# Hot and Cold Equilibrium

## Effect of Temperature on Complex Ion Equilibrium

## Introduction

A solution changes color from pink to blue when heated as the water of hydration is lost.

## Concepts

- Water of hydration
- Coordination number
- Coordination geometry

## Materials

Cobalt(II) chloride, $CoCl_2 \cdot 6H_2O$, 1.5 g
Ethyl alcohol, $C_2H_5OH$, 95%, 250 mL
Balance
Beaker, 500-mL or larger
Hot plate
Stirring rod, glass

## *Safety Precautions*

*Cobalt(II) chloride is toxic by ingestion and may cause blood damage. Ethyl alcohol is toxic by ingestion. Practice strict hygiene when using these substances. Do not use an open flame when heating the solution; ethyl alcohol is highly flammable. Use a hot plate. Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron. Please review current Material Safety Data Sheets for additional safety, handling, and disposal information.*

## Procedure

1. Place approximately 250 mL of 95% ethyl alcohol in a large beaker. The alcohol should be at room temperature.
2. Add 1.5 g of cobalt(II) chloride to the beaker of alcohol and stir until dissolved. The solution will be pink in color.
3. Warm the beaker of solution on a hot plate. *Do not warm using an open flame! Ethyl alcohol is a flammable liquid. Use only an indirect source of heat, such as a hot plate, with non-exposed heating elements.* Upon heating, the solution will turn blue in color.
4. Remove the beaker from the heat and allow it to cool. The color will return to pink.

## 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. Clean up any spills with wet paper towels. The cobalt chloride/alcohol solution may be stored in a flammables cabinet and used again. If necessary, contact a licensed removal company regarding the cobalt(II) chloride solution according to Flinn Suggested Disposal Method #27f.

## 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
Constancy, change, and measurement

***Content Standards: Grades 5–8***
Content Standard B: Physical Science, structure and properties of matter, chemical reactions, conservation of energy and increase in disorder, interactions of energy and matter



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## Tips

- Use only 95% ethyl alcohol. There must be water present in the alcohol. Pure ethyl alcohol may not contain enough water.
- Be sure the solution is pink before it is heated.
- This procedure is reversible and can be frequently repeated using the same solution.
- If a hot plate is not available, use hot tap water from the laboratory sink. The demonstration will work with 60 °C (warm) water, but will not be as immediate and dramatic. *Do not use a Bunsen burner*.

## Discussion

This demonstration illustrates the effect of a change in temperature on a system at equilibrium, reinforcing LeChâtlier's Principle (Henry Louis LeChâtlier, 1850–1936). LeChâtlier postulated that if a stress, such as a change in concentration, pressure, or temperature, is applied to a system at equilibrium, then the equilibrium is shifted in a way that compensates for the effects of that stress.

Many inorganic salts contain a specific ratio of water in their solid structure. A solid that includes water ($H_2O$) within its crystal structure is called a hydrate. The $H_2O$ molecules trapped in the solid structure are called water of hydration. A common hydrate is copper(II) sulfate, $CuSO_4 \cdot 5H_2O$. The water of hydration is indicated by the use of a centered dot. The water of hydration can usually be driven off by heating to form an anhydrous compound.

Cobalt(II) chloride (cobaltous chloride) normally exists as a hydrate, i.e., $CoCl_2 \cdot 6H_2O$. The color change occurring in this demonstration arises from a change of coordination number of the cobalt from 6 (octahedral) to 4 (tetrahedral) as it loses water of hydration. The more accurate structure for cobalt chloride as it exists in aqueous solution or as a hydrated form is the octahedral $[Co(H_2O)_6]^{2+}2Cl^-$. As the material is heated and the water of hydration is lost, the structure changes to a tetrahedral, $Co(H_2O)_2Cl_2$, and eventually to a completely nonhydrated species, $Co(II)^{2+}[Co(Cl_4)_4]^{2-}$, also tetrahedral.

$$\underset{\text{pink}}{\text{Heat} + 2[Co(H_2O)_6]Cl_2(aq)} \longleftrightarrow \underset{\text{blue}}{2Co(H_2O)_2Cl_2} + 8H_2O \longleftrightarrow \underset{\text{blue}}{2Co[CoCl_4]} + 12H_2O$$

This is ***not*** exactly a chemical reaction, but rather removing, absorbing, and recombining water from cobalt chloride into the ethyl alcohol and back. The color change arising from the coordination number and geometry change allows the hydration process to be followed.

## Materials for *Hot and Cold Equilibrium—Effect of Temperature on Complex Ion Equilibrium* are available from Flinn Scientific, Inc.

| Catalog No. | Description |
|---|---|
| C0225 | Cobalt(II) Chloride, 25 g |
| E0009 | Ethyl Alcohol, 500 mL |
| AP1366 | Hot Plate |
| AP8150 | Stirring Rod, Glass |
| OB1005 | Balance, 0.1 g Sensitivity |
| GP1025 | Beaker, Pyrex®, 400-mL |

Consult the Flinn Scientific website for current prices.