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Properties of Matter: A Forensic Science Approach

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Introduction

I am a science teacher for seventh and eighth graders at Clinton Avenue School, a neighborhood school in the Fair Haven section of New Haven. When my students enter seventh grade, they have typically have had little exposure to science. This unit will serve to introduce students to the study of science overall, but more specifically to the properties of matter as well as the scientific method. The overarching focus of the unit is how properties of matter can be used to not only understand the world around us, but to solve very concrete real-world issues. Furthermore, it is designed to engage the common interests of middle school students and provide an access point for students who may or may not be scientifically inclined.

In my experience teaching science to seventh graders, the major obstacle that they face in the curriculum around properties of matter is making meaningful connections to the content. Students can usually express to me the importance, or “the why”, behind studying language arts and math. However, my seventh graders struggle to do so with the first science content—properties of matter—with which they have the opportunity to learn. If they do not see a purpose and there is lack of natural interest in the content, then no teaching strategy will be able to lead these students to the scientific literacy that they need to make the personal and civic decisions that they will face in their lives. Furthermore, seventh grade students feel understandably lost in the amount of detail of the first unit in science, from learning about the existence and descriptions of atoms to studying properties such as solubility, density, and pH. As a result, they lose sight of the big picture and important themes related to the study of matter, such as how the structure of molecules and nature of atoms determine the properties that we experience on a larger scale.

This unit will use a thematic approach—forensic science—to teach properties of matter to seventh graders in a way that is engaging, cohesive, and full of real-world applications. Rather than viewing the unit as a collection of random and irrelevant facts and information, students will see and retain the essential concepts regarding properties of matter that they will apply not only to further studies in science but to other subject areas as well. The unit will highlight critical thinking and problem-solving skills in the context of forensic science. This approach will undoubtedly engage the majority of seventh graders who are inherently curious and competitive individuals. It will also cover ethical decision-making and the impact of science on society, providing for a multidisciplinary experience that will help to engage even those students who are not scientifically inclined.

Properties of Matter

Chemical vs. Physical Properties

Everything that has mass and volume is made of matter. Physical and chemical properties are both used to describe matter. Chemical properties are those that can only be measured by attempting to change the chemical identity of a material through a chemical reaction. Physical properties are those that can be measured without having to change a material's chemical identity. Physical properties are dependent upon the chemical structures and features of substances, i.e., how their molecules and/or atoms are arranged in space and how much energy is available to them. Physical properties include: magnetic attraction, density, boiling point, freezing point, melting point, solubility, color, and odor. Chemical properties include: flammability, pH, and reactivity with water.

Some properties depend upon how much material is present in a sample, while other properties do not. Intrinsic properties are not dependent upon how much material is present. Melting point, boiling point, density, odor, and color are all considered intrinsic properties. Extrinsic properties do depend on the size of a sample. For example, mass, volume, and heat content are all considered extrinsic properties. Forensic scientists measure both types of properties, but intrinsic properties are most useful in terms of identifying substances at a crime scene. [7]

Atoms, Compounds, and Mixtures

All matter can be broken down into atoms, which are the simplest units of chemical importance. Elements are composed of all atoms with the same atomic number (number of protons) and are the smallest units that still retain their characteristic chemical properties. Elements cannot be broken down by normal chemical means, so they are considered the most basic building blocks for creating compounds, or molecules. The periodic table organizes the 118 known elements by increasing atomic number and bears its name because the elements in the vertical columns share many physical and chemical properties—which is to say that the properties repeat periodically.

Atoms combine to form more complex units, called molecules. Two or more atoms can combine in ways that form compounds with very different properties from those of its individual atoms. For example, sodium chloride (NaCl), otherwise known as table salt, is formed from the combination of chlorine (Cl_2), a toxic gas, and sodium (Na), a highly reactive metal. Furthermore, the specific arrangements and interconnections between atoms within a molecule determine its properties. The same atoms can be rearranged in various ways to form a number of molecules that each have distinct physical and chemical properties. When the same atoms are arranged in different ways, they produce new substances called isomers. For example, ethanol (See Figure 1.) and dimethyl ether (See Figure 2.) are two isomers with the molecular formula C_2H_6O but they have very different chemical and physical properties. Ethanol is found in alcoholic beverages; it has a boiling point of 78°C and it is soluble in water. Dimethyl ether, on the other hand, has a boiling point of -23.6°C and is only partly soluble in water.

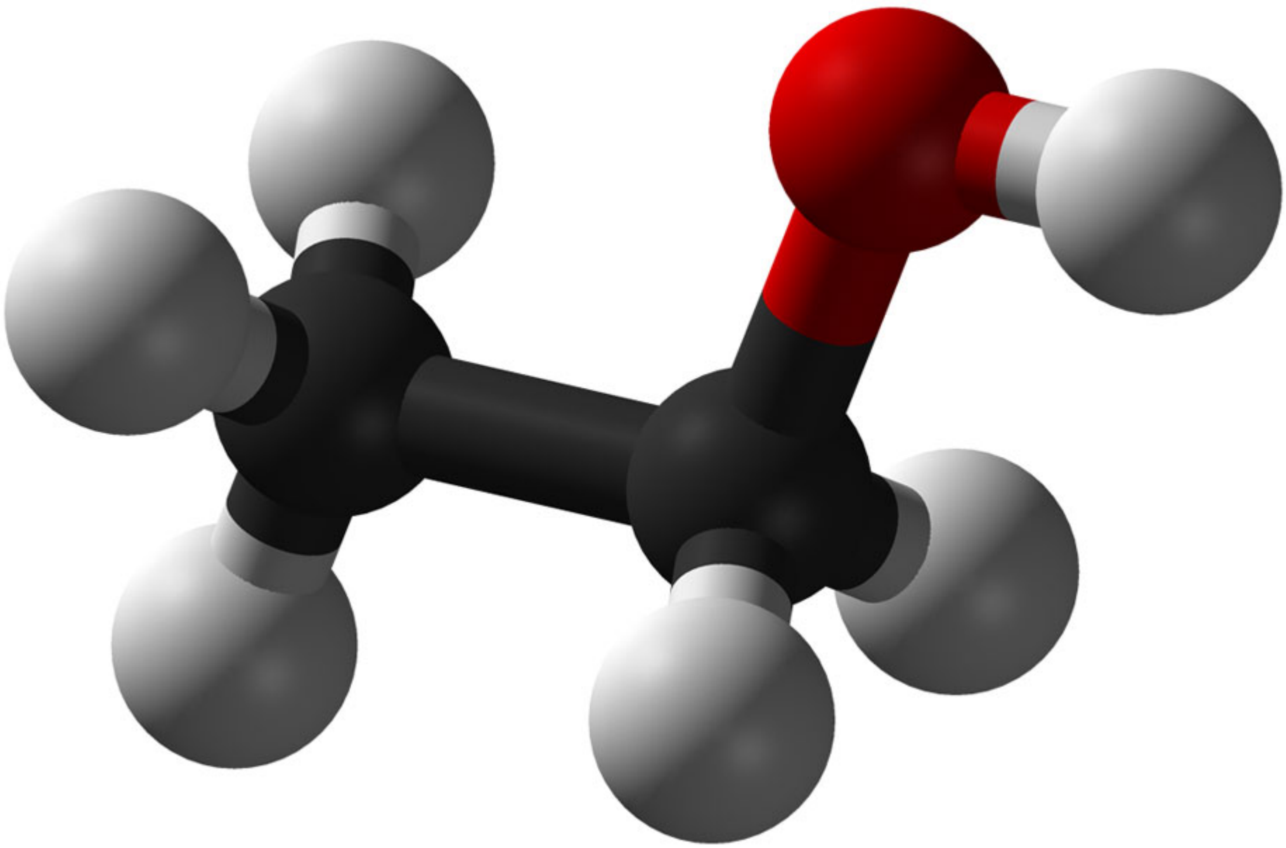

Figure 1. Ball-and-stick model of ethanol (C_2H_6O)

Retrieved: https://commons.wikimedia.org/wiki/File:Ethanol-3D-balls.png

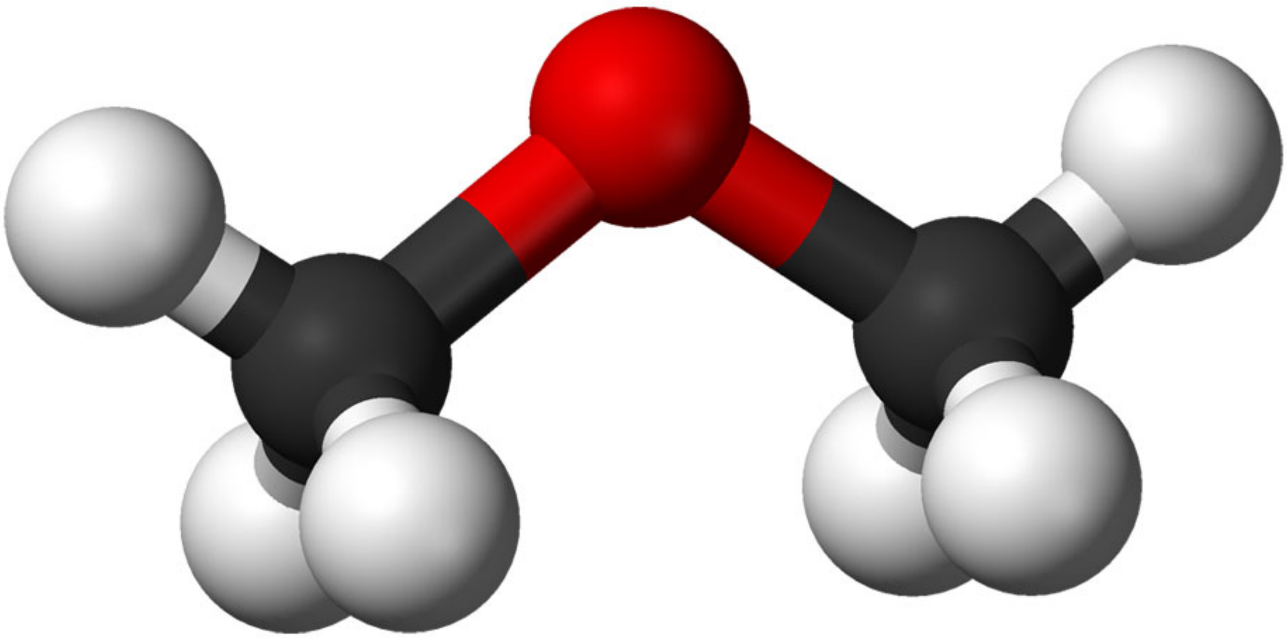

Figure 2. Ball-and-stick model of dimethyl ether (C_2H_6O)

Retrieved: https://en.wikipedia.org/wiki/Dimethyl_ether#/media/File:Dimethyl-ether-3D-balls.png

Mixtures occur when two or more compounds are mixed together but retain their own individual properties and do not chemically react. Most of what we encounter in the world, besides water, is a mixture of substances rather than pure elements or compounds. Homogenous mixtures, such as air, appear uniform throughout a sample. Individual components of the mixture cannot be distinguished physically, even though they still retain their individual identities. Heterogeneous mixtures are non-uniform throughout a sample. For example, a mixture of iron filings, sand, and salt is considered heterogeneous, as we can still see the individual components. [7]

Separating Mixtures

There are various methods for separating mixtures into their individual compounds, and they are generally divided into physical and chemical separation methods. Physical separation methods utilize the differences in physical (intrinsic) properties of each of the different components in the mixture. Individual components of a mixture retain their individual properties, so these differences—including density, boiling point, freezing point, and magnetic attraction—can be used to cause a separation.

Density is defined as the mass of material per unit of volume. If two substances have different densities, they can be separable using a liquid of intermediate density. For example, if a substance in a mixture has a density greater than that of the liquid, it will sink, and if the other substance in the mixture has a density less than that of the liquid, it will float. This method is commonly used to separate mineral and biological samples found at crime scenes, including the separation of blood cells from serum and the separation of glass samples.

Differences in solubility can also be used to separate mixtures. If one component of a mixture is soluble in a liquid while the other is not, then when that liquid is added to the mixture it will cause one to dissolve and leave the other behind. The liquid is filtered to remove the insoluble component of the mixture. The remaining liquid can be evaporated to leave behind the soluble component.

Boiling point can be used to separate a mixture of liquids. As a liquid mixture is slowly heated, the components of the liquid boil and change from liquid to gas when their unique boiling point is reached. The vapor is collected and condensed to obtain the pure liquid sample. Melting point is similarly used, except the temperature of the liquid mixture is lowered. As the temperature becomes low enough, one component may crystallize out as a solid.

Chromatography is the most powerful and commonly used separation method, and it is central in forensic chemistry. Chromatography is based upon how two substances interact with each other; substances can be attracted, repelled, or they can display an intermediate of the two. In paper chromatography, molecules that have a strong interaction with the paper bind tightly and move only slightly when the edge of the paper is placed in a solvent. Molecules that have a weak interaction are easily displaced and move rapidly across the paper in a solvent. The paper in this example is known as the stationary phase, while the solvent containing the mixture of substances is called the mobile phase. In gas chromatography, the components of a mixture are pushed through a tube (stationary phase) in a gas (mobile phase); because each component of the mixture interacts differently with the material inside the tube, they are separated similarly to paper chromatography. [7]

Applications to Forensic Science

Identifying Drugs & Illegal Substances

Forensic scientists are seeking to answer some basic questions when they analyze chemical evidence found at a crime scene: what substances are present in the material, are any components of the material illegal, and how much of the illegal substance is present? They use a number of methods for identifying illegal substances found at the crime scene, all of which fall under the umbrella of forensic chemistry. All matter has unique chemical characteristics due to the specific interactions of atoms and molecules within different substances. Forensic scientists use these characteristics in order to identify illegal substances, including drugs, poisons, and explosives. Substances found at crime scenes are often mixtures of a number of different chemicals. For example, cocaine powder will often contain caffeine or lidocaine within it. Therefore, forensic scientists must first separate these mixtures in order to identify the components of the mixture.

One method that scientists use to separate the components of a mixture is gas chromatography. In gas chromatography, substances are first dissolved in a liquid solvent. The solution is then injected into a superheated oven which vaporizes the liquid, changing it from a liquid to a gas. Helium or hydrogen gas is used to transport the vaporized liquid into a glass capillary tube; as it moves through the tube, the individual components of the mixture take varying amounts of time to emerge, thereby separating them.

After a mixture has been separated into its individual components, forensic scientists are then able to identify those components using a number of methods. Prior to running any tests, the mass of the substances is always measured. The testing that they complete is categorized as either presumptive testing—a less precise test which simply indicates that an illegal substance could be present—or confirmatory testing, which relies on a positive identification of the substance.

Examples of presumptive testing would be analysis under a microscope or colorimetric tests, i.e. if a specific substance is present, it will result in a color change. A microcrystalline test is another example in which scientists exploit the unique way in which atoms and molecules bond to form crystals to analyze those crystals and identify substances. Confirmatory testing is usually accomplished through the use of mass spectrometry, which uses a beam of electrons to break apart the components of a material. Each molecule breaks apart in its unique way due to its chemical structure, and the resulting fragments are mapped into a spectrum; scientists compare the spectrum against a database of known spectra to identify specific chemicals present in the evidence. Scientists also use melting point analysis—the temperature at which a substance melts—to identify illegal substances. Due to their differing chemical structures, all drugs have different melting points. During these tests, scientists must be cognizant of bias: how they expect the results to turn up versus accepted reference values for various substances. [5]

Identifying Hairs and Fibers

Hairs and fibers found at a crime scene can provide investigators with a wealth of information regarding the details of a crime. One of the most basic forms of analysis that forensic scientists complete on hairs and fibers is basic comparison. Scientists rely on controls to identify hairs and fibers; this type of evidence can be useless without a sample to which it can be compared, e.g. comparing the hair at the scene to the hair on the suspect. Scientists analyze fibers under a microscope to determine the material of which they are made and hair analysis can differentiate between human and animal origins. [1]

Fibers are small, long pieces of material that are typically woven together to make fabric or string. Fibers often stick to our clothes because they are a large part of our daily lives. When forensic scientists collect fibers, they need to be sure not to contaminate them, so picking them up with sticky tape should be avoided. Investigators can use static lift with a piece of plastic to collect fibers. Static electricity is an electric charge that can cause the fiber to stick to the piece of plastic. However, this method must also be used with caution, as microscopic electric sparks can destroy trace evidence.

Scientists use the shape of a fiber as one way to identify it. Some fibers are natural, while others are synthetic, or man-made. Synthetic fibers usually begin as a liquid and are squeezed through a nozzle to form strands, so the shape of their cross-section differs from that of natural fibers.

Spectrophotometry is a method that is used to examine a fiber's color. Color analysis includes every way that a substance interacts with light. Humans are only able to see the visible spectrum of light, while spectrophotometers can sense a larger range. For example, humans see an apple as red due to the separation of white light. When white light hits the apple, the red part of the light is not absorbed and bounces off, and that is the color we see. [2]

Forensic scientists sometimes use solubility testing to identify fibers that may lack a control sample. Fibers react differently in solvents depending on the makeup of their material. Some fibers will partially dissolve in solvents while others will fully dissolve. This method, however, is destructive to the evidence. In addition, swelling, shrinking, and color changes of fibers assist scientists in identifying them. Unlike solubility testing, polarized light microscopy uses polarized light to evaluate the composition of fibers in a non-destructive manner. [1]

Identifying Glass & Plastics

Glass is made mostly of silicon dioxide (silica, SiO_2), which makes up most sands and is the most common compound found in the Earth's crust. Glass is amorphous, meaning it does not have a regular, repeating crystal structure. It does flow, although so slowly that its movement is undetectable over thousands or even millions of years. Glass receives its hard and brittle properties from the inter-connecting nature of its SiO_2 network. [7]

Forensic scientists use density and color to test glass evidence. The density of a substance is its weight per volume. Because forensic scientists usually only have small pieces of glass to test, they need to use very accurate and sensitive instruments. They look to see if the density of glass particles found on a suspect match glass found at the scene of a crime. If it does, the evidence suggests the suspect was present at the scene.

Scientists also try to match samples of glass by testing the refractivity of glass, which is the degree to which light is bent by the glass. When light passes from one transparent substance to another, i.e. from air to water, it is refracted, or bent. Some materials refract light more than others. For example, some types of glass bend light more than other types of glass because they have a higher refractive index. Scientists can use this property of glass to determine if two samples match each other.

Forensic scientists have a clever way of testing refractivity with unusually small pieces of glass. Typically, glass samples used as evidence are too small to bend narrow beams of light (not to mention that they are irregularly shaped). However, if glass is placed in a transparent liquid that refracts light exactly the same way, the glass will disappear. The light treats the glass and liquid as the same substance with respect to how it bends. This property enables scientists to analyze extremely small pieces of glass found at crime scenes. Scientists use clear silicone oil for this testing because when the oil is warmed or cooled, its refractive properties change with temperature. When a glass sample disappears, the investigator can conclude that it has the same refractive index of the oil at that specific temperature. If two glass samples disappear at the same time, then they refract light in the same way. If their densities also match, then the scientist can conclude that the glass samples are likely from the same source.

Plastics are materials that can be molded and made from high molecular weight polymeric compounds. Forensic scientists use the physical and chemical properties of plastics for identification purposes. For example, density and refractive index are two physical properties commonly used to identify plastics. As for chemical properties, scientists must understand the formation of polymers from their individual monomer components to identify plastics. [7]

Identifying Soil

Soil analysis is typically accomplished using its density. Although forensic scientists are usually not able to pinpoint soil evidence to a specific location, they can determine the type of soil found which can provide further information about a crime. When soil is added to a density-gradient tube, the particles in the soil will sink to the portion of the tube that has the same density and remain suspended there. Scientists can study the soil density distribution patterns to analyze the crime scene. For example, they are able to determine if two samples of soil are from the same area.

Understanding Explosions & Identifying Explosives

Fire is defined as the rapid oxidation of substances through combustion reactions with the release of energy in the form of heat and light. Atmospheric oxygen typically acts as the oxidant in fires with hydrocarbons commonly acting as the fuel source.

Explosions can be classified as physical or chemical explosions. A physical explosion is characterized by the rapid release of gasses from a highly pressurized container, but does not contain the release of energy in the form of heat or light. A chemical explosion is characterized by an extremely rapid chemical reaction that releases heat, and it is the most common type of explosion in forensic investigations. Chemical explosive reactions are too fast for atmospheric oxygen to deliver the oxidizer quickly enough to sustain the reaction, so explosives contain both fuel and oxidizer components together. Nitroglycerin is a major component of dynamite and is an example of a substance that contains both the fuel and oxidizer components together so that atmospheric oxygen is not needed for an explosion to occur.

Forensic scientists investigate explosive materials by first separating mixtures using gas chromatography followed by mass spectrometry to identify individual components of the mixture. Each type of explosive will produce different spectra, enabling scientists to identify the specific explosive used in a crime. In addition, forensic scientists can used electron microscopic analysis for identifying explosives, as explosives leave residues with distinctive structures and shapes. [7]

Identifying Blood

Blood is a bodily substance consisting of solids within a liquid. Blood, being a mixture, can be separated into its individual components: plasma, red blood cells, and platelets/white blood cells. Plasma is the liquid portion of blood and consists of 90% water. The volume in a single drop of blood is about 0.05 milliliters (mL) – it would take 20 drops of blood to equal a milliliter.

Many times a crime scene will contain traces of blood, but it is possible that someone may have tried to clean it up. Investigators rely on chemical reactions to reveal faint traces of blood. If luminol, a chemical, is sprayed on a crime scene, it will react with iron in the blood and cause a faint blue glow for up to half an hour. [2]

The Kastyle-Meyer test has been used since the early 1900s to quickly test a sample for the presence of blood. The test uses a chemical indicator, phenolphthalein, and hydrogen peroxide. The hydrogen peroxide reacts with hemoglobin, the protein found in blood, to create water and a highly reactive form of oxygen. The oxygen subsequently reacts with the indicator molecule changing it from colorless to pink. Because the test can also detect peroxidase, an iron-containing enzyme found in plants, a positive test means the sample could be either blood or plant cell material. A negative test means the sample is definitely not blood. [4]

Scientific Method & Ethics in Forensic Science

Scientific Method

Forensic scientists report their findings, or conclusions, to law enforcement and the Court. In their reports, they include observations, data analysis, their hypotheses, tests and procedures, as well as summaries and findings of fact. Findings are scientific conclusions and can be supported by experimental data . [6]

The scientific method involves a cyclical process of hypothesis-> experimentation-> results-> revised hypothesis. Forensic science is similar in nature. An investigation of a crime scene begins with collection of data – observations, measurements, and descriptions. Afterwards, investigators develop one or several possible hypotheses that can be tested using the forensic data and other evidence. The forensic data are used to support, refine, or refute the hypothesis. If a hypothesis is refined, the investigation continues with observations followed by results and analysis. Forensic scientists must look for evidence that might refute their hypothesis of a crime while also looking for confirmatory evidence so that they do not overlook key insights and can assure that the investigation is complete and a criminal conviction is proper. [7]

It is vital that forensic scientists carefully and systematically label all evidence they come across in their process of collecting data. There is no room for mistaking or losing evidence in high-consequence cases and trials. Forensic scientists must be meticulous in their work so as to prevent inaccurate conclusions.

Pseudoscience in Forensics

Good forensic scientists only report to juries on what they know. They use language such as "this evidence is consistent with…" as opposed to "this evidence proves…". For example, forensic scientists can conclude that gunpowder molecules are present on a suspect's hand, but they may not have the evidence to conclude that the suspect actually fired the gun. Similarly, scientists may be able to state that hairs found at a scene look similar to the suspect's hair, but they cannot be certain that they are definitely from the suspect's head. Forensic scientists must keep their analysis limited to facts that can be proven in order to avoid pseudoscience. [2]

Teaching Strategies

This unit was designed to naturally incorporate the 5-Es instructional model. The following outline will a. Describe the strategy and b. Provide an example using the concept of density from this unit.

Engage

1. Begin a new concept/topic with a question, picture, video, fact/statistic, story, demo, or activity that engages students in the theme of the unit, forensic science.
2. Show students a bottle of fake blood made using oil and water dyed red. Shake it and then let it settle. Have them make observations or ask questions. Ask them why they think the two liquids separate, but don't give away the answer!

Explore

1. Students participate in a hands-on activity in which they can explore the concept or skill.
2. Have students create a density column in which they add different liquids (e.g.water, oil, maple syrup, etc.) to a graduated cylinder to explore how they can stack on top of each other. Have students draw and label a picture of the result.

Explain

1. Students, with teacher guidance, develop explanations for phenomenon they have explored and

teacher introduces academic vocabulary.
2. Begin by asking the students if they have noticed the pattern (which types of liquid tend to move toward the bottom in the graduated cylinder, and which tend to move toward the top). Record responses. Define density as a physical property of matter. Differentiate between high and low density by drawing a model of substances on the atomic level. Have students list the liquids in order from least to most dense. Have students engage with a chart of common materials and their specific densities, etc.

Elaborate

1. Students apply what they have learned to new situations to develop a deeper understanding of the concept.
2. Present students with a crime scene investigation: a clear "chemical" (e.g. corn syrup) was found at a crime scene, and it is unclear what it is. Have students compare the density of the chemical to the density of water by using graduated cylinders. Provide them with a chart listing common clear chemicals and their densities, and give them the task of determining which chemical was used in the crime.

Evaluate

1. Students review or reflect on their learning.
2. On a Post-It note, have students explain how density can be used to identify an unknown substance like a chemical at a crime scene.

Classroom Activities & Demonstrations

The following activities and demonstrations are meant to be incorporated into the unit, as appropriate, to provide students with hands-on experiences of the core science content in the unit (properties of matter, compounds, and mixtures). These activities should be adapted to fit either the "Explore" section or the "Elaborate" section of the 5-Es instructional model. Activities may be adapted into demonstrations for the "Engage" section as well.

Chemical and Physical Properties

Crime Scene Analysis – Pre-Assessment

Students will be able to use properties of matter to identify materials and substances found at a crime scene. In this pre-assessment activity students will receive a list of common materials and a list of their properties, e.g. density, solubility in water, magnetic attraction, color, melting point. Students will read about a crime that occurred and what was found at the scene, along with a report about the properties of the trace evidence. They will then work in groups to compile a list or graphic organizer of all of the ways in which they could identify the evidence.

Density of liquids/objects

Students will identify materials using their densities. Students will create a density column with different liquids (water, corn syrup, oil, rubbing alcohol). They will drop in different solid objects (beads, woods, glass, etc.) to estimate the densities of those objects by comparing them to a provided list of the liquid densities. Students will collect data and draw conclusions about the densities of the various objects.

Solubility

Students will determine which substances are soluble in water and which are not (practice measuring small volumes of liquid, using triple beam balance to measure mass of salt, sugar, baking soda, etc.) with the aim of identifying the white power found at the crime scene. Students can also explore the solubility of polymers by testing the solubility of polystyrene (Styrofoam) in acetone (nail polish remover) and comparing that to the solubility of polyethylene (common plastic).

Density of glass

Instruments for measuring tiny fragments of glass are expensive, but students can replicate glass analysis on a larger scale with different types of large glass pieces (e.g.. jars). Students can compare the densities of different types of glass.

Exploring refractive index

Students can explore how light is bent when passing from water to air by placing a pencil in a glass of water and observing it from the side. The pencil will appear to be broken at the point where it enters the water. This is due to the fact that the light reflected from the pencil that comes through the water is bent when it enters the air. As a result, the submerged portion of the pencil seems to be dislocated from the upper portion. (Crime Lab 101 Robert Gardner) Students can replicate the activity with a glass dropper – have them insert an empty glass dropper into the oil, and then have them compare that to when the dropper is full of oil.

Refractive Index

Students can dip transparent plastic tape into clear or light-colored cooking oil. Because the clear tape refracts light in almost the same exact way as the oil, it will disappear when submerged. (Crime Lab 101 Robert Gardner) Students will get a couple of different types of tape and/or transparent objects (e.g. marbles), and will identify the tape that has the same refractivity as the liquid. Students can also complete this activity using absorbing water beads and marbles.

Hair and fiber analysis

Students will analyze hairs and fibers under a microscope and compare them to a hair and fiber found at the scene of a crime. The teacher will have a group of volunteers provide one piece of hair. The teacher will choose one of those hairs and mark it as the crime scene evidence. The class will use microscopes to compare hairs from the volunteer group to the crime scene evidence to see if they can figure out to whom the hair belongs.

Boiling Point

Why do liquids have different boiling points? Boiling point depends on the intermolecular forces present between atoms or molecules in a liquid, and these forces must be interrupted when a liquid changes to a gas. Magnets are a great way for students to visualize and experience this concept. Get magnets of various sizes/strengths. Have students determine which magnets have a stronger force between them and which have a weaker force between them. As a class, compare the magnets to atoms/molecules in a liquid and your hands to the heat added to a liquid. Which liquid would have a higher boiling point and why? Which would have a lower boiling point and why? Students will see that the stronger the forces between the atoms/molecules, the more heat must be added in order to disrupt those forces. This demo/activity can be supplemented with the PHET interactive simulation on states of matter found online at https://phet.colorado.edu/en/simulation/states-of-matter.

Flammability

Dip a dollar bill into a 1:1 solution of isopropyl alcohol and water. Ignite the bill with a match. The dollar will catch on fire for roughly 10 seconds and then the flame will fade. Explain to students that although the two liquids look similar, they have different properties. One of those properties is flammability. Isopropyl alcohol is flammable, while water is not. The isopropyl alcohol burns, creating a flame. Water has a high boiling point (another physical property) due to its high specific heat; the heat from the burning isopropyl alcohol is not high enough to evaporate the water, so the water remains soaked into the bill keeping it protected from the flame.

Crime Scene Analysis –Post-Assessment

As a post-assessment for the unit, students will receive the same pile of “evidence” provided at the start of the unit, and they will come up with all of the ways they can use to describe it. Using their knowledge about properties of matter and how they are measured, they can create a list of all the ways they can describe the materials. As an alternative, they can create a graphic organizer of how they would identify the objects and substances.

Atoms, Elements, and Compounds

Elements

Students will research common materials or substances used in crimes, identify the elements that make up those materials, and use art supplies (modeling clay, pipe cleaners, wire, beads, etc.) to create physical models of their atoms. Students will create a “Wanted” poster for their atom to describe how it looks (protons, neutrons, electrons), where it is likely to be found in the Earth, as well as a list of properties that can be used to identify it. A great resource for this activity is an online interactive periodic table of elements found at http://www.ptable.com/.

Mixtures

Separating a mixture

Students will use properties of matter to separate a mixture of iron filings, sand, and salt. The mixture will be “crime scene evidence” and students must accurately report the mass of each component of the mixture for a trial. Students will work in groups to determine the best way to separate the mixture. To make it more engaging, the group that gets closest to the initial mass of each component is the group that was able to convict the suspect in the crime!

Paper Chromatography

Students will analyze the colors hidden in coloring markers using paper chromatography. Set up a scene for the students: “A note was found at a crime scene written in marker. It is your job to identify which marker was used to write the note, as that information will help to make a conviction.” Students will compare the patterns of different markers using paper chromatography to identify the marker used in the crime. Have the students draw a dot for each marker they are testing at the bottom of the paper. Hang the paper in water (making sure the marker ink does not touch the water) and give it enough time for the water to rise up the paper.

Blood as a mixture

Making blood – Students will create fake blood (water, oil, food coloring) and observe its properties as a mixture. Students can shake the fake blood in a bottle, and then let it sit. Ask them to explain what is causing the components of the blood to separate (density). Students can also complete a similar activity by using a centrifuge to separate fake blood into its individual components. This lab activity is available at: https://www.teachengineering.org/activities/view/gat_mixture_activity1

DNA

This activity fits nicely with the forensic theme. Provide students with an introduction to DNA and how it is used to solve crimes. Explain to students that they will be extracting the DNA from a strawberry, and that they will have to use properties of matter in order to separate the DNA from a mixture. In this activity, a coffee filter is used to separate DNA from the remaining parts of the cell based on its size. Cold isopropyl alcohol is used to cause the DNA to precipitate out of the solution. Review the concept of solubility with students during the activity. The procedure is outlined below:

1. Place one strawberry in a Ziploc bag.
2. Smash the strawberry using your fingers for 2 minutes to break open the cell walls. Careful not to break the bag.
3. Add 10 ml of DNA extraction solution (to the bag to break up proteins and break through the cell membrane and the nucleus membrane. (Note: extraction solution consists of 90 ml water, 10 ml dish soap, and ¼ tsp salt)
4. Mush the strawberry in the bag again for 1 minute.
5. Place a coffee filter over the plastic cup. Pour the strawberry mixture into the filter and let it drip into the plastic cup to separate the DNA from the rest of the cell.
6. Slowly pour cold rubbing alcohol into the cup to take out the DNA from the solution. Observe!
7. Dip your pipette into the plastic cup to move around the DNA and make further observation.

Appendix A. Implementing District Standards

Core Science Curriculum Framework and Grade-Level Concepts

6.1.a. Mixtures are made of combinations of elements and/or compounds, and they can be separated by using a variety of physical means.

Students should understand that…

1. Everything is made of matter. Matter has two fundamental properties: it has weight (mass) and it takes

up space (volume).
2. All matter has a variety of properties, some of which are characteristic of the substance. Characteristic properties do not depend on the amount of the substance (as mass and volume do). Properties such as magnetic attraction, conductivity, density, pH, boiling point and solubility are characteristic properties that can be used to identify substances.
3. Solids, liquids or gases can be combined to form mixtures. In a mixture, each substance keeps its individual properties. In some mixtures, each of the components can be seen (for example, rocks, twigs, insects and leaves are visible components of soil); in other mixtures, the individual substances blend so well that they appear to be a single substance (for example, oxygen, nitrogen and carbon dioxide are mixed together to form air).
4. Mixtures can be separated using different methods, depending on the physical properties of the component substances. Filtering, evaporating, floating/settling, dissolving, and using magnets are all methods for separating mixtures based on the properties of their components.
5. Solutions are mixtures that appear to be single substances because particles have dissolved and spread evenly throughout the mixture. Not all separation methods are effective for separating the components of solutions.

6.1.b. Pure substances can be either elements or compounds, and they cannot be broken down by physical means.

Students should understand that…

1. All matter is made of particles called atoms that are too small to be seen without special magnification. For example, a gold ring can be broken into smaller and smaller pieces until the pieces are no longer visible.
2. All matter is made of different combinations of about 100 pure substances called elements. The smallest particle of an element is an atom. Iron is an example of an element that is made up of only iron atoms.
3. Each element has distinct characteristic properties. The Periodic Table of Elements is used to organize elements based on properties such as their reactivity, state of matter, conductivity or density. Element names are represented by letter symbols on the Periodic Table.
4. Some elements, such as iron (“Fe”) and aluminum (“Al”), are classified as *metals* because they have similar properties. Individual metallic elements have distinct characteristic properties (for example, sodium (“Na”) is a light, soft metal that is nonmagnetic, while iron is a magnetic metal that is denser than sodium and aluminum).
5. Some elements, such as carbon (“C”), hydrogen (“H”), oxygen (“O”) and chlorine (“Cl”), are classified as *nonmetals* . Carbon is a nonmetal that occurs in several different forms (graphite, diamond, and coal), each of which has distinct properties. Hydrogen and oxygen are nonmetals that are similar in that they are both gases; however, each gas has distinct characteristic properties.
6. Atoms can combine chemically to make a molecule of a new substance with new properties called a compound. A molecule is the smallest part of a compound and is made of atoms of different elements in specific amounts . Unlike mixtures, compounds cannot be separated using the physical properties of the component elements.
7. Compounds have different properties than the individual elements of which they are made. For example, table salt (NaCl) is a compound with different characteristic properties than the elements sodium and chlorine from which it is made; water (H_20) is a compound with different characteristic properties than the elements hydrogen and oxygen from which it is made. Different amounts of the

same elements can produce compounds with different properties (for example, water (H_20) and hydrogen peroxide (H_20_2).

8. In a chemical reaction, atoms can rearrange to form different molecules of new compounds. During photosynthesis, carbon dioxide (CO_2) is taken in by green plants and combined with water (H_2O). The carbon, hydrogen and oxygen atoms rearrange to make two new compounds: glucose (made of atoms of carbon, oxygen, and hydrogen) and oxygen gas (made of atoms of oxygen).

Grade-Level Expectations

1. Distinguish between mass and density.
2. Explain that density is a ration of mass to volume. Use density to identify elements or separate mixtures.
3. Demonstrate that different substances float or sink in water depending on their density.
4. Compare and contrast the properties of metals, nonmetals, and metalloids.
5. Differentiate between a mixture and an element or a compound and identify examples.
6. Conduct and report on an investigation that uses physical means such as particle size, density, solubility, or magnetism to separate substances in a mixture.
7. Compare and contrast physical and chemical changes, and use evidence to support or refute a claim that a chemical reaction has occurred.

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