LIQUIDS

Characteristics of Liquids

Special Properties

- Cohesion and Adhesion
- Surface Tension and Capillary Action
- Pressure
- Viscosity

The great distances between atoms and molecules in a gaseous phase, and the absence of any significant interactions between them, allows for simple descriptions of many physical properties that are the same for all gases, regardless of their chemical identities.

In the liquid and solid states, these interactions are of considerable strength and play an important role in determining a number of physical properties that do depend on the chemical identity of the substance. Liquids have some intermolecular bonding, as a result, the molecules are close together but it isn't as strong as bonding in a solid. Liquids occur at temperatures above the melting point of a solid substance, but below its boiling point

Liquids have definite volume, but indefinite shape. When a liquid is inside a container, it will take its shape. When they are not inside a container, are free to form droplets and puddles.

Liquids are usually incompressible. The molecules are already close together, so it is difficult to compress them any more. Under very high pressures, liquids will actually compress, but not very much.

Properties of Liquids

The intermolecular forces between molecules in the liquid state vary depending upon their chemical identities and thus their physical properties change.

Three unique properties of liquids that intimately depend on the nature of intermolecular interactions:

For example, liquid’s viscosity (resistance to flow) and surface tension are their properties. There are two kinds of forces that are effective in liquids. One of them, cohesive forces are also responsible for these properties such as viscosity and surface tension. Adhesive forces between the molecules of a liquid and different molecules composing a surface in contact with the liquid are responsible for surface wetting and capillary rise.

Also, cohesion causes their round shape. In that case, Cohesion is the name given to liquid molecules attract each other. Molecules like methane are non-polar, so they are held together only by van der Waals forces. These molecules will have minimal cohesion. In contrast, water molecules use hydrogen bonding, so they display strong cohesion. A cohesive liquid will form more spherical droplets and have much higher surface tension.

Adhesion is the attraction of a liquid molecule to its surroundings. Adhesive liquids will demonstrate capillary action (explained below). They are also more "wet". Mercury is very cohesive, but not adhesive. As a result, it doesn't leave behind residue as it rolls across a surface. Water, on the other hand, is much more adhesive. When water rolls across a surface, it wets that surface because some of the molecules adhere to it.

Liquids are fluid, able to flow and take any shape. As a result of being fluid, in addition to liquids exhibit many interesting properties that solids do not, including capillary action and diffusion.

Liquids, like gases, undergo diffusion when mixed. This can be seen by adding food coloring to water. Different liquids, when added, will chaotically spread out and mix together. Diffusion will occur faster when the liquid is warmer because the increased kinetic energy by heat allows the molecules to move faster and collide more frequently.

Surface Tension and Capillary Action

Surface Tension

When water drops are on an impermeable surface, they tend to form beads. This is due to its surface tension. Liquid molecules pull at each other, and as a result they decrease their surface area. When water is on a permeable surface, it spreads out.

If liquids tend to adopt the shapes of their containers, then, do small amounts of water on a freshly waxed car form raised droplets instead of a thin, continuous film? The answer lies in a property called surface tension, which depends on intermolecular forces.

Surface tension is the energy required to increase the surface area of a liquid by a unit amount and varies greatly from liquid to liquid based on the nature of the intermolecular forces, e.g., water with hydrogen bonds has a surface tension of 7.29 x 10^{-2} J/m^2 (at 20°C), while mercury with metallic (electrostatic) bonds has as surface tension that is 15-times higher: 4.86 x 10^{-1} J/m^2 (at 20°C).

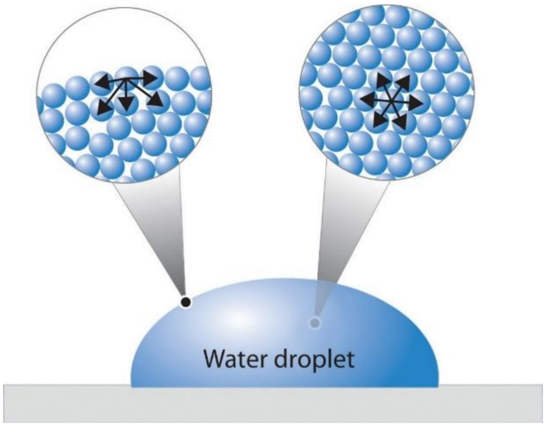

Figure: A Representation of Surface Tension in a Liquid. It presents a microscopic view of a liquid droplet.

A typical molecule in the interior of the droplet is surrounded by other molecules that exert attractive forces from all directions. Consequently, there is no net force on the molecule that would cause it to move in a particular direction. In contrast, a molecule on the surface experiences a net attraction toward the drop because there are no molecules on the outside to balance the forces exerted by adjacent molecules in the interior. Cohesive liquids have surface tension to hold themselves into droplets.

Because a sphere has the smallest possible surface area for a given volume, intermolecular attractive interactions between water molecules cause the droplet to adopt a spherical shape. This maximizes the number of attractive interactions and minimizes the number of water molecules at the surface. Hence raindrops are almost spherical, and drops of water on a waxed (nonpolar) surface, which does not interact strongly with water, form round beads (see the chapter opener photo). A dirty car is covered with a mixture of substances, some of which are polar. Attractive interactions between the polar substances and water cause the water to spread out into a thin film instead of forming beads.

Surface tension is defined as the energy required to increase the surface area of a liquid by a specific amount. Surface tension is therefore measured as energy per unit area, such as joules per square meter (J/m^2) or dyne per centimeter (dyn/cm) ($1\ dyn = 1 \times 10^{-5}\ N$)

Mercury is of very high surface tension due to the presence of strong metallic bonding.

Adding soaps and detergents that disrupt the intermolecular attractions between adjacent water molecules can reduce the surface tension of water. Because they affect the surface properties of a liquid, soaps and detergents are called surface-active agents, or surfactants.

The surfactants reduce the surface tension of water below that of fuel, so the fluorinated solution is able to spread across the burning surface and extinguish (söndürmek) the fire. Such foams are now used universally to fight large-scale fires of organic liquids.

Capillary Action

Adhesive liquids like water will rise up a narrow tube. Capillary action is the net result of two opposing sets of forces: cohesive forces, which are the intermolecular forces that hold a liquid together, and adhesive forces, which are the attractive forces between a liquid and the substance that composes the capillary.

Capillary action is a phenomenon occured by Intermolecular forces and it is the tendency of a polar liquid to rise against gravity in a small-diameter tube (a capillary), as shown in Figure.

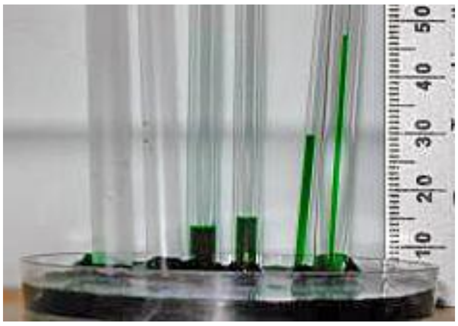

Figure : The Phenomenon of Capillary Action. Capillary action seen as water climbs to different levels in glass tubes of different diameters. Credit: Dr. Clay Robinson, PhD, West Texas A&M University.

When a glass capillary is is placed in liquid water, water rises up into the capillary. The height to which the water rises depends on the diameter of the tube. The smaller the diameter, the higher the liquid rises.

Water has both strong adhesion to glass, which contains polar SiOH groups, and strong intermolecular cohesion. When a glass capillary is put into water, the surface tension due to cohesive forces constricts the surface area of water within the tube, while adhesion between the water and the glass creates an upward force that maximizes the amount of glass surface in contact with the water.

If the adhesive forces are stronger than the cohesive forces, then the liquid in the capillary rises to the level. If, however, the cohesive forces are stronger than the adhesive forces, as is the case for mercury and glass, the liquid pulls itself down into the capillary below the surface of the bulk liquid.

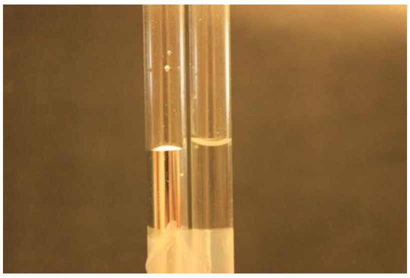

Figure: The Phenomenon of Capillary Action. Capillary action of water compared to mercury, in each case with respect to a polar surface such as glass.

Fluids and nutrients are transported up the stems of plants or the trunks of trees by capillary action.

Viscosity

Viscosity (η) is the resistance of a liquid to flow. For example, glyserol flows much slower than water, which flows relatively quickly and easily. Strong intermolecular attractive forces make it more difficult for molecules to move with respect to one another. The addition of a second hydroxyl group to ethanol, for example, increases the viscosity 15-fold.

The difference in viscosity between these two liquids is due to the attractive forces within the specific liquid. In order to flow, molecules must roll and move over each other.

A solution with low attractive forces would allow the molecules to move in a more free and easy manner, decreasing the viscosity.

Viscosity increases as intermolecular interactions or molecular size increases.

There is also a correlation between viscosity and molecular shape. Liquids consisting of long, flexible molecules tend to have higher viscosities than those composed of more spherical or shorter-chain molecules.

In most cases, the viscosity of a liquid decreases as the temperature of a liquid is increased. Increasing the temperature of a liquid causes the molecules to have a higher kinetic energy.

Some liquids, such as ethanol, and water, flow very readily and hence have a low viscosity. Others, such as motor oil, molasses (şeker kamışı) syrup, flow very slowly and have a high viscosity.

Pressure

Liquids will distribute pressure evenly. This concept, known as Pascal's Law, is crucial for equipment like hydraulic brakes. It is a result of their incompressibility. If there is no atmospheric pressure, liquids can not form.

Liquids will evaporate. The evaporation increases with temperature. It can be measured by vapor pressure, the amount of pressure exerted by the evaporated gas above the liquid's surface. Vapor pressure increases with temperature, and once it reaches the pressure of the surrounding atmosphere, the liquid will boil. Vapor pressure also depends on the intensity of intermolecular forces in the liquid.

Phase Diagrams

The temperature and pressure conditions at which a substance exists in solid, liquid, and gaseous states are summarized in a phase diagram for that substance. Phase diagrams are combined plots of three pressure-temperature equilibrium curves: solid-liquid, liquid-gas, and solid-gas. These curves represent the relationships between phase-transition temperatures and pressures. The intersection of all three curves represents the substance's triple point at which all three phases coexist.

- Explain the construction and use of a typical phase diagram
- Use phase diagrams to identify stable phases at given temperatures and pressures, and to describe phase transitions resulting from changes in these properties
- Describe the supercritical fluid phase of matter

Considering the definition of boiling point, plots of vapor pressure versus temperature represent how the boiling point of the liquid varies with pressure.

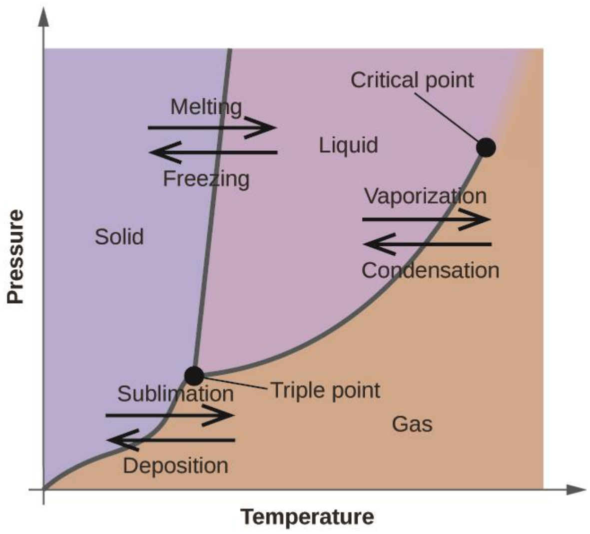

Figure : The physical state of a substance and its phase-transition temperatures are represented graphically in a phase diagram.

Consider the phase diagram for water shown in Figure

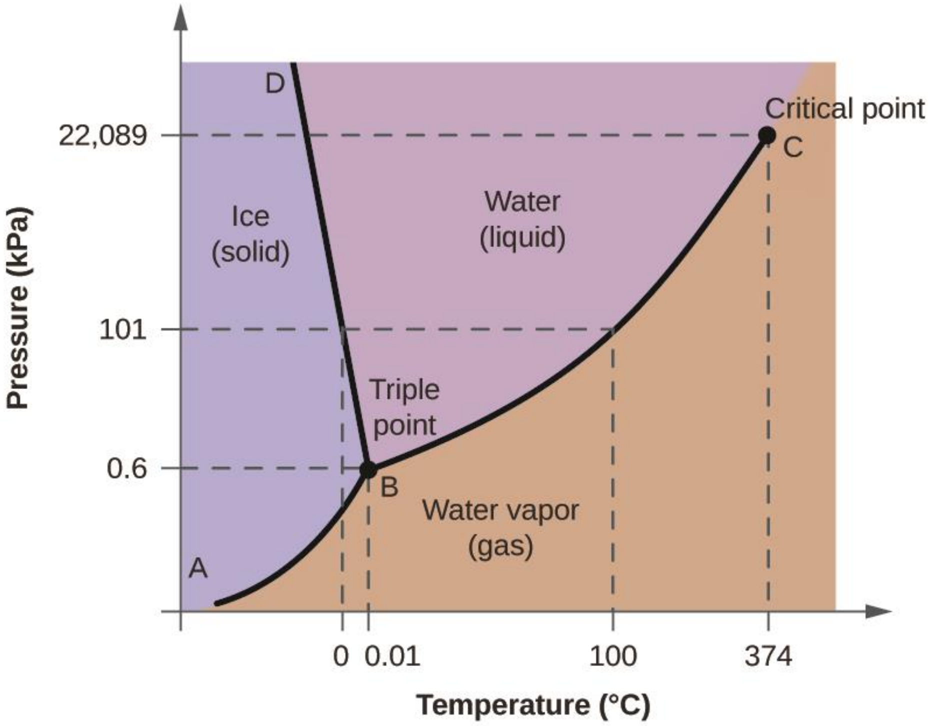

Figure : The pressure and temperature axes on this phase diagram of water are not drawn to constant scale in order to illustrate several important properties.