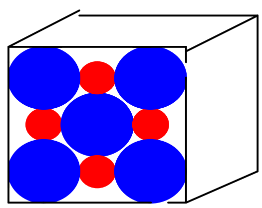
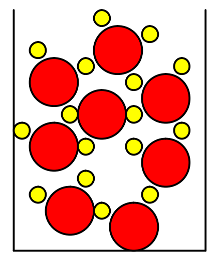
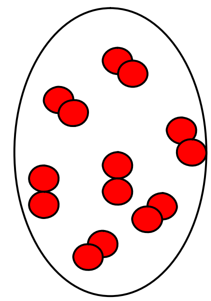
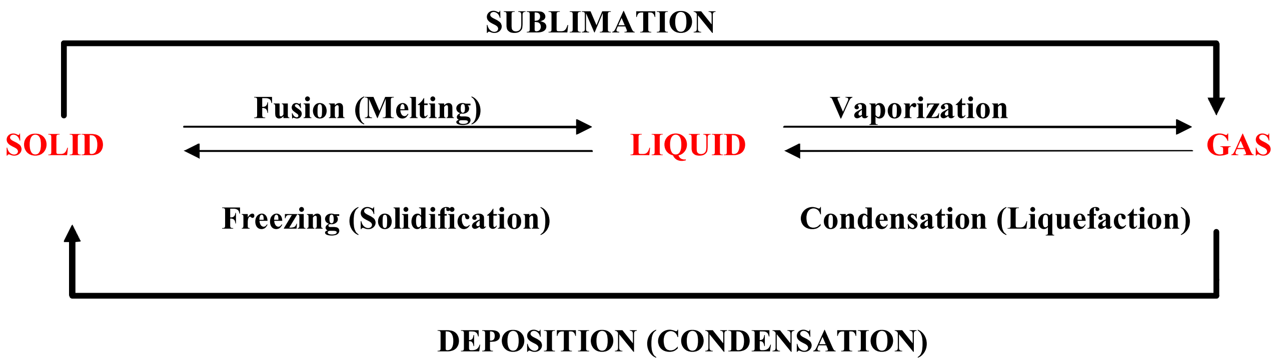
STATES OF MATTER

- All forms of matter are made of particles: ATOMS, IONS, or MOLECULES
- This is referred to as : **THE PARTICULATE NATURE OF MATTER**
- Based on their physical properties, different forms of matter may be classified as:

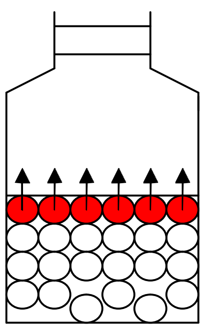
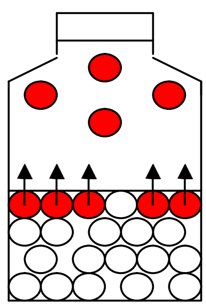
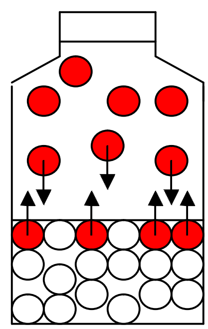
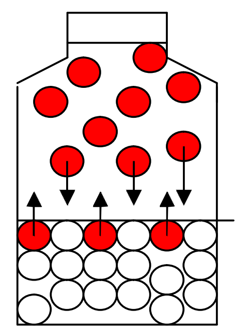
	I. SOLIDS	**II. FLUIDS**	
At Room Temperature **PARTICLES**	 Ions	1. Liquids  Polar Molecules	2. Gases  Non-polar Molecules
SUBSTANCE	Na^+ Cl^- crystal	Liquid H_2O	O_2 gas
COMPRESSIBILITY	Incompressible	Incompressible	Compressible
VOLUME	Fixed volume	Fixed volume	Takes up all available volume
SHAPTE	Fixed shape	Takes shape of container	Takes shape of container
MOVEMENT OF PARTICLES	No free movement (vibration only)	Very little Movement	Free movement
FREE (EMPTY) SPACE	Very little	Some free space	Mostly empty space
FORCE OF ATTRACTION	Very strong	Moderate	Negligible

CHANGES OF STATE (PHASE TRANSITIONS)

PHASE: A homogeneous portion of a system Examples: Salt water, Air, Cooking oil



VAPOR PRESSURE

			
High energy liquid molecules from surface evaporate	More molecules of liquid escape into the vapor phase	Molecules of liquid still vaporize, but some vapor molecules return into liquid phase	Number of molecules which evaporate is the same as number of molecules which condense
Fast evaporation	Evaporation slows down	Rate of evaporation > Rate of condensation	Rate of evaporation = Rate of condensation

- The vaporized molecules exert pressure in all directions
- This pressure is called VAPOR PRESSURE

$H_2O\,(l) \rightleftharpoons H_2O\,(g)$

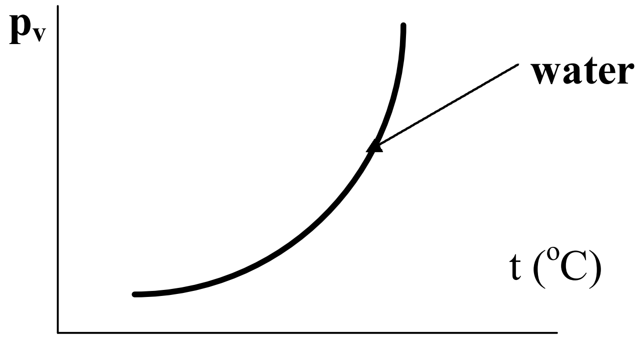
DYNAMIC EQUILIBRIUM HAS BEEN REACHED

VAPOR PRESSURE

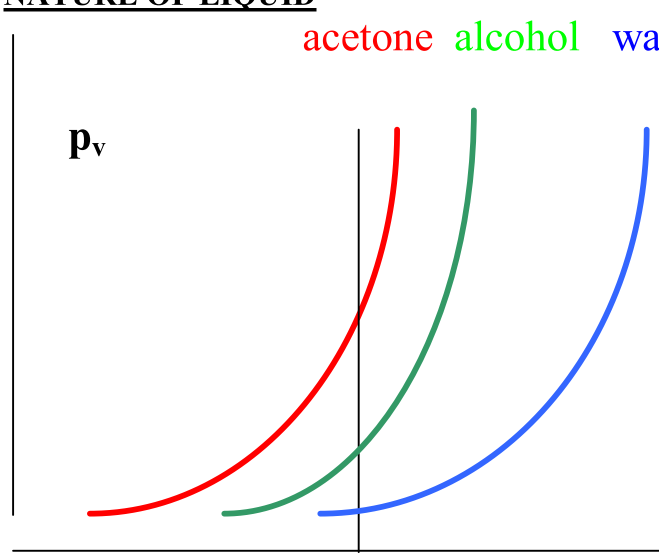
VAPOR PRESSURE OF A LIQUID: **(abbreviated p_v)** — **IS THE PRESSURE OF THE VAPOR OVER THE THE LIQUID, MEASURED AT EQUILIBRIUM, AT A GIVEN TEMPERATURE**

VAPOR PRESSURE DEPENDS ON:

1. TEMPERATURE: At higher temperature, more molecules can vaporize before equilibrium is reached



2. NATURE OF LIQUID



If the molecules of the liquid are less attracted to each other in liquid phase (acetone, alcohol), they escape easier into the vapor phase.

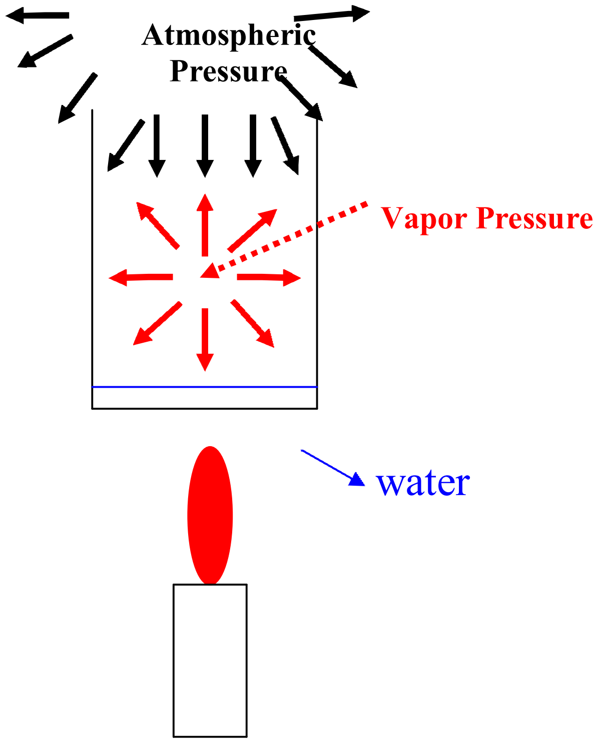
Such liquids are called **VOLATILE LIQUIDS**

NOTE: At the same temperature:

p_v(acetone) > **p_v(alcohol)** > **p_v(water)**

most volatile ... least volatile

BOILING POINT



NOTE:

- As the temperature increases, the vapor pressure (p_v) increases.
- When: $P_{atm} = P_V$

THE LIQUID BOILS

Experimental evidence of boiling:

- Bubbles of water vapor form WITHIN the liquid water

- **BOILING POINT is the temperature at which the vapor pressure of the liquid equals the atmospheric pressure**

$$(P_{atm} = P_V)$$

- Consider the following situations:

Atmospheric Pressure = 1.00 atm	Atmospheric pressure = 0.83 atm (High altitude)

- Atmospheric Pressure = 1.00 atm
- Boling occurs when:
  Vapor Pressure = 1.00 atm
- This requires a temperature of 100 °C

- Atmospheric pressure = 0.83 atm
  (High altitude)
- Boiling occurs when:
  Vapor Pressure = 0.83 atm
- This requires a temperature of 95 °C

NORMAL BOILING POINT: - the temperature at which the $\mathbf{P_V}$ **= 1.00 atm**

OR

- the boiling point at 1.00 atmosphere of pressure

CONCLUSION:

- BOILING POINTS OF ALL LIQUIDS ARE TEMPERATURE DEPENDENT.
- The higher the atmospheric pressure, the higher the boiling point of the liquid

For Water:

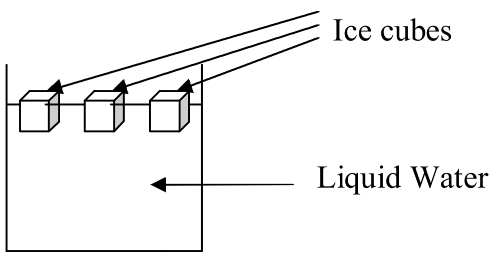
At: P_{atm} = 1.00 atm	P_{atm} < 1.00 atm	P_{atm} > 1.00 atm
P_V = 1.00 atm	P_V < 1.00 atm	P_V > 1.00 atm
B.P. = 100 °C	B.P. < 100 °C	B.P. > 100 °C
Normal Boiling Point	At high altitudes or lowered pressure	

MELTING POINT (M.P.) or FREEZING POINT(F.P.)

- F.P. - the temperature at which a pure liquid changes to a crystalline solid
- M.P. - the temperature at which a crystalline solid changes to a liquid

F.P. = M.P.

For water: F.P. = M.P. (at atmospheric pressure = 1.00 atm)



NOTE:
As long as the phases (solid water and liquid water) coexist, the temperature stays constant at 0^0 C.

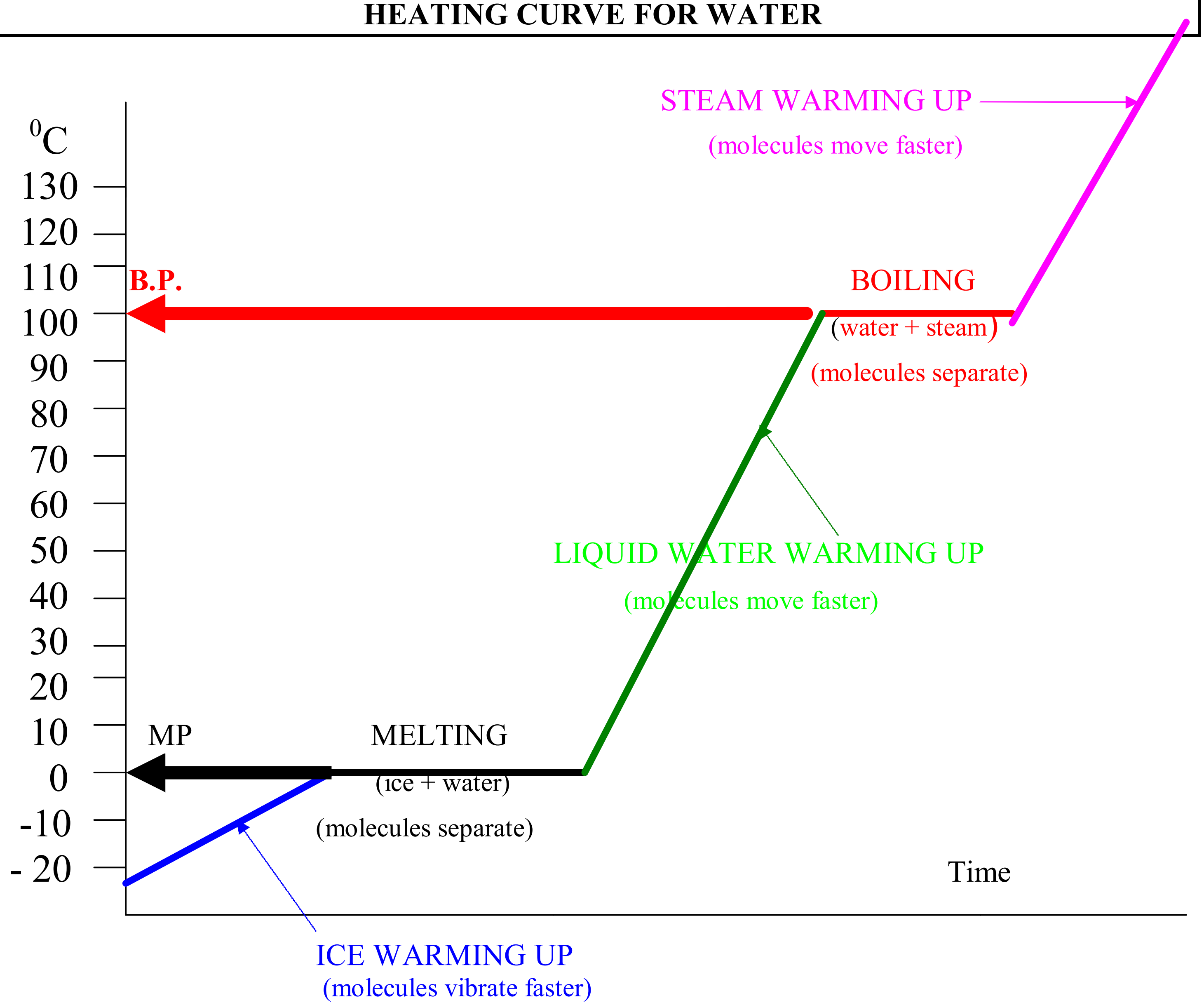
- Melting or Freezing occurs at the temperature where the solid phase and the liquid phase are in dynamic equilibrium.

$$\text{SOLID} \rightleftharpoons \text{LIQUID}$$

MELTING POINTS (OR FREEZING POINTS) OF SUBSTANCES:

- are independent of small variations in atmospheric pressure
- are affected by large pressure changes.

HEATING CURVE FOR WATER



NOTE: There is no temperature change during phase transitions

Reason: During phase transitions, the energy absorbed is used to separate the molecules and not to speed them up

$$H_2O(s) \xrightarrow{+\ 6.01\ kJ/mole} H_2O(l) \xrightarrow{+\ 40.7\ kJ/mole} H_2O(g)$$

ΔH fusion = + 6.01 kJ/mole ΔH vaporization = + 40.7 kJ/mole

Examples:

1. Isopropyl alcohol ($C_3H_7 - OH$) on the skin cools by evaporation. How much heat is absorbed by isopropyl alcohol if 10.0 g evaporates? (ΔH vaporization for isopropyl alcohol = 42.1 kJ/mol)

$$? \text{ kJ} = 10.0 \text{ g } C_3H_7-OH \times \frac{1 \text{ mole } C_3H_7-OH}{60.1 \text{ g } C_3H_7-OH} \times \frac{42.1 \text{ kJ}}{1 \text{ mole } C_3H_7-OH} = 7.00 \text{ kJ}$$

2. A 35.5 g sample of Cadmium metal was melted by an electric heater providing 4.66 J/s of heat. If it took 6.92 minutes from the time the metal began to melt until it was completely melted, what is the **ΔH_f** (in kJ/mole) of Cadmium ?

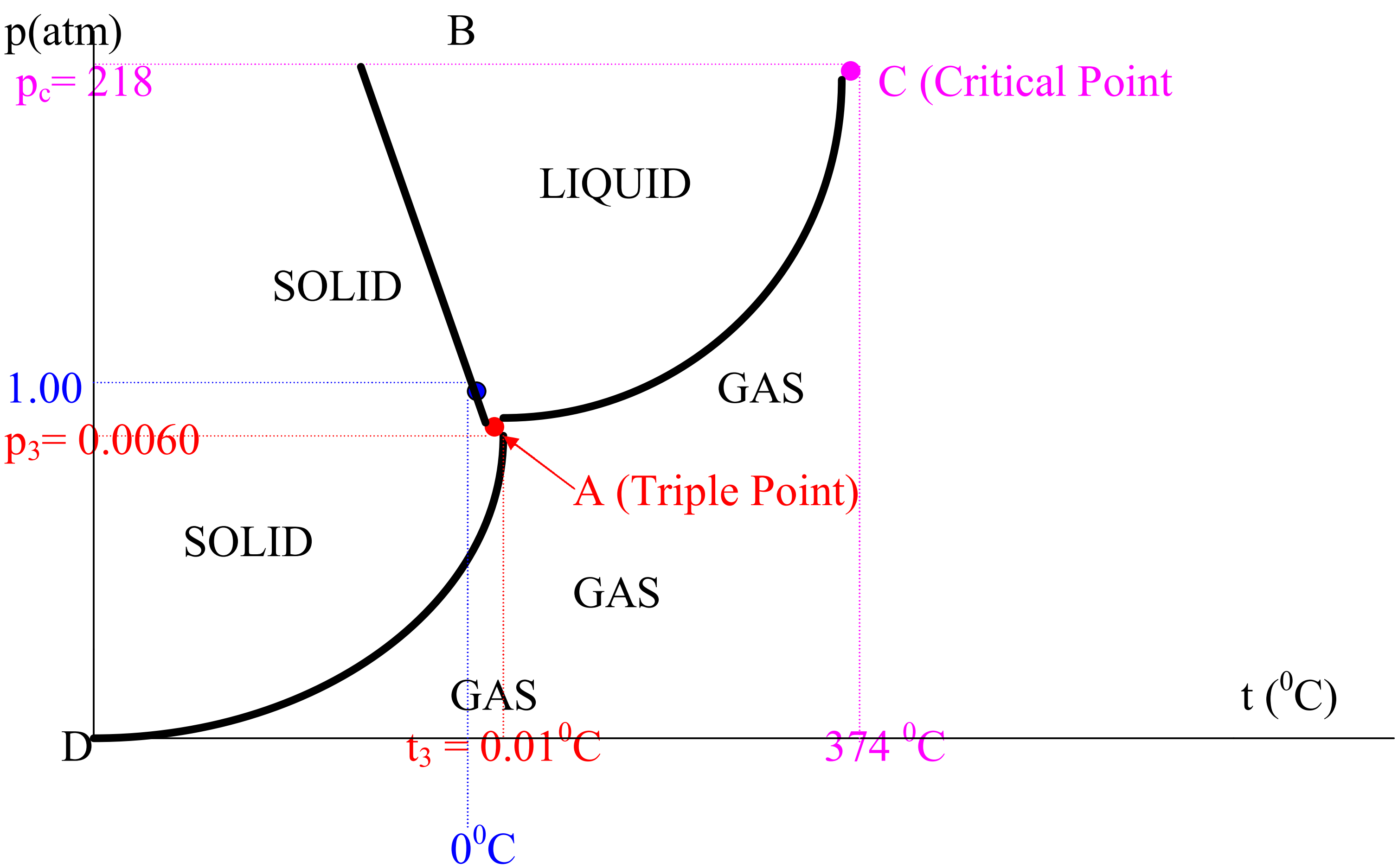
$$? \text{ J} = (6.92 \text{ min}) \times (60 \text{ sec/min}) \times (4.66 \text{ J/s}) = 19\underline{3}5 \text{ J}$$

$$? \frac{\text{kJ}}{\text{mole}} = \frac{19\underline{3}5 \text{ J}}{35.5 \text{ g } \frac{1 \text{ mole Cd}}{112.4 \text{ g Cd}}} = 6.13 \text{ kJ/mole}$$

PHASE DIAGRAMS

- Phase diagrams show graphical way to summarize the conditions under which the different physical states of a substance are stable.

PHASE DIAGRAM FOR WATER



AB = M.P. curve at different pressures; Along AB : solid $\rightleftharpoons$ liquid

- AB leans slightly to the left (true for water only) Meaning: As the pressure increases, MP decreases slightly

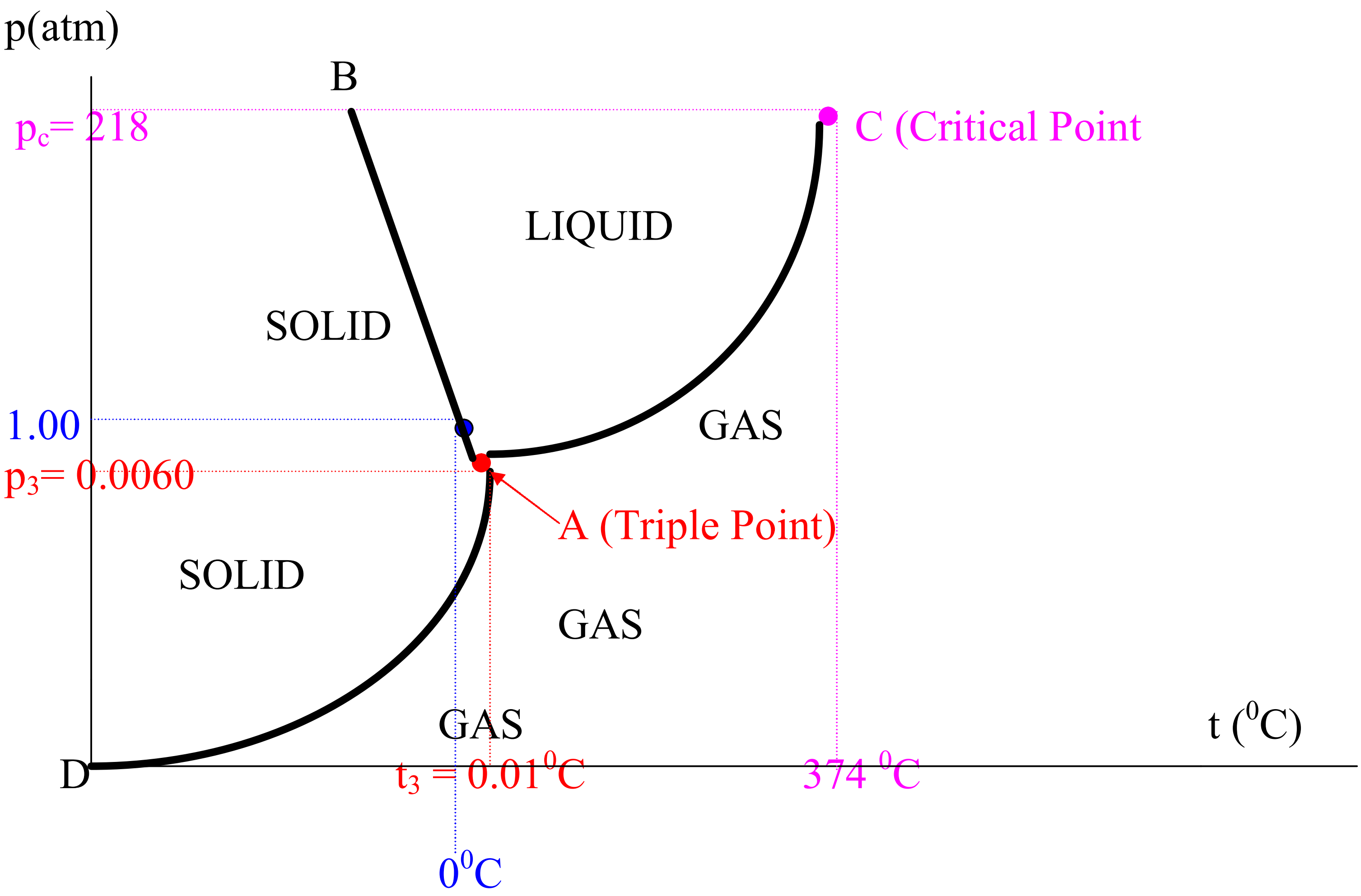
AC = B.P. curve at different pressures; Along AC : liquid $\rightleftharpoons$ gas

- As the pressure increases, BP increases considerably (true for all liquids since Vapor Pressure α temperature)

AD = Vapor Pressure of solid (ice) at different temperatures

- Solid can sublime (solid —>gas) at p < 0.0060 atm)

PHASE DIAGRAM FOR WATER



A = Triple Point for Water; p_3 = 0.0060 atm (4.58 mm Hg) t_3 = 0.01 ^{0}C (273. 16 K)

= the p and the t at which SOLID, LIQUID, and GAS coexist

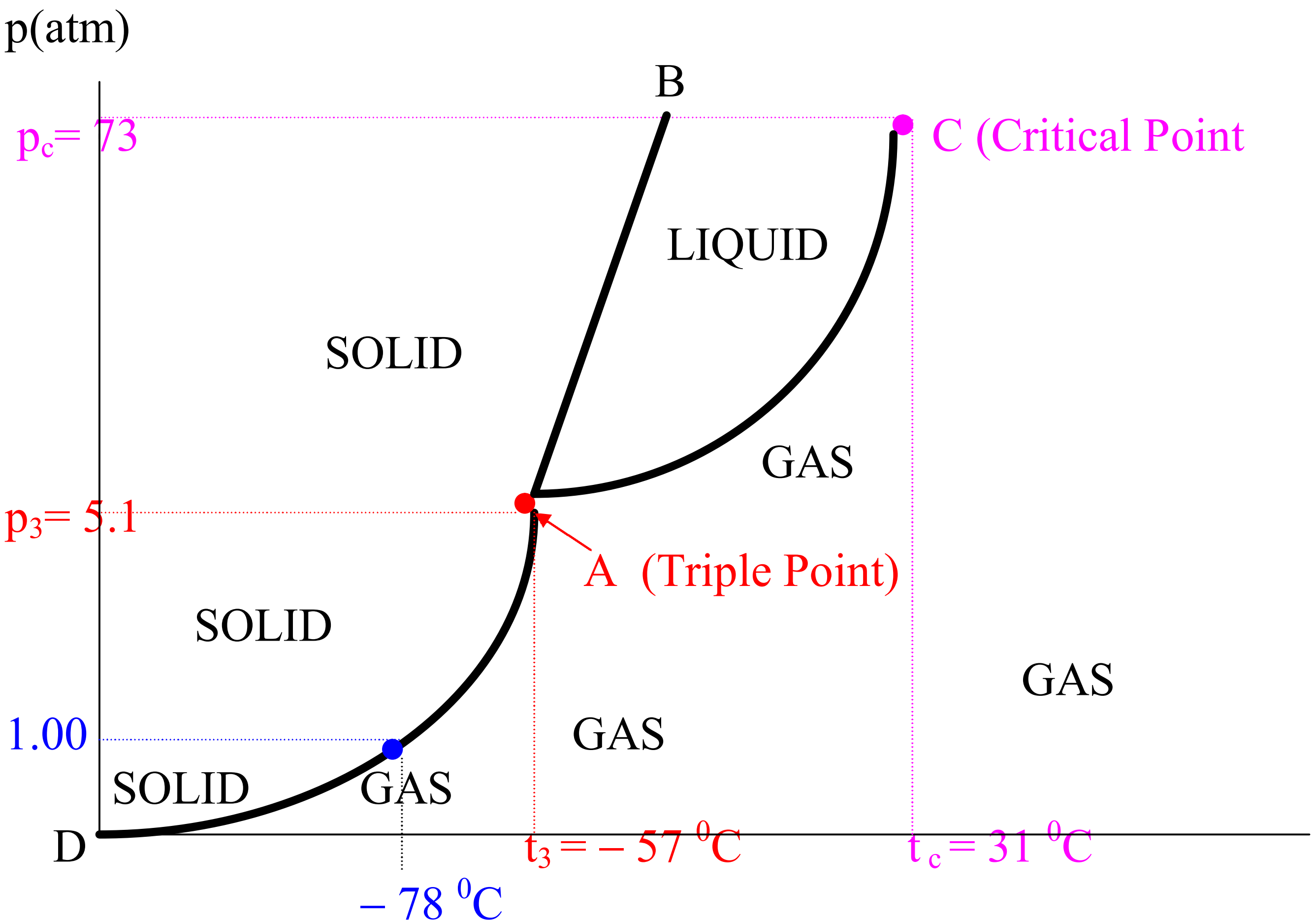
C = Critical Point for Water

p_c= critical pressure = 218 atm
pressure above which the substance can exist only as a liquid at the critical temperature(374 ^{0}C)

t_c= critical temperature = 374 ^{0}C
temperature above which the substance can exist only as a gas

- Hot steam can be turned into liquid water by applying high pressure, as long as the temperature < 374 ^{0}C
- Example: Critical temperature of Nitrogen gas = – 147 ^{0}C
  To liquefy N_2 gas, pressure must be applied at a t < -147 ^{0}C

PHASE DIAGRAM FOR CARBON DIOXIDE



AB = M.P. curve at different pressures; Along AB : solid $\rightleftarrows$ liquid

- AB leans slightly to the right (general for all liquids)
  Meaning: CO_2 can exist as a liquid only if p> 5.1 atm

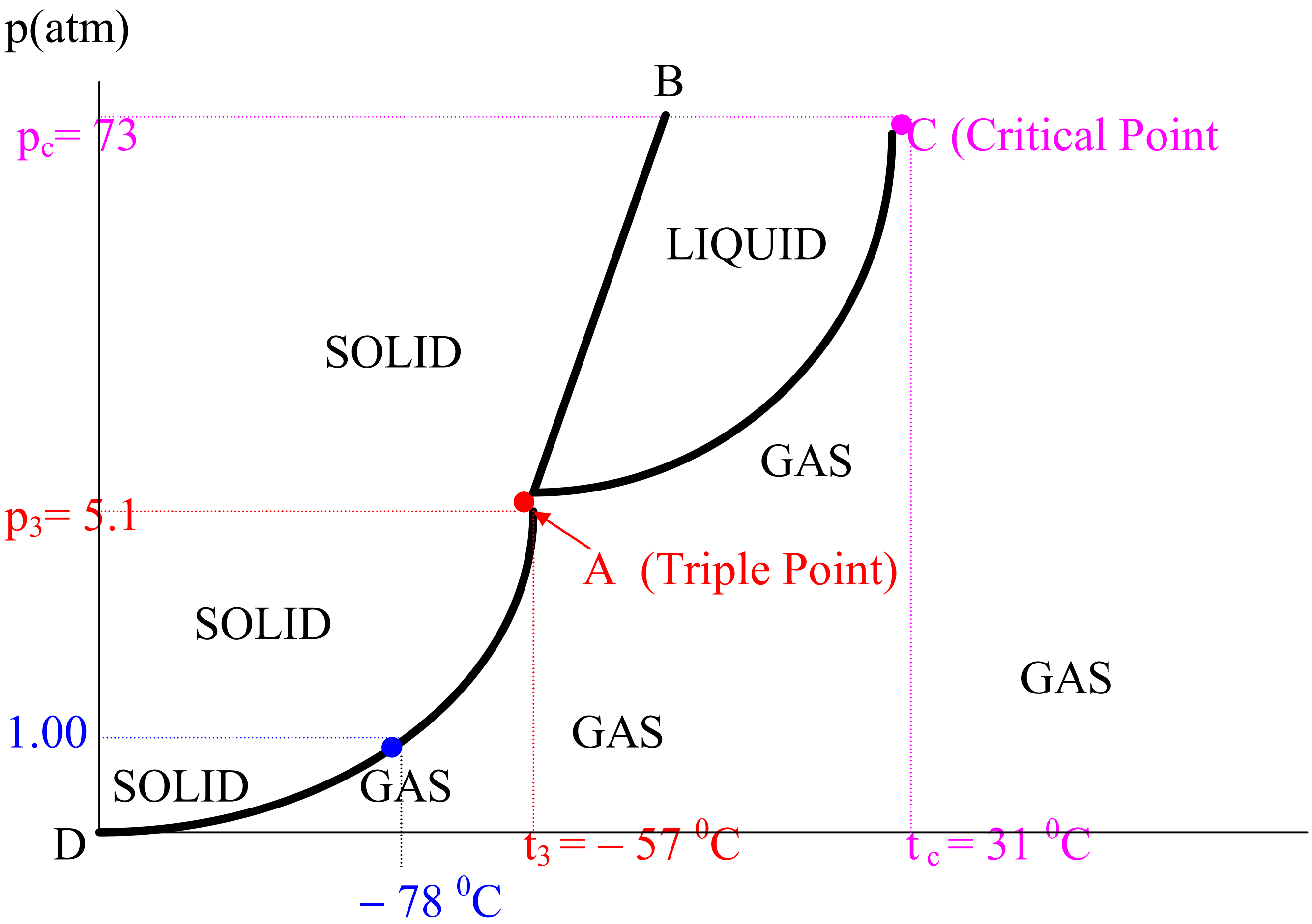
AC = B.P. curve at different pressures; Along AC : liquid $\rightleftarrows$ gas

- As the pressure increases, BP increases considerably (true for all liquids since Vapor Pressure α temperature)

AD = Vapor Pressure of dry ice at different temperatures

- Dry ice can sublime (solid ⟶>gas) at p< 5.1 atm)
  NOTE: At p = 1.00 atm: SOLID CO_2⟶> GASEOUS CO_2 at any t > – 78 ^{0}C

PHASE DIAGRAM FOR CARBON DIOXIDE



A = Triple Point for CO_2 ; $p_3 = 5.1$ atm $t_3 = -57\ ^0C$

= the p and the t at which SOLID, LIQUID, and GAS coexist

C = Critical Point for CO_2

p_c= critical pressure = 73 atm
= minimal pressure required at
31 ^0C to turn CO_2 into a liquid

t_c= critical temperature = 31 ^0C
= temperature above which
CO_2 cannot be turned into a liquid.