Chapter 1: Fun with the Periodic Table

Chapter Challenge

As you study the properties of the elements, you become able to place them into categories. You will learn how Mendeleev was able to arrange the elements according to the chemical behavior that was known at his time. Your challenge is to develop a game that can be used to teach others how to learn and use the periodic table. These games are left up to your creativity. Card, computer, or board games are some choices that you may decide to use.

Activity Summaries	Chemistry Principles
Activity 1: Organizing a Store Students organize a store by categorizing the different items that are contained in the store and discover what to do with new items that had not been accounted for.	**Periodicity Trends Mendeleev**
Activity 2: Elements and Their Properties Students determine some of the physical and chemical properties of elements and learn how to use this information to organize elements into families.	**Atoms, Elements Physical properties Chemical properties Conductivity Reactivity, pH**
Activity 3: Atoms and Their Masses Students show why they believe in atoms and how the elements of different atoms interact with each other in a single-replacement reaction.	**Atoms, Atomic mass Single replacement Double-replacement reaction Law of Definite Proportions Compounds, Filtration Quantitative analysis Measurements Mole, Avogadro's number Dalton, Gay-Lussac, Proust**
Activity 4: Are Atoms Indivisible? Students learn through experimentation the properties of electrons and how Rutherford's experiment determined the location of the proton. In addition to this, they find that the nucleus is very dense.	**Cathode rays Properties of electrons Nucleus, Alpha particles Dalton's Atomic Theory Rutherford, Thomson Nagaoka, Millikan Coulomb's Law**
Activity 5: The Electronic Behavior of Atoms Students learn that when energy is supplied to a hydrogen atom, its electron is excited to higher levels and gives off light when it falls to lower levels. They also learn how to calculate the frequency of light waves and the energy of these waves.	**Hydrogen line spectrum Frequency,Wavelength Photons, Einstein Bohr's Atomic Model Electromagnetic spectrum Spectroscopic analysis Planck, Quantum**
Activity 6: Atoms with More than One Electron Students discover that each element produces a unique line spectrum and that the ionization potential of the elements helps them to understand why the elements occupy certain positions on the periodic table.	**Element line spectrum Ionization energy, Ion Electron configuration Period, Group, *s*, *p*, *d*, *f* orbitals Excited state, Ground state Heisenberg, Wave-particle duality Atomic number**
Activity 7: How Electrons Determine Chemical Behavior Students learn how to write the electron configuration for all of the elements. They also discover how the electron configuration can be used to show why families of elements behave the same with other elements.	**Electron configuration Inert gases, Noble gases Valence electrons Chemical families Transition elements Rayleigh, Cavendish, Ramsay**
Activity 8: How Atoms Interact with Each Other Students learn why atoms combine in certain proportions by transferring or sharing electrons from one atom to another. Students also learn the difference between an ionic and covalent bond.	**Octet rule, Bonding Ionic bonds, Covalent bonds Chemical formulas Binary compounds Electron dot structure Bonding electrons Nonbonding electrons**
Activity 9: What Determines and Limits an Atom's Mass? The students learn how to determine the atomic mass of an element and how the average atomic mass is determined from the common isotopes of an element. The activity also leads them through the factors that determine nuclear stability and how fission and fusion differ.	**Atomic Mass Isotopes, Neutrons Nucleons, Beta particle Radioactivity, Half-life Binding energy Electrostatic forces Strong nuclear force Nuclear fission, Nuclear decay Nuclear fusion, Gamma ray**

Chapter 2: Movie Special Effects

Chapter Challenge

A movie producer has asked your class to create a movie scene using special effects that involve chemical concepts. You are asked to develop a script for the movie scene and to provide an explanation of the chemistry concepts you used to produce your special effect.

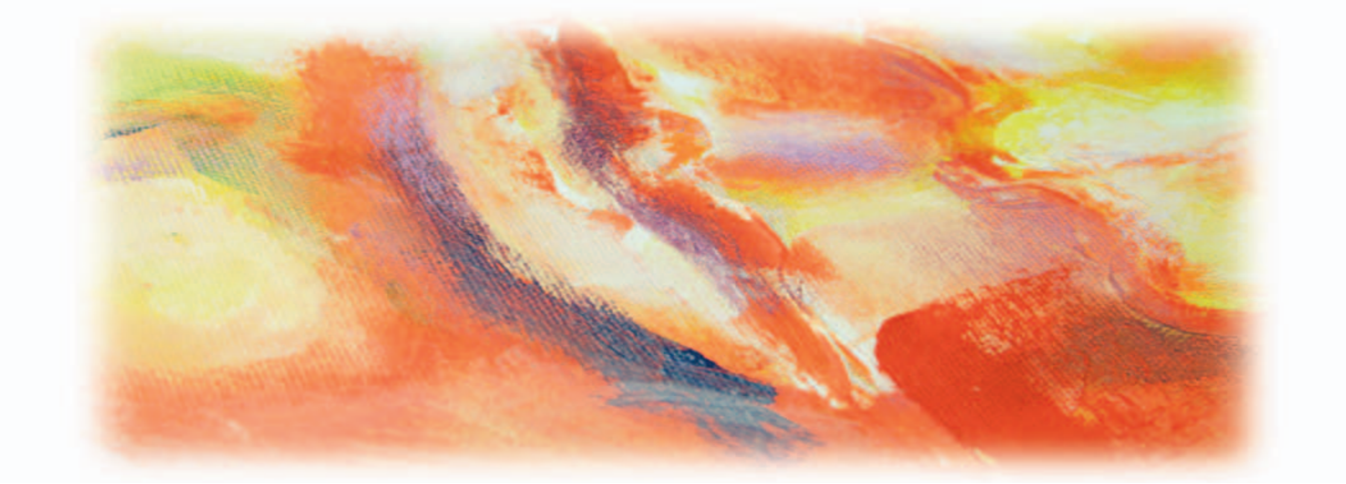
Activity Summaries	Chemistry Principles
Activity 1: Elements and Compounds The activity discusses the basic concept of what is matter and how we can change compounds back to the elements. Also, students will conduct some simple tests to identify hydrogen and oxygen gas.	Electrolysis Chemical reaction Elements Compounds Chemical properties Dissociation
Activity 2: States of Matter: Solid, Liquid, and Gas This activity helps the students develop an understanding of molecular motion in the different physical states: solid, liquid, and gas.	Heating curves, Melting point Boiling point, Vaporization Potential energy, Kinetic energy Physical states of matter Sublimation
Activity 3: Solutions, Suspensions, and Colloids This activity shows the students how to differentiate between solutions, suspensions, and colloids. The mixtures are tested for the Tyndall Effect and if they can be separated by simple filtration.	Tyndall Effect, Suspensions Emulsions, Filtration Homogeneous mixture Heterogeneous mixture Solutions, Solvent, Solute
Activity 4: Properties of Matter This activity helps the students understand how small models can be used to represent large structures. Models can be used to develop an understanding of the physical properties of a substance.	Composites Emulsions, Texture Elasticity, Malleability
Activity 5: Mass and Volume The students will determine the density of liquids and solids. The solids will be irregularly shaped, so that water displacement techniques need to be used to determine the densities.	Density, Estimation Displacement Measurements Uncertainty
Activity 6: Metals and Nonmetals This activity will study the physical properties of metals and will show how they can be differentiated from the nonmetals. They will also learn how the metals, metalloids, and nonmetals are arranged on the periodic table.	Metallic properties Nonmetals, Metalloids Oxidation Alloys
Activity 7: Polymers This activity shows the students how to make the polymer "slime" and how to test this non-Newtonian liquid. They will find that it has both solid and liquid characteristics.	Polymers, Proteins Starch, Cellulose Cross-linked polymers Commercial uses
Activity 8: Identifying Matter This activity uses flame tests to help identify metal cations. The principles of electron excitation are discussed and applied to fireworks and neon signs. Different metals can by used to produce the different colors.	Metal flame colors Electron excitation Ions, Flame tests
Activity 9: Organic Substances The students will learn what the term organic means to scientists and how the layman uses it incorrectly. They will study how to write organic structures and apply the Law of Conservation of Mass to combustion reactions.	Hydrocarbons Organic/Inorganic compounds Carbon bonding Alkanes, Alkenes Alkynes Combustion Law of Conservation of Mass

Chapter 3: Artist as Chemist

Chapter Challenge

Art is an activity found in every culture throughout history. Art can be expressed in a wide variety of media. You are asked to create a work of art that expresses yourself and to create a museum display around your artwork. The chemistry concepts you use to produce your artwork will be described in a museum placard.

Activity Summaries	Chemistry Principles
Activity 1: What Makes Something Art? The students view several examples of artwork and discuss the features which enable a work to be defined as "art."	**Cultural role of chemistry** **Societal role of chemistry**
Activity 2: Choice of Media for Durability This activity helps the students to understand the environmental impact of chemicals on sculptures. While doing this, they develop a working knowledge of acid/base chemistry by observing the effects of carbon dioxide and sulfur dioxide, followed by designing their own experiment.	**Acid/base chemistry** **pH scale, Indicators** **Chemical reactions** **Displacement reactions** **Synthesis reactions** **Arrhenius, G.N.Lewis** **Brønsted-Lowry**
Activity 3: Chemical Behavior of Metals This activity shows the students how to determine the relative reactivity of different metals and which are more durable against corrosion. Valence electrons are discussed and the concept of electroplating is demonstrated.	**Reactivity of metals** **Valence electrons** **Ions, Octet rule** **Electroplating** **Electron configuration**
Activity 4: Physical Behavior of Metals Beginning with making brass from a penny, this activity helps the students understand the common physical properties of metals. The "electron sea" model is introduced to describe metallic bonding and the concepts of hardening, tempering, and annealing are explored.	**Alloys, Brass, Bronze** **Electron sea model** **Cations, Annealing** **Tempering, Malleability** **Properties of metals**
Activity 5: Clay Students will examine and dehydrate a hydrated compound as a model to better understand the chemistry of clay. From their dehydration data, students will determine the percent of water in the compound. The mole concept will be applied to determine the formula of the hydrate.	**Nomenclature** **Mole, Molar mass** **Hydrate, Anhydrate** **Dessicants** **Ceramics**
Activity 6: Paints The students will test various combinations of soluble compounds to determine which will produce precipitates in double-replacement reactions. This data will be tabulated and used to determine the best compounds to use as pigments for their paints.	**Soluble, Insoluble** **Precipitate** **Suspension** **Anions** **Cations** **Double replacement** **Solubility rules**
Activity 7: Dyes Students will determine a procedure for extracting dyes from natural materials and use them to dye pieces of wool. Then they will be introduced to the concept that the bonding of dyes to fibers is often pH-dependent. Students will observe the effect of changing pH on the colors of two natural dyes.	**Organic compounds** **Mordant** **Chromophore** **Dye** **pH paper**
Activity 8: How Does Stained Glass Get Its Color? In this activity, students will use borax as a glass substitute to observe how different compounds produce different colors in the "glass" as they are heated in a flame.	**Borax, Minerals** **Metal oxides** **Ceramics, Glazes**



Chapter 4: Chemical Dominoes

Chapter Challenge

You are challenged to create a prototype of a "chemical-dominoes sequence" that can be sold by a toy company to 10-15 year-old children. You are asked to demonstrate the product to company executives, as well as to explain the chemistry concepts behind each step. A detailed written explanation of the chemistry is also required.

Activity Summaries	Chemistry Principles
Activity 1: Alternative Pathways Students compare different ways of producing carbon dioxide gas to blow up a balloon that tips a lever. They brainstorm criteria for selecting which method might be best for using in the *Chemical Dominoes* apparatus. After an introduction to two chemical concepts (endothermic/exothermic changes, entropy increase/decrease) and drawings of arrangements of particles in different states (before/after), each student in the group becomes an expert in one of the carbon dioxide production methods.	**Reactants, Products** **Endothermic, Exothermic** **Energy, Entropy** **Engineering design process** **Covalent bond, Ionic bond** **Excited state**
Activity 2: Balancing Chemical Equations Students first learn to recognize whether a chemical equation is balanced. Then, they learn to balance simple chemical equations by an accounting method. Along the way, they practice identifying how many of a particular element there are in a formula, which involves reading parentheses and subscripts properly. They also balance the equation for Method 2 from the previous activity, prove that it's balanced, and then design an experiment and demonstrate that mass is conserved when the reaction is run.	**Conservation of matter** **Balancing chemical equations**
Activity 3: How Much Gas is Produced? In this activity, students use pennies and a balance to explore the concept of a mole. They also learn dimensional analysis with "chemical dominoes." The point of the activity, for students, is to be able to predict ahead of time how much baking soda will be necessary to use to make this happen. Then, after an empirical solution to the problem, they learn stoichiometry and test their "hypothesis." Finally, they participate in a discussion of error analysis to query why the prediction and reality are so different.	**Stoichiometry** **Dimensional analysis** **Mole, Molar mass** **Prediction** **Error analysis** **STP**
Activity 4: What Can Destroy a Metal? Students build a circuit to light the red LED using aluminum foil as wire. They then experimentally learn to turn off the circuit by destroying the aluminum using three "mystery" chemicals. By observing the effects of known chemicals on metals, they deduce the identity of the "mystery" chemicals. They practice writing and balancing oxidation-reduction reactions. In a short activity, students address the confusion between dissolving, melting, and reacting and learn to define the terms properly.	**Metal-activity series** **Reactivity of metals** **Oxidation-reduction** **Balancing equations** **Half-reactions** **Dissolving/melting** **Acids**
Activity 5: Producing and Harnessing Light Students view the spectrum of visible light by looking at an incandescent light through a diffraction grating. After seeing that "white" light is made of many colors, they view the red LED through the diffraction grating. They then determine the minimum operating voltages for a series of colors of LEDs, leading them to conclude that as the wavelength of light decreases, the voltage (energy) required to light the LED increases. Next, students determine which colors of light can cause a glow-in-the-dark toy to phosphoresce. They conclude that for the phosphorescence to occur, a minimum amount of light energy must be added.	**Matter-energy interactions** **Emission spectroscopy** **Absorption spectroscopy** **Energy vs. wavelength** **Electromagnetic spectrum** **Visible light, Fluorescence** **Conservation of energy** **Phosphorescence** **Excited state** **Ground state**
Activity 6: Electrochemical Cells Students use their red LED to build a conductivity tester. After testing several solutions, they determine which solutions conduct electricity, and therefore contain electrolytes. Students then construct a zinc-copper battery and use the LED to determine in which direction electricity flows. Afterward, students are introduced to two ways to create more voltage (so they can light LEDs that require greater voltage): connecting batteries in series, and changing the relative concentrations of the zinc and copper ion solutions.	**Enthalpy changes** **Endothermic** **Exothermic** **Effects of catalysts,** **Bond energy** **Reaction diagrams** **Activation Energy** **Activated complex** **Spontaneous reaction**
Activity 7: Reactions that Produce Heat Students interpret observations from a military "Meals, Ready-to-Eat" (MRE) package. They operate the MRE and make sense of their observations. They learn about factors that speed up reactions, including particle size and catalysts. Finally, they use Hess's Law to determine whether changes are endothermic or exothermic, and how much heat energy the reactions require or give off.	**Electrochemical cells** **Half-reactions** **Spontaneity** **Electrolytes** **Hess's Law**
Activity 8: Rubber Bands and Spontaneity Students experiment with a rubber band, stretched and unstretched, to learn about enthalpy and entropy. They then build models to explain the behavior of the rubber bands. They formalize ideas of enthalpy and entropy change, and relate these ideas back to other activities in this chapter.	**Reaction driving forces** **System, Surroundings** **Spontaneity** **Exothermic, Endothermic** **Degree of disorder** **Gibbs free energy** **Polymers, Monomers**

Chapter 5: Ideal Toy

Chapter Challenge

You are challenged to create a toy that uses various chemical and/or gas principles. Your toy should appeal to an age group of your choice. Your final presentation to the board of the *Ideal Toy Company* will include a written proposal, either a detailed drawing or a mock prototype of the toy, a statement of any potential hazards or waste disposal issues, and a cost analysis of the item for manufacturing. An oral and written explanation of the chemistry principles used is a key part of the proposal.

Activity Summaries	Chemistry Principles
Activity 1: Batteries In this three-part activity students will first explore what they already know about batteries and examine several types of batteries. Starting on the macro level, they will make observations about commercial batteries. Then they will use the metal-activity series to guide them as they build their own electrochemical cells. They will learn the nanoscopic concepts of redox reactions and electrochemical cell chemistry. They then return to the macroscopic level as they attempt to power a toy with the cells they have created.	**Chemical properties of matter Metal-activity series Electrochemistry Redox reactions Matter/energy interactions Qualitative observations Quantitative observations Spectator ions, Cathode Anode, Voltage, Current**
Activity 2: Solid, Liquid, or Gas? In this two-part activity, students will use the free Chem Sketch and 3-D Viewer programs from ACD Labs to create representations of different molecules. The focus is on the fact that the size and shape of a molecule have an important effect on the properties of the molecule. Properties examined are boiling points and melting points of organic compounds.	**Kinetics Particle nature of matter Molecular size, shape, polarity Polar, Non-polar Electronegativity Intermolecular forces London dispersion forces**
Activity 3: Cartesian Divers This activity involves two parts. In Part A, students rotate through two stations and explore the effect of pressure on gas volume. In one station, students will simply explore pressure changes on volume using a syringe. At another station, students will explore pressure changes on buoyancy of a Cartesian diver, without using their hands. In Part B, students will use the Pressure Sensor probe and their graphing calculators to derive Boyle's Law ($P_1V_1 = P_2V_2$).	**Natural laws Units of pressure Boyle's Law Gas constant mm Hg**
Activity 4: Hot-Air Balloons Students will use an indirect measure of gas volumes at decreasing temperatures to determine the relationship between gas volume and temperature. From this data, they will graphically determine absolute zero and gain an understanding of the Kelvin scale versus the Celsius scale. Then, students will apply their understanding of temperature and gas volumes by constructing and testing hot-air balloons.	**Kelvin scale Charles' law Kinetic theory Absolute zero**
Activity 5: How are Gases Produced? In this two-part activity students will generate and test for hydrogen, oxygen, and carbon dioxide gases. They will then determine an effective ratio of hydrogen/oxygen gases to use in the propulsion of a small rocket.	**Molar relationships Reaction types, Catalysts Decomposition reactions Single-replacement reaction Double-replacement reaction Balanced equations**
Activity 6: Ideal Gas Law for the Ideal Toy This activity gives students an opportunity to use knowledge gained from the preceding activities in order to determine the volume of one mole of hydrogen gas. With this information in hand they will then calculate the gas law constant "R".	**STP, Gas law constant Combined gas law Ideal gas law**
Activity 7: Moving Molecules First, students will use pictorial and physical models to determine the effect of mass on gas effusion rates. Then, students will apply stoichiometric relationships to determine the amount of HCl and Zn needed to completely inflate a baggie with hydrogen gas. Finally, students will explain the observations made using the balloon/baggie model and the molecular weights of the gases generated.	**Kinetic molecular theory Graham's Law Limiting reagents Balanced equations Diffusion, Effusion**
Activity 8: Plastics This activity has two parts. In Parts A and B, students will make and explore a thermoplastic and a thermoset polymer. They will note the differences between the two types of plastics and construct an item, which could be a part of their prototype, from each type. In Part B, students will test different types of plastics to determine the best choice for its function. Students will identify two important criteria of the plastic needed for their toy, and then they will design tests to determine which plastic best fits their criteria.	**Types of polymers Thermoset Thermoplastic Organic compounds Polymers, Monomers**

Chapter 6: Cool Chemistry Show

Chapter Challenge

One of the best ways to demonstrate that you understand the chemical concepts that you have studied is to teach those concepts to others. Your challenge in the *Cool Chemistry Show* chapter is to demonstrate chemistry concepts to grade school children. You not only demonstrate the concepts, but also have to be able to explain them and to answer questions on the concept you are presenting.

Activity Summaries	Chemistry Principles
Activity 1: Chemical and Physical Changes Students learn what conditions are necessary in order to determine whether the process is a physical or chemical change.	Chemical change Physical change Chemical reaction Chemical tests Reactant, Product Solution, Solvent, Solute Molarity, Concentration Saturated solution, Unsaturated Precipitate, Polymer
Activity 2: More Chemical Changes Students learn what characteristics are used to identify a chemical reaction taking place, how indicators are used to identify acids and bases, and tests used to identify gases.	Chemical tests Acid-Base indicators Precipitates
Activity 3: Chemical Names and Formulas Students learn how to use the symbols from the periodic table and how to write the correct formulas of compounds. In addition to writing formulas, they will also learn how to name compounds.	Chemical symbols Chemical formulas Chemical compounds Chemical names Anions, Cations, Polyatomic ions Covalent bond Oxidation number
Activity 4: Chemical Equations Students practice writing chemical changes by using word equations and chemical equations. In addition to learning how to express an equation, they will also study single-replacement and double-replacement reactions.	Chemical equations Balancing equations Single-replacement Double-replacement Synthesis Decomposition Metal-activity series Solubility rules
Activity 5: Chemical Energy Students learn how to use chemical thermodynamics to produce products that use endothermic and exothermic reactions.	Heat energy Endothermic reactions Exothermic reactions Conservation of energy Activation energy Heat vs. Temperature
Activity 6: Reaction Rates Students study those factors that can alter the rate of a chemical reaction. The factors studied are temperature, concentration, the nature of the reactants, and catalysts.	Reaction rates Concentration Kinetic energy Collision theory Catalysts, Surface area
Activity 7: Acids, Bases, and Indicators—Colorful Chemistry Students study the special properties of acids and bases. Special properties that the student will need to understand: how they react with metals, how they feel, how they taste (however, remember that you do not taste chemicals in the laboratory), and how they can be tested for using indicators.	Acids/Bases Arrhenius acids and bases Indicators, Buffers pH Scale Titration Neutralization
Activity 8: Color Reactions that Involve the Transfer of Electrons Students investigate metal activity. They study oxidation and reduction and how we might be able to control them to our benefit.	Oxidation, Reduction Ions, Spectator Ions Polyatomic ions Single replacement Galvanization Metal plating, Rust

Chapter 7: Cookin' Chem

Chapter Challenge

This chapter challenges you to create a segment of a television cooking show that explains in detail the chemistry behind the cooking involved. This can be videotaped, live, or a voice-over of a popular television program. In your final presentation, you must discuss the chemical principles in each part of the food preparation that you select.

Activity Summaries	Chemistry Principles
Activity 1: What is Heat? By studying the heat from a light bulb, students learn the three ways in which heat can be transferred. A distinction is made between heat and temperature. Heat transfer is also discussed by examining a partially cooked potato. Students find examples in their homes that demonstrate convection, conduction, and radiation.	Heat vs. temperature Convection, Conduction Radiation, Heat energy Kelvin scale, Absolute zero Calorie
Activity 2: Safety and Types of Fires By observing a unlit and lit candle, students learn the necessary features that support combustion. This knowledge is used to discuss the control of combustion reactions.	Combustion reactions Balancing equations Hydrocarbons, Catalysts Law of Conservation of Mass
Activity 3: Cooking Fuels Using an insulated container containing water, students measure the heat content of several fuels. This leads to a discussion of how energy is stored in fuels and how it is released.	Thermochemistry Exothermic, Endothermic Activation energy Bond energy, Joules Mole concept Hydroxyl group, Alcohols Specific heat capacity
Activity 4: Boiling Water By taking data and graphing a heating curve, students learn about the heat of evaporation, and phase changes. The students also learn the effect of pressure on the boiling point.	Heating curves Phase changes Heat of vaporization Boiling point Energy of phase changes
Activity 5: Freezing Water By taking data and graphing a cooling curve, students learn about the heat of fusion, and phase changes. The students also practice their skills of graphing.	Cooling curves Phase changes Heat of fusion Melting point Energy of phase changes
Activity 6: How Do You Choose Cookware? The students examine the properties of several substances (Cu, Fe, Al, plastics, glass, ceramics) and learn about specific heat and the principles of heat transfer.	Specific heat Calorimetry Conduction Alloys
Activity 7: How Do Proteins in Foods React? Students denature raw egg protein in two ways—with heat by boiling in water and by pH change with acid. The structure of proteins is studied: primary, secondary, and tertiary.	Organic molecules Denaturation Functional groups Proteins, Amino acids Primary, secondary, tertiary structure
Activity 8: How Does the Home Canning Process Work? Students observe the effects of pressure on a heated can which is suddenly cooled. The principles are investigated more quantitatively in a simulated canning experiment using a rubber balloon as the "canned food."	Boyle's Law Kinetic theory Atmospheric pressure Inverse proportion

Chapter 8: CSI Chemistry

Chapter Challenge

You are challenged to create a crime scene and to prepare evidence that requires the use of at least three forensic chemistry techniques learned in this chapter in order to solve the crime. Before developing the story for the crime-show episode, you will need to analyze the evidence created in the laboratory and to determine which pieces the detectives in the show will use to solve the crime. Your crime story should include a police report, description of the crime, a diagram of the crime scene, a list of all the evidence found at the scene, and a thorough discussion of the chemical concepts used.

Activity Summaries	Chemistry Principles
Activity 1: Clue Me In In this activity, students use their deductive reasoning skills to identify elements based on clues about their properties, names, position on the periodic table, and history. Next, students work collaboratively to gather evidence and solve a crime using deductive reasoning.	Elements Periodic table Categorization Chemical families Group, period, series Deductive reasoning Halogens, Metals Nonmetals, Metalloids Alkali, Alkaline earth Transition metals
Activity 2: Distinguishing Glass Fragments In this activity, students determine the density of a glass sample using the slope method. They compare the density of their sample to the density of another group's sample to determine if they have the same type of glass.	Density, Measurements Graphing Chemical properties Physical properties Extensive properties Intensive properties
Activity 3: Presumptive Blood Testing: The Luminol Reaction In this activity, students learn the principles of chemiluminescence while testing bovine hemoglobin with luminol reagent. These principles include ground state, excited state, energy levels and catalysis. They also study the formation of ions through the gain or loss of electrons.	Atomic structure Spectroscopy Chemiluminescence Ions, Reactants Products, Catalyst Ground state, Excited state Energy levels
Activity 4: Identification of White Powders In this activity students learn how to use and read a flow chart. They will also create a flow chart that will identify six white powders. The creation of the flow chart will be based on the chemical and physical properties of the six white powders with which they experiment.	Anions, Cations Polyatomic ions Ionic bonds Solubility rules Double replacement Word equations Flow charts Qualitative analysis
Activity 5: Developing Latent Prints Students learn how to use a double-replacement reaction and an oxidation-reduction reaction to develop invisible fingerprints on paper.	Solvents, Solutes Oxidation Reduction Fingerprint analysis Crystalline structure
Activity 6: Metal Activity Series Students add metals to different ionic solutions to create a smaller version of the activity series.	Oxidizing agent Reducing agent Single replacement Double replacement Oxidation number Valence electrons Transition metals
Activity 7: Serial-Number Etching In this activity, students stamp a serial number into a piece of metal and then apply what they have learned about single-replacement reactions to restore that serial number after it has been obliterated. Next, they build and manipulate a clay model in order to understand what happens to metal atoms when they are stamped and how the changes caused by stamping allow restoration of serial numbers.	Redox reactions Properties of metals Nanostructure of metals Etching, Grain of metal
Activity 8: Chromatographic Capers In Part A, students perform a separation of black marker dye. In Part B, they create a model of the separation process to learn how it separates the different dyes in the ink. In this model a felt board is used to represent the paper and different colored poker chips represent the dyes in the marker ink. Finally, in Part C, they create a set of standard chromatograms R_f value of different black inks. They are then given an unknown sample of black ink and asked to determine the brand of ink.	Chromatography Mixtures Pure substances Separation methods Mobile phase Stationary phase R_f value

Chapter 9: It's Alimentary

Chapter Challenge

In this chapter you are challenged to learn the chemistry involved in the digestion of food as it passes down the alimentary canal. You will demonstrate your understanding in a skit depicting the perils you would encounter in a trip down the alimentary canal, assuming you had become one-billionth of your current size. The vehicles you ride in this futuristic theme park called Anatomy World must be a portion of food from a recently ingested meal. Most of the chemical substances that you encounter will be much larger than they are in this "nano-world." In order to survive you will have to understand chemistry at its molecular level, instead of observing only what you can see and manipulate in the "macro-world" of a chemistry laboratory.

Activity Summaries	Chemistry Principles
Activity 1: The Upper End of the Alimentary Canal The effect of salivary amylase is examined in the mouth and in the test tube. Tests for both starch and sugars are conducted on matzo crackers that have been hydrolyzed. Rate of reaction is studied.	**Hydrolysis** **Starch test** **Sugar test** **Benedict's reagent** **Reaction rates** **Enzyme/catalyst** **Amylase**
Activity 2: Antacids in the Stomach The purpose of antacids is examined. Are all antacids the same? A comparison of standard antacids' neutralizing capacity is performed. The nature of a new acid-base indicator is explored in these titrations. Heartburn and acid indigestion are compared.	**Acids** **Bases** **pH** **Titration** **Neutralization** **Indicators**
Activity 3: Studying Carbon Dioxide How can carbon dioxide be identified? A bottle of carbonated beverage is degassed and the volume measured. The volume is studied at three different temperatures. The need for an absolute temperature scale is developed and Charles' Law is introduced.	**Gas collections** **CO_2 test, Limewater** **Charles' Law** **Kelvin scale** **Precipitate**
Activity 4: Observing Real Food in Artificial Stomachs Four foods are subjected to differing conditions in artificial "stomachs" with the goal of finding out the optimum set of conditions needed to digest food in the stomach. Evidence for the type of food that can be digested in the stomach is also collected.	**Hydrolysis** **Catalytic action** **Pepsin** **Enzyme activity with pH** **Peristalsis** **Proteins, Amino acids**
Activity 5: Gas Pressure The relationship between pressure and temperature is experimentally determined by monitoring the pressure generated by carbon dioxide being produced from reaction of an effervescent antacid tablet and water. Quantitative methods are developed to calculate volume, pressure, and temperature using Gay-Lussac's Law and Charles' Law. The fundamental principles of the Kinetic-Molecular theory of gases is examined.	**Gas pressure** **Atmospheric pressure** **Gay-Lussac's Law** **Reaction rates** **Charles' Law** **Kinetic theory** **Ideal gas**
Activity 6: Size of Molecules A scale will be developed for common biochemical molecules assuming they could be enlarged from their nano-world size into the macro-world.	**Scale and models** **Nanometer**
Activity 7: Hydrolysis of Lactose The cause and treatment for lactose intolerance will be studied. The fate of certain monsaccharides and disaccharides in the presence of lactase will be explored.	**Lactose intolerance** **Disaccharides** **Monosaccharides** **Testing for glucose** **Enzymes**

Chapter 10: Soap Sense

Chapter Challenge

In this chapter, you are challenged to create a soap from natural sources that are readily available. In working through the activities, you explore variations in the two main ingredients of soap and their effect on the properties of your target soap. At the conclusion, you will prepare two presentations—one for corporate executives of a soap company and a second for the marketing department of that company.

Activity Summaries	Chemistry Principles
Activity 1: What Makes a Good Soap? Students list different cleaners and soaps and describe their characteristics. They design and administer a survey to identify the most important characteristics. They choose a characteristic they want to measure quantitatively, and design an experiment to do so. After running the experiment, they discuss possible revisions.	**Experimental design** **Cleaning agents** **Soaps vs. other cleaners** **Market research** **Detergents, Soap scum** **Quantitative tests** **Qualitative tests**
Activity 2: Modeling Molecules Students build organic molecules of steadily increasing complexity, and examine the chemical bonding rules which determine these structures. A fat molecule is modeled and subjected to saponification and a skit is performed to demonstrate this reaction.	**Molecular models** **Lewis diagrams** **Organic molecules** **Covalent bonding** **Saponification** **Fat, Fatty acid** **Bohr model, Quantum mechanics** **Valence electrons** **Functional group** **Carboxylic acid group** **Bonding and nonbonding electrons** **Cis/trans double bonds**
Activity 3: How Do You Clean Dirty Laundry? Students test different cleaning solutions of varying polarity on different types of "dirt" to see which ones are most effective. They will discover that most types of dirt fall into one of two categories (polar or non-polar) and that laundry detergent in water will wash out most of them. Students perform a couple of quick experiments involving static electricity, observing that water behaves like a charged object and kerosene does not.	**Electrostatic forces** **Hydrophilic interactions** **Hydrophobic interactions** **Polar molecules** **Non-polar molecules** **Polar covalent bonds** **Electronegativity** **Surfactant**
Activity 4: How Does Soap Work? Students explore surface tension and the effect of soap on it. They then separate various liquids and solids according to their polarity. Models to describe the behavior of interactions between polar and non-polar substances are designed. The effect of adding a surfactant is considered, and students will also observe the characteristics of a mixture of water and oil.	**Polar molecules** **Non-polar molecules** **Surface tension** **Surfactants** **Micelles**
Activity 5: How Does Chain Length Affect the Properties? Students determine the melting points of three saturated fatty acids of increasing chain length, identifying the trend. They examine a heating curve to help understand the phase transition between the solid and liquid states, and generate an explanation for this behavior. They examine three soaps made with high percentages of these three fatty acids, looking for trends between the properties and increasing chain length.	**Melting point/freezing point** **Heating/cooling curves** **Phase transitions** **Structural effects on properties** **Intermolecular forces** **London dispersion forces** **Saponification, Fats** **Fatty acids**
Activity 6: Changing the Fat: Does Unsaturation Make a Difference? Students use paper clips to model the overall shapes of a related series of fatty acids with increasing numbers of double bonds and examine the relationship between shape and melting point. They model the packing behavior of each acid, then predict and measure their melting points. Students will examine the properties of soaps containing large amounts of these fatty acids in terms of the number of double bonds. They will then predict the attributes of other soaps with these fatty acids.	**Melting points** **Molecular packing** **Molecular structure** **Single and double bonds** **Saturated/unsaturated** **Van der Waals forces** **Animal fat** **Vegetable fat** **Polyunsaturated**
Activity 7: Soap, Other Bases, and pH Students measure the pH of an array of different soaps brought from home, and use acid to neutralize the pH of the soap. Then they measure the pH of an acid solution and try to dilute the acid enough to change the pH by 1 unit. After they discover the amount of water required to change the pH by 1 unit, they make predictions for more pH changes and carry them out.	**pH scale, Logarithms** **Acids/Bases** **Arrhenius definition** **Brønsted definition** **Neutralization** **Dilution** **Mole, Molarity** **Weak acids and bases** **Strong acids and bases**
Activity 8: Making Soap Functional and Appealing Students test and compare the soap they bought as a target to the soaps they made before beginning the chapter. They consider the properties of the various fats available and choose one or more as the basis for the soap they will design. After learning about moisturizers, thickeners, pH adjustments, and foaming agents, they decide whether to include any of them or not. Finally, they make the soap they have designed.	**Experimental design** **Soap additives** **Marketing** **Moisturizers** **Humectants** **Thickeners, Waxes** **Foaming agents** **Esters**

Chapter 11: H2Woes

Chapter Challenge

You have been assigned by an international health organization, such as UNESCO, to improve the water supplies of communities in Latin America. The communities are of three types: **1. mining** and logging areas that have drawn water from mountain streams; **2. farming** areas that rely on wells, rivers, swamps, or lakes as sources of water; **3. industrialized** areas that depend on water reservoirs fed by rivers and wells. You will develop a flow chart for their recommended purification procedures, explain the chemistry behind the procedures, and present your plan to the class.

Activity Summaries	Chemistry Principles
Activity 1: What's in Natural Water? Students learn some of the minerals common to natural waters and that they are composed of ions. They also study the reactions involved when gases dissolve in water and how to measure concentrations. Different sources of pollution, such as agricultural runoff and industrial discharge, are encountered.	Hydrological cycle Aquifer Naming compounds Ionic substances Molecular compounds Polar covalent bonds Concentration units, ppm Electronegativity Hydrogen bonds Solubility rules
Activity 2: Factors Affecting Solubility of Solids Students explore solubility for ionic compounds and develop a set of rules for various combinations of cations and anions. The solubility of covalent compounds is also investigated and the importance of hydrogen bonds is discovered. The effect of temperature on solubility is observed, as well as the exothermic or endothermic nature of solution formation.	Solubility rules Chemical bonding Electrostatic forces Energy changes, Enthalpy Disorder changes Thermodynamics Gibbs free energy Ion dissolution Saturated solutions Disorder changes, Spontaneity
Activity 3: How Much Solute is in the Water? Students learn several common measurements for substances found in water. These include nitrates, iron, and the alkaline earth elements, magnesium and calcium. These quantitative analysis techniques will use colorimetry and titration.	Periodic trends Classes of substances Solubility Colorimetric analysis Precipitation reactions Acids and bases, pH Titration, EDTA Water hardness Indicators, Endpoint Ion-specific electrodes
Activity 4: Aqueous Balance: Equilibrium Students generate calcium oxalate in a micro-lab experiment and calculate the K_{sp} for the equilibrium. Similarly, the K_W of water is explored. The concept of a shift in equilibrium and methods for causing a shift are learned.	Equilibrium Equilibrium constant, K_{eq} Solubility Product, K_{sp} Acid/base equilibria, pH Law of Mass Action LeChatelier's principle Total ionic equation Net-ionic equation Spectator ions
Activity 5: Removing Suspended Particles and Iron As a model, students construct a filtration column using a syringe and use it to filter iron (as its hydroxide) from water. In a second experiment, iron is removed in a batch process and the results of the two experiments are compared. Suspended particles are removed using a gel of aluminum hydroxide.	Colloids, Tyndall Effect Suspensions, Filtration Coagulation, Alum Rate of reaction Properties of fluids Batch method, Flow method
Activity 6: Water Softening Students study the removal of magnesium and calcium ions in the water softening process using a precipitation reaction. Quantitative results are obtained and compared to removal by an ion exchange resin.	Ionic equilibrium Precipitation reactions Separation methods Soda-lime process Water hardness Ion exchange resins
Activity 7: Removing Toxic-Metal Ions Students learn the toxic heavy metals which must be removed from a water supply and what the maximum allowed concentrations are. Copper, cadmium, and nickel are removed as their sulfides by precipitation. Also by precipitation, chromium, lead, tin, or zinc concentrations can be lowered by formation of their hydroxides.	Human toxicity limits Incomplete precipitation Precipitation reactions Solubility Heavy metals Distillation, Reverse osmosis
Activity 8: Disinfection Students complete their study of water purification methods by examining the final steps of the process. Bacteria are killed by administering hypochlorite solution and the effectiveness is measured by comparing tests from agar jelly. Other bacteriocides are studied and compared with regard to safety and cost. Finally, the pH is adjusted with acid or base.	Toxic bacteria, Pathogens Bacterial origins in water Chlorination reactions Acids and bases, pH, Acid rain Chlorinated organic pollutants Ozone, Activated carbon