Science 5–6

Chapter 7 — Chemical sciences

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Contents

Particles, states and mixtures

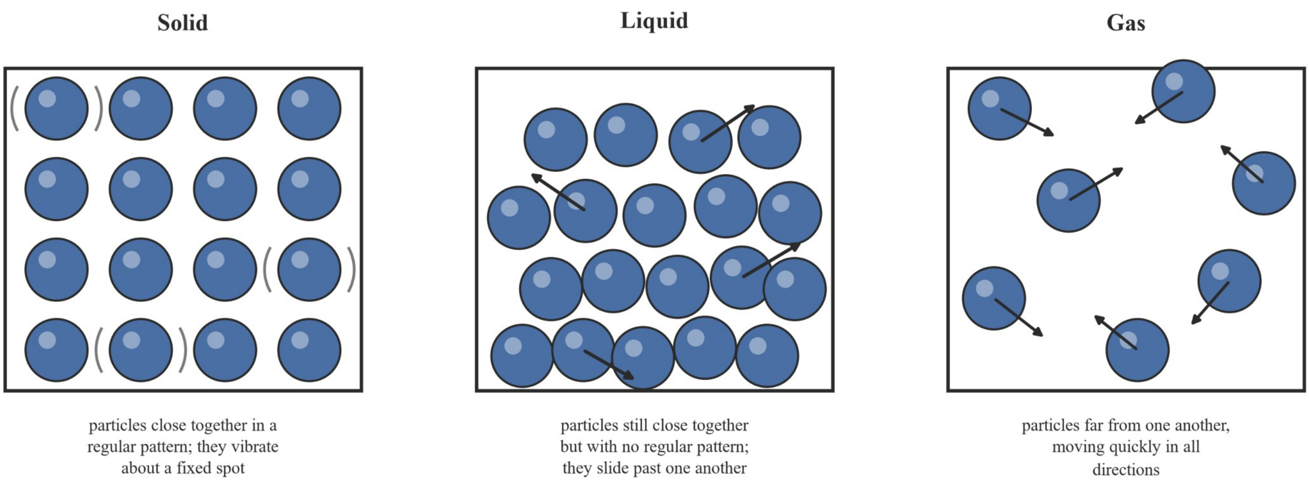
Words to know matter · particle · solid · liquid · gas · volume · mass · compress · compressibility · mixture · solution · solute · solvent · dissolve · separate

Everything you can hold, pour or smell is made of tiny pieces of matter called **particles**. A particle is a piece of matter that is far too small to see on its own. **Matter** is anything that takes up space and has mass: a brick, a cup of water and the air in a balloon are all matter. Even one grain of sand is made of millions of particles. In this section we build a particle model of matter and use it to explain what we can observe.

Theory

The three states of matter

Matter comes in three states: **solid**, **liquid** and **gas**. The particle model says the three states differ in how their particles are arranged and how the particles move.



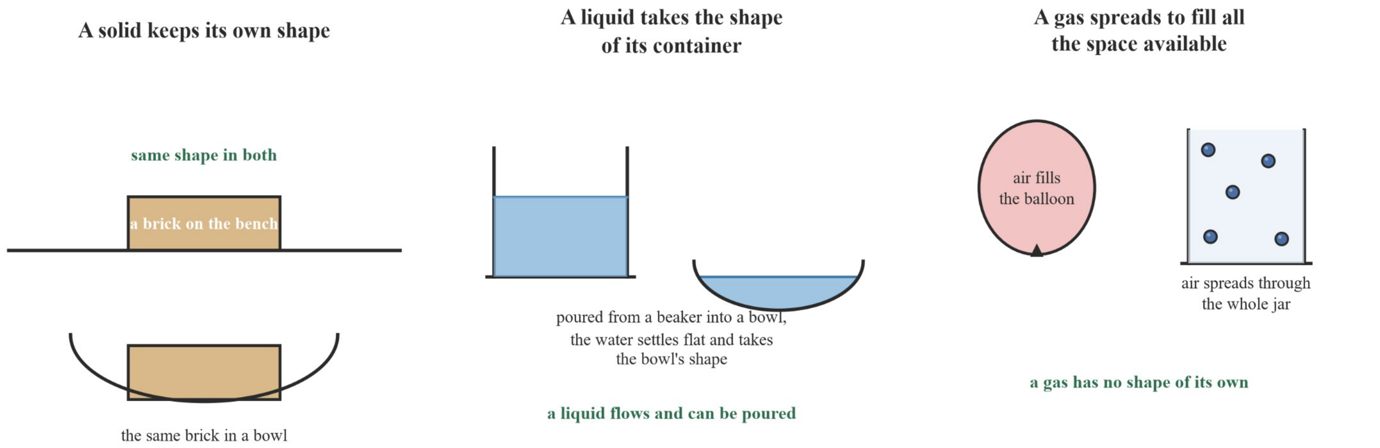
Particle diagrams of a solid, a liquid and a gas: solid particles sit close together in a regular pattern and vibrate about a fixed spot; liquid particles sit close together with no regular pattern and slide past one another; gas particles sit far from one another and move quickly in all directions.

- In a **solid**, the particles are close together in a regular pattern. Each particle vibrates about a fixed spot but cannot leave it.
- In a **liquid**, the particles are still close together, but there is no regular pattern. The particles can slide past one another.
- In a **gas**, the particles are far from one another and move quickly in all directions, bumping into each other and into the walls of their container.

A **container** is anything that holds matter, such as a bottle, a bowl or a balloon. The space a sample of matter takes up is its **volume**, measured in litres (L) or millilitres (mL). The amount of matter in something is its **mass**, measured in grams (g) or kilograms (kg).

The model explains what we observe

The particle model is useful because it explains the observable **properties** of each state — the things we can see and test. A **property** is a feature of a substance, such as its shape, its hardness or how well it flows.



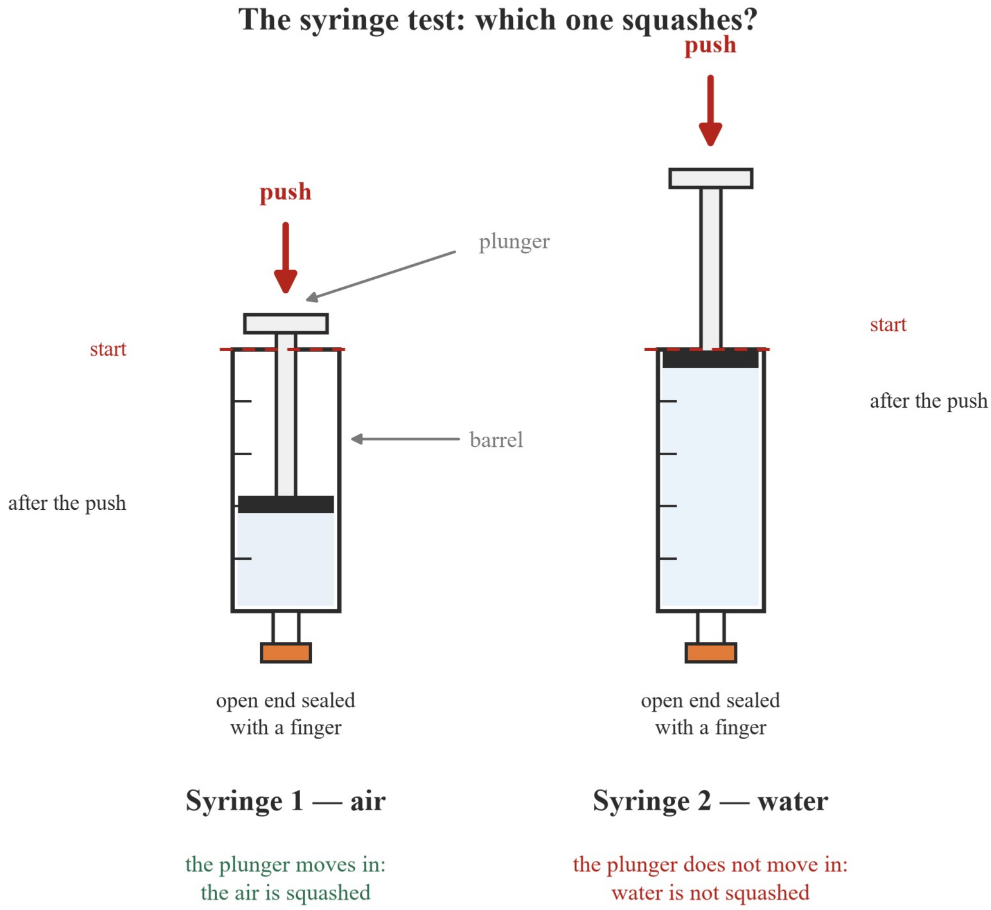
A brick keeps the same shape on a bench and in a bowl; water poured from a beaker into a bowl takes the shape of the bowl; air fills a balloon and spreads through a whole jar.

- A **solid keeps its own shape.** Its particles are locked in a regular pattern and can only vibrate, so the solid holds its shape no matter where it is put.
- A **liquid takes the shape of its container.** Its particles can slide past one another, so a liquid flows, can be poured, and settles to fill the bottom of its container.
- A **gas spreads to fill all the space available.** Its particles fly about in all directions, so a gas has no shape of its own and fills its whole container.

Squashing matter: gases compress

To **compress** something is to squash it into less space. How easy a substance is to squash is called its **compressibility**.

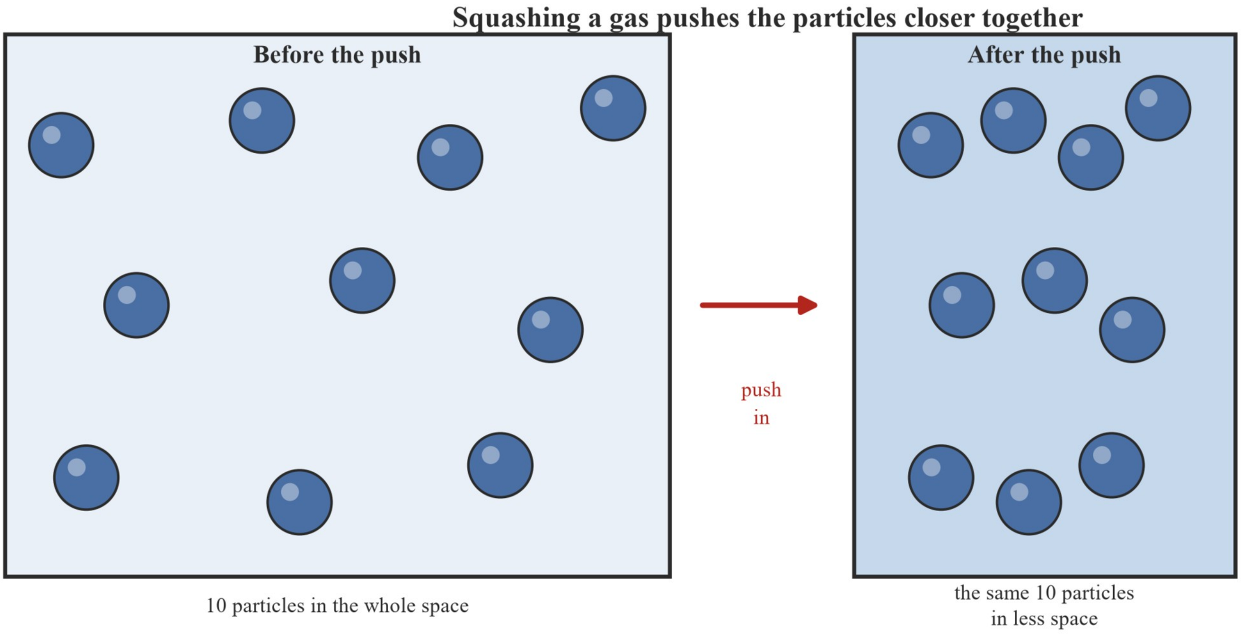
The syringe test compares the compressibility of a gas and a liquid. Two syringes of the same size are used. One holds air, one holds water. The open end of each is sealed with a finger, and the plunger is pushed.



Two sealed syringes side by side: on the air syringe the plunger moves in when pushed, and on the water syringe the plunger does not move in.

The plunger of the air syringe moves in: the air is squashed into less space. The plunger of the water syringe does not move in: the water is not squashed. Gases have a high compressibility; liquids (and solids) are very hard to squash.

The particle model explains why. In a gas there is a lot of empty space between the particles, so a push can bring the particles closer together. In a liquid the particles already touch, so there is no spare space to squeeze out.

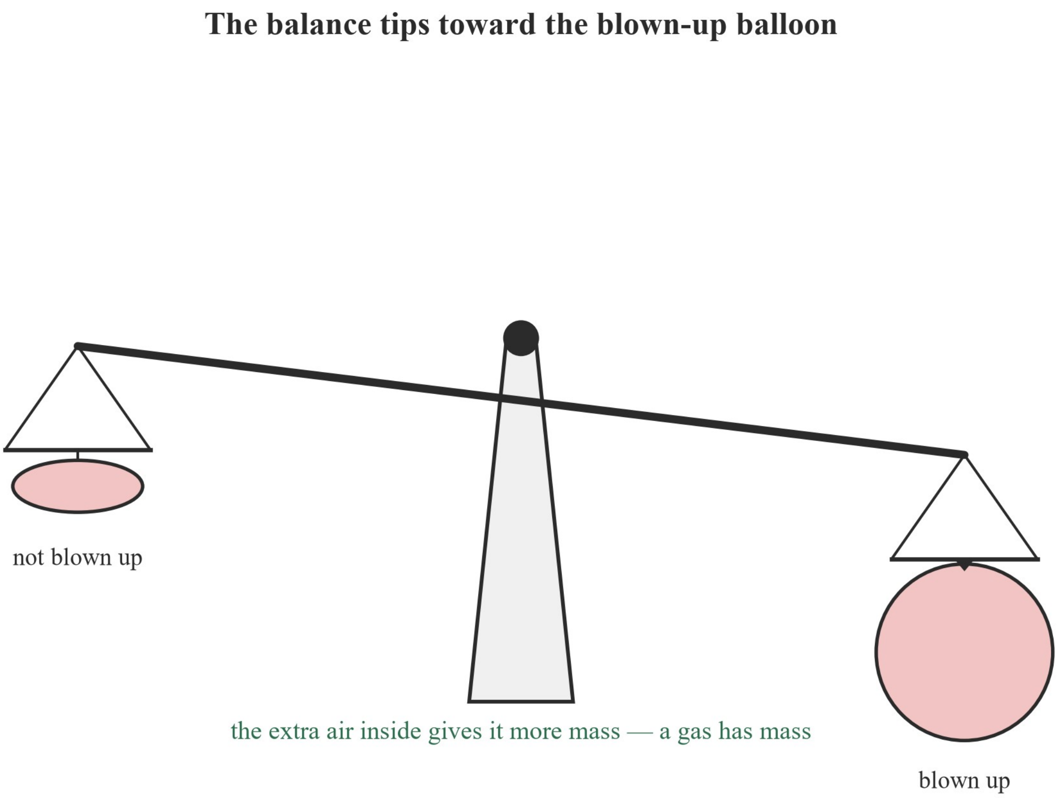


Particle view of a gas before and after a push: the same ten particles are pushed closer together into less space, and the shaded colour deepens.

Notice what does **not** change: the particles themselves stay the same size. Only the spaces between them shrink. This is also why a coloured gas looks darker when it is squashed: the same coloured particles are crowded into less space, so the colour is deeper.

Gases have mass

Air feels like "nothing", but air is matter. A simple test shows it. Two balloons that are not blown up hang on the pans of a balance, and the balance is level. One balloon is then blown up and hung back on its pan.

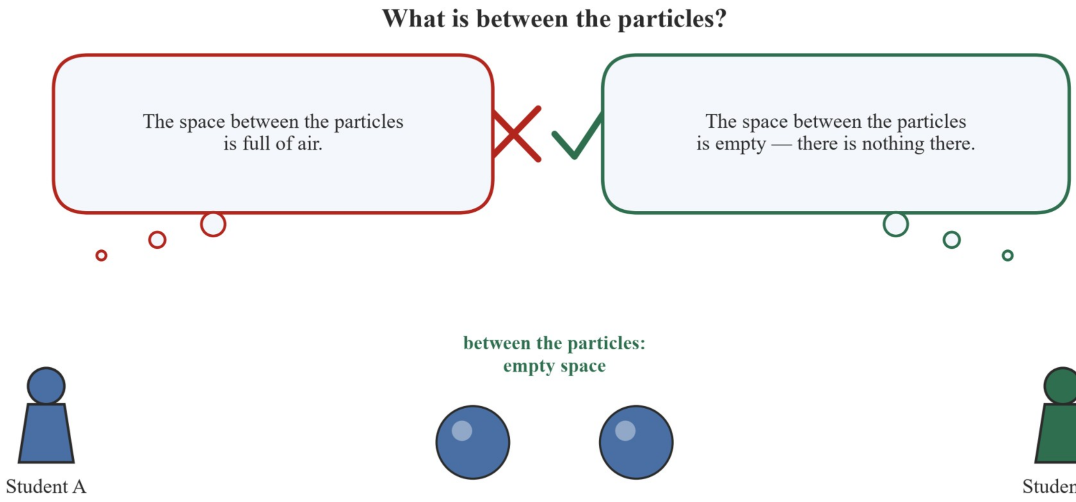


A balance with a flat balloon on one pan and a blown-up balloon on the other: the balance tips toward the blown-up balloon.

The balance tips toward the blown-up balloon. The extra air inside the balloon gives that side more mass. So a gas has mass — and, like all matter, a gas takes up space. (Blowing up a balloon also shows that a gas can be compressed: your lungs push a lot of air into a small space.)

What is between the particles?

When we draw particles with spaces between them, a fair question is: *what is in the spaces?* A common guess is "air", but that cannot be right — air is itself made of particles, so "air between the particles" would need more particles in between, and so on. The honest answer of the model is: **nothing**. The space between the particles of a gas is empty space. There is no air there and no tiny bits of matter there. There is simply nothing there.

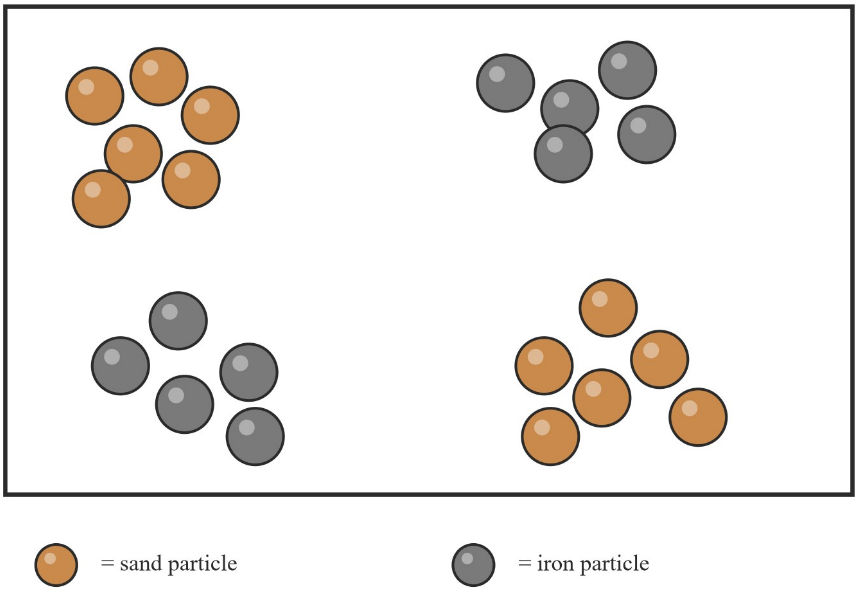


Two students share their ideas about the space between particles: the idea "full of air" is marked wrong, and the idea "empty, there is nothing there" is marked right.

Mixtures

A **mixture** forms when two or more different substances are combined. In a mixture, each substance keeps its own properties — mixing does not make a new substance. A tray holding beads, rice, pasta, buttons and coins is a mixture you can see and sort. Sand mixed with iron filings is a mixture too: the sand stays sandy and the iron stays iron.

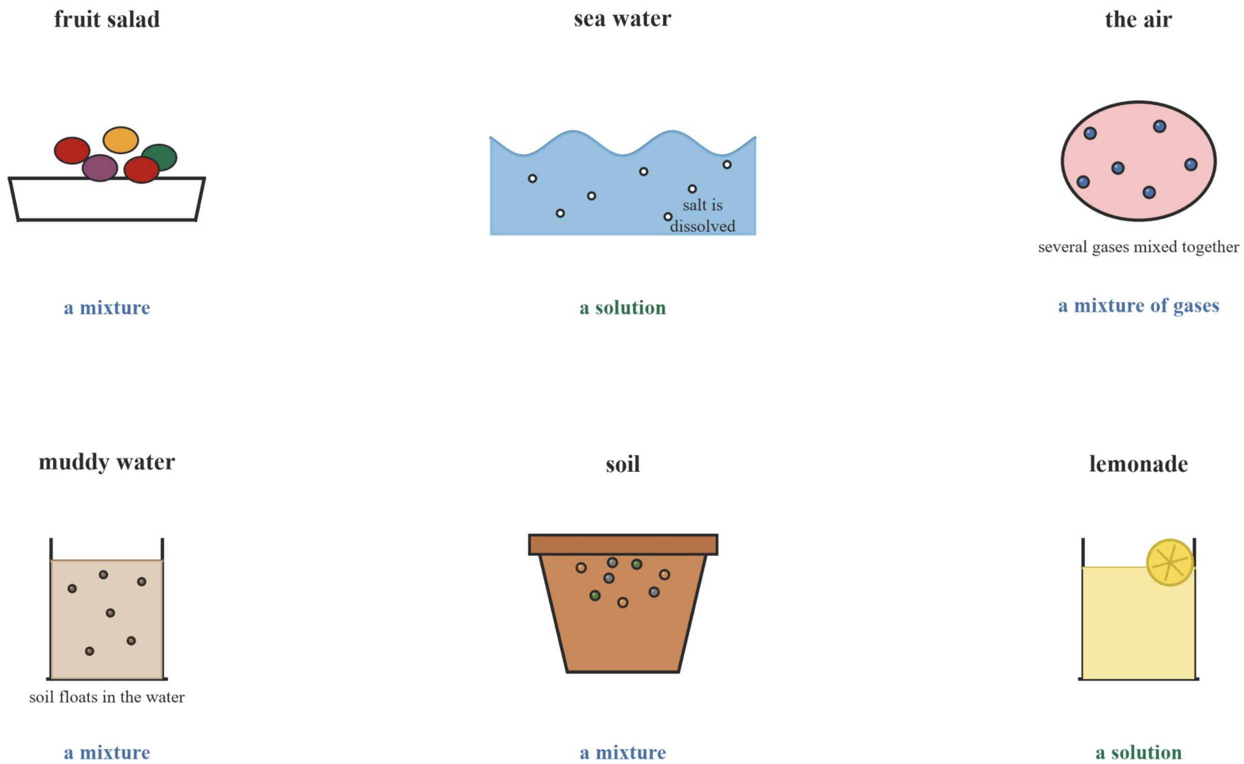
A mixture of sand and iron filings — particle model



Particle model of a mixture of sand and iron filings: clumps of tan sand particles sit beside clumps of grey iron particles, each kind keeping its own properties.

Mixtures are all around us in everyday life: fruit salad, soil, muddy water and the air itself (a mixture of several gases) are all mixtures.

Mixtures and solutions in everyday life

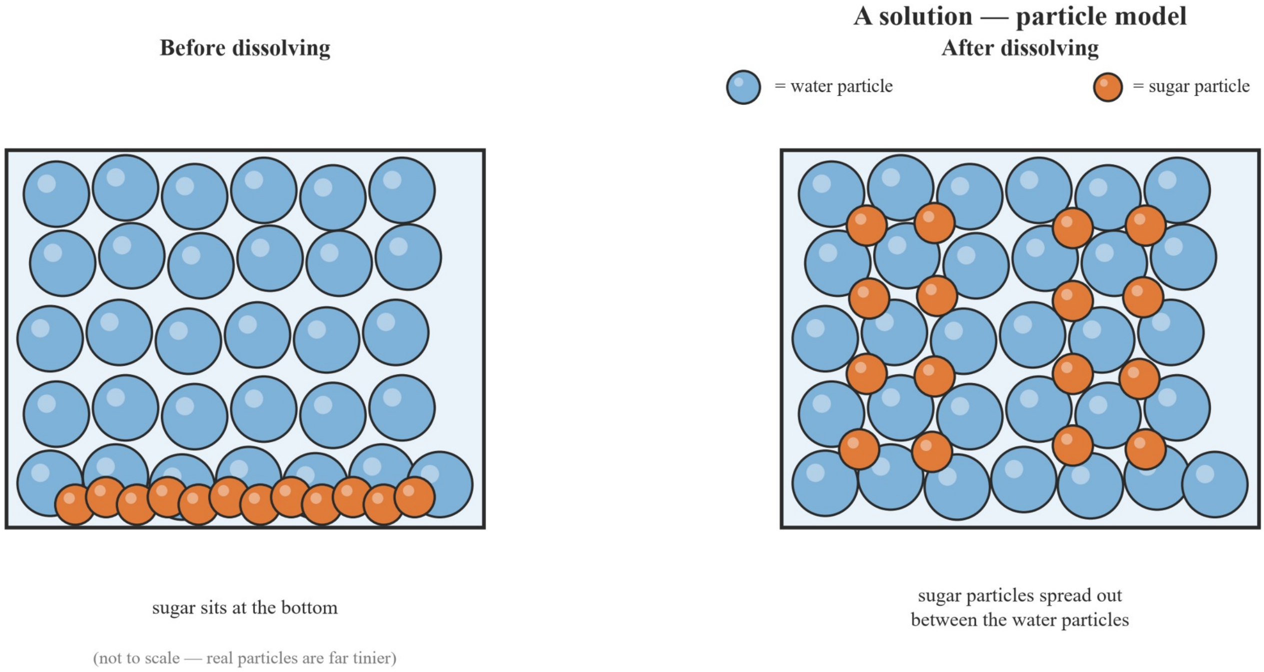


Six everyday examples in a grid: fruit salad, sea water and the air, muddy water, soil, and lemonade, each labelled as a mixture or a solution.

Solutions: one kind of mixture

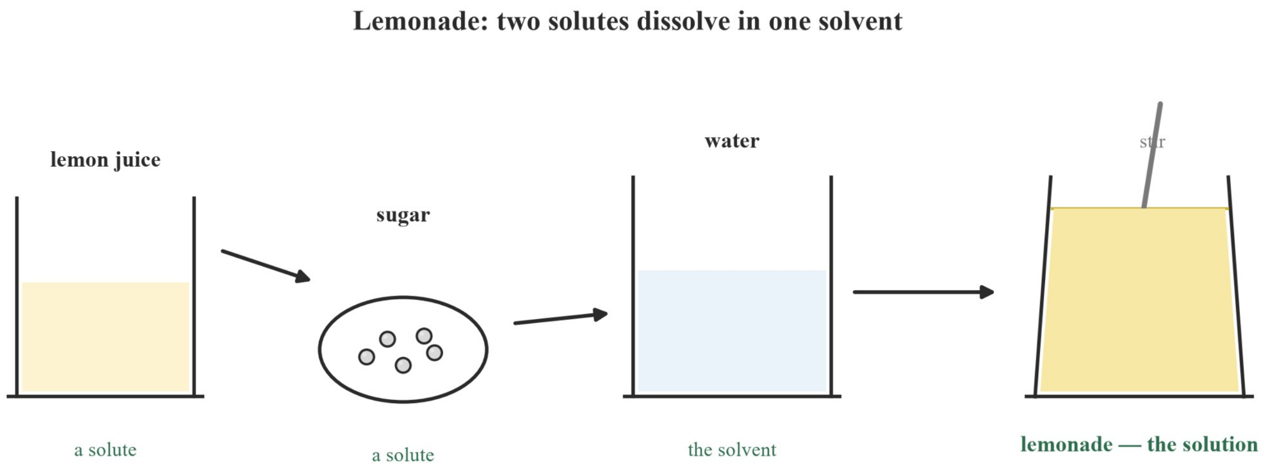
A **solution** is a mixture in which one substance **dissolves** in another. To dissolve is to break up and spread out until the mixture looks the same all through. The substance that dissolves is the **solute**. The substance that does the dissolving is the **solvent**.

Stir sugar into water and the sugar seems to disappear. The particle model says where it went: the sugar breaks up into tiny particles that spread out into the spaces between the water particles. The sugar particles are still there — that is why the water tastes sweet.



Particle model of dissolving: before stirring, orange sugar particles sit in a layer at the bottom under blue water particles; after stirring, the sugar particles are spread out between the water particles.

Lemonade is a solution with two solutes. Lemon juice and sugar both dissolve into water. The lemon juice and the sugar are the **solutes**; the water is the **solvent**; the lemonade is the **solution**.



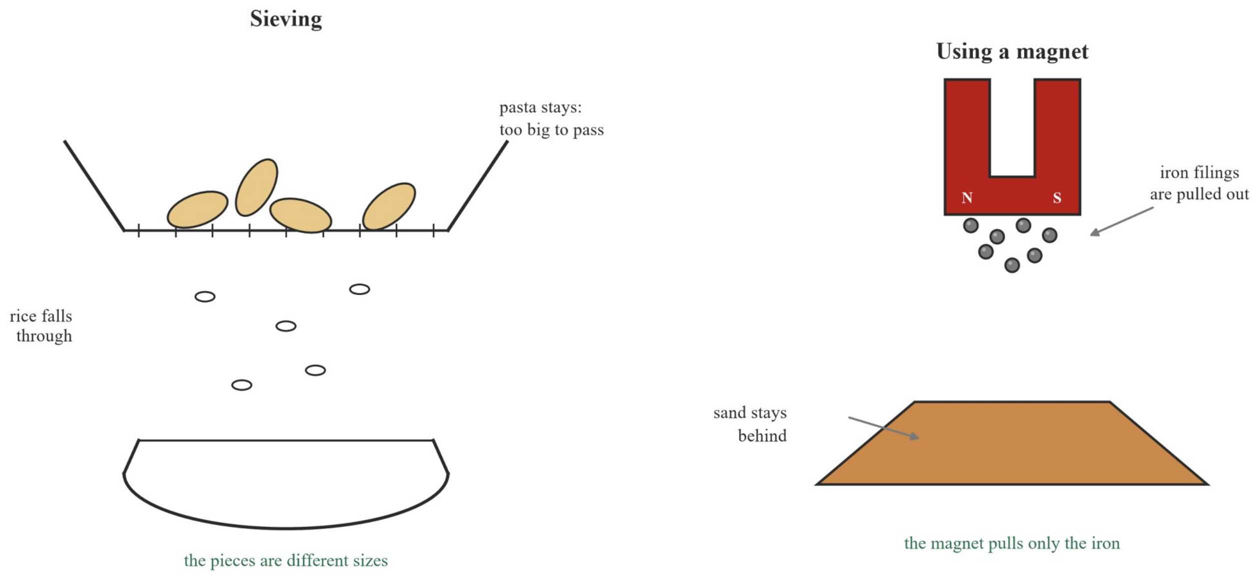
Making lemonade: a beaker of lemon juice and a bowl of sugar, the solutes, are added to a beaker of water, the solvent, and stirred to make lemonade, the solution.

A solution is still a mixture: it is two or more substances combined, and each one keeps its own properties. Sea water is another solution — the salt is dissolved in the water, which is why sea water tastes salty.

Separating mixtures

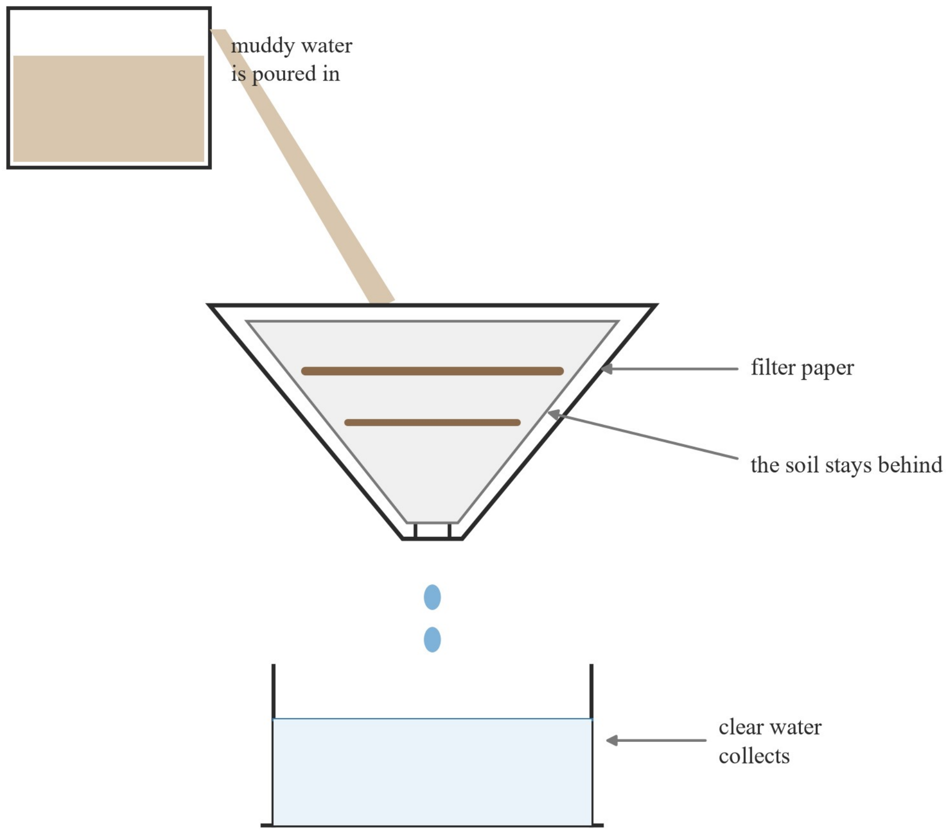
Because the substances in a mixture keep their own properties, we can often **separate** a mixture with our hands or with simple tools. Four everyday methods:

- **Sorting and picking.** Big pieces can be picked out by hand, or with tweezers or a scoop — buttons out of a tray of rice, for example.
- **Sieving.** A sieve has a mesh with small holes. Small pieces fall through and big pieces stay on top, so a mixture of rice and pasta is easy to separate.
- **Using a magnet.** A magnet pulls out anything made of iron and leaves the rest behind, so iron filings can be lifted out of sand.
- **Filtering.** A filter paper works like a very fine sieve. It takes any solid that has not dissolved out of a liquid: the solid stays on the paper and the liquid passes through.



Two panels: a sieve keeps pasta on top while rice falls through into a bowl, and a magnet lifts iron filings out of a pile of sand.

Filtering: solid that has not dissolved is taken out of a liquid



Filtering muddy water: the mixture is poured into a funnel lined with filter paper; the soil stays on the paper while clear water drips into a beaker below.

Filtering only works on a solid that has **not** dissolved. Muddy water clears, because the bits of soil are solid that has not dissolved and get caught by the paper. But a dissolved solute, like the sugar in sweet water, is spread out as particles that are far too small for any filter to catch — they pass straight through with the water. You cannot filter a solution back into its parts.

Worked examples

Example 1 — with support

Suppose a sealed syringe holds 20 mL of air. The plunger is pushed, and the volume reading falls to 12 mL. The same test is done with 20 mL of water, and the reading stays at 20 mL. Explain, using particles, why the air can be squashed and the water cannot.

Working	Comment
Air: the reading falls from 20 mL to 12 mL.	The gas takes up less space when pushed — it is compressed.
Gas particles start far from one another, with empty space between them.	It is the spaces that shrink, not the particles.
The push brings the particles closer together.	Same number of particles, in less space.
Water: the reading stays at 20 mL.	Liquid particles already touch, so there is no spare space to squeeze out.
∴ Air compresses because its particles have space between them; water does not, because its particles already touch.	The particle model explains the compressibility of gases.

Example 2 — with support

Lemonade can be made by stirring lemon juice and sugar into water. Name the solutes, the solvent and the solution, and explain why lemonade is still a mixture.

Working	Comment
Two substances dissolve: the lemon juice and the sugar.	The substances that dissolve are the solutes.
The water does the dissolving.	The substance that does the dissolving is the solvent.
The lemonade is all three combined.	A solution is one kind of mixture.
The lemonade still tastes sweet and sour.	Each substance keeps its own properties, so nothing new has been made.
∴ Solutes: lemon juice and sugar. Solvent: water. Solution: lemonade — a mixture of the three.	Solutions are mixtures in which a solute is dissolved in a solvent.

Example 3 — by yourself

Two balloons that are not blown up hang on the pans of a balance, and the balance is level. One balloon is taken down, blown up, and hung back on its pan. Predict what the balance will do, and explain your prediction using the ideas of mass and particles.

Practice questions

With support

Q1. Write a sentence, in your own words, for each word: *(3 marks)* (a) matter (b) particle (c) volume

Q2. Name the three states of matter and give one example of each. *(3 marks)*

Q3. For the particles in a **solid**, state: *(3 marks)* (a) how they are arranged (b) how they move (c) what is in the spaces between them

Q4. Use the particle model to explain each observation: *(3 marks)* (a) A liquid takes the shape of its container. (b) A solid keeps its own shape. (c) A gas fills a whole balloon.

Q5. The syringe test is done with air and with water. *(3 marks)* (a) Which state of matter is easy to squash? (b) What happens to the plunger of each syringe when it is pushed? (c) Explain the difference using particles.

Q6. Lemonade is made by stirring lemon juice and sugar into water. *(3 marks)* (a) What is a mixture? (b) Name the two solutes and the solvent in lemonade. (c) What kind of mixture is lemonade?

By yourself

Q7. A balloon full of air can be squashed in your hands, but a brick cannot. Explain why, using particles. *(2 marks)*

Q8. A teacher sprays perfume at the front of the room. A minute later, students at the back of the room can smell it. Explain this observation using the particle model of a gas. *(3 marks)*

Q9. A balance is level with two flat balloons on its pans. One balloon is blown up and hung back on its pan, and the balance tips toward it. Explain what this test shows about the air inside the balloon. *(3 marks)*

Q10. Sort these into solids, liquids and gases, and give one property you used for each group: an iron nail; orange juice; the air in a balloon; a block of ice; sea water; steam from a kettle. *(3 marks)*

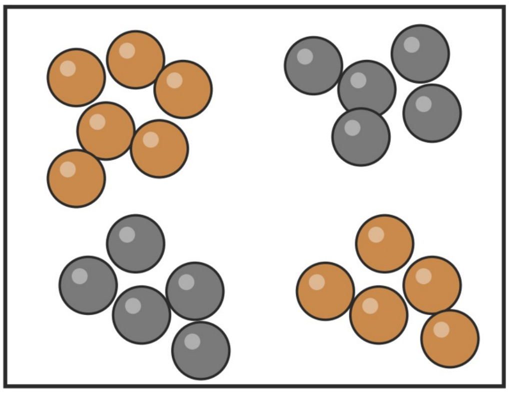
Q11. A bowl holds a mixture of dry rice and dry pasta. *(3 marks)* (a) Why is this a mixture? (b) Describe one way to separate it. (c) Which different property of the two substances makes your method work?

Q12. Muddy water is poured through a filter paper. *(3 marks)* (a) What stays on the paper, and what passes through? (b) Explain why the filter can separate this mixture. (c) Explain why the same filter could not take dissolved sugar out of sweet water.

Q13. A magnet is used to separate a mixture of sand and iron filings. *(3 marks)* (a) Why does the magnet pull out the iron filings but not the sand? (b) Would the same method work for a mixture of sand and sugar? Explain.

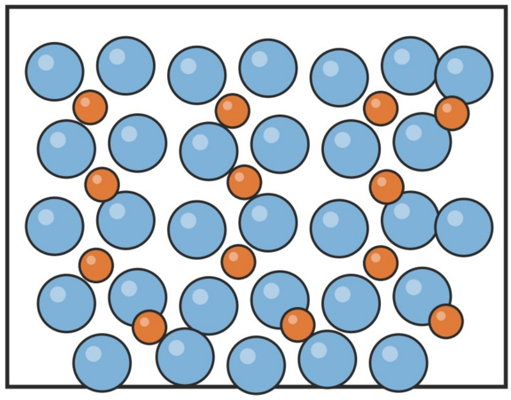
Q14. The diagrams below model two mixtures at the particle level. *(4 marks)*

Diagram A



two kinds of particle

Diagram B



one kind of particle spread through the other

Diagram A shows clumps of two kinds of particle sitting side by side; Diagram B shows small orange particles spread out one by one between big blue particles.

(a) Which diagram models a solution? How can you tell?
(b) In that diagram, which kind of particle is the solute and which is the solvent?
(c) Explain why a solution is still a mixture.

Q15. SCENARIO — A class does the syringe test. Each syringe starts at 20 mL. The plunger is pushed, and the volume reading is recorded. The test is repeated for three trials, with these results:

Trial	Air syringe reading (mL)	Water syringe reading (mL)
1	14	20
2	14	20
3	13	20

(a) Describe the pattern in the results for the air syringe and for the water syringe. *(2 marks)*
(b) Do the trials agree with each other? What does that tell you? *(1 mark)*
(c) Explain, using the particle model, why the air reading falls but the water reading does not. *(2 marks)*

Q16. Sam stirs a spoon of sugar into a cup of water and says: "The sugar has disappeared, so sweet water is not a mixture — it is just water." Use the particle model to explain why Sam is wrong. In your answer, name the solute and the solvent, and say why filtering cannot take the sugar back out. *(5 marks)*

Practical — can air be squashed?

PRACTICAL — this page plans or analyses work done in the classroom, laboratory or field. It is not a substitute for doing it.

Question: Can air be squashed? How does air compare with water?

Equipment: two syringes of the same size (no needles, ever); a cup of water; a paper towel; safety glasses.

Safety: Wear safety glasses in case water splashes when the syringes are filled. Point syringes down or away from people, and push the plunger gently. A teacher needs to be with you for this activity.

Risk	How we stay safe
A syringe pointing at someone	Point it down or away; never at a person.
Water spilled on the bench or floor	Use a paper towel; wipe spills up straight away.

Risk	How we stay safe
Pushing the plunger too hard	Push gently; stop if it does not move.

Variables (the things we change, measure and keep the same):

Variable	Choice
The one we change	the substance in the syringe: air or water
The one we measure	the volume reading after the push (mL)
The ones we keep the same	the same syringe size; the same starting volume of 20 mL; the same gentle push

Method:

1. With the plunger at 20 mL, seal the open end of syringe 1 with a finger. This syringe holds air.
2. Push the plunger gently as far as it goes. Read the new volume and record it.
3. Let the plunger go back and repeat steps 1–2 until you have three trials.
4. Fill syringe 2 with water to 20 mL. Seal the open end with a finger.
5. Push the plunger gently as far as it goes. Read the new volume and record it.
6. Repeat steps 4–5 until you have three trials.

Results: record your readings in a table like this one.

Trial	Air reading (mL)	Water reading (mL)
1		
2		
3		

Compare your three trials for each syringe. Do the readings agree with each other?

Thinking about the results:

1. Describe what happened to the air when the plunger was pushed, and what happened to the water.
2. Explain your observations with the particle model. In your explanation, say what is between the particles of the air.
3. Draw two boxes in your notebook: the air in the syringe before the push, and after the push. Draw the particles in each box, and label what is between them.

Make a claim and defend it. Finish this writing frame in full sentences:

- I claim that air ____ .
- My evidence is ____ .
- The particle model explains this because ____ .
- If someone claimed the water was squashed too, I would answer ____ .

Answers

Q1 (a) Matter is anything that takes up space and has mass. (b) A particle is a tiny piece of matter, too small to see. (c) Volume is the space a sample of matter takes up. **Q2** Solid (a brick), liquid (water), gas (air) — any sensible examples. **Q3** (a) Close together in a regular pattern. (b) They vibrate about a fixed spot. (c) Nothing — empty space. **Q4** (a) Liquid particles slide past one another, so the liquid flows and settles into the container's shape. (b) Solid particles are locked in a regular pattern and only vibrate, so the shape is kept. (c) Gas particles move quickly in all directions, so they spread out until they fill the whole balloon. **Q5** (a) A gas. (b) The air plunger moves in; the water plunger does not. (c) Gas particles have space between them that a push can squeeze out; liquid particles already touch. **Q6** (a) Two or more substances combined, each keeping its own properties. (b) Solutes: lemon juice and sugar. Solvent: water. (c) A solution. **Q7** Air particles have large spaces between them, so a push can bring them closer; brick particles already touch and cannot be pushed closer. **Q8** Perfume particles are gas particles; they move quickly in all directions through the spaces between air particles, so they spread across the room. **Q9** The blown-up balloon holds extra air; the balance tips because that air has mass, so gases have mass. **Q10** Solids: iron nail, ice (keep their own shape). Liquids: orange juice, sea water (take the container's shape, can be poured). Gases: air in the balloon, steam (fill all the space available). **Q11** (a) Two substances combined, each keeping its properties. (b) Sieving (or picking by hand). (c) The different size of the pieces (pasta too big for the holes; rice falls through). **Q12** (a) Soil stays on the paper; water passes through. (b) The soil bits are solid that has not dissolved, too big for the paper's holes. (c) Dissolved sugar particles are too small to be caught; they pass through with the water. **Q13** (a) Iron is magnetic and sand is not, so the magnet pulls only the iron. (b) No — sugar is not magnetic, so nothing would be pulled out. **Q14** (a) Diagram B — one kind of particle is spread out between the other (dissolved). (b) The small orange particles are the solute; the large blue particles are the solvent. (c) It is still two substances combined, each keeping its own properties. **Q15** (a) Air readings fall to about 13–14 mL; water readings stay at 20 mL. (b) Yes — the trials agree, so the pattern can be trusted. (c) Gas particles have space between them that a push squeezes out; liquid particles already touch. **Q16** The sugar has not gone; its particles spread out between the water particles, so it is a mixture (a solution). Solute: sugar. Solvent: water. The dissolved particles are too small for a filter to catch, so filtering cannot take the sugar out.

Worked solutions

Q1 *(3 marks: 1 each)* (a) Matter is anything that takes up space and has mass — a brick, water and air are all matter. *1 mark* (b) A particle is a tiny piece of matter, far too small to see on its own. *1 mark* (c) Volume is the amount of space a sample of matter takes up, measured in litres or millilitres. *1 mark*

Q2 *(3 marks: 1 per state with a correct example)* Solid — for example a brick or an iron nail; liquid — for example water or orange juice; gas — for example air or the gas in a balloon. *1 mark each*

Q3 *(3 marks: 1 each)* (a) The particles sit close together in a regular pattern. (b) They vibrate about a fixed spot; they do not move from place to place. (c) Nothing — the spaces are empty space, not air. *1 mark each*

Q4 *(3 marks: 1 each)* (a) Liquid particles can slide past one another, so a liquid flows and pours and settles to take the shape of whatever holds it. *1 mark* (b) Solid particles are locked in a regular pattern and can only vibrate about fixed spots, so a solid holds its own shape. *1 mark* (c) Gas particles move quickly in all directions with lots of space between them, so they spread out and fill every part of the balloon. *1 mark*

Q5 *(3 marks: 1 each)* (a) A gas is easy to squash; liquids and solids are not. *1 mark* (b) With air, the plunger moves in and the volume reading falls; with water, the plunger does not move in and the reading stays the same. *1 mark* (c) Gas particles have large spaces between them, and a push brings the particles closer together; liquid particles already touch, so there is no spare space to squeeze out. *1 mark*

Q6 *(3 marks: 1 each)* (a) A mixture is two or more different substances combined, with each substance keeping its own properties. *1 mark* (b) The solutes are the lemon juice and the sugar; the solvent is the water. *1 mark* (c) Lemonade is a solution — a mixture in which the solutes are dissolved in the solvent. *1 mark*

Q7 *(2 marks)* In a gas the particles are far from one another with large spaces between them, so a push can bring the particles closer together and the balloon squashes. *1 mark* In a solid brick the particles already touch and are locked in place, so there is no space to squeeze out and the brick does not squash. *1 mark*

Q8 *(3 marks)* The spray sends perfume particles into the air as a gas. *1 mark* Gas particles move quickly in all directions, and there is empty space between the air particles for them to travel through. *1 mark* So the perfume particles spread across the room and reach the noses of the students at the back. *1 mark*

Q9 *(3 marks)* The blown-up balloon holds extra air that the flat balloon does not have. *1 mark* The balance tips toward the heavier side, so the extra air must have mass. *1 mark* Therefore a gas has mass — gases are matter too. *1 mark*

Q10 *(3 marks: 1 per group with a property)* Solids: the iron nail and the block of ice — they keep their own shape. *1 mark* Liquids: the orange juice and the sea water — they take the shape of their container and can be poured. *1 mark* Gases: the air in the balloon and the steam — they spread to fill all the space available. *1 mark*

Q11 *(3 marks: 1 each)* (a) It is two different substances combined, and each one keeps its own properties (the rice stays rice and the pasta stays pasta). *1 mark* (b) Pour the mixture through a sieve: the rice falls through the holes and the pasta stays on top. (Picking the pasta out by hand also works.) *1 mark* (c) The size of the pieces: pasta pieces are too big for the holes, rice grains are small enough to fall through. *1 mark*

Q12 *(3 marks: 1 each)* (a) The soil stays on the filter paper and the water passes through. *1 mark* (b) The bits of soil are solid that has not dissolved; they are too big for the holes in the paper, so they are caught while the liquid goes through. *1 mark* (c) Dissolved sugar is spread out as single particles that are far too small to be caught, so they pass through the paper with the water — a filter cannot separate a solution. *1 mark*

Q13 *(3 marks: 1 for (a), 2 for (b))* (a) Iron is magnetic, so the filings are pulled to the magnet; sand is not magnetic, so it stays behind. *1 mark* (b) No. *1 mark* Sugar is not magnetic, so a magnet would pull out nothing and the mixture would stay mixed. *1 mark*

Q14 *(4 marks)* (a) Diagram B. *1 mark* In B one kind of particle is spread out, one by one, between the other kind — that is what dissolving looks like at the particle level; in A the two kinds sit in separate clumps. *1 mark* (b) The small orange particles (spread out) are the solute; the large blue particles (doing the dissolving) are the solvent. *1 mark* (c) A solution is still two substances combined, and each keeps its own properties — so it fits the definition of a mixture. *1 mark*

Q15 *(5 marks)* (a) Air: the reading falls from 20 mL to 13–14 mL, so the air is squashed. *1 mark* Water: the reading stays at 20 mL in every trial, so the water is not squashed. *1 mark* (b) Yes, the trials agree (14, 14, 13 and 20, 20, 20), so the pattern is one we can trust rather than a one-off result. *1 mark* (c) Gas particles start far from one another with empty space between them, and the push brings them closer together into less space. *1 mark* Liquid particles already touch, so there is no spare space to squeeze out and the water keeps its volume. *1 mark*

Q16 *(5 marks)* The sugar has not disappeared; when it dissolves, its particles spread out into the spaces between the water particles, so they cannot be seen. *1 mark* The cup now holds two substances combined — sugar and water — and each keeps its properties (the water tastes sweet), so it is a mixture. *1 mark* A mixture in which one substance is dissolved in another is a solution. *1 mark* The solute is the sugar and the solvent is the water. *1 mark* Filtering cannot take the sugar out because the dissolved sugar particles are far too small to be caught by any filter paper; they pass straight through with the water. *1 mark*

Reversible and irreversible change

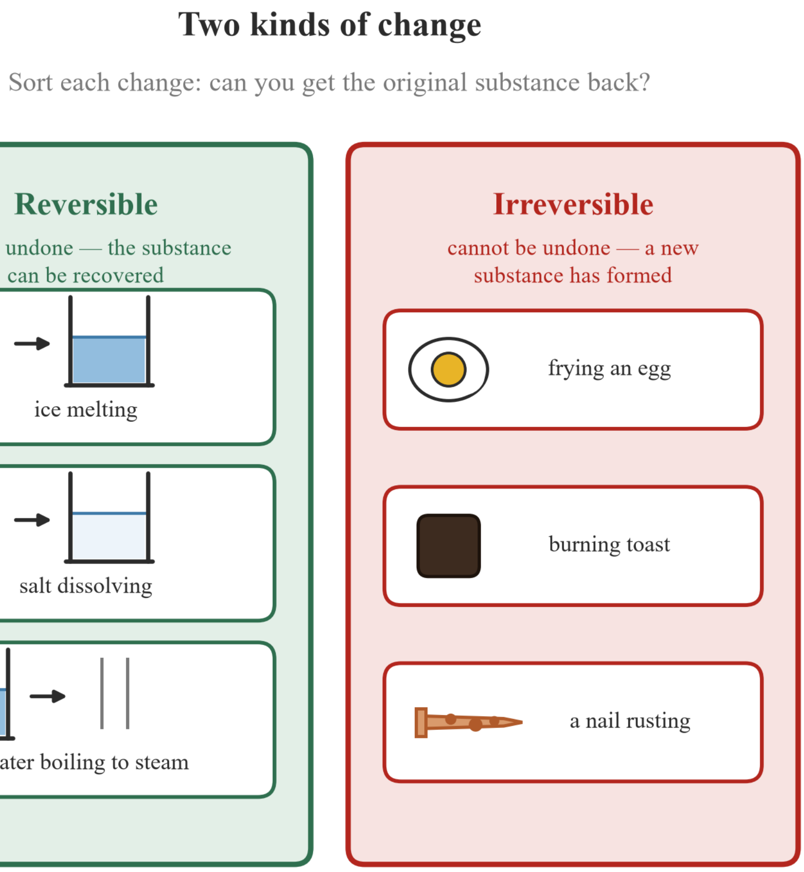
Words to know reversible · irreversible · recover · change of state · melting · freezing · evaporating · condensing · soluble · insoluble · solubility · rust · recycle

Ice melts in a glass on a hot day, and a cake rises in a hot oven. Both are changes, but they are different kinds of change. Put the melted ice back in the freezer and it becomes ice again. Do anything you like to a cake and it will never turn back into flour, egg and milk. This section sorts every change with one question: **can you get the original substance back?**

Theory

Two kinds of change

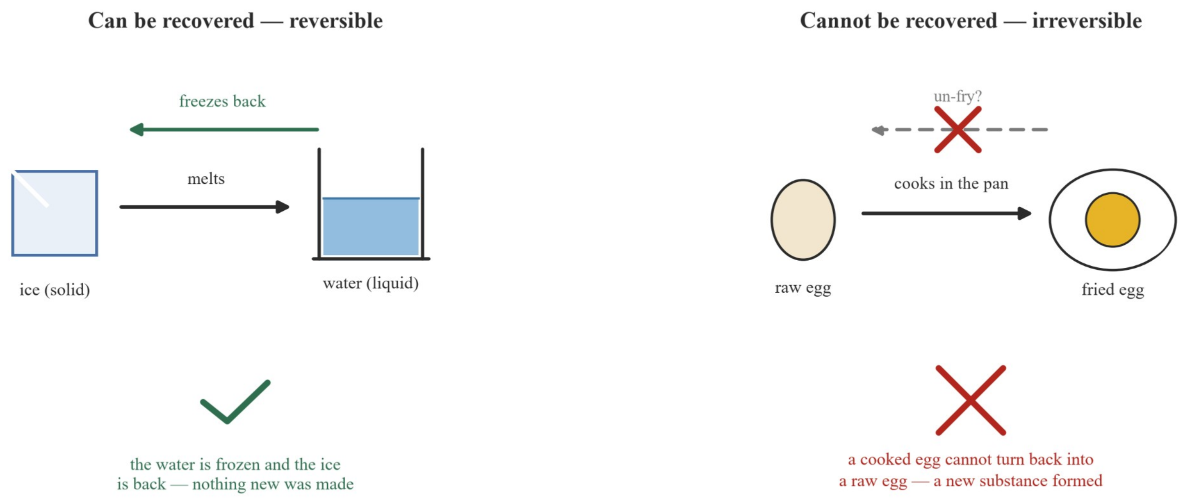
A change to a substance is **reversible** if it can be undone, so that the original substance is **recovered** — got back. A change is **irreversible** if it cannot be undone, because a new substance has formed.



Reversible changes can be reversed; irreversible changes make a new substance.

Two labelled sorting bins. The green bin, "Reversible — can be undone, the substance can be recovered", holds cards for ice melting, salt dissolving and water boiling to steam. The red bin, "Irreversible — cannot be undone, a new substance has formed", holds cards for frying an egg, burning toast and a nail rusting.

The sorting rule is the recovery test: if you can get the original substance back, the change is reversible; if you cannot, it is irreversible.

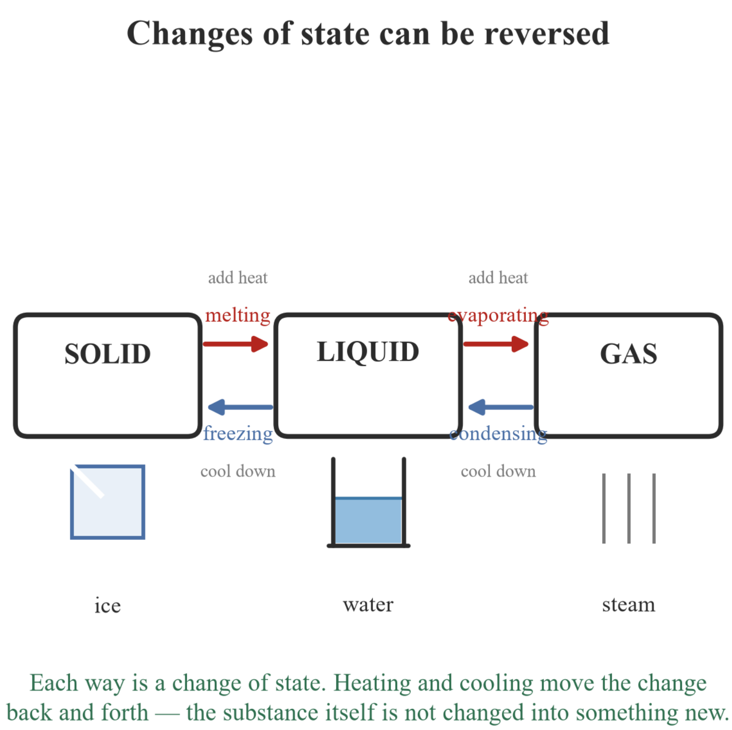


Two panels. Left: ice melts to water, and a green arrow shows the water freezing back to ice, marked with a tick — the substance is recovered. Right: a raw egg cooks in a pan to a fried egg, and the arrow back is crossed out — a cooked egg cannot turn back into a raw egg.

- **Reversible:** the melted ice is frozen and the ice is back. Nothing new was made, so the change is undone.
- **Irreversible:** the fried egg is a new substance. No cooling, stirring or waiting turns it back into a raw egg.

Changes of state are reversible

In 7A we met the three states of matter. The changes from one state to another are called **changes of state**, and every change of state can be reversed by heating or cooling.



Three boxes labelled SOLID, LIQUID and GAS, with pictures of ice, water and steam beneath them. A red arrow labelled "melting, add heat" runs from solid to liquid and a blue arrow labelled "freezing, cool down" runs back; a red arrow labelled "evaporating, add heat" runs from liquid to gas and a blue arrow labelled "condensing, cool down" runs back.

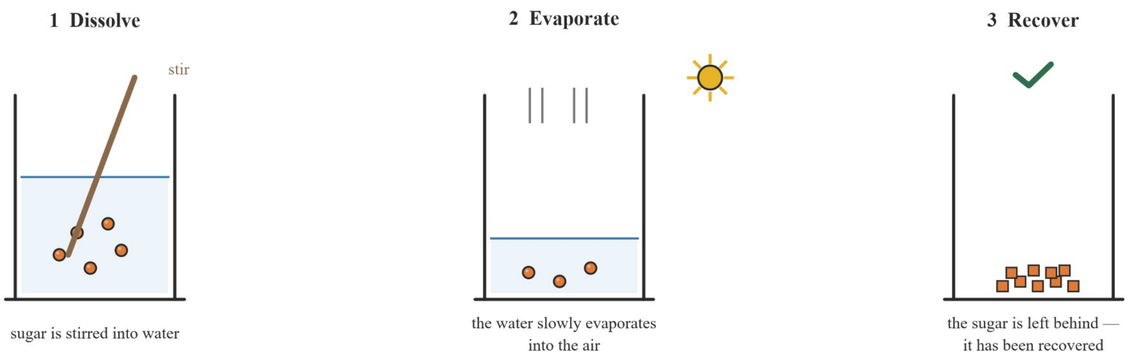
- **Melting** is the change from solid to liquid. It needs heat.
- **Freezing** is the change from liquid to solid. It needs cooling.
- **Evaporating** is the change from liquid to gas. It needs heat.
- **Condensing** is the change from gas to liquid. It needs cooling.

Each pair undoes the other, and the substance itself stays the same substance. Ice, water and steam are all water. Steam from a kettle condenses on a cold window into drops of water — the same substance, recovered. A change of state never makes a new substance, so changes of state are reversible.

Dissolving is reversible

In 7A we met solutions: a **solute** dissolves in a **solvent** to make a **solution**. Stir sugar into water and the sugar seems to disappear, but its particles are still there, spread out between the water particles — that is why the water tastes sweet.

Because the sugar is still there, dissolving can be undone: let the water **evaporate** (change to a gas and leave), and the sugar is left behind, recovered.



Three steps in a row. Step 1 "Dissolve": sugar is stirred into a beaker of water. Step 2 "Evaporate": the beaker sits in a warm place and the water slowly evaporates into the air. Step 3 "Recover": the dry beaker holds the sugar again as crystals, marked with a tick.

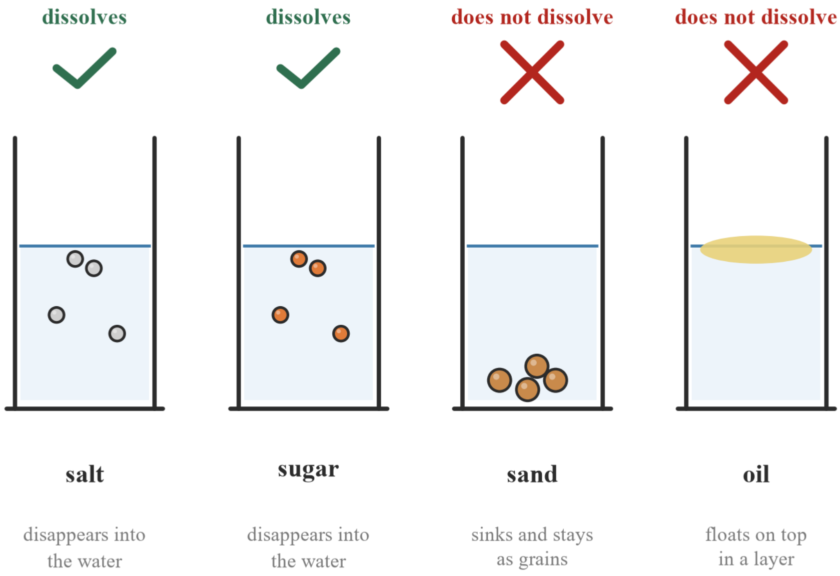
Dissolving and changes of state are the two everyday reversible changes: in both, no new substance forms, so the original substance can be recovered.

Solubility: which substances dissolve, and how much?

Not every substance dissolves in water. A substance that dissolves in water is **soluble**; a substance that does not dissolve is **insoluble**. How well a substance dissolves is called its **solubility**.

Which substances dissolve in water?

Each beaker holds the same amount of water. One substance is stirred in.

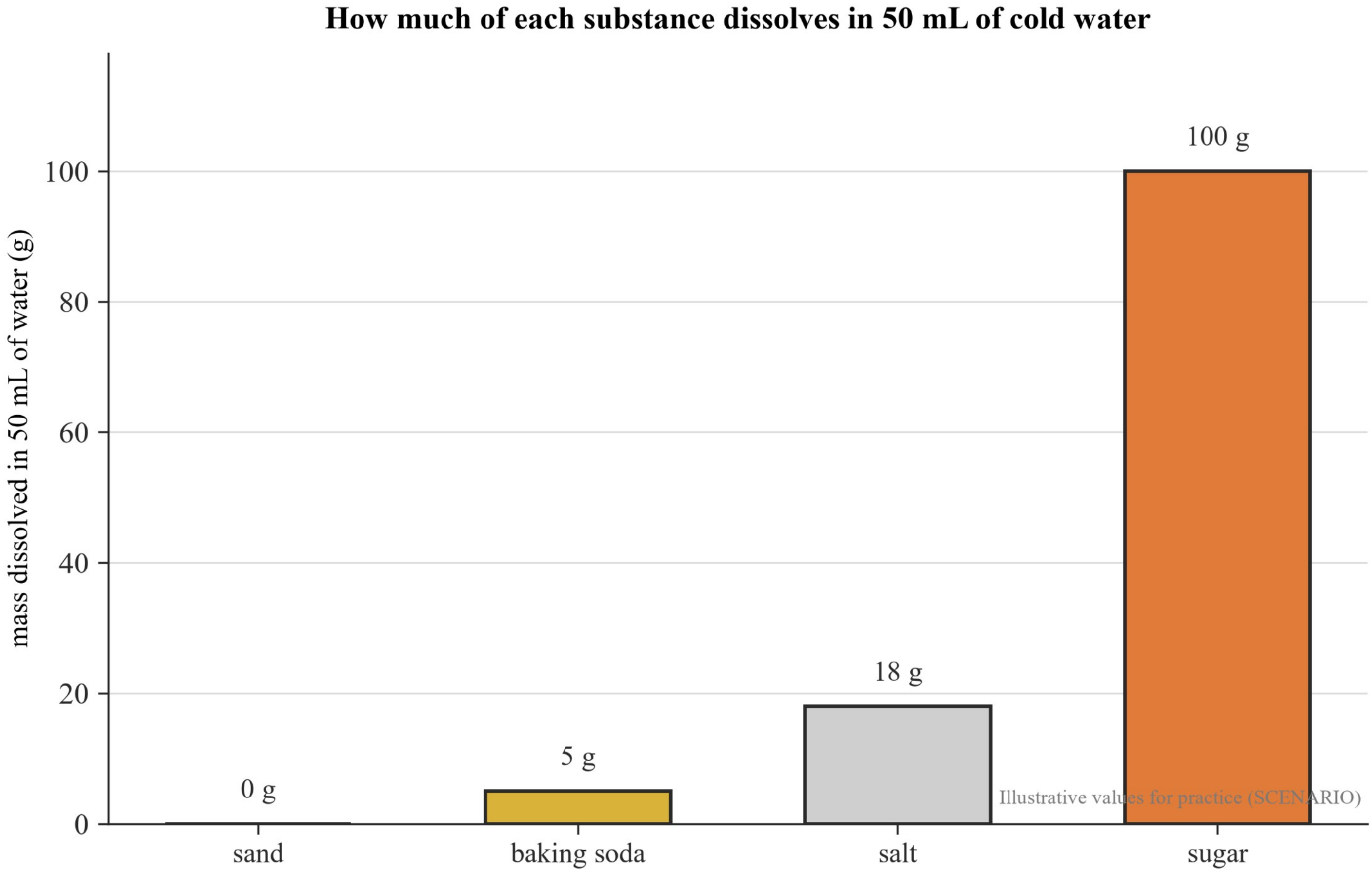


A substance that dissolves in water is soluble; one that does not is insoluble.

Four beakers of water, each with one substance stirred in. Salt and sugar are marked "dissolves" with a tick: their particles spread out and disappear into the water. Sand is marked "does not dissolve": the grains sink and stay at the bottom. Oil is marked "does not dissolve": it floats on top in a layer.

- Salt and sugar are soluble: stirred in, they spread out and the water stays clear.
- Sand is insoluble: the grains sink and stay grains, however much you stir.
- Oil is insoluble too, but it floats on top in a layer instead of sinking.

Even among soluble substances, solubility is not the same for all of them. The column graph shows example results for practice: how much of each substance dissolves in 50 mL of cold water.



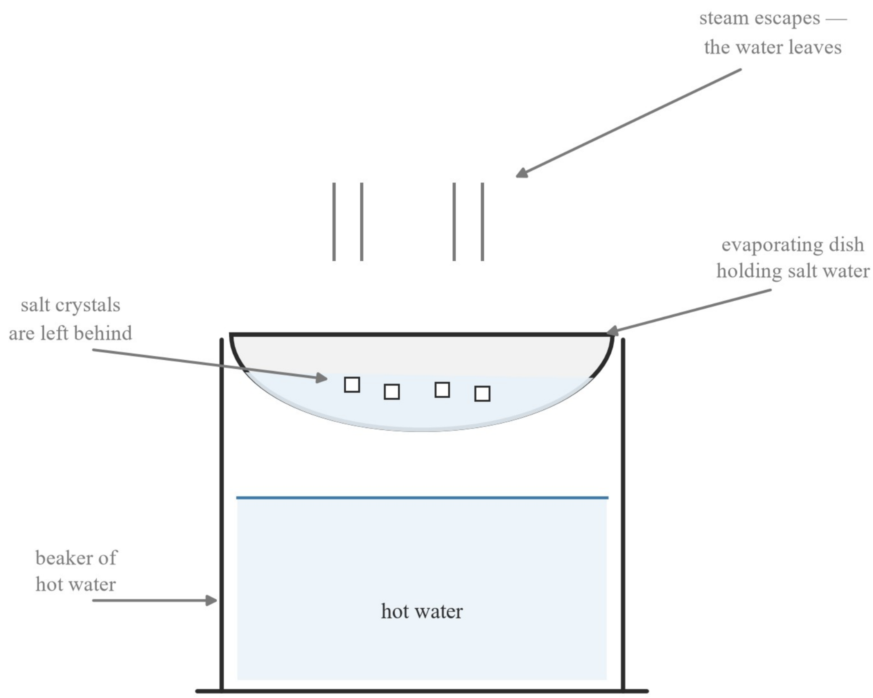
Column graph titled "How much of each substance dissolves in 50 mL of cold water". The side scale, "mass dissolved in 50 mL of water (g)", runs from 0 to over 100. Columns: sand 0 g, baking soda 5 g, salt 18 g, sugar 100 g.

Far more sugar than salt dissolves in the same amount of water, baking soda dissolves only a little, and sand not at all. When water has dissolved as much of a substance as it can, any extra stays behind without dissolving.

Recovering a dissolved solute

To recover a dissolved solute, evaporate the solvent. In the lab this is done with an **evaporating dish**: a shallow dish that sits on a beaker of hot water while the water in the dish slowly leaves as a gas.

Recovering salt from salt water



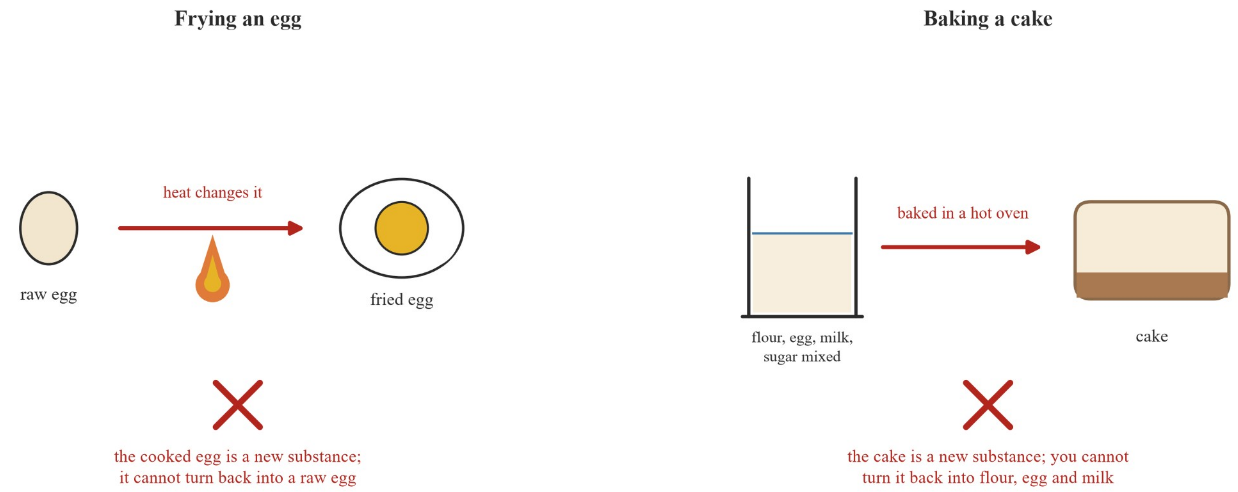
As the water evaporates, the dissolved salt is recovered as crystals.

Labelled apparatus: an evaporating dish holding salt water rests on the rim of a beaker of hot water. Steam rises from the dish, and salt crystals are left behind at the bottom of the dish as the water leaves.

As the water evaporates, the dissolved salt is recovered as **crystals** — hard, regular grains of the solid. The same idea works at the coast: sea water is let into shallow ponds, the sun evaporates the water, and the salt is collected. In every case the change is undone and the solute is got back, because dissolving is reversible.

Cooking and rusting are irreversible

Some everyday changes make new substances, and these changes cannot be undone.

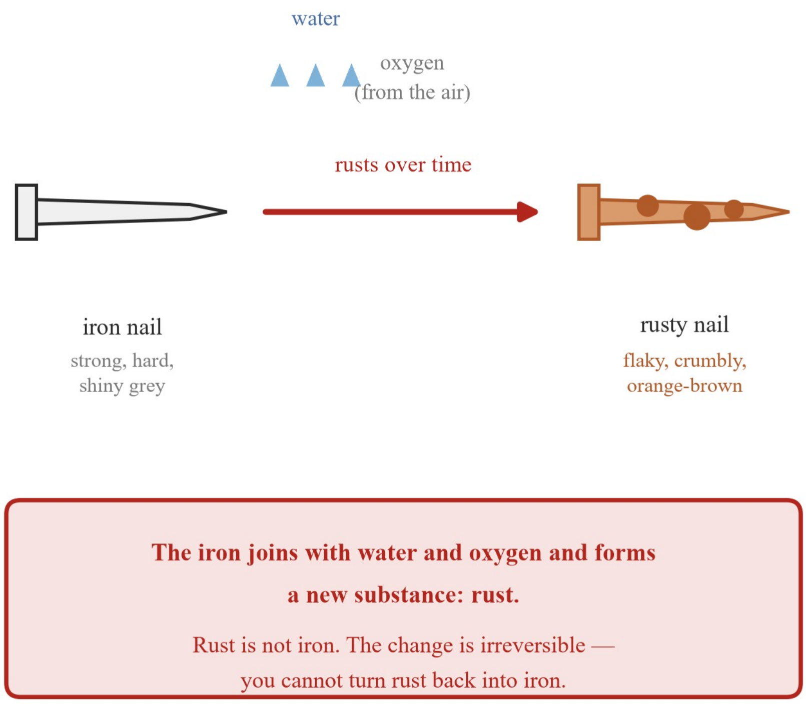


Two panels. Left: a raw egg is heated in a pan and becomes a fried egg — a new substance that cannot turn back into a raw egg. Right: a mixture of flour, egg, milk and sugar is baked in a hot oven and becomes a cake — a new substance that cannot be turned back into the mixture.

- Heat changes a raw egg into a fried egg. The fried egg is a new substance: hard, white and solid where the raw egg was runny and clear.
- A cake mixture baked in a hot oven becomes a cake. The cake is a new substance: you cannot pick the flour, egg and milk back out.

Rusting is another irreversible change. Iron is a strong, hard, shiny grey metal. Left with water and oxygen (a gas in the air), iron slowly forms **rust**, a flaky, crumbly, orange-brown substance.

Rusting — a new substance forms

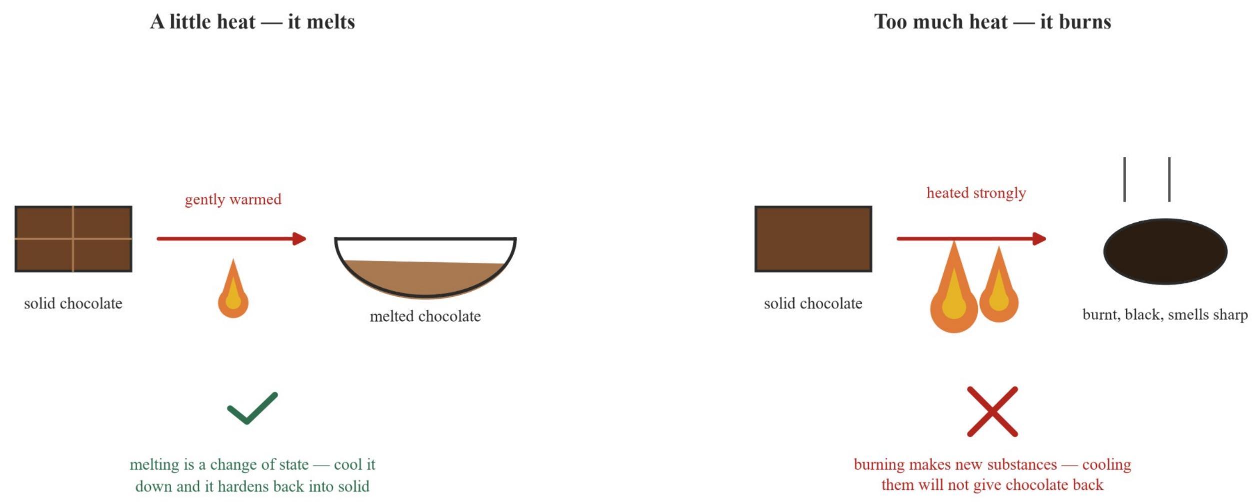


An iron nail, labelled "strong, hard, shiny grey", changes over time with water and oxygen from the air into a rusty nail, labelled "flaky, crumbly, orange-brown". A box below states that the iron joins with water and oxygen and forms a new substance, rust, and that rust cannot be turned back into iron.

Rust is not iron. It has different properties — it flakes off and crumbles — and the change cannot be undone: you cannot turn rust back into iron. Cooking and rusting are irreversible because a new substance forms.

How much heat is added decides what happens

The same substance can go through a reversible change with a little heat and an irreversible change with too much heat. Chocolate shows this well.



Two panels. Left: solid chocolate is gently warmed and melts to liquid chocolate — a change of state, marked with a tick because cooling hardens it back to solid. Right: solid chocolate is heated strongly and burns to a black lump with smoke — new substances, marked with a cross because cooling will not give chocolate back.

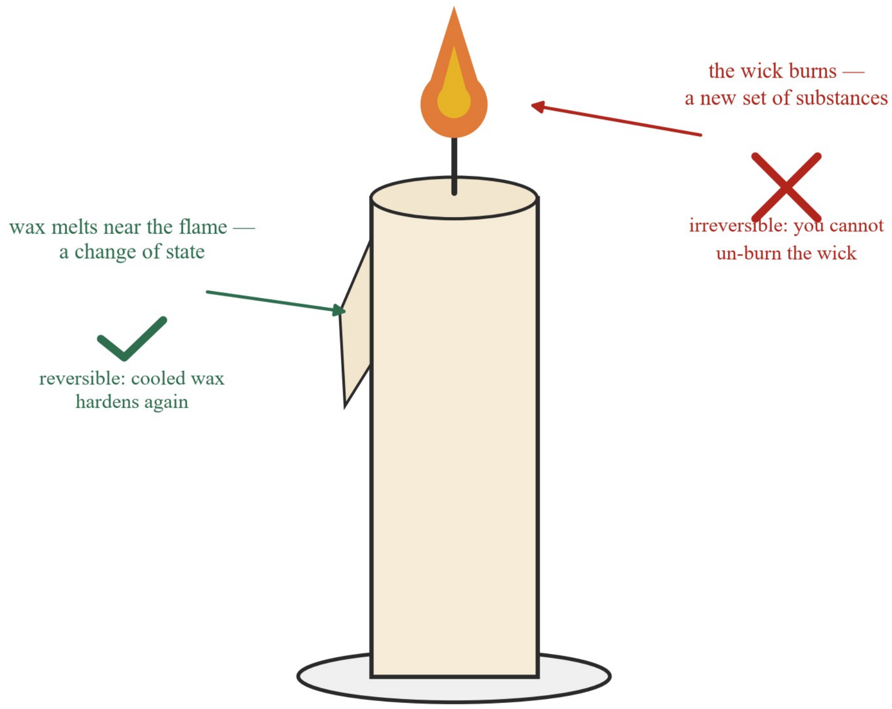
- **A little heat:** the chocolate melts. Melting is a change of state, so it is reversible — cool the melted chocolate and it hardens back into a solid.
- **Too much heat:** the chocolate burns. Burning makes new substances (the black lump and the smoke), so it is irreversible — cooling them will not give back chocolate.

So the amount of heat energy added decides whether the change is a reversible change of state or an irreversible change that makes new substances.

One object, two different changes

A burning candle shows both kinds of change at the same time.

One object, two different changes



The same candle shows both kinds of change at once.

A burning candle on a holder. A green arrow points to wax that has melted and run down the side: a change of state, reversible because cooled wax hardens again. A red arrow points to the flame at the wick: the wick burns and makes new substances, irreversible because you cannot un-burn the wick.

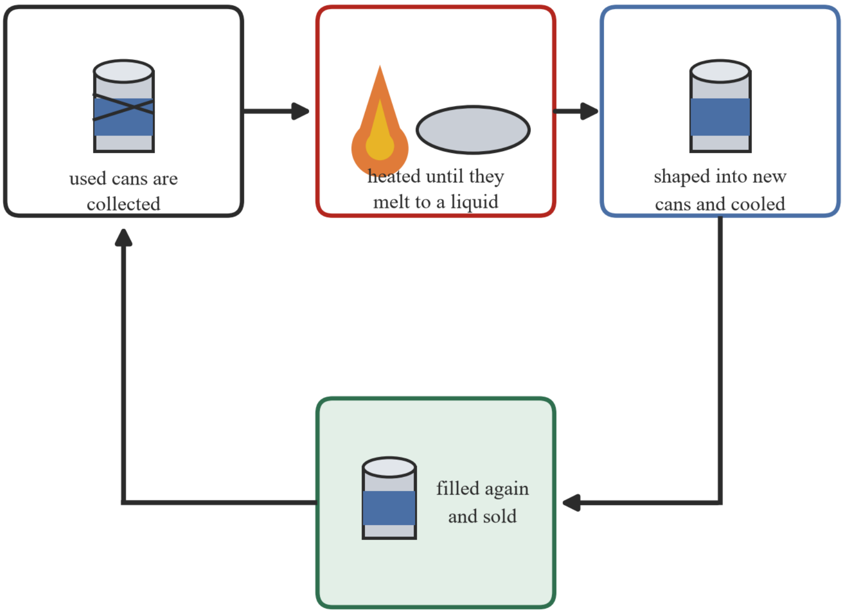
- Near the flame, the wax **melts** — a reversible change of state. Cooled wax hardens again.
- At the top, the wick **burns** — an irreversible change. The burned wick and the gases it gives off are new substances.

When you look at a change, do not just name the object: ask *which substance is changing, and can it be recovered?*

Reversible change helps us recycle

Recycling uses reversible changes to turn used materials into new objects. Aluminium drink cans are recycled by melting: the metal is heated until it is liquid, shaped into new cans, and cooled until it is solid again.

Reversible change helps us recycle



Melting is a reversible change of state: the metal is melted, shaped, and hardened again — the same aluminium is used over and over.

A four-step loop: used cans are collected; they are heated until they melt to a liquid; the liquid is shaped into new cans and cooled; the cans are filled again and sold, and the loop runs again.

Melting and freezing are changes of state, so the aluminium stays aluminium the whole way round the loop. The same metal can be melted and shaped over and over, which means less new metal has to be made. Recycling works because the change of state is reversible.

Worked examples

Example 1 — with support

An ice block melts on a hot day and leaves a puddle of liquid. Someone pours the puddle into a tray and puts it in the freezer, and it hardens into ice again. Classify the change as reversible or irreversible, and explain your answer.

Working	Comment
The original substance is ice (solid water); after melting it is liquid water.	A change of state has happened: melting.
The liquid is put in the freezer and hardens back into ice.	Freezing undoes the melting.
The original substance is recovered, and no new substance formed.	This is the test for a reversible change.
∴ Melting is a reversible change: it is undone by freezing, and the ice is recovered.	Changes of state are reversible.

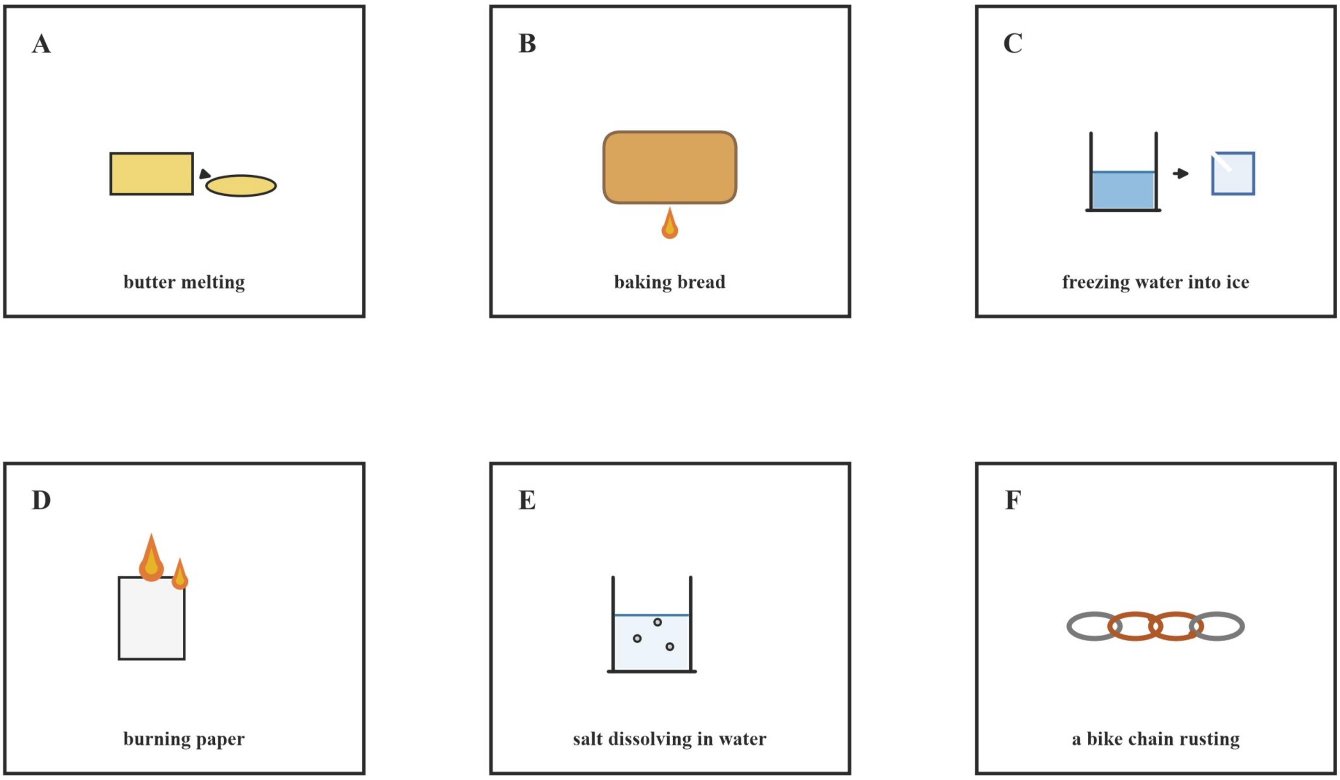
Example 2 — with support

A class is given a beaker of salt water and told to get the salt back. Plan how to recover the salt, and explain why your plan works.

Working	Comment
The salt water is a solution: salt is the solute, water is the solvent.	The salt is dissolved, not gone — its particles are spread through the water.
Pour the salt water into an evaporating dish and leave it somewhere warm.	The water slowly evaporates — it changes to a gas and leaves.
Dry salt crystals are left in the dish.	The dissolved solute is recovered.
∴ Evaporate the water and the salt is recovered, because dissolving is a reversible change.	No new substance formed when the salt dissolved, so the change can be undone.

Example 3 — by yourself

The grid below shows six everyday changes, labelled A to F.



Six labelled panels: A butter melting; B baking bread; C freezing water into ice; D burning paper; E salt dissolving in water; F a bike chain rusting.

Classify each change as reversible or irreversible. For each one, give a one-line reason using the recovery test: can the original substance be got back?

Practice questions

With support

Q1. Write a sentence of your own for each word: *(3 marks)* (a) reversible (b) irreversible (c) recover

Q2. Name the change of state in each case: *(4 marks)* (a) solid to liquid (b) liquid to solid (c) liquid to gas (d) gas to liquid

Q3. An ice cube melts into a puddle of water on a bench. *(3 marks)* (a) Is this change reversible or irreversible? (b) How would you undo it? (c) What is the name of the change that undoes it?

Q4. A spoon of sugar is stirred into a cup of water and seems to disappear. *(3 marks)* (a) Name the solute and the solvent. (b) Is the change reversible or irreversible? (c) How could you recover the sugar?

Q5. Use the rusting figure in the theory. *(3 marks)* (a) Which two things from around the nail join with the iron? (b) What is the new substance that forms? (c) Why is rusting irreversible?

Q6. Use the chocolate figure in the theory. *(3 marks)* (a) What change happens when the chocolate is gently warmed? (b) How is that change undone? (c) Why is burning the chocolate irreversible?

By yourself

Q7. Classify each change as reversible or irreversible, and give a one-line reason: *(4 marks)* (a) melting butter in a warm kitchen (b) baking bread in an oven (c) freezing water into ice blocks (d) burning paper in a fire pit

Q8. A birthday candle burns on a cake. *(4 marks)* (a) Name one reversible change happening to the candle. (b) Explain why it is reversible. (c) Name one irreversible change happening to the candle. (d) Explain why it is irreversible.

Q9. Sea water tastes salty because salt is dissolved in it. *(3 marks)* (a) Describe how you could recover the salt from a cup of sea water. (b) Describe how the water itself could be recovered as fresh water. (c) Why do both recoveries work?

Q10. A student stirs sand, salt, sugar and oil into four beakers of water, as in the solubility figure. *(3 marks)* (a) Which two substances dissolve? (b) Which two do not dissolve, and how can you tell the difference between those two just by looking? (c) What word describes a substance that does not dissolve?

Q11. SCENARIO — Use the solubility column graph from the theory. *(4 marks)* (a) Which substance has the greatest solubility in cold water? (b) Read off the mass of salt that dissolves in 50 mL of cold water. (c) How much more sugar than salt dissolves in 50 mL of cold water? (d) A student says sand must be soluble because the water went cloudy when it was stirred. Explain why the student is wrong.

Q12. Used aluminium cans are collected, melted, and shaped into new cans. *(3 marks)* (a) Name the two changes of state in this loop. (b) Why does melting not spoil the aluminium for making new cans? (c) Explain why this recycling loop is built on a reversible change.

Q13. On a hot day, an ice cream melts into a puddle, and an egg in the same sun stays cooked after being fried. *(3 marks)* (a) Classify the change to the ice cream. (b) Classify the change to the egg. (c) Explain the difference between the two changes.

Q14. SCENARIO — A class measures how much salt dissolves in 50 mL of water, repeating the test for three trials. The results are: trial 1, 17 g; trial 2, 18 g; trial 3, 25 g. *(3 marks)* (a) Do the three readings agree with each other? Explain your judgement. (b) Which reading does not fit the pattern? (c) Suggest one place the measurement could have gone wrong in that trial.

Q15. A student writes: “Evaporating is irreversible, because once the water has evaporated it is gone.” Explain why this is wrong. *(3 marks)*

Q16. A friend stirs sugar into water and says: “The sugar has disappeared, so dissolving must be irreversible.” Use the particle model of a solution to explain why your friend is wrong, and name one way to recover the sugar. *(4 marks)*

Practical — how much salt dissolves in 50 mL of water?

> **PRACTICAL** — this page plans or analyses work done in the classroom, laboratory or field. It is not a substitute for doing it.

Question: How much salt dissolves in 50 mL of water at room temperature? Where could the measurement go wrong?

Equipment: a 250 mL beaker; a 50 mL measuring cylinder; a balance; table salt; a stirring rod; three small dishes or papers for weighing; a paper towel; tap water at room temperature.

Safety: This activity uses only salt and water, but glass beakers can break and spilled water makes floors slippery. Handle the beaker gently, and wipe up any spills straight away. A teacher needs to be with you for this activity.

Risk	How we stay safe
A broken glass beaker	Carry it gently; tell the teacher straight away if it breaks.

Risk	How we stay safe
Water or salt spilled on the bench or floor	Wipe spills up straight away with a paper towel.
Salt rubbed into eyes	Do not touch your eyes; wash hands after the activity.

Variables (the things we change, measure and keep the same):

Variable	Choice
The one we change	nothing — we repeat the same measurement three times to check it
The one we measure	the mass of salt that dissolves before salt is left at the bottom (g)
The ones we keep the same	50 mL of water; the same salt; 5 g portions; the same stirring (20 stirs per portion); the same water temperature

Method:

1. Use the measuring cylinder to measure 50 mL of tap water. Pour it into the beaker.
2. Weigh a 5 g portion of salt on a dish or paper. Tip it into the beaker.
3. Stir 20 times. If all the salt dissolves, weigh and add the next 5 g portion and stir again.
4. Keep adding 5 g portions until salt stays at the bottom of the beaker even after 20 stirs. Stop there.
5. Work out the mass dissolved: count the portions that dissolved, and multiply that number by 5 g. Record it.
6. Tip the salt water away, rinse the beaker, and repeat steps 1–5 until you have three trials.

Results: record your readings in a table like this one.

Trial	Portions that dissolved	Mass dissolved (g)
1		
2		
3		

Compare your three trials. Do the readings agree with each other? If one reading is a long way from the others, that is the trial to check and re-measure.

Thinking about the results:

1. Why did the salt stop dissolving in the end, even with stirring?
2. Look at your three trials. If one reading does not fit the other two, suggest two places the measurement could have gone wrong in that trial (think about weighing, pouring, counting portions and reading the cylinder).
3. At the end of a trial the water looks cloudy with salt at the bottom. A classmate says the cloudiness is dissolved salt. Use what you know about solutions to explain why the cloudiness is salt that has **not** dissolved.

Make a claim and defend it. Finish this writing frame in full sentences:

- I claim that 50 mL of water dissolves about ____ g of salt.
- My evidence is ____ .
- I trust (or do not trust) my readings because ____ .
- One place the measurement could have gone wrong is ____ .

Answers

Q1 (a) Melting is reversible because the solid can be frozen back again. (b) Burning is irreversible because it makes a new substance. (c) To recover a dissolved solute, evaporate the water. — any sensible sentences. **Q2** (a) Melting. (b) Freezing. (c) Evaporating. (d) Condensing. **Q3** (a) Reversible. (b) Put the water in a freezer (cool it below its freezing point). (c) Freezing. **Q4** (a) Solute: sugar. Solvent: water. (b) Reversible. (c) Evaporate the water; the sugar is left behind and recovered. **Q5** (a) Water and oxygen (from the air). (b) Rust. (c) Rust is a new substance and cannot be turned back into iron. **Q6** (a) It melts — a change of state. (b) Cool it down; it hardens back into solid chocolate. (c) Burning makes new substances (black lump, smoke); cooling them does not give back chocolate. **Q7** (a) Reversible — melted butter can be hardened again by cooling. (b) Irreversible — baked bread is a new substance; it cannot turn back into dough. (c) Reversible — ice can be melted and frozen back again. (d) Irreversible — burning makes new substances (ash and smoke). **Q8** (a) The wax melts near the flame. (b) Cooled wax hardens again, so the original wax is recovered — a change of state. (c) The wick burns. (d) Burning makes new substances; the burned wick cannot be un-burned. **Q9** (a) Evaporate the water (evaporating dish, or a warm shallow dish); the salt is left behind as crystals. (b) Catch the water vapour and condense it (cool it), and it turns back to liquid fresh water. (c) Both work because dissolving and changes of state are reversible — no new substance forms. **Q10** (a) Salt and sugar. (b) Sand (sinks as grains) and oil (floats in a layer). (c) Insoluble. **Q11** (a) Sugar. (b) 18 g. (c) 100 − 18 = 82 g more. (d) Cloudiness is sand that has not dissolved, spread through the water; it settles out, and a dissolved substance would not settle or cloud the water. **Q12** (a) Melting (solid to liquid) and freezing/hardening (liquid to solid). (b) Melting is a change of state; the aluminium stays aluminium, so it is as good as before. (c) The change can be undone and redone — the same metal is recovered and reused each time around the loop. **Q13** (a) Reversible (melting; it can be frozen again). (b) Irreversible (cooking; a new substance forms). (c) Melting is a change of state with no new substance; cooking makes new substances that cannot be turned back. **Q14** (a) Not quite — 17 g and 18 g are close, but 25 g is a long way from them. (b) Trial 3 (25 g). (c) For example: salt was spilled into the beaker without being counted, a portion weighed more than 5 g, stirring was stopped too soon, or the cylinder was misread. — any one. **Q15** Evaporating is a change of state; the water is now a gas, not gone. Cooling (condensing) the vapour turns it back to liquid water, so the original substance is recovered — the change is reversible. **Q16** The sugar has not disappeared; its particles spread out between the water particles, which is why it cannot be seen (the water still tastes sweet). Evaporate the water and the sugar is left behind, so dissolving is reversible.

Worked solutions

Q1 *(3 marks: 1 each)* (a) A reversible change can be undone, so the original substance is recovered — for example, melting. *1 mark* (b) An irreversible change cannot be undone, because a new substance forms — for example, burning. *1 mark* (c) To recover something means to get the original substance back — for example, recovering salt by evaporating the water. *1 mark*

Q2 *(4 marks: 1 each)* (a) Melting. *1 mark* (b) Freezing. *1 mark* (c) Evaporating. *1 mark* (d) Condensing. *1 mark*

Q3 *(3 marks: 1 each)* (a) Reversible — the water can be turned back into ice. *1 mark* (b) Put the water somewhere cold, such as a freezer, so it freezes. *1 mark* (c) Freezing. *1 mark*

Q4 *(3 marks: 1 each)* (a) The solute is the sugar; the solvent is the water. *1 mark* (b) Reversible — the sugar is still there, dissolved. *1 mark* (c) Evaporate the water; the sugar is left behind and recovered. *1 mark*

Q5 *(3 marks: 1 each)* (a) Water and oxygen from the air. *1 mark* (b) Rust. *1 mark* (c) Rust is a new substance with different properties, and it cannot be turned back into iron. *1 mark*

Q6 *(3 marks: 1 each)* (a) It melts — a change of state from solid to liquid. *1 mark* (b) Cool it down and it hardens back into solid chocolate (freezing). *1 mark* (c) Burning makes new substances; cooling the black lump and smoke will not give chocolate back. *1 mark*

Q7 *(4 marks: 1 each)* (a) Reversible: melted butter hardens again when cooled — the original butter is recovered. *1 mark* (b) Irreversible: baked bread is a new substance; it cannot turn back into the mixture it was made from. *1 mark* (c) Reversible: ice blocks can be melted and the water frozen back into ice. *1 mark* (d) Irreversible: burning paper makes new substances (ash and smoke) that cannot be turned back into paper. *1 mark*

Q8 *(4 marks: 1 each)* (a) The wax near the flame melts. *1 mark* (b) Melting is a change of state; cooled wax hardens again, so the wax is recovered. *1 mark* (c) The wick burns. *1 mark* (d) Burning makes new substances; a burned wick cannot be un-burned. *1 mark*

Q9 *(3 marks: 1 each)* (a) Evaporate the water — for example in an evaporating dish — and the salt is left behind as crystals. *1 mark* (b) Condense the water vapour by cooling it, and it turns back into liquid fresh water. *1 mark* (c) Both recoveries work because dissolving and changes of state are reversible changes: no new substance forms, so the originals can be got back. *1 mark*

Q10 *(3 marks: 1 each)* (a) Salt and sugar dissolve. *1 mark* (b) Sand and oil do not; the sand sinks as grains while the oil floats in a layer on top. *1 mark* (c) Insoluble. *1 mark*

Q11 *(4 marks: 1 each)* (a) Sugar — the tallest column. *1 mark* (b) 18 g. *1 mark* (c) 100 g − 18 g = 82 g more sugar than salt. *1 mark* (d) The cloudiness is sand grains spread through the water; they settle to the bottom, and a dissolved substance stays spread out and would not settle or make the water cloudy. *1 mark*

Q12 *(3 marks: 1 each)* (a) Melting (solid to liquid) and freezing (liquid to solid) — the metal hardens as it cools. *1 mark* (b) Melting is only a change of state, so the aluminium stays aluminium and is just as good for making cans. *1 mark* (c) The loop depends on recovering the same substance: the change of state is reversed each time, so the metal is reused instead of lost. *1 mark*

Q13 *(3 marks: 1 each)* (a) Reversible — melting; the puddle can be frozen back into solid ice cream. *1 mark* (b) Irreversible — cooking; the fried egg is a new substance. *1 mark* (c) Melting is a change of state and makes no new substance, so it can be undone; cooking makes new substances that cannot be turned back. *1 mark*

Q14 *(3 marks: 1 each)* (a) Not quite: 17 g and 18 g are close together, but 25 g is a long way from them, so the readings do not all agree. *1 mark* (b) Trial 3 (25 g) does not fit the pattern. *1 mark* (c) Any one sensible source of error — for example, extra salt was spilled into the beaker without being counted, a 5 g portion was wrongly weighed, the water was not stirred enough before stopping, or the measuring cylinder was misread. *1 mark*

Q15 *(3 marks)* Evaporating is a change of state: the liquid water becomes water vapour (a gas). *1 mark* The water is still there as a gas, not gone. *1 mark* Cooling the vapour condenses it back to liquid water, so the original substance is recovered and the change is reversible. *1 mark*

Q16 *(4 marks)* When sugar dissolves, its particles break up and spread out between the water particles, so they are too small to see — the sugar has not disappeared (the water tastes sweet). *2 marks* A dissolved solute can be recovered: evaporate the water and the sugar is left behind, so dissolving is a reversible change. *2 marks*

Test

Topic 3 test — Chemical sciences Science 5–6 · Victorian Curriculum 2.0 · Levels 5 and 6

This is a school-designed paper. It is not a VCAA instrument. Achievement at Levels 5 and 6 is reported against the Victorian Curriculum achievement standard on teacher judgement; the marks here are one source of evidence towards that judgement.

About this test

- **Total: 30 marks** across three sections. Answer all questions.
- **Suggested time: 35 minutes.** This test is untimed: students may take as long as they need to finish it.
- **No calculator. No formula sheet. No reading time.**
- **Reading support is available.** A teacher may read any question aloud to a student who asks. Reading is not being tested.
- The paper covers Topic 3 — Chemical sciences: Chapter 07, subtopics 7A (Particles, states and mixtures) and 7B (Reversible and irreversible change).
- Science inquiry is assessed in this paper as well as chemical sciences. Inquiry items are worth **10 of the 30 marks**.

What this paper assesses

the observable properties of matter (solids, liquids and gases) can be explained by modelling the motion and arrangement of their particles; mixtures (including solutions) can be formed by combining 2 or more different substances — VC2S6U03

changes to substances may be reversible, in which case the substance may be recovered, or irreversible, in which case new substances are formed; for most substances a change of state or dissolving in water is reversible, while irreversible changes include cooking and rusting — VC2S6U04

Section A — Multiple choice (10 marks)

Answer all ten questions. Choose A, B, C or D. Each question is worth 1 mark.

Q1. Particles in a solid are: *(1 mark)*

A. Far from one another and moving fast B. Spread out and flowing past each other C. Close together and vibrating in place D. Joined into one lump with no separate particles

Q2. Which of these everyday substances is a **solution**? *(1 mark)*

A. Fruit salad B. Sea water C. Muddy water D. Soil

Q3. Why does ice (a solid) keep its shape but water (a liquid) does not? *(1 mark)*

A. Ice is much heavier than water B. Water is made of different particles than ice C. Ice has no particles inside it D. Solid particles cannot slide past each other; liquid particles can

Q4. Lemonade is made by stirring lemon juice and sugar into water. What is the name for a substance that dissolves in a solvent? *(1 mark)*

A. Solute B. Solution C. Mixture D. Liquid

Q5. A student draws a particle picture of a mixture: clumps of sand particles sit beside clumps of iron particles. Why is this a mixture and not a solution? *(1 mark)*

A. The sand has dissolved into the iron B. A new substance has been made C. The two substances are combined, and each keeps its own properties D. Both substances have become a liquid

Q6. When you push the plunger of a syringe full of WATER, the water: *(1 mark)*

A. Compresses a lot, just like air B. Does not compress much C. Heats up and turns into steam D. Expands and pushes the plunger back out

Q7. Melting ice into water is: *(1 mark)*

A. A reversible change (you can refreeze it to ice) B. Irreversible because the ice cannot be recovered C. A chemical change that makes a new substance D. Not a real change, just the ice heating up

Q8. Burning paper is: *(1 mark)*

A. Reversible if you cool the ashes down B. A physical change, like melting C. Not a real change, only the colour is different D. Irreversible (new substances are formed)

Q9. Salt is stirred into a cup of water until it dissolves. How could the salt be recovered from the salt water? *(1 mark)*

A. Filter the salt water through filter paper B. Let the water evaporate C. Pour more water into the cup D. Stir the salt water faster

Q10. Why is freezing/melting REVERSIBLE while burning is NOT? *(1 mark)*

A. Freezing uses cold and burning uses heat, so they are opposites B. Burning happens too quickly to ever be undone C. Freezing happens in nature but burning only happens in labs D. Freezing is a state change; burning is a chemical reaction that makes new substances

Section B — Short response (14 marks)

Answer all questions. Write your answers in full sentences where a question asks you to explain.

Q11. The table below describes the particles in the three states of matter. *(3 marks)*

State of matter	Arrangement of particles	Movement of particles
Solid	close together in a regular pattern	vibrate about a fixed spot
Liquid	close together, with no regular pattern	(i) __________
Gas	(ii) __________	move quickly in all directions

(a) Copy and complete cells (i) and (ii). *(2 marks)*
(b) In a gas, what is in the spaces between the particles? *(1 mark)*

Q12. Sea water from Port Phillip Bay is a **solution**. *(2 marks)*

(a) Name the **solute** in sea water. *(1 mark)*
(b) Name the **solvent** in sea water. *(1 mark)*

Q13. *(3 marks)*

(a) Classify each change as **reversible** or **irreversible**. *(2 marks)*

(b) An ice cube melting in a glass of lemonade

(ii) A steel farm gate rusting
(b) One of the changes in part (a) makes a new substance. Explain how you can tell that this change is irreversible. *(1 mark)*

Q14. A class investigates this question: *Does sugar dissolve faster in hot water than in cold water?* They do a **fair test**. *(3 marks)*

(a) Name the variable the class **changes**. *(1 mark)*
(b) Name the variable the class **measures**. *(1 mark)*
(c) Name one variable the class **keeps the same**. *(1 mark)*

Q15. SCENARIO — A class measures how long one sugar cube takes to dissolve in water at four different temperatures. Their results are listed out of order: *(3 marks)*

at 40 °C — 40 s · at 10 °C — 120 s · at 30 °C — 60 s · at 20 °C — 85 s

(a) Organise the results into a table. Label both columns and include the units. Put the rows in order from the lowest temperature to the highest. *(2 marks)*
(b) Describe the pattern the results show. Quote the figures in your answer. *(1 mark)*

Section C — Extended response (6 marks)

Q16. SCENARIO — A class investigates how much salt dissolves in 100 mL of water at room temperature. They repeat the test four times. Each repeat is called a **trial**. Their results are: *(6 marks)*

Trial	Mass of salt that dissolved (g)
1	35
2	36
3	24
4	36

(a) Three of the trials agree with one another. What do they show? Quote the figures. *(1 mark)*

(b) One reading does not fit the others.

(c) Which trial does not fit? *(1 mark)*

(ii) What should the group do next to check that reading? *(1 mark)*

(iii) State one thing that could have gone wrong in that trial to make the result lower. *(1 mark)*

(iv)

(i) Is dissolving salt in water a reversible change or an irreversible change? *(1 mark)*

(v) State how the class could recover the salt from the salt water. *(1 mark)*

Marking guide

For the classroom teacher. This paper is a school instrument: the marks are one source of evidence towards the on-balance judgement against the Levels 5 and 6 achievement standard. Mark every part as set out below. Accept any response that carries the same idea in different words; spelling and handwriting do not lose marks. There are no half-marks: each mark point is either earned or not earned.

Where the multiple-choice items come from. The band's question bank (`mcq-system/data/output/questions/L5-6_Science.csv`) holds six items keyed to `VC2S6U03` and six keyed to `VC2S6U04`, all at those codes' E01 and E02 elaborations. Section A uses five of those bank items (Q1, Q3, Q6, Q7 and Q10; the option order has been changed from the bank order, and the answer letters below are the letters as printed on the paper). In Q1, Q6 and Q7 one or more bank options carried a word above this book's word ceiling; those options are rewritten in the book's own words without changing what they test. The bank has no item on the mixtures, solutions or recovery elaborations at any difficulty, so Q2, Q4, Q5 and Q8 are new items written against the same two codes — `VC2S6U03` (drawing on `VC2S6U03.E04`, `VC2S6U03.E05` and `VC2S6U03.E06`) and `VC2S6U04` (drawing on `VC2S6U04.E05`). No item draws on a code from any other band or topic; the only codes used are the two above and the inquiry codes mapped at the end of this guide.

Section A — answers (10 marks)

Q	Answer	As printed	Source
1	**C**	Close together and vibrating in place	Bank item `VC2S6U03.E01.S01.D1.V01` (options reordered; three options in the book's words)
2	**B**	Sea water	New item — `VC2S6U03`, draws on `VC2S6U03.E05`
3	**D**	Solid particles cannot slide past each other; liquid particles can	Bank item `VC2S6U03.E01.S01.D3.V01` (options reordered)
4	**A**	Solute	New item — `VC2S6U03`, draws on `VC2S6U03.E06`
5	**C**	The two substances are combined, and each keeps its own properties	New item — `VC2S6U03`, draws on `VC2S6U03.E04`
6	**B**	Does not compress much	Bank item `VC2S6U03.E02.S01.D2.V01` (options reordered; two options in the book's words)
7	**A**	A reversible change (you can refreeze it to ice)	Bank item `VC2S6U04.E01.S01.D1.V01` (options reordered; two options in the book's words)
8	**D**	Irreversible (new substances are formed)	Bank item `VC2S6U04.E01.S01.D2.V01` (options reordered)
9	**B**	Let the water evaporate	New item — `VC2S6U04`,

Q	Answer	As printed	Source
			draws on `VC2S6U04.E05`
10	**D**	Freezing is a state change; burning is a chemical reaction that makes new substances	Bank item `VC2S6U04.E01.S01.D3.V01` (options reordered)

Each correct answer earns 1 mark. There is no working required for Section A and no part-credit.

Section B — marking (14 marks)

Q11 (3 marks · 7A · `VC2S6U03`)

(a)(i) *(1 mark)* Accept: slide past one another / slide past each other / move past one another / flow past each other. (a)(ii) *(1 mark)* Accept: far apart / far from one another / spread out with large spaces between them. A regular pattern is not required; do not accept "close together" on its own. (b) *(1 mark)* Accept: nothing / empty space / nothing — the spaces are empty. Do not accept "air".

Q12 (2 marks · 7A · `VC2S6U03`)

(a) *(1 mark)* The salt. Accept "salt" or "the dissolved salt".
(b) *(1 mark)* The water. Accept "water".

Q13 (3 marks · 7B · `VC2S6U04`)

(a)(i) *(1 mark)* Reversible. (a)(ii) *(1 mark)* Irreversible. (b) *(1 mark)* Accept any response that says the change cannot be undone because a new substance has formed and the original substance cannot be recovered — for example "a new substance, rust, has formed" or "you cannot get the iron back". The response must be about the change itself, not just "it stays rusty".

Q14 (3 marks · Science inquiry · `VC2S6I02`)

(a) *(1 mark)* The temperature of the water. Accept "how hot or cold the water is".
(b) *(1 mark)* The time it takes the sugar to dissolve. Accept "the dissolving time" or "how long the sugar takes to dissolve".
(c) *(1 mark)* Any one variable held fair, for example: the amount of water; the amount of sugar; the kind of sugar (one sugar cube each time); the same stirring; the same cup or beaker. Do not accept "the temperature" (that is the changed variable) or "the time" (that is the measured variable).

Q15 (3 marks · Science inquiry · `VC2S6I04`)

(a) *(2 marks)* Award 1 mark for a two-column table with both columns labelled with units — temperature (°C) and time (s); accept "dissolving time (s)". Award 1 mark for the rows in order from lowest to highest temperature with the values paired correctly:

Temperature (°C)	Time (s)
10	120
20	85
30	60
40	40

(b) *(1 mark)* Accept any description that says the hotter the water, the less time the sugar cube takes to dissolve, quoting at least two figures — for example "the time falls from 120 s at 10 °C to 40 s at 40 °C". Do not award the mark for a statement with no figures, such as "it goes down".

Section C — marking (6 marks)

Q16 (6 marks · 7B content with Science inquiry · `VC2S6U04`, `VC2S6I03`, `VC2S6I04`, `VC2S6I05`)

(a) *(1 mark)* About 35–36 g of salt dissolved. Accept "35 g and 36 g" or "35 g or 36 g". The figures must be quoted. (b)(i) *(1 mark)* Trial 3 (24 g). (b)(ii) *(1 mark)* Repeat that trial / do the measurement again / re-test trial 3. Do not accept "cross it out and ignore it" with nothing further. Do not accept "find the average" — averaging is not taught at this band, and the book's method for repeat readings is to compare them and repeat the one that does not fit.

(b) *(1 mark)* Any one plausible error that would give a lower reading, for example: some salt was spilled before it reached the water; some salt was left in the spoon or on the paper and never added; some water was spilled; the balance was read wrongly; some salt was left undissolved and not counted. Do not accept "human error" or "they got it wrong" with no detail. (d)(i) *(1 mark)* Reversible. (d)(ii) *(1 mark)* Let the water evaporate — for example, heat the salt water or leave it in a warm place until the water has gone — and the salt is left behind. Accept "evaporate the water" or "boil off the water".

Mark summary and curriculum map

Section	Marks	Inquiry-strand marks
A — Multiple choice	10	0
B — Short response	14	6 (Q14: 3, Q15: 3)
C — Extended response	6	4 (Q16(a): 1, Q16(b): 2, Q16(c): 1)
Total	**30**	**10** (required minimum: 8)

Evidence towards the achievement-standard extracts (§4.1 of the plan of record):

Items	Code	Achievement-standard extract
Q1, Q3, Q5, Q6, Q11	`VC2S6U03`	"They relate the movement and arrangement of the particles present in solids, liquids and gases to their observable properties, and model the particles in different mixtures."
Q2, Q4, Q12	`VC2S6U03`	as above — mixtures and solutions limb
Q7, Q8, Q10, Q13, Q16(d)	`VC2S6U04`	"They classify and compare reversible and irreversible changes to substances."
Q14	`VC2S6I02`	"They plan different scientific investigations including fair tests, describe how risks and ethical issues associated with investigations have been managed, and identify cultural considerations when planning fieldwork." (evidenced here by the fair-test variables)
Q15, Q16(a)	`VC2S6I04`	"They construct representations to organise and process data and information, and describe patterns, trends and relationships."
Q16(b), Q16(c)	`VC2S6I05`	"They compare their methods and findings with those of others including identification of possible sources of error, suggest improvements to their own and others' investigations, pose questions for further investigation and select evidence to develop

Items	Code	Achievement-standard extract
		reasoned conclusions.” (evidenced here by the non-fitting reading, the repeat, and the source of error)
Q16 stimulus and method	`VC2S6I03`	“They use equipment to generate and record data, including repeat trials.”