Chapter 17

Phase Changes

(Common) Phases of Matter

- Solid: Retains shape and volume
- Liquid: Retains volume but not shape
- Gas: Retains neither shape nor volume
- Plasma: An electrified gas

Fun Fact (?!)

- Cats seem to have the uncanny ability to change their state between solid and liquid at will:

Changing State

Evaporation: Liquid → Gas

- Evaporation is a cooling process (Why?)

  While the molecules in the liquid have some average kinetic energy per molecule, some move faster while others move slower. Those faster moving molecules near the surface that have sufficient kinetic energy can escape the liquid.

- What cools?

  The liquid that remains.

Evaporation vs. Boiling

- Evaporation: liquid to gas at the surface.
- Boiling : liquid to gas throughout the entire liquid.

Changing State

Condensation: Gas → Liquid

- Condensation is a warming process (Why?)

  The molecules in the gas have higher average kinetic energy per molecule than those of the liquid. When gas molecules slam into the liquid, they give up there excess energy to the liquid molecules thus raise the average kinetic energy per molecule of the liquid.

- What warms?

  The liquid that is forming.

Changing State

Melting: Solid → Liquid

(substance gains energy)

Freezing: Liquid → Solid

(substance releases energy)

Sublimation: Solid → Gas

(substance gains energy)

Deposition: Gas → Solid

(substance releases energy)

The phase changes described above occur at a particular temperature that depends on the material (and on the environment*.)

For H_2O under atmospheric pressure:

$$T_{melt/freeze} = 0\ ^{o}C$$

$$T_{boil/condense} = 100\ ^{o}C.$$

*Example: At lower pressure, boiling point is lower, and at higher pressure, the boiling point is higher.

Latent Heat

Energy required to cause a phase change.

- Latent heat of fusion, L_f : Solid $\longleftrightarrow$ Liquid
- Latent heat of vaporization, L_v : Liquid $\longleftrightarrow$ Gas
- Latent heat of sublimation, L_s : Solid $\longleftrightarrow$ Gas

For H_2O…

L_f = 80 calories per gram (cal/g)

L_v = 540 cal/g

Example: How much heat is needed to melt 20 grams of ice at 0 ^oC into liquid water at 0 ^oC?

$Q = mL_f$ = (20 g)(80 cal/g) = 1600 cal

Another example:

Example: How much heat is needed to melt 20 grams of ice at 0 ^{o}C into steam water at 100 ^{o}C?

Three steps involved:

1) Melt the ice:

$Q_{melt} = mL_f$ = (20 g)(80 cal/g) = 1600 cal

2) Raise the temperature of the melted ice from 0 ^{o}C to 100 ^{o}C:

$Q_{raise} = mc\Delta T$ = (20 g)(1 cal/g/ C^{o})(100 ^{o}C – 0 ^{o}C) = 2000 cal

3) Vaporize the liquid water into steam:

$Q_{vap} = mL_v$ = (20 g)(540 cal/g) = 10800 cal

Total heat required: (1600 + 2000 + 10800) cal = 14400 cal