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Water and Life & Phase Changes of Water

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I teach Phy-Chem in an urban magnet high school. Phy-Chem is understood to be a freshmen general science class with an emphasis on physics and chemistry. The Phy-Chem curriculum covers approximately half of the state science framework learning objectives that will be assessed on the Connecticut Academic Performance Test (CAPT) of a student's sophomore year. This high school is a performing arts magnet school drawing students from within New Haven as well as the surrounding districts. There are approximately 650 students all of which are focused on an art for their four-year high school enrollment. We utilize a block schedule wherein classes are 85 minutes long and repeat every other day. This presents many challenges concerning homework and turn-around time for feedback on in class work because of the long gaps between class meetings. Conversely it does allow for long class periods that lend themselves to activities that utilize multiple modalities.

The challenge in teaching and assessing the concept of phase change revolves around the difficulty of explanation. Phase change, although something one can witness in its gross form, perhaps as ice melting, involves many factors that cannot be seen and must be conceptualized. There is in inherent difficulty teaching students about something that which they cannot see. For example the energy that is being absorbed or released by matter. Consider science instruction, using evidence of the phenomenon to validate that it is occurring. On the surface level the reason for why ice melts is very straightforward, water will transition from a solid state to a liquid state as its temperature rises above zero. The difficulty resides in teaching students to be able to explain why this happens at the molecular level.

For one to effectively teach about the phase changes of water I believe it is necessary to first understand the need for teaching students understanding. One needs to consider the over whelming evidence of the importance of understanding over the memorization of facts. Understanding a concept allows one to apply their understandings to other situations impacting their ability to learn new concepts. Taking the approach that understanding is the goal of teaching a teacher can revisit their teaching methods and adjust them with that goal in mind. Assessing understanding can be difficult because it does not always lend itself to the typical assessment task such as a paper and pencil test. Different methods of assessment will be discussed.

Following the rationale behind teaching for understanding, will be the content needed to deliver effective instruction to meet the learning outcome of understanding the connection of water to life on Earth and the phase changes of water. This section will include a discussion about matter, intermolecular bonds, phases of matter, water and the emergent properties thereof, energy, molecular movement, and phase change.

Relevance of Teaching for Understanding

Teaching for understanding is about the pursuit of science literacy for our students. This is embedded in critical literacy. A scientifically literate person is perceptive about the world around them and also empowered to make decisions. If you consider that education has the broad purpose of producing an educated populous to govern and lead a country the need to pursue scientific literacy is apparent and urgent. Our students cannot be effective stewards of this planet if they do not have to the tools to engage with the knowledge that is available to them. They must be able to think critically about the issues that shape our planet, such as climate change, disease, and technology to name a few.

Maria Grant and Diane Lapp offer four actions to foster critical thinking in the classroom (Grant & Lapp, Teaching Science Literacy, 2011). Grant and Lapp argue that teachers must identify science topics of interest, engage students in reading the research, teach students to read like scientists, and guide learners to evaluate data.

Teaching Through Topics of Interest

Teaching through topics of interest is about captivating students' attention by delivering necessary standards through application of those standards within the context of a relevant issue. If students are interested in the issue the relevance of the content and skills associated with understanding the issue are important to the student. Increased interest in a topic will inherently interest classroom engagement. Often we struggle with students that think that science has nothing to do with their everyday lives when the truth is there are connections with almost everything. We are also confronted with students that feel as if science involves some sort of unobtainable un-accessible skill set, when the truth couldn't be further from this belief. Science is merely the pursuit of answers, driven by curiosity or necessity. The problem for our students is that the skills to effectively discover answers are skills that need to be directly taught. These skills can seem daunting but the trepidation that students have can be overcome when they realize that the skills used allow them to answer the questions that they have.

This unit will discuss the emergent properties of water. If such content is taught as an isolated phenomenon it is merely a list of facts. Conversely to work towards the goal of teaching scientific literacy one can deliver the content from the angle that water is essential to life. It is likely common knowledge for students that water is essential, but when probed for reasons why our high school freshmen only have cursory reasons such as we will dehydrate without it. Teaching students about the unique properties of water and how these properties allow for life helps to engage them in the learning process. A student will must be able to understand the actions and interactions of molecules to understand the emergent properties of water. They are then able to apply that understanding to the bigger question of why water is essential to life.

Engaging Students in the Research

Students require a base of knowledge to understand a concept effectively. It is important that students understand that research is always necessary to understand a concept. The issue is that science textbooks, and of course journal articles, are laden with vocabulary that our students are not normally exposed to. The vocabulary is often content specific and cannot be unmarried from the literature if descriptions are going to be left intact and complete. The necessary texts are flush with “multisyllabic words and sentences that require extensive background knowledge.” (Grant & Lapp, Teaching Science Literacy, 2011) We must be conscious of the barrier vocabulary may present and utilize appropriate level texts while teaching students how approach a reading that has new words. We must also take into consideration the amount of new words needed to understand a concept and keep it to a manageable level. Using articles focused on relevant ideas is helpful because students will want to understand the new words.

Students Reading Like Scientists

It is not enough to just offer or assign readings. To help students become scientifically literate we must instruct them on how to read like a scientist. If a student is to be learning while reading a science textbook they must know that thinking while reading is key. Direct instruction may be necessary for our students wherein the teacher can model the method. If a scientist is reading a text he/she is constantly trying to connect the new information with previous information. He/she is also trying to understand every graph, image, or table by using clues in the images and text. Furthermore, he/she will check for understanding by forming statements and arguments in thought.

Evaluating Data

Generating conclusions is pivotal to science and students need help understanding what a conclusion in science is. Nuanced within the formation of a conclusion is the correct evaluation of data. Scientific study offers seemingly endless ways to label and quantify data. It is important that teachers do not overlook all the labels and units that may be relevant to data that we use during lessons. In order for our students to make accurate conclusions they need to understand the meaning and relevance of the data presented. For example many of my freshmen struggle with the concept of concentration or that of rate. I find that I have to intentionally teach what I assume is background knowledge, but if not addressed their ability to formulate an accurate conclusion is hampered.

Background Content

Matter

Matter is anything that takes up space and has a resting mass. Matter is ultimately made up of atoms. Either an assemblage atoms or ions of a single element or atoms of different elements bonded into molecules. From this point on we will discuss that which makes up matter as particles, whether they be atoms or molecules. The bonds between and among these particles will be referred to as intermolecular bonds. These bonds may be covalent or ionic. Sometimes the bonds are even weaker and are referred to as just intermolecular forces. The intermolecular force that holds water together as a solid or liquid is due to hydrogen bonding between adjacent molecules. The slightly positively charged hydrogen atom of a water molecule is attracted to the slightly negatively charged oxygen of an adjacent water molecule. More about this will be discussed later as we consider the unique structure of the water molecule, the fact that is polar, and how this results in some amazing properties.

Students will most readily identify any solid as matter. The definition will become more difficult to accept and apply when considering gases, liquids, and especially living organisms. Essentially, by definition the students themselves are matter. Luckily though, when teaching about matter we stick with a very concrete substance called water. Water is a great example for teaching about matter and phase changes for many reasons. Water is easily accessible of course, but consider also that the three main phases of interest, solid, liquid, and gas, are normal states for water on this planet. Students will have experience water in all three phases many times throughout their lives. There are not many substances that have three phases in such a perfect temperature range such that they exist naturally. Water is thus the ideal matter to use when discussing phase and phase change considering also the fact that water is crucial to life. This allows the teacher the opportunity to have a much larger discussion about why water is so crucial to life.

Phases of Matter

Matter may exist in five different phases as a result of the energy of the particles that make up the matter. The phases that are necessary to focus on are solid, liquid, and gas. The other two phases are plasma and Bose-Einstein condensate. Neither of these two states is necessary to discuss in a freshman level science class. The big idea here is that students gain and apply a conceptual understanding of matter and what causes phase change. Solids, liquids, and gases differ among each other by amount of energy that the particles have and the resulting impact this has on the attractive forces between particles within the matter. The amount of energy that the particles have will consequently impact their amount of movement. Simply put, as the amount of energy that any given particle has increases, the movement of that particle increases as well as its ability to overcome attractive forces from other particles.

Solids

Solid, the state of matter wherein the energy needed to overcome intermolecular forces or bonds is greater than the energy of the individual particles. Solids exist when molecules are attracted to each other and do not have sufficient energy to overcome that force of attraction. This results in the properties characteristic of a solid, the fixed shape and relatively high density. Although water is an exception, the solid state of any given matter is denser than the liquid state and gaseous state. With water the solid state is slightly less dense the liquid state, a phenomenon that will be addressed later in this unit. The particles that make up a solid are “locked” in place by the bonds among them, thus the fixed shape of a solid.

There are two types of solids, crystalline and amorphous. Crystalline solids are made up of particles that have a highly regular arrangement, that is to say that there is order to the arrangement. This order is called a crystalline lattice and it is made of smaller units called cell units. A cell unit is the smallest repeating unit of the lattice. Imagine if you had 1 cm cubes and you arranged those cubes into a 10cm cube. The 1cm cubes would be the cell units and the 10cm cube would be the lattice. The crystalline structure will be further discussed, but first amorphous solids will be considered.

Amorphous solids are solids whose particles have no order. The structure is referred as being disordered. The most common example of an amorphous solid is glass. Glass is produced by melting sand. Other elements may be added to acquire different characteristics like color or to increase the melting temperature. Lead can be added to make the glass easier to cut, for example lead crystal. Considering the disorder of the particles in an amorphous solid some argue that these solids can be classified as liquids. Though this argument is beyond the scope of this unit, it is useful to consider because of the frequency that a student will state that glass is a liquid. Lastly, a normally crystalline solid, ice, can be produced as an amorphous solid. If liquid water is frozen fast enough the particles do not have time to arrange themselves into the crystalline lattice structure and an amorphous solid will be produced.

Crystalline solids, that which water normally produces, are of more importance to this unit. Crystalline solids fall into three categories, molecular, ionic, and atomic solids. Atomic solids can be further categorized by the nature of the bonds that occur between the points of the cell units.

Molecular crystalline solids are typified by the presence of a discrete molecule at the point of each cell unit and inherently the lattice points as well. They are held together by weak intermolecular forces. If the molecules are non-polar dispersion forces hold them together. With polar molecules it is the dipole-dipole interaction that holds the crystal together. In the case of water, hydrogen bonds are the relatively weak force that allows ice to have a solid form. No matter the composition of a molecular solid the intermolecular forces are weak resulting in a low melting point. Molecular crystalline solids also lack ions and are thus poor electrical conductors.

Ionic crystalline solids are composed of ions bound together by their opposite electric charges. Ions are thus present at the lattice points. This bond is stronger than that of the molecular crystalline solids but not as strong as the covalent bonds found within atomic solids. Ionic crystals may be composed of monatomic ions, polyatomic ions, or a combination of the two. This mix of anions, negatively charged ions, and cations, positively charged ions, creates a solid that is brittle, hard, and has a high melting point. Electrical conduction is not present in the solid state but is strong when in aqueous solution or molten state. Commonly these crystals are composed of Group 1 or 2 metals combined with Group 16 or 17 nonmetals or a nonmetallic polyatomic ion. The typical class room example is sodium chloride ($NaCl$). The sodium is a Group 1 metal and the chloride is a Group 17 nonmetal. This crystal is formed in a 1:1 ratio of sodium cations and chloride anions. You can see the crystalline structure with even the most basic of classroom microscopes.

Atomic crystals are solids defined by atoms at their lattice points. They fall into three categories, two of which have strong, covalent, bonds that bind them together and the third which is bonded by London dispersal forces. The third type are the crystals formed by Group 8A elements, they have extremely low melting points and are thus not appropriate for the high school classroom. The two covalently bonded atomic crystals are metallic solids and network solids. Metallic solids are composed of metal cations surrounded by loose valence electrons. These electrons are not permanently associated with any given atom but are free to travel. Metallic solids are very effective electrical conductors for this reason. The bonding that occurs because of this structure is called delocalized covalent bonding because of the “free” nature of the valence electrons. An interesting property of some metallic solids is ductility, the ability to stretch into a wire and malleability, capable of being shaped or formed. Copper is a readily available classroom example. The malleable nature and electrical conductivity can be easily demonstrated by students. Network solids have directional covalent bonds between the nonmetal atoms at the lattice points. Because of the directional nature they form large molecules and are thus relatively hard but brittle. The lack of ions in these crystals results in poor electrical conductivity. A classroom example is solids formed from carbon such as diamond or graphite.

Consider modeling solids with students in the classroom by having them attempt to arrange themselves as both a crystalline solid with an organized structure and an amorphous solid with a disorganized arrangement. This will help students to form conceptual images of the two types of solids as they are forced to apply the rules that define each type of solid. With a crystalline solid they should arrange themselves so that they equal spaced from each other and in a fixed position. With an amorphous solid they should be randomly spaced and in fixed position. You can discuss the different types of bonds that will be present among them.

Liquids

When matter is in a liquid state the molecules are in constant motion, are closely associated with each other, and are constantly forming and breaking bonds between molecules. In the case of water these bonds are hydrogen bonds between the slightly negative oxygen of one molecule and the slightly positive hydrogen of an adjacent molecule. This is due to water's polar nature and these bonds are breaking and forming trillions of times per second. The constant motion of molecules in a liquid, tempered with the attractive forces between molecules results in the properties of liquids. Liquids have low compressibility due to their high density, though molecules are in constant motion they are closely associated with each other because or intermolecular forces. This close association leaves little room for empty space, thus the low compressibility and high density. Liquids also lack rigidity and will take the shape of the container that they are placed in. This low rigidity of structure is again due to the movement of the molecules that make up the matter and lack of lasting bonds between molecules. Students will have a better understanding of why a liquid acts the way the way that it does if they have a conceptual understanding of what the molecules that make up the liquid are doing.

Surface tension is another property of liquids and can be demonstrated easily in the classroom. Surface tension is the liquids resistance to increase surface area due to the intermolecular forces. This helps to explain what water will form droplets when dripped from a pipette or bead up on a waxed surface. Water will form a spherical droplet because the water molecules are attracted to other water molecules. Conceptually one can imagine that the molecules have a high affinity for each other and no affinity for the surrounding environment. This affinity will result in the shape with smallest surface area, a sphere. Consider the example of how fish, such as sardines, will school in the open ocean.

Gases

Matter in a gaseous state has no definite volume or shape because the particles that make up the gas have enough energy to overcome the attractive forces between particles. Gases have high compressibility because of the open space between particles. In fact, unless contained, a gas will in theory expand infinitely because the particles are free to move. In the classroom an easy example to help students conceptualize a gas is to light a scented candle in one corner of the room. Eventually the gaseous molecules responsible for the scent will find their way to all corners of the room.

Phases

Ultimately it is important that students can appropriately differentiate the states of matter. Differentiation is the result of the intermolecular bonds and particle energy. If a student has a strong working concept of the three states they can begin to understand why shifts between states occur as energy thresholds are met. As students develop their understanding of phase change their ability to apply this understanding increases resulting in a better understanding of the natural world.

Phase Change

A phase change occurs when the particles that make up matter make a transition from one phase to another. Phase change can be explained by discussing particle movement, energy, and intermolecular forces. With water these phase changes happen at 0˚C and 100˚C. Solid water, or ice, must first be heated to 0˚C to melt into a liquid if pressure is held constant at 1 atm. Pressure will be discussed as factor in phase change, but for discussion purposes here after a constant pressure of 1 atm is assumed.

Evaporation and Condensation

The transition of a molecule from the liquid state to the gas state is evaporation or vaporization, conversely condensation is the transition from a gas to a liquid. Molecules in the gas state have higher energy than molecules in the liquid state, this is a fact that students will have memorized. Their understanding of this phenomenon is elicited through the explanation of why the transition occurs. Liquids normally have a vapor pressure, a propensity for molecules within the liquid to escape as gas. This vapor pressure is affected by the temperature of the liquid. If heat is added to a liquid, the kinetic energy of the molecules increases due to the absorption of heat energy. As kinetic energy increases for a molecule, that molecules ability to overcome intermolecular forces increase. This is an endothermic process because energy is being absorbed by the liquid. Thus an increase in temperature correlates with an increase in vapor pressure for liquids. Students can understand the process of evaporation if they understand that molecules have energy and are moving, and that any given molecule in a liquid needs only to have enough energy to overcome the attraction that exists between the molecule and other molecules in the liquid. This is why it is important to work with students to create models to exemplify the states of matter and then apply that understanding to phase change. State transitions in the opposite direction of vaporization require the loss of energy and are thus exothermic. If a gas loses energy it will condense into a liquid. The molecule no longer has the necessary energy to overcome attractive forces of other molecules.

Melting and Solidification

The transition of matter from a solid to a liquid or the reverse can also due to energy. To melt matter enough heat has to be absorbed by the molecules to break free from a fixed position and move about. The molecules do not have enough energy to escape completely and will continue to form and break intermolecular bonds. Solidification occurs when sufficient energy is lost preventing the molecules to move, they are then held in a fixed position as a solid.

Pressure

It is important to introduce the concept of pressure when discussing phase transitions. With the application or removal of pressure the temperature at which a phase change occurs can be manipulated. More specifically the energy threshold of a molecule to change phase can be changed. If a liquid is subjected to increased pressure the amount of energy required for molecules to change phase increases because they are combatting a force that is restricting their movement. The opposite is also true, if a liquid is exposed to conditions of reduced pressure the molecules can more readily escape the intermolecular forces and will vaporize at a lower temperature.

Real World Application

Geysers are an effective classroom example. These are explosions of ground water due to the increase of pressure that matter (water) exhibits as it is heated. Ground water is heated by magma causing it to expand and rise. The increased pressure on this water below the earth increases the energy requirement for the water to transition to a gas. As the water continues to rise, because of expansion due to phase transition, the pressure on that water continues to decrease as the amount of earth above it decreases. As the water approaches the surface there is a rapid transition to the gas state resulting in a rapid expansion due to vaporization. This water then explodes from the ground as a geyser.

Water

Fundamental understandings of phase and phase change are important in the pursuit of the bigger understanding of the importance of the properties of water. Water is so ubiquitous that it is often overlooked in the class room and is too often overlooked. Water has properties that help to explain why it is paramount to life on Earth. Connecting the concepts of phase will help students to form connections between the properties of water and its connection to life.

Water has four properties, known as emergent properties, these properties are due to the polar nature of the water molecule. Water consists of two hydrogens and one oxygen covalently bonded in a "V" shape with oxygen at the apex. The oxygen is more electronegative than the hydrogens and the electrons of the hydrogens spend more time closer to the oxygen. This results in a polar molecule wherein the oxygen has a slightly negative charge and the hydrogens a slightly positive charge. This polarity allows water molecules to interact with each forming weak hydrogen bonds between two opposite charges of adjacent molecules. Through this polarity and resulting hydrogen bonding water has four important properties: cohesive behavior, ability to moderate temperature, expansion upon freezing, and versatility as a solvent.

Cohesion

How does a tree transport water against the force of gravity? Cohesion is the attractive force between two like molecules, simply put water sticks to water. This is because water is a polar molecule allowing for interactions of opposing charges when surrounded by other water molecules. Adhesion is the attraction of water to other surfaces that have charged particles. These properties allow terrestrial plants to transport water throughout their structures through specialized networks of water conducting cells. Contained within the water are vital nutrients and minerals as well.

Cohesion and adhesion can be demonstrated in the classroom with capillary tubing. This is thin glass tubing that will draw water up, against gravity. The polar water molecules will interact with ions in the glass, bonding with the glass. The water that is bonding with the glass will also continue to be bonded with other water molecules. As molecules are attracted higher and higher up the tube they will drag behind them more water. This is how water is transported within a plant. The water is drawn into the roots of the plant and then moves upward, carrying with it dissolved nutrients. This upward movement is caused by the adhesive nature of the water. Water will continue to move up the plant, terminating at the surface of leaves. As water evaporates out of the plants leaves this opens up a new space for water to occupy and the column of water moves up to fill the void.

Moderation of Temperature

Why does our planet have such a relatively constant temperature? Water has a high specific heat. It takes one calorie of energy to raise 1 gram of water by 1˚C. Conversely as water cools, a calorie is lost for every gram of water that drops 1˚C in temperature. Water is held together by its hydrogen bonds, though weak in comparison to a covalent bond, they still require significant energy to overcome. This allows water to absorb heat without changing temperature rapidly in comparison to many other liquids. Heat is a measure of kinetic energy, a given volume of water's total heat is a measure of its total kinetic energy. Temperature is a measure of the average kinetic energy of the molecules that make up the matter. Thus it is important to note that heat and temperature are not interchangeable. Students can struggle with this concept, it may help to have them consider that a boiling cup of water has a higher temperature than a swimming pool, but the swimming pool has more heat.

Earth's temperature is relatively constant because of the water that covers 70% of its surface. This water absorbs heat during the day and summertime and releases this heat slowly at night and during winter months. The resistance of water to rapid temperature changes allows it to absorb and release massive amounts of heat while maintaining a relatively stable temperature. This has allowed for the persistence of life in our oceans as well because flora and fauna are subjected to major temperature swings.

Most organisms are primarily water by mass. Considering the high specific heat of water one can realize that this allows organisms to avoid rapid temperature changes due to environmental conditions. Furthermore, many organisms utilize evaporative cooling. In the same note that it takes an energy investment to increase the temperature of water, recall that it also requires an energy investment to cause a phase transition of water from liquid to gas. Water on the surface of an organism will absorb heat from the body as well as the surroundings and evaporate taking with it the energy. The net effect is that the molecules left behind have less energy. This is a repetitive process that helps organism to maintain their temperature by essentially passing excess energy to water molecules to cause evaporation. This process of evaporative cooling also aids lakes and ponds in maintaining their temperature.

Expansion Upon Freezing

Very few substances are less dense as a solid than a liquid, water is one of them. Ice is about 10% less dense than liquid water causing it to float. This is due to the crystalline lattice structure formed when water freezes. Because of the polar nature of the water molecule and its "V" shape it is arranged in a crystal that has spaces when solid. This ice creates an insulating layer over lakes and ponds in the winter months. The ice allows liquid water to persist below it, a necessary medium for the flora and fauna to persist. If ice were denser than water our lakes and ponds would freeze from the bottom up completely changing the survival strategy of organisms.

This property of expansion upon freezing also helps to shape our planet. As water seeps into crevices and cracks of rocks and is then caused to freeze and expand it widens those openings. Over time this property contributes to the weathering and erosion of rocks. Not to mention the creation of obnoxious pot holes on our roads.

Versatile Solvent

The polarity of water causes it to dissolve substances that are polar, ionic, or have polar or ionic regions in their molecules. This allows for water to be a wonderful biological medium in cells. Dissolving many substances readily makes for easy transportation of substances within cells and between cells.

Activities

Cohesive Nature of Water

This is a modeling activity. You want to begin by discussing and drawing the water molecule. Noting and labeling the polar nature of the molecule. The two hydrogens are bonded to the oxygen in the middle at an angle of 104˚. The hydrogen end has a slight positive charge and the oxygen end has a slight negative charge. This occurs because the oxygen is more electronegative and is able to pull the electrons shared in each of two covalent bonds with the hydrogens closer to itself. These electrons being more closely associated with the oxygen thus results in the oxygen having a slightly negative charge the polarity of the molecule. Students should not that opposites attract and adjacent water molecules will bond to each other via the slight negative charge of one end and the slight positively charged hydrogen of another molecule. Because of the bond angle within water this can result in a very complex three dimensional bond structure in ice called the crystalline lattice. Once the students have an understanding of how water molecules bond to each other you want to have them apply this to situations.

You can have the students apply their understanding of how water bonds to water with a simple activity involving a penny and a pipette or dropper. Have the students place the penny on the lab bench and begin adding water to the penny one drop at a time. Instruct them stop once a bubble is formed. Up to 40 drops of water may accumulate, creating a convex shape, like a dome. The students then have to determine how the dome shape is achieved by the water. This is because the water drops have a higher affinity for each other than other surfaces. The attractive force of other water molecules keeps the molecules stuck together despite the force of gravity and the attractive forces of surrounding materials. Instruct the students to draw what they think the molecules of water look like and how they must be arranged.

Cohesive and adhesive behavior can also be modeled in the hallways and stairwells of the building. With each student acting as water molecule you begin at the bottom the stairs. A student climbs the stairs with one hand on the hand rail and the other holding the shirt of another student behind them. Their hands represent hydrogen atoms and their bodies are oxygen atoms. This patter can be repeated. As they climb the stairs in a sort of chain they are modeling the movement of water through a plant, against the opposing force of gravity. The adhesive and cohesive attractive forces are greater than that of the pull of gravity.

Phase Change of Water and the Energy Involved

This is a demonstration to be done in front of the class. The main demonstration will show the rapid condensation of water vapor to liquid and the resulting contraction of volume. This requires a 1000ml Erlenmeyer flask with a neck spout, a 2’ vinyl hose of 3/8” ID, and a rubber stopper for the flask. Add about 200ml of water to the flask, attach the hose to the neck and insert the rubber stopper on top of the flask. Place the flask onto a hot plate and heat until boiling. The other end of hose must be submerged in a second vessel of cold water. As the water boils the resulting water vapor will expand, the only path available will be through the hose resulting in bubbling of the second container. Allow the water boil for a minute and then turn off the heat and remove the flask from the heat, place it on the lab bench. As the flask and water cools it will draw cold water back up the hose from the second vessel. As soon as the cold water reaches the hot flask it will rapidly cool the hot flask causing the water vapor to condense immediately. This will in turn suck the remaining cold water up the hose in an explosive manner.

While doing this demonstration students will discuss in pairs what is happening with energy, phase change, and molecular movement. You will want them to identify where energy is being added and what that energy is doing to the liquid water. They will be able to observe that the boiling water is the phase change of water to a gas that requires more volume. They may first mistake the bubbles in the second cold vessel as boiling. This is not boiling, it is merely the gas escaping the hot flask through the only path allowed. You will want them to identify what is happening with energy when the cold water reaches the hot flask. At this point energy is being absorbed by the cold water. This energy is coming from the water vapor, causing this water vapor to condense to a liquid. You may want to add red food coloring to the hot flask and blue to the cold.

Super Cooling Water

It is possible to cool liquid water below freezing and let it remain as a liquid. This phenomenon is possible with readily available 1L bottles of spring water. Lay an unopened bottle of water in the freezer for 45 minutes. Remove the bottle and gently take off the cap. Be careful not to shake the bottle as you may cause it to phase change to ice. After you have removed the cap, pour the water onto a piece of ice and it will instantly phase change to ice. You may have to experiment with different freeze times depending on the temperature and type of freezer that you have.

Resources

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Implementing State Standards

Connecticut Grade 9 Content Standards

D1 - Describe the effects of adding energy to matter in terms of the motion of atoms and molecules, and the resulting phase changes.

D2 - Explain how energy is transferred by conduction, convection and radiation.

D10 - Describe the general structure of the atom, and explain how the properties of the first 20 elements in the Periodic Table are related to their atomic structures.

D11 - Describe how atoms combine to form new substances by transferring electrons (ionic bonding) or sharing electrons (covalent bonding).

D20 - Explain how solar energy causes water to cycle through the major earth reservoirs.