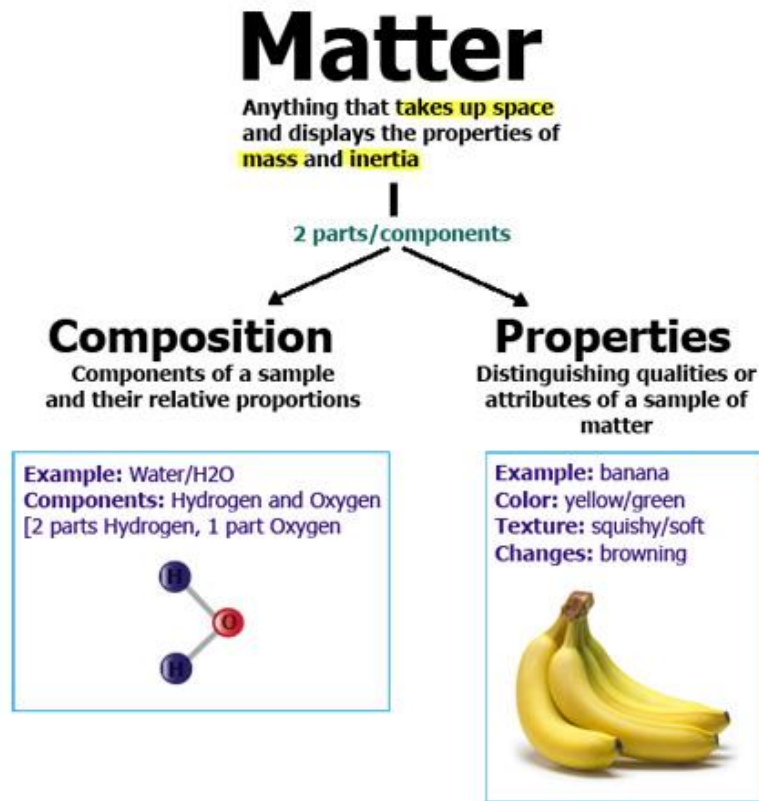


ANALYSIS OF MATERIALS

5. PHYSICAL & CHEMICAL PROPERTIES OF MATERIALS

5.1. Introduction to Physical & Chemical Properties of Materials

We are all surrounded by matter on a daily basis. Anything that we use, touch, eat, etc. is an example of matter. Matter can be defined or described as anything that takes up space, and it is composed of miniscule particles called atoms. It must display the two properties of mass and inertia. The different types of matter can be distinguished through two components: composition and properties. The composition of matter refers to the different components of matter along with their relative proportions. The properties of matter refer to the qualities/attributes that distinguish one sample of matter from another. These properties are generally grouped into two categories: physical or chemical.



5.2. Physical Properties of Materials

A physical property is any property that is measurable whose value describes a state of a physical system. The changes in the physical properties of a system can be used to describe its transformations or evolutions between its momentary states. Physical properties are often referred to as observables. They are not modal properties. Physical properties are often characterized as intensive and extensive properties. An intensive property does not depend on the size or extent of the system, nor on the amount of matter in the object, while an extensive property shows an additive relationship. These classifications are in general only valid in cases when smaller subdivisions of the sample do not interact in some physical or chemical process when combined. Properties may also be classified with respect to the directionality of their nature. For example, isotropic properties do not change with the direction of observation, and anisotropic properties do have spatial variance.

It may be difficult to determine whether a given property is a material property or not. Color, for example, can be seen and measured; however, what one perceives as color is really an interpretation of the reflective properties of a surface and the light used to illuminate it. In this sense, many ostensibly physical properties are called supervenient. A supervenient property is one which is actual, but is secondary to some underlying reality. This is similar to the way in which objects are supervenient on atomic structure. A cup might have the physical properties of mass, shape, color, temperature, etc., but these properties are supervenient on the underlying atomic structure, which may in turn be supervenient on an underlying quantum structure. Physical properties are contrasted with chemical properties which determine the way a material behaves in a chemical reaction.

Physical properties are those that can be observed without changing the identity of the substance. The general properties of matter such as color, density, hardness, are examples of physical properties. Properties that describe how a substance changes into a completely different substance are called chemical properties. Flammability and corrosion/oxidation resistance are examples of chemical properties. The difference between a physical and chemical property is straightforward until the phase of the material is considered. When a material changes from a solid to a liquid to a vapor it seems like they become a different substance. However, when a material melts, solidifies, vaporizes, condenses or sublimates, only the state of the substance changes. Consider ice, liquid water, and water vapor, they are all simply H₂O. Phase is a physical property of matter and matter can exist in four phases; solid, liquid, gas and plasma.

Physical Property: A physical property is one that is displayed without any change in composition. (Intensive or Extensive)

1. **Intensive:** A physical property that will be the same regardless of the amount of matter.
 - density: m/v
 - color: the pigment or shade
 - conductivity: electricity to flow through the substance
 - malleability: if a substance can be flattened
 - luster: how shiny the substance looks
2. **Extensive:** A physical property that will change if the amount of matter changes.
 - mass: how much matter in the sample
 - volume: how much space the sample takes up
 - length: how long the sample is

Physical Change: Change in which the matter's physical appearance is altered, but composition remains unchanged. (Change in state of matter)

- Three main states of matter are: Solid, Liquid, Gas
 - Solid is distinguished by a fixed structure. Its shape and volume do not change. In a solid, atoms are tightly packed together in a fixed arrangement.
 - Liquid is distinguished by its malleable shape (is able to form into the shape of its container), but constant volume. In a liquid, atoms are close together but not in a fixed arrangement.
 - Gas is made up of atoms that are separate. However, unlike solid & liquid, a gas has no fixed shape and volume.

5.3. Chemical Properties of Materials

A chemical property is any of a material's properties that becomes evident during a chemical reaction; that is, any quality that can be established only by changing a substance's chemical identity. Simply speaking, chemical properties cannot be determined just by viewing or touching the substance; the substance's internal

structure must be affected for its chemical properties to be investigated. However a catalytic property would also be a chemical property.

Chemical properties can be contrasted with physical properties, which can be discerned without changing the substance's structure. However, for many properties within the scope of physical chemistry, and other disciplines at the boundary between chemistry and physics, the distinction may be a matter of researcher's perspective. Material properties, both physical and chemical, can be viewed as supervenient; i.e., secondary to the underlying reality. Several layers of superveniency are possible.

Chemical properties can be used for building chemical classifications. They can also be useful to identify an unknown substance or to separate or purify it from other substances. Materials science will normally consider the chemical properties of a substance to guide its applications.

- **Chemical Property:** Any characteristic that gives a sample of matter the ability/inability to undergo a change that alters its composition. Examples: Alkali metals react with water; Paper's ability to burn.
- **Chemical Change:** Change in which one or more kinds of matter are transformed to new kinds of matter with altered compositions (or Chemical Reaction).

Chemical properties are any of the properties of matter that may only be observed and measured by performing a chemical change or chemical reaction. Chemical properties cannot be determined by touching or viewing a sample; the structure of the sample must be altered for the chemical properties to become apparent.

Here are some examples of chemical properties.

- reactivity with other chemicals
- toxicity
- coordination number
- flammability
- enthalpy of formation
- heat of combustion
- oxidation states
- chemical stability
- types of chemical bonds that will form

Uses of Chemical Properties

Scientists use chemical properties to predict whether a sample will participate in a chemical reaction. Chemical properties may be used to classify compounds and find applications for them. Understanding a material's chemical properties helps in its purification, separation from other chemicals or in identification in an unknown sample. Here is one way to define chemical property: Characteristics which are exhibited as one substance is chemically transformed into another. Here are some examples;

(1) iron rusting. When iron (an element, symbol = Fe) rusts, it combines in a complex fashion with oxygen to form a reddish-colored compound called ferric oxide (formula = Fe_2O_3). Not all substances rust.

(2) glucose, mixed with yeast, ferments to make alcohol. Glucose ($\text{C}_6\text{H}_{12}\text{O}_6$) is a chemical compound which enzymes in yeast can use to make ethyl alcohol ($\text{C}_2\text{H}_5\text{OH}$). Not all substances ferment.

(3) trinitrotoluene (TNT) reacts very, very fast when it is ignited. Among other products, it makes lots of nitrogen gas and lots of heat. Inside the proper container, it can cause an explosion. Not all substances can make an explosion.

There really isn't a set of chemical properties in the same way there is, more or less, a set of physical properties. That's because the chemical properties are tied to the change, whereas a given substance has a property (such as melting point) all to itself. Chemical properties describe the way a substance may change or react to form other substances. One example was given: flammability - the ability of a substance to burn in the presence of oxygen. Some substances (wood, alcohol) are very flammable, others are not. Iron reacts with oxygen, but so slowly we do not say the iron burns, but that it rusts.