Essential Chemistry Lab Manual: NGSS Correlations

Below is a list of the 73 activities in the Essential Chemistry lab manual. The primary Next Generation Science Standards (NGSS*) Performance Expectation supported by each activity is shown in the column on the right.

Lab #	Activity Name and Description	NGSS Performance Expectation[1] (PE) Supported
1A	Experimental Variables *Students practice identifying variables in a color fading experiment.*	(Designed to support Science and Engineering Practice 1: Asking Questions and Defining Problems rather than a specific PE)
1B	Investigating the Temperature Scale *Students use a temperature sensor to discover the relationship between the Fahrenheit and Celsius temperature scales.*	(Designed to support Science and Engineering Practice 5: Using Mathematics and Computational Thinking rather than a specific PE)
2A	Density of a Solid *Students design an experiment to determine the volume of an object with an irregular shape.*	(Designed to support Science and Engineering Practice 3: Planning and Carrying Out Investigations rather than a specific PE)
2B	Density of a Liquid *Students experimentally determine the density of water.*	(Designed to support Science and Engineering Practice 4: Analyzing and Interpreting Data rather than a specific PE)
3A	Chemical Formula *Students use the Molecular Model Set to explore representations of matter at the particle level.*	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
3B	Pure Substances and Mixtures *Students design a procedure to separate components of a mixture.*	(Designed to support Science and Engineering Practice 3: Planning and Carrying Out Investigations rather than a specific PE)
3C	Physical or Chemical Change *Students use a pH sensor, conductivity sensor, and temperature sensor to collect evidence that supports their conclusion about whether a chemical or physical change has occured.*	(Designed to support Science and Engineering Practice 4: Analyzing and Interpreting Data rather than a specific PE)
4A	Temperature and Thermal Energy *Students use a temperature sensor to help them understand how energy flows between a system and its surroundings, and the difference between the total thermal energy in a sample and its temperature.*	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).
4B	Specific Heat *Students use a temperature sensor to experimentally determine the identity of a metal based on its specific heat capacity.*	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.
4C	Energy from Food *Students use a temperature sensor to study the difference between food Calories and the calorie unit, and observe how different food samples provide a different energy per gram ratio.*	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.

[1] Performance expectations taken verbatim from NGSS Lead States. 2013. Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press

Lab #	Activity Name and Description	NGSS Performance Expectation Supported
4D	Heat of Fusion *Students use a temperature sensor to describe the flow of energy through a system during a phase change.*	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.
4E	Project: Design an Insulator *Students must engineer an insulated container to minimize heat loss according to a set of design and performance constraints; a temperature sensor is used to assess insulator performance.*	HS-PS3-3: Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy. HS-ETS1-3: Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.
4F	Research Presentation Enhancement: Insulators in the Home *Students research and write about the health effects of insulation materials used in the home.*	(Designed to support Science and Engineering Practice 8: Obtaining, Evaluating, and Communicating Information rather than a specific PE)
5A	Patterns and Trends *Students study PASCO's Periodic Trend Cards to find patterns that help them reconstruct the periodic table.*	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
5B	Naming Ionic Compounds *Students perform a series of chemical reactions and name the precipitate formed in each.*	HS-PS1-7: Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
5C	Store Labels and Model Building *Students use the Molecular Model Set to build models of ingredients found on labels of household items.*	HS-PS1-7: Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
6A	Counting by Weighing *Students use the mole concept to estimate the mass and volume of one mole of beans based on a small sample of beans.*	HS-PS1-7: Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
6B	Molar Mass *Students use the Molecular Model Set to build models of compounds and determine the molar mass; students determine the moles of chalk used to write their name to connect mass with the amount of particles in one mole.*	HS-PS1-7: Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
6C	Percent Composition of a Hydrate *Students determine the formula of a hydrate sample based on the mass lost when the sample is dehydrated.*	HS-PS1-7: Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
6D	Empirical Formula of Magnesium Oxide *Students add enough heat to a sample of magnesium to produce magnesium oxide, then analyze the product to determine its empirical formula.*	HS-PS1-7: Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
7A	Balancing Chemical Equations *Students use the Molecular Model Set to model the law of conservation of matter during chemical reactions.*	HS-PS1-7: Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.

Lab #	Activity Name and Description	NGSS Performance Expectation Supported
7B	Chemical Reactions *Students predict products of a series of chemical reactions and use a temperature, conductivity, and pH sensor to verify a chemical change.*	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.
7C	Solubility Rules *Students look for patterns to experimentally determine the solubility rules for a set of solutions.*	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.
8A	Conservation of Mass *Students experimentally determine the amount of sodium bicarbonate in an antacid tablet based on the mass of carbon dioxide formed when the tablet reacts in water.*	HS-PS1-7: Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
8B	Percent Yield *Students analyze a precipitate product to determine the percent yield of a reaction.*	HS-PS1-7: Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
8C	Modeling Limiting Reactants *Students use the Molecular Model Set to simulate reaction scenarios where there are limiting and excess reactants, and ideal reactions where all reactants are consumed.*	HS-PS1-7: Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
8D	Determining Limiting Reactants *Students use a pressure sensor to experimentally determine the limiting and excess reactant when the amount of one reactant is varied; also, data is analyzed to reveal the coefficients in the balanced reaction.*	HS-PS1-7: Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
8E	Project: Design an Airbag *Students must engineer an airbag that inflates and uses materials according to a set of design and performance constraints; a temperature and pressure sensor are used to assess airbag performance.*	HS-PS3-3: Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy. HS-ETS1-3: Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.
8F	Research Presentation Enhancement: Airbags and Consumers *Students research and write about the chemistry and function of airbags used as either wearable protection or as part of a vehicle safety system.*	(Designed to support Science and Engineering Practice 8: Obtaining, Evaluating, and Communicating Information rather than a specific PE)
9A	Isotopic Composition *Students work with model "element samples" to learn the characteristics of isotopes.*	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.
9B	What is a Wave? *Students model the relationship between wave frequency and wavelength by observing waves with different amounts of energy.*	HS-PS4-1: Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.

Lab #	Activity Name and Description	NGSS Performance Expectation Supported
9C	Light Energy *Students use different colored LEDs to determine which frequency of light transfers the most energy to a glow-in-the-dark object.*	HS-PS4-4: Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter
9D	Flame Test *Students use flame test observations to identify an unknown compound.*	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.
10A	Types of Bonding *Students use a conductivity sensor to predict the type(s) of bonding between atoms in solutions made with different substances.*	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.
10B	Lewis Structures and VSEPR *Students use the Molecular Model Set to study the relationship between the bonding capacity of individual atoms and 3D molecular structure.*	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.
10C	Surface Tension *Students apply their understanding of intermolecular forces to explain observations of different water phenomena.*	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.
11A	Evaporative Cooling *Students use a temperature sensor to determine the evaporation rates of different compounds and use the Molecular Model Set to help relate differences in rates to molecular composition and intermolecular forces.*	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.
11B	State Changes *Students predict the shape of a phase change diagram for water when it moves from the solid to liquid to gas phase, then use a temperature sensor to construct a phase change diagram supported with data.*	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.
11C	Hess's Law *Students use a temperature sensor to experimentally determine the heat of reaction for the formation of a compound.*	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.
12A	Volume of a Gas *Students use a pressure sensor to quantify a visible pressure-volume relationship in a sample of matter.*	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.
12B	Boyle's Law *Students use a pressure sensor to experimentally determine a mathematic expression of Boyle's law.*	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.
12C	Charles' Law *Students use a temperature sensor to experimentally determine the relationship between the temperature and volume of a gas.*	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.

Lab #	Activity Name and Description	NGSS Performance Expectation Supported
13A	Electrolytes *Students use a conductivity sensor to distinguish an electrolyte from a non-electrolyte, and create a calibration curve to estimate the concentration of electrolytes in a sports drink.*	HS-PS2-6: Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.
13B	Solution Concentration *Students use a colorimeter to construct a calibration curve of known solution concentrations and determine the unknown concentration of a solution (Beer's law).*	HS-PS4-4: Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter.
13C	Colored Solutions *Students use a colorimeter to develop an understanding of how different wavelengths of light interact with particles of a colored solution to produce the solution color seen.*	HS-PS4-4: Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter.
13D	Project: Design a Water Purification Process *Students must engineer a system to purify water that contains macroscopic and microscopic contaminants and evaluate the effectiveness of their design using a condenser, turbidity sensor, conductivity sensor, and qualitative observations.*	HS-PS3-3: Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy. HS-ETS1-3: Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.
13E	Writing and Discussion Enhancement: Water Purification *Students research, discuss, and write about a local water pollution issue.*	(Designed to support Science and Engineering Practice 8: Obtaining, Evaluating, and Communicating Information rather than a specific PE)
14A	Optimum Conditions *Students use a pressure and temperature sensor to observe the effect of changing various experimental conditions on the rate of a chemical reaction.*	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.
14B	Catalysts *Students compare the rate of hydrogen peroxide decomposition using a variety of catalysts and catalyst sources.*	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.
15A	Equilibrium Reactions *Students model an equilibrium reaction at the particle level as well as the visible level.*	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.
15B	Le Châtelier's Principle *Students observe the effects on a reversible reaction at equilibrium when the concentration or temperature is changed.*	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.
16A	What is pH? *Students use a pH sensor to test the pH of a set of serial dilutions and make a connection between the pH value (& pOH) of a solution and its hydrogen ion (& hydroxide ion) concentration.*	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.
16B	Titration of an Unknown Acid *Students use a pH sensor to conduct a strong acid and weak acid titration with a strong base.*	HS-PS1-7: Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.

Lab #	Activity Name and Description	NGSS Performance Expectation Supported
16C	Antacids: An Inquiry Study *Students use a pH sensor to investigate how antacid tablets work and use a back titration method to determine how much of the active ingredient is found in one tablet.*	HS-PS1-7: Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
17A	Vitamin C Titration *Students use a redox titration to determine the amount of vitamin C in an unknown food sample.*	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.
18A	Electrochemical Cells *Students use a voltage sensor to discover the function of the components of an electrochemical cell.*	HS-PS3-3: Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.
18B	Electroplating *Students build an electrolytic cell to investigate the electroplating process.*	HS-PS3-3: Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.
18C	Lemon Battery *Students use a voltage sensor to measure voltage produced by a lemon battery with copper and zinc electrodes, then use their data to design a lemon battery that produces enough voltage to light an LED.*	HS-PS3-3: Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.
18D	Project: Design a Galvanic Cell *Students use a voltage sensor and a variety of supplies to design a galvanic cell that can light LED bulbs in series or in parallel.*	HS-PS3-3: Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy. HS-ETS1-3: Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.
18E	Writing and Discussion Enhancement: Galvanic Cell *Students research, discuss, and write about the pros and cons of moving towards homes and cars fully powered by rechargeable batteries.*	(Designed to support Science and Engineering Practice 8: Obtaining, Evaluating, and Communicating Information rather than a specific PE)
19A	Half-Lives *Students model radioactive decay to determine the half-life of a "radioactive" sample.*	HS-PS1-8: Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.
20A	Bonding and Organic Chemistry *Students use the Molecular Model Set to explore the variety of bonding configurations possible by a carbon atom.*	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.
20B	Distilling Aromatic Compounds *Students use a condenser to extract an aromatic distillate from a spice sample.*	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.

Lab #	Activity Name and Description	NGSS Performance Expectation Supported
20C	Fragrant Esters *Students use a temperature sensor and a Molecular Model Set to study the properties of reactants and products of three distinct esterification reactions.*	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.
21A	Polymers *Students investigate a polymerization reaction and compare the properties of polymers with varying degrees of cross-linking.*	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.
21B	Amino Acids *Students use a Molecular Model Set to explore amino acids and a polymerization reaction where amino acids are joined to build a "protein".*	HS-LS1-6: Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules.
22A	Chlorophyll Extraction *Students use a colorimeter to investigate which wavelengths of light are best absorbed by green plants.*	HS-PS4-4: Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter.
22B	Respiration and Energy *Students use a pressure sensor to explore the effect of different energy sources on the respiration rate of yeast cells.*	HS-LS1-7: Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy.
23A	Greenhouse Gases *Students use a temperature sensor to investigate how changing the composition of air affects the rate at which its temperature will increase when energy is added and the rate at which the temperature will decrease after the addition of energy stops.*	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.
23B	The Water Cycle *Students use a turbidity sensor, a conductivity sensor, and a condenser to explore how energy drives the movement and purification of water through Earth's systems.*	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.
23C	Ocean Currents *Students use a temperature and conductivity sensor to investigate the driving forces behind ocean currents.*	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.
23D	Ocean Acidification *Students use a pH sensor to explore the effect of excess atmospheric carbon dioxide on water pH.*	HS-ESS2-6: Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.
24A	Spectroscopy *Students use PASCO's Spectrum Cards to model the use of spectroscopy to identify elements present in a compound.*	HS-PS4-1: Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.

PASCO's technology and laboratory investigations move students from the low-level task of memorizing science facts to developing higher-level data analysis skills, constructing concepts, and applying science concepts to explain everyday events. Science can be learned at a deep level when abstract science concepts are connected to "real-world" science investigations. Hands-on, technology-based laboratory experiences help bridge the gap between theory and observation, driving students toward a greater understanding of natural phenomena. Students also practice important science and engineering skills that include: *asking questions and defining problems, planning and carrying out investigations, analyzing and interpreting data, developing and using models, constructing explanations and designing solutions, engaging in argument from evidence, using mathematics and computational thinking,* and *obtaining, evaluating, and communicating information*[1].

While recognizing that each location may have specific standards to address, these materials use the NGSS as a foundation Three components comprise the NGSS: Science and Engineering Practices, Disciplinary Core Ideas, and Crosscutting Concepts. All lab activities in PASCO's science investigation manuals are compatible with the three dimensions of the NGSS:

- The *Science and Engineering Practices* help students to develop a systematic approach to problem solving that builds in complexity from kindergarten to their final year in high school. The practices integrate organization, mathematics and interpretive skills so that students can make data-based arguments and decisions.
- *Disciplinary Core Ideas* are for the physical sciences, life sciences, and earth and space sciences. The standards are focused on a limited set of core ideas to allow for deep exploration of important concepts. The core ideas are an organizing structure to support acquiring new knowledge over time and to help students build capacity to develop a more flexible and coherent understanding of science.
- *Crosscutting Concepts* are the themes that connect all of the sciences, mathematics and engineering. As students advance through school, rather than experiencing science as discrete, disconnected topics, they are challenged to identify and practice concepts that cut across disciplines, such as "cause and effect". Practice with these concepts that have broad application helps enrich students' understanding of discipline-specific concepts.

PASCO's lab activities are designed to guide students through initial investigations that help them learn scientific processes while they explore a core science topic. Students are then able to design and conduct extended inquiry investigations. The use of electronic sensors reduces the time for data collection, and increases the accuracy of results, providing more time in the classroom for independent investigations.

In addition to supporting the scientific inquiry process, the lab activities fulfill STEM education requirements by bringing together science, technology, engineering, and math. An integration of these areas promotes student understanding of each of these fields and develops their abilities to become self-reliant researchers and innovators. When faced with an idea or problem, students learn to develop, analyze, and evaluate possible solutions. This prepares students for collaboration with others to construct and test a procedure or product.

Information and computer tools are essential to modern lab activities and meeting the challenge of rigorous science standards, such as NGSS. The use of sensors, data analysis and graphing tools, models and simulations, and work with instruments, all support the science and engineering practices as implemented in a STEM-focused curriculum, and are explicitly cited in NGSS. PASCO's lab activities provide students with hands-on and minds-on learning experiences, making it possible for them to master the scientific process and the tools to conduct extended scientific investigations.

About the PASCO Essential Science Lab Manuals

This manual presents teacher-developed laboratory activities using current technologies to help you and your students explore topics, develop scientific inquiry skills, and prepare for state level standardized exams. Using electronic-sensor data collection, display and analysis devices in your classroom fulfills STEM requirements and provides several benefits. Sensor data collection allows students to:

- observe phenomena that occur too quickly or are too small, occur over too long a time span, or are beyond the range of observation by unaided human senses

[1] NGSS Lead States. 2013. *Next Generation Science Standards: For States, By States*. Washington, DC: The National Academies Press

- perform measurements with equipment that can be used repeatedly over the years
- collect accurate data with time and/or location stamps
- rapidly collect, graphically display, and analyze data so classroom time is used effectively
- practice using equipment and interpreting data produced by equipment that is similar to what they might use in their college courses and adult careers