

Evaporation: Definition Factors affecting evaporation

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Theoretically, • “Evaporation means simply vaporization from the surface of a liquid. Vaporization of a liquid below its boiling point is called evaporation.”

- Thus, no boiling occurs and the rate of vaporization depends on the diffusion of vapour through the boundary layers above the liquid.
- Thus a practical definition of evaporation is • “The removal of liquid from a solution by boiling the solution in a suitable vessel and withdrawing the vapour, leaving a concentrated liquid residue.”
- This means that heat will be necessary to provide the latent heat of vaporization and, in general the rate of evaporation is controlled by the rate of heat transfer.
- Evaporators are designed, therefore, to give maximum heat transfer to the liquid, with the largest possible area, a suitable temperature gradient.

Definition of Evaporation

- Evaporation is the process of removal of solvent from the solution by boiling the liquid in a suitable vessel and withdrawing the vapour, leaving a concentrated product.
- **Applications of Evaporation**
 1. Evaporation process is used in the manufacture of bulk drugs, particularly in pharmaceutical industries.
 2. Evaporation is used in the manufacture of biological products. e.g. Insulin, enzymes and hormones.
 3. In demineralization of water.

Objectives

- Reduces transportation cost
- Storage costs
- Prepare for the next Unit operation – drying, crystallisation etc.
- Reduces deteriorative chemical reactions
- Better microbiological stability
- Recovery of solvent

Distinguishing features of evaporation with other heat processes

S. No.	Evaporation	Other heat process
1	The residue is a concentrated liquid.	Drying: the residue is solid.
2	Evaporating liquid is only one component in most of cases.	Distillation: Evaporating liquid is a combination of two or more components.
3	No attempt is made to separate the mixture of vapour, even if any.	Distillation: It is compulsory to separate each component.
4	The purpose of evaporation is to get a concentrated liquid only, but not to get crystals as it happens in some situations.	Crystallization: The purpose of concentrating the solution is to get crystals.

Factors affecting Evaporation

1. Temperature
2. Temperature and time of evaporation
3. Temperature and moisture content
4. Types of product required
5. Effect of concentration
6. Surface area
7. Vapour pressure of the liquid to be evaporated

The relationship may be expressed mathematically as:

$$M = KS/p (b - b')$$

- Where, M = mass of vapour formed per unit time (rate), m^3/s
- S = surface area of the liquid exposed, m^2
- p = atmospheric pressure, kPa
- b = maximum vapour pressure at the temperature of air, kPa
- b' = pressure due to the vapour of the liquid, actually present in the air, kPa
- K = constant, m/s

Factors Affecting Evaporation

The following are the factors which affect the rate of evaporation of a liquid:

1. Temperature : The rate of evaporation is directly proportional to the temperature of the liquid. The evaporation can be accelerated by increasing the temperature but it will cause decomposition of heat sensitive principles of many drugs. Many glycosides and alkaloids are decomposed at a temperature below 100°C . Hormones, vitamins, enzymes and antibiotics being more heat-sensitive materials, needs special treatment in order to avoid decomposition *e.g.* Malt extract is concentrated by evaporation under their reduced pressure to avoid loss of enzyme.

2. Temperature and time of evaporation : It has been observed that exposure to a relatively high temperature for a short period of time may be less harmful to the active principles of a drug than a lower temperature with exposure for a longer period. On the basis of this fact, liquid is exposed to high temperature for a short period in film evaporator.

3. Temperature and moisture content : Some drug constituents decompose more readily in the presence of moisture if heated at a high temperature. This is due to the hydrolysis of the active constituents.

To avoid decomposition of the active principles of such materials the evaporation is done at a low temperature and then the final drying is done at a high temperature when only little moisture remains in it.

4. Types of product required : On evaporation of the liquid the concentrated liquid, semisolid and solid are formed. The selection of the method and the equipment required for evaporation depends upon the type of the product required.

5. Effect of concentration : During evaporation the upper layer of the liquid under evaporation has a tendency to form a film and formation of precipitate in the product which results in lowering down of the rate of evaporation. Therefore, efficient stirring is required in order to prevent degradation of the product at the bottom due to excessive heat and it will also prevent deposition of solids.

6. Surface area : The rate of evaporation is directly proportional to the surface area of the evaporator, in which the liquid is evaporated. The larger the surface area of the evaporator, the shorter is the time it takes to evaporate the liquid.

7. Vapour pressure of the liquid to be evaporated : The rate of evaporation is directly proportional to the vapour pressure of the evaporating liquid. The liquid has the maximum vapour pressure at its boiling point. As such the rate of evaporation can be increased by raising the temperature of the evaporating liquid. The rate of evaporation of liquid is the maximum at its boiling point.

8. Film & deposits:

When vegetable extracts are concentrated in steam pan, a film may be formed on the surface &/or precipitated matter may deposit on the heating surface. Film reduces the evaporating surface & precipitated matter hinders the transfer of heat. To avoid these problems, efficient stirring is necessary.

9. Economic factors:

Economies of labour, fuel, floor space and materials are of primary considerations. The recovery of solvents and utilization of waste heat are also important as they involve considerable reduction of costs. Heat is necessary to provide the latent heat of vaporisation Hence, rate of evaporation is controlled by rate of heat transfer therefore, evaporator is designed to give max. heat transfer to the liquid.

Classification of Evaporators

I. Evaporators with heating medium in jacket

Ex. Steam jacketed kettle (evaporating pan)

II. Vapour heated evaporators with tubular heating surfaces

(A) Evaporators with tubes placed horizontally

Ex. horizontal tube evaporator

(B) Evaporators with tubes placed vertically

i. Evaporators with short tubes

(a) Single effect evaporators Ex. Short tube vertical evaporator (standard vertical tube evaporator)

Short tube vertical evaporator with propeller

Basket type evaporator

(b) Multiple effect evaporator Ex. Triple effect evaporator

ii. Evaporators with long tube

(a) Evaporators with natural circulation Ex. Climbing film evaporator (rising film evaporator) Falling film evaporator

(b) Evaporator with forced circulation Ex. Forced circulation evaporator

THANK YOU 😊