THAPAR INSTITUTE
OF ENGINEERING & TECHNOLOGY
(Deemed to be University)

Mass Transfer-I

Introduction

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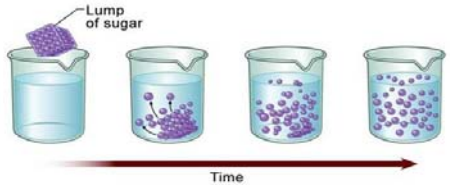
Introduction



Introduction

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Oil & Gas (Petroleum)

Edible / Essential Oils

Research Chemicals

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Need to separate

- Naturally, almost every element or compound is found in an impure state /mixture and need to purify/ refine / separate it into its individual components.
- Need for pure material in engineering application (pharmaceuticals, food, semiconductors, etc.)
- Need for pure material in chemicals production and preparation of raw materials into their components
- Need to remove toxins or inactive components from solution (drugs, food, etc.)
- Need for ultrapure samples for testing (standards, analysis, etc.)
- Need to purify water for drinking use
- A typical chemical plant is a chemical reactor surrounded by separators.
- Chemical plants commonly have 50-90% of their capital invested in separation equipment.

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Cont…

- Separation of desired material/substances from homogeneous and heterogeneous **mixtures**
- To remove unwanted dirt/material/components/ particles
- Purification of raw materials and products
- Recovery of by-products
- Recycling of solvents and unconverted reactants
- Removal of contaminants from effluents

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Mixture *vs* Solution

Mixture	Solution
• In a mixture, substances are generally just mixed and are not completely dissolved.	• In a solution, substances are dissolved completely and they cannot be filtered out.
• Mixture contains two or more substances, which are not chemically combined. They only have physical interactions.	• A solution contains two substances that are chemically mixed to form a new compound.
• The chemical properties of each substances are retained without change.	• Chemical properties usually changes.
• The amount of substances in a mixture can vary and amounts don't have a fixed ratio.	• A solution usually has a fixed ratio or amount of substances.
• Mixtures can be mainly divided into two types such as homogenous mixtures and heterogeneous mixtures.	• A solution is a type of a homogeneous mixture.

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Types of Mixtures/ Solutions

Type of mixtures	Homogeneous /Heterogeneous	Examples
Solid - Solid	Homogeneous	Alloys, e.g., brass (zinc +copper), bronze (zinc + tin + copper)
	Heterogeneous	Soil (mixture of various solid particles), mixture of grains (wheat+ pea+ gram, etc.)
Solid – Liquid (solid in liquid)	Homogeneous	Lassi, lemon soda, sweet milk, etc.
	Heterogeneous	Mud (soil + water), Beach sand (sand + water), etc.
Liquid –Solid (liquid in solid)	Homogeneous	Hydrated salts, Amalgam of Hg in Sodium, Gels, etc.
Liquid – Liquid	Homogeneous	Petroleum, Petrol, Diesel, Essential oils, Alcohol + water, etc.
	Heterogeneous	Water + oil,
Gas – Gas	Homogeneous	Air
Gas – Liquid	Homogeneous	Carbon dioxide in water, ammonia in water, etc.

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Cont…

Mixing is inherent in nature

The increase in entropy associated with the randomness of a mixture lowers the Gibbs free energy.

Therefore,
To "unmixed" a solution we must overcome the entropic driving force to "mix"

Why Separate?

There are many reasons for wanting pure substances. Some of these reasons include:

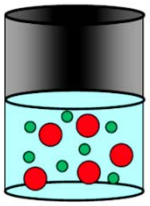
- **Need for pure material in engineering application (semiconductors)**
- **Need for pure material in chemicals production (reactors)**
- **Preparation of raw materials into their components**
- **Need to remove toxins or inactive components from solution (drugs)**
- **Need for ultrapure samples for testing**
- **Need to purify water for drinking use**

→

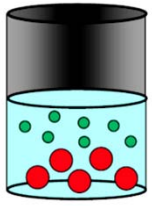
- ✓**Enrichment**
- ✓**Concentration**
- ✓**Purification**
- ✓**Refining**
- ✓**Isolation**

Separation Processes

THE GOAL OF A SEPARATION IS TO PURIFY SOLUTIONS
Separations are important to chemist & chemical engineers



mixed



separated

Historical Examples:

Extract perfume from flowers
Evaporate seawater to get salt
Distill liquors
Purification of drugs
Kidney of human beings is like membrane
Refining of crude oil
Purification of organics

Most separation process involve differential transport of species or conservation of species

Cont…

Separations are important to chemist & chemical engineers

• Analytical separation • Small scale production • Quantitative analysis	CHEMISTS	• Preparative Separations • Small scale materials • Research & Development
Example: Chromatography		Examples: Centrifugation

CHEMICAL ENGINEERING

- Industrial separations
- Large scale production
- Economical
- Quality control

Examples:
Distillation

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Available separation techniques

Phase Creation	Use energy separating agent ESA (heat or depressurize)	**Most Common**
Phase Addition	Use mass separating agent MSA (add solvent or absorber)	
Barrier Separation	Use membrane (semipermeable membrane)	**Gaining popularity**
Solid Agent separations	Use particles (reaction, absorbent film, direct absorption, chromatography)	
Separation by gradient	Use electric field, magnetic field, gravity (Hall effect, electrophoresis, mass spec)	**Lab-scale**

The list of different existing separations methods is limitless. Therefore we will emphasize the fundamentals of separations.

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Basic description of operations

- Separations processes can be run in various **modes of operation**
  - **Batchwise:** no flows
  - **Continuous:** continuous flows in and out of separators
  - **Semi-continuous:** pauses in flows.

Operations are classified as key operations and auxiliary operations

Key Operation: involves reaction or separations

Examples: Distillation, Leaching, Reactor

Auxiliary Operation: involves no change in chemical composition

Examples: Pumps, Heaters, Compressors

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Achieving separations

Enhancing the mass transfer rate of certain species

- **Rate of Separation:**

  How fast ?

  Governed by **Mass Transfer (Rate-controlled separation)**

- **Extent of Separation:**

  How far ?

  Limited by **Thermodynamics (Equilibrium-staged separation)**

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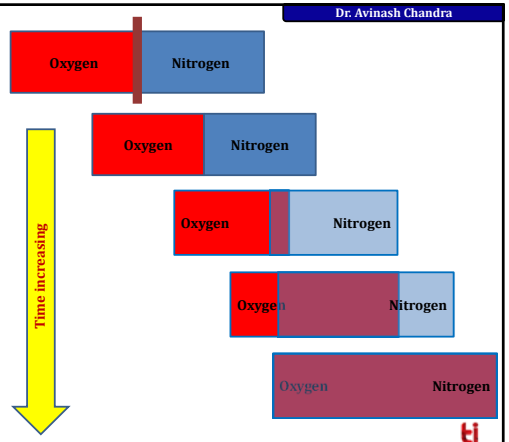
Example

- Consider a tank that is divided into two equal parts by a partition.
- Initially, the left half of the tank contains nitrogen N_2 gas while the right half contains O_2 at the same temperature and pressure.
- When the partition is removed the N_2 molecules will start diffusing into the air while the O_2 molecules diffuse into the N_2.
- If we wait long enough, we will have a homogeneous mixture of N_2 and O_2 in the tank.



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Mass Transfer

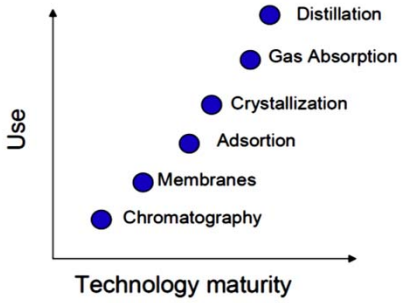
Motivation

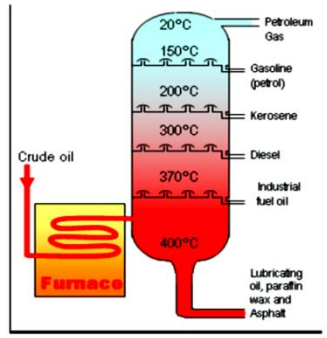
In many industrial processes we use mass transfer to achieve **separation** (enrichment or removal) of a substance from a mixture

Mass Transfer Operations

- It deals with **"unit operations"** involving **"mass transfer" (a microscopic process in a macroscopic scale)**
- Within the context of this course, mass transfer is defined as the transportation of one (or more) component from one phase to another

- Emphasis is placed on separation processes that involve **equilibrium between the phases.**
- Mass transfer operations are concerned with **the analysis and design of the equipment and process**





Why this course is useful?

Mass transfer operations is largely the responsibility of chemical engineers

Chemical plants usually have from 50 to 90% of their capital invested in separation equipment

There is virtually no industrial process that does not involve purification of raw materials or final separation of products

Approximately three quarters of Chemical Engineering Graduates will find employment in industries where mass transfer operations play a critical role.

References

ETH
Mass Transfer
Theories for Mass Transfer Coefficients
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