Material Science
Homework Set 7
Due Wednesday Jan 02, 2019

1. Prove the critical radius $r^*=\frac{-2\gamma T_m}{\Delta H_f \Delta T}$ for homogeneous nucleation, where γ is surface free energy, T_m is melting temperature, ΔH_f is latent heat of solidification ,and ΔT is overcooling.
2. (1) Briefly describe homogeneous nucleation and heterogeneous nucleation

   (2) Prove the free energy associated with the heterogeneously nucleated embryo and briefly explain why the free energy associated with homogeneous is larger than heterogeneous nucleation.

   (Hint: Gibbs free energy and surface energy will be used. Some parameters are provided,

$$A_{ls} = 2\pi r^2(1 - \cos\theta)$$

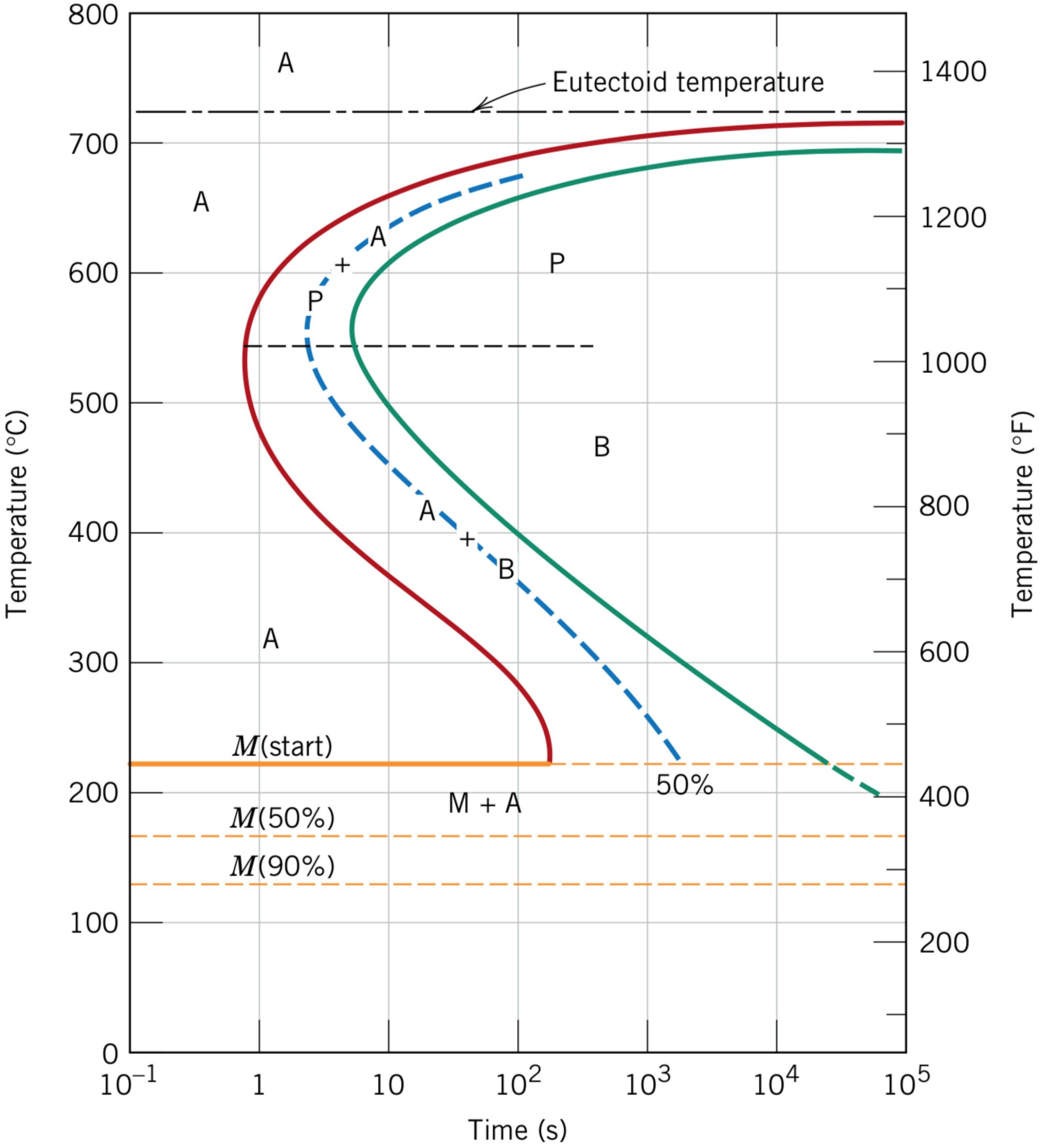
$$A_{sm} = \pi r^2 \sin^2\theta$$

$$V_c = 1/3\pi r^3(2 - 3\cos\theta + \cos^3\theta)$$

   Where V_c is the volume of the cap-shaped embryo, A_{ls} is the area of the cap that faces the liquid, A_{sm} is the area of the interface between the embryo and the mold wall.)
3. Compute the rate of some reaction that obeys Avrami kinetics, assuming that the constants n and k have values of 3.0 and 7×10^{-3}, respectively, for time expressed in seconds.
4. Answer the followings,
   (1) Briefly describe the phenomena of superheating and supercooling. Why do these phenomena occur?
   (2) Briefly cite the differences between pearlite, bainite, and spheroidite relative to microstructure and mechanical properties.
   (3) Cite two important differences between continuous cooling transformation diagrams for plain carbon and alloy steels. Why there is no bainite transformation region on the continuous cooling transformation diagram for an iron–carbon alloy of eutectoid composition.
   (4) Briefly explain why fine pearlite is harder and stronger than coarse pearlite, which in turn is harder and stronger than spheroidite.
   (5) Briefly describe the microstructural difference between spheroidite and tempered martensite, and then explain why tempered martensite is much harder and stronger.

5. Rank the following iron–carbon alloys and associated microstructures from the highest to the lowest tensile strength: (a) 0.25 wt%C with spheroidite, (b) 0.25 wt%C with coarse pearlite, (c) 0.60 wt%C with fine pearlite, and (d) 0.60 wt%C with coarse pearlite. Justify this ranking.
6. Using the isothermal transformation diagram for an iron–carbon alloy of eutectoid composition, specify the nature of the final microstructure (in terms of microconstituents present and approximate percentages of each) of a small specimen that has been subjected to the following time–temperature treatments. In each case assume that the specimen begins at 760℃ and that it has been held at this temperature long enough to have achieved a complete and homogeneous austenitic structure.
   (1) rapidly cool to 448℃ (840℉), hold for 10 s, then quench to room temperature.
   (2) Rapidly cool to 650℃, hold at this temperature for 10 s, rapidly cool to 400℃, hold for 40 s, then quench to room temperature.
   (3) Cool rapidly to 350℃ , hold for 5 s, then quench to room temperature. Reheat to 350℃ for 1.5 h and slowly cool to room temperature.
7. Using the isothermal transformation diagram for an iron–carbon alloy of eutectoid composition, and then sketch and label time–temperature paths on this diagram to produce the following microstructures:
   (1) 25% coarse pearlite, 25% fine pearlite, and 50% martensite
   (2) 50% martensite and 50% austenite
   (3) 100% spheroidite
   (4) 40% bainite and 60% martensite

※Please print next page in A4 paper and answer question 7.



Eutectoid temperature
A
A
A
A
+
P
P
B
A
+
B
M(start)
M + A
50%
M(50%)
M(90%)
Temperature (°C)
Temperature (°F)
Time (s)
800
700
600
500
400
300
200
100
0
1400
1200
1000
800
600
400
200
10^{-1}
1
10
10^2
10^3
10^4
10^5