Review Paper

Review on Mechanism of Facilitated Transport on Liquid Membranes

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Abstract
Membrane processes are used in various fields such as the environment, agriculture and different industrial sectors. These clean techniques are often adopted for directed processes such as treatment, recovery, valorization and separation. In this review article, the theoretical principles and the different classifications of liquid membranes, such as supported liquid membranes are discussed. Afterward, the mechanism of facilitated transport, and finally advantages and disadvantages of this technology are discussed, comprehensively.

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1. Introduction

Membrane processes are adopted as an ecological alternative, to purify, separate, recover or eliminate organic or inorganic substances from liquid or gas mediums, with minimal energy consumption, significantly reducing the volume waste and without addition of toxic compounds. It is possible to extract the substances which are breakable or sensitive to temperature. In addition, the membrane technology is modular and able to work continuously. These processes are applicable in several economic sectors, such as the environment, energy, health, water treatment, cosmetic, food, and chemicals. The global market for membranes increasingly occupies an important place, and exceeded a figure of several billion dollars in 2015 and its growth is very regular, i.e., more than 10% per year.

According to the definition of "European Membrane House": a membrane is a permeable barrier, or semi-permeable, separating the two phases, which blocks or limits the movement of certain compounds. The membrane may be either in liquid phase or gaseous phase.

A liquid membrane is a liquid or supported liquid barrier which separates two phases (source phase and receptor phase), the chemical species can move through the membrane from the region with a high concentration to the region of low concentration of the same substrate. In this article, different types of membranes, their advantages and disadvantages, and the process of transportation and extraction of some invaluable compounds are reviewed.

2. Classification of membrane processes

The term ‘membrane processes’, is used to designate a set of tools implementing a semi-permeable membrane for separation and recovery or removal of species contained in a mixture. The various membrane processes are distinguished by:

- The chemical nature of the membrane
- The structure of the membrane
- The implementation and operation mode
- The type of force (or force gradient) used
- The nature of the phases in contact with the membrane
- The size, nature of the substrates to be treated

2.1. Chemical nature of membrane

The chemical nature of the membrane is one of the most important criteria of preparation. In fact, membranes can be developed from polymer materials, ceramics, metals, glass or combination of two or more of these. The choice of matching the specifications and physicochemical properties of materials is then crucial. The membrane must have good inertia against chemical agents, temperature variations and mechanical stresses of use. The materials used for the preparation of membranes include three major categories of membranes: organic, inorganic and composites membranes like supported liquid membranes (SLM).

2.2. Membrane structures

The structure of the membrane is an important factor, it governs the transport mechanism and extraction. The organic, inorganic or composite membranes, can be classified into two categories using a porosity as a criteria.

2.2.1. Dense membranes

Dense membranes are considered as a homogenous material where thickness varies between 1 and 300 µm, depending on the mechanical performance of the material. The permeability decreases inversely with the thickness. For these types of membranes, the fraction of amorphous and crystalline area of the material strongly influences the performance of extraction of species, and consequently their selectivity, the result of a phenomenon of diffusion-dissolution where the polymer-solvent interactions and polymer-substrate are crucial. These non-porous membranes mainly are used in the gas treatment area (gas permeation, and pervaporation) or reverse osmosis.

2.2.2. Porous membranes

Porous membranes are heterogeneous materials that are used in the processes of liquid-liquid or solid-liquid filtration. The sizes of the pores can rank as recommended by the International Union of Pure Chemistry, and on the definition of porosity in solids, into three categories:

- Microporous for a pore diameter less than 2 nm.
- Mesoporous for a pore diameter between 2 and 50 nm
- Macroporous for a pore diameter greater than 50 nm.

according to the morphology of the two types of membranes (dense and porous), can be divided into two other categories:

2.2.3. Symmetric membranes

Symmetric membranes are isotropic materials. This defines a material which has only one compound. For porous materials, the symmetrical term specifies that the diameters of all the pores are comparable throughout the thickness.

2.2.4. Asymmetric membranes

Asymmetric membranes are anisotropic materials. They are represented by combinations of materials (composite membrane) or by a pore size variation of the same material in the thickness

2.3. Modules

By definition, a module is a basic set of a separation installation or extraction membranes comprising one or more filter elements (membranes), frames, separators, plates or inserts drains, pipes and joints needed for fluid flow [1]. There are several types of modules that correspond to the different geometries adopted for the membranes. For selecting a module and therefore a membrane geometry, many factors should be taken into account. Among them, we can mention the congestion (the ratio between the area of membrane and the volume of module configuration), the fouling that is inherent to operating mode and hydrodynamic flows, membrane cleaning, cost of investment and operation, and lifetime of membranes. The main advantages and disadvantages of the four major commercial types of modules are summarized in Table 1.
Table 1
The main advantages and disadvantages of different modules.

<table>
<thead>
<tr>
<th>Module</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat sheet</td>
<td>- Low energy consumption</td>
<td>- High investment</td>
</tr>
<tr>
<td></td>
<td>- Easy cleaning</td>
<td>- High Dimensions</td>
</tr>
<tr>
<td></td>
<td>- Fouling low</td>
<td>- Poor Pretreatment</td>
</tr>
<tr>
<td></td>
<td>- Low Filter area</td>
<td>- Fouling low</td>
</tr>
<tr>
<td>Tubular</td>
<td>- Simple technology</td>
<td>- High investment</td>
</tr>
<tr>
<td></td>
<td>- Average Cleaning</td>
<td>- High energy consumption</td>
</tr>
<tr>
<td></td>
<td>- Fouling medium</td>
<td>- High Dimensions</td>
</tr>
<tr>
<td></td>
<td>- Simplified Pretreatment</td>
<td>- Fouling medium</td>
</tr>
<tr>
<td>Spiral</td>
<td>- Fouling medium</td>
<td>- Pretreatment</td>
</tr>
<tr>
<td></td>
<td>- Low space requirement</td>
<td>- Cleaning hard</td>
</tr>
<tr>
<td></td>
<td>- Low investment</td>
<td>- Fouling medium</td>
</tr>
<tr>
<td></td>
<td>- Average Energy consumption</td>
<td>- Low investment</td>
</tr>
<tr>
<td>Capillary</td>
<td>- Low energy consumption</td>
<td>- High Fouling</td>
</tr>
<tr>
<td></td>
<td>- Very small dimensions</td>
<td>- Difficult cleaning</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- High investment</td>
</tr>
</tbody>
</table>

2.4. Driving force

Generally, any process requires an energy input to achieve the transfer operation of the material from one phase to the other. This contribution results in a difference in chemical or physical potential that is represented by the driving force of the process. The processes can be classified according to the type of employed driving force for material transfer to operate an extraction or separation process. Major driving forces used in membrane processes include i) the gradient of the concentration ($\Delta C$), ii) the electrical potential gradient ($\Delta \phi$), iii) the temperature gradient ($\Delta T$); and iv) the pressure gradient ($\Delta P$) [2].

3. Classification of liquid membranes

There are several types of membranes used in the liquid phase, like bulk liquid membranes (BLM), emulsion liquid membrane (ELM), supported liquid membrane (SLM), and supported ionic liquid membrane (SILM).

3.1. Bulk liquid membrane (BLM)

Bulk Liquid Membrane is more particularly designed to implement experiments in laboratory scale, to test a new processes or improving existing systems, so it is a fundamental tool for studying phenomena of facilitated extraction or transport. The organic membrane phase comprising a carrier, dissolved in an organic solvent that is placed in the bottom of the tube (see Figure 1). This membrane phase separates other aqueous phases, source and receiver.

The experimental device or bridge Schulmann (see Figure 1-a) consists of a U-shaped tube where the three phases are placed in contact. This system provides stable hydrodynamic conditions. Burgard et al. [3] have modified this system by using a rotary cylinder (see Figure 1-b). In this type of membrane, the volume of the membrane phase is most important with respect to the volumes of source and receiving phases, which requires a large quantity of the carrier.

![Fig. 1. Bulk liquid membrane: a) U-tube (bridge Schulmann) and b) cell with a rotating bell [3].](image)

![Fig. 2. The different steps relating to processes of ELM (adopted from) [4].](image)
BLM are used to study the selectivity and kinetic transport parameters of amino acids using the D2EHPA as a carrier, that dissolved in kerosene [6]. Chakrabarty et al. [7] conducted a comprehensive study to extract Lignosulfonate (LS) from the waste with Triocethyleneam (TOA) as the carrier. The transport of metal ions is also studied by this type of membrane such as uranium [8,9], palladium [10], vanadium [11], copper [12,13], chromium [14], and cadmium [15,16]. Recently, new configuration of BLM have been developed which includes for example: bulk hybrid liquid membrane (BHLM) [17], and bulk ionic liquid membrane (BILM) [18].

3.2. Emulsion liquid membrane (ELM)

In 1968, the ELM was used to separate the hydrocarbons [19]. This type of membrane consists of three phases (see Figure 2): an external, a membrane, and an internal phases. The external phase or the source phase contains the substrate to be extracted; the membrane phase separates physically the external and internal phases. Moreover, it contains a surfactant to stabilize the emulsion. In the internal or the receiving phase, the substrate migrates in one way of the external phase through the membrane into internal phase, where this substrate converted to another species. The driving force of this diffusion is a difference in concentration of the substrate between the external and internal phases. Figure 2 shows the four stages of this membrane process:

ELM is used to recover organic compounds. For example, Chanukya et al. [20] have used hexane and heptane solvents such as membrane phases and Span 80 as a surfactant to extract alcohol from diluted solutions, several factors are studied such as speed and time of stirring, also the concentration of the carrier. In another study, Balasubramanian et al. [5] have conducted an experimental study about the elimination of phenolic compounds from aqueous solutions using the mixed ionic liquid carrier (MILC) containing 1-Butyl 3 Methylimidazolium Hexafluorophosphate [BMIM][PF6] and Span 80 as a carrier (formation of substrate entity). The carrier is considered as a catalyst so that it can be used several times because it is recycled and reused with a small quantity [27].

3.3. Supported liquid membranes (SLM)

3.3.1. Design

The supported liquid membrane (SLM) or the immobilized liquid membranes (ILM) are the liquid impregnated or immobilized in a porous material used as support. This support can be an inert microporous polymer, chemically stable, like the polyvinylidene fluoride (PVDF) and polytetrafluoroethylene (PTFE), where the support is impregnated with an organic solvent (immiscible with water), containing a complexing agent (hydrophobic amphiphilic) (carrier) of substrates. The supported liquid membranes exhibit high selectivity to compounds extracting, by the interaction of the substrate with the carrier and the formation of (carrier-substrate) entity. The carrier is considered as a catalyst so that it can be used several times because it is recycled and reused with a small quantity [27].

The objective of using a module is to hold the wet porous polymer in the liquid phase to increase the mechanical stability of the system, ensure a large effective surface area and a free circulation of the load between the feed phase and receiving phase. Several configurations of SLM membranes, can meet these requirements. They are determined by the shape of the applied module (see Figure 5). The most popular are "Hollow-Fiber Supported Liquid Membrane (HFSLM)" (Figure 5-A), "Flat-Sheet Supported Liquid Membrane (FL-SLM)" (Figure 5-B), and there is also the spiral form (Figure 5-C).

The configuration of the hollow fibers has been used in industrial applications. For instance, Rosell et al. [28] studied the effect of the "design" of this configuration on the extraction of vanadium by Alikat 336 as carrier agent. Indeed, the membrane surface increases with the number of fibers used, but the flux decreases because of the steric hindrance effect between the fibers. Di Lucio et al. [29] demonstrated that, this configuration provides high selectivity for extraction of the compound fructose present in mixtures of sugars, using boric acid as an extractive agent. On contrary, the flat sheet configuration of SLM is often used at laboratory scale because it is simple and flexible. The transport process in SLM is a combination of two simultaneous steps, including extraction and reextraction. The first one is sharing the substrate between the aqueous source and the organic membrane phases by interaction of substrate with the free carrier in membrane (formation of substrate-carrier), and the second step is sharing the substrate between the membrane and the receiving phases by dissociation of the entity.
3.3.2. Components of SLM

Generally, SLM consists of three essential components: a polymeric support, a carrier which is often an amphiphilic supramolecule, and an organic solvent (see Figure 6). The physicochemical properties of these three components have a very important key role on the performance of the SLM and performance of the phenomenon of extraction and facilitated transport.

3.3.2.1. Support

The support is made of a hydrophobic polymer that has high strength and is chemically inert. For making membrane supports either as flat or other form, mostly the polypropylene (PP), Polyvinylidene fluoride PVDF, Polytetrafluoroethylene PTFE or polyether sulfone (PES), Celgard® 2500 are used [56–59]. In order to have the highest possible transport flows by membrane surface unit, the supports must be very porous, in other words their porosity which is the ratio of the pore volume to the total volume must be as large as possible. The porosities between 45 and 75% are available from porous polymeric membrane suppliers.

3.3.2.2. Extractive agent

The extractive agent or carrier is an amphiphilic molecule that ensures and promotes the transport of a substrate from the source phase to the receiving phase, other authors use the term complexing agent or ligand to describe the association between the molecule carrier and the substrate to be transported or extracting. This molecule should be strongly hydrophobic in order to minimize its loss by dissolution in the extra membrane phases, and stay trapped in the membrane phase. However, this agent must have a hydrophilic part as a site for binding to the substrate.

The most conventional carriers are antibiotics, carboxylic acids, phosphoric, sulfonic acids, amines, crown ethers or to extract the metal ions or organic compounds ions [34,60–62]. There is also a new family of carriers are ionic liquids where the carrier is in the form of an organic mixture of an ion pair or a single charged molecule, these carriers have an advantages over the classical carriers, especially to extract charged compounds such as metal ions [63–65].

3.3.2.3. Organic phase (Solvent)

The solvent should be immiscible with the aqueous phases, which its solubility should be as low as possible. It must also have a low vapor pressure to avoid evaporation during the extraction process. The most used solvents are kerosene, dodecane, toluene, and xylene [33,66–68]. To study the influence by the nature of the organic phase (solvent) on the facilitated transport Hassoun et al. [33] have studied the influence of the solvent on the facilitated transport of sugars by an SLM containing methyl cholate as a carrier agent (see Figure 7).

3.3.3. Experimental setup

The cell used to perform the experiments of facilitated transport is composed of two compartments (source phase F and receiving phase R), separated by the membrane (M). The system is immersed in a thermostatic bath (TB) containing water. The homogeneity is ensured by a multi-stirrer (MS) (see Figure 8).

SLM membrane is prepared by impregnation of microporous support in a solution containing a known mass of the carrier dissolved in a given volume of organic solvent for several hours (Figure 9) [69].

3.3.3. Factors affecting the efficiency and stability of SLM

3.3.3.1. The factors affecting the stability of SLM

The stability of SLM is affected by several factors including the nature of the support [70,71], solvent [33], carrier agent, extract of the substrate and also the chemical-physical composition of the source and receiving phases (pH, substrate concentration, and co-ions in nature), and other important factors, i.e., stirring speed and temperature of environment [72,73].

It should be noted that the stability of the entity (substrate-carrier) should be moderate, to ensure transportation of this entity from (source-membrane) interface, to (membrane-receiving) interface, because, it must to ensure the dissociation of this entity at the second interface. More stable entity may cause a complete fouling where the extraction of the substrate is practically zero.
3.3.3.2. Some approaches to overcome the instability of SLM

The supported liquid membranes present many advantages at laboratory scale, which make them a good candidate for some large industrial applications. However, the instability problem of membrane phase with the time affects lifetime of this membrane type. As this problem is caused by the gradual loss of membrane phase in both aqueous solutions (source and receiving), through the formation of emulsions at the two interfaces of the membrane. This failure also causes contamination of two aqueous phases and can also destroy the separation unit, completely [74]. Researchers from the University of Twente (The Netherlands) indicate that the stability of an SLM is maintained when there is no loss of membrane phase and the flow of material through the membrane remains constant [75]. Consequently, re-impregnation of the support with the membrane phase is not a good solution when the loss is significant. Zhang et al. measured the loss of membrane phase in the case of several supports (PVDF, cellulose acetate, etc.) impregnated in n-decanol as the organic phase [76].

Other researchers consider a SLM is stable if the flux remains constant, even if there is a loss of the membrane phase. Van Voode et al. have studied the stability of SLM with Celgard as support, a mixture of two carriers LIX 860-I and Cyanex 302 in kerosene as the solvent to extract the Nickel (II) with a constant flux during 650 h [77]. To overcome the problems of the instability of supported liquid membranes, several approaches have been developed, such as:

1. The support (polymer, pores, thickness, etc.) and the constituents of the organic phase (solvent and carrier agent) must be selected carefully in order to minimize the tendency of the membrane phase out the pores [78,79].

2. The re-impregnation of membrane supports with the organic phase, in the study by Yang et al. [80], the flow of copper was recovered to the initial value after re-impregnation of the membrane used about 40 h. However, for a long-term operation, the flow of copper decreased further with time even if the membrane was re-impregnated with a fresh organic solution (see Figure 10). SEM images indicate that the morphology of the membrane was changed after using it continuously for 600 hours. It is not even stable for 7 days. Authors have got to develop a new type of membrane (the pore-filled membrane (PFM)) which can be stable over 3 months. The polymer inclusion membrane is a good candidate for some large industrial applications.

3. The most common way in recent years to overcome this handicap of instability SLM and to have more effective membranes is to think about fixing or trap the carrier agent in the support matrix, hence the birth of membranes such as polymer inclusion membrane for (PIM), or grafted polymer membranes (GPM).

3.4. Polymer inclusion membrane (PIM)

Polymer inclusion membranes (PIM), plasticized polymer membrane (PPM) or fixed site membrane (FSM) are produced by the evaporation of a volatile solvent containing a matrix polymer such as cellulose triacetate (CTA) or polyvinyl chloride (PVC), a plasticizer, and a carrier [81]. They are used to extract small organic molecules and metal ions [82], orthophosphates [83], cadmium [84], chromium [85,86], and cerium [87]. Kolev et al. have elaborated a membrane with PVC and di(2-ethylhexyl) phosphoric acid (D2EHPA) agent, and they developed a mathematical model for the process of extraction and recovery facilitated the uranium ions [87].

Several studies are conducted on the stability of this type of membranes, e.g., Kagaya et al. [88] have studied the influence of salts and acids on the stability of a membrane with PVC as a polymeric support and Aliquat 336 as a carrier. Scindia et al. [89] have demonstrated that polymer inclusion membrane with CTA as a support and Aliquat 336 as a carrier, is stable for 30 days, compared to a supported liquid membrane which is not even stable for 7 days. Authors have got to develop a new type of membrane (the pore-filled membrane (PFM)) which can be stable over 3 months. The polymer inclusion membrane has low permeabilities relative to other membranes despite their significant stabilities.

3.5. Grafted polymer membranes (GPM)

The grafted polymer membranes (GPM) or functionalized polymer membranes (FPMM) are porous ultrafiltration and microfiltration membranes modified by introducing of chemical groups into the basic structure to make them physically and chemically stable to improve its selectivity and efficiency. The porous structure of the membrane acts as a support for the stabilization of the grafted molecules that may be brittle. So, a more stable composite material, for example, hydrogels are widely used in the pharmaceutical field [90,91]. However, they are unable to withstand mechanical forces, hence the idea to immobilize it in the matrix of porous membranes to increase their mechanical stability without affecting their transport process for use in industrial applications [92,93]. In order to form dense or porous polymers membranes, that can realize this operation, either in situ polymerization or by grafting large or small chain molecules on polymeric matrix. In both cases, the addition of these molecules in the membrane matrix can change the various properties of the membrane such as permeability, flux, mechanical resistance, efficiency, biocompatibility, reactivity and conductivity environment and capacity of the transport and extraction.

In general, polymers can be functionalized in any matrix where the porous structure provides sufficient interaction between the polymer and the structure to be grafted. The organic polymers used in the manufacture of this type of membranes include the fluoro-polymers [94–97], cellulose material [98–100], polysulfides [101–103], polycarbonates [104,105] and polyacrylates [106]. These polymers are widely used for the preparation of the grafted membranes because they are relatively stable.

The development of membrane materials containers immobilized biomolecules or grafted as polyacids, proteins, and enzymes enables the development of high performance materials and high selectivity. Therefore, the grafting of molecules in the polymer matrix improves the properties of the membranes as the acid-base character, the catalytic properties, so these types
of functionalized membranes can be used for the extraction and separation of ions metal, organic molecules, or decontamination and detoxification of contaminated environments.

4. Mechanisms of facilitated transport

4.1. The different types of processes related to membrane transport

In analogy to biological membranes, the transfer phenomenon of a substance through the membrane phase can be achieved either by passive transport or active transport (or directed).

4.1.1. Passive transport

Simple diffusion or passive transport occurs involving only the physical properties of the membrane. The system is governed by the sharing of the substrate between the aqueous phase and the membrane phase and by their diffusion through the membrane under the effect of the concentration gradient (see Figure 11-a).

4.1.2. Facilitated transport

In active transport or facilitated (also directed), membrane phase contains a carrier dissolved in an organic solvent the transfer of the substrate through the membrane phase is done according to the model of the double layers [111] by the following steps:

1. Diffusion of the substrate (S) in the stagnant layer of the source phase.
2. The association between the carrier (C) and the substrate at the first interface between the source and the membrane phase.
3. Diffusion of the entity (carrier-substrate (C-S)) in the membrane phase to the 2nd membrane interface.
4. Dissociation of the entity and regeneration of carrier.
5. Diffusion of the substrate in the receiving phase.

The carrier acts as a catalyst because it increases the solubility of the chemical space in the membrane by promoting the transfer speed. The transfer of the material process stops when the concentration gradient between the feed phase and receiving is zero.

If there is only one species being transported, we talk about simple facilitated transport (see Figure 11-b) and, if the source phase contains two species, that are able to associate with the carrier, we are talking about coupled facilitated transport and there are two possibilities:

- **Co-transport:** This type of transport or extraction is observed when the carrier is neutral in nature, and the feed phase contains a pair of ions (M<sup>+</sup>, X<sup>-</sup>) reversibly by carrier L (Figure 12), and each of the two interfaces can be observed in one of the reactions of the following equilibrium:

\[
M^{n+}_{aq} + mX^{-}_{aq} + L_{org} \leftrightarrow (ML_{org})_{aq} + mH^{+}_{aq}
\]

The cation and anion migrate in the same direction of the source phase to the receiving phase, under the double combined effect, the concentration gradient, especially by their association with the carrier.

- **Counter Transport:** In this case, the carrier can be acidic or basic nature, it’s possible to find counter transport of anions or cations. For counter cation transport, the carrier in the membrane phase is an acid, and this process is done by a cation-exchange proton (pH pump), cations migrate in the opposite direction protons (high pH to low pH) (Figure 13), in this case, the balance in the source-membrane interface is written as:

\[
M^{n+}_{aq} + mHL_{org} \leftrightarrow (ML_{org})_{aq} + mH^{+}_{aq}
\]

The process counter facilitated transport of anions can take place when the carrier in the membrane phase can exchange an anion (basic agent) by interaction with the substrate at source phase-membrane interface, in this case there is formation of neutral entity (A L<sup>+</sup>) on the balance:

\[
A^{-}_{aq} + XL_{org} \leftrightarrow (A^{+}L)_{org} + X^{-}_{org}
\]
In this case, the process is governed by association between the substrate and carrier, the gradient of the concentration of anion $X$ and electro neutrality of the source and receiving phases.

### 4.2. Different facilitated transport mechanisms

To exploit the transport process and the extraction existing and future design of system more selective and more efficient, we have to find models to explain these phenomena of material transfer through the membranes. Several models have been proposed to elucidate the process of facilitated transport, according to the work performed by Smith and Hassoun [34,113]. There are three different possible mechanisms:

* A solution-diffusion mechanism (Figure 14-a): the carrier is movable in the membrane phase; the migration of (substrate-carrier) and the carrier is in the opposite direction of membrane phase. This type of mechanism is favorable in the case of liquid membranes as SLM and BLM.

* One mechanism by jumping on fixed sites (Figure 14-b): the substrate moves successively by binding to several carriers fixed sites that are considered sites of interaction, this type of mechanism is common in solid membranes such as PIM and GPM.

* A mechanism by jumping on mobile sites (Figure 14-c): the substrate moves by the successive migration on several mobile carrier sites, this model is suitable for SLM to explain the higher values of the diffusion coefficients through these types of membranes.

### 5. Conclusions

This paper summarizes the different classification of membranes using several criteria’s like the chemistry, physique nature or geometry of membrane. There are the symmetric, asymmetric, dense and porous membranes. After this, the paper focuses on liquid membranes because they present many advantages like high selectivity and technical feasibility as both laboratory and industrial scales. bulk liquid membrane (BLM) and emulsion liquid membrane (ELM), and supported liquid membrane (SLM), this last one is used more and more because the thickness is very low then others liquid membranes, so, the flux and selectivity are very high, and the quantity of chemical is low. After this, the manuscript presents the preparation method, and discusses the several factors affecting the stability performance of SLM. Finally, the different type of processes and mechanisms of facilitated transport (solution-diffusion, jumping on the fixed or mobile sites) are discussed in detail. In addition, some solutions are presented to increase the stability of supported liquid membrane.

### References


