10 Living with acids and bases

Planning page

- **Getting started**
- **10.1 What are acids and bases?** page 218
  - Investigate 22 Red cabbage indicator
- **10.2 The pH scale** page 224
  - Investigate 23 Measuring pH
  - Activity page 227
- **10.3 Reactions of acids and bases** page 231
  - Investigate 24 Reactions of acids
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  - Animation Acid rain
- Assessment task 10 Acid rain
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  - Chapter 10 crossword
- **Review**
  - Chapter 10 test

Essential Learnings for Chapter 10

Essential Learnings	References		
	Student book (page number)	Workbook (page number)	Teacher Edition CD (Assessment task)
Knowledge and understanding ***Natural and processed materials*** Matter can be classified according to its structure	pp. 227–228	p. 82	Assessment task 10 Acid rain
Chemical reactions can be described using word and balanced equations	pp. 227–228, 233–234, 236	Exercise 2 p. 79 Exercise 11 p. 82	
Science as a human endeavour Immediate and long-term consequences of human activity can be predicted by considering past and present events	p. 236	Exercise 16 p. 84	Assessment task 10 Acid rain
Ways of working Conduct and apply safety audits and identify and manage risks	Investigate 22–25 pp. 221–235		
Draw conclusions that summarise and explain patterns, and that are consistent with the data and respond to the question		Exercise 4 p. 80	

QSA Science Essential Learnings by the end of Year 9

Vocabulary

alkali/alkaline
ammonia
antacid
carbonate
corrosive
fluoride
indicator
ion
litmus
magnesium
mucus
neutralisation
plaque
sodium hydroxide
stomach
sulfate
sulfuric

Focus for learning

Make sherbet and suggest inferences to explain the reaction that occurs (page 217).

Equipment and chemicals (per group)

Getting started page 217	icing sugar, citric acid, baking soda, teaspoon, paper cup
Investigate 22 page 221	2 or 3 large leaves from a fresh red cabbage, sharp knife and chopping board, two 250 mL beakers, hotplate (or burner, tripod and gauze), stirring rod, 6 test tubes and test tube rack (or spotting tile), dilute hydrochloric acid (0.5M), dilute sodium hydroxide solution (0.5M), various household substances in dropping bottles (eg window cleaner, shampoo and conditioner, antacid tablet, vitamin C, vinegar, milk, baking soda, cream of tartar, lemon juice), flower petals (eg tibouchina, hydrangea, hibiscus, yellow pansy)
Investigate 23 page 226	**Part A:** various household substances, universal indicator solution or pH paper, laboratory acids and bases, spotting tile **Part B:** universal indicator solution, barium sulfate powder for soil testing, petri dishes, soil samples, iceblock stick or spatula, powdered limestone and ammonium sulfate (Try this)
Activity page 227	small test tube, dilute hydrochloric acid, conductivity kit, sodium chloride solution
Investigate 24 pages 231–232	**Part A:** pyrex test tubes and test tube rack, dilute hydrochloric acid (1M), universal indicator solution or paper, piece of magnesium ribbon (about 2 cm), taper and matches, samples of other metals **Part B:** dilute hydrochloric acid (1M), test tubes and test tube rack, stopper for test tube, one-holed stopper fitted with glass and plastic tubing, taper and matches, limewater (calcium hydroxide solution), other carbonates (eg sodium carbonate, sodium hydrogen carbonate, copper carbonate)
Investigate 25 page 235	dilute hydrochloric acid (0.1M), small flask (eg 250 mL), 50 mL measuring cylinder, methyl orange indicator, spatula, antacid powder or crushed tablet, plastic petri dish, balance
Activity page 236	**Teacher demonstration:** gas jar, universal indicator solution, sulfur, deflagrating spoon, Bunsen burner, flower petal, piece of fruit peel or piece of coloured paper

Special preparations

Investigate 24 page 232 To make limewater, add about one heaped teaspoonful of calcium hydroxide, $Ca(OH)_2$, to 1000 mL of distilled water. Shake or stir to mix, and allow it to stand overnight if possible, then filter off the solid. Keep well stoppered.

10 Living with acids and bases

Getting Started

When you put sherbet in your mouth, you are experiencing one of the chemical reactions of acids. You can do this at home or at school, provided all your equipment is perfectly clean. Add the following to a paper cup:

- 3 teaspoons icing sugar
- ½ teaspoon citric acid
- ¼ teaspoon baking soda

Mix the ingredients thoroughly, then taste the mixture.

- Describe the taste of your homemade sherbet.

What happens when you add a few drops of water to the sherbet?

- Suggest a reason for the distinctive taste of sherbet.
- Why do you think the reaction between citric acid and baking soda occurs only when you add water?

Starting point

1 Making sherbet is an activity which allows the students to gather data through all their senses.
   - Eating in the laboratory is not often allowed, so encourage the students to view this activity as a bit of a privilege.
   - When the water is added, they should be able to see and hear it fizz.
   - If any sherbet or ingredients spill onto the workstation benches, ask them to clean the spillage up and discard the powder. Remind students about hazardous chemicals and residue which may be on the benches from prior classes.
   - Be aware of any student with a food intolerance or medical condition where sugar or citric acid is not advisable.
   - The reaction between citric acid and baking soda occurs when you add water (refer to page 228 to help explain why).

3 Initiate a class discussion about foods with different tastes, particularly ones which seem sour or cause a tingling sensation when eaten. Ask the students to infer the reason (the food is likely to be acidic). What makes a substance an acid or a base? In the discussion, come up with a class definition for an acid and a base. Students are probably more familiar with acids than they are with bases, so jog their memory about some household cleaning substances and the caustic soda used for making soap in Chapter 9.

4 Get the students to form an acid and base chart listing as many common acids and bases as they can think of. Place two poster-sized pieces of paper at the front of the room. Label one piece of paper 'Acids' and the other 'Bases'. As they work through this chapter, ask the students to add to the chart. Do they think there will be more acids on the chart? When you cover the section on pH levels, assign some students to find out the pH values for the substances listed and add them to the chart. You may like to compile a more comprehensive chart containing the chemical name, common name and common uses. You could also extend the chart by adding a third list for neutral substances.

5 The materials and activities in this chapter are obviously hazardous and students need to be reminded of safety procedures and equipment (especially safety glasses and lab coats). They should also be reminded of the appropriate first aid in the event of spillage—in most cases it will require washing with lots of water.

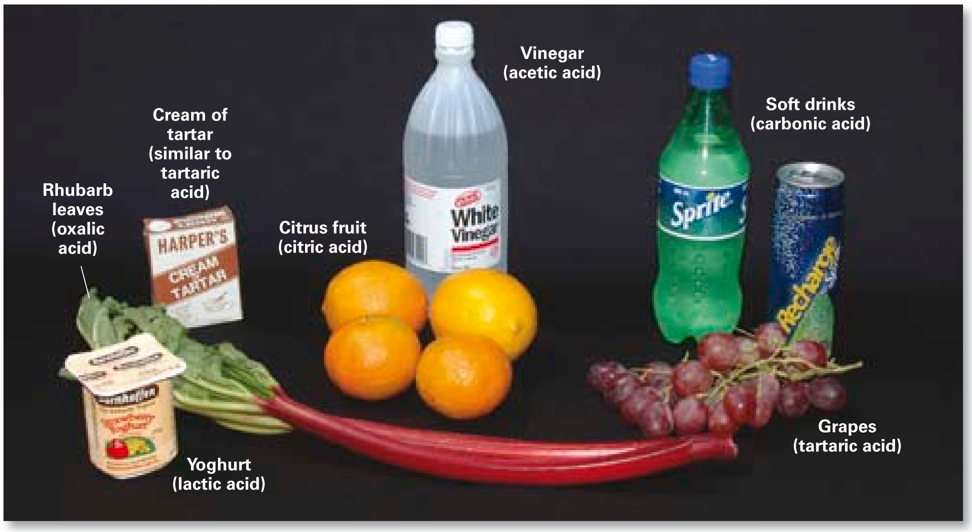
Hints and tips

- Strong acids are corrosive. They destroy living tissue and 'eat through' some surfaces. Hydrochloric acid in the stomach is a strong acid, so why doesn't it eat through the stomach lining? Before explaining the reason, see if the students can come up with their own suggestions. If any student knows the correct answer, you might like to ask them to be 'the teacher' and explain the reason to the class.
- It is not just acids which can cause severe burns—bases can too. Even just trying to smell a strong acid can cause burning to the nostrils from the fumes. Develop a new set of safety rules for using corrosive and/or hazardous chemicals with the class.
- Revise the meanings of the following words: corrosion/corrosive, dilute/concentrated, solvent, solute, solution, neutral.
- Students tend to think all bases are alkalis. Reinforce that only bases which dissolve in water are called alkalis. Water is called the 'universal solvent' because it dissolves more substances than any other liquid, hence many bases are alkalis. Copper oxide is a base but not an alkali. It will neutralise an acid.

Research

Research the difference between alkaline and acid batteries. What are some examples of each type of battery, and how are they used?

10.1 What are acids and bases?



What are acids?

Acids are very common substances and are used widely in everyday life. Some occur naturally, and some are synthetic. Some of them are potentially dangerous because they are **corrosive**—they can 'eat away' metal, wood and clothing, and burn your skin. For example, battery acid contains sulfuric acid (H_2SO_4) which will burn your skin; and hydrochloric acid (HCl) is used to clean mortar from bricks.

The photo above shows some of the many natural acids found in food and drink. They all have a sour taste. The sherbet you made in Getting Started contains citric acid, which is in all citrus fruits and tomatoes. Yoghurt contains lactic acid, vinegar contains acetic acid, and grapes contain tartaric acid. The bubbles in soft drinks are due to carbon dioxide which dissolves in water to form carbonic acid. The hydrochloric acid in your stomach is essential for digestion, and the DNA that makes you different from everybody else is deoxyribonucleic *acid*.

Acids that are corrosive attack your body tissues. This is why lemon juice stings if you get it in a cut on your finger; and bees and ants sting because they inject formic acid into you. You can eat fruit which contains acids because the acid is very dilute. A *dilute* acid is one which contains a large amount of water and a small amount of acid. The opposite of dilute is *concentrated*, and concentrated acids such as the sulfuric acid in a car battery must be handled with great care.

What are bases?

Bases neutralise (cancel out the effect of) acids. For example, some toothpastes contain a weak base to neutralise the acids formed by plaque bacteria on your teeth. Bases are also used to dissolve grease and dirt. Oven cleaners and drain cleaners usually contain caustic soda (sodium hydroxide NaOH) which dissolves grease. Other household cleaners contain ammonia, which can be used to remove grease from floors or to clean windows. Bases which are soluble in water are called **alkalis**. The reason they feel soapy is because they turn the oils on your skin into soap (as in Investigate 20 on page 199).

Learning experience

There is a myth that cola and other carbonated drinks can clean copper coins. Ask the students to test this myth and write a report describing an experiment they have devised to test the myth, and predicting the likely outcome. Make sure they scientifically justify their prediction. They should also include a theory/discussion section in their report explaining the chemistry behind the experiment. For an extension exercise, get them to come up with a way to test the effect the drink has on teeth. (What substitute could be used instead of a tooth?)

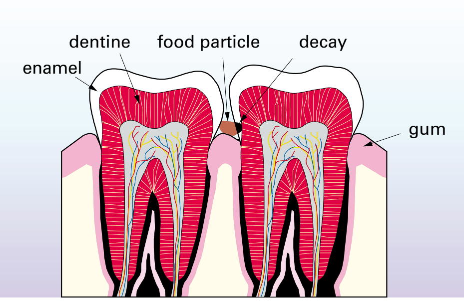
Learning experience

Reinforce the concepts of dilute and concentrated solutions by doing a simple demonstration using water and food colouring. Fill a 100 mL beaker with water and add a few drops of food dye. Suggest this models a concentrated acid. Take a small sample of the concentrated solution and put it into another 100 mL beaker, then fill it with water. The dilute solution should be obvious to see from the reduction in colour intensity.

Acids and teeth

When you eat, food often remains between your teeth. Bacteria in your mouth then feed on this food. Chemical reactions occur and the bacteria produce weak acids as waste products. These acids react slowly with your teeth, causing tooth decay. The mixture of bits of food, bacteria, acids and saliva that sticks to your teeth is called *plaque* (PLARK).

The top of a tooth is covered with enamel, which is the hardest substance in the body. The inside of the tooth is made of a softer substance called dentine. If the bacteria and acids cause this hard enamel to decay, then the tooth can be damaged very rapidly.



The best way of getting rid of plaque and food particles from your teeth is by brushing them. Toothpastes contain abrasives such as finely powdered chalk which help scrape food particles from your teeth. They also usually contain a small amount of soap or mild detergent. This makes a foam which helps brushing.

Some toothpastes are slightly basic to neutralise the acids produced by decaying food. They may also contain fluoride compounds. These react with tooth enamel in young people's teeth to form a substance which is more resistant to acid attack and less likely to decay.

Stomach acid

Gastric juice is produced in your stomach to help you digest, or break down, the food you eat. This gastric juice consists of dilute hydrochloric acid, the enzymes pepsin and rennin, and water. The hydrochloric acid helps to kill most microbes. It also helps the enzymes to work, since they will function only in the presence of an acid. These enzymes break down the proteins in food into amino acids, which are needed for growth.

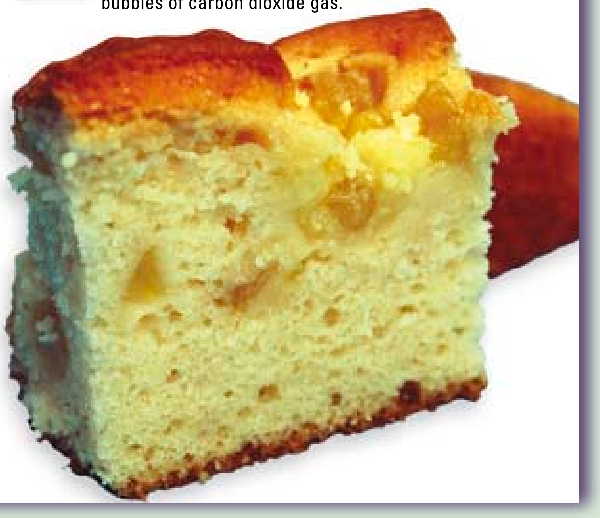
Your stomach is protected from the acid in the gastric juice by a sticky fluid called *mucus*. This protects the stomach wall and acts as a lubricant so that food passes through smoothly. If bacteria called *Helicobacter pylori* get into the lining of the stomach they can weaken the mucus layer, allowing the acid to attack the lining. This can lead to a painful stomach ulcer (sore).

Acids in food and drink

Baking powder and self-raising flour contain baking soda (sodium hydrogen carbonate $NaHCO_3$) and an acidic substance such as cream of tartar. While the baking powder or flour is dry, no reaction occurs. But when it becomes moist, the baking soda reacts with the acid to form carbon dioxide gas. The bubbles of gas are trapped inside the cake, and when it is placed in an oven, the carbon dioxide gas expands, making the cake 'rise'.

Acids are also used to preserve food. For example, when vinegar (dilute acetic acid) is used in the making of pickles or sauces, the acid prevents the growth of bacteria, some of which may be harmful.

Fig 4 The holes in this cake are produced by bubbles of carbon dioxide gas.



Hints and tips

Just about all the foods we eat are acidic and have a pH between 2 and 7. Many biological processes, such as the digestion of food, are dependent on acid. The stomach is a very acidic place and contains hydrochloric acid. Once we start eating, acid is secreted into the stomach to start the digestion process. The secretions mix with the food in the stomach and the resulting mixture can have a pH of between 1.0 and 3.0, which is very acidic. Predict what happens when you eat foods such as oranges, cherries or apples, which are already quite acidic.

Research

As a research assignment, set students the task of researching and writing a list of foods together with their pH values. They should write them in order from the highest pH (least acidic) to the lowest pH (most acidic). Then ask them to list the foods they consumed for dinner and their pH values (if known). Did they eat a relatively high-pH or low-pH meal? Estimate what the pH value of an average meal at home is.

(You may wish to leave a discussion of pH until page 224.)

Learning experience

Ask students why bicarbonate of soda (baking soda) is sometimes used as an ingredient in cooking. It is also used as a household cleaning product (explain the chemistry). How are acids/bases useful in daily life? Ask the students to come up with their own questions about everyday acids and bases to explore through research.

Issues

Ask students to design a multimedia presentation, web page or magazine advertisement to discuss the merits of using more environmentally friendly cleaning products, such as vinegar and bicarbonate of soda. Are these products just as effective with cleaning? Why are they considered to be more environmentally friendly than other commercial cleaning products? Explain the chemistry in the context of acids and bases. Allow about one lesson in class to complete this task. It could be completed as homework if more time is required. Students' final products should be marked on accuracy, creativity and clarity in all areas of the task.

Hints and tips

Compare and contrast acids and bases. You could display this information in a table. For example:

Acids	Bases
Have sour taste	Have a bitter taste
Are corrosive (caustic)	Are corrosive (caustic)
Can neutralise a base	Can neutralise an acid
Conduct electricity when mixed with water to form an aqueous solution	Conduct electricity when mixed with water to form an aqueous solution
Increase the hydrogen ion (H^+) concentration in aqueous solutions	Increase the hydroxide ion (OH^-) concentration in aqueous solutions
Turn universal indicator red	Turn universal indicator blue
pH less than 7	pH greater than 7
	Have a slippery/soapy feel

Indicators

Some solutions are *acidic* and some are *basic*, while others are *neutral* (not acidic or basic). For example tap water is usually neutral.

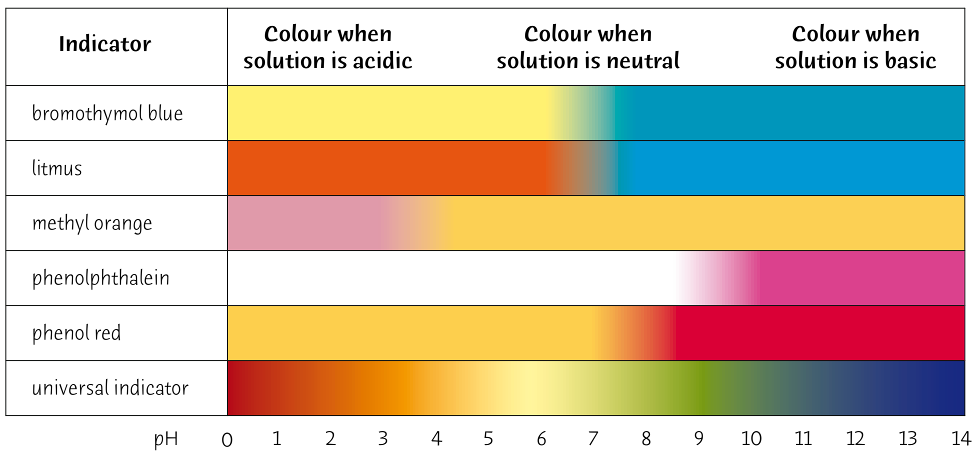
A quick way to tell whether a solution is acidic or basic is to use an acid–base **indicator**. Such substances *indicate* when an acid or base is present by changing their colour.

Some indicators occur naturally in dyes in plants. For example, litmus comes from lichens, which grow on the bark of trees and on rocks. In an acidic solution, litmus turns red; and in a basic solution it turns blue. There are also a number of synthetic indicators. One of these is called bromothymol blue (bro-mo-THY-mol). If bromothymol blue is added to an acidic solution, it changes colour from blue to yellow. If an alkali like sodium hydroxide is added, it turns blue again.

If you add bromothymol blue to a basic solution, it stays blue. But if you add acid, it turns yellow. To be sure that a substance is an acid (or a base) you must observe a *change* in the colour of an indicator. Suppose you test a solution with bromothymol blue and it stays blue. You cannot say from this that the solution is basic. It could be water. You would need to use another indicator, eg red litmus, and see if it changes colour in the solution.

Fig 5 Household cleaners contain alkalis such as ammonia and caustic soda.

Most indicators have only two colours. *Universal indicator* is a mixture of several different indicators. Because of this, universal indicator can be many different colours depending on how acidic or basic the solution is. (See the colour chart below.)



Learning experience

A fun teacher demonstration is turning colourless solutions pink and then colourless again as a way of introducing chemical indicators. Try the following:

1 Have a pre-prepared 100 mL beaker filled with water containing about 3 drops of phenolphthalein. (The solution should be colourless.) Tell the students it contains water but at this stage don't tell them about the presence of phenolphthalein.

2 Allow the students to watch you add some drops of ammonia with a dropper. The solution will turn a dramatic pinkish-purple. Now add some drops of vinegar. What happens? The liquid becomes colourless again, but why?

3 After some discussion, explain that you had pre-added an acid/base indicator to the water. Explain what an indicator is and what it detects. The phenolphthalein in the water becomes pinkish-purple when the pH of the solution exceeds about 8, so adding ammonia causes the solution to change colour. You may like to test the pH using a pH meter to get a more precise value.

Investigate

22 RED CABBAGE INDICATOR

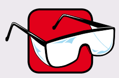
Aim

To extract the coloured substance from red cabbage, and use it to test acids and bases.

Materials

- 2 or 3 large leaves from a fresh red cabbage
- sharp knife and chopping board
- two 250 mL beakers
- hotplate (or burner, tripod and gauze)
- stirring rod
- 6 test tubes and test tube rack
- dilute **hydrochloric acid** (0.5M)
- dilute **sodium hydroxide** solution (0.5M)
- various household substances, eg:
  - window cleaner
  - shampoo and conditioner
  - antacid tablet
  - vitamin C
  - vinegar
  - milk
  - baking soda
  - cream of tartar
  - lemon juice

Corrosive



Wear safety glasses.

Wear a lab coat or apron.

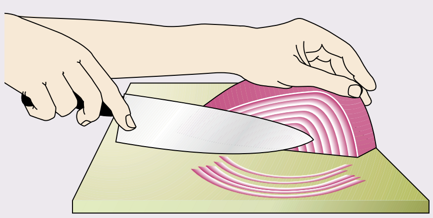
Planning and Safety Check

- What special precautions are needed when handling acids and bases?
- What should you do if you spill a corrosive liquid?
- Design a data table to record your results.

Method

1 Cut up 2 or 3 large red cabbage leaves into small pieces. Put them in a beaker.

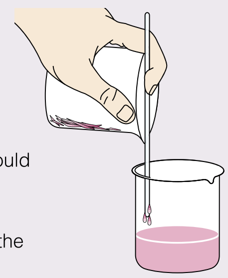
2 Add water to just cover the cabbage pieces.



3 Boil the cabbage mixture for 5–10 minutes. The water should turn a dark colour, and the leaves should almost lose their colour.

4 Let the mixture cool. Then carefully decant the coloured solution into another beaker. Alternatively you could strain the mixture through a sieve.

What colour is the extract?



5 Add a small amount of dilute hydrochloric acid to a test tube and label it. Add some sodium hydroxide solution to another test tube. Now add a few drops of red cabbage extract to each tube.

What colours are the solutions?

6 In the same way test the various household substances you have collected.

For each substance record any colour change.

Discussion

1 What colour is your red cabbage extract in a neutral solution (water)? What colour is it in acidic solutions? In basic solutions?

2 Which household substances are the most acidic? Which are the most basic? How do you know?

3 Suggest why the red cabbage extract is called an acid–base indicator.

try this

You may wish to extract and test the colour from flower petals, eg tibouchina, hydrangea, hibiscus, yellow pansies. You could also try fresh beetroot or tea leaves.

Lab notes

- Red cabbages are not available all year round so it is a good idea to get one (or more) and freeze it for use when you need it. Cut the cabbage (shredded cabbage works best) and place it in plastic bags before freezing it.
- This investigation can take about an hour, so if lessons are shorter than this the activity will need to be done over two lessons.
- If you need to keep the cabbage for more than a day or two, add a few drops of methylated spirits to preserve the indicator and put it in a sealed container in the fridge, as the cabbage has a distinctive odour!
- Spotting tiles can be used instead of test tubes.

Check!

1 Copy and complete the following sentences.
  a Litmus turns ______ in basic solutions, and ______ in acidic solutions.
  b A soluble base is called an ______.
  c Solutions may be acidic, basic or ______.
  d To be sure that a solution is acidic you must observe a ______ in the colour of an indicator.
  e Bromothymol blue turns yellow in ______ solutions.
  f Vinegar is ______, and ammonia solution is ______.

2 Give the names and uses of two alkalis found in the home.

3 Why is it that the acids in food and drink do not harm your stomach?

4 Use the information in the table below to answer these questions.
  a What acid is present in:
    - sour milk?
    - oil of wintergreen?
    - ants?
  b Where would you find:
    - citric acid?
    - tartaric acid?
  c Apart from its value as vitamin C, why else is ascorbic acid added to fruit juices?
  d If oxalic acid is a poison, why is it possible to eat rhubarb and spinach?
  e Acetic acid can be formed from one of the other acids in the table. Which one?

5 Why are some toothpastes basic?

6 Use the table of acid–base indicators on page 220 to answer these questions.
  a What is the colour of phenol red in a basic solution?
  b What colour is litmus in—
    - vinegar?
    - ammonia solution?
  c What colour would you expect if you added methyl orange to tap water?
  d Jerry added some phenolphthalein to a solution and it remained colourless. When he added bromothymol blue it turned yellow. Is the solution acidic, basic or neutral? How do you know?
  e Universal indicator is added to some dilute hydrochloric acid and excess sodium hydroxide (more than enough to neutralise the acid) is then added. What would be the order of the colour changes shown by the indicator?

7 How is self-raising flour different from ordinary flour?

8 Some food and drink labels indicate that a food acid has been added. Suggest why this food acid is added.

9 Sodium hydroxide is used for cleaning greasy ovens. Gavin spilt some on his hand and Fiona suggested that he rinse his hand with vinegar. Is Fiona's suggestion sensible? Explain.

Acid	Found in . . .	Uses
acetic	fermented grapes	vinegar, making PVA glue
ascorbic	fresh fruit and vegetables	vitamin C, food preservative
citric	citrus fruits, eg oranges and lemons	fruit drinks, medicines
formic	ants and stinging nettles	preservative and antibacterial agent in livestock feed
lactic	sour milk, tired muscles	yoghurt and cheese, cosmetics
oxalic	rhubarb leaves and spinach leaves	wood bleaching agent, rust remover
salicylic	oil of wintergreen	aspirin, acne creams, heat rubs
tartaric	grape juice	flavouring agent, cream of tartar

Check! solutions

1 a Litmus turns *blue* in basic solutions, and *red* in acidic solutions.
  b A soluble base is called an *alkali*.
  c Solutions may be acidic, basic or *neutral*.
  d To be sure that a solution is acidic you must observe a *change* in the colour of an indicator.
  e Bromothymol blue turns yellow in *acidic* solutions.
  f Vinegar is *acidic*, and ammonia solution is *basic*.

2 Two alkalis found in the home are 'cloudy ammonia' (found in the laundry and used for disinfecting surfaces) and baking soda (found in the kitchen and used in cooking).

3 The stomach is very acidic anyway and the cells and tissues are protected by a layer of mucus.

4 Using the information in the table:
  a lactic acid
    salicylic acid
    formic acid
  b citrus fruits
    grape juice
  c The reason is that vitamin C also acts as a preservative to stop the food going 'off'.
  d It is safe to eat rhubarb and spinach because they contain only a small amount of oxalic acid.
  e Acetic acid can be formed from tartaric acid which is found in grapes.

5 Food which remains in your mouth after a meal is broken down by bacteria to produce acids which cause tooth decay. The toothpaste helps to neutralise these acids and reduce tooth decay.

6 Using the information in the table on page 220:
  a Phenol red is red in a basic solution.
  b Litmus is red in vinegar. Litmus is blue in ammonia solution.
  c Methyl orange will be yellow in tap water, which is neutral.
  d The solution is acidic because it can be checked in the chart on page 220.
  e The colour changes would be red through yellow and green to blue.

7 Self-raising flour contains baking soda or sodium bicarbonate which produces carbon dioxide gas when it is heated, causing the food to rise.

8 Food acid is often added to give the food flavour or to preserve it.

9 Yes, this is a sensible suggestion because the vinegar will neutralise the sodium hydroxide which is an alkali. It would also be a good idea to then wash it all off with plenty of water.

challenge

1 When you vomit you get a sour sensation in your throat and mouth. Suggest a reason for this.

2 Water containing bromothymol blue turns yellow when carbon dioxide is bubbled into it. Suggest why this happens.

3 Huw read somewhere that a stinging nettle contains an acid which is injected into your skin if you touch it. How could he show that a stinging nettle contains an acid?

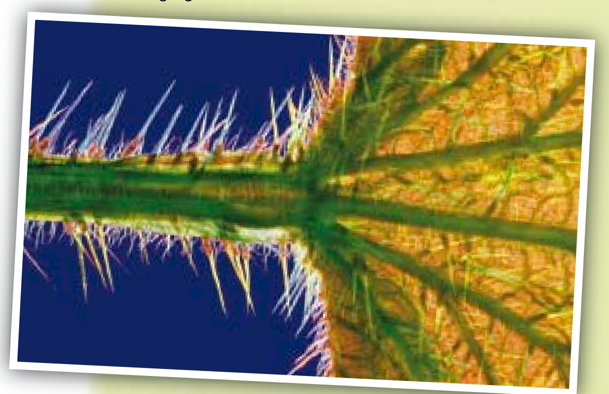


Fig 8 A close-up view of the barbs on a stinging nettle (leaf on the right)

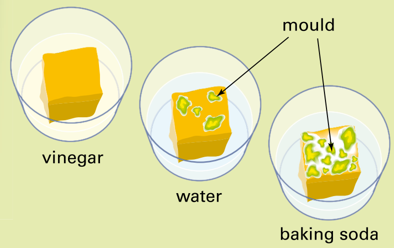
4 When Nemika put a piece of red litmus paper in an unknown liquid, nothing happened. When she added bromothymol blue it stayed blue. What inference can Nemika make from these observations?

5 Why does boiling a dilute acid make it more concentrated?

6 The dyes in some fabrics change colour when washed with certain detergents. Suggest a reason for this.

7 Andre did an experiment to investigate how well mould grows under different conditions. He placed cubes of cooked pumpkin in three jars. He half filled the first jar with water, the second with vinegar and the third with a solution of baking soda. He then covered the jars and left them in a warm, dark cupboard for two days. His results are illustrated below.

What conclusion can Andre draw from his experiment?



try this

1 Mix equal amounts of cream of tartar and baking soda in a container then add a little water. Explain your observations.

2 **Disappearing ink**

You will need phenolphthalein solution (0.1 g in 10 mL ethanol, then add 90 mL water). Add 3M sodium hydroxide, a drop at a time, until the solution turns dark red. Put the solution in a spray bottle.

Accidentally on purpose spill the red 'ink' on a white cloth or shirt. Blow on the cloth or wave it in the air.

You could try dabbing the ink spot on the cloth with a cotton ball dampened with ammonia or vinegar.

The red colour is due to the sodium hydroxide, which is basic. Carbon dioxide in the air forms carbonic acid which neutralises the sodium hydroxide. As a result the phenolphthalein turns colourless.

3 Hayley asks her mother why she squeezes lemon juice onto freshly made fruit salad. Her mother says that the acid in the lemon juice stops the apple and banana going brown.

Design and perform tests to find out whether it is the acid in the lemon juice that stops the browning, or some other substance.

Challenge solutions

1 When you vomit some of the acid from your stomach comes up through your oesophagus. Your oesophagus is made of living cells. The acid will damage some of these cells and cause the burning sensation.

2 When carbon dioxide is bubbled through water some of it dissolves to form an acid. This acid causes bromothymol blue to change colour.

3 Huw could carefully collect some of this liquid, perhaps using the blade of a knife, and test it using an indicator. The colour change will indicate whether it is an acid or not.

4 From these observations Nemika can infer that the liquid is neutral.

5 Boiling an acid causes some of the water to evaporate. This means that there is less water left but the same amount of acid. Therefore the acidic solution is more concentrated.

6 The most likely reason is that some of these dyes act as indicators and change colour when washed in different detergents that could have slightly different pH values.

7 From the results of this experiment Andre can infer that the mould will grow better in basic conditions and worse in acid conditions compared to neutral conditions.

Hints and tips

- pH is one of the most important factors in swimming pool maintenance and it should be tested and corrected weekly. The pH of our eyes is about 7.4. A pH less than this or greater than about 7.6 can cause your eyes to sting.
- A way for the students to remember that acids have a pH between 0 and 7 is to say that ‘**a**’ for **a**cids is at the start of the **a**lphabet, so to the pH scale starts at 0.
- To remember that bases turn pH paper and universal indicator blue, point out to the students that ‘**b**’ is for **b**lue and **b**ase.
- A pH meter is an electronic instrument to measure the pH of a solution. It is much more precise than using conventional methods such as indicator papers. It may need to be calibrated, so check the instructions on how to do this. Calibration is usually done by immersing the electrode in suitable buffer solutions with known pH values which are often supplied with the meter. Newer electronic meters with a USB can be connected directly to a computer. They require little recalibration.

Research

Ask students to find out which chemicals are used to change the pH of a swimming pool. Research what is used to increase the acidity of the water, how much is needed, and how toxic it is. Do the same for *decreasing* the acidity.

10.2 The pH scale

Jodie is checking the pH of the family swimming pool. She takes a sample from the pool and adds it to the test kit as shown above. She then adds a few drops of phenol red indicator and checks the colours on the scale. The pH is a little bit higher than the ideal 7.4–7.6, so she needs to add some acid to lower the pH slightly. Just what is pH?

pH is simply a scale from 0 to 14 which tells you how acidic or basic a solution is. Acidic solutions have a pH less than 7, and basic solutions have a pH greater than 7. A pH of 7 tells you that the solution is neutral.

To measure the pH of a solution you can use an indicator. For example, the phenol red that Jodie used to test the pool water changes from red to yellow at a pH of 7.4–7.6. If you use universal indicator solution, you note the colour and read the pH on the special colour chart. If you use pH paper, you simply dip the paper into the solution and note the colour, as shown in the photo. For example, if it is orange then the pH is about 4, and if it is green it is about 8. You can measure pH more accurately using an electronic pH meter.

Fig 11 Using pH paper to measure pH

Learning experience

Devise a giant concept map, not just for acids and bases, but also incorporating all chemistry concepts covered so far to show how the concepts are interrelated. An interactive whiteboard can be useful here as it allows you to save documents and modify them at a later date.

Learning experience

Ask the students to design an experiment that tests the pH of the soaps they have at home, detergents used to hand-wash dishes, shampoo, conditioner, face and hand creams, and other toiletries. Explain the following facts about soap:

- Soap is produced by the reaction of fatty substances (fatty acids) with sodium or potassium hydroxide. Sodium hydroxide (NaOH) and potassium hydroxide (KOH) are very strong bases.
- The reaction of these substances produces a salt, which is the soap.
- Soaps are usually basic and can cause irritation of the skin. Skin has a pH of about 5.5 and frequent use of soaps or detergents can change its pH.

You may like to set this as a homework activity and give each student a strip of pH paper (no more than 10 cm as it is expensive). Scan and print off some pH colour charts to go with each paper strip. Make sure to check the students’ design briefs before they experiment.

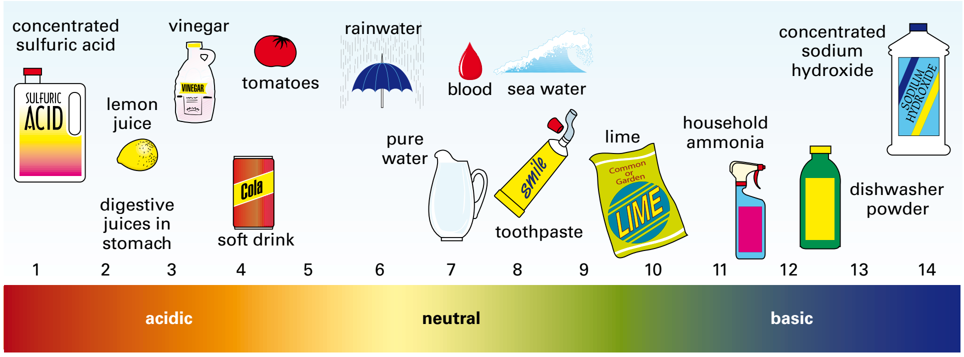
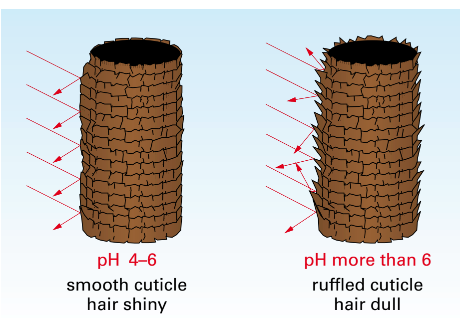


Fig 12 The pH scale, with the pH of some common substances

pH in your life

The pH of your body liquids varies from one organ to another. In your stomach, acidic conditions (pH 1.5) are needed for the digestion of proteins. In your small intestine alkaline conditions (pH 8) are needed for the further digestion of food. Your blood has a pH of 7.4, and urine can vary from 6.5 to 8.

Each strand of your hair consists of a central core surrounded by a scaly covering called the cuticle. At a pH of 4–6, the scales of the cuticle lie flat. They reflect light evenly, making the hair look shiny. If the pH is higher than 6 the cuticle becomes 'ruffled'. Light is reflected in all directions and the hair looks dull. For this reason shampoos and conditioners contain substances to keep the pH in the range 4–6.



The pH of soil is important for the growth of plants, and soil test kits can be bought to test the acidity of the soil. Some plants grow better in acidic soils and some prefer alkaline soils. If the soil is too acidic you can add basic solutions such as powdered limestone or dolomite. This is often necessary in agricultural areas where nitrogen fertilisers have been used. If the soil is too alkaline you can add compost, manure or a soluble fertiliser such as ammonium sulfate, which is acidic.

Fig 14 In acid soil hydrangea flowers are white or blue. In basic soil the flowers are pink.

Hints and tips

- Gardeners use the pH scale to determine how acidic or alkaline their soil is. The pH scale is also used to help determine water quality. Why is it necessary to monitor the pH level of drinking water?
- If soil is too acidic (low pH) to grow certain plants, gardeners add lime (calcium oxide, calcium hydroxide or calcium carbonate) to make the soil neutral or alkaline, depending on how much is used. Lime is often called agricultural lime or garden lime and is usually powdered limestone (similar to chalk). There are some places in the world that have chalky drinking water, such as Epsom Downs in Surrey, England. The chalkiness is from the calcium deposits found in the soil which have leached into the drinking water. The water is quite safe to drink; but it has a high level of calcium even after treatment.

Homework

Ask students to prepare a booklet or guide for gardeners that addresses the following questions.

- In a vegetable garden, why is it important to plant crops according to their pH preference?
- Which vegetables prefer to grow in acidic soil and which prefer alkaline soil?
- What can be added to soil to increase/decrease the pH?
- What is soil pH? Explain this concept.
- Are there different types of products differing in chemical composition? If so, which are recommended and why?
- Why should you never mix lime and fertiliser?
- Do acid-loving vegetables yield acidic crops or does it make no difference to their pH?

Learning experience

The students could produce their own DVD on the hazards of some common acids and bases, what safety precautions should be taken and why. Give clear instructions about filming it, such as length of DVD, safety precautions/procedures if using chemicals, targeted audience, and number of students in the production team. Encourage the students to be creative but scientifically accurate. Award-winning entries could have a special screening during National Science Week (usually around August) at a school assembly.

Lab notes

Part A

- This is an interesting investigation but, as usual, good organisation is critical. Materials need to be clearly labelled and spread around the room to avoid congestion.
- It is important that students record which chemical is in which spot on the tile so as not to make errors in reporting.
- Foods or other materials that are dark-coloured may need to be diluted, or tested with indicator paper which is then wiped so that the colour can be seen.

Part B

It is important to collect soil samples before the lesson and have them ready for the students to use. Make sure to note where the samples came from.

Investigate 23 MEASURING pH

Aim

To measure the pH of various substances, including soil.

Planning and Safety Check

Read both parts of the experiment.

- What safety precautions will be needed?
- Design a data table for Part A.

PART A Household substances

Materials

- various household substances in dropping bottles, eg:

window cleaner	baking soda
shampoo and conditioner	vinegar
antacid tablet	lemon juice
vitamin C	milk

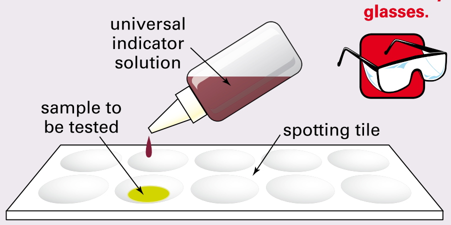
- universal indicator solution or pH paper
- **laboratory acids and bases**
- spotting tile

Corrosive

Method

Use the diagram and notes below to measure the pH of various household substances.

Wear safety glasses.



- The samples to be tested must be in solution or wet.
- Put a few drops of the sample in a cavity on a spotting tile and add a drop of indicator.
- If you are using pH paper, add a drop of the sample to a 1 cm piece of paper.

Discussion

1 Which was the most acidic substance you tested (lowest pH)? Which was the most basic (highest pH)? Make a list of the substances from the most acidic to the most basic. How do your results compare with those from Investigate 22 on page 221?

2 What is the pH of a neutral solution? Were any of the solutions you tested neutral?

3 Predict what will happen to the pH of an acid when you dilute it with water. Will it be more or less acidic? (You could test this.)

PART B Soils

Materials

- universal indicator solution
- barium sulfate powder for soil testing
- petri dishes
- soil samples
- iceblock stick or spatula

Method

1 Place half a teaspoon of soil in a petri dish.

2 Add enough universal indicator solution to make a thick paste. Stir with the iceblock stick.

3 Sprinkle this paste with a thin layer of white barium sulfate powder.

4 After 2 or 3 minutes, match the colour of the powder with the colours on the indicator colour card.

Record the pH of the soil.

5 Repeat for other soils.

Which soils were acidic, which were basic and which were neutral?

try this

Design a similar experiment to see if the soil acidity can be changed by adding powdered limestone or ammonium sulfate.

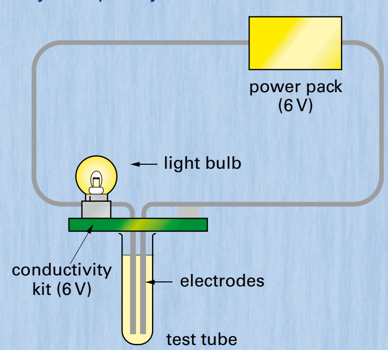
Explaining acids and bases

Acids have special properties. For example, they are corrosive. In the activity below you can test whether they conduct an electric current.

Activity

1. Half fill a small test tube with dilute hydrochloric acid.
2. Use a conductivity kit to test whether the acid will conduct an electric current, that is, light up the bulb.
3. Wash the electrodes with distilled water, then repeat the test using distilled water instead of dilute hydrochloric acid. What happens?
4. Repeat the test with sodium chloride (salt) solution.

Try to *explain* your observations.



Ions in acids and bases

In the seventeenth century one scientist suggested that the particles that make up acids had sharp spikes. He said that these spikes were the reason for the sharp biting feeling of acids on your skin. Scientists have since found that it is because they contain *hydrogen ions*.

As you probably know, an atom is a sort of ball-shaped cloud with a tiny nucleus at its centre. The nucleus is positively charged. The rest of the atom is mostly empty space containing rapidly moving electrons which are negatively charged. Some of these are close to the nucleus and others are further away.

The number of positively charged protons in the nucleus is the same as the number of negatively charged electrons surrounding the nucleus. So the atom is neutral. However, some atoms can lose electrons (usually the outermost ones), while others can gain electrons. In either case, the atom is no longer neutral. An atom that has lost or gained electrons is called an **ion** (EYE-on).

A hydrogen atom has a single proton in its nucleus, with a single electron orbiting it. This electron is easily lost to form a hydrogen ion with a single positive charge, as shown below.

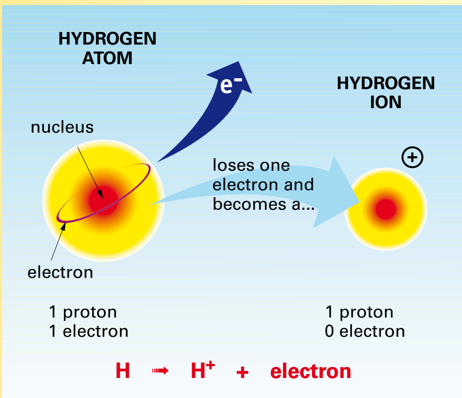


Fig 17 How a hydrogen ion is formed

Atoms of metals tend to lose electrons. For example, a copper atom can lose two electrons to form an ion with two positive charges (Cu^{2+}). In contrast to metals, atoms of non-metals tend to form ions by gaining one or more electrons. For example, chlorine atoms form negative chloride ions Cl^- as shown on the next page.

Hints and tips

- pH is a measure of the concentration of free hydrogen ions in a solution. If their concentration is high, the pH is low (acidic). If their concentration is low, the pH is high (basic). If the concentration of hydrogen ions present in solution decreases or increases by a factor of 10, the pH changes by 1. For example, if you have a 10 mL solution with a pH of 1 and you add 90 mL of water so you now have 100 mL, the solution has been diluted by a factor of 10. The new pH will be 2.
- Acids are chemical compounds which corrode materials, and their formulas usually begin with H (hydrogen), eg HCl, H_2SO_4.
- Alkalis are chemical compounds that are caustic, and a diluted alkali feels soapy/slippery to touch. Their formulas usually end in OH (hydroxide), eg NaOH, NH_4OH. The pH of an alkali is greater than 7.0.
- Remind students what ions are and how atoms become positive or negative.

Activity notes

Ask the students to explain why the electrodes need to be washed in distilled water between tests (distilled water is a neutral solution).

Learning experience

Write a fill-in-the-gaps worksheet for the students to complete using the information on pages 227–228. Add some higher order thinking questions for fast-working students. Make sure to assist those with language difficulties. It may be helpful to suggest the students work in pairs.

Hints and tips

Revise the chemical symbols for some common elements. Print some colourful copies of the periodic table for students who do not have a copy of one. Many graphic calculators allow students to view the periodic table, usually found under ‘Applications’ or ‘Programs’.

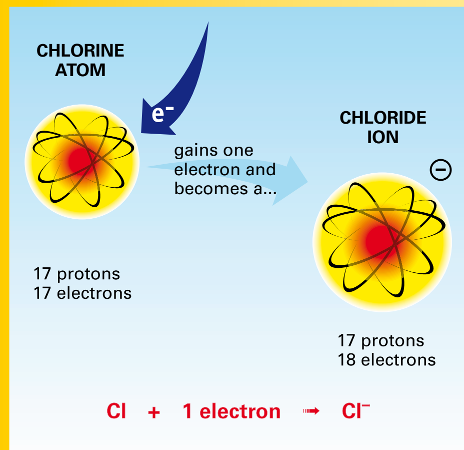


Fig 18 How a chloride ion is formed

The reason distilled water does not conduct electricity is because the water molecules are neutral. However, hydrochloric acid contains ions which can carry the electric current through the solution.

The formula for hydrochloric acid is HCl. In water it forms H^+ ions and Cl^- ions:

$$HCl \rightarrow H^+ + Cl^-$$

Similarly for sulfuric acid:

$$H_2SO_4 \rightarrow 2H^+ + SO_4^{2-}$$

So, *if a substance forms H^+ ions when dissolved in water, then it is an acid.*

The pH of a solution is a measure of the concentration of H^+ ions. The p stands for ‘power’, so pH means the ‘power of hydrogen’. Note that pH is always written with a small p and a large H.

Basic solutions contain hydroxide OH^- ions. For example, sodium hydroxide (NaOH) forms Na^+ ions and OH^- ions when dissolved in water.

$$NaOH \rightarrow Na^+ + OH^-$$

Why salt solution conducts electricity

Positive and negative ions attract each other, so many compounds consist of positive and negative ions held together by ionic bonds. For example, sodium chloride consists of Na^+ ions and Cl^- ions. When you dissolve sodium chloride in water, the sodium ions and the chloride ions break apart and spread throughout the water, as shown in Fig 19. This is why a salt solution also conducts electricity.

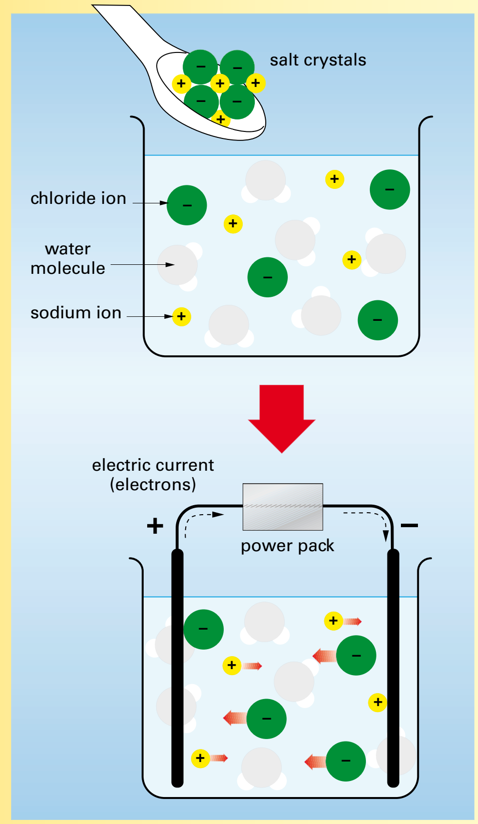


Fig 19 Sodium and chloride ions break apart in the solution. The ions carry the electric current through the solution, and electrons carry it through the wires to and from the power pack.

Learning experience

Devise a quiz to revise the material covered so far in this chapter. Include questions such as:

1. What are the characteristics of acids and bases?
2. What are some common acids and bases?
3. What are acids and bases used for?
4. What type of chemical formulae do acids and bases have?

Check!

1 Match up the following in your notebook:

pH 4	neutral
pH 7	moderately acidic
pH 1	moderately basic
pH 8	very acidic
pH 10	slightly basic

2 The words in the following sentences have been jumbled up. Rewrite the sentences correctly.
 a A pH solution has a neutral of 7.
 b An acidic solution is an example of vinegar.
 c More than 7 solutions have a basic pH.
 d H^+ ions tells you of the pH concentration.

3 a Blood has a pH of 7.4. Is this acidic, basic or neutral?
 b When you exercise, your muscles produce lactic acid. What effect might this have on the pH of your blood?

4 The pH of water in a swimming pool is 7.9. The ideal pH level is 7.4–7.6. What should you add to the pool to lower its pH—water, alkali or acid?

5 Farron is reading a booklet on the maintenance of swimming pools. He reads that if the pH falls below 7 the pool may become corroded. Suggest a reason for this.

6 An alkaline solution has a pH of 12. If it is diluted by adding water, will the pH increase, decrease or stay the same?

7 The table below shows the most favourable pH ranges for the growth of some common plants.

Flowers		Crops	
azalea	4.5–5.5	barley	6.0–8.0
calendula	6.0–7.5	clover	5.5–7.0
hibiscus	6.0–7.0	wheat	5.5–7.5
daffodil	6.0–6.5	cotton	5.0–6.0
sweet pea	7.0–8.0		

Fig 20 Farmers sometimes add lime to the soil to decrease the acidity.

The pH of a number of soils was measured:

Soil A	pH = 4.0
Soil B	pH = 5.0
Soil C	pH = 6.0
Soil D	pH = 7.5
Soil E	pH = 8.5

 a Which of the soils is the most acidic?
 b In which soil would sweet peas probably grow best?
 c Which of the crops would probably grow best in soil E? Explain your choice.
 d What could be added to soil C to make it more suitable for azaleas?
 e Of soils A, B and C, which would need most lime added to it to give a pH of 7?

8 Copy and complete these sentences in your notebook.
 a A hydrogen atom loses one electron to form a _____ hydrogen ion.
 b A chlorine atom _____ one electron to form a negative chloride ion.
 c In water, hydrochloric acid forms positive _____ ions and negative _____ ions.
 d Sodium hydroxide forms positive sodium ions and negative _____ ions when dissolved in water.

9 Suggest why tap water conducts electricity whereas distilled water does not.

10 In terms of ions, how are hydrochloric acid and sulfuric acid similar? How are they different?

Check! solutions

1 pH 4 is moderately acidic.
 pH 7 is neutral.
 pH 1 is very acidic.
 pH 8 is slightly basic.
 pH 10 is moderately basic.

2 Here are the unjumbled sentences.
 a A neutral solution has a pH of 7.
 b Vinegar is an example of an acidic solution.
 c Basic solutions have a pH more than 7.
 d pH tells you the concentration of H+ ions.

3 a If blood has a pH of 7.4 it is slightly basic.
 b An increase in the level of lactic acid will cause the pH of the blood to fall.

4 To lower the pH of the pool you need to add acid, which can be in the form of a powder or a liquid.

5 If the pH falls below 7 the pool water is acidic. This will cause corrosion of some materials in the pool, particularly the metal parts, like the pump and water pipes.

6 If an alkaline solution is diluted the pH will decrease because it will be less concentrated.

7 Using the information given:
 a Soil A is most acidic.
 b Sweet peas would probably grow best in soil D because it has the most favourable pH.
 c Sweet peas and barley would probably grow best in soil E but probably not very well.
 d To make soil C more suitable for azaleas you would need to add some compost, manure or fertilisers to lower the pH.
 e You would need to add most lime to soil A to raise the pH to 7.

8 a A hydrogen atom loses one electron to form a *positive* hydrogen ion.
 b A chlorine atom *loses* one electron to form a negative chloride ion.
 c In water, hydrochloric acid forms positive *hydrogen* ions and negative *chloride* ions.
 d Sodium hydroxide forms positive sodium ions and negative *hydroxide* ions when dissolved in water.

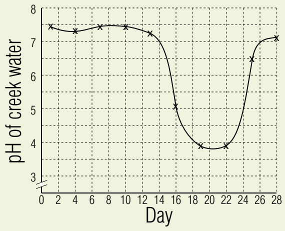
9 Tap water contains dissolved substances which form ions. These help to conduct an electric current whereas distilled water does not.

10 Hydrochloric and sulfuric acids are similar because they both contain hydrogen ions. They are different because hydrochloric acid contains chloride ions whereas sulfuric acid contains sulfate ions instead.

Challenge solutions

1 From the graph you can infer that the enzyme pepsin works best in a moderately acidic environment with a pH of about 3.

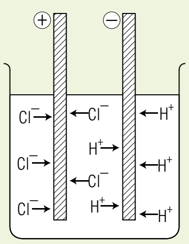
2 a



b The graph shows a decline in the pH or an increase in the acidity of the water between days 13 and 28. One possible reason for this would be that somewhere upstream an acidic solution was added to the water. This could have been from a factory, a farm or a road accident where chemicals were spilled onto the road and then washed into the creek by rainfall.

3 The reason why soil tends to become acidic is that acids are produced by decomposer organisms in the soil.

4 a



You would predict that the positive hydrogen ions will move towards the negative electrode and the negative chloride ions will move towards the positive electrode as shown on the diagram.

b If the connections are reversed you would expect the ions to move towards the opposite electrodes.

5 A silver atom will lose one electron to form a silver ion.

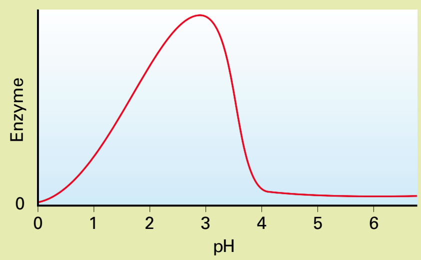
6 A chloride ion will need to lose one electron in order to become a chlorine atom.

7 A hydrogen ion is simply a proton and it will be attracted to a water molecule to form a H_3O^+ ion.

8 Compounds such as NaCl are usually neutral because the number of charges on the positive and negative ions which are packed together are equal. In this case the number of sodium and chloride ions are the same and they each carry a single charge, so they are equal and the compound is therefore neutral.

challenge

1 Pepsin is an enzyme in the human stomach which speeds up the digestion of proteins. What does the graph below tell you about the activity of pepsin?



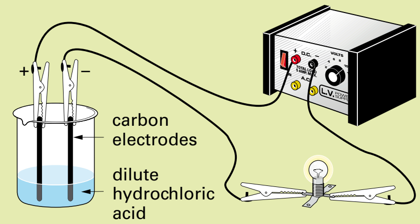
2 The pH of a creek in an industrial area was monitored by a group of Year 9 students over a period of 4 weeks. They collected this data.

Day	1	4	7	10	13	16	19	22	25	28
pH	7.4	7.3	7.4	7.4	7.2	5.1	3.9	3.9	6.5	7.2

a Plot their data on a graph.
b Infer what might have caused the dip in the graph.

3 Garden soil usually becomes more acidic as time passes. Suggest reasons for this.

4 Electricity is passed through dilute hydrochloric acid containing hydrogen ions and chloride ions.



a Draw a diagram showing what you predict will happen to the hydrogen and chloride ions in the solution. Use Fig 19 on page 228 as a guide.
b What will happen if the connections to the power pack are reversed?

5 The symbol for a silver ion is Ag^+. How many electrons does a silver atom lose to become a silver ion?

6 What would need to happen for a chloride ion Cl^- to become a chlorine atom?

7 Hydrogen ions are never found on their own. Why is this?

8 Explain why ionic compounds, which consist of electrically charged ions packed together, are electrically neutral. Use sodium chloride as an example.

try this

1 Test the effect of pH on the cooking of carrots. Put about 100 mL of water into each of three beakers. Add vinegar to the second beaker until the pH is about 4 (use indicator paper). To the third beaker add baking soda until the pH is about 9. Add thin slices of carrot to each beaker and boil for about 5 minutes. Record your results.

2 Design and carry out an experiment to test the effect of pH on the growth of seeds. You could grow the seeds on filter paper or perlite in petri dishes. Be careful to control all variables except the one you are purposely varying.

3 Design an experiment to see if the pH of different brands of hair shampoo is different. Is there any relationship between their pH and the type of hair for which they are recommended?

10.3 Reactions of acids and bases

Investigate 24 REACTIONS OF ACIDS

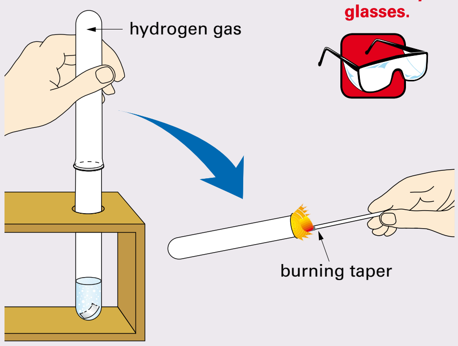
Aim

To investigate the reactions of acids with metals and with carbonates.

Planning and Safety Check

Read Part A and Part B (on the next page).

- What safety precautions will be needed?
- Design data tables for both parts.



Wear safety glasses.

PART A Reaction with metals

Materials

Corrosive

- test tubes (pyrex) and test tube rack
- dilute **hydrochloric acid** (1M)
- universal indicator solution or paper
- piece of magnesium ribbon (about 2 cm)
- taper and matches
- samples of other metals, eg aluminium, copper, iron, tin, zinc

Method

1 Add about 2 mL of dilute hydrochloric acid to a test tube and add a few drops of universal indicator.
   Record the pH.
2 Add a piece of magnesium ribbon to the acid. To trap the gas released, hold a second dry test tube upside down over the mouth of the tube as shown.
3 When the magnesium has reacted, light a taper, tilt the test tube upwards as shown and put the burning taper near its mouth. A 'pop' indicates that the gas is hydrogen.
4 Feel the test tube containing the acid and magnesium.
   Is the magnesium and acid reaction exothermic or endothermic? Justify your answer.
5 Note the pH in the tube.
   How has the pH changed as a result of the reaction?
6 Test the reactions of other metals with dilute hydrochloric acid.
   Record your observations in your data table.
   Which metals are the most reactive? Which are the least reactive?

Discussion

1 Is hydrogen gas lighter or heavier than air? How do you know?
2 Write a word equation for the reaction between magnesium and hydrochloric acid. (The colourless solution left in the test tube contains the compound magnesium chloride.)
3 Suggest why the pH increases during the reaction.

Lab notes

Part A

- It is important to have a snug fit between the two test tubes or the light hydrogen gas will escape.
- When testing for hydrogen, make sure the taper is lit before taking the stopper off the tube. When the stopper is removed, quickly place the taper into the tube before the gas mixes with air.
- Tell the students to feel the bottom of the test tube when the magnesium is reacting with the acid.
- Warn the students that under no circumstances should they burn the magnesium ribbon.

Lab notes

Part B

- Have the lab technician prepare the one-holed stopper and glass tubing beforehand. Do not allow the students to push glass tubing into the stopper.
- Some carbonates are slow to react, so encourage students to be patient and to continue writing up their practical reports.
- When testing for carbon dioxide, make sure the taper is lit before taking the stopper off the tube. When the stopper is removed, quickly place the taper into the tube before the gas mixes with air.

PART B

Reaction with carbonates

Materials

Corrosive

- dilute **hydrochloric acid** (1M)
- test tubes and test tube rack
- stopper for test tube
- one-holed stopper fitted with glass and plastic tubing, as shown below
- taper and matches
- limewater (calcium hydroxide solution)
- 2 or 3 marble chips (calcium carbonate)
- other carbonates, eg sodium carbonate, sodium hydrogen carbonate, copper carbonate

Method

1 Set up the apparatus below. Make sure the collecting tube is dry. Put two or three marble chips into the reaction tube.

2 Add about 5 mL of dilute hydrochloric acid to the reaction tube, then quickly fit the stopper and tubing.

3 After about 2 minutes remove the collecting tube and put a stopper in it. Replace it with another tube one-third full of limewater. Allow the gas to bubble into the limewater while you do Step 4.

4 Light the taper, remove the stopper from the first collecting tube, and put the taper into the tube as shown. The taper going out indicates that the gas is carbon dioxide.

5 Go back and observe the limewater from Step 3. If it has turned milky this also indicates the presence of carbon dioxide.

6 Test the reaction of other carbonates with hydrochloric acid.

Record your observations in your data table.

Discussion

1 Is carbon dioxide lighter or heavier than air? How do you know?

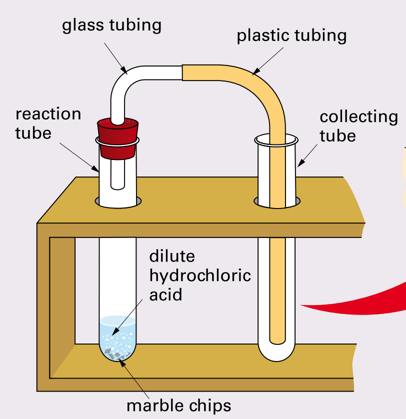
2 Suggest why carbon dioxide is used in fire extinguishers.

3 Complete this word equation for the reaction that occurred when you added hydrochloric acid to calcium carbonate:

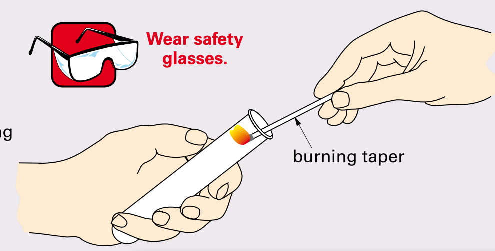
____________ + ____________ →

calcium chloride + water + ________

4 Write an inference to explain why the limewater goes milky when you bubble carbon dioxide into it.



Wear safety glasses.



try this

Design and carry out an experiment to find out whether the concentration of the hydrochloric acid affects how quickly it reacts with metals and carbonates.

You must check with your teacher before you start.

Salts

In Investigate 24 you found that dilute hydrochloric acid reacts rapidly with magnesium to produce two new substances. Hydrogen gas is released and magnesium chloride stays in solution.

magnesium + hydrochloric acid → magnesium chloride + hydrogen

Similarly, dilute hydrochloric acid reacts violently with the metal sodium to form hydrogen and sodium chloride.

sodium + hydrochloric acid → sodium chloride + hydrogen

The magnesium chloride and sodium chloride belong to a group of compounds called **salts**.

If you had continued the investigation, you would have found that dilute hydrochloric acid and all other dilute acids react with most metals. When the reaction is slow, its rate can be increased by using a more concentrated acid or by heating. You can write a general equation to describe all these reactions.

metal + dilute acid → salt + hydrogen

There are hundreds of different salts. Some are shown in the table below. Note that they are named after the acids they are made from. The most common salt is sodium chloride or table salt. Other examples include Epsom salts (magnesium sulfate) used in bath salts, ammonium nitrate used as fertiliser, and baking soda (sodium hydrogen carbonate) used in cooking.

In Investigate 24 you found that acids react with carbonates to produce carbon dioxide gas.

carbonate + acid → salt + water + carbon dioxide

Most 'health salts' consist of sodium hydrogen carbonate plus a solid acid such as citric acid, and flavouring. When the mixture is stirred with water, carbon dioxide is given off. This produces the bubbles and 'sparkle' of the drink. Carbon dioxide is also responsible for the 'fizz' when you put sherbet in your mouth.

Fig 26 A 'fizzy drink' is the result of the reaction between an acid and a carbonate.

Name of acid	Name of salts	Examples
hydrochloric acid HCl	chlorides	sodium chloride $NaCl$ calcium chloride $CaCl_2$
nitric acid HNO_3	nitrates	potassium nitrate KNO_3 ammonium nitrate NH_4NO_3
sulfuric acid H_2SO_4	sulfates	copper sulfate $CuSO_4$ magnesium sulfate $MgSO_4$
carbonic acid H_2CO_3	carbonates	calcium carbonate $CaCO_3$ sodium hydrogen carbonate $NaHCO_3$

Hints and tips

This may be a good time to give the students the opportunity to add to the giant concept map introduced in the Learning experience on page 224.

Learning experience

Make up set of cards with the names of different metals, acids, bases and salts on them (as on pages 233–234). You will also need to make cards displaying water, hydrogen and carbon dioxide. In groups, ask the students to pair up the reactants and hence determine the products.

Learning experience

Demonstrate the reaction between an acid and a carbonate to the class. Use a large beaker of vinegar (acetic acid) and some bicarbonate of soda (sodium hydrogen carbonate). Make sure the students are very quiet so they can hear the reaction (fizz). It is a good idea to put the beaker of vinegar into a plastic tub in case the reaction causes the solution to bubble over.

Hints and tips

- Point out to the students that an antacid is an ‘anti-acid’.
- If possible, you could ask the school nurse to give a short presentation about anaphylactic shock. Find out if there are any students in the class who are allergic to bee stings or other stinging creatures.
- If you have not already added neutral substances to the acid and base chart (see Starting point 4 page 217), now would be a good time to include them.

Research

Ask the students to do some research on animals that sting or inject an acid or base. They should try to find out:

- if it is an acid or base that is injected
- how the acid or base is injected
- the advantage it gives the creature
- the symptoms caused by the injected acid or base
- the suggested treatment or first aid.

Students could present their findings as a poster similar to those displayed at national parks, beaches and holiday resorts.

Neutralisation

The photo is a closeup of the jaws of an ant. Ants use them to hold you while they inject you with formic acid using a spike on their abdomen. This can be quite painful. To treat the sting you can add a weak base such as baking soda solution which neutralises the acid. Bee stings can be neutralised in the same way. On the other hand, wasp stings contain a basic substance which can be neutralised using vinegar, a weak acid. However if you are not sure what has bitten you, it is best to treat the sting with ice, which deadens the pain.

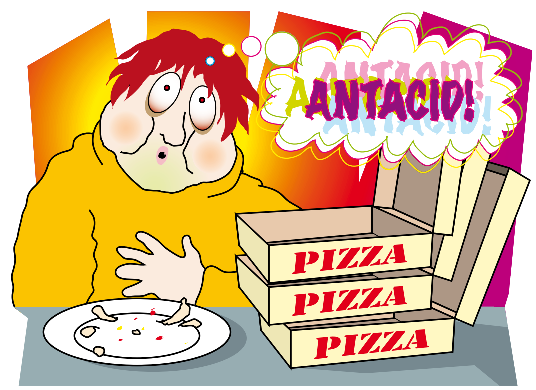
Neutralisation is a reaction in which an acid and a base cancel each other out to form a salt and water. To neutralise an acid you add a base, and to neutralise a base you add an acid.

acid + base → salt + water

There are many applications of neutralisation in everyday life. For example, the odour of fish and other seafood is due to bases called amines. Adding lemon juice or vinegar, which is acidic, neutralises the amines, giving a more pleasant smell.

Your stomach contains dilute hydrochloric acid to break down the food you eat. If the contents of your stomach become too acidic you get *indigestion*. This can happen when you have eaten too much or too quickly. To neutralise the excess stomach acid people take *antacid*. These tablets or powders contain a weak base such as baking soda (sodium hydrogen carbonate), magnesium hydroxide or aluminium hydroxide which neutralises the hydrochloric acid. The baking soda also produces carbon dioxide gas. This makes you burp, releasing the gas trapped in your stomach.

Fig 28 The smell of fish can be neutralised with lemon juice. This is an acid–base reaction.



Homework

Have students design a pamphlet about anaphylactic shock that results from a bee sting or ant bite. Their pamphlet needs to be clear, concise and creatively presented, and should include information on:

- symptoms of anaphylactic shock
- why first aid is important
- treatment required and how it is administered
- what an EpiPen is and how it is used
- instructions for using the EpiPen.

Investigate 25 ANTACID

Aim

To measure how much antacid is needed to neutralise some hydrochloric acid.

Materials

Corrosive

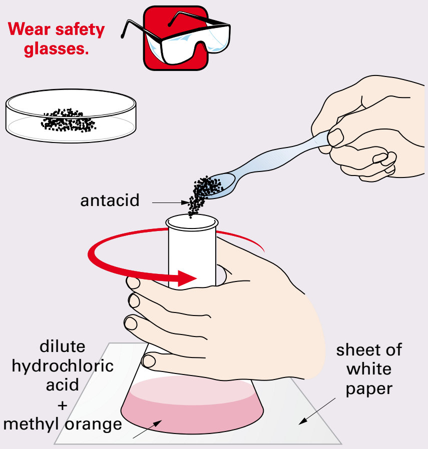
- dilute **hydrochloric acid** (0.1M)
- small flask, eg 250 mL
- 50 mL measuring cylinder
- methyl orange indicator
- spatula
- antacid powder or crushed tablet
- plastic petri dish
- balance

Planning and Safety Check

- Read the investigation, then describe to your partner what you will be doing and why.
- What do you think is the purpose of the sheet of white paper in Step 3?
- Draw up a data table like this:

mass of petri dish + antacid	= ______	(m_1)
mass of dish + unused antacid	= ______	(m_2)
mass of antacid used	= $m_1 - m_2$	
	= ______	

Wear safety glasses.



Method

1 Put a spatula of antacid powder in a petri dish.

Use the balance to measure the mass of the petri dish plus antacid. Record this in your data table.

2 Use a measuring cylinder to measure out 50 mL of dilute hydrochloric acid. This is similar to the hydrochloric acid in your stomach. Pour the acid into the flask and add 3 or 4 drops of methyl orange indicator.

3 Place a sheet of white paper under the flask and use the spatula to add antacid *bit by bit* to the acid. Swirl the flask gently to stir the mixture. Stop adding antacid when the colour changes from red to orange.

What evidence was there of a chemical reaction as the antacid was added?

4 Measure the mass of the petri dish and the unused antacid in it.

By subtraction, find the mass of antacid used to neutralise 50 mL of dilute hydrochloric acid.

Discussion

1 How much antacid was needed to neutralise 50 mL of dilute hydrochloric acid?

2 Compare your results with other groups. How accurate do you think your measurement was? Explain your answer.

3 If your stomach contained 1 litre of dilute hydrochloric acid, how much antacid powder would you need to neutralise it?

try this

Design a test to compare the effectiveness of several different antacid powders or tablets.

Lab notes

- Antacid tablets and powder are quite expensive so be sparing with them.
- It is a good idea to try the investigation beforehand to check the quantities involved.
- Students may need to be shown how to add the powder without spilling it and how to use an electronic balance properly. Remind students to 'zero' the balance before measuring the mass. It may be best to have a monitor do this.

Hints and tips

Many limestone and marble statues are affected by acid rain. Find some pictures that you could show the class of the effects of acid rain on living and non-living materials.

Activity note

This is quite a spectacular demonstration and well worth doing. It should only be done as a teacher demonstration.

Animation

Students should view the animation *Acid rain* on the CD.

Assessment task

This would be a good place to set *Assessment task 10: Acid rain*, found on the CD.

Acid rain

In northern Europe and North America millions of trees have died due to **acid rain**. Some lakes contain so much acid that all the fish have died and the birds that relied on the fish for food have left. Acid rain also speeds up the rusting of iron, and buildings made of marble, limestone and concrete have been affected.

Normal rain is usually slightly acidic, because carbon dioxide in the air dissolves in raindrops to form carbonic acid.

carbon dioxide + water → carbonic acid

However, the large amounts of waste gases from industry and motor vehicles are making rain much more acidic than normal.

Sulfur dioxide SO_2 dissolves in rainwater to form sulfurous acid. It also reacts with oxygen in the air to form sulfur trioxide SO_3, which dissolves in rainwater to form sulfuric acid. Nitrogen dioxide NO_2 also reacts with rainwater to form acids.

Scientists are not sure about the most important cause of acid rain. Power stations certainly produce sulfur dioxide, although some of them are now beginning to remove the sulfur dioxide from the waste gases they produce, so that it does not go into the air. At present, however, it looks as though the nitrogen dioxide from car exhausts is as much to blame as sulfur dioxide.

Fig 31 This forest in Poland has been damaged by acid rain.

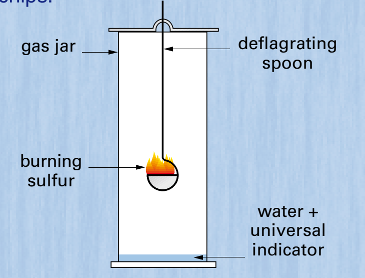
Working with technology: To learn more about acid rain, open the **Acid rain** animation on the CD.

Acid rain is not as big a problem in Australia as it is in Europe and North America. One reason for this is that the coal we burn in power stations does not contain as much sulfur as the coal used overseas. However, acid rain with a pH as low as 3.6 has been recorded in Sydney.

Activity

Because sulfur dioxide is poisonous, especially for asthmatics, this activity can be done only as a teacher demonstration.

1. Prepare a gas jar containing about 5 mL of water and a few drops of universal indicator.
2. Place a small amount of sulfur in a deflagrating spoon, and use a Bunsen burner to light it.
3. Quickly place the burning sulfur in the gas jar.
4. When the sulfur has finished burning, shake the jar to dissolve the sulfur dioxide gas.
   Note any change in the colour of the indicator. Why has this happened?
5. Add a coloured flower petal, a piece of fruit peel or a piece of coloured paper to the water in the jar.
   What do you observe?
6. Also test the acidity of the water in the jar by adding it to magnesium or marble chips.



Learning experience

Ask the students to investigate acid rain. What is it, and what are its effects? Form them into small groups and get each group to present their information from the point of view of a health scientist, biologist, chemist, environmentalist or economist. They could give an oral or multimedia presentation.

Check! solutions

1 The usual tests are as follows.
   a Expose the gas to a flame and listen for a ‘squeaky’ pop.
   b Bubble the gas through limewater and observe whether it turns ‘milky’.

2 An easy way for Rosie and Mary to find out is to add hydrochloric acid to the powder to see if it fizzes. This will occur because acids react with carbonates to produce a gas, carbon dioxide.

3 Milk of magnesia is a base which will react with the surplus acid in the stomach to neutralise it and cure the upset stomach.

Check!

1 How can you test for the following gases?
  a hydrogen
  b carbon dioxide

2 Rosie has a white powder which she thinks is calcium carbonate. Mary thinks it is calcium chloride. How could they decide which it is?

3 How does milk of magnesia (magnesium hydroxide) cure an upset stomach?

4 It is unwise to take too many antacid tablets. Why do you think this is so?

5 Why is rain slightly acidic even without air pollution?

6 Marble statues are made of calcium carbonate. Would they be affected by acid rain? How?

7 Which substances are always formed when:
  a an acid reacts with a metal?
  b an acid reacts with a carbonate?
  c an acid reacts with a base?

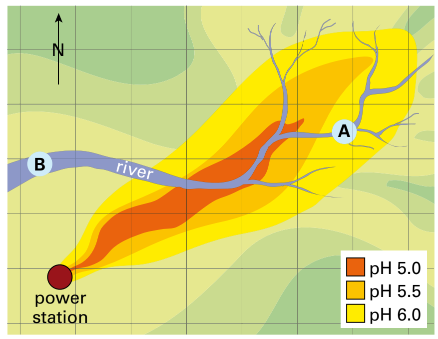
8 When Anika was stung by an ant she rubbed the bite with vinegar, but this only made it worse. What should she have done?

9 Some copper jewellery has become tarnished with greenish copper carbonate. Which of the following would you use to clean it without dissolving away the metal itself—baking soda, lemon juice, nitric acid or water? Explain your answer.

10 X and Y are white powders. X is insoluble in water, but Y is soluble and its solution has a pH of 3. When X is added to a solution of Y, bubbles form and a gas is produced.
  a One of the white powders is an acid. Is it X or Y? How do you know?
  b The other white powder is calcium carbonate. What is the gas produced in the reaction?

11 Which two chemicals would you mix to produce:
  a hydrogen?
  b carbon dioxide?

12 The map below shows a power station and the average pH of the rain which falls on the countryside around it.
  a Where does the most acidic rain fall?
  b Suggest why the water is more acidic at B than at A.
  c From which direction does the wind normally blow? How do you know?



13 Soo-Hong investigated the reaction between magnesium ribbon and acetic acid. In each test he used 15 mL of dilute acetic acid. Here are his results:

Temperature of acid (°C)	Length of magnesium (cm)	Reaction time (s)
10	2	60
10	4	79
10	6	102
20	2	31
40	2	15

  a What was the aim of the experiment?
  b Predict how long it would take for a 3 cm piece of magnesium ribbon to dissolve at 10°C.
  c Write a hypothesis linking reaction time to temperature.
  d Use a graph to predict the temperature at which a 2 cm piece of magnesium would react in 45 seconds.

4 Antacid tablets contain a base which is intended to neutralise excess acid in the stomach. Too many of these tablets will have the opposite effect by causing the contents of the stomach to become too basic, which may also cause it to become upset.

5 As rain falls it will dissolve gases in the air and form weak acids. Some of these gases are carbon dioxide, which is always present, and oxides of nitrogen, which are formed by lightning during thunderstorms.

6 Acid rain will react with the calcium carbonate in the marble statues to form a gas (carbon dioxide). This reaction slowly dissolves the stone.

7 a When an acid reacts with a metal, a salt and the gas hydrogen are always formed.
  b When an acid reacts with a carbonate, a salt and the gas carbon dioxide are always formed.
  c When an acid reacts with a base, a salt and water are always formed.

8 The ant bite probably contained formic acid which caused the inflammation and reaction. Vinegar is also acidic so it will make things worse. She should have added a weak base, such as baking soda solution, to neutralise the acid.

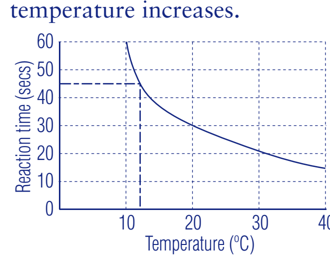
9 You would use a weak acid like lemon juice which will react with the copper oxide but not the copper. Copper oxide is a base which will react with an acid to form a salt and water. A strong acid such as nitric acid will react with the copper which you don't want.

10 a Y is an acid because when it dissolves its solution it has a pH of 3.
  b When an acid is added to calcium carbonate the gas carbon dioxide is produced.

11 a You would mix an acid (such as hydrochloric acid) and a metal (such as magnesium) to produce the gas hydrogen.
  b You would mix an acid (such as hydrochloric acid) with a carbonate (such as calcium carbonate) to produce the gas carbon dioxide.

12 a Rain becomes acidic because gases in the air dissolve in it. Most acidic rain falls in an area to the north-east of the power station.
  b The acidity increases because the river is flowing from A to B through the affected area.
  c The wind normally blows from the south-west towards the north-east. We know this because this is the area of acidic rainfall caused by factory emissions.

13 a The aim of the experiment is to see whether the temperature of the acid and the length of the magnesium strip will affect the reaction time with acid.
  b You can predict that a 3 cm length of ribbon will disappear in about 70 seconds.
  c The reaction time decreases as the temperature increases.
  d



From this graph you can estimate that the temperature of the acid would be about 13°C.

Challenge solutions

1 a The name of the salt formed is sodium fluoride.

b hydrogen fluoride + sodium hydroxide ⟶ sodium fluoride + water

$HF + NaOH \longrightarrow NaF + H_2O$

2 The likely reason is that the acid kills all of the small plants and animals in the water. It may also react with and remove any small suspended particles.

3 The salts formed are:

a chlorides

b nitrates

c sulfates

4 Referring to the graph:

a After 20 mL of alkali had been added the pH was 13.

b A volume of 12 mL of base was needed to produce a pH of 5.

c 15 mL of alkali was needed to reach a pH of 7 which is neutral.

d If the acid was more concentrated then Kristy would need more drops of alkali to neutralise it. This means that the horizontal axis would be more spread out and might go up to 50 mL or so.

e If Kristy had used more concentrated alkali then she would need less of it to neutralise the acid. This would mean that she would use a smaller volume than in **c**, eg 7 mL.

f This is difficult because, as you can see from the graph, the pH changes very quickly between a pH of 6 and 12.

5 The word equations are:

a calcium + hydrochloric acid ⟶ calcium chloride + hydrogen

b zinc carbonate + nitric acid ⟶ zinc nitrate + carbon dioxide + water

c calcium hydroxide + carbonic acid ⟶ calcium carbonate + water

6 The gases which are produced by burning coal are mixed with powdered lime and water vapour in a furnace. A reaction occurs in which sulfur dioxide reacts with the lime to form calcium sulfite. This calcium sulfite then reacts with oxygen in the air which is blown through it, forming calcium sulfate which is insoluble. This can then be drained from the bottom of the furnace and removed.

challenge

1 Hydrogen fluoride (HF) is an acid which reacts with sodium hydroxide to produce a salt that is used to help prevent tooth decay.

a What is the name of the salt that forms in this reaction?

b Write a word equation for the neutralisation of hydrogen fluoride with sodium hydroxide.

2 Lakes affected by acid rain appear to be much clearer than lakes that have not been affected. Suggest a reason for this.

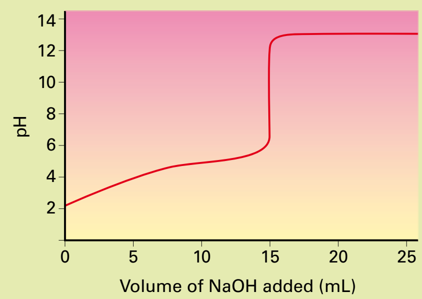
3 Name the type of salts formed by:

a hydrochloric acid

b nitric acid

c sulfuric acid

4 Kristy put 25 mL of dilute acetic acid in a beaker. She slowly added a dilute sodium hydroxide (NaOH) and used a datalogger to measure and display the pH.



a What was the pH after 20 mL of NaOH had been added?

b What volume of NaOH was needed to produce a pH of 5?

c What volume of NaOH was needed to neutralise the acetic acid?

d Suppose Kristy had used a more concentrated acetic acid. What effect would this have on the shape of the graph?

e Suppose Kristy had used more concentrated NaOH. Would the volume she used be more or less than the volume in **c**?

f Explain the shape of the graph, relating it to the neutralisation reaction.

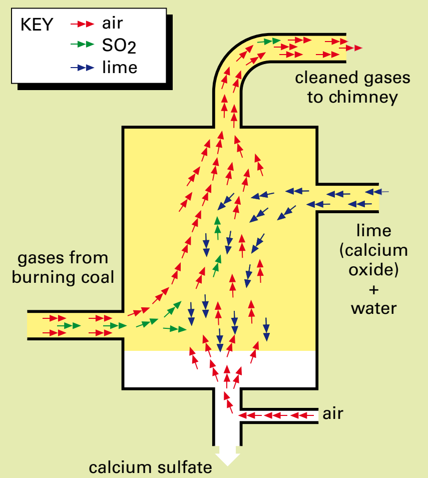
5 Write word equations for the reactions that you would expect to occur between:

a calcium metal and hydrochloric acid

b zinc carbonate and nitric acid

c calcium hydroxide and carbonic acid.

6 The diagram below shows how sulfur dioxide can be removed from the waste gases produced in a coal-burning power station. Use the information in the diagram and the equations to explain how the process works.



sulfur dioxide + calcium oxide → calcium sulfite

calcium sulfite + oxygen → calcium sulfate

try this

1 Check the labels on antacid medications. What are the active ingredients?

2 In a group, discuss who should pay for the damage caused by acid rain.

3 Use a library to find out about the damage caused by acid rain in Europe and North America.

MAIN IDEAS

Copy and complete these statements to make a summary of this chapter. The missing words are on the right.

1 Acids and bases are important in everyday life, for example in swimming pools, in your ______ and in gardening.

2 Bases are the opposite of acids. ______ are bases that are soluble in water.

3 An acid–base ______ is a substance that changes colour depending on whether it is in an acidic or basic solution.

4 An ______ is an atom or group of atoms that has a positive or negative charge, caused by the loss or gain of ______.

5 ______ is a number which indicates how acidic or basic a solution is. It is a measure of the concentration of ______ ions in solution.

6 An acid is a substance that releases hydrogen ions (H^+) in solution. A base is a substance that releases ______ ions (OH^-).

7 Dilute acids react in a predictable pattern.
- They react with most ______ to produce hydrogen gas.
- They react with carbonates to produce ______ gas.

8 ______ is the process in which an acid reacts with a base to produce a salt (neutral) and water.

9 ______ is produced when waste gases from industry and motor vehicles dissolve in raindrops to form acids.

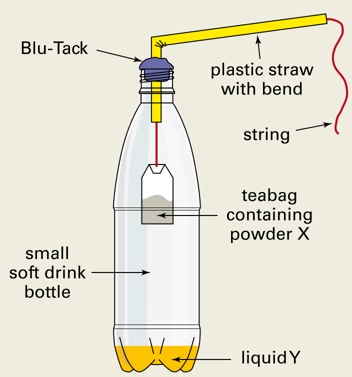
acid rain
alkalis
carbon dioxide
electrons
hydrogen
hydroxide
indicator
ion
metals
neutralisation
pH
stomach

Try doing the Chapter 10 crossword on the CD. Working with technology

REVIEW

1 Which of these household substances contain bases? (There may be more than one.)
A vinegar
B ammonia
C lemon juice
D oven cleaner

2 To work the homemade fire extinguisher on the right you let the string go so the tea bag falls into the liquid, producing carbon dioxide gas. X and Y are most likely to be:
A baking soda and vinegar
B baking soda and water
C baking soda and window cleaner
D salt and vinegar



Main ideas solutions

1 stomach
2 alkalis
3 indicator
4 ion, electrons
5 pH, hydrogen
6 hydroxide
7 metals, carbon dioxide
8 neutralisation
9 acid rain

Review solutions

1 **B** and **D**

2 **A**—Vinegar reacts with baking soda (sodium hydrogen carbonate) to produce carbon dioxide gas.

3 **D**—NaCl is a salt. It does not contain hydrogen.

4

	Unknown solutions		
	X	Y	Z
blue litmus	blue	red	blue
red litmus	red	red	blue

5 **a** P **c** V
b R **d** C

6 Lemon juice is an acid and will neutralise aluminium oxide (a base) to produce a soluble salt and water. Because the coating of aluminium oxide has been removed, the saucepan is shiny. Heating the lemon juice makes the neutralisation reaction go faster.

7 Normal rainwater (pH 6) is slightly acidic because carbon dioxide in the air dissolves in raindrops to form carbonic acid (see page 236). Acid rain is even more acidic because waste gases from power stations and cars dissolve in it. Sulfur dioxide dissolves to form sulfuric acid, and nitrogen dioxide also dissolves to form acids.

8 Some plants grow better in acidic soils and some prefer alkaline soils. If the soil is too acidic (pH less than 7) you can add powdered limestone, and if it is too alkaline (pH more than 7) you can add compost or a soluble fertiliser. See page 225.

9 A releases more H^+ ions in solution than B, and hence conducts electricity better—as indicated by the brightly glowing bulb. C doesn't contain enough H^+ ions to make the bulb glow.

Lab review

Use universal indicator solution or pH paper to decide which liquid is acidic (hydrochloric acid) and which is basic (caustic soda solution). The sodium chloride solution and the water are both neutral, but when you evaporate the sodium chloride solution you are left with a white solid.

3 Which one of the following is *not* an acid (does not form hydrogen ions in water)?
A HF
B H_3PO_4
C HCl
D NaCl

4 In the laboratory you are given three solutions marked X, Y and Z. You are also given red and blue litmus paper. Copy and complete the following table with the results that would show that:
- X is neutral
- Y is acidic
- Z is basic.

	Unknown solutions		
	X	Y	Z
blue litmus			
red litmus			

5 Shanthi has been given a number of solutions, and she has found the pH of each using indicator paper. Here are her results.

Substance	P	Q	R	S	T	U	V
pH	3	4	9	6	8	5	7

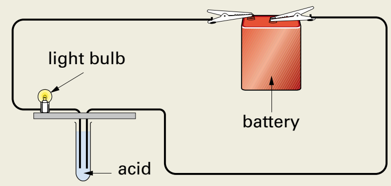
a Which solution is the most acidic?
b Which solution is the most basic?
c Which solution is neutral?
d To make solution Q more acidic you need to add:
A water
B sodium hydroxide
C solution P
D solution T

6 Aluminium saucepans lose their shine when they develop a dull coating of aluminium oxide, which is a base. Explain why boiling lemon juice in an aluminium saucepan will leave it shiny.

7 Normal rainwater has a pH of about 6, distilled water has a pH of 7, and acid rain can have a pH as low as 2. Write a short paragraph to explain these differences.

8 Write a paragraph explaining why knowing the pH of soil is important.

9 Using the set-up shown below, Gerard tested the electrical conductivity of three different acids, all of the same concentration. Here are his results.



Acid	Bulb
A	glowed brightly
B	did not glow
C	dull glow

How can you explain the differences between the acids?

LAB REVIEW

Collect unlabelled bottles of dilute hydrochloric acid, dilute caustic soda solution, sodium chloride solution and water.

Your task is to work out which one is which, using the correct safety procedures.

Collect any chemicals and equipment you will need to do your tests.

When you have finished, briefly describe the tests you did and check your answers with your teacher.

Check your answers on page 323.