Chemistry

Chapter 10

Liquids and Solids – but mostly liquids

Section 1

Chapters:

10.1 Intermolecular Forces

10.8 Changes in State

Bonding Forces in molecules

There are two types of bonding forces in molecules

1. Intramolecular forces

2. Intermolecular forces

Intramolecular Forces

Intramolecular forces occur when electrons are shared between atoms

Intra meaning “Within”

These are forces we are most familiar with

They include:

- Ionic Bonding
- Polar + Nonpolar Covalent Bonding

Intermolecular Forces

Intermolecular forces are forces between molecules.

There are three types of intermolecular forces that we will talk about.

- **Hydrogen Bonding**
- **Dipole-Dipole**
- **London Dispersion Forces**

↑ Strength of Force

Important: Intramolecular bonds are stronger than inter molecular forces.

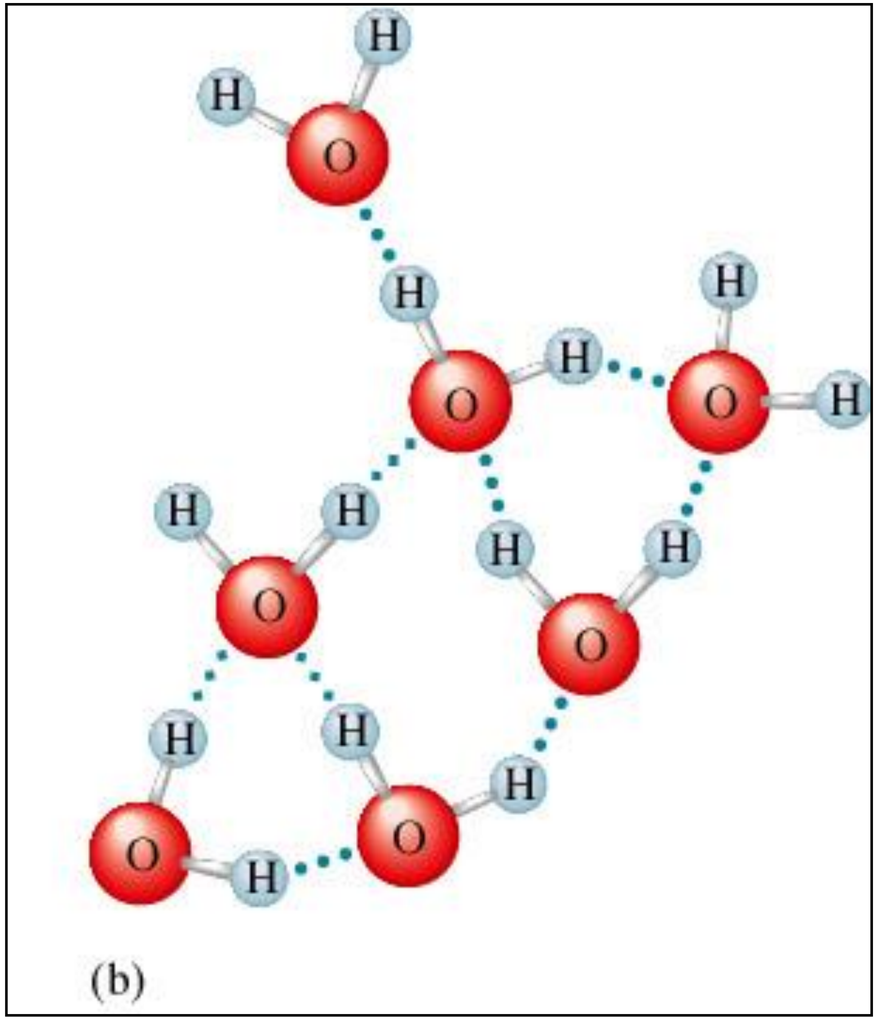
Intermolecular Forces – Hydrogen Bonding

- These are intermolecular forces that occur between molecules where the molecules have polar covalent bonds that involve hydrogen.
- The negative pole of the electronegative atom is attracted to the positive pole of the hydrogen atom.
- This is the strongest intermolecular force.

Intermolecular Forces – Hydrogen Bonding

Example: Hydrogen Bonding in Water

Note: The dotted lines represent the intermolecular forces between the molecules.



Intermolecular Forces – Dipole-Dipole Forces

- **This is similar to hydrogen bonding with the exception that there is no hydrogen atom.**

- **This can only occur when the molecule possesses polar covalent bonds.**

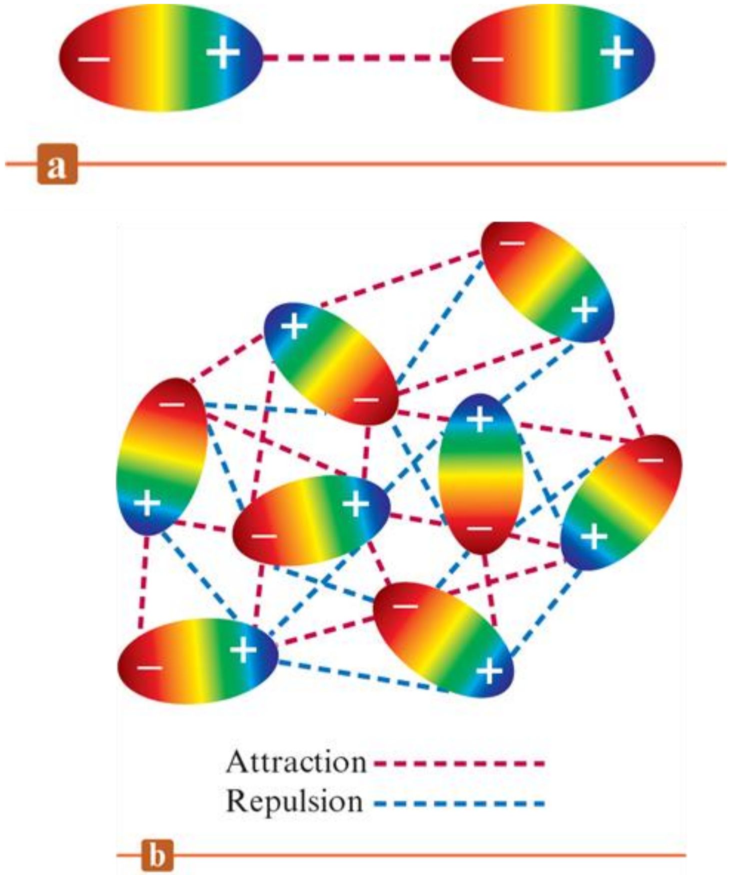
- **The negative pole of the electronegative atom is attracted to the positive pole of the less electronegative atom.**

- **This is the second strongest intermolecular force.**

Intermolecular Forces – Dipole-Dipole Forces

Example: Dipole-Dipole Interactions

Note: This intermolecular force is present in all molecules that have polar covalent bonds.



Intermolecular Forces – London Dispersion Forces

- **These are intermolecular forces that exist between Nobel Gases and nonpolar molecules**

- **These are forces that occur when instantaneous dipoles can occur within the molecule.**

- **The polarizability of the molecule will affect the London Dispersion Force**

- **In general – The higher the molecular weight = strong London dispersion force**

- **These are the weakest intermolecular forces.**

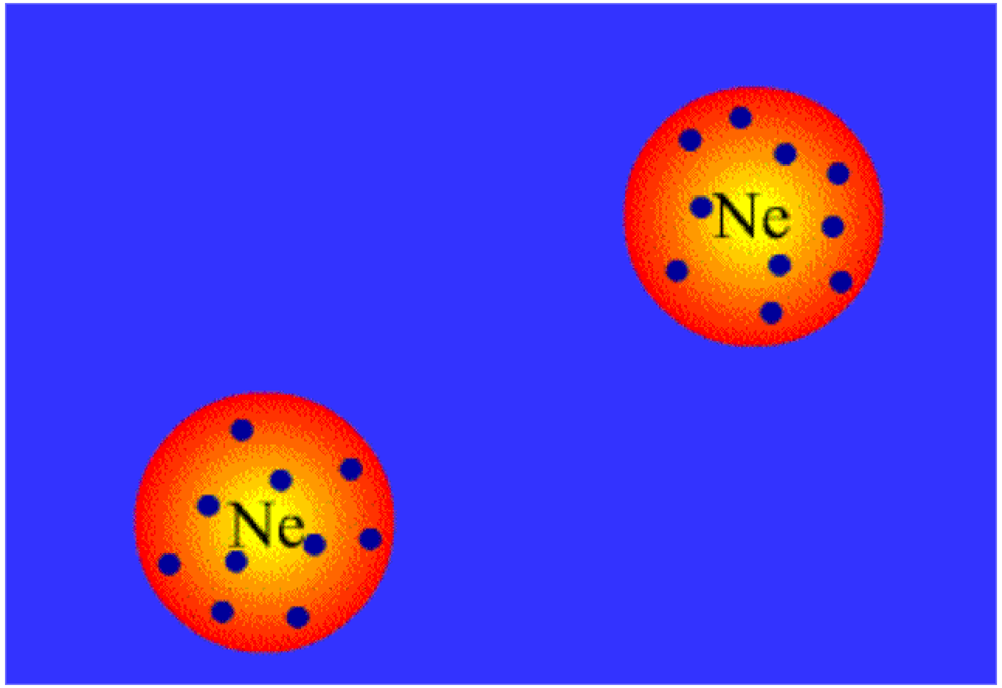
Intermolecular Forces – London Dispersion Forces

Demonstration

Intermolecular Forces – London Dispersion Forces

Example: London Dispersion Forces

Note: This intermolecular force is the main force keeping molecules together with nonpolar molecules and Nobel gases.



Intermolecular Forces – London Dispersion Forces

- Common molecules that exhibit London Dispersion Forces as the strongest intermolecular force.

- Nobel Gases

- All Hydrocarbons

- Any other nonpolar molecules

Intermolecular Forces – London Dispersion Forces

- The reality of the world is that all molecules have London Dispersion Forces.

- The only force we care about when looking at a molecule however is the strongest force.

- If a molecule has hydrogen bonding, we consider that is the main intermolecular force and we disregard the London Dispersion Force.

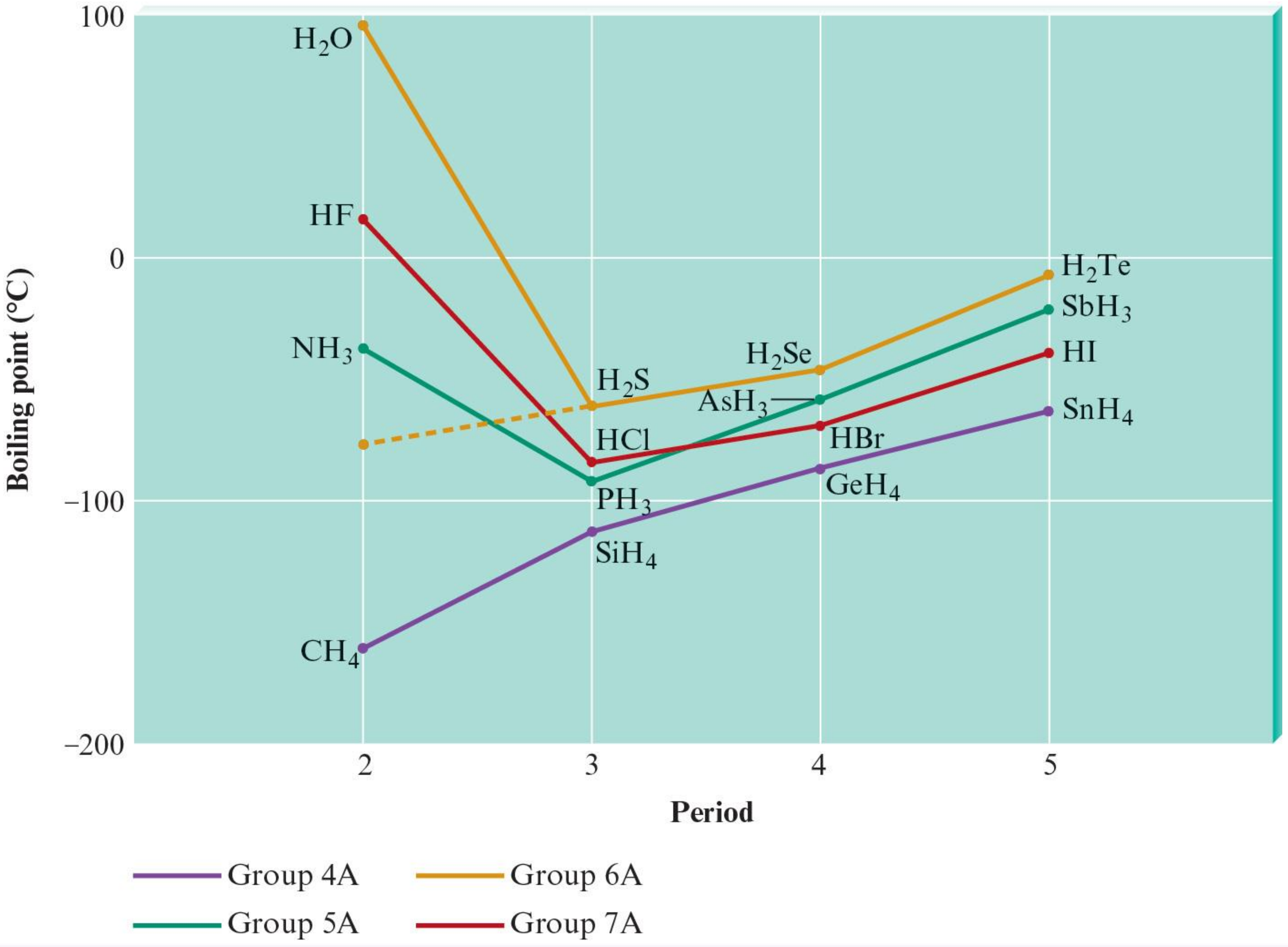
- Same with Dipole-Dipole.

Intermolecular Forces

Why do we care?

- These forces can tell us certain properties of molecules
- The stronger the intermolecular force the higher the boiling point will be, the more viscous a liquid will be, and the lower the vapor pressure will be.

Intermolecular Forces - Trends



Intermolecular Forces

Strategy for determining which molecule has the strongest intermolecular force.

1. **Look to see which molecule exhibits hydrogen bonding**
2. **Next look for Dipole-Dipole interactions**
3. **Finally look for London Dispersion Forces**
4. $LD < DD < HB$
5. **When two molecules have London dispersion forces the "bigger" molecule will have stronger intermolecular forces**

Intermolecular Forces Questions

- Which one of the following is the strongest intermolecular force experienced by noble gases?
  a. London dispersion forces
  b. Dipole–dipole attraction
  c. Hydrogen bonding
  d. Ion–ion interactions

Intermolecular Forces Questions

- Methane (CH_4) is a gas, but carbon tetrachloride (CCl_4) is a liquid at room conditions
  - Which of the following statements explains this phenomenon?
    a. CCl_4 is a polar molecule and CH_4 is not
    b. CCl_4 and CH_4 have different geometries and shapes
    c. CH_4 exhibits hydrogen bonding and CCl_4 does not
    d. Cl is more electronegative than H
    e. None of these statements is correct

Intermolecular Forces Questions

- Which of the following species exhibits the strongest intermolecular forces?
  a. CH_4
  b. H_2O
  c. N_2
  d. CO
  e. He

Intermolecular Forces Questions

- What type(s) of intermolecular forces is (are) exhibited by methane (CH_4)?
  a. Hydrogen bonding and London dispersion forces
  b. Hydrogen bonding
  c. Dipole–dipole and London dispersion forces
  d. London dispersion forces

Intermolecular Forces Questions

- When a water molecule forms a hydrogen bond with another water molecule, which atoms are involved in the interaction?
  a. A hydrogen atom from one water molecule with a hydrogen atom from another.
  b. An oxygen atom from one water molecule with an oxygen atom from another.
  c. A hydrogen atom from one water molecule with an oxygen atom from another
  d. A hydrogen atom and an oxygen atom from the same water molecule

Intermolecular Forces Questions

- Which of the following has the highest boiling point?
  a. H_2O
  b. HF
  c. NH_3
  d. N_2

Intermolecular Forces Questions

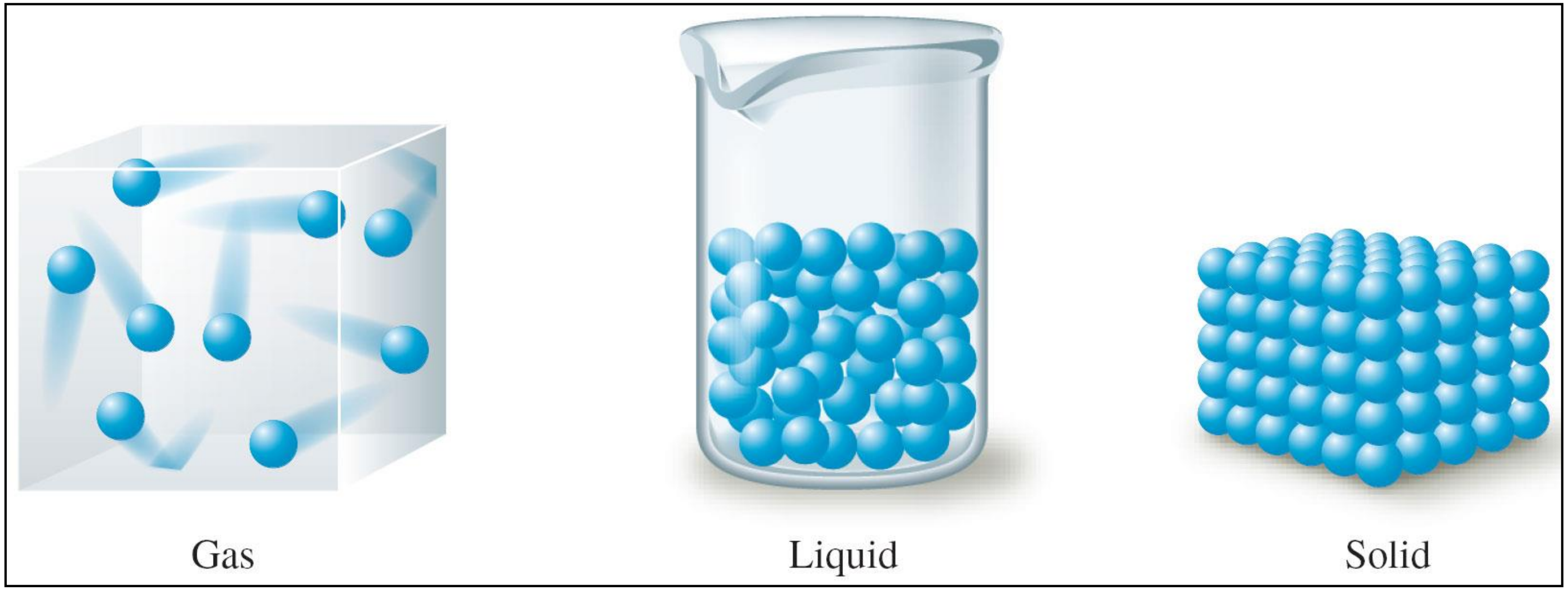
- Which of the following compounds has the lowest boiling point?
  a. C_2H_6
  b. C_3H_8
  c. CH_4
  d. C_5H_{12}
  e. C_4H_{10}

Intermolecular Forces Questions

- Which of the following is the correct order of boiling points for CH_3OH, C_2H_6, and Ne?
  a. $CH_3OH < C_2H_6 < Ne$
  b. $CH_3OH < Ne < C_2H_6$
  c. $Ne < C_2H_6 < CH_3OH$
  d. $C_2H_6 < Ne < CH_3OH$

States of Matter

The three states of matter.



Phase Changes

- **When a substance changes from one State of Matter into another State of Matter**

- **When the substance changes States of Matter, the molecules *remain intact***

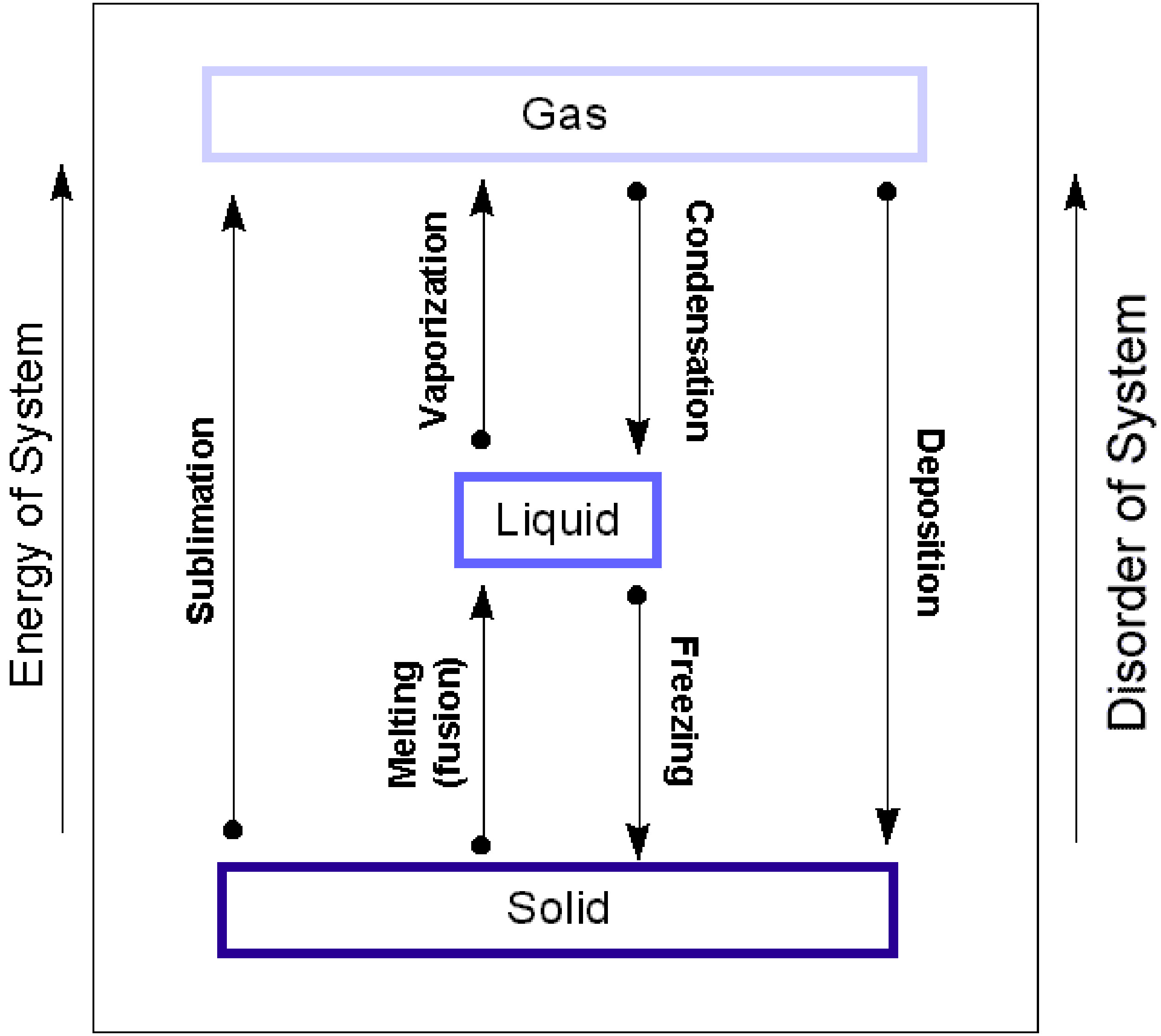
- **The changes in state are due to changes in the forces *among* molecules rather than in those *within* the molecules**

- **Phase -part of a system that has uniform composition and properties**

Phase Changes

Phase Change	Process
Solid → Liquid	Melting
Solid → Gas	Sublimation
Liquid → Solid	Freezing
Liquid → Gas	Vaporization
Gas → Liquid	Condensation
Gas → Solid	Deposition

Phase Changes



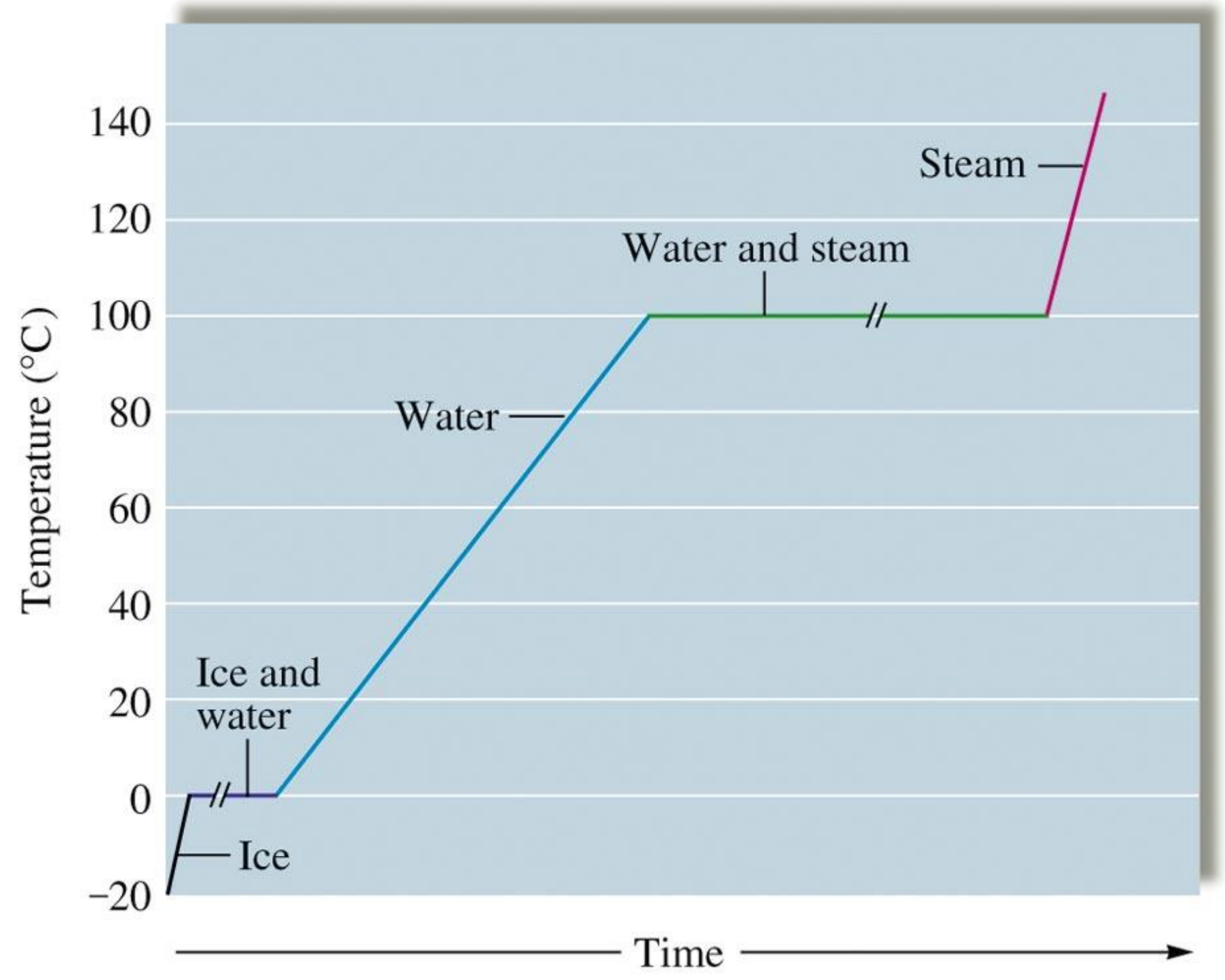
Phase Changes

- **Solid to Liquid**
  - **As energy is added, the motions of the molecules increase, and they eventually achieve the greater movement and disorder characteristic of a liquid**
- **Liquid to Gas**
  - **As more energy is added, the gaseous state is eventually reached, with the individual molecules far apart and interacting relatively little**

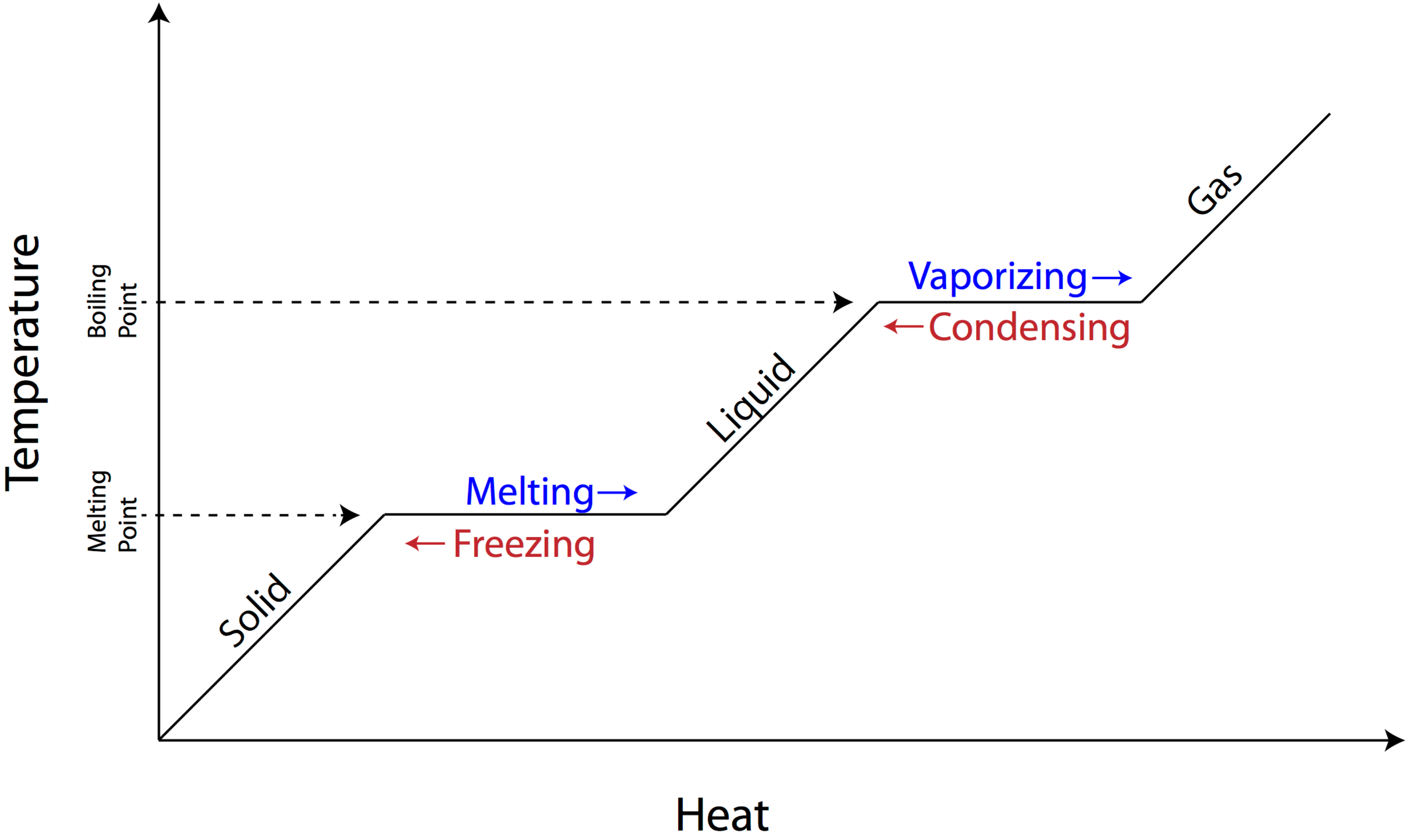
Phase Changes

- Boiling Point
- the temperature at which the equilibrium vapor pressure of the liquid enters the atmospheric pressure
  - same as the condensation point
- Freezing Point
  - the temperature at which the solid and liquid are in equilibrium at 1 atm
  - same as the melting point

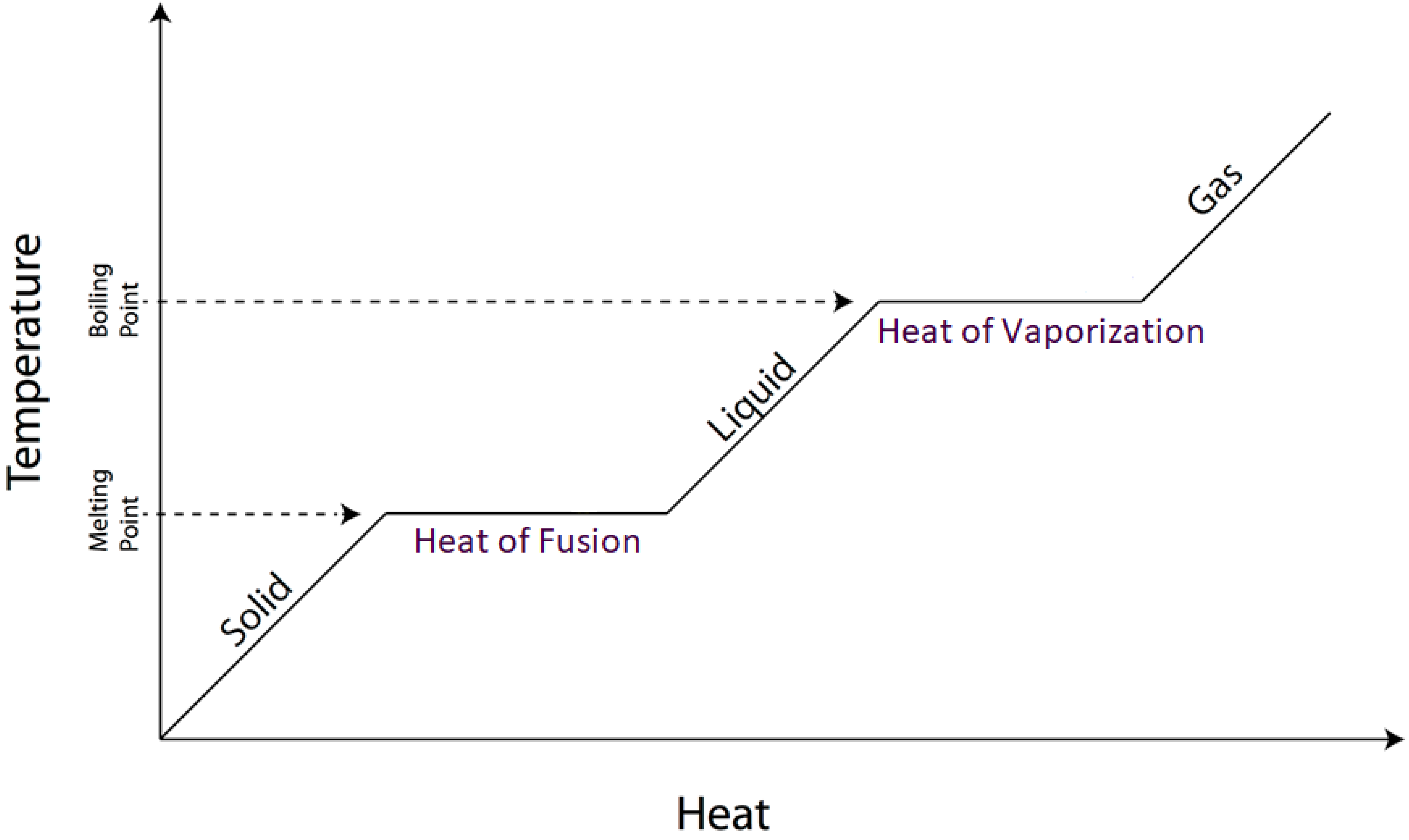
Phase Changes – Heating Curves



Phase Changes – Heating Curves



Phase Changes – Heating Curves



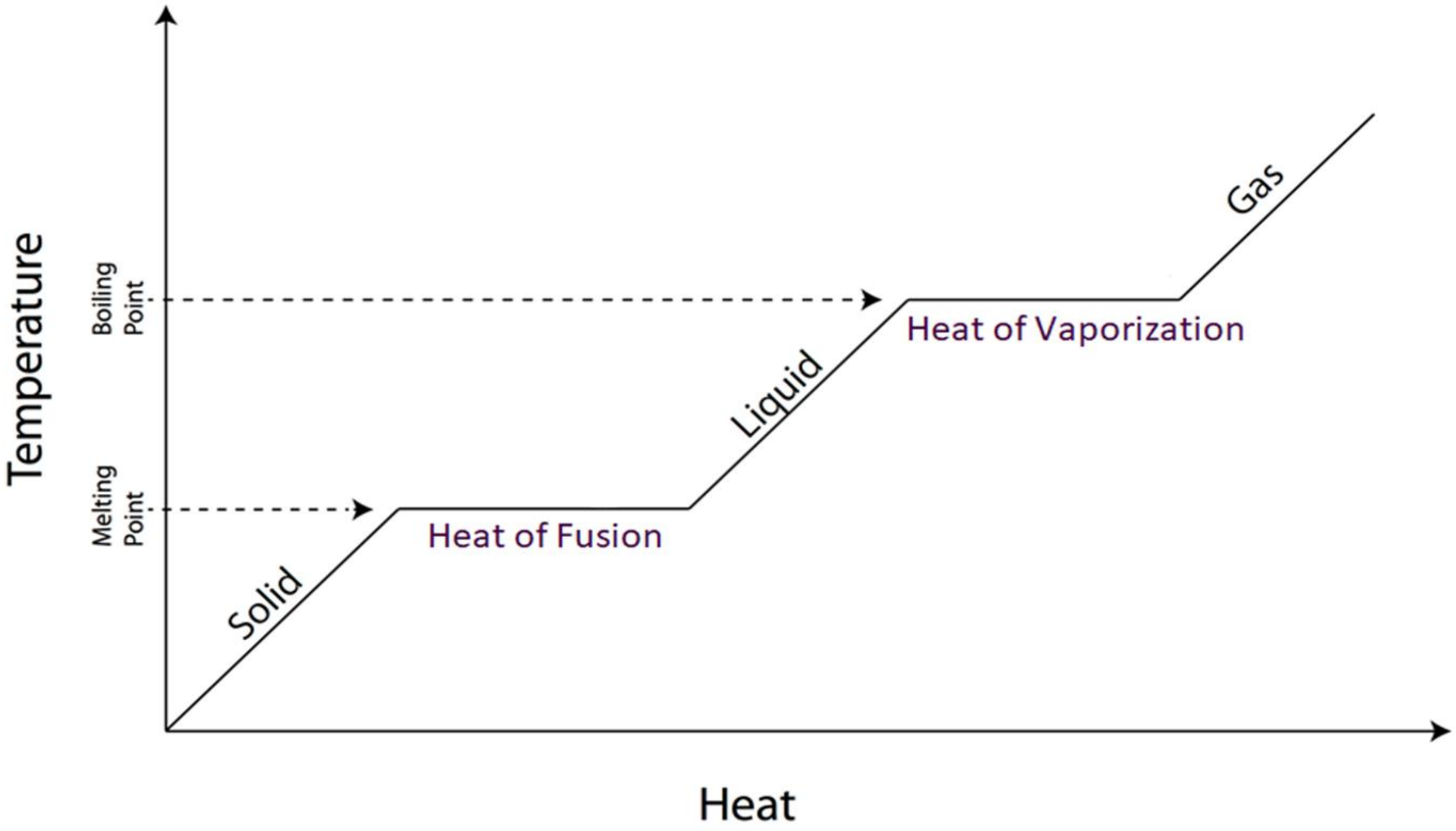
Phase Changes – Heating Curves

- The amount of Heat or Energy it takes to change a substance from a solid to a liquid is known as the heat of fusion. Units ($\frac{J}{g}$ or $\frac{J}{mol}$)

- The amount of Heat or Energy it takes to change a substance for a liquid to a gas is called the heat of vaporization. Units ($\frac{J}{g}$ or $\frac{J}{mol}$)

Phase Changes – Heating Curves

How to read this curve.



Phase Change Calculations

It is important to be able to calculate the amount of heat energy required to raise the temperature of a substance through a phase change.

Do we remember this expression?

$$Q = m * C * (T_f - T_i)$$

- Q = Specific Heat
- m = mass (g) or mol (depending on C)
- C is the specific heat (either $\frac{J}{g * ℃}$ or $\frac{J}{mol * ℃}$)
- T_f is temperature final
- T_i is temperature initial

Phase Change Calculations

We are going to modify this equation slightly.

Now it is going to be….

Solid To Liquid

$$Q = m * C_s * (T_{fs} - T_{is}) + m * Heat\ of\ Fushion + m * C_l * (T_{fl} - T_{il})$$

Liquid to Gas

$$Q = m * C_l * (T_{fl} - T_{il}) + m * Heat\ of\ Vaporization + m * C_g * (T_{fg} - T_{ig})$$

OR Solid to Gas

$$Q = Solid\ to\ Liquid\ Equation + Liquid\ to\ Gas\ Equation$$

Phase Change Calculations

Example: How much heat is required to change 15 g of ice at -15℃ into 15 g of water vapor?

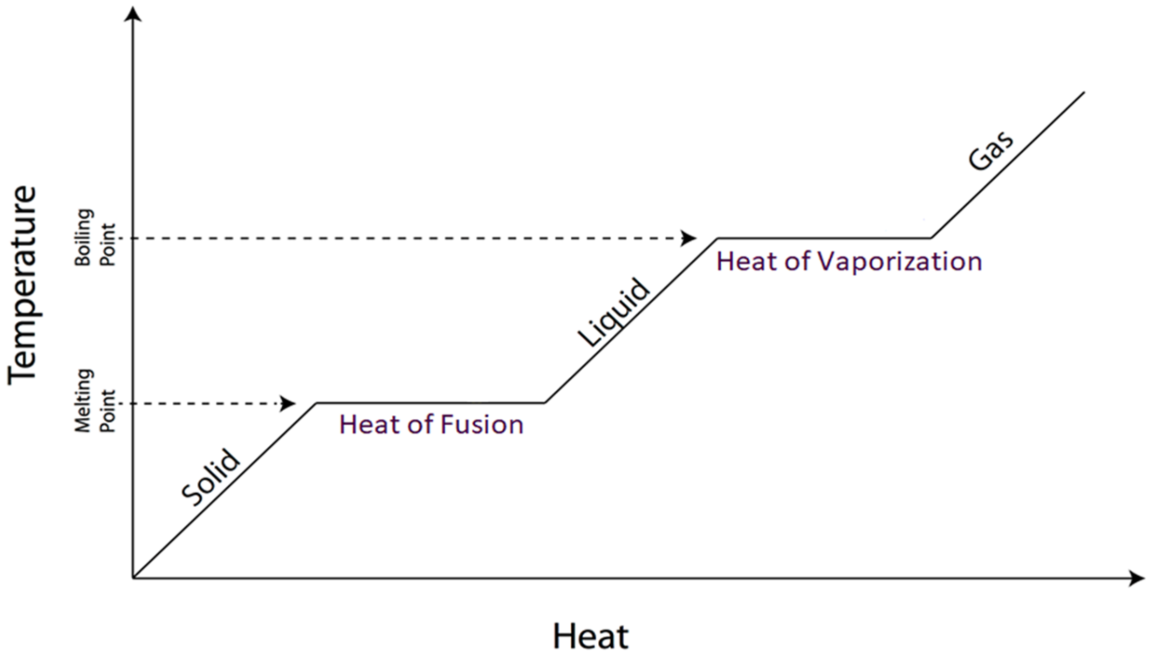
- **The Specific Heat of water is** $\mathbf{4.186\ \frac{J}{g * ℃}}$
- **The Specific Heat of Ice is 2.03** $\mathbf{\frac{J}{g * ℃}}$
- **The heat of fusion for ice is 6.01** $\mathbf{\frac{kJ}{mol}}$
- **The heat of vaporization for water is 40.7** $\mathbf{\frac{kJ}{mol}}$

Phase Changes – Heating Curves

- Which scenario would cause more damage and why?
  a. Getting burned by steam
  b. Getting burned by boiling water

Phase Changes – Heating Curves

- What would happen to the phase change diagram if my intermolecular forces increased?



Phase Changes – Heating Curves

- An ice cube tray contains enough water at $10.0\ ℃$ to make 18 ice cubes that each has a mass of 30.0g. The tray is placed in a freezer that uses CF_2Cl_2 as a refrigerant. The heat of vaporization of CF_2Cl_2 is $158\frac{J}{g}$. What mass of CF_2Cl_2 must be vaporized in the refrigeration cycle to convert all the water to ice? The heat capacities for $H_2O_{(s)}$ and $H_2O_{(l)}$ are $2.03\ \frac{J}{g*℃}$ and $4.18\ \frac{J}{g*℃}$ respectively. The enthalpy of fusion for ice is $6.02\ \frac{kJ}{mol}$.

Chemistry

Chapter 10

Liquids and Solids – but mostly liquids

Section 1

Homework: Pg 431 – 432j
Problems: Not Collected
14,15,16,17,37,38,39,40,41,42,43,44,
99,100,101,102,103
The challenge problem: 104