EXAM II Version A

MSEG 302

Introduction to Materials Science and Engineering

The University of Delaware

April 26, 2018

Prof. David C. Martin

Name: Key

Honor Pledge:

"I have neither given nor received aid on this examination, nor have I witnessed any one else giving or receiving such assistance".

Sign here only if true: DCM

Useful information:

Avogadro's number: N_{av} 6.02×10^{23} molecules/mol

Boltzmann's constant: k 1.38×10^{23} J/atom-K

Gas constant: R 8.314 J/mol-K

Score:	
1.	29
2.	18
3.	18
4.	18
5.	19
Total	102

1. Enclosed is the phase diagram for bismuth (Bi) and lead (Pb).

5 a) The single phase regions are all labeled. Label all of the two-phase regions.

2 b) What is the melting temperature of pure lead? 325 C

2 c) What is the melting temperature of pure bismuth? 270 C

4 d) What is the eutectic temperature 125 C and composition 44% Pb?

4 e) What is the peritectic temperature 180C and composition 72% Pb?

4 f) An alloy containing 60 mass% Pb is cooled from the melt. At what temperature does solid first form? 170 C What is the composition of this solid? 70% Pb

4 g) This same alloy is cooled further. At what temperature does it become a single phase? 135°C What is the identity (label) of this phase? ∈ Pb

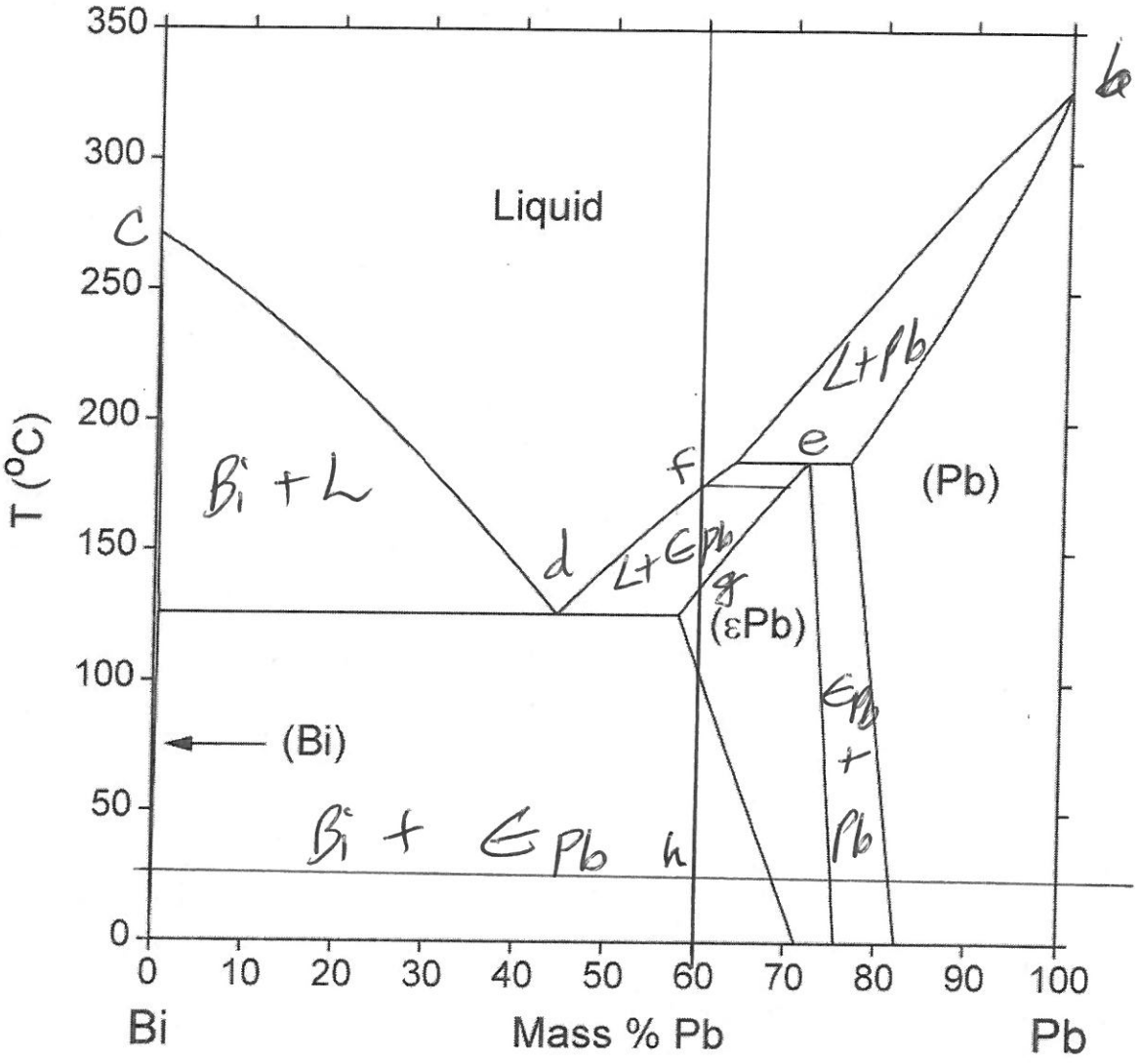
4 h) This same alloy is finally cooled to room temperature (25 C). What phase or phases are now stable? If more than one phase, estimate the relative amounts of each.

29

Bi + ∈ Pb

(0% Pb) (68% Pb)

12% 88 wt%


350
300
250
200
150
100
50
0
T (°C)
Liquid
C
b
Bi + L
d
f
e
L+Pb
(Pb)
L+∈Pb
g
(εPb)
(Bi)
∈Pb + Pb
Bi + ∈Pb
h
0
10
20
30
40
50
60
70
80
90
100
Bi
Mass % Pb
Pb

2. Enclosed is the iron-carbon phase diagram, plotted in terms of weight percent carbon.

4 a) What is the composition in weight percent of the iron-carbon alloy that has the lowest melting temperature? What is this melting temperature? 4.3 wt% 1147°C

4 b) What is the composition in weight percent of the iron-carbon alloy that has the eutectoid composition? What is the eutectoid temperature? 0.76 wt% 727°C

4 c) What is the lowest temperature and weight percent carbon at which any iron-carbon alloy shows any amount of delta phase? 1394°C 0%C

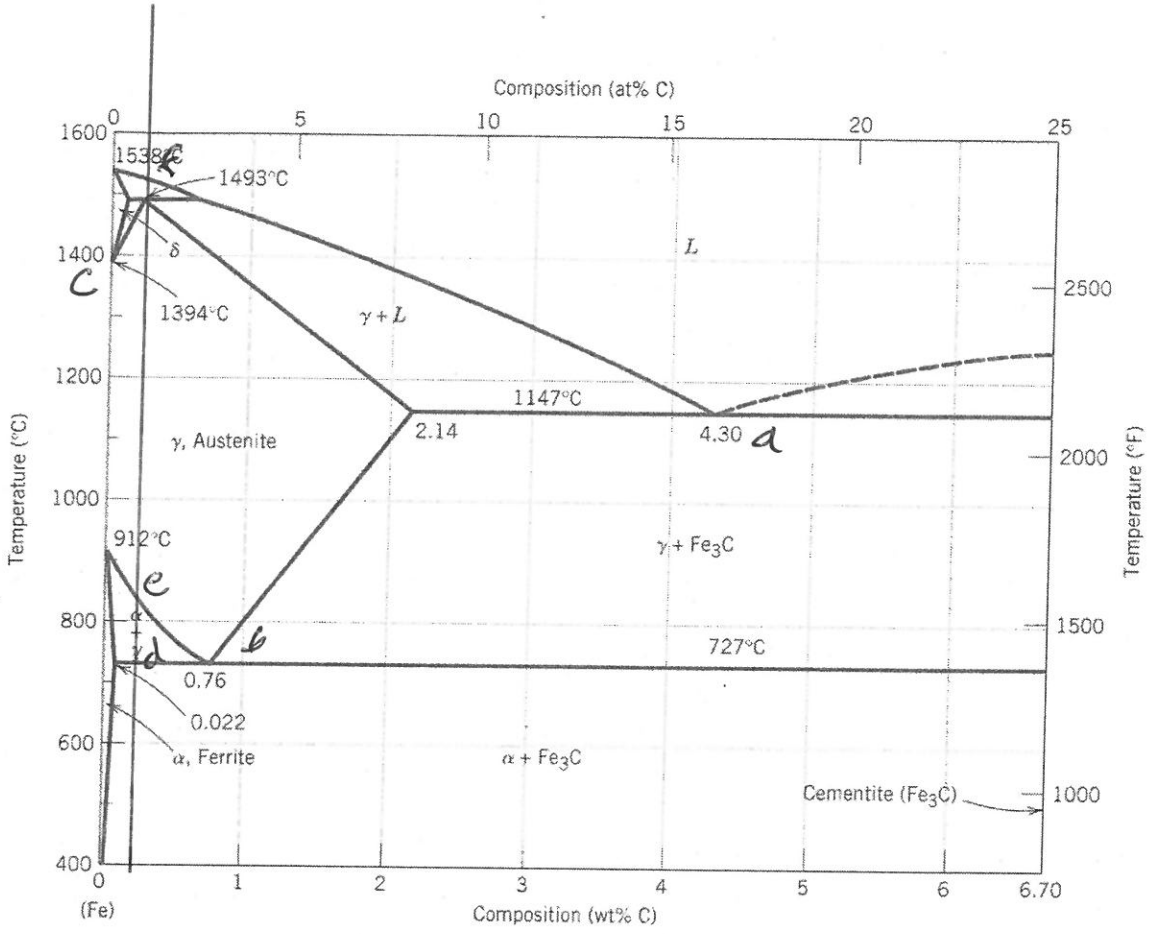
2 d) A particular iron-carbon alloy shows a final microstructure after slow cooling that consists of 80% proeutectoid ferrite and 20% pearlite. What is the carbon composition of this alloy, in weight percent? 0.17 wt%C

2 e) At what temperature would the alloy from part d become all single-phase austenite on heating? ~850°C

2 f) At what temperature would the alloy from part d become all liquid on heating? ~1525°C

18

$$0.8 = \frac{0.76 - X}{0.76 - 0.022} \qquad X = 0.17 \text{ wt\%}$$


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

3. A certain titanium alloy component is found to consistently fail whenever a tensile stress more than 500 MPa is applied. Microscopic examinations reveal that the minimum size of the surface cracks detectable is 5 mm.

6 a) What is the estimated plane strain fracture toughness for this material (in MPa $m^{1/2}$)?
62 MPa $m^{1/2}$ (35 MPa $m^{1/2}$)

6 b) If the examination methods were improved so that the minimum crack length detectable was decreased to 2 mm, what would the expected change in the failure stress for a similar part made from this same alloy? 780 MPa

6 c) If the modulus of this alloy is 110 GPa, what is the estimated specific energy (in J/m^2) for forming a crack? 17.9 kJ/m^2

18

(a) $K_{Ic} = Y \sigma \sqrt{\pi a}$

if $Y = 1$, $K_{Ic} = (500)\sqrt{\pi (0.005)} = 62 \text{ MPa } m^{1/2}$

if $K_{Ic} = Y \sigma \sqrt{a} = 35 \text{ MPa } m^{1/2}$

(b) $62 = Y \sigma \sqrt{\pi a} = \sigma \sqrt{\pi (0.002)}$

$\sigma = 780 \text{ MPa}$

(c) $\sigma_c^2 = \frac{2E\gamma}{\pi a}$ or $\gamma = \frac{\pi a \sigma_c^2}{2E}$

substituting gives $\gamma = 17{,}800 \frac{J}{m^2} = 17.8 \frac{kJ}{m^2}$

4. A certain process results in a ceramic part with some amount of (unknown) porosity. A three-point bend test reveals that the modulus of the part is exactly one-half that of the fully dense material ($E/E_0=0.5$). Also, the strength is one-tenth that of the fully dense material ($\sigma/\sigma_0=0.1$).

6 a) What is the amount of porosity of this part? $p=0.31$, $n=7.43$

6 b) What would be the relative modulus (E/E_0) of a part made from this same material, but with only 5% porosity? 0.91

6 c) What would be the relative strength (σ/σ_0) of a part made with this same material, but with only 5% porosity? 0.69

6/18

$$\frac{E}{E_0} = 1 - 1.9P + 0.9P^2$$

$$\frac{\sigma}{\sigma_0} = Exp[-nP]$$

5. Indicate the most appropriate processing method to make the item described below.

a) sand casting
b) die casting
c) forging
d) powder metallurgy
e) drawing
f) extrusion
g) welding
h) hot rolling
i) cold rolling
j) pressing and blowing
k) slip casting
l) powder pressing
m) firing
n) tape casting
o) thermal tempering
p) mixing with water
q) injection molding
r) melt spinning
s) wet spinning
t) dry spinning
u) dry-jet wet spinning
v) blow molding

Used to make a 4340 alloy steel box-end wrench	C
Used to make a small Hot Wheels toy car from zinc	B
Used to make round copper wire	E
Used to make an aluminum window frame	F
Used to thin down a 1080 plain carbon ingot into ductile sheets	H
Used to increase the hardness of thin aluminum sheets	J
Used to join two metal components together at a seam	G
Used to make a ceramic vase (green form)	K
Used to make a hard ceramic part from a green shape	M
Used to increase the strength of a glass window	O
Used to make a gray cast iron fire hydrant =	A
Used to make a concrete sidewalk from cement and gravel	P
Used to make a small, flat alumina substrate for electronics	N
Used to make polystyrene model car kit: 1972 Chevy Nova	Q
Used to make polypropylene fiber for StainMaster carpet	R
Used to make PPTA Kevlar aramid fiber	U
Used to make MPDI Nomex aramid fiber	T
Used to make Rayon fiber for a Hawaiian shirt	S
Used to make sheets of poly(vinylidene chloride) (Saran wrap)	V

Version A

5. Indicate the most appropriate processing method to make the item described below.

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Version B