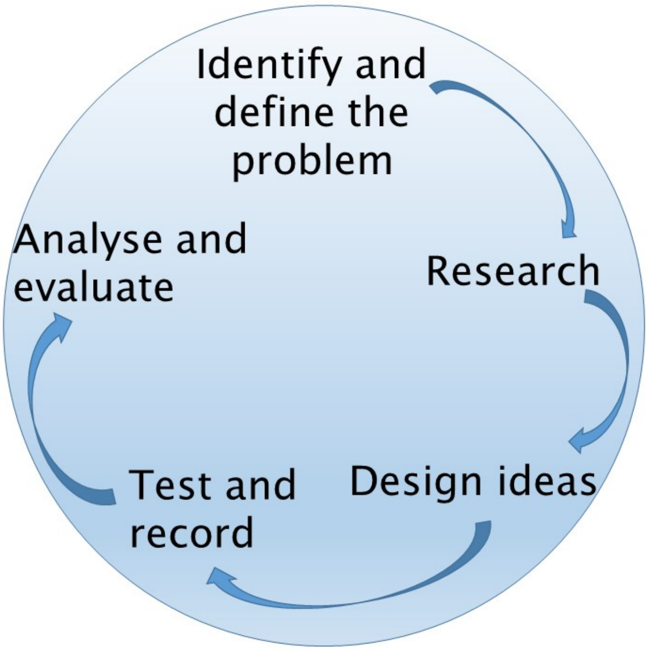
CCUS – Student Booklet

The Challenge

In a world where our understanding of the impacts of carbon dioxide (and other greenhouse gases) on our climate is expanding but our demand for energy is higher than ever, it is vital that energy production becomes more efficient and environmentally friendly. While there are renewable sources of energy, many of these are still expensive and/or inefficient. This means that for the foreseeable future, fossil fuels will play a role in our energy mix.
One of the key ideas to minimise the amount of carbon dioxide, associated with fossil fuels, being released to the atmosphere is through using carbon capture utilisation and storage (CCUS) methods.
Your job is to investigate the advantages and difficulties of CCUS and try to come up with a solution to minimise carbon release into the atmosphere.



Background Information

Carbon dioxide is a greenhouse gas in our atmosphere. There are many ways in which carbon dioxide can enter the atmosphere including; respiration of living things, volcanic eruptions, and in the production and burning of fossil fuels. Since the industrial revolution, the amount of carbon dioxide released into the atmosphere has increased (Figure 1), and climate scientists attribute much of this increase to the burning of fossil fuels to produce energy.

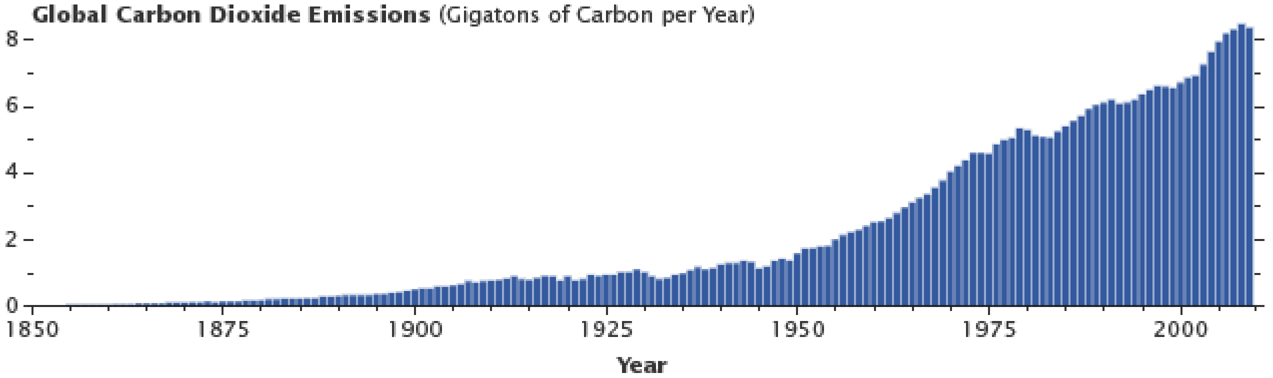


Figure 1. Global carbon dioxide emissions (gigatons of carbon per year) (Earth Observatory, 2011).

Carbon dioxide plays a vital part in the greenhouse effect, as illustrated in Figure 2. Without the greenhouse effect the Earth would be too cold to support life as we know it (like Mars) but higher levels of greenhouse gases can make a planet too warm (like Venus). Having the right amount of greenhouse gases in the atmosphere is vital to the survival of life on Earth. The increase in the amount of carbon dioxide in the atmosphere has been linked to an increase in global temperatures, which is causing polar ice to melt and sea levels to rise, among other problems.

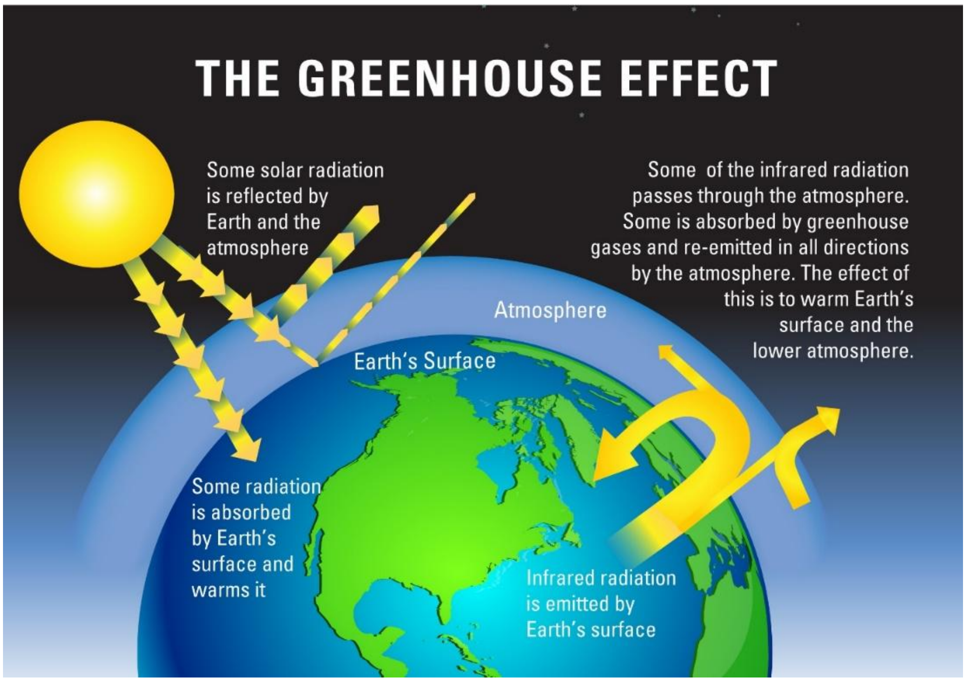


Figure 2. The greenhouse effect helps to keep the planet warm, but higher levels of greenhouse gases can lead to too much heat energy being trapped, causing an increase in global temperatures (The Royal Society, 2019).

The carbon cycle is a natural, global cycle which, when in balance, allows life on Earth as we know it to thrive. One of the largest carbon sinks is the ocean, which removes carbon dioxide from the atmosphere. It currently absorbs about one third of the carbon dioxide released by the burning of fossil fuels (NOAA, 2017). When carbon dioxide absorbs into the ocean its pH levels decrease, this is known as acidification. Acidification of the oceans has been linked to coral bleaching and thinning of shells of marine organisms, which in turn has destroyed some marine ecosystems.

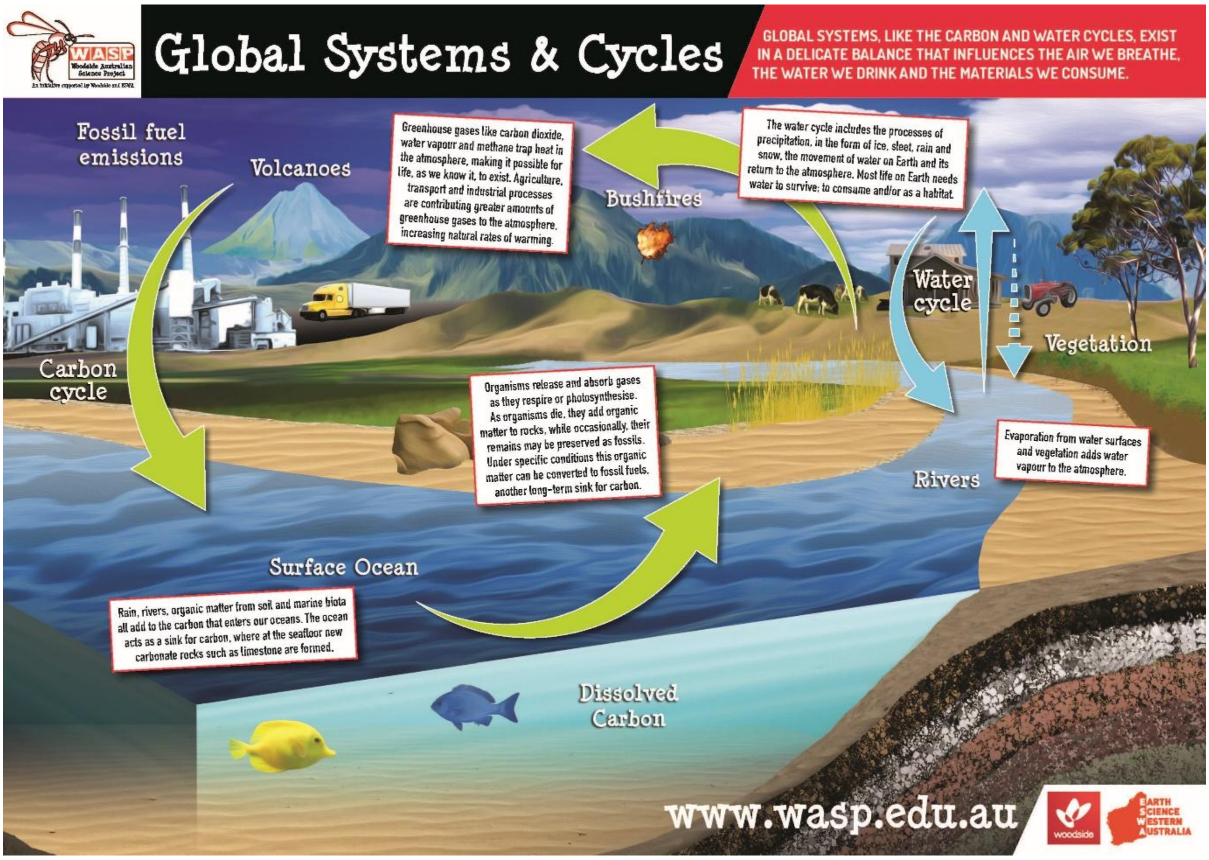


Figure 3. The carbon cycle has natural and manmade inputs. The ocean is a major sink for carbon.

As a global priority, industry and government are investigating how to minimise the amount of carbon dioxide which is released into the atmosphere through human activities. There are some companies using carbon capture and storage methods, however, at present this is very costly. Companies who aim to be both more environmentally friendly and economically competitive are investing in research to look at means of using the carbon dioxide, these processes are known as Carbon Capture, Utilisation and Storage (CCUS).

Science
Technology
Engineering and
Mathematics

Background Research

1. What are some of the industrial uses for carbon dioxide?

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2. Why aren't all of the carbon dioxide emissions from power plants used for industrial purposes?

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3. Explain the following different ways of capturing carbon and describe the pros and cons of each process.

Name	Method	Pros	Cons
Pre-combustion capture			
Post-combustion capture			
Oxy-fuel combustion			

4. Fill in the table below for three locations where carbon capture is being conducted.

Location	Carbon capture capacity (millions of tonnes/annum)	Year opened or expected to open

5. Draw and label an ideal location to store carbon dioxide, include the key words: porous, and permeable and name any geological structures, such as fault or folds.

6. Without considering cost, what are some of the reasons that carbon capture utilisation and storage (CCUS) methods are not used at all power stations?

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7. What is enhanced oil recovery? Draw and label diagrams to aid your explanation.

8. What are some of the effects of climate change, and possible outcomes in the future?

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Science
Technology
Engineering and
Mathematics

Enhanced Oil Recovery

Objective

To model the process of enhanced oil recovery (EOR) and relate this to its suitability for carbon utilisation and storage.

Equipment

- 2 x conical flasks
- 2 x bungs/stoppers with two holes in them
- 3 x delivery tubes
- Calcium carbonate powder
- Dilute hydrochloric acid in dropper bottle and a syringe
- Beaker
- Safety glasses

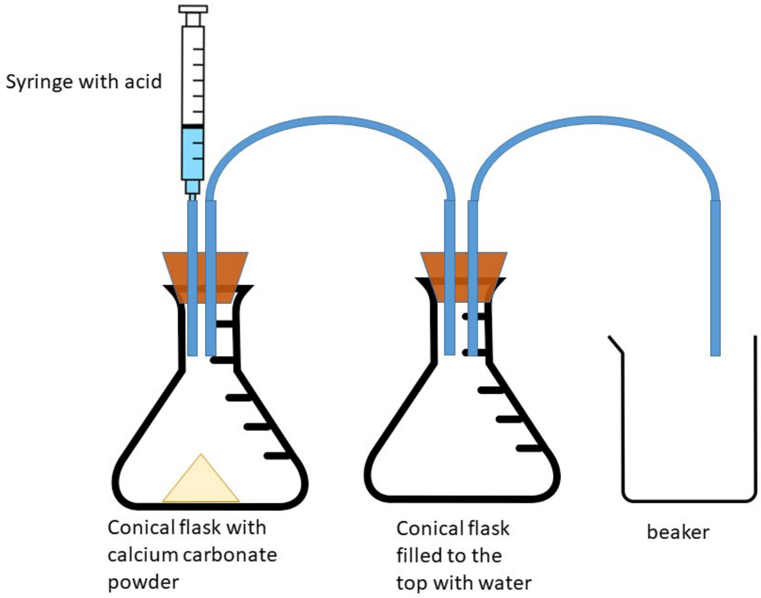

Figure 4. Experimental set up for enhanced oil recovery model

Method

Using the equipment list and diagram above develop a safe method to model enhanced oil recovery. Gain teacher approval before conducting your experiment.

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Results and Analysis

1. Describe what happened in the experiment.

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2. What were the strengths and weaknesses of your method?

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3. How much “oil” did you recover? (How much water was pushed into the beaker?)

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4. How could you increase the speed and volume of “oil” recovery?

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5. Explain what each stage in the model represented in relation to EOR.

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6. What were the reactants in the experiment?

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7. What were the products in the experiment?

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8. Write a word equation to show the chemical reaction that occurred in the experiment.

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9. Instead of using the dilute acid to react with the calcium carbonate a student suggested they lit an oil burner under a funnel and collected the gas from the burning of the oil.
   a) What are the strengths of this suggestion in relation to demonstrating enhanced oil recovery?
   b) What are the weakness of this suggestion in relation to classroom safety?

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10. What suggestions can you make to improve the model so that is more realistic, but also safe?

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Science
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Mathematics

Investigating the Effect of Carbon Dioxide on the pH of Water

Objective

To determine the relationship between the amount of dissolved carbon dioxide in water and the pH of the water. Then use this information to highlight any challenges in designing carbon capture utilisation and storage (CCUS) systems.

Hypothesis

As the amount of dissolved carbon dioxide increases, the pH of the water will____________.

This is because ____.

Equipment

- 2 x conical flask
- 2 x bungs/stopper
- Length of delivery tube
- Marble chips
- Dilute hydrochloric acid
- Universal indicator/pH probe
- Measuring cylinder
- Weighing scales
- Safety glasses

Method

1. Half fill a conical flask with water and add a few drops of Universal indicator (or use a pH probe to determine the pH of the water).
2. Stopper this flask with a bung/stopper with delivery tube in it.
3. Zero the weighing scales and place the other conical flask on them.
4. Add 5g of marble chips to the conical flask and remove it from the scales.
5. Use the measuring cylinder to collect 10 mL of dilute hydrochloric acid and add this to the marble chips (Note: 10 mL = ~10g).
6. Quickly place the other bung/stopper with delivery tube into the top of this flask to ensure all the gas passes through into the water.
7. Watch the reaction takes place and note the pH of the water once it is complete (bubbling has stopped). Add this to the table.
8. Use the scales to find the mass of the conical flask with the reactants (acid and marble chips) in after the reaction and add to the table.
9. Repeat the experiment using an increased amount of chips and acid each time (as per the results table), so that you are increasing the amount of carbon dioxide produced each time.

Draw a diagram to represent how you will set up this experiment.

Results and Analysis

1. What was the pH of the water before the carbon dioxide was added?

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2. Complete the table below with your results.
   Note: The total mass of carbon dioxide produced can be found by subtracting the final mass from initial mass of the flask and reactants.

Volume of HCl (mL) 1 mL = ~1 g	**Mass of calcium carbonate chips (g)**	**Total initial mass of conical flask and contents (g)**	**Total final mass of conical flask and contents (g)**	**Mass of Carbon Dioxide produced (g)**	**pH of water after experiment**
10	5				
15	10				
20	15				
25	20				

3. Collect results from the rest of your class to work out averages for each trial.

4. Plot a graph to show the relationship between the mass of carbon dioxide produced (x-axis) and the pH of the water (y-axis).

5. If your line of best fit is a straight line, find the gradient of the line: _______________

6. Describe the relationship between the amount of dissolved carbon dioxide and the pH of the water.

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7. Does an increasing amount of dissolved carbon dioxide make water more acidic or alkaline?

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8. What effects might adding carbon dioxide to liquids have on the equipment and the rocks used for carbon capture and storage, and why does this cause design challenges for CCUS systems?

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Evaluation

1. Were there any potential sources of error in your investigation?

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2. Were there any outliers or anomalous results? If so, what do you think might have caused them?

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3. How could you improve this investigation?

4. Outline any ideas you have to investigate the relationship between concentration of dissolved carbon dioxide and pH of water further.

Investigating the Effects of Acid on Materials

Objective

To investigate how different metals and rocks react to acid. Then relate your findings to the design of suitable methods for transporting and storing carbon dioxide.

Background Information

Adding carbon dioxide to water increases its acidity (see ocean acidification). To assist with appropriate design, it is vital that engineers designing carbon capture utilisation and storage (CCUS) models are aware of how different materials will react to acidic water. Using pipeline materials which are easily corroded will result in ongoing need for replacement, making them costly. Storing carbon dioxide underground, within and around the wrong type of rock, could lead to it migrating upwards, entering freshwater aquifers or even the atmosphere. This defeats the point of burial. Therefore, it is vital that the scientists and engineers designing the CCUS processes understand the properties of materials involved.

Equipment

- Small samples of different types of metals
- Small samples of a range rock types (e.g. sandstone, limestone, marble, granite, basalt)
- Dilute hydrochloric acid
- A beaker for each sample
- Sticky labels and markers
- Small tongs
- Camera
- Weighing scales
- Safety goggles

Method

1. Label each beaker ready for the samples.
2. Measure out the same volume of acid into each beaker. Ensure that there is enough to cover the samples you will be using.
3. Take photos of the samples and weigh the samples on the scales, recording your results in the table.
4. Place each sample in its own beaker of acid (carefully) and note any reactions that occur in the observations table.
5. Leave the samples in the beakers until the next lesson. Ensuring you have stored them in a safe place.
6. During the next lesson safely remove the samples and dispose of the acid as directed by your teacher. Rinse and dry the samples then take photos of them and weigh them again on the scales – recording observations in the table.

Results and Analysis

Create your own table to capture your results and observations, adding photos (if possible).

1. Were any of the materials unaffected by the acid, if so which ones? Use data to support your answer.

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2. Which materials were the most affected? Use data to support your answer.

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3. Calculate the percentage of mass lost for each sample during this experiment (final mass/initial mass x 100).

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4. Why is finding the percentage mass lost more useful than just looking at change in mass?

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5. Did any of the samples lose mass, if so, which ones and what does that suggest?

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6. Did any of the samples gain mass, if so, which ones and what could that suggest?

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7. Would there be any issues with using the least reactive materials in the process of transporting and storing carbon dioxide (cost, weight etc.)?

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Evaluation

1. Were there any potential sources of error in your investigation?

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2. How could you improve this investigation?

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3. Outline any ideas you have to investigate the reactivity of materials that might be involved in CCUS further.

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Investigating the Effect of Temperature on Solubility of Carbon Dioxide

Objective

To investigate the relationship between the temperature of a liquid and solubility of carbon dioxide gas. Then relate this to storing carbon dioxide at depth in saline aquifers.

Background Information

A method currently under investigation for trapping carbon dioxide is by injecting carbon dioxide gas into saline aquifers deep below ground. It will then dissolve into the brine (salty water) and eventually react to form precipitates, such as calcium carbonate. Injection needs to occur at a depth of 800-2000 metres to ensure that the carbon dioxide does not contaminate any freshwater aquifers. As you move deeper underground temperature increases, this is known as the geothermal gradient. The average geothermal gradient is 25^{0}C per kilometre, which means for every kilometre you go below ground the temperature increases by 25^{0}C. It is important to know how temperature affects the solubility of carbon dioxide as the deeper the aquifer the higher the temperature will be.

Hypothesis

As the temperature of the water increases the amount of dissolved carbon dioxide will

_____________________. This is because ____.

Equipment

- Boiling tube or a large test tube
- Delivery tube with flexible hose in bung
- Dilute hydrochloric acid
- Marble chips
- Thermometer
- Ice cubes
- Ice cream tub
- Scales
- 2 x 100 mL measuring cylinder
- Beehive shelf (if available)

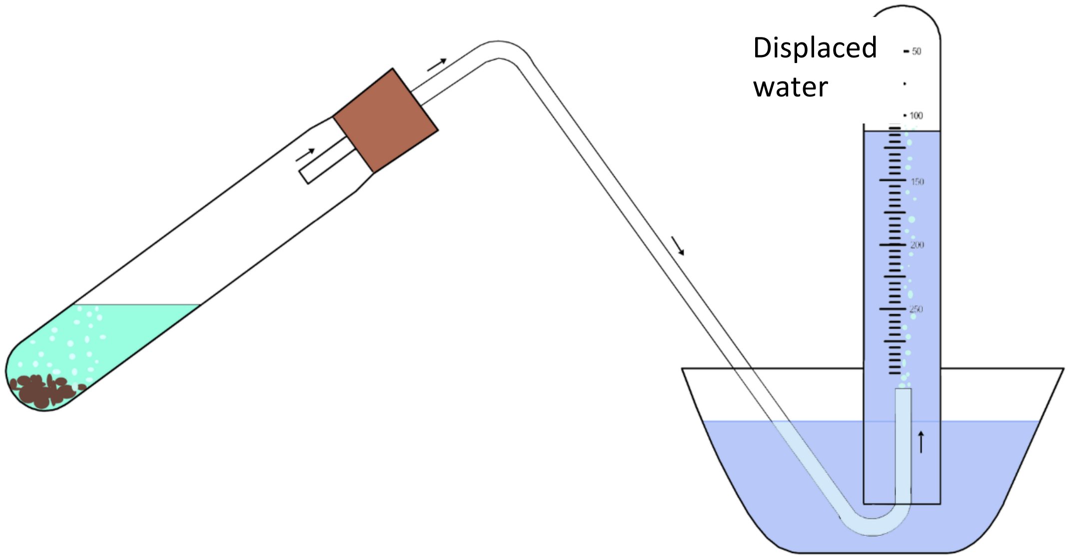

Figure 5. Set up of experiment, delivering the carbon dioxide into the water of different temperatures and measuring how much has been displaced.

Method

1. Fill the ice-cream container with 750 mL water.
2. Fill one of the measuring cylinders with water then invert it under the surface of the water in the ice-cream container so the cylinder remains full. Insert the flexible hose attached to the delivery tube into the bottom of the upturned measuring cylinder.
3. Measure the temperature of the water and record this in your results table.
4. Weigh out 5g of calcium carbonate chips and add them to the boiling tube/large test tube.
5. Measure out 50 mL of dilute HCL (using a measuring cylinder) and add this to the boiling tube/large test tube with the calcium carbonate chips in it.
6. Quickly put the bung into the top of the boiling tube/large test tube. The calcium carbonate will start to react with the hydrochloric acid, releasing carbon dioxide gas which will travel along the delivery tube (make sure your seals are tight). The carbon dioxide will then dissolve in the water in the upside-down measuring cylinder. Note: Any gas which does not dissolve will displace (push out) the water in the upside-down measuring cylinder).
7. When the reaction has stopped (no more bubbles are being produced), measure how much water has been displaced in the upturned measuring cylinder and record your results in the table.
8. Repeat the experiment changing the starting temperature of the water at least three times (you can add the ice to make it really cool).
   Note: Be careful handling hot water, do not make it so hot that it burns.

Results and Analysis

1. Create a results table to capture your own data and that of your class. Use this information to work out average results.

2. Use the averages to plot a scatter graph with temperature on the x- axis and displaced water on the y- axis. Disregard any anomalies to create a line of best fit.

3. If your line of best fit is a straight line, find the gradient of the line: _______________.

4. What is the relationship between the temperature of the water and the volume of water displaced?

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5. What is the relationship between the temperature of the water and the amount of gas dissolved? (Remember if more gas has dissolved then less water will have been displaced).

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6. Considering the geothermal gradient, could more or less gas be dissolved in a deeper aquifer? Use your data to justify your answer.

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For consideration:

7. If global temperatures continue to increase, will that make it easier or harder for oceans to trap the carbon dioxide from the atmosphere and what does that mean in terms of the rate of global warming?

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Evaluation

1. Were there any potential sources of error in your investigation?

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2. How could you improve this investigation?

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3. Outline any ideas you have to investigate how the geothermal gradient may impact CCUS methods further.

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Investigating the Effect of Pressure on the Solubility of Carbon Dioxide

Objective

To investigate the relationship between pressure and the solubility of carbon dioxide. Then relate this to carbon storage at depth.

Background Information

A method currently under investigation for trapping carbon dioxide is by injecting carbon dioxide gas into saline aquifers deep below ground. It will then dissolve into the brine (salty water) and eventually react to form precipitates, such as calcium carbonate. Injection needs to occur at a depth of 800-2000 metres to ensure that the carbon dioxide does not contaminate any freshwater aquifers. As pressure increases with depth, it is important that engineers are aware of the effect of pressure on dissolved gas and can model how much gas can be dissolved at certain depths below Earth's surface.

Equipment

- 2 x beakers
- Syringe with cap (Blu tac or plasticine could be used)
- Bromocresol green or methyl red indicator and colour chart
- Stirring rod
- Soda/carbonated water
- Tap water

Method

1. Fill one beaker with soda water and the other beaker with tap and add a few drops of indicator, stir with a rod and note the pH of the water by comparing to the supplied colour chart.
   How does the pH of carbonated water compare to the pH of tap water? Does adding carbon dioxide (carbonated) to water make it acidic or alkaline?

   ____

2. Suck up 10mL of the soda water from the beaker into the syringe and put the cap on it.
3. Pull the plunger back slowly, 5mL at a time, reducing the pressure on the liquid, and note any observations, such as colour and amount of bubbles.
4. Try to match the colour of the liquid to the colour chart to determine the pH of the soda water and record this in the table.

Results and Analysis

1. Create a table for your results and observations.

2. If possible (*depending on how clear your colour change was*) create a scatter graph with pH on your y – axis and volume on the x – axis, adding a trend line.

3. What is the relationship between the volume of water and gases in the syringe and the pH of the soda water?

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4. As the volume in the syringe increased what happened to the pH of the soda water?

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5. What is the relationship between pressure and volume? Was the pressure increasing or decreasing as you increased the volume in the syringe?

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6. What is the relationship between pressure and the pH of the soda water?

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7. The more carbon dioxide dissolved the more acidic the water is therefore, what is the relationship between pressure and the solubility of dissolved carbon dioxide?

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8. Considering your results, will carbon dioxide dissolve better in an aquifer that is 1,000 m underground or 2,000 m underground? Use your data to support your answer.

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Evaluation

1. Were there any potential sources of error in your investigation?

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2. How could you improve this investigation?

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3. Outline any ideas you have to investigate the impact of pressure on the solubility of carbon dioxide.

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Investigating the Effect of Salinity on the Solubility of Carbon Dioxide

Objective

To determine the relationship between the salinity of a solution and the amount of carbon dioxide it can dissolve. Then relate this to proposed carbon capture utilisation and storage (CCUS) methods.

Background Information

A method currently under investigation for trapping carbon dioxide is by injecting carbon dioxide gas into saline aquifers deep below ground. It will then dissolve into the brine (salty water) and eventually react to form precipitates, such as calcium carbonate.

Equipment

- An ice cream tub
- 2 x measuring cylinders
- Water
- Salt
- Teaspoon
- Stirring rod
- Boiling/large test tube
- Bung/stopper with delivery tube in it and flexible hosing attached
- Marble chips
- Dilute hydrochloric acid
- Weighing scales
- Beehive shelf (if available)

Draw a diagram to represent how you will set up this experiment.

Method

1. Fill the ice cream tub with 500 mL of water.
2. Keep adding salt to the water, one spoonful at a time stirring each in. Count how many teaspoons you had to add until it became saturated (no more salt will dissolve), creating a saline solution. Record the number in the table below.
3. Fill a measuring cylinder with the saline solution then invert this cylinder under the surface of the water in the ice cream container so it remains full. Rest the cylinder on the beehive shelf, if available, if not, hold the cylinder upright and insert the tubing.
4. Measure out 20mL of hydrochloric acid and pour this into the boiling/large test tube.
5. Weigh out 15g of marble chips and add this to the hydrochloric acid in the boiling/ large test tube – quickly inserting the bung/stopper into the top and collecting the gas in the inverted measuring cylinder.
6. When the reaction is complete (no more bubbles are being released) measure how much of the saline solution in the measuring cylinder has been displaced and record this in your table.
7. Repeat the experiment, reducing the amount of salt added to the ice cream tub by one spoonful each time, ensuring you record how much water was displaced.

Results and Analysis

Create a table for the results and observations of your group and of your class (to calculate averages).

1. Plot average results as a scatter graph, with amount of salt added on the x-axis and the volume of solution displaced on the y-axis.
2. If your line of best fit is a straight line, calculate the gradient of the line: __________.
3. Was there a relationship between the volume of salt added and the amount of saline solution displaced?

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4. Which solution was able to dissolve the most carbon dioxide?

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5. Do your results indicate that it is a good idea to store carbon dioxide in saline aquifers? Explain your answer using your data to justify your conclusions.

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Evaluation

1. Were there any potential sources of error in your investigation?

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2. How could you improve this investigation?

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3. Outline any ideas you have to investigate the impact of salinity on the solubility of carbon dioxide.

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Selecting Rocks

Objective

Investigate the properties of different rocks to determine their suitability for carbon storage.

Background Information

Common sites for carbon storage are depleted oil and gas reservoirs and deep, un-mineable coal seams.

This is because they often have the two main geological characteristics which are desirable for a carbon storage site:

- Rocks which are porous and permeable allowing the carbon dioxide to be injected into them and to spread throughout the formation so that it can be filled.
- A cap rock which is not permeable and will prevent carbon dioxide migration upwards.

Equipment

- A range of rock samples (about the size of the palm of your hand will work well)
- 1 x 500 mL beaker for each rock sample to be tested
- 1 x gauze mat for each rock sample to be tested
- 1 x large ball of plasticine for each rock sample to be tested
- 1 x measuring cylinder

Method

Write a method to determine the permeability of the rock types using the equipment listed above. Draw a diagram to show experimental set up. Show this to your teacher to gain approval before conducting the investigation.

Results and Analysis

Create a table for the results and observations of your group.

1. Define the following terms, in relation to rocks:
   a. Porous ____
   b. Permeable ____
   c. Impermeable ____
2. Were any of the rock samples very permeable? Use your results to support your answer.

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   ____
3. Were any of the samples impermeable? Use your results to support your answer.

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4. Were any of the samples porous but not permeable? Use your results to support your answer.

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5. Were any of the rock types suitable to act as a storage rock, allowing the carbon dioxide to be injected and spread throughout them?

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6. Were any of the rock types suitable to act as a cap rock, to prevent the carbon dioxide from migrating upwards?

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7. Long periods of time are required for injected carbon dioxide to dissolve into brine in saline aquifers. Due to density differences the carbon dioxide will float on top of the brine and push up against the caprock – this causes an uplift pressure on the caprock. It is therefore vital that the rocks will not fracture with this increased pressure. *Were any of the rocks impermeable, but had the potential to split or fracture easily if there was a lot of pressure on them – thus making them unsuitable as a cap rock?*

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Evaluation

1. Were there any potential sources of error in your investigation?

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2. How could you improve this investigation?

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3. Outline any ideas you have to investigate the porosity and permeability of rocks to determine their suitability for carbon storage further.

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Mineral Trapping

Part 1 - Research

Objective

Research how minerals might play a role in the storage of carbon and discuss the difficulties of the processes involved. Then investigate the formation of calcium carbonate through experimentation.

Background Information

One of the main advantages of carbon capture utilisation and storage (CCUS) is that the carbon dioxide gas dissolves into brine or reacts with the surrounding rock, forming carbonate minerals. Therefore, it is trapped as a solid which reduces the risk of carbon dioxide leaking and entering the atmosphere.

Research Questions

1. Provide three examples of carbonate rocks

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2. Write a word and a chemical equation for the formation of calcium carbonate.

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3. Recent studies in Iceland on the CarbFix project, have shown that the carbonation process can be accelerated when carbon dioxide is injected into basalts. Why are interactions with basalts to form carbonates more effective than with sedimentary rocks?

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4. What are some of the weaknesses of the CarbFix method, and why might it be difficult to do in Australia?

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Part 2 - Investigation

Objective

To investigate the formation of calcium carbonate through experimentation.

Equipment

- Boiling/large test tube
- Bung/stopper with delivery tube and flexible hose attached
- Marble chips
- Dilute hydrochloric acid
- 500 mL beaker
- Limewater
- Measuring cylinder
- Spatula

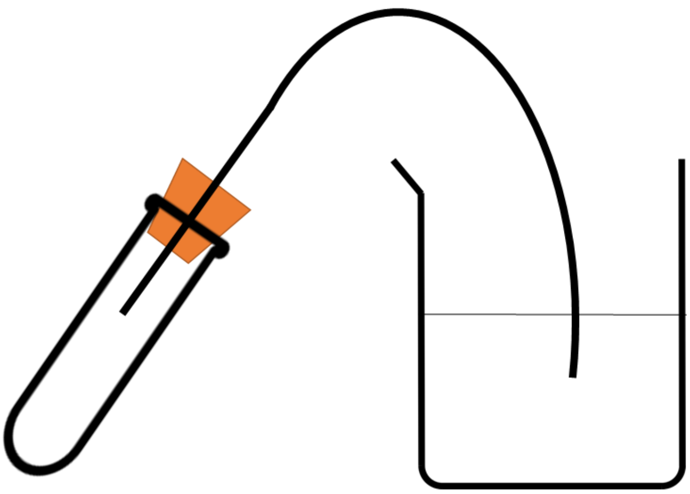

Figure 6. Passing carbon dioxide through limewater to create calcium carbonate precipitate.

Method

1. Place two spatulas of marble chips into the boiling/large test tube.
2. Pour 300mL of limewater into the beaker.
3. Pour 20mL of hydrochloric acid into the boiling/large test tube and quickly insert the bung/stopper, placing the other end of the delivery tube into the beaker of limewater.
4. Record your observations.

Results and Analysis

1. What did you observe during the experiment?

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2. Write a word and chemical equation for the reaction that was occurring in the boiling/large test tube.

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3. Write a word and chemical equation for the reaction that was occurring in the beaker.

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Extension

Filter the calcium carbonate that precipitated from the limewater using a funnel and filter paper over a conical flask. Allow the calcium carbonate residue on the filter paper to dry out and then weigh the calcium carbonate you collected.

Using your results and considering the quantities of materials you used in this investigation determine how much of each reactant you should use to give you 5g of calcium carbonate.

Repeat the investigation using these quantities to test your calculations.

3D Models for Structural Trapping

Objective

To interpret seismic data to determine the best geological location to store carbon dioxide and to create a 3D model of that site.

Background Information

Choosing an area to store carbon dioxide can be complicated. Firstly, there must be two very different rock types on top of each other with the lower being porous and permeable (enabling it to hold the carbon dioxide gas) and the upper rock type impermeable (to prevent the carbon dioxide from migrating upwards). The deeper the site the less likely it is that carbon dioxide will leak and reach fresh groundwater aquifers or the atmosphere.

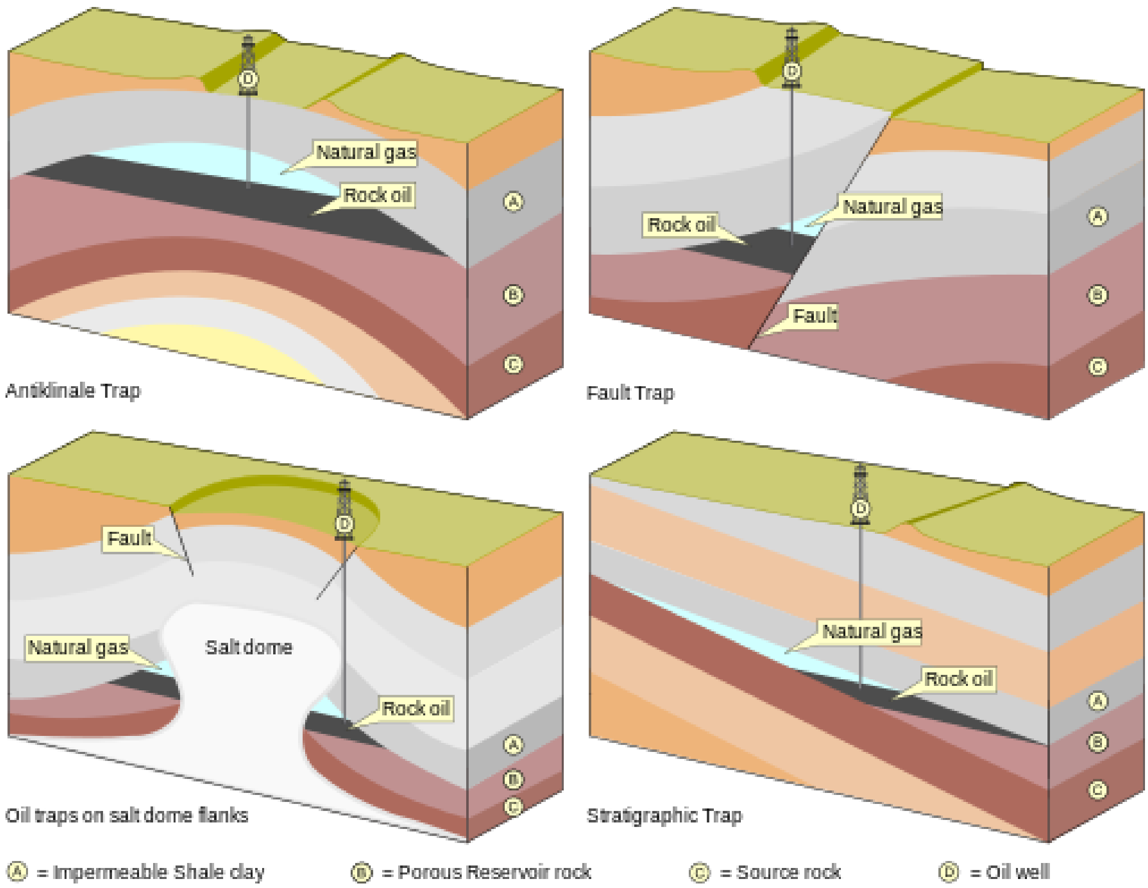


Figure 7. Often oil and gas reservoirs are considered good sites to store carbon dioxide - as they have already trapped oil and gas for millions of years prior to drilling. In these images, rocks types A and C and the salt dome are impermeable and B is permeable and porous, making them ideal geological structures for trapping gas (Wikimedia Commons, 2015).

To determine what is going on below the surface seismic studies are carried out. These result in images which geophysicists interpret to work out the rock types and structures that exist below the surface and ultimately determine the suitability of the area. Folds and faults in rocks occur when there have been compression or tensional forces acting on the rocks squashing them or pulling them apart. An anticline is a fold which bends upwards, these can make excellent traps if they contain the right rock types. Sometimes faults will move rock layers relative to each other (see Figure 7).

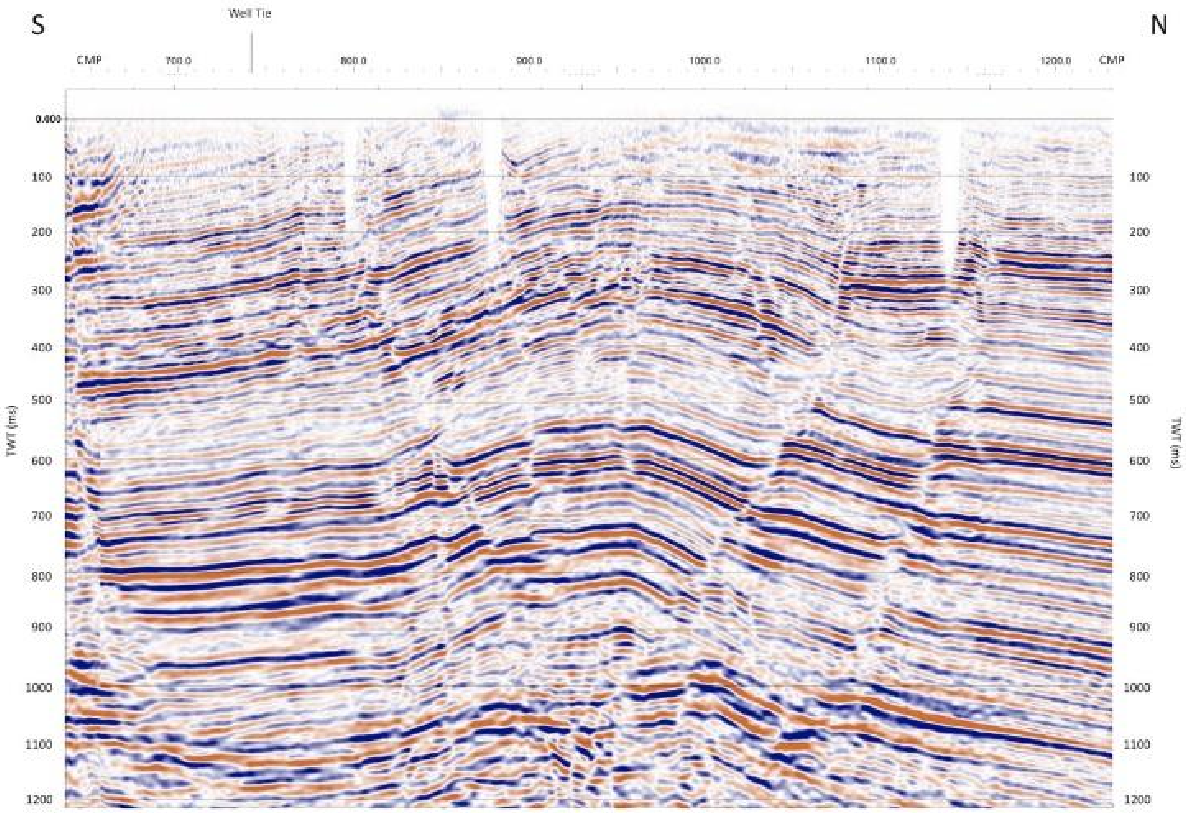


Figure 8. Seismic image - this area contains an anticline (fold) and some faults - can you pick them out? (Sub-Surf Rocks!, 2018)

Method

1. Draw and label the following geological structures:

Anticline	
Syncline	

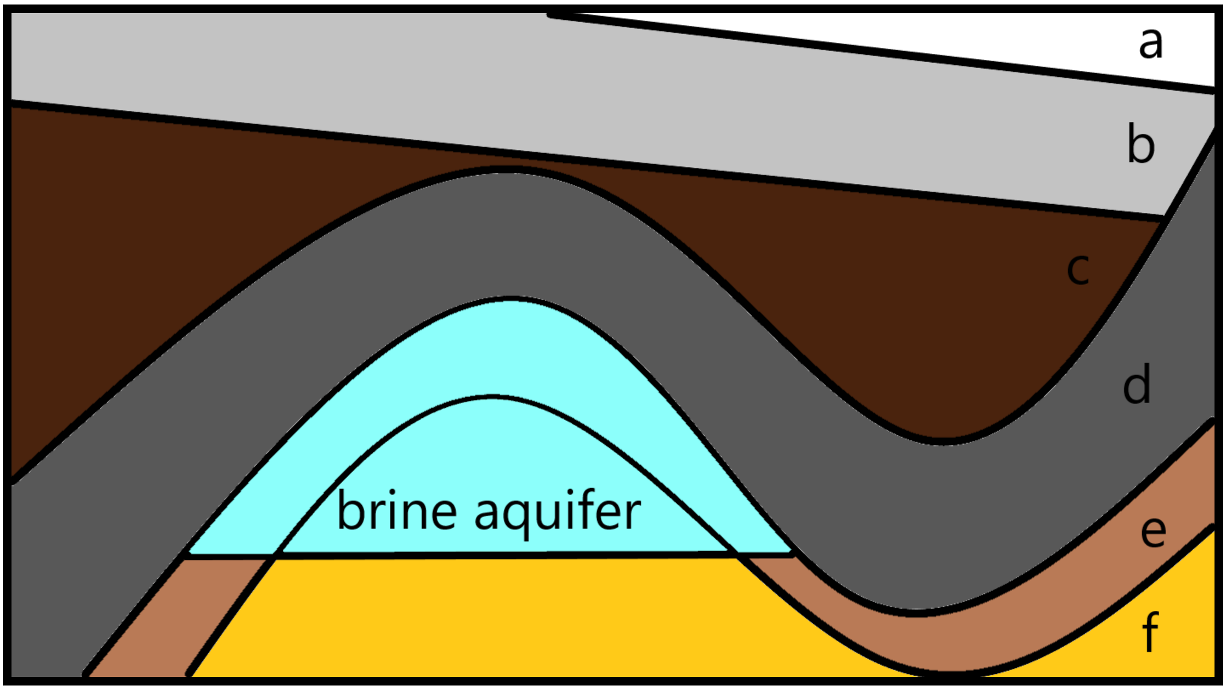
Normal Fault	
Reverse fault	

2. Explain how each trap in Figure 7 prevents gases from leaking and migrating upwards. (Hint: think about the rock types and use the terms impermeable, permeable and porous).

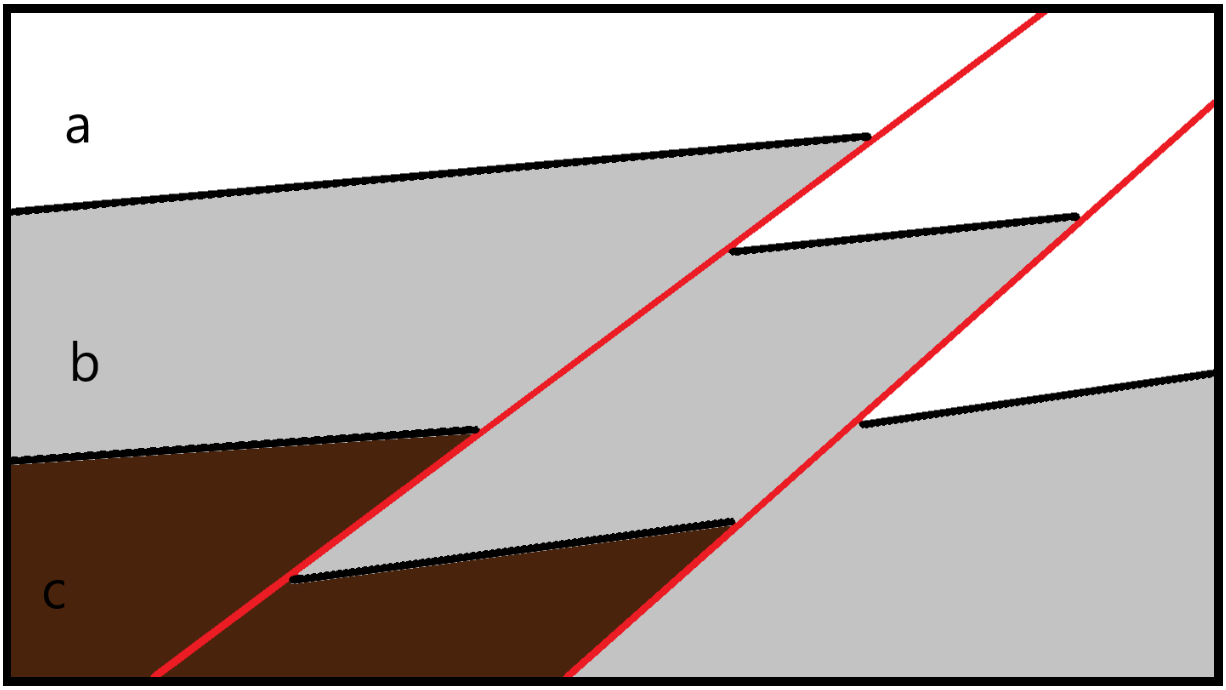
Anticlinal trap	
Fault trap	
Salt dome	
Stratigraphic trap	

3. Below are some geological structures which have been interpreted from seismic data. The red lines show faults. Some drilling has enabled the rock types to be determined:

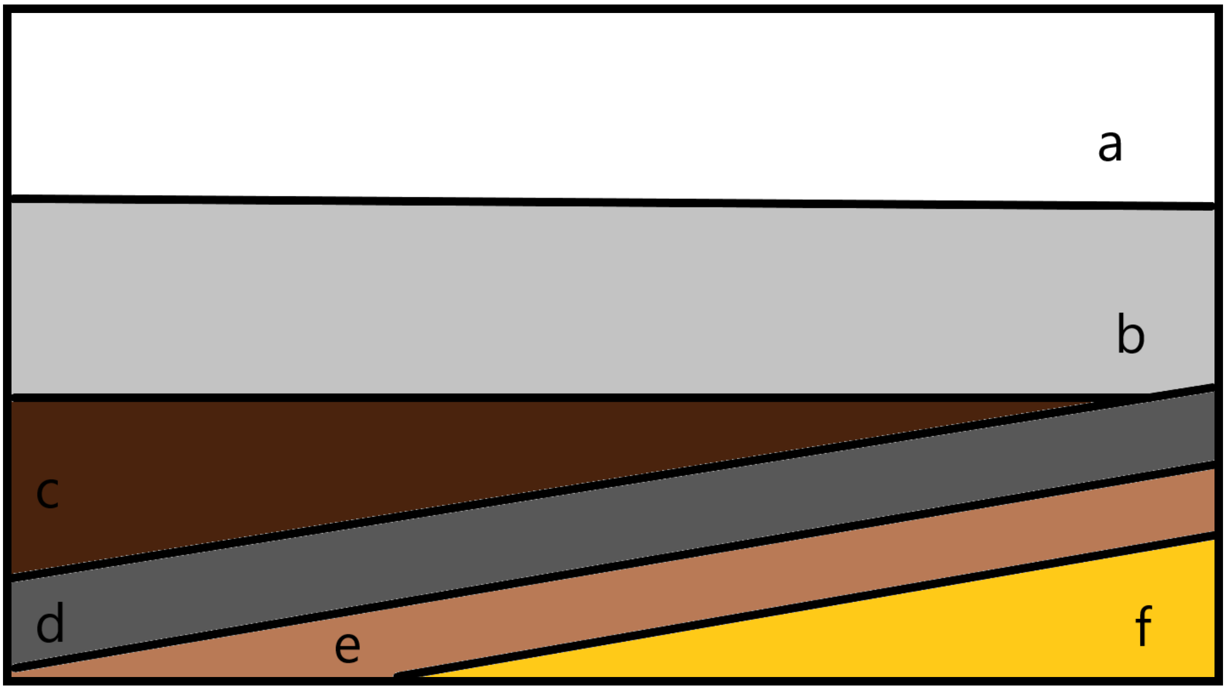
A	Impermeable quartzite	B	Impermeable porous basalt
C	Permeable sandstone	D	Impermeable shale
E	Porous and permeable mudstone	F	Porous and permeable limestone



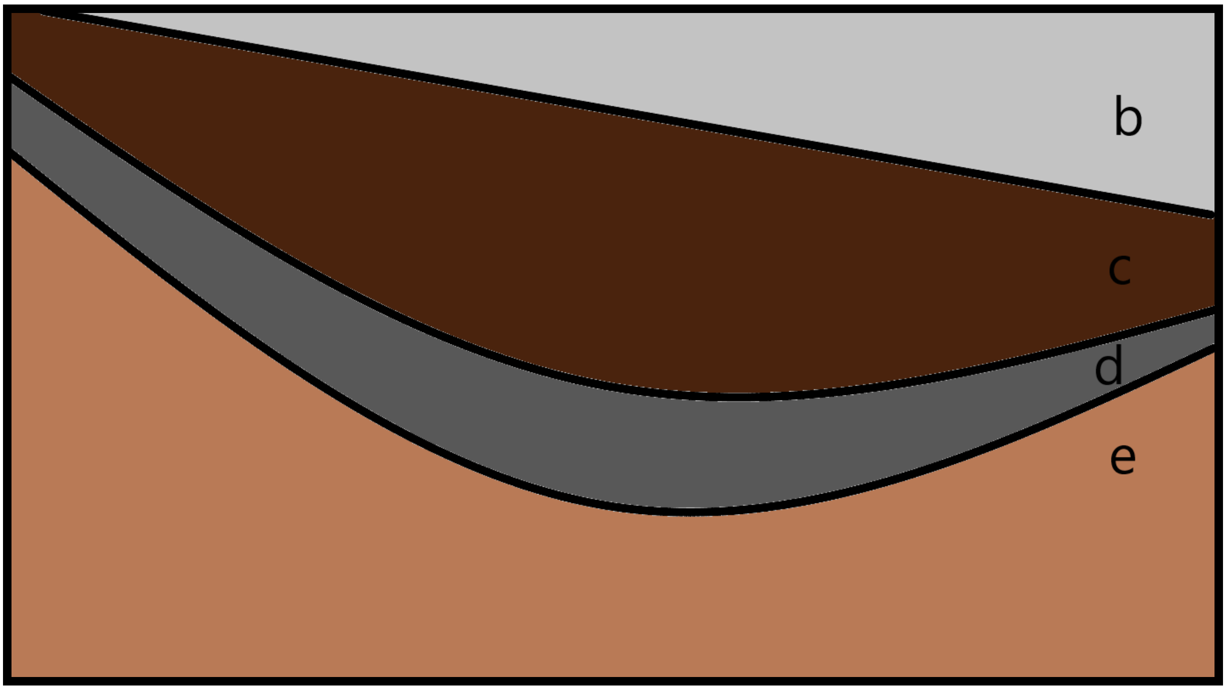
Site 1



Site 2



Site 3



Site 4

Using your knowledge and understanding of carbon storage methods discuss the pros and cons of each site and suggest if and where carbon could be injected.

	Site 1	Site 2	Site 3	Site 4
Pros				
Cons				
Where would you inject the carbon dioxide?				

4. Decide which site (from the four shown above) you would use to inject carbon dioxide in to be stored and create a model of the site to show how it could be safely stored.

CCUS – Student Booklet

Suggested Equipment

- Clear plastic food container
- Sand
- Salt
- Cleaning sponge
- Coloured water
- Plasticine
- Plaster of Paris
- Plastic

Explain how you will test your model.

____

____

Evaluation of Model

1. Was your model successful in preventing leakage? How do you know?

____

2. How well do you think your model compared to actual geological structures?

____

____

3. After making your model, do you still feel that the site you selected was suitable for storing carbon dioxide?

____

____

4. While making your model was there any other information that might have been useful?

____

____