MODEL TEXTBOOK OF

CHEMISTRY

Based on National Curriculum of Pakistan 2022-23

9

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A Textbook of Chemistry
for Grade 9

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First Edition - First Impression

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Preface

learning experience. It features high-quality pictorial representations, real-life applications, and experimental skills. The book includes high-order thinking exercises, skill sheets for testing understanding, group activities, and recorded video lectures with animations and simulations. It is structured to aid teachers in creating assessment questions based on Bloom's Taxonomy. At the end of the book, a comprehensive glossary provides quick term references. This educational tool aim s to enrich students' knowledge and appreciation of Chemistry. Thiss Grade 9 Chemistry textbook, aligned with the 2023 curriculum, is designed to enhance students'

The QR codes in the Chemistry textbook provide easy access to video lectures for gaining knowledge and skill sheets for practical application. They make learning more interactive, letting students watch lectures and practice skills right when they need them, making studying chemistry more engaging and effective.

What inside this QR Cord

- Model video lecture of relevant knowledge along with ppts simulations and 3D animations
- Updated research related to knowledge
- Work sheets plus Skill sheets
- Slo based question bank
- Answers to all numerical and self-test questions are accessible through the relevant QR code.

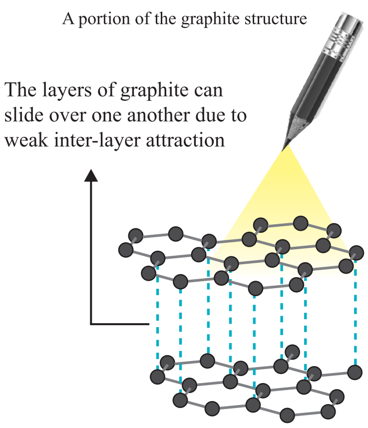
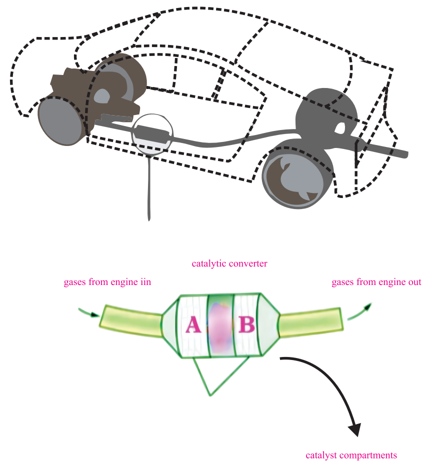


Fig 2.10 Graphite is a carbon-based material with high electrical conductivity. Its unique properties come from the free electrons that become delocalized. The layers of graphite can slide over one another due to weak inter-layer attraction, but the covalent bonds are strong making it have a high melting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

Diagrams in a chemistry textbook create strong mental images that stick with students, making it easier to remember and understand complex information quickly. These visuals serve as powerful memory aids, reinforcing concepts in a way that stays in students' mind for a long time.



In **A**, oxides of nitrogen are removed by **reduction**.
For example:
$2NO (g) \rightarrow N_2 (g) + O_2 (g)$
$NO (g) + 2CO (g) \rightarrow N_2 (g) + 2CO_2 (g)$
Note that the second reaction removes carbon monoxide too. The gases then flow into **B**.

In **B**, the remaining carbon monoxide, and unburnt hydrocarbons, are removed by **oxidation**. This uses the oxygen from A:
$2CO (g) + O_2 (g) \rightarrow 2CO_2 (g)$
hydrocarbons $(g) + O_2 (g) \rightarrow xCO_2 (g) + YH_2O (g)$
The gases flow out the exhaust pipe and into the air. Now only the carbon dioxide is harmful!

Real life examples in a Grade 9 chemistry book help us see how chemistry applies to the world around us. They make learning more interesting and show us how important chemistry is in our daily lives.

SLO based Model Video lecture

Salient Features

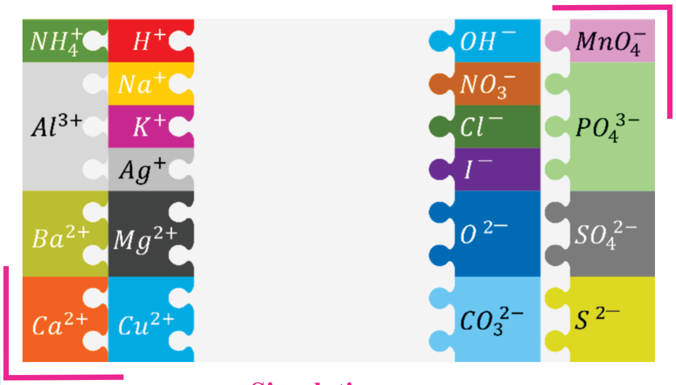
Comprehensive Learning
Engage students with videos, simulations, and practical worksheets.

Structured Lesson Plan
Well-organized with clear objectives, PPTs, and a question bank.

Engaging Multimedia
Visual appeal through PPTs and interactive simulations.

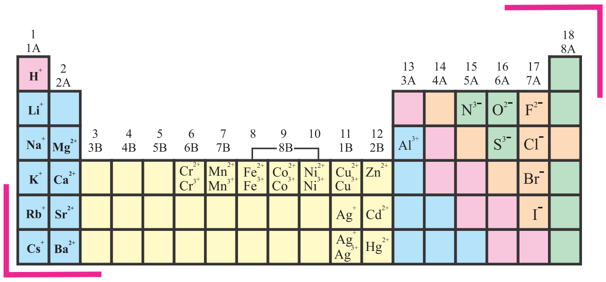
Assessment & Tracking
Diverse question bank and progress monitoring.

Adaptable & Accessible
Scalable and accessible, suitable for all learners.



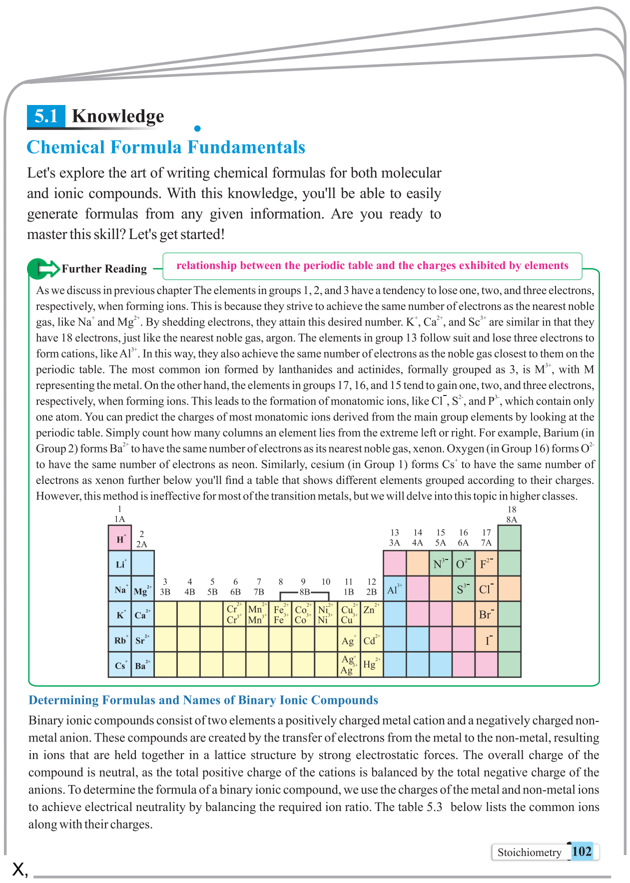
Simulation

SLO:C09 B45
Deduce the formula and name of a binary compound from ions given relevant information.



Power Point Presentation

Knowledge


5.1 Knowledge

Chemical Formula Fundamentals

Let's explore the art of writing chemical formulas for both molecular and ionic compounds. With this knowledge, you'll be able to easily generate formulas from any given information. Are you ready to master this skill? Let's get started!

Further Reading — relationship between the periodic table and the charges exhibited by elements

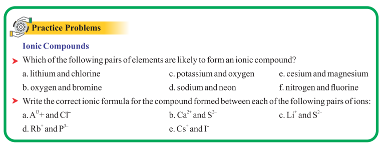
As we discuss in previous chapter The elements in groups 1, 2, and 3 have a tendency to lose one, two, and three electrons, respectively, when forming ions. This is because they strive to achieve the same number of electrons as the nearest noble gas, like Na^+ and Mg^{2+}. By shedding electrons, they attain this desired number. K^+, Ca^{2+}, and Sc^{3+} are similar in that they have 18 electrons, just like the nearest noble gas, argon. The elements in group 13 follow suit and lose three electrons to form cations, like Al^{3+}. In this way, they also achieve the same number of electrons as the noble gas closest to them on the periodic table. The most common ion formed by lanthanides and actinides, formally grouped as 3, is M^{3+}, with M representing the metal. On the other hand, the elements in groups 17, 16, and 15 tend to gain one, two, and three electrons, respectively, when forming ions. This leads to the formation of monatomic ions, like Cl^-, S^{2-}, and P^{3-}, which contain only one atom. You can predict the charges of most monatomic ions derived from the main group elements by looking at the periodic table. Simply count how many columns an element lies from the extreme left or right. For example, Barium (in Group 2) forms Ba^{2+} to have the same number of electrons as its nearest noble gas, xenon. Oxygen (in Group 16) forms O^{2-} to have the same number of electrons as neon. Similarly, cesium (in Group 1) forms Cs^+ to have the same number of electrons as xenon further below you'll find a table that shows different elements grouped according to their charges. However, this method is ineffective for most of the transition metals, but we will delve into this topic in higher classes.

Determining Formulas and Names of Binary Ionic Compounds

Binary ionic compounds consist of two elements a positively charged metal cation and a negatively charged non-metal anion. These compounds are created by the transfer of electrons from the metal to the non-metal, resulting in ions that are held together in a lattice structure by strong electrostatic forces. The overall charge of the compound is neutral, as the total positive charge of the cations is balanced by the total negative charge of the anions. To determine the formula of a binary ionic compound, we use the charges of the metal and non-metal ions to achieve electrical neutrality by balancing the required ion ratio. The table 5.3 below lists the common ions along with their charges.

Stoichiometry 102

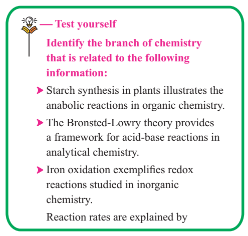
X,


Practice Problems

Ionic Compounds

- Which of the following pairs of elements are likely to form an ionic compound?
  a. lithium and chlorine c. potassium and oxygen e. cesium and magnesium
  b. oxygen and bromine d. sodium and neon f. nitrogen and fluorine
- Write the correct ionic formula for the compound formed between each of the following pairs of ions:
  a. A^{l3}+ and Cl^- b. Ca^{2+} and S^{2-} c. Li^+ and S^{2-}
  d. Rb^+ and P^{3-} e. Cs^+ and I^-

Question Bank

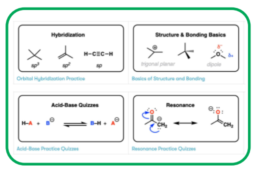

— Test yourself

Identify the branch of chemistry that is related to the following information:

- Starch synthesis in plants illustrates the anabolic reactions in organic chemistry.
- The Bronsted-Lowry theory provides a framework for acid-base reactions in analytical chemistry.
- Iron oxidation exemplifies redox reactions studied in inorganic chemistry.

Reaction rates are explained by

Work sheet



Skill Sheet

The periodic table

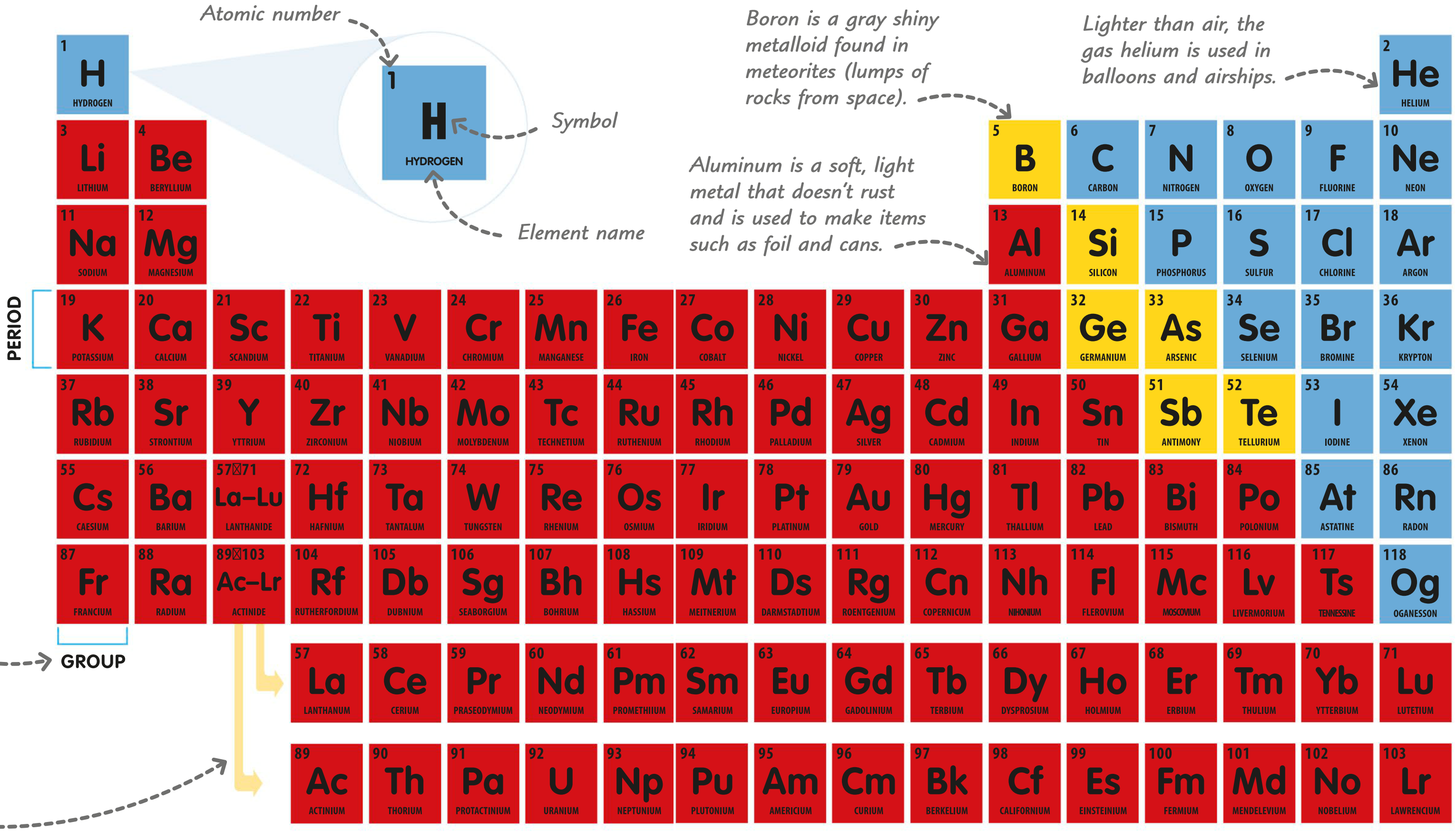
The periodic table is a chart of all the chemical elements known to science. They are arranged in order of their atomic number the number of protons in their atoms.

1 Element
Each box gives information about an element, including its name, chemical symbol, and atomic number

2 Period
The atomic number increases as you go along a row. This means that each element has one more proton in the nucleus of its atoms than the element to its left.

3 Group
If you know what one element in a group is like, you can make predictions about the other elements in the group. For example, all the metals in group 1 react strongly with water.

4 Extra rows
These two sections, made up of the rare earth metals, are too long to fit the shape of the table. They are usually shown on their own at the bottom.



KEY

METALS

Most elements are metals. Generally, they share similar properties they are strong, have a shiny appearance, conduct heat and electricity, and can be shaped without breaking.

METALLOIDS

Metalloids, which we also call semimetals, have properties of both metals and nonmetals. Some metalloids partially conduct electricity, and are used in calculators and computers have a shiny appearance, conduct heat and electricity, and can be shaped without breaking.

NONMETALS

Most nonmetals are solid and share similar properties—they are dull, conduct heat and electricity poorly, and are brittle when solid. Some of them are very reactive, such as fluorine (F) and oxygen (O). Eleven of the nonmetals are gases. The gases in the group that starts with helium (He) are the least reactive of all the elements. and nonmetals. Some metalloids partially conduct electricity, and are used in calculators and computers have a shiny appearance, conduct heat and electricity, and can be haped without breaking.

CONTENT

CHAPTER 1

Nature of Science

The development of COVID-19 vaccines showcases the power of science and technology, as researchers used cutting-edge techniques like mRNA to rapidly create effective vaccines. This achievement underscores the importance of scientific research and vaccines in combating public health emergencies and infectious diseases.

Curious why bouncy balls bounce or flames dance? Wonder how food fuels you? Chemistry, the science of matter and change, holds the answers! This chapter is your first step into this exciting world. Imagine exploring tiny atoms, shaping medicines, and designing cleaner energy! Through different branches of chemistry, you will unlock the secrets of our universe, one intriguing molecule at a time. Are you ready? Let us begin!

Students' Learning Outcomes

- Differentiate between 'science', 'technology' and 'engineering' by making reference to examples from the physical sciences.
- Define chemistry as the study of matter, its properties, composition, and interactions with other matter and energy.
- Explain with examples that chemistry has many sub-fields and interdisciplinary fields. (Some examples include: Biochemistry, Medicinal Chemistry, Polymer Chemistry, Geochemistry, Environmental chemistry, Analytical chemistry, Physical chemistry, Organic chemistry, Inorganic chemistry, Astrochemistry.
- Formulate examples of essential questions that are important for the branches of Chemistry(e.g. for Analytical Chemistry a question would be 'how can we accurately determine the chemical composition of a sample?')
- Explain the scientific method to solve the scientific problems.

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 1.1: Science, Technology and Engineering

- Differentiate between 'science', 'technology' and 'engineering' highlighting their specific role in science.

Knowledge 1.2: Chemistry and its domains

- Define chemistry as a field to explores matter's properties and interactions across disciplines like biochemistry and environmental chemistry, addressing crucial questions from drug design to pollution control, embodying the essence of scientific inquiry from molecular to global scales.

Knowledge 1.3: How science work?

- Explain the scientific method as a systematic approach to solving scientific problems, involving steps such as observation, hypothesis formulation, experimentation, data analysis, and conclusion drawing.

Skills

Skill 1.1:

- Demonstrate the ability to differentiate between science, technology, and engineering by providing examples from the physical sciences

Skill 1.2:

- Evaluate the significance of each sub-field of chemistry by formulating essential questions that highlight key inquiries within each branch.

Skill 1.3:

- Apply the scientific method to hypothetical scenarios or real-world problems in chemistry, demonstrating proficiency in designing experiments, analyzing data, and drawing evidence-based conclusions.

1.1 Knowledge

Science, Technology and Engineering

The world of knowledge is very vast where science, technology, and engineering co-exist within these shared boundaries. Let us explore their unique approaches.

Science-The explorer

Science is the systematic study of the natural world through observation, experimentation, and the formulation of theories to understand and explain natural phenomena.

For example, Galileo Galilei did not simply build a telescope (technology); he used it to observe celestial bodies, leading to groundbreaking discoveries about planetary motion (science). Other examples include:

- Observing the stars to understand the formation of galaxies (Astronomy).
- Experimenting with chemicals to explain how they react (Chemistry).
- Analyzing light waves to discover their properties (Physics).

Technology- The Inventor

While science unveils the "how" and "why", technology embodies the "what can be". It is the application of scientific knowledge to create practical solutions and innovations. Skilled engineers transform scientific knowledge into tangible tools and applications. They design, develop, and test these innovations, constantly refining them to improve our lives.

For example, based on the understanding of electromagnetism (science), engineers developed MRI machines, revolutionizing medical imaging technology. Other examples include:

- Building telescopes to study distant galaxies based on astronomical knowledge.
- Developing new medicines based on our understanding of chemical reactions.
- Creating lasers based on the science of light behavior.

Engineering-The Problem-Solver

Engineering is the application of scientific and technological knowledge and mathematical principles to design and build systems, structures, devices, and processes that address specific problems or meet desired objectives.

For Example:

- Designing a spacecraft to reach Mars based on astronomical and physical principles.

Student Learning Outcomes

Differentiate between science, technology and engineering by making reference to examples from the physical sciences.

Update Yourself

Activities in 'Science'

Develops theories, conducts experiments, collects data, analyzes results, and communicates findings

Update Yourself

Activities in 'Technology'

Designs, develops, tests, and implements tools, devices, and processes

Update Yourself

Activities in 'Engineering'

Designs, analyzes, builds, tests, and maintains systems and structures

Think of it this way

Imagine discovering a new star (science). Then, designing a telescope to study it further (technology). Finally, building the telescope and using it for observation (engineering).

- Building bridges using scientific understanding of materials and forces.
- Developing solar panels to harness energy based on principles of light and electricity.

Table 1.1 Key Differences between science, technology and engineering

Aspect	Science	Technology	Engineering
Focus	Science is about understanding.	Technology is about application.	Engineering is about problem-solving.
Process	Science uses observation and experimentation.	Technology uses design and development.	Engineering uses analysis and building.
Output	Science generates knowledge.	Technology creates tools.	Engineering builds solutions.

1.2 Knowledge

Chemistry and its Domains

Scientific knowledge is incredibly diverse. In order to grasp, organize, and effectively advance innovation, scientific knowledge is divided into many branches such as biology, physics, and chemistry, each dealing with a unique aspect of the natural world.

Chemistry is all about the matter that makes up everything around you from your clothes and phone to the air you breathe and the food you eat. It is the science that explores what this matter is made of (atoms and molecules), how it changes (chemical reactions), and why it behaves in the way it does (properties).

The chemists (persons who study chemistry) use experiments and observations to solve mysteries like:

- What happens when baking soda mixes with vinegar? (Hint: it is not just fizzy fun!)
- Why does iron rust? (And, how can we prevent it?)
- How do plants capture sunlight to make food? (It is all about a cool process called photosynthesis!)

However, chemistry is not just about solving mysteries; it is also about creating amazing things! We use our knowledge of chemistry to develop:

- Life-saving medicines that fight diseases
- Sustainable energy sources like solar panels
- New materials with incredible properties, like super-strong plastics or self-cleaning fabrics

Conclusion

- Science informs technology.
- Technology empowers science.
- Engineering relies on both.

Skill:1.1

Differentiation between Science, Technology and Engineering

Objective: to help students make informed decisions about their education and clarify their objectives.

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.

Student Learning Outcomes

- Define chemistry as the study of matter, its properties, composition, and interactions with other matter and energy.
- Explain with examples that chemistry has many sub-fields and interdisciplinary fields.

At its core, chemistry involves the exploration of matter and its transformations. It is defined as a field of science that is dedicated to studying matter and its properties, composition, and behaviour when interacting with other substances and energy.

Branches of Chemistry

Chemistry acts like the glue, connecting different areas like biology, physics, and even geology! This is called its interdisciplinary nature. It means we can use chemistry like a bridge to understand things:

- Why plants turn sunlight into food (with biology!)
- How atoms stick together to make different materials (with physics!)
- What makes rocks and minerals unique (with geology!)

However, with so much to learn, chemistry has different branches, like branches of a tree! These branches, like organic chemistry or inorganic chemistry, help us focus on specific areas and tackle complex problems better.

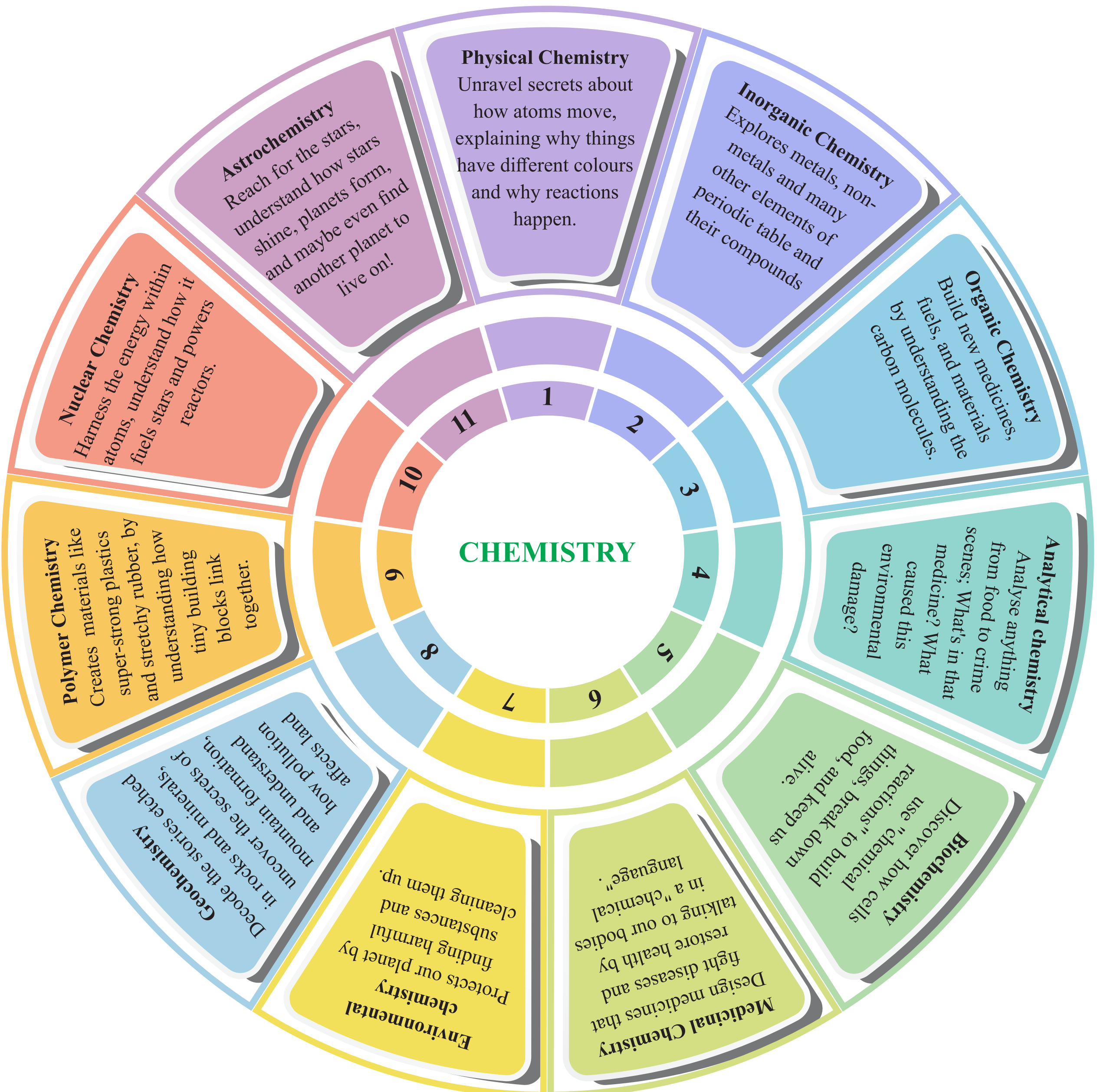


Fig. 1.1 Diverse world of chemistry through its specialised branches

1. Physical chemistry

Physical chemistry is defined as the branch of chemistry that deals with the relationship between the composition and physical properties of matter along with the changes in them. The properties such as structure of atoms or formation of molecules behavior of gases, liquids and solids and the study of the effect of temperature or radiation on matter are studied under this branch.

Some of the key areas of study in physical chemistry include thermodynamics, which is the study of energy and its transformations, quantum chemistry which is the application of quantum mechanics to understand the behavior of electrons in atoms and molecules, chemical reactions, and statistical mechanics which involves the use of statistics to explain the behavior of a collection of particles.

In what field of chemistry is the process of melting discussed? Which is depicted in fig.

2. Inorganic chemistry

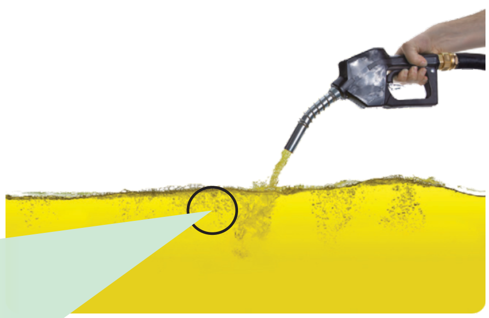
Inorganic chemistry deals with the study of all elements and their compounds except those of compounds of carbon and hydrogen (hydrocarbons) and their derivatives. It has applications in every aspect of the chemical industry such as glass, cement, ceramics and metallurgy (extraction of metals from ores).

Fig. 1.2 A Spectrum of Inorganic Compounds

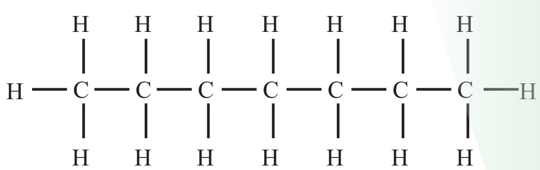
3. Organic chemistry

Organic chemistry is a field of study that focuses on covalent compounds consisting of carbon and hydrogen, known as hydrocarbons, and their derivatives.

Key concepts within this branch include the study of hydrocarbons, functional groups, and the diverse molecules that form the basis of life. Real-world applications are widespread, encompassing pharmaceuticals, agrochemicals, polymers, and the materials essential to life, making organic chemistry foundational to fields like medicine and materials science.



In this figure, gasoline is shown along with its chemical formula. Can you explain why gasoline is an organic compound and how it is used as fuel in automobiles?



n heptane

4. Polymer chemistry: Building Blocks of Materials Science

Polymer chemistry is a field of study that deals with polymers, which are large molecules made up of small repeating units called monomers. The process of linking monomers together to form a molecule of high molecular mass is called polymerization.

Update Yourself

Polymers are sometimes called macromolecules. Can you tell the reason?

There are many different types of polymer (plastics), including polythene, PVC, perspex, teflon and polystyrene. Polymers contain very large molecules, often with hundreds or thousands of atoms. Within each molecule, the atoms are joined to each other by covalent bonds. As shown in Figure 1.3.

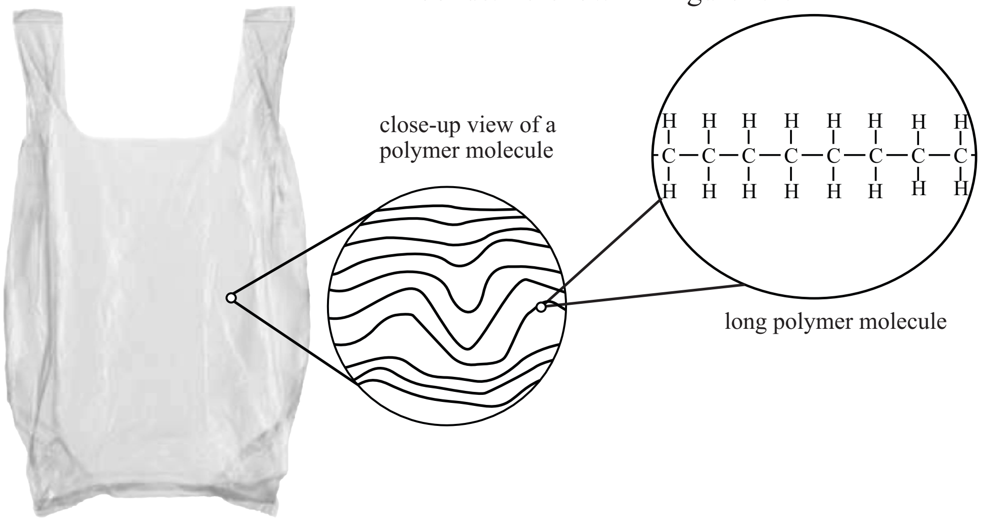


Fig. 1.3 Polythene bag is made up of polymer called polyethen. It is made up of repeatedly joined ethene molecule.

In the picture above, there appears to be a connection between living organisms, specifically plants, and some chemicals. Can you predict which subfield of chemistry this interaction might fall under?

5. Biochemistry

Biochemistry is the branch of science that combines both biology and chemistry to understand and analyze life processes. It focuses on the chemical substances and reactions that occur within living organisms.

It involves the synthesis and metabolism of biomolecules such as carbohydrates, proteins and fats. This field emerged as a separate discipline when scientists began investigating how living things obtain energy from food and how fundamental biological changes occur during a disease. Biochemistry has a wide range of applications in various fields like medicine, food science and agriculture.

Could you make any predictions based on the pictures above regarding the actions performed by the pharmacists?

6. Medicinal chemistry: The Art of Drug Design

Medicinal chemistry is a field where chemists design and build molecules that act as medicines.

They modify existing molecules or create new ones to fight diseases, improve health, and prevent illnesses.

By understanding the weak spots of viruses, like the one that caused COVID-19, medicinal chemists design molecules that can disable the virus, protecting our cells. Vaccines are developed this way. Medicinal chemistry also help create medicines for other conditions like pain relief, diabetes control, and cancer treatment.

7. Analytical chemistry

Analytical chemistry is a branch of science that deals with the study of the composition of matter.

It primarily focuses on identifying, separating, and quantifying chemicals present in various samples of matter. To achieve this, an analytical chemist may use complex instruments to analyze an unknown material and determine its various components. Analytical chemistry plays a vital role in various fields such as science, engineering, medicine, and industry. It helps to solve both qualitative and quantitative problems by providing accurate and reliable results.

Have you recently undergone a medical check-up, during which your doctor recommended a blood test?
Do you to know which branch of chemistry is responsible for dealing with such matters?

8. Environmental xhemistry

Environmental chemistry studies the chemical and biochemical processes in the natural environment like air, water, and soil.

It's a multi disciplinary field that combines several environmental sciences such as geology, biology, ecology, and physics. The goal is to understand the sources, reactions, transport, effects, and fates of chemical species in the environment, including pollutants and contaminants. Its ultimate goal is to develop strategies to prevent or mitigate the negative impact of human activities on the environment while preserving the natural balance of ecosystems.

Can you guess which sub field of chemistry we will discuss major factory issues and how we can control factory smoke from entering the air?

9. Geochemistry: Solving earth chemical mysteries

Geochemistry is a scientific discipline that focuses on the chemical composition of the Earth, including its rocks and beyond our minerals. It also extends planet to encompass the entire Solar System.

The field uses the principles of chemistry to explain the mechanisms behind major geological systems, such as mantle convection and planet formation. Additionally, geochemistry includes the study of the relative abundance, distribution, and migration of the Earth's chemical elements and their isotopes. It is an integrated field that combines both chemistry and geology.

Have you ever wondered what kind of discoveries metallurgical engineer can make during a geological survey?

10. Nuclear chemistry

Nuclear Chemistry is a branch of chemistry that deals with radioactivity, nuclear processes, and properties.

The primary focus of this field is on atomic energy and its applications in everyday life. It involves the study of chemical effects that occur due to radiation absorption in living organisms, plants, and other materials. Nuclear Chemistry has vast applications in

The Karachi Nuclear Power Plant (KANUPP) has a power generating capacity of 1.1GW. The K-3 nuclear unit was built with an investment of $2.7bn and is expected to help alleviate Pakistan's ongoing energy crisis. Can you predict which field of chemistry will be discussed in relation to this project?

various fields such as medical treatment (radiotherapy), food preservation, and generation of electrical power through nuclear reactors, among others.

11. Astrochemistry

Astrochemistry is a branch of science that deals with the study of molecules in space and their reactions. Astro chemists examine the composition of celestial objects (heavenly bodies).

Such as nebulae, which are massive clouds of gas and dust in space. They use advanced tools like telescopes and spectrometers to analyze the light emitted or absorbed by these objects. By doing so, they can determine which elements and compounds are present in the nebula.

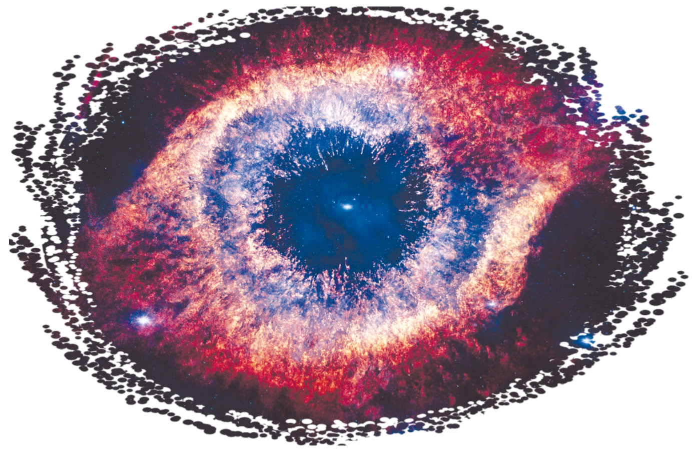


Fig. 1.4 "The Helix Nebula is a big cloud of gas and dust in space found in the Aquarius constellation. It's glowing and made up of different kinds of gas, dust, and hydrogen, and elements picture credit from NASA."

Test yourself

Identify the branch of chemistry that is related to the following information:

- Starch synthesis in plants illustrates the anabolic reactions?
- The Bronsted-Lowry theory provides a framework for acid-base reactions?
- Iron oxidation exemplifies redox reactions studied?
- Reaction rates are explained by collision theory?
- The molecular structure of DNA is a key study area?
- The study of intermolecular forces is essential in understanding states of matter?

Skill:1.2

Formulation of questions for branches of chemistry

Objective: to help identify key problems or challenges within a particular area of chemistry.

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.

1.3 Knowledge

How science work?

Student Learning Outcomes

Explain the scientific method to solve the scientific problems.

In science, it is essential to recognize that the journey of scientific discovery is a structured process. Think back to when you were a child, exploring your surroundings using your senses, touching and tasting things to understand them better. As you have grown, so has your curiosity, leading you to ask questions that are more complex about the world, such as why is the sky blue, where do rainbows come from, or how does lightning form? These childhood wonders are like the stepping-stones that have paved the way for the scientific method, a systematic approach scientists use to unravel the secrets of the natural world.

In the field of chemistry, the scientific method is a structured process involving several key steps that guide you in exploring and understanding chemical phenomena. These steps are observation, hypothesis, experimentation, and drawing conclusions.

Observation: Ask a question

Does adding baking soda to vinegar actually make it clean faster?

Hypothesis: Propose solution

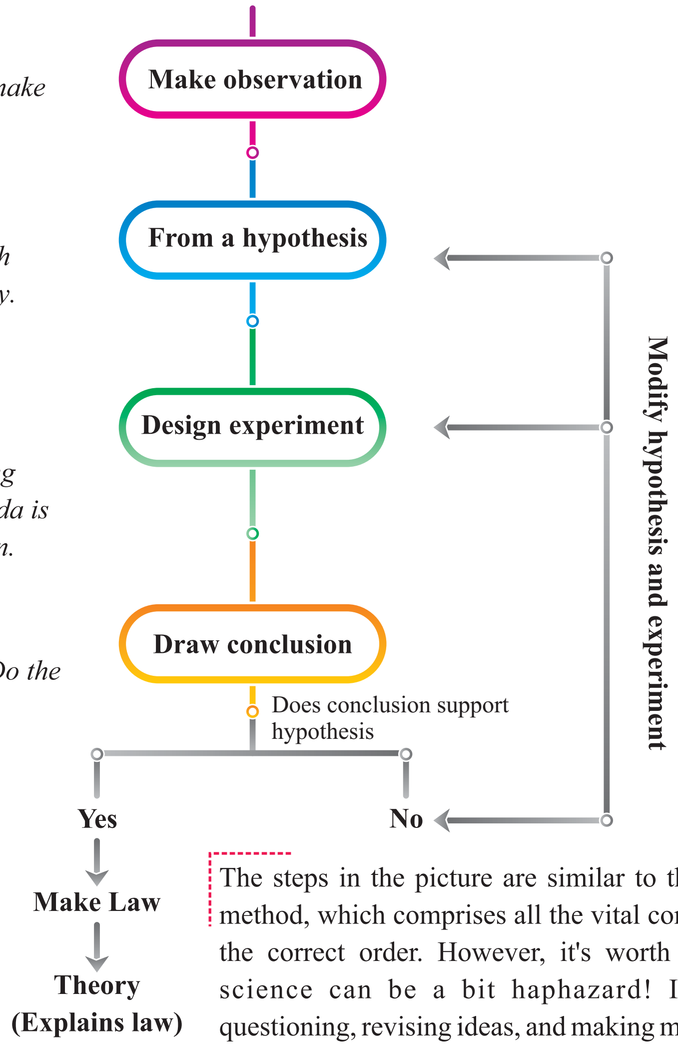
Maybe baking soda fizzes because it reacts with vinegar, creating tiny bubbles that lift dirt away.

Experimentation: Test hypothesis

Mixing different amounts of baking soda and vinegar in separate containers. Keep everything else the same so you can be sure the baking soda is the only 'suspect'. Measure the time of reaction.

Draw conclusions: Analyse and conclude

Analyse your data (cleaning times) carefully. Do the results support your hypothesis? If not, make changes accordingly in hypothesis and experimentation.



The steps in the picture are similar to the scientific method, which comprises all the vital components in the correct order. However, it's worth noting that science can be a bit haphazard! It involves questioning, revising ideas, and making modifications based on new discoveries.

1. Observation

Observation is the starting point. Remember those moments when you observed the colour of the sky changing or noticed the different flavors when you tasted various things? In chemistry, observations involve keenly examining the properties of substances, noting changes during reactions, and using specialized tools to gather data. These observations become the foundation for your scientific exploration.

2. Hypothesis

Based on your observations, what do you think will happen? This guess, called a hypothesis, is your starting point. Maybe baking soda fizzes because it reacts with vinegar, creating tiny bubbles that lift dirt away. In chemistry, a hypothesis is a potential explanation for an observation. It is way of proposing a solution based on existing knowledge. For instance, if you are curious about what makes some materials magnetic, your hypothesis might suggest a connection between certain elements and magnetic properties.

Challange

Identify each of the following as an observation, a hypothesis, an experiment, or a conclusion:

- During an assessment in the emergency room, a nurse writes that the patient has a resting pulse of 30 beats/min.
- Repeated studies show that lowering sodium in the diet leads to a decrease in blood pressure.
- A nurse thinks that an incision from a recent surgery that is red and swollen is infected.

Nurses make observations in the hospital.

Test yourself

Identify each of the following as an observation, a hypothesis, an experiment, or a conclusion:

- Drinking coffee at night keeps me awake.
- I will try drinking coffee only in the morning.
- If I stop drinking coffee in the afternoon, I will be able to sleep at night.
- When I drink decaffeinated coffee, I sleep better at night.
- I am going to drink only decaffeinated coffee.
- I sleep better at night because I stopped drinking caffeinated drinks.

3. Experimentation

Next is putting your hypothesis to the test i.e. experimentation. Just like you might have experimented by mixing different ingredients in the kitchen as a child, in chemistry, experiments involve combining substances, measuring reactions, and carefully recording results. This hands-on approach allows you to explore the behaviour of matter in a controlled setting.

4. Analysing and Drawing conclusions

After conducting experiments and collecting data, you analyze the results to see if they support or challenge your hypothesis. If experimental results indicate that the hypothesis is not valid, it is modified or replaced.

In essence, the scientific method is your guide in the world of chemistry, leading you to explore, question, experiment, and draw meaningful conclusions. As you delve into this exciting journey, keep in mind that each step brings you closer to unlocking the secrets of the substances that make up our universe. Get ready to be a young scientist, ready to tackle the mysteries that lie ahead! Your conclusions contribute not oly to your knowledge but also to the broader scientific community.

Further Reading — Using the Scientific Method in Everyday Life

Did you know that you use the scientific method in your everyday life? Let's say you visit a friend's home and notice that your eyes start to itch and you begin to sneeze. On observing your friend's new cat, you may form the hypothesis that you are allergic to cats. To test your hypothesis, you leave your friend's home. If your sneezing stops, your hypothesis may be correct. You can test your hypothesis further by visiting another friend who also has a cat. If you start to sneeze again, then your experimental results support your hypothesis and you can conclude that you are allergic to cats. However, if you continue to sneeze even after leaving your friend's home, then your hypothesis is not supported. In that case, you need to come up with a new hypothesis, which could be that you have a cold.

Project 1

Materials

Different types of paper towels (e.g., standard, recycled, premium), Water dropper or small bowl of water, Ruler, Stopwatch, Notebook

Experiment Steps:

1. Cut four squares of equal size from each type of paper towel. Label them clearly.
2. Mark a line 1 cm from the edge of each square with a pencil.
3. Place a drop of water in the centre of each square, exactly between the markings.
4. Start the stopwatch immediately. Observe how long it takes for the water to reach the marked line on each square. Record the time in your notebook.
5. Repeat steps 3 and 4 for two more drops of water on each square (total of 3 trials per material).

Question: Which type of paper towel absorbs water the fastest?

Hypothesis: (Choose which material you think will absorb water fastest based on your observations)

Prediction: Explain why you think that material will absorb water the fastest.

Analyze your data by calculating the average absorption time for each material. Did your results support your hypothesis? Explain why or why not.

Challenges

- Investigate the impact of different liquids (e.g., oil, juice) on the same materials.
- Research the science behind absorption and how different materials are structured.
- Design an experiment to test the reusability of different paper towels based on their absorption properties.
- Share your findings with your classmates and discuss the practical applications of your discoveries!

Key Points

- Chemistry is the science of matter and change.
- It explores the composition, properties, and behavior of matter.
- Science systematically studies the natural world through observation, experimentation, and theory formulation.
- Technology applies scientific knowledge to create practical solutions and innovations.
- Engineering uses scientific and technological knowledge to design and build systems, structures, and devices.
- Structured Scientific Method involves observation, hypothesis, experimentation, and drawing conclusions.
- Different branches of chemistry help unlock the secrets of the universe.
- Chemistry connects biology, physics, and geology (interdisciplinary nature).
- Different branches (e.g., organic, inorganic) focus on specific areas to tackle complex problems better.
- Chemistry's scientific method explores the behavior of matter in a controlled setting.
- Organic chemistry studies carbon-containing compounds.
- Inorganic chemistry focuses on non-carbon compounds.
- Physical chemistry applies physics principles to understand chemical systems.
- Analytical chemistry identifies and quantifies substances in various samples.
- Biochemistry explores chemical processes within living organisms.

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

Exercise

A Encircle the most suitable option against each statement.

Note: Answer the questions 1-4 after reading the given scenario.

During a school science fair project, Aisha noticed something strange while growing crystals from different salt solutions. She observed that crystals grown from a copper sulfate solution were a vibrant blue color, while those from a sodium chloride solution were colorless. She decided to investigate further.

1 Which of the following is the MOST appropriate question for Aisha to investigate?

a) Why are crystals blue? **b)** Do all salts form crystals?
c) How can we grow the biggest crystals? **d)** Does the color of the solution affect the crystal color?

2 Aisha plans to test her hypothesis by growing crystals from solutions with different concentrations of copper sulfate. Which variable should she KEEP CONSTANT?

a) The type of salt used **b)** The temperature of the solution
c) The volume of the solution **d)** The color of the container

3 After analyzing her results, Aisha finds that the intensity of the blue color in the crystals increases with the concentration of copper sulfate. What is the NEXT step in her investigation?

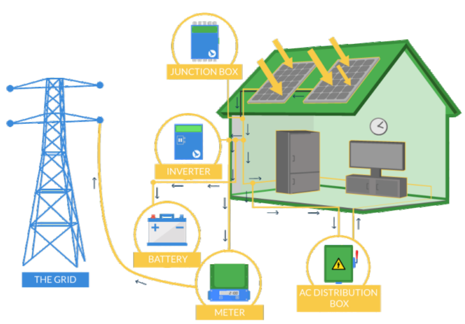
a) Declare her hypothesis proven and present her findings.
b) Repeat the experiment with different types of salts.
c) Investigate the chemical properties of copper sulfate.
d) Design an experiment to explain the mechanism of color formation.

4 Aisha shares her findings with her classmates. Some suggest using different colored salts to see if the crystal color changes. This is an example of:

a) A valid extension of Aisha's investigation. **b)** A criticism of Aisha's methodology.
c) An irrelevant observation. **d)** A personal opinion on the results.

Note: Answer the questions 5 and 6 after reading the given scenario.

Imagine a solar panel soaking up the sun's rays on a rooftop.
Each of these fields plays a part in its existence.



5 Which field discovered the photovoltaic effect, the scientific principle behind solar panels?

a) Technology **b)** Engineering
c) Science **d)** Mathematics

6 Which field is responsible for designing the structure and integrating solar panels into a functional system?

a) Technology **b)** Engineering
c) Science **d)** Manufacturing

7 Polymer Chemistry focuses on the properties and uses of large molecules like plastics. An important application of this field is:

a) Dating ancient artifacts **b)** Analyzing water quality
c) Developing lightweight materials **d)** Predicting the weather

8 Environmental Chemistry aims to minimize pollution and protect our environment. Which of the following is NOT a relevant technique used in this field?

a) Measuring pollutants in air and water samples

b) Developing sustainable energy sources
c) Recycling and waste management
d) Analyzing the chemical content of stars

9 Astrochemistry studies the chemical composition of celestial objects. How does this field contribute to our understanding of the universe?
a) By predicting future weather patterns
b) By developing new medical treatments
c) By understanding the origins of life and planets
d) By improving communication technologies

10 Imagine you discover a new material with unique properties. Which sub-field of chemistry would be most helpful in characterizing its structure and potential uses?
a) Analytical Chemistry
b) Physical Chemistry
c) Organic Chemistry
d) Geochemistry

11 In the scientific method, what is the primary purpose of conducting experiments?
a) To prove the hypothesis
b) To collect data and analyze results
c) To gather anecdotal evidence
d) To establish personal opinions

12 Which of the following steps in the scientific method involves formulating a clear and specific hypothesis based on observations and background knowledge?
a) Analysis
b) Conclusion
c) Hypothesis
d) Experimentation

B Answer the following short questions.

1 When does a Hypothesis get accepted as a theory? Give example.

2 Why is the scientific method important?

3 Explain the difference between scientific theory and technological innovation. Use an example from the field of renewable energy generation to illustrate your answer.

4 Differentiate between 'science', 'technology' and 'engineering' by making reference to examples from the below given example.

5 Define the following branches of chemistry: Physical chemistry, Polymer chemistry, organic chemistry

6 There are two branches of chemistry categorised into chemistry of life. Name these branches. Give reason for your answer.

7 Define nuclear chemistry. How it is different from the branches designated as 'chemistry of life'?

8 Draw a self-explanatory flowsheet diagram showing the sequence of stages of scientific method.

9 What are the qualities of a workable hypothesis?

10 Differentiate between the fields of "organic chemistry" and "inorganic chemistry" based on the type of matter they primarily study.

11 Compare and contrast the roles of science, technology, and engineering in addressing environmental issues. Provide specific examples related to Environmental Chemistry.

12 You are a forensic chemist investigating a crime scene. You find a white powder at the scene and need to determine its identity. Which branch of chemistry would you use to identify the powder? Give reason.

C Answer the following questions briefly.

1 Explain the scientific method, emphasizing its key stages such as observation and hypothesis. Additionally, provide a definition for the term 'law' and elucidate the circumstances under which a law is established in the field of chemistry.

2 Here is a diagrammatic representation of a famous law in chemistry known as: Boyle's law:

The law states that: *When the temperature of a gas is held constant, the pressure exerted by the gas is inversely proportional to its volume.*

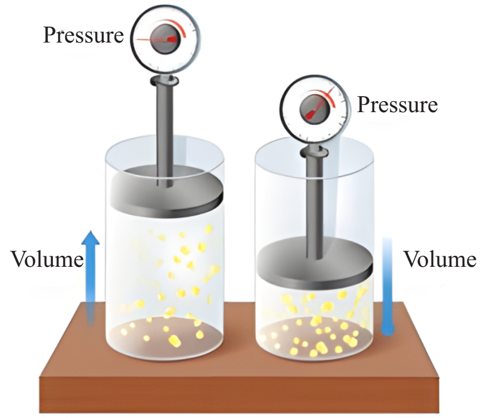
A students studies the law as an example of scientific method. He has made an observation:

Gases shrank when squeezed, expanded when released.

Your task is to extend his study by:

a. Deducing hypothesis

b. Designing an experiment to test the hypothesis



3 Differentiate between 'science', 'technology' and 'engineering' by giving suitable examples.

Write a note on geochemistry and biochemistry.

4 Explain “chemistry' as a diverse field of science. Discuss the nature of the field, its relation with other discipline as well as role to solve the problems with the help of suitable examples.

D Assertion – Reason type questions

In each of the following questions, two statements are given, one labelled as Assertion (A) and the other as Reason (R). Examine the statements carefully and mark the correct answer according to the instructions given below:

a) If both A and R are correct and R is the correct reason for A

b) If both A and R are correct but R is not the reason for A

c) If A is correct and R is wrong

d) If A is wrong and R is correct

1. **Assertion (A):** Studying the properties of light using prisms is an example of science.
   Reason (R): Science focuses on understanding the natural world through observation and experiments. ☐

2. **Assertion (A):** Designing a bridge that can withstand strong winds is an example of engineering.
   Reason (R): Engineering considers both scientific principles and practical constraints to create solutions. ☐

3. **Assertion (A):** Studying the reactions between drugs and the human body belongs to medicinal chemistry.
   Reason (R): Medicinal chemistry applies chemical principles to design and develop new drugs. ☐

4. **Assertion (A):** Understanding the formation of stars requires knowledge of both chemistry and physics.
   Reason (R): Astrochemistry is an interdisciplinary field that combines chemistry and astronomy. ☐

5. **Assertion (A):** "How can we measure the trace amounts of heavy metals in food?" is an important question for analytical chemistry.

Reason (R): Analytical chemistry develops methods to detect and analyze the composition of samples. ☐

6. **Assertion (A):** Observing a new chemical reaction requires designing an experiment to test its properties.

Reason (R): The scientific method relies on experimentation to confirm observations and draw conclusions. ☐

7. **Assertion (A):** A scientific theory is always accepted as absolute truth.

Reason (R): Theories are continually tested and refined as new evidence emerges in the scientific method. ☐

8. **Assertion (A):** Communicating research findings in scientific journals is crucial for peer review and future research.

Reason (R): Sharing results allows other scientists to validate and build upon existing knowledge. ☐

Sample Problem 1

Scientific Method: Thinking Like a Scientist

Identify each activity, "a to f", as an observation, a hypothesis, an experiment, or a conclusion. At a popular restaurant, where Imran is the head chef, the following occurred:

a. Imran determined that sales of the house salad had dropped.

b. Imran decided that the house salad needed a new dressing.

c. In a taste test, Imran prepared four bowls of sliced cucumber, each with a new dressing: sesame seed, olive oil and balsamic vinegar, creamy Italian, and blue cheese.

d. Tasters rated the sesame seed salad dressing as the favorite.

e. After two weeks, Imran noted that the orders for the house salad with the new sesame seed dressing had doubled.

f. Imran decided that the sesame seed dressing improved the sales of the house salad because the sesame seed dressing enhanced the taste.

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.

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.

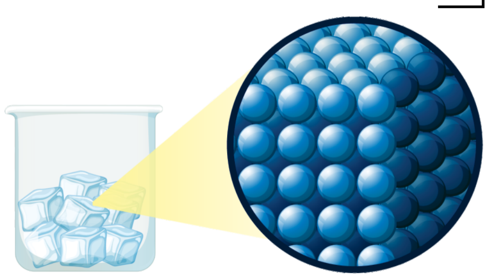
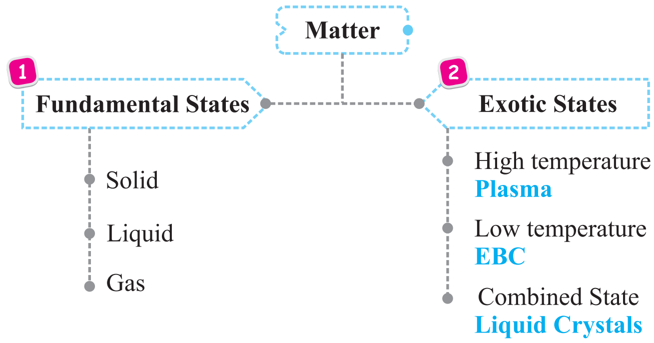


Fig. 2.1: In a solid, particles remain in fixed positions and only vibrate around them. They form a regular structure.

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 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.

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.

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.)

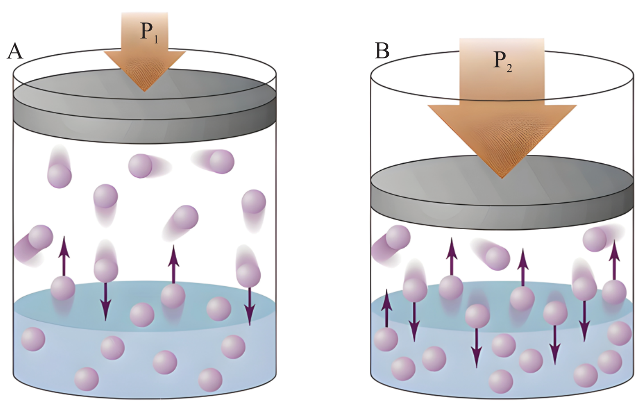


Fig. 2.4 : The Compressibility of gases: Gases can be compressed squeezed into a smaller volume because there is so much empty space between atoms or molecules in the gaseous state.

— 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.

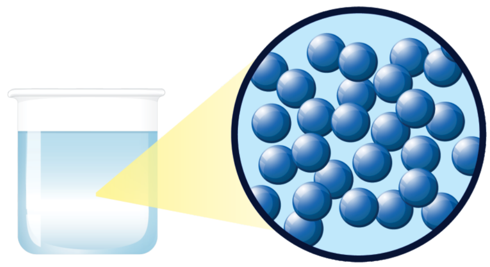


Fig. 2.2: In a liquid, particles have more freedom than in a solid. They can move around each other and collide often.

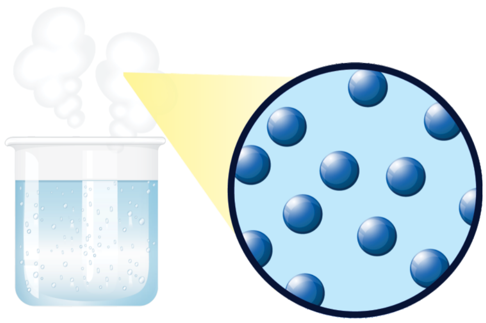


Fig. 2.3: In a gas, particles move randomly and freely throughout all the available space. They collide less often than in a liquid.

—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.

Student Learning Outcomes

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

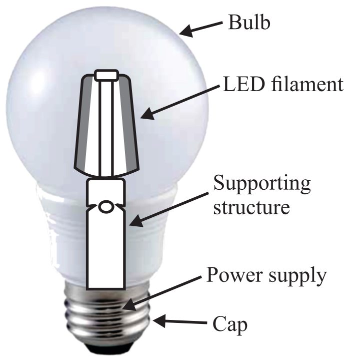


Fig. 2.5 (a) Plasma in LED bulb

- 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).

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

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.

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).

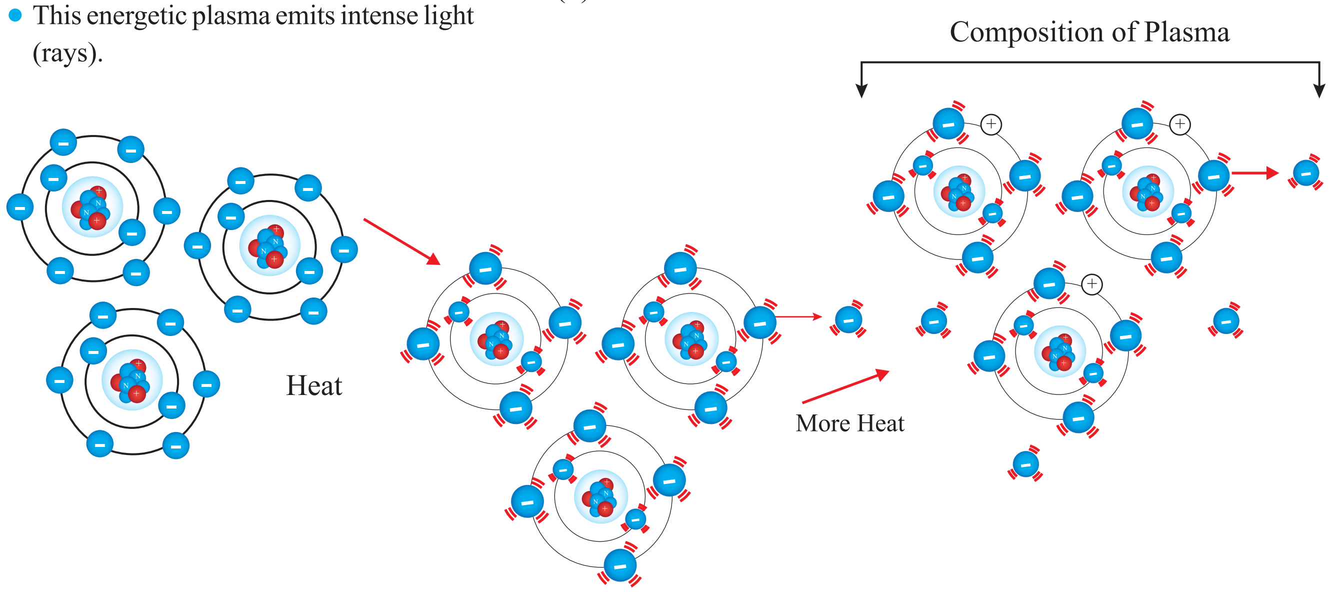


Fig. 2.5 (b): How plasma is formed Once a gas is heated to an extremely high temperature, the electrons within its atoms begin to oscillate, potentially leading to their release from the atom itself. As a result, certain atoms may acquire a positive charge. This process gives rise to a unique state of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

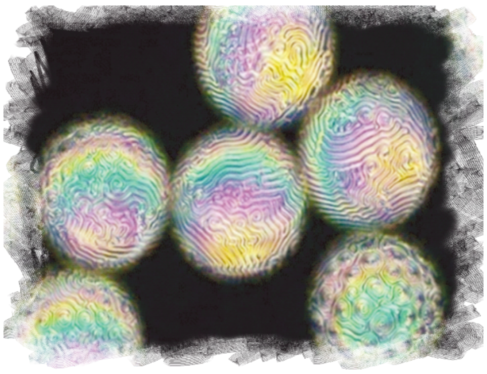


Fig. 2.7 (a) Common household soaps can exhibit LC behaviour in water depending on concentration and temperature.

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.

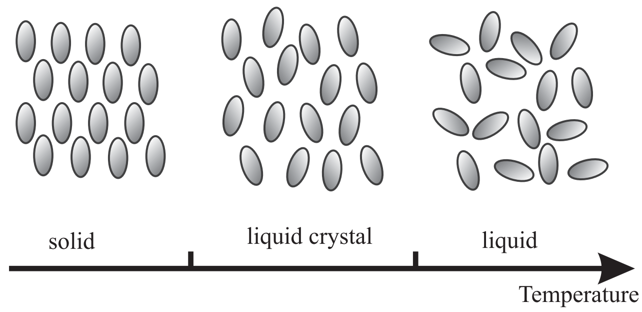


Fig. 2.7 (b) In liquid crystals, particles are more ordered than in a regular liquid but less structured than in a solid crystal.

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

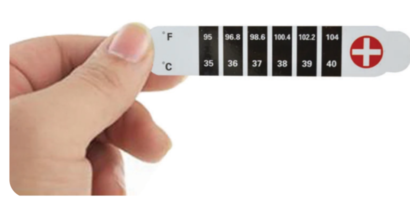


Fig. :2.8 (b, c) Forehead strip changes color based on body temperature due to liquid crystals

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?

2.3 Knowledge

Allotropic forms of Carbon

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.

Skill:2.2

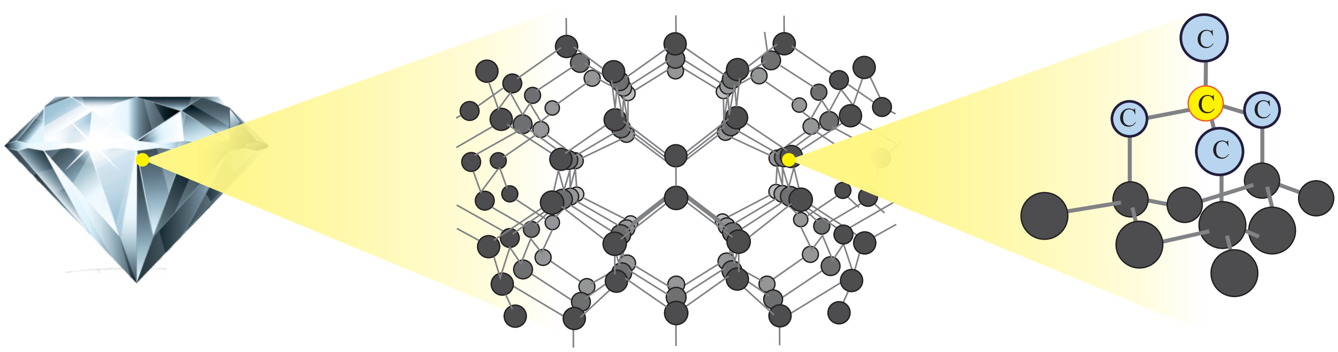
Classification of matter into exotic states

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.

Student Learning Outcomes

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

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.

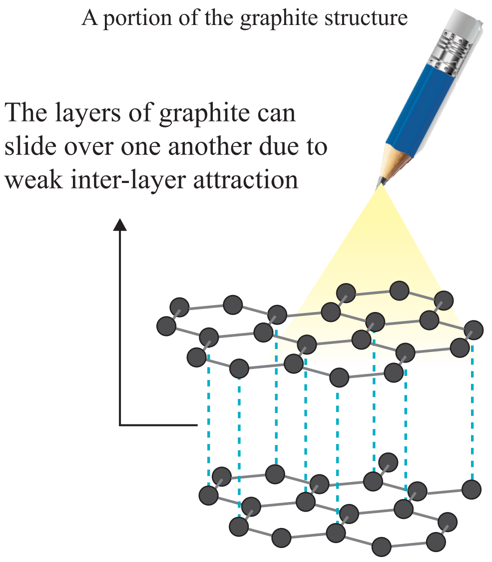


Fig 2.10 Graphite is a carbon-based material with high electrical conductivity. Its unique properties come from the free electrons that become delocalized. The layers of graphite can slide over one another due to weak inter-layer attraction, but the covalent bonds are strong making it have a high melting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

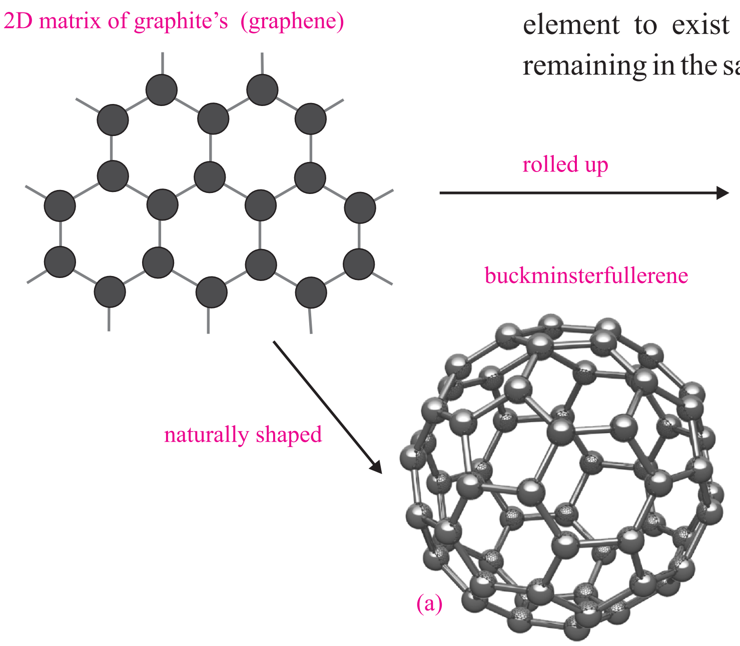


Fig. 2.11 Graphene is the single layer of graphite, which is extremely strong, lightweight, and can be used to enhance the strength of other materials. It has superior electrical conductivity compared to many other materials. If Transformation of a single graphene sheet into spherical (a) buckminsterfullerene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

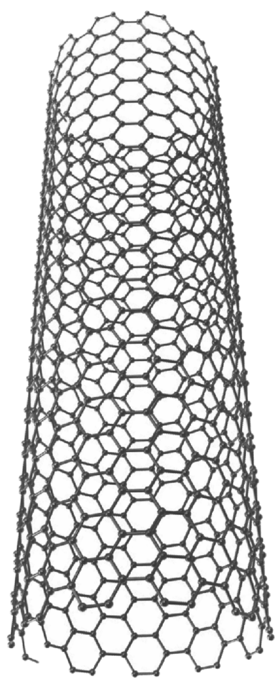


Fig. 2.12 Carbon Nanotube

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

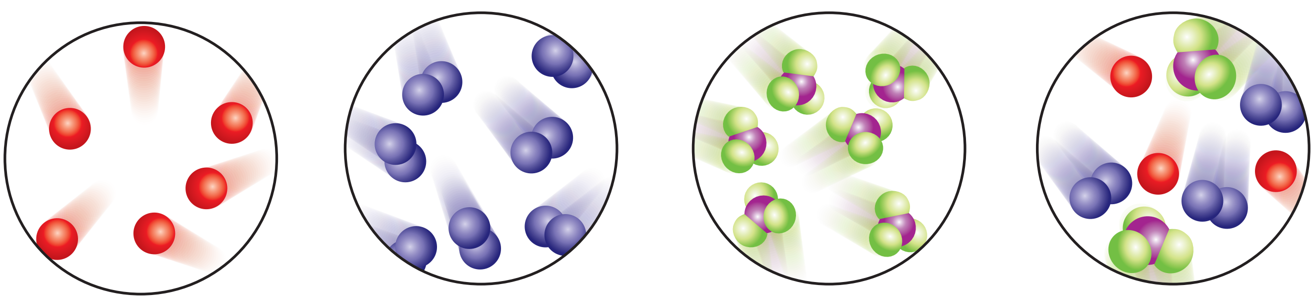
Types of Matter Based on Their Chemical Composition

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.

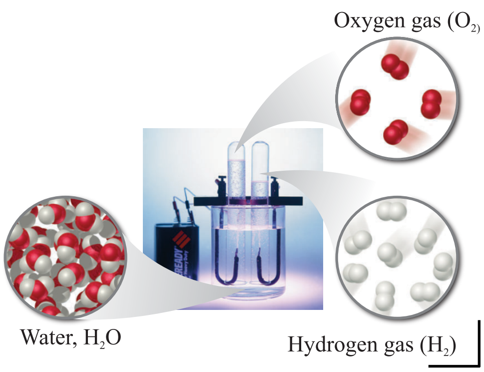


Fig. 2.15b

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

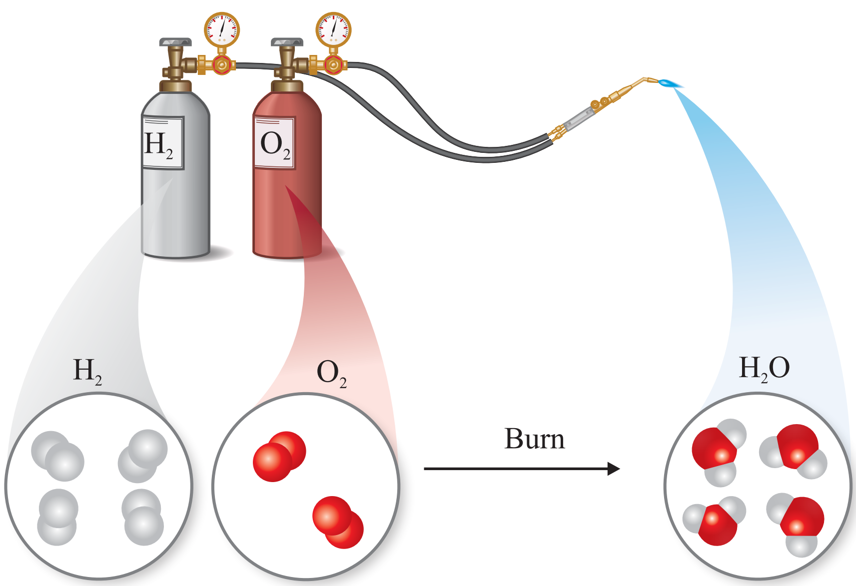


Fig. 2.15a A chemical reaction between H_2 and O_2

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.***

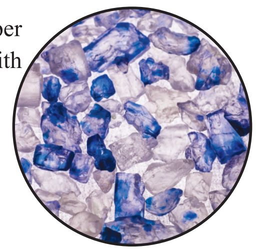
A heterogeneous mixture of soil and water

When the mixture is poured through the filter paper, the larger soil particles are trapped and the water passes through.

The water passing through the filter is more pure than in the mixture.

Purifying a hetero geneous mixture by filtration

The individual particles of white rock salt and blue copper sulfate can be seen clearly with the naked eye.



A heterogeneous mixture.

A homogeneous mixture.

A solution of salt in water. The model shows that salt in water consists of separate, electrically charged particles (ions), and particals are uniformily distributed.

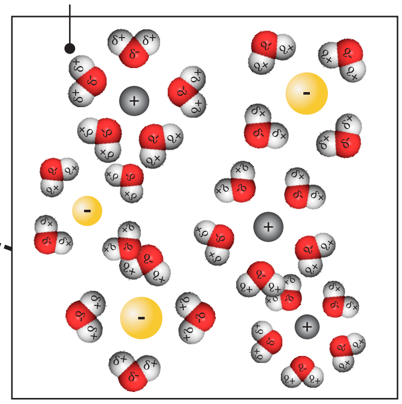
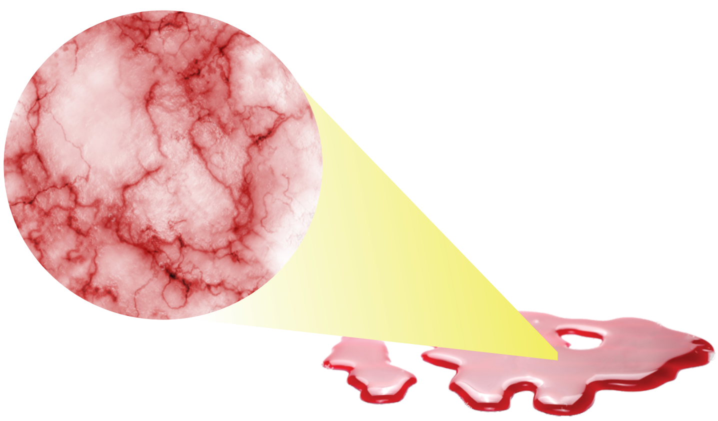


Fig. 2.17 Heterogeneous and homogeneous mixtures.

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

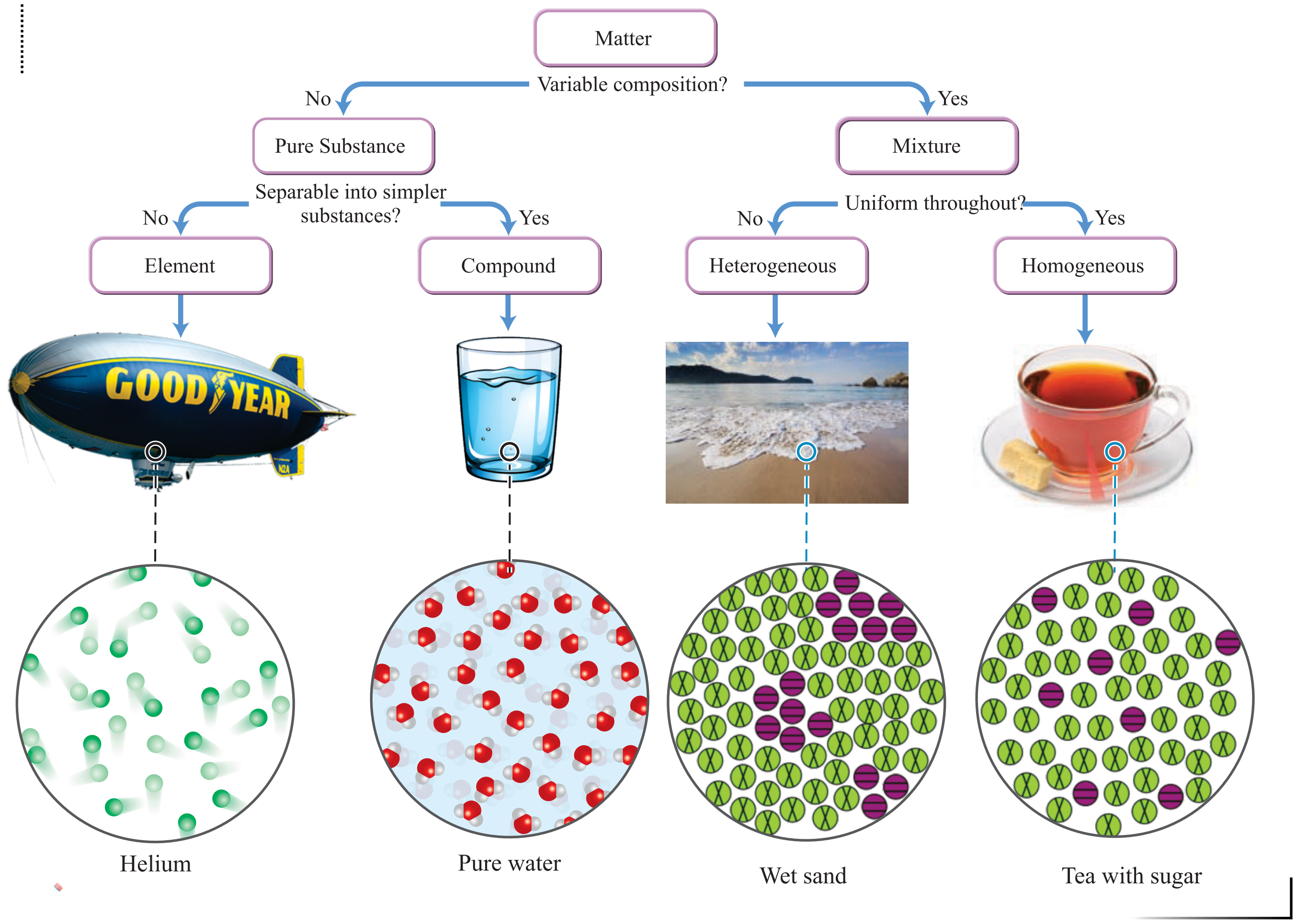


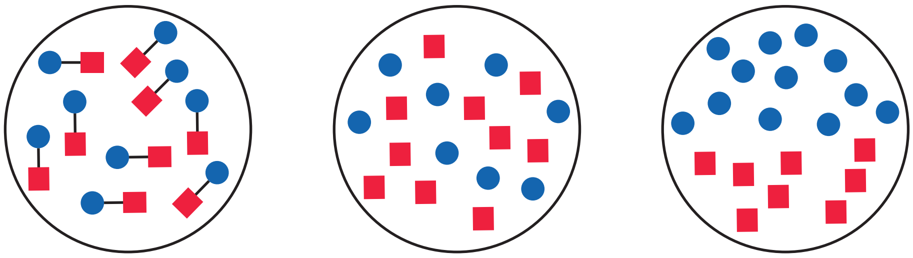
Table 2.4: Difference between element, compounds and mixtures

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.

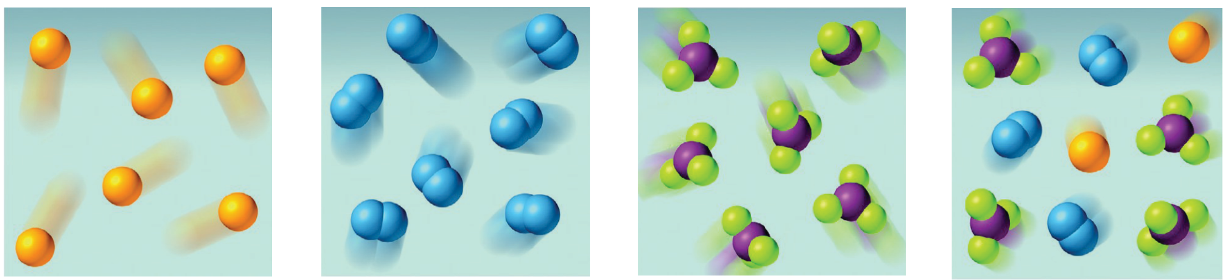
Challange

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)

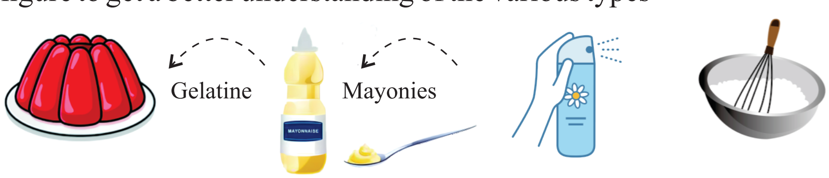


(a) Isolated atoms of an element. (b) Molecules of an element. (c) Molecules of a compound, consisting of more than one element. (d) A mixture of atoms of an element and molecules of an element and a compound. Which one we can separated by physical methodseparated by physical method?

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



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

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.

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

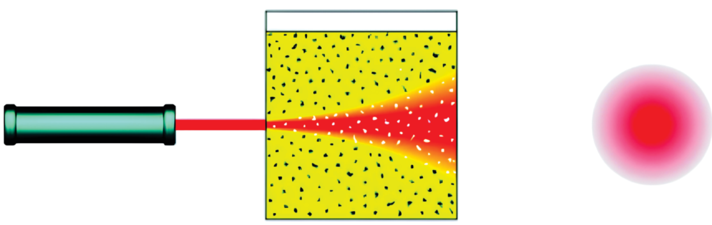
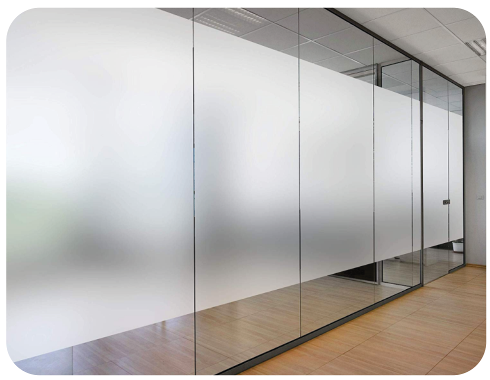


Fig 2.18 Tyndall effect



Frosted glass is a daily life application of Tyndall effect

Real World Application

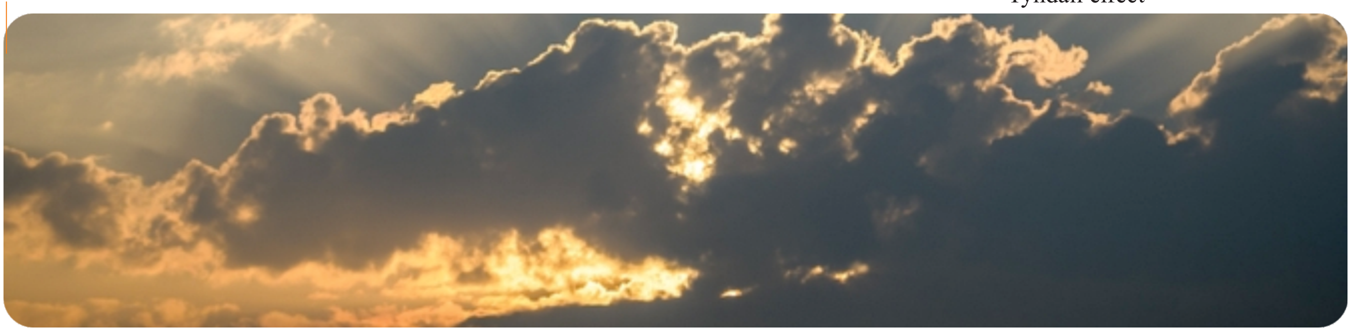


Fig 2.19 Beautiful Tyndall phenomenon (Tyndall effect) sunlight comes down through the clouds in the sky.

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.

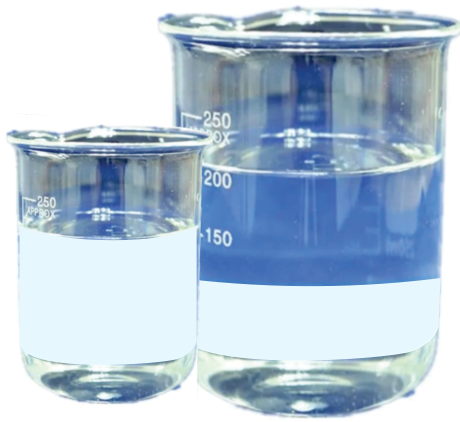


Fig. 2.19 (b) Particles in suspension disperse initially but eventually settle down in the form of crystals

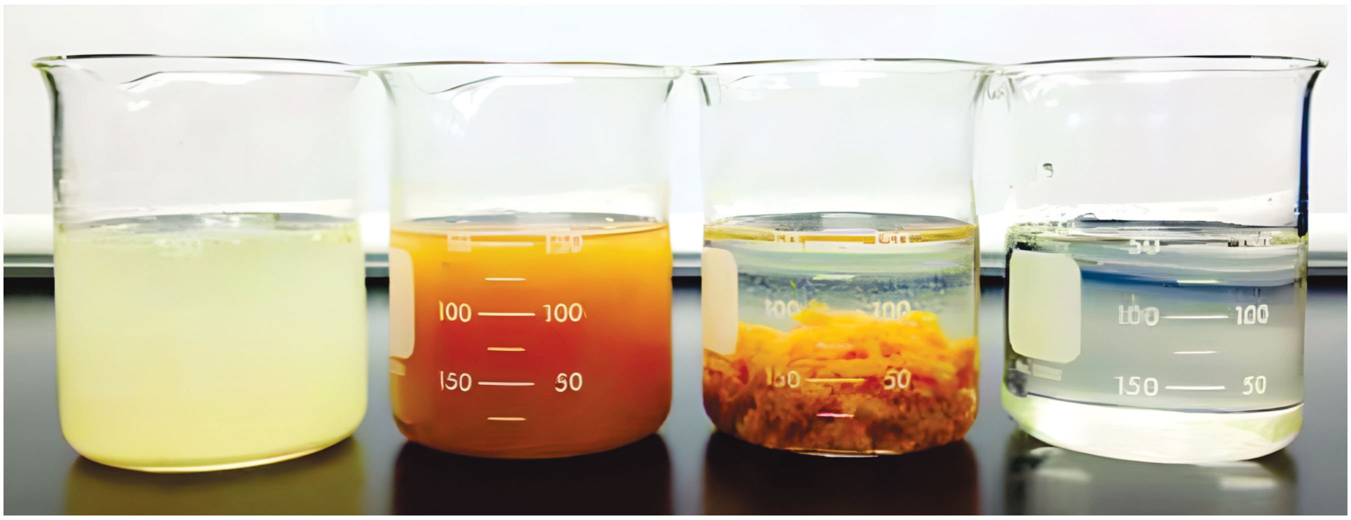


Fig. 2.19 (a) Suspensions separate into solids and water that can be removed by filtration.

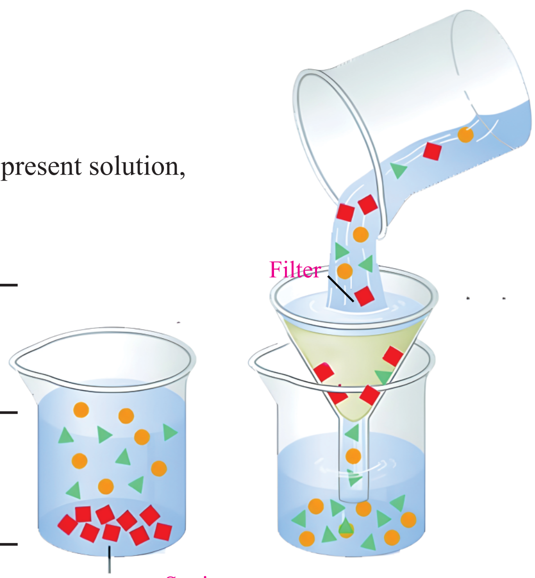
Challange

Identify which partical represent solution, colloids and suspension

● ____________

▲ ____________

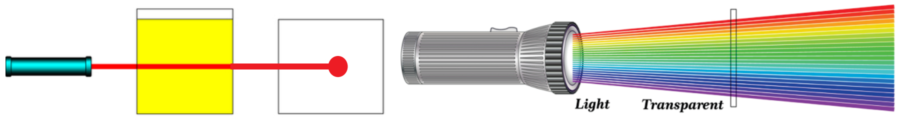
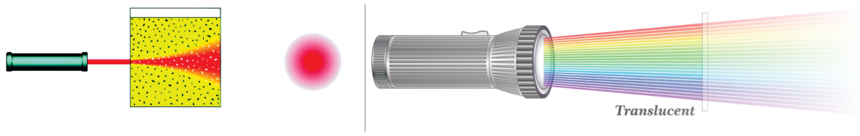
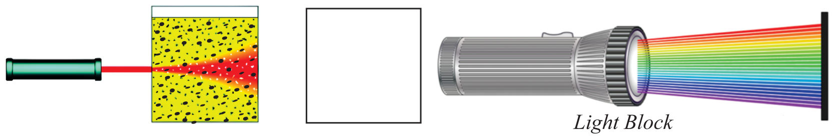
■ ____________



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

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."	 **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.
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."	 **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
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."	 **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.

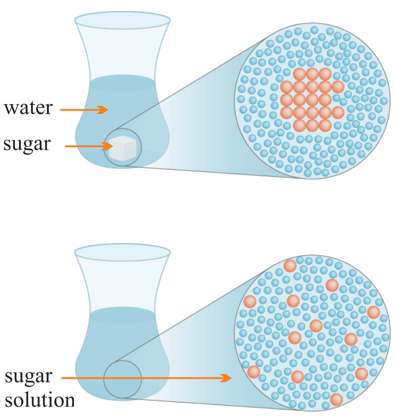


Fig. 2.20 Dissolving sugar in water

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.**

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:

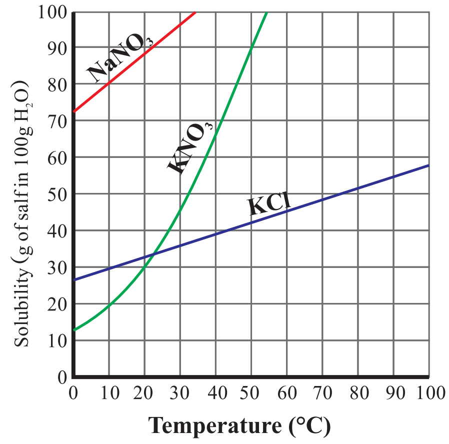
Heat is absorbed: When substances like KNO_3 , $NaNO_3$, and KCl are added to water, the test tube becomes cold, indicating that heat is absorbed during the dissolution process. This type of dissolving process is called 'endothermic'. For such solutes, solubility usually increases with an increase in 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.

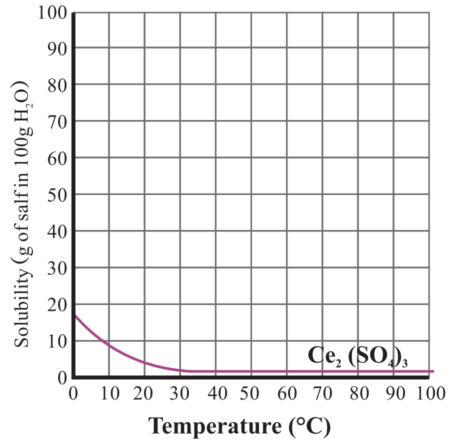
$$\text{Solvent} + \text{Solute} + \text{Heat} \longrightarrow \text{Solution}$$

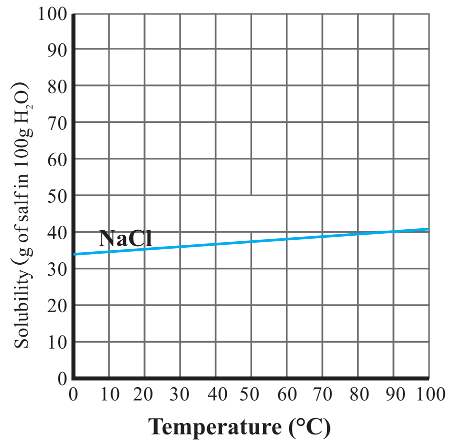
Heat is given out: On the other hand, when substance like Lithium sulphate (Li_2SO_4) and cerium(III) sulphate ($Ce_2(SO_4)_3$) are dissolved in water, the test tube becomes warm, indicating that heat is released during the dissolution process. In such cases, the solubility of the salts decreases with 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.

$$\text{Solvent} + \text{Solute} \longrightarrow \text{Solution} + \text{Heat}$$

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.







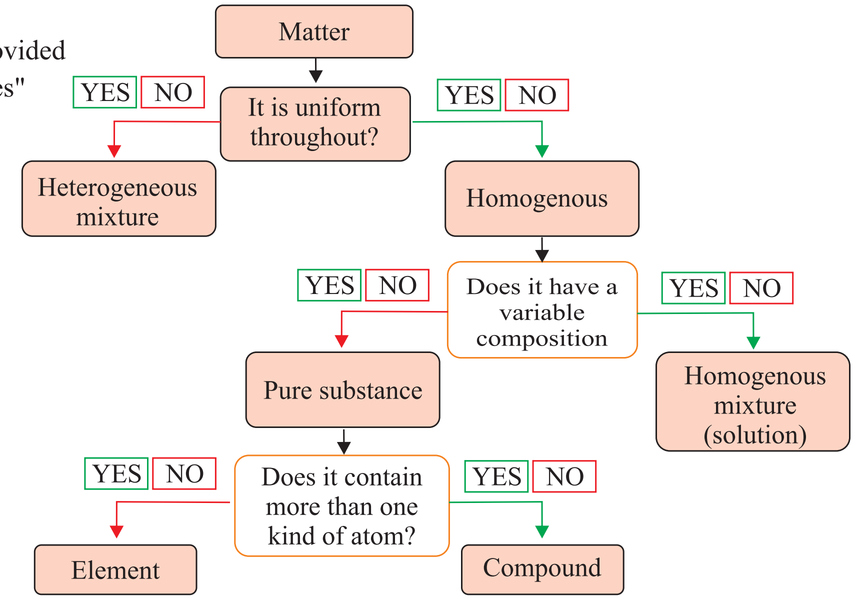
Skill:2.4

Differentiate between unsaturated and saturated solutions.

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

Challange

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

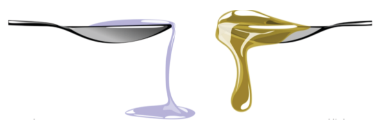
12 You are investigating the solubility of sugar in water. You add sugar to a cup of water until no more dissolves, forming a saturated solution. If you continue to heat the solution, what would you expect to observe?

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?

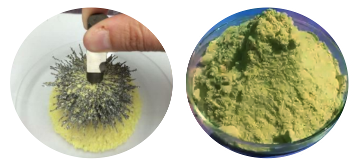
2 Why do these liquids flow differently?



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?



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

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)?

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