QUEEN'S UNIVERSITY BELFAST
ESTD 1845

QUEEN'S UNIVERSITY
IONIC LIQUID
LABORATORIES
QUILL

Thermo-responsive tetrabutylphosphonium 5-phenyltetrazolate solution as draw solutes for forward osmosis applications

Junzhe Quan*, Sanskrita Madhukailya, Dr. Leila Moura, Dr. Timken Hye-Kyung, Prof. John D Holbrey

1. Introduction

Background

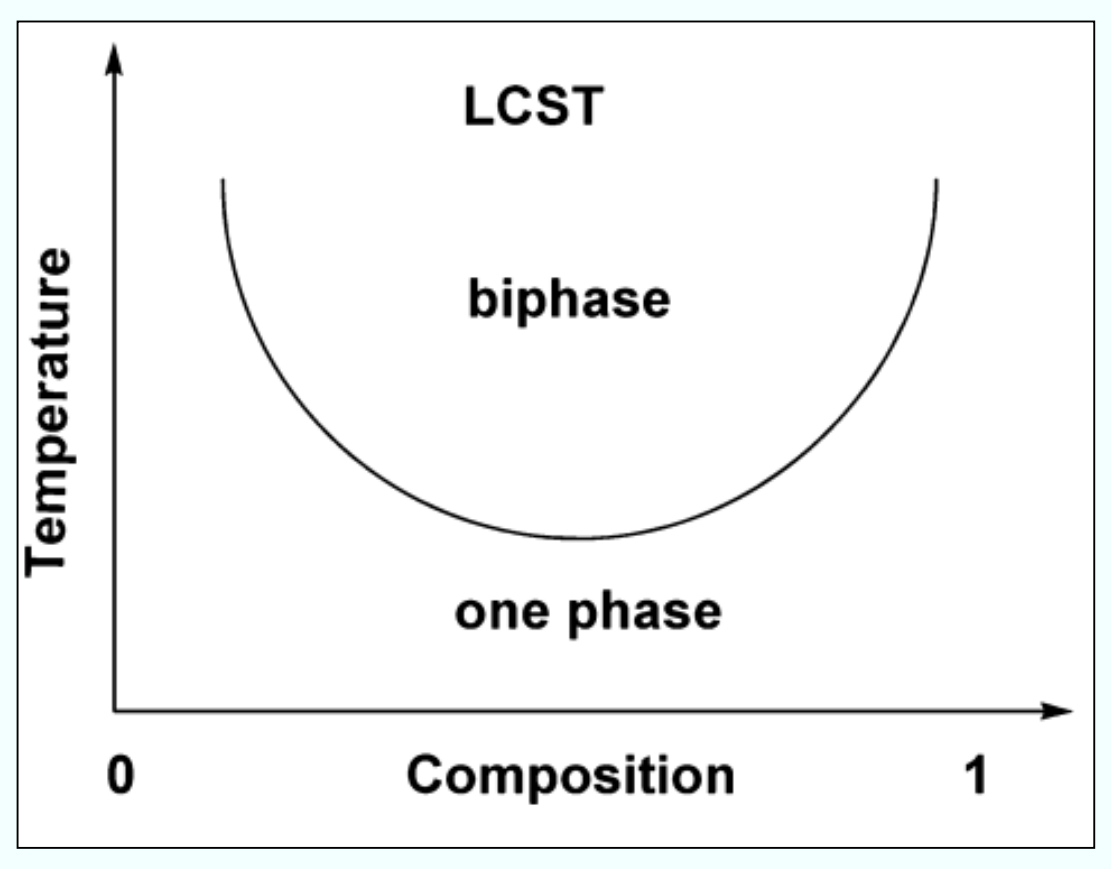


Fig - Phase diagram of LCST

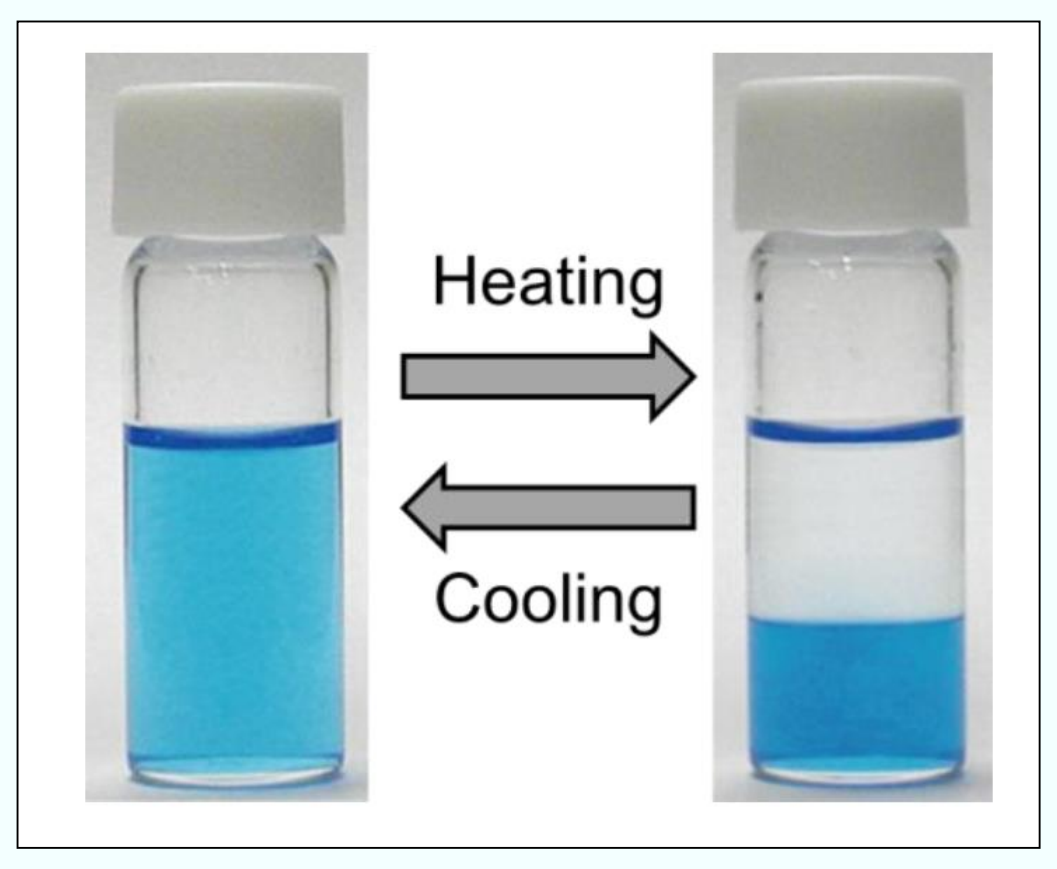


Fig - Example of LCST Behaviour[1]

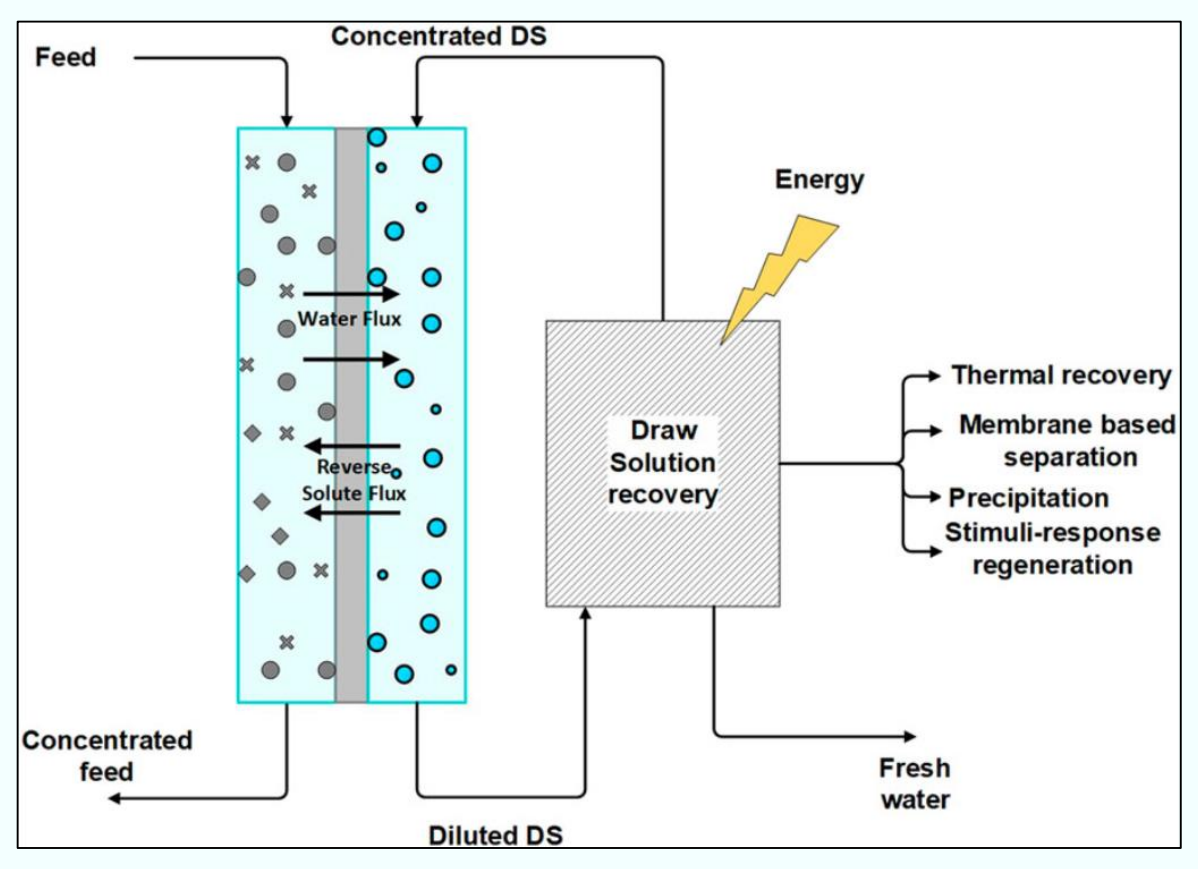


Fig – Mechanism of forward osmosis process[2]

Lower critical solution temperature (LCST) is the critical temperature below which the components of a mixture are miscible for all compositions. Cai and co-workers at Nanyang Technological University[3] described a kind of use of ionic liquid(IL) draw fluids for forward osmosis desalination and reported efficient reuse and recycling, separation, and decreases in low-level energy consumption. The process makes use of LCST phase behavior between the ionic liquids and water system, where solutions of the ionic liquid in water separate on heating into two separate phases. To predict the influence of system salinity on LCST behavior, we investigated it and found that there is a strong negative correlation between salinity(sodium chloride) and LCST.

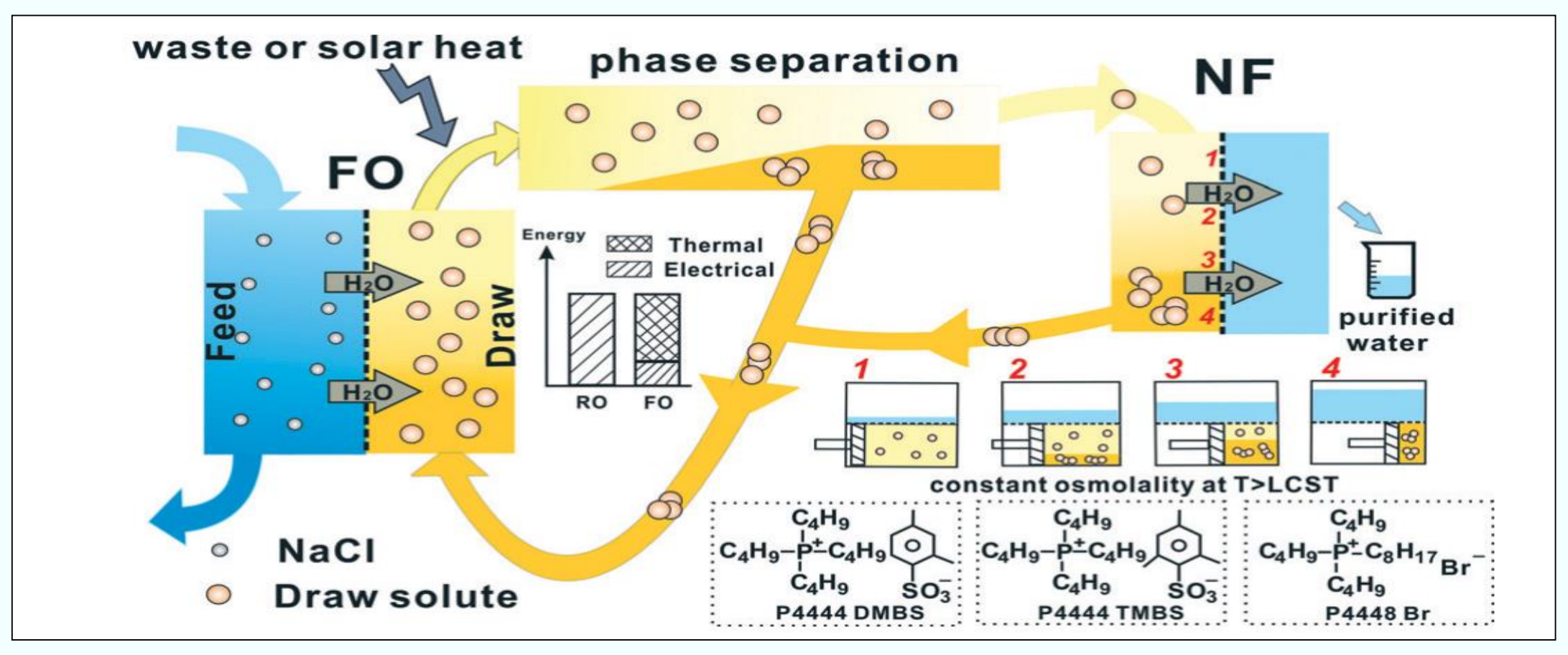


Fig - Schematic representation of FO desalination using LCST IL[3]

Materials and methodology

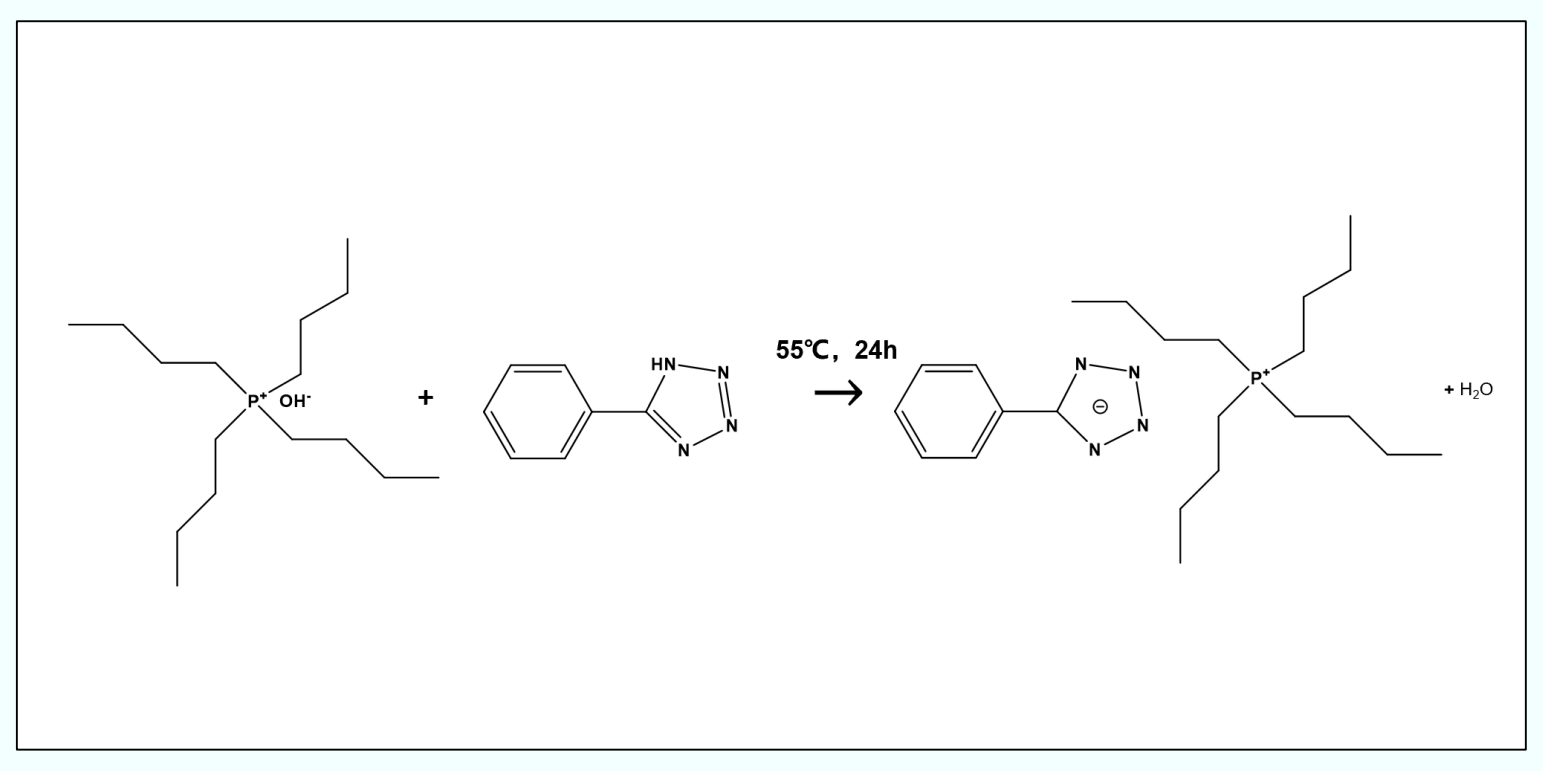
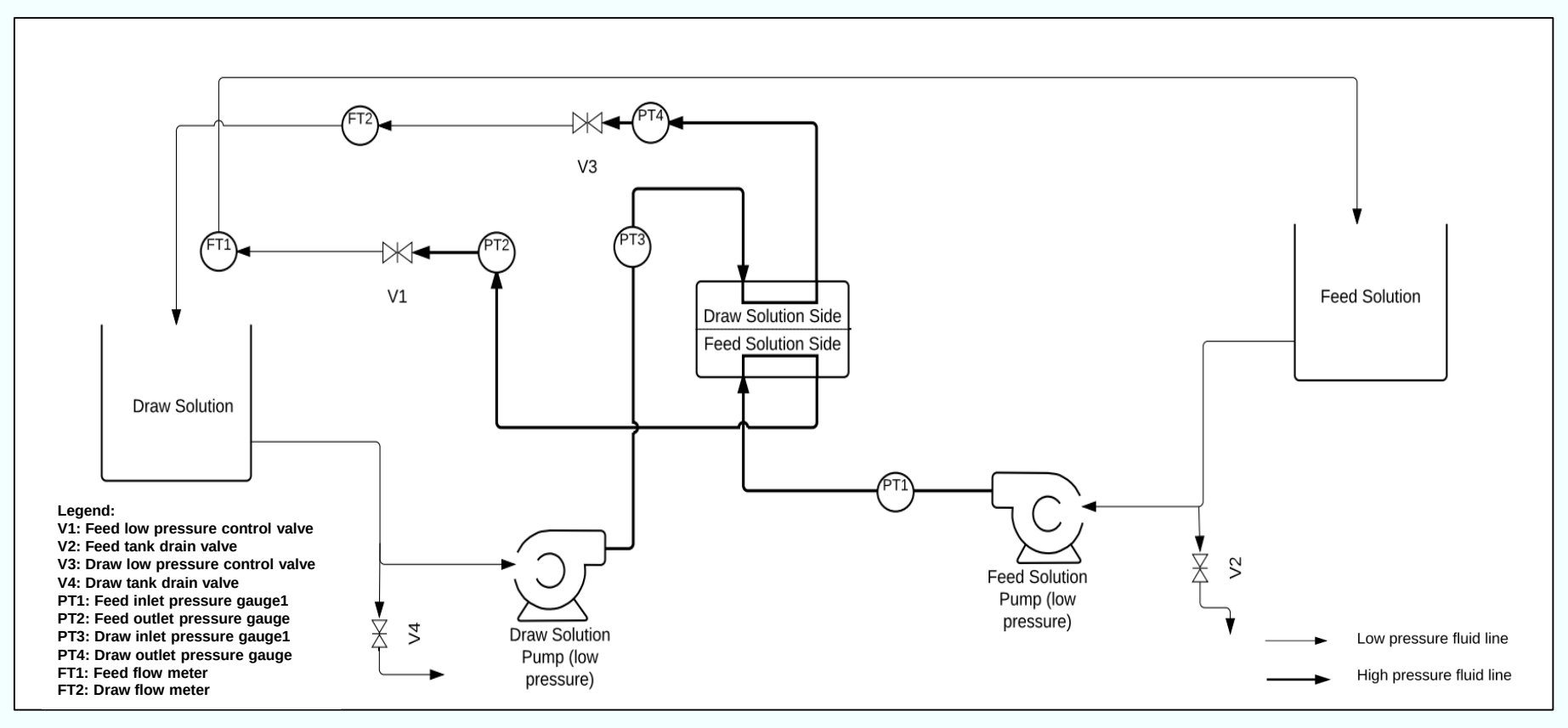


Fig – Preparation of tetrabutylphosphonium 5-phenyltetrazolate



Legend:
V1: Feed low pressure control valve
V2: Feed tank drain valve
V3: Draw low pressure control valve
V4: Draw tank drain valve
PT1: Feed inlet pressure gauge1
PT2: Feed outlet pressure gauge
PT3: Draw inlet pressure gauge1
PT4: Draw outlet pressure gauge
FT1: Feed flow meter
FT2: Draw flow meter

Fig – Lab-scale FO test system Outline

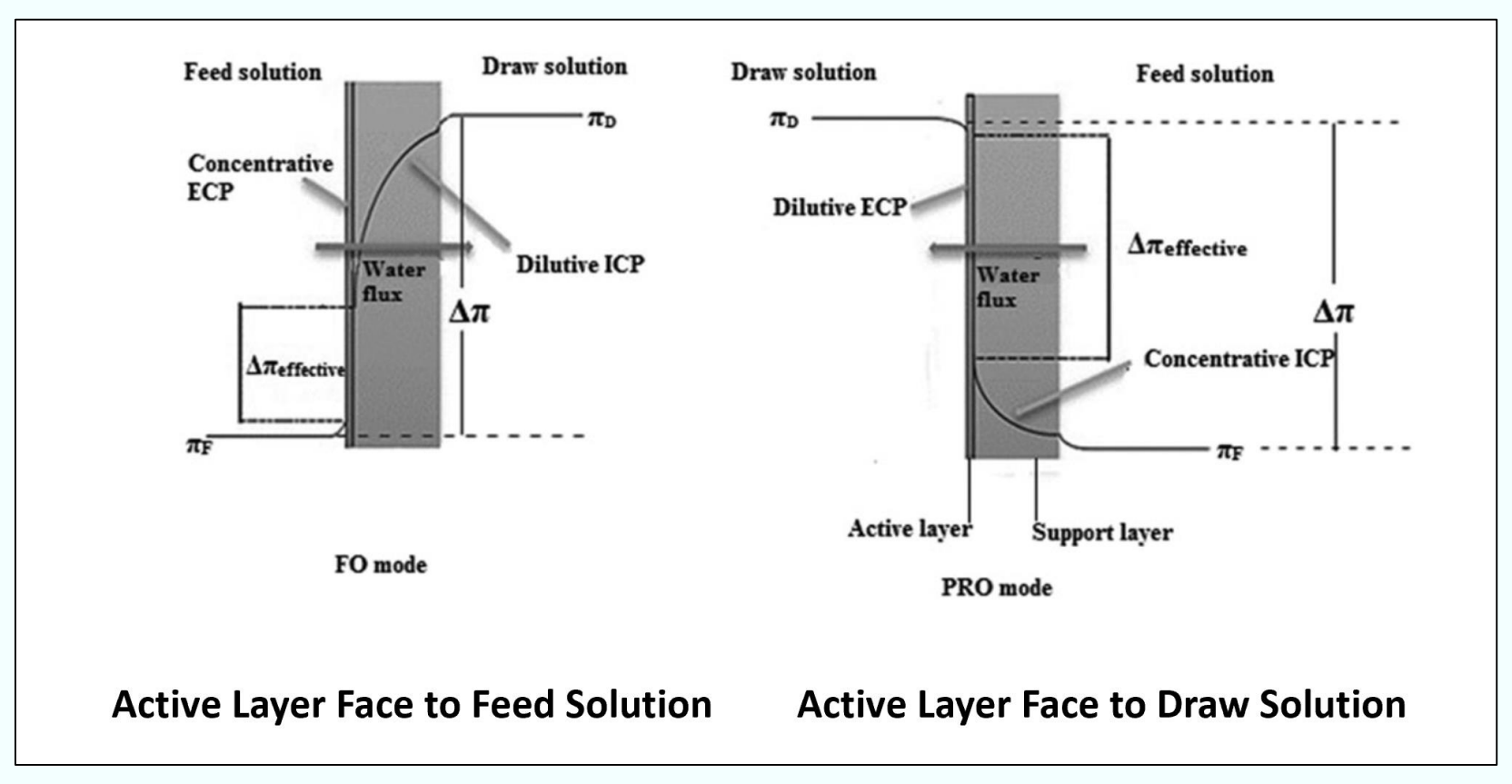


Fig – Scheme of FO mode and PRO mode

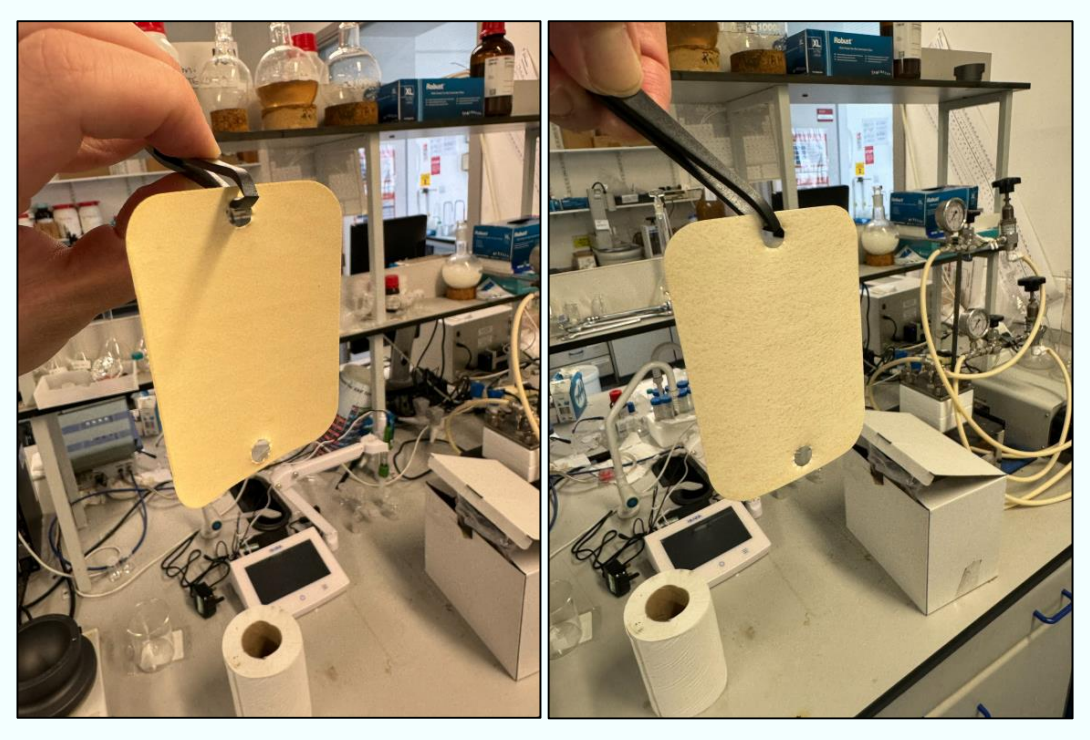
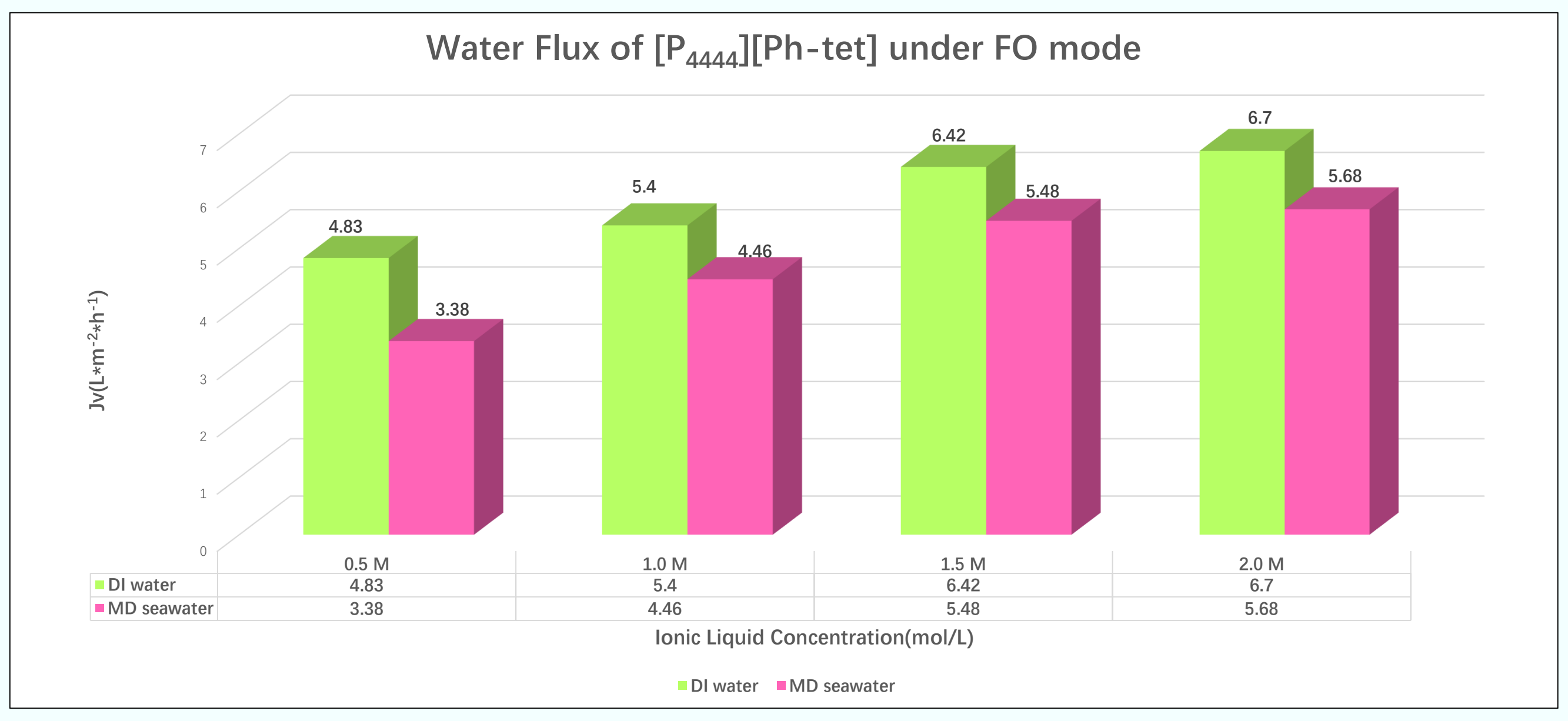
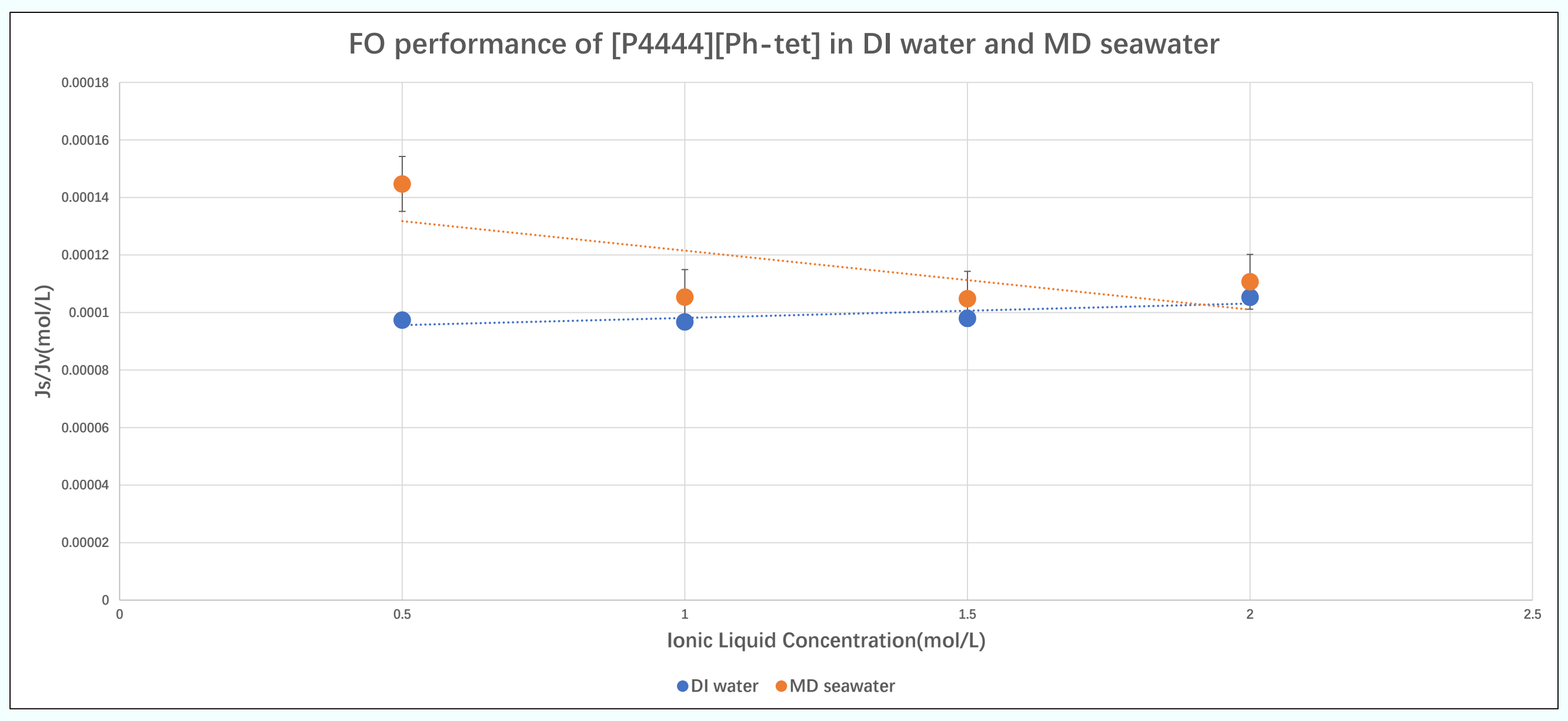


Fig - Active Layer (Left) and Support Layer (Right)

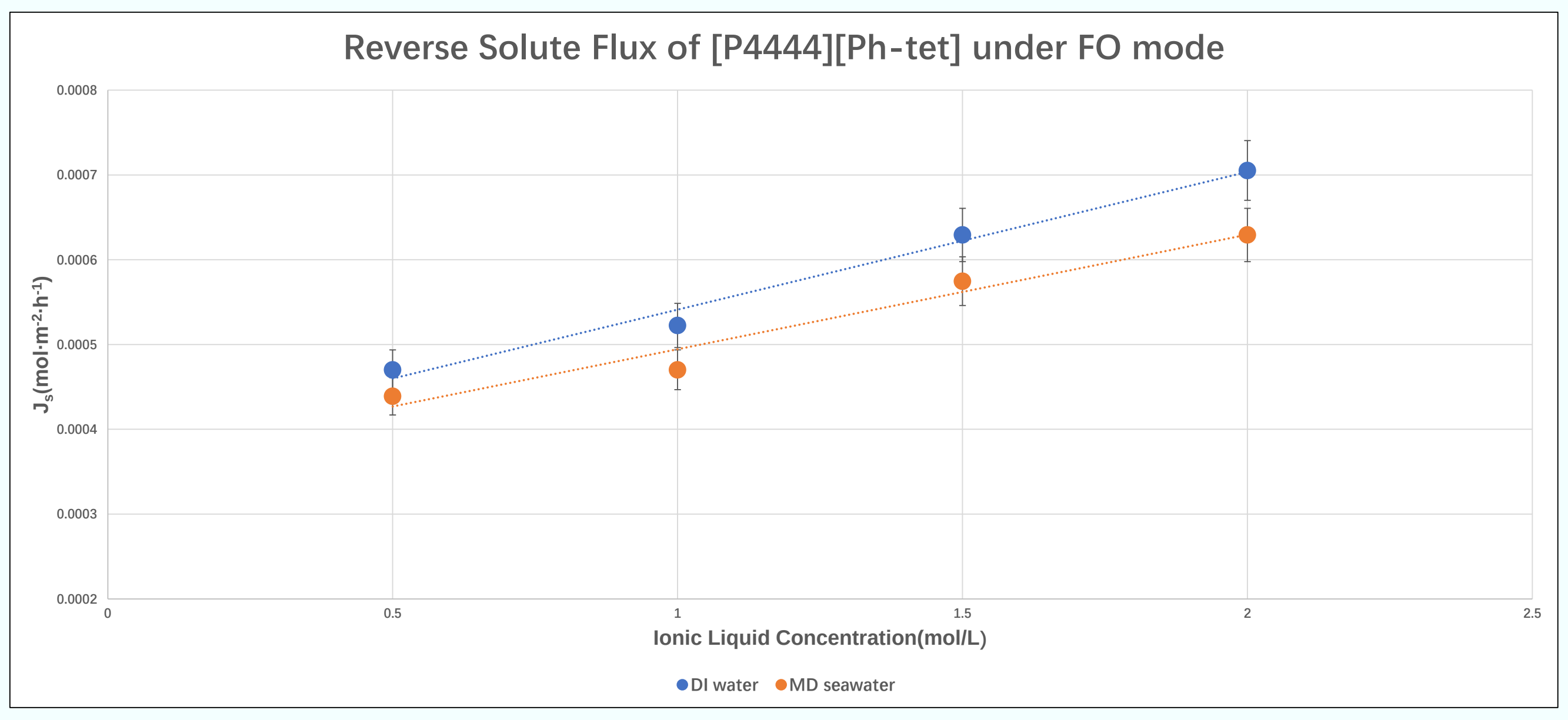
$[P_{4444}]$[Ph-tet] is tested in both DI water and model seawater from 0.5 M to 2.0 M concentration under both FO and PRO mode. (15L/h flow rate). TFC-PA membranes are used in this system. Each test is repeated for five times to delete the error.

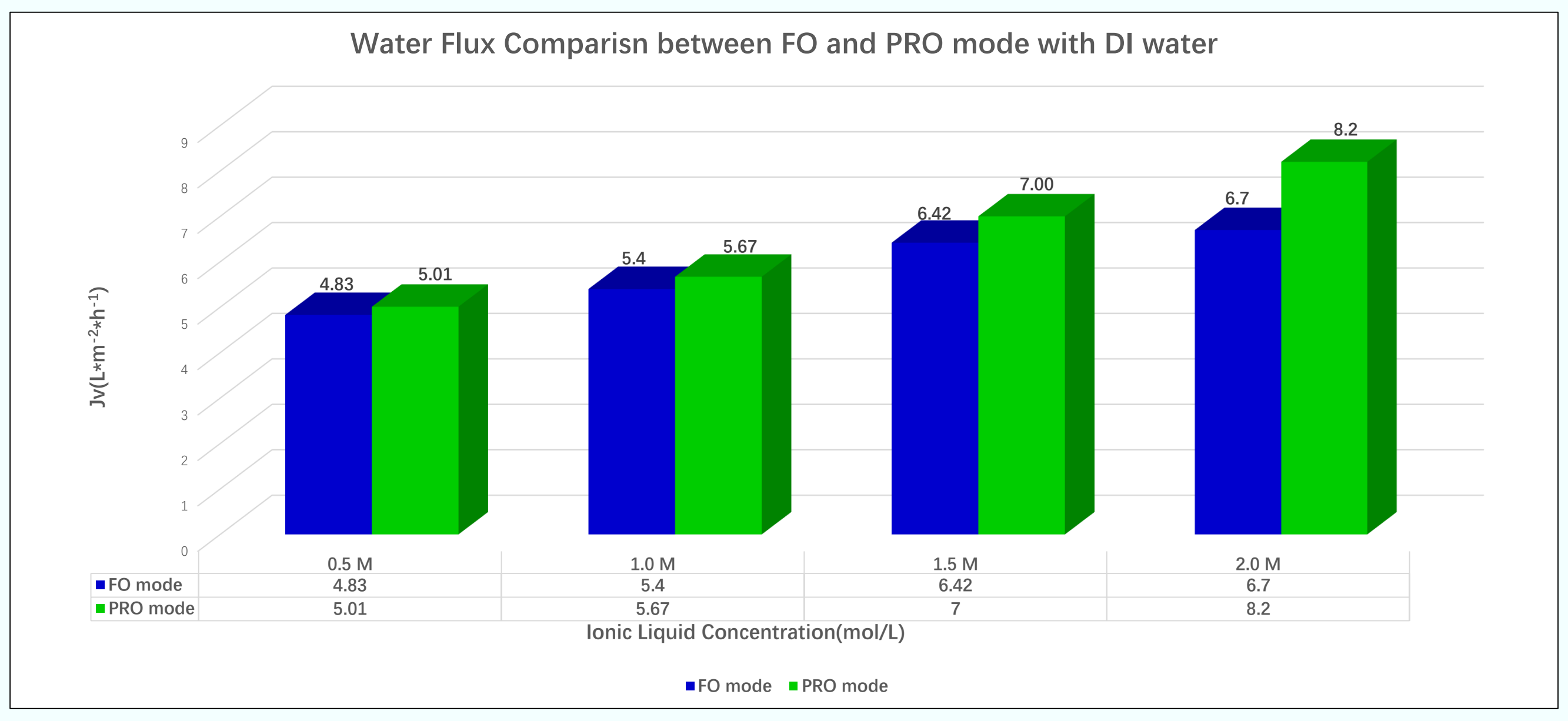
2. Results and Discussion





1. **Water flux and revers solute flux shows an increasing trend when the concentration is up.**
2. **Water flux will be decreased when our feed solution is model seawater under FO mode because of the concentrative external concentration polarization.**
3. **In model seawater, reverse solute flux is lower than in DI water because of the membrane fouling by sodium chloride.**
4. **In DI water, lower concentration perform more efficient and higher concentration perform more efficient in model seawater.**
5. **In DI water, FO mode contain a lower water flux resulting from the internal concentration polarization.**





3. Conclusion

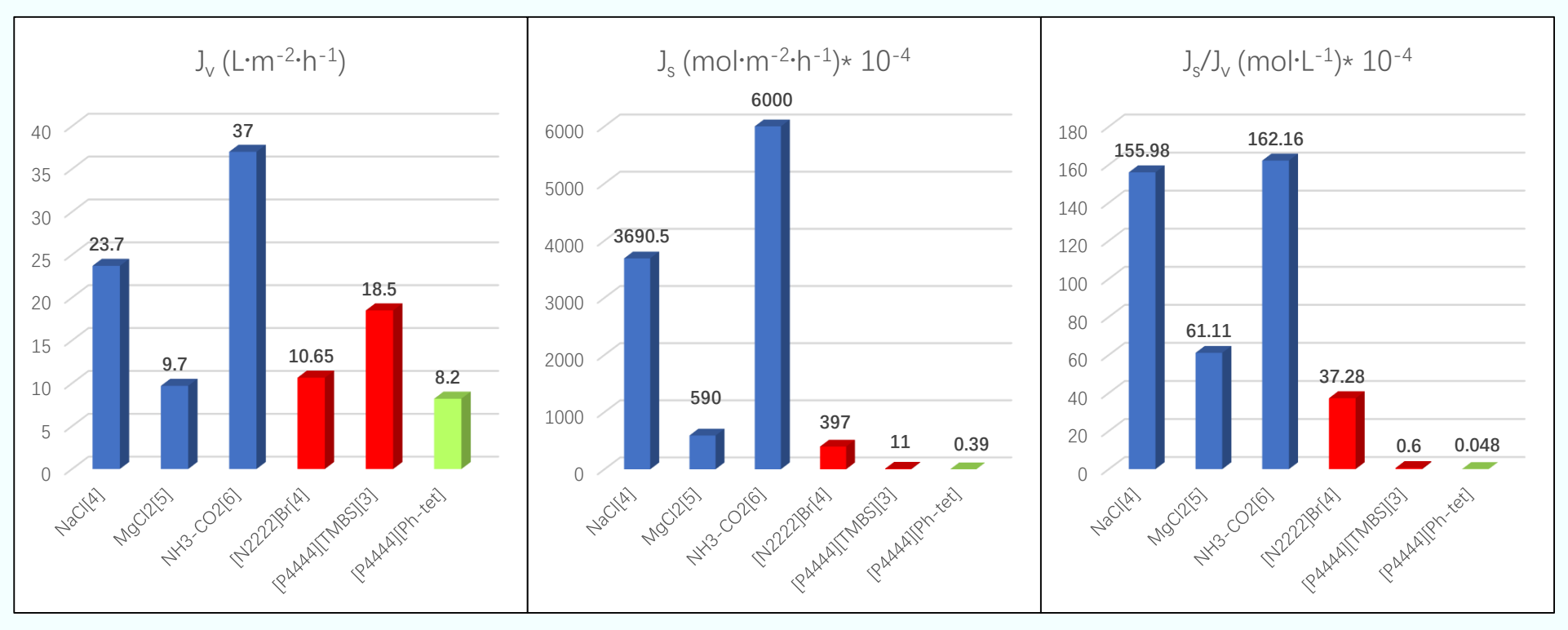


Fig- J_v,J_s,J_v/J_s comparison between traditional inorganic draw solute and IL draw solute

As for the $[P_{4444}]$[Ph-tet], the increasing Jv and Js trends are expected as higher driving force because of the higher chemical gradient resulting in higher osmotic pressure between feed solution and draw solution. Obtained Jv of $[P_{4444}]$[Ph-tet] shows similar water flux value with other kind of IL draw solute (Red in Fig) but lower than some traditional inorganic draw solute(Blue in Fig) just like NaCl[4] and NH_3-CO_2[5] solution. It can be explained by the large molecular size of IL resulting in a lower bulk aqueous diffusion coefficient which makes dilutive external concentration polarization (DECP) occurs more in draw solute side. Although its larger molecular size diminishes the water flux (Jv), this very attribute proves advantageous for its solute flux (Js). The increased molecular size results in a reduction in membrane diffusivity and back transport through the Thin-Film Composite Forward Osmosis (TFC-FO) membrane. Our material $[P_{4444}]$[Ph-tet] shows an excellent reverse solute flux compared with other thermo-responsive ionic liquids which means that in the same volume of water to be drawn, the loss of material is lowest for $[P_{4444}]$[Ph-tet]. However, the lower water flux also means the more energy consumption so it is necessary to find a balance between water flux and reverse solute flux when we choose draw solute.

4.References

1. *S. Saita, Fine Control of LCST-type Phase Transition of Ionic Liquid/Water Mixtures.*
2. *Imane Chaoui Water desalination by forward osmosis: draw solutes and recovery methods review*
3. *Y. Cai, W. Shen, Ji. Wei, T. H. Chong, R. Wang, W. B. Krantz, A. G. Fane, X. Hu, Environ. Sci.: Water Res. Technol., 2015,* ***1****, 341-347.*
4. *Zeweldi, H. G. et al. Desalination* ***444****, 94-106, doi:10.1016/j.desal.2018.07.017 (2018).*
5. *Achilli, A., Cath, T. Y. & Childress, Journal of Membrane Science* ***364****, 233-241, doi:10.1016/j.memsci.2010.08.010 (2010).*
6. *Boo, C., Khalil, Y. F. & Elimelech, M. Journal of Membrane Science* ***473****, 302-309, doi:10.1016/j.memsci.2014.09.026 (2015).*

5.Acknowledgement

Supervisor: Prof. John Holbrey，Dr. Leila Moura and Dr. Timken Hye-Kyung
Sanskrita Madhukailya
Dr. Yoan Delavoux
All other QUILL members