4.6 The greenhouse effect

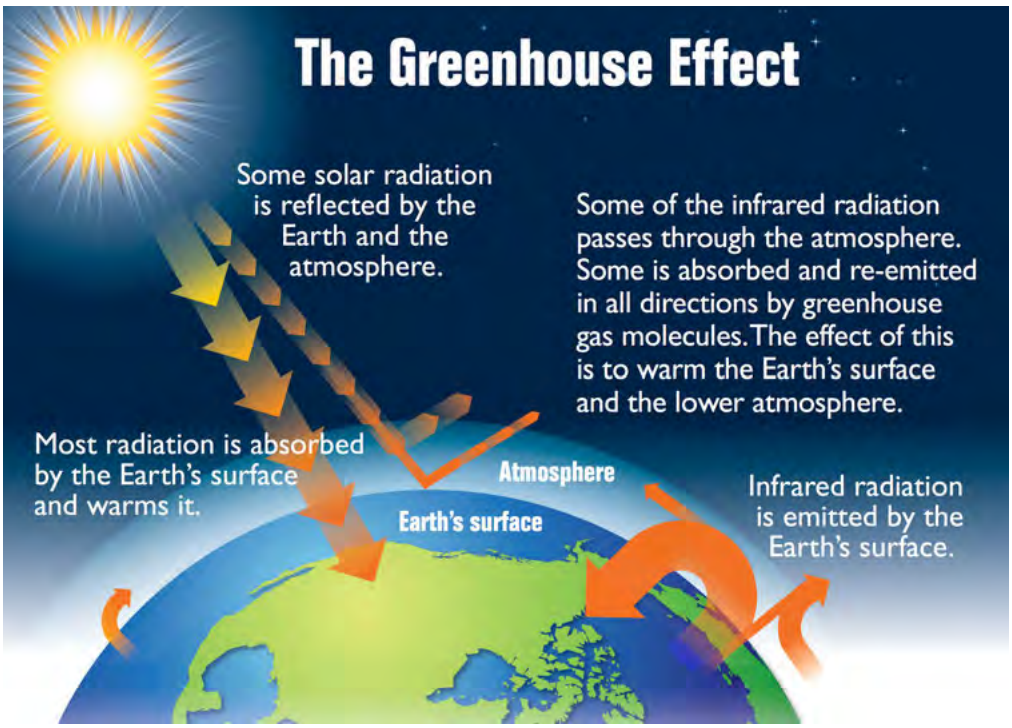
NEW WORDS

- greenhouse gases
- greenhouse effect
- global warming
- climate change
- carbon dioxide
- methane
- water vapour
- radiation

You have learned a lot about greenhouse gases in Natural Sciences. In this section we will be looking at how important greenhouse gases are to sustain life on Earth.

Earth's atmosphere contains mostly (99%) nitrogen and oxygen, but a small percentage (1%) of the atmosphere contains gases like **water vapour** (H_2O), **carbon dioxide** (CO_2) and **methane** (CH_4). Carbon dioxide is a product of respiration in all organisms and also a gas given off by industrial processes and the burning of fossil fuels and vegetation. Methane is a gas, also called natural gas, which occurs in reservoirs beneath the surface of the Earth. It is also given off by decomposing plant and animal material and animals give off methane as part of their digestion. Water vapour is formed when water evaporates on Earth.

Water vapour, methane and carbon dioxide are gases which let through incoming visible light from the Sun. The incoming radiation from the Sun is absorbed by the Earth's surface and warms it. The Earth's surface emits **infrared radiation**. Infrared radiation is absorbed by the greenhouse gases and re-emitted in all directions. This increases the temperature of the Earth's surface and lower atmosphere, above what it would be without the gases, called the **greenhouse effect**. These gases are very important to regulate the Earth's temperature.



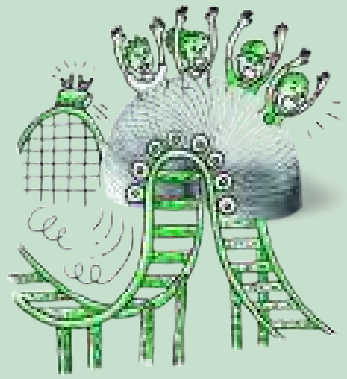
VISIT

Learn more about the greenhouse effect with this simulation.

bit.ly/192V4iT

As you can see in the diagram, the radiation from the Sun is able to reach the Earth and warm it up. The energy that is given off by the Earth is trapped by the water vapour, carbon dioxide and methane. This ensures that the Earth stays warm. It is almost as if the gases form a blanket around the Earth keeping some of the heat inside. The gases are referred to as **greenhouse gases**. A greenhouse is a glass structure that is used to grow plants. The glass lets the heat of the Sun through, but then keeps the heat inside the structure so that the plants have a moderate climate in which to grow. Water vapour, carbon dioxide and methane act in the same way.

The Earth is a very unique planet due to the make-up of its atmosphere. In this chapter you have learned about the composition of the Earth's atmosphere. Let us compare the atmosphere of Earth to its neighbouring planets, Mars and Venus.



ACTIVITY: Comparing Earth, Mars and Venus

Venus, Earth and Mars.

INSTRUCTIONS:

1. The table below gives information about the gases in the atmospheres of the three planets: Venus, Earth and Mars.
2. Study the table and answer the questions that follow.

Percentage of gases making up the atmospheres of Venus, Earth and Mars.

	Venus	**Earth**	**Mars**
Carbon dioxide (CO_2)	96,5%	0,03%	95%
Nitrogen (N_2)	3,5%	78%	2.7%
Oxygen (O_2)	Trace	21%	0,13%
Argon (Ar)	0,007%	0,9%	1,6%
Methane (CH_4)	0	0,002%	0

QUESTIONS:

1. Compare the data for Venus and Earth. What similarities and difference do you notice?

2. Compare the data for Venus and Mars. What similarities and difference do you notice?

3. What is the biggest difference between Earth's atmosphere and the atmospheres of the other two planets?

4. Why is the level of oxygen so much higher on Earth than on the other two planets?

5. Why do you think there is no methane gas on Venus and Mars?

6. Predict whether you think the temperature on the surface of Venus will be low or high. Give reasons for your answer.

VISIT

Carbon dioxide and the greenhouse effect.

bit.ly/Hcf0pe

DID YOU KNOW?

Venus is the hottest planet in the solar system; the temperature is hot enough to melt lead.

The atmospheres of Venus and Mars are very similar. Both planets have mainly carbon dioxide in the atmosphere, and very little other gases. However, the two planets are quite different.

Venus has a very dense atmosphere which results in a high concentration of carbon dioxide on its surface. This causes an extreme greenhouse effect and very high temperatures on the surface of Venus. Venus has an average surface temperature of 462 °C. This is too high to sustain life as we know it.

Mars, on the other hand, has almost no atmosphere, so, although there is carbon dioxide present, the density is very low and almost no greenhouse effect takes place. Mars is also much further away from the Sun. It is a very cold planet, with an average temperature of -55°C. This is too low to sustain life as we know it.

Earth has the right composition of atmospheric gases to sustain life. It has the right balance between oxygen and nitrogen so that plants and animals can

breathe, and just enough carbon dioxide and methane to keep the planet warm enough so that life can be sustained. Many scientists think that it is the life on Earth that keeps the atmosphere in this perfect balance. Plants produce oxygen and re-circulate carbon dioxide on Earth. They believe that if life were to disappear from Earth, the atmosphere would become like Mars or Venus.

INVESTIGATION: A model of the greenhouse effect

In the greenhouse effect, carbon dioxide traps the heat of the Sun. In this investigation, you will use bottles with air and carbon dioxide, respectively, to model the greenhouse effect. You are going to investigate the following question: Does air or carbon dioxide absorb more heat?

AIM: Write an aim for this investigation.

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HYPOTHESIS: Write a hypothesis for this investigation.

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MATERIALS AND APPARATUS:

- two glass bottles or clear cold drink bottles with lids
- 2 thermometers
- Prestik
- heat source (two study lamps)
- vinegar
- bicarbonate of soda
- small cold drink bottle with lid

METHOD:

Set up the experiment as in the photograph.

Experimental set-up.

1. Mark one bottle as 'Air' and the other bottle as 'CO_2'.
2. If the lids do not have the thermometers in them already, prepared by your teacher, make a hole in each of the lids. You can do this using a hammer and nail and hammering the nail through the lid into a wooden block. Secure the thermometer in each lid. You can use Prestik to do this.
3. Fill the first bottle with air and secure the thermometer and close the lid tightly.
4. Fill the second bottle with carbon dioxide:

    a) To collect a bottle of carbon dioxide, add one tablespoon of bicarbonate of soda to the small bottle.
    b) Add 10-20 ml of vinegar and place the lid back on.
    c) Hold the mouth of the small bottle over the large CO_2 container and pour the CO_2 collecting in the small container into the large container. Hold the small bottle horizontal so that the vinegar does not spill into the bigger bottle, only the heavier carbon dioxide gas pours into the large container.
    d) Add more vinegar when the effervescence stops. Repeat 2-3 times until the bottle is full. If a burning match at the mouth of the bottle goes out immediately, the bottle is full.
    e) Secure the thermometer and close the lid tightly.

Pouring carbon dioxide from the small bottle into the large bottle. Your teacher will prepare the carbon dioxide for you.

5. Measure and record the starting temperature of both bottles.
6. Switch on the heat source and measure the temperature increase in both bottles. You need to decide for yourself what time increments are appropriate and record these in the table.

The CO_2 container with the light positioned to shine on it.

RESULTS:

Complete the following table.

Time (minutes)	Temperature of air bottle (°C)	Temperature of CO_2 bottle (°C)

Represent your results by drawing a graph for each of the experiments to show how the temperature for each bottle changed over time. You need to decide what values to use for each axis. Label the axes clearly and provide a heading for each graph.

What have you observed?

CONCLUSION:

What do you conclude for your experiment?

Extension investigation: What factors make the temperature of the atmosphere increase faster?

Design your own investigation to answer one or more of the following questions. Use the experiment above to guide your experimental set-up.

1. Does dark soil make the temperature increase faster?
2. Does water vapour make the temperature increase faster?
3. Does the thickness of the layer of gases make the temperature increase faster?
4. Does the presence of dust/aerosols make the temperature increase faster?
5. Does the distance of the Sun make the temperature increase faster?

Global warming

What do you think will happen if the levels of carbon dioxide and other greenhouse gases increase? Think about what you discovered in the last investigation and look at the diagram of the greenhouse effect again. Write your answer below.

If there are more greenhouse gases in the atmosphere, more ultraviolet radiation will be trapped and the Earth will heat up. This will result in more of the polar ice melting than usual. Even a one degree difference in the average temperature has an effect on the melting of polar ice. If more ice than usual melts, the water levels in the oceans will rise and low-lying areas could flood.

A change in the temperature will also result in a change in weather patterns. More rain will fall in some areas, and less in others. If this change is permanent, it is called **climate change**, and if it occurs on a worldwide scale it is called global climate change, which is what is being discussed here.

Global warming affects weather patterns which in turn has a knock-on effect on agriculture and food production. This has an impact on food production and can lead to food shortage for humans and animals. Long term climate change can lead to the extinction of plants and animals, which are unable to adapt to changed conditions.

The levels of greenhouse gases vary naturally over time. A question that scientists often ask is whether the concentration of greenhouse gases is rising more than it would naturally as a result of human activities? How do you think

this can be investigated?

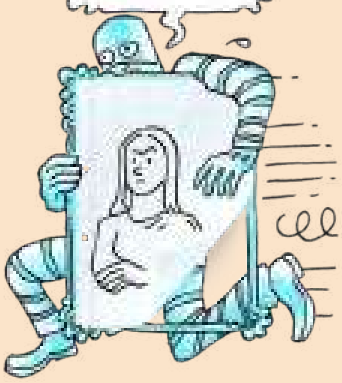
Since the industrial revolution humans have burned more fossil fuels than ever before. Human activities have resulted in the increase of carbon dioxide emissions over time. Carbon dioxide is therefore the main greenhouse gas under discussion amongst scientists and environmentalist. The following investigation will look at the levels of carbon dioxide over thousands of years.

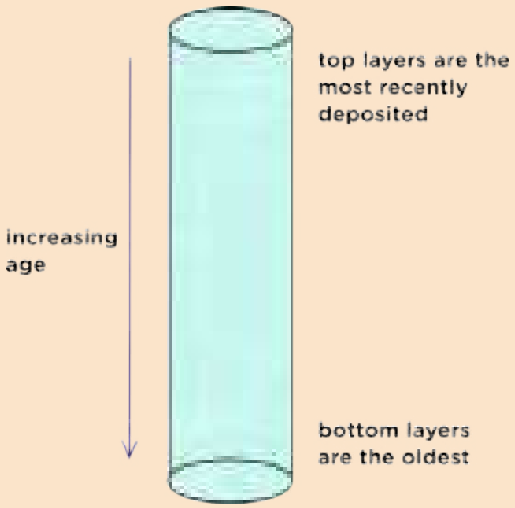
INVESTIGATION: Ice core analysis

Carbon dioxide is trapped in the ice which forms at the poles. As the ice is compacted and becomes thicker over thousands of years, the carbon dioxide remains trapped. The levels of carbon dioxide in ice can be determined by analysing the ice cores. A research team in Antarctica drilled an ice core containing ice from 160 000 years ago. They analysed the ice for carbon dioxide and presented their data in the following table.

TAKE NOTE

An **ice core** is a core sample from the accumulation of snow and ice over many years that have recrystallized and have trapped air bubbles from previous time periods.





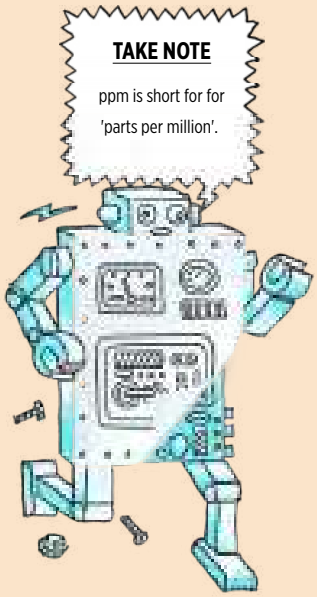
Ice cores trap carbon dioxide over time periods.

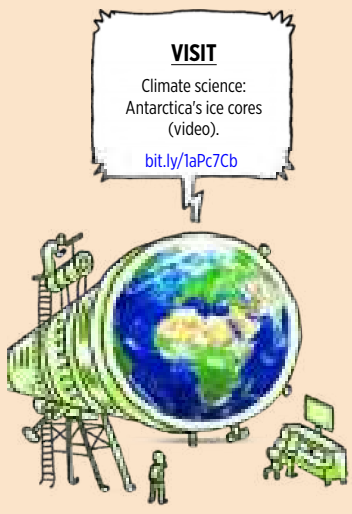
Drilling through the ice to obtain ice cores.

Sawing through the ice core to obtain samples for analysis.

Results from the ice core analysis.

Number of years ago	CO_2 levels (ppm)
160 000	190
150 000	205
140 000	240
130 000	280
120 000	278
110 000	240
100 000	225
90 000	230
80 000	220
70 000	250
60 000	190
50 000	220
40 000	180
30 000	225
20 000	200
10 000	260
8160	280
0	387





INVESTIGATIVE QUESTION: Write down an investigative question for this study.

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ANALYSIS:

1. Draw an accurate graph to represent your data. You need to choose your own set of axes, and label them appropriately.

2. What is the link between the levels of CO_2, core ice and global warming?

CONCLUSION:

1. Write down a conclusion for this investigation.

2. What is the impact of global warming on the planet?

SUMMARY:

Key Concepts

- The layer of gases around the Earth is called the atmosphere.
- The density of the gas molecules decreases as the distance from the Earth increases - the further away from the Earth you travel, the fewer gas molecules there are.
- The atmosphere can be divided into different layers - the troposphere, stratosphere, mesosphere and thermosphere.
- The exosphere is the uppermost layer directly above the thermosphere, where the gases thin out and the atmosphere merges with space. It is considered part of outer space.

- The troposphere is the densest layer, has the highest air pressure and is closest to the surface of the Earth. It is on average about 12 km thick and temperature decreases with altitude.
- The stratosphere stretches from 12 - 50 km and contains the ozone layer. Aeroplanes fly in this layer because the air is more stable. Temperature increases with altitude, from -60°C to 0°C.
- The mesosphere stretches between 50 - 80 km. The air is very thin. Meteorites usually burn up in the mesosphere. Temperature decreases with altitude from 0°C to -90°C.
- The thermosphere stretches up to 480 - 600 km. It absorbs ultraviolet light and X-rays. Temperature increases with altitude and can reach 1500°C.
- The ionosphere is the layer where molecules are ionised by the Sun's ultraviolet light. Radio waves can be transmitted and reflected due to the ionised layer.
- The greenhouse effect is a natural phenomenon - it warms the atmosphere sufficiently to sustain life.
- Greenhouse gases trap the re-radiation from Earth's surface and reflect it back to the Earth (like inside a greenhouse).
- The most common greenhouse gases are carbon dioxide, water vapour and methane.
- An increase in greenhouse gases leads to global warming.
- Global warming is an increase in the average temperature of the atmosphere.
- Global warming is a potentially life threatening situation on Earth. It can lead to climate change, rising sea levels, food shortages and the extinction of organisms on Earth.

Concept Map

Through the past 2-3 years you have come across concept maps in Natural Sciences. Use what you know about concept maps and design a map for this chapter. You must add terms and examples to the list. Remember to use linking words between concepts, and arrows to indicate the direction in which information is read. Plan your concept map on rough paper first before drawing the final one into your workbook. Use the following terms to help you with your map:

- atmosphere
- layers
- mesosphere
- thermosphere
- troposphere
- stratosphere
- weather
- ozone
- satellites
- radio waves
- global warming
- greenhouse gases
- greenhouse effect
- oxygen
- carbon dioxide
- water vapour