Section 12.3
Rate Laws

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Learning Objectives

- Explain the form and function of a rate law
- Use rate laws to calculate reaction rates
- Use rate and concentration data to identify reaction orders and derive rate laws

Rate Laws

- **Rate laws** or rate equations are mathematical expressions that describe the relationship between the rate of a chemical reaction and the concentration of its reactants.

$$aA + bB \longrightarrow products$$

$$\text{rate} = k[A]^m[B]^n$$

- [A] and [B] represent the molar concentrations of reactants, and *k* is the **rate constant**, which is specific for a particular reaction at a particular temperature.

Reaction Order

$$\text{rate} = k[A]^m[B]^n$$

- The exponents *m* and *n* are the **reaction orders** and are typically positive integers, though they can be fractions, negative, or zero.
- The **overall reaction order** is the sum of orders for each reactant.

Reaction Orders Examples

$$\text{rate} = k\left[\text{H}_2\text{O}_2\right]$$

- Describes a reaction that is first order in hydrogen peroxide and first order overall.

$$\text{rate} = k[\text{C}_4\text{H}_6]^2$$

- Describes a reaction that is second order in C_4H_6 and second order overall.

$$\text{rate} = k\left[\text{H}^+\right]\left[\text{OH}^-\right]$$

- Describes a reaction that is first order in H^+, first order in OH^-, and second order overall.

Determining *k* and Reaction Order

- The rate constant, *k*, and the reaction orders *m* and *n* must be determined experimentally
- Observations are made of how the rate of a reaction changes as the concentrations of the reactants are changed.
- The rate constant *k* is independent of the reactant concentrations, but it does vary with temperature.

Method of Initial Rates

- The **method of initial rates** involves measuring reaction rates for multiple experimental trials carried out using different initial reactant concentrations.
- Comparing the measured rates for these trials permits determination of the reaction orders.
- Combining reaction orders with reaction rate data allows us to formulate a rate law.

Rate Constant Units

- The units of the rate constant depends on the overall reaction order.
- Units can be a complicated as the reaction order can be a fraction.
- In our problems, we will assume the the rate constants have the appropriate units.

Rate Constant Units

Rate Constant Units for Common Reaction Orders

Overall Reaction Order (x)	Rate Constant Unit ($L^{x-1}\ mol^{1-x}\ s^{-1}$)
0 (zero)	$mol\ L^{-1}\ s^{-1}$
1 (first)	s^{-1}
2 (second)	$L\ mol^{-1}\ s^{-1}$
3 (third)	$L^2\ mol^{-2}\ s^{-1}$