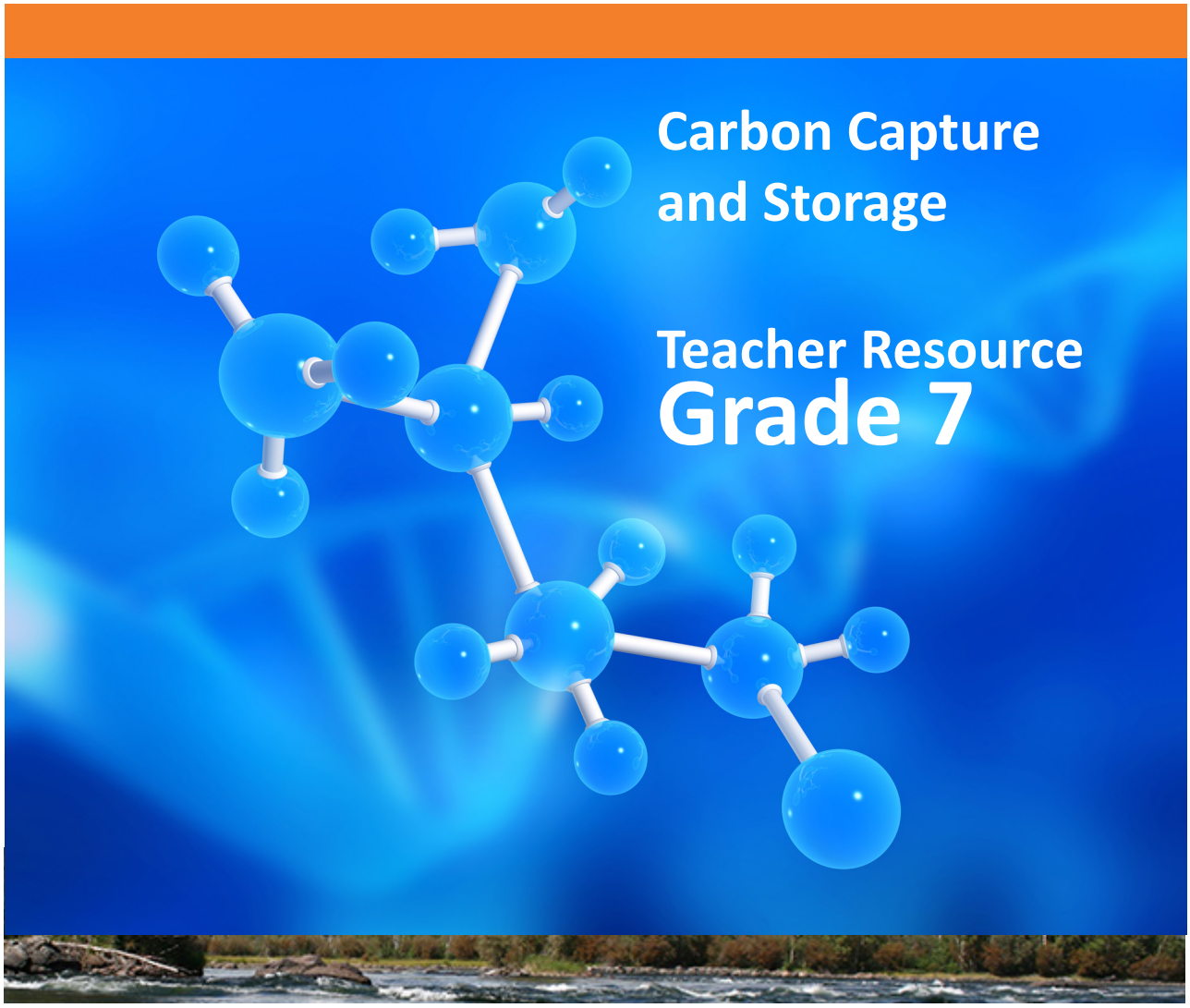

Carbon Capture and Storage

Teacher Resource
Grade 7

Produced by:

Regina Catholic Schools
www.rcsd.ca

Carbon Capture - Grade 7
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Grade 7 Authors	Paul Owens, St. Jerome School
	Christine Treptau, St. Gabriel School
Project Team	Heather Haynes, Miller Comprehensive High School
	Leah Maier, Archbishop M.C. O'Neill High School
	Elizabeth Stephenson, St. Mary School
	Mark Wernikowski, Archbishop M.C. O'Neill High School
Project Consultant	Donna Ell, Regina Catholic School Division

These materials have been externally peer reviewed by:

Kirsty Anderson, Global Carbon Capture and Storage Institute

Additional resources provided by:

Richland Community College

Commonwealth Scientific Industry Research Organization's (CSIRO)

SaskPower

THEME 1

Ecosystems - First Nations Perspectives

This section will be an opportunity for students to investigate how CCS connects with First Nations teachings by hearing from an Elder and a University Professor. In addition an exploration into how our actions impact the ecosystem will help students determine their ecological footprint.

Lessons developed in part by the Regina Catholic School Division provide outcome-based experiments and activities that align to the grade 7 science curriculum.

OUTCOME(S)

IE7.1 - Relate key aspects of Indigenous knowledge to their understanding of ecosystems.

IE7.4 - Analyze how ecosystems change in response to natural and human influences, and propose actions to reduce the impact of human behaviour on a specific ecosystem.

INDICATOR(S):

IE7.1 a) Gather information about traditional Indigenous practices with respect to the relationships and connections between people and their ecological environment.

IE7.4 g) Be sensitive and responsible in maintaining a balance between human needs and a sustainable environment by considering both immediate and long-term effects of their course of action or stated position.

BIG IDEAS

How does Carbon Capture and storage connect with First Nations teachings? 4 - 5

How do our actions impact the ecosystem? 6-10

THEME 1

Ecosystems - First Nations Perspectives

HOW DOES CCS CONNECT WITH FIRST NATIONS TEACHINGS

Activity - Work Sheet 1.0

Making Connections

OUTCOMES / INDICATOR (S)

IE7.1 (a), IE7.4 (g)

The Environmental Stewardship Unit works on a broad spectrum of international, national and regional/local environmental issues. The ESU has a mandate to conduct research, develop policy, and advocate on behalf of First Nations, in a manner consistent with the recognition of Aboriginal and Treaty Rights as they relate to environmental stewardship. Generally, the Unit pursues more specific initiatives to deal with fish, forestry, biological diversity and climate change, among other things. Improvements in the state of the environment will help to strengthen the health and well-being of First Nations communities.

The traditional philosophy of First Nations is centered on the holistic view that everything is interconnected. Humanity is part of the ecosystem. First Nation peoples live closer to the land and are more directly affected by environmental degradation than most other Canadians. First Nations recognize the link between the health of the environment and the health of their people. They have experienced the ravages of poor environmental stewardship first hand including contaminated lands, air, water, traditional foods and medicines.

From the broadest perspective, the work of the Environmental Stewardship Unit is described within the context of the four basic elements: EARTH, AIR, WATER and FIRE. A healthy environment means undertaking measures to protect these elements from the entry of any deleterious substance that could compromise their quality. A healthy environment also means that risks to human health are being effectively controlled; that the negative effects of exposure to harmful substances are minimized. First Nations' aspirations include relying upon traditional ways of life with the security that these activities pose no risk to health.

Many First Nations continue to assert that they have the responsibility to protect the environment for future generations. First Nation communities represent the youngest, fastest growing segment of the Canadian population. While the pursuit of economic opportunities for First Nations and others must be supported, this must be done in a way that retains a balance with the environment. Economic Lesson cannot come at the expense of environmental sustainability.

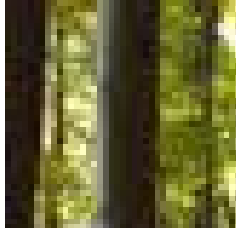
Assembly of First Nations

LESSON - 1.0

1) Watch video with Elder discussing First Nations beliefs about ethical use of environment and ecosystems.

2) Watch video "Carbon Capture and Storage at the University of Regina: Interview with Dr. Malcom Wilson".

3) Complete worksheet while watching the videos then discuss in small groups.



LESSON - 1.0

HOW DOES CCS CONNECT WITH FIRST NATIONS TEACHINGS STUDENT WORK SHEET

A) How would you summarize the First Nations understanding of an ecosystem and our relationship with it?

B) How does the Elder see the overuse of resources and the pollution of our environment as fitting in with this understanding?

C) How does the Elder see the balance between progress/growth/development and protecting nature?

D) What does the Elder think can be done?

E) According to the second video, what is Carbon Capture? How does it work?

F) In the second video, what are the risks and potential hazards of carbon emissions?

G) Compare the First Nations perspective on our role to protect the environment with what is hoped from Carbon Capture. How do they connect? Are there any differences?

HOW DO OUR ACTIONS IMPACT THE ECOSYSTEM?

Activity - Work Sheet 1.1

Web-based Ecological Footprint

OUTCOMES / INDICATOR (S)

IE7.4 (g)

In today's world, where humanity is already exceeding planetary limits, ecological assets are becoming more critical. Each country has its own ecological risk profile: Many are running ecological deficits, with Footprints larger than their own biological capacity. Others depend heavily on resources from elsewhere, which are under increasing pressure.

In some areas of the world, the implications of ecological deficits can be devastating, leading to resource loss, ecosystem collapse, debt, poverty, famine and war. The Ecological Footprint is a resource accounting tool that helps countries understand their ecological balance sheet and gives them the data necessary to manage their resources and secure their future.

Global Footprint Network

LESSON 1.1

1.Go to **http://www.footprintnetwork.org/en/index.php/GFN/page/calculators/** and select "Calgary" as your location on the map.

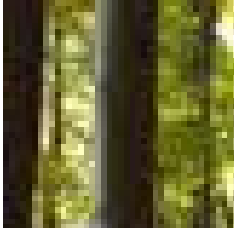
2.Select "kids' version'

3. Select detailed version.

4.Create an "avatar" or randomly generate one and the click "ok" to continue.

5.Answer the questions on the quiz the best you can or ask your teacher for help.

6. Complete your ecological footprint worksheet



LESSON 1.1

YOUR ECOLOGICAL FOOTPRINT STUDENT WORK SHEET

A) When you are finished the quiz answer the following:

a.Your ecological footprint is _____ global hectares.

b.Your current consumption requires an area of productive land equivalent to _____ Canadian football fields.

(The average for Calgary is _____ global hectares)

(The average for Canada is _____ global hectares)

B) Read "Some ideas to reduce your Footprint" and state how you can reduce your energy use.

ENERGY

1) Reduce your household energy use – turn down your _____ when not occupied and at night.

2) Use energy efficient _____.

3) Replace _____ with Energy Star® rated models.

4) Add insulation and _____ proofing.

5) Use public transit, _____, ride a bike or walk.

6) Keep tires properly _____, have your vehicle properly _____ and avoid _____.

LOCAL FOODS

1) In season, purchase _____ _____foods that require less transportation and processing to get products to market.

GOODS

1) Reduce consumption of _____ use products.

2) Purchase _____ products when possible.

3) Avoid products that produce excess waste.

4) Purchase goods that are made _____ to reduce their transportation Footprint.

C) Go to the website http://www.ec.gc.ca/education/ and then click on "What You Can Do" on the left hand side. Read through the things you can do "At Home, On the Road, At Work, At School, and In Your Community" and list at least three things you would be willing to do to reduce your ecological footprint.

D) Check out http://www.nationmaster.com/graph/env_eco_foo-environment-ecological-footprint to see a ranking of average ecological footprint.

1) What is the country with the highest ecological footprint and what is the value?

2) What is the country with the lowest ecological footprint and what is the value?

3) Why do you think there is such a difference in ecological footprints from the highest country to the lowest country?

HOW DO OUR ACTIONS IMPACT THE ECOSYSTEM?

Activity - Experiment 1.2
Acidic Oceans

OUTCOMES / INDICATOR (S)
IE7.4 (g)

Much of the man made CO_2 caused by burning fossil fuels such as coal, natural gas and oil has been absorbed over time by the earth's oceans. This benefits us by slowing the climate change these emissions would have instigated if they had remained in the air.

However, the introduction of massive amounts of CO_2 into the oceans is altering water chemistry and affecting the life cycles of many marine organisms, particularly those at the lower end of the food chain. When CO_2 dissolves in the ocean, carbonic acid is formed. This leads to higher acidity, mainly near the surface, which has been proven to inhibit shell growth in marine animals and is suspected as a cause of reproductive disorders in some fish.

YOU'LL NEED

- 2 plastic cups
- Permanent marker
- Drinking straw
- Bromothymol blue indicator (usually available in pet stores)
- Safety Glasses
- Used straw container
- Waste water bucket

WHAT TO DO

1. Put on safety glasses and use one cup and straw per person.
2. Label the cups A and B
3. Add 5 drops of Bromothymol blue to each cup.
4. Fill the cups 2/3 with water.
5. Using one straw, blow into the cup B for 30 seconds. Note the change of colour of the water.
6. Place the straw in the used straw container and tip the water into the bucket.

RECORD

1) Write what happens to the water in the cup that you blow in.

a) Starting colour: _____

b) End colour: _____

2) What do you think is happening in the water to make the colour change? Why could this be a problem for creatures in the ocean?

_____

_____

_____

_____

HOW DO OUR ACTIONS IMPACT THE ECOSYSTEM?

Activity - Experiment 1.3
Exploring Global Warming

OUTCOMES / INDICATOR (S)
IE7.4 (g)

In this experiment, the jars are like the Earth's atmosphere and the heat lamp is like the sun. You will see what effect, if any, CO2 has on the earth.

YOU'LL NEED

- Two 32 ounce jars with lids
- 8 oz of water (4 oz per jar)
- Two thermometres
- Safety glasses
- 3 effervescent tablets (like Alka Seltzer)
- Heat lamp
- Clock or timer

WHAT TO DO

1. Put on safety glasses.
2. Place two 32 oz jars side by side
3. In each jar add 4 oz of water
4. In each jar, stick a thermometre above the water level.
5. In jar 1, add 3 effervescent tablets and quickly cover jar with lid
6. In jar 2, do not add effervescent tablets. Cover jar with lid
7. Shine a heat lamp equally on both jars.
8. Wait 10 minutes and read the temperature in both jars.

RECORD

1) Write what you think will happen.

_____ _____
_____

2) Was your prediction correct? Write down what happened.

_____
_____
_____
_____

WHAT'S HAPPENING

The temperature in jar 1 should be greater than the temperature in jar 2. In jar 1, the effervescent tablets mixing with water create a chemical reaction and release CO2. The CO2 levels in jar 1 increase, and so jar 1 absorbs more heat, radiating the heat back toward the thermometre.

NOTES

THEME 2

Carbon Capture and Storage

This is an introduction to Carbon Capture and Storage (CCS). Students will learn all about how CCS works and have access to the latest and most relevant information regarding CCS as it relates to Canada and the world. Lessons developed in part by the Regina Catholic School Division provide outcome-based experiments and activities that align to the grade 7 science curriculum.

OUTCOME(S)

IE7.4 - Analyze how ecosystems change in response to natural and human influences, and propose actions to reduce the impact of human behaviour on a specific ecosystem.

EC7.2 - Identify locations and processes used to extract Earth's geological resources and examine the impacts of those locations and processes on society and the environment.

INDICATOR(S):

IE7.4 b) Propose ecological questions to investigate arising from practical problems and issues (e.g., "What is the impact of clearing land for farming?", "How could a community prolong the life of its landfill site?", "How could a community reduce the amount of garbage it produces?", "What is the impact of a sports field being constructed in a particular location?").

IE7.4 d) Identify and refine questions and problems related to the effects of natural or human influences on a particular ecosystem.

IE7.4 e) Select and synthesize information from various sources to develop a response to specific questions related to natural or human influences on a particular ecosystem.

IE7.4 f) Be sensitive and responsible in maintaining a balance between human needs and a sustainable environment by considering both immediate and long-term effects of their course of action or stated position.

IE7.4 g) Provide specific examples to illustrate that scientific and technological activities related to ecosystems take place in a variety of individual or group settings, locally and globally, and by men and women from a variety of cultural backgrounds (e.g., individual and community gardening, impact studies done by environmental engineers, and research done by teams of international scientists).

EC7.2a) Identify questions to investigate arising from practical problems and issues related to the study of Earth's geological resources (e.g., "What types of rocks are best for cement-making or road construction?" and "What are some environmental concerns related to open-pit mining?").

EC7.2 f) Provide examples of technologies used to further scientific research related to extracting geological resources (e.g., satellite imaging, magnetometer, and core sample drilling).

EC7.2 i) Suggest solutions to economic and environmental issues related to the extraction of geological resources in Saskatchewan (e.g., managing mine tailings and pollutants; reclaiming open pit mining sites; ecological impact of pipelines; resource depletion; maintaining water quality; and increasing urbanization).

BIG IDEAS INSIDE

What is Carbon Capture and Storage (CCS)?	12-17
Exploring injecting CO2 underground	18-21
All about Carbon Dioxide (CO2)	22-27
CCS in Canada and the world	28-29
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WHAT IS CARBON CAPTURE AND STORAGE?

Activity - Work Sheet 2.0
What is CCS Web Hunt

OUTCOMES / INDICATOR (S)
IE7.4 (d), (e), (g), EC7.2 (f)

This is a basic introduction to the science behind Carbon Capture and Storage (CCS) and the methods used to extract and store Carbon Dioxide (CO2).

This web hunt activity is useful to help kids source out answers to questions on CO2

***Note: The questions have been leveled according to difficulty: A (lowest) – C (highest). Choose the questions according to your classroom level and ability.**

LESSON 2.0

1) Go to http://www.ico2n.com

2) Have students complete the work sheet while watching the video.

(Answer key on page 42)

LESSON 2.0

WHAT IS CCS STUDENT WORK SHEET

Go to MAIN PAGE (http://www.ico2n.com) to answer the following questions.

1. A - How many Tonnes of CO2 have currently been sequestered (stored) in Canada?
2. B - What is GHG?
3. C – Click on the PDF link for "10 Things to Know About Carbon Capture and Storage". Identify and explain in your own words, three of the main ideas summarized in this article.

Go to the WHAT IS CCS page to answer the following questions.

4. A – What are the three actions typically involved with CCS?
5. B - What are two examples of sites that could use the CCS technology?
6. B – What are the three geological formations that can be used for carbon storage?
7. A – How far down into the earth's crust is the CO2 stored?

Click on CAPTURE BASICS from the left side menu.

8. A – What are the three ways to capture CO2?
9. B – Explain in your own words one of the three processes of capturing carbon. To help you click on the links on the left menu to read more about the three capture processes, view the diagrams, or watch the video.
10. C – Form a group with two students that did different capture methods than you. Create a 3-circle Venn diagram to compare the similarities and differences of each capture process.

Click on CO2 TRANSPORT from the left side menu.

11. A – How is CO2 normally transported?
12. B – What is a "dense phase"?
13. C – Why does the CO2 need to reach a dense phase?

Click on CO2 STORAGE from the left side menu.

14. A – What does sequestration mean?
15. A – How many years of emissions can Canada safely store?
16. B – What is the total storage capacity of Canada?

Use the links on the left side menu under CO2 STORAGE to research the following questions.

17. A – What are the four ways to safely trap CO2 in geological formations?
18. A – What does MMV stand for?
19. B – Explain in expanded form what is MMV is?
20. B – What is Canada's potential storage capacity in Deep Saline Formations?
21. C – Why are saline formations a good site for CO2 storage?
22. A – What is EOR?
23. C – How can EOR economically help the oil industry?
24. B – Why does it "make sense" to use Depleted Oil and Gas Reservoirs as storage sites?
25. B – How is CO2 stored in Unmineable Coal Seams?

Click on CCS ECONOMICS from the left side menu.

26. C – Summarize the ideas that explain why many factories and industries that could use CCS technology choose not to.

WHAT IS CARBON CAPTURE AND STORAGE?

Activity - Experiment 2.1

Investigator Getting oil and gas out of the ground (Part 1)

OUTCOMES / INDICATOR (S)

IE7.4 (g), EC7.2 (a)

Carbon Capture is all about putting CO2 into the ground. In some cases it is used to help get oil and gas out of the ground. But how does this happen? How can putting CO2 into the ground help get oil and gas out? How does the CO2 stay in the ground?

This experiment is two parts in which the student is investigator and problem solver. As investigator, students create a Carbon Capture simulation using the suggested materials. As problem solver, students purposely create a problem to discuss implications.

YOU'LL NEED

- Erlenmeyer Flask
- Mid-sized Beaker (~300 ml)
- Rubber Stopper with two holes
- Large Syringe (60 cc)
- Rubber Tubing
- Food colouring

Note:
If rubber tubing is unavailable, students can use bendable straws.
If rubber stopper is unavailable, students can use plasticine, be sure to instruct students to create a good seal with the plasticine, otherwise experiment will be flawed.

INVESTIGATOR PROCEDURE

1. Feed 1.5m rubber tubing into one hole in the rubber stopper so that the end of the tube will reach to just above the bottom of the Erlenmeyer flask
2. Feed .15m rubber tubing into the other hole in the rubber stopper so that the end is about 3 cm past the stopper.
3. Fill the Flask with water to just below the end of the short tubing.
4. Blow on the shorter tube until the water is pushed along the length of the longer tube.
5. Fill the Beaker with water and add a few drops of food colouring to be able to see the water.
6. Fill syringe with coloured water from beaker and attach to end of shorter rubber tubing.
7. Place the end of the long tube into the beaker to catch water.
8. Slowly compress the syringe.

Have kids complete the Student Data Sheet on following page (part 1)

LESSON 2.1

INVESTIGATOR STUDENT DATA SHEET

(PART 1)

A) How was the water in the flask affected?

_____

_____

_____

B) What happened to the water in the flask?

_____

_____

_____

C) What colour is the water in the longer tube now?

_____

_____

_____

D) Draw a diagram that shows the movement of water. Use arrows to clearly indicate the path the water took.

E) Present your results in a summary paragraph. Your summary should include your observation and answer the following question. “Why did the water move the way it did?”

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

WHAT IS CARBON CAPTURE AND STORAGE?

Underground oil and gas are two of our most important energy sources. The oil is refined into fuel for cars, trucks, airplanes, ships, etc. It is also burnt in power stations to make electricity. Unfortunately burning oil and gas produces CO_2.

We need to decrease the amount of CO_2 we produce and stop it getting into the atmosphere. One of the ways we can do this is by catching it at power stations and burying it underground. Oil and gas deposits are deep underground. They formed there over millions of years and are trapped under a cap of rock. To get oil and gas from the earth we drill down with an enormous drill. When we take it from a reservoir it leaves room to pump in the CO_2 caught at power stations.

Used oil and gas deposits are a good place to store CO_2 because we already know they can contain it – they have kept natural gas securely for millions of years so they should be able to trap the CO_2 as well. CO_2 is actually pumped in as a liquid because of the high pressure underground. When extra CO2 is pumped in, the existing oil or gas is pushed out and collected at the surface to be processed. This process of pumping out oil or gas while storing CO2 is called Enhanced Oil Recovery (EOR).

Activity - Experiment 2.2

What happens if there is a leak underground (Part 2)

OUTCOMES / INDICATOR (S)

IE7.4 (g), EC7.2 (a)

YOU'LL NEED

- Erlenmeyer Flask
- Mid-sized Beaker (~300 ml)
- Plasticine stopper with two holes
- Large Syringe (60 cc)
- Rubber Tubing
- Food colouring

PROBLEM SOLVER PROCEDURE

1. Feed 1.5m rubber tubing into one hole in the plasticine so that the end of the tube will reach to just above the bottom of the Erlenmeyer flask
2. Feed .15m rubber tubing into the other hole in the plasticine so that the end is about 3 cm past the stopper.
3. Fill the Flask with water to just below the end of the short tubing.
4. Blow on the shorter tube until the water is pushed along the length of the longer tube.
5. Fill the Beaker with water and add a few drops of food colouring to be able to see the water.
6. Fill syringe with coloured water from beaker and attach to end of shorter rubber tubing.
7. Place the end of the long tube into the beaker to catch water.
8. Slowly compress the syringe.

Have kids complete the Student Data Sheet on following page (part 2)

LESSON 2.2

PROBLEM SOLVER STUDENT DATA SHEET (PART 2)

A) What connections can you make between both experiments (Part 1 and Part 2)

_____

_____

_____

B) What happens in the experiment when the tubes into the flask are not tightly sealed like they were in the first experiment.

_____

_____

_____

C) Consider what would happen in the real world if the tubes going into the cap rock were not tightly sealed. Present your results in a summary paragraph. Your summary should include your observation and answer the following question: what happens if the seal is not tight?

_____

_____

_____

_____

_____

EXPLORING INJECTING CO_2 UNDER-GROUND

Activity - Case Study 2.3

Kerr investigation of leak on their property

OUTCOMES / INDICATOR (S)
IE7.4 (b), (d), (e);
EC 7.2 (a), (i)

In January 2011, allegations were made that certain events that occurred on the farm of Cameron and Jane Kerr were the result of the Weyburn-Midale CCS project. The Kerrs claimed that CO2 was leaking into their property. Response to these allegations, which received international news coverage via the Internet, were investigated by IPAC-CO2 who brought in experts from around the world to test for a CO2 leak, and at the same time, identify a standard for testing future leak concerns. The result of the test was that there was no leak found on the site.

LESSON

1) Hand out and read excerpt taken from Article on following page: "*Carbon injected underground now leaking, Saskatchewan farmer's study says*". Have the students discuss or write the answers to the following questions (*possible answers provided*):

a) Why did the Kerr's' believe that the occurrences at their farm were from a CO2 leak?

- They lived close to the injection site.
- Dug up gravel from property to make a road for the injection site.
- The CCS technology is too new to know exactly what a leak may look like on a farm.
- The occurrences on the farm could be connected to a CO2 leak.

b) What data events occurred that sparked this investigation?

- animals dying, water fizzing, algae growing, foam and scum, small explosions in the gravel pit, oil on the top of the water.

2. Explain to the class that as a result of the unusual events an investigation was started to see if there really was a CO2 leak. **You may want to review the process of a scientific investigation for the class and during the video have the students outline the scientific process that the experts followed.*

Question: Is the CCS site leaking CO2?
Hypothesis: student generated
Materials and Equipment: as outlined in the video
Procedure: as outlined in the video
Data Analysis: see Summary Report at: http://www.ipac-co2.com/projects/investigations
Conclusion: student generated

3. Watch video IPAC-CO2_The Kerr Investigation http://rcsdcarboncapture.weebly.com/video-resources.html and answer questions on the student work sheet
**Note: The questions have been leveled according to difficulty: A (lowest) – C (highest). Choose the questions according to your classroom level and ability.*

4. After watching the video, read the Kerr Report – Conclusions. Have the students discuss or write down the answers to the following questions (*possible answers provided)*:

a) What was the official conclusion from the investigation?

- Carbon dioxide found was produced by a natural process and not by a CO2 leak.

b) What was the data collected that supported this conclusion?

- Soil-gas analysis determined that all of the CO2 originated through a natural source like respiration.
- Noble Gas analysis determined that no Noble Gases migrated from a lower depth.
- Water analysis determined that the film on the water was from iron oxidizing bacteria.

Excerpt taken from Article:
Carbon injected underground now leaking, Saskatchewan farmer's study says

A Saskatchewan farm couple whose land lies over the world's largest carbon capture and storage project says greenhouse gases that were supposed to have been injected permanently underground are leaking out, killing animals and sending groundwater foaming to the surface like shaken-up soda pop.

Cameron and Jane Kerr, who own nine quarter-sections of land above the Weyburn oilfield in eastern Saskatchewan, released a consultant's report Tuesday that claims to link high concentrations of carbon dioxide in their soil to the 8,000 tonnes of the gas injected underground every day by energy giant Cenovus in its attempt to enhance oil recovery and fight climate change.

"We knew, obviously, there was something wrong," said Jane Kerr.

Cameron Kerr, 64, said he has farmed in the area all his life and never had any problems until 2003, when he agreed to dig a gravel quarry.

That gravel was for a road to a plant owned by EnCana — now Cenovus — which had begun three years earlier to inject massive amounts of carbon dioxide underground to force more oil out of the aging field.

Cenovus has injected more than 13 million tonnes of the gas underground. The project has become a global hotspot for research into carbon capture and storage, a technology that many consider one of the best hopes for keeping greenhouse gases out of the atmosphere.

By 2005, Cameron Kerr had begun noticing problems in a pair of ponds which had formed at the bottom of the quarry. They developed algae blooms, clots of foam and several colours of scum — red, yellow and silver-blue. Sometimes, the ponds bubbled. Small animals — cats, rabbits, goats — were regularly found dead a few metres away.

Then there were the explosions.

"At night we could hear this sort of bang like a cannon going off," said Jane Kerr, 58. "We'd go out and check the gravel pit and, in the walls, it (had) blown a hole in the side and there would be all this foaming coming out of this hole."

"Just like you shook up a bottle of Coke and had your finger over it and let it spray," added her husband.

The water, said Jane Kerr, came out of the ground carbonated. "It would fizz and foam." Alarmed, the couple left their farm and moved to Regina.

"It was getting too dangerous to live there," Cameron Kerr said.

THE CANADIAN PRESS

http://www.ipolitics.ca/2011/01/11/

LESSON 2.3

CASE STUDY - KERR INVESTIGATION
STUDENT WORK SHEET

ANSWER THE FOLLOWING QUESTIONS AS YOU WATCH THE VIDEO (A-lowest degree of difficulty; C-highest)

1. **A** – Who are Cameron and Jane Kerr? _____
2. **A** – Where did the Kerr's live? _____
3. **C** – Why is it important to note that the Kerr's farm was near the Weyburn CCS test site?_____
   _____
4. **A** - What was the name of the company that is leading the investigation? _____
5. **C** – Why does this investigation need to be "unbiased"? _____
   _____
6. **B** – Why did they fly in scientists from Texas and Europe?_____
   _____
7. **C** – What was unique about this investigation?_____
   _____
8. **B** – Explain what they were doing in their investigation?_____
   _____
9. **C** – What made Stuart Gilfillan an expert that would be helpful in this investigation?_____
   _____
10. **B** - What was Stuart Gilfillan's job in the Kerr investigation?_____
    _____
11. **A** – Why are the Noble Gases useful in this investigation?_____
    _____
12. **C** – How did testing for Noble Gases help this investigation?_____
    _____
13. **C** – What was the secondary reason for testing the Kerr site as stated by Katherine Romanak?_____
    _____
14. **B** – Why did they take samples at different levels?_____
    _____

LESSON 2.3

CASE STUDY - KERR INVESTIGATION
STUDENT WORK SHEET (CON'T)

15. **C** – How does taking samples at different levels help?_____
_____

16. **A** – What was Brad Wolaver's role?_____
_____

17. **A** – How did Brad collect the soil samples?_____
_____

18. **B** – What specifically were the scientists looking for when they collected the soil samples?_____
_____

19. **A** – What was Janis Dale's role?_____
_____

20. **B** – How does this kind of investigation help the public? _____
_____

21. **A** – What was found during the investigation?_____
_____

22. **B** – Why was Jennifer Stroh hired? What was her job? _____
_____

23. **C**- Why was Jennifer's job just as important as the other scientists?_____
_____

24. **C** – How did the discovery of the amphibians help support the investigation?_____
_____

25. **B** – How did this investigation support CCS technology?_____
_____
_____

26. **C** – If there was a leak found, how could this investigation still help CCS technology?_____
_____
_____

ALL ABOUT CARBON DIOXIDE (CO_2)

Industry produces more than 35 per cent of Canada's total greenhouse gases. In fact, a small handful of industries produce the vast majority of these emissions. Oil and gas extractors and refiners are by far the largest contributors, accounting for 38 per cent of industry emissions. Utilities, cement, iron and steel, chemical and aluminum industries are also major contributors. There are a number of practical ways for industry to reduce greenhouse gas emissions one of which is carbon capture.

The David Suzuki Foundation

LESSON 2.4

Student Basic – Use student hand-out to create a double-bar graph comparing the output and capture of CO2 emissions by province found below.

Student Enhanced – Students go to Global CCS Institute website (www.globalccsinstitute.com/projects/brows) and use the map to identify the annual carbon capture storage at current CCS sites in Canada. Students will compare these numbers with the provincial output of CO2 found below.

Activity - Work Sheet 2.4

Carbon Dioxide Air Data Study

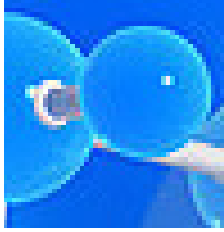
OUTCOMES / INDICATOR (S)
IE7.4 (b), (d)

Carbon Emissions Capture per Year (2013) - chart 01

Site Name	Province	Approximate Amount Captured (tonnes)
Weyburn-Midale Project	Saskatchewan	2 million
Boundary Dam and Aquistore	Saskatchewan	1 million
Quest	Alberta	1.2 million
Swan Hills	Alberta	1.4 million
Agrium and Enhance	Alberta	1.2 million
Husky	Alberta	100 000

Provincial Amount of Carbon Emissions Produced per Year (2013) - chart 02

Province	Approximate Emissions (tonnes)
Saskatchewan	21 847 456
Alberta	117 675 609



LESSON 2.4

CARBON DIOXIDE AIR DATA STUDY
STUDENT WORK SHEET

A) STUDENT BASIC: Create a double bar graph comparing the output and capture of CO2 emissions by province found in chart 01 on previous page.

C) STUDENT ENHANCED: Compare annual carbon capture storage at current CCS sites in Canada with provincial output of CO2 as found in chart 02 on previous page.

ALL ABOUT CARBON DIOXIDE (CO_2)

Activity 2.5
Making Molecules

OUTCOMES / INDICATOR (S)
IE7.4 (b), (d),

Carbon Dioxide (CO2) is best known as a greenhouse gas (GHG) in the earth's atmosphere. The two major GHGs responsible for climate change are: carbon dioxide and methane (CH4). It is produced by humans and other animals during respiration - the process that breaks down the energy that they all need to live. CO2 is taken up from the atmosphere by plants during photosynthesis - a process that stores the Sun's energy and the carbon from the CO2, then releases the oxygen from the CO2 that humans and animals need to breath. Large volumes of CO2 are also produced when fossil fuels (coal, oil and gas) are burnt for energy. There is a great concern that humans' daily activities are causing the release of too much CO2 into the atmosphere, contributing to climate change.

This activity explores the molecular makeup of CO2 and CH4 and will show your students how atoms can form together to make molecules.

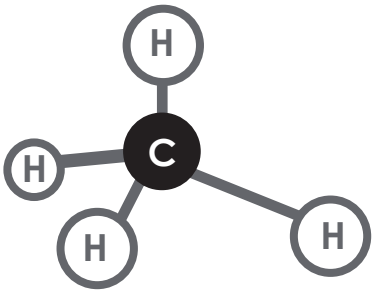
YOU'LL NEED

- 1 Molymod Kit (purchased through amazon, about $30) **OR**
- 8 toothpicks (bonds)
- Play-doh: red for oxygen (2 atoms total); black for carbon (2 atoms total); white for hydrogen (4 atoms total).

PROCEDURE

1. Take 1 black atom, 2 red atoms and 4 toothpicks
2. Gently put together the atoms to make a carbon dioxide (CO_2) molecule.

3. Take 1 black atom, 4 white atoms and 4 toothpicks.
4. Gently put together the atoms to make a methane (CH_4) molecule.



WHAT'S HAPPENING

The balls that you have used represent atoms, while the grey plastic pieces represent bonds. The bonds are at different angles in each molecule because the electrons that surround the atoms hold them together differently in each case.

ALL ABOUT CARBON DIOXIDE (CO_2)

Carbon is an element that's found all over the world and in every living thing. Oxygen is another element that's in the air we breathe. When carbon and oxygen bond together, they form a colorless, odorless gas called carbon dioxide (CO2), which is a heat-trapping greenhouse gas. Whenever we burn fossil fuels such as coal, oil, and natural gas—whether it's to drive our cars, use electricity, or make products—we are producing CO2. The atmosphere isn't the only part of the Earth that has carbon. The oceans store large amounts of carbon, and so do plants, soil, and deposits of coal, oil, and natural gas deep underground. Carbon naturally moves from one part of the Earth to another through the carbon cycle. But right now, by burning fossil fuels, people are adding carbon to the atmosphere (in the form of CO2) faster than natural processes can remove it. That's why the amount of CO2 in the atmosphere is increasing, which is causing global climate change.

YOU'LL NEED

- 1 clear film canister (must have lid with round edge)
- Teaspoon
- 1/4 canister vinegar
- Baking soda in separate small container

PROCEDURE

1. Put on safety glasses to prevent vinegar or bicarb splashing in eyes.
2. Take the lid off the film canister
3. Practice putting the lid on the canister and placing it upside down. The best way to do this is for one partner to hold the body of the canister flat to the table (or floor), the other partner will use both hands to press the lid down tight, quickly placing the canister, lid down, on a level surface and stand back.
4. Pour vinegar into the body of the canister to 1/4 full.
5. Using the teaspoon place enough baking soda to fill the dip in the lid.
6. One partner holds the body o of the canister flat to the table, (or flor0, while the other uses both hands to press the lid down as practiced above. Quickly and firmly press the lid completely on. Place the canister (lid down) on the table (or floor) and stand back.

WHAT'S HAPPENING

When the vinegar (acetic acid) and baking soda (sodium bicarbonate) mix together,, there is a fast chemical reaction where CO2 gas is produced. The CO2 builds up i the canister which is what eventually forces the lid to pop off. As more and more CO2 is produced, the CO2 molecules are squashed together and begin to push, or apply force on all the inside surfaces of the canister, including the lid. CO2 gas pushes down on the lid, but because it is sitting on a flat surface, it has no choice but to go anywhere but upward.

1) Write or draw what happens to the canister.

2. How high did the canister go into the air? _____

Activity - Experiment 2.6

Make Carbon Dioxide - it's a blast!

OUTCOMES / INDICATOR (S)

IE7.4 (b), (d)

ALL ABOUT CARBON DIOXIDE (CO_2)

The three components of CCS are carbon, capture and storage. This experiment looks at one way carbon dioxide is formed and how its natural tendency, once created, is to move upwards until it is released into the air. CO2 gas is colourless but the food colouring allows students to watch the CO2 bubbles move through both water and oil until the gas escapes the bottle and leaves the food colouring behind to fall back through the oil to the water.

In later experiments student will learn how although the CO2 can move through oil and water, there are some things it is unable to move though and this is what allows both the capture and storage of CO2 so that even if produced, it is possible to prevent it from being released into the atmosphere.

Activity - Experiment 2.7

Making a CO_2 Lava Lamp

OUTCOMES / INDICATOR (S)

IE7.4 (b), (d)

YOU'LL NEED

- 20 ounce clear water/pop bottle with label removed
- 5 ounces water - to fill above bottle 1/4 of the way
- 14 ounces of vegetable oil, pre-measured in a separate bottle
- Any colour of food colouring
- 1/2 an Alka Seltzer tablet or similar effervescent tablet
- Funnel

PROCEDURE

1. Add the oil to the water in the 20 ounce plastic water bottle to nearly the top but not quite
2. Add 15 drops of food colouring to the bottle.
3. Add 1/2 of the Alka Seltzer tablet to the bottle.

WHAT'S HAPPENING

- Water and oil do not mix well. Water is denser than oil and this is what causes the oil to rise to the top o of the bottle and the water to stay underneath.
- The food colouring works its way through the oil and happily mixes with the he water.
- When the he Alka Seltzer is introduced, it reacts with the water and releases CO2 gas which wants to go straight to the top of the bottle.
- The CO2 gas bubbles take some of the coloured water all the way to the top with them, then as the CO2 escapes the bottle, the coloured water falls back to the bottom.

ALL ABOUT CARBON DIOXIDE (CO_2)

One technique that could limit CO2 emissions from human activities into the atmosphere and prevent the continued rise of climate change, is Carbon Capture and Storage (CCS). CCS involves collecting, at its source, the CO2 that is produced by power plants or industrial facilities and storing it away for a long time in underground layers, in the oceans, or in other materials.

Carbon dioxide resulting from combustion, particularly in the electricity sector, can be captured using a couple different methods, all of which generally do the same thing, they all prevent the majority of CO2 gas from being released into the air.
The goal of this experiment is to faciliateate the release of CO2 by twisting off athe bottle cap and then capture it with the balloon. This is the same concept as capturing CO2 at an industrial source, the idea is that the gas is captured and unable to make its way into the atmosphere.

YOU'LL NEED

- Safety glasses
- Balloon
- Small soda water bottle with screw top lid

PROCEDURE

1. Put on safety glasses.
2. Secure the ballloon over the neck of the screw top soda bottle.
3. Gently unscrew the lid (with teh balloon over the top of the bottle).
4. Note observations. You should be able to see something happening in both the liquid and the balloon.
5. Observ e what is happening in the bottle - the bubbles of gas filling the balloon are carbon dioxide.

RECORD

A) Explain what happened to the balloon._____

_____

B) What happens to the soda water if you shake the bottle? Does the balloon get bigger? _____

_____

WHAT'S HAPPENING

CO2 is found in soda wather and other soft drinks. The CO2 cannot be seen as it is dissolved in the water at room temperature. The bottle is pressurised and sealed. This keeps more CO2 in the water than would normally be possible. When the lid of the bottle is unscrewed a pressure change is created, pressure is released. This causes the CO2 to come out of solution and appear as the bubbles that we see. These bbbles rise up ot of the solution. If there was no balloon on the bottle the CO2 would be released out into the atmosphere. However, in this experiment you have captured the CO2 inside the balloon. Capturing CO2 is the first part of carbon capture and storage (CCS), however, capturing the large volumes of CO2 from a power station or industrial plant ususally requires a nuimber of chemicla processes to separate CO2 out from other gases.

Activity - Experiment 2.8
Capturing CO_2

OUTCOMES / INDICATOR (S)
IE7.4 (b), (d)

CCS IN CANADA AND THE WORLD

Activity - Work Sheet 2.9

Canada's Role in CCS Web Hunt

OUTCOMES / INDICATOR (S)

IE7.4 (g), EC7.2 (a)

Carbon Capture and Storage (CCS) is a crucial part of Canada's long-term energy and environment strategies, and Canada has the essential components to make CCS a success.

We have:

- **Many large industrial CO2 emission sources where capture can occur**
- **World-class geological storage locations that are close to the capture locations**
- **Engineering expertise developed over 100 years of oil and gas development**

Successful development and implementation of CCS will enable Canada to meet its international and domestic commitments to reduce greenhouse gases in a way that will also:

- **Reduce the environmental impact of oil sands resources so they can continue to create jobs and wealth, and**
- **Help establish a secure electricity supply by enabling the clean use of Canada's abundant coal resources.**

Information taken from ICO2N

This Web Hunt activity is designed to allow three different levels of understanding and learning. The levels are based on the difficulty of getting the answer and the level of independent understanding needed to answer the question - A (lowest), C (Highest). Choose the level and the quantity of questions that are appropriate for your class.

LESSON - 2.7

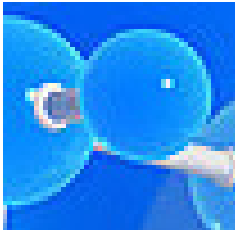
1) Go to http://www.ico2n.com

2) What is Canada's Role in CCS? A look at the projects in Canada and internationally.

Also looks at the industry, economics and practical applications for CCS.

Complete the work sheet.

(Answer key page 43)



LESSON - 2.9

CANADA'S ROLE IN CCS STUDENT WORK SHEET

Go to the CCS IN CANADA page to answer the following questions.

1. A – Along with meeting Canada's commitment to reduce GHGs what else can CCS help the environment in Canada?
2. C – By studying and interpreting the Table on the bottom of the page, what can you infer about Canadian CO2 Emissions and the role CCS plays?

Click on Canada's Energy Context from the left side menu.

3. A – What are the 4 main resources we rely on as exports in Canada?
4. B – How does the production of these resources impact the environment?

Click on The Role of CCS from the left side menu.

5. B – What is the role that CCS will play in the Canadian commitment to reduce greenhouse gases?
6. A – How much electricity is produced from coal-fired plants?
7. C – Use the links from this section to help explain why CCS is considered a "Transition Strategy".

Click on Canada's CCS Story from the left side menu.

8. A – What are the three essential components that Canada has that would make CCS a success?
9. B – Look at the map of Canada to estimate the percentage of Canadian land that has the potential to be used as a CCS site.

Click on Canadian Carbon Capture and Storage Projects from the left side menu.

10. C - Choose one of the projects stated on this page and use the links on the left side to learn more about the project you chose. Draw a brainstorming web that summarizes the information that you learned about your CCS project. Include information like the location, kind of storage, capture process, unique features, start date, etc.

Click on Industry's Potential from the left side menu.

11. A – Using the graph at the bottom of the page, what is the percentage of industries that could benefit from CCS?
12. C – Choose two of the four industries that could potentially benefit from CCS. Use the links on the left side to create jot notes that will explain specifically how these industries could benefit from CCS.

Go to the CCS INTERNATIONAL page to answer the following questions.

13. B – Summarize in your own words the three reasons why CCS is considered a global necessity.
14. A – What is the forecasted amount of emission reductions that CCS will contribute by 2050?

Click on Global CCS Projects form the left side menu.

15. B – Use an Atlas to research the locations mentioned in the section. Then label a map with the current international CCS projects. The CCS Institute has an interactive CCS Map that is kept up to date that also could be a useful resource for this exercise which can be found at: http://globalccsinstitute.com/projects/browse

THE ROLE OF CCS IN THE OIL INDUSTRY?

Activity - Work Sheet 2.11
Enhanced Oil Recovery

OUTCOMES / INDICATOR (S)
IE7.4 (f), EC7.2 (f)

Carbon dioxide can be used to enhance oil recovery from oil fields. In some parts of the world, like Saskatchewan, oil companies are using CO2 to push the oil out of the ground that traditionally would have been very hard to reach. This process is referred to as Enhanced Oil Recovery (EOR).

Conventional oil production has three phases – primary, secondary and tertiary:

- **Primary recovery techniques typically enable a recovery of approximately 25% of a reservoir's oil reserves. Recoverable oil is limited to the hydrocarbons that naturally rise to the surface or those recovered via an artificial lift device, like a pump jack.**
- **Secondary recovery begins when natural flow rates decrease. It involves injecting water or gas into the reservoir to displace the oil and drive it to the surface.**
- **Tertiary recovery is the stage where CO2 can be used. It is particularly successful in fields with heavy oil or poor permeability. At this stage, steam, chemicals or gas (CO2) can be injected into the reservoir to generate additional oil recovery.**

CO2 flooding for EOR is growing in popularity, and typically leads to an additional 7 to 20% of recoverable oil to an operation. CO2 is injected into oil wells under supercritical conditions (high pressure and low temperature). The CO2 has three effects on the underground oil that lead to an increase in recoverable oil:

1. **The CO2 acts as a solvent, cleaning oil trapped in the microscopic pores of the reservoir rock.**
2. **The CO2 also acts as a pressurizing agent pushing more oil out of the rock.**
3. **The CO2 reduces the oil's viscosity helping it flow easier.**

EOR can create a market for CO2 that can generate revenues that could play a vital part in contributing to the large capital investment that is required for Carbon Capture and Storage deployment.

Information taken from ICO2N

LESSON - 2.8

1) Watch the video **Carbon in Underland** (an introduction to the EOR process)

http://www.youtube.com/watch?v=gr9cznZFuIc

2) Watch the video Enhanced oil recover http://www.youtube.com/watch?v=azLVjYij5U4

3) Complete the worksheet on the following page.

4) Complete the two experiments that follow: CO2 injection and fluid displacement and EOR

LESSON - 2.11

ENHANCED OIL RECOVERY STUDENT WORK SHEET

A) As you watch the videos, note the following:

1. What is enhanced oil recovery? What is the process (order of events)

2. Why is EOR done? What is the purpose?

3. What are some characteristics of the layers of earth needed in an EOR site?

B) Write a descriptive paragraph outlining what Enhance Oil Recovery is. Be sure to specifically identify the reasons and results for EOR and describe the process followed in EOR.

THE ROLE OF CCS IN THE OIL INDUSTRY

Activity - Experiment 2.12

CO2 Injection and Fluid Displacement

OUTCOMES / INDICATOR (S)
IE7.4 (f), EC7.2 (f)

CO2 Enhanced Oil Recovery (EOR) works most commonly by injecting CO2 into already developed oil fields where it mixes with and releases the oil from the formation, thereby freeing it to move to production wells. CO2 that emerges with the oil is separated in above-ground facilities and re-injected into the formation. CO2 EOR projects resemble a closed-loop system where the CO2 is injected , produces oil, is stored in the formation, or is recycled back into the injection well.

Today, most of the CO2 used in EOR operations is from natural underground domes of CO2. With the natural supply of CO2 limited, man-made CO2 from the captured CO2 emissions of power plants and industrial facilities (e.g., fertilizer production, ethano0l production, cement and steel plants) can be used to boost oil production through EOR. Once CO2 is captured from these facilities, it is compressed and transported by pipeline to oil fields.

This experiment looks at the storage component of CCS. There are two ways that CO2 can be injected and stored underground. The most simple way is to inject it into a storage well that goes deep below the surface on the earth. Another way is by injecting the CO2 into the ground in order to push through to reach oil to the surface. This is referred to as enhanced oil recovery (EOR). EOR uses the CO2 to displace oil. This experiment allows students to observe how CO2 can be used to displace fluid, only on a much smaller scale.

YOU'LL NEED

- 20 ounce clear water/pop bottle with label removed
- Food colouring any colour
- 12 ounce plastic cup
- Sticky tack to seal the mouth of the water bottle
- 2 bendable drinking straws

PROCEDURE

1. Put safety goggles on to prevent any food colouring splashing into your eyes and only use one straw per person.
2. Fill the medium bottle with coloured water - just leave a small space at the top to f the bottle.
3. Use the sticky tack to create a lid for this bottle with two bendy straws going into it. One has the short end going into the bottle to stay above the water level and the other has the one end in the bottle going into the water. Mold the sticky tack to make it as airtight around the straws as possible.
4. Carefully bend the straw from the water over to drain into the plastic cup.
5. Blow gently into the long straw that ends above the water.

THE ROLE OF CCS IN THE OIL INDUSTRY

Activity - Experiment 2.13
Enhanced Oil Recovery

This experiment allows students to observe how CO2 can be used to displace fluid, even when the oil is hiding between multiple layers of rock, marble and sand. Even thought the students will not see the transfer of CO2 gas through the straw of the one jar to the other, they will see the oil be pushed out of the rock layer jar.

OUTCOMES / INDICATOR (S)
IE7.4 (f), EC7.2 (f)

YOU'LL NEED

- 1 mason jar lid with two 1/4 inch holes
- 1 mason jar lid with one 1/4 inch hole
- 1 empty water bottle
- Two, 24" x 1/4" tubing
- Effervescent tables (Alka-Seltzer)
- Assorted rocks, sand and marbles
- 150ml of vegetable oil or lamp oil
- Silicon sealant

PROCEDURE

1. Put safety goggles on to protect your eyes
2. Label the jar with 2 holes **Reservoir Jar** and the jar with one hole as **Injection Jar**.
4. Put one piece of tubing through one of the two holes of the Reservoir Jar. Slide the tube all the way down to the bottom on the inside of the jar. Tape the tubing to the inside of the jar to hold it in place. Place the other end of the tube into the water bottle to serve as your **Production Bottle.**
5. Insert the second piece of tubing about 5cm through the second hole into the **Reservoir Jar**. And insert the other end of the tubing about 5 cm through the **Injection Jar** lid's hole.
6. Seal the space around each piece of tubing and hole with the sticky tack, so there is no opening
7. Fill the **Reservoir Jar** with marbles, rocks and sand, leaving about 1" of open space at the top of the jar.
8. Add oil to the **Reservoir Jar**. Fill only to the top of the rocks.
9. Holding the lid of the injection jar close to the mouth of the jar, quickly drop 6 Alka-Seltzer tablets into the jar and immediately tighten the lid.
10. Be prepared for the production bottle to start filling up with recovered oil from the **Reservoir Jar.**

TRANS-PORTING CO_2 TO A STORAGE SITE

Activity - Experiment 2.14

How much pressure is needed?

OUTCOMES / INDICATOR (S)
IE7.4 (f), EC7.2 (f)

In Carbon Capture and Storage (CCS), a process is used to move CO2 from where it is collected at the power station or industrial plant, to where it is stored in an underground reservoir. By using massive amounts of pressure - over 73 times more than in the air around us - we can squash CO2 so much that it turns from a gas into a sort of liquid. At normal pressure, like in our atmosphere, there is lots of room between the CO2 molecules, but as we squash them more and more, the space between molecules get smaller and smaller until the CO2 eventually turns from a gas into a kind of liquid.

For CCS, the CO2 is squashed until it turns into a super critical liquid, which is a substance that is somewhere in-between a gas and a liquid.

YOU'LL NEED

- Electrical or duct tape
- Four or more metres of garden hose or similar tubing
- Foot pump or bicycle pump
- Balloons
- Thick rubber bands

PROCEDURE

1. Attach the tube to the pump and seal with lots of electrical or duct tape so you have an airtight seal.
2. Attach the balloon to the other end of the tube, securing with the rubber band.
3. Separate the group into two teams. Team 1 will do the pumping of the gas, while Team 2 will monitor the reservoir (the balloon).
4. Arrange the two teams so you can hear, but can't see each other (i.e. around a corner, or with a divider between you - no peeking!)
5. Team 1: slowly start pumping, sending gas through the tube into the balloon (which you can't see).
6. Team 2: communicate with Team 1, letting them know the gas is getting there, listening for any leaks, and anything else you think is helpful.
7. When you think the balloon reservoir is full, Team 2 should tell Team 1 to stop pumping - don't pop your balloon reservoir!
8. Carefully slide the balloon off the tube making sure no gas escapes and tie it off - did any gas leak from your balloon reservoir?

WHAT'S HAPPENING?

By using a pump, we are able to squash or slightly compress air by increasing the pressure it is under. Gases and liquids always move from areas of high pressure to areas of lower pressure - they always aim to be in a state of balance. That is why the balloon inflates, Basically we squash the air in the pump (high pressure) and it gets pushed along the tube and into the balloon (low pressure).

WHAT DOES CO_2 LOOK LIKE?

Activity 2.15
Determining Parts Per Million

OUTCOMES / INDICATOR (S)
IE7.4 (g)

In scientific language, gases such as CO2 are often represented as parts per million or PPM. This can be a difficult term to visualize. This activity helps students visualize what it might look like.

YOU'LL NEED

- Yellow dried peas
- Green dried peas
- One clear container

PROCEDURE

1) Collect 9 green peas and place into container. Add 1 yellow pea to make a total of 10 peas. This is one yellow pea, per ten peas, or one part per ten.

QUESTIONS

1. What might 1 part per million look like if you had 1 green pea per 1 million yellow peas?

_____

_____

2. What volume (how much space) do you think this will take? Would it over flow the container?

_____

_____

WHAT IS NEEDED FOR A SAFE STORAGE SITE?

Activity - Experiment 2.16

CO2 Storage and Porosity

OUTCOMES / INDICATOR (S)

EC7.2 (a)

Tiny holes between and inside rocks are called pores, so the measure of how much water, gas or oil can be held in a rock is called porosity. Finding porous rocks where carbon dioxide (CO2) can be safely stored underground is a key step for every CCS project.

This experiment demonstrates that when you fill the containers, the water works into the gaps between the pebbles and rocks, even the gaps that are too small for us to see. The water is heavier than air so it pushes the air up and out as bubbles. The different sized materials let more or less water through, depending on how well they fit together. If more water gets into the gaps, there will be less left at the top of the container. So the container with the lowest water level has the most porous material and the highest water level has the least porous material.

YOU'LL NEED

- 3 containers the same size and shape
- 3 different material samples - pebbles, small rocks, larger rocks
- A measuring cup
- Water (add a few drops of food colouring to make it easier to see)
- A permanent marker

PROCEDURE

1. Use the permanent marker to mark all three containers at the same height - around halfway.
2. Fill each container with a different material sample up to the halfway mark, so each container has the same amount of material in it.
3. What do you think will happen if you pour water into the containers - will it go all the way to the bottom? Where does the water go? Which material do you think will hold the most water? Write down your predictions on the work sheet before trialling the experiment.
4. Use the measuring cup to pour the same amount of water into each container. Make sure you have more water than the amount of material in there bu not enough to fill the container. Wait to make sure the water has filtered all the way through the materials and the bubbles have stopped.
5. Compare the water levels in the containers.

LESSON - 2.16

CO2 STORAGE AND POROSITY

STUDENT WORK SHEET

1) What will happen? Which material will hold the most water? Write your predictions here.

_____

_____

_____

_____

2) Were your predictions correct? If not, write what happened.

_____

_____

_____

_____

3) What happened when you blew through the Tim Tam (Kit Kat)?

_____

_____

_____

_____

4) What happened when you blew through the bubbly chocolate and the normal chocolate? What?

_____

_____

_____

_____

5) How can this be connected to carbon storage?

_____

_____

_____

_____

WHAT IS NEEDED FOR A SAFE STORAGE SITE?

When we talk about storing CO2 in rocks, we usually are looking for two kinds of rock.

1) Rocks that have lots of tiny, connected holes to hold the CO2 (permeability)

2) Rocks that have no connected holes, so that the CO2 gets stuck in the holey rock beneath it. (porosity)

We call non-porous and non-permeable rocks "cap rocks"

In this experiment we look at how a fluid cannot move through a rock with holes but no pathways. We also look at rocks which can allow carbon dioxide to flow into the storage spaces. Remember that to store carbon dioxide we compress it to a very dense gas that has liquid-like properties.

Activity - Experiment 2.17

Cap Rock Properties

OUTCOMES / INDICATOR (S)

EC7.2 (a)

YOU'LL NEED

- Tim Tam (or Kit Kat) chocolate biscuits
- Glass of milk
- Aero chocolate bars

PROCEDURE

1) Bite off both ends of the Tim Tam and investigate the layering in the biscuit.

2) Bite off a little bit from both ends of the Aero and investigate the layering in the biscuit.

3) Hold one end of the Tim Tam into the glass of milk and then put the other end in your mouth. Blow as hard as you can!

4) Hold one end of the Aero into the glass of milk and then put the other end in your mouth. blow as hard as you can!

WHAT'S HAPPENING

If you look at the cut Tim Tam you will notice that the actual biscuit part absorbs milk. There must be very small holes (porosity) in the biscuit and pathways for the milk to move through (permeability).

Even though the Aero has holes (porosity) it is very hard to blow the milk through the bubbly chocolate. None of the holes are connected so there are no pathways through the chocolate for the milk to travel. The Aero has lots of porosity but no permeability.

LESSON - 2.17

CAP ROCK STUDENT DATA SHEET

DATA COLLECTION:

	Aero	Tim-Tam
Describe the layers (draw pictures if you like)		
1) What happens when you blow milk through the Tim Tam and why?		
Prediction		
Actual		
2) What happens when you blow milk through the Aero and why?		
Prediction		
Actual		

1.Explain your observations. _____

_____

_____

_____

2.What are the properties of the two cookies and how did they affect the outcomes of the experiment?

_____

_____

3.How can this be connected to Carbon Storage?

_____

_____

4. What properties are needed for a rock formation to make a good storage site?

_____

_____

_____

_____

THEME 2
SUMMARY QUIZ

Name:_____ **Date:**_____

1.What is Carbon Dioxide?

(A) A gas released by plants
(B) A liquid found in rocks
(C) A gas released by animals
(D) A liquid found at the bottom of the ocean

2. In the CO_2 Experiment, what does the rubber stopper represent?

(A) Pipeline
(B) Cap Rock
(C) Carbon Dioxide
(D) The Factory

3.What happens if there isn't an appropriate seal?

(A) There is a leak
(B) There is an explosion
(C) There is a flood
(D) Nothing happens

4.What are the three actions involved with CCS?

(A) Precombustion, Postcombustion and Oxyfuel
(B) Burning, Storage and Release
(C) Capture, Transportation and Storage
(D) Mining, Piping and Liquifying

5.How far down is CO_2 stored?

(A) 7-10 km
(B) 100 - 200 m
(C) 20- 30 km
(D) 1-5 km

6.What percentage of Canadian land could be used as a storage site/

(A) 10%
(B) 50%
(C) 75%
(D) 25%

7.What is the name of the Saskatchewan site that currently is in operation?

(A) Cenovus
(B) Boundary Dam
(C) Val Verde
(D) Weyburn - Midale

8. What were the Kerrs worried about?

(A) A leak of CO_2
(B) An infestation of Leopard Frogs
(C) Small explosions in their house
(D) There electronic devices stopped working

9. What were the three tests conducted?

(A) Water Purity, Nobel Gasses, Soil Analysis
(B) Pollen Air Count, Nobel Gasses, Amphibian Census
(C) Soil Analysis, Litmus Test, Pollen Air Count
(D) Litmus Test, Amphibian Census, Water Purity

10.What much carbon emissions are released in Saskatchewan per year?

(A) Over 21 billion
(B) Over 12 billion
(C) Over 12 million
(D) Over 21 million

11.How much CO_2 emission will be captured by Boundary Dam?

(A) Ten million
(B) One million
(C) Three million
(D) Fourteen million

THEME 2

SUMMARY QUIZ (con't)

12.What is EOR? (1 point)

(A) Enhanced Oil Recovery

(B) Emission Online Registry

(C) External Oxygen Release

(D) A sad donkey in Winnie the Pooh

13.What are the three effects CO2 has on underground oil? (1 point)

(A) Emission Reducing, Oxidizing, and Enhanced Oil Recovery

(B) Pre Combustion, Post Combustion, and Oxyfuel

(C) Solvent, Pressurizing Agent, and Reduces Viscosity

(D) Sealant, Polishing, Reduction

14. What is the benefit of EOR?

(A) A decrease of emissions

(B) An increase of recoverable oil

(C) Adds value to the oil

(D) Prevents leaks of oil

15. What did the inside of the Tim Tam chocolate biscuit represent?

(A) A oil reservoir

(B) A cap rock

(C) A pipeline

(D) A permeable rock formation

16.What properties do you need for a storage site?

(A) Cap rock and porous rock layer

(B) A thick layer of topsoil and cap rock

(C) Porous rock layer and top soil

(D) A water basin, cap rock and topsoil

17. What is the Environmental purpose of CCS?

(A) To allow us to keep depending on fossil fuels as an energy resource

(B) To get more oil out of the ground

(C) To create a temporary solution while industries change to cleaner energy sources

(D) To get rid of CO2 completely

18. What will happen if Canada doesn't use CCS technology?

(A) We will make more money

(B) We will not meet our goal to reduce emissions

(C) We will reduce greenhouse gasses

(D) We will run out of energy

19. Who is involved in developing Carbon Capture technology?

(A) Canada

(B) North America

(C) North America and Europe

(D) World Wide

20. What do you believe?

(A) CCS is a "band-aid" solution that will not fix the problem.

(B) CS is a good resource that needs to be used more often.

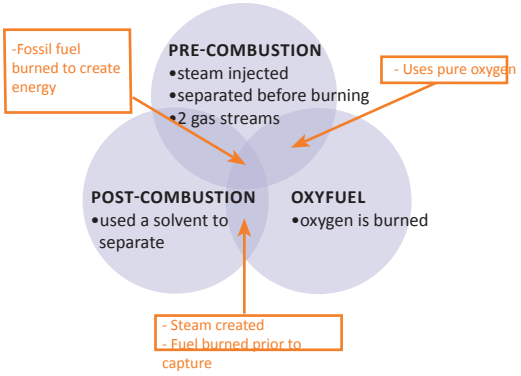
(C) CCS has a negative impact on the environment.

(D) CCS needs to be tested more before it is used in public.

WHAT IS CCS TEACHER ANSWER KEY (LESSON - 2.1)

1. **A** How many Tonnes of CO2 have currently been sequestered in Canada? – use the counter on the right side of the page.
2. **B** What is GHG? – greenhouse gases
3. **C** Click on the PDF link for "10 Things to Know About Carbon Capture and Storage". Identify and explain in your own words, three of the main ideas summarized in this article. Some example answers (refer to website for complete information)
   - Global Priority – will help meet emission reduction targets and accounts for 20% of reduction needed.
   - Component of Canada's energy strategy – helps develop sustainable fossil fuel resources to help as Canada transitions into low-carbon sources.
   - Cost Comparison – just as costly as wind and solar energy sources. Currently expensive but will get better as technology advances.
   - Proven Technology – used around the world. In US since 1970; In Norway since 1996
   - Can Be Safe – Uses locations with impermeable rock and has constant monitoring systems.
4. **A** What are the three actions typically involved with CCS? – capture, transport and storage
5. **B** What are two examples of sites that could use the CCS technology? – coal fired power plants, oil sands, oil and gas upgraders and refineries, fertilizer, chemical or cement factories
6. **B** What are the three geological formations that can be used for carbon storage? – depleted oil and gas reservoirs, saline formations, coal seams
7. **A** How far down into the earth's crust is the CO2 stored? – 1-5 km
8. **A** What are the three ways to capture CO2? – post-combustion, pre- combustion, oxyfuel
9. **B** Explain in your own words one of the three processes of capturing carbon. To help you click on the links on the left menu to read more about the three capture processes, view the diagrams, or watch the video.
   - Post combustion – the fossil fuel is burned to create steam. At the time the steam is removed a solvent us used to separate the CO2 from the exhaust. It is then compressed and transported.
   - Pre-combustion – pure oxygen is mixed with fossil fuel to create a synthesis gas of hydrogen and CO. Steam is added to create H2 and CO2. The hydrogen and CO2 are separated. The hydrogen is burned and the CO2 is compressed and transported.
   - Oxyfuel – pure oxygen is burned with the fossil fuel to create a steam but the oxygen added results in a less contaminated exhaust so the CO2 is easier to separate. It is then compressed and transported.
10. **C** Form a group with two students that did different capture methods than you. Create a 3-circle Venn diagram to compare the similarities and differences of each capture process.

Sample Venn:



11. **A** How is Co2 normally transported? -pipeline
12. **B** What is a "dense phase"? –gas that acts like a liquid
13. **C** Why does the CO2 need to reach a dense phase? – to transport it easier; creates a predictable flow through the pipeline
14. **A** What does sequestration mean? – the process of storing CO2 in geological formations
15. **A** How many years of emissions can Canada safely store? – 200 years
16. **B** What is the total storage capacity of Canada? – 69 110 Mt
17. **A** What are the four ways to safely trap CO2 in geological formations? – Structural, Residual, Dissolution, Mineral
18. **A** What does MMV stand for? - Measurement, Monitoring, and Verification.
19. **B** Explain in expanded for what MMV is? – measures the amount of CO2, monitors the storage integrity, verifies that it is stored properly
20. **B** What is Canada's potential storage capacity in Deep Saline Formations? 50 510Mt
21. **C** Why are saline formations a good site for CO2 storage? – because of the high salt content the water is undrinkable and cannot be used for farming; these formations have "cap rock"
22. **A** What is EOR? – Enhanced Oil Recovery
23. **C** How can EOR economically help the oil industry? – able to capture more oil to sell because it forces the oil out of the rock.
24. **B** Why does it "make sense" to use Depleted Oil and Gas Reservoirs as storage sites? - because this is where oil and gas have naturally been stored for millions of years
25. **B** How is CO2 stored in Unmineable Coal Seams? – injected into the field where it is absorbed by the coal and permanently lock in the mineral formation.
26. **C** Summarize the ideas that explain why many factories and industries that could use CCS technology choose not to. – high up-front costs and the projects are very large

CCS IN CANADA AND THE WORLD TEACHER ANSWER KEY (LESSON - 2.7)

1. **A** Along with meeting Canada's commitment to reduce GHGs what else can CCS help the environment in Canada? Reduce the impact of the oil sands, help secure a stable supply of electricity by allowing us to continue using coal.

2. **C** By studying and interpreting the Table on the bottom of the page, what can you infer about Canadian CO2 Emissions and the role CCS plays? CCS is only part of the solution, CCS is the largest factor in reducing emissions, we will likely not make our emission reduction target for 2050 without CCS.

3. **A** What are the 4 main resources we rely on as exports in Canada? oil, natural gas, electricity, nuclear

4. **B** How does the production of these resources impact the environment? create the GHG emissions that are affecting climate change.

5. **B** What is the role that CCS will play in the Canadian commitment to reduce greenhouse gases? one of the three core strategies to reduce CO2 emissions

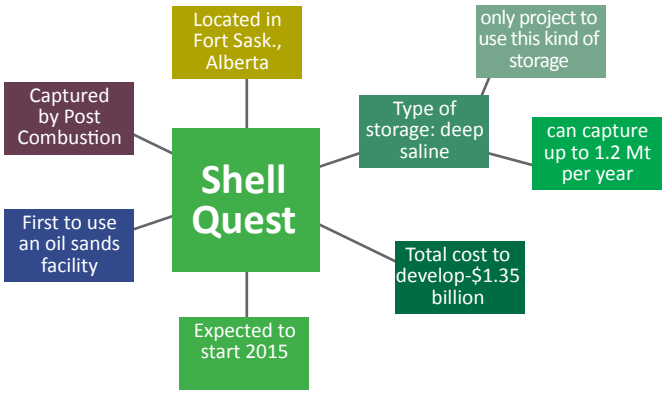
6. **A** How much electricity is produced from coal-fired plants? 20%

7. **C** Use the links from this section to help explain why CCS is considered a "Transition Strategy". CCS is meant to be a support to bridge Canada's movement to low-emission energy resources. CCS allows us to continue to use coal-burning resources to meet the growing energy demands of Canada and the export market until more energy efficient products and practices become available and used.

8. **A** What are the three essential components that Canada has that would make CCS a success? many large industrial emission sources, many storage locations are close to capture locations, 100 years of engineering expertise

9. **B** Look at the map of Canada to estimate the percentage of Canadian land that has the potential to be used as a CCS site. about 50%

10. **C** Choose one of the projects stated on this page and use the links on the left side to learn more about the project you chose. Draw a brainstorming web that summarizes the information that you learned about your CCS project. Include information like the location, kind of storage, capture process, unique features, start date, etc. Sample Web: (refer to website for complete information)



11. **A** Using the graph at the bottom of the page, what is the percentage of industries that could benefit from CCS? 50%

12. **C** Choose two of the four industries that could potentially benefit from CCS. Use the links on the left side to create jot notes that will explain specifically how these industries could benefit from CCS.

Electricity

Coal

- can continue to use coal but minimize the environmental impact.
- technology development for CCS will help other countries that are in earlier stages of development.

Natural Gas

- CO2 capture can be used to in facilities that purify natural gas and can make more electricity.

Oil Sands

- can be applied to upgraders to make capture more efficient
- can allow for the next phase of oil sands production called SAGD

Fertilizers and chemicals

- can capture CO2 from ammonia production

Cement

- contribute to 6%-8% of CO2 emissions which CCS can help lower.

13. **B** Summarize in your own words the three reasons why CCS is considered a global necessity. Answer should contain these points: global demand for energy will continue to increase; need to continue to use fossil fuels to meet the demands, environmental stresses are increasing

14. **A** What is the forecasted amount of emission reductions that CCS will contribute by 2050? 10 Billion Tonnes

15. **B** Use an Atlas to research the locations mentioned in the section. Then label a map with the current international CCS projects. map should include these facilities: Sleipner, Norway; Snohvit, Norway; In Salah, Algeria; Weyburn-Midale, Saskatchewan; Val Verde, Texas; Enid Fertilizers, Oklahoma; Century Plant, Texas.

KERR INVESTIGATION TEACHER ANSWER KEY (LESSON - 2.3)

1. A – Who are Cameron and Jane Kerr? - The people that started the inquiry into the Weyburn CCS site
2. A – Where did the Kerr's live? – on a farm in Weyburn Sask.
3. C – Why is it important to note that the Kerr's farm was near the Weyburn CCS test site? – because their farm was close enough to the CCS site that they CO2 was getting injected directly underneath them. This means that they had credible concern for thinking there may have been a leak.
4. A - What was the name of the company that is leading the investigation? IPAC- CO2
5. C – Why does this investigation need to be "unbiased"? -so the data collected wouldn't be influenced by either site of the investigation.
6. B – Why did they fly in scientists from Texas and Europe? – these were the leading scientists in their research with CCS. Because the technology is so new, there has been very few investigations about leaks therefore they were the best and more knowledgeable to do the investigation.
7. C – What was unique about this investigation? – they are finding gas samples in soil and water
8. B – Explain what they were doing in their investigation? – drilling a series of wells at different depths and installing collection chambers for gas; and collecting soil from the drilling to map the different layers of soil.
9. C – What made Stuart Gilfillan an expert that would be helpful in this investigation? – he was currently studying the tracking of CO2 storage underground and long term tracking
10. B - What was Stuart Gilfillan's job in the Kerr investigation? – completed a Nobel Gas study of the ground waters; he was an independent "unbiased" consultant.
11. A – Why are the Noble Gases useful in this investigation? – they can be used as tracers to show if CO2 is moving in the water
12. C – How did testing for Noble Gases help this investigation? – showed if the CO2 came from the ground or the atmosphere depending on where the Nobel gases were found during testing.
13. C – What was the secondary reason for testing the Kerr site as stated by Katherine Romanak? – to develop an accurate, safe and cost effective protocol to use of future concerns.
14. B – Why did they take samples at different levels? – allows to get a cross section of data gas distribution.
15. C – How does taking samples at different levels help? – gives a 3-D picture to see gas movement
16. A – What was Brad Wolaver's role? – soil – gas analysis, and water quality analysis; with ground water he constructed the wells and collected soil samples to map out the soil layers
17. A – How did Brad collect the soil samples? – taken off the drill (auger) and put into labeled jars
18. B – What specifically were the scientists looking for when they collected the soil samples? – soil permeability – is it sand/gravel or clay/silt
19. A – What was Janis Dale's role? – tested soil samples for hydrocarbons; the onsite geologist
20. A – What was found during the investigation? – Northern Leopard Frog
21. B – Why was Jennifer Stroh hired? What was her job? – Environmental monitor for the safety of the frogs; flush all the frogs away from the testing sites towards the wetlands; to ensure the safety of the species in that environment.
22. C- Why was Jennifer's job just as important as the other scientists? – shows environmental responsibility; the frog is a "species of concern" and therefore needed to be protected.
23. C – How did the discovery of the amphibians help support the investigation? – amphibians are usually the first to feel the stress of negative impacts of the wetlands and since they were thriving on the farm it showed that the wetlands were not "under stress" from leaking CO2
24. B – How did this investigation support CCS technology? – helped establish "best practices" for future CCS projects globally
25. C – If there was a leak found, how could this investigation still help CCS technology? – they can figure out what caused the leak and develop better practices to resolve this problem in the future.

CARBON CAPTURE SUMMARY QUIZ TEACHER ANSWER KEY

Answer Key:

1. C	5. D	9. A	13. C	17. C
2. B	6. B	10. D	14. B	18. B
3. A	7. D	11. B	15. D	19. D
4. A	8. A	12. A	16. A	20. opinion (all correct)