



6. Pyrolysis

Lesson Overview: Students learn the steps of combustion and pyrolysis through videos or demonstrations.

Lesson Goal: Increase students' understanding of the combustion process.

Objectives:

- Students can explain the steps necessary for fuels to combust.
- Students can explain that gaseous, pyrolyzed molecules are the source of the flames from combustion.

Subjects: Science, Reading, Writing, Speaking and Listening, Arts


Duration: 40 minutes

Group size: Whole class

Setting: Indoors

Vocabulary: *cellulose, pyrolysis*

*Fire activity is optional



Standards:		9th	10th	11th	12th
CCSS	Writing	2, 4, 10		2, 4, 10	
	Speaking/Listening	1, 2, 4, 6		1, 2, 4, 6	
	Language	1, 2, 3, 4, 6		1, 2, 3, 4, 6	
	Writing Standards Science/Tech	1, 4, 6, 7, 10		1, 4, 6, 7, 10	
NGSS	Matter and Its Interactions	PS1.B			
	Energy	PS3.D			
EEEEGL	Strand 1	A, B, C, E, F, G			

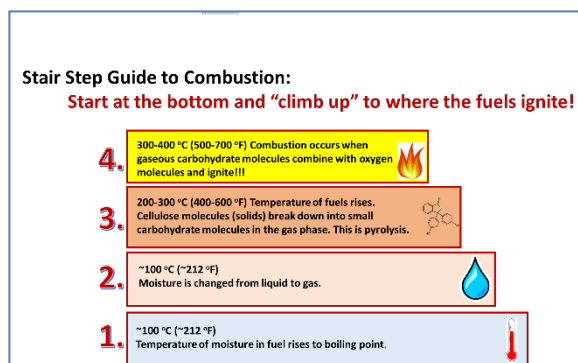
Teacher Background: In order for wildland fuels to burn, several things have to occur:

1. The temperature of the fuels and any moisture in the fuels must rise to the boiling point of water (~100° C (212° F))
2. The moisture must change from liquid phase to gas phase (stays at 100° C (212° F))
3. The temperature of fuels must rise to the point where carbohydrates pyrolyze—that is, break down into small gaseous molecules (200°-300° C (400°-600° F))
4. The small, gaseous carbohydrate molecules must combine with oxygen. This is combustion!


See **StairstepGuideToCombustion.pptx** for a diagram of this process. View videos of pyrolysis online for further explanation. There are many. Two are suggested in Step 3 below.

Materials and Preparation:

- Make sure you can play the video referred to in Step 1 and the Assessment:
<https://www.frames.gov/documents/fireworks/videos/Pyrolysis.mp4>.
- Decide whether to have students try this demonstration in the lab. If you do, set up the materials needed.
- Download ***StairStepGuideToCombustion.pptx***.
- Decide whether to use an online video of pyrolysis in Step 3 or do a similar demonstration in class.



Procedure:

1. Show this 33-second video of a candle being lighted:
<https://www.frames.gov/documents/fireworks/videos/Pyrolysis.mp4>. If possible, set up a lab so students can try this themselves. Ask students to describe what they see. You may need to show the video several times for them to pick up on it. **When the candle is lighted for the second time, the match does not come in contact with the wick.**

2. Ask how this can happen. **Discussion. Perhaps no one can explain it. That's OK.** Explain: You will get some explanation from the next video (or demonstration).
3. EITHER watch a video demonstration of pyrolysis (2 possibilities are listed below) or do a demonstration like one of these for the class:
 - <https://www.youtube.com/watch?v=XEbnWfCtxSE> (1:41 min), in which a structural firefighter shows pyrolysis of wood chips in an Erlenmeyer flask
 - https://www.youtube.com/watch?v=Rpm_L6WiYtw (4:17 min), in which a scientist shows 2-3 forms of ignition, emphasizing the need for fuels to be in the gas phase (pyrolyzed) in order to combust
4. Review the video/demonstration by asking: When you light something on fire, what exactly is burning? What is making the flames? **The burning material is actually a cloud of tiny carbohydrate molecules in the gaseous phase, which were produced when heat broke apart the big carbohydrate particles in the fuel. Flaming combustion occurs only when the fuel has been pyrolyzed into gaseous molecules.**
5. Project ***StairStepGuideToCombustion.pptx***. Let's watch the second video/demonstration (https://www.youtube.com/watch?v=Rpm_L6WiYtw) again and use the stair step guide to explain what is happening.

- a. When you first observe a white fog in the container, what are you seeing? **Water is being driven off from the fuel (Steps 1-2 of the stair step diagram). We're seeing some of it, condensed into fog, as it leaves the hot wood. As the fuels get hotter, the cloudy substances in the container become more yellowish. These are fuel particles that have been partly broken down by pyrolysis (Step 3 in the stair step diagram).**
- b. When a flame is held at the top of the fuel container, it ignites whatever gases are at the top but does not easily ignite what's inside. Why is that? **The container is filled with pyrolyzed fuels in the gas phase. They are crowding the oxygen out of the container, and they can't ignite without oxygen. That happens only at the top of the container, where oxygen is available (Step 4 in the stair step diagram).**

Assessment: Show the video from Step 1

(<https://www.frames.gov/documents/fireworks/videos/Pyrolysis.mp4>) again. Have students answer this question orally or in writing:

When the candle is lit for the second time, what material is burning in the flame?

The material burning in the flame is a cloud of gaseous carbohydrate molecules that have been broken apart from - pyrolyzed from - large fuel particles. When the candle was first lighted, the fire produced these flammable gases. However, they had not all burned up before the flame went out. (It went out because pyrolyzed gases had filled the cup and crowded the oxygen out.) The flammable gases were trapped under the cup, so they were still present when the second match reached them and ignited them. Combustion of these gases then re-ignited the wax beneath, in the candle wick.

Evaluation:

Fully successful	Moderately successful	Not successful
-Student explained that pyrolyzed fuels from the first ignition remained and were ignited before the wick ignited.	-Student's explanation referred to pyrolysis but was incomplete or only partly correct.	-Student did not refer to either pyrolysis or interpreted it incorrectly.