Phase Diagrams

Thapar Institute of Engineering & Technology
(Deemed to be University)
Bhadson Road, Patiala, Punjab, Pin-147004
Contact No. : +91-175-2393201
Email : info@thapar.edu

THAPAR INSTITUTE
OF ENGINEERING & TECHNOLOGY
(Deemed to be University)

Syllabus

Equilibrium diagram: Solids solutions and alloys, Gibbs phase rule, Unary and binary eutectic phase diagram, Examples and applications of phase diagrams like Iron - Iron carbide phase diagram.

CLO: Distinguish between isomorphous and eutectic phase diagram.

Why Study Phase Diagrams?

- Phase diagrams are maps that give the relationships between phases in equilibrium in a system as a function of temperature, pressure and composition.

- The knowledge and understanding of phase diagrams is important to the engineer relates to the design and control of heat-treating procedures; some properties of materials are functions of their microstructures, and, consequently, of their thermal histories.

Phase

Physically distinct, chemically homogenous and mechanically separable region of a system (e.g. gas, crystal, amorphous...).

Gases

- Gaseous state always a single phase
- Mixed at atomic or molecular level.

Liquids:

- Liquid solution is a single phase
- No mixing at the atomic/molecular level.
- Liquid mixture can consist of two or more phases (e.g. sugar in water, NaCl in water and oil in water)

Solids

- In general due to several compositions and crystals structures many phases are possible.
- For the same composition different crystal structures represent different phases. e.g. Fe (BCC) and Fe (FCC) are different phases.

Gibbs Phase Rule

The phase rule connects the degrees of Freedom, the number of Components in a system and the number of Phases present in a system via a simple equation.

$$P + F = C + N$$

$$P + F = C + 2$$

$$F = C - P + 2$$

The ‘2’ comes from pressure and temperature

N = 2 for Unary system
N = 1 for Binary system

Where
P: Number of phases present
F: Degree of freedom (externally controllable parameters e.g. T, P and C)
C: Number of components
N: Number of non-compositional variable (temperature and pressure)

Gibbs Phase Rule

$$F = C - P + 2$$

The degree of freedom can be thought of as the difference between what you (can) control and what the system controls

$$F \quad = \quad C+2 \quad - \quad P$$

F	C+2	P
Degree of freedom: how many of variable we can choose independently	What we can control : number of components added and P & T	What the system controls: System decide how many phases to produce at the given conditions

Gibbs Phase Rule

What are the degrees of freedom of a system of two components when the number of phases is one, two, there and so on ?

$C = 2$

No. of Phases	Total variables $P(C-1) + 2$	Degree of Freedom $F = C - P + 2$
1	3	3
2	4	2
3	5	1
4	6	0

System can not have more than four phases in equilibrium

At Pressure 1 atm., the Gibbs rule change as F= C-P+1. In this case, system can not have more than three phases in equilibrium

Phase equilibrium

- Equilibrium: minimum energy state for a given T, P, and composition (i.e. equilibrium state will persist indefinitely for a fixed T, P and composition).
- An equilibrium phase will stay constant over time.
- Phase diagrams tell us about equilibrium phases as a function of T, P and composition (here, we'll always keep P constant for simplicity.

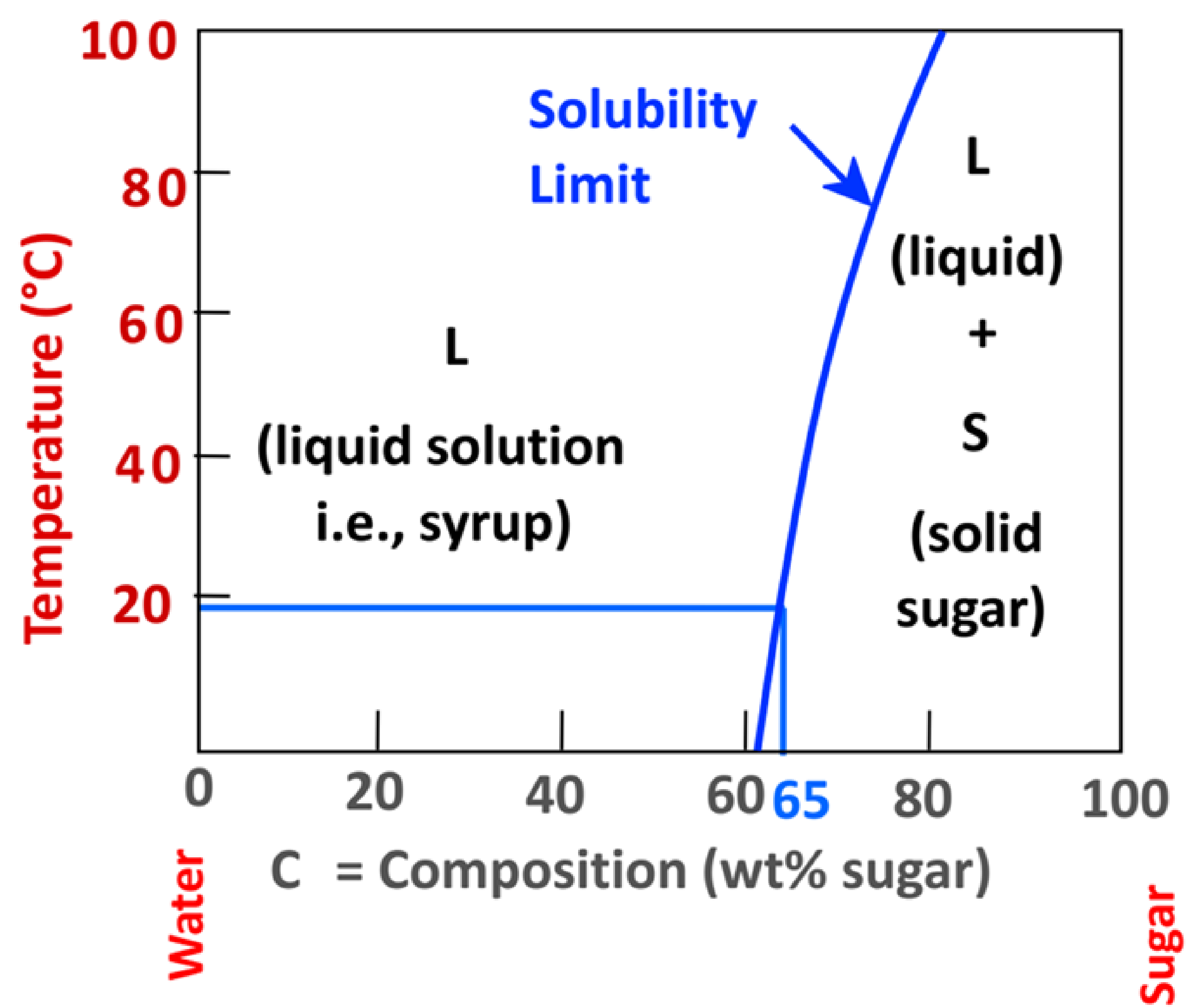
Phase Equilibria: Solubility Limit

- Solution: Solid, liquid, or gas solutions, single phase
- Mixture: more than one phase
- Solubility Limit: Maximum concentration for which only a single phase solution exists.

Question: What is the solubility limit for sugar in water at 20°C?

Answer: 65 wt% sugar.
At 20°C, if C < 65 wt% sugar: syrup
At 20°C, if C > 65 wt% sugar: syrup + sugar

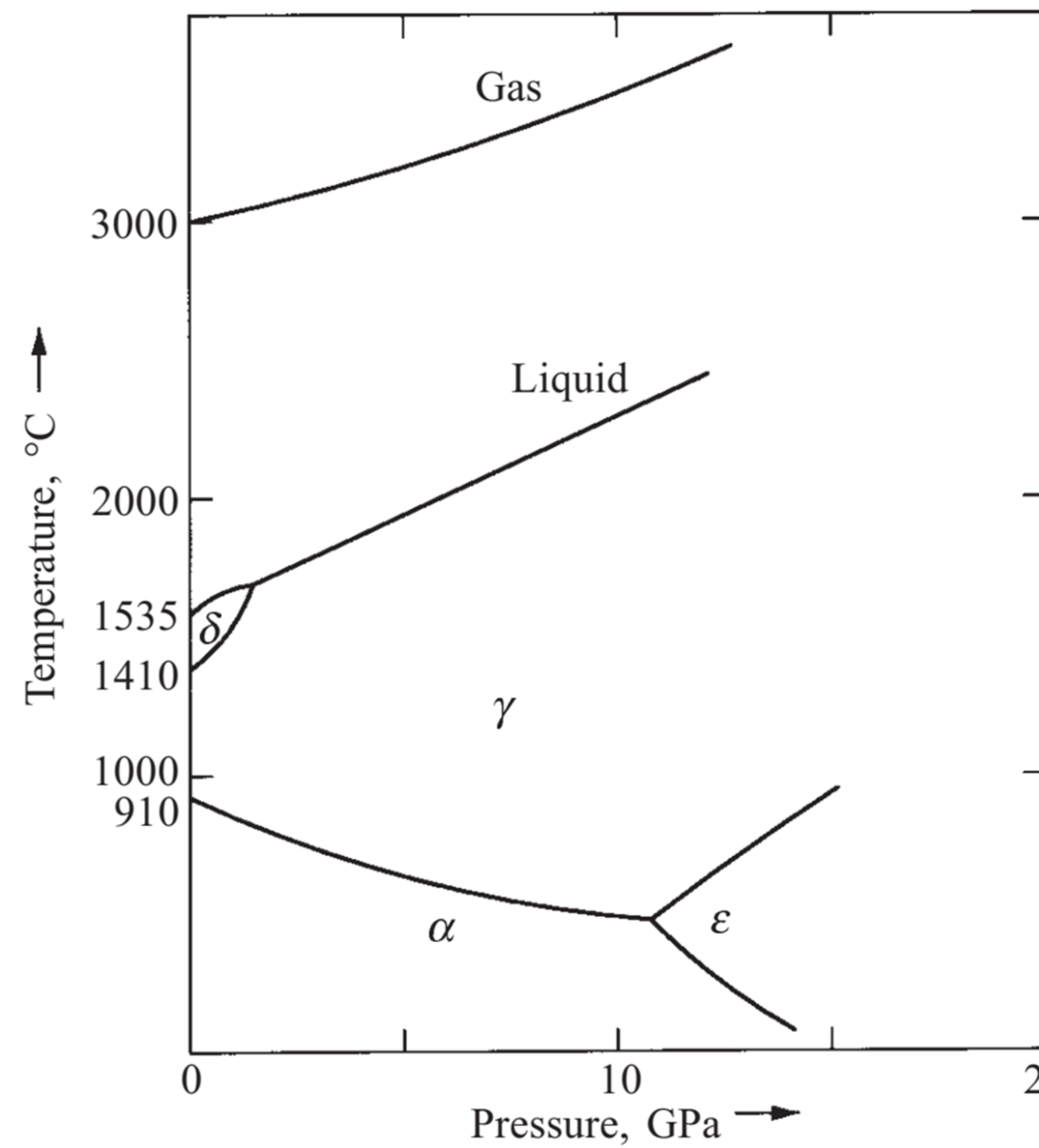
Sugar/Water Phase Diagram



Unary Phase Diagram

There is no composition variable and the only other variables are temperature and pressure.

- C = 1 and P = 1 F = 2, both temperature and pressure can be varied independently within the limits prescribed by the boundaries of the region.
- C = 1 and P = 2, F = 1, either temperature or pressure can be varied independently, but not both. Two-phase equilibrium exists along the phase boundaries.
- C = 1 and P = 3, F = 0, triple points (three phase boundaries meet) neither pressure nor temperature can be varied arbitrarily.
- Three phases will co-exist at only one particular combination of pressure and temperature.



Pressure-temperature phase diagram of pure iron.

Summary

1. Phase diagram is the relationship of different phases of a material in equilibrium with the variables.
2. Solid can have more than one phases based on crystal structure.
3. In liquid and gases, the phases can be identified based on miscibility.
4. Gas always has a single phase.
5. Unary phase diagram has only one component.