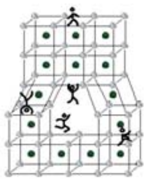
Phases



Wednesday, Oct. 8, 2003

MATS275: INTRODUCTION TO MATERIALS SCIENCE

- Phases - One Component
- Gibbs Phase Rule
- Two Component Phase Diagrams
  - Normal
  - Lever Law
  - Miscibility Gap
  - Eutectic

What is a Phase?

- A homogeneous, physically distinct, mechanically separable portion of a material.
- Characterized by a sharp difference in physical and/or chemical characteristics.

Ice - water - steam

Single Component

C, O_2 --> CO_2

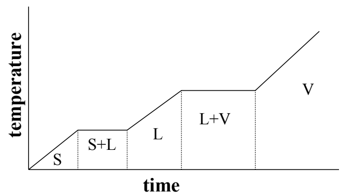
Multiple Component

What Determines a Phase?

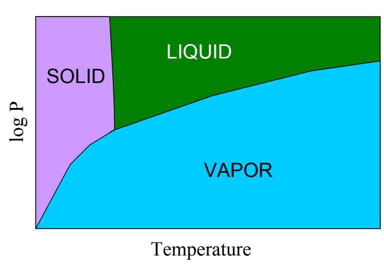
- History
- Temperature
- Composition
  - *Component* - a distinct chemical species
  - *System* - a collection of bodies that can be physically isolated.
  - *Equilibrium* - when a system has its minimum Gibbs free energy

Melting Ice

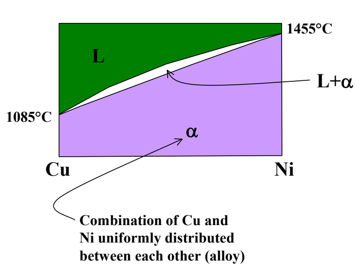
- Place a block of ice on a constant source of heat...



One-Component Phase Diagram



A SIMPLE PHASE DIAGRAM
Cu:Ni

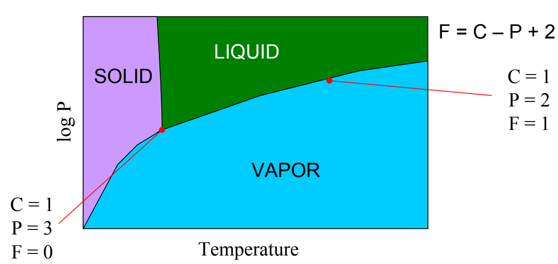


Gibbs Phase Rule

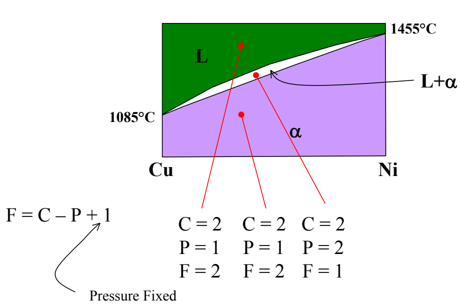
P + F = C + N
(F = C – P + 2 or 1)

- P = number of phases
- F = degrees of freedom
- C = number of components
- N = number of non-compositional variables
  - Temperature & Pressure varying = 2

One-Component Phase Diagram



A SIMPLE PHASE DIAGRAM
Cu:Ni



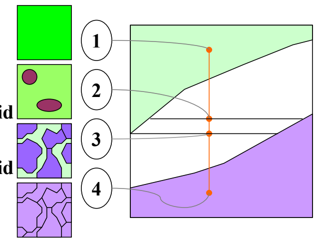
COOLING
Cu:Ni (40% Ni)

At (1) - 1300°C
- all liquid

At (2) - 1250°C
- part liquid part solid

At (3) - 1240°C
- part liquid part solid

At (4) - 1200°C
- all solid



Using the Lever Law

- To find what percentage is α at 1250°C:

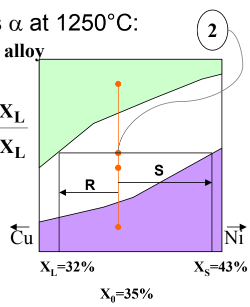
$$(\%\text{Ni in }\alpha)f_S + (\%\text{Ni in L})(1-f_S) = \%\text{Ni in alloy}$$

$$X_S f_S + X_L f_L = X_0$$

$$f_S = \frac{(\%\text{Ni in alloy}) - (\%\text{Ni in L})}{(\%\text{Ni in }\alpha) - (\%\text{Ni in L})} = \frac{X_0 - X_L}{X_S - X_L}$$

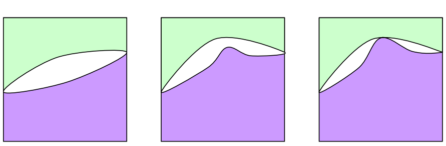
$$f_S = \frac{X_0 - X_L}{X_S - X_L} = \frac{R}{R+S}$$

$$= \frac{35-32}{43-35} = 0.375 = 37.5\%$$



Non-Ideal Behvior

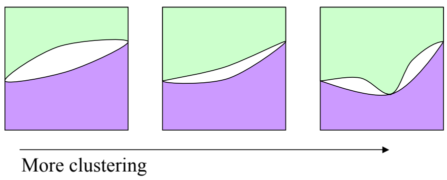
- Liquid clusters



More clustering

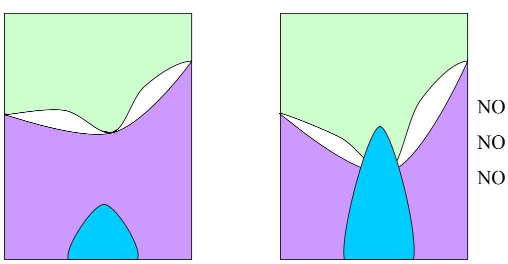
Non-Ideal Behvior

- Or solid clusters



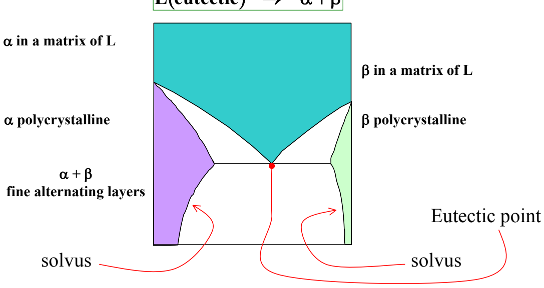
Miscibility Gaps

- Throw in a miscibility gap...

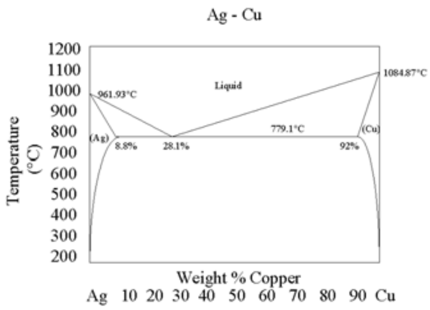


Eutectics

$$\mathrm{L(eutectic)} \xrightarrow{\text{cooling}} \alpha + \beta$$

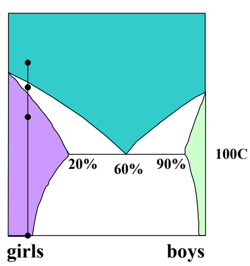


Au/Cu Phase Diagram



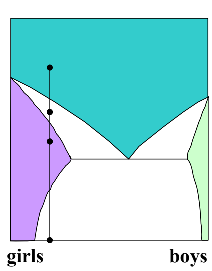
Eutectic Cooling Paths

- All liquid (2% boys)
- Some boys begin to condense out after crossing liquidus line. The composition of the a phase is determined by the lever law.
- Everything solid (2% boys)



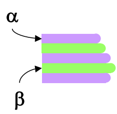
Eutectic Cooling Paths

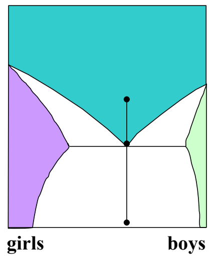
- All liquid (15% boys)
- Condensed boys in liquid girls (use lever law).
- All solid with 15 % boys
- Boys precipitate out - form β particles in α matrix with compositions given by solvus lines and lever law.



Eutectic Cooling Paths

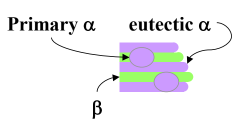
- All liquid (60% boys)
- Begins to condense both boys and girls in a lamellar structure at the eutectic temperature.

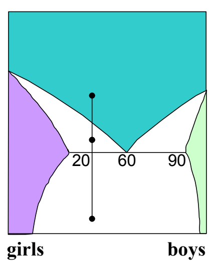




Eutectic Cooling Paths

- All liquid (40% boys)
- Solid areas of α form down to Eutectic temp, where they will have a concentration of 20 %.
- The earlier solid (primary or proeutectic α) stays and the rest becomes lamellar (eutectic α).

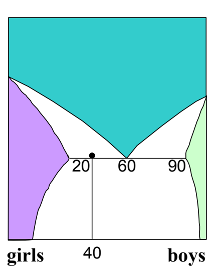




USING THE LEVER LAW

- 40 % boys (L + α)

$$f_S = \frac{X_L - X_0}{X_L - X_S} = \frac{60-40}{60-20} = 50\%$$



USING THE LEVER LAW

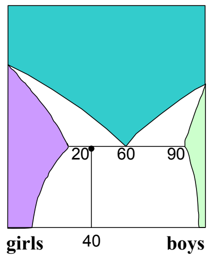
- 40 % boys ($\alpha + \beta$)

$$f_\alpha = \frac{X_\beta - X_0}{X_\beta - X_\alpha} = \frac{90-40}{90-20} = 72\%$$

$$f_\beta = \frac{X_0 - X_\alpha}{X_\beta - X_\alpha} = \frac{40-20}{90-20} = 28\%$$

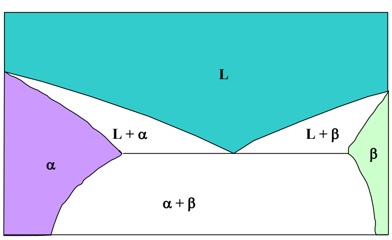
50% is proeutectic

22% is eutectic



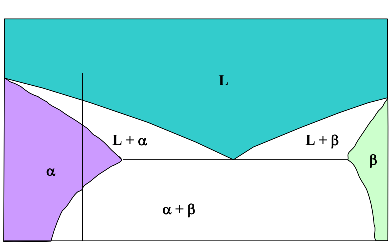
Eutectics

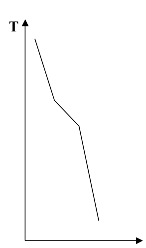
$$\boxed{L(\text{eutectic}) \xrightarrow{\text{cooling}} \alpha + \beta}$$



How Do We Figure This Out?

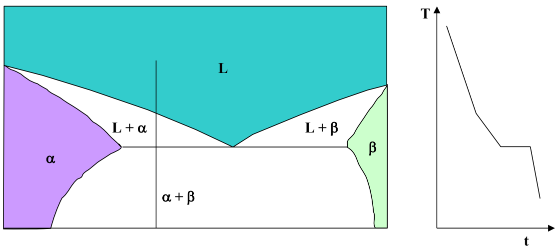
- Look at cooling curves...





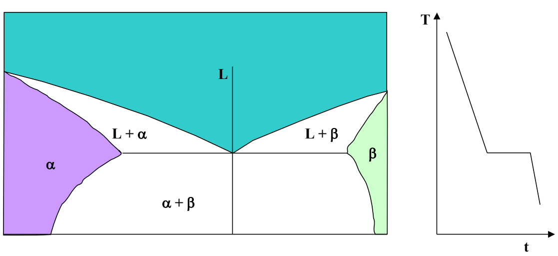
How Do We Figure This Out?

- Look at cooling curves...

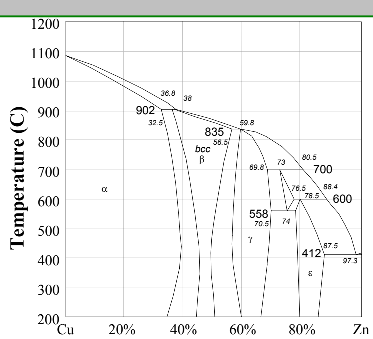


How Do We Figure This Out?

- Look at cooling curves...

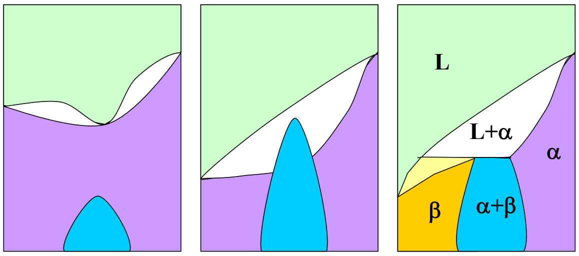


Cu-Zn Phase Diagram



Miscibility Gaps

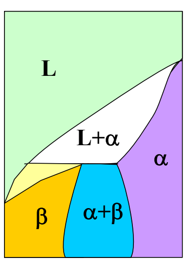
- Enhanced clustering in solid



Peritectic

- Spontaneous formation of new phase on cooling:

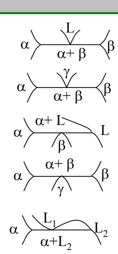
$\alpha + L \rightarrow \beta$



OTHER ELEMENTS

invariants

- Eutectic
- Eutectoid
- Peritectic
- Peritectoid
- Monotectic



$L \rightarrow \alpha + \beta$

$\gamma \rightarrow \alpha + \beta$

$\alpha + L \rightarrow \beta$

$\alpha + \beta \rightarrow \gamma$

$L_1 \rightarrow L_2 + \alpha$

- Intermetallic compounds