Entropy

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, before Lecture #22: Enthalpy, Entropy
- Prior knowledge: the idea that energy is quantized, the thermodynamic definition of a system and its surroundings

Key Information

Duration: 13:33
Narrator: Prof. John Lienhard
Materials Needed:
- Paper
- Pencil

Learning Objectives

After watching this video students will be able to:

- Describe, at a basic level, the concept of a microstate.
- Discuss what entropy measures in a conceptual way.

Motivation

- Because of its colloquial use, many students incorrectly think of disorder when they hear the term "entropy."
- This video will provide a more accurate foundation for understanding entropy from a statistical mechanics point-of-view.

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:

- Review the definition of a spontaneous process.
- Predict the sign of the entropy change for the system and surroundings in a heat diffusion experiment.
- Perform a simplified calculation to check their predictions.

Video Highlights

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

Time	Feature	Comments
1:26	Examples of spontaneous processes	A balloon deflating, dye diffusing, and a hot pan cooling are presented as examples of spontaneous processes.
3:00	Discussion of the 2nd Law of Thermodynamics and what entropy is begins here.	
4:38	Explanation of the term "microstate"	A dice analogy is used to explain the term "microstate."
6:05	Heat diffusion example begins	Students observe heat diffusion from a hot brass bar to a cold brass bar. After making a prediction about the sign of the entropy change of each bar, students go through a simplified calculation in order to check their predictions.

Video Summary

This video begins with observations of spontaneous processes from daily life and then connects the idea of spontaneity to entropy. Entropy is described as a measure of the number of possible ways energy can be distributed in a system of molecules. Students apply this description to understand the entropy change in a heat diffusion experiment.

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 a small group, have students define the system and surroundings in the following scenarios:

(a) A candle burns in a room.

(b) Butter melts in a hot pan.

(c) A plant absorbs CO_2 from the atmosphere.

(d) Sodium chloride dissolves in water.

2. Have the class generate a list of processes that they think are spontaneous. Post the list on a piece of chart paper or the board. Have students come back to the list after watching the video and add to it or cross out the processes they no longer think are spontaneous. Students should share their reasoning with the class.

3. To have students begin thinking about how energy might be distributed in a system of molecules, present them with the following system of 5 identical atoms with 1 quantum of energy to be shared among the atoms. There are 5 possible ways in which the quantum can be distributed:

Atom 1	Atom 2	Atom 3	Atom 4	Atom 5
1	0	0	0	0
0	1	0	0	0
0	0	1	0	0
0	0	0	1	0
0	0	0	0	1

(a) Ask the students to consider the same system of 5 atoms, but this time with 2 quanta of energy. How many ways are there to distribute the energy now? (Answer: 15)

(b) Ask students to consider what mathematical tools might be helpful in determining the number of ways energy might be distributed over this system of molecules, aside from making a list. If students don't think of it, point out that the math concept of combinations can be used, where

$$\text{\# of combinations} = \frac{(N+q-1)!}{(N-1)!q!}$$, N = # of atoms, q = # of quanta

Post-Video Materials

Use the following activities to reinforce and extend the concepts in the video.

1. How might you calculate the entropy change for the heat diffusion experiment in the video? What information do you need to know? What macroscopic quantities would be helpful?

2. It is much more common to use Gibbs free energy to determine the spontaneity of a reaction. Why?

3. Using what you learned in the video, answer the following questions.

(a) What does the standard state entropy of a substance represent?

(b) What trend do you notice when looking at the standard state entropies for solids, liquids, and gases? How can you explain this trend?

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Additional Resources

Going Further

After students have a good grasp of entropy from a molecular standpoint, you may wish to introduce them to the Carnot cycle. This will help them understand how they can calculate entropy changes based on macroscopic quantities. This will also provide a good foundation for future study of entropy in engineering courses. The OCW lectures listed below may be helpful.

References

The following textbook has a nice treatment of entropy.

- DeHoff, R. T. (1993) *Thermodynamics in Materials Science.* New York: McGraw-Hill.

The following education articles discuss student difficulties with entropy and possible approaches for teaching.

- Kozliak, E. (2004). Introduction of Entropy via the Boltzmann Distribution in Undergraduate Physical Chemistry: A Molecular Approach. *Journal of Chemical Education, 81*(11), 1595-1598.
- Lambert, F. L. (2007). Configurational Entropy Revisited. *Journal of Chemical Education, 89*(9), 1548-1550.

The following MIT Open CourseWare lectures address the 2nd Law of Thermodynamics and the Carnot cycle.

- Nelson, Keith A., and Moungi Bawendi. 5.60 Thermodynamics , Spring 2008. (Massachusetts Institute of Technology: MIT OpenCourseWare), ocw.mit.edu (Accessed 27 Mar, 2012). License: Creative Commons BY-NC-SA
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