Physical Properties of Matter

A Review of States of Matter

Recall that gases:

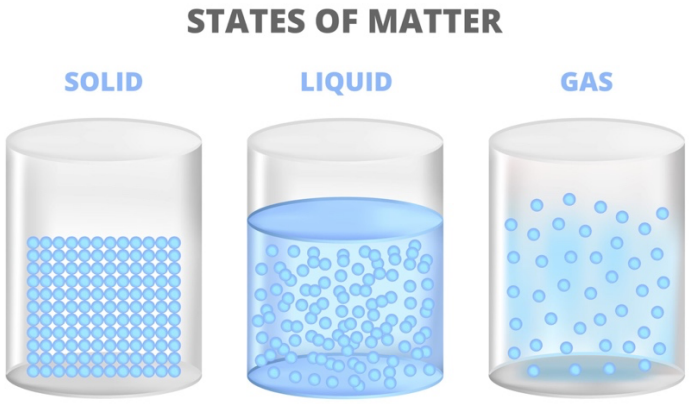
- consist of particles that are far apart, in constant random motion, and exert relatively small forces on each other
- do not have a definite shape (take the shape of their container)
- do not have a definite volume (expand to fill their container)
- are easily compressed
- are very low density compared to solids and liquids

Solids are obviously very different from gases. Solids:

- consist of particles that are very close together, vibrate in place, and exert relatively large forces on each other
- are rigid and have a definite shape
- have a definite volume
- are compressible only to a very slight extent
- have much greater densities than gases

Liquids have properties that lie somewhere between those of solids and gases, but not midway between. Liquids are more similar to solids than they are to gases. Liquids:

- consist of particles that are close together, have limited freedom to move around, and exert forces of attraction on each other that are similar to but not as strong as those in the solid state
- do not have a definite shape
- have a fixed volume
- are compressible only to a slight extent
- are less dense than solids, but not by much



Intermolecular Forces

In previous units (and courses) we have learned about the forces involved in forming bonds between atoms in order to form compounds. These are known as **intramolecular forces**, or forces that exist *within the molecule*.

In this unit, we will discuss the forces that hold the particles of a solid or a liquid together. These forces may involve covalent or ionic bonding, or they may involve weaker interactions called **intermolecular forces**, or forces that exist *between two different molecules*.

It is important to recognize that when a substance such as water changes from solid to liquid to gas, the molecules remain intact. The changes of state are due to changes in the forces *between* the molecules rather than those *within* the molecules.

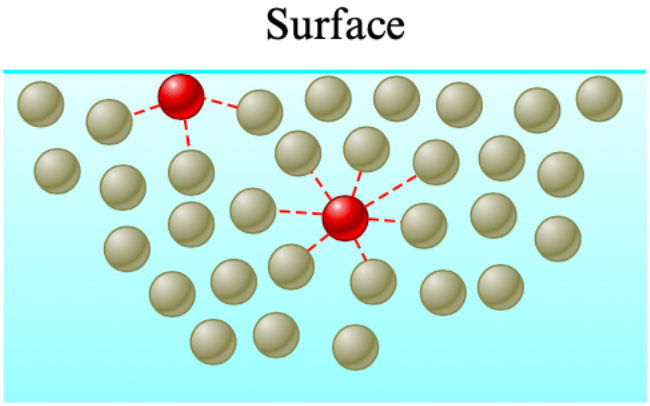
In ice, for example, the molecules are virtually locked in place, although they can vibrate about their positions. When energy is added (by heating the ice), the movement of the molecules increases, and they eventually achieve the greater movement and disorder characteristic of liquid water. The ice has melted. As more energy is added, the gas state is eventually reached, with the individual water molecules far apart and interacting relatively little.

The Liquid State

Liquids exhibit many characteristics that help us understand their nature, such as:

- low compressibility
- lack of rigidity
- high density (compared to gases)

Many of the properties of liquids give us direct information about the forces that exist among the particles. For example, when a liquid is poured onto a solid surface, it tends to form droplets. This is a direct result of the intermolecular forces between the liquid particles. Molecules in the interior of the liquid are surrounded by other molecules, but those on the surface are only subject to intermolecular attractions from the side and below.

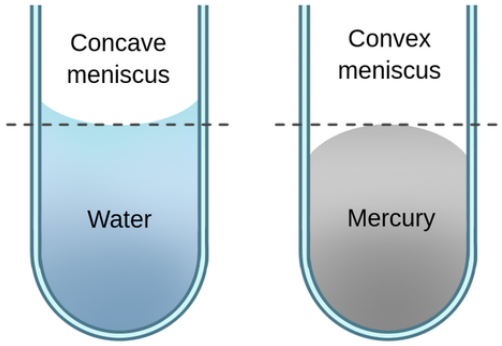


This uneven pull on the surface molecules tends to draw them in towards the center of the body of the liquid, causing the droplet to assume a shape that has the minimum surface area — a sphere.

To increase a liquid's surface area, molecules must move from the interior of the liquid to the surface. This requires energy in order to overcome the intermolecular forces. The resistance of a liquid to changes in its surface area is called **surface tension**. Liquids with strong intermolecular forces tend to have relatively high surface tensions.

Many liquids exhibit a behavior called **capillary action** — the spontaneous rising of a liquid in a narrow tube. Two different types of forces are responsible for this behavior: *cohesive forces*, the intermolecular forces between the molecules of the liquid, and *adhesive forces*, the forces between the liquid molecules and their container.

When a liquid like water forms a **meniscus**, this is also a result of the cohesive and adhesive forces. If the adhesive forces are stronger than the cohesive forces then the meniscus will be concave. If the cohesive forces are stronger than the adhesive forces then the meniscus will be convex.



Another property of liquids that is strongly dependent on intermolecular forces is **viscosity**, a measure of a liquid's resistance to flow. Liquids with strong intermolecular forces tend to be highly viscous.

Structural Model for Liquids

Liquids are best viewed as consisting of a large number of relatively tightly packed particles (similar to a solid) but with considerably more disorder and freedom of movement. The arrangement of particles in a liquid is highly dynamic, with rapid changes occurring throughout the liquid at all times.

Worksheet #1

1. What are intermolecular forces? How do they differ from intramolecular forces?

2. Define surface tension and explain how it depends on the strength of the intermolecular forces.

3. Define viscosity and explain how it depends on the strength of the intermolecular forces.

4. Which are stronger, intermolecular or intramolecular forces for a given molecule?

5. The shape of the meniscus of water in a glass tube is different from that of mercury in a glass tube. Why?

6. Explain why water forms into beads on a waxed car finish.