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It’s Important to Know!

BP304T — Pharmaceutical Engineering

B.Pharm Semester 3 · Unit 2 — Heat transfer, evaporation and distillation

Unit II: Heat transfer, evaporation and distillation

Heat transfer

Heat moves by conduction, convection and radiation. Fourier's law relates conductive heat flow to thermal gradient and material conductivity. Convection combines fluid motion with molecular transfer. Radiation transfers energy through electromagnetic waves and does not require a material medium. Overall heat transfer also depends on resistance at surfaces and fouling.

Heat exchangers transfer energy between streams without necessarily mixing them. Counter-current arrangements can provide a useful temperature driving force. Equipment selection depends on material compatibility, viscosity, fouling and cleaning requirements.

Evaporation

Evaporation removes solvent by vaporisation to concentrate a solution. It differs from drying because the feed is usually a liquid solution and the product is a concentrated liquid. Steam-jacketed kettles, horizontal-tube, climbing-film, forced-circulation and multiple-effect evaporators use different circulation and heat-transfer arrangements.

Factors include temperature difference, pressure, viscosity, foaming, scaling, residence time and thermal sensitivity. Multiple-effect systems reuse vapour heat and can improve steam economy, but require more control and may increase residence time.

Distillation

Distillation separates volatile components using vapour-liquid equilibrium. Simple distillation suits a large volatility difference or a volatile component from non-volatile material. Fractional distillation uses repeated vaporisation and condensation. Flash distillation is a single equilibrium stage. Reduced-pressure distillation lowers boiling temperature. Steam distillation suits certain water-immiscible volatile substances. Molecular distillation uses a short path and very low pressure. Exact equipment limits should be checked against the manufacturer's instructions.

Unit II: Frequently asked questions

Q: What are the three modes of heat transfer?

A: They are conduction, convection and radiation.

Q: Why can multiple-effect evaporation save steam?

A: Vapour generated in one effect can supply heat to another effect operated at a lower pressure and boiling temperature.

Q: When is reduced-pressure distillation useful?

A: It is useful when lowering the boiling temperature may protect a heat-sensitive material or permit separation at lower operating temperature.

Unit II: Key takeaways

- Heat transfer depends on driving force and thermal resistance.
- Evaporation concentrates a solution by removing solvent.
- Distillation depends on volatility and vapour-liquid equilibrium.
- Pressure reduction can lower boiling temperature.
- Fouling, foaming and thermal degradation must be controlled.

Unit II: Practical correlation

Practical correlation: concentration of a heat-sensitive solution. Vacuum operation, short residence time and suitable circulation may reduce thermal stress, but the process must be validated for potency and impurities. The operating range is set out in the validated procedure.