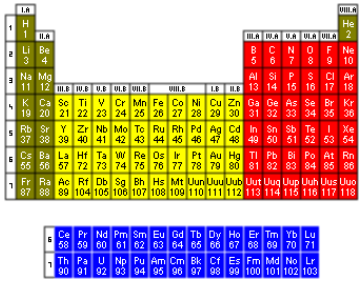
PROPERTIES AND APPLICATION OF METALS

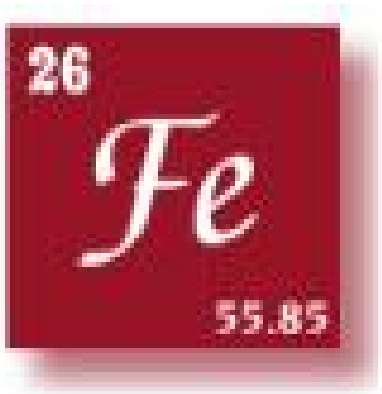
Classification of Metals

What is a 'ferrous metal' or 'ferrous alloy'?

It is simply a metal or alloy that contains Iron (the element ferrous) as the base (starting) metal.



← 26th element →
←Iron or Ferrous →
55.85 Atomic Mass



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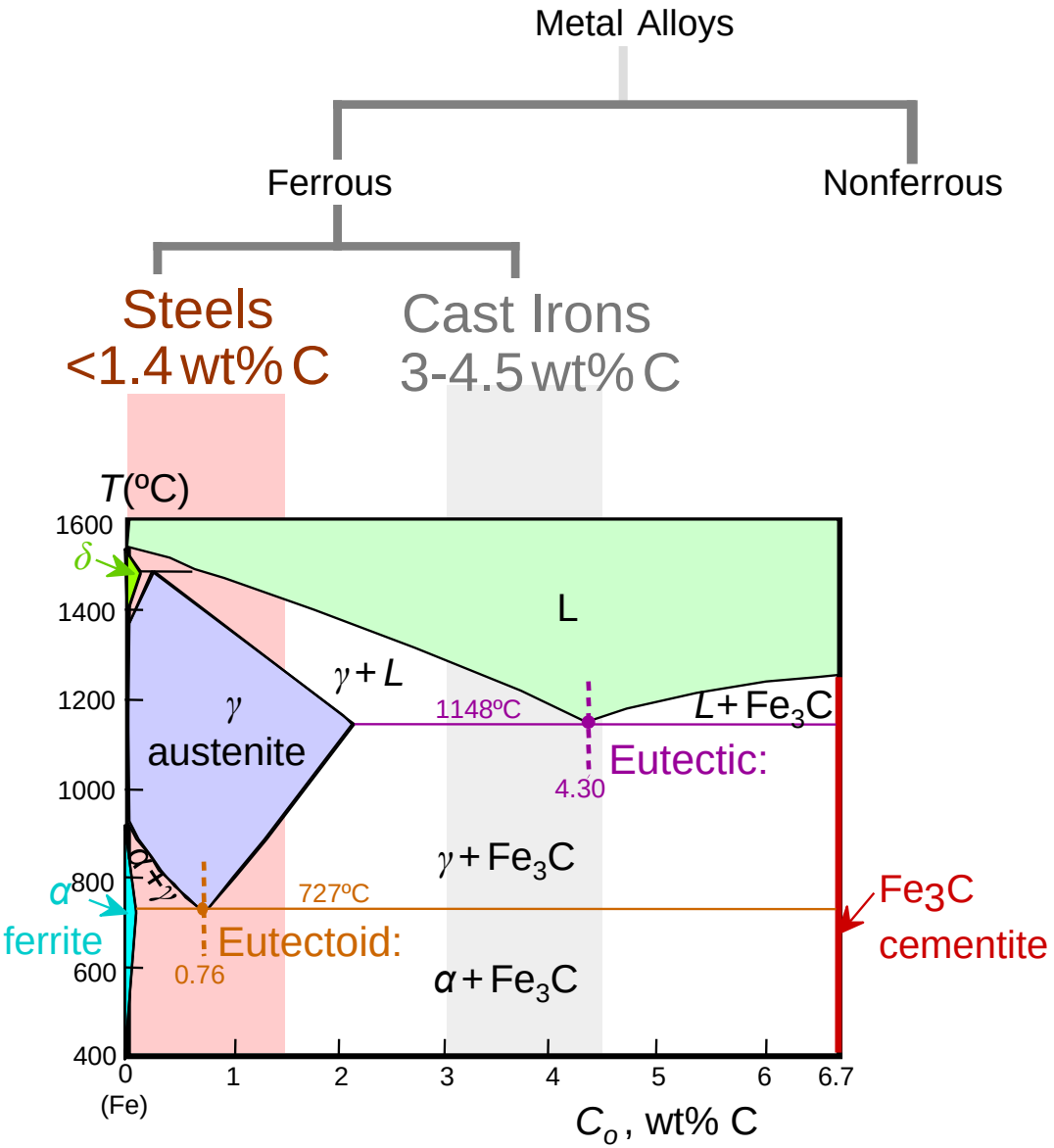
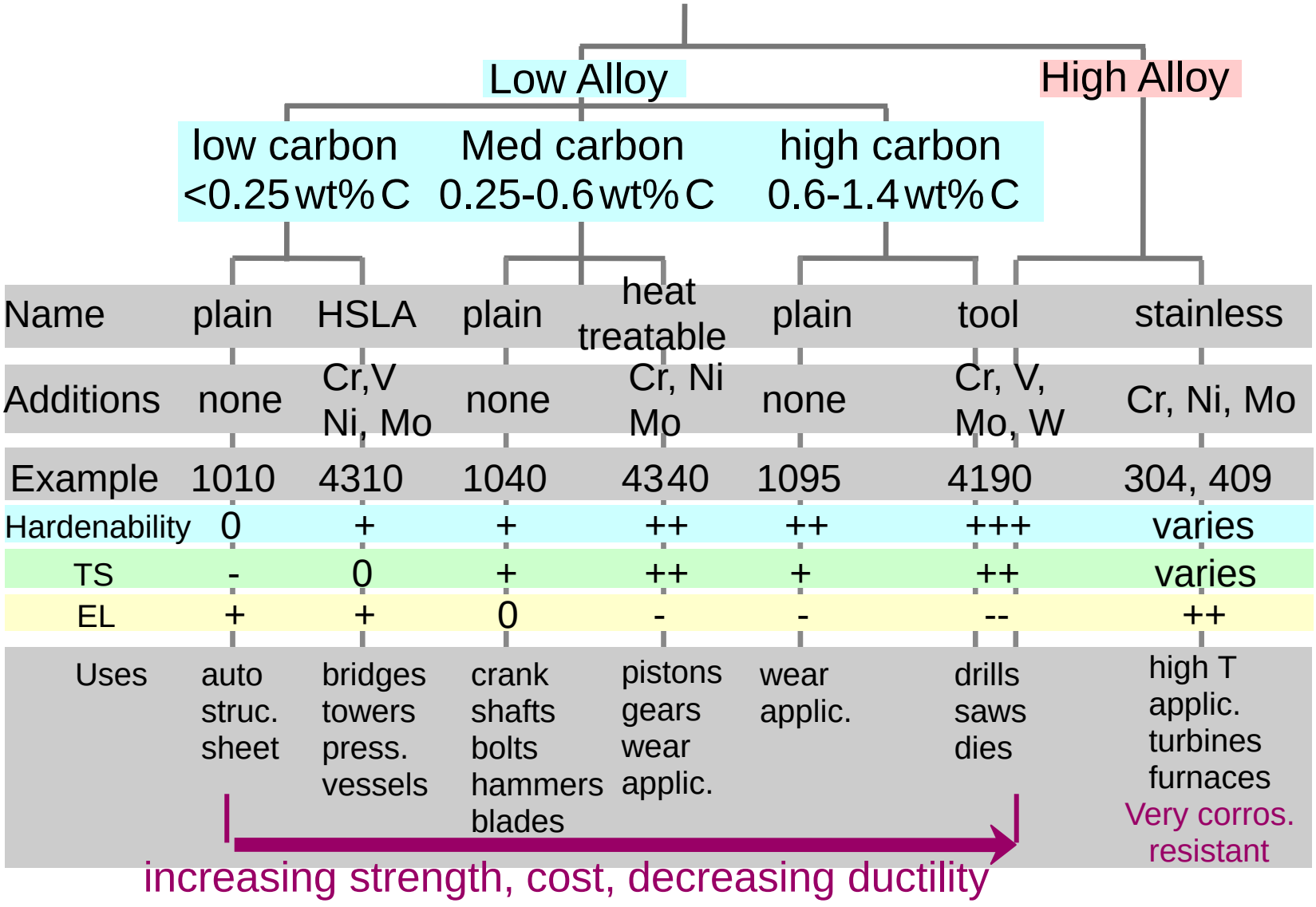


Steels

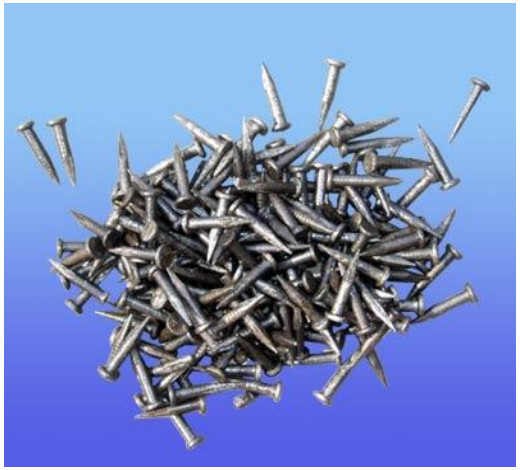

Low Alloy
High Alloy
low carbon <0.25 wt% C
Med carbon 0.25-0.6 wt% C
high carbon 0.6-1.4 wt% C
Name
plain
HSLA
plain
heat treatable
plain
tool
stainless
Additions
none
Cr,V Ni, Mo
none
Cr, Ni Mo
none
Cr, V, Mo, W
Cr, Ni, Mo
Example
1010
4310
1040
4340
1095
4190
304, 409
Hardenability
0
+
+
++
++
+++
varies
TS
-
0
+
++
+
++
varies
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
Very corros. resistant
increasing strength, cost, decreasing ductility

Carbon and Alloying Steel

- Carbon and alloying steels are the most commonly used metals
- The structural makeup and controlled processing of these steels make them suitable for many different functions.
- Basic product shapes include plate, sheet, bar, wire, tube, castings, and forgings.
- Different elements are added to steels to given the steel different properties.
- The elements pass on properties such as hardenability, strength, hardness, toughness, wear resistance, etc.
- E.g. **Chromium**: improves toughness, hardenability, wear and corrosion resistance, and high-temperature strength; **Nickel**: improves strength, toughness, and corrosion resistance; it improves hardenability.

i. Carbon Steel

- Carbon steels are group by their percentage of carbon content per weight. The higher the carbon content the greater the hardness, strength and wear resistance after heat treatment.
- **Low-carbon steel,** also called mild steels, has less than 0.30% carbon. Used in everyday industrial products like bolts, nuts, sheet, plate and tubes.
- **Medium-carbon steel** has 0.30% to 0.60% carbon. Used for jobs requiring higher strength such as machinery, automotive equipment parts, and metalworking equipment.
- **High-carbon steel** has more than 0.60% carbon. Used parts that require the highest strength, hardness, and wear resistance. Once manufactured they are heat treated and tempered



High carbon steel nails

ii. Alloy Steel

- **High-strength, low-alloy steels** (HSLA) steels were developed to improve the ratio of strength to weight.
- Commonly used in automobile bodies and in the transportation industry (the reduced weight makes for better fuel economy).

Stainless Steel

- **Stainless steels** are primarily know for their corrosion resistance, high strength, and ductility and chromium content.

Tool Steel

- **Tool steels** are alloyed steels design for high strength, impact toughness, and wear resistance at normal and elevated temperatures.

Drill bits

Cast Irons

- Ferrous alloys with > 2.1 wt% C
- more commonly 3 - 4.5 wt% C
- Low melting – relatively easy to cast
- Generally brittle
- Types of cast iron:
  - Gray iron
  - Ductile iron
  - Malleable iron
  - White iron
  - Compacted graphite iron

Limitation of Ferrous Alloys

- Relatively high densities
- Relatively low electrical conductivities
- Generally poor corrosion resistance

Non-Ferrous Metals and Alloys

- Nonferrous metals and alloys
  - Common- aluminum, copper, and magnesium
  - High-strength, high-temperature alloys include: tungsten, tantalum, and molybdenum.
- Higher cost than ferrous metals but have good properties such as:
  - Corrosion resistance
  - High thermal and electrical conductivity
  - Low density and ease of fabrication

NonFerrous Alloys

- **Cu Alloys**

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

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

Cu-Be: precip. hardened for strength

- **Al Alloys**

-low ρ: 2.7 g/cm^3

-Cu, Mg, Si, Mn, Zn additions

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

- **Mg Alloys**

-very low ρ: 1.7 g/cm^3

-ignites easily

-aircraft, missiles

- **Ti Alloys**

-relatively low ρ: 4.5 g/cm^3 vs 7.9 for steel

-reactive at high *T's*

-space applic.

- **Refractory metals**

-high melting *T's*

-Nb, Mo, W, Ta

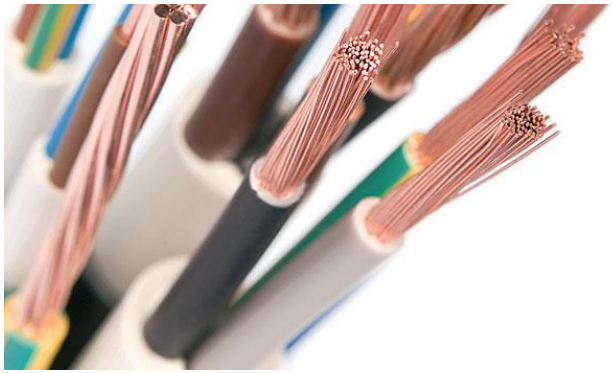
- **Noble metals**

-Ag, Au, Pt

-oxid./corr. resistant

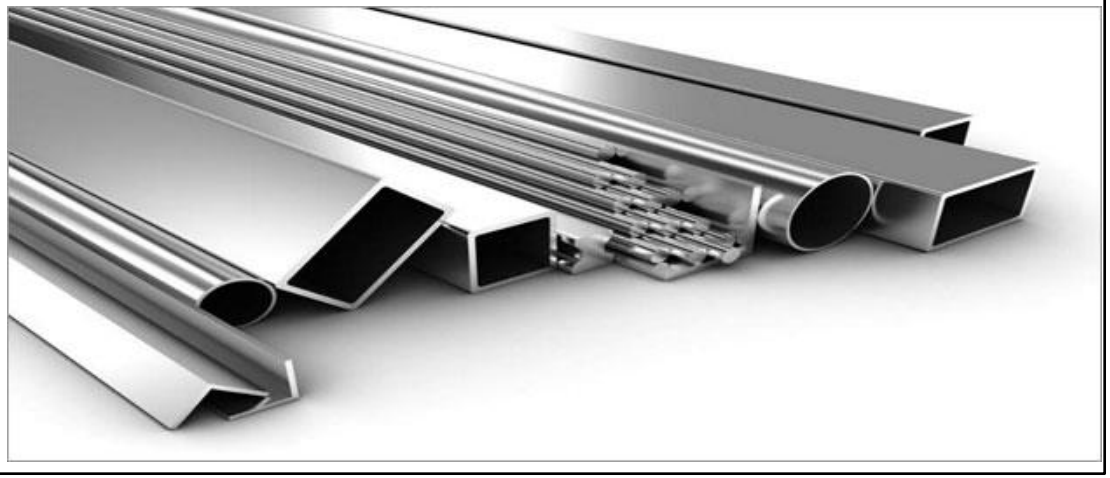
Copper Alloys

- Properties:
  -Best conductors of electricity and heat, good corrosion resistance, and easily processed.
- Uses:
  -Electronics, springs, cartridges, plumbing, heat exchangers, and marine equipment.
- Common alloys:
  -Brass, Bronze, Beryllium copper



Aluminium Alloys

- Most abundant metallic element
- High strength to weight ratio
- Resistant to corrosion
- High thermal and electrical conductivity
- Nonmagnetic
- Easy formability and machinability



Magnesium Alloys

- Lightest of all metals
- Not sufficiently strong in pure form but alloyed to increase strength.
- Uses

  -Aircraft and missile components, bikes, luggage, portable power tools…

Refractory Metals

- 4 refractory metals: Molybdenum (Mo), Niobium (Nb), Tungsten (W), and Tantalum (Ta).
- Called refractory because of their high melting points.
- Used in steels because they maintain their strength at high temperatures.
- Temperature range of 1100 to 2200° C (2000 to 4000° F).

Refractory Metals - Applications

- Mo- Used in solid-propellant rockets, jet engines, honeycomb structures, electronic computers, heating elements, and dies for die casting.
- Nb- Used in rockets and missiles and in nuclear, chemical, and superconductor applications.
- W- Used in hottest part of missiles and rockets, welding electrodes, spark-plug electrodes, and the wire filament in incandescent bulbs.
- Ta- Used mainly in electrolytic capacitors and various electrical, electronic and chemical industries

Tungsten filament

Titanium Alloys

- Has the highest strength to weight ratio
- Uses:
  - Jet engines, race cars, golf clubs, submarines, hip replacement and armor plates.
- Pure state: strong and light
- Alloys: improved workability, strength, hardenability
- High cost due to long production process with small amount