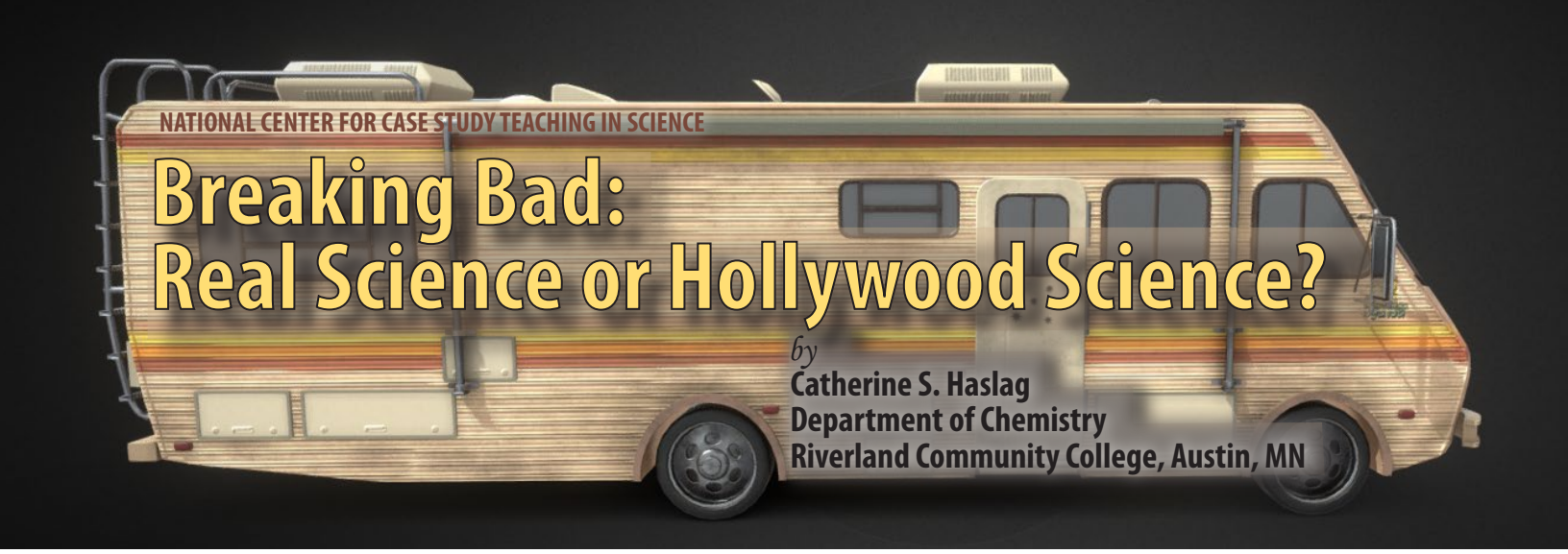

NATIONAL CENTER FOR CASE STUDY TEACHING IN SCIENCE

Breaking Bad: Real Science or Hollywood Science?

by
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Part I – Setting the Scene

Susan grabbed her popcorn and headed for the living room. She was ready for an evening of binge-watching her favorite new television series, *Breaking Bad.* The main character of the show was "Walter White," a high school chemistry teacher diagnosed with incurable lung cancer. Worried about what will happen to his family after he dies, Walter applies his knowledge of chemistry to make ("cook") and sell methamphetamine in order to develop a nest egg to leave to his family. Although Susan didn't agree with Walter's newest career choice, the show was engaging and she was hooked.

She turned on the TV and started watching the next episode. Walter and his business associate and former student, Jessie Pinkman, had driven a mobile RV meth lab into the New Mexico desert to cook meth for four days. At the end of their cook, they discovered that their RV wouldn't start because of a dead battery. They were out of food and water, had no cell phone service, and were too far away to walk for help without dying from dehydration. Since they had deliberately hidden their location and plans it would be days before anyone realized that they were missing, and no one would look for them or come to their rescue before it was too late.

Susan watched as Pinkman and Walter discussed their options. Pinkman threw out all kinds of ideas: building a dune buggy, mixing up some rocket fuel to send up a signal flare, or building a robot or a battery with the materials in the RV. That last one caught Walter's attention; they in fact had everything they needed to build a battery. He and Pinkman gathered the necessary items: galvanized (zinc coated) nuts and bolts, brake pads, potassium hydroxide, and copper wire.

Susan sat on the edge of her seat as Walter and Pinkman constructed and then connected six battery cells to the RV battery. *Fzzzt!* Susan was startled, but Walter explained to Pinkman that the spark was a good sign since it meant that the battery was producing electricity. Susan held her breath with Walter and Pinkman as they climbed into the RV and turned the key. At first, the RV sputtered and stalled. Walter paused a moment, took a deep breath, gave the RV dashboard a reassuring pat, and tried again. This time the RV roared to life. Susan let out a sigh of relief with Walter and Pinkman, and smiled. It appeared that they would be safe after all, thanks to Pinkman's panicked rant and Walter's creative and quick thinking.

The next morning Susan told her friend Melissa about the episode she had watched. She described in detail the battery Walter and Pinkman had built. Melissa, who was a first-year chemistry major, listened intently as Susan explained how the characters constructed an electrochemical cell by using a brake pad as the cathode, zinc metal as the anode, and a sponge soaked in potassium hydroxide as the salt bridge. Melissa thought quietly for a moment; it seemed that such a battery had all of the parts necessary to create an electrochemical cell, but she still wondered if it could really jump-start an RV. It seemed like a bit of "Hollywood science" to her. She shared her opinion with Susan, who agreed it sounded far-fetched. Could it really work? They decided to find out. Melissa said they could get most of the supplies at the local hardware store and that she could ask her mechanic for an old brake pad.

After gathering up the needed materials, Susan and Melissa decided they needed to learn a little more about how a car battery works. They found several websites on the topic.

In the next part of this case study you will join Susan and Melissa as they attempt to build an electrochemical cell. Before doing so it is important that you have an understanding of some key concepts. Please review the information provided at the two following websites and then answer the questions below. Be prepared to explain how a car battery works and to define the following terms: *cold cranking amps, voltage, current, terminal, alternator, cathode, anode, electrolyte solution, series circuit,* and *parallel circuit.*

- Donut Media. 2018. Alternators and batteries: how they work. [Video]. Running time: 7:17 min. <https://youtu.be/nuLl_Z9_T9E>.
- "Current vs Voltage." *n.d.* [Webpage.] *Diffen.com*. <http://www.diffen.com/difference/Current_vs_Voltage>.

Questions

1. Melissa used the term "Hollywood science." What do you think she meant by this?

2. What is the cathode and anode in a lead-acid battery? What reactions happen at the cathode and anode?

3. What is the electrolyte solution in a lead-acid battery? What is the purpose of the electrolyte solution in a lead-acid battery?

4. Based on the information provided so far, develop a hypothesis for this experiment that addresses the following questions: *Do you think the electrochemical cell will produce an electrical current?* (No need to predict how much current it will produce, but hypothesize if it will produce an electrical current.) *Do you think it will be enough to jump-start an RV?* You can either write one hypothesis that addresses both of these questions or two separate hypotheses, each addressing one of the questions.

5. Define voltage and current. What units are each measured in?

Part II – Testing Walter and Pinkman's Electrochemical Cell

That night, Melissa and Susan gathered all of the supplies used by Walter and Pinkman and built their own electrochemical cell to test if the cell really worked and to determine if it really could jump-start an RV.

They discovered that soaking the sponges in the electrolyte as portrayed in the television episode did not effectively create a complete circuit, so they decided to directly pour the potassium hydroxide into the container instead. Susan and Melissa also quickly discovered that the show didn't give them all of the information they needed to replicate Walter and Pinkman's electrochemical cell, so they had to make a few assumptions:

- They didn't know the concentration of potassium hydroxide Walter used, so they decided to make a dilute solution for their experiment (0.1M).
- Since the electrochemical cell was not attached to the battery long enough to charge it, Melissa and Susan assumed that the issue with the RV battery was the absence of flow of current (amperage) and not lack of charge (voltage). Based on this, they decided to measure the current produced by the cell and not the voltage.
- They assumed Walter and Pinkman wired their cells together in a parallel circuit since that would have produced the most current.

They also noted that Walter and Pinkman used six of these cells to jump-start the RV. Melissa and Susan didn't have enough materials to make six of these cells, so they decided to multiply the current their cell produced by six to estimate the total amount of current Walter and Pinkman's cells would have produced. But how much current would they need to jump-start an RV?

Melissa and Susan's searched the internet and found that although approximately 40–50 amps are typically needed to jump-start a normal car, larger vehicles usually require at least 75 amps of current. They figured that a standard RV would fall in the latter category, and so would probably require at least 75 amps to jump-start.

Below is an outline of the materials Melissa and Susan used and the steps they performed to build an electrochemical cell. Your job is to reproduce their experiment and gather more information to help determine if such an electrochemical cell produces electricity and is able to jump-start an RV.

Equipment and Materials

Sponge
Copper wire
0.1M Potassium hydroxide or sodium hydroxide
400mL or 600mL beaker
Digital multimeter
25 zinc nuts
File or sand paper
Plastic container
Alligator clips
Brake pad
Nitrile Gloves

NOTE: Wear the nitrile gloves provided by your instructor throughout this experiment to prevent the KOH or NaOH from contacting your skin. KOH and NaOH are highly corrosive and should not come in contact with skin or clothing. Wear googles throughout this experiment.

Steps

1. Obtain a sponge and dampen it with deionized (DI) water. Place it in the center of your plastic container.
2. Connect the copper wire to the zinc nuts. Place the zinc nuts in the plastic container to one side of the sponge.
3. Obtain a brake pad. Using the file or sandpaper, clean away the surface of the brake pad and create a groove for the copper wire to sit in.
4. Wrap the copper wire around the brake pad and secure it so it sits in the grooves created in Step 3. Place the brake pad in the plastic container on the side of the sponge opposite the zinc nuts.
5. Connect alligator clips to the end of each of the copper wires attached to the zinc nuts and brake pad.
6. Pour 250 to 300mL of 0.1M NaOH or KOH in the container, making sure the solution covers the entire bottom of it and the zinc nuts and brake pad are mostly submerged.
7. Connect the alligator clip attached to the zinc nuts to the black terminal on the multimeter.
8. Connect the alligator clip attached to the brake pad to the red terminal on the multimeter.
9. Turn the dial on the multimeter to measure amps. A digital reading should appear on the screen of the multimeter. *Record the highest number that appears on the multimeter.* It sometimes helps to gently shake the container in which the electrochemical cell is placed to increase the output of the cell. *Record the highest current produced by the cell on Table 1.*
10. Once you have recorded the data, turn off and disconnect the multimeter. Carefully remove the contents of the electrochemical cell, rinsing all of them well with DI water. Pat the brake pad and nuts dry with a paper towel.
11. Pour the solution in the plastic container into the waste container provided in the hood.
12. Rinse the plastic container with DI water and pat dry with a paper towel.
13. Return all of the materials for constructing the electrochemical cell to your instructor.

Table 1. Voltage and Current Produced

Maximum current produced:	
Current – class average:	
Minimum current needed to jump battery	

Questions

1. Does the electrochemical cell produce electricity?

2. Why is it important that all of the metal Pinkman gathered from the RV be galvanized?

3. Is the electricity produced by six of these cells enough to jump-start an RV? Justify your response. Is the science represented in this scene accurate to real life? Explain your answer.

4. Based on the results of this experiment, do you accept or reject your hypothesis/hypotheses? Be sure to address both of the questions addressed in your original hypothesis/hypotheses.