Carbon Capture & Storage

Student worksheet

Introduction to Carbon Capture

There is evidence to show that increased levels of carbon dioxide (CO_2) gas in the atmosphere have contributed to an increase in the average global temperature over the last century, by a process called global warming. CO_2 is produced when fossil fuels including coal, oil and natural gas are burnt in electricity generation as well as other industrial processes such as the manufacture of cement. Scientists and engineers are investigating carbon capturing methods that may be used to capture the CO_2 released from such processes, in order to prevent it from entering the atmosphere and adding to the impact of global warming.

During this activity, you will be investigating the chemical reaction between compounds called amines and CO_2 gas. You will be simulating some aspects of the research and development currently being undertaken to find the best systems to capture the massive amounts of CO_2 being released into the atmosphere. You will make comparisons between two different amines and decide which one might be best for the carbon capture process.

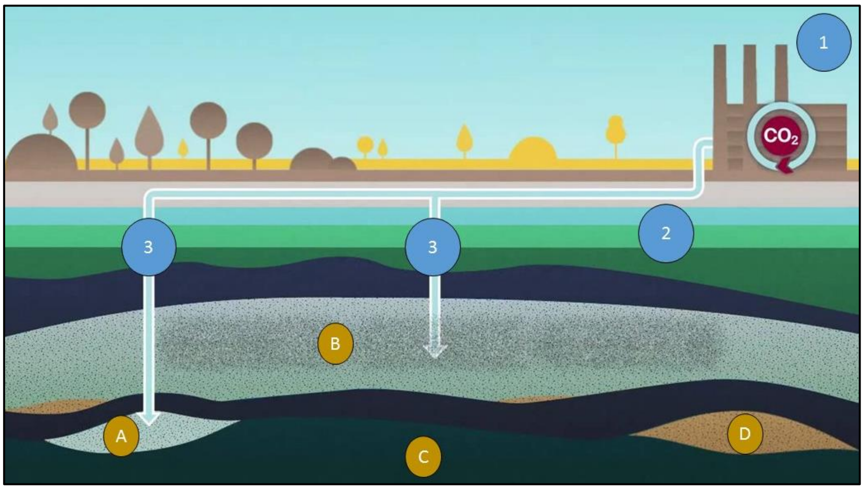
The test system will be a plastic water bottle containing water and CO_2. The CO_2 atmosphere in the bottle can be produced by using carbonated (sparkling) water that has been shaken in the bottle to release the gas. Inserting a rubber bung called a Suba seal closes the bottle and creates a sealed environment. This seal also allows amine samples to be injected into the bottle without losing the CO_2 gas inside.

Spotlight on Carbon Capture & Storage

Carbon Capture and Storage (CCS) is the process of capturing CO_2 generated from industrial processes, transporting it and then storing it in an appropriate vessel.

What does Carbon Capture & Storage do?

Industrial settings such as power stations and manufacturing plants are one of the biggest contributors to global CO_2 emissions and as a result global warming. But what if this CO_2 could be caught at the source before it got released into the atmosphere? CCS does exactly this! CCS is the name for the process that captures the gases that result from burning fossil fuels, separates out CO_2 from other gases, and transports it to a storage unit. The diagram below illustrates the whole process:



1. Fossil fuels are burnt in industrial plants, releasing CO2 that is separated from the other gases and captured
2. Captured CO2 transported via pipelines to storage site
3. CO2 injected into suitable storage site such as deep (A) water aquifers, (B) depleted oil and gas reservoirs, (C) salt beds or (D) unmined coal beds

The carbon capture and storage process
Image modified from: https://i.ytimg.com/vi/GglSLuWP5cM/maxresdefault.jpg

Methods of carbon capture

Scientists are researching different methods to capture CO_2. One system that has been successful is using chemicals called amines to absorb the CO_2. This process results in both the amines and CO_2 being in a liquid state, which ultimately means they take up less space, and makes them easier to transport.

Public Opinion

Although some individuals think of CCS as a temporary solution until renewable energy sources are commonplace, others think that using CCS is just pushing the problem under the carpet and stopping companies investing in finding new cleaner energy technologies. There is also the problem of finding appropriate storage sites and securing them so no leakage occurs – to do this can be very expensive. There are also concerns that if CCS is not done properly then leaks will occur, leaching both CO_2 and other storage chemicals into the environment, which could be detrimental to both livestock and people.

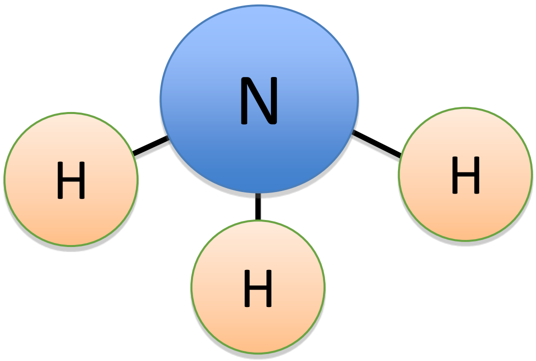
An energy cost is also associated with CCS: the machines that separate out the CO_2 from other gases use electricity to run; the lorries that transport the CO_2 require the use of petrol. The pumps that pump the CO_2 underground use electricity. These factors all mean that a power plant that has CCS technology has to spend approximately 20% of its energy usage on removing the CO_2 and storing it.

CCS doesn't eliminate the problem of CO_2 emissions, but it does provide a temporary solution. Hopefully one day, we won't burn fossil fuels therefore CCS won't be necessary.

About Amines

Amines are a family of organic molecules with some similarities to ammonia.

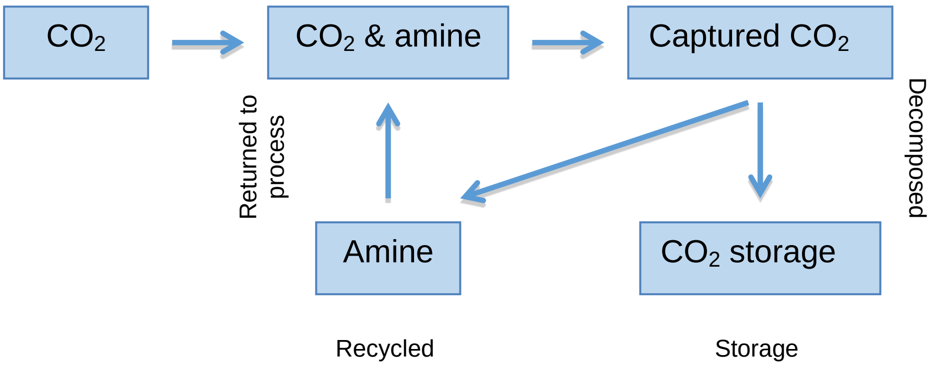
Ammonia molecules contain three hydrogen atoms linked to a nitrogen atom by a covalent chemical bond:



Ammonia produces an alkaline solution in water and so will turn universal indicator from green to blue.

If one or more of the hydrogen atoms in the ammonia molecule is replaced by a hydrocarbon chain the new molecule is called an amine. Amines also produce alkaline solutions in water but depending on the exact nature of the attached hydrocarbon chains, some are more soluble than others. Also, some are more alkaline than others in solution.

Amines have different reactivity with CO_2 in the carbon capture process. Scientists and engineers are trying to identify amines that both react with CO_2 at a good rate, and also give a reversible reaction so that the CO_2 can be released and stored away from the industrial process that generated it. The amine can then returned and reused to capture more CO_2.



Pumping CO_2 back into the underground wells (reservoirs) that originally produced the gas and oil is a potential location to store the gas, as are deep geological formations, or deep ocean water reservoirs. However storage solutions are a current area of research as there are concerns that CO_2 stored underground could leak out, thereby reversing the potential benefit of the whole capture and storage process.

Carbon Capture Experiment

Student worksheet

Equipment required per student

- Lab coats
- Safety glasses or goggles
- Nitrile gloves
- Optional - video camera or camera phone (to be used by a designated operator who is not in contact with the chemicals)

Kit per pair

- 2 empty plastic water bottles (500 cm^3)
- 2 rubber suba seals
- 300 cm^3 chilled carbonated water
- Marker pen

Chemicals – inform your teacher when you require these

- Syringe containing monoethanolamine (MEA)
- Syringe containing dimethylethanolamine (DMEA)
- Universal Indicator

Procedure

1. Gather the equipment you need from the list provided

2. Measure out 150 cm^3 of carbonated water and add this amount to each of your two plastic bottles. Each bottle should be about a quarter full

3. Give the bottles a slight shake in order to release the CO_2 gas from the carbonated water. The water should effervesce (fizz) when you do this

4. Add about 5-7 drops of universal indicator solution to each bottle and note down the colour change. What does this tell you?

5. After about 20 - 30 seconds, insert the suba seals into the neck of each bottle and fold the sides over to create an air-tight seal

6. Label one bottle MEA and the other bottle DMEA

7. You will be provided with 5 cm^3 of each of the amines (MEA and DMEA) in a syringe. A blunt needle will be attached to the top of each syringe so take care when handling them; the needle will be covered by a removable sheath/shield that should be removed ONLY when you are ready to start the experiment

8. Hold the bottle firmly, and carefully (watch the tip of the needle!) insert the needle through the suba seal and once firmly through the rubber seal, push the contents of the syringe into the bottle. Do the same for the other amine in the second bottle

9. Remove the needle and syringe from the suba seal and immediately give it to a

member of staff who will dispose of it in a sharps bin **(DO NOT remove needle from syringe or re-sheath the needle!)**

10. Give the bottle a little shake to start the reaction and observe! Describe what you see happening

11. Compare the reactions for the two different amines. What factors might you compare? What differences do you observe? You could take a video of the reaction to help with this

Do not open the bottles at the end of the experiment

Document your observations here: