Connected Chemistry
Thermodynamics Unit
Lesson 7: Exploring Factors that Affect Entropy

Student's Lesson at a Glance

Lesson Summary

In the Connecting Activity, students recall factors that affect gas behavior and how these same factors will affect entropy. Students are introduced to the idea of how these factors influence a system through an analogy with a game of billiards (pool). Students make predictions about how phase changes, temperature, volume, and the complexity of molecules will affect entropy. Students apply knowledge of phase changes to predict the order of increasing entropy for solids, liquids, gases, and aqueous solutions. Using the CCC simulation, teachers simulate how water molecules in solid ice change over time. Students use data collected from the simulation and their submicroscopic sketches to answer analysis questions. Using the same simulation, students collect data from adding liquid water, adjusting the heat level, adding oxygen gas, and adjusting volume. In the activity, five students explore the complexity of molecules, create sketches, and gather data as their teacher adds one of substance at a time to the simulation. In the final activity, students consider what bonds really are and how they are modeled. The activity concludes with an exploration of the fossil fuel pentane and its isomers.

SWBAT (Students Will Be Able To)

- Identify the factors that affect entropy
- Identify how each of the factors increase or decrease entropy
- Identify and explain the relationship between bonding and entropy

Essential Vocabulary

Keep a list of all important words from this lesson. This list, in addition to the lists from other lessons, will make studying easier and improve scientific communication skills. The essential vocabulary from the unit is in bold. Additional words that will expand your scientific vocabulary are in italics.

CCC Reminder

- Students and teachers from many different schools helped designed CCC so that the lessons are more helpful and meaningful for all classroom participants.
- Many questions will ask you "what you think" or "to make predictions." The only answer that is wrong is the answer that is left blank.
- A chemical bond is an attraction between atoms that allows the formation of substances that contain two or more atoms. Chemical changes that occur are a result of bonds breaking and reforming.
- Use the vocabulary section and note section to take good notes so that studying for tests and quizzes is easier.
- Supporting claims with evidence is not only a skill that scientists use, but a skill that will help you in other classes and everyday life.
- Draw a key when you are sketching. Symbolic keys can help you and others decode your sketches at a later time.
- Gas laws and thermodynamics are closely connected. Looking back on previous concepts and notes you took from gas laws may be helpful in this unit.

Notes

Homework

Upcoming Quizzes/Tests

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Activity 1: Connecting

1. What do you think is the relationship between the states of matter and entropy?

Playing billiards (pool) involves a system, defined as a pool table and fifteen billiard balls, which goes from an ordered state to a disordered state. To start the game, the billiard balls are racked together in an ordered triangle pattern in one single location on the table. The white cue ball is driven into the billiard balls, which causes them to bounce into each other and scatter across the table. After "the break," the system becomes disordered; the high-speed cue stick introduces kinetic energy, ultimately coming from the muscles of the pool player, into the system. The energy of the pool balls, table, pool stick, and player have undergone a change and the entropy of the system has increased.

Other factors beside kinetic energy can cause a change in system entropy. When learning about gas behavior, you explored how temperature, volume, pressure, and the number of gas particles in a system could affect the behavior of particles. In the following lesson, you will explore how these factors, among others, cause changes in entropy.

2. What objects or materials make up the system in the game of pool?

3. In a game of pool, pool balls at rest are an example of what type of energy?

4. When pool balls are in motion, what type of energy is this?

5. Even though pool balls can be reordered over and over, how can the total system and surroundings obey the Second Law of Thermodynamics? *Please explain your answer.*

6. Considering what you already know about matter and energy, make predictions in the table below, about how each process or factor results in an entropic change. Make sure to support your selection with your reasoning.

Process or Factor	Increase or Decrease Entropy (select one); Support your selection with reasoning
A solid becoming a gas	
Temperature of a liquid increasing	
Volume of a gas decreasing	
Molecule complexity increasing	

Complexity is defined here as the number of atoms a molecule has, the bonds the molecule contains, the position and arrangement of the atoms, and how the bonds move.

Activity 2: Demonstrating Phase Change and Entropy

Demonstration: *Use Simulation 5, Set 1*

The location and behavior of molecules changes as state changes occur. This knowledge allows you to apply the Laws of Thermodynamics to understand how energy is transformed during state changes. Taken together, the First and Second Laws of Thermodynamics state that during a state change (e.g., solid to liquid) the total energy of a system is conserved and the total chemical potential energy of the system decreases with a simultaneous increase in the entropy of the system.

7. Consider the following statement: "All matter moves towards greater entropy." Predict the order of the phases of water according to increasing entropies, from the most ordered to least ordered. *Support your claim with evidence from what you already know about each phase.*

8. Where would an aqueous solution be placed in the order of entropies you just completed above? Why?

- *In the following simulation, your teacher will demonstrate how water molecules of solid ice change over time in a system at room temperature. None of the other variables will be manipulated.*
- *Create a submicroscopic sketch of the system, record data from the available monitors, and write down your submicroscopic observations at time 0 s, 5 s, and 15 s.*
- *The teacher will pause the simulation at each time point.*

	Sketch a submicroscopic representation of the water	Record Data from Monitors			
0 Seconds		Temperature of the System		Entropy of Water	
		Create a written explanation of your drawing including what the symbols in your drawing mean.			
	Sketch a submicroscopic representation of the water	Record Data from Monitors			
5 Seconds		Temperature of the System		Entropy of Water	
		Create a written explanation of your drawing including what the symbols in your drawing mean.			
	Sketch a submicroscopic representation of the water	Record Data from Monitors			
15 Seconds		Temperature of the System		Entropy of Water	
		Create a written explanation of your drawing including what the symbols in your drawing mean.			

Key

9. How did the energy change over time? *Be sure to describe how it relates to the states of matter at the submicroscopic level.*

10. Was energy transferred from the water to the chlorine gas or from the chlorine gas to the ice? *Support your claim with evidence.*

11. In your own words, describe the relationship between state change and entropy. *Be sure to use evidence from the simulation to support your claim.*

12. How do molecules behave when there is less entropy?

13. How do molecules behave when there is more entropy?

Activity 3: Simulating Temperature and Entropy

Simulation: *Use Simulation 5, Set 2*

- *Using the previous simulation, add liquid water.*
- *Adjust the heat dial to level one and allow the simulation to run for ten seconds. Do not adjust any other variables in the interface.*
- *Create a submicroscopic sketch of the system, record data from the monitors, and write down your submicroscopic observations.*
- *Conduct two more trials with the heat dial set to levels 2 and 3.*

	Sketch a submicroscopic representation of the water	Record Data from Monitors			
Heat Level 1		Temperature of the System		Entropy of Water	
		Create a written explanation of your drawing including what the symbols in your drawing mean			
	Sketch a submicroscopic representation of the water	**Record Data from Monitors**			
Heat Level 2		Temperature of the System		Entropy of Water	
		Create a written explanation of your drawing including what the symbols in your drawing mean			

Heat Level 3	Sketch a submicroscopic representation of the water	Record Data from Monitors			
		Temperature of the System		Entropy of Water	
		Create a written explanation of your drawing including what the symbols in your drawing mean			
Key					

14. At what temperature was entropy the greatest? At what temperature was entropy the least?

15. Because entropy changes, would you expect the potential energy of water to change? *Support your claim with evidence.*

16. In your own words, describe the relationship between temperature and entropy.

17. Based on how molecules behave at the submicroscopic level, why does entropy increase with the addition of more energy? How is this similar and different from how billiard balls move in a game of billiards (pool)?

Activity 4: Simulating Volume and Entropy

Simulation: *Use Simulation 5, Set 3*

- *The system in this simulation is an* ***isobaric*** *and* ***isothermic*** *system, meaning it has a constant pressure and a constant temperature.*
- *Create a submicroscopic sketch of the system, record data from the monitors, and write down submicroscopic observations.*
- *Conduct three trials by adjusting the decreasing volume of the container.*
- *Create a submicroscopic sketch of the system, record data from the monitors, and write down submicroscopic observations for each trial.*

Trial 1	**Sketch a submicroscopic representation of the oxygen**	**Record Data from Monitors**			
		Volume of the Oxygen		Entropy of the Oxygen	
		Create a written explanation of your drawing including what the symbols in your drawing mean			
Trial 2	**Sketch a submicroscopic representation of the oxygen**	**Record Data from Monitors**			
		Volume of the Oxygen		Entropy of the Oxygen	
		Create a written explanation of your drawing including what the symbols in your drawing mean			

Trial 3	Sketch a submicroscopic representation of the oxygen	Record Data from Monitors			
		Volume of the Oxygen		Entropy of the Oxygen	
		Create a written explanation of your drawing including what the symbols in your drawing mean			
Key					

18. At what volume was the entropy of the gas the greatest? At what volume was the entropy of the gas the least?

19. In your own words, describe the relationship between volume of a gas in the container and entropy.

20. Based on how the molecules behave, why does entropy change as volume changes?

Activity 5: Demonstrating Molecule Complexity and Entropy

Use Simulation 6, Sets 1-8

- *Your teacher will add several different substances one at a time to the simulation. Your teacher will not adjust any other variables.*
- *Create a submicroscopic sketch, write the chemical formula, record data from the monitors, and write down observations for each new substance*

H_2 Hydrogen Gas	Sketch a submicroscopic representation of fuel	Entropy of Substance	
		Explain your drawing, including your symbols	
CH_4 Methane Gas	Sketch a submicroscopic representation of fuel	Entropy of Substance	
		Explain your drawing, including your symbols	
H_2O Water Vapor	Sketch a submicroscopic representation of fuel	Entropy of Substance	
		Explain your drawing, including your symbols	
H_2O Liquid Water	Sketch a submicroscopic representation of fuel	Entropy of Substance	
		Explain your drawing, including your symbols	

H_2O Ice	Sketch a submicroscopic representation of fuel	Entropy of Substance	
		Explain your drawing, including your symbols	
CO_2 Carbon Dioxide	Sketch a submicroscopic representation of fuel	Entropy of Substance	
		Explain your drawing, including your symbols	
C_3H_8 Propane	Sketch a submicroscopic representation of fuel	Entropy of Substance	
		Explain your drawing, including your symbols	
C_5H_{12} Pentane	Sketch a submicroscopic representation of fuel	Entropy of Substance	
		Explain your drawing, including your symbols	
Key			

21. Compare and contrast liquid water, water vapor, and ice. How can you account for differences in entropy?

22. Compare and contrast the three fossil fuels propane, methane, and pentane. How can you account for differences in entropy?

23. Considering the structure of water and carbon dioxide, what do you think gives these molecules different entropy values?

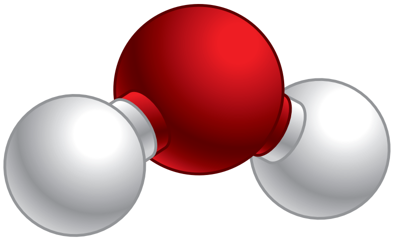
Activity 6: Ideas to Consider - Unseen Bonds

The force that holds a molecule together is known as a bond. This force can stretch, bend, and vibrate without breaking. In describing a complex molecule, we consider the number of atoms a molecule possesses, the location and position of the molecule, the bonds the molecule contains, and how these bonds vibrate.

24. As the molecules in the table in Activity 5 transitioned from simple to more complex, how did the relative entropy of the molecules compare?

25. As the bending, stretching, and vibration of bonds increases, the entropy of a substance **increases** or **decreases**. *Circle one, and support your claim with evidence.*

26. Look at the animation of water molecules your teacher is running. How are bonds represented? Describe the motion of the bonds in the animation. Be as specific as possible.



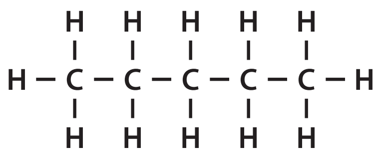
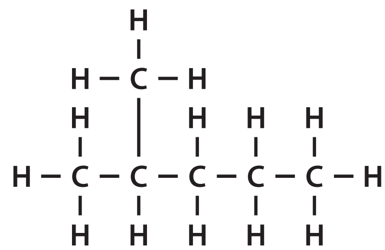
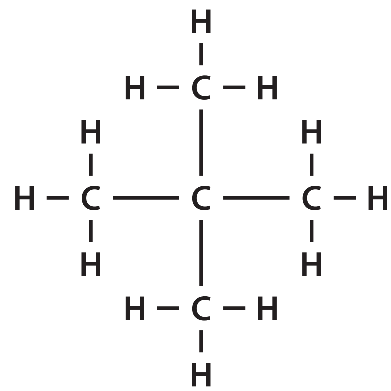
27. How could this way of representing bonds create problems with understanding what bonds really are and how they behave?

28. Consider the CCC representation of a water molecule. How does the Connected Chemistry Curriculum water molecule differ from the ones in the animation?

29. How does what we know about the attraction of subatomic particles help to explain the motion you described in question 26?

Some substances can form **isomers**. An isomer is a compound that has the same number of atoms, but has different atomic arrangements. Even though the substances possess the same number and type of atoms, the isomers can possess different chemical and physical properties.

Isomers of Pentane

pentane	methylbutane	dimethylpropane
		

30. Which isomer is the most flexible and easy to bend? Why?

31. Based on what you have learned about bonds, which isomer is the least flexible and more difficult to bend? Why?

32. Based on your answers for Questions 30 and 31, order the three isomers from greatest entropy to least entropy.

Lesson Reflection Question

33. How are the **First Law of Thermodynamics** and the **Second Law of Thermodynamics** related?