CLAIMS

What is claimed is:

1. A method, comprising:

transporting a feed solution comprising a solvent and a solute to a retentate side of a feed osmotic module such that:

a feed osmotic module retentate outlet stream exits the retentate side of the feed osmotic module, the feed osmotic module retentate outlet stream having a concentration of the solute that is greater than a concentration of the solute within the feed solution entering the retentate side of the feed osmotic module, and

at least a portion of the solvent from the feed solution is transported from the retentate side of the feed osmotic module, through an osmotic membrane of the feed osmotic module, to a permeate side of the feed osmotic module where the portion of the solvent is combined with a feed osmotic module permeate inlet stream to form a feed osmotic module permeate outlet stream that is transported out of the permeate side of the feed osmotic module;

wherein:

during a first period of time, the retentate side of the feed osmotic module receives at least a portion of the feed osmotic module retentate outlet stream;

during a second period of time that is after the first period of time, the retentate side of the feed osmotic module no longer receives any portion of the feed osmotic module retentate outlet stream or receives an amount of the feed osmotic module retentate outlet stream that is less than the amount of the feed osmotic module retentate outlet stream received by the retentate side of the feed osmotic module during the first period of time;

during both the first period of time and the second period of time, at least a portion of an isolation osmotic module retentate inlet stream is transported to a retentate side of an isolation osmotic module, and at least a portion of an isolation osmotic module permeate inlet stream is transported to a permeate side of the isolation osmotic module such that:

an isolation osmotic module retentate outlet stream, having an osmotic pressure that is greater than an osmotic pressure of the isolation osmotic module retentate inlet stream, exits the retentate side of the isolation osmotic module, and

at least a portion of liquid from the isolation osmotic module retentate inlet stream is transported from the retentate side of the isolation osmotic module, through an osmotic membrane of the isolation osmotic module, to the permeate side of the isolation osmotic module where the portion of the liquid is combined with the isolation osmotic module permeate inlet stream to form an isolation osmotic module permeate outlet stream that is transported out of the permeate side of the isolation osmotic module;

the feed osmotic module permeate inlet stream comprises at least a portion of the isolation osmotic module retentate outlet stream; and

the isolation osmotic module permeate inlet stream comprises at least a portion of the isolation osmotic module retentate outlet stream.

2. The method of claim 1, wherein during the second period of time, the retentate side of the feed osmotic module receives a percentage of the feed osmotic module retentate outlet stream that is reduced by at least 10 wt%, relative to the percentage of the feed osmotic module retentate outlet stream that is received by the retentate side of the feed osmotic module during the first period of time.

3. The method of any one of claims 1-2, wherein, during the second period of time, the retentate side of the feed osmotic module receives less than or equal to 90 wt% of the feed osmotic module retentate outlet stream.

4. The method of claim 1, wherein, during the second period of time, the retentate side of the feed osmotic module receives no longer receives any portion of the feed osmotic module retentate outlet stream.

5. The method of any one of claims 1-4, comprising, during the first period of time and the second period of time, transporting a purification osmotic module retentate inlet stream to a retentate side of a purification osmotic module such that:

a purification osmotic module retentate outlet stream exits the retentate side of the purification osmotic module, the purification osmotic module retentate outlet stream having an osmotic pressure that is greater than an osmotic pressure of the purification osmotic module retentate inlet stream, and

at least a portion of liquid from the purification osmotic module retentate inlet stream is transported from the retentate side of the purification osmotic module, through an osmotic membrane of the purification osmotic module, to a permeate side of the purification osmotic module.

6. The method of claim 5, wherein the isolation osmotic module retentate inlet stream comprises at least a portion of the purification osmotic module retentate outlet stream.

7. The method of any one of claims 5-6, wherein the purification osmotic module retentate inlet stream comprises at least a portion of the isolation osmotic module permeate outlet stream.

8. The method of any one of claims 5-7, wherein the purification osmotic module retentate inlet stream comprises at least a portion of the feed osmotic module permeate outlet stream.

9. The method of any one of claims 1-8, wherein the solute comprises solubilized ions.

10. The method of any one of claim 9, wherein the concentration of solubilized ions within the feed solution is at least 60,000 ppm.

11. The method of any one of claims 1-10, wherein the feed solution is an aqueous feed solution.

12. The method of any one of claims 1-11, wherein the feed solution comprises Na^+, Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}, Cl^-, carbonate anions, bicarbonate anions, sulfate anions, bisulfate anions, and/or silica.

13. The method of any one of claims 1-12, wherein the solute concentration in the feed osmotic module retentate outlet stream is at least 1% higher, on a mass basis, than the concentration of the solute in the feed solution.

14. A method, comprising:

transporting, over a first period of time, a first feed solution to a retentate side of a feed osmotic module such that, during the first period of time:

a first feed osmotic module retentate outlet stream exits the retentate side of the feed osmotic module, the first feed osmotic module retentate outlet stream having a solute concentration that is greater than a solute concentration of the first feed solution entering the retentate side of the feed osmotic module, and

at least a portion of solvent from the first feed solution is transported from the retentate side of the feed osmotic module, through an osmotic membrane of the feed osmotic module, to a permeate side of the feed osmotic module where the portion of the solvent is combined with a first feed osmotic module permeate inlet stream to form a first feed osmotic module permeate outlet stream that is transported out of the permeate side of the feed osmotic module; and

at least a portion of the first feed osmotic module retentate outlet stream is recycled back to an inlet of the retentate side of the feed osmotic module;

transporting, over a second period of time that is after the first period of time, a second feed solution to the retentate side of the feed osmotic module such that, during the second period of time:

a second feed osmotic module retentate outlet stream exits the retentate side of the feed osmotic module, the second feed osmotic module retentate outlet stream having a solute concentration that is greater than a solute concentration of the second feed solution entering the retentate side of the feed osmotic module, and

at least a portion of solvent from the second feed solution is transported from the retentate side of the feed osmotic module, through the osmotic membrane of the feed osmotic module, to the permeate side of the feed osmotic module where the portion of the solvent is combined with a second feed osmotic module permeate inlet stream to form a second feed osmotic module permeate outlet stream that is transported out of the permeate side of the feed osmotic module; and

a percentage of the second feed osmotic module retentate outlet stream that is recycled back to the retentate side of the feed osmotic module is reduced by at least 10 wt%, relative to the percentage of the first feed osmotic module retentate outlet stream that is recycled back to the retentate side of the feed osmotic module during the first period of time; and

transporting, during both the first period of time and the second period of time, an isolation osmotic module retentate inlet stream to a retentate side of an isolation osmotic module and an isolation osmotic module permeate inlet stream to a permeate side of the isolation osmotic module, wherein the isolation osmotic module is fluidically connected to the feed osmotic module, such that:

an isolation osmotic module retentate outlet stream exits the retentate side of the isolation osmotic module, the isolation osmotic module retentate outlet stream having an osmotic pressure that is greater than an osmotic pressure of the isolation osmotic module retentate inlet stream, and

at least a portion of liquid from the isolation osmotic module retentate inlet stream is transported from the retentate side of the isolation osmotic module, through an osmotic membrane of the isolation osmotic module, to a permeate side of the isolation osmotic module where the portion of the liquid is combined with the isolation osmotic module permeate inlet stream to form an isolation osmotic module permeate outlet stream that is transported out of the permeate side of the isolation osmotic module.

15. The method of claim 14, wherein, during the second period of time, less than or equal to 90 wt% of the second feed osmotic module retentate outlet stream is recycled back to the retentate side of the feed osmotic module.

16. The method of any one of claims 14-15, wherein, during the second period of time, none of the second feed osmotic module retentate outlet stream is recycled back to the retentate side of the feed osmotic module.

17. The method of any one of claims 14-16, comprising, during the first period of time and the second period of time, transporting a purification osmotic module retentate inlet stream to a retentate side of a purification osmotic module such that:

a purification osmotic module retentate outlet stream exits the retentate side of the purification osmotic module, the purification osmotic module retentate outlet stream having an osmotic pressure that is greater than an osmotic pressure of the purification osmotic module retentate inlet stream, and

at least a portion of liquid from the purification osmotic module retentate inlet stream is transported from the retentate side of the purification osmotic module, through an osmotic membrane of the purification osmotic module, to a permeate side of the purification osmotic module.

18. The method of claim 17, wherein the isolation osmotic module retentate inlet stream comprises at least a portion of the purification osmotic module retentate outlet stream.

19. The method of any one of claims 17-18, wherein the purification osmotic module retentate inlet stream comprises at least a portion of the isolation osmotic module permeate outlet stream.

20. The method of any one of claims 17-19, wherein, during the first period of time, the purification osmotic module retentate inlet stream comprises at least a portion of the first feed osmotic module permeate outlet stream.

21. The method of any one of claims 17-20, wherein, during the second period of time, the purification osmotic module retentate inlet stream comprises at least a portion of the second feed osmotic module permeate outlet stream.

22. The method of any one of claims 14-21, wherein the first feed solution and/or the second feed solution comprises a solute comprises solubilized ions.

23. The method of claim 22, wherein the concentration of solubilized ions within the feed solution is at least 60,000 ppm.

24. The method of any one of claims 14-23, wherein the first feed solution and/or the second feed solution is an aqueous feed solution.

25. The method of any one of claims 14-24, wherein the first feed solution and/or the second feed solution comprises Na^{+}, Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}, Cl^{-}, carbonate anions, bicarbonate anions, sulfate anions, bisulfate anions, and/or silica.

26. The method of any one of claims 1-25, wherein the feed osmotic module is operated as a reverse osmosis module.

27. The method of any one of claims 5-13 and 17-26, wherein the purification osmotic module is operated as a reverse osmosis module.

28. The method of any one of claims 1-27, wherein the isolation osmotic module is operated as a reverse osmosis module.

29. The method of any one of claims 1-28, wherein the feed osmotic module comprises a plurality of osmotic membranes.

30. The method of claim 29, wherein the plurality of osmotic membranes are connected in series.

31. The method of claim 29, wherein the plurality of osmotic membranes are connected in parallel.

32. The method of any one of claims 5-13 and 17-31, wherein the purification osmotic module comprises a plurality of osmotic membranes.

33. The method of claim 32, wherein the plurality of osmotic membranes are connected in series.

34. The method of claim 32, wherein the plurality of osmotic membranes are connected in parallel.

35. The method of any one of claims 1-34, wherein the isolation osmotic module comprises a plurality of osmotic membranes.

36. The method of claim 35, wherein the plurality of osmotic membranes are connected in series.

37. The method of claim 35, wherein the plurality of osmotic membranes are connected in parallel.

38. The method of any one of claims 14-37, wherein the solute concentration in the first feed osmotic module retentate outlet stream is at least 1% higher, on a mass basis, than the concentration of the solute in the first feed solution.

39. The method of any one of claims 14-38, wherein the solute concentration in the second feed osmotic module retentate outlet stream is at least 1% higher, on a mass basis, than the concentration of the solute in the second feed solution.

40. The method of any one of claims 1-39, wherein, during the first period of time, the total amount of osmotic membrane surface area within the retentate side of the feed osmotic module is changed and/or the total amount of osmotic membrane surface area within the retentate side of the isolation osmotic module is changed.

41. The method of any one of claims 5-7 and 17-40, wherein, during the first period of time, the total amount of osmotic membrane surface area within the retentate side of the feed osmotic module is changed, the total amount of osmotic membrane surface area within the retentate side of the isolation osmotic module is changed, and/or the total amount of osmotic membrane surface area within the retentate side of the purification osmotic module is changed.

42. The method of any one of claims 1-41, wherein, during the first period of time, the total amount of osmotic membrane surface area within the retentate side of the feed osmotic module decreases, as a function of time, by at least 5%.

43. The method of any one of claims 1-42, wherein, during the first period of time, the total amount of osmotic membrane surface area within the retentate side of the isolation osmotic module increases, as a function of time, by at least 5%.

44. The method of any one of claims 1-43, wherein, during the first period of time, the retentate side of the isolation osmotic module receives at least a portion of the isolation osmotic module retentate outlet stream.

45. A method, comprising:

operating a feed osmotic module to produce a feed osmotic module retentate outlet stream having a solute concentration that is greater than a solute concentration of a feed solution entering a retentate side of the feed osmotic module; and

operating an isolation osmotic module that is fluidically connected to the feed osmotic module to produce an isolation osmotic module retentate outlet stream having an osmotic pressure that is greater than an osmotic pressure of an isolation osmotic module retentate inlet stream entering a retentate side of the isolation osmotic module;

wherein:

during a first period of time, the retentate side of the feed osmotic module receives at least a portion of the feed osmotic module retentate outlet stream; and

during a second period of time, the retentate side of the feed osmotic module no longer receives any portion of the feed osmotic module retentate outlet stream or receives an amount of

the feed osmotic module retentate outlet stream that is less than the amount of the feed osmotic module retentate outlet stream received by the retentate side of the feed osmotic module during the first period of time.

46. The method of claim 45, further comprising transporting a first portion of the isolation osmotic module retentate outlet stream to a permeate side of the feed osmotic module.

47. The method of any one of claims 45-46, further comprising transporting a second portion of the isolation osmotic module retentate outlet stream to a permeate side of the isolation osmotic module.

48. The method of any one of claims 45-47, further comprising operating a purification osmotic module that receives a purification osmotic module retentate inlet stream to produce a purification osmotic module retentate outlet stream and a purification osmotic module permeate outlet stream.

49. The method of claim 48, wherein the purification osmotic module permeate outlet stream has an osmotic pressure that is lower than an osmotic pressure of the feed solution entering the feed osmotic module.

50. The method of any one of claims 45 and 47-49, wherein a feed osmotic module permeate inlet stream entering a permeate side of the feed osmotic module comprises at least a portion of the isolation osmotic module retentate outlet stream.

51. The method of any one of claims 45 and 47-50, wherein an isolation osmotic module permeate inlet stream entering a permeate side of the isolation osmotic module comprises at least a portion of the isolation osmotic module retentate outlet stream.

52. The method of any one of claims 48-51, wherein the isolation osmotic module retentate inlet stream comprises at least a portion of the purification osmotic module retentate outlet stream.

53. The method of any one of claims 48-52, wherein the purification osmotic module retentate inlet stream comprises at least a portion of the feed osmotic module permeate outlet stream.

54. The method of any one of claims 48-53, wherein the purification osmotic module retentate inlet stream comprises at least a portion of the isolation osmotic module permeate outlet stream.

55. The method of any one of claims 45-54, wherein, during the second period of time, the retentate side of the feed osmotic module receives less than or equal to 90 wt% of the feed osmotic module retentate outlet stream.

56. The method of any one of claims 45-55, wherein, during the second period of time, the retentate side of the feed osmotic module receives none of the feed osmotic module retentate outlet stream.

57. The method of any one of claims 45-56, wherein the solute comprises solubilized ions.

58. The method of claim 57, wherein the concentration of solubilized ions within the feed solution is at least 60,000 ppm.

59. The method of any one of claims 45-58, wherein the feed solution is an aqueous feed solution.

60. The method of any one of claims 45-59, wherein the feed solution comprises Na^{+}, Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}, Cl^{-}, carbonate anions, bicarbonate anions, sulfate anions, bisulfate anions, and/or silica.

61. The method of any one of claims 45-60, wherein the feed osmotic module is operated as a reverse osmosis module.

62. The method of any one of claims 49-61, wherein the purification osmotic module is operated as a reverse osmosis module.

63. The method of any one of claims 45-62, wherein the isolation osmotic module is operated as a reverse osmosis module.

64. The method of any one of claims 45-63, wherein the feed osmotic module comprises a plurality of osmotic membranes.

65. The method of claim 64, wherein the plurality of osmotic membranes are connected in series.

66. The method of claim 64, wherein the plurality of osmotic membranes are connected in parallel.

67. The method of any one of claims 49-66, wherein the purification osmotic module comprises a plurality of osmotic membranes.

68. The method of claim 67, wherein the plurality of osmotic membranes are connected in series.

69. The method of claim 67, wherein the plurality of osmotic membranes are connected in parallel.

70. The method of any one of claims 45-69, wherein the isolation osmotic module comprises a plurality of osmotic membranes.

71. The method of claim 70, wherein the plurality of osmotic membranes are connected in series.

72. The method of claim 70, wherein the plurality of osmotic membranes are connected in parallel.

73. The method of any one of claims 45-72, wherein the solute concentration in the feed osmotic module retentate outlet stream is at least 1% higher, on a mass basis, than the concentration of the solute in the feed solution.

74. The method of any one of claims 45-73, wherein, during the first period of time, the total amount of osmotic membrane surface area within the retentate side of the feed osmotic module is changed and/or the total amount of osmotic membrane surface area within the retentate side of the isolation osmotic module is changed.

75. The method of any one of claims 49-74, wherein, during the first period of time, the total amount of osmotic membrane surface area within the retentate side of the feed osmotic module is changed, the total amount of osmotic membrane surface area within the retentate side of the isolation osmotic module is changed, and/or the total amount of osmotic membrane surface area within the retentate side of the purification osmotic module is changed.

76. The method of any one of claims 49-75, wherein, during the first period of time, the total amount of osmotic membrane surface area within the retentate side of the feed osmotic module decreases, as a function of time, by at least 5%.

77. The method of any one of claims 45-76, wherein, during the first period of time, the total amount of osmotic membrane surface area within the retentate side of the isolation osmotic module increases, as a function of time, by at least 5%.

78. The method of any one of claims 45-77, wherein, during the first period of time, the retentate side of the isolation osmotic module receives at least a portion of the isolation osmotic module retentate outlet stream.