UNIT- I

PHASE DIAGRAMS 9

Solid solutions - Hume Rothery's rules – the phase rule - single component system - one-component system of iron - binary phase diagrams - isomorphous systems - the tie-line rule - the lever rule - application to isomorphous system - eutectic phase diagram - peritectic phase diagram - other invariant reactions – free energy composition curves for binary systems - microstructural change during cooling.

Learning Objectives

- Learn solid solutions based on Hume Rothery's rules.
- Discuss the phase rule for unary and binary phase diagrams.
- Explain binary isomorphous systems based on tie-line rule and the lever rule
- Compare eutectic phase diagram and peritectic phase diagram
- Analyze the importance of invariant reactions.
- Describe the free energy composition curves for binary systems.
- Learn the microstructural change during cooling.

Introduction

A solution (liquid or solid) is phase with more than one component; a mixture is a material with more than one phase. Solute does not change the structural pattern of the solvent, and the composition of any solution can be varied. In mixtures, there are different phases, each with its own atomic arrangement. It is possible to have a mixture of two different solutions! A pure substance, under equilibrium conditions, may exist as either of a phase namely vapor, liquid or solid, depending upon the conditions of temperature and pressure.

Basic terms used in phase diagrams

System

- ❖ A portion of the universe that has been isolated so that its properties can be studied. System may also refer to a specific body of material under consideration.

Components

- ❖ Macroscopic basic unit of a material is called component. It refers to an independent chemical species. The components of a system may be elements, ions or compounds. Component is either pure metal and/or compounds of which an alloy is composed. A component can exist in many phases.
- ❖ In **brass** the main components are Cu and Zn. In **carbon steel** the main components are Fe and C. A **binary alloy** contains two components. A **ternary alloy** contains three; a **quaternary alloy**, four, etc.
- ✓ E.g.: Water exists as ice, liquid water, and water vapor.
  Carbon exists as graphite and diamond.

Composition

- ➢ Alloys are defined by their composition – i.e. the concentrations of the components in weight % (wt.%) or atom % (at%).

Mixtures

- ❖ Processing of metallic alloys (which are mixtures of elements) leads to microstructures in which the component elements are distributed in a number of ways. In the liquid state for metals, more or less everything dissolves completely, therefore forming a single phase. But in the solid state, things are more complex – for example, in a binary alloy (i.e. a mixture of two components) the solid microstructure usually takes one of three forms:

- A single solid solution (one phase);
- Two separated solid solutions (two phases);
- A chemical compound (phase 1), with a separated solid solution (phase 2).

Alloys

- ❖ A metallic alloy is a mixture of a metal with other metals or non-metals.
- ❖ The element which is present in the largest portion is called the base metal, and other elements present are called alloying elements.
- ✓ For example: ***Brass*****:** a mixture of Copper (Cu) and Zinc (Zn).

Carbon steel**:** based on Iron (Fe) and Carbon (C).

Spinel**:** a ceramic alloy made of Magnesia (MgO) and Alumina (Al_2O_3).

Equilibrium:

- ➢ A system is at equilibrium if its free energy is at a minimum. Characteristics of the system do not change with time, i.e., the system is stable. If you change the temperature, pressure, or composition, the free energy will change.

Phase

- Physically distinct, chemically homogenous and mechanically separable region of a system.

Phase diagram

- ❖ A phase diagrams is a type of graph used to show the equilibrium conditions between the thermodynamically-distinct phases; or to show what phases are present in the material system at various temperature, pressure and compositions.

Phase transformation

Phase Transformation is the change of one phase into another.

- ➢ E.g.: Water →Ice

Classification of Phase diagrams

- ✓ Phase diagrams are classified based on the number of components in the system.
  - ✓ Single component systems have unary diagrams
  - ✓ Two-component systems have binary diagrams
  - ✓ Three-component systems are represented by ternary diagrams, and so on

Phase diagram –Useful information

- ✓ It is actually a collection of solubility limit curves. It is also known as equilibrium or constitutional diagram.
- ✓ It shows phases present at different compositions and temperatures under slow cooling (equilibrium) conditions.
- ✓ It indicates equilibrium solid solubility of one element/compound in another.
- ✓ It suggests temperature at which an alloy starts to solidify and the range of solidification.
- ✓ It signals the temperature at which different phases start to melt.
- ✓ Amount of each phase in a two-phase mixture can be obtained.
- ✓ Useful terminology related to phase diagrams are liquidus, solidus, solvus, terminal solid solution, invariant reaction, intermediate solid solution, inter-metallic compound, etc.