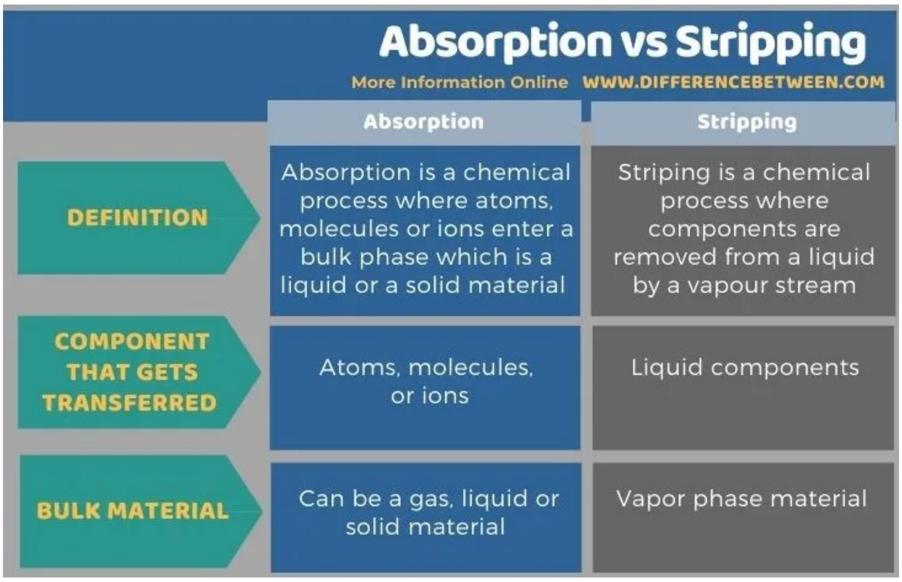
Swati Neogi Mam Qs

1. **Asked to draw qualitatively the operating line and the equilibrium line in gas absorption process.**
   Ans: slope of operating line = Ls/Gs (solute free basis flow rate), above the equilibrium curve

2. **Difference between absorption and stripping.**



Absorption vs Stripping

More Information Online WWW.DIFFERENCEBETWEEN.COM

	Absorption	Stripping
DEFINITION	Absorption is a chemical process where atoms, molecules or ions enter a bulk phase which is a liquid or a solid material	Striping is a chemical process where components are removed from a liquid by a vapour stream
COMPONENT THAT GETS TRANSFERRED	Atoms, molecules, or ions	Liquid components
BULK MATERIAL	Can be a gas, liquid or solid material	Vapor phase material

3. **All Dimensionless No.s Derivation & Significance.**

   For Dimensionless Numbers :-

1. List of All Important Dimensionless Numbers and Their Significance
2. Dimensionless Numbers in Chemical Engineering

- ***Nusselt No.***: Ratio of convective to conductive heat transfer at a boundary in a fluid
  - **Formula:** $Nu_L = \frac{Convective\ Heat\ Transfer}{Conductive\ Heat\ Transfer} = \frac{h}{k/L} = \frac{hL}{k}$
    - h: Convective Heat Transfer Coefficient
    - L: Characteristic length
    - K: Thermal conductivity
  - **Ranges & Meaning:**

    - **Nu=1 =>** Pure Conduction
    - **1<Nu<10: =>** Laminar/Slug Flow
    - **10<Nu<100: =>** Active convection with turbulence
  - Emperical Correlations:
    - Free Convection: $Nu = f(Ra, Pr)$
    - Forced Convection: $Nu = f(Re, Pr)$
- ***Biot No.:*** Ratio of conductive thermal resistances to convective ones at the surface of the body. Defined for solids.
  - Formula: $Bi = \frac{hL}{k}$
    - h & k: same as Nu no,
    - $L = \frac{V}{A_Q}$ Charateristic Length
  - **Ranges & Meaning**
    - **Bi<0.1 =>** Heat conduction inside the body is much faster than heat convection away from its surface. Temperature can be assumed constant across the surface of the body.
- ***Prandtl No.:*** Ratio of momentum diffusivity to thermal diffusivity
  - **Formula:** $Pr = \frac{\nu}{\alpha} = \frac{\mu/\rho}{k/(c_p \rho)} = \frac{c_p \mu}{k}$
    - μ: Dynamic Viscosity ($Pa\, s = N\, s/m^2$)
    - k: Thermal Conductivity ($W/(m \cdot K)$)
    - c_p: Specific heat ($J/(kg \cdot K)$)
  - **Significance:**
    - Helps us in comparing heat transfer through heat diffusion (conduction) Vs. Mass Diffusion (Convection)
    - It controls the relative thickness of the momentum and thermal boundary layers.in heat transfer problems.
  - **Ranges & Meaning**
    - **Pr<<1:** Thermal diffusivity (Conduction) Dominates. Thermal boundary layer >> velocity boundary layer
      - Eg- Liquid Metals
    - **Pr>>1:** Mass Diffusivity (Convection) Dominates
      - Eg- Oils
    - **Pr=1** Both thermal & mass diffusivity are significant
- ***Schmidt No.:*** Its the ratio of momentum diffusivity and mass diffusivity
  - **Formula:** $Sc = \frac{Kinematic\ Viscosity}{Mass\ Diffusivity} = \frac{\nu}{D_{AB}} = \frac{\mu}{\rho D_{AB}}$

        - ν: Kinematic Viscosity (m^2/s)
        - D: Mass Diffusivity (m^2/s)
    - **Significance:**
        - Prandtl No. Analogy for Mass Transfer
        - Gives ratio of fluid and mass transfer boundary layers
        - Used for fluids with Mass & Momentum diffusion
- ***Lewis No.:*** Ratio of thermal diffusivity to mass diffusivity.
    - **Formula:** $Le = \frac{\alpha}{D_{AB}} = \frac{k}{\rho C_P D_{AB}} = \frac{Sc}{Pr}$
    - **Significance:**
        - It is also the ratio of Schmidt number to Prandtl number.
        - Fluid flow with simultaneous Heat & mass transfer by convection.
    - **Range & Meaning:** Puts thickness of the thermal boundary in relation to the concentration boundary layer.
- ***Sherwood No.:*** Ratio of convective Mass transfer to the rate of diffusive mass transport
    - **Formula:**

$$Sh = \frac{h}{D/L} = \frac{Convective\ Mass\ Transfer\ Rate}{Diffusion\ Rate}$$

- ***Grashof No.:*** Ratio of buoyancy to the viscous force acting on a fluid.
    - **Formula:** $Gr_L = \frac{g\beta(T_S - T_\infty)L^3}{\nu^2}$ OR

$$Gr_L = \frac{g\beta(T_S - T_\infty)D^3}{\nu^2}$$

        - g: Gravtiational acceleration
        - β: Coefficient of thermal expansion
        - T_s: Surface Temp. | T_∞: Bulk Temperature
        - ν: Kinematic Viscosity
        - $L\ (Flat\ Plates)$: Vertical Length
        - $D\ (Pipes)$: Diameter
    - **Significance:** It plays a role similar to Reynold's no. for natural convection. High values implies forced convection while low values imply natural convection
    - **Ranges & Meaning:**
        - Vertical Plates:
            - **Gr>109 =>** Forced Convection
            - **Gr<109 =>** Natural Convection
- ***Peclet Number:*** Ratio of heat transported by convection to Heat transported by conduction.

- **Formula**
  - $Pe = Re * Pr$ for Heat Transfer
  - $Pe = Re * Sc$ for Mass Transfer

4. **Difference between Biot number and Nusselt number.**

   Biot number provides a measure of the temperature drop in the solid relative to the temperature difference between the solid's surface and the fluid. It is the ratio of Conductive resistance by convective resistance.

   Bi = hL/k.

   Nusselt Number is the dimensionless temperature gradient at the surface, and it provides a measure of the convection heat transfer occurring at the surface.

   Nu = hL/kf

   K in Biot's number is that of the solid medium.
   K_f in Nusselt number is that of the fluid medium.

5. **Nusselt No. value when the spherical solid particle is surrounded by quiescent fluid.**

6. **Pradntl No. for air.**
   Ans : 0.7

7. **Which dimensionless no is used for simultaneous heat and mass transfer?**

   Lewis Number

8. **What is Lewis Number?**
   Ans: Le=thermal diffusivity/mass diffusivity = (k/pho*Cp)/(Dab)

9. **What is the basic law of mass transfer? Write its expression.**

10. **Analogy among Momentum, Heat and Mass Transfer**
    Ans: Fick's law of diffusion is analogous to Fourier's law of heat conduction in Heat and Newton's law of viscosity in Momentum.

$$J_A = -D_{AB}\frac{dC_A}{dz} \quad q_z = -k\frac{dT}{dz} \quad \tau_{zx} = -\mu\frac{du_x}{dz}$$

11. **Explain how Mass diffusivity is the analogy to Thermal diffusivity.**

    Ans : Mass diff. =Dab, Thermal diff. = k/rho*Cp

As per 1st Fick's Law, J=-D(dC/dz) and q=-(k/rho*Cp)*(d(rho*Cp*T)/dx) as per Fourier's Law

12. **Shell & Tube Heat exchanger**

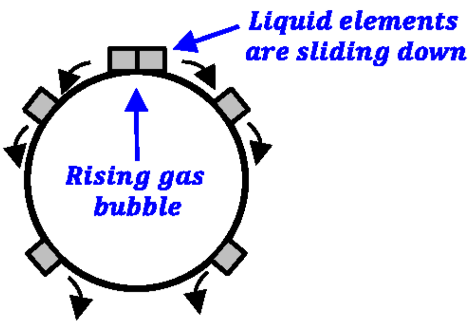
13. **What is the use of Stefan Tube?**

Ans: To find diffusivity in gas phase. The volatile liquid is kept at the bottom of the pool and evaporates, over the top of which a gas flows

14. **What are the various theories of mass transfer? What were the model parameters in each theory?**
https://www.intechopen.com/chapters/48887
    - **<u>Film Theory:</u>** It considers the resistance to mass transfer in a given turbulent fluid phase is present in a thin layer adjacent to the interface that is called a film. Beyond this thin layer, the concentration is homogenous.
        - So the Mass transfer coefficient is proportional to

$$K_L = \frac{D_{AB}}{\delta}$$

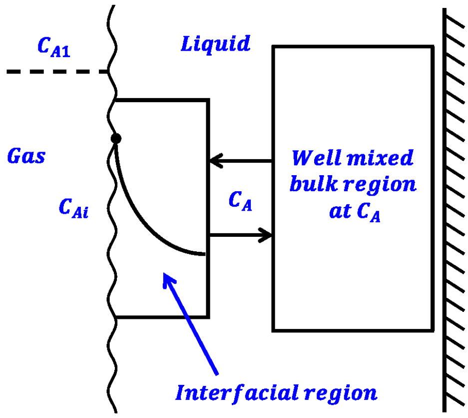
        - **<u>Assumptions:</u>**
            - Mass Transfer occurs by molecular diffusion through the film beyond which the concentration is homogenous.
            - The mass transfer through the film occurs under steady state conditions
            - The flux is small and the mass transfer occurs at low concentration.
    - ***<u>Penetration Theory:</u>*** It assumes that each liquid element at the gas-liquid interface is exposed to the gas for a short time. It expresses the liquid-side mass transfer coefficient in terms of the contact time (θ) and the molecular diffusivity



$$k_L = 2\left(\frac{D_{AB}}{\pi\theta}\right)^{0.5}$$

        - **<u>Assumptions</u>**
            - Mass transfer from gas-liquid occurs under unsteady-state once in contact
            - Each of the liquid elements stays in contact with the gas for the same time period
            - Equilibrium exists at the gas-liquid interface.

- ***Surface Renewal Theory:*** The liquid is pictured as two regions, a large well mixed bulk region and an interfacial region, which is renewed so fast that it behaves as a thick film.
    - **Assumptions**
        - Liquid elements at the interface are being randomly swapped by fresh elements of the bulk
        - At any moment, each of the liquid elements at the interface has the same probability of being substituted by a fresh element.
        - Mass transfer from the gas into the liquid element during its stay at the interface takes place under unsteady-state conditions.



$$k_L = (D_{AB})^{0.5}$$

Ans: 1. Film Theory: steady-state, m.t.c proportional to Dab/thickness of the film
2. Penetration theory: unsteady state, Kc proportional to sqrt(Dab)
3. Surface renewal: unsteady state,Kc prop. To Dab^.5 *(surface renewal freq)^.5
4. Boundary layer theory: flow on flat plate, m.t.c prop. To Dab^2/3

15. Different ways of representing mass fluxes in different frames of references

a. **Ans:** i(mass avg. vel.), j(molar avg. vel.) and n(stationary)

16. How will you define molar flux J? How does it varies with different frames of reference?

Ans Ji=ci(ui-U), molar diffusion flux

17. **Molar flux formula for multi-component mixture.**
Ans. Ji = Ni - (Ci/C) * ΣCi

18. **What are the conditions which make Dab= Dba relation valid?**
    a. **Ans:** Ideal solutions, closed system, constant concentration(i.e. c=ca+cb is constant)

19. **W = K* Driving force. Is this valid for all mass transfer processes?**
    a. yes

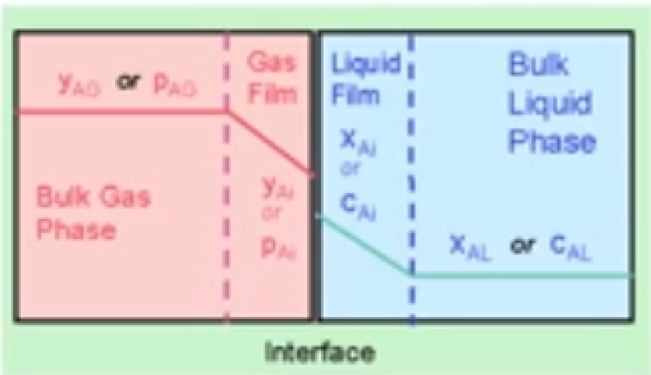
20. **How can you say mass transfer is taking place in a G-L system?**
Ans : Absorption , stripping interfacial m.t.

21. **How to calculate rate of mass transfer if mass transfer coefficient is not given?**

22. **Difference between Penetration and Surface renewal theory?**

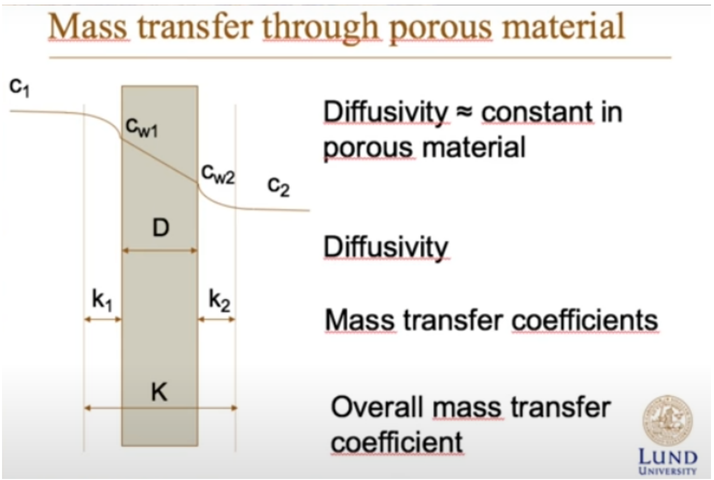
Ans : Model parameter in Penetration theory is t(contact time), in surface renewal it is s(surface renewal freq.)

23. **Two (2) film theory and its applications.**



    a. It states that despite turbulent flows, significant amount of mass transfer occurs between two phases..
    b. Phase boundary is relatively stagnant
    c. Ans: Molecular diffusion, steady state, m.t.c. prop. To Dab/delta

24. **Derive overall mass transfer coefficient in two film.**
Let the two films be:



1. Mass Transfer in 1st Film

$$N_{A1} = k_1 A(c_1 - c_{w1})$$

2. Diffusion:

$$N_{A2} = \frac{D}{\delta} A(c_{w1} - c_{w2})$$

3. Mass Transfer in 2nd film

$$N_{A3} = k_2 A(c_{w2} - c_2)$$

Now, let Overall Mass Transfer Coefficient be:

$$N_A = KA(c_1 - c_2)$$

On equating these equations:

$$\frac{N_A}{KA} = \frac{N_{A1}}{k_1 A} + \frac{N_{A2}\delta}{DA} + \frac{N_{A3}}{k_2 A} \Rightarrow \frac{1}{K} = \frac{1}{k_1} + \frac{\delta}{D} + \frac{1}{k_2}$$

25. NPSH & its importance

NPSH stands for net positive suction head. (total head of fluid near the impeller's center minus the vapor pressure of the fluid) It is essential to provide sufficient inlet pressure to avoid evaporation of fluid inside the pump and formation of bubbles to cause cavitation.

26. Rault's Law & what would you use in case of a non-ideal solution?

27. Distillation column, equation used and significance of q(the term that comes in operating line equation)

28. Assumptions in Distillation Column analysis.

- Binary Mixture
- Constant Pressure
- Constant Relative Volatility
- Equilibrium on all stages

- Constant molar flows
- No vapour holdup

29. **Define boundary layer.**
=> Boundary layer is the thin layer of fluid in the immediate vicinity of a bounding surface formed by the fluid flowing along the surface.

30. **What are the different types of boundary layer?**
=> Laminar boundary is a very smooth flow, it creates less skin friction drag than the turbulent but is less stable. As the flow continues back from the leading edge, the laminar boundary layer increases in thickness.
Turbulent boundary layer contains swirls or "eddies". The low energy laminar flow, however tends to break down more suddenly that the turbulent layer.

31. **What makes boundary layer different from free stream?**

32. **Why Boundary layer forms, how many types of boundary layers are there**

33. **Continuity Equation**

34. **Navier Stockes Equation & its Origins**

35. **Force terms used in Navier Stokes equation, what governing equations used to describe flow through a pipe.**

36. **Bernoulli's equation. Modification required for bends and viscous flows.**

37. **Losses in fluid flow in a pipe**

38. **Rotameter, Orifice, Venturi Meters.**

39. **Flow meters in which Bernoulli's Equation is applied.**
    a. **Orifice, Venturymeter**

40. **In which flow meter Bernoulli equation is not used**
Rotameter

41. **Experimental methods used to find Diffusion coefficient**
42. Stefan Tube, Twin bulb apparatus

43. **Relation between gas diffusion coefficient, Temperature and Pressure.**
    a. **D as a function of T^1.5/P**
44. **How can we predict Gas-phase diffusion coefficient? (She expected me to remember the whole Chapman-Enskog eqn but I just told her the variation of T ^1.5 and P)**
45. **Working Principle of Rotameter**
46. **Types of diffusion (in terms of diffusing, non diffusing) Ans: Na=0, Nb#0 ; counter diffusing (equi and non equimolar)**
47. **There is carbon charcoal and air is passed on it, what kind of diffusion is it ?**
    a. **Ans: C + O2 ---> CO2 (equimolar counter diffusion)**
    b. **2C + O2 ---> 2CO (non-equimolar counter diffusion)**
48. **Type of diffusion in distillation column.**
49. **Methods used for finding diffusivity, both gas phase and liquid phase**
50. **Knudsen diffusivity, applicability/necessary condition?**

Ans: Pore diff. Is when the size of particle is comparable to the diameter of pore instead of colliding with molecules it collides with wall more frequently, applicable if Knudsen no. = (mean free path/pore diameter) >1

51. **Is molar flux in molecular diffusion different from knudsen discussion.**
52. **Application of knudsen diffusion.**
53. **Fick's law.**
    Flux (Rate of diffusion of a substance across unit area) is directly proportional to Concentration Gradient => J = - D * dc/dx , Unit of D(diffusivity) is m^2/s.
54. **Types of Mass Flux**
55. **Dimensionless no for convective heat and mass transfer, what type of molar flux is used in Ficks law**
    Ans: Lewis No. , Ja is used in Fick’s law

Heat

1. **Different modes of heat transfer and their formulas**
2. **There are two tanks one filled with oil and other with water, both tanks are separated by a wall. How will heat transfer take place?**
3. **How to calculate heat transfer coefficient?**
4. **To determine convective heat flux through the wall of the pipe flow, what kind of driving force is used (LMTD)**
5. **LMTD (Logarithmic Mean Temperature Difference)**
6. **Critical insulation thickness, does heat loss can be minimized by infinitely increasing the insulation thickness?**
7. **Heat Exchanger**