CHAPTER

# 2 Matter



Have you ever wondered about the tiny particles that make up everything around us? Understanding the nature and composition of matter has led to the development of amazing nanomaterials that have revolutionized several industries. The field of nanotechnology has given us better and more affordable solar cells, like perovskite solar cells, which can achieve high power conversion efficiencies similar to traditional silicon-based solar cells, but at a lower cost. How cool is that?

Ever wonder what things you see and touch are made of? Get ready to discover the amazing world of matter! This chapter explores the basics, like what "matter" even means, and how it comes in different forms like solids, liquids, and even hot space stuff like plasma. We will even see how one element like carbon can be different things, like sparkly diamonds or black graphite! We will learn the difference between simple building blocks, mixed-up things, and things dissolved in water. Finally, we will see how heat plays a role in how things mix and dissolve. Join us on this exciting journey to understand the stuff all around us!

## Students' Learning Outcomes

- Define matter as a substance having mass and occupying space.
- State the distinguishing macroscopic properties of commonly observed states of solids, liquids and gasses in particular density, compressibility, and fluidity.
- Identify that state is a distinct form of matter (examples could include familiarity with plasma, intermediate states and exotic states e.g. BEC or liquid crystals)
- Explain the allotropic forms of solids (some examples may include diamond, graphite, and fullerenes).
- Explain the differences between elements, compounds, and mixtures.
- Identify solutions, colloids, and suspensions as mixtures and give an example of each.
- Explain the effect of temperature on solubility and formation of unsaturated and saturated solutions.

**All the above mentioned SLOs are classified into knowledge and skills for the better understanding of students.**

**After studying this Unit, the students will be able to understand:**

## Knowledge

**Knowledge 2.1. Matter and its States**

- Matter is defined as any substance that has mass and occupies space. The commonly observed states of matter are solids, liquids, and gases, each having distinctive macroscopic properties such as density, compressibility, and fluidity.

**Knowledge 2.2. Exotic State of Matter**

- Matter exists in various distinct forms, including common states like solids, liquids, and gases, as well as unique states such as plasma, Bose-Einstein Condensates, and liquid crystals, each with specific properties and behaviors

**Knowledge 2.3. Allotropic forms of Carbon**

- Allotropic forms of solids are different structural arrangements of solid elements with distinct atomic patterns, leading to unique properties. Notable examples include diamond, graphite, and fullerenes, all of which exhibit varying carbon atom arrangement

**Knowledge 2.4. Type of Matter Based on their Chemical Composition**

- Elements are composed of single types of atoms, compounds result from the chemical combination of multiple elements, and mixtures are combinations of substances that can be physically separated. Mixtures can include solutions, colloids, and suspensions, each with varying particle sizes and properties. Solubility is influenced by temperature, leading to the creation of unsaturated and saturated solutions

## Skills

**Skill 2.1**

- Analyze and compare the physical properties (density, compressibility, and fluidity) of different states of matter (solids, Liquids, gases).

**Skill 2.2**

- Classify by understanding and Categorizing the various forms of matter based on their specific properties and behaviors, Including common states like solids, liquids, and gases, as well as unique states like plasma, Bose-einstein condensates, and liquid crystals.

**Skill 2.3**

- To understand the concept of allotropy in solids enhances a student's ability to recognize and analyze the diverse structural arrangements of elements.

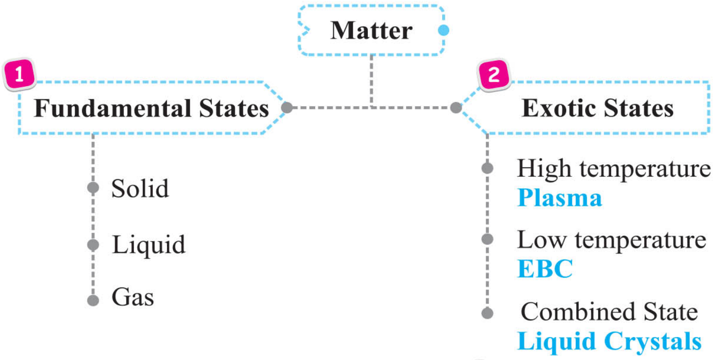
**Skill 2.4**

- To Identify and categorize the substances and mixture and understanding how temperature affects solubility and solution formation.

## 2.1 Knowledge

## Matter and its states

You have studied that everything that has mass and volume is called matter. Or everything around us, consisting of material particles (listed in the margin of the textbook), is called matter. Matter in the universe exists in three fundamental states i.e. solids, liquids and gases. However, beside these states, there are "exotic states of matter" as well (See organogram 2.1). The word exotic means rare, unusual, or non-traditional compared to the more familiar phases of matter.




**Organogram 2.1:** Macroscopic properties are the Characteristic of matter that can be observed with the naked eye or measured without the need for special magnification

## Fundamental states of matter

Matter exists in various forms in our surroundings, exhibiting distinct states. Solid, liquid, and gas are the three primary states of matter commonly encountered daily. These states are also referred as the standard states of matter.

In exploring the states of matter – solid, liquid, and gas – we focus on how the properties of matter's particles give rise to these distinct states. Each state is characterized by unique particle arrangements and behaviors, which influence key properties such as density and fluidity.

**Solid State:** In solids, the atoms or molecules are tightly packed in fixed positions. Although they can vibrate, they cannot move past each other. This close arrangement makes solids have a fixed volume and a rigid shape, as shown in figure 2.1.

For example, substances such as ice, aluminum, and diamond are solids at room temperature. Solids are non-compressible and cannot diffuse into each other due to this reason. Solids generally have high density because their particles are closely packed together. They lack fluidity and do not flow or conform to the shape of their container.

**Liquid State:** Liquids consist of atoms or molecules that are closely packed, similar to solids. However, unlike solids, the molecules in

**Student Learning Outcomes**

- Define matter as a substance with mass and volume.
- Describe the three main states of matter (solid, liquid, gas) and their distinguishing macroscopic properties: density, compressibility, and fluidity.

**Update Yourself**

List of material particles that have mass: electrons, protons, neutrons, atoms, molecules, ions, alpha particles, beta particles, and quarks

**Do you Know**

**Kinetic theory of particles.**

The kinetic theory of particles explains the relationship between particle arrangement and properties of solids, liquids, and gases.

- All matter is made up of tiny particles in constant motion.
- The type of particles varies across different matters.
- Particle movement is proportional to temperature.
- Lighter particles move more swiftly than heavier ones at a given temperature.

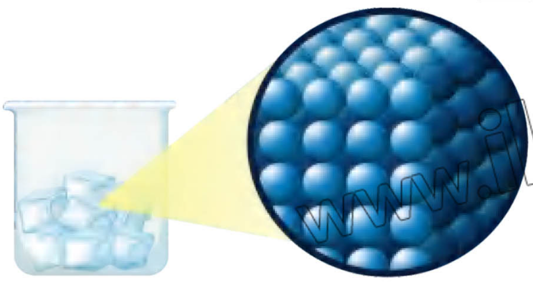


**Fig. 2.1:** In a solid, particles remain in fixed positions and only vibrate around them. They form a regular structure.

liquids can move relative to each other, providing mobility. This characteristic allows liquids to have a fixed volume but not a fixed shape, taking the shape of their containers, as shown in Figure 2.2

For example, ice water, alcohol, and gasoline are all examples of liquids at room temperature. The densities of liquids are much greater than those of gases but are similar to those of solids. The spaces among the molecules of liquids are negligible, similar to solids. In terms of fluidity, liquids are fluid, meaning they can flow and spread within their containers.

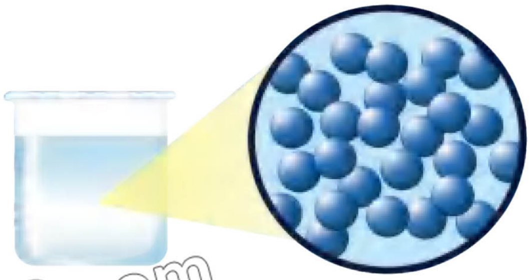


**Fig. 2.2:** In a liquid, particles have more freedom than in a solid. They can move around each other and collide often.

### Gaseous State

In a gas, atoms or molecules are widely spaced and move freely, which makes gases highly compressible by applying pressure. This occurs because there are large empty spaces between their molecules, as shown in Figure 2.3 and 2.4.

For example, when you compress air in a balloon or sit on an air mattress, you observe this phenomenon. Gases adopt the shape and volume of their containers. Helium, nitrogen, and carbon dioxide are examples of gases at room temperature.

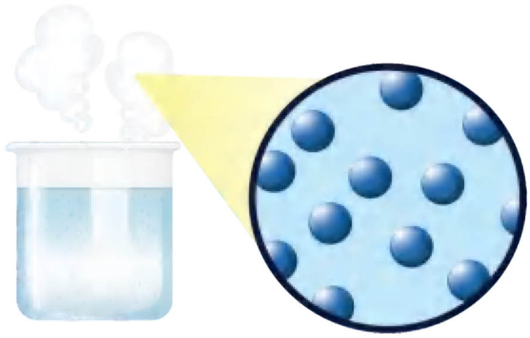


**Fig. 2.3:** In a gas, particles move randomly and freely throughout all the available space. They collide less often than in a liquid.

The density of gases is low compared to solids and liquids because their particles are much more spread out. Fluidity of gases is very high, and they can spread out to fill the entire volume of their container. Gases can also diffuse and effuse, which is negligible in solids but operates in liquids as well. (Compressibility, fluidity and density of liquid, solid, gases for more detail scan QR Code.)

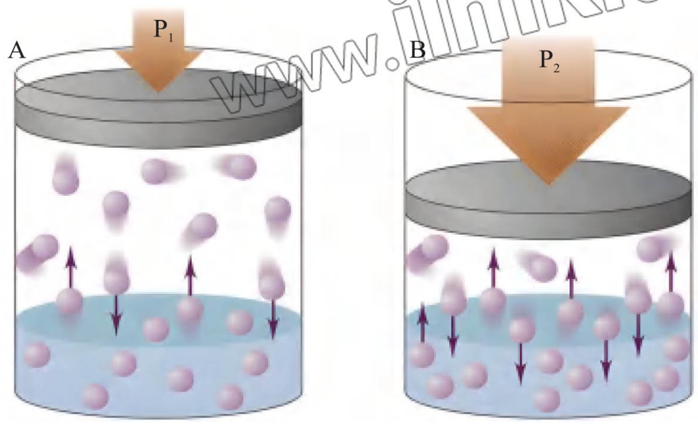



**Fig. 2.4 :** The Compressibility of gases: Gases can be compressed squeezed into a smaller volume because there is so much empty space between atoms or molecules in the gaseous state.

**Skill:2.1**

**Study of fundamental states of matter**

**Objective:** Analyzing and comparing the physical properties (density, compressibility, and fluidity) of different states of matter (solids, liquids, gases).

**Instructions:** An activity-based worksheet is attached to the QR code provided at the beginning of this knowledge section. Scan the code, read the worksheet, and complete it.

**Test yourself**

- Sketch diagrams to show the arrangement of particles in:
  **i.** solid oxygen **ii.** liquid oxygen **iii.** oxygen gas.
- Describe how the particles move in these three states of matter.
- Explain, using the kinetic particle theory, what happens to the particles in oxygen as it is cooled down.

## 2.2 Knowledge

# Exotic states of matter

Exotic states of matter are the physical states that are less common than fundamental states of matter. These states exist under extreme conditions, such as ultra-cold temperatures or high energies. They are not widely understood. These states of matter can be classified into three categories:

**i.** High-temperature states **ii.** Low-temperature states

**Iii.** Combined states

**Student Learning Outcomes**

Recognize other forms of matter beyond the three basic states (e.g., plasma, bose-einstein condensates, liquid crystals).

## I. High-temperature states

The exotic state of matter that requires extreme heat to form is known as high-temperature state. Such states include plasma, quark gluon plasma, hot dense matter, degenerate matter, and strange matter. Here we will only discuss plasma.

Plasma is the fourth state of matter. Naturally, plasma is present in the sun and other stars and produces through lightning. It is produced through certain high-intensity lamps on earth as shown in figure 2.5(a) that are used in streetlights, gymnasiums, warehouses, large retail facilities, stadiums, and plant growing rooms, etc.

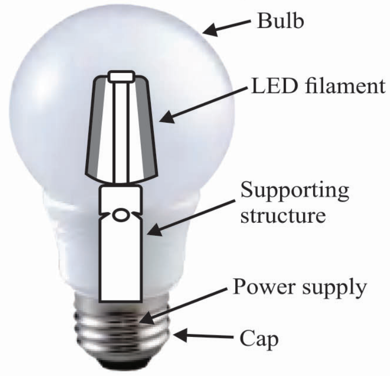



**Fig. 2.5** (a) Plasma in LED bulb
- Electrical energy (arrows) excites atoms in the gas mixture (colored circles).
- Electrons escape, creating a sea of charged particles: plasma (glowing mass).
- This energetic plasma emits intense light (rays).

In plasma, atoms gain a significant amount of energy, leading to the loss of their electrons. This creates a mixture of positively charged ions and hot free electrons and some neutral atoms as shown in figure 2.5(b).

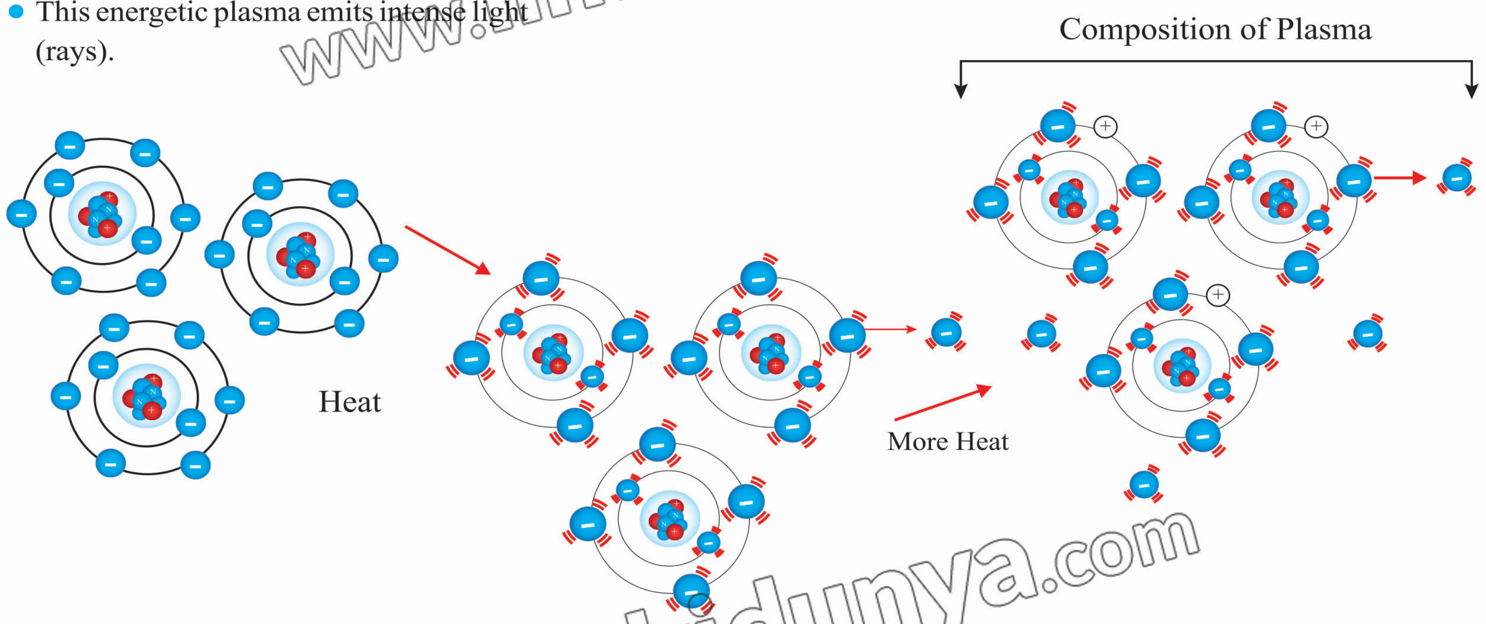



**Fig. 2.5 (b):** How plasma is formed Once a gas is heated to an extremely high temperature, the electrons within its atoms begin to oscillate, potentially leading to their release from the atom itself. As a result, certain atoms may acquire a positive charge. This process gives rise to a unique state of matter known as plasma, which comprises of positively charged ions, neutral atoms, and unbound electrons

**Table 2.1:** Comparison of plasma with fundamental states of matter

| Properties | Plasma |
|---|---|
| Particles | Charged particles (ions, electrons) |
| Shape & volume | Indefinite shape & volume |
| Conductivity | Excellent conductor |

## ii. Low-Temperature States

The exotic states of matter that form under extremely cold conditions are called low-temperature states. Such states include Bose-Einstein Condensate (BEC), Fermionic Condensate, and Quantum. In advanced classes, you will delve deeper into these more complex examples. For now, let's focus on developing a basic understanding of Bose-Einstein Condensate (BEC).

Bose-Einstein Condensate (BEC) is fifth and unique state of matter. You can imagine a group of dancers on a dance floor, moving independently like particles in a gas as shown in figure 2.6 (a). Now, imagine these dancers slowing down and moving together, forming a single, coordinated group as shown in figure 2.6 (b).

In a BEC state, particles, when cooled to almost absolute zero (-273.15 degrees Celsius or -459.67 degrees Fahrenheit), merge into a unified state, acting like a giant "super-particle. All atoms have the same energy and momentum, perfectly synchronized. It is worth noting that BECs are not found naturally they are created in labs under specific conditions.

**Table 2.2:** Properties of Bose-Einstein Condensate (BEC)

| Property | Bose-Einstein Condensate (BEC) |
|---|---|
| Particle Distribution | Large fraction of particles occupy the lowest energy state (Bose-Einstein condensate) |
| Temperature | Extremely low (near absolute zero) |
| Order | all particles in phase |
| Fluidity | Superfluid (no viscosity) |
| Conductivity | Superconductor (perfect conductivity) |
| Shape & Volume | Can be deformed, but maintains coherence |

## iii. Combine state (intermediate states)

Have you ever heard of a state of matter that shares properties with solid, liquid, and gas? It is called a combined state. A few examples of these states include amorphous solids, plastic crystals, and liquid crystals. In higher classes, you will delve deeper into these examples, but for now, let us focus on the liquid crystals. It is an excellent example of a combined state or intermediate state.

**Think of it this way**

Using the table 2.1, compare the properties of plasma with fundamental states of matter.

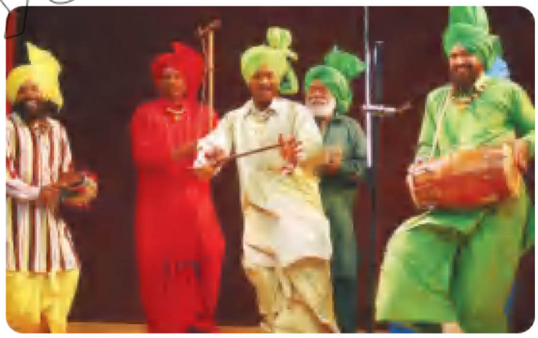


**Fig. 2.6 (a)** Random dance

**Fig. 2.6 (b)** Synchronized dance

Dancers transitioning from chaotic freedom to harmonious unity, mirroring the magic of Bose-Einstein Condensate.

**Think of it this way**

Using the table 2.2, compare the properties of Bose-Einstein Condensate (BEC)with fundamental states of matter.

**Update Yourself**

Following substances that have been used to create Bose-Einstein condensates (BECs)

- Rubidium-87
- Sodium-23
- Lithium-6
- Hydrogen
- Photons (light particles)
- Helium atoms etc.

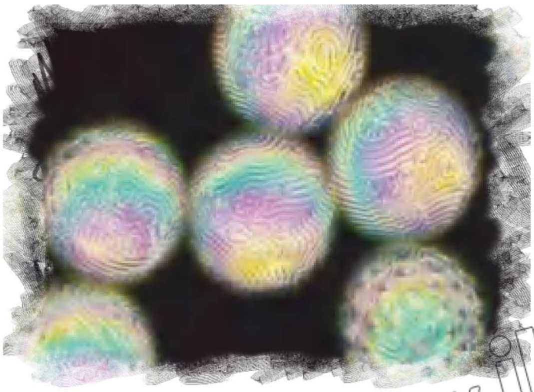


**Fig. 2.7 (a)** Common household soaps can exhibit LC behaviour in water depending on concentration and temperature.

Liquid crystals are a state of matter that exist in a state between solid and liquid. They have a unique arrangement of particles [figure 2.7 (a,b)]. The molecules in a liquid crystal are typically rod-shaped and can flow like a liquid while maintaining some degree of alignment.

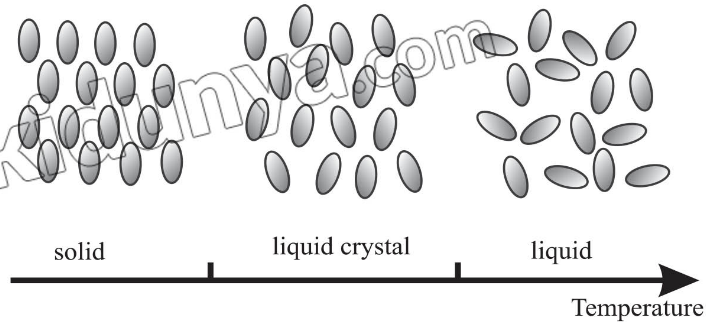



**Fig. 2.7 (b)** In liquid crystals, particles are more ordered than in a regular liquid but less structured than in a solid crystal.

Liquid crystals are highly responsive to changes in temperature and electrical signals, which makes it possible to adjust their molecular alignment and alter their colour. These characteristics make liquid crystals useful in a wide range of technological applications, particularly in electronic device displays, where their ability to control colour through temperature or electrical inputs is essential.

**Think of it this way**

Using the table 2.3, Compare the properties of Liquid crystals with fundamental states of matter.

**Table 2.3:** Properties of liquid crystals

| Property | Liquid Crystal |
|---|---|
| Order | Partially ordered, intermediate between solid and liquid |
| Shape & Volume | Can flow but retains some order, variable depending on type |
| Fluidity | Exhibits both rigid and fluid-like behavior depending on type |
| Molecular Arrangement | Molecules arranged with some long-range order, but not a rigid structure |

A few common examples of these applications include Liquid Crystal Displays (LCDs), Oscillographic and TV displays that also use liquid crystal screens as shown in figure 2.8 (a, b, c).


**Fig. 2.8 (a)** Electronic liquid crystal clock with digital indication of time

**Fig. :2.8 (b, c)** Forehead strip changes color based on body temperature due to liquid crystals

**Test yourself**

- What are the three common states of matter that we encounter in our everyday lives?
- What is plasma, and in which natural phenomena can it be observed?
- Discuss the conditions required for the formation of a Bose-Einstein Condensate, and what unique properties does it exhibit at such extreme temperatures?
- How liquid crystals exhibit properties of both liquids and solids?

**Skill:2.2**

**Classification of matter into exotic states**

**Objective:** Classify by understanding and Categorizing the various forms of matter based on their specific properties and behaviors, Including common states like solids, liquids, and gases, as well as unique states like plasma, Bose-einstein condensates, and liquid crystals.

## 2.3 Knowledge

### Allotropic forms of Carbon

**Student Learning Outcomes**

Explain the allotropic forms of solids (some examples may include diamond, graphite, and fullerenes).

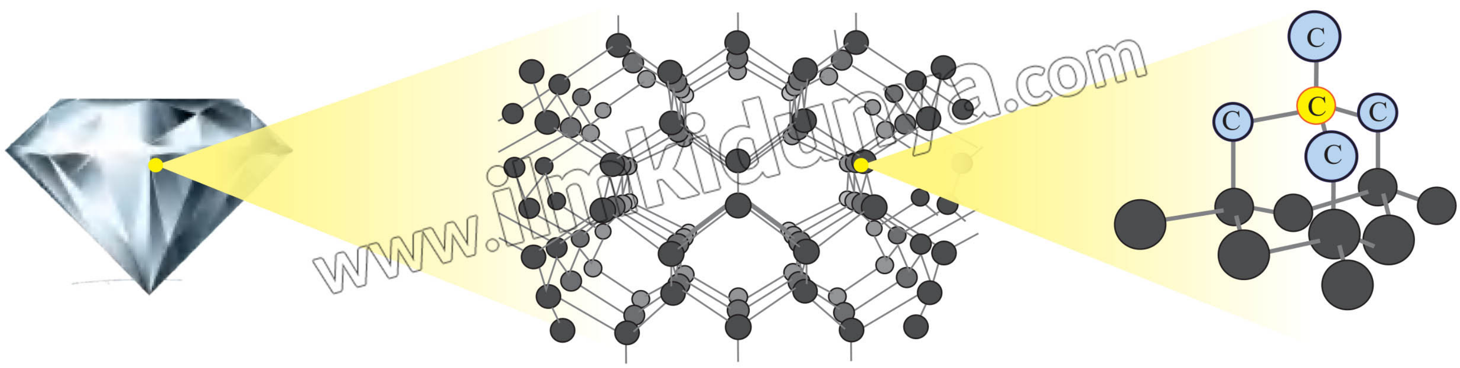
Solids are generally known for their fixed shape, high density, and resistance to compression, which result from the close packing of particles held together by strong, attractive forces, as we discussed earlier . However, it's essential to recognize that not all solids have the same particle arrangement.

An excellent example is carbon, which can exist in a diamond, graphite, Buckminsterfullerene etc. Each of these forms of carbon has distinct properties attributed to its unique arrangement of particles, as illustrated in Figure 2.9.

The figure 2.9 provides a visual representation of the composition of a diamond. It is composed of carbon atoms arranged in a tetrahedral configuration, where each carbon atom forms four strong covalent bonds with others. This type of bonding results in a rigid, three-dimensional structure that accounts for the diamond's remarkable hardness.

Due to this strong bonding, diamonds are unable to conduct electricity. This is because all of the outer shell electrons of the carbon atoms are involved in bonding, leaving no free electrons for electrical conductivity.

**The structure of diamond**




**A view of a much larger part of the structure**

**Fig. :2.9** Diamond is a hard material with strong covalent bonds that doesn't conduct electricity but has good thermal conductivity.

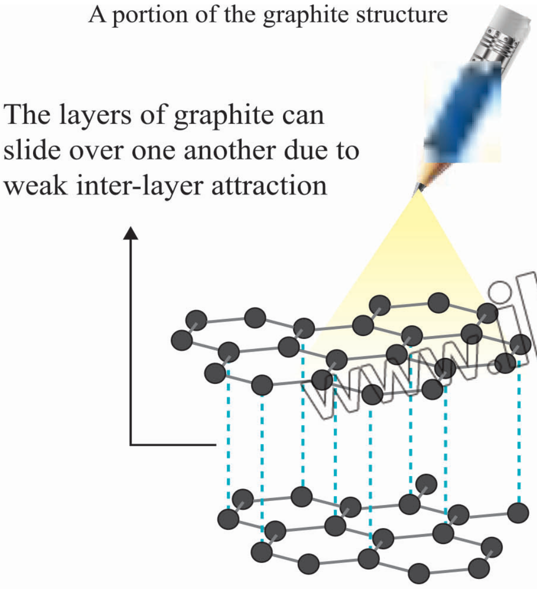



**Fig 2.10** Graphite is a carbon-based material with high electrical conductivity. Its unique properties come from the free electrons that become delocalized. The layers of graphite can slide over one another due to weak inter-layer attraction, but the covalent bonds are strong making it have a high melting point.

In contrast, the composition of graphite is distinct from that of a diamond. Graphite has a layered arrangement of carbon atoms bonded to three other carbon atoms through covalent bonds as shown in figure 2.10. This creates a giant molecule-like structure that results in a slippery and conductive composition. There is a weak bond present between the layers of graphite, allowing them to easily glide over one another.

An unbonded electron on each carbon atom within each layer allows delocalized electrons to move freely between the layers, as shown in figure 2.10. This is what enables graphite to conduct electricity. Back in 1985, Rice University's Richard Smalley and Robert Curl employed a laser beam to vaporize a graphite sample, transforming it from a 3D matrix into a 2D one. The 2D matrix is then naturally shaped into a round configuration of carbon atoms known as buckminsterfullerene, or "buckyballs". Figure 2.11 illustrates the structure of buck minster fullerene.

With the help of some experimental modification, we can convert a 2D matrix of graphene into rolled shapes as shown in figure 2.12. This substance has proven valuable in nanotechnology and other scientific disciplines.

The phenomenon where an element can exist in the same physical state (solid, in this case) but exhibit different structural arrangements is called allotropy. So, in summary, allotropy is the ability of an element to exist in various forms with distinct properties while remaining in the same physical state.

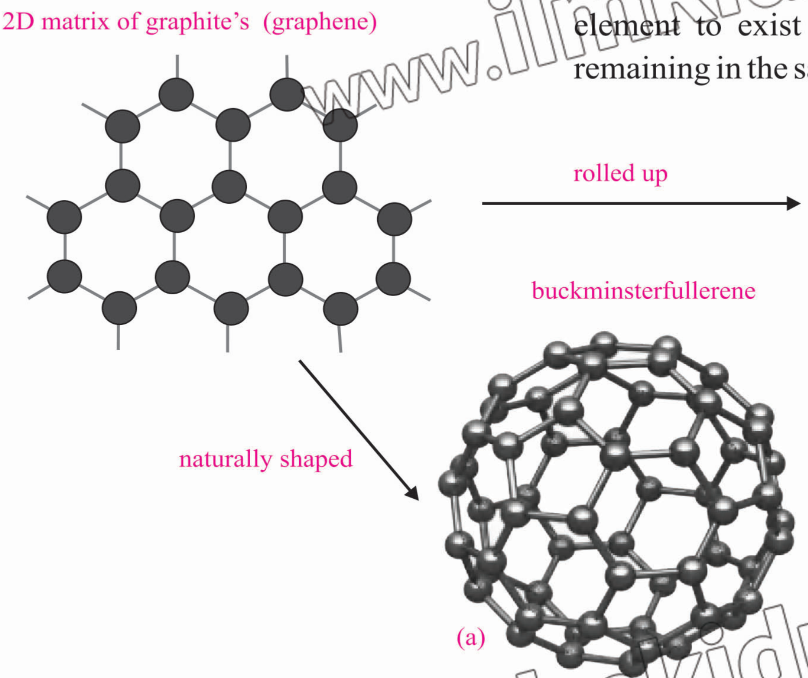



**Fig. 2.11** Graphene is the single layer of graphite, which is extremely strong, lightweight, and can be used to enhance the strength of other materials. It has superior electrical conductivity compared to many other materials. If Transformation of a single graphene sheet into spherical (a) buckminsterfullerene and carbon nanotubes 2.12.

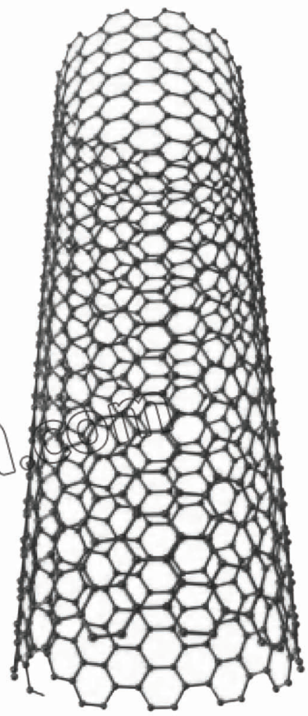


**Fig. 2.12** Carbon Nanotube

**Test your self**

- What are allotropic forms of solids, and why do they have distinct properties?
- Provide examples of allotropic forms of carbon, and briefly describe their structural differences.
- How does the atomic arrangement in diamond differ from that in graphite, and how do these differences affect their properties?
- Can you compare and contrast the electrical conductivity of diamond, graphite, and fullerenes based on their atomic structures?

**Skill:2.3**

**Comparing Allotropic Forms**

**Objective:** Understand the concept of allotropy and compare different forms of carbon, specifically focusing on diamond, graphite, and fullerenes.

## 2.4 Knowledge

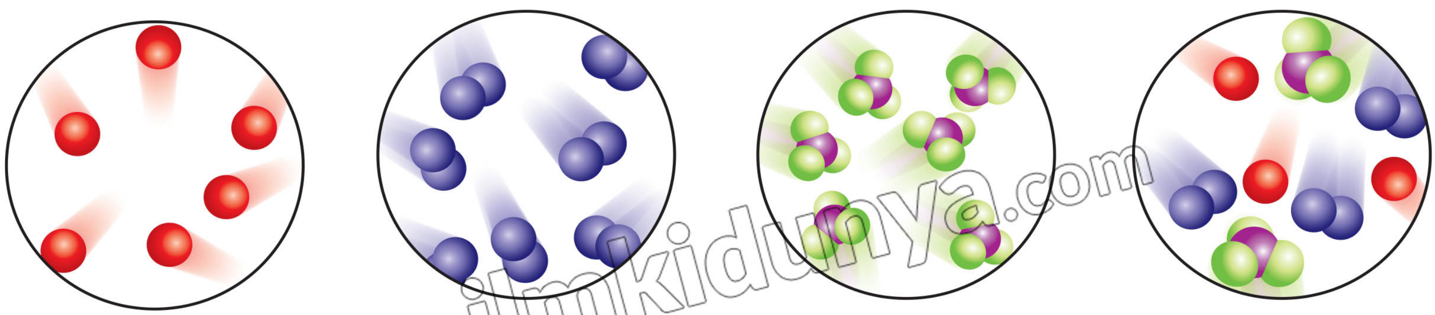
## Types of Matter Based on Their Chemical Composition

Most of the matter we encounter in our daily lives, such as the air we breathe (a gas), the fuel we burn in our cars (a liquid), and the road we drive on (a solid), are not pure substances. However, we can separate these forms of matter into pure substances. A pure substance, also known as a substance, is matter that has uniqueproperties and a composition that remains the same from sample to sample. Examples of pure substances include water and table salt (sodium chloride). All substances are either elements or compounds. Elements are substances that cannot be broken down into simpler substances. On the molecular level, each element is made up of only one type of atom (as shown in Figure 2.13. Compounds are substances composed of two or more elements; they contain two or more kinds of atoms (as shown in Figure Water, for instance, is a compound made up of two elements, namely hydrogen and oxygen. Figure illustrates a mixture of substances. Mixtures are combinations of two or more substances in which eachsubstance retains its chemical identity.

**Student Learning Outcomes**

- Explain the differences between elements, compounds and mixtures.
- Identify solutions, colloids, and suspensions as mixtures and give an example of each.
- Explain the effect of temperature on solubility and formation of unsaturated and saturated solutions.

**How do the molecules of a compound differ from the molecules of an**



(a) Atoms of an element (b) Molecules of an element (c) Molecules of a compound (d) Mixture of elements and a compound

Elements are composed of only one kind of atom. Compounds must have at least two kinds of atoms.

**Fig. 2.13** Representation of elements, compounds, and mixtures.

**Do you Know**

When two or more elements chemically combine in a fixed ratio by mass, the obtained product is known as a compound. e.g $H_2O$ (2H:1O), $CO_2$ (1C:2O)

**Update Yourself**

Electrolysis of water (chemical change). Water decomposes into its component elements, hydrogen and oxygen, when an electrical current is passed through it.

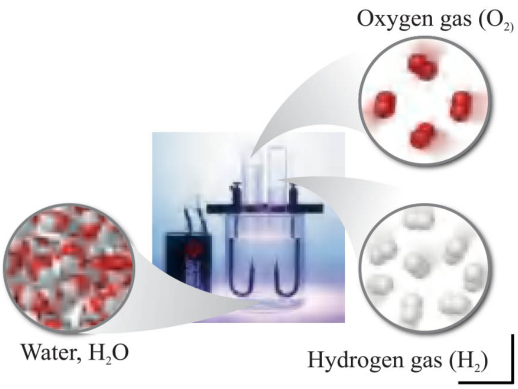



**Fig. 2.15b**

## Compounds

There are many elements that can combine with each other to form compounds. For example, when hydrogen gas burns in oxygen gas, the elements hydrogen and oxygen come together in a fixed ratio of 2:1 and create the compound water. Likewise, water can be separated into its constituent elements by passing an electrical current through it, which is a chemical reaction as shown in figure 2.15 a and b.

| hydrogen | oxygen | → | water |
|---|---|---|---|
| Hydrogen a pure element | Oxygen a pure element | Hydrogen and oxygen mixed together | Water a pure compound formed from hydrogen burning in oxygen |

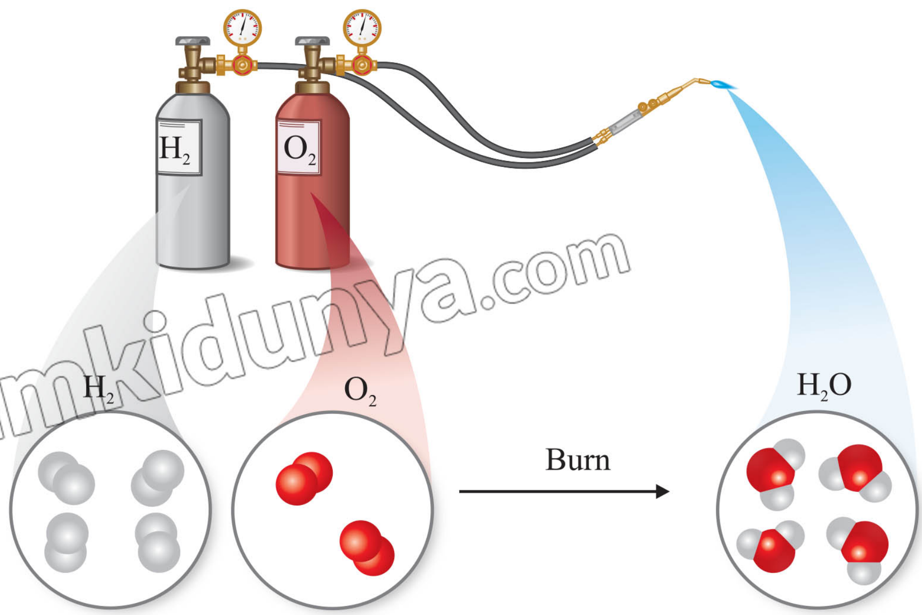



**Fig. 2.15a** A chemical reaction between $H_2$ and $O_2$

### Mixtures: Heterogeneous and Homogeneous

Heterogeneous mixtures are mixtures containing non-uniformly distributed components. These mixtures consist of distinct phases, where each phase has different properties. Examples of heterogeneous mixtures include wet sand and milk, oil and water mixtures, and salads. As shown in Figure 2.16. The components of these mixtures can often be separated by simple physical means such as filtration.

For example, soil particles can be separated from water by filtration. When the mixture is passed through a filter, many of the particles are removed. Repeated filtrations will give water with a higher state of purity.

**Fig 2.16** Heterogenous mixture of oil and water, salads.

**On the other hand, homogeneous mixtures** exhibit a uniform composition and properties throughout. These mixtures are also known as solutions. Examples of homogeneous mixtures include saltwater, air, and brass. The uniformity of these mixtures is due to the molecular level mixing of their components. Homogeneous mixtures can be more challenging to separate into their original components, often requiring processes such a s distillation Crystallization or chromatography. These processes will be discussed in more detail in Chapter 16, ***Chemical Analysis.***


Purifying a hetero geneous mixture by filtration

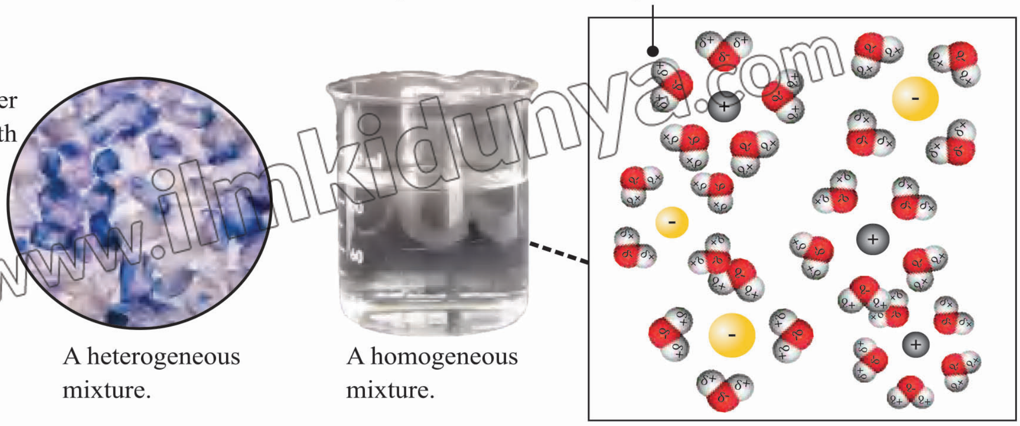
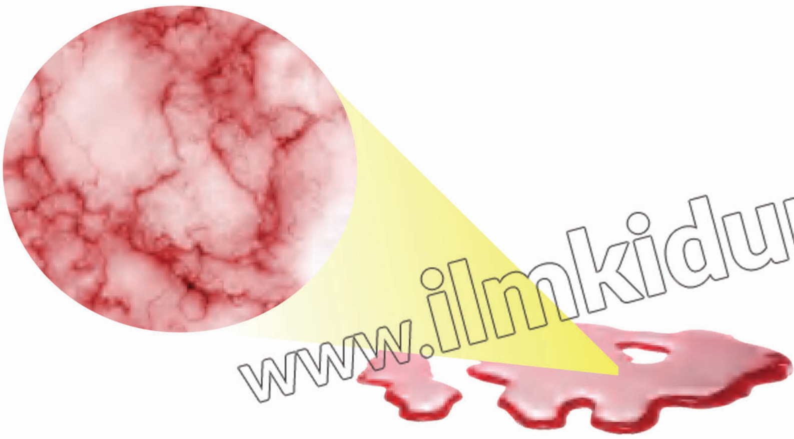



**Fig. 2.17** Heterogeneous and homogeneous mixtures.

**Further Reading** — **heterogeneity at micro microscopic level**



It is essential to understand that the differentiation between homogeneous and heterogeneous mixtures is not always straightforward. The classification can be influenced by the scale of observation; a mixture that appears homogeneous at the macroscopic level may turn out to be heterogeneous when viewed under a microscope. Blood is a perfect example of this phenomenon. It appears uniform to the naked eye but reveals heterogeneity when magnified.

You have learnt about them in previous grades. See the organogram 2.2 for revision.

**Summary**

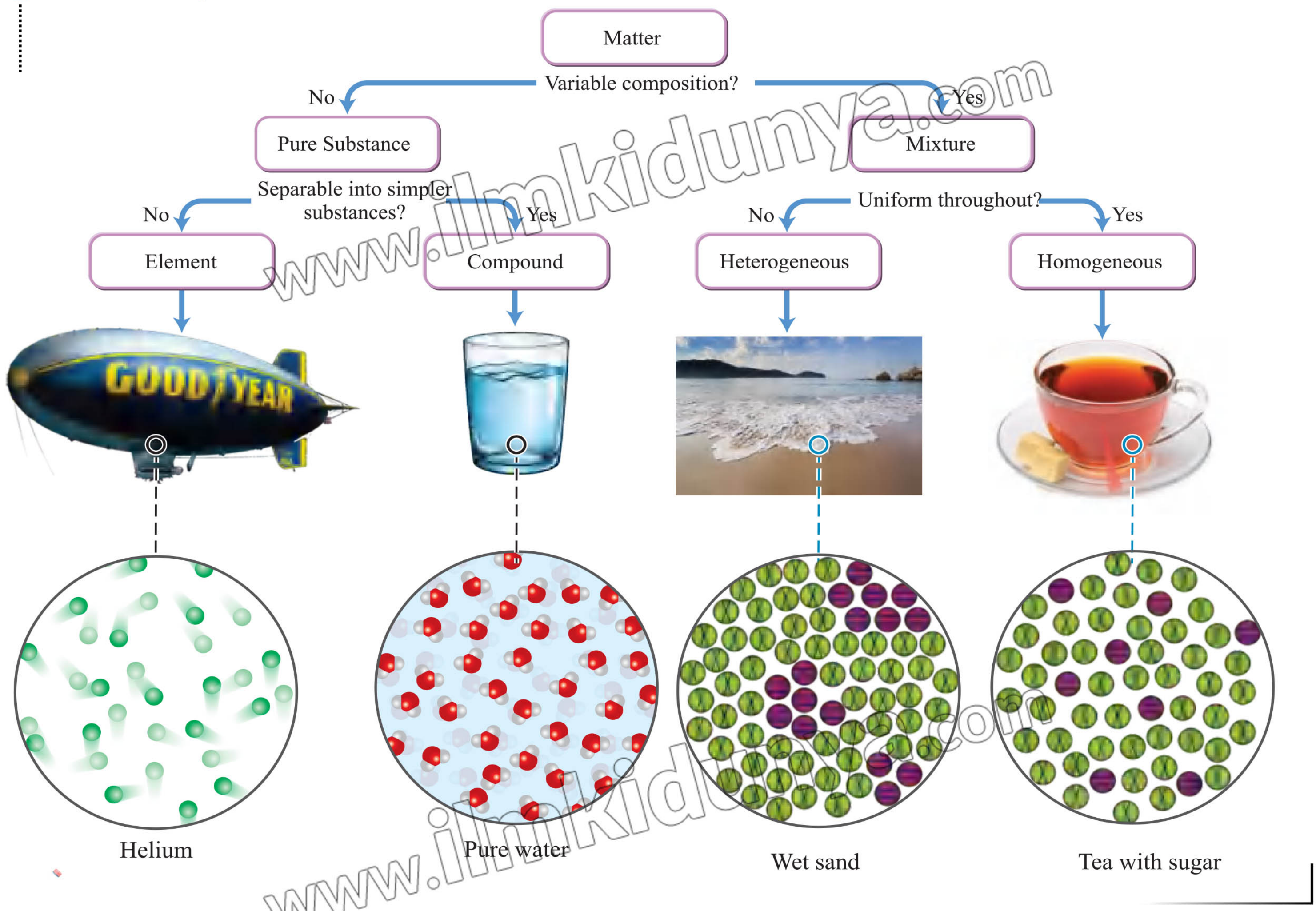




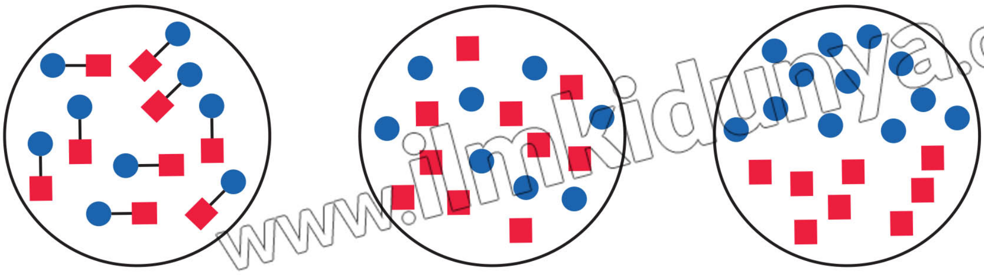

**Table 2.4:** Difference between element, compounds and mixtures

| Feature | Element | Compound | Mixture |
|---|---|---|---|
| Composition | Single type of atom | Two or more elements chemically combined | Two or more substances physically combined |
| Properties | Unique to each element | Entirely new properties compared to elements | Individual components retain their properties |
| Separation | Cannot be broken down further chemically | Can be separated chemical means like electrolysis | Can be separated physically |

*For detailed study, scan the provided QR code for additional study material.*

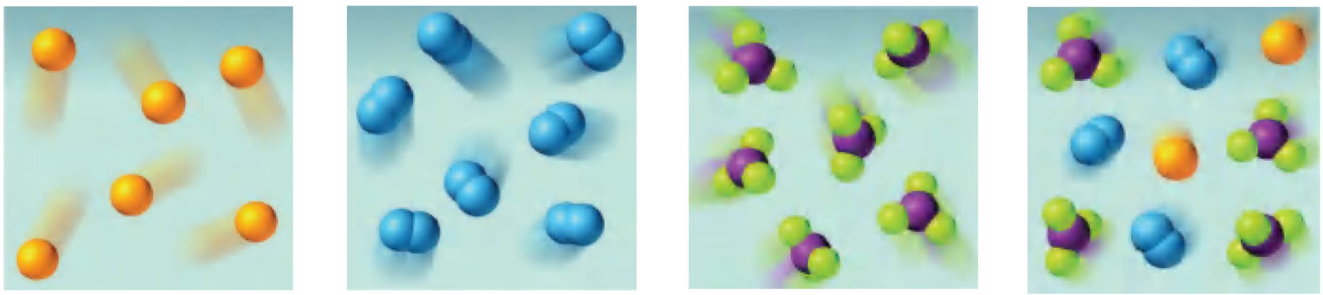
## Challange

**PURE SUBSTANCES AND MIXTURES** In these images, a blue circle represents an atom of one type of element, and a red square represents an atom of a second type of element.Which image is a pure substance?



None of the these

(a) (b) (c) (d)



(a) Isolated atoms of an element. (b) Molecules of an element. (c) Molecules of a compound, consisting of more than one element. (d) A mixture of atoms of an element and molecules of an element and a compound. Which one we can separated by physical methodseparated by physical method?

## Types of Heterogeneous mixtures

### i. Colloids

In previous grades, you have studied the composition of blood. In blood, solids cells (blood cells and platelets) float around in a liquid called plasma. The cells they might seem mixed up, they aren't actually dissolved like sugar in water. Instead, they are like tiny boats in liquid plasma. Such a mixture is called a colloid. Apparently, colloids (keep the example of blood in mind) appear uniform and might seem homogeneous because, particles are evenly distributed, however, under microscope, they possess two distinct phases: dispersed particles (e.g. blood cell) and the dispersion medium (e.g. liquid plasma). Both, phases may be in any form as given in the table 2.5. **Types of colloids** are a mixture of solids, liquids, or gas, and each combination has specific name. The figure below and the table provide examples of these different combinations. Take a look at the figure to get a better understanding of the various types

**Do you Know**

Colloids are often considered heterogeneous mixtures because They consist of distinct phases: dispersed particles (or droplets) and the dispersion medium. However, on a macroscopic scale, Colloids appear uniform and might seem homogeneous, because the dispersed particles are evenly distributed throughout the medium.


**Gel** Liquid droplets dispersed in a solid

**Emulsion** Liquid droplets dispersed in a liquid

Aerosol Liquid droplets dispersed in a gas

FormGas bubbles dispersed in a solid or liquid

**Table 2.5:** Identification of types of colloids through their components

| Colloid Substance | Dispersed phase | Dispersion Medium | Type of colloid |
|---|---|---|---|
| Blood plasma, paints (latex), gelatin | Solid | Liquid | Sol |
| Dust, smoke | Solid | Gas | Aerosol |
| Cheese, butter | Liquid | Solid | Gel |
| Mayonnaise, homogenized milk | Liquid | Liquid | Emulsion |
| Fog, clouds, hair sprays | Liquid | Gas | Aerosol |
| Styrofoam, marshmallows | Gas | Solid | Foam |
| Shaving cream, whipped cream, soapsuds | Gas | Liquid | Foam |



**Tyndall effect** is the main characteristic which distinguishes colloids from solutions. Hence, these solutions are also called false solutions or colloidal solutions and can be translucent in nature. Colloids are translucent because they scatter light blurring objects behind This is due to particle size, which causes the Tyndall effect a distinguishing feature between colloids and true solutions.as shown in figure 2.18

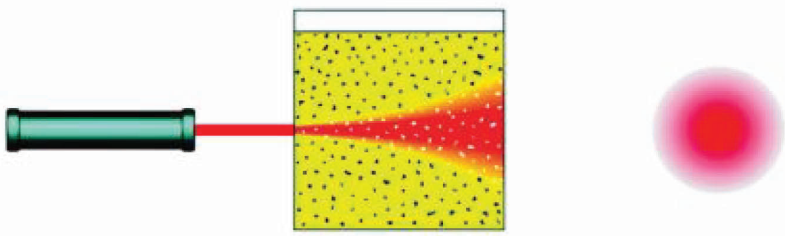
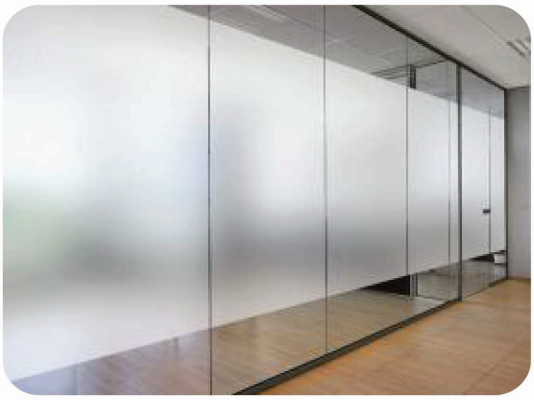


**Fig 2.18** Tyndall effect



Frosted glass is a daily life application of Tyndall effect

**Real World Application**

**Fig 2.19** Beautiful Tyndall phenomenon (Tyndall effect) sunlight comes down through the clouds in the sky.

## ii Suspensions

You often have seen on medicine bottles the word 'suspension' or 'mix well before use'. What does that mean? These words indicates that content in the bottle has some particles can be settled at bottom. Therefore, mixing them ensure their uniform distribution making the medicine effective. These suspensions are another type of heterogeneous mixtures in which particles are undissolved, and can be settled down at bottom if undisturbed. Particles in suspension are big enough to be seen with the naked eye. They cannot pass through the filter paper. Some other examples are chalk in water (milky suspension), paints and milk of magnesia (suspension of magnesium oxide in water)as shown in figure 2.19 (a,b). For a better understanding of true solutions, false solutions and suspension, A comparison of their characteristics is given in QR.

**Fig. 2.19 (b)** Particles in suspension disperse initially but eventually settle down in the form of crystals

**Fig. 2.19 (a)** Suspensions separate into solids and water that can be removed by filtration.

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Identify which partical represent solution, colloids and suspension

 ____________________

 ____________________

 ____________________


Suspensions are separated by a filter. Suspensions settle out


"Mucaine: The Soothing 'Milk of Magnesia' Suspension for Rapid Relief from Gastric Pain and Heartburn"

**Table 2.6:** Indemnification of solution, colloids and suspension through Tyndall effect

<table>
<tr><td>

**Solution**

Particles are so small that they cannot. Scatter the rays of light, thus do not show Tyndall effect. **Particle size: 1 nm** "and particles can pass through the pores of filter paper."

</td><td>


**1.** The objects through which most of the light can pass are called transparent objects. We can see the things through these objects. Examples: Glass, water, air etc.

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**Colloids**

Particles scatter the path of light rays, i.e. Exhibiting the Tyndall effect. **Particle size: 1 to 1000nm** "and particles can pass through the pores of filter paper."

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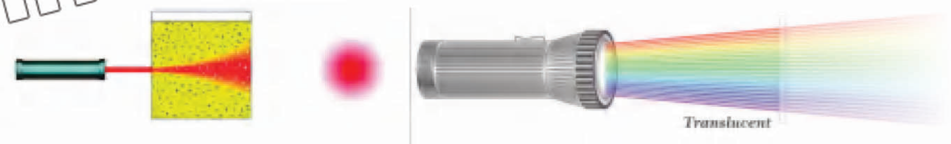


**2.** The objects through which light can pass partially are called translucent objects. We can not see the things clearly through these objects. Examples: Frosted glass

</td></tr>
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**Suspensions**

Particles are so big that light is blocked and difficult to pass. **Particle size: More then 1000 nm.** "and particles can not pass through the pores of filter paper."

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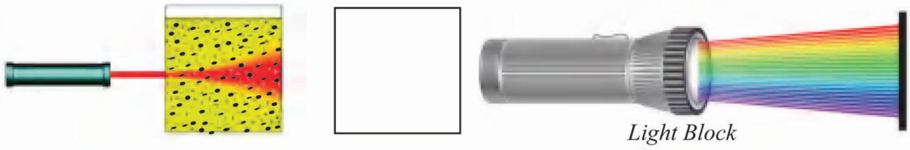



**3.** Did you know that the presence of particles in suspension can block light? It's true! This can have a major impact on various processes and applications that rely on light transmission. It's important to keep this in mind when working with suspensions.

</td></tr>
</table>

## Homogenous mixtures and their types

**Imagine a sugar water syrup.** Components have uniform physical appearance. In these mixtures, the solute (sugar) is completely dissolved in the solvent (water), resulting in a single-phase system. It means that sugar is evenly distributed in water. These are the characteristics of **Homogenous mixtures.**

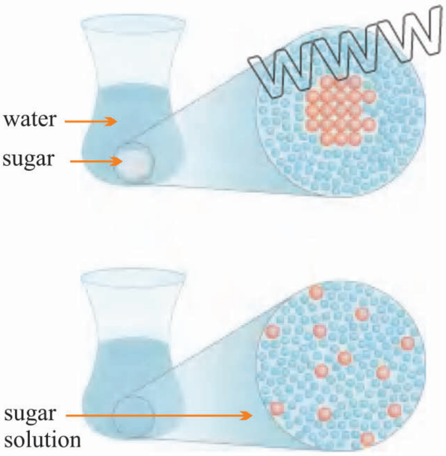



**Fig. 2.20** Dissolving sugar in water

The distinctive properties of homogenous mixtures are given below:

- **Invisibility of particles:** The solute particles are so small that they cannot be seen, even with a microscope and solute particles can pass easily through a filter paper.
- **Stability:** The particles do not settle out or separate on standing

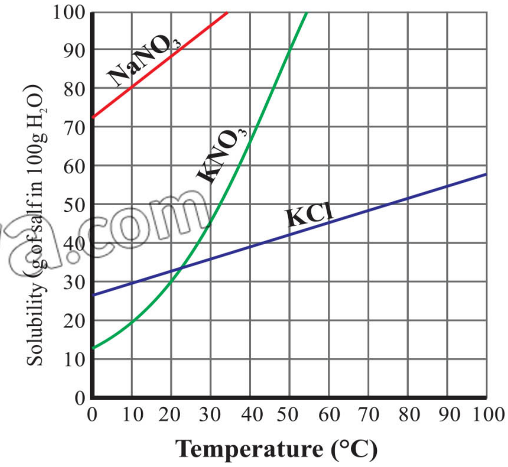
Examples of homogeneous mixtures include true solutions such as saltwater, gaseous mixtures such as air, and alloys such as brass. The uniformity of these mixtures is due to the molecular level, mixing of their components. Homogeneous mixtures can be more challenging to separate into their original components, often requiring processes such as distillation, crystallization, or chromatography. These processes will be discussed in detail in Chapter 16.

## True solutions

In these mixtures, the solute (the substance being dissolved) is completely dissolved in the solvent (the substance in which the solute is dissolved), resulting in a single-phase system. An example is a copper sulphate solution, where copper sulphate (solute) is uniformly dissolved in water (solvent).

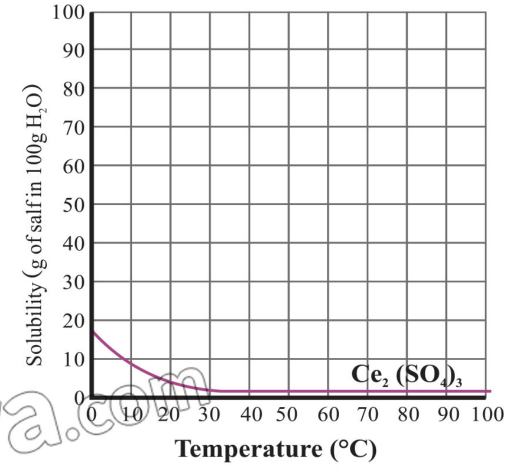
## Solubility

*Solubility is the amount of solute that can be dissolved in 100 g of solvent to form a saturated solution at a specific temperature. The temperature has a significant effect on the solubility of most substances.*



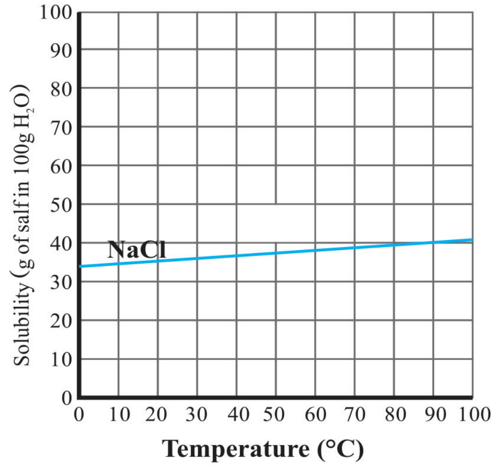

Generally, solubility increases with an increase in temperature, but this is not always the case. When a substance is added to a solvent to form a solution, the effect of temperature on solubility can vary. There are three possibilities:

**Heat is absorbed:** When substances like $KNO_3$ , $NaNO_3$ , and KCl are added to water, the test tube becomes cold, indicating that heat is absorbed during the dissolution process. This type of dissolving process is called 'endothermic'. For such solutes, solubility usually increases with an increase in temperature. This is because heat is required to break the attractive forces between the ions of the solute. The surrounding molecules fulfil this requirement, causing their temperature to fall, and the test tube to become cold.




Solvent + Solute + Heat ⟶ Solution

**Heat is given out:** On the other hand, when substance like Lithium sulphate ($Li_2SO_4$ ) and cerium(III) sulphate ($Ce_2(SO_4)_3$) are dissolved in water, the test tube becomes warm, indicating that heat is released during the dissolution process. In such cases, the solubility of the salts decreases with an increase in temperature. This is because attractive forces among the solute particles are weaker than solute solvent interactions, resulting in the release of energy.




Solvent + Solute ⟶ Solution + Heat

**Skill:2.4**

**Differentiate between unsaturated and saturated solutions.**

**Objective:** To Identify and categorize the substances and mixture and understanding how temperature affects solubility and solution formation.

**No change in heat:** In some cases, during the dissolution process, neither heat is absorbed nor released. When salt like NaCl is added to water, the solution temperature remains almost the same. In such cases, temperature has the minimum effect on solubility.

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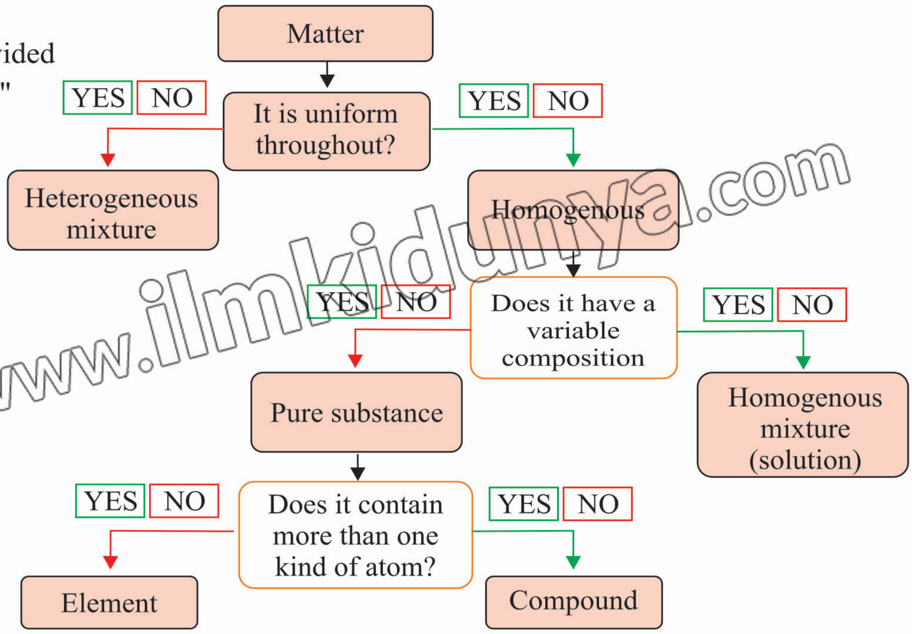
whether the diagram provided should be marked as "yes" or "no".




**Test yourself**

- What are elements, and how are they different from compounds and mixtures?
- Give an example of an element, a compound, and a mixture from everyday life.
- Write down the difference between a solution, a colloid, and a suspension, including the particle sizes and properties of each.
- Provide a real-world example of a suspension and explain why its particles settle over time.
- Describe the factors that influence the solubility of a substance, with a specific focus on the effect of temperature.
- If you have a saturated solution of sugar in water, what will happen if you increase the temperature, and why?

## Key Points

**Matter Definition:** Matter is anything that has mass and occupies space.

**States of Matter:**

- Solids: Have a definite shape and volume, high density, low compressibility, and are not fluid.
- Liquids: Have a definite volume but take the shape of their container, moderate density, moderate compressibility,
- and flow easily.
- Gases: Have neither definite shape nor volume, low density, high compressibility, and exhibit fluidity.

**Distinct Forms of Matter:**

- Plasma: A state of matter where atoms are ionized, found in stars and lightning.
- Intermediate States: States between solid and liquid or liquid and gas, like liquid crystals.
- Exotic States: Examples include Bose-Einstein Condensate (BEC), where atoms are cooled to near absolute zero.

**Allotropic Forms of Solids:**

- Diamond: Composed of carbon atoms arranged in a tetrahedral lattice.
- Graphite: Consists of layers of carbon atoms arranged in hexagonal rings.
- Fullerenes: Molecules composed entirely of carbon, such as buckyballs or nanotubes.
- Elements, Compounds, and Mixtures:

# Exercise

A detailed summary, chapter roadmap, multiple projects, and extensive exercises are accessible via QR code.

## A Encircle the most suitable option against each statement.

**1** In which state of matter do particles have the least compressibility?
- a) Solid
- b) Liquid
- c) Gas
- d) Plasma

**2** Light is not considered as matter despite the fact that it can behave like a particle. The reason behind the fact is that light lacks:
- a) Frequency
- b) material particle
- c) Wavelength
- d) Velocity

**3** A sealed container holding a gas is heated. Which of the following changes is most likely to occur?
- a) Decrease in pressure and volume
- b) Increase in volume and pressure
- c) Decrease in volume and increase in pressure
- d) No change in volume or pressure

**4** A material exhibits fluidity like a liquid but can be oriented in specific directions like a solid. This behavior is most likely characteristic of:
- a) Plasma
- b) Bose-Einstein condensate
- c) Liquid crystal
- d) Neutron star

**5** A cold, saturated salt solution is heated. What is most likely to happen?
- a) All salt dissolves, forming a supersaturated solution
- b) More salt dissolves due to increased solubility
- c) No change in the amount of dissolved salt
- d) Salt crystals precipitate due to decreased solubility

**6** What happens when a solution becomes saturated?
- a) More solute can dissolve
- b) No more solute can dissolve
- c) It becomes a colloid
- d) It turns into a suspension

**7** Analyze the concept of an element. What distinguishes it from compounds and mixtures?
- a) Consists of multiple types of atoms
- b) Comprises different molecules
- c) Composed of only one type of atom
- d) Demonstrates variable properties

**8** Evaluate the nature of particles in a colloid. How do they differ from those in a solution?
- a) Solids that settle over time
- b) Molecules evenly dispersed in a solvent
- c) Large particles suspended in a medium
- d) Ions forming a homogeneous mixture

**9** Which of the following pairs does not represent allotropes of the same element?
- a) Diamond and graphite
- b) Oxygen and ozone
- c) Phosphorus and sulfur
- d) Fullerenes and buckminsterfullerene

**10** Diamond and graphite are allotropes of carbon, yet they exhibit vastly different properties. This difference is primarily due to:
- a) Their atomic number
- b) The arrangement of their atoms
- c) Their isotopic composition
- d) The presence of impurities

**11** What is the primary characteristic distinguishing elements, compounds, and mixtures?
- a) Colour
- b) Composition
- c) State of matter
- d) Density

**12** You are investigating the solubility of sugar in water. You add sugar to a cup of water until no more dissolves, forming a saturated solution. If you continue to heat the solution, what would you expect to observe?

a) The sugar will completely dissolve.
b) The undissolved sugar will settle at the bottom.
c) The solution will turn cloudy.
d) The water will evaporate.

## B Answer the following questions briefly.

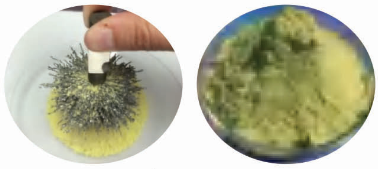
**1** Why does pouring juice from a carton seem effortless compared to pushing a block of cheese across the table?

**2** Why do these liquids flow differently?

**3** What makes exotic states different from fundamental states of mater?

**4** The display on your phone or laptop utilizes a special type of matter called a "liquid crystal." How does this state differ from a typical liquid, and what unique properties does it possess?

**5** Where might you encounter plasma outside of a laboratory, and what are some key features that distinguish it from the other states?



**6** How is a mixture of Sulphur and iron (in powder form) different from their compound -iron sulphide (it is formed by heating iron and Sulphur together)?

iron + sulfur $\xrightarrow{\text{heat}}$ iron (II) sulfide

**7** Sugar dissolves in water to form a clear liquid, while orange juice appears cloudy.

**8** What type of mixture is each? Explain the key difference between them based on particle size and distribution.

**9** Fog and smoke appear hazy compared to clean air. How would you classify these mixtures based on their dispersed particles? What makes them different from clean air?

**10** After a while, sand in a glass of water settles to the bottom, while milk remains uniformly mixed. What type of mixture is each? Why the suspended particles in sand water behave differently from those in milk.

**11** Why does more cocoa powder dissolve in hot milk compared to cold milk? How temperature affects the solubility of a solute in a solvent?

**12** How does the arrangement of atoms differ between allotropes of carbon?

**13** Can allotropy occur in other elements besides carbon?

**14** State which of the substances listed below are:

**a.** metallic elements **b.** non-metallic elements **c.** compounds **d.** mixtures.

silicon, sea water, calcium, argon, water, air, carbon monoxide, iron, sodium chloride, diamond, brass, copper, dilute sulfuric acid, sulfur, oil, nitrogen, ammonia.

## C Answer the following questions briefly.

**1** Differentiate between elements, compounds, and mixtures.
Explain allotropes and their significance.

**2** Differentiate between solutions, colloids, and suspensions as types of mixtures and provide examples of each.
Explain how temperature affects the solubility of a solid solute in a liquid solvent.

**3** You are tasked with designing a separation process for a mixture containing sand, salt, and oil. Explain the steps involved in separating each component based on their physical properties and justify your chosen methods.

**4** Write a detailed note on: Plasma, Bose-Einstein condensate