S 1.1 Introduction to the particulate nature of matter

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Guiding question: How can we model the particulate nature of matter?

Standard level and higher level: 2 hours

The students should understand the following concepts from

Structure 1.1.1:

Elements are the primary constituents of matter, which cannot be chemically broken down into simpler substances. Compounds consist of atoms of different elements chemically bonded together in a fixed ratio.

Compounds consist of atoms of different elements chemically bonded together in a fixed ratio.

Mixtures contain more than one element or compound in no fixed ratio, which are not chemically bonded and so can be separated by physical methods.

Structure 1.1.2
The kinetic molecular theory is a model to explain the physical properties of matter (solids, liquids and gases) and state changes.

Structure 1.1.3
The temperature, *T*, in Kelvin (K) is a measure of average kinetic energy *E*k of particles.

Applications of the structure1.1:

Distinguish between the properties of elements, compounds and mixtures.
Distinguish the different states of matter.
Use state symbols (s,l , g and aq) in chemical equations.
Interpret observable changes in physical properties and temperature during changes of state.
Convert between values in the Celsius and Kelvin scales.

Guidance to the Students and Teachers:

Solvation, filtration, recrystallization, evaporation, distillation and paper chromatography should be covered.

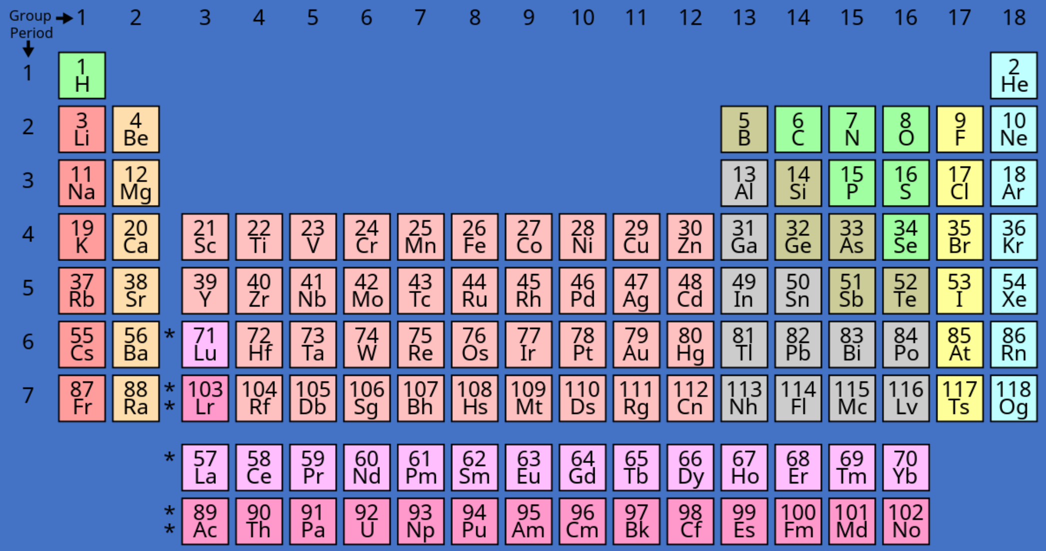
- The differences between homogeneous and heterogeneous mixtures should be understood.
- Names of the changes of state should be covered: melting, freezing, vaporization (evaporation and boiling), condensation, sublimation and deposition.
- The kelvin (K) is the SI unit of temperature and has the same incremental value as the Celsius degree (°C).

Pure Substance

Pure substance has only one type of particles.

Example: Iron(Element) and Water(Compound)

Element



It is a pure substance which contains only one type of atoms.

Example: Hydrogen, oxygen, Iron, Mercury etc.

There are about 118 elements recognized so far.

about 85% elements are Metals, rest non-metals and semi-metals.

Compound and Law of definite proportions

According to this law Atoms combine in definite ratio thus compound have definite proportion of atoms irrespective of the source of the compound.

Example Water,H_2O has 11.11% Hydrogen no matter what ever is the source of water.

In other words, hydrogen and oxygen has mass in the ratio of 1 : 8 irrespective the source of water.

Impure substance

Impure substance has two or more than two types of substances.

Example: Mixtures

The Mixture

The Mixture is the physical combination of two or more types of substances.

Example: Air is a mixture of gases, dust particles and water vapour.

Types of Mixtures

- **Homogeneous Mixture:** Homo means equal, thus such mixture contains equal distribution of particles. We cannot see particles of such mixture by naked eyes. All solutions are Homogeneous mixtures.
- **Example :** Acid solutions, Salt solution etc
- **Heterogeneous Mixture:** Hetero means unequal, such mixture contain unequal distribution of particles and we can see the particles either by naked eyes or microscope.
- **Example:** colloid and suspension

What is a solution?

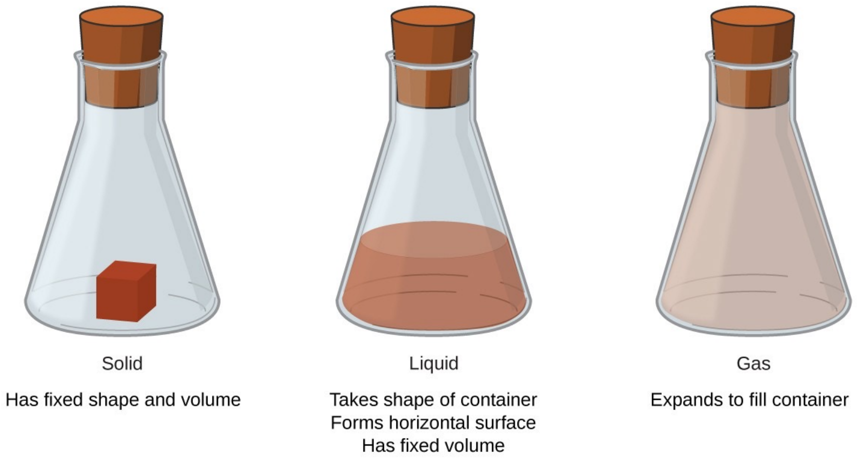
Solution is a combination of solute and solvent.

Solute: substance with smaller amount in a solution.

Solvent: substance with larger amount in a solution.

Example: If Sulphuric acid is dissolved in water, sulphuric acid is a solute and water is a solvent.

Matter



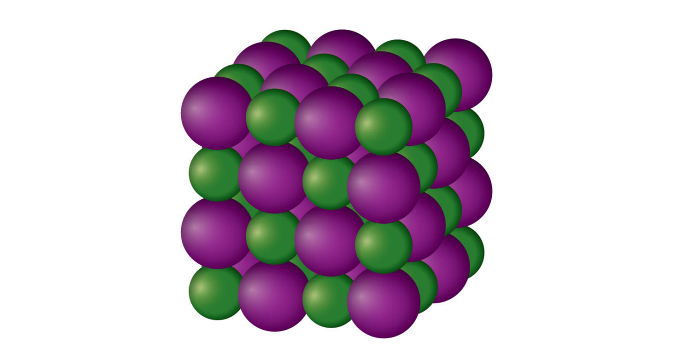
Anything which occupy space and has a mass is called matter.

Example: Air, Water, Oil, wood , Iron etc

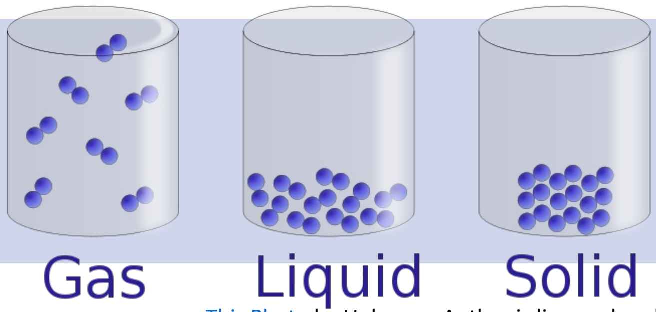
Types of matter: matter is basically of three types: Solid,Liquid,Gas

Solid

- Particles are held very close to each other in solids in a regular order and there is very little freedom of movement due to strong attractive forces between particles. As a result, Solids have definite volume and definite shape.
- Question: Write few examples of solids.
- Challenge: Is Clay solid or liquid? Why is it solid or liquid?



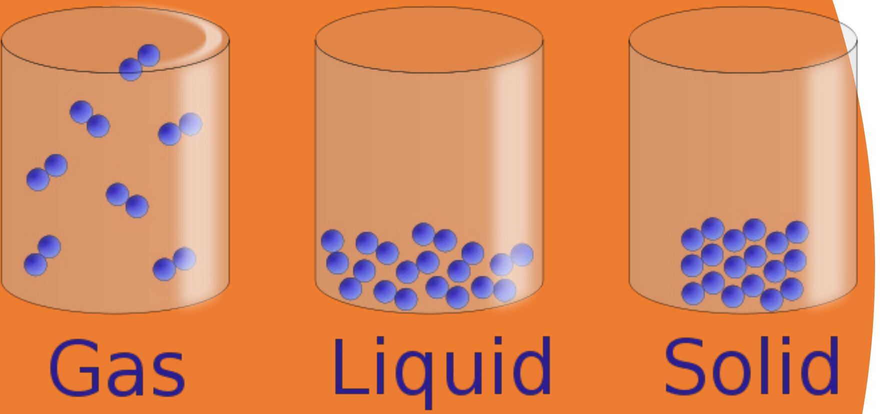
Liquid



Particles are close to each other but they can move around due to weaker attractive forces between particles compared to solid particles. As a result, Liquids have definite volume but do not have definite shape.

They acquire the shape of the container in which they are kept.

Question: Name 5 liquids. Is toothpaste a liquid?



Gas

- Particles are far apart their movement is easy and fast due to negligible attractive forces between particles. Gases have neither definite volume nor definite shape. They completely occupy the space in the container in which they are placed.
- Question: Name 5 gases.
- Challenge: Is gas or vapour same?
- Why or why not?

- Celsius and Kelvin are two temperature scales used in scientific applications. Celsius is based on a system where the freezing point of water is 0 degrees Celsius and the boiling point is 100 degrees Celsius at standard atmospheric pressure.
- Kelvin is an absolute temperature scale where the zero point is the theoretical temperature at which all molecular motion stopes, known as absolute zero.

- To convert between Celsius and Kelvin, you can use the following formulas:
- Celsius to Kelvin: K = C + 273.15
- Kelvin to Celsius: C = K - 273.15

Suppose a temperature of 25 degrees Celsius and want to convert it to Kelvin. Using the formula above, you would calculate:

$K = C + 273.15$

$K = 25 + 273.15$

$K = 298.15$ So 25 degrees Celsius is equal to 298.15 Kelvin.

Suppose you have a temperature of 400 Kelvin and want to convert it to Celsius. Using the formula above, you would calculate:

$C = K - 273.15$

$C = 400 - 273.15$

$C = 126.85$ So 400 Kelvin is equal to 126.85 degrees Celsius.

Inter-conversion of States of matter

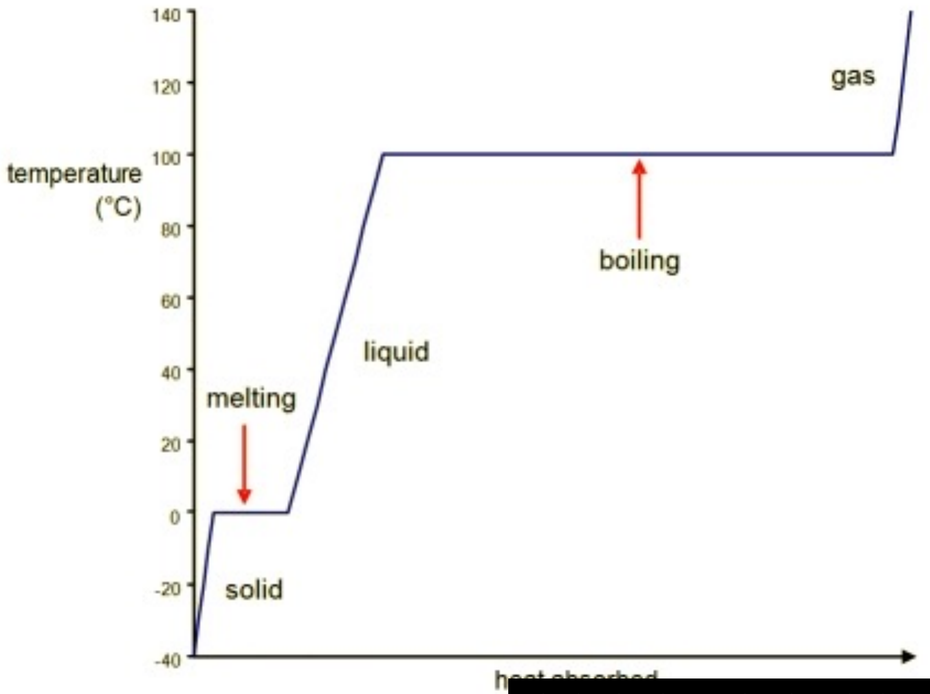
The states of matter are inter-convertible by changing the conditions of temperature and pressure.

On **heating**, a solid usually changes to a liquid, and the liquid on further heating changes to gas or vapour.

In the reverse process, a gas on cooling liquifies to a liquid and the liquid on further **cooling** freezes to the solid.

Sublimation: Sublimation is the change of solid state in to gaseous state without changing in to liquid. For example: Camphor, Ammonium chloride, Naphthaline.

Deposition: Deposition is the change of gaseous state into solid state. For Example gas deposition on water.



Dalton's atomic theory

Matter is made up of tiny particles called Atoms.

Atoms of same elements are same while atoms of different elements are different however discovery of Isotopes and Isobars proved him Wrong.

Isotope: Atoms of same elements with different number of neutrons or mass number.

Example of Isotopes: Hydrogen has three isotopes, Protium(H-1), Deuterium(H-2) and Tritium(H-3). Carbon has C-12, C-13 And C-14.

Atoms combine in fixed ratios to form compounds.

Atoms can neither be created nor destroyed. Latest discoveries proved that new elements can be created by nuclear reactions.

What is a chemical Equation?

Symbolic representation of a chemical reaction is called a chemical equation.

For example to represent the chemical reaction between Sodium metal and oxygen, the following equation is represented.

$Na + O_2 \rightarrow Na_2O$

What is a balanced chemical equation?

The chemical equation which has equal number of atoms on left hand side (reactant) and right hand side (product), is called a balanced chemical equation.

In the above equation, the number of atoms is not equal on left and right sides. So we should balance the above equation.

It is to be noted that we cannot change the formula of molecules of elements and compounds to balance. We can only use the number of moles in the front of reactants and products.

Balancing of equation

Step 1: Atom of Sodium on left side is 1 while right is 2 so we should equal the number.

$2\ Na + O_2 \rightarrow Na_2O$

Step 2: Atom of oxygen on left side is 2 while on right is 1 so we should equal this number by dividing the oxygen mole by 2 on left side.

$2\ Na + 1/2O_2 \rightarrow Na_2O$

Step 3: Lastly the states symbols should be assigned to reactants and products. Sodium is a solid metal at room temperature, Oxygen is a gas while sodium oxide is a white solid.

$2\ Na(s) + 1/2O_2(g) \rightarrow Na_2O(s)$

- **State symbols** in Chemical Equations are very key to get marks in IB diploma exams. It is not difficult to use state symbols in chemical equations. State symbols are symbols used to represent the physical state of reactants and products in a chemical equation.

- Example: White solid magnesium Oxide is formed when Magnesium metal ribbon is burned in air(oxygen gas).
- $2Mg(s) + O_2(g) \rightarrow 2\ MgO(S)$

Try to write the state symbols of the following equations

- $Ag^+ + X^- \rightarrow AgX(s)$
- $Na_2O + H_2O \rightarrow 2NaOH$
- $MgO + H_2O \rightarrow Mg(OH)_2$
- $Li_2O(s) + 2HCl \rightarrow 2LiCl + H_2O$
- $MgO + 2HCl \rightarrow MgCl_2 + H_2O$
- $P_4O_{10} + 6\ H_2O \rightarrow 4H_3PO_4$

Separating Mixtures

- Mixtures are combinations of two or more substances that are not chemically bonded

- Separating mixtures is important in various fields such as chemistry, biology, and engineering

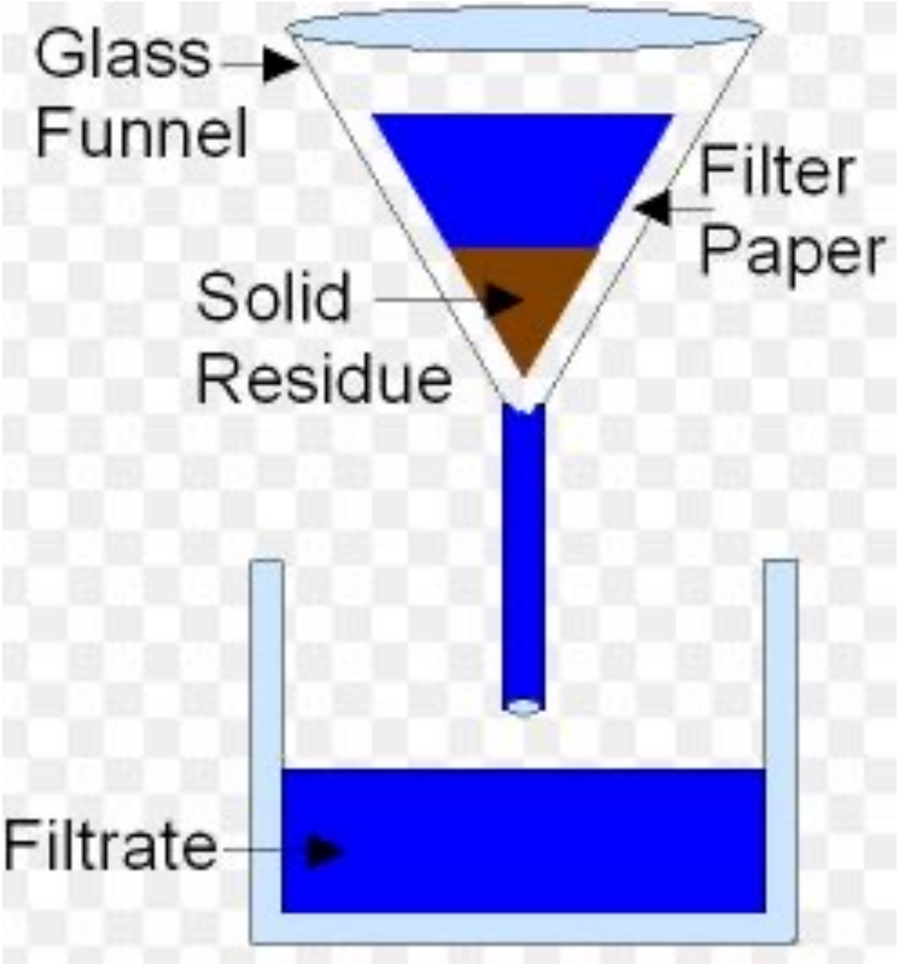
Separating Mixtures Through Solvation

Definition of solvation

- The process of dissolving a solute in a solvent to form a homogeneous solution

Use of solvation for separating mixtures

- Dissolving one component of a mixture and leaving others behind
- Example: dissolving sugar in water to separate it from other solids



Definition of filtration	The process of separating solids from liquids by passing the mixture through a filter
Use of filtration for separating mixtures	Retaining solid particles and allowing the liquid to pass through Example: filtering tea leaves from hot tea

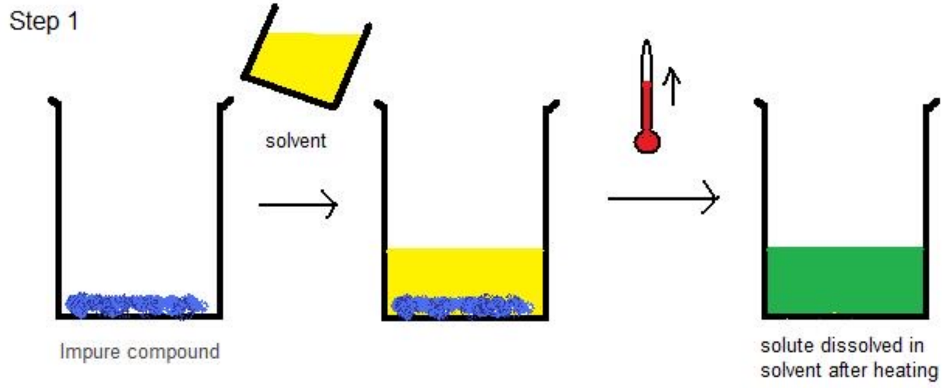
Separating Mixtures Through Recrystallization

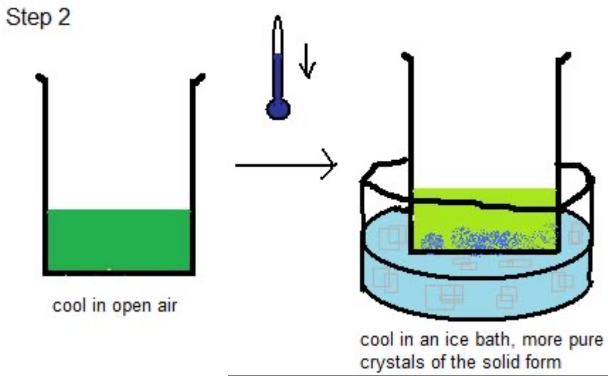
Definition of recrystallization

- The process of dissolving a solid in a hot solvent, then cooling the solution to form pure crystals

Use of recrystallization for separating mixtures

- Removing impurities from a solid
- Example: purifying table salt by dissolving it in water, then cooling the solution



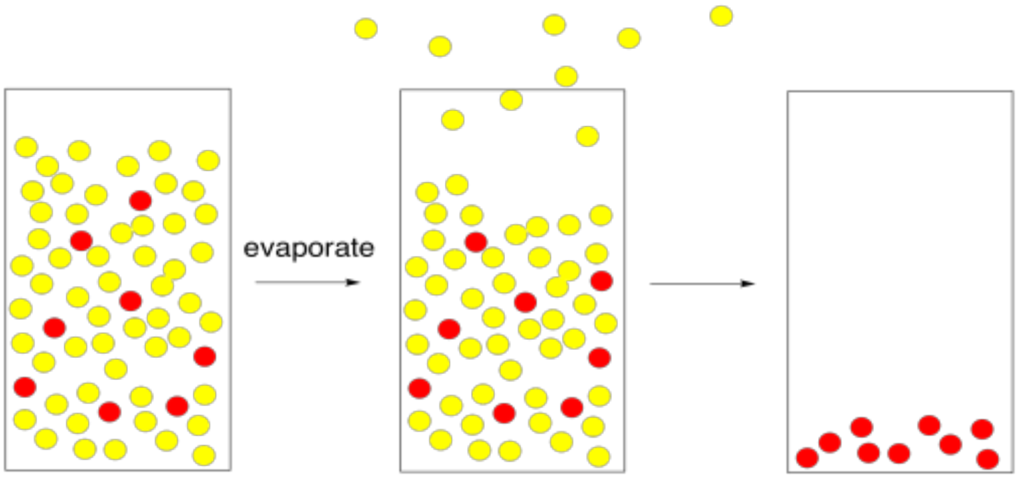


Definition of evaporation

- The process of heating a solvent to cause it to vaporize, leaving the solute behind

Use of evaporation for separating mixtures

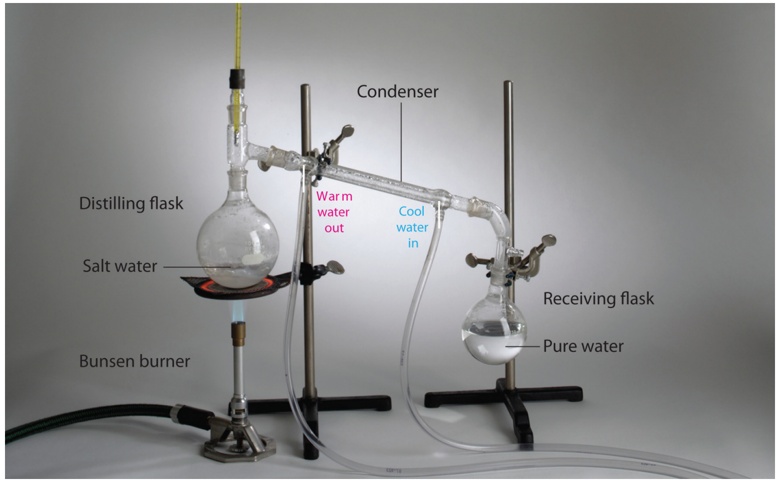
- Separating a mixture of liquids or purifying a solid
- Example: removing water from salt water to obtain pure salt

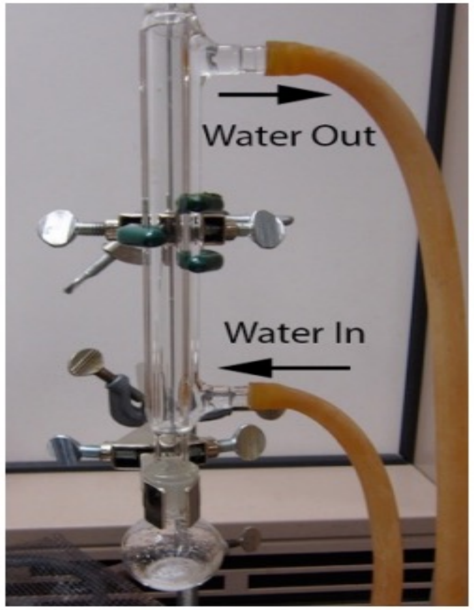


Distillation

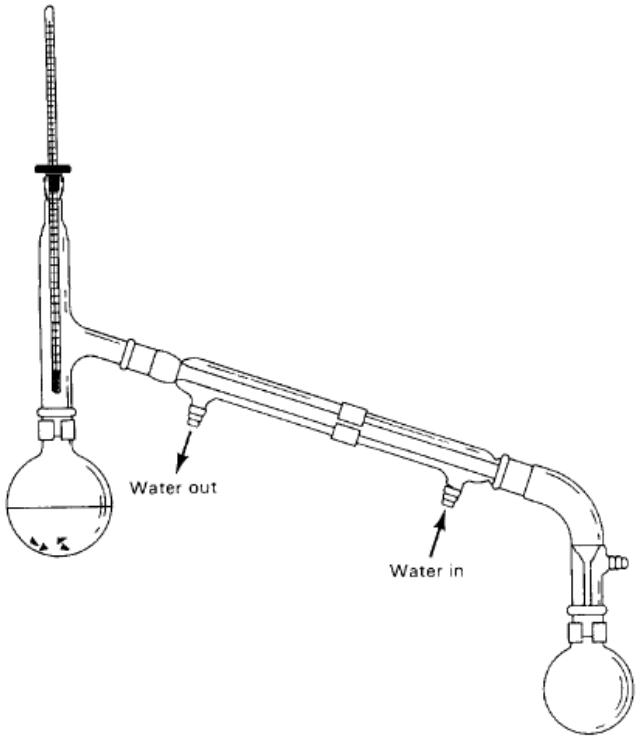
Definition of distillation: A separation process that involves heating a mixture to vaporize its components and then condensing the vapor to separate the components.

Purpose of distillation: To separate mixtures based on their boiling points.





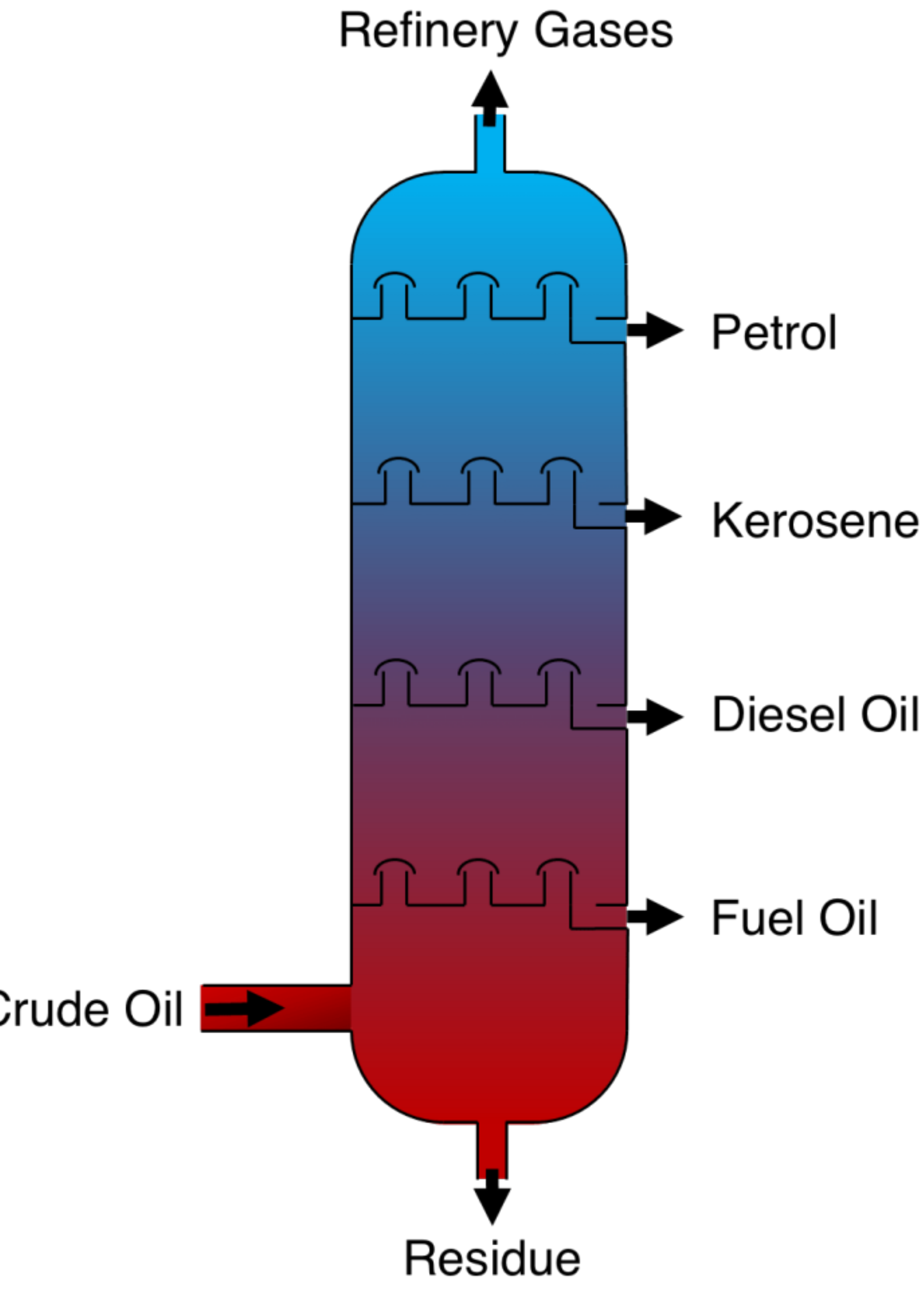
- Simple distillation
- Fractional distillation
- Vacuum distillation
- Steam distillation



Definition: The simplest form of distillation that involves heating a mixture to vaporize its components and then condensing the vapor.

Advantages: Easy to perform, inexpensive

Limitations: Not very effective for separating closely boiling components



Fractional Distillation

Definition: A more efficient form of distillation that involves repeated vaporization and condensation of a mixture to separate its components.

Advantages: Can separate closely boiling components, more efficient than simple distillation

Limitations: Requires a more complex setup, more time-consuming

Vacuum Distillation

Definition: A form of distillation that is performed under reduced pressure to lower the boiling points of the components.

Advantages: Can separate components that have high boiling points, useful for separating heat-sensitive compounds

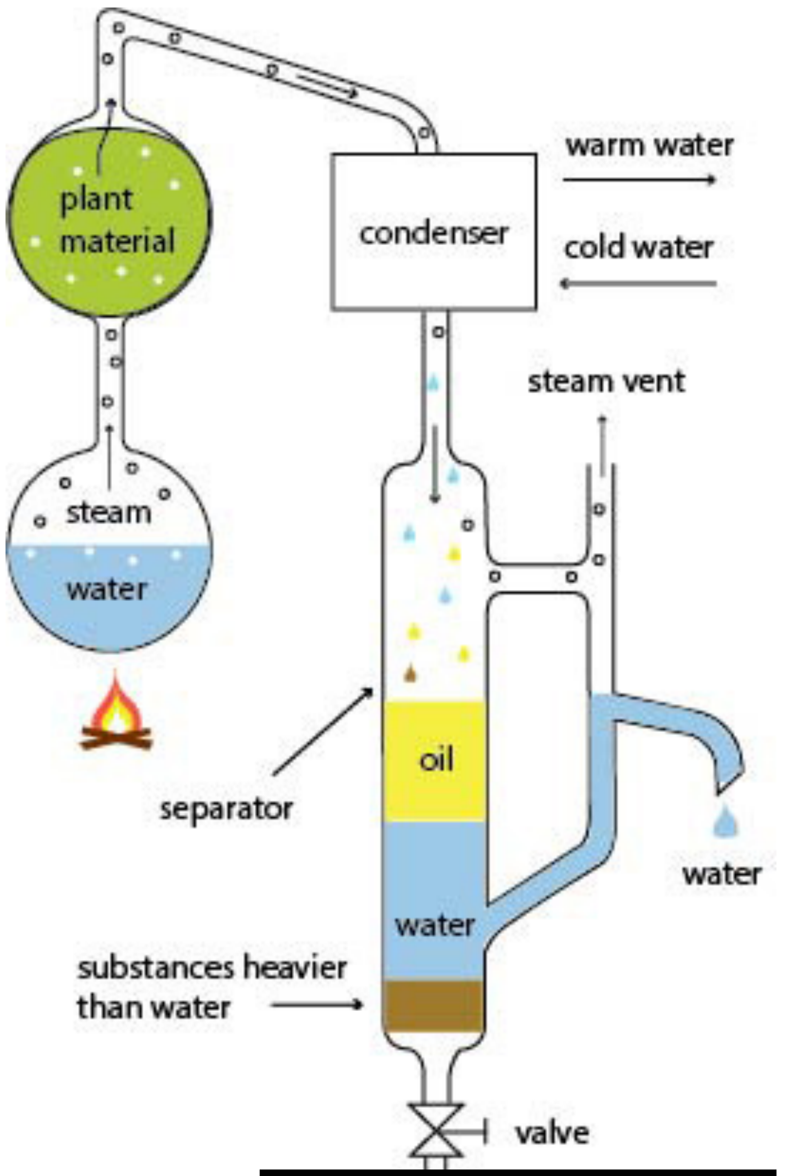
Limitations: Requires specialized equipment, more time-consuming

Steam Distillation

Definition: A form of distillation that involves using steam to vaporize the components of a mixture.

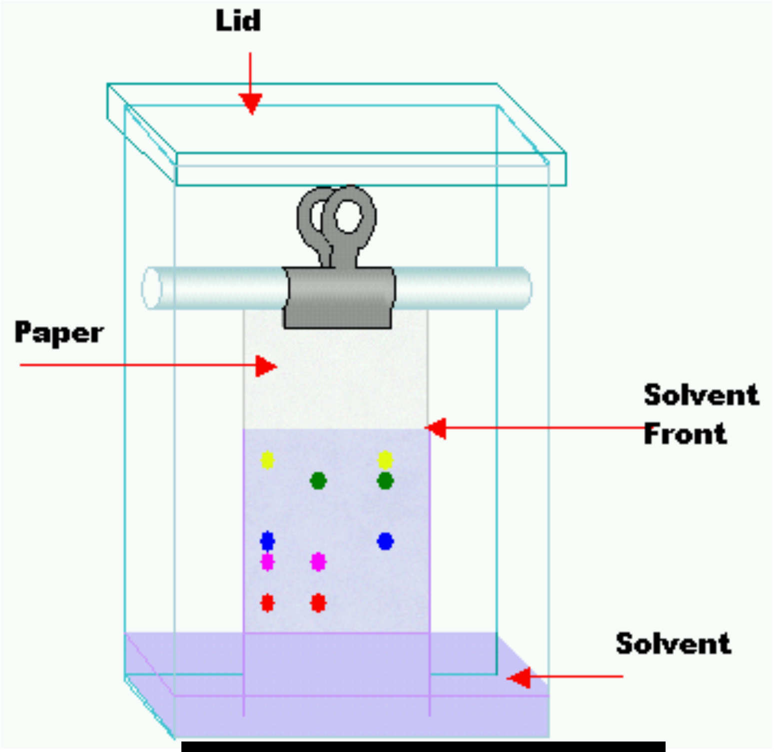
Advantages: Can separate heat-sensitive compounds, useful for separating essential oils from plant materials

Limitations: Requires specialized equipment, more time-consuming



Definition: Chromatography is a separation technique used to separate mixtures based on differences in their physical and chemical properties.

Importance: Widely used in the analysis and purification of chemical compounds and biological substances, as well as in environmental, food, and pharmaceutical testing



Rf value (Retention Factor value)

Rf value (Retention Factor value) is a term used in chromatography to quantify the distance that a component of a mixture has traveled relative to the distance traveled by the solvent front. It is calculated by dividing the distance traveled by the solute (component of interest) by the distance traveled by the solvent

Rf= the distance traveled by the solute / the distance traveled by the solvent

Types of Chromatography

Column Chromatography: Involves passing a mixture through a packed column filled with a stationary phase.

Thin Layer Chromatography (TLC): A simple and fast chromatography technique for the qualitative analysis of mixtures.

Gas Chromatography (GC): Separates volatile components in a mixture.

High-Performance Liquid Chromatography (HPLC): A high-resolution chromatography technique for the analysis of complex mixtures.

Column Chromatography

Definition: A chromatography technique where a mixture is passed through a packed column filled with a stationary phase.

Advantages: Widely used in the purification of biological and chemical substances.

Example: Commonly used in biochemistry and pharmaceutical industries.

Definition: A simple and fast chromatography technique for the qualitative analysis of mixtures.

Advantages: Easy to perform, cost-effective and fast results.

Example: Used in the food industry for food contamination analysis.

Gas Chromatography (GC)

Definition: A chromatography technique that separates volatile components in a mixture.

Advantages: Widely used for the analysis of volatile compounds.

Example: Used in the environmental industry for air and water pollution analysis.

High-Performance Liquid Chromatography (HPLC)

Definition: A high-resolution chromatography technique for the analysis of complex mixtures.

Advantages: Capable of separating complex mixtures with high resolution.

Example: Used in the pharmaceutical industry for the analysis of drug purity and quality.