Module 4.4: The Change of Concentration with Time

Learning Objectives

By the end of this sub-module, students should be able to:

- LO 4.4.1: Use math to explain how the average reaction rate and rate laws merge to form the integrated rate law.
- LO 4.4.2: Perform integrated rate law calculations for 0, 1st, and 2nd order reactions.
- LO 4.4.3: Define half life and perform related calculations for the different order reactions.
- LO 4.4.4: Identify reaction order based on integrated rate law treatment of timed concentration data.

Instructional Materials

Textbook Sections

- OpenStax: OpenStax: Chemistry Atoms First 2e
    - Section 17.4 (LO 4.4.1-4.4.4)

Video Resources

- Derivation of First Order Integrated Rate Law (LO 4.4.1, 4.4.4)
    - Description: A video showing how one obtains the first order integrated rate law starting by setting chemical reaction rate and the rate law equal to each other and using calculus to derive the equation.
    - Teaching Tip: At 1:20 through 4:00, the video uses calculus to derive the first order integrated rate law. Prior calculus knowledge is not typically required for Gen Chem II courses, so a teaching option is to tell the students to ignore how the integrated rate law derivation takes place and focus rather on its origins - i.e. equating rate law and average reaction rate. The video then continues on to

show how the integrated rate law can be rearranged to form the linear equation for data plotting purposes.

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- First order integrated rate law example (LO 4.4.2)
    - Description: A worked example using a first order reaction to show how the concentration of reactant changes with time.
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- Half-life first order reaction (LO 4.4.3)
    - Description: A similar example to the previous video, only half-life for a first order reaction is used.
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- Plotting first order reaction data (LO 4.4.4)
    - Description: A first order reaction is presented with concentration data as a function of time. The data is plotted and it is shown how proper integrated rate law treatment of the data can be used to show that the reaction is first order.
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- Derivation of Second Order Integrated Rate Law (LO 4.4.1, 4.4.4)
    - Description: A video showing how one obtains the second order integrated rate law starting by setting chemical reaction rate and the rate law equal to each other and using calculus to derive the equation.
    - Teaching Tip: At 1:20 through 5:00, the video uses calculus to derive the second order integrated rate law. Prior calculus knowledge is not typically required for Gen Chem II courses, so a teaching option is to tell the students to ignore how the integrated rate law derivation takes place and focus rather on its origins - i.e. equating rate law and average reaction rate. The video then continues on to show how the integrated rate law can be rearranged to form the linear equation for data plotting purposes.
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- Second order integrated rate law example (LO 4.4.2)

    - Description: A worked example using a second order reaction to show how the concentration of reactant changes with time.
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- Half-life second order reaction (LO 4.4.3)
    - Description: A similar example to the previous video, only half-life for a second order reaction is used.
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- Plotting second order reaction data (LO 4.4.4)
    - Description: A second order reaction is presented with concentration data as a function of time. The data is plotted and it is shown how proper integrated rate law treatment of the data can be used to show that the reaction is second order.
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- Derivation of Zero Order Integrated Rate Law (LO 4.4.1,4.4.4)
    - Description: A video showing how one obtains the zero order integrated rate law starting by setting chemical reaction rate and the rate law equal to each other and using calculus to derive the equation.
    - Teaching Tip: At 1:28 through 3:40, the video uses calculus to derive the zero order integrated rate law. Prior calculus knowledge is not typically required for Gen Chem II courses, so a teaching option is to tell the students to ignore how the integrated rate law derivation takes place and focus rather on its origins - i.e. equating rate law and average reaction rate. The video then continues on to show how the integrated rate law can be rearranged to form the linear equation for data plotting purposes.
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Other Resources

- Instructor Google Slides (Slides #32-46) (LO 4.4.1-4.4.4)
    - Description: Editable OpenStax slides for use in this chapter either via asynchronous pre-recorded content or synchronous lectures.

Activities and Assessments

Application Activities/Assessments

- OpenStax: Chemistry Atoms First 2e Sec. 17.4 Integrated Rate Laws Exercises # 49 (LO 4.4.2) Exercises # 36,39 (LO 4.4.2,4.4.3) Exercises # 34,35 (LO 4.4.4)
    - Description: Problem #49 is a first order integrated rate law problem asking the students to solve for concentration of an industrially relevant chemical. Problems 36 (first-order) and 39 (second order) are half life math problems. Problems 34 and 35 are graphical analysis problems asking the student to perform the proper integrated rate law treatment to discern the order of the reaction.
    - Teaching Tip: Either assign as worked problems for use in an asynchronous lecture or modify as exam problems.
- Kinetics Overview Worksheet (LO 4.4.2, 4.4.3)
    - Description: Problems 4 and 5 on this worksheet deal with first order integrated rate law issues and related half-life processes.
    - Teaching Tip: Either assign as worked problems for use in an asynchronous lecture or modify as exam problems.
    - Answer Key: Answer Key to Kinetics Overview
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