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**Various Separation processes and
identification of novel separation processes**

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Various Separation processes and Identification of novel separation processes

As discussed in the earlier chapter, the separation processes are divided in equilibrium and rate governed separation process. In equilibrium governed separation processes, the product phases are in equilibrium with the inlet phases. In rate governed separation processes, difference of rate of physical transport of species brings the separation. Some of the specific separation processes under these two categories are elaborated below.

2.1 Equilibrium governed processes

Four popular and quite common equilibrium governed separation processes are described.

Distillation

Distillation is based on the differences in boiling points of the constituents in a mixture. The component having the lower boiling point will go to the vapor phase earlier, leaving behind the other component in the residual mixture. In this process, external heating is required to heat up the system. Therefore, the top vapor phase is condensed and is rich in one component and the residual liquid phase is rich in other component. This is known as flash distillation. In another process, a part of the condensed stream from the top is recycled down the column. This is known as reflux. In this case, there is intimate mixing of the liquid stream coming down and vapor going up. This operation is carried out in counter current fashion and this enhances the efficiency of the process. This is generally used for separation of aqueous mixture of various organic solvents, like, toluene, benzene, acetone, ethyl benzene, etc.

Absorption

In this process, a vapor in an inert gas is absorbed in a liquid stream. The vapor is soluble in the liquid. The liquid stream rich in solubilized vapor components is separated by distillation or some other suitable techniques. The liquid can be recovered and reused in the process itself. An example is removal of ammonia from ammonia – water mixture using water as solvent. Removal of carbon dioxide from a mixture of air and carbon dioxide using a solvent like primary or secondary or tertiary amines is another example. Typically this operation is carried out in counter current manner to enhance the efficiency of this process. Sometimes, the packed beds or staged beds like trays are used to have better mixing during the transfer process. It may be mentioned that absorption is a bulk phenomena, i.e., the gaseous solutes are transported to the bulk of the liquid stream. It may be noted that to effect separation, a matter is introduced in the system.

Adsorption

Separation of solutes by transporting it from gaseous or liquid streams on a solid surface is known as adsorption. As opposed to absorption it is a surface phenomenon. The solute is fixed on the solid surface only. Typically, the solid surface is specific for a particular component present in the feed stream. For example, in a liquid stream having organic as well as inorganic components, the organics are preferentially adsorbed on the surface of activated carbon. Typically, in a bed, the adsorbent particles are kept and the fluid is pumped through the system for intimate mixing. In the process, the solute is transferred to the solid phase. After sometime, the solid phase is completely saturated and the

transfer of species becomes extremely slow due to lack of driving force. In such case, the bed has to be replaced by new adsorbents or the bed has to be regenerated by a suitable washing protocol. It may be noted, that a reasonably lower particle size of adsorbents provides sufficient surface area for separation. Removal of organics from an aqueous mixture using activated carbon is an example of adsorption. It may be noted that to effect separation, a matter is introduced in the system.

Drying

In drying, water vapors from a solid material are removed by using a vapor stream to an acceptable small limit. Generally it is carried out by applying thermal energy as compared to introduction of a matter in case of absorption or adsorption. The process efficiency depends on the temperature, relative humidity and other thermo physical properties of the drying vapor as well as the temperature and other thermo-physical properties of the solid.

2.2 Rate governed processes

Most of the membrane based processes are the rate governed. The main crux of the separation lies in the difference of transport of various species through the membrane. The driving force of such transport is generally gradient of chemical potential. If we recall the definition of gradient of chemical potential, it is composed of four parts. These are concentration gradient, pressure gradient, temperature gradient and electrochemical potential gradient. Presence of these causes (one or more of such gradients) results into effects (the difference in separation and hence effects). Some of these systems are described below.

Osmosis

Osmosis is observed when a solution is separated from the solvent by a semipermeable (only solvent is permeable species) membrane. Apparently, difference in osmotic pressure across the membrane causes the transport of the solvent. Actually, osmotic pressure is a colligative property and it is a function of concentration. Therefore, the concentration (or more generally activity) gradient of the solvent is the main driving force in osmosis. In this case, the solvent flows from the solvent side to the solution side until, the solvent activity becomes almost equal in both the sides. This results in generation of hydrostatic pressure difference between the two sides, known as osmotic pressure. If the initial concentration of solute is more in the solution side, more solvent will flow in from the solvent side to equalize the solvent activity on both the sides, resulting in more osmotic pressure difference.

Reverse Osmosis

It must be understood that osmosis is a natural phenomenon. In case of reverse osmosis, pressure is applied on the solution side externally (using a pump or a compressor), so that the osmotic pressure is overcome and the solvents are forced out of the solution side. The efficiency of this process depends on the porosity, morphology and thickness of the membrane. These factors influence the transport of the solvent through the membrane immensely and thereby, dictating the throughput of the process and the quality of the product. Since, reverse osmosis membranes have very small pore size, this is used for separation of lower molecular weight species, like, salts. A salt having very osmotic pressure, the operating pressure in the feed side of a reverse osmosis process is therefore extremely high. This will lead to deposition of salts near the membrane surface, leading

to build up of a concentration boundary layer. Therefore, the pressure gradient in this system leads to concentration difference.

Dialysis

In this case, two liquid streams are separated by a permeable barrier or membrane. In the feed side, a specific set of solutes are permeated through the membrane to the other side. The upstream feed is known as the feed side and the downstream is known as the dialysate. Typically, dialysate stream is pure distilled water. Thus, the concentration gradient between the two streams is the maximum. The transport is effected by the concentration gradient between two streams. The duration of separation entirely depends on the rate of the solutes through the membrane. An example is removal of urea, creatinin from blood stream.

2.3 Novel separation processes

The separation processes those are not conventional and routine fall under this category. Therefore, some of the equilibrium and rate governed separation processes are included this. Some of the processes are identified as, (i) Membrane based separation processes; (ii) Chromatographic separation processes; (iii) Electric field assisted separation processes; (iv) Ion exchange processes, etc.