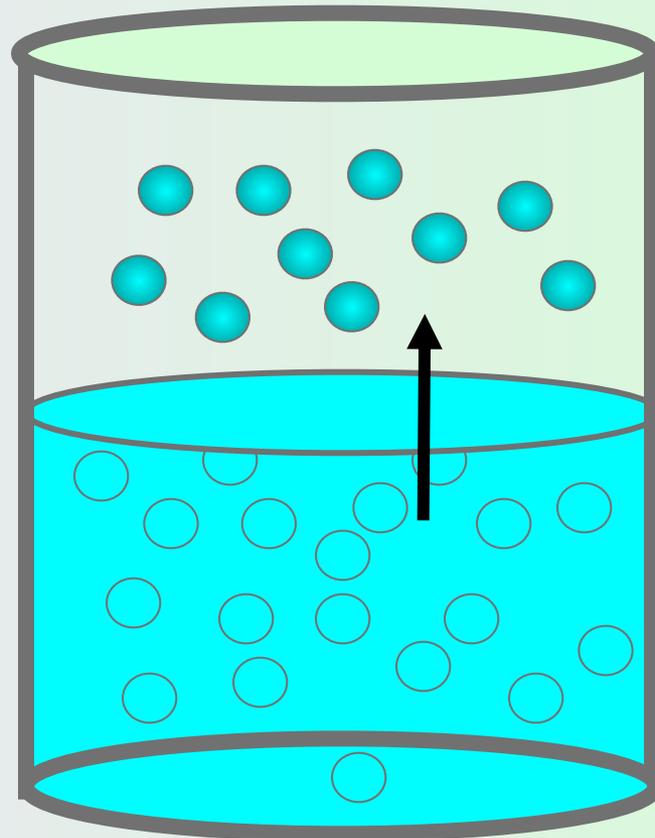
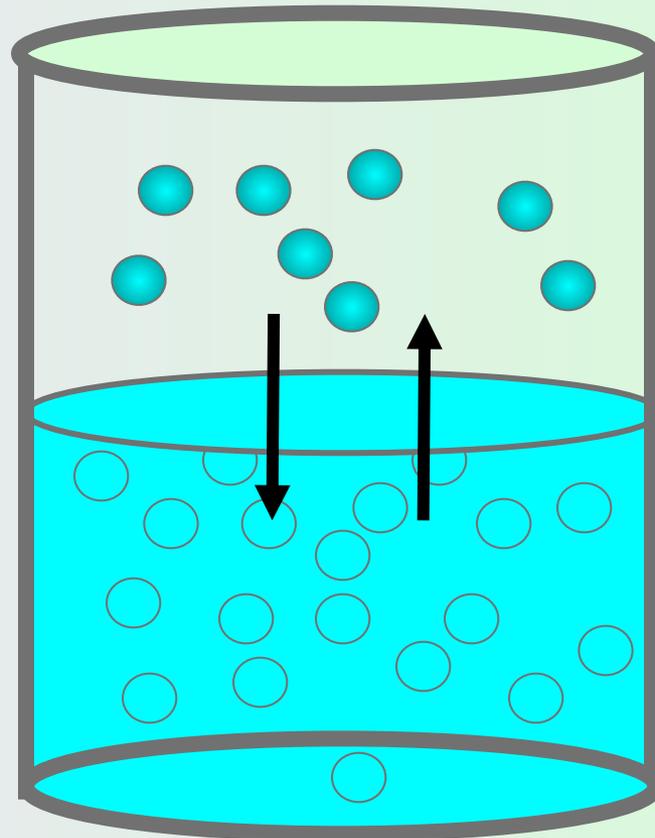


Phase Changes

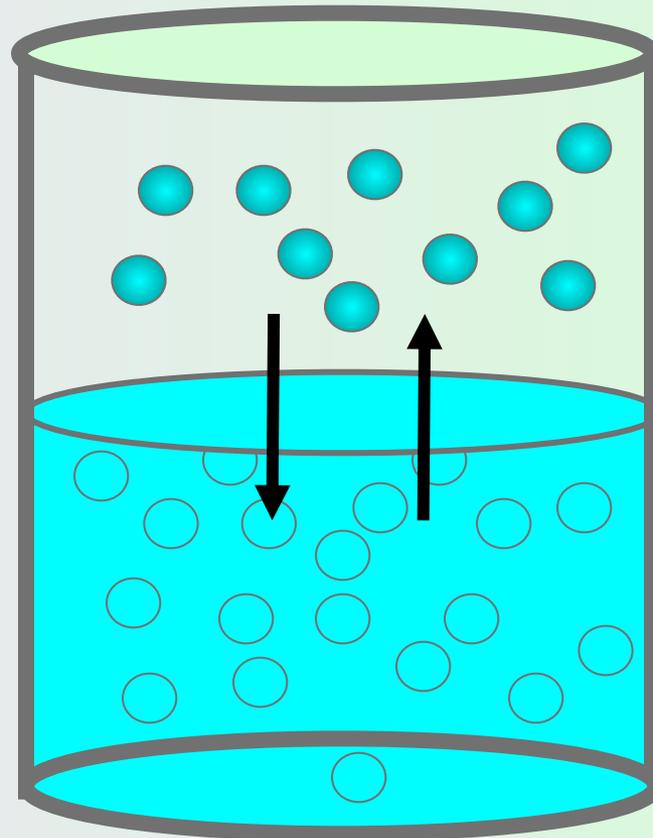
Liquid-Vapor Equilibrium



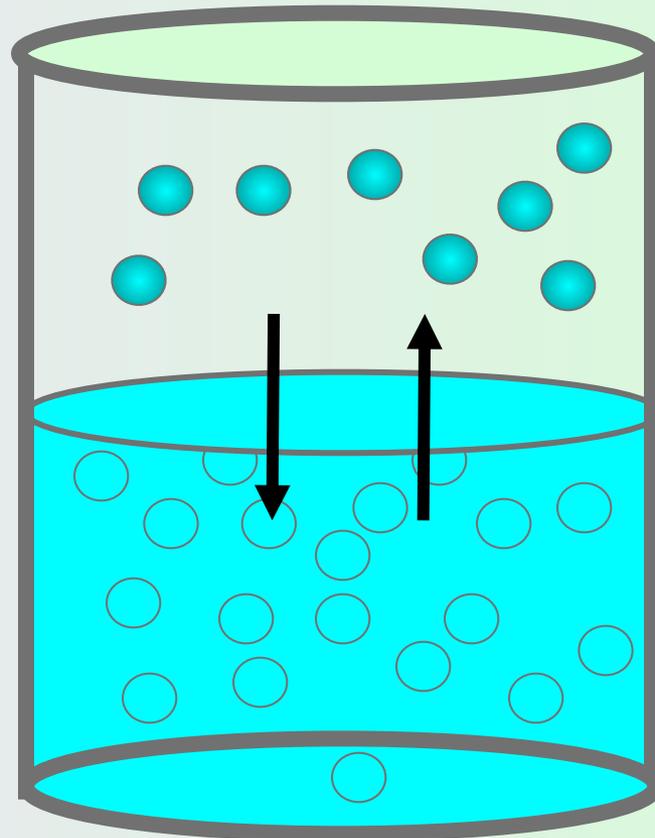
Liquid-Vapor Equilibrium



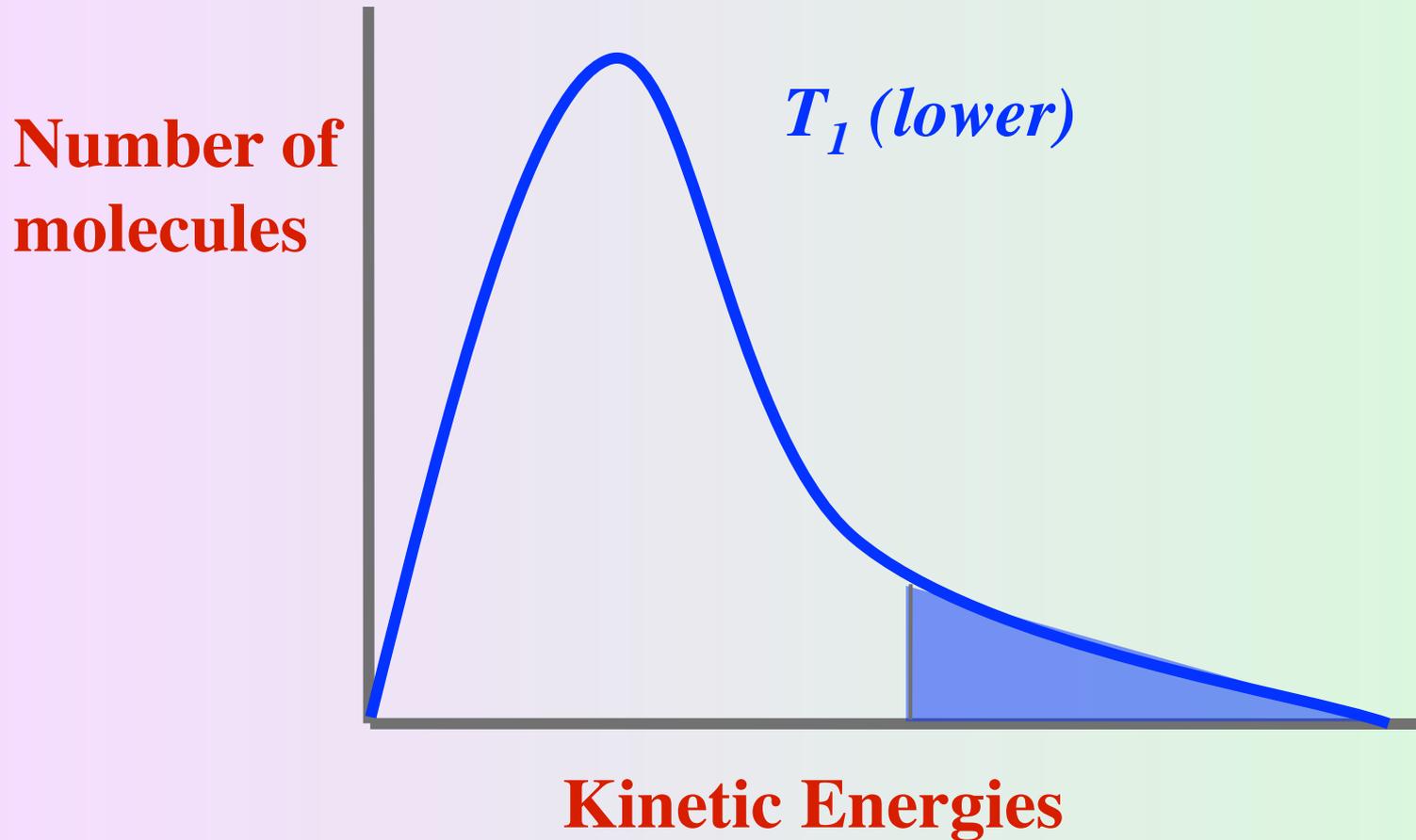
Liquid-Vapor Equilibrium



Liquid-Vapor Equilibrium

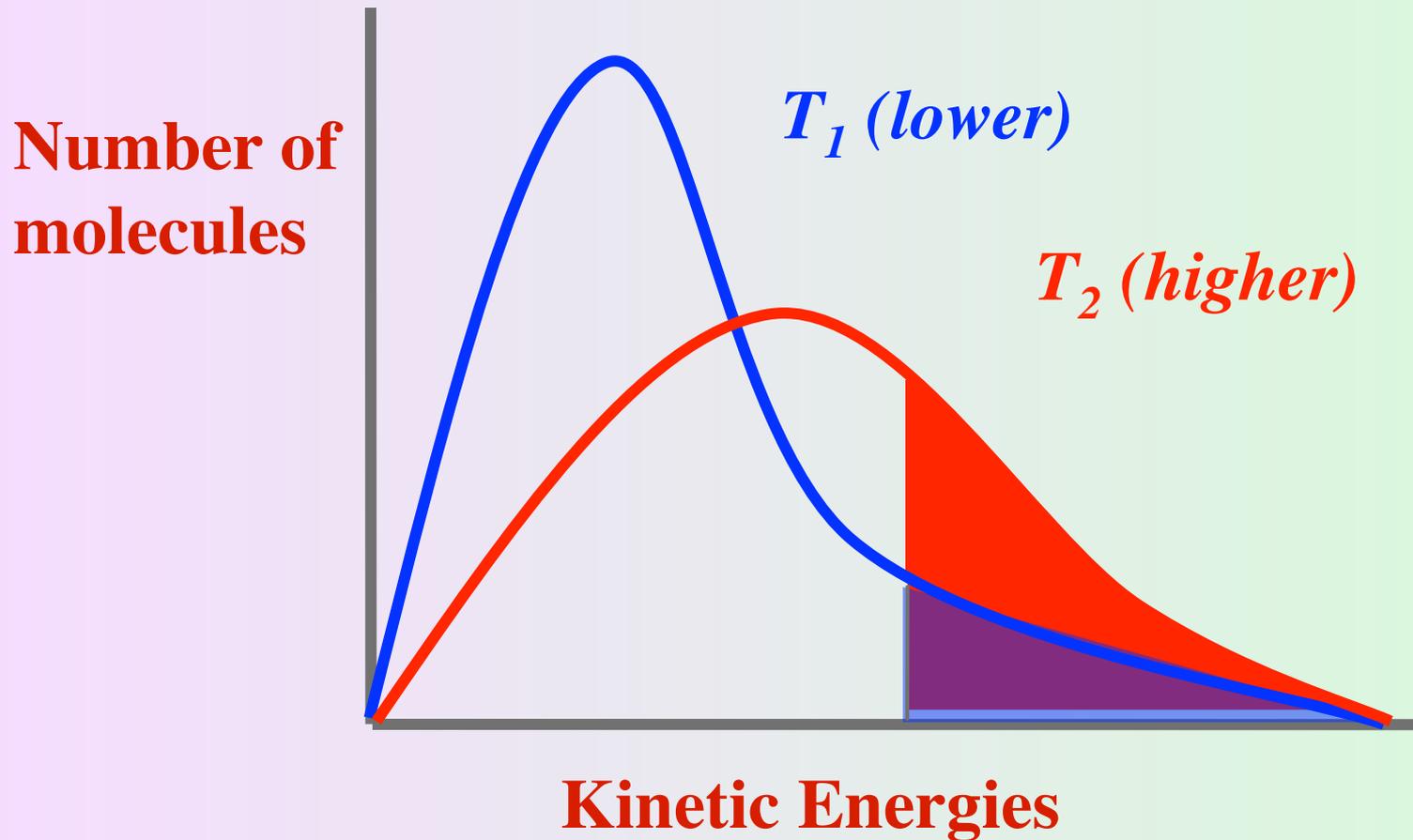


Distribution of kinetic Energies



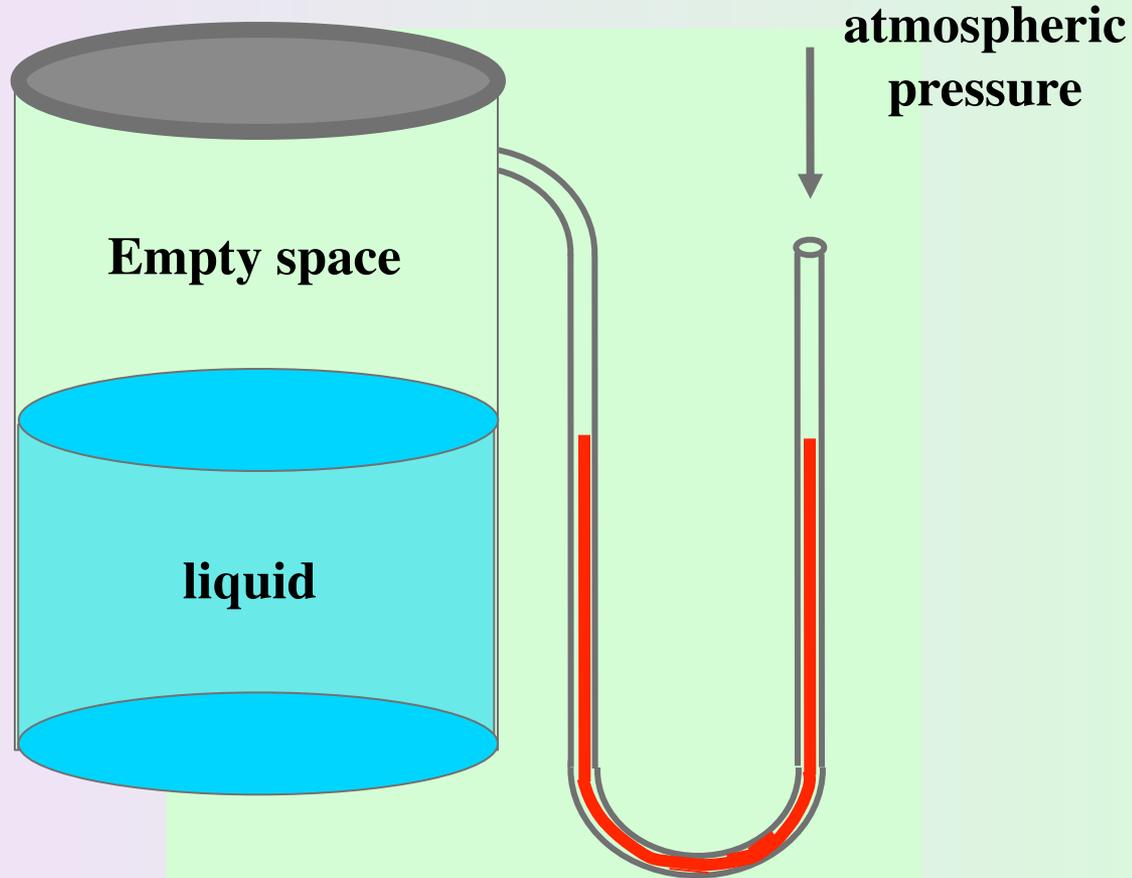
At any given temperature a certain number of molecules in a liquid possess sufficient kinetic energy to escape from the surface

Distribution of kinetic Energies



At higher temperatures more molecules in a liquid possess sufficient kinetic energy to escape from the surface

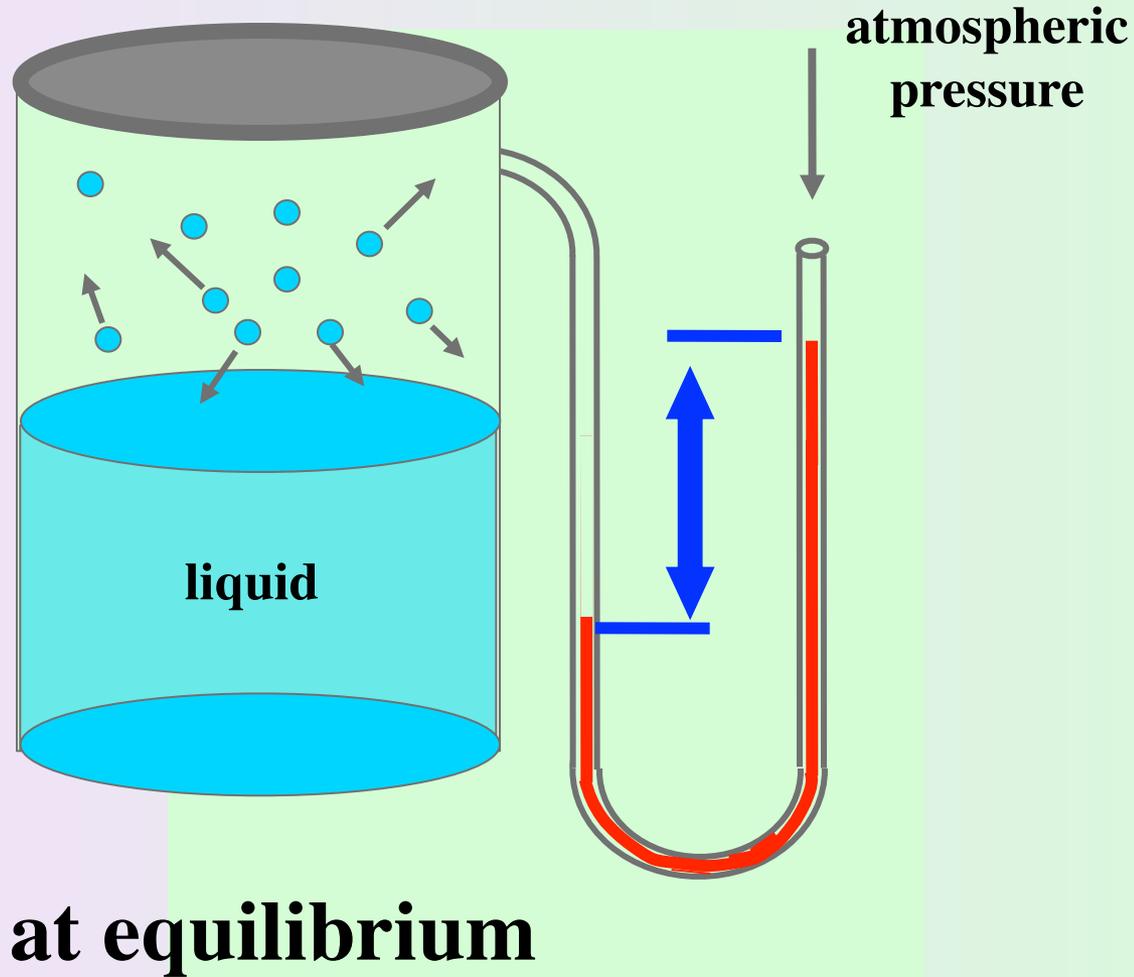
Vapor Pressure



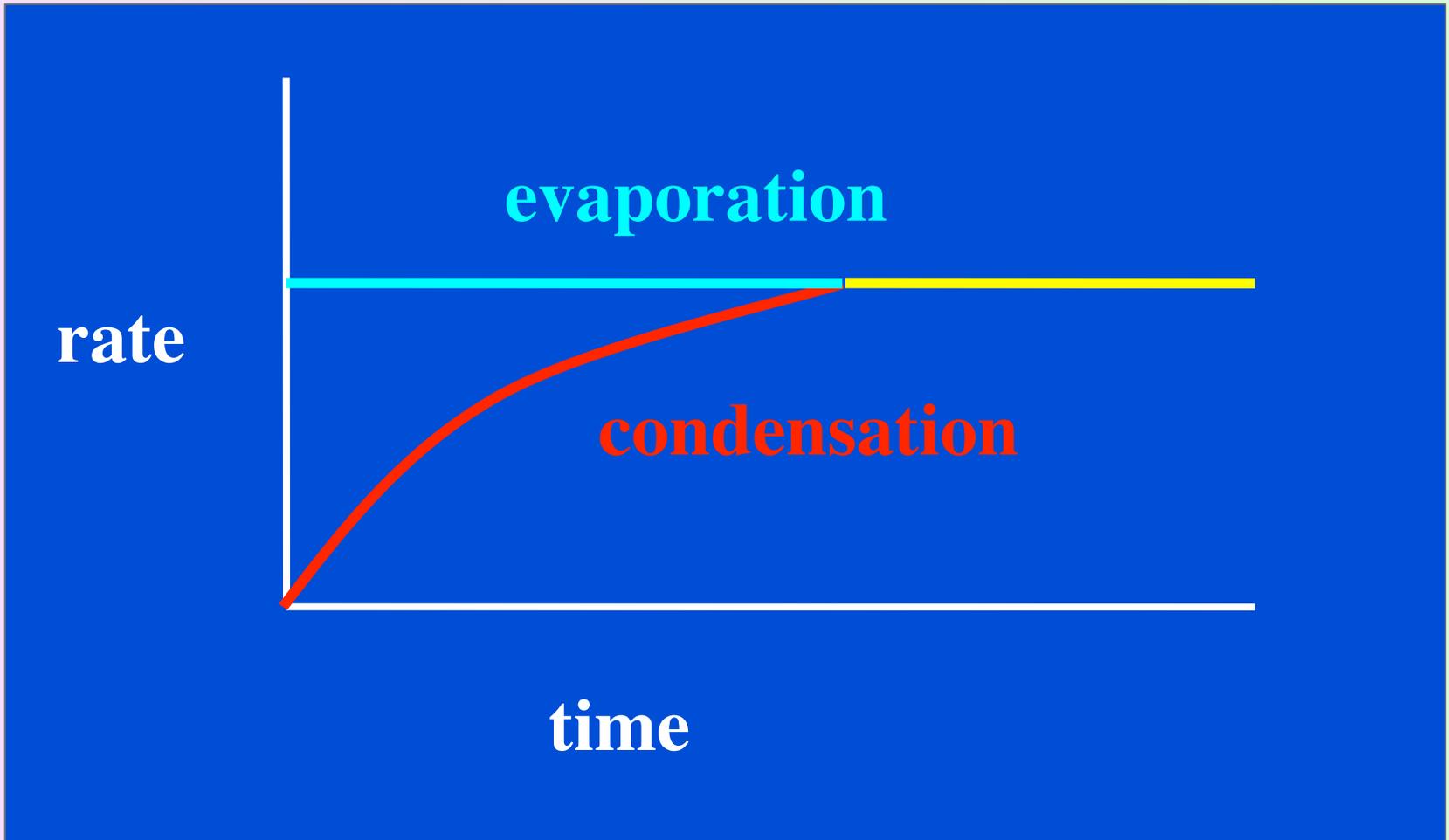
before evaporation

Manometer

$$P_{\text{v.p.}} = P_{\text{atm}} + h_{\text{Hg}}$$



At equilibrium the rates of evaporation and condensation are equal.



Condensation and Evaporation

evaporation and condensation are dynamic processes

evaporation and condensation occur simultaneously

the rate of evaporation depends on the temperature and the surface area

the rate of condensation increases as the number of molecules in the gas phase increases

a system is at equilibrium when the rates of the forward and reverse processes are equal

Vapor Pressure

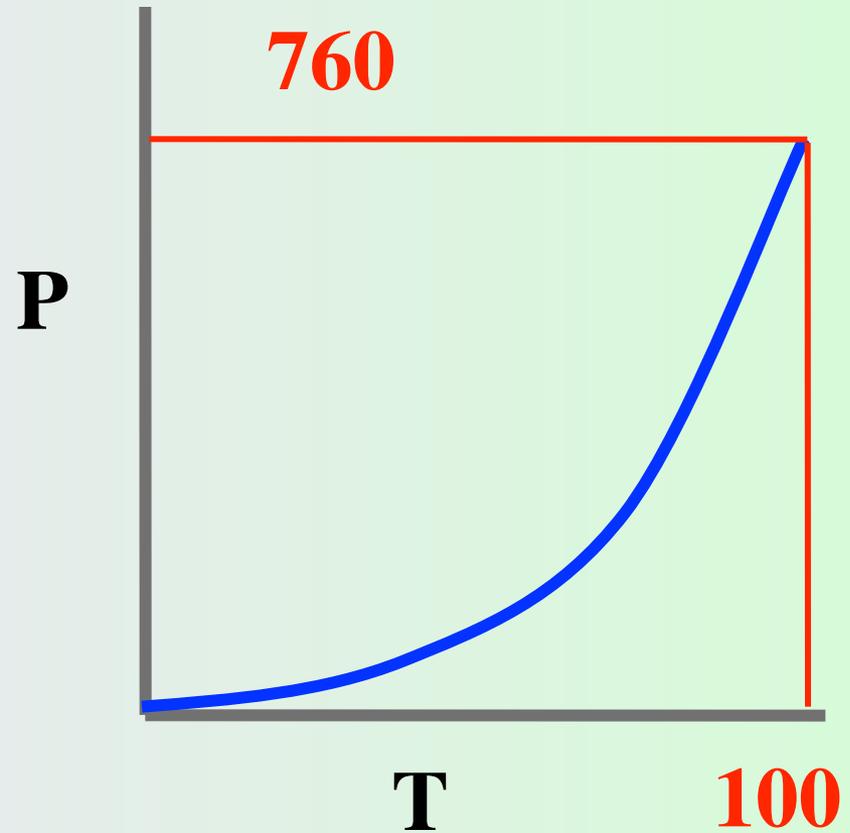
pressure of the vapor, when vapor and liquid are in equilibrium with one another

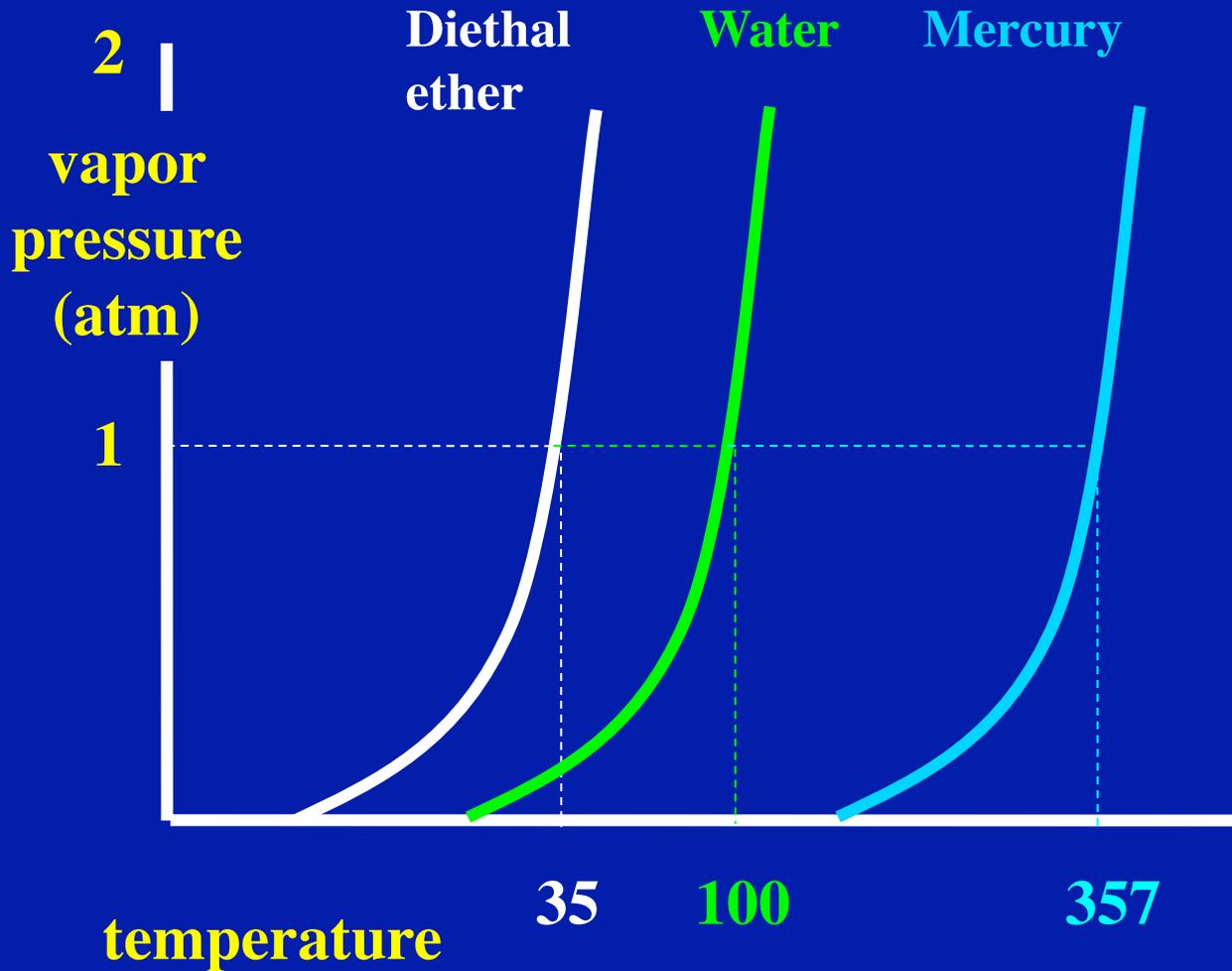
vapor pressure is a characteristic property of a particular substance

Increases with temperature

Vapor Pressure of Water

T (C°)	P (torr)
0.0	4.579
10.0	9.209
20.0	17.535
25.0	23.756
30.0	31.824
40.0	55.324
60.0	149.4
70.0	233.7
90.0	525.8





The increase in vapor pressure with temperature for three liquids at 1 atm pressure are shown on the horizontal axis.

Definition of Boiling Point

temperature at which vapor pressure of a substance equals external pressure

***normal boiling point:* boiling point when the external pressure equals 1 atmosphere**

Critical Points

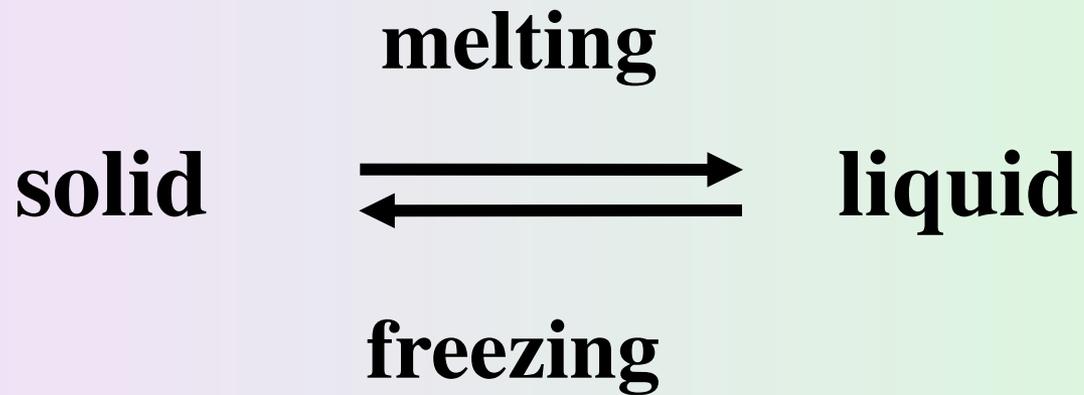
critical temperature: temperature above which gas cannot be liquefied no matter how great the applied pressure (is the highest temperature at which a substance can exist as a liquid)

critical pressure: the minimum pressure required to bring about liquefaction at the critical temperature

Critical Pressures and Temperatures for selected compounds

substance		T_c (°C)	P_c (atm)
Argon	Ar	- 186	6.3
Methane	CH ₄	- 83.0	45.6
Carbon dioxide	CO ₂	31.0	73.0
Ethanol	CH ₃ CH ₂ OH	243	63
Benzene	C ₆ H ₆	288.9	47.9
Water	H ₂ O	374.4	219.5
Mercury	Mg	1462	1036

Solid-Liquid Equilibrium



Liquid-Solid Equilibrium

melting point

temperature at which solid and liquid phases coexist in equilibrium

***normal melting point:* melting point at a pressure of 1 atmosphere**

Solid - Vapor Equilibrium



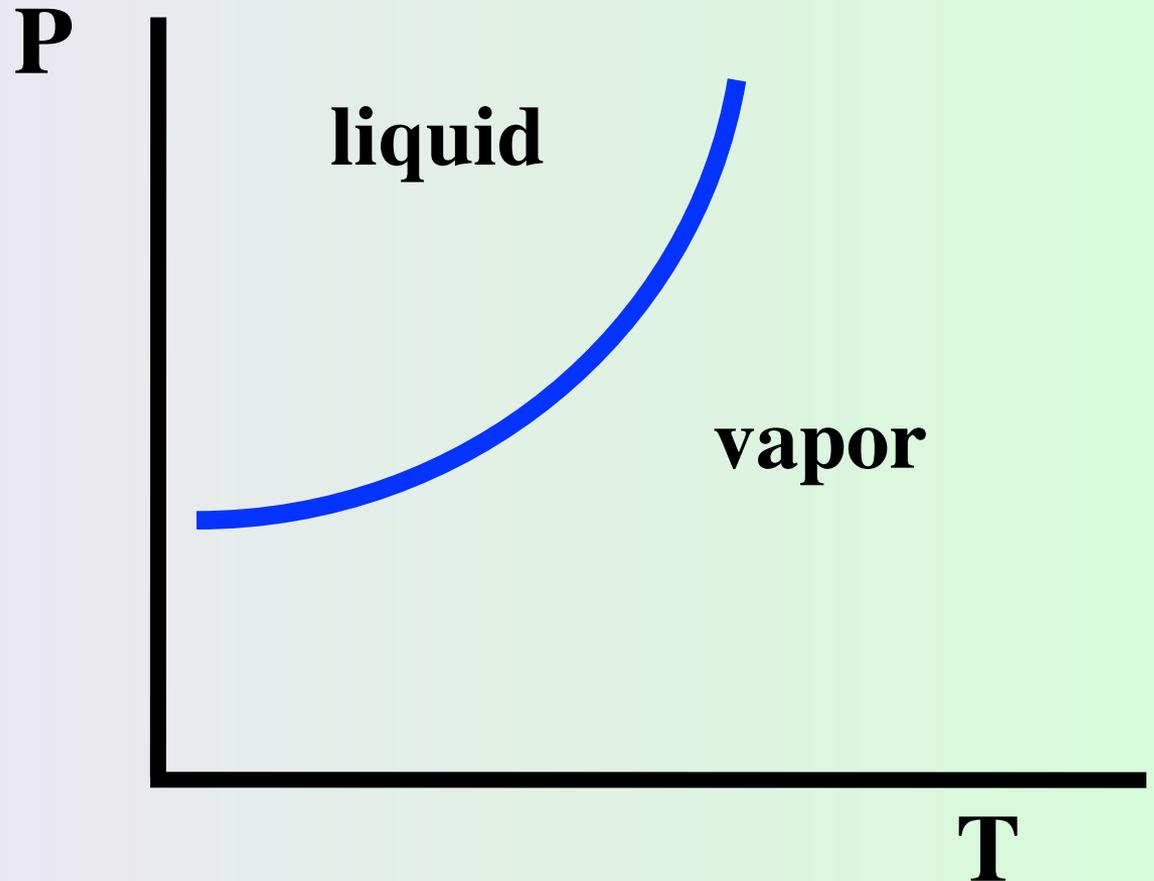
The process in which molecules go directly from the solid into the vapor phase is called **sublimation**.

Phase Diagrams

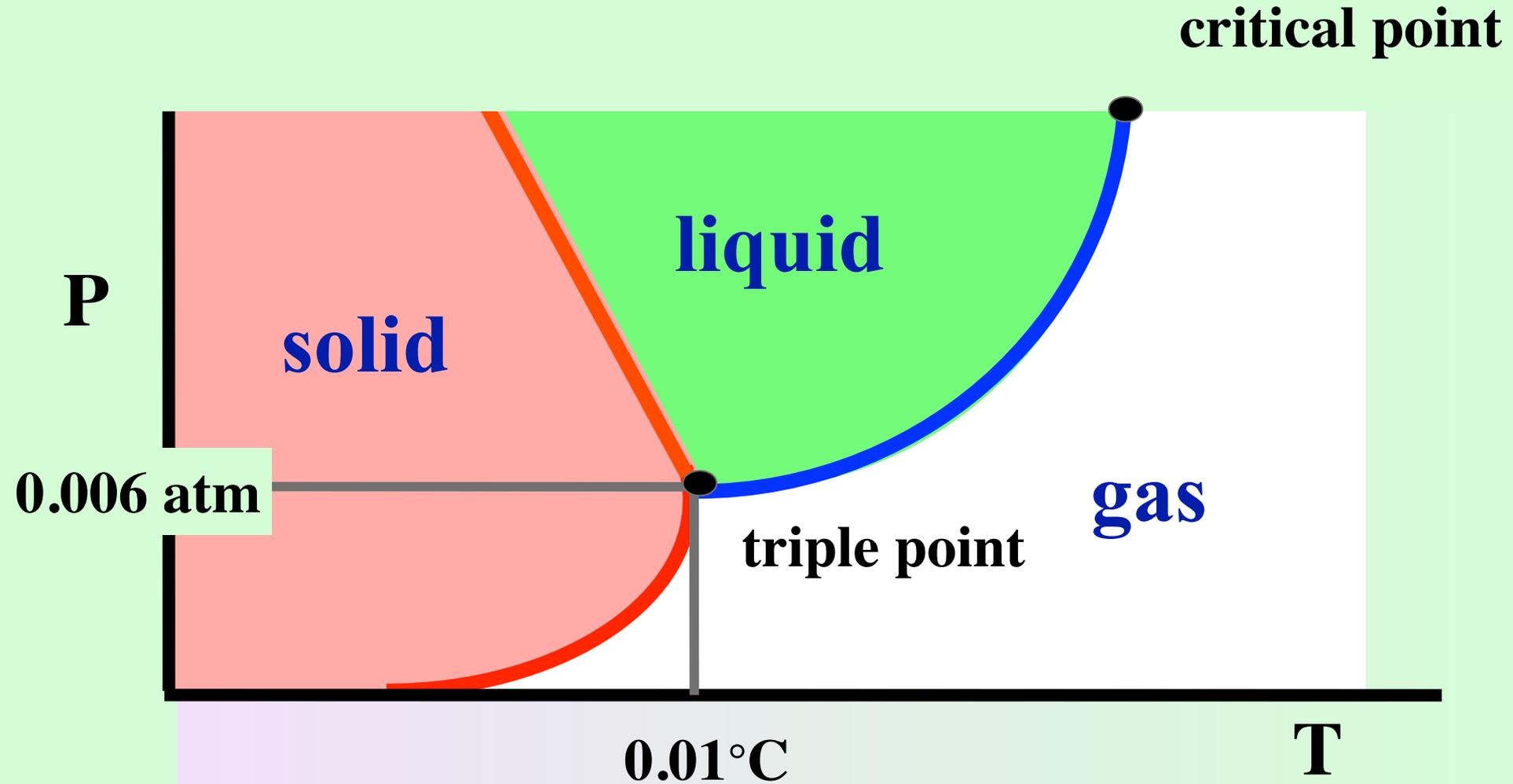
Phase diagrams are graphs that summarize conditions (temperature, pressure) under which a substance exists as a solid, liquid, or gas.

A Familiar Phase Diagram

**Vapor pressure
curve for water**

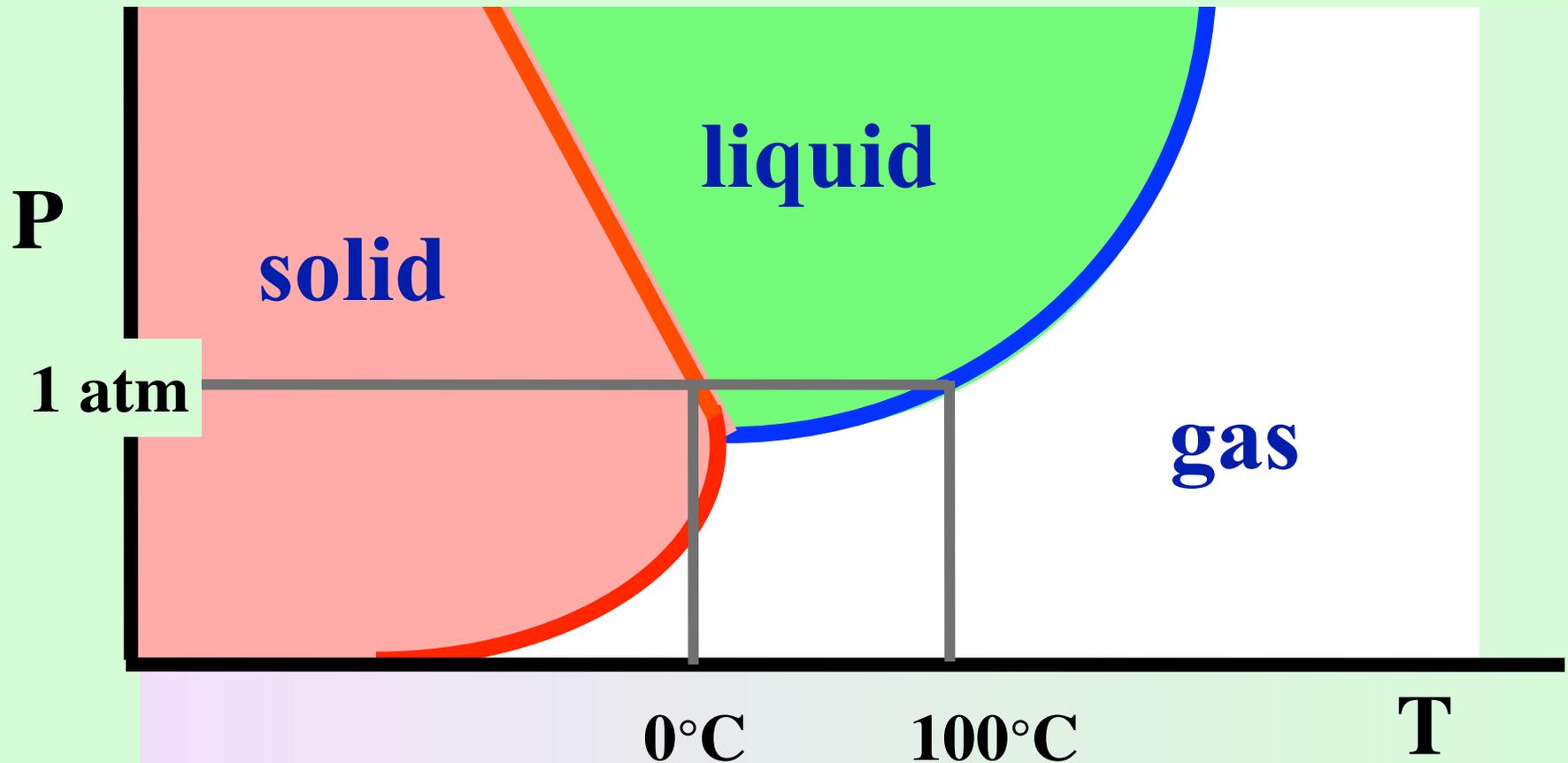


Including the Solid Phase



Normal melting and boiling point of water

Pressure = 1 atm



Carbon dioxide phase diagram

