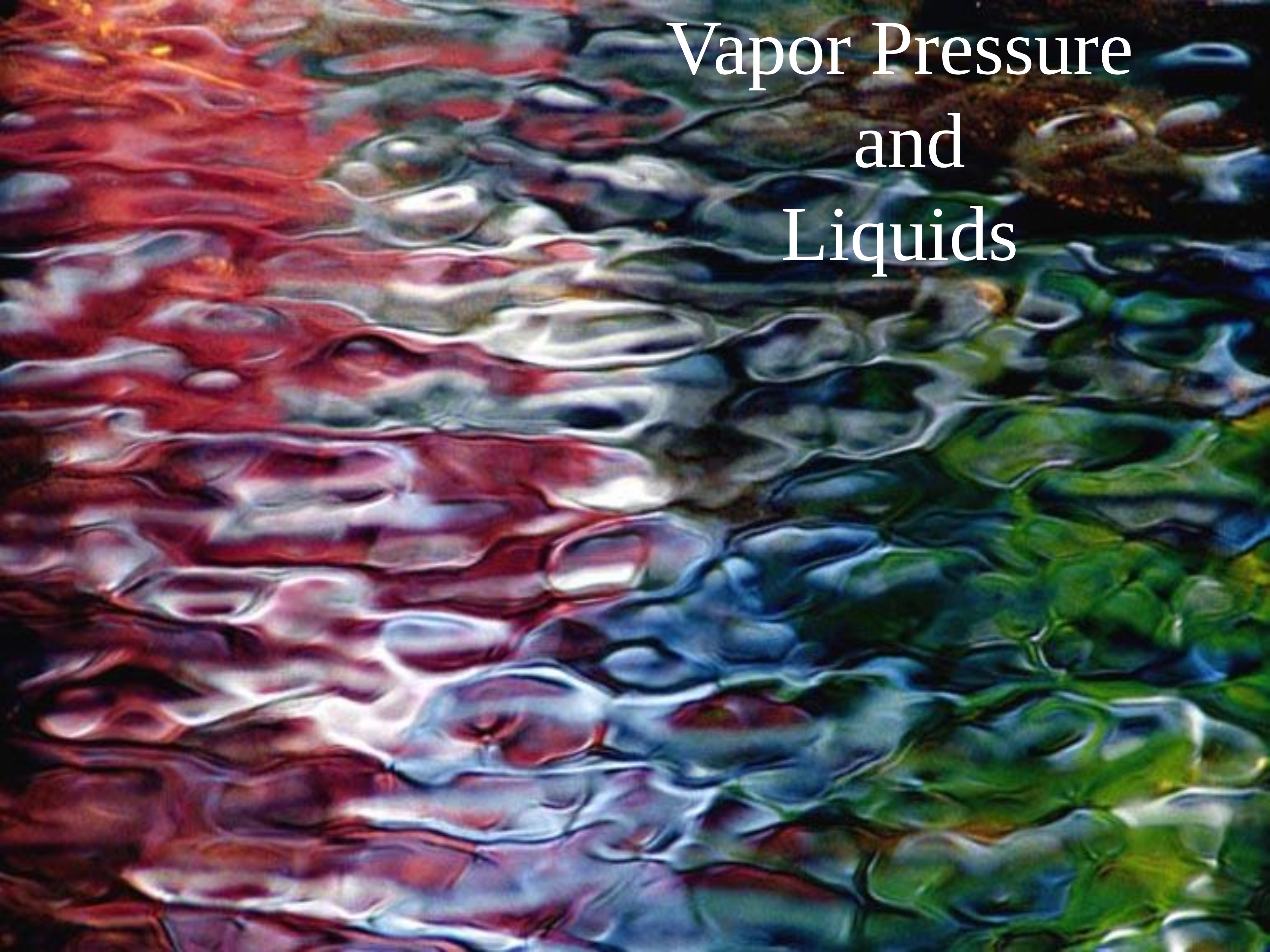
Vapor Pressure and Liquids



Liquids

- are a substance where particles move far enough apart to slip by each other

Vapor Pressure and Equilibrium

- Vapor pressure - The pressure generated by a vapor in equilibrium with its liquid

Energy of Particles

- **Average kinetic energy of particles in a gas are constant for all substances at a given temperature no matter the mass**
- **Some would have more and some would have less kinetic energy than the average**
- **Some molecules have enough energy to become a vapor or gas**
- **In an open container gases remain a gas and do not return to the container that they originated**
- **In a closed container just as many molecules return to the surface as leave the surface at a certain point called equilibrium. (Dynamic equilibrium)**
- **Physical changes from a liquid to vapor are represented as follows**

  1) $X_{(l)} \rightarrow X_{(g)}$

  2) $X_{(g)} \rightarrow X_{(l)-}$

  3) $X_{(l)} \rightarrow X_{(g)}$

Vapor Pressure

Explaining Vapor Pressure on the Molecular Level

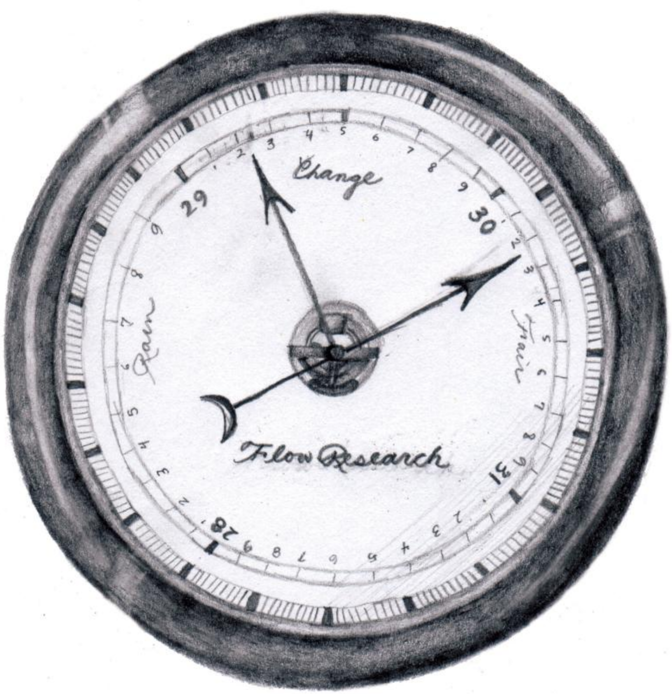
- Some of the molecules on the surface of a liquid have enough energy to escape the attraction of the bulk liquid.
- These molecules move into the gas phase.
- As the number of molecules in the gas phase increases, some of the gas phase molecules strike the surface and return to the liquid.
- After some time the pressure of the gas will be constant at the vapor pressure.

Le Chateliers Principle

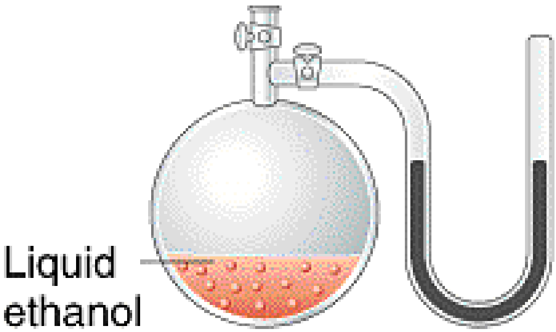
- If stress is applied to a system at equilibrium, the system readjusts so stress is reduced
- Ice skating

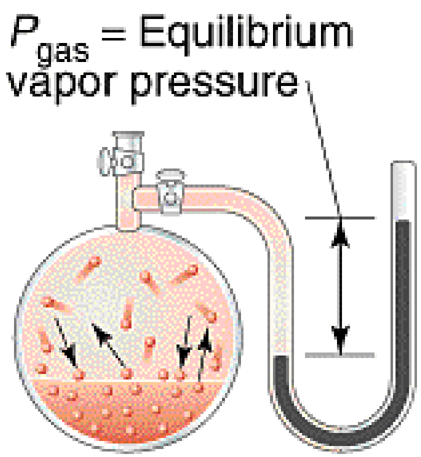
Measuring Vapor Pressure

- Manometer
- Barometer



Vapor Pressure





Explaining Vapor Pressure on the Molecular Level

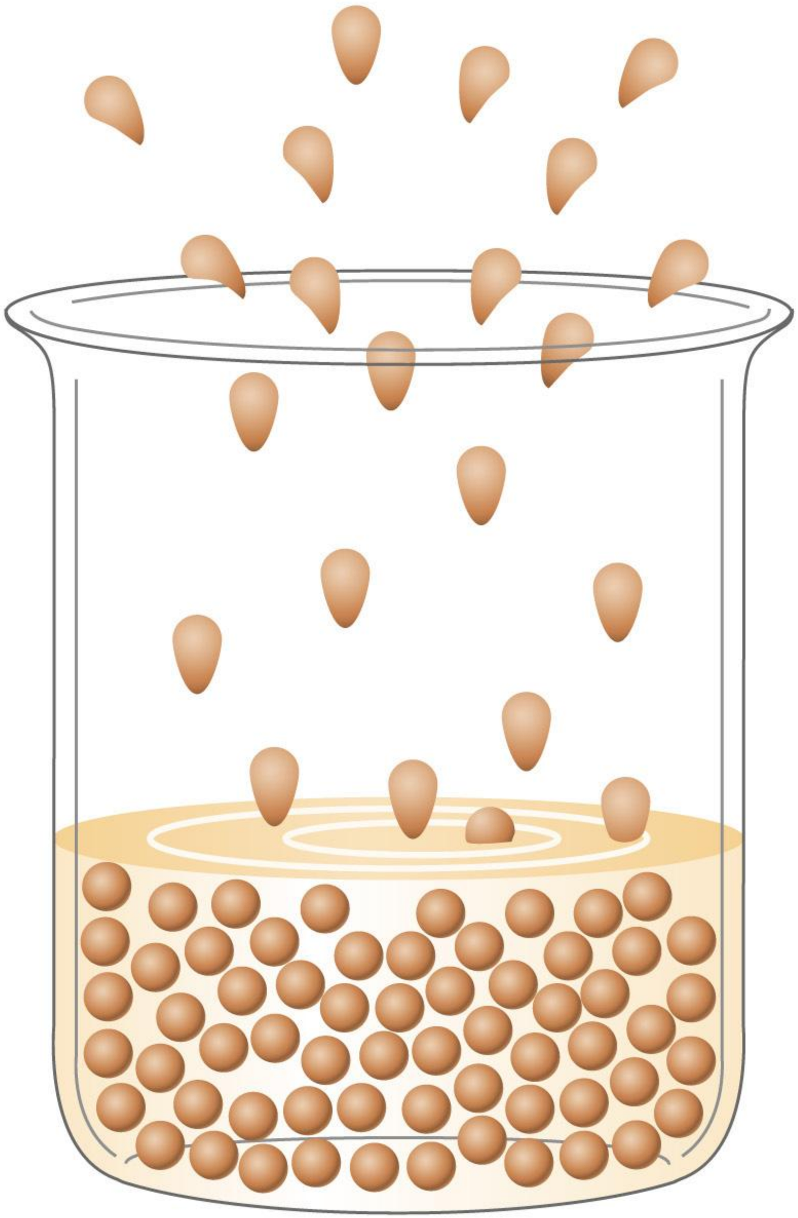
- Dynamic Equilibrium: the point when as many molecules escape the surface as strike the surface.
- Vapor pressure is the pressure exerted when the liquid and vapor are in dynamic equilibrium.

Vapor Pressure

Volatility, Vapor Pressure, and Temperature

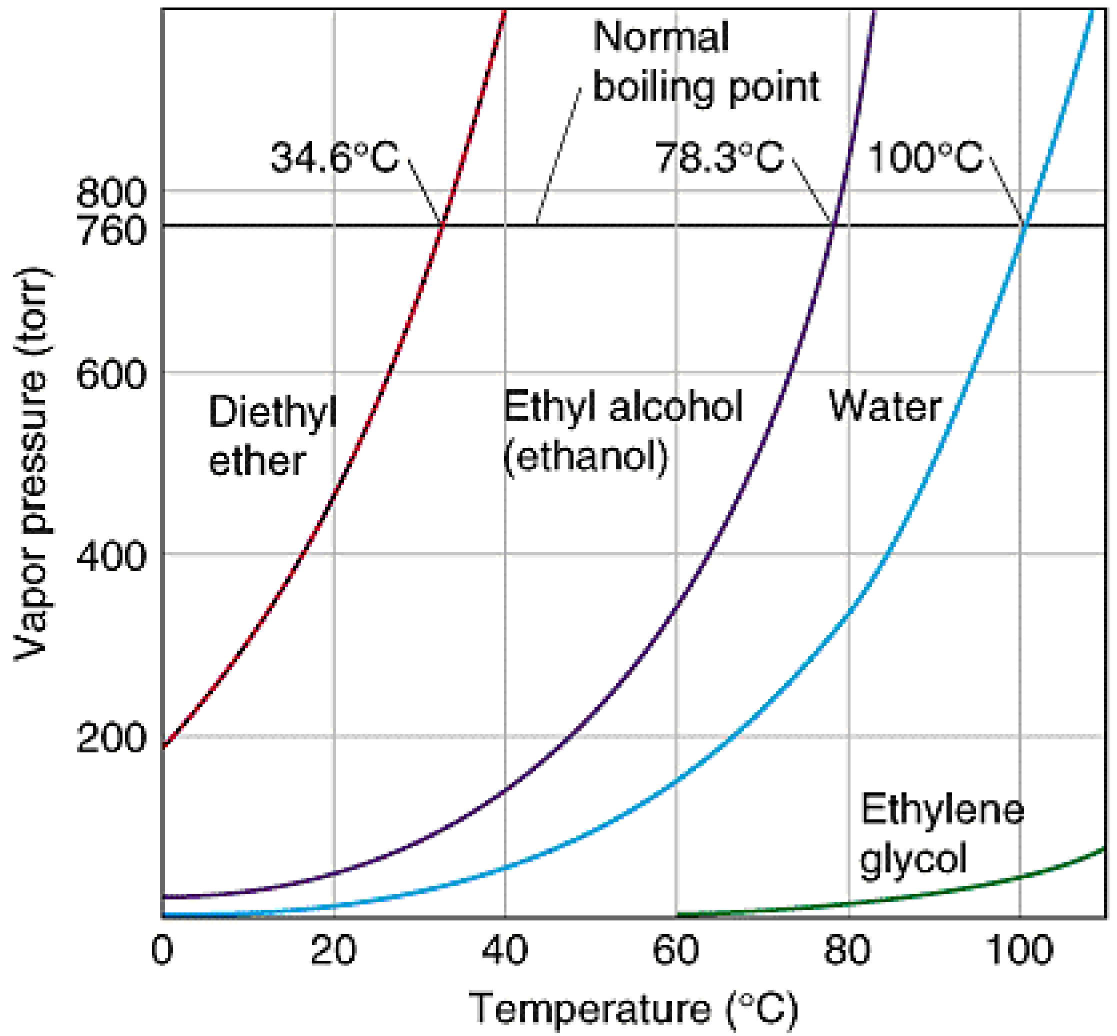
- If equilibrium is never established then the liquid evaporates.
- Volatile substances evaporate rapidly.
- The higher the temperature, the higher the average kinetic energy, the faster the liquid evaporates.

Liquid Evaporates when no Equilibrium is Established



Vapor Pressure

Volatility, Vapor Pressure, and Temperature



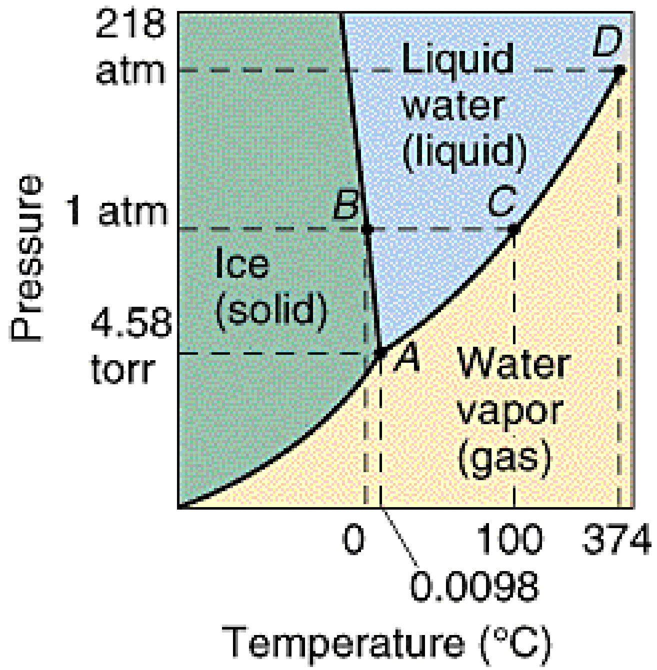
Vapor Pressure

Vapor Pressure and Boiling Point

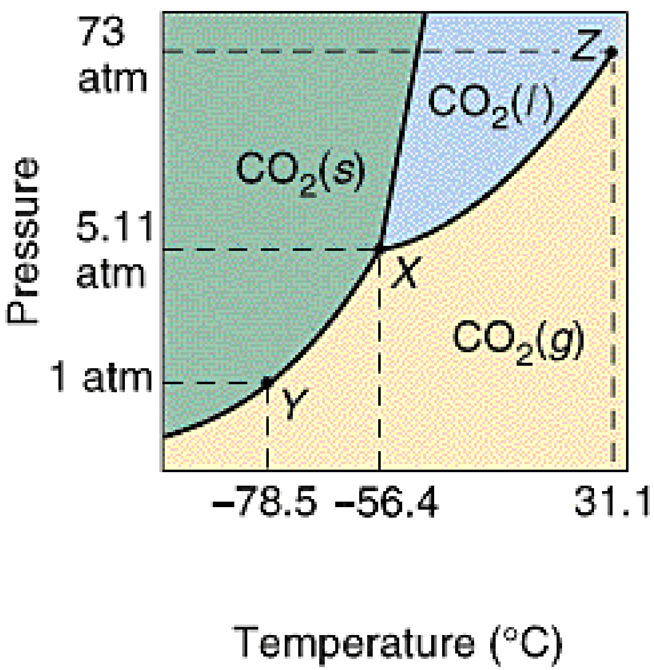
- Liquids boil when the external pressure equals the vapor pressure.
- Temperature of boiling point increases as pressure increases.
- Two ways to get a liquid to boil: increase temperature or decrease pressure.
  - Pressure cookers operate at high pressure. At high pressure the boiling point of water is higher than at 1 atm. Therefore, there is a higher temperature at which the food is cooked, reducing the cooking time required.
- Normal boiling point is the boiling point at 760 mmHg (1 atm).

Phase Diagrams

The Phase Diagrams of H_2O and CO_2



(a)



(b)

Vapor Pressure and Phase change

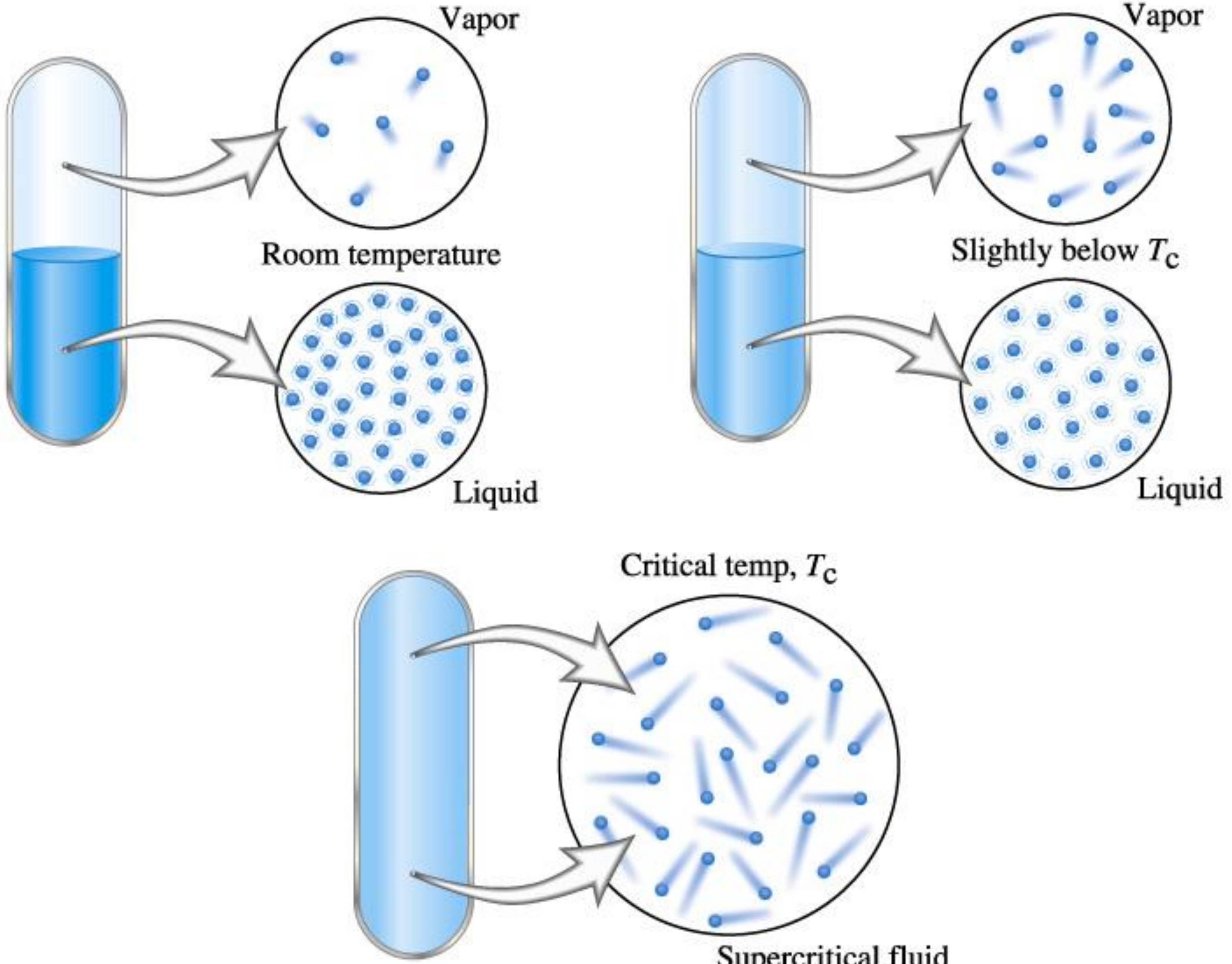
- Melting Point - point at which the vapor pressure of the liquid is equal
- Boiling point - Is the temperature at which the vapor pressure is equal to standard atmospheric pressure (you increase temp. you increase pressure of vapor)
  - Boiling is a function of pressure
  - Liquids that boil at low temperatures are said to be volatile
  - Volatile substances have high vapor pressure and nonvolatile liquids have low vapor pressure

Vapor Pressure & Phase change

- Substances with low vapor pressure have strong intermolecular forces. Those with high vapor pressures have weak intermolecular forces.
- Liquefaction of Gases - Condensation of substances normally in found as gases

Critical Temperature (Tc)

- Temperature above which no pressure will cause the gas to liquefy Critical Pressure – the pressure that will cause the gas to liquefy at (Tc)

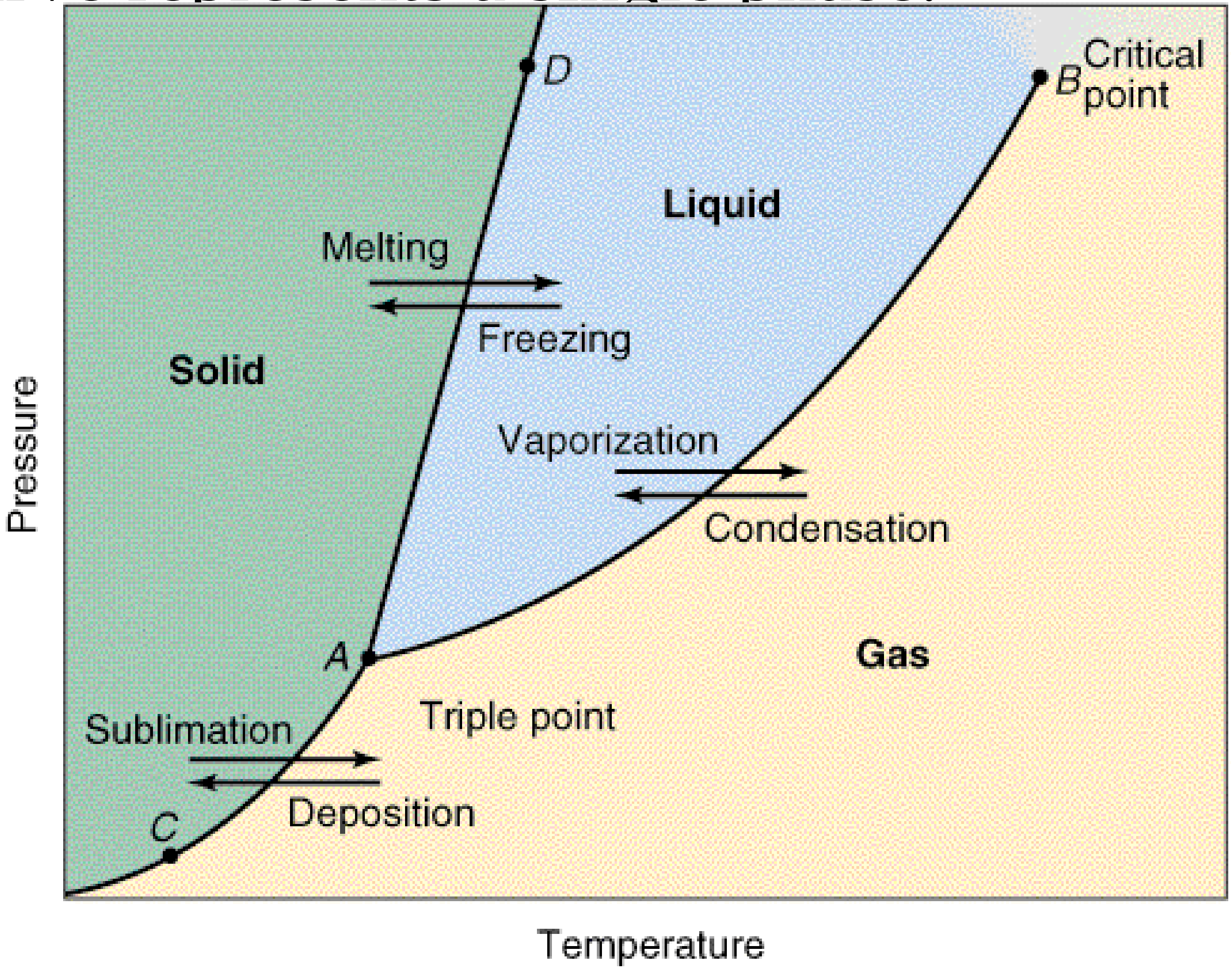

Vapor
Room temperature
Liquid
Vapor
Slightly below T_c
Liquid
Critical temp, T_c
Supercritical fluid

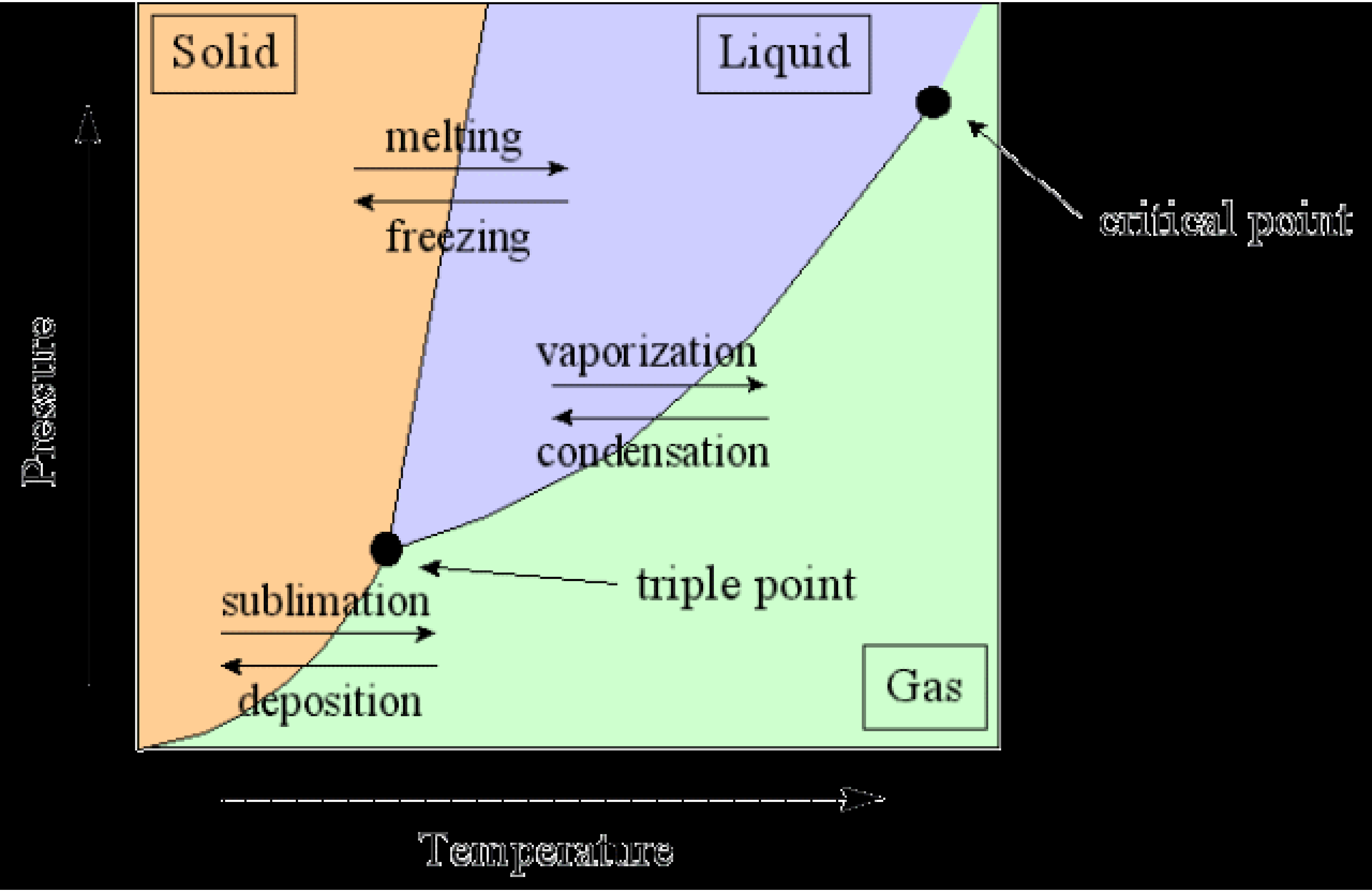
Triple point

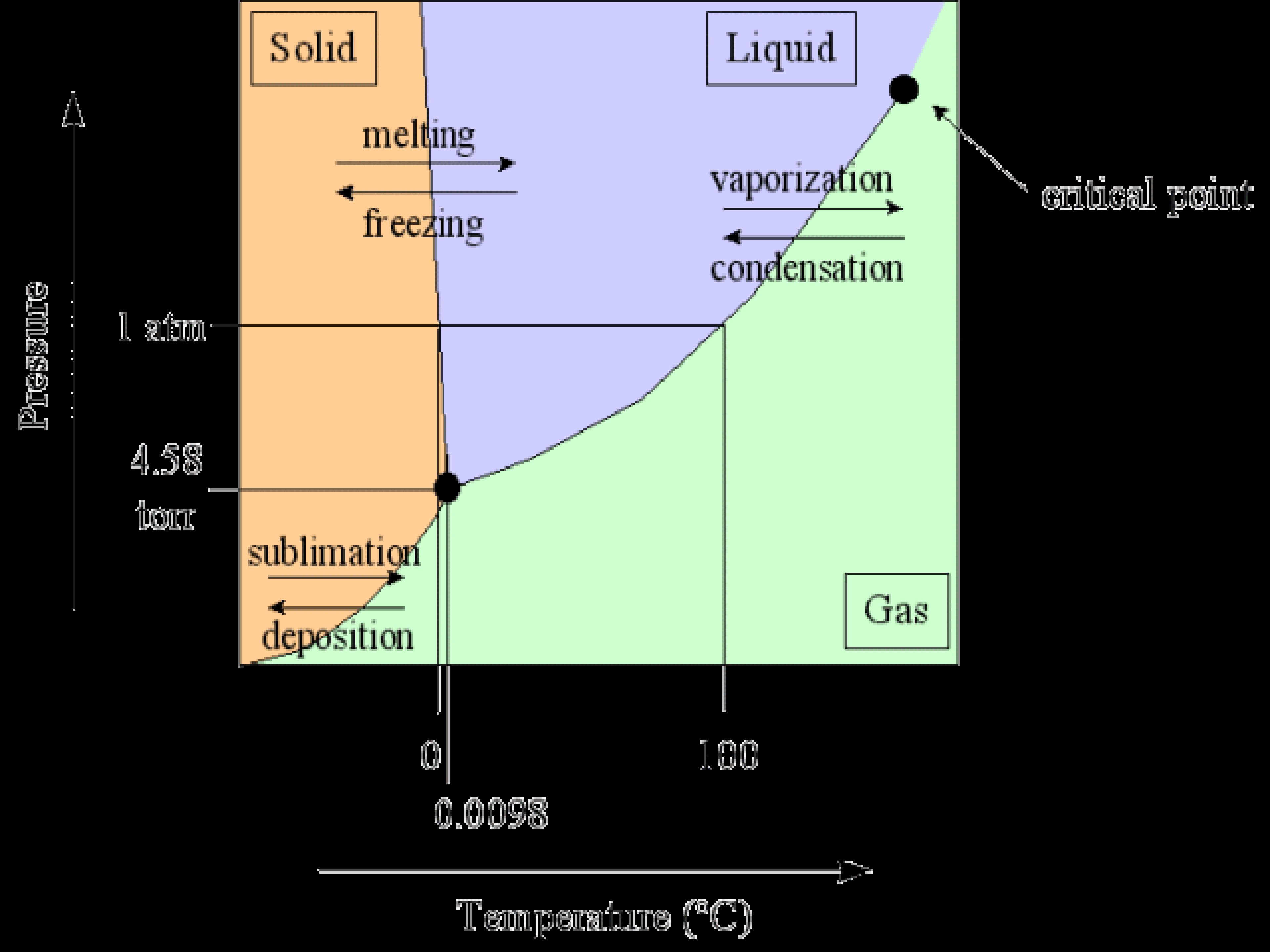
- is the point that all three states of matter can exist in equilibrium
- Phase Diagrams - show the relationship among temperature, pressure and physical state.
- Triple point - all three states are in equilibrium (Y)
- X - Critical point
- YZ - Temperature pressure where H_2O liquid and solid are at equilibrium
- Note H-$_2$O has a negative equilibrium line
- Increased pressure on water lowers the freezing point

Phase Diagrams

- Any temperature and pressure combination not on a curve represents a single phase.




Solid
Liquid
Gas
melting
freezing
vaporization
condensation
sublimation
deposition
triple point
critical point
Pressure
Temperature

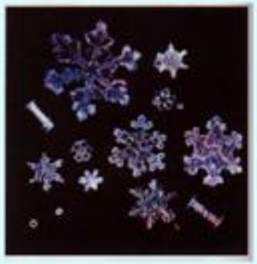

Solid
Liquid
Gas
melting
freezing
vaporization
condensation
sublimation
deposition
critical point
Pressure
1 atm
4.58
torr
0
0.0098
100
Temperature (°C)

Sublimation

Sublimation-- changing from gas to solid or vice versa sans passing through the liquid state.

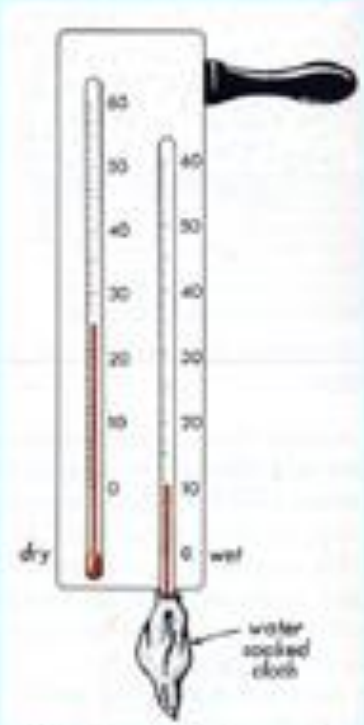
Examples:

Freezer frost	*(vapor to solid)*
Iodine (I_2)	*(solid to gas)*
Moth Crystals	*(solid to gas)*
Snow	*(vapor to solid)*
Cirrus clouds	*(vapor to solid)*
Dry ice (solid CO_2)	*(solid to gas)*



Sublimation of Dry Ice and Iodine

Relative Humidly



The Sling Psychrometer measures Relative Humidity by comparing the dry and wet bulb temperatures. The wet bulb is cooled by evaporation. The dryer the air the cooler the wet bulb.

Relative Humidity Table (in percent)

Dry Bulb **Dry Bulb Minus Wet Bulb (degrees celsius)**

°C	1	2	3	4	5	6	7	8	9	10
10	88	77	66	55	44	34	24	15	6	
11	89	78	67	56	46	36	27	18	9	
12	89	78	68	58	48	39	29	21	12	
13	89	79	69	59	50	41	32	22	15	7
14	90	79	70	60	51	42	34	25	18	10
15	90	81	71	61	53	44	36	27	20	13
16	90	81	71	63	54	46	38	30	23	15
17	90	81	72	64	55	47	40	32	25	18
18	91	82	73	65	57	49	41	34	27	20
19	91	82	74	65	58	50	43	36	29	22
20	91	83	74	67	59	53	46	39	32	26
21	91	83	75	67	60	53	46	39	32	26
22	91	83	76	68	61	54	47	40	34	28
23	92	84	76	69	62	55	48	42	36	30
24	92	84	77	69	62	56	49	43	37	31
25	92	84	77	70	63	57	50	44	39	33

Phase Diagrams

The Phase Diagrams of H_2O and CO_2

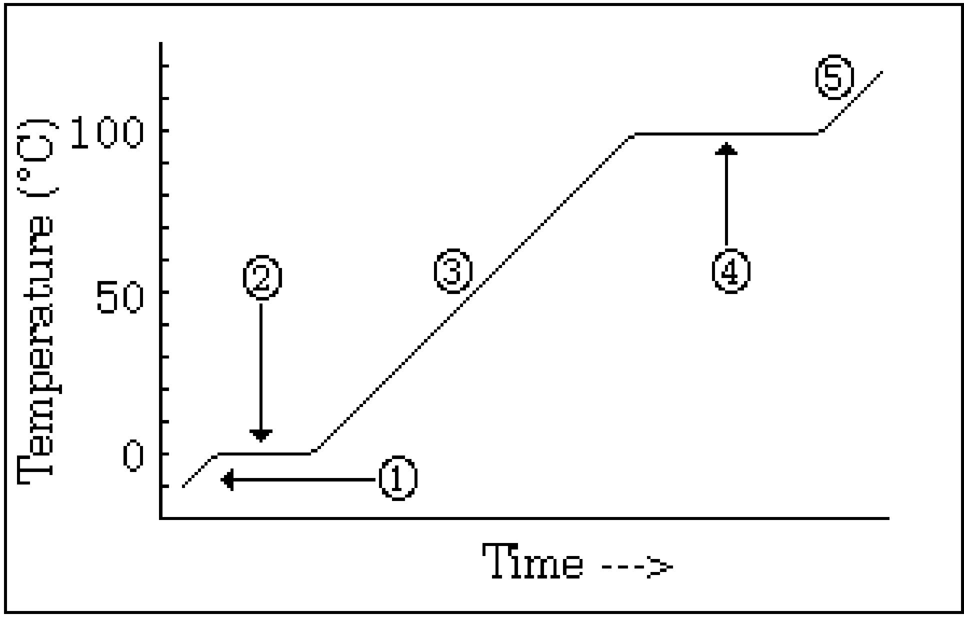
- Water:
  - The melting point curve slopes to the left because ice is less dense than water.
  - Triple point occurs at 0.0098°C and 4.58 mmHg.
  - Normal melting (freezing) point is 0°C.
  - Normal boiling point is 100°C.
  - Critical point is 374°C and 218 atm.
- Carbon Dioxide:
  - Triple point occurs at -56.4°C and 5.11 atm.
  - Normal sublimation point is -78.5°C. (At 1 atm CO_2 sublimes it does not melt.)
  - Critical point occurs at 31.1°C and 73 atm.

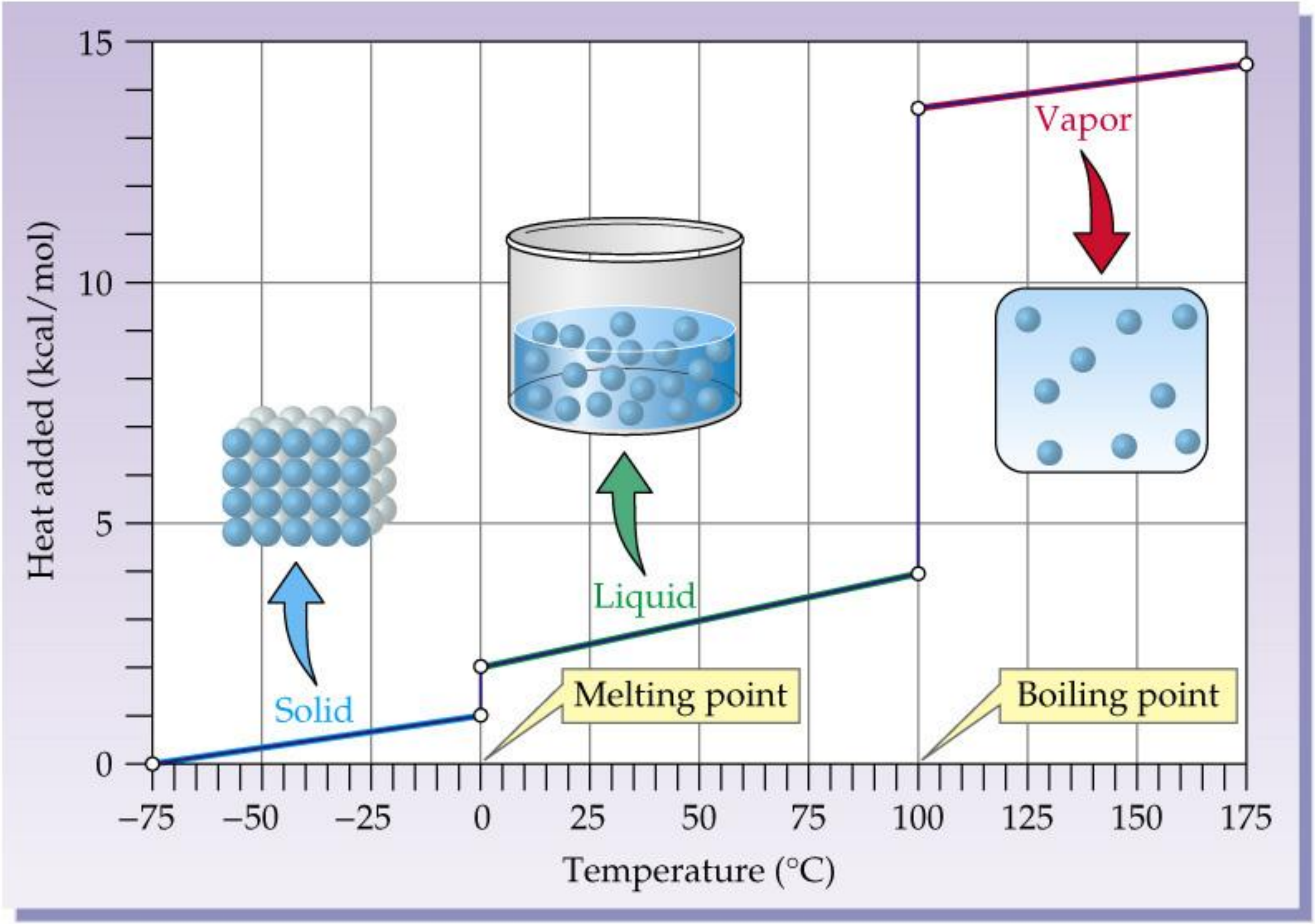
Phase Diagrams

- Phase diagram: plot of pressure vs. Temperature summarizing all equilibria between phases.
- Given a temperature and pressure, phase diagrams tell us which phase will exist.
- Features of a phase diagram:
  - Triple point: temperature and pressure at which all three phases are in equilibrium.
  - Vapor-pressure curve: generally as pressure increases, temperature increases.
  - Critical point: critical temperature and pressure for the gas.
  - Melting point curve: as pressure increases, the solid phase is favored if the solid is more dense than the liquid.
  - Normal melting point: melting point at 1 atm.

Energy and change of state

- Enthalpy of fusion (Hfus) – energy required to melt one gram of a substance
- Enthalpy of vaporization (Hvap) - energy required to vaporize one gram of a substance at its boiling point
- Hvap of water = 2260 J/g
- Hfus of water = 334 j/g
- Cp of ice 2.06 J/g°C
- Cp of water 4.18 J/g°C
- Cp of steam + 2.02 J/g°C





15
10
5
0
Heat added (kcal/mol)
–75
–50
–25
0
25
50
75
100
125
150
175
Temperature (°C)
Solid
Liquid
Vapor
Melting point
Boiling point

Hydrogen bonding

- **dipole attraction**
- **Electronegative atom will take almost complete control of electron**
- **The result is a highly polar molecule**
- **The highly polar molecule forms a weak hydrogen bond with other polar molecules**
- **Though this is strong it is not nearly as a chemical bond**

Hydrogen bonding in water

- **Crystal structure is rigid and less dense than liquid**
- **Water is most dense at 3.98°C**

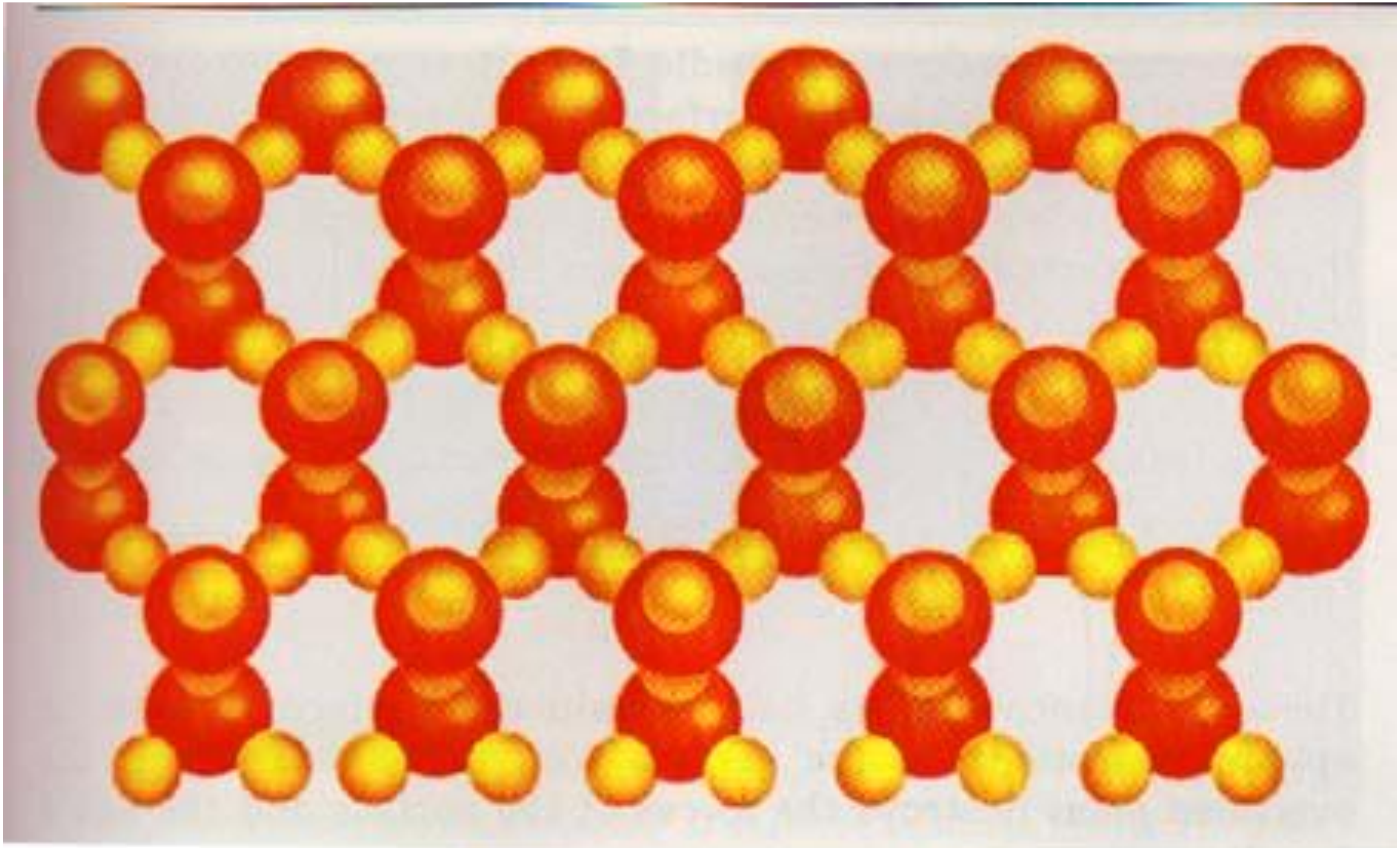
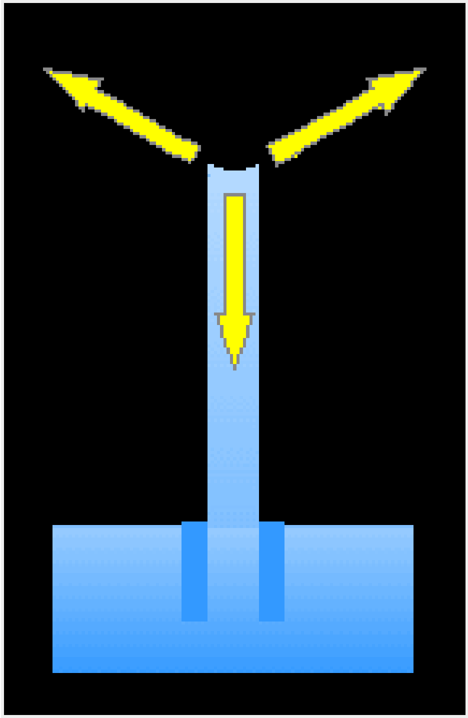


FIGURE 17-15. Hydrogen bonding causes water to expand as the temperature falls below 3.98°C. This expansion is seen by the model for ice.

Surface tension and capillary action

- Surface tension is the result net force attraction between molecules that are alike



Crush the Tanker

After steam cleaning, the tanker was sealed up. The steam condensed to water, and left low pressure inside! 1 kg/cm²!

Refrigeration

Refrigeration-- Cooling by evaporation.

Compress & cool to liquefy a gas (outside the fridge) then boil it in a vacuum (inside the fridge) to absorb heat.

Ice Plant Refrigeration

Cooling by Boiling a liquid. A gas is compressed and cooled until liquefied. Then the liquid is piped into the refrigerator where it is boiled by a vacuum. ***Boiling is endothermic.***

Critical Temperature is the maximum that a gas may have and become a liquid. *Critical Pressure* is the minimum that a gas may have to liquefy.