Read Sections 6.3 and 6.4 before viewing the slide show.
Unit 22
Forces Between Molecules and in Solution

• Three types of Intermolecular Forces (6.3)
• Forces in Solution (6.4)
The fact that particles condense into liquids and solids requires some sort of explanation. Some aspects of interest include:

- Electrically neutral atoms, such as He, will actually be attracted to each other to the point of liquefying or becoming solid if the temperature is low enough.
- Atoms of different sizes condense at different temperatures, with heavier atoms condensing at lower temperatures.
- Molecules condense because of attractions of molecules for each other, not because they form new covalent bonds.
- Even similarly-sized molecules of different compounds will condense at different temperatures.

There are three fundamental types of intermolecular forces:

- Dispersion forces
- Dipole-dipole interactions
- Hydrogen bonding

These three forces will be covered on the next few slides.
Consider the figure below that very marginally represents two He atoms. The nuclei are indicated by the small blue circles with the “+” sign. The large pink circles represent where the electrons are – the charge is distributed throughout the pink circles.

As the nuclei approach each other, the electrons which are mobile tend to migrate away from the other atom since like charges repel. At the same time, the nuclei become more exposed but now the electrons from the other atom can be attracted to the other nuclei.

This temporary shift of charge allows the two atoms to be attracted to one another. Dispersion forces exist between any two particles – nonpolar atoms or molecules, polar molecules, and ions.
Dipole-Dipole Forces (6.3)

• Dipole-dipole forces occur between molecules that are polar (reference Unit 16). A polar molecule has a permanent separation between the positive and negative charge centers as seen in \( \text{NH}_3 \) to the right. The separation of charge may also be represented by the arrow.

• If polar molecules are close together, the molecules may align themselves so the negative ends are close to positive ends. The result is an overall attraction of one molecule for another.

• The more polar the molecules (the larger the arrow is) the stronger the forces will be.

• The primary differences between the dispersion forces and the dipole-dipole forces are that the dispersion are between temporarily polar species with small degrees of polarity while the dipole-dipole are between molecules that are permanently polar.
Hydrogen Bonding (6.3)

- Hydrogen bonding occurs when molecules have a hydrogen atom bonded to a fluorine, nitrogen, or oxygen.
- The attractive force results from the interaction of the H to the N, O, or F on another molecule. For example, in water the oxygen atoms (red) can form hydrogen bonds with the hydrogen atoms (gray) from other molecules as indicated by the dashed lines in the figure.
Identifying the Presence of Intermolecular Forces (6.3)

• Identification of intermolecular forces present in a given compound is based on the following considerations:

  • Dispersion forces – present between molecules of all substances

  • Dipole-dipole forces – present between polar molecules

  • Hydrogen bonding – present between molecules that contain hydrogen atoms bonded directly to nitrogen, oxygen, or fluorine

• The greater the intermolecular forces between particles of a substance the more difficult it will be to separate them. This means that, when comparing two substances, the one with stronger intermolecular forces will boil at a higher temperature and freeze at a higher temperature.
The previous forces discussed (dispersion, dipole-dipole, and hydrogen bonding) were considered in the context of pure substances. The ideas may be extended to the process of forming solutions.

In forming a solution, the particles of the solvent must be able to accommodate the particles of the solute, meaning the intermolecular forces must be similar. Pictorially:

To form the solution, the intermolecular forces between solvent particles have to be similar to those between solute particles so that in the combined solution neither component has experienced a large difference in attractive forces.

This observation is sometimes summarized in the expression “like dissolves like”. This expresses the observation that, for example, polar compounds will likely dissolve other polar compounds, nonpolar will dissolve nonpolar, but polar will not dissolve nonpolar.
• When an ionic compound, such as NaCl, dissolves in water, the polar nature of the water molecules allows them to surround the Na\(^+\) and Cl\(^-\) ions and tear apart the crystal structure as in the figure to the right. The red ends of the water molecules are the oxygen (more negative end of the molecule) and the gray ends are the hydrogen atoms (more positive end of the molecule). The orange spheres are Cl\(^-\) ions and the yellow spheres are Na\(^+\) ions.

• Whether an ionic compound will dissolve well or not depends on the relative attraction of its ions for each other – how strongly the lattice is held together – compared to the strength of the attractions between the solvent and the ions.

• You may recall that solutions of ionic compounds in water conduct electricity. The image to the right helps explain that – when the ionic compound dissolves, it forms charged particles that can then conduct electricity.