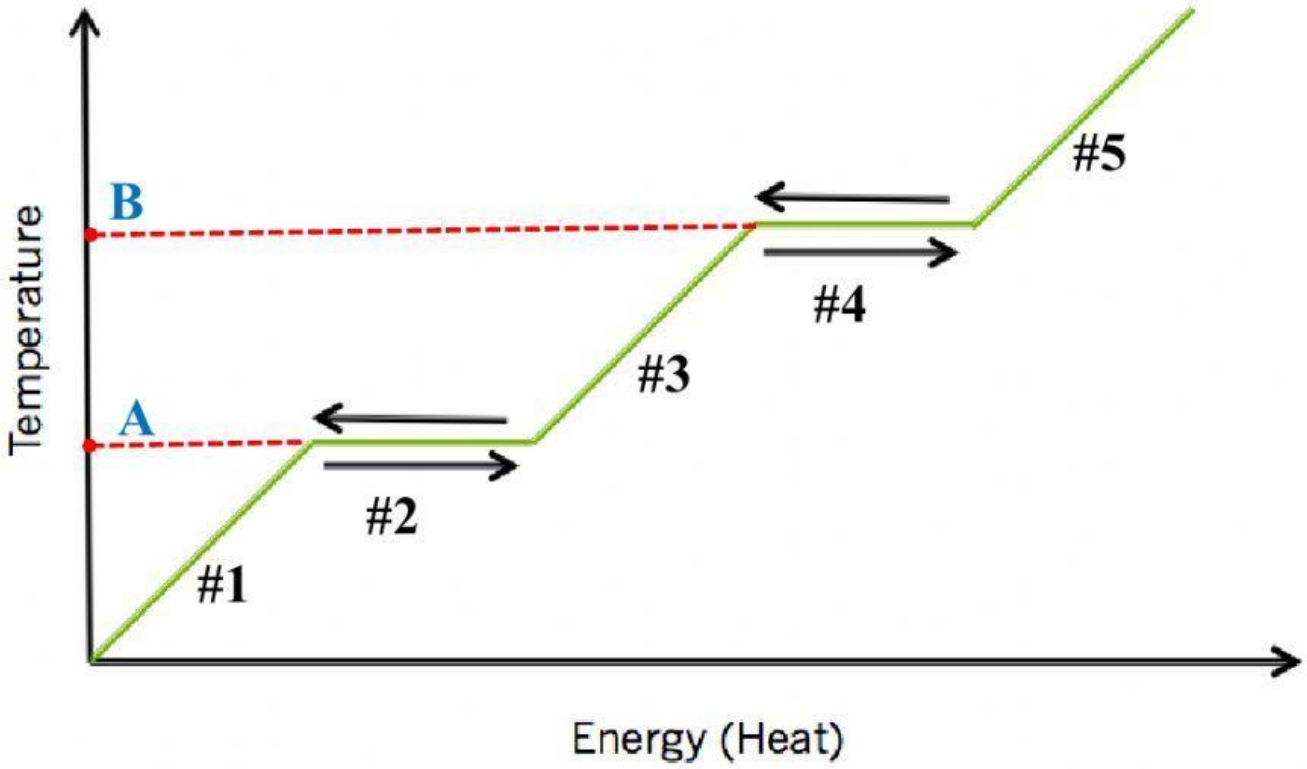
Name: _____ Date: _____

CHEMISTRY

Phase Changes and Phase Change Diagrams

The diagram is a generic phase change diagram. The x-axis is the change of energy of the system. Energy of the system increases from left to right. The y-axis of the diagram is the temperature of the system. Temperature increases in the up direction from bottom (cold) to top (hot). The red dashed horizontal lines that extend from the y-axis to the diagram represent the melting point temperature (A) and the boiling point temperature (B).



Phase changes are reversible. That is why there is the double reverse arrow at each of the phase change temperatures (temperatures A and B).

If the system gains energy from the environment, the phases or states of matter change from a lower energy state to a higher energy state. The molecule motion becomes faster, more random, and amount of contact between molecules decreases. The arrangement of the molecules become more and more disordered.

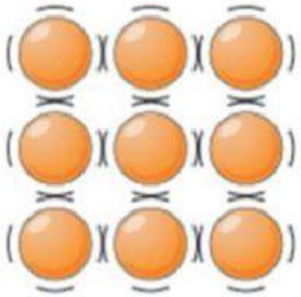
Solid —(Melting)→ **Liquid** —(Vaporization)→ **Gas (vapor)**

If the system releases (loses) energy to the environment, the phases or states of matter change from a higher energy state to a lower energy state. The molecule motion becomes slower, less random, and amount of contact between molecules increases. The arrangement of the molecules of the substance become more and more ordered.

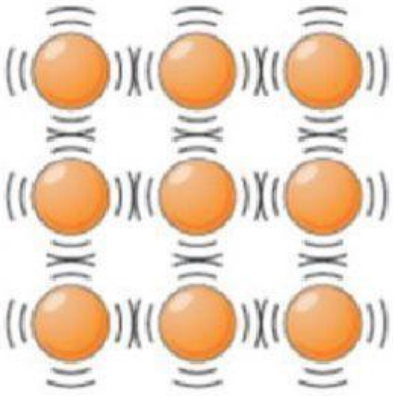
Solid ←(Freezing)— **Liquid** ←(Condensation)— **Gas (vapor)**

#1. SOLID PHASE. The substance begins as a cold solid. The temperature of the substance is very cold. As a result, the molecules that make up the substance vibrate slowly (left figure). As energy (heat) is added to the solid, the temperature of the solid gets warmer and warmer. The molecules that make up the substance vibrate faster and faster, with more force the molecules knock against each other (right figure), but remain in a fixed position with the same neighbors.

Very cold solid



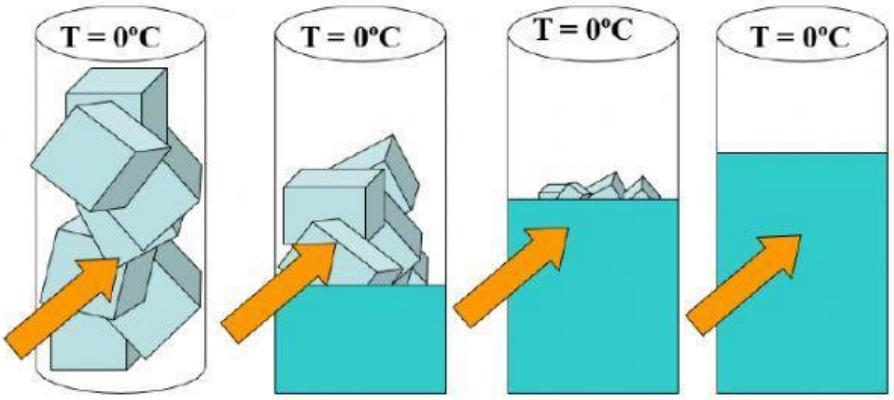
Warm solid



#2. MELTING. The temperature is at the **melting point temperature** (A). The phase change from solid to liquid is in progress. Both solid and liquid coexist as the phase change is in progress. The addition of more energy (heat) to the solid substance at the melting point

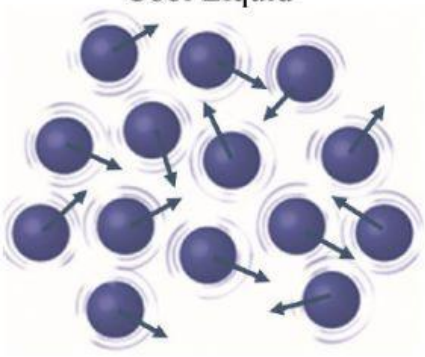
temperature DOES NOT increase the temperature. The temperature remains constant while the solid is melting to liquid. The addition of energy (heat) at the melting point temperature is making the molecules vibrate so fast that they break free from rigid contact with their neighboring molecules. The molecules freely and randomly move as they slide and slip over each other. The temperature of the substance will remain at the melting point temperature with increase of energy until all the solid has melted to liquid.

Example: The melting point temperature of water (H_2O) is 0° C. As energy (heat) is added to the ice (solid water), the ice melts. Both ice and liquid water will coexist, and the temperature will remain at 0° as long as the phase change is in progress. The addition of more energy to the ice DOES NOT increase the temperature of the ice/water, it remains at 0°C. The addition of energy makes the water molecules move so fast that they break rigid contact with their neighbors in the solid form. The molecules can now move randomly over and around each other as the new liquid form.

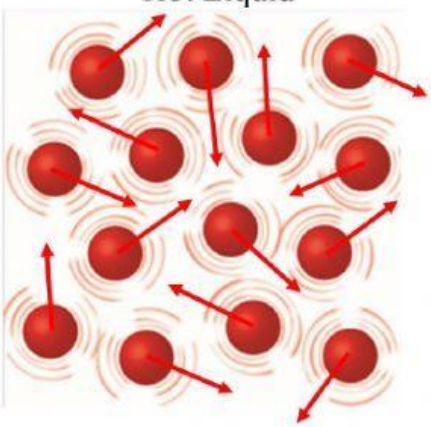


#3. LIQUID PHASE. The temperature is above the melting point temperature. All the substance is in the liquid phase. The liquid molecules have much more energy than the molecules of the solid. Molecules of the liquid are moving randomly in all directions rather than simply vibrating in a fixed position with common neighbors. However, the liquid molecules are still touching each other as they move around—they do not have a enough energy to break free from contact with other liquid molecules. As more and more energy (heat) is added to the liquid, the molecules of the liquid move faster and in more random motion.

Cool Liquid



Hot Liquid

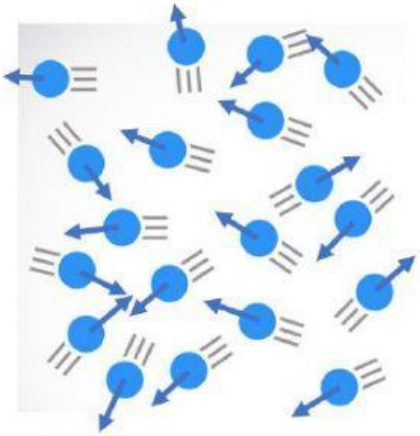


#4. VAPORIZATION (BOILING). The temperature is at the **boiling point temperature** (B). The phase change from liquid to gas is in progress. Both liquid and vapor coexist as the phase change is in progress. The addition of more energy (heat) to the solid substance at the boiling point temperature DOES NOT increase the temperature. The temperature remains constant while the liquid is vaporizing to gas (vapor). The addition of energy (heat) at the boiling point temperature is making the molecules of liquid move so fast that they break free from all contact with other liquid molecules. The molecules now move the fastest, move randomly and totally free from each other in 3-dimensional space.

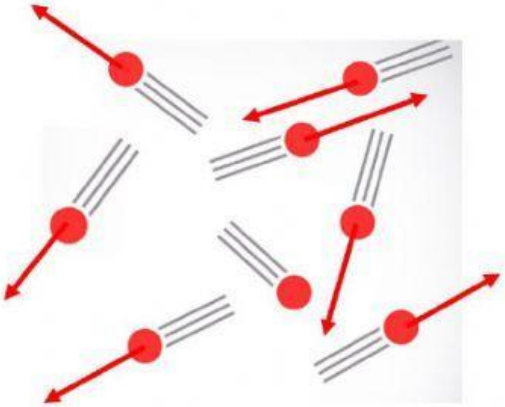
Example: The boiling point temperature of water (H_2O) is 100° C. As energy (heat) is added to the liquid water, the water boils to gas. Both liquid water and gas coexist, and the temperature will remain at 100° as long as the phase change is in progress. The addition of more energy to the ice DOES NOT increase the temperature of the liquid water/gas bubbles and steam in the kettle, it remains at 100°C. The addition of energy makes the water molecules move so fast that they total break free from contact with other water molecules. The molecules of water vapor are now totally independent of each other moving randomly in 3-dimensional space in all directions.

#5. GAS PHASE. The temperature is above the boiling point temperature. All the substance is in the gas phase (a vapor). The gas molecules have the most energy of three states of matter. Molecules of the gas are moving at very fast speeds and move randomly in all directions in 3-dimensional space. They move totally independently of each other. There is no contact between gas molecules. As more and more energy (heat) is added to the gas, the molecules of the gas move faster with more and more random motion. In an unrestricted space, the gas cloud will also expand very quickly with increasing temperature.

Cool gas



Very hot gas



Part 1. Use the chart to answer the questions about temperature and phase changes for the six substances. Some of the questions are multiple choice, choose the correct letter. If the answer is a temperature, type only the number value of the temperature into the box, do not include the °C.

Substance	Melting Point Temp (°C)	Boiling Point Temp (°C)
Oxygen	-218	-182
Ethanol	-114	78
2-propanol	-89	83
Linseed oil	-24	316
Water	0	100
Lead	327	1620

_____ 1. At which temperature are the molecules of lead vibrating with the fastest vibrational speed?

A. 300°C C. 1600°C
B. 320°C D. 1640 °C

_____ 2. At which temperature will ethanol be a gas but 2-propanol will be a liquid?

A. 60°C C. 80°C
B. 70°C D. 90°C

_____ 3. At which temperature will ethanol be a liquid but 2-propanol will be a solid?

A. -140°C C. -120°C
B. -130°C D. -110°C

_____ 4 At which temperature will a liquid and a solid of the same substance coexist in the same system?

A. -218°C C. -150°C
B. -182°C D. -75°C

_____ 5 At which temperature will linseed oil and water both be in the liquid phase.

A. -10°C C. 110°C
B. 20°C D. 300°C

_____ 6. At which temperature will a liquid and gas of the same substance coexist in the same system?

A. -89°C C. 78°C
B. 24°C D. 200°C

Study the phase change diagrams. Match the phase change diagrams with the substances. Hint…all of the diagrams are on the same scale for temperature and energy. Look at the melting point temperatures and boiling point temperatures.

Diagram #1

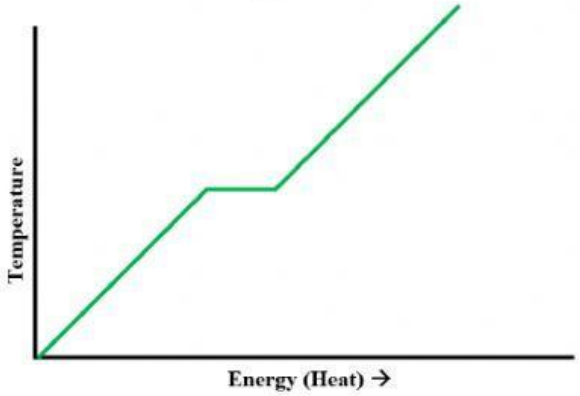


Diagram #2

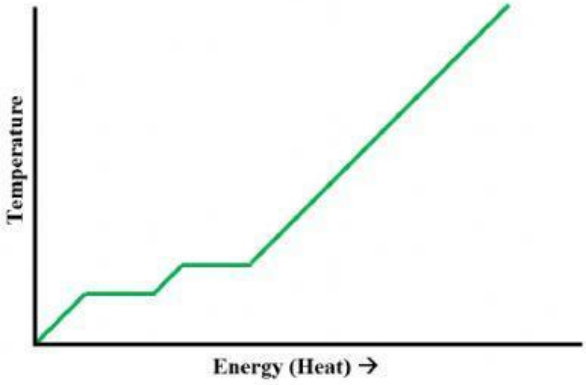


Diagram #3

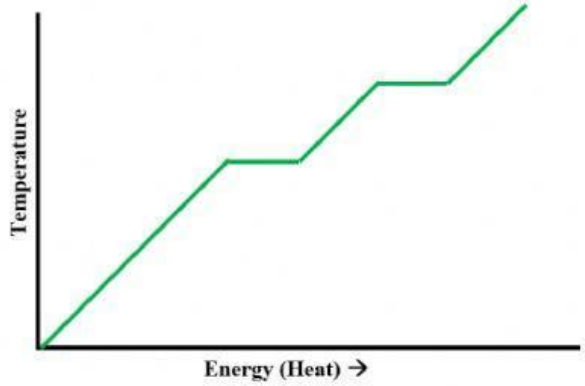
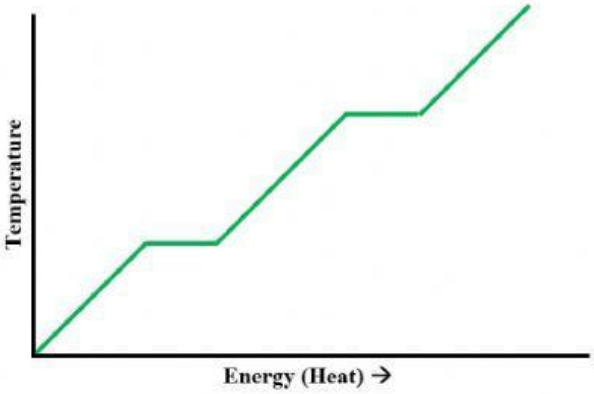


Diagram #4



_____ 7. Which substance is represented by phase change diagram #1?

A. Ethanol C. Oxygen
B. Linseed oil D. Water

_____ 8. Which substance is represented by the phase change diagram #2?

A. Ethanol C. Oxygen
B. Linseed oil D. Water

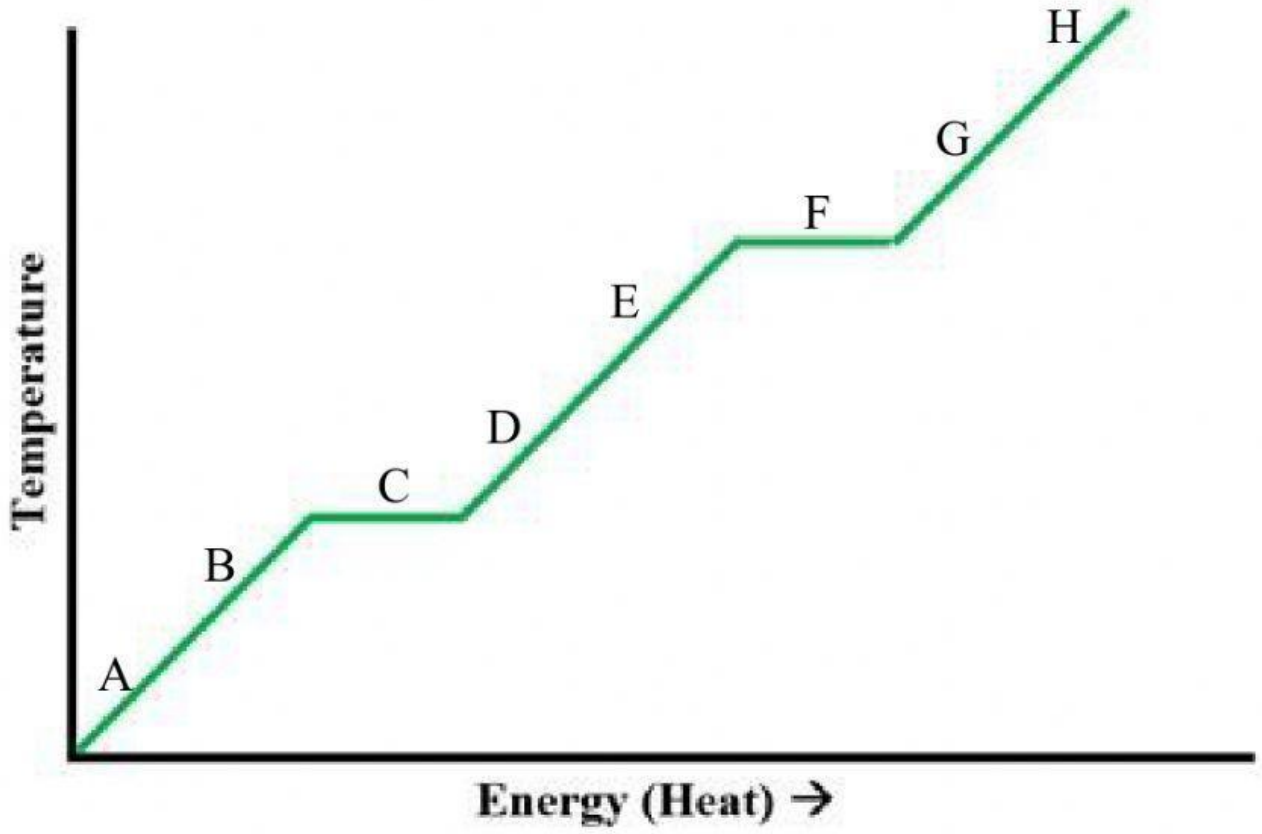
_____ 9. Which substance is represented by the phase change diagram #3?

A. Ethanol
B. Linseed oil
C. Oxygen
D. Water

_____ 10. Which substance is represented by the phase change diagram #4?

A. Ethanol
B. Linseed oil
C. Oxygen
D. Water

Study the phase change diagram. Match the pictures of the molecules with where they would be on the phase change diagram. Hint: Look back through the background information on phase change diagrams. Each letter is used only once.



_____ 11 Diagram #1

_____ 12 Diagram #2

_____ 13 Diagram #3

_____ 14 Diagram #4

_____ 15 Diagram #5

_____ 16 Diagram #6

_____ 17 Diagram #7

_____ 18 Diagram #8

Diagram #1

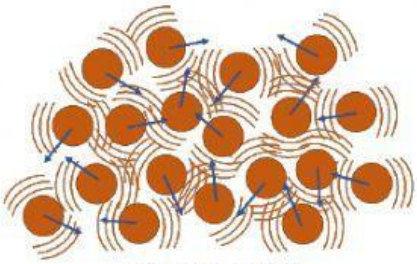


Diagram #2

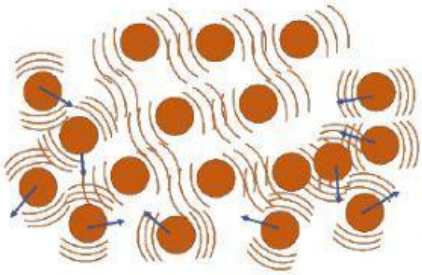


Diagram #3

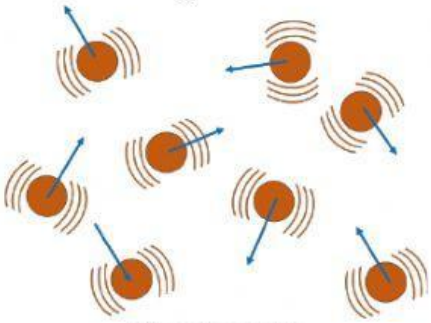


Diagram #4

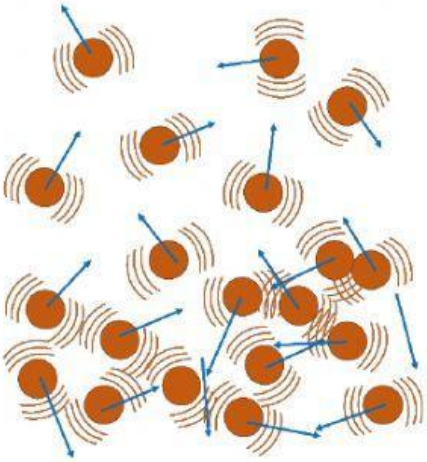


Diagram #5

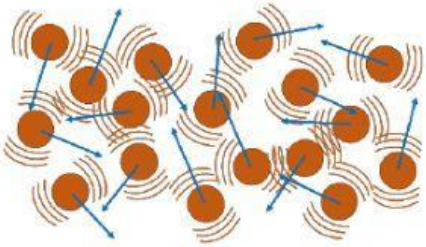


Diagram #6

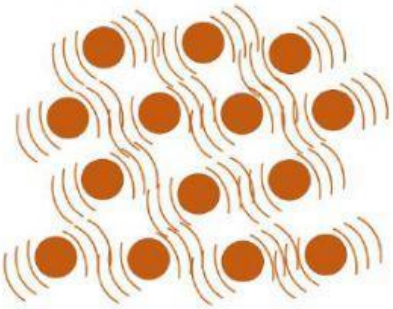


Diagram #7

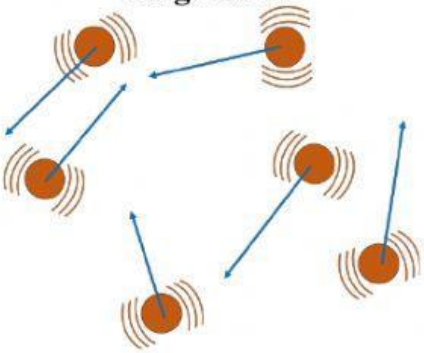


Diagram #8