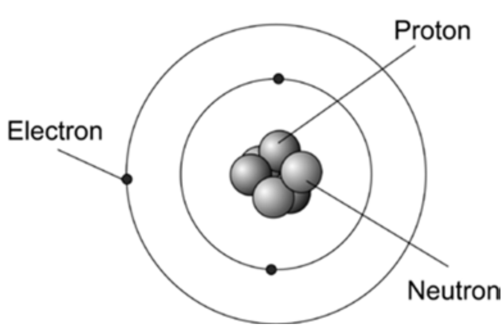
Getting to the Core

Chemistry Unit of Study

Student Resources

Structure and Properties of Matter



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SAUSD Common Core High School Chemistry Unit – Matter

Contents:

Big Idea- Forces within particles hold matter together: Substances with different bulk properties undergo phase transformations that result in changes to the attractive forcers between the particles.

States of Matter and Forces of Attraction

Extended Anticipatory Guide Day 1/ Day 13

Question	Day 1		Day 13		Day 13
	Agree	Disagree	Support	No Support	Evidence from the text: Explain using your own words
1. Surface tension is an incredibly strong force that holds molecules of water together.					
2. The three different states of matter are different on an elemental level (have different types of elements and/or number of atoms).					
3. A single molecule of water, H_2O, is held together by intermolecular and intramolecular forces.					
4. Water melts and freezes at the same temperature.					
5. The temperature of water changes when it goes through a phase change.					

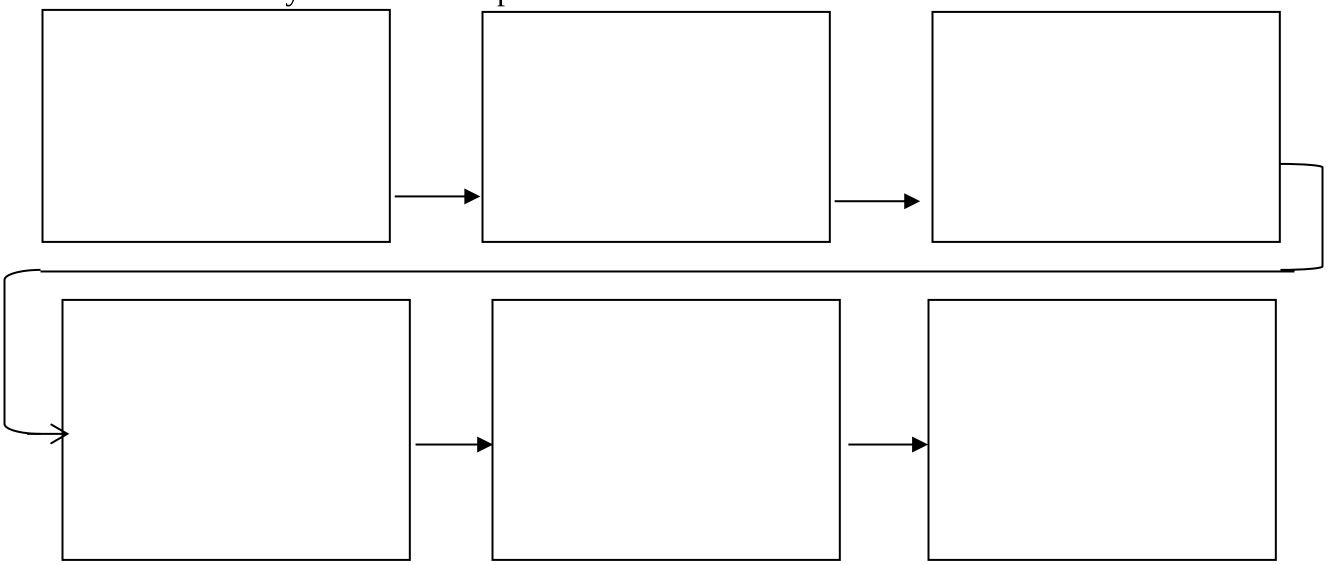
Question	Day 1		Day 13		Evidence from the text: Explain using your own words
	Agree	Disagree	Support	No Support	
6. As water transforms from a solid to a gas, the individual molecules move closer together.					
7. Intermolecular forces of attraction in order from strongest to weakest are: Hydrogen bonds, London-Dispersion forces, and Ionic/Covalent bonds.					
8. When graphing a heating curve of a substance, the graph is flat during a phase change.					
9. As a substance absorbs heat, the intermolecular forces between molecules weaken due to a decrease in kinetic energy.					
10. Intra-molecular bonds (between molecules) are weaker than inter-molecular bonds (between atoms of a single molecule).					

Name________________________

Penny Drop Lab

Question: How many drops of water can you get to fit onto the "heads up" side of a penny?

Directions: Create a flow chart from the instructions your teacher gives you on how to complete the penny drop lab. Remember this procedure should be clear enough for a non-chemistry student to complete the lab.



Hypothesis: I think the____
because ____

Trial #	Number of Drops of Water
1	
2	
3	
Average	

Conclusion & Analysis Paragraph. Three sentences minimum. (1) Support or reject your initial hypothesis; (2) compare your data to your hypothesis (use data numbers to prove your point); (3) suggest a reason for your observations.

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Penny Drop Lab Re-Design

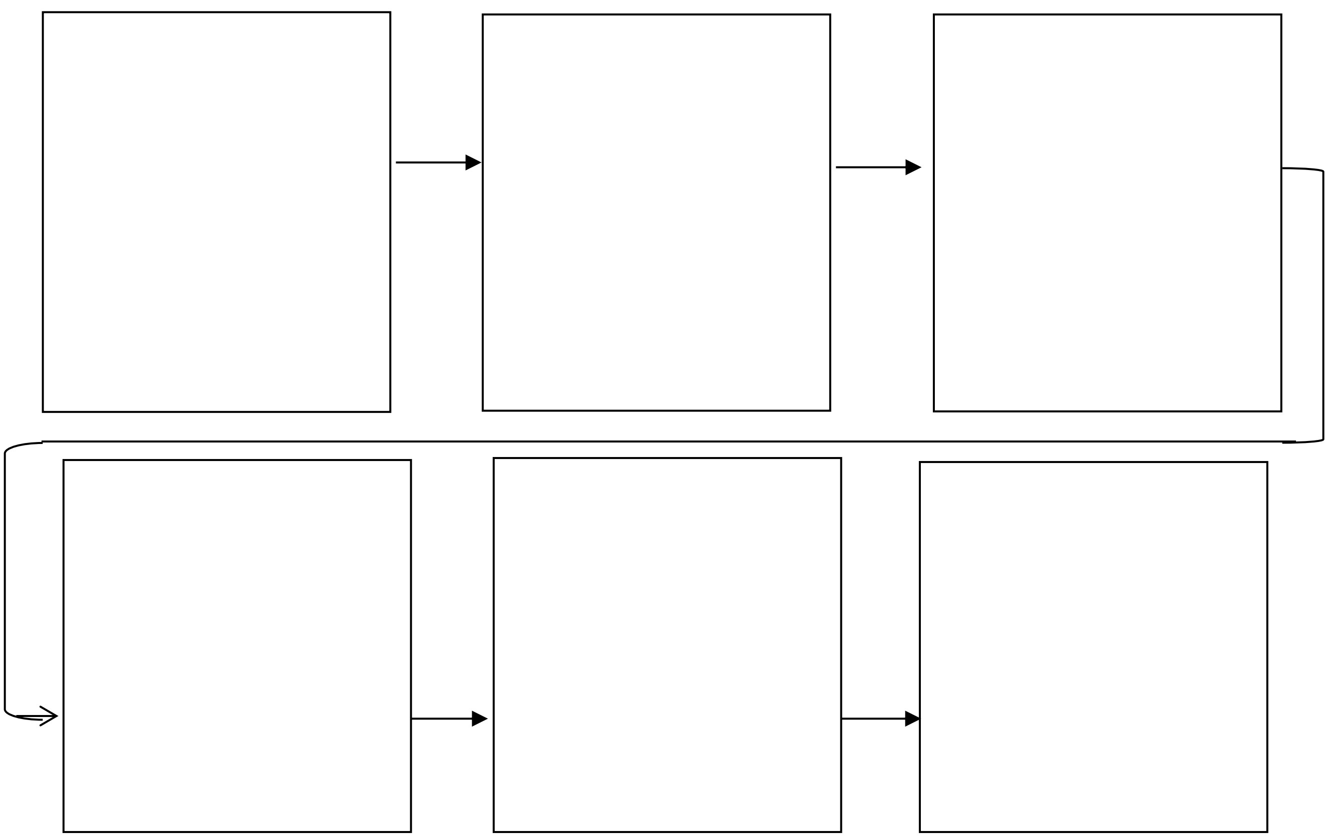
Background: Cohesion is when water molecules are attracted to other water molecules. The oxygen end of water has a negative charge and the hydrogen end has a positive charge. The hydrogens of one water molecule are attracted to the oxygen from other water molecules. This attractive force is what gives water its cohesive properties.

Surface tension refers to water's ability to "stick to itself". Surface tension is the name we give to the cohesion of water molecules at the surface of a body of water. The cohesion of water molecules forms a surface "film" or "skin." Some substances may reduce the cohesive force of water, which will reduce the strength of the surface "skin" of the water.

Challenge: Re-design the penny drop lab with your team to see how soap (or another liquid-check with your teacher) will affect the surface tension of water. Make a hypothesis before you begin to explain your prediction.

Hypothesis: I think ____
because ____
____

Directions: There are many different ways you can set up this lab. Agree upon your procedure with your lab team. Complete the flow chart using words and/or pictures explain each step you will need to follow to complete the penny drop re-design. Make sure your procedure is clear and could be followed by anyone, not just a chemistry student. Add more boxes if necessary.



Add your own titles to the data table below based on your team's experiment. You may not need all the columns.

Trial #		
1		
2		
3		
Average		

Post Lab: Conclusion & Analysis Paragraph FIVE sentences minimum. (1) Reference your initial hypothesis about the amount of water you can get onto a penny—support or reject your hypothesis; (2) compare your data to that prediction; (3) compare regular water to soapy water data; (4) using the background information, explain what factor influenced the results; (5) how did surface tension change with your redesign?

If time permits: Extension Activity

What if the experimental question was "How does sugar affect the surface tension of water?" Describe how you would answer this question using the scientific method. If you have time, you can test this or another liquid.

What is it? Non-Newtonian Substances

Pre-Video Questions

1. Describe two characteristics of a solid.
   -
   -
2. Describe two characteristics of a liquid.
   -
   -

Discuss with your partner. Add any additional properties your partner may have included that you did not think of.

Post-Video Questions

1. What are four characteristics of the substance shown in this video clip?
   -
   -
   -
   -
2. Using your reasoning, what state of matter is the "slime" featured in this video clip? If you cannot decide, explain why you are undecided.
3. Jell-O is another substance like slime. What are two other substances that aren't easily classified as a solid or liquid?

   -
   -

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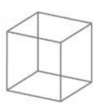
Day 3/Day 4 Extended Anticipatory Guide

	Day 3 **Hypothesis**	Day 4 **Findings**	Day 4 **Support with Evidence**
	Using a circle to represent an individual molecule, draw the molecules to represent each state of matter. Add arrows to show if the molecules move.	Using a circle to represent an individual molecule, draw the molecules to represent each state of matter. Add arrows to show if the molecules move.	Explain your molecular structure using <u>your own words</u>.
Solid 			
Liquid 			
Gas 			

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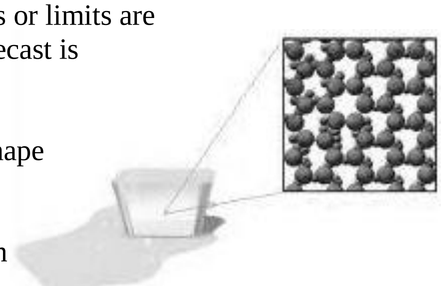
Zooming in on States of Matter

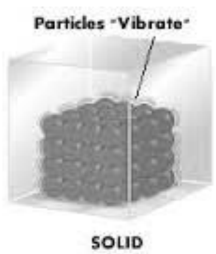
1. What makes a gas different from a liquid or solid? Why are some substances gases at room temperature, while others are not?

2. Solids, liquids, and gases are three states of matter. The fourth state of matter is called plasma (a man-made version is found in a plasma TV, but we'll save that topic for later). The following definitions will help you to identify a substance's state of matter and to describe the changes from one state to another.

3. Before you being, make sure you know the following terms. "Definite" means a clearly defined or unchanging set of limits. For example, the sun will always rise in the East. This happens every day without fail. "Indefinite" means just the opposite where properties or limits are flexible, uncertain, and changeable. For example, the weather forecast is indefinite.



4. *Solids* have a definite shape and volume. True solids keep their shape and take up a definite volume for a given amount of mass. The particles are packed closely together in solids. They are "locked" into a fixed position. This happens because the forces of attraction between particles of a solid are very strong. Because of this tightly packed and highly organize arrangement, solids cannot be compressed and they are unable to flow like a liquid. All materials become solid if their temperatures are lowered enough or the pressure exerted on them becomes high enough. Many people will mistakenly believe that particles of a solid are not moving. They do move! If you could see the molecules with a high powered microscope you would see that they vibrate slightly. It's almost like they are buzzing. The solid state of H_2O (water) is ice.



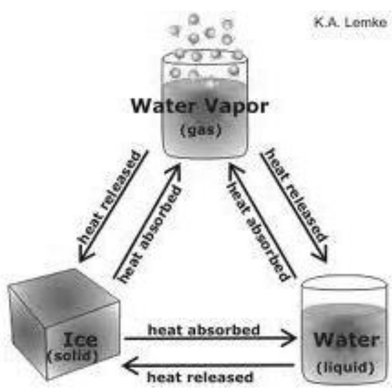
5. *Liquids* however do not have a definite shape and are not compressible. The particles in a liquid are close together. Liquids do have a definite volume for a given mass. This means that liquids are not easily compressed as they are NOT squishable. You might be able to squirt water through your fingers or slosh it around in the bathtub, but you cannot make the water take up less space (it is not compressible). Liquids, unlike a solid, will flow to take the shape of the container they are in. A cup of water will change its shape to fit in a bottle, a cup, or spilled on the table. This happens because there is slightly less attraction between the particles of a liquid substance than those of a solid. Therefore, they are able to move more than the particles of a solid. They are able to slip and slide over and around one another. The liquid state of H_2O is water.

6. *Gases* have no definite shape or volume of their own. Therefore, if the volume of a gas container changes, do does the volume of the gas. This means if you have a can of Axe Body Spray in the classroom and it cracks open, the volume of the gas will expand to take the shape of the classroom (the new container). The particles are very far apart in a gas because the attractive forces are so weak that they cannot hold the particle together, allowing them to move freely and independently of other gas molecules. All of these individual characteristics of gases are due to the fact that at room temperature the particles of a gas have almost no attraction for one another. The gas state of H_2O is water vapor. Take note that individual molecules do not change size when they are vaporized (the fancy word for turning something into a gas), or when undergoing any phase change.

Intermolecular Forces of Attraction

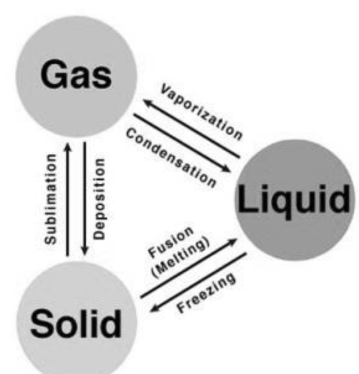
7. The fundamental difference between the states of matter is the space between the molecules due to the strength of the intermolecular forces (IMF) of attraction!

8. In the *solid phase*, the particles (atoms or molecules) are not able to move around much because they have a fairly strong attraction for one another that lock them in place. These intermolecular forces are electrical in nature with a positive charge attracting a negatively charged particle. IMFs are related to the number of electrons in a molecule. In a solid, particle motion consists only of vibrating in place, giving solids a definite volume and shape. Solids can be heated until the vibrations become so severe that the particles begin to break free from their place in the structure and become liquid. This happens because heat energy becomes kinetic (moving) energy and overcomes some of the intermolecular forces of attraction, allowing the solid to transform into a liquid. Solids have less kinetic energy than liquids.



9. In the *liquid phase*, the particles are still attracted to each other and are still in contact with each other. However, they are not locked into a fixed place by the attractive forces. The liquid particles are free to move past each other, as well as vibrate. Liquids have a definite volume but not a definite shape. A liquid can be heated until the kinetic energy of its particles overcomes the remaining forces of attraction and the substance becomes a gas. Gases have the highest kinetic energy of the three phases.

10. The intermolecular forces of attraction have not been changed by these phase changes. The process of going from solid to liquid to gas by adding heat energy can be reversed by cooling. By removing heat energy, a gas will become a liquid, and a liquid will become a solid. This happens because the particles are slowed enough that the still-present intermolecular forces of attraction exert their effect.



Changes of State: A Physical Change

11. In your upcoming lab, you are exploring boiling, also called vaporization. Boiling is a change from a liquid to a gas phase.

12. The temperature at which this occurs for a given substances can also be called the condensation point. Condensation is when a gas becomes a liquid. The condensation point and the boiling point occur at the same temperature.

13. When water boils or steam condenses, a physical change takes place. A physical change is one that involves changes in the state or phase of a material. It does not involve the creation of new materials. The water boils and turns to water vapor (steam) and water vapor condenses to form liquid water. However, there is no change to the molecular structure or size of the water molecules. It is still H_2O. The phase change does involve changes the heat though. To boil water, the water must gain heat energy and to condense water or freeze it, water must lose heat energy.

Zooming in on States of Matter Analysis Questions

Vocabulary: Define the following terms:

- Definite:
- Indefinite:

Definite or Indefinite?	**Solid**	**Liquid**	**Gas**
Shape			
Volume			

Change of state	**From**	**To**	**Heat Energy (gained or lost)**
Boiling	Liquid	Gas	Gained (added heat)
	Gas	Liquid	
Evaporation	Liquid		
Vaporization			
	Liquid	Solid	
Fusion			Gained (added heat)

What does it mean?

Chemistry explains the *macroscopic* phenomenon (what you observe) with a description of what happens at the *nanoscopic* level (atoms, molecules, bonding) using *symbolic* structures as a way to communicate. Complete the chart below:

MACRO	NANO (10^{-9})	SYMBOLIC
Describe two observable features (sight, touch, feel…) of water as a solid (ice), liquid and gas (vapor).	Compare and contrast the nanoscopic nature of a solid, a liquid, and a gas by examining the atoms, molecules, or intermolecular forces.	A phase change graph can be used to summarize the change from solid to liquid to gas. Create your own phase change graph.

MACRO:____

____

____

NANO: ____

____

____

SYMBOLIC:

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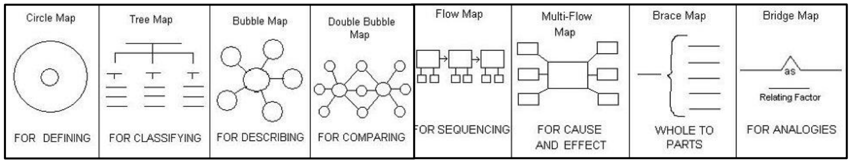
States of Matter

Directions: Using what you learned reading "Zooming in on states of matter," select a thinking map that best organizes your knowledge. Describe the bonds, the characteristics of each state, and/or include a picture to visually represent this information. Make sure to include at least four supporting details for each state of matter.



Last up: Create a frame of reference for your map by citing the paragraph number(s) where you found the information next to the fact.

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States of Matter Skits

State of Matter	Cite Evidence from the Skit to Explain your Team's Guess

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WATER-RELATED VIDEOS/QUICKWRITE

DIRECTIONS: **(1)** At the end of watching each video below, reflect upon the ***theme of the video.*** Write down your one sentence paraphrase of the ***theme of the video*** below. **(2)** At the end of watching all the videos, go into your Base Group and you will share ***one*** of your ***theme of the video*. (Tallest Student** in Base Group begins by sharing his/her ***theme for Video #1).*** **(3)** Student to the right of the Tallest Student responds with *"I agree with _____ because…"* ***or*** *"I disagree with _____ because…".* **(4)** Continue clockwise from the Tallest Student with steps 2 and 3 for Videos #2 – 4.

VIDEO:	**1. Engineering Safer Drinking Water in Africa** **LINK:** http://science360.gov/obj/video/02bc18ee-9d02-4b6e-ba3b-a794748e70fc/engineering-safer-drinking-water-africa **Time:** 2:34 (ALL)	**2. Chemistry of Ice** **LINK***:* http://science360.gov/obj/video/8037e238-41a8-4bbb-b903-9da2557caf9c/chemistry-ice **Time:** 5:22 (first 4:30)	**3. Boiling Point of Water as a Function of Altitude** **DISCOVERY EDUCATION**: Search for "Boiling Point as a Function of Altitude" **Time:** 3:28 (ALL)	**4. Measuring Evaporation From Crops** **LINK:** http://science360.gov/obj/video/5b86956d-b1b0-4d3f-8071-a2dcb8e2906c/measuring-evaporation-crops **Time:** 1:43 (ALL)
THEME OF THE VIDEO: (INDIVIDUAL REFLECTION)				

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6 Clarifying Bookmarks

What I can do	What I can say	How I can respond to my partner
I am going to think about what the selected text may mean.	I'm not sure what this is about, but I think it may mean…	*I agree/disagree because...*
	This part is tricky, but I think it means…	*I think I can help, this part means...*
	After rereading this part, I think it may mean…	
I am going to summarize my understanding so far.	What I understand about this reading so far is…	*I agree/disagree because...*
	I can summarize this part by saying…	*I don't understand, can you explain more?*
	The main points of this section are…	

12 Clarifying Bookmarks

What I can do	What I can say	How I can respond to my partner
I am going to think about what the selected text may mean.	I'm not sure what this is about, but I think it may mean…	*I agree/disagree because...*
	This part is tricky, but I think it means…	*I think I can help, this part means...*
	After rereading this part, I think it may mean…	
I am going to summarize my understanding so far.	What I understand about this reading so far is…	*I agree/disagree because...*
	I can summarize this part by saying…	*I don't understand, can you explain more?*
	The main points of this section are…	
I am going to use my prior knowledge to help me understand.	I know something about this from…	*I think I can help, I read/heard about this when...*
	I have read or heard about this when…	*I also know something about this, and I would like to add...*
	I don't understand the section, but I do recognize…	
I am going to apply related concepts and/or readings.	One reading/idea I have encountered before that relates to this is..	*Tell me more about _________; I don't think I studied about....*
	We learned about this idea/concept when we studied…	*I agree/disagree, I think the concept is related to...*
	This concept/idea is related to…	

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"WHAT-ER" YOU GOING TO DO ABOUT WATER CONSERVATION?

Mini Joke

Q: What happens when you illegally park a frog?
A: It gets toad away!

FAST FACTS

About 780 million people around the world don't have access to safe drinking water.

Less than 1 percent of our planet's water is freshwater that we can drink.

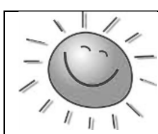
About 70 percent of the planet's freshwater is used for **irrigation**, or supplying water to land and crops.

2, 072 gallons of water is used to make four new tires.

The Water Cycle

Most decisions about water use are made by ordinary people, such as farmers and factory managers. Experts say children who learn about water at a young age can become leaders in meeting our planet's challenges.

We can begin with the water cycle. We never get "new" water. Nature recycles water over and over again. Here's how it works:

 1. The sun shines on lakes, rivers, streams and oceans. Heat turns water into invisible water vapor. This is called **evaporation**.	 2. The vapor rises into the sky, where it cools. When it gets cold enough, the vapor turns into clouds. This is **condensation**. Air currents move clouds all around the Earth.
 3. The clouds get cooler. Tiny drops of water vapor turn into rain, snow, sleet or hail. We call this **precipitation**. Snow may melt and turn into runoff, which flows into rivers and the ocean, as well as into the ground.	 4. Most precipitation falls back into the ocean, but some falls on land. Most of the water eventually finds its way back into the ocean through rivers and underground sources. Some of the runoff seeps into the ground. Plants use the water, and it evaporates from their leaves.

Used Water to "New" Water

What happens to the wastewater that flows from your toilet, kitchen sink, and bathroom shower?

The process below begins with how wastewater from homes in Orange County first travels to the Orange County Sanitation District (OCSD) before flowing to the Orange County Water District (OCWD).

Step One: Pre-Purification (at OCSD)

Wastewater is first treated at the Orange County Sanitation District (OCSD). OCSD collects more than 200 million gallons of wastewater per day and removes a high degree of impurities through several processes. A stringent source control program limits metals and chemicals flowing into OCSD's plants in Fountain Valley and Huntington Beach. The wastewater undergoes treatment through bar screens, grit chambers, trickling filters, activated sludge, clarifiers and disinfection processes before it is sent to the Groundwater Replenishment System at the Orange County Water District (OCWD) where it undergoes a state-of-the-art purification process consisting of microfiltration, reverse osmosis, and ultraviolet light with hydrogen peroxide.

Step Two: Microfiltration (at OCWD)

Microfiltration is a separation process that uses polypropylene hollow fibers, similar to straws, with tiny holes in the sides that are 0.2 micron in diameter (1/300 the diameter of a human hair). By drawing water through the holes into the center of the fibers, suspended solids, protozoa, bacteria and some viruses are filtered out of the water.

Step Three: Reverse Osmosis (at OCWD)

Reverse osmosis (RO) membranes are made of a semi-permeable polyamide polymer (plastic). During the RO process, water is forced through the molecular structure of the membranes under high pressure, removing dissolved chemicals, viruses and pharmaceuticals in the water. The end result is near-distilled-quality water so pure that minerals have to be added back to stabilize the water.

Step Four: Ultraviolet (UV) Light with H_2O_2 (at OCWD)

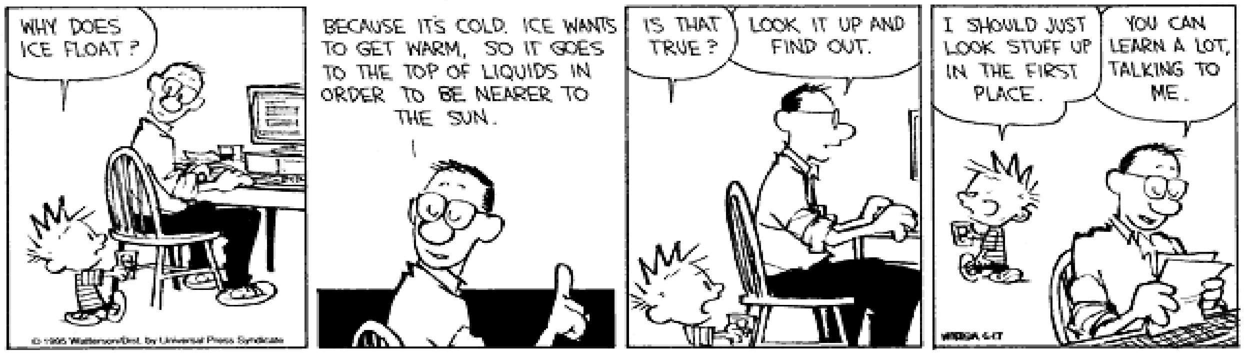
After RO, the water is exposed to high-intensity ultraviolet (UV) light with hydrogen peroxide (H_2O_2) to disinfect and to destroy any trace organic compounds that may have passed through the reverse osmosis membranes.

Approximately 35 million gallons per day of the GWRS water are pumped into injection wells to create a seawater intrusion barrier. Another 35 million gallons are pumped daily to Orange County Water District's percolation basins in Anaheim where the GWRS water naturally filters through sand and gravel to the deep aquifers of the groundwater basin that serve as an underground reserve of water.

Quick and Easy Water Conservation Tips

1. Water your lawns early in the morning before sunrise or in the evenings after sunset. This will maximize water **absorption** into the soil and minimize loss due to **evaporation**.
2. Take five-minute or less showers, and draw less water for baths.
3. Turn off the water while brushing your teeth or shaving.
4. Only wash laundry with full loads.
5. Use a bowl or fill up the sink to clean vegetables.
6. Wash the car with a bucket instead of the hose.
7. Use a broom instead of water to clean your sidewalks and driveways.

THE HIDDEN FORCE IN WATER



Calvin and Hobbes

A Molecular Comparison of Gases, Liquids, and Solids

Some of the characteristic properties of gases, liquids, and solids are listed in Table 1 below.

Table 1. Some Physical Properties of the States of Matter	
Gas	Assumes both the volume and shape of its container Is compressible Flows readily Diffusion within a gas occurs rapidly
Liquid	Assumes the shape of the portion of the container it occupies Does not expand to fill container Is virtually incompressible Flows readily Diffusion within a liquid occurs slowly
Solid	Retains its own shape and volume Is virtually incompressible Does not flow Diffusion within a solid occurs extremely slowly

These physical properties can be understood in terms of the energy of motion (kinetic energy) of the particles of each state by comparing them to the **intermolecular forces** between those particles. Intermolecular forces are the forces of attraction that exist *between molecules*. In other words, these forces of attraction are the "glue" that holds molecules together. On the other hand, forces of attraction *between atoms* in a molecule are **intramolecular forces.**

Gases consist of a collection of widely separated molecules in a constant, chaotic motion. The average energy of the attractions between the molecules is much smaller than their average kinetic energy. The lack of strong attractive forces between molecules allows a gas to expand to fill its container.

In liquids the intermolecular attractive forces are strong enough to hold molecules close together. Thus, liquids are much denser and far less compressible than gases. Unlike gases, liquids have a definite volume, independent of the size and shape of their container. The attractive forces in liquids are not strong enough, however, to keep the molecules from moving past one another. Thus, any liquid can be poured and it assumes the shape of whatever portion of its container it occupies.

In solids the intermolecular attractive forces are strong enough not only to hold molecules close together, but to virtually lock them in place. Solids, like liquids, are not very compressible because the molecules have little free space between them. Because the particles of a solid are not free to undergo long-range movement, solids are rigid.

Figure 1 below compares the three states of matter. *The state of a substance depends largely on the balance between the kinetic energies of the particles and the interparticle energies of attraction.* The kinetic energies, which depend on temperature, tend to keep the particles apart and moving. The interparticle attractions tend to draw the particles together. Substances that are gases at room temperature have weaker interparticle attractions than those that are liquids; substances that are liquids have weaker interparticle attractions than those that are solids.

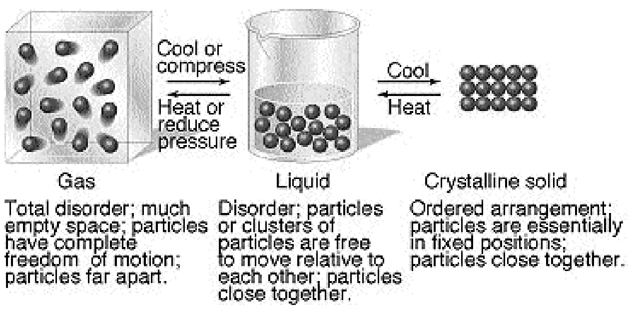


Figure 1. Molecular-level comparison of gases, liquids, and solids. The particles can be atoms, ions, or molecules.

Intermolecular Forces in Water

The strengths of intermolecular forces such as hydrogen bonding are generally much weaker than ionic or covalent bonds (Figure 2). Less energy, therefore, is required to **vaporize, or evaporate**, a liquid or to melt a solid than to **break** covalent bonds in molecules. For example, only about 4 kJ/mole to 25 kJ/mole of energy is required to overcome the intermolecular attractions between H_2O molecules in solid H_2O to melt it to liquid H_2O and then to vaporize it. In contrast, the energy required to break the covalent bond to dissociate (split apart) H_2O into H and O atoms is 463 kJ/mole. Thus, when a molecular substance like H_2O changes from solid to liquid to gas, the molecules themselves remain intact.

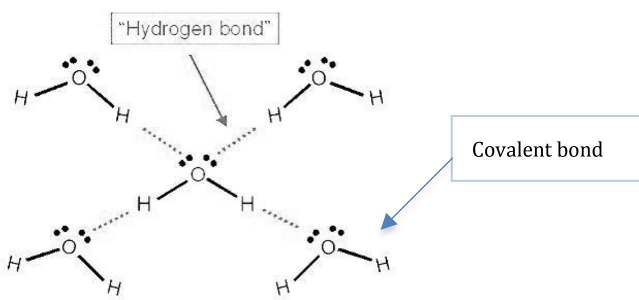


Figure 2. Intermolecular attraction. Comparison of a covalent bond (intramolecular force) and an intermolecular force (hydrogen bond).

One of the remarkable consequences of hydrogen bonding is found when the densities of ice and liquid water are compared. In most substances the molecules in the solid are more densely packed than in the liquid. Thus, the solid phase is denser than the liquid phase. However, the density of ice at 0°C (0.917 g/mL) is less than that of liquid water at 0°C (1.00 g/mL), so ice floats on liquid water (Figure 3).

Figure 3. Comparing densities of liquid and solid phases. The solid phase of water, ice, is less dense than its liquid phase, causing the ice to float on the water.

The lower density of ice compared to that of water can be understood in terms of hydrogen-bonding interactions between H_2O molecules. In ice the H_2O molecules assume an ordered, open arrangement as shown in Figure 4 below. This arrangement optimizes the hydrogen bonding interactions between molecules, with each H_2O molecule forming hydrogen bonds to four other H_2O molecules. These hydrogen bonds, however, create the open cavities shown in the structure. When the ice melts, the motions of the molecules cause the structure to collapse. The hydrogen bonding in the liquid is more random than in ice, but it is strong enough to hold the molecules close together. Consequently, liquid water has a more dense structure than ice, meaning that a given mass of water occupies a smaller volume than the same mass of ice.

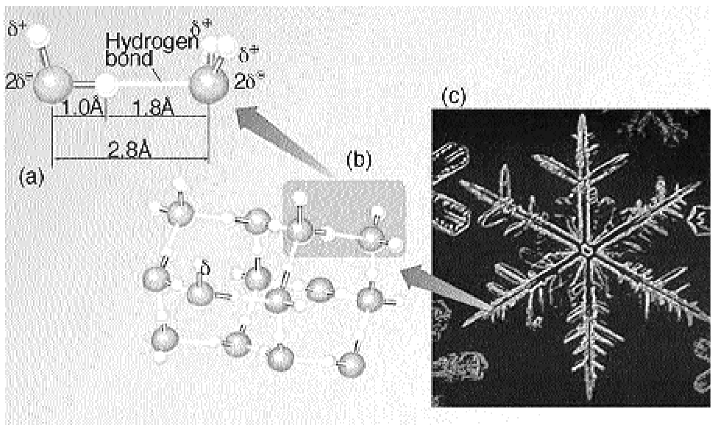


Figure 4. Hydrogen bonding in ice. (a) Hydrogen bonding between water molecules. (b) The arrangement of H_2O molecules in ice. Each hydrogen atom on one H_2O molecule is oriented toward an adjacent H_2O molecule. (c) As a result, ice has an open, hexagonal arrangement of H_2O molecules, characteristic of snowflakes.

The lower density of ice compared to liquid water profoundly affects life on Earth. Because ice floats (Figure 3), it covers the top of the water when a lake freezes in cold weather, thereby insulating the water below. If ice were denser than water, ice forming at the top of a lake would sink to the bottom, and the lake could freeze solid. Most aquatic life could not survive under these conditions. The expansion of water upon freezing (Figure 5) is also what causes water pipes to break in freezing weather.

Figure 5. Expansion of water upon freezing. Water is one of the few substances that expand upon freezing. The expansion is due to the open structure of ice relative to that of liquid water.

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WHAT' S TAKING SO LONG?

Mini Joke

Q: Is it dangerous to swim on a full stomach?
A: *Yes. It's better to swim in water.*

FAST FACTS

Water makes up 70 – 75% of your total body weight.

Reducing water in the body as little as 5% can result in as much as 20-30% drop in physical performance, 10% reduction can make you sick, and 20% can mean death.

39, 090 gallons of water are used to manufacture a new car, including tires.

Do We Really Need Water to Survive?

Water is a colorless and odorless liquid made up of molecules containing two atoms of **hydrogen** and one atom of **oxygen (H_2O)**. Water is essential for all life to exist, as it makes up more than 70 percent of most living things. While a human can survive more than a week without food, a person will die within a few days without water.

Water serves as a solvent (something that dissolves) for nutrients and delivers nutrients to cells, while it also helps the body eliminate waste products from the cells. Both the spaces **between cells** (**inter**cellular spaces) and the spaces **inside cells** (**intra**cellular spaces) are filled with water. Water lubricates joints and acts as shock absorbers inside the eyes and spinal cord. Amniotic fluid, which is largely water, protects the fetus from bumps and knocks.

Water also helps the body maintain a constant temperature by acting as a thermostat. When a person is too hot, whether from being in a hot environment or from intense physical activity, the body sweats. When sweat evaporates, it lowers the body temperature and restores homeostasis.

The most efficient way for the body to get water is for a person to drink water. It is recommended that an adult drink eight to ten eight-ounces of glasses of water a day. Athletes and active teens should drink at least ten to twelve glasses daily. However, many foods and beverages contain water, which can make up part of this daily intake. Fresh fruits and vegetables, cooked vegetables, canned and frozen fruits, soups, stews, juices, and milk are all sources of water. Most fruits and vegetables contain up to 90 percent water, while meats and cheeses contain at least 50 percent. Metabolic processes in the human body generate about 2.5 liters of water daily. So, yes! Water is essential to survive!

Bubbles Or No Bubbles?

Evaporation occurs when molecules have sufficient kinetic energy to escape the surface of a liquid into the gas (vapor) phase. Essentially, all liquids in an open container will evaporate but not necessarily boil. Some liquids have a higher rate of evaporation than others though. Why? The molecules on the surface of the liquid must possess sufficient kinetic energy to overcome the intermolecular forces of their neighbors and escape into the gas phase. Vapor pressure, the pressure exerted by molecules in the gas phase, thus depends on the intermolecular forces of molecules. The weaker the attractive forces, the larger the number of molecules that are able to escape and therefore, the higher is the vapor pressure. The stronger the attractive forces, the smaller the number of molecules that are able to escape and therefore, the smaller is the vapor pressure. Substances with high vapor pressure (such as gasoline) evaporate more quickly than substances with low vapor pressure (such as motor oil).

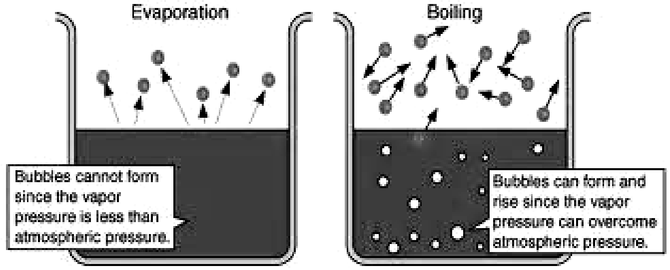

Figure 1. Evaporation versus Boiling Evaporation occurs when vapor escapes from the surface of the liquid. Boiling occurs when enough heat has been absorbed by the liquid and bubbles of vapor form within the liquid.

For water, hot water evaporates more quickly than cold water because vapor pressure increases with increasing temperature. As the temperature of liquid water increases, the molecules move more energetically and a greater number can therefore escape more readily from their neighbors and change from a liquid molecule of H_2O to a vapor molecule of H_2O. As Figure 1 illustrates, **evaporation** occurs without bubbles (vapor) forming while **boiling** occurs when bubbles (vapor) form in the liquid and consequently, a higher rate of vaporization occurs.

So when does water **boil?**

Why Does It Take Longer To Cook At Higher Altitudes?

A liquid boils when its vapor pressure **equals** the atmospheric pressure acting on the surface of the liquid. At this point bubbles of vapor are able to form within the liquid as shown in Figure 1. The following table shows the approximate boiling point of pure water at various altitudes:

Table 1 Boiling Point of Pure Water.

Place	**Altitude (feet)**	**Boiling Point (°F)**	**Boiling Point (°C)**
Dead Sea	- 1, 312	215	101.7
Sea Level (Orange County)	0	212	100.0
Mammoth Mountain (California)	11,060	191.3	88.5
Mount Everest (Himalayas)	29, 028	157	69.4

At sea level, water boils at 100.0 °C while at a higher altitude in Mammoth Mountain, water boils at lower temperature of 88.5°C. Why is there a difference in boiling point of water at different altitudes? At sea level, since there are a few miles of air above us, lots of stuff (molecules) in the air is all pulled to the earth by gravity. Thus, the amount of air pushing down on you increase. Conversely, as you go higher up in the atmosphere (11,060 feet), there is less atmospheric pressure (i.e. much less air pressing down on

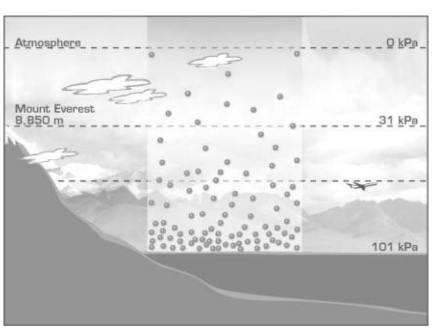

Figure 2. Molecules in the Air. More molecules at Earth's surface (sea level) result in a higher atmospheric pressure. Less molecules at high altitudes (mountains) result in a lower atmospheric pressure.

you). As Figure 2 shows above, more molecules at sea level (Earth's surface) results in a higher atmospheric pressure while at higher altitudes (mountains) there are less molecules and thus, a lower atmospheric pressure.

The same is true for being underwater: the closer to the surface you are, the less pressure you feel in your ears; the deeper you go, the greater the pressure. But as you go up in the atmosphere, the surrounding air pressure is less.

> **Question**: So why *does* it take more time to cook an egg in water at a higher altitude (11,060 feet) up in the atmosphere if the boiling point of water is lower at higher altitudes?

As long as water is present, the maximum temperature of the food being cooked is the boiling point of water. We now understand that water boils when the vapor pressure of the water equals the atmospheric pressure. When there is less atmospheric pressure, a lower vapor pressure is required to get the water boiling, hence a lower boiling temperature.

Even though the boiling point of water at the top of Mammoth Mountain is 88.5°C, which means water will boil sooner, the egg needs to be in the boiling water for a **longer time** before being *fully cooked*. Thus, the time to cook an egg in water at the top of Mammoth Mountain is 5 minutes 27 seconds while at sea level in Orange County, it only takes 3 minutes 29 seconds.

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MR. FREEZE – WHAT'S YOUR PHASE?

Ms. B. Haven: Freezy, I'm feeling hot.
Mr. Freeze: I find that unlikely.
Ms. B. Haven: Okay, so my hair is brittle and my skin is dry. I'd weather the blizzards just to have you. You're the most perfect man I've ever known. What do you say we heat things up?
Mr. Freeze: My passion thaws for my bride alone.
Ms. B. Haven: Ooh. Talk about your cold shoulder.

What Will Happen to Mr. Freeze With Heat Energy?

Batman: I saw what happened to your wife, I'm sorry.
Mr. Freeze: I'm beyond emotions. They've been frozen dead in me.
Batman: That suit you wear, a result of the coolant?
Mr. Freeze: Very good, a detective to the last. I can no longer survive outside a sub-zero environment.

Every **phase change** is accompanied by a change in energy (or heat) of the system. Mr. Freeze survives at *sub-zero* temperatures, at temperatures less than 0°C! Assuming Mr. Freeze is made of water molecules, where does this place him on the heating curve of water shown in Figure 1? If thermal energy (heat) is added to him, he does not change and melt from ice to liquid immediately. But something about Mr. Freeze does change. What do you notice happens to his *sub-zero* body temperature of -20°C when heat is added? *Mr. Freeze's body temperature increases to 0°C.*

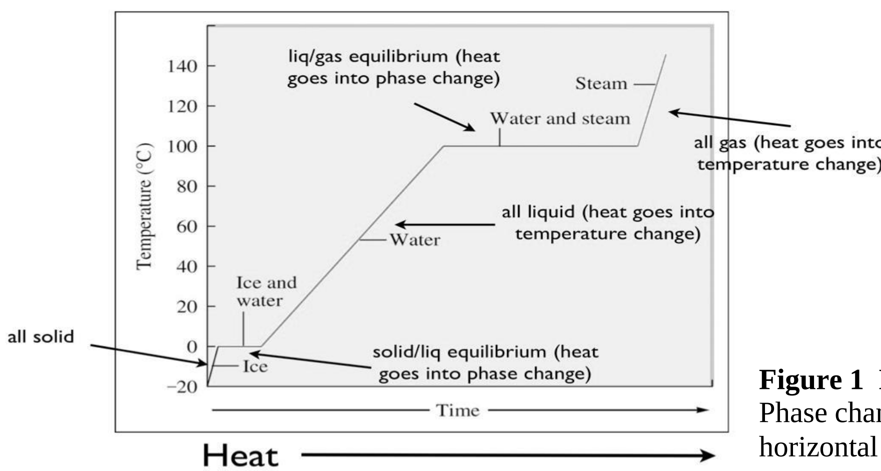

Figure 1 Heating Curve of Water. Phase changes only occur on the horizontal sections.

Question: So why did Mr. Freeze *not immediately* melt once heat was absorbed?

In a solid as Mr. Freeze (who is at a *sub-zero* temperature *less than 0°C*), the ice molecules of water are in a fixed position with respect to one another and closely arranged to minimize motion. The initial heat absorbed by Mr. Freeze is being used to **weaken** the intermolecular attractive forces that hold his ice molecules close together. As more and more heat is absorbed, the **kinetic energy** (energy of motion) of the solid ice molecules increases. The increasing vibration and movement of the ice molecules due to the increasing kinetic energy **causes** the temperature of the solid ice to increase. Mr. Freeze is still pure solid ice at this point.

Since water has a **normal melting point of 0°C**, the temperature at which water changes from a solid to a liquid state, any heat absorbed is used to bring the temperature of *sub-zero* Mr. Freeze **up to 0°C.** Therefore, it is *only when the ice molecules of Mr. Freeze have reached a temperature of 0°C* does Mr. Freeze *begin* to melt with continuous heat being added! At 0°C, Mr. Freeze experiences a **melting phase change**, from solid ice →liquid water.

Thus at 0°C, the water molecules of Mr. Freeze will **coexist** as a solid and as a liquid, in a solid/liquid **equilibrium**. The first horizontal section of the heating curve in Figure 1 represents this. Additional heat energy added to Mr. Freeze at this point *does not* change his temperature of 0°C. The heat absorbed (called the **Heat of Fusion)** is now transforming the solid ice to liquid water. Once enough heat is absorbed to overcome the attractive forces between <u>all</u> the ice molecules, Mr. Freeze has completely transformed into *Mr. Liquid,* existing as only liquid molecules. Mr. Freeze will essentially have thawed.

Batman: Freeze! *Mr. Freeze*: That's Mr. Freeze to you.

Can It Get Worse for Mr. Freeze?

Absolutely!

We have seen liquid water over several days begin to evaporate. In general, each state of matter (solid, liquid, or gas) can change into either of the other two states. For example, liquid water can change to solid water (ice) by losing heat (enthalpy decreases) or change to gas (water vapor) by absorbing heat (enthalpy increases). Figure 2 shows the name associated with each of these transformations. These transformations are called either **phase changes** or changes of state. **Changes of state** are changes in physical properties, not chemical properties. The water molecule is still H_2O whether it is ice, water, or steam (gas).

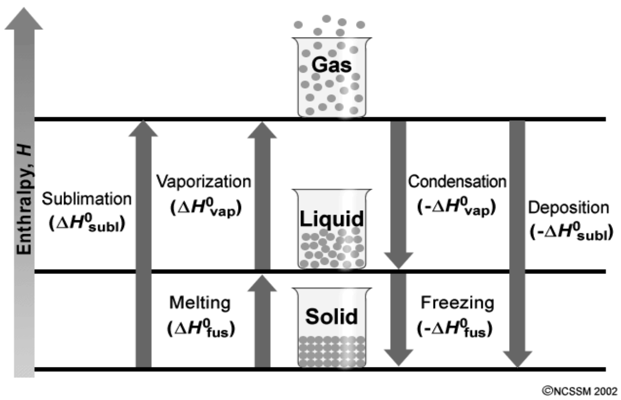

Figure 2. Phase changes and the names associated with them. The changes represented by red arrows indicate energy absorbed while the blue arrows indicate energy released.

Mr. Liquid's temperature, with additional heat energy added, increases as shown in section C of Figure 3. All the additional heat energy at this point is being used to overcome the intermolecular attractive forces of the liquid water molecules. *Mr. Liquid's* temperature will increase to100°C and at this temperature, *Mr. Liquid* will begin the **vaporization phase change**, transforming into *Mr. Vapor* and he will cease to exist in one location!

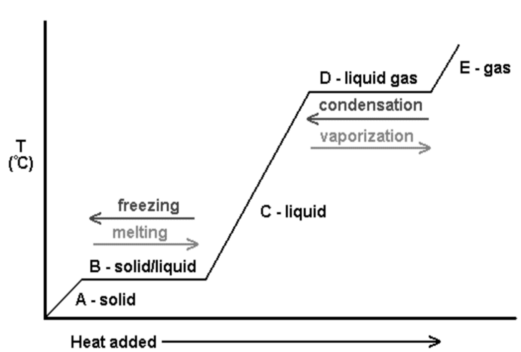

Figure 3. Heating Curve of Water. Heat absorbed at Sections A, C, and E are used to overcome intermolecular attractive forces. As a result, only temperature increases and no phase change occurs.

#1: *"WHAT-ER" YOU GOING TO DO ABOUT WATER CONSERVATION?*

1. Evaporation and condensation are opposite processes; evaporation occurring when heat is absorbed by liquid water molecules that then change into gas water molecules. Compare and contrast the two processes by drawing a thinking map that best represents your information.

2. The article writes: "We never get new water." What is the implication of this statement regarding our usage of water and Africa's access to safe drinking water?

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3. Roughly 80 to 90 percent of Southern California's water is imported from Northern California or the Colorado River. The transportation of the water has been an environmental concern due to the deterioration of habitats for endangered species. The costs for recycling wastewater and importing water are about the same. In addition, a little known fact is that bottled water (i.e. Crystal Geyser and Arrowhead) is essentially the same as recycled water, minerals are just added to perfectly good drinking water for taste. Your task: Develop an argument that you will share with the staff and students at Godinez that explains the process of recycling wastewater and convincing them that the end product is perfectly good drinkable water without the extra cost of a plastic bottle.

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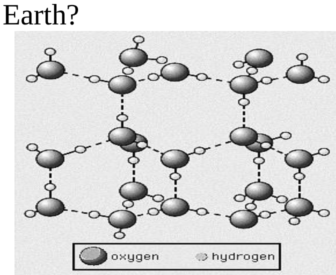
#2: *THE HIDDEN FORCE IN WATER*

1. Redraw Figure 2 from the article showing all the details. Your Task: (1) In the figure you have drawn, next to **hydrogen bond** and **covalent bond,** write the name of the corresponding force, **intermolecular forces** or **intramolecular forces**. (2) Above each bond/force, label with the **amount of energy** needed to overcome or break the bond/force. (3) Write one to two complete sentences using all of the bolded phrases from this prompt to explain the figure.
Figure 2:

2. For each category, order the three states of matter (solid, liquid, and gas) with respect to H_2O from **lowest (weakest) to highest (strongest).**

CATEGORY	**ORDER (Lowest/Weakest→Highest/Strongest)**
1. Strength of Intermolecular Forces (Interparticle Attraction)	Gas < Liquid < Solid
2. Ability to Flow (Move)	
3. Absorbed the Most Heat	
4. Amount of Kinetic Energy	
5. Density	

3. Examine the figure below. (1) What geometric shape are the water molecules forming and which state of matter does it represent? Explain. (2) "The density of ice (solid water) is fortunately less than the density of liquid water". Interpret this statement and how is this statement significant to life on Earth?



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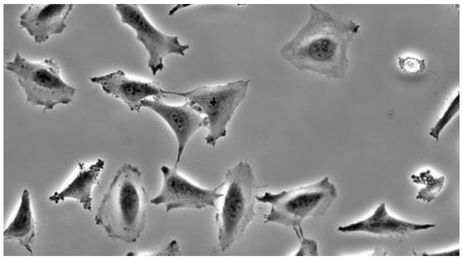
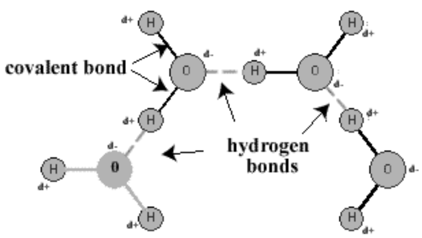
#3: *WHAT'S TAKING SO LONG?*

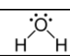
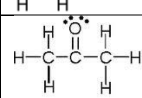
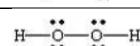
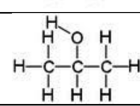
1. Examine the image below of human cells in a petri dish as seen from a microscope. Identify and label where the **intercellular spaces** versus **intracellular spaces** could be found. Write a complete sentence using the all of the bolded phrases from this prompt plus the words **between** and **inside** to explain your understanding.



2. Carefully examine the figure below of water (H_2O) molecules. Applying your knowledge of the difference between intercellular space and intracellular space, match **covalent bond** and **hydrogen bonds** with either **intermolecular forces** of attraction or **intramolecular forces** of attraction and label these **forces** in the figure. Explain your matching of the bond with the force using all of the bolded phrases plus the words **between**, **inside, molecule,** and **atoms**.



3. Analyze the substances, formulas and boiling points. Your Task: (1) In the table, predict the order of the substances' **vapor pressure** and **intermolecular forces (IMF)**. (1 = highest or strongest and 4 = lowest or weakest).

Substance	**Chemical Formula**	**Structural Formula**	**Boiling Point**	**Vapor Pressure**	**IMF**
Water	H_2O		100 °C		
Acetone	C_3H_6O		56 °C		
Hydrogen Peroxide	H_2O_2		150.2 °C		
Isopropyl Alcohol	C_3H_7OH		82.5 °C		

(2) Justify the order of your substances by explaining the relationship between **boiling point, vapor pressure** and **IMF**. (3) How and why will acetone's boiling point and vapor pressure change but not its IMF at the top of Mount Everest?

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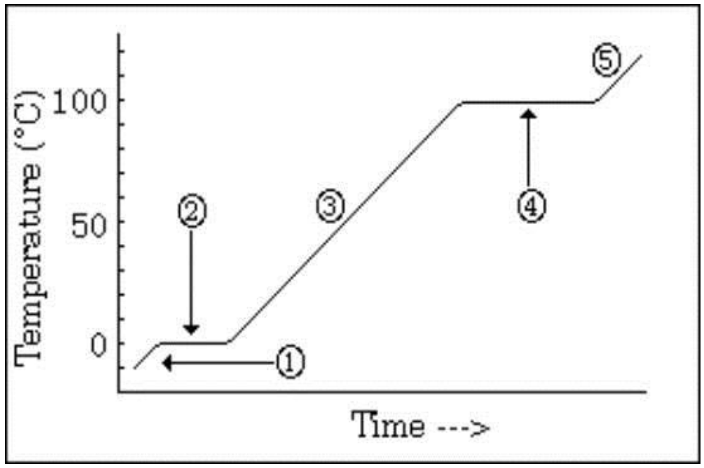
#4: *MR. FREEZE – WHAT' S YOUR PHASE?*

1. Examine the heating curve.

Your Task: (1) Label the phase(s), or states of matter, that exists at each part of the curve (*1 – 5*). (2) Explain why temperature remains constant during parts *2* and *4* of the curve although heat is continuously being absorbed. (3) What is the name of the endothermic transformation (phase change) occurring at part *4*



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2. Using the heating curve above: (1) Draw a dot on the curve to identify the **freezing point** of this substance and identify the temperature of this **freezing point**. (2) Compare and contrast **freezing point** with **melting point.**

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3. Referencing key information from the heating curve and relevant evidence from the article, identify and explain which phase will most likely exhibit the highest **kinetic energy** and how does this relate to the phase's **intermolecular forces** and the **distance between** the particles? Use all <u>bolded phrases</u> in this prompt in your response.

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THEME OF WATER – RELATED ARTICLES

#1: ***"WHAT-ER" YOU GOING TO DO ABOUT WATER CONSERVATION?***

#2: ***THE HIDDEN FORCE IN WATER***

#3: ***WHAT'S TAKING SO LONG?***

#4: ***MR. FREEZE – WHAT'S YOUR PHASE?***

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Name ________________________________ Period________ Date ____________

Heating Curve of Water Lab

SAFETY GOGGLES MUST BE WORN AT ALL TIMES!

Purpose Create a graph to represent the heating curve of water. Observe that heat energy can be used to raise the temperature of a substance OR to weaken the intermolecular forces (a.k.a. bonds) in a substance and cause a phase change.

Materials: 250 ml Beaker, crushed ice cubes, thermometer, spatula, timers (only use cellphone times IF your teacher approves it), Bunsen burner set up (Bunsen burner, rubber tubing, ring stand, wire mesh, thermometer clamp), matches, timer. Alternatively use a hot plate.

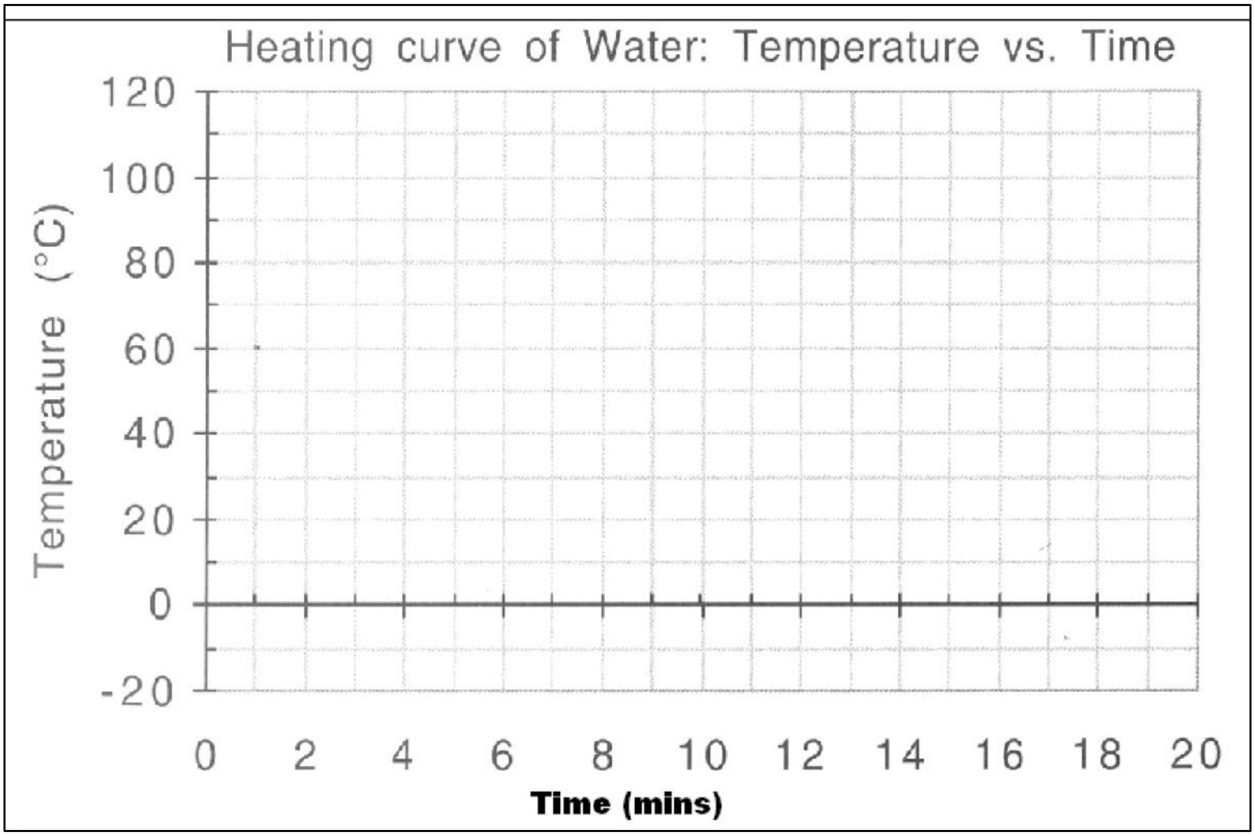
Procedure: *Remember: If you don't have a thermometer clamp, a hand MUST ALWAYS hold the thermometer when using it. Thermometer MUST stay in the beaker throughout the lab so it doesn't measure air temp*erature.

1. Set up your beaker on the wire mesh above the Bunsen burner OR on the hot plate. Do NOT turn it on.
2. Put about 100ml of crushed ice cubes into the beaker. Record this temperature at time 0. (*DO NOT let the thermometer rest on the glass).*
3. Record the temperature & phases WITHOUT adding heat for 5 minutes.
4. Adjust your Bunsen burner so medium heat is applied to your beaker with ice. If using a heating plate, turn the plate to LOW and stir the ice occasionally with a metal spatula.
5. Record the temperature & phases (solid, liquid, gas) every 1 minute until the water has been boiling (with LOTS of bubbles) for 5 minutes. *REMEMBER, there may be more than one phase present. Record all phases present.*
6. After water has boiled for 5 minutes, all remaining water can go into the sink. Dry off your lab bench and return all lab materials.
7. Work with your lab team to graph your data and answer the questions below.

Data/Observations:

Time (1 minute)	Temp. °C	Phase/Phases water is in	Time (1 minute)	Temp. °C	Phase/Phases water is in
Starting Temp	0 °C	Ice (solid phase)	10		
0			11		
1			12		
2			13		
3			14		
4			15		
5			16		
6 (light Bunsen burner!)			17		
7			18		
8			19		
9			20		

Graphing: Use your data from above to create a "Line Graph"



Graph Analysis: Label the following points on the graph above

1. Phase change between solid and liquid as "A"
2. Phase change between liquid and gas as "B"
3. Heating the liquid as "C"

Post Lab Analysis:

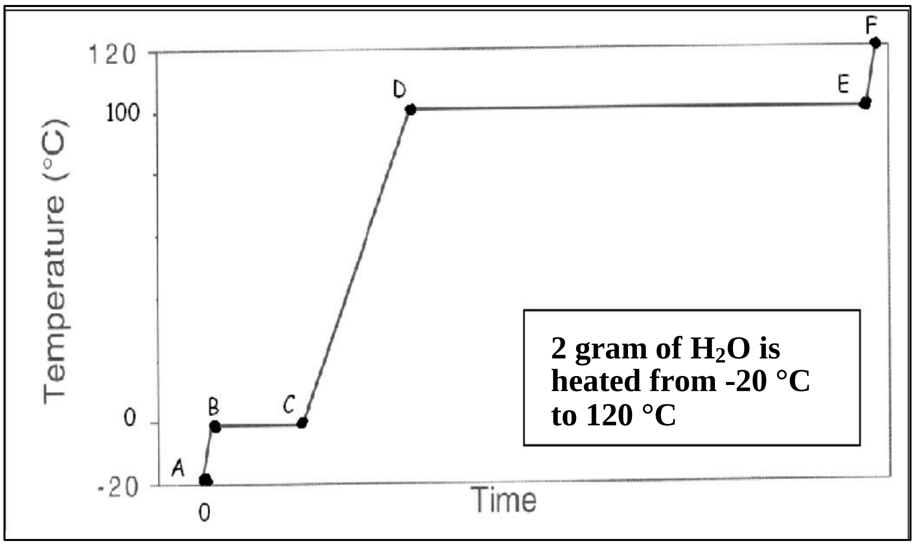
1. What is the chemistry term for a phase change when a solid becomes a liquid?
2. What is the chemistry term for a phase change when a liquid becomes a gas?
3. Describe the phase change that occurs during solidification:
4. Describe the phase change that occurs during condensation:
5. What happens to the intermolecular forces of attraction inside an ice cube when it melts?
6. Why did the temperature of the liquid stop right around 100°C even though you continued heating the water?

Name ________________________________ Period__________ Date___________

Heating Curve of Water Lab: Analysis Questions

Purpose: Examine the heating curve of H_2O and determine what is happening at the molecular level at each stage and why.

Heating Curve of Water: The graph is not drawn to scale, but it is drawn to emphasize differences in the amount of time required for each of the 5 steps.



Point on the Graph	Phase or phases of matter (s, ℓ, g)	Point on the Graph	Phase OR Temp. Change?	If it is a phase change, name it.
A		A→B		
B		B→C		
C		C→D		
D		D→E		
E		E→F		
F		B→A		

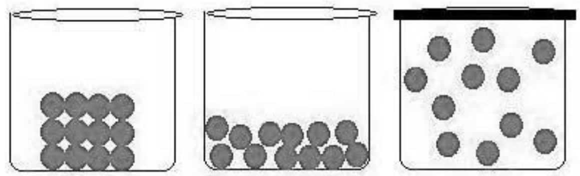
1. Write in the following 4 phase changes in the appropriate location on the graph above:

   Vaporization ℓ →g Condensation g→ ℓ Fusion s→ ℓ Solidification ℓ →s

2. At what point (A,B, C, D, E, or F) on the graph
   a. Is all the ICE gone? __________ b. Is all of the LIQUID gone?_________

3. **Heat** and **temperature** are related, yet different. During phase changes, the water is being heated, yet the temperature does not increase. What is the heat being used to do during these phase changes?

4. Label the substances in the containers below as solid, liquid, or gas. The round dots represent the individual molecuels in each substance.



5. Using the pictures above, identify two differences between the molecule arrangement or intermolecular force strength of a liquid and a solid.

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6. Using the pictures above, identify two differences between the molecule arrangement or intermolecular force strength of a gas and a solid.

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7. Looking at the graph above, why does it take so much more time & heat to **boil water completely** than to **melt ice completely?** ***HINT:*** *Think about the intermolecular force strength in a solid versus a gas.*

Conclusion: In this two day lab you learned what a heating curve for water looks like as well as what occurs at the molecular level during the phase changes. Use this knowledge to:
1) Describe the difference between a phase change and a temperature change.
2) Explain the 3 different states of matter and how the intermolecular force strength changes as the phase changes.

Directions: After arranging your Sort Cards and checking your work with the teacher, carefully fill in the Table below

Substance	**Formula**	**Melting Point (˚C)**	**Boiling Point (˚C)**	**Molar Mass**	***Intra*-molecular Force(s) (bonds between *atoms*)**	***Inter*-molecular Force(s) (bonds between *molecules)***	**Lewis Dot Structure**

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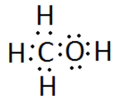
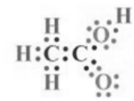
Name ____________________________________



Card Sort Analysis Questions



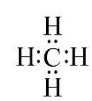
Directions: With your group, look at the Card Sort Table you created and answer the questions below to explain your thinking. Be specific with each of your responses.

1. Explain how did you sort your table? Which columns were the main characteristics in determining order? Why did you use these characteristics?

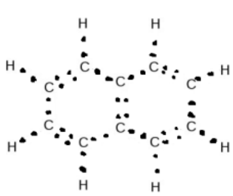
2. Which compound is a liquid for the narrowest range of temperatures?

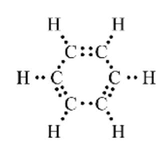
3. Find two compounds in the table with similar molar masses. Compare their melting points. Which of the characteristics listed appears to correlate with the differences in melting point?

4. Compare the covalent compounds with the ionic compounds and make a generalization about structure and melting point.



5. Compare the characteristics of methane, benzene, and naphthalene. What factor seems to be responsible for the differences in melting?





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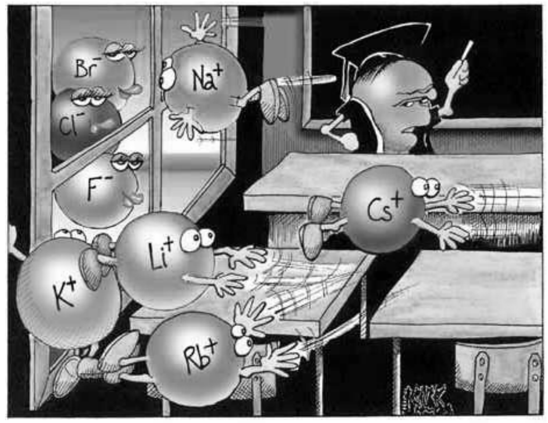
Who is the STRONGEST?

Intermolecular Forces of Attraction

Directions: As you read this article, use the annotation chart below to mark up text. Be sure to read the information provided in the figures as well as the main body text.

Symbol/ Section	Comment/ Question/ Response
?	▪ Questions I have ▪ Wonderings I have ▪ Confusing parts for me
*	▪ Key ideas expressed ▪ Author's main points
!	▪ Surprising details/claims ▪ Emotional response
O	▪ Ideas/sections you connect with ▪ What this reminds you of



"Perhaps one of you gentlemen would mind telling me just what it is outside the window that you find so attractive...?"

Solids, Liquids, and Gases

In solids, such as ice, the particles are not able to move around much because they have a fairly strong attraction for one another. When energy is added to the ice, the heat energy becomes kinetic energy and overcomes or "breaks" some of the intermolecular forces of attraction. These intermolecular forces are electrical in nature, meaning they are related to the number and position of electrons. Intermolecular forces are weaker than either ionic or covalent bonds but we should not underestimate the importance of these forces.

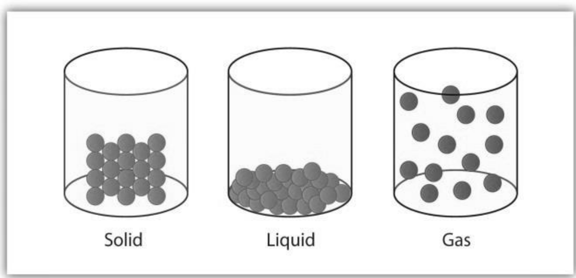
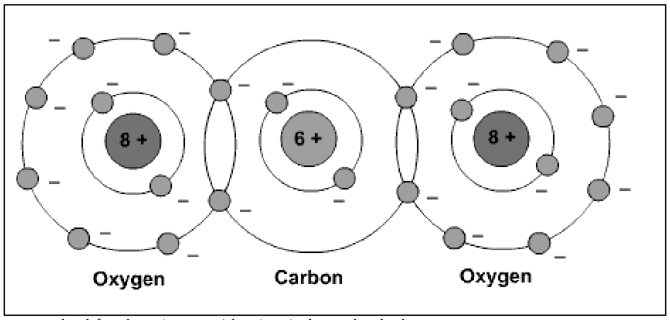


Figure 1. Intermolecular forces are not changed by phase changes from solid to liquid to gas. In gases the molecules are moving too fast for the intermolecular forces to have any effect, so it is almost like they do not exist. But in solids, the particles are slowed enough for the intermolecular forces of attraction to exert their effect and draw the molecules close together.

The strength of these attractive forces are responsible for determining if a compound is a gas, liquid, or a solid at room temperature. The more tightly they cling to each other, the more compressed the molecules in the compound. The most tightly attracted particles are found in solids and the compounds with the weakest attractions between molecules are in a gas.

Intermolecular Forces of Attraction in Non-polar Molecules

Nonpolar molecules, such as the halogens (F_2, Cl_2, Br_2), oxygen (O_2), nitrogen (N_2), carbon dioxide (CO_2), and methane (CH_4) have shapes and bonds that are symmetrical (Fig. 2). The electrons of these molecules are distributed evenly so that there is no permanent electrical charge anywhere on the molecule, and the intermolecular forces are small. The balanced and symmetrical shapes of nonpolar molecules cause them to have very little attraction to each other. Small, nonpolar molecules tend to be gases or liquids with low boiling points.

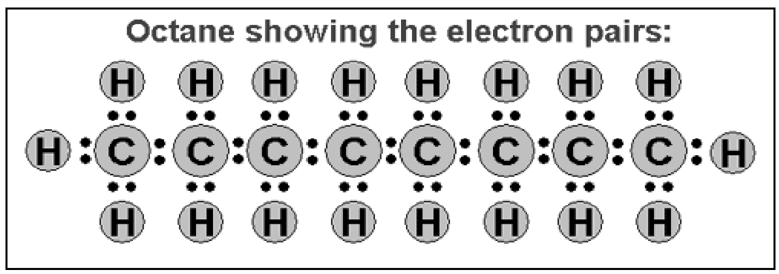


www.school-for-champions.com/chemistry/polar_molecules.htm

Figure 2. If you drew a line through the middle of this CO_2 molecule, both sides would be identical, including the location of the electrons. Because electrons are balanced, neither side of the molecule is more negative than the other side. Overall, a non-polar molecule is neutral (has no charge).

When there are larger sized nonpolar molecules, such as a hydrocarbon found in gasoline, octane (C_8H_{18}), the attractive forces between molecules begins to increase (Fig. 3). Larger molecules have more electrons. When there are more electrons, which are in constant motion, there is more chance that they may be distributed unevenly, causing one part of the molecule to briefly have a greater number of electrons. Because the electron distribution is uneven, there is a temporary partial negative charge, with one part of the molecule having an abundance of electrons and another part having a deficiency in electrons. This makes the molecule temporarily polar (having two poles) and can trigger the formation of more dipole molecules

Figure 3. Octane's larger structure has many more electrons. The Lewis Dot Diagram (right) does not accurately show that the electrons are constantly moving around the hydrogen and carbon atoms.



http://www.green-planet-solar-energy.com/what-is-octane.html

These attractive forces, called London dispersion forces, are much weaker than ionic or covalent bonds which hold atoms together by sharing or giving up electrons. When larger molecules have London dispersion forces, the molecules are more difficult to separate, which is what happens when a substance boils. Because of this, larger molecules tend to have higher boiling points and can be liquids or solids at room temperature. They simply require more energy (heat) to break apart the London dispersion forces holding the molecules together.

Intermolecular Forces of Attraction in Polar Molecules

Not all molecules share electrons equally like covalent bonds. Polar molecules have permanent, separated charges as a result of their shape and the types of atoms in the molecule. Some atoms, particularly oxygen, nitrogen, and fluorine, have a greater tendency to pull the electrons of a covalent bond toward themselves when bonded to different elements. This property is called electronegativity and is one of the trends on the periodic table. In water, oxygen has a stronger pull on the electrons than hydrogen, so the oxygen portion of the atom is slightly negative while the hydrogen ends are slightly positive (Fig. 4).

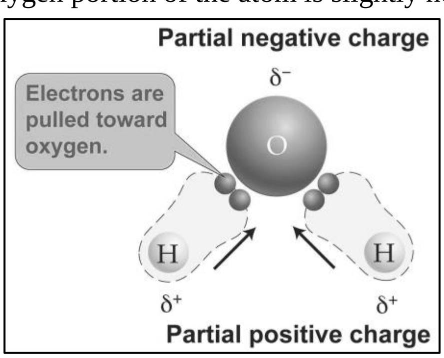
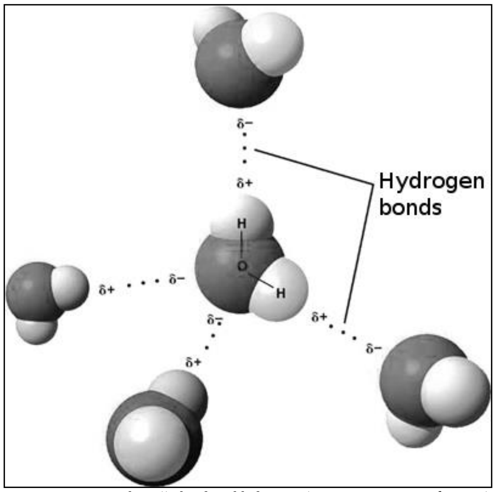


Figure 4. Oxygen wants the electrons to complete its octet shell and pulls strongly on each hydrogen's electron. The electrons are closer to oxygen than they are to the hydrogen atoms, giving the oxygen end of water a slightly negative charge. The hydrogen ends, therefore, are slightly positive in charge.

The positive hydrogen atoms are attracted to the negative oxygen atoms of nearby water molecules and form hydrogen bonds. While hydrogen bonds are not real bonds, they are importance intermolecular forces. In terms of strength, they are much weaker than ionic bonds, and located between covalent bonds and the weak London dispersion forces.

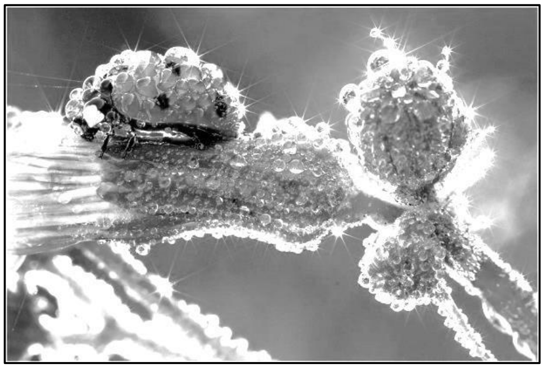
Figure 5. Because of the slight charges on either end of a single water molecule, and the fact that "opposites attract," additional water molecules are attracted. They are held together using hydrogen bonds. Take note that the water molecules are arranged so the hydrogen atom of one water molecule orients itself to face an oxygen atom of another water molecule.

You observed the cumulative power of hydrogen bonds when you completed the Penny Drop Lab and were able to fit many water drops onto a single penny.



http://schoolworkhelper.net/unique-properties-of-water/.

The strong attractions between water molecules cause the water to pull together into small drops rather than spread out over the surface of your car's windshield. Surface tension, the attraction of water molecules to other water molecules, allowed us to fit 20, 30 or even 50 drops of water on the surface of one penny.



This and many of the other unique properties of water are a result of hydrogen bonding. A water molecule has only 3 atoms with a low molar mass of 18amu, but has a relatively high freezing point of 0ºC and high boiling point of 100ºC. A similarly sized nonpolar compound, methane, CH_4, has a boiling point of -161ºC. This is because

it is much easier to pull the molecules of methane apart as it lacks hydrogen bonds.

When there is a strong attraction between molecules, the substances are probably liquids or solids at room temperatures, and inversely, when there are weaker attractive forces, the substances are probably gases at room temperature.

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Who is the Strongest? Intermolecular Forces

Collaborative Annotation Chart

Directions: After you have read and annotated the article, discuss the various comments and marks you and your partner made. You will need to record the comments you made on the article as well as your partners responses in the table below. Use the "sample language support" to get your discussion flowing.

Symbol/ Section	Comment/ Question/ Response	Sample Language Support
?	▪ Questions I have ▪ Wonderings I have ▪ Confusing parts for me	▪ The statement, "…" is confusing to me because… ▪ I am unclear about the following sentence(s) ▪ I don't understand what s/he means when s/he states…
*	▪ Key ideas expressed ▪ Author's main points	▪ One significant idea in this text is… ▪ The author is trying to convey…
!	▪ Surprising details/claims ▪ Emotional response	▪ I was surprised to read that… ▪ How can anyone claim that…
O	▪ Ideas/sections you connect with ▪ What this reminds you of	▪ This section reminded me of… ▪ This connects with my experience in that…

Symbol/ Section	Comment/ Question/ Response	Partner's Comment/ Question/ Response

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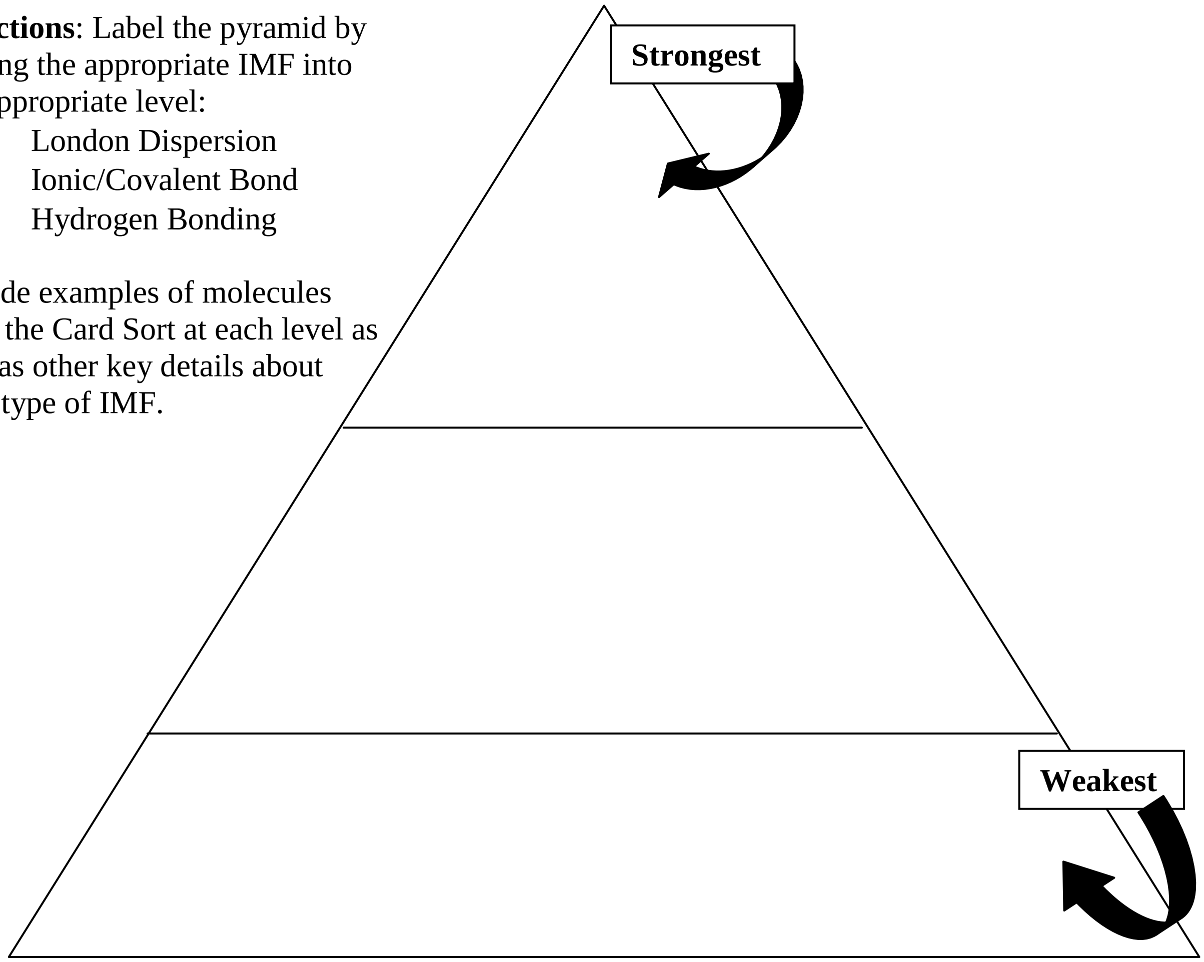
Name ______________________________

Pyramid of Intermolecular Forces

Directions: Label the pyramid by placing the appropriate IMF into the appropriate level:

- London Dispersion
- Ionic/Covalent Bond
- Hydrogen Bonding

Include examples of molecules from the Card Sort at each level as well as other key details about each type of IMF.



Summary:

What influence do Intermolecular forces have on determining if a substance is a gas at room temperature (review Card Sort Table if needed)?

Compare and contrast the intermolecular forces between benzene and water (3 sentences minimum).

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Name ______________________Lab Partners __________________ & ___________________
Date____________ Period_____

LET'S CHILL
An Inquiry Lab to Freezing-Point Depression

Hypothesis
It's a warm day in the summer and a lone can of soda sits on a shelf in the kitchen cabinet. You're wishing for a cold soda and wonder how to chill it as quickly as possible in the least amount of time. You have four chilling methods listed below.

Your Task: Using your best judgment, number the chilling methods below from one to four (one represents requiring the least amount of time to chill). Explain your hypothesis.

Chilling Options ____

____ *Soda in freezer* ____
____ *Soda in refrigerator* ____
____ *Soda in an ice/water bath* ____
____ *Soda in an ice/salt/water bath* ____
____

Purpose
(1) Understand and explain how changes in temperature correlates with microscopic changes of the kinetic energy and the strength of the intermolecular force between water molecules, and to the overall macroscopic observation of phase changes.
(2) Evaluate changes to the *freezing (melting) point* of water with the addition of a solute such as NaCl with explanations correlating with microscopic changes to kinetic energy and intermolecular forces.
(3) Become familiar with colligative properties, more specifically, *freezing-point depression (lowering)* and how it relates to drivers of automobiles and party hosts chilling drinks.

Materials/Chemicals
1. Ice, crushed
2. 150ml of soda
3. Solid NaCl (sodium chloride)
4. Tap water
5. Digital balance (500 g capacity required)
6. Thermometer (2-you may need to share)
7. 600-mL or 1000-mL beakers (2)
8. 100-ml beakers (2)
9. 100-ml graduated cylinder
10. Spatula
11. Freezer
12. Refrigerator
13. Goggles

Procedure
Part I
1. Acquire the materials/chemicals listed above if not already at your lab bench.
2. Ice/Water Bath (1000-ml beaker #1):
   A. Use graduated cylinder to measure out 100-ml tap water and pour into 1000-ml beaker.
   B. Use digital balance to measure out 100 g of ice into 1000-ml beaker. Swirl the beaker.
3. Ice/Salt/Water Bath (1000-ml beaker #2):
   A. Use digital balance and a spatula to measure out 60 grams of NaCl into 1000-ml beaker.
   B. Use graduated cylinder to measure out 100-ml tap water and pour into 1000-ml beaker.
   C. Swirl the beaker to dissolve the NaCl in the tap water to create a salt/water solution.
   D. Use digital balance to measure out 100 g of ice into 1000-ml beaker. Swirl the beaker.
4. Use graduated cylinder to measure out 50 mL of soda into two 100-mL beakers.

5. Using separate thermometers, concurrently read the initial temperature (T_0) of the soda in both 100-ml beakers. *Record your values in the Data Table.*
6. At the same time, place one 100-ml beaker of soda into the 1000-ml beakers and begin a countdown of 5 minutes.
7. Observe the 1000-ml beakers of ice/water and of ice/salt/water with the following questions in mind: What is happening to the ice? What phase change(s) are occurring? Is there evidence of a change in intermolecular forces between the water molecules in the ice? *Record your observations below.*
8. At the end of 5 minutes, read the final temperature (T_5) of the soda. *Record your values in the Data Table.*

Part II (OPTIONAL)

1. Use graduated cylinder to measure out 25 mL of soda into two 100-mL beakers.
2. Using separate thermometers, concurrently read the initial temperature (T_0) of the soda in both 100-ml beaker. *Record your values in the Data Table.*
3. At the same time, place one of the 100-ml beakers in the refrigerator and one in the freezer and begin a countdown of 5 minutes.
4. At the end of 5 minutes, take the samples out of the refrigerator and the freezer and read the final temperature (T_5) of the soda. *Record your values in the Data Table.*

Data Table

Sample	T_0 (initial temperature) ^{0}C	T_5 (final temperature) ^{0}C
1. Soda in ice/water bath		
2. Soda in ice/salt/water bath		
3. Soda in refrigerator (optional)		
4. Soda in freezer (optional)		

Observations

____

____

____

____

Data Analysis

Revisit your hypothesis. How did your hypothesis compare to your results? Which "chilling method" would you choose to chill your soda? Support your claim using evidence from your data table and observations. *Underline These Key Words: (1) temperature; (2) initial; (3) final; (4) hypothesis; (5) results; and (6) compare.*

____

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The Power of Salt (NaCl): A Look at Freezing-Point Depression

1. Water alone, without any substance dissolved in it, is called a *pure solvent.* Water, with sodium chloride dissolved in it, is no longer a pure solvent but is now a *solution. Solutions* are homogeneous mixtures that contain two or more different substances. The major component is called the *solvent*, and the minor component is called the *solute*. From the lab, the ice/salt/water bath prepared was a solution of 200 grams total of water *(solvent*) and 60 grams of NaCl (*solute*).

2. One of the physical properties of pure water is a freezing point of 0°C, but solutions with water as the solvent freeze at *lower* temperatures below 0°C. The opposite affect is observed for the boiling point. Pure water has a boiling point of 100°C but once a solute is added to water to form a solution, the boiling point of the solution is now *above* 100°C. The *lowering of the freezing point* and the *raising of the boiling point* are physical properties that depend on the *quantity* of the solute particles added to the pure solvent but *not* on the *kind* or *identity* of the solute particles. Such properties are called **colligative properties.**

3. A common application of the principles of *freezing-point depression* and *boiling-point elevation* is the coolant in radiators of cars. Ethylene glycol ($C_2H_6O_2$, antifreeze) is added to the water (coolant) in cars to lower the freezing point of the water below 0°C and raise the boiling point of water above 100°C. Cars can thus withstand subfreezing temperatures without freezing up in Minnesota and the engine can operate at a higher temperature without over-heating in Arizona. Another useful application of the principle of *freezing-point depression* is the sprinkling of salt (NaCl) on an icy road or sidewalk to make them safer for people to drive or walk on them. Adding the salt (NaCl) essentially melts the ice by lowering the freezing point of water.

4. How does the addition of a solute (NaCl) to a pure solvent (water) lower the freezing point of water (ice)?

5. When water freezes at 0°C the hydrogen bonds give water a rigid structure (water expands as it freezes) as shown in Figure 1.

6. Ice (solid water) is typically coated with a thin film of liquid water. Once salt is sprinkled on the ice, the ice begins to melt to form an increasing amount of liquid water and essentially, a *salt solution* is formed with a *lower freezing point* of 0°C. The presence of the salt in the water disrupts the crystalline structure of the ice and *interferes* with the attraction of the hydrogen bonds between the water molecules. In other words, the salt prevents the melting ice from *re-freezing.* As a result, water molecules experience a weaker attraction to each other and move with a greater amount of kinetic energy. In order for the liquid water in the salt solution to re-freeze, the temperature must be lower than 0°C to extract the additional kinetic energy from these liquid water molecules. The freezing point of this salt solution is thus lower than the freezing point of pure water. This difference between the freezing point of a solution and the freezing point of the pure solvent is referred to as the ***freezing-point depression***.

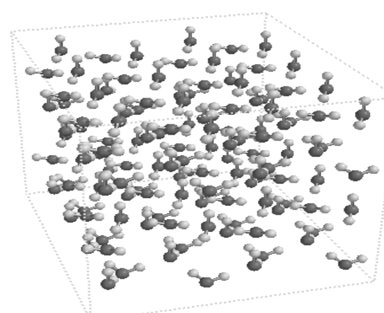

Figure 1 The solid water has a definite crystalline structure as a result of the hydrogen bonding.

Figure 2 Salt melts ice by lowering the freezing point of the water around the ice. The ice melts and is unable to re-freeze except at a much lower temperature.

Collaborative Annotation Chart

Directions: As you reread independently, annotate the article with the symbols below and write a comment/question/or response about what you read. When you and your partner are each finished reading, have a conversation using the language support about at least three of your comments. As you record your partner's response, paraphrase in your own words what your partner said rather than writing their response word for word.

Symbol	Comment/Question/Response	Sample Language Support
*	• Article's main points • Key ideas expressed • Significant ideas	• One significant idea in this text is… • The article is trying to explain that…
!	• Shocking statements or parts • Emotional response • Surprising details/claims	• I was shocked to read that …(further explanation) • How part about…made me feel…
O	• Ideas/sections you connect with • Something you have seen in your personal life • What this reminds you of	• I can connect with what the author said because… • This experience connects with my own experience that…

Symbol and Paragraph #	Comment/Question/Response	Paraphrase your Partner's Comments/Question/Response

<u>**Discussion Questions related to Let's Chill Lab**</u>

1. Use at least two of the four articles from Lesson 3 (Day 5 and 6) to respond to the following:
   a) Explain how the intermolecular force that exists between water molecules in the solid phase is different in the liquid phase?

   ____
   ____
   ____
   ____
   ____

   b) Why does ice float in liquid water?

   ____
   ____
   ____
   ____
   ____

2. Using your observation notes from the Heating Curve of Water lab and article 3.3d, how does a change in temperature correlate with <u>microscopic changes</u> of the kinetic energy and the strength of the intermolecular force between water molecules in the solid phase, and to the overall <u>macroscopic observation</u> of phase changes?

   ____
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3. How does the addition of a solute (NaCl) change the kinetic energy and the intermolecular forces of the water molecules in the solid phase (ice) and prevent the liquid water molecules from "re-freezing"?

   ____
   ____
   ____
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4. What are colligative properties and how does the knowledge of *freezing-point depression (lowering)* benefit drivers of an automobile? Or party hosts trying to chill their drinks for their guests?

   ____
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Quick Write: "*Water – What I Now Know*"

TASK #1: Review the lessons, articles, activities, labs, etc. from the past 12 days (six lessons).

You ONLY have TWO minutes. READY, SET, GO!!

TASK #2: **TOP TEN -** Recall and write down ten different water-related concepts that demonstrates the learning that you have accomplished in the six lessons. Refer back to the resources if needed. Complete sentences are not required. Use all the NEW academic vocabulary/language that you have learned.

You ONLY have FIVE minutes. GO!

1. ____________________
2. ____________________
3. ____________________
4. ____________________
5. ____________________
6. ____________________
7. ____________________
8. ____________________
9. ____________________
10. ____________________

TASK #3: Find your partner and sit together ASAP. Youngest person reads their list first. If you are listening, listen for a concept that you do not have on your list. Add this concept to your TOP TEN if you do not have ten; otherwise, add the concept below. Ask your partner to re-read the concept if needed. Switch roles. *IF you and your partner have 10 concepts that are very similar, then together you will come up with 2 NEW concepts. Take the challenge!*

You ONLY have FIVE minutes! GO!

1. ____________________
2. ____________________

TASK #4: You and your partner must decide which water-related concepts were the most important, intriguing, or fascinating. Three complete sentences are required. Provide justification for your choices.

You ONLY have THREE minutes! GO!

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