Audience-Pleasing Physical Models to Support CO_2 Outreach

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Abstract

Outreach to increase public understanding is critical to implementation of carbon capture and storage, but conventional lectures may fail to engage a non-technical audience. In this presentation we will exhibit a selection of do-it-yourself demonstrations that are proven to grab an audience's attention and can be adapted for use with a variety of groups.

Using interesting and engaging physical models, and without use of PowerPoint, posters or handouts, speakers can show a non-technical audience (1) how CO_2 is formed from the combustion of hydrocarbon molecules (2) how much CO_2 we produce in daily activities, (3) why CO_2 works to trap heat in the atmosphere 4) the properties of CO_2 and its health and safety risks (5) how geologic storage of CO_2 would work to reduce emissions. These demonstrations require only readily available, low-cost materials and have been used successfully with a variety of audiences, from adults to elementary school-age children. They are simple enough to be replicated by audience members for use in school and community programs.

Objective

Our objective is to provide the Carbon Capture and Storage research and outreach community with some easily transferable demonstrations that are designed to increase public understanding and comfort with issues related to greenhouse gas issues and CSS processes. Our intended audience is the public and elementary-middle school students. We are approaching these issues from an allegorical and experiential perspective, assuming minimal background with physics and chemistry.

Materials and supplies

Demo 1

- Styrofoam balls in three sizes (1, 1 ¼, 1 ½)
- Paint to color balls, three colors of your choice
- Precut 1 inch long pieces of pipe cleaner
- Candle and match

Demo 2

- 5 lb bag of charcoal briquettes
- Large white garbage bag (to spread briquettes on)
- Wet wipes for clean up

Demo 3

- Two 10" x 10" sheets of 4 wires/inch (¼ inch mesh) galvanized hardware cloth (from a builders supply)
- Tape to seal and sharp cut ends of hardware cloth
- Several ordinary pipe cleaners from a craft shop

Demo 4

- 10 gallon aquarium or similar container
- Plastic tray to fit inside fish tank (dry ice placed directly on glass may crack it, a container will provide insulation)
- Bubble mix with bubble-blowing wand from toy store
- Candle
- Matches or lighter
- Several clear plastic cups, 12oz size
- Two hot pads (gloves are nice, for safe handling of dry ice)
- Several 1-pint water bottles filled with drinking water
- Ice pick
- Plastic bag to cover work surface
- 5-12 lb block of dry ice
- Small Styrofoam ice chest for transporting dry ice

Demo 5

- Clear glass marbles from hobby or garden supply (enough to fill the jar). Several sizes OK.
- 1 quart jar clear with water-tight lid
- Colored lamp oil from hobby or hardware store
- Tap water to fill jar

Demo 1 Chemistry of Burning

Why is CO_2 increasing in the atmosphere? Who is doing it?

Many people think that CO_2 is "pollution", so that clean burning should be a way to eliminate greenhouse gas emissions.

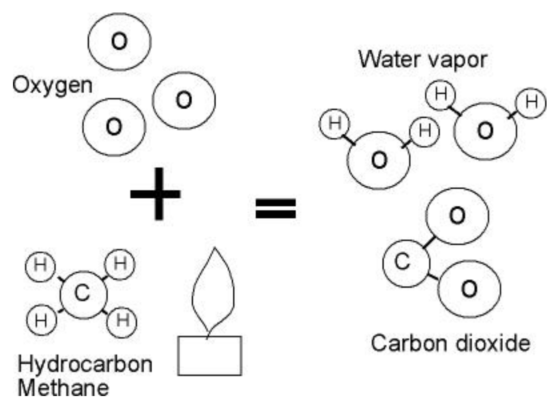

Figure 1. Models made of Styrofoam balls are used to illustrate the chemistry of combustion.

In this demonstration, we review basic chemistry (figure 1) to realize that producing CO_2 is an inevitable waste product of burning any fossil fuel.

Set up: prepare a box of different size Styrofoam balls painted to represent oxygen (largest ball, at least 3), carbon (at least one), hydrogen (smallest ball, at least four). Cut several pipe cleaner into 1 inch lengths. A candle or oil lamp is a useful prop.

Ask "what is in a hydrocarbon? "(answer: hydrogen and carbon). One carbon with four hydrogens attached to it is methane, the simplest of the hydrocarbons. Have participants make some hydrocarbons by linking Styrofoam balls representing hydrogen (small) with carbon (medium sized) with short pieces of pipe cleaner.

Ask "How do we get energy from hydrocarbon?" (Answer: burn it, which means add oxygen to the fuel in the presence of threshold heat.) If time allows, light a candle or small oil lamp with a match, and let this sink in (hydrocarbons from candle or oil lamp, oxygen from the air). Add Styrofoam balls that represent oxygen, and pull the hydrogen off the methane (Say "pop" or "bang" as you do it to symbolize the release of energy). Add two hydrogens to each oxygen and two oxygens to each carbon to complete the chemical reactions.

Ask "what are the products of combustion of fossil fuel?" and coach the audience to figure out the answer from the models (C O2 = carbon–di-oxide and H2 O is water). Throw the molecules in the air to emphasize what happens to them under "business as usual". People are usually surprised that water is released by combustion. Ask them to think about what they have seen coming out of tail pipes of cars or from smoke stacks on a cool morning. (White "smoke" is water vapor condensing) You cannot see the CO_2, but there is at least half as much CO_2 produced as water from most kinds of combustion.

Demo 2 Imagine you could see the carbon in CO_2

How much CO_2 is produced during combustion of fossil fuel?

CO_2 is a colorless gas transparent to light so it feels like it must be unimportant and harmless. This visual demonstration provides an analog to give participants a sense of the amount of carbon going into the atmosphere.

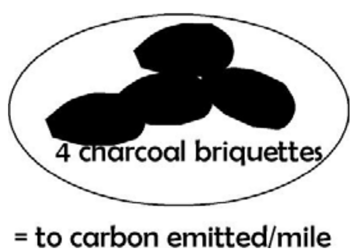

Figure 2 Briquettes help people imagine the carbon in CO_2 emissions.

Set up: Pour the charcoal out on a white plastic bag as a visual aide (figure 2)
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Explain:
One gallon of gasoline has about 5.2 lbs (2.3 kg) of carbon.
Charcoal briquettes are almost entirely carbon.

A 5 lbs bag of charcoal holds about 100 briquettes
At 26 miles/gallon, that's 0.2 lbs of C (about 4-5 charcoal briquettes)/mile

Participants can pile the briquettes to equal the amount of carbon they release to the atmosphere during a normal drive.

Conclusion "A standard US car throws a charcoal briquette (or more) of carbon from its tail pipe about every 1/4 mile. If you could see the carbon that was being released when everyone threw the equivalent of a briquette out of their car every 1/4 mile would this make a difference in how people act?"

Demo 3 What is the Greenhouse Effect?
How can increasing the a little bit of CO_2 in the atmosphere increase global temperature?

This visual analogy (figure 3) provides a way to think about atmospheric physics in terms of familiar objects.

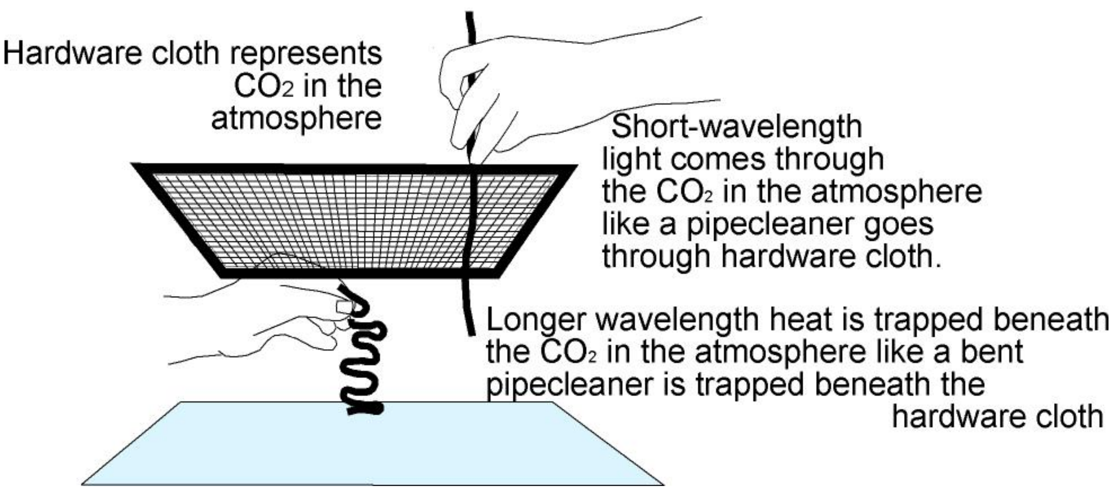

Figure 3. Model of the interaction of the atmosphere with light and heat.

Preparation:
Cut hardware cloth (wire mesh with 1/4 inch openings) into two pieces about 10" by 10" square. Fold heavy tape over any sharp edges to make them safe to handle.

The hardware cloth helps us image how CO_2 in the atmosphere interacts with light and heat energy. Whoosh the hardware cloth through the air to show there is only a little bit of wire in the hardware cloth, so it is like CO_2 in the atmosphere in that there is only at little bit of CO_2 mixed in with other gasses to make up the Earth's atmosphere.
A pipe cleaner will represent light energy coming from the sun. Light energy has a short wavelength. We imagine the fuzz on the pipe cleaner as representing the wavelength of light.

Have a volunteer hold the “CO_2 in the atmosphere” horizontally above a table, so that it looks like the atmosphere as seen from space. Show with a pipe cleaner how light from the sun can easily go right through the “atmosphere”.

After light goes through the atmosphere, it hits the earth. Who knows what happens to it then? Does all of it reflect back as light into space? Think about the effect of sunshine hitting the ground on a summer day. (Some light is absorbed by objects and the ground and then radiated as heat).

Heat energy has a longer wavelength than light. We can imagine this as the pipe cleaner being bent in five or six zigzags. With your fingers, bend the pipe cleaner into a long wavelength spring.

Try transmitting this long-wavelength heat energy through the CO_2 in the atmosphere (hardware cloth). Much of the” heat” is trapped and bounces around between the atmosphere and earth.

Put another sheet of hardware cloth representing more CO_2 in the atmosphere. Will this make it harder for heat to escape? The CO_2 rich atmosphere is trapping heat like the glass roof of a greenhouse (hence the name greenhouse effect).

Demo 4 CO_2 is a Gas
Is CO_2 dangerous? Does it explode? Can it be transported safely?

This set of experiments are used in introductory physics and chemistry to examine properties of gases. Our motive here is to increase public understanding of the basic properties of CO_2 so that they can be informed about safe handling and so that fears derived from absence of information will be reduced.

Set-up
Freeze caution: warn participants not to touch dry ice with bare skin.
Using hot pads, place the dry ice block in a shallow plastic tub.
The plastic will provide insulation so that the cold from the dry ice does not crack the glass. Use the ice pick to break off a number of chunks of dry ice, ice cube-size or smaller for the experiments. Place the dry ice in the tub in the bottom of a 10 gallon fish tank.
In a turbulent or breezy setting it is helpful to cover the tank with a piece of newspaper to allow the CO_2 to build up and to break the dry ice block into more pieces to increase the rate of sublimation. Not suitable for outside demos.

Dry ice is frozen CO_2. Does anyone know where the CO_2 goes as the dry ice sits in the room and warms up? Do you see any liquid CO_2 drips? (No, liquid CO_2 does not exist at atmospheric pressure. Frozen CO_2 “thaws” or sublimes directly to gas.) Can anyone see the CO_2?

Even though the CO_2 gas is invisible (transparent to light), we can test for it. CO_2 gas is heavier than air (air is mostly nitrogen and oxygen). So if we blow bubbles full of regular air, they will float on CO_2. Try it (figure 4). (participants should gently blow soap bubbles into the tank and watch them “float’ on CO_2.) Too vigorous swooshing of the bubble wand or blowing of bubbles will displace the CO_2 and no effect will be seen.

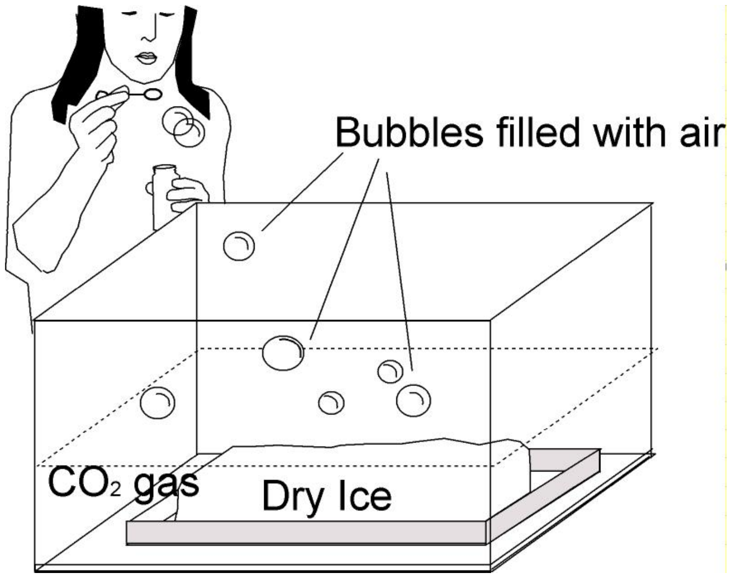

Figure 4. Using the property of density to test for CO_2 gas that collects in the tank as the dry ice sublimes.

Another way to see the gas is to collect it (figure5). Fill a small water bottle nearly to the top. Drop an ice cube-size piece of dry ice (broken in several pieces) into the water. Put a balloon over the top of the bottle and watch the CO_2 gas blow up the balloon.

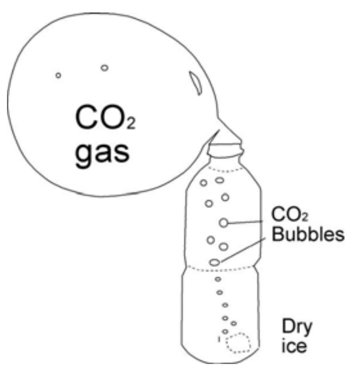

Figure 5. As dry ice sublimes, gas expands and fills the balloon.

Is CO_2 dangerous? Is it explosive? CO_2 collects in low places and displaces the lighter oxygen. Being put in the tank full of CO_2 would kill a hamster. If we light a candle and put it in the tank, we will see that there is not enough oxygen for the candle to burn. Try putting a lighted candle into the tank (figure 6).

CO_2 is not explosive, it is used to put out fires. Moving slowly, fill a plastic cup with CO_2 gas from the bottom of the fish tank and pour it on a lighted candle (short fat candles are easier to hit) (figure 6).

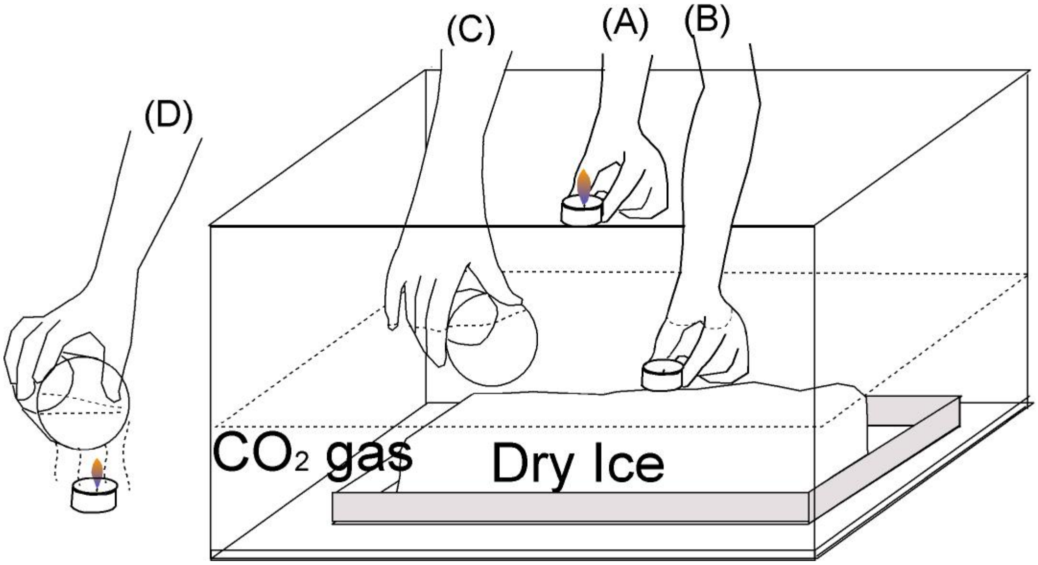

Figure 6. Testing for CO_2 by extinguishing flame.

In low and moderate concentrations, CO_2 is not dangerous to people. Pour a transparent cup half full of drinking water. Add a small ice cube of frozen CO_2. The water warms the frozen CO_2 causing it to form gas, which fizzes (figure7). CO_2 makes the fizz in carbonated beverages. As some of it dissolves in the water, it forms a weak acid. If you drink the water, it tastes slightly tangy (like lemon), this is the taste of acid. (this has proved to be very popular, and brings home the message). Don't let people touch the dry ice, though.

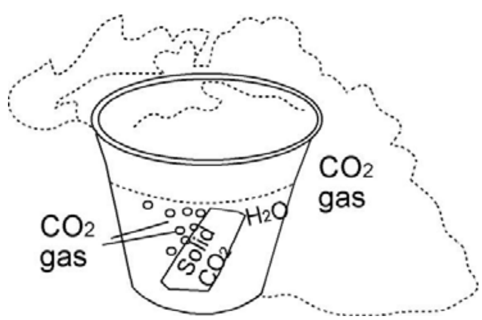

Figure 7. Making carbonated water with dry ice.

Demo 5 Reservoir in a jar

We tell people that one of the options to releasing CO_2 to the atmosphere is to capture it and store or sequester it underground. What exactly does this mean? Many people imagine a big cave, which seems like it might collapse or blow out. This model lets people see how CO_2 could be stored underground in pores in the rock and how it is trapped by reservoir seals and phase trapping.

Preparation

Check jar to make sure the lid can be fastened water-tight. Just like real CO_2 storage, we want to make sure that our demo doesn't leak. Fill jar with clear glass marbles, don't overfill. Several sizes of marbles makes an interesting model. Add about 2-3 oz of colored lamp oil. Fill jar full with tap water, and put lid on tightly (figure 8).

Demo: The jar shows what you would see if you had a microscopic view of CO_2 storage site underground. The marbles are sand grains, the water is salt water that fills the spaces. Tip the jar from vertical to near horizontal and watch the "CO_2" move through the holes in the between the marbles. CO_2 floats on top of water, so it tries to move upward. It is held underground by the seals on the injection zone, like the "CO_2" is held in by the sides and walls of the jar. The small pores are the "micro caves" that would store the CO_2 underground. It is also prevented from escape because it is trapped as small bubbles snap-off from the main body. This is a persistent characteristic of two phase behavior, and may be important in assuring that CO_2 stays underground. Try jostling the bottle. It is pretty hard to get those phase-trapped bubbles to move!

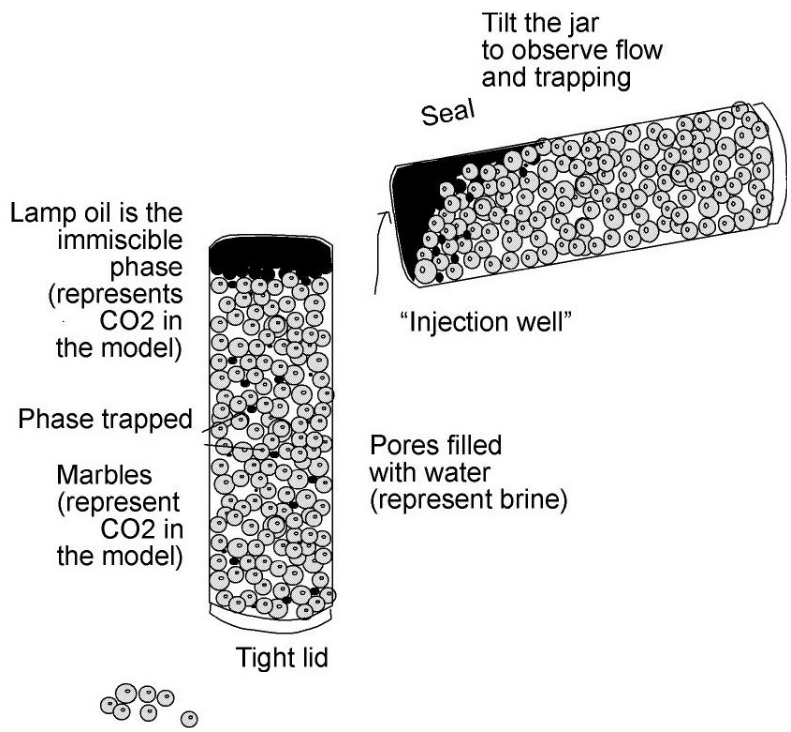

Figure 8. Using marbles in a jar to help visualize two-phase flow underground.