MSE 2001-B: Exam #3

Answer Key
<Printed Name>

November 12th, 2010

In taking this test, I agree that I will not participate in cheating or any other forms of academic fraud inconsistent of university policies. I understand that if I am caught participating in these types of actions, my exam grade will immediately default to 0% and I will be unable to retake the exam. AK
<initials> .

Part I: Conceptual

True/False/Maybe: 20 points (2 point each)
(The answer to the following questions are either true, false, or maybe)

(1) T Interstitial diffusion mechanisms are generally faster than vacancy diffusion mechanisms.

(2) T Diffusion-based phase transformations are highly dependent on time, whereas diffusionless phase transformations are near instantaneous.

(3) T When casting steel and aluminum, shrinkage is always experienced as the material solidifies.

(4) T Sintering of ceramic particles at high temperatures allows the particles to join together via diffusion but results in tiny formation of pores (i.e. porosity).

(5) T Cold working (i.e. strain hardening) tends to align the grains of a sample in the direction of the applied stress.

(6) F The yield strength of a material, σ_y, is highly dependent on the cross-sectional area of the material.

(7) F Process annealing is a heat treatment used to harden a material by restricting/limiting dislocation motion.

(8) F A material phase begins to melt (i.e. turn to liquid) above the Solvus Line in a Eutectic Phase Diagram.

(9) F A carbon-carbon double bond (C=C) is considered a "saturated" bond.

(10) M A change in a material's composition (i.e. adding/subtracting substitutional atoms) will result in a phase transformation in an effort to minimize energy and reach equilibrium.

Fill in the Blank: 8 points (1 points each)
(Using the answers to the right, fill in the blanks in the correct order)

# of Carbons in Chain	Application	Answers
1-4	Propane	Candles/Wax
5-11	Gasoline	Gasoline
9-16	Kerosene	Propane Gas
16-25	Oil n' Grease	Bulletproof vests
25-50	Candles/Wax	Adhesives
50-1000	Adhesives	Kerosene
1000-5000	Plastic Bottles	Plastic Bottles
3-6 x 10^5	Bulletproof Vests	Oil and Grease

Conceptual:

(1) You happen to crash your motorcycle at the track and need to replace a critical part in the frame. You order the part from two different manufacturers to compare the quality of the parts. Even though they are supposed to be the same part, one is much heavier than the other. Furthermore, one part was much more expensive than the other. Which part was likely "cast" and which part was likely "formed/wrought? (5 pts) Why? (5 pts)

Heavier / Cheaper Part ⇒ Cast

Lighter / Expensive Part ⇒ Formed (5pts)

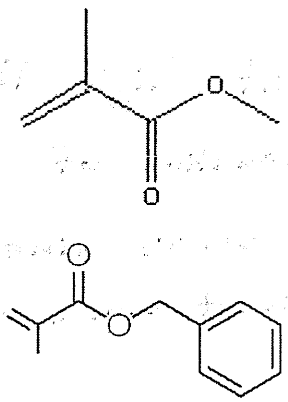
Cast materials are bulky / over designed and hence heavier. (2.5 pts)

Forming processes require extra processing steps and are expensive. (2.5 pts)

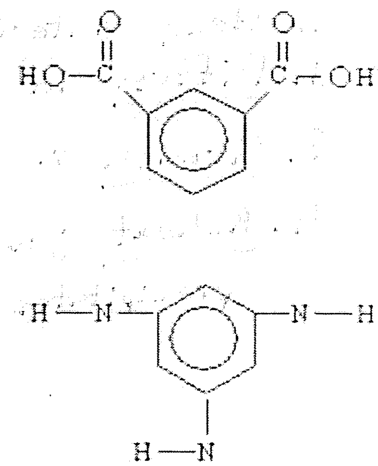
↳ note: casting may require extra machining to finish a part; however, this is relatively inexpensive.

↳ note: if student mentions castings are rougher (on surface) than formed parts, credit should be given.

(2) Which pair of monomers is designed to polymerize via step-growth polymerization and which set is designed to polymerize via chain-growth polymerization? (5 pts)



Set 1



Set 2

Chain Growth

Step Growth

Which set will synthesize a thermoplastic and which set will synthesize a thermoset? (2 pts) Why? (3 pts)

Set 1 ⇒ thermoplastic (1pt) → mono-functional monomers
Set 2 ⇒ thermoset (1pt) → tri-functional monomer
} 3pts.

If you were to manufacture a plastic toy dinosaur out of the thermoplastic and thermoset, name a processing technique you could use to create the dinosaur? (i.e. how would you process the thermoset and how would you process the thermoplastic?) (5 pts)

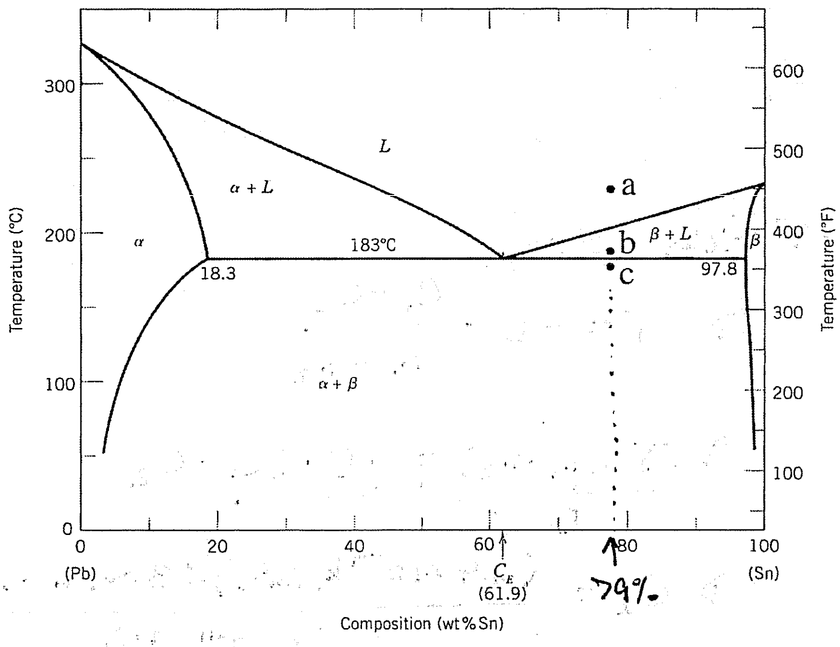
Thermoplastic	Thermoset
- Machine	~ Machine
- Cast	~ Cast
- Mold	↳ I will accept "synthesize in mold" but <u>not</u> injection mold or other mold techniques
- Injection Mold	
- Compression Mold	

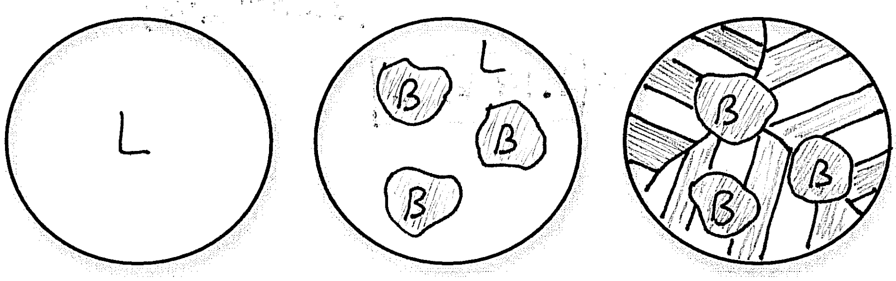
(3) Starting with a piece of pure iron (i.e. carbon-less iron), how could you create a piece of precipitate hardened steel. Remember, you need to control the growth of precipitates in precipitate hardening. *(Hint: There are 4 steps).* (3 pts each)

1. Heat material
2. Diffuse in Carbon at high Temp.
3. Quench to prevent formation of precipitates.
4. Reheat just below soluus line to form precipitates. (will accept anneal or age material)

Conceptual + Quantitative

(1) Draw the microstructure of at each location (a, b, and c) during equilibrium cooling. (2 pts, 4 pts, 4 pts)





a b c

Calculate the amount of each primary and eutectic constituent at c. *(Note: There are 3 mass fractions you need to calculate)*.(5pts each).

Primary $\beta \Rightarrow W_{\beta}' = \dfrac{79-61.9}{97.8-61.9} = \boxed{0.476}$

Eutectic $\alpha \Rightarrow W_{\alpha E} = \dfrac{97.8-79}{97.8-18.3} = \boxed{0.236}$

Eutectic $\beta \Rightarrow W_{\beta E} = 1 - W_{\beta}' - W_{\alpha E}$

$= 1 - (0.476) - (0.236)$

$= \boxed{0.288}$

2 ways to solve for $W_{\beta E}$

or Total $\beta \Rightarrow W_{\beta} = \dfrac{79-18.3}{97.8-18.3} = 0.764$

(2) A plate of iron is exposed to a carburizing (carbon-rich) atmosphere on one side and a decarburizing (carbon-deficient) atmosphere on the other side. The temperature is at 700°C, with a diffusion coefficient (D) of 3 x 10^{-11} m^2/s. The diffusion flux (J) is 2.4 x 10^{-9} kg/m^2s. If steady-state diffusion is assumed and the concentration of carbon at 3 mm beneath the carburizing surface is 1.5 kg/m^3, what is the concentration of carbon at 7.5 mm. (10 pts)

→ Ficks Law

$$\hookrightarrow J = -D \cdot \frac{C_1 - C_2}{X_1 - X_2}$$

$$\Rightarrow \frac{J(x_1 - x_2)}{D} + C_1 = C_2$$

$$\Rightarrow C_2 = \frac{(2.4 \times 10^{-9}\ kg/m^2 \cdot s)(0.003m - .0075m)}{(3 \times 10^{-11}\ m^2/s)} + (1.5\ kg/m^3)$$

$$= \boxed{1.14\ kg/m^3}$$

Extra Credit: (1) Swell thermoset in solvent (i.e. H_2O)

(2). Diffuse in drugs

J = -D · dc/dx

D = D_o · e^(Q·d/R·T)