Binary Phase Diagrams

Another type of extremely common phase diagram is one in which temperature and composition is variable parameters, and pressure is held constant-normally 1 atm. There are several different varieties; in the present discussion, we will concern ourselves with binary alloys those that contain two components. If more than two components are present, phase diagrams become extremely complicated and difficult to represent. An explanation of the principles governing and the interpretation of phase diagrams can be demonstrated using binary alloys even though most alloys contain more than two components.

Binary phase diagrams are maps that represent the relationships between temperature and the compositions and quantities of phases at equilibrium, which influence the microstructure of an alloy. Many microstructures develop from phase transformations, the changes that occur when the temperature is altered (ordinarily upon cooling).This may involve the transition from one phase to another, or the appearance or disappearance of a phase. Binary phase diagrams are helpful in predicting phase transformations and the resulting microstructures, which may have equilibrium or nonequilibrium character.

1. Binary Isomorphous Systems

Possibly the easiest type of binary phase diagram to understand and interpret is the type that is characterized by the copper–nickel system (Figure 4). Temperature is plotted along the ordinate, and the abscissa represents the composition of the alloy, in weight percent (bottom) and atom percent (top) of nickel.

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The composition ranges from 0 wt% Ni (100 wt% Cu) on the left horizontal extremity to 100 wt% Ni (0 wt% Cu) on the right. Three different phase regions, or fields, appear on the diagram, an alpha (α) field, a liquid (L) field, and a two-phase α + L field. Each region is defined by the phase or phases that exist over the range of temperatures and compositions delineated by the phase boundary lines.
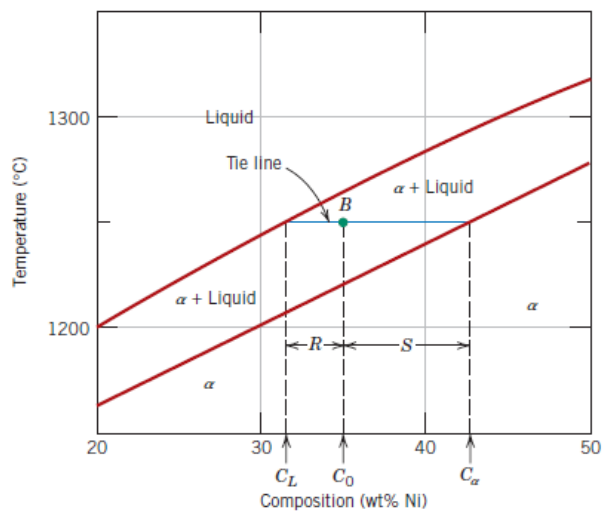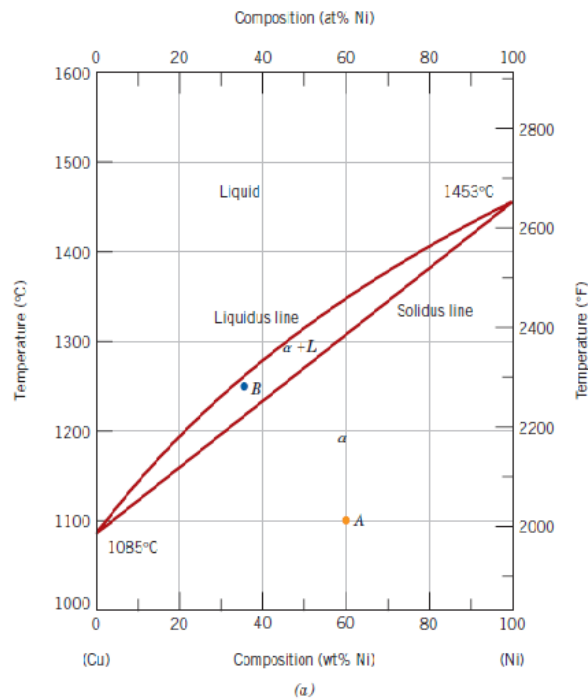

Figure 4: (*a*) The copper–nickel phase diagram. (*b*) A portion of the copper–nickel phase diagram for which compositions and phase amounts are determined at point *B*.

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The liquid *L* is a homogeneous liquid solution composed of both copper and nickel. The α phase is a substitutional solid solution consisting of both Cu and Ni atoms, and having an FCC crystal structure. At temperatures below about 1080 ºC, copper and nickel are mutually soluble in each other in the solid state for all compositions.

This complete solubility is explained by the fact that both Cu and Ni have the same crystal structure (FCC), nearly identical atomic radii and electronegativities, and similar valences. The copper–nickel system is termed *isomorphous* because of this complete liquid and solid solubility of the two components. A couple of comments are in order regarding nomenclature. First, for metallic alloys, solid solutions are commonly designated by lowercase Greek letters (α,β, γ etc.). Furthermore, with regard to phase boundaries, the line separating the *L* and $\alpha + L$ phase fields is termed the *liquidus line,* as indicated in Figure 4*a*; the liquid phase is present at all temperatures and compositions above this line. The *solidus line* is located between the α and $\alpha + L$ regions, below which only the solid α phase exists.

For Figure 4*a*, the solidus and liquidus lines intersect at the two composition extremities; these correspond to the melting temperatures of the pure components. For example, the melting temperatures of pure copper and nickel are 1085ºC and 1453ºC, respectively. Heating pure copper corresponds to moving vertically up the left-hand temperature axis. Copper remains solid until its melting temperature is reached. The solid-to-liquid transformation takes place at the melting temperature, and no further heating is possible until this transformation has been completed. For any composition other than pure components, this melting phenomenon will occur over the range of temperatures between the

solidus and liquidus lines; both solid α and liquid phases will be in equilibrium within this temperature range. For example, upon heating an alloy of composition 50 wt% Ni- 50 wt% Cu (Figure 4*a*), melting begins at approximately 1280ºC (2340ºF); the amount of liquid phase continuously increases with temperature until about 1320ºC (2410ºF), at which the alloy is completely liquid.