Phase Equilibrium Diagrams:-

Phase equilibrium diagram is a graphic relationship between temperature and weight ratios of elements and alloys contribute to the built of the diagram.

Where *Phase* is a uniform part of an alloy, having a certain chemical composition and structure, and which is separated from other alloy constituents by a phase boundary.

For example the salt – water solution have a four possible phases:
- Water vapor (steam)
- Liquid salt solution (sodium chloride in water)
- Crystals of water (ice)
- Crystals of salt (sodium chloride)

**Alloying systems :**

*Alloy* is a metal composing of a mixture of elements. Most of alloys are composed of a base metal with small amounts of additives or alloying elements.

The typical examples of alloys are steel/cast iron (iron base alloys), bronze/brass (copper base alloys), aluminum alloys, nickel base alloys, magnesium base alloys, titanium alloys.

There are many types of alloying systems which they are:

1- Binary system
   It means that alloying have two metals only.

2- Ternary system
   It means that alloying have three metals only.

3- Multi system
   It means that alloying have three and more than that metals.
In general, binary alloys can be classified into the following types.

1- *Simple eutectic type*
   The two components are soluble in each other in the liquid state but are completely insoluble in each other in the solid state.

2- *Solid solution type*
   The two components are completely soluble in each other both in the liquid state and in the solid state.

3- *Combination type*
   The two components are completely soluble in the liquid state, but are only partially soluble in each other in the solid state.

Thus this type of alloy combines some of the characteristics of both the previous types, hence the name ‘combination type’ phase equilibrium diagram.

Let's now consider these three types of binary alloy systems and their phase equilibrium diagrams in greater detail.

1) *Phase equilibrium diagrams (Eutectic type):*
   In general case, consider for studying a two components presents which are referred to as metal A and metal B, with the phase diagram as shown in figure 1.
Figure 1. Phase equilibrium diagram (eutectic type).

This type of equilibrium diagram gets its name from the fact that at one particular composition (E), the temperature at which solidification commences is a minimum for the alloying elements present. With this composition the liquidus and the solidus coincide at the same temperature, thus the liquid changes into a solid with both A crystals and B crystals forming instantaneously at the same temperature. This point on the diagram is called the eutectic, the temperature at which it occurs is the eutectic temperature, and the composition is the eutectic composition.

In practice, few metal alloys from simple eutectic type phase diagrams. It is identical with this type of phase diagram is produced for a salt (sodium chloride) and water solution, it is total solubility of the salt in water in the liquid state and total insolubility (crystals of ice and separate crystals of salt) in the solid state. As an example of eutectic are carbon steels.
2) *Phase equilibrium diagrams (Solid solution type):*

*Solid solution* is a phase, where two or more elements are completely soluble in each other. Depending on the ratio of the solvent (matrix) metal atom size and solute element atom size, two types of solid solutions may be formed: substitution or interstitial.

- **Substitution solid solution**
  
  If the atoms of the solvent metal and solute element are of similar sizes (not more, than 15% difference), they form *substitution solid solution*, where part of the solvent atoms are substituted by atoms of the alloying element as shown in figure 2. For example, copper and nickel.

![Substitution solid solution](image)

Figure 2. Substitution solid solution.

Some substitution solid solutions may form ordered phase where ratio between concentration of matrix atoms and concentration of alloying atoms is close to simple numbers like AuCu₃ and AuCu.
• *Interstitial solid solution*

If the atoms of the alloying elements are considerably smaller, than the atoms of the matrix metal, *interstitial solid solution* forms, where the matrix solute atoms are located in the spaces between large solvent atoms as shown in figure 3.

![Interstitial solid solution](image_url)

**Figure 3.** Interstitial solid solution.

These compounds (WC, Fe₃C etc.) play important role in strengthening steels and other alloys.

**Solid solution formation usually causes increase of electrical resistance and mechanical strength and decrease of plasticity of the alloy.**

Copper-nickel alloys is shown in figure 4.
3) Phase equilibrium diagrams (Combination type):

Many metals and non-metals are neither completely soluble in each other in the solid state nor are they completely insoluble. Therefore they form a phase equilibrium diagram of the type shown in figure 5.

In this system there are two solid solutions labelled $\alpha$ and $\beta$. The use of the Greek letters $\alpha$, $\beta$, $\gamma$, etc., in phase equilibrium diagrams may be defined, in general, as follows:

1- A solid solution of one component A in an excess of another component B, such that A is the solute and B is the solvent, is referred to as solid solution $\alpha$. 

Figure 4. Copper-nickel phase equilibrium diagram.
2- A solid solution of the component B in an excess of the component A, so that B now becomes the solute and A becomes the solvent, is referred to as solid solution $\beta$.

3- In a more complex alloy, any further solid solutions or intermetallic compounds which may be formed would be referred to by the subsequent letters of the Greek alphabet. That is, $\gamma$, $\beta$, etc.

Figure 5. Combination type phase equilibrium diagram.