

### Activity 1: Global warming jars

#### Materials (per station)

- 2 glass jars
  - 2 thermometers, preferably digital thermometers with corded probes
  - 1 heat lamp (if experiment is to be performed indoors. Under proper weather conditions the sun can be substituted)
  - 1 stopwatch (or one class-wide timer)
- Different colored mesh, in each of dark and light colors  
Worksheet (either one per student, one per group, or up on the projector)

#### Pre-class procedure:

Set up one station per group of students.

1. For each station, fill one jar with white mesh and one jar with black mesh as pictured.
2. Put one thermometer in the top of each jar, either secured with tape or in a piece of Styrofoam. The temperature probe should hang into the jar slightly, rather than being against the lid.
3. Put the two jars in front of a heat lamp, equal distance from and orientation to the lamp.



#### In-class procedure:

1. Hand out worksheets to the class. Have them answer the pre-lab questions (1-2).
2. Have the groups record the initial temperatures inside each jar.
3. At time  $t=0$ s as measured by each group's designated timekeeper, turn on the lamp. Have them record temperature (reminding them that scientists always use Celsius) every minute for 10 minutes (can be shortened to every 30 seconds for 5 minutes if a shorter class period. 5 minutes is about the minimum to see the heating difference). *What should happen:* in each setup, the black mesh jar should heat more than the white mesh jar.
4. After everyone is done and has had a chance to plot temperature (y) vs time (x) (depending on

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the class level, it may be necessary to walk around and verify that everyone is doing this properly), and at least look at the questions on the rest of the worksheet, reconvene and discuss as a class what happened in each setup. This can be done by having volunteer(s) from each group write on the board each jar's starting temperature, ending temperature, and total temperature change.

5. It is likely that each group will have seen an increase in temperature for both jars, with the black jar heating more than the white jar for an individual setup. It is also possible, depending on the different lamps used, or slightly different setup orientations, or locations of some groups near to a door or window, that some setups will have increased far more or less than the others.
6. This is a good teachable moment to discuss why these differences may have happened. Why might Group A's results be different from Group B's? Why in science do we do many iterations of the same experiment? But be sure to land the take-home message that all the jars increased in temperature, but the dark jars increased more than the white jars when exposed to the same lamp. This is because the dark material absorbs more energy than the light material does, so it heats up. Discuss questions 9-10 on the worksheet.
7. If time permits, discuss the last 5 questions on the worksheet. A common misconception that was encountered include (but are probably not limited to): heat is a molecule, and it is in the jar. Discuss how the air in the jar is the same as the air in the atmosphere. This can instead be addressed at a later point, when atmospheric composition is discussed in the lecture.

## **Activity 2: Sunset in a jar**

### Materials (per station)

- 1 ~5-gal aquarium
  - 1 flashlight (white color, LED preferred)
  - 3 laser pointers, one of each color: red, green, blue (optional)
- water  
milk (small amount)

### Pre-class procedure:

1. Fill the aquarium with a few inches of water. Do not put the milk in yet. If materials permit, this can be done as a station activity (split the students into 2-3 groups with one setup per group).

### In-class procedure:

1. Pass out the worksheets, have them answer question 1. Optional: discuss Question 1 as a class before starting.
2. Pass out the flashlights and laser pointers to the students, while first emphasizing the importance of laser safety (do not point them at anyone's eyes, do not pretend to point them at anyone's eyes, be aware to not accidentally point them at anyone's eyes).
3. Have the students experiment with shining the flashlight and lasers through the tank of water.
  - a. Be sure to have them look from above and through the tank. For the latter observation, the flashlight can be observed with the tank at eye-level, looking at the flashlight through the water. The laser pointers (because of eye safety) can be viewed by placing someone's hand on the opposite side of the tank; you should see a colored dot on their palm, which shows that the light is traveling through the tank.
  - b. *What should happen:* the flashlight will look white when viewed through the water. You will probably not be able to see the flashlight beam when looking into the tank from above. For different colors of laser pointers, the red will be invisible in the tank, but should be visible as a strong dot on the opposite side. For the blue laser pointer, the laser will be visible as a beam in the tank ("like a light saber"). The green beam is somewhere in the middle; will probably be visible somewhat in the tank but more "sparkly" rather than as a solid beam.
    - i. This is an excellent time to introduce the concept of scattering, color, and light. What has to happen for us to see color? Is the red beam or the blue beam scattering more here? They will likely say the red beam is scattering, because they can't see it. Of course, the blue is scattering more; we can see color only when light is bouncing off of something and changes trajectory into our eyeballs. With the red beam, this doesn't happen until the beam has crossed the water and hit your hand, but we can see the blue because the blue laser is *scattered* by water molecules (hits the molecules, and is diverted from its original path from the laser pointer to the hand, and some of that light changes direction so that it's coming to your eye instead) along the path of the tank. This is probably the most difficult concept for them to grasp, so as much time as can be spent here the better.



4. Come around and add “mystery particles” (the milk) to each tank. Not a lot of milk is needed; a tablespoon is probably plenty. Have them shine their lights through the tank as you add it; it will make a milk “cloud” that looks neat. Then stir the container so it’s uniformly distributed.
5. What happens when you shine the light through now? *What should happen:* the red laser becomes visible in the tank. The blue laser is even more scattered: it doesn’t look like a beam anymore, but is more a blue cloud. The white flashlight should appear as a yellow circle when viewed from the other side of the tank; the other parts of the tank should have a bluish tinge.
  - a. Again bring up the concept of scattering: what is happening here? Now which lasers are being scattered? (both) Which is being scattered more? (the blue, still) Why is this? (because of Rayleigh scattering, the same principle at play in a sunset) Because the blue light has a shorter wavelength (as we learned last week in our discussion of the EM spectrum), it is scattered more by the molecules it encounters. This means it’s scattered by water molecules in the tank at the beginning of the experiment, and when we add milk (which adds small globules to the tank, i.e. particles larger than a water molecule), then we see even more scattering.

### **Activity 3: Smog in a bottle**

#### Materials (per station)

- 1 Erlenmeyer flask, with stopper
- 1 UV pen light, such as this one: <http://uvp.com/lightsources.html>
- 1 orange
- 1 laser pointer (or one of each color, as used in the last experiment)
- aluminum foil

#### Pre-class procedure:

This activity should be set up at the beginning of the class (~30-40 minutes before the activity), so the UV has time to work.

1. Put the UV pen inside the flask. Cover the flask with aluminum foil and put the stopper in the top (the cord connecting the UV pen to the power supply will be sticking out; just put it on as well as possible). The foil is to prevent the UV light from shining in any eyes, so the bottom doesn't necessarily need to be covered.
2. Once the foil and the stopper are secure, turn on the UV pen. Leave the pen on until ready to do the experiment.

#### In-class procedure:

1. As you explain to students what they're about to do, turn off each UV pen, remove the aluminum foil, and as quickly as possible remove the pen from each flask and immediately replace the stopper. Instruct the students to not remove the stopper.
2. Encourage them to make observations of the flask (also may follow the worksheet). What do they see in it? What do they think is in it? What happens when you shine the laser pointers into the flask? What does it look like?
3. Come around and add "mystery particles" to each flask. Do this by adding  $\frac{1}{4}$  to  $\frac{1}{2}$  an orange's-worth of peel (depending on orange size): quickly remove the stopper, add the peel, replace the stopper, and shake the flask before returning it to the students.
4. Have the students again shine the laser into the flask. *What should happen:* before the orange peel was added, the light was not visible inside the flask. After the orange peel is added, it appears cloudy (actually smoggy) inside the flask. This is because the UV pen produced ozone molecules from the air (the same reason why the ozone layer protects us from solar ultraviolet radiation; see [http://en.wikipedia.org/wiki/Ozone-oxygen\\_cycle](http://en.wikipedia.org/wiki/Ozone-oxygen_cycle)). The orange peel produces volatile organic compounds (VOCs) which are the same reason you get that orange smell. The VOCs and the ozone interact to form tiny particles. This is how smog is formed in most major cities (particularly LA), although the VOCs in play there are not orangey, but come from cars. See the lesson plan for more information.
5. For another description of this activity, refer to [http://aerosols.ucsd.edu/classes/COSMOS12\\_Lab\\_Smog.pdf](http://aerosols.ucsd.edu/classes/COSMOS12_Lab_Smog.pdf)



**Activity 4: Cloud in a bottle**

Materials (per station)

- 1 plastic bottle (2L soda bottle, clear color)
- 1 bicycle pump
- 1 stopper with metal tube
- 1 book of matches

Water

Pre-class procedure:

The materials here merit a bit of description. Be sure to check that the bike pumps fit on the stopper; some of them don't.

1. Fill the bottle with an inch or two of tap water. Fix the stopper in the bottle.

In-class procedure:

1. Have the students (carefully, especially if teenage boys are doing the pumping) add pressure to the bottle with the bicycle pump. You can tell when it has enough pressure because the bottle will be firm when squeezed. Then release the pressure. *What should happen:* Nothing, although you may get a small cloud depending on how clean the water and bottle were.
2. Now come around and add "mystery particles" to the experiment. For this one, light a match, let it burn, then blow it out and put it into the bottle. The mystery particles are not the fire or heat, the particles are the smoke coming from the just-blown-out match.
3. Repeat step 1. *What should happen:* a cloud should form in the bottle. This can be verified by students either with the laser pointer (should scatter off the cloud now) or by gently squeezing the bottle: a cloud should be seen to come out the top.

