RESOURCE GUIDE: Tips for Teaching Science, Technology, Engineering, and Math (STEM)

Even if you don't have a background in chemistry, you can still lead a chemistry experiment and other STEM activities in your class! Below are suggestions to help you prepare and present a STEM lesson to students!

PLAN IN ADVANCE

- **Read through the lesson and experimental procedure very carefully.** Thoroughly reading the material will enhance your comfort level with the background information, important terms, and experimental procedure. It will also prepare you to answer questions from students.

- **Note any questions you may have so that you can research them before you teach the lesson.** Many of your questions may be answered in the ***Observation & Research*** section of the lesson. Other questions may require you to do additional outside research.

- **Determine how you would like to conduct the experiment in class (groups, individually, etc.).** How you present the experiment, the quantity of materials needed, and the type of classroom discussions will vary depending on how you plan to conduct the experiment. You may also choose to use the experiments as demonstrations if you do not have enough class time allotted for hands-on experiments.

- **Obtain the necessary materials.** All of the materials used in the Activity Guide can be easily found at a grocery or all-purpose store (Walmart, Target, etc.). For a complete list of materials needed for each lesson in the Activity Guide, review the blue introductory box on the first page of each lesson. If you have difficulty finding certain materials, please contact us at comments@chemed.org.

- **Conduct a practice run of the experiment.** Having done the experiment beforehand, you will have a better idea of what to expect, how to instruct your students, and what hints or tips you can provide them throughout the process. Testing the experiment will also help you to resolve any potential issues, such as faulty materials, beforehand.

- **Become well versed in the concepts and specific topics that you want the students to learn.** Creating a list of key points and concepts that you want to convey to students will help you present the lesson in a fun, educational, and organized format. Remember, all of these lessons can be modified to address various concepts, so you can select which concepts best suit your classroom needs and tailor the lesson to your chosen curriculum.

- **Generate a list of related topics and potential questions that your students might ask.** Preparing a list can help you define the scope of the lesson plan and also ensure that you are covering the intended concepts. Students often ask questions about topics related to the experiment but not necessarily contained within the ***Observation & Research*** section. While additional background information and real-world examples are provided, researching potential questions and related topics will further develop background knowledge to help you to answer their questions and connect other interesting concepts to the lesson.

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SAFETY DISCUSSION

- **Obtain the necessary safety materials (goggles, aprons, etc.).** Your school may already have these materials. If not, ask your administration about how to obtain them. Review the ***Safety First*** section of this ***Resource Guide*** and the notes in the relevant lesson to determine the appropriate safety materials and procedures.

- **Before beginning the experiment with the class, be sure to go over the necessary safety precautions.** It is never too early to introduce students to safety practices. Even if certain information does not apply to your classroom, providing an overview and then discussing safety rules specific to your classroom is a great way to make them aware of the importance of safety when conducting experiments.

- **Discuss the importance of a safety plan.** Have students create a plan for the classroom, and then post it where everyone can see it. You may want to make this an assignment. Ask each student to research and write down 4–5 laboratory safety procedures. Then, compile a list together in class to develop your plan.

- **Model appropriate behavior by obeying the safety rules and procedures outlined in your classroom safety plan.** Your students are looking to you to set the standard for safety! Be their best safety example.

- **Check out the *Safety First* section on pages 421–423 in this guide for a more specific list of suggested classroom safety tips.** If you are not sure where to start or what safety procedures your students should understand, the ***Safety First*** section of this ***Resource Guide*** will help! Remember, you can't be too cautious with safety in the classroom. Even if certain information does not apply to your lesson, it is always good for students to learn about various safety procedures.

UTILIZE RESOURCES

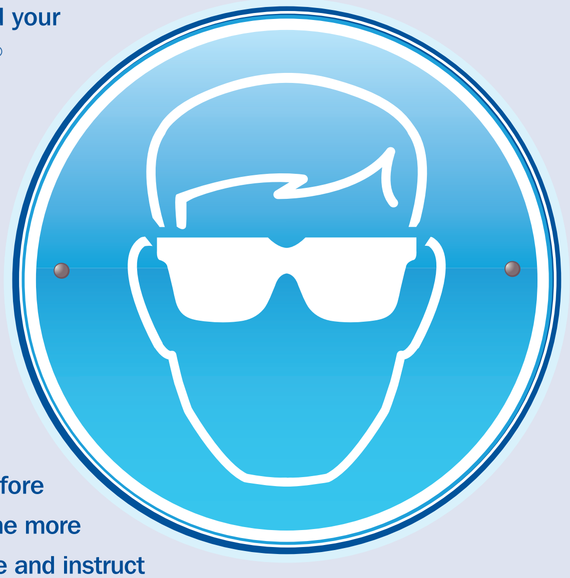
- **Use the activity sheets following each lesson.** The activity sheets (and answer keys) will help to reinforce students' understanding of the concepts covered in the lesson and assess their learning.

- **The *Lesson Plan Vocabulary* and *Notable Chemists* sections of this *Resource Guide* are tools provided to assist in teaching scientific concepts.** They also reinforce the importance of inquiry and experimentation to discover new things.

- **Periodically review and reinforce the concepts covered.** Use the ***Review Games Suggestions & Content*** in this ***Resource Guide*** to devise a fun way to go over the material with students.

RESOURCE GUIDE: Safety First

The Chemical Educational Foundation® (CEF) hopes you and your students will enjoy the lessons in the *You Be The Chemist®* Activity Guide, but before the fun begins, remember … ***Safety First!*** For the chemistry experience to be truly enjoyed, safety should be an essential component of all science lesson plans. Students should learn the importance of classroom, laboratory, and general chemical safety at an early age. CEF encourages you to reinforce the importance of safety before every lesson.



Science activities are diverse, often require several steps, and can be more difficult to supervise than other instructional activities. As the teacher, you should perform each lesson first before assigning it to your students. A practice run will allow you to become more comfortable with teaching the lesson, enable you to better supervise and instruct your students, and help you recognize potential risks that could exist as students learn new skills and work with new materials.

Below are suggestions on how to better prepare your students for safety in the chemistry classroom and lab. While some of the tips may not apply to your grade level or lesson, it is never too early to teach your students about the importance of classroom and lab safety while conducting experiments!

To ensure everyday safety in your classroom, create and post a safety plan specific to your classroom environment, complete with evacuation procedures. To reinforce the safety rules, engage the students in a discussion or activity about safety. At the elementary level, something as simple as a poster contest (or assignment), in which the winning (or all) posters are displayed, is an easy and creative way to reinforce the rules. At the middle school level, group activities that involve safety scenarios or question-and-answer sessions will help reinforce the rules. Most important, educators should always model appropriate behavior by obeying safety rules and procedures in class.

In your safety discussion, be sure to stress that horseplay in the classroom or lab is dangerous and will not be tolerated. Emphasize the importance of understanding how to safely store, handle, and use chemicals before performing any lessons. Explain that this information can be found in many places, such as on the container's warning label. Product container labels include key warnings about storage, handling, and, if necessary, first aid and other emergency information. Another information source is the Material Safety Data Sheet (MSDS), which is available for most chemicals. The MSDS contains more detailed information about chemical characteristics, hazards, emergency information, storage and handling precautions, and disposal information.

You should also educate students about proper personal protection, such as wearing aprons, gloves, and safety goggles when performing any experiment.

The following pages list general classroom and lab safety tips for you to discuss with your students.

Be safe and have fun!

RESOURCE GUIDE: Safety First

- **Chemists Have No Taste**—As a general rule, chemists never use their sense of taste in the lab.

- **Ban All Food**—Food should not be stored or consumed in a lab setting. Even in harmless situations, eating food in a lab sets a poor safety example.

- **Smell It Properly**—Chemists never hold a chemical container under their nose to test for an odor. The proper method is called "wafting." Hold the open bottle at least 18 inches from your nose. Use your free hand to "fan" vapor over the bottle opening toward your nose and you can safely inhale only a slight amount of chemical vapor.

- **Protect the "Corner" of Your Eyes**—Eye protection should be provided and worn by teachers and students when performing lab experiments. Regular eyeglasses provide insufficient protection. Proper lab glasses protect both the front and sides of the eyes. It's those hazards, just out of normal view—to the sides of the eyes—that often do the most damage!

- **Eye Wash Times Three**—When working with chemicals, a chemist always makes provisions for an eye wash. If you do not have access to a professional eye wash station or wash bottle, keep on hand a supply (300–500 mL) of distilled water in a sterilized container.

- **Wear That Apron**—Most lab accidents are caused by spilled liquids. A nonabsorbent apron will direct liquid toward the floor, away from you. Do not use cloth aprons in the lab.

- **No Bag, No Sag**—Loose clothing can create a hazard in a lab setting. Sleeves and shirttails can interact with labware to create a spill.

- **Tie Back Hair**—Long hair in a chemistry lab can create a safety problem, especially around flames or caustic chemicals. Keep rubber ties, caps, or other hair accessories available for temporarily securing longer hair.

- **Turn Your Head to Talk**—Many heated lab vessels have been shattered by a tiny speck of saliva accidentally emitted as a chemist talks while working.

- **Love Your Labels**—Make sure that all chemicals and storage areas in your classroom or lab are clearly labeled. Chemicals should never be stored in an unlabeled container, even for a short period of time.

- **No ABCs with Chemical Storage**—While storing chemicals in alphabetical order may be convenient, it may not be safe to do so. Chemicals should be stored only by reactivity risk and compatibility.

- **A Partnership with MSDS**—A container of chemicals in your lab should always have a partner in your filing cabinet or computer file: a Material Safety Data Sheet (MSDS). Make certain all students and teachers have easy and immediate access to your MSDS file.

- **Stay Out of the Sun**—Direct sunlight will not only initiate the decomposition of many chemicals, it can also affect labware, stoppers, tubing, labels, etc.

- **Amber Bottles**—You may notice that some chemicals are stored in amber or dark-brown glass bottles. Amber glass is used to filter out ultraviolet (UV) light. Some chemicals will readily decompose in the presence of UV light. Keep chemicals in the same type of container in which they arrived from the manufacturer.

- **Neutralizers**—When planning to use hazardous chemicals, even in diluted form, a chemist will always prepare an appropriate neutralizing chemical beforehand and keep it handy.

- **Splash Guard**—Chemists must always prevent water from splashing out of the lab sink. When filling a beaker or other open-mouthed vessel in a lab sink, turn on the water first. Then bring the beaker mouth into the stream. This action prevents splashing.

- **Acid to Water**—A general chemical rule when diluting acids and other active chemicals: always add acid to water; NEVER add water to acid.

RESOURCE GUIDE: Safety First

- **Labware Not Glassware**—Do not substitute common glassware for labware. Household bottles and jars are usually made of common flint glass. They are unsuitable for heating chemicals over open flames or high-temperature heaters. Their ability to resist thermal shock is very limited. Most common glassware will shatter when heated. Most labware is made of borosilicate glass, which has a much greater resistance to thermal shock.

- **Stir Silently**—During manufacture, lab glassware is specially heated at the factory to create a completely smooth and nonporous surface. This surface provides no pores or pits in which chemicals can "hide." To avoid creating chemical hiding places, do not strike, scrape, or touch the interior surface of the vessel with a hard instrument when stirring the contents of the vessel. Otherwise, you may create microscopic nicks and scratches that will hold contaminating chemicals.

- **Watch Where You Point**—When opening chemical containers or heating lab vessels, always keep in mind the direction of the container's mouth. Point the opening away—away from you, away from others, and away from points of safety concern.

- **Preheating Procedure**—Although lab glassware is usually made of thermal, shock-resistant borosilicate glass, it is not immune to shattering from radical temperature changes. Do not thrust a room-temperature vessel into a burner flame. Instead, swirl the vessel as you slowly bring it into the heat source in several stages.

- **Tilt That Test Tube**—When heating a solution in a test tube, avoid holding the tube vertically in a flame. The hot liquid near the bottom of the tube can create a "geyser" effect and suddenly push liquid out of the tube. To avoid such action, chemists always tilt a test tube 30 degrees from vertical when heating.

- **Burner Flames**—A properly adjusted burner flame of natural gas or propane is pale and light blue in color. In a brightly lit room, the flames are often difficult to see. When not in direct use, either extinguish the flame or adjust the airflow to create a bright-yellow, easily visible flame.

- **Burner Temperature**—A typical Bunsen burner flame has a temperature of approximately 950 °C. If substituting a propane torch for a Bunsen burner, remember that the torch flame is about 1500 °C.

- **Boiling to Dryness**—When using lab glassware, avoid boiling liquids to the point at which the container is completely dry. A small amount of boiling liquid can create a "spot" of relatively cool glass. The tension between the cool spot and the surrounding hot glass could cause the vessel to crack or shatter.

- **Wire Gauze**—Place a piece of heavy gauge wire screen or wire gauze between a glass vessel and a burner flame or heat source. The screen conducts heat, creating a spread of heat over the entire under-surface of the vessel. This trick helps prevent breakage from thermal shock.

- **Wash Up**—Students should wash their hands with soap and water after completing an experiment. They should avoid touching their eyes and mouth until after they have washed their hands.

CHEMICAL DISPOSAL

It is unlikely that waste generated in introductory-level chemistry experiments will be harmful to the environment. However, discussing safe disposal teaches students about environmental health and safety.

Remember, disposal procedures vary. Before handling or moving a chemical for disposal, be sure to refer to the MSDS for disposal precautions. For more information, contact your school district's safety coordinator.

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RESOURCE GUIDE: Lesson Plan Vocabulary

A

Absorption: A process by which matter soaks up or takes in another substance

Accuracy: The closeness of a given measurement to the actual (true) value for that quantity of substance; to measure a quantity as close as possible to the true measurement (true value) of that quantity

Acid: A solution that contains an excess of hydrogen ions (H^+); acids have a higher concentration of hydrogen ions than pure water

Acid-base indicator: A substance that reveals the acidity or basicity of a solution through characteristic color changes; also simply known as an *indicator*

Adhesion: An attractive force that holds atoms or ions of different substances together

Aerobic respiration: The chemical process by which food molecules, such as glucose, combine with oxygen to release energy, carbon dioxide, and water

Air: A colorless and odorless gaseous mixture, composed mainly of nitrogen and oxygen

Air pressure: The cumulative force exerted on a surface by the weight of the air particles above that surface; also known as *atmospheric pressure*

Alloy: A uniform mixture made up of two or more metals or of a metal and a nonmetal

Amino acid: A type of substance that makes up proteins; amino acids are the building blocks of proteins

Amorphous solid: A solid made up of atoms or molecules that are locked into place but do not have a specific form or neat, repeating structure

Anemia: A condition in which the red blood cell count or the hemoglobin in red blood cells is abnormally low

Aqueous solution: A solution in which the solvent is water

Atom: The fundamental unit of an element; the smallest particle of an element that maintains the chemical properties of that element

Atomic number: The number of protons found in the nucleus of an atom; it is used to identify elements

Attraction: A force that draws particles together

Avogadro's Law: A scientific law stating that equal volumes of gases at the same temperature and pressure will contain the same number of molecules (n), regardless of their chemical nature and physical properties

B

Base: A solution that has an excess of hydroxide ions (OH^-); bases have a lower concentration of hydrogen ions than pure water

Boiling point: The temperature at which a liquid begins to form a gas

Boyle's Law: A scientific law stating that at a constant temperature, the product of the pressure and volume of an ideal gas is always constant

Buoyancy: An upward force that a fluid exerts on an object, enabling the object to float

Byproduct: A secondary product that is created from a chemical reaction at the same time as the primary, desired product(s)

C

Capillary: A tiny tube or vessel that is able to hold or transport liquids

Capillary action: The ability of a substance to be drawn (possibly upward) through a tiny tube or vessel by adhesive and cohesive forces; also known as *capillarity*

Carbohydrate: The most abundant group of organic compounds found in living organisms that are made up of sugars; carbohydrates are broken down during chemical processes to generate energy

RESOURCE GUIDE: Lesson Plan Vocabulary

Carbonation: The process of dissolving carbon dioxide gas in water or an aqueous solution under pressure

Catalyst: A substance that helps to change the rate of a reaction but is not consumed or changed during the reaction

Charles' Law: A scientific law stating that under constant pressure, the volume and temperature of a gas are directly proportional; therefore, the proportion of volume to temperature of a gas equals a constant

Chemical bond: A strong force of attraction that holds atoms together in a molecule

Chemical change: See *chemical reaction*

Chemical energy: Energy stored in the structures of chemical substances that may be released or transformed during a chemical reaction

Chemical property: A property of a substance that can be revealed by the way the substance interacts with other substances; describes an object's "potential" to undergo some chemical change or reaction due to its composition

Chemical reaction: A change that takes place when atoms of one or more substances are rearranged, and the bonds between the atoms are broken or formed to produce new substances; also known as a *chemical change*

Chemistry: A science that deals with the composition, structure, properties, and reactions of matter

Chromatography: A group of separation processes used to separate and analyze complex mixtures based on differences in their structure or composition

Cohesion: An attractive force that holds atoms or ions of a single body together; an attraction between particles of the same kind

Colloid: A mixture, between homogeneous and heterogeneous, in which very small particles are spread evenly throughout another substance

Compound: A pure substance made up of two or more elements joined in a defined ratio

Concentration: The amount of solute in a solution

Concentration gradient: The difference between the concentration of two fluids

Conclusion: A statement scientists make explaining whether a tested hypothesis was valid or invalid

Condensation: A physical change in which a substance changes states from a gas to a liquid

Conduction: The transfer of energy by collisions between nearby atoms

Control: Something that does not change throughout an experiment; a setup that is not changed

Controlled experiment: An experiment in which all conditions except one are held constant

Controlled variable: A thing that should not change during an experiment

Convection: The transfer of energy by the bulk molecular motion within a liquid or gas

Cosmic dust: Clouds of fine, solid particles that exist in outer space

Cross-linking: The formation of chemical bonds between complex molecules or molecular chains, such as polymers

Crude oil: A mixture made of hydrocarbon compounds that is used to produce various fuels, such as gasoline

Crystalline solid: A solid made up of atoms or molecules organized in specific, repeating patterns; these regular, repeating patterns form crystals

RESOURCE GUIDE: Lesson Plan Vocabulary

D

Data: Pieces of information that are collected and recorded before, during, or after an experiment

Decomposition: A chemical reaction in which a compound breaks apart into two or more products

Density: A physical property of matter that describes how closely packed together the atoms of an element or the molecules of a compound are; the amount of matter per unit of volume (d = m/v)

Dependent variable: The variable that you observe when the independent variable is changed; also known as the *responding variable*

Deposition: A physical change in which a substance changes states from a gas to a solid

Desalination: The process of removing salt from a saltwater solution, such as sea water

Dew point: The temperature at which a gas begins to condense into a liquid

Diatomic molecule: Molecules consisting of two atoms bound together, such as diatomic oxygen gas (O_2)

Diffusion: The movement of particles from an area of high concentration to an area of low concentration

Displacement: The act of moving something out of its original position or of one substance taking the place of another; also a type of chemical reaction in which a reactant takes the place of some part of a compound to produce a new compound and release a separate product

Disposable: An object that is designed to be used once and then thrown away

Dissolve: To cause a substance to mix uniformly with a solvent, creating a solution

Distillation: A method of separating a liquid mixture based on the differences between the boiling points of the mixture's parts

Double displacement: A chemical reaction in which parts of two compound reactants replace each other to form two or more different compound products

Drag: The resistance of motion through a fluid; a mechanical force that opposes an aircraft's motion through the air

Ductility: The ability of a metal to be stretched into a thin wire or thread without breaking

Dye: A soluble substance used to stain or color fabrics and fibers, such as paper, cotton, etc.

E

Electric charge: A basic property of some subatomic particles that can be classified as either positive or negative; a characteristic property of matter identified by an imbalance of electrons, whether an excess or deficiency of electrons

Electrical conductivity: A measure of the rate at which electricity can travel through a material

Electrical energy: A form of energy that results from the flow of charged particles, such as electrons or ions; also known as *electricity*

Electrically neutral: An atomic state in which the number of protons in an atom equals the number of electrons, thus, the positive and negative charges are balanced

Electricity: See *electrical energy*

Electromagnetic wave: A wave (continuous vibration through space) that carries energy through space by radiation

Electron: A subatomic particle that carries a negative charge and occupies the space outside the nucleus of an atom

Element: A pure substance that cannot be broken down into simpler substances by ordinary chemical or physical means; an element is made up of only one type of atom

RESOURCE GUIDE: Lesson Plan Vocabulary

Emulsion: A colloid that consists of liquids spread throughout other liquids; the liquids in an emulsion do not completely mix and are often unstable

Endothermic change: A change that needs energy added to take place

Energy: The ability to do work or produce heat

Enzyme: A type of protein found in living cells that acts as a catalyst by increasing the rate of a chemical reaction within living organisms

Equilibrium: A state of balance between opposing forces or elements; a state of balance in which a chemical reaction and its reverse reaction occur at equal rates

Error: A concept associated with inaccuracy or a flaw in measurement

Evaporation: A vaporization process that occurs at the surface of a liquid

Exothermic change: A change that gives off energy, generally sensed as heat

Experiment: An operation carried out under controlled conditions in order to discover an unknown effect or phenomenon; to test or establish a hypothesis as valid or invalid

F

Filter paper: A porous paper that can be used to separate suspended solids from a liquid

Filtrate: A liquid collected, following a filtration process, that is free of solid particles

Filtration: A separation process that uses the different sizes of a mixture's parts to separate those parts

Fluid: Any substance made up of particles that flow or move freely, such as a liquid or gas

Force: A push or pull acting on an object, sometimes causing a change in position or motion

Freezing: A physical change in which a substance changes states from a liquid to a solid

Freezing point: The temperature at which a substance begins to change from a liquid to a solid

Frequency: The number of complete waves or pulses that pass a given point per second

Friction: The force that resists motion between two substances in contact

G

Gas: A state of matter that has no definite volume or shape

Gas laws: A set of laws that describe the relationships between volume, temperature, and pressure of gases

Gay-Lussac's Law: A scientific law stating that the pressure exerted on a container by a gas is directly proportional to the temperature of the gas

Gravity: The force of attraction between all masses in the universe; the force that tends to draw all substances in the earth's atmosphere toward the center of the earth

H

Heat: The flow of thermal energy from one substance to another because of differences in temperature

Hemoglobin: A protein found in red blood cells that contains iron and transports oxygen from the lungs to different parts of the body

Heterogeneous mixture: A type of mixture in which the makeup is not the same throughout; the substances are not evenly mixed

Homogeneous mixture: A type of mixture that is considered to be the same throughout; the substances are evenly mixed

RESOURCE GUIDE: Lesson Plan Vocabulary

Hydrocarbon: A compound made of only the elements hydrogen (H) and carbon (C)

Hypothesis: A possible explanation of an observation that can answer a scientific question

I

Ideal gas law: A combination of gas laws that relates temperature, pressure, and volume through the formula, $PV = nRT$, where P is pressure, V is volume, T is temperature, n is the number of moles, and R is the ideal gas constant

Immiscible: The inability to mix evenly; the inability of two or more substances to form a homogeneous mixture when combined

Independent variable: The variable you are going to change in an experiment

Index of refraction: The ratio of the speed of light in a vacuum to the speed of light in a substance

Indicator: See *acid-base indicator*

Inertia: The resistance of an object to a change in its state of motion

Insoluble: The inability of a substance to be dissolved into another substance

Insulation: Any material that resists the flow or transfer of heat, sound, or electric current; also known as an *insulator*

Ion: An atom or group of atoms that has lost or gained one or more of its outer electrons; an ion will have either a positive or a negative charge

K

Kinetic energy: A form of energy associated with motion, calculated using the formula $KE = {}^{1}/_{2}mv^2$

L

Law of conservation of energy: A scientific law stating that while energy can change form, it cannot be created or destroyed; also known as the *first law of thermodynamics*

Light: A specific group of electromagnetic waves that travels freely through space and can be detected by the human eye; also known as *visible light*

Lipid: A type of organic compound that is insoluble in water and helps with insulation and the regulation of body functions; lipids are also used to store energy in the body

Liquid: A state of matter that has a definite volume but no definite shape; a liquid will take the shape of the container that holds it, filling the bottom first

Litmus paper: An acid-base indicator that changes color in the presence of acids and bases; blue litmus paper turns red in the presence of an acid, and red litmus paper turns blue in the presence of a base

Luster: The ability of a metal to reflect light; this property gives metals a shiny appearance

M

Magnet: An object that creates a strong magnetic field and is able to attract iron

Magnetic field: An area of magnetic force around certain substances (metals) that causes them to move in certain ways even if they do not touch

Magnetism: A force of attraction or repulsion between materials that produce a magnetic field

Malleability: The ability of a metal to be flattened, shaped, or formed without breaking when pressure is applied

Mass: A measure of the amount of matter in a substance

Matter: Any substance that has mass and takes up space; matter is generally found as a solid, liquid, or gas on the earth

RESOURCE GUIDE: Lesson Plan Vocabulary

Measure: To mark or fix in multiples of a specific unit based on a comparison to some sort of standard

Measurement: A technique in which properties of a substance are determined by comparing it to some sort of standard

Mechanical energy: A form of energy determined by the motion or position of a substance; the total mechanical energy of a substance is the sum of its kinetic and potential energy

Melting: A physical change in which a substance changes states from a solid to a liquid

Melting point: The temperature at which a substance begins to change from a solid to a liquid

Metalloids: See *semi-metals*

Metals: A set of elements that are usually solid at a normal room temperature and are found primarily on the left side of the periodic table; most metals have similar characteristics, such as good thermal and electrical conductivity, luster, malleability, and ductility

Miscible: The ability to mix evenly; the ability to mix in all proportions to form a homogeneous solution

Mixture: A physical combination of two or more substances that can be physically separated

Mobile phase: The mixture that flows over the stationary material in a chromatography separation process

Molecule: The simplest structural unit of an element or compound that is made up of atoms held together by chemical bonds and maintains the chemical properties of the element or compound

Monomer: A single molecule capable of combining with other similar molecules to form a polymer

N

Neutral: A particle that carries no electric charge; a solution that contains a concentration of hydrogen ions that is equal to pure water

Neutron: A subatomic particle that carries no electric charge and is found in the nucleus of an atom

Newton's First Law of Motion: The first part of Sir Isaac Newton's theory of motion stating that an object at rest stays at rest, and an object in motion stays in motion with the same speed and in the same direction, unless acted upon by an unbalanced force

Newton's Second Law of Motion: The second part of Sir Isaac Newton's theory of motion stating that the relationship between an object's mass (m), its acceleration (a), and the applied force (F) is described by the formula $F = ma$

Newton's Third Law of Motion: The third part of Sir Isaac Newton's theory of motion stating that for every action, there exists an equal and opposite reaction

Newtonian fluid: A fluid that has a constant viscosity at a constant temperature, regardless of any applied force or rate of flow

Nonmetals: A set of elements that are generally gases or solids at a normal room temperature and are found primarily on the right side of the periodic table

Non-Newtonian fluid: A fluid that does not have a constant viscosity; the viscosity of a non-Newtonian fluid varies based on the force applied or how fast an object is moving through the liquid

Nonpolar substance: A substance made up of particles that have an even distribution of electrons; the charges on these particles are neutralized

Nonvolatile solute: A solute that has little tendency to escape from a solution

Nuclear energy: A form of energy released when the nucleus of an atom is split or fused

RESOURCE GUIDE: Lesson Plan Vocabulary

Nucleation site: An area where droplets of liquid can condense from a vapor, bubbles of gas can form in a boiling liquid, or new crystals can grow in a solution

Nucleus: The center of an atom containing protons and neutrons

O

Osmosis: The diffusion of water across a semi-permeable membrane (a membrane that allows some ions or molecules to pass through but not others)

Outer space: A region beyond the limit of the earth's atmosphere or any other celestial body (planet, star, asteroid, etc.)

Oxidation: The loss of at least one electron when two or more substances interact, which may or may not involve oxygen

P

Paraffin wax: A white, pliable solid that can be obtained from crude oil

Periodic table of elements: An arrangement of the chemical elements by atomic number so that elements having similar properties fall in the same column

Permanent magnet: A type of magnetic substance that keeps a certain level of magnetism for a long time

pH: A measure of the concentration of hydrogen ions in a solution; used to characterize acids and bases

pH scale: A scale that is used to measure the acidity of (concentration of hydrogen ions in) a solution; the pH scale generally ranges from 0 to 14

Photosynthesis: The process by which some living organisms, primarily green plants, convert light energy, carbon dioxide, and water into oxygen gas and sugars that store chemical energy

Physical change: A change that alters the form or appearance of a substance but does not change its chemical makeup or create a new substance

Physical property: A property of a substance that can be experienced using the human senses and often detected through a measuring device; physical properties can be observed without reacting the substance with some other substance

Polar substance: A substance made up of particles that have an uneven distribution of electrons, creating a negative and a positive side

Polarity: The state of having a positive or a negative charge

Poles: The ends of a magnet, each having an opposite charge, one positive and one negative; these poles are called the north pole (N) and the south pole (S)

Polymer: A large molecule formed by combining many smaller molecules (monomers) in a regular pattern

Potential energy: The energy stored in a substance

Power: The rate at which energy is converted or work is performed

Precipitate: A solid formed from a solution following a chemical reaction, specifically a precipitation process

Precipitation: A separation process that separates a particular component from a solution by reacting the solution with another substance to form a solid

Precision: The degree to which repeated measurements under unchanged conditions show the same results

Pressure: The amount of force exerted on an area

Product: A substance formed as a result of a chemical reaction

Protein: A type of complex organic compound made up of amino acids and involved in various cell functions; proteins help the body to grow and repair damage

RESOURCE GUIDE: Lesson Plan Vocabulary

Proton: A subatomic particle that carries a positive charge and is found in the nucleus of an atom

Pyrex® glass: A heat-resistant glass used to make scientific and cooking equipment

R

Radiant energy: A form of energy carried by electromagnetic waves, which includes X-rays, microwaves, ultraviolet radiation, and light

Radiation: The transfer of energy (as electromagnetic waves) through an empty space or clear material without heating the empty space or clear material

Random error: A type of error or flaw in measurement that is not controllable and is due to chance

Reactant: A starting material for a chemical reaction

Refraction: The bending of light as it passes from one medium to another

Respiration: A set of reactions that take place inside cells to convert the energy stored in food into another type of chemical energy that can be used by the body

Rocket: A device propelled by the ejection of matter (usually a gas) and often expelled as a result of the combustion of some internal material

Rocketry: A branch of engineering science that studies the design and operation of rockets

Rust: The reddish-brown brittle substance formed by the oxidation of iron; also known as *iron (III) oxide*

S

Saturation: The point at which no more of a solute can be dissolved into a solvent or solution

Semi-metals: A set of elements that have some properties of both metals and nonmetals and are found along a zigzag dividing line between metals and nonmetals on the periodic table; also known as *metalloids*

Separation process: A process that divides a mixture into two or more distinct substances

Shear stress: A pressure or force in the structure of a substance that arises when its layers are shifted horizontally in relation to each other

Sieving: A separation process by which solids of different sizes are separated from a mixture by passing the mixture through a screen

Sol: A colloid made up of fine solid particles suspended in a liquid or another solid

Solid: A state of matter characterized by a definite volume and a definite shape

Solubility: A measure of the amount of solute that can be dissolved in a solvent

Soluble: The ability of a substance to dissolve in another substance

Solute: A substance that is dissolved in a solution

Solution: A homogeneous (uniform) mixture in which one or more substances (solutes) are dissolved in another substance (solvent)

Solvent: A substance capable of dissolving another substance

Static electricity: The buildup of electric charges on the surface of an object, which occurs when electrons are pulled from the surface of one material and relocated onto the surface of another material

Stationary phase: A stationary material over which a mixture flows during a chromatography separation process

Sublimation: A physical change in which a substance changes states from a solid to a gas

Suction: A force that attracts a substance to a region of lower pressure when there is a difference in pressure

RESOURCE GUIDE: Lesson Plan Vocabulary

Surface tension: A property of liquids that describes the attraction of liquid particles at the surface; the strong attraction of particles at the surface of a liquid creates a surface "film"

Surfactant: Any substance with the ability to reduce the surface tension of a liquid; also known as a *surface active agent*

Synthesis: A chemical reaction in which two or more reactants combine to form a product

Systematic error: A type of error or flaw in measurement that is controllable and has a known cause, such as instrument error, method error, or human error

T

Temperature: A measure of the average kinetic energy of particles in a substance, generally identified by sensations of hot and cold

Temporary magnet: A type of magnet that acts like a permanent magnet when it is within a strong magnetic field but loses its magnetism when the magnetic field is removed

Thermal conductivity: The measure of the rate at which thermal energy can travel through a material

Thermal energy: The total energy of particles in a substance

Thrust: The mechanical force that pushes a rocket or an aircraft through the air

Transparent: A substance that allows light to pass through it easily so that objects beyond or behind the substance can be seen clearly

Triatomic molecule: A molecule consisting of three atoms bound together, such as ozone (O_3)

Triglyceride: A type of organic compound that is part of the lipid family and is made up of a glycerol (a type of alcohol) and three fatty acids

V

Vacuum: A volume of space that has essentially no matter; also known as a *partial vacuum*

Vapor: A common term used to describe a substance in its gaseous state, such as water vapor

Vaporization: A physical change in which a substance changes states from a liquid to a gas

Viscosity: The measure of a fluid's thickness or resistance to flow

Volatility: The tendency of a substance to vaporize (change into a gaseous state)

Volume: A physical property that measures the amount of space a substance occupies

W

Watercolor paint: A pigment dissolved in water that is used to create colorful designs on fibrous materials, such as paper

Wavelength: The distance between one wave crest (top of the wave) and the next, or between one wave trough (bottom of the wave) and the next

Weight: A measure of the pull of gravity between an object and the earth or the planets, sun, etc.

Work: The measure of a change in energy that occurs when a force causes an object to be displaced

X

Xylem: A complex plant tissue made up of networks of vessels (or small hollow tubes) that transport water and dissolved minerals through the plant; provides structural support to the plant

RESOURCE GUIDE:
Review Game Suggestions & Content

The following questions are provided as a means of reviewing and reinforcing the concepts that your students have learned in the lessons provided. This content is supplied to benefit you and your class in a number of ways—be creative and have fun!

Suggestions for review game setups:

- Divide your class into groups, and use the content on the following pages to create a fun question-and-answer competition.
- Choose a few lessons or major content topics to create a Jeopardy-style game.
- Use the material taken from the Fun Facts as bonus questions on tests!

LESSON 1: GOOFY PUTTY

1. A(n) __________ is made of two or more substances that are combined physically.
a. mixture

2. A uniform mixture in which one or more substances are dissolved in another substance is a(n) _________.
a. solution

3. Color, shape, boiling point, melting point, and density are examples of _________ properties of matter.
a. physical

4. Acidity, toxicity, and flammability are examples of _________ properties of matter.
a. chemical

5. Any change in a substance's form that does not change its chemical makeup is a(n) _____________.
a. physical change

6. During a(n) _____________, the structure or composition of the materials in a substance is changed or rearranged.
a. chemical reaction (or chemical change)

7. A(n) __________ is the smallest structural unit of an element or compound that keeps the chemical properties of that element or compound.
a. molecule

8. Long, chain-like molecules that are formed by connecting many repeating units are called __________.
a. polymers

9. A(n) ________ is a single molecule capable of combining with other similar molecules.
a. monomer

10. Hydrous sodium borate is also known as ________.
a. borax

RESOURCE GUIDE:
Review Game Suggestions & Content

LESSON 2: "AGELESS" APPLES

1. A solution containing a concentration of hydrogen ions (H^+) greater than pure water is called a(n) ______.
   a. acid

2. A solution containing an excess of hydroxide ions (OH^-) or an H^+ concentration less than pure water is called a(n) _________.
   a. base

3. The _________ measures the concentration of hydrogen ions in acids and bases.
   a. pH scale

4. The lower the concentration of H^+, the ________ the pH will be.
   a. higher

5. A substance with a pH higher than 7 is considered to be ______.
   a. basic (or a base)

6. Pure water is a(n) ________ substance with a pH of 7.
   a. neutral

7. __________ are complex organic compounds that are involved in almost all cell functions.
   a. Proteins

8. A(n) ___________ is a substance that helps change the rate of reaction.
   a. catalyst

9. Proteins that act as catalysts by increasing the rate of chemical reactions are called ___________.
   a. enzymes

10. __________ are the building blocks of proteins.
    a. Amino acids

LESSON 3: RUSTING WOOL

1. A(n) ________ is a uniform mixture made up of two or more metals or a metal and a nonmetal.
   a. alloy

2. Two atoms of oxygen bound together forming a molecule of O_2 is referred to as a(n) __________ molecule.
   a. diatomic

3. The triatomic form of oxygen is commonly called _________.
   a. ozone

4. ___________ often occurs when oxygen molecules interact with other substances.
   a. Oxidation

5. Iron oxide, a brittle reddish-brown substance that forms on iron, is most commonly called ________.
   a. rust

6. Rust is formed through a(n) _____________ between oxygen, water, and iron.
   a. chemical reaction (or chemical change)

7. A(n) _____________ is any change in a substance's form that does not change its chemical makeup.
   a. physical change

8. When the atoms of a substance are rearranged and the bonds between the atoms are broken or formed, a substance has undergone a(n) _____________.
   a. chemical reaction (or chemical change)

9. ____________ occurs when one substance takes the place of another.
   a. Displacement

10. The set of reactions that take place inside the cells of living things to convert energy from nutrients into a type of stored energy that can be used by the body is called ___________.
    a. respiration

RESOURCE GUIDE:
Review Game Suggestions & Content

LESSON 4: BUOYANT BUTTER

1. __________ is a measure of the amount of matter in a substance.
   a. Mass

2. The amount of space an object occupies is the object's __________.
   a. volume

3. __________ is the physical property of matter that describes how closely packed together the atoms or molecules of a substance are.
   a. Density

4. __________ occurs when one substance takes the place of another.
   a. Displacement

5. Measurements are ________ if they are close to the true measurement of an object or substance.
   a. accurate

6. Measurements are _________ if you take the same measurement and get the same result over and over.
   a. precise

7. The density of a solid is measured in what units?
   a. g/cm^3 or kg/m^3

8. The formula for calculating density is _________.
   a. $d = m/v$

9. In terms of density, a stick of butter is _______ than water.
   a. less dense

10. Which is denser: freshwater or salt water?
    a. Salt water

LESSON 5: LUMPY LIQUIDS

1. _________ are made of two or more substances that are combined physically.
   a. Mixtures

2. A uniform mixture in which one or more substances are dissolved into another substance is a(n) _________.
   a. solution

3. A(n) _____________ divides a mixture of substances into two or more distinct products.
   a. separation process

4. __________ is a separation process in which a solid is formed in a solution following a chemical reaction.
   a. Precipitation

5. The solid that forms from a solution after a chemical reaction is called a(n) __________.
   a. precipitate

6. The process by which a mixture is separated based on the sizes of the parts that make up the mixture is called _________.
   a. filtration

7. The liquid that flows through the paper during a filtration separation process is called the _________.
   a. filtrate

8. A physical property that describes the ability of a chemical substance to dissolve in a solvent to create a uniform solution is called __________.
   a. solubility

9. If a substance does not dissolve in another substance, it is __________.
   a. insoluble

10. A(n) _____________ is any solution in which the solvent is water.
    a. aqueous solution

RESOURCE GUIDE:
Review Game Suggestions & Content

LESSON 6: RUBBER EGGS

1. Pure substances that cannot be broken down further by normal chemical means are ________.
   a. elements

2. A(n) ________ is a pure substance made up of two or more elements joined in a defined ratio.
   a. compound

3. A(n) ________ is made of two or more substances that are combined physically.
   a. mixture

4. A change that takes place when atoms of a substance are rearranged, and the bonds between the atoms are broken or formed, is a(n) ____________.
   a. chemical reaction (or chemical change)

5. The bubbles that form during the experiment contain ___________ gas, which is produced from the chemical reaction between the vinegar and the eggshell.
   a. carbon dioxide

6. A(n) _______ is an atom or molecule that has lost or gained one or more of its outer electrons.
   a. ion

7. A solution containing a concentration of hydrogen ions (H^+) greater than pure water is called a(n) _________.
   a. acid

8. A solution containing an excess of hydroxide ions (OH^-) or an H^+ concentration less than pure water is called a(n) _______.
   a. base

9. A solution containing an H^+ concentration equal to pure water is _______.
   a. neutral

10. Substances that change colors at different levels of acidity are ________, which are used to determine whether a solution is an acid or a base.
    a. indicators

LESSON 7: MILK RAINBOW

1. _______ have a definite volume and definite shape.
   a. Solids

2. ______ have a definite volume but no definite shape.
   a. Liquids

3. ______ have no definite volume and no definite shape.
   a. Gases

4. A property of liquids that describes the attraction of liquid particles at the surface is called __________.
   a. surface tension

5. A(n) ___________ is a substance that has the ability to reduce the surface tension of a liquid.
   a. surfactant

6. A(n) ________ is a mixture in which very small particles are spread evenly throughout another substance.
   a. colloid

7. A mixture that is considered to be the same throughout is called a(n) ___________.
   a. homogeneous mixture

8. A mixture in which the makeup is not the same throughout is called a(n) ___________.
   a. heterogeneous mixture

9. A(n) __________ is a mixture that consists of liquids spread throughout other liquids.
   a. emulsion

10. ________ is an emulsion of fats and proteins spread throughout water.
    a. Milk

RESOURCE GUIDE:
Review Game Suggestions & Content

LESSON 8: THE MOVING MOLECULE STOMP

1. A substance undergoes a(n) ________ change when only its form, not its chemical makeup, is changed.
   a. physical

2. Particles in a(n) ________ are generally locked into place giving the substance a definite shape and volume.
   a. solid

3. ____________ are made up of atoms or molecules that have a specific, repeating arrangement.
   a. Crystalline solids

4. Solids made up of atoms or molecules that are locked into place but do not have a specific, repeating structure are known as _____________.
   a. amorphous solids

5. Particles in a(n) ________ move around freely, allowing it to flow, but still experience attractive forces.
   a. liquid

6. Particles in a(n) ________ are spaced far apart and move around freely and rapidly in random directions.
   a. gas

7. A physical change from a solid to a liquid is called ________.
   a. melting

8. A physical change from a liquid to a solid is called ________.
   a. freezing

9. A physical change from a liquid to a gas is called ________.
   a. vaporization

10. A physical change from a gas to a liquid is called ________.
    a. condensation

LESSON 9: EGG-DYE SOLUTIONS

1. A(n)______ is an atom or molecule that has lost or gained one or more of its outer electrons.
   a. ion

2. A solution containing a concentration of hydrogen ions (H^+) greater than pure water is called a(n) _______.
   a. acid

3. A solution containing an excess of hydroxide ions (OH^-) or an H^+ concentration less than pure water is called a(n) ________.
   a. base

4. A solution containing an H^+ concentration equal to pure water is ________.
   a. neutral

5. The concentration of hydrogen ions in acids and bases is measured on the ________.
   a. pH scale

6. Substances that change colors at different levels of acidity are _________, which are used to determine whether a solution is an acid or a base.
   a. indicators

7. A(n) ___________ occurs when two or more substances interact, producing a change in the structure of the substance(s).
   a. chemical reaction (or chemical change)

8. A(n) ________ is the starting material for a chemical reaction.
   a. reactant

9. The substance or substances produced from a chemical reaction are called ________.
   a. products

10. A secondary product created at the same time as a desired product during a chemical reaction is called a(n) _________.
    a. byproduct

RESOURCE GUIDE:
Review Game Suggestions & Content

LESSON 10: IRON IN CEREAL

1. _______ is the metal element needed to transport oxygen throughout the body.
   a. Iron

2. ________ is the protein molecule in red blood cells that picks up oxygen in the lungs and transports it to different parts of the body.
   a. Hemoglobin

3. Iron deficiencies, such as _________, occur when the body has an insufficient amount of healthy red blood cells.
   a. anemia

4. A force of attraction or repulsion between materials that produce a magnetic field is called _________.
   a. magnetism

5. _________ are pure substance that cannot be broken down further by normal chemical means.
   a. Elements

6. A(n) _______ is a pure substance made up of two or more elements joined in a defined ratio.
   a. compound

7. A(n) _______ is made of two or more substances that are combined physically.
   a. mixture

8. In this lesson, a(n) ________ is used to separate iron particles from the cereal mixture.
   a. magnet

9. Iron, cobalt, and nickel are the only elements known to produce a(n) _________.
   a. magnetic field

10. A(n) ______________ divides a mixture of substances into two or more distinct products.
   a. separation process

LESSON 11: DIAPER POLYMERS

1. A(n) ________ is the smallest particle of an element or compound that retains the chemical properties of that element or compound.
   a. molecule

2. Long, chain-like molecules that are formed by connecting many repeating units are called _________.
   a. polymers

3. A(n) ________ is a single molecule capable of combining with other similar molecules.
   a. monomer

4. ________ is the movement of particles from an area of high concentration to an area of low concentration.
   a. Diffusion

5. The diffusion of water across a semi-permeable membrane is called ________.
   a. osmosis

6. A(n) _______ is any substance made up of particles that flow or move freely.
   a. fluid

7. Both _______ and _______ are considered fluids.
   a. liquids, gases

8. Sodium chloride is commonly known as ________.
   a. table salt

9. ___________ is the bonding of separate polymer chains in a network that makes the polymer stronger.
   a. Cross-linking

10. ___________ is added to the polymer in the experiment to draw the water back out of the polymer.
   a. Table salt

RESOURCE GUIDE:
Review Game Suggestions & Content

LESSON 12: THE GREAT ESCAPE

1. _________ are pure substances that cannot be broken down further by normal chemical means.
   a. Elements
2. A(n) _________ is a pure substance made up of two or more elements joined in a defined ratio.
   a. compound
3. A(n) _________ is made of two or more substances that are combined physically.
   a. mixture
4. A uniform mixture in which one or more substances are dissolved in another substance is a(n) ________.
   a. solution
5. _________ is a physical property that describes the ability of a chemical substance (the solute) to dissolve in a solvent to create a uniform solution.
   a. Solubility
6. For solid solutes, as temperature increases, solubility __________.
   a. increases
7. For gas solutes, as temperature increases, solubility __________.
   a. decreases
8. __________ is defined as the capacity to do work or produce heat.
   a. Energy
9. The law of _______________ states that while energy can change from one form to another, it can neither be created nor destroyed.
   a. conservation of energy
10. _________ is a measure of the average kinetic energy of particles in a substance.
    a. Temperature

LESSON 13: DISAPPEARING GLASS

1. _________ is a measure of the ability to do work or produce heat.
   a. Energy
2. Light, microwaves, and X-rays are all types of ______________.
   a. electromagnetic waves
3. _________ is a property of light that describes the bending of light as it passes from one medium to another.
   a. Refraction
4. The ____________ refers to the angle that is formed between the light and the surface of the object.
   a. index of refraction
5. ________ is the distance between one wave crest (top of the wave) and the next, or between one wave trough (bottom of the wave) and the next.
   a. Wavelength
6. _________ is the number of complete waves or pulses that pass a given point per second.
   a. Frequency
7. _________ is the measure of the amount of matter in a substance.
   a. Mass
8. __________ is the measure of the amount of space an object occupies.
   a. Volume
9. ________ have a definite volume and a definite shape.
   a. Solids
10. ________ have a definite volume but no definite shape.
    a. Liquids

RESOURCE GUIDE:
Review Game Suggestions & Content

LESSON 14: WACKY WAXY WATERCOLORS

1. __________ is a white, pliable solid obtained from crude oil.
   a. Paraffin wax

2. A(n) _________ is made of two or more substances that are combined physically.
   a. mixture

3. A uniform mixture in which one or more substances are dissolved in another substance is a(n) _________.
   a. solution

4. A substance that has the ability to dissolve in another substance is__________.
   a. soluble

5. A substance that does not dissolve in another substance is __________.
   a. insoluble

6. A(n) ________ is a compound made of only the elements hydrogen and carbon.
   a. hydrocarbon

7. __________ are made up of atoms or molecules that have a specific, repeating structure.
   a. Crystalline solids

8. __________ are made up of atoms or molecules that are locked into place but do not have a specific, structured pattern.
   a. Amorphous solids

9. __________ are made up of particles that have an uneven distribution of electrons, creating a negative and a positive side.
   a. Polar substances

10. __________ are made up of particles that have an uneven distribution of electrons.
    a. Nonpolar substances

LESSON 15: FLOATING PAPER CLIPS

1. ___________ are a state of matter that have a definite volume but no definite shape.
   a. Liquids

2. ___________ is a property of liquids that describes the attraction of liquid particles at the surface.
   a. Surface tension

3. The upward force that a fluid exerts on an object that enables the object to float is called _________.
   a. buoyancy

4. A(n) _______ is any substance made up of particles that move freely, such as liquids and gases, and that easily changes shape when force is applied.
   a. fluid

5. _________ is the act of moving something out of its original position or of one substance taking the place of another.
   a. Displacement

6. The measure of the pull of gravity between an object and the earth is ________.
   a. weight

7. A(n) __________ is a substance that has the ability to reduce the surface tension of a liquid.
   a. surfactant

8. Anything that has mass and takes up space is called _________.
   a. matter

9. _________ is a measure of the amount of matter in a substance.
   a. Mass

10. _________ is a measure of the amount of space an object occupies.
    a. Volume

RESOURCE GUIDE:
Review Game Suggestions & Content

LESSON 16: FOUNTAIN OF SODA POP

1. A(n) ________ is a uniform mixture in which one or more substances are dissolved in another substance.
a. solution

2. __________ is a physical property that describes the ability of a chemical substance to dissolve in a solvent and create a uniform solution.
a. Solubility

3. A substance that has the ability to dissolve in another substance is __________.
a. soluble

4. A substance that does not dissolve in another substance is ________.
a. insoluble

5. As pressure increases, the solubility of gases in a liquid ___________.
a. increases

6. ___________ are made up of particles that have an uneven distribution of electrons, creating a negative and a positive side.
a. Polar substances

7. ___________ are the tiny nooks and crannies where bubbles form during the reaction between the Mentos® mints and the soda pop.
a. Nucleation sites

8. The reaction between the Mentos® mints and the soda pop creates __________ gas.
a. carbon dioxide

9. Soda pop is an example of a(n) _________ in which carbon dioxide gas is dissolved in the water and sugar.
a. solution

10. In a soda pop solution, carbon dioxide gas is a(n) _________.
a. solute

LESSON 17: BALLOON ROCKETS

1. ________ is the amount of push or pull on an object.
a. Force

2. The mechanical force that pushes a rocket or aircraft through the air is known as _______.
a. thrust

3. Newton's __________________ states that the relationship between an object's mass (m), its acceleration (a) and the applied force (F) is F = ma.
a. Second Law of Motion

4. Newton's ________________ states that for every action there is an equal and opposite reaction.
a. Third Law of Motion

5. _________ is the amount of force exerted on an area.
a. Pressure

6. When the gas is released from the balloon, the rocket is propelled forward by a force called ________.
a. thrust

7. ________ is a mechanical force that opposes a rocket or aircraft's motion through the air.
a. Drag

8. ________ is the rate at which energy is converted or work is performed.
a. Power

9. Drag is generated by the difference in velocity between a solid object and a(n) ________.
a. fluid

10. In this experiment, the gas particles in the balloon create _________ on the inside of the balloon.
a. pressure

RESOURCE GUIDE:
Review Game Suggestions & Content

LESSON 18: PUFFED RICE FLEAS

1. _________ are pure substances that cannot be broken down further by normal chemical means.
   a. Elements

2. A(n) ________ is the fundamental unit of an element; it is the smallest particle of an element that retains the elements chemical properties.
   a. atom

3. Atoms are made up of smaller parts called ________, ________, and _______.
   a. protons, neutrons, electrons

4. The nucleus of an atom consists of _______ and ________.
   a. protons, neutrons

5. ________ occupy the space outside of the nucleus within an atom.
   a. Electrons

6. _________ is the buildup of electric charges on the surface of an object, which occurs when electrons are pulled from the surface of one material and relocated onto the surface of another material.
   a. Static electricity

7. _________ is a general term that includes a variety of occurrences that result from the flow of electric charges.
   a. Electricity

8. Protons have a(n) _______ electric charge.
   a. positive

9. Neutrons have a(n) _______ electric charge.
   a. neutral

10. Electrons have a(n) _______ electric charge.
    a. negative

LESSON 19: LIQUID RAINBOW

1. _________ is a measure of the amount of matter in a substance.
   a. Mass

2. _________ is the amount of space an object occupies.
   a. Volume

3. _________ is a physical property of matter that describes how closely packed together the atoms or molecules of a substance are.
   a. Density

4. A(n) ________ is a uniform mixture in which one or more substances are dissolved in another substance.
   a. solution

5. As more salt is dissolved in water, the density of the solution _________.
   a. increases

6. ____________ is a physical property that describes the ability of a chemical substance to dissolve in a solvent to create a uniform solution.
   a. Solubility

7. A substance that has the ability to dissolve in another substance is __________.
   a. soluble

8. A substance that does not dissolve in another substance is ________.
   a. insoluble

9. Salt is ________ in water.
   a. soluble

10. Butter is _______ in water.
    a. insoluble

RESOURCE GUIDE:
Review Game Suggestions & Content

LESSON 20: HOLD THE SALT

1. ________ are made of two or more substances that are combined physically.
   a. Mixtures

2. A(n) _________ is a uniform mixture in which one or more substances are dissolved in another substance.
   a. solution

3. A(n) __________ is a means of separating a mixture of substances into two or more distinct products.
   a. separation process

4. _________ is a method of separating a liquid mixture based on the differences between the boiling points of the mixture's parts.
   a. Distillation

5. _________ is a physical change from a liquid to a gas.
   a. Vaporization

6. ________ is a physical change from a gas to a liquid.
   a. Condensation

7. ________ is a physical change from a solid to a liquid.
   a. Melting

8. ________ is a physical change from a solid directly to a gas.
   a. Sublimation

9. ________ is a physical change from a gas directly to a solid.
   a. Deposition

10. A(n) ___________ is any change in a substance's form that does not change its chemical makeup.
    a. physical change

LESSON 21: SEWER LEECHES

1. A(n) ________ is a uniform mixture in which one or more substances are dissolved into another substance.
   a. solution

2. _________ is a physical property that describes the ability of a chemical substance (the solute) to dissolve in a solvent to create a uniform solution.
   a. Solubility

3. _________ is the physical property of matter that describes how closely packed together the atoms or molecules of a substance are.
   a. Density

4. ________ occurs when one substance takes the place of another.
   a. Displacement

5. The upward force that a fluid exerts on an object that enables the object to float is called __________.
   a. buoyancy

6. A substance that dissolves in another substance is__________.
   a. soluble (or a solute)

7. A substance that does not dissolve in another substance is __________.
   a. insoluble

8. ________ is the process of dissolving carbon dioxide gas in water.
   a. Carbonation

9. ________ refers to the distribution of electrons in an atom.
   a. Polarity

10. ___________ are made up of particles that have an uneven distribution of electrons, creating a negative and a positive side.
    a. Polar substances

RESOURCE GUIDE:
Review Game Suggestions & Content

LESSON 22: MYSTERIOUS MIXTURES

1. A(n) ________ is made of two or more substances that are combined physically.
a. mixture

2. A mixture that is considered to be the same throughout is called a(n) _______________.
a. homogeneous mixture

3. A uniform mixture in which one or more substances are dissolved in another substance is a(n) _________.
a. solution

4. A mixture in which the makeup is not the same throughout is called a(n) _______________.
a. heterogeneous mixture

5. A(n) ______________ divides a mixture of substances into two or more distinct products.
a. separation process

6. ________ is a group of separation processes used to separate and analyze complex mixtures based on differences in their structure or composition.
a. Chromatography

7. During chromatography, a mixture is moved over a certain material called the _______________.
a. stationary phase

8. The mixture that flows over the material during a chromatography separation process is called the _______________.
a. mobile phase

9. In this experiment, the coffee filters are used as the _______________.
a. stationary phase

10. In this experiment, the colored water is used as the _______________.
a. mobile phase

LESSON 23: EXPLODING BAGS

1. _____________ are properties of matter identified by using our senses or taking measurements.
a. Physical properties

2. ____________ are properties of matter identified by observing how a chemical reacts with other substances.
a. Chemical properties

3. A(n) ____________ is any change in a substance's form that does not change its chemical makeup.
a. physical change

4. A(n) ____________ is a change that takes place when atoms of a substance are rearranged, and the bonds between the atoms are broken or formed.
a. chemical reaction (or chemical change)

5. The substance or substances that start a chemical reaction are called ___________.
a. reactants

6. The new substance or substances produced as a result of a chemical reaction are called ________.
a. products

7. A(n) _______ is an atom or molecule that has lost or gained one or more of its outer electrons.
a. ion

8. A solution containing a concentration of hydrogen ions (H^+) greater than pure water is called a(n) _______.
a. acid

9. A solution containing an excess of hydroxide ions (OH^-) or an H^+ concentration less than pure water is called a(n) ___________.
a. base

10. A solution containing an H^+ concentration equal to pure water is ___________.
a. neutral

RESOURCE GUIDE:
Review Game Suggestions & Content

LESSON 24: GRASPING FOR AIR

1. _______ is anything that has mass and takes up space.
   a. Matter

2. _______ is a state of matter with a definite shape and a definite volume.
   a. Solid

3. _______ is a state of matter with a definite volume but no definite shape.
   a. Liquid

4. _______ is a state of matter with no definite volume and no definite shape.
   a. Gas

5. _______ is the amount of force exerted on an area.
   a. Pressure

6. The force exerted on a surface by the weight of the air above that surface is called ___________.
   a. air pressure (or atmospheric pressure)

7. The act of moving something out of its original position or of one substance taking the place of another is known as _______.
   a. displacement

8. _______ is the amount of space an object occupies.
   a. Volume

9. A(n) _______ is a volume of space that has essentially no matter.
   a. vacuum

10. A(n) _______ is a force that attracts a substance or object to a region of lower pressure when there is a difference in pressure.
    a. suction

LESSON 25: CAPILLARY CARNATIONS

1. _______ have a definite volume and definite shape.
   a. Solids

2. _______ have a definite volume but no definite shape.
   a. Liquids

3. _______ have no definite volume and no definite shape.
   a. Gases

4. ___________ is the movement of liquids upward through a narrow tube, cylinder, or permeable substance because of cohesive and adhesive forces interacting between the liquid and the surface.
   a. Capillary action (or capillarity)

5. ___________ is the attractive force that exists between like particles in a certain liquid.
   a. Cohesion

6. ___________ is a property of liquids that describes the attraction of liquid particles at the surface.
   a. Surface tension

7. ___________ is the force of attraction between unlike particles.
   a. Adhesion

8. ___________ are made up of particles that have an uneven distribution of electrons, creating a negative and a positive side.
   a. Polar substances

9. ___________ is a complex plant tissue made up of networks of vessels that transport water and dissolved minerals through the plant and also provides structural support to the plant.
   a. Xylem

10. ___________ causes water droplets to form into a sphere rather than spreading out flat.
    a. Surface tension

RESOURCE GUIDE:
Review Game Suggestions & Content

LESSON 26: MELTING ICE WITH SALT

1. Pure substances that cannot be broken down further by normal chemical means are _________.
   a. elements

2. A(n) _________ is a pure substance made up of two or more elements in a defined ratio.
   a. compound

3. Sodium chloride is commonly known as _______.
   a. table salt

4. A(n) _________ is any change in a substance's form that does not change its chemical makeup.
   a. physical change

5. _________ is a physical change from a liquid to a solid.
   a. Freezing

6. The temperature at which a liquid begins to form a solid is known as the _________.
   a. freezing point

7. _________ is a physical change from a solid to a liquid.
   a. Melting

8. The ________ is the temperature at which a substance begins changing states from a solid to a liquid.
   a. melting point

9. _________ describes the tendency of a substance to vaporize.
   a. Volatility

10. A(n) _________ is a solute that has little tendency to escape from a solution.
    a. nonvolatile solute

LESSON 27: SEPARATING SALT & PEPPER

1. _________ are made of two or more substances that are combined physically.
   a. Mixtures

2. A(n) ____________ separates a mixture of substances into two or more distinct products.
   a. separation process

3. ____________ are properties of matter identified by using our senses or taking measurements.
   a. Physical properties

4. ____________ are properties of matter identified by observing how a chemical reacts with other substances.
   a. Chemical properties

5. _________ is the buildup of electric charges on the surface of an object, which occurs when electrons are pulled from the surface of one material and relocated onto the surface of another material.
   a. Static electricity

6. Pure substances that cannot be broken down further by normal chemical means are _________.
   a. elements

7. A(n) _________ is a pure substance made up of two or more elements in a defined ratio.
   a. compound

8. _________ are the fundamental units of an element.
   a. Atoms

9. The nucleus of an atom is comprised of _________ and _________.
   a. protons, neutrons

10. Electrons are found outside of the nucleus and have a(n) _________ charge.
    a. negative

RESOURCE GUIDE:
Review Game Suggestions & Content

LESSON 28: ANTIGRAVITY WATER

1. Anything that has mass and takes up space is called ________.
a. matter

2. ________ have a definite volume and definite shape.
a. Solids

3. ________ have a definite volume but no definite shape.
a. Liquids

4. ________ have no definite volume and no definite shape.
a. Gases

5. ________ is the attractive force that exists between like particles in a certain liquid.
a. Cohesion

6. ________ is a property of liquids that describes the attraction of liquid particles at the surface.
a. Surface tension

7. ________ is the force of attraction between unlike particles.
a. Adhesion

8. ________ occurs when one substance takes the place of another.
a. Displacement

9. ________ is the amount of force exerted on an area.
a. Pressure

10. The force exerted on a surface by the weight of the air above that surface is called ________.
a. air pressure (or atmospheric pressure)

LESSON 29: SOLID OR LIQUID?

1. ________ have a definite volume and definite shape.
a. Solids

2. ________ have a definite volume but no definite shape.
a. Liquids

3. ________ have no definite volume and no definite shape.
a. Gases

4. A(n) ________ is any substance made up of particles that flow or move freely.
a. fluid

5. Both ________ and ________ are considered fluids.
a. liquids, gases

6. ________ is a measure of a fluid's resistance to flow.
a. Viscosity

7. A(n) ___________ fluid has a viscosity that remains constant, regardless of any applied force or rate of flow.
a. Newtonian

8. A(n) ___________ fluid is one that has a viscosity that varies based on the force applied or how fast an object is moving through the fluid.
a. non-Newtonian

9. ___________ is a pressure or force in the structure of a substance that arises when its layers are shifted horizontally in relation to each other.
a. Shear stress

10. Peanut butter, gravy, and ________ are examples of a unique type of matter known as non-Newtonian fluids because they exhibit different physical properties based on the amount of force applied.
a. ketchup

RESOURCE GUIDE:
Review Game Suggestions & Content

LESSON 30: BALLOON IN A BOTTLE

1. Anything that has mass and takes up space is called ________.
a. matter

2. ________ is the measure of the amount of matter in a substance.
a. Mass

3. ________ is the measure of the amount of space an object occupies.
a. Volume

4. ________ have a definite volume and definite shape.
a. Solids

5. ________ have a definite volume but no definite shape.
a. Liquids

6. ________ have no definite volume and no definite shape.
a. Gases

7. ________ is a measure of the ability to do work or produce heat.
a. Energy

8. ________ is a measure of the average kinetic energy of particles in a substance.
a. Temperature

9. ___________ states that the volume and temperature of a gas are directly proportional.
a. Charles' Law

10. The law of ______________ states that while energy can change from one form to another, it can neither be created nor destroyed.
a. conservation of energy

LESSON 31: MARSHMALLOW LAUNCHERS

1. Anything that has mass and takes up space is called ________.
a. matter

2. ________ is the measure of the amount of matter in a substance.
a. Mass

3. ________ is the measure of the ability to do work or produce heat.
a. Energy

4. ________ occurs when a force causes an object to be moved from its original position.
a. Work

5. The law of ______________ states that while energy can change from one form to another, it can neither be created nor destroyed.
a. conservation of energy

6. A form of energy determined by the motion or position of a substance is called ________.
a. mechanical energy

7. A form of energy that exists when an object is in motion is called ________.
a. kinetic energy

8. ________energy is stored energy.
a. Potential

9. ________ is the resistance of an object to a change in its state of motion.
a. Inertia

10. ________ is the amount of push or pull on an object.
a. Force

RESOURCE GUIDE:
Review Game Suggestions & Content

LESSON 32: T-SHIRT TIE-DYE

1. ________ is a process by which matter takes in another substance.
   a. Absorption

2. A(n) ________ is made up of two or more substances that are combined physically.
   a. mixture

3. A uniform mixture in which one or more substances are dissolved in another substance is a(n) ________.
   a. solution

4. ________ is a physical property that describes the ability of a chemical substance to dissolve in a solvent to create a uniform solution.
   a. Solubility

5. A substance that has the ability to dissolve in another substance is ________.
   a. soluble

6. A substance that does not dissolve in another substance is ________.
   a. insoluble

7. ________ are made up of particles that have an uneven distribution of electrons, creating a negative and a positive side.
   a. Polar substances

8. ________ are made up of particles that have an uneven distribution of electrons.
   a. Nonpolar substances

9. ________ is the movement of particles from an area of high concentration to an area of low concentration.
   a. Diffusion

10. ________ is a group of separation processes used to separate and analyze complex mixtures based on differences in their structure or composition.
    a. Chromatography

LESSON 33: ELEPHANT TOOTHPASTE

1. Pure substances that cannot be broken down further by normal chemical means are called ________.
   a. elements

2. A(n) ________ is a pure substance made up of two or more elements in a defined ratio.
   a. compound

3. A(n) ____________ is any change in a substance's form that does not change its chemical makeup.
   a. physical change

4. When the atoms of a substance are rearranged, and the bonds between the atoms are broken or formed, a substance has undergone a(n) _____________.
   a. chemical reaction (or chemical change)

5. A(n) ________ is the starting material for a chemical reaction.
   a. reactant

6. The substance or substances produced from a chemical reaction are called _______.
   a. products

7. A secondary product that is created at the same time as a desired product during a chemical reaction is called a(n) ________.
   a. byproduct

8. During a(n) ____________, a compound breaks apart into two or more products.
   a. decomposition reaction

9. A(n) _____________ is a reaction that gives off energy.
   a. exothermic reaction

10. A(n) _____________ is a reaction that requires or absorbs energy.
    a. endothermic reaction

RESOURCE GUIDE:
Sample Review Game Board

MATTER	MIXTURES & SEPARATIONS	PHYSICAL PROPERTIES & CHANGES	CHEMICAL REACTIONS	ACIDS & BASES	POLYMERS
A state of matter that has a definite volume but no definite shape is called a(n) ____________.	A(n) ________ is a uniform liquid mixture composed of two or more substances.	A physical property that measures the amount of matter in an object is called __________.	A starting material for a chemical reaction is called a(n) _______.	Acids and bases are characterized on the __________ scale.	Any molecule that can combine with other molecules to form a polymer is called a(n) _________.
All matter is composed of ______, which are made up of protons, neutrons, and electrons.	A process that transforms a mixture of substances into two or more distinct products is called a(n) ________.	_________ is a physical change in which a substance changes states from a liquid to a gas.	A substance formed as a result of a chemical reaction is called a(n) _________.	Solutions that contain a higher concentration of hydrogen ions than pure water are known as _________.	Atoms of the element ________ make up the most common polymers.
The center of an atom is called the ________.	Several factors can affect solubility, including _________, pressure, and the nature of the solute or solvent.	________ is a physical property that describes how closely packed together the atoms of an element or molecules of a compound are.	When two or more substances interact to form new substances, a(n) _________ takes place.	A substance that reveals the acidity of a solution through characteristic color changes is called a(n) _________.	A large molecule formed by combining many smaller molecules in a regular, repeating pattern is called a(n) ________.
A(n) _________ is a state of matter characterized by a definite volume and a definite shape	In a solution, one substance, called the _________, is dissolved into another substance.	Condensation is a physical change in which a substance changes states from a(n) _______ to a(n) ________.	The loss of at least one electron when two or more substances interact is called ________.	Which is *not* an acid: vinegar, lemon juice, milk of magnesia, or orange juice? _________	A polymer with the capability to absorb large amounts of water is called a(n) ________________.
An atom is considered to be neutral when it has an equal number of protons and ________.	A porous paper that can be used to separate solids from liquids is called ______ paper.	A physical change from a solid state to a liquid state is called ____________.	The reddish-brown brittle substance formed by the oxidation of iron is known commonly as _________.	________ can be used to neutralize acids.	The formation of chemical bonds between molecular chains of a polymer is known as _________.

RESOURCE GUIDE:
Sample Review Game Board ANSWER KEY

MATTER	MIXTURES & SEPARATIONS	PHYSICAL PROPERTIES & CHANGES	CHEMICAL REACTIONS	ACIDS & BASES	POLYMERS
Liquid	Solution	Mass	Reactant	pH	Monomer
Atoms	Separation process	Vaporization	Product	Acids	Carbon
Nucleus	Temperature	Density	Chemical reaction (or chemical change)	Acid-base indicator	Polymer
Solid	Solute	Gas, liquid	Oxidation	Milk of magnesia	Super-absorbent polymer
Electrons	Filter	Melting	Rust	Bases	Cross-linking

RESOURCE GUIDE: Notable Chemists

AMEDEO AVOGADRO 1776–1856

Amedeo Avogadro was born on August 9, 1776, in Turin, Italy. He received his formal education in law, so he pursued his interest in physics and mathematics in his spare time.

In 1811, while teaching natural sciences at a high school in Vercelli, he published a memoir declaring a hypothesis now known as Avogadro's Law. His hypothesis stated that equal volumes of gases, at the same temperature and pressure, contain the same number of molecules. Avogadro's Law implies that relative molecular masses can be calculated from the masses of gas samples.

One of Avogadro's most important contributions to science was his resolution that particles could be composed of molecules and that molecules could be composed of even simpler units (atoms). The number of molecules in a mole (one gram molecular weight) was named "Avogadro's number" in honor of his theories of molarity and molecular weights. Avogadro's number has been determined to be about 6.02×10^{23}. This number is commonly used when working with chemical equations, allowing chemists to determine specific amounts of substances that are produced from a reaction.

NIELS BOHR 1885–1962

Niels Bohr was born in Copenhagen, Denmark, in 1885. He earned his doctorate in physics in 1911 from Copenhagen University.

In the spring of 1912, Bohr began working in Ernest Rutherford's laboratory in Manchester, England. Based on Rutherford's atomic theories, Bohr published his model of atomic structure in 1913, which introduced the concept of electrons traveling in orbits around the nucleus. He also proposed that the chemical properties of an element were determined by the number of electrons in the outer orbits.

In 1920, he was appointed head of the Institute for Theoretical Physics at Copenhagen University, a position he held for the remainder of his life. In 1922, he received the Nobel Prize in Physics for his work on the structure of atoms.

ROBERT BOYLE 1627–1691

Robert Boyle was born in Lismore, Ireland, in 1627. In 1635, Boyle's father, a wealthy Englishman, sent him away to school, where he initially did very well. After a few years, Boyle stopped progressing, so his father brought him home in 1638 to be privately tutored. When he was 12 years old, Boyle was sent on a grand tour of Europe to learn the great ideas of the time.

In 1646, he moved to Stalbridge, a manor house in the English countryside that his father had left him when he died. During his visits to London, Boyle attended what he called the "Invisible College," which consisted of a group of scientists who would hold regular meetings. This group would eventually become known as the Royal Society of London.

As a member of the original Royal Society of London, Boyle believed in acquiring knowledge by experimental investigation. His most famous discovery is known as Boyle's Law, which states that if temperature remains constant, the volume of a given mass of gas is inversely proportional to the absolute pressure. His other discoveries included showing that sound does not travel in a vacuum and that flames require air.

RESOURCE GUIDE: Notable Chemists

ROBERT BUNSEN 1811–1899

Robert Wilhelm Bunsen was born on March 31, 1811, in Göttingen, Germany. Bunsen began his study of chemistry at the University of Göttingen, where he received his doctorate when he was only 19 years old. From 1830 to 1833, he traveled throughout Germany and to Paris and Vienna, meeting fellow scientists and creating a valuable network of contacts. When Bunsen returned to Germany, he became a lecturer at Göttingen and began experimental studies with arsenious acid. His experiments produced the best known antidote against arsenic poisoning to date.

In 1838, Bunsen accepted a position at the University of Marburg. There he conducted studies of cacodyl compounds, which are products made from arsenic and are known to be poisonous, highly flammable, and extremely nauseating when inhaled. Bunsen's risky experiments helped advance his career and the studies of many other scientists, but his success was not without sacrifice. Bunsen nearly killed himself from arsenic poisoning and lost sight in one eye because of an explosion of an arsenic compound.

In 1852, Bunsen took a position at Heidelberg, where he experimented with nitric acid to produce pure metals, such as chromium, magnesium, and sodium by electrolysis. At this time, he also began collaborating with Sir Henry Enfield Roscoe on the formation of hydrogen chloride from hydrogen and chlorine.

In 1855, Bunsen perfected a special gas burner (invented by Michael Faraday) that is now known as the Bunsen burner. He used this burner to study emission spectroscopy of heated elements with Gustav Robert Kirchhoff. Through these studies, they discovered the elements cesium and rubidium.

JOCELYN BELL BURNELL 1943-PRESENT

Jocelyn Bell Burnell was born on July 15, 1943, in Belfast, Northern Ireland. She graduated from the University of Glasgow in 1965 with a Bachelor of Science in physics, and she completed her Ph.D. from New Hall, part of the University of Cambridge, in 1969.

While studying at Cambridge, she assisted in the construction of an 81.5 megahertz radio telescope that was used to track quasars—sources of electromagnetic energy, such as radio waves and visible light. As a postgraduate student, she discovered the first radio pulsars with her thesis supervisor Antony Hewish. A pulsar is a highly magnetized, rotating neutron star that emits a beam of electromagnetic radiation.

After finishing her Ph.D., Bell Burnell worked in England at the University of Southampton and University College London and at the Royal Observatory in Edinburgh, Scotland. She was appointed professor of physics at the Open University in 1991. Before retiring, she was Dean of Science at the University of Bath, and she was the President of the Royal Astronomical Society between 2002 and 2004. She is currently a visiting professor of astrophysics at the University of Oxford and a Fellow at Mansfield College. Her two-year term as president of the Institute of Physics ended in October 2010.

RESOURCE GUIDE: Notable Chemists

WALLACE CAROTHERS 1896–1937

Wallace Hume Carothers was born in Burlington, Iowa, in 1896. After high school, Carothers attended Capital City Commercial College in Des Moines, Iowa, studying accounting and secretarial administration. He then went on to a four-year college in Missouri to complete a bachelor's degree in chemistry. In 1924, he earned his doctorate from the University of Illinois. After graduating, he began teaching at Harvard but was soon recruited by the DuPont Company.

In April 1930, one of Carothers' assistants at DuPont, Arnold M. Collins, isolated a new liquid compound that spontaneously polymerized to produce a rubber-like solid. The new polymer was named neoprene and became the first commercially successful specialty rubber.

In early 1934, Carothers and his team used amines rather than glycols to produce polyamides instead of polyesters. Polyamides are synthetic fibers that behave like natural silk and are more stable than polyesters, which are structurally similar to natural fats and oils. Carothers' group soon discovered a new polyamide fiber called nylon. Nylon, however, was not commercialized as an alternative to silk stockings until after Carothers' death. Nylon went into production in 1939, and a display of the new nylon stockings was a sensational hit at the World's Fair in New York that same year.

EMMA PERRY CARR 1880–1972

Emma Perry Carr was born in 1880 in Holmesville, Ohio. After high school, she attended Mount Holyoke College. Although she did not graduate from Mount Holyoke, she would be involved with the school for the rest of her life.

Carr transferred first to The Ohio State University and then to the University of Chicago, where she earned her bachelor's degree in 1905. She began teaching as an instructor at Mount Holyoke but soon returned to the University of Chicago to earn her Ph.D. in 1910. Once equipped with her doctorate, she joined the faculty of Mount Holyoke, determined to strengthen the chemistry program. Carr taught freshman general chemistry but believing that students should conduct research to obtain hands-on experience with how chemistry works, she started a research program at Mount Holyoke.

Carr initiated research on ultraviolet spectroscopy, a method for studying materials by looking at how they respond to ultraviolet radiation. In 1919, she spent a year working in a lab at Queen's University in Belfast, Ireland, to learn more about the technique. Her research led to a better understanding of the nature of double bonds between carbon atoms in molecules. Carr retired in 1946 but continued to be engaged in science and education until her death in 1972.

RESOURCE GUIDE: Notable Chemists

MARIE CURIE 1867–1934

Marie Curie was born in Warsaw, Poland, in 1867. She left Poland at the age of 24 to attend classes at the Sorbonne in Paris. In 1893, Curie received her master's degree in physics and then received a second master's degree in math the following year.

In 1903, Curie became the first woman in France to receive a doctorate degree. She and her husband, Pierre, worked together, winning a Nobel Prize in 1903 for their work with radiation. Pierre passed away in 1906, and the Sorbonne offered Curie her late husband's position as professor.

Her acceptance made her the first female teacher at the Sorbonne. Curie won her second Nobel Prize in 1911 for her work with radium and radiation.

During World War I, Curie drove around battlefields with her invention, the X-ray machine, to evaluate the wounds of soldiers. As a result, she was named the director of the Red Cross Radiology Service. Unfortunately, Curie was not properly protected and was frequently exposed to dangerous levels of radiation. After the war, Curie founded the Radium Institute in Paris, which became a world center for the study of radioactivity. She continued to work until the end of her life.

JOHN DALTON 1766–1844

John Dalton was born in 1766 in Eaglesfield, England. He moved to the city of Manchester in 1793 after teaching for ten years at a Quaker boarding school near his home. He joined the Manchester Literary and Philosophical Society, and was provided with the facilities to conduct scientific studies. His early research dealt with color blindness, which was then sometimes referred to as "Daltonism."

Dalton's interest in meteorology prompted him to keep a meteorological diary in which he recorded over 200,000 observations. These observations first led him to his view of atomism. He proposed the Atomic Theory, stating that all matter was composed of small indivisible particles called atoms; atoms of a given element are identical but different from atoms of any other element, and atoms of one element can combine to form compounds with other elements.

Dalton also revealed that air is not a vast chemical solvent, but is, instead, a mechanical system, wherein the pressure exerted by each gas in a mixture is independent of the pressure exerted by the other gases. Thus, the total pressure is the sum of the pressures of each gas, a conclusion known today as Dalton's law of partial pressures.

RESOURCE GUIDE: Notable Chemists

HUMPHRY DAVY 1778–1829

Sir Humphry Davy was born in Penzance, England, in 1778. He was apprenticed to a surgeon but explored a wide range of other subjects, including chemistry. In 1798, he took a position at Thomas Beddoes' Pneumatic Institution in Bristol, investigating the use of newly discovered gases in the cure and prevention of disease. At the Institution, Davy discovered the anesthetic effect of nitric oxide (laughing gas).

In 1800, Davy began research on electricity and realized that the production of electricity was dependent upon a chemical reaction. He used electrolysis to discover new metals, including potassium, sodium, magnesium, and calcium.

Two years later, Davy became a professor of chemistry at the Royal Institution and continued to conduct research. His research and inventions led to improved safety and conditions in many industries, including agriculture and mining. Davy became a fellow of the Royal Society of London in 1803 and served as president from 1820 to 1827. In 1812, he was knighted by King George III.

MICHAEL FARADAY 1791–1867

Michael Faraday was born on September 22, 1791, in London, England. He received a basic education and was apprenticed to a local bookbinder when he was 14 years old. During his years as an apprentice, he educated himself by reading books on a wide range of scientific topics.

Faraday attended a series of lectures by chemist Humphry Davy at the Royal Institution in 1812. Following the lectures, Faraday wrote to Davy requesting a job as his assistant. In 1813, Davy appointed him to the job of chemical assistant at the Royal Institution. In 1814, Faraday accompanied Davy on an 18-month tour of Europe, during which he had opportunities to meet prominent scientists. Following his travels, Faraday worked with Davy conducting experiments at the Royal Institution. In 1821, he published his research on electromagnetic rotation, establishing the principle behind the electric motor. A decade later, he discovered electromagnetic induction, which led to the development of the electric transformer and generator. These inventions enabled electricity to become a mainstream technology.

RESOURCE GUIDE: Notable Chemists

JOSEPH LOUIS GAY-LUSSAC 1778–1850

Joseph Louis Gay-Lussac was born on December 7, 1778, in Saint-Léonard-de-Noblat, France, and grew up during the French Revolution. He was selected to attend the École Polytechnique, an institution founded during the French Revolution and designed to educate scientific and technical leaders, especially for the military. Gay-Lussac began his professional career as a professor of physics and chemistry at the École Polytechnique.

Gay-Lussac shared Antoine-Laurent Lavoisier’s interest in the quantitative study of the properties of gases. Throughout 1804, Gay-Lussac ascended close to 23,000 feet (7,000 meters) above sea level in hydrogen-filled balloons to investigate the composition of the atmosphere. During these experiments, he gathered magnetic measurements at various altitudes, collected samples of air, and took pressure, temperature, and humidity measurements.

In 1808, Gay-Lussac discovered that gases at constant temperature and pressure combine in simple numerical proportions by volume. The resulting product or products—if gases—also bear a simple proportion by volume to the volumes of the reactants.

With his fellow professor, Louis-Jacques Thénard, Gay-Lussac decomposed boric acid by using fused potassium, thus discovering the element boron. The two also took part in contemporary debates that modified Lavoisier's definition of acids and furthered his program of analyzing organic compounds for their oxygen and hydrogen content.

DOROTHY HODGKIN 1910–1994

Dorothy Crowfoot Hodgkin, a British biochemist and crystallographer, was born on May 12, 1910, in Cairo, Egypt. She obtained degrees from Oxford and Cambridge Universities.

In 1964, Hodgkin won the Nobel Prize in Chemistry for determining the structures of biologically important molecules. She used X-rays to find the structural layouts of atoms and the overall molecular shape of over 100 molecules, including penicillin, vitamin B-12, vitamin D, and insulin. Hodgkin confirmed the molecular structure of vitamin B-12 with the help of one of the first computers. Through this understanding, scientists were able to determine how the body uses B-12 to build red blood cells and prevent some types of anemia. Likewise, her discovery of the molecular layout of penicillin helped scientists to develop other antibiotics. In 1969, with over 30 years of studying molecules, Hodgkin unlocked the key to the three-dimensional structure of insulin, helping scientists control the disease diabetes.

Hodgkin’s improvements using X-ray crystallography established this technique as an important analytical tool. For her work, Hodgkin received many awards and honors, including the Order of Merit, one of the highest civilian honors awarded in Great Britain. She was only the second woman, after Florence Nightingale, to receive this award.

RESOURCE GUIDE: Notable Chemists

PERCY JULIAN 1899–1975

Percy Lavon Julian was born on April 11, 1899, in Montgomery, Alabama. During his childhood, it was rare for African Americans to pursue an education beyond eighth grade, but his father encouraged him to strive for a higher education.

Julian graduated first in his class from DePauw University in 1920. He worked as a chemistry instructor at Fisk University in Tennessee until 1923, when he attended Harvard University for his master's degree. In 1929, Julian continued his graduate work at the University of Vienna, Austria, receiving his Ph.D. in 1931.

In 1935, while teaching organic chemistry at DePauw, Julian and Josef Pikl completed the total synthesis of physostigmine, a drug used to treat glaucoma. Julian was offered the position of director of research in the Soya Products Division at Glidden in Chicago as a result of his work on physostigmine. In this position, Julian designed and supervised the construction of the world's first facility for the production of industrial-grade, isolated soy protein. He later began work on synthesizing progesterone and testosterone to produce these hormones on a large scale and reduce the cost of treating hormonal deficiencies.

Julian left Glidden after 18 years to found his own company, Julian Laboratories, Inc., in Franklin Park, Illinois. He sold the company in 1961, and three years later, he founded Julian Associates and the Julian Research Institute, which he managed for the rest of his life.

AUGUST KEKULÉ 1829–1896

Friedrich August Kekulé was born on September 7, 1829, in Darmstadt, Germany. He entered the University of Giessen in 1847 to study architecture, but after hearing lectures by Justus von Liebig, he decided to explore chemistry. In 1858, he was appointed professor of chemistry at the University of Ghent. In 1865, he was called to the University of Bonn to fill a similar position, which he held for the rest of his career.

Kekulé's studies and ideas led to the development of the theory of chemical structure, specifically regarding the structure of carbon compounds. He believed that carbon atoms combine to form chains of any length and complexity. In 1865, Kekulé published a paper revealing the structure of benzene as a six-member ring of carbon atoms with alternating single and double bonds.

Kekulé attributed his structural theory to visions of atoms and molecules, the first appearing to him while traveling on a bus in London and the second while dozing in front of a fire.

RESOURCE GUIDE: Notable Chemists

STEPHANIE KWOLEK 1923–PRESENT

Stephanie Kwolek was born in New Kensington, Pennsylvania, on July 31, 1923. After graduating from Margaret Morrison Carnegie College of Carnegie-Mellon University, she applied for a position as a chemist with the DuPont Company. Her research on polymers at DuPont inspired her to drop her plans for medical school and pursue a career in chemistry.

Kwolek specialized in the creation of long molecule chains at low temperatures that resulted in extremely strong and rigid petroleum-based synthetic fibers. In the 1960s, she discovered an entirely new branch of synthetics and liquid crystalline polymers. Her most important research resulted in the discovery of Kevlar®, a synthetic fiber five times stronger than steel but with half the density of fiberglass. Kevlar® was first marketed in 1971 and is best known as the material that is used to make bullet-resistant vests.

For her work, Kwolek received or was the co-recipient of 17 U.S. patents. She worked as a Research Associate in DuPont's Pioneering Lab until her retirement but continued to consult part-time for DuPont afterward.

ANTOINE-LAURENT LAVOISIER 1743–1794

Known as the "Father of Modern Chemistry," Antoine-Laurent Lavoisier was born on August 26, 1743 in Paris, France. In 1754, Lavoisier enrolled at the Collège Mazarin, which was well known for its science and math departments. At Mazarin, he was a model student, received many awards, and conducted many of his first serious experiments. In addition to his scientific studies, Lavoisier studied law, earning a bachelor's degree and a license to practice law in 1764. Although initially, he worked as a tax collector, Lavoisier realized his true calling was science, so he resumed his studies in mineralogy and chemistry.

In 1771, Lavoisier married Marie-Anne Pierrette Paulze, who expertly illustrated and recorded his experiments. Lavoisier conducted hundreds of experiments, all of which challenged the ideas of the time. He showed that oxygen was responsible for combustion and proved that water consisted of hydrogen and oxygen. He also proposed new chemical terms, including the word "element," which formed a basis for later chemists.

In 1793, the French Revolution had been raging for almost five years, and on December 24, soldiers broke into Lavoisier's laboratory to arrest him for being a former tax collector. On May 7, 1794, Lavoisier was tried before the Revolutionary Tribunal and executed by guillotine.

RESOURCE GUIDE: Notable Chemists

CARL VON LINDE 1842–1934

Carl von Linde was born on June 11, 1842, in Berndorf, Germay. He received his early education in science and engineering at the Federal Polytechnic in Switzerland. After working for locomotive manufacturers in Berlin and Munich, he joined the faculty at the Polytechnic in Munich.

From 1873 to 1877, his research led to the invention of the first reliable compressed ammonia refrigerator. He founded a successful company to promote his invention, but after a decade, he ceased his business activities to focus on research.

In 1895, he succeeded in liquefying air by first compressing it and then letting it expand rapidly to cool. Then, he slowly warmed the liquid air to obtain oxygen and nitrogen. Von Linde was soon extracting oxygen in large quantities and supplying it to hospitals and industries.

DMITRI MENDELEEV 1834–1907

Dmitri Mendeleev was born on February 8, 1834, in Siberia, Russia. He graduated with a master's degree from the Pedagogical Institute in St. Petersburg. Mendeleev was awarded a fellowship to study at the University of Heidelberg, Germany, and after completing studies there, he returned to St. Petersburg, where he successfully defended his doctoral dissertation and became a professor of chemistry at the University of St. Petersburg.

In 1869, Mendeleev published a periodic table, which arranged the 63 known elements based on relative atomic mass (atomic weight). He arranged the elements in ascending order of atomic weight and grouped them according to similar properties. He also left space on his periodic table, predicting the existence and properties of elements that had not yet been discovered.

Mendeleev was known to quarrel with political and academic authorities. Following his resignation from the University of St. Petersburg, the Russian government appointed him director of the Bureau of Weights and Measures in 1893. He held the position for the rest of his life.

ISAAC NEWTON 1643–1727

Sir Isaac Newton was born prematurely on January 4, 1643, in Woolsthorpe, England. He attended grammar school and received a standard education, although he did not excel in school. He was fascinated with mechanics and began inventing his own machines. Newton began studying at the University of Cambridge in June of 1661. At Cambridge, he was exposed to many philosophical ideas, prompting him to question the environment around him.

In his early twenties, Newton developed a new mathematical method that is now known as calculus. He then moved to the science of mechanics. Newton used the concepts of gravity and centrifugal force to explain why the earth's rotation does not cause people to fly off into space. He also developed the law of universal gravitation.

In 1668, Newton's development of the reflecting telescope brought him into the spotlight among the scientific community. His telescope was only six inches long and one inch in diameter, yet it magnified over 30 times! Newton also experimented with colors, proving that white light was made up of a mixture of colors.

In 1703, Newton was elected president of the Royal Society of London; less than two years after his election, Queen Anne knighted Newton in Cambridge. Newton remained president of the Royal Society until his death.

RESOURCE GUIDE: Notable Chemists

ALFRED NOBEL 1833–1896

Alfred Nobel was born in Stockholm, Sweden, on October 21, 1833. His family moved to St. Petersburg, Russia, in 1842, where he was educated by private teachers. His primary interests were in English literature, poetry, chemistry, and physics. Nobel's father wanted his son to join his business as an engineer, so he sent Nobel abroad for further training in chemical engineering. During this time, Nobel visited Sweden, Germany, France, and the United States.

While in Paris, Nobel met the Italian chemist Ascanio Sobrero, who had invented nitroglycerin. Nobel became very interested in nitroglycerin and how it could be used safely in construction work. Nobel experimented with different additives to make nitroglycerin safer to handle. He discovered that adding diatomaceous earth turned the liquid into a paste that could be shaped into rods for insertion into drilling holes. In 1867, he patented this material, which he called "dynamite." He also invented a detonator (blasting cap) that could be ignited by lighting a fuse. He obtained 355 patents in his lifetime.

In his will, Nobel designated his fortune to be used for prizes in physics, chemistry, physiology or medicine, literature, and peace, all of which reflected his passions in life. The executors of his will established the Nobel Foundation to handle his fortune and coordinate the Nobel Prize awards.

LOUIS PASTEUR 1822–1895

Louis Pasteur was born on December 27, 1822, in Dole, France. He focused his education on physics and chemistry and earned a doctorate degree from École Normale in Paris in 1847.

In 1849, Pasteur was appointed lecturer of chemistry at Strasbourg University, and in 1854, he was made professor of chemistry and dean of the new Faculty of Sciences at Lille. While there, he studied the process of fermentation, concluding that the presence of microorganisms caused liquids to sour. He discovered that it was possible to prevent souring by heating the liquids to a certain temperature and pressure before boiling, a process now known as pasteurization.

In 1864, Pasteur developed his "germ theory," arguing that germs attacked the body from the outside and made people sick. He persisted with his theory and concluded that doctors should disinfect their hands and instruments before touching a patient to avoid spreading germs. Through his experiments, Pasteur also realized that people could be protected against disease by infecting them with a small amount of the weakened virus. He went on to invent the vaccines for rabies, anthrax, and diphtheria.

Pasteur's research on rabies resulted in the founding of a special institute in Paris for the treatment of the disease. This became known as the Institut Pasteur, and it was directed by Pasteur himself until his death.

RESOURCE GUIDE: Notable Chemists

LINUS PAULING 1901–1994

Linus Pauling was born in 1901, in Portland, Oregon, and worked as a laborer while earning his bachelor of science degree at Oregon State University at Corvallis. He went on to earn a Ph.D. in chemistry at the California Institute of Technology.

In the 1920s, Pauling revolutionized chemistry by incorporating the study of quantum physics. He used the new theory of wave mechanics to explain the chemical bonds in molecules. Pauling's resonance theory was critical in the creation of many of the drugs, dyes, plastics, and synthetic fibers commonly used today.

After the 1945 atomic bomb detonation, Pauling began to study the effects of radiation. Pauling educated the public about radiation hazards and campaigned for peace, disarmament, and the end of nuclear testing. These activities were considered to be treasonous during the first years of the Cold War and resulted in his passport being revoked by the U.S. State Department. When Pauling won the Nobel Prize in Chemistry in 1954 and could not leave the U.S. to accept it, pressure from around the world forced the government to lift this restriction.

Pauling continued his peace activism, and in 1957, he drafted a petition calling for an end to the atmospheric testing of nuclear weapons. This campaign led to a Nobel Peace Prize for Pauling in 1962 and to the first Nuclear Test Ban Treaty.

WILLIAM PERKIN 1838–1907

William Henry Perkin was born on March 12, 1838, in London, England. In 1853, Perkin entered the Royal College of Chemistry in London at only 15 years old. While on Easter break in 1856, Perkin conducted experiments in a simple laboratory in his London apartment. Through his experiments, he discovered that aniline could be transformed into a crude mixture that resulted in a bright-purple color when mixed with alcohol. Perkin soon realized that his solution could be used to color fabric, therefore becoming the first synthetic dye.

Perkin quickly patented his new dye, which he called mauveine, and began to consider ways to commercialize his product. With the help of his father and brother, Perkin set up a factory near the Grand Union Canal outside of London. His company received an unexpected boost when the Empress Eugenie of France decided the new color flattered her. Perkin's success demonstrated that chemistry could be financially and academically profitable!

Perkin continued research in organic chemistry for the rest of his life. He discovered and marketed other synthetic dyes, including Britannia Violet and Perkin's Green. In 1874, Perkin sold his factory and retired a very wealthy man.

ELEUTHÈRE IRÉNÉE DU PONT 1771–1834

Eleuthère Irénée du Pont was born in Paris, France, in 1771. Chemist Antoine Lavoisier hired du Pont to work in the Essonne Gunpowder factory. At this factory, du Pont learned how to manufacture gunpowder.

During the French Revolution, the du Ponts, like many others, found themselves under attack. In 1799, they left for the United States. Once in the U.S., du Pont recognized a business opportunity stemming from the poor quality of the gunpowder that was generally available. In 1802, he set up a powder works on the banks of the Brandywine River in Delaware. Initially, du Pont had difficulty getting things started and accumulated considerable debt. However, du Pont persevered, becoming the founder of the successful DuPont Company.

The DuPont Company became a major American business enterprise. When du Pont died in 1834, the company was producing over one million pounds of gunpowder per year.

RESOURCE GUIDE: Notable Chemists

JOSEPH PRIESTLEY 1733–1804

Joseph Priestley was born in Fieldhead, England, in 1733. He was educated to be a minister and spent most of his life working as a preacher or a teacher. In 1794, he emigrated to the United States.

Priestley's first scientific work, *The History of Electricity* (1767), was encouraged by Benjamin Franklin, whom he had met in London. In preparing the publication, Priestley began to perform experiments, at first merely to reproduce research reported in the literature but later to answer questions of his own. In the 1770s, he began his most famous scientific research on the nature and properties of gases. At that time, he was living next to a brewery, which provided him with an ample supply of carbon dioxide.

His first chemical publication was a description of how to carbonate water, an imitation of some naturally occurring bubbly mineral waters. Priestley began examining all the "airs" that might be released from different substances. Many following Aristotle's teachings still believed there was only one "air." By clever design of apparatus and careful manipulation, Priestley isolated and characterized eight gases, including oxygen, a record not equaled before or since. In addition, he contributed to the understanding of photosynthesis and respiration.

ERNEST RUTHERFORD 1871–1937

Lord Ernest Rutherford was born on August 30, 1871, in Nelson, New Zealand. Rutherford received his early education in government school and entered Nelson Collegiate School when he was 16. In 1889, he attended the University of New Zealand, Wellington, studying mathematics and physical science. In 1894, he entered Trinity College, in Cambridge, England as a research student and became J.J. Thomson's first graduate student at the Cavendish Laboratory.

Rutherford began experimenting with the transmission of radio waves but soon turned to the new field of radioactivity. In 1898, he reported the existence of alpha and beta rays in uranium radiation and indicated some of their properties. He also demonstrated that radioactivity was the spontaneous disintegration of atoms. In 1907, Rutherford became chair of physics at the University of Manchester, and in 1908, he received the Nobel Prize in Chemistry for his work with radioactivity.

At Manchester, Rutherford postulated the concept of the nucleus and developed the basis for the atomic model. He was also the first scientist to successfully transmute one element, nitrogen, into another, oxygen. In 1914, Rutherford was knighted, and in 1931, he was deemed First Baron Rutherford of Nelson, New Zealand, and Cambridge.

WILLIAM THOMSON (LORD KELVIN) 1824–1907

William Thomson (Lord Kelvin) was born on June 26, 1824, in Belfast, Ireland. At 10 years old, Thomson attended the University of Glasgow in Scotland, which provided facilities for elementary school students. In 1845, Thomson received his B.A. degree from the University of Cambridge in England and a year later, he became the chair of natural philosophy at the University of Glasgow in Scotland.

In 1848, Thomson introduced a new scale of absolute temperature measured in units that are now called Kelvins. Absolute zero on the Kelvin scale, the temperature at which atoms stop moving, equals negative 273 degrees Celsius.

Thomson's scientific work covered a variety of subjects, and he was well known for unifying different theories. His collaboration with James Joule played a major role in developing the second law of thermodynamics. They also observed what is now called the Joule-Thomson effect—that the temperature of a gas decreases when it expands in a vacuum.

Thomson also played a major role in laying the first transatlantic telegraph cable, risking his life several times during this process. In 1866, he was knighted by Queen Victoria for his work, and he was raised to the peerage of Baron Kelvin of Largs in 1892. He was a fellow of the Royal Society and served as president between 1890 and 1895.

EVANGELISTA TORRICELLI 1608–1647

Evangelista Torricelli was born in Faenza, Italy, on October 15, 1608. In 1624, he entered a Jesuit College to study mathematics and philosophy. In 1626, he traveled to Rome to study Galileo's laws of motion. He succeeded Galileo as grand-ducal mathematician and professor of mathematics at the University of Pisa. At the university, Torricelli solved some of the great mathematical problems of that time.

In 1634, while working to solve a problem facing pumpmakers, Torricelli made an important discovery. He used mercury, which has a density that is 14 times that of water, to raise water in a pump to the desired height. During his experiments, he realized that the column of mercury fluctuated with the atmospheric pressure, thus inventing the first barometer and demonstrating that a vacuum exists.

Torricelli also designed and built a number of telescopes and simple microscopes. Several large lenses, engraved with his name, are still preserved at the Museum of Science in Florence.

FRIEDRICH WÖHLER 1800–1882

Friedrich Wöhler was born on July 31, 1800, in Eschersheim, Germany. He began his education at the Gymnasium in Frankfurt, and in 1820, he entered the University of Marburg planning to become a physician. After receiving his medical degree in 1823, he began his study of chemistry with Europe's leading chemist Jöns Jacob Berzelius in Stockholm. Wöhler worked with Berzelius for a year, adopting his techniques and learning the chemistry of new elements.

Wöhler returned to Germany in 1825 to teach chemistry at the municipal technical school in Berlin. During his years at the school, Wöhler made two of his most notable discoveries. In 1828, he synthesized urea (an organic compound) from a completely inorganic substance. His discovery opposed the traditional belief that only living things could produce organic compounds and revealed that all matter, living or not, is governed by the same chemical laws. During this time, Wöhler also developed a method for preparing metallic aluminum on a small scale.

In the following years, Wöhler often collaborated with Justus von Liebig, advancing the study of organic chemistry. Together, they discovered organic radicals—groups of atoms in a molecule that tend to stay together during chemical reactions. They also investigated the family of plant bases called alkaloids, which include caffeine, nicotine, and morphine.

Celebrate Chemistry All Year!

There are many notable days on the calendar that can easily be related to chemistry. Celebrate with your students by conducting a science experiment!

NATIONAL STATIC ELECTRICITY DAY	JANUARY 9
NATIONAL INVENTORS' DAY	FEBRUARY 11
NATIONAL POISON PREVENTION WEEK	3RD WEEK IN MARCH
WORLD HEALTH DAY	APRIL 7
NATIONAL TEACHER APPRECIATION DAY	APRIL 7
EARTH DAY (U.S.)	APRIL 22
NATIONAL ENERGY EDUCATION DAY	APRIL 23
SPACE DAY	1ST FRIDAY IN MAY
NATIONAL TEACHER DAY	TUESDAY OF THE 1ST FULL WEEK IN MAY
TEACHER APPRECIATION WEEK	2ND WEEK IN MAY
WEIGHTS AND MEASURES DAY	MAY 20
NATIONAL SAFETY MONTH	JUNE
WORLD ENVIRONMENT DAY	JUNE 5
PETROLEUM DAY	AUGUST 27
NATIONAL CHILD HEALTH DAY	1ST MONDAY IN OCTOBER
FIRE PREVENTION DAY	OCTOBER 9
NATIONAL METRIC WEEK	2ND WEEK IN OCTOBER
NATIONAL MOLE DAY	OCTOBER 23
NATIONAL CHEMISTRY WEEK	3RD WEEK IN OCTOBER
NATIONAL HEALTH EDUCATION WEEK	3RD WEEK IN OCTOBER
MAKE A DIFFERENCE DAY	4TH SATURDAY IN OCTOBER
AMERICA RECYCLES DAY	NOVEMBER 15
AMERICAN EDUCATION WEEK	2nd WEEK IN NOVEMBER
UNIVERSAL CHILDREN'S DAY	NOVEMBER 20
NOBEL PRIZE DAY	DECEMBER 10