SEPARATION PROCESS

ADSORPTION
Part 2

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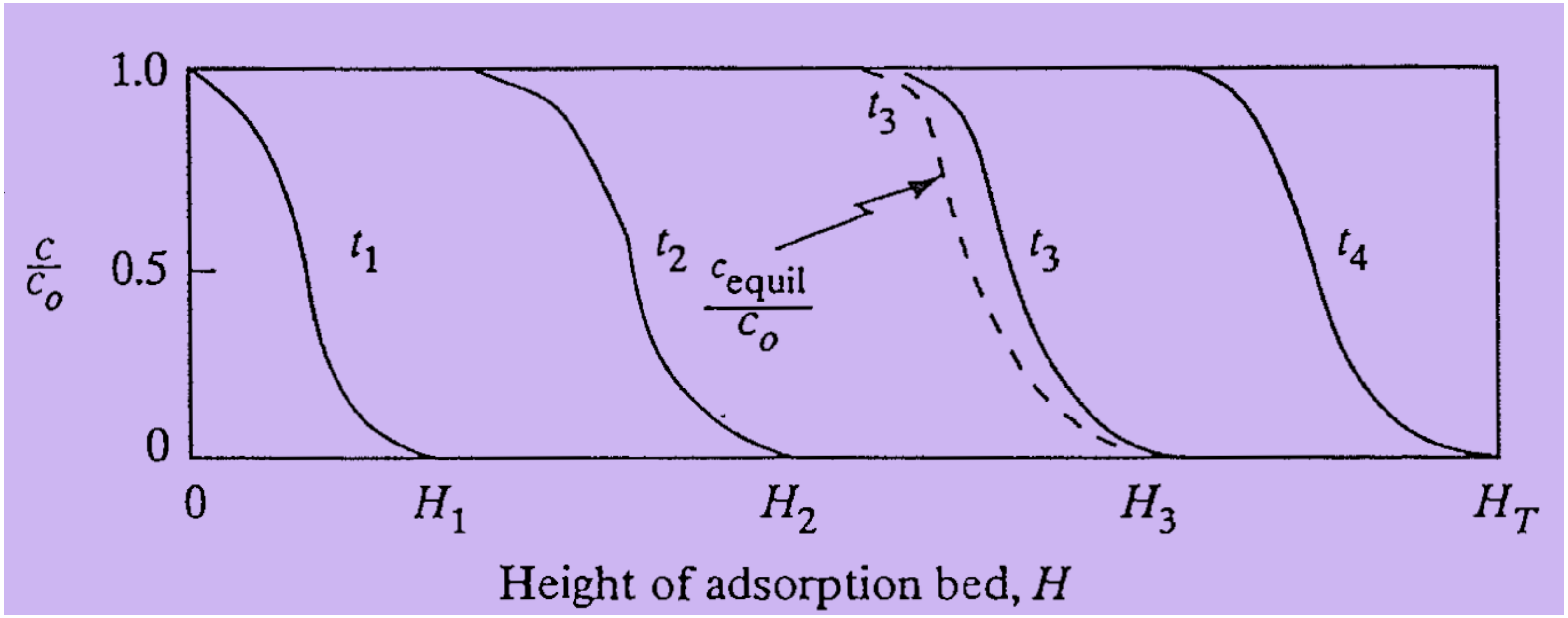
Design of Fixed Bed Adsorption Column

- The fluid to be treated is usually passed down through the packed bed of adsorbent at constant flow rate
- Mass transfer resistances are important in the fixed bed process and the process is unsteady state
- The overall dynamics of the system determine the efficiency of the process rather than just the equilibrium consideration
- The concentrations of the solute in the fluid phase and of the solid adsorbent phase change with time and with position in the fixed bed as adsorption proceeds.
- No solute contain at the bed inlet at the start of the process
- As the fluid first comes in contact with the inlet of the bed, most of the mass transfer and adsorption takes place here
- As the fluid passes through the bed, the conc in this fluid drops very rapidly with distance in the bed and reaches zero well before the end of the bed is reached
- After a short time, the solid near the entrance is almost saturated and most of the mass transfer and adsorption now takes place at slightly farther from the inlet
- At a later time, the mass tranfer zone where most of the conc change takes place has moved farther down the bed

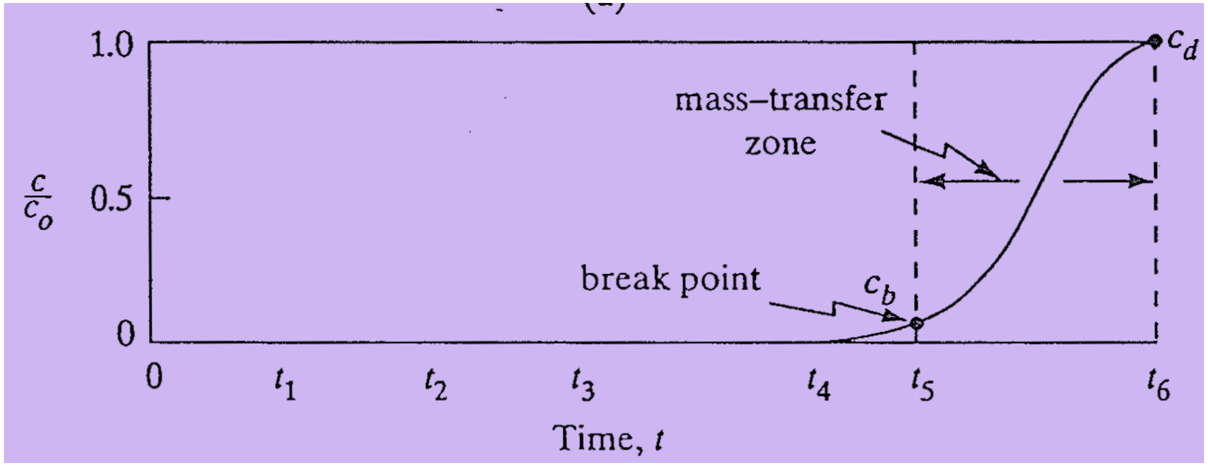
Design of Fixed Bed Adsorption Column

- Concentration profile at various positions and times in the fixed bed adsorption.

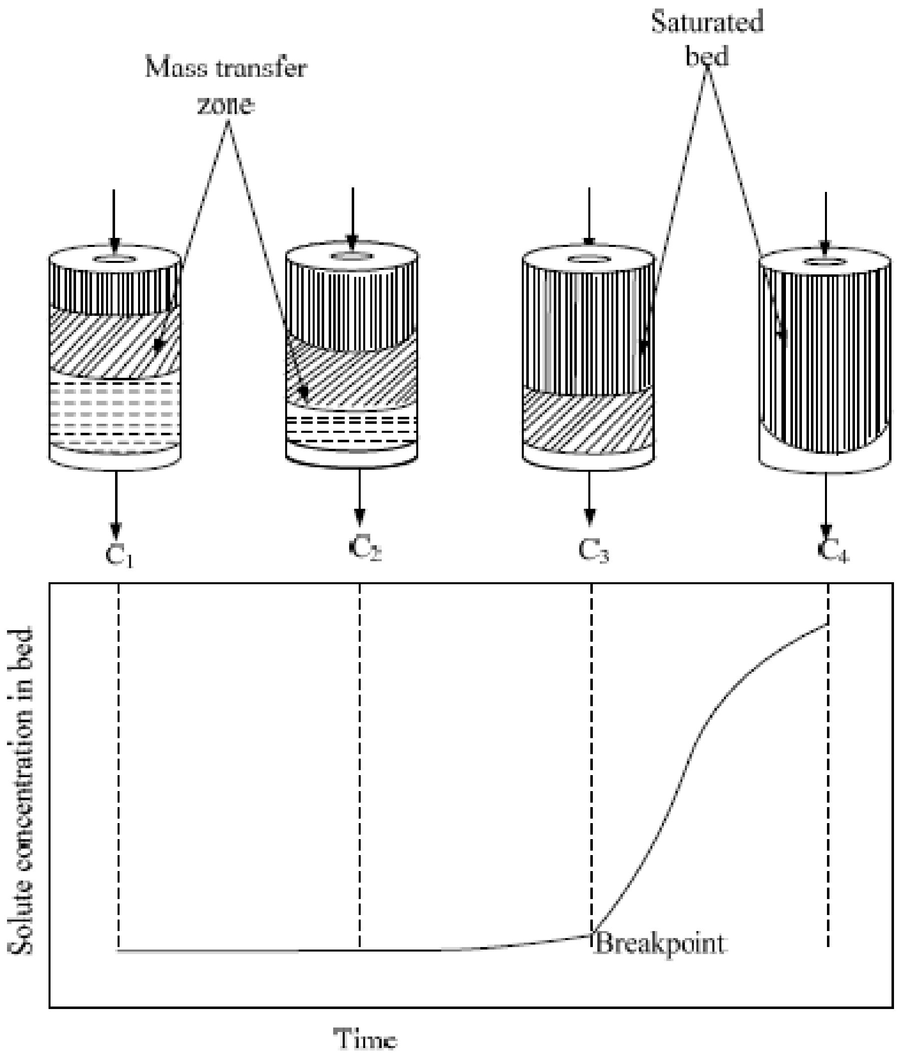


Breakthrough Concentration Curve

- The break point occurs when the concentration of the fluid leaving the bed rise to c_b, which call break point.
- The concentration rises very rapidly up to point c_d, which is the end of the breakthrough curve, where the bed become ineffective.
- The break point conc represent the maximum that can be discarded and is often taken as 0.01 to 0.05 for c_b/c_o
- The value c_d/c_o is taken as the point where cd is approximately equal to c_o
- For narrow mass transfer zone, the breakthrough curve is very step and most of the bed capacity is used at the break point. This makes efficient use of the adsorbent and lowers energy cost for regeneration



Breakthrough Concentration Curve



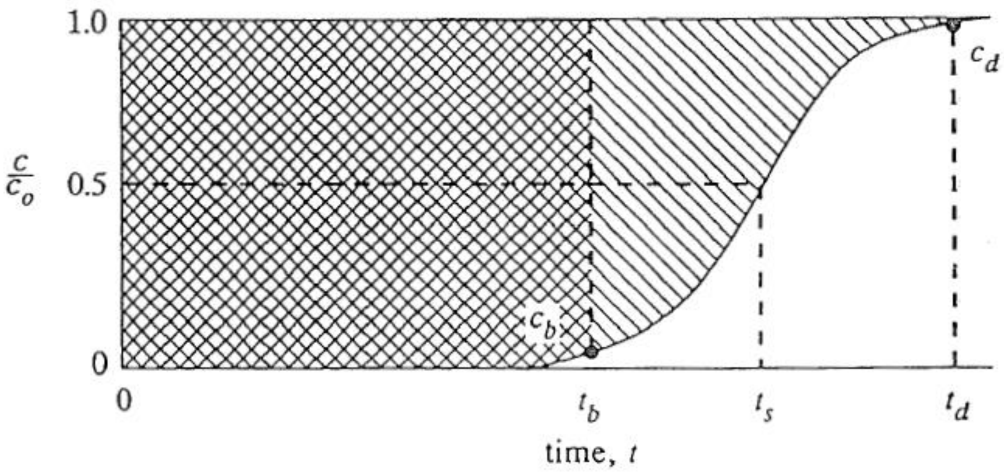
Capacity of Column and Scale-Up Design Method

- Mass transfer zone width and shape depend on the adsorption isotherm, flow rate, mass transfer rate to the particles and diffusion in the pores
- The total or stoichiometric capacity of the packed bed tower is proportional to the area between the curve and a line at c/c_o = 1.0 (shaded area)
- Time equivalent to the total capacity, t_t

$$t_t = \int_0^{\infty} \left(1 - \frac{c}{c_o}\right) dt$$

- The usable capacity of the bed up to the break point time t_b (i.e time at which the effluent conc reaches its maximum permissible level)is given as

$$t_u = \int_0^{t_b} \left(1 - \frac{c}{c_o}\right) dt$$



- The can be determine graphically or numerically, or
- Assume breakthrough curve symmetrical at c/co = 0.5 and ts, then tt = ts
- This assume that the area below the curve between tb and ts is equal to the area above the curve between ts and td

Capacity of Column and Scale-Up Design Method

- Length of bed used up to the break point, H_B

$$H_B = \frac{t_u}{t_t} H_T$$

- Length of unused bed, H_{UNB}

$$H_{UNB} = \left(1 - \frac{t_u}{t_t}\right) H_T$$

- The H_{UNB} represent the mass transfer section or zone. It depends on the fluid velocity and is essentially independent of the total length of the column, H_T
- The full scale adsorber bed can be designed simple by first calculating the length of bed need to achieve the required usable capacity, H_B. Then the total length , H_T is simply added H_B with H_{UNB}

$$H_T = H_{UNB} + H_B$$

- The mass velocity in the bed remain constant for scale-up, the diameter of the bed should be adjusted to keep it constant.
- Typical packed bed operation: height 0.3-1.5m, 15 – 50cm/s gas velocity, 0.3-5mm adsorbent particle size, adsorption time 0.5-8h, 0.3-0.7cm/s liquid velocity, practical bed depth is 5-10 times the length of bed of the mass transfer zone

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