Instructor's Guide to Climate Connections Chemistry Worksheet

NPR's "Climate Connection" video series is available online at:
http://www.npr.org/news/specials/climate/video/

The series is hosted by Robert Krulwich, an award-winning science journalist and co-host of the program *Radio Lab*. There are five total videos, each 3 or 4 minutes long, with clever cartoons and just the right blend of information and jokes to keep the mood light and engaging.

One potential criticism of the series is that through its attempts to make carbon "personal" (*i.e.,* anthropomorphize it), the carbon atom is depicted as "male," and the oxygen and hydrogen atoms with which it bonds are depicted as "female." Instructors will have to weigh for themselves whether this "atomic sexism" is sufficiently distracting as to scuttle the whole activity.

For the purposes of this Carbon Cycle unit, Videos 2, 3, and 4 are the most critical, although the middle portion of Video 1 sets the stage for these later ones.

Video 1: ***Global Warming: It's All About Carbon*** [play time 3 minutes & 20 seconds; content starts at 0:11 and concludes at 2:43]

> Notes to instructors: There are two problems with this video. First, from 2:29 to 2:38, footage used to illustrate the global warming problem comes from the hyperbolic movie *The Day After Tomorrow*. I would stop before you get there. There are also clichéd polar bears at the start.
>
> Second, the "preview" of the rest of the video series that occurs at the end of Video 1 is inaccurate. It lists video titles/topics that do not match the videos that actually ended up being produced. So I would skip that, too.
>
> I recommend starting at 0:30 and stopping at 2:28. The key content is in those two minutes: Carbon's "four points of attachment" (four vacancies in its outermost valence level/electron shell), the proportion of a person that is carbon (about 2/3 of dry weight), and the ubiquity of carbon in the Earth system, with different forms due to different bonding arrangements.

Video 2: ***Making carbon bonds*** [play time 3 minutes & 3 seconds; content starts at 0:11 and concludes at 2:45]

> Excellent overview of carbon bonding. Includes geological perspective on the petroleum deposits in the Middle East.

Video 3: ***Breaking carbon bonds*** [play time 4 minutes & 15 seconds; content starts at 0:11 and concludes at 3:46]

> Pretty good overview of how breaking bonds releases energy, though a criticism would be that it shows carbon reforming bonds after burning with other carbons (rather than with oxygen). Ties

the release of energy from carbon bonds to the rise of human civilization, which is an important point to make.

Video 4: ***Carbon in love*** [play time 3 minutes & 50 seconds; content starts at 0:11 and concludes at 3:31]

Funny, and rectifies the criticism noted above for Video 3: this time carbon bonds with oxygen. Two of them, in fact ("Carbon is a polygamist!").

Video 5: ***What do we do?*** [play time 2 minutes & 38 seconds; content starts at 0:11 and concludes at 2:04]

More gratuitous polar bear imagery. This video is a brief overview of general solutions to the burgeoning carbon imbalance in the Earth system, including: non-carbon-based fuels, carbon sequestration, global development, and efficiency. Criticism: the geoengineer is a stereotypical "mad scientist" caricature (lab coat, gizmos, socially awkward, white, male). On the other hand, a good point it makes is that carbon's chemistry is inherent to the element. It is not something we can change – so that leaves any change that might occur in humanity's court, not carbon's.

Objective: To familiarize students with the atomic transformations critical to the carbon cycle.

Student learning outcome: Students will be able to accurately render the "stories" of photosynthesis, respiration, geological carbon sequestration, and fossil fuel burning on an atomic/molecular level.

Instructions for simplified version:

1) Have students watch the video(s) or portion of videos you deem appropriate. I recommend the middle of video 1 (0:30 to 2:28), then all of videos 2, 3, and 4.
2) Distribute the worksheet and scissors.
3) Have students complete the worksheet in pairs, and coach them through the respective bonding "dramas" at the introductory level. The cartoon character cut-outs (pages 2 and 3 of the worksheet) can be placed on the backdrop (page 4) to "set the stage."
4) Students will then add personal details to enliven one of the four stories. Give them 5 minutes for this.
5) Show time! Host a contest for the best photosynthesis story, the best respiration story, the best geological carbon sequestration story, and the best fossil fuel burning story. Issue awards, if you think that is appropriate for your student population.
6) Facilitate a discussion about the scientific accuracy, dramatic merits, and creativity of the various dramas. Commend students who bring in other aspects of the carbon cycle, such as the bonding of carbon to calcium and oxygen to make $CaCO_3$ shells in marine creatures, or the addition of other steps, such as the fermentation of sugars to make alcohol before respiration.

Instructions for more advanced version:

1) Have students watch the video(s) or portion of videos listed above. For more information on the carbon cycle see the following: NASA Earth Science Week: Keeping Up With Carbon https://www.youtube.com/watch?v=FgEZpX3n5mo

2) Distribute the worksheet and scissors, and have students complete the worksheet in pairs.

3) Students will cut out the carbon, hydrogen, oxygen atom diagrams and arrange them to form molecules. Molecule shapes can be found online at the following websites or similar ones:
   a. Living in a Carbon World, Part C: Building Carbon Compounds http://serc.carleton.edu/eslabs/carbon/1c.html
   b. Hydrocarbons https://cnx.org/contents/nIpsyG9H@4/Hydrocarbons
   c. Gallery of Greenhouse Gas molecules http://serc.carleton.edu/resources/42839.html

4) Students balance the chemical equations for photosynthesis and respiration. Answers are as follows:
   a. $6\ CO_2 + 6\ H_2O \xrightarrow{\text{Sunlight energy}} C_6H_{12}O_6 + 6\ O_2$

   b. $C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O +$ energy

5) For carbon sequestration, hydrogen and oxygen atoms are removed, leaving the carbon.

6) For fossil fuel burning: $C + O_2 = CO_2$
   "If one ton of coal is burned, approximately how many tons of carbon dioxide will be produced?" The answer is **approximately three tons of carbon dioxide**.

   One atom of carbon combines with two atoms of oxygen for a total of three atoms, which would weigh approximately three times as much as one atom. But since carbon and oxygen have different atomic masses or weights, the answer is not exactly three. The atomic weight of carbon is 12.011 and the atomic weight of oxygen is 15.999, so CO_2 has an atomic weight of about 44. This is approximately 3.67 times the weight of the carbon atom alone (44 divided by 12). But coal is not pure carbon. For coal that is about 75% carbon, the weight of CO_2 that results from burning a ton of coal would be about 2.75 tons (3.67 times 0.75.) For coal that is about 51% carbon, the answer would be 1.87 tons (3.67 times 0.51).

   For more information, see "Why do carbon dioxide emissions weigh more than the original fuel?" https://www.eia.gov/tools/faqs/faq.cfm?id=82&t=11