**1.1 and 1.2 Matter – states, particulate theory, mixtures, separation techniques.**

If you look around you, you will notice that different things (called materials or substances or matter) have different characteristics: they may be dull or shiny, soft or hard, solid or liquid or even gas, metallic or not, man-made (manufactured) or natural. Understanding the nature of the different materials is essential if one plans to use them for different purposes. For example, a pot needs to be able to be placed on heat without melting, and a candle needs to burn to give light; clothing needs to be made of soft, comfortable materials while boots need to be tougher.

**Activity 4.1: Teach yourself to see**

Anyone interested in Chemistry needs to be curious about the world around him/her and needs to learn to ask questions. So here’s a game you can start playing:

Each day choose 3 different man-made objects to look at and think about. Then ask yourself these questions:

* Must this object that I see be made from a material which is
  + Strong or not?
  + Waterproof or not?
  + Able to conduct heat or not/
  + Able to conduct electricity or not?
  + Heat resistant or not?
  + Hard, soft or brittle?
  + Magnetic or not?
  + Long-lasting (durable) or not?
  + Able to keep you warm or not?
  + Cheap or not?

You will be training yourself to look at the world through the eyes of a scientist – particularly a chemist as you learn to do this.

Enjoy the game!

**4.1 Properties of matter**

The properties of matter determine and describe what it is and how it behaves. Chemists need to be very observant so that they can determine and understand the properties of matter.

Properties have been divided into two types:

* physical and
* chemical.

A *physical property* is a characteristic that we can observe or measure without changing the composition of the substance that we are studying. Some examples of physical properties are the following:

* the appearance of a substance – its colour and physical state (solid, liquid or gas)
* its melting point and boiling point,
* its density,
* its conductivity,
* its solubility and many others.

A *chemical property* is a characteristic that a substance demonstrates when it undergoes a reaction to change into something new. One chemical property of oxygen would be, for example, the fact that it can react with hydrogen to become water.

Example

1. Copper has a reddish brown colour.
2. Sugar ferments to form alcohol.

Solution

1. Copper has a reddish brown colour describes a physical property because it can be observed without changing copper in any way.
2. Sugar ferments to from alcohol describes a chemical property because the sugar undergoes a chemical reaction to form something new, namely alcohol.

**Activity 4.2: Identifying physical and chemical properties of matter.**

Study each of the following statements and determine whether they represent a physical or a chemical property. Explain your answer.

|  |  |
| --- | --- |
| Wax melts | A candle gives light |
| Water can be broken down to H2 and O2 | Iron is magnetic |
| Water boils at 100oC | Iron sulfide is black |
| Mercury is toxic | Iron rusts to form iron oxide |
| Mercury is a liquid at room temperature | Iron sulfide is made from iron and sulfur |

**Activity 4.2: Solutions/hints:**

|  |  |
| --- | --- |
| **Statement** | **Answer** |
| Wax melts | Physical property - changing from solid to liquid state |
| Water can be broken down to H2 and O2 | Chemical property – need a chemical reaction to cause water to break down to hydrogen and oxygen |
| Water boils at 100oC | Physical property – the BP is the temperature at which water changes from a liquid into a gas (vapour). |
| Mercury is toxic | Physical property - no change needed in mercury to make it toxic. |
| Mercury is a liquid at room temperature | Physical property - describes physical state at a particular temperature. |
| A candle gives light | Chemical property – the light comes when the candle burns and changes into new substances. |
| Iron is magnetic | Physical property – describes something about the nature of iron |
| Iron sulfide is black | Physical property – describes the appearance of iron sulphide |
| Iron rusts to form iron oxide | Chemical property – describes a change that occurs by chemical means |
| Iron sulfide is made from iron and sulfur | Chemical property – describes the formation of a new substance from iron and sulphur. |

**4.2 Physical and chemical changes**

Substances can be changed in various ways.

A physical change is one in which the substance might change its state, for example, but it does not change into a new substance. Its chemical composition does not change. For example, when ice changes to water it undergoes a physical change, but it still has the same chemical formula, H2O.

When a chemical change takes place, the substance undergoing the chemical reaction changes into something entirely new. For example, propane gas burns to release heat, and changes into carbon dioxide and water.

**Key Concept**

Physical changes can be seen without changing the composition of the substance undergoing the change. Chemical changes always involve a change in composition as new products form.

Example

1. Fireworks explode when ignited.
2. Sugar dissolves in water

Solution

1. Chemical change because the fireworks burn up to form new products.
2. Physical change because it is a homogeneous mixture of sugar and water that forms. Sugar and water are still both present, chemically unchanged.

**Activity 4.3: Identifying physical and chemical changes**

Study each of the following statements and determine whether they represent a physical or a chemical property. Explain your answer.

|  |  |
| --- | --- |
| Hydrogen and oxygen explode when ignited | Milk goes sour |
| Sand does not dissolve in water | Air is pumped into a tyre |
| Water evaporates | Wood burns |
| Mercury cools to a silvery solid | Copper and nickel form an alloy |
| Sodium reacts with chlorine to form sodium chloride | Sugar makes coffee sweet |

**Activity 4.3: Solutions/hints:**

|  |  |
| --- | --- |
| **Statement** | **Answer** |
| Hydrogen and oxygen explode when a flame is applied to them. | Chemical change. Something new (water) is being formed in explosive chemical reaction. |
| Sand does not dissolve in water | Physical change – the water and sand are mixed but still visible separately. |
| Water evaporates | Physical change – water changes from a liquid to a gas but is chemically the same. |
| Mercury cools to a silvery solid | Physical change – mercury changes from a liquid to a solid but is chemically the same. |
| Sodium reacts with chlorine to form sodium chloride | Chemical change – sodium and chlorine combine chemically to form a completely new substance, sodium chloride (salt) |
| Milk goes sour | Chemical change – sour milk is made of different substances from sweet milk |
| Air is pumped into a tyre | Physical change – air fills tyre without changing in any way. |
| Wood burns | Chemical change – the products after burning are different from wood |
| Copper and nickel form an alloy | Physical change – this is a homogeneous mixture of two metals. |
| Sugar makes coffee sweet | Physical change – sugar dissolves in coffee but remains sugar. |

**4.3 Classification and Separation of Matter**

When you try to understand something such as matter, it is important to be able to classify it into different groupings that have similar characteristics. And as you become clearer and clearer about the topic the classification can become more and more precise.

**Terminology:**

**Pure substance:** something made up of one substance only, not combined with anything else

**Mixture:** a combination of two or more substances.

**Impurity:** something mixed into something else when you do not want it to be there.

**Contaminant:** something mixed into something else when you do not want it to be there – same as impurity.

**Homogeneous mixture**: a mixture where the different components cannot be seen.

**Heterogeneous mixture**: a mixture where the different components can still be seen.

**Dissolve:** to disappear into another substance e.g. sugar dissolves in water.

**Soluble:** able to dissolve

**Insoluble:** unable to dissolve

Firstly, matter can be divided into two categories:

**Mixtures** and **Pure substances**

Pure substancesare made up of themselves and nothing else while mixtures are made from mixing two or more different substance together (without causing any change to each of the substances in the mixture).

So, for example, a pure substance would be a piece of copper wire which is made up only of copper or some sugar.

A mixture could be a cup of tea with milk and sugar which contains sugar, water, tea, and milk.

Let’s look at this cup of tea:

* You would make it on purpose because you wanted it to be mixed in the way you like it. If someone put some salt into the tea it would still be a mixture, but you would not want the salt to be there. It would then be called an **impurity** or a **contaminant**.
* After the mixture has been made you can no longer see which part is water or sugar or tea or milk. This is called a **homogeneous mixture**. You cannot see the separate components. It can also be called a **single phase mixture** because it looks like only one kind of substance.
* If you mix oil and water together it would still be a mixture but you could see the different components and it would be called a **heterogeneous mixture**. A homogeneous mixture can be called a **multiple phase mixture** because you can see the different parts from which it ismade.

**Activity 4.4: Separating mixtures**

If a mixture is made up of different substances which do not change into anything new then you should be able to separate the mixture into its parts again. This can be quite easy to do or it might be very challenging, depending on the nature of the components making up the mixture.

Here you will make mixtures and then try to separate them again into their parts.

1. Mixture A  
   Take a glass and half fill it with clean water.  
   Add a teaspoon full of builder’s sand.  
   Mix well.  
   Is this a homogeneous or a heterogeneous mixture?  
   How do you think you could remove the sand from the water?  
   See if your idea works.
2. Mixture B  
   Take a glass and half fill it with clean water.  
   Add a teaspoon full of sugar and stir to dissolve completely so that you can no longer see any sugar there.  
   Is this a homogeneous or a heterogeneous mixture?  
   How do you think you could get the sugar back out of this mixture?  
   See if you idea works.

**Activity 4.4: Solutions/hints:**

1. Mixture A is a heterogeneous mixture because the sand remains visible in the water after mixing.  
   A possible way to remove the sand from the water would be to pour the mixture through a piece of fine cloth and collect the water that comes through in a clean container. The sand should remain in the cloth. The finer the cloth the more sand will be removed.  
   In an equipped laboratory you would use filter paper instead of cloth and a funnel to hold the filter paper.
2. Mixture B is a homogeneous mixture. Because the sugar disappears into the water and can no longer be seen.  
   A possible way to get the sugar back is to leave the glass in a safe place in the sun. The water will **evaporate** off leaving the sugar behind.  
   In an equipped laboratory you would heat the container with the mixture to speed up the process. You could also collect the water coming off as steam by letting it **condense** as liquid using suitable equipment.

**Assessment 4.1: Check that you understand about pure substances and mixtures.**

Study the following substances and then classify them as pure substances, heterogeneous mixtures of homogeneous mixtures:

1. Coca cola
2. Milk
3. Air
4. Tap water
5. Stew
6. Table salt
7. Oil and water
8. Sugar
9. Paraffin
10. Egg

**Solutions for Assessment 4.1: Check that you understand about pure substances and mixtures.**

1. Coca cola: homogeneous mixture of water, sugar, colourants, flavours, gas (for the fizz).
2. Milk: homogeneous mixture of water, fats, sugar and all sorts of other soluble foods.
3. Air (clean): homogeneous mixture of gases like nitrogen, oxygen and hydrogen
4. Tap water: homogeneous mixture of water and dissolved gases and salts.
5. Stew: a heterogeneous mixture of meat, vegetables, water, salt.
6. Table salt: pure substance made up of only one thing. The chemical name of salt is sodium chloride.
7. Oil and water: heterogeneous mixture because the oil will remain separate from the water as soon as you stop shaking the container.
8. Sugar: Pure substance made up of only one thing. The chemical name of sugar is sucrose.
9. Paraffin: a homogeneous mixture of fuels that can burn to give heat and energy.
10. Egg: a heterogeneous mixture of the yellow part (yolk) and the white part and the shell.

**Some Methods for Separating mixtures**

## Filtration

This is probably the simplest way of separating mixtures. It is used for separating an **insoluble solid from a liquid** – a heterogeneous mixture.

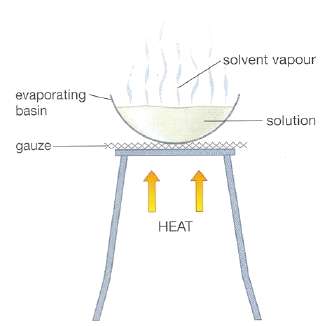
For example, a mixture of sand and water can be separated by filtration. The mixture is poured through a filter. The solid material stays behind and the water goes through the filter. The reason for this is that the water molecules are small enough to go through the pores (holes) in the paper while the sand particles are too big, so stay behind on the paper.



## Evaporation

Evaporation is used to **separate a soluble solid (solute) from the liquid** in which it is dissolved (solvent) to form a homogeneous mixture.

For example, sugar crystals can be separated from a sugar solution using evaporation. The water evaporates off when the solution is heated, leaving the sugar behind.



Think about this: How would you separate a mixture of two solids? Here are a few examples:

* Sugar mixed with sand
* Iron mixed with sand

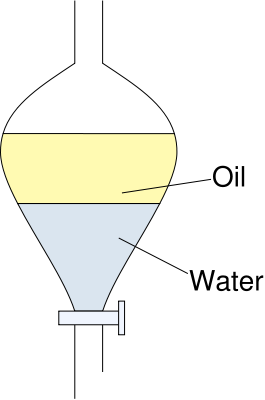
Answers:

* Sugar dissolves in water, so the mixture can be mixed with water. The sugar would dissolve into the water and would filter through the filter paper leaving the sand behind on the paper. Then the sugar water could be heated to evaporate the water off and leave the sugar behind.

**Separating funnel**

Some mixtures are made with two liquids that do not dissolve together - a heterogeneous mixture forms.

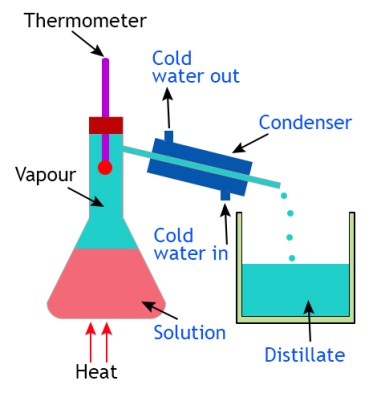
To separate these kinds of mixtures a piece of apparatus called a separating funnel is used. The lighter liquid (liquid with lower density), oil, floats to the top. The lower liquid (higher density), water, can be removed through a tap at the bottom of the funnel, leaving the lighter liquid inside.



## Simple distillation

Some mixtures are made from a two liquids mixed together to form a homogeneous solution.

These can be separated using a simple distillation technique if the boiling points of the two liquids in the mixture are not too close to each other. The mixture is heated. When the temperature of the lower BP is reached that liquid vapourises and leaves the mixture as a gas. If a distillation apparatus this vapour can be collected, cooled and collected as a liquid again – called the distillate.

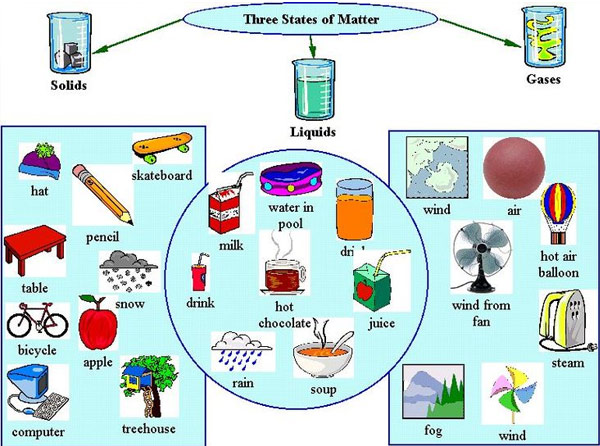


For example, alcohol (ethanol) mixed with water can be separated from each other. The boiling point of the ethanol (78oC) is lower than that of water (100oC) so will distil off and can be collected as distillate.

**4.2 States of Matter and State Changes**

Matter exists in three physical states (four, actually, but one is so rare that we will ignore it for now). These physical states are:

* Solids
* Liquids and
* Gases



**Activity 4.3: Thinking about the states of matter**

Consider the following three substances:

* Ice
* Water and
* Steam

1. What is ice? Where would you find ice? How could you make ice? What do you know about the temperature of ice? Would ice be a solid or a liquid or a gas?
2. What is water? Where would you find water? Could you make water? What do you know about the temperature of water? Would water be a solid or a liquid or a gas?
3. What is steam? Where would you find steam? How could you make steam? What do you know about the temperature of steam? Would steam be a solid or a liquid or a gas?
4. How are ice, water and steam different from one another?
5. How are ice, water and steam similar to one another?

**Activity 4.3: Solutions/hints:**

1. Ice is found in cold places either in nature (frozen streams in the winter) or man-made (freezers). Ice has a very low temperature (0oC)  
   Ice is a solid  
   Ice is made by cooling water down until it becomes cold enough to become solid
2. Water is found in rivers and taps.  
   Water cannot be made. It occurs naturally.  
   Water can vary in temperature from very cold (when it gets close to freezing), to very hot (when it boils).  
   Water is a liquid.
3. Steam is found where water is at very high temperatures e.g. above a pot of boiling water, in a hot shower. Steam rises off boiling water. Steam has a high temperature (100oC) and burns badly. Steam is a gas or vapour.
4. Ice is a solid, water is a liquid and steam is a gas so they appear very different.
5. Ice, water and steam are actually the same thing, namely water, appearing in different states.

The different states of matter are determined by the temperature at which the matter is observed.

* Some materials are usually seen as solids. If you think of iron, you think of it as a strong, heavy solid, and it usually is like that. But if you want to make iron into a useful shape you might have to melt it (turn it into its liquid state) to pour it into a mold where it takes the shape you want. To make iron a liquid needs a very high temperature (1,538oC) and for it to be a gas needs even higher temperatures. So we consider iron to be a solid at usual, practical temperatures.
* Some substances are usually seen as liquids. Water is a good example of this, although we can cool it enough to turn it into a solid (ice) or heat it enough to turn it into a gas (steam). Another example would be alcohol (chemical name ethanol). You do not often see solid alcohol because its needs to be cooled to -114.6oC before it becomes a solid (solidifies). So at normal (room) temperatures ethanol is a liquid.
* Other substances are usually seen as gases, for example oxygen. To make oxygen a liquid the temperature would have to be reduced to -183oC and to make it a solid the temperature would have to be reduced to -218.8oC.

The **melting point** of a substance is the temperature at which it changes from a solid to a liquid. So the MP of water is 0oC.

The **freezing point** of a substance is the temperature at which it changes from a liquid to a solid. So the FP of water is 0oC. Notice that the MP and FP are the same temperature for any particular substance!

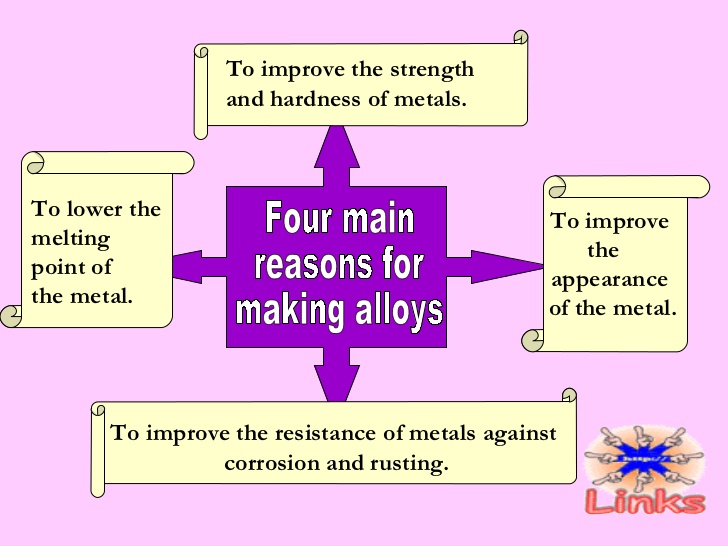
The **boiling point** of a substance is the temperature at which it changes from a liquid to a gas. So the BP of water is 100oC.

**Fascinating facts**

Mixtures can occur as liquids, solids and gases. So the air that we breathe is a mixture of gases, and the water that we drink is a mixture of water and dissolved salts and gases. But have you ever heard of an alloy?

An **alloy is a homogeneous mixture of two or more metals or metals and other substances.** An example of an alloy is steel. Steel is mainly made of iron but added to it can be carbon, nickel, chromium or tungsten in different amounts for different purposes.

Other well know alloys are brass, bronze, pewter and stainless steel.



Think about this. How can you make a homogeneous mixture of solids?

You can melt the solids, mix them well while they are in the liquid state and then let the mixture cool and become solid again (solidify).

**Activity 4.4: The changing states of matter**

Consider the following 5 substances and their M Ps and BPs.

In what state would they be present in the regular environment where the temperature is around 25oC? Explain your reasoning.

1. Nitrogen (MP -209.9oC, BP -195.8oC)
2. Iodine (MP 113.5oC, BP 184.0oC)
3. Mercury (MP -38.9oC, BP 356.6oC)
4. Sulfur (MP 115.2oC, BP 444.6oC)
5. Benzene (MP 5.5oC, BP 80.2oC)

**Activity 4.4: Solutions/hints:**

1. Nitrogen (MP -209.9oC, BP -195.8oC): Nitrogen would be a gas at 25oC because it would boil (become a gas) at -195.8oC which is a lower temperature.
2. Iodine (MP 113.5oC, BP 184.0oC): Iodine would be a solid at 25oC because it’s melting point is 113.5oC and it would only become a liquid at that temperature.
3. Mercury (MP -38.9oC, BP 356.6oC): Mercury would be a liquid at 25OC because it would melt at -38.9oC but only become a gas at 356.6oC
4. Sulfur (MP 115.2oC, BP 444.6oC): Sulfur would be a solid at 25oC because it’s melting point is 115.2oC and it would only become a liquid at that temperature.
5. Benzene (MP 5.5oC, BP 80.2oC): Benzene would be a liquid at 25OC because it would melt at 5.5oC but only become a gas at 80.2oC

**The Particulate and Kinetic Theory of Matter**

In 1803 an English school teacher named James Dalton developed the *Particulate Theory of Matter* to explain what people knew about matter at that time. His theory has been refined since then, but some of his ideas are still useful for our understanding of the behaviour of matter,

The useful points are summarised as follows:

* Elements are made up of very small, indivisible, indestructible particles.
* All the particles of a particular element are identical, and have the same properties.
* Particles from different elements can combine to form new substances, called compounds.
* When particles combine with other particles they do so is small whole numbers – there are no fractions of particles involved.
* Particles of one element can combine with particles of another element in different ratios to form different compounds with different properties.
* Chemical changes are the result of rearranging the ways in which the particles are joined together.

**The Kinetic Molecular Theory of Matter** builds on these ideas in the following way:

* The particles (here called molecules) are always moving – this energy of movement is called **kinetic energy**.
* The amount of kinetic energy increases as temperature increases. Therefore, gas particles have more energy than the same particles in the solid or liquid phase.
* The particles are held together by **intermolecular forces of attraction**. In a solid, these intermolecular forces of attraction are strong enough to hold the particles in place. When the kinetic energy increases upon heating a solid, the kinetic energy of the particles increases and the intermolecular forces can no longer hold the particles together strongly. At this point, changes of state start to take place. Firstly, when the particles start to move with a bit more energy, the intermolecular forces begin to lose their strong hold between particles. As a result, the particles can start to move, the solid starts to flow, and the solid becomes a liquid. As the temperature increases further, the particles move faster and faster and the intermolecular forces are no longer strong enough to hold them together. So they part company completely and become a gas.

The Particulate and Kinetic Theory of Matter helps us to explain the properties of the different states of matter. It answers the questions: “Why do substances change state at different temperatures”? and “Why do solids, liquids and gases behave differently”?

The theory proposes that all matter is made up of very tiny particles. These particles are arranged differently in different substances. They are also able to move, but at different rates (speeds) depending on the amount of energy they have. The amount of energy available to the particles depends on the temperature of the substance – the hotter the temperature the more energy available and the faster the particles can move. Conversely, when the temperature is cold, the energy is low and less movement of the particles is possible. In solids the particles would have low energy, move very little and stay in one place to give a fixed shape. When the temperature increases enough the solid would become a liquid where the particles have more energy and can start flowing around each other. At an even higher temperature the particles get more energy, they break free from each other, they move wherever they want and a gas forms.

This information can be arranged in a table which makes it easier to compare solids, liquids and gases.

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Solid** | **Liquid** | **Gas** |
| **Arrangement of particles** | Close together | Close together | Far apart |
| **Relative temperature** | Low | Medium | High |
| **Movement of particles** | Very little. Just vibrate (shake) on the spot | Greater movement – vibrating and rolling around each other | Lots of quick movement in all directions |
| **Arrangement of particles** | Closely packed and stay in one place | In contact with each other but do not stay in a fixed position | Moving all the time, never in a fixed position |
| **Diagram** | Image result for particle diagrams of solids liquids and gases | | |
| **Behaviour based on arrangement of particles (properties)** | Fixed shape  Cannot flow  Cannot be compressed (pushed into a smaller space) | Take the shape of the container holding the liquid  Flow easily  Cannot be compressed (pushed into a smaller space) | Completely fill a closed container whatever the size or shape  Flow rapidly and easily  Can be compressed into smaller spaces |

**The particles making up matter**

The particles that are spoken about in the Particulate Theory of Matter are elements, molecules or formula units.

**Terminology:**

**Element:** a substance that cannot be broken down or changed into simpler substances by chemical means e.g. copper, oxygen, hydrogen.

**Compound:** a substance made up of more than one kind of element chemically joined together e.g. water is a combination of 2 hydrogen atoms and one oxygen atom to form a new substance.

**Atom:** the smallest possible particle of an element that still has all the characteristics of the element.

**Periodic Table:** an organised table of all the elements known to man.

**Crystalline:** m up of crystals which are organised groupings of the elements making up the compound.

**Heterogeneous mixture**: a mixture where the different components can still be seen.

**Dissolve:** to disappear into another substance e.g. sugar dissolves in water.

**Soluble:** able to dissolve

**Insoluble:** unable to dissolve

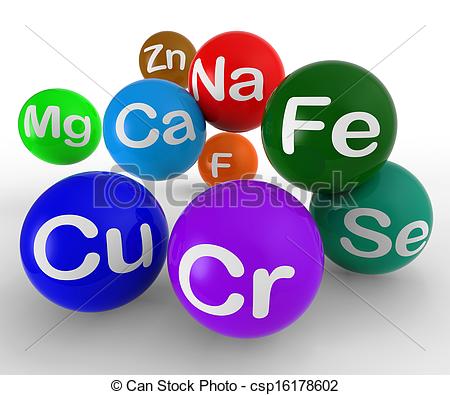
In order to think about the particles from which matter is made we need to look more closely at pure substances. Remember how you learned that matter can be divided into groups – pure substances and mixture? You have looked more closely at mixtures in a previous section. Now let’s explore pure substances.

As you have already learned, a pure substance is made up of one substance only. So a piece of copper pipe would be made of pure copper, and a packet of table salt would be a pure substance, sodium chloride (one hopes!). But there is a fundamental chemical difference between these two types of substances: copper is an *element,* and salt is a *compound*.

**Elements**

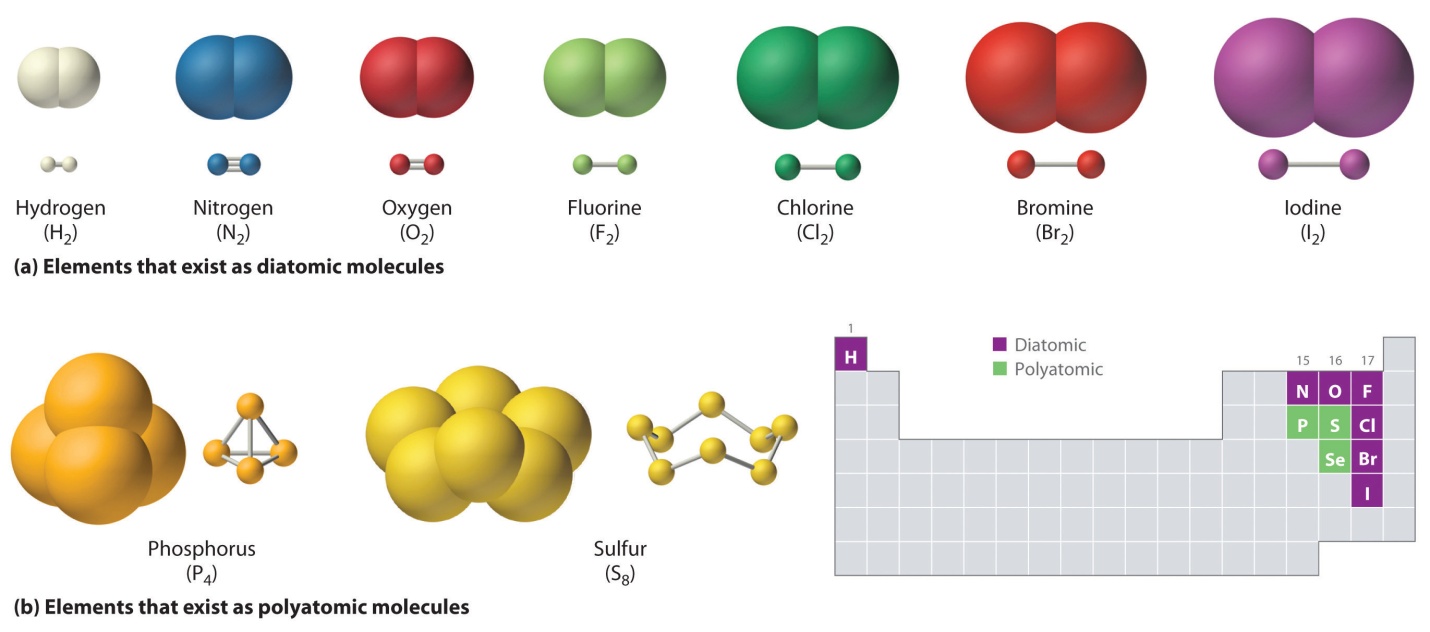
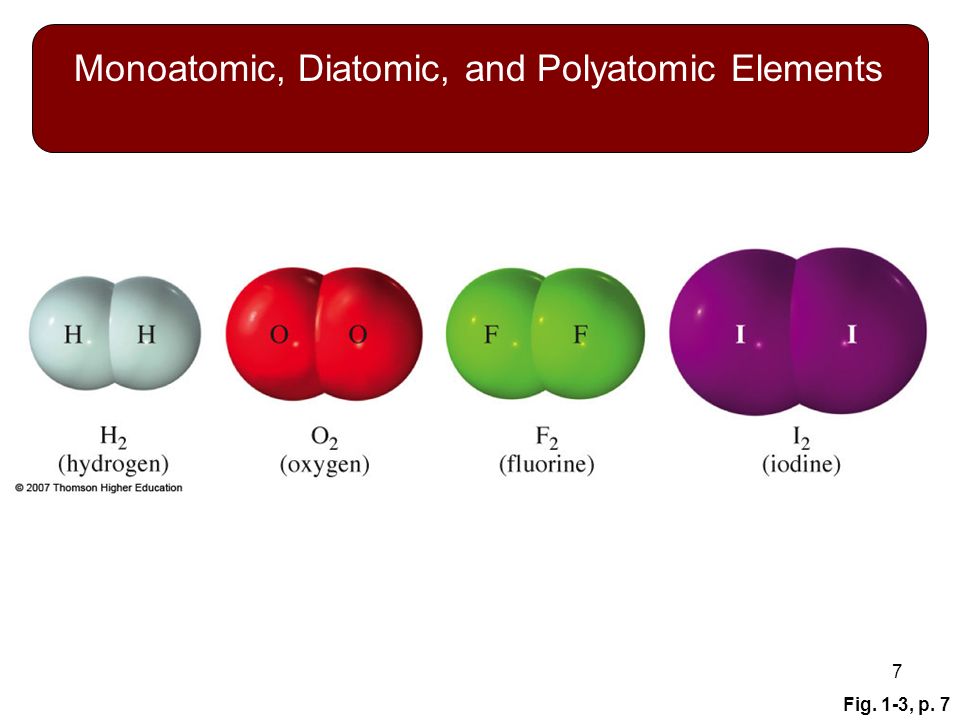
An element is a pure substance which cannot be broken down into simpler substances by ordinary chemical reactions. Examples of elements are oxygen, hydrogen, sodium and chlorine. Each particle of an element is called an **atom.**

All the elements known to mankind have been given a name and a symbol and arranged in the Periodic Table which you will be studying soon. So every substance we know is made from either a pure element or combinations of elements.



All pure substances (and mixtures) are made up of elements. Some substances are composed of a single type of element, as in the copper example already discussed.

Sometimes elements exist as single atoms, such as Cu (copper). However, some other elements are only stable when 2 or more atoms joining together. For example, oxygen is only stable as O2 where two atoms of oxygen are joined together. It is still an element (made of only one kind of atom}, but two of these atoms are joined together for stability. Such an element is called a **molecule** (or a molecular element).

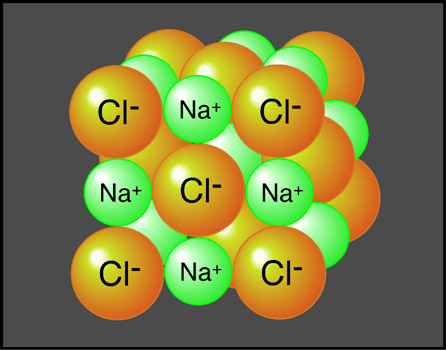


Other pure matter is made up of more than one kind of element chemically linked together to give something new, called a compound.

**Compounds**

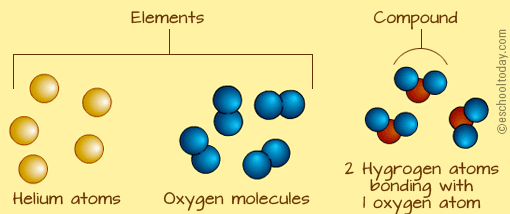
A compound is a pure substance which *can* be broken down into simpler substances by chemical reactions. A compound is also given a name. Sometimes these are common names which do not tell us anything about the elements making up the compound e.g. water we all know, but the name does not tell us that water is made up of two hydrogen atoms and one oxygen atom combined in a particular way (H2O). But often the name we use is also the chemical name which does give more information. For example, carbon dioxide is made from one carbon atom and two oxygen atoms (CO2). You will learn more about naming compounds later in this course.

Salt, the example already mentioned, is made up of a chemical combination of sodium and chlorine in a 1:1 ratio. That means that a single particle (atom) of the element sodium (Na) combines with a single atom of the element chlorine (Cl) to make the new compound, salt (NaCl) which has completely different properties from either of the elements making it up. For example, salt is a white, crystalline substance but sodium is a soft silvery metal and chlorine is a greenish gas! A single particle of an ionic compound like NaCl is called a **formula unit**.



Definitions:

Use diagram of this sort:



(Include non-metal and metal elements, molecular elements, molecular compounds, formula units)

Atom: the smallest particle of matter that has the properties of a chemical element.

Element: a substance that cannot be broken down into simpler substances by chemical means. Elements can be metals or non-metals.

Molecule: a group of *non-metal atoms* bonded together, forming the smallest fundamental unit of a chemical compound that can take part in a chemical reaction. These can be combinations of the same elements e.g. oxygen O2 or different elements e.g. water H2O. Oxygen would be a molecular element (made up of the same non-metal components) but water would be a molecular compound (made up of two or more different non-metal elements).

Compound: a substance formed when two or more different chemical elements are chemically bonded together.

Formula unit: the smallest particle of a compound made of *metal and non-metal elements* that can take part in a chemical reaction.

**Holding matter together**

The particles of matter are held together in different ways:

* When elements combine to form compounds or molecules **chemical bonds** hold them together. These are also called **intramolecular bonds**, meaning that they occur within a molecule. This topic will be looked at in detail later.
* When molecules or compounds are held together **intermolecular forces** are involved. These are forces between molecules. Intermolecular forces are much weaker than chemical bonds, but they are vitally important as they allow materials to exist in the three states of matter, solid, liquid and gas. Intermolecular bonds will also be looked at in more detail later.

**Activity 4.5: Atoms or compounds?**

Look at the chemical symbols of substances given below and decide whether the substance is an element of a compound. Explain your answer.

1. Hydrogen fluoride (HF)
2. Gold (Au)
3. Iron oxide (Fe2O3)
4. Sodium sulfide (NaS)
5. Calcium carbonate (CaCO3)

**Activity 4.5: Solutions/hints**

1. HF is a compound as it is made of two different kinds of elements, hydrogen (H) and fluorine (F). There is 1 H atom and 1 F atom for each particle of the compound. (Note: the combining ratio of atoms would be 1:1, H:F).
2. Gold is an element as it is not combined with anything else (Au). (Note: in the symbol for an element if the second letter is lower case it is part of the symbol, not a separate element).
3. Iron oxide is a compound made of two different kinds of elements, iron (Fe) and oxygen (O). (Note: the combining ratio of atoms would be 2:3, Fe:O).
4. Sodium sulfide is a compound made of two elements, sodium (Na) and sulfur (S). There is 1 Na atom and 1 S atom in each particle of the compound. (Note: the combining ratio of atoms would be 1:1, Na:S)
5. Calcium carbonate is a compound made of three different kinds of elements, calcium (Ca), carbon (C) and oxygen (O). (Note: the combining ratio of atoms would be 1:1:3, Ca:C:O)