Vapor Pressure of Liquids

- The vapor pressure of a liquid is measure of its “volatility”
- Vapor pressure is defined as the pressure exerted by the gas-phase molecules over a liquid
- Vapor pressure is a strong function of temperature—the higher the temperature, the higher the vapor pressure

Vapor Pressure and Boiling Point

- The **boiling point** of a liquid is defined as that temperature when the vapor pressure of the liquid is equal to the total pressure of gas over the liquid
- The **normal boiling point** is defined as that temperature when the vapor pressure of the liquid is equal to 1 atm
  - For H_2O, the normal boiling point is 100.0 ^oC
  - For CH_3OH, the normal boiling point is 64.6 ^oC
  - For C_2H_5OH, the normal boiling point is 78.3 ^oC

Vapor Pressure and Boiling Point

- The vapor pressure of a liquid is related to its heat of vaporization, ΔH_{vap}, through the Clausius-Clapeyron Equation:

$$\ln\left(\frac{P_2}{P_1}\right) = \frac{-\Delta H_{vap}}{R}\left[\frac{1}{T_2} - \frac{1}{T_1}\right]$$

- If P_1 = 1 atm, then T_1 is the normal boiling point, and we can determine the vapor pressure at any other temperature

Vapor Pressure and Boiling Point

<u>Example:</u> Determine the vapor pressure of H_2O at 50.0 ^oC

ΔH_{vap} = 40.79 kJ mol^{-1}

T_b = 100.0 ^oC

$$\ln\left(\frac{P_2}{P_1}\right) = \frac{-\Delta H_{vap}}{R}\left[\frac{1}{T_2} - \frac{1}{T_1}\right]$$

T_1 = 100.0 + 273.2 = 373.2 K P_1 = 760 Torr

T_2 = 50.0 + 273.2 = 323.2 K

$$P_2 = (760 \text{ Torr})\exp\left\{\frac{-40{,}790 \text{ J mol}^{-1}}{8.314 \text{ J mol}^{-1}\text{K}^{-1}}\left[\frac{1}{323.2 \text{ K}} - \frac{1}{373.2 \text{ K}}\right]\right\} = 99.4 \text{ Torr}$$

Phase Changes

- Changes in the phase of a substance (solid, liquid, or vapor) occur when the amount of kinetic energy in the substance is changed
- When energy is put into the system from the surroundings, we get:

  Melting—transition from solid ⇒ liquid

  Boiling—transition from liquid ⇒ vapor

  Sublimation—transition from solid ⇒ vapor
- When energy is removed from the system, we get condensation, freezing, or deposition

Phase Changes

- The energy associated with a phase transition is called the enthalpy of:

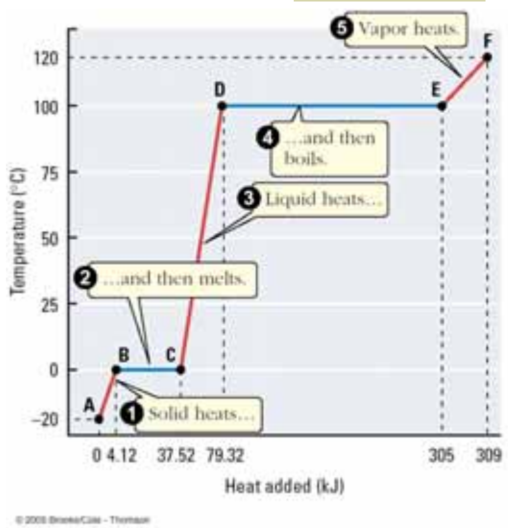
  vaporization, ΔH_{vap}—boiling

  fusion, ΔH_{fus}—melting

  sublimation, ΔH_{sub}—sublimation
- $\Delta H_{vap}(H_2O) = 40.79$ kJ mol^{-1}: you must put 40,790 J of energy in to boil 1 mole of water at its normal boiling point
- If 1 mole of water condenses, you get 40,790 J of energy out of the system

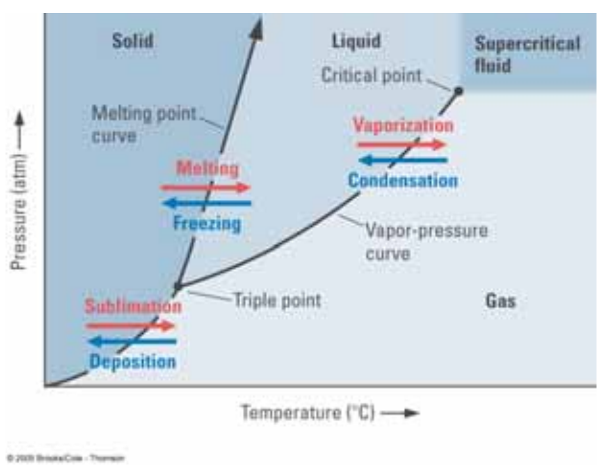
Heating Curves

- If you begin with a pure solid and add energy to the system, we can plot the temperature of the system as a function of time to produce a heating curve

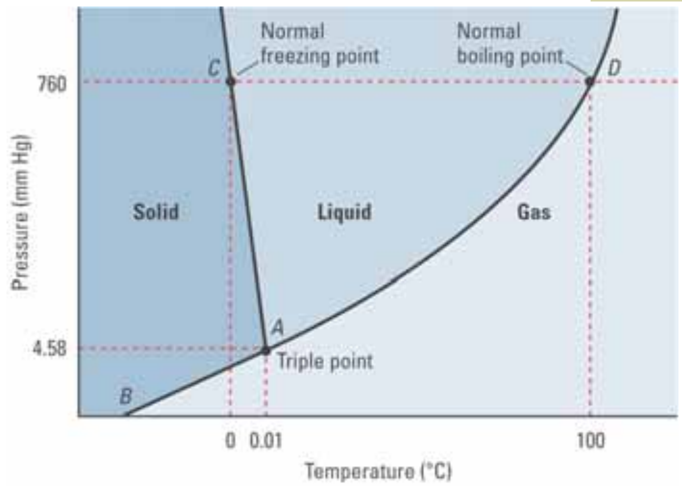


Phase Diagrams

- We can plot the different phases of a substance as a function of temperature and pressure to produce a phase diagram



Phase Diagram of Water



Types of Solids

- There are different types of solids depending on the bonding and attractive forces that occur within each type

1. Ionic solids: one or more electrons are transferred from a metal to a non-metal, and the resulting ions are held together by electrostatic attraction

   $NaCl$, $CaCl_2$, $(NH_4)_3PO_4$

Types of Solids

2. Metallic solids: the valence atomic orbitals of the individual metal atoms combine to form molecular orbitals in which the electrons are no longer associated with an individual nucleus, but rather are free to move throughout the entire metallic solid

   Fe, Ag, Au, Cu, alloys

Types of Solids

3. Molecular solids: individual molecules are held together by intermolecular attractive forces such as dispersion forces, dipole-dipole interactions, or hydrogen bonding

   H_2O(ice), CO, CO_2, CH_3COCH_3 (acetone)

Types of Solids

4. Network solids: atoms are held together in an network by covalent bonds with a very specific solid crystalline structure

The network may be either one-, two-, or three-dimensional

C(diamond), C(graphite), SiO_2(quartz), $KAlSi_3O_8$ (K-feldspar)

Types of Solids

5. Amorphous solids: atoms are held together in a three-dimensional network by covalent bonds, but the solid does not have a specific crystalline structure

SiO_2(glass), polyethylene, nylon