MASS TRANSFER LABORATORY

Simple Questions with Answer

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கல்வி கற்பது பணியோ, சுமையோ, சிக்கலோ அல்ல
உலகில் வாழ ஓர் உன்னத வழி
- ரிக்டர்

Dear Students,

I take great pride and happiness in sharing this document with you. It contains a collection of simple yet important questions and answers for the **Mass Transfer Laboratory** course in **B.E. Chemical Engineering**.

This booklet is designed to help you confidently face **viva-voce examinations** and **placement interviews** related to mass transfer. There is no need to memorize these answers — instead, **read through the entire document carefully** and try to **recollect and understand the basic concepts** behind each question.

Remember, true learning comes from **understanding the principles and applying them** rather than rote memorization. Use this material as a guide to strengthen your fundamentals and to explore the subject further through experiments, discussions, and reference materials.

Wishing you all the best in your learning journey and future endeavours.

With best wishes,

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A Message to My Dear Students

23 October 2025 marks a very special day — the first day of my 25th year of teaching in higher education. Looking back, I feel immensely grateful for this journey filled with learning, growth, and countless memories.

At this meaningful moment, I wholeheartedly thank all my past and present students. You are the reason behind my passion for teaching. Your curiosity, enthusiasm, and achievements have shaped me just as much as I have tried to shape you.

A teacher's greatest strength lies in patience and kindness — for every student carry within them a spark waiting to be ignited. My joy has always been in watching that spark grow into the light of confidence, knowledge, and leadership.

Remember, education is the most powerful tool to overcome poverty, ignorance, and injustice. It builds not only a career but also character, compassion, and courage.

To my dear students — past, present, and future —

Believe in yourself, stay curious, and never stop learning. Let your knowledge serve not only your success but also the betterment of society.

With heartfelt gratitude and blessings,

Dr. S. Dhanasekaran

CONTENTS

1 – DIFFUSIVITY

Aim – To study the effect of temperature on diffusivity of volatile liquid into air

1. What is diffusion?

Diffusion is the process by which molecules or particles move from a region of higher concentration to a region of lower concentration due to random molecular motion.

2. What is diffusivity?

Diffusivity (or diffusion coefficient) is a measure of the rate at which a substance diffuses. It quantifies how fast molecules spread out in a medium.

3. What is the principle of the diffusivity experiment?

The principle is based on Fick's laws of diffusion, which relate the diffusion flux to the concentration gradient. The experiment measures the rate of mass transfer to determine the diffusion coefficient.

4. State Fick's first law of diffusion.

Fick's first law states:

$$J_A = -D_{AB} \frac{\partial C_A}{\partial Z}$$

where J_A = diffusion flux,
D_{AB} = diffusivity, and
$\frac{\partial C_A}{\partial Z}$ = concentration gradient.

It applies to **steady-state diffusion**.

5. State Fick's second law of diffusion.

Fick's second law describes unsteady-state diffusion:

$$\frac{\partial C}{\partial t} = D \frac{\partial^2 C}{\partial Z^2}$$

It relates the change of concentration with time to the spatial concentration gradient.

6. What is the aim of the diffusivity experiment?

To determine the diffusion coefficient (diffusivity) of a vapor in air by measuring the rate of mass transfer under controlled conditions.

7. What are the main components of the setup?

- Diffusion tube (vertical, transparent)
- Volatile liquid (e.g., naphthalene or acetone)

- Balance for measuring mass loss
- Thermometer
- Water bath or temperature control (option

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8. What is the working principle of the setup?

A volatile liquid evaporates at the top of a vertical tube. The vapor diffuses down the tube through stagnant air. The mass loss over time is measured to calculate diffusivity using Fick's law.

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9. What are the typical systems studied in the lab?

- Naphthalene–air
- Acetone–air
- Benzene–air

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10. Write the equation used to calculate flux for steady state diffusion of A through non-diffusing B.

$$N_A = \frac{D_{AB} P_t}{RTz\, \bar{P}_{B,m}} [\bar{P}_{A1} - \bar{P}_{A2}]$$

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11. Write the equation used to calculate flux for steady state equimolar counter diffusion.

$$N_A = \frac{D_{AB}}{RTz} [\bar{P}_{A1} - \bar{P}_{A2}]$$

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12. Relate flux, coefficient, and concentration difference.

Flux = Coefficient x Concentration difference

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13. What assumptions are made in the diffusivity experiment?

- Diffusion occurs only in one dimension (vertical).
- Air is stagnant (no convection).
- Steady-state conditions.
- Temperature is constant.
- Vapor behaves ideally.

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14. What is the relation between diffusion flux and diffusivity?

$$J_A = -D_{AB} \frac{\partial C_A}{\partial Z}$$

Diffusion flux (J_A) is proportional to the diffusivity and the concentration gradient.

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15. What are the units of diffusivity?

m^2/s

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16. What are typical values of diffusivity for gases?

On the order of 10^{-5} to 10^{-6} m^2/s at room temperature.

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17. How is the rate of diffusion measured in this experiment?

By recording the mass loss of the volatile liquid over time using a sensitive balance.

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18. Why is temperature kept constant during the experiment?

Because diffusivity is temperature-dependent, and fluctuations would affect the accuracy of measurements.

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19. What is the difference between molecular diffusion and convective mass transfer?

- Molecular diffusion: caused by random molecular motion, independent of bulk motion.
- Convective mass transfer: caused by bulk fluid motion, not random motion.

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20. What is the difference between steady-state and unsteady-state diffusion?

- Steady state: concentration profile does not change with time
- Unsteady state: concentration changes with time

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21. What factors affect diffusivity?

- Temperature
- Pressure
- Nature of the diffusing species and medium
- Molecular size

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22. How does temperature affect diffusivity?

Diffusivity increases with temperature due to higher molecular velocity.

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23. How does pressure affect diffusivity in gases?

Diffusivity decreases with increasing pressure because molecular collisions become more frequent.

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24. Mention industrial applications of diffusion.

- Gas absorption and stripping
- Drying processes
- Chemical reactors
- Separation processes like distillation and extraction

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25. Why is diffusivity important in chemical engineering?

It determines rate of mass transfer, crucial for designing reactors, separators, and other unit operations.

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26. What is the difference between gas-phase and liquid-phase diffusivity?

- Gas-phase: higher diffusivity (10^{-5} m^2/s) due to lower density.
- Liquid-phase: lower diffusivity (10^{-9} m^2/s) due to higher viscosity and molecular crowding.

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27. What is the physical meaning of the diffusion coefficient?

It represents how fast a substance spreads in a medium; higher diffusion coefficient means faster diffusion.

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28. What is Knudsen diffusion?

Diffusion in narrow pores where molecular collisions with the walls dominate over collisions between molecules.

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29. Why should volatile liquids like acetone be handled carefully?

- Highly flammable
- Produces toxic vapours
- Can evaporate quickly, causing rapid mass loss

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30. Why must the diffusion tube be vertical and undisturbed?

To maintain one-dimensional diffusion and prevent convective currents that would alter the measurement.

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31. Why should the experiment be started only after thermal equilibrium is achieved?

To ensure constant temperature, which stabilizes the diffusion rate and avoids errors.

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32. How can diffusivity be estimated theoretically?

Using kinetic theory of gases or empirical correlations.

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33. What is the typical value of diffusivity for naphthalene–air system at room temperature?

Approximately 0.11×10^{-4} m^2/s.

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34. What is the conclusion drawn from the diffusivity experiment?

The diffusion coefficient of the vapor in air is determined, demonstrating Fick's law of diffusion and showing how mass transfer depends on concentration gradient, temperature, and pressure.

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35. What is significance of Fick's first law of diffusion?

Fick's First Law describes how molecules move from a region of higher concentration to a region of lower concentration under a steady-state condition (when the concentration does not change with time).

1 Predicts mass transfer rate:

It provides a quantitative relation between diffusion flux and concentration gradient, helping to calculate how fast a substance diffuses.

2 Fundamental to mass transfer operations:

The law forms the basis for design and analysis of many chemical engineering processes such as drying, distillation, absorption, leaching, and membrane separation.

3 Helps determine diffusivity:

By measuring diffusion flux and concentration gradient, diffusion coefficients (D) of various gases, liquids, or solids can be determined experimentally.

4 Explains steady-state diffusion behaviour:

It shows that at steady state, the rate of mass transfer remains constant with position, which simplifies analysis of diffusion systems.

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36. What is difference between Flux J_A and Flux N_A?

J_A → Diffusion flux (relative motion only); N_A → Total flux (diffusion + bulk flow)

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37. What is meant by flux?

Flux is the rate of mass transfer per unit area. It shows how many moles (or mass) of a substance pass through a unit area per unit time.

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38. What is diffusive flux J_A?

Diffusive flux J_A is the flux of component A due to molecular diffusion only, measured relative to the molar average velocity of the mixture.

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39. What is total flux N_A?

Total flux N_A is the overall flux of component A, which includes both diffusion and bulk motion (convection).

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40. Write the relation between N_A and J_A.

$N_A = J_A + y_A N$

where y_A is the mole fraction of A and $N = N_A + N_B$, is the total molar flux.

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41. When does $N_A = J_A$?

When there is no bulk flow.

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42. Give one example where J_A and N_A are different.

During evaporation of water into still air, water vapor diffuses upward, but the air remains almost stationary — here $J_A \neq N_A$.

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43. What are the units of flux?

$mol/m^2 \cdot s$ (moles per square meter per second).

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2 - SIMPLE DISTILLATION

Aim – To verify the Rayleigh Equation by graphically and analytically.

1. What is distillation?

Distillation is a separation process that involves heating a liquid to create vapor and then cooling the vapor to obtain the liquid again. This method exploits differences in boiling points to separate components from a mixture.

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2. What is simple distillation?

Simple distillation is a technique used to separate a volatile component from a non-volatile component or to purify a liquid by boiling it and then condensing the vapor back into liquid form. It is effective when the boiling points of the components differ significantly, typically by 25°C or more.

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3. What is the principle of simple distillation?

The principle of simple distillation is based on the difference in boiling points of components in a mixture. The component with the lower boiling point vaporizes first, and upon condensation, it is collected separately.

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4. What is meant by volatility?

Volatility refers to the tendency of a substance to vaporize. A more volatile substance has a lower boiling point and evaporates more readily than a less volatile substance.

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5. Give examples where simple distillation is used.

Simple distillation is used in purifying liquids, such as:

- Purification of water from saltwater.
- Separation of ethanol from fermented mixtures.
- Purification of organic solvents in laboratories.

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6. What are the main components of a simple distillation setup?

The main components include:

- Distillation flask (boiling flask).
- Thermometer.
- Condenser.
- Receiving flask.
- Heat source.
- Boiling chips or anti-bumping granules.

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7. What is the function of the condenser?

The condenser cools the vapor produced during distillation, causing it to condense back into liquid form, which is then collected in the receiving flask.

8. What is the function of the thermometer in distillation?

The thermometer monitors the temperature of the vapor, indicating when the more volatile component is boiling and when to collect the distillate.

9. Why is a water inlet provided at the lower end of the condenser?

Water enters the lower end of the condenser to ensure that the entire length of the condenser is filled with cold water, maximizing the efficiency of condensation.

10. Why is the mixture heated slowly during distillation?

Slow heating allows for gradual vaporization of the more volatile component, ensuring better separation and preventing bumping or sudden boiling.

11. What is vapor–liquid equilibrium (VLE)?

Vapor–liquid equilibrium is the condition where the rate of evaporation of a liquid equals the rate of condensation of its vapor, resulting in a stable concentration of components in both phases.

12. What is Raoult's Law?

For an ideal solution, the equilibrium partial pressure $\bar{P}_A^*$ of a component at a fixed temperature equals to the product of its vapour pressure P_A when pure at this temperature and its mole fraction in the liquid x_A.

$$\bar{P}_A^* = P_A * x_A$$

13. What is Dalton's Law?

Dalton's Law states that the total pressure exerted by a mixture of non-reacting gases is equal to the sum of the partial pressures of the individual gases.

14. What is boiling point?

The boiling point is the temperature at which the vapor pressure of a liquid equals the external pressure, causing the liquid to transition into the vapor phase.

15. Why can simple distillation not separate liquids with close boiling points?

Simple distillation is ineffective for separating liquids with close boiling points because the vapor produced contains a mixture of both components, making complete separation challenging.

16. What is the aim of the simple distillation experiment?

The aim is to separate a volatile component from a non-volatile component or to purify a liquid by exploiting differences in boiling points.

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17. What are the common liquid mixtures used in this experiment?

Common mixtures include:

- Water and salt.
- Ethanol and water.
- Toluene and water.

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18. How is the composition of the distillate determined?

The composition can be determined by measuring the boiling point and comparing it to known values, or by using analytical techniques such as gas chromatography.

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19. How is the purity of the distillate checked?

Purity is checked by comparing the boiling point of the distillate to the known value of the pure component, or by using techniques like refractive index measurement or chromatography.

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20. Why is the distillation flask filled only half full?

Filling the flask only halfway allows space for the liquid to boil and prevents overflow or bumping.

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21. What is the difference between simple and fractional distillation?

Simple distillation is used when the boiling points of components differ significantly, while fractional distillation is used when the boiling points are close, allowing for better separation through multiple vaporization-condensation cycles.

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22. What is meant by azeotrope?

An azeotrope is a mixture of two or more liquids whose proportions cannot be altered by simple distillation because the vapor has the same composition as the liquid.

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23. Give an example of an azeotrope.

A common example is the ethanol-water mixture, which forms a minimum boiling azeotrope at approximately 95.6% ethanol and 4.4% water by mass.

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24. What is meant by distillate?

The distillate is the liquid collected after the vapor has been condensed during the distillation process.

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25. What is meant by residue?

The residue is the non-volatile component that remains in the distillation flask after the volatile components have been vaporized and condensed.

26. What are the main assumptions in simple distillation?

Assumptions include:

- The components have significantly different boiling points.
- The system is at atmospheric pressure.
- The distillation process is ideal, with no heat losses.

27. What is relative volatility?

Relative volatility is the ratio of the vapor pressures of two components in a mixture, indicating how easily they can be separated by distillation.

28. What is the effect of pressure on boiling point?

Increasing pressure raises the boiling point, while decreasing pressure lowers the boiling point. This principle is utilized in techniques like vacuum distillation.

29. Why are anti-bumping granules added to the flask?

Anti-bumping granules provide nucleation sites, promoting smooth boiling and preventing sudden, violent boiling or "bumping."

30. Why is the receiving flask kept in a cool place or ice bath?

Cooling the receiving flask ensures that the distillate condenses efficiently and prevents the collection of vapours in the receiving flask.

31. Mention industrial applications of simple distillation.

Industrial applications include:

- Purification of water.
- Production of distilled spirits.
- Separation of solvents in chemical manufacturing.

32. What are the limitations of simple distillation?

Limitations include:

- Ineffectiveness in separating components with close boiling points.
- Inability to separate azeotropic mixtures.

33. Why must the condenser water flow from bottom to top?

Water should flow from bottom to top to ensure that the entire length of the condenser is filled with cold water, maximizing the efficiency of condensation.

34. Why should open flames be avoided near volatile solvents?

Open flames can ignite volatile vapours, leading to fires or explosions. It is safer to use electric heating sources in such cases.

35. What should be done if bumping occurs during distillation?

If bumping occurs, reduce the heat source and add boiling chips to promote smooth boiling.

36. Write the Rayleigh's Equation.

$$\ln\left(\frac{F}{R}\right) = \int_{x_R}^{x_F} \frac{dx}{y^* - x}$$

F = moles of feed
R = moles of residue
x_F = mole fraction of more volatile component in feed
x_R = mole fraction of more volatile component in residue
x = mole fraction of more volatile component in liquid phase
y^* = mole fraction of more volatile component in vapour phase under equilibrium condition.

37. Why simple distillation is also called differential distillation?

Simple distillation is also called differential distillation because the composition of the liquid mixture changes continuously as the distillation proceeds. In short, it involves the continuous, differential change in composition of the liquid and vapour phases during distillation.

38. What is meant by cuts in simple distillation?

As the distillation proceeds, the temperature of the vapour gradually increases, because the more volatile (lower boiling) components distill first, followed by the less volatile (higher boiling) ones. To separate these, the distillate is collected in different portions, called CUTS.

The term CUTS refers to the different portions of the distillate that are collected over specific temperature ranges during the distillation process.

39. Why is it important to note the temperature when the first drop of distillate appears?

- The temperature at which the first drop of distillate appears is called the boiling point of the liquid being distilled.
- It helps to identify the liquid if it is a pure substance, because each pure substance has a characteristic boiling point.

- Noting this temperature ensures that the distillation is done safely and accurately, and it helps to monitor the efficiency of separation.
- It also indicates the point at which the vapor starts to condense, which is essential for proper collection of the distillate.

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40. What is the conclusion drawn from the simple distillation experiment?

- Simple distillation can separate a liquid from a solution if the liquid has a significantly different boiling point than the other components (e.g., separating water from salt solution).
- The experiment demonstrates the principle of volatility, showing that the more volatile component evaporates first.
- It confirms that pure liquids boil at a constant temperature and measuring the temperature of the first drop helps in identifying the substance.
- It is not suitable for separating liquids with very close boiling points—for that, fractional distillation is required.

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41. Define bubble point temperature.

The bubble point temperature is the temperature at which the first bubble of vapor forms from a liquid mixture when it is heated at a constant pressure.

At this temperature, the liquid and its vapor are in equilibrium, and the composition of the vapor phase starts to differ from that of the liquid phase.

In short: Bubble point temperature = Temperature at which vaporization begins for a liquid mixture at a given pressure.

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42. Define dew point temperature.

The dew point temperature is the temperature at which the first drop of liquid condenses from a vapor mixture when it is cooled at a constant pressure.

At this temperature, the vapor and liquid phases are in equilibrium, and condensation just begins to occur.

In short: Dew point temperature = Temperature at which condensation begins for a vapor mixture at a given pressure.

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43. What is the significance of Rayleigh's Equation

Rayleigh's Equation is a fundamental relationship in batch (differential) distillation, which describes how the composition of a liquid mixture changes as the more volatile component is progressively vaporized.

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44. State few salient points about Rayleigh/s Equation.

1 Describes Composition Change in Batch Distillation

In batch distillation, the liquid composition in the still changes continuously as distillation proceeds. Rayleigh's equation provides a quantitative relation between:

- the amount of liquid remaining (R),
- the initial amount of liquid (F), and

- the liquid compositions (x_F and x_R).

$$\ln\left(\frac{F}{R}\right) = \int_{x_R}^{x_F} \frac{dx}{y^{*}-x}$$

where y∗ is the vapor composition in equilibrium with liquid of composition x.

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2 Connects Equilibrium Data with Process Design

The equation links vapor–liquid equilibrium data (VLE) with the mass balance of the distillation process. Using experimental or tabulated VLE data, engineers can determine:

- How much distillate can be obtained for a desired purity, or
- How the composition changes with time during the operation.

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3 Useful for Predicting Distillation Performance

Rayleigh’s equation helps estimate:

- Fraction of the charge vaporized
- Composition of distillate and residue
- Extent of separation achievable in a single batch still

It is particularly important when no rectification column (no plates or packing) is used.

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4 Foundation for Further Analysis

Rayleigh’s equation forms the basis for advanced distillation models, including:

- Multistage batch distillation
- Continuous distillation column design
- Differential mass transfer studies

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3 – STEAM DISTILLATION

Aim – To find out the teorerical steam distillation temperature, vapourization efficieny and thermal efficient.

1 What is steam distillation?

Steam distillation is a separation technique used to isolate temperature-sensitive liquids or volatile compounds from a mixture using steam. It allows the compound to distil at a temperature below its normal boiling point.

2. What is the principle of steam distillation?

The principle is that the total vapor pressure of two immiscible liquids (water and the volatile compound) is the sum of their individual vapor pressures. The mixture boils when this total vapor pressure equals the atmospheric pressure, allowing distillation at lower temperatures.

3. What types of compounds are separated by steam distillation?

Steam distillation is used for essential oils, volatile organics, perfumes, and heat-sensitive compounds.

4. Why is steam used instead of direct heating?

Direct heating may decompose heat-sensitive compounds. Steam allows distillation at lower temperatures, preserving the integrity of the compound.

5. What are the main components of a steam distillation setup?

Steam generator/boiler
Distillation flask containing the mixture
Condenser
Receiver (for collecting distillate)
Thermometer

6. What is the role of the condenser?

The condenser cools the vapor back into liquid form for collection as distillate.

7. What is the role of the thermometer in steam distillation?

To monitor the temperature of the vapor, ensuring the distillation occurs at the correct boiling range of the mixture.

8. Why can steam distillation separate compounds with high boiling points?

Because the compound distils at a temperature lower than its normal boiling point, reducing the risk of decomposition.

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9. What type of distillation is used if the boiling points of components are close?

Fractional distillation is used if the boiling points are close, not steam distillation.

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10. What is the advantage of steam distillation over simple distillation?

Steam distillation is suitable for heat-sensitive compounds and allows separation without decomposition.

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11. How do you know when to stop the distillation?

When the distillate stops coming over or the temperature rises significantly, indicating most of the volatile compound has been collected.

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12. Define Theoretical Steam Distillation Temperature.

It is the temperature at which a mixture of an immiscible organic liquid and water boils during steam distillation. At this temperature, the sum of the vapor pressures of the components (organic liquid and water) equals the atmospheric pressure.

In other words, it is the boiling point of the mixture under steam distillation conditions, which is lower than the boiling points of either component alone.

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13. What is meant by vaporization efficiency?

Vaporization efficiency is the measure of how effectively a liquid is converted into vapor during a process such as distillation or evaporation. It is defined as the ratio of the actual amount of liquid vaporized to the theoretical amount that should vaporize under ideal conditions.

$$Vaporization\ Efficiency = \frac{Actual\ vaporized\ amount}{Theoretical\ vaporized\ amount}\ x\ 100$$

A higher vaporization efficiency means the process is more effective in converting liquid into vapor with minimum losses or incomplete vaporization.

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14. What is meant by thermal efficiency?

Thermal efficiency is the measure of how effectively a system converts supplied heat energy into useful work or desired output. It is defined as the ratio of the useful energy output to the total heat energy input, usually expressed as a percentage.

$$Thermal\ Efficiency = \frac{Useful\ Energy\ Output}{Heat\ Energy\ Input}\ x\ 100$$

A higher thermal efficiency indicates that the system makes better use of the input heat energy with fewer losses (for example, in engines, boilers, or distillation systems).

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15. Give some examples of substances separated by steam distillation.

- Aniline–water mixture
- Toluene–water mixture
- Essential oils (e.g., clove oil, eucalyptus oil)

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16 What is meant by partial pressure?

Partial pressure is the pressure exerted by each component gas in a mixture if it alone occupied the entire volume at the same temperature.

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17. What is meant by vapour pressure?

Vapour pressure is the pressure exerted by the vapour of a liquid (or solid) in equilibrium with its liquid (or solid) phase at a given temperature in a closed system.

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18. What is the relation between vapor pressures and distillate composition?

The ratio of moles of components in the vapor phase is proportional to their vapor pressures at the distillation temperature.

$$\frac{N_A}{N_B} = \frac{P_A}{P_B}$$

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19. What is the main application of steam distillation in industries?

Used for the extraction of essential oils, purification of organic compounds, and separation of high-boiling substances without decomposition.

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20. What is the role of vapor pressure in steam distillation?

Each component exerts its own vapor pressure, and the mixture boils when the sum of vapor pressures equals the atmospheric pressure.

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21. What is the nature of the distillate obtained?

The distillate usually consists of two immiscible liquid layers — an aqueous layer (water) and an organic layer.

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22. What happens to the boiling point when steam is passed through the liquid mixture?

The boiling point decreases because the total vapor pressure increases due to the addition of the vapor pressure of water (steam).

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23. What is the conclusion drawn from the steam distillation experiment?

Steam distillation successfully separates volatile and heat-sensitive compounds at temperatures below their normal boiling points, demonstrating the principle of immiscible liquids and total vapor pressure.

4 - Height Equivalent to a Theoretical Plate (HETP)

Aim – To determine the HETP in a packed column by experimental and by analytical method.

1 What is a theoretical plate?

A theoretical plate is a hypothetical equilibrium stage in which the liquid and vapor (or two phases) leaving the stage are in vapor–liquid equilibrium. It is an idealized separation step used to model staged contact processes.

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2. What is HETP?

HETP (Height Equivalent to a Theoretical Plate) is the height of packing that is equivalent to one theoretical plate. It quantifies the separation efficiency of packing:

$$HETP = \frac{Height\ of\ Packing}{Number\ of\ Theortical\ Plates}$$

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3. What is the aim of the HETP experiment?

To determine the number of theoretical plates (N) produced by a packed column for a given separation and to calculate the HETP (i.e., packing height per plate), thereby assessing packing efficiency.

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4. State the principle of the experiment.

Use a known binary mixture and operating conditions to obtain concentration or composition profiles. From the measured separation determine N and compute HETP = packing height / N.

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5. Which methods are used to obtain N in this experiment?

Common methods:

- Fenske equation (at total reflux, for distillation systems, gives minimum number of stages).
- McCabe–Thiele graphical method (for staged distillation).

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6. Write the HETP formula.

$$HETP = \frac{Height\ of\ Packing}{Number\ of\ Theortical\ Plates}$$

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7. What is the Fenske equation? When is it used?

Fenske equation gives minimum number of theoretical stages at total reflux for a binary mixture:

$$N_{min} = \frac{\log\left[\frac{\frac{x_D}{1-\ x_D}}{\frac{x_B}{1-\ x_B}}\right]}{\log \alpha_{avg}}$$

Used for binary distillation with constant relative volatility α\alphaα at total reflux.

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8. What are the assumptions of the Fenske equation?

Binary mixture, constant and known relative volatility, equilibrium stages, operation at total reflux.

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9. Difference between HETP and HTU?

- HETP (Height Equivalent to a Theoretical Plate) relates packing height to equilibrium stages.
- HTU (Height of a Transfer Unit) belongs to rate-based models (e.g., for absorption or stripping) and quantifies height required for a specified transfer of mass; HTU relates to mass transfer coefficients and driving force. They are different concepts: HETP is stage-based, HTU is rate-based.

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10. List the main apparatus used in the HETP experiment.

Packed column with packing,
reboiler/boiler (if distillation),
condenser (if required),
reflux divider (for total reflux),
thermometers,
sampling points,
flow controllers,
concentration analyser (e.g., refractometer, gas chromatograph),
stopwatch (for tracer method).

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11. What packing types are commonly used?

Raschig rings, Berl saddles, Pall rings, Intalox saddles, structured packings. Mention which packing you used in the lab.

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12. How do you prepare the column for the experiment?

Clean column and packing, pack uniformly without voids, fix packing height, install thermometers and sampling points, check for leaks, establish required flow (or set to total reflux if doing Fenske).

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13. How do you operate at total reflux? Why is it used?

At total reflux, all condensed vapor is returned to the column (no product withdrawn). It creates the maximum internal circulation and is used to determine theoretical stages (e.g., via Fenske) because it removes the effect of reflux ratio.

14. If you used a tracer/pulse method, what is the plate-count formula?

For chromatographic/tracer response:

$$N = \frac{t_R^2}{\sigma^2}$$

where t_R = mean residence/retention time

σ^2 = variance of the response curve

15. What units does HETP have?

Length units (e.g., cm or m).

16. What does a smaller HETP indicate?

Higher separation efficiency of the packing (more theoretical plates per unit height).

17. What factors affect HETP?

Packing type and condition,
liquid & vapor flow rates,
physical properties (viscosity, surface tension),
distributor quality,
flooding,
channelling,
temperature,
presence of fouling,
relative volatility (for distillation).

18. How do you estimate N from composition data (binary distillation)?

Using Fenske (for total reflux) or McCabe–Thiele (graphical) to count theoretical stages required to achieve given distillate and bottoms compositions. Explain which method you used and why.

19. What is relative volatility? How does it affect N?

$$Relative\ Volatility\ (\alpha) = \frac{K_A}{K_B}$$

α is the ratio of vapor–liquid equilibrium constants. Higher α (components easier to separate) reduces the number of stages N required for a given separation.

20. How do you calculate percentage efficiency of packing?

If theoretical plate height ideal is known, sometimes efficiency = (actual N / ideal N) × 100. More commonly, one compares experimental HETP with literature or manufacturer values.

---

21. Give common sources of error in HETP experiment.

Poor packing (voids),
channelling,
inaccurate sampling or analysis,
temperature gradients,
incorrect flow measurement,
not reaching steady state,
leaks,
non-ideal behaviour (nonconstant α),
human timing errors in tracer measurement.

---

22. What precautions do you take during the experiment?

Ensure uniform packing, avoid air pockets, use correct flow rates, ensure steady state before sampling, calibrate analyser (refractometer/GC), record temperatures accurately, avoid overfilling condensers, maintain safety.

---

23. How do you detect flooding and why avoid it?

Flooding indicated by sudden pressure rise, liquid carryover, and unstable operation. Avoid because it destroys orderly contact and invalidates HETP measurement.

---

24. If HETP increases with flow rate, why?

At high flow rates, increased turbulence and maldistribution can reduce contacting efficiency, increase back-mixing or channelling, and therefore increase HETP (worse performance).

---

25. What is the physical meaning of a theoretical plate in a packed column?

It represents a small height of packing providing the same separation as an ideal equilibrium stage; the packing is thought of as many infinitesimal stages.

---

26. How would you improve the packing efficiency (reduce HETP)?

Use better structured packing, ensure good liquid distribution, reduce channelling, operate at optimal flow rates, clean packing to remove fouling, use smaller packing elements (if pressure drop acceptable).

---

27. How is experimental N reported if using the McCabe-Thiele method?

McCabe-Thiele yields the number of equilibrium stages graphically — count the stages (steps) between feed and distillate lines; that count is N (use reflux ratio used in experiment).

---

28. Why is accurate temperature measurement important?

Temperature indicates vapor–liquid equilibrium and helps calculate relative volatility; errors lead to wrong composition/α estimation and therefore wrong N and HETP.

---

29. How do you decide whether to use plate (stage)-based or rate-based analysis?

Use plate-based when equilibrium stage modelling is appropriate (e.g., design/analysis via Fenske/McCabe).

Use rate-based (HTU-NTU) when kinetics/mass transfer limitations are important or when packing behaviour must be modelled in design.

---

30. What is the relation between HETP, and column height required for a given separation?

Required packing height L = HETP × N required

So, for target separation, knowing HETP gives the packed bed height needed.

---

31. How do you report and present your experimental results?

Include packing type and height, feed and operating conditions, method used to find N, computed N and HETP (with units), error analysis/uncertainty, graphs (concentration profiles or tracer response), and discussion comparing to literature or expected values.

---

32. What is the number of theoretical plates?

It is the total number of equilibrium stages (N) that a column effectively provides for the given separation and operating conditions.

---

33. How to reduce experimental error in HETP?

Calibrate measurement instruments, ensure steady state, improve liquid distribution, pack carefully, repeat measurements and average, use proper sampling technique.

---

34. Define Equal molar overflow.

The equal molar overflow is the assumption which states that the molar flow rates of liquid and vapor phases remain constant from stage to stage in a distillation, absorption, or stripping column. In short: Equal molar overflow means the number of moles of liquid condensed is equal to the number of moles of vaporized, keeping liquid and vapor flow rates constant throughout the column.

35. State the valid assumptions in Equal molar overflow.

The heat of vaporization of the components is nearly the same,
There is no significant heat loss or gain, and
Liquid and vapor densities do not change much between stages.

5 - Liquid-Liquid Extraction

Aim – To establish the equilibrium curve and obtain the tie line for the given Water (A) – Benzene (B) – Acetic Acid (C) system.

1. What is liquid–liquid extraction?

It is the process of separating a solute from one liquid phase into another immiscible liquid phase based on differences in solubility.

---

2. What is the principle of liquid–liquid extraction?

The principle is differential solubility of solute in two immiscible liquids, where solute distributes between the two phases until equilibrium is reached.

---

3. What are the two phases involved in extraction?

- Organic phase (solvent)
- Aqueous phase (feed solution)

---

4. What is a solvent?

A solvent is the liquid in which the solute preferentially dissolves to be separated from the other phase.

---

5. Give examples of solvent systems used in extraction.

- Acetic acid–water–kerosene
- Benzene–water–acetic acid
- Ether–water systems

---

6. What is the aim of the liquid–liquid extraction experiment?

To study distribution of a solute between two immiscible liquids and determine the distribution coefficient and extraction efficiency.

---

7. State the distribution (partition) law.

At equilibrium, for a solute A:

$$K_D = \frac{C_1}{C_2}$$

where C1 and C2 are equilibrium concentrations in the two immiscible phases.

---

8. What does the distribution coefficient represent?

It represents the ratio of solute concentration in the two phases at equilibrium.

---

9. How is equilibrium achieved in the experiment?

By shaking the mixture in a separating funnel and allowing it to stand until the two phases separate clearly.

---

10. Why is a separating funnel used?

To mix the two immiscible liquids and then separate the phases based on density differences.

11. What solute is generally used in this experiment?

Acetic acid or other organic acids.

12. What are the solvents used?

- Kerosene
- Benzene
- Ether (depending on the experiment)

13. How is the concentration of acetic acid determined?

By titration with standard NaOH solution or using a pH indicator.

14. What type of extraction is performed—single stage or multistage?

Usually single-stage extraction in lab experiments; multistage extraction is used industrially.

15. How is the distribution coefficient calculated?

$$K_D = \frac{C_{Solvent}}{C_{Aqueous}}$$

using equilibrium concentrations measured experimentally.

16. What type of plot is obtained from the experimental data?

- Concentration of solute in solvent vs. concentration in aqueous phase
- Sometimes a log–log plot is drawn for correlation.

17. Why are the solvents required to be immiscible?

They form two distinct layers, allowing solute transfer without mixing completely.

18. What happens if the two solvents are completely miscible?

No phase separation occurs, making extraction impossible.

19. What factors affect the efficiency of extraction?

- Distribution coefficient Kd
- Volume ratio of solvent to feed
- Number of stages
- Temperature
- Mixing efficiency

20. What is meant by single-stage extraction?

Extraction performed once, with one contact between solute-containing solution and solvent.

---

21. What is multistage extraction?

Extraction performed in successive stages, with fresh solvent contacting the raffinate repeatedly for better solute recovery.

---

22. Which gives better recovery: single-stage or multistage extraction?

Multistage extraction gives higher solute recovery and is more efficient.

---

23. Mention some industrial applications of liquid–liquid extraction.

- Recovery of acetic acid from aqueous solutions
- Extraction of metals (e.g., copper, uranium)
- Pharmaceutical and chemical industry solvent extractions
- Oil refining (e.g., caffeine from coffee, vegetable oils)

---

24. What are the advantages of liquid–liquid extraction over distillation?

- Can separate **thermally sensitive compounds**
- Less energy-intensive
- Works when boiling points are very close

---

25. What are the disadvantages?

- Requires large quantities of solvent
- Emulsions may form
- Solvent recovery needed
- Slower process than some distillation methods

---

26. What is a triangular diagram in extraction?

A ternary diagram showing the composition of three-component systems: solute, feed solvent, and extract solvent.

---

27. What does the tie line represent in a triangular diagram?

Connects equilibrium compositions of the two liquid phases in contact.

---

28. What is meant by plait point?

The point at which the two phases become indistinguishable, i.e., phase separation is no longer possible.

---

29. What is selectivity of a solvent?

Its ability to preferentially dissolve the desired solute over other components.

---

30. What are the desirable properties of a good solvent for extraction?

- High solubility for solute
- Immiscible with feed
- Chemically inert
- Low boiling point for easy recovery
- Non-toxic and safe

31. Why is kerosene or benzene used carefully?

- Flammable
- Toxic
- Requires proper ventilation and safety precautions

32. What precautions are taken during extraction?

- Avoid excessive shaking to prevent emulsion
- Use proper safety gear
- Ensure correct solvent volumes
- Observe temperature limits

33. Why should the interface between the two liquids be observed carefully?

To accurately separate the two layers and avoid loss or contamination of solute.

34. Define Extract.

The *extract* is the phase that contains the desired solute after a liquid–liquid extraction process. It is the solvent-rich phase in which the solute has preferentially dissolved. Example: In the extraction of acetic acid from water using ether as a solvent, the ether layer (which contains most of the acetic acid) is the *extract*.

35. Define Raffinate.

The *raffinate* is the residual phase left after extraction, which contains the remaining portion of the original feed that has not been extracted. It is usually the diluent rich phase. Example: In the same process, the water layer (which now contains less acetic acid) is the *raffinate*.

36. Define area of homogeneity in liquid-liquid Extraction.

The *area of homogeneity* (also called the single-phase region – outside of the dome shaped binodal solubility curve) in liquid–liquid extraction is the region of a ternary phase diagram where only one liquid phase exists.

In this area, the components (solute, solvent, and diluent) are completely miscible with each other and form a uniform (homogeneous) solution.

In simple terms: All three components mix completely without separating into layers.

37. Define area of heterogeneity in liquid-liquid Extraction.

The *area of heterogeneity* (also called the two-phase region – inside of the dome shaped binodal solubility curve) is the region of the ternary phase diagram where two immiscible liquid phases coexist.

In this area, the mixture separates into; one extract phase (solvent-rich) and one raffinate phase (diluent-rich).

In simple terms: The components do not mix completely and form two distinct liquid layers.

6 - AIR-DRYING

Aim – To study the drying characteristics of the given material in a current of hot air and evaluating the heat and mass transfer coefficients.

1. What is drying?

Drying is the process of removing moisture from a material by using heat and/or air movement.

---

2. What is the principle of drying?

Moisture evaporates from the material into the surrounding air when the vapor pressure of water in the material is higher than in the air, creating a concentration gradient.

---

3. What is the objective of the air-drying experiment?

To study the rate of drying of a material, determine moisture content at different times, and understand the drying curve.

---

4. What is the drying medium in this experiment?

Hot air is commonly used as the drying medium.

---

5. What is moisture content?

Moisture content is the amount of water present in a material, expressed as a percentage of wet or dry weight.

---

6. What are the main stages of the drying process?

- Constant rate period
- Falling rate period

---

7. What happens during the constant rate period?

- Surface is saturated with moisture.
- Rate of drying is limited by heat transfer to the surface.
- Evaporation occurs at a constant rate.

---

8. What happens during the falling rate period?

- Surface moisture decreases.
- Drying rate decreases as moisture diffuses from inside to the surface.
- Controlled by internal mass transfer resistance.

---

9. What is the critical moisture content?

The moisture content at which the drying rate starts to fall (transition from constant to falling rate).

10. What is equilibrium moisture content (EMC)?

The moisture content at which the material no longer loses water because it is in equilibrium with the surrounding air.

---

11. What are the main components of the air-drying setup?

- Drying chamber/tray dryer
- Heater
- Blower/fan for air circulation
- Thermometer
- Humidity sensor (optional)
- Sample tray

12. What is the working principle of the setup?

Hot air is passed over the material. Moisture evaporates from the surface and is carried away by air. Mass loss is measured over time to study drying kinetics.

---

13. What is the drying medium temperature used in the experiment?

Typically, 50–70°C for laboratory air-drying experiments; depends on material sensitivity.

---

14. What materials are commonly used in the air-drying experiment?

- Sand
- Sawdust
- Food materials (e.g., grains, vegetables)
- Wet chemicals or powders

---

15. Why is the air flow rate controlled?

To maintain uniform drying and avoid excessive turbulence or uneven moisture removal.

---

16. How is the rate of drying calculated?

Rate of drying=dw/dt.
dw = amount of water removed
dt = time of drying

---

17. What does the slope of the drying curve indicate?

The rate of drying at that moment; slope decreases during falling-rate period.

---

18. How is the moisture content determined experimentally?

By weighing the sample at intervals and calculating mass loss using:

$$Moisture\ content = \frac{W_{initial} - W_{Dry}}{W_{Dry}} \text{ X } 100$$

---

19. What parameters are measured in the experiment?

- Sample mass
- Drying time

- Air temperature
- Air flow rate
- Relative humidity (optional)

---

20. What are the mechanisms of moisture movement inside solids?

- Liquid diffusion through capillaries
- Vapor diffusion through pores
- Surface evaporation

---

21. What factors affect the rate of drying?

- Air temperature
- Air velocity
- Relative humidity
- Material properties (porosity, particle size)
- Sample thickness

---

22. Why is relative humidity important in drying?

High relative humidity reduces the driving force for moisture evaporation, slowing drying.

---

23. What is the difference between batch drying and continuous drying?

- Batch drying: material is dried in batches; process stops after each batch.
- Continuous drying: material moves continuously through dryer.

---

24. What is the role of air velocity in drying?

Higher air velocity increases the mass transfer coefficient, removing moisture faster.

---

25. Where is drying used in chemical industries?

- Food processing
- Pharmaceuticals
- Fertilizers
- Chemical powders
- Pulp and paper

---

26. Why is hot air used instead of cold air?

Hot air increases vapor pressure difference, accelerating moisture removal.

---

27. What is the main difference between natural and mechanical drying?

- Natural: uses sunlight or ambient air.
- Mechanical: uses controlled hot air, vacuum, or other methods.

---

28. What is the function of the heater in the setup?

To raise the air temperature, providing energy for moisture evaporation.

---

29. Why is air drying preferred for heat-sensitive materials?

Because it can use moderate temperatures, reducing risk of decomposition.

---

30. Explain the concept of psychrometry in drying.

Psychrometry is the study of air-water vapor mixtures, relating temperature, humidity, and moisture content, important for designing air-drying systems.

---

31. What is the difference between absolute humidity and relative humidity?

- Absolute humidity: mass of water vapor per unit volume of air.
- Relative humidity: percentage of water vapor in air relative to saturation at same temperature.

---

32. What is the dew point temperature?

The temperature at which air becomes saturated, and water vapor begins to condense.

---

33. What is the main resistance to drying in the constant-rate period?

External resistance: heat and mass transfer between air and surface.

---

34. What is the main resistance to drying in the falling-rate period?

Internal resistance: diffusion of moisture from inside the material to the surface.

---

35. Why should the air temperature not exceed a certain limit?

To avoid damaging heat-sensitive materials or causing degradation.

---

36. Why must the sample be spread uniformly on the tray?

To ensure uniform exposure to air and consistent drying rate.

---

37. Why should the air flow rate be steady throughout the experiment?

To maintain constant mass transfer conditions and accurate measurement.

---

38. Why is the sample weighed quickly during drying?

To minimize moisture loss during weighing, which can affect accuracy.

---

39. What precautions are taken to avoid heat loss in the system?

- Use of insulated walls
- Covering the dryer properly
- Minimizing open doors or leaks

---

40. What is the conclusion of the air-drying experiment?

The experiment demonstrates the drying behaviour of materials, shows the constant and falling rate periods, and allows calculation of drying rate and critical moisture content.

---

41. What is the main inference from the drying curve?

- The drying rate is initially constant (surface moisture evaporation).
- Later, drying rate decreases (internal diffusion limits).
- Critical and equilibrium moisture content can be determined.

42. Define bound moisture.

Bound moisture is the moisture contained by the substance which exerts an equilibrium vapour pressure less than that of the pure liquid at the same temperature

43. Define Unbound Moisture

Unbound moisture is the moisture contained by the substance which exerts an equilibrium vapour pressure less equal to that of the pure liquid at the same temperature

44. Define Equilibrium Moisture Content.

This is the moisture content of the substance when at equilibrium with a given partial pressure of the vapour.

45. Define Free Moisture Content.

Free moisture is the moisture present more than the equilibrium moisture content. It is the removable portion of moisture during the drying process. Mathematically: Free Moisture = Total Moisture − Equilibrium Moisture

46. Define moisture content.

Moisture content is the amount of water present in a material, usually expressed as a percentage of the total weight of the material. It indicates how much water is contained in a wet solid and is an important parameter in drying and other mass transfer operations.
Mathematically:

- On a Wet Basis:

Moisture content (wet basis) = $\frac{Weight\ of\ water}{Totel\ weighrt\ of\ wet\ solid}\ x\ 100$

- On a Dry Basis:

Moisture content (dry basis) = $\frac{Weight\ of\ water}{Totel\ weighrt\ of\ dry\ solid}\ x\ 100$

47. State the heat balance condition during the constant rate period of drying.

During constant rate period of drying, the rate heat transferred from hot bulk air to surface of the wet solid is equal to the rate of heat required for evaporation.

48. State the mass balance condition during the constant rate period of drying.

During this period, the rate of moisture evaporated at the surface of the wet solid is equal to the rate movement moisture form the depth of the solid to its surface.

7 - Leaching
(stagewise, counter-current and co-current)

Leaching - stagewise
Aim – To find the optimum number of stages

Leaching – Counter current
Aim – To leach the sodium carbonate from the given feed mixture of sand and washing soda using water as a solvent by a three-stage counter current process and to find the efficiency of the leaching for last two stages.

Leaching – Co-current
Aim - To leach the washing soda from the feed mixture of sand and washing soda using water as solvent by a three stage co current leaching and to find out the efficiency of individual stages and overall efficiency.

1. What is leaching?

Leaching is the process of extracting a soluble component (solute) from a solid using a suitable solvent.

---

2. What is the principle of leaching?

Leaching works on the principle of solubility: the solute dissolves in the solvent and is separated from the insoluble solid.

---

3. Give some examples of leaching in industry.

- Sugar extraction from sugarcane or sugar beet
- Caffeine extraction from coffee
- Gold extraction using cyanide solution
- Oil extraction from oilseeds

---

4. What is the main objective of the leaching experiment?

To study the extraction of solute from solid, determine solute concentration in extract and raffinate, and analyse stage-wise or counter-current leaching efficiency.

---

5. What is a solvent in leaching?

The liquid used to dissolve the solute, e.g., water, alcohol, or chemical solution.

---

6. What is the solute?

The substance to be extracted from the solid, e.g., sugar, caffeine, salt.

---

7. What is the inert solid?

The solid matrix from which the solute is extracted, which does not dissolve in the solvent.

---

8. What are the phases involved in leaching?

- Solid phase: contains solute and inert material
- Liquid phase: solvent that dissolves the solute

---

9. What is underflow and overflow in leaching?

- Underflow: liquid leaving from the bottom of the leaching stage
- Overflow: liquid leaving from the top of the leaching stage

---

10. Define extract and raffinate.

- Extract: solvent containing dissolved solute after leaching
- Raffinate: solid remaining after partial or complete solute removal

---

11. What is stage-wise leaching?

Leaching performed in discrete stages, where fresh solvent contacts the solid in each stage.

---

12. What is single-stage leaching?

Leaching in one stage, where solvent contacts the solid only once.

---

13. What happens in multi-stage leaching?

The solid contacts solvent in successive stages, improving solute recovery.

---

14. What are the advantages of multi-stage leaching over single stage?

- Higher solute recovery
- More efficient use of solvent
- Better control over concentration

---

15. How is the performance of stage-wise leaching evaluated?

By calculating solute recovery, concentration in extract/raffinate, and overall efficiency.

---

16. What is counter-current leaching?

The solid moves opposite to the flow of solvent, maximizing concentration gradient and extraction efficiency.

---

17. Why is counter-current leaching preferred in industries?

- Reduces solvent usage
- Achieves higher solute recovery
- Energy and cost-efficient

---

18. What is the flow pattern in counter-current leaching?

- Solvent flows from last stage to first stage
- Solid moves from first stage to last stage

---

19. How is equilibrium approached in each stage?

- Solvent dissolves solute until saturation or equilibrium is reached in that stage.

---

20. What is the main difference between stage-wise and counter-current leaching?

- Stage-wise: single direction or batch solvent in each stage
- Counter-current: solvent flows opposite to solid movement, higher efficiency

---

21. What are the main components of the leaching apparatus?

- Leaching columns or stages
- Solvent feed system
- Agitation mechanism
- Collection tanks for extract and raffinate

---

22. What is the procedure for stage-wise leaching in the lab?

- Place solid in first stage
- Add solvent and stir/agitate
- Allow contact time
- Separate extract and solid (raffinate)
- Repeat in subsequent stages if multi-stage

---

23. How is counter-current leaching performed in the lab?

- Solvent enters the last stage first
- Solid fed from first stage
- Extract collected from each stage
- Process continues until desired solute recovery

---

24. What material system is commonly used for leaching experiments?

- Salt–sand–water
- Sugar–sand–water
- Other soluble solute–insoluble solid systems

---

25. How is concentration of solute determined experimentally?

- Titration (for salts or acids)
- Gravimetric analysis
- Refractometry or density measurement (for sugar solutions)

---

26. What data are obtained from the leaching experiment?

- Solute concentration in extract and raffinate
- Mass of solid remaining
- Solvent volume used
- Number of stages required

---

27. What is meant by equilibrium data in leaching?

Data showing the maximum solute that can dissolve in each volume of solvent at a particular stage.

---

28. What is the purpose of drawing a McCabe–Thiele diagram in leaching?

To graphically determine the number of theoretical stages required for desired solute recovery.

---

29. What are the axes in a leaching McCabe–Thiele diagram?

- x-axis: solute concentration in solid (raffinate)
- y-axis: solute concentration in liquid (extract)

---

30. What do the equilibrium and operating lines represent?

- Equilibrium line: solute concentration ratio at equilibrium
- Operating line: actual process concentrations per stage

---

31. How do you find the number of stages graphically?

By stepping off stages between operating and equilibrium lines from feed to final raffinate.

---

32. What does the slope of the operating line depend on?

The solvent-to-solid ratio in the process.

---

33. What are the factors affecting the rate of leaching?

- Solubility of solute
- Temperature
- Particle size
- Agitation
- Solvent-to-solid ratio

---

34. Why is particle size important in leaching?

Smaller particles increase surface area, speeding up solute extraction.

---

35. What is diffusion-controlled leaching?

When the rate of solute transfer is controlled by diffusion inside the solid particles rather than surface dissolution.

---

36. What are the advantages of counter-current leaching in industry?

- Higher solute recovery
- Less solvent consumption
- Economical and efficient

---

37. Give some examples of industrial leaching equipment.

- Percolation columns
- Rotary extractors
- Agitated tanks
- Continuous counter-current leaching columns

---

38. Why should the solid–liquid separation be done carefully?

To avoid loss of solute and ensure accurate measurement of extract and raffinate.

---

39. Why should agitation time be controlled?

Too short: incomplete extraction

Too long: unnecessary energy consumption or degradation

---

40. Why must solvents be handled with care?

- Toxicity or flammability
- Environmental hazards
- Evaporation losses

---

41. What should be done if solvent loss due to evaporation occurs?

- Replace lost solvent
- Conduct experiment under closed conditions to minimize evaporation

---

42. What is the main conclusion of the leaching experiment?

The experiment demonstrates solute extraction efficiency, effectiveness of stage-wise and counter-current leaching and provides equilibrium and process data.

---

43. What is the significance of this experiment in chemical engineering?

- Teaches principles of solid–liquid extraction
- Helps design industrial leaching and extraction processes
- Demonstrates mass transfer, equilibrium, and stage efficiency concepts

---

44. Define full miscella.

A miscella is a solution of oil in a solvent (commonly hexane) obtained during the solvent extraction process. Full miscella refers to the final solution that contains the maximum possible concentration of oil dissolved in the solvent, i.e., the richest oil–solvent mixture obtained after complete extraction of oil from the material (such as oilseed).

Full miscella = oil-rich solution formed after complete extraction in solvent extraction process.

45. Define half miscella.

Half miscella is the partially concentrated solution of oil in solvent obtained before complete extraction of oil from the material. It contains about half the oil concentration of the full miscella and is formed in the earlier stages of the solvent extraction process.

Half miscella = partially extracted oil–solvent mixture with lower oil concentration than full miscella.

46. What is meant by co-current leaching?

In co-current leaching, both the solid and the solvent flow in the same direction through the extraction unit.

47. What is the difference between co-current and counter-current leaching?

- In co-current leaching, solid and solvent move in the same direction.
- In counter-current leaching, solid and solvent move in opposite directions, resulting in higher extraction efficiency.

48. What is the objective of the co-current leaching experiment?

The objective is to determine the **extraction efficiency** and to study the **effect of operating parameters** (like solvent flow rate and contact time) on the leaching process.

49. What is miscella?

Miscella is the **solution of solvent and solute** obtained after leaching.

50. What is the driving force in leaching?

The **concentration difference** between the solute in the solid phase and in the liquid solvent.

51. What type of mass transfer takes place in leaching?

Solid-liquid mass transfer, involving diffusion of solute from solid to liquid phase.

52. What is extraction efficiency?

It is the **percentage of solute removed** from the solid by the solvent during leaching.

$$percentage\ of\ Efficieny = \frac{Amount\ of\ solute\ extracted}{Total\ solute\ extracted}\ x\ 100$$

53. Why is co-current leaching less efficient than counter-current leaching?

Because in co-current leaching, the solvent becomes progressively loaded as it moves along with the solid, reducing the concentration gradient and thus lowering extraction efficiency.

---

54. What are the assumptions made in leaching experiments?

- Solute is uniformly distributed in the solid.
- Equilibrium is reached between solid and liquid phases.
- The solvent does not react chemically with the solute or solid.

---

55. What is the purpose of agitation in leaching?

Agitation increases **mass transfer rate** by reducing film resistance around solid particles.

---

56. What is meant by percolation leaching?

A leaching process where solvent passes through a **bed of solid** under gravity or pressure, dissolving the solute as it percolates.

---

57. What is the difference between batch and continuous leaching?

- **Batch leaching:** All materials are charged and removed together.
- **Continuous leaching:** Solvent and solid are continuously fed and withdrawn, as in industrial units.

---

58. Why is particle size important in leaching?

Smaller particles have **larger surface area**, increasing the rate of solute diffusion and overall extraction efficiency.

---

59. What is the meaning of residue in leaching?

Residue is the **insoluble solid material** left behind after the solute is extracted.

---

60. What are common solvents used in leaching?

Water, alcohol, hexane, benzene, or other suitable organic solvents depending on the solute’s solubility.

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8 - ROTARY DRYER

Aim

To find out the holdup volume of the dryer, residence time and constants a and b in the equation X = a (N_{Fe})b

1. **What is a rotary dryer?**

A rotary dryer is a **continuous, cylindrical, rotating equipment** used to remove moisture from solids by direct or indirect heating with hot air or gas.

---

2. **What is the working principle of a rotary dryer?**

The wet material is fed into a **rotating drum**, where it is lifted and cascaded by flights through a **stream of hot air**, causing moisture to evaporate.

---

3. **What are the main components of a rotary dryer?**

- Rotating cylindrical drum
- Flights (lifting blades)
- Support rollers and drive system
- Burner or heat source
- Air inlet and outlet
- Dust collector or cyclone (optional)

---

4. **What is the function of flights in a rotary dryer?**

Flights **lift and shower the material**, increasing contact with hot air, improving **heat and mass transfer efficiency**.

---

5. **What is the direction of flow in a rotary dryer?**

- **Co-current:** material and air flow in the same direction
- **Counter-current:** material and air flow in opposite directions

---

6. **Which type of flow gives better thermal efficiency?**

- **Counter-current flow** generally gives better thermal efficiency for heat recovery.

---

7. **What are the factors affecting the performance of a rotary dryer?**

- Drum rotation speed
- Drum inclination angle
- Air temperature and flow rate
- Material properties (size, moisture content)
- Flight design and number
- Residence time

---

8. **What is the typical speed of rotation of a rotary dryer?**

Usually **1–6 rpm**, depending on material and drum diameter.

---

9. **Why is the drum of the rotary dryer slightly inclined?**

To allow **material movement by gravity** from inlet to outlet. Typical inclination is **2–5°**.

---

10. **What type of materials are dried in a rotary dryer?**

- Minerals (sand, ores)
- Chemicals and fertilizers
- Food grains and biomass
- Sludges and powders

---

11. **How is the moisture removed from the dryer?**

By **evaporation due to contact with hot air**, which carries the vapor out of the dryer.

---

12. **How is heat supplied in a rotary dryer?**

- Direct heating: hot air or combustion gases pass through the drum
- Indirect heating: heat transferred through drum walls (less common)

---

13. **Mention some industrial applications of rotary dryers.**

- Drying of cement, fertilizers, and minerals
- Food processing (grains, cereals)
- Chemical and pharmaceutical powders
- Biomass and sludge drying

---

14. **What are the advantages of a rotary dryer?**

- Handles large capacities continuously
- Can process **varied materials**
- Simple design, low maintenance
- Efficient for **free-flowing solids**

---

15. **What are the disadvantages of a rotary dryer?**

- Not suitable for **heat-sensitive materials**
- High energy consumption for very wet materials
- Dust generation
- Large footprint

---

16. **What is residence time in a rotary dryer?**

The **time the material spends inside the dryer**. Depends on drum length, inclination, rotation speed, and material flow.

---

17. **How is the performance of a rotary dryer evaluated?**

By measuring:

- Moisture content reduction
- Drying rate
- Energy efficiency
- Uniformity of drying

---

18. What is the function of the dust collector in a rotary dryer setup?

To **remove fine particles from exhaust air**, preventing air pollution and material loss.

---

19. Why are rotary dryers not suitable for heat-sensitive materials?

Because high temperatures and long residence times can **degrade, burn, or denature the material**.

---

20. How can drying efficiency be improved in a rotary dryer?

- Optimize **drum inclination and rotation speed**
- Use **proper flight design**
- Increase **air temperature or flow rate** (within material limits)
- Reduce **moisture load per pass**
- Implement **counter-current operation**

9- ADSORPTION

Aim

To study the adsorption characteristics of acetic acid - water system on charcoal to find the best adsorption isotherm which represents the adsorption characteristics of acetic acid - charcoal system

1. **What is adsorption?**

Adsorption is the **accumulation of molecules (adsorbate) on the surface of a solid or liquid (adsorbent)**, forming a molecular or atomic layer.

---

2. **What is the difference between adsorption and absorption?**

- **Adsorption:** Surface phenomenon; molecules stick on the surface.
- **Absorption:** Bulk phenomenon; molecules penetrate the bulk of the material.

---

3. **What is an adsorbent? Give examples.**

An adsorbent is the **material on whose surface adsorption occurs**, e.g., activated charcoal, silica gel, alumina.

---

4. **What is an adsorbate?**

The **molecule or substance that is adsorbed** on the adsorbent, e.g., acetic acid, gases, dyes.

---

5. **Give some examples of adsorption in daily life.**

- Activated charcoal in water purification
- Silica gel in moisture control packets
- Gas masks adsorbing toxic gases
- Adsorption of pollutants on activated carbon

---

6. **What are the types of adsorptions?**

- **Physical adsorption (physisorption):** Weak van der Waals forces
- **Chemical adsorption (chemisorption):** Strong chemical bonds

---

7. **What factors affect adsorption?**

- Surface area of adsorbent
- Temperature
- Pressure (for gases)
- Nature of adsorbent and adsorbate
- Concentration of adsorbate

---

8. **What is the effect of temperature on adsorption?**

- Physisorption: **Decreases with increase in temperature** (exothermic)
- Chemisorption: May **increase at moderate temperatures** due to activation energy

---

9. What is the effect of surface area on adsorption?

Higher surface area → more sites for adsorption → **higher adsorption capacity**.

10. What is the aim of the adsorption experiment?

To **study the adsorption of acetic acid on activated charcoal** and determine the adsorption isotherm.

11. What is the Freundlich adsorption isotherm?

An empirical relation:

$q = K C_{eq}^{1/n}$

linear form

$\ln q_{eq} = \ln K + (1/n) \ln C_{eq}$

$$\ln q_{eq} = \ln K + \frac{1}{n} \ln C_{eq}$$

where,

q - amount of solute adsorbed per unit weight of sorbent, (mg/g)
Ceq - solute equilibrium concentration, (mg/L)
K & n - experimental constants,
K - an indication of the adsorption capacity of the adsorbent
n - an indication of the effect of concentration on the adsorption capacity and represents adsorption intensity.

12. What is plotted in the Freundlich isotherm graph?

in x axis $\ln C_{eq}$ and in y axis $\ln q_{eq}$

13. What is the slope and intercept of the Freundlich isotherm plot?

- Slope = 1/n
- Intercept = ln k

14. What does the constant k represent?

It represents the **adsorption capacity** of the adsorbent.

15. What does the constant 1/n represent?

It represents the **adsorption intensity**; $0 < 1/n < 1$ indicates favourable adsorption.

16. What is the role of acetic acid in this experiment?

Acetic acid acts as the **adsorbate** whose adsorption on activated charcoal is studied.

17. Why is activated charcoal used?

- High surface area
- Porous structure
- Chemically inert
- Effective adsorbent for organic compounds

18. How is the equilibrium concentration determined?

By **titration of the filtrate** or using a **spectrophotometer** after adsorption.

---

19. Why is shaking required during the experiment?

To **ensure uniform contact** between adsorbent and adsorbate, achieving equilibrium faster.

---

20. Why is filtration done after shaking?

To **separate the adsorbent from the solution** before measuring equilibrium concentration.

---

21. Mention industrial applications of adsorption.

- Water and wastewater treatment
- Gas purification and separation
- Air pollution control
- Recovery of valuable chemicals
- Catalysis support

---

22. What is adsorption isotherm?

A curve showing the **relationship between amount adsorbed and equilibrium concentration at constant temperature**.

---

23. What is adsorption isobar?

A curve showing **variation of adsorption with temperature at constant pressure or concentration**.

---

24. Why is adsorption exothermic?

Because **energy is released** when molecules adhere to the surface of the adsorbent.

---

25. What are the limitations of the Freundlich isotherm?

- Empirical, not valid at high concentrations
- Does not predict **monolayer adsorption**
- Limited to **heterogeneous surfaces**

---

26. What other adsorption isotherms are known besides Freundlich's?

- **Langmuir isotherm**
- **BET isotherm** (multilayer adsorption)

---

27. What is the Langmuir adsorption isotherm?

It assumes **monolayer adsorption on a homogeneous surface** with finite number of sites:

---

28. Differentiate between Langmuir and Freundlich isotherms.

Aspect	Freundlich	Langmuir
Basis	Empirical	Theoretical
Surface	Heterogeneous	Homogeneous
Adsorption	Multilayer	Monolayer
Validity	Low to moderate concentrations	Wide range, until monolayer saturation

29. What is the significance of adsorption in wastewater treatment?

Removes **organic pollutants, dyes, and heavy metals**, improving water quality.

30. Why is adsorption important in catalysis?

- Catalysts often **work via adsorption of reactants** on their surface
- Increases **reaction rate** by bringing reactants closer

31. State Langmuir adsorption isotherm.

Empirical form

$$q_{eq} = \mathrm{b}\mathrm{C}_{\mathrm{eq}} \; \frac{\mathrm{q}_{\mathrm{max}}}{1+\mathrm{b}\mathrm{C}_{\mathrm{eq}}}$$

Linear form

$$\frac{\mathrm{C}_{\mathrm{eq}}}{q_{eq}} = \frac{1}{\mathrm{b}\mathrm{q}_{\mathrm{max}}} + \frac{\mathrm{C}_{\mathrm{eq}}}{\mathrm{q}_{\mathrm{max}}}$$

where

q - amount of solute adsorbed per unit weight of sorbent, (mg/g)

C_{eq} - solute equilibrium concentration, (mg/L)

q_{max} - maximum uptake capacity of the sorbent, (mg/g)

b - adsorption equilibrium constant (k adsorption/ k desorption)

32. What is plotted in the Langmuir isotherm graph?

in x axis ln C_{eq} and in y axis ln C_{eq}/q_{eq}

33. What is the slope and intercept of the Langmuir isotherm plot?

- Slope = $1/q_{max}$
- Intercept = $1/b.q_{max}$

10 - Surface Evaporation

Aim

To evaluate the constants namely K and n in the Himus equation NA = K (P*-P)n where, NA is the flux; P* -the vapor pressure and P-partial pressure.

1. What is evaporation?

Evaporation is the **process of converting a liquid into vapor** at a temperature below its boiling point.

---

2. What is surface evaporation?

Evaporation that occurs **only at the liquid–air interface**, without bulk boiling of the liquid.

---

3. What is the principle of the surface evaporation experiment?

Mass transfer occurs from the **liquid surface to the air** due to a **concentration gradient of vapor**; dry air passing over the surface enhances evaporation.

---

4. What is the aim of the surface evaporation experiment?

To **determine the rate of evaporation**, calculate the **mass transfer coefficient**, and study the factors affecting surface evaporation.

---

5. What is the driving force for mass transfer in evaporation?

The **difference in vapor concentration** between the liquid surface and the bulk air.

---

6. Write the expression for the rate of evaporation.

$$N_A = K_C\ (C_{VS} - C_{VA})$$

where N_A = mass flux,
K_C = mass transfer coefficient,
C_{VS} = vapor concentration at surface,
C_{VA} = vapor concentration in air.

---

7. What is mass transfer coefficient?

A proportionality constant that **relates mass flux to the concentration difference**, representing the efficiency of mass transfer.

---

8. What is humidity?

The **amount of water vapor present in air**.

---

9. What is relative humidity?

$$RH = \frac{Actual\ vapour\ pressure}{Saturation\ vapour\ pressure}\ x\ 100$$

---

10. What is saturation humidity?

The **maximum amount of water vapor air can hold** at a given temperature.

11. What are the main components of the surface evaporation setup?

- Evaporation pan containing liquid
- Air blower or supply of dry air
- Thermometer
- Hygrometer or humidity sensor
- Timer

12. What is measured in the experiment?

- Mass loss of liquid
- Air temperature
- Humidity
- Air velocity

13. Why is dry air passed over the liquid surface?

To **maintain a high concentration gradient**, increasing the rate of evaporation.

14. How is the rate of evaporation determined experimentally?

By **measuring mass loss of liquid per unit time**:

$$N_A = \frac{dW}{A\ x\ dt}$$

15. How is the mass transfer coefficient calculated?

$$\boldsymbol{K_C = \frac{N_A}{C_{VS} - C_{VA}}}$$

16. On what factors does the rate of surface evaporation depend?

- Air velocity
- Temperature
- Relative humidity
- Surface area
- Nature of liquid

17. What happens to the rate of evaporation if air velocity increases?

It **increases** because the vapor concentration near the surface decreases, maintaining the driving force.

18. What happens when air is already saturated with vapor?

Evaporation **stops**, as the driving force C_{VS} - C_{VA} becomes zero.

19. Why does evaporation cause cooling?

Because molecules with **higher kinetic energy escape**, lowering the average kinetic energy of the remaining liquid.

20. Why is evaporation slower at higher humidity?

Because the concentration difference (driving force) is smaller when air is humid.

---

21. Mention some industrial applications of evaporation.

- Concentration of solutions in chemical and food industries
- Salt production
- Cooling ponds
- Drying of liquids

---

22. Where is surface evaporation particularly important?

- Open water bodies
- Cooling towers
- Evaporation ponds
- Laboratory-scale solution concentration

---

23. What is the difference between evaporation and drying?

- **Evaporation:** Only liquid → vapor
- **Drying:** Removal of moisture from solid or liquid–solid mixtures

---

24. What are the dimensionless numbers associated with mass transfer?

- **Sherwood number (Sh)**: Convective mass transfer
- **Reynolds number (Re)**: Flow characteristics
- **Schmidt number (Sc)**: Viscosity effect

---

25. What is the analogy between heat and mass transfer?

- **Heat transfer ↔ Mass transfer**
- Temperature difference ↔ Concentration difference
- Heat transfer coefficient h ↔ Mass transfer coefficient K_C

---

26. Why does temperature of liquid remain nearly constant during evaporation?

Because latent heat of vaporization absorbs energy, maintaining constant temperature.

---

27. What is the latent heat of vaporization?

The **energy required to convert unit mass of liquid into vapor** without changing its temperature.

---

28. What is steady-state evaporation?

Evaporation occurring at a **constant rate**, with **unchanging driving force and conditions**.

---

29. What is the typical range of the mass transfer coefficient for air–water systems?

Approximately **0.001–0.01 m/s**, depending on conditions.

---

30. Why should air velocity be controlled?

To maintain **uniform and reproducible evaporation conditions**.

31. Why should the setup be airtight?

To **prevent external moisture inflow** and ensure accurate measurement of evaporation rate.

---

32. Why should readings be taken after steady-state conditions are reached?

To ensure **reliable mass transfer data**, avoiding transient effects at the start.

---

33. What is the overall conclusion drawn from this experiment?

The experiment demonstrates the **effect of concentration gradient, air velocity, and humidity** on evaporation rate and allows calculation of the **mass transfer coefficient**, highlighting principles of **surface mass transfer**.

---

34. State Himus equation.

The Himus equation is an empirical correlation used in surface evaporation experiments to relate the rate of evaporation to various influencing parameters such as air velocity, humidity, and temperature.

$$N_A = k_G\,(p_A^* - p_A)$$

or in terms of mass transfer rate per unit area:

$$E = C(1 + 0.54v^{0.53})\,(p_A^* - p_A)$$

Where:

Symbol	Quantity	Units
E	Rate of evaporation (mass flux)	$kg/m^2 \cdot s$
C	Empirical constant (depends on system)	varies
V	Air velocity over the surface	m/s
p_A^*	Saturation vapor pressure of the liquid at surface temperature	N/m^2
p_A	Partial pressure of vapor in the bulk air	N/m^2

---

35. Explain Himus Equation

- The term $(p_A^* - p_A)$ represents the driving force for evaporation (difference in vapor pressure between the surface and bulk air).
- The term $(1+0.54v^{0.53})$ shows that air velocity enhances evaporation — higher air speed reduces the boundary layer thickness and increases mass transfer.
- C is an empirical constant that depends on temperature, nature of the liquid, and system geometry.

---

36. State the applications of Himus equation.

- Determination of mass transfer coefficients in surface evaporation.
- Study of air–water interface evaporation.
- Design of dryers and cooling ponds.

---

37. What is the aim of the surface evaporation experiment?

To determine the mass transfer coefficient for the evaporation of water into an air stream and to study the effect of air velocity on the rate of evaporation.

---

38. What is the Himus equation?

The Himus equation is an empirical relation used to express the rate of evaporation from a liquid surface as:

$$E = C(1 + 0.54v^{0.53})\,(p_A^* - p_A)$$

Where E is the evaporation rate,
v is air velocity,
p_A^* is the saturation vapor pressure at the liquid surface, and
p_A is the partial pressure of vapor in the bulk air.

---

39. What is the driving force for mass transfer in surface evaporation?

The difference in vapor pressure between the liquid surface and the bulk air acts as the driving force.

---

40. What is the effect of air velocity on the rate of evaporation?

As air velocity increases, the boundary layer thickness decreases, enhancing the rate of evaporation.

---

41. What does the constant 'C' in the Himus equation represent?

It is an empirical constant that depends on system geometry, temperature, and the nature of the liquid.

---

42. What type of mass transfer takes place in surface evaporation?

Gas-phase mass transfer of water vapor into the air stream.

---

43. What are the main components of a surface evaporation setup?

An air blower, flow control valve, air heater, evaporation chamber with water tray, temperature sensors, and humidity measuring devices.

---

44. How is the rate of evaporation determined experimentally?

By measuring the loss of water mass over a specific time interval and dividing it by the surface area and duration.

$$E = \frac{\Delta m}{A * t}$$

---

45. What are the main assumptions in the Himus equation?

- Steady-state conditions
- Uniform air velocity over the liquid surface
- Negligible temperature gradient in the liquid

---

46. What is the practical importance of the surface evaporation study?

It helps in the design of dryers, cooling towers, evaporators, and air-conditioning systems.