# Kinetics and Equilibrium

## Equilibrium Series

*Instructor's Guide*



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Developed by the Teaching and Learning Laboratory at MIT
for the Singapore University of Technology and Design

# Introduction

## When to Use this Video

- In Chem 101, in class or in recitation, after introducing chemical kinetics.
- Prior knowledge: basic understanding of chemical equilibrium

## Key Information

*Duration:* 12:59
*Narrator:* George Zaidan, Chemistry Alumnus, MIT
*Materials Needed:*
• paper
• pencil

## Learning Objectives

After watching this video students will be able to:

- Understand how reaction rate is influenced by reactant concentration.
- Explain how reaction rates change as a system establishes equilibrium.
- Predict relative equilibrium concentrations of reactant and product, based on rates of forward and reverse processes.

## Motivation

Students often mistakenly think that, for a reaction at equilibrium, the concentration of products must equal the concentration of reactants. This video provides a visual way of conceptualizing changing reaction rates on approach to equilibrium, as well as equivalent forward and reverse reaction rates at equilibrium. The visualization demonstrates how reactant and product concentrations remain constant at equilibrium, but that the concentrations are not equal.

## Student Experience

It is highly recommended that the video is paused when prompted so that students are able to attempt the activities on their own and then check their solutions against the video.

During the video, students will:

- Draw a reaction coordinate diagram and label the forward and reverse reaction paths.
- Suggest what the relationship might be between the activation energy and the relative rates of the forward and reverse reactions.
- Predict the relative rates of the forward and reverse reactions for four different hypothetical reactions, given their reaction coordinate diagrams.
- Predict the relative concentrations of the reactants and products at equilibrium for four different hypothetical reactions, given their reaction coordinate diagrams.

## Video Highlights

This table outlines a collection of activities and important ideas from the video.

| Time | Feature | Comments |
|---|---|---|
| 0:38 | Prerequisites and Learning Objectives | |
| 1:05 | Chapter 1: Activation Energy and Reaction Rate | |
| 2:33 | Student activity | Students are asked to do a back of the envelope calculation to predict the likelihood of a given reaction under given conditions. |
| 3:36 | Reaction coordinate diagram | |
| 4:47 | Student activity | Students are asked to draw a reaction coordinate diagram and label the forward and reverse reaction paths. Students are asked to suggest what the relationship might be between the activation energy and the relative rates of the forward and reverse reactions. |
| 5:55 | Student activity | Students are asked to predict the relative rates of the forward and reverse reactions given 4 reaction coordinate diagrams on screen. |
| 7:02 | Chapter 2: Modeling a Dynamic Equilibrium | |
| 7:20 | Student activity | Students are prompted to consider what happens to reaction rates as the concentrations of reactants and products change throughout a reaction. |
| 10:14 | Student activity | Given the same 4 reaction coordinate diagrams, students are asked to predict the relative concentrations of the reactants and products at equilibrium. |
| 12:03 | To Review | |

## Video Summary

In this video, the effect of activation energy and reactant concentration on the rate of a reaction is explored. Lego® molecules are used to visualize the ideas that reactions are reversible, reaction rates change with time, and at equilibrium, the rate of the forward reaction equals the rate of the reverse reaction.

# Chem 101 Materials

## Pre-Video Materials

When appropriate, this guide is accompanied by additional materials to aid in the delivery of some of the following activities and discussions.

**1.** What does it mean to say that a chemical reaction mixture is "at equilibrium"? What does this mean in terms of reaction rates? In terms of concentrations of participating species?

**2.** Once a system has achieved equilibrium, what kinds of events could perturb the equilibrium state?

## Post-Video Materials

**1.** At equilibrium, the rate of the forward reaction is equal to the rate of the reverse reaction.

(a) Represent this idea mathematically.

(b) For the elementary reaction, $2A \rightarrow B$, write a mathematical expression for the concentration of B at equilibrium in terms of the concentration of A and the forward and reverse reaction rate constants, $k_f$ and $k_r$.

(c) Explain to a partner what the above expression means in words. How is the concentration of A related to [B] at equilibrium? What conditions would be necessary for [A] = [B]?

(d) Repeat steps (b) and (c) for the elementary reaction $C \rightarrow D$.

(e) This activity should emphasize that it is only under very specific conditions that the concentration of products and reactants can be equal at equilibrium.

# Additional Resources

## References

These papers emphasize the importance of addressing the topics of chemical kinetics and chemical equilibrium and discuss common student difficulties and misconceptions related to these topics.


- Lambert, F. (1998). Chemical kinetics: As important as the second law of thermodynamics? *The Chemical Educator, 3*(2), 1-6.
- Bergquist, W., Heikkinen, H. (1990). Student ideas regarding chemical equilibrium. *Journal of Chemical Education, 67*(12), 1000-1003.


The following simulation may be useful for follow-up activities in class or outside of class.

- PhET Interactive Simulation: http://phet.colorado.edu/en/simulation/reactions-and-rates

# RES.TLL.004 STEM Concept Videos

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