Electronegativity, Bonding, and Bioluminescence

BiteScis

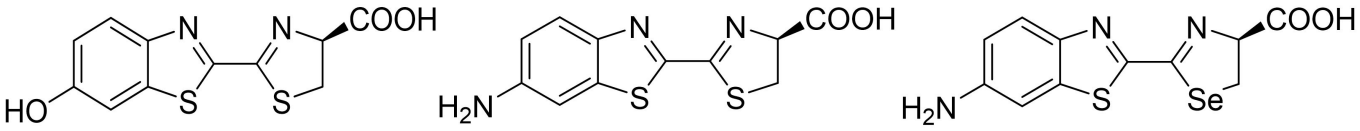
Student Handout

Electronegativity, Bonding, and Bioluminescence

Introduction

The properties of molecules depend on the properties of the atoms that make them up and how those atoms are connected. In this lesson, we are going to look at three different molecules and think about how they are similar, how they are different, and how their structure affects the properties we can observe.

Figure 1 below includes models of three molecules involved in a Stanford University study. The researchers were exploring how specific properties of these molecules differ, and comparing how useful each is for a particular application—studying cancer! You will learn more about the research later in the activity.



D-luciferin **amino-D-luciferin** **aminoseleno-D-luciferin**

Figure 1. Three Luciferin Molecules.

What To Do

Answer the analysis questions below, reading the Bite when instructed.

Analysis Questions

1. Examine the molecules in **Figure 1.**

a. What do all three molecules have in common?

b. What is different about the structures for D-luciferin and amino-D-luciferin?

c. What is different about the structures for amino-D-luciferin and aminoseleno-D-luciferin?

2. Which atom has a higher electronegativity value, sulfur or selenium? Explain how you know. In your answer, describe how **and** explain why electronegativity changes from top to bottom in a group in the periodic table.

3. Which atom has a higher electronegativity value, oxygen or nitrogen? Explain how you know. In your answer, describe how **and** explain why electronegativity changes from left to right across a row in the periodic table.

Each unlabeled point in the six- and five-sided structures in **Figure 1** represent a carbon atom. Part of the structures of the D-luciferin and aminoseleno-D-luciferin are modeled as Lewis dot structures below in **Figure 2**.

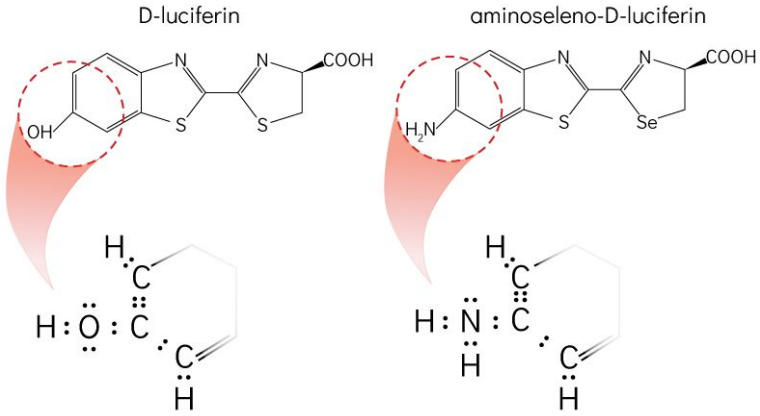


Figure 2. Two Luciferin Molecules. D-luciferin and aminoseleno-D-luciferin. Dashed circles represent the part of the molecules shown as Lewis dot structures.

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4. Study **Figure 2** and answer the following questions.
   - **a.** Circle the electrons that form the covalent bond between oxygen and carbon in D-luciferin and nitrogen and carbon in aminoseleno-D-luciferin.

b. Electrons are shared in covalent bonds. Compare how the electrons are shared in the nonpolar covalent bond between two carbon atoms (C–C) to how they are shared in the polar covalent bonds you circled in part a. Are they shared equally or unequally? Explain your answer. *Hint:* Think about what periodic trend you could use to help you.

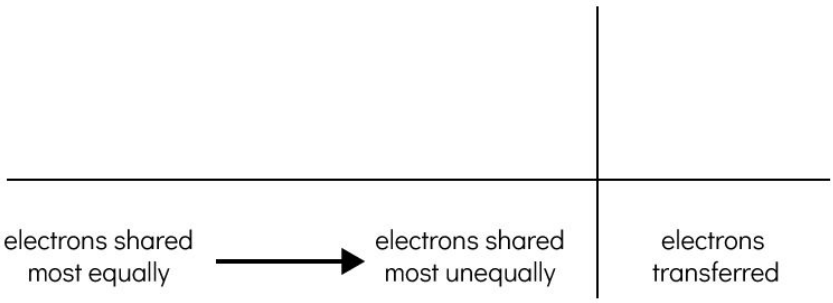
c. Compare how the electrons are shared in the polar covalent bond between carbon and oxygen (C–O) in D-luciferin to how they are shared in the polar covalent bond between carbon and nitrogen (C–N) in aminoseleno-D-luciferin. Are they shared equally or unequally? Explain your answer. *Hint:* Think about what periodic trend you could use to help you.

d. It's helpful to think of bonds on a continuum based on how equally electrons are shared. In a continuum, a property, such as how equally electrons are shared, changes gradually from one extreme to another without clear divisions.

Place the following bonds and labels on the continuum below:

Bonds: C–C, C–O, C–N, Na–Cl

Labels: ionic bonds, nonpolar covalent bonds, polar covalent bonds



e. Does the difference in electronegativity between the two bonded atoms increase or decrease as you move from “electrons shared equally” to “electrons transferred”? Explain why that make sense.

STOP & read Science Bite:

How Do Fireflies Help Scientists Fight Cancer?

5. Citing details from the Bite, describe what researchers did to make aminoseleno-D-luciferin **and** explain why it is a more useful molecule to cancer researchers than D-luciferin is.

Information about the bioluminescence of D-luciferin, amino-D-luciferin, and aminoseleno-D-luciferin are shown in **Figure 3** below.

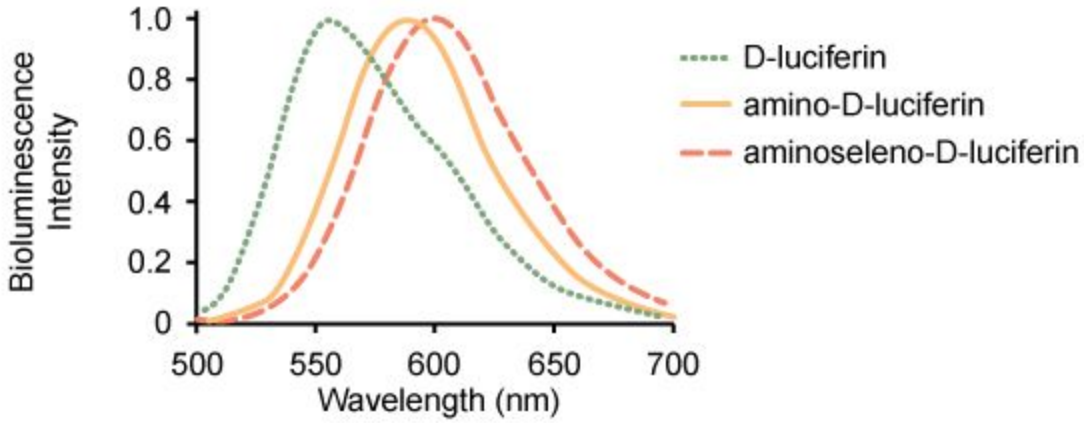


Figure 3. Bioluminescence of Three Luciferin Molecules. The graph includes information about how intense (bright) the light is (measured along the *y*-axis) at different wavelengths (measured along the *x*-axis). *Source:* Modified from Conley *et. al.* 2012.

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6. In cancer studies, do surrounding cells mostly absorb wavelengths greater than or less than 600 nm? Explain your answer citing specific information from the Bite and the diagram.

7. How did decreasing the electronegativity of atoms in D-luciferin affect the properties of the molecule? Discuss both amino-D-luciferin and aminoseleno-D-luciferin in your response.

8. Why did the scientists conduct the research described in the Bite? Describe the hypothesis they were testing or the problem they were attempting to solve.

9. **Connect to the Big Question.** In the last paragraph of the Bite, the author compares aminoseleno-D-luciferin to a telescope. Thinking about the importance of observation in science, what do you think the author meant by that comparison? How can new observation tools help scientists today like the invention of microscopes and telescopes have helped further scientific research?

_v2: revised April 2, 2018
_v3: formatting changes June 22, 2018