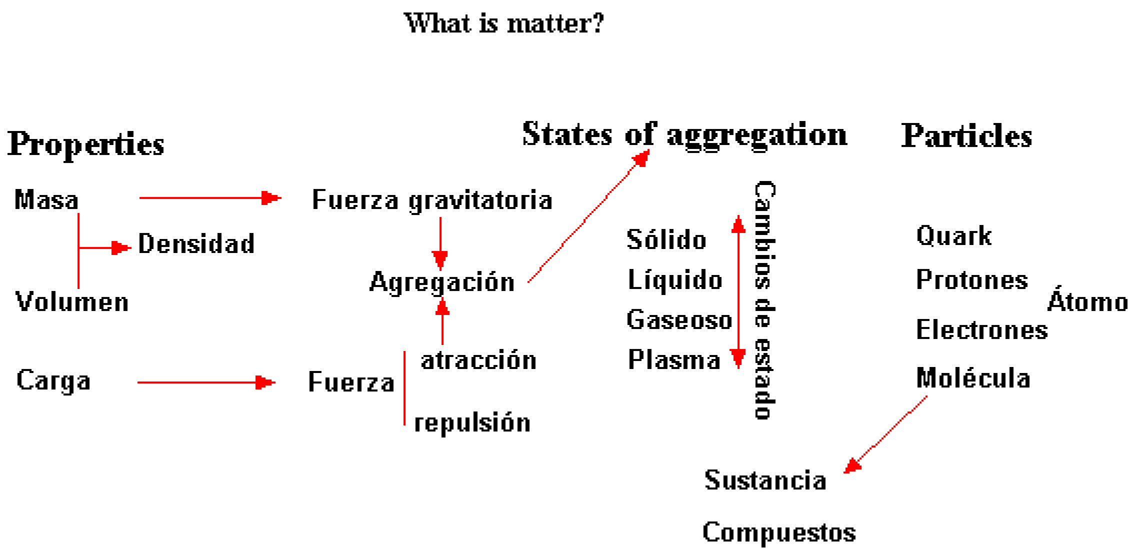
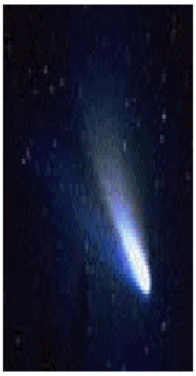
MATTER

The map of the unit matter



What is matter?



Everything we can see and touch is matter. Things that we cannot see, like air, are also matter.

We see that matter occupies a certain part of space which we call volume. In the case of the air this is not immediately evident, but the following experiment will help us to prove it.

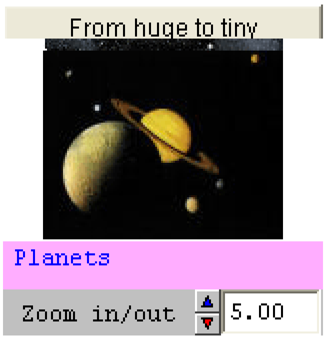
Click on "Practical experiment" read the instructions and carry out the suggested experiment.

Submerge an "empty" tube or a glass upside down in a beaker containing water. The water does not enter it because the tube is full of air, and the air occupies its own volume (for the water to enter the tube there would have to be an opening to the air at the top of the tube).

This is a general property of matter: matter occupies volume.
Another essential property of matter is that matter has mass, something which we experience every time we weigh different objects on some scales.
Not only what is at hand is matter. The planets, the sun and the rest of the stars, the galaxies...are also matter. And also at a microscopic level, cells, viruses, DNA are also matter...
We can say that everything that occupies a volume and has mass is matter.
Matter forms all the bodies in the universe.

This sequence of illustrations shows the aspect of matter on different scales: from enormous bodies to minuscule ones.

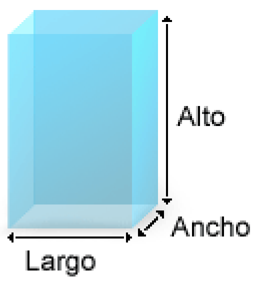


To make this journey has meant a great challenge for the human mind, which has been able to understand how matter is formed by "looking" beyond what the eyes can see. Physics transcends the senses, goes beyond common sense and by means of the scientific method investigates different material systems.

The remotest galaxies which we have seen are approximately 10,000 million light years away. This is the distance that light covers in 10,000 million years travelling at a speed of 300,000 km/s, so that in fact we are seeing them as they were then, when the Earth and the Solar system still did not exist.

At the other extreme, in the minuscule world, the distance among quarks which are in the nuclei of atoms is very small, about 0.000 000 000 000 001 m.

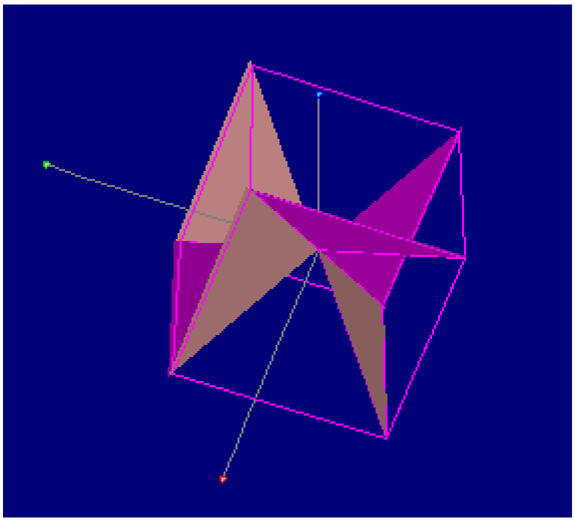
Length - Surface area – Volume



All objects have length, width and height, and they occupy a part of space (volume).

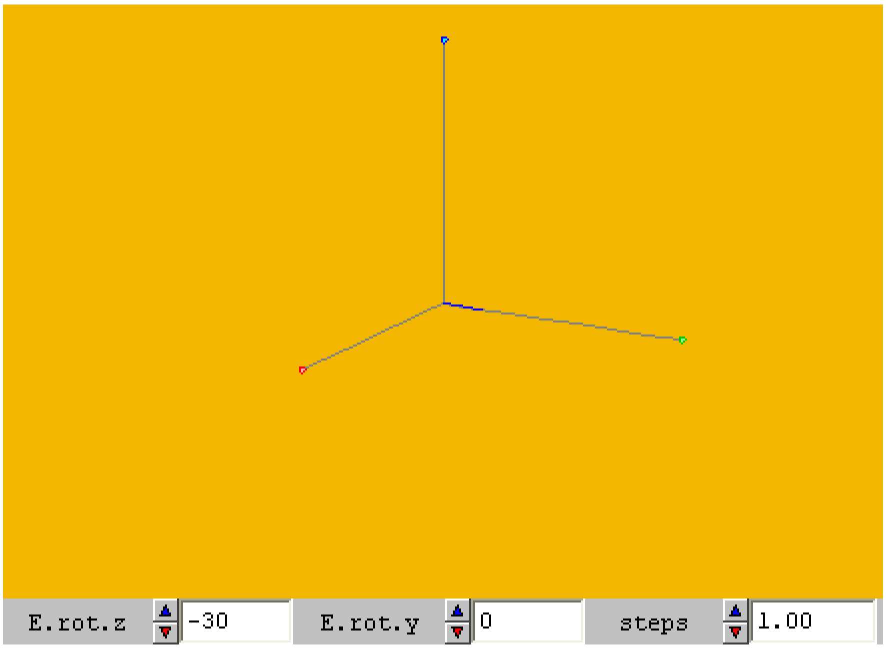
We can measure the length between different parts of the same body and the distance between different bodies.

Observe the three directions of space, the cube and the pyramids inside it. Using left click, drag and turn the object to see it better.



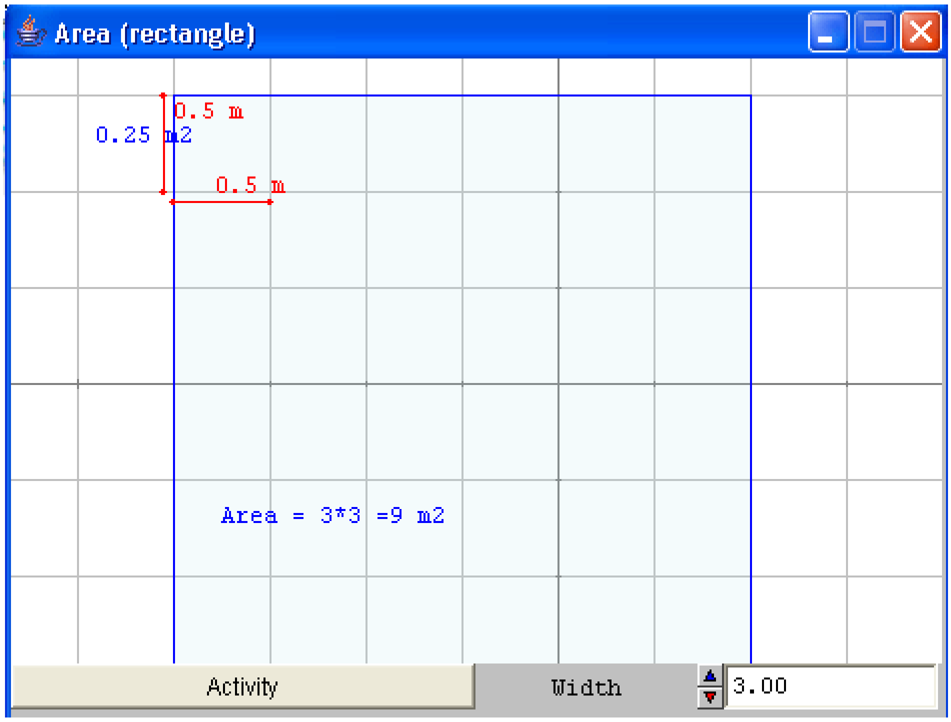
Lenght

In long bodies, like cables or roads, we are only interested in their length, because, in comparison their width and depth are very small. That is why we measure cables and roads using the unit of length, the metre (or the centimetre, kilometre, etc.). If the other dimensions are not very small we should also consider the surface area and the volume.
In the following visual you can increase the steps to form a body which is longer and longer. If you continue to increase the steps, you will see how a second dimension appears, surface area, and then another dimension, volume. Turn the object around to compare its length with the other two dimensions.



Surface area

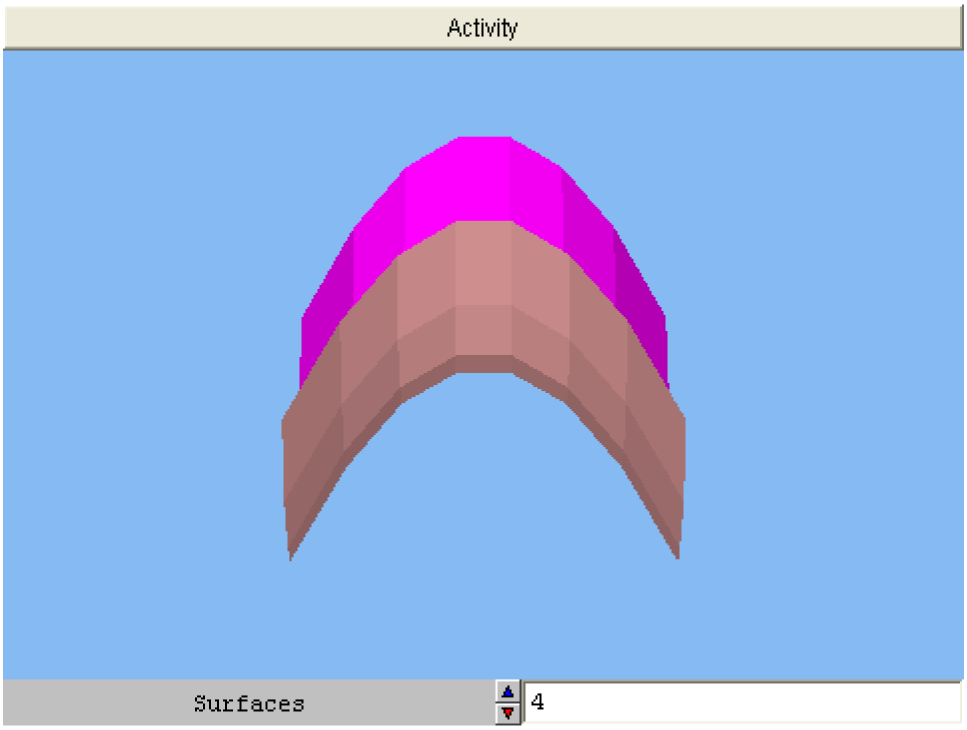
In extensive bodies like sheets, or land to cultivate or to build on, we are interested in two dimensions: length and width, but not thickness. This is why in this case the magnitude we use is surface area, the product of height and width and a number which depends on the type of figure (triangle, quadrangle, etc.). For example, the surface area (or area) of a triangle is: base x height x 0.5.



Activity: Change the width and use your calculator or the computer to calculate the area of the rectangle shown. Check that you can get the same result by multiplying the area of one tile (a square of 0.25 m2) by the number of tiles in the rectangle.

We can imagine the surface of any body like its "skin" or outside covering. When we multiply the length of this skin by the height, we multiply a number of metres by another number of metres, which gives us metres raised to the power of two, and this is why we measure sheets, land, with the unit of square metres (or square millimetres, square kilometres, etc.).

In the following application you can see different types of surfaces, which you can turn with the mouse.



Activity: If you click on the control you will see different surfaces. Click and drag to make them turn.

Volume

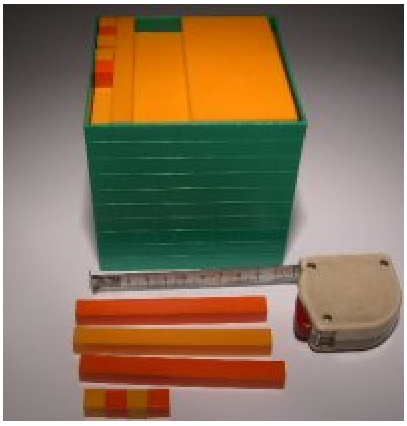
When none of the dimensions of an object is much smaller than the others, like a ball or a television, we are interested in their volume, which is the product of length by width by depth (and by a number which depends on the geometric shape of the body).

So we measure volumes with the unit of (metre x metre x metre) or cubic metre (or cubic decametre, cubic decimetre, etc.).

The volume of a solid or a liquid is due to the volume of its particles and their distribution in space - how they are arranged amongst themselves.

In contrast, the volume of a gas depends on the separation among the particles, which is very large compared with their size which is negligible.

It is difficult to compare the volume of two bodies just by looking at them. In the photographs presented below we have a cubic receptacle with a side measuring 1 dm. What volume (of air, water or whatever) can be held in the cube? The answer is 1 dm^3. Therefore we say that the receptacle has a capacity of 1 l. It seems impossible that the water in the test tube which fills it to the 1 litre mark can be contained in the cube, but it can!



This cube with a side measuring 1 dm can hold 1000 smaller cubes of 1 cm^3.
The smaller cubes are 1 cm x 1cm x 1 cm: volume = 1 cm^3.
By placing 10 of these smaller cubes in a row we can make a bar of 10 pieces: a body 10 cm or 1 dm long. If we place 10 of these bars together side by side we will have a layer of 100 pieces: an extense surface area of 100 cm^2 or 1 dm^2.
If we put 10 of these layers one on top of the other we will have a cubic body of 1000 pieces: its volume will be 1 dm^3.

Mass

Mass, an essential property of matter, is measured on scales.

The more matter a body has, the more mass it will have and the more it will weigh. Mass is expressed in kilograms (kg). For example, an apple has a mass of 0.15 kg.

But we can also use other units of mass, for example gram (g), tonne (t) or gigagram (Gg), etc.

The mass of a body only depends on the mass of its particles: it is the sum of the mass of all of them.

Organization of matter: gravitational force

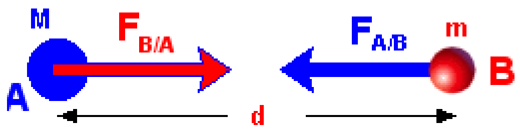
Matter is almost always grouped to form bodies, and this is helped by the gravitational force acting among their masses, and the electrostatic force, acting among their electric charges. These two forces regulate the way in which matter groups, although grativy only produces appreciable effects on bodies which have an enormous mass (planets, stars, etc.).

The force of gravity

In the 17th century, Isaac Newton had the idea that any two bodies, like the Earth and an apple, or Mars and the Sun, mutually attract one another due to their mass and with a force which is greater:

a) the greater the mass of the two bodies

b) the shorter the distance between their centres (the nearer one is to the other)



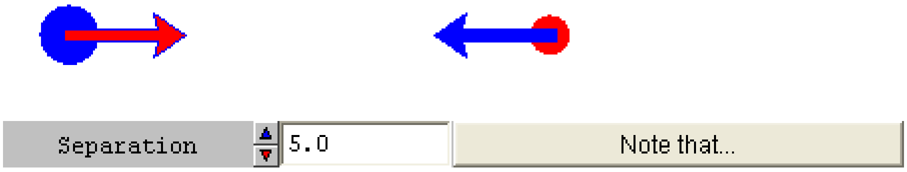
Body B exerts a force on body A, which we express as force of B on A ($F_{B/A}$). At the same time body A does the same on body B. The two forces $F_{A/B}$ and $F_{B/A}$ are equal. The attraction is mutual.

Gravitational force is caused by a property of bodies (mass) which means that they attract one another.

a) Click to vary the mass of the body with the red surface and see how mass influences the force of attraction.

Note that… If you increase the value of one of the masses without changing the distance between them the force of attraction changes. If the mass increases, the attraction increases. The blue mass creates a force of attraction on the sphere with a red surface, and the sphere creates a force with the same strength in the opposite direction on the blue mass.

b) Click to vary the distance between the two bodies and see how distance influences the force of attraction.

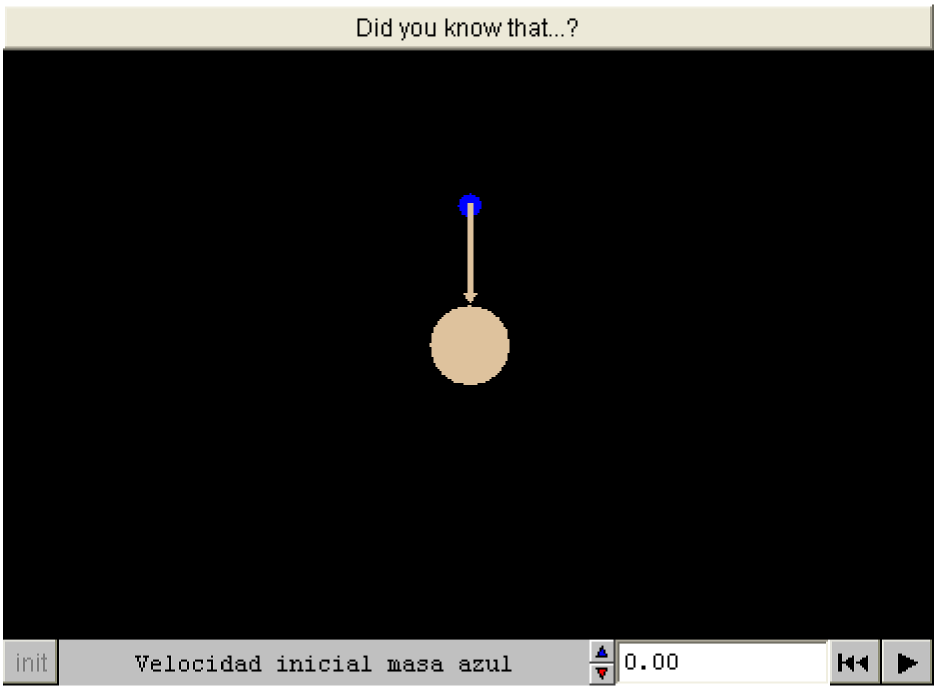


Note that…The masses create forces equal in strength but with opposite directions. When you change the distance between the masses the force diminishes very quickly: if the distance is double, the force is four times weaker.

Effects of gravity: weight

The weight of an apple is the force of gravity with which the Earth attracts it and depends on the masses of the Earth and the apple. But you must understand that the mass of the apple is a property which depends only on the apple.
On the moon the apple weighs less, but its mass is the same as on the Earth.

The gravitational force of attraction is responsible not only for the falling of bodies, but also for the trajectory of any heavenly body around another. And also, or course, for the movement of artificial satellites and of the moon around the Earth. Depending on the speed with which the satellite moves parallel to the ground, the trajectory can be very different. Observe the demonstration.

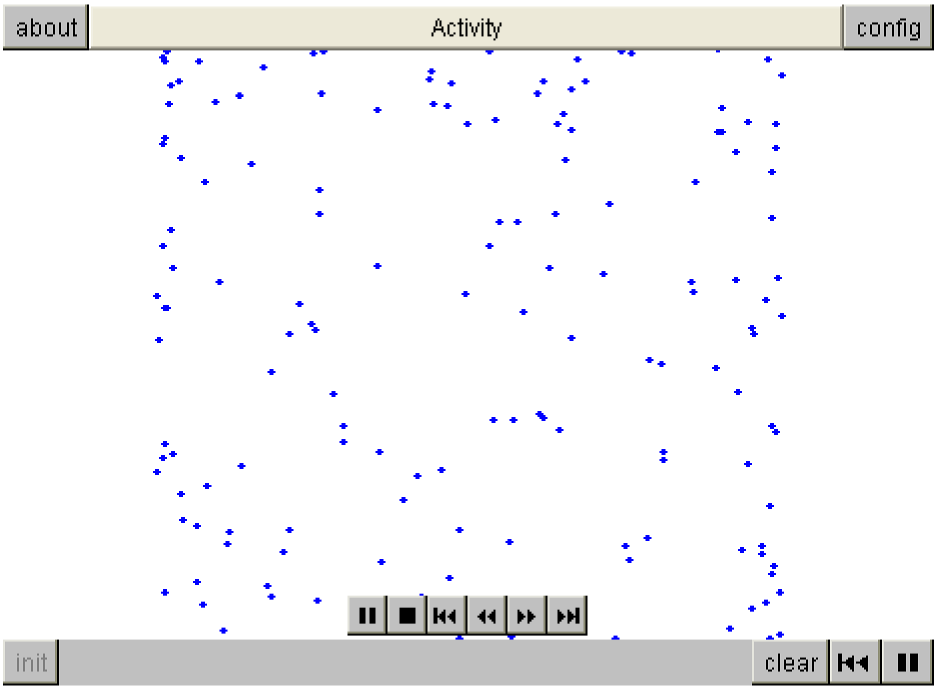


Did you know that…? Masses attract each other. Two masses initially at rest fall towards each other. If one of them moves horizontally, depending on its speed, it may begin to orbit around the other body or fall towards it following a curved trajectory. Try using different speeds for the blue mass.

The brown mass remains still and the force which it exerts on the blue mass (brown arrow) conditions the movement.

Effects of gravity: the birth of the stars

If in an area of the galaxy there are many particles more or less near to each other (clouds of gas and interstellar dust), gravitation causes them to attract one another, producing an aggregate of particles which grows and grows. The final result may be a star.



Activity: Note that the force of attraction exerted among the different particles draws them together until they form a sphere.

Electric charge

Matter also has another property called an electric charge, which can be of two types: positive and negative.

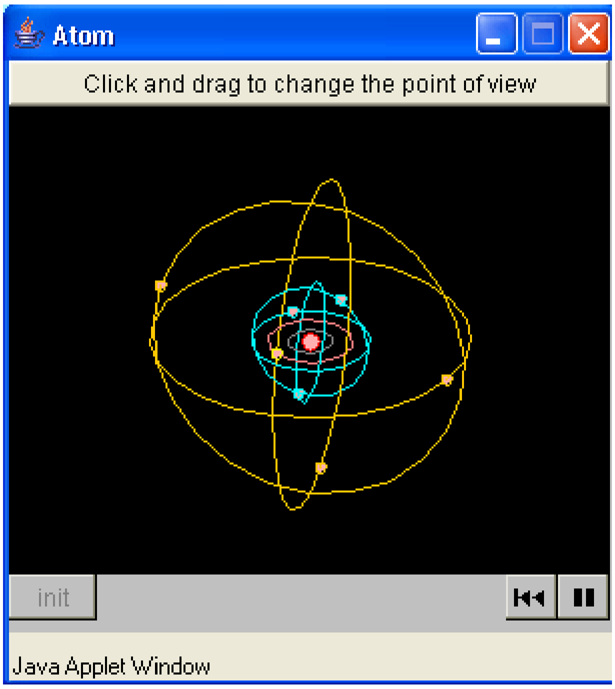
a) Bodies with different signs attract each other.

b) Bodies with the same sign repel each other.

Electric force, both attractive and repulsive, is much more intense that the force of gravity. It governs the spacial distribution of atoms and ions in matter and sometimes produces beautiful crystals like the amethysts you can see in the photograph.

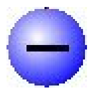
However, the charge almost never manifests itself in ordinary objects, but remains hidden in the particles which make up their atoms.

These particles are protons and neutrons in the atomic nucleus, and electrons which spin around it. The neutrons have no charge (they are neutral); the protons have a positive charge and the electrons have a negative charge with the same value. As there is an equal number of protons and electrons in the atom, the net charge of the atom and of all matter in general is nil.



The electrons are attracted by the nucleus and repelled by the other electrons. The resulting force determines the movement of each electron.

Atoms can gain or lose an electron, losing their electric neutrality and turning into ions.



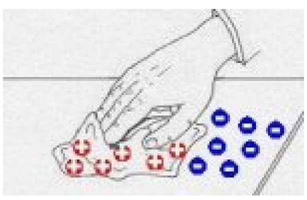
If an atom picks up the electrons that another loses it becomes a negative ion or anion.

The atom which loses electrons turns into a positive ion or  cation.

The particles which are transferred from one atom to another are always electrons, never protons.

Macroscopic bodies can also be electrified. How?

The most simple method is to rub one against the other.

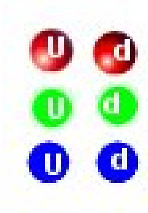


Try the following experiment yourself: take two sheets of plastic of the type you use to separate the pages in a folder, and keeping them separate, rub them with a cloth for a few seconds. Then move them nearer to each other and observe how they repulse each other.

Lastly, move one of them near to the cloth and see how it is attracted to it. The explanation is that when you rubbed the plastic sheets with the cloth there was a transfer of electrons between the sheets and the cloth, so that the sheets were charged with the same sign and the cloth with the opposite sign.

From simple to complex

As far as we know to date, ordinary matter is made up exclusively of two types of elemental particles: up (u) and down (d) quarks, and electrons.



The "quarks" can exist in three different forms (three "colours" red, green, blue). The property called "colour" has nothing to do with what we normally understand as colour.

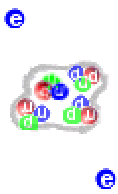
Electron

The quarks are grouped in threes forming in this way, depending on the types which group together, protons and neutrons:

Protons (two type -u- and one type -d-).These quarks should be of complementary colours.

Neutrons (two type -d- and one type -u-). These quarks should be of complementary colours.

In the colour theory (with which we study the colours of the things we see) we call complementary colours those which show as white when combined.



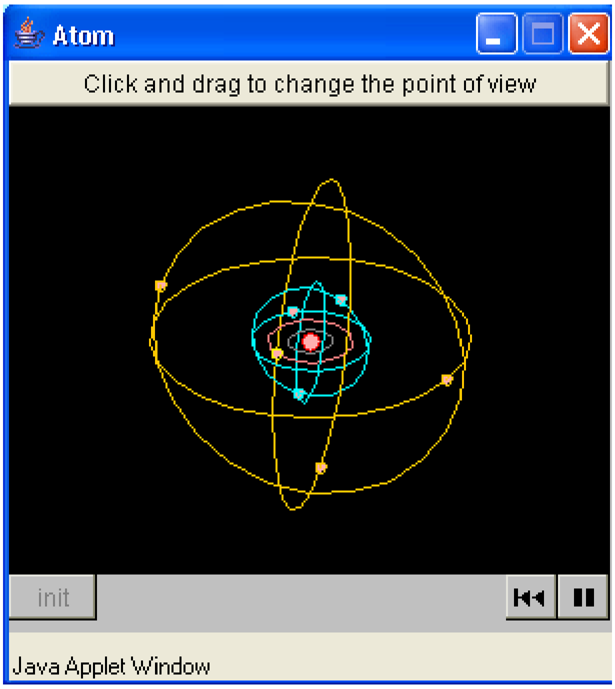
An atom of helium

Protons and neutrons group together to form atomic nuclei, and these are surrounded by electrons spinning around them.

In an atom, the number of electrons is equal to that of the protons. So, iron has 26 protons and 26 electrons.

This structure, formed by the nucleus and the electrons spinning around it, is an atom, and all the particles in it are in continuous movement.

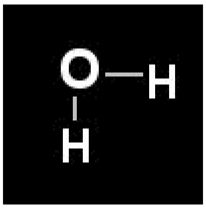
In the animation the sizes and distances are not to scale. If the nucleus of an atom was the size seen in the animation, we should draw the electrons a kilometre away! Actually the nucleus is 10 billion times smaller than that shown in the animation.



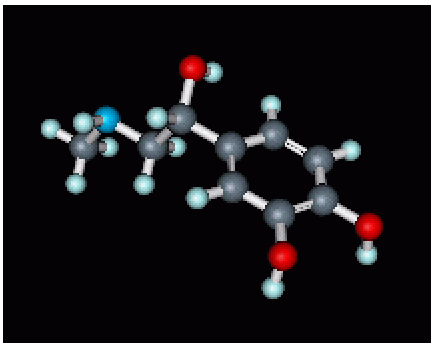
The simplest atom is that of hydrogen. Its nucleus is a simple proton, with a single electron spinning around it. The next is helium with two protons and two neutrons in the nucleus, and two electrons around it. And so on up to the largest atoms which can have as many as 100 protons and a little more than 150 neutrons in the nucleus.

Atoms also group together and form molecules. Molecules can be formed by a different number of atoms, 2,3.. or thousands (as in the case of DNA).
All the atoms in a molecule can be the same, like in the oxygen molecule (O_2), or be formed by four or five different ones (C, N, P, O, H), like the large molecules in you body.

The position of the atoms in the molecules is not fixed, but they vibrate moving from one side to the other of their point of equilibrium.



A water molecule

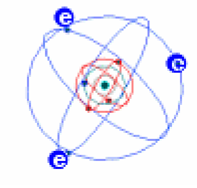
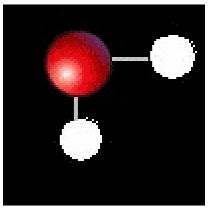
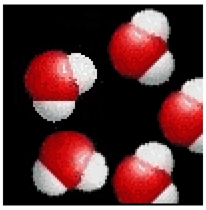


an adrenaline molecule

As the size of these particles is extraordinarily small, very many molecules are needed to form the macroscopic world (the bodies which we can see). Fore example, the number of molecules of water which fill a small glass is, approximately, one quadrillion (short scale) (1 followed by 15 zeros).

In this sequence of images we go from the inside of a nucleus of a water molecule, from near to a quark to outside the glass.

From about 0.000000000000001m (15 zeros) near to the quarks to a metre from the glass.

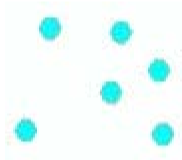

H_2O

Elements and compounds

Matter can be formed by different types of groupings of atoms:

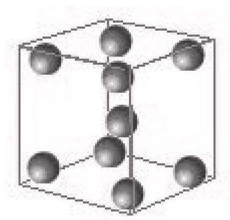
1. The grouping of identical atoms (atoms are considered identical when they have the same number of protons).
   When all the atoms which constitute a material system are identical, the grouping is called a chemical element.
   The atoms of a chemical element can be:

    - separate and very widely spaced (in gases like neon and radon)



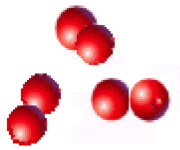
The gas neon

- together and arranged in crystalline networks (iron, diamond)



In iron the atoms are arranged like this.

- joined together forming innumerable atomic groups, generally of a few atoms called molecules: oxygen (O_2), hydrogen (H_2), nitrogen (N_2), etc.



Oxygen molecules

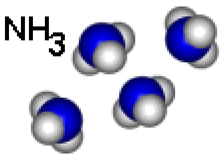
110 different chemical elements are known.

2. The grouping of different atoms.

When the atoms which constitute a material system are different, the agglomeration formed is called a chemical compound.

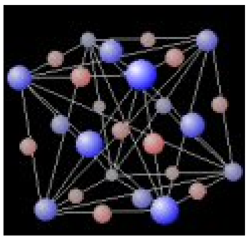
The atoms can be:

- joined in groups forming molecules of the compound (water, ammonia, etc.)



Ammonia

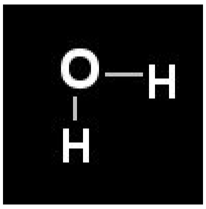
- or constituting ionic crystalline structures (sodium chloride or common salt, calcium carbonate, etc.).



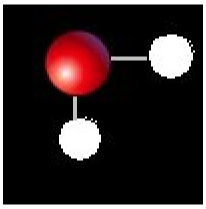
Common salt

Both elements and compounds receive the general name of pure substances, or simply substances, with fixed properties which make them different from others (physical properties like density or melting temperature, and chemical properties, like their reactivity with other substances).

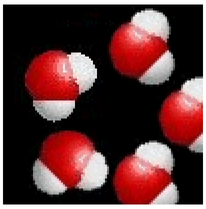
The smallest portion of a substance which conserves its chemical properties is the molecule. We can break the molecule, but then the substance disappears and becomes another substance or substances, with different properties.



The formula for water



A molecule of water (H_2O)



Molecules of water

If the substance does not form molecules, then the atom is the smallest portion with the same chemical properties.

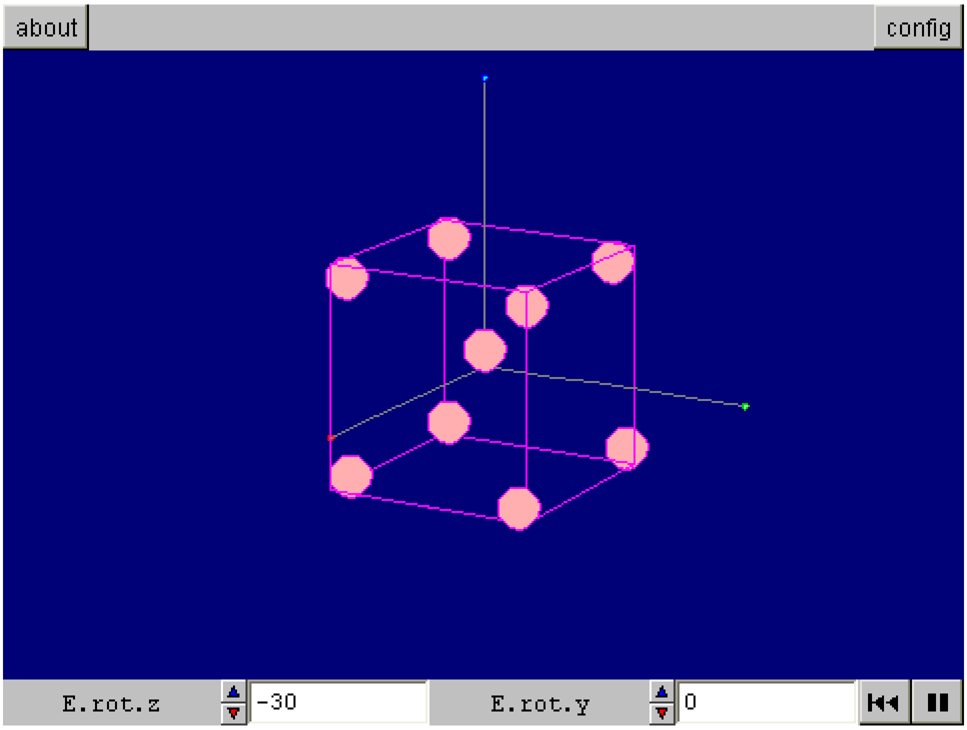
Most commonly the different compounds are found in Nature mixed together to form minerals, rocks, dissolutions like sea water, etc.

States of aggregation: solid

Matter can appear in three states of aggregation: **solid, liquid and gas**.

In the solid state bodies have an almost invariable volume (**incompressibility**) due to the fact that their particles (atoms, ions and molecules) are practically in contact with each other and so cannot get any nearer.

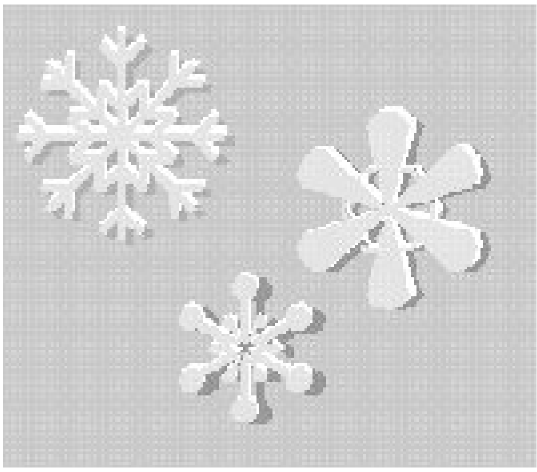
The shape of solids is also invariable, because their particles are perfectly arranged and occupy fixed positions in repeated three-dimensional structures called crystals. The particles are not static in their positions but vibrate ceaselessly, the more intensely the greater the temperature. If this becomes sufficiently high (melting point) the particles lose their fixed positions and even though they continue to be close together, the crystalline structure, exclusive to solids, disappears and they change into liquids.



In the animated visual some atoms arranged in a cubic structure (one of the many that are possible) show their continual vibration. When this structural unit (structural cell) is repeated in every direction they form a crystalline solid.

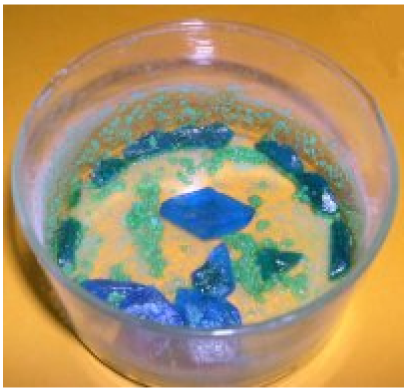
A substance in a solid state can adopt different crystalline structures, which correspond to more than one way in which the atoms come together.

According to the conditions, snowflakes can adopt shapes like those shown below:



Crystalline substances which are soluble in water crystallize once more when it evaporates. This is not a change of state, but a crystallization, a way of obtaining beautiful crystals.

Activity



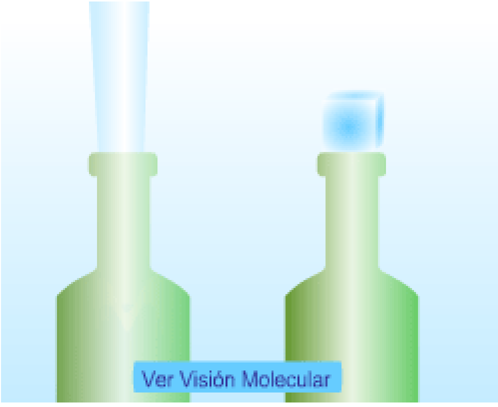
Dissolve a handful of cooking salt or copper sulphate which is used to spray plants, in a glass of water and shake and heat it gently. If some does not dissolve, filter it using a funnel and a filter paper like those used in some coffee machines. Wash your hands and the material you have used thoroughly after touching the copper sulphate.

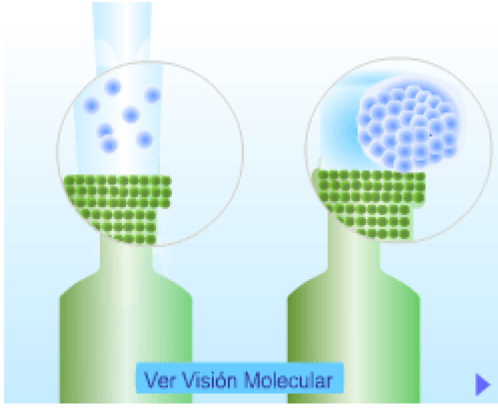
Leave the dissolution in a wide glass, covered with a piece of paper so that the water slowly evaporates. A few days later when the water has totally evaporated, you will see some beautiful crystals.

States of aggregation: liquid

The shape of liquids is variable (they adopt the shape of the container) because, when the temperature is above their melting point the particles cannot maintain the fixed positions that they have when they are in a solid state and they move in a disorderly fashion.

When not affected by gravity, the natural form of liquids is a sphere (a drop). If an astronaut in a space station orbiting the Earth spills a glass of water, the liquid adopts the form of large drops suspended in the air.





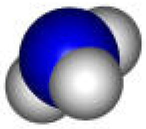
The volume of liquids is practically invariable, because the particles, although not forming a fixed structure as in the case of solids, remain relatively near to each other as they do in the solid state.

Liquids can flow, because their particles have freedom of movement and are not in fixed positions so that they can move into the spaces among them, allowing the movement of the whole of the liquid mass.

A stream of liquid pours into the bottle and adopts its shape as its particles are widely separated and can "flow". The particles in the ice cube cannot enter. Look at the animated visual and click on "See molecular view" to understand what is happening at that level.

States of aggregation: gas

The movements of the particles in a liquid become more extense and rapid when it is heated and its temperature rises. Above its boiling point, the particles lose contact with each other and move freely in all directions (gaseous state)



A molecule of ammonia:

an atom of nitrogen joined

to three of hydrogen

Gases diffuse until they occupy the whole of the receptacle that contains them because, in contrast to solids and liquids, their particles are very separated and move chaotically in all directions. The movement of each particle will not be obstructed as long as it doesn't bump into another particle or the walls of the container. This is why gases end up occupying the whole volume of the container. The innumerable collisions can push against the walls to such an extent that they may eventually break.

The shape of gases is variable, they adopt that of whatever receptacle they are contained in.

The volume of gases is easily modifiable because they can be compressed and expanded.

By compressing a gas the separation of its particles diminishes, something which cannot be done in the solid and liquid state.

Gases can flow in the same way as liquids. So gases and liquids receive the generic name of fluids.

A special gas: plasma

Atoms are normally in a neutral state: the positive charge of the nucleus is equal to the negative charge of the electrons.

The agitation of a gas increases when it absorbs heat. If enough heat is absorbed, electrons are lost from the atoms and matter is ionized, and we say that it is in the plasma state.

All incandescent gases formed of atoms (sometimes molecules) converted into positive ions and negative electrons, and in a continual state of agitation are called plasma. The gas may also contain some atoms and molecules which have not been ionized (neutral particles).

Some example of plasmas are:

Some areas of flames, the gas in fluorescent lamps, the air in the path of a lightening bolt.

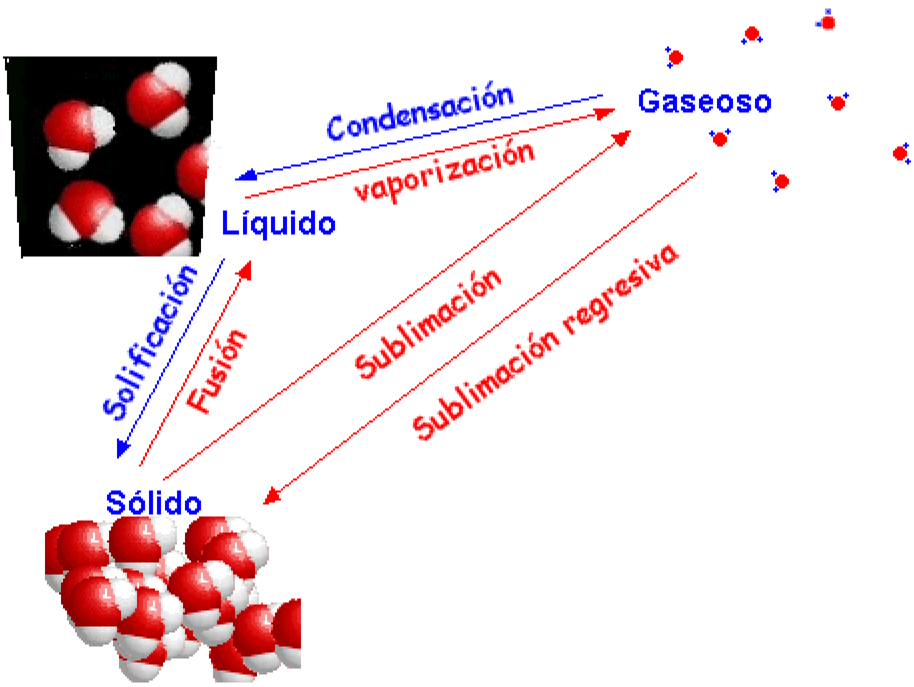
The matter which forms the stars is also in the plasma state.

Changes of states of aggregation

The cycle of water in nature shows us the different states of water.

Look at these photographs and observe the form which water takes in each one of them.

The internal structure of the molecules does not change in any change of state: ice and steam are the same substance as liquid water. What changes is the intensity with which the molecules attract each other and the way in which they group together. The water molecules have the same shape and the same atoms in the three states.



Fusion (I)

In general any substance is solid at a low temperature and gaseous at a high temperature.

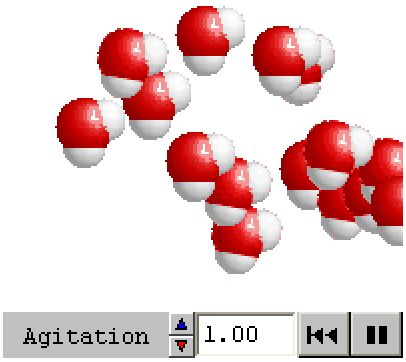
Let's take for example an ice crystal at (-10 ºC) and increase its temperature by slowly heating it; the water molecules which constitute its crystalline network increase the amplitude of their vibrations until at 0 ºC, the vibrations become so intense that the molecules lose their fixed positions and loosen their mutual attraction, becoming sufficiently free to be able to move around; we say that the ice has changed its state.

The water and the ice in this glass receive heat from the air which surrounds them, this is why all the ice will end up melting.

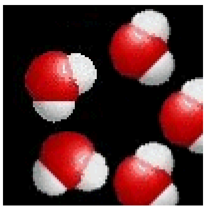
The change of state from solid to liquid is called fusion. While there is fusion the heat applied will not raise the temperature above 0 ºC, but rather will be used to "loosen" the molecules more and more until all the ice has changed into a liquid state.
The change from liquid to solid is called solidification.

In their solid state molecules vibrate slightly in their positions. Inside them the electrons and other particles also vibrate.

In a piece of ice like the one in the animation, the molecules increase their vibration and separation if the temperature rises.



Ice



Water in its liquid state.

As a general rule, in solids the particles (atoms or molecules) are closer together than in liquids. This is why the density of a substance in its solid state is greater than in its liquid state. But water is an exception and this is why ice floats in liquid water.

Observe the simulation of the water molecules in their liquid state vibrating in their positions. They can also move.

Evaporation and ebullition

If we keep heating the water which has been formed in this way, its temperature again begins to rise, which is seen in faster and faster movements (now of displacement) of its molecules. The fastest can escape by breaking the surface and turning into gas. This process called evaporation, intensifies as temperature increases, but when it gets to 100 ºC, all the mass of liquid begins suddenly to change into gas forming bubbles in the middle of the liquid water. These bubbles rise and burst into the atmosphere: we say that the water is boiling. The process is called ebullition. Evaporation and ebullition are two different ways in which a liquid changes state and becomes a gas, a process called vapourization.

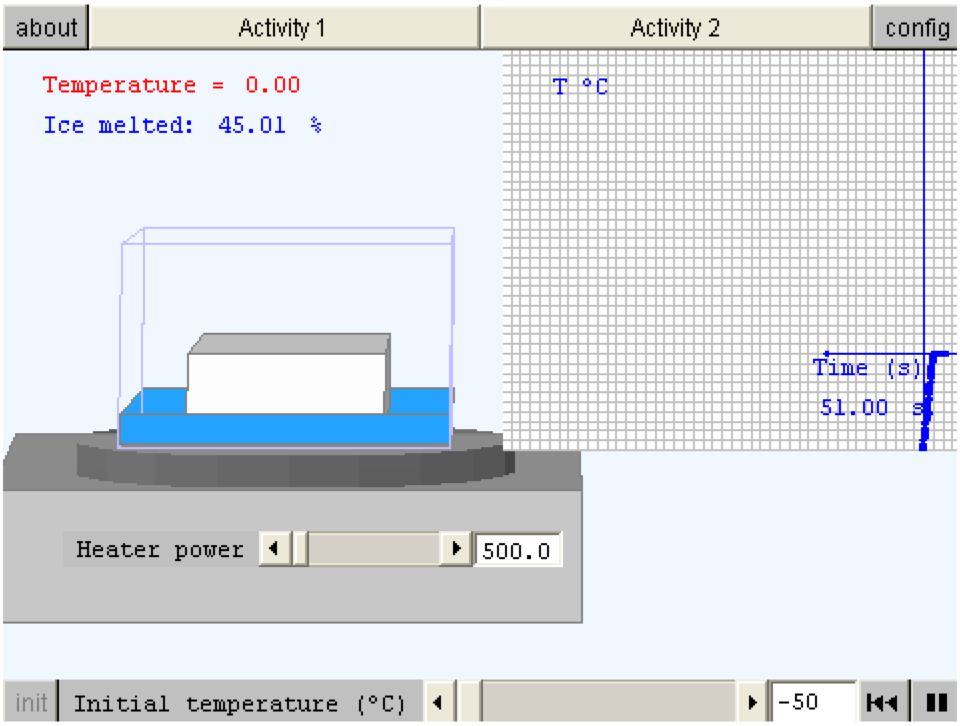
Clothes dry because the water they contain evaporates, but it is not necessary for the clothes to have a temperature of 100º C.
In a saucepan on the gas water reaches 100º and starts to boil.

This journey from solid to gas can be made in the opposite direction. In this case it is not only unnecessary to heat the system but it must in contrast lose the same amount of heat that it gained before. The change from a gas to a liquid is called condensation, and from a liquid to a solid, solidification (in the case of water it is also called freezing).

Finally, on some occasions a solid changes directly into a gas, this is called sublimation, and from a gas to a solid, reverse sublimation.

Animation

In this animation you will see the changes of state of a block of ice in an open container. Observe how the temperature varies and the values shown during the process. You can vary the power of the heater and see how it influences the time the whole process takes. The process of vapourization takes longer and you have to apply much more heat to evaporate all the water than to melt all the ice (the mass of the water and the ice are the same).
Copy the diagram into your exercise book and write down your observations. Notice that the steam bubbles form (in a much greater number than those seen on the animation) inside the liquid and burst when they reach the air.



Activity 1: Click on play. The graph shows the changes in temperature as time goes by. What happens to the temperature during the changes of state? At what temperatures do the changes take place for water? You can check that the changes of state always take place at the same temperature, even if you change the initial temperature of the ice.

Activity 2: Observe the process a few times changing the power of the heater. When the temperature remains constant, what is the heat produced used for?

To see this topic in greater depth you can go to this one (4th year of secondary education).

EVALUATION

1. Here are two fundamental properties of matter:

   A. ? Weight and molecular structure.

   B. ? Mass and taste.

   C. ? Volume and mass.

2. Air is a gas that...

   A. ? does not weigh.

   B. ? has no mass.

   C. ? has mass and volume.

3. Matter is made up of particles

   A. ? which are immaterial, without mass or volume.

   B. ? which are spiritual and undetectable.

   C. ? which are material.

4. The units used to measure mass are:

   A. ? kg, g, mg, t (tonnes).

   B. ? Weight.

   C. ? Kg/m3

5. The volume of a cube is...

A. ? The cube (the third power) of the length of the edge.

B. ? The square (second power) of the length of the edge.

C. ? Triple the area of the base times the height.

6. A volume can be measured in the following units (mark all the correct answers):

A. ? Cubic milimetres.

B. ? Square metres.

C. ? Square centimetres multiplied by kilometres.

7. If we pour water into a test tube until it reaches the 300 ml mark (300 cubic centimetres) and we then drop a 220 g stone that moves the water up to the 350 ml mark, what is the stone's density?

A. ? 0.227 cubic centimetres per gram.

B. ? 4.4 grams per cubic centimetre.

C. ? 40 grams per cubic centimetre.

8. The gravitational force (of attraction) between two bodies is greater...

A. ? the greater the mass of the bodies and the shorter the distance that separates them.

B. ? the greater the mass of the bodies and the distance between them.

C. ? the smaller the mass of the bodies and the shorter the distance between them.

9. What particles make up the atom?

A. ? Protons and neutrons in the nucleus and quarks orbiting around them.

B. ? Neutrons orbiting around the nucleus, which is formed by protons and electrons.

C. ? Electrons orbiting around the nucleus, which is formed by protons and neutrons (which in turn are made up of quarks).

10. The particles that make up matter

A. ? are so close to one another that they leave no space among them. They form a continuous entity.

B. ? are separated from one another. The electrons are separated from the nuclei and the protons are separated from the neutrons. They therefore form a discontinuous entity.

C. ? are so close to each other that it is impossible to separate them.

11. When a living being dies...

A. ? all the particles in the matter that it is made of stop moving.

B. ? all the particles in the matter that it is made of except electrons stop moving.

C. ? all the particles that made up the living being continue to move in the dead body and in the matter that the corpse will turn into.

12. How would you define inanimate matter?

A. ? Matter which is not alive.

B. ? Matter in which the particles are at rest.

C. ? Matter at rest in which the particles are at rest.

13. The atoms and other particles that make up matter are...

A. ? at rest in solid matter, moving slightly in liquids and moving freely in gases.

B. ? always moving around.

C. ? at rest in fixed positions.

14. An element is distinguished from a compound because...

A. ? an element does not form molecules, while a compound does.

B. ? elements are made up of molecules and compounds are made up of atoms that form crystals.

C. ? an element is made up of identical atoms (it does not matter whether or not they form molecules), while a compound is made up of different kinds of atoms (that may or may not form molecules).

15. The distance between the atoms (or molecules) of solids, liquids and gases are...

A. ? identical or very similar.

B. ? similar in solids and liquids, but different in gases (where they are much greater).

C. ? large in solids, small in liquids and even smaller in gases.

16. During a change of state from solid to liquid or liquid to gas, the temperature...

A. ? increases.

B. ? decreases.

C. ? remains constant.

17. What do you call the change of state that goes directly from solid to gas?

A. ? ebullition.

B. ? evaporation.

C. ? sublimation.

18. What do you call the change of state from liquid to solid?

A. ? Condensation.

B. ? Sublimation.

C. ? Solidification.