# Honors Chemistry in the Earth System 361413H/14H

Title: Honors Chemistry in The Earth System
Length of course: Full Year
Subject area: Laboratory Science (D) / Chemistry
UC honors designation? Yes
Prerequisites:
BIOLOGY OF LIVING EARTH (Required)
ALGEBRA 1 (Required)
Co-requisites:
GEOMETRY (Recommended)
Integrated (Academics / CTE)? No
Grade levels:10th, 11th, 12th

## Course Description

Course overview:

Chemistry in the Earth System Honors is an NGSS-aligned course that fulfills a physical science laboratory requirement for graduation as well as an entrance requirement for the University of California and California State University schools. Chemistry is a sequential, hierarchical science that is descriptive and theoretical and requires high-level problem-solving skills, such as designing experiments and solving word problems. Students will discover and be able to explain the nature of matter and its transformations when they study atomic and molecular structure, the effects of electron interaction, chemical bonds, and stoichiometry. Additionally, students will study the properties of gases, acids, and bases, solutions, and organic and inorganic compounds. Students will also explore chemical systems as they study solutions, reactions, and nuclear processes. This Honors course is an in-depth version of Chemistry in the Earth System.

Course content:

**Unit 0: Reviewing Science and Engineering Practices (SEP)**

In this introductory unit, students will get reacquainted with the ***science and engineering practices*** from prior science and/or engineering classes, most likely Biology of Living Earth. In this unit, students will design a small experiment, and in doing so will build on their previous scientific skills including: safety procedures and policies, research

background information and prior findings, design an experiment, identify independent and dependent variables, conduct experiment, read measuring instruments (temperature, length, weight/mass), log data into notebook, organize data into tables, convert data tables into graphs, analyze and evaluate results, account for experimental error, and communicate results using CLAIM, EVIDENCE, and REASON and through a scientific report. While, we will cover some SEPs in this introductory unit, all SEPs will be addressed in further depth and detail throughout the yearlong course as they become applicable to the unit in question.

CONTENT (to be covered as students conduct their experiment):

The nature of science and the scientific processes allow scientists to be able to study natural phenomena by following a collective series of steps, in which observations lead to questions, questions to possible hypotheses, then testing of the hypothesis by only changing one variable, analyzing the results, and drawing conclusions to determine the validity of both the data (experiment) and the hypothesis. In the scientific community, if a hypothesis has obtained substantial evidence, then it can become a theory. On the other hand, a law is a statement (can be mathematical) that describes (not explains) natural phenomena.

One significant differentiation in this honors course is attention to and analysis of experimental error. When conducting an experiment, it is important to note the quality of the data. There will always be human error, and this should always be noted in the discussion part of a lab report. It is important to be both accurate AND precise. (Accuracy is how close the experimental value is to the true value, and precise is how exact the experimental value is.) Measurement uncertainties and significant figures will be used to reflect the exactness of such measurements. Significant figures are important because they indicate the “certain” versus the “uncertain” values that are obtained from a measuring tool. In addition, percent experimental error is used to calculate the accuracy of the data, how close the experimental value is to the actual value. The formula for percent error is the following:

% Error = (Theoretical Value - Experimental Value)/Theoretical Value) x 100

It is important to understand how to read instruments in science, especially in Chemistry where things are read at a smaller scale. The ability to read and collect data both accurately and precisely will determine the quality of the data. Chemistry studies matter and its properties, which can be measured in multiple ways. The volume (the amount of space an object occupies) matter takes up can be determined by using several measuring tools, (beaker, Erlenmeyer flask, graduated cylinder, pipette, burette, etc. Matter can also be measured by determining its mass, which is different than the weight. Mass is the amount of matter/substance, while weight is how the gravitational force acts on the matter. A balance is used to determine the mass of a substance (electronic balance, triple-beam balance, etc).

Chemistry uses the SI units: meter for length, kilogram for mass, second for time, kelvin for temperature, and mole for amount of substance. It also uses prefixes to easily convert between a large unit and a small unit. Some of the prefixes are as follow: *Kilo- (k)* is for 1000, *centi- (c)* is for 1/100, and *Milli- (m)* is for 1/1000. Some units are derived, meaning they come from a combination of units. Volume is one of these units: 1L = 1000 ml = 1000 cm3.

**Unit Assignment(s):**

**Sample Assignment:** Where in the World is Carbon Dioxide?

**Major Focus Question:** What are the relative concentrations of $CO_2$ from different sources?

**Assignment Overview:** Students will be taking a look at the amount of carbon dioxide that is released from different sources. Now that students are aware that carbon dioxide is a greenhouse gas that is a major cause for today’s climate change, they will be able to determine where most of the carbon dioxide is coming from. Using a balloon, students (or teacher) will collect carbon dioxide from breathing (cellular respiration), fossil fuels (car exhaust), and outside air. They will determine the amount of carbon dioxide in each solution using Bromothymol Blue solution, in which $CO_2$ reacts with water to form carbonic acid, and the carbonic acid will change the color of the solution from blue to green and then to yellow. Students will use this information to identify the pH of the solution, and therefore the amount of carbon dioxide in each of the tested variables. Students will be placing their data in a designated bound notebook. Students will need to submit a finalized lab report on their findings. In addition, students will research the current carbon dioxide levels are for Los Angeles, have heavily populated cities and compare it to rural cities. Students will also look at whether the amount of carbon dioxide has increased throughout the years.

**Unit Lab Activities:**

The laboratory activities are inquiry-based and discovery-based, and serve to prepare students for university-level study. Through these labs, students will engage in hands on activities utilizing their scientific thinking. Each lab will allow students to observe natural phenomena, identify methods of collecting and organizing data, evaluating the data, and interpreting/analyzing the data. Students will be required to make observations and predictions of their observations. With this information, students will be aided in forming a testable hypothesis, and in turn they will design an experiment to test their hypothesis, collect the data, and draw a conclusion of their hypothesis by linking their data and analysis of data to evaluate their overall experimental design. The overall goal is for students to learn that science is more than just theories, but a process of learning about the natural world through experimentation and research.

**Unit 1: Combustion**

NGSS Standards: *(note: many standards in this unit are not going to be fully covered until a later unit)*

**HS-PS1-3. Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.** [Clarification Statement: Emphasis is on understanding the strengths of forces between particles, not on naming specific intermolecular forces (such as dipole-dipole). Examples of particles could include ions, atoms, molecules, and networked materials (such as graphite). Examples of bulk properties of substances could include the melting point and boiling point, vapor pressure, and surface tension.] [Assessment Boundary: Assessment does not include Raoult's law calculations of vapor pressure.]

**HS-PS1-4. Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.** [Clarification Statement: Emphasis is on the idea that a chemical reaction is a system that affects the energy change. Examples of models could include molecular-level drawings and diagrams of reactions, graphs showing the relative energies of reactants and products, and representations showing energy is conserved.] [Assessment Boundary: Assessment does not include calculating the total bond energy changes during a chemical reaction from the bond energies of reactants and products.]

**HS-PS1-7. Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.** [Clarification Statement: Emphasis is on using mathematical ideas to communicate the proportional relationships between masses of atoms in the reactants and the products, and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale. Emphasis is on assessing students' use of mathematical thinking and not on memorization and rote application of problem-solving techniques.] [Assessment Boundary: Assessment does not include complex chemical reactions.]

**HS-PS3-1. Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.** [Clarification Statement: Emphasis is on explaining the meaning of mathematical expressions used in the model.] [Assessment Boundary: Assessment is limited to basic algebraic expressions or computations; to systems of two or three components; and to thermal energy, kinetic energy, and/or the energies in gravitational, magnetic, or electric fields.]

**Guiding Questions:**

- What is energy, how is it measured, and how does it flow within a system?
- What mechanisms allow us to utilize the energy of our foods and fuels?

**Unit Overview:**

The focus of this unit will be nutrition and combustion. Students will start by looking at the nutrition facts of different "groups" of food: lipids, carbohydrates, and protein. Students will use explore how each different type of macromolecule provides energy to the body. This exploratory assignment is to determine students' current understanding of nutrition, specifically calories, what chemical components of food actually gives us energy. Students will explore questions like: What are Calories? and How do we measure Calories? Students will use the questions they obtain from this engagement assignment to construct their own calorimetry experiment. Students will be asked to analyze the data from their experiment and to determine temperature and mass patterns, and eventually come up with the conclusion that 'large mass = more energy.' Students will investigate what happens to mass during combustion, while learning about conservation of mass. They will also develop a model to represent to flow of energy in the system to understand where the unaccounted for mass/energy went, and prompted to ask questions that will lead them to ask about how changing their experimental design can change their results. Will a different can cause different increases in temperature (specific heat capacity)? Will using something other than water cause a different change in temperature (specific heat capacity and thermal conductivity)?  This subsection will end by having students revise their design and repeat their experiment using one of their new questions to discover more information about

specific heat capacity and combustion. The next subsection will expand on prior knowledge. Students will focus on the similarities and differences between combustion and cellular respiration, and why their calorimetry experiment does not account for non-digestible calories. In this section students will also focus on an introduction into endothermic and exothermic process, and be able to connect the net reaction of photosynthesis to an exact opposite net reaction of cellular respiration.

**Unit Assignment(s):**

**Sample Assignment:** Combustion Machines Research (Machine Efficiency)

**Major Focus Question:** What is internal-combustion? How do car engines work, and why is gasoline a very inefficient way of making a car move?

**Assignment Overview:** In this assignment, students will work in groups to research different combustion machines. Students will pick one of the following combustion machines: automobile, steam engine, coal facility plant, ships, motorcycles, water vehicles, airplanes, etc. Students will research the efficiency of obtaining the energy from each engine. They will take a look at how much energy is lost to the environment within the system. Students will create a slide presentation to present their findings to their classmates.

**Unit Lab Activities:**

**Lab 1:** Calorimetry Lab Part 1

**Major Focus Question:** Where does the mass of the food go after combustion?

**Lab Overview:** Students will be working on the Calorimetry experiment twice this semester, specially because there is now a greater emphasis on combustion this year. During this initial Calorimetry experiment, students will be comparing reactions such as combustion to food digestion and cellular respiration. Students will also focus on where both energy and mass goes after combustion. Students will conduct the calorimetry lab to explore where the energy stored in food goes. Students will draw a model that illustrates the flow of energy within the system. The goal is for students to recognize that energy never created or destroyed, but that it is transferred from one system to another. From the food into the water. Students will only be collecting initial mass of food, final mass of food, initial temperature of water, and final temperature of water. They should note that the temperature of water has increased, so therefore the calories in food has been transferred to the water. This is an opportunity for students to ask questions (SEP #1) about what they observed.  The teacher should direct the students to notice that the mass decreased and initiate the discussion question, "Where did the mass go?" Students might also note that the mass has decreased, and after being prompted to research, also determine that the mass did not disappear but has been released in the form of gas.

**Unit 2: Heat and Energy in the Earth System**

NGSS Standards:

**HS-PS3-1. Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.** [Clarification Statement: Emphasis is on explaining the meaning of mathematical expressions used in the model.] [Assessment Boundary: Assessment is limited to basic algebraic expressions or computations; to systems of two or three components; and to thermal energy, kinetic energy, and/or the energies in gravitational, magnetic, or electric fields.]

**HS-PS3-2. Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as either motions of particles or energy stored in fields.** [Clarification Statement: Examples of phenomena at the macroscopic scale could include the conversion of kinetic energy to thermal energy, the energy stored due to position of an object above the earth, and the energy stored between two electrically-charged plates. Examples of models could include diagrams, drawings, descriptions, and computer simulations.]

**HS-PS3-4. Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).** [Clarification Statement: Emphasis is on analyzing data from student investigations and using mathematical thinking to describe the energy changes both quantitatively and conceptually. Examples of investigations could include mixing liquids at different initial temperatures or adding objects at different temperatures to water.] [Assessment Boundary: Assessment is limited to investigations based on materials and tools provided to students.]

**HS-ESS2-3. Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection.** [Clarification Statement: Emphasis is on both a one-dimensional model of Earth, with radial layers determined by density, and a three-dimensional model, which is controlled by mantle convection and the resulting plate tectonics. Examples of evidence include maps of Earth's three-dimensional structure obtained from seismic waves, records of the rate of change of Earth's magnetic field (as constraints on convection in the outer core), and identification of the composition of Earth's layers from high-pressure laboratory experiments.]

**HS-ESS2-2. Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth's systems.** [Clarification Statement: Examples should include climate feedbacks, such as how an increase in greenhouse gases causes a rise in global temperatures that melts glacial ice, which reduces the amount of sunlight reflected from Earth's surface, increasing surface temperatures and further reducing the amount of ice. Examples could also be taken from other system interactions, such as how the loss of ground vegetation causes an increase in water runoff and soil erosion; how dammed rivers increase groundwater recharge, decrease sediment transport, and increase coastal erosion; or how the loss of wetlands causes a decrease in local humidity that further reduces the wetland extent.]

**HS-ESS2-3. Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection.** [Clarification Statement: Emphasis is on both a one-dimensional model of Earth, with radial layers determined by density, and a three-dimensional model, which is controlled by mantle convection and the resulting plate tectonics. Examples of evidence include maps of Earth's three-dimensional structure obtained from seismic waves, records of the rate of change of Earth's magnetic field (as constraints on convection in the outer core), and identification of the composition of Earth's layers from high-pressure laboratory experiments.]

**HS-ETS1-4. Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.**

**Guiding Questions:**

- How is energy transferred and conserved?
- How can energy be harnessed to perform useful tasks?

**Unit Overview:**

This unit's focus is on the laws of thermodynamics at the atomic scale, but also on the system as large as the Earth. Students will start to investigate the different forms of energy, and classify them as either potential or kinetic. Students will also connect energy to motion, motion of atoms (microscale) and the motion of the planet (macroscale). The amount of energy can be measured using temperature. Students will conduct a last Calorimetry experiment in which they will use the temperature to calculate the total amount of energy that transferred from one system into another. Temperature is the measurement of the average kinetic energy. Molecules are constantly moving, and the more energy they have, the more they move. Additionally, as such molecules collide, they can interact.

Also, energy is always moving from an area of high energy, into an area of low energy, until both (closed) systems have reached equilibrium. The energy is transferred through the collision of the molecules. Yet, no energy is created nor destroyed, it is only transformed from one form into another.

This unit will allow students to connect the chemistry to the earth science. Students will understand that the First Law of Thermodynamics applies to all earth systems, and systems in the universe. Energy comes into the biosphere as solar energy, which is then converted into chemical energy by photosynthetic organisms, it can then be transferred between one living organism into another. Also, such energy can cause the movement of wind and ocean currents.

The Second Law of Thermodynamics states that the amount of entropy in the universe (energy equilibrium and energy unavailability) is constantly increasing. Entropy is the driving force for diffusion and equilibrium. A system at equilibrium has no energy. However, two systems with different energy distributions have available energy. Students will use their knowledge to expand on their Energy Flow Model from unit 1.

Students will spend a good amount of time in this section taking a look at the macroscopic scale (the earth systems). The Second Law of Thermodynamics is the driving force for conduction, convection, and radiation. Because of the constant input of energy from either the Sun or radiation, the Earth system is constantly trying to reach equilibrium, but will never arrive unless all internal and external energy sources are depleted. To better understand convection, students will complete a simple convection lab, with water at different temperatures. Students will use this to develop a model that illustrates how convection affects the Earth's interior. The constant convection of the earth's mantle can cause seismic waves. Students will analyze models of the earth's core based on this data. Students will finish this unit by connecting the motion of plate tectonics to energy flow, and the changes that occur to the Earth over both short and long periods of time.

**Unit Assignment(s):**

**Sample Assignment 1: Process Oriented Guided Inquiry Learning** (POGIL)- Calorimetry

**Major Focus Question:** How can heat transfer help calculate the number of calories?

**Assignment Overview:** Staying with the topic of combustion and helping students make connections, students will on their own determine the formula for the specific heat of a substance. Students will work in groups and use different models to determine the relationship between energy (change of temperature) and volume. Students will use this information to build the foundation for the specific heat formula. In addition, students will test their formula by using it to predict the amount of heat that will be released in a chemical reaction. Lastly, students will compare the specific heat capacity of water to mercury to determine the ability of these two molecules to absorb and retain energy. (Students will be using their findings on a later assignment to learn the different properties of water.)

**Sample Assignment 2:** POGIL- Gas Variables

**Major Focus Question:** How does energy disperse within a container?

**Assignment Overview:** As students are taking a look at conventions, they will also take a look at the properties of gas. What can cause implosion, explosion within reactions? What causes the movement of the earth's mantle? What causes ocean currents or wind currents? This activity will help students understand and determine the gas laws that govern the earth. Students will work in groups to analyze different models in which they will determine the role in which factors such as volume, pressure, and temperature play on each other and molecular collisions. This assignment will also help students identify independent, dependent and controlled variables. In model 1, students will look at the gases in a non-flexible container. In model 2, students will look at gas inside a flexible (balloon) container. Using the models, students will work together to determine the relationships between the pressure and temperature, temperature and volume, and volume and pressure. Students will also be able to identify the Ideal Gas Law (from a list of several, all but one correct) that correctly indicates the relationship between all the three variables. Lastly, students will draw their own model to predict what happens if all three given examples were to cool down.

**Unit Lab Activities:**

**Sample Lab 1:** Calorimetry Lab Part -2

**Major Focus Question:** Which types of fuels are the most efficient?

**Lab Overview:** Students will once again explore Calorimetry, but this time using different types of biodiesel fuels, and now also calculate the total number of joules (calories) in each of the different types. Students will also be given the opportunity to design their experiment and to change their soda can with something else, or the water inside of the soda can with something else. This in turn will prompt students to think about specific heat capacity of metals and water. Nonetheless, they should notice that using the Specific Heat Capacity Formula will still heed similar results. Lastly, students will share and compare their group results to the rest of the class to evaluate the data obtained from the experiment from the expected outcome (what the research says) to determine where the rest of the energy escaped. Students will be placing their data in a designated bound notebook. Student will need to submit a finalized lab report on their findings.

**Sample Lab 2:** Convection currents

**Major Focus Question:** How is the bulk movement of water affected by temperature?

**Lab Overview:** Students set up an apparatus of 2 beakers of hot and cold water placed under a shoebox sized plastic tub filled with water. Drops of red and blue food coloring are added to opposite ends of the shoebox, which yields a visible convection current. To better visualize the effect, it is recommended to have students take time lapse videos with their personal electronic devices. This activity supports student interpretation of models of convection currents in the earth's mantle.

**Sample Lab 3:** Epicenters and Magnitude Lab Activity

**Major Focus Question:** Where Did the Earthquake Originate?

**Lab Overview:** After learning about conventions, students will dive deeper into the flow of energy within the earth systems. In this activity, students will use their gained knowledge to analyze seismogram measurements to determine the epicenter of two earthquakes, and determine the magnitude of the earthquakes according to Richter and Mercalli scales. In this lab, students will identify the p-wave and s-wave data, and determine the lag time for each seismogram. Students will also determine the distance using the Earthquake P-wave and S-wave travel time graph. Lastly, students will create a model that represents how the flow of energy in the earth systems can cause the movement of the tectonic plates. Students will not be required to turn in a finalized lab report, instead, they will be graded on the lab practices (including their bound notebook).

**Unit 3: Atoms, Elements, and Molecules**

NGSS Standards:

**HS-PS1-1. Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.** [Clarification Statement: Examples of properties that could be predicted from patterns could include reactivity of metals, types of bonds formed, numbers of bonds formed, and reactions with oxygen.] [Assessment Boundary: Assessment is limited to main group elements. Assessment does not include quantitative understanding of ionization energy beyond relative trends.]

**HS-PS1-2. Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.** [Clarification Statement: Examples of chemical reactions could include the reaction of sodium and chlorine, of carbon and oxygen, or of carbon and hydrogen.] [Assessment Boundary: Assessment is limited to chemical reactions involving main group elements and combustion reactions.]

**HS-PS1-7. Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.** [Clarification Statement: Emphasis is on using mathematical ideas to communicate the proportional relationships between masses of atoms in the reactants and the products, and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale. Emphasis is on assessing students' use of mathematical thinking and not on memorization and rote application of problem-solving techniques.] [Assessment Boundary: Assessment does not include complex chemical reactions.]

**Guiding Questions:**

- What is inside atoms and how does this affect how they interact?
- What models can we use to predict the outcomes of chemical reactions?

**Unit Overview:**

In this unit, students will finally take a look at the particles and properties of particles that account for the microscopic change in energy in the previous unit. They will start by exploring the development of the periodic table and the atomic model. Demitri Mendeleev was one of the scientist that looked at the patterns of both physical and chemical properties of elements, and used it to re-organize the periodic table by placing them into columns and rows. Students will be given similar information as Mendeleev. Students will be given cards with several pieces of information, asked to sort and categorize them, and lastly organize them in a way that makes sense. Students should be able to point out the repeating patterns: atomic mass, chemical properties, radius of atom, etc. Students will use their models, along with research they have conducted on their own, to connect the patterns to the atom's structure: protons, neutrons, and electrons.

Students will take a look at the noble gases to determine the best electron configuration. They will determine that atoms need a total of 8 valence electrons to be stable. Electrons that do not have such a configuration can either share electrons, or steal or lose electrons to obtain similar configurations to that of noble gasses. Such information can be used to predict which atoms are most likely to lose or gain electrons, and/or which atoms are most likely to create bonds by looking at the element's position within the periodic table. Students will connect electronegativity to the type of bond that it will make: non-polar covalent, polar covalent, ionic bond. Students will also look at metallic bonding and its special properties. There will be a greater emphasis on students using both SEP 6 and SEP 7, to construct explanations and argue from evidence, as they understand and recognize patterns that can be used to explain both physical and chemical properties of elements.

In this unit, students will also take a look at the conservation of matter and the Law of Definite proportions. Students will study what the mole is, and how to use the periodic table to calculate the amount of moles of a substance. Students will eventually use stoichiometry to show proof of the law of conservation of mass, from understanding how ratios (molar ratios) can be used to calculate and predict the total amount of products from the total amount of reactants obtained.

**Unit Assignment(s):**

**Sample Assignment 1:** POGIL- Bond Enthalpies

**Major Focus Question:** Where is the energy in chemicals stored?

**Assignment Overview:** The purpose of this activity is to help students relate the breaking or forming of bond with the absorption of energy (endothermic) or a release of energy (exothermic), define fond energy as energy needed to break ONE mole of bonds of a particular type, and calculate the approximate enthalpy change for a reaction using a table of average bond enthalpies. Students will look at several models. In model 1, students will compare two tables (bond breaking and bond forming) to conclude that these reactions are exact opposites of each other. The amount of energy that is needed to break a bond the the amount of energy need to make a bond of the same but reverse reaction. Students will also connect bond making to exothermic reactions and bond forming to endothermic reactions. Students will also be able to compare the bond enthalpies of single to double to triple bonds. Students will be able to work together to determine that the bond enthalpy for a double bond is NOT simply double that of a single bond, but that in fact, it has a tested enthalpy of it's own. Lastly, students will use their knowledge to learn how to calculate the net energy change of a reaction, and compare this to a single versus double carbon bond.

**Unit Lab Activities:**

**Sample Lab 1:** Atomic Theory

**Major Focus Question:** How were scientists able to determine the structure of the atom without being able to directly observe it?

**Lab Overview:** In this activity, students will follow in the footsteps of major scientists that helped develop today's atomic theory. There are three parts to this lab, each part exploring a subatomic particle that was discovered. Students will explore negative and positive charges using tape and balloon. Students will conclude that depending on the treatment of the tape, it will either be neutral (does not attract or repel), negative or positive. In addition, students will determine whether like things or dislike things repel or attract. In turn, they will use this information to see how JJ Thomson determined that there must have been an electron in the atom. In the second activity, students will be trying to determine the shape of styrofoam hidden under a board. The only way they can determine the shape is by tossing small marbles and tracking its path along the sand. Students will use this to understand how significant it was for Rutherford to see alpha particles both going through the gold foil and bouncing back. What did this say about the structure of the atom? Lastly, students will look at the nucleus. They will take a look at containers that are opened versus similar containers that are closed. The open containers represent what scientists knew; they knew that there were protons. However, the closed containers represent what scientists encountered. The mass that they expected was never the one that they obtained. Students will also have to hypothesize what makes the mass different. Students will be placing their data in a designated bound notebook. Students will need to submit a finalized lab report on their findings.

**Sample Lab 2:** Interpreting the Periodic Table

**Major Focus Question:** How can the periodic table be used to make useful predictions?

**Lab Overview:** Students will explore the most important properties of the periodic table through the following four activities. During Activity 1, students will rotate around the room in stations to gather information about the physical properties of certain specific elements. They will use their information to determine if any of the elements share properties. In Activity 2, students will explore the Halide Family. Students will add drops of Silver Nitrate into medicine cups with NaCl, KBr, and KI. These three compounds have elements from the Halide family that will react in a similar way (they will get cloudy), but also differently (different colors). Students should be able to conclude that elements from the same family react in a similar way. In Activity 3, students will explore the reactivity of several metals. They will explore reactivity of calcium, copper, magnesium, and zinc. Three of these metals are in the same period, and two of the metals are in the same group. Students will gather information about the overall reactivity of the metals to predict where the most reactive metals are on the periodic table. Students should conclude reactivity increases going down the periodic table and decreasing moving from left to right on the periodic table. Students will later investigate their predictions to see if they were close the expected outcome. The last activity, 4, students will be given several cards which are color coded, have the first ionization energy, electronegativity, atomic radius, atomic mass, and reactions with oxygen and chlorine. They will need to find a way to organize the cards so that it displays the physical and chemical properties in a categorical order. The ideal outcome would be one in which students organize the data using ALL of the properties and come up with a table similar to that of the modern periodic table. Students will be placing their data in a designated bound notebook. Student will need to submit a finalized lab report on their findings.

**Unit 4: Chemical Reactions**

NGSS Standards:

**HS-PS1-3. Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.** [Clarification Statement: Emphasis is on understanding the strengths of forces between particles, not on naming specific intermolecular forces (such as dipole-dipole). Examples of particles could include ions, atoms, molecules, and networked materials (such as graphite). Examples of bulk properties of substances could include the melting point and boiling point, vapor pressure, and surface tension.] [Assessment Boundary: Assessment does not include Raoult's law calculations of vapor pressure.]

**HS-PS1-4. Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.** [Clarification Statement: Emphasis is on the idea that a chemical reaction is a system that affects the energy change. Examples of models could include molecular-level drawings and diagrams of reactions, graphs showing the relative energies of reactants and products, and representations showing energy is conserved.] [Assessment Boundary: Assessment does not include calculating the total bond energy changes during a chemical reaction from the bond energies of reactants and products.]

**HS-PS2-4. Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.** [Clarification Statement: Emphasis is on both quantitative and conceptual descriptions of gravitational and electric fields.] [Assessment Boundary: Assessment is limited to systems with two objects.]

**HS-PS3–5. Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.** [Clarification Statement: Examples of models could include drawings, diagrams, and texts, such as drawings of what happens when two charges of opposite polarity are near each other.] [Assessment Boundary: Assessment is limited to systems containing two objects.]

**HS-PS1-5. 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.** [Clarification Statement: Emphasis is on student reasoning that focuses on the number and energy of collisions between molecules.] [Assessment Boundary: Assessment is limited to simple reactions in which there are only two reactants; evidence from temperature, concentration, and rate data; and qualitative relationships between rate and temperature.]

**HS-PS1-7. Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.** [Clarification Statement: Emphasis is on using mathematical ideas to communicate the proportional relationships between masses of atoms in the reactants and the products, and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale. Emphasis is on assessing students' use of mathematical thinking and not on memorization and rote application of problem-solving techniques.] [Assessment Boundary: Assessment does not include complex chemical reactions.]

**Guiding Questions:**

- What holds atoms together in molecules?
- How do chemical reactions absorb and release energy?

**Unit Overview:**

In this unit, students will build upon their understanding chemical energy which began with Unit 2. At this point, students should know that both mass and energy are conserved. They will determine that the same is true for a chemical reaction. First students will explore different classifications of compounds by examining the following properties: conductivity, melting point and solubility. The students will use the properties to group the different substances and infer the strength of the forces and attractions holding the particles together. Using Coulomb's Law, students will apply the principles of electrostatic attraction to predict the attraction that occurs due to ionic bonds. Students will investigate the different forms of attractions. There are different types of intermolecular forces, these forces are what causes surface tension and viscosity.

Students will take a look at endothermic and exothermic chemical reactions, using phenomena such as hand warmers and instant cold packs. Students will use the information they gather from their experiments to form a model that explains why there was an energy increase in one and an energy decrease in another. They will form a model that shows the amount of energy in the system over time, by obtaining the temperature as the reactions happen over time.

After students have looked at the different types of bonds and attractions, they will try to connect this to the amount of energy that is stored in the different types of forces (and bonds). Students will analyze data from their investigation, along with data provided to them from other investigations.

Students will use the information they that have obtained so far to make calculations. Students will calculate the total amount of energy in chemical bonds, or predict the amount of energy that will be released in the form of heat.

**Unit Assignment(s):**

**Sample Assignment 1:** Chemical Reactions Calculator

**Major Focus Question:** Which products will come out of a chemical reaction?

**Assignment Overview:** Students will make simple predictions using the periodic table about possible chemical reactions. Students will work together to predict the products given the reactants. They will use a slide-chart from Flinn Scientific to determine the type of reaction that will occur when two substances are mixed. Students will be using their findings of this assignment to make predictions for the labs of the same unit.

**Sample Assignment 2:** Stoichiometric Predictions

**Major Focus Question:** How many products will there be? What are molar ratios? How are moles used to calculate the outcome? How is the estimated outcome compared to the experimental outcome?

**Assignment Overview:** This assignment will help students practice their fundamental skills in stoichiometry. It will be the last assignment for this unit, and will have students using all gained knowledge to apply their understanding to different scenarios. In this activity, students will need to 1) balance an unbalanced equation, 2) use the periodic table to calculate the molar mass of a substance, 3) find the limiting reagent in the reaction 4) predict the amount of product that will come out of a reaction. Students will use these steps, for example, to determine what happens to all the excess carbon dioxide that is not being absorbed by plants through the photosynthetic process. Students could research current methods for carbon fixation to determine which would yield the most potential benefits. They will then apply their understanding of stoichiometry to evaluate the effectiveness of different proposed solutions to reduce carbon dioxide in the atmosphere

**Unit Lab Activities:**

**Sample Lab 1:** Balancing Chemical Equations

**Major Focus Question:** How does chemical reaction affect matter?

**Lab Overview:** Students have already learned about conservation of mass. However, students will now take a look at it through the representation of a chemical reaction. Students will analyze different types of chemical reactions and work in groups to determine the products that are formed. Students will use the data that they gather from the reactions to determine possible chemical equations that account for both reactant and product mass. They will use this information to add coefficients to the formulas and classify the type of chemical reaction observed. At the end of the activity, students should be able to observe and record chemical changes in substances, determine the product(s) of a chemical reaction, write and balance a chemical equation, and design and conduct an experiment to determine the type of reaction that is being observed.

**Sample Lab 2:** Stoichiometry and Limiting Reactants

**Major Focus Question:** What is a Limiting reactant and how does it affect the chemical reaction?

**Lab Overview:** In this activity, students will observe and record data for different types of chemical reactions. They will learn about the mole ratio and how it can be used to calculate the expected chemical reaction outcome. To do this, students will have 0.10 M of CaCl2, Na2C2O4, and Na3PO4. Students will take a look at the amount of reactants that turn into products to determine the perfect combination of drops of reactant 1 to reactant 2 ratio. At the end of this, students will be able to understand what limiting reactants are, determine the combining ratios of calcium chloride and sodium oxalate and sodium phosphate, and write balance equations for each reaction.

**Unit 5: Chemistry of Climate Change**

NGSS Standards:

**HS-ESS2-2. Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth's systems.** [Clarification Statement: Examples should include climate feedbacks, such as how an increase in greenhouse gases causes a rise in global temperatures that melts glacial ice, which reduces the amount of sunlight reflected from Earth's surface, increasing surface temperatures and further reducing the amount of ice. Examples could also be taken from other system interactions, such as how the loss of ground vegetation causes an increase in water runoff and soil erosion; how dammed rivers increase groundwater recharge, decrease sediment transport, and increase coastal erosion; or how the loss of wetlands causes a decrease in local humidity that further reduces the wetland extent.]

**HS-ESS2-4. Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.** [Clarification Statement: Examples of the causes of climate change differ by timescale, over 1-10 years: large volcanic eruption, ocean circulation; 10-100s of years: changes in human activity, ocean circulation, solar output; 10-100s of thousands of years: changes to Earth's orbit and the orientation of its axis; and 10-100s of millions of years: long-term changes in atmospheric composition.] [Assessment Boundary: Assessment of the results of changes in climate is limited to changes in surface temperatures, precipitation patterns, glacial ice volumes, sea levels, and biosphere distribution.]

**HS-ESS2-6. Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.** [Clarification Statement: ****The carbon cycle is a property of the Earth system that arises from interactions among the hydrosphere,**

**atmosphere, geosphere, and biosphere.** Emphasis is on modeling biogeochemical cycles that include the cycling of carbon through the ocean, atmosphere, soil, and biosphere (including humans), providing the foundation for living organisms.]

**HS-ESS3-2. Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.*** [Clarification Statement: Emphasis is on the conservation, recycling, and reuse of resources (such as minerals and metals) where possible, and on minimizing impacts where it is not. Examples include developing best practices for agricultural soil use, mining (for coal, tar sands, and oil shales), and pumping (for petroleum and natural gas). Science knowledge indicates what can happen in natural systems—not what should happen.]

**HS-ESS3-5. Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.** [Clarification Statement: Examples of evidence, for both data and climate model outputs, are for climate changes (such as precipitation and temperature) and their associated impacts (such as on sea level, glacial ice volumes, or atmosphere and ocean composition).] [Assessment Boundary: Assessment is limited to one example of a climate change and its associated impacts.]

**HS-ESS3-6. Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.** [Clarification Statement: Examples of Earth systems to be considered are the hydrosphere, atmosphere, cryosphere, geosphere, and/or biosphere. An example of the far-reaching impacts from a human activity is how an increase in atmospheric carbon dioxide results in an increase in photosynthetic biomass on land and an increase in ocean acidification, with resulting impacts on sea organism health and marine populations.] [Assessment Boundary: Assessment does not include running computational representations but is limited to using the published results of scientific computational models.]

**Guiding Questions:**

- What regulates weather and climate?
- What effects are humans having on the climate?

This unit is extremely heavy on the Earth Science NGSS standards. In this unit, students will use all the understanding they have gathered about energy, combustion, chemical reactions, convection, etc, to get a better understanding of Climate Change. After taking a look at chemical reactions, students will take a look at combustion of hydrocarbon fuels. Due to the increase in hydrocarbon consumption in the world, the amount of carbon dioxide in the atmosphere is increasing. Carbon dioxide is a greenhouse gas and therefore has great impact on the Earth's climate. The greenhouse gases disrupt the flow of energy, entrapping energy in the atmosphere.

In this unit, students will take a look at different forms of data to determine the effects of combustion on the environment. Where is most of the Earth's energy coming from? Once that energy comes in, where does it go? How does it circulate the earth? How do small changes to the atmosphere affect the earth's climate? Students will look at the change in the amount of greenhouse gases over the years and correlate this to the change in the atmosphere, hydrosphere, and biosphere. Students will investigate feedback loops, and look at cause and effects. There will be a major focus on the earth's increasing temperature and its effect on the climate. For example, the amount of ice on our planet is shrinking, rising sea water, but also decreasing the concentration of salinity in the oceans. Also, the constant energy input is increasing the temperature of the ocean and the ocean is absorbing more carbon dioxide, making it more acidic. This has caused mass coral bleaching, and is also responsible for endangerment of species, such as those of the Great Barrier Reef. Students will conduct a research study in which they will investigate the magnitude of how human activity has harmed the earth.

The increase in temperature, also has caused more ocean water evaporation, which eventually precipitates back into the earth in the form of heavy rain, storms, snow and snow storms, and most recently tropical storms and hurricanes (cyclones). Students will focus on how feedback loops can intensify over the years, but also, how the earth is a extremely dynamic system. As a culminating activity, students will build devices that use alternative energy to demonstrate how technology can reduce human impacts on the environment.

**Unit Assignment(s):**

**Sample Assignment 1:** Carbon Footprint Calculation

**Major Focus Question:** What is my contribution to global warming?

**Assignment Overview:** Students will use an online calculator to determine their own carbon footprint. Students will devise a plan to reduce their carbon footprint.

**Sample Assignment 2:** Climate Change Debate

**Major Focus Question:** Is climate change happening? Or are we just misinterpreting data? What type of human activity may be causing the climate change we see today?

**Assignment Overview:** Students will investigate the current arguments, claims and evidence for and against human impacted climate change. Students will be given different sources of data and different viewpoints to determine whether or not humans have been causing the climate change we see today, and whether or not climate change is happening. The purpose of this activity is to get students acquainted with the environmental impact that humans have on the environment. In the second part of the activity, students will investigate alternative energy options that are not as harmful for the environment, and propose them as solutions to their classmates.

**Unit Lab Activities:**

**Sample Lab 1:** Carbon Cycle Lab (Combustion Part 2)

**Major Focus Question:** Where does all the carbon go? Where is the extra carbon (from carbon dioxide and monoxide) end up?

**Lab Overview:** This lab will help students take a closer look at combustion and the extra carbon dioxide that is being produced. Students will look at the carbon cycle by going around to different carbon cycle stations. Each cycle station will have students explore the mechanisms in which carbon is using to move through the earth. Students will also explore which human factors increase the amount of carbon into the environment. Students will not be required to turn in a finalized lab report, instead, they will be graded on the lab practices (including their bound notebook).

**Sample Lab 2:** Greenhouse Effect and Global Warming Lab (Combustion Part 3)

**Major Focus Question:** What is the greenhouse effect and how do greenhouse gases contribute to global warming?

**Lab Overview:** Students will take a look at the lasting effects of greenhouse gases on global warming. During part one of this lab, students will take a look at what happens when a bottle that is covered with black paper is exposed to light. The temperature of a uncovered bottle and a half-covered bottle will be compared to that of a full covered bottle. In part two, students will collect carbon dioxide samples from different sources. (Unlike the first activity, students will be asked to pick different sources of carbon dioxide than the ones they used in Unit 1.) Students will use their understanding of the carbon cycle to complete a titration lab in which students will determine the amount of solution needed to be added to the solution (carbonic acid solution) that will return the solution back to its original color.

**Unit 6: The Dynamics of Chemical Reactions and Ocean Acidification**
NGSS Standards:

**HS-PS1-5. 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.** [Clarification Statement: Emphasis is on student reasoning that focuses on the number and energy of collisions between molecules.] [Assessment Boundary: Assessment is limited to simple reactions in which there are only two reactants; evidence from temperature, concentration, and rate data; and qualitative relationships between rate and temperature.]

**HS-PS1-6. Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.*** [Clarification Statement: Emphasis is on the application of Le Chatelier's Principle and on refining designs of chemical reaction systems, including descriptions of the connection between changes made at the macroscopic level and what happens at the molecular level. Examples of designs could include different ways to increase product formation including adding reactants or removing products.] [Assessment Boundary: Assessment is limited to specifying the change in only one variable at a time. Assessment does not include calculating equilibrium constants and concentrations.]

**HS-PS1-7. Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.** [Clarification Statement: Emphasis is on using mathematical ideas to communicate the proportional relationships between masses of atoms in the reactants and the products, and the translation of these relationships to the macroscopic scale using the mole as the conversion from the atomic to the macroscopic scale. Emphasis is on assessing students' use of mathematical thinking and not on memorization and rote application of problem-solving techniques.] [Assessment Boundary: Assessment does not include complex chemical reactions.]

**HS-ESS2-2. Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth's systems.** [Clarification Statement: Examples should include climate feedbacks, such as how an increase in greenhouse gases causes a rise in global temperatures that melts glacial ice, which reduces the amount of sunlight reflected from Earth's surface, increasing surface temperatures and further reducing the amount of ice. Examples could also be taken from other system interactions, such as how the loss of ground vegetation causes an increase in water runoff and soil erosion; how dammed rivers increase groundwater recharge, decrease sediment transport, and increase coastal erosion; or how the loss of wetlands causes a decrease in local humidity that further reduces the wetland extent.]

**HS-ESS2-6. Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.** [Clarification Statement: ****The carbon cycle is a property of the Earth system that arises from interactions among the hydrosphere, atmosphere, geosphere, and biosphere.** Emphasis is on modeling biogeochemical cycles that include the cycling of carbon through the ocean, atmosphere, soil, and biosphere (including humans), providing the foundation for living organisms.]

**Guiding Questions:**

- How can you alter chemical equilibrium and reaction rates?
- How can you predict the relative quantities of products in a chemical reaction?

**Unit Overview:**

This unit will have students focusing on the ocean systems and chemical equilibrium. Previously, students looked at how an increase in energy means an increase in ocean water temperature.

Students will investigate environmental implications of feedback loops (positive and negative) and how they contribute to the changes we are now experiencing in our ocean.

Not all reactions reach completion, but just as the forward reaction is happening, so is the reverse reaction. When the rate of the forward reaction is equal to that of the reverse reaction, it is said that the system has reached dynamic equilibrium. Our oceans for many years have been able to maintain a dynamic equilibrium. However, increased carbon dioxide levels have shifted the equilibrium, leading to increased levels of carbonic acid, and lowered pH. Students will gather evidence and construct a scientific explanation to determine what causes the directional shifts. They will create a model that shows what is happening at the microscopic level, including atomic collision and bond formation. Students will conduct a lab in which they will take a look at what factors affect the rate of reaction: temperature, concentration, and surface area.

Students will then explore Le Chatelier's principle to predict how a reaction at equilibrium will respond to introduced changes. Will products or reactants increase? What happens when the temperature of the reactants increase? Does it speed up the reaction, or does it slow it down? And how is this explained by Le Chatelier's principle? What effects does increased carbon dioxide have on the ocean?

Students will take a look at how increase in carbon dioxide in the ocean increases carbonic acid. Increase in carbonic acid means that shells, which are made of calcium carbonate, will dissolve. Students will also study current and future carbon dioxide projections to determine the extent to which humans have been dramatically changing the climate, and harming and destroying important ecosystems.

**Unit Assignment(s):**

**Sample Assignment 1:** Acid Rain

**Major Focus Question:** How is pollution affecting our freshwater?

**Assignment Overview:** Students will research the effect of pollution on rainwater (and other freshwater sources). Students will explore significant historical structures and the effects of acid rain. Students will write a 4-5 page research paper in which they will explore possible solutions to improve the rainwater.

**Sample Assignment 2:** Ocean Acidification

**Major Focus Question:** How do higher temperature and extra carbon dioxide harm the coral reefs?

**Assignment Overview:** In this assignment, students will be taking a look at the toll climate change is having on the ocean ecosystems. Students will research what coral bleaching is, how it is impacting the species, what chemicals causes coral bleaching, and what can be done to reverse the effects. Students will present their unique solutions to the class.

**Unit Lab Activities:**

**Sample Lab 1:** Alka-Seltzer Reaction Time

**Major Focus Question:** What factors can speed up chemical reactions?

**Lab Overview:** As students are learning about the environment, and human influence on the environment, they will also take a look at the factors that can speed up or slow down chemical reactions. There are many chemical reactions happening around the globe at all times, however, some chemical reactions are happening because of chemical exposure caused by man-made products. Some countries have restrictions, while other countries do not. Students will take a look at different factors that can affect a chemical reaction: temperature, concentration, pressure, and surface area. Students will plan and conduct their own experiment to test which factors can speed up chemical reactions and which factors can slow down chemical reactions by using Alka-Seltzer tablets. Students will be placing the tablets into film canisters to test the time it takes for the canister to increase in pressure and explode into the air.

**Sample Lab 2:** Ocean Acidification Red Cabbage pH Indicator Lab

**Major Focus Question:** How does natural selection work?

**Lab Overview:** This experiment will help students learn about alkalinity, which helps seawater resist changes in pH. Students will test different waters (just as they did for the air) to their own made Red Cabbage pH indicator. The larger emphasis is on Le Chatelier's principle about what happens to a system at equilibrium that encounters stress. Students will look at the pH as a way to determine how well a body of water has been able to resist stress. There will be a greater focus on carbonic acid, and its forward and reverse reaction. The major types of water students will be testing are: seawater, tap water, distilled water, and Alka-Seltzer Water. Students will rank the fluids based on how much alkalinity they believe the water has. Students will then test the water using the red cabbage indicator to determine its true alkalinity.

Honors Final Exam Details:

The fall final exam will cover the first three units and will assess students' understanding through the use of multiple choice questions, short answer responses, and long answer responses. The spring final exam will be a cumulative exam, consisting of all four units and all concepts covered. Students will be assessed through multiple choice, short answer responses, and long answer responses. Both mathematical and conceptual concepts will be assessed, with the long answer responses focusing primarily on the application of mathematics and the integration of various chemistry concepts. Additionally, students will also be assessed through a laboratory final, which will assess students' ability as it applies to hands on performance. The laboratory final will be drawn from one of the last five units and will cover titrations, calorimetry, and/or galvanic/voltaic cells. Students will be assessed not only on their performance in the lab, but also on post-lab questions that delve into the core mathematical and conceptual concepts at hand. Students will submit a written final report that will serve as a portion of their final examination grade.

# Course Materials

## Websites

| Title | Author(s)/Editor(s)/Compiler(s) | Affiliated Institution or Organization | URL |
|---|---|---|---|
| CK12 | CK12 Foundation | CK12 Foundation | www.ck12.org |
| Phet Simulations | [ empty ] | University of Colorado | https://phet.colorado.edu/en/simulations/category/new |