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What's the... Matter?

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by Larissa Spreng

Introduction

One of the things I love most about being a teacher is that each day I get to see the direct impact of the work I do. Over the past four years, I have seen just how high the stakes are for my students. But every skill or life-lesson I teach them can open the door for opportunities and put them on the life path to becoming engaged global citizens in an ever changing society. The world around us is filled with matter and I want my students to be able to be able to quantify and describe it at both a microscopic and macroscopic level so they can fully understand it.

This curriculum unit will focus on changes that occur in matter. Middle school students will first learn about the three states of matter (solids, liquids, and gases). We will then examine the role thermodynamics (energy, heat, and work) plays in phase transitions. Students will practice modeling molecules and describing the molecular properties of each state of mater and mixtures. Through hands on experiments, students will be able to compare and contrast physical and chemical changes. Finally, students will gain a deeper understanding of the law of conservation of matter and chemical equilibrium by writing chemical equations for everyday chemical reactions.

This curriculum unit will allow me to enrich my students' knowledge and understanding of the world around them, which is filled with matter. Academically, my students will gain exposure to real-world scientific connections. And finally, this unit will provide my students with a deeper understanding of STEM careers and hopefully spark their interest in pursuing a degree in physical science and physical chemistry.

The New Haven 7th grade curriculum includes content aligned with the Physical Science and Physical Chemistry seminar topic. This seminar will connect with the first two units in the 7th grade curriculum (Properties of Matter and Chemical Properties) including: states of matter, phase transitions, units of measurement, mixtures, and chemical equations. However, this unit will address a gap in the current New Haven curriculum, which does not consider *why* phase changes occur. Students will learn about enthalpy and entropy and be able to use mathematical skills to analyze the Gibbs free energy equation ($\Delta G = \Delta H - T\Delta S$).

Matter

Everything around us is made of matter. Matter is anything that has mass and volume. [4] The physical form in which matter exists is called a state of matter. The term phase can also be used to describe which state matter is in. Most matter on Earth exists in three states: solid, liquid, and gas. [5] Examples of solids, liquids, and gases can be found all around us. Often we can determine the state of matter by observing the substance with the naked eye. For instance, the land we walk on is solid, oceans and rain are liquid, and the air we breathe is a mixture of gases. The classification of the state of matter is based on observable characteristic properties.

Atoms and Elements

Matter is made of particles called atoms and molecules. [10] Atoms are the basic building blocks of most matter around us. An element is a pure substance made up only of a single type of atom. Atoms are too small to be seen without special magnification. [10] For example, a gold ring can be broken into smaller and smaller pieces until the pieces are no longer visible. Scientists have discovered 118 elements. Of these elements, 92 are naturally found in nature such as carbon, oxygen, gold, silver, and iron. [12] The remaining elements are synthetic and not found naturally; instead they are made in the laboratory. [12]

All matter is made of different combinations of about 100 pure substances called elements. [12] An atom is the smallest particle of an element that has all the properties of that element. Each element is made up of atoms that differ from other elements. The main differences between atoms are the structure of the atom that makes it up. Atoms are made up of different numbers of subatomic particles (neutrons, protons, and electrons). [12] Elements are represented by their chemical symbol on the Periodic Table of Elements. This letter symbol is typically made up of one or two letters. For example, carbon is represented by C, oxygen by O, and He for helium. [8]

Properties of Elements

Each element also has different properties or characteristics. The structure of the atoms determine an elements' properties. The Periodic Table of Elements is used to organize elements based on properties such as their reactivity, state of matter, conductivity or density. [12] 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. Properties such as magnetic attraction, conductivity, density, pH, boiling point and solubility are characteristic properties that can be used to identify substances. [8]

Some elements, such as iron (Fe) and aluminum (Al) are classified as metals. [12] Iron and aluminum are two shinny metals, but they differ slightly in their properties. Iron is silvery grey and heavy, while aluminum is silvery white and lightweight in comparison. [8,12] Individual metallic elements have distinct characteristic properties such as malleability, ductility, and relatively high density. 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. [12]

Other elements, such as carbon (C), hydrogen (H), oxygen (O) and chlorine (Cl), are classified as nonmetal. [8] Carbon is a nonmetal that is a solid at room temperature, but exists in several different forms (graphite, diamond, and coal), each of which has distinct properties. One form, graphite, is a soft grey substance that makes up pencil lead. [12] Another form that looks very different from graphite is diamond. Diamond is transparent and the hardest material found in nature. [12] Hydrogen and oxygen are nonmetals that are similar in that they are both colorless gases; however, each gas has distinct characteristic properties. [8,12]

Elements also have different reactivity, which describes there ability to form chemical bonds with other substances. Oxygen is highly reactive and it readily combines with other substances during burning. [12] Hydrogen is another element that is highly reactive and it causes explosions when it comes in contact with certain elements. Iron is a metal that reacts easily with water forming rust, while aluminum does not. [12]

Mixtures and Compounds

Most substances or matter are not made of just one element. Elements can combine in different ways to form other substances called compounds and mixtures. [12]

Mixtures

Solids, liquids or gases can be combined to form mixtures. A mixture is a combination of two or more substances that are not chemically combined. [12] Since substances that form mixtures are not bonded together mixtures are not pure substances. In a mixture, each substance keeps its individual properties and identity. In some mixtures, each of the components can be seen. For example, rocks, twigs, insects and leaves are visible components of soil. [8] Salad and a bowl of cereal are other examples of a mixture with distinct parts. [12] In other mixtures, the individual substances appear to be a single substance because they are so well blended together. Solutions are mixtures that appear to be single substances because particles have dissolved and spread evenly throughout the mixture. [8] Air is a mixture of gases, including oxygen, nitrogen and carbon dioxide. [12]

Mixtures can be separated using different methods, depending on the physical properties of the component substances. Particle size, density, solubility, boiling point, and magnetic attraction are methods for separating mixtures based on their physical properties. [12] However, not all separation methods are effective for separating the components of solutions.

Compounds

Atoms can combine chemically to make a molecule of a new substance with new properties called a compound. Like elements compounds are pure substances that have the same chemical composition throughout. [12] A compound forms when two or more elements join chemically creating a molecule. A molecule is the smallest part of a compound and is made of atoms of different elements in specific amounts . A molecule is a group of two or more atoms held together by very strong chemical bonds. [12] These bonds form between atoms that share or transfer their electrons. [12]

A molecule can be made up of more than one atom of the same element. Oxygen gas (O_2) is an example of this since it is made of two oxygen atoms joined together. Molecules can also be made of two or more different elements. [8] Water (H_2O) is an example of this since it is made of two hydrogen atoms and one oxygen atom. [12]

Since they are chemically combined, compounds cannot be separated using the physical properties of the elements that make them up. As a result, compounds often have different properties than the individual elements that make them up. For example, table salt (NaCl) is a compound with very different characteristic properties from the elements sodium and chlorine, which make it up. Sodium (Na) is a soft metal that explodes when combined with water. [12] Chlorine (Cl), on the other hand is a poisonous gas. [12] When chemically combined sodium and chlorine for sodium chloride (NaCl), an edible white solid we enjoy on French fries, better known as table salt. Water (H_2O) is another compound with different characteristic properties from the elements that form it. [12] Water is a liquid at room temperature; however, hydrogen and oxygen are gases at room temperature. Hydrogen is combustible, but water does not burn. Different amounts of the same elements can also produce compounds with different properties. For example, water (H_2O) and hydrogen peroxide (H_2O_2) are both made up of hydrogen and oxygen atoms, but have very different properties. [8]

Chemical Equations

Molecules are identified by chemical formulas. A chemical formula is a group of chemical symbols and numbers that show the kids and number of atoms in a molecule. For example, the formula for water is H_2O. H is the chemical symbol for hydrogen. O is the chemical symbol for oxygen. The small number 2 is called a subscript. [12] It shows that the molecule contains two atoms of hydrogen. The O has no subscript, which means that the molecule contains only one atom of oxygen. [12] (Note: It is not necessary to write 1 as a subscript in chemical formulas or equation. No subscript recognizes there is only one atom.)

In a chemical reaction, atoms can rearrange to form different molecules of new compounds. For example, 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 using energy from sunlight to make two new compounds: glucose ($C_6H_{12}O_6$) (made of atoms of carbon, oxygen, and hydrogen) and oxygen gas (O_2). [12]

Balancing Chemical Equations

In a chemical equation, certain conditions must be met. A chemical reaction is simply the rearrangement of atoms to form something with a new chemical formula and different properties. [12] In a chemical reaction, the same amount of matter (mass) is present at the start and the end, since the atoms are not created or destroyed but simply rearranged.

Unbalanced chemical equation for photosynthesis:

$CO_2 + H_2O + \text{Sunlight} \rightarrow C_6H_{12}O_6 + O_2$

Balanced chemical equation for photosynthesis:

$6\,CO_2 + 6\,H_2O + \text{Sunlight} \rightarrow C_6H_{12}O_6 + 6\,O_2$

Balanced chemical equations involve an equal number of atoms on both the product and the reactant side of the equation. In the photosynthesis equation there is 1 C, 3 O, and 2 H on the reactant side and 6 C, 12 H, and 8 O on the product side. The following numbers need to be added in order to make both sides of the equation have 6 C, 18 O, and 12 H.

Three States of Matter

Solids, Liquids, and Gases

Matter is made up of very tiny particles known as atoms and molecules. [4] These particles have energy and are in a constant state of motion. The motion and arrangement of the particles that make up a substance determines its state of matter. [3]

In a solid the particles are packed tightly together. The energy that bonds these particles together is very strong and prevents the particles from moving around freely. Particles in a solid, as a result, vibrate in their positions. [12] It is these strong bonds that give solids their definite shape and volume. [12]

Liquids have particles that are able to move throughout the container that the liquid is in. The bonds that hold the particles of a liquid together are weaker then in solids, which is the reason that particles in a liquid slide and move past one another. [3] Since the particles can move, liquids are able to change their shape and conform to the container that holds them. Their volume however is definite.

Gases are the state of mater that have the weakest bonds between their particles. [12] Particles in a gas are able to move around freely and it is this movement that allows gases to expand or contract. Gases therefore do not have a definite shape or definite volume. [12]

State of Matter	Solid	Liquid	Gas
Shape	Definite shape	No definite shape	No definite shape
Volume	Definite volume	Definite volume	No definite volume
Particle arrangement	Densely packed	Close	Far apart
Energy binding particles	Very strong	Strong	Weak

Figure 1. State of matter and their properties. [12]

Solids are substances that have both definite shapes and definite volumes. [4] A liquid, on the other hand, has a definite volume, but does not have a definite shape. Unlike solids, liquids take on the shape of their container. [3] Gases do not have definite shapes or definite volumes and like liquids gases take the shape of their containers. Since gases do not have a definite volume they can spread out in all directions. Liquids and gases are known as fluids because both substances are able to flow.

Phase Changes

Substances change their state of matter when heat is added or removed. [12] When heat is added particles move faster. This can overcome the bonds holding them together causing a solid to become a liquid. After adding even more heat, the particles spread farther apart and expand, thus becoming a gas, which is much less dense. [12] When heat is removed the opposite happens and particles slow down and move closer together, therefore becoming denser. One exception to this rule of heat affecting density is water. When heat is removed from water it freezes becoming ice. Ice is actually less dense then liquid water. Ice floats on top in a glass of ice water.

There are some positive and negative implications of the fact that ice is less dense than water. When lakes freeze the ice is able to insulate the water below so it does not freeze and fish do not die. If ice sank than the entire lake would freeze each winter. On the other hand, water in cracks on roads freezes in the winter and expands, as this happens over and over, small cracks can become large potholes. Another negative aspect is that when pipes freeze in the winter they can burst. Frost can also wipe out entire crops if an unexpected freeze happens in the late spring.

When heat is added to a solid the particles gain energy and they move around faster and spread further apart. When enough heat is added to a solid it can change into a liquid. This phase change is called melting. [12]

Particles in a liquid continue to move even faster and spread further apart when more heat is added. When liquids reach a certain temperature their particles gain enough energy to escape the surface of the liquid and change into a gas. This phase change is called evaporation. [12]

When heat is removed from a substance the particles lose energy, slow their motion, and pack together more tightly. Cooling a substance enough can cause a change in its state. [12] Substances undergo condensation when they change from a gas to a liquid. [12] Condensation can be observed on a cold glass of water on a hot summer day. The temperature at which a substance condenses is the same as the temperature at which it boils. When a substances changes from a liquid to a solid, freezing occurs. [12] The temperature at which a substance freezes is the same as the temperature at which it melts.

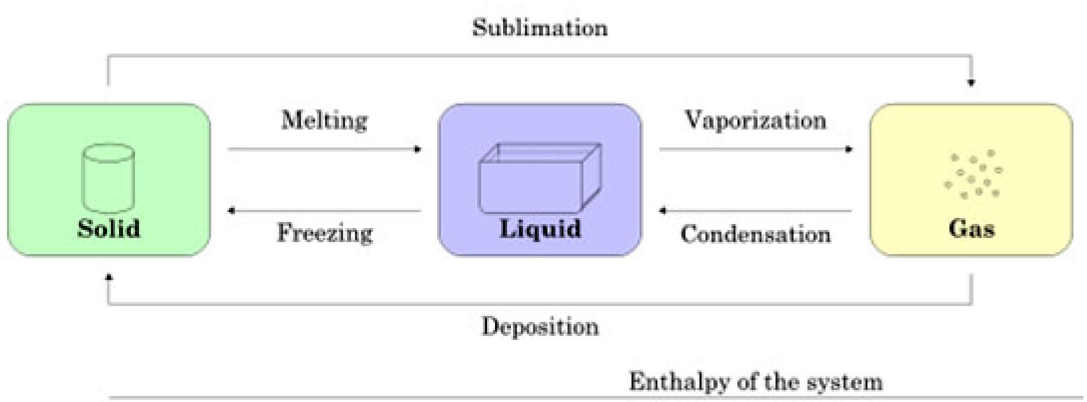

Figure 2. This diagram shows the phase transitions or changes that matter undergoes. [1] (ElfQrin, 2011. Copyright fee licensing under Creative Commons.)

A phase change diagram can be used to show the relationship between temperature and changes of states of matter. During a phase change, the temperature remains constant. [12] The temperature only changes after a substance has changed from one state to another. The temperature will increase or decrease depending on whether heat is being added or removed from the substance. Substances also absorb or release heat at different rates. For example, land absorbs and releases heat faster than water does. [12]

Effects of Temperature and Pressure [4, 10]

Both temperature and pressure affect the states of matter. In order to discuss what state a specific substances is in temperature and pressure must be specified. Most consider “normal” conditions to be room temperature (20 $^{\circ}$C) and an atmospheric pressure of 1 atm. [10] At normal conditions oxygen is a gas, motor oil is a liquid, and iron is a solid. [10] But materials can exist in different states depending on their temperature and pressure. For example, water can be observed in all three states of matter over the temperature range 0 ^{o}C to 100 ^{o}C at 1 atm pressure. [4]

Increasing pressure can liquefy many gases, even if the temperature is well above the normal boiling point. Increasing pressure causes gas molecules to move closer and closer together. When molecules get close enough, "their tendency to behave independently is overcome by the strength of the intermolecular attractions, and the gas condenses into the liquid state." [10] Butane is a gas at room temperature and 1 atm pressure, but if the pressure is increased butane can also exist as a liquid at room temperature. [10] Some lighters have clear cases that show butane in its liquid state inside the case. [10] When the value to the lighter is opened, the pressure is decreased, and butane comes out as a gas instead of a liquid. Propane is another example of a pressures effect on matter. Propane moves about in its container by when the valve is opened gas is released. [10]

Boyle's Law

The pressure-volume relationship of a gas is known as Boyle's law. [11] This law states that volume is inversely related to pressure at constant temperature and constant amount of gas. Therefore as volume increase, pressure decreases. Similarly, if the volume decreases, pressure increases.

Energy Changes

Energy changes accompany changes of states. The symbol ΔH represents the change in heat content that accompanies each phase transition, known as enthalpy. [10] A positive ΔH means that heat is added to the substance and heat is absorbed from the surroundings. Changes with a positive ΔH are endothermic. Changes in states that have a negative ΔH means that heat is lost from the substance and released to the surroundings. [10] These phase changes are exothermic.

Change of State	**Energy Change**	**ΔH**
Solid to liquid (fusion, melting)	Heat absorbed, endothermic	+
Liquid to solid (crystallization, freezing)	Heat released, exothermic	-
Liquid to gas (vaporization, evaporation)	Heat absorbed, endothermic	+
Gas to liquid (condensation)	Heat released, exothermic	-
Solid to gas (sublimation)	Heat absorbed, endothermic	+
Gas to solid (deposition)	Heat released, exothermic	-

Figure 3. Changes of state and accompanying energy changes. [10]

In order to change a liquid into a gas, energy must be added. This addition of energy is called the heat of vaporization, making it endothermic. [12] The reverse process is called condensation and it releases energy into the environment, making it exothermic. [12] This energy released is also known as the heat of condensation. The amount of heat transferred during the vaporization and condensation is exactly the same. The same is true for the heat of melting and freezing and the heat transfers in sublimation and deposition. [12]

Water requires a lot of energy to boil because water molecules have very strong forces of attraction. The hydrogen bones in water molecules cause water molecules to be highly attracted to one another. [12] These "forces must be overcome before water molecules can escape the gas phase" and become independent of the other water molecules. [12] This is also why a large amount of energy is released when steam condenses. [12] Often steam burns are more serious than hot water burns. [12]

Gibbs Free Energy

Gibbs free energy (ΔG) describes the energy associated with a chemical reaction that can be used to do work. The free energy of a system is the sum of its enthalpy (ΔH) plus the product of the temperature (Kelvin) and the entropy (ΔS) of the system. [11] Entropy (ΔS) is the measure of disorder in a system. Gas particles have random motion and therefore have high entropy values. Liquids have much lower entropies and solids even lower. Solutions have higher entropies than pure liquids because their particles are more separated and random. [11]

Gibbs free energy is a balance between enthalpy and entropy. That is, the enthalpy of melting is independent of temperature. The entropy is also independent of temperature, but since in Gibbs free energy equation $\Delta G = \Delta H - T\Delta S$, then the phase that has higher entropy will be the one that exists at higher temperature. [11] Alternatively, the one with lower entropy will be the one that exists at lower temperatures. Processes that have a -ΔG are spontaneous and process that have a +ΔG are non-spontaneous. [11] Matter will change spontaneously to minimize its free energy. One analogy for this is the fact that a ball on a rap will roll downward, thus decreasing its potential energy.

There is also a particular temperature where ΔH is equal to TΔS, and therefore there is no spontaneous tendency to go in either direction, and both phases would be in equilibrium indefinitely. [11]

Superheated and Supercooled Liquids

Superheated and supercooled liquids illustrate that water can exist at temperatures below 0 ^{o}C and above 100 ^{o}C. They are not the lowest energy state, but they still exist. They will spontaneously change phase when given the chance. [11]

Teaching Strategies

Marshmallow in a Syringe [10]

Students will use marshmallows to study the effect that changing pressure has on the volume of a gas. [10]

Materials [10]

140-mL syringe with end cap

mini-marshmallow

Procedure

Take the syringe apart. Place one mini-marshmallow in the syringe and replace the plunger, pushing it down until it just reaches the marshmallow. [10] Place the cap or your fingertip over the tip of the syringe. Pull the plunger and observe the marshmallow. Release the cap or your finger and then pull the syringe back to allow more air. [10] Place the cap or your fingertip back on the syringe tip. Push the plunger and observe the marshmallow. If desired, repeat this several times. Remove the end cap, pull the syringe apart, and remove the marshmallow. Observe the marshmallow.

Explanation

A gas will expand to fill its container. When the pressure inside the syringe is reduced, by pulling the plunger out, the volume of air trapped in the marshmallow expands and the volume of the marshmallow increases. [10] The marshmallow is filled with air. Under reduced pressure, the air expands to fill the container, or syringe, causing the marshmallow to increase in size. [10] When the plunger is pushed in the pressure is increased causing the volume of the marshmallow to contract because the volume is decreasing. After removing the marshmallow from the syringe, the marshmallow may appear smaller in size than a normal mini-marshmallow. [10] This is a result of air escaping from the marshmallow when the pressure is decreased. [10]

Moving Molecules [7]

Students conclude that temperature affects the rate of movement of molecules in liquids and gases. [10]

Materials

A clear glass beaker filled with hot water

A clear glass beaker filled with cold water

Food coloring

An eye dropper

Procedure [7, 10]

1. Fill the glass beakers with the same amount of water, one cold and one hot.
2. Put one drop of food coloring into both glasses as quickly as possible.
3. Ask students to watch what happens to the food coloring and record their observations

Explanation

The particles of liquids and gases are in constant motion. If you watch closely you will notice that the food coloring spreads faster throughout the hot water than in the cold. [7] The molecules in the hot water move at a faster rate because they have greater energy than those in the cold water. The molecules in the hot water spread the food coloring faster than the cold water molecules, which move slower. This type of movement is called diffusion. [7]

Tissue in a Cup [6, 10]

Students explore how you can keep a tissue dry underwater.

Materials [10]

Large clear container, 2/3 full with water.

Clear plastic cup

Tissue paper

Food coloring

Tape

Pushpin

Procedure [6, 10]

- Add several drops of food coloring to the container 2/3 full of water.
- Poke a hole in the bottom of a plastic up using a pushpin.
- Crush a piece of the tissue paper and stuff it inside the plastic cup. Use the tape to hold the tissue in place. (Note: Make sure it does not cover the hole in the bottom of the cup.)
- Ask students to predict what will happen with the cup is submerged opening down into the water.
- Place your finger firmly over the hole at the bottom of the cup. With the open side down push the cup into the into the container of water.
- Keeping your finger over the hold withdraw the plastic cup from the water.
- Take out the tissue paper and let students determine if the tissue is dry or wet and report their observations.
- Leaving your finger off the hold on the bottom of the cup, repeat Steps 3-7.
- Ask students to explain why the tissue paper stayed dry in the first example.

Explanation [6, 10]

Air is matter and it takes up space. Air is trapped in the cup when it is submerged with your finger over the bottom of the hole. [10] The air in the cup keeps the water out, so the tissue stays dry. [10] When the demonstration is repeated with the hole open air is pushed out of the cup through the hole as the water enters. Since air can escape, water fills the cup, and the tissue gets wet. [10]

Cross-Curricular Integration [10]

Discuss the historic use of the diving bell, which is another example of how air takes up space. The hollow diving bell was lowered into the water with the open end pointed down. [10] Air was trapped and passengers could use it to breathe when they worked underwater recovering sunken wreckage. [10]

Boiling Water in a Syringe [2, 10]

Water boils at 100°C right? Not always! Students will see a demonstration of water boiling at room temperature. [10]

Materials [10]

Water

250mL Beaker

Hot plate

Stopcock Syringe, without needle, 140-mL

Thermometer

Procedure [2]

1. Ensure the stopcock is open and fill the syringe with approximately 25 mL of the hot water.
2. Hold the syringe so that the stopcock is up and carefully adjust the volume of the syringe to remove any air bubbles.
3. Close the stopcock.
4. Pull back on the plunger and observe the water.
5. Eject the water from the syringe and repeat the activity with warm tap water.

Explanation [2, 10]

Every liquid boils at the temperature at which its vapor pressure equals the pressure above its surface. By decreasing the pressure inside the syringe, water will boil below 100°C. [2] When the plunger is originally pulled the air pressure in the syringe falls below the water's vapor pressure, causing the water to boil. If the plunger is held back long enough, the boiling slows and eventually stops. [2] As the water boils, the water vapor produced is pressurizing the area above it. The water will continue to boil until the pressure equals that of the vapor pressure or until there is no liquid left. [2]

Disappearing Air Freshener [10]

Students will discover how air freshener evaporates from a liquid gel to a gas. [10]

Materials [10]

1 solid air freshener

Balance

Procedure [10]

- Place a closed air freshener on the balance and record the mass.
- Leave the air freshener open and record its mass each day for 5 days.
- Have students graph their data and discuss observations.

Explanation

Air fresheners are made of a gel that contains carrageenan, water, and small amount of liquid fragrance. The solid air fresher undergoes slow evaporation, which allows the liquid fragrance to be released. [10]

Key Vocabulary Words

Key Vocabulary Words [8]

state

solid

liquid

gas

melting

evaporation

condensation

freezing

volume

density

boiling point

particle

atom

molecule

compound

chemical reaction

phase change

Essential Questions

Essential Questions [8]

1. How can matter have mass and volume?
2. What is the difference between physical and chemical properties?
3. What are the most common elements?
4. How can elements have different properties?
5. How small is an atom?

Essential Content/Concepts

Essential Content/Concepts [8]

1. Matter is anything that has mass and takes up space (volume).
2. All matter has both physical and chemical properties.
3. The basic building blocks of matter are called atoms and molecules. Elements are a substance that is made up of only one type of atom.
4. Elements are represented by a chemical symbol.
5. The smallest particle of element that has the properties of the element is called an atom.
6. Elements are only made up of one type of atom.
7. The atoms of different elements, such as hydrogen, oxygen, iron, and aluminum, have different properties.
8. Elements can combine (react) to form molecules such as water (H_2O).

Teacher Resources

Kahn, Sal. “States of Matter.” *Kahn Academy* . Accessed July 15, 2016. https://www.khanacademy.org/science/chemistry/states-of-matter-and-intermolecular-forces/states-of-matter/v/states-of-matter. This 20 minute tutorial video provides an introduction to the three states of matter.

NGSS Lead States. *Next Generation Science Standards: For States, By States -*

MS.Structure and Properties of Matter . Washington: The National Academies Press, 2013. http://www.nextgenscience.org/topic-arrangement/msstructure-and-properties-matter. Provides an overview of performance expectations, science and engineering practices, disciplinary core ideas, and crosscutting concepts.

Sarquis, Jerry, Hogue, Lynn, Sarquis, Mickey, and Linda Woodward. *Investigating Solids, Liquids, and Gases with Toys: States of Matter and Changes of State - Activities for Middle and High School Grades* . Middletown: Terrific Science Press, 1997. This book provides a variety of hands on investigations that allow students to explore matter and changes in state. Students can use inexpensive toys and household items to observe everyday scientific phenomenon.

Student Resources

Flocabulary. "States of Matter." *Flocabulary* . Accessed July 22, 2016. https://www.flocabulary.com/unit/states-of-matter/video/. This video on the states of matter can help middle school and high school students remember the difference between the states.

Flocabulary. "Three States of Matter." *Flocabulary* . Accessed July 22, 2016. https://www.flocabulary.com/unit/three-states-of-matter/video/. This video on the three states of matter can help upper elementary and middle school students remember the difference between the states.

PHET. "States of Matter." *University of Colorado Boulder* . Accessed July 4, 2016. https://phet.colorado.edu/en/simulation/states-of-matter. This interactive simulation allows students to watch molecules in a solid, liquid, or gas. Students can add or remove heat and watch the phase change. They can also change the temperature of volume of a container and see a pressure-temperature diagram, which allows them to compare forces between molecules.

PHET. "States of Matter: Basics. *" University of Colorado Boulder* . Accessed July 4, 2016. https://phet.colorado.edu/en/simulation/states-of-matter-basics. This interactive simulation allows students to heat, cool, and compress atoms and molecules and watch as they change between solid, liquid, and gas phases.

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[3] Goodstein, David . *States of Matter* . Mineola: Dover Publications, 2002.

[4] Idaho Public Television. "States of Matter: Facts." Idaho Public Television. Accessed June 22, 2016. http://idahoptv.org/sciencetrek/topics/matter/facts.cfm

[5] Kahn, Sal. "States of Matter." *Kahn Academy* . Accessed July 15, 2016. https://www.khanacademy.org/science/chemistry/states-of-matter-and-intermolecular-forces/states-of-matter/v/states-of-matter.

[6] Kaskel, A. *Principles of Science: Activity-Centered Program Teacher's Guide.* Columbus: Charles E Merril, 29-30.

[7] Membane, R and Rybolt, T. *Adventures with Atoms and Molecules.* Hillside: Enslow, 1985, 10-11.

[8] New Haven Public Schools. *7 th Grade Pacing Guide* . New Haven: New Haven Public Schools. Last modified November 12, 2007. http://www.newhavenscience.org/7curroverview.htm

[9] NGSS Lead States. *Next Generation Science Standards: For States, By States - MS.Structure and Properties of Matter* . Washington: The National Academies Press, 2013. http://www.nextgenscience.org/topic-arrangement/msstructure-and-properties-matter.

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Appendix A. Implementing District Standards

Connecticut Content Standards

Conceptual Theme

Properties of Matter – How does the structure of matter affect the properties and uses of materials? [8]

Content Standard [8]

6.1 - Materials can be classified as pure substances or mixtures, depending on their chemical and physical properties.

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

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

Grade-Level Concepts

Grade-Level Concept 1

Pure substances can be either elements or compounds, and they cannot be broken down by physical means. [8]

Grade-Level Concept 2

Mixtures are made of combinations of elements and/or compounds, and they can be separated by using a variety of physical means. [8]

CMT Expected Performance [12]

C 1. Describe the properties of common elements, such as oxygen, hydrogen, carbon, iron and aluminum.

C 2. Describe how the properties of simple compounds, such as water and table salt, are different from the properties of the elements of which they are made.

C 3. Explain how mixtures can be separated by using the properties of the substances from which they are made, such as particle size, density, solubility and boiling point.

C 7. Describe the effect of heating on the movement of molecules in solids, liquids, and gases.

Next Generation Science Standards [9]

Performance Expectations

MS-PS1-1. Develop models to describe atomic composition of simple molecules and extended structures. [9]

MS-PS1-3. Gather and make sense of information to describe that synthetic materials come from natural resources and impact society. [9]

MS-PS1-4. Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed. [9]