Chemistry Curriculum Guide

Standard CH.1 (scientific process) is below at the end of this document.

Standard CH.2 a, b, c

The student will investigate and understand that the placement of elements on the periodic table is a function of their atomic structure. The periodic table is a tool used for the investigations of

a) average atomic mass, mass number, and atomic number;
b) isotopes, half lives, and radioactive decay; and
c) mass and charge characteristics of subatomic particles.
d) families or groups;
e) series and periods; and
f) trends including atomic radii, electronegativity, shielding effect, and ionization energy.
g) electron configurations, valence electrons, and oxidation numbers.
h) chemical and physical properties.
i) historical and quantum models.

AVERAGE ATOMIC MASS, MASS NUMBER, AND ATOMIC NUMBER

· The periodic table is arranged in order of increasing atomic numbers.
· The atomic number of an element is the same as the number of protons.
· In a neutral atom, the number of electrons is the same as the number of protons.
· All atoms of an element have the same number of protons.
· The atomic mass for each element is the weighted average of that element's naturally occurring isotopes.
· *Electrons* have little mass and a negative (–) charge. They are located in electron clouds or probability clouds outside the nucleus.
· *Protons* have a positive (+) charge. *Neutrons* have no charge. Protons and neutrons are located in the nucleus of the atom and comprise most its mass.
· *Using a periodic chart, determine the atomic number, atomic mass, the number of protons, the number of electrons, and the number of neutrons of any neutral atom of a particular element.*

ISOTOPES, HALF LIVES, AND RADIOACTIVE DECAY

· An *isotope* is an atom that has the same number of protons as another atom of the same element but has a different number of neutrons. Some isotopes are radioactive; many are not.
· *Half-life* is the length of time required for half of a given sample of a radioactive isotope to decay.
· *Determine the half-life of a radioactive substance.*
· *Describe alpha, beta, and gamma radiation with respect to penetrating power, shielding, and composition.*

FAMILIES OR GROUPS; SERIES AND PERIODS;

· *Periodicity* is regularly repeating patterns or trends in the chemical and physical properties of the elements arranged in the periodic table.
· Horizontal rows called *periods* have predictable properties based on an increasing number of electrons in the outer orbitals.
· Vertical columns called *groups* have similar properties because of their similar valence electron configurations.
· The Periodic Law states that when elements are arranged in order of increasing atomic numbers, their physical and chemical properties show a periodic pattern.
· The names of groups and periods on the periodic chart are alkali metals, alkaline earth metals, transition metals, halogens, noble gases, and metalloids.
· Periods and groups are named by numbering columns and rows.
· Some elements, such as oxygen, hydrogen, fluorine, chlorine, bromine, and nitrogen, naturally occur as diatomic molecules.

TRENDS INCLUDING ATOMIC RADII, ELECTRO-NEGATIVITY, SHIELDING EFFECT, AND IONIZATION ENERGY

· Electronegativity increases from left to right within a period and decreases from top to bottom within a group.
· Shielding effect is constant within a given period and increases within given groups from top to bottom.
· Atomic radius decreases from left to right and increases from top to bottom within given groups.
· Ionization energies generally increase from left to right and decrease from top to bottom of a given group.

ELECTRON CONFIGURATIONS, VALENCE ELECTRONS, AND OXIDATION NUMBERS

· Electron configuration is the arrangement of electrons around the nucleus of an atom based on their energy level.
· Atoms can gain, lose, or share electrons within the outer energy level.
· Electrons are added one at a time to the lowest energy levels first (Aufbau Principle).
· An orbital can hold a maximum of two electrons (Pauli Exclusion Principle).
· Electrons occupy equal-energy orbitals so that a maximum number of unpaired electrons results (Hund's Rule).
· Energy levels are designated 1–7. Orbitals are designated s, p, d, and f according to their shapes
· s, p, d, f orbitals relate to the regions of the Periodic Table.
· Loss of electrons from neutral atoms results in the formation of an ion with a positive charge (cation)
· Gain of electrons by a neutral atom results in the formation of an ion with a negative charge (anion)
· Transition metals can have multiple oxidation states.
· *Use an element's electron configuration to determine the number of valence electrons and possible oxidation numbers.*

CHEMICAL AND PHYSICAL PROPERTIES

· Matter is classified by its chemical and physical properties.
· *Physical properties* refer to the condition or quality of a substance that can be observed or measured without changing the substance's composition.
· *Chemical properties* refer to the ability of a substance to undergo chemical reaction and form a new substance.
· Matter occurs as elements (pure), compounds (pure), and mixtures, which may be homogeneous (solutions) or heterogeneous.
· Important physical properties are density, conductivity, melting point, boiling point, malleability, and ductility.
· *Reactivity* is the tendency of an element to enter into a chemical reaction.

HISTORICAL AND QUANTUM MODELS

· Discoveries and insights related to the atom's structure have changed the model of the atom over time.
· The modern atomic theory is called the Quantum Mechanical Model.
· Major insights regarding the atomic model of the atom and principal scientists include:
- particles – Democritus
- first atomic theory of matter – John Dalton
- discovery of the electron – J. J. Thompson

- discovery of the nucleus – Ernest Rutherford
- discovery of charge of electron – Robert Millikan
- planetary model of atom – Niels Bohr
- periodic table by atomic mass – Demitry Mendeleev
- periodic table by atomic number – Henry Moseley
- quantum nature of energy – Max Planck
- uncertainty principle – Werner Heisenberg
- wave theory – Louis de Broglie.

Standard CH.3 a, b, c, d
The student will investigate and understand how conservation of energy and matter is expressed in chemical formulas and balanced equations. Key concepts include
a) nomenclature;
b) balancing chemical equations;
c) writing chemical formulas (molecular, structural, and empirical; and Lewis diagrams); and
d) bonding types (ionic and covalent).
e) reaction types (synthesis, decomposition, single and double replacement, oxidation-reduction, neutralization, exothermic, and endothermic); and
f) reaction rates and kinetics (activation energy, catalysis, and degree of randomness).

NOMENCLATURE; BALANCING CHEMICAL EQUATIONS; WRITING CHEMICAL FORMULAS (MOLECULAR, STRUCTURAL, AND EMPIRICAL; AND LEWIS DIAGRAMS);
· Conservation of matter is represented in balanced chemical equations.
· Chemical formulas are used to represent compounds.
· *Subscripts* represent the relative number of each type of atom in a molecule or formula unit.
· A *coefficient* is a quantity that precedes a reactant or product symbol or formula in a chemical equation and indicates the relative number of particles involved in the reaction.
· When pairs of elements form two or more compounds, the masses of one element that combine with a fixed mass of the other element form simple, whole-number ratios (Law of Multiple Proportions).
· The *empirical formula* shows the simplest whole-number ratio in which the atoms of the elements are present in the compound.
· The *molecular formula* shows the actual number of atoms of each element in one molecule of the substance.
· *Structural formulas* also show the arrangements of atoms and bonds.

BONDING TYPES (IONIC AND COVALENT)
· Bonds form between atoms to achieve stability.
· *Covalent bonds* involve the sharing of electrons.
· *Ionic bonds* involve the transfer of electrons.
· *Ionization energy* is the energy required to remove the most loosely held electron from a neutral atom. Elements with low ionization energy form positive ions (cations) easily. Elements with high ionization energy form negative ions (anions) easily.
· *Electronegativity* is the measure of the attraction of an atom for electrons in a covalent bond.
· *Polar molecules* result when a molecule behaves as if one end were positive and the other end negative.
· The IUPAC system is used for naming compounds.
· *Name binary covalent compounds.*
· *Name binary ionic compounds (using the Roman numeral system where appropriate).*
· *Predict, draw, and name molecular shapes (bent, linear, trigonal planar, tetrahedral,*

and trigonal pyramidal)
· *Determine formulas, write equations, and balance chemical equations.*
· *Write the chemical formulas for certain common substances, such as ammonia, water, carbon monoxide, carbon dioxide, sulfur dioxide, and carbon tetraflouride.*
· *Recognize the formulas and names of certain polyatomic ions, such as carbonate, sulfate, nitrate, hydroxide, phosphate, and ammonium, and use these polyatomic ions for naming and writing the formulas of ionic compounds.*
· *Draw Lewis Dot Diagrams to show covalent bonding*.

REACTION TYPES (SYNTHESIS, DECOMPOSITION, SINGLE AND DOUBLE REPLACEMENT, OXIDATION-REDUCTION, NEUTRALIZATION, EXOTHERMIC, AND ENDOTHERMIC);
· Elements and compounds react in different ways.
· Spontaneous reactions may be fast or slow.
· Randomness (entropy), heat content (enthalpy), and temperature affect spontaneity.
· Major types of chemical reactions are
- synthesis **(A+B ® AB)**
- decomposition **(BC ® B+C)**
- single replacement **(A+BC ® B+AC)**
- double replacement **(AC+BD ® AD+BC).**
· Chemical reactions based on the net heat energy are exothermic reaction (heat producing) and endothermic reaction (heat absorbing).
· Reactions can occur in two directions simultaneously.

REACTION RATES AND KINETICS (ACTIVATION ENERGY, CATALYSIS, AND DEGREE OF RANDOMNESS)
· Reaction rates/kinetics are affected by activation energy, catalysis, and the degree of randomness (entropy).
· Le Chatelier's Principle indicates the qualitative prediction of direction of change with temperature, pressure, and concentration.
· Catalysts decrease the amount of activation energy needed.
· *Recognize equations for redox reactions and neutralization reactions.*
· *Interpret reaction rate diagrams.*

Standard CH.4 a, b
The student will investigate and understand that quantities in a chemical reaction are based on molar relationships. Key concepts include
a) Avogadro's principle and molar volume; and
b) stoichiometric relationships.
c) partial pressure;
d) gas laws;
e) solution concentrations; and
f) chemical equilibrium.
g) acid/base theory: strong electrolytes, weak electrolytes, and nonelectrolytes; dissociation and ionization; pH and pOH; and the titration process.

AVOGADRO'S PRINCIPLE AND MOLAR VOLUME; STOICHIOMETRIC RELATIONSHIPS
· Atoms and molecules are too small to count by usual means.
· A *mole* is a way of counting any type of particle (atoms, molecules, and formula units).
· Stoichiometry involves quantitative relationships.
· Stoichiometric relationships are based on mole quantities in a balanced equation.

· Avogadro's number = 6.02×10^{23} particles per mole.
· Molar volume = 22.4 dm^3/mole and/or 22.4 L/mole for any gas at STP.
· Molar mass of a substance is its average atomic mass in grams from the Periodic Table.
· Total grams of reactant(s) = total grams of product(s).
· *Make calculations involving the following relationships:*
- *mole-mole;*
- *mass-mass;*
- *mole-mass;*
- *mass-volume;*
- *mole-volume; and*
volume-volume.
· *Identify the limiting reactant (reagent) in a reaction.*
· *Calculate percent yield of a reaction.*

PARTIAL PRESSURE; GAS LAWS;
· Gases have mass and occupy space.
· Gas particles are in constant, rapid, random motion and exert pressure as they collide with the walls of their containers.
· Gas molecules with the lightest mass travel fastest.
· Relatively large distances separate gas particles from each other.
· An Ideal Gas does not exist, but this concept is used to model gas behavior.
· A Real Gas exists, has intermolecular forces and particle volume, and can change states.
· Equal volumes of gases at the same temperature and pressure contain an equal number of particles.
· The pressure and volume of a sample of a gas at constant temperature are inversely proportional to each other (Boyle's Law).
· At constant pressure, the volume of a fixed amount of gas is directly proportional to its absolute temperature (Charles' Law).
· The sum of the partial pressures of all the components in a gas mixture is equal to the total pressure of a gas mixture (Dalton's law of partial pressures).
· Ideal Gas Law states that PV = nRT.

SOLUTION CONCENTRATIONS; CHEMICAL EQUILIBRIUM
· Solutions can be a variety of solute/solvent combinations: gas/gas, gas/liquid, liquid/liquid, solid/liquid, gas/solid, liquid/solid, or solid/solid.
· Molarity = moles/dm^3 or moles/L of solution.
· Pressure Units include K Pa and mm of Hg.
· *Solve problems and interpret graphs involving the gas laws.*

ACID/BASE THEORY: STRONG ELECTROLYTES, WEAK ELECTROLYTES, AND NONELECTROLYTES; DISSOCIATION AND IONIZATION; PH AND POH; AND THE TITRATION PROCESS.
· Two important classes of compounds are acids and bases.
· Acids and bases are defined by several theories.
· Acids and bases dissociate in varying degrees.
· Arrhenius acids are characterized by their sour taste, low pH, and the fact that they turn litmus paper red. Arrhenius bases are characterized by their bitter taste, slippery feel, high pH, and the fact that they turn litmus paper blue.
· Bronsted-Lowry-acids are proton donors, whereas bases are proton acceptors.
· The pH number denotes hydrogen (hydronium) ion concentration. The pOH number

denotes hydroxide ion concentration.

- pH + pOH = 14
- pH is a number scale ranging from 0 to 14 that represents the acidity of a solution.
- [ ] refers to molar concentration.
- Strong acid-strong base titration is the process that measures [H+] and [OH-].
- Indicators show color changes at certain pH levels.
- Strong electrolytes dissociate completely. Weak electrolytes dissociate partially.

Standard CH.5 a, b
The student will investigate and understand that the phases of matter are explained by kinetic theory and forces of attraction between particles. Key concepts include

a) pressure, temperature, and volume; and
b) vapor pressure.
c) phase changes;
d) molar heats of fusion and vaporization;
e) specific heat capacity; and
f) colligative properties.

PRESSURE, TEMPERATURE, AND VOLUME; VAPOR PRESSURE.

- Atoms and molecules are in constant motion.
- The Kinetic Molecular Theory is a model for predicting and explaining gas behavior.
- Forces of attraction between molecules determine the physical changes of state.
- Vapor pressure is a property of a substance determined by intermolecular forces.
- Pressure, temperature, and volume changes can cause a change in physical state.
- Forces of attraction include hydrogen bonding, dipole-dipole attraction, and London dispersion (van der Waals) forces.

PHASE CHANGES; MOLAR HEATS OF FUSION AND VAPORIZATION; SPECIFIC HEAT CAPACITY; COLLIGATIVE PROPERTIES

- Solid, liquid, and gas phases of a substance have different energy content.
- Specific amounts of energy are absorbed or released during phase changes.
    - Specific heat capacity is a property of a substance.
- Polar substances dissolve ionic or polar substances; nonpolar substances dissolve nonpolar substances.
- The number of solute particles changes the freezing point and boiling point of a pure substance.
- A liquid's boiling point and freezing point are affected by changes in atmospheric pressure.
- A liquid's boiling point and freezing point are affected by the presence of certain solutes.
- *Graph and interpret a heating curve (temperature vs. time)*
- *Calculate energy changes, using specific heat capacity.*
- *Calculate energy changes, using molar heat of fusion and molar heat of vaporization.*
- *Interpret a phase diagram of water.*
- *Perform calorimetry calculations.*
- *Recognize polar molecules and non-polar molecules.*

Standard CH.1 a, b, c
The student will investigate and understand that experiments in which variables are measured, analyzed, and evaluated produce observations and verifiable data. Key concepts include
a) designated laboratory techniques;
b) safe use of chemicals and equipment; and
c) proper response to emergency situations.
d) manipulation of multiple variables, using repeated trials; and
e) accurate recording, organization, and analysis of data through repeated trials.
f) mathematical and procedural error analysis; and
g) mathematical manipulations (SI units, scientific notation, linear equations, graphing, ratio and proportion, significant digits, dimensional analysis).
h) use of appropriate technology including computers, graphing calculators, and probeware, for gathering data and communicating results; and
i) construction and defense of a scientific viewpoint (the nature of science).

· Measurements of quantity include length, volume, mass, temperature, time, and pressure to the correct number of significant digits.
· Techniques for experimentation involve the identification and the proper use of chemicals, the description of equipment, and the recommended statewide framework for high school laboratory safety.
· Measurements are useful in gathering data about chemicals and how they behave.
· Make the following measurements, using the specified equipment:
- volume: graduated cylinder, pipette, volumetric flask, buret
- mass: electronic or dial-a-gram
- temperature: thermometer and/or temperature probe
- pressure: barometer or pressure probe.
· Identify, locate, and know how to use laboratory safety equipment, including aprons, goggles, gloves, fire extinguishers, fire blanket, safety shower, eye wash, broken glass container, and fume hood.
· Demonstrate the following basic lab techniques: filtering, decanting, using chromatography, and lighting a gas burner.
· Identify the following basic lab equipment: beaker, flask, graduated cylinder, test tube, test tube rack, test tube holder, ring stand, wire gauze, clay triangle, crucible with lid, evaporation dish, watch glass, wash bottle, and dropping pipette.
· Understand Material Safety Data Sheet (MSDS) warnings, including handling chemicals, lethal dose (LD), hazards, disposal, and chemical spill cleanup.
· Repeated trials during experimentation ensure verifiable data.
· Data tables are used to record and organize measurements.
· Graphs are used to summarize the relationship between the independent and dependent variable.
· Design and perform experiments to test predictions.
· Identify variables.
· Predict outcome(s) when a variable is changed.
· Record data, using the significant digits of the measuring equipment.
· Demonstrate precision (reproducibility) in measurement.
· Recognize accuracy in terms of closeness to the true value of a measurement.
· Measurements must be expressed in SI units.
· Scientific notation is used to write very small and very large numbers.
· Algebraic equations represent relationships between dependent and independent variables.
· Graphed data give a picture of a relationship.
· Ratios and proportions are used in calculations.
· *Significant digits* of a measurement are the number of known digits together with one estimated digit.

· The last digit of any valid measurement must be estimated and is therefore uncertain.
· *Dimensional analysis* is a way of translating a measurement from one unit to another unit.
· Graphing calculators can be used to manage the mathematics of chemistry.
· Mathematical procedures are used to validate data.
· Discover and eliminate procedural errors.
· Know most frequently used SI prefixes and their values (milli-, centi-, deci-, kilo-).
· Demonstrate the use of scientific notation, using the correct number of significant digits with powers of ten notation for the decimal place.
· Correctly utilize the following when graphing data:
- dependent variable (vertical axis)
- independent variable (horizontal axis)
- scale and units of a graph
- regression line (best fit curve).
· Calculate mole ratios, percent composition, conversions, and relative atomic mass.
· Use the rules for performing operations with significant digits.
· Utilize dimensional analysis.
· Use graphing calculators correctly.
· Read a measurement from a graduated scale, stating measured digits plus the estimated digit.
· Use data collected to calculate percent error.
· Determine the mean of a set of measurements.
· Constant reevaluation in the light of new data is essential to keeping scientific knowledge current. In this fashion, all forms of scientific knowledge remain flexible and may be revised as new data and new ways of looking at existing data become available.
· Explain the emergence of modern theories based on historical development. For example, students should be able to explain the origin of the atomic theory beginning with the Greek atomists and continuing through the most modern Quantum models.