Module 25.3

Occurrence and principles of extraction of Cu

Copper (Cu):

A. Occurrence:

Copper is a chemical element with symbol “Cu” comes from Latin word “cuprum” and atomic number 29. It occurs in the combined state mostly. The important minerals of copper are given below

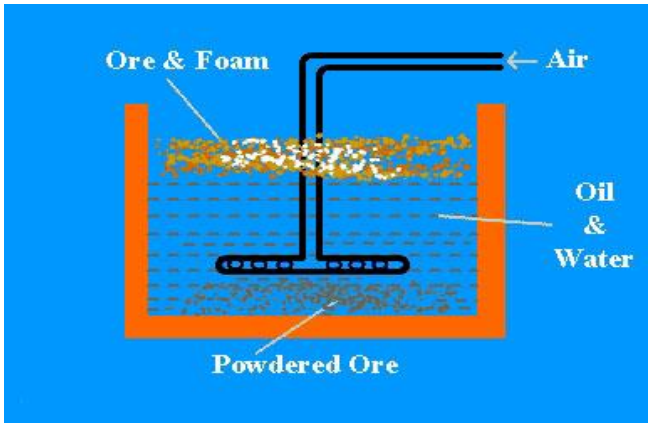
Name of the mineral	formula
Cuprite	Cu_2O
Chalcocite or copper glance	Cu_2S
Copper pyrite or chalcopyrite	$CuFeS_2$
Malachite green	$CuCO_3.Cu(OH)_2$
Azurite blue	$2CuCO_3.Cu(OH)_2$

B. Extraction of copper from sulphide ore:

Copper pyrites is the main source of copper metal. From it copper metal is obtained by smelting process. Following steps are involved in the extraction of copper by smelting process.

a. Concentration:

The finely crushed ore is concentrated by Froth-Floatation process. The finely crushed ore is suspended in water containing a little amount of pine oil. A blast of air is passed through the suspension. The particles get wetted by the oil and float as a froth which is skimmed. The gangue sinks to the bottom. The froth is separated and about 95% concentrated ore is obtained.



b. Roasting:

The concentrated ore is then roasted in a furnace in a current of air. Sulphur is oxidized to SO_2 and impurities of arsenic and antimony are removed as volatile oxides.
The following reaction takes place.

$$2CuFeS_2 + O_2 \rightarrow Cu_2S + 2FeS + SO_2$$

Cuprous sulphide and ferrous sulphide are further oxidized into their oxides.

$$2Cu_2S + 3O_2 \rightarrow 2Cu_2O + 2SO_2$$
$$2FeS + 3O_2 \rightarrow 2FeO + 2SO_2$$

c. Smelting:

The roasted ore is mixed with coke and silica (SiO_2) and is introduced in to a blast furnace. The hot air blast converts FeO in to ferrous silicate ($FeSiO_3$).

$$FeO + SiO_2 \rightarrow FeSiO_3$$
$$Cu_2O + FeS \rightarrow Cu_2S + FeO$$

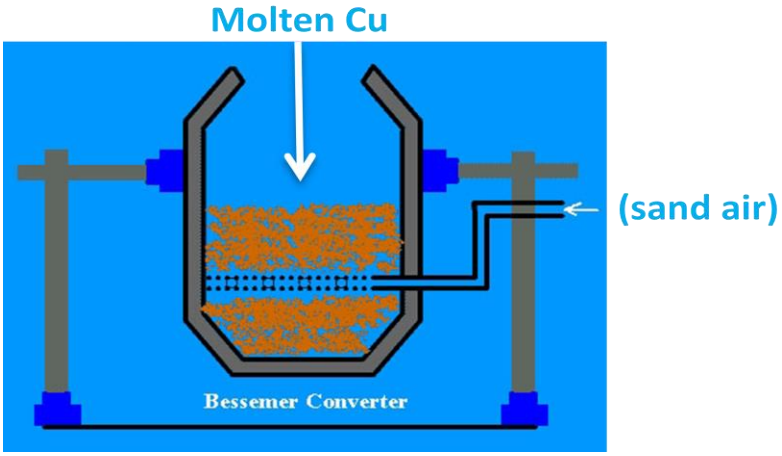
The product of the blast furnace consists mostly of Cu_2S and a little of ferrous sulphide. This product is known as "**Matte".** It is collected from the outlet at the bottom of the furnace.

d. Bessemerization process:

Copper metal is extracted from molten matte through bessemerization. The matte is introduced in to Bessemer converter which is upheld by tuyers. The air is blown through the molten matte. Blast of air converts Cu_2S partly into Cu_2O which reacts with remaining Cu_2S to give molten copper.

$$2Cu_2S + 3O_2 \rightarrow 2Cu_2O + 2SO_2$$
$$2Cu_2O + Cu_2S \rightarrow 6Cu + SO_2$$

The copper so obtained is called "Blister copper" (98% pure) because, as it solidifies, SO_2 escapes out producing blisters on its surface.

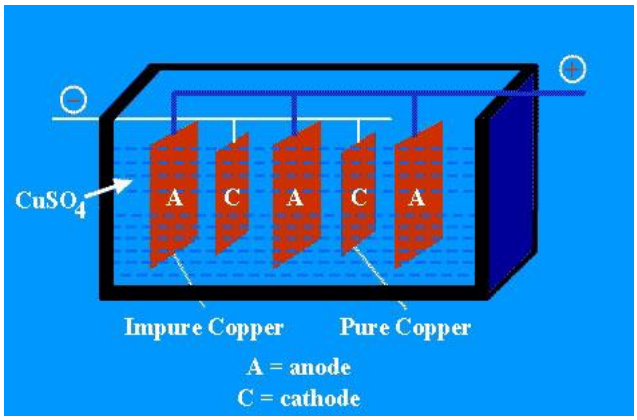


e. Refining of copper:

Blister copper is refined by electrolysis. Blocks of blister copper (impure copper) are used as anodes and thin sheets of pure copper act as cathodes. The cathode plates are coated with graphite in order to remove deposited copper. The electrolyte is copper sulphate ($CuSO_4$) mixed with a little amount of H_2SO_4 to increase the electrical conductivity. Optimum potential difference is 1.3 volt for this electrolytic process. During electrolysis, pure copper is deposited on the cathode plates and impurities which are soluble and fall to the bottom of the cell as anode mud.

$$\text{anode: } Cu \rightarrow Cu^{+2} + 2e^-$$
$$\text{cathode: } Cu^{+2} + 2e^- \rightarrow Cu$$

This electrically refined copper is 100% pure.



Uses:

It is used as thermal conductor, an electrical conductor, a building material and a constitute of various metal alloys.

Assignment questions:

1. Write an essay on the Belgain process for the extraction of Zinc metal?
2. Write the short notes on concentration of Zinc ores.
3. How is copper pyrites concentrated?

Example set:

1. What is symbol of copper?
   a. Cd
   b. Cu
   c. Cr
   d. Co

Solution: b)

2. Which of the following is Sulphide mineral of copper
   a. Cuprite
   b. Azurite
   c. Malachite

d. Chalcocite

Solution: d)

3. Froth floatation method is used to increase the concentration of
   a. Chalcopyrites
   b. Bauxite
   c. Haematite
   d. Calamine

Solution: a)

4. Blister copper is _____ % pure
   a. 20
   b. 40
   c. 80
   d. 98

Solution: d)

5. In the electrolysis of $CuSO_4$, H_2SO_4 is added to _____
   a. Increase the conductivity
   b. Decrease the conductivity
   c. Remove impurities from $CuSO_4$
   d. Both b and c

Solution: a)

6. The most commonly method used for the reduction of the zinc oxide
   a. Baeyer's process
   b. Hall's process
   c. Serpek's process
   d. Belgain process

Solution: d)

7. The Zinc obtained by electrolytic refining _____ % pure
   a. 80

b. 90
c. 99.99%
d. 70

Solution: c)

8. Write the name of any three minerals of Cu with their formulae.

Solution:

Cuprite (Cu_2O); Covellite (Cus); Chalocite or copper glance (Cu2S).

9. What is the primary product of Bessemerization of matte?

Solution:

Copper metal is extracted from molten matte through bessemerization. The matte is introduced in to Bessemer converter which is upheld by tuyers. The air is blown through the molten matte. Blast of air converts Cu_2S partly into Cu_2O which reacts with remaining Cu_2S to give molten copper.

10. Write the names of minerals with the following formulae.
    a. $ZnO.Fe_2O_3$
    b. Zn_2SiO_4
    c. $ZnCO_3$

Solution:

$ZnO.Fe_2O_3$ - Franklinite

Zn_2SiO_4 - willemite

$ZnCO_3$ – Calamine

Problem set:

1. Heating pyrites in air to remove sulphur is known as _____
    a. calcination
    b. fluxing

c. smelting
d. roasting

Solution: d)

2. In smelting, the roasted ore is mixed with coke and _____
   a. sulphur
   b. silica
   c. copper
   d. zinc

Solution: b)

3. Which of the following is sulphide ore of zinc
   a. Zinc blende
   b. Zincite
   c. Calamine
   d. Willemite

Solution: a)

4. Froth floatation method may be used to increase the concentrion of ----
   a. Hemiatite
   b. Bauxite
   c. Calmanie
   d. Zinc blende

Solution: d)

5. Heating pyrites in air to remove sulphur is known as
   a. Calcination
   b. Fluxing
   c. Roasting
   d. Smelting

Solution: c)

6. Describe the smelting of copper ore.

Solution:

Smelting:

The roasted ore is mixed with coke and silica (SiO_2) and is introduced in to a blast furnace. The hot air blast converts FeO in to ferrous silicate ($FeSiO_3$).

$$FeO + SiO_2 \rightarrow FeSiO_3$$
$$Cu_2O + FeS \rightarrow Cu_2S + FeO$$

The product of the blast furnace consists mostly of Cu_2S and a little of ferrous sulphide. This product is known as "**Matte".** It is collected from the outlet at the bottom of the furnace.

7. Write on essay how copper matte is treated to get pure copper.

Solution:

BESSEMERIZATION:

Copper metal is extracted from molten matte through bessemerization. The matte is introduced in to Bessemer converter which upheld by tuyers. Air is blown through the molten matte. Blast of air converts Cu_2S partly into Cu_2O which reacts with the remaining Cu_2S to give molten copper.

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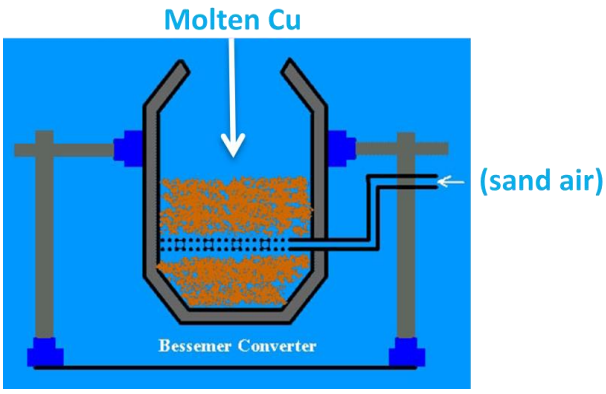

Exercise questions:

1. Write only the chemical reactions that take place in the metallurgy of Zinc.
2. Why is the extraction of copper from pyrites more difficult than that from its oxide ore through reduction?
3. State the role of silica in the metallurgy of copper.
4. Copper *matte* is put in silica lined converter. Give an explanation.
5. Why is zinc not extracted from zinc oxide through reduction with CO?

Solution to exercise questions:

1.

$$2Zns + 3O_2 \longrightarrow 2ZnO + 2SO_2 \text{ (Roasting)}$$

$$ZnCO_3 \xrightarrow{\Delta} ZnO + CO_2 \quad \text{(Calcination)}$$

$$ZnO + C \rightarrow Zn + CO \quad \text{(Reduciton)}$$

$$ZnO + CO \rightarrow Zn + CO_2 \quad \text{(Reduction)}$$

2. Cu – pyrites, when reduced with H_2, gives H_2S; it gives CS_2 on reduction with C gives CS_2The Gibbs free energy of formation ($\Delta_f G$) of Cu_2S is less than that of H_2S and CS_2. Therefore, H_2 and C cannot reduce Cu_2S to Cu.

   On the other hand, the Gibbs free energy of formation of Cu_2O is greater than that of CO. Hence, C can reduce Cu_2O to Cu.

$$C_{(s)} + Cu_2O_{(s)} \longrightarrow 2Cu_{(s)} + CO_{(g)}$$

Hence, the extraction of copper from its pyrites ore is difficult than from its oxide ore through reduction.

3. During the roasting of pyrites ore, a mixture of FeO and Cu_2O is obtained.

$$2\,CuFeS_2 + O_2 \xrightarrow{\Delta} Cu_2S + 2\,FeS + SO_2$$

$$2Cu_2S + 3O_2 \xrightarrow{\Delta} 2Cu_2O + 2SO_2$$
$$2FeS + 3O_2 \xrightarrow{\Delta} 2FeO + 2SO_2$$

The role of silica in the metallurgy of copper is to remove the iron oxide obtained during the process of roasting as 'slag'. If the sulphide ore of copper contains iron, then silica (SiO_2) is added as flux before roasting. Then, FeO combines with silica to form iron silicate, $FeSiO_3$ (slag).

$$FeO + SiO_2 \xrightarrow{\Delta} FeSiO_3$$
$$(\text{Slag})$$

4. Copper *matte* contains Cu_2S and FeS. Copper *matte* is put in a silica-lined converter to remove the remaining FeO in the *matte* as slag ($FeSiO_3$). Also, some silica is added to the silica-lined converter. When a hot air blast is blown, As a result, the remaining FeS is changed to FeO and FeO is converted to iron silicate ($FeSiO_3$) and Cu_2S is converted into metallic copper.

The reaction are represented as

$$2FeS + 3O_2 \longrightarrow 2FeO + 2SO_2$$
$$FeO + SiO_2 \longrightarrow FeSiO_3 \quad \text{(slag)}$$

$$2Cu_2S + 3O_2 \longrightarrow 2Cu_2O + 2SO_2$$
$$2Cu_2O + Cu_2S \longrightarrow 6Cu + SO_2$$

5. The standard Gibbs free energy of formation of ZnO from Zn is lower than that of CO_2 from CO. Therefore, CO cannot reduce ZnO to Zn. Hence, Zn is not extracted from ZnO through reduction using CO.