DISTILLATION (CONVENTIONAL, MULTI-COMPONENT & AZEOTROPIC)

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PRESENTATION OUTLINE

- Unit process Description
- Basic mass and energy balance equations
- Basic design and operating principles
- Uses of distillation
- Limitations of distillation
- Applications of distillation in industries
- Differences with other unit operations

PROCESS DESCRIPTION

- Distillation is the separation of liquid mixtures by virtue of differences in the volatilities of the mixture components.
- It takes place in a vessel called distillation column. They are of different sizes depending on the requirements of the separation process.
- The rectifying section in a distillation column is where the lighter distillate is being enriched and heavier components removed.
- The stripping section is where the lighter components are being stripped out of the bottom product and the heavier components consequently concentrated

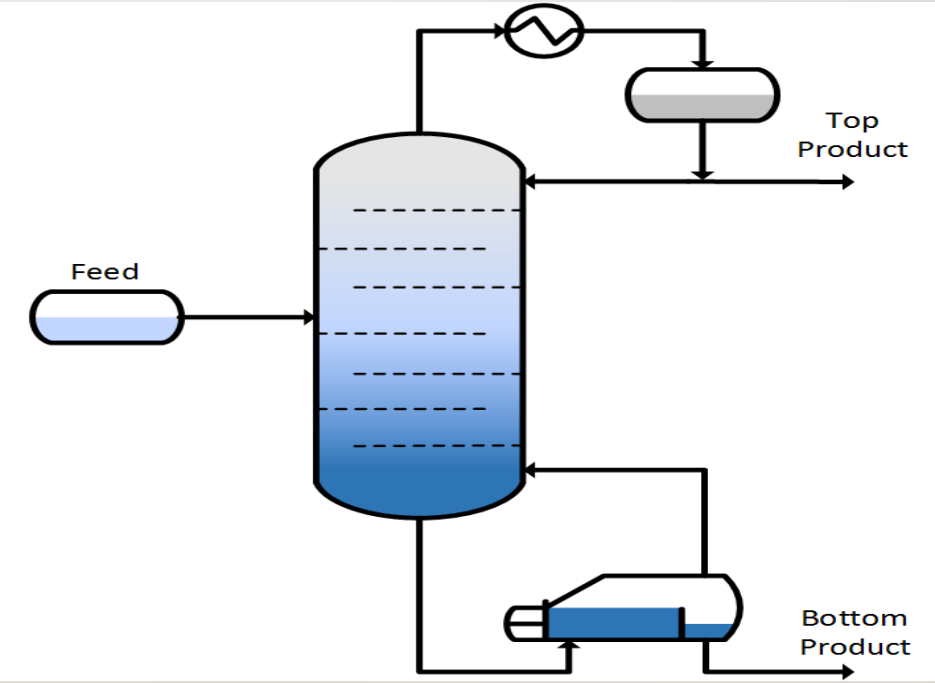
PROCESS DESCRIPTION

Industrial distillation is usually performed in large, vertical cylindrical columns known as distillation columns or towers. They can have diameters ranging from about 65 centimeters to 6 meters and heights ranging from about 6 meters to 60 meters or more

En.wikipedia.org. 2021. *Continuous Distillation*. [online] Available at: <https://en.wikipedia.org/wiki/Continuous_distillation> [Accessed 27 January 2021].

CONVENTIONAL, AZEOTROPIC AND MULTI-COMPONENT DISTILLATION

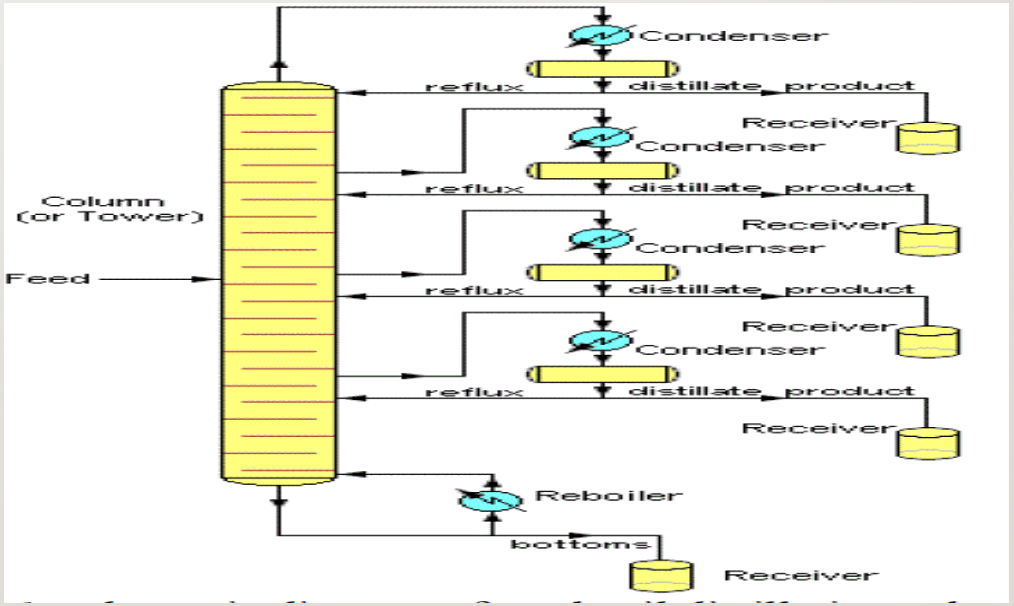
A conventional distillation is the simple distillation process that contains two components as feed.
An example is a mixture of ethanol and water.



Neutrium.net. 2021. *Distillation Fundamentals | Neutrium*. [online] Available at: <https://neutrium.net/unit-operations/distillation-fundamentals/> [Accessed 27 January 2021].

MULTI-COMPONENT DISTILLATION

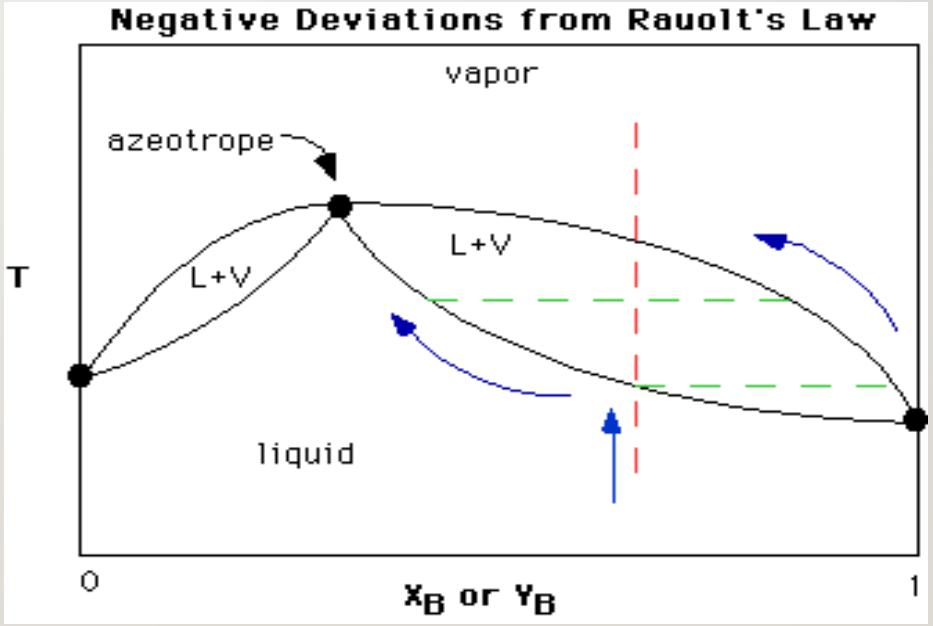
A multi-component distillation contains either more than two components in the feed or more than one feed.
As can be seen from this picture, it has multiple products. A typical example is the distillation of crude oil to produce kerosene, diesel, gasoline, lubricating oil, asphalt, etc



En.wikipedia.org. 2021. *Continuous Distillation*. [online] Available at: <https://en.wikipedia.org/wiki/Continuous_distillation> [Accessed 27 January 2021].

AZEOTROPIC DISTILLATION

- Azeotropes are constant boiling mixtures.
- At this point, separation cannot be achieved by simple distillation
- Examples are:
- A mixture of (95.5%) ethanol with (4.5%)water
- Mixture of (68%) HNO_3 with (32%) water.



AglaSem Schools. 2021. *CBSE Class 12 Chemistry Notes: Solutions - Types Of Azeotropic Mixtures | Aglasem Schools*. [online] Available at: <https://schools.aglasem.com/4724> [Accessed 27 January 2021].

MASS AND ENERGY BALANCE

MASS BALANCE

$$V_{n+1}y_{n+1} + L_{n-1}x_{n-1} + F_n z_n = V_n y_n + L_n x_n + S_n x_n$$

ENERGY BALANCE

$$V_{n+1}H_{n+1} + L_{n-1}h_{n-1} + Fh_f + q_n = V_n H_n + L_n h_n + S_n h_n$$

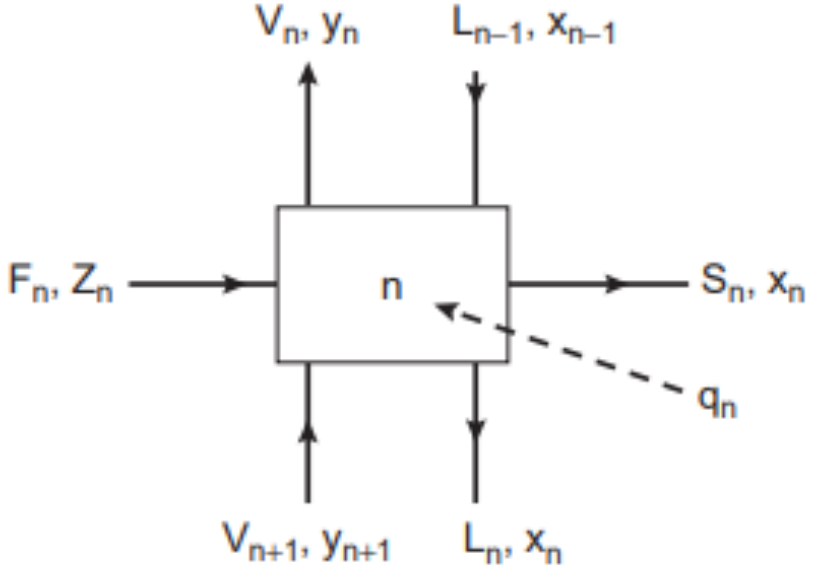


Figure 11.2. Stage flows.

Sinnott, R., 2005. *Chemical engineering*. 4th ed. Amsterdam: Elsevier Butterworth-Heinemann, p.497.

MASS AND ENERGY TRANSPORT IN THE DISTILLATION COLUMN

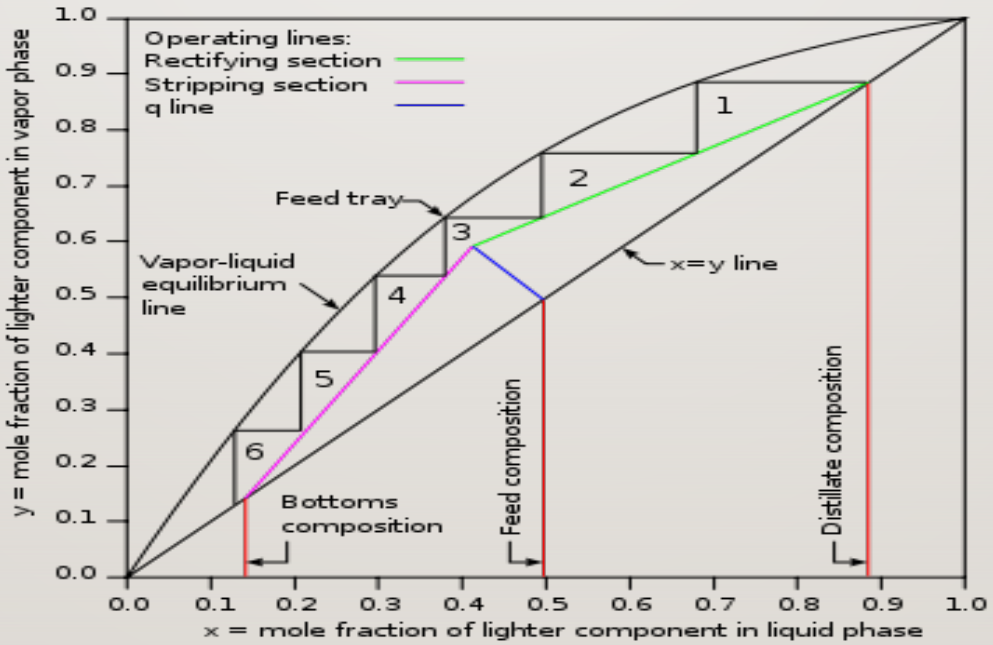
- Mass and energy transport occur by continuous contact between liquid and gas components at each tray of the column.
- Mass and energy balances are done for each stage of the column

BASIC OPERATING & DESIGN PRINCIPLES

To design a distillation column, you need to determine the following:

- Reflux ratio: The **reflux ratio** is defined as the **ratio** of the liquid returned to the column divided by the liquid removed as product
- Column pressure
- Key components (top products and bottoms)
- Feed components
- Number of stages required

DISTILLATION: MCCABE-THIELE DIAGRAM



En.wikipedia.org. 2021. *McCabe–Thiele method*. [online] Available at: <https://en.wikipedia.org/wiki/McCabe%E2%80%93Thiele_method> [Accessed 29 January 2021].

USES OF DISTILLATION

- Water purification-distilled water
- Alcoholic beverages- whiskey, Gin, alcoholic wines, etc.
- Petroleum products-gasoline, diesel fuel, lubricating oil, fuel oils, paraffin wax, kerosene, etc.
- Perfumes- Perfume oils, body sprays, etc.
- Food flavoring-citrus oils

LIMITATIONS OF DISTILLATION

- Heat input: Based on the heating demands required to vaporize part of the bottom product back into the column, the heating element (water, electricity, etc) may have limitations to reaching the required temperature for vaporization
- Azeotropes: When components that are desired to be separated form a new boiling point, this can limit the operation of a simple distillation. As such other approaches would be required (Azeotropic distillation) to change the component volatilities for easier separation
- Relative volatilities of the components of the liquid mixture. If the volatilities are close, more stages would be required for effective separation and thus imply the need for more trays, more trays = taller columns = increased cost and complexities

LIMITATIONS OF DISTILLATION

- Energy consumption & high costs: Also there is the heat demand on the operating costs of the plan, costs of erecting a tall column (more steel, more internal trays, more capital cost, etc.)
- Condensation of the gas: If the ambient temperature of the air around the location of the plant used to cool the gas at the top of the column gets hotter (perhaps in summer), the heat transfer required for condensation becomes poorer and such limits the performance of the unit
- Operational hazards

INDUSTRIAL APPLICATIONS OF DISTILLATION

- Refineries
- Water purification
- Alcoholic beverage industries

DIFFERENCES BETWEEN DISTILLATION & CENTRIFUGATION

DISTILLATION

- used to separate soluble components of a liquid mixture
- The process involves evaporation followed by condensation of the liquid leaving the soluble components behind
- Example: Removing the impurities from water

CENTRIFUGATION

- used to separate insoluble components of a liquid mixture
- The process involves mechanical rotation that allows the settling of the insoluble solid particles.
- Example: Removing cream from milk.

DIFFERENCES BETWEEN DISTILLATION & CHROMATOGRAPHY

DISTILLATION

Separates components of a liquid mixture based on their boiling points

Usually separates soluble components of a liquid mixture

CHROMATOGRAPHY

- Separates components of a liquid mixture based on their chemical properties which could be molecular size/shape, ionic character or any difference in their chemical properties
- Usually separates different colors from a liquid mixture

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