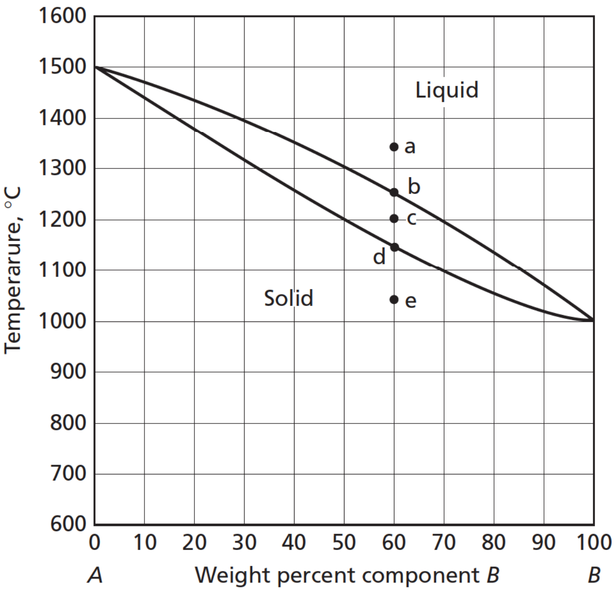
this, consider an alloy with overall composition of 30 wt. % *A*, 15 wt. % *B*, and 55 wt. % *C*, as shown by point *z* in Fig. 11.25. Let's assume that the alloy contains two phases α and β with compositions given by points *m* and *n*, respectively. The fraction of the α phase in the alloy is equal to the length of line *zn* divided by the length of line *mn*. The fraction of the β phase would be *zm*/*mn*. A similar procedure can be used to determine the phase fractions in alloys containing three phases. For this case, a triangle is first formed between the compositions of the three phases. In order to satisfy mass balance for the components, the triangle will surround the overall alloy composition. An example is shown in Fig. 11.25 for an alloy composition given by point *Y*, which is considered to contain three phases given by points *p*, *q*, and *r*. The line drawn from a corner through *y* to point *s* can then be used to calculate the fractions.

The above-mentioned ternary diagram is a relatively simple one since it only deals with three solid phases. The diagrams can become quite complicated if the binaries include intermediate phases or other solid-state reactions. Examples of these systems can be found in phase diagram handbooks or other similar sources.

For alloys which contain four or more components, the phase relations cannot be described by a single diagram since more than a three-dimensional space would be required. These alloys are generally described by multiple quasi-binary diagrams in which the concentration of one component is changed at a time.

PROBLEMS

11.1



The points *a*, *b*, *c*, *d*, and *e* on the 60 percent component *B* line give some temperatures through which a slowly cooled alloy containing 60 percent *B* will pass on freezing from a liquid to a solid. Identify the phase or phases and the amount of each that should exist in the microstructure at each indicated point.

11.2 A gold-nickel alloy containing 60 percent nickel is heated to 1100°C and allowed to come to equilibrium. Determine the amount and composition of the liquid and solid phases when equilibrium is attained.

11.3 (a) A copper-75 percent silver alloy is slowly cooled from the liquid state to 900°C and allowed to come to equilibrium. Estimate the amount and composition of both the liquid and solid phases.

(b) Make a sketch of the 900°C equilibrium structure of the alloy.

(c) Now assume the alloy is slowly cooled to just below the eutectic temperature. What are the weight percentages and compositions of the phases and constituents at this point?

11.4 (a) Sterling silver is an alloy of silver with 7.5 percent copper. Describe the structure that one should expect if a specimen of sterling silver were to be heated from room temperature to 782°C and allowed to come to equilibrium at this latter temperature.

(b) If the specimen of sterling silver equilibriated at 782 °C is now cooled very slowly to 400°C, what would be the nature of the microstructure? Give the amount and composition of each phase.

(c) Finally assume the specimen is cooled very rapidly (quenched) from 782°C to 400°C. Describe the structure that one might expect.

11.5 The alloy that formerly was used in U.S. silver coins contained 10 percent copper.

(a) If one were to heat one of these coins to 782°C, what would be the expected effect on the microstructure?

(b) Would one successfully be able to mechanically work the metal in the coin at 782°C? Explain.

11.6 Consider the iron-nickel peritectic transformation in Fig. 11.18.

(a) What are the compositions and weight percentages of the phases just above the peritectic temperature (1512°C)?

(b) Answer this same question with regard to a temperature just below the peritectic temperature.

11.7 Given that the rate of diffusion of nickel in iron is very much greater in the liquid state than in the solid state, what effect should this have on the ease of obtaining an equilibrium microstructure (i.e., one that is homogeneous) when an alloy containing the peritectic composition 4.5 percent nickel is cooled through the peritectic temperature?

11.8 Answer the following questions with regard to an alloy of copper with 64 percent lead that is slowly cooled in a crucible without being stirred from 1100°C to room temperature.

(a) What is the nature of the alloy at 1100°C?

(b) Now consider the alloy at a temperature just above the monotectic temperature at 955°C where it is composed of two liquids of different compositions. Do the liquids have the same density? If not, what would you expect to happen?

(c) One of these liquids has the composition of the monotectic point. What should happen to this liquid as it passes through the monotectic temperature of 955°C? Describe the physical nature of the contents of the crucible after the alloy is cooled below 955°C and until it reaches the eutectic temperature at 326°C.

11.9 (a) What phases are in equilibrium at the peritectic temperature of the iron-nickel alloy system?

(b) What relationship exists between the partial-molal free energies of these phases at this temperature?

(c) Sketch the relationship that must exist between the free energy versus composition curves of these phases at 1512°C.

11.10 Make two additional sketches for the free-energy-composition curves of the iron-nickel system corresponding to a temperature about 25°C above and 25°C below 1512°C.

11.11 Label all regions of the Cu-Zn diagram in Fig. 11.23 and identify transformations that take place at each horizontal line.

11.12 For the three phase alloy *y* shown in Fig. 11.25, Calculate the weight fractions of the constituent phases. The alloy composition is given by Point *y*, and those of the constituent phases by *p*, *q*, and *r*.

REFERENCES

1. For example, see “Alloy Phase Diagrams,” *ASM Handbook*, Vol. 3, ASM International, 1992.

2. Averbach, B. L., Flinn, P. A., and Cohen, M., *Acta Met.*, **2** 92 (1954).