UNIVERSITI SAINS MALAYSIA

First Semester Examination
Academic Session 2010/2011

November 2010

EBB 512/3 – Phase Diagram and Phase Equilibra

Duration : 3 hours

Please ensure that this examination paper contains ELEVEN printed pages and TWO pages APPENDIX before you begin the examination.

This paper consists of SEVEN questions.

Instruction: Answer **FIVE** questions. If candidate answers more than five questions only the first five questions answered in the answer script would be examined.

The answers to all questions must start on a new page.

All questions must be answered in English.

…2/-

1. Considering a binary solution containing A and B, based on quasi-chemical model show that for an ideal solution the following relationship is true

$$E_{AB} = (E_{AA} + E_{AB})/2$$

where:

E_{AA} is the bond energy for A-A bonds

E_{BB} is the bond energy for B-B bond

E_{AB} is the bond energy for A-B bons.

Define clearly other terms used in the derivation.

Explain what is/are the characteristic of the solution when $E_{AB} < (E_{AA} + E_{BB})/2$ and $E_{AB} > (E_{AA} + E_{BB})/2$.

(100 marks)

2. For the following questions please refer to Figure 1 for your answer. [**Figure 1 in Appendix should be submitted together with the answer script**].

[a] Label all the two-phase fields on the SiO_2 – Al_2O_3 phase diagram.

(15 marks)

[b] Identify the invariant reactions in the SiO_2-Al_2O_3 system.

(15 marks)

[c] Because of their high-temperature stability and their resistance to hot environments the include liquids and gases,ceramic materials are used as refractories. The SiO_2-Al_2O_3 system forms the basis for the production of a class of materials used in the refractories industry. A starting material that is readily available is kaolinite, $Al_2O_3.2SiO_2.2H_2O$. If kaolinite is heated to 1500^oC and held until it has been equilibrated, what phases will be present,what are their compositions and how much of each phase is present?

(35 marks)

[d] What is the maximum use temperature for a refractory made from kaolinite?

(15 marks)

[e] How much Al_2O_3 must be added to kaolinite in order to significantly increase its maximum use temperature?

(20 marks)

3. [a] Based on the free energy curves given in Figure 2, sketch the possible phase diagram of this binary system.

Figure 2

(35 marks)

[b] Calculate the phase present, compositions and the amount (in weight percent) for the microstructure at 1000^{o}C for a spinel ($MgO.Al_2O_3$) refractory with 1 wt% excess MgO (i.e 1 g MgO per 99 g $MgO.Al_2O_3$). Refer Figure 3.

Figure 3

(45 marks)

[c] Briefly explain why upon solidification an alloy of eutectic composition forms a microstructure consisting of alternating layers of two solid phases.

(20 marks)

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4. [a] A partially stabilized zirconia (for a novel structural application) is desired to have an equal weight fractions of tetragonal and cubic zirconia at an operating temperature of 1500^{o}C. Calculate the proper CaO content (in weight %) for this structural ceramic. Refer Figure 4.

Figure 4

(35 marks)

[b] A solder batch is made by melting together 64 g of a 40:60 Pb-Sn alloy with 53 g of a 60:40 alloy. Calculate the amounts of α and β phase that would be present in the overall alloy, assuming it is slowly cooled to room temperature, 25^{o}C. Refer Figure 5.

Figure 5

(35 marks)

[c] For an iron-carbon alloy of composition 5wt%C-95wt%Fe , draw sketches of microstructure that would be observed for conditions of very slow cooling at the following temperatures: (i) 1175^{o}C (ii) 1145^{o}C and (iii) 700^{o}C. Refer Figure 6.

Figure 6

(30 marks)

5. [a] When a phase transformation occurs such as a liquid phase transforming to a solid below its melting temperature, what are the two steps involved in the process. Briefly describe each.

(30 marks)

[b] The expression $X = 1-\exp[-(kt)^n]$ is a powerful empirical function that is useful in describing the kinetics of diffusional transformations. In the equation, X is the fraction transformed, k is a rate constant having units of reciprocal time, t is time and n is a unitless constant. Sketch the behavior of this function over a range times that demonstrated why this expression is useful for describing microstructural changes like recrystallisation,or the decomposition of austenite to form pearlite.

(25 marks)

[c] Figure 7 are IT or time-temperature transformation diagrams for a hypoeuctectoid, eutectoid and hypereutectoid alloy.

(i) Which diagram is associated with a composition that is hypoeutectoid,eutectoid and hypereutectoid, and why? **[Figure 7 in Appendix should be submitted together with the answer script]**.

(ii) Label the regions on each diagram.

(iii) If a thin specimen of alloy II is quenched instantaneously from 900^{o}C to 550^{o}C, held for 1 second, and quenched to room temperature,what phases will be present in the microstructure.

(45 marks)

6. A ternary Ag-Cu-Cu_3P system is represented in the following Figure 8. Each of the binary systems contains a eutectic and the ternary system contains an invariant eutectic: $L \leftrightarrow Ag + Cu + Cu_3P$. Solid solubility, which is small at room temperature, is neglected here. For an alloy containing 50 wt% Cu_3P and 5 wt% Ag, determine:

   (i) The percentage of liquid present at the temperature where separation of Cu_3P begins.

   (ii) The proportion of the phases present at the stage when the liquid contains 10 wt% Ag and lies on the $L \leftrightarrow Ag + Cu + Cu_3P$ valley.

   (iii) The percentage of primary phase, and of binary and ternary eutectic mixtures respectively present at room temperature (assume equilibrium conditions and neglect solid solubility).

Figure 8

(20 marks)

7. [a] Elaborate on the following cases. In each case, which phase diagram would you refer to? Discuss what would be the purpose of using the phase diagram you mentioned and the result that you will get out of the diagram.

(i) Study of the IMC formation of lead-free Sn-Ag-Cu solder reflow on Ni-P/gold substrate and effect of alloying elements (Fe, Sb, Bi and In).

(ii) Study of composition (and possible adjustment in composition) of slag from iron making process (EAF slag or blast furnace slag). The slag contains mainly CaO, SiO_2 and Al_2O_3 plus some remaining iron oxides.

(iii) Formulation of a ceramic whiteware body (typical combination of clay, flux and filler).

(12 marks)

[b] Figure 9 is the phase diagram of the ABC system. Discuss solidification paths for the compositions p, q and r indicated on the diagram.

Figure 9: Phase diagram of ABC system

(8 marks)

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APPENDIX (Figure 1)

APPENDIX (Figure 7)

IT diagrams for three plain carbon steels: a hypoeutectoid, a hypereutectoid, and a eutectoid