CRx: Teacher Guide for Burning Ethanol

Goals: In the immediate sense, we burn ethanol in order to better understand the workings of exothermic chemical reactions. This activity focuses on ethanol as a fuel and a **proxy for food**, so we hope to keep students grounded in our larger aim: **we are trying to understand how we get the matter and energy we need from food**. At this point in the model (learning segments 9 and 10 both draw upon this activity), we've declared a shift to focusing on the energy aspect of the bigger question. However, in thinking about the chemical reaction we observe here, we need to track both matter and energy. In the first portion of the activity, we track the matter in the reaction (LS 09), asserting that it is conserved and pondering what the reactants and products might be. It's really in the second portion (LS 10) that we attend to making sense of the energy. Where did it come from and where did it go?

Curriculum Note: The idea of using burning ethanol to make sense of matter and energy in part comes from the Carbon Time™ curriculum (http://carbontime.bscs.org/). In that context, the central focus in burning ethanol is about tracking the carbon atoms in the reaction. Students are also asked to track the other elements and to wonder what is happening with energy. We draw upon a few of the resources associated with the Carbon Time™ project, being careful to focus on our specific sense-making goals in MBER-bio.

Supplies you will need:

- heat-safe Pyrex petri dishes – two for each group or demo
- ethanol, 95% pure (100% pure is expensive and not necessary for our purposes)
- pipettes, graduated cylinders, and/or small beakers for measuring small amounts of ethanol
- fire-resistant covers to "smother" the reactions—see notes below
- BTB, bromothymol blue, to test for the presence of carbon dioxide
- Ice and a chilled watch-glass or microscope slides (to test for water as a product)
- beakers or Erlenmeyer flasks to catch gases
- campfire lighter or long matches to start the reaction
- optional: battery-powered carbon monoxide detector

Preparation: To get your bearings and sense of what this reaction might look like in your classroom, first watch the video, "Burning Ethanol" on GLBioenergy's YouTube channel. (https://www.youtube.com/watch?v=o9XSE_7xn8I&t=215s)

The video demonstrates the reaction, and some ways students might be able to identify and track the inputs/reactants and outputs/products. We do not invoke the "carbon question" / "matter question" / "energy question" structure in MBER-bio, but the clip gives you a general sense of how you might scaffold some of the conversations about matter and energy with your students. Perhaps more critically, it demonstrates the need for thinking ahead about safety as you will be dealing with open flame in your classroom. For teachers working in a standard classroom (and not a "proper laboratory"), preparation and forethought are perhaps even more critical. Be sure to review your fire safety SOPs for the classroom and refer to the NSTA website for some guidelines regarding safety in the classroom (www.nsta.org/safety/alcohol.aspx).

In addition to broadly thinking about safety, you'll want to prepare the materials, test the equipment and run the reaction and associated procedures (tests for products of the reaction) before doing so with students in the room. You'll need to obtain the petri dishes, ethanol, BTB, lighters, and other supplies well ahead of time. Many of these items can be ordered through Amazon or other on-line sources if your department does not already have them available.

Engineering the Reaction Chamber: One item that is a less obvious is the fire-resistant cover for the reaction. In the video, you can see BSCS uses standard plastic terrariums / plastic containers to suffocate the reaction. If you follow their lead, please be sure to select a container that is tall enough to avoid damage or catching from the ethanol flames yet is short enough to minimize the volume of air in the reaction chamber. This is especially important when you are trying to trap products like carbon dioxide and test for their presence: too much air in the container leads to an undetectable concentration of products. We have used deep, shoebox-sized Tupperware (available in the organization section of your local hardware or department store) and lined the bottom (the ceiling when you invert it over the reaction) with three layers of aluminum foil for temporary heat resistance. Do be aware that foil can catch fire, so the ceiling must still clear the flames when you test your set-up. Besides height/volume, the second criterion for choosing a reaction chamber container is its potential for creating a tight seal with the surface where you are carrying out the reaction. You need to create an air-tight seal with the substrate in order to trap the gases inside. The video makes this look deceptively easy, but most lab tables (and most Tupperware) are warped in some manner that makes it difficult to create a closed system. One solution is to place the glass petri dishes on the lid that comes with the container you've purchased. This will (in most cases) create a sufficiently close box. Pyrex petri dishes, however, get very HOT during the reaction. You will need to find a way to ensure the heat does not damage the lid or start a fire. Use of a metal mesh or cooling rack to elevate the petri dishes slightly above the surface is one possible solution.

Lesson Sequence:

Day 1 / LS09—Matter:

1. Demonstrate the ethanol reaction from the front of the room, allowing the flame to go out when the ethanol has been exhausted.
2. Lead a student conversation about burning. What are the inputs in this reaction? What are the outputs? What can we observe about both? Have students briefly work in small groups to generate a list of possibilities. As a class, generate a reactant → products representation and explicitly talk about the relationship to inputs → outputs.
3. Introduce the idea of designing experiments to test for the presence of reactants and products. Give students a moment to write about how they would test for any of substances they think might be involved in this reaction. Let them share ideas and then reveal the ways in which you think the class might be able to accommodate the tests.
4. Work with students to design specific approaches to test for the presence of reactants and products. Either demo the tests or have students run the experiments on their own. (Preparing for this step may require a break. That is, this step may need to span two class days. You may need time to consider how exactly to best test the identity of products. Plan your endpoint accordingly.)
5. Work to write an equation (perhaps unbalanced at first) for the reaction that follows the Law of Conservation of Matter.

6. Run the reaction again and have students pay attention to the energy.
7. Following the reaction ask them, where does the energy come from? Use this as a transition into making sense of energy.

Lesson Sequence Details Part 1 (Matter):

1. When burning ethanol as a demo, you'll need to decide how much to use. The easiest way to do this is to fill your glass petri or other fire-resistant vessel with a small amount of ethanol and then time how long it takes for the burning to run its course. Record this amount and use it as a guideline for how much to use in ensuing demos and for the students should you have them run the reaction independently. If you choose to have students handling open flame, be certain you have considered all safety needs for your school and your student population before proceeding.
2. The PowerPoint slides lead you through a series of conversations about what the inputs and outputs for the reaction might be. Candidate inputs should come rather readily. Students will generally say ethanol and oxygen or air. They may also say something like "flame". This assertion (which has to do with something often called "activation energy") should be set aside. Identify the flame as having to do with energy, but parking lot the concept that you need energy to get things started. If students don't generate any ideas about requirements beyond ethanol, you might prod them with a question like, what is the ethanol reacting with? (We've even subtly prompted them for the idea of another reactant by leaving a space for one or more on the left side of our equation in the PowerPoint.)

   In terms of outputs, try to anticipate student answers and think ahead realistically about which are testable and which we can test for and which we cannot. If students seem stuck regarding outputs, this is a time to invoke the Law of Conservation of Matter. What are the possibilities? (That is, what invisible output gases have C, H and O?)
3. Students are given the chance to consider ways to test for the inputs and the outputs, but don't let the conversations go on too long. It seems likely that most classes will consider smothering the flame to see what happens when you deprive the reaction of oxygen. In testing the outputs, they will need some information from you about the supplies available.
4. We ask student groups to decide which potential reactant or product they are most interested in testing for. It is not recommended to have student run the tests, but they should have a hand in designing them. You'll have to let them know what you have available as they generate ideas. This portion of the triangle is less scripted in the PowerPoint. Spend time reasoning through the reactants and products and ways in which we might logically or experimentally confirm and/or eliminate them. This is an opportunity to engage them in experimental designing along with reasoning. Take the time you need. Some ideas about how you might test for certain reactants and products are given below. If you are having trouble in helping your students convince themselves of the identity of reactants and products, post your questions to the MBER Forum.
   a. Carbon Dioxide- Use a shallow dish of BTB in the reaction chamber and close the system as demonstrated in the YouTube video from BSCS. There are many protocols online for this particular test.

b. Oxygen- Test for the presence of oxygen by capturing the gases with an inverted Erlenmeyer flask, beaker, or test tube. Stick a match into the captured gases to see what happens to the flame.

c. Water Gas- Hold a cooled watch-glass, microscope slide, or other piece of glassware above the flame to test for condensation of any steam. Water should appear as small beads on the glass. Be sure to keep the glass cool right up until use. Dry it off as there will likely be condensed water from the air in the room.

d. Ethanol Gas- Test for the presence of ethanol gas by capturing the products with an inverted Erlenmeyer flask, beaker, or test tube. Stick a match into the captured gases to see what happens to the flame. Students should know that ethanol gas would ignite.

e. Carbon Monoxide- Consider the use of a carbon monoxide detector. Ask students what they know about carbon monoxide. It *is* something that is a byproduct of burning, but, like hydrocarbons, is often the result of "inefficient" burning. It is not likely a product here, but since it is a colorless gas that could be made from the products, it is difficult to completely eliminate from the equation. A carbon monoxide detector placed in the closed reaction chamber (akin to BTB detection of carbon dioxide) should be able to detect the presence of even small amounts of CO.

f. Hydrogen Gas- Test for the presence of hydrogen by capturing the gases with an inverted Erlenmeyer flask, beaker, or test tube. Stick a match into the captured gases to see what happens to the flame. You can demo the flammability of hydrogen gas through YouTube videos or a narrative about the Hinderberg disaster.

g. Smoke- Smoke is not colorless and really should not be observed in this reaction, but students may need to unpack this as a potential output. Have them compare their observations of ethanol burning to the Cheeto or marshmallow burn they observed earlier. Is there smoke here? What might be in smoke? What color is smoke/was the smoke when we burned the food? What color were the products in both the case of burning ethanol and burning food? Is there a relationship between the presence of smoke and the appearance of the products? (Yes- clean, non-smoky reaction=clear products, smoke present=blackened products.) Maybe there is a similarity between smoke and the charred remains of the food items.

5. As the tests should have indicated the presence of some products and (hopefully) eliminated others, the class should attempt to write an equation depicting the relationship between reactants and products. Invoke conservation of matter again at this point. Students may be satisfied that C, H and O go in, and C, H and O come out. Other student groups may recognize the need to balance the equation. This is also another chance to recognize that the list of products may not have been complete. If students thought that hydrogen gas was the main hydrogen-containing product and never seriously entertained water as a product, but they have since recognized that the products are not flammable, they might entertain the idea that water gas is a potential product. If the class never tested this, you could return to steps 3 and 4 above for a moment.

   Some teachers have found that a culminating step here that focuses on balancing the equation really helps to accomplish two things: (1) it reinforces what conservation of matter really means and how that relates to chemical reactions and the idea of rearrangement, and (2) it helps students to settle on carbon dioxide and water as the only products that are required to balance the equation. Testing for their presence in combination with this realization may be enough for students to set aside their reservations about eliminating other products. If it doesn't assuage them, that's OK, but let them know your representation for this reaction will include those two products.

Lesson Sequence Details Part 2 (Energy):

6. In turning to the observation of energy, run the demo again, or have students light a small amount of ethanol in their groups and observe, considering the following questions: What is happening with energy? What do we know about energy? What do we start with? What do we end with? What happens in between?
7. Return to the PowerPoint slides to move into a whole-class conversation about where energy comes from. Be sure to invoke Conservation of Energy. Leverage student ideas to launch you back into the slides where the concept of potential energy is explored through analogy. Students will use this discussion to generate a representation of what they think is happening with energy in reactions such as burning ethanol.