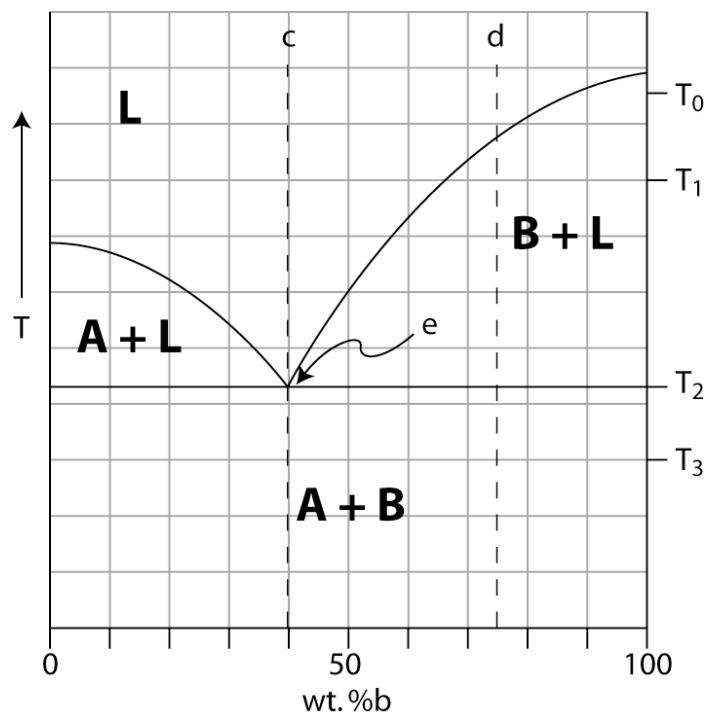
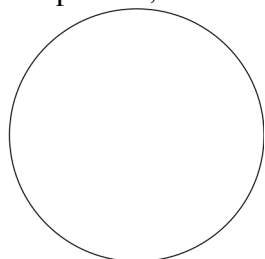


**Question 1.**

1A. Using the phase rule, determine the degrees of freedom:

- at point e
- within the field A + B
- within the field A + L

1B. Envision this system as a *slowly* cooling magma chamber. Start with a liquid of bulk composition *d* at T<sub>0</sub>. In the circles below, show schematically the appearance of the system at temperatures T<sub>0</sub>, T<sub>1</sub>, T<sub>2</sub>, + 0.01°C (i.e., just above T<sub>2</sub>) and T<sub>3</sub>. When drawing, think about the crystallization process, not just the numbers! Also, try to portray the proportions of phases somewhat correctly. In the blanks, list the phases present, and the amount & composition of each. Not every text line will be needed.

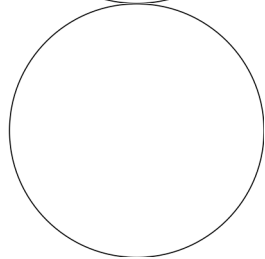


Temperature = T<sub>0</sub>

Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition= \_\_\_\_\_

Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition= \_\_\_\_\_

Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition= \_\_\_\_\_

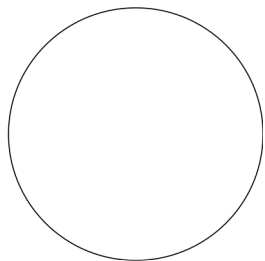


Temperature = T<sub>1</sub>

Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition= \_\_\_\_\_

Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition= \_\_\_\_\_

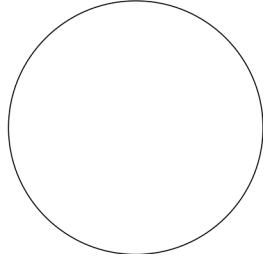
Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition= \_\_\_\_\_

Temperature =  $T_2 + 0.01^\circ\text{C}$ 

Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition= \_\_\_\_\_

Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition= \_\_\_\_\_

Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition= \_\_\_\_\_

Temperature =  $T_3$ 

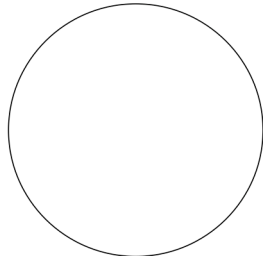
Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition= \_\_\_\_\_

Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition= \_\_\_\_\_

Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition= \_\_\_\_\_

1C. For a given pressure, why can't the temperature of the system be lowered beyond  $T_2$  until all of L has crystallized? (hint: use the phase rule)

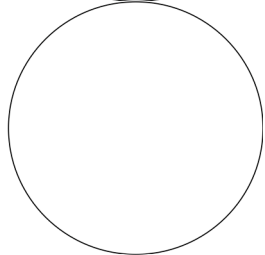
1D. Follow the instructions for 1B. above for a liquid of bulk composition  $c$  and temperatures  $T_1$ ,  $T_2$ , +  $1^\circ\text{C}$  and  $T_3$

Temperature =  $T_1$ 

Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition= \_\_\_\_\_

Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition= \_\_\_\_\_

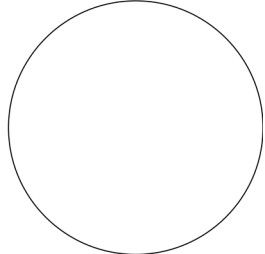
Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition= \_\_\_\_\_

Temperature =  $T_2 + 0.01^\circ\text{C}$ 

Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition= \_\_\_\_\_

Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition= \_\_\_\_\_

Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition= \_\_\_\_\_

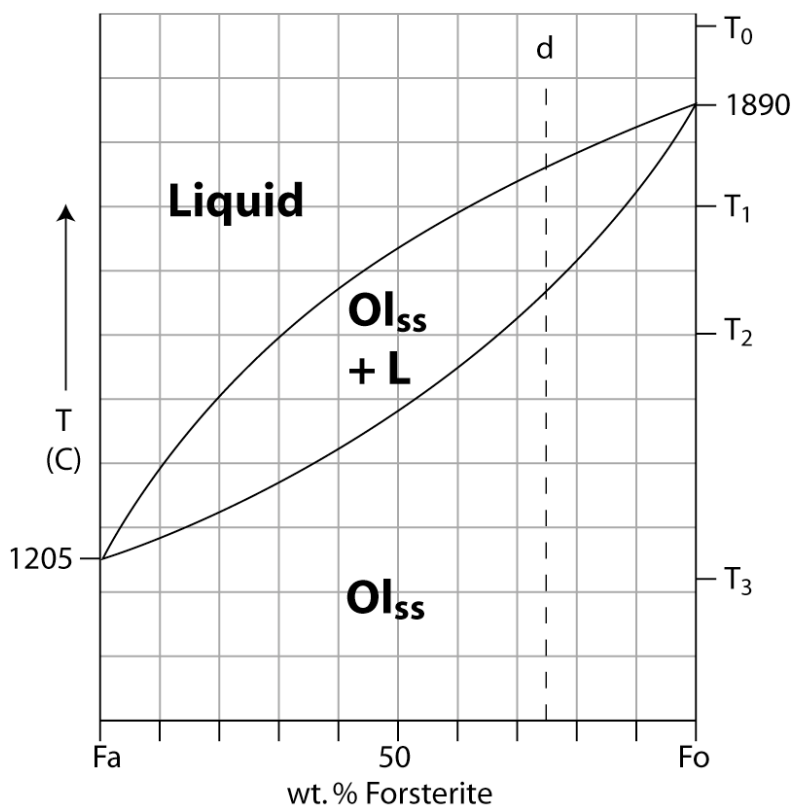
Temperature =  $T_3$ 

Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition= \_\_\_\_\_

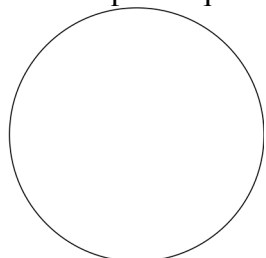
Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition= \_\_\_\_\_

Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition= \_\_\_\_\_

## QUESTION 2



2A. Follow the instructions in question 1B for a liquid of bulk composition *d* at T<sub>0</sub>, T<sub>1</sub>, T<sub>2</sub>, and T<sub>3</sub>. Assume complete equilibration during cooling (relatively slow cooling). Describe the texture of the final product.

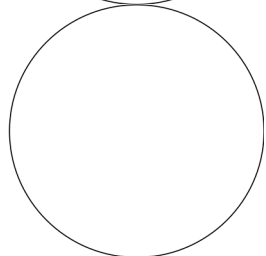


Temperature = T<sub>0</sub>

Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition = \_\_\_\_\_

Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition = \_\_\_\_\_

Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition = \_\_\_\_\_

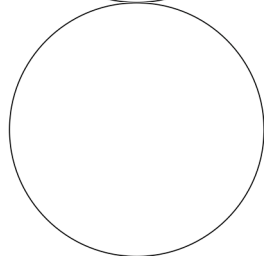


Temperature = T<sub>1</sub>

Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition = \_\_\_\_\_

Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition = \_\_\_\_\_

Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition = \_\_\_\_\_



Temperature = T<sub>2</sub>

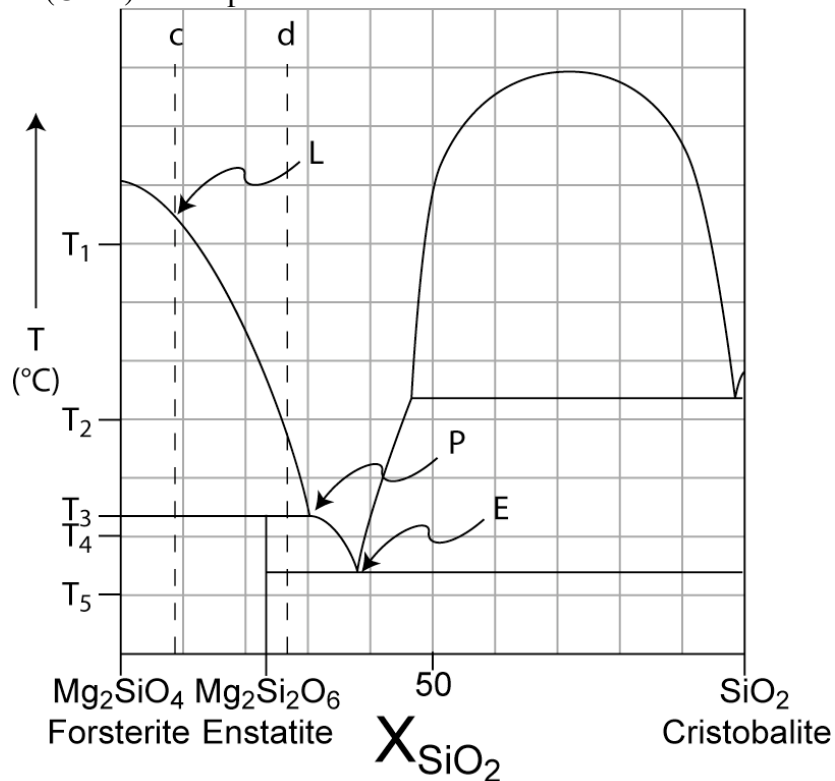
Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition = \_\_\_\_\_

Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition = \_\_\_\_\_

Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition = \_\_\_\_\_

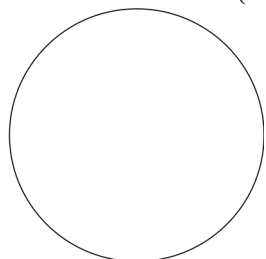
**QUESTION 3**

3A. Label each of the fields in this simplified phase diagram, except for the tiny one at the right. You may wish to use your text (Ch. 6) for help.



3B. Use the Phase Rule to determine the degrees of freedom at points P, E, and L

3C. Follow the instructions in question 1B for composition  $c$  at temperatures  $T_1$ ,  $T_2$ ,  $T_3 + 0.01^{\circ}\text{C}$ , and  $T_4$ . Assume slow (equilibrium) cooling.

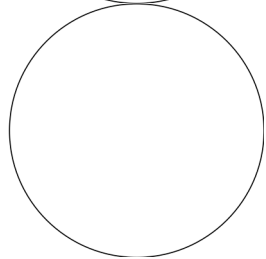


Temperature =  $T_1$

Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition = \_\_\_\_\_

Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition = \_\_\_\_\_

Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition = \_\_\_\_\_

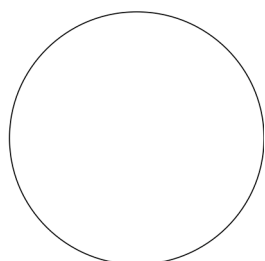


Temperature =  $T_2$

Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition = \_\_\_\_\_

Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition = \_\_\_\_\_

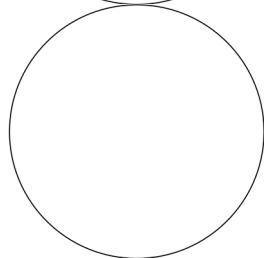
Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition = \_\_\_\_\_

Temperature =  $T_3 + 1\text{ }^{\circ}\text{C}$ 

Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition= \_\_\_\_\_

Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition= \_\_\_\_\_

Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition= \_\_\_\_\_

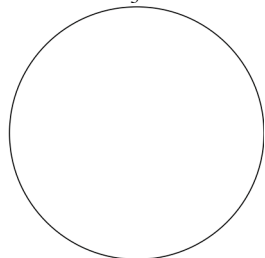
Temperature =  $T_4$ 

Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition= \_\_\_\_\_

Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition= \_\_\_\_\_

Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition= \_\_\_\_\_

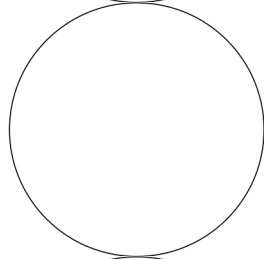
3D. Follow the instructions in question 1B for composition  $d$  at temperatures  $T_3 + 0.01^{\circ}\text{C}$ ,  $T_3 - 0.01^{\circ}\text{C}$ ,  $T_4$  and  $T_5$ . Assume slow (equilibrium) cooling.

Temperature =  $T_3 + 1\text{ }^{\circ}\text{C}$ 

Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition= \_\_\_\_\_

Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition= \_\_\_\_\_

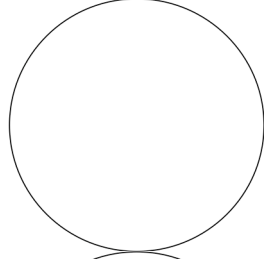
Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition= \_\_\_\_\_

Temperature =  $T_3 - 1\text{ }^{\circ}\text{C}$ 

Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition= \_\_\_\_\_

Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition= \_\_\_\_\_

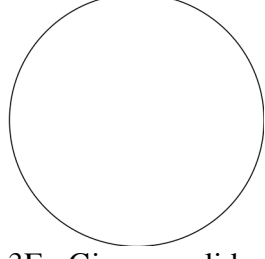
Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition= \_\_\_\_\_

Temperature =  $T_4$ 

Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition= \_\_\_\_\_

Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition= \_\_\_\_\_

Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition= \_\_\_\_\_

Temperature =  $T_5$ 

Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition= \_\_\_\_\_

Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition= \_\_\_\_\_

Phase \_\_\_\_\_: Volume % = \_\_\_\_\_ . Composition= \_\_\_\_\_

3E. Given a solid of composition  $\text{Mg}_2\text{Si}_2\text{O}_6$ , at what temperature will the solid first melt? What will be the product(s) of melting? What are their compositions?