

**California State Science Curriculum Standards
Grades K-12 – Spiraled**

Content Area: CHEMISTRY

The following document lists the standards that should be covered from Kindergarten through 12th grade in this content area.

Kindergarten

1. Properties of materials can be observed, measured, and predicted. As a basis for understanding this concept:
 - b. *Students know* water can be a liquid or a solid and can be made to change back and forth from one form to the other.

Grade 1

1. Materials come in different forms (states), including solids, liquids, and gases. As a basis for understanding this concept:
 - a. *Students know* solids, liquids, and gases have different properties.
 - b. *Students know* the properties of substances can change when the substances are mixed, cooled, or heated.

Grade 3

1. Energy and matter have multiple forms and can be changed from one form to another. As a basis for understanding this concept:
 - e. *Students know* matter has three forms: solid, liquid, and gas.
 - f. *Students know* evaporation and melting are changes that occur when the objects are heated.
 - g. *Students know* that when two or more substances are combined, a new substance may be formed with properties that are different from those of the original materials.
 - h. *Students know* all matter is made of small particles called atoms, too small to see with the naked eye.
 - i. *Students know* people once thought that earth, wind, fire, and water were the basic elements that made up all matter. Science experiments show that there are more than 100 different types of atoms, which are presented on the periodic table of the elements.

Grade 8

Structure of Matter

3. Each of the more than 100 elements of matter has distinct properties and a distinct atomic structure. All forms of matter are composed of one or more of the elements. As a basis for understanding this concept:
 - a. *Students know* the structure of the atom and know it is composed of protons, neutrons, and electrons.
 - b. *Students know* that compounds are formed by combining two or more different elements and that compounds have properties that are different from their constituent elements.
 - c. *Students know* atoms and molecules form solids by building up repeating patterns, such as the crystal structure of NaCl or long-chain polymers.
 - d. *Students know* the states of matter (solid, liquid, gas) depend on molecular motion.
 - e. *Students know* that in solids the atoms are closely locked in position and can only vibrate; in liquids the atoms and molecules are more loosely connected and can collide with and move past one another; and in gases the atoms and molecules are free to move independently, colliding frequently.
 - f. *Students know* how to use the periodic table to identify elements in simple compounds.

Reactions

5. Chemical reactions are processes in which atoms are rearranged into different combinations of molecules. As a basis for understanding this concept:

- a. *Students know* reactant atoms and molecules interact to form products with different chemical properties.
- b. *Students know* the idea of atoms explains the conservation of matter: In chemical reactions the number of atoms stays the same no matter how they are arranged, so their total mass stays the same.
- c. *Students know* chemical reactions usually liberate heat or absorb heat.
- d. *Students know* physical processes include freezing and boiling, in which a material changes form with no chemical reaction.
- e. *Students know* how to determine whether a solution is acidic, basic, or neutral.

Chemistry of Living Systems (Life Sciences)

6. Principles of chemistry underlie the functioning of biological systems. As a basis for understanding this concept:

- a. *Students know* that carbon, because of its ability to combine in many ways with itself and other elements, has a central role in the chemistry of living organisms.
- b. *Students know* that living organisms are made of molecules consisting largely of carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur.
- c. *Students know* that living organisms have many different kinds of molecules, including small ones, such as water and salt, and very large ones, such as carbohydrates, fats, proteins, and DNA.

Periodic Table

7. The organization of the periodic table is based on the properties of the elements and reflects the structure of atoms. As a basis for understanding this concept:

- a. *Students know* how to identify regions corresponding to metals, nonmetals, and inert gases.
- b. *Students know* each element has a specific number of protons in the nucleus (the atomic number) and each isotope of the element has a different but specific number of neutrons in the nucleus.
- c. *Students know* substances can be classified by their properties, including their melting temperature, density, hardness, and thermal and electrical conductivity.

Chemistry (High School)

Atomic and Molecular Structure

1. The periodic table displays the elements in increasing atomic number and shows how periodicity of the physical and chemical properties of the elements relates to atomic structure. As a basis for understanding this concept:

- a. *Students know* how to relate the position of an element in the periodic table to its atomic number and atomic mass.
- b. *Students know* how to use the periodic table to identify metals, semimetals, non- metals, and halogens.
- c. *Students know* how to use the periodic table to identify alkali metals, alkaline earth metals and transition metals, trends in ionization energy, electronegativity, and the relative sizes of ions and atoms.
- d. *Students know* how to use the periodic table to determine the number of electrons available for bonding.
- e. *Students know* the nucleus of the atom is much smaller than the atom yet contains most of its mass.
- f. **Students know* how to use the periodic table to identify the lanthanide, actinide, and transactinide elements and know that the transuranium elements were synthesized and identified in laboratory experiments through the use of nuclear accelerators.
- g. * *Students know* how to relate the position of an element in the periodic table to its quantum electron configuration and to its reactivity with other elements in the table.
- h. * *Students know* the experimental basis for Thomson's discovery of the electron, Rutherford's nuclear atom, Millikan's oil drop experiment, and Einstein's explanation of the photoelectric effect.
- i. **Students know* the experimental basis for the development of the quantum theory of atomic structure and the historical importance of the Bohr model of the atom.
- j. * *Students know* that spectral lines are the result of transitions of electrons between energy levels and that these lines correspond to photons with a frequency related to the energy spacing between levels by using Planck's relationship ($E = h\nu$)

Chemical Bonds

2. Biological, chemical, and physical properties of matter result from the ability of atoms to form bonds from electrostatic forces between electrons and protons and between atoms and molecules. As a basis for understanding this concept:

- Students know* atoms combine to form molecules by sharing electrons to form covalent or metallic bonds or by exchanging electrons to form ionic bonds.
- Students know* chemical bonds between atoms in molecules such as H₂, CH₄, NH₃, HCCH₂, N₂, Cl₂, and many large biological molecules are covalent.
- Students know* salt crystals, such as NaCl, are repeating patterns of positive and negative ions held together by electrostatic attraction.
- Students know* the atoms and molecules in liquids move in a random pattern relative to one another because the intermolecular forces are too weak to hold the atoms or molecules in a solid form.
- Students know* how to draw Lewis dot structures.
- **Students know* how to predict the shape of simple molecules and their polarity from Lewis dot structures.
- * *Students know* how electronegativity and ionization energy relate to bond formation.
- * *Students know* how to identify solids and liquids held together by van der Waals forces or hydrogen bonding and relate these forces to volatility and boiling/ melting point temperatures.

Conservation of Matter and Stoichiometry

3. The conservation of atoms in chemical reactions leads to the principle of conservation of matter and the ability to calculate the mass of products and reactants. As a basis for understanding this concept:

- Students know* how to describe chemical reactions by writing balanced equations.
- Students know* the quantity *one mole* is set by defining one mole of carbon 12 atoms to have a mass of exactly 12 grams.
- Students know* one mole equals 6.02×10^{23} particles (atoms or molecules).
- Students know* how to determine the molar mass of a molecule from its chemical formula and a table of atomic masses and how to convert the mass of a molecular substance to moles, number of particles, or volume of gas at standard temperature and pressure.
- Students know* how to calculate the masses of reactants and products in a chemical reaction from the mass of one of the reactants or products and the relevant atomic masses.
- * *Students know* how to calculate percent yield in a chemical reaction.
- * *Students know* how to identify reactions that involve oxidation and reduction and how to balance oxidation-reduction reactions.

Gases and Their Properties

4. The kinetic molecular theory describes the motion of atoms and molecules and explains the properties of gases. As a basis for understanding this concept:

- Students know* the random motion of molecules and their collisions with a surface create the observable pressure on that surface.
- Students know* the random motion of molecules explains the diffusion of gases.
- Students know* how to apply the gas laws to relations between the pressure, temperature, and volume of any amount of an ideal gas or any mixture of ideal gases.
- Students know* the values and meanings of standard temperature and pressure (STP).
- Students know* how to convert between the Celsius and Kelvin temperature scales.
- Students know* there is no temperature lower than 0 Kelvin.
- * *Students know* the kinetic theory of gases relates the absolute temperature of a gas to the average kinetic energy of its molecules or atoms.
- * *Students know* how to solve problems by using the ideal gas law in the form $PV = nRT$.
- * *Students know* how to apply Dalton's law of partial pressures to describe the composition of gases and Graham's law to predict diffusion of gases.

Acids and Bases

5. Acids, bases, and salts are three classes of compounds that form ions in water solutions. As a basis for understanding this concept:

- Students know* the observable properties of acids, bases, and salt solutions.
- Students know* acids are hydrogen-ion-donating and bases are hydrogen-ion accepting substances.
- Students know* strong acids and bases fully dissociate and weak acids and bases partially

dissociate.

- d. *Students know* how to use the pH scale to characterize acid and base solutions.
- e. * *Students know* the Arrhenius, Brønsted-Lowry, and Lewis acid–base definitions.
- f. * *Students know* how to calculate pH from the hydrogen-ion concentration.
- g. * *Students know* buffers stabilize pH in acid–base reactions.

Solutions

6. Solutions are homogeneous mixtures of two or more substances. As a basis for understanding this concept:

- a. *Students know* the definitions of *solute* and *solvent*.
- b. *Students know* how to describe the dissolving process at the molecular level by using the concept of random molecular motion.
- c. *Students know* temperature, pressure, and surface area affect the dissolving process.
- d. *Students know* how to calculate the concentration of a solute in terms of grams per liter, molarity, parts per million, and percent composition.
- e. **Students know* the relationship between the molality of a solute in a solution and the solution's depressed freezing point or elevated boiling point.
- f. **Students know* how molecules in a solution are separated or purified by the methods of chromatography and distillation.

Chemical Thermodynamics

7. Energy is exchanged or transformed in all chemical reactions and physical changes of matter. As a basis for understanding this concept:

- a. *Students know* how to describe temperature and heat flow in terms of the motion of molecules (or atoms).
- b. *Students know* chemical processes can either release (exothermic) or absorb (endothermic) thermal energy.
- c. *Students know* energy is released when a material condenses or freezes and is absorbed when a material evaporates or melts.
- d. *Students know* how to solve problems involving heat flow and temperature changes, using known values of specific heat and latent heat of phase change.
- e. **Students know* how to apply Hess's law to calculate enthalpy change in a reaction.
- f. **Students know* how to use the Gibbs free energy equation to determine whether a reaction would be spontaneous.

Reaction Rates

8. Chemical reaction rates depend on factors that influence the frequency of collision of reactant molecules. As a basis for understanding this concept:

- a. *Students know* the rate of reaction is the decrease in concentration of reactants or the increase in concentration of products with time.
- b. *Students know* how reaction rates depend on such factors as concentration, temperature, and pressure.
- c. *Students know* the role a catalyst plays in increasing the reaction rate.
- d. * *Students know* the definition and role of activation energy in a chemical reaction.

Chemical Equilibrium

9. Chemical equilibrium is a dynamic process at the molecular level. As a basis for understanding this concept:

- a. *Students know* how to use Le Chatelier's principle to predict the effect of changes in concentration, temperature, and pressure.
- b. *Students know* equilibrium is established when forward and reverse reaction rates are equal.
- c. * *Students know* how to write and calculate an equilibrium constant expression for a reaction.

Organic Chemistry and Biochemistry

10. The bonding characteristics of carbon allow the formation of many different organic molecules of varied sizes, shapes, and chemical properties and provide the biochemical basis of life. As a basis for understanding this concept:

- a. *Students know* large molecules (polymers), such as proteins, nucleic acids, and starch, are formed by repetitive combinations of simple subunits.
- b. *Students know* the bonding characteristics of carbon that result in the formation of a large variety of structures ranging from simple hydrocarbons to complex polymers and biological molecules.
- c. *Students know* amino acids are the building blocks of proteins.
- d. **Students know* the system for naming the ten simplest linear hydrocarbons and isomers that contain single bonds, simple hydrocarbons with double and triple bonds, and simple molecules that contain a benzene ring.
- e. **Students know* how to identify the functional groups that form the basis of alcohols, ketones, ethers, amines, esters, aldehydes, and organic acids.
- f. **Students know* the R-group structure of amino acids and know how they combine to form the polypeptide backbone structure of proteins.

Nuclear Processes

11. Nuclear processes are those in which an atomic nucleus changes, including radioactive decay of naturally occurring and human-made isotopes, nuclear fission, and nuclear fusion. As a basis for understanding this concept:

- a. *Students know* protons and neutrons in the nucleus are held together by nuclear forces that overcome the electromagnetic repulsion between the protons.
- b. *Students know* the energy release per gram of material is much larger in nuclear fusion or fission reactions than in chemical reactions. The change in mass (calculated by $E = mc^2$) is small but significant in nuclear reactions.
- c. *Students know* some naturally occurring isotopes of elements are radioactive, as are isotopes formed in nuclear reactions.
- d. *Students know* the three most common forms of radioactive decay (alpha, beta, and gamma) and know how the nucleus changes in each type of decay.
- e. *Students know* alpha, beta, and gamma radiation produce different amounts and kinds of damage in matter and have different penetrations.
- f. **Students know* how to calculate the amount of a radioactive substance remaining after an integral number of half-lives have passed.
- g. ** Students know* protons and neutrons have substructures and consist of particles called quarks.