**SIMSMC JUNE 2003**

**Module: THE POWER OF METAL IN THE ANDEAN WORLD/ Laboratory**

# DIRECT REDUCTION SMELTING OF COPPER OXIDE ORE

## Part 1: Preparation of the crucible charge

In this experiment, we will smelt a copper carbonate ore [malachite: $Cu_2(OH)_2CO_3$] with charcoal. The smelting enclosure is a clay-graphite crucible. The charge is a mixture of ore and charcoal in a 3:1 ratio of ore-to-charcoal, by weight.

**Procedure:**

Both ore and charcoal should be comminuted to small pieces that range in size from about 3 mm to 5 mm. Crush ore and charcoal separately; use a sieve to eliminate the powder and fine particles that are smaller than about 3 mm in size.

Weigh out 90 g of ore and 30 g of charcoal. Mix ore and charcoal thoroughly. The mixture constitutes the smelting charge.

Students will work in teams of two. Each team should charge two clay-graphite crucibles. The charge in both crucibles should be virtually identical.

During smelting, copper will be extracted from the malachite ore. The efficiency of our smelting process will be determined by calculating the copper yield: the percent of copper in the ore that was extracted by the smelt. Before coming to class, calculate the amount of copper in each crucible charge. Since you know the chemical formula of the mineral malachite and the total weight of malachite ore in each crucible, you can calculate how many grams of copper are contained in the ore mineral. After smelting, we will weigh the copper ingot and prills produced to see how that weight compares with the total weight of copper in the ore charged into the crucible. That will give us a good estimate of the copper yield obtained during smelting.

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## Part 2: Crucible smelting

Students will work in teams of two. Each team will carry out a smelting trial with two clay-graphite crucibles.

Procedure:

Mr. Bashaw will set each crucible on a bed of hot coal in the forge and will heap the coal around the crucible so that it is heated evenly. One student in the team should monitor the temperature of the charge with a direct-reading thermocouple. Keep track of the length of time of the smelt. As soon as the crucible is set onto the hot coals, begin timing the operation. Record the time when Mr. Bashaw turns up the air flow to intensify the heat. Once the air flow has been increased, take a temperature reading of the charge inside the crucible about every 2 – 3 minutes.

Continue smelting and recording the temperature until the charge reaches about 1250˚C. The second student in the team should remove the crucible with a pair of tongs as soon as the temperature reads approximately 1250˚C. Set the crucible to cool on a firebrick.

**DO NOT ALLOW THE CRUCIBLE TO HEAT ABOVE 1250˚C**.

Repeat the smelting procedure with the second crucible. Team members should switch tasks: thermocouple and tongs.

After each smelt, when the crucible contents have reached room temperature, dump out the contents and retrieve the copper metal. The metal may have consolidated into an ingot; it may be present in the form of small prills; or the copper may occur in some combination of

ingot-and-prills.

Separate all the copper metal carefully from any charcoal and ash remaining in the crucible. Weigh the metal. Calculate the yield [in %] of metal smelted from the malachite ore. Did any product form during the smelting process, other than copper?

**SOME COMMON SULFIDE AND OXIDE ORE MINERALS OF COPPER**

| *Mineral* | *Formula* | *Composition* | *(Percent, by weight)* |
|---|---|---|---|
| Cuprite | $Cu_2O$ | Cu | 88.82 |
| | | O | 11.18 |
| Malachite | $Cu_2(OH)_2CO_3$ | CuO | 71.95 |
| | | $CO_2$ | 19.90 |
| | | $H_2O$ | 8.15 |
| Azurite | $Cu_3(OH)_2(CO_3)_2$ | CuO | 69.24 |
| | | $CO_2$ | 25.53 |
| | | $H_2O$ | 5.23 |
| Chalcanthite (Blue vitriol) | $CuSO_4•5H_2O$ | CuO | 31.87 |
| | | $SO_3$ | 32.06 |
| | | $H_2O$ | 36.07 |
| Brochantite | $Cu_4(SO_4)(OH)_6$ | CuO | 70.36 |
| | | $SO_3$ | 17.70 |
| | | $H_2O$ | 11.94 |
| Atacamite | $Cu_2(OH)_3Cl$ | Cu | 14.88 |
| | | CuO | 55.87 |
| | | Cl | 16.60 |
| | | $H_2O$ | 12.65 |
| Chrysocolla | $CuSiO_3•2H_2O$ | CuO | 45.2 |
| | | $SiO_2$ | 34.3 |
| | | $H_2O$ | 20.5 |
| Chalcocite | $Cu_2S$ | Cu | 79.86 |
| | | S | 20.14 |
| Covellite | CuS | Cu | 66.48 |
| | | S | 33.52 |
| Chalcopyrite (Copper pyrites) | $CuFeS_2$ | Cu | 34.64 |
| | | Fe | 30.42 |
| | | S | 34.94 |
| Bornite | $Cu_5FeS_4$ | Cu | 63.33 |
| | | Fe | 11.12 |