ENGINEERING CHEMISTRY

Department of Science and Humanities

Class content:

- ***Phase diagram of a 1-component system***
- ***Phase diagram of water***

Phase diagram

A diagram which represents the **conditions** under which a substance exists in **different phases** in a system

Phase diagram of a 1-component system

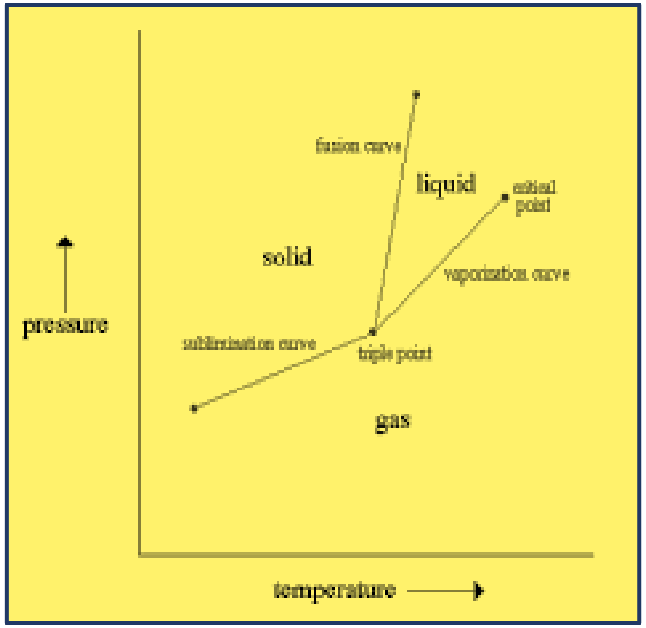
$F = C - P + 2$

For a 1-component system **$F = 3 – P$**

Single phase : $F = 2$ **; Area in a diagram**

Two phases in equilibrium : $F = 1$ **; line in a diagram**

Three phases in equilibrium : $F = 0$ **; point in a diagram**



High pressure, low temperature: **solid phase**
High temperature, low pressure : **vapour phase**
In between : **liquid phase**

solid ⇌ liquid
liquid ⇌ vapour
vapour ⇌ solid

Solid ⇌ liquid ⇌ vapour

Source:http://abyss.uoregon.edu/~js/glossary/triple_point.html

Application of Gibb's phase rule **F = C-P+ 2** to 1-component system:

Water system

When only 1 phase is present :

C = 1, P = 1; F = 2 ;Temperature and Pressure can be varied independently

Bivariant system

When 2 phases are in equilibrium:

C = 1, P = 2; F = 1 ; Temperature or Pressure can be varied independently

Univariant system

When all 3 phases are in equilibrium:

C = 1, P = 3; F = 0 ; Neither Temperature nor Pressure can be varied

Invariant system

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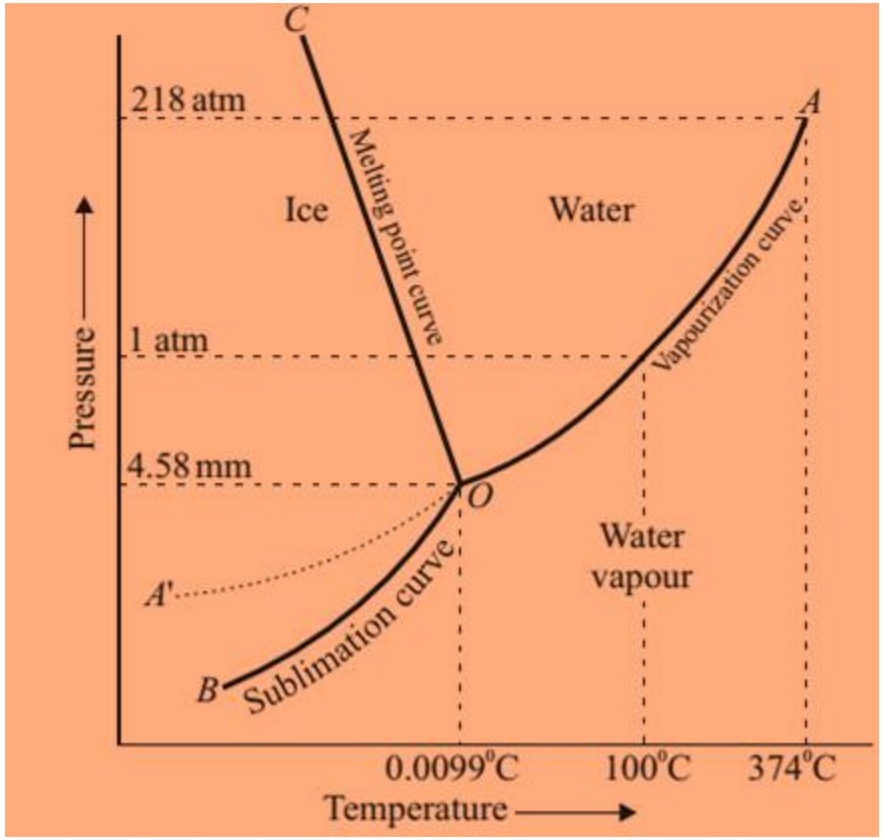
Module 2- Phase equilibria

Phase diagram of water



OC : Melting point curve

OA : Vaporisation curve

OB : Sublimation curve

O: Triple Point

A: Critical point

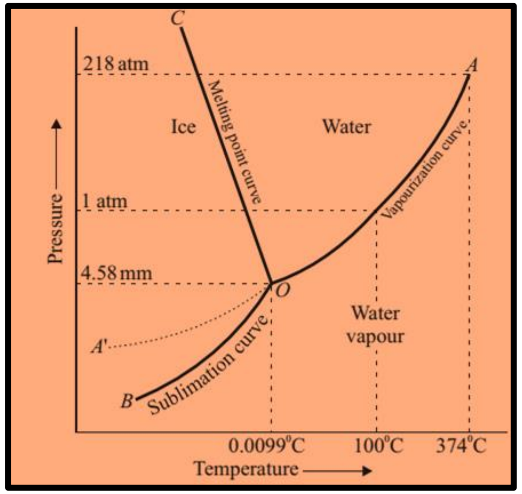
OA': Metastable equilibrium

Source: https://imbooz.com/engineering-chemistry/phase-diagram-for-water-system/

Equilibrium between solid and liquid (fusion curve OC)

- ice $\rightleftharpoons$ water
- F=1, monovariant system
- variation of melting point of ice with pressure
- slope is negative; as ice melts its volume decreases or density increases
- Clausius-Clapeyron equation

$$\frac{dp}{dT} = \frac{\Delta H_{Fusion}}{T\Delta V} = negative$$



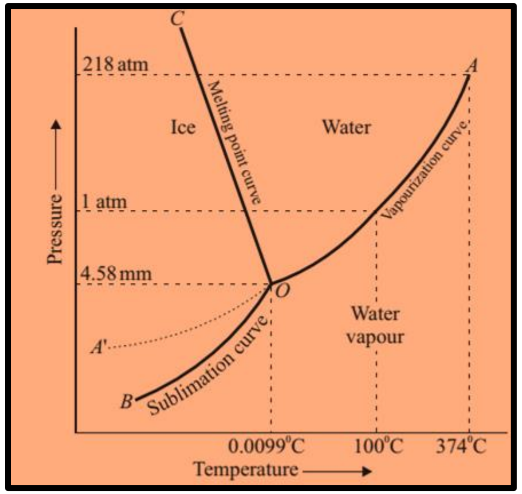
Where,

ΔV = decrease in volume as ice melts is -ve; $\Delta H_{fusion} = endothermic, +ve$

Equilibrium between solid and vapour (sublimation curve OB)

- ice $\rightleftharpoons$ water vapour
- F=1, monovariant system
- variation of sublimation temperature of ice with pressure
- slope is positive
- Clausius Clapeyron equation

$$\frac{dp}{dT} = \frac{\Delta H_{sub}}{T\Delta V} = positive$$



Where ,

ΔV = Increase in volume as ice sublimates ,+ve ;$\Delta H sublimation$ = endothermic reaction, $+ve$

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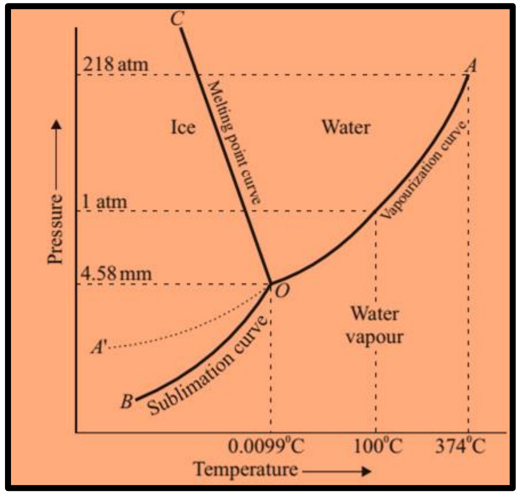
Equilibrium between liquid and vapour (vaporization curve OA)

- **liquid water $\rightleftharpoons$ vapour**
- F=1, **monovariant system**
- variation of boiling temperature of water with pressure
- **slope is positive**
- Clausius - Clapeyron equation

$$\frac{dp}{dT} = \frac{\Delta H_{Vapourisation}}{T\Delta V} = positive$$

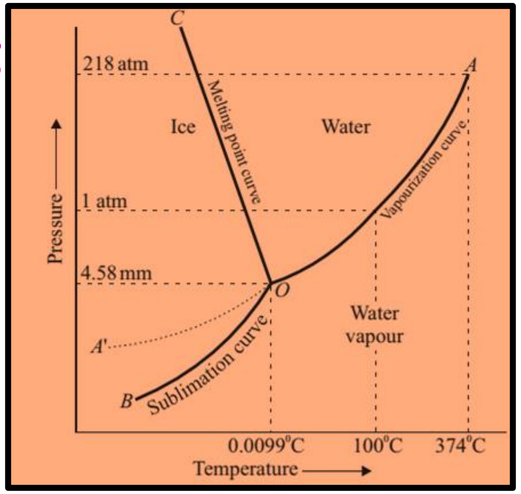


Where,

ΔV = Increase in volume as liquid water vapourises,+ve;$\Delta H_{Vapourisation}$ $=$ endothermic reaction, $+ve$

Triple point "O":

- Represents equilibrium between liquid, vapour and solid water (ice)
- All three phases are present together
- F = 0, **invariant system**
- Triple point for water lies at **0.0098 ^{0}C and 4.58 mmHg**

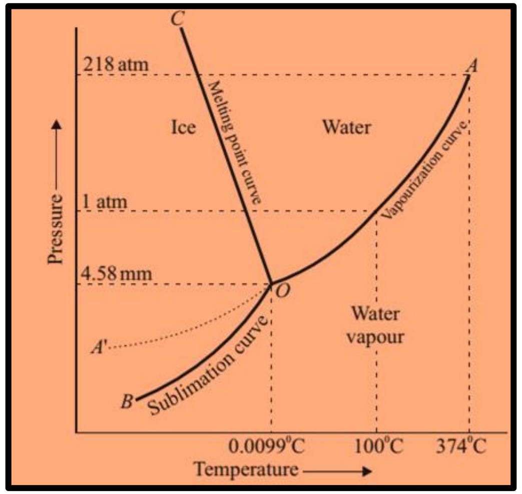


Critical point "A":

- the interface between liquid water and water vapour vanishes
- a point above which water does not exist in liquid state
- Critical point lies at **374^{0}C and 218 atm** pressure

Metastable equilibrium (OA'):

- Ice fails to form at the triple point and water continues to exist in liquid phase
- The vapour pressure of the liquid continues along OA'
- This is called **super cooled water** and represents metastable equilibrium involving liquid and vapour phases.
- Any disturbance will cause the system to go back to stable equlilibrium (OB)
- The vapour pressure of the system in the metastable region is more than that of the stable system ice at the same temperature



THANK YOU

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