3 Nature and Properties of Matter

Recall what you have learnt about the properties of matter in grade 8. You may call back to your mind how matter was classified as pure substances and non-pure substances (mixtures). Based on that knowledge engage in the activity 3.1.

Activity 3.1

Classify and tabulate the substances given below as pure substances and mixtures.

Air, drinking water, aluminium, silver, copper, salt solution, distilled water, carbon, sulphur, zinc, copper sulphate, sodium chloride

Matter that contains only one constituent with specific properties are called **pure substances**. Accordingly aluminium, silver, copper, distilled water, carbon, sulphur, zinc, copper sulphate and sodium chloride belong to the class of pure substances.

Matter that contains two or more constituents are known as **mixtures**. Hence, air, drinking water and salt solution can be named as mixtures.

In grade 8 you have learnt that pure substances can be further classified as **elements** and **compounds**. To strengthen that knowledge further involve in the activity 3.2.

Activity 3.2

Classify and tabulate the following pure substances as elements and compounds.

Sulphur, glucose, chlorine, sodium chloride, silver, copper, copper sulphate, zinc.

The pure substances with specific properties which cannot be further divided by either physical or chemical methods into substances with different properties are called **elements**. Accordingly iron, sulphur, chlorine, silver, zinc and copper belong to elements. There are about 120 elements have been discovered upto now.


Copper


Iron


Sulphur


Mercury


Carbon


Aluminium


Silver

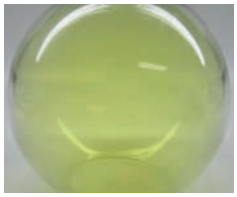
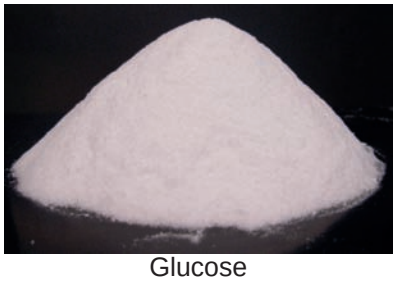

Chlorine

Figure 3.1- Some common elements

The **compounds** are pure substances with specific properties formed by the chemical combination of two or more elements in a fixed ratio. Thus, sodium chloride, copper sulphate and glucose belong to the class of compounds. In nature, there are very large number of compounds occur in various elements in various forms.


Glucose


Copper sulphate


Sodium chloride

Figure 3.2 - Some common compounds

3.1 Elements

3.1.1 Symbols for elements

We know that in various instances we use various symbols to facilitate communication. Symbols are also used to indicate elements. All countries in the world use these internationally accepted symbols to indicate elements.

Very often, english name of the element is used as the base for these symbols. In such case the first letter of the name of the element is used as the symbol. When a single letter is used as the symbol, compulsorily it should be a capital letter. Table 3.1 presents some examples.

Table 3.1

Elements	Symbol
Carbon	C
Oxygen	O
Sulphur	S

When the names of several elements commence in the same letter, the next letter or another letter in the name is added to the symbol. In that, the second letter is a simple letter. Table 3.2 gives some examples.

Table 3.2

Elements	Symbol
Chlorine	Cl
Calcium	Ca
Magnesium	Mg
Aluminium	Al

In some elements, the symbol originates in its Latin name. Table 3.3 lists some examples for such symbols.

Table 3.3

English name	Latin Name	Symbol
Sodium	Natrium	Na
Copper	Cuprum	Cu
Lead	Plumbum	Pb
Gold	Aurum	Au
Mercury	Hydrargyrum	Hg
Iron	Ferrum	Fe
Silver	Argentum	Ag

Table 3.4 illustrates names of several elements and their symbols.

Table 3.4

Elements	Symbol
Hydrogen	H
Carbon	C
Oxygen	O
Nitrogen	N
Sulphur	S
Chlorine	Cl
Aluminium	Al

Elements	Symbol
Magnesium	Mg
Zinc	Zn
Silicon	Si
Phosphorous	P
Argon	Ar
Calcium	Ca
Iodine	I

3.1.2 Building units of elements

Figure 3.3 - John Dalton

You have learnt that matter is composed of particles. These particles cannot be observed by the naked eye or even by the powerful microscopes. These very small particles are called **atoms**.

John Dalton (1766 - 1844) was the first scientist to use the term atom for the smallest, indivisible particle from which matter is made. The English name 'atom' for this particle has originated from the greek word 'atomos' meaning cannot be divided further.

An element is composed of the atoms of the same type. The atoms which form different elements are different to each other. For example, the element iron is formed from iron atoms. Aluminium is formed from aluminium atoms. The structure of aluminium atoms and iron atoms is different from each other.

The units formed by the combination of one or more atoms of the same type or one or more atoms of different types are called **molecules**.

Under normal conditions, the element oxygen exists as oxygen molecules composed of two oxygen atoms. The smallest form in which oxygen can exist independently is a molecule. Some examples for the elements which can exist as molecules are given in table 3.5.

Table 3.5

Elements	Symbol of the molecule
Oxygen (O)	O_2
Nitrogen (N)	N_2
Chlorine (Cl)	Cl_2
Hydrogen (H)	H_2
Fluorine (F)	F_2

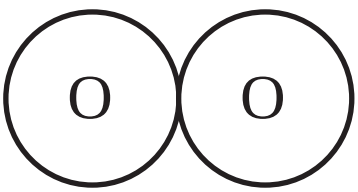


Figure 3.4
A representation
of an Oxygen molecule

Figure 3.5
A representation
of a Hydrogen molecule

Since the above molecules are formed by the atoms of the same elements they are known as **homo-atomic molecules**.

Therefore, elements are composed of either atoms of the same kind or molecules formed by the combination of same kind of atoms. Thus, they cannot be further divided into simple substances chemically.

3.1.3 Atomic structure

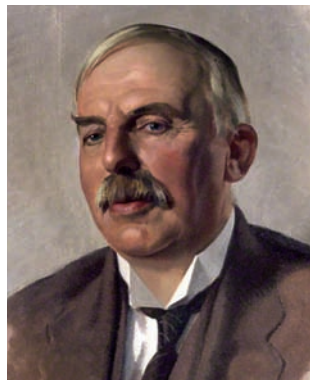


Figure 3.6 - Ernest Rutherford

We know that the building units by which matter is composed are atoms. What is wonderful is the fact that a greater part of an atom is empty space. Almost the entire mass of the atom is concentrated at a central core. This central core is positively charged and is called the **nucleus**. It was **Ernest Rutherford** (1871-1937), a British physicist who for the first time discovered that the atom consists of a large empty space and a positively charged central nucleus.

In the past, the atom was considered as a very small particle which cannot be divided further. But, according to findings of the experiments conducted later, the atom is formed by a collection of subatomic particles. These subatomic particles are known as electrons, protons and neutrons.

Protons and neutrons are found in the nucleus the centre of the atom. Electrons which are very much lighter than the protons and neutrons exist moving around the neucleus. Relative to the entire volume of the atom, the volume of the nucleus is extremely small.

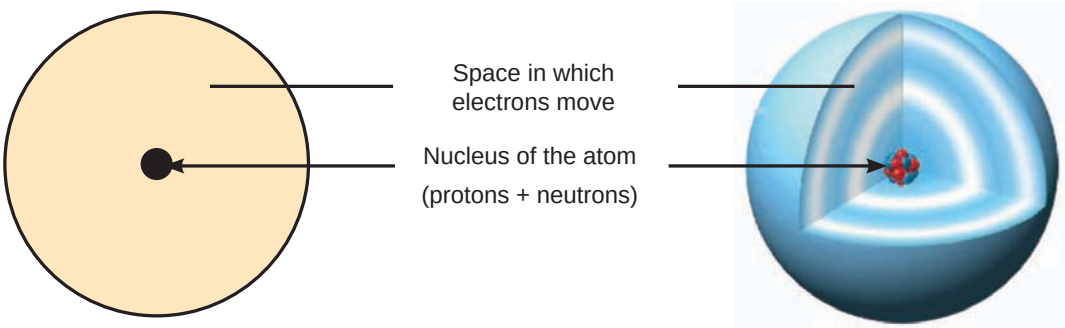


Figure 3.7 - Illustration of an atom

Table 3.6 presents location and some properties of the subatomic particles.

Table 3.6 - Relative masses and relative charges of subatomic particles

	Protons	Neutrons	Electrons
Location	in the neuleus	in the neucles	around the nucleus
Mass (relative to proton)	1	1	$\frac{1}{1840}$
Charge (relative to electron)	+1	0	-1

Atomic number (Z)

The number of protons present in the nucleus of a given atoms of an element is called the atomic number. It is generally designated by the symbol Z. The atomic number or the number of protons in the nucleus is a unique property of the element. As an atom is electrically neutral, number of protons and number of electrons are equal. The atomic numbers of some elements are given in table 3.7.

Table 3.7 – Atomic number of atoms of some elements

Element	Number of Protons	Number of Electrons	Atomic Number
Carbon (C)	6	6	6
Nitrogen (N)	7	7	7
Oxygen (O)	8	8	8
Fluorine (F)	9	9	9
Neon (Ne)	10	10	10
Sodium (Na)	11	11	11

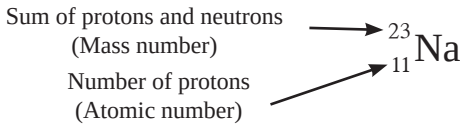
Mass number (A)

The sum of the number of protons and neutrons in the nucleus of an atom of an element is called the mass number of the atom of that element. The mass number is represented by the symbol A.

Table 3.8 - Mass number of atoms of some elements

Element	Number of protons (p)	Number of Neutrons (n)	Mass number (p + n)
N	7	7	14
O	8	8	16
F	9	10	19
Na	11	12	23
Cl	17	18	35

There is a standard method of representing atomic number and mass number of an atom. This standard method is, writing atomic number at the left hand side bottom end and mass number at the left hand side top end of the symbol of the atom. The information related to an atom of element sodium (Na) is given below.



3.2 Compounds

Compounds are formed by the chemical combination of two or more elements in a certain ratio. Some of those compounds exist in nature as molecules. Since those molecules contain atoms that are different from one another, they are called **hetero-atomic molecules**.

e.g. A Hydrogen chloride molecule is formed by the combination of one hydrogen atom and one chlorine atom.

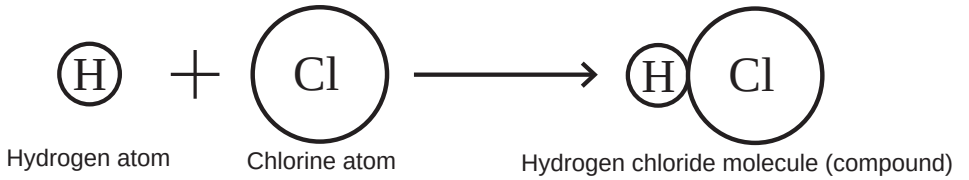


Figure 3.8 - Illustration of the formation of a hydrogen chloride molecule

Thus, a main difference between elements and compounds is that an element is composed of the atoms of the same kind while a compound is formed from atoms belonging to two or more elements.

e.g. A water molecule is formed by the combination of an oxygen atom and two hydrogen atoms.

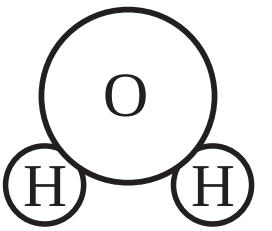


Figure 3.9 - Water molecule

Assignment 3.1

Using various materials create models for several homo-atomic and hetero-atomic molecules. Display the models you made in the classroom.

A carbon dioxide molecule is formed by the combination of a carbon atom and two oxygen atoms. This is shown by figure 3.10.

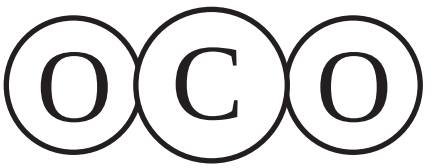


Figure 3.10 - Carbon dioxide molecule

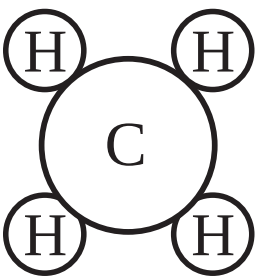


Figure 3.11 - Methane molecule

A methane molecule is formed by the combination of a carbon atom with four hydrogen atoms. This is illustrated by figure 3.11.

An ammonia molecule is formed by the combination of nitrogen atom with three hydrogen atoms. This is illustrated by figure 3.12.

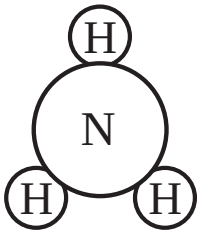


Figure 3.12 - Ammonia molecule

There are specific chemical symbols for compounds also. These symbols are known as **chemical formula** of compounds. You will study them in higher grades.

Table 3.9

Compound	Chemical formula of the compound	Elements contained
Water	H_2O	H and O
Glucose	$C_6H_{12}O_6$	C, H and O
Methane	CH_4	C and H
Carbon dioxide	CO_2	C and O
Sodium chloride (Common salt)	NaCl	Na and Cl
Copper sulphate	$CuSO_4$	Cu, S and O
Calcium carbonate	$CaCO_3$	Ca, C and O

The elements contained in the smallest unit that goes to form a compound cannot show the properties of that compound.

The different compounds formed by even the same set of elements have different chemical properties.

e.g. 1: Same compounds formed by the set of elements C, H are given below.

- Methane (a component of biogas) - CH_4
- Hexane (a solvent) - C_6H_{14}
- Benzene (a solvent) - C_6H_6
- Acetylene (a gas burnt to generate heat essential for welding metals) - C_2H_2
- Ethene (a gaseous raw material needed to make polythene) - C_2H_4

e.g. 2 : Given below are some compounds formed by the set of elements C, H, O

- Glucose (a simple sugar) - $C_6H_{12}O_6$
- Acetic acid (contained in vinegar) - CH_3COOH
- Ethanol (contained in alcoholic beverages) - C_2H_5OH
- Dimethyl ether (an anaesthetic) - CH_3OCH_3
- Sucrose (contained in sugar cane) - $C_{12}H_{22}O_{11}$

3.3 Mixtures

Next let us study about the non-pure substances (mixtures).

Pay your attention to sea water. Various salts and various gases are dissolved in it. That means, it contains several constituents. Therefore, sea water is a mixture. In natural environment mostly we come across mixtures and not pure substances. Air, soil, river water and rocks around us are all mixtures. Yoghurt, ice cream and fruit salad we eat are also mixtures. The drinks such as tea, coffee and soft drinks too are mixtures.

Fruit salad

Coffee

Ice cream

Figure 3.13 - Some mixtures

Mixtures are formed when two or more pure substances get mixed. The pure substances in a mixture are called as constituents.

Let us identify constituents in some mixtures. Let us study table 3.10.

Table 3.10 - Mixtures and their constituents

Mixture	Constituents
Air	nitrogen, oxygen, argon, carbon dioxide, water vapour
Sea water	water, salts, dissolved oxygen, dissolved carbon dioxide
Cake mixture	sugar, flour, water, colouring, butter, eggs
Crude oil	diesel, petrol, kerosene, tar

The specific feature of a mixture is that its constituents can be separated by physical methods. When rice is mixed with sand they can be separated by sifting using the sifting bowl. So, sifting is a physical method of separating constituents in a mixture. Let us involve in activity 3.3 to study about the physical methods of separating constituents in a mixture.

Activity 3.3

- You are provided with the following mixtures. Suggest suitable methods for separating the constituents in the mixtures.
    1. A mixture of sugar and sand
    2. A mixture of salt and water
    3. A mixture of iron powder and sulphur powder
    4. A mixture of rice and sand
    5. A mixture of chaff and stone
- Describe how the constituents of the mixtures were separated.

Given below are some physical methods of separating constituents in a mixture and some instances in which they are used. They will be studied in detail in grade 11.

Panning	- Separating sand from rice, Separating gems from ores
Winnowing	- Separating chaff from rice
Floating on water	- Separating sterile seeds from seed paddy
Sifting	- Separating gravel from sand
Vapourisation	- Obtaining salt from sea water
Fractional distillation	- Separating various fuels from crude oil
Steam distillation	- Separating cinnamon oil from cinnamon leaves
Crystallization	- Separating sugar from cane sugar syrup
Uses of magnets	- Separating some minerals from mineral sands

Figure 3.14 - Gem mining

Figure 3.15 - Winnowing paddy

Assignment 3.2

Prepare a chart to show the physical methods used to separate constituents of a mixture and the instance in which those methods are used.

According to that mixtures can be described as follows.

A matter which consists of two or more constituents which can be separated by physical methods are called mixtures.

According to the nature, mixture can be divided into two categories.

1. Homogeneous mixtures 2. Heterogeneous mixtures

Homogeneous mixtures

Let us involve in activity 3.4 to study about homogeneous mixtures.

Activity 3.4

1. Weigh about 2 g of salt, add it to a beaker containing 500 ml of water, mix well with a glass rod and allow to stand for a few minutes.
2. Observe carefully.

You will be able to see that properties like colour and transparency are alike throughout the mixture. The mixtures with a uniform composition right throughout the mixture are called **homogeneous mixtures**.

e.g. Salt solution, sugar solution, sea water

Heterogeneous mixtures

Dissolve a little clay in water, allows to stand from some time and observe. If you observe carefully you may be able to see that the colour and transparency of the mixture is different from place to place.

The mixtures in which the composition is not uniform throughout the mixture are known as **heterogeneous mixtures**.

e.g. Muddy water, mortar mixture, ice cream, fruit salad

Assignment 3.3

- Prepare mixtures by mixing each of the following with small amount of water and observe these mixtures.

  salt, soap, copper sulphate, limestone, washing blue, chilli powder
- Record the observations
- Classify the mixtures you have prepared as homogeneous and heterogeneous.

Summary

- Matter can be classified as pure substances and non-pure substances (mixtures).
- Pure substances can be further classified as elements and compounds.
- The pure substances which bear specific properties and cannot be further divided into substances with different properties by physical or chemical methods are called elements.
- The pure substances which have specific properties and are formed by the chemical combination of two or more elements in a definite ratio are termed as compounds.
- Atoms and molecules are the building units of elements.
- Homo-atomic molecules are formed by the combination of two or more atoms of the same kind whereas hetero-atomic molecules are formed by the combination of two or more atoms of different kinds.
- The atom consists of subatomic particles.
- Electrons, protons and neutrons are the subatomic particles in an atom.
- An atom comprises a large empty space and a positively charged nucleus at the centre of it.
- Protons and neutrons are contained in the nucleus. Electrons move around the nucleus.
- The number of protons in the nucleus of an atom is called the atomic number of that element. It is a unique property for that element.
- The sum of the protons and neutrons in the nucleus of an atom is called the mass number.
- Mixtures are matter consisting of two or more pure constituents that can be separated by physical methods.
- Mixtures can be classified as homogeneous mixtures and heterogeneous mixtures.

Exercise

01) Select the correct or most suitable answer.

1. The number of protons, neutrons and electrons in the $^{35}_{17}Cl$ atom respectively are
   1. 17, 18, 18 2. 17, 18, 17 3. 17, 17, 18 4. 17, 17, 17

2. Of the following statements given about the atom select the **false** statement.
   1. Atoms are the building units of matter.
   2. A large portion of an atom is empty space
   3. There is a positively charged nucleus at the center of an atom
   4. An atom cannot be further divided.

3. A unique property for a certain atom is,

1. Its atomic number
2. The number of neutrons in the nucleus
3. Its mass number
4. The sum of the number of neutrons and protons

4. Which of the following contains matter belonging to the same set?

1. Sodium, carbon, oxygen
2. Oxygen, water, air,
3. Water, carbon, sodium
4. Air, carbon, oxygen

5. Of the following statements given about the element nitrogen, select the **false** statement.

1. Nitrogen is a pure substance.
2. Nitrogen molecules are the building units of nitrogen.
3. Nitrogen molecule is formed by the combination of a large number of nitrogen atoms.
4. Nitrogen is a constituent of air.

6. Of the following substances given, a pure substance is

1. Air
2. Salt solution
3. Vinegar
4. Copper sulphate

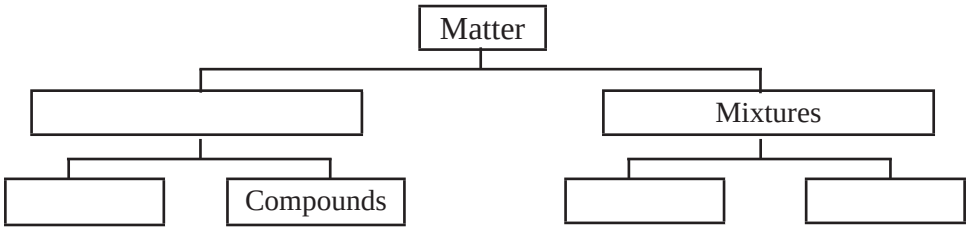
02) Fill the blanks considering proton and neutron amounts of particular elements.

Elements	Number of protons	Number of neutrons	Atomic number	Mass number
Sodium	11	.....	.....	23
Calcium	.....	20	20	.....
Iron	.....	.....	26	56
Sulphur	.....	16	16	.....
Bromine	35	.....	.....	80

03) Indicate whether the mixtures given below are homogeneous or heterogeneous.

1. Tea
2. Sea sand
3. Rice mixed with chaff
4. Vinegar
5. Copper sulphate solution

04) Copy the following figure on classification of matter in your book and fill in the blanks.



05) Give short answers.

1. Name three pure elements and three pure compounds.
2. Write the formula of three compounds which you know and name the elements in them.
3. Write the chemical symbols and names of five elements symbolized by a single letter.
4. Write the chemical symbols and names of five elements symbolized by two letters.

Technical Terms

Atom	-	පරමාණුව	-	அணு
Molecule	-	අණුව	-	மூலக்கூறு
Matter	-	පදාර්ථය	-	மேட்டர
Elements	-	මූලද්‍රව්‍ය	-	மூலகங்கள்
Nucleus	-	න්‍යෂ්ටිය	-	கரு
Proton	-	ප්‍රෝටෝන	-	புரோத்தன்
Electron	-	ඉලෙක්ට්‍රෝන	-	இலத்திரன்
Neutron	-	නියුට්‍රෝන	-	நியுத்திரன்
Homogeneous mixture	-	සමජාතීය මිශ්‍රණ	-	ஏகவினக் கலவை
Heterogeneous mixture	-	විෂමජාතීය මිශ්‍රණ	-	பல்லினக் கலவை
Compounds	-	සංයෝග	-	சேர்வைகள்
Atomic number	-	පරමාණුක ක්‍රමාංකය	-	அணுவெண்
Mass number	-	ස්කන්ධ ක්‍රමාංකය	-	திணிவெண்
Homo-atomic molecules	-	සමපරමාණුක අණු	-	ஏகவின அணுமூலக்கூறுகள்
Hetero-atomic molecules	-	විෂමපරමාණුක අණු	-	பல்லின அணுமூலக்கூறுகள்