CHEMICAL ALCHEMY: COPPER INTO SILVER AND GOLD!

MATERIALS:

powdered zinc
6 M NaOH
ring stand
burner
evaporating dish
tongs
steel wool
beaker with water

PROCEDURE:

1. Put about 4 grams of powdered zinc into the dish. Put enough of the NaOH into the dish to fill the dish about one-third.

2. Place the dish over the burner and carefully heat to boiling.

3. Thoroughly clean a copper penny (steel wool works well) and gently place it into the boiling mixture in the dish.

4. Allow the penny to remain in the boiling NaOH for 2-3 minutes, or until it becomes a silver color.

5. Remove the penny, rinse with water and carefully blot dry with paper towels. Otherwise the zinc coating will rub off.

(In this step the zinc reacts with the sodium hydroxide to form sodium zincate, Na_2ZnO_2 which is reduced to metallic zinc by the copper in the penny. You could tell your class that your alchemy has changed the copper into silver.)

6. Using tongs hold the dry, zinc-coated penny in the flame of the burner. In a few seconds a gold color should appear. Remove the coin, allow to cool and display to the class.

(In this step the heat causes the zinc and copper to fuse into an alloy of brass.)

HAZARDS:

The hot sodium hydroxide is caustic. Goggles and apron should be worn. Students should be some distance from the boiling NaOH.

Zinc + sodium hydroxide → Sodium Zincate
Na_2ZnO_2

CHEM FAX!

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Colorful Copper Compounds

An Interesting Copper Phenomenon

Publication No. 279

Introduction:

Are all copper compounds the same color? How about their solutions? Dissolve some and observe this interesting, colorful phenomenon about copper compounds.

Chemical Concepts:

- Complex ions
- Transition metals

Copper II bromide + water →
Copper hydroxide + Bromine

Copper II chloride + water →
copper hydroxide + chlorine

Copper sulfate + water →
Copper hydroxide + sulfuric Acid

Materials Needed:

Cupric bromide, anhydrous, $CuBr_2$, 6 g
Cupric chloride, anhydrous, $CuCl_2$, 6 g
Cupric sulfate, anhydrous, $CuSO_4$, 6 g
Distilled or deionized water
Balance
Beakers, 400-mL, 3
Stirring rods, 3

Caution:

This activity requires the use of hazardous components and/or has the potential for hazardous reactions. Please review the Safety Precautions section on the following page and relevant Material Safety Data Sheets before beginning this activity.

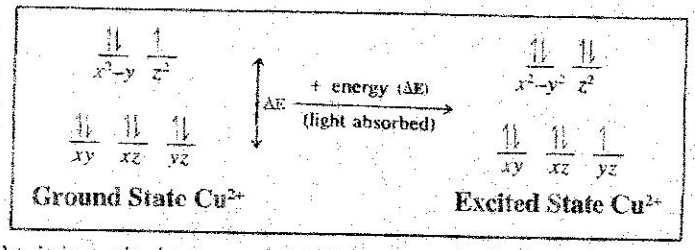
Procedure:

1. Weigh out approximately 6 g of cupric bromide, 6 g of cupric chloride, and 6 g of cupric sulfate in three separate, clean, dry, 400-mL beakers.
2. Before proceeding, observe and record the color and crystalline properties of the three anhydrous solids. Make a record chart. [*Cupric bromide is a black crystalline solid, cupric chloride is a light brown powder, and cupric sulfate is an off-white powder.*]
3. Add approximately 20 mL of distilled water to each beaker and, *without stirring*, make observations. Record observations and color changes. [*The beaker of cupric bromide contains a rust-colored solid with a yellow-green solution, the beaker of cupric chloride contains a green solid with a green solution, and the beaker of cupric sulfate contains a blue solid with a blue solution.*]
4. Add 20 mL more of distilled water to each beaker and, *with stirring*, observe the slight difference in the color of the solutions. What color are the three solutions? [*Cupric bromide solution is green, cupric chloride solution is teal, and cupric sulfate solution is blue.*]
5. Continue adding water (approximately 100 mL) with stirring. What is the end result? [*All three solutions are the same blue color.*]

Discussion:

One of the most interesting properties of transition metals is that their compounds are usually colored (both as solids and in solution), while those of the main group metals are almost always white as solids and colorless in solution. In simplest terms, this phenomenon is attributed to the fact that transition metals have unpaired *d* electrons while main group metals do not.

Many transition metal ions form complex ions (also called coordination compounds), which are complexes between the metal atom or ion and neutral molecules or anions (called ligands). In solid form and in solution, coordination compounds display a rainbow of vibrant colors. Copper (II) compounds, when dissolved in water, tend to form blue solutions. This is because the copper (II) ion, whether from copper (II) sulfate, copper (II) bromide, copper (II) chloride, or another copper (II) compound, forms a copper (II)–water complex ion, $[Cu(H_2O)_n]^{2+}$, where n = 4 or 6.



Transition metal complex ions, such as the copper (II)–water complex ion, are colored because transition metals have only partially filled *d* subshells, and thus have unpaired *d* electrons. In coordination compounds, the five *d* orbitals (xy, yz, xz, x^2–y^2, z^2) are not degenerate, or equal energy, orbitals. Instead, the xy, yz, and xz orbitals are approximately degenerate, lying lower in energy than the two degenerate x^2–y^2 and z^2 orbitals. If an electron in the xy, yz, or xz orbitals absorbs energy in the form of light, it is excited to one of the higher energy x^2–y^2 or z^2 orbitals (see figure). In the case of copper ions in solution, the energy of the absorbed light corresponds to wavelengths in the red-orange-yellow region of the visible spectrum, according to the equation $\Delta E = hc/\lambda$, where ΔE represents the energy spacing between the orbitals and λ represents the wavelength of light. The transmitted wavelengths of light correspond to violet, blue, and green colors and, as a result, the solution appears blue (since the transmitted wavelengths are those perceived by the eye).

In addition to coordination compounds, transition metals can also form simple binary compounds with ions such as chloride or bromide. The three copper compounds used in this demonstration, $CuSO_4$, $CuCl_2$, and $CuBr_2$, display different colors in the solid, anhydrous state. The reasons for this are quite complex and not fully understood. It may be due to the size or shape of the anion attached to the copper ion or it may be due to the bond length between the ions. While nearly all complexes and compounds of copper are blue or green, exceptions seem to be caused by strong ultraviolet bands (charge-transfer bands) tailing off into the blue end of the visible spectrum which cause substances to appear various colors, such as red or brown or black. For further information on coordination chemistry and crystal field theory, refer to the references provided.

Safety Precautions:

Cupric chloride is highly toxic by ingestion and inhalation and is a body tissue irritant. Cupric sulfate is a skin and respiratory irritant and is moderately toxic by ingestion and inhalation. Cupric bromide is a mild tissue irritant. Avoid all contact with eyes, skin, and clothing. Wear chemical splash goggles, chemical-resistant gloves and a chemical-resistant apron.

Disposal:

Flush all solutions down the drain with generous quantities of water according to Flinn Suggested Disposal Method #26b. Please consult your current *Flinn Chemical & Biological Catalog/Reference Manual* for proper disposal procedures.

References:

Brady, J. E.; Holum, J. R. *Fundamentals of Chemistry*, 2nd ed; John Wiley & Sons: New York, 1984; pp. 724–729.

Cotton, F. A.; Wilkinson, G. *Advanced Inorganic Chemistry*; John Wiley & Sons: New York, 1980; pp. 814–815.

Gilbert, G. L.; Alyea, H. N.; Dutton, F. B.; Dreisbach, D. *Tested Demonstrations in Chemistry*, Vol. I.; American Chemical Society: Washington, D.C., 1994; p. E–3.

Kotz, J. C.; Purcell, K. F. *Chemistry & Chemical Reactivity*; Saunders College: Philadelphia, 1987; pp. 976–981.

Zumdahl, S. S. *Chemistry*, 4th ed; Houghton Mifflin: Boston, 1997; pp. 967–971.

Materials for *Colorful Copper Compounds* are available from Flinn Scientific, Inc.:

Catalog No.	Description	Price/Each
C0210	Cupric bromide, 25 g	Consult Your Current *Flinn Catalog/Reference Manual*
C0282	Cupric chloride, 25 g	
C0215	Cupric sulfate, 25 g	