

## Comparative Properties of the States

Property	gases	liquids	solids
molecular velocity	high	medium	low
kinetic energy	high	medium	low
order	low	medium	high
fluidity	high	medium	low
viscosity	low	medium	high
rate of diffusion	high	medium	low
molecular contact	low	medium	high
effect of $P$ on $V$	$V \propto 1/P$	slight	almost none

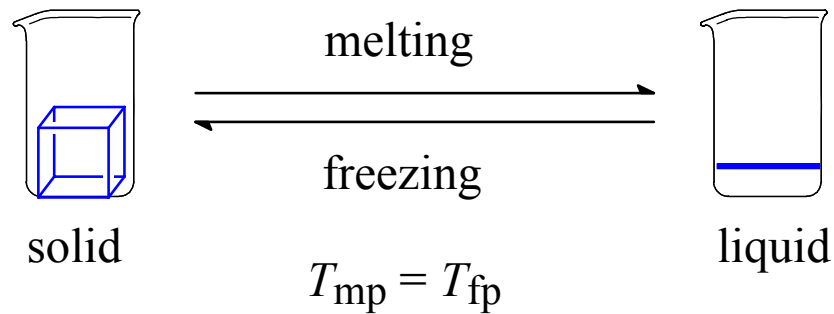
## Intermolecular Forces

- ✓ The tendency of a substance to be found in one state or the other under certain conditions is largely a result of the forces of attraction that exist between the particles comprising it.
- ✓ Forces existing between molecules are called *intermolecular forces*.
- ✓ Forces existing within molecules, such as chemical bonds, are called *intramolecular forces*.
- ☞ The greater the overall intermolecular forces, the more likely the substance is to be found in a condensed state; i.e., either a liquid or solid.

## Intermolecular Forces and Phase Changes

- ✓ Although the collection of intermolecular forces determines the state of a substance under certain conditions, most substances can be found in any of the three states under appropriate conditions of temperature and pressure.
- ✓ Changing conditions of temperature and/or pressure can induce a change in the state of the substance, called a *phase transition*.

## Phase Transitions Melting & Freezing (same temperature)

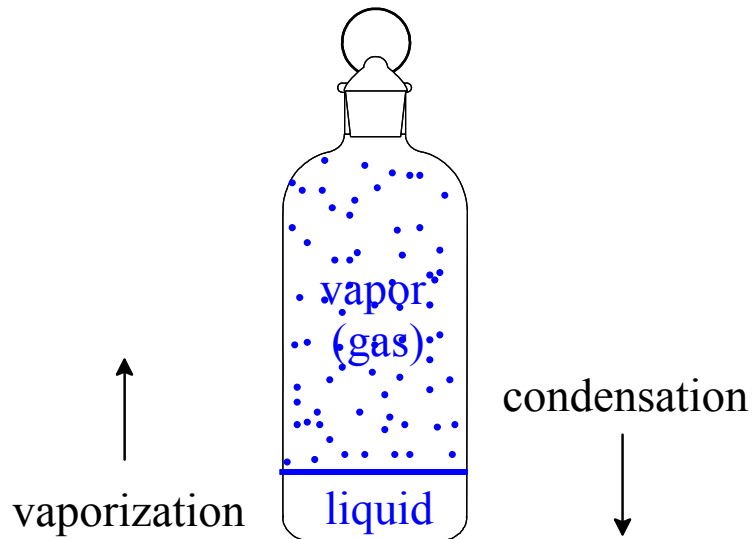


- ☞ Melting point and freezing point are the same temperature.
- ☞ For most substances, melting point or freezing point temperatures do not change significantly with small to moderate changes in pressure.

# Phase Transitions

## Vaporization & Condensation

(all temperatures in the liquid range)



- ☞ The **boiling point** is the temperature at which the vapor pressure equals the atmospheric pressure,

$$P_{\text{vapor}} = P_{\text{atm}}$$

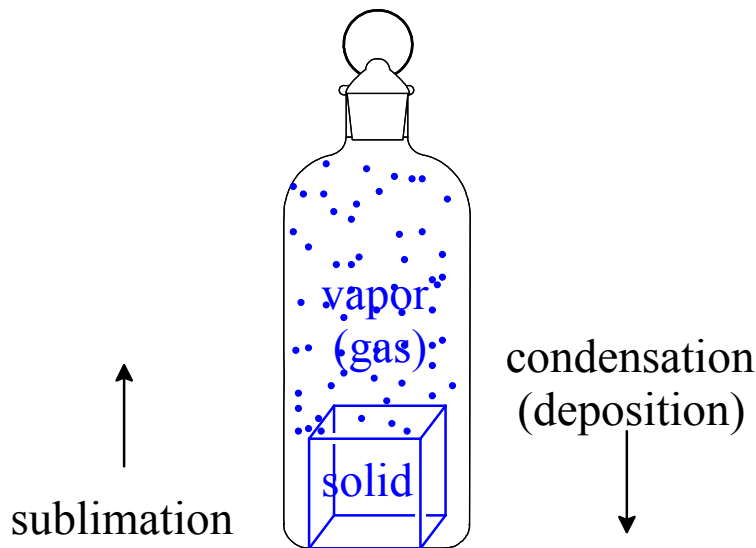
- ☞ The **normal boiling point** is the boiling point at exactly 1 atm of pressure,

$$P_{\text{vapor}} = P_{\text{atm}} = 1 \text{ atm}$$

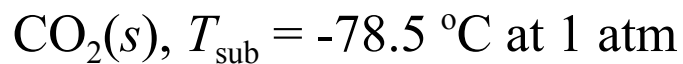
# Phase Transitions

## Sublimation & Condensation

(all temperatures in the solid range at low pressure)



- ☞ Sublimation typically occurs at low pressures for most substances.  
 $\text{H}_2\text{O}(s)$  sublimates if  $P < 4.58$  torr
- ☞ Some substances do not have a liquid-vapor transition at atmospheric pressure, but do have a solid-vapor transition over a range of temperatures at 1 atm.
  - ✓ Such substances can have a **normal sublimation point** rather than a normal boiling point.



# Temperature vs. Heat Supplied for a Typical Substance Through Solid-Liquid-Vapor Phase Changes

