

# Equilibrium Constants and Le Châtelier's Principle: $\text{CoCl}_2$

## INTRODUCTION

A well-known equilibrium system involves cobalt chloride in water, as the two cobalt-containing species have distinctly different colors (Equation 1). The equilibrium expression for this system is given in Equation 2.



Equation (2)

$$K = \frac{[\text{CoCl}_4^{2-}]}{[\text{Co}(\text{H}_2\text{O})_6^{2+}] \cdot [\text{Cl}^{-}]^4}$$

$$\frac{1}{1 \times 10^{-4}} = \frac{1}{1}$$

Changing the cobalt concentration (i.e., the ratio of cobalt ions to water) and the chloride concentration shifts the position in accord with Le Châtelier's principle—when disturbed, an equilibrium system shifts in a direction such that the disturbance is minimized.

The conversion of  $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$  to  $[\text{CoCl}_4]^{2-}$  involves converting an octahedral complex into a tetrahedral complex (Figure 1).



FIGURE 1 Structure of  $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$  and  $[\text{CoCl}_4]^{2-}$ .

The bond dissociation energy for a cobalt(II) bond to a neutral oxygen atom is about the same as that for the bond between cobalt(II) and a chloride anion. The conversion from an octahedral complex to a tetrahedral complex involves breaking six bonds and forming four bonds. As breaking bonds is endothermic and forming bonds is exothermic, the net result is that the conversion from the pink octahedral complex to the blue tetrahedral complex is endothermic. Consequently, the equilibrium is temperature-sensitive, as shown in Equation 3. Thus, the application of heat or the removal of heat shifts the position of the equilibrium.



In this experiment, you will measure the room temperature effective equilibrium constant for this system,  $K$  of Equation 2. You will also examine the effects of the addition of water, the addition and removal of chloride, and changes in temperature on the position of the equilibrium to determine whether they are consistent with Le Châtelier's principle.

From Chapter 20 of *Laboratory Manual for Chemistry: A Molecular Approach*, Fourth Edition, Nivaldo J. Tro, John B. Vincent and Erica Livengood. Copyright © 2017 by Pearson Education, Inc. All rights reserved.

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