

## How rocks and buildings change

M

What happens to rocks and building materials over time?

### Standing the test of time

These two monuments are in two very different environments. The climate in London is much wetter and cooler than in Egypt. Both cities suffer pollution from cars and industry. On Cleopatra's needle you can see that more detail has been eaten away. The monument in Egypt has not been exposed to so much pollution and acidic rain, or to freezing temperatures.

### How do rocks and building materials change?

Rocks are made from individual crystals or grains of minerals. These are cemented together into lumps. Weathering weakens rocks, breaking them up into smaller pieces and eventually into individual grains and crystals. The diagram on the opposite page reminds you how rocks and buildings become weathered.

*If soil is acidic, the acid can weather rocks below the surface. Here the rock exposed to air is weathered very slowly, but below the surface of the soil chemical weathering has been much quicker.*



*Cleopatra's Needle dates back to about 1500 BC, and came to London in 1819.*



*This monument in Luxor, Egypt dates back to about 1300 BC.*

### Guess what?

*How quickly a rock weathers depends on rock type, climate, soil type, local pollution levels, which plants are growing and even which way the rock faces.*



### Physical weathering

**Exfoliation:** the surface of the rock is heated through the day, when it expands. It is cooled at night, when it contracts. This regular expansion and contraction of the rock surface makes it flake off like peeling an onion.

### Physical weathering

**Freeze-thaw weathering:** water is an unusual chemical in that it expands when it solidifies. Liquid water seeps into small cracks. When the temperature falls, the water freezes and expands, making the cracks bigger. Eventually this can cause lumps of rock to fall off.

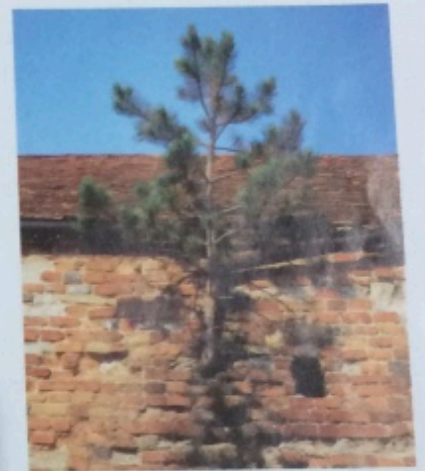
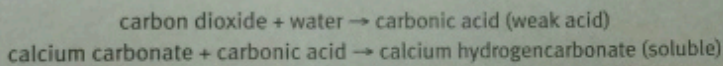
### Chemical weathering

Rainwater is naturally acidic because it contains dissolved carbon dioxide. It reacts with carbonate minerals in rocks, as shown by the equations below. Acid rain, which contains more strongly acidic pollutants, is even more damaging. It reacts more quickly with minerals in the rock, causing it to fall apart.

### Biological weathering

Plant roots can grow into cracks in rocks. As they grow they can push the rock apart, making the crack bigger. Eventually bits of the rock start to fall away, weathering the rock. Small burrowing animals living in cracks can also weather the rock.

### The reactions of chemical weathering by rainwater



Plants cause biological weathering to both rocks and buildings.

### Language bank

biological weathering  
carbon dioxide  
carbonic acid  
cemented  
chemical weathering  
climate  
crystals  
exfoliation  
freeze-thaw weathering  
grains  
minerals  
physical weathering  
rainwater  
weathering

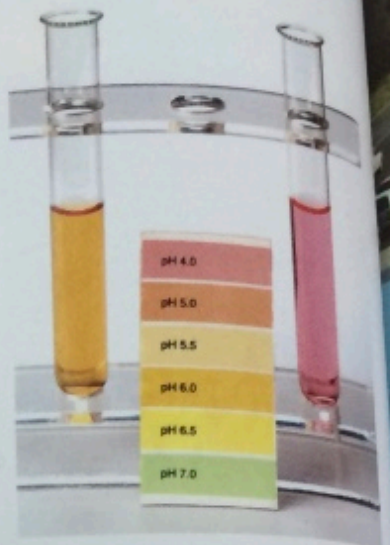
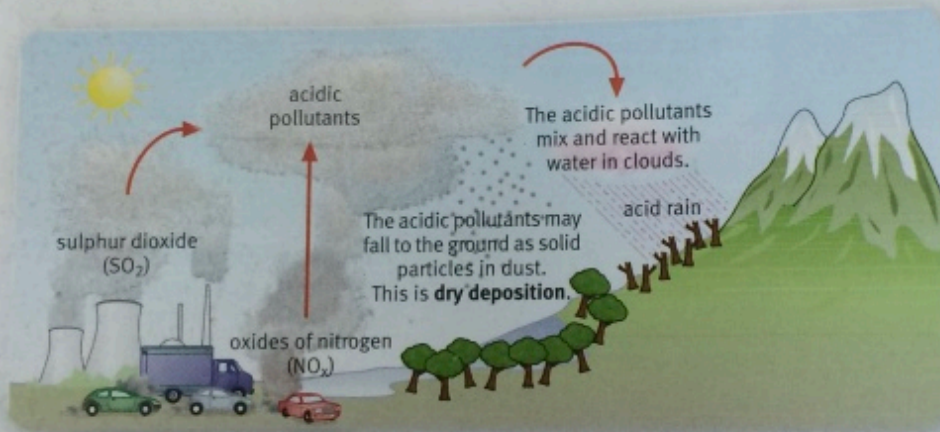
- 1 Copy and complete using words from the Language bank:  
Rocks and the buildings made from them contain small crystals and \_\_\_\_\_ of minerals, \_\_\_\_\_ together in lumps. These rocks are worn away by the processes of \_\_\_\_\_. There are three main types of weathering: physical weathering, \_\_\_\_\_ and \_\_\_\_\_.
- 2 a Describe two forms of physical weathering.  
b What sort of climate will speed up physical weathering?
- 3 How can acidic soils weather rocks?
- 4 What do you think is the most important factor that has made Cleopatra's needle weather more quickly since it came to London? Explain which processes have caused this.

### What causes acid rain?

You know that rocks are chemically weathered by rainwater, because it is naturally slightly acidic. Carbon dioxide in the atmosphere dissolves in rainwater, forming the weak acid carbonic acid. Sometimes rain can have an even lower pH. This **acid rain** speeds up the decay of building materials and paints, making rocks and buildings weather more quickly. It can make rivers, streams and lakes more acidic, killing plants and fish. It affects the soil so that trees and other plants cannot grow in it. Acid rain is a serious environmental problem.

### How does acid rain form?

The burning of fossil fuels produces carbon dioxide and water vapour. It also produces other gases such as sulphur dioxide and nitrogen dioxide. Like carbon dioxide these also dissolve in rainwater, but they form stronger acids so are more corrosive. The acidic pollutants may be carried many miles by the wind before they fall as acid rain.



Carbon dioxide is a non-metal oxide, and these tend to be acidic. Rainwater containing dissolved carbon dioxide has a pH of about 6, but more acidic pollutants reduce its pH even further.

Sulphur dioxide and nitrogen oxides are non-metal oxides. They react with rainwater to make strong acids, causing acid rain.

### Where do the acidic pollutants come from?

Fossil fuels such as petrol, diesel, coal and oil contain **hydrocarbons**. When these are burned the carbon and hydrogen are oxidised.

**carbon + oxygen  $\rightarrow$  carbon dioxide**

**hydrogen + oxygen  $\rightarrow$  hydrogen oxide (water)**

Fossil fuels also have impurities that contain other elements apart from carbon and hydrogen. These include sulphur and nitrogen, which are also oxidised when the fuel burns.

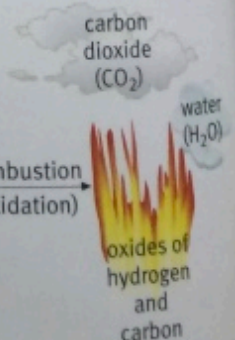
**sulphur + oxygen  $\rightarrow$  sulphur dioxide**

**nitrogen + oxygen  $\rightarrow$  oxides of nitrogen**

These oxides are acidic pollutants. With water in clouds they form acids such as sulphuric and nitric acids, which make acid rain.



contain hydrogen (H) and carbon (C)  $\xrightarrow{\text{combustion (oxidation)}}$





Nitrogen oxides come mainly from vehicle engines, along with other industrial processes. We can't usually see acidic pollutants, but nitrogen dioxide can form brown smog.



Burning coal in power stations is a major source of sulphur dioxide. This pollutant also comes from smelting metal ores, and industrial burning and incineration processes.

### Guess what?

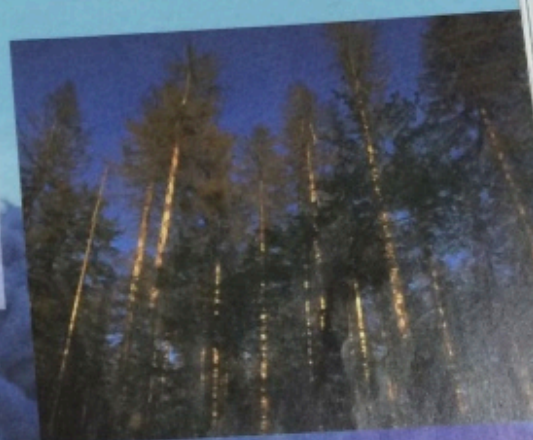
Nitrogen forms many different oxides, including:

- nitrogen oxide (NO)
- nitrogen dioxide (NO<sub>2</sub>)
- dinitrogen oxide (N<sub>2</sub>O).

Scientists use NO<sub>x</sub> to represent the mixture of oxides of nitrogen that form. Sometimes SO<sub>x</sub> is also used to represent a mixture of different oxides of sulphur.

### Where do acidic pollutants go?

Acidic pollutants can be carried long distances in the atmosphere before falling as acid rain. For example, the prevailing winds blow from the UK to Scandinavia, so that is where our pollutants tend to go. In the 1980s Britain was known in Scandinavia as 'the dirty old man of Europe'. Emissions have been reduced but the UK still produces pollution.



Acid rain causes tree leaves to go yellow and fall off, killing the trees. Some parts of Germany also suffer from the effects of acid rain.

Sulphur dioxide and nitrogen oxides are also produced by natural processes including volcanoes and lightning.

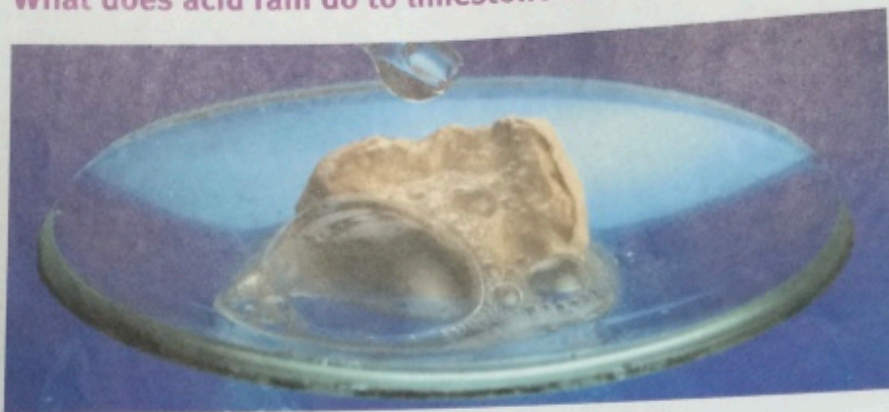
### Language bank

- acid rain
- acidic pollutants
- carbon dioxide
- chemical weathering
- dry deposition
- fossil fuels
- hydrocarbons
- nitric acid
- nitrogen oxides, NO<sub>x</sub>
- non-metal oxides
- sulphur dioxide, SO<sub>2</sub>
- sulphuric acid

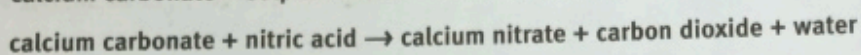
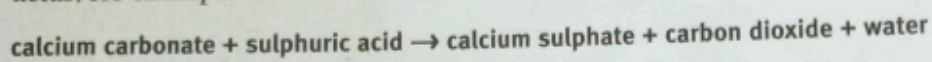
- 1 Copy and complete using words from the Language bank:  
 \_\_\_\_\_ makes rainwater slightly acidic. \_\_\_\_\_ is more strongly acidic, and this is caused by acidic pollutants dissolving in rainwater. These pollutants include \_\_\_\_\_ and \_\_\_\_\_.
- 2 Which human processes are the main producers of:  
 a sulphur dioxide      b nitrogen oxides?
- 3 Draw a flow diagram with equations to explain how acid rain forms. Include the following words, and add a diagram if you want:  
 sulphur dioxide    nitrogen oxides    pollutants    dissolve    acidic

- What are the effects of acid rain and how can they be reduced?
- Is pollution worse now?

### What does acid rain do to limestone rocks?



Chalk and limestone are mainly calcium carbonate. They react with acids, for example:



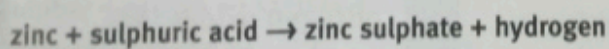
*King's College Chapel in Cambridge has been standing for about 500 years. It is made of limestone so it is being weathered by acid rain. This has been happening for many years, and is still going on today.*

### Guess what?

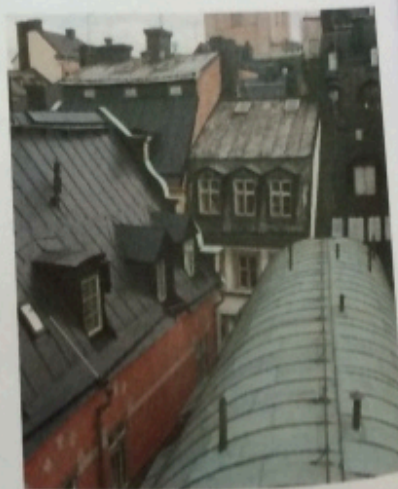
*The salt calcium sulphate is insoluble, so if it forms on the surface of a rock it can actually slow down any further weathering.*

### What does acid rain do to metals?

Metals such as zinc, iron and lead are used in buildings and sculptures. Exposed metals can react with acidic pollutants to produce a salt and hydrogen, for example:



Lead is less reactive than zinc and iron, so it is less affected by acid rain. Lead is used on roofs as it is soft and can be bent into shape.



*Lead is unreactive enough to be used for roofing.*

## What does acid rain do to living things?

Plants can tolerate a range of pH, but very acidic rain reacts with minerals in the soil. This allows some useful minerals to be washed away, and can also cause toxic aluminium to be released into the soil. These changes to the soil damage the plants growing there.

Aquatic animals are sensitive to pH changes, especially when young. At pH 5 most fish eggs cannot hatch. Most lakes and rivers have a pH between 6 and 8, and if they are on carbonate rock this will help neutralise acid rain. But some lakes and rivers become so acidic that nothing can survive. Toxic aluminium is washed into the water from the surrounding soil, and this kills fish and insects. Lakes that contain no life are crystal clear.

## Reducing acidic emissions

We have reduced our emissions of sulphur and nitrogen oxides over the last few years by the following:

- Using less fossil fuels by making engines more efficient, switching things off when we are not using them, or using alternative energy resources. This also helps us conserve supplies of fossil fuels.
- Using **catalytic converters**. Cars with petrol engines are fitted with devices which convert carbon monoxide (a poisonous gas) to carbon dioxide, and also convert oxides of nitrogen to nitrogen.
- Using **scrubbers**. These are devices in the chimneys of power stations and factories. They spray the waste gases with a scrubbing agent, which reduces sulphur dioxide emissions.

These measures have all helped, but many lakes affected by acid rain still have not recovered.

- Copy and complete using words from the Language bank:  
Acid rain reacts with rocks and buildings made of \_\_\_\_\_. It also reacts with exposed metals such as zinc and \_\_\_\_\_. Acid rain affects the \_\_\_\_\_ in soil and damages both plant and animal life.
- What measures can we take to reduce air pollution?
- a Look at the diagram above. Which animal is least tolerant of acidic conditions? Which is most tolerant?  
b How might acidic rain pollution affect organisms in a pond?

## Environmental chemistry

pH	4.0	4.5	5.0	5.5	6.0	6.5
trout	danger	danger	danger	acceptable pH	acceptable pH	acceptable pH
perch	danger	danger	danger	acceptable pH	acceptable pH	acceptable pH
frogs	danger	danger	danger	acceptable pH	acceptable pH	acceptable pH
snails	danger	danger	danger	danger	danger	danger

Key  danger  acceptable pH

A change in pH can seriously affect the food chains in a habitat.



Some kinds of lichen will only grow in clean air. Scientists can use them as **indicator organisms**. The types of lichen growing in an area give an indication of how clean the air is.

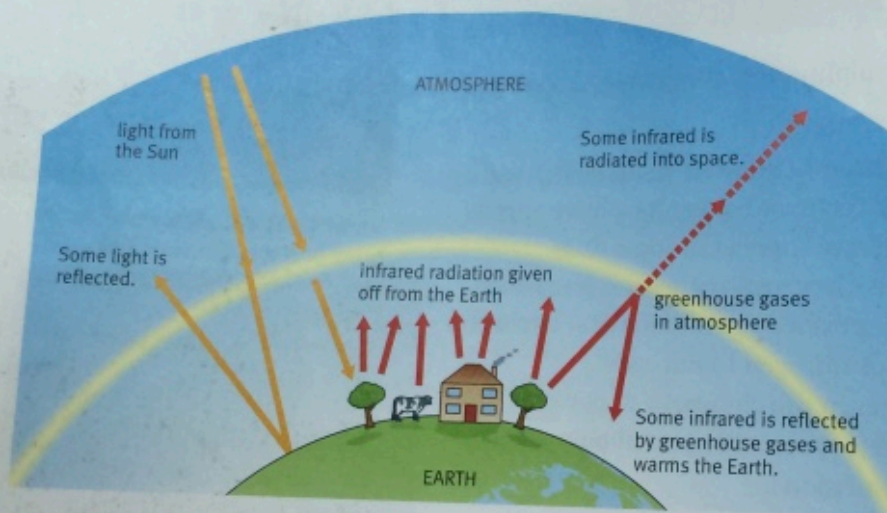
## Language bank

acid rain  
aluminium  
carbonate  
catalytic converters  
cement  
chalk  
indicator organisms  
iron  
lichens  
limestone  
minerals  
reactive  
scrubbers  
sulphuric acid  
zinc

### Is global warming happening?

Plants grow better in a greenhouse because it's warmer inside than outside. Sunlight passes through the glass. The plants and other objects inside the greenhouse absorb the light, and they give out some infrared radiation. This cannot pass through the glass, so it is kept inside the greenhouse, warming the air and everything else inside.

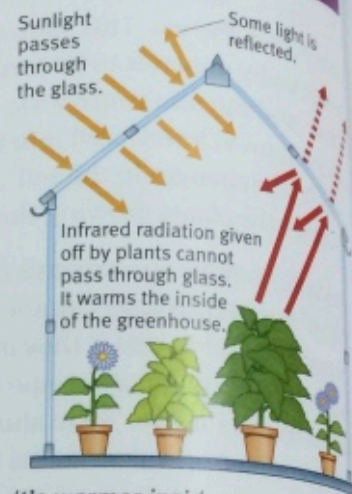
The atmosphere around the Earth acts like the glass in a greenhouse. Sunlight passes through the atmosphere to the Earth's surface. The Earth gives out infrared radiation, and some gases in the atmosphere reflect this back to the Earth rather than letting it go out into space. This keeps the Earth warmer than it would otherwise be. Without this greenhouse effect, life as we know it would not exist.



### Greenhouse gases: what's the problem?

The gases in the atmosphere that reflect the infrared radiation are called **greenhouse gases**. They are shown in the table.

Greenhouse gas	Produced by
carbon dioxide	burning fossil fuels for generating electricity and for transport; also by respiration, rotting organic material, volcanic eruptions
methane	rotting organic material (agriculture and landfill sites)
HFCs (hydrofluorocarbons) CFCs (chlorofluorocarbons)	CFCs used to be used in aerosols and fridges but they caused damage to the ozone layer (see page 90). Now HFCs are used instead.
NO <sub>x</sub>	traffic pollution, also produced naturally by bacteria
water vapour	many natural sources, burning fossil fuels



It's warmer inside a greenhouse.

So the atmosphere keeps us warm.

Yes, like a blanket around the Earth.

### Guess what?

If we had no atmosphere, Earth temperatures would be about 33 °C lower.

The problem is that we are producing more and more greenhouse gases. Scientists think that because of this the greenhouse effect is increasing, making the Earth warmer. This is called **global warming**.

The Earth's average temperature has warmed by  $0.6\text{ }^{\circ}\text{C}$  over the last 100 years or so. Some people predict that the average UK temperature may rise by  $2\text{--}3.5\text{ }^{\circ}\text{C}$  by 2080. This does not mean we will all have better weather, as global warming can cause many climate changes:

- **Temperature change:** some areas may get warmer, others colder.
- **Flooding:** oceans expand as they get warmer, which may cause flooding. Millions of people's homes could flood regularly. The sea level may rise by 50 cm by 2080.
- **Rainfall changes:** some areas might become wetter, such as North America and South East Asia. Some areas might become drier, such as Africa and India.
- **Plant life:** some areas might be able to grow better or different crops. Others may not be able to grow crops at all.

Is our increased production of carbon dioxide really causing global warming? Look at the graphs. The first shows that we are putting more and more carbon dioxide into the atmosphere. The second graph shows how the average temperature is changing. There have always been fluctuations in temperatures, and it is difficult to be sure what the long-term trend will be. Not all scientists agree.

### How can we reduce greenhouse gas emissions?

Use less fossil fuels:

- use alternative energy resources
- switch off electrical appliances when not in use
- use energy-efficient devices.

We should also stop deforestation (stop cutting down trees) and plant more trees.

1 Copy and complete using words from the Language bank:

There are gases in the \_\_\_\_\_ that act like a greenhouse. They help reflect \_\_\_\_\_ back to the Earth, warming it up. These gases are called \_\_\_\_\_ and they include \_\_\_\_\_ and methane.

2 a Explain how the atmosphere keeps the Earth warm.

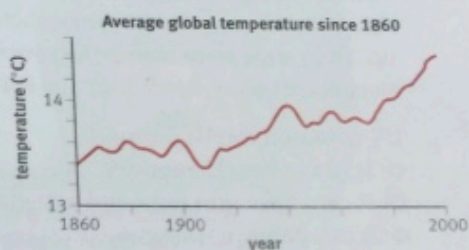
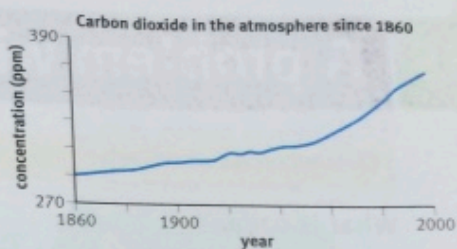
b Why is this effect increasing?

3 How would planting more trees help reduce global warming?

4 Compare the measures for reducing greenhouse gas emissions with those for reducing acidic pollutants on page 87.

5 Using a search engine, type in 'global warming' and try to find evidence to support the theory that global warming is happening.

### Environmental chemistry



Compare these two graphs. Do you think carbon dioxide emissions are making the Earth warmer?



Scientists monitor lakes, rivers and the air to see if conditions are changing over time.

### Language bank

atmosphere  
carbon dioxide  
fossil fuels  
global warming  
greenhouse effect  
greenhouse gases  
infrared radiation  
methane



○ Is pollution worse now?

### What is ozone?

Ozone is a form of oxygen which is formed in the atmosphere. There is a thin layer of ozone in the atmosphere around the Earth, about 30 km up. This **ozone layer** absorbs ultraviolet (UV) radiation from the Sun, stopping much of it reaching the Earth's surface.

UV radiation can be harmful:

- It can cause skin cancer.
- It can make skin tight and non-elastic.
- It can damage your eyes.

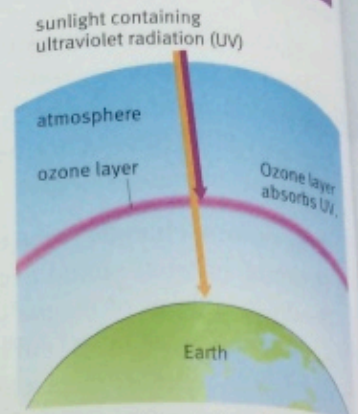
Our natural defence against harmful UV radiation is a pigment in our skin called **melanin**. This is what makes our skin darker if we spend time in the sun. The dark-coloured melanin absorbs the harmful radiation, stopping it getting through the skin to the tissues beneath.

### The hole in the ozone layer

The problem is that we are producing gases which react with the ozone layer, damaging it and letting more harmful UV radiation through. Chemicals called CFCs (chlorofluorocarbons) used to be used in fridges, aerosol sprays and air-conditioning units. These CFCs reacted with the ozone molecules, creating a 'hole' in the ozone layer. The hole allows more UV light to reach the Earth, increasing the risk of skin cancer and also having other effects such as killing sea plankton. Nowadays new chemicals called HFCs have largely replaced CFCs, and these do not react with ozone. However, some countries are still using ozone-destroying chemicals. It is hoped that all CFCs will be banned in Europe by 2015.

### Confused by all this pollution?

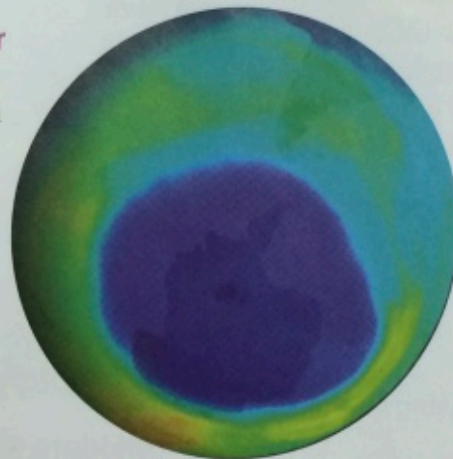
Acid rain? The greenhouse effect? The hole in the ozone layer? It is easy to become confused about pollution. The table opposite summarises the three major problems that we face.



The ozone layer absorbs UV radiation.

### Guess what?

Cars and fossil fuel power stations produce ozone gas. At the Earth's surface ozone is a pollutant, causing asthma and other lung problems. But the ozone layer high in the atmosphere protects us. We don't want ozone pollution at ground level, but we do want the ozone layer high in the atmosphere.



This picture of the atmosphere shows the hole in the ozone layer (dark blue) in September 2003. The 'hole' changes size at different times of year.

Problem	Pollutants that cause it
acid rain	sulphur dioxide and oxides of nitrogen
global warming	increased levels of greenhouse gases including carbon dioxide, methane, nitrogen oxides and CFCs
hole in the ozone layer	CFCs and other chlorine-based chemicals

## Anti-pollution measures

Many countries have agreed to reduce the amount of carbon dioxide they put into the air each year. Between 1990 and 2000, sulphur dioxide emissions were reduced by 71%. The use of CFCs is declining and will soon be banned outright. So things are improving in some ways.

But every country wants industrial and economic development, to give its people a better standard of living. We must agree to develop in a way that does not destroy what we have. This is called **sustainable development**. Here are just a few views on how we can achieve this.

We should tax the sale of cars. This would help cover the cost of dismantling old cars in an environmentally friendly way.



We should tax fuels and electricity to fund research into alternative energy resources such as wave power which do not produce carbon dioxide.

We need to encourage people to car share and use public transport.



Trees absorb carbon dioxide and produce oxygen. When trees are cut down for paper or timber, more trees should be planted.

We need to monitor the environment to make sure we are not destroying valuable habitats for the plants and animals that live in our country.



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1 Copy and complete using words from the Language bank:

\_\_\_\_\_ is a form of oxygen which makes up a layer high in the atmosphere. This layer filters out harmful \_\_\_\_\_ which can cause skin cancer. Some chemicals including \_\_\_\_\_ have reacted with the ozone layer. We refer to this problem as the \_\_\_\_\_.

2 Summarise the differences between acid rain, global warming and the hole in the ozone layer. Start with the table opposite, and add two columns showing what activities cause the pollution and what problems it causes for us.

3 Look at the ideas above. For each one, explain how it will help in reducing pollution and sustaining the Earth's resources. Do you think it would be a measure that people would like to see introduced?

4 We all want to breathe clean air. Identify ten everyday things you and your friends could do to help save the Earth's resources and reduce pollution.

### Language bank

acid rain  
carbon dioxide  
CFCs  
global warming  
greenhouse effect  
hole in the ozone layer  
ozone  
recycling  
sustainable development  
UV radiation

# Checkpoint

## 1 Matching reactions

Match up each environmental process with the correct chemical reaction.

### Processes

Acid rain quickly weathers limestone rocks and buildings.

Naturally acidic rainwater slowly weathers limestone rocks and buildings.

Carbon dioxide dissolves in water.

Carbon dioxide is formed when coal and hydrocarbon fuels are burned.

Metals are corroded by acid rain.

### Reactions

carbon + oxygen → carbon dioxide

carbon dioxide + water → carbonic acid

zinc + sulphuric acid → zinc sulphate + hydrogen

calcium carbonate + nitric acid → calcium nitrate + carbon dioxide + water

calcium carbonate + carbonic acid → calcium hydrogencarbonate

## 2 The greenhouse effect

Copy and complete these sentences, unscrambling the bold words.

Carbon dioxide and methane are **geeserhuno** gases. This means they help to reflect **raferdin** radiation back to Earth, keeping the Earth warm. This is effect called the **reshenogue tecfef**.

Humans are putting more and more greenhouse gases into the **pathosmere**. Scientists think this is causing **goball marwing**.

## 3 Indicator organisms

Look at the diagram on page 87. A scientist suspects acidic pollution in a lake, because during routine monitoring she has observed changes in the organisms that live there.

- a If she has observed that perch and frogs are living there, but no trout or snails, what might you expect the pH to be?

- b Which is the most acid-tolerant organism shown?

- c Which mineral below is washed into water following acid rain pollution, killing fish?  
nitrate    ammonium    aluminium

## 4 True or false?

Decide whether the following statements about the ozone layer are true. Write down the true ones. Correct the false ones before you write them down.

- a Ozone is a form of the element hydrogen.  
b The ozone layer absorbs harmful ultraviolet radiation.  
c CFCs do not react with ozone.  
d A hole has appeared in the ozone layer, exposing us to more ultraviolet radiation.  
e This means more people are suffering from skin cancer and eye damage.  
f The hole is getting bigger because everyone is still using CFCs.

## 5 Pollutants and problems

For each problem below, choose the pollutants and processes that cause it.

### Problems

acid rain: dying trees and fish

global warming: climate change

hole in the ozone layer: increased skin cancer

### Pollutants

increased carbon dioxide, methane, NO<sub>x</sub>  
CFCs

sulphur dioxide and oxides of nitrogen

### Processes

used in fridges and air-conditioning units

fossil-fuel power stations and vehicles

increased combustion and cutting down forests