METALS

The metals are classified by their importance in:

Non-ferrous: - Heavy: Cu, Sn, Pb, Zn, ...
- Light: Al, Ti } -->
- Ultralights: Mg, Be

Metallurgy is the technology of metals: the way in which science is applied to the production of metals, and the engineering of metal components for usage in products for consumers and manufacturers.

Ferrous: iron, steel, ferro-alloys, ... ---> **Siderurgy or ferrous metallurgy or black metallurgy: the iron and steel industry**

(The production of ferrous metals accounts for 95 percent of world metal production)

The production of metals

1. **Look for the ore ---> Mining**

Ore (Definition): is a type of rock that contains sufficient minerals with important elements including metals that can be economically extract from the rock. (En español no existe ese concepto, sería el conjunto de **mena más ganga**, aunque a veces se traduce como mena o como mineral. Ademas, como la definición es económica lo que hoy es rock, en el futuro puede ser ore)

The cost of extraction must thus be weighed against the metal value contained in the rock to determine what ore can be processed and what ore is of too low a grade to be worth mining (then, it is a rock).

There are basically two types of mining:

- **Surface mining**: the ores to be mined are exposed at the surface or very close to the surface

Open pit mining in South Cotobato (Philippines)

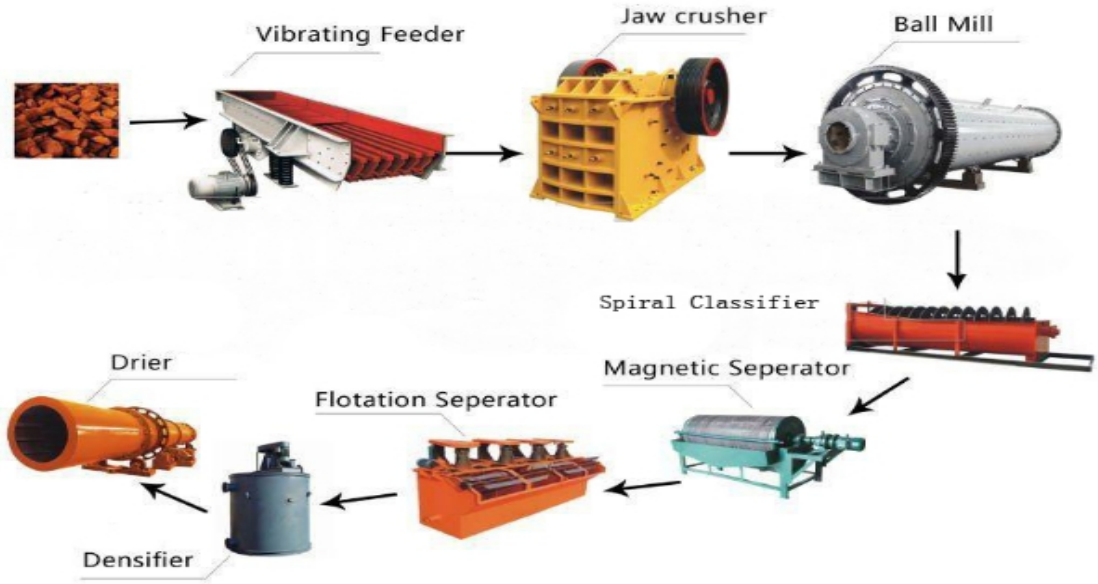
- Underground mining: It requires more money that will be spent on drilling, assuring miners' safety, and erecting safety-centric equipment. Mining companies opt to conduct underground excavation when the mineral or ore to be extracted becomes impossible to extract through surface mining. Underground mining is often utilized by mining firms to extract more ore and minerals. Higher production volume mitigates the costs spent on initiating the very expensive method of underground mining (**Uso mineria subterranea cuando no hay una manera de hacerla de superficie).**

2. Mineral proccesing or **mineral dressing** or **ore dressing:** it is the separation of mineral from gangue (ganga) that is the commercially worthless material that surrounds, or is closely mixed with a wanted mineral. In Galena case, for example, it is a complicated proccess but in the case of cassiterite is easy.

First step in mineral proccesing is **Comminution** (Trituración) to reduce the size of the particles. We use **Crushing and Grinding.**

Then, depending on the mineral can be used centrifugal forces, magnetic forces, froh flotation, ...

The last process is **Dewatering** to remove water. For instance, rotary dryers can be used



Barite mineral proccessing. With barite i get barium

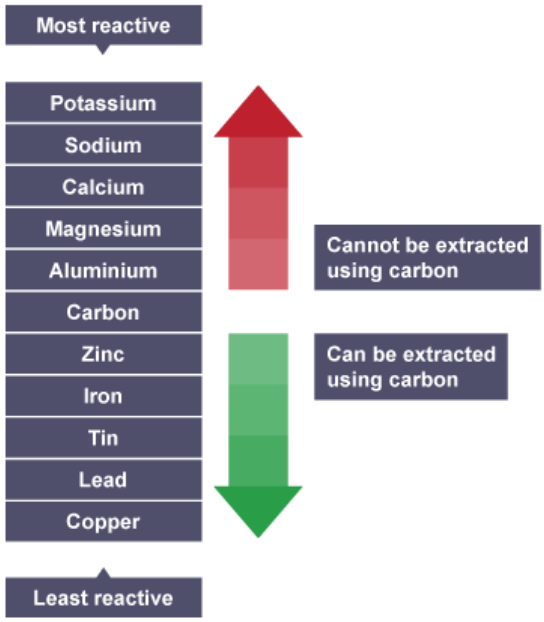
3. Obtaining metals from metal oxides

Carbon is a non-metal but it is more reactive than some metals. This means that some metals can be extracted from their metal oxides using carbon.

Less reactive metals than carbon can be extracted from their oxides by heating with carbon. In general:

metal oxide + carbon → metal + carbon dioxide

This works for zinc, iron, tin, lead and copper. Copper is the least reactive of these five metals.



Example: Extracting copper from copper oxide

To extract copper, you mix copper oxide powder with carbon powder. You then heat the mixture strongly for a few minutes in a crucible. It is important to keep a lid on the crucible, (es importante que el crisol tenga una tapa) otherwise the carbon will react with oxygen in the air, rather than with the copper oxide. The carbon dioxide formed in the reaction escapes into the air.

After letting the crucible cool down, you tip the mixture into cold water. Pieces of brown copper sink to the bottom, leaving unreacted powder suspended in the water.

Copper is so unreactive, it does not react with cold or hot water, so it is used for water pipes

These equations represent the reaction:

copper oxide + carbon → copper + carbon dioxide
$2CuO + C \rightarrow 2Cu + CO2$

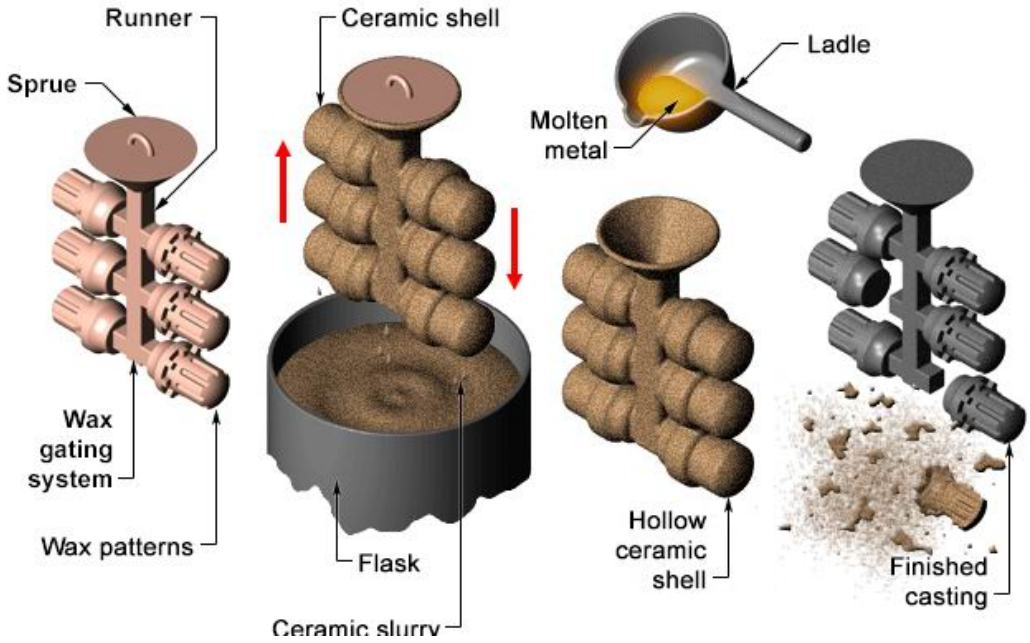
In the Copper Age to shape the metal, Men began to use **Sand Casting or Green Casting**

1. I make a model with solid wax (cera)

2. This model is surrounded with clay and then heated in order to remove the wax and harden the clay (hard = duro --> harden = endurecer)

3. Next, the mold is inverted and molten metal poured into it

4. When the metal cools, the bronze-smith breaks open the clay model to reveal a solid bronze object.



In the picture you can see the process now (Problem: the mould is removed)

Alloys: It is a mixture of two or more chemical elements, of which one must be a metal.

You can watch how made a bronze sword here: https://www.youtube.com/watch?v=eEWIuyeNp2k

Extracting iron from iron oxide

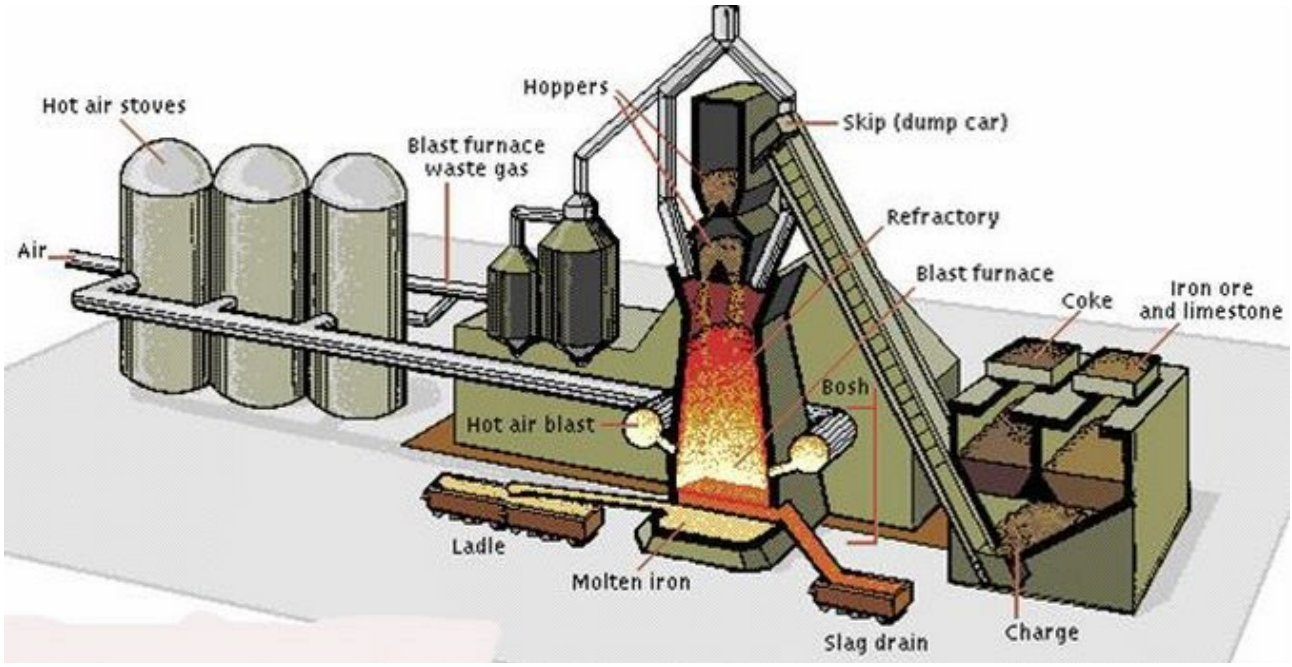
Iron is less reactive than carbon, so it can be extracted from iron oxide using carbon. This is done on an industrial scale in a huge container called a blast furnace.

Lumps (terrones, pedazos) of iron oxide are mixed with carbon and dropped into the top of the blast furnace. Hot air is blasted in at the bottom. The oxygen in the air reacts with the carbon, forming carbon monoxide:

carbon + oxygen → carbon monoxide
$2C + O_2 \rightarrow 2CO$

It is hot enough in the blast furnace for the carbon monoxide to react with the iron oxide:

iron oxide + carbon monoxide → iron + carbon dioxide
$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$



You get molten iron and slag (escoria). Slag floats and it is easy to remove.

History

There are two theories about the discovery of iron, the first says that some men found primitive meteorite fragments that predominated in the iron (allied with nickel), and the second says that at some point in history someone has made a fire on a mountain rich in iron ore . It seems that in 1500 B.C (early Iron Age) a forest fire on Mount Ide (ancient Troy, in Turkey) merged deposits producing iron. The metals obtained were of low quality but exceeded by far the characteristics of the Bronze Age.

Then, **to make iron you need: iron ore, limestone** (the mount had that type of soil), **coal** (or, failing that, wood) **and air**. Some examples of iron ore: magnetite, siderite in the limonite, pyrite, ... It seems that the first people to work iron were the Hittites (in Turkey) in Anatolia, from about 1500 BC. In its simple form iron is less hard than bronze, and therefore of less use as a weapon. So, at the beginning, the iron has been used as an element of social differentiation, a mere object of luxury the

scope of the high hierarchies.

But over time (thanks to bellows, hammering and tempering) became a material of great strategic importance such as military equipment, powerful and indispensable. The Hittites kept the secret until the 1200s B.C which allowed them to survive until then at their enemies, the Egyptians (culturally far superior). The Hittites were mighty due to iron and its naval power.

Letter from a Hittite king

A Hittite king writes to a valued customer about his order for iron. The letter is probably addressed to a king of Assyria:

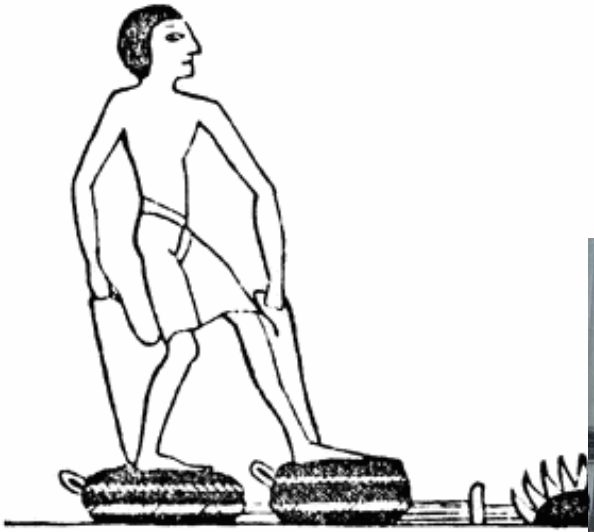
'In the matter of the good iron about which you wrote, good iron is not at present available in my storehouse in Kizzuwatna. I have already told you that this is a bad time for producing iron. They will be producing good iron, but they won't have finished yet. I shall send it to you when they have finished. At present I am sending you an iron dagger-blade.'

After of Hitites, Egiptians invented the bellows . Then they could inject air into the forge (furnace = horno) and improve the process.

Advantages of iron with bronze:

- The iron ores are everywhere (easy to find **PYRITE**) but in order to have bronze you have to look for copper (**MALACHITE** in Cyprus) and tin (**CASSITERITE** in Erzgebirge “the Ore Mountains” in the border of Germany and Czech Republic) in distant places.

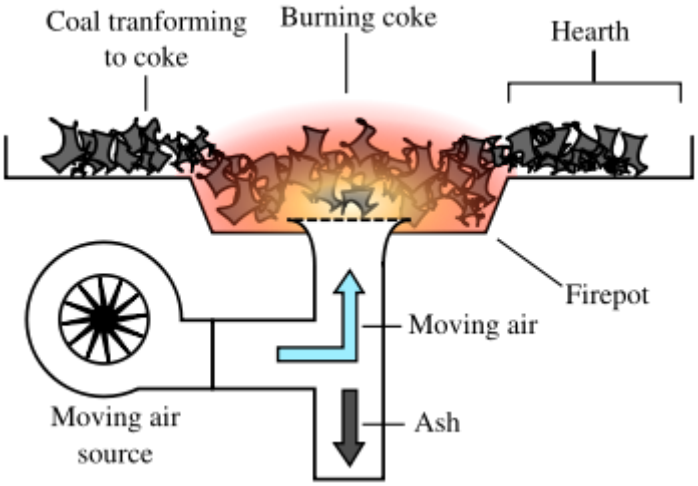
- The iron weapons are toughter (after forging and tempering) and can be longer. Iron weapons are easy to fix if they bended. Bronze weapons were fragiles and broke frequently. In 490 B.C 10000 Greeks beat 30000 Persians at Marathon, which still employ the bronze. Balance of casualties: 192 dead against 6400.



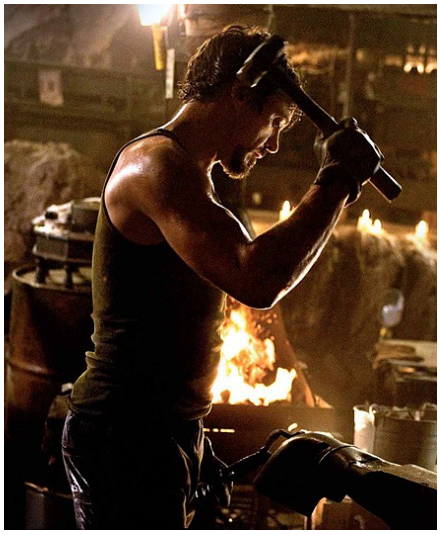
Egiptian working wit a pair of **foot bellows**

Blacksmith operating the bellows

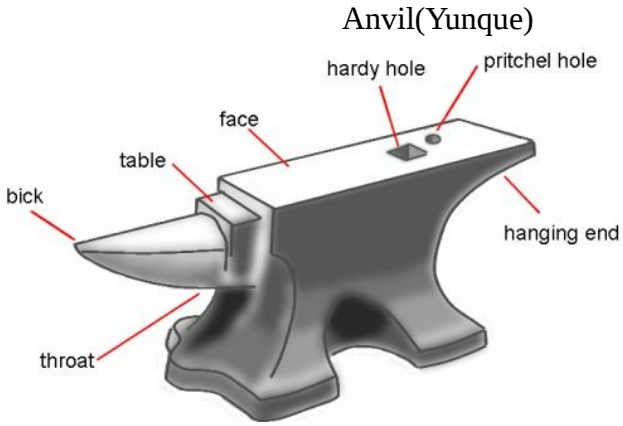
Forge



Forging (Hammering) -- El forjado



Tony stark at work : hammering

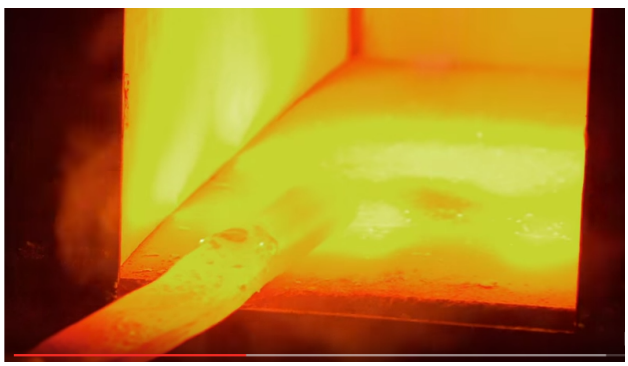


Forging change the internal grain and **improve the strength characteristics** You should hit with the hammer in the direction of the fiber. If you hit in the direction perpendicular to the fiber the mechanical qualities worsen.

The Tempering or The Quench – El temple o templado

In the Odissey (s VIII BC), Homer explain this technique:

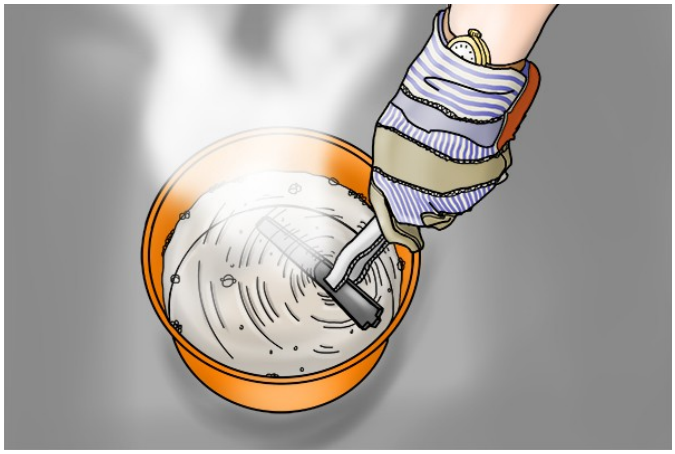
1. The blacksmith puts the metal to the red, to the critical temperature of the metal. He knows the temperature thanks to the color of the metal.



2. Then you cool immediately it.

If you cool in water, the cooling may be too fast and cause blade failure.

Cooling is more gradual if you use oil, but the heat of the blade can ignite the oil and then you see the "fire of the dragon"



Quenching toughens (El templado aumenta la tenacidad, el objeto soporta mejor los golpes)

tough = tenaz --> to toughen = hacer tenaz

Environmental effects

From the foundation of Rome until 165 AD (Anno Domini, despues de Cristo), **the romans deforested** huge areas for arable land. There was a high level de air pollution in Rome due to the extensive wood burning for fuel and for getting iron.

You need 4 kg of wood to get 1 kg de iron.

The weather becames cooler and drier. The climate was very variable from circa (from Latin, meaning “around”, “about”) 200 AD to 600: coolings, droughts (sequías), ...

APPLICATIONS OF METALS

FERROUS

Every year spent $ 31,000 million (11% of global spending on raw materials).

Known reserves for 228 years

Pure iron: (less 0,03% of carbon):

Low mechanical properties --> not to many industrial applications

In electronics --> Electromagnets, relays and transformers

Steel is an alloy of iron and other elements, primarily carbon (less of 2%)

If you increase the rate of carbon then the alloy is more difficult to scratch, works better under tensile stress but is more difficult to make wires.

Today, steel is one of the most common materials in the world, with more than 1.3 billion tons produced annually. It is a major component in buildings, infrastructure, tools, ships, machines, appliances, and weapons

Cast iron (FUNDICIÓN) is a group of iron-carbon alloys with a carbon content greater than 2% and lower than 6.7%.

Cast iron tends to be brittle (FRAGILE)

Uses in cookware (utensilios de cocina), machinery (piezas de maquinaria), ...

The steel can also be allied. They are alloy steels. The best known are:

- Stainless steel: get mixed steel with chromium (Cr) and a bit of nickel (Ni) to prevent oxidation. So is Fe + C + Cr + Ni

There are also alloy iron with other materials, without carbon, such as manganese (for lightness), silicon, ...

NON FERROUS

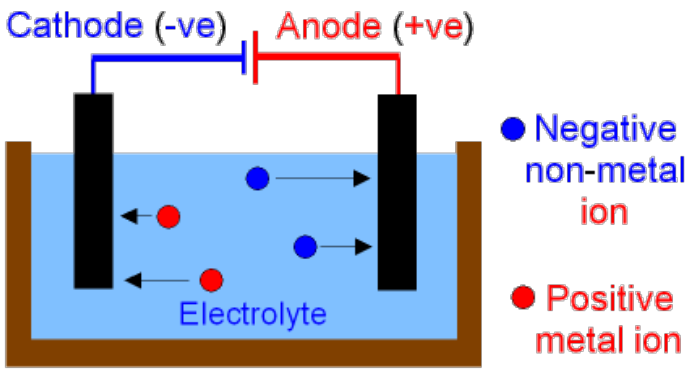
For its economic importance the main are:

1. ALUMINIUM (Al)

12% of global spending on raw materials. Reservations: 243 years Discovered in 1827

It is an abundant element, but not in a pure state. The metal ore more used is **BAUXITE.**

Get the aluminum by electrolysis: the mineral and dissolved and introduced two electrodes in the solution, causing electricity to flow through them. The pure metal is deposited in one of the electrodes to measure current flowing.



The energy of the electric power station of As Pontes de García Rodríguez, is used in a high percentage for aluminum in the aAumina plant.

The process is:

EXPENSIVE (because of the energy that needs) and

POLLUTING (because the electrolyte is an acid, sulphuric acid for instance).

The aluminium is:

RESISTANT TO CORROSION

NOT TOXIC --> It is used in food packaging

GOOD CONDUCTOR ELECTRICITY --> It is used for high-voltage power lines

LOW DENSITY --> THEN you can alloy with another metals to dicrease the density.

2. COPPER (Cu)

Copper: 8% of global spending. Reservations: 56 years

Found natively (pure in nature) in Asia Minor in 6000 B.C, in Europe in 5000 B.C. and in Spain in 4000 B.C. (Copper Age).

When native metal was finished, men begin to use the ore **MALACHITE** (NOW we have to look for it in Congo, Gabon, Zambia, ...) reduced with coal (carbon), in 4000 B.C. in Anatolia (Turkey).

In 3000 B.C. the Bronze was invented (copper alloy with tin). Bronze came to Europe 500 year later and 500 years later to Spain (Bronze Age)

Other alloys of copper:

Brass (Latón): Cu + Zn. Appeared in the Greek Asia Minor color like gold and was easy to work and is used in jewelery. Germicidal and antimicrobial

Nickel silver or German silver or Alpacca (Alpaca): Zn + Cu + Ni + Sn --> Used as fake silver

Copper Nickel: Ni + Cu. Is used to produce coins

The properties of copper are:

• Aesthetic.

• Ductile, malleable and relatively soft.

• High corrosion resistance.

• Bactericide.

• High thermal conductivity.

• You can ally with other metals.

• The most important property is its high electrical conductivity (2nd best conductor of nature after the silver) and the ability to transmit voice and data. ---> USE ELECTRICITY

3. ZINC(Zn)

Zinc 5% of global spending. Reserves: 55 years

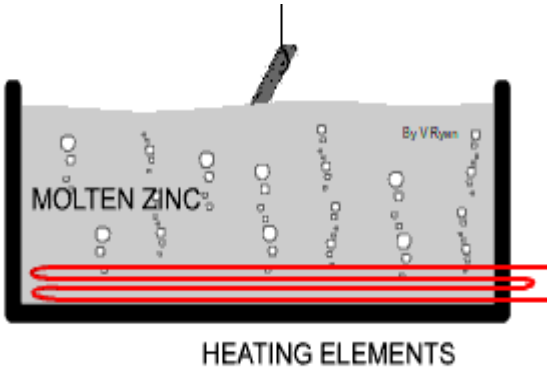
The main mineral extraction is **BLENDE**. The pure zinc metal is a soft bright blue-white. It is one of the most common in nature.

Is used as:

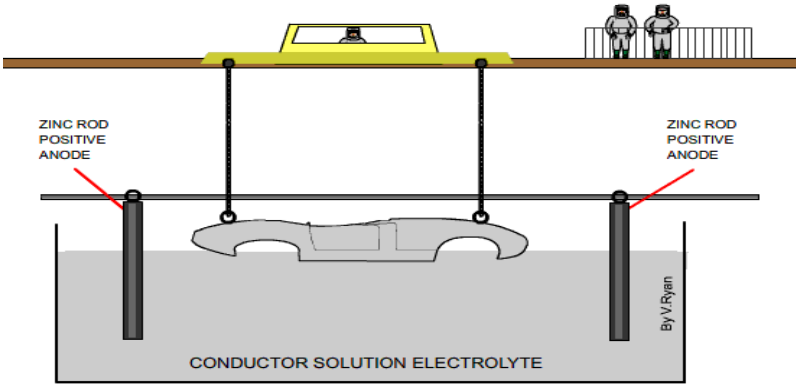
- coating (eg iron) to prevent corrosion ---> **galvanize** (55% in USA)

HOT-DIPPING GALVANISING

-



ELECTROPLATING OR ELECTRO-GALVANISING



- for dry batteries (the negative pole)

- **alloys** such as brass (Cu + Zn) (21%) and nickel silver (Cu + Zn + Ni + Sn) (other alloys 16%)

- Used in paint to protect from weather metals ...

4. LEAD (Pb)

Obtained from **GALENA**.

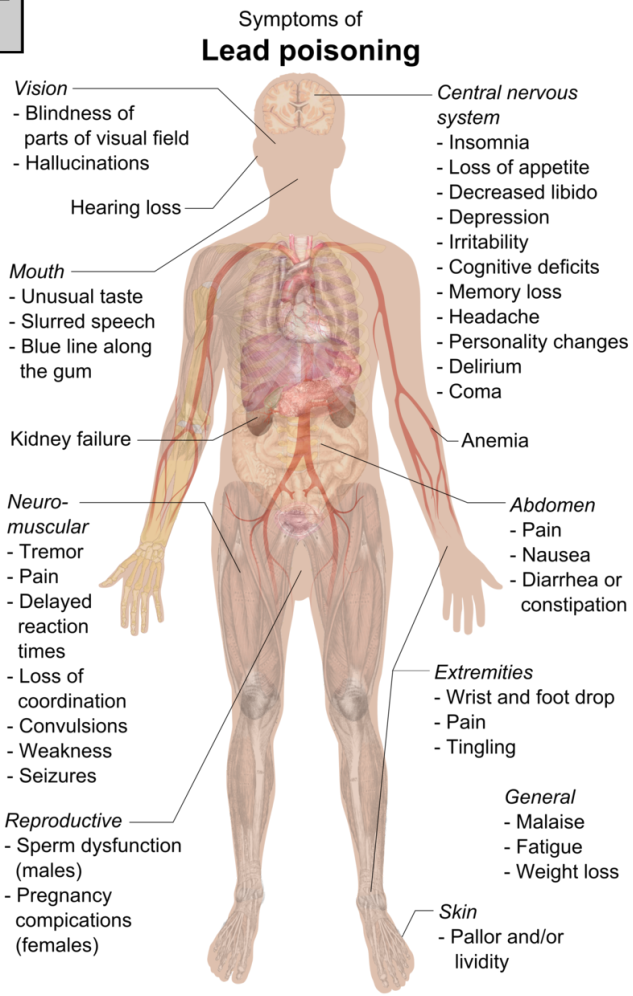
The main alloys are tin and antimony. Heavy metal gray-white bright that it tarnishes the rust. When oxidized oxide layer protects the rest of the metal properties: It is soft and ductile Not good conductor of electricity

It is resistant to radiation ---> X-ray protection

It has a low melting temperature -> Easy to merge

It is quite resistant to corrosion.

Before he had many more uses to make water pipes (that is the reason why the name of PLUMBER, plomero in South-American) but **is TOXIC**



5. TITANIUM (Ti)

Obtained from **ILMENITE** (Ilmenita) or **RUTILE** (Rutilo).

It was discovered in XVIIIth century but was not achieved the pure metal until 1910.

Today it is an extraordinarily expensive metal. Has properties similar to steel but is much lighter than most metals

Is used in:

- aerospace military industry (warplanes)

-Replacing bones of the body (the body does not reject but the people who have it can not pass through metal bows airports) t

The most used alloy is 3Al-2.5V (ie 94.5% Ti, Al 3% and 2.5% V)

6. TIN (Sn)

Obtained from **CASSITERITE** (Casiterita) The tin is so malleable and ductile, which can be rolled into sheets less than a thousandth of a cm thick, forming a tin foil wrap.

It is also used as:

- protective coating of copper and iron (and other metals) in cans.

-To manufacture bronze.

-The alloy of lead and tin 50% is used for soldering.

-So that the glass is not so fragile. In fungicides, dyes, ...

EXERCISES

1. Match the metal with its mineral

IRON	ILMENITE
LEAD	BLENDE
TITANIUM	GALENA
COPPER	CASSITERITE
TIN	MALAQUITA
ZINC	BAUXITE
ALUMINIUM	PYRITE

2. A metal with 98.5% iron and 1.5% carbon is called ...

3. A galvanized is cover a ..... with ..... to avoid .....

4. The first to manage iron were the .....

5. A native metal is .....

6. The tin is alloyed with ..... to make soldering line

7. Machinery is made with ..... (a type of iron)

8. The alloy of copper and zinc is called .....

9. The first bronze was made in .....

10. To cool quickly a metal is called .....and make the metal .....

12. The metallurgy is .....

13. An alloy is .....

14. Why use civilian aircraft aluminum instead of titanium, if the second one has much better qualities?

15. For that is used pure iron?

16. If heavy metals are toxic, why we use tin foil (papel de estaño) in the kitchen?

17. The metal in which world currently spend more money is ....

18. The cupronickel is used for ...

19. In Galicia we have the 9th most polluting factory in Europe, in As Pontes de García Rodriguez. We used the electricity of this plant to make ....

20. Why we use PVC instead of lead in water pipes?

21. Explains a normal metallurgical process

2. Why we use copper instead of silver in electrical cables? Why we are thinking about replace the copper wires and making in aluminum? Environmental consequences if we take this decission?

24. All metals are solid at room temperature but one. What?

25 The mercury (Hg) in thermometers is being replaced for other materials. The mercury is a heavy metal, which is the reason for this substitution?

26. On Saturday 1/3/08 there was a demonstration of hunters, the reason was that lead has been banned as ammunition in protected spaces

A. Of which mineral is extracted lead

B. Because it was banned in this, and also in gasoline, pipes, ...

C. Di two current lead applications

27. Steel can replace lead as ammunition

A. The steel is an alloy of

B The metal, of which ore is extracted?

C. The use of this metal had an environmental effect. Explain what happened and why.

28. Explain how obtein iron in a brast furnace. How the ancients did

29. In USA, Bolivia and Chile there are mines of malachite and even metal in the native state

A. What metal is obtained from malachite

B. What does the native state mean?

C. If we find cassiterite, what alloy can we make. Justify your answer

D. The main use of this metal at present and due to that quality

30. In Norway there are ilmenite mines.

A. What metal is extracted from this mineral

B. Say two applications of this metal

31. Many days arrive at the port of Ferrol boats loaded with bauxite

A. What metal is extracted from bauxite

B. Explain electrolysis

C. Explain why electrolysis is expensive and polluting

32. The Romans came to Galicia in search of **galena**

A. What metal is obtained from this mineral

B. For which the Romans used this mineral

C. Why it is not currently used for this purpose (or others like gasoline)

D. Say two current uses of this mineral

33. Make the complete classification of metals

34. Answer:

A. What is galvanizing?

B. Tell the types of galvanizing

C. What metal we need to galvanize

D. From which mineral is extracted

35. What effects do tempering and forging on the steel?

36. Explain tempering

37. Explain forging