periods.
f. how to predict the trend in ionization energy for groups and periods.
g. how to predict the trend in electronegativity for groups and periods.

## **Compounds**

14. The names and formulas of chemical compounds reflect their makeup and structure. As a basis for understanding this concept, students know:

a. how to classify a compound as being ionic, covalent or an acid.
b. how to classify a compound as being binary or ternary.
c. how to identify the metal of an ionic compound as being a fixed charged metal or a variably charged metal.
d. how to correctly name covalent compounds using Greek prefixes to indicate the number of atoms and the -ide suffix for the second element.
e. how to correctly name ionic compounds using the stock system.
f. how to correctly name the binary and ternary acids.
g. how to correctly translate the name of a covalent compound to the correct formula.
h. how to write neutral formulas for ionic compounds and for acids.

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## The Mole

15. The concept of "the mole" is useful in calculating quantitative results in chemistry. As a basis for understanding this concept, students know:

a. "one mole" is simply the words for the number $6.02 \times 10^{23}$ just as "one dozen" is 12.
b. how to correctly predict the mass of a mole of an element and of a compound.
c. how to state the number of atoms in a mole of an element, the number of molecules in a mole of a covalent compound, and the number of formula units in a mole of an ionic compound.
d. how to solve problems converting between entities, moles, liters of a gas at STP, and grams.
e. how to calculate the percentage composition of a compound given the formula of the compound.
f. how to determine the formula of a compound given the percentage composition.
g. how to determine the formula of a compound given experimental data.
h. how to determine the molecular formula given the empirical formula and the molar mass.
i. how to calculate the density of a known gas at STP.
j. how to perform a lab in which they determine the formula of a compound.

## Chemical Reactions

16. The law of conservation of matter rules chemical reactions. As a basis for understanding this concept, students know:

a. how to recognize and balance chemical equations - combination (synthesis), decomposition, single replacement, double displacement, and combustion.
b. how to balance redox reactions using either the half-reaction method or the oxidation number method.
c. how to predict the products of a combination (synthesis) reaction by writing a correctly balanced chemical equation.
d. how to predict the products of a decomposition reaction by writing a correctly balanced chemical equation.
e. how to predict the products of a single replacement reaction by writing a correctly balanced chemical equation.
f. how to predict the products of a double displacement (precipitation and neutralization) reaction by writing a correctly balanced chemical equation.
g. how to predict the products of a combustion reaction by writing a correctly balanced chemical equation.
h. how to perform a lab to arrange a five element in order of increasing activity.
i. how to perform a lab to identify precipitates in double displacement reactions.

17. Stoichiometry deals with the application of the laws of definite proportions and the conservation of matter and energy to the study of chemical activity. As a basis for understanding this concept, students know:

a. how to solve a variety of problems including mass/mass, mass/volume, mole/mole, volume/volume, and limiting reactant.
b. how to calculate the percent yield given the actual yield and the theoretical yield.

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## Chemical Reactions (17. continued)

c. how to perform a lab where they complete a chemical reaction, measure the amount of product formed, compare that amount to the stoichiometric (theoretical) amount by means of a percent yield.
d. if a chemical reaction is endothermic or exothermic using the $\Delta H$.
e. how to calculate the $\Delta H$ for a reaction using heats of formation.
f. how to solve mass/heat problems.

## Chemical Bonding

18. The enormous variety of biological, chemical, and physical properties of matter can be related to the structure of atoms and molecules, strengths of chemical bonds and the configuration of the atoms in molecules and crystals. As a basis for understanding this concept, students know:

a. how to explain the difference between ionic bonds and covalent bonds.
b. how to explain the difference between formula units and molecules.
c. how to describe the formation of an ionic bond between a metal atom and a nonmetal atom.
d. how to distinguish between anions and cations.
e. how to distinguish the formation of a covalent bond between two nonmetal atoms.
f. how to distinguish between ionic and covalent (molecular) compounds from the properties of the compound
g. how to draw electron dot structures for molecules and polyatomic ions.
h. how to identify a coordinate covalent bond from the dot structure.
i. using marshmallows as atoms and toothpicks for bonds, how to apply the VSEPR theory and predict the shapes of molecules and the bond angles.
j. how to identify the polarity of a bond using delta notation.
k. how to predict whether a bond is nonpolar, polar, or ionic using electronegativity.
l. how to determine if a molecule is polar by analyzing the symmetry of the geometry.
m. how to predict the hybridization of the central atom of a molecule.

## The Gaseous State

19. Understanding the gaseous state is founded on the empirical result known as the Ideal Gas Law. As a basis for understanding this concept, students know:

a. how to describe the five observed properties of gases.
b. how to convert between the common units of pressure (atmosphere, torr, and mm Hg).
c. using Boyle's Law, how to calculate the volume of a gas after a pressure change or calculate the pressure after a volume change.
d. using Charles' Law, how to calculate the volume of a gas after a temperature change or he temperature of a gas after a volume change.
e. using Gay-Lussac's Law, how to calculate the temperature after a pressure change or the pressure after a temperature change.
f. how to use the combined gas law to calculate a new P, V, or T after a change in conditions.
g. how to explain Boyle's Law, Charles' Law, and Gay-Lussac's Law in terms of the kinetic molecular theory.
h. how to use the ideal gas law to find the pressure, volume, moles or temperature of a gas given any three of the four variables.

## The Gaseous State (19. continued)

i. how to use the ideal gas law to find the density of a gas at any temperature and pressure.
j. how to use the ideal gas law to find the molar mass of a compound given mass, pressure, temperature, and volume.
k. how to use Dalton's law to calculate the total pressure of a mixture of gases.
l. how to use Dalton's law to correct for the vapor pressure of water when collecting a gas over water.
m. how to perform a chemical reaction which produces a gas and collect the gas over water to measure the volume of gas produced and compare that volume to the theoretical volume found using the ideal gas law.

## Liquids, Solids, and Water

20. The properties of gases and solutions are a function of solubility and physical properties. As a basis for understanding this concept, students know:

a. how gas solubility is affected by temperature and pressure.
b. how solid solubility is affected by temperature, surface area, and stirring.
c. how to predict whether two liquids are miscible or immiscible based on polarity.
d. how to determine if a solution is unsaturated, saturated, or supersaturated.
e. how to calculate the mass percent, the molarity, and the molality of a solution.
f. how to predict the freezing point and boiling point of a solution.
g. how to calculate the molar mass of a substance using colligative property data.
h. how colloids differ from solutions and suspensions using properties like the Tyndall Effect.

21. The chemistry of acids and bases is governed by the pH scale. As a basis for understanding this concept, students know:

a. how to determine if a solution is acidic or basic using chemical properties, pH, and common indicators (litmus).
b. how to perform a titration to determine the concentration of a solution.
c. how to explain an acid base reaction in terms of the Arrhenius Theory and the Brönsted-Lowry Theory.
d. how to calculate the pH, pOH, [H+], and [OH-] given one of the four.
e. the difference between a strong electrolyte and a weak electrolyte.
f. how to convert a molecular equation to a net ionic equation.

## Chemical Equilibrium

22. The rate and extent of reactions of matter are related to the internal disordered motion of atoms and molecules in combination with the strength of the chemical bonds. As a basis for understanding this concept, students know:

a. why the reaction rate is affected by type of reaction, concentration, temperature, surface area, pressure, and the presence of a catalyst.
b. how to determine the rate law for a chemical reaction using concentration/rate data.
c. how to explain the process of equilibrium in terms of reaction rates.
d. how to write an equilibrium expression for a reaction.
e. how to calculate a value for K given equilibrium concentrations.

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## Chemical Equilibrium (22. continued)

f. how to use Le Chatelier's Principle to predict the affect on the equilibrium when the concentrations, temperature or pressure is changed.
g. how to calculate the pH of a weak acid solution given the initial concentration and Ka.
h. how to calculate solubility of a slightly soluble salt given the Ksp, and calculate the Ksp given the the solubility.

## Oxidation and Reduction

23. During chemical reactions certain atoms, ions, molecules lose electrons (are oxidized) while others gain electrons (are reduced). As a basis for understanding this concept, students know:

a. how to predict the oxidation numbers for each element in a species.
b. how to use oxidation numbers to determine which element was oxidized and which element was reduced in a chemical change.
c. how to determine the oxidizing agent and the reducing agent in a chemical change.
d. how to balance a redox equation using either the oxidation number method or the half-reaction method.
e. how to predict whether a redox reaction is spontaneous using E° values.
f. given a cell reaction, how to label the anode, the cathode, the direction of electron flow.
g. how to state the purpose of a salt bridge and state the direction of ion flow.
h. how to explain the difference between an electrolytic cell and a voltaic cell.

## Investigation and Experimentation

24. In the context of investigations designed to develop understanding of the content of the other strands students will:

a. select and use appropriate tools and technology (such as computer linked probes, spread sheets, and graphing calculators) to perform tests, collect data, analyze relationships, and display data.
b. identify and communicate the sources of error inherent in experimental design.
c. identify discrepant results and identify possible sources of error or uncontrolled conditions.
d. formulate and revise explanations using logic and evidence.
e. apply mathematical relationships involving quadratic equations, simple trigonometric relationships, exponential growth and decay laws, and logarithmic relationships to scientific situations.
f. distinguish between a guess, a hypothesis and a theory as these terms are used in science.
g. recognize the use and limitations of models and theories as scientific representations of reality.
h. read and interpret a topographic map, and a geologic map for evidence.
i. identify natural events by sequence and time from natural phenomena (e.g., relative ages of rocks and intrusions).
j. recognize the issues of statistical variability and the need for controlled tests.

**Investigation and Experimentation** (24. continued)

k. recognize the cumulative nature of scientific evidence.

l. analyze situations and solve problems that require combining concepts from more than one topic area of science and applying these concepts to real world situations.

m. investigate a science-based societal issue by researching the literature, analyzing data where appropriate and communicating their findings. Examples include irradiation of food, cloning of animals by somatic cell nuclear transfer, choice of energy sources, and land and water use decisions (including California).