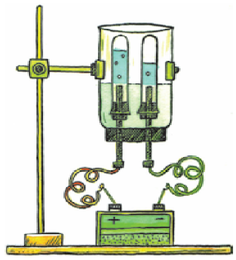
Chapter 2

Matter : Nature and Behaviour



Are there any similarities between light, an iron nail, the sound of a *dholak*, chairs and tables, smiles, steam, etc.? What are the similarities between them and what are the differences? Let us do an activity to try and understand this.

Activity-1

- Take a trough or bucket and fill it 3/4th with water.
- Now take a glass or glass beaker. Turn it upside-down and place it in the water as shown in Fig.1.
- Does the entire beaker get filled with water?
- Is the beaker empty?
- Now shine light on the beaker using a laser torch. (Note:*laser torch beams can harm your eyes so use it only under your teacher's guidance*).
- Are the light beams able to enter (go inside) the beaker?

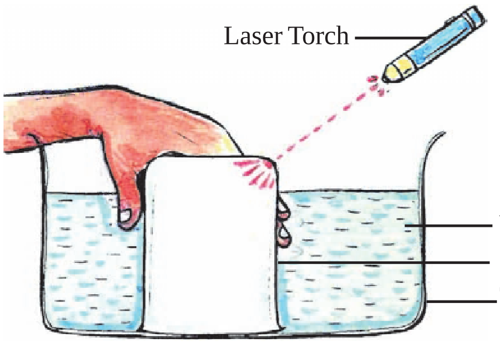


Fig. 1 : Matter occupies space

Let us try and understand why light was able to enter the beaker but water could not. What is there inside the beaker that stops water from getting inside? We know that air, water, chairs-tables, etc. occupy space. Water could not enter the beaker because air is already present in it. Air occupies space inside the beaker.

You must have noticed that a bottle filled with water is heavier than an empty bottle. The weight of an object is due to its mass. The objects described above such as iron nails, chairs & tables, steam occupy space and have mass. Whereas light, the sound of a *dholak*, smile etc. neither have mass nor occupy space. Since light does not need space it is able to enter the beaker. Anything that occupies space and has mass is called matter. Since light, the sound of a *dholak*, smile do not have this property therefore they are not matter.

Now, can you tell : Among air, water and light which can be called matter?

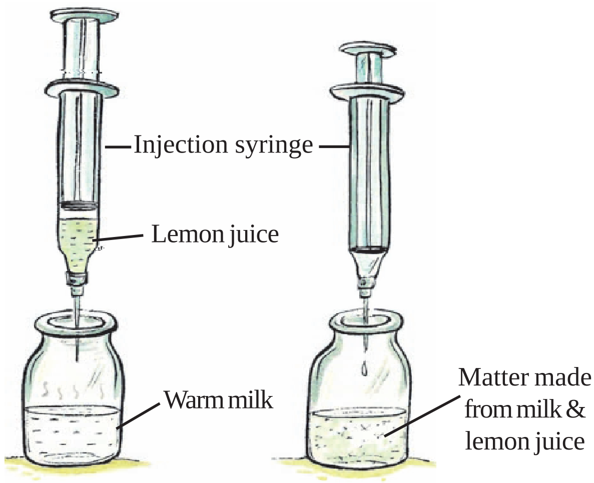
2.1 Conservation of matter

If we look at matter around us, we see that it undergo some changes. We can identify these by looking for changes in colour or in smell/odour or in state.

Let us try to understand this through an example. When we light a candle, it burns down completely after some time. Think: What has happened to the components (wax and wick) of the candle? For a long time it was believed that they get used up or destroyed in the burning process. Later, attempts were made to understand the burning of a candle and we realized that it is a chemical process where oxygen is also involved along with wax. During the process, carbon dioxide and water vapour are obtained as products but this was not known till we learnt to identify the gases being used or produced in a reaction. When the sum of the masses of all the reactants was determined it was found to be equal to the sum of the masses of all the products. This was the first time it became clear that the reactants taking part in a chemical reaction are converted into products and not destroyed.

Try this too

- Put 10 mL hot milk in a clean, injection bottle and put the cap back on the bottle.
- Take 2 mL lemon juice in an injection syringe.
- Insert the syringe in the cap of the injection bottle as shown in Fig-A. Weigh the arrangement. Make sure that there is no contact between the milk and lemon juice.
- Now press the injection piston slowly so that the lemon juice falls drop by drop into the milk.
- Observe the changes in the milk in the bottle.
- Do you think a chemical reaction has taken place here?
- Now, again weigh the entire arrangement and note the weight (Fig-B).



(A) Before reaction (B) After reaction
Matter cannot be destroyed

- Were there any changes in the masses of the apparatus before and after the experiment?

Note: Correct conclusions can be drawn from the experiment only if the weighing instrument is accurate and measures correctly.

In the study of many other chemical reactions, it was again found that the sum of the masses of all reactants is always equal to the sum of the masses of all the products.

This understanding was stated in the form of a law: Mass can neither be created nor destroyed during a chemical reaction. This is known as the law of conservation of matter or the law of conservation of mass. The law was formulated by Lavoisier.

Lavoisier's contribution

Attempts to understand the nature of matter had been going on for centuries. But in the absence of modern instruments, several misconceptions remained. At one time it was thought that one substance could be transformed into another. For example, when water was distilled in a glass container for a long time then fine, sand like particles were found in the container. Therefore, people thought that when water is heated for a long time it gets transformed into earth.

Antoine Laurent Lavoisier (1743-94), a French chemist, repeated the same experiment. He carefully weighed the entire glass apparatus before the experiment and also after distillation. He noticed that the mass of the apparatus was decreasing. This change was equal to the mass of the sand-like particles. He realized that the type of glass being used was slightly soluble in water. The glass would dissolve a little in water and after evaporation, its particles would remain behind. He concluded that water was not being transformed into earth. It was only after this that we could start building our modern understanding of chemical reactions.

Questions

1. Identify matter from among the following –
   water, air, chair, stone, scent of a flower, iron, thoughts.
2. 20g 'A' and 40g 'B' give 25g 'C', 15g 'D' and 20g 'E' in a reaction. Use these observations to explain the law of conservation of mass.

2.2 Matter around us

Have you ever run a magnet through sand? When we put a magnet in sand and turn it around, iron filings separate out and stick to the magnet. Similarly, when tap water kept in a container evaporates it leaves behind some white residue. Therefore, we can say that most of the matter around us exists as mixtures of two or more constituents (substances) which can be separated.

Sea-water is a mixture of different salts dissolved in water. One of the salts (sodium chloride) found in sea-water can be separated by evaporating the water. Similarly, cold-drinks are a mixture of sugar, salt and carbon dioxide in water. The components of a mixture can be separated by using physical techniques. Therefore, we can say that a mixture has more than one substance which can be separated from each-other using simple physical techniques. When we try to learn more about mixtures we find that they are of many different types.

2.3 Types of mixtures

Different types of mixtures are formed based on the nature of their components and how the components interact with each other. Let us understand this through some activities:

Activity-2

- Form your students into four groups 'A', 'B', 'C', 'D'.
- Ask group 'A' to take 100 mL of water in a beaker and add one spoonful salt to it.
- Ask group 'B' to take 100 mL of water in a beaker and add one spoonful sugar to it.
- Ask group 'C' to take 100 mL of water in a beaker and add one spoonful chalk powder to it.
- Ask group 'D' to take 100 mL of water in a beaker and add one spoonful cooking oil in it.
- Each group should stir their mixtures using a glass rod. Now leave the beakers undisturbed for some time.
- Observe all the beakers and try and answer the following questions:
  - In which of the beakers are the components mixed completely and appear uniform?
  - In which of the beakers can the constituents still be seen separately?

We see that groups 'A' and 'B' get mixtures whose components seem uniformly distributed. Such mixtures are called homogeneous mixtures.

In the mixtures obtained by groups 'C' and 'D', the constituent substances can be seen separately. Such mixtures where the constituent substances are not uniformly distributed and can be seen separately are called heterogeneous mixtures.

Let us do an activity to try and understand the properties of homogeneous and heterogeneous mixtures :

Activity-3

- Ask your students to form three groups 'A', 'B' and 'C'.
- Ask group 'A' to take 100 mL of water in a beaker and add one spoonful salt to it.
- Ask group 'B' to take 100 mL of water in a beaker and add one or two drops of either milk or ink to it.
- Ask group 'C' to take 100 mL of water in a beaker and add one spoonful chalk powder to it.
- Each group should stir their mixture well using a glass rod. In which beaker are the particles visible separately in the water?

- Using a laser torch direct a beam of light through each beaker from the side. Observe the beaker from above, that is, perpendicular to the direction of the laser beam. In which beaker(s) is the path of light visible (Fig. 2)?

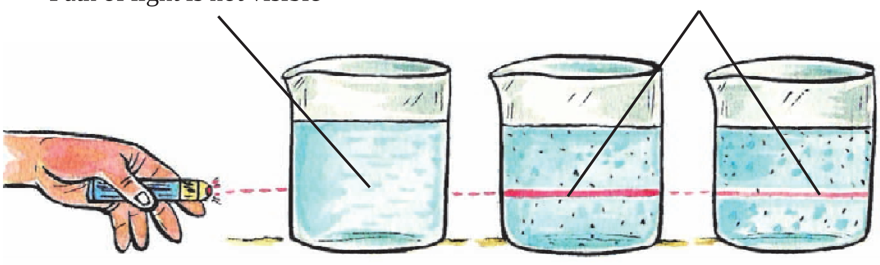


Fig. 2

- Now leave the three beakers undisturbed for 15 minutes. Then observe in which beakers the mixture is stable and in which the particles have started to settle down after some time?
- Each group should filter their mixture separately using filter paper (Fig.3). Which group has some residue left behind on their filter paper?

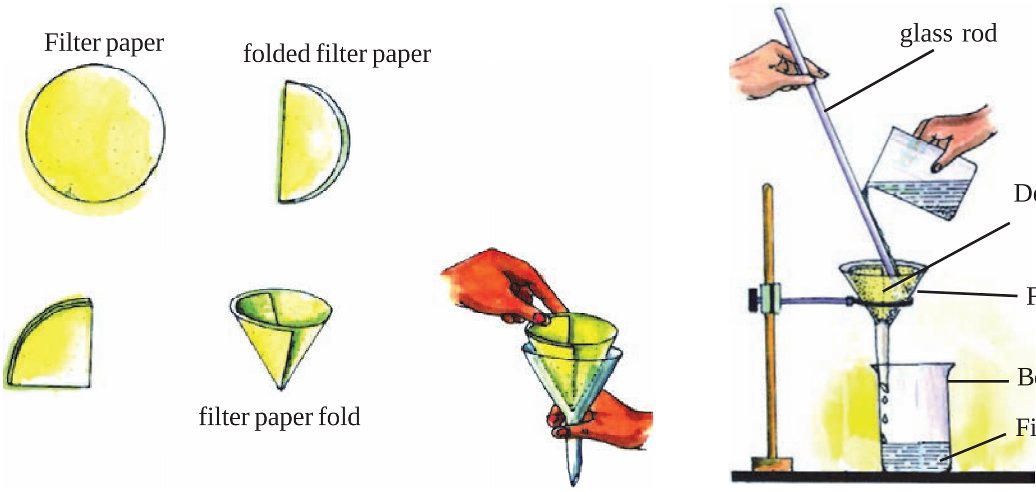


Fig. 3 : Filtration

Based on the observed properties of these three mixtures, we can say that:

- Separate particles are not visible in mixture 'A' and the path of light is also not seen. The constituent particles do not settle down at the bottom of the beaker and cannot be separated by filtration. Such mixtures are called solutions and here the constituent particles are uniformly distributed.

- In mixture 'B', separate particles are not visible. The constituent particles do not settle down at the bottom of the beaker and cannot be separated by filtration. But unlike mixture 'A', the path of laser light beam can be seen in mixture 'B'. Such types of mixtures are known as colloids.
- The constituent particles of mixture 'C' can be filtered and they settle down if left undisturbed. The particles in this mixture are so big that not only can they be seen but they also scatter a beam of light. Such mixtures are called suspensions.

We will now try to understand solutions, colloids and suspensions in some detail.

2.4 What is a solution?

We come across many solutions like soda water, lemonade, etc. in our daily lives. Usually, a solution has two parts - solute and solvent. The constituent of a solution whose quantity is more than any of the other constituents and which dissolves the other components in it is called the solvent. The constituent(s) that are in lesser quantity and which dissolve in the solvent are called solutes. Solutes and solvents can be solid, liquid, or gas. The solute and solvent particles are evenly distributed in a solution. Because of the uniform distribution of particles, if we examine any portion of a solution its properties will be same. For example, the solution of salt and water will taste the same throughout. Therefore, solutions are homogeneous mixtures.

You must have applied tincture iodine on a wound. The solution of iodine (solute) in alcohol (solvent) is known as 'tincture of iodine'. It is commonly believed that solutions are mixtures of solids, liquid, or gases dissolved in a liquid but solid and gaseous mixtures are also known. For example, alloys are solid solutions and air (nitrogen 78%, oxygen 21% and other gases in trace amounts) is a gaseous mixture.

Alloys

Alloys are homogeneous mixtures of solids. Although the constituent particles of alloys cannot be separated by physical means still we consider them as mixtures. For example, brass is a mixture of 60-80% copper and 40-20% zinc. Alloys display the properties of the metals of which they are composed.

2.4.1 Properties of a solution

- Solute and solvent together constitute a solution. A solution can have more than one solute.
- The constituents of a solution are uniformly distributed at the level of atoms and molecules. That is, its particles are very small.
- Because of very small particle size, the particles of a solution cannot be separated by filtration. Nor are the particles heavy enough to settle down.

- Because of very small particle size, they do not scatter a beam of light passing through the solution. So we do not see the path of a light beam in a solution.

2.4.2 Types of Solutions

Solutions can be categorized based on the amount of solute present in them. Let us understand this further through an activity.

Activity-4

- Take two beakers and fill them each with 100 mL water.
- In one beaker add a spoonful of sugar and in the other add a spoon of salt. Mix well using a glass rod.
- Keep adding sugar in the first beaker and salt in the second beaker with continuous stirring till no more can be dissolved.
- Were the quantities of sugar and salt that dissolved same?
- Now heat both the solutions with the help of a spirit lamp. Did the extra sugar and salt dissolve?
- Now add one spoonful sugar to the first beaker and one spoonful salt to the second beaker. Did they dissolve in the solution?

From this activity, we can conclude that at a given temperature a solvent is capable of dissolving a fixed amount of a solute and cannot dissolve more than that. If at a given temperature and for a given volume of solvent, it is not possible to dissolve any more solute, then the solution is called saturated solution. The amount of solute present in the saturated solution at this temperature is called its solubility. If the amount of solute present in a solution is less than the saturation level, it is called an unsaturated solution. In activity-4, we saw that if the saturated solution of solute at a given temperature is heated, then more solute can be dissolved in it. Now, if we cool this solution slowly then the extra solute will remain dissolved in the solution. This solution at the lower temperature where the amount of solute dissolved is more than the saturation level is called a super-saturated solution. For example, *chashni* is a supersaturated solution of sugar in water. Under appropriate conditions, the extra solute separates out as crystals.

On the basis of activity-4 we can say that different substances in a given solvent can have different solubilities at the same temperature. Can we divide solutions into concentrated and dilute solutions based on the amount of solute present? For this we need to learn about concentration of solutions. Let us understand this through an activity.

Activity-5

- Take two beakers and label them ‘A’ and ‘B’. Take 100 mL water in each beaker.
- Add ½ spoon salt to beaker ‘A’ and 2 spoonful salt to beaker ‘B’.

- Stir the contents of both beakers vigourously with a glass rod.
- The quantity of salt in beaker 'A' is less than the quantity of salt in beaker 'B'. We say that the solution in beaker 'A' is dilute as compared to the solution in beaker 'B'. The solution in beaker 'B' is concentrated as compared to solution in beaker 'A'. Concentrated and dilute are relative terms.

• Nutritional Facts	g/100g
Protein	3.0
Carbohydrate	4.7
Fat	3.0
Saturate	1.8
Trans Fat	ND
Calories K cal	58

Fig. 4 : Percent concentration of constituents of milk

We can express concentration in quantitative terms as well. The concentration of a solution is the amount of solute present in a given amount (mass or volume) of a solution.

We see many examples of concentrations being used in our daily life. For example, on a packet of milk which shows that there is 3.0 g protein, 4.7 g carbohydrate and 3.0 g fat in 100 g of milk (Fig. 4). Medicine bottles also show component concentrations in percentages.

There are several ways to describe the concentration of solution. One of them is:

$$\text{Mass percentage of a solution} = \frac{\text{mass of solute}}{\text{mass of solution}} \times 100$$

Example-1 : Find the concentration of a solution of 40 g common salt (solute) in 520 g water (solvent).

Mass of solute (common salt) = 40 g

Mass of solvent (water) = 520 g

Mass of solution = mass of solute + mass of solvent

40 g + 520 g

= 560 g

$$\text{Mass percentage of a solution} = \frac{\text{mass of solute}}{\text{mass of solution}} \times 100$$

$$= \frac{40}{560} \times 100 = 7.14\%$$

2.5 What is a suspension?

The mixture (chalk powder in water) obtained by group 'C' in activity-3 is an example of a suspension. Muddy water which is a mixture of soil in water is another example of suspension. Here, the solute particles do not dissolve and remain suspended in the medium (solvent). The suspended particles can be seen with the naked eye. A mixture of sand and water, *haldi* in water etc. are also examples of suspensions.

We can identify the following main properties of a suspension on the basis our observations:

- Suspensions are heterogeneous mixtures because they show different compositions in different parts.
- Their particles are so big that they can be seen with the naked eye and they can scatter a beam of light. This shows its path and also shows the particles of the mixture.
- The size of the particles in a suspension is so big that they start settling down if left undisturbed. The particles can also be separated using filter paper.

2.6 What is a colloid?

Is the mixture (milk/ink in water) obtained by group 'B' in activity-3, a solution or suspension? If it is neither, what is it?

On the basis of our observations, we can conclude that this is a type of mixture that is between suspensions and solutions. Such mixtures are called colloids. The particles of a colloid are smaller than that of a suspension. That is why they look homogeneous but are actually heterogeneous.

- The size of particles of a colloid is so small that they cannot be seen by the naked eye. They cannot be separated by filtration and do not settle down when left undisturbed. But they can be separated by using centrifugal force. You must have seen butter being separated from curd using a hand-churn. Here also, the particles are separated from a colloid using centrifugal force. If you have a centrifugation machine in your school, take some milk in a test tube and spin it for two minutes. Does the cream separate out from the milk?
- The particles of a colloid easily scatter a light beam to show the path of light rays. This effect is known as Tyndall effect (Fig. 5). The effect was discovered by the scientist, John Tyndall (1820-1893).

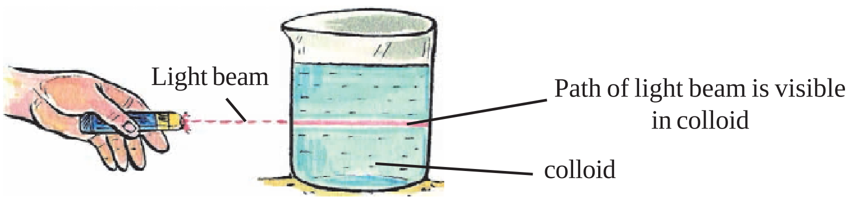


Fig. 5 : Tyndall effect

This effect can also be seen in a dark room when light enters it through a small opening. This effect is due to the scattering of light by dust and smoke particles.

- In a colloid, the solvent particles exert an unbalanced force on the solute particles. This causes the solute particles in the colloid to move in a zig-zag manner (Fig. 6). This event was studied by Robert Brown (1773-1858) in 1827 and such zig-zag motion of particles is called Brownian motion after him.

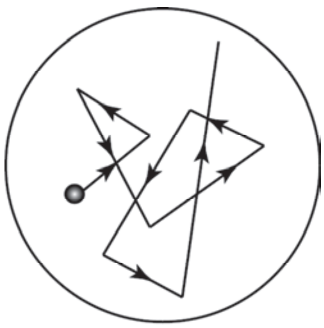


Fig. 6 : Brownian motion

Questions

1. Identify solutions, suspensions and colloids from among the given mixtures – salt dissolved in water, mud in water, milk in water.
2. Which amongst the following mixtures will show Tyndall effect – sugar in water, ink in water, starch solution, salt solution.
3. 250 g of washing soda was dissolved in 1 kg of water. Find the concentration of the solution in terms of mass percentage.
4. When we add 1-2 drops of rice water (*pasiya)* in 100 mL water, what do we get – a colloid or a suspension? Explain with reasons.

We know that mixtures are of many types and their components can be separated using different separation techniques. On separation, if we get substances that cannot be further separated using simple physical techniques then the separated substances are called pure substances.

Many new separation techniques are being developed. With the advance in separation techniques, it is possible that what we consider as a pure substance today may turn out to be a mixture. For example, for a long time in the past, air was considered as a pure substance but now we know that air is a mixture of gases. Come, let us understand pure substances in more detail.

2.7 What are the types of pure substances?

Pure substances can be classified as either elements or compounds on the basis of their chemical composition.

2.7.1 Elements

You know that elements are those substances that cannot be further broken into simpler substances by using chemical methods (heat, light, electricity or reactions with other chemical substances). Hydrogen is an element. Similarly, sodium (Na), iron (Fe), copper (Cu) etc. are also elements. Can you add more names to this list of elements? How many more names were you able to add?

Lavoisier (1743-94) was the first to give the modern definition of elements based on experiments. According to Lavoisier, element is a basic form of matter that cannot be broken down into simpler substances by chemical methods.

An element cannot be further broken into simpler substances because it is made of only one type of atoms. For example, copper is made of only copper atoms and iron is made of only iron atoms. Elements are found in solid, liquid and gaseous states.

Do you know?

- The number of elements known to us so far is more than 100. Of these, 92 are naturally occurring and the remaining are man-made.
- Most of the elements are solids.
- Two elements – mercury and bromine – are liquid at room temperature.
- The elements gallium and cesium become liquid at a temperature slightly above room temperature (300 K).
- Eleven elements are gases at room temperature.

2.7.2 Compounds

There are many substances around us that are formed by chemical reactions between two or more elements in a fixed proportion. These substances are called compounds. The properties of the compound formed after a chemical reaction is different from its constituent elements. For example, water (H_2O) is a compound which is formed by reaction between an inflammable gas, hydrogen, and oxygen gas which is needed for combustion. But water is neither combustible nor does it help in combustion. In fact, it puts out fires. Let us do an activity to find the ratio of the constituent elements in water.

Activity–6

- Do this activity under your teacher's supervision.
- Take a plastic bottle with a wide opening. Cut off its base. Fit a rubber cork with two holes on the mouth of the bottle. Insert one graphite rod in each of the holes. Set up your apparatus as shown in the figure.
- Fill the bottle about two-thirds with water and add a few drops of dilute sulphuric acid to it.
- Now place two test tubes over the graphite rods in such a way that they are completely filled with water and there are no air bubbles inside them.
- Connect the two electrodes to a 9 V battery.
- Observe the gases that start collecting in the test tubes. Is the rate of collection of gases the same in the two test tubes?

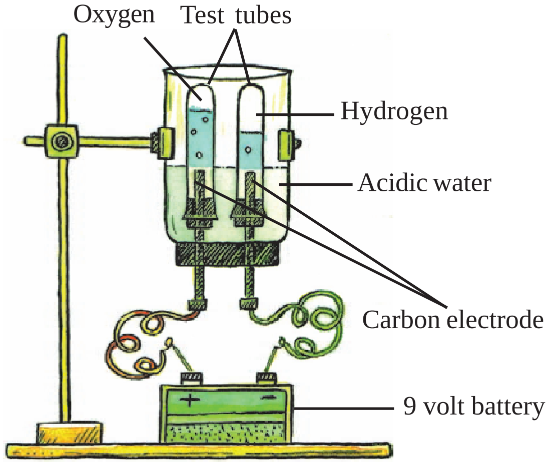


Fig. 7 : Electrolysis of water

- When one of the test tubes is completely filled with the gas, that is, no water is left in it then note the level and volume of gas collected in the other test tube.

- Is there any difference in the volumes of gas collected in the two test tubes?
- Remove the gas-filled test tube and replace it with another test tube filled with water, similar to the previous set-up. Put a lighted match-stick close to the mouth of the test tube filled with gas. Observe.
- When the second test tube get completely filled with gas, remove it. Put a lighted match-stick close to the mouth of this test tube. Observe.
- What is the ratio of the volume of the gas that helps in burning (O_2) to the volume of gas that itself burns (H_2)? What would be their ratio by volume when they combine to form water?

On the basis of the above activity, we can say that water is a compound that is formed by the chemical combination of hydrogen and oxygen in the ratio 2:1 by volume. The properties of the compound formed are different from the properties of oxygen and hydrogen. The constituents of water can be obtained by chemical methods such as electrolysis.

If we try to calculate the ratio of hydrogen to oxygen in water by mass, we find that it is always 1:8 irrespective of the source of water. This means that if 9 g of water undergoes electrolysis, we will always get 1 g hydrogen and 8 g oxygen. Similar results are obtained in case of other compounds as well. For example, on analysing carbon dioxide, the ratio of carbon to oxygen by mass was always 3:8.

Based on such experiments, Proust (1754-1826), a French chemist, gave the law of definite or constant proportions. According to this law, a compound always contains the same (fixed) proportion by mass of its two or more constituent elements. Ammonia and baking soda are some examples of compounds. The constituent elements of these compounds follow the law of constant proportions.

Questions

1. Group the following substances into elements or compounds:

   potassium, lime water, sulphur, washing soda, carbon, lead, vinegar
2. We get a white powder when we burn magnesium ribbon in air. Is this powder an element or a compound? Give reasons for your answer.
3. What is common salt – element, compound or mixture? Explain.

Keywords

Solution, colloid, suspension, homogeneous mixture, heterogeneous mixture, solvent, solute,saturated solution, unsaturated solution, supersaturated solution, concentration, solubility, Tyndall effect, Brownian motion, centrifugal force.

What we have learnt

- Matter occupies space and has mass.
- Matter can be divided into mixtures and pure substances.
- A mixture contains more than one substance mixed in any proportion and shows the properties of its constituents. Mixtures can be separated into its constituent components using appropriate separation techniques.
- When the constituent components of a mixture are uniformly distributed then it is called a homogeneous mixture and when they are non-uniformly distributed then it is called heterogeneous mixture.
- A solution is a homogeneous mixture of two or more substances. The component of a solution present in larger quantity is called the solvent, and the one present in lesser quantity, the solute.
- The concentration of a solution is the amount of solute present in a given amount of solution.
- A mixture where the solute particles are insoluble in the solvent and can be seen by the naked eye is called a suspension.
- The size of particles in a colloid is too small to be seen with the naked eye, but is big enough to scatter light and show the path of light.
- Pure substances can be elements or compounds. An element is a form of matter that cannot be broken down by chemical reactions into simpler substances. A compound is a substance composed of two or more different types of elements, chemically combined in a fixed proportion. Properties of a compound are different from its constituent elements.
- During a chemical reaction, the sum of the masses of the reactants is equal to the sum of the masses of the products. This is known as the law of conservation of mass.
- In a compound, elements are always present in a definite proportion by mass. This is known as the law of definite proportions.

Exercises

1. Choose the correct option:

   (i) Homogeneous mixture is :

   (a) iron (b) bronze

   (c) 24 carat gold (d) oxygen

(ii) Heterogeneous mixture is

(a) pure water (b) concrete

(c) solution of salt in water (d) lime (calcium oxide)

(iii) Oxygen is

(a) an element (b) a compound

(c) a heterogeneous mixture (d) a homogeneous mixture

(iv) Sugar is

(a) an element (b) a compound

(c) a heterogeneous mixture (d) a homogeneous mixture

(v) Which of the following will show Tyndall effect

(a) solution of salt in water (b) starch solution

(c) solution of baking soda in water (d) vinegar

(vi) Which of the following is not a pure substance

(a) ice (b) iron

(c) mercury (d) milk

2. Choose solutions from the given mixtures –

soil, sea water, air, soda water, mixture of glue in water, mixture of milk in water

3. Separate the following into elements, mixtures and compounds –

lemonade, rocks, copper, diamond, salt, neon gas, salad, pure water, aluminium, silver, soap, blood, carbon dioxide, sodium

4. Choose the appropriate option to fill in the blanks:

(i) An element has .... type of particles (same/different).

(ii) The scattering of light by colloid particles is called .... (Tyndall effect/ Brownian motion).

(iii) In tincture iodine solution, iodine is the .... (solvent/ solute)

(iv) The particles in a .... can be separated by filtration using filter paper. (suspension/ colloid).

(v) Particles in a .... cannot be seen with the naked eye (solution/ suspension).

5. Explain the following with examples –

   Pure substances, saturated solutions, colloid, suspension

6. Through an activity, demonstrate that the sugar dissolved in water is a solution.

7. What is the effect of temperature on the solubility of a solid in a liquid? Explain through an activity.

8. Write the differences between solutions, colloids and suspensions.

9. How will you differentiate between homogeneous and heterogeneous mixtures?

10. Seema took three solids, A, B and C and made their saturated solutions in 100 g water at different temperatures. The amounts of A, B and C used to form saturated solutions are shown in the table:

Solute	**Temperature in K**			
	293 K	313 K	333 K	353 K
a	35 g	36 g	37 g	38 g
b	32 g	62 g	106 g	167 g
c	34 g	40 g	46 g	54 g

(i) What are the amounts of A, B and C needed to form saturated solutions at 293 K? What can you conclude based on this observation?

(ii) Calculate the amount of solutes A, B and C needed to form saturated solutions in 500 g water at 313 K.

(iii) Find the concentration in mass percent of A and C at 353 K.