# Kinetic Theory

## Governing Rules 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, at home or in recitation, after Lecture #20: Ideal gas law
- Prior knowledge: kinetic theory of gases

## Key Information

*Duration:* 10:53
*Narrator:* Prof. Jeff Grossman
*Materials Needed:*
• Paper
• Pencil

## Learning Objectives

After watching this video students will be able to:

- Discuss the physical significance of a gas molecule's mean free path.
- Discuss the physical parameters that affect the mean free path.

## Motivation

- Kinetic theory provides important scaffolding for student understanding of the behavior of molecules.
- The assumptions of kinetic theory are frequently introduced in isolation without any opportunities for students to invoke them in real-world problem solving.

## 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:

- Brainstorm questions and ideas they have related to the problem of light bulb blackening.
- Apply their knowledge of kinetic theory to explain light bulb blackening.
- Consider factors that affect collision frequency.
- Think about what properties may be important for a gas used to fill a light bulb.

## Video Highlights

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

| Time | Feature | Comments |
|---|---|---|
| 1:10 | The problem of light bulb blackening is introduced to students. | After hearing about the problem, students are prompted to think about things that might be relevant to the problem. |
| 2:01 | An animation is used to go over the basic anatomy of an incandescent light bulb. | |
| 3:15 | The assumptions of kinetic theory are reviewed. | This should be a review for students. |
| 4:30 | The connection between light bulb blackening and kinetic theory is made explicit to the students. | |
| 4:58 | The concept of mean free path is introduced. | The video goes through a derviation for an approximate calculation of mean free path. Students then use this to think about what light bulb parameters they might change in order to decrease light bulb blackening. |
| 6:37 | Relative velocity calculation | See Post-Video Materials #4 |
| 8:09 | An animation illustrates the localized blackening that is seen in incandescent light bulbs used today. | |
| 9:10 | Students hear how Irving Langmuir worked on the problem of light bulb blackening. | |

## Video Summary

This video encourages students to access their knowledge of kinetic theory and apply it to the real-world problem of light bulb blackening. Students are also introduced to the concept of mean free path.

# 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.** In small groups, have students discuss the following question:
You have two containers of hydrogen. One container has twice the volume of the other. The two containers contain the same number of moles of gas and are at the same temperature. How will the collision frequency of the atoms in the two containers compare?

**2.** Cornely-Moss (1995) and Nurrenbern (1987) contain concept questions that may be helpful to review in class before watching the video.

## Post-Video Materials

**1.** In small groups, have students use their knowledge of kinetic theory to discuss why clothes on a clothesline take longer to dry in a humid environment compared to a dry environment.

**2.** The video mentions that krypton and xenon may be more effective fill gases for incandescent light bulbs than argon. First in small groups, and then as a class discussion, have students use what they know about kinetic theory and what they learned in the video to explain why.

**3.** Tungsten halogen light bulbs use a tungsten filament but last longer and stay cleaner than argon-filled incandescent bulbs. For homework, have students do some research and then explain why. They should compare and constrast the design specifications of the two bulb types and explain their significance keeping in mind kinetic theory.

**4.** Relative velocity calculation

The video quickly goes through a calculation of average relative velocity (the average velocity of a molecule relative to another molecule in the system). Be sure to go over this calculation with students or have them go over it for homework so that they understand where the square-root of 2 in the calculation of mean free path comes from.

# Additional Resources

## Going Further

Diffusion is a nice follow-up application of kinetic theory. The Gradient Concept Vignette covers this topic well. Davidson University's Virtual Chemistry Experiments website (reference below) provides simulations showing the displacement and random walk of a tracer molecule diffusing.

## References

The following website provides a nice overview of kinetic theory, including a simulation of diffusion.


- Blauch, D. N. (2009). Virtual Chemistry Experiments: Kinetic Molecular Theory of Gases. Retrieved from http://www.chm.davidson.edu/vce/kineticmoleculartheory/index.html


The following papers highlight student difficulties with kinetic theory and provide additional resources for in-class discussion questions.


- Cornely-Moss, K. (1995). Exam Question Exchange. Kinetic Theory of Gases. *Journal of Chemical Education. 72*(8), 715-716.
- Nurrenbern, S. (1987). Concept Learning versus Problem Solving: Is There a Difference? *Journal of Chemical Education. 64*(6), 508-510.
- Plumb, R. C. (1975). Chemical Principles Exemplified. Light Bulbs Filled with Krypton Gas. *Journal of Chemical Education. 52*(6), 388-389.


The following book provides interesting and detailed information about Irving Langmuir's work on the incandescent light bulb.


- Suits, C. G., Way, H. E. (Eds.) (1960). *Heat Transfer - Incandescent Tungsten: Vol. 2. The Collected Works of Irving Langmuir.* New York: Pergamon Press.


The following MIT Open CourseWare lecture addresses kinetic theory.


- Cummins, Christopher, and Sylvia Ceyer. 5.112 Principles of Chemical Science, Fall 2005. (Massachusetts Institute of Technology: MIT OpenCourseWare), http://ocw.mit.edu (Accessed 10 Mar, 2012). License: Creative Commons BY-NC-SA
–Video Lecture #13 discusses kinetic theory.

# RES.TLL.004 STEM Concept Videos

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