honors (not AP®)

Phases & Phase Changes*

Unit: Thermal Physics (Heat)

MA Curriculum Frameworks (2016): HS-PS1-3, HS-PS2-8(MA)

AP® Physics 2 Learning Objectives: N/A

Mastery Objective(s): (Students will be able to…)

- Compare observable states of matter and phase transitions with behavior at the molecular level.

Success Criteria:

- Descriptions include connectedness and motion of molecules.
- Descriptions include comparative descriptions of molecular speed.
- Descriptions relate molecular motion and speed to temperature.

Language Objectives:

- Explain phase changes in terms of changes in molecular behavior.

Tier 2 Vocabulary: phase, solid, liquid, gas, vapor

Labs, Activities & Demonstrations:

- evaporation from boiling water on cloth

Notes:

macroscopic: objects or bulk properties of matter that we can observe directly.

microscopic: objects or properties of matter that are too small to observe directly.

Note that *macroscopic* properties of a substance are often determined by *microscopic* interactions between the individual molecules.†

phase: a term that relates to how rigidly the atoms or molecules in a substance are connected.

* Phase changes are generally taught in chemistry classes. However, because the calorimetry and heating curves topics were moved from chemistry to physics in the Massachusetts Curriculum Frameworks starting in 2016, it is useful to review them here.

† In this section, the term "molecules" is used to refer to the particles that make up a substance. In chemistry, a molecule is a group of atoms that are covalently bonded together, and a substance can be made of individual atoms, molecules, crystals, or other types of particles. In these notes, the term "particles" is preferred, but "molecules" is used in this section because it conjures the impression of particles that are attached or bonded together in some way. This gives most students a reasonably correct picture of entities that are firmly attached to each other and cannot be pulled apart by physical means.

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solid: molecules are rigidly connected. A solid has a definite shape and a definite volume.

liquid: molecules are loosely connected; bonds are continuously forming and breaking. A liquid has a definite volume, but not a definite shape.

gas: molecules are not connected. A gas has neither a definite shape nor a definite volume. Gases will expand to fill whatever space they occupy.

plasma: the system has enough heat to remove electrons from atoms, which means the system is comprised of charged particles moving very rapidly.

phase change: when an object or substance changes from one phase to another through gaining or losing heat.

Breaking bonds requires energy. Forming bonds releases energy. This is true for the intermolecular bonds that hold a solid or liquid together as well as for chemical bonds.

As you probably know from experience, you need to add energy to turn a solid to a liquid (melt it), or to turn a liquid to a gas (boil it).

- This is why evaporation causes cooling—because the system (the water) needs to absorb heat from its surroundings in order to make the change from a liquid to a gas (vapor).
- This is also why lids keep drinks hot. The lid is a barrier which significantly reduces the amount of evaporation.
- When you perspire, the water absorbs heat from you in order to evaporate, which cools you off.

It is less obvious that energy is released when a gas condenses or a liquid freezes.

- Ice in your ice tray needs to give off heat in order to freeze. (Your freezer needs to remove that heat in order to make this happen.)
- Burns from steam are much more dangerous than burns from water, because the steam releases a large amount of heat (which is absorbed by your body) as it condenses.

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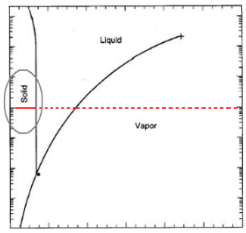
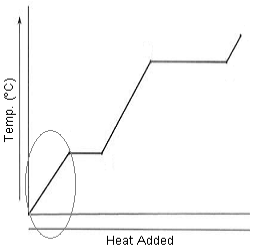
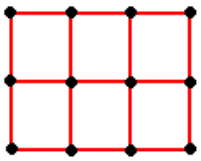
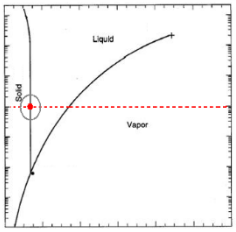
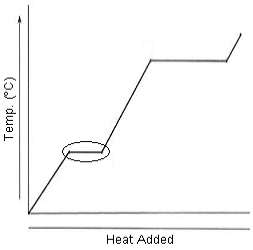
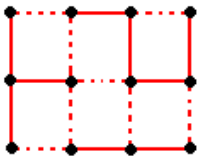
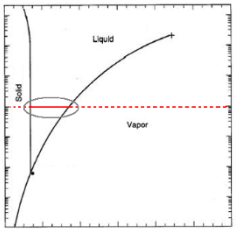
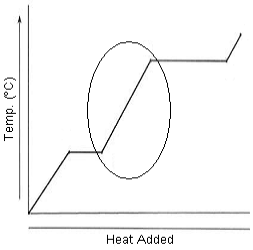
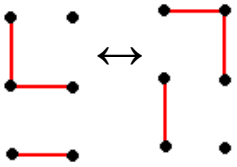
States of Matter

The following table shows interactions between the molecules and some observable properties for solids, liquids and gases. (The table includes heating curves, which will be discussed in more detail later in the next section, *Heating Curves* starting on page 212. For now, understand that a heating curve shows how the temperature changes as heat is added. Notice in particular that the temperature stays constant during melting and boiling.)

state	phase diagram	heating curve	molecules
solid			rigidly bonded 
adding energy makes molecules move faster; temperature increases			
melting			some bonds breaking 
adding energy breaks some of the bonds; temperature remains constant			
liquid			bonds breaking & re-forming rapidly 
adding energy makes molecules move faster; temperature increases			

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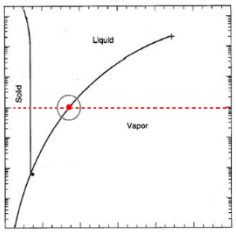
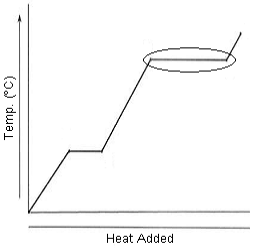
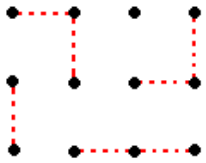
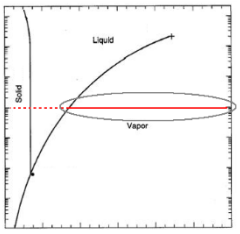
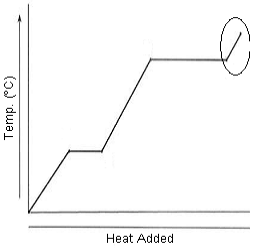
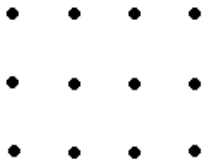
state	phase diagram	heating curve	molecules
boiling			all bonds breaking 
	adding energy breaks all remaining bonds; temperature remains constant		
vapor (gas)			molecules moving freely 
	adding energy makes molecules move faster; temperature increases		

Note that because liquids are continually forming and breaking bonds, if a liquid molecule at the surface breaks its bonds with other liquids, it can "escape" from the attractive forces of the other liquid molecules and become a vapor molecule. This is how evaporation happens at temperatures that are well below the boiling point of the liquid.

Use this space for summary and/or additional notes: