●●●○○ Level 3 · Science S3.6

Elements, mixtures, reactions and acids

Some things are pure and some are mixed, and some changes make brand new substances.

Learn what an element and a compound are, why air and sea water are mixtures, and how to separate them. Then follow rusting and burning, test acids and alkalis with red cabbage, and see how an acid and an alkali cancel out.

YOU ARE READY FOR THIS BOOK IF

You can explain why sugar seems to vanish when you stir it into water.

One step up	S4.6 Atoms, bonding and the periodic table
This book	**S3.6 Elements, mixtures, reactions and acids**
One step down	S2.4 Solids, liquids, gases and the water cycle

Contents

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S3.6.2 Pure substances and mixtures

S3.6.3 Separating mixtures

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S3.6.5 Rusting and other reactions

S3.6.6 Burning and fire safety

S3.6.7 Acids and alkalis

S3.6.8 Neutralisation

Key words, A to Z

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S3.6.1 CHAPTER 1

Elements and compounds

Gold, water and air are all made of tiny particles. Are the particles inside them all the same kind?

YOUR GUESS

Pick one before you read on. It is fine to be wrong.

- ☐ **A** Some materials have one kind of atom. Others have different kinds of atom joined together.
- ☐ **B** Every material has its own kind of tiny bit, and no two materials share one.
- ☐ **C** All materials are made from the very same atoms, only arranged in different ways.

IF THIS FEELS HARD, READ THIS FIRST

- Level 3, Particles, S3.5.1. You drew particles as circles there. Now you look at the kinds of particle.

BY THE END YOU CAN

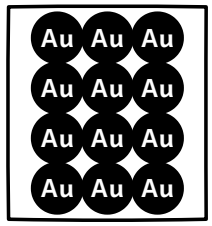
- Explain that an element has only one kind of atom
- Name common elements, such as oxygen, carbon, iron and gold
- Explain that a compound has elements joined together, such as water

A gold ring, a drink of water and the air you breathe are very different. Yet all three are made of tiny particles. In this chapter you look at the particles themselves.

The smallest bits of most materials are called ***atoms***. There are only about a hundred kinds of atom. Everything around you is built from them, a little like words built from letters.

DRAW IT FIRST

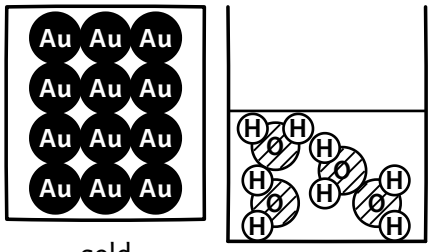
Draw an element and a compound



gold

Au gold O oxygen
H hydrogen

1 Draw circles that are all the same. Write Au inside each one. This is gold. It has one kind of atom.

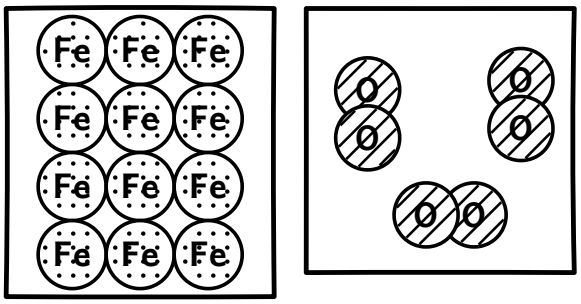


gold water

Au gold O oxygen
H hydrogen

2 Draw a big circle with O joined to two small circles with H. Draw more groups like it. This is water. It has two kinds of atom.

Gold is an **element**. An element has only one kind of atom. Every atom in a gold ring is a gold atom.



iron oxygen

Fe iron O oxygen

Iron has one kind of atom. Oxygen gas also has one kind of atom, though they are joined in pairs. Both are elements.

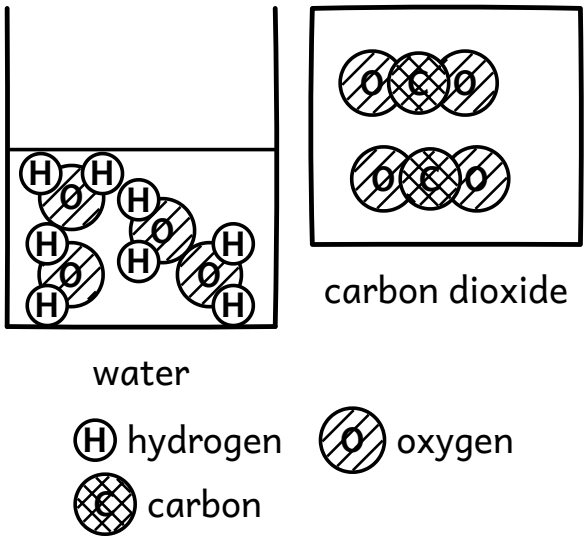
Look at oxygen. Its atoms are joined in pairs. But every atom is still an oxygen atom. So oxygen is an element. Joined atoms do not make a compound. Different kinds of atom joined together do.

Each element has a **symbol**, one or two letters. Oxygen is O and carbon is C. Iron is Fe and gold is Au. Those two come from old Latin names. A symbol is a short way to write the name.

element	symbol	found in
oxygen	O	the air
carbon	C	charcoal
iron	Fe	a nail
gold	Au	a ring

Four elements you meet every day.

Now think about water. Its atoms are not all alike. Each small group has one oxygen atom joined to two hydrogen atoms. Water is a **compound**. A compound has atoms of two or more elements joined together.



Two compounds. Water is a liquid and carbon dioxide is a gas. Each is made of small groups that are all alike. Some compounds, such as salt, are one big block of joined atoms instead.

compound	formula
water	H_2O
carbon dioxide	CO_2

A formula shows the atoms in one group. The small number says how many.

We write water as H_2O. The H is hydrogen and the small 2 means two atoms. The O is oxygen, one atom. Carbon dioxide is CO_2: one carbon atom and two oxygen atoms.

A compound is not like the elements inside it. Hydrogen is a gas that burns. Oxygen is a gas that helps things burn. Water, made from the two, is a liquid that puts fires out.

SEE IT THREE WAYS

With things

Think of table salt. It is made from sodium, a metal that reacts fiercely with water, and chlorine, a poisonous gas. Yet you sprinkle it on your food. A compound can be very different from its elements.

As a picture

substance	what it does
hydrogen	burns
oxygen	helps burning
water	puts out fire

In words

Water is made of hydrogen and oxygen. Yet it is nothing like either. When atoms join, they make a new substance with its own properties.

TRY IT

Build water from paper circles

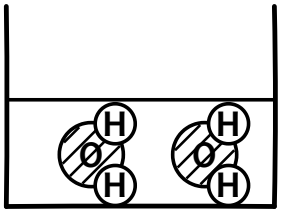
You need: paper, scissors, a pencil.

Be safe: Take care with scissors. Ask a grown up to cut if you are unsure.

1. Cut out 2 big circles and 4 small circles from paper. Write O on each big one and H on each small one.
2. Make one water group. Lay 1 big circle on the table. Put 2 small circles touching it.
3. Make a second group the same way. Count the circles of each kind. Then count all the atoms.

What you will see: Each group has 1 oxygen and 2 hydrogen, which is 3 atoms. Two groups use 2 oxygen and 4 hydrogen, which is 6 atoms. Every group is the same.

If you cannot try it, this is what happens.



two water groups

O oxygen Ⓗ hydrogen

A WRONG IDEA MANY PEOPLE HAVE

~~Water is just hydrogen and oxygen mixed together.~~

Why it feels right: Water is made of hydrogen and oxygen. So it seems the two gases must sit in there side by side.

The test that breaks it: Hydrogen burns. Oxygen helps things burn. If water held the two gases side by side, it would feed a fire. But water puts fires out.

What is true: In water the atoms are joined in groups of H_2O. That makes a new substance. It does not behave like hydrogen or oxygen.

KEY WORDS

atoms
the smallest bits that most materials are made of.

element
a substance with only one kind of atom.

symbol
one or two letters that stand for an element.

compound
a substance with atoms of two or more elements joined together.

BACK TO YOUR GUESS

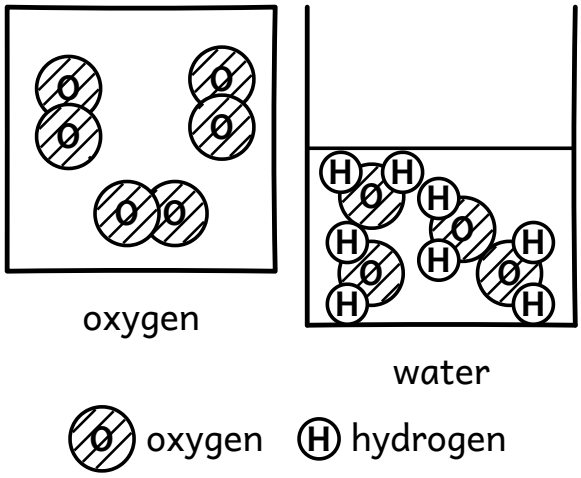
The answer is A: Some materials have one kind of atom. Others have different kinds of atom joined together.

Gold has one kind of atom. Water has two kinds joined together. There are only about a hundred kinds of atom, and they build everything.

CHECK YOURSELF

Try each one before you look. A wrong answer tells you where to go next.

1. One box holds oxygen gas, with atoms joined in pairs. The other box holds water. Which box shows an element?



A The oxygen box. It has only one kind of atom.

B The water box, because its atoms are joined together.

C Both boxes, because both have oxygen atoms in them.

Answer at the back of the book.

2. Which list has only elements?

A oxygen, water, iron and gold

B oxygen, carbon, iron and gold

C carbon, carbon dioxide, iron and gold

Answer at the back of the book.

3. A formula shows one group of water as H_2O. How many atoms are joined in one group?

A 2 atoms

B 3 atoms

C 1 atom

Answer at the back of the book.

4. Why is water called a compound?

   A It has hydrogen gas and oxygen gas mixed together, side by side.

   B It has only one kind of atom.

   C Its hydrogen and oxygen atoms are joined together in groups.

   Answer at the back of the book.

5. Hydrogen burns and oxygen helps things burn. Water is made from both, yet it puts fires out. What does this show?

   A The water must still hold hydrogen and oxygen as two separate gases.

   B Water is an element, because it is one substance.

   C A compound can behave very differently from the elements in it.

   Answer at the back of the book.

6. A tray holds 5 water groups. Each group is H_2O. How many hydrogen atoms are on the tray?

   Answer at the back of the book.

KEEP IT

Copy this into your exercise book.

An element has one kind of atom. A compound has different atoms joined, such as water, H_2O. A compound is not like the elements in it.

Draw: Draw one water group: a big circle O joined to two small circles H. Label it H_2O.

S3.6.2 CHAPTER 2

Pure substances and mixtures

> **A bottle says pure spring water, and the water is clear. Would a scientist call it pure?**

YOUR GUESS

Pick one before you read on. It is fine to be wrong.

- ☐ **A** Not always. In science, pure means only one substance, and clear water can hold others.
- ☐ **B** Yes. If water looks clean and clear, there is nothing else in it.
- ☐ **C** Yes. Water from the ground is always one substance.

IF THIS FEELS HARD, READ THIS FIRST

- Level 3, Particles, S3.5.7. Salt dissolving in water gives a solution, which is a kind of mixture.

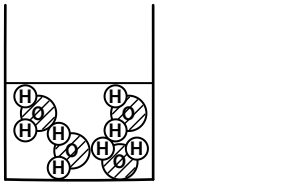
BY THE END YOU CAN

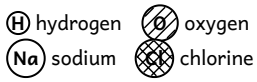
- Tell a pure substance from a mixture
- Explain why sea water and air are mixtures

In shops, pure often means clean or natural. A scientist uses the word in a different way. This chapter shows you how.

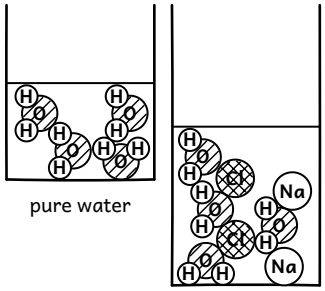
DRAW IT FIRST

Draw *a* pure substance *and a* mixture





1 Draw water groups, all the same. Nothing else is in the box. This is *a* pure substance.

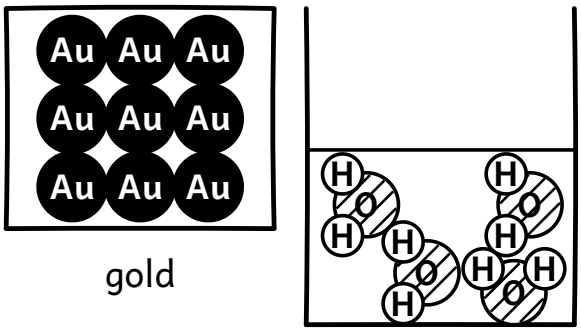




2 Draw water groups, *and* add single circles, Na *and* Cl, for the dissolved salt. They *are* not joined to the water. This is *a* mixture.

A **pure substance** is only one substance. It is either *an* element, such *as* gold, or *a* compound, such *as* water. All its groups of *atoms are* the same.

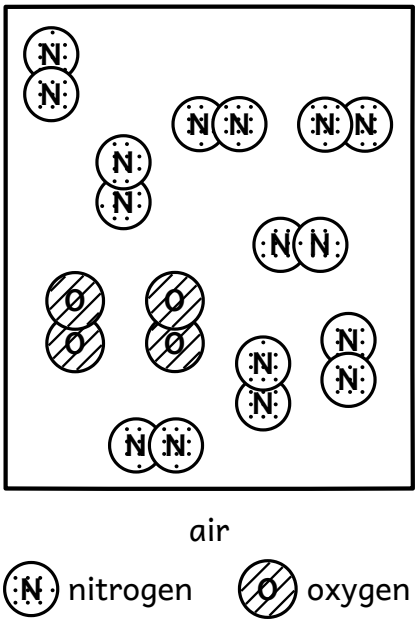
A **mixture** has two or more substances that *are* not joined together. The substances in *a* mixture keep their own properties.



Two pure substances. Gold is *an* element. Water is *a* compound. Each box has only one kind of group.

Pure does not mean clean. Pure also does not mean natural or safe. A glass of clear tap water is a mixture. It has dissolved salts in it that you cannot see.

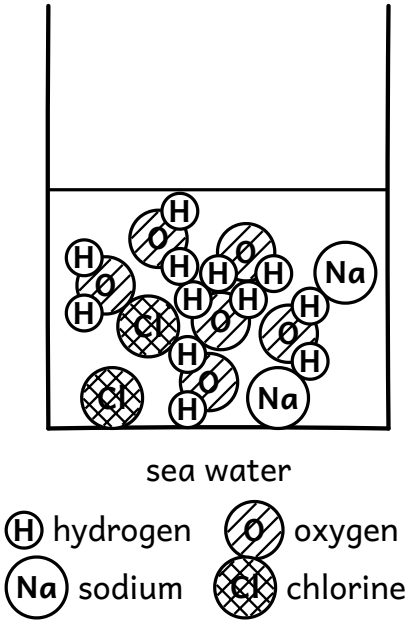
Air is a mixture of gases. About 78 of every 100 parts are nitrogen. About 21 parts are oxygen. The rest, about 1 part, is argon, carbon dioxide and a few other gases.



A small sample of air: 8 pairs of nitrogen and 2 pairs of oxygen. The gas particles are far apart, and the two gases are mixed, not joined.

Each gas in the air keeps its own properties. The oxygen in the air still helps things burn. The nitrogen does not. The gases are side by side, so air is a mixture.

Sea water is a mixture too. It is mostly water, with salt dissolved in it, and a little of other things. When salt dissolves, it splits into separate particles among the water groups. Its parts are not joined.



Sea water. The dissolved salt is split into separate Na and Cl particles among the water groups. This is a small drawing: real sea water has many more water groups for each Na and Cl.

SEE IT THREE WAYS

With things

Think of a bowl of rice and beans. You can see two things, and each is still rice or beans. A compound is different. Its parts are joined, and it has new properties.

As a picture

idea	compound	mixture
atoms	joined	separate
amounts	fixed	can vary
example	water	air

In words

In a compound, the atoms are joined and the amounts are always the same. In a mixture, the substances are not joined, and you can have more or less of each.

TRY IT

Mix and take apart

You need: a bowl, a handful each of dried rice, dried beans and small stones, a spoon.

Be safe: Wash the stones and your hands afterwards. Do not eat anything from the bowl.

1. Pour the rice, the beans and the stones into the bowl. Stir with the spoon.
2. Look at the bowl. Can you still tell the three things apart?
3. Pick out the stones by hand. Then pick out the beans. Rice is left in the bowl. Wash your hands afterwards.

What you will see: Each thing is still itself. The rice is still rice. The beans and stones are unchanged. You can take them apart again, because a mixture has no joined parts.

If you cannot try it, this is what happens.



A WRONG IDEA MANY PEOPLE HAVE

~~Clear water must be pure.~~

Why it feels right: You can see through it, and nothing in it shows. So it seems there is nothing else in it.

The test that breaks it: Sea water is clear, yet it is salty. Leave a dish of it in the sun until the water has gone. A white crust of salt is left. The salt was in the water all the time.

What is true: Pure means only one substance. Many clear liquids are mixtures, because dissolved things cannot be seen.

KEY WORDS

pure substance
a substance that is only one thing, an element or a compound.

mixture
two or more substances together that are not joined.

BACK TO YOUR GUESS

The answer is A: Not always. In science, pure means only one substance, and clear water can hold others.

Pure means only one substance. Clear water can still have salts dissolved in it, so it is a mixture. Air and sea water are mixtures too.

CHECK YOURSELF

Try each one before you look. A wrong answer tells you where to go next.

1. Which of these is a pure substance?

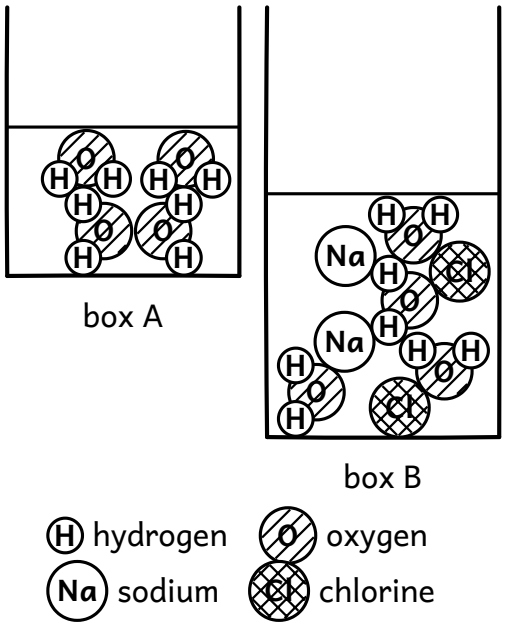
   A air

   B sea water

   C oxygen gas

Answer at the back of the book.

2. Box A holds pure water. Box B holds salty water. Which box is a mixture, and why?



A Box A. Its atoms are joined together, so it is a mixture.

B Box B. It has two substances, water and salt, that are not joined together.

C Both boxes, because both have water in them.

Answer at the back of the book.

3. Why is air a mixture?

A It is made only of oxygen, because oxygen is the gas we breathe.

B It has different gases, such as nitrogen and oxygen, side by side and not joined.

C It is a compound, because its gases are joined together.

Answer at the back of the book.

4. Sea water is clear, so you can see through it. Why is it still a mixture?

A It is not a mixture, because you cannot see any salt in it.

B It is a compound of salt and water, with the two joined.

C It has water and dissolved salt together, and the salt is not joined to the water.

Answer at the back of the book.

5. Air holds nitrogen and oxygen side by side. The oxygen in it still helps things burn. What does this show?

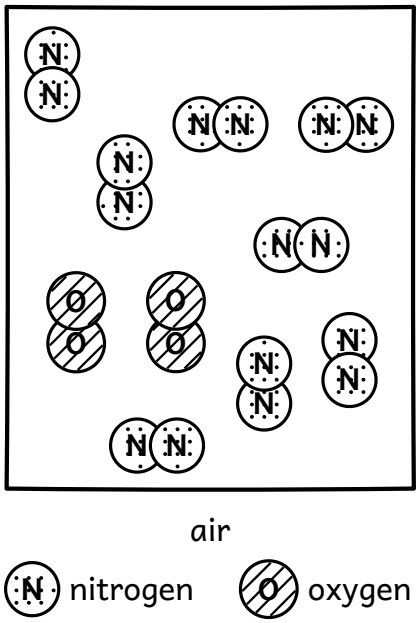
   A Air is a compound, because the nitrogen and oxygen are joined.

   B Air is a mixture, because each gas keeps its own properties.

   C Air is a pure substance, because oxygen is the gas that matters.

   Answer at the back of the book.

6. The picture of air shows 10 pairs of gas particles in all. 2 pairs are oxygen. How many pairs are not oxygen?



   Answer at the back of the book.

7. **From an earlier chapter**

   Which of these is a compound?

   A water

   B gold

   C oxygen gas

   Answer at the back of the book.

8. About 21 cm^3 of every 100 cm^3 of air is oxygen. A sample of air is 200 cm^3. About how much oxygen is in it?

   Answer at the back of the book.

KEEP IT

Copy this into your exercise book.

A pure substance is only one thing. A mixture has two or more things not joined. Clear does not mean pure. Air and sea water are mixtures.

Draw: Draw a box of water groups, and a second box with water groups and salt pairs. Label them pure water and mixture.

S3.6.3 CHAPTER 3

Separating mixtures

> **How can you get salt back out of sea water, or take the mud out of muddy water?**

YOUR GUESS

Pick one before you read on. It is fine to be wrong.

- ☐ **A** Leave the water in the sun. The water goes into the air and the salt stays behind.
- ☐ **B** You can only get salt back by pouring the water through paper.
- ☐ **C** You cannot get it back. Once salt dissolves, it is gone for ever.

IF THIS FEELS HARD, READ THIS FIRST

- Level 2, Solids, liquids, gases and the water cycle, S2.4.7. You filtered dirty water there.
- Level 2, Solids, liquids, gases and the water cycle, S2.4.4. Water leaves a wet place as a gas there.

BY THE END YOU CAN

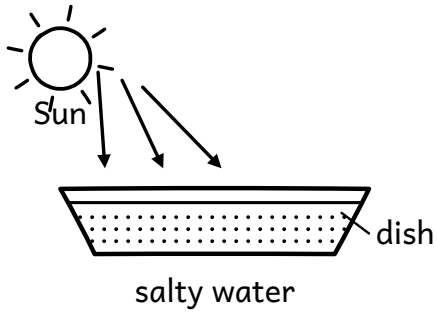
- Choose sieving, filtering or evaporating to separate a mixture
- Get salt back from salty water by leaving it in the sun
- Separate the colours in ink using paper and water

The parts of a mixture are not joined. That is the good news. It means you can separate them again, without any chemistry. You choose a method that suits the mixture.

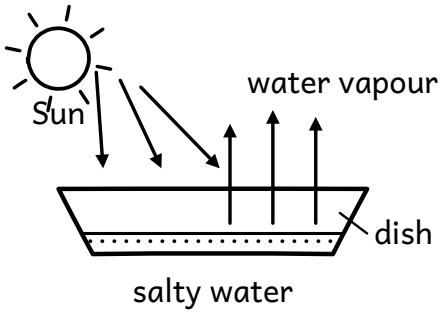
Each method uses a difference between the parts. They may be different in size. One may dissolve and one may not. Or the liquid may turn to a gas while the other part stays.

DRAW IT FIRST

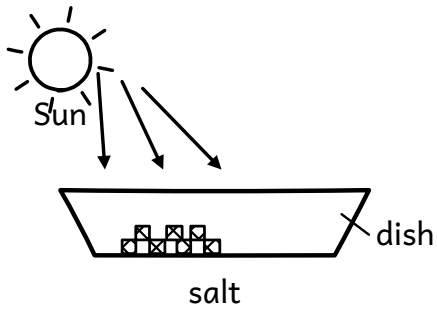
Draw salt coming back from salty water



1 Draw a shallow dish of salty water in the sun.



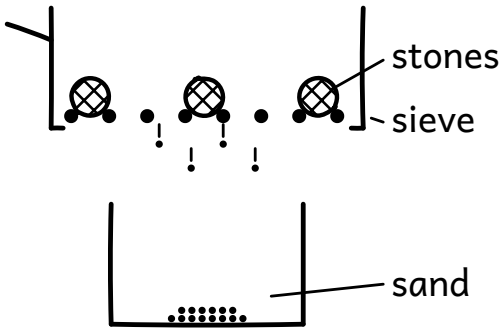
2 Draw it later. The water is lower. Draw arrows rising from it. The water is leaving as water vapour.



3 Draw it later still. The water has all gone. The salt is left in the dish.

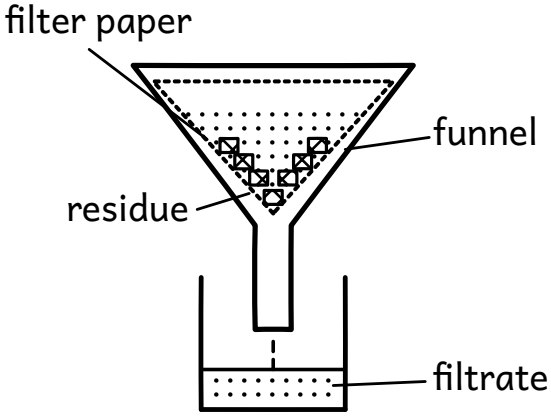
To **evaporate** is to turn from a liquid into a gas. The water in the dish evaporates, and its vapour goes into the air. Salt does not evaporate in the sun, so it stays in the dish. This is how salt is made from sea water in hot places.

Now a different mixture: small stones and sand. They do not dissolve, and they are different in size. A **sieve** is a bowl with a mesh of holes. It lets small pieces fall through and holds big pieces back.



The holes are wider than a grain of sand and narrower than a stone. The stones stay on top.

Next, muddy water. Mud does not dissolve, but it is too small for a sieve. Use a **filter**. Filter paper has holes so small that mud cannot get through. The mud stays on the paper.



The solid left on the paper is the **residue**. The clear liquid that passes through is the **filtrate**.

Filtering takes out a solid that does not dissolve. It cannot take out dissolved salt. Salt particles are so small that they pass through the paper with the water. The filtrate of salty water is still salty.

SEE IT THREE WAYS

With things

Think of what each method uses. A sieve uses size. A filter uses the fact that a solid does not dissolve. Evaporating uses the fact that water becomes a gas and salt does not.

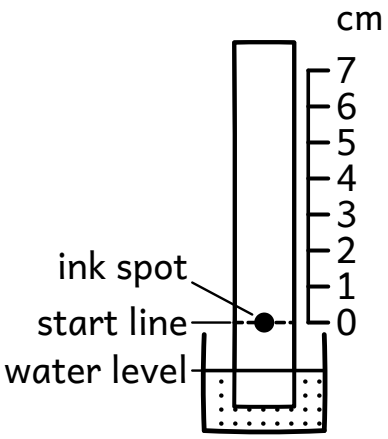
As a picture

mixture	method
stones and sand	sieve
muddy water	filter
salty water	evaporate

In words

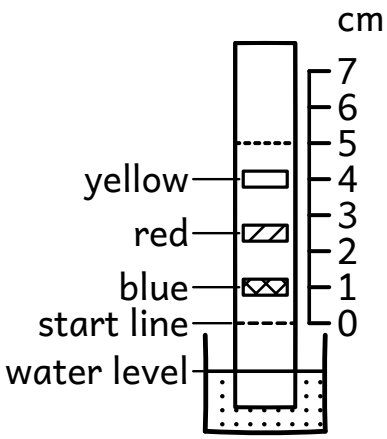
Match the method to the mixture. Sieve when the pieces are different sizes. Filter when a solid is in a liquid. Evaporate when a solid is dissolved.

One more mixture is a drop of ink. The black ink in a felt-tip pen is often a mixture of several coloured substances. **Chromatography** separates them. A strip of paper and a little water are all you need.



The ink spot starts above the water. If the spot were under the water, the ink would wash into the glass.

The water soaks up the paper and carries the ink with it. Each colour is carried a different distance. Some colours cling to the paper and travel only a little. Others dissolve well in water and travel far.



The colours have separated. Yellow travelled 4 cm, red 2.5 cm and blue 1 cm from the start line.

TRY IT

Get salt back from salty water

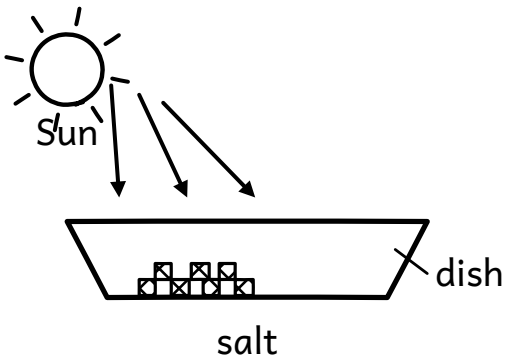
You need: a dark plate or a flat dish, a cup of water, a spoon of salt, a sunny, safe place.

Be safe: Do not taste the salt. Keep the plate away from small children and pets.

1. Stir a spoon of salt into half a cup of water until it has all dissolved.
2. Pour a thin layer of the salty water onto the plate. Put the plate in a sunny place where nobody will knock it.
3. Wait until the water has all gone. This may take a day or two. Look at the plate.

What you will see: The water disappears into the air. A white crust of salt is left on the plate. The salt was in the water all the time.

If you cannot try it, this is what happens.



TRY IT

Split an ink into colours

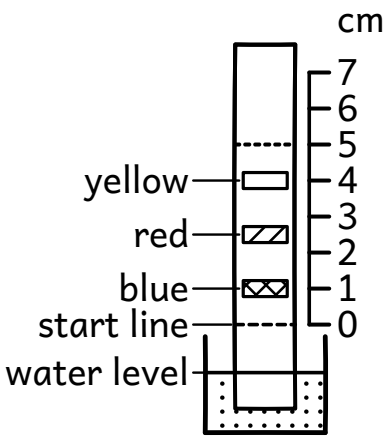
You need: a strip of coffee filter paper or kitchen paper, about 3 cm wide, a pencil, a felt-tip pen with washable ink, a tall glass, water.

Be safe: Use only washable pens. Do not drink the water.

1. Draw a pencil line across the strip, 2 cm from one end. Use a pencil, not a pen. Pencil does not dissolve in water, so the line stays put. Put a dot of ink on the line.
2. Pour water into the glass, about 1 cm deep. Hang the strip so its end dips in the water. The ink spot must stay above the water.
3. Wait about 10 minutes. Take the strip out and lay it flat. Look at the colours, and measure how far each one went from the line.

What you will see: The water climbs the paper. A black or brown ink often splits into several colours. Each colour stops at its own height. Your colours will differ from the picture.

If you cannot try it, this is what happens.



A WRONG IDEA MANY PEOPLE HAVE

~~Filtering salty water takes the salt out.~~

Why it feels right: Filter paper takes the mud out of muddy water. So it seems it should take salt out of salty water too.

The test that breaks it: Pour salty water through filter paper. Taste is not a safe test, so leave the filtrate in a dish in the sun. A white crust of salt is left. The salt went through the paper.

What is true: A filter holds back only solids that are too big to pass through. Dissolved salt is far smaller, so it passes through. To get salt back, evaporate the water.

KEY WORDS

evaporate
turn from a liquid into a gas.

sieve
a mesh of holes that lets small pieces fall through.

filter
paper with tiny holes that holds back solid pieces.

residue
the solid left on the filter paper.

filtrate
the liquid that passes through the filter.

chromatography
a way to separate coloured substances using paper and water.

BACK TO YOUR GUESS

The answer is A: Leave the water in the sun. The water goes into the air and the salt stays behind.

The water evaporates into the air as vapour. The salt does not evaporate, so it is left behind. Dissolved salt is still there, and you can get it back.

CHECK YOURSELF

Try each one before you look. A wrong answer tells you where to go next.

1. You have small stones mixed with sand. Which method separates them?

   A Evaporate them. The stones go into the air.

   B Filter them through paper.

   C Sieve them. The sand falls through and the stones stay.

   Answer at the back of the book.

2. Muddy water is poured through filter paper. What happens?

   A The mud passes through with the water, but it is cleaner.

   B The water stays on the paper and the mud passes through.

   C The mud stays on the paper as the residue, and clear water passes through as the filtrate.

   Answer at the back of the book.

3. How can you get the salt back from a cup of salty water?

   A Leave it in a dish in the sun until the water has gone. The salt is left behind.

   B Pour it through filter paper. The salt stays on the paper.

   C Pour it through a sieve. The salt stays in the sieve.

   Answer at the back of the book.

4. A dish of salty water stands in the sun until it is dry. What is in the dish at the end?

   A Nothing. The salt goes into the air with the water.

   B White salt.

   C A little clean water.

   Answer at the back of the book.

5. A spot of black ink is put on a strip of paper. After the water has climbed up, the spot has split into yellow, red and blue. What does this show?

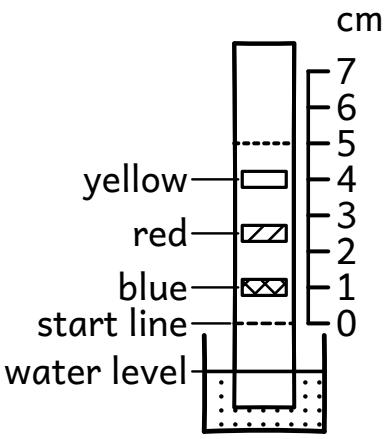
   A The black ink is a mixture of different coloured substances.

   B The water made the colours. The ink is only black.

   C The black ink is a pure substance that broke apart.

   Answer at the back of the book.

6. How much farther above the start line did the yellow colour travel than the blue colour?



   A 3 cm

   B 4 cm

   C 5 cm

   Answer at the back of the book.

7. **From an earlier chapter**

   Why is sea water a mixture?

   A It is a compound of salt and water, with the two joined.

   B It has water and dissolved salt that are not joined, and the salt can be got back.

   C It is pure, because you can see through it.

   Answer at the back of the book.

8. An empty dish has a mass of 40 g. After salty water has dried in it, the dish and salt have a mass of 55 g. What is the mass of the salt?

   Answer at the back of the book.

KEEP IT

Copy this into your exercise book.

Sieve to separate by size. Filter to remove a solid. Evaporate to get a dissolved solid back. Chromatography splits an ink into its colours.

Draw: Draw a funnel with paper in it, mud on the paper, and clear water in a beaker below. Label residue and filtrate.

S3.6.4 CHAPTER 4

Physical and chemical changes

> **Ice melting and wood burning are both changes. Are they the same kind of change?**

YOUR GUESS

Pick one before you read on. It is fine to be wrong.

- ☐ **A** Yes. In both, the stuff stays the same stuff and only its looks change.
- ☐ **B** No. Melting makes no new substance. Burning makes new substances that you cannot easily turn back.
- ☐ **C** Yes. In both, a new substance forms because the thing looks different afterwards.

IF THIS FEELS HARD, READ THIS FIRST

- Level 3, Particles, S3.5.3. Melting and boiling are changes of state there.
- Level 3, Particles, S3.5.7. Dissolving is a change where nothing new is made.

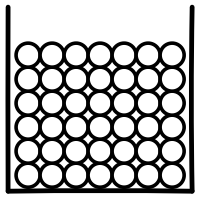
BY THE END YOU CAN

- Sort changes into physical and chemical
- List signs of a chemical change, such as gas, heat or colour

Things change all the time. Ice melts. Milk turns sour. Paper burns. Sugar vanishes in tea. In science we sort these changes into two kinds. The question to ask is whether a new substance is made.

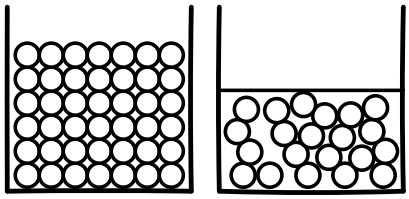
DRAW IT FIRST

Draw ice melting



ice

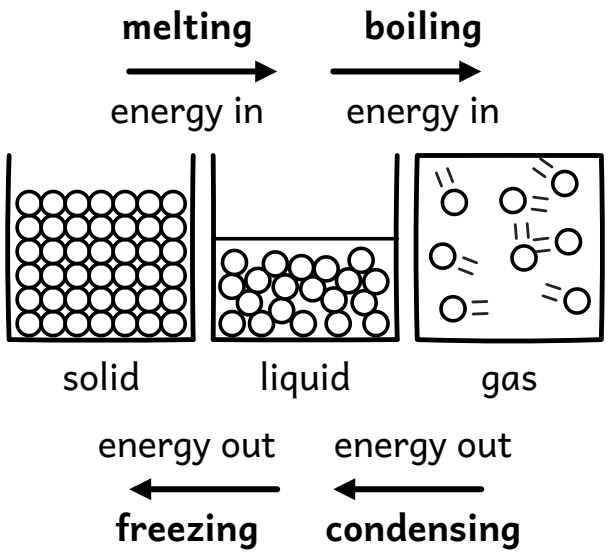
1 Draw the particles of ice, in neat rows. They hold each other in place.



ice water

2 Draw the same particles as water. They are jumbled and slide past each other. They are the same particles.

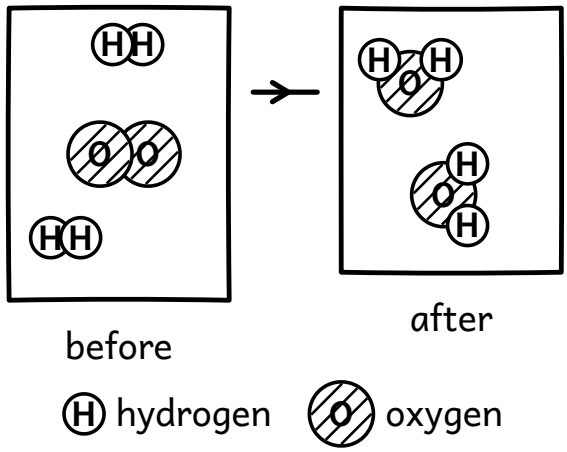
Melting is a **physical change**. The particles are the same before and after. No new substance is made. Only the way the particles are arranged has changed.



Every change of state can go both ways. Melting can be reversed by freezing.

A physical change can often be turned back, so we say it is **reversible**. Freeze the water and you get ice again. Dissolve sugar in water and you can get the sugar back by evaporating. Crushing a can or cutting paper are also physical changes.

In a **chemical change**, the atoms are joined in new ways, and a new substance is made. The new substance has new properties. A chemical change is not easy to turn back.



Hydrogen burns in oxygen and makes water. There are 6 atoms before and 6 atoms after. The atoms are not lost. They join in new groups.

How can you tell if a change is chemical? Look for signs. These are clues that a new substance may be forming.

sign	example
a new gas	rising bread
heat or light	candle flame
colour change	cut apple
a new solid	rust on iron

Four signs of a chemical change. A cut apple turns brown because it reacts with oxygen in the air.

But a sign alone is not proof. Some physical changes show the same signs. The real test is whether a new substance has been made.

A kerosene lamp burns its fuel to give light and heat, and that is a chemical change. An electric bulb gives light and heat with no new substance, and that is physical.

sign	but physical
a gas	boiling water
heat or light	electric bulb
colour change	mixing paint
a solid	ice forming

Each of these looks like a sign, but no new substance is made.

SEE IT THREE WAYS

With things

Ask two questions. Is a new substance made? Can it be turned back easily? Melting ice: no new substance, and it turns back. Burning wood: new substances, and no way back.

As a picture

change	kind
melting ice	physical
burning wood	chemical
dissolving sugar	physical
a nail rusting	chemical
cooking an egg	chemical
crushing a can	physical

In words

In a physical change no new substance is made, and it can often be reversed. In a chemical change a new substance is made, and it is hard to reverse.

TRY IT

Fizz or no fizz

You need: two large cups, a plate, a spoon of sugar, a spoon of baking soda, water, vinegar.

Be safe: Use a big cup, because the fizz can spill over. Keep your face back from the cup. If any splashes in your eyes, rinse them with plenty of clean water. Do not taste anything. Do not seal the mixture in a bottle.

1. Cup A: stir a spoon of sugar into half a cup of water. Watch for bubbles and for any change in heat.
2. Cup B: put a spoon of baking soda in a large cup. Slowly pour in a little vinegar.
3. Watch cup B. Then pour a thin layer of the sugar water from cup A onto the plate. Leave it in the sun until the water has gone. What is left?

What you will see: In cup A the sugar vanishes with no bubbles. The water evaporates and a sticky layer of sugar is left on the plate. So dissolving is a physical change. In cup B a gas forms and fizzes. The gas is carbon dioxide, a new substance, so this is a chemical change.

If you cannot try it, this is what happens.

mixture	new gas?
sugar in water	no
soda and vinegar	yes

A WRONG IDEA MANY PEOPLE HAVE

~~If something changes colour, it must be a chemical change.~~

Why it feels right: Burning wood goes black and rust is brown. So colour seems to be the sign that matters.

The test that breaks it: Stir a drop of food colouring into a glass of water. The water changes colour. Now leave it in the sun until the water has gone. The colouring is left, unchanged. Nothing new was made.

What is true: A colour change is only a clue. Ask if a new substance has been made, and if the change can be turned back.

KEY WORDS

physical change
a change where no new substance is made.

reversible
able to be turned back.

chemical change
a change where atoms join in new ways and a new substance is made.

BACK TO YOUR GUESS

The answer is B: No. Melting makes no new substance. Burning makes new substances that you cannot easily turn back.

Melting is a physical change. The water is still water. Burning is a chemical change. It makes new substances, such as ash and gases, that you cannot easily turn back.

CHECK YOURSELF

Try each one before you look. A wrong answer tells you where to go next.

1. Which of these is a physical change?

   A A candle burns down.

   B An egg cooks and goes hard.

   C Ice melts into water.

   Answer at the back of the book.

2. Which of these is a chemical change?

   A Wood burns to ash and gases.

   B Sugar dissolves in tea.

   C Water boils and turns to steam.

   Answer at the back of the book.

3. You heat a pan of water. Bubbles rise and steam leaves. Is this a chemical change?

   A Yes. Bubbles are a gas, and a new gas always means a chemical change.

   B No. The bubbles are water vapour, so no new substance is made.

   C Yes. Heat is added, so it must be chemical.

   Answer at the back of the book.

4. Baking soda is mixed with vinegar, and a gas fizzes out. Which sign of a chemical change is this?

   A A colour change.

   B A new solid forming.

   C A new gas is made.

   Answer at the back of the book.

5. What is the best test for a chemical change?

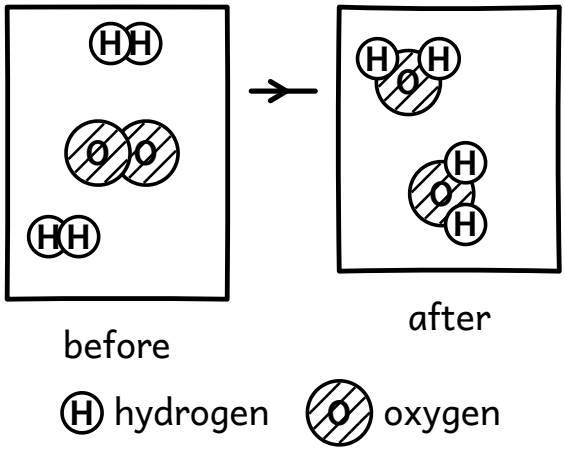
   A A new substance is made.

   B The thing changes colour.

   C The thing gets hot.

   Answer at the back of the book.

6. In the picture, hydrogen and oxygen change into water. Which sentence is true?



A Some of the atoms are lost, because water is a liquid.

B The hydrogen and oxygen atoms change into new kinds of atom.

C The same atoms join in new groups, and a new substance forms.

Answer at the back of the book.

7. After the change there are 2 water groups, and each group has 3 atoms. How many atoms are there in all?

Answer at the back of the book.

8. **From an earlier chapter**

Which method gets the salt back from a dish of salty water?

A Filter the water through paper.

B Pour the water through a sieve.

C Evaporate the water in the sun.

Answer at the back of the book.

KEEP IT

Copy this into your exercise book.

A physical change makes no new substance. A chemical change makes a new substance. Gas, heat or light, colour or a new solid are clues, not proof.

Draw: Draw two boxes, before and after, with atoms joined in new groups. Label it chemical change.

S3.6.5 CHAPTER 5

Rusting and other reactions

Why do iron nails turn orange-brown outside, but stay shiny in a dry drawer?

YOUR GUESS

Pick one before you read on. It is fine to be wrong.

- ☐ **A** Only water makes iron rust. The air does nothing.
- ☐ **B** Iron rusts when it has both air and water. A dry drawer has no water.
- ☐ **C** Rust is just dirt that sticks to wet iron.

IF THIS FEELS HARD, READ THIS FIRST

- Level 3, Particles, S3.5.7. Mass stays the same when things dissolve. Here you will see mass change when atoms join.

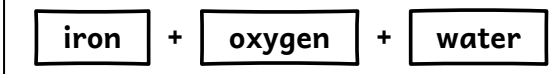
BY THE END YOU CAN

- Write word equations for rusting and other reactions
- Test what iron nails need to rust, using three jars

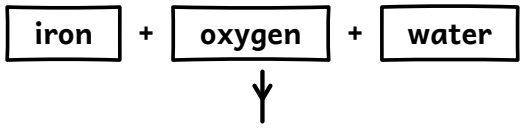
An iron gate that stays wet goes brown and flaky. A bicycle chain left in the rain does the same. The brown stuff is rust. It is not iron any more, and it is not dirt. It is a new substance.

DRAW IT FIRST

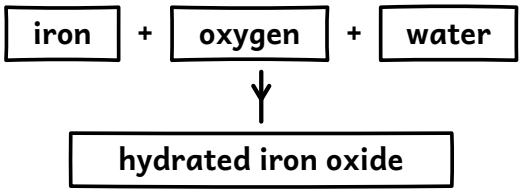
Draw the word equation for rusting



1 Write the starting substances, with plus signs between them: iron, oxygen and water.



2 Draw an arrow. It means makes. Here it points down.



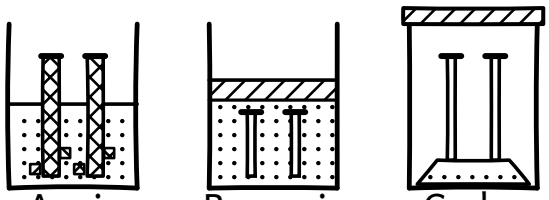
3 Write what is made after the arrow: hydrated iron oxide. This is rust.

A chemical change is also called a **reaction**. The substances that react are the **reactants**. The new substances are the **products**. We write a reaction as a **word equation**, with an arrow that means makes.

Reactants come before the arrow, and products come after it. In our pictures the arrow points down, so the reactants are above it and the products are below.

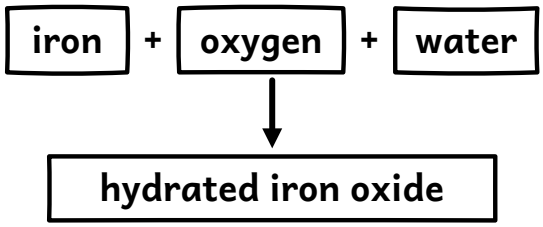
Rust is **hydrated iron oxide**. It is iron joined with oxygen and water. It is crumbly and weak, and it is nothing like strong iron.

Does iron need air, or water, or both? You can test it. Put iron nails in three jars. In jar A there is air and water. In jar B there is water but no air. In jar C there is air but no water.



After some days, only the nails in jar A are rusty.

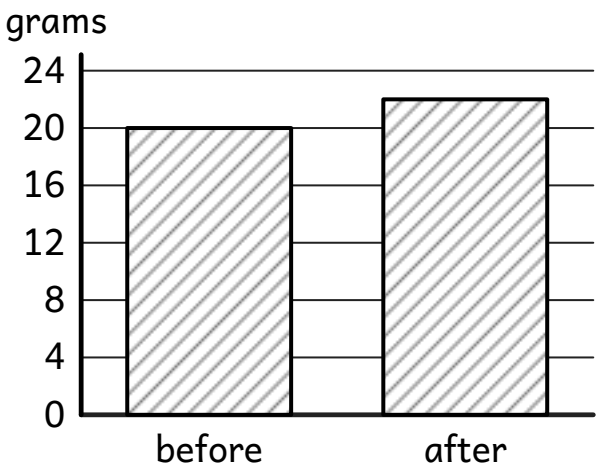
Jar B has water, but a layer of oil on top keeps air out. Boiled water has lost most of the air that was in it. Jar C has air, but the rice keeps it almost dry and the lid keeps wet air out. Only jar A has both. So iron needs both oxygen and water to rust.



The word equation for rusting.

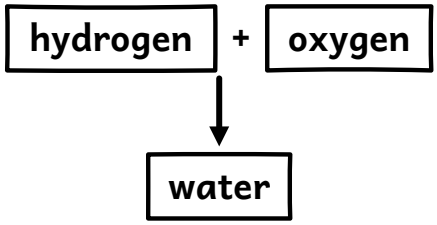
Salt in the water makes iron rust faster. That is why iron rusts so fast near the sea. Paint, oil and a coat of zinc keep air and water away from iron.

A nail gets heavier when it rusts. The oxygen and water come from outside and join the iron. Their mass is added. Nothing is lost. The gain is small, and it takes many months outside, with every flake kept, to weigh it.

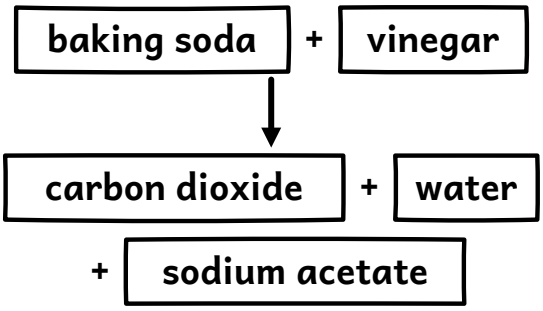


A nail before and after many months outside. Its mass went from 20 g to 22 g. The bars are close, but the gain is real.

Rusting is one reaction. There are many more, and each can be written as a word equation. Hydrogen burns in oxygen to make water. Baking soda and vinegar make a gas, carbon dioxide, with water and a salt.



Hydrogen burns in oxygen. The product is water.



Baking soda and vinegar. The fizz is carbon dioxide gas. Sodium acetate is a salt.

SEE IT THREE WAYS

With things

Think of a recipe. Flour, eggs and milk go in. Pancakes come out. A word equation is a recipe for a reaction. The ingredients come before the arrow. What you make comes after it.

As a picture

jar	air	water	rust
A	yes	yes	yes
B	no	yes	no
C	yes	no	no

In words

Rust forms only when iron has air and water together. Take away either one, and the iron does not rust.

TRY IT

What do nails need to rust?

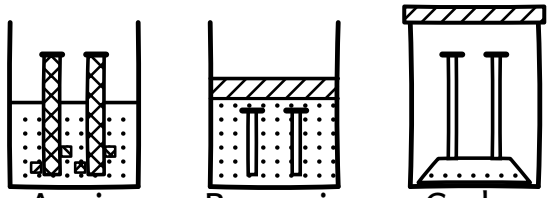
You need: 3 jars, 6 plain iron nails, water, cooking oil, dry rice, a lid for one jar.

Be safe: A grown up must boil the water and let it cool. Use plain iron nails, not shiny coated ones. Rusty nails can cut, so do not squeeze them. Wash your hands afterwards.

1. Jar A: put 2 nails in. Pour in water until it covers half of each nail. Leave the jar open.
2. Jar B: a grown up boils water and lets it cool all the way. Put 2 nails in the jar and fill it with the cool water. Pour a layer of oil on top.
3. Jar C: put dry rice in the bottom. Stand 2 nails on it. Screw the lid on tight.
4. Put the jars somewhere safe. Look at them each day for a week or more. Write down what you see.

What you will see: The nails in jar A turn orange-brown, most of all where air meets water. The nails in B and C stay much cleaner. The rice in C cannot dry the air fully, so a little change is possible. The test is a fair one, because only air and water change.

If you cannot try it, this is what happens.



A: air and water	B: no air oil layer	C: dry rice, lid
rust	**no rust**	**no rust**

A WRONG IDEA MANY PEOPLE HAVE

~~Iron rusts because of water alone.~~

Why it feels right: Rust shows up where things are wet, such as gates and bicycles left in the rain.

The test that breaks it: In jar B the nails sit in water, but oil stops air reaching them. They stay clean. In jar C the air reaches the nails, but there is almost no water. They stay almost clean too.

What is true: Iron needs oxygen from the air and water together. If either is missing, it will not rust.

KEY WORDS

reaction
a chemical change, where substances join in new ways.

reactants
the substances that react.

products
the new substances that are made.

word equation
a way to write a reaction in words, with an arrow.

BACK TO YOUR GUESS

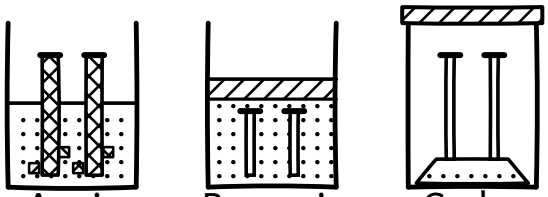
The answer is B: Iron rusts when it has both air and water. A dry drawer has no water.

Iron needs oxygen from the air and water together. Rust is a new substance made when the iron joins with them. It is not dirt.

CHECK YOURSELF

Try each one before you look. A wrong answer tells you where to go next.

1. Which jar has nails that rust?



A: air and water	B: no air oil layer	C: dry rice, lid
rust	**no rust**	**no rust**

A Jar B, with water and a layer of oil.

B Jar C, the dry jar with a lid.

C Jar A, with air and water.

Answer at the back of the book.

2. The nails in the jar with the oil layer stayed clean. Why?

A The oil cleaned the iron.

B There was no water in the jar.

C The oil kept air out, so the iron had water but no oxygen.

Answer at the back of the book.

3. Which word equation is right for rusting?

A hydrated iron oxide → iron + oxygen + water

B iron + oxygen + water → hydrated iron oxide

C iron + water → iron + oxygen

Answer at the back of the book.

4. In a word equation, what is written before the arrow?

A The reactants, which are the substances that react.

B The products, which are the new substances.

C The products, because they come first.

Answer at the back of the book.

5. Baking soda and vinegar fizz. The gas that bubbles is carbon dioxide. Which are the products?

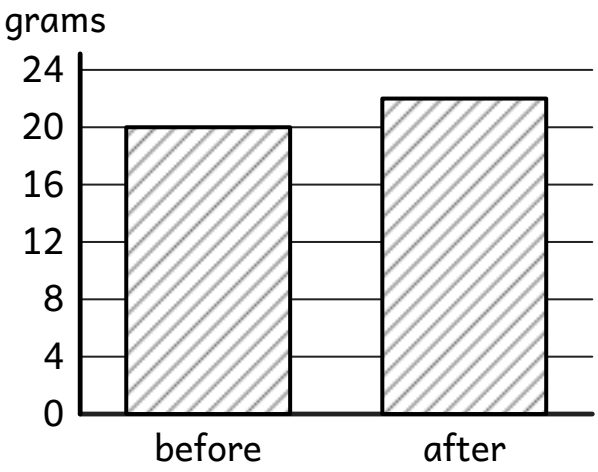
   A baking soda and vinegar

   B carbon dioxide only

   C carbon dioxide, water and sodium acetate

   Answer at the back of the book.

6. A nail has a mass of 20 g. After many months outside, the nail and all its rust have a mass of 22 g. How many grams of oxygen and water joined the iron?



   Answer at the back of the book.

7. **From an earlier chapter**

   Rust forms on an iron nail, and the nail gets weaker. What kind of change is this?

   A A physical change, because the iron is still iron.

   B A chemical change, because a new substance forms.

   C A physical change, because it happens slowly.

   Answer at the back of the book.

KEEP IT

Copy this into your exercise book.

Iron + oxygen + water → hydrated iron oxide. Iron needs air and water to rust. Reactants go before the arrow, and products go after it.

Draw: Draw three jars: air and water, water with oil on top, and dry with a lid. Mark which nails rust.

S3.6.6 CHAPTER 6

Burning and fire safety

Why does a candle go out under a jar, and why is water wrong for some fires?

YOUR GUESS

Pick one before you read on. It is fine to be wrong.

- ☐ **A** A fire needs only something to burn. Take that away and the fire goes out.
- ☐ **B** A fire needs fuel, oxygen and heat. Take away any one of them and the fire goes out.
- ☐ **C** Water puts out every fire, because water is wet.

IF THIS FEELS HARD, READ THIS FIRST

- Level 3, Particles, S3.5.3. Burning makes gases such as water vapour, which you met there.

BY THE END YOU CAN

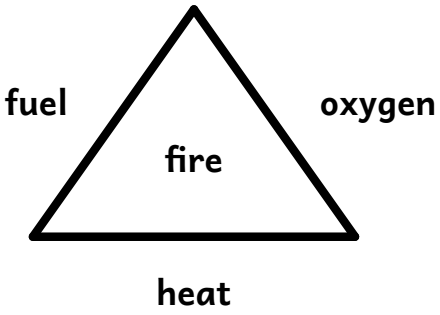
- Name the three things a fire needs: fuel, oxygen and heat
- Explain how each way of putting out a fire works
- Write a word equation for burning a fuel

Fire cooks food and gives light. It also burns down homes. To use it safely, you need to know what a fire is made of and how it stops.

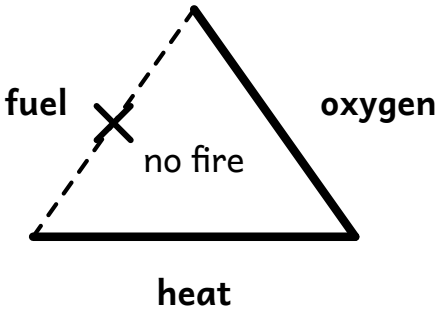
Be safe. Never light a fire yourself. Use a candle only with a grown up beside you. If a fire starts, get away and get a grown up. Do not try to put out a big fire.

DRAW IT FIRST

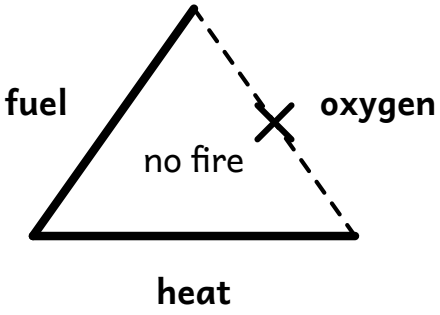
Draw the fire triangle



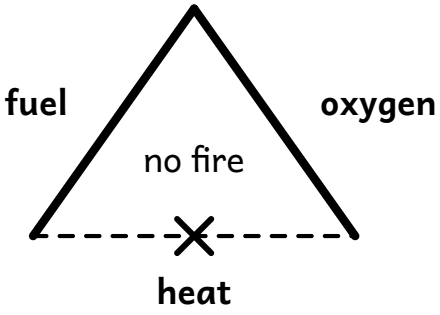
1 Draw a triangle. Write fuel, the thing that burns, on one side. Write oxygen on another side and heat along the bottom. Write fire in the middle.



2 Draw it again. Take away the fuel. There is no fire.



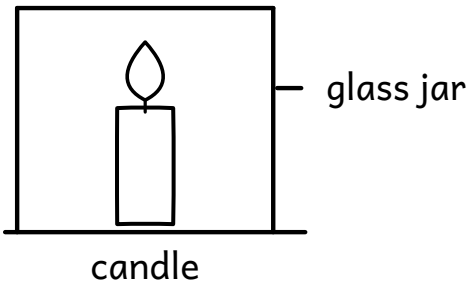
3 Draw it again. Take away the oxygen. There is no fire.



4 Draw it again. Take away the heat. There is no fire.

This is the **fire triangle**. A fire needs fuel, oxygen and heat, all three at once. Take away any one side, and the fire goes out.

Burning is a chemical change. A **fuel** is something that burns, such as wood, wax or gas. It joins with oxygen from the air and gives out heat and light. The gases it makes float away.



A jar over a candle holds only so much air. The flame uses the oxygen, and when too little is left it goes out.

A bigger jar holds more air, and more oxygen. So the flame lasts longer. This is a fair test, because only the jar changes.

Each way of putting out a fire takes away one side of the triangle. Water takes away heat. A lid or sand **smothers** a fire. It covers it so no air reaches it, and that takes away oxygen. Turning off the gas takes away the fuel.

way	takes away
pour water	heat
cover with sand	oxygen
switch gas off	fuel

Three ways to put out a fire, and the side of the triangle each one takes away.

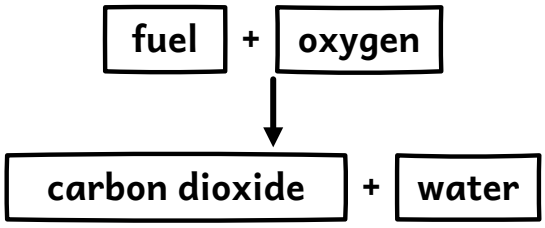
But water is not right for every fire. Oil is lighter than water, so it floats on it. Water poured on burning oil sinks, turns to steam and throws burning oil about. For an oil fire in a pan, turn off the heat. Slide a lid or a baking tray over it. Never use water. Leave the lid on until the pan is cold, or the oil may flare up again. If the fire is big, get out and call for help.

Water also carries electricity. Never pour water on an electrical fire. If it is safe, switch off the power first. Otherwise get away and get help.

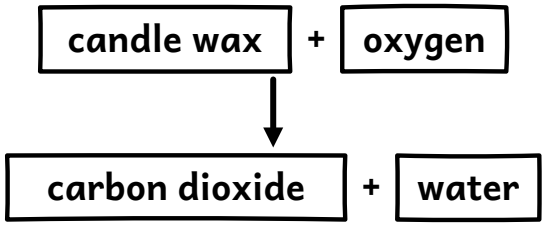
fire	use	never
pan of oil	a lid	water
electrical	power off	water

Two fires where water is the wrong choice.

Now the reaction. Wax and cooking gas are made of carbon and hydrogen. Wood is made of carbon, hydrogen and oxygen. When these burn, the carbon joins with oxygen to make carbon dioxide. The hydrogen joins with oxygen to make water vapour.



Burning a fuel made of carbon and hydrogen.



A candle burning. The wax seems to vanish, but it has become gases.

These equations hold when there is plenty of air. With too little air, a fire makes soot and carbon monoxide. Carbon monoxide is a poison gas, and you cannot see or smell it. Never burn charcoal, wood or gas in a closed room. Always let fresh air in.

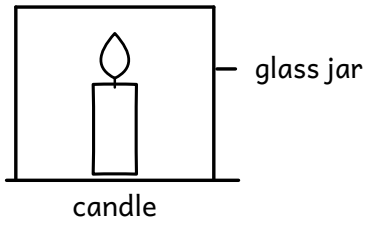
A burning candle gets shorter. The wax has not been destroyed. It has become carbon dioxide and water vapour, which go into the air. Burning adds carbon dioxide to the air.

SEE IT THREE WAYS

With things

Cover a burning candle with a jar. The flame goes out after a few seconds. The jar did not cool it or remove the wax. It kept fresh air away.

As a picture



In words

The flame uses oxygen. Under a jar there is only a little. When too little is left, the flame goes out.

TRY IT

Time a flame under two jars

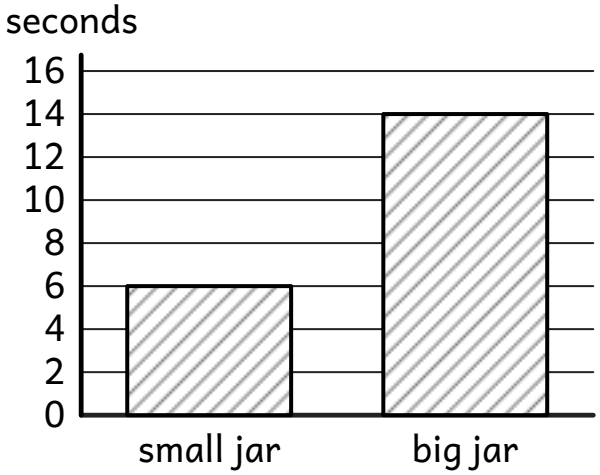
You need: a candle on a saucer, two glass jars, one small and one big, a clock or a way to count seconds, a grown up with matches.

Be safe: Only a grown up lights the candle. Do not touch the jar while it is hot. Never leave a flame alone. Keep paper and cloth away.

1. A grown up lights the candle. Everyone else stays back. Tie long hair back.
2. Lower the small jar over the flame. Count the seconds until the flame goes out. Write it down.
3. Wait until the jar has cooled. A grown up lights the candle again. Do the same with the big jar. Compare the times.

What you will see: The flame lasts longer under the big jar, because there is more air and so more oxygen. Your times will differ from the picture.

If you cannot try it, this is what happens.



A WRONG IDEA MANY PEOPLE HAVE

~~Water puts out every fire.~~

Why it feels right: Water is what we throw on a campfire, and fire engines carry it.

The test that breaks it: Water takes away heat. It does not stop an oil fire from burning. Burning oil floats, and hot oil and water spit and splash. Water also carries electricity.

What is true: Pick the way that takes away one side of the triangle safely. A lid for an oil fire. Switch off the power for an electrical fire.

KEY WORDS

fuel
something that burns, such as wood, wax or gas.

fire triangle
the three things a fire needs: fuel, oxygen and heat.

smothers
covers a fire so no air reaches it.

BACK TO YOUR GUESS

The answer is B: A fire needs fuel, oxygen and heat. Take away any one of them and the fire goes out.

A fire needs fuel, oxygen and heat. A jar takes away oxygen. Water takes away heat, but it makes some fires worse, so it is not right for every fire.

CHECK YOURSELF

Try each one before you look. A wrong answer tells you where to go next.

1. What three things does a fire need?

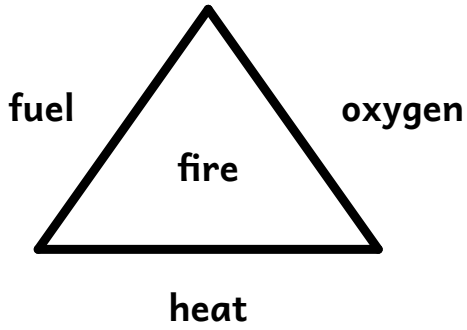
    A fuel, oxygen and heat

    B fuel, carbon dioxide and heat

    C fuel, water and oxygen

    Answer at the back of the book.

2. A lid is slid over a small fire in a pan of cooking oil. Which side of the fire triangle does it take away?



    A fuel

    B oxygen

    C heat

    Answer at the back of the book.

3. Why does water put out a wood fire?

    A It takes away the fuel.

    B It takes away the oxygen.

    C It takes away heat by cooling the wood.

    Answer at the back of the book.

4. Why must you never pour water on burning cooking oil?

    A The water sinks, turns to steam and throws burning oil about.

    B The water mixes with the oil and makes it burn more slowly.

    C The water takes away the oxygen, which is what you want.

    Answer at the back of the book.

5. Candle wax is made of carbon and hydrogen. Which word equation shows it burning?

   A candle wax → carbon dioxide + oxygen

   B candle wax + carbon dioxide → oxygen + water

   C candle wax + oxygen → carbon dioxide + water

   Answer at the back of the book.

6. Why does a candle go out when a jar is put over it?

   A The jar cools the wax too much.

   B There is only a little air under the jar, and the oxygen runs low.

   C The jar takes away the wax.

   Answer at the back of the book.

7. A gas ring on a cooker is burning. Which action takes away the fuel?

   A Turn off the gas.

   B Pour water on the flame.

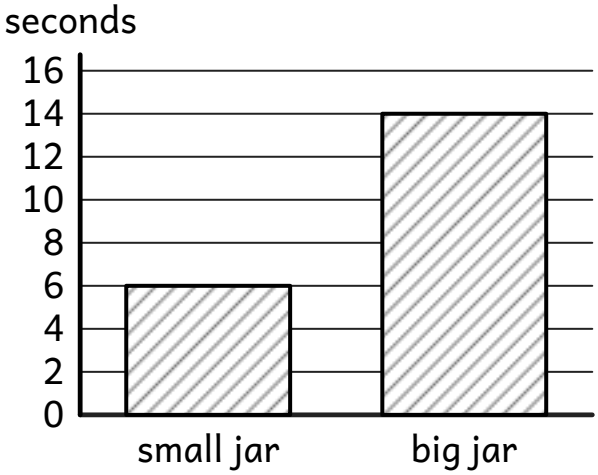
   C Cover the flame with a lid.

   Answer at the back of the book.

8. A candle has a mass of 20 g. After it has burned for a while its mass is 14 g. How much wax became gas?

   Answer at the back of the book.

9. The chart shows how long a flame lasted. How many more seconds did it last under the big jar than under the small jar?



Answer at the back of the book.

10. **From an earlier chapter**

Burning wood is a chemical change. How can you tell?

A New substances are made, such as carbon dioxide and ash.

B The wood changes shape.

C It gets hot, and heat is always a chemical sign.

Answer at the back of the book.

KEEP IT

Copy this into your exercise book.

A fire needs fuel, oxygen and heat. Take away one and it goes out. Never use water on oil or electrical fires. Fuel + oxygen → carbon dioxide + water.

Draw: Draw the fire triangle with fuel, oxygen and heat on its sides.

S3.6.7 CHAPTER 7

Acids and alkalis

> **Lemon juice is sour and soap feels slippery. Can you sort them without tasting them?**

YOUR GUESS

Pick one before you read on. It is fine to be wrong.

- ☐ **A** No. The only way to tell is to taste them.
- ☐ **B** Yes. A plant dye can show which is an acid and which is an alkali.
- ☐ **C** No. All liquids at home are the same, so you cannot sort them.

IF THIS FEELS HARD, READ THIS FIRST

- Level 3, Particles, S3.5.7. You make test liquids by dissolving things in water.

BY THE END YOU CAN

- Make an indicator from red cabbage, turmeric or hibiscus flowers
- Sort lemon juice, vinegar, soap and baking soda into acids and alkalis
- Place common substances on the pH scale from 0 to 14

Some liquids are sour, like lemon juice. Some feel slippery, like soapy water. Scientists sort these into three groups. They are acids, neutral liquids and alkalis.

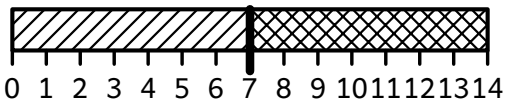
Be safe. Use only kitchen liquids: lemon juice, vinegar, baking soda and soap. Never use bleach or toilet cleaner, and never mix them with anything. Never taste or smell a test liquid close up. A grown up pours any hot water. Wash your hands afterwards.

An **acid** tastes sour. Lemon juice, vinegar and the juice in your stomach are acids. An **alkali** is the opposite of an acid. Soap and baking soda are alkalis. Strong ones feel slippery and burn.

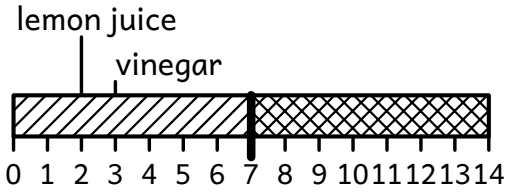
Tasting is not a safe test. Instead we use an **indicator**. This is a dye that has one colour in an acid and another in an alkali. A liquid that is neither is **neutral**. Pure water is neutral.

DRAW IT FIRST

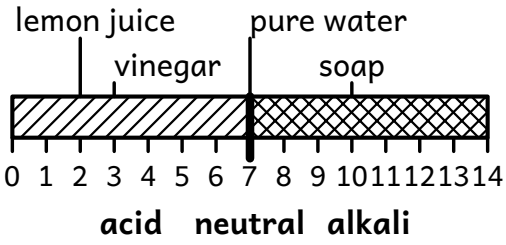
Draw the pH scale



1 Draw a strip and number it from 0 to 14. Mark 7 in the middle as neutral. Write acid on the left and alkali on the right.

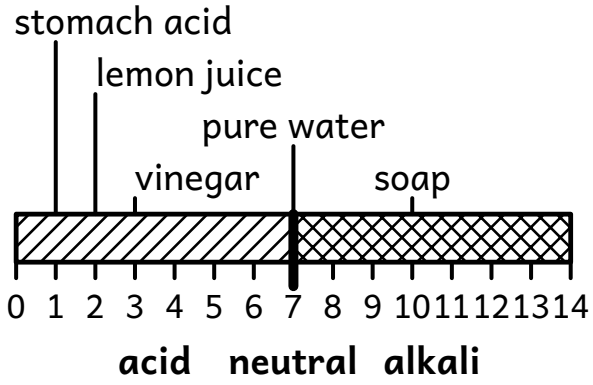


2 Add the acids. Lemon juice goes at 2 and vinegar at 3.

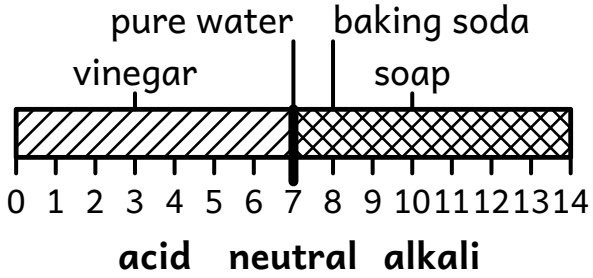


3 Add pure water at 7, the neutral place, and soap at 10 on the alkali side.

The **pH scale** runs from 0 to 14. Below 7 is acid, and the lower the number, the stronger the acid. 7 is neutral. Above 7 is alkali, and the higher the number, the stronger the alkali.

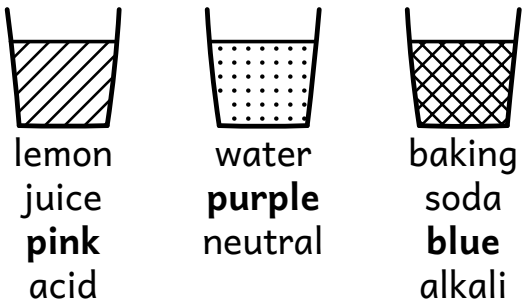


The pH of some things at home. These values are about, and real ones vary. Stomach acid is about 1 and lemon juice about 2.



Baking soda in water is a weak alkali, at about 8. Soap is stronger, at about 10.

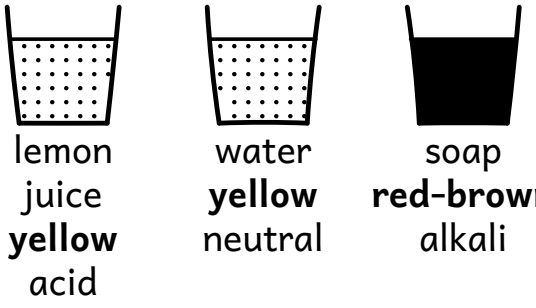
Red cabbage makes a good indicator. Its juice is red or pink in an acid. It is purple in a neutral liquid. It turns blue, then green, in an alkali, and yellow in a very strong one.



Red cabbage indicator in three liquids. The word under each cup says the colour.

Turmeric is a yellow spice. It is yellow in acids and neutral liquids. It turns red-brown in an alkali. Hibiscus flowers also work, as red or pink in an acid and green or blue in an alkali. Colours vary a little with the plant and the water.

To make a turmeric indicator, stir a pinch of turmeric into a cup of water. To make a hibiscus indicator, a grown up pours hot water over a few dried petals. Wait until the water is coloured.



Turmeric stays yellow in an acid. It changes only in an alkali.

SEE IT THREE WAYS

With things

Each liquid gives a pair of colours. Together they say what the liquid is. You can check one indicator with the other.

As a picture

liquid	cabbage	turmeric
lemon	pink	yellow
water	purple	yellow
soap	green	red-brown

In words

An acid turns cabbage pink and leaves turmeric yellow. A neutral liquid turns cabbage purple. An alkali turns cabbage blue or green, and turmeric red-brown.

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acids	alkalis
lemon juice	soap
vinegar	baking soda

Four things from the kitchen, sorted into acids and alkalis.

TRY IT

Make a red cabbage indicator

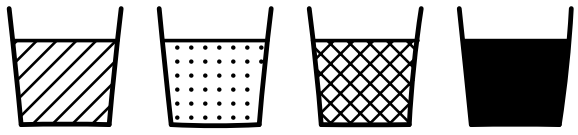
You need: 3 leaves of red cabbage, a bowl, hot water, poured by a grown up, a spoon, 4 clear cups, vinegar, baking soda, a little bar soap or laundry soap, scraped into flakes, water.

Be safe: A grown up pours the hot water. Use only these kitchen liquids. Never use bleach or toilet cleaner. Do not taste the liquids. Wash your hands when you finish.

1. Tear the cabbage into small pieces and put them in the bowl. A grown up pours hot water over them.
2. Wait about 15 minutes until the water is deep purple. Let it cool. Pour the purple liquid into a cup and throw the leaves away.
3. Set out 4 clear cups. Put vinegar in the first. Put plain water in the second. Stir a spoon of baking soda into water in the third. Stir a little scraped bar soap into water in the fourth. Liquid hand soap and dish liquid are often close to neutral, so they may show no change.
4. Add 2 spoons of the purple liquid to each cup. Watch the colours. Write them down.

What you will see: The vinegar turns pink. The plain water stays purple. The baking soda turns blue. The soap turns green. Your colours may be a little different.

If you cannot try it, this is what happens.



vinegar **pink** | water **purple** | baking soda **blue** | soap **green**

A WRONG IDEA MANY PEOPLE HAVE

~~Acids are always strong and dangerous.~~

Why it feels right: We hear about acids that burn through metal, and we learn to keep away from them.

The test that breaks it: You eat acids every day. Lemon juice and vinegar are acids. They are weak enough to eat. Your stomach makes a strong acid to digest food. Mucus on its lining protects it. Soap and baking soda are alkalis you handle at home too.

What is true: Strength varies. A strong acid or strong alkali can burn. The pH scale tells you how strong, as well as which kind.

KEY WORDS

acid
a substance with a pH below 7. Many taste sour.

alkali
a substance with a pH above 7. Soap is one.

indicator
a dye that changes colour in acids and alkalis.

neutral
neither an acid nor an alkali, with a pH of 7.

pH scale
a scale from 0 to 14 for how acid or alkali something is.

BACK TO YOUR GUESS

The answer is B: Yes. A plant dye can show which is an acid and which is an alkali.

An indicator is a dye that changes colour. It tells acids, neutral liquids and alkalis apart, with no tasting at all.

CHECK YOURSELF

Try each one before you look. A wrong answer tells you where to go next.

1. A drop of red cabbage indicator turns pink in a liquid. What kind of liquid is it?

   A Neutral

   B An alkali

   C An acid

   Answer at the back of the book.

2. Which pair are both acids?

   A vinegar and soap

   B lemon juice and vinegar

   C soap and baking soda

   Answer at the back of the book.

3. Which of these is an alkali?

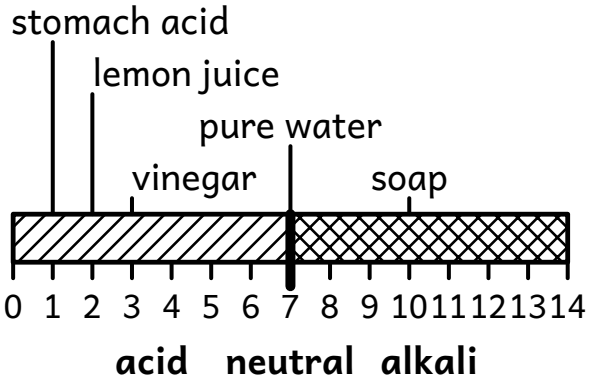
   A soap in water

   B vinegar

   C pure water

   Answer at the back of the book.

4. On the pH scale in the picture, how many steps below the neutral line, 7, is vinegar?



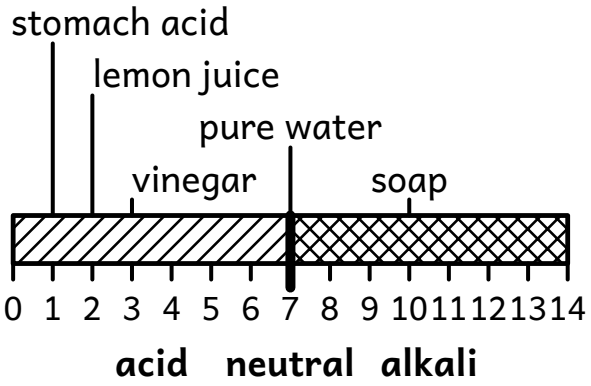
A 4 steps

B 3 steps

C 7 steps

Answer at the back of the book.

5. Which substance in the picture is the strongest acid?



A soap

B pure water

C stomach acid

Answer at the back of the book.

6. How do you get the dye out of red cabbage to make an indicator?

   A Rub the leaves in cooking oil.

   B Tear the leaves and soak them in hot water that a grown up has poured.

   C Soak the leaves in vinegar.

   Answer at the back of the book.

7. A turmeric solution is yellow. You add soap solution to it. What happens, and what does it show?

   A It turns red-brown. The soap is an alkali.

   B It turns pink. The soap is an acid.

   C It stays yellow. The soap is neutral.

   Answer at the back of the book.

8. **From an earlier chapter**

   Which two things does a fire need besides fuel?

   A water and oxygen

   B carbon dioxide and heat

   C oxygen and heat

   Answer at the back of the book.

9. On the pH scale, lemon juice is about 2 and pure water is 7. How many steps apart are they?

   Answer at the back of the book.

KEEP IT

Copy this into your exercise book.

Acids are below 7 on the pH scale, neutral is 7 and alkalis are above 7. Cabbage is pink in acid, purple in neutral and blue or green in alkali.

Draw: Draw a strip numbered 0 to 14. Write acid, neutral and alkali. Mark lemon juice, water and soap.

S3.6.8 CHAPTER 8

Neutralisation

Why does a chalky tablet ease a sore stomach, and why do farmers spread white powder on soil?

YOUR GUESS

Pick one before you read on. It is fine to be wrong.

- ☐ **A** The tablet adds more acid, so the stomach pain goes away.
- ☐ **B** The tablet soaks up all the acid, so the stomach cannot digest food.
- ☐ **C** The tablet is a weak alkali. It cancels some of the extra acid.

IF THIS FEELS HARD, READ THIS FIRST

- Level 3, Particles, S3.5.7. Acids and alkalis work in water, as dissolved substances.

BY THE END YOU CAN

- Explain neutralisation as an acid and an alkali cancelling out
- Explain how an antacid eases indigestion
- Explain why farmers add lime to sour soil

An acid and an alkali are opposites. When you mix them, each one weakens the other. This is useful for a sore stomach and for sour soil.

DRAW IT FIRST

Draw a neutralisation

acid + **alkali**

1 Write acid and alkali, with a plus sign between them. These are the substances you start with.

acid + **alkali**

↓

2 Draw an arrow. It means makes.

acid + **alkali**

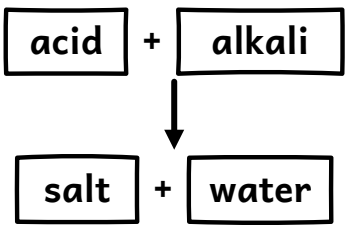
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salt + **water**

3 Write what they make: a salt and water. The acid and the alkali are used up.

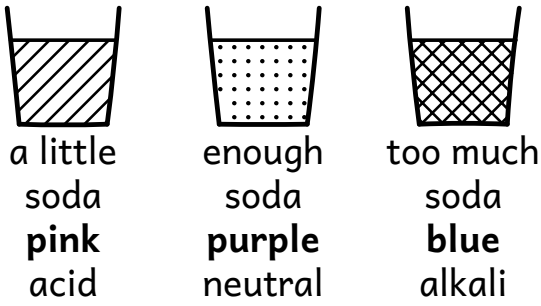
When an acid and an alkali react, they cancel each other out. We call this **neutralisation**. The reaction makes a salt and water.

Here a **salt** means any substance made when an acid and an alkali react. Table salt is one salt, but there are many others.



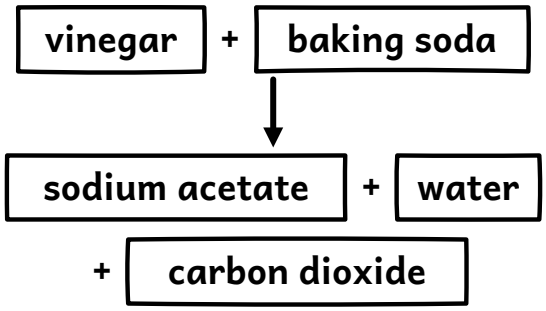
The word equation for neutralisation.

You can watch it with an indicator. Put red cabbage indicator in vinegar, an acid. It turns pink. Add baking soda a little at a time. At first it stays pink, because some acid is left. With enough soda it turns purple, which is neutral. Add too much, and it turns blue.



Too little alkali leaves some acid. Enough makes the liquid neutral. Too much leaves an alkali.

Baking soda also makes gas as it reacts with vinegar. That is the fizz. The fizz is carbon dioxide.



Vinegar is the acid. Sodium acetate is the salt. The gas makes the fizz.

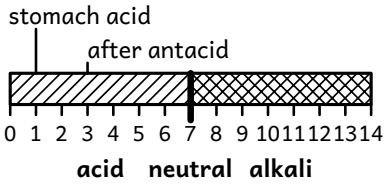
Your stomach makes acid to break down food. Sometimes it makes too much, and your stomach hurts. This is called indigestion. An **antacid** is a medicine that eases it. An antacid is a weak alkali, often a chalky tablet. It cancels some of the extra acid.

SEE IT THREE WAYS

With things

Think of a bath that is too hot. You add cold water, and it cools. An antacid does the same job for acid. It cancels some, so the stomach is less sour.

As a picture



In words

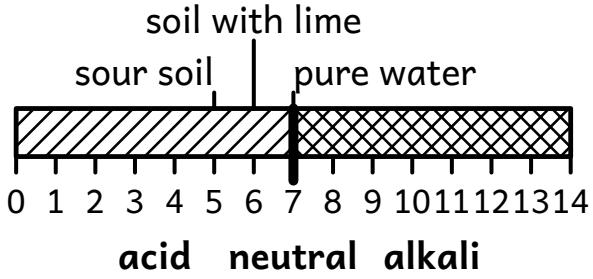
The stomach acid is at about pH 1. An antacid raises the pH to about 3. It does not go all the way to 7, because the stomach still needs some acid.

In symbols

3 − 1 = 2

An antacid must be a weak alkali. A strong alkali would burn the inside of the body. Only use medicine that a grown up or a health worker says is right for you.

Soil can be acid too. Rain, and some plant waste, make it acid. Many crops grow poorly in sour soil. Farmers fix this with **lime**. Lime is made from limestone, and it is an alkali.



Sour soil is about pH 5. Lime raises it, here to about 6, which is closer to neutral. Most crops grow best near neutral soil.

problem	fix
indigestion	antacid
sour soil	lime

Two problems of too much acid, and the alkali that fixes each.

Farmers wear gloves and masks when they spread lime. It is an alkali and it can burn skin and eyes. They also test the soil first, so they add only as much as the soil needs.

TRY IT

Cancel out vinegar

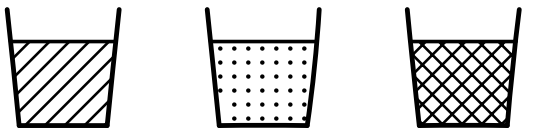
You need: red cabbage indicator from the last chapter, vinegar, baking soda, a large cup, a spoon.

Be safe: Use a large cup, because the fizz can spill over. Keep your face back from the cup. If any splashes in your eyes, rinse them with plenty of clean water. Do not taste anything. Wash your hands afterwards.

1. Put 2 spoons of vinegar in a large cup. Add 2 spoons of cabbage indicator. It turns pink.
2. Add a pinch of baking soda. Stir. It fizzes. Watch the colour.
3. Keep adding one pinch at a time. Stir each time. At first the colour stays pink. Stop when it turns purple. Then add more, and see it turn blue.

What you will see: The colour stays pink at first, because there is still acid. It turns purple when the acid has been cancelled. A little more soda turns it blue, because now there is too much alkali. The fizz is carbon dioxide gas.

If you cannot try it, this is what happens.



a little soda	enough soda	too much soda
pink	**purple**	**blue**
acid	neutral	alkali

A WRONG IDEA MANY PEOPLE HAVE

~~Adding more alkali always makes an acid safer.~~

Why it feels right: An alkali cancels an acid. So it seems that more alkali must cancel more.

The test that breaks it: Add baking soda to cabbage indicator in vinegar, a pinch at a time. The colour goes pink, then purple, then blue. After purple, more soda only leaves an alkali.

What is true: Neutralisation needs the right amount. Too little leaves some acid. Too much leaves an alkali. This is why farmers test their soil.

KEY WORDS

neutralisation
a reaction where an acid and an alkali cancel each other out.

salt
a substance made when an acid reacts with an alkali.

antacid
a weak alkali that cancels some stomach acid.

lime
an alkali that farmers add to sour soil.

BACK TO YOUR GUESS

The answer is C: The tablet is a weak alkali. It cancels some of the extra acid.

An antacid is a weak alkali. It cancels, or neutralises, some of the extra acid. Farmers use lime for the same job in soil.

CHECK YOURSELF

Try each one before you look. A wrong answer tells you where to go next.

1. What happens in neutralisation?

    A An acid and an alkali join to make a stronger acid.

    B An acid and an alkali cancel each other out, and make a salt and water.

    C The acid vanishes and nothing new is made.

    Answer at the back of the book.

2. Which word equation shows neutralisation?

    A acid + alkali → salt + water

    B acid + alkali → acid + alkali

    C salt + water → acid + alkali

    Answer at the back of the book.

3. How does an antacid ease indigestion?

    A It is a weak alkali that cancels some of the extra stomach acid.

    B It adds more acid, so the stomach stops hurting.

    C It makes the stomach very strongly alkali.

    Answer at the back of the book.

4. Why must an antacid be a weak alkali and not a strong one?

    A A weak alkali neutralises acid faster.

    B A strong alkali has a lower pH.

    C A strong alkali would burn the inside of the body.

    Answer at the back of the book.

5. Why do farmers add lime to sour soil?

    A Lime is an alkali. It cancels some of the acid and raises the soil pH.

    B Lime is an acid that makes the soil richer.

    C Lime makes the soil more acid.

    Answer at the back of the book.

6. Cabbage indicator in vinegar is pink. You add baking soda until it turns blue. What does the blue show?

   A There is more acid than before.

   B The liquid has just become neutral.

   C There is too much baking soda, so the liquid is now an alkali.

   Answer at the back of the book.

7. **From an earlier chapter**

   What colour does red cabbage indicator turn in vinegar?

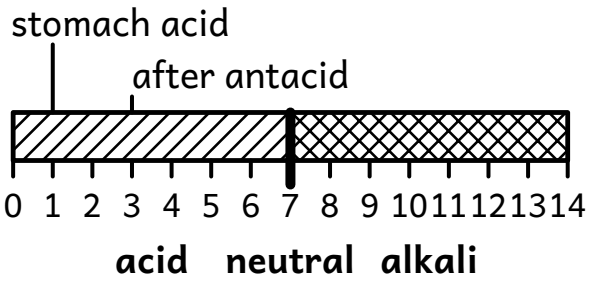
   A Blue, because vinegar is an alkali.

   B Pink, because vinegar is an acid.

   C Purple, because vinegar is neutral.

   Answer at the back of the book.

8. Stomach acid has a pH of 1. After an antacid, the pH is 3. By how much did the pH rise?



   Answer at the back of the book.

9. A field has a soil pH of 5. After lime is added, the pH goes up by 1. What is the new pH?

   Answer at the back of the book.

KEEP IT

Copy this into your exercise book.

Acid + alkali → salt + water. This is neutralisation. An antacid eases stomach acid. Lime raises the pH of sour soil. Too much alkali leaves an alkali.

Draw: Draw three cups of cabbage indicator: pink for acid, purple for neutral, and blue for too much alkali.

Key words, A to Z

Every key word in this book, what it means, and the chapter that teaches it.

acid
a substance with a pH below 7. Many taste sour. S3.6.7

alkali
a substance with a pH above 7. Soap is one. S3.6.7

antacid
a weak alkali that cancels some stomach acid. S3.6.8

atoms
the smallest bits that most materials are made of. S3.6.1

chemical change
a change where atoms join in new ways and a new substance is made. S3.6.4

chromatography
a way to separate coloured substances using paper and water. S3.6.3

compound
a substance with atoms of two or more elements joined together. S3.6.1

element
a substance with only one kind of atom. S3.6.1

evaporate
turn from a liquid into a gas. S3.6.3

filter
paper with tiny holes that holds back solid pieces. S3.6.3

filtrate
the liquid that passes through the filter. S3.6.3

fire triangle
the three things a fire needs: fuel, oxygen and heat. S3.6.6

fuel
something that burns, such as wood, wax or gas. S3.6.6

indicator
a dye that changes colour in acids and alkalis. S3.6.7

lime
an alkali that farmers add to sour soil. S3.6.8

mixture
two or more substances together that are not joined. S3.6.2

neutral
neither an acid nor an alkali, with a pH of 7. S3.6.7

neutralisation
a reaction where an acid and an alkali cancel each other out. S3.6.8

pH scale
a scale from 0 to 14 for how acid or alkali something is. S3.6.7

physical change
a change where no new substance is made. S3.6.4

products
the new substances that are made. S3.6.5

pure substance
a substance that is only one thing, an element or a compound. S3.6.2

reactants
the substances that react. S3.6.5

reaction
a chemical change, where substances join in new ways. S3.6.5

residue
the solid left on the filter paper. S3.6.3

reversible
able to be turned back. S3.6.4

salt
a substance made when an acid reacts with an alkali. S3.6.8

sieve
a mesh of holes that lets small pieces fall through. S3.6.3

smothers
covers a fire so no air reaches it. S3.6.6

symbol
one or two letters that stand for an element. S3.6.1

word equation
a way to write a reaction in words, with an arrow. S3.6.5

Answers

S3.6.1. Elements and compounds

1. **The oxygen box. It has only one kind of atom.**

   The pairs in the oxygen box are joined, but every atom is oxygen. So it is an element. Water has two kinds of atom, hydrogen and oxygen.

   - **If you chose B:** Atoms of two kinds joined together make a compound, not an element. An element has one kind of atom only. Go to S3.6.1.
   - **If you chose C:** Water has hydrogen atoms too. An element has only one kind of atom, so water is not an element. Go to S3.6.1.

2. **oxygen, carbon, iron and gold**

   Oxygen, carbon, iron and gold each have one kind of atom. Water and carbon dioxide each have two kinds, so they are compounds.

   - **If you chose A:** Water is a compound. It has hydrogen atoms and oxygen atoms joined together. Go to S3.6.1.
   - **If you chose C:** Carbon dioxide is a compound. It has carbon atoms and oxygen atoms joined together. Go to S3.6.1.

3. **3 atoms**

   One oxygen atom and two hydrogen atoms are joined. 1 + 2 = 3.

   - **If you chose A:** The 2 counts only the hydrogen. Count the oxygen atom too. Go to S3.6.1.
   - **If you chose C:** One group of water is a single group, but it holds more than one atom. Count the H and the O. Go to S3.6.1.

4. **Its hydrogen and oxygen atoms are joined together in groups.**

   A compound has atoms of two or more elements joined together. In water, each group is one oxygen atom joined to two hydrogen atoms.

   - **If you chose A:** In water the atoms are joined. They are not separate gases side by side. Go to S3.6.1.
   - **If you chose B:** One kind of atom makes an element. Water has hydrogen atoms and oxygen atoms. Go to S3.6.1.

5. **A compound can behave very differently from the elements in it.**

   When atoms join, they make a new substance with its own properties. Water is nothing like hydrogen or oxygen.

   - **If you chose A:** If it did, it would feed a fire. The atoms are joined, so a new substance has formed. Go to S3.6.1.
   - **If you chose B:** One substance can still be a compound. Water has two kinds of atom, hydrogen and oxygen, so it is a compound. Go to S3.6.1.

6. **10 hydrogen atoms**

   Each group has 2 hydrogen atoms. 5 × 2 = 10.

S3.6.2. Pure substances and mixtures

1. **oxygen gas**

   Oxygen gas has only one kind of atom, so it is one substance. Air and sea water each have several substances in them.

   - **If you chose A:** Air looks clear and clean, but it holds nitrogen, oxygen and other gases side by side. That is a mixture. Go to S3.6.2.
   - **If you chose B:** Sea water is clear, but it has salt dissolved in the water. That is a mixture. Go to S3.6.2.

2. **Box B. It has two substances, water and salt, that are not joined together.**

   Box B holds water and salt side by side. Box A holds only water groups, all alike, so it is pure.

   - **If you chose A:** Joined atoms in groups that are all the same make a pure compound. A mixture has different groups, not joined. Go to S3.6.1.
   - **If you chose C:** Box A has only water. A mixture needs two or more substances. Go to S3.6.2.

3. **It has different gases, such as nitrogen and oxygen, side by side and not joined.**

   The gases in air are mixed but not joined, and each keeps its own properties. That is what makes air a mixture.

   - **If you chose A:** Oxygen is only about one fifth of the air. Most of it is nitrogen. Go to S3.6.2.
   - **If you chose C:** The gases in air are not joined to each other. Each gas keeps its own properties, so air is a mixture. Go to S3.6.2.

4. **It has water and dissolved salt together, and the salt is not joined to the water.**

   Two substances, water and salt, are mixed together. Neither is joined to the other, so it is a mixture.

   - **If you chose A:** Dissolved salt is far too small to see. Clear does not mean pure. Go to S3.6.2.
   - **If you chose B:** The salt is not joined to the water. It is spread through it, and you can get it back. Go to S3.5.7.

5. **Air is a mixture, because each gas keeps its own properties.**

   The gases in air are side by side and not joined. So each still behaves as it does on its own. That is what a mixture is.

   - **If you chose A:** The gases in air are not joined to each other. If they were joined, the oxygen would not behave like oxygen any more. Go to S3.6.1.
   - **If you chose C:** A pure substance is only one thing. Air holds several gases, so it is a mixture, even though we need only the oxygen. Go to S3.6.2.

6. **8 pairs**

   There are 10 pairs in all, and 2 are oxygen. 10 − 2 = 8. These are nitrogen pairs.

7. **water**

   Water has hydrogen and oxygen atoms joined together, so it is a compound. Gold and oxygen gas are elements.

   - **If you chose B:** Gold has only one kind of atom, so it is an element. Go to S3.6.1.
   - **If you chose C:** Oxygen atoms are joined in pairs, but all are oxygen. One kind of atom is an element. Go to S3.6.1.

8. **42 cm^3**

   200 cm^3 is 2 lots of 100 cm^3. 2 × 21 = 42.

S3.6.3. Separating mixtures

1. **Sieve them. The sand falls through and the stones stay.**

   The sand grains are smaller than the holes, and the stones are bigger. Size is the difference a sieve uses.

   - **If you chose A:** Neither sand nor stones turn to gas in the sun. Evaporating separates a dissolved solid from its liquid. Go to S3.6.3.
   - **If you chose B:** Sand grains are too big to pass through filter paper, so it blocks. A sieve is the right tool for solids of different size. Go to S2.4.7.

2. **The mud stays on the paper as the residue, and clear water passes through as the filtrate.**

   The mud does not dissolve, and its pieces are bigger than the holes in the paper. The water is not held back.

   - **If you chose A:** The holes in filter paper are too small for mud to pass through. It stays on the paper. Go to S2.4.7.
   - **If you chose B:** Water is made of tiny particles and passes through the holes easily. The mud is too big. Go to S3.6.3.

3. **Leave it in a dish in the sun until the water has gone. The salt is left behind.**

   The water evaporates into the air and the salt does not. So the salt is left in the dish.

   - **If you chose B:** Dissolved salt is far too small to be held back. It passes through the paper with the water. Go to S3.5.7.
   - **If you chose C:** The salt has dissolved, so its particles are spread through the water. They pass through the holes of a sieve with ease. Go to S3.5.7.

4. **White salt.**

   Water particles leave the dish as vapour. The salt does not evaporate, so it stays.

   - **If you chose A:** Water evaporates in the sun. Salt does not. It stays in the dish. Go to S2.4.4.
   - **If you chose C:** The question says the dish is dry. The water has all gone into the air as vapour. Go to S2.4.4.

5. **The black ink is a mixture of different coloured substances.**

   Each coloured substance in the ink travels a different distance. So they are separated. That shows the ink was a mixture.

   - **If you chose B:** The water only carried the colours. They were in the ink before the water reached it. Go to S3.6.3.
   - **If you chose C:** A pure substance would stay as one spot. Splitting into several colours shows the ink is a mixture. Go to S3.6.2.

6. **3 cm**

   The yellow band is at 4 on the ruler and the blue band is at 1. 4 − 1 = 3.

   - **If you chose B:** That is how far the yellow went from the start line. The question asks how much farther it went than the blue. Go to S3.6.3.
   - **If you chose C:** That is yellow plus blue added together. To compare two distances, take the smaller from the larger. Go to S3.6.3.

7. **It has water and dissolved salt that are not joined, and the salt can be got back.**

   Water and salt keep their own properties. Because they are not joined, we can separate them by evaporating.

   - **If you chose A:** The salt is not joined to the water. It is spread through it, and you can get it back by evaporating. Go to S3.6.2.
   - **If you chose C:** Clear does not mean pure. The salt is dissolved, so it cannot be seen. Go to S3.6.2.

8. **15 g**

   The salt is the extra mass. 55 − 40 = 15.

S3.6.4. Physical and chemical changes

1. **Ice melts into water.**

   Ice and water are the same substance. Melting only changes how the particles are arranged, and freezing turns it back.

   - **If you chose A:** Burning makes new substances, such as carbon dioxide and water vapour. That is a chemical change. Go to S3.6.4.
   - **If you chose B:** Cooking changes the substances in the egg for good, and you cannot turn it back. That is a chemical change. Go to S3.6.4.

2. **Wood burns to ash and gases.**

   New substances are made, with new properties, and you cannot turn them back into wood.

   - **If you chose B:** The sugar is still there, spread through the tea. You can get it back by evaporating. That is physical. Go to S3.5.7.
   - **If you chose C:** Steam is still water. This is a change of state, which is physical. Go to S3.5.3.

3. **No. The bubbles are water vapour, so no new substance is made.**

   Boiling is a change of state. Water vapour is water as a gas. A sign alone is not proof of a chemical change.

   - **If you chose A:** A gas is only a clue. Here the gas is water vapour, which is still water. It is not a new substance. Go to S3.6.4.
   - **If you chose C:** Heat also melts ice and boils water, which are physical changes. Heat alone is not proof. Go to S3.6.4.

4. **A new gas is made.**

   The fizz is carbon dioxide gas, a new substance. A new gas is one of the signs of a chemical change.

   - **If you chose A:** The mixture does not change colour. What you see is bubbles of gas. Go to S3.6.4.
   - **If you chose B:** No solid forms. The fizz is a gas leaving the mixture. Go to S3.6.4.

5. **A new substance is made.**

   The signs are clues. The real test is whether a new substance with new properties has been made.

   - **If you chose B:** Mixing paint changes colour with no new substance. Colour is only a clue. Go to S3.6.4.
   - **If you chose C:** An electric bulb gets hot, and so does a pan on a stove, with no new substance. Heat is only a clue. Go to S3.6.4.

6. **The same atoms join in new groups, and a new substance forms.**

   The atoms are only rearranged. They join in new groups, and the new groups are a new substance, water.

   - **If you chose A:** Atoms are not lost in a chemical change. There are 6 atoms before and 6 after. Go to S3.6.4.
   - **If you chose B:** An atom stays the same kind. The water groups still hold hydrogen atoms and oxygen atoms. Go to S3.6.1.

7. **6 atoms**

   2 groups with 3 atoms each. 2 × 3 = 6. This is the same number of atoms as before.

8. **Evaporate the water in the sun.**

   The water evaporates and the salt does not, so the salt is left in the dish.

   - **If you chose A:** Dissolved salt passes through filter paper with the water. Go to S3.6.3.
   - **If you chose B:** A sieve separates pieces of different size. Dissolved salt is spread through the water and passes through. Go to S3.6.3.

S3.6.5. Rusting and other reactions

1. **Jar A, with air and water.**

   Only jar A has both air and water. Jar B has no air, and jar C has no water.

   - **If you chose A:** The oil keeps air out. Iron has water but no oxygen, so it does not rust. Go to S3.6.5.
   - **If you chose B:** The jar has air but no water. Iron needs both to rust. Go to S3.6.5.

2. **The oil kept air out, so the iron had water but no oxygen.**

   Boiled water has lost most of its air, and the oil stops new air getting in. Iron needs oxygen to rust.

   - **If you chose A:** Oil is only a cover. It stops air reaching the iron. It does not clean it. Go to S3.6.5.
   - **If you chose B:** The jar was full of water. It was the air that was missing. Go to S3.6.5.

3. **iron + oxygen + water → hydrated iron oxide**

   Iron, oxygen and water react, so they come before the arrow. The new substance, hydrated iron oxide, comes after it.

   - **If you chose A:** The arrow is backwards. The reactants come before the arrow, and the product comes after it. Go to S3.6.5.
   - **If you chose C:** Iron cannot be on both sides if it changes. It joins with oxygen and water to make a new substance. Go to S3.6.5.

4. **The reactants, which are the substances that react.**

   Read the equation as: reactants make products. The reactants go before the arrow.

   - **If you chose B:** The products come after the arrow. The arrow means makes. Go to S3.6.5.
   - **If you chose C:** The products come after the arrow. The substances that react come first, and they are the reactants. Go to S3.6.5.

5. **carbon dioxide, water and sodium acetate**

   Baking soda and vinegar react to make carbon dioxide, water and sodium acetate. The fizz is the gas.

   - **If you chose A:** These are the reactants. They go before the arrow. The products are the new substances. Go to S3.6.5.
   - **If you chose B:** The gas is not the only new substance. Water and a salt, sodium acetate, are made too. Go to S3.6.5.

6. **2 g**

   The extra mass came from outside. 22 − 20 = 2.

7. **A chemical change, because a new substance forms.**

   Rust has new properties. It is crumbly and brown, and it is not iron. A new substance means a chemical change.

   - **If you chose A:** The iron has joined with oxygen and water to make rust. Rust is a new substance, so this is chemical. Go to S3.6.4.
   - **If you chose C:** Speed does not decide. A slow change can still make a new substance. Go to S3.6.4.

S3.6.6. Burning and fire safety

1. **fuel, oxygen and heat**

   These are the three sides of the fire triangle. A fire needs all three at once.

   - **If you chose B:** Carbon dioxide is made when a fuel burns. It does not feed the fire. The fire needs oxygen. Go to S3.6.6.
   - **If you chose C:** Water takes heat away, so it puts fires out. A fire needs heat. Go to S3.6.6.

2. **oxygen**

   The lid covers the fire, so no air reaches it. With no oxygen, the fire goes out.

   - **If you chose A:** The oil is still there under the lid. The lid only covers it so air cannot reach it. Go to S3.6.6.
   - **If you chose C:** A lid does not cool the oil. It smothers the fire by keeping the air out. Go to S3.6.6.

3. **It takes away heat by cooling the wood.**

   Water soaks up heat. If the wood cools enough, one side of the triangle is gone.

   - **If you chose A:** The wood is still there when the water goes on. The water cools it. Go to S3.6.6.
   - **If you chose B:** Water does not take oxygen away from a wood fire. It cools the wood below the heat the fire needs. Go to S3.6.6.

4. **The water sinks, turns to steam and throws burning oil about.**

   Oil floats on water. The water boils under the burning oil and splashes it out of the pan.

   - **If you chose B:** Water and oil do not mix. The water sinks under the oil and boils, which makes things worse. Go to S3.6.6.
   - **If you chose C:** Water does not smother oil. It sinks and boils. A lid takes away the oxygen. Go to S3.6.6.

5. **candle wax + oxygen → carbon dioxide + water**

   Wax joins with oxygen. The carbon makes carbon dioxide and the hydrogen makes water.

   - **If you chose A:** Burning needs oxygen, so oxygen must be a reactant. It goes before the arrow. Go to S3.6.5.
   - **If you chose B:** Carbon dioxide is made when wax burns. It is a product, after the arrow. Go to S3.6.5.

6. **There is only a little air under the jar, and the oxygen runs low.**

   The flame uses the oxygen in the jar. When too little is left, the fire goes out.

   - **If you chose A:** A jar does not cool the flame quickly. The flame goes out because too little oxygen is left. Go to S3.6.6.
   - **If you chose C:** The wax is still there under the jar. It is the oxygen that runs low. Go to S3.6.6.

7. **Turn off the gas.**

   The gas is the fuel. With no more gas, there is nothing to burn.

   - **If you chose B:** Water takes away heat, and it may not be safe. Turning off the gas takes away the fuel. Go to S3.6.6.
   - **If you chose C:** A lid takes away oxygen. It does not stop the fuel from coming. Go to S3.6.6.

8. **6 g**

   The wax that was lost became carbon dioxide and water vapour. 20 − 14 = 6.

9. **8 seconds**

   The big jar holds more air. 14 − 6 = 8.

10. **New substances are made, such as carbon dioxide and ash.**

    Wood burns with oxygen into new substances. They are not wood, and they cannot be turned back.

    - **If you chose B:** Cutting wood also changes its shape, with no new substance. The test is a new substance. Go to S3.6.4.
    - **If you chose C:** An electric bulb gets hot too. Heat is a clue, but only a new substance is proof. Go to S3.6.4.

S3.6.7. Acids and alkalis

1. **An acid**

   Red cabbage is red or pink in an acid. It is purple in a neutral liquid, and blue or green in an alkali.

   - **If you chose A:** Cabbage indicator is purple in a neutral liquid. Pink shows an acid. Go to S3.6.7.
   - **If you chose B:** In an alkali, cabbage indicator turns blue or green. Pink shows an acid. Go to S3.6.7.

2. **lemon juice and vinegar**

   Lemon juice and vinegar are sour, and they turn cabbage indicator pink. Soap and baking soda are alkalis.

   - **If you chose A:** Soap is an alkali. It feels slippery and turns cabbage indicator green. Go to S3.6.7.
   - **If you chose C:** Both of these are alkalis, not acids. Go to S3.6.7.

3. **soap in water**

   Soap turns cabbage indicator green and turmeric red-brown. Both show an alkali.

   - **If you chose B:** Vinegar is sour. It is an acid, and it turns cabbage indicator pink. Go to S3.6.7.
   - **If you chose C:** Pure water is neutral. It is neither an acid nor an alkali. Go to S3.6.7.

4. **4 steps**

   The stem for vinegar stands on the 3. Neutral is 7. 7 − 3 = 4.

   - **If you chose B:** That is the pH of vinegar, its place on the scale. The question asks how far it is below 7. Go to S3.6.7.
   - **If you chose C:** That is the distance from vinegar up to soap, which is on the other side of 7. The question asks only how far vinegar is below 7. Go to S3.6.7.

5. **stomach acid**

   The lower the pH below 7, the stronger the acid. Stomach acid has the lowest number in the picture.

   - **If you chose A:** Soap has the highest number, but a high number means a strong alkali, not a strong acid. Go to S3.6.7.
   - **If you chose B:** Pure water is at 7, the middle. It is neutral. Go to S3.6.7.

6. **Tear the leaves and soak them in hot water that a grown up has poured.**

   The purple dye dissolves in hot water. The water turns purple, and you can pour it off the leaves.

   - **If you chose A:** The dye dissolves in water, not in oil. Oil would not carry it out of the leaves. Go to S3.6.7.
   - **If you chose C:** Vinegar is an acid, so it would turn the dye pink from the start. Then it could not show you anything. Go to S3.6.7.

7. **It turns red-brown. The soap is an alkali.**

   Turmeric is yellow in an acid or neutral liquid and red-brown in an alkali. So red-brown shows an alkali.

   - **If you chose B:** Pink is the colour of red cabbage in an acid. Turmeric turns red-brown in an alkali. Go to S3.6.7.
   - **If you chose C:** Turmeric stays yellow in acids and neutral liquids. Soap is an alkali, so it turns red-brown. Go to S3.6.7.

8. **oxygen and heat**

   A fire needs fuel, oxygen and heat. Take away any one and it goes out.

   - **If you chose A:** Water takes heat away, so it puts fires out. A fire needs heat. Go to S3.6.6.
   - **If you chose B:** Carbon dioxide is made when a fuel burns. A fire needs oxygen. Go to S3.6.6.

9. **5 steps**

   Count the steps from 2 up to 7. 7 − 2 = 5.

S3.6.8. Neutralisation

1. **An acid and an alkali cancel each other out, and make a salt and water.**

   The acid and the alkali use each other up. The new substances are a salt and water.

   - **If you chose A:** They work against each other. The result is closer to neutral, not a stronger acid. Go to S3.6.8.
   - **If you chose C:** It is a chemical change, so new substances are made. They are a salt and water. Go to S3.6.8.

2. **acid + alkali → salt + water**

   The acid and the alkali are the reactants. They make a salt and water.

   - **If you chose B:** Nothing changes in this one. A reaction makes new substances. Go to S3.6.8.
   - **If you chose C:** The arrow is backwards. The acid and alkali are the reactants, so they come before the arrow. Go to S3.6.8.

3. **It is a weak alkali that cancels some of the extra stomach acid.**

   The stomach has too much acid. The antacid is an alkali that reacts with some of it, so the stomach is less sour.

   - **If you chose B:** More acid would make it worse. An antacid cancels acid. Go to S3.6.8.
   - **If you chose C:** It is a weak alkali, and it only raises the pH a little. A very strong alkali would burn. Go to S3.6.8.

4. **A strong alkali would burn the inside of the body.**

   Strong alkalis burn, as strong acids do. A weak alkali is gentle enough to be safe.

   - **If you chose A:** Strength does not make it faster to neutralise. Strong alkalis burn, so a weak one is used. Go to S3.6.7.
   - **If you chose B:** A strong alkali has a higher pH, such as 13 or 14. That is why it burns. Go to S3.6.7.

5. **Lime is an alkali. It cancels some of the acid and raises the soil pH.**

   Sour soil is acid. Lime is an alkali, so it neutralises some of the acid and brings the pH closer to 7.

   - **If you chose B:** Lime is an alkali. Sour soil is already too acid. Go to S3.6.8.
   - **If you chose C:** Lime is an alkali. Sour soil is already too acid, and lime cancels some of that acid. Go to S3.6.8.

6. **There is too much baking soda, so the liquid is now an alkali.**

   The vinegar was cancelled first, at purple. The extra baking soda left an alkali, so the colour went blue.

   - **If you chose A:** Blue shows an alkali. Cabbage indicator turns pink in an acid. Go to S3.6.7.
   - **If you chose B:** Neutral is purple. Blue means the liquid has gone past neutral, into an alkali. Go to S3.6.7.

7. **Pink, because vinegar is an acid.**

   Red cabbage is pink in an acid. It is purple in a neutral liquid and blue or green in an alkali.

   - **If you chose A:** Vinegar is sour. It is an acid, and cabbage turns pink in an acid. Go to S3.6.7.
   - **If you chose C:** Purple is the colour in a neutral liquid, such as pure water. Vinegar is an acid. Go to S3.6.7.

8. **2**

   The pH went from 1 up to 3. 3 − 1 = 2.

9. **6**

   Lime raises the pH. 5 + 1 = 6.

About this book

For learners who can read a page alone and use the four operations. In many schools this fits children of about 11 to 13, and older learners can use it too. Every activity uses things from a kitchen: water, salt, jars, nails, paper, vinegar, baking soda and red cabbage. Hot water for the cabbage, and any candle, need a grown up. Bleach, toilet cleaner and every other cleaning product stay out of the activities, and nothing is tasted. A learner can work alone: every exercise has its answer and the reason for it.

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