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Carbon dioxide

In recent issues of CATALYST *we have seen how carbon dioxide can be used as a solvent in industry, or as a regulator of blood pH. This article looks at some other uses of carbon dioxide and considers its importance in global warming.*

Left: *Fizzy drinks are 'carbonated' with carbon dioxide*

GCSE key words
Atmosphere
Global warming
Respiration
Fermentation

Carbon dioxide has always been part of the Earth's atmosphere. It was spewed from volcanoes when the Earth was formed. Today the atmosphere contains only about 0.04% carbon dioxide. This is kept fairly constant by the carbon cycle (Figure 1).

Carbon dioxide is removed from the atmosphere by photosynthesis, by dissolving in oceans and by the locking away of carbon in fossil fuels. It is released into the atmosphere in the processes of respiration, fermentation and combustion of organic compounds. Fermentation occurs when yeast, a fungus, uses sugar as an energy source, breaking the sugar down into ethanol and carbon dioxide:

glucose ⟶ ethanol + carbon dioxide

$$C_6H_{12}O_6 \longrightarrow 2C_2H_5OH + 2CO_2$$

Bread-making also involves yeast. In this case the bubbles of carbon dioxide gas in the dough make it rise. The heat of the oven kills the yeast and drives off the ethanol.

THE GREENHOUSE EFFECT AND GLOBAL WARMING

It is important to understand that the greenhouse effect is a natural part of the operation of the Earth's atmosphere. Without it the average temperature over the surface of the Earth would be about –15°C rather than the +15°C that it is now.

Radiation from the Sun reaches the Earth in the form of visible, ultraviolet and infrared rays. Most of this radiation passes through the atmosphere, and is absorbed or reflected by the Earth's surface. The Earth is warmed by this radiation and, because it is warm, it emits infrared radiation. This low-energy, long-wavelength radiation tends to be absorbed by carbon dioxide in the atmosphere. The carbon dioxide molecules thus gain energy, and so the molecules vibrate more. The carbon dioxide molecules

In CATALYST Vol. 14, No. 3 we discussed how carbon dioxide regulates blood pH, and in Vol. 14, No. 1 we looked at how carbon dioxide could be used as a solvent for large organic molecules.

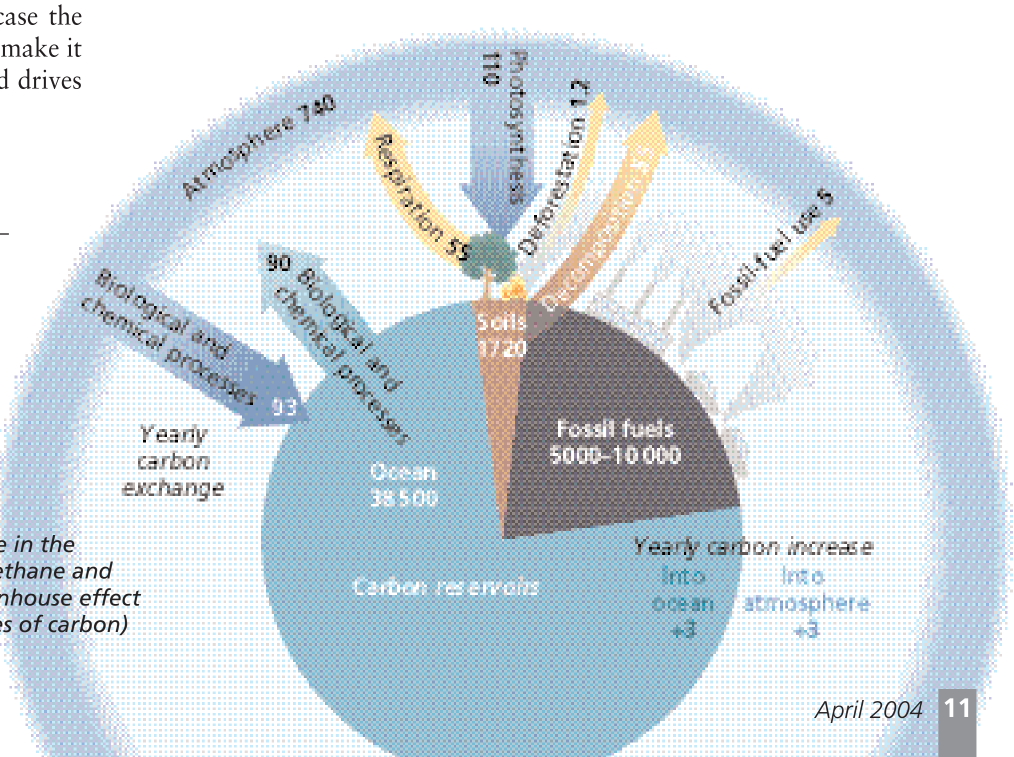
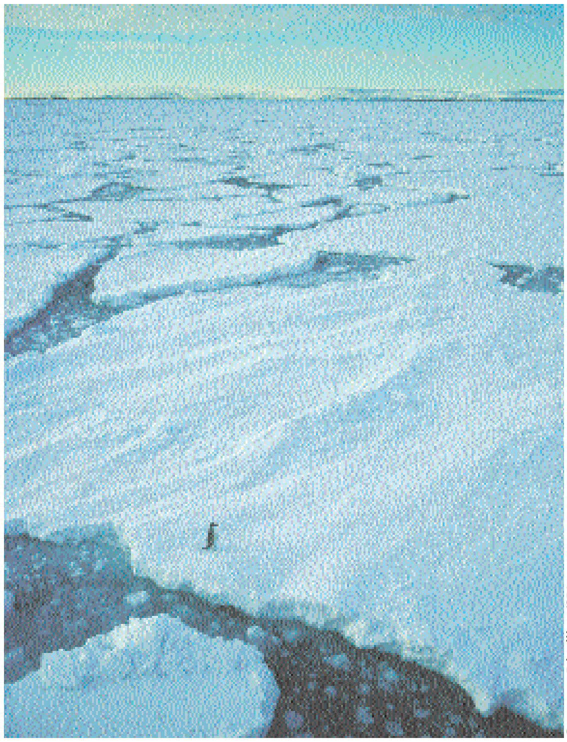


Figure 1 *The carbon cycle. The carbon dioxide in the atmosphere (together with water vapour, methane and some other gases) is responsible for the greenhouse effect and global warming. (Figures in billion tonnes of carbon)*

Right: *Antarctic pack ice could melt if global temperatures increase*



Gregory Dimijian/SPL

Carbon dioxide dissolved in water forms a weak acid called carbonic acid.

- **Can you write the equation for the reaction of calcium carbonate with hydrochloric acid?**

- **Find out the freezing point of carbon dioxide.**

re-radiate infrared radiation in all directions. The effect is that the Earth's infrared radiation finds it hard to escape, and warms up the atmosphere (Figure 2).

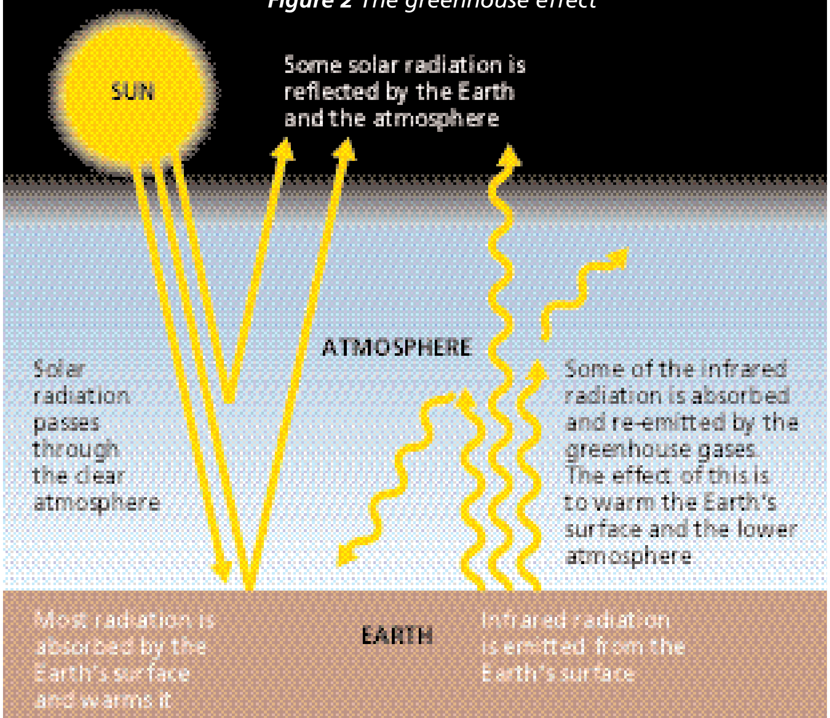
The burning of fossil fuels in power stations and vehicles is gradually increasing the amount of carbon dioxide in the atmosphere (see Try This, p.13). This is having an effect on its temperature. The consequences could be dire if levels of carbon dioxide get out of hand. It is probable that sea levels will rise because the increased temperature will cause the water in the oceans to expand in volume and will melt land and sea ice. There may be more clouds in the sky as the oceans warm up, which will also trap more heat in the atmosphere, changing the climate.

There are problems involved in modelling this process. No-one knows just how much carbon dioxide the oceans can hold, or how much they can remove from the atmosphere. It is an example of a reversible reaction:

$$CO_2(g) + H_2O(l) \longleftrightarrow H_2CO_3(aq)$$

An increase in global temperature will push the equilibrium to the left. More carbon dioxide will be released because gases become less soluble in water as temperature increases.

Figure 2 The greenhouse effect



HOW IS CARBON DIOXIDE MADE?

Carbon dioxide can be made in a lab by reacting an acid with a carbonate, usually calcium carbonate in the form of chalk or marble.

Making carbon dioxide like this is not feasible on an industrial scale. Most carbon dioxide used in industry is a by-product of the manufacture of ammonia (see CATALYST Vol. 14, No. 3). It is also a by-product from the manufacture of quicklime (calcium oxide). Calcium carbonate is heated to make quicklime and carbon dioxide is given off.

WHAT DO WE USE IT FOR?

Carbon dioxide is used in many commercial products, most notably drinks. It is pumped into soft drinks, beer and water at about 7 atmospheres pressure to make them fizzy, or **carbonated**. When the bottle top is released the gas, which was under pressure and also partially dissolved, comes out of solution, forming bubbles.

The gas is also used in food packaging. As carbon dioxide does not react with foodstuffs it is used to modify the atmosphere around pre-packed foods to reduce oxidation and stop the food spoiling.

Some fire extinguishers contain carbon dioxide. It is useful on electrical fires as it does not conduct electricity. The dense gas smothers the burning object, shutting out oxygen and extinguishing the fire.

Carbon dioxide gas is also used as a coolant in nuclear reactors. The gas is blown in through the core of the reactor to transfer heat away. This prevents the reactor (which operates at about 600°C) from catching fire, and the heat is used to generate electricity.

Some carbon dioxide is combined with ammonia to make urea ($CO(NH_2)_2$), a water-soluble nitrogenous fertiliser.

Carbon dioxide is easily solidified — in this form it is known as dry ice. Highly compressed carbon dioxide is allowed to expand rapidly. As it does so it cools and solidifies. Solid carbon dioxide **sublimes** readily (at −78°C). When this happens, water droplets in the air may condense in the cold gas, giving rise to the familiar clouds of white 'smoke' used in stage effects.

Solid carbon dioxide is also used as a coolant, for example aboard aeroplanes. Food can be kept cool by packing it in dry ice which, unlike frozen water, does not release liquid as it warms up.

TESTING FOR CARBON DIOXIDE

Carbon dioxide forms a precipitate when it is bubbled through limewater, which is a solution of calcium hydroxide in water. Calcium hydroxide is not very soluble in water so the actual amount present in the solution is quite small. Carbon dioxide reacts with the calcium hydroxide to form a white suspension of calcium carbonate.

If an excess of carbon dioxide is passed through this solution the precipitate disappears as soluble calcium hydrogencarbonate is formed. It is however only stable in solution — if the mixture is evaporated the precipitate of calcium carbonate reappears. These reactions are responsible for the formation of underground caves, stalagmites and stalactites in limestone areas.

Richard Folwell/SPL

***Left:** Dry ice is often used to create dramatic effects*

● What is sublimation?

The equations for the reactions are:

$$Ca(OH)_2 + CO_2 \longrightarrow CaCO_3 + H_2O$$

$$CaCO_3 + H_2O + CO_2 \longrightarrow Ca(HCO_3)_2$$

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See http://www.darvill.clara.net/altenerg/nuclear.htm for more details about the use of carbon dioxide in nuclear reactors.

Carbon dioxide graph

TRY this

This activity is designed to test your ICT skills and also to get you to make predictions.

The observatory at Mauna Loa in the South Pacific is situated well away from sources of pollution and so is an ideal site at which to measure carbon dioxide levels.

Go to the following website: **http://www.atmos.washington.edu/~klarson/ta211/co2.html**

Here you will find a list of carbon dioxide concentrations from 1976 to 1997. Cut and paste the two columns headed TIME (years) and [CO2] into Excel (or a similar spreadsheet package). Use the graph-plotting abilities of this program to print out a graph of year (on the horizontal axis) against concentration in parts per million (on the vertical axis). You should end up with a graph similar to that shown in Figure 1. If you have problems in your graph plotting ask your teacher for help.

Print out your graph and add your predicted curve continuing the trend from 1997 to the present day.

Now look up on **http://cdiac.esd.ornl.gov/pns/current_ghg.html** the current carbon dioxide concentration. How close was your predicted point to that given on this website? Do you think your predicted curve could be reliably used in the future? Why do you think the curve wiggles up and down? And why does it show a steadily rising trend?

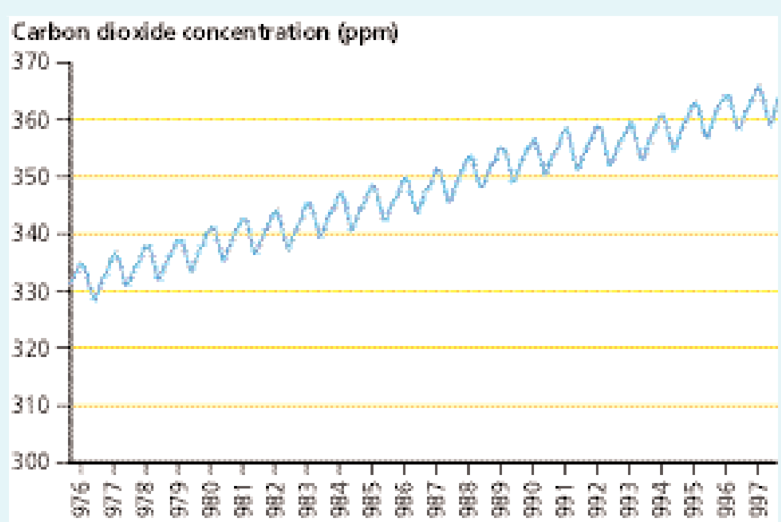

***Figure 1** Carbon dioxide variations at Mauna Loa*