Heat and Mass Transfer (DI05019071)

Complete Lecture Deck

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Modes of Mass Transfer

- Course: Heat and Mass Transfer (DI05019071)
- Unit 5: Mass Transfer
- Lecture 41: Modes of Mass Transfer

Lecture Agenda

- 1. Introduction to Mass Transfer
- 2. Driving Force for Mass Transfer
- 3. Everyday Examples
- 4. Molecular Diffusion
- 5. Convective Mass Transfer
- 6. Analogy between Heat and Mass Transfer

What is Mass Transfer?

- Mass transfer is the net movement of mass from one location, usually meaning a stream, phase, fraction or component, to another.
- It occurs in mixtures containing two or more chemical species.
- Mass transfer occurs whenever there is a difference in the concentration of a species in a mixture.

The Driving Force for Mass Transfer

- The driving force for heat transfer is a temperature gradient.
- The driving force for mass transfer is a **concentration gradient**.
- Species in a mixture will naturally move from a region of higher concentration to a region of lower concentration.
- The system tends to reach a state of equilibrium where concentration is uniform.

Everyday Examples of Mass Transfer

- Dissolving sugar in a cup of coffee.
- Drying of wet clothes (water evaporating into the air).
- Spreading of a perfume scent in a room.
- Oxygen dissolving into blood in the lungs.
- Sweating to cool the human body.

Modes of Mass Transfer: Overview

- Similar to heat transfer, mass transfer can occur in different modes:
- 1. **Molecular Diffusion**: Mass transfer by random molecular motion in a stagnant fluid or solid.
- 2. **Convective Mass Transfer**: Mass transfer between a boundary surface and a moving fluid or between two immiscible moving fluids.

Molecular Diffusion

- Analogous to heat conduction.
- Occurs in stationary fluids (gases and liquids) or solid mediums.
- Transport occurs due to the random thermal motion of molecules.
- Governed by Fick's Law of Diffusion.

Convective Mass Transfer

- Analogous to heat convection.
- Involves the transport of mass between a boundary surface (solid or liquid) and a moving fluid.
- Relies on the bulk motion of the fluid.
- Can be classified into:
- - Free (natural) convective mass transfer
- - Forced convective mass transfer

Analogy between Heat and Mass Transfer

- Many mass transfer concepts can be mapped directly to heat transfer:
- **Heat Transfer** — **Mass Transfer**
- Temperature Gradient (dT/dx) — Concentration Gradient (dC/dx)
- Heat Conduction — Molecular Diffusion
- Heat Convection — Convective Mass Transfer
- Fourier's Law — Fick's Law
- Thermal Conductivity (k) — Diffusion Coefficient (D)

Key Differences

- Despite the strong analogy, there are key differences:
- 1. No mass transfer equivalent to thermal radiation.
- 2. Mass transfer strictly requires a mixture; heat transfer can occur in a pure substance.
- 3. High rates of mass transfer can induce a velocity at the fluid-solid boundary, altering the flow field (unlike heat transfer where the boundary is impermeable).

Summary

- Mass transfer is driven by a concentration gradient.
- The two main modes are molecular diffusion (analogous to conduction) and convective mass transfer (analogous to convection).
- Molecular diffusion relies on random microscopic motion, whereas convective mass transfer relies on bulk fluid flow.
- The heat and mass transfer analogy provides a strong foundation for understanding mass transfer equations.

Next Lecture Preview

- Topic: Concentrations, Velocities, and Fluxes
- Key questions to ponder:
- - How do we mathematically define the concentration of a mixture?
- - What is the difference between mass concentration and molar concentration?
- - How do we define the average velocity of a mixture where different species are moving at different speeds?