Properties of Matter

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Gases

Particles very far apart with almost no attractive interparticle forces.

This gives them no shape or definite volume.

All gases have similar properties such as expansion when heated and contraction when cooled. The rate of expansion/contraction is the same for all gases.

Liquids

Liquids are held loosely together by attractive interparticle forces. Particles can move away from each other but only so far. This gives a definite volume but not a definite shape.

To understand a liquid's properties we must know the strength of the interparticle forces.

All liquids <u>except water</u> expand uniformly as they are heated and contract as they are cooled. The rates of expansion/contraction differ for each liquid.

Solids

The particles of a solid are held into a repeating pattern by the attractive interparticle forces. This repeating pattern dictates a definite volume and shape.

To understand a solid we need to know the strength of the interparticle force and the arrangement of the particles.

All solids expand uniformly as they are heated and contract as they are cooled. The rates of expansion are different for each solid.

Some Selected Liquid Properties

Evaporation **– At a given temperature, not all particles have the same KE. Some have enough KE to escape from the attractions of their nearest neighbors on the surface. This is called evaporation. Evaporation increases as the temperature increases.**

Vapor pressure **– Gas pressure exerted by evaporating particles.**

What is *pressure*? Pressure is defined as force/area. P = F/A [=] N/m^2 = Pascal (Pa)
In the English system you should be familiar with the units of psi or pounds per square inch.

Usually we measure gas pressure indirectly by what gas pressure does. Example – a barometer.

Units and their values for what is called "standard atmospheric pressure". This means that all these values equal the same pressure.

14.7 lb/in^2	**760. mm Hg or Torr**
101.3 kPa	**1.013 bar**
1.00 Atm	**29.9 in of Hg**

As the temperature increases the vapor pressure increases. This affects the boiling pt of the liquid.

Boiling point **– temperature at which VP = pressure of the atmosphere.**

If a substance has a high vapor pressure then the interparticle forces are low and it will be easier for its vapor pressure to equal the pressure of the atmosphere. This leads to a low BP.

A high BP means strong interparticle forces and a low vapor pressure. The temperature must be high enough for the pressure of the escaping particles to equal the pressure of the atmosphere.

Example – Which of the following liquids has the highest vapor pressure? Highest BP? Strongest interparticle forces? Water, rubbing alcohol

The BP can be changed by changing the atmospheric pressure. If we increase the pressure, then the BP of the water will increase. If we decrease the pressure, the BP will decrease. Applications – car radiator, pressure cooker, cooking at high elevations

Another way to change the BP of a liquid is by adding a solid or liquid to it that does not evaporate very quickly. Such a substance is called *nonvolatile*.

The nonvolatile substance takes up spaces on the liquid surface and slows the evaporation process. This decreases the VP and makes the BP higher. Can you explain this in terms of the definition of BP? A good example is adding antifreeze to your car's radiator.

Surface tension **is another property of liquids that shows the interparticle forces. It is the apparent elastic film on a liquid surface that results from the unbalanced forces on the surface particles.**

There is a net downward pull on these particles. This enables the floating of objects on the surface of a liquid even though the objects have densities greater than the liquid. Example – floating a pin or old double edge razor blade on top of water.

When a liquid is put into a container the attractive forces between the liquid particles (called *cohesion*) may be less or more than the attractive forces for the container (called *adhesion*)

If the container is a small tube you may see this difference as a *meniscus* or an *inverted meniscus*.

If the attractive forces are greater between the liquid and container than between the liquid particles themselves you will see a concavity (meniscus) in the tube. (adhesion > cohesion) Example – water in a small glass tube

As the tube gets smaller and smaller this attraction of the liquid for the container results in what is called *<u>capillary rise</u>*.

The absorption of water by a paper towel can be thought of as water rising through small cellulose tubes in the paper. Part of the reason that the roots of plants can absorb water and transport it to the leaves is by capillary rise.

It is also possible for the attractive forces between the liquid particles to be stronger than the forces between the liquid and the container. In a small tube this causes an *inverted meniscus*. A good example is mercury in a small glass tube. (cohesion > adhesion)

Viscosity **is the resistance to liquid flow. It also shows the strength of the cohesive forces of a liquid. The higher the viscosity the greater the attractive interparticle force. Which of the following has the highest attractive interpaticle forces? Water, alcohol, molasses**

Freezing point/melting point

A liquid freezes (or a solid melts) at the temperature where the vapor pressure of the solid and liquid phases are equal. If we can change the VP, we can change the FP/MP.

It is fairly easy to change the VP of a liquid since we can dissolve a liquid in another liquid or a solid in a liquid. We call the substance that dissolves the *solute* (smaller amount) and the substance that does the dissolving the *solvent* (larger amount). Together they make a *solution*.

So as we have learned. . . if we dissolve a nonvolatile solute into a liquid, we decrease the VP of the liquid since part of the surface is taken up by the solute.

But very importantly. . . when a liquid solution freezes the solvent usually freezes out as a pure substance.

These 2 facts lead to the decrease of the FP of a liquid. <u>Decreasing the VP of the liquid</u> while keeping the <u>VP of the solid the same</u> causes the solid and liquid VP's to equal at a lower temperature and thus the <u>FP/MP is decreased</u>.

This is why salt is added to icy roads in the winter and causes the ice to melt. The amount of the FP depression can be impressive. Explain what happens in making homemade ice cream.

Water

The importance of water to life on this planet cannot be overstated. About 70% of the planet is covered by water and 70% of the mass of each person is water.

The water molecule is small, 2 hydrogens and 1 oxygen yet it provides a <u>solvent</u> for the dissolving of more compounds than any other liquid.

It's properties of relatively <u>high BP/MP</u>, <u>high heat capacity</u>, and <u>expansion upon freezing with a maximum density at 4°C</u> are unusual to say the least. Let's explore these.

High BP/MP

The interparticle forces which hold water in the liquid and solid phase are very high for the size of the molecule. The special name for these interparticle forces is called *hydrogen bonding*. The high BP/MP means that water is a liquid at room temp and liquid water is necessary for life as we know it.

High Specific Heat Capacity

Liquid water has a very high C_p. As a result it is a great heat storage substance. Ocean currents such as the Gulf Stream transport heat from one part of the world to another.

Water heats and cools more slowly than land. Winds blowing across water are responsible for the milder climate of islands and seacoasts where the prevailing winds blow onshore.

Water is also used for its heat storage in car radiators and in passive solar collectors for heating buildings.

Expansion and Contraction

Normally substances expand uniformly when heated starting with the solid phase and extending into the gaseous phase. They contract when cooled. Water is the only common substance which does not.

For most temperatures water does act like other substances. It is from 4°C to 0°C and during freezing that it is different.

Let's think about the water in a lake and how it cools down in the winter. As the air temperature decreases the density increases until we reach 4°C. Since the density is increasing the surface water sinks to the bottom and the bottom water is forced to the top. This causes the water in the lake to "overturn".

At this temperature water's unusual special type of interparticle force (hydrogen bonding) causes the water molecules to start rearranging into a more open hexagonal structure where the molecules are farther apart. The density starts to decrease and the water remains on the surface.

At the FP of water, 0°C, the water completes its rearrangement into the more open hexagonal structure. This means that as liquid water changes into ice it expands and the density decreases even more. The ice floats on the liquid water and the lake starts to freeze slowly from the top down.

The water at the bottom of the lake remains at 4°C throughout the winter and <u>aquatic life survives</u>.