

# Colorful Copper Compounds

An Interesting Copper Phenomenon



## Introduction

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

## Concepts

- Complex ions
- Transition metals

## Materials

Copper(II) bromide, anhydrous, $\text{CuBr}_2$ , 6 g	Balance
Copper(II) chloride, anhydrous, $\text{CuCl}_2$ , 6 g	Beakers, 400-mL, 3
Copper(II) sulfate, anhydrous, $\text{CuSO}_4$ , 6 g	Stirring rods, 3
Water, distilled or deionized	

## Safety Precautions

*Copper(II) chloride is highly toxic by ingestion and inhalation and is a body tissue irritant. Copper(II) sulfate is a skin and respiratory irritant and is moderately toxic by ingestion and inhalation. Copper(II) 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. This activity requires the use of hazardous components and/or has the potential for hazardous reactions. Please review current Material Safety Data Sheets for additional safety, handling, and disposal information.*

## Procedure

1. Weigh out approximately 6 g of copper(II) bromide, 6 g of copper(II) chloride, and 6 g of copper(II) 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. [*Copper(II) bromide is a black crystalline solid, copper(II) chloride is a light brown powder, and copper(II) 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 copper(II) bromide contains a rust-colored solid with a yellow-green solution, the beaker of copper(II) chloride contains a green solid with a green solution, and the beaker of copper(II) 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? [*Copper(II) bromide solution is green, copper(II) chloride solution is teal, and copper(II) 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.*]

## Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures, and review all federal, state and local regulations that may apply, before proceeding. All solutions may be flushed down the drain with generous quantities of water according to Flinn Suggested Disposal Method #26b.

## Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

**Unifying Concepts and Processes: Grades K–12**

Evidence, models, and explanation

**Content Standards: Grades 5–8**

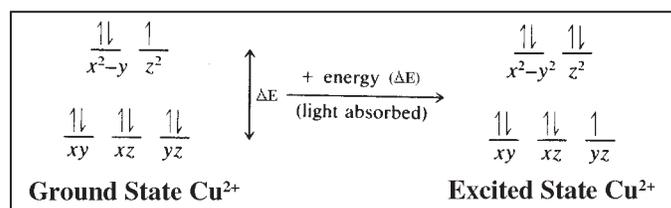
Content Standard B: Physical Science, properties and changes of properties in matter

**Content Standards: Grades 9–12**

Content Standard B: Physical Science, structure and properties of matter, chemical reactions

## 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,  $[\text{Cu}(\text{H}_2\text{O})_n]^{2+}$ , 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  $\Delta E$  represents the energy spacing between the orbitals and  $\lambda$  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,  $\text{CuSO}_4$ ,  $\text{CuCl}_2$ , and  $\text{CuBr}_2$ , 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.

## 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
C0210	Copper(II) Bromide, 25 g
C0282	Copper(II) Chloride, 25 g
C0215	Copper(II) Sulfate, 25 g

Consult the [Flinn Scientific website](#) for current prices.