SEPARATION PROCESS

ADSORPTION
Part 1

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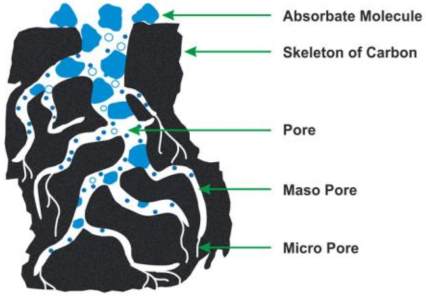
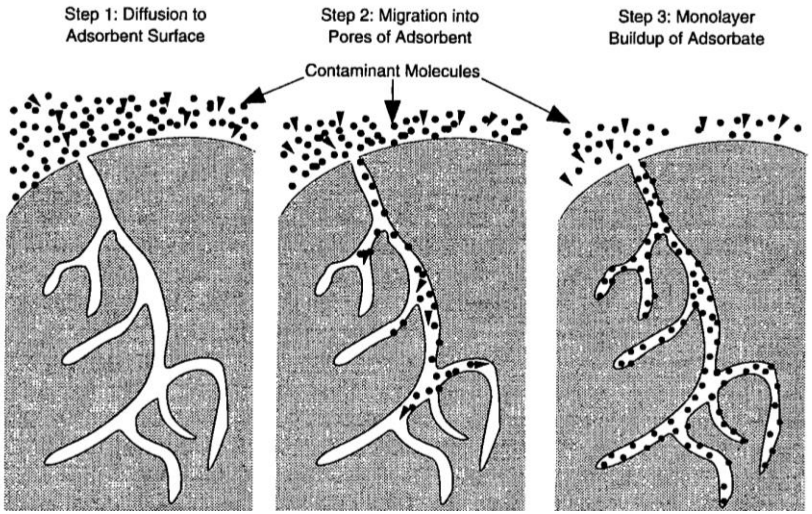
Adsorption Process

- One or more components of gas or liquid stream are adsorbed on the surface of solid adsorbent.

– Physical adsorption or van der Waals adsorption occurs between the adsorbed molecule and pore surface and is readily reversible

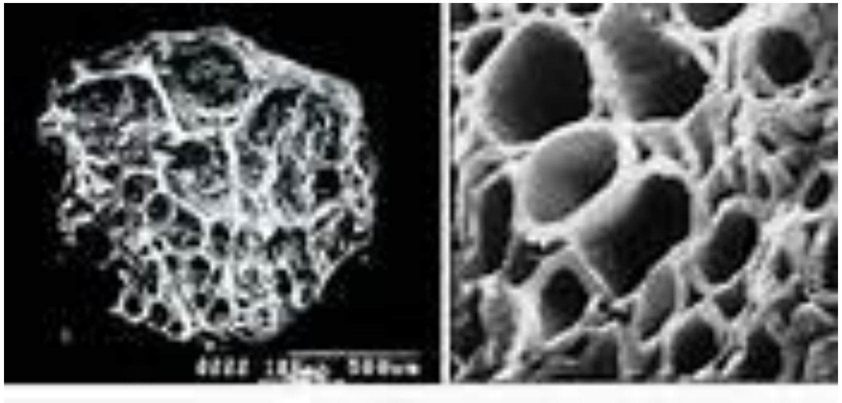
- Overall adsorption process consist several steps – solute diffuses from the bulk liquid to the exterior surface of adsorbent, then diffuse inside the pore to the surface of the pore
- Saturated adsorbent can be regenerated by several method
  - Temperature swing (unfavourable)
  - Pressure swing
  - Inert/Purge stripping
  - Displacement purge cycle





Adsorbent

- Adsorbent
  - pellets, beads, or granules from 0.1 mm-12 mm
  - Porous structure, with many fine pores and pore volumes up to 50% of total particle volume
  - Physical adsorption or van der Waals adsorption occurs between the adsorbed molecule and pore surface and is readily reversible



Adsorbent

Activated carbon

- Microcrystalline material made by thermal decomposition of wood, vegetable shells, coal and etc.
- Surface area 300 – 1200 m^2/g
- Average pore diameter 10 – 60A
- Adsorb organic compound

Adsorbent

Silica gel

- Made by acid treatment of sodium silicate solution and then drying
- Surface area 600 – 800 m^2/g
- Average pore diameter 20 – 50A
- To dehydrate gases and liquids, and to fractionate hydrocarbon

Adsorbent

Activated alumina

- Hydrated aluminum oxide is activated by heating to drive off the water
- Surface area 200 – 500 m^2/g
- Average pore diameter 20 – 140A
- Mainly used to dry gases and liquids

Adsorbent

Molecular sieve zeolite

- Porous crystalline aluminosilicates that form an open crystal lattice containing precisely uniform pores
- Pore diameter 3 – 10A
- Used for drying, separation of hydrocarbon mixture, etc

Adsorbent

Synthetic polymer or resin

- By polymerizing two major types of monomers
- Made from styrene and divinylbenzene used to adsorb nonpolar organics from aqueous solution
- Made from acrylic esters used to adsorb more polar solutes in aqueous solution

Adsorbents (Ion Exchange)

Anion Resin

Cation Resin

Adsorbent - Applications

Typical Applications of Commercial Adsorbents

Type	*Typical Applications*
Silica Gel	Drying of gases, refrigerants, organic solvents Dessicants in packings and double glazing Dew point control of natural gas
Activated alumina	Drying of gases, organic solvents, transformer oils Removal of HCl from hydrogen Removal of fluorine and boron-fluorine compounds in alkylation process
Activated carbon	Nitrogen from air Hydrogen from syn-gas and hydrogenation processes Ethene from methane and hydrogen Removal of odours from gases Removal of solvent vapors Removal of SOx and NOx Decolorising of syrups, sugars and molasses Water purification

Adsorbent - Applications

Typical Applications of Commercial Adsorbents (cont'd)

Type	*Typical Applications*
Zeolites	Oxygen from air Drying of air Removing water from azeotropes Purification of hydrogen Separation of ammonia and hydrogen Recovery of carbon dioxide Separation of and oxygen argon Removal of acetylene, propane and butane from air Separation of xylenes and ethyl benzene Separation of olefins and aromatics from paraffins Pollution control (removal of Hg, SOx, NOx)
Polymers and resins	Water purification Recovery and purification of steroids, amino acids and polypeptides Separation of fatty acids from water and toluene Recovery of proteins and enzymes Removal of colours from syrups

Regeneration of Adsorbent

Adsorbent Regeneration

Temperature Swing

- Also known as thermal swing cycle
- Heating with embedded stream coils or with a hot purge gas stream
- The elevation of temperature shift the adsorption equilibrium curve
- Bed must be cooled for used in the next cycle
- Time taken few hours or more

Pressure Swing Cycle

- Pressure is reduced at constant temperature and then purging the bed at this low pressure
- Reduction of pressure shift the adsorption equilibrium
- Time taken is very short compared to temperature swing cycle

Inert Purge Gas Stripping Cycle

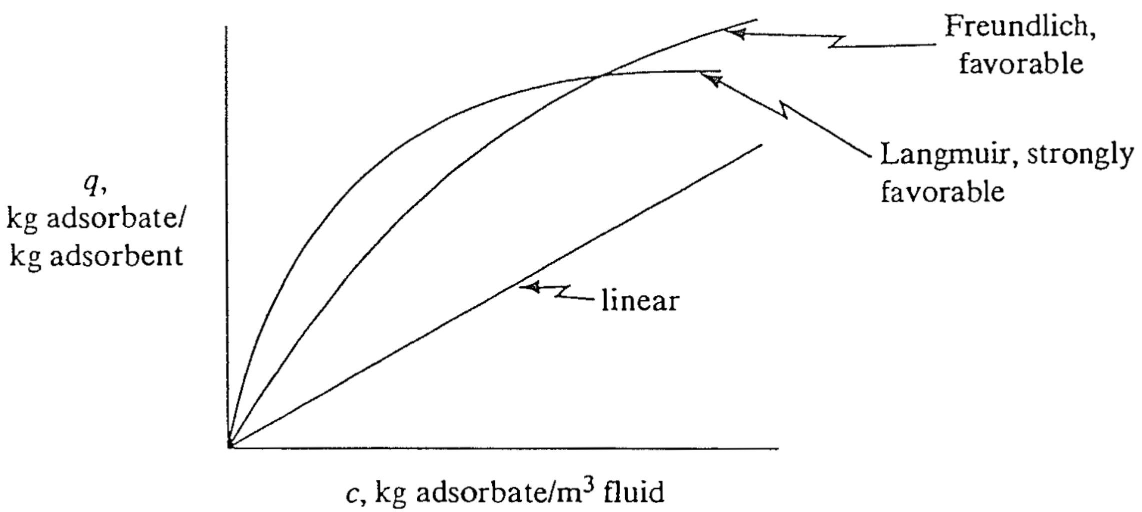
- By passing a nonadsorbing or inert gas through the bed
- The partial pressure or concentration around the particle is low and desorption occurs
- Regeneration time only a few minute

Displacement Purge Cycle

- The pressure and tempearture are kept constant as in purge gas stripping, but a gas or liquid is used that is adsorbed more strongly than the adsorbate and displace the adsorbate
- Regeneration time only a few minute

Adsorption Isotherm

Linear	Freundlich	Langmuir
• Is not common, normally valid in dilute region $$q = Kc$$	• By plotting log q vs loq c, slope is n $$q = Kc^n$$	• Only a fixed number of actives available for adsorption • Monolayer adsorption • Adsorption is reversible and reaches an equilibrium condition • By plotting 1/q vs 1/c, slope is K/q_0 and intercept is $1/q_0$ $$q = \frac{q_0 c}{K + c}$$



Batch Adsorption

- To adsorb solutes from liquid solutions when the quantities treated are small in amount, as in pharmaceutical.
- Material balance

$$q_F M + c_F S = qM + cS$$

q_F = initial concentration of solute in adsorbent (kg/kg adsorbent)
c_F = initial concentration of solute in solution (kg/m^3)
q = concentration of solute in adsorbent (kg/kg adsorbent)
c = concentration of solute in solution (kg/m^3)
M = amount of adsorbent, kg
S = volume of feed solution, m^3

- The intersection of material balance equation and equilibrium line intersection gives the final equilibrium value of q and c.

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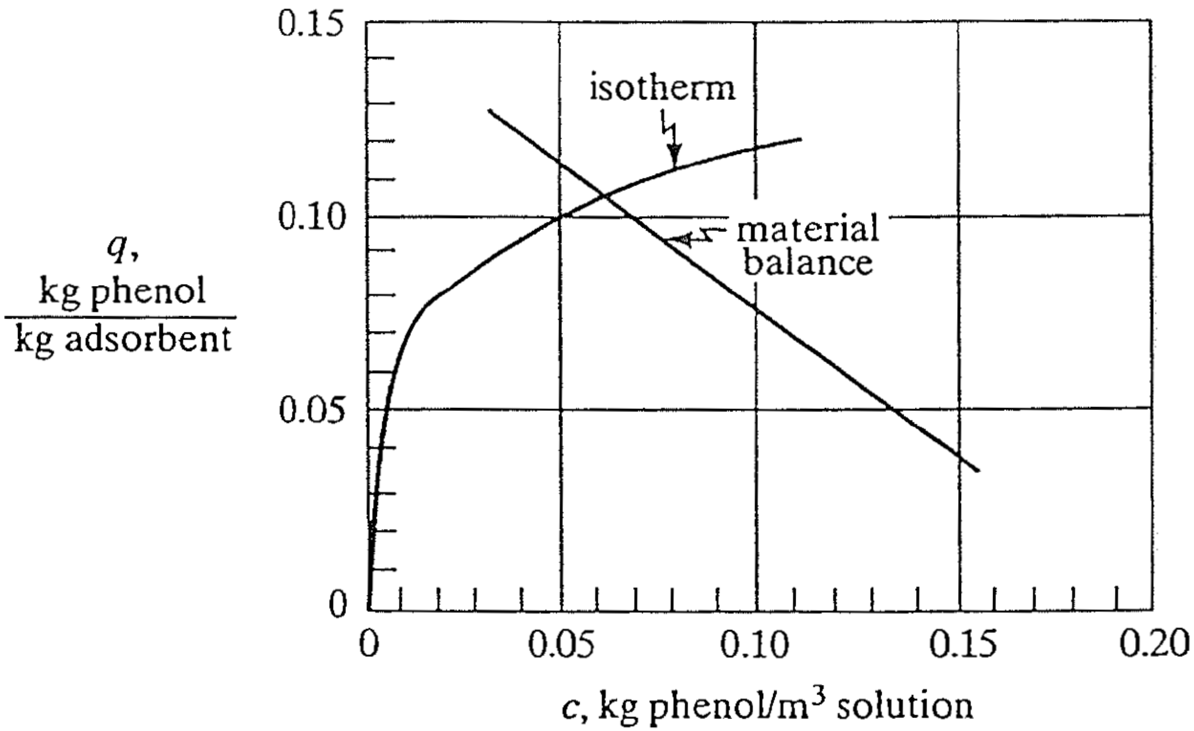

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