THE PROPERTIES AND STRUCTURE OF MATTER
1. Define matter and state of matter
2. Properties of solids, liquids and gases
3. Changes in matter
   - Physical and chemical changes
   - Phase changes of matter
4. Classification of matter
   - Elements, compounds and mixtures
5. Separation of mixtures
OBJECTIVES

• Distinguish between physical and chemical properties.
• Define physical change and list several common physical changes.
• Define chemical change and list several indications that a chemical change has taken place.
• Explain the gas, liquid and solid states in terms of particles.
• Distinguish between mixtures, elements and compounds.
• Classify mixtures as homogeneous or heterogeneous.
• List and describe several techniques used to separate mixtures.
DEFINITION OF MATTER

- **CHEMISTRY** → study of the composition, structure, and properties of matter and the changes it undergoes

- The two properties of **MATTER** are:
  - **Mass** – amount or quantity of matter
  - **Volume** – amount of space occupied

- Therefore... **MATTER** is anything that has mass and takes up space.
DEFINITION OF MATTER

• All matter is composed of atoms

• Atom:
  – Extremely small chemically indivisible particle
  – Atom is Greek for “that which cannot be divided”

• There is so many different kinds of matter, which are organized by their composition and properties

• Composition - the types and amounts of atoms that make up a sample of matter

• Properties - the characteristics that give each substance a unique identity
PROPERTIES OF MATTER

- Properties of matter allow us to distinguish between substances and classify them.
- Can reveal the identity of an unknown substance.
- Divided into two groups:
  - PHYSICAL PROPERTIES
  - CHEMICAL PROPERTIES
PHYSICAL PROPERTY

• **Defined as** - a characteristic that can be observed or measured without changing the identity or composition of the substance

• **Example include:**
  – Colour
  – Odor
  – Taste
  – Size
  – Physical state (liquid, gas, or solid)
  – Boiling point
  – Melting point
  – Density
PHYSICAL PROPERTIES

- Physical properties used to describe matter can be classified as:
  1) **Extensive** – depends on the *amount* of matter in the sample
     - e.g. Mass, volume, length
  2) **Intensive** – depends on the *type* of matter, not the amount present
     - Hardness, density, boiling point
Extensive vs. Intensive

**Extensive Properties**
- Depend on the amount of matter present
- Mass, volume, length, height, amount of energy, etc.

**Intensive Properties**
- Do not depend on the amount of matter present
- Density, boiling point, melting point, color, ability to conduct electricity, etc.
CHEMICAL PROPERTIES

• Defined as - ability or inability of a substance to combine with or change into one or more other substances i.e. ability of a substance to undergo a chemical reaction

• Example include:
  – Charcoal burning in air
  – iron rust
  – Decomposition of wood
CHEMICAL PROPERTIES

• Consider terms such as:
  – burn
  – rot
  – rust
  – decompose
  – ferment
  – explode
  – oxidize
  – corrode
  – grow
  – precipitate
  – gas formation
  – digest
Classify each as a physical or chemical property:

1. Iron and oxygen form rust.
2. Iron is more dense than aluminum.
3. Magnesium burns brightly when ignited.
4. Oil and water do not mix.
5. Mercury melts at -39°C.
STATES OF MATTER

• Matter can be classified according to its physical state and its composition

• Physical State:
  ➢ Solid
  ➢ Liquid
  ➢ Gas

• Classification into different states based upon:
  ➢ Particle arrangement
  ➢ Energy of particles
  ➢ Distance between particles

• State of matter is dependent on temperature and pressure of the surroundings
SOLIDS

- Has a definite shape and volume
- True solids have very rigid, ordered structures, in fixed positions i.e. high density
- Atoms held tightly together, therefore incompressible
- Atoms move through vibration only, therefore small thermal expansion
LIQUIDS

- Has a definite volume, atoms are not widely separated, therefore high density and small compressibility
- No definite shape i.e. follows the shape of its container
- Atoms move rapidly enough to slide over one another i.e. ability to flow
- Small thermal expansion
GASES

• Also known as vapour

• No fixed volume or shape, conforms to the volume and shape of its container

• Atoms far apart i.e. low density and can be compressed

• moving at high speeds, colliding with container, moderate thermal expansion
SUMMARY

• **Matter** is anything that has mass and takes up space.

• **Composition** - the types and amounts of atoms that make up a sample of matter.

• **Properties** - the characteristics that give each substance a unique identity.

• Properties divided into two groups:
  - Physical properties
  - Chemical properties
SUMMARY

• Physical properties - a characteristic that can be observed or measured without changing the identity or composition of the substance.

• Physical properties used to describe matter can be classified as:
  1) Extensive – depends on the amount of matter in the sample
     - e.g. Mass, volume, length
  2) Intensive – depends on the type of matter, not the amount present
     - Hardness, density, boiling point
SUMMARY

• **Chemical properties** - ability or inability of a substance to combine with or change into one or more other substances i.e. ability of a substance to undergo a chemical reaction
  – burn
  – rot
  – rust
  – decompose
  – ferment
  – explode
  – oxidize
SUMMARY

• Matter can be classified according to its physical state and its composition

• Physical states – solid, liquid gas

• Classification into different states based upon:
  - Particle arrangement
  - Energy of particles
  - Distance between particles

• State of matter is dependent on temp and pressure of the surroundings
<table>
<thead>
<tr>
<th>States of Matter</th>
<th>Definite Volume?</th>
<th>Definite Shape?</th>
<th>Result of a Temperature increase?</th>
<th>Will it Compress?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid</td>
<td>YES</td>
<td>YES</td>
<td>Small Expans.</td>
<td>NO</td>
</tr>
<tr>
<td>Liquid</td>
<td>YES</td>
<td>NO</td>
<td>Small Expans.</td>
<td>NO</td>
</tr>
<tr>
<td>Gas</td>
<td>NO</td>
<td>NO</td>
<td>Large Expans.</td>
<td>YES</td>
</tr>
</tbody>
</table>
CHANGES IN MATTER

• All matter can undergo physical and chemical changes

• **Physical change** – occurs when a substance alters its state (phase change), but does not change its chemical composition
  – E.g. Grinding, cutting

• **Phase change** – transition of a substance from one state to another
  – Depend on temperature and pressure
  – E.g. Boiling, freezing, melting, and condensing

• Physical changes can be classified as reversible or irreversible.
PHASE CHANGES

• Depend on **Temperature and Pressure**
• Affects:
  - Particle arrangement
  - Energy of particles
  - Distance between particles
• Phase change is either an exothermic or endothermic process
  - **Exothermic** – heat is given off i.e. Removal of E
  - **Endothermic** – absorption of heat i.e. Input of E
• Phase changes include:
  - melting, evaporation/boiling, condensation, freezing, sublimation and reverse sublimation
CHANGES OF STATE

• Melting - solid to liquid
• Freezing - liquid to solid
• Evaporation/boiling - liquid to gas
• Condensation - gas to liquid
• Sublimation – solid to gas
• Reverse Sublimation – gas to solid
PHASE CHANGES

- **SOLID**
- **LIQUID**
- **Gas**

**Processes**
- Melting
- Freezing
- Evaporation
- Condensation
- Sublimation
- Reverse sublimation

**Energy of system**
CHANGES IN MATTER

• **Chemical change** – occurs when a substance is converted into a new or different substance i.e. Change in the composition of a substance

• Also referred to as a **chemical reaction**

• Chemical reaction consists of reactants and products
  - reactants – starting substances
  - products – substances which are form/produced

![Chemical reaction diagram](image)
Law of Conservation of Mass

- The law of the conservation of mass applies to chemical reactions
- Mass is neither created nor destroyed during a chemical reaction
- Mass is conserved!
- $\text{Mass}_{\text{reactants}} = \text{Mass}_{\text{products}}$
Classify each as a physical or chemical change:

1. A dead fish rotting
2. Dissolving salt in water
3. Boiling salt water until only salt remains
4. Melting steel
5. Bending steel
6. Cracking ice
Identify the following as physical or a chemical change:

- Sugar ferments to form alcohol.
- Gallium metal melts in your hand.
- Platinum reacts with hydrogen peroxide at room temperature.
- Leaves turn colour in the Fall.
- Milk turns sour.
Identify the following as physical or a chemical change:

• Wax is melted over a flame and then catches fire and burns.
• You make scrambled eggs.
• You step on a piece of chalk and it becomes powdered.
• You light a candle when the electricity goes out.
• Steam from your hot shower condenses on a cold
SUMMARY

• Physical change – occurs when a substance alters its state (phase change), but does not change its chemical composition
  – E.g. Grinding, cutting

• Phase change – transition of a substance from one state to another
  – Depend on temperature and pressure
  – Affects:
    » Affects particle arrangement
    » Energy of particles
    » Distance between particles
  – Either exothermic or endothermic process
SUMMARY

• Chemical change – occurs when a substance is converted into a new or different substance i.e. Change in the composition of a substance
• Also referred to as a chemical reaction
• Chemical reaction consists of reactants and products
CLASSIFICATION OF MATTER

• All matter is composed of atoms
• All matter can be classified or identified as either pure substances or mixtures
• Substance – kind of matter that cannot be separated by any physical process
• Pure substances are considered as either elements or compounds
ELEMENTS

• **Element** – a substance that cannot be broken down into simpler substance by physical and chemical reaction

• Consists only of **one kind of atom**

• Building blocks for other substances

• Elements are organised on the periodic table, based on their properties
  – Consists of name and symbol (one, two or three letters)
  – 92 naturally occurring elements, 25 synthesised
  – E.g. Fe, Cu, Ag, Si etc.
COMPOUNDS

- **Compound** – a substance that consists of two or more elements chemically bonded
- Compound is always composed of the same elements, in the same proportion by mass
  - Represented by a formula e.g. $\text{NaCl, H}_2\text{O}$
  - **NOTE:** Understand method of writing formula
- Most of matter in the universe exists as compounds
- Compounds can be synthesised or decomposed
- **Synthesis** – combination of elements to form compounds
- **Decomposition** – splitting of compounds into their individual elements
COMPOUNDS

• Properties of a compound are different from its component elements

• Ex: water—liquid at room temp.

- **Hydrogen**—a colorless, tasteless gas
- **Oxygen**—a colorless, tasteless gas
Sodium Chloride

- As a compound, it is a white, unreactive solid that adds flavour to food
- Its component elements:
  - **Chlorine**—poisonous, pale, green gas
  - **Sodium**—a highly reactive metal
MIXTURES

• Mixture – combination of two or more substances in which each substance retains its individual properties

• Therefore, substances **ARE NOT** chemically combined, just mixed physically

• Mixtures can be separated by physical methods

• Mixtures can either be classified as:
  - Homogeneous
  - Heterogeneous

  Based on the distribution of the components
MIXTURES

• Homogeneous – mixture where the composition of the substances is constant throughout i.e. Uniform
• Therefore, individual substances are indistinguishable
• Also referred to as solutions – mixture of solute and solvent
  – Solute = substance in a smaller amount, which is dissolved in the solvent
  – Solvent = the liquid in which the solution is made of and is in a greater amount.

➢ NOTE: differentiate between dilute, concentrated and saturated solutions
MIXTURES

• **Heterogeneous** – mixture where the individual substances remain distinct i.e. not uniform
• Therefore, individual components can be distinguished
• May form suspensions, lumps due to insolubility
• Mixture can easily be separated by physical methods e.g. Filtration
• E.g. Sand and water
SUMMARY

Matter

Can it be separated physically?

Mixtures
- Is the composition uniform?
  - Yes
    - Homogeneous (air, sugar in water)
  - No
    - Heterogeneous (granite, blood)

Pure substances
- Can it be decomposed by chemical means?
  - Yes
    - Compounds (H2O, NaCl)
  - No
    - Elements (gold, oxygen)
SEPARATION OF MIXTURES

• The different substances within a mixture can be separated as they are not chemically bonded

• Different techniques can be used, depending on the phase the two components exist.

• Techniques include:
  ➢ magnetisation, filtration, centrifugation, evaporation, simple distillation, fractional distillation, separating funnel, chromatography
SEPARATION OF MIXTURES

- MAGNETISATION – use of a magnet to separate a magnetic substance from a non-magnetic substance
  - E.g. Sand and iron
- FILTRATION – used to separate an insoluble solid or suspension from a liquid
  - Based on size
  - Substances separated into a filtrate and a residue
  - Filtrate = liquid that passes through the filter paper
  - Residue = solid that remains on the filter paper
  - E.g. Sand and water
SEPARATION OF MIXTURES

• CENTRIFUGATION – used to separate insoluble solid or suspension from a liquid
  – Use of rotational force to separate substance based on their density
  – Sometimes used instead of filtration

• Evaporation – used to separate a solute from a solution
  – The solution is heated until all of the solvent evaporates
  – E.g. Salt from water
SEPARATION OF MIXTURES

• SEPARATING FUNNEL – use to separate two immiscible liquids
  – Depends on the density
  – E.g. Oil and water
SEPARATION OF MIXTURES

• SIMPLE DISTILLATION – used to separate a pure solvent from a solution
  – Involves vaporization, condensation and collection
  – E.g. Water from salt
SEPARATION OF MIXTURES

• FRACTIONAL DISTILLATION – used to separate one liquid from a mixture of liquids, that have different boiling points
  – E.g. Ethanol and water
SEPARATION OF MIXTURES

• CHROMATOGRAPHY – used to separate a mixture of substances based on their solubility within a given solvent
  – Components which prefer the solvent move faster and further up the chromatography paper, causing separation
  – E.g. Separation of ink
THE END