4 MATTER IN NATURE

YOU WILL LEARN TO...

- Recognise the relationship between the states of matter and their properties.
- Explain changes in state applying the Kinetic Particle Theory.
- Draw a heating curve.
- Distinguish between homogeneous and heterogeneous mixtures.
- Identify the solute and the solvent in a solution.
- Recognise the importance of aqueous solutions, alloys and colloids.
- Prepare solutions with known concentrations in the lab.
- Propose methods for separating substances in a mixture.

- *Can you think of a substance that you have seen in all three states?*
- *What is the property of gases that allows them to expand and contract so easily?*
- *When you put a drop of red food colouring in a glass of water, why does all the water change colour after a certain amount of time?*
- *Do you know of any substance that can change from solid to gas directly, without passing through a liquid state first?*
- *If you leave a chocolate milkshake to settle for a while, what do you think will happen?*

Final task

Extracting salt: salt mines

In this unit, we propose that you carry out research into the main method of extracting one of the most widely used seasoning by humans; salt. It is possible to make your own salt at home. Are you up to it?

- How do you think we extract salt from sea water?
- Can you think of a way to extract salt from salty water?

1. THE STATES AND PROPERTIES OF MATTER

1.1. Matter

Matter is all around us. We understand that it is anything that has mass and occupies a space, that is, everything that we can find in the Universe, whether visible like a rock or invisible like air.

Although these jars look empty, there is a gaseous substance inside them: air.

1.2. The three states of matter and their properties

If we look at everything around us, we observe that matter can be found in three states; **solid** (like our desk), **liquid** (like the ink in our pen) and **gaseous** (like the air we breathe).

Let us look at some experiments that will help us demonstrate the main properties of each state of matter.

Take a stone and put it into a beaker and then into a measuring cylinder. Answer these questions:

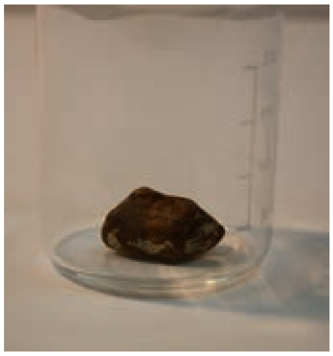
a) Does it have mass? Can you weigh it on a set of scales?

When you change the container:

b) Does the mass of the stone change?

c) Is its volume different?

d) Does its shape change?



Put 75 ml of water with some food colouring into a beaker and pour it very carefully into a measuring cylinder without dripping any of it or leaving any water in the beaker. Answer these questions:

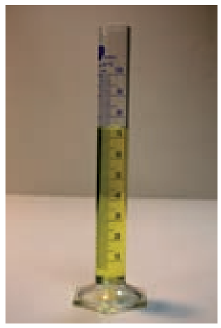
a) Does it have mass? Can you weigh it on a set of scales?

When you change the container:

b) Does the mass of the coloured liquid change?

c) Is its volume different?

d) Does its shape change?



Now look at the next pair of photos. We put a five cent coin into nitric acid (HNO_3), which creates nitrogen dioxide (NO_2), a brownish gas that can be collected in a syringe. Let's take 50 cm^3 of this gas and inject it very carefully into a different container (hermetically sealed with a rubber top). Answer these questions:

a) Does it have mass?

When we change the container:

b) Does the mass of the gas change?

c) Is its volume different?

d) Does its shape change?

1.2.1. The properties of the states of matter

The states of matter have properties that are very different from each other and that makes them behave in different ways.

Solids	
	The cube doesn't change shape or mass, even if we put it in a different container. The same is true for its volume; it doesn't change.
Liquids	
	Water changes shape if we transfer it from one container to another. However, its mass and volume don't change. So if we have a litre at the beginning, it will always be a litre.
Gases	
	The air in these balloons, as with all gases, has mass and volume. Both the volume and the shape will depend on the shape of the container holding it.

This table summarises the most important properties:

Solids	Liquids	Gases
Definite mass	Definite mass	Definite mass
Invariable shape	Variable shape	Variable shape
Constant volume	Constant volume	Variable volume
Cannot be **compressed**[1]	Cannot be compressed	Easy to compress
Impenetrable	Penetrable	Penetrable

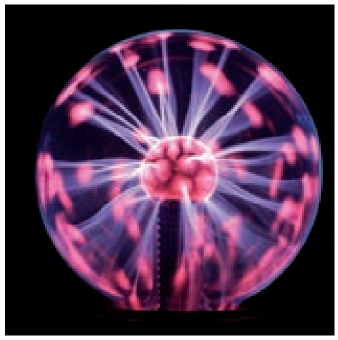
As you can see, all liquids and gases change their shape according to the container holding them. However, only gases take up the entire volume of the container they are in (we can observe this if we open a bottle of perfume in one corner of the classroom; after a short period of time, we notice the smell all around the room).

Understand

1. Are there any properties that are repeated in the three states of matter? Are there any properties that are exclusive to one state only?
2. Which state do you think has the highest density? Which has the lowest? Explain your answers.

The fourth state of matter

You may have seen a plasma ball or perhaps you have a plasma TV at home. **Plasma** is considered the **fourth state of matter.** It occurs when matter is exposed to extremely high temperatures. You may not have heard of it because it's not easy to find on the Earth, but in the Universe almost all matter is in this state. For example, it's the main component of the nucleus of stars.

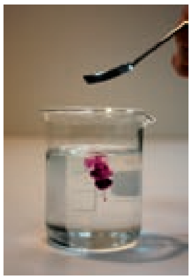


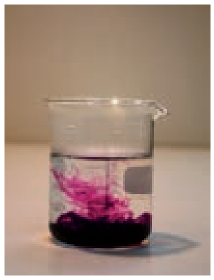
[1]**compress:** to make something smaller so it fits into a smaller space

Key concepts

- Solids have a definite mass, shape and volume.
- Liquids have a definite mass and volume, but a variable shape.
- Gases have a definite mass, but a variable volume and shape.

2. THE KINETIC PARTICLE THEORY

a) 
b) 
c) 

d) 
e) 
f) 

In the lab, we put a small amount of potassium permanganate into a beaker of water. Look at the photos to see what happens. In the top row, the water in the beaker is cold and in the bottom row, the water is hot.

If we look very closely, we can see that the particles behave in very different ways depending on the temperature of the water. It looks like the water molecules in the beaker with hot water are moving, which makes the potassium permanganate dissolve faster.

This phenomenon is the basis for the **Kinetic Particle Theory** (also called the **Kinetic Theory of Matter**) which states:

- Matter is composed of particles, invisible to the naked eye, that are in some way attracted to each other (have cohesive force).
- These particles are in constant motion. As the temperature rises, the speed of the particles increases.

Understand

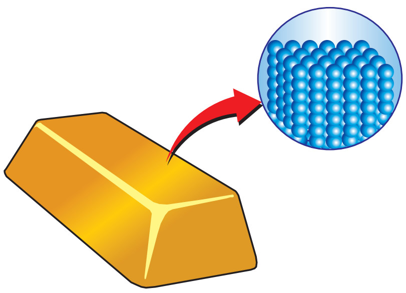
3. Explain why solids have a fixed shape and a constant volume.

Apply

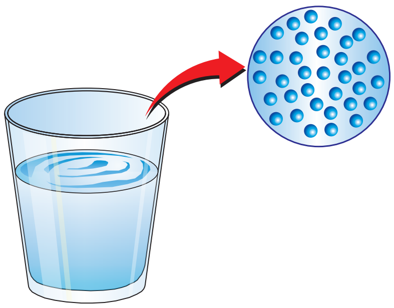
4. Why can we compress gas contained in a syringe but we can't do the same with a syringe filled with water? Explain this applying the Kinetic Particle Theory.

Analyse

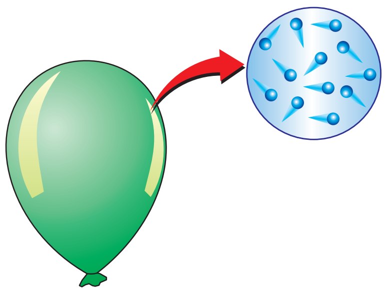
5. At a microscopic level, explain why the density of solids is only slightly greater than the density of liquids but the density of liquids is considerably greater than the density of gases.



In solids, the particles are very close together. As a result, the forces of attraction are very strong and they have a fixed position in which they can vibrate but cannot move.



In liquids, the particles are close together. The forces of attraction are not as strong as in solids, which means they can move more and vibrate. As a result, liquids can flow, change shape and are penetrable.



In gases, the particles are far apart. The forces of attraction are very weak, which means they can move freely. As a result, gases occupy all the space available in a container and take its shape.

The state of matter depends on how close together (or aggregated) the particles are. So we talk about the **state of aggregation of matter.**

3. CHANGES OF STATE

You have probably seen how an ice cube melts when you take it out of the freezer. The only thing needed is a heat supply (we might not realise it but the temperature in the room is a heat supply because the room temperature is higher than the temperature in the freezer).

On the other hand, if we want to make ice cubes, we put water in an **ice-cube tray**[2] and leave it in the freezer for a while, to cool down.

In both cases, water is going from one state of matter to another; what we call a change of state.

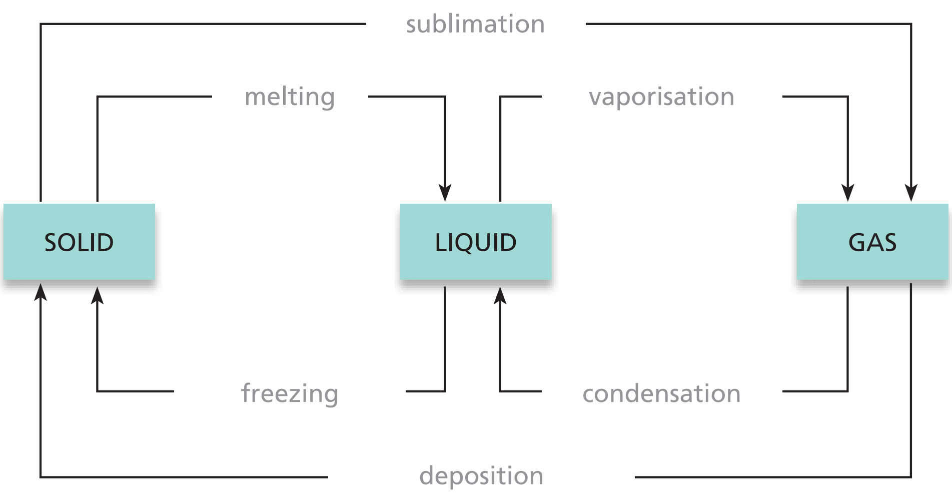
> A **change of state** is a change in the state of aggregation of matter without changing its chemical composition (the substance doesn't change).

Given that the state of aggregation of matter depends on the **arrangement**[3] of its particles, changes of state imply a modification of this arrangement but not of the type of particles (so the substance is still the same).

All substances can exist in each of the three states of matter; they can all change from one to another if the temperature changes. However, there are some substances that we only know in one state, for example, oxygen as a gas.

To observe oxygen in a liquid or solid state, we need temperatures below −183 °C for liquid oxygen and below −218 °C for solid oxygen. Such low temperatures are very rare but it's possible to reach them in laboratories.

This diagram shows the process involved in the changes of state in matter:



[2] **ice-cube tray:** a piece of metal or plastic with square shapes to make small blocks of ice

[3] **arrangement:** the way things are organised

Dry ice (solid CO_2) changes from a solid state directly to a gaseous state without becoming a liquid first.

Evaluate

6. Can you find the relationship between global warming and the melting of polar ice caps? Explain it using the concepts of temperature and the states of aggregation.

Remember

7. Listen and say the process involved in the change of state.

Key structure

Such + adjective + countable or uncountable noun to emphasise a quality

Such low temperatures

At sea level, ice melts at 0 °C.

Evalauate

8. Why do you think we refer to sea level? Research and find out.

3.1. The temperature at which changes of state occur

3.1.1. Change from solid ⇔ liquid

The change of state from solid to liquid is called **melting.** The temperature of the melting point is not the same for all substances. For example, ice (frozen water) melts at 0 °C at sea level but gold melts at 1 063 °C.

The temperature at which a solid melts and becomes a liquid is called the **melting point** and it's different for every substance.

The opposite of melting is called **freezing** (that is, changing from liquid to solid).

The temperature at which a substance changes to a solid is the same as its melting point and is called the **freezing point.**

For example, if we put a thermometer in a glass of water and we leave it by a window on a very cold day, the water will not turn to ice until the temperature is 0 °C. Remember that this is also the temperature at which ice cubes melt.

3.1.2. Change from liquid ⇔ gas

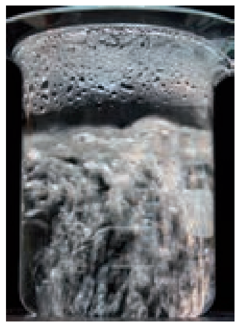
The change from liquid to gas is called **vaporisation** and can happen in two ways:

- **Evaporation:** occurs **at any temperature on the surface** of the liquid. Thanks to evaporation we can dry our clothes **in summer and in winter.**

  You can test how evaporation works by putting a small amount of perfume into a glass and leaving it outside. After a few days, all the perfume will have disappeared due to evaporation.

- **Boiling:** occurs **at a fixed temperature for every substance** in the whole mass of the liquid vigorously. We can seen this at home when we heat up (boil) water for cooking.

  The boiling point of a substance is different for every substance. For example, water boils at 100 °C at sea level, but gold boils at 2 857 °C.



The temperature at which a substance boils is called the **boiling point.** It is different for every substance.

The change of state from a gas to a liquid is called **condensation** and is the opposite of vaporisation.

Understand

9. What is the relationship between the temperature at which a substance melts and the temperature at which the same substance freezes?

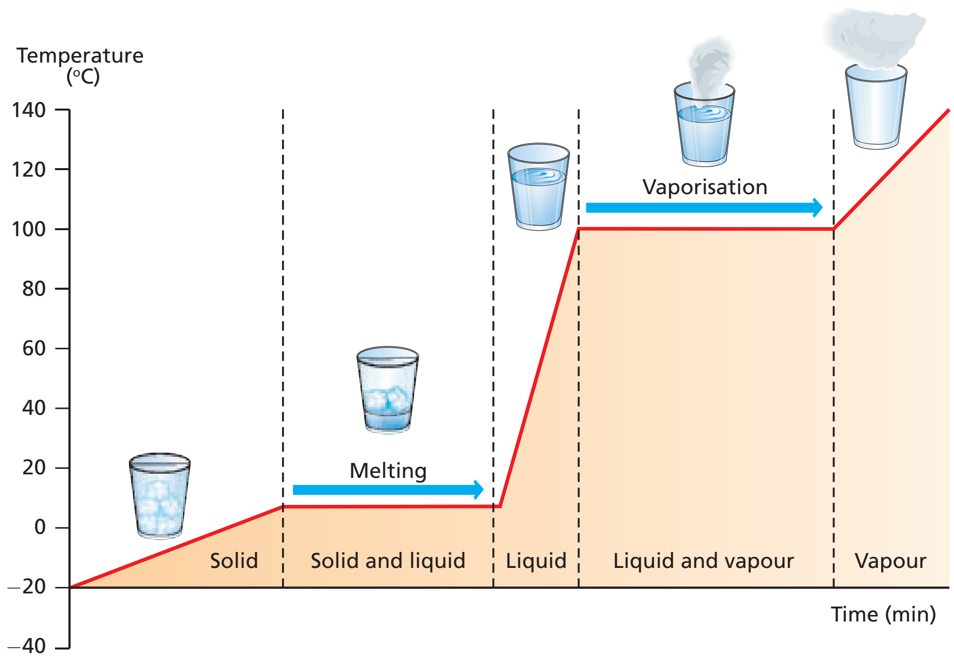
10. Does a liquid have to boil to change from liquid to gas? Explain your answer with an example.

3.2. A heating curve

If we heat ice cubes at −20 °C up to 130 °C and represent the change in temperature over time on a graph, we would expect to see the line go up little by little. However, we will see that the temperature on the thermometer remains stable at two different points in the process:

1. When it reaches 0 °C, the transformation point from ice to liquid (melting).
2. When it reaches 100 °C, the transformation point from liquid to vapour (vaporisation).

It's curious to see that while these changes of state are happening, the temperature stays the same and doesn't go up again until the transformation has happened entirely (until there is no ice left in the first case and no water left in the second). Remember that the temperature for each change of state is different for every substance.



The graph shown above is known as a **heating curve.** If we cooled something down rather than heating it up, we would get a similar graph going down instead of up, called a **cooling curve.**

Apply

11. Draw the cooling graph of water going from water vapour at 130 °C and cooling down to −10 °C.

Analyse

12. Work out from the graph above what the aggregation state of water is at 50 °C and at 125 °C.

Create

13. Describe in detail how you would carry out an experiment into the changes of state of water in the laboratory. Include all the materials you would need.

Gas *vs* vapour

We talk about **gas** to refer to substances in that state in the environment, like oxygen or nitrogen.

However, we use the word **vapour** to refer to the gaseous state of a substance that we normally find as a solid or liquid in the environment, like water vapour.

Key concepts

- Every change of state happens at a different temperature for each substance.
- The temperature of a change of state and its opposite change is the same.
- Graphs that represent temperature versus time are called heating curves or cooling graphs.

4. CLASSIFYING MATTER

If we had two beakers, one with fresh water and the other with salt water, it would be impossible to tell them apart without tasting the contents first. With matter, we distinguish between different types of substance by whether or not we can separate them using **physical methods** (for example: filtration, distillation or magnetic attraction):

- **Pure substances:** matter that cannot be separated into other substances using physical methods, for example, iron, oxygen or water.
- **Mixtures:** matter that can be separated into other substances using physical methods, for example, air, salt water or fizzy drinks.

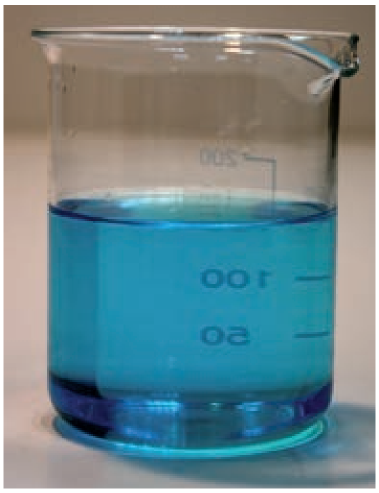
So a **mixture** is a combination of two or more pure substances in which the identities of the original pure substances are maintained.

This is how we can solve the mystery of the two beakers of water. They both look the same, but we can separate the two substances in the mixture of salt and water using a physical method. In this case, the easiest thing to do is to heat the beakers to evaporate the water. The beaker with a solid (salt) at the bottom was the mixture.

Mixtures can be:

- **Heterogeneous mixtures:** are those whose components we can see **with the naked eye**[4] or with a microscope. Their composition and properties vary from one point of the mixture to another, for example, granite or water with oil.
- **Homogeneous mixtures or solutions:** are those whose components we can't see with the naked eye or a microscope. They have the same composition and properties at every point, for example, water with sugar or air.

[4]**with the naked eye:** seen without the help of an instrument, for example a microscope



The mixture of water with copper sulphate is homogeneous. We can't see its components with the naked eye or a microscope.

In this mixture, you can easily see the water and the oil, even though we stirred it well. So, it's a heterogeneous mixture.

Key concepts

- Matter is classified into pure substances and mixtures.
- Mixtures can be separated by physical methods but pure substances can't.

Understand

14. Listen to the following mixtures. Write them down and decide if they are homogeneous (Hom) or heterogeneous (Het).

5. HOMOGENEOUS MIXTURES OR SOLUTIONS

Some mixtures are not easy to recognise because we can't see where each substance is. If we mix sugar and water, we know the sugar is there because we taste it, but we can't see it. This is a **homogeneous mixture.**

In this example, we say that the sugar has dissolved in the water, which is why it is called a homogeneous mixture or **solution.** In a solution, the particles of all the substances are mixed together so well that it's impossible to distinguish them. All solutions have two components:

- The **solvent** is the main component in a solution.
- The **solute** is the other substance or substances in a solution, found in smaller quantities.

The solvent and the solute can be found in any state of aggregation. The solvent is most often a liquid, usually water, in which case we talk about an **aqueous solution.** Here are some examples:

Solute	Solvent	Example
Solid	Liquid	Water with sugar
Liquid	Liquid	Water with alcohol
Gas	Liquid	Fizzy drinks

Although, as we said, solvents are often liquids, there are also solvents that are not liquid (they can be solid or gas). For example:

- Air and natural gas. All the components are gaseous.
- **Alloys:** solutions formed by two or more chemical elements of which one is a metal, such as bronze, steel or brass. All the components are solids.

Natural gas is a gaseous mixture.

Brass is an alloy, where all the components are solid.

Analyse

15. Read the label on a bottle of mineral water. What solutes does it contain?

16. Name two non-liquid solutions that are not mentioned on this page.

17. Find out about the mixture of gases that make up natural gas.

Analyse

18. Is the silver that jewellers use a pure substance or a mixture? What about 1, 2 and 5 cent coins? Use the Internet to find out.

Key concepts

- In a solution, the solvent is the substance found in greater quantity. The other substance is the solute.

5.1. Calculating concentrations

To work with solutions, we need to know the proportion of the solute and solvent, that is, the concentration.

The **concentration of a solution** indicates the quantity of the solute in a given quantity of a solvent or of a solution.

5.1.1. Percent composition (by mass)

There are many ways to express a concentration but the easiest and most commonly-used one is the percent composition (by mass).

The **percent composition** of a solute in a solution is the mass of solute found in 100 units of the mass of the solution. If we use grams as the units of mass:

$$\%\text{ by mass (solute)} = \frac{\text{mass of the solute (g)}}{\text{mass of the solution (g)}} \times 100$$

It's not necessary to work in grams. You just have to make sure to use the same units of mass in the numerator and denominator.

The result will not have units because it is a percentage.

A sterling silver ring

EXAMPLE EXERCISE

1. **To make a 925 sterling silver ring, a jeweller uses 15.73 g of pure silver and 1.27 g of copper. Calculate the percent composition of the solute in the alloy.**

First, we have to work out what the solute is and what the solvent is in the solution (alloy):

- Solute → copper (in a lower proportion)
- Solvent → silver (in a higher proportion)

Next, we calculate the mass of the solution from the data:

$$m\text{ (solute)} = 1.27\text{ g}$$

$$m\text{ (solvent)} = 15.73\text{ g}$$

$$m\text{ (solution)} = m\text{ (solute)} + m\text{ (solvent)} = 1.27\text{ g} + 15.73\text{ g} = 17\text{ g}$$

Finally, we substitute our values in the equation for the percent composition of the solute:

$$\%\textit{ by mass}\text{ (solute)} = \frac{\text{mass of the solute (g)}}{\text{mass of the solution (g)}} \times 100 =$$

$$= \frac{1.27\text{ g}}{17\text{ g}} \times 100 \approx 7.5\ \%$$

Therefore, 925 Sterling Silver always contains 92.5 % of pure silver and 7.5 % of another metal, usually copper, as in this case.

Apply

19. Calculate the mass of acetic acid in 10 g of a commercial vinegar with a label indicating a percent composition of 6%.

5.1.2. Mass concentration

Another common way to express a concentration relates the amount of solute to the volume of the solution.

The **mass concentration (g/L)** of a solute in a solution indicates the mass of the solute (in grams) that is dissolved in every litre of the solution:

$$g/L = \frac{\text{mass of the solute (g)}}{\text{volume of the solution (L)}}$$

Remember the relationship that exists between units of capacity and volume: if we make a cube of 1 dm and we fill it up to the top with liquid, the volume of the liquid in the cube is 1 L. So:

1 dm^3 is equivalent to 1 L

EXAMPLE EXERCISE

2. A student has to prepare an iodine alcoholic solution by dissolving 15 g of iodine in alcohol to obtain a solution with a volume of 250 mL. Calculate the mass concentration of the final solution.

As in the previous example exercise, we first have to identify the solute and the solvent:

- Solute → iodine (in a smaller quantity)
- Solvent → alcohol (in a greater quantity)

Next, given the grams of the solute (15 g), we have to calculate the volume of the solution in litres:

$$m \text{ (solute)} = 15\,g$$
$$V \text{ (solution)} = 250\,mL = 0.25\,L$$

Finally, we substitute these values into the mass concentration equation:

$$g/L = \frac{\text{mass of the solute (g)}}{\text{volume of the solution (L)}} = \frac{15\,g}{0.25\,L} = 60\,g/L$$

Therefore, the solution will have a concentration of 60 g/L.

Apply

20. Calculate the mass concentration in g/L of a solution that has 7 g of a pure substance in half a litre of water.

21. In how many litres of water would we have to dissolve 100 g of salt to obtain a solution with a mass concentration of 5 g/L?

22. What is the mass concentration of a solution with 12 g of potassium chloride and 300 cm of water?

23. What is the percent composition of sugar in water if it contains 30 g of solute in 600 g of water?

24. We know that the mass concentration of sodium chloride in a solution is 8 %. How many grams of sodium chloride is dissolved in 75 g of the solution?

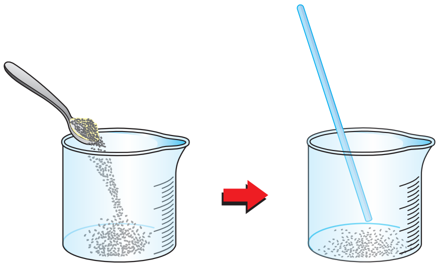
Key concepts

- The mass concentration of a solution gives the quantity of solute in a certain quantity of a solution.
- There are different ways to express the concentration: in percent composition (by mass) or in g/L.

5.2. Preparing solutions

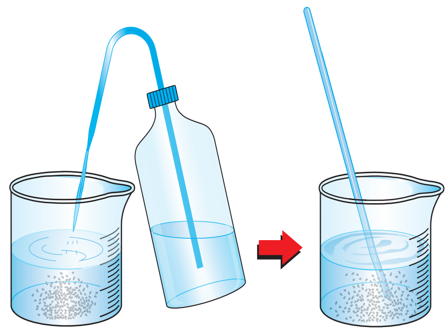
Physiological saline solution is made with sodium chloride ($NaCl$, otherwise known as salt) in water with 0.9% mass and is used a lot in hospitals. Here's how to prepare 100 mL.

1. **Calculate the mass of the solute** ($NaCl$) that we need: to do this, we just have to remember that 0.9 % solute means that for every 100 g of (saline) solution, there is 0.9 g of $NaCl$.

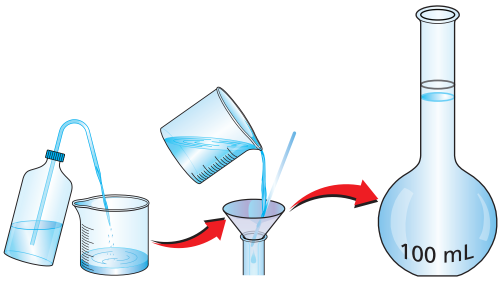


2. **Weigh the NaCl** (0.9 g) with a digital scale, using a beaker.

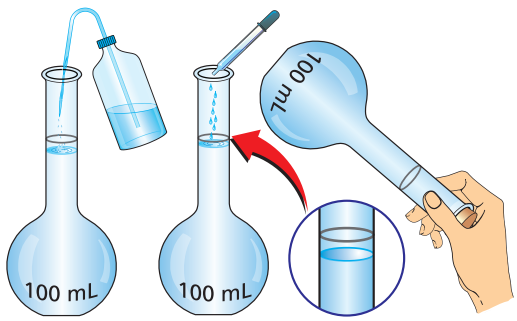
3. **Add a little distilled water** to the beaker (in this case about 20 mL is sufficient). **Stir** well with a glass rod until it dissolves completely.



4. With a funnel, **pour the solution** you have just obtained into a graduated flask of the volume you need (100 mL). **Rinse the beaker** a few times to get out all the remains of the NaCl.

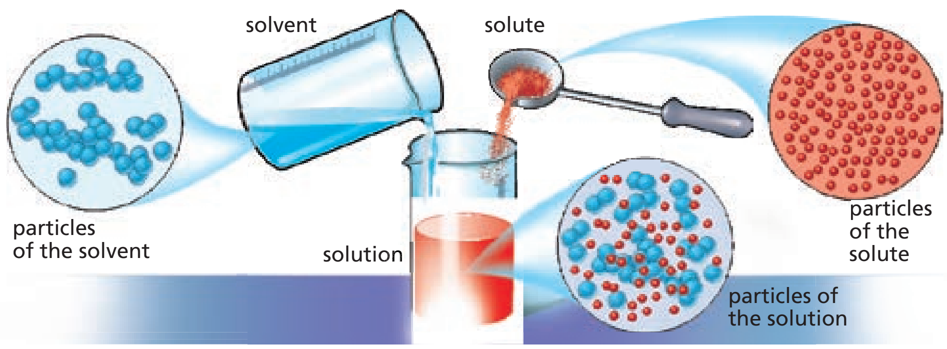


5. **Add water to the flask up to the mark.** We use a dropper to reach the exact mark of volume required so that we don't go over. **Put a top** on the graduated flask and **shake** the contents well.



5.3. Solutions and the Kinetic Particle Theory

When we mix two substances to make a solution, the solute particles leave their original position and get distributed among the particles of the solvent; that way, the particles of the solute move in to occupy positions that were previously occupied by solvent particles.

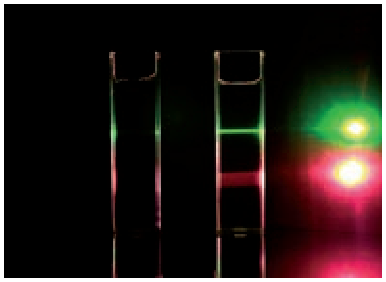


Key concepts

- In the process of making a solution, the particles of the solute spread out among the particles of the solvent.

6. A VERY SPECIAL MIXTURE: COLLOIDS

If we look at the two measuring cylinders in the photo, we can see that the laser beam doesn't behave in the same way in both cylinders; we cannot see its trajectory in the cylinders on the left but, we can in the one on the right.



Sometimes mixtures look like 'real' solutions but if we experiment on them with light, as shown in the experiment in the photos, we can see that they aren't solutions. You might observe this phenomenon when you see a car driving with the lights on in fog. The light from the headlamps spreads out in many directions because of the water drops in the air. It makes it easier to see the beams and even the water in the air. This phenomenon is called the **Tyndall effect** and is caused by the fact that fog, just as the water in the cylinder on the right in the photo, is a **colloidal[5] dispersion.**

[5] **colloid:** colloid comes from the Greek word *kolas,* which means something that can stick; it refers to the principal property of a colloid: it sticks together or clots

Colloidal dispersions are a special type of mixture (between a homogenous and heterogeneous mixture) in which the solute particles (invisible to the naked eye) are bigger than the particles in a solution (homogeneous mixture) but smaller than the particles in a heterogeneous mixture.

However, we wouldn't see the beam passing through a 'real' solution, such as water or salt. That is, the beam of light is only visible when it passes through a colloidal dispersion, not when it passes through a solution.

We can find lots of colloidal dispersions in our everyday lives: soaps, butter, creams, foams, fog, aerosols, clouds, jelly...

The Tyndall effect is easy to see on foggy days due to the dispersion of the light from the headlamps through the tiny droplets of water in the air.

Apply

25. Can you think of another everyday situation where you can see this effect?

Understand

26. Search the Internet to find examples of colloids in food products.

27. Find out about the main applications of colloidal dispersions. Make a mural or poster with several examples with photos explaining the most common uses of these dispersions.

Key concepts

- A colloidal dispersion is not a homogeneous mixture, even though it might look like it.

7. METHODS FOR SEPARATING MIXTURES

[6]**filings:** very small pieces of metal made when the metal is filed

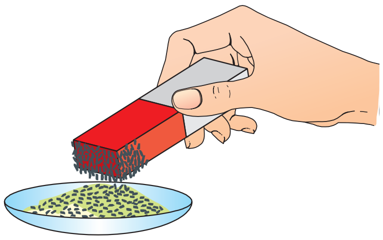
[7]**fastener:** a device like a button used to close a bag

[8]**pore:** a very small hole

If you had a mixture of iron and aluminium **filings[6],** how would you separate them? We often find that we have homogeneous and heterogeneous mixtures in which we have to separate the components without altering the nature of the pure substances in the process.

The most common methods for separating the components of a mixture are:

7.1. Magnetic separation



Magnetic separation

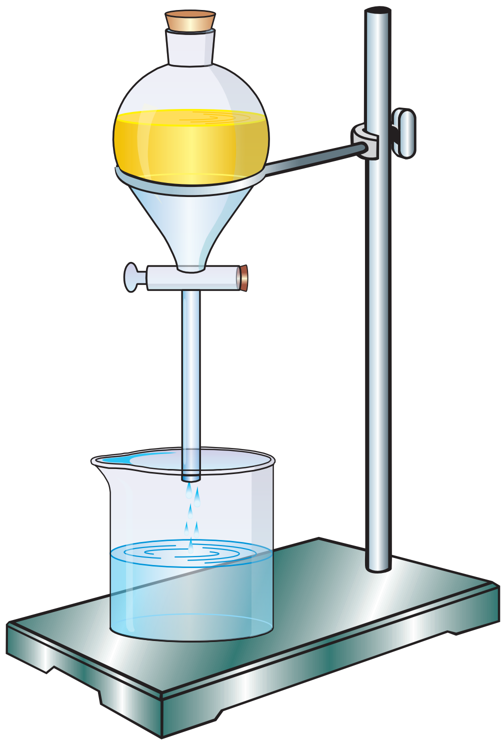
You may have thought of using a magnet as the easiest and quickest way to separate the iron from the aluminium and you'd be right. If you don't have a magnet, you could use magnetic **fasteners[7]** on handbags or the covers for mobile phones as they both possess magnetic properties. The iron is attracted to the magnet and the aluminium isn't.

This method for separating the two components of a heterogeneous mixture is called **magnetic separation.** It can only be used when one of the components has **magnetic properties** (like iron) and the others don't.

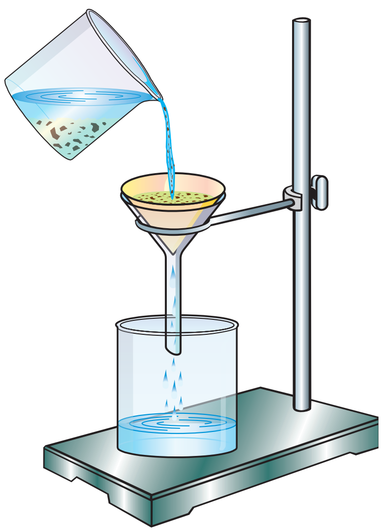
7.2. Decantation

We use decantation for **liquids with different densities** that don't mix together (immiscible), such as oil and water. For this, you use a decantation funnel:

1. Pour the mixture into the funnel, making sure beforehand that you have closed the tap at the bottom (turned it to a horizontal position) so that the mixture doesn't come out.
2. Leave the mixture to settle until the two liquids have separated.
3. Put a beaker below the funnel and open the tap. The denser liquid (the one at the bottom of the mixture) will begin to flow out.
4. Close the tap when all the denser liquid is out.
5. The less dense liquid will stay in the funnel. To get it out, simply pour it out the top of the funnel so it doesn't mix with the residue of the other substance that has stayed in the tap.



Decantation



Filtration

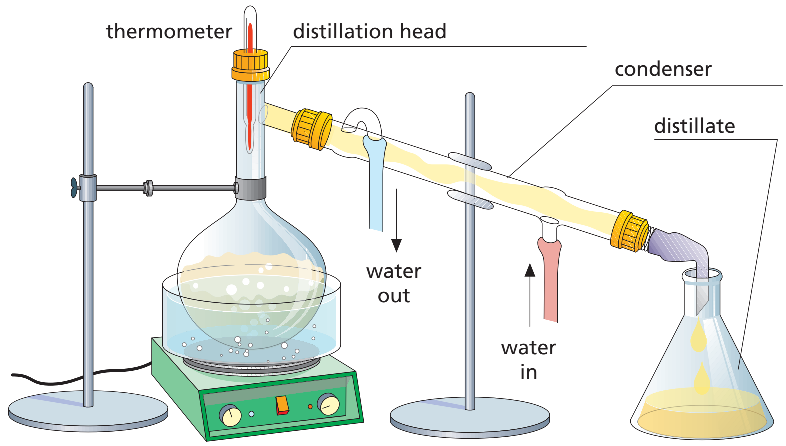
7.3. Filtration

We use this method to separate **a solid from a liquid** that hasn't dissolved (insoluble), such as sand and water. To do this, we pass the heterogeneous mixture through a filter with the correct **pore[8]** size (smaller than the particles that we want to separate). The filter usually goes through a funnel.

7.4. Distillation

We use distillation to separate **soluble liquids** with very **different boiling points** from each other, such as water and alcohol.

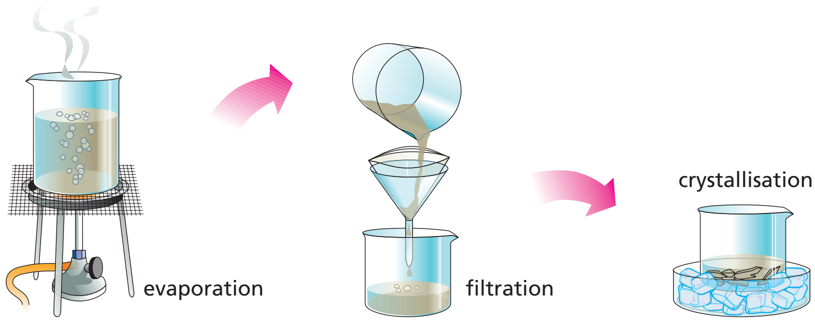
Put the mixture into a round-bottom distillation flask and heat it up. When it reaches the lower boiling point of one of the two substances, this substance will turn to vapour and pass through the condenser, where it will cool down and condense. The resulting liquid, called the **distillate,** is collected in a container (a beaker, for example).



Distillation

7.5. Evaporation and crystallisation

We use this method to separate a **solid dissolved in a liquid,** such as salt in water. The process starts with evaporating (naturally or forced via heat) the solvent and ends with the depositing of the solid in the form of crystals at the bottom of the container (usually a crystalliser). The slower the evaporation of the solvent, the larger the crystals will be.



Evaporation and crystallisation

7.6. Chromatography

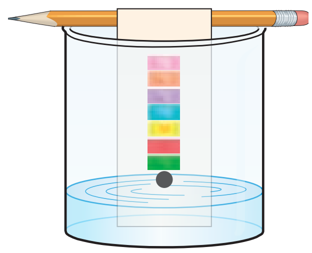
We use this to separate two components in a mixture according to how **soluble** they are in a **particular solvent.**

One of the simplest techniques is chromatography in paper, which uses a strip of filter paper.

Put a tiny drop of the mixture onto the strip of filter paper and put the bottom part of the paper into a solvent, such as alcohol. This will move slowly up the filter paper by capillary action, pulling the different components of the mixture with it.

Because each component dissolves to a greater or lesser extent in a particular solvent, those that are higher up the strip at the end of the process are more soluble than those at the bottom.

This method can be used, for example, to separate photosynthetic pigments (chlorophyll and carotenes) present in spinach and other vegetables.


Chromatography

Apply

28. How would you separate the components in a mixture of oil and vinegar?

29. How would you separate the components in a mixture of sawdust and water?

30. Can you think of a way to separate the different colours used to make up the black ink in a marker pen? Explain your answer.

31. How would you separate the components in a mixture of sulphur and water, given that sulphur is insoluble in water?

Key concepts

- The components of mixtures can be separated using different methods.
- The most common methods are magnetic separation, decantation, filtration, distillation, evaporation and crystallisation and chromatography.
- The separation methods make use of the different properties of the substances in a mixture.

The states and properties of matter

32. Have you ever seen the same substance in the three states of matter? What substance was it?

33. Indicate which state of aggregation the following substances are in:

Oxygen in the air, mercury in a thermometer, a concrete block, carbon dioxide expelled by breathing, oil, a stainless steel fork and the water from a lake in summer.

Which of them can be compressed?

34. Are the following statements true or false? If false, modify the statement to make it true in your notebook.

a) The particles in a liquid have complete freedom of movement.

b) Liquids and solids are not compressible.

c) Liquids tend to occupy the entire volume of their container.

d) The forces of attraction between the particles of gas are very strong.

e) The particles of solids occupy fixed positions.

The Kinetic Particle Theory

35. Why are states of matter also called states of aggregation?

36. How does the Kinetic Particle Theory explain the process of evaporation?

37. Explain why liquids can adopt the shape of their container.

38. Liquids and gases are called fluids. Look up the meaning of the word fluidity in a dictionary or on the Internet and explain why they are called fluids. Why are solids not called fluids?

39. Complete the following statements.

a) Matter can be found in three ___ of aggregation: ___, ___ and ___.

b) In ___, the forces of ___ are very strong, so their particles are close together. Therefore, their shape and volume are ___.

c) In ___, the forces between particles are strong, although less than in solids. They can move, and as a result their shape is ___, although their volume is ___.

d) In ___, the forces of ___ are very weak and the particles are far apart. As a result, their shape and volume are ___.

40. Keeping in mind the Kinetic Particle Theory, explain the change of state from solid to liquid.

Changes of states

41. Copper melts at 1 083 °C and boils at 2 567 °C.

a) At which state of aggregation will it be at 500 °C?

b) And at 2 700 °C?

c) And at 1 600 °C?

42. Explain the process that lets us perceive the scent of a perfume in a bottle that is open.

43. Why does the bathroom mirror fog up when we have a shower? Explain your answer.

44. Given the following table, answer the questions:

Substance	*T* fusion (°C)	*T* boiling point (°C)
Iron	1 536.5	2 863
Gold	1 063	2 857
Mercury	−38.4	357
Ethanol	−117.3	78.5
Chloroform	−63.5	61.7
Water	0	100
Oxygen	−218	−183
Helium	−272	−260
Propane	−187	−45

a) Which substances will be solid at a room temperature of 25 °C?

b) Which of them will be in a liquid state? And in a gaseous state?

c) In which state is ethanol at −20 °C? And at 85 °C?

d) In which state is helium found at −150 °C? And at −270 °C?

e) In which state is iron at 1 300 °C? And at 3 000 °C? And at 2 500 °C?

Classifying matter

45. Classify the following mixtures as homogeneous or heterogeneous:

Bronze, seawater, smoke, beach sand, steel, granite, water with petrol, alcohol with water and salt with iron filings.

46. Complete the following statements in your notebook:

a) In a solution, the substance found in a lower proportion is called the ___ and the one in a higher proportion is the ___.

b) If we evaporate the solvent from a solution very slowly, we get large ___.

c) In ___ mixtures, we can distinguish the components, while in ___ mixtures this is not possible, even with a microscope.

Homogeneous mixtures or solutions

47. The composition of a fizzy drink is: 10% sugar, 45% water, 30% orange juice, 14.9% carbon dioxide and 0.1% preservatives and dyes. Indicate which one is the solvent, which are the solutes and the states of each one.

48. 15 g of sugar and 5 g of salt are dissolved in 230 g of water. Calculate the percentage of mass of each solute in the resulting solution.

Methods for separating mixtures

49. Say how you would separate the components of the following mixtures:

a) alcohol with sand

b) water with oil

c) sand with iron filings

d) water with salt

50. Match each laboratory tool with the separation technique.

Tool: crystalliser, magnet, funnel with a stopcock, coolant and a paper strip.

Technique: distillation, chromatography, magnetic separation, evaporation and crystallisation and decantation.

READ AND UNDERSTAND SCIENCE

[…] In the museum, there was also a huge block of galena – it must have weighed a ton – that created some grey cubes with sides of ten or fifteen centimetres, inside which there were often smaller cubes. And, through my pocket magnifying glass, I could see that within these there were other smaller cubes that apparently sprang from them. When I mentioned this to Uncle Dave, he told me that galena was a cubic mineral through and through and that if I could see it a million times bigger, I would still see smaller cubes associated with the previous ones, and so on. The shape of the galena cubes, of all crystals, said my uncle, was the expression of how its atoms were arranged, of the rigid structures in three dimensions or grids that were formed […].

O. Sacks. *Uncle Tungsten.* Ed. Anagrama. (translated and adapted)

a) What type of solid is discussed in the text? Explain your answer.

b) What is the relationship between the cubes that is easily visible in this mineral and its structure at microscopic level?

c) What is the composition of galena?

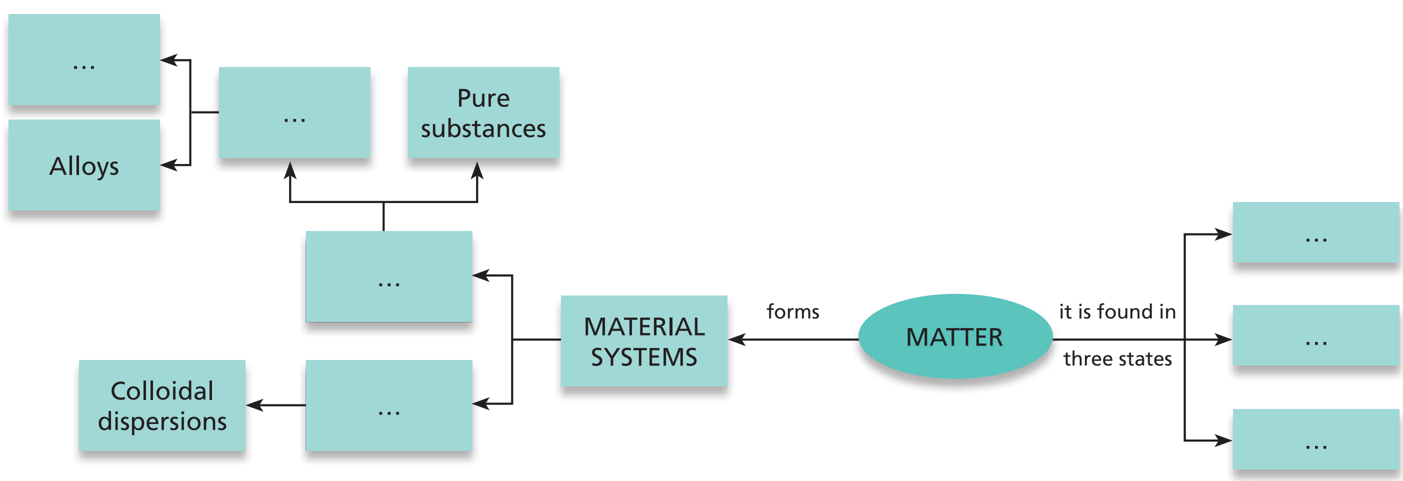
d) Search on the Internet or in an encyclopaedia for the main uses of this mineral.

e) Look for other examples of minerals with an external appearance similar to galena.

STUDY SKILLS

You can record your summary and listen to it as many times as you like for revision purposes.

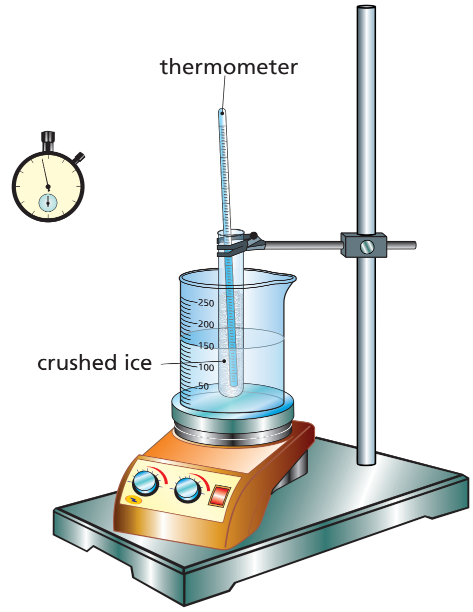
- Create your own summary of the unit using the Key concepts. Add any other important information.
- Copy the following diagram and add the missing information to create a conceptual map of the unit.



- Create your own scientific glossary. Include the following words: *matter, Kinetic Particle Theory, melting point, boiling point, solidification, evaporation, condensation, pure substances, heterogeneous mixtures, homogeneous mixtures, solutions* and *colloids.* Add any other terms you consider important.

Obtaining a heating curve

In the following science experiment, we are going to study the changes of state of water when we heat ice to get water vapour.



Materials

- A beaker of 250 mL
- A thermometer
- A test tube
- A hotplate and magnetic stirrer
- A stand with base and a clamp nut
- Crushed ice and water

Procedure

1. Fill the beaker with approximately 150 mL of water and put in the magnetic stirrer.
2. Fill the test tube two thirds full with crushed ice and put this in the beaker with water. Attach it firmly using the clamp nut.
3. Insert the thermometer into the test tube, so that the bottom (bulb) is well covered with ice, but without allowing it to touch the bottom of the test tube.
4. Turn on the hotplate and the magnetic stirrer. Make sure the temperature is neither too hot nor too cold.
5. Turn on the timer and write down the temperature on the thermometer at certain intervals of time (for example, every 30 s).
6. Turn the heat off when the thermometer is near its peak.

Analysis of the results

a) Gather the data of both the temperature (in °C) and the time (in min.) in a table.

b) Using the data, plot a temperature-time graph.

c) Indicate the state of aggregation for each section of your graph.

d) What is the melting point of water? And the boiling point?

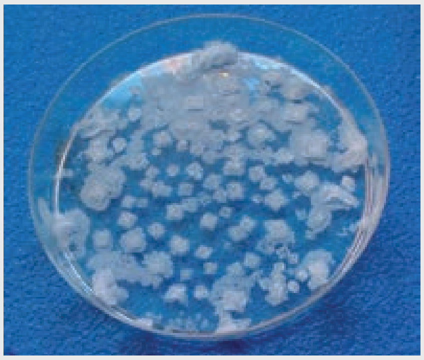
e) What happens to the temperature during the changes of states? Is the water in one or several states of aggregation?

1. Plot the heating curve for a substance X initially in a solid state at −50 °C, given that its melting and boiling points are 70 °C and 190 °C, respectively.
2. In what state of aggregation will the substance above be found at the following temperatures: 20 °C, 75 °C, 110 °C and 220 °C?

FINAL TASK

Extracting salt: salt mines

In this final task, you are going to learn how one of the most common seasonings in our everyday lives is obtained: table salt.



1. Research

a) What is a salt mine?

b) How does it work? Explain using your own words.

c) What other chemical elements are often added to table salt?

2. Experiment

Build a home-made salt mine. To do this, fill a glass with water. Then put in a few tablespoons of salt (NaCl) and stir the mixture until the salt is completely dissolved. Pour the solution into a deep dish and put it in a safe place in the house, where nobody is going to move or touch it. Leave it for a few days until you see the salt deposited at the bottom.

Repeat the experiment, leaving the dish near a heat source (a radiator in winter) and write down the changes that you observe compared with the previous experiment.

3. Presentation

a) In class, make a mural or poster showing the process of obtaining salt from the salt mine. Include a section discussing other ways to obtain salt apart from salt mining.

b) Research places in Spain where there are working salt mines and make a list in your notebook.

c) Write a short report of the results of your home-made salt mine, explaining the differences you have found between the two ways of carrying out the experiment.

d) Present the results of your experiment in class with a slide show presentation. Emphasise the differences observed in the crystals. Include real pictures of the crystals you obtained at home.

Procedure

Search for information

- Find information using the Internet or encyclopaedias about the procedure used in salt mining to get salt.
- Write down the web pages and books consulted, in the bibliography section at the end of your work.
- Consult and contrast information from various sources; don't rely on just one. Check that it is the same in all the sources.

Formulating the hypothesis

- Do you think there will be differences between the crystals obtained when there is heat?

Presenting the results

- Present the results of your experiment to your classmates.
- Take notes about the presentations they make and compare your work.

SELF-ASSESSMENT

Answer the following questions to assess your work:

1. Did you participate in the design and elaboration of the mural or poster about how salt mines work?
2. Did you make the list of the existing salt mines in Spain?
3. Did you formulate a hypothesis about the result of your home-made experiment before carrying it out?
4. Did you write the report of the results obtained in your home-made salt mine?
5. Did you make the presentation of your results clear and simple?
6. Did you include pictures of your crystals in your presentation?