Chapter 10-A

Binary Phase Diagrams

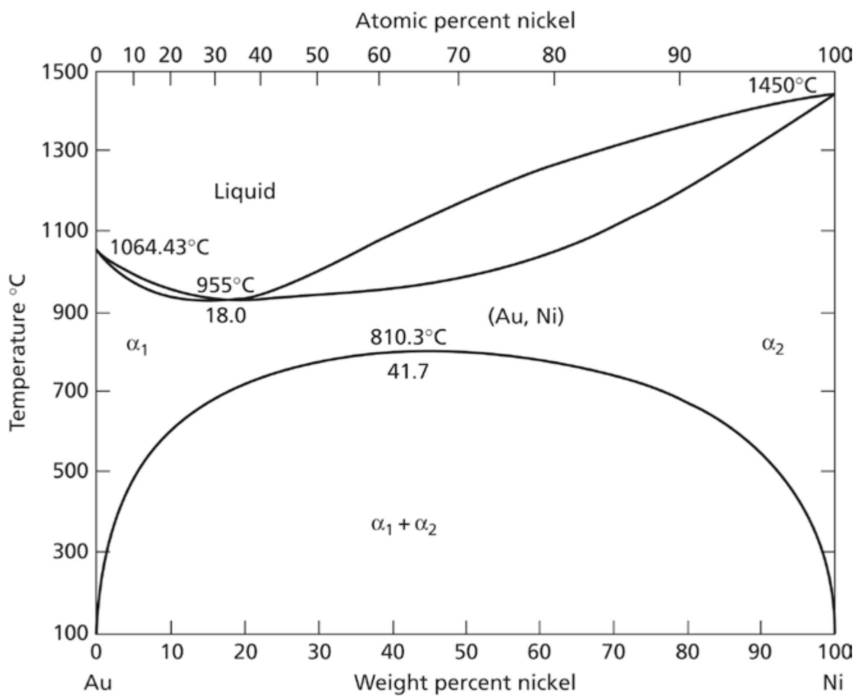


FIG. 11.7 Gold-nickel phase diagram. (From *Binary Alloy Phase Diagrams*, Massalski, T.B., Editor-in-Chief, ASM International, 1986, p. 289. Reprinted with permission of ASM International(R). All rights reserved. www.asminternational.org)

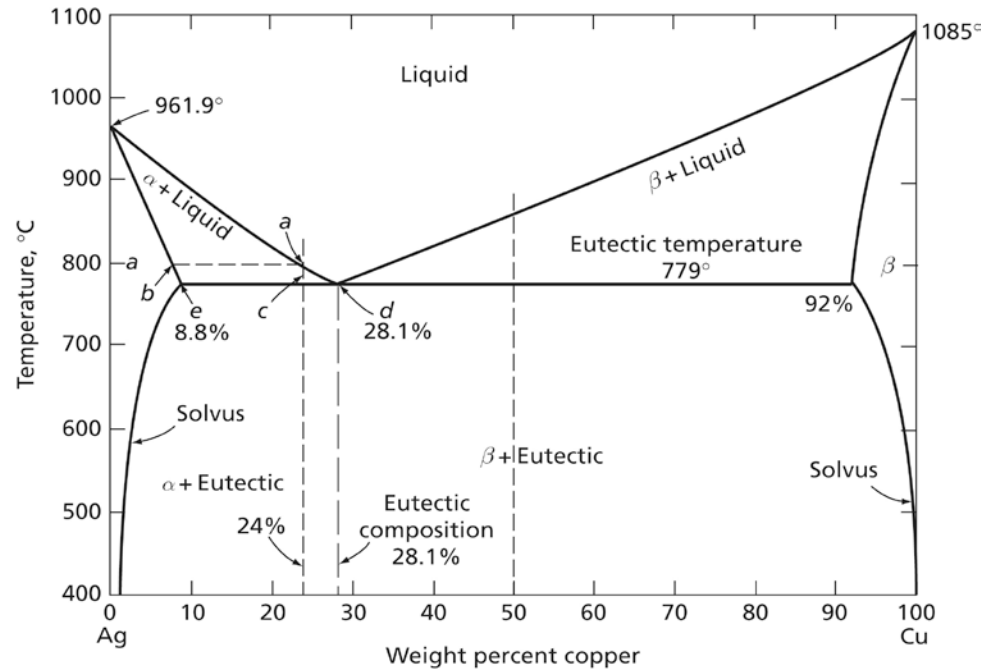


FIG. 11.13 Copper-silver phase diagram. (From *Constitution of Binary Alloys*, by Hansen, M., and Anderko, K. Copyright, 1958. McGraw-Hill Book Co., Inc., New York, p. 18. Used by permission.)

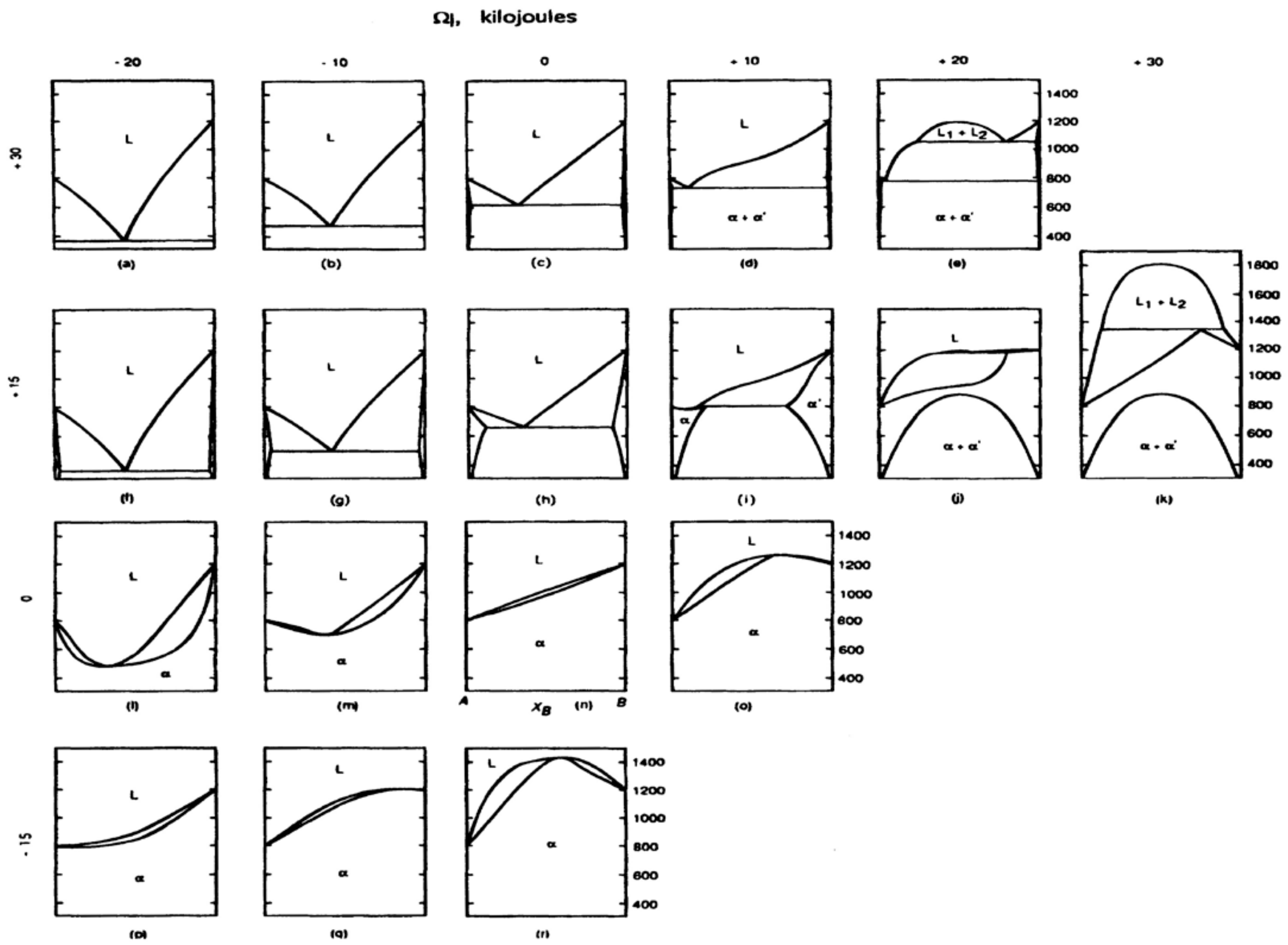


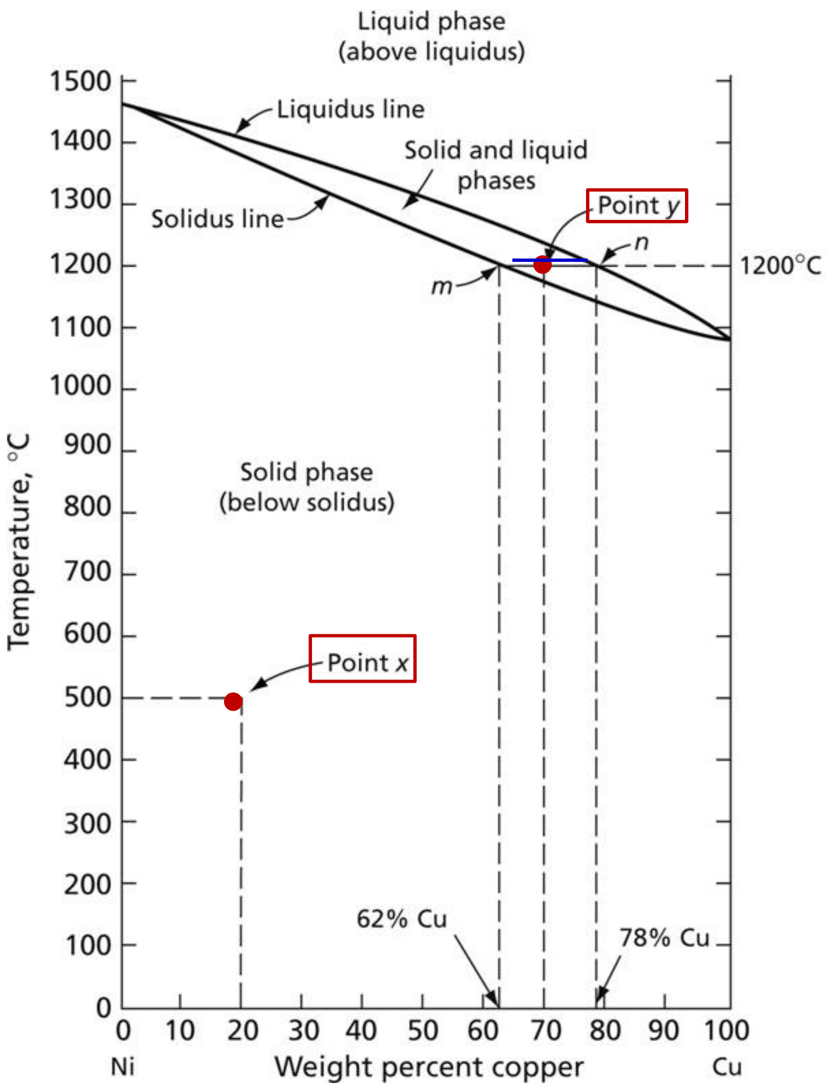
Figure 10.23 Topological changes in the phase diagram for a system *A*–*B* with regular solid and liquid solutions, brought about by systematic changes in the values of Ω_s and Ω_l. The melting temperatures of *A* and *B* are, respectively, 800 and 1200 K, and the molar entropies of melting of both components are 10 J/K. (From A. D. Pelton and W. T. Thompson, *Prog. Solid State Chem.* (1975), vol. 10, part 3, p. 119).

Informations Provided from Binary Phase Diagram

For P= 1 atm, at a specific T and composition:

1. What are the equilibrium phases?
2. What are the compositions of equilibrium phases?
3. What is the relative amount of each phase?

Equilibrium $\Leftrightarrow$ Very Slow Cooling or Heating
Keeping at T for a long time.



Point x : 20% Cu + 80% Ni, at 500 °C

1. equilibrium phase: homogeneous solid solution.
2. composition: 20% Cu
3. Amount: 100%

Point y : 70% Cu + 30%Ni, at 1200 °C

1. Equilibrium phases: liquid + solid
2. Compositions:
   Liquid solution: 78% Cu
   Solid solution: 62% Cu
3. Amount:

$$\text{Liquid: } \frac{my}{mn} = \frac{70-62}{78-62} = 50\%$$

$$\text{Solid: } \frac{yn}{mn} = \frac{78-70}{78-62} = 50\%$$

Lever Rule: calculate the relative amount of each phase when two phases are equilibrium (coexist).

Amount of solid = (zn/mn)

Amount of liquid = (mz/mn)

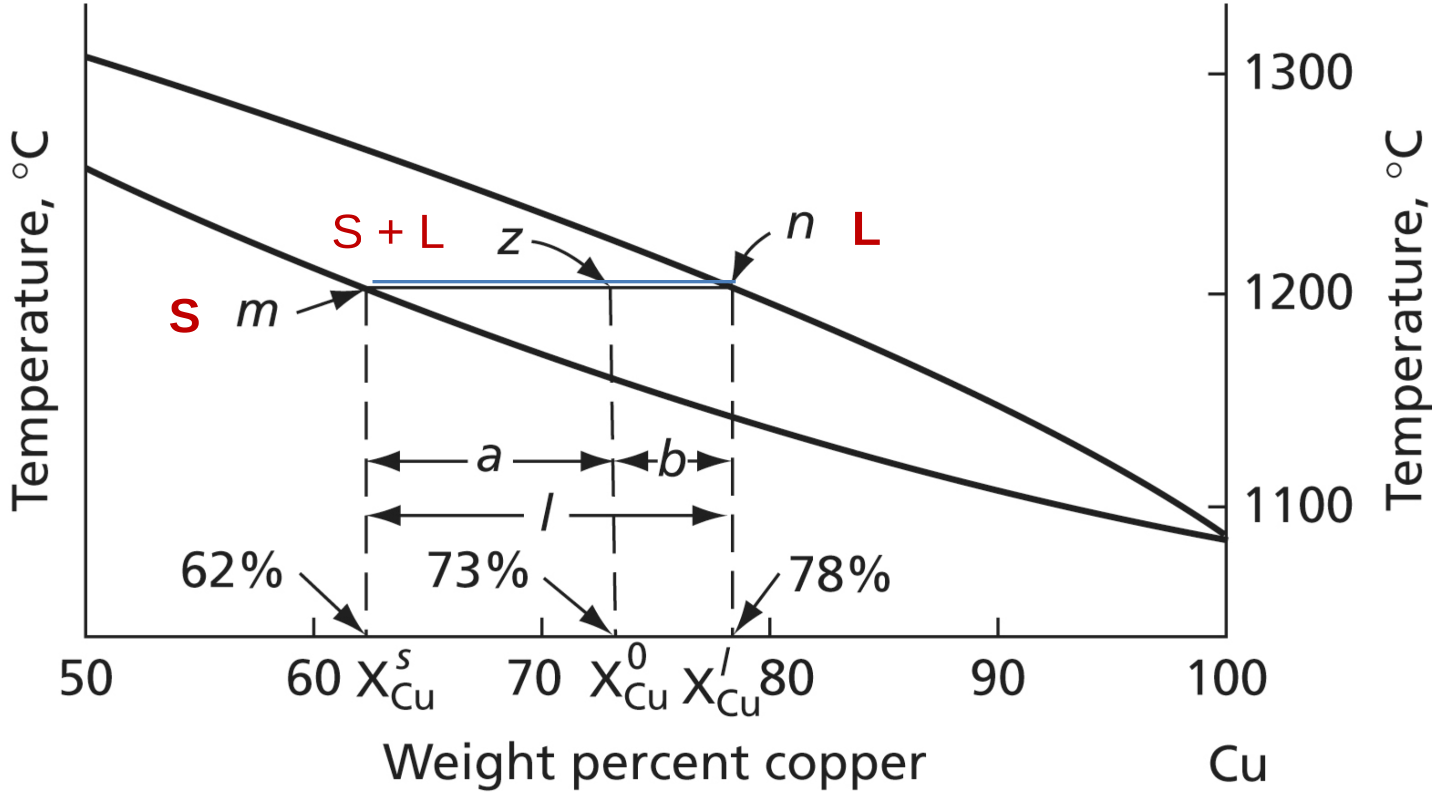
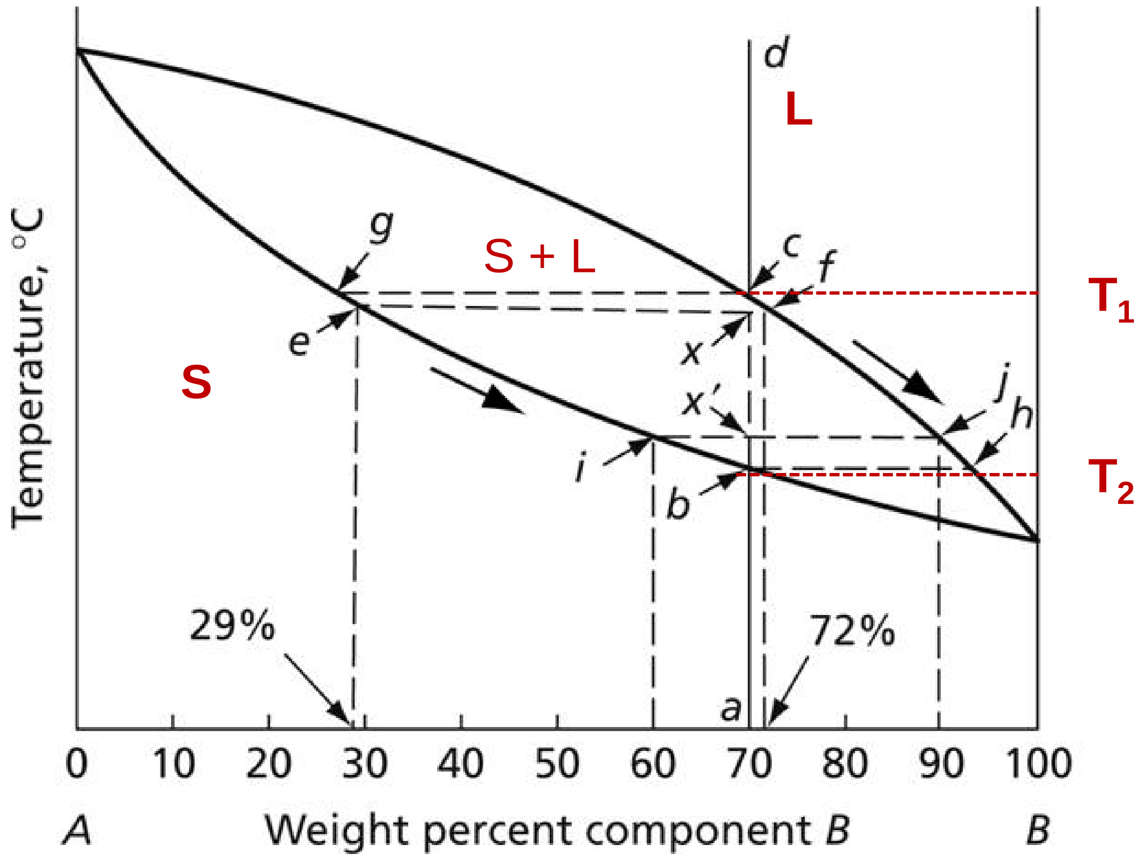


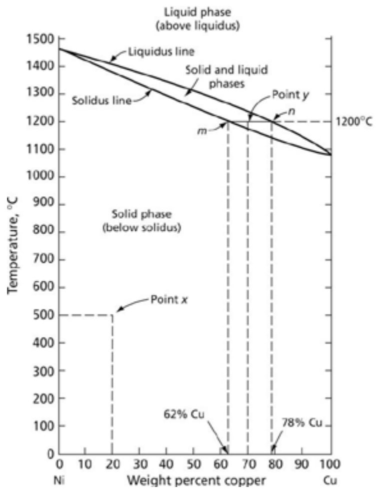
FIG. 11.2 The lever rule

For very slow cooling from T_1 to T_2

composition of liquid changes: $c \rightarrow f \rightarrow j \rightarrow h$

composition of solid changes: $g \rightarrow e \rightarrow i \rightarrow b$





G(X_{Cu}):
Gibbs Free Energy-composition curves
at some specific temperatures.

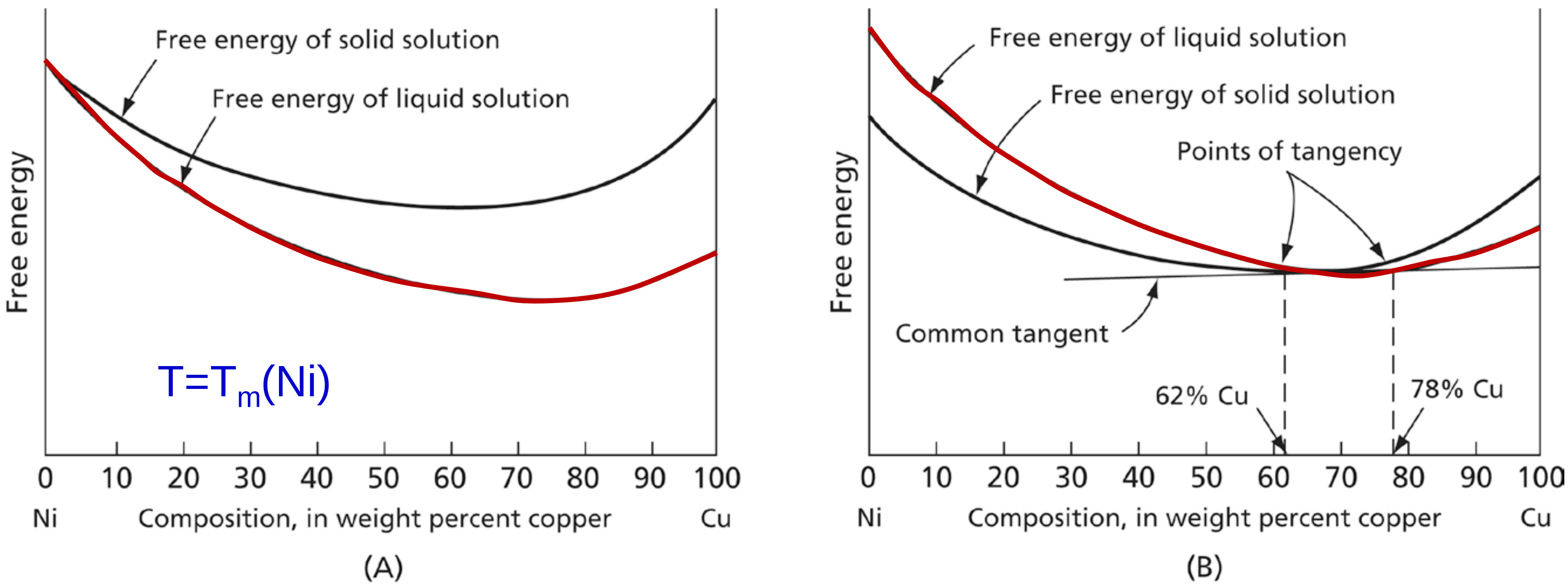
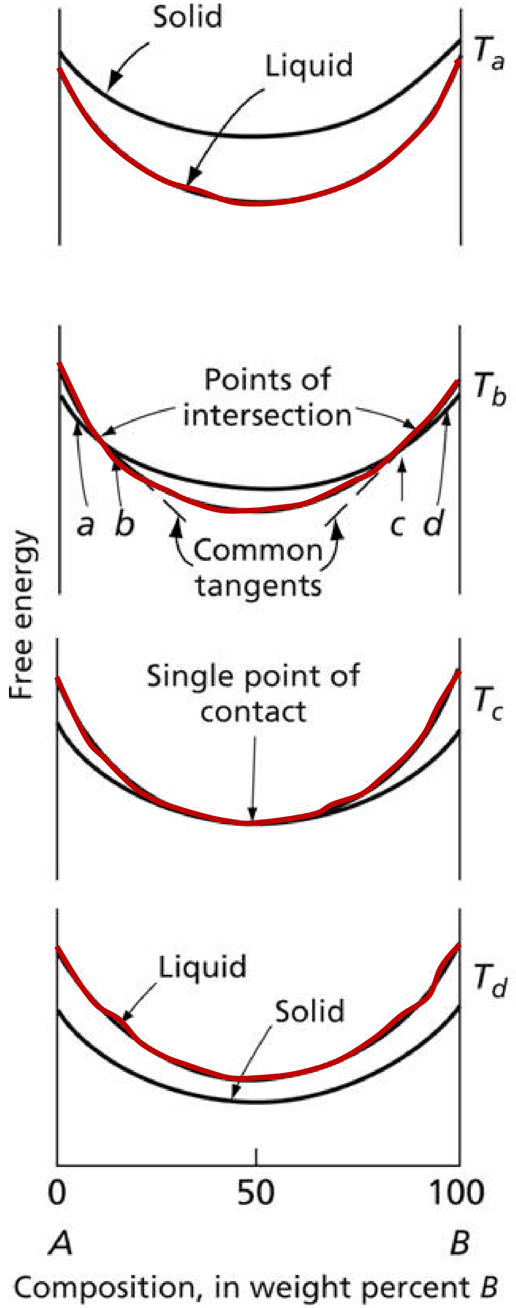
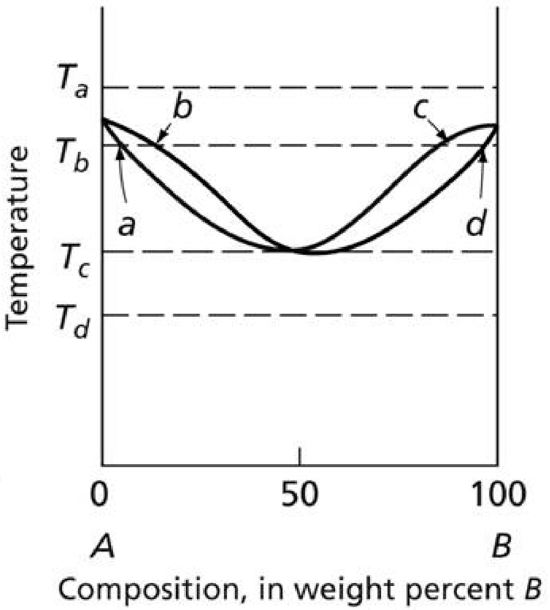


FIG. 11.4 Free-energy-composition curves for the copper-nickel alloy system. **(A)** Freezing point of pure nickel; 1455°C **(B)** 1200°C

Isomorphous phase diagram with minimum T_m

$G(X_B)$:
Gibbs Free Energy-composition curves at some specific temperatures.





Isomorphous phase diagram with maximum T_m

$G(X_B)$:

Gibbs Free Energy-composition curves at some specific temperatures.

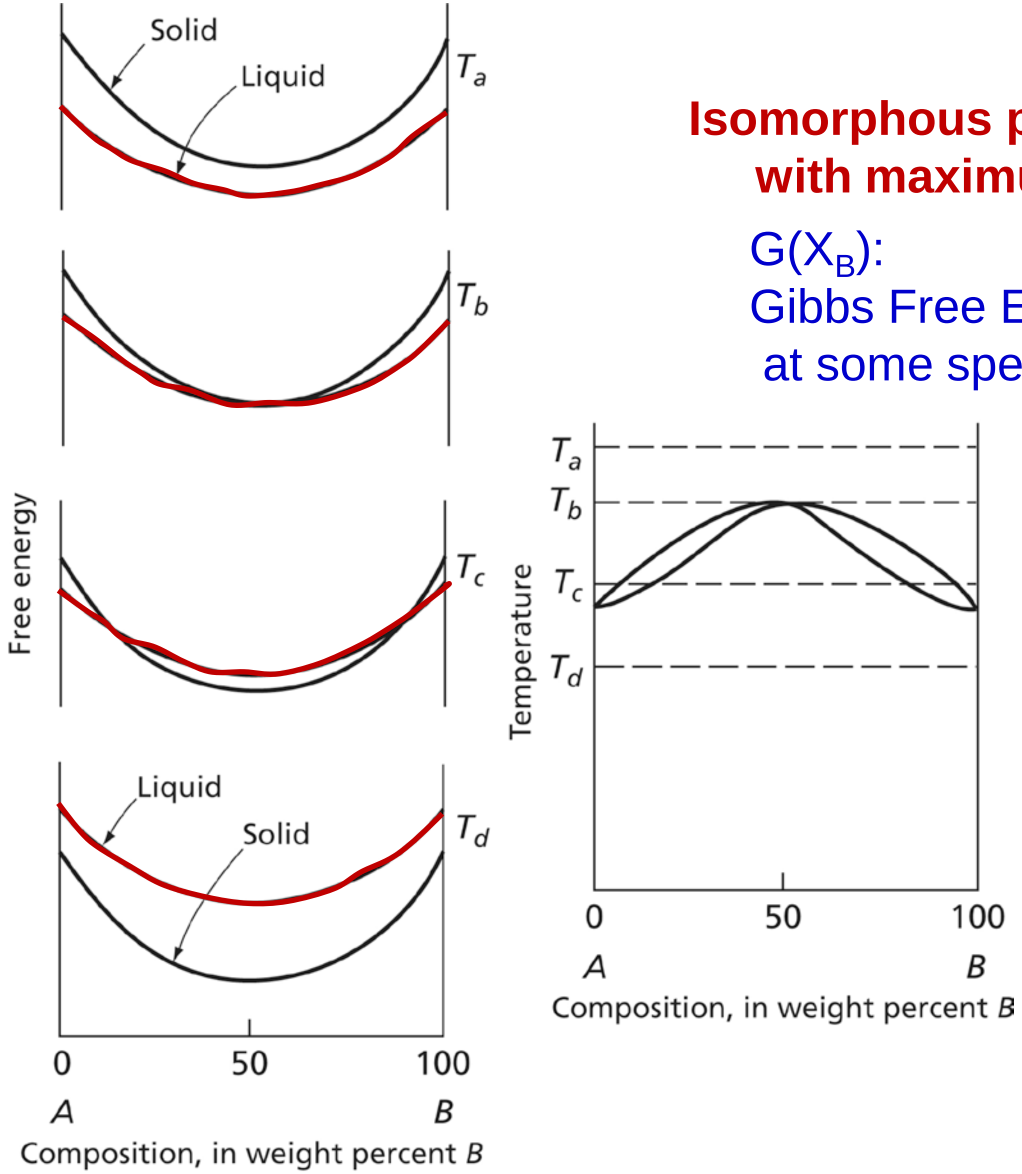


FIG. 11.6 Relationship of the free-energy curves that lead to a maximum

Imissible (missibility gap) of solid solution at low T.

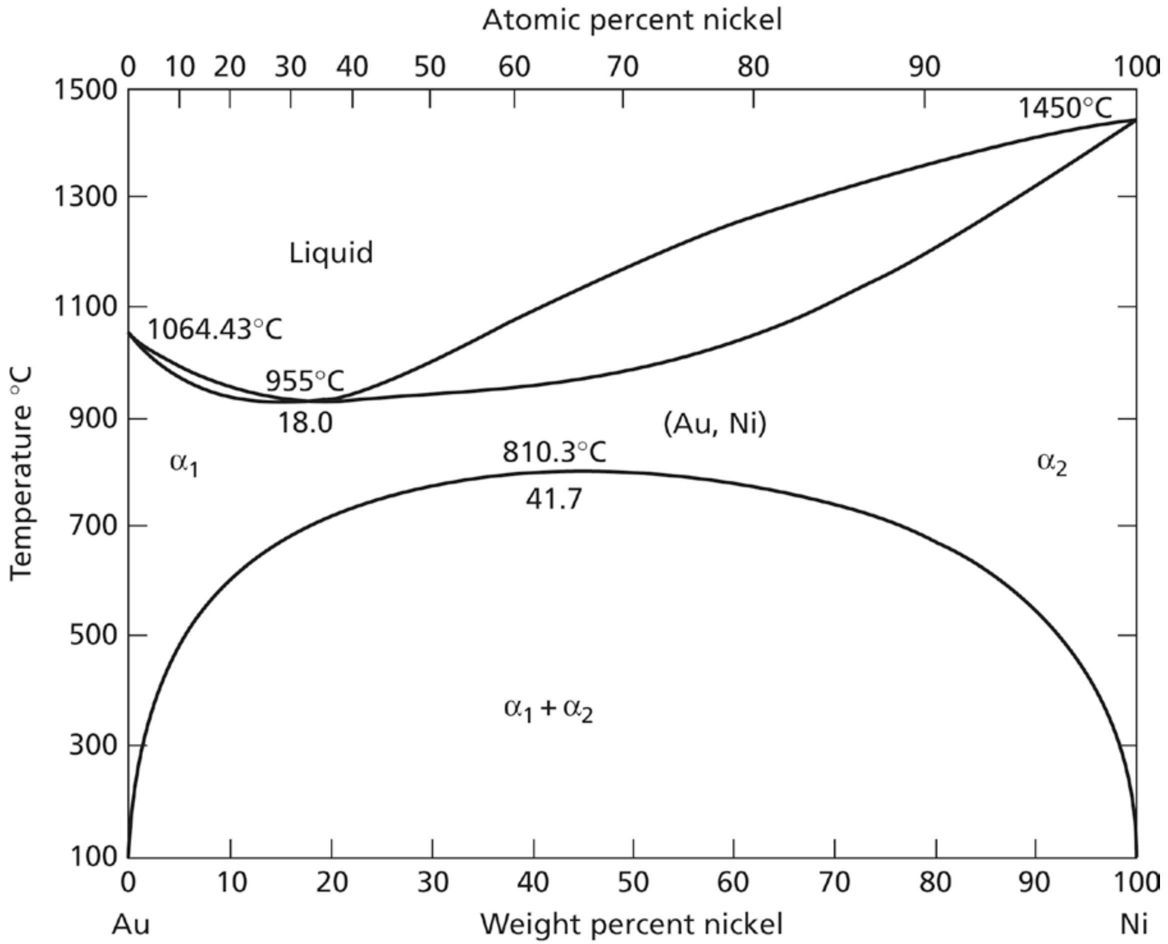


FIG. 11.7 Gold-nickel phase diagram. (From *Binary Alloy Phase Diagrams*, Massalski, T.B., Editor-in-Chief, ASM International, 1986, p. 289. Reprinted with permission of ASM International(R). All rights reserved. www.asminternational.org)

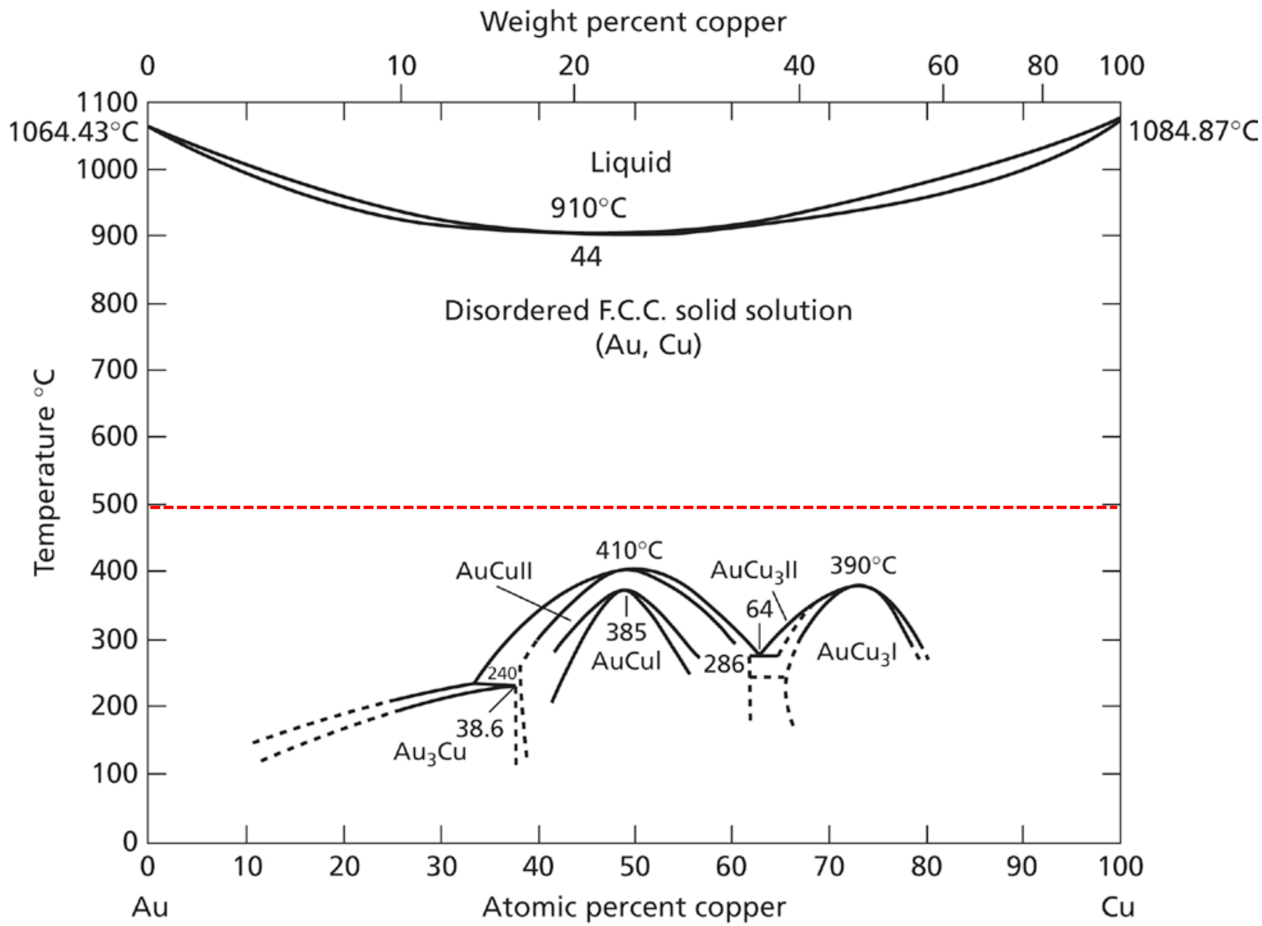


FIG. 11.9 Copper-gold phase diagram. (From *Bulletin of Alloy Phase Diagrams*, Vol. 8, No. 5, by Okamoto, H., Chakrabarti, D. J., Laughlin, D. E., and Massalski, T. B., 1987, p. 454. Reprinted with permission of ASM International (R). All rights reserved www.asminternational.org)

Eutectic Phase Diagram

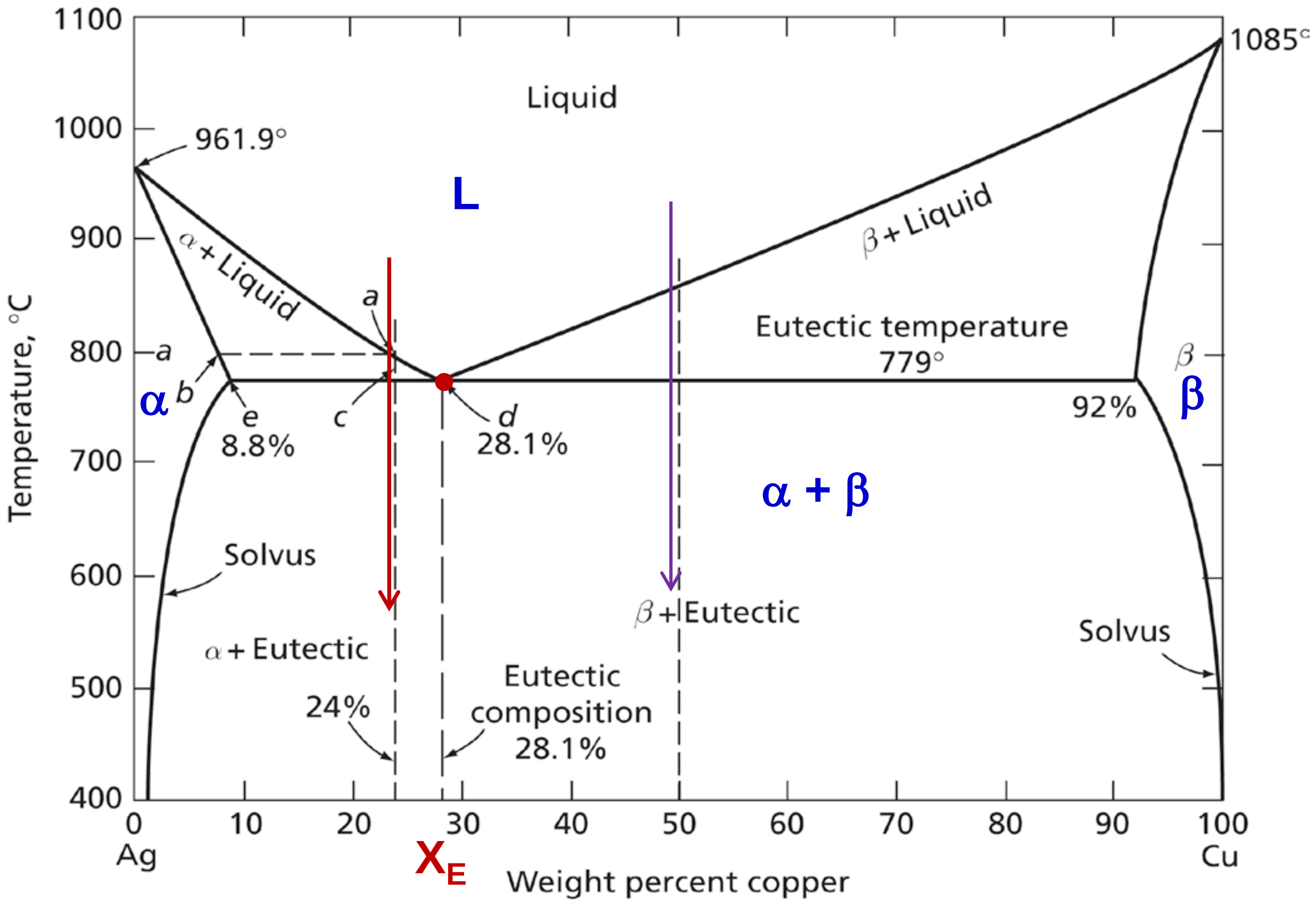


FIG. 11.13 Copper-silver phase diagram. (From *Constitution of Binary Alloys*, by Hansen, M., and Anderko, K. Copyright, 1958. McGraw-Hill Book Co., Inc., New York, p. 18. Used by permission.)

Hypoeutectic: $X_{Cu} < X_E$

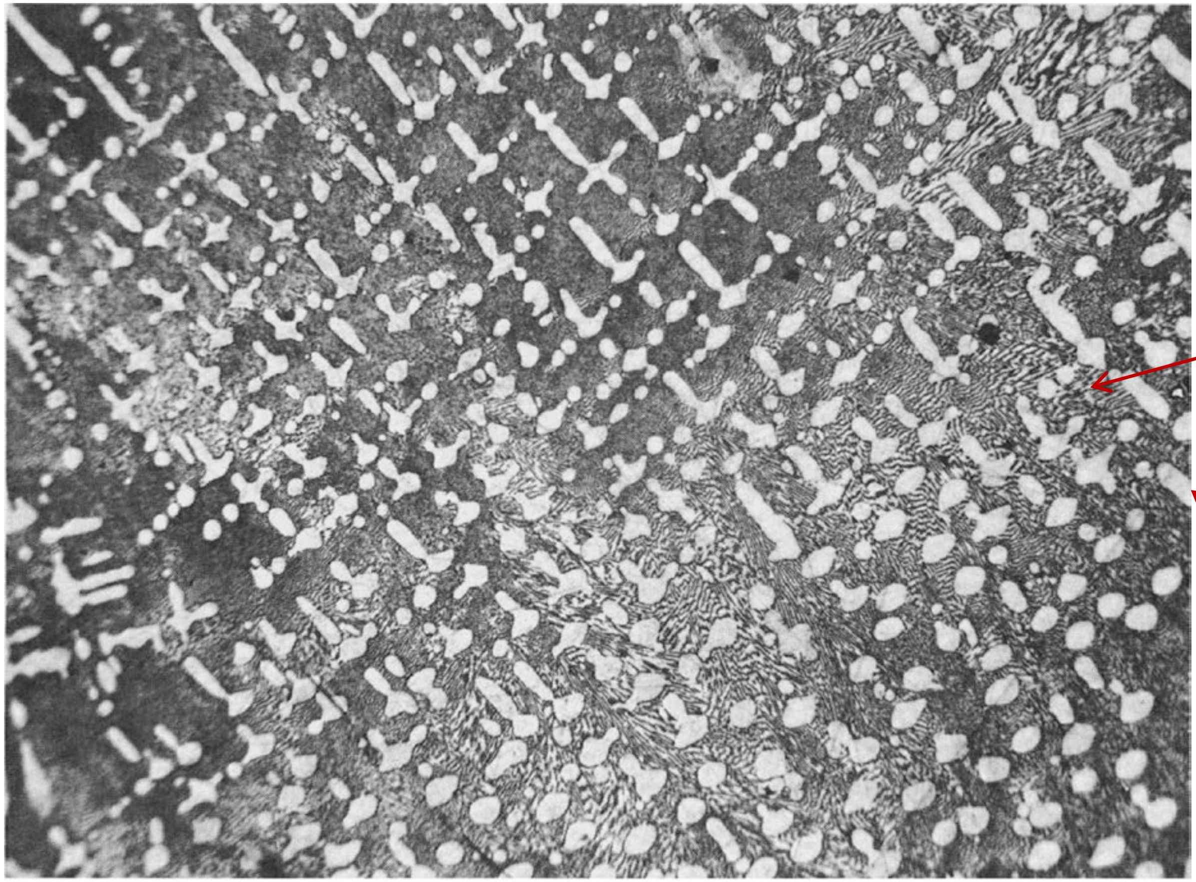


FIG. 11.14 A hypoeutectic structure from the copper-silver phase diagram containing approximately 24 percent copper. Lighter oval regions are proeutectic alpha dendrites, while the gray background is the eutectic structure

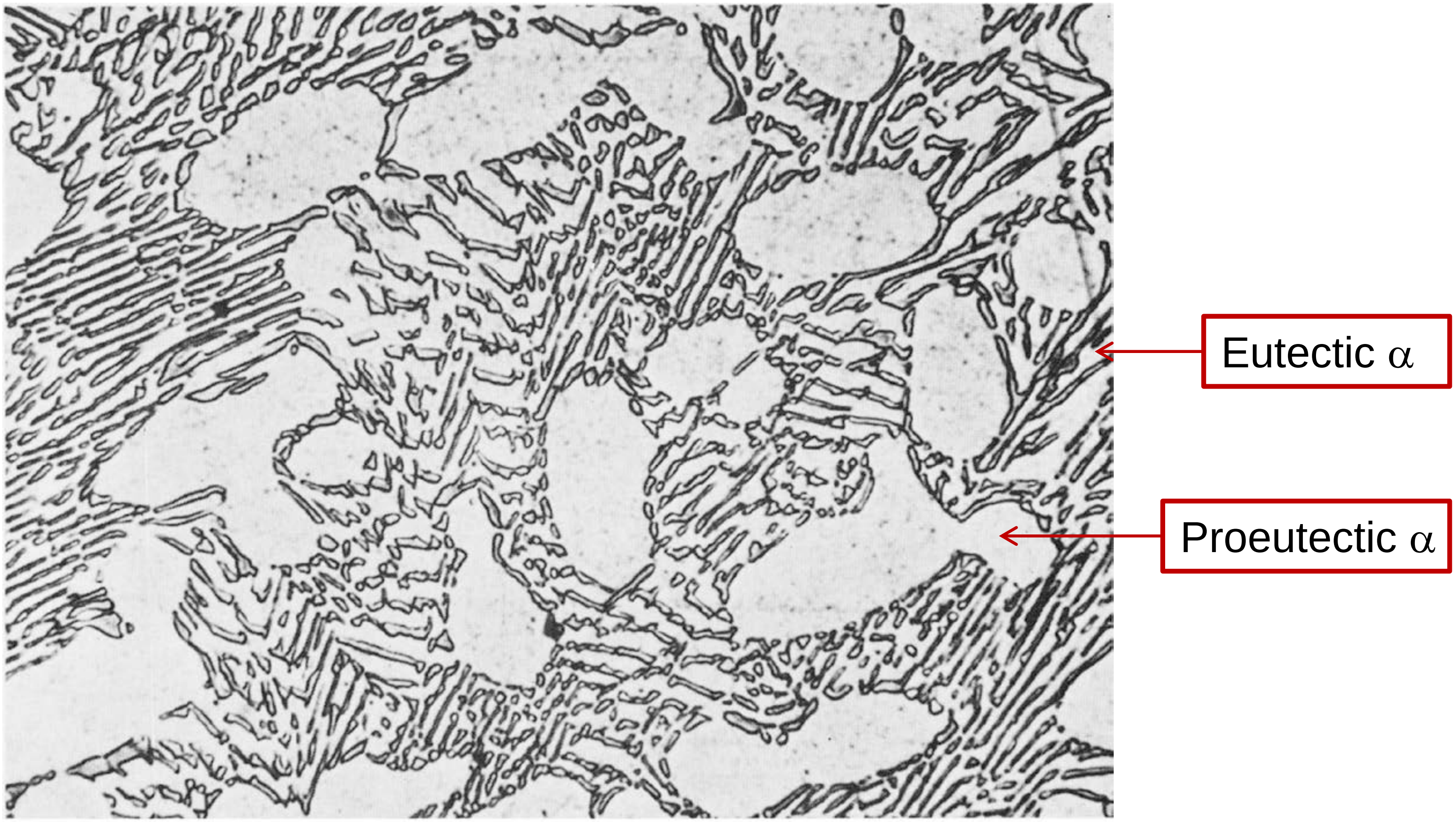


FIG. 11.15 The microstructure of Fig. 11.14 shown at a greater magnification. (White matrix is the alpha or silver-rich phase. Dark small platelets are the beta or copper-rich phase. The eutectic structure is thus composed of beta platelets in an alpha matrix.)

Hypereutectic:
$X_{Cu} > X_E$

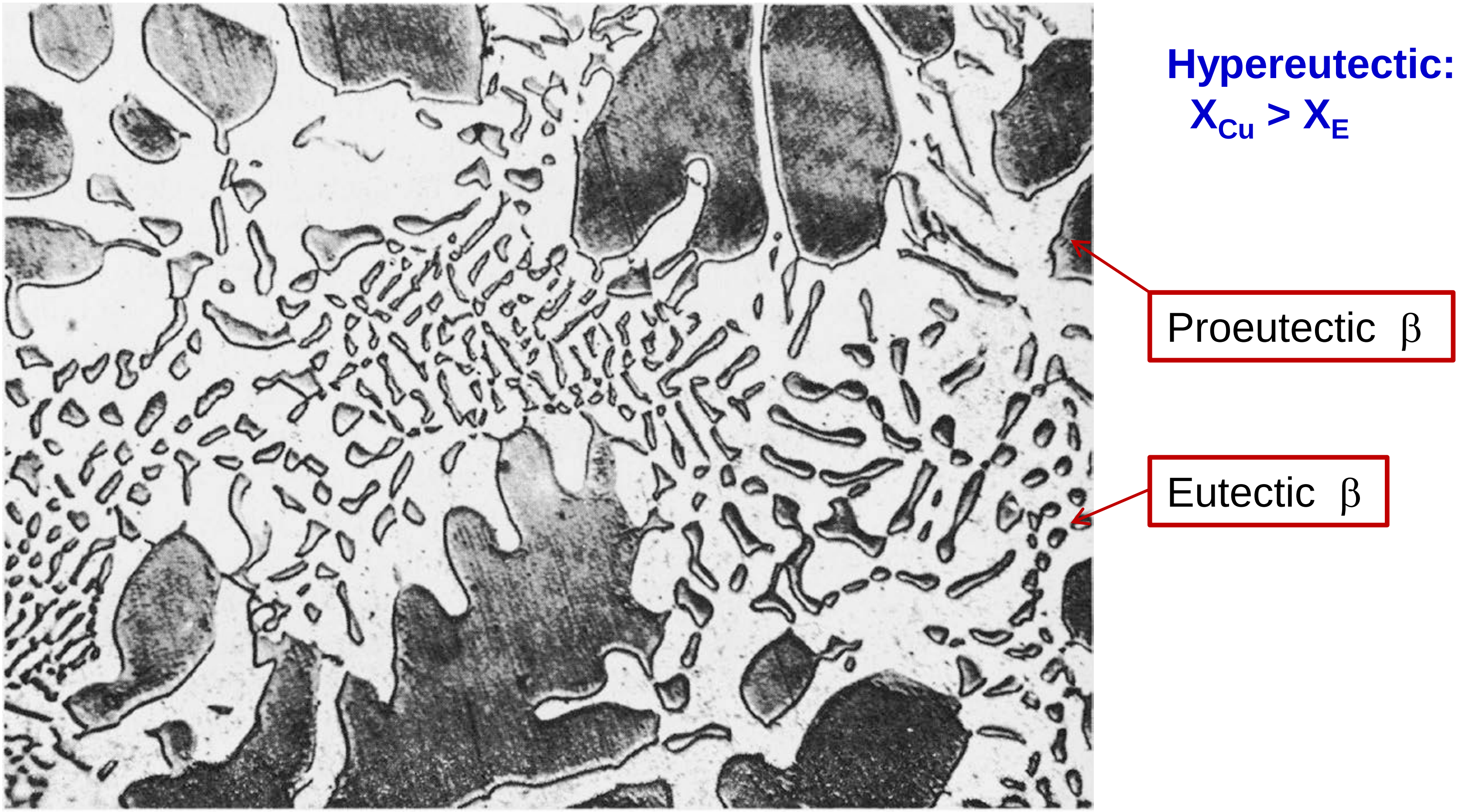


FIG. 11.16 Hypereutectic copper-silver structure consisting of proeutectic beta (large dark areas) and eutectic.

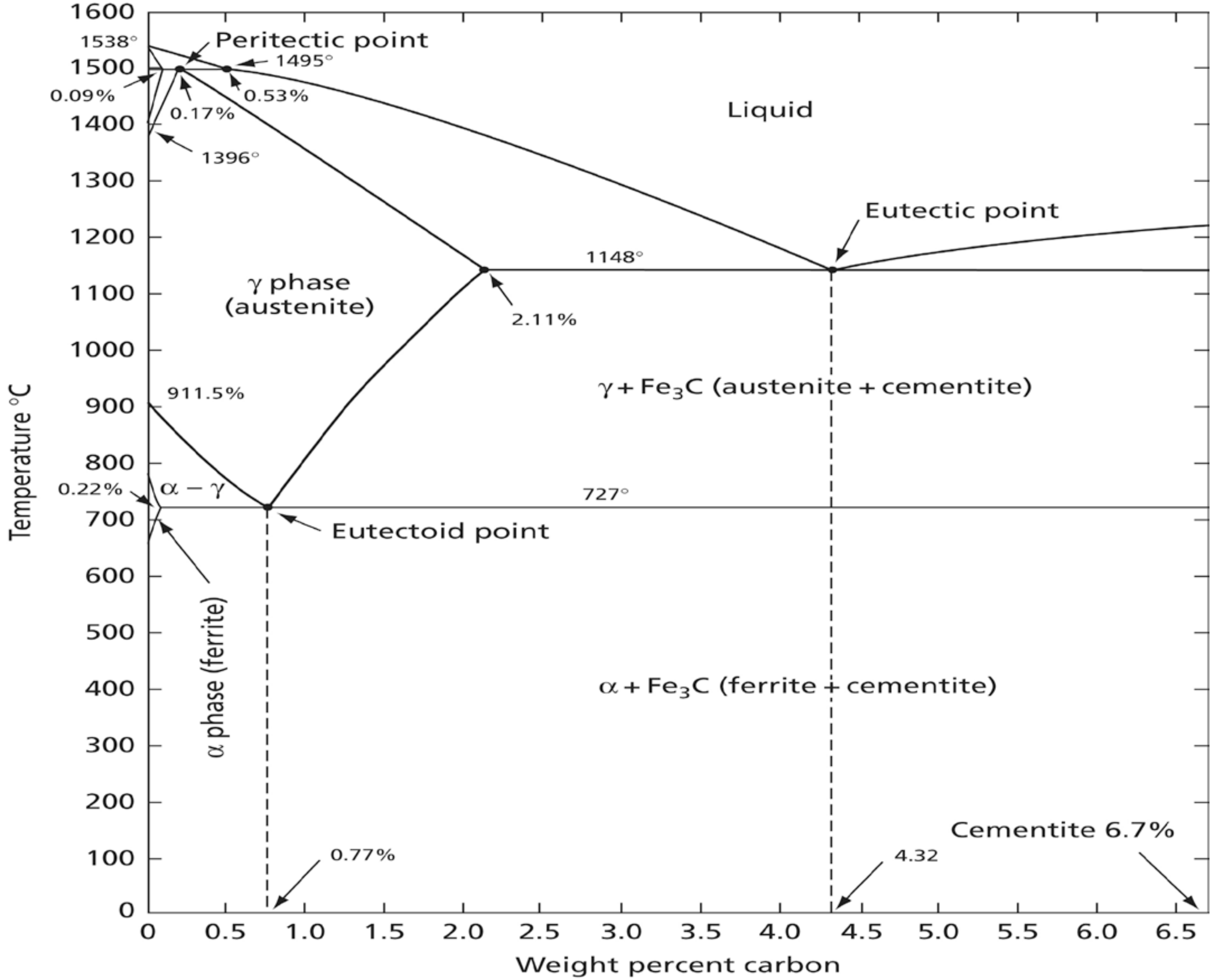
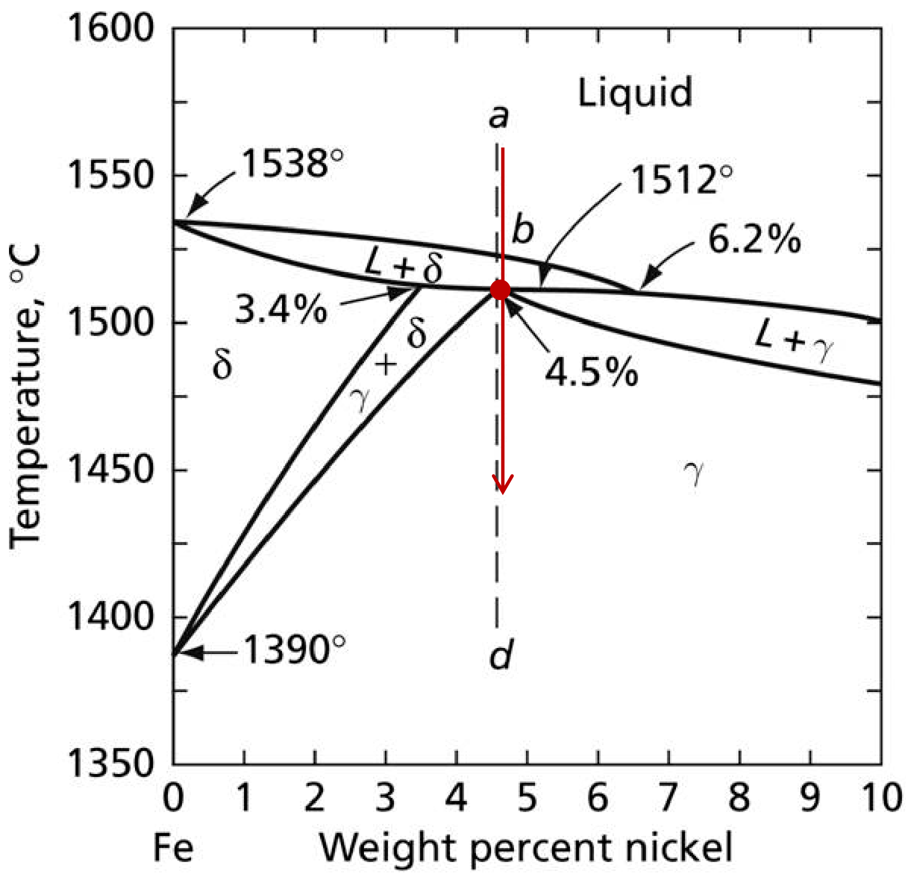
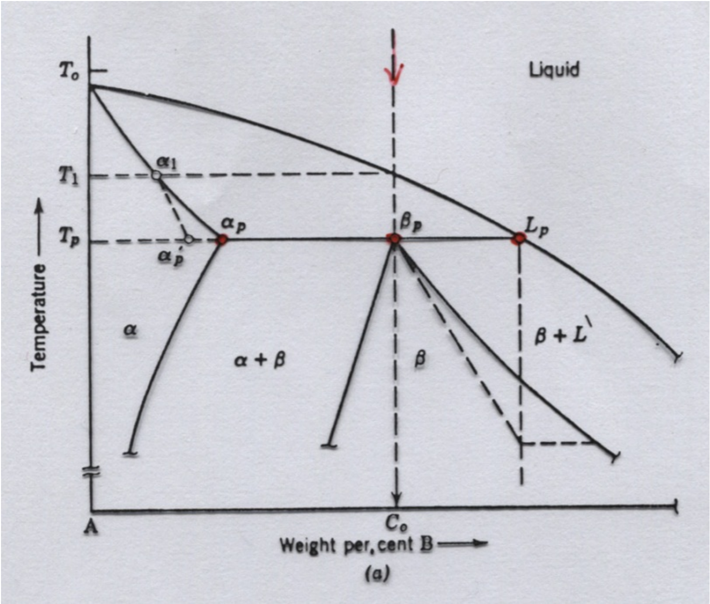
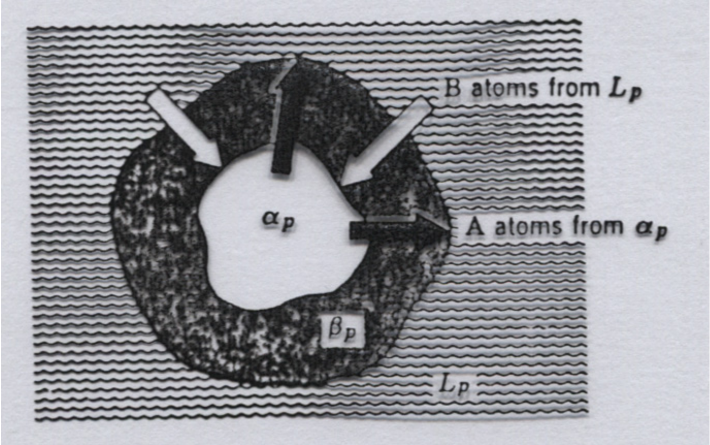


FIG. 18.2 The Fe-Fe_3C metastable phase diagram. (After Chipman, J., *Met. Trans.*, **3** 55 [1972].)

Peritectic Phase Diagram: L + δ → γ







Monotectic and missibility gap in Liquid solution.

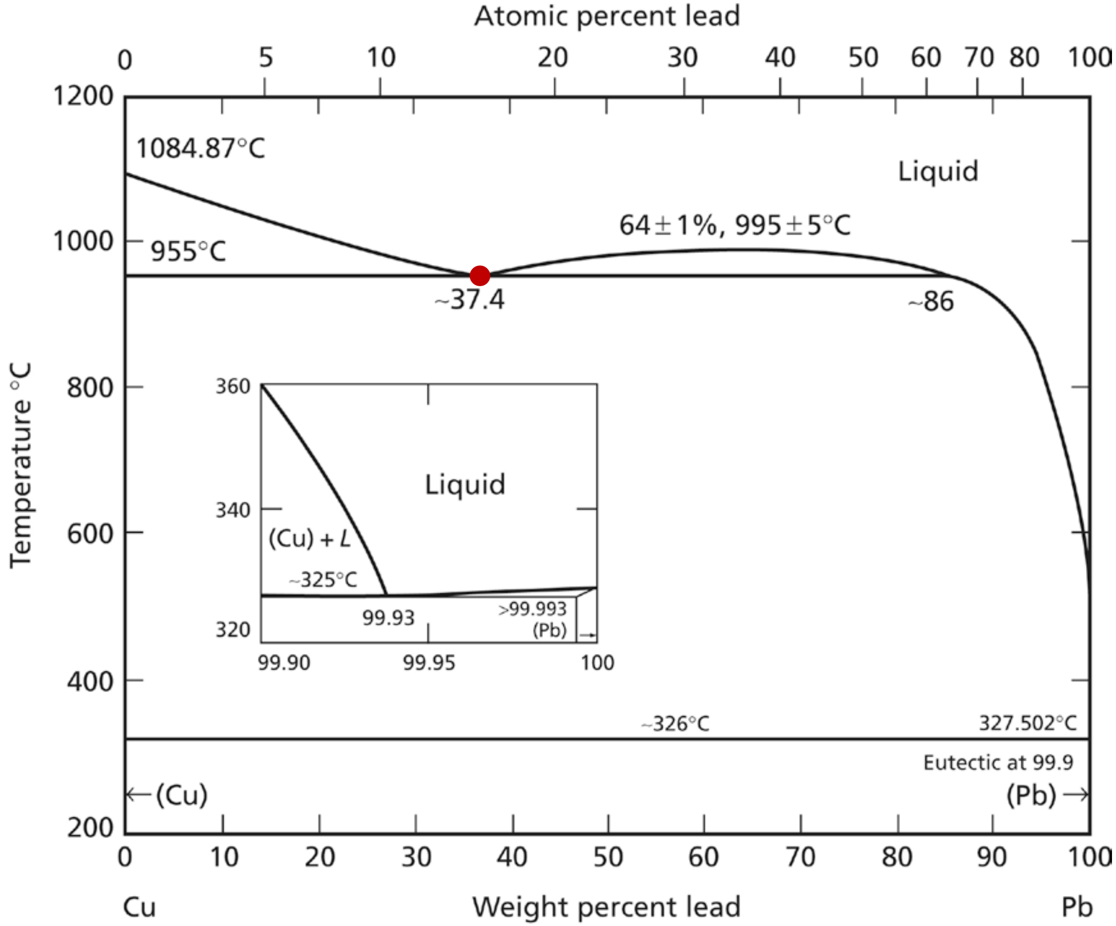
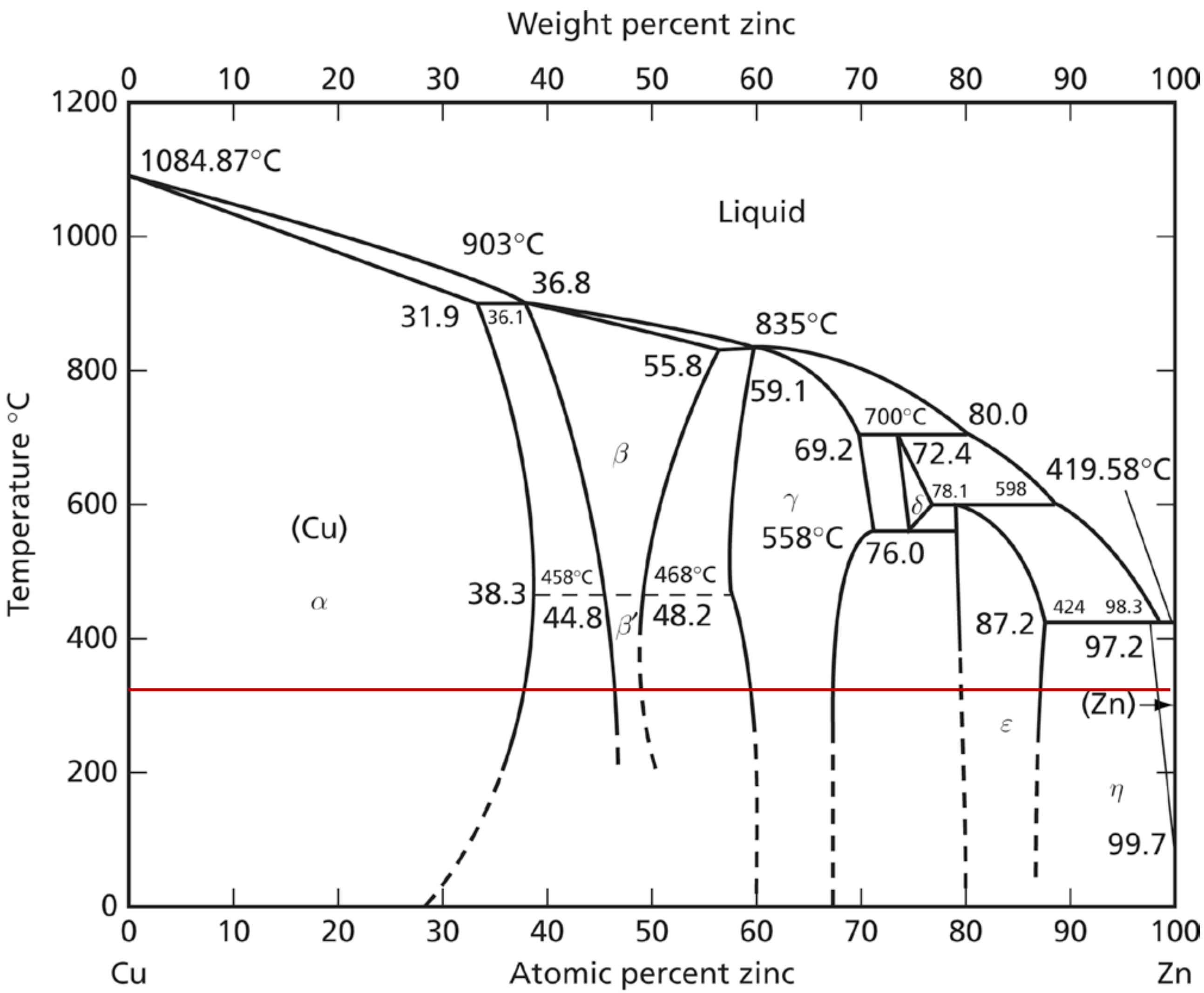
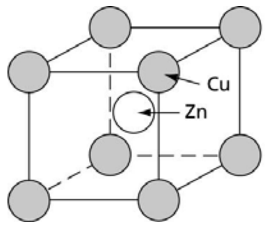


FIG. 11.19 Copper-lead phase diagram. (From *Binary Alloy Phase Diagrams*, Massalski, T.B., Editor-in-Chief, ASM International, 1986, p. 946. Reprinted with permission of ASM International(R). All rights reserved. www.asminternational.org)





β' - brass

Diffusion couple
Cu + Zn

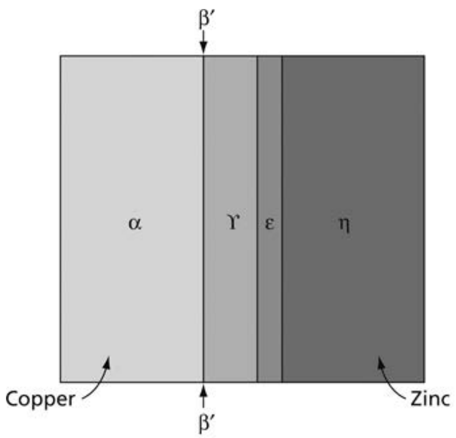


FIG. 11.23 Copper-zinc phase diagram. (From *Binary Alloy Phase Diagrams*, Massalski, T.B., Editor-in-Chief, ASM International, 1986, p. 981. Reprinted with permission of ASM International(R). All rights reserved. www.asminternational.org)

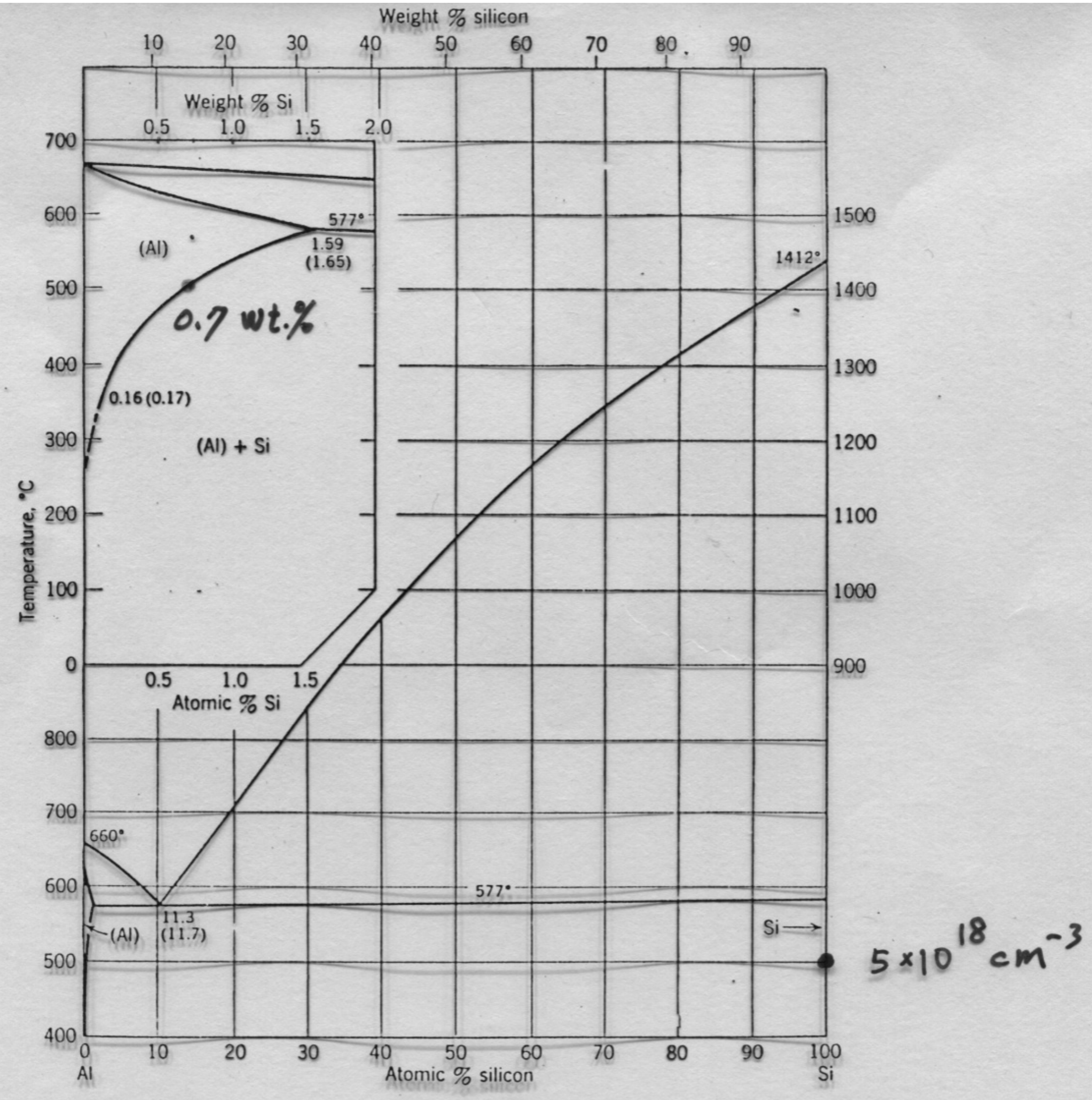
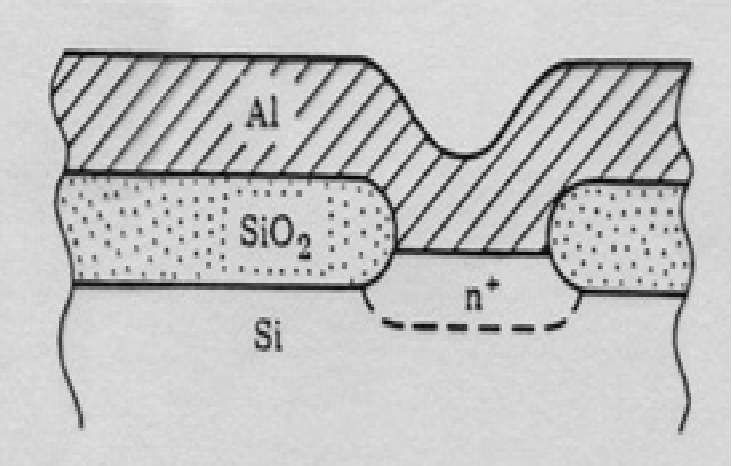


Fig. 2.6 The aluminum–silicon system. From M. Hansen and A. Anderko, *Constitution of Binary Alloys* [1], 1958. Used with permission of the McGraw-Hill Book Company.



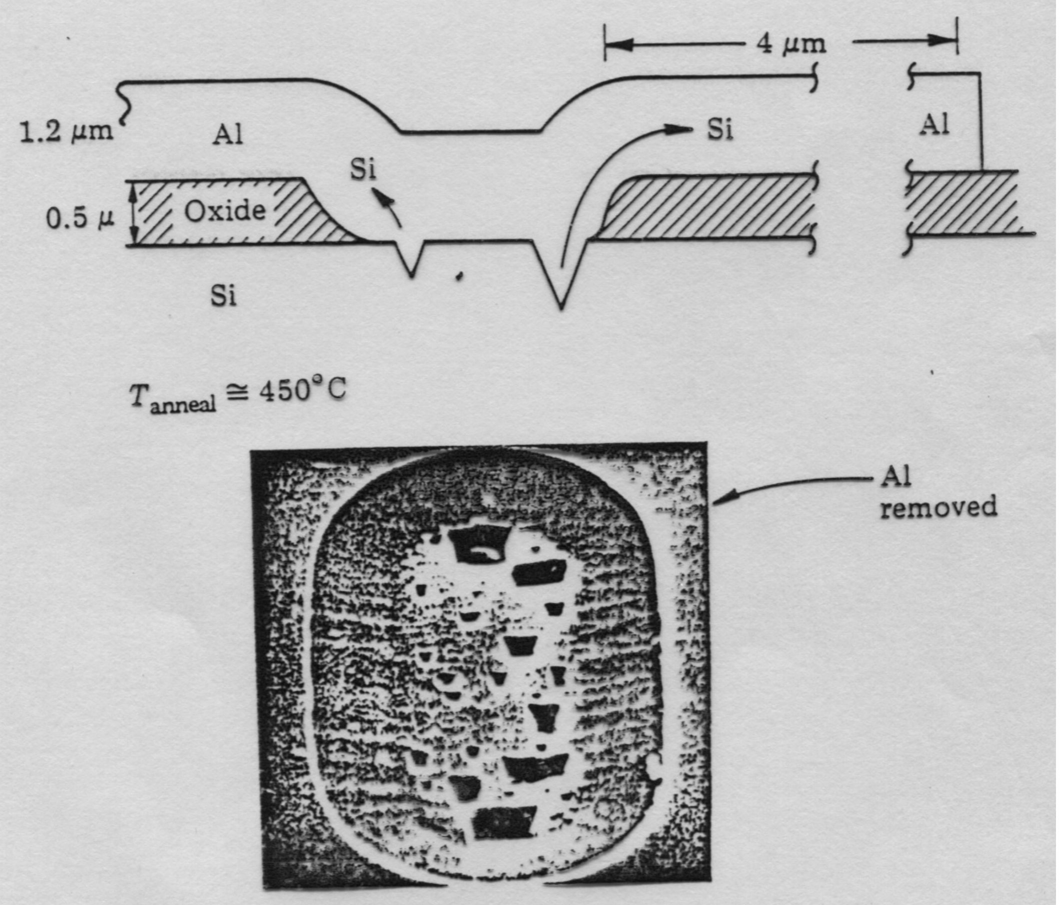
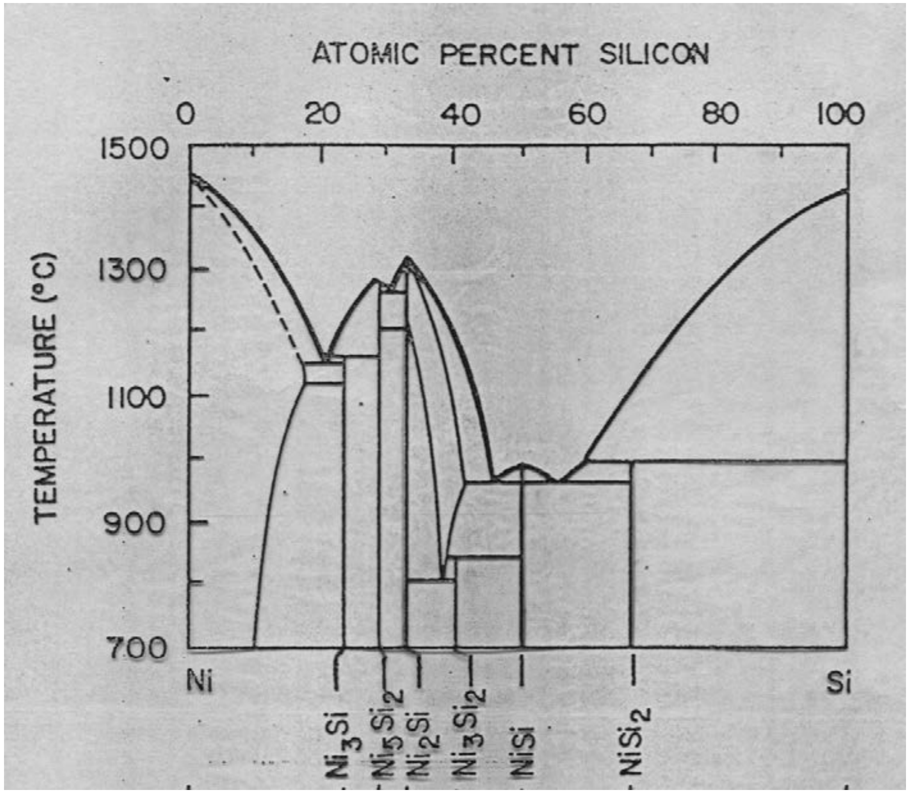
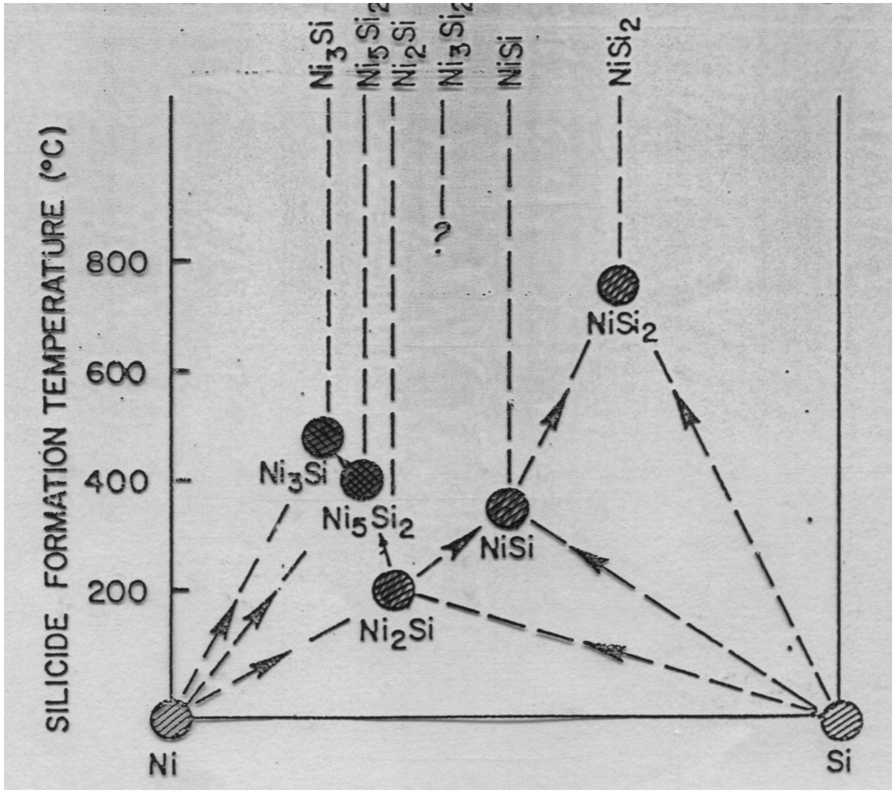


FIGURE 10.5 Pit formation of Al contact to Si.


ATOMIC PERCENT SILICON
0
20
40
60
80
100
1500
1300
1100
900
700
TEMPERATURE (°C)
Ni
Si
Ni3Si
Ni5Si2
Ni2Si
Ni3Si2
NiSi
NiSi2


Ni3Si
Ni5Si2
Ni2Si
Ni3Si2
NiSi
NiSi2
?
SILICIDE FORMATION TEMPERATURE (°C)
800
600
400
200
Ni3Si
Ni5Si2
NiSi2
NiSi
Ni2Si
Ni
Si

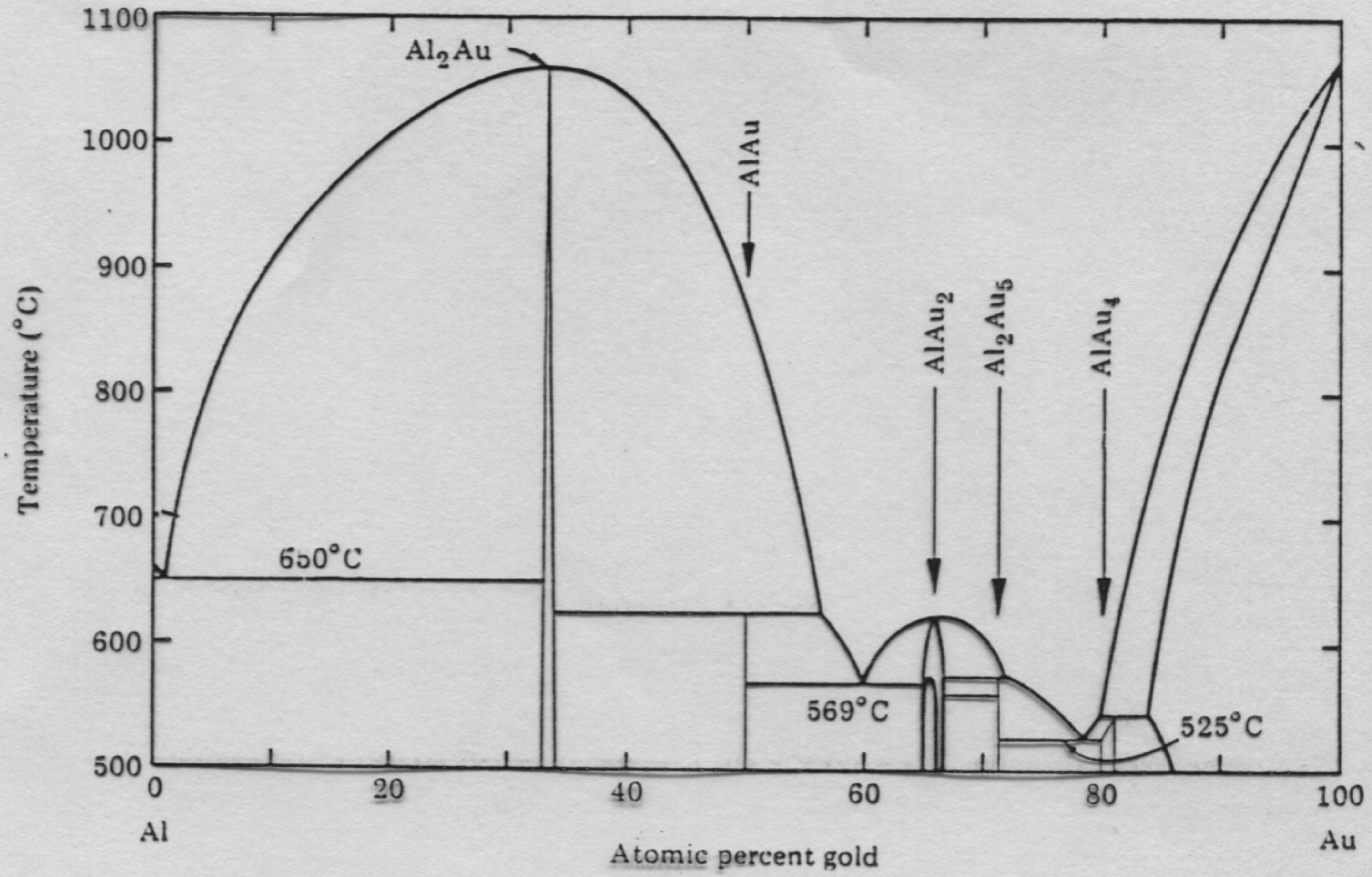


FIGURE 11.14 Phase diagram of the Au–Al system. [Adapted from the *Bull. Alloy Phase Diagrams* 8(1), 71 (1987).]

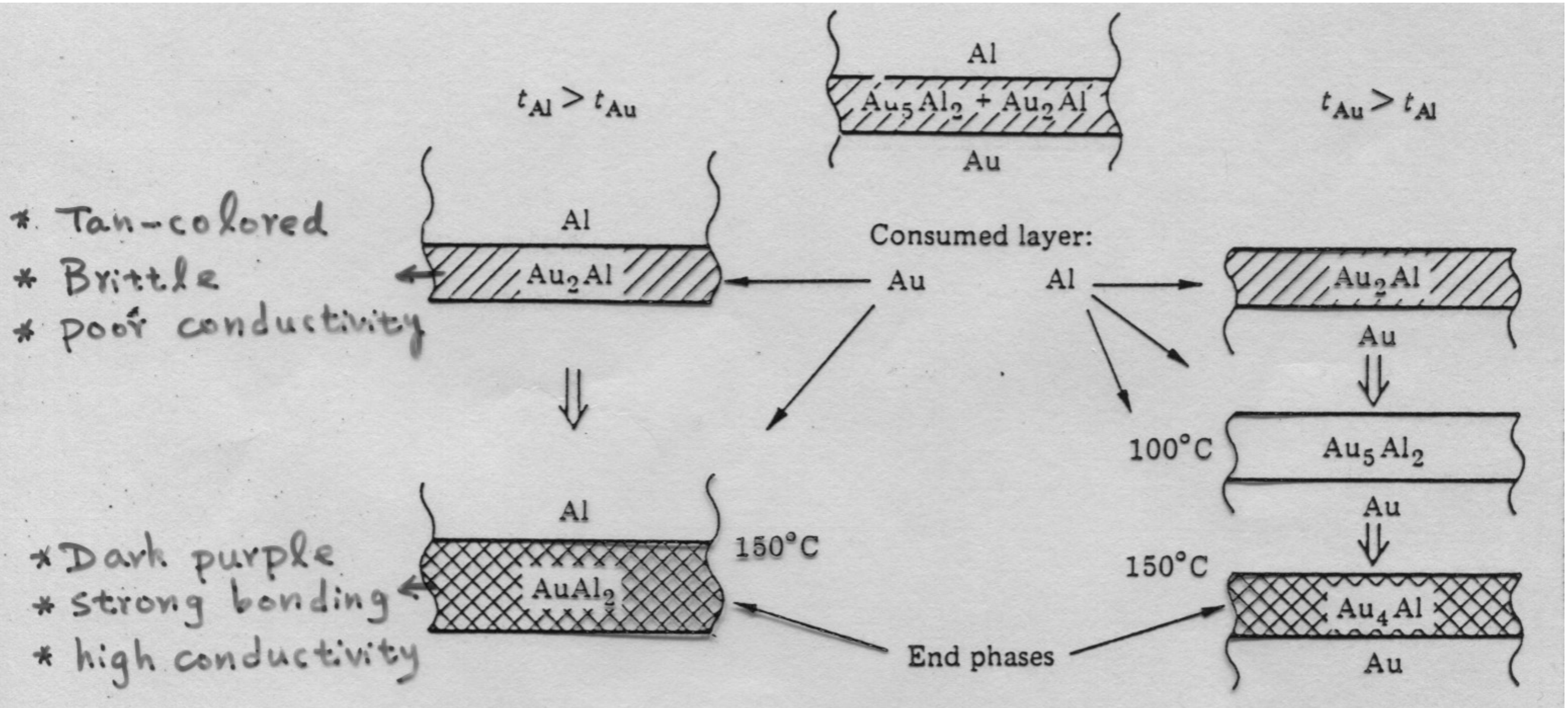


FIGURE 11.15 Schematic diagrams showing the phase formation in Au–Al thin-film couples. The indicated temperatures are those typically required for the formation of phases in films several thousand angstroms thick after an anneal time on the order of 1 hour. Initially, Au_5Al_2 is formed, followed by the formation of Au_2Al with a transition to Au_2Al at higher temperatures. When the Al layer is consumed, Au_5Al_2 is formed at temperatures ≥ 100°C, and at higher temperatures (≥ 150°C), Au_4Al is formed. When Au layer is consumed, $AuAl_2$ is formed at 150°C. [After Campisano et al. (1975).]

Ternary Phase Diagram

3D Ternary Phase Diagram

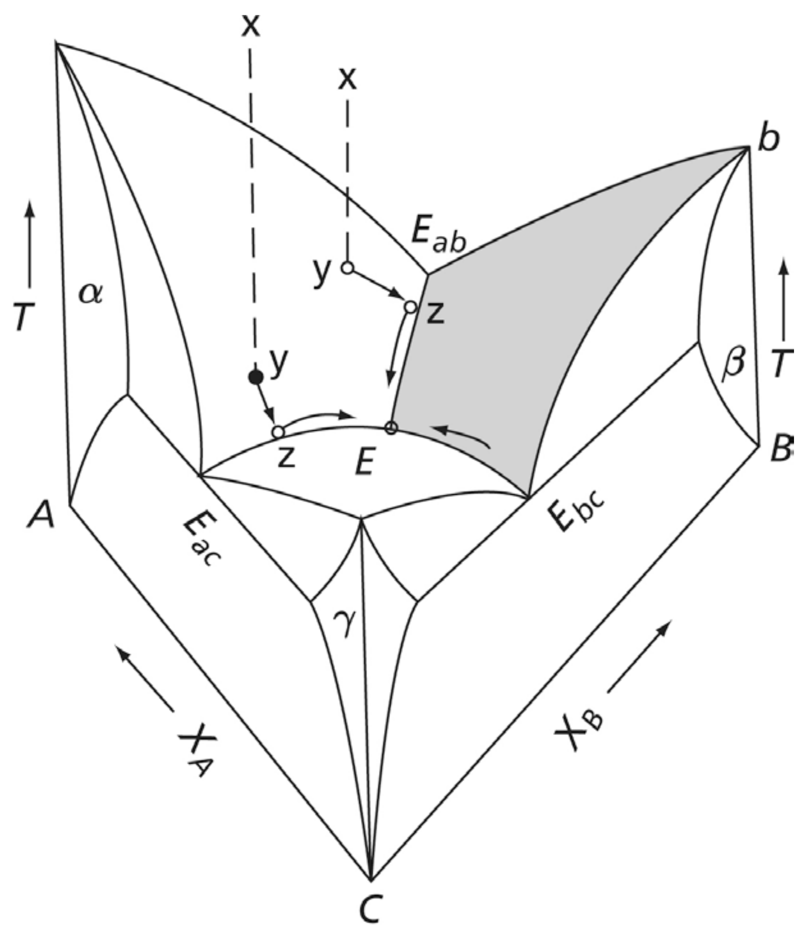


FIG. 11.26 A ternary phase diagram with three eutectic binaries between *A*, *B*, and *C*

Ternary Phase Diagram at specific temperature.
Isothermal section of 3D phase diagram.

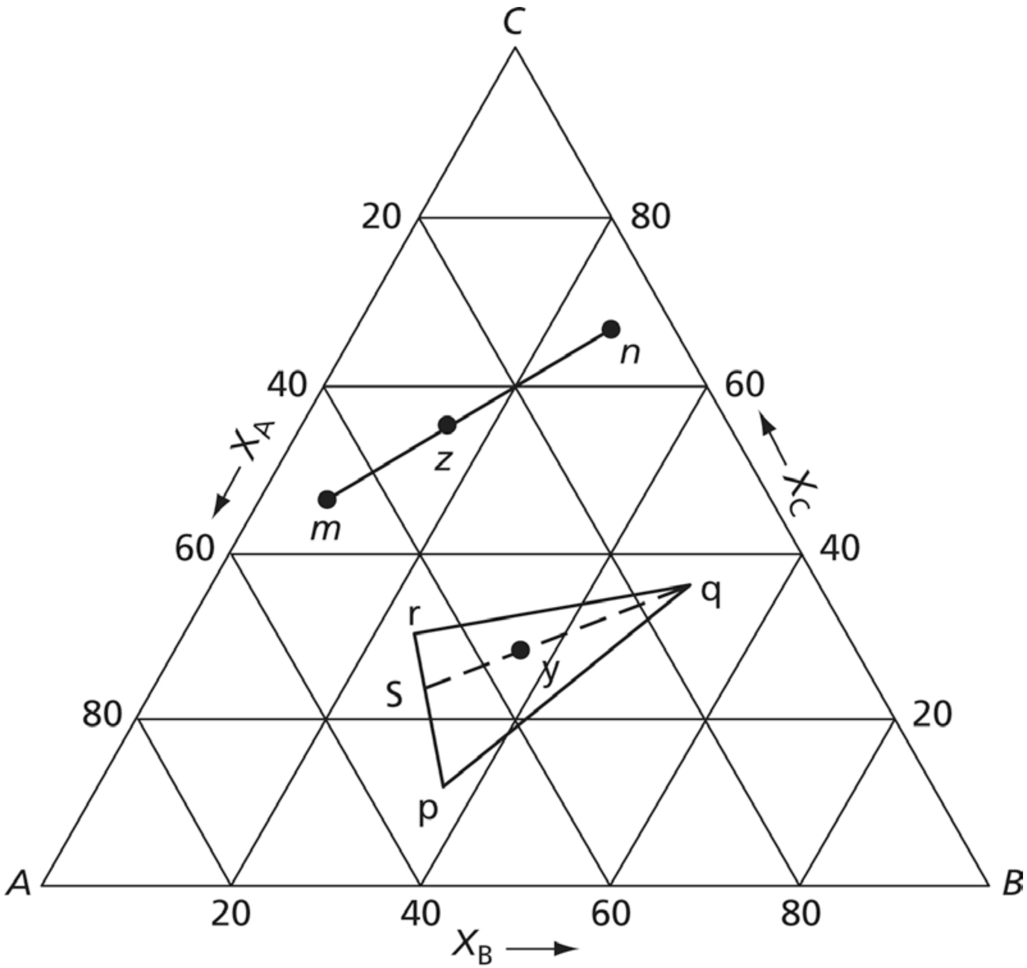


FIG. 11.25 Gibbs triangle for ternary alloy compositions

Ternary Phase Diagram at some specific temperatures.

Isothermal section of 3D phase diagram.

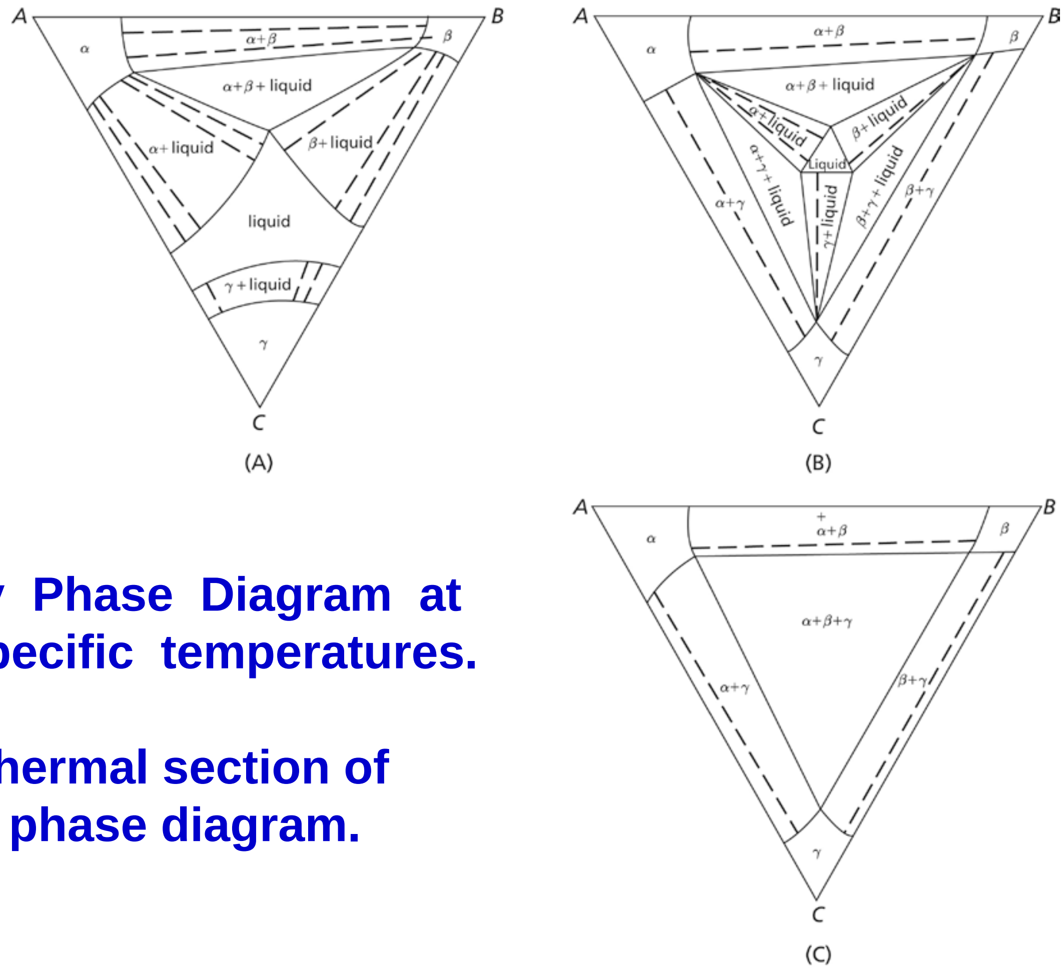


FIG. 11.27 Three isothermal sections for the ternary diagram shown in Fig. 11.26. A few of the tie lines are shown by the dotted lines. **(A)** At a temperature below *A-B* eutectic temperature but above eutectic temperatures of the ternary, *A-C* and *B-C*; **(B)** at a temperature below the three binary eutectics but above the ternary eutectic, and **(C)** at a temperature below the ternary eutectic temperature

END