

Restoring Balance

LeChâtelier's Principle and Equilibrium

Introduction

Chemical equilibrium is a true balancing act. What happens when the balance is disturbed? The purpose of this lab is to observe the effects of concentration and temperature on equilibria and to visualize how balance can be restored, based on LeChâtelier's Principle.

Concepts

- Chemical equilibria
- Complex ion reaction
- LeChâtelier's principle
- Exothermic vs. endothermic reactions

Background

Not all chemical reactions proceed to completion, giving 100% yield of products. In fact, most chemical reactions are reversible, meaning they can go both ways. In the forward direction, reactants interact to make products while in the reverse direction, the products revert back to reactants. This idea is represented symbolically using double arrows as shown for the reversible reaction of iodine molecules and iodide ions to give triiodide ions (Equation 1).



In a closed system, any reversible reaction will eventually reach a dynamic balance between the forward and reverse reactions. A system is said to reach chemical equilibrium when the rate of the forward reaction equals the rate of the reverse reaction. At this point, no further changes will be observed in the amounts of either the reactants or products. Chemical equilibrium can be further defined, therefore, as the state at which the concentrations of reactants and products remain constant with time. This does not mean the concentrations of reactants and products are equal. The forward and reverse reactions create an equal balance of opposing rates.

What happens when the balance is disturbed—due to the addition of more reactants or products or due to changes in the temperature or pressure? LeChâtelier's Principle predicts how equilibria can be restored:

"If an equilibrium system is subjected to a stress, the system will react in such a way as to reduce the stress."

Any change that is made to a system at equilibrium is considered a stress—this includes adding or removing reagents or changing the temperature. To reduce the stress, one of two things can happen. A reversible reaction can shift in the forward direction and make more products, thus using up some of the reactants. Alternatively, the reaction can shift in the reverse direction and reform the reactants, thus using up some of the products.

The effect of temperature on a system at equilibrium depends on whether a reaction is endothermic (absorbs heat) or exothermic (produces heat). If a reaction is endothermic, heat appears on the reactant side in the chemical equation. Increasing the temperature of an endothermic reaction shifts the equilibrium in the forward direction to consume some of the excess energy and make more products. The opposite effect is observed for exothermic reactions. In the case of an exothermic reaction, heat appears on the product side in the chemical equation. Increasing the temperature of an exothermic reaction shifts the equilibrium in the reverse direction.

Experiment Overview

The purpose of this experiment is to investigate the effect of reaction conditions on the reversible formation of cobalt complex ions. When cobalt(II) chloride hexahydrate ($CoCl_2 \cdot 6H_2O$) is dissolved in ethyl alcohol, three different solute species are present: Co^{2+} cations, Cl^- anions and water molecules. These can react to form two different complex ions, $Co(H_2O)_6^{2+}$, where the cobalt ion is surrounded by six water molecules, and $CoCl_4^{2-}$, in which the cobalt ion is surrounded by four chloride ions.

Pre-Lab Questions

- Iodine (I_2) is only sparingly soluble in water (Equation 2). In the presence of potassium iodide, a source of iodide (I^-) ions, iodine reacts to form triiodide (I_3^-) ions (Equation 3).



Use LeChâtelier's Principle to explain why the solubility of iodine in water increases as the concentration of potassium iodide increases.

- Dissolving ammonium chloride in water is an endothermic reaction (Equation 4). Use LeChâtelier's Principle to predict whether ammonium chloride will be more soluble in hot or cold water.



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