

به نام خدا



مرکز دانلود رایگان
مهندسی متالورژی و مواد

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Alloys & Their Phase Diagrams



Objectives of the class

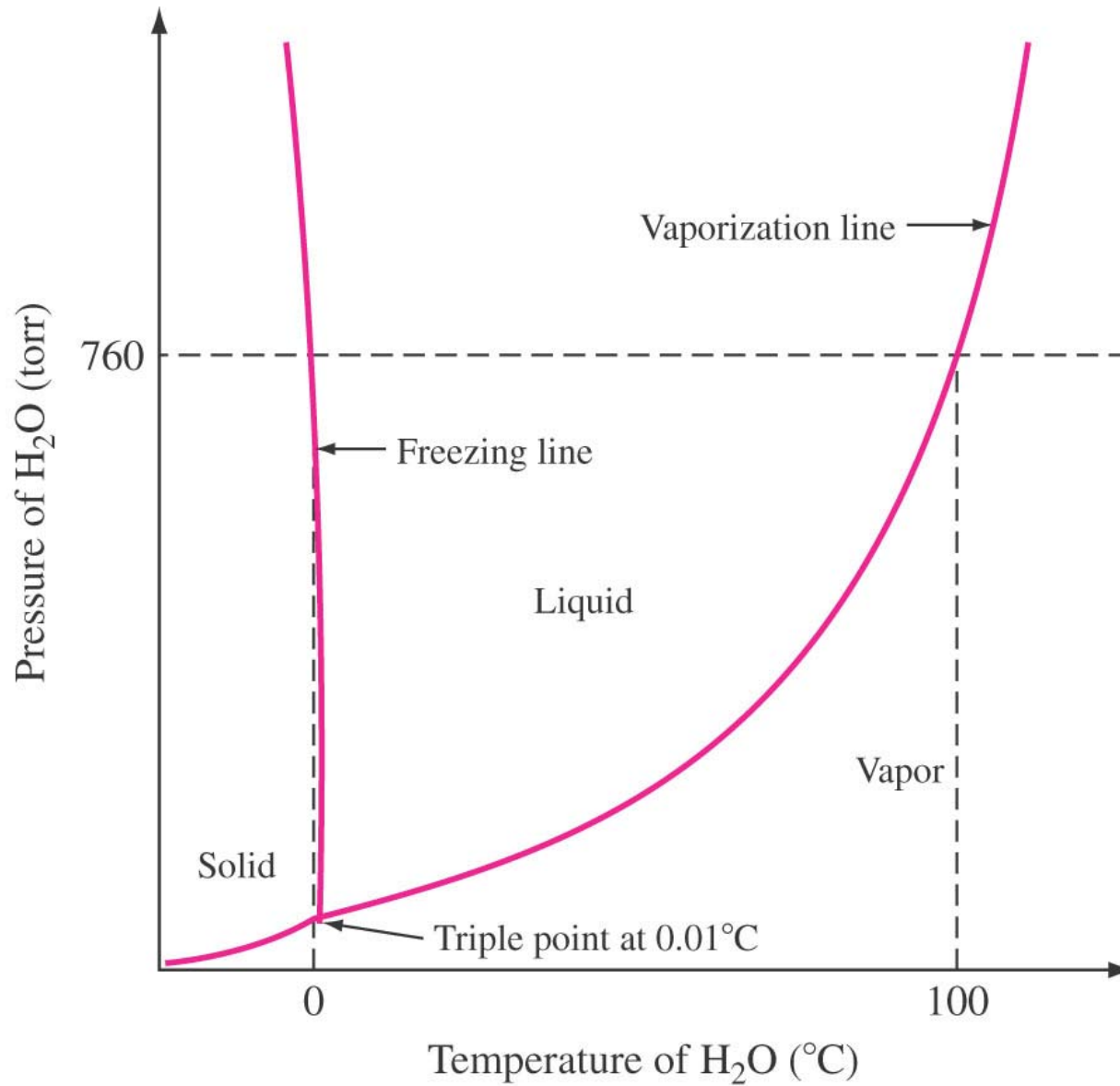
Gibbs phase rule

Introduction to phase diagram

Practice phase diagram

Lever rule

***Important Observation: One question in the
midterm***





Gibbs phase rule

$$P + F = C + 2$$

P: number of phases (ie, solid, liquid, or gas)
C: number of components
F: Degree of freedom



Simple Example

Water:

a) At the triple point:

$P = 3$ (solid, liquid, and gas)

$C = 1$ (water)

$P + F = C + 2$

$F = 0$ (no degree of freedom)

b) liquid-solid curve

$P = 2$

$2 + F = 1 + 2$

$F = 1$

One variable (T or P) can be changed

c) Liquid

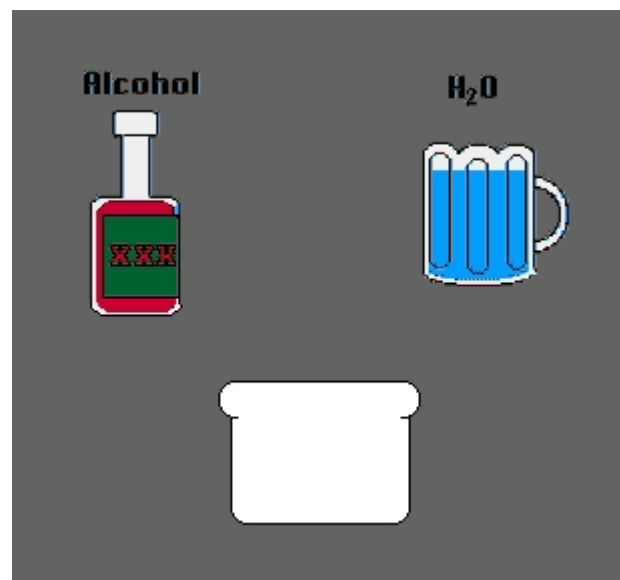
$P = 1$

So $F = 2$

**Two variables (T and P) can be varied independently
and the system will remain a single phase**

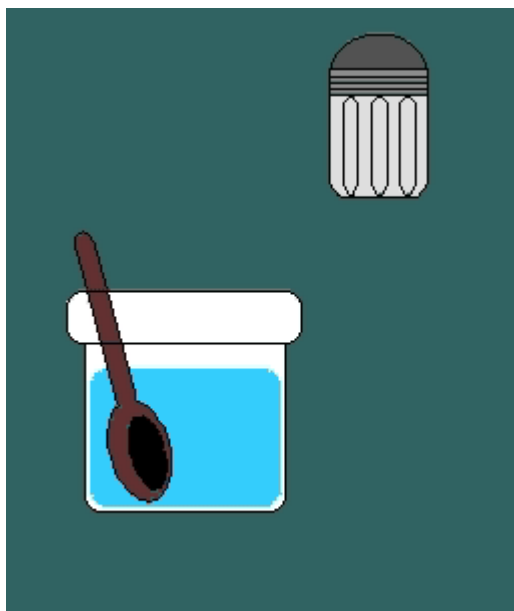


Unlimited Solubility



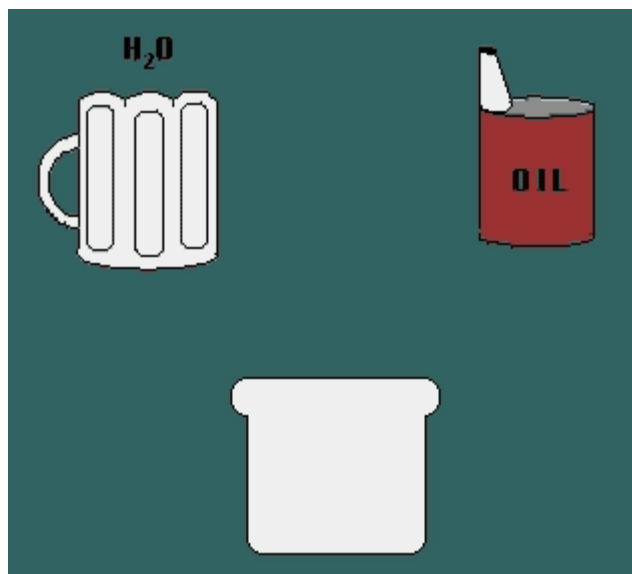


Limited solubility





No Solubility





Binary Isomorphous Alloy Systems

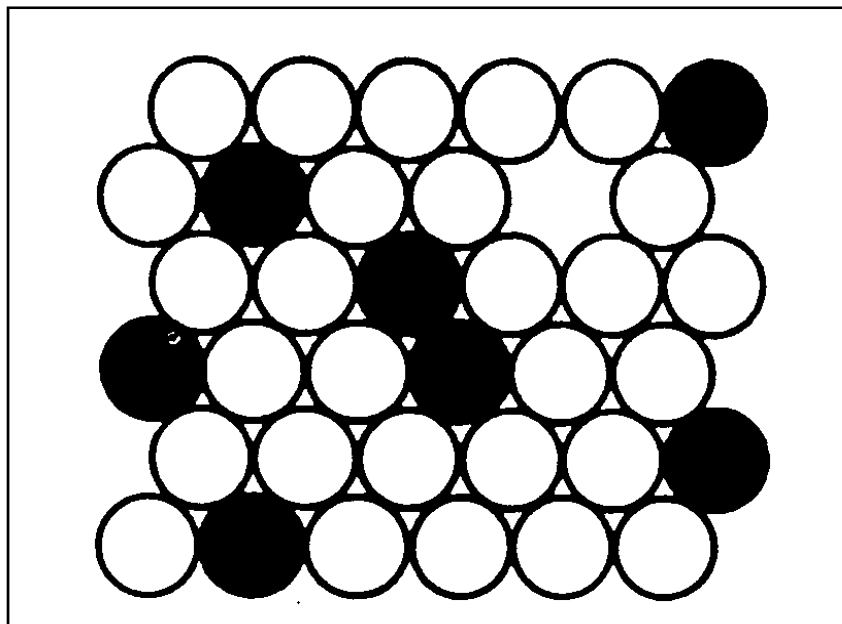
A mixture of two metals is called a **binary alloy** and constitutes a **two-component** system.

Each metallic element in an alloy is called a separate **component**.

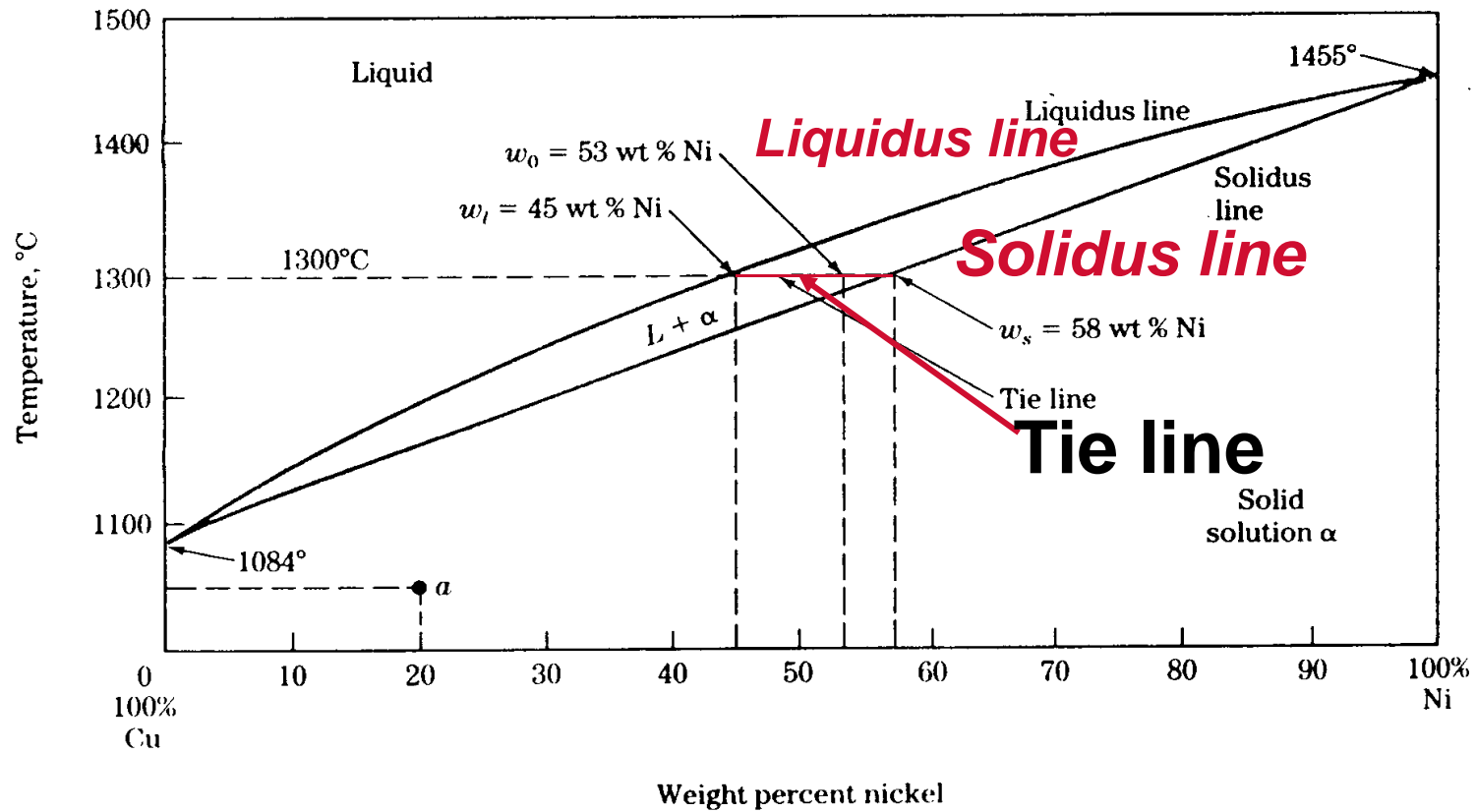
Isomorphous systems contain metals which are completely soluble in each other and have a single type of crystal structure.



Cu-Ni: A Substitutional Solid Solution



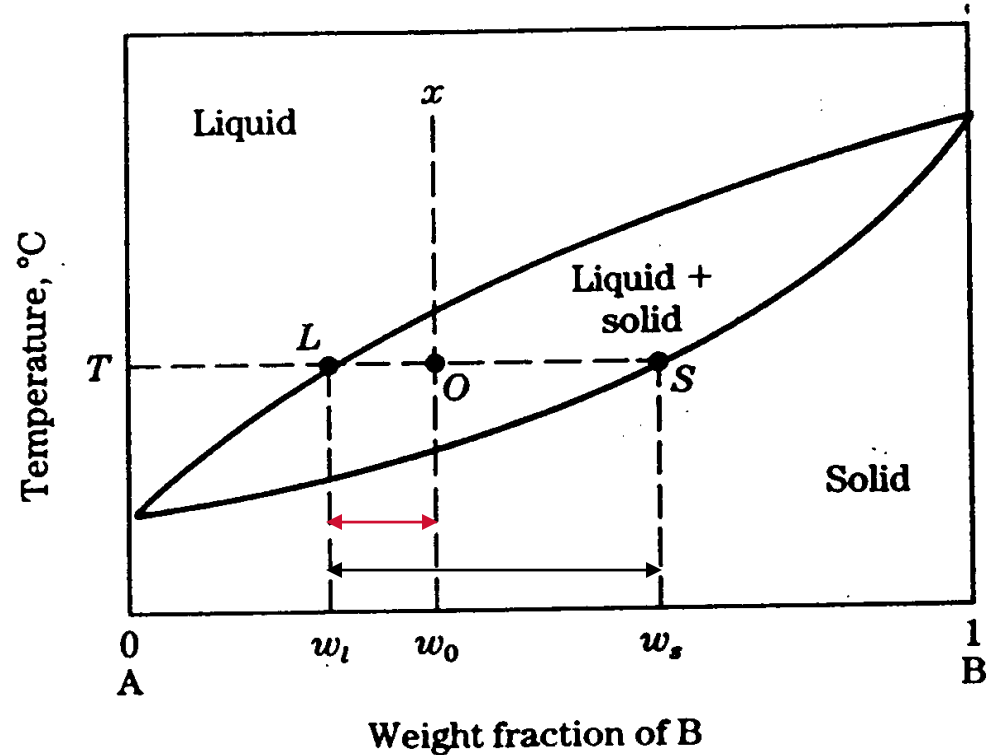
Cu-Ni: Binary Isomorphous Alloy Example





The Lever Rule

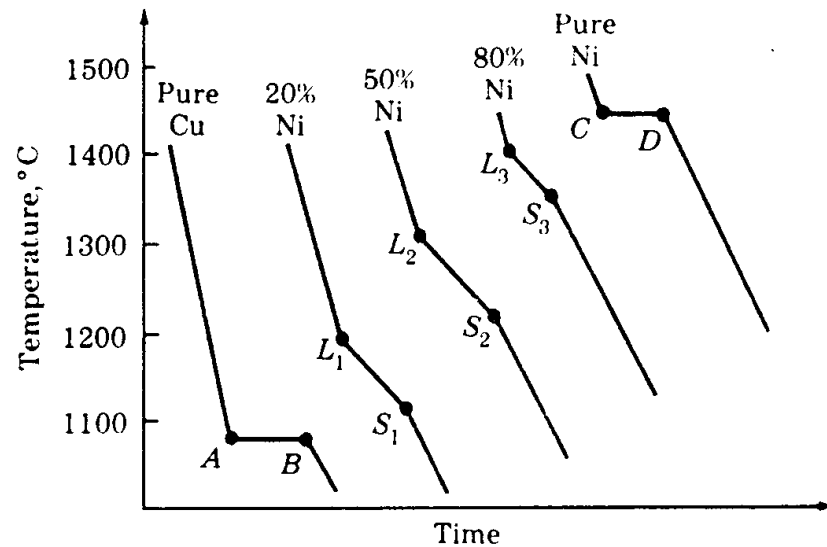
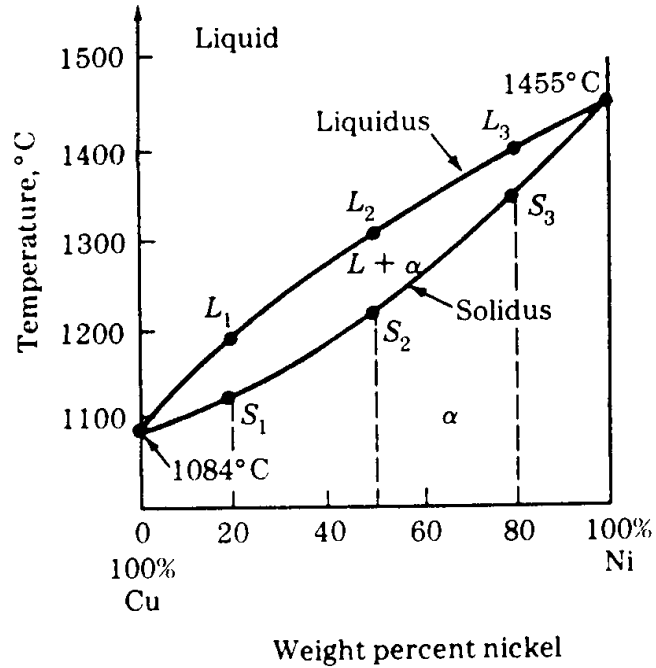
To compute the amount of solid phase:



$$\text{Fraction of the solid phase} = (w_0 - w_l) / (w_s - w_l)$$

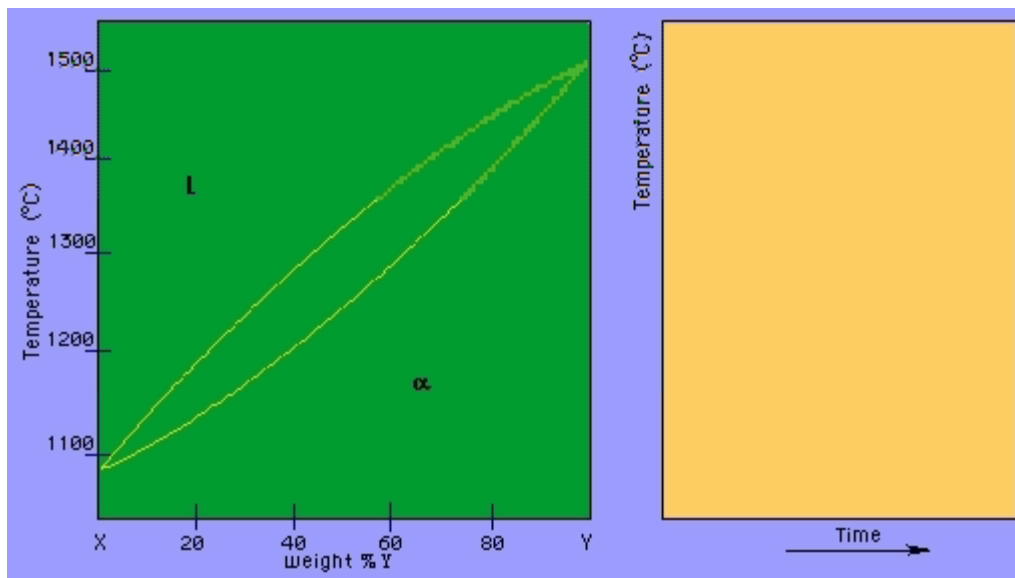


Cu-Ni: Cooling Curves





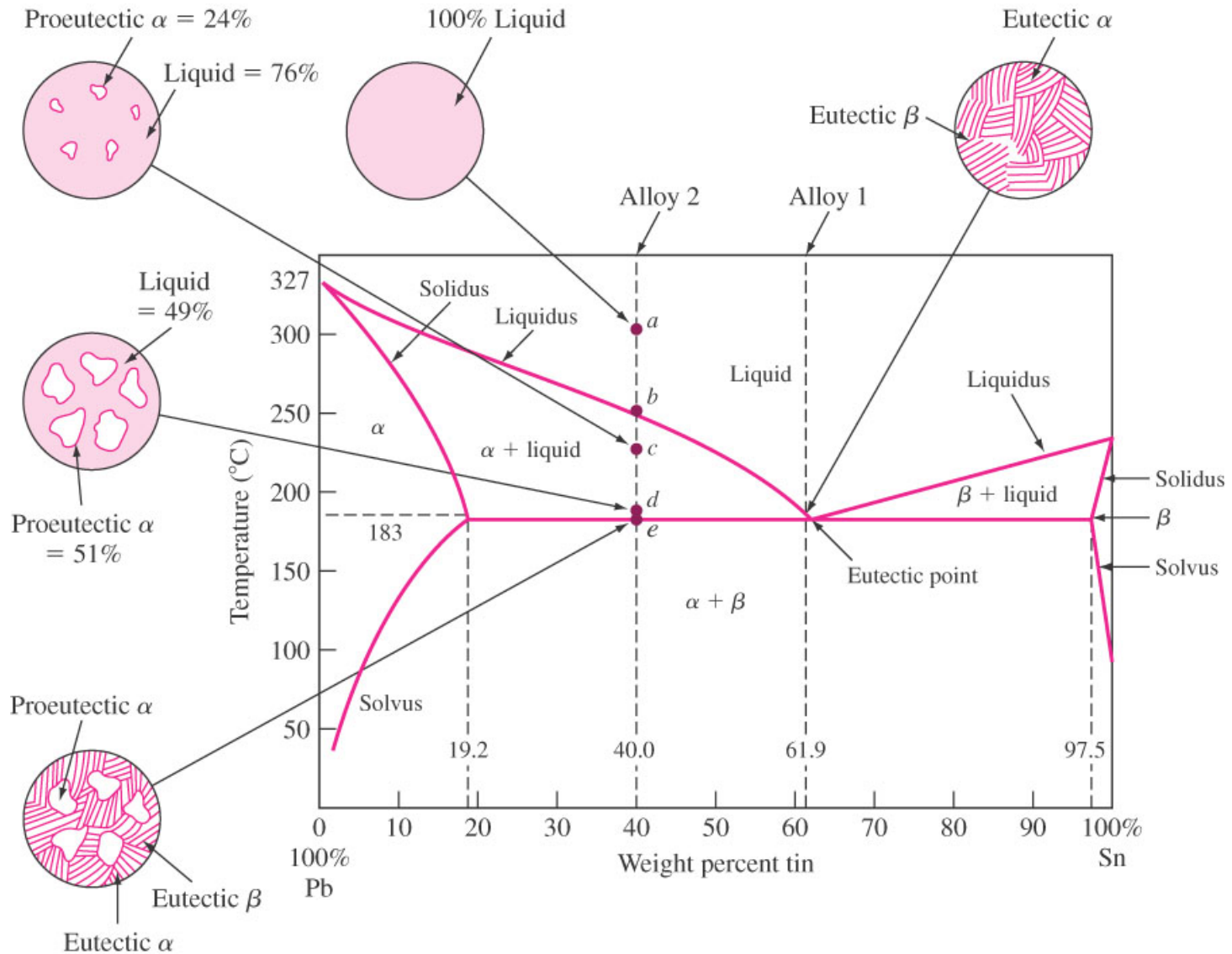
Cooling curve





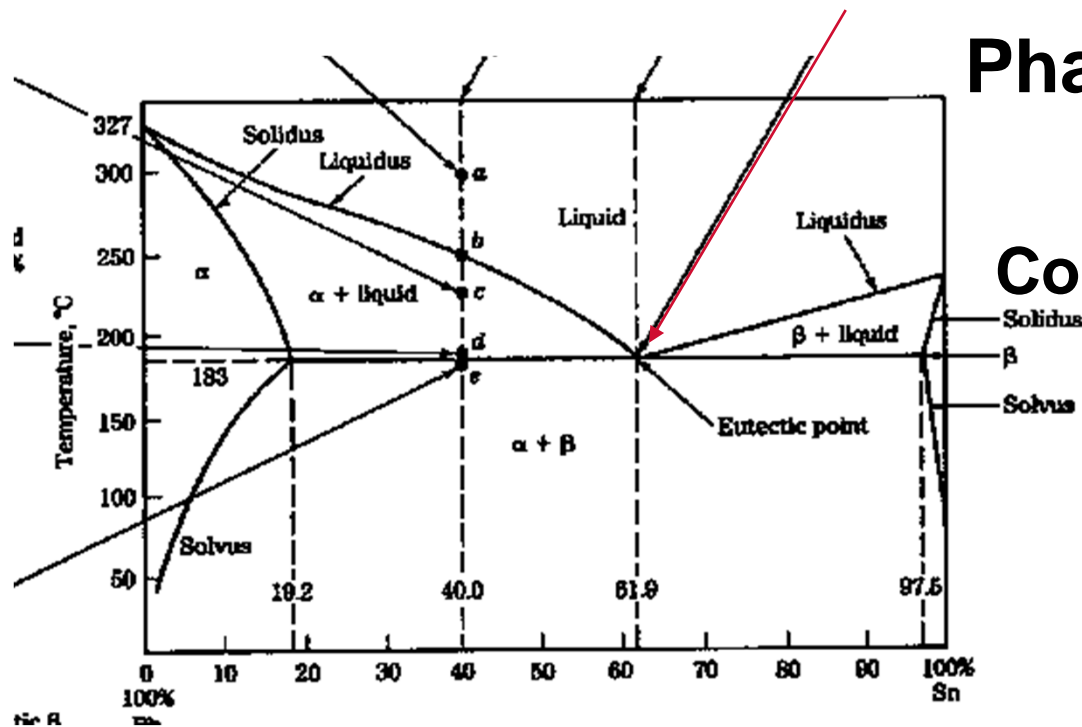
Some examples

Binary Eutectic Alloy Systems





Eutectic composition:



Phases: alpha and beta

Composition of the phases:

Alpha: 19.2% Sn

Beta: 97.5% Sn

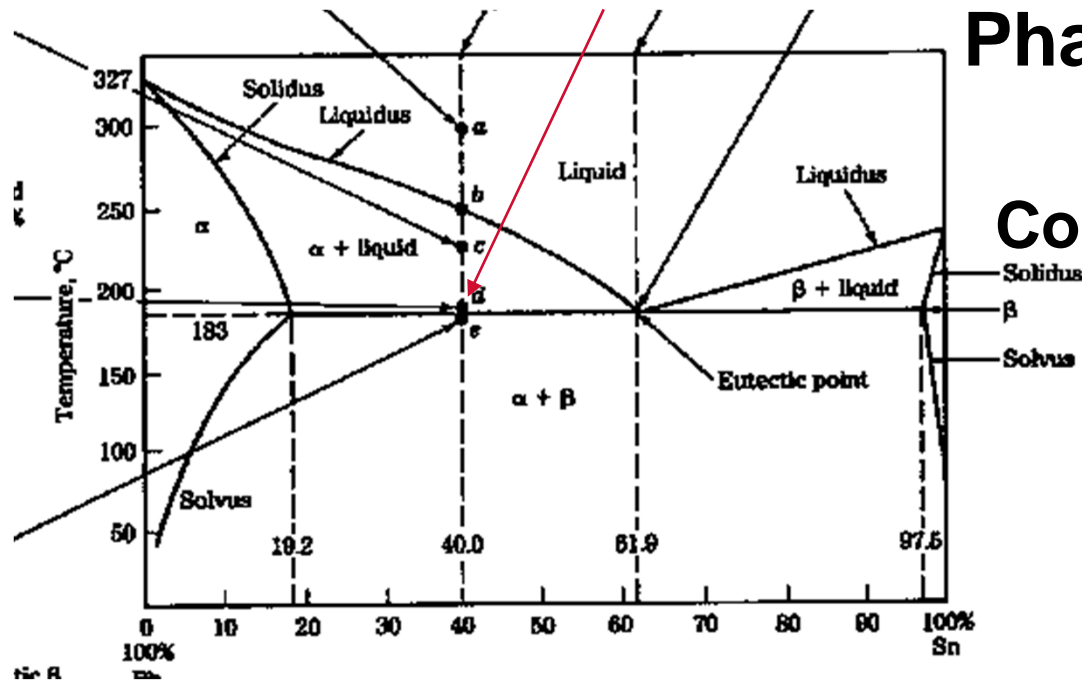
Amount of phases:

45.5% of alpha: $(97.5 - 61.9) / (97.5 - 19.2)$

54.5% of beta phase



Example: Point D



Phases: liquid and alpha

Composition of the phases:

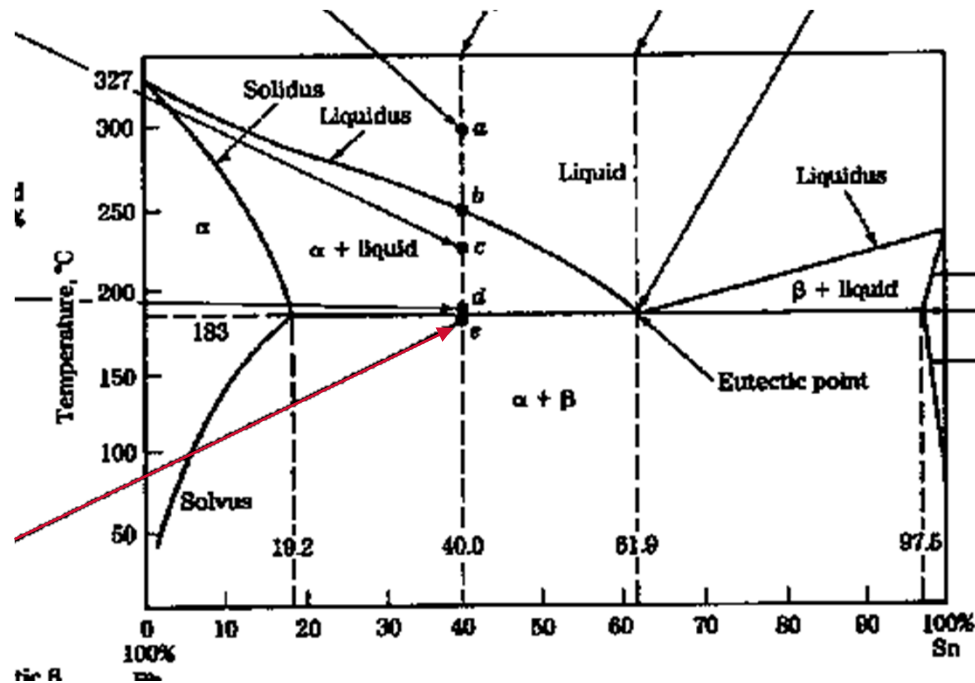
Alpha: 19.2% Sn

Liquid: 61.9% Sn

Amount of phases:
51% of alpha phase: $(61.9-40)/(61.9-19.2)$
49% of liquid phase



Example: Point E



Phases: alpha and beta

Composition of the phases:
Alpha: 19.2% Sn
beta: 97.5% Sn

Amount of phases:

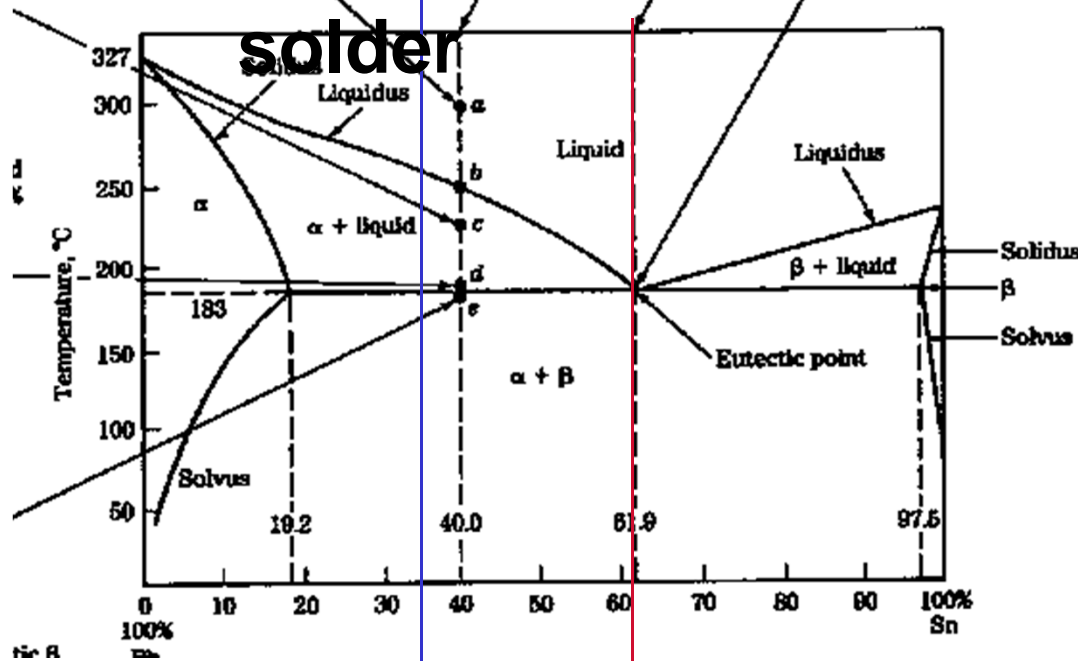
73% of alpha phase: $(97.5-40)/(97.5-19.2)$

27% of beta phase

So what?

High-melting solder

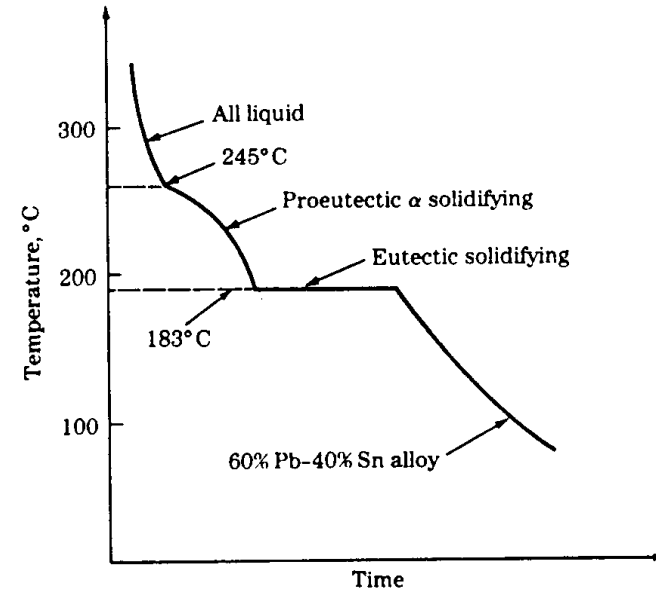
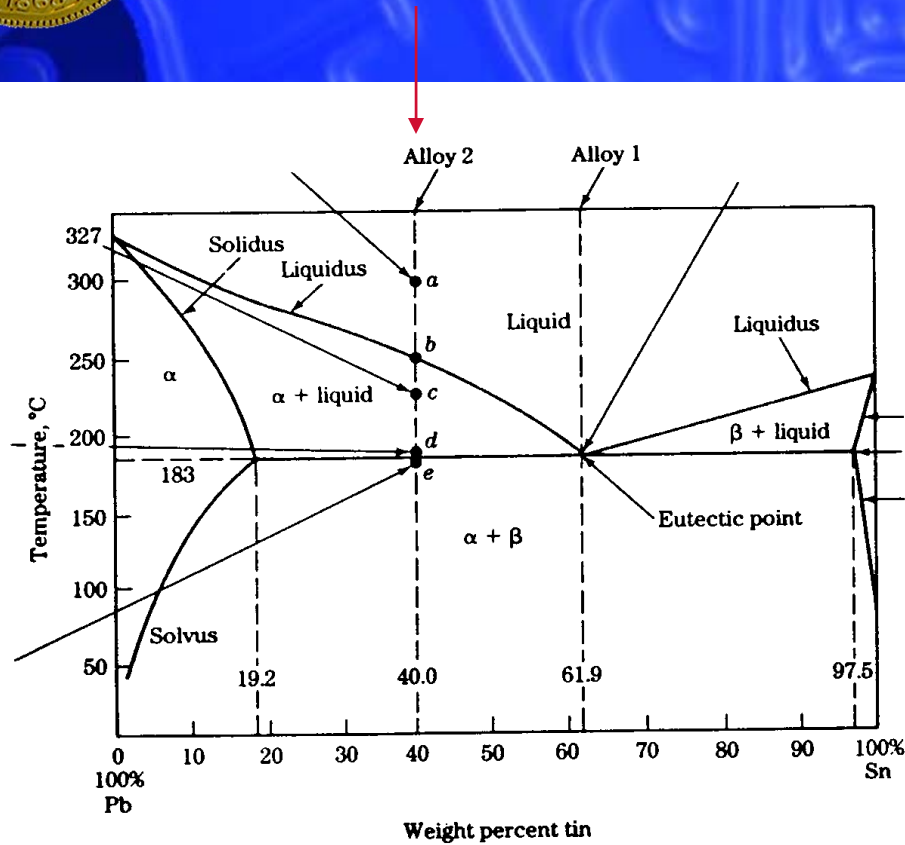
Example solder: pasty used in joints (Romans) and car body filling



Soft: eutectic (free flowing): electronic assembly
Eutetic: from the Greek
easy melting



A Eutectic Cooling Curve



Temperature-time cooling curve for 60% Pb – 40% Sn alloy



Eutectic Microstructures

There are a number of different "morphologies" for the two phases in a binary eutectic alloy.

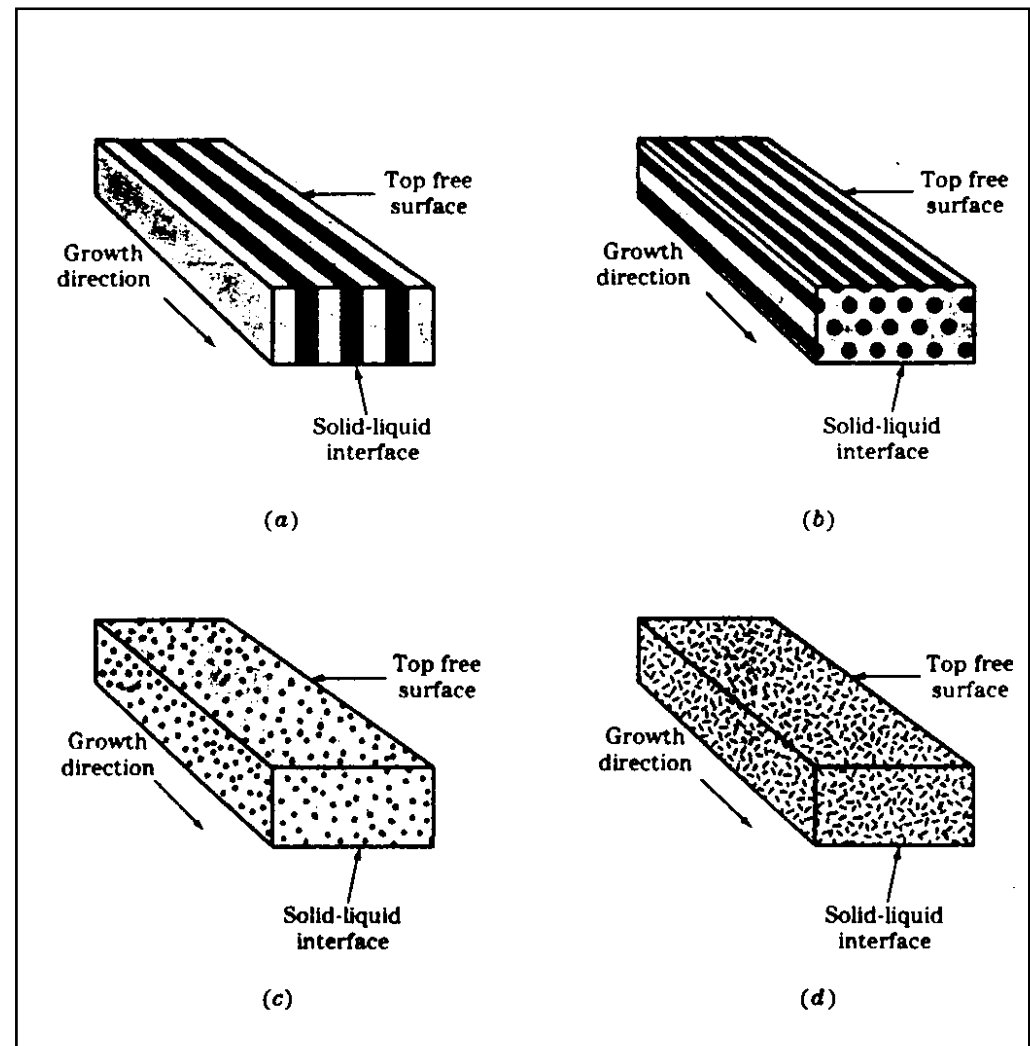
Of prime importance is the minimization of the interfacial area between the phases.

The rate of cooling can also have an important effect.

Eutectic Microstructures

Schematic illustration of the various eutectic microstructures: (a) lamellar, (b) rodlike, (c) globular, and (d) acicular (or needlelike).

Morphology means the "form", "shape" or "outward microstructure" of a phase.





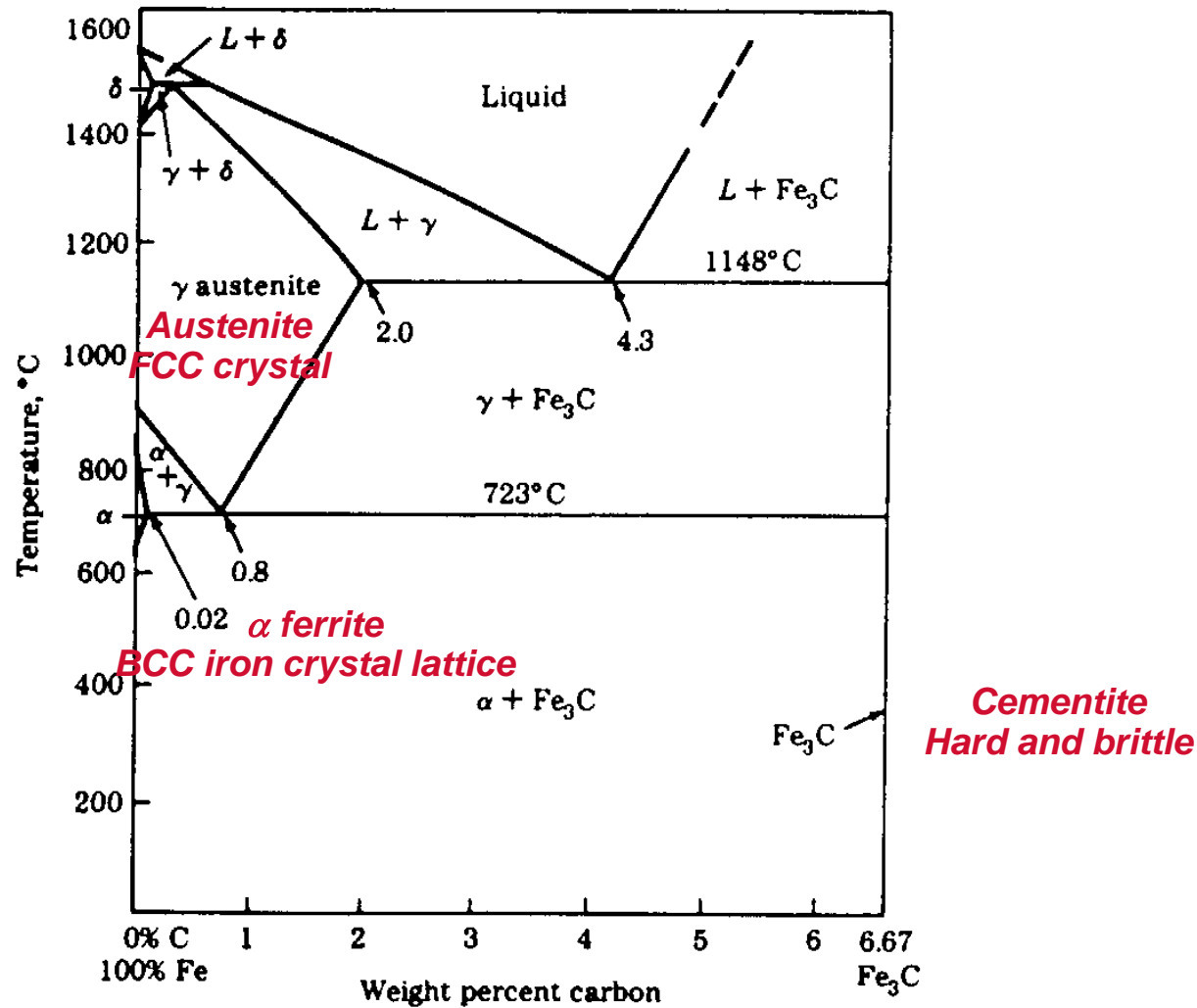
Microstructure evolution





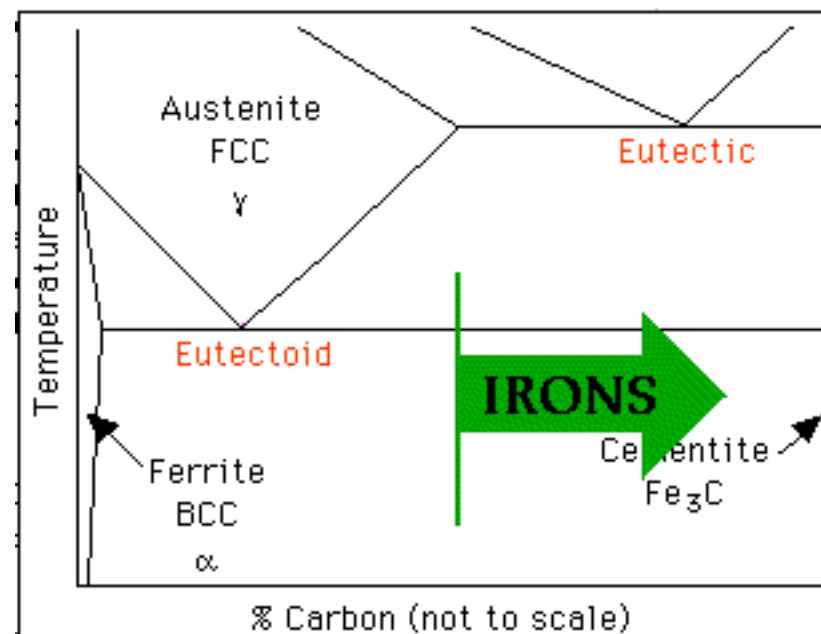
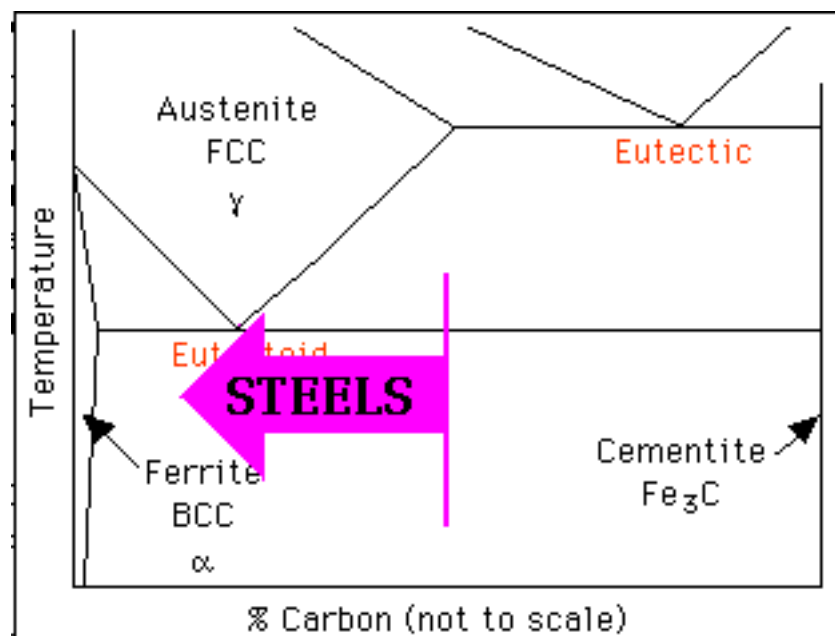
Equilibrium Microstructure of Steel Alloys

The Iron-Iron Carbide Phase Diagram



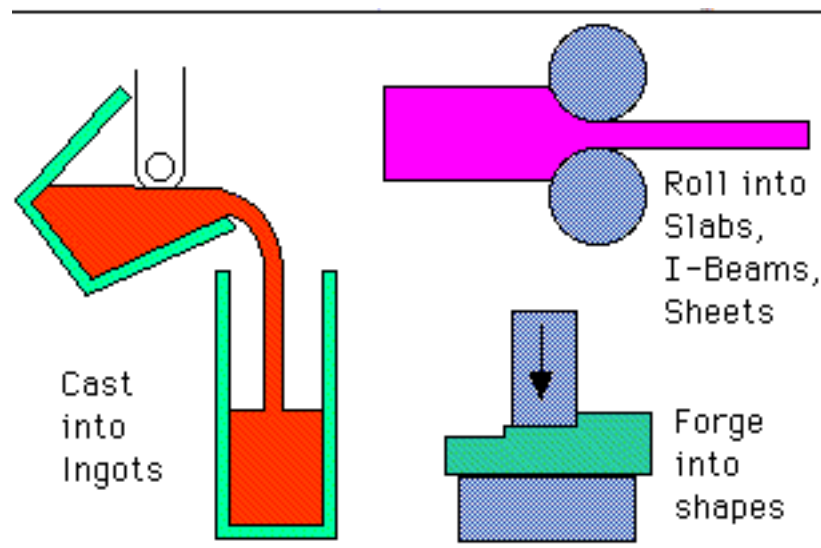


Steels and Irons





Forging





Forging





Plain-Carbon Steel

Steel can be defined as an Iron alloy which transforms to *Austenite* on heating.

A plain-carbon steels has no other major alloying element beside carbon.

When a plain-carbon steel is slowly cooled from the Austenitic range it undergoes the eutectoid transformation.

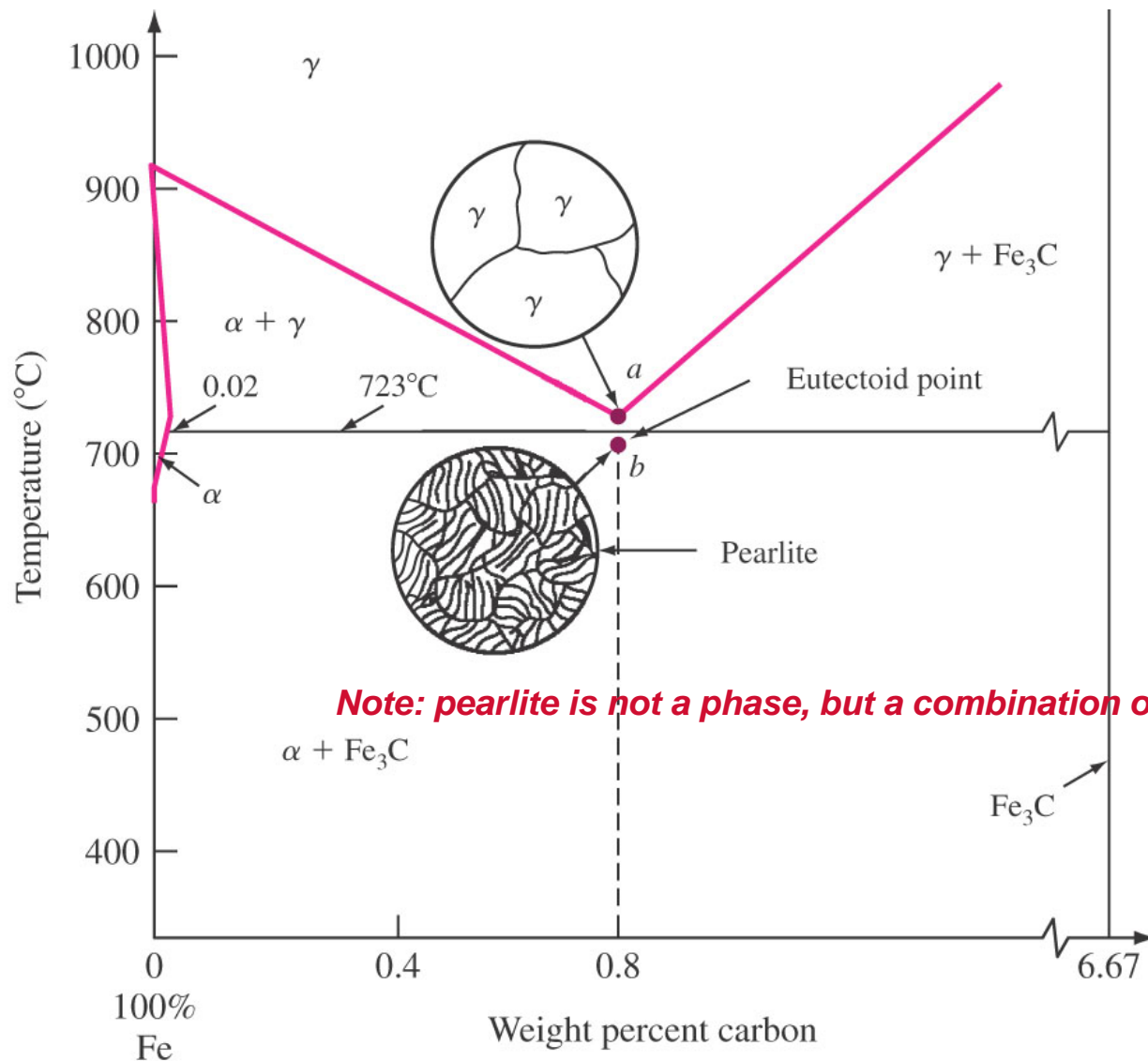


Construction steel

Construction steel alloys used for concrete reinforcing bars and structural shapes have been traditionally been 0.1-0.2% C plain-carbon steels with only minor additional elements.

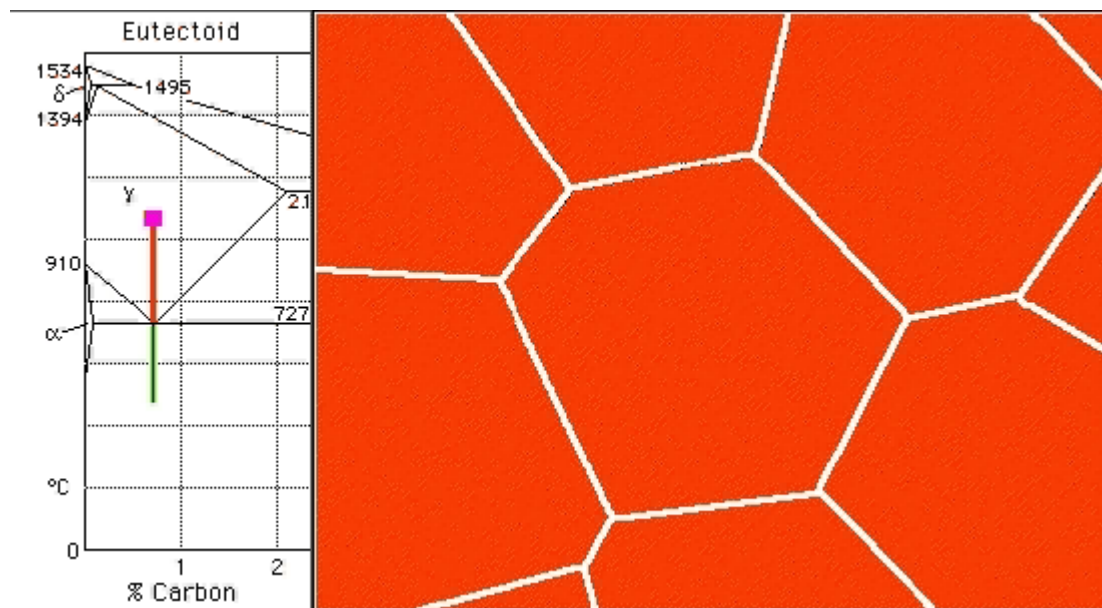
In general these alloys are called Low-alloy Steel and for most purposes they can be considered plain-carbon steel.

The Iron-Iron Carbide Eutectoid System





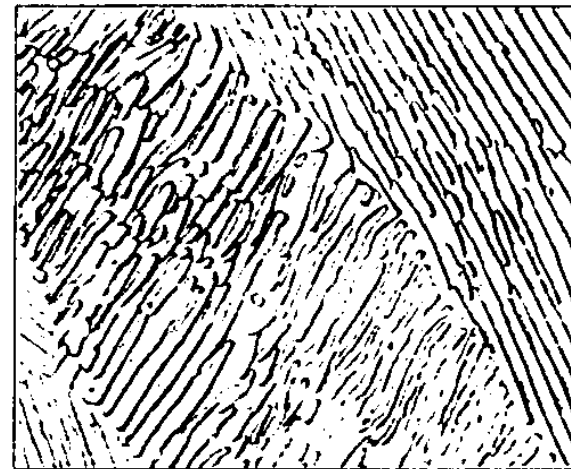
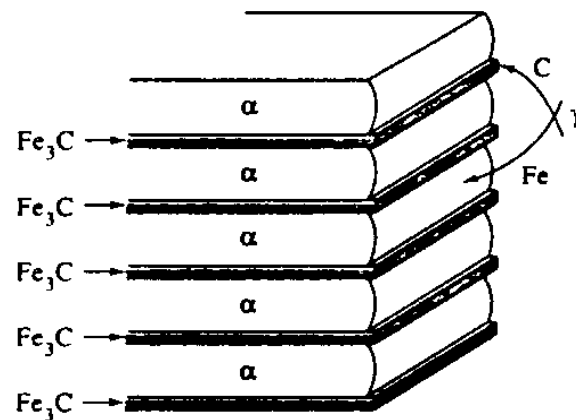
Eutectoid



Eutectoid Microstructures

Just like the eutectic systems there are a number of different "morphologies" for the two phases in a binary eutectic alloy.

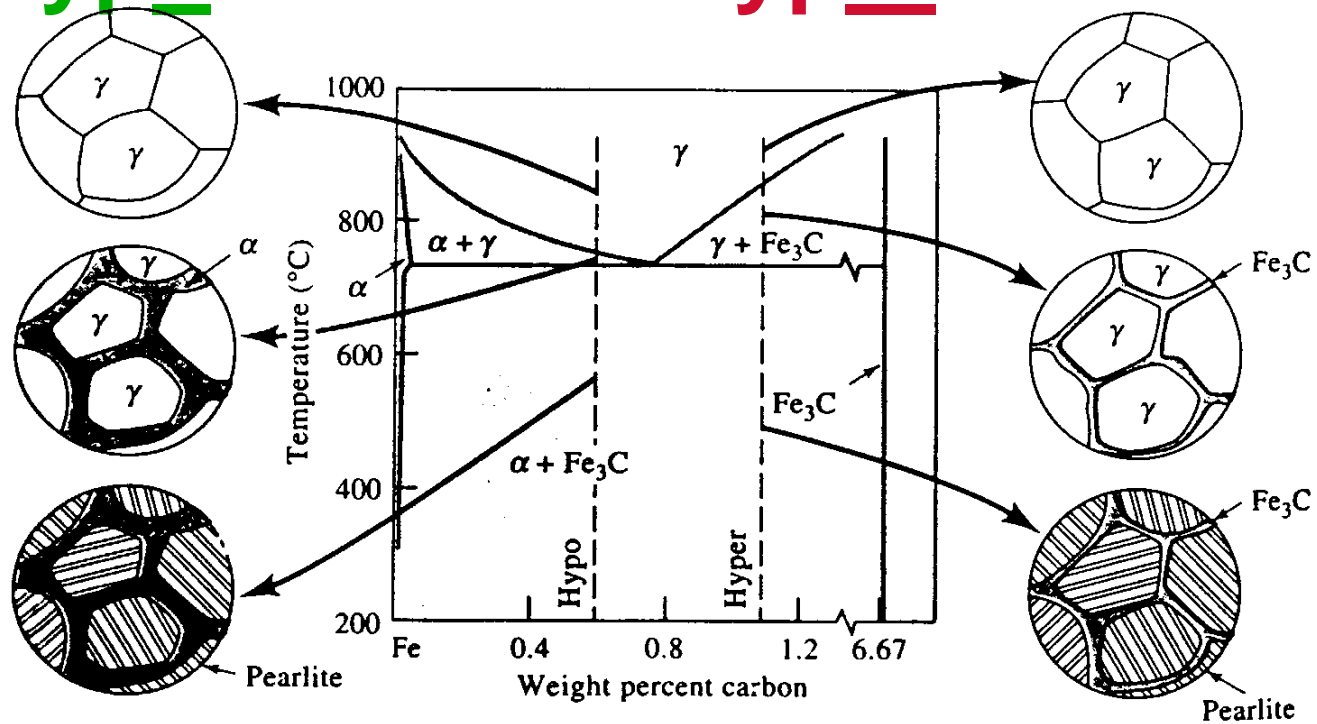
The most common morphology for eutectoid areas in the Fe-Fe₃C system is lamellar. (This is because most steel is relatively slowly cooled through the eutectoid phase transformation.)





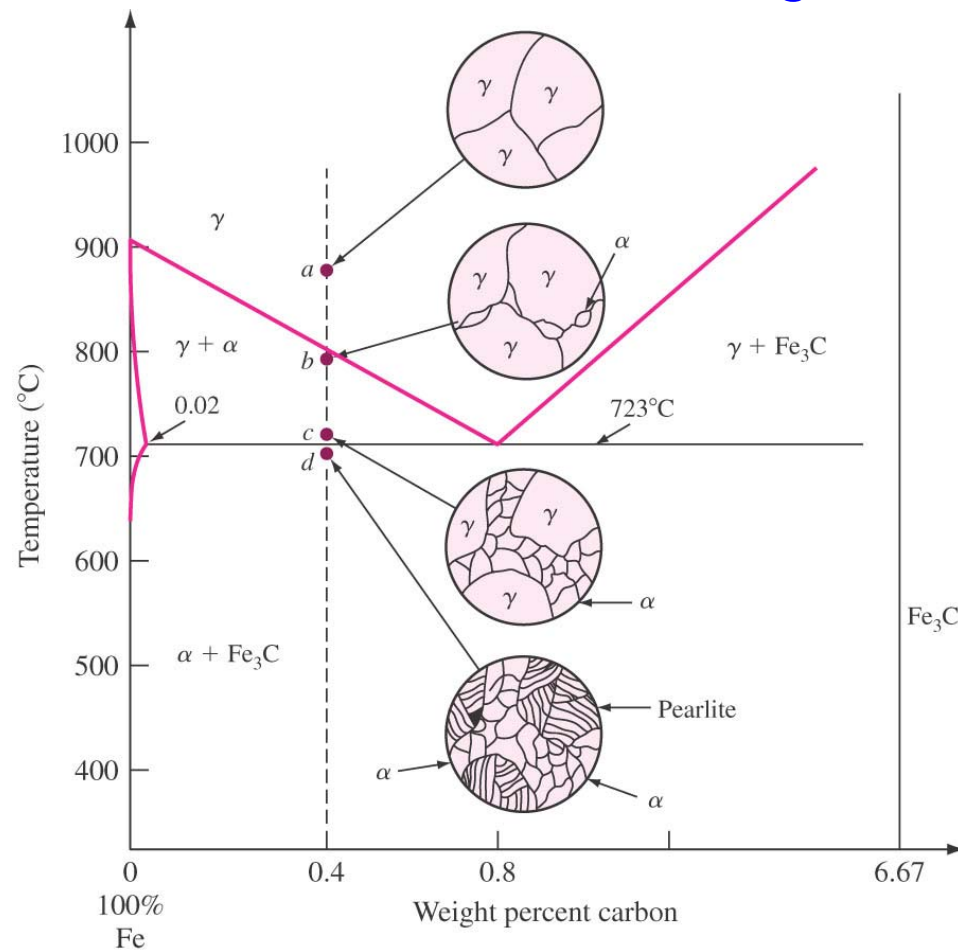
Evolution of Eutectoid Steel Microstructure

Hypoeutectoid Hypereutectoid



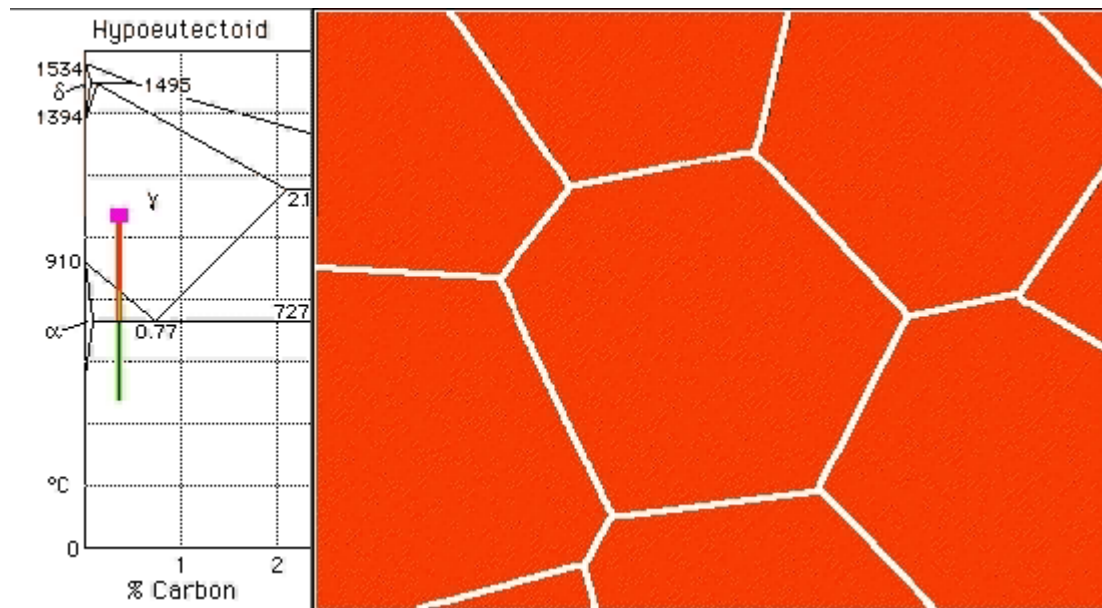
Slow Cooling of Plain-Carbon Steels

Transformation of a 0.4% C hypoeutectoid plain-carbon steel with slow cooling.



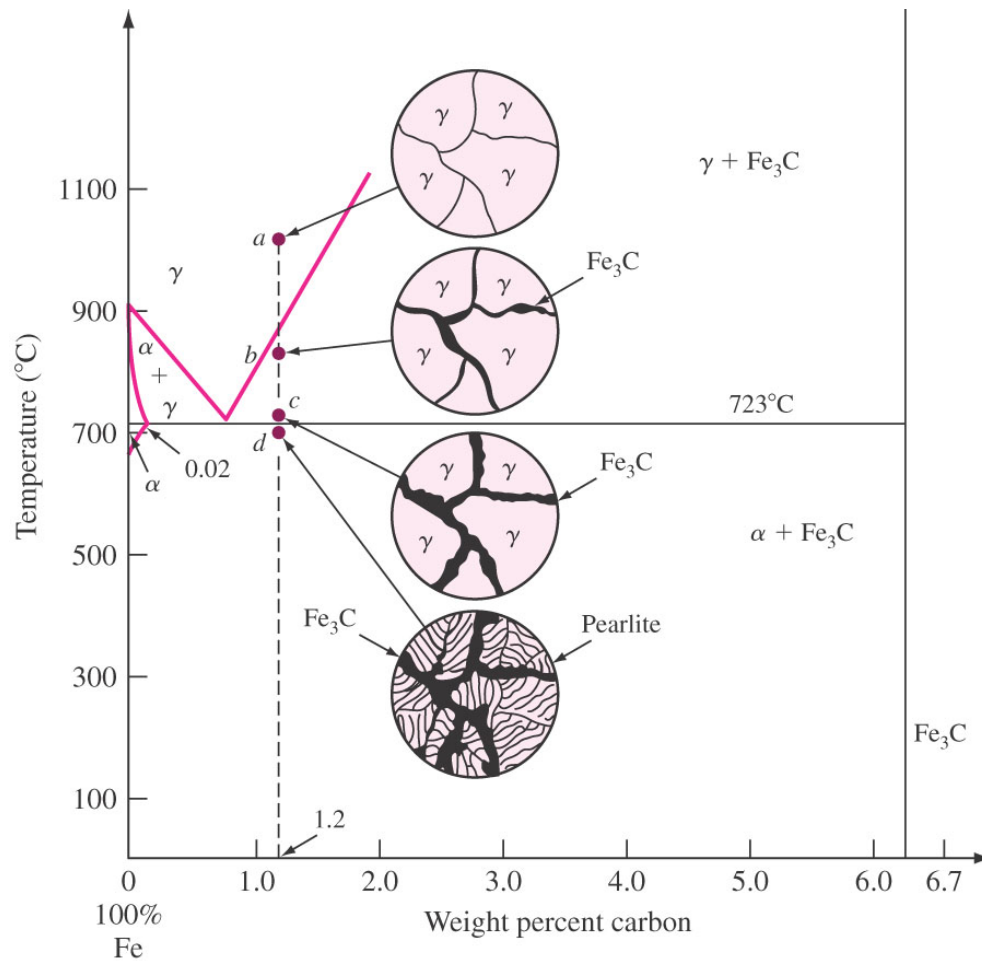


Hypoeutectoid



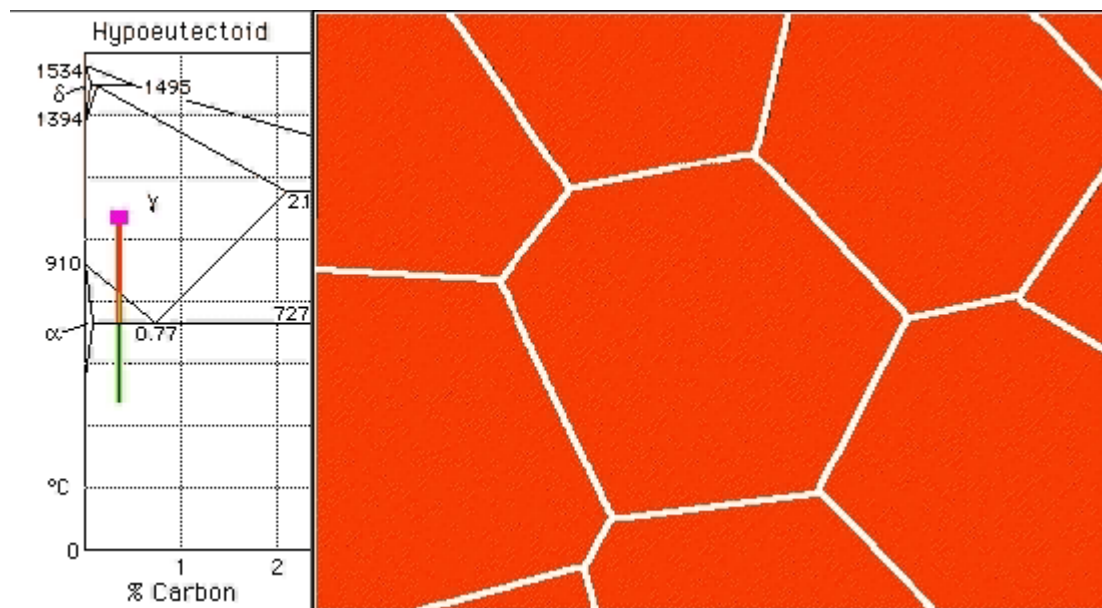
Slow Cooling of Plain-Carbon Steels

Transformation of a 1.2% C hypereutectoid plain-carbon steel with slow cooling.





Hypereutectoid





Carbon Steel (90% of the steel production)

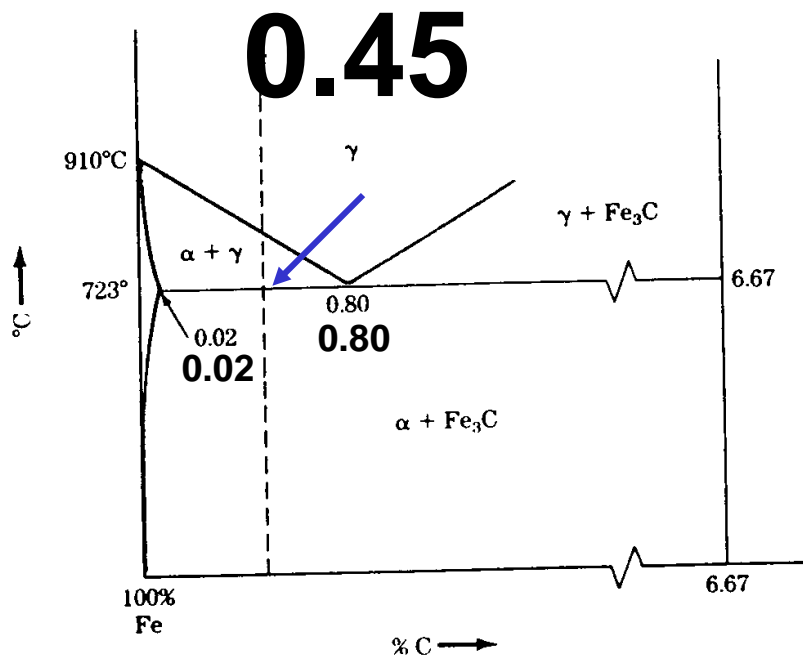
Low alloy steel (up to 6% of chromium, nickel, etc)

Stainless steel (18% chromium and 8% nickel)

Tool steels (heavy alloyed with chromium, molybdenum, tungsten, vanadium, and cobalt).

Problem

A 0.45%C hypoeutectoid plain-carbon steel is slowly cooled from 950 C to a temperature just slightly above 723 C. Calculate the weight percent austenite and weight percent proeutectoid ferrite in this steel.



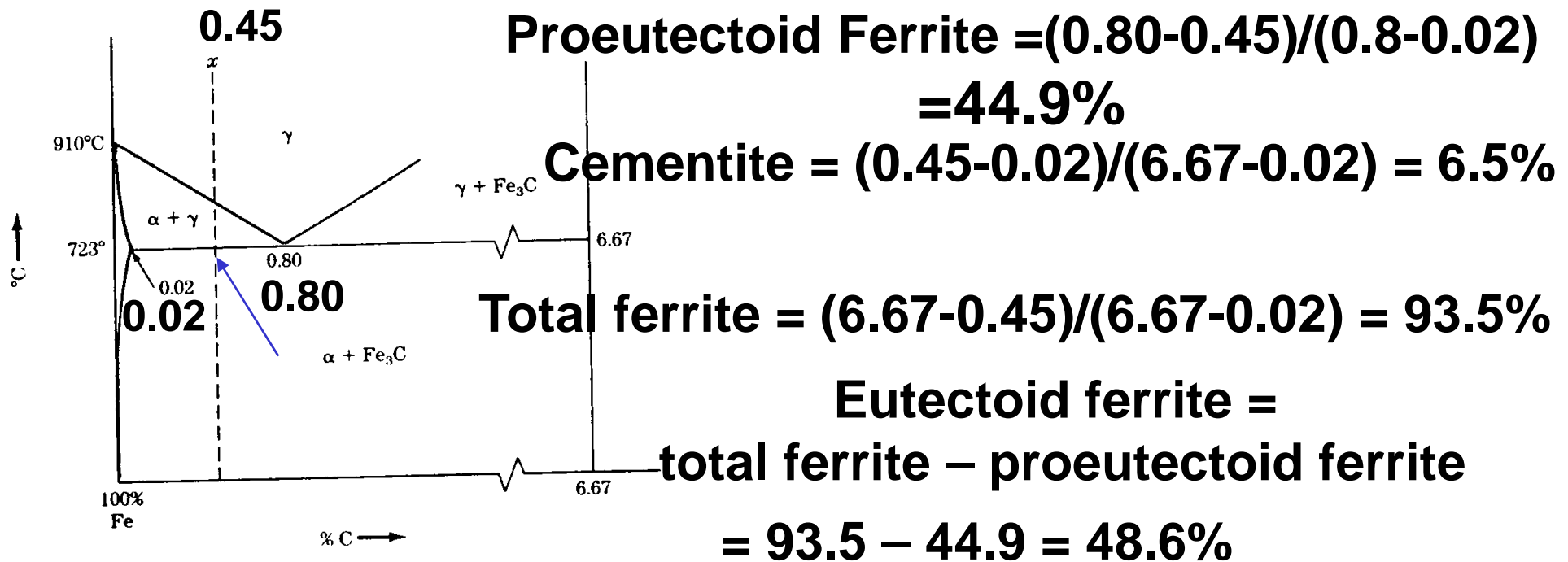
$$\text{Austenite} = \frac{(0.45 - 0.02)}{(0.80 - 0.02)} = 55.1\%$$

$$\text{Proeutectoid Ferrite} = \frac{(0.80 - 0.45)}{(0.8 - 0.02)} = 44.9$$

A 0.45%C hypoeutectoid plain-carbon steel is slowly cooled from 950 C to a temperature just slightly below 723 C.

(a) Calculate the weight percent proeutectoid ferrite in this steel.

(b) Calculate the weight percent eutectoid ferrite and the weight percent eutectoid cementite in this steel.





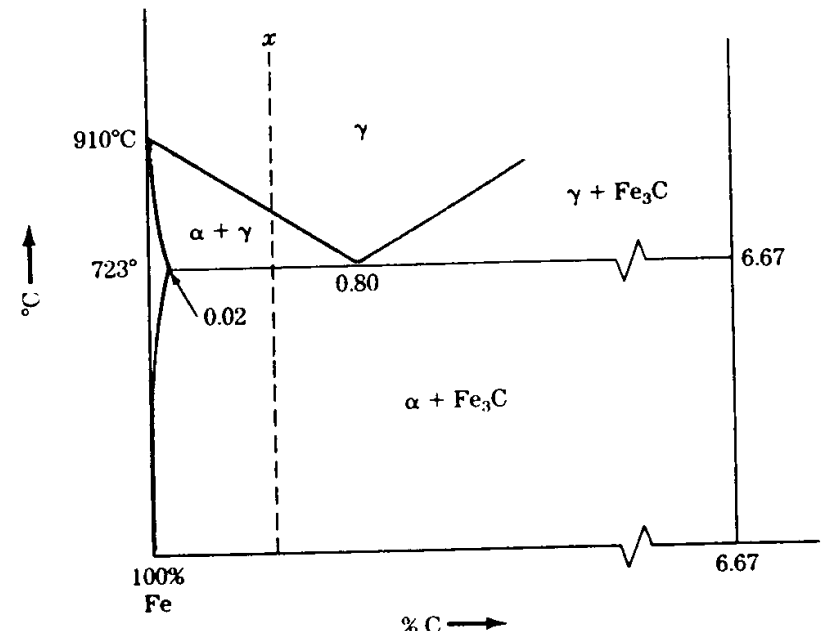
Problem

A hypoeutectoid steel contains 22.5% eutectoid ferrite. What is the average carbon content?

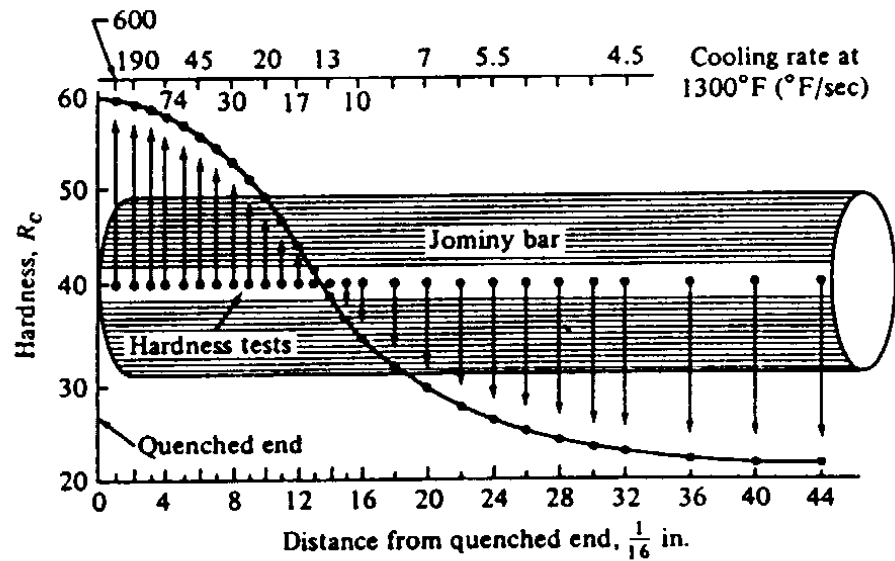
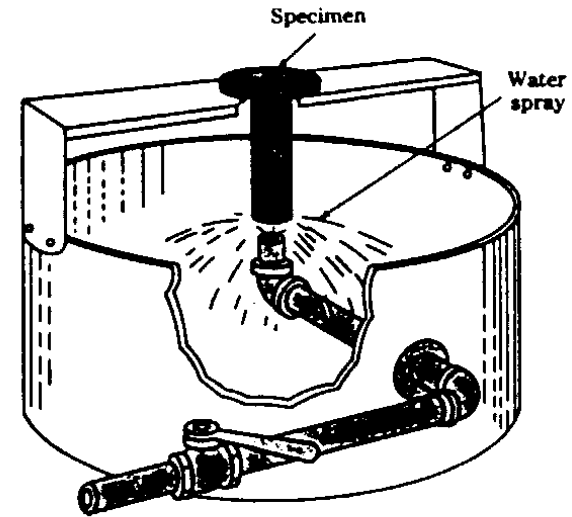
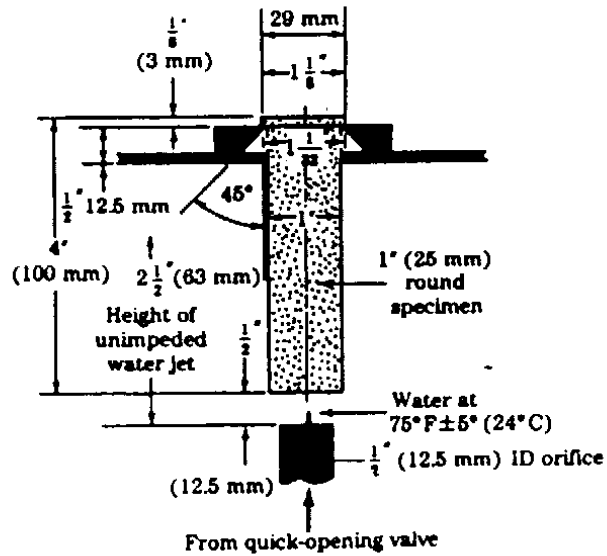
Total ferrite = proeutectoid ferrite + eutectoid ferrite

$$(6.67-x)/(6.67-0.02) = (0.80 -x)/(0.8-0.02) + 0.225$$

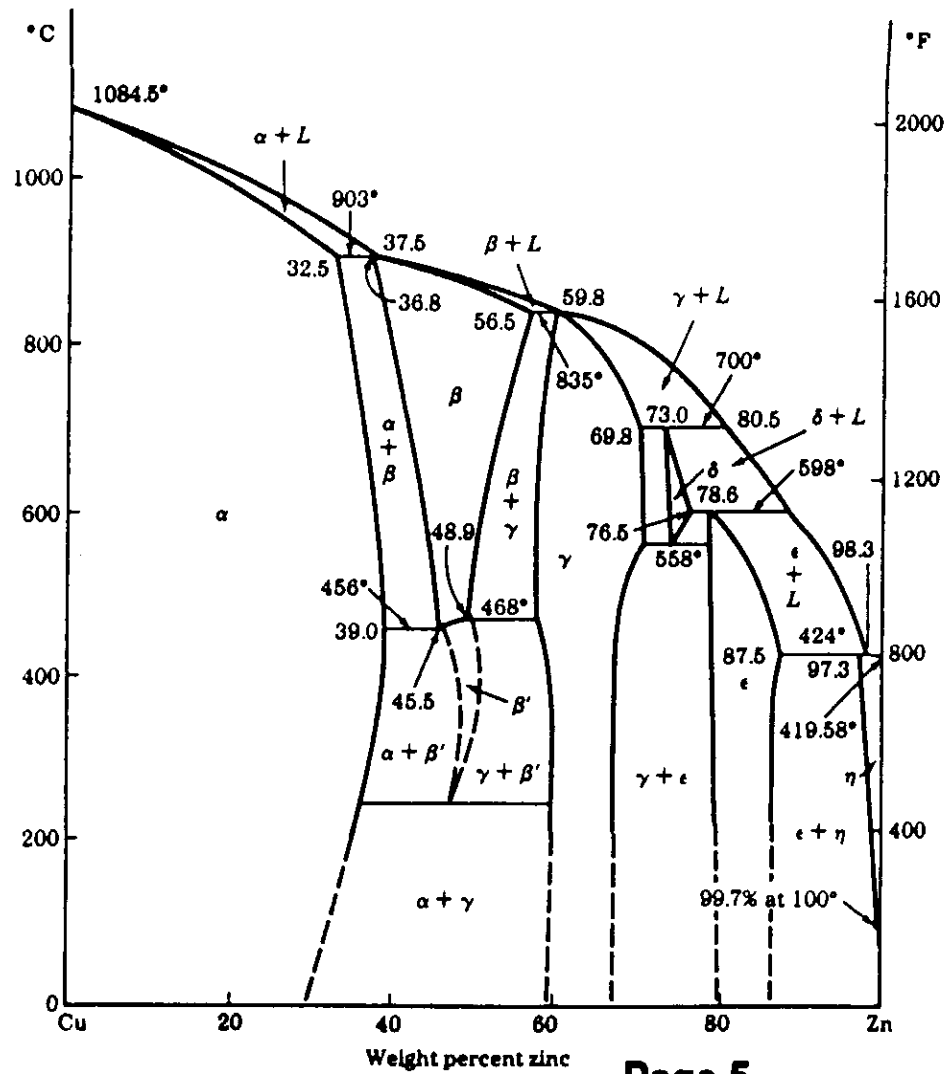
$$X = 0.2$$



Jominy Hardenability Test



Intermediate Phases - Cu-Zn Example



Hypoeutectoid Phase Diagram

If a steel with a composition $x\%$ carbon is cooled from the Austenite region at about $770\text{ }^{\circ}\text{C}$ ferrite begins to form. This is called proeutectoid (or pre-eutectoid) ferrite since it forms before the eutectoid temperature.

