Today's Schedule

- See the missing movie (from last time).
- A bit about transmission lines
- The last words about phase diagrams
  - All of the different reaction types.
  - Where phase diagrams come from.

- Finish with a list of topics and breakdown of Callister for the mid-term.

Kickoff with the missing movie

- **http://www.exn.ca/Stories/2003/12/04/51.asp?t=dp**

Composite Materials

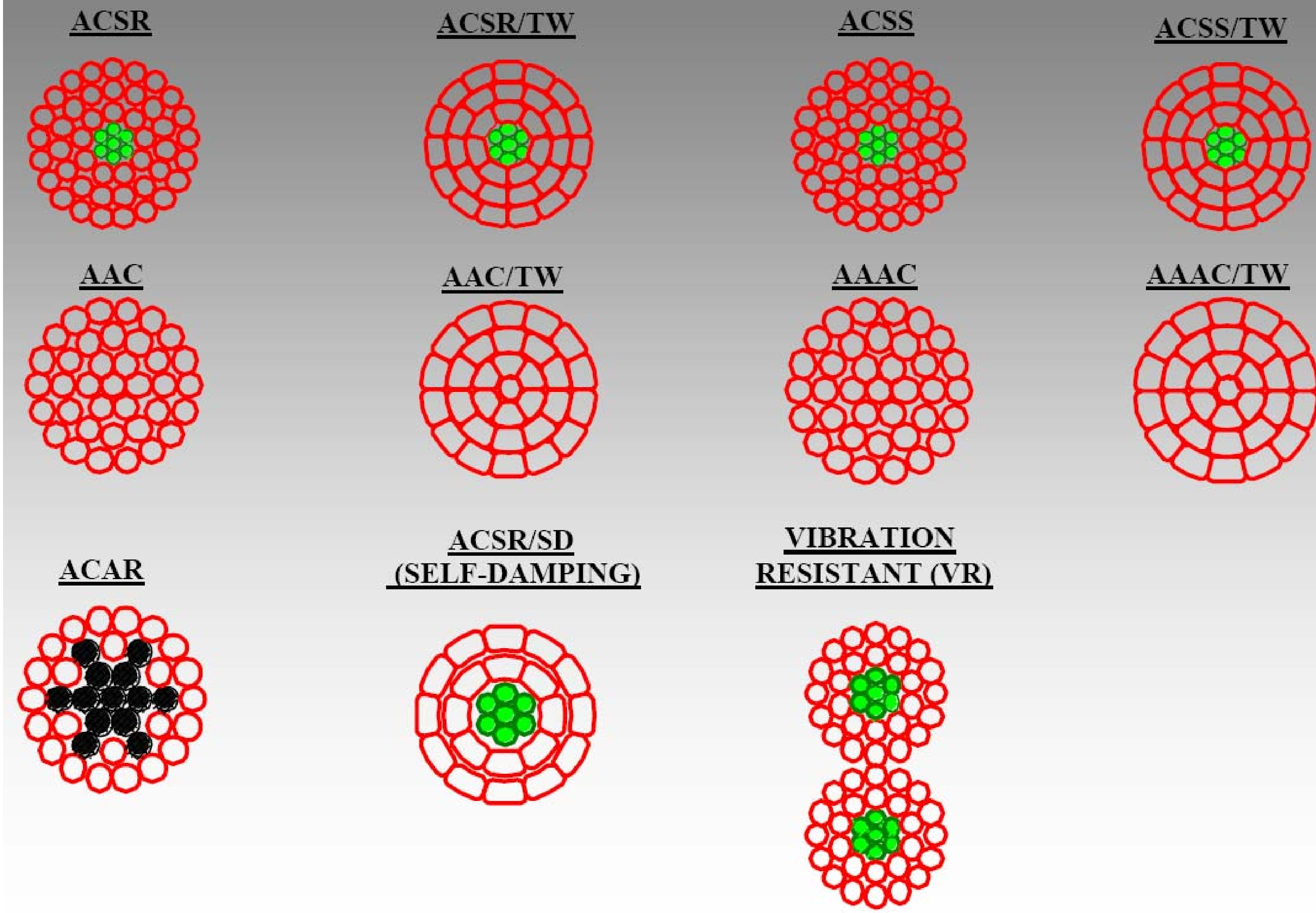
- **Combine two or more materials to gain benefits from each.**
- **Which materials and why depends on the application.**
  - **What properties do we need?**
  - **What are the operating conditions?**
  - **How long does it need to last?**

Transmission Lines

- **Transmission lines use ACSR (aluminum cable, steel reinforced) and ACAR (aluminum cable, alloy reinforced) conductors. In an ACSR conductor, a stranded steel core carries the mechanical load, and layers of stranded aluminum surrounding the core carry the current. An ACAR conductor is a stranded cable made of an aluminum alloy with low resistance and high mechanical strength. ACSR conductors are usually used for high-voltage lines, and ACAR conductors for subtransmission and distribution lines. Ultrahigh-voltage (UHV) and extrahigh-voltage (EHV) lines use bundle conductors. Each phase of the line is built with two, three, or four conductors connected in parallel and separated by about 1.5 ft (0.5 m). Bundle conductors reduce corona discharge.**

from answers.com

Variety Of Conductor Designs Available



from IEEE TP&C

Why Al and not Cu?

How will Al or Cu interact w/ Steel

Al is lighter

Al is cheaper ?

Al oxidizes and stops

Galvanic corrosion.

Why Al and not Cu?

- Topic created on WebCT regarding 'Materials in EE.'
- Post on transmission lines created.
- Feel free to create other posts. I will post a few more throughout the semester.

- OPTIONAL component of the course. Discuss among your peers what you find about materials commonly used in EE.

What did the movie and the TL example have to do with phase diagrams?

Steel processing need phase diagram:

Transmission line alloy Al

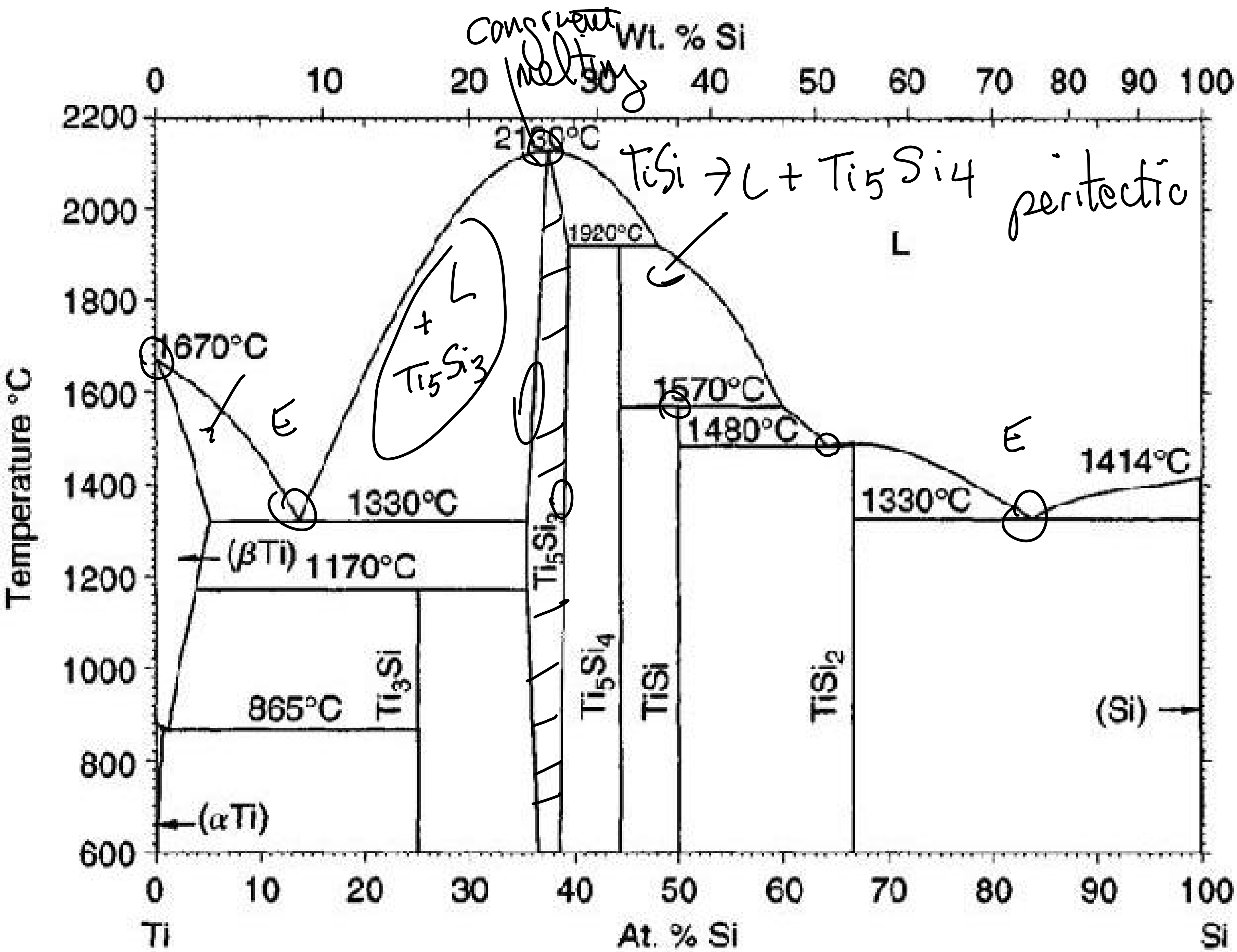
alloy steel

A phase diagram is a map

- All of the different regions mark where phase(s) will exist.
  - For a given T and composition
  - Under equilibrium conditions

Kinetics

- Phase boundaries mark where/when a phase becomes unstable
  - Outside of its given phase boundaries, a phase is not stable. A reaction will proceed that results in other phases at the expense of the phase we started with.


Wt. % Si
0
10
20
30
40
50
60
70
80
90
100
2200
2000
1800
1600
1400
1200
1000
800
600
Temperature °C
2130°C
1920°C
L
1670°C
1570°C
1480°C
1414°C
1330°C
1330°C
(βTi)
1170°C
865°C
(αTi)
Ti_3Si
Ti_5Si_3
Ti_5Si_4
TiSi
$TiSi_2$
(Si)
Ti
Si
At. % Si
congruent melting
$TiSi \to L + Ti_5Si_4$
peritectic
E
E
$Ti_5Si_3 + L$

Invariant points tell us something about the reactions

- What phases are involved
- Whether it involves all solids or solid AND liquids
- Allows us to ask questions
  - How fast might the reaction proceed?
  - How much heat is associated with the reaction?

Invariant points tell us something about the reactions

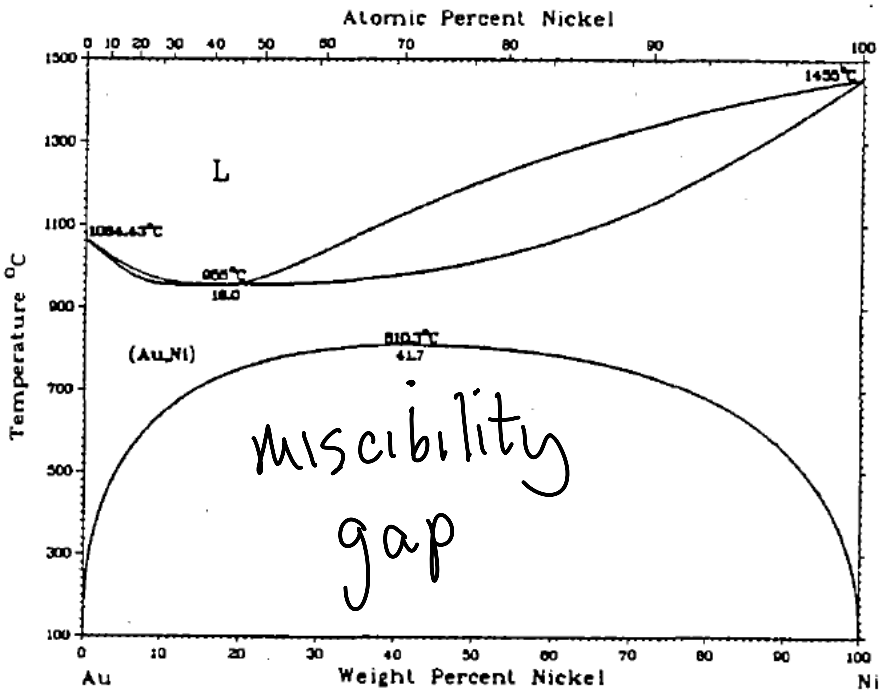
I. Critical Temperatures

a. Melting points and allotropes of pure elements

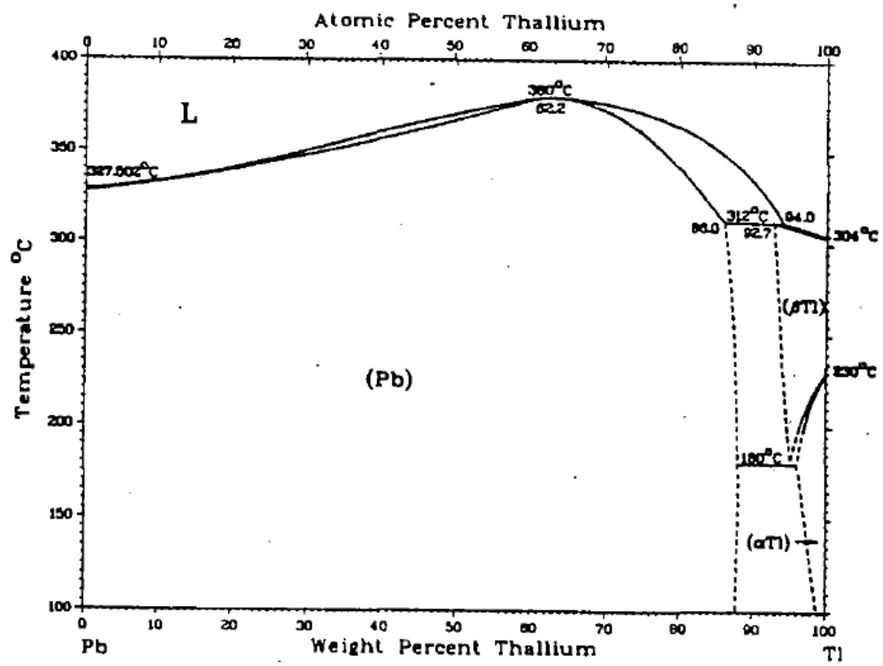
b. Melting point minima ($CaSiO_3$-$SrSiO_3$) and maxima (Tl - Pb)

c. Congruent melting of intermediate compounds and phases ($MnAl_2O_4$)

Au-Ni


Atomic Percent Nickel
L
1084.43°C
955°C
18.0
1455°C
810.3°C
41.7
(Au,Ni)
miscibility gap
Temperature °C
Weight Percent Nickel
Au
Ni

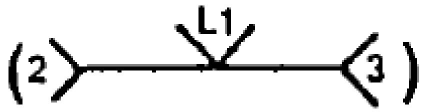
Pb-Tl


Atomic Percent Thallium
L
327.502°C
380°C
62.2
312°C
86.0
92.7
94.0
304°C
(βTl)
230°C
(Pb)
180°C
(αTl)
Temperature °C
Weight Percent Thallium
Pb
Tl

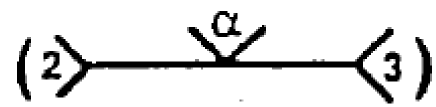
Temp

II. Eutectic Types

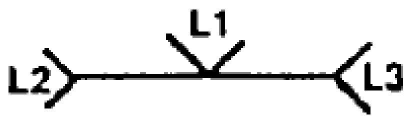
Eutectoid Types



(involves L)

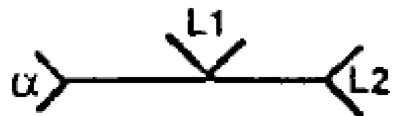


(involves S only)

e. 

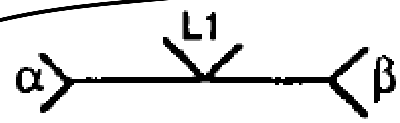
Probably does not occur

No name - no known examples

f. 

Monotectic

Ce-Mn, Cu-Pb, Cu-Tl, Cu-W, Ga-Pb, Ga-Tl, Pb-Zn

g. 

Eutectic

Cu-Ag, MgO-CaO, MnO-$MnAl_2O_4$, Pb-Sn

h. 

Probably does not occur

No name - no known examples

i. 

Metatectic (Catatectic)

Ag-In, Ag-Li, Bi-Mg, Cu-Sn, Eu_2O_3- MgO, Fe-Fe_2Zr, HfO_2-TiO_2

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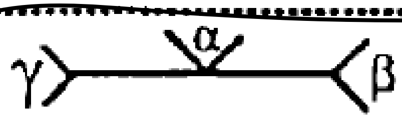
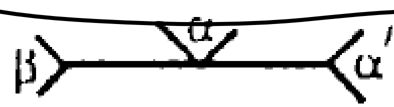
j. 

Eutectoid

Cu-Sn, Fe-Fe_3C

k. 

Monotectoid

Al-Zn, Ta-Zr

III. Peritectic Types

Peritectoid Types

Temp

(involves L)

(involves S only)

l. 

m. 

n. 

l., m., n.: Probably do not occur — No names - No known examples

o. 

Syntectic — Ca-Cd, K-Pb, K-Zn, Na-Zn, Pb-U

p. 

Peritectic — Ag-Pt, V_2O_5-Cr_2O_3

q. 

Peritectoid — Ag-Al, Cu-Al, Cu-Sn

Eutectoid & Peritectic

- Eutectic - liquid in equilibrium with two solids

$$L \underset{\text{heat}}{\overset{\text{cool}}{\rightleftharpoons}} \alpha + \beta$$

- Eutectoid - solid phase in equation with two solid phases

$$S_2 \rightleftharpoons S_1 + S_3$$

austenite

intermetallic compound
- cementite

$$\gamma \underset{\text{heat}}{\overset{\text{cool}}{\rightleftharpoons}} \alpha + Fe_3C \qquad (727^oC)$$

- Peritectic - liquid + solid 1 → solid 2 (Fig 9.21)

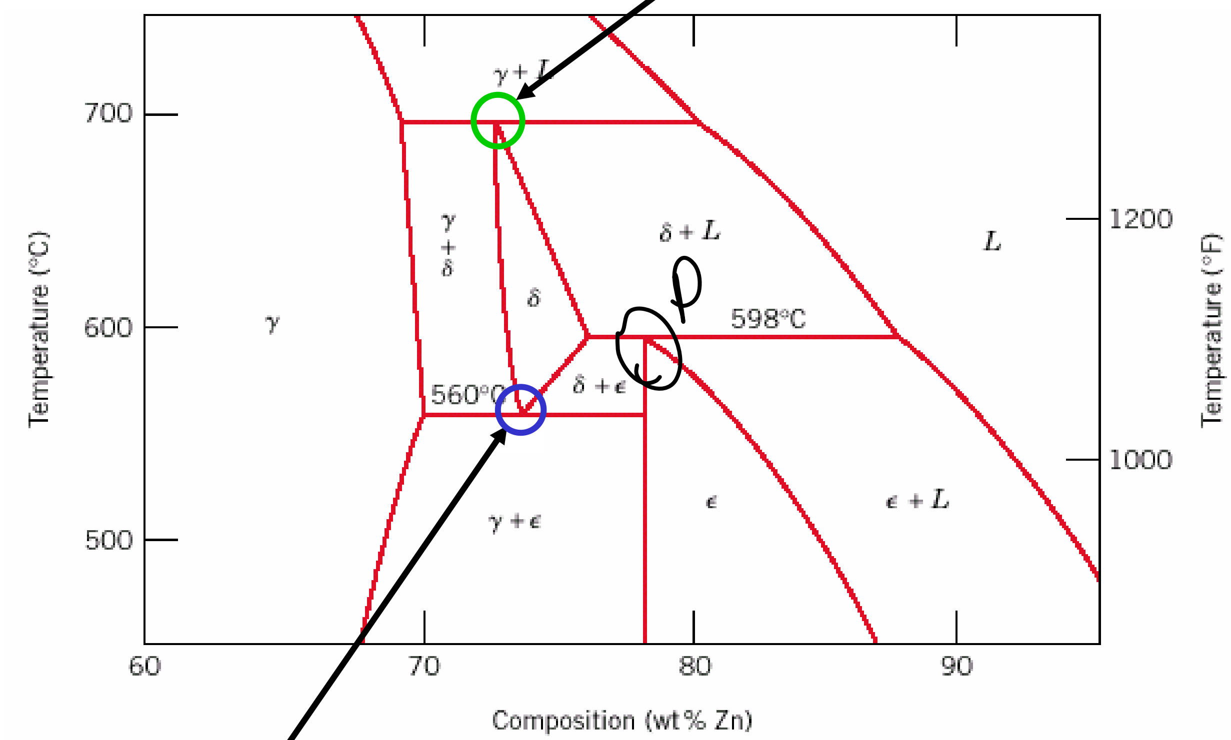
$$S_1 + L \rightleftharpoons S_2$$

$$\delta + L \underset{\text{heat}}{\overset{\text{cool}}{\rightleftharpoons}} \gamma \qquad (1493^oC)$$

Eutectoid & Peritectic

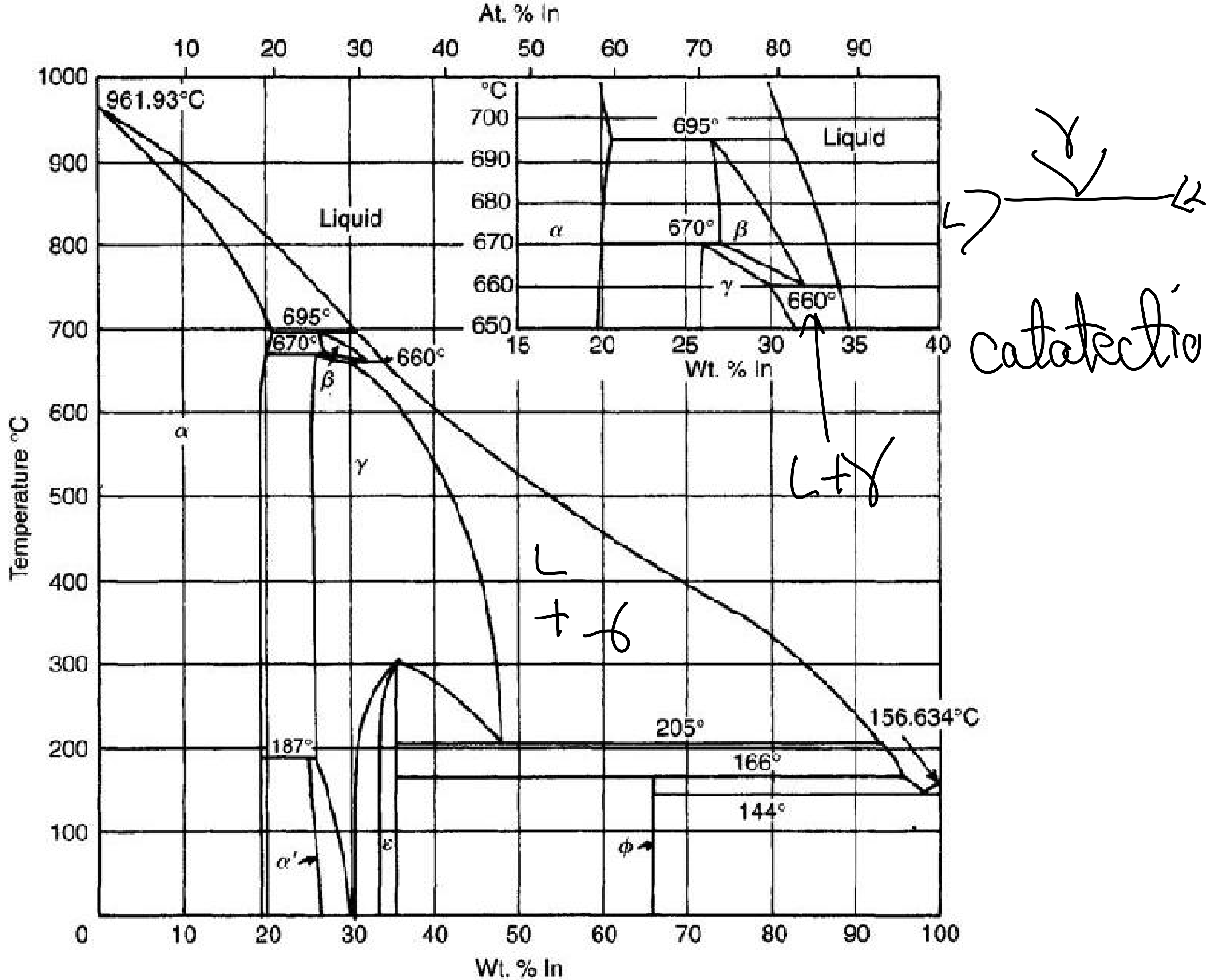
Peritectic transition $\gamma + L \rightleftharpoons \delta$

Cu-Zn Phase diagram



Adapted from
Fig. 9.21, *Callister 7e.*

Eutectoid transition $\delta \rightleftharpoons \gamma + \varepsilon$


At. % In
10 20 30 40 50 60 70 80 90
1000
900
800
700
600
500
400
300
200
100
0
961.93°C
Liquid
695°
670°
660°
β
α
γ
Temperature °C
187°
α′
ε
205°
166°
144°
156.634°C
φ
10 20 30 40 50 60 70 80 90 100
Wt. % In
°C
700
690
680
670
660
650
15 20 25 30 35 40
Wt. % In
L + δ
L+γ
catatectic

Where does a phase diagram come from?

- **Method 1**
  - Anneal an alloy of a given composition for a long time in a closed environment at a give T
  - Quench the alloy
  - Examine it with a battery of characterization techniques (chemical, structural, etc.)
  - Determine what phases are present and add a point to the diagram!

Where does a phase diagram come from?

- **Method 2**
  - Measure thermodynamic data for all the known phases
  - Conduct a somewhat complex thermodynamic calculation
  - Predict the phase diagram based on thermodynamic principles

    Gibbs free energy
    - Lowest energy is most stable
    - Solubility limits
    - Entropy

Summary

MAP

- Phase diagrams are useful tools to determine:

  --the number and types of phases,
  --the wt% of each phase,
  --and the composition of each phase

  for a given *T* and composition of the system.

phase diagram + processing conditions + kinetic data =

prediction of phases present and microstructure

Summary

Phase diagrams compiled in various sources:

- http://www.knovel.com/knovel2/Toc.jsp?BookID=717
- **Binary alloy phase diagrams, ed. T.B. Massalski (ASM International, Materials Park, OH, 1990).**
- **Scholarly journal articles**
- **Company documents (unreleased)**

User Beware:

- **Published phase diagrams are not always accurate**
- **Popular alloy systems generally have better data**

Quick Mid-Term Summary

"There will no laughing and learning… only PAIN."

from mycathatesyou.com

Quick Mid-Term Summary

- **Exam is closed book. NO equation sheets.**
- **You will be given solutions to Fick's second law and the erfc(z) graph.**
- **Any other equation you think you might need?**
  - **Derive it from dimensional analysis**
  - **Memorize it**
- **Study tips for an exam such as this**
  - **Simply memorizing equations will not help you**
  - **Work many problems out. You will naturally memorize the formula through understanding how it is used.**
  - **Study everything: Callister, the assigned homework, quizzes, lecture notes, etc.**

Callister

- **The exam is on Ch. 1, 2, 3, 4, 5, and 9**
- **These sections were not covered**
  - **4.9, 4.10, 4.11**
  - **9.16, 9.17, 9.20**
- **Monday lecture of next week will also be on the mid-term.**

Questions?

- **Three tutorial sections prior to mid-term**
  - **14Feb, Wed**
  - **15Feb, Thurs**
  - **26Feb, Mon (day of mid-term, not recommended, but do come with questions if necessary)**
- **Office hours**
- **WebCT email**