Extracting a metal from its ore

Minerals are solid elements or compounds found naturally in the Earth's crust. Those minerals that contain sufficient metal to be of practical and economic use are called ores. Metals are usually extracted from ores using a combination of heating and reduction with carbon in the form of charcoal or coke. Not all metals can be extracted from their ores in this manner and may need to be extracted by a process called electrolysis.

Metals with low chemical activity, such a gold and silver are normally found in their pure state. Copper, tin, lead, and iron are more reactive and must be heated with carbon to extract the metals. Aluminum, calcium, sodium and other active metals are extracted using electrolysis.

Copper can be extracted from its ores by reduction. One of the common copper ores, malachite, which is composed of mainly copper carbonate, $CuCO_3 \cdot Cu(OH)_2$, is heated to produce copper oxide with the release of carbon dioxide.

$$CuCO_3 \cdot Cu(OH)_2 \rightarrow 2\,CuO + CO_2 + H_2O$$

The copper oxide is then heated with carbon to get copper.

$$2\,CuO + C \rightarrow 2\,Cu + CO_2$$

The resulting copper, however, is pure enough to be used for many industrial applications, but it has to be further refined for electrical uses. That copper is cast into thick sheets known as anodes and are placed in large electrolytic cells filled with a copper sulfate solution. A DC electric current is passed through the cells causing the copper anodes to dissolve and deposits pure copper on the opposite pole called the cathode. The final product is between 99.94 and 99.96% Cu.

Figure 1. A copper anode consists of approximately 95% pure copper

Figure 2. A copper cathode consists of 99.9% pure copper

In this experiment, copper will be extracted from malachite by reaction with sulfuric acid and then reduced from the acid solution using metallic iron. The reactions for these processes are

$$CuCO_3 \cdot Cu(OH)_2 + 2\ H_2SO_4 \rightarrow 2\ CuSO_4 + 3\ H_2O + CO_2$$

$$Fe + CuSO_4 \rightarrow FeSO_4 + Cu$$

Mineral	**Composition**	**Copper % by mass**	**Color**	**Luster**
Native copper	Cu	98 +	Copper red	Metallic
Cuprite	Cu_2O	88.8	Red	
Chalcocite	Cu_2O	79.9	Dark gray	Metallic
Chalcopyrite (a form of fool's gold)	Fe_xCu_yS	10	Gold	Metallic
Covellite	CuS	66.4	Indigo blue	
Bornite	Cu_5FeS_4	63.3	Golden brown to copper red	Metallic
Malachite	$CuCO_3 \cdot Cu(OH)_2$	57.5	Bright green	
Azurite	$2\ CuCO_3 \cdot Cu(OH)_2$	55.3	Blue	
Antlerite	$Cu_3SO_4(OH)_4$	53.7	Green	
Chrysocolla	$CuSiO_3 \cdot 2H_2O$	36.2	Bluish green to sky blue	

Table 1. Common ores of copper

Safety Precautions

Wear safety goggles at all times in the laboratory.

Sulfuric acid is corrosive. The sulfuric acid used in this experiment is dilute, but irritations or burns can occur. In the event of skin contact, the affected area should be washed with water. If redness or broken skin occurs, medical attention should be obtained.

Disposal

Dispose of all materials in the proper containers supplied in the laboratory.

Materials needed

Malachite The sample may be the malachite prepared in a previous experiment or a piece of low grade malachite from a mineral shop.
Sulfuric acid, H_2SO_4, 3 M (prepared by diluting 167 mL of concentrated H_2SO_4 to one liter)
Iron, small nails
Steel wool, fine
Hammer
Plastic bags, sandwich size
2 Beakers, 250 mL
funnel

funnel holder or ring
filter paper
stirring rod
tongs or forceps

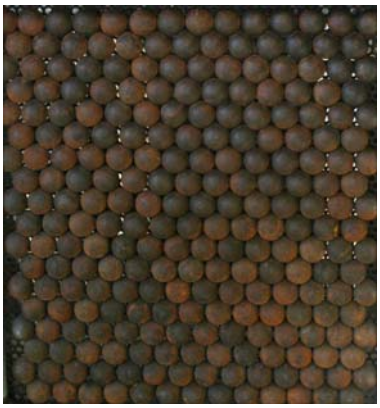

Figure 3. Steel balls used in a ball mill

Procedure

You will need approximately 5 g of malachite.

If the malachite is in a lump form, you will have to crush the ore. Place the piece of malachite into a plastic bag. Place the bag on the floor or another hard surface which will not be harmed by the hammer, and gently pound the malachite with the hammer. At a commercial mine, the ore is normally crushed in a ball mill, a large rotating cylinder containing steel balls which, as the cylinder rotates, crushes the ore. Determine the mass of the crushed malachite.

Mass of malachite used _____ g

Place the crushed ore in a 250 mL beaker. Add 50 mL of the 3 M H_2SO_4 to the beaker. Stir to dissolve the malachite. All the malachite ore may not dissolve due to impurities.

After all bubbling has stopped and there appears to be no further reaction, add an additional 10 mL 3 M H_2SO_4 to test for completeness of reaction. If necessary, up to an additional 40 mL of 3 M H_2SO_4, in 10 mL increments can be added to the sample until all reaction is complete.

Filter the solution into a clean 250 mL beaker. You should obtain a clear blue solution. The color is due to the presence of Cu^{2+} ions in the solution. If the solution is not clear, it may be necessary to filter it a second time. Save the solids that remain in the filter paper. Allow them to dry and determine their mass. How much of the original malachite was dissolved?

Mass of remaining solids _____ g

Mass of malachite that reacted _____ g

Obtain approximately 6 g of iron in the form of small iron nails. Clean the iron nails with the steel wool.

Place the iron in the clear blue solution. Observe what is occurring in the solution. After a few minutes, using tongs, remove one of the nails from the solution for observation, then replace the nail in the solution. In the mining industry, scrap iron obtained from various sources including old car parts is used for this process. You may have to let the solution stand overnight or until the next laboratory period for the reaction to go to completion.

After the reaction is complete, filter the solution to obtain and reduced copper. Allow the copper to dry and determine its mass.

Mass of copper obtained from the malachite _____ g

Discard all waste solutions in the proper containers.

Questions

What changes occurred in the solution?

What changes occurred with the nails?

Give an explanation for the changes that occurred?

Calculate the percent of the original malachite sample that reacted.

$$\%\, malachite\, reacted = \frac{mass\, of\ malachite\, reacted}{mass\, of\ malachite\, sample} x100$$

Calculate the percent of the copper obtained from the malachite.

$$\%\, copper = \frac{mass\, of\ copper\, obtained}{mass\, of\ malachite\, reacted} x100$$