Chemistry: Chemistry of Earth Systems
Units and Objectives

This course covers the skills and content of a first-year Chemistry course within the context of Earth Systems. Topics include: The Big Bang and the origin of elements, atomic structure, chemical reactions and their role in Earth processes, bonding, chemistry topics applied to environmental issues, stoichiometry, thermodynamics, and equilibrium. (Fall 2020)

Units	NGSS
Big Bang and Nuclear Chemistry	ESS1-1, ESS1-2, ESS1-3, PS1-8
Atomic Structure	PS1-1
The Periodic Table	PS1-1
Chemical Bonding	PS1-3
Chemical Quantities	PS1-2
Chemical Reactions	PS1-2
Stoichiometry	PS1-7
Copper Unlimited Project	ESS3-2
Thermochemistry	PS1-4, PS3-1, PS3-4
Gases	
Weather and Climate	ESS2-2
Climate Change	ESS2-4, ESS3-5, ESS3-6
Reaction Rates and Equilibrium	PS1-5, PS1-6
Acid-Base Equilibria	
Ocean Acidification	ESS2-6
Organic Chemistry	PS2-6

Chemistry: Chemistry of Earth Systems

1: WHERE DOES "STUFF" COME FROM? (Investigation 1 and 17)

Big Bang, Nuclear (10 days)

Question: Where does "stuff" come from?

Extension (project?) if time: Experience 3: Nuclear Technologies (Nuclear power plants, nuclear medical technology)

1a	**The Big Bang**
1a1	Describe the big bang theory and compositional evidence for it.
1b	**Investigation 1 Experience 2: Modeling atoms (p. 12-21)**
1b1	Describe atomic structure using a model of the atom that includes protons, neutrons and electrons.
1b2	Compare and contrast atoms of different elements and isotopes of the same element including mass number, atomic mass, isotopic notation and isotopic abundance.
1c	**Investigation 17 Experience 2: Fusion: Stars/Life Cycle, Formation of Elements**
1c1	Explain the role of fusion in the formation of new elements in the three different life cycles of stars.
1c2	Develop models to explain the conservation of mass and energy during the processes of fission and fusion.
1c3	Describe conversions between mass and energy during the Big Bang and other nuclear processes.
1d	**Investigation 17 Experience 1: Radioactivity and Half-Lives, Radioactive Decay, Half-life and Applications**
1d1	Describe the particles and forces present in the atomic nucleus.
1d2	Develop models to illustrate the changes in the composition of the atomic nucleus and the energy released during radioactive decay.
1d3	Use mathematics to calculate the half-life of a radioactive substance and the approximate age of earth materials in order to decipher the age and history of the earth.
1d4	Calculate the age of ocean crust to infer plate movement direction and rate of movement.

2: WHERE DOES "STUFF" COME FROM? (Investigation 1)

Atomic structure, Emissions Spectra and Electrons (9 days)

Phenomena: What causes colors in a fireworks display?

2a	**Investigation 1 Experience 3: Atomic Emissions Spectra and the Bohr model (p. 19-20)**
2a1	Develop and use Bohr models for atoms illustrating electron energy levels and the placement of electrons within those levels with an emphasis on valence electrons.
2a2	Use the Bohr model to explain why elements have unique atomic emission spectra and use spectra as an identification technique.
2a3	Relate the Spectra of elements to the structure of their atoms, particularly the patterns of electrons and the changes in their energy.
2a4	Evaluate the spectra of different light sources and differentiate between spectral types.
2a5	Use spectra to gauge the composition of stars, galaxies, nebulae
2a6	Evaluate the Doppler effect on spectra to determine direction and relative speeds of objects and as evidence for the Big Bang.
2b	**Investigation 1 Experience 5: Electrons in Atoms (33-39)**
2b1	Predict the valence electrons in an atom using the periodic table as a model.
2b3	Use electron dot structures to represent an atom's valence electrons.

2. THE PERIODIC TABLE

The Periodic Table (9.5 days)

Phenomena: Why are elements in pure form so rare?

3a	**Investigation 1 Experience 1: The Particle Nature of Matter (p. 6-11)**
3a1	I can define and differentiate between atoms, molecules, elements and compounds and develop models to describe the
3a2	Use particle level models to explain interactions of energy and matter within a system as it relates to states of matter.
3a3	Use evidence to determine whether a physical or chemical change has occurred.
3b	**Investigation 2 Experience 1: The Periodic Table - An Overview (p. 44-49)**
3b1	Identify various groups of elements on the periodic table (e.g., families, periods, metals, nonmetals, metalloids).
3b2	Describe how elements in the periodic table are arranged by the number of protons in atoms.
3b3	Identify how the arrangement of the main groups of the periodic table reflects the patterns of valence electrons.
3b4	Explain how the position of an element in the table can be used to predict some of its chemical and physical properties.
3c	**Investigation 4 Experience 4 Comparing Metals & Nonmetals (p. 141-145)**
3c1	Analyze data comparing metals and nonmetals and construct explanations for their differences.
3c2	Summarize defining properties of metals.
3c3	Describe how delocalized electrons give rise to metallic properties.
3d	**Investigation 2 Experience 3: Periodic Trends (p. 56-64)**
3d1	Investigate and explain reactivity patterns in the periodic table using concepts of ionization energy, net effective charge
3d2	Use models of elements to explain the formation of ions.
3d3	Use periodic trends to predict and explain elemental properties: metallic character, nonmetallic character, electron affini ionization energy, common charges for group numbers.

3. CHEMICAL BONDING

Chemical Bonding (11.5 days)

Phenomena: Why do gems have different properties than metals?

4a	**Experience 1: Ionic Bonds (p. 68-76)**
4a1	Explain that atoms gain or lose electrons to become ions so that they have a full valence shell.
4a2	Explain that ionic bonds are electrostatic attractions between cations and anions.
4a3	Describe how the structure of ionic compounds affects their properties (including becoming electrolytes when dissolved).
4b	**Experience 2: Metallic Bonds (77-80)**
4b1	Describe the electron sea model of metallic bonds.
4b2	Explain how the bonding in metals and alloys affects their properties.
4c	**Experience 3: Covalent Bonds (81-90)**
4c1	Explain how nonmetals share electrons to share their valence shell octet, resulting in the formation of a covalent bond.
4c2	Identify single and double and triple covalent bonds and draw electron dot diagrams for each.
4c3	Describe how elements of different electronegativities can share electrons unequally, leading to the formation of a polar covalent bond.
4c4	Use VSEPR theory to determine shapes of molecules.
4c5	Determine the polarity of a molecule based on the shape of a molecule.
4d	**Experience 4: Intermolecular Attractions (p. 91-96)**
4d1	Describe the types of attractions between molecules.
4d2	Explain how intermolecular attractions between molecules influence the bulk properties of a material (ex. Surface tension, boiling point, state of matter at room temp).
4d3	Describe mineral crystalline structures and how they influence mineral properties including cleavage, fracture, and hardness
4e	**Experience 5: Names and Formulas of Compounds (p. 97-106)**

4e1	Given the name, write the formulas of molecular compounds and ionic compounds.
4e2	Predict bond types in a compound based on its name or formula.
4e3	Describe the ways in which mineral resources impact our daily lives and how these resources are extracted and processed.

5. CHEMICAL QUANTITIES

Chemical Quantities (9.5 days)

Phenomena: Why do we quantify matter in different ways?

5a	**Experience 1: The Mole Concept (p. 174-182)**
5a1	Investigate the three methods used to measure matter -- count, mass, and volume.
5a2	Explain the relationship between the mole and Avogadro's number (for atoms, molecules, and formula units).
5a3	Use Avogadro's number to convert from moles to particles and particles to moles.
5a4	Use the periodic table to find the molar mass of elements and compounds.
5b	**Experience 2: Molar Relationships (p. 183-191)**
5b1	Convert mole quantities to masses or volumes (for a gas at STP), and mass or Volume (gas at STP) quantities to moles.
5c	**Experience 3: Percent Composition and Empirical Formulas (p. 192-202)**
5c1	Explain how to find the percent composition of a compound.
5d	**Experience 4: Concentrations of Solutions (p. 203-212)**
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5d2	Investigate how the ratio of solute to solvent affects the concentration of a solution.
5d3	Devise a method to make a solution of a specific concentration.

6. CHEMICAL REACTIONS

Chemical Reactions (7.5 days)

Phenomena: How is energy obtained from chemical reactions? Rocket launching.

6a	**Experience 1: Modeling Chemical Reactions (p. 216-226)**
6a1	Identify the parts of a chemical reaction, and balance equations for these chemical reactions.
6b	**Experience 2: Predicting Outcomes of Chemical Reactions (p. 227-240)** **Experience 3: Reactions in Aqueous Solution (p. (241-248)**
6b1	Identify the five general types of chemical reactions.
6b2	Predict the outcome of certain reactions based on the reactants, including identifying precipitates.

7. STOICHIOMETRY

Stoichiometry (8 days) + Copper Unlimited project (5 days)

Phenomena: What can make a recipe fail?

Project: Copper Unlimited

7a	**Experience 1: Quantifying Reactants and Products (p. 252-258)**
7a1	Analyze data on proportionality of reactants and products to predict their stoichiometric ratios in the corresponding chemical equation.
7a2	Develop a model that demonstrates conservation of mass in a chemical equation.
7b	**Experience 2: Chemical Calculations (p, 259-268)**
7b1	Use the mole ratio in a chemical reaction to relate amounts of participating substances.
7b2	Use stoichiometry to convert between grams and moles in a chemical reaction.
7c	**Experience 3: Limiting Reagent and Percent Yield (p. 269-278)**
7c1	Explain the concept of limiting reactant and compute theoretical yield.
7c2	Explain the theoretical and actual yield and calculate percent yield.

Copper Unlimited Lab Project

7d	**Copper Unlimited Lab Project**
7d1	ESS3-2: Evaluate competing design solutions for developing, managing and utilizing energy and mineral resources on cost benefit ratios.
7d2	Describe the ways in which energy resources are extracted and processed, as well as their environmental costs.

8. THERMOCHEMISTRY

Thermochemistry (8 days)

Phenomena: Why do you get hot when you exercise?

8a	**Experience 1: Energy in Chemical Bonds (p. 282-290)**
8a1	Explain how molecules must collide with each other with sufficient energy and in the correct orientation for a chemical reaction to take place.
8a2	Represent energy changes in exothermic and endothermic reactions using an enthalpy diagram.
8a3	Calculate enthalpy of reaction from bond energies and molar enthalpy of reaction data.
8b	**Experience 3: Enthalpy in Changes of State**
8b1	Understand how and why substances change in enthalpy when transitioning between physical states.
8b2	Calculate the change in enthalpy for state changes between solid, liquid, and gas.
8b3	Describe the link between state change enthalpies and the strength of intermolecular forces.
8c	**Enthalpy and Changes in Temperature**
8c1	Calculate the quantity of energy involved in temperature changes ($q=sm\Delta T$).
8c2	Explain how specific heat of water compared to other Earth materials produces differences in the temperature profile of: locations at the same latitude near and far from oceans, locations at the same latitude in the Northern vs. Southern Hemisphere

9. GASES

The Behavior of Gases (9.5 days)

Phenomena: What causes the Santa Ana winds?

9a	**Experience 1: Properties of Gases (p. 6-9)**
9a1	Use particle pictures to explain the differences between solids, liquids and gases.
9a2	Use the kinetic theory to explain the properties of gases (motion of particles, diffusion, compressibility, have mass, volume, exert pressure, etc.)
9a3	Describe the effects on gases of changes in volume, temperature, pressure, and the number of particles.
9b	**Experience 2: The Gas Laws (p. 11-22)**
9b1	Investigate and explain the relationship between the volume, temperature, and pressure of a gas.
9b2	Develop and use models to explain the gas laws.
9b3	Relate the patterns of interaction between gas particles at the molecular scale to the patterns of gas behavior at the macroscopic scale.
9c	**Experience 4: Gases in Earth's Atmosphere (p. 37-40)**
9c1	Identify the main gases in Earth's atmosphere.
9c2	Explain Dalton's law of partial pressure.
9c3	Describe the process that causes wind and its impact at local, regional, and global scales.
9c4	Relate relative humidity to water vapor partial pressure and air temperature.

10. WEATHER AND CLIMATE

Weather and Climate (10.5 days)

Phenomena: What is causing a drought in California?

10a	**Experience 1: Earth's Surface Systems (p. 37, 39, 52, 75)**
10a1	Analyze data to make a claim that a change to Earth's surface can cause changes to other Earth systems; describe the impact of various geochemical cycles.
10b	**Experience 2: Water and Energy in the Atmosphere**
10b1	Discuss how small changes can affect Earth's energy budget and climate.
10b2	Explain the impact of albedo in Earth's climate.
10b3	Analyze the amount of incoming and outgoing energy absorbed by the atmosphere.
10b4	Explain how unequal heating of the Earth's surface produces local winds, but when combined with the Coriolis Effect can produce consistent, predictable global winds.
10b5	Identify the processes and the reservoirs of the carbon cycle, and identify the impacts humans have had on this cycle
10c	**Experience 3: Atmospheric System Feedbacks**
10c1	Investigate and model the effects of changes on Earth's systems, including feedback that accelerates or slows changes to the systems.
10c2	Differentiate between positive and negative feedback loops; describe examples of each, particularly as relate to climate change
10d	**Experience 4: Long-Term Climate Factors**
10d1	Describe the factors that affect carbon dioxide concentration in Earth's atmosphere and use these factors to make predictions about the atmosphere under changing conditions.
10d2	Analyze and interpret data relating to the impact of carbon dioxide in Earth's atmosphere.
10e	**Experience 5: Short-Term Climate Factors**
10e1	Understand how changes in solar energy, ocean circulation, tectonic events, and human activity can cause changes in regional and global climate on a variety of time scales.

11. CLIMATE CHANGE

Climate Change (13 days)

Phenomena: What is causing an increase in floods?

11a	**Experience 1: The Chemistry of Earth's Atmosphere**
11a1	Develop a model to explain what happens when the sun's energy is absorbed by Earth's surface and then converted into infrared radiation.
11a2	Describe how a greenhouse gas differs from other atmospheric gases such as nitrogen and oxygen.
11a3	Describe the three ways molecules oscillate as they absorb energy.
11a4	Identify the most common greenhouse gases.
11b	**Experience 2: Evidence of Climate Change**
11b1	Discover how ice cores can be used to reconstruct a picture of past changes in Earth's climate.
11b2	Investigate the relationship between past sea levels and average global temperatures.
11b3	Discover how living organisms, such as coral and trees, can be used to make inferences about climate trends.
11c	**Experience 3: Anthropogenic Carbon Emissions**
11c1	Investigate the relationship between atmospheric carbon dioxide concentrations and global climate change.
11c2	Describe how the isotopic composition of atmospheric carbon can be used to predict its source.
11d	**Experience 4: Climate Models**
11d1	Discover how computer models are used to predict long-term climate trends.
11d2	Investigate the relationship between climate change and extreme weather events.

12. REACTION RATES AND EQUILIBRIUM

Investigation 12: Reaction Rates and Equilibrium (10.5 days)

Phenomena: How do limestone caves form?

12a	**Experience 1: Rate of Reaction**
12a1	Develop and use a model to show the effect of concentration and temperature on reaction rate (collision theory).
12a2	Use a graph of concentration changes vs time to describe how rates change.
12a3	Make predictions about changes in reaction with changes in concentration and temperature.
12b	**Experience 2: The Progress of Chemical Reactions**
12b1	Interpret an energy diagram, being able to explain activation energy, activated complex and the impact of catalysts/enzymes on the diagram.
12c	**Experience 3: Reversible Reactions and Equilibrium**
12c1	Define equilibrium and use Le Chatelier's principle to predict the direction a reaction at equilibrium will shift if disrupted by a change in concentration, temperature, or pressure.
12c2	Explain how variables such as temperature and pressure can be adjusted to increase or decrease yield in a reaction.
12d	**Phenomena: Limestone Cave Formation**
12d1	Explain how limestone is dissolved by (and precipitates from) underground water and what features result.

13. ACID-BASE EQUILIBRIA

Investigation 13: Acid-Base Equilibria (10 days)

Phenomena: How does acid rain impact the environment?

13a	**Experience 1: Acids, Bases, and Salts**
13a1	Be able to identify and describe why molecules behave as acids or bases (Bronsted-Lowry).
13a2	Calculate the pH value for a solution given its H+ ion concentration.
13a3	Describe the differences in properties between acids and bases.
13b	**Experience 2: Strong and Weak Acids and Bases**
13b1	Explain the difference between strong and weak acids and bases.
13c	**Experience 3: Reactions of Acids and Bases**
13c1	Describe acid-base neutralization reactions, both qualitatively and quantitatively.
13c2	Perform an acid-base titration, and use the data to find the concentration of unknown solutions.
13c3	Design an experiment that investigates how the properties of water (pH) affect earth materials (limestone)

14. OCEAN ACIDIFICATION

Investigation 14: Ocean Acidification (8 days)

Phenomena: What is happening to the world's coral reefs?

14a	**Experience 1: Ocean pH Levels**
14a1	Identify global patterns of ocean pH.
14a2	Apply principles of chemical equilibrium to explain ocean pH.
14b	**Experience 2: The Ocean as a Carbon Sink**
14b1	Explain the relationship between temperature and dissolved gas in ocean water.
14b2	Analyze data to explain how human carbon emissions have affected ocean pH.
14b3	Develop a model of the cycling of carbon in the ocean and explain the multiple factors affecting ocean pH
14c	**Experience 4: Consequences of Ocean Acidification**
14c1	Investigate how the presence of carbonate or bicarbonate ions affects the formation and breakdown of calcium carbonate in a marine environment.
14c2	Argue a claim, using evidence and reasoning, about the impact of temperature and pH on ocean ecosystems.
14c3	Analyze data to make the claim that one change in Earth's surface can create feedbacks that cause changes to other Earth systems.
14c4	Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.
14c5	Describe other consequences of ocean acidification; including coral bleaching, red tides, and the disruption of marine ecosystems

Unit 16: ORGANIC CHEMISTRY

Investigation 16: Organic Chemistry (7.5 days)

Phenomena: How is energy stored in food?

16a	**Experience 1: Hydrocarbons**
16a1	Use models to represent straight-chain, branched, and cyclical hydrocarbons.
16b	**Experience 2: Functional Groups and Polymers**
16b1	Identify functional groups in organic molecules.
16b2	Use models to represent various reactions involving organic molecules, including addition, substitution, and condensation reactions.
16b3	Describe the process of polymerization.
16c	**Experience 3: The Chemistry of Life**
16c1	Distinguish the structures and functions of the major classes of biomolecules, including carbohydrates, lipids, proteins, and nucleic acids.
16c2	Explain how large biomolecules form from smaller molecules.

Additional Units (if time):

Nuclear Power Plants, nuclear medical technologies (Investigation 17, Experience 3)

Redox: The Battery

Chemistry Honors: Chemistry of Earth Systems
Units and Objectives

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Units	NGSS
Big Bang and Nuclear Chemistry	ESS1-1, ESS1-2, ESS1-3, PS1-8
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The Periodic Table	PS1-1
Chemical Bonding	PS1-3
Chemical Quantities	PS1-2
Chemical Reactions	PS1-2
Stoichiometry	PS1-7
Copper Unlimited Project	ESS3-2
Thermochemistry	PS1-4, PS3-1, PS3-4
Gases	
Weather and Climate	ESS2-2
Climate Change	ESS2-4, ESS3-5, ESS3-6
Reaction Rates and Equilibrium	PS1-5, PS1-6
Acid-Base Equilibria	
Ocean Acidification	ESS2-6
Organic Chemistry	PS2-6

Regular and Honors have the same units, however the Honors course has additional learning objectives within units that increase the rigor of the course. In addition, Honors level students will be asked to delve deeper into

objectives, to use critical thinking skills that incorporate multiple learning objectives across multiple units, and to apply those skills to novel situations.

Chemistry: Chemistry of Earth Systems

1: WHERE DOES "STUFF" COME FROM? (Investigation 1 and 17)

Big Bang, Nuclear (10 days)

Question: Where does "stuff" come from?

Extension (project?) if time: Experience 3: Nuclear Technologies (Nuclear power plants, nuclear medical technology)

1a	**The Big Bang**
1a1	Describe the big bang theory and compositional evidence for it.
1b	**Investigation 1 Experience 2: Modeling atoms (p. 12-21)**
1b1	Describe atomic structure using a model of the atom that includes protons, neutrons and electrons.
1b2	Compare and contrast atoms of different elements and isotopes of the same element including mass number, atomic mass, isotopic notation and isotopic abundance.
1b3	I can calculate the atomic mass of an element given isotope data.
1c	**Investigation 17 Experience 2: Fusion: Stars/Life Cycle, Formation of Elements**
1c1	Explain the role of fusion in the formation of new elements in the three different life cycles of stars.
1c2	Develop models to explain the conservation of mass and energy during the processes of fission and fusion.
1c3	Describe conversions between mass and energy during the Big Bang and other nuclear processes.
1d	**Investigation 17 Experience 1: Radioactivity and Half-Lives, Radioactive Decay, Half-life and Applications**
1d1	Describe the particles and forces present in the atomic nucleus.
1d2	Develop models to illustrate the changes in the composition of the atomic nucleus and the energy released during radioactive decay.
1d3	Use mathematics to calculate the half-life of a radioactive substance and the approximate age of earth materials in order to decipher the age and history of the earth.
1d4	Calculate the age of ocean crust to infer plate movement direction and rate of movement.

2: WHERE DOES "STUFF" COME FROM? (Investigation 1)

Atomic structure, Emissions Spectra and Electrons (9 days)

Phenomena: What causes colors in a fireworks display?

2a	**Investigation 1 Experience 3: Atomic Emissions Spectra and the Bohr model (p. 19-20)**
2a1	Develop and use Bohr models for atoms illustrating electron energy levels and the placement of electrons within those levels with an emphasis on valence electrons.
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2a4	Evaluate the spectra of different light sources and differentiate between spectral types.
2a5	Use spectra to gauge the composition of stars, galaxies, nebulae
2a6	Evaluate the Doppler effect on spectra to determine direction and relative speeds of objects and as evidence for the Big Bang.
2b	**Investigation 1 Experience 4: Modern Atomic Theory (p. 28-32)**
2b1	Explain how the quantum mechanical nature of the electron gave rise to modern atomic orbital theory.
2b2	Evaluate how the quantum mechanical nature of the electron can be used to refine models of the atom up to and including atomic orbitals.
2c	**Investigation 1 Experience 5: Electrons in Atoms (33-39)**
2c1	Predict the valence electrons in an atom using the periodic table as a model.
2c2	Write the electron configuration of an atom using the periodic table as a model, including Noble gas shorthand configuration.
2c3	Use electron dot structures to represent an atom's valence electrons.

2. THE PERIODIC TABLE

The Periodic Table (9.5 days)

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3d	**Investigation 2 Experience 2: The Periodic Table and Atomic Structure (p. 50-55)**
3d1	Explain how the periodic table can be used to predict the electron configuration of an element.
3d2	Use Coulomb's law to explain effective nuclear charge and why the positive charge exerted by an atomic nucleus is not protons.
3d3	Describe how electron configuration and Coulomb's law give rise to trends in the periodic table.
3d4	Explain periodic table patterns of effective nuclear charge across a period of main group elements.
3e	**Investigation 2 Experience 3: Periodic Trends (p. 56-64)**
3e1	Investigate and explain reactivity patterns in the periodic table using concepts of ionization energy, net effective charge
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5b2	Calculate the density of a gas at STP, given the molar mass of the gas.
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Chemical Reactions (7.5 days)

Phenomena: How is energy obtained from chemical reactions? Rocket launching.

6a	**Experience 1: Modeling Chemical Reactions (p. 216-226)**
6a1	Identify the parts of a chemical reaction, and balance equations for these chemical reactions.
6a2	Distinguish between endothermic reactions and exothermic reactions.
6a3	Develop a basic conceptual and mathematical model for the generation of energy from the reaction of two substances based on bond energies.
6b	**Experience 2: Predicting Outcomes of Chemical Reactions (p. 227-240)** **Experience 3: Reactions in Aqueous Solution (p. (241-248)**
6b1	Identify the five general types of chemical reactions.
6b2	Predict the outcome of certain reactions based on the reactants, including identifying precipitates.
6c1	Be able to write net ionic equations in order to describe reactions in aqueous solution and identify the spectator ions.

7. STOICHIOMETRY

Stoichiometry (8 days) + Copper Unlimited project (5 days)

Phenomena: What can make a recipe fail?

Project: Copper Unlimited

7a	**Experience 1: Quantifying Reactants and Products (p. 252-258)**
7a1	Analyze data on proportionality of reactants and products to predict their stoichiometric ratios in the corresponding chemical equation.
7a2	Develop a model that demonstrates conservation of mass in a chemical equation.
7b	**Experience 2: Chemical Calculations (p, 259-268)**
7b1	Use the mole ratio in a chemical reaction to relate amounts of participating substances.
7b2	Use stoichiometry to convert between grams and moles in a chemical reaction.
7c	**Experience 3: Limiting Reagent and Percent Yield (p. 269-278)**
7c1	Explain the concept of limiting reactant and compute theoretical yield.
7c2	Explain the theoretical and actual yield and calculate percent yield.
7c3	Compute the amount of excess reactant remaining in a limiting reactant situation.

Copper Unlimited Lab Project

7d	**Copper Unlimited Lab Project**
7d1	ESS3-2: Evaluate competing design solutions for developing, managing and utilizing energy and mineral resources on cost benefit ratios.
7d2	Describe the ways in which energy resources are extracted and processed, as well as their environmental costs.

8. THERMOCHEMISTRY

Thermochemistry (8 days)

Phenomena: Why do you get hot when you exercise?

8a	**Experience 1: Energy in Chemical Bonds (p. 282-290)**
8a1	Explain how molecules must collide with each other with sufficient energy and in the correct orientation for a chemical reaction to take place.
8a2	Represent energy changes in exothermic and endothermic reactions using an enthalpy diagram.
8a3	Calculate enthalpy of reaction from bond energies and molar enthalpy of reaction data.
8b	**Experience 3: Enthalpy in Changes of State**
8b1	Understand how and why substances change in enthalpy when transitioning between physical states.
8b2	Calculate the change in enthalpy for state changes between solid, liquid, and gas.
8b3	Describe the link between state change enthalpies and the strength of intermolecular forces.
8c	**Enthalpy and Changes in Temperature**
8c1	Calculate the quantity of energy involved in temperature changes ($q=sm\Delta T$).
8c2	Explain how specific heat of water compared to other Earth materials produces differences in the temperature profile of: locations at the same latitude near and far from oceans, locations at the same latitude in the Northern vs. Southern Hemisphere

9. GASES

The Behavior of Gases (9.5 days)

Phenomena: What causes the Santa Ana winds?

9a	**Experience 1: Properties of Gases (p. 6-9)**
9a1	Use particle pictures to explain the differences between solids, liquids and gases.
9a2	Use the kinetic theory to explain the properties of gases (motion of particles, diffusion, compressibility, have mass, volume, exert pressure, etc.)
9a3	Describe the effects on gases of changes in volume, temperature, pressure, and the number of particles.
9b	**Experience 2: The Gas Laws (p. 11-22)**
9b1	Investigate and explain the relationship between the volume, temperature, and pressure of a gas.
9b2	Develop and use models to explain the gas laws.
9b3	Relate the patterns of interaction between gas particles at the molecular scale to the patterns of gas behavior at the macroscopic scale.
9c	**Experience 4: Gases in Earth's Atmosphere (p. 37-40)**
9c1	Identify the main gases in Earth's atmosphere.
9c2	Explain Dalton's law of partial pressure.
9c3	Describe the process that causes wind and its impact at local, regional, and global scales.
9c4	Relate relative humidity to water vapor partial pressure and air temperature.

10. WEATHER AND CLIMATE

Weather and Climate (10.5 days)

Phenomena: What is causing a drought in California?

10a	**Experience 1: Earth's Surface Systems (p. 37, 39, 52, 75)**
10a1	Analyze data to make a claim that a change to Earth's surface can cause changes to other Earth systems; describe the impact of various geochemical cycles.
10b	**Experience 2: Water and Energy in the Atmosphere**
10b1	Discuss how small changes can affect Earth's energy budget and climate.
10b2	Explain the impact of albedo in Earth's climate.
10b3	Analyze the amount of incoming and outgoing energy absorbed by the atmosphere.
10b4	Explain how unequal heating of the Earth's surface produces local winds, but when combined with the Coriolis Effect can produce consistent, predictable global winds.
10b5	Identify the processes and the reservoirs of the carbon cycle, and identify the impacts humans have had on this cycle
10c	**Experience 3: Atmospheric System Feedbacks**
10c1	Investigate and model the effects of changes on Earth's systems, including feedback that accelerates or slows changes to the systems.
10c2	Differentiate between positive and negative feedback loops; describe examples of each, particularly as relate to climate change
10d	**Experience 4: Long-Term Climate Factors**
10d1	Describe the factors that affect carbon dioxide concentration in Earth's atmosphere and use these factors to make predictions about the atmosphere under changing conditions.
10d2	Analyze and interpret data relating to the impact of carbon dioxide in Earth's atmosphere.
10e	**Experience 5: Short-Term Climate Factors**
10e1	Understand how changes in solar energy, ocean circulation, tectonic events, and human activity can cause changes in regional and global climate on a variety of time scales.

11. CLIMATE CHANGE

Climate Change (13 days)

Phenomena: What is causing an increase in floods?

11a	**Experience 1: The Chemistry of Earth's Atmosphere**
11a1	Develop a model to explain what happens when the sun's energy is absorbed by Earth's surface and then converted into infrared radiation.
11a2	Describe how a greenhouse gas differs from other atmospheric gases such as nitrogen and oxygen.
11a3	Describe the three ways molecules oscillate as they absorb energy.
11a4	Identify the most common greenhouse gases.
11b	**Experience 2: Evidence of Climate Change**
11b1	Discover how ice cores can be used to reconstruct a picture of past changes in Earth's climate.
11b2	Investigate the relationship between past sea levels and average global temperatures.
11b3	Discover how living organisms, such as coral and trees, can be used to make inferences about climate trends.
11c	**Experience 3: Anthropogenic Carbon Emissions**
11c1	Investigate the relationship between atmospheric carbon dioxide concentrations and global climate change.
11c2	Describe how the isotopic composition of atmospheric carbon can be used to predict its source.
11d	**Experience 4: Climate Models**
11d1	Discover how computer models are used to predict long-term climate trends.
11d2	Investigate the relationship between climate change and extreme weather events.

12. REACTION RATES AND EQUILIBRIUM

Investigation 12: Reaction Rates and Equilibrium (10.5 days)

Phenomena: How do limestone caves form?

12a	**Experience 1: Rate of Reaction**
12a1	Develop and use a model to show the effect of concentration and temperature on reaction rate (collision theory).
12a2	Use a graph of concentration changes vs time to describe how rates change.
12a3	Make predictions about changes in reaction with changes in concentration and temperature.
12b	**Experience 2: The Progress of Chemical Reactions**
12b1	Interpret an energy diagram, being able to explain activation energy, activated complex and the impact of catalysts/enzymes on the diagram.
12c	**Experience 3: Reversible Reactions and Equilibrium**
12c1	Define equilibrium and use Le Chatelier's principle to predict the direction a reaction at equilibrium will shift if disrupted by a change in concentration, temperature, or pressure.
12c2	Explain how variables such as temperature and pressure can be adjusted to increase or decrease yield in a reaction.
12c3	Quantitatively describe equilibrium using Keq values. (ICE tables, etc.)
12d	**Experience 4: Free Energy and Entropy**
12d1	Explain what entropy is.
12d2	Identify the four kinds of changes that increase the disorder or predictability of a system.
12d3	Relate entropy, enthalpy, and free energy.
12e	**Phenomena: Limestone Cave Formation**
12e1	Explain how limestone is dissolved by (and precipitates from) underground water and what features result.

13. ACID-BASE EQUILIBRIA

Investigation 13: Acid-Base Equilibria (10 days)

Phenomena: How does acid rain impact the environment?

13a	**Experience 1: Acids, Bases, and Salts**
13a1	Be able to identify and describe why molecules behave as acids or bases (Bronsted-Lowry).
13a2	Calculate the pH value for a solution given its H+ ion concentration.
13a3	Describe the differences in properties between acids and bases.
13b	**Experience 2: Strong and Weak Acids and Bases**
13b1	Explain the difference between strong and weak acids and bases.
13b2	Rank acids in order of strength.
13b3	Describe how the equilibrium conditions for strong and weak acids and bases are different.
13b4	Use the acid ionization constant (K_a) to predict the relative concentrations of the acid and hydronium ion at equilibrium.
13b5	Calculate the pH for weak acids and bases, using K_a and K_b expressions.
13c	**Experience 3: Reactions of Acids and Bases**
13c1	Describe acid-base neutralization reactions, both qualitatively and quantitatively.
13c2	Perform an acid-base titration, and use the data to find the concentration of unknown solutions.
13c3	Design an experiment that investigates how the properties of water (pH) affect earth materials (limestone)

14. OCEAN ACIDIFICATION

Investigation 14: Ocean Acidification (8 days)

Phenomena: What is happening to the world's coral reefs?

14a	**Experience 1: Ocean pH Levels**
14a1	Identify global patterns of ocean pH.
14a2	Apply principles of chemical equilibrium to explain ocean pH.
14b	**Experience 2: The Ocean as a Carbon Sink**
14b1	Explain the relationship between temperature and dissolved gas in ocean water.
14b2	Analyze data to explain how human carbon emissions have affected ocean pH.
14b3	Develop a model of the cycling of carbon in the ocean and explain the multiple factors affecting ocean pH
14c	**Experience 4: Consequences of Ocean Acidification**
14c1	Investigate how the presence of carbonate or bicarbonate ions affects the formation and breakdown of calcium carbonate in a marine environment.
14c2	Argue a claim, using evidence and reasoning, about the impact of temperature and pH on ocean ecosystems.
14c3	Analyze data to make the claim that one change in Earth's surface can create feedbacks that cause changes to other Earth systems.
14c4	Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.
14c5	Describe other consequences of ocean acidification; including coral bleaching, red tides, and the disruption of marine ecosystems

Unit 16: ORGANIC CHEMISTRY

Investigation 16: Organic Chemistry (7.5 days)

Phenomena: How is energy stored in food?

16a	**Experience 1: Hydrocarbons**
16a1	Use models to represent straight-chain, branched, and cyclical hydrocarbons.
16b	**Experience 2: Functional Groups and Polymers**
16b1	Identify functional groups in organic molecules.
16b2	Use models to represent various reactions involving organic molecules, including addition, substitution, and condensation reactions.
16b3	Describe the process of polymerization.
16c	**Experience 3: The Chemistry of Life**
16c1	Distinguish the structures and functions of the major classes of biomolecules, including carbohydrates, lipids, proteins, and nucleic acids.
16c2	Explain how large biomolecules form from smaller molecules.

Additional Units (if time):

Nuclear Power Plants, nuclear medical technologies (Investigation 17, Experience 3)

Redox: The Battery