# Trapping $CO_2$

*Climate Change Science Lesson*

Goal: Students will understand how to capture carbon dioxide.

Objectives: Students will …

- Understand the difference between $CO_2$ and air
- Examine the chemical properties of carbon dioxide
- Using a chemical reaction to trap carbon dioxide

Materials (per lab group):

- 3 gas collection jars with caps
- 100mL of vinegar
- 1 – #6, 2-hole rubber stopper with plastic tubes
- 1 250ml flask
- 1 length rubber tubing, 45cm long
- safety glasses
- 1 250mL beaker
- 1 30mL syringe (no needle)
- 1 small plastic tub
- supply of water
- box of baking soda
- 50ml Phenol Red
- 50ml Limewater
- matches
- straws or rigid plastic tubing
- Copies of Trapping $CO_2$ – Background Information
- Copies of Trapping $CO_2$ – Lab Procedure
- Copies of Trapping $CO_2$ – Student Sheet

Time Required: 45-60 minutes

Standards Met: S2, S3, S7, S8, M1, M3, M13

Procedure:

PREP

- Gather all of the necessary lab materials and run a test lab to be certain of safety procedures.

DAY ONE

- Explain to students that they will be creating and trapping $CO_2$ today in class. They will begin to see the characteristics of the gas in order to understand how they relate to global climate change. For more information on this topic, click here.
- Give students copies of the Trapping $CO_2$ – Background Information and review.
- Divide students into lab groups of 4.
- Hand out the Trapping $CO_2$ – Lab Procedure Sheets to each group. Review safety precautions and lab procedures with students.

- Allow students time to complete the lab as they follow steps on their procedure sheets. Remind students to record any observations on their Trapping $CO_2$ – Lab Procedure Sheets.
- Review clean up procedure with students and give them time to complete a thorough clean up of their lab stations.
- Hand out Trapping $CO_2$ – Student Sheet and ask students to answer the questions.
- Discuss the implications of methane and carbon dioxide emissions and its relationship to global climate change.

Note:

Vinegar and baking soda reaction:

- Vinegar is acetic acid: $CH_3COOH$
- Baking soda is sodium bicarbonate: $NaHCO_3$
- Mixing the two is simply an acid base reaction.
- $CH_3COOH + NaHCO_3 \text{--->} CH_3COONa + H_2CO_3$
- That last product is carbonic acid which quickly decomposes into carbon dioxide and water:
  - $H_2CO_3 \text{--->} H_2O + CO_2$
  - The $CO_2$ is what you see foaming and bubbling in this reaction.

Assessment:

- Completed lab procedures
- Completed Trapping $CO_2$ – Student Sheet

# Trapping $CO_2$ – Teacher Answer Key

Name: ________________________________________ Date: ________________

1. Where did the carbon dioxide that you collected in the gas collection jars come from?

   *It was produced from the reaction between the vinegar and the baking soda.*

2. Why did the gas push out the water in the gas collection jars? Isn't the water denser than the gas?

   *The water is denser than the gas, but the gas built up pressure in the container greater than the pressure of the water in the gas collection jars, forcing the water out of the jars.*

3. Why did you let your apparatus bubble for 30 seconds before you began collecting gas in the jars?

   *It is important to let the gas bubble for a while to ensure that all of the gas that was in the jar (air) has been removed, and the gas that is collected is entirely a product of the reaction between the vinegar and baking soda.*

4. Does carbon dioxide gas have a color? An odor?

   *Carbon dioxide is a colorless, odorless gas.*

5. How can you test for the presence of $CO_2$? Give at least three ways.

   *Tests that can be used to confirm the presence of carbon dioxide are: will extinguish a lit match, turns limewater cloudy, and turns phenol red yellow.*

6. How does $CO_2$ differ from normal air?

   *"Normal" air is a mixture of several gases (78.084% nitrogen, 20.947% oxygen, 0.934% Argon, 0.033% carbon dioxide and several trace gases). Carbon dioxide is a pure gas produced as a product of respiration and combustion.*

7. If you were to exhale into the rubber tubing and collect the gas in jars, would the tests you performed above have the same results? Explain. (You may want to ask your instructor to try this experiment if time permits.)

   *Yes, as a person exhales, a certain percentage of the gas that is emitted from their lungs is carbon dioxide (a product of cellular respiration) and this would give similar result to the experiment. Note: The concentration of the gas (carbon dioxide) emitted from the experiment is greater that what a person would normally exhale.*

8. Write a simple chemical equation for the experiment you did in this activity.

   *Vinegar + baking soda* $\longrightarrow$ *carbon dioxide*

9. Why didn't we produce carbon dioxide by using limestone calcination?

   *Limestone calcination requires a great deal of heat (the use of a kiln) and is not feasible for the production of carbon dioxide in the classroom.*

# Trapping $CO_2$ – Background Information

Before $CO_2$ gas can be sequestered from power plants or industrial sources, it must be captured as a relatively pure gas. $CO_2$ is routinely separated and captured as a by-product from industrial processes such as synthetic ammonia production, hydrogen production and limestone calcination.

**CHEMISTRY OF LIME**
*Limestone vs. Lime:*
In everyday usage the terms *"limestone"* and *"lime"* are used by the general public interchangeably to mean the same material, however there are some significant differences between the two materials. Limestone is a sedimentary rock whereas lime is a manmade chemical that is produced from a sufficiently pure sedimentary rock by heating it to high temperature in a kiln. This process is referred to as *"calcining"* the limestone.

**LIMESTONE:** This term refers to a naturally occurring sedimentary rock that is relatively inert, except in the presence of a strong acid. With the proper purity the rock deposit can be used to produce *"lime"*, a manmade chemical. Most often, limestone is found in nature in a mixed form known as *"dolomite"*, which is a blend of calcium carbonate and magnesium carbonate in varying proportions. (In the Shelby County, AL area there are large deposits of limestone, primarily composed of calcium carbonate, which are used as the "raw material" for producing high calcium lime products.)

**LIME**: This term refers to either *"quicklime"*, the product that is produced by heating the limestone to its dissociation temperature, or *"hydrated lime"*, the product that is produced by the reaction of quicklime with water. (Lime in the form of high calcium quicklime, CaO readily reacts with water to form hydrated lime, which provides a pH of up to 12.454 when in an aqueous solution. Because of elemental differences between magnesium (Mg) and calcium (Ca) the compound magnesium oxide, MgO does not readily react with water at normal temperatures and pressures.

*Quicklime Production:*
The production of high calcium quicklime (calcium oxide) requires a large amount of heat, which is generated in the kiln environment. The quarried and sized high calcium limestone travels through a rotary kiln and is subjected to these high temperatures where the calcium carbonate begins to dissociate with the resultant formation of calcium oxide. The minimum temperature for the dissociation of calcium carbonate is $1648^{o}$F ($898^{o}$C). For practical production purposes, however, the kiln temperature range is from an initial temperature of about $1750^{o}$F ($954^{o}$C) to a final temperature of about $1950^{o}$F ($1066^{o}$C). These temperatures can vary dependent upon the nature of the limestone being calcined.

*"High Calcium"* Limestone Calcination:
$CaCO_3$ + Heat ---> CaO + $CO_2$
$1750^{o}$ to $1950^{o}$F
$954^{o}$ to $1066^{o}$C

*"Dolomitic"* Limestone Calcination:
$CaCO_3 \bullet MgCO_3$ + Heat ---> $CaO \bullet MgO + 2CO_2$

*Hydrated Lime Production:*
High calcium quicklime readily reacts with water to form hydrated lime. The reaction is highly exothermic and the process is known as *"slaking"*. The reaction is usually carried out in a *"slaker"* (a specially designed mixer) which, through a process of rigorous mixing, makes certain that all of the quicklime has come into intimate contact with water and no unreacted quicklime remains. From a general viewpoint the hydrated lime produced can be in the form of dry hydrate, putty slurry, or "milk of lime". The exothermic reactions are shown below: (There are various types of slakers available on the market.)

*"High Calcium"* Quicklime Hydration:
$CaO + H_2O$ ---> $Ca(OH)_2$ + Heat

*"Dolomitic"* Quicklime Hydration:
$CaO \bullet MgO + H_2O$ ---> $Ca(OH)_2 + MgO$ + Heat

Note: CaO will readily react with water under normal temperatures and pressures, whereas MgO will not. However, existing capture technologies are not cost-effective when considered in the context of $CO_2$ sequestration.

Carbon dioxide capture is generally estimated to represent three-fourths of the total cost of a carbon capture, storage, transport, and sequestration system. The program area will pursue evolutionary improvements in existing $CO_2$ capture systems and also explore revolutionary new capture and sequestration concepts. The most likely options currently identifiable for $CO_2$ separation and capture include the following:

* Absorption (chemical and physical)
* Adsorption (physical and chemical)
* Low-temperature distillation
* Gas separation membranes
* Mineralization and biomineralization

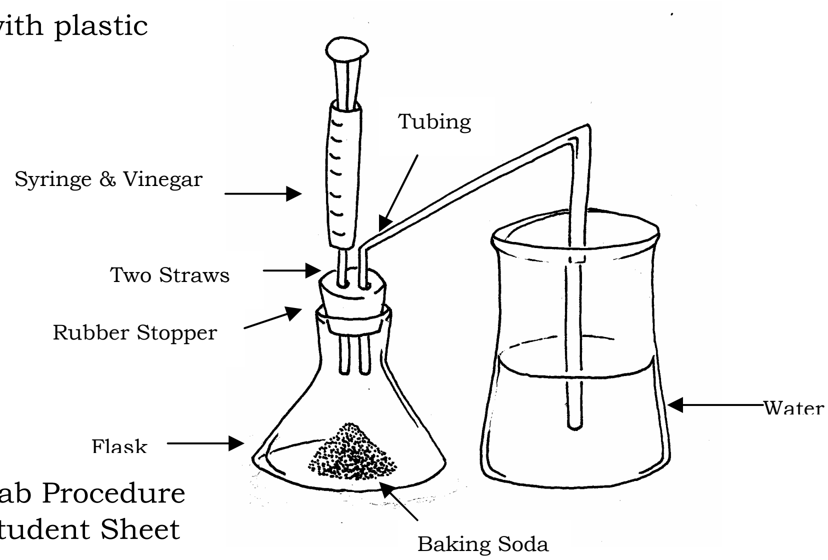
Opportunities for significant cost reductions exist since very little R&D has been devoted to $CO_2$ capture and separation technologies. Several innovative schemes have been proposed that could significantly reduce $CO_2$ capture costs, compared to conventional processes. "One box" concepts that combine $CO_2$ capture with deduction of criteria-pollutant emissions are concepts to be explored.

This activity will introduce students to the gas $CO_2$ (carbon dioxide), how it is formed, and tests to tell that it is present. For this activity the students will produce carbon dioxide from a reaction between vinegar and baking soda.

# Trapping $CO_2$ – Lab Procedure

Gather the following materials (per lab group)

- 1 30ml syringe
- 100ml of white vinegar
- 1 box of baking soda
- 1 – 2-hole rubber stopper with plastic tubes
- 3 gas collection jars
- 3 matches
- 250ml flask
- 1 length rubber
- Tubing, 45cm long
- 1 small plastic tub
- Supply of water
- Baking soda to cover bottom of flask
- 50ml Phenol Red
- 50ml Limewater
- Copies of Trapping $CO_2$ – Lab Procedure
- Copies of Trapping $CO_2$ – Student Sheet




**$CO_2$ Generator Set-up**

- Test the properties of the air inside the gas collection jars. First, **strike a match** and quickly add it to one of the jars, then record your observations on the worksheet. Next, add about **10ml of Limewater** to one of the jars, cap it quickly, shake, and record your observations on the worksheet. In the last gas collection jar, add about **10ml of Phenol Red**, cap it quickly, shake, and record your observations on the worksheet.
- Assemble the $CO_2$ generator using the drawing above. Make sure that all unions are airtight.
- Place enough baking soda in the flask to cover the bottom.
- Pour about 40ml of vinegar into a 250ml beaker. **Make sure you have your safety glasses on**.
- Put the tip of the 30ml syringe into the vinegar making sure the plunger is all the way down. Keep the tip of the syringe below the surface as you pull back on the plunger to fill it to the 30ml mark. If you get air bubbles in the syringe, empty it, and repeat the procedure again.
- Put the free end of the rubber tube under the water in the pan. The depth of the water should be enough to completely cover a gas collection jar.
- Place the syringe into the straw on the rubber stopper and slowly add 10ml of vinegar to the baking soda. Do not have the tubing under the jars at this time.
- Let the gas bubble from the rubber tube for about 30 seconds before moving on.

- Place one of the gas collection jars into the tank of water and completely fill it with water.
- Invert it so that the top (open end) is facing down (it must still be completely filled with water … no air pockets).
- Slip the end of the tube just under the mouth of the gas collection jar.
- Slowly add more vinegar to the baking soda until the gas collection jar fills with gas.
- Cap the jar tightly while it is still inverted under water.
- Repeat the procedure with the other two gas collection jars.
- Test the properties of CO2 by completing the following:

**Strike a match** and quickly add it to one of the jars. Observe what happens and record your observations below.

| Before adding the CO2 | After adding the CO2 |
|---|---|
| | |

Add about **10ml of Limewater** to one of the jars, cap it quickly and shake. Observe what happens and record your observations below.

| Before adding the CO2 | After adding the CO2 |
|---|---|
| | |

Add about **10ml of Phenol Red** to one of the jars, cap it quickly and shake. Observe what happens and record your observations below.

| Before adding the CO2 | After adding the CO2 |
|---|---|
| | |

- When you have finished this activity, your teacher will tell you how to clean up your materials and then complete Trapping $CO_2$ – Student Sheet.

# Trapping $CO_2$ – Student Sheet

Name: ___________________________________________ Date: __________________

**Hypothesis:** What will happen when you **strike a match**, add **10mL of limewater**, and add **10mL of phenol red** to a gas collection jar containing CO2**?**

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1. Where did the carbon dioxide that you collected in the gas collection jars come from?

2. Why did the gas push out the water in the gas collection jars? Isn't the water denser than the gas?

3. Why did you let your apparatus bubble for 30 seconds before you began collecting gas in the jars?

4. Does carbon dioxide gas have a color? An odor?

5. How can you test for the presence of $CO_2$? Give at least three ways.

6. How does $CO_2$ differ from normal air?

7. If you were to exhale into the rubber tubing and collect the gas in jars, would the tests you performed above have the same results? Explain. (You may want to ask your instructor to try this experiment if time permits.)

8. Write a simple chemical equation for the experiment you did in this activity.

9. Why didn't we produce carbon dioxide by using limestone calcination?

**WORKSHOP COPY**

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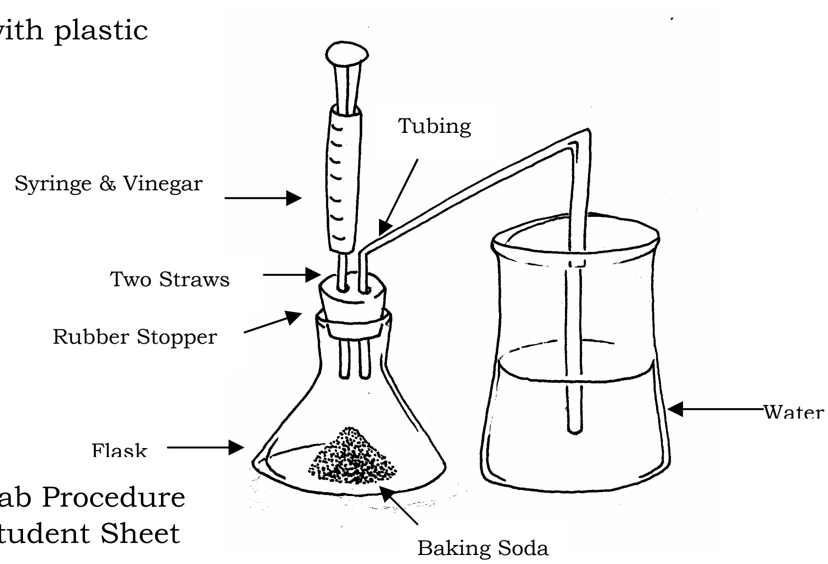


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| --- | --- |
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| --- | --- |
| | |

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