CHAPTER 2

Matter and Measurement

Learning Objectives:

At the end of this chapter, the students should be able to:

1. Understand the use of SI system of measurement;
2. Convert from one system of measurement to another;
3. Identify the properties of matter and its characteristics;
4. Distinguish the methods of separating mixture;
5. Classify the states matter;
6. Discuss the classification of matter by its chemical composition;

Overview

Matter and measurement are the fundamental pillars of science. Matter is anything that has mass and occupies space, while measurement is the process of quantifying the properties of matter. These two concepts are inextricably linked, as measurement provides a means to characterize and understand the various forms of matter that make up our universe.

Matter exists in three primary states: solid, liquid, and gas. Solids have a definite shape and volume, while liquids have a definite volume but no definite shape. Gases have neither a definite shape nor a definite volume.

Matter is composed of elements, the most basic substances that cannot be broken down into simpler substances by chemical means. There are currently 118 known elements, each with unique properties and characteristics.

Lesson 1: Matter

The term **matter** refers to anything that occupies space and has mass—in other words, the “stuff” that the universe is made of. All matter is made up of substances called elements, which have specific chemical and physical properties and cannot be broken down into other substances through ordinary chemical reactions. Everything you can see and touch is made of matter, including you! The only things that aren’t matter are forms of energy, such as light and sound.

Matter has mass and volume. Mass and volume measure different aspects of matter. **Mass** is a measure of the amount in a substance or an object. The basic SI unit for mass is the Kilogram (Kg), but smaller masses may be measured in grams (g). **Volume** is a measure of the space that a substance or an object takes up. The basic SI unit for volume is the cube meter (m^3), but smaller volumes may be measured in cm^3, and liquids may be measured in liters (L) or milliliters (mL)

Ordinary matter is made of tiny particles called **atoms**. The atoms have spaces between them and they move or vibrate all the time. The particles move faster and move further apart when heated, and the reverse when cooled.

Non- matter is either no mass or else don't fill a volume.

Example: Energy, light, heat, kinetic and potential energy, and sound.

Properties of Matter

Matter can be directly experienced through the senses. It has properties which can be measured, such as mass, volume, density, and qualitative properties such as tastes, smell and color, for instance.

1. **Physical properties** – The measurement of mass and other characteristics that can be seen without changing how that object looks are its physical characteristics. When you look at the oranges, you know that they are oranges because of their color, shape, and smell.

   Example: Density is an important physical property. **Density** is the mass of a substance per unit volume. **Volume** is the amount of space an object occupies.

   All physical bodies in the Universe are made of matter: galaxies, stars, and planets, rocks, water, and air. Living organisms like plants, animals, and humans are also composed of matter.

   Mass, color, shape, volume and density are some physical properties.

   Formulas:

   Mass = vxd
   Density = m/v
   Volume= m/d

   Examples:

   a. If 96.5 grams of gold has volume of 5 cm^3. What is the density of gold?

      Given:

      Mass = 96. 5g
      Volume = 5 cm^3

Density = ?

Solution:

Formula:

$D = m/v \quad = 96.5g/5\ cm^3$
$= \mathbf{19.3\ g/cm^3}$

b. If a 96. 5 grams piece of Aluminum has a density of 2. 7 grams per cm^3. What its volume?

Given:

Mass = 96.5 g
Density = 2.7 g/cm^3
Volume = ?

Solution:

Formula:

$V = m/d \quad = 96.5\ g/2.7\ g/cm^3$
$= \mathbf{35.74\ cm^3}$

Note: unit of Mass is kilogram, density is kilogram per cubic meter, and volume is Liter

2 types of Physical Properties

- Intensive Physical Properties – do not depend on the amount of the substance present ex. Density, color, melting point, boiling point, odor, temperature, ductility, and malleability.
- Extensive Physical Properties – depend on the amount of matter being measured. Ex. Mass, volume, length, shape, size, and weight.

2. **Chemical Properties** – these are properties that can only be observed by changing the identity of the substance. A piece of paper burns and turns to a black substance.

   Examples: Flammability, toxicity, acidity, reactivity, heat combustion, spoiling of milk, and burning toast.

States of Matter

1. Solids – are material objects made up of molecules and atoms so strongly bond together that they tend to keep their shape even when moved around, tough they can deform under stress.

   Examples: rocks, a table, a knife, a block of ice.
2. Fluids – are amounts of matter composed of molecules and atoms weakly bonded together. They do not have a proper shape.

   Examples: water, air, blood, Mercury, honey, gasoline, any other gas or liquid.

   2 types of fluids

   - Liquids – include condensed forms of matter, like solids, but where the bonds between the constituting elements allow them to move with respect to each other while continuing to stick together in bulk.

     Examples: water, oil, blood, lava, soft drinks
   - Gases- are amounts of matter where the bonds between the constituting elements are so loose or weak that they can move independently from each other. Gases do not exhibit a proper surface, they tend to expand to occupy the whole volume available.

     Examples: air, water vapor, helium, hydrogen, nitrogen, carbon dioxide, carbon monoxide, neon, argon, ozone.

3. Plasma – (change of particles) are made of ionized matter (radiation), they ae mostly of interest to scientist.

   Examples:
   The Earth's ionosphere, the Su's corona. The particles in plasma are a mixture between a liquid and a gas. The particles are free to move, like a liquid, and the attraction is weak, like gas.

   Lightning, Sun, Nebula, Neon lights, Auroras, Solar wind, fluorescent light, Nuclear fire ball.
4. A Bose – Einstein Condensate (BEC)- is a state of matter of a dilute gas of bosons cooled to temperature very near absolute zero (0 K or – 273. 15 Celsius)

   Examples: Super fluids – such as cold liquid helium
   Super conductor – such as nucleus inside a neutron star.

Composition of Matter

The structure and composition of matter is investigated by breaking matter into smaller and smaller pieces. Hence, living organisms are made up of cells. Cells are composed of molecules, which are set of atoms bonded together.

Classification of Matter by its Chemical Composition

1. An **Element** is a pure substance made up of atoms with the same number of protons. As of 2011, 118 elements have been observed, 92 of which occur naturally.
   Examples: Carbon (C), Oxygen (O), Hydrogen (H)

   Pure substance cannot be further broken down or decomposed into simpler substance by physical or chemical methods.

   Elements are further subdivided into:

   - Metals – are generally solids which have some characteristics like bright luster, good conduction of heat and electricity and hardness.
     Example: Na, K, Ca etc.
   - Non- Metals – are generally bad conductors of heat and electricity, non-lustrous and brittle.
     Example: O_2, H_2 etc.
   - Metalloids – are elements which have common characteristics of both metals and non- metals.
     Example: B, Si, Ge, Ar, Sb, Po etc.
2. A **compound** – consist of two or more chemical elements that are chemically bonded together.
   Example: water (H_2O), Sodium (Na), table salt (NaCl), table sugar (C_{12} H_{22} O_{11})

   Types of Compounds
   - Organic compounds are the compounds which are obtained from plant and animals sources.
     Examples: Methane, DNA, Table sugar, and Ethanol
   - Inorganic compound obtained from non- living sources.
     Example: Minerals, Table salt
3. **Mixture** – consist of two or more substances mixed together without any chemical bond.
   Examples: Salad, the mixture can be separated into its individual components by mechanical means, sand and water, water and oil.

   Classification of Mixtures

- **Homogeneous mixture** – is a mixture where the components that make up the mixture are uniformly distributed throughout the mixture.
  Example: Air, rain, sea water

  Another example of homogenous mixture is a **solution.** The substance that's gets dissolved is the **solute**. The substance that does the dissolving is the **solvent.** Together they make a **solutions.**

- **Heterogeneous mixtures** – is a mixture where the components the mixture of the mixture are not uniform or have localized regions with different properties.

  A heterogeneous mixture is not uniform, different samples may have compositions, like chocolate chips ice cream, concrete, soil, blood, and salad.

  Suspensions are heterogeneous mixture that will eventually settle. They are usually, but not necessarily, composed of phases in different states of matter. Italian salad dressing has three phases: the water, the oil, and the small pieces of seasoning. The seasonings are solids that will sink to the bottom, and the oil and water are liquids that will separate. **Colloid**s is a heterogeneous mixture of two substances of different phases. Shaving cream and other foams ae gas dispersed in liquid.

Methods for Separating Mixtures

There is no chemical bonding in a mixture, the phases can be separated by mechanical means.

Filtration - the process in which solid particles in a liquid or gaseous fluid are removed by the use of a filter medium that permits the fluid to pass through but retains the solid particles.

Example: using a coffee filter to separate the coffee flavor from the coffee beans.

Distillation- is the boiling of a mixture to separate its phases.

Example: salt is a solid at room temperature, water is a liquid. Water boil far before salt even begins to melt, so separating the two is a simple as boiling the water until all that remains is the solid salt. If desired, the water vapor can be collected, condensed, and used as a source of pure water.

Centrifugation and Sedimentation- The process of sedimentation can be observed by a small experiment. Take a jar and fill it with garden variety mud, pour some water, shake well and keep it untouched for a few minutes. In a while it can be noticed that the gravel and rocks have settled below, stand above and so on. Basically, the garden variety mud has formed layers of soil based on varied. **Sedimentation** can be used to separate particles based on their size by applying a **centrifugal force** to the required solution. In the process of **Centrifugation**, a centrifugal force is applied to a heterogeneous mixture which will separate the mixture according to its density. The denser components shift away from the centrifugal axis whereas the less dense ones stay closer to the centrifugal axis. Thus separating the constituents of the mixture.

Separating Homogeneous Mixtures

Some common methods of separating homogeneous mixture into their components.

Distillation- a mixture of two volatile liquids is partly boiled away, the first portions of the condensed vapor will be enriched in the component having the lower boiling point.

Example; Distillation of alcoholic beverages: the production of alcoholic beverages, such as whisky, vodka, and brandy.

Fractional crystallization- Fractional crystallization is a method of refining substances based on differences in solubility.

Examples: Purification of table salt (NaCl): When water is evaporated to produce salt, Formation of frost, crystallization of sugar.

Liquid- liquid extraction – solvent extraction or partitioning- is a method separate compound or metal complexes based on their relative solubility's two different immiscible liquid usually water and organic solvent.

Examples: Separation of organic compounds from water: solution of caffeine in water (like coffee) remove caffeine, add organic solvent dichloromethane (methylene chloride) to water – caffeine mixture. This two liquids are immiscible, meaning they don't mix well.

Coffee and tea liquids/solids type in which a compound (caffeine) is isolated from a solid mixture by using a liquid extraction solvent (water).

Solid- liquid extraction – is similar to liquid – liquid extraction, except that the solute is dispersed in the solvent and mixed. The solute is extracted from the solid phase to the solvent, and the solid phase is then removed by filtration.

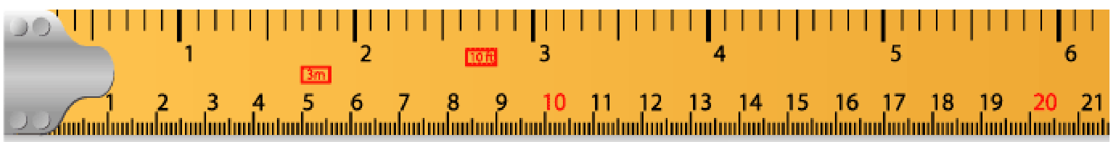
Example: Coffee brewing, which involves the mixing of solids coffee grounds with water. The coffee flavor compounds are extracted into the water from coffee.

Lesson 2: Measurement

It is the process or result of determining the magnitude of a quantity, such as length or mass, relative to a unit of measurement, such as a meter or kilogram.

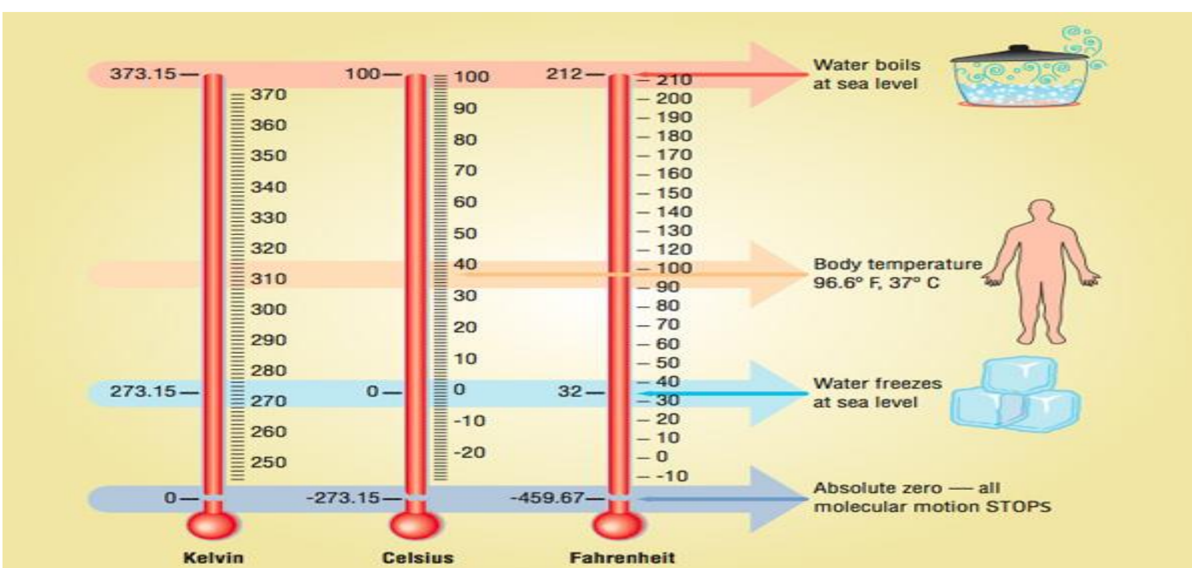
Uses of Measurement

- Purchasing clothes – depending on size and proper fitting
- Intake of Medicine when ill- time interval, dose (amount of medicine)
- Cooking properly – temperature
- Playing sports – distance, time, mass, and so on.



Temperature Measurement

Temperature is the measurement of the hotness and coldness of a body. It is measured with the help of a device called thermometer. The three units in which temperature is measured are **Celsius**, **Fahrenheit**, and **Kelvin**. Hence, there are three different scales for measuring temperature. Every unit can be converted to another unit with the help of a conversion formula that we are going to study in this lesson.



Anders Celsius – is most familiar as the inventor of the temperature scale that bears his name. The Swedish astronomer, however, also is notable as the first person to make a connection between the radiant atmospheric phenomenon known as the aurora borealis, or the northern lights, and the magnetic field of the Earth. Celsius scale was Invented in 1742 by Swedish astronomer Anders Celsius and hence named after him. Celsius, also called centigrade, is based on the freezing point of water which is 0°, and the boiling point of water which is 100° the temperature in Celsius is represented with °C. Normal human body temperature is 37°C.

By the early 1700's at least 35different temperature scales had been proposed. At that time, a Dutch instrument maker by the name **Daniel Gabriel Fahrenheit** became famous for his mercury thermometers. The Fahrenheit scale he developed is still the most widely used temperature scale in the United States. This scale has the boiling point of water at 212° F and the freezing point at 32° F. The temperature in Fahrenheit is represented with °F. The normal human body temperature is 98.6°F.

William Thomson, known as Lord Kelvin, was one of the most eminent scientist of the nineteenth century and 1st best known today for inventing the International System of absolute temperature that bears his name. Kelvin is the SI unit of temperature. The unit symbol is K. It is named after the physicist William Thomson, 1st Baron Kelvin (1824–1907)

Here are the temperature conversion formulas:

- Celsius to Kelvin: K = C + 273.15
- Kelvin to Celsius: C = K - 273.15
- Fahrenheit to Celsius: C = (F-32) (5/9)
- Celsius to Fahrenheit: F = C(9/5) + 32
- Fahrenheit to Kelvin: K = (F-32) (5/9) + 273.15
- Kelvin to Fahrenheit: F = (K-273.15) (9/5) + 32

Temperature Conversion Formulas between Celsius and Kelvin

Conversion of temperature between Celsius and Kelvin is done using the following formulas:

- The temperature conversion formula from Celsius to Kelvin is:
  K = C + 273.15
- The temperature conversion formula from Kelvin to Celsius is:
  C = K − 273.15

Example: Convert 16°C into Kelvin.

Solution:

C = 16°C (Given). Using the Celsius to Kelvin conversion formula,

K = C + 273.15

= 16 + 273.15

= 289.15 K

Therefore, **16°C is equivalent to 289.15 K**.

Temperature Conversion Formulas between Fahrenheit and Celsius

Conversion of temperature between Fahrenheit and Celsius is done using the following formulas:

- The temperature conversion formula from Fahrenheit to Celsius is:
  C = (F − 32) × 5/9
- The temperature conversion formula from Celsius to Fahrenheit is:
  F = C(9/5) + 32

Example: What is 115°F on the Celsius scale?

Solution:

F = 115°F.

Using Fahrenheit to Celsius conversion formula,

C = (F − 32) × 5/9

= (115 − 32) × (5/9)

= 46.11°F

Therefore, **115°F is 46.11°C on the centigrade scale.**

Temperature Conversion Formulas between Fahrenheit and Kelvin

Conversion of temperature between Fahrenheit and Kelvin is done using the following formulas:

- The temperature conversion formula from Fahrenheit to Kelvin is:
  K = (F − 32) × 5/9 + 273.15
- The temperature conversion formula from Kelvin to Fahrenheit is:
  F = (K – 273.15) × 9/5 + 32

Example: Convert 100 degrees Fahrenheit to Kelvin.

Solution:

Temperature in Fahrenheit, F = 100 F (Given). Using Fahrenheit to Kelvin Formula,

$K = (F - 32) \times 5/9 + 273.15$

$(100 - 32) \times 5/9 + 273.15$

$= 310.93$ K

Therefore, **100 degree Fahrenheit = 310.93 K**

Examples:

Example 1: We know that one degree Celsius is equal to 273.15 Kelvin. Calculate 30°C in Kelvin.

Solution:

To find: Convert 30°C in Kelvin.

Given,

One-degree Celsius is equal to 273.15 Kelvin.

Using temperature conversion formulas,

Kelvin (K) = Celsius(C) + 273.15

Putting the value:

K = 30 + 273.15 K = 303.15 K

= 303.15 K

Answer: 30°C in Kelvin is 303.15 K

Example 2: The body temperature is generally 98.6ºF. Find the body temperature in Celsius using temperature conversion formulas.

Solution:

To find: The body temperature in Celsius.

Given,

The body temperature on the Celsius scale is 98.6ºF.

The formula to convert Fahrenheit to Celsius is,

$C = (F - 32) \times 5/9$

On putting the value, we get

$C = (98.6 - 32) \times 5/9$

$= 37°C$

Answer: The body temperature in Celsius is 37°C.

Example 3: Convert 220 K to Celsius as well as Fahrenheit.

Solution:

We apply temperature conversion formulas.

Using Kelvin to Celsius conversion formula
$C = K - 273.15$
$= 220 - 273.15$
$= -53.15°C$

Using Kelvin to Fahrenheit conversion formula
$F = (K - 273.15) \times 9/5 + 32$
$= (220 - 273.15) \times 9/5 + 32$
$= -53.15 \times 9/5 + 32 = -95.67 + 32 = -63.67°F$

Answer: 220K in Celsius is -53.15°C and Fahrenheit is -63.67°F.

Unit Conversion and Conversion Factor

A **unit conversion** expresses the same property as a different unit of measurement. For instance, time can be expressed in minutes instead of hours, while distance can be converted from miles to kilometers, or feet, or any other measure of length. Often measurements are given in one set of units, such as feet, but are needed in different units, such as chains. A conversion factor is a numeric expression that enables feet to be changed to chains as an equal exchange.

A **conversion factor** is a number used to change one set of units to another, by multiplying or dividing. When a conversion is necessary, the appropriate conversion factor to an equal value must be used. For example, to convert inches to feet, the appropriate conversion value is 12 inches equal 1 foot. To convert minutes to hours, the appropriate conversion value is 60 minutes equal 1 hour.

The International System of Units (SI), commonly known as the metric system, is the international standard for measurement. The International Treaty of the Meter was signed in Paris on May 20, 1875 by seventeen countries, including the United States and is now celebrated around the globe as World Metrology Day.

SI Base Units			
Base quantity		**Base unit**	
Name	**Typical symbol**	**Name**	**Symbol**
time	*t*	second	s
length	*l, x, r*, etc.	meter	m
mass	*m*	kilogram	kg
electric current	*I, i*	ampere	A
thermodynamic temperature	*T*	kelvin	K
amount of substance	*n*	mole	mol
luminous intensity	I_v	candela	cd

Source: NIST Special Publication 330:2019, Table 2.

Examples:

1. How many cm are in 18.9 inches?

   Given: 18.9 inches
   Cm is unknown
   Solution: (using conversion table)

   18.9 inches multiply by 2. 54 cm /1in, in which 1 inches is equivalent to 2.54 cm.

   The answer would be **47. 5 cm**, since it has the same unit you do cancellation which inches.
2. 10.3 km to mi

   Given: 10.30 km
   mi is unknown

   Solution:
   1.30 km multiply by 0.62137119 mi/1 km is equal to **6. 4 mi.**