UNIT: III **(DRYING)**

CLASS:21

TOPIC: OBJECTIVES, APPLICATIONS AND MECHANISM OF DRYING PROCESS

DRYING

Drying is defined as the removal of small amounts of water or other liquid from a material by the application of heat.

Drying is a downstream operation and commonly utilized in the last stage of the process and thus has considerable importance. Drying means complete dryness or a condition known as air-dry. The liquid can be organic such as chloroform, ethanol, and isopropanol. Drying is also applied for removal of small quantities of water or liquid from gases, as in case of drying of gases. But this is not described in this chapter. The liquid medium may be removed from the solids mechanically by a filter press or centrifuge or thermally by vaporisation. It is cheaper to remove liquid by mechanically than thermally. Therefore, it is advisable to reduce the liquid as much as possible before subjecting to the drying process. The material to be treated is a solid and liquid is present in traces. However, methods such as spray drying are available in which solutions and suspensions can be processed for drying in one operation itself.

Drying is defined as the removal of all or most of the liquid by supplying heat to cause thermal vaporization.

Drying and evaporation are distinguishable by the relative quantities of liquid removed from the solid. In evaporation, the product obtained is either concentrated solution or suspension or wet slurry. In drying. Dry solid is the product. In evaporation, water is removed at its boiling point, but in drying, vapour is removed at a temperature below its boiling point.

The liquid to be vaporised may remain:

- On the surface of the solid, as in drying of salt crystals,
- Entirely inside the solid, as in solvent removal from a sheet of polymer.
- Partly outside and partly inside, as in case of solvent remove from pharmaceutical powders.

Drying is possible when the environment is unsaturated with the water vapour. Hence, humidity in the environment is an important determinant for drying of the solids. Though several methods are available, thermal methods and freeze-drying technique (nonthermal method) are included here. This chapter deals with the theoretical principles and equipment employed for drying.

Objectives

The drying unit operation is used extensively in the pharmaceutical industry, but often a lack of understanding of the impact of the presence of moisture, environmental conditions., and drying process parameters on active pharmaceutical ingredients critical quality attribute This can create challenges during product development, manufacturing, storage, and use. Thus, following are the objectives of drying

(i) To overcome common challenges in pharmaceutical drying development, including material constraints for scale-up studies and transferring to different equipment types and sizes.

(ii) To understand drying development related to chemical and physical stability, drying kinetics, and powder properties and highlights common development gaps for improving drying development workflows within the industry.

(iii) To encourage further fundamental research and technological advancements for improving the drying process.

(iv) Other objectives are to carry outsize reduction, to avoid deterioration on storage, to dry the tablet granules to reduce the moisture, to reduce the bulk and weight to lower transportation charges and for certain preparations such as spray dried lactose.

(v) To design and produce a dryer that conserves energy consumption for optimal utilization in terms of acquisition and operating cost and with optimal local content and versatility.

(vi) To understand the impact of factors and establish the product specifications, as well as the nature and limits of residual solvents, in agreement with current regulations.

Applications

Preparation of bulk drugs: In the preparation of bulk drugs, drying is the final stage of processing. A few examples are:

- Dried aluminium hydroxide
- Spray dried lactose
- Powdered extracts

Drying step is essential after certain operations such as crystallization and filtration.

Preservation of drug products: Drying is necessary in order to Avoid deterioration.

A few examples are:

Crude drugs of animal and vegetable origin - chemical decomposition

Blood products, skin, tissue - microbial growth

Synthetic and semisynthetic drugs - chemical decomposition

Effervescent tablets (aspirin, penicillin) - Chemical decomposition

Improved characteristics: Drying produces materials of spherical shape, uniform size, free flowing and enhanced solubility.

Some specific areas of importance are:

(1) Granules are dried to improve the fluidity and compression characteristics. These are essential for the production of tablets and capsules

(2) Viscous and sticky materials are not free flowing. Drying modifies these characteristics. Examples are male fern extract, malt extract and oleoresin.

Improved handling: Removal of moisture makes the material light In weight and reduces the bulk. Thus, cost of transportation will be less and storage will be efficient. If moisture is present, size reduction of drugs is difficult. Drying reduces the moisture content.

THEORY OF DRYING

In a wet solid mass, water may be present as bound water and unbound water.

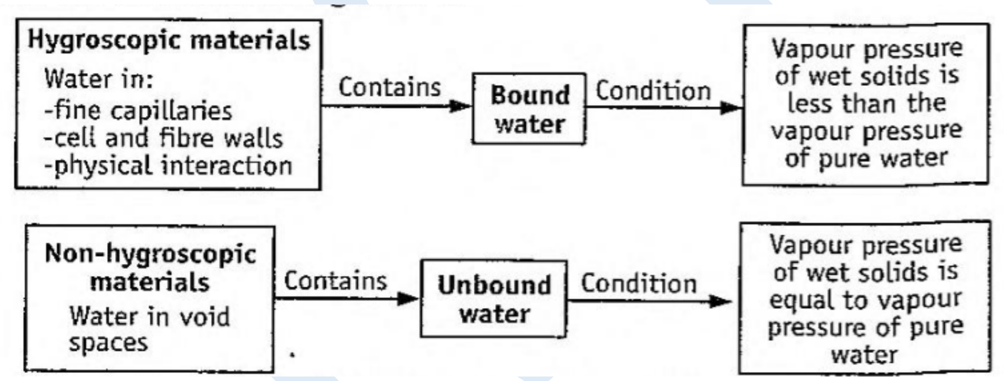
Bound water (moisture) is the minimum water (moisture) held by the material that exerts an equilibrium vapour pressure less than the pure water at the same temperature.

Unbound water (moisture) is the amount of water (moisture) held by the material that exerts an equilibrium vapour pressure equal to that of pure water at the same temperature.

During drying process, water is easily lost, but the resulting solid is not completely free from water molecules. This is known as air-dry. Easily removable water is the unbound water at the defined environmental conditions. After removal of water completely, the material is said to be 'bone-dry'.

Unbound water exists largely in the voids of the solid. Thus, in a non-hygroscopic material, all the liquid is unbound water. In a hygroscopic material, the unbound moisture is the liquid in excess of the equilibrium moisture content, corresponding to saturation humidity. Sub- stances containing bound water are often called hygroscopic substances. The distinction between bound and unbound water depends on the material itself. These are described in Figure.

Heat must be transferred to the material to be dried in order to supply the latent heat required for vaporisation of the moisture. Water diffuses through the material to the surface and subsequently evaporates into the air stream. Thus drying involves both heat transfer and mass transfer operations simultaneously.



Differences of bound and unbound water

Theory can be discussed in three heads namely mechanisms of drying, equilibrium relationships and rate relationships.

Mechanisms of Drying Process

Drying involves both heat transfer and mass transfer processes simultaneously.

- Heat transfer takes place from the heating medium to the solid material
- Mass transfer involves the transfer of moisture to the surface of the solids and subsequently vaporisation from the surface into surroundings.

Various theories are proposed to explain the movement of moisture. These are given below.

1. Diffusion theory
2. Capillarity theory
3. Pressure gradient theory

4. Gravity flow theory
5. Vaporisation and condensation mechanisms

A few of these theories are explained in the following sections.

Diffusion theory: Diffusion theory assumes that the effect of capillarity, gravitational, and friction forces are too small. In diffusion theory, the rate of flow of water is proportional to moisture gradient. According to this theory, moisture movement may be as follows.

Water diffuses through the solid to the surface and subsequently evaporates into the surroundings.

Evaporation of water occurs at an intermediate zone, much below the solid surface, then vapours diffuse through the solid into air.

Due to limitations in predicting the drying rate over a range of moisture gradients, this theory is not much applicable.

*Limitation*s: Diffusivity decreases as the moisture content and temperature decreases, while increases with pressure.

Capillarity theory: Capillarity theory is applicable to porous granular solids. Porous material contains a network of inter-connected pores and channels, which are not circular or straight. At the surface, the cross-section of these capillaries forms various sizes of pores. As the drying starts, a meniscus is formed in the capillary and exerts a force This is the driving force for the movement of water through pores towards the surface. The curvature of the meniscus depends on the pore diameter and determines the strength of capillary force. The capillary force is greater in small pores compared to the large pores. Therefore, small pores pull more water from the larger pores and thus large pores get emptied first. Air enters into the emptied pores and the moisture content is relatively higher near the surface.

Capillary theory holds good only for free water in the bed. This type of movement of liquid takes place in the granules (pores) as well as in the spaces between the granules (void spaces). As the pore diameter is considerably smaller inside a granule than the surrounding granules, liquid surrounding the granules can be removed initially. Then pore liquid inside a granule is vaporized. Diffusion theory is applicable to hygroscopic material.

Pressure gradient theory: Pressure gradient theory is applicable to drying of solids by the application of radiation (not external heating), Radiation is a source for generating internal heat. The radiation interacts with the polarized molecules and ions of the material. This field aligns the molecules in order, which are otherwise randomly oriented. When the field is reversed, the molecules return to the original orientation. In this process, it gives up random kinetic energy (or heat) to the inside surface of the solids itself. Therefore, liquid inside the solids is vapourised. As a result, vapour pressure gradient is developed which is the driving force for the movement of vapour to the surface.

This type of drying mechanism is applicable to radiation drying. Provided such rays penetrate deep inside the solid mass.

MCQ Each carry 1 mark

1. Drying is essential after one of the following unit operations
    a. **Crystallisation**
    b. Evaporation
    c. Mixing

   d. Size reduction
2. For fixing the effective drying conditions, which processing factor is essential?
   a. Height
   b. Humidity
   c. Pressure
   d. Temperature
3. At a given temperature and humidity, if the moisture content of a material is greater than equilibrium moisture content, then the following process takes place
   a. Absorption
   b. Adsorption
   c. Desorption
   d. Sorption
4. The final removal of liquid from solids by vaporization with the aid of heat is known as
   a. Evaporation
   b. Drying
   c. Sublimation
   d. Desiccation
5. Proper drying improves the ______ of the product
   a. Solubility
   b. Weight
   c. Deterioration
   d. Volume
6. Drying involves________ transfer operation
   a. Mass
   b. Heat
   c. Mass and heat
   d. Either mass or heat

Each carry 2 marks

1. Distinguish drying and evaporation.
2. Give suitable dryers:
   a) Granular free flowing solids
   b) Wet bricks before sending to kilns
   c) Sticky pastes
   d) Food products like Horlicks.
3. Explain the importance of drying in the pharma industry with examples.
4. Mention the factors affecting constant drying rate.
5. Define drying. Give its importance in the manufacture of dosage forms.
6. For the removal of solvent from solids, drying is a preferred method than filtration or evaporation. True or false. Explain.
7. Why is environment (humidity and temperature) controlled during drying

Each carry 5 marks

1. Recommend a suitable dryer for drying the following substances and substantiate your answer with at least two reasons:

a) Pasty extracts
b) Granular solids
d) Vitamin B complex granules
e) Colloidal solutions

c) Liver extracts

2. Describe the mechanisms involved in the process of drying