Milford Public Schools Curriculum

Department: Science
Course Name: Chemistry

UNIT 1 – Structure of Matter

Matter is made up of atoms and the interactions between and within them. The types, interactions and motions of atoms determine the state, properties and reactions of matter. Within atoms there are subatomic particles. The amount and arrangement of the particles within an atom determine the properties of each atom. Changes to the particles within the nucleus of an atom may alter the identity of the atom.

LEARNING GOALS

Enduring Understanding(s):

- Scientists construct and use models to generate knowledge and advance understanding.
- Matter can be described, organized and classified for understanding.
- Changes occurring in the nucleus of an atom may alter the identity of an atom and often result in large changes in energy.
- The interactions of electrons between and within atoms are the primary factors that determine the properties of matter.

Essential Question(s):

- How are elements, compounds and mixtures different from one another?
- How has experimental evidence changed the model of the atom over time?
- How does electromagnetic radiation interact with atoms?

Content:

Level 3

- Atomic models
- Subatomic particles
- Symbols, atomic #, mass #
- Ions and isotopes
- Electron configuration
  *Up to Calcium
- Emission/electromagnetic spectrum
- Pure substances vs. mixtures
- Heterogeneous vs. homogeneous mixtures
- Chemical and physical properties

Level 1/2 **all of the above plus the following*

- Quantum model of the atom
- Electron configuration
  *Beyond Calcium
- Absorption/electromagnetic spectrum
- Atomic history – more in depth **(L1)**
- Radioactive isotopes/nuclear decay
- Extensive vs. intensive properties

All Levels

1. Compare and contrast pure substances and mixtures.
2. Compare and contrast heterogeneous and homogeneous mixtures.
3. Demonstrate how specific mixtures can be separated into their components.

4. Compare and contrast subatomic particles, in terms of electrical charge, mass, location and purpose.
5. Describe the progression of human understanding about the structure of the atom.
6. Identify the symbols, atomic numbers and mass numbers of various elements.
7. Use the periodic table to locate information about specific elements.
8. Explain why atoms form specific ions.
9. Utilize mathematical operations to analyze properties of atoms, isotopes and ions.
10. Distinguish between isotopes of a specific element.
11. Identify which isotopes of a certain element are more stable than others and why.
12. Describe specifically where electrons are located, using electron configurations.
13. Create models (Lewis) of atoms that explain electron configuration of atoms.
14. Explain how the electron configuration translates to color of light.
15. Describe properties of light waves.

Standards Addressed

CT SDE Science

- **9.4: Atoms react with one another to form new molecules.**
    - **D10** – Describe the general structure of the atom, and explain how the properties of the first 20 elements in the Periodic Table are related to their atomic structures.

Framework for K-12 Science Education

NGSS

- **PS1.A: Structure of matter**
    - The sub-atomic structural model and interactions between electric charges at the atomic scale can be used to explain the structure and interactions of matter, including chemical reactions and nuclear processes.

- **PS4. B: Electromagnetic radiation**
    - Both electromagnetic wave model and a photon model explain features of electromagnetic radiation broadly and describe common applications of electromagnetic radiation.

UNIT 2 - Periodicity and Bonding

Elements are organized on the periodic table according to specific properties. Placement on the periodic table can be used to predict and determine the properties of individual elements. Atoms of elements combine in certain ratios to form compounds or molecules due to the atom's valence electrons. The manner in which valence electrons are used to form compounds determines whether it is ionic, covalent or metallic. The naming of a compound is specific to the type of compound and follows specific rules based on formula.

LEARNING GOALS

Enduring Understanding(s):

- The periodic table is an organizational tool that can be used for the prediction and classification of the trends and properties of elements.
- Atoms combine in specific ratios to form new compounds based on their structure and properties.
- Matter can be described, organized and classified for understanding.
- The large variety of chemical structures, ranging from simple hydrocarbons to complex biological molecules and synthetic polymer, result from the unique bonding characteristics of carbon.

Essential Questions:

- How does the atomic structure relate to the location of elements in the periodic table?
- How does the structure of matter affect its properties and its uses by people?
- Why do different atoms form different types of bonds?

Content:

Level 3

- Periodic table history
- Periodic table trends
  - Atomic radii and valence only
- Periodic table organization
- Covalent & ionic bonding
- Metallic bonding
- Covalent & ionic compounds & properties
- Chemical nomenclature
- Polar/nonpolar molecules
  - Focus on H_2O, O_2, and CO_2
  - conceptual
- Organic compounds and carbon cycle
  - Focus on hydrocarbons
- Structure of hydrocarbons
- Structure and formation of polymers
- Synthetic vs. natural (biopolymers) polymers and their uses

Level 1/2 **all of the above plus the following:*

- Periodic table trends
  - Ionization energy, electron affinity, ionic radii, electronegativity
- VSPER theory
- Bond energy
- Resonance **(L1)**

- Intermolecular forces
- Polar/nonpolar molecules
    - Beyond H_2O, O_2, and CO_2

Learning Objectives:

All Levels

1. Trace the history of the periodic table.
2. Describe characteristics of an element based on its location on the periodic table.
3. Interpret how the number of valence electrons relates to the electron configuration of an element, based on its location in the periodic table.
4. Analyze similarities and differences among elements within the same period/group in the periodic table.
5. Describe the general trend going across a period and down a group for atomic and ionic radii, ionization energy, electronegativity, and electron affinity.
6. Explain why the trends of atomic and ionic radii, ionization energy, electronegativity, and electron affinity occur.
7. Predict the behavior of an element based upon information about size, electronegativity and electron affinity.
8. Translate between names and formulas of chemical compounds.
9. Distinguish between the types of compounds.
10. Explain why atoms form bonds, using the octet rule.
11. Classify the bonding of atoms of elements as ionic or covalent.
12. Determine how many times an atom will bond and/or whether an atom will form a multiple bond (double and triple bonds).
13. Draw the Lewis structures of ionic compounds and molecular compounds.
14. Using electronegativities, classify bonds as ionic, polar covalent or nonpolar covalent.
15. Distinguish the difference between polar and nonpolar molecules.
16. Interpret how the classification of a compound determines its physical properties.
17. Describe the characteristics of carbon that contribute to the diversity of organic compounds.
18. Differentiate between alkanes, alkenes and alkynes.
19. Draw alkanes, alkenes and alkynes through the use of structural formulas.
20. Translate the structural formula of a hydrocarbon into a name and reverse.
21. Compare and contrast saturated and unsaturated hydrocarbons.
22. Summarize how monomers combine to form polymer chains.
23. Distinguish between linear, branched and cross-linked polymers.
24. Describe properties of linear, branched and cross-linked polymers.
25. Differentiate between synthetic and natural (biopolymers) polymers.
26. Analyze the relationships among structure, properties and use of a polymer.

Level 1/2 only **in addition to the above*

27. Using Lewis structure and electronegativity values, classify molecules as polar or nonpolar.
28. Explain and draw resonance structures.
29. Describe the intermolecular force at work between neighboring particles.

Standards Addressed:

CT SDE Science

- **9.4: Atoms react with one another to form new molecules**
    - **D11** – Describe how atoms combine to form new substances by transferring electrons (ionic

bonding) or sharing electrons (covalent bonding).

- **9.5: Due to its unique chemical structure, Carbon forms many organic and inorganic compounds**
    - **D13 -** Explain how the structure of the Carbon atoms affects the type of bonds it forms in organic and inorganic molecules.
    - **D15 –** Explain the general formation and structure of carbon based polymers, including synthetic, such as polyethylene, and biopolymers, such as carbohydrates.
- **9.6: Chemical technologies present both risks and benefits to the health and well-being of humans, plants and animals**
    - **D16 –** Explain how simple chemical monomers can be combing to create linear, branched and/or cross-linked polymers.
    - **D17 –** Explain how the chemical structure of polymers affects their physical properties.

Framework for K-12 Science Education

NGSS

- **PS1.A: Structure of matter**
    - Repeating patterns of the periodic table reflect patterns of outer electrons. A stable molecule has less energy than the same set of atoms separate; one must provide at least this energy to take the molecule apart.
- **PS1.B: Chemical reactions**
    - Chemical processes are understood in terms of collisions of molecules, rearrangement of atoms, and changes in energy as determined by properties of elements involved.

UNIT 3 - Chemical Interactions of Matter

Unit Overview:

A chemical reaction is a process in which one or more substances are changes into one or more different substances. Reactants are the original substances and products are the resulting substances. In any chemical reaction, the law of conservation of mass must be satisfied, meaning that the total mass of the reactants must equal the total mass of the products. Chemical reactions are represented by chemical formulas, symbols and relative amounts of the reactants and products. There are several types of reactions that exist; synthesis, decomposition, single-replacement, double-displacement, combustion (complete/incomplete), acid/base neutralization, and nuclear reactions.

LEARNING GOALS

Enduring Understanding(s):

- When any change occurs, energy is transferred and/or transformed, but it is never lost.
- Chemical reactions are processes where chemical bonds are broken, atoms are rearranged to form new substances, and new bonds are formed.
- Matter is conserved whenever any chemical change occurs

Essential Questions:

- How does matter interact to form new substances?
- How is the environment impacted from chemical reactions?

Content:

Level 3

- Law of conservation of (mass) matter and energy
- Writing and balancing equations
- Chemical changes & evidence of
- Reaction types
    - Focus on complete/incomplete combustion and polymerization
    - Identification of synthesis, decomposition
- Reaction rates (kinetics)
- *Predicting products* (at discretion of teacher)*
- Nuclear reactions & decay
- Applications of chemical reactions
    - Hydrogen Fuel Cell

Level 1/2 **all of the above plus the following:*

- Collision theory
- Reaction types (all types plus acid/base)
- Predicting products
    - Activity series & precipitation
- Acid/base/neutralization reactions
    - Neutralization titration **(L1)**
- Equilibrium **(L1)**
- Identification of **(L2)**

Learning Objectives:
All Levels

1. Demonstrate how any chemical reaction supports the law of conservation of mass.
2. Balance chemical equations to support the law of conservation of mass.
3. Differentiation between chemical change and physical change.
4. Describe the evidence of a chemical change.
5. Classify the type of reaction.
6. Explain how the law of conservation of energy applies to a specific reaction.
7. Explain the differences between the types of reactions (synthesis, decomposition, and complete/incomplete combustion)
8. Evaluate the solubility rules to determine if a precipitate will form in a reaction.
9. Predict how a substance will decay by writing nuclear equations.
10. Explain how hydrogen fuel cells, batteries and combustion engines operate.
11. Describe the types of energy transformations involved in fuel cells, batteries and combustion engines.
12. Explain how the combustion engine contributes to the greenhouse effect.

Level 1/2 only * *in addition to the above*

13. Discuss why a reaction would or would not occur, in terms of the collision theory.
14. Explain the differences between the types of reactions (double displacement, single displacement and acid/base, in addition to #7 above)
15. Predict the products that are formed in a chemical reaction.
16. Analyze the activity series to predict if a reaction will occur.

Standards Addressed:

CT SDE Science

- **9.5: Due to its unique chemical structure, carbon forms many organic and inorganic compounds.**
  - **D14.** Describe combustion reactions of hydrocarbons and their resulting by-products.
- **9.6: Chemical technologies present both risks and benefits to the health and well-being of humans, plants and animals.**
  - **D18.** Explain the short and long terms impacts of landfills and incineration of waste materials on the quality of the environment.
- **9.7**: **Elements on Earth move among reservoirs in the solid earth, oceans, atmosphere and organisms as part of biogeochemical cycles.**
  - **D19.** Explain how chemical and physical processes cause carbon to cycle through the major earth reservoirs.
- **9.8: The use of resources by human populations may affect the quality of the environment.**
  - **D23.** Explain how the accumulation of carbon dioxide in the atmosphere increases Earth's "greenhouse" effect and may cause climate changes.
- **9.9: Some materials can be recycled, but others accumulate in the environment and may affect the balance of the Earth systems.**
  - **D25.** Explain how land development, transportation options and consumption of resources may affect the environment.
  - **D26.** Describe human efforts to reduce the consumption of raw materials and improve air and water quality.

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- **PS1.B: Chemical Reactions**
  - Chemical processes are understood in terms of collisions of molecules, rearrangement of atoms, and changes in energy as determined by properties of elements involved.
- **PS3.B: Conservation of energy and energy transfer**
  - The total energy within a system is conserved.
- **PS3.D: Energy in chemical processes and everyday life**
- Energy cannot be destroyed; it can be converted to less

UNIT 4 - Chemical Quantities

Stoichiometry is the calculation of relative quantities of reactant and products in chemical reactions. It utilizes the quantitative analysis of the relationships between moles, mass, particles and volume of compounds in chemical reactions

LEARNING GOALS

Enduring Understanding(s):	**Essential Question(s):**
• Balanced chemical equations can be used to determine mathematical relationships among reactants and products. • Matter is conserved whenever any chemical change occurs. • The unit of measurement which chemists rely on to predict quantities in chemical reactions is the mole.	• How can the relationship between moles, mass and particles determine the identity of a substance? • Using the relationships from a balanced chemical equation, what can be predicted?

Content:

Level 3

- Formula mass
- Moles/particles/mass/volume relationships
- Stoichiometry
- Percentage by mass
- Limiting and excess reactant (conceptual)
- Percent yield

Level 1/2 * *all of the above plus the following*

- Empirical formula/molecular formula

Learning Objectives:

1. Calculate the formula mass of a given substance.
2. Establish a relationship between particles, mass, volume and moles of a given substance.
3. Describe the importance of the mole ratio in stoichiometric calculations.
4. Analyze a compounds chemical makeup by percent composition to determine its identity.
5. Establish relationships between different compounds in a reaction using the balanced chemical equation.
6. Describe the method for determining which reactant in a reaction is the limiting and excess reactants.
7. Justify the determination of the limiting and excess reactants of a reaction.
8. Describe how the percentage yield shows the relationship between the theoretical yield and the actual yield for the product of a reaction.

Standards

CT SDE Frameworks

HS Chemistry Enrichment Standards:

Chemical reactions can be described by writing balanced equations.

The quantity one mole is set by defining one mole of carbon; 12 atoms to have a mass of exactly 12 grams.

One mole equals 6.02.x 1023 particles (atoms or molecules).

The molar mass of a molecule can be determined from its chemical formula and a table of atomic masses.

The mass of a molecular substance can be converted to moles, number of particles, or volume of gas at standard temperature and pressure.

UNIT 5 - Chemistry of Fluids

Liquids and gases are referred to as fluids due to the unique nature based upon the arrangement of their particles. The ability to flow and move more freely is based upon the energetics of the particles. This imparts special properties to liquids and gases such as exerting pressure, forming solutions, and obeying the gas laws. A change in phases of matter is determined by the conditions of temperature and pressure of the substance. Liquids and gases can readily form solutions of different concentrations. Those concentrations can be expressed in several different ways such as molarity, mass percent, or volume percent. There are various factors like temperature and pressure that influence the solubility of a substance in a fluid.

LEARNING GOALS

Enduring Understanding(s):

- The kinetic molecular theory explains certain properties of matter.
- Gases can be described in terms of volume, pressure, temperature and quality of particles.
- Acids dissociate to produce hydronium ions and some bases dissociate to produce hydroxide ions.
- Water also dissociates into hydronium and hydroxide ions.
- The relative amounts of solute and solvent in a solution are described by different units of concentration.

Essential Questions:

- What are the physical characteristics of fluids and how do these characteristics affect solution formation?
- How does the accumulation of solutes in solutions have an impact on our environment?

Content and Skills:

Level 3

- Kinetic Molecular Theory
- Characteristics of gases
  - Gas laws
  - Gas pressure
- Characteristics of liquids
  - Vapor pressure
- Characteristics of solutions
  - Solubility
  - Concentrations of solutions – molarity
- Acidic/basic solutions
- pH scale
- Impacts of solutes in solution on our environment (atmosphere, water quality, organisms)

Level 1/2 **all of the above plus the following*

- Combined gas laws
- Dalton's law of partial pressure **(L!)**
- Ideal gas law **(L1)**
- Diffusion/effusion
- Aqueous stoichiometry **(L1)**
  - Concentrations – molality and % volume

Learning Objectives:

1. Convert between different units of pressure.
2. Describe gas behavior using kinetic molecular theory.
3. Perform calculations involving pressure, temperature, amount and volume of gases.
4. Describe the components of a specific solution.
5. Differentiate between molarity and molality.
6. Calculate the concentration of solutions using various methods.
7. Describe how to prepare a dilute solution from a concentrated solution.
8. Describe the factors that affect the rate of dissolution.
9. Explain what the solubility of a substance tells.
10. Differentiate between saturated, unsaturated and supersaturated solutions.
11. Determine the solubility of a substance using the solubility graph.
12. Identify whether a compound dissociates and write the dissociation equation.
13. Identify and explain what colligative properties are involved in certain situations.
14. Calculate boiling point elevation and freezing point depression.
15. Relate boiling point elevation and freezing point depression to real world applications.
16. Identify general properties of aqueous acids and bases.
17. Describe ionization.
18. Explain how water ionizes.
19. Distinguish between a strong and weak acid.
20. Distinguish between a strong and weak base.
21. Use the pH scale to identify what makes a solution acidic or basic.
22. Relate the concentration of a solution to pH number.
23. Explain the process of neutralization.
24. Define acid rain.
25. Give examples of compounds that can cause acid rain.
26. Describe the effects of acid rain.

Standards Addressed:

CT SDE Science

- **9.4: Atoms react with one another to form new molecules**
  - **D12 -** Explain the chemical composition of acids and bases and explain the change in pH in neutralization reactions.
- **9.8: The use of resources by human populations may affect the quality of the environment**
  - **D24 –** Explain how the accumulation of mercury, phosphates and nitrates affects the quality of water and the organisms that live in rivers, lakes and oceans.
- **9.9: Some materials can be recycled, but others accumulate in the environment and may affect the balance of the Earth systems**
  - **D26 –** Describe human efforts to reduce the consumption of raw materials and improve air and water quality.

UNIT 6 - Interactions of Chemicals and Energy

Energy changes are involved in both physical and chemical processes. These changes cannot be measured directly, but can be determined experimentally through calorimetry. Because the energy lost/gained by a system is equal to the energy lost/gained by the surroundings, energy is always conserved.

LEARNING GOALS

Enduring Understanding(s):	**Essential Questions:**
• Depending on the identity and quantity of a substance undergoing a physical or chemical change the quantity of heat released or absorbed is directly related. • Energy is conserved during any change - energy may be transformed into another type of energy, but it never disappears. • There are environmental issues related to the use of renewable and non-renewable energy in the production of electricity. • Various forms of energy are used to generate electricity.	• How can kinetic theory and forces of attraction be used to explain the behavior of gases, liquids, and solids? • How is energy converted from one form to another and why? • How is heat transferred through matter?

Content and Skills:

Level 3

- Heat vs. temperature
- Heat capacity & specific heat
- Exothermic vs. endothermic
- Phase changes
- Standard heats of formation
- Uses of thermochemical reactions (combustion of organic compounds)
- Alternative energy (hydrogen fuel cells and nuclear fission and fusion)

Level 1/2 * *all of the above plus the following*

- Hess's law
- Spontaneity **(L1)**
- Calorimetry

Learning Objectives:

1. Distinguish between heat and temperature.
2. Compare and contrast heat capacity and specific heat.
3. Describe what specific heat can tell about an object.
4. Demonstrate how to calculate specific heat.
5. Distinguish between exothermic and endothermic.
6. Summarize how a substance changes from one physical state to another.
7. Describe how calorimetry can be used to determine heat changes in processes.
8. Analyze thermochemical equations to establish relationships between quantity of heat and reactants/products.
9. Describe what the enthalpy change tells about a reaction.
10. Demonstrate how to use Hess's law, calorimetry and standard heats of formation to determine the change in enthalpy.
11. Describe the role organic compounds play in the production of energy for everyday life.

Standards Addressed:

CT SDE Science

- **9.1: Energy cannot be created or destroyed, however energy can be converted from one form to another.**
    - **D1.** Describe the effects of adding energy to matter in terms of the motion of atoms and molecules, and the resulting phase changes

- **9.3: Various sources of energy are used by humans and all have advantages and disadvantages.**
    - **D7.** Explain how heat is used to generate electricity.

    - **D8.** Describe the availability, current uses and environmental issues related to the use of fossil and nuclear fuels to produce electricity.

    - **D9.** Describe the availability, current uses and environmental issues related to the use of hydrogen fuel cells, wind and solar energy to produce electricity.

Framework for K-12 Science Education

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- **PS1.A: Structure of matter**
    - A stable molecule has less energy than the same set of atoms separate; one must provide at least this energy to take the molecule apart.
- **PS3.A: Definitions of energy**
    - The total energy within a system is conserved. Energy transfer within and between systems can be described and predicted in terms of fields or interactions of particles.
- **PS3.B: Conservation of energy and energy transfer**
    - Systems move toward stable states