

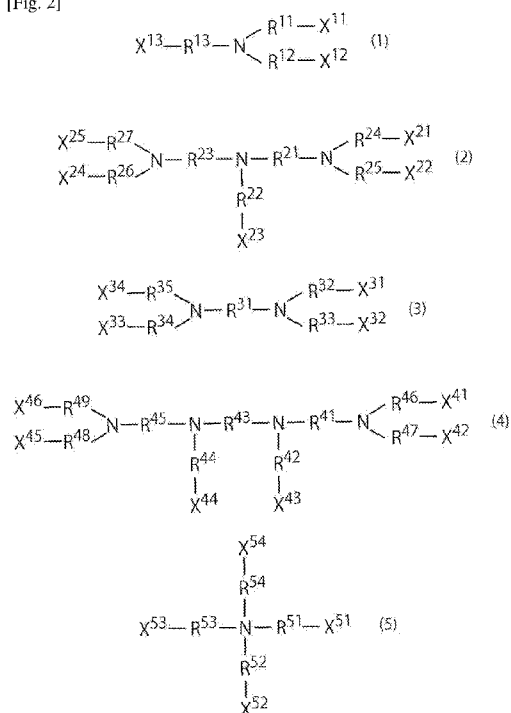
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THE SAME

[Fig. 2]

(57) Abstract: Embodiments provide a water treatment system capa-
ble of separating water at low cost and a working medium. A water
treatment system of an embodiment includes: a first treatment con-
tainer having an osmosis membrane to partition a first chamber for
accommodating water to be treated and a second chamber for accom-
modating a working medium to induce osmotic pressure. The work-
ing medium is an aqueous solution containing a compound having a
metal salt structure of a carboxylic acid group in a main chain, a side
chain, or a main chain and a side chain, a compound having a metal
salt structure of a phosphonic acid group in a main chain, a side chain,
or a main chain and a side chain, or a compound having a metal salt
structure of a carboxylic acid group in a main chain, a side chain, or
a main chain and a side chain and a metal salt structure of a phosphonic
acid group in a main chain, a side chain, or a main chain and a side
chain and an inorganic salt as a solute.

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Description

Title of Invention: DRAWING AGENT FOR FORWARD OSMOSIS AND PRESSURE RETARDED OSMOSIS AND A SYSTEM USING THE SAME

Technical Field

[0001] Embodiments described herein relate to a water treatment system and a working medium.

Background Art

[0002] When a solution having a low solute concentration and a solution having a high solute concentration are isolated from each other by an osmosis membrane, the solvent of the low concentration solution permeates through the osmosis membrane and moves to the high concentration solution side. A desalination system which performs desalination such as seawater desalination and an osmotic power generation system which generates power by turning a turbine are known, and both of them utilize a phenomenon that the solvent moves. In addition, concentration systems which concentrate foods and sludge by utilizing this phenomenon are also known. At this time, the solution to be used on the higher concentration side is the working medium (draw solution), and various kinds of working mediums have been proposed so far.

[0003] As the solute of the draw solution, kitchen salt is generally used. Organic salts are also used as the solute of the draw solution. However, a draw solution of an organic salt has an inferior permeate flux of water to a draw solution of kitchen salt.

[0004] A draw solution in which two or more kinds of solutes are mixed has been proposed. A synergistic effect is observed in a mixture of plural inorganic salts, but the flux passing through the osmosis membrane may decrease due to an adverse effect in the case of a mixture of an inorganic salt with saccharose.

Citation List

Patent Literature

[0005] PTL 1: Patent JP2010-509540A

Summary of Invention

Technical Problem

[0006] Embodiments provide a water treatment system capable of separating water at low cost and a working medium.

Solution to Problem

[0007] A water treatment system of an embodiment includes: a first treatment container having an osmosis membrane to partition a first chamber for accommodating water to be treated and a second chamber for accommodating a working medium to induce

osmotic pressure. The working medium is an aqueous solution containing a compound having a metal salt structure of a carboxylic acid group in a main chain, a side chain, or a main chain and a side chain, a compound having a metal salt structure of a phosphonic acid group in a main chain, a side chain, or a main chain and a side chain, or a compound having a metal salt structure of a carboxylic acid group in a main chain, a side chain, or a main chain and a side chain and a metal salt structure of a phosphonic acid group in a main chain, a side chain, or a main chain and a side chain and an inorganic salt as a solute.

Brief Description of Drawings

- [0008] [fig.1]Fig. 1 is a schematic diagram of a water treatment system according to an embodiment;
- [fig.2]Fig. 2 is chemical formulas of a solute according to an embodiment;
- [fig.3]Fig. 3 is a schematic diagram of a water treatment system according to an embodiment;
- [fig.4]Fig. 4 is a schematic diagram of a water treatment system according to an embodiment; and
- [fig.5]Fig. 5 is a schematic diagram of a water treatment system according to an embodiment.

Description of Embodiments

- [0009] Hereinafter, water treatment systems and working mediums to be used in the water treatment systems of embodiments will be described.

(First Embodiment)

A water treatment system according to a first embodiment will be described with reference to the schematic diagram illustrated in Fig. 1. In a water treatment system 100 according to the first embodiment illustrated in Fig. 1, a working medium B induces osmotic pressure in an osmotic pressure generator 1 including a first treatment container 11 equipped with an osmosis membrane 12 to partition a first chamber 13 for accommodating water to be treated A and a second chamber 14 for accommodating the working medium B.

- [0010] According to such a water treatment system 100, water C in the water to be treated A in the first chamber 13 permeates through the osmosis membrane 12 and moves to the working medium B in the second chamber 14 by the osmotic pressure difference generated between the water to be treated A in the first chamber 13 and the working medium B in the second chamber 14.
- [0011] The water treatment system of the embodiment is preferable from the viewpoint of being able to permeate the water C in the water to be treated A in the first chamber 13 through the osmosis membrane and to move the water C to the working medium B in

the second chamber 14 at a high permeate flux by using the working medium B of the embodiment. The working medium B of the embodiment is used in a water treatment system which can be operated at low cost and a water treatment system.

[0012] The first treatment container 11 is partitioned into the first chamber 13 and the second chamber 14 by the osmosis membrane 12. The first treatment container 11 is a resin or metal container which accommodates the water to be treated A in the first chamber 13 and the working medium B in the second chamber 14.

[0013] The osmosis membrane 12 may be, for example, a forward osmosis membrane (FO membrane) or a reverse osmosis membrane (RO membrane). A preferred osmosis membrane is a FO membrane.

[0014] As the osmosis membrane 12, for example, a cellulose acetate membrane, a polyamide membrane, or the like can be used. The osmosis membrane preferably has a thickness of 45 micrometre or more and 250 micrometre or less.

[0015] The first chamber 13 is a region in the first treatment container 11 for accommodating the water to be treated A, and it is partitioned by the osmosis membrane 12. The first chamber 13 may be provided with an introduction and discharge path (not illustrated) through which the water to be treated A is introduced and discharged.

[0016] The water to be treated A is a liquid having a lower solute concentration than the working medium. Examples of the water to be treated A may include a salt water (seawater and the like), lake water, river water, marsh water, domestic wastewater, industrial wastewater, or a mixture thereof. When the water to be treated A is a salt water, the salt (sodium chloride) concentration of the salt water may be, for example, from 0.05% to 8%. The water to be treated A contains salts such as sodium chloride, magnesium chloride, magnesium sulfate, calcium sulfate, and potassium chloride and suspended substances, and substances other than water are concentrated.

[0017] The second chamber 14 is a region in the first treatment container 11 for accommodating the working medium B, and it is partitioned by the osmosis membrane 12. The second chamber 14 may be provided with an introduction and discharge path (not illustrated) through which the working medium B is introduced and discharged.

[0018] The working medium B of the first embodiment is an aqueous solution containing a compound having a metal salt structure of a carboxylic acid group in a main chain, a side chain, or a main chain and a side chain, a compound having a metal salt structure of a phosphonic acid group in a main chain, a side chain, or a main chain and a side chain, or a compound having a metal salt structure of a carboxylic acid group in a main chain, a side chain, or a main chain and a side chain and a metal salt structure of a phosphonic acid group in a main chain, a side chain, or a main chain and a side chain and an inorganic salt as a solute. The working medium B is an aqueous solution, and it thus contains water as a solvent. The working medium B containing such a solute is

preferable since it exhibits a high osmotic pressure inducing action and suppresses the loss of solute of an inorganic salt. Hence, it is possible to generate a high permeate flux (J_w L/m²h) when water in the water to be treated A in the first chamber 13 permeates through the osmosis membrane 12 and moves to the working medium B in the second chamber 14.

[0019] Consequently, in the embodiment, it is possible to provide a water treatment system which can be operated at low cost and can efficiently perform a treatment such as desalination and concentration of the water to be treated A. The water treatment system of the embodiment is also preferably utilized as a water treatment system which further includes a body of rotation and generates electricity by generating a water flow by induction of osmotic pressure and rotating the body of rotation by the water flow.

[0020] There is a phenomenon that the solute contained in the working medium B leaks out to the water to be treated A side via the osmosis membrane 12, and this loss of solute causes a decrease in quality of the water to be treated A and further increases the running cost of the forward osmosis system.

[0021] It has been found that the solute reverse permeate flux (J_s mmol/m²h) can be decreased when a compound having a metal salt structure of a carboxylic acid group in a main chain, a side chain, or a main chain and a side chain, a compound having a metal salt structure of a phosphonic acid group in a main chain, a side chain, or a main chain and a side chain, or a compound having a metal salt structure of a carboxylic acid group in a main chain, a side chain, or a main chain and a side chain and a metal salt structure of a phosphonic acid group in a main chain, a side chain, or a main chain and a side chain and an inorganic salt are contained as the compound of solute contained in the working medium B. It is considered that this is because the carboxylic acid group and the phosphonic acid group of the dissolved compound coordinate the metal ion of the inorganic salt in the solution to form a chelate complex and the metal ion of the inorganic salt thus hardly permeates through the osmosis membrane 12. Hence, the working solution of the embodiment maintains both a high solute concentration and a high osmotic pressure.

[0022] The compound (molecule) having a metal salt structure of a carboxylic acid group in a main chain, a side chain, or a main chain and a side chain and the compound having a metal salt structure of a phosphonic acid group in a main chain, a side chain, or a main chain and a side chain are expressed by $C_xH_yP_zO_wN_sM_t$. M is a metal. In order to increase the permeate flux, it is preferable to satisfy $2 \leq x \leq 20$, $8 \leq y \leq 30$, $1 \leq z \leq 6$, $3 \leq w \leq 18$, $0 \leq s \leq 3$, and $2 \leq t$

$\leq$ (being less than or equal to) 10. In order to decrease the solute reverse permeate flux, it is preferable to satisfy $2 \leq$ (being less than or equal to) $x \leq$ (being less than or equal to) 30, $8 \leq$ (being less than or equal to) $y \leq$ (being less than or equal to) 35, $2 \leq$ (being less than or equal to) $z \leq$ (being less than or equal to) 5, $3 \leq$ (being less than or equal to) $w \leq$ (being less than or equal to) 15, $0 \leq$ (being less than or equal to) $s \leq$ (being less than or equal to) 3, and $2 \leq$ (being less than or equal to) $t \leq$ (being less than or equal to) 10. Moreover, in order to increase the permeate flux and to decrease the solute reverse permeate flux, it is preferable to satisfy $2 \leq$ (being less than or equal to) $x \leq$ (being less than or equal to) 20, $8 \leq$ (being less than or equal to) $y \leq$ (being less than or equal to) 23, $2 \leq$ (being less than or equal to) $z \leq$ (being less than or equal to) 5, $3 \leq$ (being less than or equal to) $w \leq$ (being less than or equal to) 15, $0 \leq$ (being less than or equal to) $s \leq$ (being less than or equal to) 3, and $2 \leq$ (being less than or equal to) $t \leq$ (being less than or equal to) 10. The metal expressed by M is a metal of a metal salt of a carboxylic acid group or a metal of a metal salt of a phosphonic acid group. The metal of the metal salt is preferably an alkali metal. The metal of the metal salt is preferably Na, K, or Na and K. The elements or structures contained in the solute of the embodiment can be determined by analyzing the solute by liquid chromatography, separating the compounds having the respective peaks, and analyzing the compounds by using a NMR or organic element analyzer.

[0023] The compound having a metal salt structure of a carboxylic acid group in a main chain, a side chain, or a main chain and a side chain, the compound having a metal salt structure of a phosphonic acid group in a main chain, a side chain, or a main chain and a side chain, or the compound having a metal salt structure of a carboxylic acid group in a main chain, a side chain, or a main chain and a side chain and a metal salt structure of a phosphonic acid group in a main chain, a side chain, or a main chain and a side chain is preferably a compound in which a carboxylic acid group, a phosphonic acid group, or a carboxylic acid group and a phosphonic acid group of a compound having a structure expressed by Formula (1), (2), (3), (4), or (5) in Fig. 2 have a metal salt structure. Some or all of the carboxylic acid groups of the compound having a structure expressed by Formula (1), (2), (3), (4), or (5) in Fig. 2 are a metal salt of a carboxylic acid group. Some or all of the phosphonic acid groups of the compound having a structure expressed by Formula (1), (2), (3), (4), or (5) in Fig. 2 are a metal salt of a phosphonic acid group. Some of the side chains contained in the compound of the solute may contain a phosphonic acid group or a carboxylic acid group which is not a salt.

[0024] R^{11} to R^{13} in Formula (1) are an alkyl chain of $C_{n1}H_{2n1}$ ($n1$ is any integer from 0 to 2). X^{11} to X^{13} in Formula (1) are each any one selected from the group consisting of -COOH, $-P(OH)_2$, and OH. At least two X in one molecule are -COOH or $-P(OH)_2$. As

the compound having a structure expressed by Formula (1) in Fig. 2, nitrilotriacetic acid, N-(2-hydroxyethyl)iminodiacetic acid, and nitrilotris(methylenephosphonic acid) are preferable. Examples of the compound in which a carboxylic acid group, a phosphonic acid group, or a carboxylic acid group and a phosphonic acid group of the compound having a structure expressed by Formula (1) in Fig. 2 have a metal salt structure may include nitrilotriacetic acid 2Na salt, N-(2-hydroxyethyl)iminodiacetic acid 2Na salt, and nitrilotris(methylenephosphonic acid) 5Na salt.

[0025] R^{21} to R^{27} in Formula (2) are an alkyl chain of $C_{n2}H_{2n2}$ ($n2$ is any integer from 0 to 2). X^{21} to X^{27} in Formula (2) are each any one selected from the group consisting of H, -COOH, $-P(OH)_2$, and OH. At least two X in one molecule are -COOH or $-P(OH)_2$. At least three X in one molecule are a functional group other than H. As the compound having a structure expressed by Formula (2) in Fig. 2, diethylenetriaminepentaacetic acid and diethylenetriaminepenta(methylenephosphonic acid) are preferable. Examples of the compound in which a carboxylic acid group, a phosphonic acid group, or a carboxylic acid group and a phosphonic acid group of the compound having a structure expressed by Formula (2) in Fig. 2 have a metal salt structure may include diethylenetriaminepentaacetic acid 3Na salt, diethylenetriaminepentaacetic acid 5Na salt, and diethylenetriaminepenta(methylenephosphonic acid) 7Na salt.

[0026] R^{31} to R^{35} in Formula (3) are an alkyl chain of $C_{n3}H_{2n3}$ ($n3$ is any integer from 0 to 3). R^{31} may have a hydroxyl group and may be bonded via one or more ether bonds. In addition, R^{32} to R^{35} may optionally contain a carboxylic acid group. X^{31} to X^{34} in Formula (3) are each any one selected from the group consisting of H, -COOH, $-P(OH)_2$, and OH. At least two X in one molecule are -COOH or $-P(OH)_2$. At least three X in one molecule are a functional group other than H. As the compound having a structure expressed by Formula (3) in Fig. 2, N-(2-hydroxyethyl)ethylenediamine-N,N',N'-triacetic acid, 1,3-propanediaminetetraacetic acid, 1,3-diamino-2-propanol-N,N,N',N'-tetraacetic acid, glycol ether diaminetetraacetic acid, ethylenediaminedisuccinic acid, and ethylenediaminetetramethylenephosphonic acid are preferable. Examples of the compound in which a carboxylic acid group, a phosphonic acid group, or a carboxylic acid group and a phosphonic acid group of the compound having a structure expressed by Formula (3) in Fig. 2 have a metal salt structure may include N-(2-hydroxyethyl)ethylenediamine-N,N',N'-triacetic acid 3Na salt, 1,3-propanediaminetetraacetic acid 4Na salt, 1,3-diamino-2-propanol-N,N,N',N'-tetraacetic acid 2Na salt, glycol ether diaminetetraacetic acid 4Na salt, ethylenediaminedisuccinic acid 3Na salt, and ethylenediaminetetramethylenephosphonic acid 5Na salt.

[0027] R^{41} to R^{49} in Formula (4) are an alkyl chain of $C_{n4}H_{2n4}$ ($n4$ is any integer from 0 to 2).

X⁴¹ to X⁴⁶ in Formula (4) are each any one selected from the group consisting of H, -COOH, -P(OH)₂, and OH. At least two X in one molecule are -COOH or -P(OH)₂. At least three X in one molecule are a functional group other than H.

[0028] R⁵¹ to R⁵⁴ in Formula (5) are an alkyl chain of C_{n5}H_{2n5} (n5 is any integer from 0 to 2). X⁵¹ to X⁵⁴ in Formula (5) are each any one selected from the group consisting of H, -COOH, -P(OH)₂, and OH. At least two X in one molecule are -COOH or -P(OH)₂. At least three X in one molecule are a functional group other than H. As the compound having a structure expressed by Formula (5) in Fig. 2,

3-carboxy-3-phosphonohexanedioic acid is preferable. Examples of the compound in which a carboxylic acid group, a phosphonic acid group, or a carboxylic acid group and a phosphonic acid group of the compound having a structure expressed by Formula (5) in Fig. 2 have a metal salt structure may include 3-carboxy-3-phosphonohexanedioic acid 5Na salt.

[0029] Accordingly, the compound having a metal salt structure of a carboxylic acid group in a main chain, a side chain, or a main chain and a side chain is preferably at least one kinds selected from the group consisting of nitrilotriacetic acid 2Na salt, N-(2-hydroxyethyl)iminodiacetic acid 2Na salt, diethylenetriaminepentaacetic acid 3Na salt, diethylenetriaminepentaacetic acid 5Na salt, N-(2-hydroxyethyl)ethylenediamine-N,N',N'-triacetic acid 3Na salt, 1,3-propanediaminetetraacetic acid 4Na salt, 1,3-diamino-2-propanol-N,N,N',N'-tetraacetic acid 2Na salt, glycol ether diaminetetraacetic acid 4Na salt, ethylenediaminedisuccinic acid 3Na salt, and 3-carboxy-3-phosphonohexanedioic acid 5Na salt.

[0030] Accordingly, the compound having plural metal salt structures of a phosphonic acid group in a main chain, a side chain, or a main chain and a side chain is preferably at least one kinds selected from the group consisting of nitrilotris(methylenephosphonic acid) 5Na salt, diethylenetriaminepenta(methylenephosphonic acid) 7Na salt, and ethylenediaminetetramethylenephosphonic acid 5Na salt.

[0031] Accordingly, the compound having a metal salt structure of a carboxylic acid group and a metal salt structure of a phosphonic acid group in a main chain, a side chain, or a main chain and a side chain is preferably at least one kinds selected from the group consisting of 3-carboxy-3-phosphonohexanedioic acid 5Na salt.

[0032] The number of substitution of the metal salt changes depending on the pH. For example, diethylenetriaminepentaacetic acid 3Na salt is weakly alkaline and diethylenetriaminepentaacetic acid 5Na salt is strongly alkaline. It is desirable to use the working medium B in the vicinity of a neutral pH range from the viewpoint of resistance of FO membrane, but it is preferable that the number of substitution is larger from the viewpoint of osmotic pressure. Hence, the pH of the working medium B in

the embodiment is preferably 2 or more and 12 or less. The pH of the working medium B is measured by using the glass electrode type hydrogen ion densitometer manufactured by HORIBA, Ltd. and the method described in the manual.

[0033] The total number of the carboxylic acid group and the phosphonic acid group contained in the compound having a metal salt structure of a carboxylic acid group in a main chain, a side chain, or a main chain and a side chain, the compound having a metal salt structure of a phosphonic acid group in a main chain, a side chain, or a main chain and a side chain, or the compound having a metal salt structure of a carboxylic acid group in a main chain, a side chain, or a main chain and a side chain and a metal salt structure of a phosphonic acid group in a main chain, a side chain, or a main chain and a side chain is preferably 5 or more. The chelate is more stabilized and the effect of decreasing the loss of solute is more remarkable as the number of carboxylic acid groups and phosphonic acid groups contained is larger.

[0034] In addition, the total number of the carboxylic acid group having a salt structure and the phosphonic acid group having a salt structure which are contained in the compound having a metal salt structure of a carboxylic acid group in a main chain, a side chain, or a main chain and a side chain, the compound having a metal salt structure of a phosphonic acid group in a main chain, a side chain, or a main chain and a side chain, or the compound having a metal salt structure of a carboxylic acid group in a main chain, a side chain, or a main chain and a side chain and a metal salt structure of a phosphonic acid group in a main chain, a side chain, or a main chain and a side chain is preferably 5 or more. The chelate is more stabilized and the effect of decreasing the loss of solute is more remarkable as the total number of the carboxylic acid group and phosphonic acid group having a salt structure is larger.

[0035] The concentration of the compound (solute) having a metal salt structure of a carboxylic acid group in a main chain, a side chain, or a main chain and a side chain, the compound having a metal salt structure of a phosphonic acid group in a main chain, a side chain, or a main chain and a side chain, or the compound having a metal salt structure of a carboxylic acid group in a main chain, a side chain, or a main chain and a side chain and a metal salt structure of a phosphonic acid group in a main chain, a side chain, or a main chain and a side chain in the working medium B is 0.05 mol/L or more and less than 1.0 mol/L and preferably 0.05 mol/L or more and 0.6 mol/L or less. It is not preferable that the concentration is too low since the osmotic pressure is weakly induced. In addition, it is not preferable that the concentration is too high since the loss of solute is great. A more preferable concentration range is 0.2 mol/L or more and 0.6 mol/L or less.

[0036] The inorganic salt (solute) in the working medium B is preferably a salt of an alkaline earth metal or an ammonium salt. The alkaline earth metal ion and the

ammonium ion have an advantage of forming a stable chelate with the compound having a metal salt structure of a carboxylic acid group in a main chain, a side chain, or a main chain and a side chain, the compound having a metal salt structure of a phosphonic acid group in a main chain, a side chain, or a main chain and a side chain, or the compound having a metal salt structure of a carboxylic acid group in a main chain, a side chain, or a main chain and a side chain and a metal salt structure of a phosphonic acid group in a main chain, a side chain, or a main chain and a side chain in the solution and thus decreasing the loss of solute. It is preferable that the inorganic salt (solute) is at least one kinds selected from the group consisting of a salt of carbonic acid, a salt of nitric acid, a salt of sulfonic acid, a salt of phosphoric acid, and a salt of a halogen element for the reason of low cost. A specific preferred alkaline earth metal is Mg, Ca, or Mg and Ca, and Mg is more preferable. A specific preferred halogen element is Cl. As the inorganic salt, a salt of sulfonic acid or a salt of Cl is more preferable.

[0037] The concentration of the inorganic salt (solute) in the working medium B is preferably 0.05 mol/L or more. The formation of chelate complex and the effect of decreasing the loss of solute decrease when the amount of inorganic salt is too small. More specifically, the concentration of the inorganic salt (solute) in the working medium B is preferably 0.4 mol/L or more and 10.0 mol/L or less and more preferably 0.4 mol/L or more and 5.0 mol/L or less. In addition, the concentration of the inorganic salt (solute) in the working medium B is preferably higher than the concentration of the compound having a metal salt structure of a carboxylic acid group in a main chain, a side chain, or a main chain and a side chain, the compound having a metal salt structure of a phosphonic acid group in a main chain, a side chain, or a main chain and a side chain, or the compound having a metal salt structure of a carboxylic acid group in a main chain, a side chain, or a main chain and a side chain and a metal salt structure of a phosphonic acid group in a main chain, a side chain, or a main chain and a side chain from the viewpoint of forming a chelate complex.

[0038] (Second Embodiment)

The second embodiment is common to the first embodiment except that an amino acid having a metal salt structure of a carboxylic acid group is used instead of the compound having a metal salt structure of a carboxylic acid group in a main chain, a side chain, or a main chain and a side chain, the compound having a metal salt structure of a phosphonic acid group in a main chain, a side chain, or a main chain and a side chain, or the compound having a metal salt structure of a carboxylic acid group in a main chain, a side chain, or a main chain and a side chain and a metal salt structure of a phosphonic acid group in a main chain, a side chain, or a main chain and a side chain of the first embodiment.

[0039] An amino acid is a low molecule, thus the solute moves to the liquid to be treated A side and the loss of solute is likely to be caused, but a complex is formed as an inorganic salt is used concurrently. Accordingly, the embodiment has an advantage that an amino acid hardly permeates through the osmosis membrane 12 even when being used as the solute to induce osmotic pressure. A salt of an amino acid is inexpensive, and the water treatment system of the embodiment having minor loss of solute is thus effective for cutting down the running cost.

[0040] Examples of the amino acid having a metal salt structure of a carboxylic acid group may include arginine. The concentration of the amino acid (solute) having a metal salt structure of a carboxylic acid group in the working medium B is less than 1.0 mol/L. The concentration of the amino acid (solute) having a metal salt structure of a carboxylic acid group in the working medium B is preferably 0.05 mol/L or more and 0.4 mol/L or less and more preferably 0.05 mol/L or more and 0.4 mol/L or less.

[0041] (Second Embodiment)

Next, a desalination system which is one example of a water treatment system will be described with reference to the schematic diagram illustrated in Fig. 3. In the second embodiment, the first chamber 13, the water to be treated A, the second chamber 14, the working medium B, and the osmosis membrane 12 are common to those in the first embodiment and the second embodiment. The water to be treated A is a salt water (aqueous solution of sodium chloride) such as seawater. The working medium B to be used in the second embodiment is the working medium B of the first embodiment or the second embodiment. In Fig. 3 and subsequent figures, the reference numerals of water to be treated, working medium, and water in the water treatment system are not illustrated, but the reference numerals thereof are common to those in the water treatment system in Fig. 1.

[0042] A desalination system 200 is equipped with an osmotic pressure generator 1, a diluted working medium tank 2, a reverse osmosis membrane separator 3, and a concentrated working medium tank 4. The osmotic pressure generator 1, the diluted working medium tank 2, the reverse osmosis membrane separator 3, and the concentrated working medium tank 4 are connected in this order to form a loop. The working medium B (draw solution) which induces osmotic pressure circulates through this loop. In other words, the working medium B circulates through the osmotic pressure generator 1, the diluted working medium tank 2, the reverse osmosis membrane separator 3, and the concentrated working medium tank 4 in this order. Incidentally, the upper and the lower are the directions illustrated in the drawings, and for example, the concentrated working medium tank 4 is on the upper side of the diluted working medium tank 2, and the osmotic pressure generator 1 is on the left side of the reverse osmosis membrane separator 3.

- [0043] A tank of water to be treated 15 is connected to the upper part of a treatment container 10 in which the first chamber 13 is located through a pipeline 101a. A first pump 16 is provided to the pipeline 101a. A pipeline 101b for discharging the concentrated water to be treated A is connected to the lower part of the first treatment container 11 in which the first chamber 13 is located.
- [0044] The reverse osmosis membrane separator 3 is equipped with, for example, an airtight second treatment container 21. The second treatment container 21 is partitioned in, for example, the horizontal direction by a reverse osmosis membrane (RO membrane) 22, and a third chamber 23 is formed on the left side of the reverse osmosis membrane 22 and a fourth chamber 24 is formed on the right side thereof.
- [0045] The diluted working medium tank 2 is connected to the lower part of the second treatment container 21 in which the third chamber 23 is located through a pipeline 101e. A third pump 25 is provided to the pipeline 101e. The upper part of the second treatment container 21 in which the third chamber 23 is located is connected to the concentrated working medium tank 4 through a pipeline 101f. The lower part of the second treatment container 21 in which the fourth chamber 24 is located is connected to a pure water tank 26 through a pipeline 101g. In the pure water tank 26, the water (fresh water) which has moved to the fourth chamber through the reverse osmosis membrane 22 when concentrating the working medium B is accommodated. A pipeline 101h for delivering pure water in the pure water tank 26 to the outside and recovering the pure water is connected to the pure water tank 26. An on-off valve 27 is provided to the pipeline 101h. For example, the on-off valve 27 is opened when pure water in the pure water tank 26 exceeds a certain amount.
- [0046] The concentrated working medium tank 4 is connected to the upper part of the first treatment container 11 in which the second chamber 14 is located through a pipeline 101c. A second pump 17 is provided to the pipeline 101a. The lower part of the treatment container 10 in which the second chamber 14 is located is connected to the diluted working medium tank 2 through a pipeline 101d.
- [0047] Next, the operation of desalination by the desalination system 200 illustrated in Fig. 3 will be described.
- [0048] The first pump 16 is driven to supply the water to be treated A (for example, seawater) from the tank of water to be treated 15 into the first chamber 13 of the osmotic pressure generator 1 through the pipeline 101a. Before and after the supply of seawater, the second pump 17 is driven to supply the concentrated working medium B from the concentrated working medium tank 4 into the second chamber 14 of the osmotic pressure generator 1 through the pipeline 101c. At this time, the solute concentration of the concentrated working medium B supplied to the second chamber 14 is higher than the salt concentration of the seawater supplied to the first chamber 13.

Hence, an osmotic pressure difference is generated between the seawater in the first chamber 13 and the concentrated working medium B in the second chamber 14, and water in the seawater permeates through the osmosis membrane 12 and moves into the second chamber 14. The concentrated working medium B in the second chamber 14 is an aqueous solution containing the solute of the first embodiment or the second embodiment and exhibits a high osmotic pressure inducing action. Hence, a high permeate flux is generated when water in the seawater in the first chamber 13 permeates through the osmosis membrane 12 and moves to the concentrated working medium B in the second chamber 14. As a result, it is possible to move a large amount of water in the seawater in the first chamber 13 to the concentrated working medium B in the second chamber 14 and thus to perform a highly efficient desalination treatment for extracting water (pure water) from a salt water.

[0049] In the osmotic pressure generator 1, the seawater is discharged as condensed seawater from the first chamber 13 through the pipeline 101b and the concentrated working medium B is diluted with the water moved as the water in the seawater moves from the first chamber 13 to the concentrated working medium B in the second chamber 14.

[0050] The diluted working medium B in the second chamber 14 is delivered to the diluted working medium tank 2 through the pipeline 101d and stored therein. When the diluted working medium B is stored in the diluted working medium tank 2 to a predetermined water level, the third pump 25 is driven to supply the diluted working medium B in the diluted working medium tank 2 to the third chamber 23 of the second treatment container 21 of the reverse osmosis membrane separator 3 through the pipeline 101e at a desired pressure. The water in the diluted working medium B supplied to the third chamber 23 at a desired pressure forcibly permeates through the reverse osmosis membrane (RO membrane) 22 and moves to the fourth chamber 24. The diluted working medium B in the third chamber 23 is concentrated as water moves to the fourth chamber 24. The concentrated working medium B is delivered from the third chamber 23 to the concentrated working medium tank 4. The concentrated working medium B in the concentrated working medium tank 4 is supplied into the second chamber 14 of the osmotic pressure generator 1 as the second pump 17 is driven, and it is utilized in the desalination treatment for extracting water (pure water) from a salt water as described above.

[0051] Meanwhile, the water (pure water) moved to the fourth chamber 24 is delivered to the pure water tank 26 through the pipeline 101g. When the amount of water in the pure water tank 26 exceeds a certain amount, the on-off valve 27 is opened and the water is delivered to the outside through the pipeline 101h and recovered.

[0052] Consequently, it is possible to provide a desalination system which can be operated

at low cost and can efficiently perform a desalination treatment of seawater (recovery of pure water).

[0053] Incidentally, in the desalination system 200 illustrated in Fig. 3, the first treatment container 11 of the osmotic pressure generator is partitioned in the horizontal direction by an osmosis membrane to form the first chamber 13 and the second chamber 14, but the first treatment container may be partitioned into upper and lower parts by an osmosis membrane to form the first chamber 13 and the second chamber 14.

[0054] It is preferable to add the solute to the concentrated working medium tank 4 and the like when the solute concentration in the working medium B is decreased by the desalination treatment.

[0055] In the desalination system 200 illustrated in Fig. 3, the concentration of the diluted working medium B is not only performed by using a reverse osmosis membrane separator equipped with a reverse osmosis membrane (RO membrane) but also may be performed by using any device as long as it can remove water in the diluted working medium B.

[0056] (Fourth Embodiment)

Next, a concentration system 300 which is one example of a water treatment system will be described with reference to the schematic diagram illustrated in Fig. 4. The working medium B to be used in the fourth embodiment is the working medium B of the first embodiment or the second embodiment.

[0057] A concentration system 300 is equipped with an osmotic pressure generator 31, a diluted working medium tank 32, a membrane distillation and separation device 33, and a concentrated working medium tank 34. The osmotic pressure generator 31, the diluted working medium tank 32, the membrane distillation and separation device 33, and the concentrated working medium tank 34 are connected in this order to form a loop. The working medium B (draw solution) circulates through this loop. In other words, the working medium B circulates through the osmotic pressure generator 31, the diluted working medium tank 32, the membrane distillation and separation device 33, and the concentrated working medium tank 34 in this order.

[0058] The osmotic pressure generator 31 is equipped with, for example, an airtight first treatment container 41. The first treatment container 41 is partitioned in, for example, a horizontal direction by an osmosis membrane 42 (for example, a forward osmosis membrane: FO membrane), and a first chamber 43 is formed on the left side of the osmosis membrane 42 and a second chamber 44 is formed on the right side thereof. A tank of water to be treated 45 containing water to be treated A, for example, a stock solution such as industrial wastewater, is connected to the upper part of the first treatment container 41 in which the first chamber 43 is located through a pipeline 201a. A first pump 46 is provided to the pipeline 201a. A pipeline 201b for discharging

the concentrated stock solution in the first chamber 43 to the outside is connected to the lower part of the first treatment container 41 in which the first chamber 43 is located.

[0059] The concentrated working medium tank 34 is connected to the upper part of the first treatment container 41 in which the second chamber 44 is located through a pipeline 201c. A second pump 47 is provided to the pipeline 201c. The diluted working medium tank 32 is connected to the lower part of the first treatment container 11 in which the second chamber 44 is located through a pipeline 201d.

[0060] The membrane distillation and separation device 33 is equipped with, for example, an airtight second treatment container 51. The second treatment container 51 is partitioned in, for example, a horizontal direction by a dehydration membrane 52 formed of, for example, a porous latex membrane, and a third chamber 53 is formed on the left side of the dehydration membrane 52 and a fourth chamber 54 is formed on the right side thereof.

[0061] The diluted working medium tank 32 is connected to the lower part of the second treatment container 51 in which the third chamber 53 is located through a pipeline 201e. A first on-off valve 61, a heat exchanger 62, and a third pump 63 are provided to the pipeline 201e along the flow direction of the working medium B in this order. The heat exchanger 62 intersects, for example, a pipeline 201f of exhaust heat gas, and the working medium B is heated by heat exchange between the working medium B flowing through the pipeline 201e and the exhaust heat gas. The upper part of the second treatment container 51 in which the third chamber 53 is located is connected to the upper part of a circulation tank 64 through a pipeline 201g. The circulation tank 64 is connected to the portion of the pipeline 201e located between the first on-off valve 61 and the heat exchanger 62 through a pipeline 201h. A second on-off valve 65 is provided to the pipeline 201h.

[0062] By such a configuration, a loop is formed by the third chamber 53 of the membrane distillation and separation device 33, the circulation tank 64, and the pipelines 201e, 201g, and 201h which connect these members to each other. In other words, a diluted working medium circulation system is formed that the diluted working medium B which has been subjected to the dehydration treatment in the third chamber 53 to be described later and stored in the circulation tank 64 is circulated through the pipeline 201h, the pipeline 201e, the third chamber 53, and the pipeline 201g by opening the second on-off valve 65 and driving the third pump 63. Incidentally, in the circulation of the diluted working medium B, the diluted working medium circulation system is isolated from the diluted working medium tank 32 by closing the first on-off valve 61.

[0063] The circulation tank 64 is connected to the concentrated working medium tank 34 through a pipeline 201i. A fourth pump 66 is provided to the pipeline 201i.

- [0064] A first pure water tank 71 is connected to the upper part of the second treatment container 51 in which the fourth chamber 54 is located through a pipeline 201j. The second pure water tank 72 is connected to the lower part of the second treatment container 51 in which the fourth chamber 54 is located through a pipeline 201k. A third on-off valve 73 is provided to the pipeline 201k and closed when pure water is not circulated to store the pure water in the fourth chamber 54. The second pure water tank 72 is connected to the first pure water tank 71 through a pipeline 201m. A fifth pump 74 is provided to the pipeline 201m. By such a configuration, a loop is formed by the first pure water tank 71, the fourth chamber 54 of the membrane distillation and separation device 33, the second pure water tank 72, and the pipelines 201j, 201k, and 201m which connect these members to each other. In other words, a pure water circulation and cooling system is formed that the pure water in the second pure water tank 72 is circulated through the pipeline 201m, the first pure water tank 71, the pipeline 201j, the fourth chamber 54, and the pipeline 201k by opening the third on-off valve 73 and driving the fifth pump 74.
- [0065] The second pure water tank 72 is connected to a pipeline 201n for delivering pure water in the second pure water tank 72 to the outside and recovering the pure water. A fourth on-off valve 75 is provided to the pipeline 201n. The fourth on-off valve 75 is closed when pure water is circulated described above, and it is opened when the pure water in the second pure water tank 72 exceeds a certain amount.
- [0066] Next, the operation of concentration by the concentration system 300 illustrated in Fig. 4 will be described.
- [0067] The first pump 46 is driven to supply the stock solution of the water to be treated A (for example, industrial wastewater) from the tank of water to be treated 45 into the first chamber 43 of the osmotic pressure generator 31 through the pipeline 201a. Before and after the supply of the stock solution, the second pump 47 is driven to supply the concentrated working medium B from the concentrated working medium tank 34 into the second chamber 44 of the osmotic pressure generator 31 through the pipeline 201c. The concentrated working medium B supplied to the second chamber 44 has a higher concentration than the stock solution supplied to the first chamber 43. Hence, an osmotic pressure difference is generated between the stock solution in the first chamber 43 and the concentrated working medium B in the second chamber 44, and water in the stock solution permeates through the osmosis membrane 42 and moves into the second chamber 44. At this time, the concentrated working medium B in the second chamber 44 is an aqueous solution containing the solute of the em-bodiment and exhibits a high osmotic pressure inducing action. Hence, a high permeate flux is generated when water in the stock solution in the first chamber 43 permeates through the osmosis membrane 42 and moves into the working medium B in the

second chamber 44. As a result, it is possible to move a large amount of water in the stock solution in the first chamber 43 to the working medium B in the second chamber 44 and to highly efficiently perform the concentration treatment of the stock solution.

[0068] The stock solution is discharged from the first chamber 43 through the pipeline 201b and recovered as a concentrated stock solution as the water in the stock solution moves from the first chamber 43 to the concentrated working medium B in the second chamber 44 in the osmotic pressure generator 31. The concentrated working medium B is diluted with the water moved.

[0069] The diluted working medium B in the second chamber 44 is delivered to the diluted working medium tank 32 through the pipeline 201d and stored therein. When the diluted working medium B is stored in the diluted working medium tank 32 to a predetermined amount, the first on-off valve 61 provided to the pipeline 201e is opened, the second on-off valve 65 provided to the pipeline 201h is closed, and the third pump 63 is driven. By this, the diluted working medium B in the diluted working medium tank 32 is supplied to the third chamber 53 of the second treatment container 51 of the membrane distillation and separation device 33 through the pipeline 201e. While the diluted working medium B is supplied to the third chamber 53, the diluted working medium B flowing through the pipeline 201e is heated by heat exchange between the diluted working medium B and the exhaust heat gas flowing through the pipeline 201f in the heat exchanger 62 which intersects the pipeline 201f. In addition, by opening the third on-off valve 73 and driving the fifth pump 74, the pure water in the second pure water tank 72 is circulated through the pipeline 201m, the first pure water tank 71, the pipeline 201j, the fourth chamber 54, and the pipeline 201k, and the dehydration membrane 52 formed of a porous latex membrane of the membrane distillation and separation device 33 is cooled with pure water on the fourth chamber 54 side. In other words, the dehydration membrane 52 on the fourth chamber 54 side is cooled by the pure water circulation and cooling system.

[0070] By cooling the dehydration membrane 52 of the membrane distillation and separation device 33 with circulating pure water in the fourth chamber 54 while supplying the diluted working medium B thus heated to the third chamber 53 of the membrane distillation and separation device 33 through the pipeline 201e, the water in the diluted working medium B evaporates in the third chamber 53 and the vapor permeates through the dehydration membrane 52 formed of a porous latex membrane, moves to the fourth chamber 54, and is cooled and condensed with circulating pure water to be incorporated into the pure water. In other words, the diluted working medium B is subjected to the dehydration treatment in the third chamber 53. The diluted working medium B subjected to the dehydration treatment in the third chamber 53 is delivered to the circulation tank 64 through the pipeline 201g and stored therein. The diluted

working medium B stored in the circulation tank 64 is concentrated to a certain concentration by the dehydration treatment.

[0071] However, the working medium B has a low concentration by the concentration to such an extent, and the working medium B is not suitable for use as the concentrated working medium B described above. Hence, when the diluted working medium B subjected to the dehydration treatment is stored in the circulation tank 64 in a certain amount, the second on-off valve 65 is opened and the diluted working medium B subjected to the dehydration treatment in the tank 64 is allowed to flow out to the pipeline 201h. At the same time, the first on-off valve 61 is closed to isolate the diluted working medium circulation system including the circulation tank 64, the pipeline 201h, the pipeline 201e, the third chamber 53, and the pipeline 201g from the diluted working medium tank 32.

[0072] In such a diluted working medium circulation system and the pure water circulation and cooling system, the diluted working medium B is concentrated so as to be used as the concentrated working medium B by repeatedly performing the dehydration treatment including the evaporation of water in the diluted working medium B in the third chamber 53, the permeation of the vapor through the dehydration membrane 52, the movement of the vapor to the fourth chamber 54, and the cooling and condensation of the vapor with the circulating pure water on the fourth chamber 54 side plural times. After such circulation and dehydration of the diluted working medium B, the second on-off valve 65 is closed to store the concentrated working medium B in the circulation tank 64. The water (pure water) moved to the fourth chamber 54 is delivered to the second pure water tank 72 together with the circulating pure water through the pipeline 201k.

[0073] After the concentrated working medium B at a concentration capable of being used as the concentrated working medium B is stored in the circulation tank 64, driving of the fifth pump 74 is stopped, circulation of pure water to the fourth chamber 54 is stopped, and the third on-off valve 73 is then closed. Incidentally, when the amount of pure water in the second pure water tank 72 exceeds a certain amount, the first on-off valve 61 is opened, and the pure water is delivered to the outside through the pipeline 201n and recovered.

[0074] The fourth pump 66 is driven to deliver the concentrated working medium B in the circulation tank 64 to the concentrated working medium tank 34 through the pipeline 201i. The concentrated working medium B in the concentrated working medium tank 34 is supplied into the second chamber 44 of the osmotic pressure generator 31 by driving the second pump 47, and it is utilized in the concentration treatment of the stock solution as described above.

[0075] Accordingly, in the osmotic pressure generator 31, the stock solution is supplied to

the first chamber 43, the concentrated working medium B is supplied to the second chamber 44, the water in the stock solution is moved from the first chamber 43 to the concentrated working medium B in the second chamber 44 to concentrate the stock solution, and the stock solution is discharged from the first chamber 43 through the pipeline 201b and recovered. The concentrated working medium B is diluted with the water moved, and the diluted working medium B is delivered to the diluted working medium tank 32 and stored therein.

- [0076] During the operation of stock solution concentration by the osmotic pressure generator 31, the diluted working medium B stored in the diluted working medium tank 32 is subjected to the operation of concentration by the diluted working medium circulation system including the third chamber 53 of the membrane distillation and separation device 33 and the pure water circulation and cooling system including the fourth chamber 54 of the membrane distillation and separation device 33 and delivered to the concentrated working medium tank 34 and the water (pure water) moved to the fourth chamber 54 is delivered from the second pure water tank 72 and recovered. In other words, it is possible to continuously perform the operation of stock solution concentration by the osmotic pressure generator 31 and the concentration of the diluted working medium B by the membrane distillation and separation device 33.
- [0077] Consequently, it is possible to provide the concentration system 300 which can be operated at low cost and can efficiently perform the concentration treatment of a stock solution (water to be treated A) such as industrial wastewater and the recovery of water.
- [0078] Incidentally, in the concentration system 300 illustrated in Fig. 4, the first treatment container 41 of the osmotic pressure generator is partitioned in the horizontal direction by an osmosis membrane to form the first chamber 43 and the second chamber 44, but the first treatment container may be partitioned into upper and lower parts by an osmosis membrane to form the first chamber 43 and the second chamber 44.
- [0079] In the concentration system 300 illustrated in Fig. 4, the concentrated water to be treated A (for example, stock solution) in the first chamber 43 of the osmotic pressure generator 31 is delivered to the outside through the pipeline 201b, but the pipeline 201b may be connected to the tank of water to be treated 45 to form a loop by the tank of water to be treated 45, the pipeline 201a, the first chamber 43 of the osmotic pressure generator 31, and the pipeline 201b in the case of obtaining a stock solution concentrated to a higher concentration. In this case, it is desirable to determine the concentration degree of the stock solution in consideration of the osmotic pressure difference generated between the concentrated stock solution and the concentrated working medium B in the osmotic pressure generator 31.
- [0080] In the concentration system 300 illustrated in Fig. 4, the dehydration membrane 52 of

the membrane distillation and separation device 33 is not limited to a porous latex membrane, and any membrane may be used as long as it has the function of permeating vapor.

[0081] In the concentration system 300 illustrated in Fig. 4, the concentration of the diluted working medium B is not only performed by the membrane distillation and separation device 33 equipped with the dehydration membrane 52 but also may be performed by using any device as long as it can remove water from the diluted working medium B.

[0082] (Fourth Embodiment)

Next, a circulating osmotic power generation system 400 which is one example of a water treatment system according to the fourth embodiment will be described with reference to the schematic diagram illustrated in Fig. 5. Incidentally, in Fig. 5, the same members as those in Fig. 4 are denoted by the same reference numerals, and the description thereon is omitted. The working medium to be used in the fourth embodiment is the working medium B of the first embodiment or the second embodiment.

[0083] The water treatment system according to the fifth embodiment is a circulating osmotic power generation system. The circulating osmotic power generation system 400 is equipped with an osmotic pressure generator 31 for generating a water flow and a body of rotation 82 for generating electricity by the water flow generated by the osmotic pressure generator 31.

[0084] The circulating osmotic power generation system 400 is equipped with the first chamber 43 for accommodating water, the second chamber 44 for accommodating the working medium B (draw solution) which induces osmotic pressure, the osmosis membrane 42 for partitioning the first chamber and the second chamber, a pressure exchanger 81 connected to the second chamber 44, and the body of rotation 82 connected to the pressure exchanger 81. According to such a water treatment system, by the osmotic pressure difference generated between the water in the first chamber 43 and the working medium B in the second chamber 44, the water in the first chamber 43 permeates through the osmosis membrane 42 and moves to the working medium B in the second chamber 44. The body of rotation 82 is rotated by the water flow accompanying the movement of water to the working medium B to generate electricity.

[0085] In the fifth embodiment, the working medium B is an aqueous solution containing the solute of the embodiment and exhibits a high osmotic pressure inducing action. Hence, it is possible to generate a high permeate flux when the water in the first chamber 43 permeates through the osmosis membrane 42 and moves to the working medium B in the second chamber 44. As a result, the working medium B containing water thus moved forms a water flow having a high pressure, and it is thus possible to rotate the body of rotation 82 at a higher speed to generate electricity. Consequently, it is possible to provide a water treatment system which can be operated at low cost and

can efficiently rotate the body of rotation 82 to generate electricity.

[0086] As the body of rotation 82, for example, a turbine or a water wheel can be used.

[0087] In the circulating osmotic power generation system 400, the pressure exchanger 81 and the body of rotation 82 are provided to the pipeline 201b connected to the lower part (the exit side of the working medium B) of the first treatment container 41 in which the second chamber 44 of the osmotic pressure generator 31 is located along the flow direction of the working medium B in this order. In addition, in the pipeline 201c which connects the concentrated working medium tank 34 with the upper part of the first treatment container 41 in which the second chamber 44 is located, the portion of the pipeline 201c on the downstream side in the flowing direction of the working medium B of the second pump 47 is connected to the upper part of the first treatment container 41 in which the second chamber 44 is located via the pressure exchanger 81. In other words, in the osmotic pressure generator 31, the diluted working medium B having a flux generated when water has moved from the first chamber 43 to the second chamber 44 through the osmosis membrane 42 is allowed to flow out from the lower part of the first treatment container 41 in which the second chamber 44 is located through the pipeline 201b provided with the pressure exchanger 81. During this time, the pipeline 201c through which the concentrated working medium B flowed out from the concentrated working medium tank 34 flows passes through the pressure exchanger 81. Hence, the pressure of the diluted working medium B is lowered and the pressure of the concentrated working medium B is raised by pressure exchange between the concentrated working medium B and the diluted working medium B flowed out from the second chamber 44 in the pressure exchanger 81.

[0088] Incidentally, in the circulating osmotic power generation system 400, water is accommodated in the tank of water to be treated 45.

[0089] Next, the operation of power generation by the circulating osmotic power generation system 400 illustrated in Fig. 5 will be described. The first pump 46 is driven to supply water from the tank of water to be treated 45 into the first chamber 43 of the osmotic pressure generator 31 through the pipeline 201a. Before and after the supply of water, the second pump 47 is driven to supply the concentrated working medium B from the concentrated working medium tank 34 into the second chamber 44 of the osmotic pressure generator 31 through the pipeline 201c. The concentrated working medium B supplied to the second chamber 44 has a sufficiently higher concentration compared to the water only of the solvent supplied to the first chamber 43. Hence, the osmotic pressure difference is generated between the water in the first chamber 43 and the concentrated working medium B in the second chamber 44, and the water permeates through the osmosis membrane 42 and moves into the second chamber 44. At this time, the working medium B in the second chamber 44 is an aqueous solution

containing the solute of the embodiment and exhibits a high osmotic pressure inducing action. Hence, a high permeate flux is generated when water in the first chamber 43 permeates through the osmosis membrane 42 and moves to the working medium B in the second chamber 44. As a result, a large amount of water in the first chamber 43 can move to the concentrated working medium B in the second chamber 44 and a diluted working medium B which has a high pressure and is diluted with water is produced. Incidentally, the water in the first chamber 43 is discharged through the pipeline 201b.

[0090] The diluted working medium B having a high pressure in the second chamber 44 is delivered to the diluted working medium tank 32 through the pipeline 201d and stored therein. The pressure exchanger 81 and the body of rotation 82 are provided to the pipeline 201d along the flow direction of the working medium B in this order.

[0091] Hence, the pressure of the diluted working medium B is lowered and the pressure of the concentrated working medium B is raised by pressure exchange between the concentrated working medium B which flows from the concentrated working medium tank 34 through the pipeline 201c and the diluted working medium B which has a high pressure and flows from the second chamber 44 (through the body of rotation 82) through the pipeline 201d in the pressure exchanger 81 as described above. The diluted working medium B having an appropriate pressure by pressure exchange flows to the body of rotation 82 and efficiently rotates it to generate electricity. In addition, the concentrated working medium B having an appropriate pressure by pressure exchange is supplied to the second chamber 44.

[0092] The diluted working medium B stored in the diluted working medium tank 32 is concentrated by the diluted working medium circulation system including the third chamber 53 of the membrane distillation and separation device 33 and the pure water circulation and cooling system including the fourth chamber 54 of the membrane distillation and separation device 33 in the same manner as the concentration system 300 illustrated in Fig. 4 described above. In other words, the diluted working medium B is stored in the circulation tank 64 as a working medium B (concentrated working medium B) at a concentration capable of being used as the concentrated working medium B by repeatedly performing the dehydration treatment including the evaporation of water in the diluted working medium B in the third chamber 53, the permeation of the vapor through the dehydration membrane 52, the movement of the vapor to the fourth chamber 54, and the cooling and condensation of the vapor with the circulating pure water on the fourth chamber 54 side plural times, and the concentrated working medium B is returned to the concentrated working medium tank 34. The concentrated working medium B in the concentrated working medium tank 34 is supplied into the second chamber 44 of the osmotic pressure generator 31 by driving the second pump 47 in order to rotate the body of rotation 82 and thus to generate electricity as

described above.

- [0093] Consequently, it is possible to continuously perform the operation of power generation by the rotation of the body of rotation 82 using the osmotic pressure generator 31 and the concentration of the diluted working medium B using the membrane distillation and separation device 33. Hence, it is possible to provide the circulating osmotic power generation system 400 which can be operated at low cost and can efficiently rotate the body of rotation 82 such as a turbine to generate electricity.
- [0094] Incidentally, in the circulating osmotic power generation system 400 illustrated in Fig. 5, the first treatment container of the osmotic pressure generator is partitioned in the horizontal direction by an osmosis membrane to form the first chamber 43 and the second chamber 44, but the first treatment container may be partitioned into upper and lower parts by an osmosis membrane to form the first chamber 43 and the second chamber 44.
- [0095] In the circulating osmotic power generation system 400 illustrated in Fig. 5, the water in the first chamber 43 of the osmotic pressure generator 31 is delivered to the outside through the pipeline 201b, but the pipeline 201b may be connected to the tank of water to be treated 45 to form a loop by the tank of water to be treated 45, the pipeline 201a, the first chamber 43 of the osmotic pressure generator 31, and the pipeline 201b.
- [0096] In the circulating osmotic power generation system 400 illustrated in Fig. 5, the dehydration membrane 52 of the membrane distillation and separation device 33 is not limited to a porous latex membrane, and any membrane may be used as long as it has the function of permeating vapor.
- [0097] In the circulating osmotic power generation system 400 illustrated in Fig. 5, the concentration of the diluted working medium B is not only performed by using the membrane distillation and separation device 33 equipped with the dehydration membrane 52 but also may be performed by using any device as long as it can remove water from the diluted working medium B.
- [0098] Hereinafter, Examples will be described.
- [0099] A forward osmosis test was performed as follows. The CTA-ES membrane manufactured by HTI Corporation was set in a FO cell, pure water was placed on the active face side of the membrane as water to be treated, and the working medium was then placed on the support layer side. The time when the working medium was completely placed was counted as 0 minute, and this state was left to stand for 20 minutes. After the test, the weight of the liquid on the active face side was measured, and the permeate flux (Jw) was calculated from the difference before and after the test by taking the specific gravity of the liquid as 1. In addition, the total organic carbon concentration in the liquid on the active face side after the test was measured by using a

total organic carbon meter and the cation concentration was measured by ion chromatography to calculate the loss of solute (Js). The solute contained in the working medium and the concentration thereof and the experimental results are presented in Table 1.

[0100] [Table 1]

	Solute		Compound	Concentration of compound mol/L	Js	Jw	Js/Jw
	Inorganic salt	Concentration of inorganic salt mol/L			mmol/m ² h	L/m ² h	mmol/L
Comparative Example 1	—	—	DTPA	0.4	1.6	11.5	0.14
Comparative Example 2	—	—	DTPA	0.6	4.9	12.5	0.39
Comparative Example 3	—	—	DTPA	1.1	16.6	17.2	0.97
Comparative Example 4	MgCl ₂	0.4	—	—	7.1	6.1	1.15
Comparative Example 5	MgCl ₂	1.0	—	—	8.7	9.7	0.90
Comparative Example 6	MgCl ₂	2.0	—	—	12.3	15.6	0.79
Comparative Example 7	MgCl ₂	2.3	—	—	14.9	14.9	1.00
Comparative Example 8	MgCl ₂	3.7	—	—	23.3	19.2	1.22
Comparative Example 9	MgSO ₄	2.5	—	—	2.5	6.7	0.37
Comparative Example 10	NH ₄ SO ₄	2.5	—	—	13.0	14.0	0.93
Example 1	MgCl ₂	0.4	DTPA	0.4	1.7	11.0	0.15
Example 2	MgCl ₂	1.0	DTPA	0.4	1.5	13.3	0.11
Example 3	MgCl ₂	2.3	DTPA	0.4	5.5	20.7	0.27
Example 4	MgCl ₂	0.4	DTPA	0.6	1.7	13.5	0.13
Example 5	MgCl ₂	1.0	DTPA	0.6	1.9	14.0	0.14
Example 6	MgCl ₂	2.3	DTPA	0.6	0.8	17.0	0.04
Example 7	MgCl ₂	2.0	DTPA	0.5	4.0	15.6	0.26
Example 8	MgCl ₂	3.7	Arginine	0.1	6.5	17.0	0.38
Example 9	MgCl ₂	3.7	Arginine	0.1	5.7	17.4	0.33
Example 10	MgCl ₂	3.7	Arginine	0.3	15.4	15.1	1.02
Example 11	MgCl ₂	3.7	Arginine	0.4	12.2	13.4	0.91
Example 12	MgCl ₂	1.8	DTPMP	0.2	8.5	19.2	0.44
Example 13	MgSO ₄	2.5	DTPA	0.5	1.7	7.3	0.23
Example 14	NH ₄ SO ₄	2.5	DTPA	0.5	8.5	13.2	0.64

DTPA: diethylenetriaminepentaacetic acid 5Na salt

DTPMP: diethylenetriaminepenta(methylenephosphonic acid) 7Na salt

[0101] As is apparent from Table 1, in Examples 1 to 7 in which a compound containing plural phosphonic acid groups is used as a draw solution, the loss of solute of an inorganic salt to be generally used is significantly minor. In addition, Comparative Examples in which a sodium salt having a carboxylic acid group is used as a solute is inferior to Examples in Js/Jw. It is possible to cut down the running cost of the water treatment system utilizing the osmotic pressure by using a working medium having such properties. In addition, it is possible to generate electricity at low cost by using the water flow generated by the osmotic pressure inducing action of these to generate electricity.

Here, some elements are expressed only by element symbols thereof.

- [0102] While certain embodiments have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of the inventions. Indeed, the novel embodiments described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions and changes in the form of the embodiments described herein may be made without departing from the spirit of the inventions. The accompanying claims and their equivalents are intended to cover such forms or modifications as would fall within the scope and spirit of the inventions.

Reference Signs List

- [0103] A Water to be treated,
 B Working medium,
 C Water
 1, 31 Osmotic pressure generator,
 2, 32 Diluted working medium tank,
 3 Reverse osmosis membrane separator,
 4, 34 Concentrated working medium tank,
 11, 41 First treatment container,
 12, 42 Osmosis membrane,
 13, 43 First chamber,
 14, 44 Second chamber,
 15, 45 Tank of water to be treated,
 16 First pump,
 17 Second pump,
 21, 51 Second treatment container,
 22 Reverse osmosis membrane (RO membrane),
 23, 53 Third chamber,
 24, 54 Fourth chamber,
 25 Third pump,
 26 Pure water tank,
 27 On-off valve,
 33 Membrane distillation and separation device,
 52 Dehydration membrane,
 61 First on-off valve,
 62 Heat exchanger,
 64 Circulation tank,
 65 Second on-off valve,

66 Fourth pump,
71 First pure water tank,
72 Second pure water tank,
73 Third on-off valve,
74 Fifth pump,
75 Fourth on-off valve,
81 Pressure exchanger,
82 Body of rotation,
100 Water treatment system,
101 Pipeline,
200 Desalination system,
201 Pipeline,
300 Concentration system, and
400 Circulating osmotic power generation system

Claims

[Claim 1]

A water treatment system comprising:

a first treatment container having an osmosis membrane to partition a first chamber for accommodating water to be treated and a second chamber for accommodating a working medium to induce osmotic pressure, wherein

the working medium is an aqueous solution containing a compound having a metal salt structure of a carboxylic acid group in a main chain, a side chain, or a main chain and a side chain, a compound having a metal salt structure of a phosphonic acid group in a main chain, a side chain, or a main chain and a side chain, or a compound having a metal salt structure of a carboxylic acid group in a main chain, a side chain, or a main chain and a side chain and a metal salt structure of a phosphonic acid group in a main chain, a side chain, or a main chain and a side chain and an inorganic salt as a solute.

[Claim 2]

The system according to claim 1, wherein a concentration of the compound having a metal salt structure of a carboxylic acid group in a main chain, a side chain, or a main chain and a side chain, the compound having a metal salt structure of a phosphonic acid group in a main chain, a side chain, or a main chain and a side chain, or the compound having a metal salt structure of a carboxylic acid group in a main chain, a side chain, or a main chain and a side chain and a metal salt structure of a phosphonic acid group in a main chain, a side chain, or a main chain and a side chain in the working medium is 0.05 mol/L or more and 1.0 mol/L or less.

[Claim 3]

The system according to claim 1 or 2, wherein the compound having a metal salt structure of a carboxylic acid group in a main chain, a side chain, or a main chain and a side chain, the compound having a metal salt structure of a phosphonic acid group in a main chain, a side chain, or a main chain and a side chain, or the compound having a metal salt structure of a carboxylic acid group in a main chain, a side chain, or a main chain and a side chain and a metal salt structure of a phosphonic acid group in a main chain, a side chain, or a main chain and a side chain is expressed by $C_xH_yP_zO_wN_sM_t$, wherein

M is an alkali metal and x, y, z, w, s, and t satisfy $2 \leq x$ (being less than or equal to) $x \leq 20$, $8 \leq y$ (being less than or equal to) $y \leq 30$, $1 \leq z$ (being less than or

equal to) $z \leq$ (being less than or equal to) 6, $3 \leq$ (being less than or equal to) $w \leq$ (being less than or equal to) 18, $0 \leq$ (being less than or equal to) $s \leq$ (being less than or equal to) 3, and $2 \leq$ (being less than or equal to) $t \leq$ (being less than or equal to) 10.

[Claim 4]

The system according to any one of claims 1 to 3, wherein the compound having a metal salt structure of a carboxylic acid group in a main chain, a side chain, or a main chain and a side chain, the compound having a metal salt structure of a phosphonic acid group in a main chain, a side chain, or a main chain and a side chain, or the compound having a metal salt structure of a carboxylic acid group in a main chain, a side chain, or a main chain and a side chain and a metal salt structure of a phosphonic acid group in a main chain, a side chain, or a main chain and a side chain is a compound in which a carboxylic acid group, a phosphonic acid group, or a carboxylic acid group and a phosphonic acid group of a compound having a structure expressed by Formula (1), (2), (3), (4), or (5) have a metal salt structure, wherein R^{11} to R^{13} in Formula (1) are an alkyl chain of $C_{n1}H_{2n1}$ ($n1$ is any integer from 0 to 2), X^{11} to X^{13} are each any one selected from the group consisting of $-COOH$, $-P(OH)_2$, and OH , and at least two X in one molecule are $-COOH$ or $-P(OH)_2$,

R^{21} to R^{27} in Formula (2) are an alkyl chain of $C_{n2}H_{2n2}$ ($n2$ is any integer from 0 to 2), X^{21} to X^{27} are each any one selected from the group consisting of H , $-COOH$, $-P(OH)_2$, and OH , at least two X in one molecule are $-COOH$ or $-P(OH)_2$, and at least three X in one molecule are a functional group other than H ,

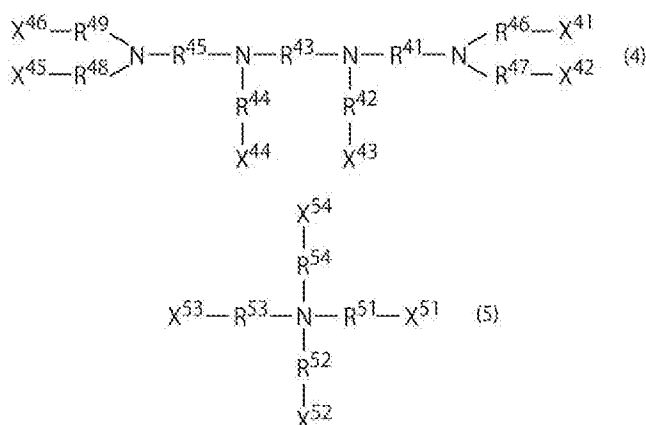
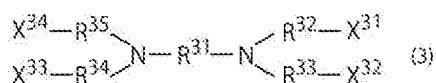
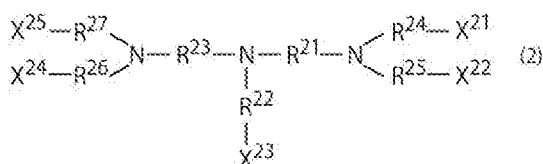
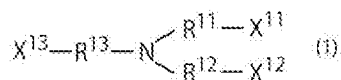
R^{31} to R^{35} in Formula (3) are an alkyl chain of $C_{n3}H_{2n3}$ ($n3$ is any integer from 0 to 3), R^{32} to R^{35} in Formula (3) optionally contain a carboxylic acid group, X^{31} to X^{34} in Formula (3) are each any one selected from the group consisting of H , $-COOH$, $-P(OH)_2$, and OH , at least two X in one molecule are $-COOH$ or $-P(OH)_2$, and at least three X in one molecule are a functional group other than H ,

R^{41} to R^{49} in Formula (4) are an alkyl chain of $C_{n4}H_{2n4}$ ($n4$ is any integer from 0 to 2), X^{41} to X^{46} in Formula (4) are each any one selected from the group consisting of H , $-COOH$, $-P(OH)_2$, and OH , at least two X in one molecule are $-COOH$ or $-P(OH)_2$, and at least three X in one molecule are a functional group other than H ,

R^{51} to R^{54} in Formula (5) are an alkyl chain of $C_{n5}H_{2n5}$ ($n5$ is any integer from 0 to 2), X^{51} to X^{54} in Formula (5) are each any one selected from

the group consisting of H, -COOH, -P(OH)₂, and OH, at least two X in one molecule are -COOH or -P(OH)₂, and at least three X in one molecule are a functional group other than H:

[Chem.1]

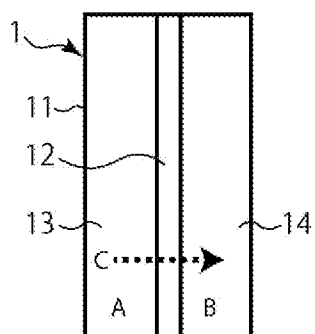


[Claim 5]

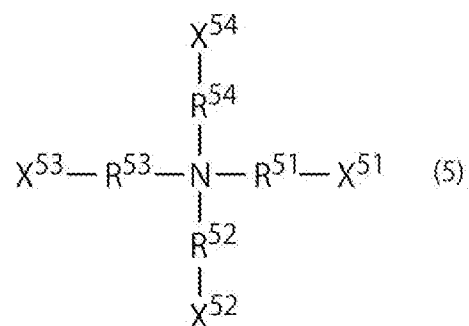
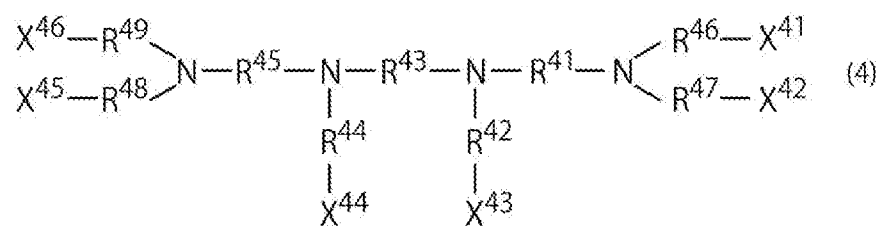
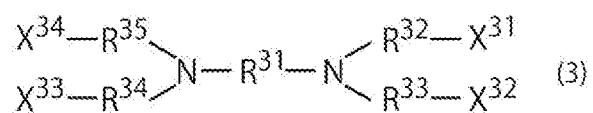
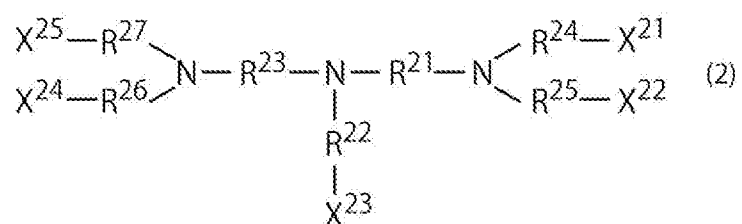
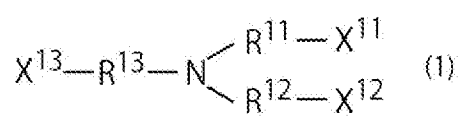
The system according to any one of claims 1 to 4, wherein the compound having a metal salt structure of a carboxylic acid group in a main chain, a side chain, or a main chain and a side chain, the compound having a metal salt structure of a phosphonic acid group in a main chain, a side chain, or a main chain and a side chain, or the compound having a metal salt structure of a carboxylic acid group in a main chain, a side chain, or a main chain and a side chain and a metal salt structure of a phosphonic acid group in a main chain, a side chain, or a main chain and a side chain is at least one kinds selected from the group consisting of nitrilotriacetic acid 2Na salt, N-(2-hydroxyethyl)iminodiacetic acid 2Na salt, nitrilotris(methylenephosphonic acid) 5Na salt, diethylenetriaminepentaacetic acid 3Na salt, diethylenetriaminepentaacetic acid 5Na salt, diethylenetriaminepenta(methylenephosphonic acid) 7Na salt, N-

(2-hydroxyethyl)ethylenediamine-N,N',N'-triacetic acid 3Na salt, 1,3-propanediaminetetraacetic acid 4Na salt, 1,3-diamino-2-propanol-N,N,N',N'-tetraacetic acid 2Na salt, glycol ether diaminetetraacetic acid 4Na salt, ethylenediaminedisuccinic acid 3Na salt, ethylenediaminetetramethylenephosphonic acid 5Na salt, and 3-carboxy-3-phosphonohexanedioic acid 5Na salt.

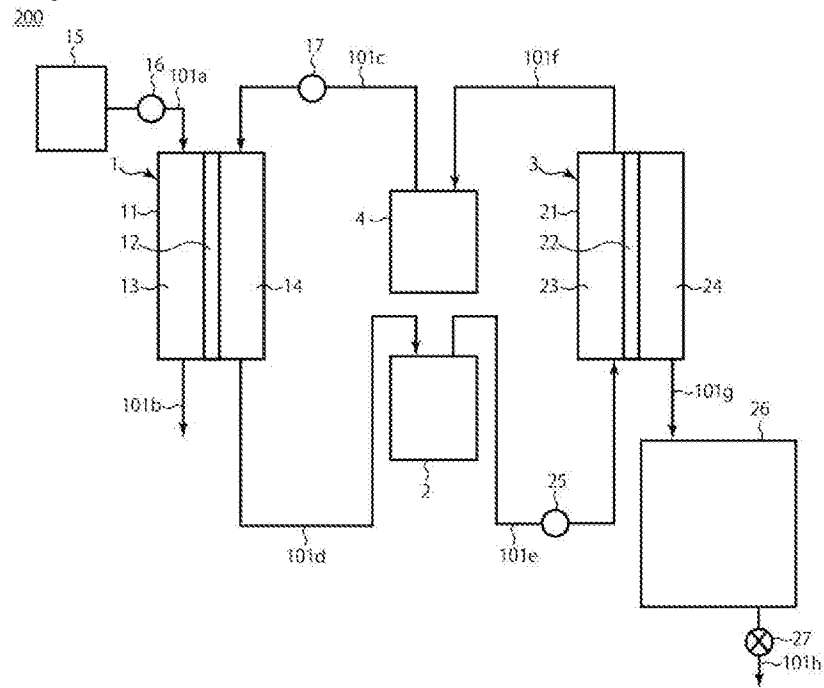
- [Claim 6] The system according to any one of claims 1 to 5, wherein a total number of a carboxylic acid group and a phosphonic acid group contained in the compound having a metal salt structure of a carboxylic acid group in a main chain, a side chain, or a main chain and a side chain, the compound having a metal salt structure of a phosphonic acid group in a main chain, a side chain, or a main chain and a side chain, or the compound having a metal salt structure of a carboxylic acid group in a main chain, a side chain, or a main chain and a side chain and a metal salt structure of a phosphonic acid group in a main chain, a side chain, or a main chain and a side chain is 5 or more.
- [Claim 7] The system according to claim 1 or 3, wherein the compound having a metal salt structure of a carboxylic acid group in a main chain, a side chain, or a main chain and a side chain is an amino acid.
- [Claim 8] The system according to any one of claims 1 to 3 and 7, wherein the compound having a metal salt structure of a carboxylic acid group in a main chain, a side chain, or a main chain and a side chain is arginine.
- [Claim 9] The system according to any one of claims 1 to 8, further comprising a body of rotation, wherein
a water flow is generated by the induction of osmotic pressure, and the body of rotation is rotated by the water flow to generate electricity.
- [Claim 10] A working medium to be used in the water treatment system according to any one of claims 1 to 9.
- [Claim 11] A working medium of an aqueous solution containing a compound having a metal salt structure of a carboxylic acid group in a main chain, a side chain, or a main chain and a side chain, a compound having a metal salt structure of a phosphonic acid group in a main chain, a side chain, or a main chain and a side chain, or a compound having a metal salt structure of a carboxylic acid group in a main chain, a side chain, or a main chain and a side chain and a metal salt structure of a phosphonic acid group in a main chain, a side chain, or a main chain and a side chain and an inorganic salt as a solute.

[Fig. 1]
100

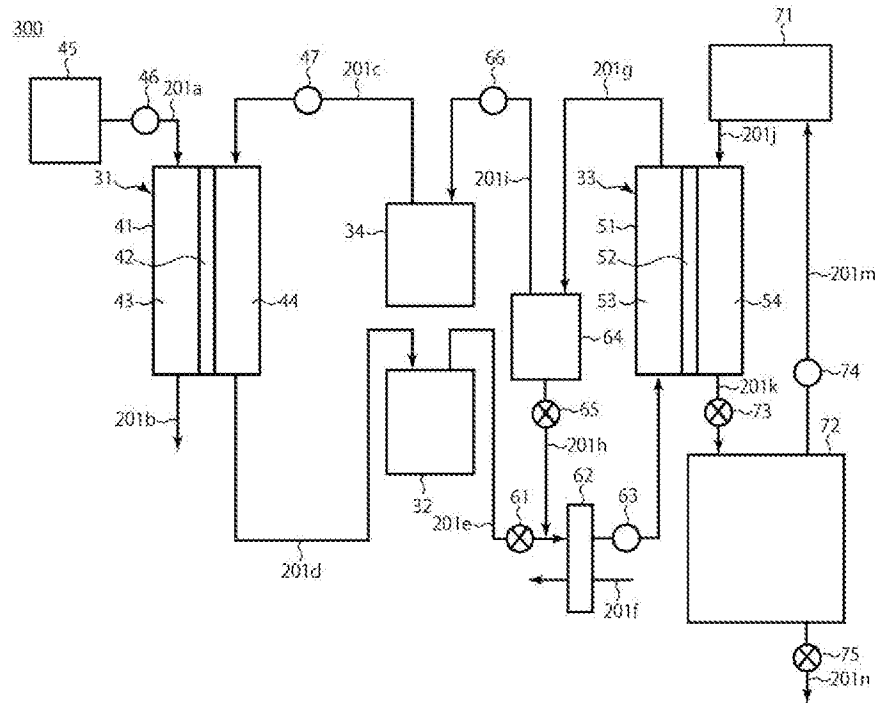
[Fig. 2]



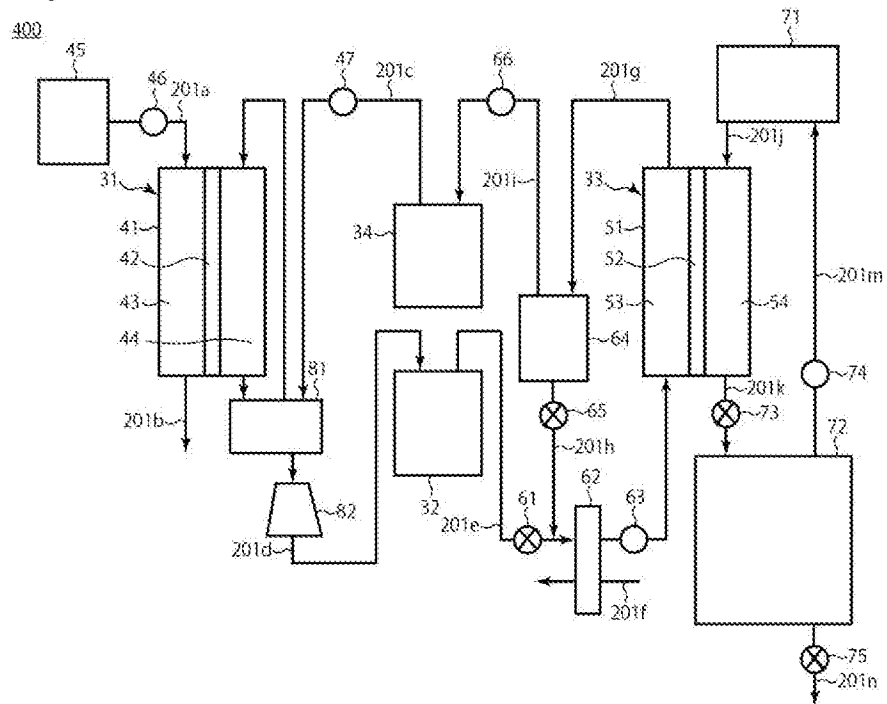
[Fig. 3]



[Fig. 4]



[Fig. 5]



INTERNATIONAL SEARCH REPORT

International application No
PCT/JP2017/033661

A. CLASSIFICATION OF SUBJECT MATTER
INV. B01D61/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B01D F03G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2002 238598 A (ASAHI KASEI CORP) 27 August 2002 (2002-08-27) paragraph [0020] -----	10,11
X	WO 2008/050087 A1 (SURREY AQUATECHNOLOGY LTD [GB]; SHARIF ADEL [GB]) 2 May 2008 (2008-05-02) page 27; figure 1 -----	1-6,9-11
X	CN 105 597 540 A (UNIV HUAZHONG SCIENCE TECH) 25 May 2016 (2016-05-25) abstract paragraphs [0047], [0076] -----	1-6,9-11
X	US 9 221 018 B1 (HARRIS JAMES M [US]) 29 December 2015 (2015-12-29) column 3, lines 54-63 ----- -/-	1-4,9-11



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

14 March 2018

Date of mailing of the international search report

27/03/2018

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
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Fax: (+31-70) 340-3016

Authorized officer

Hennebrüder, K

INTERNATIONAL SEARCH REPORT

International application No

PCT/JP2017/033661

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	LAW JENG YIH ET AL: "Multiple-solute salts as draw solution for osmotic concentration of succinate feed by forward osmosis", JOURNAL OF INDUSTRIAL AND ENGINEERING CHEMISTRY, vol. 51, 12 March 2017 (2017-03-12), pages 264-270, XP029991065, ISSN: 1226-086X, DOI: 10.1016/J.JIEC.2017.03.011 abstract table 1	1-4,9-11
X	----- US 2013/220581 A1 (HERRON JOHN R [US] ET AL) 29 August 2013 (2013-08-29) paragraph [0029] the whole document	1-4,7-11
X	----- WO 2013/036111 A1 (KWR WATER B V [NL]; CORNELISSEN EMILE ROBIN [NL]; VAN LIER JULIUS BERN) 14 March 2013 (2013-03-14) page 17, lines 4-6; figure 5 page 7, paragraph 1 the whole document	1-4,7-11
X	----- US 2013/256228 A1 (BHARWADA UPEN J [US] ET AL) 3 October 2013 (2013-10-03) paragraphs [0018] - [0029] -----	1-4,7-11

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2017/033661

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☒ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 5(completely); 1-4, 6, 9-11(partially)

A drawing solution for forward osmosis/pressure retarded osmosis comprising a carboxylate/phosphonate and optionally an inorganic salt
wherein the carboxylate/phosphonate is selected from specific carboxylates, i.e. ones having multiple acid groups (chelating agents)

2. claims: 7, 8(completely); 1-4, 6, 9-11(partially)

A drawing solution for forward osmosis/pressure retarded osmosis comprising a carboxylate/phosphonate and optionally an inorganic salt
wherein the carboxylate/phosphonate is an amino acid

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/JP2017/033661

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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WO 2008050087 A1	02-05-2008	AR 063364 A1 AT 475473 T AU 2007310694 A1 CL 2007003077 A1 CY 1110855 T1 EP 2089142 A1 ES 2347608 T3 IL 198367 A JO 2697 B US 2010206743 A1 WO 2008050087 A1 ZA 200902815 B	21-01-2009 15-08-2010 02-05-2008 18-04-2008 04-11-2015 19-08-2009 02-11-2010 30-04-2012 03-03-2013 19-08-2010 02-05-2008 28-07-2010
CN 105597540 A	25-05-2016	NONE	
US 9221018 B1	29-12-2015	NONE	
US 2013220581 A1	29-08-2013	US 2013220581 A1 WO 2013126895 A1	29-08-2013 29-08-2013
WO 2013036111 A1	14-03-2013	NL 2007353 C WO 2013036111 A1	07-03-2013 14-03-2013
US 2013256228 A1	03-10-2013	US 2013256228 A1 WO 2013148289 A1	03-10-2013 03-10-2013