Phase Transition Part-1
Order of Phase Transition

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Phases and Phase Transition

- *Phases* are states of matter characterized by distinct macroscopic properties.

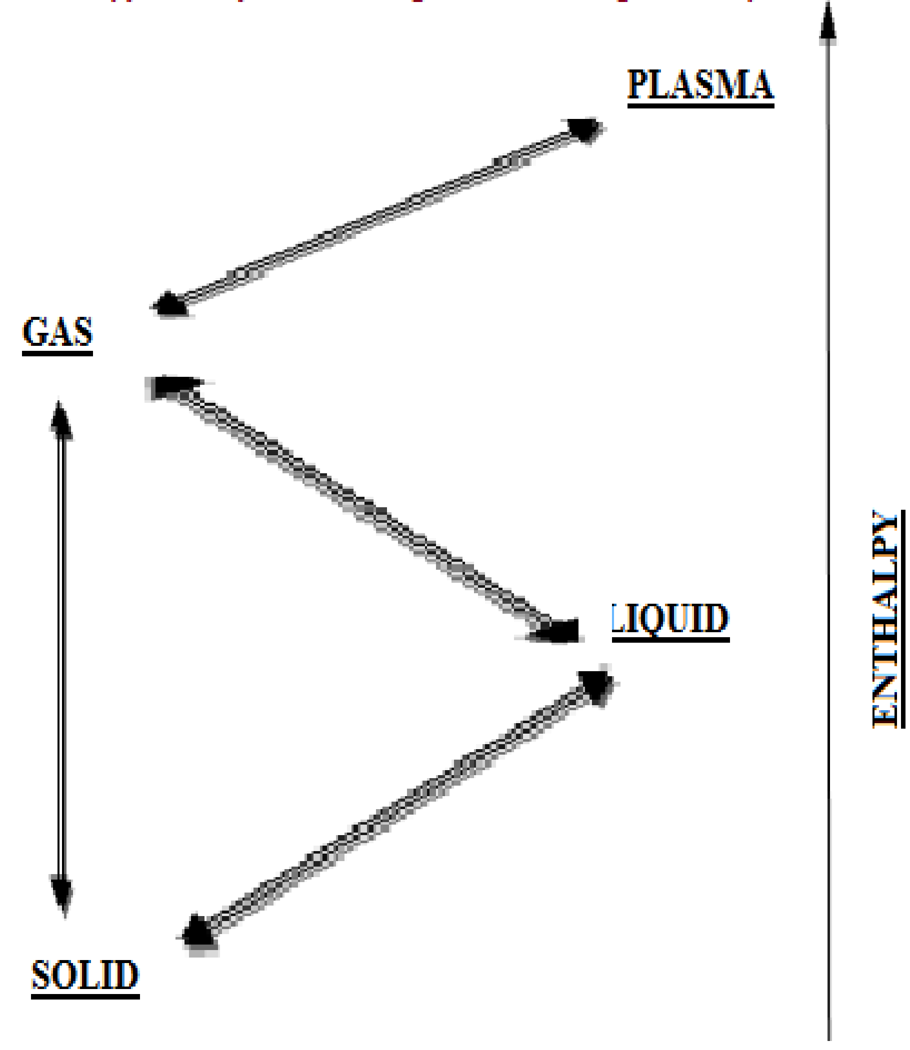
- Typical phases we know are liquid, solid and gas.

- Other important phases are superconducting, Superfluidity, magnetic states etc.

Phase Transitions

What we generally understand with the phase transition is conversion of state of material from solid to liquid to gas to plasma and or any other such kind of procedure as shown in figure

Different types of phase change which we generally observe



Is there any other kind of phase transition

Of course ...there are

when there are other phases then transition between those phases are also defined as phase transition

Like Transition from

- Normal conductor to superconductor
- Liquid He going to super fluid state
- Paramagnetic to ferromagnetic transition etc.

In these transitions

- Physical state of matter is not changed

- but it has totally different property and so the state is defined as new state or we can say state is changed

- So the question arises that How do thermodynamically we differentiate between the phase transition which we generally discuss in our day to day life, to the type of phase transition discussed above.

- What is the scientific terminology to understand the difference.

First Order and Second Order Phase Transition

- The order of the lowest derivative of the Gibbs enthalpy G showing a discontinuity upon crossing the coexistence curve is the order of a phase transition.

- Phase transitions in the P - T phase diagram are described by the Gibbs Energy G(T, P, N), which is itself a function of the pressure P and of the temperature T.

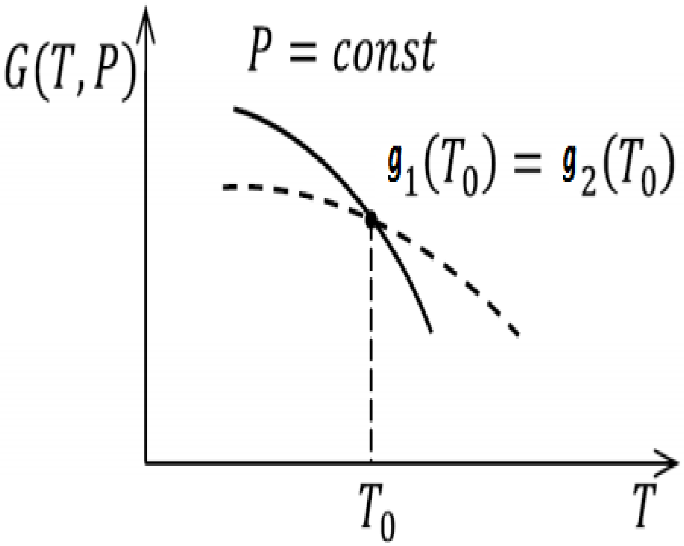
In case of **FIRST ORDER PHASE TRANSITION** G(T, P, N) changes continuously across the phase boundary

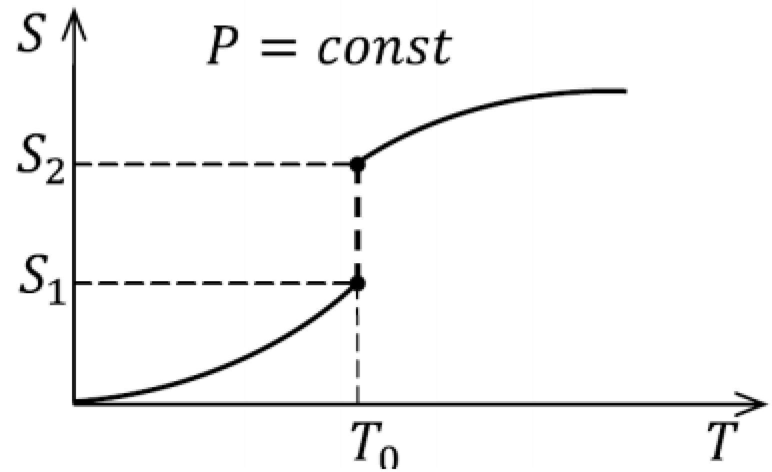
$$dG = -SdT + V\,dP + \mu dN = 0$$

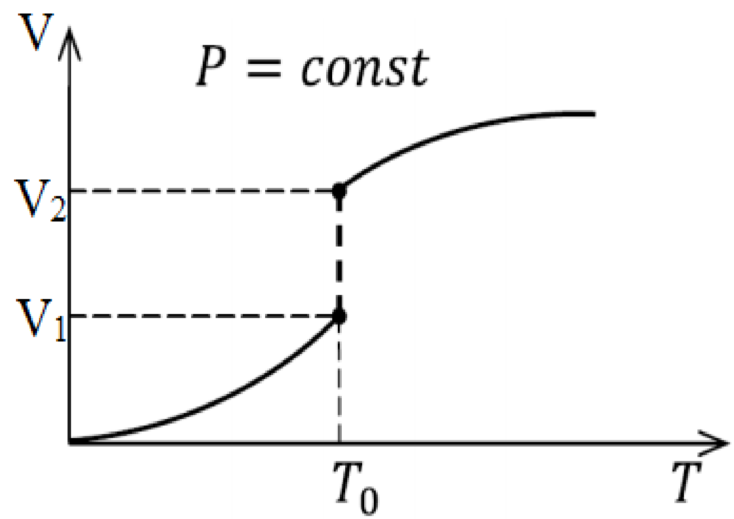
- The entropy S and volume V , which are given by the first order derivatives of the Gibbs potential, are in contrast discontinuous.

$$V = \left(\frac{\partial G}{\partial P}\right)_T \qquad S = -\left(\frac{\partial G}{\partial T}\right)_P$$

Here g1=g2 at phase transition that means it is continuous. But S1 and V1 are not equal to S2 and V2 (respectively) so they are discontinuous.
Phase transition satisfying these criteria are called First Order Phase Transition







- Two phases 1 and 2 coexisting at a temperature T_0 have different entropies S_1 and S_2. The system must therefore absorb or release heat, the latent heat ΔQ_L (or let us call it L)

- So latent heat [$L = T_0(S_2 - S_1)$] exists during a first order phase transition.

- First Order Phase transition have following characteristics
- $\Delta G_{Tras}=0$ $\quad$ $\Delta S_{Tras} \neq 0$
- $\Delta V_{Tras} \neq 0$ $\quad$ $\Delta H_{Tras} \neq 0$

- In case of **SECOND ORDER PHASE TRANSITION** alsoG(T, P, N) changes continuously across the phase boundary i.e.

$$dG = -SdT + V\,dP + \mu dN = 0$$

- Along with it's first order derivatives also i.e.

- $\Delta S_{Tras}=0,$ $\Delta V_{Tras}=0,$ $\Delta H_{Tras}=0$

- Then what is discontinuous at transition point
- C_p at transition has finite discontinuity
- The second order derivatives are discontinuous i.e.

$$
\begin{aligned}
C_P &= T\left(\frac{\partial S}{\partial T}\right)_P = -T\left(\frac{\partial^2 G}{\partial T^2}\right)_P \\
\kappa_T &= -\frac{1}{V}\left(\frac{\partial V}{\partial P}\right)_T = -\frac{1}{V}\left(\frac{\partial^2 G}{\partial P^2}\right)_T \\
\alpha &= \frac{1}{V}\left(\frac{\partial V}{\partial T}\right) = \frac{1}{V}\left(\frac{\partial^2 G}{\partial T \partial P}\right)
\end{aligned}
$$

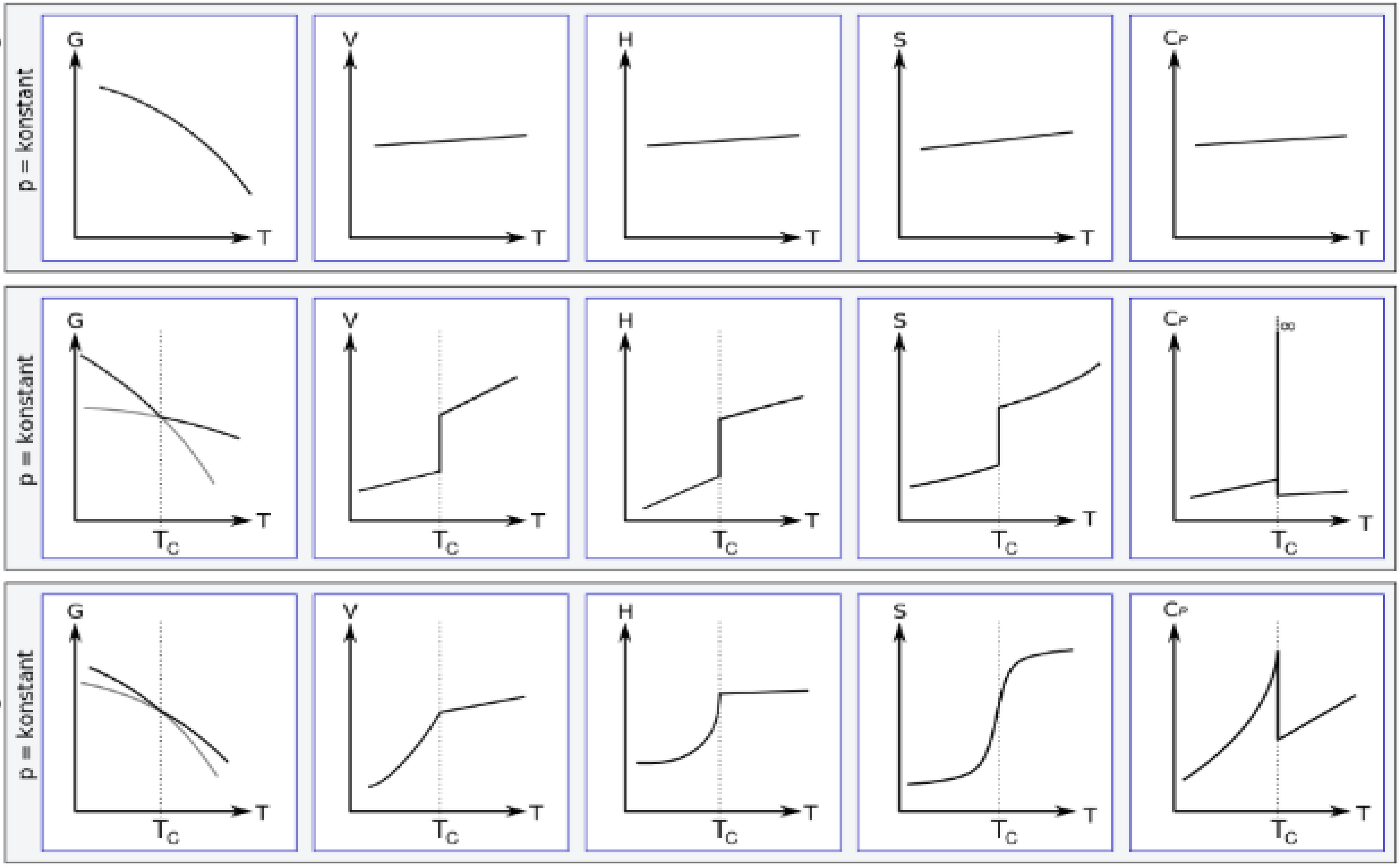


Fig. 1: The behavior of various thermodynamic quantities (Gibbs free energy G, volume V, enthalpy H, entropy S and specific heat C_P) during a phase transition. First line: no phase transition. Second line: first-order phase transition. Third line: second-order phase transition. From Wikipedia.

Taken from :https://physics.stackexchange.com/tags/phase-transition/info

Study material

- https://youtu.be/kKZsq0_xqNQ
- https://youtu.be/MIL7MOGKDOM
- https://youtu.be/MIL7MOGKDOM
- https://youtu.be/Wya57SmeN00
- https://www.worldscientific.com/doi/pdf/10.1142/9789813274181_0001
- http://casey.brown.edu/chemistry/misspelled-researh/crp/Edu/Documents/00_Chem201/7_phase_equil_1/7-phase_equilibria1-frames.htm

Study material

- https://chem.libretexts.org/Bookshelves/Physical_and_Theoretical_Chemistry_Textbook_Maps/Supplemental_Modules_(Physical_and_Theoretical_Chemistry)/Physical_Properties_of_Matter/States_of_Matter/Phase_Transitions/Fundamentals_of_Phase_Transitions

- https://web.stanford.edu/~peastman/statmech/phasetransitions.html
- https://slideplayer.com/slide/5103880/
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