CHE 318 Lecture 01

Introduction and Diffusion Laws

Dr. Tian Tian

2026-01-05

Land Acknowledgement

The University of Alberta acknowledges that we are located on Treaty 6 territory, and respects the histories, languages, and cultures of the First Nations, Métis, Inuit, and all First Peoples of Canada, whose presence continues to enrich our vibrant community.

Learning Outcomes

After today's lecture, you will be able to:

- **Identify** the key components of the course syllabus, content and grading schemes.
- **Recall** common interaction methods and resources available in the course.
- **Define** basic concepts in mass transfer, including concentration, mass fraction, and molar flux.
- **State** Fick's First Law of Diffusion and **identify** its components and units
- **Describe** the general shape of solutions for stationary Fick's Law.

Course Information

- **Course:** CH E 318 – Mass Transfer
- **Term:** Winter 2026
- **Lectures:** Mon, Wed, Fri
- **Time:** 10:00 – 10:50
- **Location:** MEC 3-1

Meet the Instructor

- **Office**: DICE 12-245
- **Email**: tian.tian@ualberta.ca
- **Office hour**: by appointment (will send survey in Canvas)
  - *Updated:* office hour will now be Wednesday 11:15 - 12:15 at DICE 12-245
- I joined CME in 2025. CHE 318 is my first course at UofA
- Research fields: machine learning, multiscale materials simulations, computational tools
- Let's enjoy learning together!

TAs & Seminar Sessions

- **Teaching Assistants**
  - Ethan Lockwood — elockwoo@ualberta.ca
  - Prince (Nkenna) Ezeano — ezeano@ualberta.ca
- **Seminar (Lab) Session**
  - **Time:** Tuesday 15:30 – 17:20
  - **Location:** MEC 4-3
- **What seminars are for**
  - Problem-solving practice
  - Worked examples and discussion
  - Concept clarification and Q&A

Course Grading

- **Assignments:** 25%
  - 8 total (best 7 counted)
  - Deadlines to be posted on Canvas.
- **Midterm Exam:** 30%
  - In class (**50 min**), closed book
  - Time to be determined by end of Janurary 2026
- **Final Exam:** 45%

- In person
- Scheduled **Apr 15, 2026 · 8:30 a.m.**

Details please see the course syllabus

Textbook

Our primary textbook for this course is:

- **Christie J. Geankoplis.** *Transport Processes and Separation Process Principles (Includes Unit Operations), 4th Edition*

What do Mass Transfer Study (1)?

Scent diffuser:

$$J = -D\nabla C$$

What do Mass Transfer Study (2)?

Thin-membrane gas exchange:

$$N_A = D_A \frac{C_{A,1} - C_{A,2}}{\delta}$$

What do Mass Transfer Study (3)?

Packed tower:

$$N_A = K_y(y_{AG} - y_A^*)$$

What do Mass Transfer Study (4)?

Manhattan project (U^{235} enrichment) :

$$D \propto 1/\sqrt{M}$$

Let's Get to Know You!

We will use Wooclap in this course!

Participation link: https://app.wooclap.com/318L01?from=instruction-slide

Results to be published after the class

Basic Quantities and Their Units in Mass Transfer (1)

We will only deal with **SI units** in this course!

- (Molar) Concentraion of A: c_A
  - Unit: $\text{mol} \cdot \text{m}^{-3}$ or $\text{kg mol} \cdot \text{m}^{-3}$
  - Total concentration: $c_T = \sum_i c_i = c_A + c_B + \cdots$
- Molar fraction of A: $x_A = \dfrac{c_A}{c_T}$
- Molar ratio (or binary mixture): $Y_A = \dfrac{x_A}{x_B} = \dfrac{x_A}{1 - y_x}$
  - For ideal gas: $x_A = \dfrac{p_A}{p_T}$ (partial pressure of A and total pressure, respectively)

Basic Quantities and Their Units in Mass Transfer (2)

- Mass concentraion of A: ρ_A -Unit: $\text{kg} \cdot \text{m}^{-3}$
  - Total mass concentration $\rho_T = \sum_i \rho_i = \rho_A + \rho_B + \cdots$
  - $c_i = \dfrac{\rho_i}{m_i}$ (m_i: molecular weightunit $\text{kg} \cdot \text{kg mol}^{-1}$ **Non-SI!**)
- Mass fraction of A: $w_A = \dfrac{\rho_A}{\rho_T}$, $\sum_i w_i = 1$
- For *chemists* in this class, engineering unit kg mol = kmol = 1000 mol

Introduction to Molecular Transport Equations (1)

[1]

$$[\text{rate of transfer process}] = \frac{[\text{driving force}]}{[\text{resistance}]}$$

[1] *Geankoplis 4ed, eq 2.3-1*

Introduction to Molecular Transport Equations (2)

The governing equation for transport phenomena can also be written as

$$\psi_z = -\delta \frac{d\Gamma}{dz}$$

Properties Γ to be transferred:

- Momentum (fluid mechanics)
- Heat (thermodynamics / heat transfer)
- **Species** (**mass transfer**)

Introduction to Molecular Transport Equations (3)

Units:

- Flux (ψ_z): $[\text{property}] \cdot \text{m}^{-2} \cdot \text{s}^{-1}$
- Concentration of property Γ: $[\text{property}] \cdot \text{m}^{-3}$
- What is the unit of coefficient δ?: $\text{m}^2 \cdot s^{-1}$
- Why is there a **negative** sign before δ¿‘: to match the sign of the flux

Fick's First Law of Diffusion

The flux due to diffusion is described in Fick's first law (more details next lecture).

- Original form:

$$J^*_{Az} = -D_{AB} \frac{dc_A}{dz}$$

- In molar fraction:

$$J^*_{Az} = -c_T D_{AB} \frac{dx_A}{dz}$$

- For ideal gas ($p_A = c_A RT$)

$$J^*_{Az} = -D_{AB} \frac{1}{RT} \frac{dp_A}{dz}$$

Fick's First Law in Velocity Term

The flux can also be written using velocity terms:

- Diffusive velocity:

$$J^*_{Az} = v_{Ad}\bar{c}_A$$

  - v_{Ad}: diffusive velocity of A ($\mathrm{m \cdot s^{-1}}$)
  - $\bar{c}_A$: average concentration of A ($\mathrm{mol \cdot m^{-3}}$)
  - Which reference frame is used?

Combining Diffusion and Convection

- Real-world mass transfer scenarios have diffusion + convection
- Using a lab frame, the total mass transfer flux can be written in diffusive + fluid velocities

The **total molar flux** of species A, N_A, can be expressed as:

$$N_A = J^*_{Az} + c_A v_m$$

- N_A is the **total** molar flux of A ($\mathrm{mol \cdot m^{-2} \cdot s^{-1}}$)
- J^*_{Az} is the **diffusive** molar flux of A relative to the molar average velocity ($\mathrm{mol \cdot m^{-2} \cdot s^{-1}}$)
- c_A is the molar concentration of A ($\mathrm{mol \cdot m^{-3}}$)
- v_m is the average velocity of the mixture ($\mathrm{m \cdot s^{-1}}$)

Governing Equation: Diffusion + Convection

For **binary mixture** of A and B, we have total flux for 2 components N:

$$N = N_A + N_B = v_m c_T = v_m(c_A + c_B)$$

Substituting v_m we get

$$N_A = J^*_{Az} + \frac{c_A}{c_T}(N_A + N_B)$$

which further rewrites to

$$N_A = -c_T D_{AB}\frac{dx_A}{dz} + \frac{c_A}{c_T}(N_A + N_B)$$

This is the **governing equation** for all steady-state mass transfer in the following lectures!

Brief Introduction to Course AI Helper

- A Socratic Gemini chatbot aiming to help course learning and key concepts
- **Access the AI helper here:** https://gemini.google.com/gem/f2d47200f0bf

Summary

What we learned today:

- Syllabus / course contents of CHE 318
- Basic concepts in mass transfer
- Fick's 1st law of diffusion
- Governing equation of mass transfer

See you next time!