

Demonstrating Climate Change in a Bottle

Carbon dioxide is a greenhouse gas that heats up more quickly than other gases in the atmosphere during the day and cools down more slowly at night. As humans release more and more carbon dioxide into the air by burning fossil fuels and through deforestation, this is leading to an overall warming of the Earth and significant changes in weather patterns.

It's possible to demonstrate the overall warming effect of carbon dioxide using a sealable glass jar. This is a simple and fun experiment that can help children understand the complex conditions driving climate change.

The sealed glass jar simulates the Earth's atmosphere. An incandescent/halogen lightbulb is used to simulate the Sun and produce heat. Human production of carbon dioxide is simulated by mixing vinegar and bicarbonate of soda in the bottom of the jar. Switching the light on simulates daytime and switching it off simulates night-time. By measuring the temperature inside the glass container over time using a cheap probe thermometer, students will see that when the glass container is filled with carbon dioxide, the container reaches a higher temperature and cools down more slowly, compared to when the container is filled with normal air. This allows students to see how the carbon dioxide humans are releasing into the atmosphere leads to climate change by changing the daily heating and cooling of the Earth.

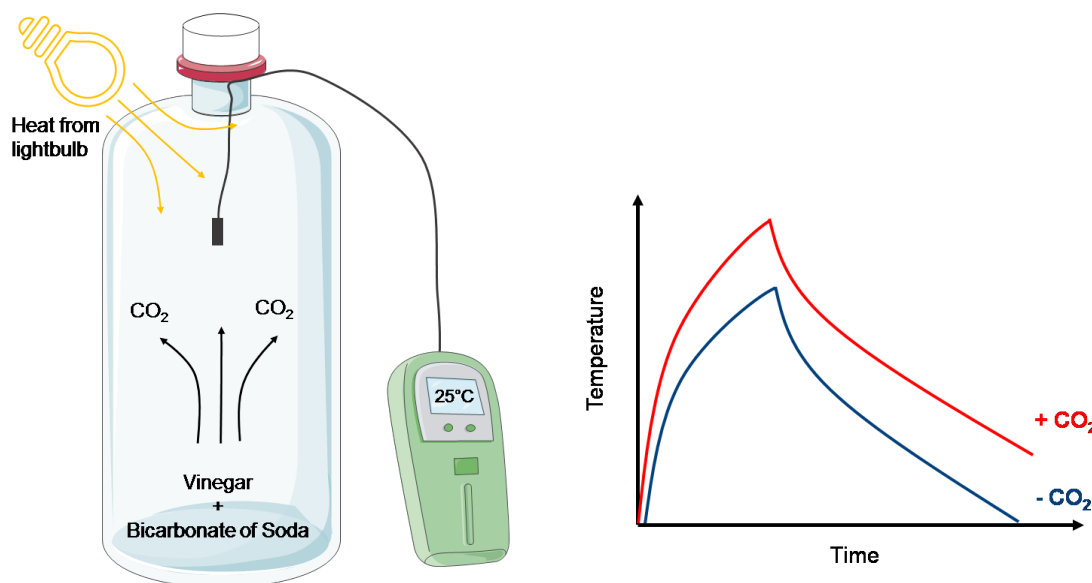
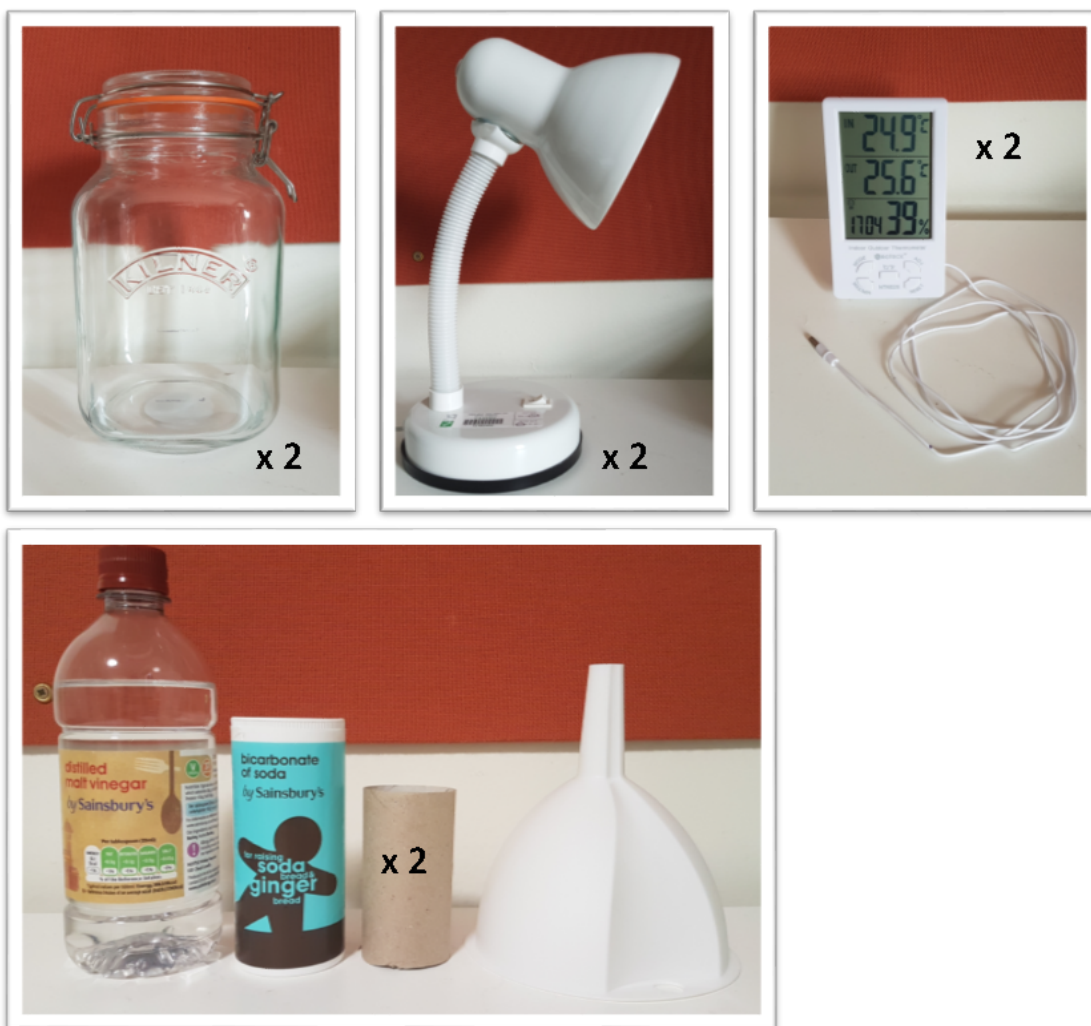


Image contains graphics adapted from Servier Medical Art.

What you need:	Approximate cost:
<ul style="list-style-type: none"> • 50 mL distilled malt vinegar 	50 p
<ul style="list-style-type: none"> • 1 heaped teaspoon (7 g) bicarbonate of soda 	£1.20
<ul style="list-style-type: none"> • 2 identical 2L glass jars with air-tight clasp lid 	£4 each
<ul style="list-style-type: none"> • 2 indoor/outdoor thermometers (with a wire probe) Recommendation: Neoteck Thermometer	£8.50 each
<ul style="list-style-type: none"> • 2 identical lamps that can accommodate 30 W halogen lightbulbs 	£8.50 each
<ul style="list-style-type: none"> • 2 halogen lightbulbs (30 W) 	£6
<ul style="list-style-type: none"> • 2 cardboard tubes (empty toilet rolls) 	
<ul style="list-style-type: none"> • Sellotape 	
<ul style="list-style-type: none"> • Funnel 	
<ul style="list-style-type: none"> • Teaspoon and small measuring jug (or kitchen scales) 	



Important Safety Information

READ BEFORE STARTING THE EXPERIMENT!

- The lamps will be hot after being switched on for 1.5 hours
- Carbon dioxide gas will be produced in the jar as a result of mixing the vinegar and bicarbonate of soda – **the quantities of vinegar and bicarbonate of soda have been specified so that the amount of gas produced won't cause excessive pressure inside the glass jar. Using significantly larger quantities of vinegar and bicarbonate of soda may lead to an excessive build-up of pressure inside the glass jar, which in extreme cases could cause an explosion.**

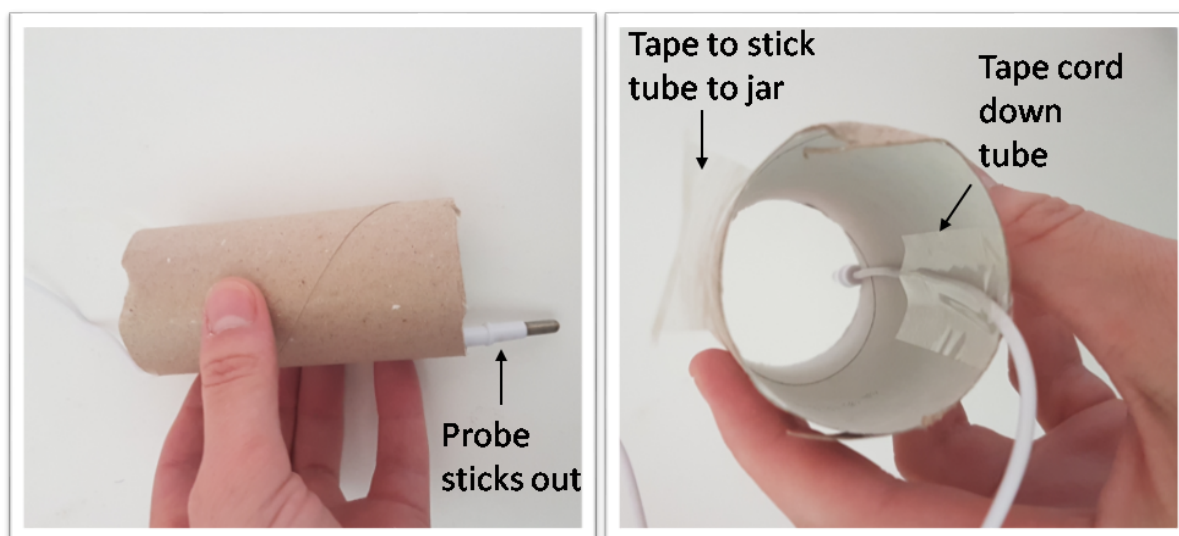
Instructions:

NOTE: You can watch an accompanying video showing how the experiment should be set up here:

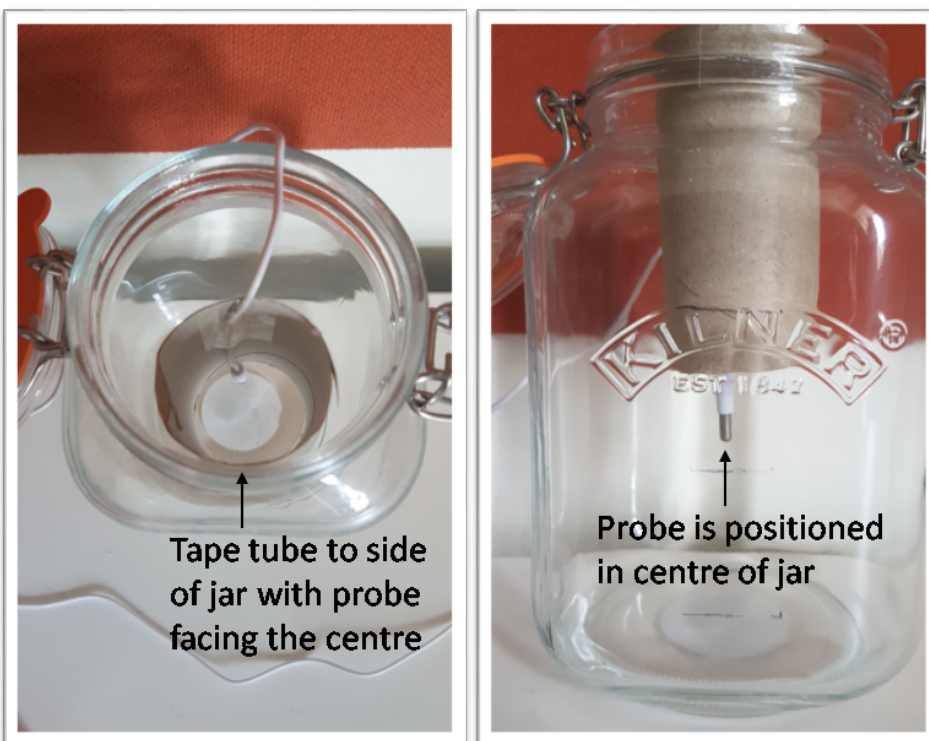
<http://ypte.org.uk/videos/climate-change-in-a-bottle-how-to-set-up-the-experiment>

When setting up the experiment, make sure to use the recommended type of equipment to ensure that the experiment works as expected. It's also important to set up the two containers in exactly the same way so that the only thing contributing to the differences in temperature that you will see is the addition of carbon dioxide. Finally, ensure that the sun isn't shining on the jars through a window – it can heat up the jars! This is particularly a problem because it can lead to one jar temperature being much higher than the other depending on where the sun shines.

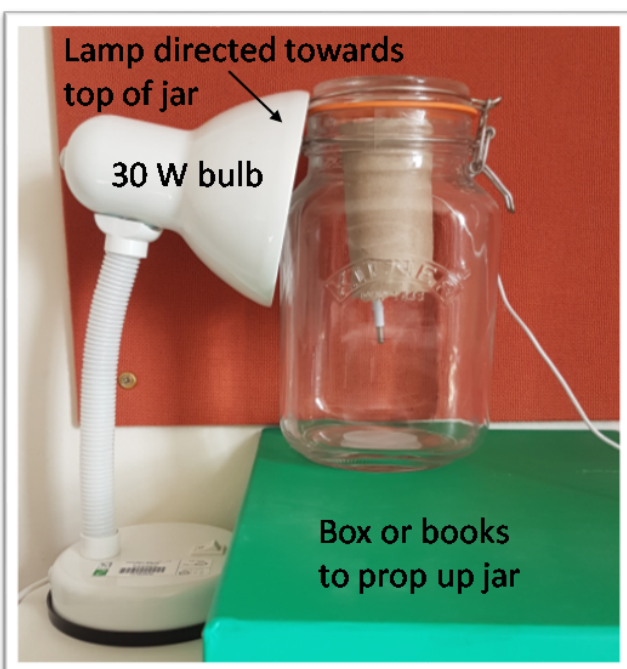
1. Put 1 heaped teaspoon (7 g) bicarbonate of soda in the bottom of one glass jar and make sure it is spread evenly. Label the jar “added carbon dioxide.” Label the second jar “normal air only.”
2. Tape the cord of the temperature probes to the inside of the cardboard tubes so that only the probe sticks out of the bottom of the tube by about 2.5 cm. Make sure both probes stick out the same amount.



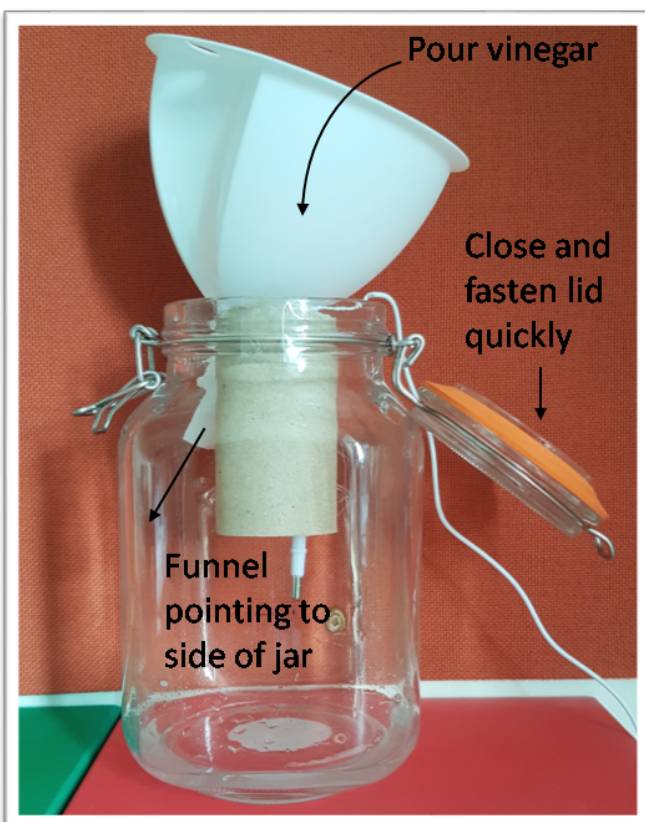
3. Tape the cardboard tubes to the side of the glass jars so that the probes face towards the centre of the jars. **Note:** it's important to use the cardboard tubes as the probes need to be in the middle of the jars to accurately measure the air temperature, and the tubes help to make sure the probes in each jar are in exactly the same position.



4. Close the lid of the “normal air only” glass jar and place the head of the lamp at the top of the glass jar as shown in the picture below. Use a box or books to prop up the jar. The lamp should be as close to the jar as possible. **Note:** it's important to put the lamp at the top of the jar, not the bottom, to avoid heating up the vinegar and bicarbonate of soda too much (the vapour produced interferes with the experiment).



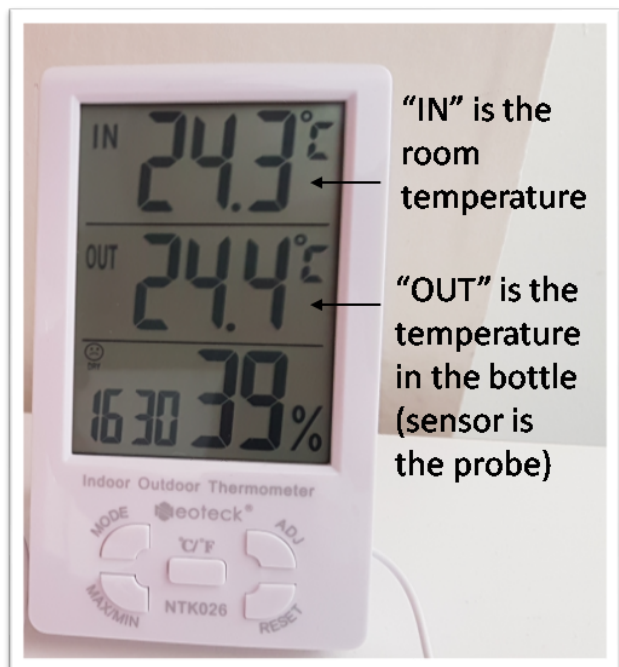
5. Use the funnel to add 50 mL vinegar to the bottom of the “added carbon dioxide” jar, angling the funnel towards the side of the jar to prevent the vinegar from splashing onto the temperature probe. Then, close the lid immediately – it’s very important to close the lid as quickly as possible to prevent the carbon dioxide from escaping from the jar. It might be helpful to practise this once before attempting the experiment in the classroom.



6. Swirl the vinegar in the bottom of the jar to help release the carbon dioxide and then arrange the jar and the lamp as in step 5.



7. Wait 10 minutes for the carbon dioxide to release fully. **Note:** adding the vinegar might cause the temperature inside the jar to drop temporarily. The temperature should have returned to normal after 10 minutes, but if not, wait until the temperatures inside and outside both glass jars are all the same (within 0.2°C).



Note: The thermometers show two temperatures. The “IN” temperature is the room temperature. The sensor that records this temperature is on the main display console. The “OUT” temperature is the temperature in the glass jars as the sensor that records the “OUT” temperature is the wire probe.

The experiment is now ready to use with students.

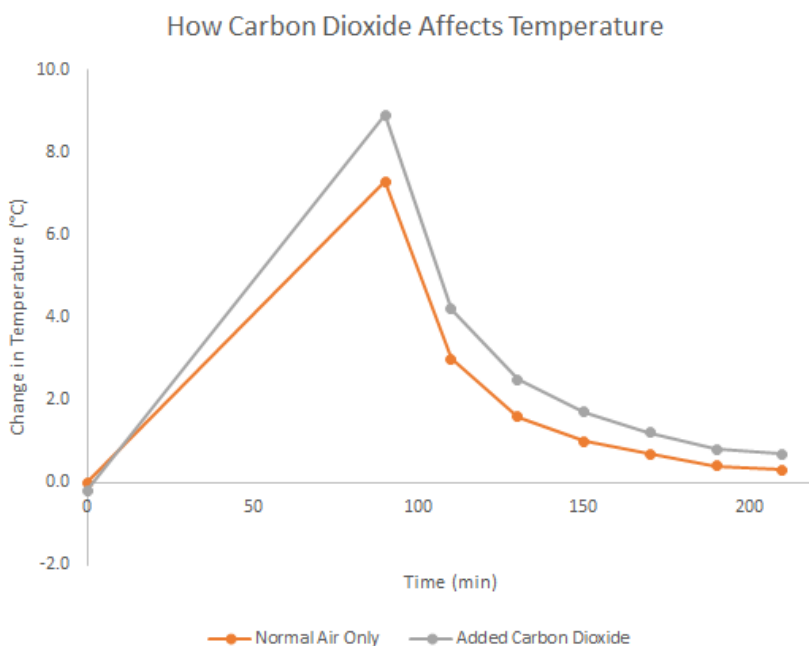
8. Record the starting temperatures (room temperature and jar temperature) with the students and then switch both lamps on. Use the template Excel spreadsheets provided (ClimateChange_GraphTemplate.xlsx) to record the temperatures. The first tab on the spreadsheet is some example data, the second tab contains a blank template. This will automatically generate a graph for you as you enter the temperatures. **Note:** you could draw a simple graph on the white board to show the temperatures and how they change instead.

9. Allow the glass jars to heat up for 1.5 hours and then record the temperatures inside and outside both jars again. It's ok to leave the lamps heating the jars for more than 1.5 hours if this suits the classroom schedule. You should see that the temperature in the “added carbon dioxide” jar is higher than in the “normal air only” jar. **Note:** this experiment is designed to work when the starting temperature is approx. 23°C. If the starting temperature is lower, it may take slightly longer to see a difference in temperature between the two jars. Also, if the lightbulb wattage is lower

than 30 W, this will also cause the jars to heat up more slowly – there may still be a detectable difference between the two jars after a longer period of time but it's recommended to use 30 W bulbs to ensure the experiment works.

10. Switch off both lamps and then record the temperatures inside and outside the jars every 20 minutes for a total of 60 minutes. You should see that the temperature drops over time but that the temperature in the “added carbon dioxide” jar remains higher than in the “normal air only” jar. **Note:** The temperature in the “added carbon dioxide” jar will eventually (after 2 hours or more) cool down to the same temperature as the “normal air only” jar (and the outside room temperature). However, the sun rising and setting every day limits the real-world “cool down” time and this is why climate change occurs when our human activities put more carbon dioxide into the atmosphere!

Here's an example of what the experiment results might look like:



Notes for teachers:

- 1) Water vapour is also a greenhouse gas and some will evaporate from the vinegar during the heating process. For this reason, you may wish to place the same amount of vinegar in both bottles. (Bicarbonate of soda should only be added to one of them!)
- 2) It may be worth testing the thermometers first to ensure that they both give the same reading at room temperature. If not, ask your students for ways to adjust their results to take any variations into account.

- 3) Another important question your students might ask is why the temperature in both bottles increases. The answer is that there is greenhouse gas in both jars, but there was not as much in the jar without the added CO₂.
- 4) As an extension, you could try adding a third jar to the experiment that contains no CO₂. It should be heated with a lamp that produces the same amount of light but less heat i.e. a low energy/ LED bulb.

Written by Renee Tonkin and funded by Imperial College London.