Section 10.3
Phase Transition

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Learning Objectives

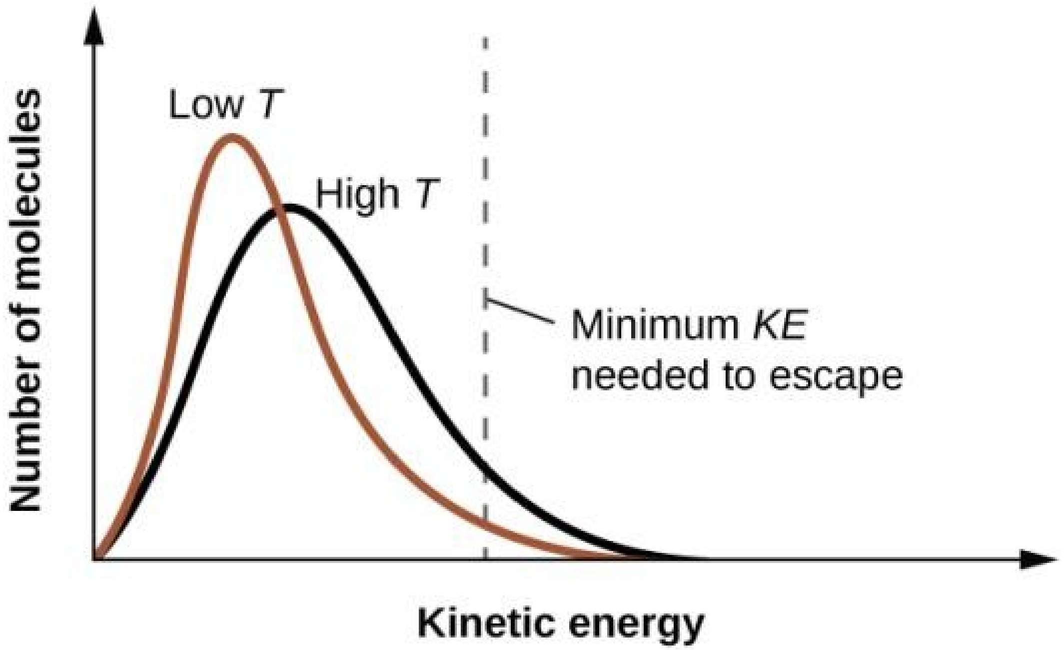
- Define phase transitions and phase transition temperatures
- Explain the relation between phase transition temperatures and intermolecular attractive forces
- Describe the processes represented by typical heating and cooling curves, and compute heat flows and enthalpy changes accompanying these processes

Condensation and Vaporization

- **Vaporization** is the phase transition from a liquid to a gas.
- **Condensation** is the phase transition from a gas to a liquid.
- This process is a **Dynamic Equilibrium**. Molecules are always moving between the two phases.
- The **Vapor Pressure** will determine where this equilibrium lies. It depends on temperature.
- When the **Partial Pressure** of a compound is equal to the **Vapor Pressure**, equilibrium is reached.

Vapor Pressure and Temperature

- Temperature affects the distribution of kinetic energies for the molecules in a liquid. At the higher temperature, more molecules have the necessary kinetic energy, KE, to escape from the liquid into the gas phase.

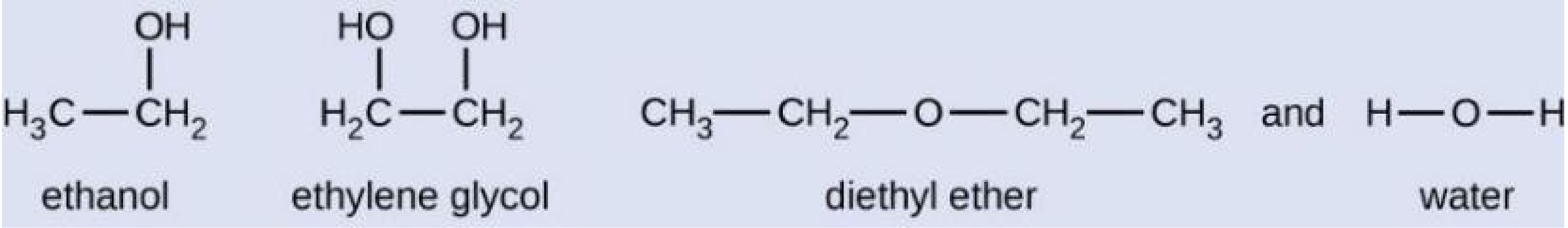


Boiling

- **Boiling** occurs when the vapor pressure of a liquid exceeds the atmospheric pressure above the liquid.
- **Boiling Point** is the temperature at which this occurs. It depends on the atmospheric pressure.
- **Normal Boiling Point** is the boiling point at 1 atm of pressure.
- During boiling the temperature remains constant.

Intermolecular Forces at Work

- When the intermolecular forces between a liquid's molecules are stronger than the intermolecular forces between the liquid molecules and air molecules, the **vapor pressure** will be relatively low.
- When the intermolecular forces between the air and liquid are stronger than the IMFs between liquid molecules, the vapor pressure will be relatively high.



Clausius-Clapeyron Equation

$$\ln P = -\frac{\Delta H_{\text{vap}}}{RT} + \ln A$$

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

$$R = 8.314\ \frac{\text{J}}{\text{mol} \cdot \text{K}}$$

Enthalpy of Vaporization

- Remember enthalpy from thermochemistry? ΔH_{vap} is a special case of a phase change from liquid to gas.
- Because gases are higher energy species than liquids the process is endothermic.
- The sign of ΔH_{vap} indicates the direction.

$$H_2O(l) \longrightarrow H_2O(g) \qquad \Delta H_{\text{vap}} = 44.01\ \text{kJ/mol}$$

$$H_2O(g) \longrightarrow H_2O(l) \qquad \Delta H_{\text{con}} = -\Delta H_{\text{vap}} = -44.01\ \text{kJ/mol}$$

Melting and Freezing

- **Melting** describes the phase transition from a solid to a liquid.
- **Freezing** describes the phase transition from a liquid to a solid.
- The temperature at which this transition happens is called the **Melting Point** or **Freezing Point.**
- ΔH_{fus} data can be found in Appendix G of the Textbook.

$$H_2O(s) \longrightarrow H_2O(l) \qquad \Delta H_{\text{fus}} = 6.01\ \text{kJ/mol}$$

$$H_2O(l) \longrightarrow H_2O(s) \qquad \Delta H_{\text{frz}} = -\Delta H_{\text{fus}} = -6.01\ \text{kJ/mol}$$

Sublimation and Deposition

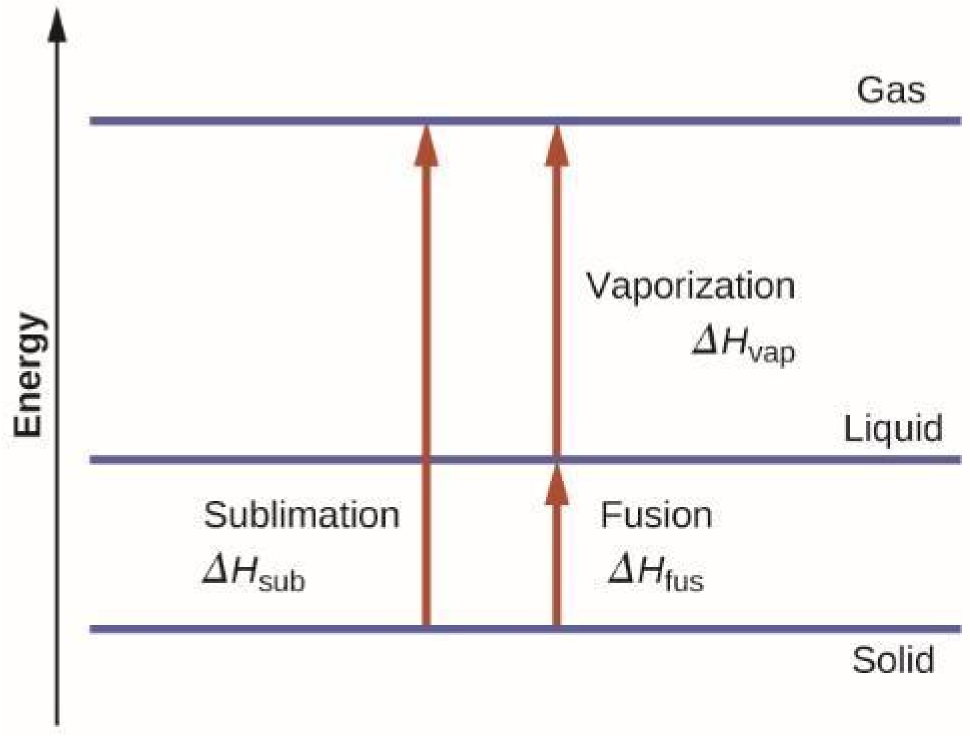
- **Sublimation** describes the transition from a solid to a gas.
- **Deposition** describes the transition from a gas to a solid.
- Whether or not a compound will melt or sublime depends on the its identity, the pressure, and the temperature.

$$CO_2(s) \longrightarrow CO_2(g) \qquad \Delta H_{sub} = 26.1\ \text{kJ/mol}$$

$$CO_2(g) \longrightarrow CO_2(s) \qquad \Delta H_{dep} = -\Delta H_{sub} = -26.1\ \text{kJ/mol}$$

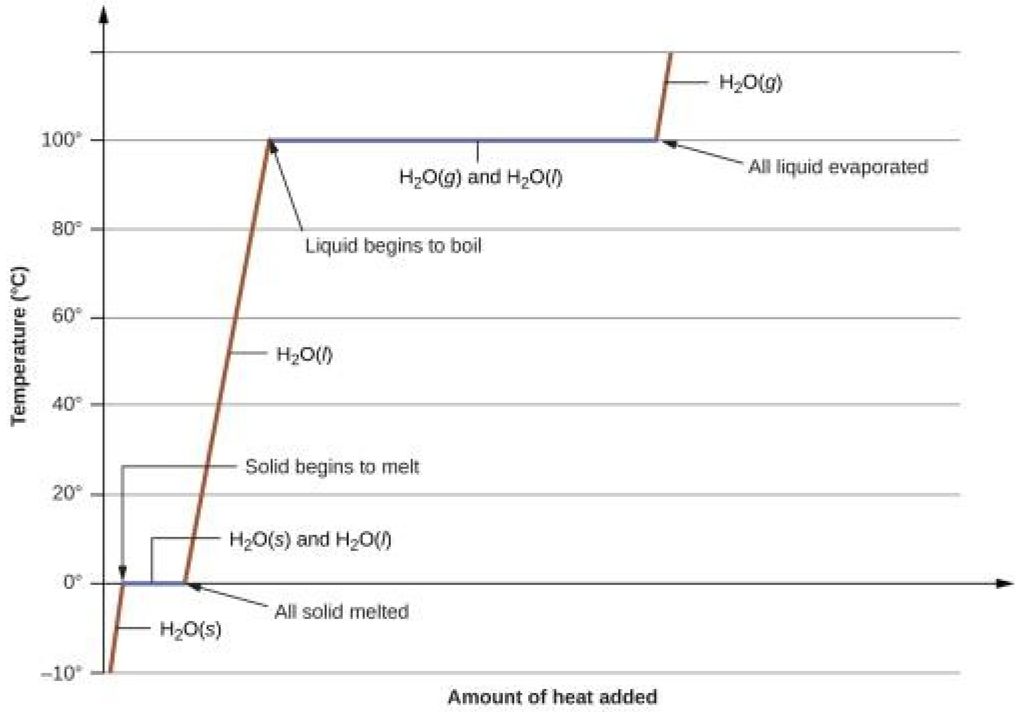
Phase Transition Enthalpy

- For a given substance, the sum of its enthalpy of fusion and enthalpy of vaporization is approximately equal to its enthalpy of sublimation.



Heating Curves

- A typical heating curve for a substance depicts changes in temperature that result as the substance absorbs increasing amounts of heat. Plateaus in the curve (regions of constant temperature) are exhibited when the substance undergoes phase transitions.



Conclusions

- Each type of phase transition has its own enthalpy value associated with it.
- The sign of these enthalpy changes indicate direction. The magnitude indicates the strength of IMFs.
- The Clausius-Clapeyron equation relates the P, T, and ΔH_{vap}.
- The temperature of a compound will remain constant during phase transitions.