GIBBS Phase Rule

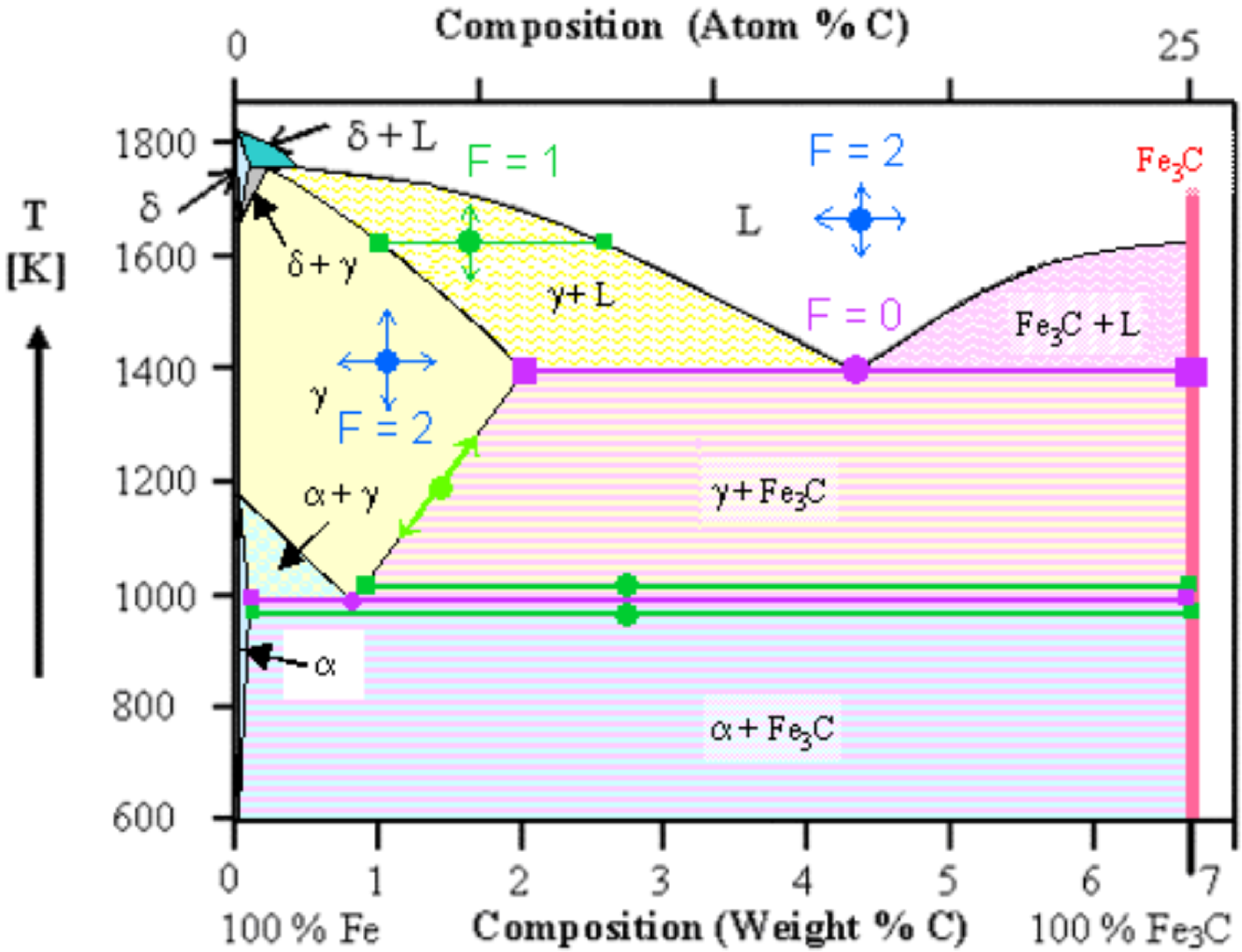
$$P + F = C + N$$

P is the number of phases present
F is the externally controlled variables (e.g., temperature, pressure, composition)
C *is* the number of components in the system.
N *is* number of noncom positional variables (e.g., temperature and pressure).

Because pressure is constant (1 atm)
N = 1 (Temperature is the only noncompositional variable)
Number of components C is 2

$$P + F = 2 + 1 = 3$$

$$F = 3 - P$$



Composition (Atom % C)
0
25
T [K]
1800
1600
1400
1200
1000
800
600
δ + L
δ
δ + γ
F = 1
F = 2
L
Fe_3C
γ + L
F = 0
Fe_3C + L
γ
F = 2
γ + Fe_3C
α + γ
α
α + Fe_3C
0
1
2
3
4
5
6
7
100 % Fe
Composition (Weight % C)
100 % Fe_3C

For binary systems, when three phases are present, there are no degrees of freedom because

$$\begin{aligned} F &= 3 - P \\ &= 3 - 3 = 0 \end{aligned}$$

Concept Question 1 For a ternary system, three components are present; temperature is also a variable. What is the maximum number of phases that may be present for a ternary system, assuming that pressure is held constant?

Answer: For a ternary system (C = 3) at constant pressure (N = 1), Gibbs phase rule,

$$P + F = C + N = 3 + 1 = 4$$

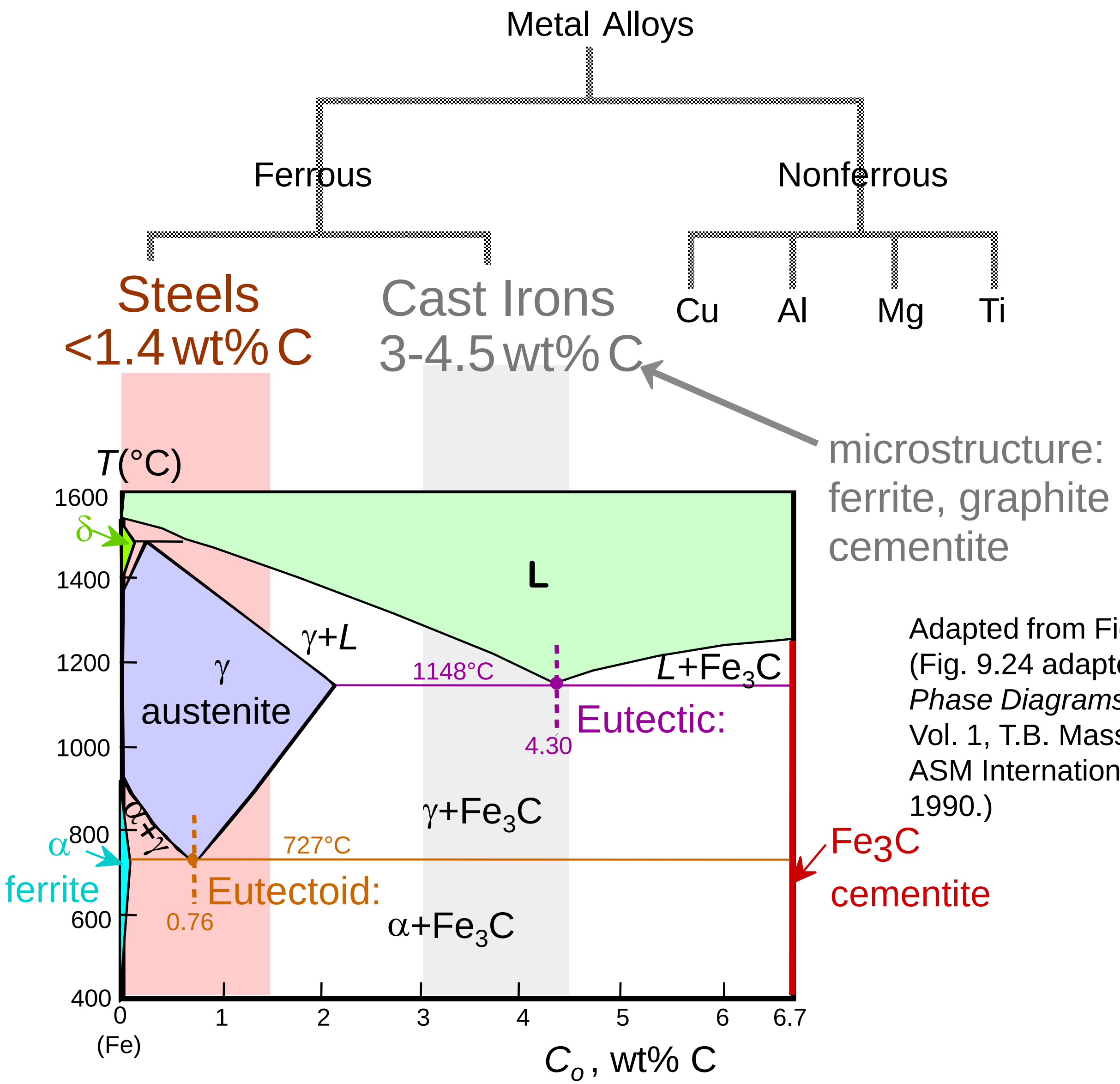
Or,

$$P = 4 - F$$

Thus, when $F = 0$, P will have its maximum value of 4, which means that the maximum number of phases present for this situation is 4.

Classification of Ferrous and Non ferrous Alloys

Taxonomy of Metals



Adapted from Fig. 11.1, *Callister 7e*.

Adapted from Fig. 9.24, *Callister 7e*. (Fig. 9.24 adapted from *Binary Alloy Phase Diagrams*, 2nd ed., Vol. 1, T.B. Massalski (Ed.-in-Chief), ASM International, Materials Park, OH, 1990.)

Steels

	Low Alloy						High Alloy
	low carbon <0.25 wt% C		Med carbon 0.25-0.6 wt% C		high carbon 0.6-1.4 wt% C		
Name	plain	HSLA	plain	heat treatable	plain	tool	austenitic stainless
Additions	none	Cr,V Ni, Mo	none	Cr, Ni Mo	none	Cr, V, Mo, W	Cr, Ni, Mo
Example	1010	4310	1040	4340	1095	4190	304
Hardenability	0	+	+	++	++	+++	0
TS	-	0	+	++	+	++	0
EL	+	+	0	-	-	--	++
Uses	auto struc. sheet	bridges towers press. vessels	crank shafts bolts hammers blades	pistons gears wear applic.	wear applic.	drills saws dies	high T applic. turbines furnaces V. corros. resistant

increasing strength, cost, decreasing ductility

Based on data provided in Tables 11.1(b), 11.2(b), 11.3, and 11.4, *Callister 7e*.

Ferrous Alloys

Iron containing – Steels - cast irons

Nomenclature AISI & SAE

10xx	Plain Carbon Steels
11xx	Plain Carbon Steels (resulfurized for machinability)
15xx	Mn (10 ~ 20%)
40xx	Mo (0.20 ~ 0.30%)
43xx	Ni (1.65 - 2.00%), Cr (0.4 - 0.90%), Mo (0.2 - 0.3%)
44xx	Mo (0.5%)

where xx is wt% C x 100

example: 1060 steel – plain carbon steel with 0.60 wt% C

Stainless Steel -- >11% Cr

Cast Iron

- Ferrous alloys with > 2.1 wt% C
  - more commonly 3 - 4.5 wt%C
- low melting (also brittle) so easiest to cast

- Cementite decomposes to ferrite + graphite

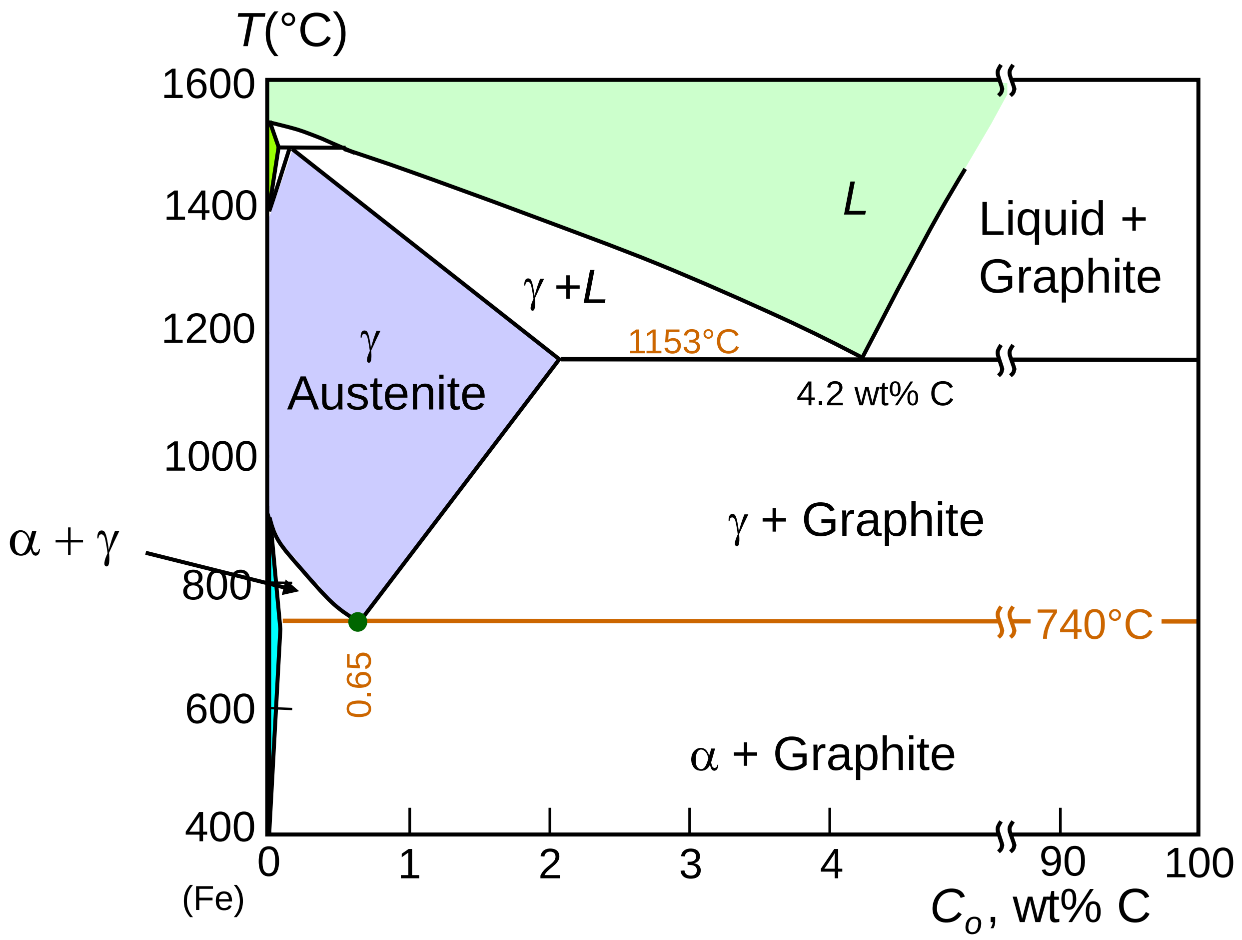
  $Fe_3C \rightarrow 3\ Fe\ (\alpha) + C\ (graphite)$

  - generally a slow process

Fe-C True Equilibrium Diagram

Graphite formation promoted by

- Si > 1 wt%
- slow cooling



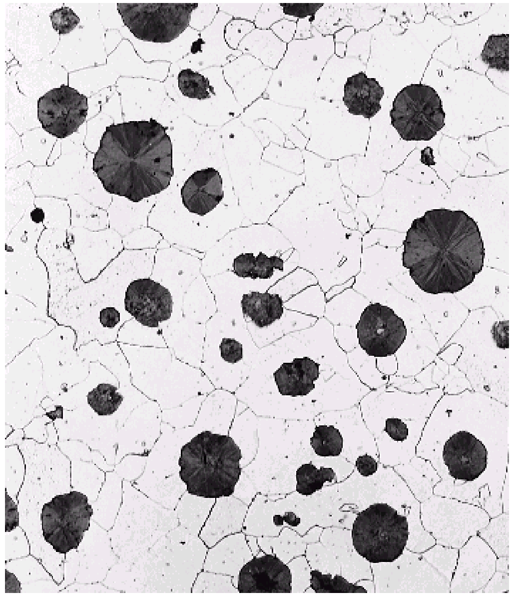
Adapted from Fig. 11.2,*Callister 7e*. (Fig. 11.2 adapted from *Binary Alloy Phase Diagrams*, 2nd ed., Vol. 1, T.B. Massalski (Ed.-in-Chief), ASM International, Materials Park, OH, 1990.)

Types of Cast Iron

Gray iron

- 2-4% C, 1-3% Si
- graphite flakes
- weak & brittle under tension
- stronger under compression
- excellent vibrational dampening
- wear resistant
- Least expensive

Adapted from Fig. 11.3(a) & (b), *Callister 7e*.



Ductile iron

- add Mg or Ce
- graphite in nodules not flakes
- matrix often pearlite - better ductility
- Stronger and more ductile than gray iron

Types of Cast Iron

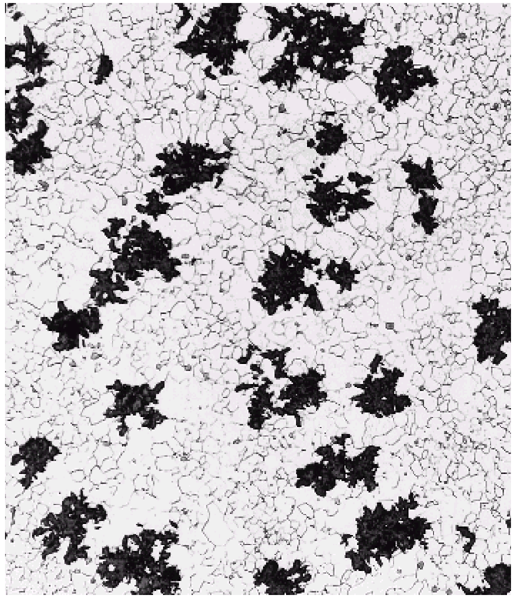
White iron

- <1wt% Si and faster cooling rate
- so harder but brittle
- unmachinable
- more cementite
- Rollers in mills

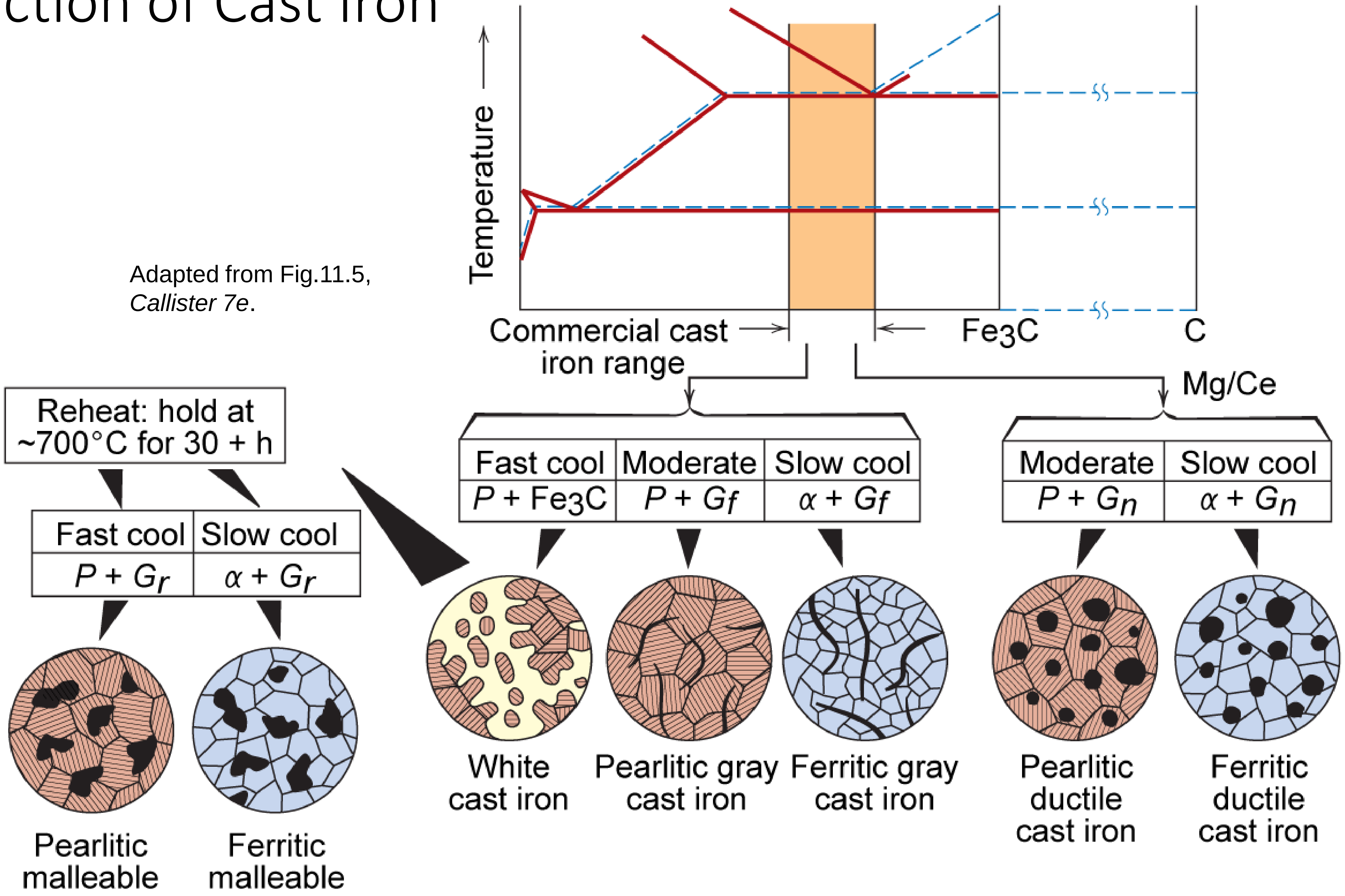
White iron:
the light cementite regions are surrounded by pearlite, which has the ferrite–cementite layered structure.

Malleable iron

- heat treat white iron at 800-900ºC
- graphite in rosettes
- Strong and ductile
- Automobile industry



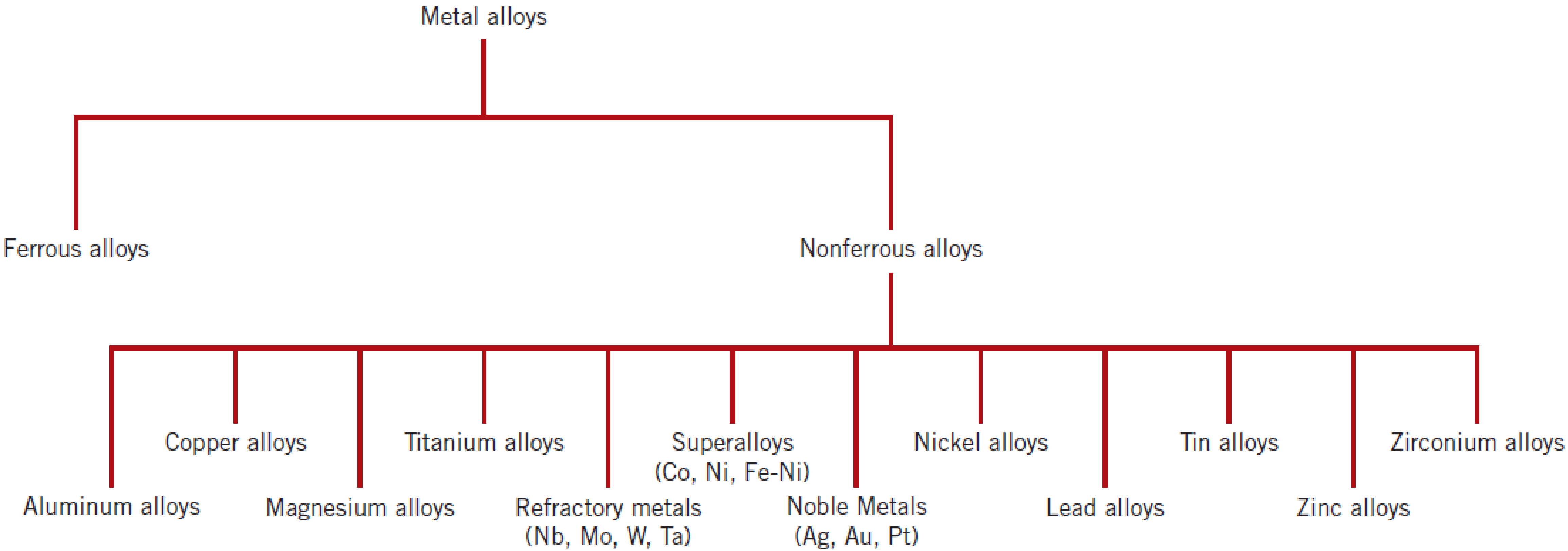
Production of Cast Iron



Adapted from Fig.11.5, *Callister 7e*.

Limitations of Ferrous Alloys

1) Relatively high density
2) Relatively low conductivity
3) Poor corrosion resistance


Metal alloys
Ferrous alloys
Nonferrous alloys
Copper alloys
Titanium alloys
Superalloys
(Co, Ni, Fe-Ni)
Nickel alloys
Tin alloys
Zirconium alloys
Aluminum alloys
Magnesium alloys
Refractory metals
(Nb, Mo, W, Ta)
Noble Metals
(Ag, Au, Pt)
Lead alloys
Zinc alloys

Nonferrous Alloys

NonFerrous Alloys

- **Cu Alloys**

Brass: Zn is subst. impurity (costume jewelry, coins, corrosion resistant)

Bronze : Sn, Al, Si, Ni are subst. impurity (bushings, landing gear)

Cu-Be: precip. hardened for strength

- **Al Alloys**

-lower ρ: 2.7g/cm^3

-Cu, Mg, Si, Mn, Zn additions

-solid sol. or precip. strengthened (struct. aircraft parts & packaging)

- **Mg Alloys**

-very low ρ: 1.7g/cm^3

-ignites easily

-aircraft, missiles

- **Ti Alloys**

-lower ρ: 4.5g/cm^3 vs 7.9 for steel

-reactive at high T

-space applic.

- **Noble metals**

-Ag, Au, Pt

-oxid./corr. resistant

- **Refractory metals**

-high melting T

-Nb, Mo, W, Ta