26

NAME: [illegible] UCLA

Department of Materials Science and Engineering
Henry Samueli School of Engineering and Applied Science
University of California, Los Angeles

MSE 104, Midterm ver 1 (2 hr)
Winter 2017

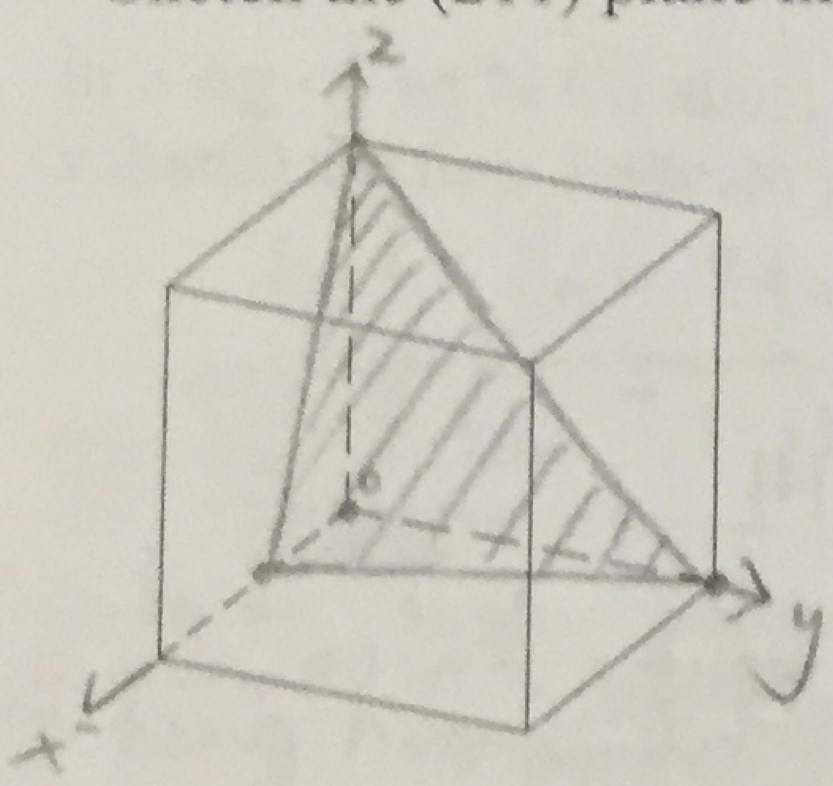
15 February 2017
Instructor: Mike Boldrick

Show all work and include units for full credit

1 (20 pts)	17
2 (25 pts)	25
3 (31 pts)	25
4 (24 pts)	23
TOTAL (100)	90

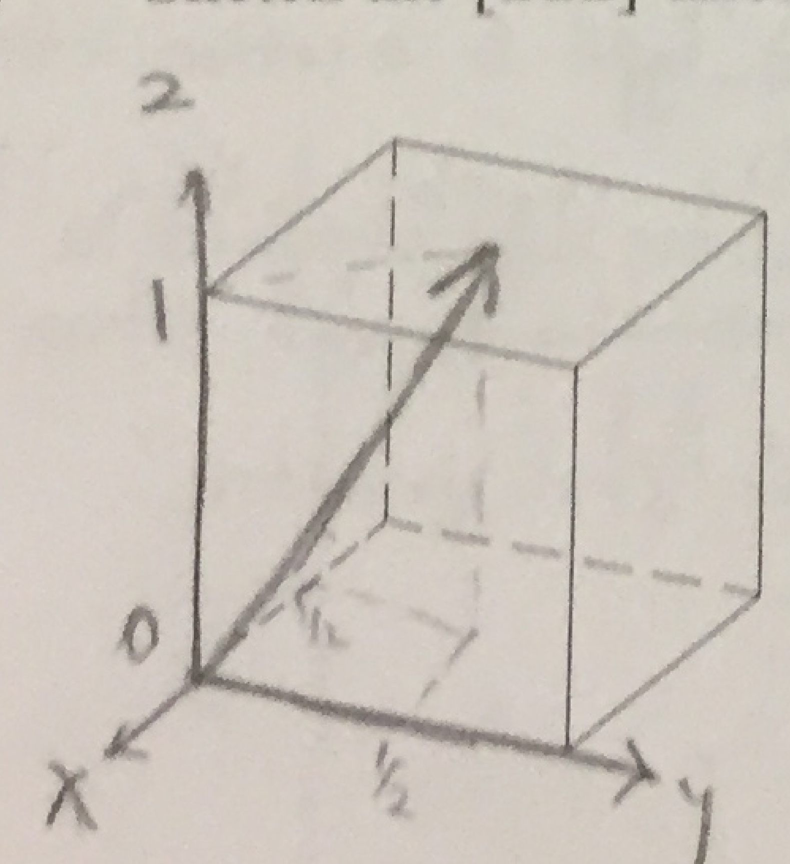
1. Short answer problems. **[20]**

(a) Sketch the (211) plane in the unit cell below. **[4]**



4

(b) Sketch the $[\bar{1}12]$ direction in the unit cell below. **[4]**



4

(c) What is the maximum solubility of Cu in Ni at room temperature? [4]

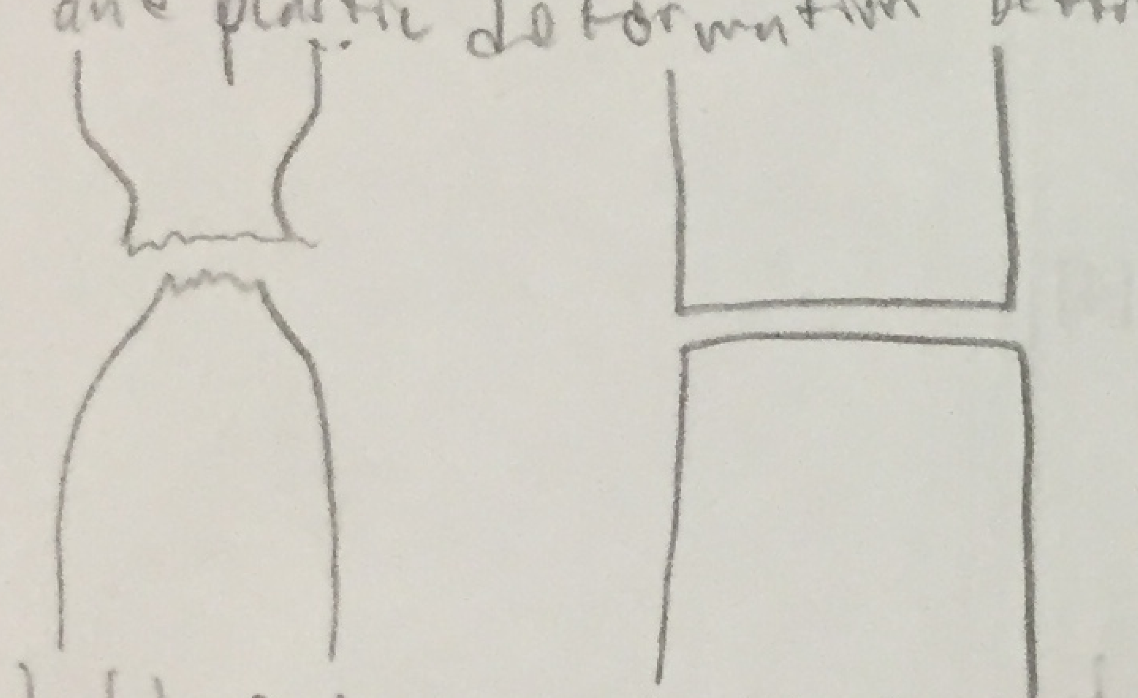
Room temp = 20 °C Below T = 1085 °C, Cu-Ni is all α-phase solid that can vary from 0 to 100 wt% Cu in Ni. Therefore, the maximum solubility of Cu in Ni is 100 wt% Cu.

4

(d) Materials with the body-centered cubic structure exhibit a distinct ductile-to-brittle transition. Describe, including a sketch, the ductile-to-brittle transition. [4]

Below a certain temperature (T_c)?, a body-centered cubic material will experience a ductile-to-brittle transition. This means the material will experience a significant decrease in strain for a given tensile stress, resulting in a sharp increase in ~~elastic modulus~~. This is accompanied by an increase in ~~hardness~~ and a lack of necking and plastic deformation before fracture.

2



ductile fracture   brittle fracture

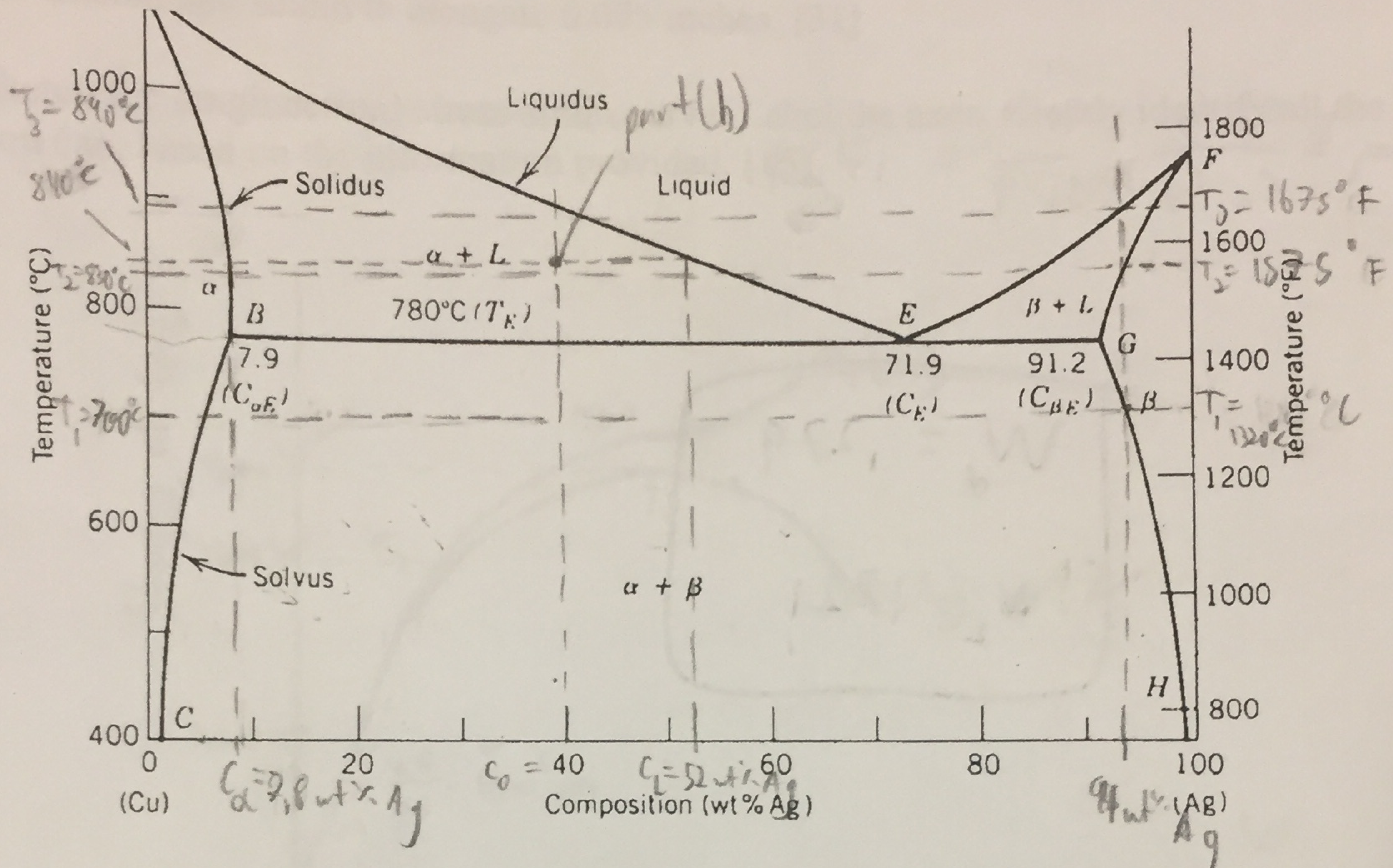
(e) Name and describe two types of defects found in ceramics. [4]

One type of defect found in ceramics is a vacancy, where an atom or formula unit is taken from its place in the crystal lattice and placed at an edge. This causes a hole and straining coulombic forces, but maintains stoichiometry. This can occur with either cations or anions. A second type is a cation interstitial, in which an extra cation is inserted in a gap in the crystal lattice. This not only induces straining coulombic forces, but also causes the overall cation-anion ratio of the compound to deviate from the stoichiometric

kind of

3

The phase diagram for the Cu-Ag system is shown below. The atomic weight and density of Cu are 63.55 g/mol and 8.96 g/cm^3, respectively. The atomic weight and density of Ag are 107.87 g/mol and 10.5 g/cm^3, respectively. **[25]**



(a) In a Ag - 6 wt.% Cu alloy, what are the temperature range(s) where two phases exist? Estimated value(s) are fine. Indicate your choice(s) on the phase diagram. **[5]**

6 wt% Cu = 94 wt% Ag   2 phases when α+β or β+L

α+β from T_0 = -273°C to T_1 = 700°C , β+L from 830°C to 890°C

5

(b) In a Cu - 40 wt.% Ag alloy, what phases are present at 840°C? **[5]**

α + L

5

(c) In (b) above, what are the compositions of the phases? **[5]**

C_α = 7.8 wt% Ag, 92.2 wt% Cu

C_L = 52 wt% Ag, 48 wt% Cu

5

(d) In (b) above, what are the amounts (in fraction or percent) of the phases present? **[10]**

$$W_\alpha = \frac{C_L - C_0}{C_L - C_\alpha} = \frac{52-40}{52-9} = .279$$

$$W_L = \frac{C_0 - C_\alpha}{C_L - C_\alpha} = \frac{40-9}{52-9} = .721$$

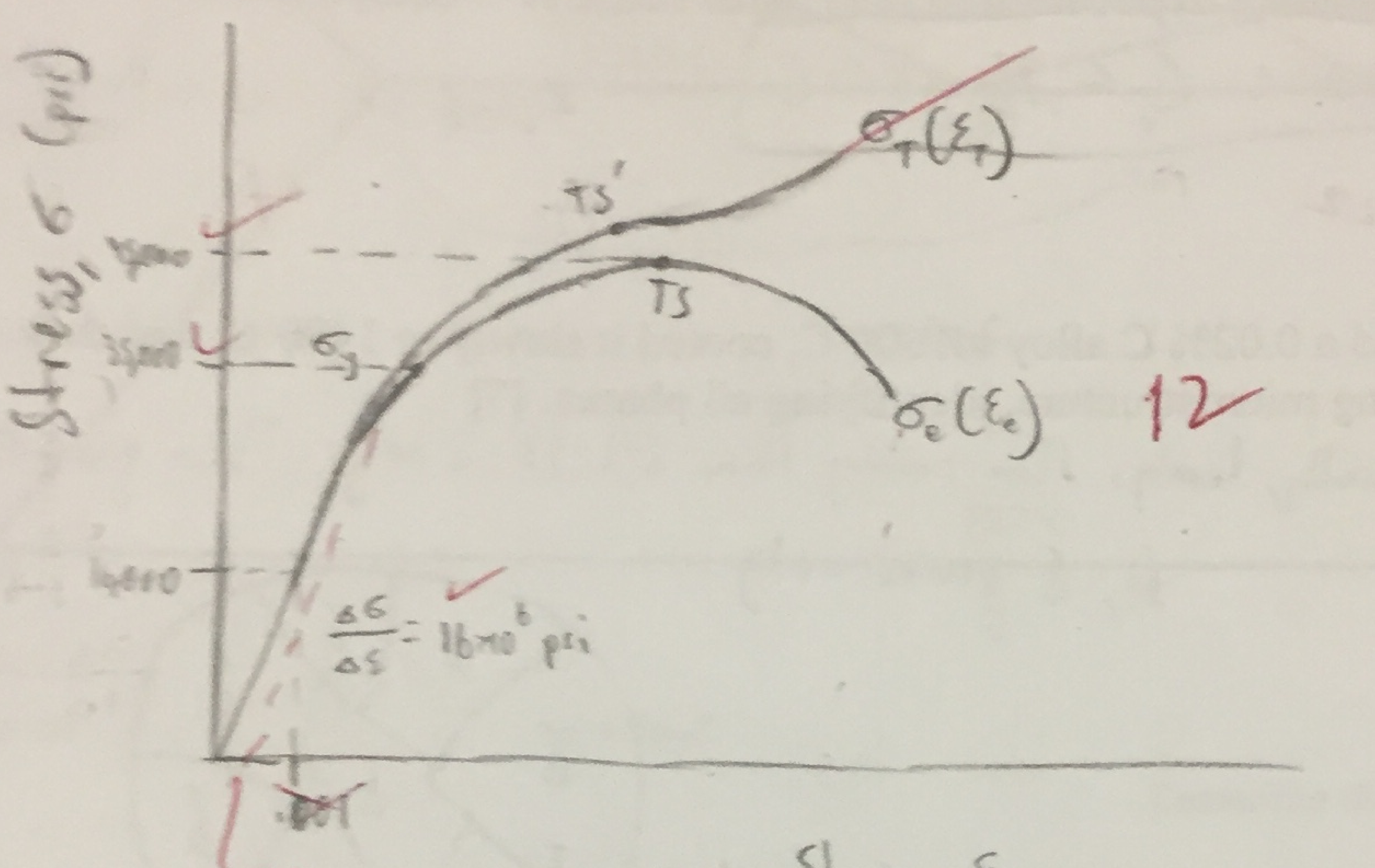
$W_\alpha = .279$,

$W_L = .721$

10

The job market was tough when you graduated, and you were forced to take a job with an ammunition manufacturer. One line of bullet shells is fabricated from cartridge brass (70 wt.% Cu). That alloy is known to have a yield strength of 35,000 psi, a tensile strength of 45,000 psi, and a modulus of elasticity of 16 x 10^6 psi. A cylindrical specimen of this alloy, 0.60 inches in diameter and 15 inches long, is stressed in tension and found to elongate 0.075 inches. **[31]**

(a) Sketch the (engineering) stress-strain curve. Label the axes. Clearly identify all the key points you can, based on the information provided. **[15]**



(b) On your sketch in part (a), sketch (and identify) the true stress – true strain curve. Exact numbers are *not* necessary. You only need to show its position relative to the engineering stress-strain curve. **[4]**

3

(c) If your company had not had the budget to perform a load-deflection test, what less-expensive test might you have performed to estimate the tensile strength of the brass? **[2]**

A Brinell hardness test could have been executed instead since HB and TS are related in a known way. This would work budgetarily since it does not require special samples or equipment and does not cause part failure. 2

(d) Identify two measures that might be taken to improve the fatigue resistance of this sample **[4]**

The fatigue resistance of this sample could be improved by shot-peening to induce compressive stresses to the surface to counter the applied tensile stress. Polishing to remove surface stress concentrators could also help reduce the likelihood of fatigue failure. 4

(e) What are the qualitative effects of strain hardening on this brass alloy (in terms of yield strength, tensile strength, and ductility)? Briefly explain the mechanism of strain hardening. **[6]**

Strain hardening causes the yield strength and tensile strength of the alloy to occur at stresses lower than the corresponding true strain values. As the material strain hardens, it can withstand greater applied stress with the same strain due to a decrease in ductility, requiring greater stress applications to further plastically deform.

A bit confused/confusing 4

4. You were such an outstanding performer at the ammunitions manufacturer that you got offered a new job … at an armor manufacturer. The company is fabricating its armor plates from steel. **[24]**

(a) What is the most important mechanical property for armor (material that will be exposed to high-velocity impact loads)? **[4]**

Fracture toughness is the most important characteristic, as the steel armor must resist critical failure with high-energy impacts. 4

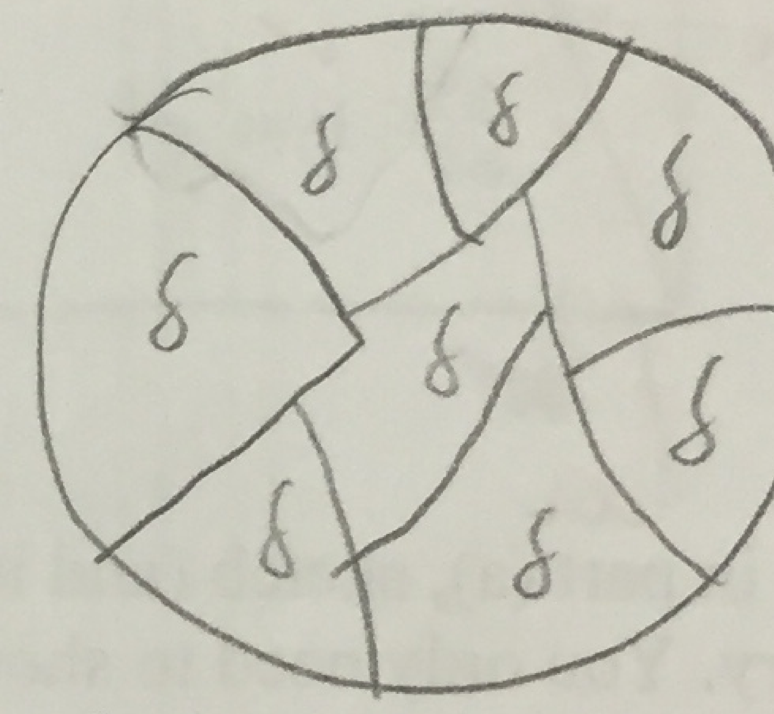
(b) If you must use a hypoeutectoid steel, what range of C compositions is available to you? **[5]**

~~.008 wt% C~~ $C < .76$ wt% C $< .008$ wt% C is "Pure iron", so

0.022   4

(c) You heated a 0.02% C alloy to1600°C, cooled it slowly to 1490°C, and then quenched it. Sketch the resulting microstructure, identifying all phases. **[7]**

Initially, L only, Slow cooling thru δ+L to δ only, Then quenched, retaining δ structure, δ1, δ grains only



7

(d) One sample steel armor plate you tested has a plane-strain fracture toughness of 62 MPa$\sqrt{\text{m}}$. You found that this sample failed at a stress of 250 MPa when the maximum length of a surface crack was 1.6 mm. What is the maximum allowable surface crack length (in mm) without fracture for a similar plate exposed to a stress of 250 MPa, but made from an alloy that has a plane strain fracture toughness of 51 MPa$\sqrt{\text{m}}$? **[8]**

$K_{IC} = Y\sigma_f\sqrt{\pi a}$ a = surface crack length K_{IC} = plane-strain fracture toughness σ_f = failure stress

$Y = \frac{K_{IC}}{\sigma_f\sqrt{\pi a}}$ $K_{IC}^2 = Y^2\sigma_f^2\pi a$

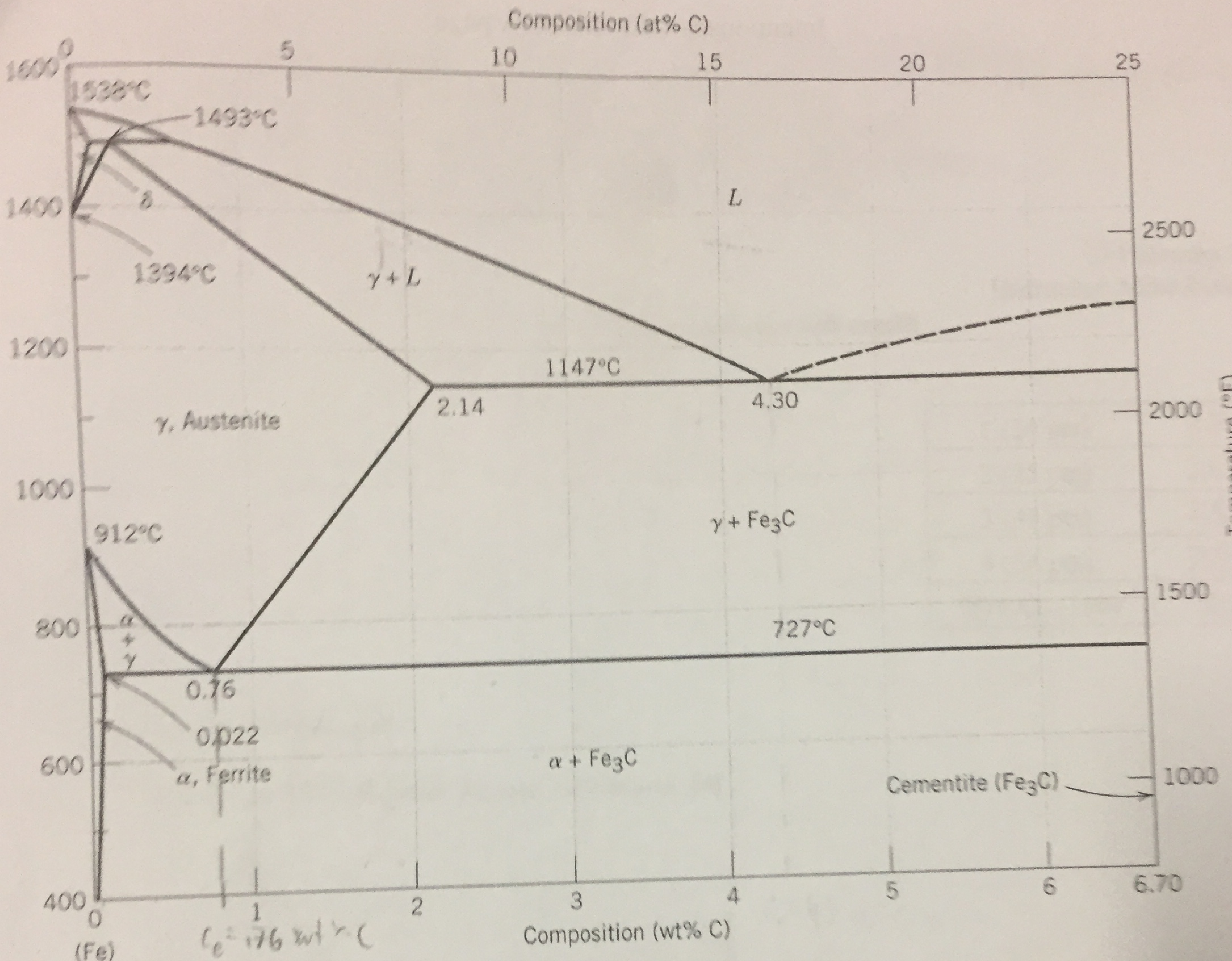
$= \frac{62 \text{ MPa}\sqrt{m}}{250 \text{ MPa}\sqrt{\pi \cdot .0016 m}}$ $a = \frac{1}{\pi}\left(\frac{K_{IC}}{Y\sigma_c}\right)^2$

$= 3.50$ $a = \frac{1}{\pi}\left(\frac{51 \text{ MPa}\sqrt{m}}{3.50 \cdot 250 \text{ MPa}}\right)^2$ 8

$a = .00108$ m

$a = 1.08$ mm

17.2


Composition (at% C)
0
5
10
15
20
25
1600
1538°C
1493°C
1400
δ
L
2500
1394°C
γ + L
1200
1147°C
2.14
4.30
γ, Austenite
2000
1000
912°C
γ + Fe3C
Temperature (°C)
Temperature (°F)
1500
800
α + γ
727°C
0.76
0.022
600
α, Ferrite
α + Fe3C
Cementite (Fe3C)
1000
400
0
(Fe)
1
2
3
4
5
6
6.70
Composition (wt% C)