Engineering 45
The Structure and Properties of Materials
Midterm 2 Examination
March 23, 2007

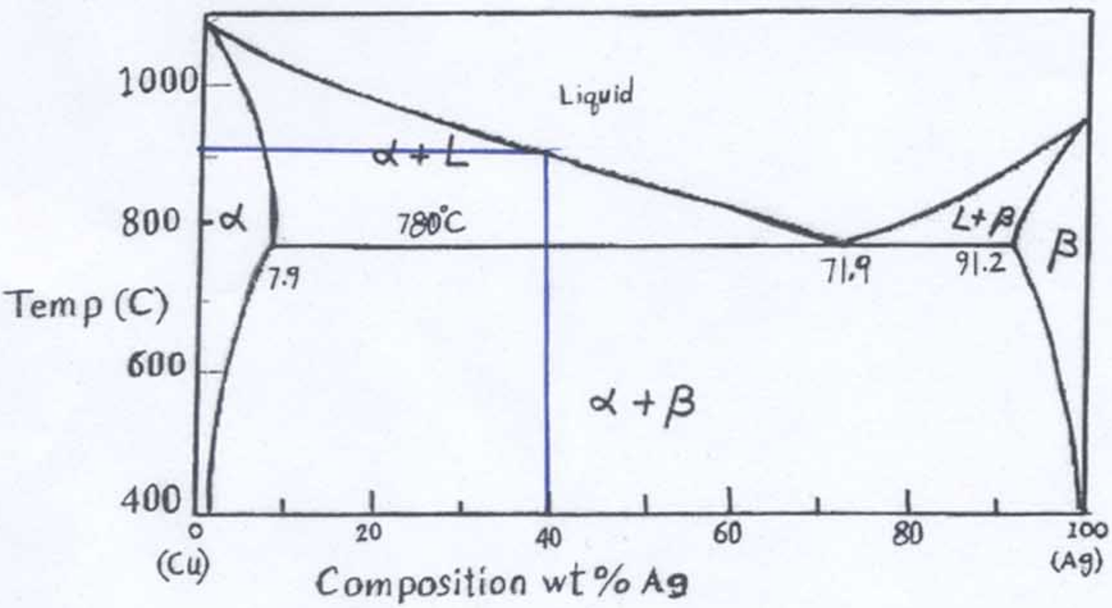
1a – 5pts	
1b – 5pts	
1c – 5pts	
1d – 5pts	
1e – 10pts	
2a – 10pts	
2b – 10pts	
2c – 10pts	
3a – 10pts	
3b – 5pts	
4a – 10pts	
4b – 5pts	
4c – 5pts	
4d – 5pts	

Name:	
Student ID number:	

Show all work!
No partial credit if you do not show your work!
Box your final answer on calculations!
Good Luck!

Problem 1:

Using the copper-silver phase diagram below: With 60 wt% Cu, 40 wt% Ag composition alloys slowly cooled from the liquid,



a) At what temperature does the first solid appear?
b) What phase is it?
c) What phases are present just below the eutectic temperature?
d) What are the compositions of the phases from part c?
e) What are the weight fractions of these phases?

5pts a) ~900°C

5pts b) α

5pts c) α + β

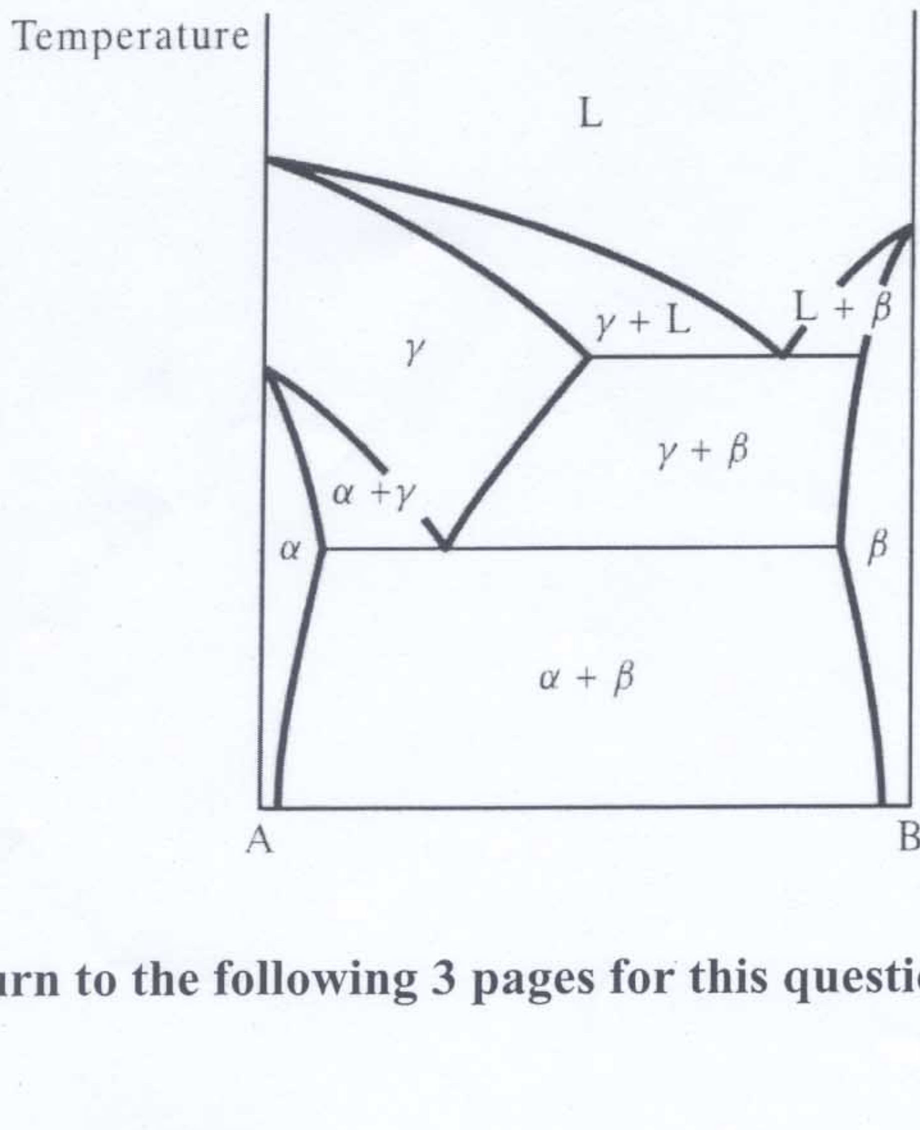
d) 2.5pts { α: Cu 92.1 wt%, Ag 7.9 wt%
2.5pts { β: Cu 8.8 wt%, Ag 91.2 wt%

e) 5pts $f_\alpha = \frac{91.2 - 40}{91.2 - 7.9} = 61.5\%$

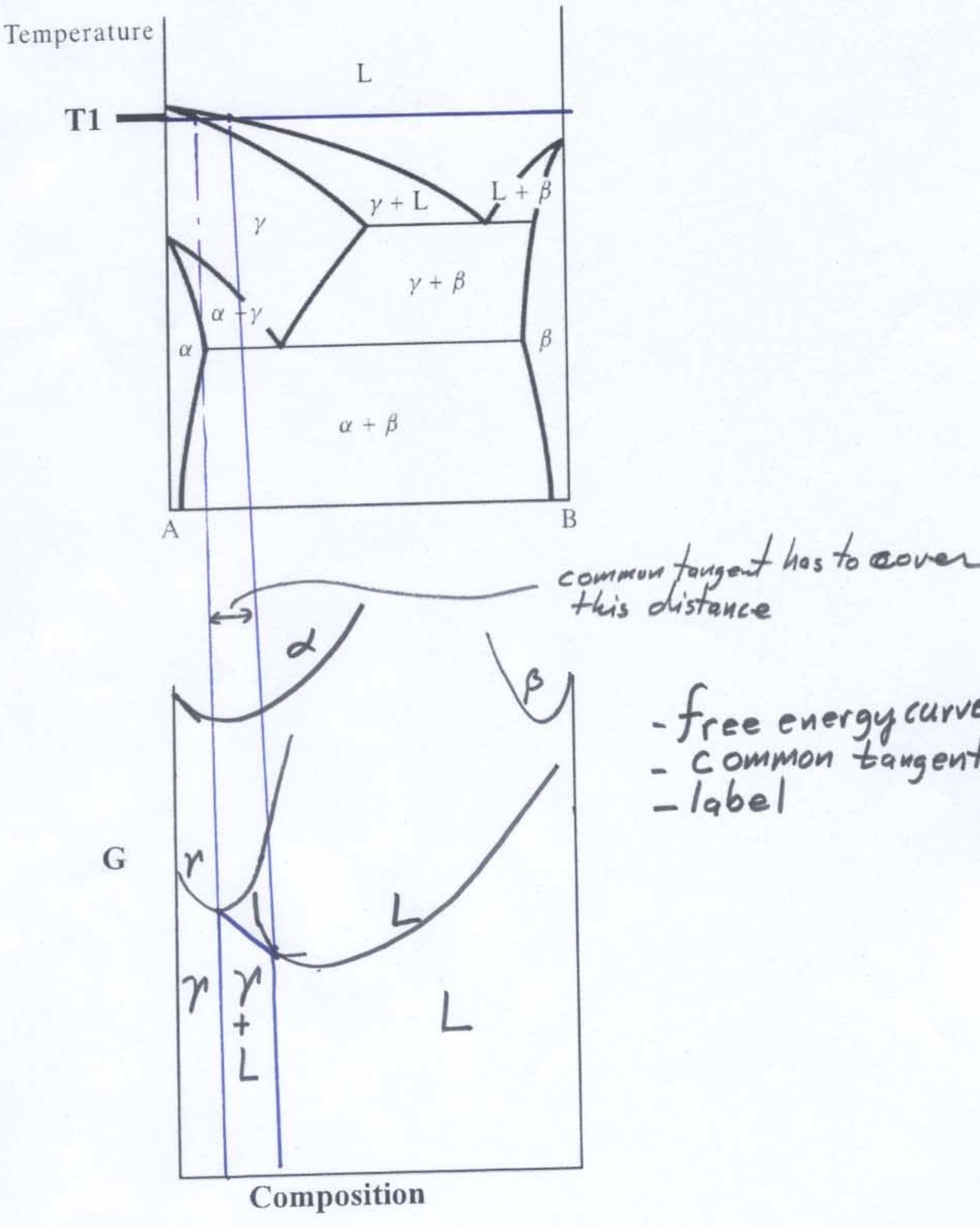
5pts $f_\beta = 1 - f_\alpha = 38.5\%$

Problem 2:

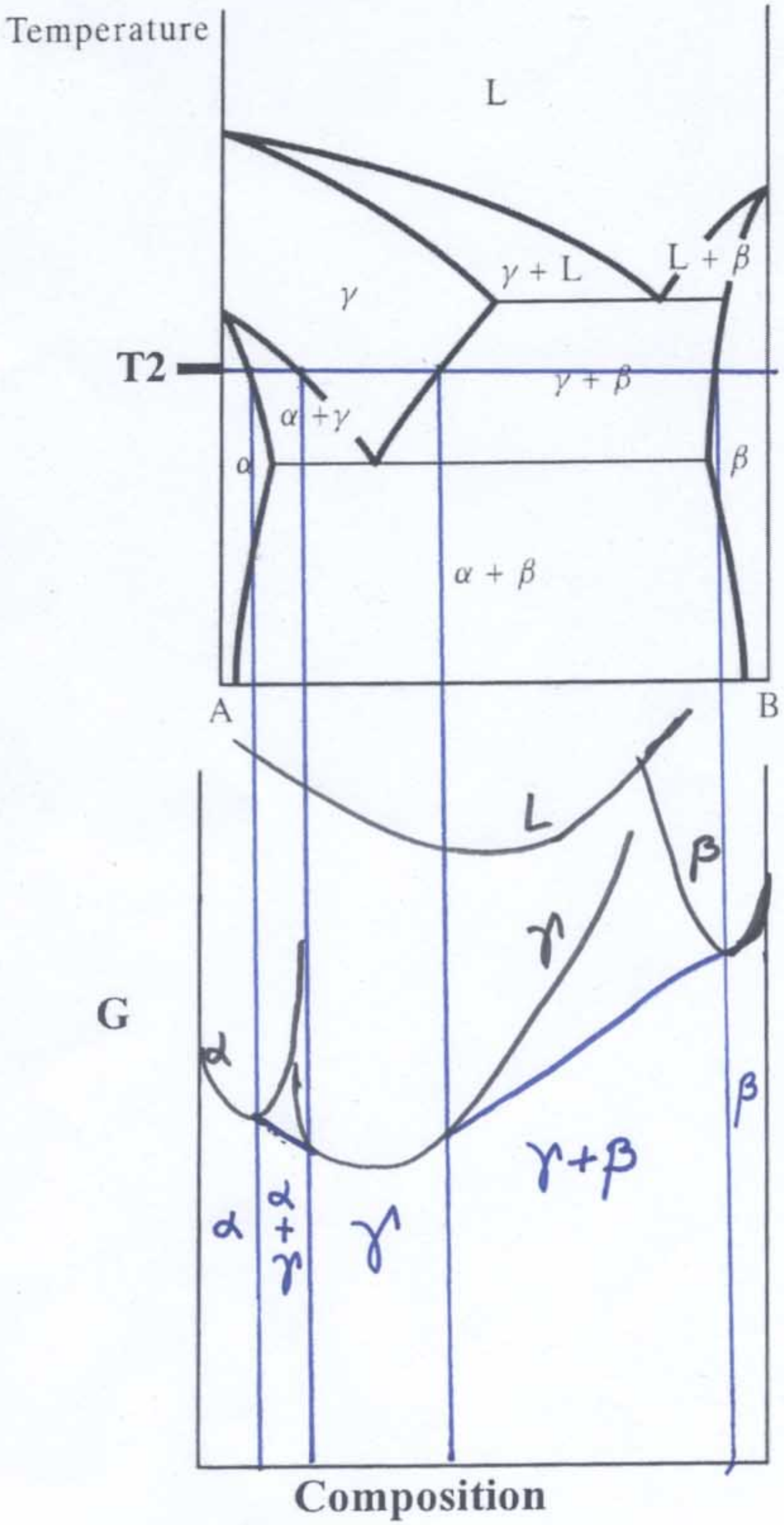
For the phase diagram below, ***on the following pages***, draw the appropriate free energy vs. composition curves for each of the three temperatures labeled on the phase diagram. Also draw in the isothermal lines which correspond to these temperatures.



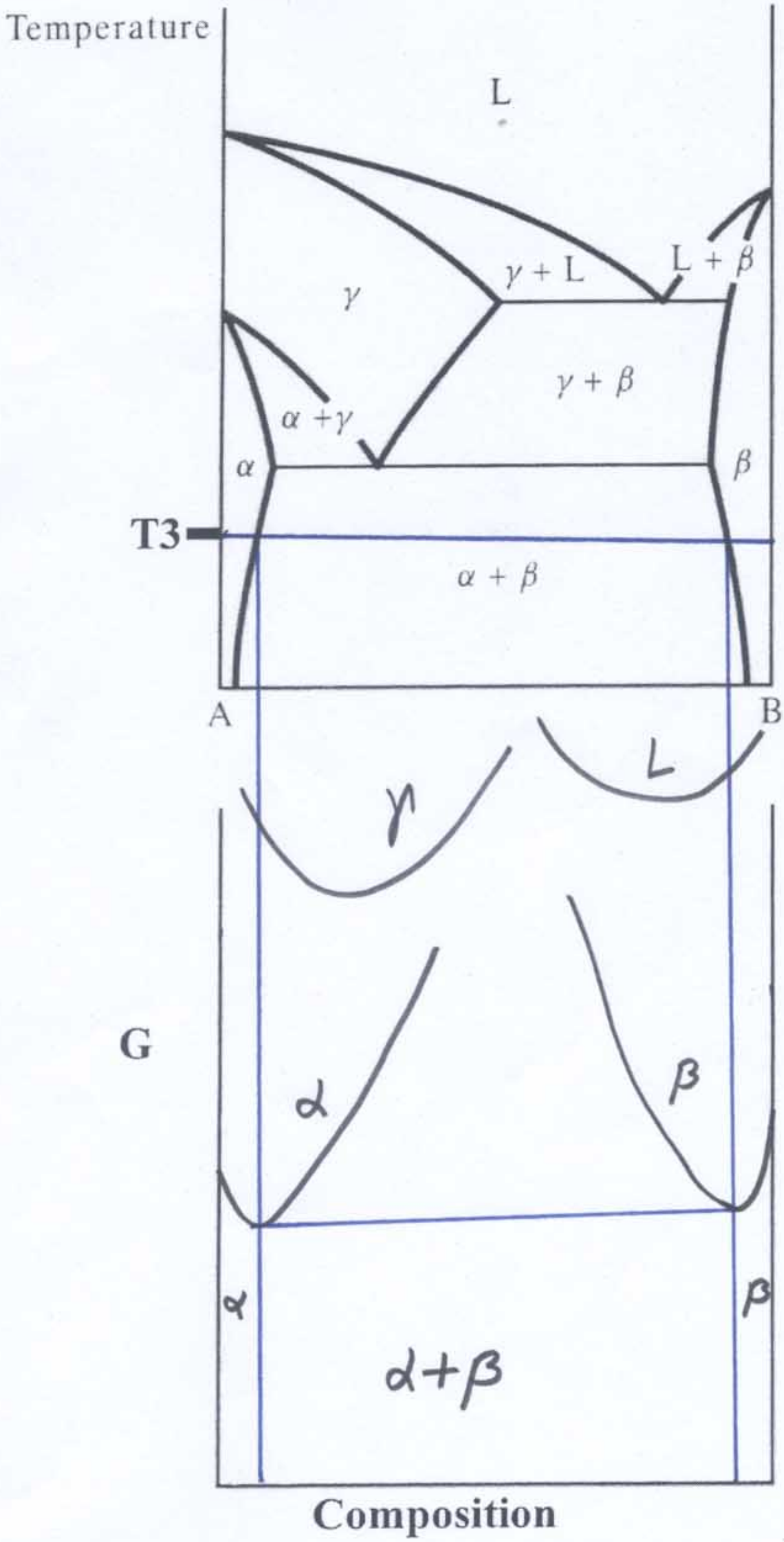
Turn to the following 3 pages for this question!



- free energy curves
- common tangents
- label



- curves
- common tangents
- label



- free energy curves
- common tangent
- label

Problem 3:

The diffusion rate of carbon in *alpha*-Fe and *gamma*-Fe are given below:

Constants: $D_0^{\alpha} = 7.9 \times 10^{-3}\ cm^2/s$

$D_0^{\gamma} = 2.1 \times 10^{-1}\ cm^2/s$

R = 1.987 cal/mol/K;

For the alpha phase: D_0 = 7.9e-3 cm^2/s; E = 18.1 kcal/mole

For the gamma phase: D_0 = 2.1e-1 cm^2/s; E = 33.8 kcal/mole

a) Calculate the respective diffusion coefficients for carbon in iron at 700 degrees C and 1000 degrees C.

b) Explain the magnitude of D (*alpha*) and D (*gamma*) in terms of the respective crystal structures. (Short Answer)

a) $T_1 = 700 + 273 = 973\,k$

$T_2 = 1000 + 273 = 1273\,K$

2pts for the correct eqn. $D = D_0 \exp\left(-\frac{E}{RT}\right)$

$D_{\alpha(973)} = 7.9 \times 10^{-3} \frac{cm^2}{s} \exp\left(\frac{-18100\ cal/mole}{1.987 \frac{cal}{mol\,k} \cdot 973k}\right)$

2pts → $= 6.8 \times 10^{-7}\ cm^2/s$

$D_{\alpha(1273)} = 7.9 \times 10^{-3} \frac{cm^2}{s} \exp\left(\frac{-18100 \frac{cal}{mole}}{1.987 \frac{cal}{mole \cdot k} \cdot 1273k}\right)$

2pts → $= 6.16 \times 10^{-6} \frac{cm^2}{s}$

$D_{\gamma(973)} = 2.1 \times 10^{-1} \frac{cm^2}{s} \exp\left(\frac{-33800\ cal/mole}{1.987 \frac{cal}{mole \cdot k} \cdot 973k}\right)$

2pts → $= 5.4 \times 10^{-9} \frac{cm^2}{s}$

$D_{\gamma(1273)} = 2.1 \times 10^{-1} \frac{cm^2}{s} \exp\left(\frac{-33800\ cal/mole}{1.987 \frac{cal}{mole \cdot k} \cdot 1273k}\right)$

2pts → $= 3.3 \times 10^{-7} \frac{cm^2}{s}$

b) - γ – high temperature phase; stable @ 1000°C

- α – low temperature phase; stable @ 700°C

5pts → - Diffusion of Carbon in α is 2 orders of magnitude larger at 700°C, while at 1000°C the diffusion coefficients are much closer.

Close packed structure vs. a more open structure.

Problem 4:

a) Consider a phase transformation that occurs at 1025 degrees C. The boundary energy, sigma (surface energy) = 0.50 J/m^2, and the value for the change in the volume free energy delta G for the reaction is -2.1e9 J/m^3 at 900 degrees C (it is 0 at 1025 degrees C).

   a. Determine the critical nucleus radius for homogeneous nucleation at 900 degrees C.
   b. Draw a ***G vs. T*** plot for a phase change for a liquid and solid. Label as needed.
   c. Draw the respective curves for ***r (radius of nucleus) vs.*** ~~T~~ ΔG for homogeneous nucleation for the following conditions. Label as needed.
      i. T > T(melt)
      ii. T = T(melt)
      iii. T < T(melt)
   d. Draw a typical ***T vs. ln(t)*** curve. Label as needed.

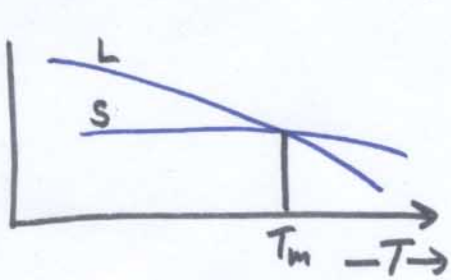
4a)

3pts - $\Delta G = \frac{4}{3}\pi r^3 \Delta G_v + 4\pi r^2 \sigma$

3pts - $\frac{d\Delta G}{dr} = 0 = 4\pi r^2 \Delta G_v + 8\pi r \sigma \Rightarrow r^* = -\frac{2\sigma}{\Delta G_v}$

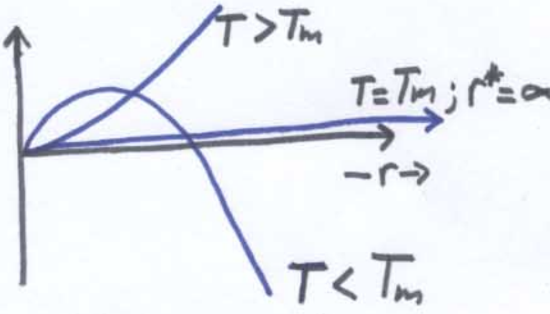
4pts - $r^* = -\frac{2(0.5\ J/m^2)}{(-2.1\times10^9\ J/m^3)} \simeq 0.5\times10^{-9}\ m$

4b)



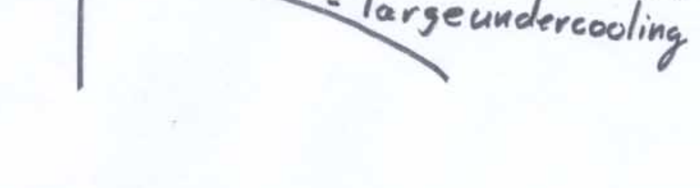
- 3pts General shape
- 2pts label

4c)



- ~~4~~pts General curves
- 1pts label

4d)



- 2pts curve
- 1pt label
- 2pts Identifying regions