UNIVERSITI SAINS MALAYSIA

KSCP Examination
Academic Session of 2006/2007

June 2007

**EBB 512/3 – Phase Diagram and Phase Equilibra**

Time : 3 hours

Please ensure that this paper consists of SEVEN printed pages and SIX pages APPENDIX before you proceed with the examination.

This paper contains SEVEN questions.

Answer FIVE questions. If a candidate answer more than five questions, only the first five answered will be examined and awarded marks.

Answer to any question must start on a new page.

All questions must be answered in English.

1. [a] Consider the phases $\alpha$ and $\beta$ which are in equilibrium. Using the fundamental equations, derive the Clapeyron equation.

(50 marks)

[b] Shown in Figure 1 is the free energy of mixing versus composition of the A-B binary system at the temperature T and the pressure P. The diagram shows two terminal phases $\alpha$ and $\beta$, and one intermediate phase $\gamma$. If the overall composition of the system is given by point X shown in the diagram, find the stable equilibrium phase(s) at T and P.

(50 marks)

2. [a] Liquids A and B exhibit a miscibility gap shown in the following phase diagram. A mixture of 60 mol% of A and 40 mol% of B was prepared at 600°C. Calculate the mole fraction of the liquid rich in A. Refer to Figure 2.

(50 marks)

[b] Describe the cooling behaviour of the liquid d,e,f as shown in Figure 3.

(50 marks)

3. [a] Is it possible to have a 50 wt% Mg – 50 wt% Pb alloy for which the mass fraction of α and $Mg_2$ Pb phases are 0.25 and 0.75 respectively? If so give the approximate temperature of the alloy. If this is not possible than state why. Refer Figure 4.

(50 marks)

[b] In a hypereutectoid steel, both eutectoid and proeutectoid ferrite exist. Explain the difference between them. What will be the carbon concentration in each?

(20 marks)

[c] Briefly explain why a proeutectoid phase forms along austenite grain boundaries.

(30 marks)

4. [a] For some metal alloy it is known that the kinetics of recrytallisation obey the Avrami equation, and that the value of k in the exponential is $1.2 \times 10^{-6}$, for time in seconds. If, at some temperature, the rate of recrystallisation is $5 \times 10^{-3}\ s^{-1}$, what total time is required for the recrystallisation reaction to go to 95% completion?

(60 marks)

[b] Figure 5 shown a continous cooling transformation diagram for a 0.35 wt% C iron-carbon alloy. A specimen of this alloy is austenized at $900^0C$ and then continuously cooled to room temperature. Two cooling curves are noted and labeled on this Figure – corresponding to the cooling of center and surface regions. Also included are plots of hardness versus carbon concentration of fine pearlite, coarse pearlite, spheroidite and martensite (Figure 6 and 7). On the basis of the information provided in these plots specify the hardness at each of the surface and center positions. (**IMPORTANT**: Indicate your work in Figure 6 and 7 and submit them together with your answer script).

(40 marks)

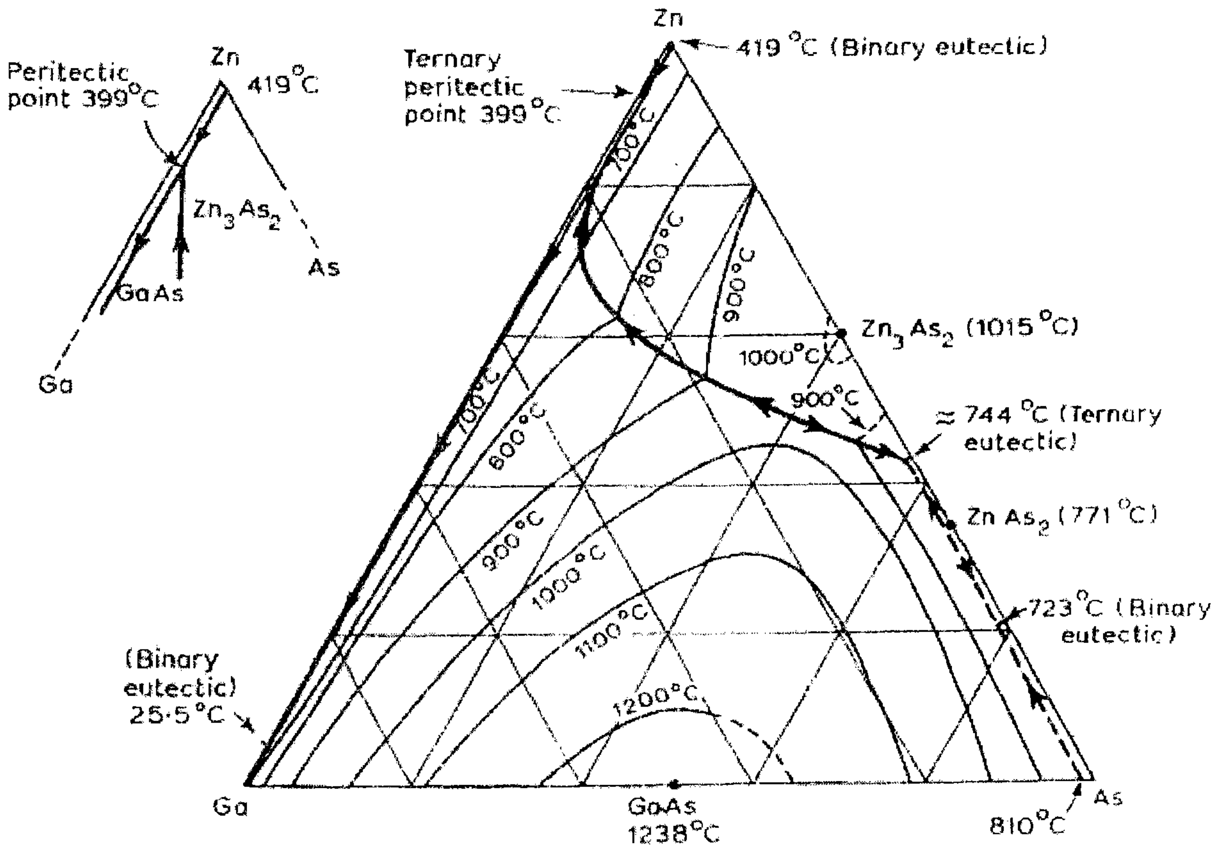
5. Ternary phase diagrams for Ga-As-Q (for Q : Zn , Ag and Au) are important in relation to the incorporation of a dopant material into GaAs to produce *p-n* junction. Using the Ga-As-Zn system depicted by the figure below, consider the alloy composition of 5Ga-50As-45Zn (at%) lying in a three phase solid state region of GaAs + $Zn_3As_2$ + $ZnAs_2$ at temperatures below ~ 740 $^{o}C$:

[a] Draw an isothermal section in the figure for the system at 700 $^{o}C$.

(40 marks)

[b] By reference to this section calculate the proportion by weight of the phases present in the above mentioned alloy composition equilibrated at 700 $^{o}C$. (*More marks will be given for solution obtained by "center of gravity" principle*).

(60 marks)



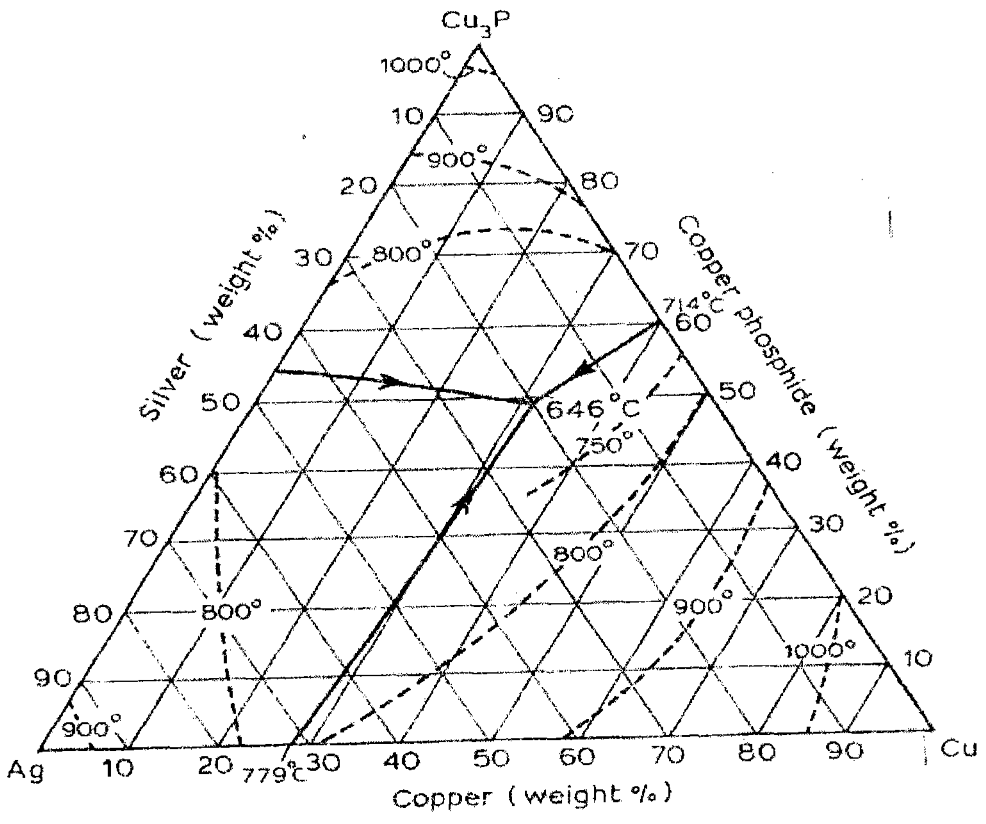
6. A ternary Ag-Cu-$Cu_3P$ system is represented in the following figure. Each of the binary systems contains a eutectic and the ternary system contains an invariant eutectic: L ↔ Ag + Cu + $Cu_3P$. Solid solubility, which is small at room temperature is neglected here. For an alloy containing 50 wt-% $Cu_3P$ and 5 wt-% Ag determine:

   [a] The percentage of liquid present at the temperature where separation of $Cu_3P$ begins.

   [b] The proportion of the phases present at the stage when the liquid contains 10 wt-% Ag and lies on the L ↔ Ag + Cu + $Cu_3P$ valley.

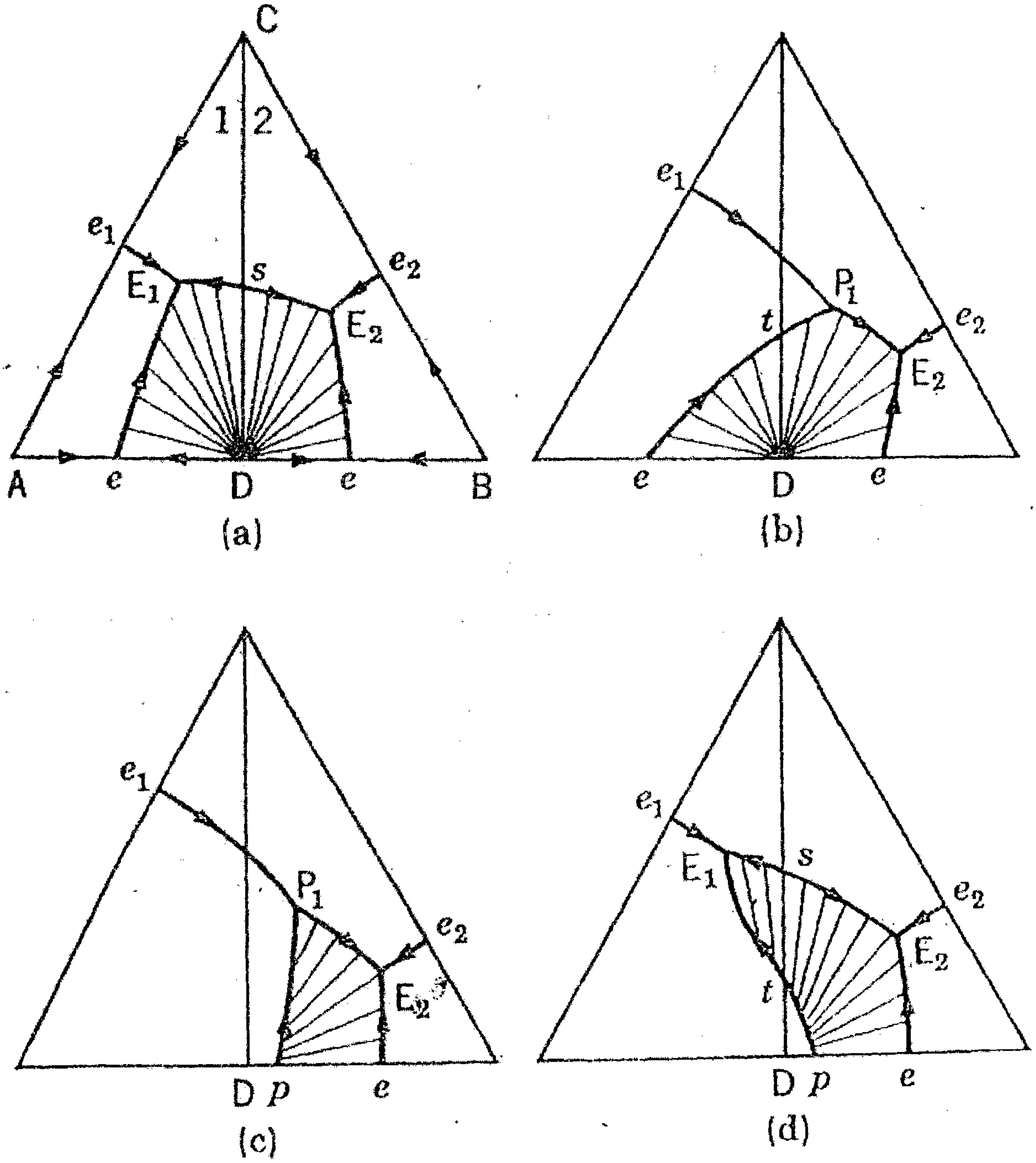
   [c] The percentages of primary phase and of binary and ternary eutectic mixtures respectively present at room temperature. (Assume equilibrium conditions and neglect solid solubility).

(100 marks)



7. Construct the vertical cross-sections of the four ternary ABC systems shown below from corner C to the mid-point of side AB.

(100 marks)



## APPENDIX

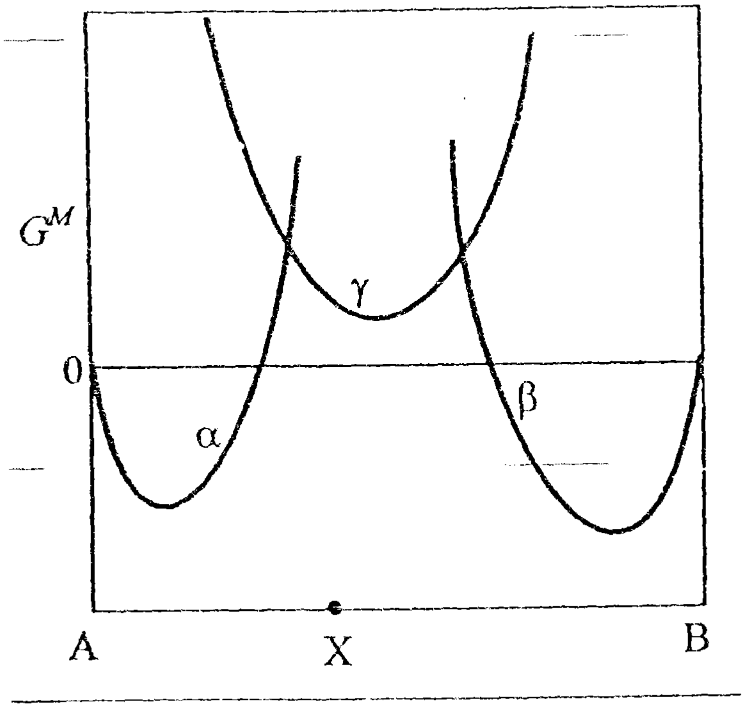



Figure 1

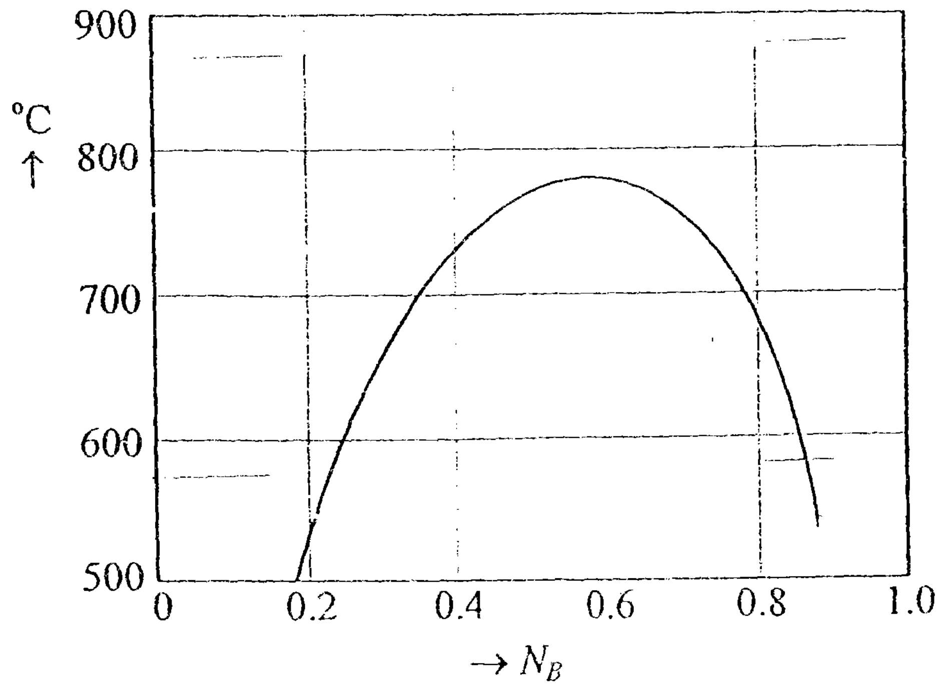



Figure 2

**APPENDIX**

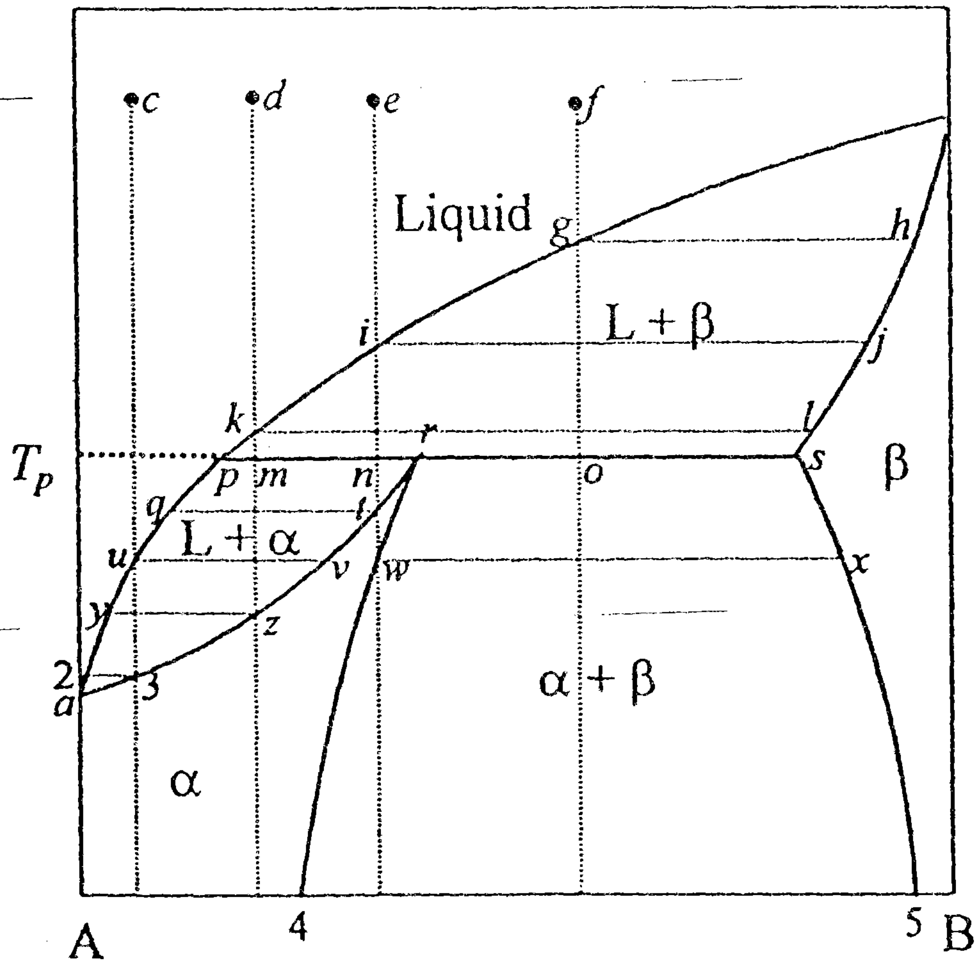
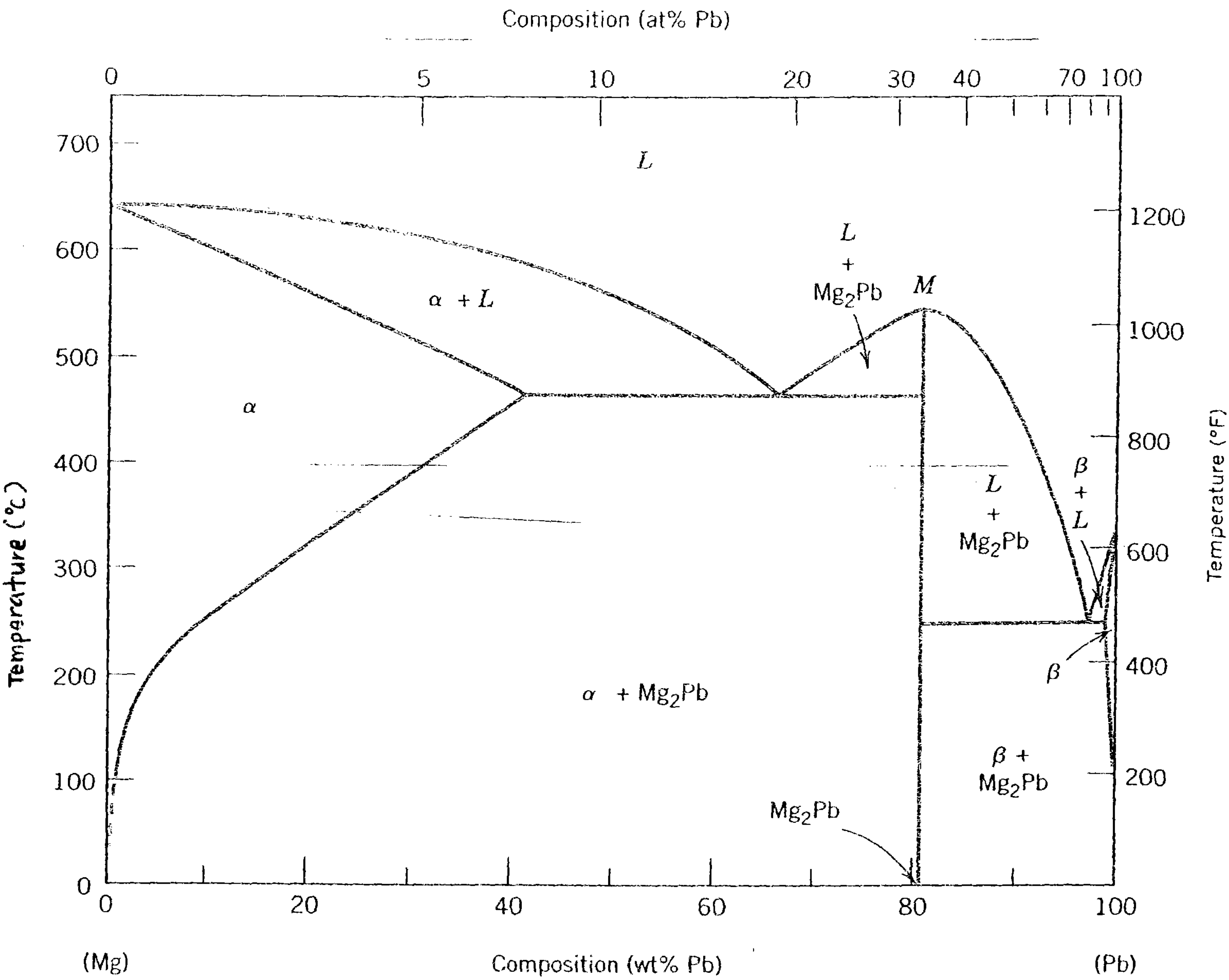



Figure 3

**APPENDIX**




The magnesium–lead phase diagram. (Adapted from *Phase Diagrams of Binary Magnesium Alloys,* A. A. Nayeb-Hashemi and J. B. Clark, Editors, 1988. Reprinted by permission of ASM International, Materials Park, OH 44073-0002.)

Figure 4

APPENDIX

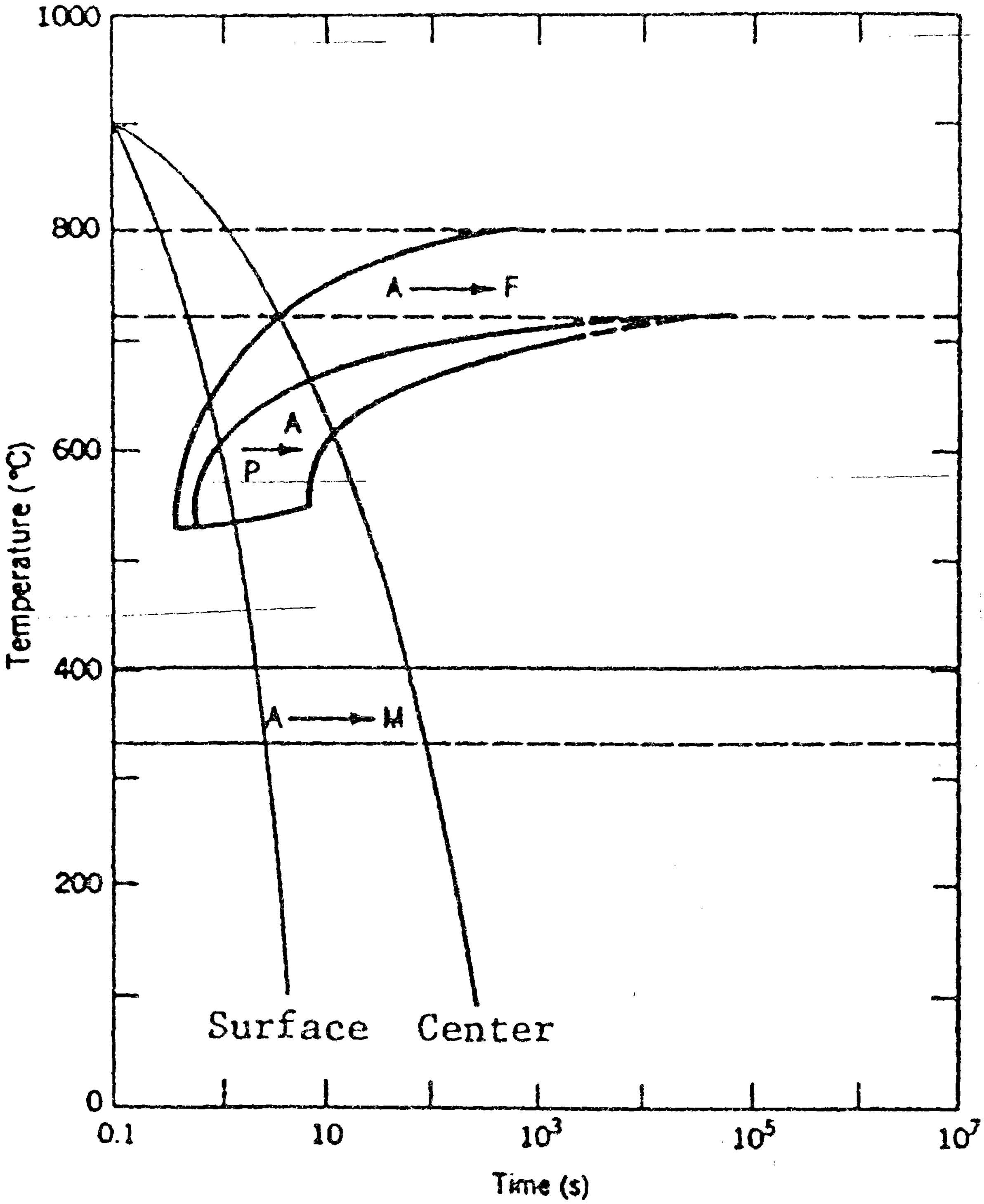
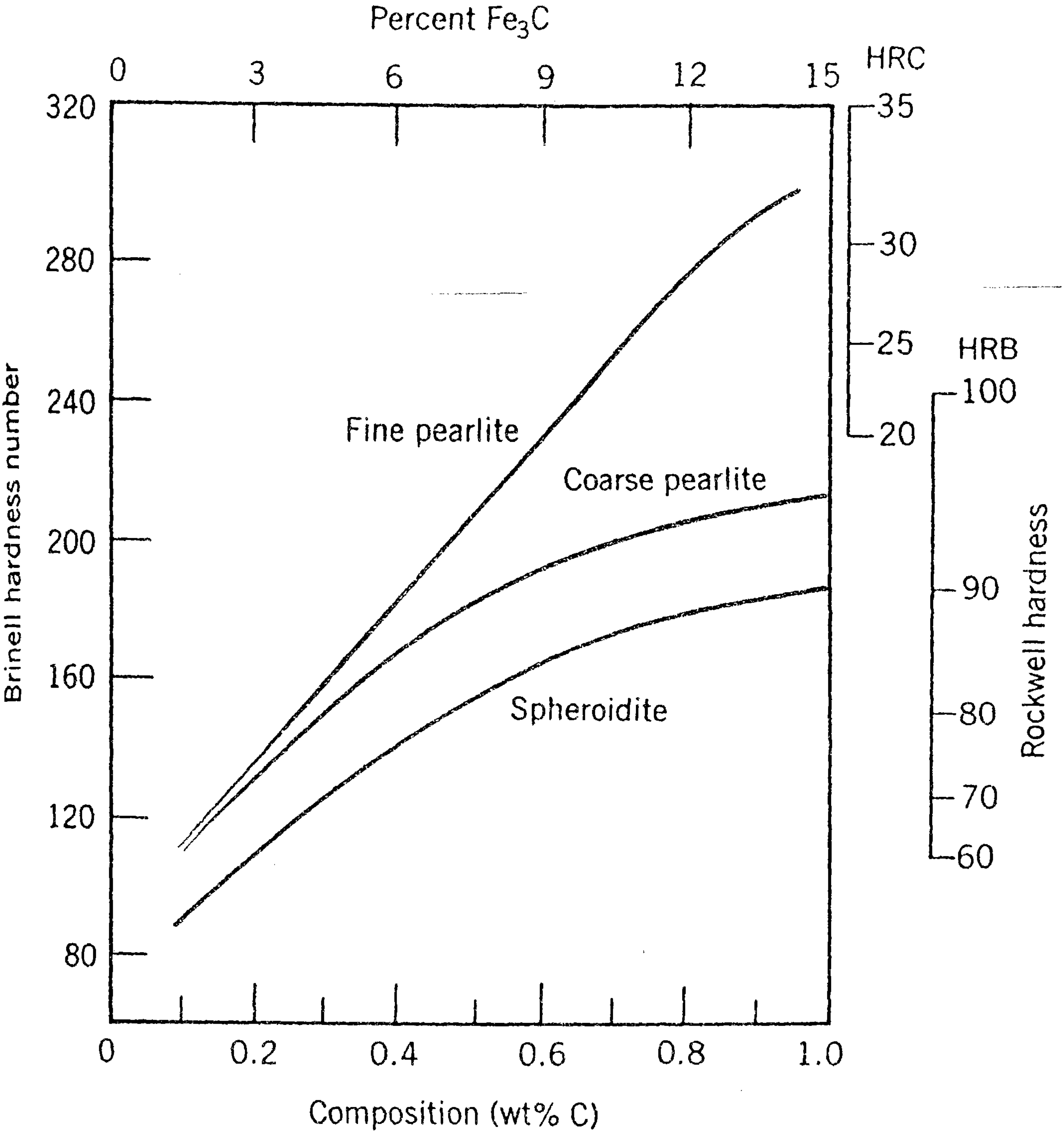



Figure 5

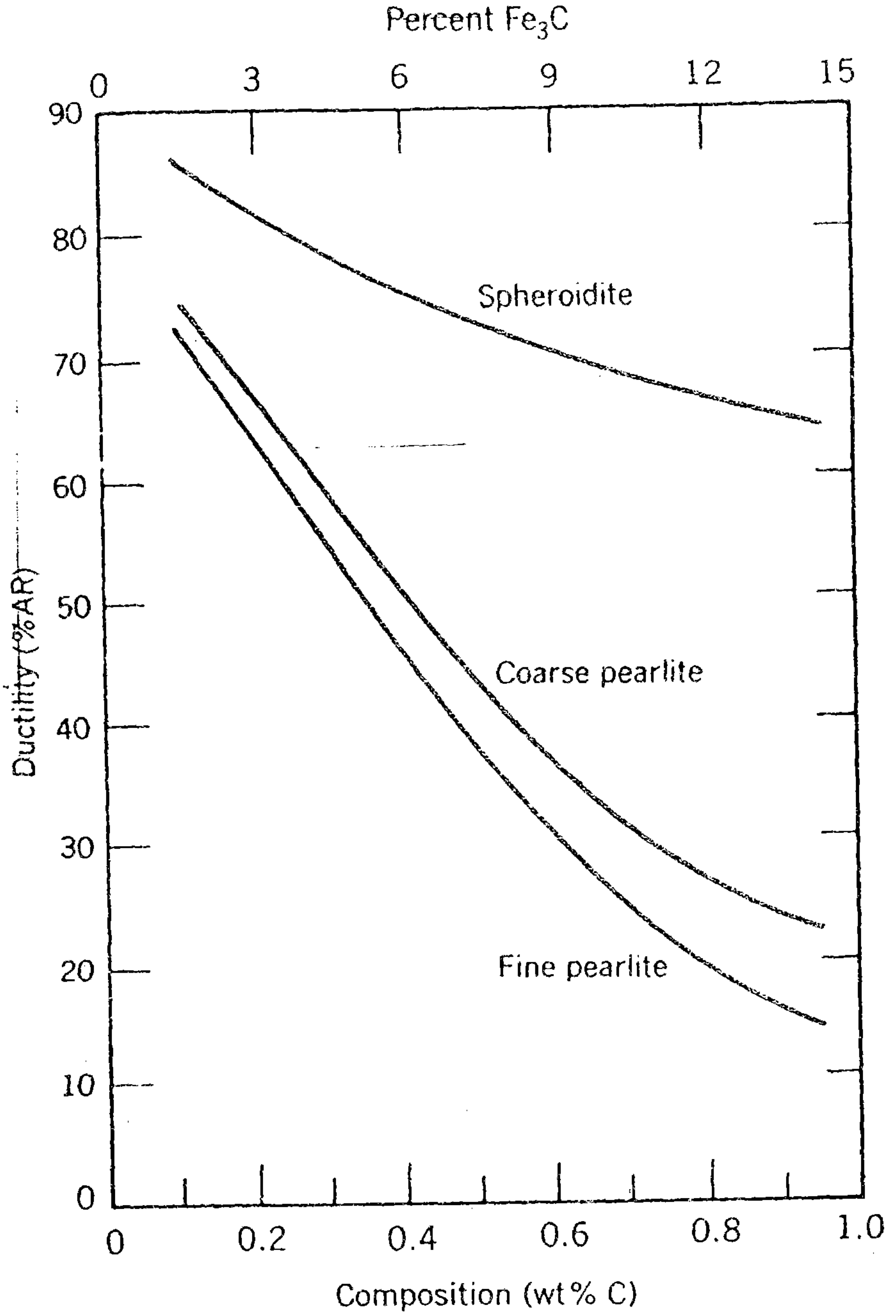
**APPENDIX**




*(a)*

Figure 6

**APPENDIX**




*(b)*

Figure 7