Ch 14-Making use of metals (chapter summary)

Earth's crust

1. Mainly made of compounds
2. Some elements occur ***NATIVE***, or uncombined
3. Oxygen and Silicon make up almost 75% of the earth's crust, they occur together in compounds such as silicon dioxide
4. Oxygen can also be found in other compounds such as $CaCO_3$, Al_2O_3

Scarce and precious metals

- Metals such as Lead, Zinc, Copper composite a very less % of the earth's crust, hence they are scarce.
- Gold, Platinum are precious metals since they are rare and expensive and often used as a store of wealth

Ore – A rock containing a large amount of a metal or metal compound from which the metal is extracted.

Rock salt = NaCl Bauxite = Al_2O_3 Hematite = Fe_2O_3

Is mining economical?

1. How much ore is there?
2. How much metal can be obtained?
3. Any special problems in getting the ore out?
4. What will be the total cost of operation (including transport costs, etc.)?
5. How much will we be able to sell the metal for
6. Will a profit be made

(answers to these questions change every year. Sometimes low grade metals become worth mining)

Extraction of metals

- **Extracting a metal depends on the metal's reactivity**
- Native elements occur in their ores as elements. The metal needs to be separated from sand and other impurities e.g., by panning.
- All other metals occur in compounds and therefore must be reduced to give the metal.
- The most reactive metals are very stable in compounds and are extracted using electrolysis.
- Lesser reactive metals can be reduced using chemical reactions.

Extraction using Carbon

- Carbon will reduce oxides of metal less reactive than itself
- Many compounds such as hydroxides, nitrates, carbonates can easily be converted to oxides. E.g., using thermal decomposition.
- Lead, Zinc, iron oxides will be reduced using carbon. Usually, carbon is in the form of coke, which is heated with metal oxide in a furnace. Sometimes the C reacts with limited supply of Oxygen to from carbon monoxide. In this case CO brings about reduction.

Zinc blende

1. ZnS is roasted in air forming ZnO.
   $2ZnS + 3O_2 \quad 2ZnO + 2SO_2$

   Oxide is then reduced in one of 2 ways:

   i) Using carbon monoxide

   $ZnO + CO \quad Zn + CO_2$

   (final mixture contains Zinc and slag of impurities. Separated by fractional distillation, it boils at 907*c)

   ii) Electrolysis

   Zinc Oxide is dissolved in H_2SO_4 (since Zinc Oxides melting point is too high)
   ZnO neutralizes H_2SO_4 forming $ZnSO_4$

   ZnSO4 undergoes electrolysis, and zinc is deposited at Cathode.
   $Zn^{2+} + 2e^- \quad Zn$
   Zinc produced is extremely pure and is sold in bars.

Extraction of Iron

- Iron is extracted using a blast furnace
- Charge is added to the top of the furnace. Charge contains:
  1. Hematite (Fe_2O_3 mixed with sand and other compounds)
  2. $CaCO_3$
  3. Coke (almost pure Carbon)
- Hot air is blasted from the bottom to the top of the furnace causing four main reactions to take place

Reactions:

1. Hot air reacts with the coke (this is a redox reaction. It is also a exothermic reaction which helps to heat the furnace)
   $C + O_2 \quad CO_2$

2. CO2 reacts with more coke. (CO2 is reduced. This reaction is endothermic which lowers the temperature of furnace which is important for step 3)
   $C + CO_2 \quad 2CO$

3. CO reacts with hematite to give liquid iron (CO reduces Fe_2O_3)
   $Fe_2O_3 + 2CO \quad 2Fe + 3CO_2$

4. Limestone undergoes thermal decomposition due to heat of furnace
   $CaCO_3 \quad CaO + CO_2$

   CaO is basic oxide. Silica/Silicon dioxide is an acidic oxide.
   Hence a salt forms...
   $CaO + SiO_2 \quad CaSiO_3$ (calcium silicate)
   SiO3 forms a slag which floats on molten Fe. Once it solidifies it is used for road building.

(Waste gasses CO_2 and N which are hot, are used to heat incoming blast of air. CO_2 is the CO_2 obtained from Fe_2O_3 reduction. N was gas in first blast of incoming air it has not changed)

Products

- Iron that is produced is called pig iron
- Very impure, sand and Carbon are main impurities
- Some is run into molds to produce “cast iron”
- Cast iron is very hard but very brittle as well due to high carbon content
- Most of iron is turned into steels

Extracting Aluminum

- Aluminum is the most abundant metal in the Earth's crust
- Main ore is Bauxite, which is Al_2O_3 mixed with impurities such as sand and Fe_2O_3.
- Impurities make it look reddish brown
- This ore is usually found near the surface
- Aluminum is extracted using electrolysis. A large steel tank lined with carbon is used.

1. Alumina has an extremely high melting point. Hence it is dissolved in molten cryolite (sodium aluminum fluoride [notice that electrolyte contains aluminium]) which has a lower melting point.

2. At cathode
   $4Al^{3+}+12e^-$ $4Al$
   The Al drops to the bottom of the cell as molten metal. This is run off at intervals. Some will be used to make alloys, some will be run into molds to harden into blocks.

3. At Anode
   $6O^{2-}$ $3O_2 + 12e^-$
   The O2 reacts with the Carbon Electrodes to form CO2. The Anodes hence dissolve

Overall reaction

$2Al_2O_3$ $4Al + 3O_2$

Properties of aluminum

- Non toxic
- Doesn’t corrode
- Low density
- Malleable and ductile
- Bluish, silver, shiny
- Not strong in pure form, stronger as alloys

Using Metals

- We use metals for specific things based on its properties

Alloys

- A mixture where at least one other substance is added to a metal, to improve it properties; the other substance is often a metal too but not always
- Brass- 30% zinc, 70% copper.
- Alloys often are stronger (as new atoms enter lattice which doesn't allow layers to slide as easily)
- Alloys may be more resistant to corrosion.

Alloys of Iron

- **Iron**
  1. very soft
  2. stretches quite easily
  3. rusts
- **Mild Steel**
  1. Hard
  2. Strong
  3. Rusts
- **Stainless steel**
  1. Hard
  2. Strong
  3. Rust proof

Making steels

Iron from the blast furnace is impure. It contains 5% Carbon, silica, Phosphorus, Sulfur

Extraction:

1. Molten iron is poured into furnace called basic oxygen converter
2. Jet of oxygen is turned on
3. Oxygen reacts with C and S to form CO_2 and SO_2. Reacts with Phosphorus to form P_2O_5 (a solid)
4. CaO is added which reacts with SiO_2 and P_2O_5 to form a slag which floats on the iron and is skimmed off.

For some steels all impurities are removed. However, since most steels contain some carbon, the carbon content is continually checked in the converter until its % becomes right. Then the oxygen jet is switched off.

Then other elements such as N and Cu are added to molten iron in correct amounts.

Notes provided by Jeyan Mehta