CLAIMS

[Claim 1]

A method for recovering a rare metal salt, the method comprising:

an acid treatment step of obtaining a rare metal-containing acidic aqueous solution by bringing a material comprising a monovalent rare metal and a polyvalent rare metal into contact with an acidic aqueous solution;

a separation step of obtaining permeated water comprising the monovalent rare metal and non-permeated water comprising the polyvalent rare metal from the rare metal-containing acidic aqueous solution by using a nanofiltration membrane satisfying the condition (1) below; and

a concentration step of obtaining non-permeated water having a higher concentration of the monovalent rare metal and permeated water having a lower concentration of the monovalent rare metal than that of the permeated water in the separation step, by using a reverse osmosis membrane,

condition (1):

a difference between a removal ratio of magnesium sulfate and a removal ratio of magnesium chloride is 20% or less when a 2000 mg/L magnesium sulfate aqueous solution and a 2000 mg/L magnesium chloride aqueous solution, each having a pH of 6.5 and a temperature of 25°C, are respectively allowed to pass through the nanofiltration membrane under an operating pressure of 0.5 MPa; and

a difference between a removal ratio of glucose and a removal ratio of isopropyl alcohol is 40% or more and the removal ratio of glucose is 70% or more when a 1000 mg/L glucose aqueous solution and a 1000 mg/L isopropyl alcohol aqueous solution, each having a pH of 6.5 and a temperature of 25°C are respectively allowed to pass through the nanofiltration membrane under an operating pressure of 0.5 MPa.

[Claim 2]

The method for recovering a rare metal salt according to claim 1, wherein raw water in the separation step comprises lithium as the monovalent rare metal, and a lithium ion concentration in the raw water is in a range of 0.5 mg/L or more and 50000 mg/L or less.

[Claim 3]

The method for recovering a rare metal salt according to claim 1 or 2, wherein a total ion concentration of the polyvalent rare metal in the raw water in the separation step is in a range of 0.5 mg/L or more and 100000 mg/L or less.

[Claim 4]

The method for recovering a rare metal salt according to any one of claims 1 to 3, wherein the raw water in the separation step comprises at least one metal of cobalt, nickel, and manganese as the polyvalent rare metal.

[Claim 5]

The method for recovering a rare metal salt according to any one of claims 1 to 4, wherein the separation step comprises at least a first separation step of obtaining permeated water and non-permeated water by a nanofiltration membrane and a 2a-th separation step of obtaining permeated water and non-permeated water by further treating the permeated water obtained in the first separation step by a nanofiltration membrane.

[Claim 6]

The method for recovering a rare metal salt according to any one of claims 1 to 5, wherein the separation step comprises at least the first separation step of obtaining permeated water and non-permeated water by a nanofiltration membrane and a 2b-th separation step of obtaining permeated water and non-permeated water by further treating the non-permeated water obtained in the first separation step by a nanofiltration membrane.

[Claim 7]

The method for recovering a rare metal salt according to any one of claims 1 to 6, wherein permeated water having a lithium ion concentration (mg/L) of 1000 times or more as high as a polyvalent metal ion concentration (mg/L) is obtained in the separation step.

[Claim 8]

The method for recovering a rare metal salt according to any one of claims 1 to 7, wherein an operating pressure in the separation step is equal to or lower than an osmotic pressure of the raw water supplied to the nanofiltration membrane.

[Claim 9]

The method for recovering a rare metal salt according to any one of claims 1 to 8, further comprising, between the acid treatment step and the separation step, a pretreatment step of treating the rare metal-containing acidic aqueous solution with a microfiltration membrane having an average surface pore diameter of 0.05 μm to 10 μm.

[Claim 10]

The method for recovering a rare metal salt according to any one of claims 1 to 8, further comprising, between the acid treatment step and the separation step, a pretreatment step of treating the rare metal-containing acidic aqueous solution with an ultrafiltration membrane having an average surface pore diameter of 3 nm to 16 nm.

[Claim 11]

The method for recovering a rare metal salt according to claim 9 or 10, wherein in the pretreatment step, a temperature of the rare metal-containing acidic aqueous solution to be treated is 0°C to 100°C.

[Claim 12]

The method for recovering a rare metal salt according to any one of claims 1 to 11, wherein

the concentration step comprises a concentration step of obtaining non-permeated water having a higher concentration of the monovalent rare metal than that of the permeated water in the separation step and permeated water having a lower concentration of the monovalent rare metal than that of the permeated water in the separation step, by using a reverse osmosis membrane satisfying the following condition (2),

condition (2):

a removal ratio of isopropyl alcohol is 95% or more and a removal ratio of boron ions is 75% or more when the reverse osmosis membrane is immersed in a sulfuric acid aqueous solution having a pH of 1 and a temperature of 25°C for 24 hours, and then an aqueous solution having a pH of 6.5 and a temperature of 25°C and comprising 30 mg/L boric acid, 100 mg/L isopropyl alcohol, and 30000 mg/L lithium chloride is allowed to pass through the reverse osmosis membrane under an operating pressure of 5.5 MPa.

[Claim 13]

The method for recovering a rare metal salt according to any one of claims 1 to 12, wherein the concentration step comprises at least first and second concentration steps which use the reverse osmosis membrane, and non-permeated water obtained in the first concentration step is treated in the second concentration step.

[Claim 14]

The method for recovering a rare metal salt according to any one of claims 1 to 13, further comprising a mixing step of mixing the permeated water produced in the concentration step with the rare metal-containing acidic aqueous solution obtained in the acid treatment step,

wherein, in the separation step, the permeated water and the non-permeated water are obtained from a mixed water obtained in the mixing step.

[Claim 15]

The method for recovering a rare metal salt according to any one of claims 1 to 14, wherein a nanofiltration membrane having a positive value of surface zeta potential at pH 3 is used as the nanofiltration membrane.

[Claim 16]

The method for recovering a rare metal salt according to any one of claims 1 to 15, wherein

the nanofiltration membrane comprises a base material, a porous support layer on the base material, and a separation function layer on the porous support layer,

the separation function layer comprises a crosslinked polyamide, and

a total proportion of halogen in elements measured in X-ray photoelectron spectroscopy measurement of a surface on a separation function layer side is less than 0.1%.

[Claim 17]

The method for recovering a rare metal salt according to any one of claims 1 to 16, wherein

the nanofiltration membrane comprises a base material, a porous support layer on

the base material, and a separation function layer on the porous support layer, and

there is only one peak having a maximum in a range of 1600 cm^{-1} to 1700 cm^{-1} when a surface on the separation function layer side is measured by a total reflection infrared absorption spectrum method, and when the peak is defined as a peak A, a peak intensity ratio (I_A/I_{1242}) measured after immersing the nanofiltration membrane in a 1 M sulfuric acid aqueous solution at 40°C for 21 days is 0.40 or more and 1.0 or less as compared with a peak intensity ratio (I_A/I_{1242}) measured before the immersion,

provided that I_A and I_{1242} are the following absorption peak values, respectively,

I_A: absorption peak value corresponding to the separation function layer present in the range of 1600 cm^{-1} to 1700 cm^{-1}

I_{1242}: absorption peak value corresponding to the porous support layer at 1242 cm^{-1}.

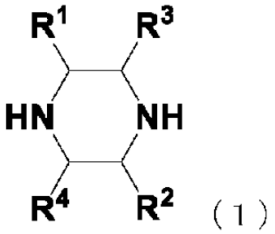
[Claim 18]

The method for recovering a rare metal salt according to any one of claims 1 to 17, wherein

the nanofiltration membrane comprises a base material, a porous support layer on the base material, and a separation function layer on the porous support layer, and

the separation functional layer comprises a crosslinked polyamide having a structure derived from a polyfunctional aliphatic amine represented by the following general formula (1),

[Chem. 1]



(1)

provided that R^1 and R^2 each independently means an alkyl group having 1 to 6 carbon atoms, a phenyl group, a benzyl group, $COOR^5$, $CONHR^5$, $CON(R^5)_2$, or OR^5, and R^5 means a hydrogen atom, an alkyl group having 1 to 6 carbon atoms, a phenyl group, or a benzyl group; and R^3 and R^4 each independently means hydrogen, an alkyl group having 1 to 6 carbon atoms, a phenyl group, a benzyl group, $COOR^6$, $CONHR^6$, $CON(R^6)_2$ or OR^6, and R^6 means a hydrogen atom, an alkyl group having 1 to 6 carbon atoms, a phenyl group or a benzyl group.

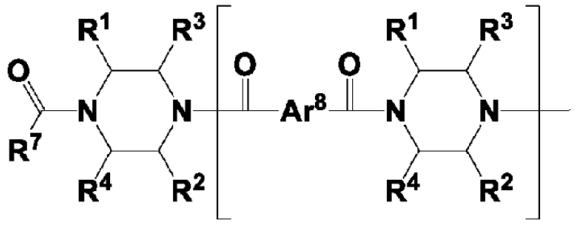
[Claim 19]

The method for recovering a rare metal salt according to any one of claims 1 to 18, wherein

the nanofiltration membrane comprises a base material, a porous support layer on the base material, and a separation function layer on the porous support layer, and

the separation function layer comprises a crosslinked aromatic polyamide, and the crosslinked aromatic polyamide has a structure represented by the following general formula (2),

[Chem. 2]



(2)

provided that R^1 to R^4 have the same meanings as R^1 to R^4 in the general formula (1), and R^7 is an aliphatic chain or an aliphatic ring comprising only a carbon atom and a hydrogen atom as a constituent element, and Ar^8 is an aromatic ring having 6 to 14 carbon atoms which may have a substituent.

[Claim 20]

The method for recovering a rare metal salt according to any one of claims 12 to 19, wherein a reverse osmosis membrane having a negative value of surface zeta potential at pH 3 is used as the reverse osmosis membrane used in the concentration step.

[Claim 21]

The method for recovering a rare metal salt according to any one of claims 12 to 20, wherein

the reverse osmosis membrane used in the concentration step comprises a base material, a porous support layer on the base material, and a separation function layer on the porous support layer, and

the separation function layer comprises a crosslinked aromatic polyamide.

[Claim 22]

The method for recovering a rare metal salt according to any one of claims 12 to 21, wherein

the reverse osmosis membrane used in the concentration step comprises a base material, a porous support layer on the base material, and a separation function layer on the porous support layer,

the separation function layer comprises a crosslinked aromatic polyamide, and

a total proportion of halogen in elements measured in X-ray photoelectron spectroscopy measurement of a surface on a separation function layer side is less than 0.1%.

[Claim 23]

The method for recovering a rare metal salt according to any one of claims 12 to 22, wherein

the reverse osmosis membrane used in the concentration step comprises a base material, a porous support layer on the base material, and a separation function layer on the porous support layer,

the separation function layer has a fold structure in which convex portions and concave portions are repeated, the convex portion and the concave portion being formed of a thin membrane of a crosslinked aromatic polyamide, and

a convex portion having a deformation amount of 2.5 nm or less when the convex portion is pressed in pure water with a force of 5 nN occupies 40% or more.

[Claim 24]

The method for recovering a rare metal salt according to any one of claims 12 to 23, wherein

the reverse osmosis membrane used in the concentration step comprises a base material, a porous support layer on the base material, and a separation function layer on the porous support layer,

the separation function layer has a fold structure in which convex portions and concave portions are repeated, the convex portion and the concave portion being formed of a thin membrane of a crosslinked aromatic polyamide, and

a reverse osmosis membrane in which, among the convex portions, a proportion of a convex portion having a deformation amount of 2.5 nm or less when the convex portion is

pressed in a sulfuric acid aqueous solution having a pH of 1 with a force of 5 nN is 0.50 times or more as large as a proportion of a convex portion having a deformation amount of 2.5 nm or less when the convex portion is pressed in pure water with a force of 5 nN is used.

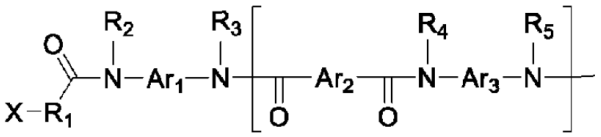
[Claim 25]

The method for recovering a rare metal salt according to any one of claims 12 to 24, wherein

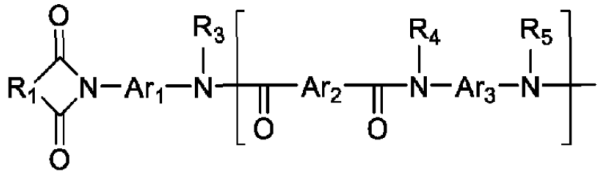
the reverse osmosis membrane used in the concentration step comprises a base material, a porous support layer on the base material, and a separation function layer on the porous support layer, and

the separation function layer comprises a crosslinked aromatic polyamide, and the crosslinked aromatic polyamide has at least one of structures represented by the following general formula (3) or (4),

[Chem. 3]



(3)



(4)

provided that Ar_1 to Ar_3 are each independently an aromatic ring having 5 to 14 carbon atoms which may have a substituent, R^1 is an atomic group having neither an aromatic ring nor a heteroatom, X is a hydrogen atom or a carboxy group, and R^2 to R^5 are each independently a hydrogen atom or an aliphatic chain having 1 to 10 carbon atoms.

[Claim 26]

The method for recovering a rare metal salt according to any one of claims 1 to 25, wherein, in the acid treatment step, the rare metal-containing acidic aqueous solution comprises a monovalent anion, and the acid treatment step comprises a step of, when a ratio of a molar concentration of the monovalent anion with respect to a molar concentration of a whole anion is less than 0.1, adding a monovalent ion to adjust the ratio to 0.1 or more.

[Claim 27]

The method for recovering a rare metal salt according to any one of claims 1 to 26, wherein the acid treatment step comprises a step of adjusting a pH of the rare metal-containing acidic aqueous solution to 0.5 or more and 7.0 or less.

[Claim 28]

The method for recovering a rare metal salt according to any one of claims 1 to 27, wherein the monovalent anion is a fluoride ion, a chloride ion, a bromide ion, an iodide ion, a nitrate ion, or an acetate ion.