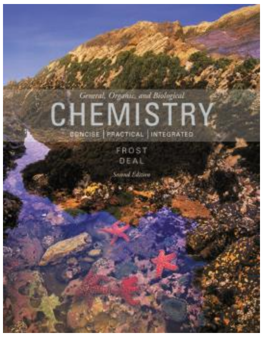

Lecture Presentation

Chapter 7

What's the Attraction?

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Fortis College
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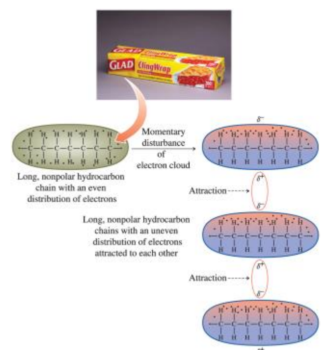
Outline

7.1 Types of Attractive Forces

London Forces

- These attractive forces occur when electrons become unevenly distributed over a molecule's surface.
- When this happens, the partially positive side of this temporary dipole attracts the electrons of the second molecule, creating an attraction between these two molecules and inducing a temporary dipole in the second molecule.
- While *all compounds exhibit London forces*, these forces are significant only in the case of nonpolar molecules because London forces are the only attractive force in which nonpolar molecules participate.
- The terms *induced dipole* and *dispersion force* describe the same attractive force as London forces.

7.1 Types of Attractive Forces



7.1 Types of Attractive Forces

Dipole–Dipole Attractions

- Polar molecules have a permanently uneven distribution of electrons caused by electronegativity differences in the atoms that make up the molecules.
- Such molecules have a **permanent dipole**.
- Because the dipole in these molecules does not come and go, the attraction of the partially positive end of one molecule for the partially negative end of another molecule is stronger than London forces.
- This type of attraction involves the interaction of two dipoles and is called a **dipole–dipole attraction**.
- Molecules with dipoles also have London forces, but they are negligible.

7.1 Types of Attractive Forces

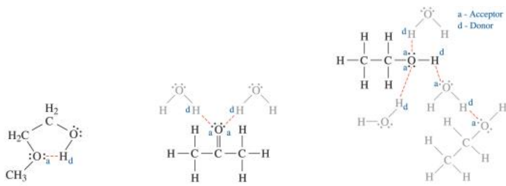
Hydrogen Bonding

- **Hydrogen bonding** involves a polarized hydrogen and is much stronger than other dipole–dipole forces.
- Hydrogen bonding requires the interaction of a donor hydrogen and an acceptor pair of electrons.
- Water can act as both donor and acceptor.
- Hydrogen bonds are illustrated as dashed lines.

TABLE 7.1 Requirements for Hydrogen Bonding

Name	Description
Hydrogen-bond donor (δ^+)	A molecule with a hydrogen atom covalently bonded to an oxygen, nitrogen, or fluorine (O, N, or F)
Hydrogen-bond acceptor (δ^-)	A molecule with a nonbonding (lone) pair of electrons on an oxygen, nitrogen, or fluorine (O, N, or F)

7.1 Types of Attractive Forces



Intramolecular hydrogen bonding in a molecule containing an ether and alcohol group

Intermolecular hydrogen bonding between acetone and water

Intermolecular hydrogen bonding between ethanol and water

7.1 Types of Attractive Forces

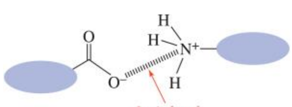
Ion–Dipole Attraction

- The **ion–dipole attraction** occurs between ions and polar molecules such as water.
- Ion–dipole attractions are an important attractive force often seen in biological systems.
- This attractive force is stronger than hydrogen bonding.

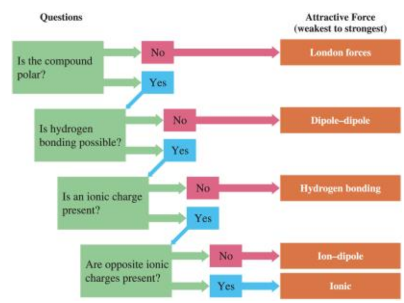
7.1 Types of Attractive Forces

Ionic Attraction

- An ionic attraction is the strongest attractive force because it involves more than just an uneven distribution of electrons.
- Ionic attractions are sometimes called *salt bridges*.
- The organic functional groups carboxylate and protonated amine are found in the amino acids that form proteins and can form salt bridges when they come into contact with each other.



7.1 Types of Attractive Forces



7.1 Types of Attractive Forces

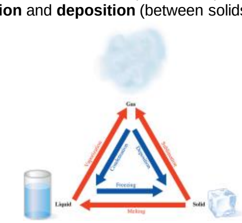
Attractive Forces Keep Biomolecules in Shape

- The attractive forces discussed in this section are used extensively in nature to hold biological molecules together.
- Cellulose molecules are held tightly together through hydrogen bonding between neighboring molecules.
- London forces hold cell membranes together.
- Hydrogen bonding holds a DNA double helix in its twist.
- Protein structures are held together by combinations of all the attractive forces discussed.

7.2 Liquids and Solids: Attractive Forces Are Everywhere

Heat and Attractive Forces

- As a substance is heated, the particles (molecules or ions) begin to move faster and can change phase.
- These transitions are **changes of state.**
- These include **freezing** and **melting** (between liquids and solids), **evaporation** and **condensation** (between liquids and gases), and **sublimation** and **deposition** (between solids and gases).



7.2 Liquids and Solids: Attractive Forces Are Everywhere

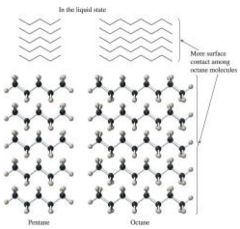
Boiling Points and Alkanes

- For a liquid to boil, the molecules of the liquid must push back the atmosphere at the surface of the liquid, allowing gas molecules of the liquid to escape.
- The liquid molecules must also overcome their attractive forces to the other molecules in the liquid.
- The heat supplied during boiling provides the energy necessary for each molecule to evaporate, moving individually from the liquid into the gas phase.
- When the **boiling point** is reached, the molecules have enough energy to change from a liquid to a gas.
- **Boiling** occurs when gas bubbles form in a liquid and escape at the surface.

7.2 Liquids and Solids: Attractive Forces Are Everywhere

Boiling Points and Alkanes

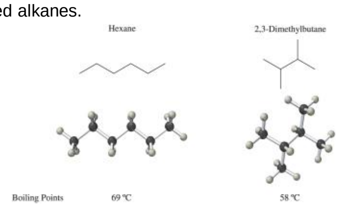
- Straight-chain alkanes with more carbons have stronger attractions between molecules.
- Because these attractions must be overcome for the compound to boil, the boiling point is higher, as is the melting point.



7.2 Liquids and Solids: Attractive Forces Are Everywhere

Boiling Points and Alkanes

- The molecules of branched alkanes have less surface contact than do the straight-chain molecules.
- The more contact between two molecules, the greater the attraction of London forces between them.
- Straight-chain alkanes have higher boiling points than do branched alkanes.



7.2 Liquids and Solids: Attractive Forces Are Everywhere

The Unique Behavior of Water

- Water's electrons are always unevenly distributed, unlike the electrons of alkanes.
- Water molecules strongly attract each other through hydrogen bonding, a much stronger attractive force than London forces.
- For water to boil, there must be enough heat energy to disrupt the hydrogen-bonding interactions, leading to the unusually high boiling point of water.
- Melting points follow the same trends.
- For example, hydrogen sulfide, H_2S, has a similar structure to H_2O but cannot form hydrogen bonds. The melting points of the compounds are extremely different.
- Hydrogen sulfide has a melting point of -80°C, water 0°C.

7.2 Liquids and Solids: Attractive Forces Are Everywhere

TABLE 7.3 Boiling and Melting Point Trends

Nonpolar Molecules	Similar-Sized Molecules, Different Forces	Molecules with Same Forces
The greater the surface area, the higher the boiling or melting point.	The stronger the forces, the higher the boiling or melting point.	The stronger and more numerous the forces, the higher the boiling or melting point.

Predicting Boiling Points

- Step 1: Determine the strongest attractive force present in each.
- Step 2: Predict the higher boiling point based on the strength and number of forces present.

7.3 Attractive Forces and Solubility

The Golden Rule of Solubility: *Like Dissolves Like*

- *Molecules that have similar polarity and participate in the same types of attractive forces will dissolve each other*.

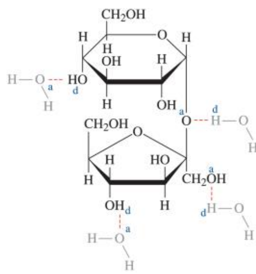
Predicting Solubility: Nonpolar Compounds

- Oils are attracted to neighboring molecules through London forces.
- Water is a polar molecule and interacts with other substances through dipole–dipole, hydrogen bonding, and ion–dipole attractions.
- Oil and water are very *unlike* each other.
- The attractions among the water molecules are much greater than the attraction between a water molecule and an oil molecule.

7.3 Attractive Forces and Solubility

Predicting Solubility: Polar Compounds

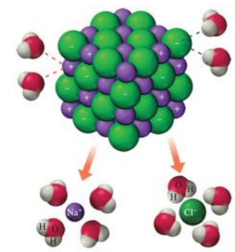
- The hydroxyl groups of sucrose make it a polar compound and give it the ability to interact with water through dipole–dipole and hydrogen-bonding interactions.
- Because table sugar and water are both polar and share these attractive forces, table sugar is an organic compound that is soluble in water.



7.3 Attractive Forces and Solubility

Predicting Solubility: Ionic Compounds

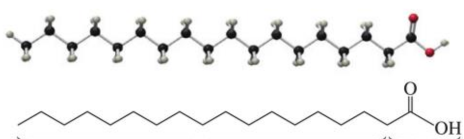
- Individual ion–dipole attractions are not stronger than an ionic bond, but when multiple water molecules interact with an ion, the sum of these attractive forces is greater than the strength of the ionic bonds.
- This process is called **hydration.**



7.3 Attractive Forces and Solubility

Predicting Solubility: Amphipathic Compounds

- Molecules like fatty acids that have both polar and nonpolar parts are called **amphipathic** (from the Greek *amphi* meaning "both" and *pathic* meaning "condition") compounds.



7.3 Attractive Forces and Solubility

Predicting Solubility: Amphipathic Compounds

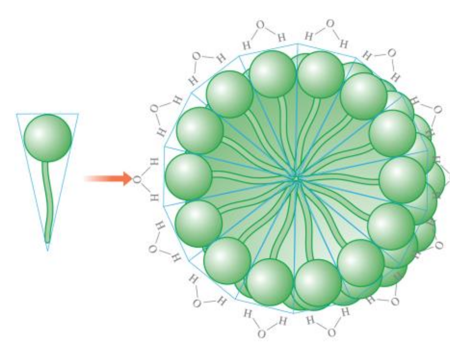
- Soap is composed of fatty acid salts.
- Fatty acid salts are ionic because they contain the carboxylate (hydrogen removed) form of the functional group at one end.
- The charge on the carboxylate makes this end of the molecule ionic.
- Fatty acid salts have long nonpolar hydrocarbon *tails* and extremely polar (ionic) *heads,* so they are amphipathic.

7.3 Attractive Forces and Solubility

Predicting Solubility: Amphipathic Compounds

- The nonpolar tails are **hydrophobic** (water fearing) and will be excluded from the water.
- The ionic heads, which are **hydrophilic** (water loving), interact with the water.
- The tails associate with each other, creating the core of a spherical structure called a **micelle**.
- The polar heads form the shell of the micelle.
- Micelles form because the ion–dipole and hydrogen-bonding attractions between water molecules and the ionic heads are stronger than (and preferred to) water interactions with the hydrocarbon tails.

7.3 Attractive Forces and Solubility



7.3 Attractive Forces and Solubility

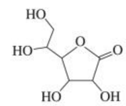
How Soap Works

- Based on the golden rule, greasy dirt is not soluble in water.
- When skin or clothing with a greasy dirt stain is washed with soapy water, the stain is attracted to the nonpolar hydrocarbon tails of the soap and is dissolved in the interior of the micelle formed by the soap molecules.
- Because the surface of the micelle is covered with the polar head groups, the entire micelle is soluble in water and is washed down the drain.
- Amphipathic compounds like soaps are called **emulsifiers** because they allow nonpolar and polar compounds to be suspended in the same mixture.

7.3 Attractive Forces and Solubility

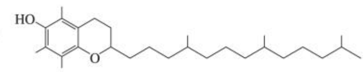
Predicting Solubility in Water

- Step 1: Determine the number of polar attractive forces in each.
- Step 2: Predict the more soluble substance based on the overall polarity of the entire molecule.



Vitamin C, ascorbic acid

or



Vitamin E, alpha-tocopherol

7.4 Gases: Attractive Forces Are Limited

Gases and Pressure

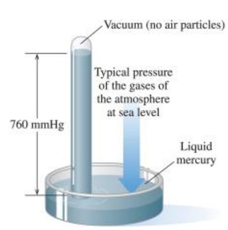
- To illustrate the concept of pressure, imagine an empty syringe.
- If the plunger of the syringe is drawn all the way out, the syringe will fill with air.
- If you close the tip of the syringe and depress the plunger, the sample of air is "squeezed."
- The particles of a gas are usually far apart: a sample of gas is mostly empty space.
- By depressing the plunger, you are compressing the gas by applying pressure to it.
- **Pressure** is a force exerted against a given area.

7.4 Gases: Attractive Forces Are Limited

- **Pounds per square inch (psi)** is a measure of force (measured in pounds) applied to an area of 1 square inch.
- The pressure of the atmosphere at sea level is about 14.7 pounds per square inch, 14.7 psi.
- The unit **millimeters of mercury (mmHg)** can also be used to measure the pressure exerted by the atmosphere surrounding Earth.
- The typical pressure exerted by the atmosphere at sea level supports a column of mercury 760 mm high.

7.4 Gases: Attractive Forces Are Limited

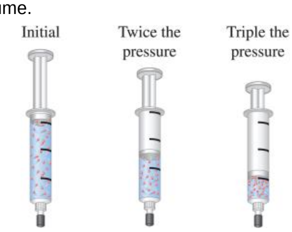
- The pressure of the atmosphere can be measured using a mercury barometer.
- This is a long, sealed glass tube with liquid mercury inverted into a dish of mercury without letting air into the tube.
- The force of the atmosphere prevents most of the mercury in the tube from draining out.
- If the tube is long enough, a column of mercury 760 mm high (29.92 in) will remain inside the tube at sea level.



7.4 Gases: Attractive Forces Are Limited

Pressure and Volume—Boyle's Law

- In the mid-1600s, Irish chemist Robert Boyle began to experiment with the effect of pressure on the volume of a gas.
- Boyle discovered that that when the pressure on a gas was doubled, the volume of the gas was reduced to half of its initial volume.



7.4 Gases: Attractive Forces Are Limited

- Boyle found *that the volume of a fixed amount of gas at constant temperature is inversely proportional to the pressure*.

$$P_1V_1 = P_2V_2$$

- where P_1 is the initial or starting pressure
- V_1 is the initial or starting volume
- P_2 is the final or ending pressure
- V_2 is the final or ending volume

7.4 Gases: Attractive Forces Are Limited

Solving a Problem: Boyle's Law

- Step 1: Determine the given information.
- Step 2: Solve for the missing variable using the Boyle's law relationship
- Step 3: Substitute the given information into the equation and solve.
- Check to make sure your answer makes sense.

7.4 Gases: Attractive Forces Are Limited

- Breathing is a practical application of Boyle's law.
- When you breathe in, the volume of your chest cavity increases, the air pressure inside your lungs decreases, and the pressure of the atmosphere causes air to rush into your lungs to equalize the internal and external pressures.
- When the muscles relax, the volume of your chest cavity decreases, increasing the pressure in your lungs above that of the outside, and air flows out to the lower pressure (atmosphere).

7.4 Gases: Attractive Forces Are Limited

Temperature and Volume—Charles's Law

- If the pressure and amount of a gas are not allowed to change, the volume of the gas is directly proportional to its absolute temperature.
- French scientist Jacques Charles discovered that when the absolute temperature of a gas was doubled, the volume of the gas also doubled.
- Charles's law states: *The volume of a fixed amount of gas at constant pressure is directly proportional to its absolute temperature.*

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

7.4 Gases: Attractive Forces Are Limited

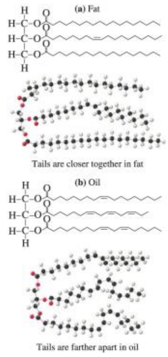
Solving a Problem: Charles's Law

- **Step 1: Determine the given information.** In gas law problems, temperatures must be converted to the absolute temperature scale, Kelvin.
- **Step 2: Solve for the missing variable using the Charles's law relationship.**
- **Step 3: Substitute the given information into the equation and solve.**
- Make sure your answer makes sense!

7.5 Dietary Lipids and Trans Fats

- Animal **fat** is a solid or semisolid material at room temperature that is a triglyceride made up of three fatty acids joined to a glycerol backbone.
- When hydrocarbon chains (tails) of fatty acids are mostly saturated, the triglyceride product is a fat.
- When hydrocarbon chains (tails) of fatty acids are mostly unsaturated, the triglyceride product is an oil.

7.5 Dietary Lipids and Trans Fats



7.5 Dietary Lipids and Trans Fats

- Fats are solids at room temperature because the motion of their hydrocarbon tails is restricted by London forces.
- When a substance melts, attractive forces are disrupted, and molecular motion increases.
- For a fat to melt, the forces that have to be disrupted are weak London forces.
- Fats are typically solid substances but with low melting points. Fats are often said to be semisolid.

7.5 Dietary Lipids and Trans Fats

Oils Are Liquids

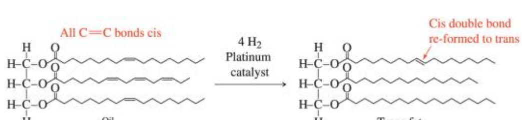
- **Oils** are derived from plants and are also triglycerides.
- Oils are liquids and fats are solids.
- Cis double bonds in the tails of the oil creates kinks in the normally straight hydrocarbon chain.
- Greater molecular freedom of motion among the hydrocarbon tails in the oil does not allow enough stacking of the tails for a solid to form, so oils remain liquid.

7.5 Dietary Lipids and Trans Fats

Partial Hydrogenation and Trans Fats

- The only difference between fats and oils is the number of double bonds in the fatty acid chains.
- The hydrogenation of plant-derived oils is controlled so that some double bonds become saturated while others remain intact.
- *Partial hydrogenation* allows producers to create margarines that are less saturated than butter, making them easier to spread.
- Some of the double bonds in these compounds re-form as the more stable trans form, resulting in *trans fats*.

7.5 Dietary Lipids and Trans Fats

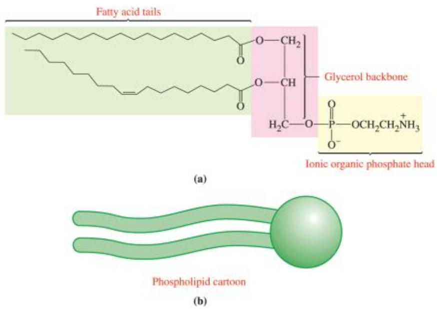


7.6 Attractive Forces and the Cell Membrane

A Look at Phospholipids

- The main structural components of cell membranes are **phospholipids**.
- Phospholipids have a glycerol backbone with fatty acids linked to it through an ester bond.
- Phospholipids have only *two* fatty acids on their glycerol backbone. The third OH group of the glycerol is bonded to a phosphate-containing group.

7.6 Attractive Forces and the Cell Membrane

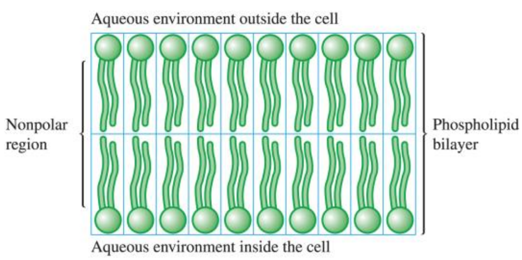


7.6 Attractive Forces and the Cell Membrane

The Cell Membrane Is a Bilayer

- A cell membrane composed of phospholipids cannot exist as a single layer.
- Instead, the phospholipids form a double layer called a *bi*layer.
- The polar heads are directed out into the surrounding aqueous environment and into the aqueous interior of the cell.
- This arrangement leaves the nonpolar tails of both layers directed toward each other, creating a nonpolar interior region.

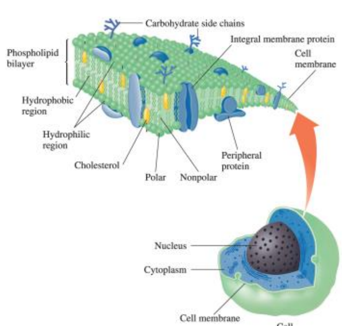
7.6 Attractive Forces and the Cell Membrane



7.6 Attractive Forces and the Cell Membrane

- Protein molecules can span the bilayer (integral membrane proteins) or associate with one surface (peripheral membrane proteins).
- Proteins are the membrane's functional components, allowing selected molecules to move into and out of the cell.
- The exterior surface of the cell membrane also contains carbohydrates that act as cell signals.
- The **fluid mosaic model** creates "icebergs" of protein floating in a "sea" of lipids.
- The membrane is fluidlike: the phospholipids move freely within their bilayer.

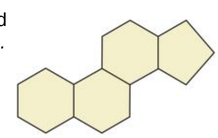
7.6 Attractive Forces and the Cell Membrane



7.6 Attractive Forces and the Cell Membrane

Steroids in Membranes: Cholesterol

- **Steroids** contain a four-membered fused ring called a *steroid nucleus.*
- Even though the steroid structure differs greatly from fatty acids and triglycerides, because they are nonpolar, steroids are classified as lipids.
- These molecules have a variety of functions in the body including regulating sexual development (testosterone and estrogens) and emulsifying dietary fats (bile acids).

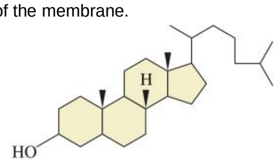


A steroid nucleus

7.6 Attractive Forces and the Cell Membrane

Steroids in Membranes: Cholesterol

- Cholesterol contains the steroid nucleus with a polar end.
- Cholesterol situates itself so that the –OH group protrudes out into the aqueous environment, while the rest of the molecule nestles in the nonpolar interior of the membrane.
- Cholesterol can slip in between the saturated hydrocarbon tails of phospholipids, increasing fluidity.
- Cholesterol can also interact with unsaturated tails, increasing the rigidity of the membrane.



Chapter Seven Summary

7.1 Types of Attractive Forces

- The attractive forces present in a substance can be determined by the polarity of the compound.
- The types of attractive forces present between compounds (from weakest to strongest) are London forces, dipole–dipole, hydrogen bonding, ion–dipole, and ionic attractions.
- Each of these forces involves the attraction of an area of negative charge (either partial or full) on one molecule to an area of positive charge on a second molecule.
- The ionic attraction occurs between a full + and – charge and occurs between any two oppositely charged ions.

Chapter Seven Summary

7.2 Liquids and Solids: Attractive Forces Are Everywhere

- The boiling point is the temperature where the change of state from liquid to gas occurs.
- For a compound to boil, the molecules of the compound must overcome the attractive forces between molecules.
- The boiling points and melting points of compounds can be predicted by examining the attractive forces present.
- Compounds with stronger attractive forces require more heat to disrupt those attractions and have higher boiling points.
- Water has a very high boiling point.
- In contrast, for alkanes that have only London forces between molecules, the boiling point depends largely on the surface area of the molecule—the greater the surface area, the higher the boiling point.

Chapter Seven Summary

7.3 Attractive Forces and Solubility

- The solubility of one substance in another is described by the golden rule of solubility, *like dissolves like*, which means that polar compounds dissolve polar compounds and nonpolar compounds dissolve other nonpolar compounds.
- In other words, the more attractive forces that two compounds have in common, the more soluble they will be in each other.
- Soap is an amphipathic compound.
- In water, soap molecules form spherical structures called micelles with the hydrophobic tails gathered in the nonpolar interior of the micelle, while the hydrophobic heads cover the surface and interact with the aqueous external environment.
- Most organic compounds containing functional groups are soluble to various extents in water based on the number and distribution of polar or ionic groups.

Chapter Seven Summary

7.4 Gases: Attractive Forces Are Limited

- Gases have few attractive forces because particles in a gas are often too far apart for an attraction to occur.
- Pressure is force exerted on a given area and is typically measured in units of psi or mmHg.
- Changing the pressure or temperature of a gas causes a change in the volume of the gas.
- Boyle's law compares volume and pressure. Pressure and volume are inversely related at constant temperature. As volume decreases, pressure increases.
- Charles's law compares volume and temperature. Temperature and volume are directly related at constant pressure. As temperature increases, volume increases.

Chapter Seven Summary

7.5 Dietary Lipids and Trans Fats

- Melting is the change of state from solid to liquid. This change involves a decrease in attractive forces and an increase in the motion of the molecules in the substance.
- Fats are solid triglyceride compounds that have low melting points.
- Oils are also triglycerides, but they are liquids at room temperature. The fatty acid tails of oils are highly unsaturated, and they have fewer London forces between their fatty acid tails than fats.
- Oils can be converted into fats by hydrogenation of the double bonds to increase the saturation of the fatty acid tails. This is the process used to create margarine from oils derived from plants.
- Hydrogenation often results in the conversion of naturally occurring cis double bonds to trans isomers. The products of this process are less healthful trans fats.

Chapter Seven Summary

7.6 Attractive Forces and the Cell Membrane

- Cell membranes are composed of phospholipids, which are amphipathic.
- Phospholipids have a strongly polar head and two nonpolar tails.
- Because of their shape, phospholipids of the cell membrane arrange themselves in a bilayer around the cellular contents with the polar heads of one layer oriented out into the surrounding aqueous environment and the polar heads of the second layer directed inward toward the aqueous interior of the cell.
- This results in a hydrophobic interior layer formed by the nonpolar tails.
- The fluid mosaic model describes the complete structure of the cell membrane.
- Cell membranes also contain cholesterol, a steroid lipid, which helps modulate the fluidity of the membrane.

Chapter Seven Study Guide

7.1 Types of Attractive Forces

- Describe five types of attractive forces present in compounds.
- Determine the attractive forces present in a compound from its chemical structure.

7.2 Liquids and Solids: Attractive Forces Are Everywhere

- Describe the process of boiling.
- Predict boiling points for liquids based on the attractive forces present.
- Predict melting points for solids based on the attractive forces present.

Chapter Seven Study Guide

7.3 Attractive Forces and Solubility

- State the golden rule of solubility.
- Predict the solubility of a molecule in water.
- Recognize an amphipathic molecule.
- Define the role of an emulsifier.
- Draw a fatty acid micelle.

7.4 Gases: Attractive Forces Are Limited

- Contrast the attractive forces present in a gas with those in a solid or liquid.
- Define pressure.
- Apply Boyle's law.
- Apply Charles's law.

Chapter Seven Study Guide

7.5 Dietary Lipids and Trans Fats

- Distinguish a fat from an oil.
- Describe the differences in melting points of fats and oils based on their attractive forces.
- Predict the products of the complete hydrogenation of a triglyceride.

7.6 Attractive Forces and the Cell Membrane

- Draw a phospholipid bilayer.
- Describe the structure of a cell membrane.
- Locate the polar and nonpolar regions of a phospholipid and cholesterol.
- Classify molecules as steroids based on their structure.