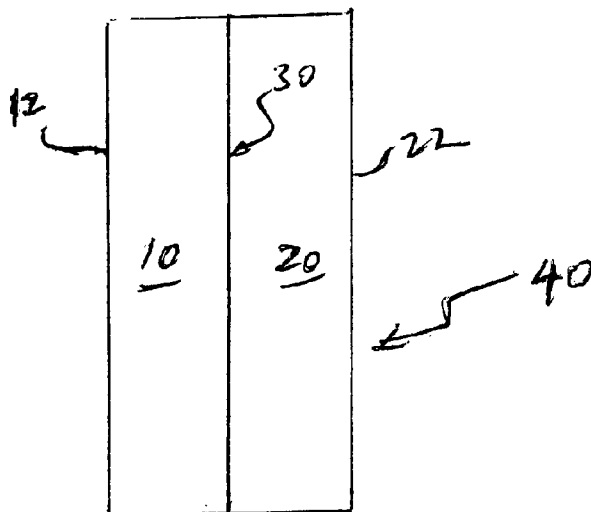




(86) Date de dépôt PCT/PCT Filing Date: 2012/06/07
(87) Date publication PCT/PCT Publication Date: 2012/12/13
(45) Date de délivrance/Issue Date: 2021/05/25
(85) Entrée phase nationale/National Entry: 2013/12/06
(86) N° demande PCT/PCT Application No.: CA 2012/000554
(87) N° publication PCT/PCT Publication No.: 2012/167362
(30) Priorité/Priority: 2011/06/07 (US61/494,204)

(51) Cl.Int./Int.Cl. *B01D 61/38* (2006.01),
B01D 53/22 (2006.01), *B01D 65/00* (2006.01)
(72) Inventeurs/Inventors:
FENG, XIAN SHE, CA;
TOWE, IAN GLENN, CA;
HAMZA, ALI, CA;
PEREZ, JUAN CARLOS, CA
(73) Propriétaire/Owner:
IMTEX MEMBRANES CORP., CA
(74) Agent: RIDOUT & MAYBEE LLP

(54) Titre : PROCÉDE DE SEPARATION DU GAZ AU MOYEN D'UNE MEMBRANE DE GEL AVEC
REAPPROVISIONNEMENT EN LIQUIDE
(54) Title: GAS SEPARATION PROCESS USING GEL MEMBRANE WITH LIQUID REPLENISHMENT



(57) **Abrégé/Abstract:**

There is provided a process for effecting separation of at least a gaseous permeate-disposed operative material from a gaseous supply material that is being supplied to a gaseous supply material receiving space that is disposed in mass transfer communication with a permeate receiving space through a membrane, the gaseous supply material including an operative material that defines a gaseous supply material-disposed operative material, and the membrane including a gel. The process includes replenishing liquid material that has become depleted from the gel.

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property
Organization
International Bureau



WIPO | PCT



(10) International Publication Number
WO 2012/167362 A1

(43) International Publication Date
13 December 2012 (13.12.2012)

- (51) International Patent Classification:
B01D 61/38 (2006.01) *B01D 65/00* (2006.01)
B01D 53/22 (2006.01)
- (21) International Application Number:
PCT/CA2012/000554
- (22) International Filing Date:
7 June 2012 (07.06.2012)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:
61/494,204 7 June 2011 (07.06.2011) US
- (71) Applicant (for all designated States except US): **IMTEX MEMBRANES CORP.** [CA/CA]; 2596 Dunwin Drive, Mississauga, Ontario L5L 1J5 (CA).
- (72) Inventors; and
- (75) Inventors/Applicants (for US only): **FENG, Xianshe** [CA/CA]; 708 Willow Wood Place, Waterloo, Ontario N2T 2T7 (CA). **TOWE, Ian Glenn** [CA/CA]; 4830 Char-

leston Sideroad, Caledon, Ontario L7K 0R8 (CA). **HAMZA, Ali** [CA/CA]; 1208 - 20 Mississauga Valley Blvd., Mississauga, Ontario L5A 3S1 (CA). **PEREZ, Juan Carlos** [CA/CA]; 40 Burton Road, Brampton, Ontario L6X 1M7 (CA).

(74) Agent: **SAJEWYCZ, Mark**; Norton Rose Canada LLP/ S.E.N.C.R.L., S.R.L., 1 Place Ville Marie, Suite 2500, Montreal, Quebec H3B 1R1 (CA).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH,

[Continued on next page]

(54) Title: REPLENISHING LIQUID MATERIAL TO MEMBRANE

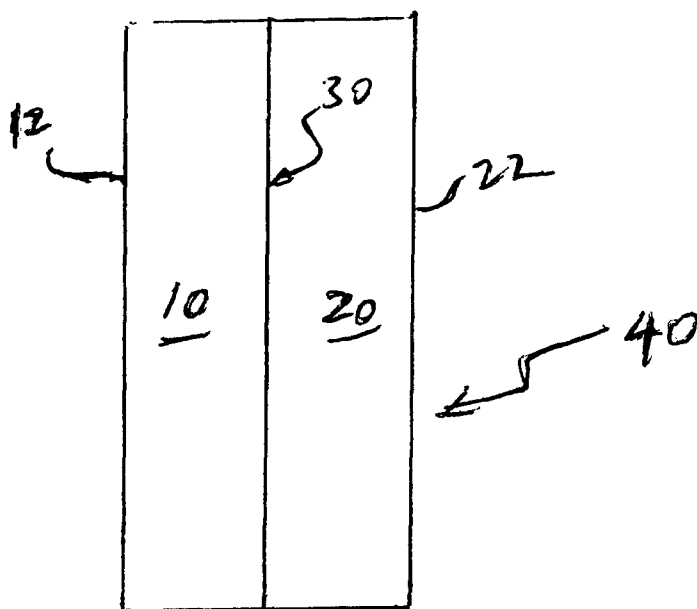


FIG. 1

(57) Abstract: There is provided a process for effecting separation of at least a gaseous permeate-disposed operative material from a gaseous supply material that is being supplied to a gaseous supply material receiving space that is disposed in mass transfer communication with a permeate receiving space through a membrane, the gaseous supply material including an operative material that defines a gaseous supply material-disposed operative material, and the membrane including a gel. The process includes replenishing liquid material that has become depleted from the gel.

WO 2012/167362 A1



GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ,
UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ,
TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK,
EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU,
LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK,

SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ,
GW, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

GAS SEPARATION PROCESS USING GEL MEMBRANE WITH LIQUID REPLENISHMENT

RELATED APPLICATION

[0001] This application claims the benefits of priority to U.S. Provisional Patent Application Serial No. 61/494,204, filed on June 7, 2011, the subject matter of which is incorporated by reference in its entirety.

FIELD

[0002] This relates to improving the performance of permeation processes.

BACKGROUND

[0003] Membrane-based separation has proved to be an efficient technology for gaseous separations. Some of the mechanisms for facilitating selective permeation of material through the membrane involve bonding with a carrier that is dissolved within a solution disposed within the membrane polymer matrix. This carrier forms a reversible complex with at least one component of a given mixture and thus enables enhanced transport across the membrane. During operation, the liquid media within the membrane polymer matrix becomes depleted, which affects membrane separation performance.

SUMMARY

[0004] In one aspect, there is provided a process for effecting separation of at least a gaseous permeate-disposed operative material from a gaseous supply material that is being supplied to a gaseous supply material receiving space that is disposed in mass transfer communication with a permeate receiving space through a membrane, the gaseous supply material including an operative material that defines a gaseous supply material-disposed operative material, and the membrane including a gel, comprising:

supplying the gaseous supply material to the gaseous supply material receiving space, and while the supplying of the gaseous supply material to the gaseous supply material receiving space is being effected, effecting permeation of at least a separation fraction of the gaseous supply material-disposed operative material from the gaseous supply material receiving

space, through the membrane, and into the permeate receiving space, wherein the permeation of at least a separation fraction of the gaseous supply material-disposed operative material to the permeate receiving space effects production of the gaseous permeate-disposed operative material, and wherein the permeation is effected in response to a differential in chemical potential of the operative material, as between the gaseous supply material receiving space and the permeate receiving space, and wherein the permeation includes transporting of a carrier-transported fraction of the gaseous supply material-disposed operative material through the membrane, wherein the carrier-transported fraction of the gaseous supply material-disposed operative material is defined by at least a fraction of the at least a separation fraction of the gaseous supply material-disposed operative material, and while the at least a carrier-transported fraction of the gaseous supply material-disposed operative material is being transported through the membrane and towards the permeate receiving space, and during at least a fraction of the transporting of the at least a carrier-transported fraction of the gaseous supply material-disposed operative material through the membrane and towards the permeate receiving space, the at least a carrier-transported fraction of the gaseous supply material-disposed operative material is associated with a carrier material that is dissolved within a liquid material that is disposed within the membrane gel; and

effecting contacting of the membrane with a replenishment liquid material, wherein the replenishment liquid material includes a replenishment liquid material-disposed carrier material that is dissolved within replenishment liquid material-disposed liquid material, wherein the replenishment liquid material-disposed liquid material of the replenishment liquid material defines liquid material of the replenishment liquid material, and wherein the replenishment liquid material-disposed carrier material that is dissolved within the replenishment liquid material-disposed liquid material defines dissolved carrier material of the replenishment liquid material, such that, in response to the contacting of the membrane with the replenishment liquid material, at least a fraction of the replenishment liquid material becomes disposed within the membrane gel.

[0005] In another aspect, there is provided a process for effecting separation of at least a gaseous permeate-disposed operative material from a gaseous supply material that is

being supplied to a gaseous supply material receiving space that is disposed in mass transfer communication with a permeate receiving space through a membrane, the gaseous supply material including an operative material that defines a gaseous supply material-disposed operative material, and wherein the membrane includes a gel, comprising:

while supplying the gaseous supply material to the gaseous supply material receiving space and effecting permeation of at least a separation fraction of the gaseous supply material-disposed operative material from the gaseous supply material receiving space, through the membrane, and into the permeate receiving space, wherein the permeation of at least a separation fraction of the gaseous supply material-disposed operative material to the permeate receiving space effects production of the gaseous permeate-disposed operative material, and wherein the permeation is effected in response to a differential in chemical potential of the operative material, as between the gaseous supply material receiving space and the permeate receiving space, and wherein the permeation includes transporting of a carrier-transported fraction of the gaseous supply material-disposed operative material through the membrane, wherein the carrier-transported fraction of the gaseous supply material-disposed operative material is defined by at least a fraction of the at least a separation fraction of the gaseous supply material-disposed operative material, and while the at least a carrier-transported fraction of the gaseous supply material-disposed operative material is being transported through the membrane and towards the permeate receiving space, and during at least a fraction of the transporting of the at least a carrier-transported fraction of the gaseous supply material-disposed operative material through the membrane and towards the permeate receiving space, the at least a carrier-transported fraction of the gaseous supply material-disposed operative material is associated with a carrier material that is dissolved within a liquid material that is disposed within the membrane gel, periodically, effecting contacting of the membrane with a replenishment liquid material, wherein the replenishment liquid material includes a replenishment liquid material-disposed carrier material that is dissolved within replenishment liquid material-disposed liquid material, wherein the replenishment liquid material-disposed liquid material of the replenishment liquid material defines liquid material of the replenishment liquid material, and wherein the replenishment liquid material-disposed carrier material which is dissolved within the replenishment liquid material-disposed liquid material defines dissolved carrier

material of the replenishment liquid material, such that, in response to the contacting of the membrane with the replenishment liquid material, at least a fraction of the replenishment liquid material becomes disposed within the membrane gel. .

[0006] In another aspect, there is provided a process for effecting separation of at least a gaseous permeate-disposed operative material from a gaseous supply material that is being supplied to a gaseous supply material receiving space that is disposed in mass transfer communication with a permeate receiving space through a membrane, the gaseous supply material including an operative material that defines a gaseous supply material-disposed operative material, and wherein the membrane includes a gel, comprising a repeating set of steps, the repeating set of steps comprising:

supplying the gaseous supply material to the gaseous supply material receiving space and, while the supplying of the gaseous supply material to the gaseous supply material receiving space is being effected, effecting permeation of at least a separation fraction of the gaseous supply material-disposed operative material from the gaseous supply material receiving space, through the membrane, and into the permeate receiving space, wherein the permeation of at least a separation fraction of the gaseous supply material-disposed operative material to the permeate receiving space effects production of the gaseous permeate-disposed operative material, and wherein the permeation is effected in response to a differential in partial pressure of the operative material, as between the gaseous supply material receiving space and the permeate receiving space, and wherein the permeation includes transporting of a carrier-transported fraction of the gaseous supply material-disposed operative material through the membrane, wherein the carrier-transported fraction of the gaseous supply material-disposed operative material is defined by at least a fraction of the at least a separation fraction of the gaseous supply material-disposed operative material, and while the at least a carrier-transported fraction of the gaseous supply material-disposed operative material is being transported through the membrane and towards the permeate receiving space, and during at least a fraction of the transporting of the at least a carrier-transported fraction of the gaseous supply material-disposed operative material through the membrane and towards the permeate receiving space, the at least a carrier-transported fraction of the gaseous supply material-disposed operative material is

associated with a carrier material that is dissolved within a liquid material that is disposed within the membrane gel;

suspending the supplying of the gaseous supply material to the gaseous supply material receiving space;

after the suspension of the supplying of the gaseous supply material has been effected, effecting contacting of the membrane with a replenishment liquid material, wherein the replenishment liquid material includes a replenishment liquid material-disposed carrier material that is dissolved within replenishment liquid material-disposed liquid material, wherein the replenishment liquid material-disposed liquid material of the replenishment liquid material defines liquid material of the replenishment liquid material, and wherein the replenishment liquid material-disposed carrier material that is dissolved within the replenishment liquid material-disposed liquid material defines dissolved carrier material of the replenishment liquid material, such that, in response to the contacting of the membrane with the replenishment liquid material, at least a fraction of the replenishment liquid material becomes disposed within the membrane gel; and

suspending the effecting of the contacting of the membrane with a replenishment liquid material..

BRIEF DESCRIPTION OF DRAWING

[0007] The preferred embodiments will now be described with the following accompanying drawings:

[0008] Figure 1 is a schematic illustration of an embodiment of a system in which is practised an embodiment of the process; and

[0009] Figure 2 is illustrative of the association effected in response to contacting of an olefin (ethylene) and a carrier material (silver ion).

DETAILED DESCRIPTION

[0010] Unless stated otherwise, such as in the examples, all amounts and numbers used in this specification are intended to be interpreted as modified by the term 'about'. Likewise, all compounds or elements identified in this specification, unless stated otherwise, are intended to be non-limiting and representative of other compounds or elements generally considered by those skilled in the art as being within the same family of compounds or elements.

[0011] The term "associated" and grammatical variations thereof include any type of interaction, including chemical bonds (for example, covalent, ionic and hydrogen bonds) and/or Van der Waals forces, and/or polar and non-polar interactions through other physical constraints provided by molecular structure, and interactions through physical mixing.

[0012] In one aspect, there is provided a process for effecting separation of at least a gaseous permeate-disposed operative material from a gaseous supply material that is being supplied to a gaseous supply material receiving space 10 that is disposed in mass transfer communication with a permeate receiving space 20 through a membrane 30. The gaseous supply material includes an operative material that defines a gaseous supply material-disposed operative material. The membrane includes a gel (a "membrane gel").

[0013] The process includes, supplying the gaseous supply material to the gaseous supply material receiving space 10, and while the supplying of the gaseous supply material to the gaseous supply material receiving space 10 is being effected, effecting transfer (or permeation) of at least a fraction of the gaseous supply material-disposed operative material (hereinafter, such fraction being referred to as a "separation fraction") from the gaseous supply material receiving space 10, through the membrane 30, and into the permeate receiving space 20. The transfer (or "permeation") of at least a separation fraction of the gaseous supply material-disposed operative material to the permeate receiving space effects production of the gaseous permeate-disposed operative material. The transfer (or "permeation") is effected in response to a differential in chemical potential of the operative material, as between the gaseous supply material receiving space and the permeate receiving space. In this respect, while the transfer (or "permeation") is being effected, the

chemical potential of the operative material disposed in the gaseous supply material receiving space (i.e. the gaseous supply material receiving space-disposed operative material) is greater than the chemical potential of the operative material disposed within the permeate receiving space (i.e. the permeate receiving space-disposed operative material). In some embodiments, for example, the chemical potential is defined by partial pressure, such that the transfer (or “permeation”) is effected in response to a differential in partial pressure of the operative material, as between the gaseous supply material receiving space and the permeate receiving space. In this respect, while the transfer (or “permeation”) is being effected, the partial pressure of the operative material disposed in the gaseous supply material receiving space (i.e. the gaseous supply material receiving space-disposed operative material) is greater than the partial pressure of the operative material disposed within the permeate receiving space (i.e. the permeate receiving space-disposed operative material).

[0014] The effecting of the transfer (or “permeation”) of at least a separation fraction of the gaseous supply material-disposed operative material to the permeate receiving space 20 includes effecting contacting of, or interaction between, at least a carrier-transported fraction of the gaseous supply material-disposed operative material and a carrier material that is dissolved within a liquid material that is disposed within the membrane gel, so as to effect association between the at least a carrier-transported fraction and the carrier material. The at least a carrier-transported fraction of the gaseous supply material-disposed operative material is defined by at least a fraction of the at least a separation fraction of the gaseous supply material-disposed operative material. A fraction of the operative material-derived material is derived from the gaseous supply material-disposed operative material, and the operative material-derived material includes the at least a carrier-transported fraction of the gaseous supply material-disposed operative material, and such that the at least a carrier-transported fraction of the gaseous supply material-disposed operative material is disposed as a fraction of the operative material-derived material within the membrane 30. It is believed that, in some embodiments, in response to the contacting of, or interaction between, the at least a separation fraction of the gaseous supply material-disposed operative material and a carrier material, a reversible chemical reaction is effected between the at least a separation fraction of the gaseous

supply material-disposed operative material and the carrier material, so as to effect production of the operative material-derived material. In those embodiments where the operative material includes an olefin and the carrier material includes a silver ion dissolved in an aqueous solution that is included with the membrane gel, a reactive process is effected such that the olefin becomes chemically modified by bonding with the silver ion through π -complexation.

[0015] Because of the difference in chemical potential of the operative material, as between the gaseous supply material receiving space and the permeate receiving space, the concentration of the at least a carrier-transported fraction of the gaseous supply material-disposed operative material within that portion of the membrane proximate to the gaseous supply material receiving space 10 is greater than the concentration of the at least a carrier-transported fraction of the gaseous supply material-disposed operative material within that portion of the membrane proximate to the permeate receiving space 20, and thereby effects a driving force for the transport.

[0016] While the at least a carrier-transported fraction of the gaseous supply material-disposed operative material (as defined by at least a fraction of the at least a separation fraction of the gaseous supply material-disposed operative material) is being transported through the membrane 30 and towards the permeate receiving space 20, and during at least a fraction of (or, at least some of) the transporting of the at least a carrier-transported fraction of the gaseous supply material-disposed operative material through the membrane 30 and towards the permeate receiving space 20, the at least a carrier-transported fraction of the gaseous supply material-disposed operative material is associated with the carrier material. In some embodiments, for example, the association is one of chemical bonding. In this respect, in those embodiments where the operative material includes an olefin and the carrier material includes a silver ion dissolved in an aqueous solution that is included with the membrane gel, the association between the at least a carrier transported fraction of the olefin and the silver ion is one of chemical bonding through π -complexation.

[0017] It is believed that, in some embodiments, the transporting of the at least a carrier transported fraction of the gaseous supply material-disposed operative material across the membrane 30 and towards the permeate receiving space 20 includes that effected by the transporting of an operative material-derived material across the membrane 30 and towards the permeate receiving space 20. The operative material-derived material is produced by contacting of the at least a carrier transported fraction of the gaseous supply material-disposed operative material with the carrier material. In this respect, in some embodiments, the transporting of the operative material-derived material across the membrane 30 and towards the permeate receiving space 20 is facilitated by mobility of the operative material-derived material within the membrane 30. In some of these embodiments, for example, the transporting of the operative material-derived material across the membrane 30 and towards the permeate receiving space 20 is facilitated by mobility of the operative material-derived material within the liquid material of the membrane gel.

[0018] It is also believed that, in some embodiments, the transporting of the at least a carrier transported fraction of the gaseous supply material-disposed operative material across the membrane 30 and towards the permeate receiving space 20 includes that effected by “hopping” of the at least a carrier transported fraction of the gaseous supply material-disposed operative material from association with one carrier material to the next until reaching the permeate receiving space 20.

[0019] It is also believed that, in some embodiments, the transporting of the at least a carrier transported fraction of the gaseous supply material-disposed operative material across the membrane 30 and towards the permeate receiving space 20 includes that effected by a combination of both of the above-described transport mechanisms.

[0020] In some embodiments, for example, while the transfer (or “permeation”) of at least a separation fraction of the gaseous supply material-disposed operative material to the permeate receiving space 20 is being effected, a gaseous operative material-depleted residue is discharged from the gaseous supply material receiving space. The molar concentration of the operative material within the gaseous supply material, which is being

supplied, is greater than the molar concentration of the operative material within the gaseous operative material-depleted residue, which is being discharged.

[0021] In some embodiments, for example, while the transfer (or “permeation”) of at least a separation fraction of the gaseous supply material-disposed operative material to the permeate receiving space 20 is being effected, a gaseous operative material-depleted residue is discharged from the gaseous supply material receiving space, and a gaseous permeate product, including the gaseous permeate-disposed operative material, is discharged from the permeate receiving space. The molar concentration of the operative material within the gaseous supply material, which is being supplied, is greater than the molar concentration of the operative material within the gaseous operative material-depleted residue, which is being discharged. The molar concentration of the operative material within the gaseous permeate product, which is being discharged, is greater than the molar concentration of the operative material within the gaseous supply material, which is being supplied.

[0022] The process further includes effecting contacting of the membrane 30 with a replenishment liquid material. The replenishment liquid material includes a replenishment liquid material-disposed carrier material that is dissolved within replenishment liquid material-disposed liquid material. The replenishment liquid material-disposed liquid material of the replenishment liquid material defines liquid material of the replenishment liquid material. The replenishment liquid material-disposed carrier material that is dissolved within the replenishment liquid material-disposed liquid material defines dissolved carrier material of the replenishment liquid material. In response to the contacting of the membrane with the replenishment liquid material, at least a fraction of the replenishment liquid material becomes disposed within the membrane. Also, in this respect, any liquid material that has become depleted, during the transferring of at least a fraction of the gaseous supply material-disposed operative material, is at least partially replenished by virtue of the effecting of the disposition of the replenishment liquid material (which includes the liquid material) within the membrane. In some embodiments, for example, liquid material, within the membrane, is depleted during the transferring of at least a fraction of the gaseous supply material-disposed operative material, and the

contacting of the membrane with the replenishment liquid material effects at least partial replenishment of the liquid material within the membrane gel.

[0023] Such replenishment is desirable as liquid material is depleted due to mass transfer from the membrane 30 into both of the gaseous supply material receiving space 10 and the permeate receiving space 20. The rate and extent of liquid material depletion depends on operating conditions, such as operating temperatures and pressures, rate of material flow through the gaseous supply material receiving space, and rate of discharge of permeate product from the permeate receiving space, and also on the water content within each one of the gaseous supply material receiving space and the permeate receiving space. Maintaining a minimum concentration of liquid material within the membrane assists in effecting continuous separation and permeation as a desirable mobility of the operative material-derived material is facilitated while a desirable structural integrity of the membrane is maintained. Complete depletion of liquid material may lead to uneven stresses, fractures or pinholes that would compromise performance. By including carrier material within the replenishment liquid material, stripping of the carrier material from the membrane, during the contacting of the membrane with the replenishment liquid material, is mitigated.

[0024] In some embodiments, for example, the effecting of the contacting of the membrane with a replenishment liquid material is effected after at least a fraction of the liquid material, which is disposed within the membrane gel, becomes depleted. In some embodiments, for example, the effecting of the contacting of the membrane with a replenishment liquid material is effected in response to sensing that at least a fraction of the liquid material, which is disposed within the membrane gel, becomes depleted.

[0025] In some embodiments, for example, the contacting of the replenishment liquid material is effected at predetermined time intervals determined by several factors, where the anticipated impact of those factors is determined by experimental data. These factors include the volume of gas passed through the membrane, operating temperature, pressure differential, thickness of chitosan membrane, molarity of the hydration solution, characteristics of substrate, etc. (some of these are of course dependent on each other). The

experiments would have revealed the onset time of changes in membrane permeability, membrane selectivity or both at a given combination of operating conditions and membrane composition due to dehydration of the membrane. The liquid material is replenished at appropriate intervals to maintain steady performance and/or protect membrane integrity.

[0026] In some embodiments, for example, the effecting of the contacting of the membrane with a replenishment liquid material is effected while the supplying of the gaseous supply material to the gaseous supply material receiving space is being effected. In some of these embodiments, the effecting of the contacting of the membrane with a replenishment liquid material is periodic, such that the minimum concentration of dissolved carrier material within the replenishment liquid material being supplied during at least one of the periods is greater than the maximum concentration of dissolved carrier material within the replenishment liquid material being supplied during at least another one of the periods. In some embodiments, for example, the minimum concentration of dissolved carrier material within the replenishment liquid material being supplied during at least one of the periods is greater than the maximum concentration of dissolved carrier material within the replenishment liquid material being supplied during at least another one of the periods by a multiple of between 1.05 and 2.0. In some implementations, it is desirable that a replenishment liquid material, that is more dilute in the dissolved carrier material, be supplied during at least one of the periods in order to promote dissolution of any carrier material that may have precipitated onto the membrane 30 during the process.

[0027] In some embodiments, for example, the effecting of the contacting of the membrane with a replenishment liquid material is effected after the supplying of the gaseous supply material to the gaseous supply material receiving space has been suspended. In some of these embodiments, for example, the process further includes suspending the effecting of the contacting of the membrane with a replenishment liquid material such that a first liquid replenishment time interval is completed. After the effecting of the contacting of the membrane with a replenishment liquid material has been suspended, resumption of the supplying of the gaseous supply material to the gaseous supply material receiving space is effected such that, while the resumed supplying of the

gaseous supply material to the gaseous supply material receiving space is being effected, the permeation of at least a separation fraction of the gaseous supply material-disposed operative material from the gaseous supply material receiving space, through the membrane, and into the permeate receiving space is effected. Subsequently, the resumed supplying of the gaseous supply material to the gaseous supply material receiving space is suspended. After the suspending of the resumed supplying of the gaseous supply material to the gaseous supply material receiving space, resumption of the effecting of the contacting of the membrane with a replenishment liquid material is effected such that a second liquid replenishment time interval during which the effecting of the contacting of the membrane with a replenishment liquid material is being effected. In some of these embodiments, for example, the minimum concentration of dissolved carrier material within the replenishment liquid material being supplied during one of the first and second liquid replenishment time intervals is greater than the maximum concentration of dissolved carrier material within the replenishment liquid material being supplied during the other one of the first and second liquid replenishment time intervals. In some embodiments, for example, the minimum concentration of dissolved carrier material within the replenishment liquid material being supplied during one of the first and second liquid replenishment time intervals is greater than the maximum concentration of dissolved carrier material within the replenishment liquid material being supplied during the other one of the first and second liquid replenishment time intervals by a multiple of between 1.05 and 2.0. In some implementations, it is desirable that a replenishment liquid material, that is more dilute in the dissolved carrier material, be supplied during one of the liquid replenishment time intervals in order to promote dissolution of any carrier material that may have precipitated onto the membrane 30 during the process.

[0028] In another aspect, there is provided a process for effecting separation of at least a gaseous permeate-disposed operative material from a gaseous supply material that is being supplied to a gaseous supply material receiving space that is disposed in mass transfer communication with a permeate receiving space through a membrane. The gaseous supply material includes an operative material that defines a gaseous supply material-disposed operative material. The membrane includes a gel. The process includes, while supplying the gaseous supply material to the gaseous supply material receiving space

and effecting permeation of at least a separation fraction of the gaseous supply material-disposed operative material from the gaseous supply material receiving space, through the membrane, and into the permeate receiving space, wherein the permeation of at least a separation fraction of the gaseous supply material-disposed operative material to the permeate receiving space effects production of the gaseous permeate-disposed operative material, and wherein the permeation is effected in response to a differential in chemical potential of the operative material, as between the gaseous supply material receiving space and the permeate receiving space, wherein the effecting of the permeation of at least a separation fraction of the gaseous supply material-disposed operative material to the permeate receiving space includes effecting contacting of, or interaction between, at least a carrier-transported fraction of the gaseous supply material-disposed operative material and a carrier material that is dissolved within a liquid material that is disposed within the membrane gel, so as to effect association between the carrier-transported fraction and the carrier material. The at least a carrier-transported fraction of the gaseous supply material-disposed operative material is defined by at least a fraction of the at least a separation fraction of the gaseous supply material-disposed operative material. While the at least a carrier-transported fraction of the gaseous supply material-disposed operative material (defined by at least a fraction of the at least a separation fraction of the gaseous supply material-disposed operative material) is being transported through the membrane and towards the permeate receiving space, and during at least a fraction of (or, at least some of) the transporting of the at least a carrier-transported fraction of the gaseous supply material-disposed operative material through the membrane and towards the permeate receiving space, the at least a carrier-transported fraction of the gaseous supply material-disposed operative material is associated with the carrier material, periodically, effecting contacting of the membrane with a replenishment liquid material. The replenishment liquid material includes a replenishment liquid material-disposed carrier material that is dissolved within replenishment liquid material-disposed liquid material. The replenishment liquid material-disposed liquid material of the replenishment liquid material defines liquid material of the replenishment liquid material. The replenishment liquid material-disposed carrier material, which is dissolved within the replenishment liquid material-disposed liquid material, defines dissolved carrier material of the replenishment liquid material. In response to the

contacting of the membrane with the replenishment liquid material, at least a fraction of the replenishment liquid material becomes disposed within the membrane gel. In some of these embodiments, for example, the minimum concentration of dissolved carrier material within the replenishment liquid material being supplied during at least one of the periods is greater than the maximum concentration of dissolved carrier material within the replenishment liquid material being supplied during at least another one of the periods. In some embodiments, for example, the minimum concentration of dissolved carrier material within the replenishment liquid material being supplied during at least one of the periods is greater than the maximum concentration of dissolved carrier material within the replenishment liquid material being supplied during at least another one of the periods by a multiple of between 1.05 and 2.0. In some implementations, it is desirable that a replenishment liquid material, that is more dilute in the dissolved carrier material, be supplied during at least one of the periods in order to promote dissolution of any carrier material that may have precipitated onto the membrane 30 during the process.

[0029] In another aspect, there is provided a process for effecting separation of at least a gaseous permeate-disposed operative material from a gaseous supply material that is being supplied to a gaseous supply material receiving space that is disposed in mass transfer communication with a permeate receiving space through a membrane. The gaseous supply material including an operative material that defines a gaseous supply material-disposed operative material. The membrane includes a gel. The process includes a repeating set of steps.

[0030] The repeating set of steps includes:

[0031] (a) supplying the gaseous supply material to the gaseous supply material receiving space and, while the supplying of the gaseous supply material to the gaseous supply material receiving space is being effected, effecting permeation of at least a separation fraction of the gaseous supply material-disposed operative material from the gaseous supply material receiving space, through the membrane, and into the permeate receiving space, wherein the permeation of at least a separation fraction of the gaseous supply material-disposed operative material to the permeate receiving space effects

production of the gaseous permeate-disposed operative material, and wherein the permeation is effected in response to a differential in chemical potential (for example, defined by partial pressure) of the operative material, as between the gaseous supply material receiving space and the permeate receiving space, wherein the effecting of the permeation of at least a separation fraction of the gaseous supply material-disposed operative material to the permeate receiving space includes effecting contacting of, or interaction between, at least a carrier-transported fraction of the gaseous supply material-disposed operative material and a carrier material that is dissolved within a liquid material that is disposed within the membrane gel, so as to effect association between the carrier-transported fraction and the carrier material. The at least a carrier-transported fraction of the gaseous supply material-disposed operative material is defined by at least a fraction of the at least a separation fraction of the gaseous supply material-disposed operative material. While the at least a carrier-transported fraction of the gaseous supply material-disposed operative material (as defined by at least a fraction of the at least a separation fraction of the gaseous supply material-disposed operative material) is being transported through the membrane and towards the permeate receiving space, and during at least a fraction of (or, at least some of) the transporting of the at least a carrier-transported fraction of the gaseous supply material-disposed operative material through the membrane and towards the permeate receiving space, the at least a carrier-transported fraction of the gaseous supply material-disposed operative material is associated with the carrier material;

[0032] (b) suspending the supplying of the gaseous supply material to the gaseous supply material receiving space;

[0033] (c) after the suspension of the supplying of the gaseous supply material has been effected, effecting contacting of the membrane with a replenishment liquid material, wherein the replenishment liquid material includes a replenishment liquid material-disposed carrier material that is dissolved within replenishment liquid material-disposed liquid material, the replenishment liquid material-disposed liquid material of the replenishment liquid material defining liquid material of the replenishment liquid material, and the replenishment liquid material-disposed carrier material that is dissolved within the replenishment liquid material-disposed liquid material defining dissolved carrier material

of the replenishment liquid material, such that, in response to the contacting of the membrane with the replenishment liquid material, at least a fraction of the replenishment liquid material becomes disposed within the membrane gel; and

[0034] (d) suspending the effecting of the contacting of the membrane with a replenishment liquid material.

[0035] In some of these embodiments, for example, the repeating set of steps is completed at least twice such that at least two completed sets of steps are defined. The minimum concentration of dissolved carrier material within the replenishment liquid material being supplied during at least one of the at least two completed sets of steps is greater than the maximum concentration of dissolved carrier material within the replenishment liquid material being supplied during at least another one of the at least two completed sets of steps.

[0036] In some embodiments, for example, the minimum concentration of dissolved carrier material within the replenishment liquid material being supplied during at least one of the at least one of the at least two completed sets of steps is greater than the maximum concentration of dissolved carrier material within the replenishment liquid material being supplied during at least another one of the at least two completed sets of steps by a multiple of between 1.05 and 2.0. In some implementations, it is desirable that a replenishment liquid material, that is more dilute in the dissolved carrier material, be supplied during at least one of the completed sets of steps in order to promote dissolution of any carrier material that may have precipitated onto the membrane 30 during the process.

[0037] In some embodiments, for example, the contacting of the membrane 30 with the replenishment liquid material is effected for a time interval of between 1 second and 100 minutes. In some embodiments, for example, the contacting of the membrane 30 with the replenishment liquid material is effected for a time interval of between 10 seconds and 30 minutes. In some embodiments, for example, the contacting of the membrane 30 with the replenishment liquid material is effected for a time interval of between 15 second and 20 minutes.

[0038] In some embodiments, for example, the contacting of the membrane 30 with the replenishment liquid material is effected within the gaseous supply material receiving space 10. In some embodiments, for example, the contacting of the membrane with the replenishment liquid material is effected within the permeate receiving space 20. In some embodiments, for example, the contacting of the membrane with the replenishment liquid material is effected within both of the gaseous supply material receiving space 10 and the permeate receiving space 20. In some of these embodiments, for example, the contacting is effected by a stationary or stagnant soak by the replenishment liquid material.

[0039] In some embodiments, for example, while the contacting of the membrane 30 with the replenishment liquid material is being effected, supplying of the replenishment liquid material, for effecting the contacting with the membrane, is being effected. In some embodiments, for example, the supplying of the replenishment liquid material is effected to the gaseous supply material receiving space 10. In some embodiments, for example, the supplying of the replenishment liquid material is effected to the permeate receiving space 20. In some embodiments, for example, the supplying of the replenishment liquid material is effected to both of the gaseous supply material receiving space 10 and the permeate receiving space 20.

[0040] In some embodiments, for example, the process is effected within a membrane module 40, and the gaseous supply material receiving space 10 and the permeate receiving space 20 are defined by respective compartments 12, 22. In some of these embodiments, the supplying of the replenishment liquid material to either one or both of the gaseous supply material receiving compartment 12 and the permeate receiving compartment 22 is effected by flowing the replenishment liquid material in an upwardly direction. This effects improved contacting between the supplied replenishment liquid material and the membrane 30.

[0041] In some embodiments, for example, the replenishment liquid material is supplied to one of the gaseous supply material receiving space 10 and the permeate receiving space 20 such that transport is effected through the membrane 30 from the one of the gaseous supply material receiving space 10 and the permeate receiving space 20 to the

other one of the gaseous supply material receiving space 10 and the permeate receiving space 20, and wherein the pressure within the other one of the gaseous supply material receiving space and the permeate receiving space is below atmospheric pressure. By effecting the transport of the replenishment liquid material through the membrane and into a space disposed below atmospheric pressure, condensation of the liquid material is mitigated. Such condensation effects backpressure on the membrane, interfering with the transfer (or permeation) of the separation fraction of the gaseous supply material-disposed operative material from the gaseous supply material receiving space to the permeate receiving space.

[0042] In some embodiments, for example, the replenishment liquid material includes an aqueous solution including a molar concentration of silver ion of at least 1.0. In some embodiments, for example, the replenishment liquid material includes an aqueous solution including a molar concentration of silver ion of between 2.0 and 10.0. In some embodiments, for example, the replenishment liquid material includes an aqueous solution including a molar concentration of silver ion of between 5.0 and 8.0. In some of these embodiments, for example, the membrane includes chitosan.

[0043] In some embodiments, for example, the liquid material is water, or includes water. In this respect, in some embodiments, for example, the carrier material is dissolved in water such that there is provided an aqueous solution including dissolved carrier material.

[0044] In some embodiments, for example, the replenishment liquid material includes between 10 and 90 weight% water, based on the total weight of the replenishment liquid material. In some embodiments, for example, the replenishment liquid material includes between 25 and 75 weight% water, based on the total weight of the replenishment liquid material. In some embodiments, for example, the replenishment liquid material includes between 30 and 50 weight% water, based on the total weight of the replenishment liquid material.

[0045] In some embodiments, for example, the liquid material of the replenishment liquid material may also include other additives, such as co-solvents and hygroscopic material.

[0046] In some embodiments, for example, the transferring of the separation fraction is effected while the temperature within each one of the gaseous supply receiving space and the permeate receiving space is between 5 degrees Celsius and 70 degrees Celsius. In some embodiments, for example, the transferring of the separation fraction is effected while the temperature within each one of the gaseous supply receiving space and the permeate receiving space is between 10 degrees Celsius and 60 degrees Celsius. In some embodiments, for example, the transferring of the separation fraction is effected while the temperature within each one of the gaseous supply receiving space and the permeate receiving space is between 15 degrees Celsius and 50 degrees Celsius.

[0047] In some embodiments, for example, the gaseous supply material has a relative humidity of between 0 and 100%. In some embodiments, for example, the gaseous supply material has a relative humidity of between 70 and 99%. In some embodiments, for example, the gaseous supply material has a relative humidity of between 95 and 99%.

[0048] In some embodiments, for example, the operative material includes at least one operative compound. In some of these embodiments, for example, the operative material-derived material includes at least one operative material-derived compound. For each one of the at least one operative material-derived compound, at least a fragment of the operative material-derived compound is derived from the operative material. Each one of the at least one operative material-derived compound includes at least a fragment of one or more operative compounds.

[0049] In some embodiments, for example, a suitable operative compound is an olefin, and suitable olefins include ethylene, propylene, 1-butene, and 2-butene. Figure 2 is illustrative of the association effected in response to contacting of an olefin (ethylene) and a carrier material (silver ion).

[0050] In some embodiments, for example, the operative material is defined by at least one operative compound, and the at least one operative compound is an olefin. In some embodiments, for example, each one of the at least one operative compound is an olefin.

[0051] In some embodiments, for example, the operative material is defined by at least one operative compound, and each one of the at least one operative compound is an olefin. In some embodiments, for example, the operative material is defined by at least one operative compound, and the at least one operative compound is a single operative compound, and the single operative compound is an olefin.

[0052] In some embodiments, for example, a suitable olefin is an olefin having a total number of carbon atoms of between two (2) and eight (8).

[0053] In some embodiments, for example, one or more of the olefins is an alpha olefin.

[0054] In some embodiments, for example, the carrier material includes at least one metal cation. In some embodiments, for example, the carrier material includes at least one of silver ion and cuprous ion. In some embodiments, for example, the carrier material includes silver ion. In this respect, in some embodiments, for example, the liquid material includes dissolved silver nitrate, and the carrier material includes the silver ion of the silver nitrate. In some of these embodiments, for example, the silver nitrate is dissolved in the liquid material such that there is provided an aqueous solution, that is included within the membrane gel, including dissolved silver nitrate. In some embodiments, for example, the membrane includes polymeric material, and the carrier material is complexed with, or chelated to, the polymeric material.

[0055] In some embodiments, for example, the membrane 30 includes polymeric material. In some of these embodiments, for example, the polymeric material includes at least one polymer compound. In some embodiments, for example, the at least one polymer compound is chitosan. In some embodiments, for example, each one of the at least one polymer compound is hydrophilic. In some embodiments, for example, each one of the at

least one polymer compound has a number average molecular weight of between 20,000 and 1,000,000.

[0056] In some embodiments, for example, the membrane 30 includes polysaccharide. In this respect, in some embodiments, for example, the membrane includes one or more polysaccharides.

[0057] Suitable polysaccharides include natural polysaccharides such as alginic acid, pectic acid, chondroitin, hyaluronic acid and xanthan gum; cellulose, chitin, pullulan, derivatives of natural polysaccharides such as C₁₋₆ esters, esters, ether and alkylcarboxy derivatives thereof, and phosphates of these natural polysaccharide such as partially methylesterified alginic acid, carbomethoxylated alginic acid, phosphorylated alginic acid and aminated alginic acid, salts of anionic cellulose derivatives such as carboxymethyl cellulose, cellulose sulfate, cellulose phosphate, sulfoethyl cellulose and phosphonoethyl cellulose, and semi-synthetic polysaccharides such as guar gum phosphate and chitin phosphate. Specific examples of membranes of polysaccharides include those composed of salts of chitosan and its derivatives (including salts of chitosan) such as N-acetylated chitosan, chitosan phosphate and carbomethoxylated chitosan. Of these, membranes composed of alginic acid, and salts and derivatives thereof, chitosan and salts and derivatives thereof cellulose and derivatives thereof (other than the mono-, di-, and tri-acetate derivatives thereof which are not intended to be included in the present invention) are preferred in view of their film-formability, mechanical strength and film functions.

[0058] In some embodiments, for example, the membrane 30 includes one or more polysaccharides, and also includes one or more other polymeric compounds. In this respect, in some embodiments, for example, the membranes is comprised of blends of a major amount (e.g. at least 60 weight %) of one or more polysaccharides and lesser amounts (e.g. up to 40 weight %) of one or more other compatible polymeric compounds, such as, for example, polyvinyl alcohol (PVA), or neutral polysaccharides such as starch and pullulan. In some embodiments, for example, the membrane is comprised of grafted ionized polysaccharides obtained by grafting a hydrophilic vinyl monomer such as acrylic acid.

[0059] In some embodiments, for example, the manufacturing of the membrane 30 includes casting a solution of polymeric material (such as one or more polysaccharides) as a film. In some embodiments, for example, the solution includes less than five (5) weight percent water, based on the total weight of solution. In some embodiments, for example, the solution includes less than two (2) weight percent water, based on the total weight of solution. In some embodiments, for example, the solution is an acidic aqueous solution. In some embodiments, the acid is an organic acid such as an organic acid having a total number of carbons of between one (1) and four (4). In some embodiments, for example, the acid includes acetic acid. In some embodiments, for example, the resulting solution may be cast as a film on a flat plate to effect production of a membrane intermediate. Suitable casting surfaces include glass or TeflonTM or the like (e.g. a smooth substrate to which the polymer film will have a low adhesion). The solution is then dried to form a film. In other embodiments, for example, the resulting solution may be cast as a film on a substrate material to effect production of a membrane intermediate supported on a substrate material. Suitable substrate material may itself be a film or a non-woven support, and can also be a hollow fiber substrate.

[0060] In some embodiments, for example, the membrane 30 includes chitosan.

[0061] Chitin may be deacetylated by treatment with hot alkali to effect production of chitosan. The polysaccharide may then be treated with a base to generate the protonated derivative (NH_3^+) or the unprotonated amino form (NH_2).

[0062] Chitosan is a generic term for deacetylation products of chitin obtained by treatment with concentrated alkalis. It is obtained by heating chitin, the principal constituent of shells of crustaceans such as lobsters and crabs to a temperature of at least 60.degree. C. together with an alkaline solution having an alkali concentration of 30 to 50% by weight (such as an aqueous solution of sodium hydroxide) and thereby deacetylating chitin. Chemically, chitosan is a linear polysaccharide composed of randomly distributed β -(1-4)-linked D-glucosamine (de-acetylated unit) and N-acetyl-D-glucosamine (acetylated unit). Chitosan readily dissolves in a dilute aqueous solution of an acid, such as acetic acid and hydrochloric acid, with the formation of a salt, but when contacted again with an

aqueous alkaline solution, is again coagulated and precipitated. In some embodiments, for example, chitosan has a deacetylation degree of at least 50%, and in some of these embodiments, for example, chitosan has a deacetylation degree of at least 75%.

[0063] An intermediate chitosan membrane can be obtained by dissolving chitosan in dilute aqueous acid solution, casting the solution as a film onto a flat plate to form a homogeneous chitosan fraction, or onto a substrate material (such as a hollow fibre substrate) to form a composite membrane. The cast film may then be contacted with an aqueous alkaline solution to neutralize the acidity and render it less soluble or substantially insoluble in water, or air-dried and then contacted with the aqueous alkaline solution.

[0064] To prepare the chitosan-type polysaccharide membrane, the amino groups of the intermediate composite membrane are at least partly neutralized with one or more acids to form an ammonium salt. Examples of suitable acids that can be utilized for neutralization include inorganic acids such as hydrochloric acid, hydrobromic acid, sulfuric acid and phosphoric acid; and organic acids such as acetic acid, methanesulfonic acid, formic acid, propionic acid, oxalic acid, malonic acid, succinic acid, fumaric acid, maleic acid, glutaric acid, phthalic acid, isophthalic acid, terephthalic acid, trimesic acid, trimellitic acid, citric acid, aconitic acid, sulfobenzoic acid, pyromellitic acid and ethylenediaminetetraacetic acid.

[0065] Protonation of the intermediate chitosan-type polysaccharide membrane using these acids can be effected, for example, by a method which comprises immersing the intermediate chitosan-type polysaccharide membrane in a solution containing the acid to ionize the amino groups in the membrane; or by a method which comprises subjecting the chitosan-type polysaccharide membrane to pervaporation with a mixed liquid containing the acid to convert the amino groups in the chitosan-type polysaccharide membrane successively to ammonium ions.

[0066] In some embodiments, for example, the membrane intermediate has a thickness from 0.5 to 20 microns, such as from three (3) to ten (10) microns, or such as from five (5) to eight (8) microns. In some embodiments, for example, the substrate

material has a thickness from 30 to 200 microns, such as from 50 to 150 microns, or such as from 80 to 110 microns.

[0067] The membrane intermediate is then contacted with a salt of a metal cation (such as silver ion or cuprous ion). In some embodiments, for example, the contacting includes immersing the membrane intermediate in an aqueous solution including a salt of a metal cation (such as a 5 to 8 M aqueous silver nitrate solution). The contacting effects disposition of metal cations into (through chelation) and throughout the matrix of the membrane, and within its pores, and effects formation of a gel.

[0068] The membrane 30 can be embodied in any one of several configurations, including flat sheet, plate and frame, spiral wound, tubular, or hollow fibre.

[0069] In some embodiments, for example, the gaseous supply material further includes slower permeating material. The slower permeating material includes at least one slower permeating compound. A slower-permeating compound is a compound that is characterized by a lower permeability through the membrane 30 than that of each one of the at least one operative compound. Such lower permeability may be derived from its relatively lower diffusivity in the membrane, its relatively lower solubility in the membrane, or both.

[0070] In some embodiments, for example, the slower permeating compound has substantially no permeability through the membrane 30.

[0071] In some embodiments, for example, the transfer (or “permeation”) of the at least a separation fraction of the gaseous supply material-disposed operative material is effected while at least one slower-permeating compound is transferring (or permeating) from the gaseous supply material receiving space 10, through the membrane 30 and into the permeate receiving space 20. For each one of the at least one operative compound of the at least a separation fraction of the gaseous supply material-disposed operative material there is provided an operative compound-associated operative ratio defined by the ratio of the molar rate of permeation of the operative compound to the mole fraction of the operative compound within the gaseous supply material receiving space, such that a plurality of

operative compound-associated operative ratios are defined, and at least one of the plurality of operative compound-associated operative ratios is a minimum operative compound-associated operative ratio. For each one of the at least one transferring (or permeating) slower permeating compound, the ratio of the molar rate of permeation of the slower permeating compound to the mole fraction of the slower permeating compound within the gaseous supply material receiving space is less than the minimum operative compound-associated operative ratio, such that, for each one of the at least one operative compound, the molar concentration of the operative compound within a gaseous permeate, that is transferred (or permeated) from the gaseous supply receiving space, through the membrane, and into the permeate receiving space, is greater than the molar concentration of the operative compound within the gaseous supply material. In some embodiments, for example, while the transferring is being effected, the gaseous permeate is discharged from the permeate receiving space as the gaseous permeate product.

[0072] In some embodiments, for example, each one of the at least one slower permeating compound is a paraffin.

[0073] In some embodiments, for example, the at least one slower permeating compound is a single slower permeating compound, and the single slower permeating compound is a paraffin.

[0074] In some embodiments, for example, a suitable paraffin is a paraffin having a total number of carbon atoms of between one (1) and ten (10).

[0075] In the above description, for purposes of explanation, numerous details are set forth in order to provide a thorough understanding of the present disclosure. However, it will be apparent to one skilled in the art that these specific details are not required in order to practice the present disclosure. Although certain dimensions and materials are described for implementing the disclosed example embodiments, other suitable dimensions and/or materials may be used within the scope of this disclosure. All such modifications and variations, including all suitable current and future changes in technology, are believed to be within the sphere and scope of the present disclosure. All references mentioned are hereby incorporated by reference in their entirety.

Claims:

1. A permeation process comprising:
 effecting fractionation of a gaseous mixture via a membrane such that a permeate and a retentate are obtained, wherein the membrane includes:
 a polymeric matrix co-operating with liquid material to define a liquid material-comprising gel; and
 a carrier material for facilitating permeation through the membrane;
 wherein:
 the carrier material is dissolved within the liquid material;
 the carrier material includes at least one metal cation; and
 the at least one metal cation is disposed throughout the polymeric matrix via chelation to, or complexing with, the polymeric matrix;
 and
 replenishing the liquid material within the membrane, in response to depletion of the liquid material effected during the fractionation, wherein the replenishing includes contacting the membrane with a replenishing liquid material including dissolved carrier material.
2. The process as claimed in claim 1;
 wherein the membrane includes a polysaccharide.
3. The process as claimed in claim 1;
 wherein the membrane includes chitosan.
4. The process as claimed in any one of claims 1 to 3;
 wherein the gaseous material is a mixture including an olefin and a paraffin.
5. The process as claimed in any one of claims 1 to 4;
 wherein the carrier material includes silver ion.

6. The process as claimed in any one of claims 1 to 5;
Wherein the carrier material includes copper ion.

7. The process as claimed in any one of claims 1 to 6;
wherein:

the fractionation is effected in response to contacting of the gaseous material with the membrane;

the contacting is effected in response to supplying of the gaseous material to the membrane; and

the replenishing includes replenishing effected while the supplying is being effected.

8. The process as claimed in any one of claims 1 to 7;
wherein:

the fractionation is effected in response to contacting of the gaseous material with the membrane; and

the contacting is effected in response to supplying of the gaseous material to the membrane;

and further comprising:

prior to the replenishing, suspending the supplying, such that the replenishing includes replenishing effected while the supplying is suspended.

9. The process as claimed in any one of claims 1 to 8;
wherein the liquid material includes water.

10. The Process as claimed in any one of claims 1 to 8;
wherein the liquid material is water.

11. The process as claim in claim 10; wherein:
The replenishing liquid material is an aqueous solution.

12. The process as claimed in claim 8;

Wherein the suspending of the supplying of the gaseous material to the membrane is with effect that a first fractionation time interval is completed, such that the replenish is effected while the supplying is effected, is effected after the first fractionation time interval; and further comprising:

suspending the effecting of the contacting of the membrane with a replenishment liquid material such that a first liquid replenishment time interval is completed;

after the completion of the first liquid replenishment time interval; , effecting resumption of the supplying of the membrane such that a second fractionation time interval is completed;

suspending the resumed supplying of the gaseous supply material; and

after the completion of the second fractionation time interval, effecting resumption of the replenishing during a second liquid replenishment time interval,

wherein the minimum concentration of dissolved carrier material within the replenishment liquid material being supplied during one of the first and second liquid replenishment time intervals is greater than the maximum concentration of dissolved carrier material within the replenishment liquid material being supplied during the other one of the first and second liquid replenishment time intervals.

13. The process as claimed in claim 12;

wherein the liquid material includes water.

14. The process as claimed in claim 12;

wherein the liquid material is water.

15. The process as claimed in claim 13 or 14;

wherein the replenishment liquid material is an aqueous solution.

16. The process as claimed in any one of claims 1 to 15;

wherein the replenishing is effected in response to sensing that at least a fraction of the liquid material becomes depleted from the membrane.

17. The process as claimed in any one of claims 1 to 16;

as effected within a membrane module, wherein the supplying of the replenishment liquid material for the effecting of the contacting of the membrane with a replenishment liquid material, is effected by flowing the replenishment liquid material in an upwardly direction.

18. The process as claimed in any one of claims 1 to 17;

wherein the replenishing includes flowing the replenishment liquid material through the membrane and into a space whose pressure is below atmospheric pressure.

19. The process as claimed in any one of claims 1 to 18;

wherein the membrane includes a polysaccharide, and the replenishment liquid material includes an aqueous solution of silver ion having a molar concentration of at least 1.0.

20. The process as claimed in any one of claims 1 to 19;

wherein the replenishment liquid material includes between 10 and 90 weight% water, based on the total weight of the replenishment liquid material.

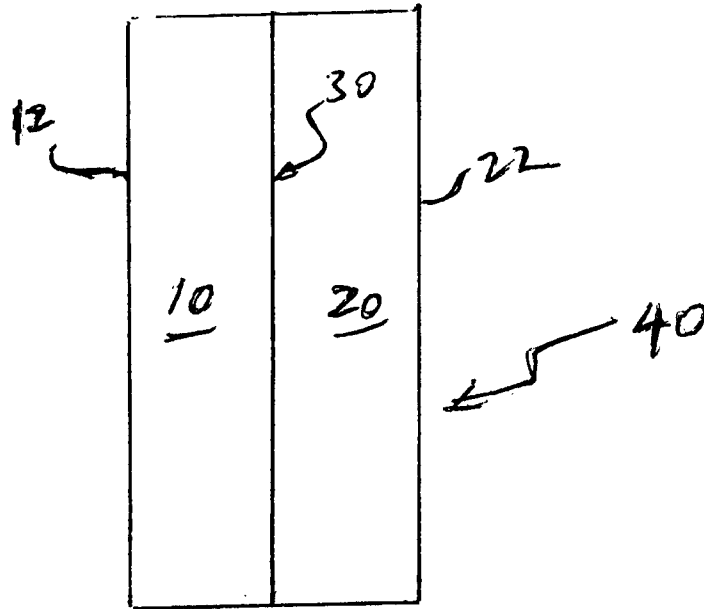


FIG. 1

2/2

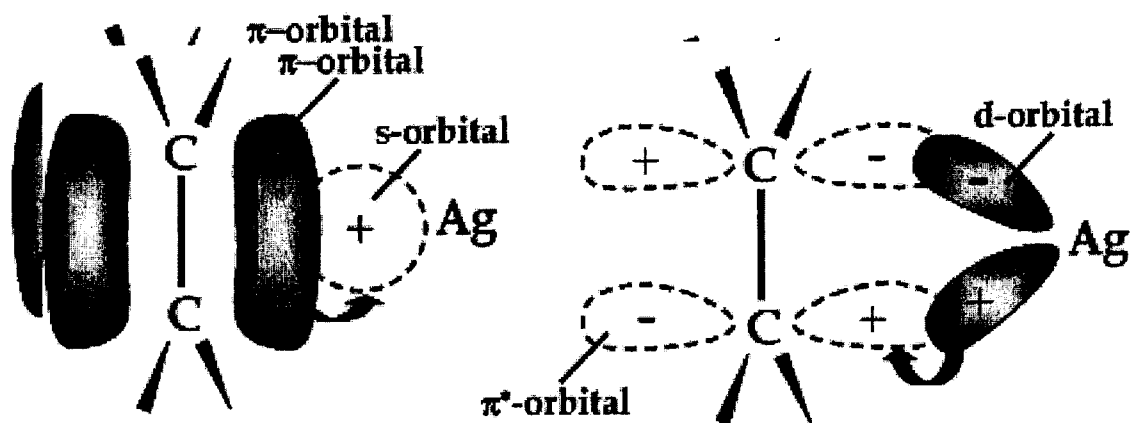


FIG. 2

