### 1.1 and 1.2 The Three States of Matter and the Particulate Theory of Matter

**Introduction**

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 : 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!

**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 is made.

**Activity : 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 : 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 : 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 : 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.

**States of Matter**

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 : 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: 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.

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).

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.