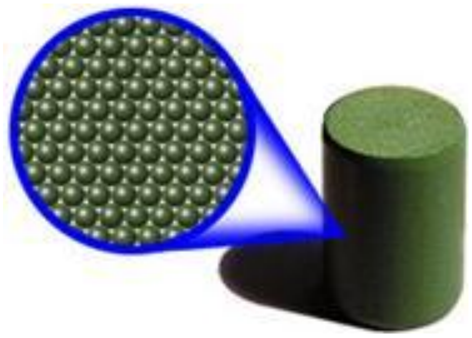
THE CORPUSCULAR NATURE OF MATTER



Matter is integrated by several substances. Water, copper, oxygen, etc., are substances and we can find these substances in different states: solid, liquid and gaseous. If we want to understand the matter we need to begin with the learning of the easiest state: gaseous state.

1. GASES AND THE STRUCTURE OF MATTER

Sometimes gases are invisible and so this state seems strange, but in the History of Science the knowledge of matter started with the study of the gaseous state.

1.1. Properties of substances in gaseous state

The gaseous state is the simplest one of these three states of matter and shows the greatest uniformity in behaviour. Gases show almost similar behaviour apart from their chemical nature: this property is very different in liquids and solids (why? Start thinking about this problem).

The gas state is characterized by:

- Gases maintain neither the volume nor the shape. They completely fill the container in which they are placed.
- They expand appreciably when heated.
- Gases are highly compressible. The volume of the gas decreases when the pressure increases.
- They diffuse rapidly into space.
- Gases exert equal pressure in all directions.
- Another characteristic of gases is their **low *densities***, compared with those of liquids and solids. For example, in normal conditions, water vapour occupies 1000 times more volume than liquid water.

We will see later that each of these ***macroscopic*** characteristic of gases follows directly from the ***microscopic*** view (corpuscular nature of matter).

A.1. If a perfume bottle is opened in a corner of a room, you can quickly smell it in any other part of the room. And CFC molecules can destroy the ozone located many kilometers away. What does this fact mean about gases properties?

A.2. Using a plastic syringe you have to research the different behaviour of a gas like air, a liquid like water, or a solid like a piece of chalk by changing the pressure (by increasing or decreasing it) that you apply with your fingers on the piston. Write a short report about this research and give conclusions.

A.3. Using a balloon you have to research the qualitative relationship between the volume of a gas and its temperature. Write a short report about this research and give conclusions.

Gases can change their volume by different causes:

- Changing the pressure: **expansion** is when a gas gets bigger by pressure. The amount of the substance doesn't increase, it just spreads out to occupy more volume. **Expansion** is the opposite of **compression**.
- Changing the temperature: **expansion (dilatation)** is when a gas gets bigger by heat. In this case the opposite of **expansion** is **contraction**.

1.2. Kinetic theory of matter

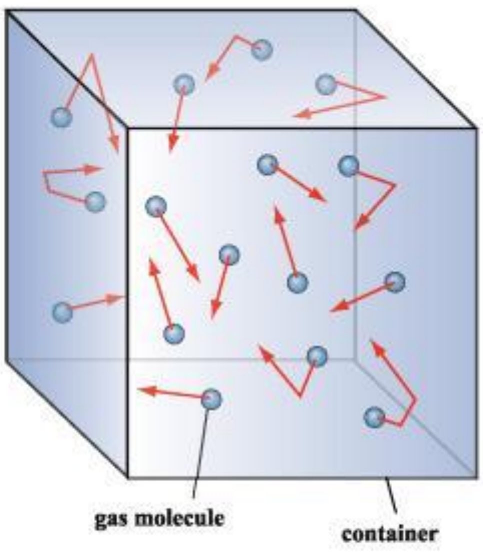
The problem is: how can we understand the behaviour of gases? The first treatment of gases was only **descriptive** but if we want to explain their behaviour we need an **explanatory** one. In general when our aim is to explain different phenomena we need a **theory**. If our problem is to understand the gases we need **the kinetic theory of matter**.

The basic tenets (or postulates) of the kinetic-molecular theory are as follows:

- All matter is composed of particles (they can be atoms or molecules).
- The particles of every substance are the same and proper of this substance, obviously different from other particles of other substances, for example in mass.
- Gases are composed of a large number of particles that behave like spherical objects in a state of constant, random motion.
- These particles move along a straight line until they collide with another particle or the walls of the container. These collisions produce pressure in a gas.

- These particles are much smaller than the distance between particles. Most of the volume of a gas is therefore empty space.
- There is no force of attraction between gas particles or between the particles and the walls of the container.
- Collisions between gas particles or collisions with the walls of the container are perfectly elastic. None of the energy of a gas particle is lost when it collides with another particle or the walls of the container.
- The average kinetic energy of a collection of gas particles depends only on the temperature of the gas. When temperature changes particles move at a different speed.

Summary about kinetic theory of gases in flash animation



1.3. Using kinetic theory to understand gases

A.4. Experimental activity: you have to dispose two pieces of cotton soaked in concentrated ammonia solution, NH_3 (aq), and concentrated hydrogen chloride solution, HCl (aq), placed at each end of a sealed glass tube, like the picture below, and then answer these questions:

a) What happens?

b) Can you explain this phenomenon using kinetic theory?

c) Why does the white substance appear closer than hydrogen chloride solution?

d) Can your order the mass of molecules involved in this experiment?

e) What is the general conclusion?

A.5. In the following link you can watch a video about bromine (Br_2) diffusion:

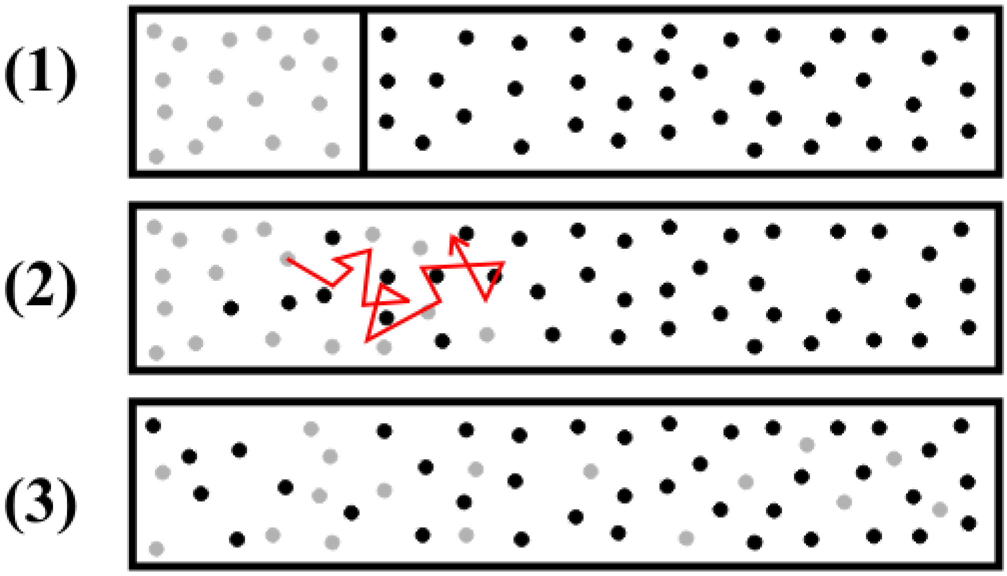
Video

Answer these questions about this video;

a) What is the difference between the first and second experiment?

b) Explain the results of experiments using kinetic theory of gases.

Diffusion is a net transport of molecules from a region of higher concentration to one of lower concentration by random molecular motion. Basically, this phenomenon is caused by the free movement of molecules and it finishes when the concentration of molecules is the same in all container.



A.6. Draw the molecules in normal air, expanded air and compressed air in a syringe as you imagine they are located. What happens with the distance between molecules in these processes? Do you think the size of molecules changes in the three different situations? Why are expansion and compression more difficult in liquid and solid states?

A.7. When you change the position of the piston in the syringe (expansion or compression) it also changes:

a) The total volume of air.

b) The weight of air.

c) The amount of air.

d) The number of molecules.

e) The distance between molecules.

f) The speed of molecules.

g) The size of molecules.

h) The mass of molecules.

i) The chemical composition of air.

Explain your answers.

A.8. You researched using air in a balloon and changing the temperature. Now answer these questions:

a) Why does increasing the temperature of the balloon cause its volume to increase?

b) Why does decreasing the temperature of the balloon cause its volume to decrease?

Explain your answers using the postulates of kinetic theory of gases.

A.9. When you change the temperature of the air in a balloon (expansion or contraction) it also changes:

a) The total volume of air.

b) The weight of air.

c) The amount of air.

d) The number of molecules.

e) The distance between molecules.

f) The speed of molecules.

g) The size of molecules.

h) The mass of molecules.

i) The chemical composition of air.

Explain your answers.

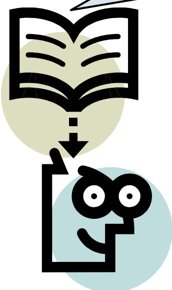
Molecules don't expand or compress!

Molecules don't expand or contract!

Molecules don't change their size or mass!

Molecules change the distance between themselves!

Molecules change their speed only with temperature!



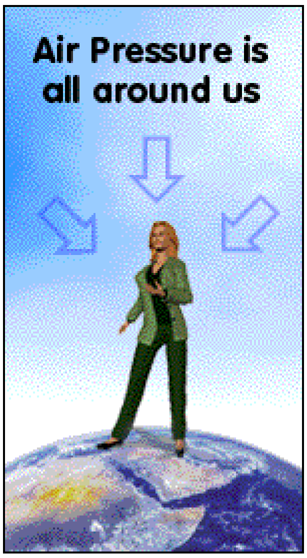
A.10. We studied that pressure is caused by hits of molecules against the wall of the container. What different factors do you think influence on the pressure exerted by a gas?

Atmospheric pressure is the force per unit of area exerted on a body by hits of molecules of air in all directions. There are more of these molecules near the sea level than higher levels because gravity force attracts the air. Therefore, this parameter is maximum at the sea level and decreases until zero when the atmosphere ends.

Air at sea level is what we are used to, in fact, we are so used to it that we forget we are actually feeling air pressure all the time! There is another reason to not feel the enormous amount of hits of molecules: we have air within our body constantly hitting and the final balance can be zero. But, what happens when your ear is blocked and you go up or down quickly, for example in a plane?

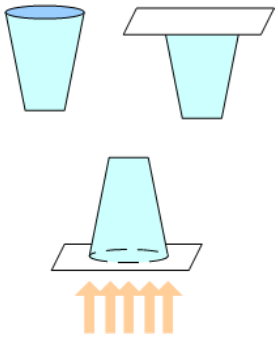
Weather forecasters measure air pressure with a ***barometer***. Barometers are used to measure the current air pressure at a particular location in "millimeters of mercury" or in "millibars" (mb). A measurement of 760 millimeters of mercury is equivalent to 1013.25 millibars and this is the normal atmospheric pressure at sea level.

Adapted from this link.



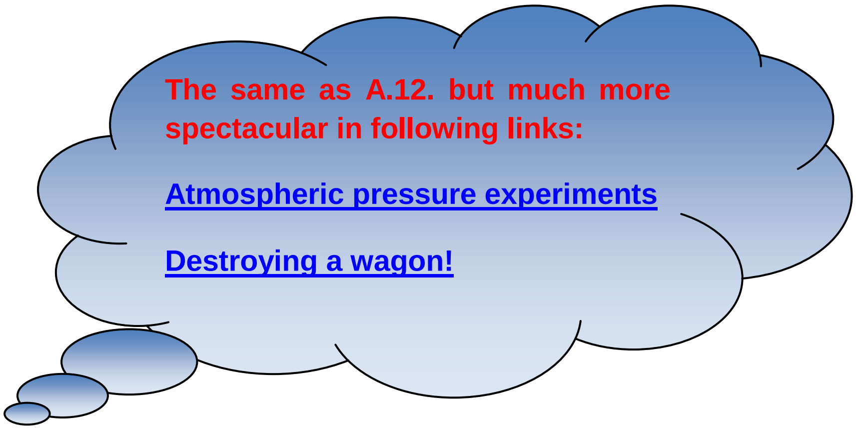
A.11. If you fill totally a glass with water and cover it with a paper sheet, you can turn the glass 180º and water doesn't fall (look at the picture). If the glass contains some air, water will fall down.

Explain this behaviour using the kinetic theory of gases.



A.12. When you heat a can of soft drink with some water and then you put this hot can quickly in cold water (be careful, don't get burnt), what happens?

Explain this experiment using the kinetic theory of gases.



A.13. Using the kinetic theory of gases you should be able to predict the behaviour of a gas in the following situations:

a) What would happen with a gas in a syringe if you increase the pressure without changing the temperature? The same if it decreases.

b) What would happen with a gas in a syringe if you increase the temperature without changing the volume? The same if it decreases.

c) What would happen with a gas in a syringe if you increase the temperature without changing the pressure? The same if it decreases.

d) What would happen with a gas in a balloon if you increase the amount of molecules without changing the temperature? The same if it decreases.

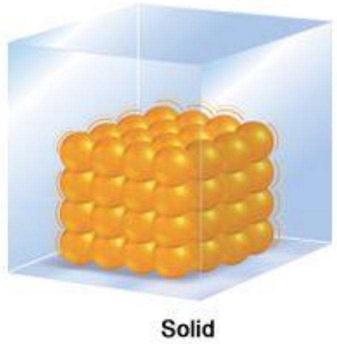
Compare your answers with the next flash animations.

1.4. Kinetic theory of solid and liquid states

We can extend the kinetic theory of gases to liquid and solid states assuming new ideas. Summarizing:

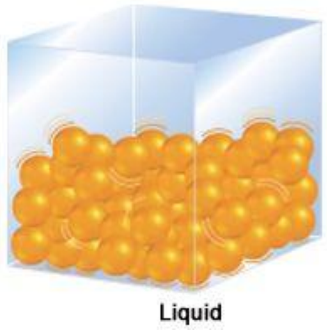
Solid state:

- Particles are close together, slowly vibrating.
- Rigid, geometric arrangement.
- Fixed volume and shape.
- Intense attractive forces between particles: molecules cannot get separated.



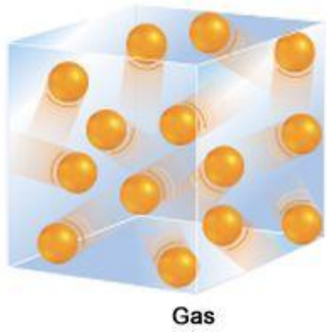
Liquid state:

- Particles have more kinetic energy than they did in the solid state (vibrating faster).
- Particles can slip and slide past one another, but not separate.
- Fixed volume.
- Flow to change shape (they can take on the shape of the container).
- Attractive forces have, more or less, the same intensity than solid but the particles move quickly.



Gas state:

- Particles have even more kinetic energy than they did in the liquid state.
- Particles can move far away from each other.
- No fixed volume or shape.
- Highly compressible.
- Attractive forces are almost non-existent and overcome by the speed of molecules: it is not possible to join them in a liquid state.



A.14. Using the kinetic theory, answer these questions:

a) Why do solid and liquid states have much less compressibility than gas state?

b) Does solid state have diffusion? Why?

c) Why does solid state have fixed volume and shape?

d) Why does liquid state have fixed volume but the shape can change?

e) Why does gas state have no fixed volume and shape?

f) Why can gases and liquids flow but not solids?

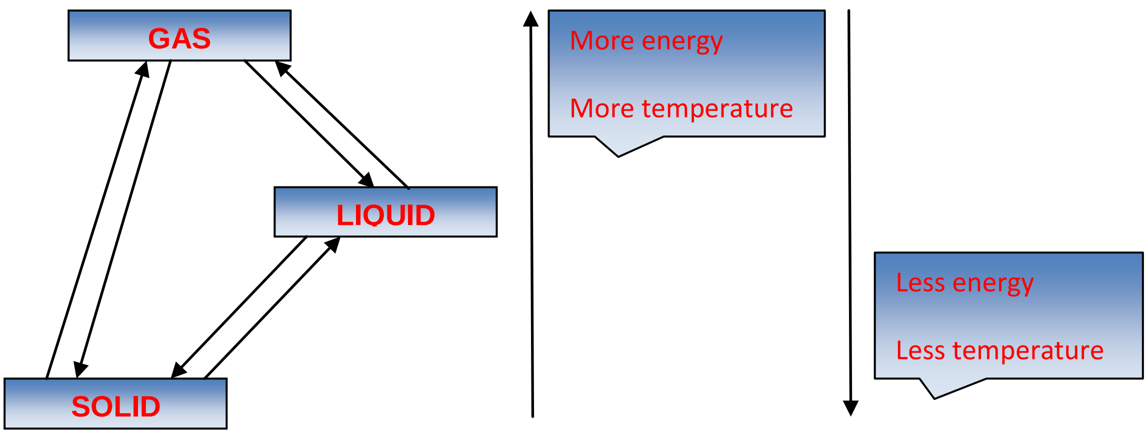
g) Is it possible to transform a gas into a liquid by means of pressure?

h) Is it possible to transform a liquid into a solid by means of pressure?

To understand expansion and contraction in solids see next link.

1.5. Kinetic theory and changes of state

A.15. In the diagram below you have to complete the name of every change of state using the following list: melting, condensation, vaporization (boiling), reverse sublimation, solidification (freezing), sublimation.



A.16. a) Explain every change of state using the kinetic theory of matter.

b) Why does every change of state always happen at the same and characteristic temperature?

c) What is the meaning of this temperature of change of state?

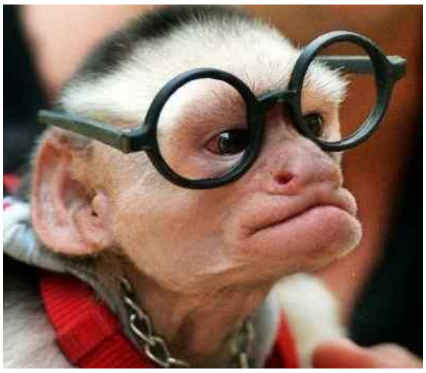
d) During the change of state, the temperature is constant, can you explain this strange fact?

e) What do you think about attractive forces in molecules of substances that experiment sublimation, like for example iodine?

A.17. Vaporization is not the same phenomenon as evaporation. Explain the differences between both concepts. Why can you dry your clothes by air if the water is not boiling?

A.18. Why do we sweat a lot if we have a high temperature? Explain this fact using the kinetic theory of matter.

You can review all you have learnt until now in the next summary in PowerPoint.



1.6. Interpreting climatic phenomena

There are two important substances for the climate in our planet: air and water. Air contains water itself: it can be dry or wet. The changes of state in water are involved in many climatic phenomena.

- **Clouds and fog**

A.19. People usually think that water in a cloud or fog is in a state of gas, but there is water in the air of your room and there are not any clouds or fog inside it. What do you think about the state of water in clouds and fog?

Look for information about this problem and try to answer the question.

A.20. Watch the video “Making clouds in a bottle” and answer the questions:

a) What change of state can you see in the video?

b) Why is the clouds’ formation better with the smoke from a match?

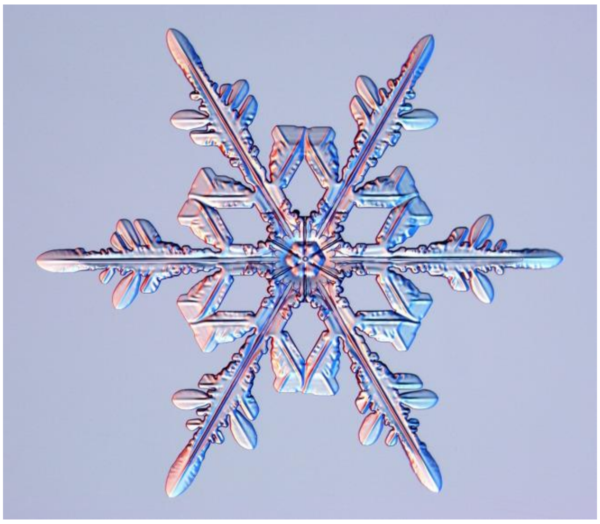
c) Why doesn’t natural clouds’ formation need the smoke from a match?

d) Look for information about **dimethyl sulfide,** and its source **phytoplankton,** and its role in the natural processes of clouds formation like **condensation nuclei**.

- **Rain, snow and hail**

A.21. Research the different weather conditions that produce rain, snow or hail on the web page:

Rain, Snow and Hail - Our Ever Changing Weather



You can see other beautiful pictures of snow crystals on the web page:

Snow crystals

- **Dew**

A.22. Explain the dew formation using the kinetic theory of matter and answer the following questions:

a) Why is dew formation more intense at dawn?

b) Why is dew formation more intense near the sea, rivers or lakes?

c) Why is dew formation more intense in nights without clouds?

➢ Humidity, evaporation, evotranspiration and desertification

A.23. Research the relationship between humidity, evaporation, evotranspiration and desertification and answer these questions:

a) How many sources of humidity do you know in nature?

b) Why is the air wet near the sea, rivers or lakes?

c) Why is the air dry in the desert?

d) Why is the air dry in the poles?

e) Why are tropical forests some of the wettest places in the world?

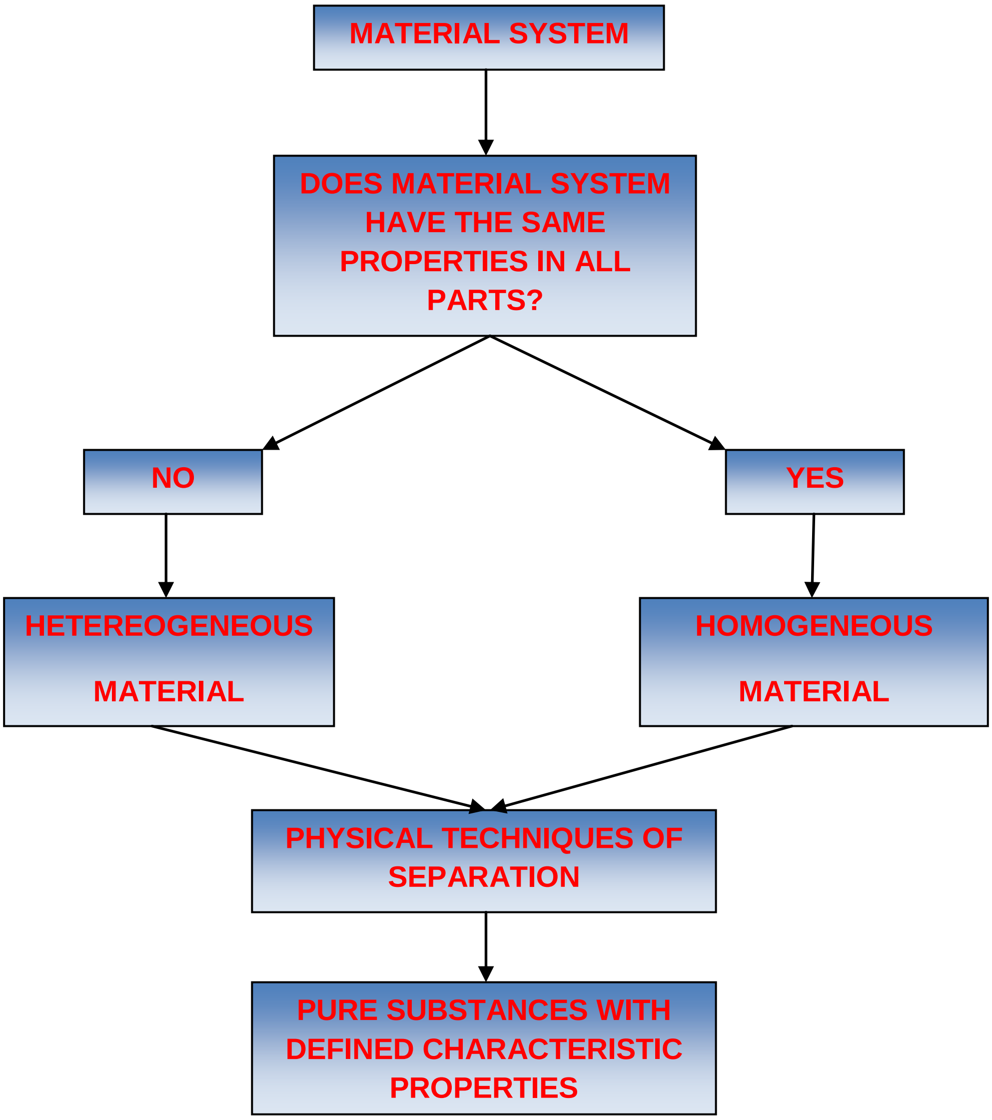
f) Why is desertification more probable if vegetation cover disappears in a place?

2. NATURE IS MADE BY SUBSTANCES AND MIXTURES OF SUBSTANCES

All the materials you can see are composed by substances or mixtures of them. Every substance has an "identity card" like us. Every substance has several chemical and physics properties. Some of them are typical and you can recognize the substance if it has exactly these **characteristic properties**. For example, if you have 1 kilogram of some material you can't guess what material it is. Temperature is not a characteristic property of a material but the melting point or the boiling point are also temperatures, but characteristics because only water melts at 0ºC and boils at 100ºC. Melting and boiling point, density, electrical conductivity, rate of diffusion, hardness, solubility in water, specific heat… are **characteristic properties.** Temperature, mass, length, time, volume…not.

A.24. Compare the density of a nail and a beam of iron. Do characteristic properties depend on the amount of substance? Why?

2.1. Classifying different types of materials



2.2. How can we separate mixtures using physical techniques?

- **Heterogeneous mixtures**

Filtration

Decantation

To separate heterogeneous mixtures of liquids we can use the different density in a decantation funnel

Centrifugal decantation

➢ **Homogeneous mixtures**

Crystallization

Spectacular crystallization

Advanced explanation about crystallization in video

Distillation

Web Quiz: distillation

Simple distillation in video

Fractional distillation in video

Steam distillation in video

Fractional distillation in a fractionating column: refining petroleum

A.25. In the next link you have to match problems and solutions about mixtures separation, indicating the separation mechanism and physical properties that allow separation.

Separating mixtures exercises

3. SOLUTIONS

Solution, by definition, is a homogeneous mixture. A material system should satisfy two conditions to become a solution:

- To have several substances.
- To have the same properties in all the points of the system.

A.26. If you mix water and alcohol:

a) Is this material system a solution?

b) What are the characteristic properties of this material, typical of water or typical of alcohol?

c) Can a solution have defined characteristic properties?

A.27. A solution is not only a solid in a liquid, like for example sugar in water. There are a lot of kinds of solutions. Give one example, at least, of the following solutions: solid-solid; liquid-liquid; gas-gas; solid-liquid; solid-gas; liquid-gas.

A.28. Think about three methods, at least, to distinguish water and salty water.

A.29. You have to research in the laboratory the different behaviour of pure water and salty water when you heat the material system from the room temperature to the boiling point. Write an experimental report including your conclusions.

Solution is a homogeneous mixture composed of two or more substances. In such a mixture, a **solute** is dissolved in another substance, known as a **solvent**. Normally we consider the solute as the substance in less proportion and the solvent as the other substance

Gases may get dissolved in liquids, for example, carbon dioxide or oxygen in water. Liquids may get dissolved in other liquids. Gases can combine with other gases to form solutions. Examples of solid solutions are alloys and certain minerals.

The ability of one compound to get dissolved in another compound is called **solubility**. The physical properties of compounds such as melting point and boiling point change when other compounds are added. When a liquid is able to get completely dissolved in another liquid the two liquids are **miscible**. Two substances that can never mix to form a solution are called **immiscible**.

Adapted from Wikipedia.

3.1. Using kinetic theory to understand solutions

A.30. Salt is a white crystalline substance. If you dissolve salt in water seemingly this crystalline substance disappears.

a) What happens with salt molecules?

b) Can you draw the solution process using little circles representing molecules?

c) What do you think about molecular attraction forces between salt and water molecules, are they intense or weak?

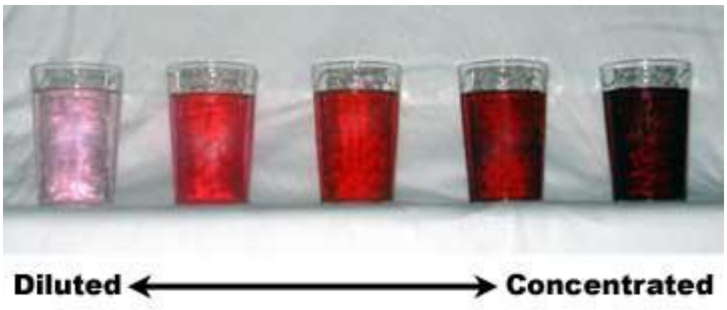
d) Salt doesn't dissolve in petrol. Can you explain this fact, using kinetic theory ideas? What is the meaning of this fact about molecular attraction forces?

e) In general, why can some substances be dissolved in some solvents but not in others?

The solution of salt in water is not so easy: salt can't be represented only by a little circle because it is composed of two kinds of ions (sodium with positive charge and chlorine with negative charge). The real situation is better represented by the next flash animation:

Dissolving salt in water in flash animation.

3.2. Concentration in solutions



Concentration is the measure of how much of a given substance is mixed with another substance. Concentration is the relative proportion between solute and solvent. If we have a low concentration we can say that solution is **diluted** and if the concentration is high the solution is **concentrated**.

How can we measure the concentration of a solution? There are a lot of quantitative forms (see next link) but we need to begin with only two:

- **Mass percentage**: grams of solute in 100 grams of solution (weight percentage, abbreviated as wt%).
- **Grams of solute per liter of solution**: measured in g/L.

Mass percentage exercises (be careful, in this web site you have the solutions, try every exercise without looking at them).

Mass percentage and g/L exercises (be careful because the second one is referred to a % in volume and mg is milligram, 10^{-3} g, and µg is microgram, 10^{-6} g).

4. CORPUSCULAR NATURE OF MATTER WEBQUESTS

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APPENDIX 1: GENERAL VOCABULARY OF THE UNIT

APPENDIX 2: SPECIFIC VOCABULARY OF THE UNIT