10-6 What is a copolymer? What is the advantage to forming copolymers?

10-7 What is the ABS copolymer? State some of the applications of this material.

Section 10-3 Conditions for Unlimited Solid Solubility

10-8 Briefly state the Hume-Rothery rules and explain the rationale.

10-9 Based on Hume-Rothery's conditions, which of the following systems would be expected to display unlimited solid solubility? Explain. **(a)** Au-Ag; **(b)** Al-Cu; **(c)** Al-Au; **(d)** U-W; **(e)** Mo-Ta; **(f)** Nb-W; **(g)** Mg-Zn; and **(h)** Mg-Cd.

Section 10-4 Solid-Solution Strengthening

10-10 Suppose 1 at% of the following elements is added to copper (forming a separate alloy with each element) without exceeding the solubility limit. Which one would be expected to give the higher strength alloy? Are any of the alloying elements expected to have unlimited solid solubility in copper? **(a)** Au; **(b)** Mn; **(c)** Sr; **(d)** Si; and **(e)** Co.

10-11 Suppose 1 at% of the following elements is added to aluminum (forming a separate alloy with each element) without exceeding the solubility limit. Which one would be expected to give the least reduction in electrical conductivity? Are any of the alloy elements expected to have unlimited solid solubility in aluminum? **(a)** Li; **(b)** Ba; **(c)** Be; **(d)** Cd; and **(e)** Ga.

10-12 Which of the following oxides is expected to have the largest solid solubility in Al_2O_3? **(a)** Y_2O_3; **(b)** Cr_2O_3; and **(c)** Fe_2O_3.

10-13 What is the role of small concentrations of Mg in aluminum alloys used to make beverage cans?

10-14 Why do jewelers add small amounts of copper to gold and silver?

10-15 Why is it not a good idea to use solid solution strengthening as a mechanism to increase the strength of copper for electrical applications?

Section 10-5 Isomorphous Phase Diagrams

10-16 Determine the liquidus temperature, solidus temperature, and freezing range for the following MgO-FeO ceramic compositions. (See Figure 10-17.)

(a) MgO-25 wt% FeO; **(b)** MgO-45 wt% FeO; **(c)** MgO-65 wt% FeO; **(d)** MgO-80 wt% FeO.

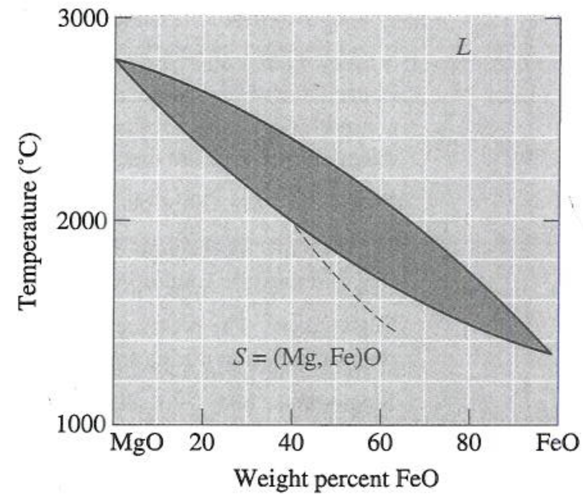

Figure 10-17 The equilibrium phase diagram for the MgO-FeO system (for Problems 10-16, 10-17, 10-24, 10-25, 10-32 and 10-36). The dashed curve represents the solidus for non-equilibrium cooling.

10-17 **(a)** Determine the phases present, the compositions of each phase, and the amount of each phase in wt% for the following MgO-FeO ceramics at 2000°C. (See Figure 10-17.) **(i)** MgO-25 wt% FeO; **(ii)** MgO-45 wt% FeO; **(iii)** MgO-60 wt% FeO; and **(iv)** MgO-80 wt% FeO. **(b)** Consider an alloy of 65 wt% Cu and 35 wt% Al. Calculate the composition of the alloy in at%.

10-18 Consider a ceramic composed of 30 mol% MgO and 70 mol% FeO. Calculate the composition of the ceramic in wt%.

10-19 A Nb-60 wt% W alloy is heated to 2800°C. Determine **(a)** the composition of the solid and liquid phases in both wt% and at%; **(b)** the amount of each phase in both wt% and at%; and **(c)** assuming that the density of the solid is 16.05 g/cm^3 and that of the liquid is 13.91 g/cm^3, determine the amount of each phase in vol%. (See Figure 10-18.)

10-20 How many grams of nickel must be added to 500 grams of copper to produce an alloy that has a liquidus temperature of 1350°C? What is the ratio of the number of nickel atoms to copper atoms in this alloy?

10-21 How many grams of nickel must be added to 500 grams of copper to produce an alloy that contains 50 wt% α at 1300°C?

10-22 How many grams of MgO must be added to 1 kg of NiO to produce a ceramic that has a solidus temperature of 2200°C?

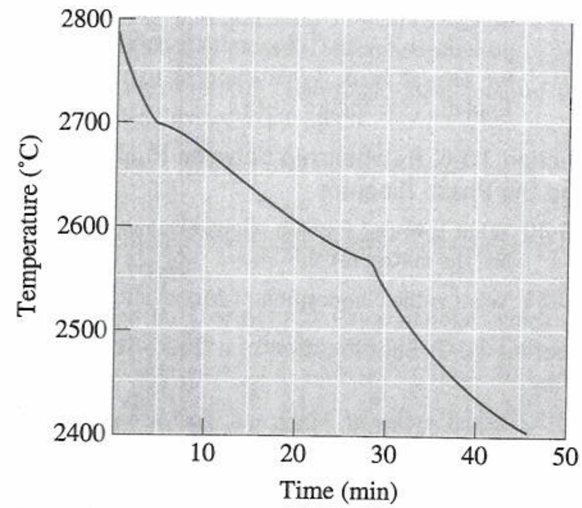

Figure 10-19 Cooling curve for a NiO-MgO ceramic (for Problem 10-37).

10-38 For equilibrium conditions and a Nb-80 wt% W alloy, determine **(a)** the liquidus temperature; **(b)** the solidus temperature; **(c)** the freezing range; **(d)** the composition of the first solid to form during solidification; **(e)** the composition of the last liquid to solidify; **(f)** the phase(s) present, the composition of the phase(s), and the amount of the phase(s) at 3000°C; and **(g)** the phases(s) present, the composition of the phase(s), and the amount of the phase(s) at 2800°C. (See Figure 10-18.)

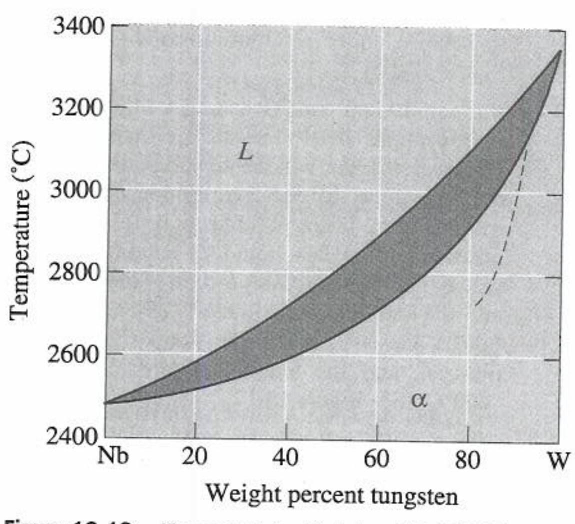

Figure 10-18 (Repeated for Problem 10-38). The equilibrium phase diagram for the Nb-W system. The dashed curve represents the solidus for non-equilibrium cooling.

10-39 Figure 10-20 shows the cooling curve for a Nb-W alloy. Determine **(a)** the liquidus temperature; **(b)** the solidus temperature; **(c)** the freezing range; **(d)** the pouring temperature; **(e)** the superheat; **(f)** the local solidification time; **(g)** the total solidification time; and **(h)** the composition of the alloy.

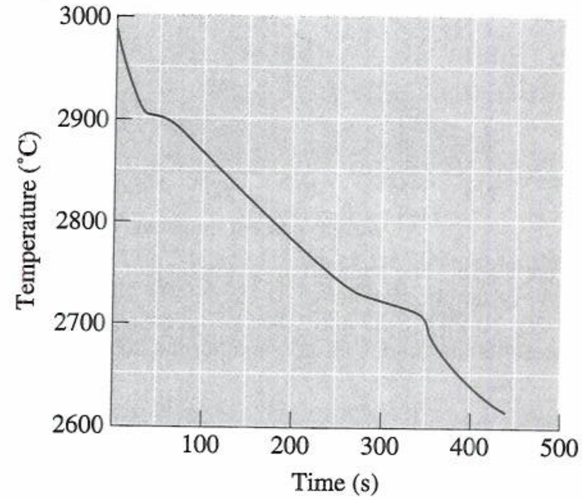

Figure 10-20 Cooling curve for a Nb-W alloy (for Problem 10-39).

10-40 Cooling curves are shown in Figure 10-21 for several Mo-V alloys. Based on these curves, construct the Mo-V phase diagram.

10-41 What are the origins of chemical segregation in cast products?

10-42 How can microsegregation be removed?

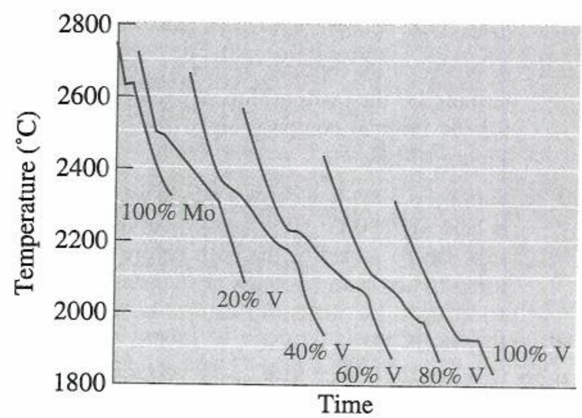

Figure 10-21 Cooling curves for a series of Mo-V alloys (for Problem 10-40).

Precipitation hardening A strengthening mechanism that relies on a sequence of solid-state phase transformations in generating a dispersion of ultrafine precipitates of a second phase (Chapter 12). This is the same as age hardening. It is a form of dispersion strengthening.

Primary microconstituent The microconstituent that forms before the start of a three-phase reaction.

Solvus A solubility curve that separates a single-solid phase region from a two-solid phase region in the phase diagram.

Stoichiometric intermetallic compound A phase formed by the combination of two components into a compound having a structure and properties different from either component. The stoichiometric intermetallic compound has a fixed ratio of the components present in the compound.

PROBLEMS

Section 11-1 Principles and Examples of Dispersion Strengthening

11-1 What are the requirements of a matrix and precipitate for dispersion strengthening to be effective?

Section 11-2 Intermetallic Compounds

11-2 What is an intermetallic compound? How is it different from other compounds? For example, other than the obvious difference in composition how is TiAl different from, for example, Al_2O_3?

11-3 Explain clearly the two different ways in which intermetallic compounds can be used.

11-4 What are some of the major problems in the utilization of intermetallics for high-temperature applications?

Section 11-3 Phase Diagrams Containing Three-Phase Reactions

11-5 Define the terms eutectic, eutectoid, peritectic, peritectoid, and monotectic reactions.

11-6 What is an invariant reaction? Show that for a two-component system the number of degrees of freedom for an invariant reaction is zero.

11-7 A hypothetical phase diagram is shown in Figure 11-25.

(a) Are there any intermetallic compounds present? If so, identify them and determine whether they are stoichiometric or non-stoichiometric.

(b) Identify the solid solutions present in the system. Is either material *A* or *B* allotropic? Explain.

(c) Identify the three-phase reactions by writing down the temperature, the reaction in equation form, the composition of each phase in the reaction, and the name of the reaction.

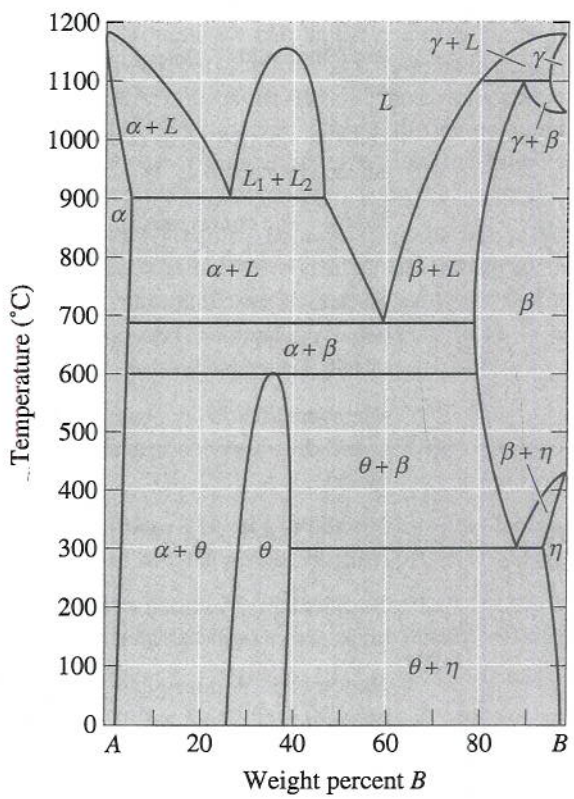

Figure 11-25 Hypothetical phase diagram (for Problem 11-7).

11-8 The Cu-Zn phase diagram is shown in Figure 11-26.

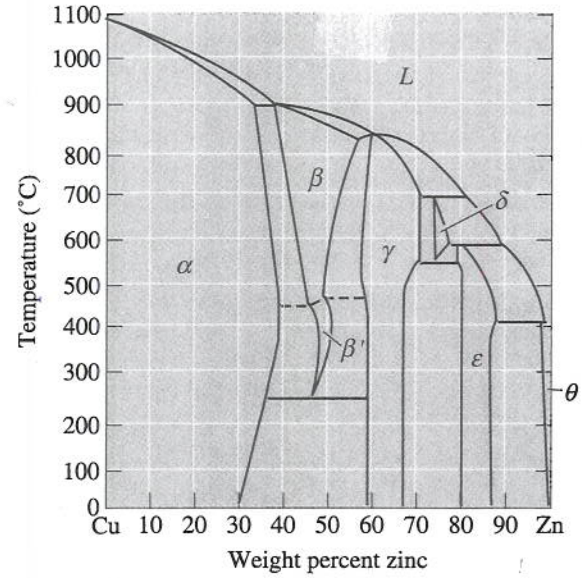

Figure 11-26 Binary phase diagram for the copper-zinc system (for Problem 11-8).

(a) Are any intermetallic compounds present? If so, identify them and determine whether they are stoichiometric or nonstoichiometric.
(b) Identify the solid solutions present in the system.
(c) Identify the three-phase reactions by writing down the temperature, the reaction in equation form, and the name of the reaction.

11-9 The Al-Li phase diagram is shown in Figure 11-27.

(a) Are any intermetallic compounds present? If so, identify them and determine whether they are stoichiometric or nonstoichiometric. Determine the formula for each compound.
(b) Identify the three-phase reactions by writing down the temperature, the reaction in equation form, the composition of each phase in the reaction, and the name of the reaction.

11-10 An intermetallic compound is found for 38 wt% Sn in the Cu-Sn phase diagram. Determine the formula for the compound.

11-11 An intermetallic compound is found for 10 wt% Si in the Cu-Si phase diagram. Determine the formula for the compound.

Section 11-4 The Eutectic Phase Diagram

11-12 Consider a Pb-15% Sn alloy. During solidification, determine

(a) the composition of the first solid to form,
(b) the liquidus temperature, solidus temperature, solvus temperature, and freezing range of the alloy,
(c) the amounts and compositions of each phase at 260°C,
(d) the amounts and compositions of each phase at 183°C, and
(e) the amounts and compositions of each phase at 25°C.

11-13 Consider an Al-12% Mg alloy (Figure 11-28). During solidification, determine

(a) the composition of the first solid to form,
(b) the liquidus temperature, solidus temperature, solvus temperature, and freezing range of the alloy,
(c) the amounts and compositions of each phase at 525°C,
(d) the amounts and compositions of each phase at 450°C, and
(e) the amounts and compositions of each phase at 25°C.

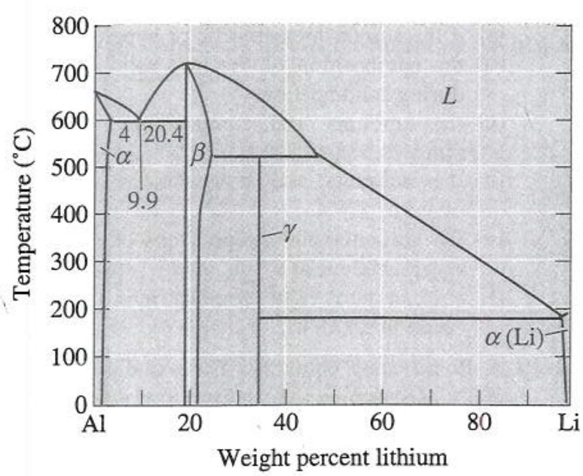

Figure 11-27 The aluminum-lithium phase diagram (for Problem 11-9).

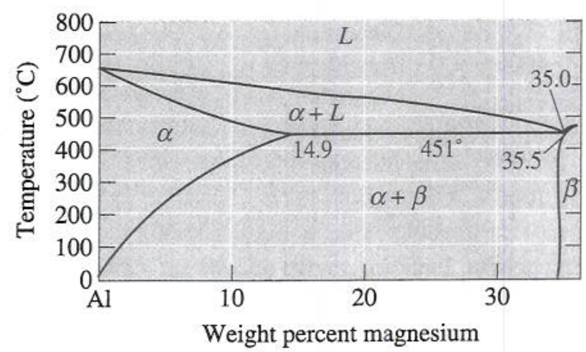

Figure 11-28 Portion of the aluminum-magnesium phase diagram (for Problems 11-13).