States of Matter Booklet

Physical Change – Physical changes occur when substances undergo a change that does not change their chemical nature. Compound formula stays the same!

Ex – ice melting

Chemical Change – In a chemical change where there is a chemical reaction, a new substance is formed. Evidence that a chemical reaction has taken place might include a colour change or a release of heat.

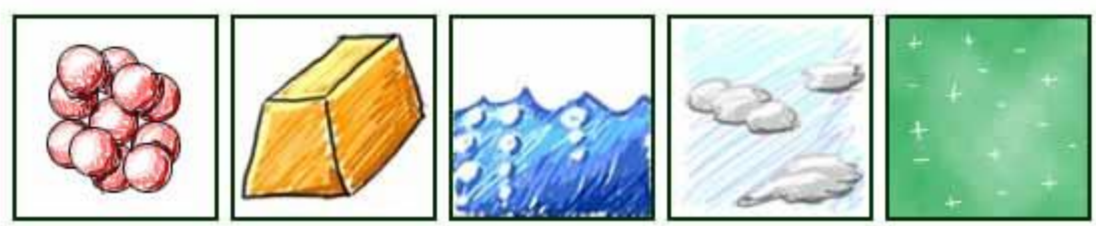
Ex – baking cookies

In this unit we focus on physical changes. For the rest of the year we will focus on chemical changes.

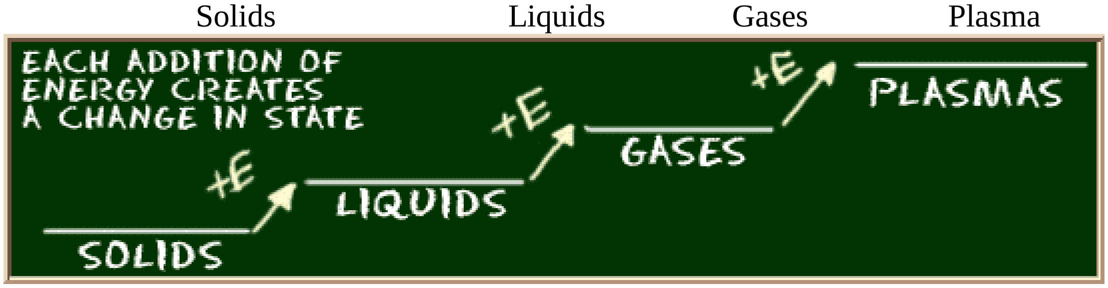
Physical (Phase) Changes – A Change of State

A phase describes a physical state of matter. Substances only move from one phase to another through physical changes. If energy is added (like increasing the temperature or increasing pressure) or if energy is taken away (like freezing something or decreasing pressure) you have created a physical change.

Examples of physical changes –
–
–



Solids Liquids Gases Plasma



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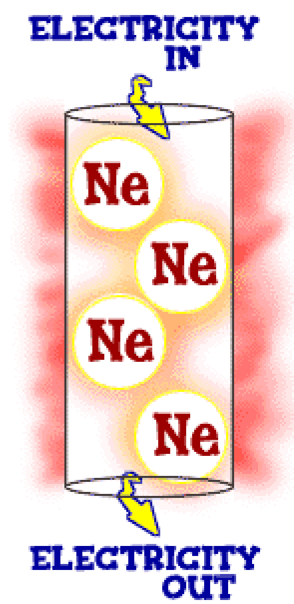
Solids – Solids are usually hard because their molecules have been packed together. The closer the molecules are together, the harder the substance will be. Because solids are so 'hard' one of their important characteristics is that they **hold their own shape**.

Liquids – Liquids are an in-between state of matter. They can be found in between the solid and gas states. An important characteristic of a liquid is that if you pour liquid into a container it will **take the shape of the bottom** of the container.

Gases – Gases are random groups of atoms. Gases are really spread out and the atoms and molecules are full of energy, colliding constantly. Gases can **fill a container** of any size or shape.

Plasma – Plasmas are a lot like gases, but the atoms are different because they are made up of free electrons and ions of the element.



We do not find plasma often on Earth. There are special requirements needed for plasma to exist which makes them different from the other states of matter.

Natural examples are the Northern Lights, stars or ball lightning. Other examples of plasmas include a fluorescent light bulb or neon signs. Inside the long tube of the light or sign is a gas. Electricity flows through the tube when we turn the light on. The electricity acts as a special energy and charges up the gas exciting the atoms and creates glowing plasma inside the bulb.

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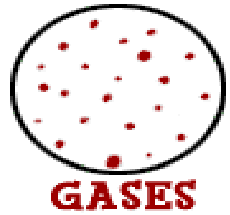
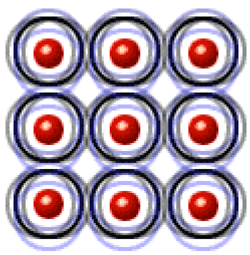
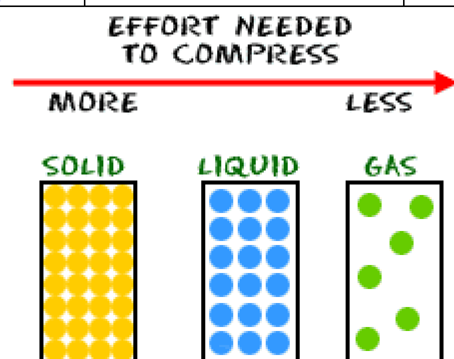
States Table

	Solids	Liquids	Gases
Diagram			
Particle Arrangement What do the particles look like?	The molecules in a solid are stuck in place. 	Atoms in liquids are bouncing and floating around, free to flow but are still attracted to each other. ____________ **Station 1** – There are spaces in between liquid molecules.	Atoms and molecules in gases are rapidly bouncing and floating around, free to move where they want.
Compressibility Can you squeeze them together?			
	Station 5 – **Hardest**	**Station 5** – **Easier**	**Station 5** – **Very Easy**
Diffusion The process by which molecules move from areas of high concentration, to areas of low concentration.	**Hypothesis** – **Solids do not undergo diffusion because their particles are barely moving.**	**Station 6** – **Liquids undergo diffusion slowly because their particles are moving, but not as rapidly as gas molecules.**	**Station 6** – **Gas molecules diffuse quickly because their particles are moving rapidly and can spread to an area of low concentration quickly.**

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Fluidity Do they flow and change shape?	**Station 2 –** **Solids do not flow**	**Station 2 –** **Liquids do flow**	**Station 2 –** **Gases flow**
Density (g/mL)	Average density of Zn = Pb = **Solids are the most dense.**	Average density of Water = Bleach = **Liquids are medium dense.**	Average density of CO_2 = **Gases are the least dense.**

Station 1 – Particle Arrangement in Liquids

1. Measure 15 mL of ethanol using the marked graduated cylinder.
2. Pour the ethanol into a large dry test tube.
3. Using the black marker draw a line on the test tube at the meniscus of the ethanol.
4. Measure 15 mL of water using the marked graduated cylinder.
5. Carefully and slowly pour (try not to let the liquids mix too much) the water into the same large test tube that has your ethanol.
6. Using the black marker draw a line on the test tube at the very top meniscus.
7. How many millilitres of liquid do you have in your test tube now? ____________
8. Cork your test tube and shake it vigorously. Please keep your thumb on the cork so that no liquid goes flying. Shake for 30 seconds to a minute.
9. Once the liquid has settled check to see how the meniscus now compares to the line you drew on the test tube. What do you see? _________________________
   ____
10. Pour all of your liquid in your test tube into a clean dry 50 mL graduated cylinder. How many millilitres of liquid do you have now? _________________________
11. Describe what happened? **We combined water & ethanol and our volume decreased.**
12. Looking at your results, what could this mean about the particle arrangement in liquids? **There are spaces between liquid molecules and the smaller water molecules were able to fit in between the larger ethanol molecules.**
13. Put a one sentence summary in the **states table** where it says station 1.
14. Please put the used graduated cylinders back in the tray.

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Station 2 – Fluidity

Gases

1. Crush up two alka seltzer tablets (or Tums) in the mortar and pestle.
2. Light the candle.
3. Dump the alka seltzer into 50 mL of tap water in a small 100 mL beaker.
4. Once fizzing starts tilt the beaker towards the lit candle – essentially pouring the gas that is being released onto the candle.
5. Be careful not to let any of the water pour onto the candle.
6. The gas being released is carbon dioxide. If you are successful in pouring your gas the candle should be extinguished (go out), or at least flicker.
7. If you successfully 'poured' gas put a **yes** in the fluidity row under gases.
8. Please put used beakers back in the tray.

Liquids

9. Look at the small beads in the beaker.
10. Transfer them between a few different containers.
11. Notice how they can be poured and they take the shape of the bottom of the new container but do not fill the container as a gas would.
12. Put a one sentence summary under liquids in the fluidity row.

Solids

13. Do solids flow? ___________________________. Record this in your table.

Station 3 – Density of Solids

1. Weigh the two solid metals on the scale. Record their mass in grams.
2. Calculate the volume of metal by filling a 50 ml graduated cylinder to 35 ml with water. Drop the metal into the graduated cylinder. The amount that the volume of water increased is the volume of the metal. For example if the volume now reads 38 ml the volume of metal is 3 ml.
3. Record the volume in the table on the next page.
4. Calculate the density of the two solids and record in the table on the next page.

Station 4 – Density of Liquids and Gases

5. Weigh 2 small graduated cylinders and record their mass here.________________
6. Now pour 10 ml of water into one and 10 ml of bleach into the other.
7. Re-weigh the graduated cylinders and record their mass here. ________________
8. The difference in the mass from before and after you added the liquids, is how much the liquid weighs. Record that value in the table below.
9. In the chart on the next page record the volumes of the two liquids.

10. Weigh an empty balloon and record its weight here. _________________
11. Weigh the blown up balloon and record its mass here. _______________

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12. The difference in the mass from the empty balloon to the full balloon is how much the gas weighs. Record that value in the table below.
13. The volume of the balloon is 250ml; trust me.
14. Calculate the density of carbon dioxide.
15. Calculate the densities of the two liquids.

16. Rank the densities from most dense to least dense. ___________________________
17. Record your generalizations & observations in the density row of the states table.
18. If you run out of time at this station that is ok because station 5 is a short one.

Substance	Mass (g)	Volume (ml)	Density (g/ml)
Lead			
Zinc			
Water			
Bleach			
Carbon dioxide			

Station 5 – Compressibility of Solids, Liquids and Gases

1. Compare the three filled balloons at this station. Balloon 1 has a solid in it. Balloon two has a liquid in it. And balloon 3 has a gas in it.
2. Try and hold the balloon in your hand so that balloon can not change shape and then try and press down on the balloon.
3. Which one is the easiest to compress? ______**gases**_____
4. Which is the most difficult? ________**solids**______________
5. Explain why this might be the case. **The further apart the particles are the easier they are to compress. Because gas particles are far apart they can be pushed together. Solid particles are already so close together that they can not be compressed any more.**
6. Rank them in terms of compressibility and record your results in the table.
7. If you are done this station early finish the math in station 3 or work on the crossword puzzle on the last page of this booklet.

Station 6 – Diffusion of Liquids and Gases

Liquids
1. Place a few drops of vanilla into a balloon and rub the vanilla around.
2. Blow up your balloon. If you can smell the vanilla through the balloon then the liquid is diffusing through the membrane of the balloon.
3. Record your results in the table. Do liquids undergo diffusion? ___________
4. Please pop your balloons (quietly) and place the used balloons back in the beaker.

Gases
5. Have two group members stand about 5 meters apart in the hallway.
6. Have one group member squirt the perfume provided.
7. Observe how quickly your partner can smell the gas.

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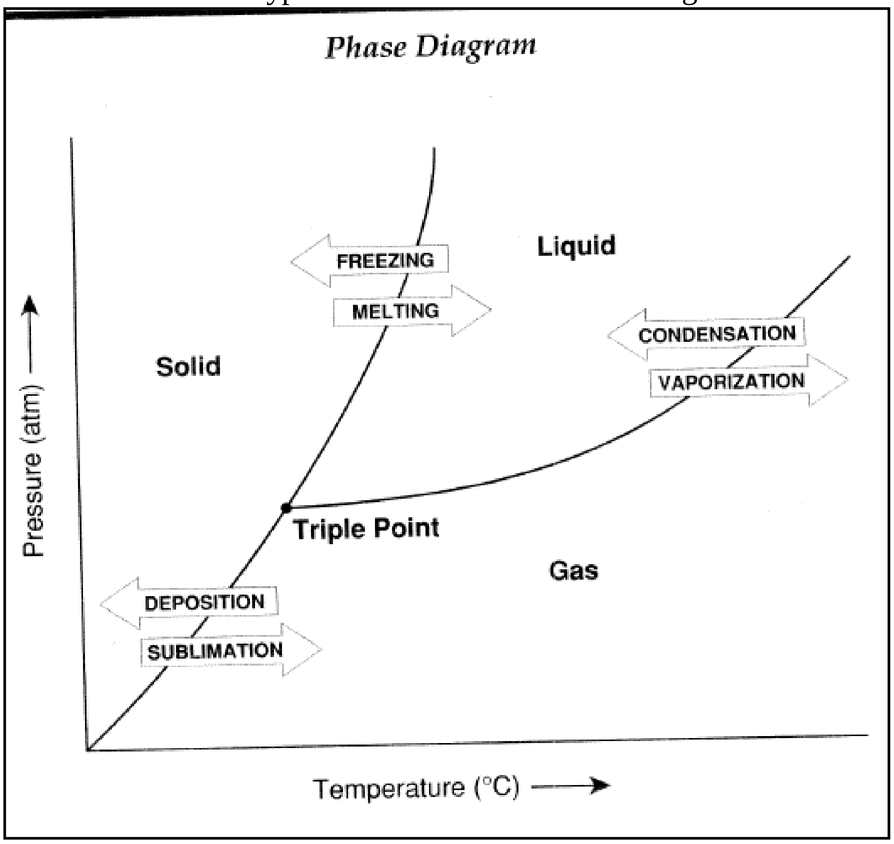
8. Does this make you think that gases undergo diffusion? ________________
   Record your results in the table.

Solids

9. In the table hypothesize if solids would undergo diffusion.



Give this try a…..

Science Crossword Puzzles

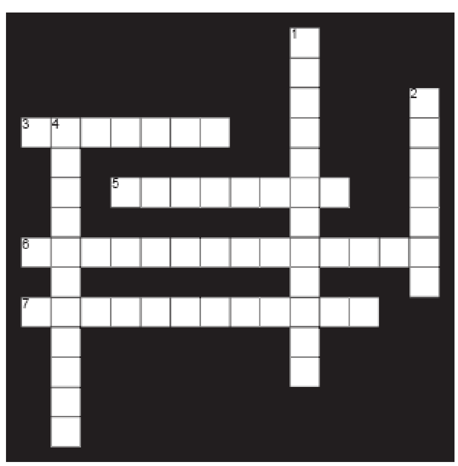
Matter Changing States

Across

3. An ice cube changing to water.
5. A liquid turning into a solid.
6. Hot lava cooling and hardening.
7. Another word for four down.

Down

1. Dew forming on grass.
2. A kettle whistles because the liquid inside of it is...
4. A puddle of water disappearing.



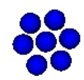
The Kinetic Molecular Theory

The Kinetic Molecular Theory explains the forces between molecules and the energy that they possess.

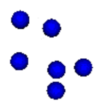
The theory has three main points.

1. Matter is composed of small particles (molecules).

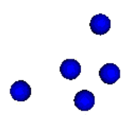
2. The molecules are in constant motion. This motion is different for the three states of matter.
   Solid - Molecules will bend and/or vibrate, but will stay in close proximity.

   Liquid - Molecules will flow or glide over one another; the motion is a bit more random than that of a solid.

   Gas - Molecules are in continual motion. The kinetic energy of the molecule is greater than the attractive force between them; therefore the molecules are much farther apart and move freely of each other.

3. When the molecules collide with each other, or with the walls of a container, there is no loss of energy.

Kinetic Molecular Theory and Gases

1. A gas consists of a collection of small particles traveling in straight-line motion and obeying Newton's Laws.
2. The molecules in a gas occupy no volume (it is all the space between the molecules that occupy volume).
3. There are no attractive or repulsive forces between the molecules
4. Collisions between molecules are perfectly elastic (that is, no energy is gained or lost during the collision).
5. The average kinetic energy of a system increases as temperature increases.

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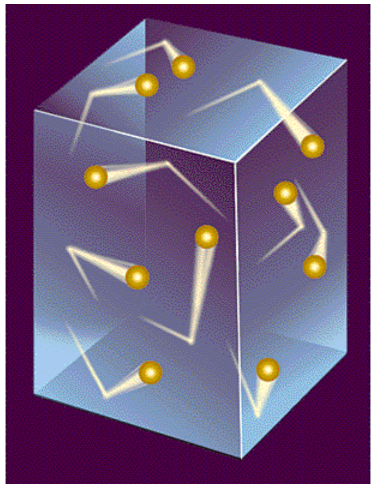
Random Motion

1. A gas consists of a collection of small particles traveling in straight-line motion and obeying Newton's Laws.
2. The molecules in a gas occupy no volume (it is all the space between the molecules that occupy volume).



Intermolecular Forces

3. There are no attractive or repulsive forces between the molecules.

If the forces between gas molecules were significant, the molecules would stick together. This is what happens when it rains and gaseous water molecules stick together to form a liquid. Because gases are not always 'sticking' together we can conclude that in a gas, molecular attractive forces are not just small, but essentially zero. This is not true of liquids and solids.

Elastic Collisions

4. Collisions between molecules are perfectly elastic (that is, no energy is gained or lost during the collision).

An elastic collision means that no energy is lost or gained during the collision. The walls do not add any energy to the system. Therefore, the gas molecules speed is not changed.

Collision animation

http://www.chm.davidson.edu/chemistryApplets/KineticMolecularTheory/BasicConcepts.html

Watch this demonstration with one gas molecule and answer the following questions.

a) Is the lone gas molecule undergoing an elastic collision or an inelastic collision?
b) What does the speed graph show about the gas particle?

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Now watch the demonstration with more than one gas molecule and answer the following questions.

c) When the gas molecules collide with each other are they undergoing an elastic collision or an inelastic collision?
d) What does the speed graph show about the gas particle collisions?

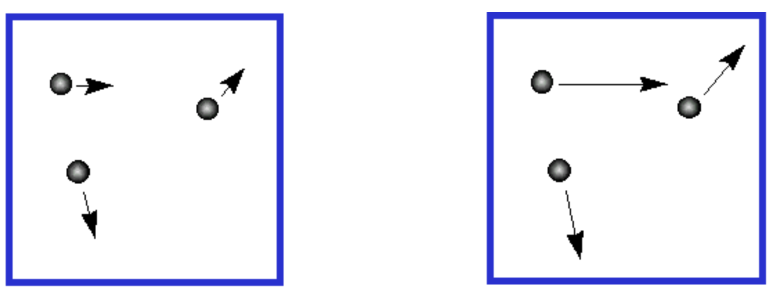
Note that each collision causes an abrupt change in speed and in direction.

Average Kinetic Energy & Temperature

5. The average kinetic energy of a system increases as temperature increases.

Absolute Temperature

- The absolute temperature of a gas is a measure of the average kinetic energy of its' molecules.
- If two different gases are at the same temperature, their molecules have the same average kinetic energy.
- If the absolute temperature of a gas is ***doubled***, the average kinetic energy of its molecules is ***doubled.***
- If the temperature approaches absolute zero, the kinetic energy of the molecules approach zero and they 'stop'.



Lower average kinetic energy **Higher average kinetic energy**
Lower absolute temperature **Higher absolute temperature**

Temperature & Particle Speed Relationship
http://www.chm.davidson.edu/chemistryApplets/KineticMolecularTheory/Maxwell.html

How does an increase in temperature affect the speed of gas particles?
How does an increase in temperature affect the range of speeds of gas particles?

Balloon Demonstration

When we placed the three different balloons in different temperatures what did we observe? Why did that happen?

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Kinetic Molecular Theory of Solids & Liquids

Complete this table using what you already know about solids, liquids and gases as a guide line. Sometimes it helps to rank them or compare the different phases.

	Solids	Liquids	Gases
Distance Between Particles			
Intermolecular Forces of Attraction			
Average Kinetic Energy			

Summary

As temperature increases, random motion increases, causing the particles to move farther apart, which reduces the strength of intermolecular forces.

The overall reduction in forces holding particles in a particular phase allows phases to change as energy is absorbed.

So, if the temperature of a liquid is raised enough the kinetic energy increases to the point where it **over comes the forces of attraction** and a gas is formed. This is what causes phase changes.

Do page 503 #1-3, 5

Solid Structures

Amorphous

Amorphous solids are solids with random unoriented molecules that lack a regular three-dimensional arrangement of atoms (glass and plastic). They are considered super-cooled liquids where the molecules are arranged in a

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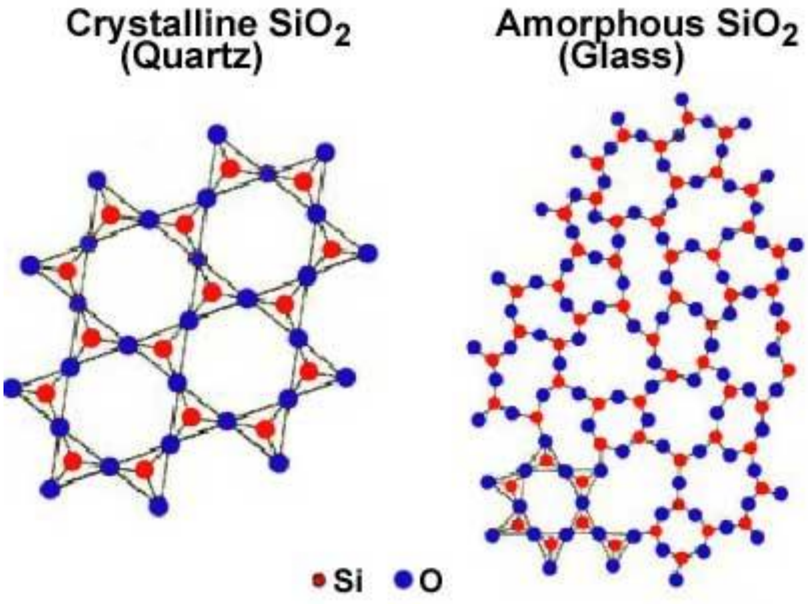
random manner (like in the liquid state) and then rapidly cooled causing solidification.



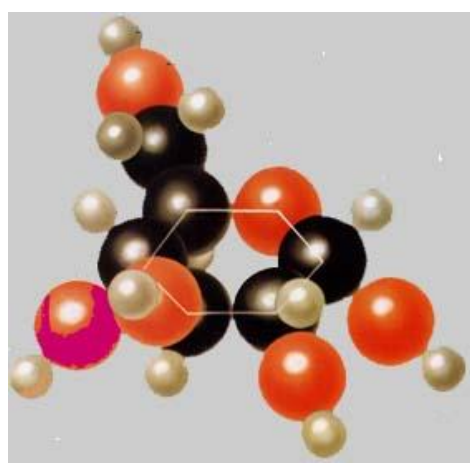
Crystalline

Crystalline solids are arranged in fixed geometric patterns or lattices. They have orderly arranged particles and are practically incompressible.

- Covalent network (diamonds and graphite)
- Ionic (NaCl, CaF_2)
- Molecular (I_2, S_8)
- Metallic (Cu, Ag)

Covalent Network Solids

Atoms are held together by covalent bonds.



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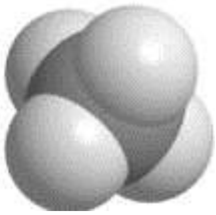
Sugar $C_6H_{12}O_6$



CH_4

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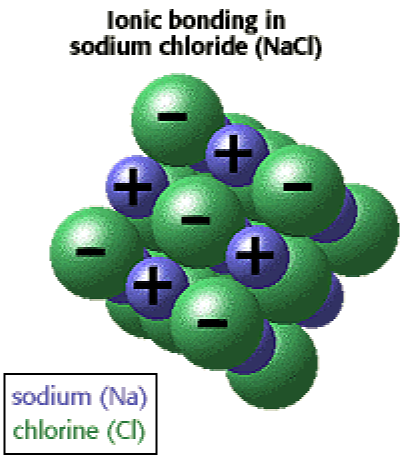
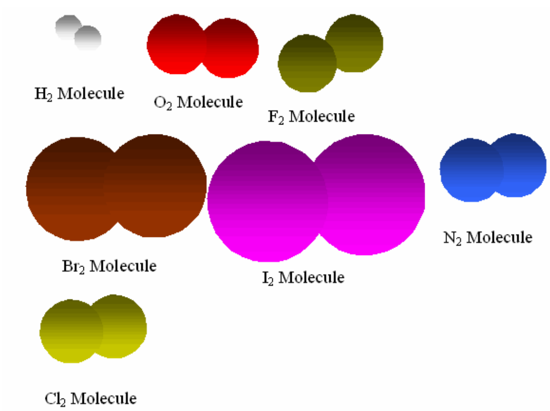
Ionic Compounds

Oppositely charged ions are held together by attractive forces. Positives and negatives attract each other. The positive sodium ions line up so that they are arranged near to a chlorine ion.

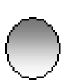


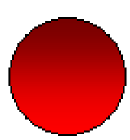
www.biology.arizona.edu

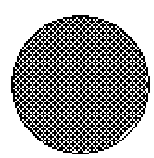
Molecular Solids



Metallic Solids







Cu atom	**Ag** atom	**Au** atom

http://www.chem4kids.com/files/matter_liquid.html
Adapted form the Manitoba Science Curriculum.

14–1 Explore

Turn Up the Heat, I'm Slowing Down!

In this activity you will explore how temperature affects the rate of movement of particles.

Materials (per group)

three identical glasses, jars, or beakers
cold water
room-temperature water
hot water
food coloring

Procedure

1. Place three identical glasses on a table and fill one with cold water, one with room-temperature water, and one with hot water. CAUTION: Be careful with hot water.
2. Wait for the motion of the water in the glasses to stop.
3. Place a few drops of food coloring in the water of each glass, a few millimeters above the surface center region of the water. CAUTION: Avoid getting food coloring on your clothes.
4. Observe how the drop of food coloring mixes with the water in each glass.
5. After several minutes, note any differences in the amount of mixing of the food coloring in the three glasses.

Questions

1. Compare the movement of the food coloring in the three glasses.

____

____

2. What factor(s) do you think account for the differences in movement you detected? Explain.

____

____

____

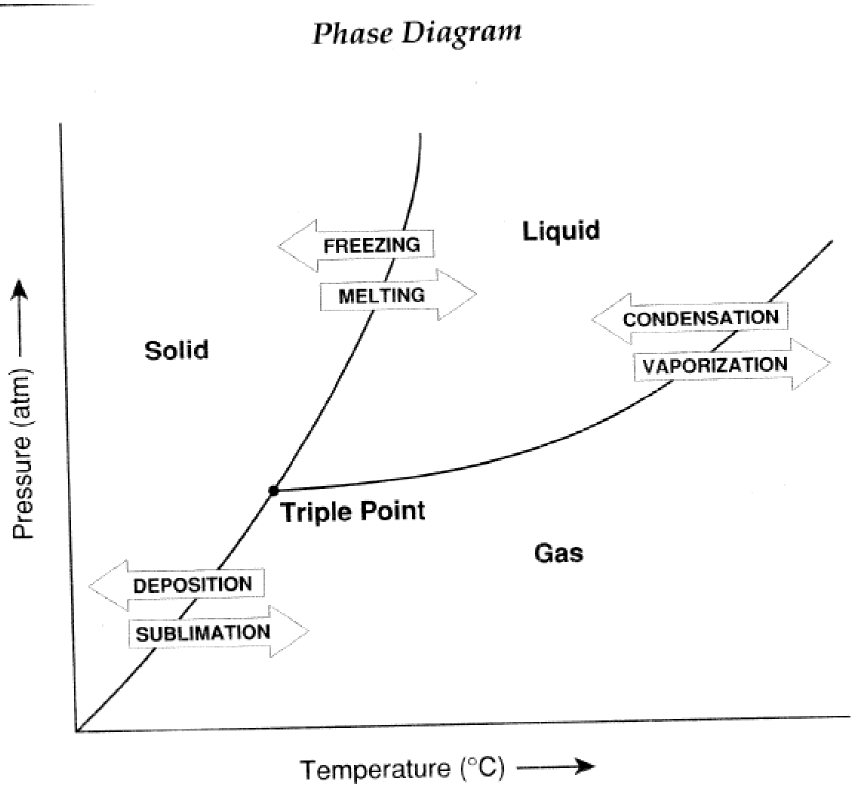
3. Use your observations to predict what would happen if you placed one teabag in a glass of hot water and another teabag in a glass of cold water. Explain.

____

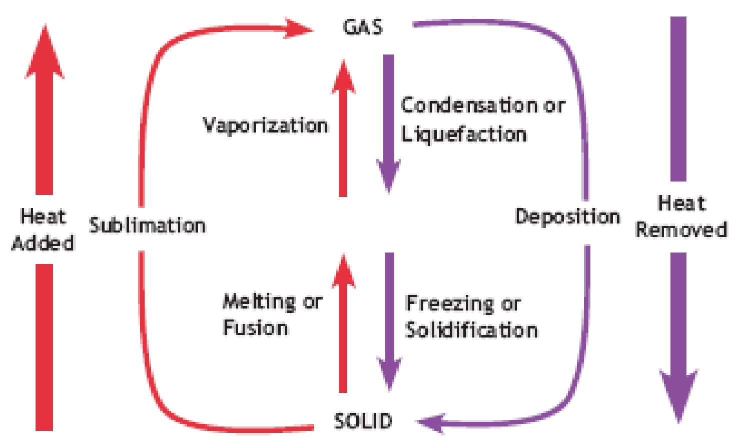
____

____

Kinetic Molecular Theory and State Changes

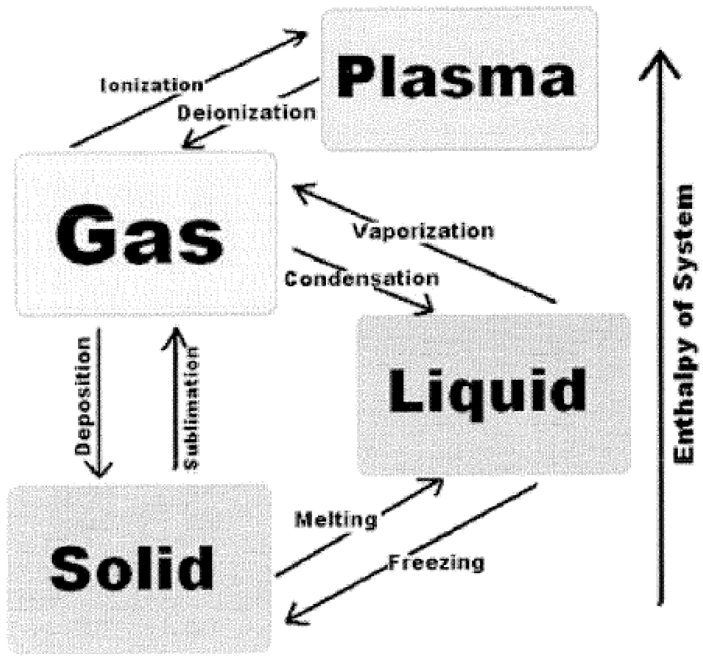


Diagram



We are going to focus on where heat is added and where heat is released. Add arrows to your diagram (in another colour if you can) to show where heat is added and where heat is released.

http://www.chem4kids.com/files/matter_liquid.html
Adapted form the Manitoba Science Curriculum.



Terminology

Endothermic – when heat is absorbed by a reaction. The substance will often feel cold because it is absorbing (taking) the heat from your hand. You can remember this because heat is **en**tering the system.

Exothermic - when heat is released by a reaction. The substance will often feel hot because it is releasing (giving) heat to your hand. You can remember this because heat is **ex**iting the system.

Which three state changes are endothermic? Evaporation, melting, sublimation

Which three state changes are exothermic? Condensation, freezing, deposition

What the heck is going on?

The reason we must add energy to move from a solid to a liquid to a gas is because we must overcome the forces of attraction between the molecules. Once we have enough energy to overcome these forces the molecules move farther apart and start moving around more rapidly. The addition of heat energy causes an increase in kinetic energy, which breaks the forces of attraction causing a state change.

http://www.chem4kids.com/files/matter_liquid.html
Adapted form the Manitoba Science Curriculum.

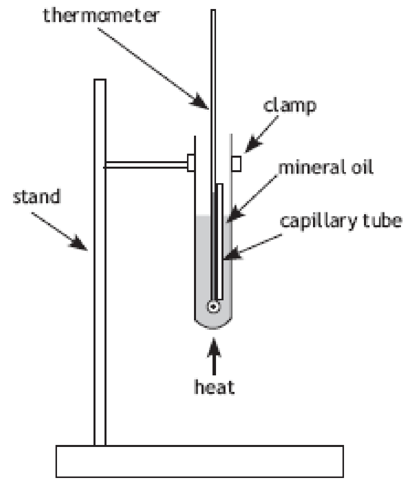
A minimum amount of kinetic energy is required for particles to change to the next phase and overcome the intermolecular forces; this is called the threshold energy. This energy is released when we go in the opposite direction from a gas to a liquid to a solid.

How strong these intermolecular forces are account for the variations in melting point, boiling point and other characteristics of compounds.

Looking at the melting points below, which solid has the highest intermolecular forces? How can you tell? Stearic acid, because it has the highest boiling point which means we needed the most energy to overcome the intermolecular forces.

Any of the following solids could be used for this lab:

- stearic acid MP 69.6°C
- palmitic acid MP 63.0°C
- thymol MP 50.0°C
- maleic anhydride MP 53.0°C
- cinnamic acid MP 42.0°C



http://www.chem4kids.com/files/matter_liquid.html
Adapted form the Manitoba Science Curriculum.

Iodine & Fingerprinting

Remember **sublimation** is the change of a solid substance directly into a vapor without first passing through the liquid state. An example of sublimation is seen when iodine, on being heated, changes from a dark solid to a purplish vapor that condenses directly to a crystalline solid upon striking a cool surface. In this way pure crystals of iodine are prepared. Interestingly, the deposition of iodine vapour (going from a gas directly to a solid) was used in the past in fingerprint detection. To retrieve fingerprints off of the skin of people. Think about the purple fingerprints they are able to pull up on CSI.

Appendix 1.7: Making Fingerprints Visible

Materials

- unlined white index cards or white paper
- iodine (I_2) crystals
- Erlenmeyer flask (250 or 125 mL)
- burner
- tongs
- scissors

Procedure

1. Cut narrow strips of paper small enough to be held in the neck of the Erlenmeyer flask.
2. Press one of your fingers firmly on one end of a paper strip.
3. Place some iodine crystals (an amount about the size of a pencil eraser) in the flask. Heat gently with a burner or on a hot plate until the iodine begins to vaporize. **Caution:** Be careful. Do not breathe iodine vapour. Perform this in the fume hood.
4. Place the paper strip into the flask to expose it to the iodine vapour. Hold until changes to the paper are observed.

Questions

1. What changes of state are happening in this experiment?
2. What is the heat adding to the system?
3. What might the phase change diagram of iodine look like?

http://www.chem4kids.com/files/matter_liquid.html
Adapted form the Manitoba Science Curriculum.

Intermolecular Forces between Liquids

Activities

A number of activities can be done to measure qualitatively the differences in the intermolecular forces in liquids by measuring the relative rates of evaporation. The following liquids are suggested for the first two activities: water, ethanol, methanol, acetone, isopropyl alcohol, and cyclohexane.

1. Swab each liquid onto an impermeable smooth surface and observe the time it takes for the liquid to disappear. **Do not** place on skin.

Questions

1. Which liquid has the highest intermolecular forces? Water – it was the last to evaporate.
2. Which liquid has the least intermolecular forces? Acetone or cyclohexane or isopropyl – both evaporated really fast!
3. How can you tell?
4. Which liquid needed the least amount of kinetic energy to evaporate? Acetone or cyclohexane
5. What happened to the liquid particles as they changed state?
    a. They became gases
    b. They sped up
    c. They spread out
    d. They overcame the intermolecular forces!!!!!!!

14–1 Review and Reinforcement

Condensed States of Matter

Fill in the following chart comparing solids and liquids.

Physical Property	Liquids	Solids
1. Compressibility		
2. Density		
3. Shape		
4. Rate of Diffusion		

Answer each of the following questions in the space provided.

5. Describe the behavior of the molecules in a liquid. Explain this behavior in terms of intermolecular forces.

____

____

6. How do intermolecular forces determine molecular arrangement in solids?

____

____

If the statement is true, write "true." If it is false, change the underlined word or words to make the statement true. Write your answer on the line provided.

______________ **8.** Intermolecular forces are forces of attraction between <u>atoms</u>.

______________ **9.** Chemical bonds are the forces between <u>molecules</u>.

______________ **10.** Covalent bonds result from electrons being shared between atoms in a <u>molecule</u>.

______________ **11.** <u>Intermolecular</u> forces result from the electron interactions between neighboring molecules.

Complete each of the sentences below.

15. The stronger the intermolecular forces in a liquid, the ______________ its boiling point.

16. The state of a substance at room temperature depends on ______________.

17. Water molecules in an ice cube are held together by ______________ forces or, more specifically, ______________ bonds.

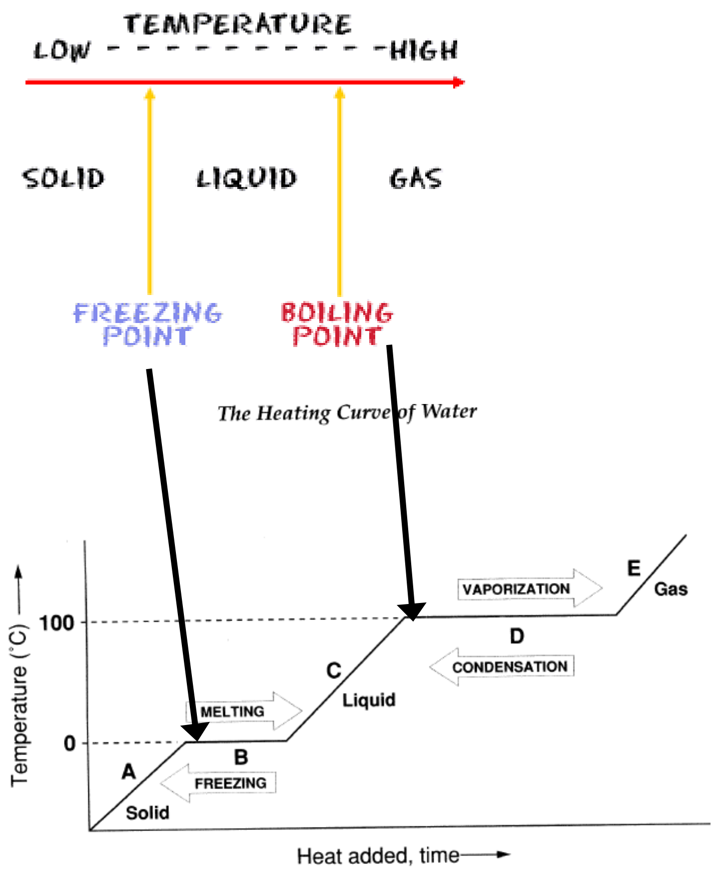
http://www.chem4kids.com/files/matter_liquid.html
Adapted form the Manitoba Science Curriculum.

Evaporation & Condensation

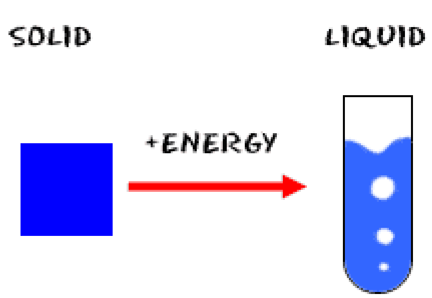
In our lab last class we looked at the heating curve for water. You were supposed to specifically identify the melting point and boiling points.

Melting point – The temperature at which a solid begins turning to a liquid.

Boiling Point – The temperature at which a liquid begins turning to a gas.



The plateau of the graph represents the absorption of energy as the state changes. The plateau happens because while more energy is being added to the system that energy is being used to overcome the forces of attraction between particles and not raising the temperature of the system. The temperature goes up again once all the forces of interaction have been broken. Hopefully you saw a plateau around 100°C on your water heating curve.



http://www.chem4kids.com/files/matter_liquid.html
Adapted form the Manitoba Science Curriculum.

Energy is added causing the change of state from a solid to a liquid and from a liquid to a gas. As the forces that keep the particles together are broken the particles have more energy and are free to move apart.
As the temperature increases, the average kinetic energy of the solid substance increases and more particles would have enough energy to "escape" and become particles of the liquid phase. This is also true of liquid particles changing to the gaseous phase.

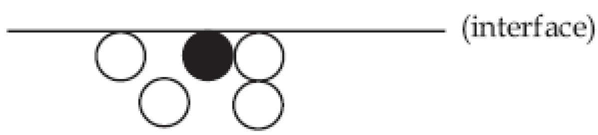
Vaporization & Evaporation

Vaporization is the process by which a liquid changes to a gas or a vapour. When vaporization occurs at the surface of a liquid, the process is called *evaporation*.

Evaporation from the Surface

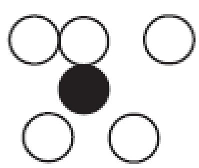
If a sample of liquid is left open to the air, particles at the surface collide with other particles and absorb enough kinetic energy to overcome the forces of attraction and change into the gaseous state.

The reverse is true if a particle collides with an air particle above it, it may lose energy and become part of the liquid again. Particles cross back and forth across a state interface (see diagram below).



Vaporization from within the Liquid

There are more particles surrounding the particle causing greater forces of attraction within the liquid.

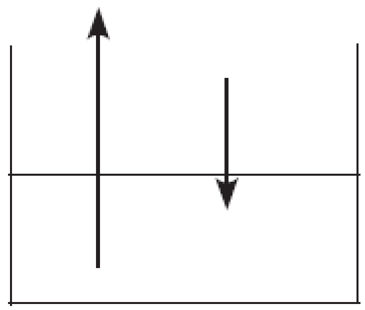


If a particle within the liquid absorbs enough energy to change into a gaseous particle, it is more likely to collide with another liquid particle, lose energy, and return to the liquid state.

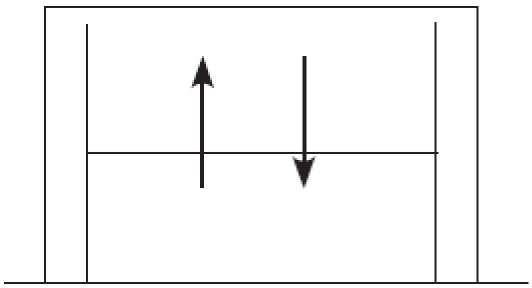
This argument can be used to explain why evaporation happens at the surface. If the surface area is increased, the rate of evaporation increases.

http://www.chem4kids.com/files/matter_liquid.html
Adapted from the Manitoba Science Curriculum.

At the surface, two processes are occurring: a rate of evaporation and a rate of condensation as gaseous particles are "recaptured" by the liquid state.



If a container of liquid is open, the rate of evaporation will usually exceed the rate of condensation and the level of the liquid will drop as liquid particles move into the gaseous state.



However, if the container is closed, the rate of condensation will eventually equal the rate of evaporation and the level of the liquid will no longer change; assuming the temperature is kept constant. This is called a ***dynamic equilibrium***; the liquid level will not change.

Example – a glass of water vs. a sealed water bottle.

Evaporation causes the formation of vapours. A **vapour** is the gaseous state of a substance that would normally be liquid or solid at room temperature. Substances that evaporate rapidly are said to be **volatile**. They have lower intermolecular forces of attraction holding particles into the liquid phase.

Examples of volatile liquids -

Equilibrium Discussion

1. Describe a sport that works as an analogy for equilibrium.

2. What might happen to equilibrium if temperature is added?

3. Why do liquids evaporate at different rates?

Boiling Point and Vapour Pressure
The Link between Temperature & Pressure

At low temperatures there is low kinetic energy, and only the particles at the surface of a liquid are able to evaporate into the gaseous state. As the temperature of the liquid increases the number of particles having enough energy to overcome the intermolecular forces of attraction increases so that particles within the liquid are also able to change to gaseous particles.

These gaseous particles form micro-bubbles within the liquid. If the vapour pressure in these micro-bubbles is less than the atmospheric pressure above the liquid, then the gas bubbles collapse and the gas particles within the bubbles return to the liquid state.

(Pressure $_{\text{bubble}}$ < Pressure $_{\text{atmospheric}}$) then the bubbles collapse (gas → liquid)

Diagram:

However, if the vapour pressure of these micro-bubbles equals or exceeds the atmospheric pressure above the liquid, then the bubbles become larger and rise to the surface.

(Pressure $_{\text{bubble}}$ > Pressure $_{\text{atmospheric}}$) then the bubbles rise to the surface and gas escapes.

Diagram:

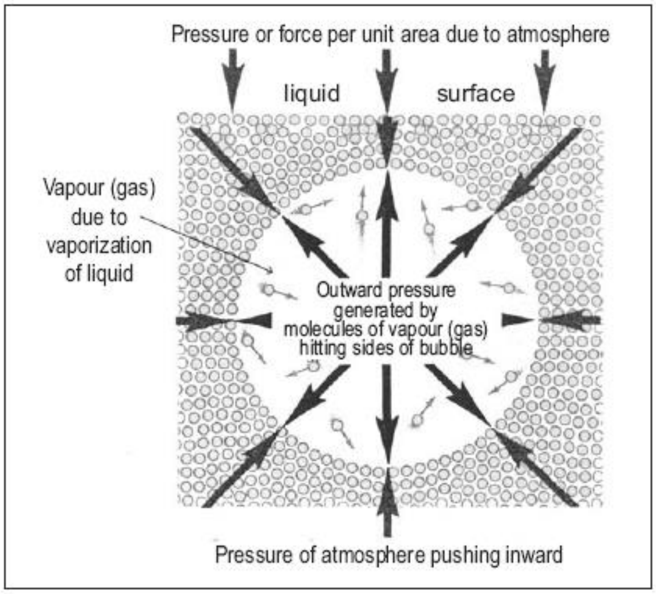
As the temperature of the liquid increases, more micro-bubbles form because more particles have enough energy to change phase. **The boiling point is the temperature at which the vapour pressure of the liquid (pressure within the micro-bubbles) equals the atmospheric pressure above the liquid and you "see boiling".**

The ***Normal boiling point*** occurs when the atmospheric pressure above the liquid is standard pressure (1 atmosphere, 101.3 kilopascals [kPa], or 760 mm of mercury).

Again – the vapour pressure is the gaseous pressure within the liquid (not at the surface) forming micro-bubbles.

What might happen if the pressure above a liquid was decreased to the same value as the vapour pressure?
The liquid will boil, because the vapour pressure will equal the atmospheric pressure and we will see "boiling". Liquids will boil at almost any temperature if the atmospheric pressure above the liquid is low enough.

http://www.chem4kids.com/files/matter_liquid.html
Adapted from the Manitoba Science Curriculum.



Bubble in a boiling liquid.

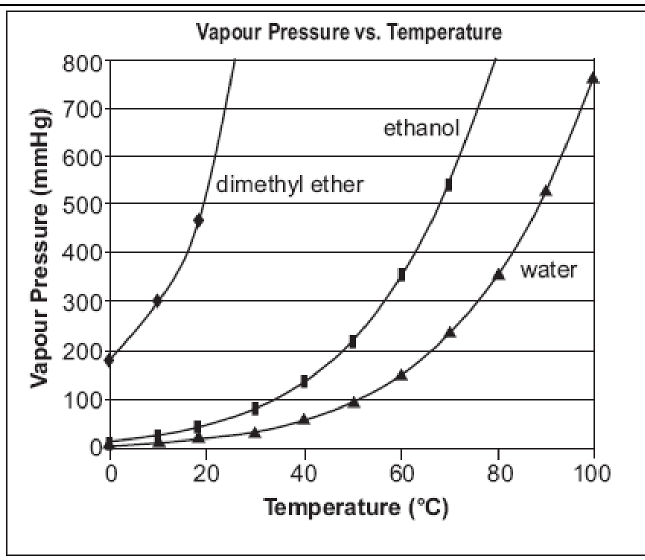
Questions

1. What is boiling?
2. What two ways can you make a liquid boil?

i) Heating up the liquid so that the vapour pressure of the gas inside the liquid equals the atmospheric pressure outside the liquid

ii) Decrease atmospheric pressure so that it matches the vapour pressure inside the liquid

Using the graph below answer the following questions:



Using the graph above answer the following questions:

1. What is the vapour pressure (VP) of ethanol at 40°C?
(135 mmHg)
2. Which substance would evaporate the slowest at 20°C? Explain your reasoning.
(water—lowest VP at any temperature)
3. Which substance has the least intermolecular forces of attraction? Explain your reasoning. **(dimethyl ether—greatest VP at any temperature)**
4. List substances in increasing order of intermolecular forces.
(dimethyl ether, ethanol, water)
5. Which substance would have the least viscosity at 20°C? Explain your reasoning.
(dimethyl ether—most volatile, least forces)
6. Determine the atmospheric pressure required to have dimethyl ether boil at 20°C.
(450 mmHg or lower)

States of Matter Dictionary

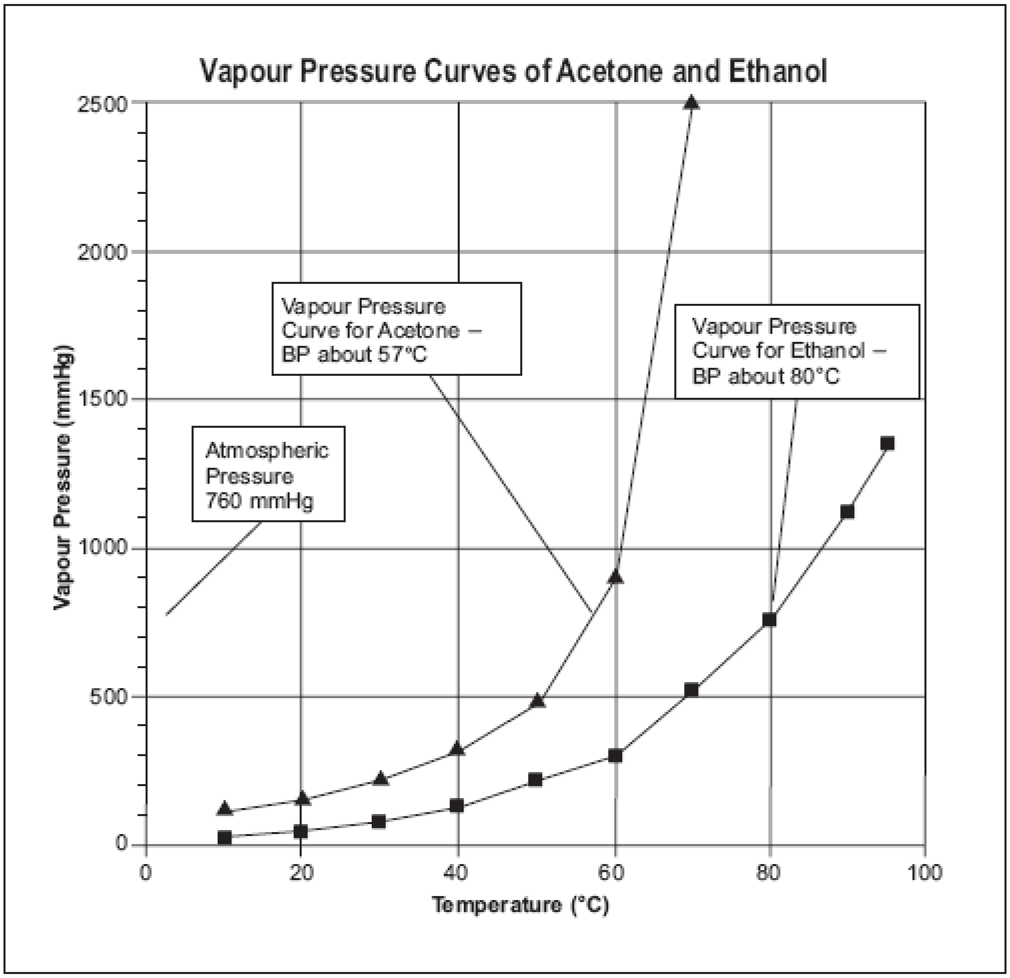
Term	Definition	In your own words
Melting Point		
Boiling Point		
Plateau		
Forces of Attraction		
Vaporization		
Evaporation		
Condensation		
Dynamic Equilibrium		
Vapour		
Volatile		

http://www.chem4kids.com/files/matter_liquid.html
Adapted from the Manitoba Science Curriculum.

Forces between Particles Worksheet

Question
What is the relationship between the pressure and the temperature of a gas?

Sample Data



Analysis

1. How are the graphs of pressure versus temperature the same between acetone and ethyl alcohol?
Both graphs have a similar sloping shape.

2. How are the graphs of pressure versus temperature different between acetone and ethyl alcohol?

Acetone's graphed curve has a steeper slope.

Conclusion

3. Based on the graphical data and graph, what is the general relationship between pressure and temperature?
As the temperature of a gas is decreased, its pressure also decreases. As the temperature of a gas is increased, its pressure also increases.

4. Is this relationship direct or indirect?
direct

Applications

5. Based on the vapour pressure measurements at room temperature, which compound do you predict has stronger intermolecular forces at work? Explain your reasoning.
Ethanol has stronger intermolecular forces at work. A larger amount of energy is required to overcome the stronger intermolecular forces that hold the liquid together.

6. Define the term *volatile*. Which of the two liquids do you expect to be the least volatile? Why?

***Volatile* means that a substance is easily vaporized at a lower temperature. Acetone is more volatile than ethanol because it has lower intermolecular forces. We can tell that because it has a higher vapour pressure.**

7. Why do you think that most pressurized cans labelled with warnings not to dispose of the cans by throwing them into a fire?

With extremely high temperatures created by fire, the contents of pressurized cans will also become very high, resulting in possible explosions.

CHE30S Name ___________________________

Worksheet Date ___________________________

Heating and Cooling Curves

The following data was collected after solid olive oil was placed in a hot water bath.

Time (min)	Temp (ºC)
0	-11.5
1	-10.0
2	-8.5
3	-7.1
4	-6.0
5	-6.0
6	-6.0
7	-6.0
8	-5.8
9	-4.0
10	-2.3

1. Graph the data on graph paper. Include all parts of a graph.

2. What was the starting temperature of the oil?

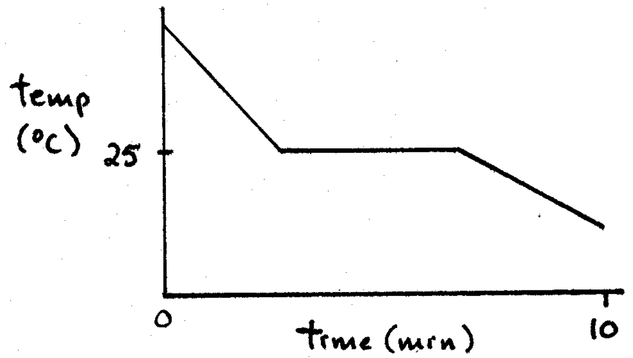
3. How was the oil changing during the first 3 minutes and the last 2 minutes that data was collected?

4. How was the oil changing during the time from 4 minutes to 7 minutes?

5. What is the melting temperature of olive oil?

6. What is the freezing temperature of olive oil?

The following graph shows the data obtained when liquid coconut oil was placed in an ice water bath.



Cooling curve for coconut oil (starting as liquid)

7. Describe what is happening to the oil during the time period shown.

8. What is the freezing temperature of coconut oil?

9. What is the melting temperature of coconut oil?

Appendix 1.14: Chemistry is Super: "Bingo" Review Game

Time: 1 hour

Purpose

To review the learning outcomes and concepts addressed in Topic 1: Physical Properties of Matter.

Game Instructions

1. Supply each student with a minimum of two slips of paper.
2. Assign each student two learning outcomes/concepts from Topic 1. (Vary the outcomes from student to student so that all outcomes/concepts for this topic are addressed.)
3. Ask students to create a question related to each of their assigned learning outcomes/concepts, and explain that the questions will be used in the review game to follow. Each question must be written in such a way that the answer will be a one-word response (i.e., fill-in-the-blank). The answer should be included on the slip of paper, along with the question. (In order for the game to work, at least 40 questions and answers must be provided.)
4. As students finish their questions, collect and verify them, and start to create a Word Splash of all the answers on the classroom board. (Time allotment up to this point should be no more than 30 minutes.)
5. When all slips have been submitted, and an entire Word Splash is on the board, hand out the Chemistry Is Super game sheet.
6. Have students randomly place 25 of the words written on the board onto their game sheet (one word per square). If two words are the same, students can put it down twice on their game sheet if they want to.
7. The teacher (or student) can read the questions from the slips one at a time to the class. As students determine the correct answer to a question, they cross out the answer on their game sheet.
8. When a student successfully crosses out a line (any direction), he or she must clearly and enthusiastically call out "Chemistry Is Super" to win. Play can continue until the end of class and multiple winners can be awarded, if desired.
9. Answers can be shared or discussed within the class for additional review. The game can also be played silently, with individual students trying to determine the answers on their own.

Game Sheet

A copy of the Chemistry Is Super game sheet is provided on the following page.

Chemistry Is				
S	U	P	E	R

http://www.chem4kids.com/files/matter_liquid.html
Adapted from the Manitoba Science Curriculum.

Properties of Matter Test Review

Terms to Know – You should be able to describe each of these words. As part of your review I would write each word in a scientific sentence.

Physical Change
Chemical Change
Solids
Crystalline
Amorphous
Liquids
Gases
Plasma
Melting
Freezing
Boiling
Vaporization
Evaporation
Condensation
Sublimation
Deposition
Particle Arrangement
Compressibility
Diffusion
Fluidity
Density
Intermolecular Forces
Kinetic Energy
Melting Point
Boiling Point
Heating curve
Plateau
Volatile
Threshold Energy
State change
Dynamic Equilibrium
Vapour
Atmospheric Pressure
Vapour Pressure
Pressure vs. Temp Graphs
Normal Boiling Point
Endothermic
Exothermic

You must be able to:

- Describe the properties of gases, liquids, solids, and plasma in terms of particle arrangement, density, compressibility and diffusion.
- Use the Kinetic Molecular Theory (5 main points specific to gas) to explain the properties of gases.
- Explain how the kinetic molecular theory relates to the difference between solids, liquids, and gases. (ie. particle movement and energy)
- Construct and interpret heating graphs from experimental data.
- Determine the melting and boiling temperatures of a liquid from a temperature versus time (heating curve) graph.
- Describe and explain the process of evaporation and condensation.
- Describe and explain the difference between evaporation and vaporization; you might want to use diagrams.
- Describe two ways that it is possible to boil a liquid.

- Explain how atmospheric pressure and vapour pressure relate to cause evaporation.
- Compare the normal boiling temperatures of various liquids, and relate these temperatures to intermolecular forces.
- Construct and interpret a graph of vapour pressure versus temperature.

What you should do to prepare for the test:

1. Review over your notes. Ask questions about anything you do not understand.
2. Write your own definitions for the terms above so that you can explain them on the test.
3. Make sure you have completed all the worksheets and handouts given in class. If not do them as practice now. If so go over some of the questions you had trouble with and do it again.
4. Go over your practice quiz. Those are great test questions.
5. Get a good night's sleep and have a good breakfast. You will do great!