

## 13.1: Phase Properties

### Learning Objectives

- Describe the solid and liquid phases.

Solids and liquids are collectively called *condensed phases* because their particles are in virtual contact. The two states share little else, however.

#### Solids

In the solid state, the individual particles of a substance are in fixed positions with respect to each other because there is not enough thermal energy to overcome the intermolecular interactions between the particles. As a result, solids have a definite shape and volume. Most solids are hard, but some (like waxes) are relatively soft. Many solids composed of ions can also be quite brittle.



Figure 13.1.1: A crystalline arrangement of a quartz crystal cluster. (JJ Harrison via Wikipedia Commons)

Ionic solids usually have their constituent particles arranged in a regular, three-dimensional array of alternating positive and negative ions called a crystal. The effect of this regular arrangement of particles is sometimes visible macroscopically, as shown in [Figure 13.1.1](#). Some solids, especially those composed of large molecules, cannot easily organize their particles in such regular crystals and exist as amorphous (literally, “without form”) solids. Glass is one example of an amorphous solid.

#### Liquids

If the particles of a substance have enough energy to partially overcome intermolecular interactions, then the particles can move about each other while remaining in contact. This describes the liquid state. In a liquid, the particles are still in close contact, so liquids have a definite volume. However, because the particles can move about each other rather freely, a liquid has no definite shape and takes a shape dictated by its container.



Figure 13.1.2: The formation of a spherical droplet of liquid water minimizes the surface area, a natural result of surface tension in liquids. (José Manuel Suárez via Wikimedia Commons)

## Gases

If the particles of a substance have enough energy to completely overcome intermolecular interactions, then the particles can separate from each other and move about randomly in space. Like liquids, gases have no definite shape, but unlike solids and liquids, gases have no definite volume either.

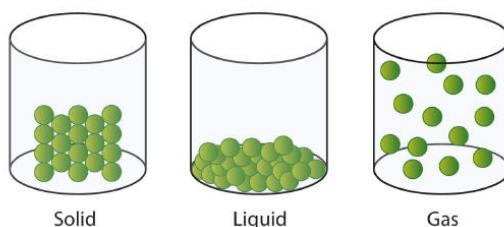


Figure 13.1.3: A representation of the solid, liquid, and gaseous states. A solid has definite volume and shape. A liquid has a definite volume, but no definite shape. A gas has neither a definite volume nor shape.

The change from solid to liquid usually does not significantly change the volume of a substance. However, the change from a liquid to a gas significantly increases the volume of a substance, usually by a factor of 1000 or more. Figure 13.1.3 shows the differences among solids, liquids, and gases at the molecular level, while Table 13.1.1 lists the different characteristics of these states.

Table 13.1.1: Characteristics of the Three States of Matter

Characteristic	Solid	Liquid	Gas
shape	definite	indefinite	indefinite
volume	definite	definite	indefinite

Characteristic	Solid	Liquid	Gas
relative intermolecular interaction strength	strong	moderate	weak
relative particle positions	in contact and fixed in place	in contact but not fixed	not in contact, random positions

### ✓ Example 13.1.1

What state or states of matter does each statement describe?

- A. This state has a definite volume.
- B. This state has no definite shape.
- C. This state allows the individual particles to move about while remaining in contact.

#### Solution

- A. This statement describes either the liquid state or the solid state.
- B. This statement describes either the liquid state or the gas state.
- C. This statement describes the liquid state.

### Exercise 13.1.1

What state or states of matter does each statement describe?

- A. This state has individual particles in a fixed position with regard to each other.
- B. This state has individual particles far apart from each other in space.
- C. This state has indefinite shape.

#### Answer A

solid

#### Answer B

gas

#### Answer C

liquid or gas

### Looking Closer: Water, the Most Important Liquid

Earth is the only known body in our solar system that has liquid water existing freely on its surface; life on Earth would not be possible without the presence of liquid water.

Water has several properties that make it a unique substance among substances. It is an excellent solvent; it dissolves many other substances and allows those substances to react when in solution. In fact, water is sometimes called the *universal solvent* because of this ability. Water has unusually high melting and boiling points (0°C and 100°C, respectively) for such a small molecule. The boiling points for similar-sized molecules, such as methane (BP = -162°C) and ammonia (BP = -33°C), are more than 100° lower. Though a liquid at normal temperatures, water molecules experience a relatively strong intermolecular interaction that allows them to maintain the liquid phase at a higher temperature than substances that have a similar molecular mass as water yet have weaker intermolecular forces.

Unlike most substances, the solid form of water is less dense than its liquid form, which allows ice to float on water. In colder weather, lakes and rivers freeze from the top, allowing animals and plants to continue to live underneath. Water also requires an unusually large amount of energy to change temperature. While 100 J of energy will change the temperature of 1 g of Fe by 230°C,

this same amount of energy will change the temperature of 1 g of  $\text{H}_2\text{O}$  by only  $100^\circ\text{C}$ . Thus, water changes its temperature slowly as heat is added or removed. This has a major impact on weather, as storm systems like hurricanes can be impacted by the amount of heat that ocean water can store.

Water's influence on the world around us is affected by these properties. Isn't it fascinating that such a small molecule can have such a big impact?

### Summary

- Solids and liquids are phases that have their own unique properties.

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