
UNIVERSITI SAINS MALAYSIA

First Semester Examination
Academic Session of 2003/2004

September/October 2003

EBB 512/3 - Phase Diagram and Phase Equilibra

Time : 3 hours

Please ensure that this paper consists of TEN printed pages before you proceed with the examination.

This paper contains SEVEN questions.

Answer any 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 can be answered in Bahasa Malaysia or English.

...2/-

1. Use the phase diagram in Figure 1 to answer the following questions.

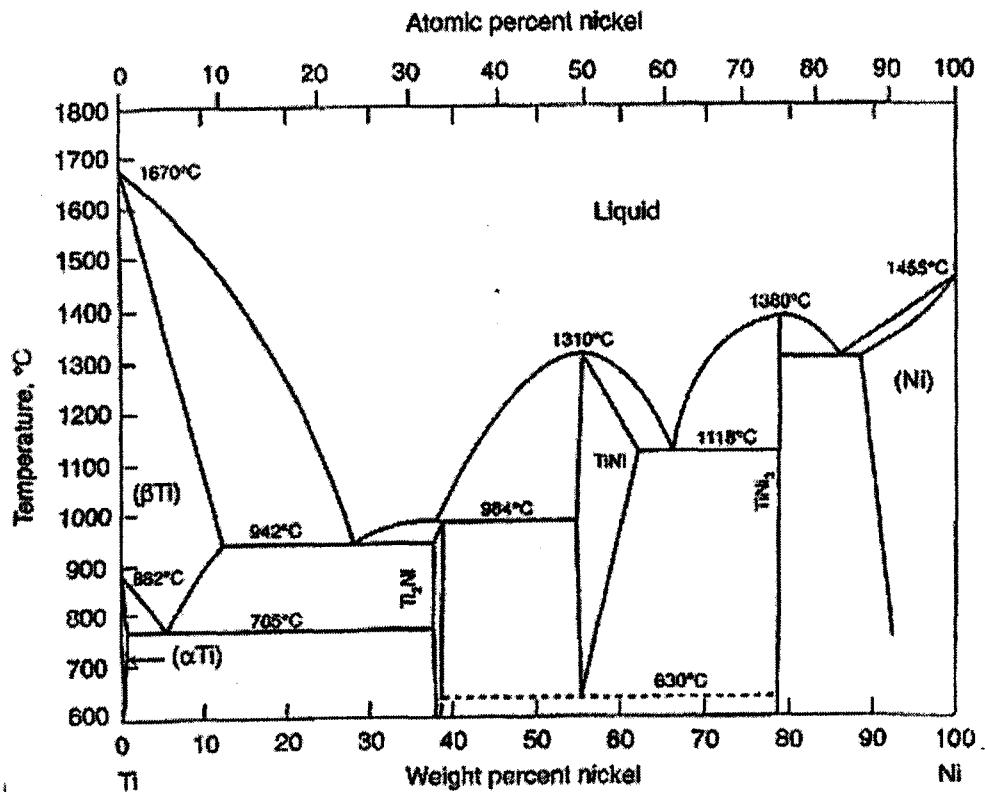


Figure 1

- (a) List the composition and temperature of ALL of the invariant points, congruent points, monotectics and miscibility gaps and what kind of reaction it is. (30 marks)
- (b) Given what you know the binary system in the phase diagram, how many free energy curves would be required to FULLY determine the phase diagram? Why? (30 marks)
- (c) Based on the phase diagram, would you expect Ni and Ti to have the same crystal structure? Why or why not? (40 marks)

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2. [a] (i) A eutectoid steel is cooled at a steady rate from 727°C to 200°C in exactly 1 day. Superimpose this cooling curve on the TTT diagram of Figure 2 (ii) From the result of your plot for part (a), determine at what temperature a phase transformation would first be observed. (iii) What would be the first phase to be observed?

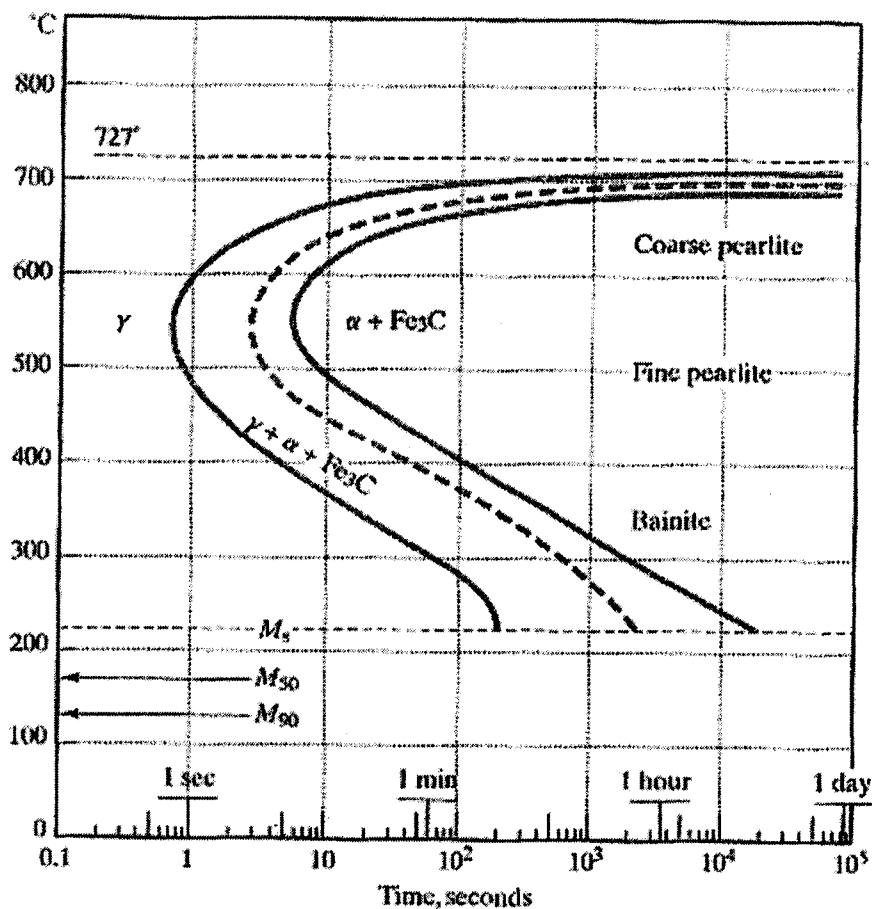


Figure 2

(50 marks)

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- [b] Derive an expression for r_c as a function of σ , the surface energy per unit area of the nucleus, and ΔG_v , the volume energy reduction per unit volume. Recall that the area of a sphere is $4\pi r^2$, and its volume is $\left(\frac{4}{3}\right) \pi r^3$.

The work of formation, W , for a stable nucleus is the maximum value of the net energy change (at r_c). Derive an expression for W in terms of σ and ΔG_v . r_c is the critical radius.

(50 marks)

3. [a] The ideal stoichiometry of the γ phase in the Al-Mg system is $Al_{12}Mg_{17}$.
 (i) What is the atomic percentage of excess Al in the most aluminum-rich γ composition at $450^\circ C$? (ii) What is the atomic percentage of excess Mg in the most magnesium-rich γ composition at $437^\circ C$?

(See Figure 3)

Atomic weight : Al : 26.98
 : Mg : 24.31

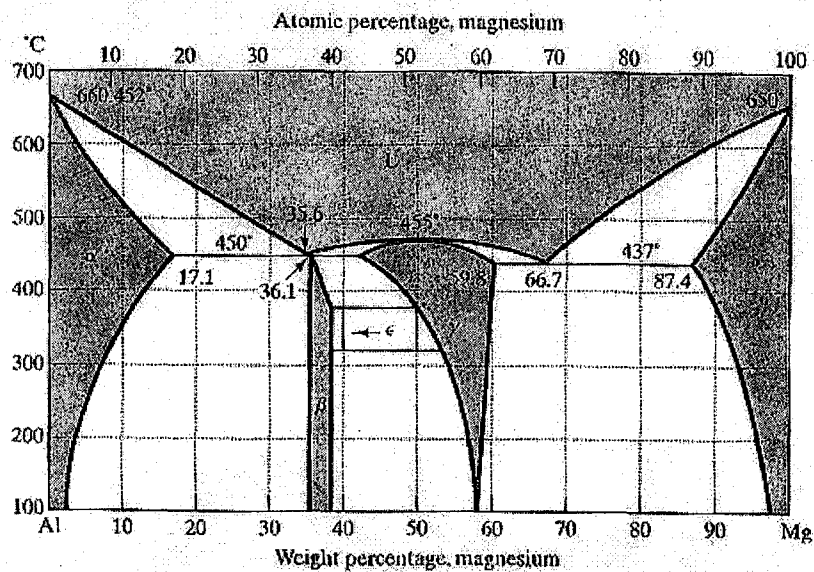


Figure 3

(75 marks)

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- [b] Suppose that you have a crucible containing 1 kg of an alloy of composition 90 wt % Sn-10 wt % Pb at a temperature of 184°C. How much Sn would you have to add to the crucible to completely solidify the alloy without changing the system temperature? (Figure 4)

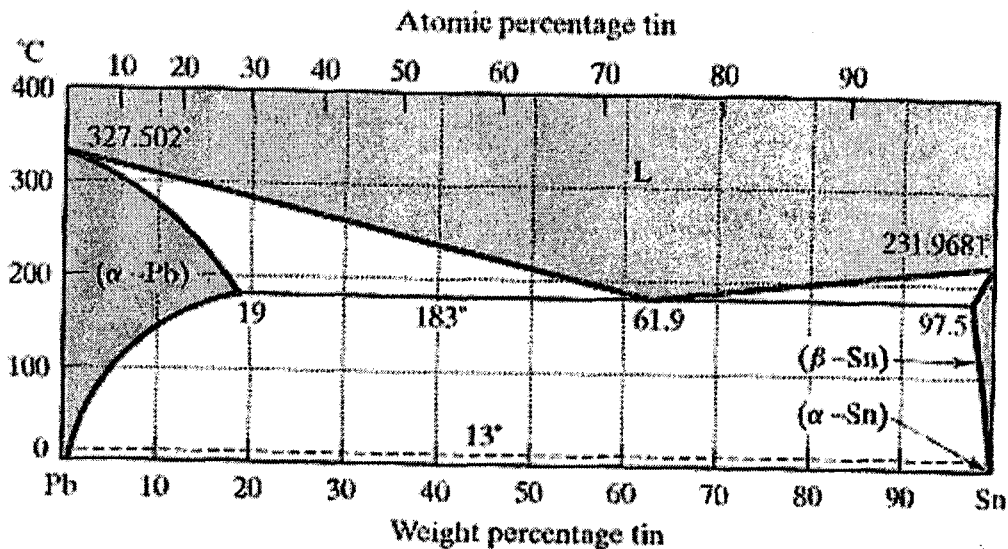


Figure 4

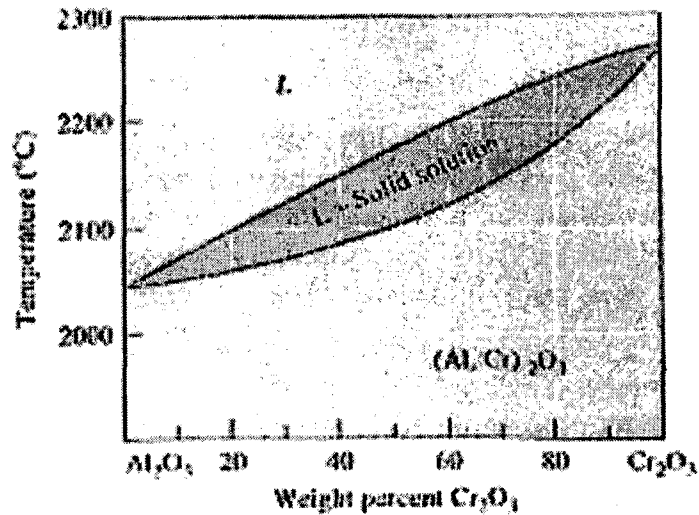
(25 marks)

4. [a] One way to repair dents in a metal is to wipe a partly liquid-partly solid material into the dent, then allow this filler material to solidify. For our application, the wiping material should have the following specifications: (1) a melting temperature below 230°C, (2) a tensile strength in excess of 6000 psi, (3) be 60% to 70% liquid during application, and (4) the lowest possible cost. Design an alloy and repair procedure that will meet these specifications. Consider the Pb-Sn system for your answer. (Refer again Figure 4)

(50 marks)

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- [b] One method to improve the fracture toughness of a ceramic materials is to reinforce the ceramic matrix with ceramic fibers. A materials designer has suggested that Al_2O_3 could be reinforced with 25% Cr_2O_3 fibers, which would interfere with the propagation of any cracks in the alumina. The resulting composite is expected to operate under load at 2000°C for several months. Criticize the appropriateness of this design.



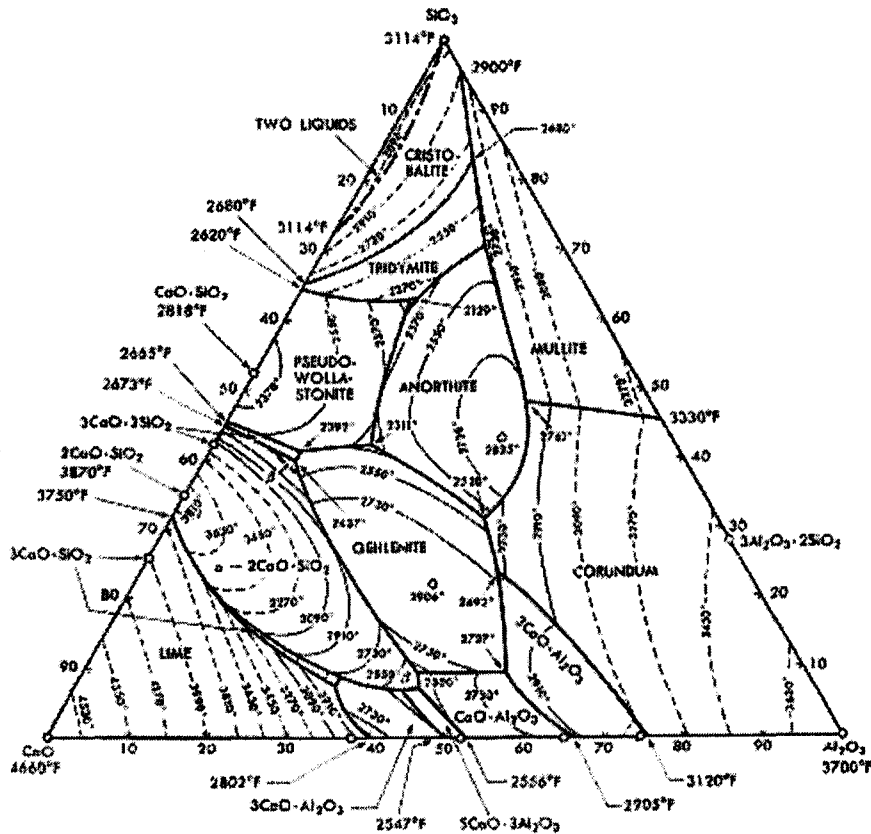
✓ The Al_2O_3 - Cr_2O_3 phase diagram

Figure 5

(50 marks)

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5. A 500 kg batch of impure clay has been fired to give a mixture containing 68% SiO_2 , 28% Al_2O_3 and 4% CaO . It is mixed with calcined limestone (95% CaO , 5% SiO_2) to make portland cement.



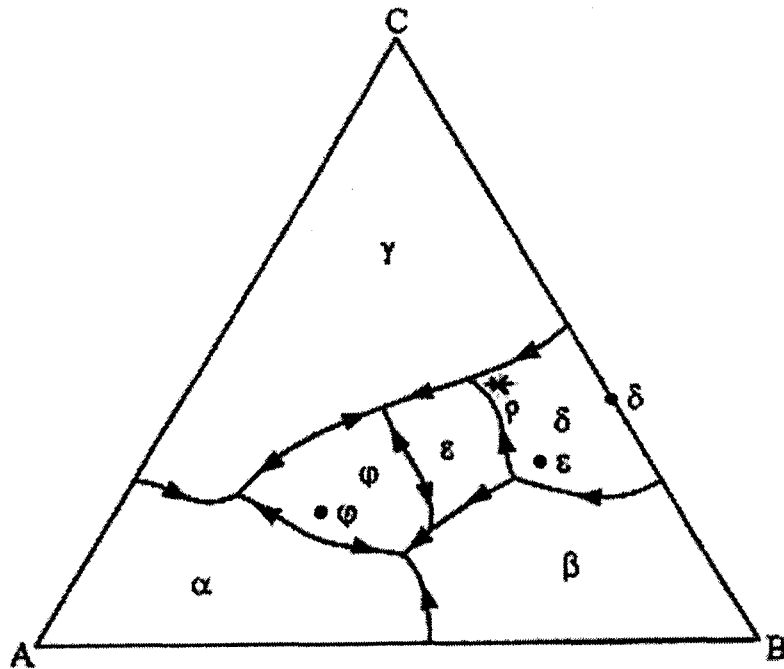
The $\text{CaO-Al}_2\text{O}_3\text{-SiO}_2$ liquidus diagram. The isotherms may be compared with elevation contours on a topographic map. (U.S. Steel, Making, Shaping and Treating of Steel, 7th ed. Pittsburgh: U.S. Steel Corp., 1957)

- How many kilograms of calcined limestone are required if the CaO/SiO_2 ratio of the cement is to be $\frac{1}{3}$?
- What would be the composition and the liquidus temperature of the mixture?

(100 marks)

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6. Referring to the figure given below :

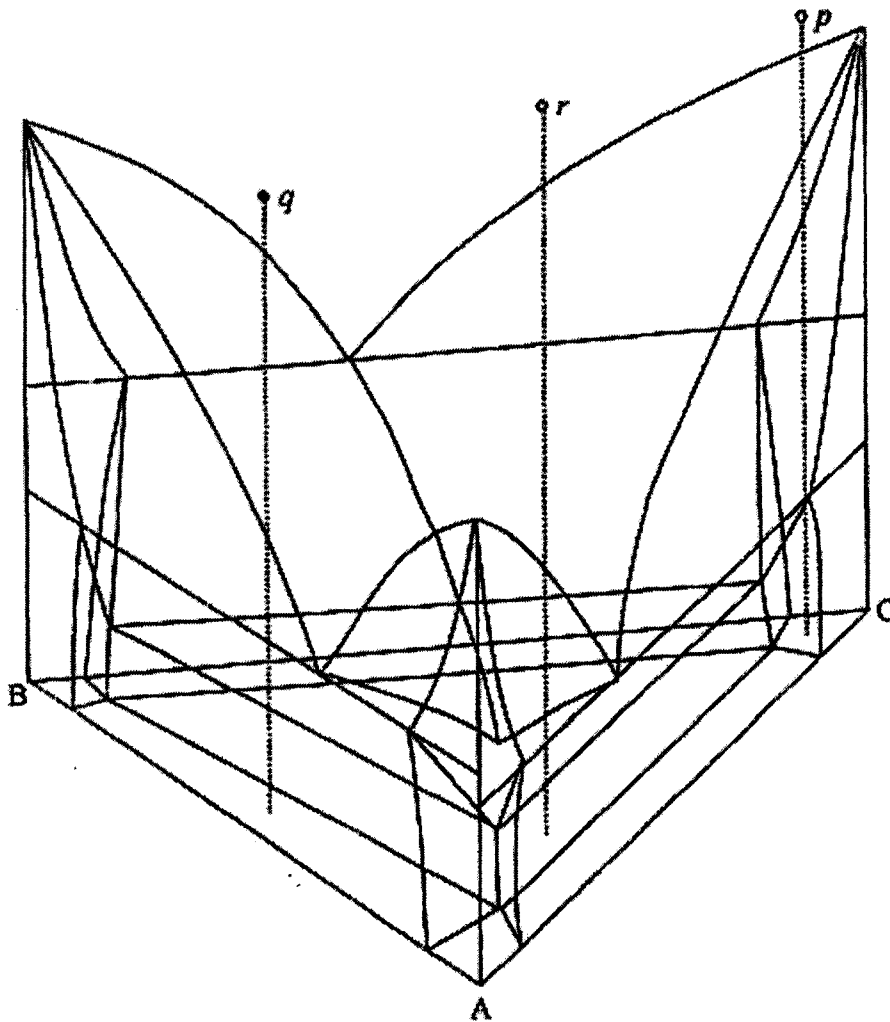


- Determine whether binary compound δ and ternary compounds ϵ and ϕ melt congruently or incongruently.
- Draw all Alkemade lines.
- Determine the crystallization path of a liquid of composition p.

(100 marks)

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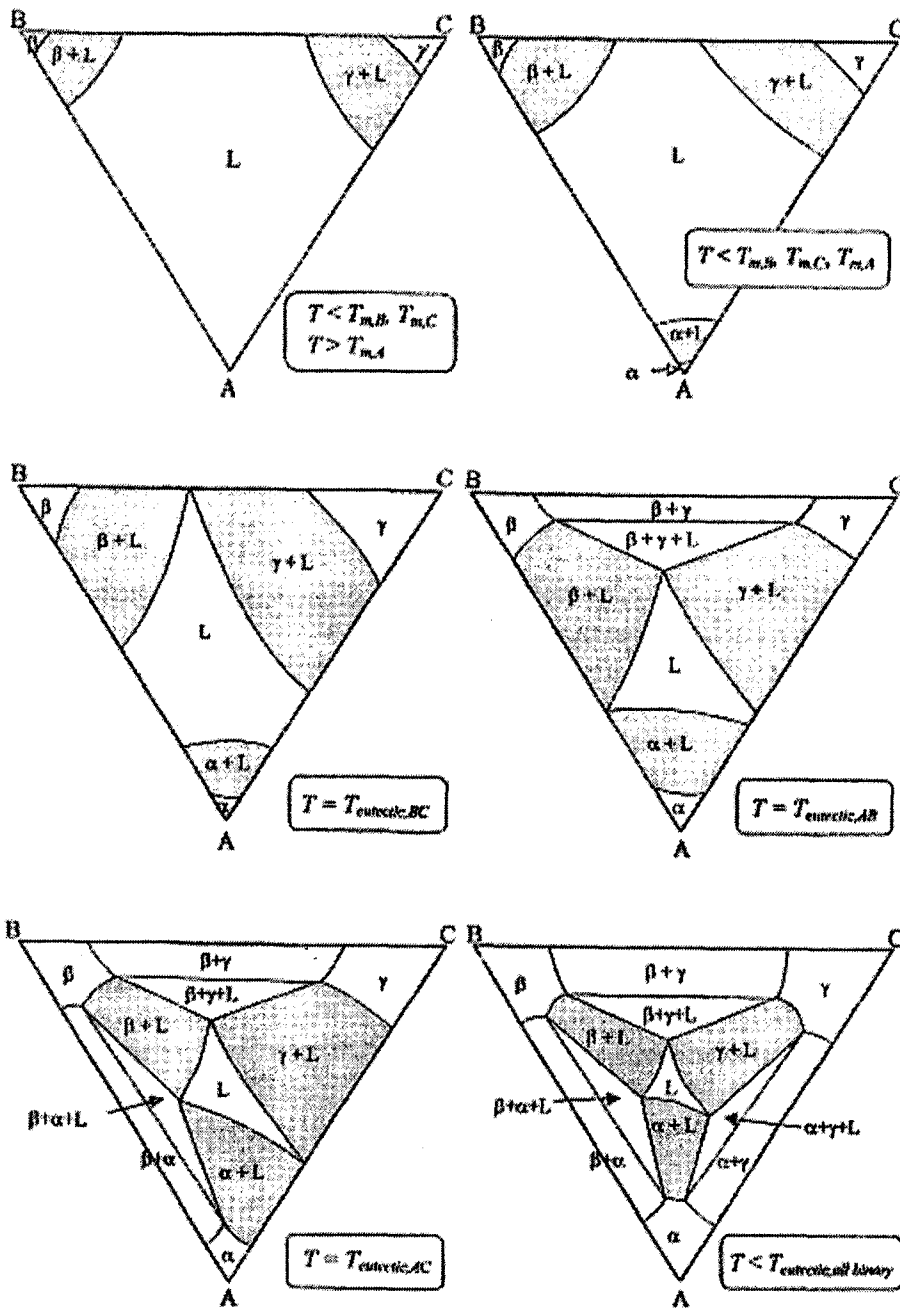
7. ABC ternary system forms three binary eutectics and a ternary eutectics as shown below. Discuss equilibrium cooling paths for the overall compositions p , q and r indicated in the diagram. Discuss also the change in microstructure that should occur during cooling.



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Shown in the following are the isothermal sections at a number of different temperatures of the hypothetical system ABC given above :

(100 marks)



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