Claims

1. A method of concentrating a solute-containing solution under a $\triangle\pi$ reduction condition in a feed output split counter-current (FOS-CC) manner using a zero osmotic pressure difference concentrator including a feed tank, a product tank, a multiple zero osmotic pressure difference chamber and an external reservoir (ER),

wherein the multiple zero osmotic pressure difference chamber comprises a feed chamber, an osmotic equalizer chamber (OE chamber), and an osmotic membrane disposed between the feed chamber and the osmotic equalizer chamber, and

a ratio of a velocity (OE-vel) of Q2 to a velocity (F-vel) of Q1 satisfies Equation 1 below;

Equation 1: F-vel/OE-vel=1/n

wherein Q1 is part of a concentrated solution that is output from the feed chamber of the multiple zero osmotic pressure difference chamber, and Q2 is another part of the concentrated solution that is output from the feed chamber and recycled to the osmotic equalizer chamber of the multiple zero osmotic pressure difference chamber, wherein the velocity of Q2 is higher than the velocity of Q1,

wherein n is a real number from 2 to 30,

a sum of Q1 and Q2 is equal to a total weight of the solution concentrated in the multiple zero osmotic pressure difference chamber,

wherein the method using the zero osmotic pressure difference concentrator comprises:

(i) transferring the solute-containing aqueous solution to the feed chamber of the zero osmotic pressure difference chamber, feeding a solution having the same osmotic pressure as the aqueous solution transferred to the feed chamber to the osmotic equalizer chamber to form a zero osmotic pressure state between the feed chamber and

the osmotic equalizer chamber; and

(ii) transferring water from the aqueous solution to the osmotic equalizer chamber by applying a pressure of 10 to 100 atm to the feed chamber through the reverse osmosis membrane in the zero osmotic pressure state to concentrate the aqueous solution, and

wherein the exterior reservoir stores the osmotic equalizer chamber's solution output in order to recycle the solution output to the feed tank.

2. The method according to claim 1, wherein the zero osmotic pressure difference concentrator further comprises a reverse osmosis chamber that functions to recover the concentrated solution or the solute.

3. The method according to claim 1, wherein a ratio of the volume of the osmotic equalizer chamber (Voe) to the volume of the feed chamber (Vf) satisfies the following Equation 2, and the volume of the osmotic equalizer chamber (Voe) and the volume of the feed chamber (Vf) are calculated using the following Equations 3 and 4, respectively:

Equation 2: Voe/Vf=1/n

Equation 3: Voe=A*OE-h

Equation 4: Vf=A*F-h

wherein A is an area of the osmotic membrane shared by the feed chamber and the osmotic equalizer chamber, OE-h is a height of the osmotic equalizer chamber, and F-h is a height of the feed chamber,

wherein n is a real number from 2 to 30.

4. The method according to claim 1, further comprising passing an output of the osmotic equalizer chamber of the zero osmotic pressure difference concentrator as a feed stream through a second zero osmotic pressure difference concentrator to increase concentration efficiency.

5. The method according to claim 1, further comprising recovering a solidified solute from the concentrated solute-containing aqueous solution using thermal energy, electrical energy, or pressure.

6. A method of separating a solvent and a solute from a solute-containing aqueous solution using the method according to any one of claims 1 to 5.

7. The method according to claim 6, wherein the solute is a salt or a liquid, and the solvent is water.