

# Liquids, Solids and Phase Changes

## 12.1 Physical States and Phase Changes

- **Physical states** – gas, liquid and solid
  - **Phases** – physically distinct, homogeneous parts of a sample of matter (can be gaseous, liquid or solid)
  - **Condensed phases** – liquid or solid
    - A sample can contain more than one liquid phases (immiscible) or more than one solid phases
  - **Phase changes** – conversions between the different phases of a substance

- **Intramolecular** (bonding) forces – exist within each molecule or polyatomic ion (influence the chemical properties)
- **Intermolecular** (interparticle) forces – exist between the particles (molecules or ions) of a substance (influence the physical properties)

### Kinetic-Molecular View of the Three States

- The physical state of a substance is governed by the relative magnitudes of the potential energy of **intermolecular attraction** and the kinetic energy of **molecular motion**

- **Gas** – the particles are far apart; the energy of motion dominates the energy of attraction
- **Liquid** – the particles are close together; the energies of attraction and motion are comparable
- **Solid** – the particles are close together; the energy of attraction dominates the energy of motion

**Table 12.1** A Macroscopic Comparison of Gases, Liquids, and Solids

State	Shape and Volume	Compressibility	Ability to Flow
Gas	Conforms to shape and volume of container	High	High
Liquid	Conforms to shape of container; volume limited by surface	Very low	Moderate
Solid	Maintains its own shape and volume	Almost none	Almost none

### Types of Phase Changes

- Phase changes are caused by changing conditions such as temperature and pressure
  - At high  $T$ , the  $E_k$  of molecular motion increases
  - At high  $P$ , the molecules get closer together and the  $E_p$  of intermolecular attraction increases
- **Vaporization** – conversion from liquid to gas
- **Condensation** – conversion from gas to liquid
- **Melting (fusion)** – conversion from solid to liquid
- **Freezing** – conversion from liquid to solid
- **Sublimation** – conversion from solid to gas
- **Deposition** – conversion from gas to solid

## Enthalpies (Heats) of Phase Changes

- Phase changes are accompanied by energy and enthalpy changes
  - Vaporization, melting and sublimation are always endothermic** – energy must be absorbed to overcome the intermolecular forces
  - Condensation, freezing and deposition are always exothermic** – energy is released as the molecules get closer and attract each other
- Heat of vaporization ( $\Delta H_{vap}$ )** – enthalpy change for the conversion of **1 mol** of a substance from liquid to gas

- Heat of fusion ( $\Delta H_{fus}$ )** – enthalpy change for the conversion of **1 mol** of a substance from solid to liquid
- Heat of sublimation ( $\Delta H_{sub}$ )** – enthalpy change for the conversion of **1 mol** of a substance from solid to gas
- The heats of the reverse processes (condensation, freezing and deposition) have the same magnitudes but opposite signs (For example:  $\Delta H_{cond} = -\Delta H_{vap}$ )
- For most substances:

$$0 < \Delta H_{fus} < \Delta H_{vap} < \Delta H_{sub}$$

- According to Hess's law:

$$\Delta H_{fus} + \Delta H_{vap} = \Delta H_{sub}$$

