Geologic Sequestration

Science

Goal: Students learn about geologic sequestration as a technique used to reduce carbon dioxide in the atmosphere.

Objectives: Students will ...

- Understand geologic sequestration as an idea being considered to reduce carbon dioxide in the atmosphere
- Use chemistry to simulate oil mining

Materials needed (per lab group):

- 100ml of vinegar
- 2 – #6, two-hole rubber stopper with plastic tubes
- 2 – 250ml flask
- 2 lengths of rubber tubing, 45cm long each
- Safety glasses for each student
- 2 – 250ml beaker
- 1 – 30ml syringe (no needle)
- Supply of water
- Yellow food color to represent oil
- Box of baking soda
- Several straws or rigid plastic tubing
- 30 copies of Geologic Sequestration-Student Sheet

Time Required: 45-60 minute period

Standards Met: M1, M12, M13, S1, S2, S3, S7

Procedure:

PREP

- Prepare 10 lab stations each with the materials listed above.
- Photocopy Geologic Sequestration Lab Procedure and Student Sheet.
- Review the teacher sheet and familiarize yourself with geologic sequestration.

IN CLASS

- Explain that students will conduct an experiment to learn about the method of geologic carbon sequestration.
- Divide students into groups of 3. They should then move to a lab station with the appropriate materials needed to complete the lab.
- Hand out Geologic Sequestration Lab Procedure. Review.
- Allow students to conduct the lab while you roam the room and help.
- When students have completed the lab, ask them to clean their lab materials and station so that the next class can use the materials.
- Hand out Geologic Sequestration-Student Sheet.
- Discuss experiment results using the student sheet as a guide.

Assessment:

- Participation in the lab activity
- Completed Geologic Sequestration – Student Sheet

Geologic Sequestration – Teacher Sheet

Introduction and Teacher Background: Carbon dioxide sequestration in geologic formations includes oil and gas reservoirs, unmineable coal seams and deep saline reservoirs.

Oil and Gas Reservoirs. In some cases, production from an oil or natural gas reservoir can be enhanced by pumping CO_2 gas into the reservoir to push out the product, which is called enhanced oil recovery (EOR). The United States is the world leader in enhanced oil recovery technology, using about 32 million tons of CO_2 per year for this purpose. From the perspective of the sequestration program, enhanced oil recovery represents an opportunity to sequester carbon at low net cost, due to the revenues from recovered oil and gas. In an enhanced oil recovery application, the integrity of the CO_2 that remains in the reservoir is well understood and very high, as long as the original pressure of the reservoir is not exceeded. The scope of this EOR application is currently economically limited to point sources of CO_2 emissions that are near an oil or natural gas reservoir.

Coal Bed Methane. Coal beds typically contain large amounts of methane-rich gas that is adsorbed onto the surface of the coal. The current practice for recovering coal bed methane is to depressurize the bed, usually by pumping water out of the reservoir. An alternative approach is to inject carbon dioxide gas into the bed. Tests have shown that CO_2 is roughly twice as adsorbing on coal as methane, giving it the potential to efficiently displace methane and remain sequestered in the bed. CO_2 recovery of coal bed methane has been demonstrated in limited field tests, but much more work is necessary to understand and optimize the process.

Similar to the by-product value gained from enhanced oil recovery, the recovered methane provides a value-added revenue stream to the carbon sequestration process, creating a low net cost option. The U.S. coal resources are estimated at 6 trillion tons, and 90 percent of it is currently unmineable due to seam thickness, depth and structural integrity. Another promising aspect of CO_2 sequestration in coal beds is that many of the large unmineable coal seams are near electricity generating facilities that are large point sources of CO_2 gas. Thus, limited pipeline transport of CO_2 gas would be required. Integration of coal bed methane with a coal-fired electricity generating system can provide an option for additional power generation with low emissions.

Saline Formations. Sequestration of CO_2 in deep saline formations does not produce value-added by-products, but it has other advantages. First, the estimated carbon storage capacity of saline formations in the United States is large, making them a viable long-term solution. It has been estimated that deep saline formations in the United States could potentially store up to 500 billion tons of CO_2.

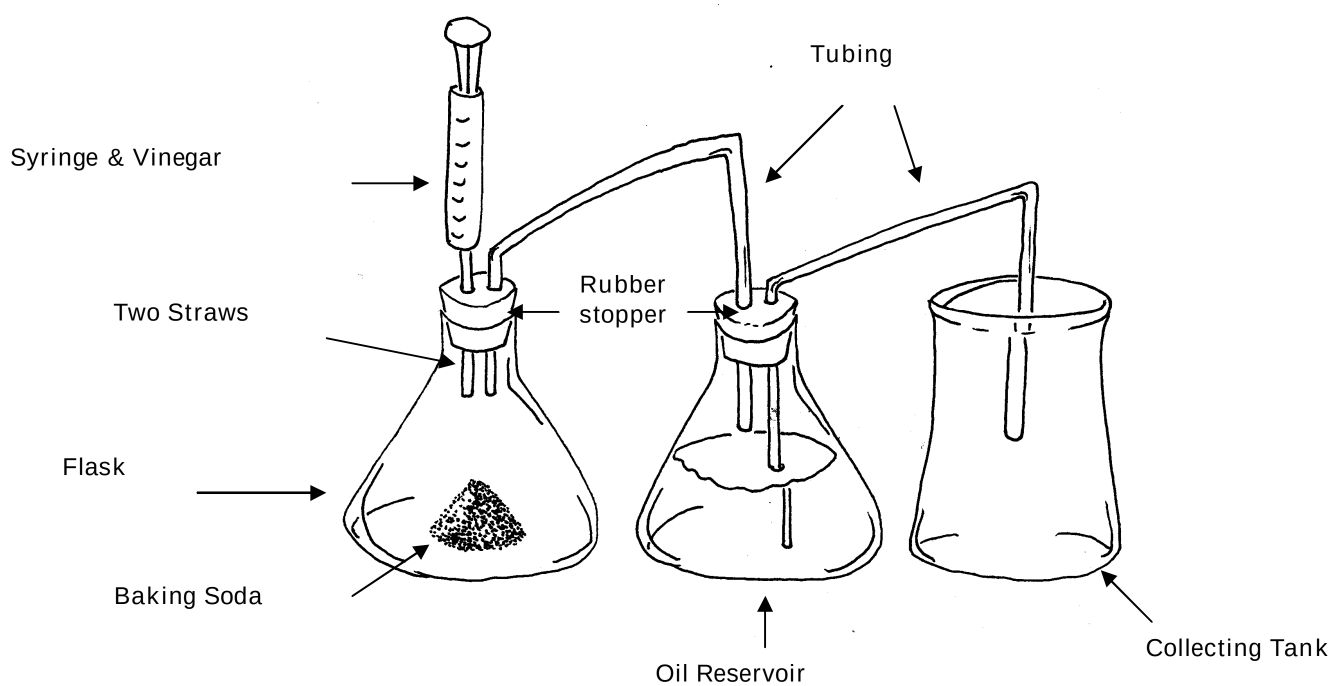
Second, most existing large CO_2 point sources are within easy access to a saline formation injection point, and therefore sequestration in saline formations is compatible with a strategy of transforming large portions of the existing U.S. energy and industrial assets to near-zero carbon emissions via low-cost carbon sequestration retrofits.

Assuring the environmental acceptability and safety of CO_2 storage in saline formations is a key component of this program element. Determining that CO_2 will not escape from formations and either migrate up to the earth's surface or contaminate drinking water supplies is a key aspect of sequestration research. Although much work is needed to better understand and characterize sequestration of CO_2 in deep saline formations, a significant baseline of information and experience exists. For example, as part of enhanced oil recovery operations, the oil industry routinely injects brines from the recovered oil into saline reservoirs, and the U.S. Environmental Protection Agency (EPA) has permitted some hazardous waste disposal sites that inject liquid wastes into deep saline formations.

The Norwegian oil company, Statoil, is injecting approximately one million tonnes (metric tons, or 1000kg) per year of recovered CO_2 into the Utsira Sand, a saline formation under the sea associated with the Sleipner West Heimdel gas reservoir. The amount being sequestered is equivalent to the output of a 150-megawatt coal-fired power plant. This is the only commercial CO_2 geological sequestration facility in the world.

FOR THIS LAB

Review the diagram below. This is the set-up students should have to ensure a successful lab.



Geologic Sequestration – Teacher Answer Key

Name: ______________________________ Date: ____________________

1. What caused the oil to leave the reservoir? Be specific.

   As the reaction between the vinegar and baking soda produced carbon dioxide gas, pressure increased inside the first container and forced the gas into the second container. As the pressure increased in the second container, the only escape route for relieving the pressure is to force liquid out through the tube that is submerged in the "oil" causing it to be pumped into the third container.

2. What percentage of the oil that was added to the reservoir was recovered?

   Answers will vary.

3. Why can't you recover all the oil from a reservoir using this technique?

   Some of the oil is located below the surface of the tube and will not be forced out once the level of the oil drops to this point.

4. Where does the CO_2 for this type of sequestration come from?

   CO_2 is produced by industries in a variety of ways. It can be the product of a chemical reaction or a combustion process. Companies that produce CO_2 as part of their production process could use it for this type of sequestration.

5. What happens to the CO_2 once it is pumped into the ground?

   Usually, the well or reservoir is capped and the CO_2 remains trapped underground. However, there is always the possibility that cracks could occur within the sealed reservoir that could allow the CO_2 to escape back into the atmosphere.

6. Do you think that this is a practical method to reduce CO_2 emissions into the atmosphere? Explain your answer.

   Large amounts of CO_2 could be stored by using this process, and there is some economic gain (recovered oil). This could be a temporary solution to reducing the CO_2 presently in our atmosphere. However, there is always a possibility that these storage areas could leak, which could cause a rapid influx of concentrated CO_2 within a small geographical area.

Geologic Sequestration – Lab Procedure

1. Be sure you have the materials listed below at your lab station.
   - 100ml of vinegar
   - 2 – #6, two-hole rubber stopper with plastic tubes
   - 2 – 250ml flask
   - 2 lengths of rubber tubing, 45cm long each
   - Safety glasses for each student
   - 2 – 250ml beaker
   - 1 – 30ml syringe (no needle)
   - Supply of water
   - Yellow food color to represent oil
   - Box of baking soda
   - Several straws or rigid plastic tubing

2. Assemble the CO_2 generator, oil reservoir and collecting tank using Diagram 1 below. Make sure that all unions are airtight. Place enough baking soda in the flask to cover the bottom.

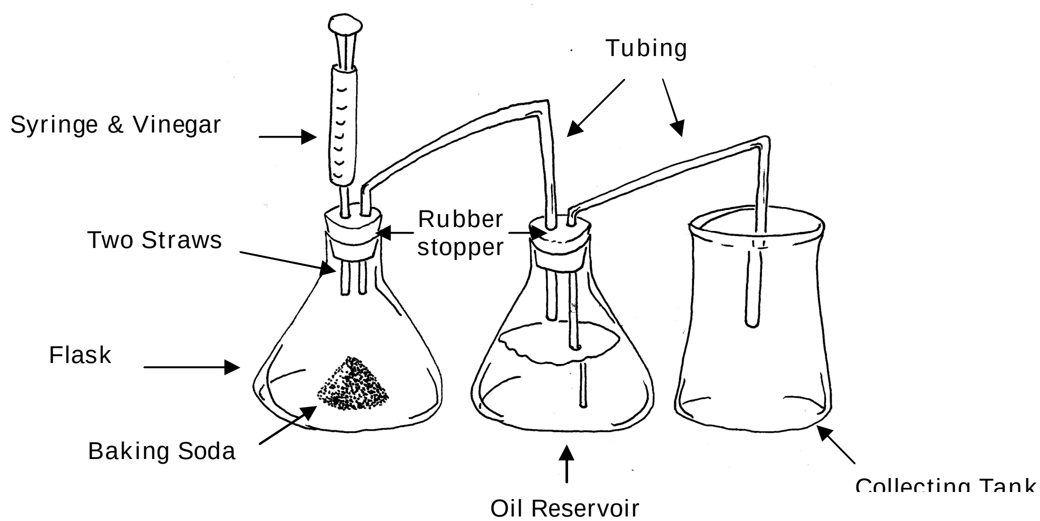


DIAGRAM 1

3. Put on your safety glasses.
4. Pour about 40ml of vinegar into a 250ml beaker. Put the tip of the 30ml syringe into the vinegar making sure that 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.

5. In your second beaker, add about 200ml of water and some yellow food coloring, this will represent oil. Pour your "oil" into the oil reservoir. This will represent an underground oil deposit.
6. Place the syringe into the straw on the rubber stopper and slowly add 10ml of vinegar to the baking soda. The gas that is being produced (carbon dioxide) will push oil out of the underground deposit and into the collecting tank.
7. Slowly add more vinegar to the baking soda until the oil stops flowing into the collecting tank.
8. When you have finished this activity, your instructor will tell you how to clean up your materials. Answer the questions on the Geologic Sequestration – Student Sheet.

Geologic Sequestration – Student Sheet

Name: ______________________________ Date: ____________________

Hypothesis: If I add CO_2 to the "oil reservoir" I think…

___

___

1. What caused the oil to leave the reservoir? Be specific.

2. What percentage of the oil was recovered from the reservoir?

3. Why can't you recover all the oil from a reservoir using this technique?

4. Where does the CO_2 for this type of sequestration come from?

5. What happens to the CO_2 once it is pumped into the ground?

6. Do you think that this is a practical method to reduce CO_2 emissions into the atmosphere? Explain your answer.

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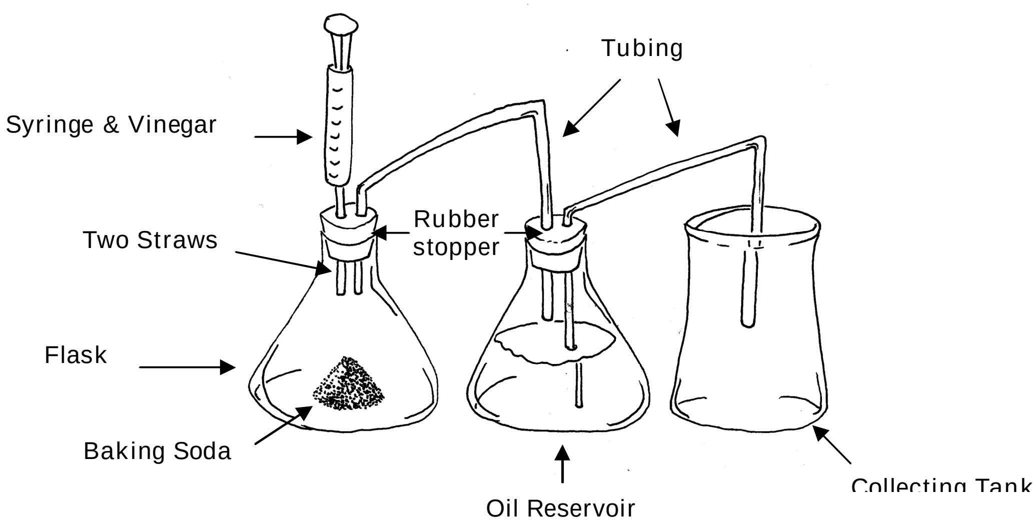

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