


Materials around us:

Metals, plastics and paper


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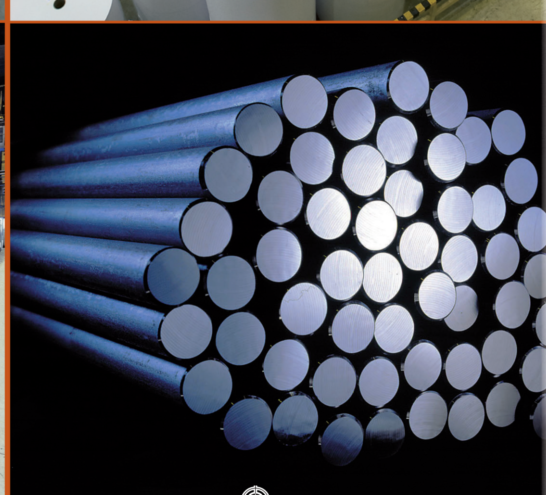

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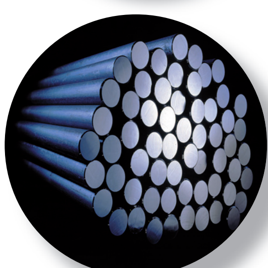


1 Substances and materials

MARIMEKKO OY

Cotton is a raw material and t-shirt a product

The liquid form of water is a clear liquid that we can drink

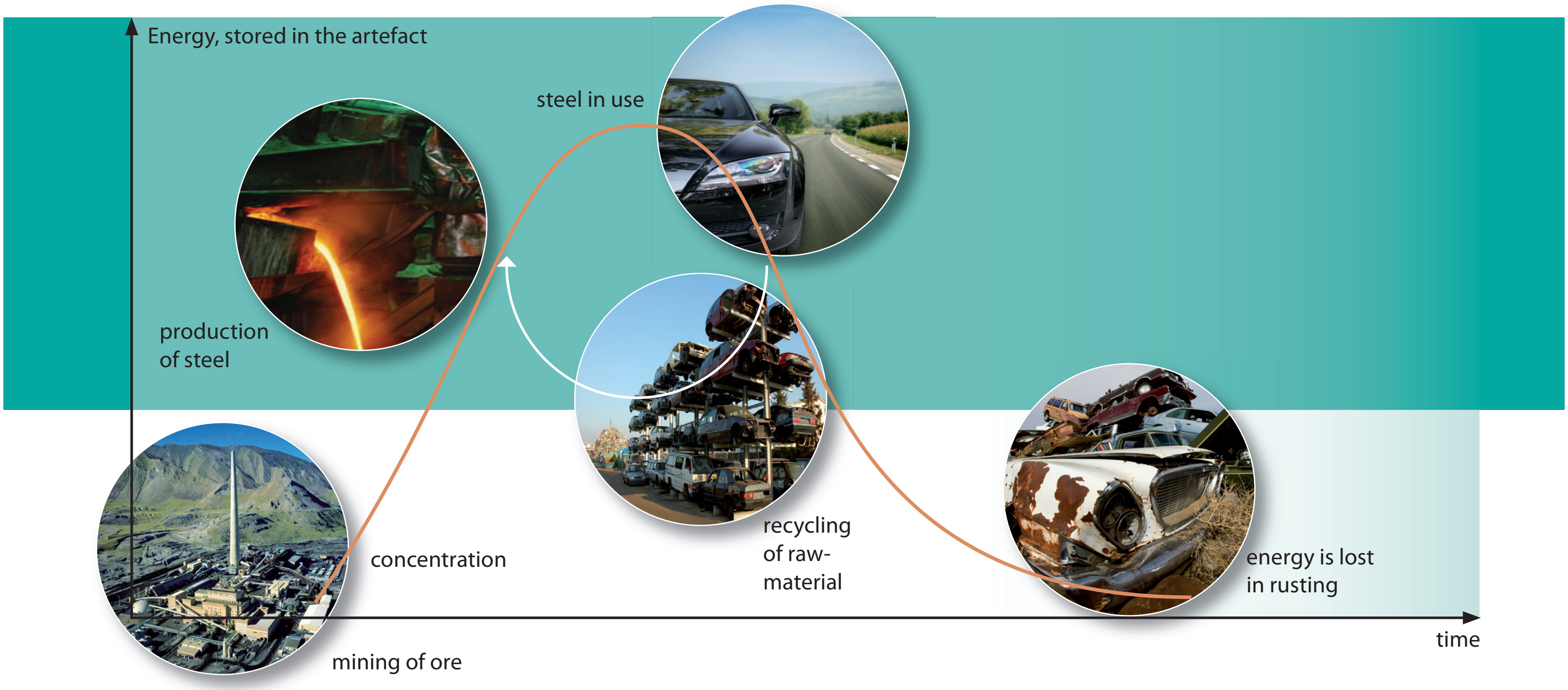
Raw materials, materials and substances

Substances can be identified on the basis of their typical properties. Colour, smell, elasticity or shininess of the surface can be at least roughly recorded by using our senses, whereas density and melting point are identified by a measurement.

Materials are substances which are used as inputs in production or manufacturing. For example, wood is a raw material for paper production. On the other hand, all substances are not regarded as materials. For example, air and water are substances, but they are not considered as materials. However, water could be a raw material for the production of bottled water. Then some chemicals could be added to the water.

Raw materials are first extracted or harvested from nature and processed into a form that can be easily transported and stored, then processed further to produce semi-finished materials. These can be brought into a new cycle of production and finishing processes to create finished products, ready for distribution and consumption.

An example of a raw material is cotton, which can be processed into thread, and then be woven into cloth, a semi-finished material. Cutting and sewing the fabric turns it into a garment, which is an example of a finished material. Steelmaking is another example—raw



LIFE-CYCLE OF AN IRON ATOM: FROM SOIL TO USE.

materials are mined, refined and processed into steel, a semi-finished material. Steel is then used as an input in many other industries to make finished products. After the product has been used, the materials in the product should be recycled. Otherwise, energy and raw materials, which are used in the production of the product, are lost.

Production of steel is a complex process. First ore, a raw material, is mined from the soil. After ore beneficiation it is processed in a blast furnace. An output is raw iron. The raw iron is processed further into steel. Recycling is important to prevent loss of raw material and energy used in the processing of raw material.

Properties of materials

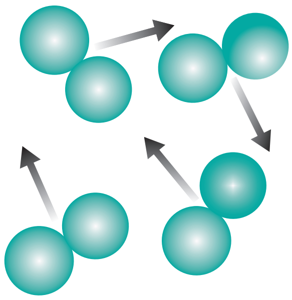
Materials can be identified through their properties. Iron and paper are solid materials; so they have common properties. Iron is grey, and its surface shines. Paper is hard but brittle. Consequently you could separate iron and paper each other with the help of their different properties.

Physical properties of materials are, for example, colour, hardness, and density. These properties and their alterations can be determined without changing the composition of the material.

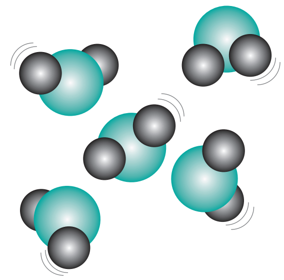
Chemical properties of materials are, for example, flammability, reactivity with acids and bases, and corrosiveness. Oxygen is part of the reaction in rusting, wood combustion and many chemical reactions in our organism. In combustion, materials react with oxygen. The reaction ability of a material can be investigated by examining for example flammability, the combustion process and combustion products.

Materials can be identified based on their physical and chemical properties.

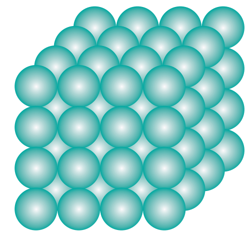
THREE STATES OF MATERIALS



Gaseous oxygen consists of oxygen molecules, which are at varying distances from each other.



Liquid water consists of water molecules which are close to each other, but their orientation and relative position change continuously.



Arrangements of atoms or molecules in crystalline solids are repeated regularly over a very large number of units.

Phases of materials and models of phases

Material can exist in three phases: gas, liquid, and solid. They are known as the three states of material. A solid has a definite shape and volume. A liquid has a definite volume but it takes the shape of a container whereas a gas fills the entire volume of a container. Solids are divided into subclasses of amorphous (or glassy) solids and crystalline solids.

Arrangements of atoms or molecules in crystalline solids are repeated regularly over a very long range of millions of atoms, but their arrangements in amorphous solids are somewhat random or regular over a short range of say some tens or hundreds of atoms only. Amorphous solids are actually like very stiff liquids. For instance, they do not have any definite melting point but they soften gradually.

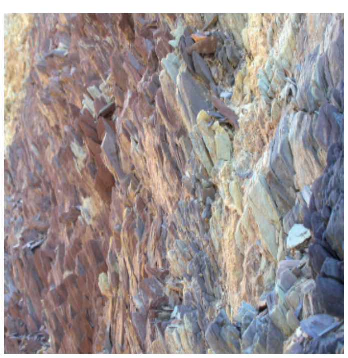
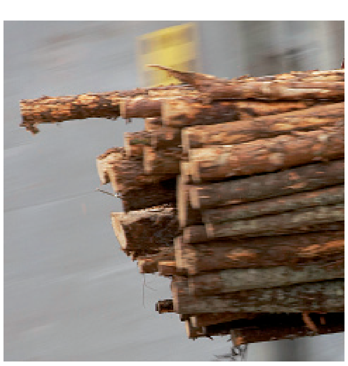
The change of crystal materials into fluid is performed at the melting point. Amorphous materials do not have a melting point. For example, glass softens gradually after a certain temperature. It is therefore impossible to say, which form it is. Liquid becomes gas by evaporating and by boiling. Boiling takes place at the boiling point.

The structure of material can be described with components. A component could be an atom, an ion or a molecule.

The components of crystal materials are “in order”, and the structure is repeated similarly throughout the material. Between the components there is strong interaction. When material melts, its components can move more freely. The components are near each other, however, because there is interaction between them. When material boils, it will become gaseous in which case there is really no interaction between its components. The components in gas could be far away from each other. The components fill the whole volume of the room in a moment.

FISKARS OY

TABLE. EXAMPLES OF RAW MATERIALS AND PRODUCTS

Raw material	State	Properties	Product	State	Properties
sugarcane 	solid	living material, green, soft, malleable, chemically passive, mixture of substances	sugar crystals 	solid	white, hard, robust, very small piece, somewhat transparent, chemically active, pure substance
oil 	liquid	black, fluent, viscous, sticky, dense, chemically active, mixture of substances	plastics 	solid	colourless, varying density, elastic, hardness varies, chemically passive, almost pure substance
ore 	solid	crystalline, hard, various colours from red to green and brown to grey, robust, chemically passive, mixture of substances	steel 	solid	grey, shiny, high density, hard, ductile, chemically active, almost pure substance
wood  Kemira Oy	solid	living material, brown, soft, malleable, chemically passive, mixture of substances	paper  Kemira Oy	solid	can be white or colored, hardness varies, robust, chemically passive, almost pure substance.

Exercises

In the exercises you will familiarise yourself with the materials and their properties by classifying objects used at home and in construction of buildings and objects. First you make the classifications by using your senses. Thereafter you (will) make classifications based on easy experiments.

1. In the picture below, there are objects used in the kitchen.

- Categorise the objects seen in the picture in a meaningful way. Have a look at the example given in the Table below. Fill in the names of the categories in the table.
- Name the objects belonging to the same category. Fill in their names in the Table.
- Describe the properties of the objects or the main material used in the object from the point of view of kitchen use. Write the description in the Table below.

Name of the category	Objects belonging to the category	Properties of the objects or the main material used in the object from the point of view of kitchen use
Paper objects	*Baking paper, egg carton, paper flour bags, cardboard cereal package, paper napkin,*	

- How many object categories did you come up with? ________
- On what grounds did you categorise the objects?

____

____

2. Analyse the materials used in the following artefacts.
Why has a particular material been selected to be used in an artefact?

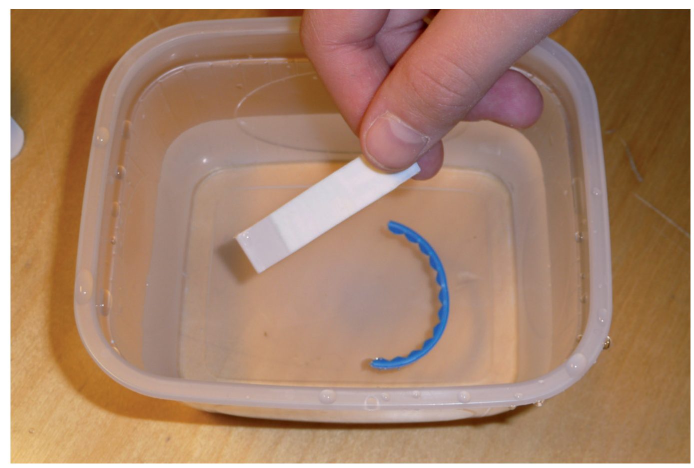
Artefact	Material and reason for material selection
	*Styrox*
	
	
	
	

3. Categorisation of plastics based on experiments: Are all plastics similar?

- You need small pieces of different plastics. Cut out plastic pieces the size of a thumbnail from different plastic objects, such as a plastic mug, a bottle, a bag, pantyhose and a cup.
- You need a cup of water and a candle in/for your investigations. The combustion test can be done outside or in a fume cupboard.

3a. Floating test

If the density of a plastic piece is greater than the density of water, the piece will sink. If the density of a plastic piece is less than the density of water, the piece will float.



Try the floating test to find out whether all plastic pieces have the same density. Classify the plastic pieces according to those with the following:
a) a density lower than that of water,
b) a density higher than that of water.

3b. Combustion test

Try to burn a plastic piece. Classify the plastics based on their combustion properties.

3c. Bending test

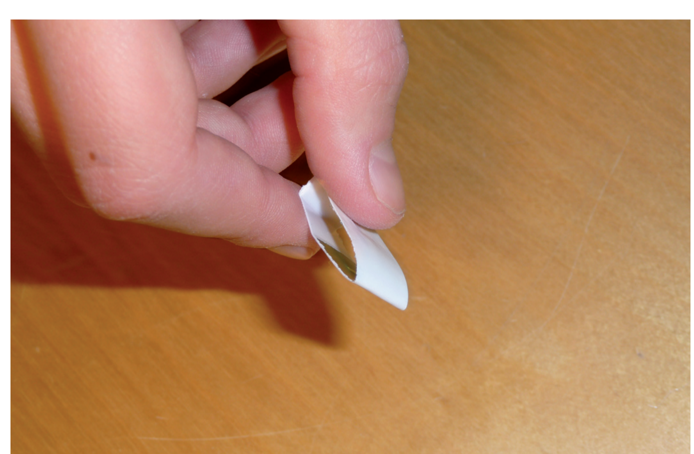
Bend a plastic piece in your hands with strength. Observe the behaviour of the material you are bending. Classify the plastics based on their bending properties.

What are the similarities between plastics?

____

____

____



How do the plastics differ from each other?

____

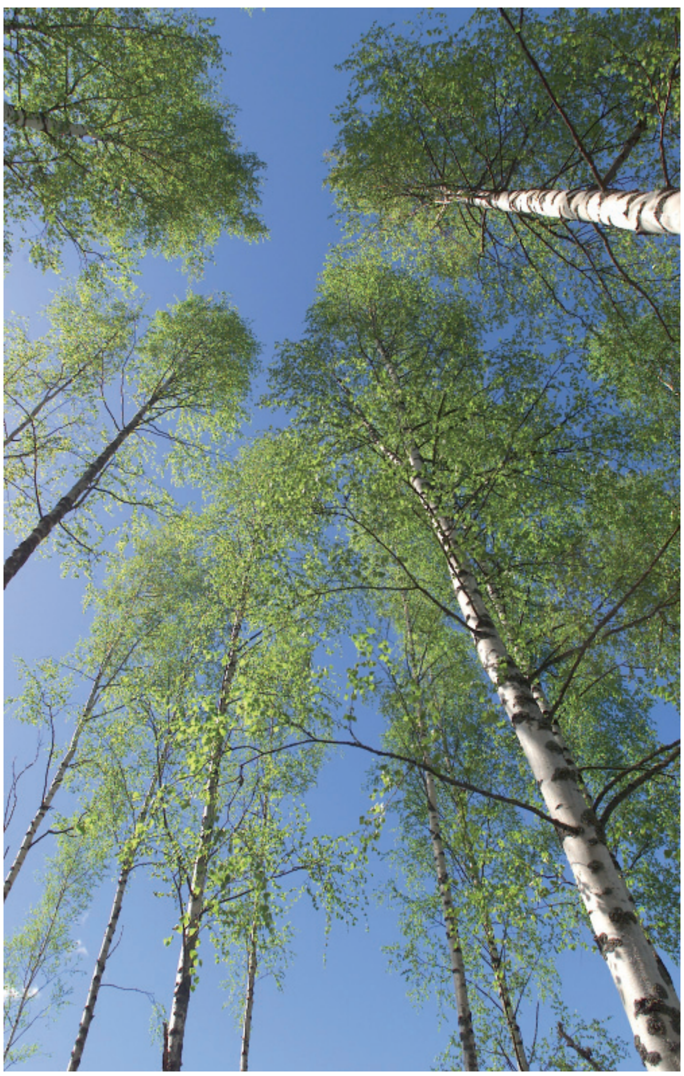
____

____

4. Search on the Internet (Wikipedia) for information on plastics. Fill in the table. Name five plastics, describe their properties and examples of their use.

Plastics	Properties	Use

2 Wood and paper as materials



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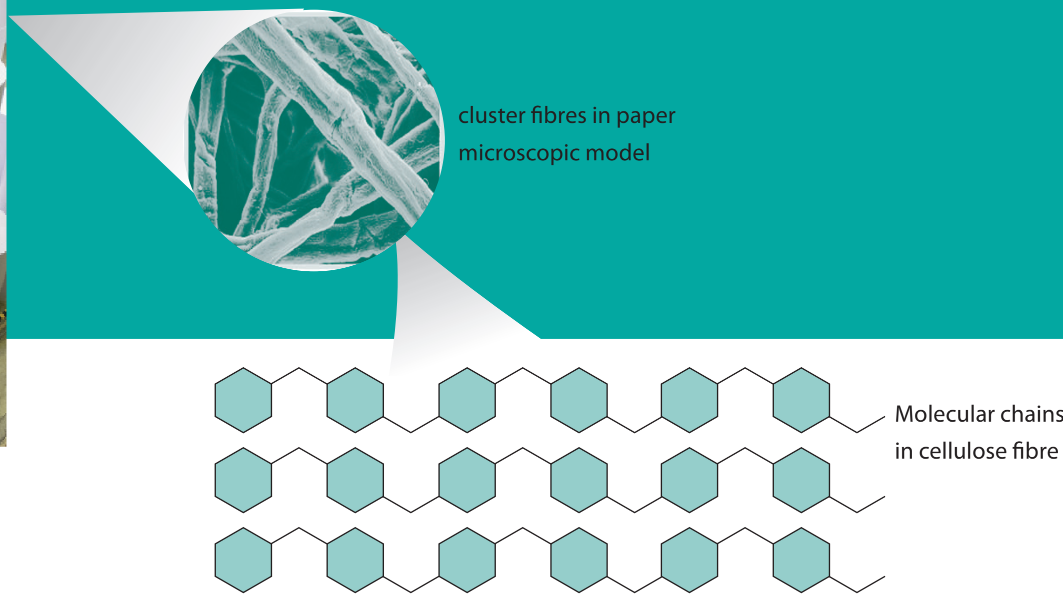
Wood is the hard substance that makes up trees and bushes. It consists of cellulose fibres (50%) and lignin. Cellulose is naturally in a fibrous form and in wood these fibres are held together with lignin. One of the most important material products of wood is paper. Paper is a thin, soft and light material that has been made by pressing. Paper is used for example for writing, printing or packaging.

Properties of paper

Paper is suitable for graphic use (for writing, drawing, copying and printing), for hygiene (toilet paper and kitchen towels) and for packing material. Some products that have been made from paper are newspapers, books, juice and milk cartons and packing material for biscuits and sweets. Also some building materials, such as wallpaper are made from strong paper. Paper money and other bonds are made from high-quality paper. Cotton or rags could be used for this high-quality paper.

The properties of paper can be described in several different ways. Some of its properties are, among others, firmness and stiffness and porosity. When paper is produced, an attempt will be made to make its properties such that it is suitable for the making of a certain product. Among others, the manufacturing process, raw material and the filling and surface materials affect the properties of paper material. For example, writing paper is a thin and flexible material, which is suitable for a writing base.



Paper is composed of cluster fibres and they of cellulose fibres

Structure of paper

The structure of paper can be described on two levels as follows: There is a distribution of macroscopic fibre sizes; the finer ones interpenetrate into the web of larger ones and small clusters of these hold together the larger ones and so on. These “macro-fibres” or cluster fibres can be seen in newspaper paper through a microscope or even by the naked eye. The cluster fibres consist of several cellulose chains. These chains are in the atomic scale and cannot be seen through a standard microscope.

A cellulose chain consists of about 5000 glucose, $C_6H_{12}O_6$, units and has a linear fibre-structure. This kind of fibre-structure is similar to many other everyday materials, such as carbon fibre, plastic fibre, glass fibre and nylon fibre. Common to all these are the long chains of atoms or other structure units that constitutes it. Glucose is an example of a carbohydrate, which refers to a family of compounds, the simplest of which have the formula $C_nH_{2n}O_n$.

In writing paper, the surface has a top layer of fine fibre particles, which gives it a glossy appearance. While good varieties of paper have finer particles in the surface to provide better glaze, the relatively inexpensive varieties like the newsprint paper have very little or no glazing layer at all. That is why the larger fibres of the newspaper paper are clearly visible even to the naked eye.

During paper production, the cluster fibres get a parallel orientation. This is the reason why newspaper paper behaves in a different way when torn vertically and horizontally.

PHASES OF PAPER MAKING

Extracting usable cellulose fibres from wood through pulping.

Bleaching (if required) the pulp

Manufacture of paper and recycling

Paper is produced by pressing together cellulose fibres, additives and filling material, such as chalk or china clay, and drying them into flexible sheets.

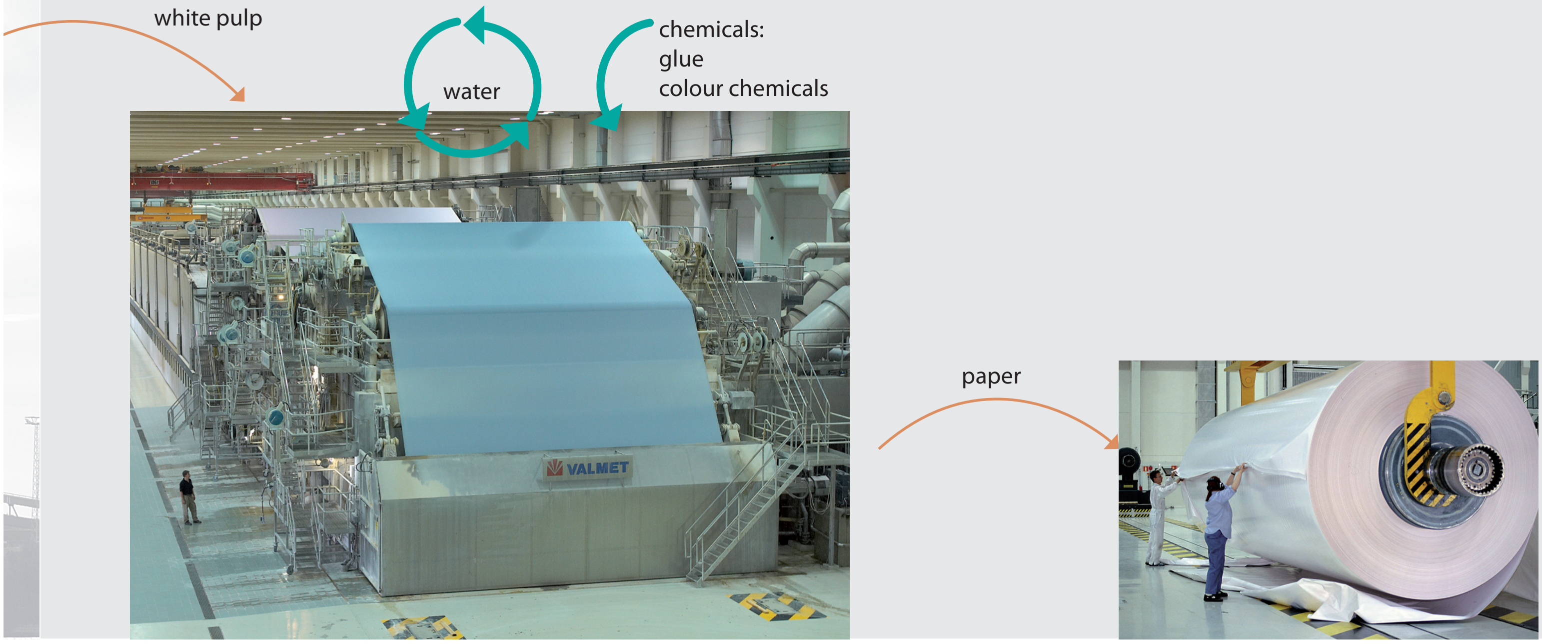
Wood is the raw material of paper. Wood is ground into woodchips after which it is boiled in an alkaline solution. This is called the pulping process. During the pulping the lignin dissolves in the alkaline solution and the fibres of the wood differ from each other. The created fibre “porridge” is called chemical pulp. During the pulping process some fragrant gases can be smelt in the air and due to this people know where factories are in the locality.

The pulp can also be produced mechanically. In the making of the mechanical pulp the fibres of the wood are loosened from each other by chafing. The chafing softens lignin and loosens the fibres from each other.

After the pulping process the lignin dyes the pulp brown. It can be used for the making of unbleached paper or it can be bleached. Oxygen or hydrogen peroxide is used for the bleaching.

After the bleaching water is added to the pulp and it is pumped into a paper machine. In the paper machine the pulp forms an unbroken pulp disk over the wire. The wire is a very smooth and dense plastic network. There is more than 90 per cent of water in the pulp on the wire. Water transports pulp and divides it on the wire evenly. The water is removed gradually from the pulp by absorption. Finally, the paper is formed by pressing the pulp between rotating cylinders in a paper-making machine. The created paper is wound into big circular rolls.

In paper different glue materials are used for the binding of fibres. The writing and duplication properties of the paper are made better when some fillings and covering materials or pigment materials are added to the paper. In general, the filling materials and other additives affect the properties of paper types, such as strength, non-transparency, smoothness and printing abilities



Paper sheet formation in a paper-making machine.

In newspaper paper it is possible to see the fibres of the paper even with the bare eye when the paper is held against light. There are almost no pigment materials in newspaper material. The kitchen towel paper is made of nearly pure cellulose.

Waste paper could also be used for the making of the paper. The recycling of waste paper saves energy and raw material, wood.

KEMIRA OY

Exercises

1. What products are manufactured of **a)** paper, **b)** pasteboard and **c)** recycled paper?

a)

b)

c)

2. Generate at least five ideas, for recycling **a)** newspaper paper, **b)** copy paper **c)** pasteboard and **d)** paper cups.

a)

b)

c)

d)

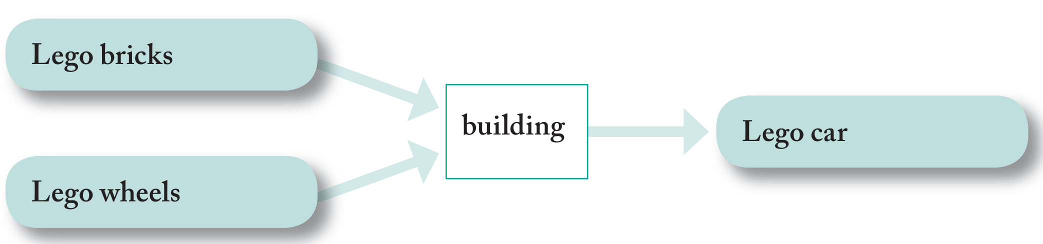
3. **a)** What materials can you use instead of paper?

b) What were the materials used instead of paper for writing in the past?

4. Describe the structure of paper. Draw a figure.

5. Processes in manufacturing can be illustrated by a flow chart.
In a flow chart, there is input, output and a process.

For example, a flow chart that illustrates the building of a Lego car can look like this:



Make a flow chart of paper production: from wood to paper sheet.

3 Plastics as materials

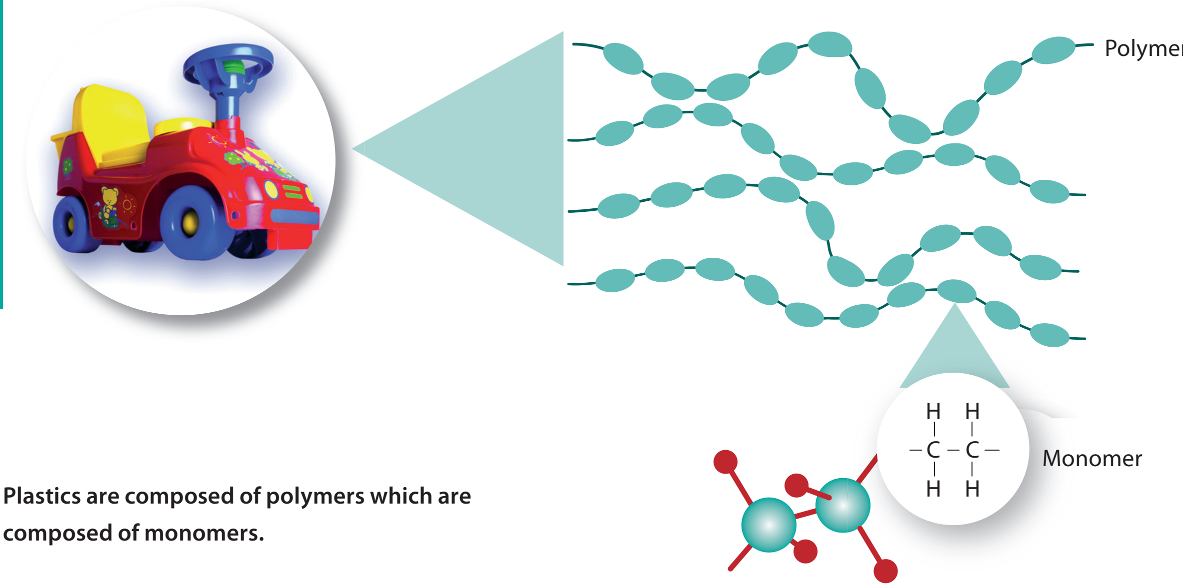

PlasticsEurope

Plastic is the general term for a wide range of synthetic solid materials suitable for the manufacture of industrial products and artefacts. The word "plastic" derives from the Greek πλαστικος (plastikos), "fit for moulding". It refers to the plasticity of the material that allows them to be cast and pressed during manufacture, or extruded into a variety of shapes—such as films, fibres, plates, tubes, bottles, boxes and much more.

Properties of plastics

The use of plastics was started in the early 1900s in the making of electrical apparatuses due to its good properties. Almost all plastics are good insulators, or in other words do not conduct electrical currents. Several plastics are also firm and durable. Thus plastic is an ideal material for the making of plugs, the covers of electricity cables and of electrical apparatuses. The use of plastics as the raw material of different cloths was started also in the early 1900s. Rayon was the first plastic fibre for making cloths. The invention of Nylon in the 1930s was one of the biggest events in the history of the use of plastics.

Several properties have been developed for plastics, and traditional raw materials such as wood and steel have been replaced with plastics. In the construction business plastic has become commonly used in drainpipes, in floor materials, in heat and water insulators and wallpapers. In the car industry plastics are used in the interior, in the buffers and parts of the motor. Plastics are used as the surface material and heat insulator of clothes. Plastic is a general packing material. The lightness, the corrosion freeness and the easiness of the manufacturing are properties of plastics which



Plastics are composed of polymers which are composed of monomers.

affect their use. Consequently, plastics are used both in ordinary objects and in complicated and more demanding applications of technology and medicine.

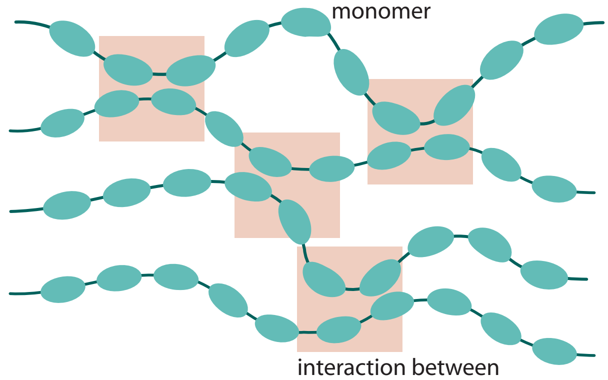
In general, changes in temperature affect plastics differently compared to metals or small-molecular materials. At room temperature several plastics are hard, glasslike. Plastics begin to soften when the temperature rises. Therefore plastics are not suitable to be used in high temperatures. Also the tenability of plastic is a problem. The used products that have been made from the plastic do not disappear from nature. Hence, the developing of plastics that decompose in nature has started.

Structure of plastics

The micro-structure of plastic is that of a chain. Chains are called polymers and are made of small molecules, monomers, which are all identical. Consequently, a polymer is a molecule in which several small molecules, the monomers, have been connected with chemical bonds. The process in which a polymer is made from the monomers is the polymerisation process. Plastics differ from each other according to how the polymers are connected to each other and according to what monomer in the polymer is repeated. For example, polyethylene, polyacrylic, polyester and polyurethane are polymers. The prefix "poly" means that the polymer contains many monomers. The term after the word "poly" is connected to the monomer or to the syntheses (production) of the polymer. For example, the polyethylene has been created in the polymerisation of the ethene monomer. The monomers of the chain give different properties to the material, as do the types of chemical bonds or interactions between the chains.

The type of monomers, chain structure and the netting of chains affect the properties of plastics, such as solubility, heat durability, density, firmness and strength. The bigger the structural units, the harder the plastic is to treat. An amorphous structure, softness and elasticity are usually found together while hard and fragile materials often have a nearly crystalline structure. Plastics are classified as thermoplastics and as thermosetting plastics according to how the polymers are connected to each other. The bigger the components of plastic (the polymers), the harder they are.

ORTHEX OY



In thermoplastics the polymer chains are bonded to each other only in places where the chains are located close to each other. The chains have space to move and the plastic is soft and may be stretched out of its original shape.

Thermoplastics

Thermoplastics are composed of polymers loosely plugged into each other. Thermoplastics become soft when heated because the chains can move easily past each other. Thermoplastics can also be melted and formed again or recycled. Thermoplastic is an amorphous material, in other words it does not have an exact melting point but it will soften gradually when the temperature rises.

An example of a thermoplastic, composed of not-bonded polymers, is cling wrap, commonly used to cover food. Plastics of this kind melt when heated. Heat makes the chains vibrate and so puts extra distance between them, which weakens the bonds between the chains and lets them move past one another. This explains why cling wrap becomes more pliable after having been in a warm temperature for a period of time. When thermoplastic cools, the bonds will be created again and the plastic returns to a solid state.

Of those plastics used in daily life, 80% are thermoplastics, such as polyethylene PE, polypropylene PP, polystyrene PS or polyvinyl chloride PVC. PE and PP plastics are used a lot in the packages of groceries. PP has a nearly crystalline structure, solid and strong, and it endures heat better than PE. PE is divided into low density PE (LDPE) and high density PE (HDPE) materials. Both endure well the most common acidic and soapy materials in households, but nitric and sulphuric acids or acetone cause changes in the material.

PS and EPS (extruded polystyrene) are hard , solid and fragile. They are used in making disposable plates and cups. They soften at a rather low temperature and endure badly acetone and oils. PVC is dense and endures solvents well other than organic ones, like acetone. PVC is used to manufacture pipes, furniture, plastic carpets, rain coats, and packages. Thermoplastics are used in bottles, foils, liquid crystal displays, boats, foam plastics, and urethane foams, among others.

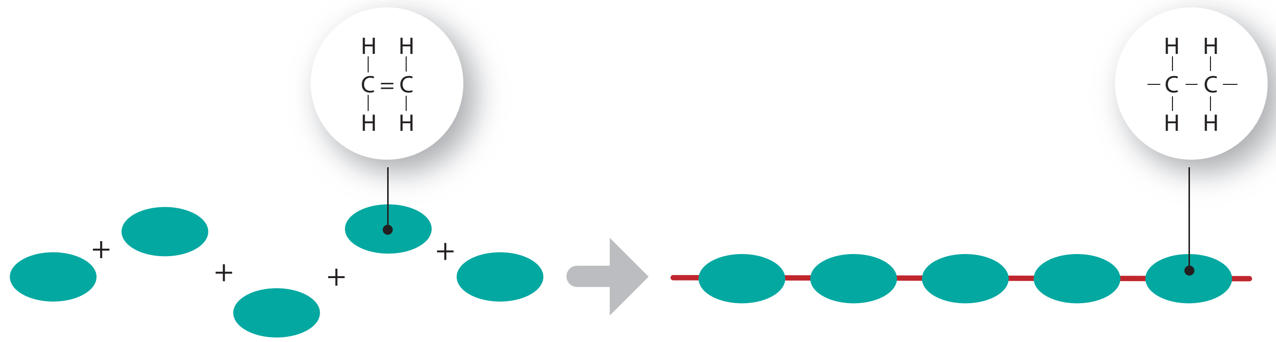
Some plastics and their uses are: polystyrene (PS) (vessels, toys, boxes); polyethylene terephthalate PET (soft drink bottles, lures); polyvinyl chloride (PVC) (building products, insulators of cables, and rain coats); polyamide (PA) (nylon clothes, tooth brushes, machine parts); polycarbonate (PC) (lenses of sunglasses, plastic bottles); and polytetrafluorethylene (PTFE) (the Teflon surface of frying pans, gaskets, transparencies). Plastics which are used in machines and structures are called technical plastics. Some such plastics are, among others, PA (nylon), PC and PTFE (Teflon). Technical plastics are firm and often also transparent and they have a small friction.

Thermosetting plastics

Thermosetting plastics are composed of a network-like structure. They are hard and rigid plastics, resistant to higher temperatures than thermoplastics. Once set, thermoset plastics cannot be remoulded.

If the polymers in plastic are chemically bonded to one another, the plastic is hard and brittle. The micro-structure is like a net.

When thermosetting plastics are heated, the chains do not move. They tend to burn and char rather than melt. They are technically referred to as thermosetting polymers. These plastics are stronger than the types with little cross linking and are used where strength is the desirable property, such as in the handles of cooking pots. These plastics require more effort to recycle.



Plastics are made of small-molecular compounds by polymerising, which means attaching similar recurrent units into long chains.

Manufacture of plastics and recycling

As described above, plastics can be classified by their chemical structure, namely the molecular units (micro structure) that make up the polymer's backbone and side chains. Plastics can also be classified by the chemical process used in their synthesis, like condensation or polyaddition. Other classifications are based on qualities that are relevant for manufacturing or product design. Examples of such classes are the biodegradable and electrically conductive plastics.

Oil refining produces raw materials for plastics: around 4% of produced crude oil is used yearly in manufacturing plastic products. Plastics, synthetic rubber and synthetic fibres are made of small-molecular organic compounds by polymerising. Polymerisation is a reaction in which large numbers of small structural units are attached together into a giant molecule. Many common plastics are manufactured like this. A plastic manufactured by polymerising is commonly called a polymer. Polymers can be categorised on the basis of their production method, properties, use or the structure of the polymer chain.

Around 150 million tons of different kinds of plastics are manufactured yearly in the world. Plastics are light and handy, and easy to cast and attach together. In the newest plastics, it is possible to combine the best properties of metals and plastics. Plastics can be made stronger with natural fibres, which make them stronger and firmer and more pro-environmental to manufacture and use.

Plastic objects are manufactured by casting and pressing. Foils are manufactured by pressing the melted plastic pulp into thin sheets between rotating rollers or by blowing plastic bubbles from it. If the foil is tightened in the manufacturing phase, the tightening leaves tension in the foil. The tensions are discharged in heating and the foil shrinks. For example, yoghurt pots can be restored to their original sheet-like forms when heated carefully.

Plastics extrusion is a high volume manufacturing process in which raw plastic material is melted and formed into a continuous profile. Extrusion produces items such as pipe/tubing, weather stripping, window frames, adhesive tape and wire insulation.

The thermosetting plastic objects are made by a direct casting process. In the process the unfrozen plastic mass is pressed through the nozzle to the mould. The plastic part solidifies quickly in the mould. So the making of plastic objects is quick.

The thermoplastics can be recycled and reused. The reuse is reasonable when plastic waste has been sorted on the basis of a type of plastic and colour. Also the miscellaneous plastic waste can be used. For example, plastic planks can be made from the mixed waste.

Most plastics can be burnt as energy waste without the emission of harmful substances. The temperature of the burning material must then be kept above 300 °C throughout the burning process to avoid forming of harmful compounds. The burning then results only in carbon dioxide and water from the clean plastics. However, the pigments and additives used in production of plastics could form poisonous compounds when plastic is burned. PVC plastics are unsuitable for burning because of the chlorine, among other things, contained in them.

Exercises

1. What products are manufactured from **a)** thermoplastics, **b)** thermosetting plastics?

a)

b)

2. Generate at least five ideas for recycling **a)** plastic bottle, **b)** plastic bag, **c)** pasteboard and **d)** plastic pack used for mince.

a)

b)

c)

d)

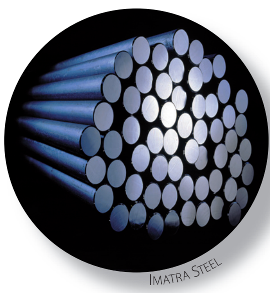
3. What materials can you use instead of plastics for a purpose of your choice? Give five examples.

4. Describe the structure of thermoplastics. Draw a figure.

5. Make a flow chart of plastic production: from oil to plastic cup. Look for help from the text below, underline the most fundamental concepts:

Crude oil varies in its composition, like gasoline and naphtha, gas oil, lube distillate and residuum. Refinery processes turn low quality material into higher quality products which can be used also for production of plastics. These high quality products in the case of plastic production are monomers, like ethene or propene. Plastic consists of large polymers that are made up of monomers that can be linked together in various ways in a process called polymerisation. There are two categories of producers in the plastic industry. The first consists of those chemical factories that make the polymers: polyethylene, polypropylene, polystyrene, PVC, polyesters, nylons, etc. Most of the materials they produce can be considered as raw-materials for the second type of industry. The second type process polymers in different kinds of processes into films, fibres, paints, adhesives, composites (e.g., glass fibre reinforced polyesters) and the extraordinary range of plastic goods that are used in modern society. Plastic cups can be produced from films.

4 Metals as materials


Imatra Steel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Ecomond


Fiskars

Except for mercury, all metals are solid in room temperature. The traditional definition of metal focuses on the bulk properties of metals. They tend to be lustrous, ductile, malleable, and good electric and heat conductors, while non-metals are generally brittle (if solid), lack lustre, and are insulators.

Properties of metals

Most metals have certain characteristic physical properties: they are usually shiny (they have metallic lustre), have a high density, are ductile and malleable, have a high melting point, are hard, are usually solid at room temperature and conduct electricity, heat and sound well. Some metals and metal alloys are strong and resilient. These properties make them useful materials for carrying large loads or resisting impact damage. Because of their properties, metals are used for many different purposes. Electric wires contain copper to conduct electricity, kettles are made of metallic compounds since metals conduct heat, and metals are also used in mirrors and jewellery because of their shine. However, there are also some metals that have low density, are soft, and have low melting points.

The properties of the metals can be influenced by alloying metals. Alloys are composed of two or more pure metals or low percentages of other elements like carbon or silicon. Their properties can differ from the properties of the original metals quite markedly in the same way as the properties of salt and water differ from those of salt water. The melting point of an alloy is

OUTOKUMPU OY

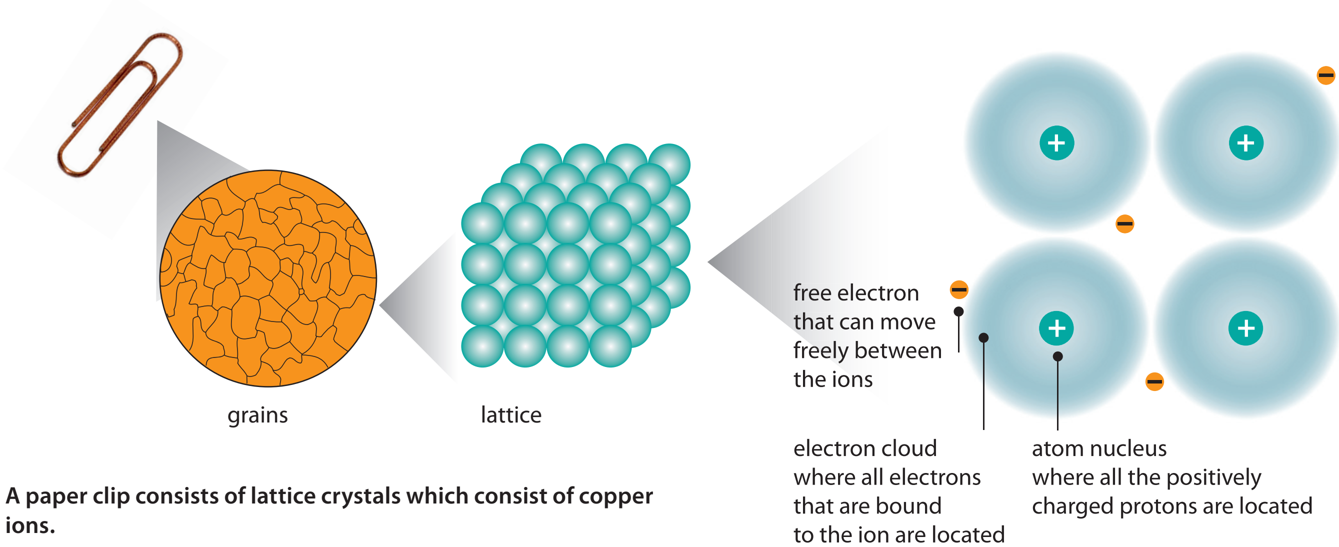
usually lower than that of pure metals. For instance, the melting point of antimony (Sb) is 630 °C and that of lead (Pb) 327 °C, but a compound that contains 87% of lead and 13% of antimony melts at 246 °C.

Steel is mainly iron but there are other metals, such as nickel, chromium, cobalt, tungsten, molybdenum, vanadium and aluminium in addition to coal. Stainless steel contains fewer than 1.2% of coal and more than 12% of chromium and 8% of nickel. Due to the addition of chromium the surface of steel does not rust like the surface of an iron object. Steel is an ideal material. Steel can be worked by rolling or by forging. In the rolling the metal object goes several times through the rolls which work the metal into the desired form. Steel products are extremely firm and tough. For example, the body of a high-rise building, bridges, towers, railroad tracks, trains, ships and cars can be manufactured from steel.

Metals are divided into two groups, light and heavy metals, based on their density. The line between the two is considered to be the density value 5g/cm^3. Lithium is the lightest, with the density of 0.53g/cm^3, but other common alkalic metals (Na and K) are lighter than water as well. The heaviest metals are platinum-related osmium and iridium, the density of which is over 22g/cm^3. They have about two times the density of lead (11g/cm^3).

The metals can be arranged as an electrochemical series according to their generosity.

On the basis of their ability to be oxidised, metals can be arranged in a list called the electromotive series. It is a list of metals in an order which indicates the relative tendency to be oxidised. Metals at the beginning of the series, like cesium and lithium, are more readily oxidised than those toward the end, like platinum and gold. Therefore gases of air, oxygen and water vapour, are harmful to most metals. For example, iron oxidises or rusts. Therefore the surface of iron must be protected with the help of oil or paint to prevent rusting. Some metals, like aluminium and titanium, form a protective oxide layer, which prevents them from oxidising in the air.



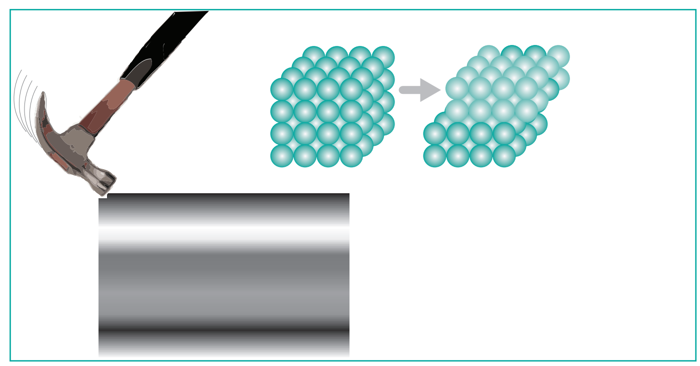
A paper clip consists of lattice crystals which consist of copper ions.

Structure of metal

When the uniform surface of a metal is observed through a microscope, crystalline grains will be seen on the surface. These grains are created after the liquid metal has solidified. In the area of one grain the components of the metal, metal atoms, are tightly packed and in a crystalline lattice structure. This structure is a regular arrangement of atoms that repeats itself many times. As this micro structure cannot be seen through a microscope, the structure is illustrated with a ball model in which the balls present the metal atom.

The properties of the metals can be explained with the help of the structure of the metal. Components of the metal, metal atoms, are bonded together with a metal bond. Metal atoms are as positive ions in the metal crystal. In crystal, common free electrons can move freely. The electrons prevent positive ions meeting each other and function "as a glue which keeps the metal together". When metal is forged by hammering for example, the electrons move with ions and prevent it breaking. Even though the regular crystalline structure does not continue without faults from one crystal to another, crystals are strongly bound together.

Electric and heat transfer property of metals can be explained also with the help of the model of the metal. The electric and heat conductivity are a consequence of the fact that the electrons are able to move freely in the space between the ions. Also the metal luster is a consequence of the free electrons, which hinder the light going through the metal.

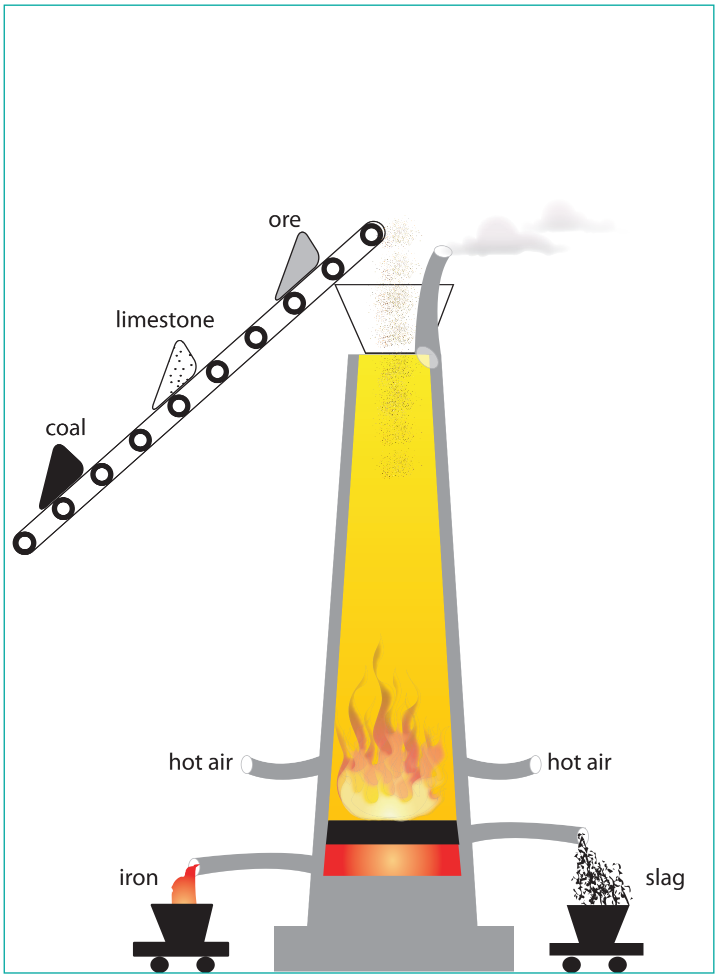


Forming of metals can be explained with the microscopic structure of metals.

Manufacture of metals and recycling

Ore mineral is raw material for metals. In ore the concentration of the desired metal is high enough for the mining to be financially beneficial. Mined ore is ground fine, and the valuable minerals are separated from the valueless side stone by enriching. Enriching is generally done by foaming. Heavy minerals are enriched by allowing the particles to stratify at the bottom of the dish, which is called sedimentation. Magnetic minerals, on the other hand, can be enriched magnetically.

As an example, production of iron in a blast furnace is analysed. After enrichment, the ore is blended with limestone and coke and goes to the blast furnace. A blast furnace is a tower-shaped structure, made of steel, and lined with refractory or heat-resistant bricks. At the bottom of the furnace, very hot air is blown in. Coke burns in the presence of hot air. Oxygen in air reacts with carbon in coke to form carbon monoxide. Carbon monoxide then reacts with iron ore to form carbon



Production of iron in a blast furnace.


Imatra Steel

dioxide and pure iron. Melted iron sinks to the bottom of the furnace. Limestone combines with rock and other impurities in the ore to form a slag, which is lighter than iron and floats on top. As the volume of the charge is reduced, more is continually added at the top of the furnace. Iron and slag are drawn off separately from the bottom of the furnace. Melted iron might go to a further alloying process, or might be cast into ingots called pigs. Slag is carried away for disposal.

Pure metal is rarely usable as such. By using suitable compound materials the properties can be modified in many ways. Iron is the most used metal these days. Iron is usually used only as compounds, since pure iron is too soft and easily rusts. Cast iron contains around 3-4% of carbon and often the same percentage of silicon. Cast iron is hard but fragile, and it does not endure treating.

Steel is made of cast iron in a converter. Pure oxygen is fed to the converter and then carbon, soluted in a cast iron, is oxidised. The carbon concentration of steel varies from 0.3 to 1.7%. The properties of steel can be adjusted with different compound materials depending on the use. Hardness and durability can be generated with vanadium and tungsten. Stainless steel contains nickel and chromium.Aluminium is the most common metal in the lithosphere. It is light and very durable, since an oxide layer is developed on its surface that protects the metal. Aluminium is also used a lot as packing material (foil) and in deodorants as the bacteria killing ingredient.

Copper is used a lot in electrical, heat and refrigerating engineering since it is one of the best electric and thermal conductors. In buildings copper is used as a coating and in decorations, because it is chemically durable and has a beautiful colour (copper is the only coloured pure metal in addition to gold). Many alloys contain copper. Bronze is the compound of copper and tin, and brass contains copper and zinc. Copper is usually added to gold and silver objects to increase the hardness of the otherwise too soft noble metals.

Exercises

1. What products are manufactured of **a)** iron **b)** aluminium?

a)

b)

2. Generate at least five ideas for recycling **a)** metal tin **b)** metal cans.

a)

b)

3. What materials instead of metals can be used for a purpose of your choice?
Give five examples.

4. Describe the structure of metals. Draw a figure.

5. Make a flow chart of steel production from ore to steel.

5 Material properties inquiries

Through the inquiry activities you will integrate the macroscopic and microscopic view of materials. You will create an explanation for the structure, properties and behaviour of materials.

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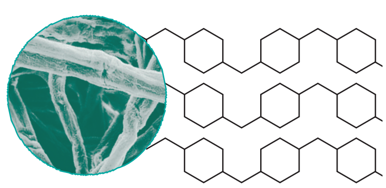
Activities

1. Dropping test

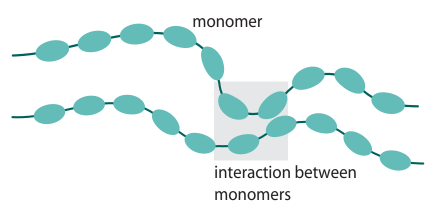
Appliance and materials:

- newspaper paper or silk paper
- aluminium foil
- plastic wrapping
- adhesive tape
- a marble or a small stone
- measuring tape for measuring the dropping height

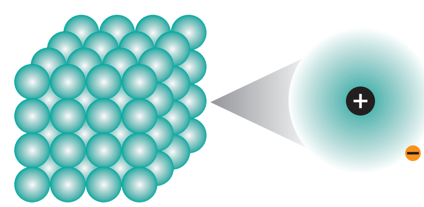
Working instructions: Read the working instructions. After reading, compile a prediction (hypothesis) of what is about to happen in the test. Write the prediction in the space allocated for it. Make your prediction based on the micro model of the materials:



Paper is composed of cluster fibres and they of cellulose molecules having a polymer structure.



Plastic consists of chain-like polymer molecules. The polymer molecules have bound themselves weakly to each other.



Metal has a crystal structure. In the crystal the free electrons bind metal ions together.

Tauten paper, plastic wrapping and aluminium foil between two tables with adhesive tape. Drop a stone or a marble on them from the same height. Measure the height to be sure. Repeat the experiment by dropping the stone from an increased height. Keep increasing the height until you can make conclusions of the strength of the materials.

Predict

What will happen in the test? Pay attention to the spot where the stone hit the material. Base your prediction on the micro models of the materials.

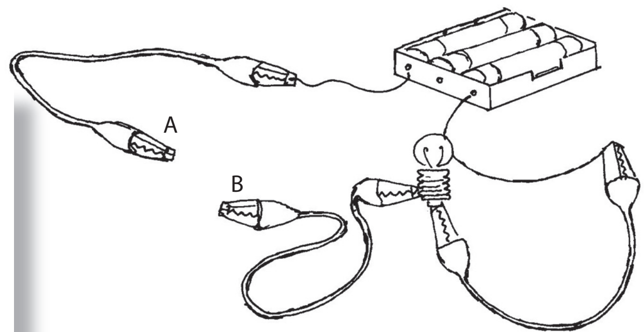
Observe

What happens in the test?

Explain

How can the observed phenomena be explained with models? How are the particles of the material organised in the material?

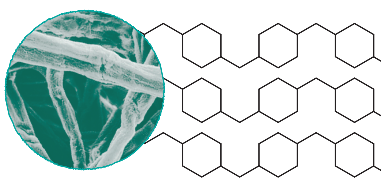
2. Conductivity test



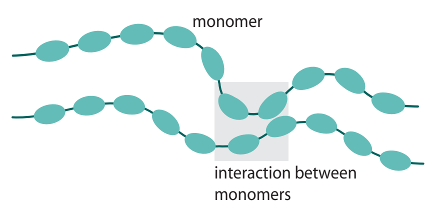
Appliance and materials:

- batteries
- three cords
- bulbs
- silk paper
- copy paper
- aluminium foil
- copper plate
- plastic object

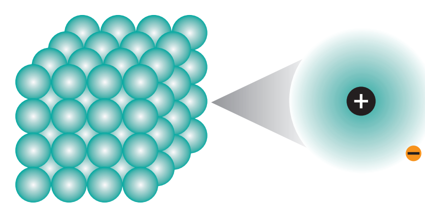
Working instructions: Read the working instructions. After reading compile a prediction (hypothesis) of what you predict is about to happen in the test. Write the prediction in the space allocated for it. Make your prediction based on the micro model of the materials:



Paper is composed of cluster fibres and they of cellulose molecules having a polymer structure.



Plastic consists of chain-like polymer molecules. The polymer molecules have bound themselves weakly to each other.



Metal has a crystal structure. In the crystal the free electrons bind metal ions together.

Build a closed electric circuit like in the picture above. Try to get the light to switch on. Add one cord and piece of material the conductivity of which should be found out. Can you get the light to switch on this time? Repeat the procedure with other materials. Which material is conductive, which is not?

Predict

What will happen in the test? Base your prediction on the micro models of the materials.

Observe

What happens in the test?

Explain

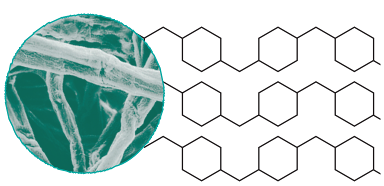
How can the observed phenomena be explained with models? How are the particles of the material organised in the material?

3. Ripping test

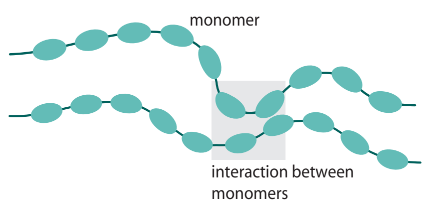
Appliance and materials:

- kitchen towels
- copy paper
- aluminium foil
- plastic wrapping

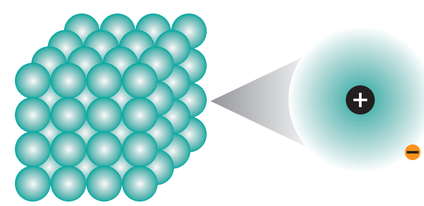
Working instructions: Read the working instructions. After reading compile a prediction (hypothesis) of what is about to happen in the test. Write the prediction in the space allocated for it. Make your prediction based on the micro model of the materials:



Paper is composed of cluster fibres and they of cellulose molecules having a polymer structure.



Plastic consists of chain-like polymer molecules. The polymer molecules have bound themselves weakly to each other.



Metal has a crystal structure. In the crystal the free electrons bind metal ions together.

Try to rip materials in different directions, lengthwise and crosswise. What do you notice?

Predict

What will happen in the test? Base your prediction on the micro models of the materials.

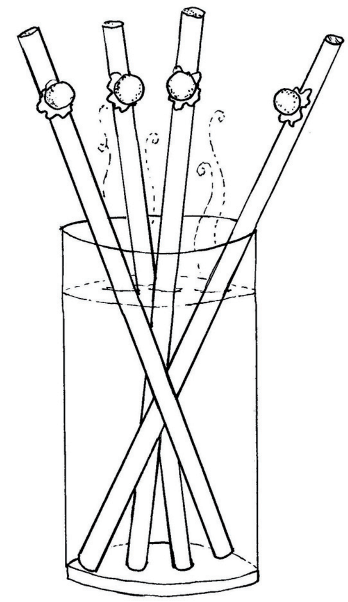
Observe

What happens in the test?

Explain

How can the observed phenomena be explained with models? How are the particles of the material organised in the material?

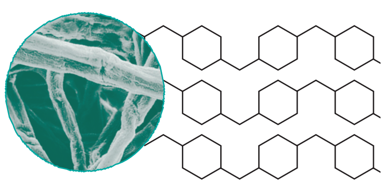
4. Heat conductivity test



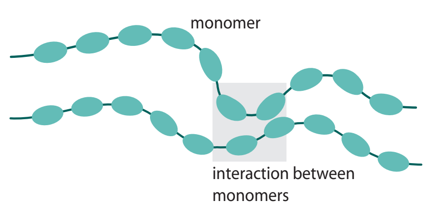
Appliance and materials:

Same size:
- strip of thick cardboard
- big nail
- plastic stick
- butter
- peas
- beaker
- hot water

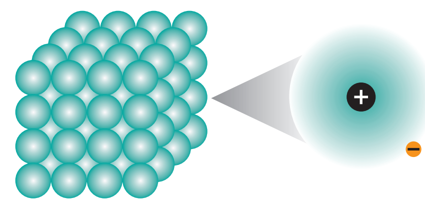
Working instructions: Read the working instructions. After reading compile a prediction (hypothesis) of what is about to happen in the test. Write the prediction in the space allocated for it. Make your prediction based on the micro model of the materials:



Paper is composed of cluster fibres and they of cellulose molecules having a polymer structure.



Plastic consists of chain-like polymer molecules. The polymer molecules have bound themselves weakly to each other.



Metal has a crystal structure. In the crystal the free electrons bind metal ions together.

Attach peas to the samples of materials with butter. Attach the pea to the same height in all materials. Pour hot water carefully into the beaker and place the sticks to the water. Make sure the peas are well above the water. Observe the peas.

Predict

What will happen in the test? Base your prediction on the micro models of the materials.

Observe

What happens in the test?

Explain

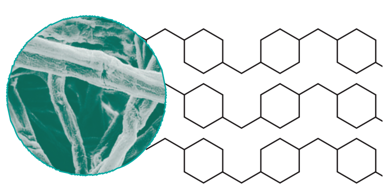
How can the observed phenomena be explained with models? How are the particles of the material organised in the material?

5. Bending test

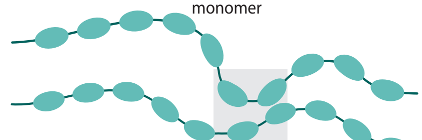
Appliance and materials:

- thick metal wire
- two strips of cardboard, other cut crosswise and other cut lengthwise
- plastic spoon

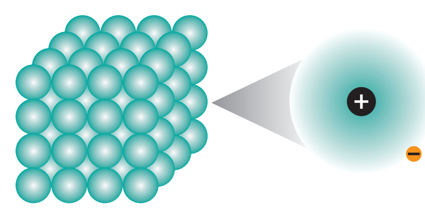
Working instructions: Read the working instructions. After reading compile a prediction (hypothesis) of what is about to happen in the test. Write the prediction in the space allocated for it. Make your prediction based on the micro model of the materials:



Paper is composed of cluster fibres and they of cellulose molecules having a polymer structure.



Plastic consists of chain-like polymer molecules. The polymer molecules have bound themselves weakly to each other.



Metal has a crystal structure. In the crystal the free electrons bind metal ions together.

Bend the strips of materials in your hands first gently and then carefully with increasing strength. Observe the behavior of the material you are bending.

Predict

What will happen in the test? Base your prediction on the micro models of the materials.

Observe

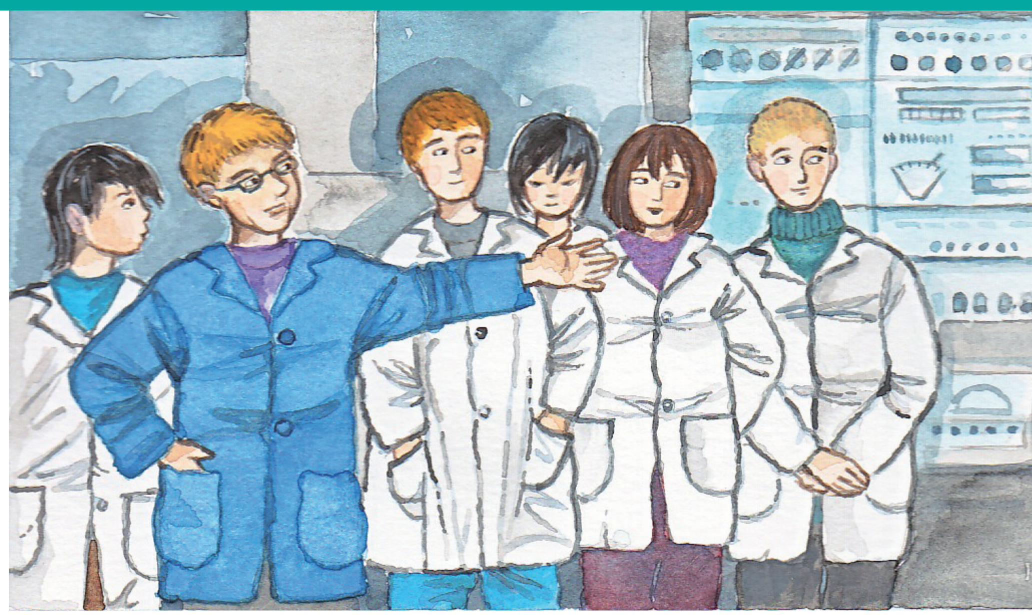
What happens in the test?

Explain

How can the observed phenomena be explained with models? How are the particles of the material organised in the material?

6 Industry site visit

You will become familiar with material science and technology, different materials, and use and processing of materials through an industry site visit. Moreover, you will become familiar with careers at an industrial site.



Planning the site visit

Became familiar with the syntax of the site visit:

1. Preliminary tasks before the site visit (1 – 2 hours):
- forming of student groups for tasks and project work,
- discussing about goals of the visit,
  - co-planning of the tasks or project work,
  - co-planning of the structure of the report and presentation style,
  - co-planning of the ICT use
  - co-planning of the evaluation of the visit and the report,
- allocating tasks for and within each group
- preparation of the project plans of the group (goals, tasks, reporting plan),
- planning of the preliminary questions to be sent to the experts of the site

2. The actual site visit (2 – 4 hours):
- introduction (plant, what they are doing, what kind of people are working there),
- "sightseeing" around the plant,
- group work, different topics as agreed with students.

3. Student group reports (1 – 2 hours):
- preparation of the reports, articles,
- presentation of the reports, articles
- contacting the site for comments,
- discussion about what students have learnt and what could be improved,
- preparation of publication of reports

4. Evaluation (0.5 – 1 hour):
- evaluation of the reports and presentations,
- evaluation of the ICT use during the project,
- evaluation of the arrangements and visit,
- evaluation of learning outcomes,
- evaluation of student motivation and behaviour

5. Ideas for planning future site visits (0.2 – 0.5 hours).

Visits

Become familiar with the site to be visited through their Web page and booklets.

- What is the name of the site?
- What raw materials are used?
- What are the main products?
- What would you like to know about raw materials used at the site?
- What would you like to know about the products of the site?
- What would you like to know about the production and processes at the site?
- What would you like to know about the occupations at the site?

Discuss about previous issues in your group. Decide what are the most interesting issues to you and your group members. Plan the group work and agree on the allocation of the tasks with your group members. Agree with other groups about your study topic.

Projects and tasks for the site visit

1. Questions which will be sent to the site

It is important that the staff at the site are familiar with your particular interests, so that when they prepare their presentation of the site, they can focus on your interests. Therefore, prepare first in pairs questions which will be sent to the site. Before forming the questions think about what you would like to know about the products, processes and occupations of the site. Prepare at least five questions. Compare your questions with those of another student. Combine and develop the questions further. Choose the 2 – 3 most interesting questions for you and your group. Try to find a compromise. If you cannot agree on the best questions you should take a vote.

Discuss in your classroom about the questions. Select the 5 – 8 most interesting questions. Try to find a compromise. If you cannot agree on the 5 – 8 best questions you should take a vote.

Send the questions to the contact person before the visit.

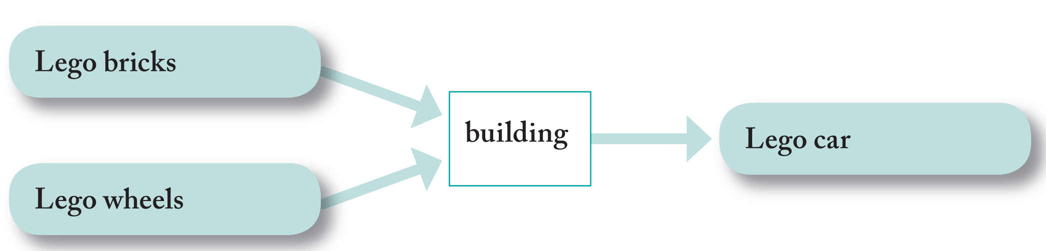
2. An article or a report about the site

Write an article/ a short report.

3. Modelling a manufacturing process

Processes in manufacturing can be illustrated by a flow chart. On a flow chart, there is input, output and a process.

For example, a flow chart that illustrates the building of a Lego car is:



Interview in your group a staff member working with materials at the site. Make a flow chart, which describes what s/he is doing. What artefacts/materials s/he is using? What s/he is making with them? What is the output of his/her work?

Interview another staff member working with materials at the site. Make a flow chart, which describes what s/he is doing. If possible, combine the flow charts.

4. Notes from the site

Below you will find several guiding questions, which help you and your group to make notes during the visit. You can decide in the classroom who or which group will take care of certain questions. It is also possible to decide that all students will make notes about all questions. Make notes during the visit.

Materials

- Which raw materials are used at the site?

- How and where from does the site obtains the materials in order to produce products for sale?

- How does the site test the quality of the materials it is using in its products?

Production

- How does the site process and modify the raw materials and make products out of them?

- What are the products made at the site?

- How are they developing the production processes at the site?

Occupations and careers

- What occupations do people working at the site have?

- Become familiar with one occupation. Describe a typical day in that occupation.

- Become familiar with one occupation. Describe the education and training needed for the occupation.

Evaluation

Please evaluate your own learning during the site visit by answering the following questions.

	Very little				Very much
I learned about physics and chemistry at the site	○	○	○	○	○
I learned how physics and chemistry are applied in practice in efforts to innovate and develop new products	○	○	○	○	○
I learned about properties of materials	○	○	○	○	○
I learned about how the site tests the quality of the materials it is using in its products	○	○	○	○	○
I learned about how the site processes the raw materials and makes products out of them	○	○	○	○	○
I learned about products and their properties	○	○	○	○	○
I learned about working life during the visit	○	○	○	○	○
I learned about professions during the visit	○	○	○	○	○
I learned about the education needed in the different professions at the site during the visit	○	○	○	○	○
I would like my school to arrange site visits more often	○	○	○	○	○
I liked this site visit	○	○	○	○	○

For each of the following, please describe some aspects that interested you during the visit.

- Science and Technology and their role in society
- Manufacturing processes
- Converting raw materials into products
- Occupations and careers related to science or technology
- Connections between the natural environment and human activities

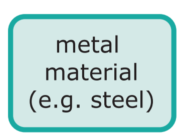
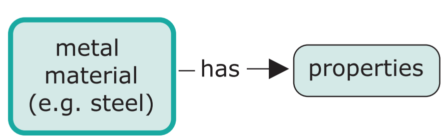
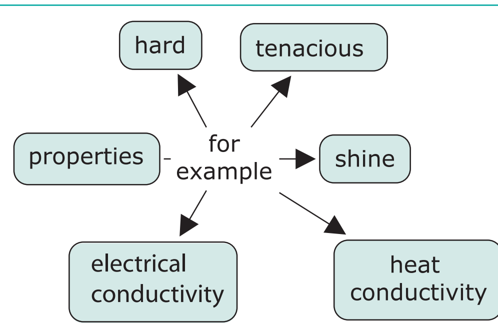
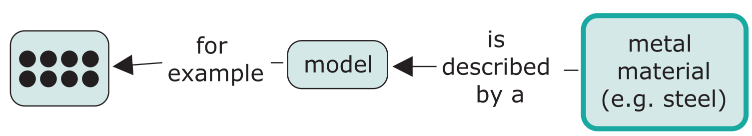
7 Holistic view of materials around us

You will form a holistic view of materials around us in this unit through concept mapping. You can summarise properties, manufacture and use of materials with the help of previous units and other information sources. In addition to school textbooks and books in the school library, information on materials can be found in newspapers, websites (of industries/companies, Wikipedia) and in the brochures of related companies, among others. You can make a concept map, either drawing them by hand or with CmapTools software.

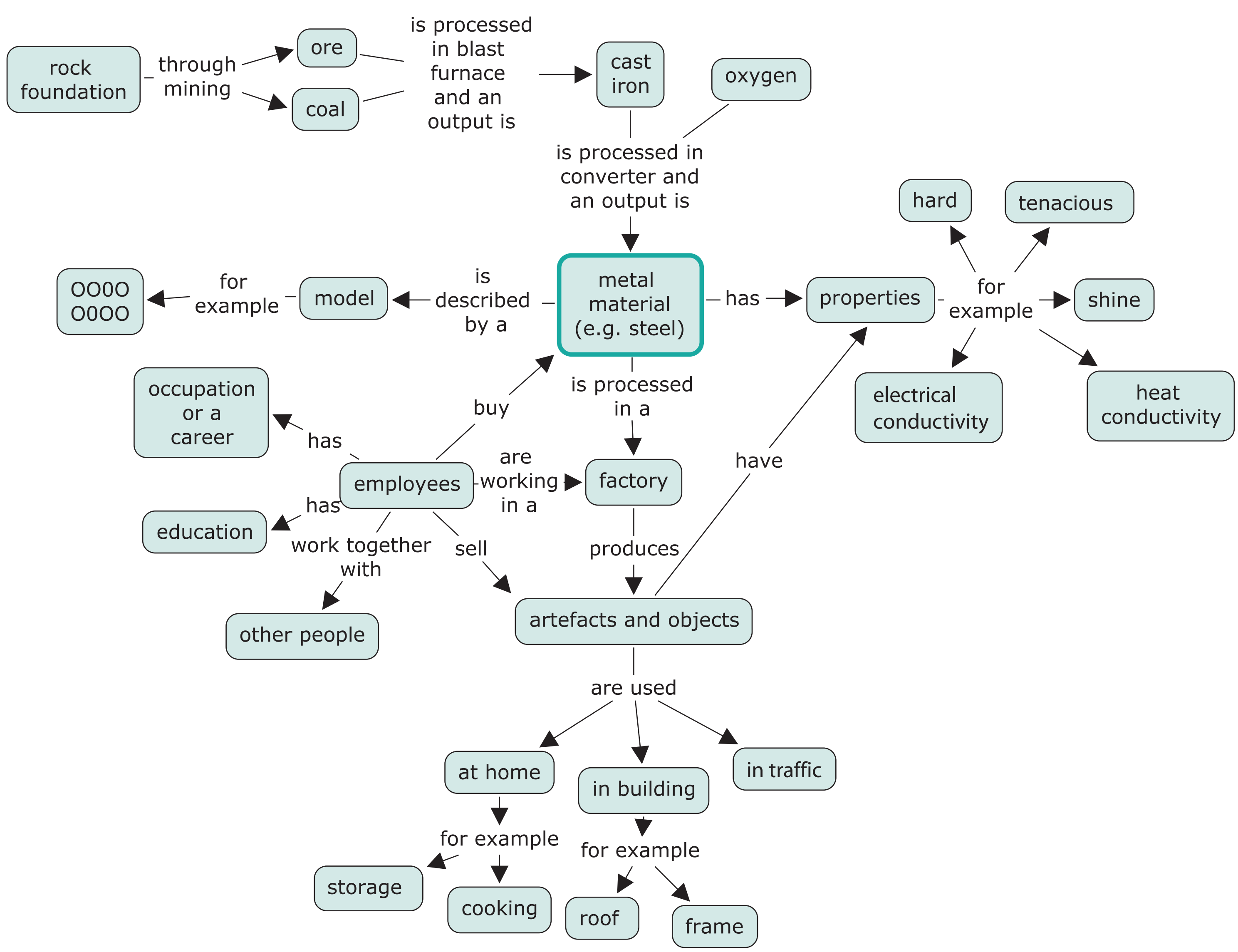
CmapTools is free software, which is very suitable for drawing a concept map. It facilitates the designing and manipulation of a concept map. It can be downloaded from the website of IHMC, A University Affiliated Research Institute of the University of West Florida http://cmap.ihmc.us/download/. More info about the use of CmapTools can be found on the CmapTools help page (http://cmap.ihmc.us/Support/Help/).

As an example, the procedure of making a concept map of steel as a material is presented below. When the map is ready, it will show the properties of steel, as well as how it is manufactured and how it can be used. A model that describes the structure of steel is added to the map. For example, the following texts from school textbooks can be the basis of making the concept map:

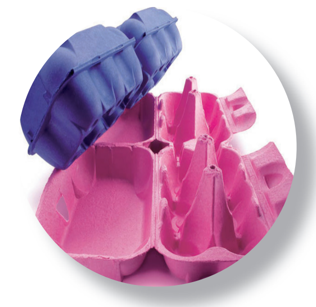
Steel has diverse properties. It is hard, tenacious and has a shiny surface. Water can be boiled in a steel kettle. Steel endures heating well above the boiling point of water. … Steel consists mainly of iron atoms. For instance a small percentage of chromium atoms are mixed with iron atoms. …

Draw the central concept in the middle of the CmapTools sheet.	
The first idea that is used to make a map by connecting two or more concepts is: Steel has properties.	
The properties of steel, such as shine, tenaciousness and hardness, are connected with an arrow to the concept properties.	
The next step is to connect the idea of a model to steel: Steel is described by a model.	

The concept map below is one possibility for describing the material steel in a varied way.



Concept map



1. Make a concept map of plastic material. Make sure that the map answers the following questions:
   - What properties does plastic have?
   - For what kind of purposes is plastic used at home, in construction and in cars?
   - What kind of structure does plastic have or what kind of structural units does plastic consist of?
   - How is plastic manufactured, and what are the raw materials of plastic?
2. Make a concept map of paper material. Make sure that the map answers the

plastic

following questions:

- What properties does paper have?
- For what purposes is paper used at home, in construction and in cars?
- What kind of structure does paper have or what kind of structural units does paper consist of?
- How is paper manufactured and what are the raw materials of paper?

3. Make a concept map of glass material. Make sure that the map answers the following questions:

paper

Concept map

- What properties does glass have?
- For what purposes is glass used at home, in construction and in cars?
- What kind of structure does glass have or what kind of structural units does glass consist of?
- How is glass manufactured and what are the raw materials of glass?

glass





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