TEACHER GUIDE

Atmosphere in a Jar

In this activity, students take samples of different beans and peas from a jar which represent the different molecules in Earth's atmosphere. By counting the numbers of each bean in their sample, and using proportional reasoning, they can determine what the different gases are in the atmosphere, and in what proportions.

Materials:

- Digital scale for measuring materials
- A large clear container big enough to hold all of the beans and peas required for an entire class, preferably one with a lid
- Different kinds of dried beans and peas[1]. See "preparation" below for approximate amounts and weights of different beans. You will likely need a whole bag of two different beans (ex. black beans and black-eyed peas) and a bag of mixed beans for the rest.
- Small sample cups for students (approx. 2 oz) – 1 per student group

Background information:

The vast majority of Earth's atmosphere is made up of just two gases: nitrogen or N_2 (78.09%) and oxygen or O_2 (20.95%). Trace gases such as argon (0.93%), carbon dioxide (0.04%), and others are also present in very small amounts. Air also contains a variable amount of water vapor, on average around 1% at sea level and 0.4% across the entire atmosphere.

Nitrogen: While nitrogen is important to human life, we cannot use the nitrogen in form it takes in the atmosphere. Bacteria take this nitrogen out of the air and "fix" it into a form that plants use. We therefore get the nitrogen that we need from the food that we eat.

Oxygen: The Earth did not always have so much oxygen in its atmosphere. It was not until about 2.7 billion years ago that blue-green algae (cyanobacteria) evolved the process of photosynthesis which began producing oxygen. Today, the majority of our oxygen is made by phytoplankton and other plants in the ocean.

Argon: Argon is a colorless, odorless, non-toxic, inert gas. Today, argon is commonly used in light bulbs. Argon is a great insulator used in double pane windows minimizes transfer of heat.

Water vapor: The amount of water vapor in the atmosphere is highly variable, based on different weather conditions. At low humidity, water vapor may only make up 0.2% of the atmosphere, but at high humidity, that percentage can get over 4%.

Carbon dioxide: Even though most animals produce carbon dioxide from cell respiration, and carbon dioxide is released by many human activities, this gas still makes up only a very small proportion of Earth's atmosphere (0.04%). However, even this small percentage can have large consequences for Earth's climate.

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[1] Beans and peas are suggested because they are inexpensive, easy to handle and clean up, and easy to distinguish from one another. Small Lego blocks, rice grains, beads, and popcorn kernels work equally well.

Preparation:

- Determine which beans will represent which gases in your "atmosphere". You will need 5 different beans, with the majority being the beans representing nitrogen and oxygen.
- Create your "atmosphere." These directions are based on the chart below which will provide a large enough atmosphere for a full class of students[2].
    - Count out and weigh 100 of your "nitrogen" beans
    - Multiply the weight by 39 (because you need 3900 beans) and record
    - Weigh out the recorded amount and add to your atmosphere container
    - Count out and weigh 100 of your "oxygen" beans
    - Multiply the weight by 10.5 (because you need 1050 beans) and record
    - Weigh out the recorded amount and add to your atmosphere container
    - Count and add 50 "argon" beans to the container
    - Count and add 50 "water vapor" beans to the container
    - Count and add 2 "carbon dioxide" beans to the container

Bean	Gas	Percentage	Number	Approximate Weight
Black bean	Nitrogen	78%	3,900	858g
Black-eyed pea	Oxygen	21%	1,050	220g
Pinto bean	Argon	1%	50	n/a
White bean	Water vapor	1%	50	n/a
Kidney bean	Carbon dioxide	0.04%	2	n/a
Total			**5,052**	

*Note: The percentages do not add up to 100% due to rounding and variability with respect to water vapor. See NASA's website for more information about Earth's atmosphere: https://nssdc.gsfc.nasa.gov/planetary/factsheet/earthfact.html

- Put a lid on your atmosphere container, and mix thoroughly. The atmosphere should look uniform when you are finished.

[2] If for any reason you choose to use different amounts based on the same proportions, be sure to mark down how many of each material (bean) you include in your "atmosphere" to use in later activities.

Leading the Activity:

- Show students the atmosphere jar and tell them that the materials in the jar represent the molecules that make up our atmosphere. In this activity, they are going learn about what gases make up out atmosphere by studying what's in the jar.

- Have students look at the jar and jot down (on their lab sheets) initial observations of what they see.

- Remind students that during their warm up, they mentioned some different gases that they think are in Earth's atmosphere. Tell them that each bean (or other material) in this jar represents one molecule of a gas in our atmosphere. Note: If this is the first time you have used the word "molecule" with students, take a moment to discuss what this word means.

- Tell students that the amount of each bean in the jar is proportional to the amount of the actual gas it represents in the atmosphere. In other words, if there is a gas that makes up 10% of the gases our atmosphere, that bean makes up 10% of the beans in the jar. We are going to use this information to figure out what gas each bean in the jar represents.

- Ask students if they would like to take the rest of the week to count all the beans in the jar so they can find out how many of each bean there is. When they (hopefully) reject this idea, tell them that scientists use a technique called "sampling" to count things when there are a lot of things to count. Instead of counting all the beans, we will take "samples" from the jar and count those instead. As long as the samples are similar to the whole jar, we can use our samples to calculate what percentage of each bean there is in the jar.

- Go over the sampling and counting procedure that students will do in groups. You may want to do one as an example:
    - Take a sample cup and scoop a full cup of beans from the jar
    - With your group, separate all the different types of beans
    - Count the number of beans of each type and record the names and numbers on your data sheet.
    - Make sure to hold up each bean for students and tell them what it is called so they can aggregate data together with the class.

- Break students into groups and have them collect their samples and count their beans.
    - Teacher tip: when counting, have students make groups of 10 with their beans so that they don't lose count.
    - Teacher tip: Because there are so few carbon dioxide beans, try to ensure that at least one group gets one.

- Once all students have finished counting their beans, have them total the number of beans in their sample and write the total on their data sheet. They should also fill in the column for ratio of number to total.

- Discuss with students how to calculate the percent of each bean that is in their sample compared to the whole (molecule total/overall total x 100). Once students understand the procedure, have them calculate the percentage of each bean in their sample and write it on their data sheet.
    - Teacher tip: Calculating percentages is a 7th grade standard in many states, so students may or may not have learned how to do this already.

- Have groups share aloud what percentages they got for each bean. There will be differences, so ask them why they think their numbers are different. Use this opportunity to discuss that sampling does not give us a "correct" number. It is like an estimate of the percentage. Scientists use sampling because it is much faster than trying to count all the beans in the jar. Because each group had a slightly different sample, they got different percentages. Ask students if they think counting more means or less beans would give them a more accurate sample. Use discussion to build student understanding that larger samples provide better estimates of the "real" number they are trying to estimate.

- Ask students how they can use their data to get the best estimate of the actual percentages. Use discussion to help them realize that if they combine their data, they will have a better estimate than if they use just their own group's data. Have them pool their data (using a spreadsheet on a computer, a whiteboard, etc.). Just pool the raw numbers (not the percentages). Have students record this information in the "class data" portion of their data sheet.

- Have students write the ratio of each number of beans to the total using the class data. They should then calculate the percentage of each bean, and record their percentages on their data sheets. Take a moment when students are finished to have them compare the class data with their own data. Some things will likely be higher, and others will be lower.

- Once all the data has been calculated, share the list of gases in the atmosphere with students. See if they can guess which material goes with which gas in the space on their data sheets.

- Share the correct answers about which material goes with which gas. Have students share whether they were surprised or not. Most students will likely be surprised that nitrogen (a gas they are not very familiar with) makes up the largest part of Earth's atmosphere, while carbon dioxide and water vapor (gases they are likely more familiar with) make up such a small part.

- Optional: Have students complete one or more of the follow-up tasks related to this activity:
    - Answer the summary questions (see handout below)
    - Create a bar graph or pie chart showing the make-up of Earth's atmosphere
    - Calculate the volume of each gas we breathe each day (see handout below)