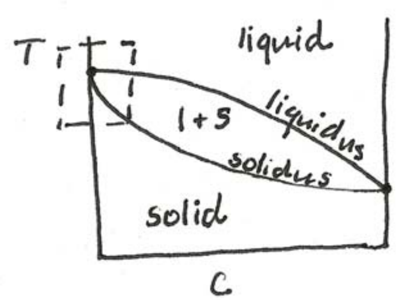
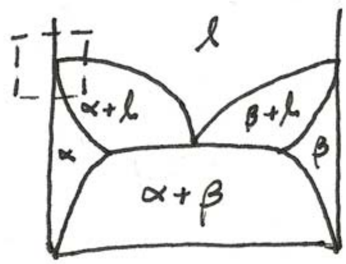
3.044 MATERIALS PROCESSING

LECTURE 11

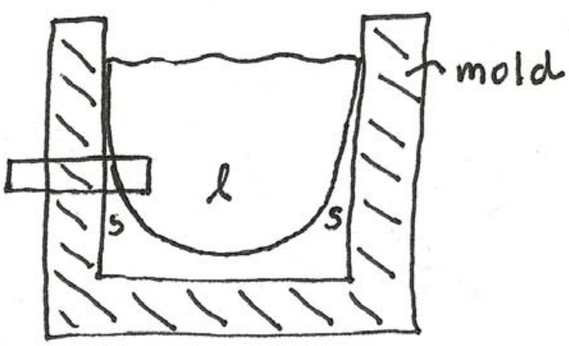
Solidification of Multicomponent Liquids

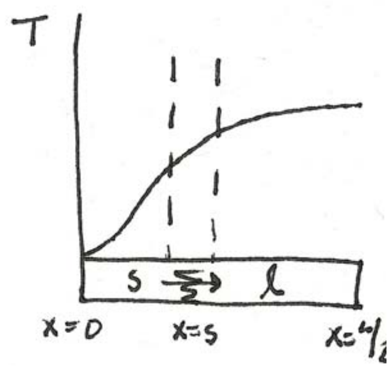




single component system: single T_m

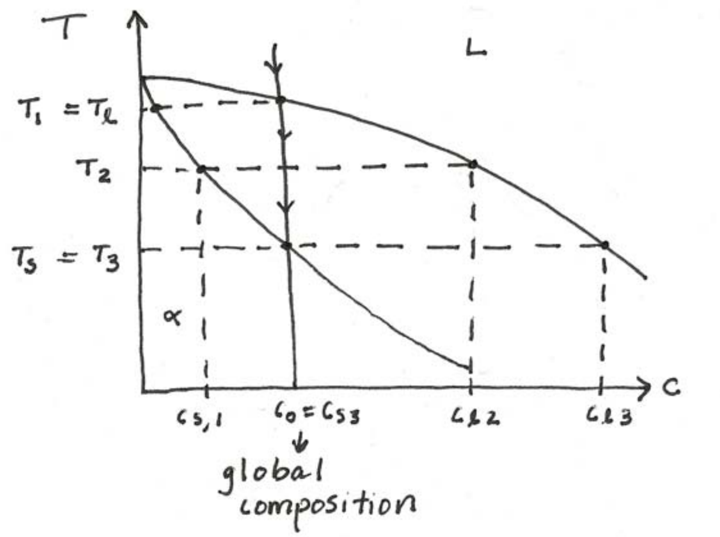
multicomponent system: solidify over a range of T

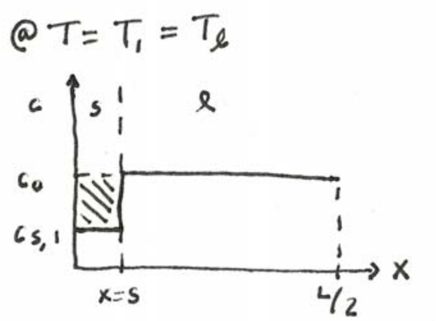


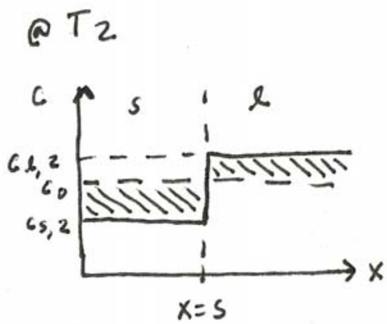


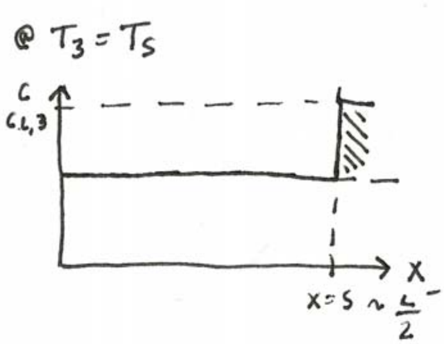
Date: March 19th, 2012.

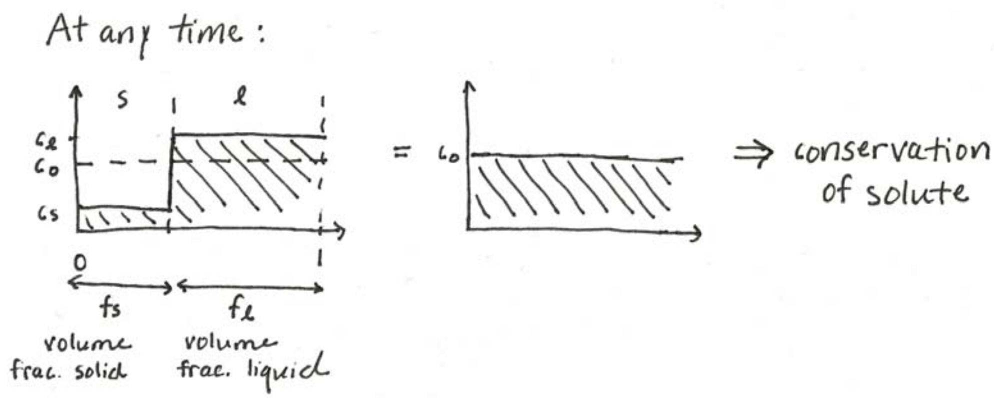
1. **Assume:** equilibrium solidification (rapid diffusion in both liquid and solid)







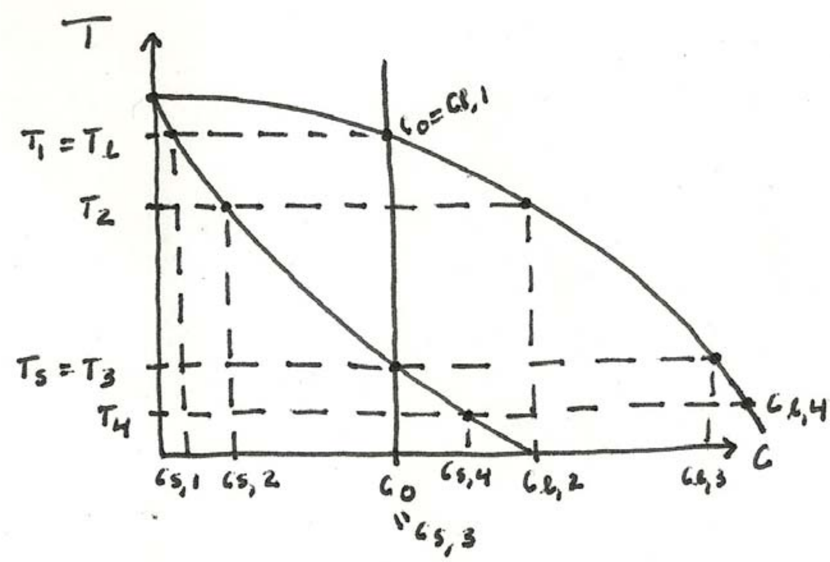


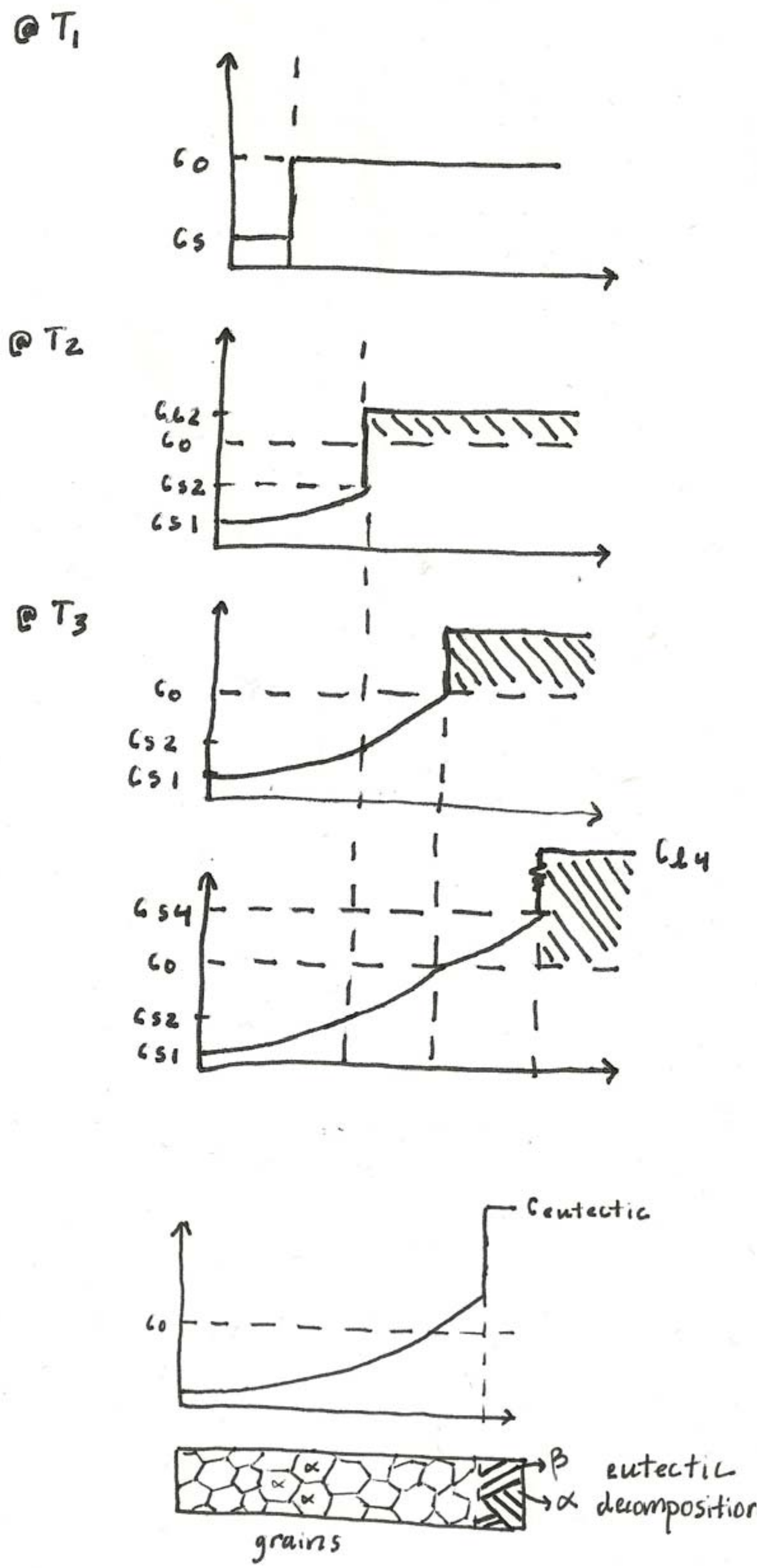


Key Lesson: phase transformations push solute around

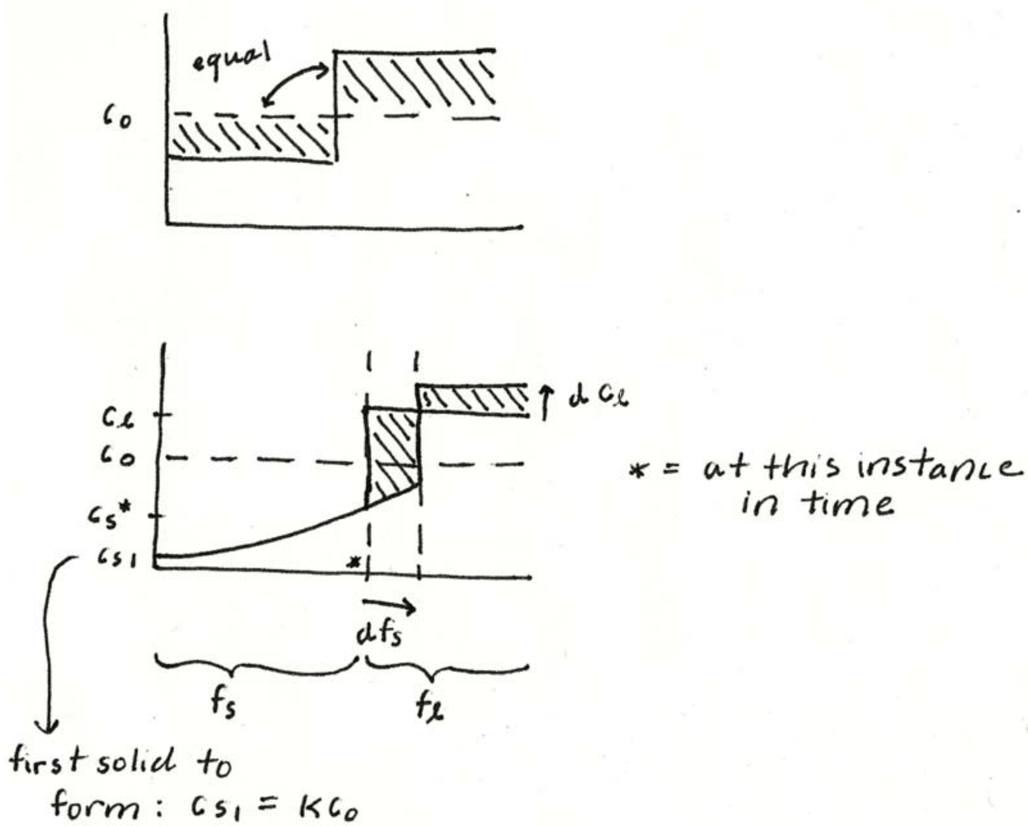
Conservation of Solute: **Lever Rule:** $c_0 = f_s \cdot c_s + f_l \cdot c_l$

2. **More realistic assumption:** diffusion is fast in liquid and non-existent in solid




@ T1
C0
Cs
@ T2
CL2
C0
Cs2
Cs1
@ T3
C0
Cs2
Cs1
CL4
Cs4
C0
Cs2
Cs1
Ceutectic
C0
α
α
α
β
α
eutectic
decomposition
grains

Solute Balance:



$$(c_l - c_s^*)\, df_s = f_l \cdot dc_l$$
$$(c_l - c_s^*)\, df_s = (1 - f_s) \cdot dc_l$$
$$\frac{df_s}{1 - f_s} = \frac{dc_l}{c_l - c_s^*}$$

B.C. @ $f_s = 0 :\ c_l = c_0\ \ \&\ \ c_s^* = c_{s,1}$

Define ***k***: partition coefficient

$$k = \frac{c_s}{c_l}$$

- from phase diagram, k describes the width of a 2-phase field
- k is a materials constant if and only if the solidus and liquidus are lines
- first solid to form is of composition $\boldsymbol{c_{s,1}}$

$$c_{s,1} = kc_0$$
$$c_s^* = c_{s,1} = kc_0$$

<u>Solve:</u> **Non-Equilibrium Lever Rule**

$$\boxed{c_S^* = kc_0(1 - f_s)^{(k-1)}} \quad \text{or} \quad \boxed{c_l = c_0 f_l^{(k-1)}}$$

⇒ The <u>Non-Equilibrium Lever Rule</u> applies to stirred liquids, rapid diffusion in liquid, slow solid diffusion