Registration No. : | | | | | | | | | | |

Total number of printed pages – 3

B. Tech

PCMT 4301

Fifth Semester Examination – 2013

PHASE TRANSFORMATIONS AND HEAT TREATMENT

BRANCH : MM, MME

QUESTION CODE : C-405

Full Marks – 70

Time : 3 Hours

*Answer Question No. 1 which is compulsory and any **five** from the rest. The figures in the right-hand margin indicate marks.*

1. Answer the following questions : 2×10

(a) What is chemical potential ? Show how the chemical potentials can be obtained from the free energy composition curve of an ideal binary solution.

(b) Show and explain the condition for equilibrium in a heterogeneous system containing two phases.

(c) Calculate the undercooling that is required for liquid to crystal transformation in tin. The enthalpy of fusion for tin is 0.42 GJm^{-3} (14 cal/gm). Appreciable nucleation occurs when the free energy of the critical nucleus is 1.5×10^{-19} J. The liquid-crystal interfacial energy is 0.055 Jm^{-2}. The melting temperature of tin is 232°C.

(d) Calculate the critical radius of the copper nucleus during solidification of liquid copper at 983°C. The enthalpy of fusion of copper is 1.88 GJm^{-3} (50 cal/gm). The liquid-crystal interfacial energy is 0.144Jm^{-2}. The melting temperature of copper is 1083°C.

(e) What are the basic processes taking place during recovery ?

(f) How do the dissolved impurities in a deformed metal influence the recrystallization kinetics ?

(g) Distinguish between lath and plate martensite.

(h) Calculate the degrees of freedom in the $(\alpha + \gamma)$ region of $Fe\text{-}Fe_3C$ system.

(i) What factors influence the Critical Cooling Rate and the position of the TTT curve of a steel ?

P.T.O.

(j) How do the alloying elements in steel influence the eutectoid temperature and the eutectoid composition ?

2 (a) Derive and explain the expression for the molar Gibbs free energy as a function of composition of a regular binary solution by using the quasichemical approach. Show and explain through suitable diagrams the Gibbs free energy change on mixing a regular binary solution for different values of ΔH_{mix} (when $\Delta H_{mix} < 0$ and when $\Delta H_{mix} > 0$) and temperature. 5

(b) Consider a one-dimensional diffusion couple problem, where two infinitely long bars of different but uniform concentrations, say C_2 and C_1 ($C_2 > C_1$), respectively, are joined end to end. Diffusion is then carried out for a specific period of time at a higher temperature. Give the boundary conditions in this problem. When coefficient of diffusion, D is independent of concentration, derive the expression for C (x, t) and graphically show the concentration of solute as a function of the distance from the interface, x at different values of time, t. 5

3. (a) Give the total free energy change, ΔG, accompanying the formation of a spherical new phase particle by homogeneous nucleation. Graphically show and explain the variation of free energy change, ΔG, during homogeneous nucleation, as a function of particle radius, r, at different temperatures. Explain critical free energy of nucleation and critical radius. 5

(b) Explain the nucleation of the new phase particle, β, at the grain boundary between two α grains. Derive the free energy change during this type of heterogeneous nucleation, ΔG_{het}. Give the critical values of Gibbs free energy of heterogeneous nucleation, ΔG^*_{het} and the rate of heterogeneous nucleation, I_{gb}. 5

4. (a) Calculate the homogeneous nucleation rate in liquid copper at undercoolings of 180K and 200K using the following data and give your observations:

Latent heat of fusion per unit volume, $L = 1.88 \times 10^9\ Jm^{-3}$,

Melting temperature of copper, $T_m = 1356$ K,

Solid-liquid interfacial energy, $\gamma_{SL} = 0.177 J\ m^{-2}$,

The frequency with which any one of the atoms in the parent phase facing the critical sized particle can cross the interface to join the product particle, $\nu' = 10^{11}\ s^{-1}$,

Number of atoms per unit volume in the liquid, $N_t = 6 \times 10^{28}$ atoms m^{-3},

Boltzmann's constant, $k = 1.38 \times 10 \times 10^{-23}\ JK^{-1}$ 5

(b) Explain diffusion controlled growth during the continuous precipitation of β phase particles from a supersaturated solid solution of α in a binary system of A and B. Show the concentration of B atoms as a function of distance during continuous precipitation of β. Derive a general expression for the growth rate of β particles. For spherical particles, how does the growth rate, U, and the particle size, r, vary with time, t ? 5

5. (a) Draw the Iron-Iron carbide phase diagram and label the important phase fields, temperatures and compositions. State the invariant reactions occurring in the system. 5

(b) Draw and explain the microstructures of a hypoeutectoid steel, a eutectoid steel and a hypereutectoid steel that have been cooled slowly to room temperature.

Calculate the fractions of proeutectoid ferrite, eutectoid ferrite and cementite in a 0.2% C steel that has been slow cooled to a temperature just below the eutectoid temperature. 5

6. (a) Explain the driving force for particle coarsening and the interaction between neighbouring precipitate particles using the Thomson-Freundlich equation and the coarsening kinetics using Greenwood's Model. 5

(b) Explain the mechanism and the kinetics of growth during pearlitic transformations. 5

7. (a) Draw the T-T-T diagram of eutectoid steel and label the phase fields. Label the time–temperature paths to produce the following microstructures : 5

(i) pearlite,

(ii) pearlite and martensite

(iii) bainite and

(iv) martensite

(b) Explain the characteristics of martensitic transformations. 5

8. Write short notes on any **two** : 5×2

(a) Carburizing

(b) Jominy end quench test

(c) Age hardening of Al-Cu alloys

(d) Martempering and austempering.
