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Application of membrane separation processes in petrochemical industry: a review

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Abstract

In this paper a general review on different membrane processes and membrane reactors was done. As the main aim of this paper is to review the application of membrane processes in petrochemical industry, processes such as olefin/paraffin separation, light solvent separation, solvent dewaxing, phenol and aromatic recovery, dehydrogenation, oxidative coupling of methane and steam reforming of methane were discussed in detail. Besides, separation using polymer-inorganic nano composite membranes and wastewater treatment using membrane bio-reactors were reviewed.

Keywords: Membrane process; Facilitated transport; Olefin; Paraffin; Nano composite membrane; Pervaporation; Reverse osmosis (RO); Membrane aromatic recovery system (MARS); Dehydrogenation; Oxidative coupling of methane (OCM); Steam reforming of methane (SMR); Water gas shift (WGS) reaction; Membrane bio-reactor (MBR)

1. Introduction

Nowadays, membrane technologies are becoming more frequently used for separation of wide varying mixtures in the petrochemical-related industries and can compete successfully with traditional schemes [1–5]:

- The technology behind membrane gas separation is potentially an energy-saving one, because the separation process takes place without phase transition.
- It is also better for the environment, since the membrane approach requires the use of relatively simple and non-harmful materials.

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- The recovery of minor but valuable components from a main stream using membranes can be done without substantial additional energy costs.
- Compared with conventional techniques, membranes can offer a simple, easy-to-operate, low-maintenance process option.
- The development of novel materials for gas membrane manufacturing such as organic polymeric, hybrid organic-inorganic and inorganic will expand the use of membrane technology into new fields of applications in the petrochemical industry.
- The process is simple.
- There are diverse applications which can be studied by the same basic formulations.
- The process is generally carried out at atmospheric conditions which, besides being energy efficient, can be important for sensitive applications encountered in pharmaceutical and food industry.
- Modules can be added and optimized in a process design to achieve the desired separation.
- Their systems have a low capital cost, compact size, modular configuration, and low specific power consumption, which reduce the production cost.
- It is a clean process and requires simple and inexpensive filtration.
- The process is continuous and the membranes do not require regeneration, unlike the adsorption or the absorption processes, which require a regeneration step leading to the use of two solid beds or a solvent regeneration unit.

In the petrochemical industry, olefins such as ethylene and propylene are the most important chemicals used for the production of polyolefins such as polyethylene, polypropylene, styrene, ethyl benzene, ethylene dichloride, acrylonitrile, and isopropanol. An important step in the manufacture of olefins is large-scale separation of the olefin from the corresponding paraffin [6]. Furthermore, dehydrogenation, oxidative coupling of methane, steam reforming of methane and water gas shift reaction are some important reactions in petrochemical industry.

Membrane gas separation is attractive because of its simplicity and low energy cost, but it has one major drawback and that is a reverse relationship between selectivity and permeability. Nano composite membranes, in which selectivity and permeability can simultaneously be improved, solve this problem.

Petrochemical waste streams may contain phenolic compounds or aromatic amines. They are highly toxic and at high concentrations are inhibitory to biological treatment. Membrane aromatic recovery system (MARS) is a relatively new process for recovery of aromatic acids and bases.

Wastewater in petrochemical industry is currently treated by activated sludge process with pretreatment of oil/water separation. Tightening effluent regulations and increasing need for reuse of treated water have generated interest in the treatment of petrochemical wastewater with the advanced membrane bio-reactor (MBR) process.

In this paper, membrane and their application in some important petrochemical processes, nano composite membranes and membrane bioreactors are reviewed.

2. What is a membrane?

Membrane is defined essentially as a barrier, which separates two phases and restricts transport of various chemicals in a selective manner. A membrane can be homogenous or heterogeneous, symmetric or asymmetric in structure, solid or liquid; can carry a positive or negative charge or be neutral or bipolar. Transport through a membrane can be affected by convection or by diffusion of individual molecules, induced by an electric field or concentration, pressure or temperature gradient. The membrane thickness may vary from as small as 10 microns to few hundred micrometers. The principal types of membrane are shown sche-