Thin Film Composite Nanofiltration Membrane: from Aqueous to Organic Solvent Nanofiltration Application.

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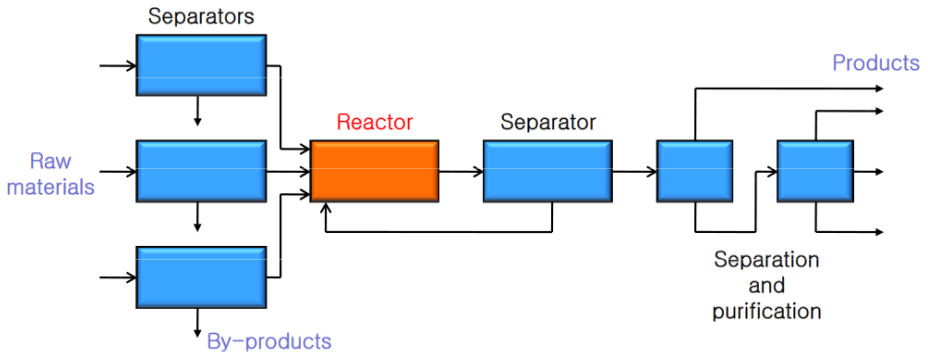
- Nanofiltration membrane
- Organic solvent nanofiltration membrane
- Membrane synthesis
- OSN membrane high permeance

Separation and Purification

- How much separation and purification process is important in the chemical plant?



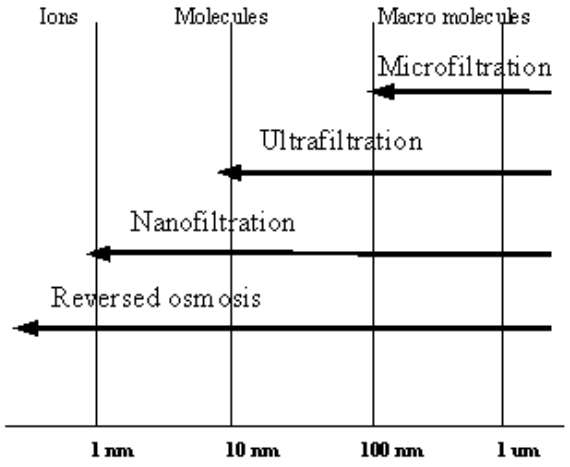
Separation processes can account for generally **40 - 70%** of chemical plant costs

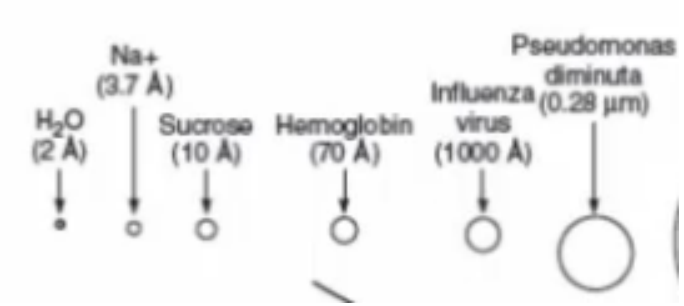
S. Sholl and P. Lively, nature (2016) 532 pp 435-437

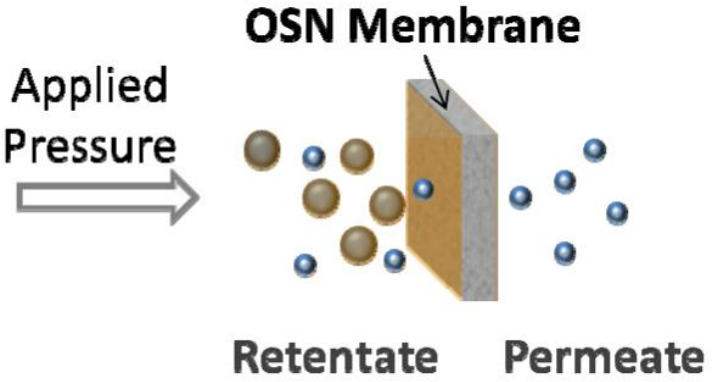
- separation and purification include distillation, crystallization, adsorption, **membrane processes**, absorption and stripping, and extraction.

Nanofiltration definition

- Nanofiltration process involving separating a dissolved molecules in liquid
- Pressure is the most common driving force
- Molecular weigh cut off (MWCO) 200-1000 g/mol





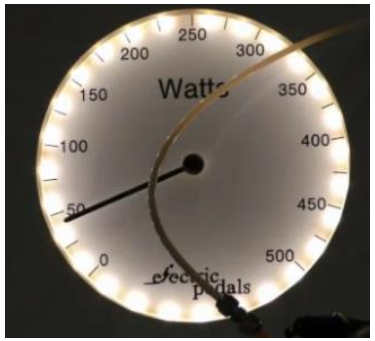


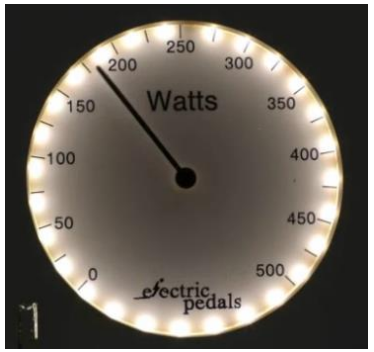
Separation by membrane VS evaporation
Energy consumption

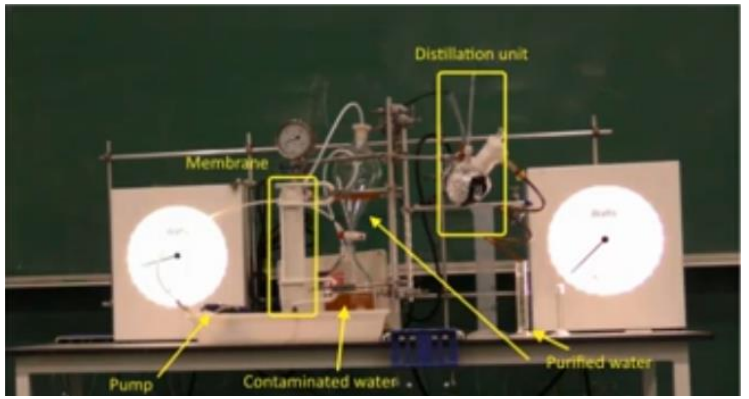
- Membrane nanofiltration vs other separation technology;

  suitability, economic efficiency.

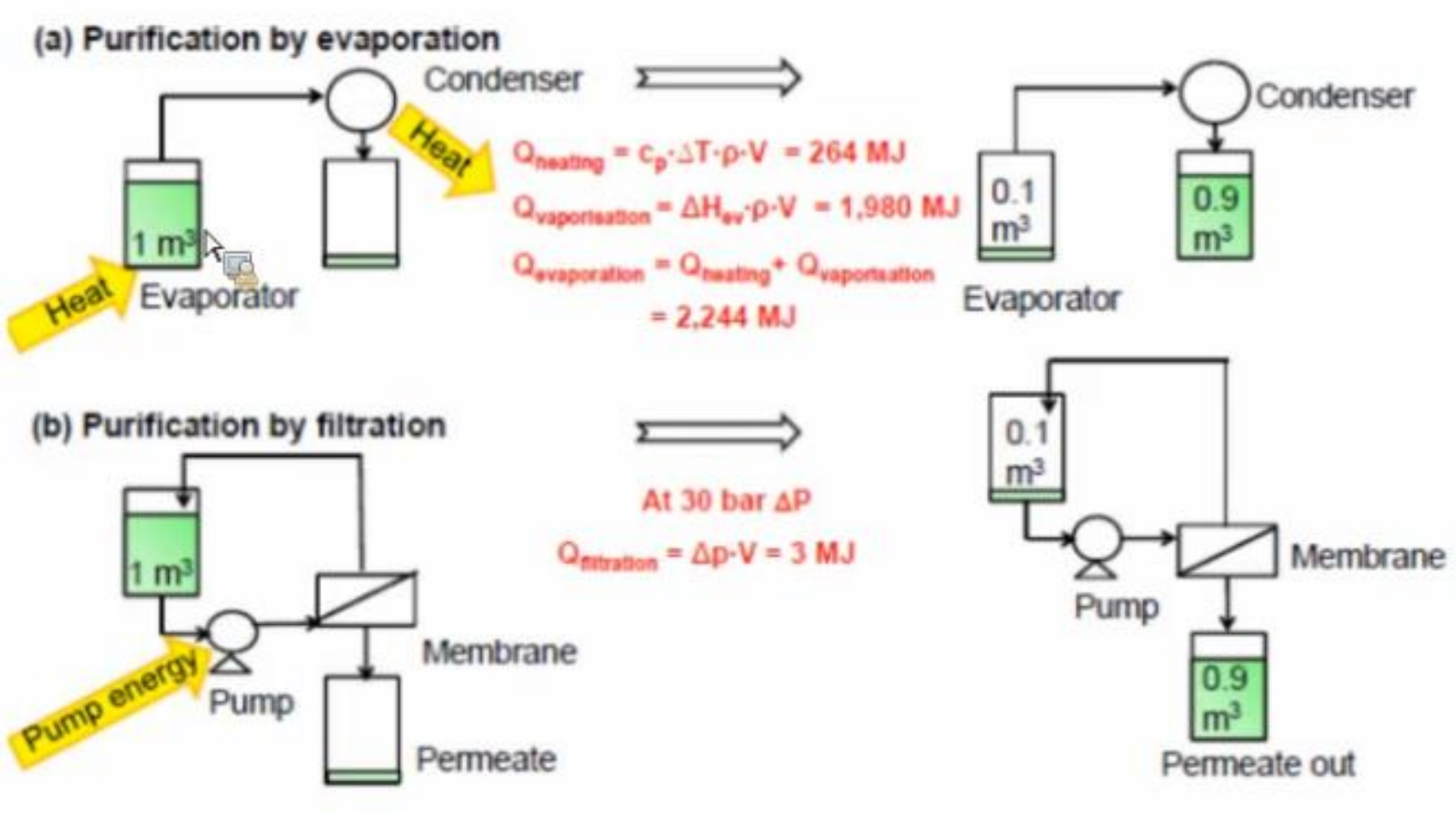
Membrane	VS traditional distillation
50 watts	200 watts
50 ml/min	2 ml/min



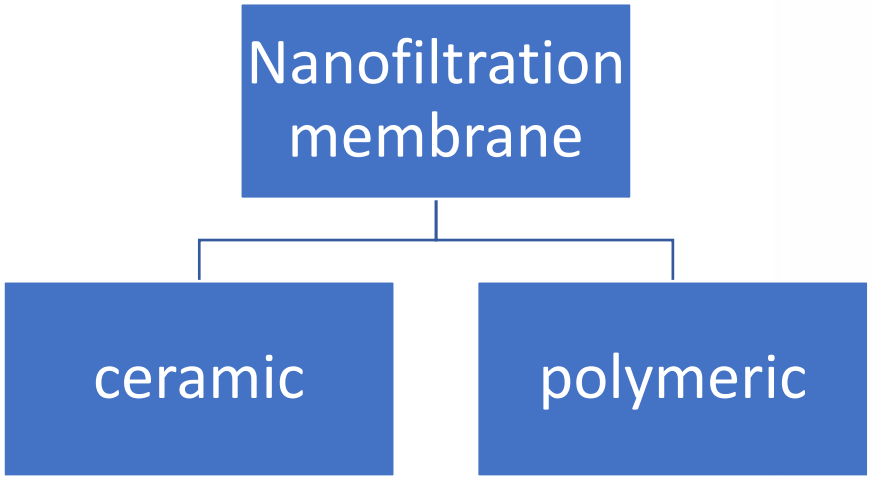




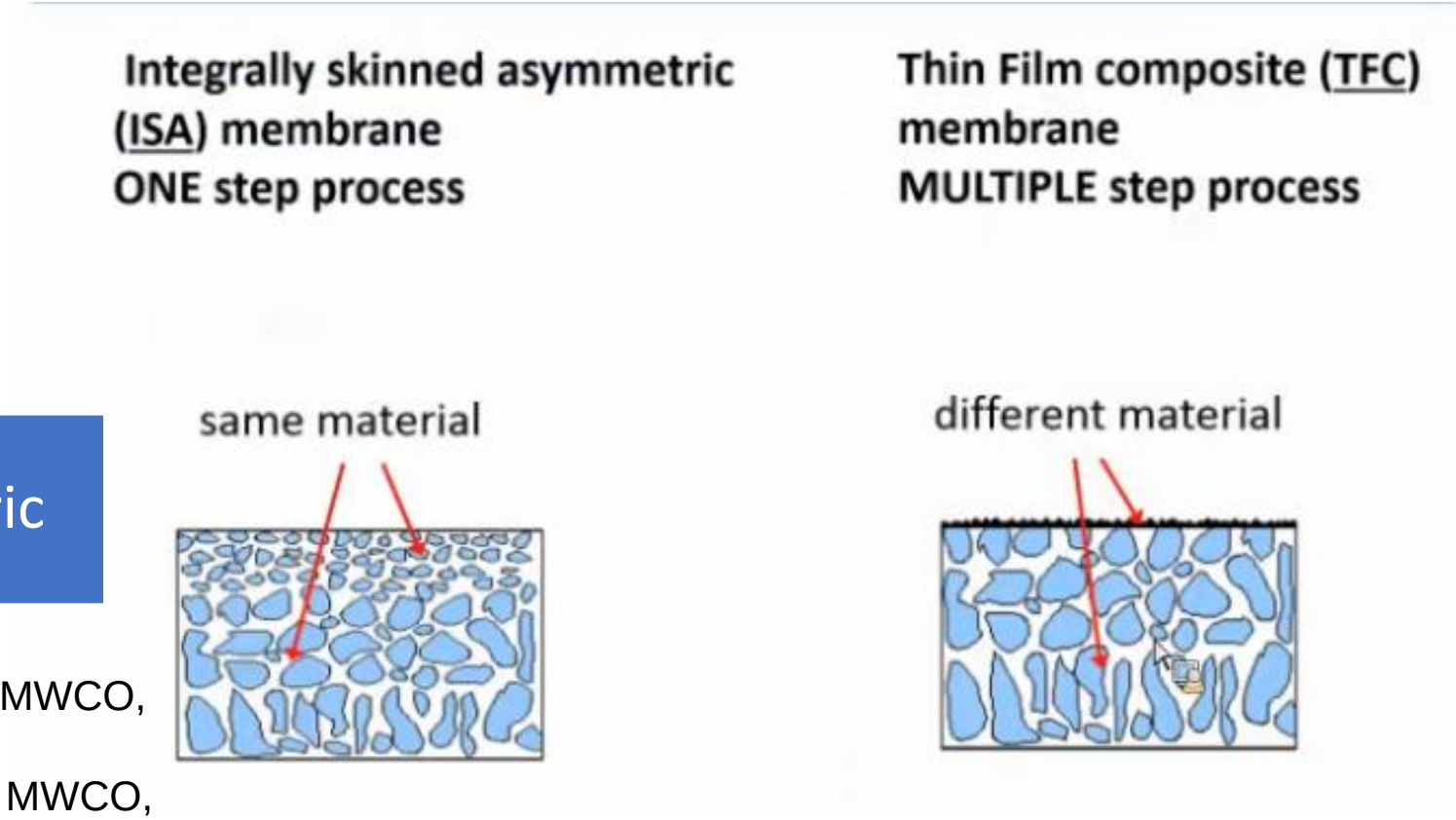
Separation by membrane VS evaporation
Energy consumption



Nanofiltration membrane types

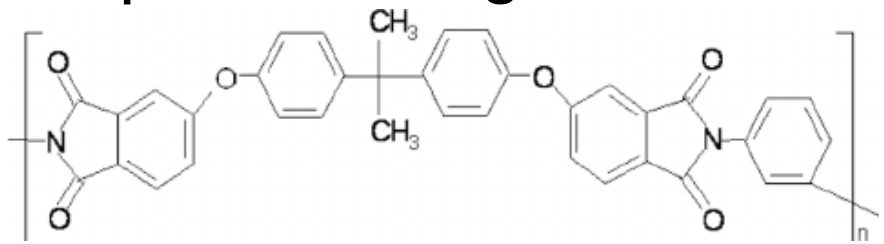


Ceramic membrane; more stable, high MWCO, Difficult to fold
Polymeric membrane; easy to fold, low MWCO, Less stable

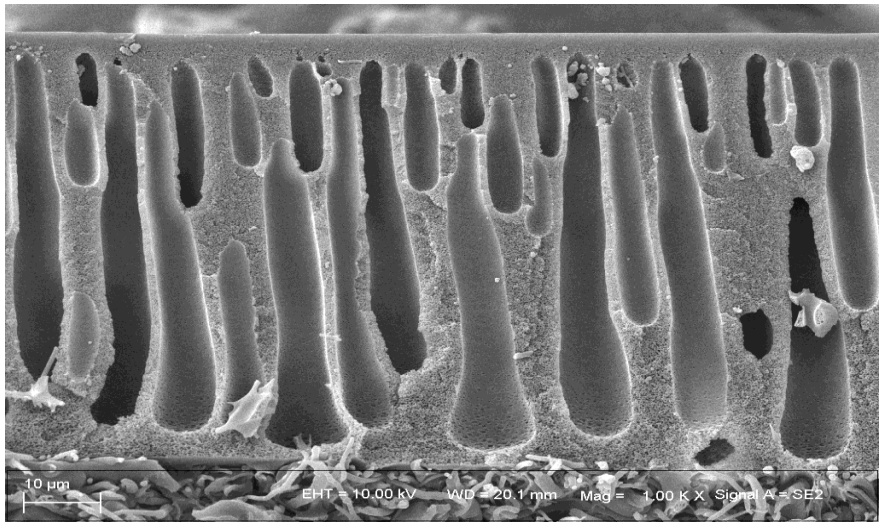


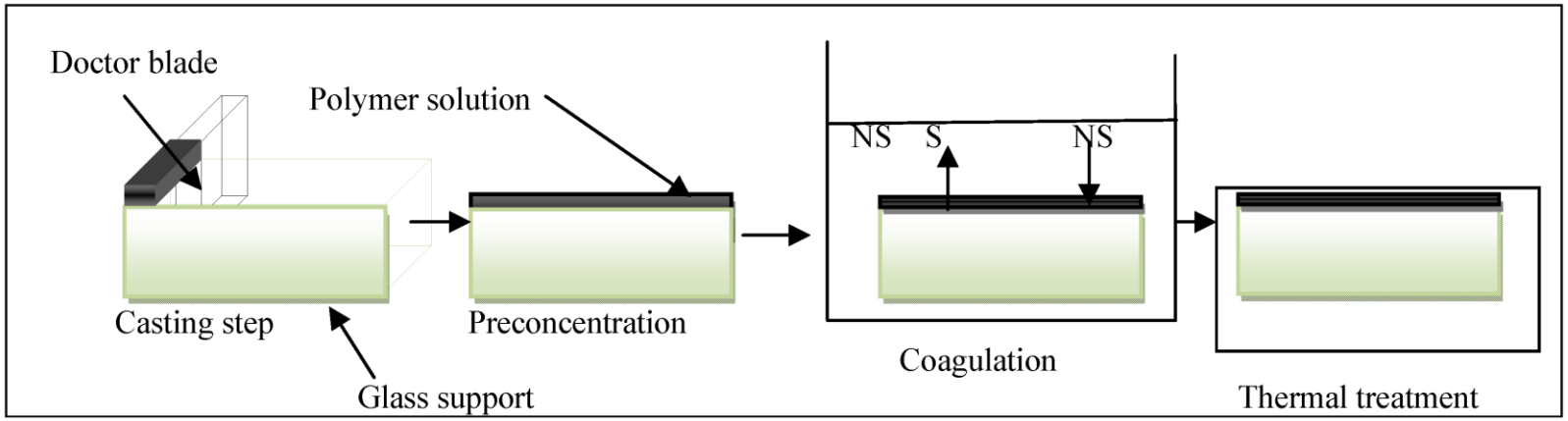
Polymeric membrane preparation
ISA membrane

- Casting the membrane
- Aqueous coagulation



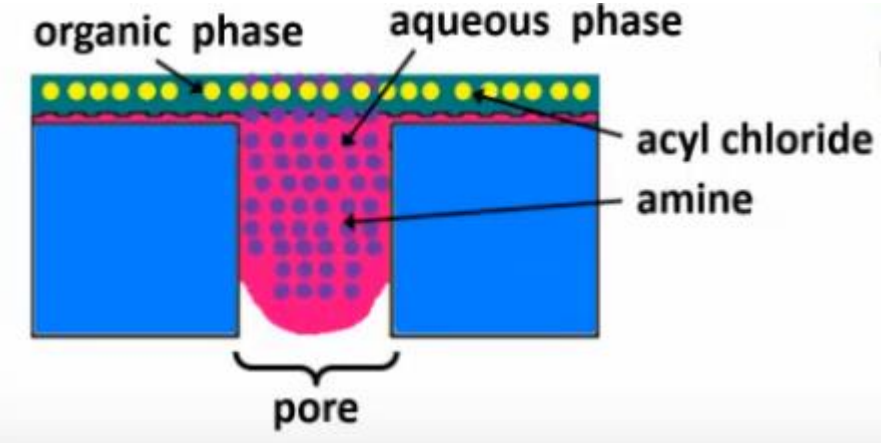
Polyetheramide PEI 23% wt/wt in DMAc

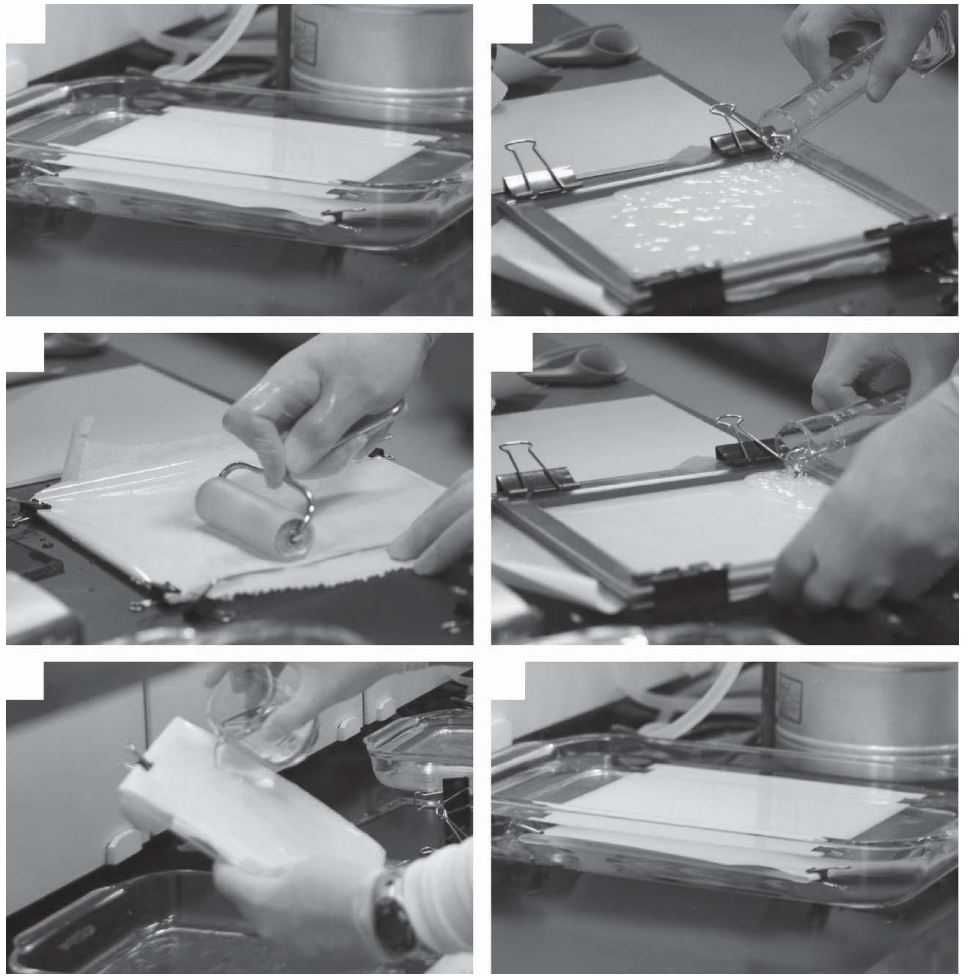




Polymeric membrane preparation
TFC membrane

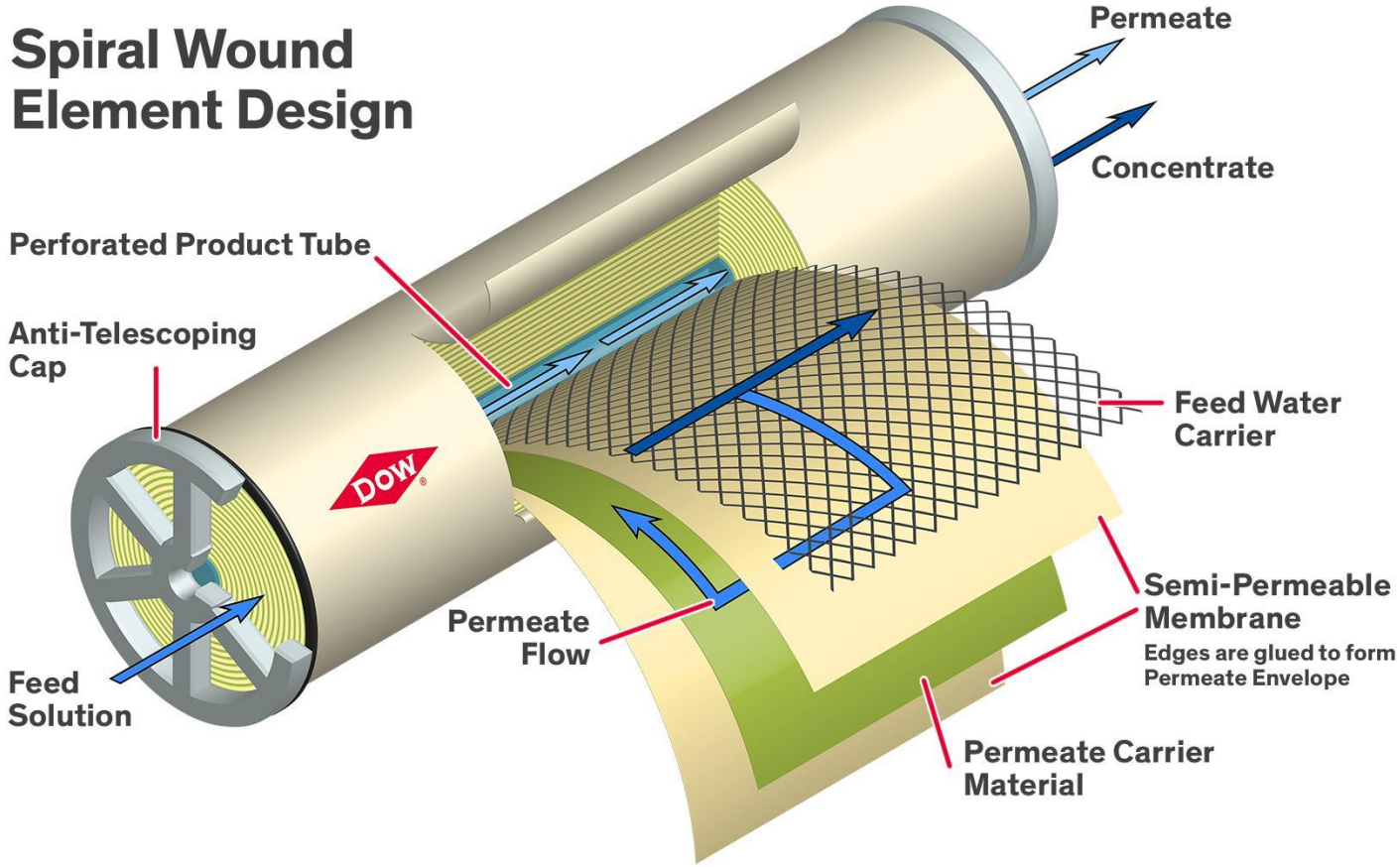
- Interfacial polymerization (IP)
- Aqueous phase
- Organic phase



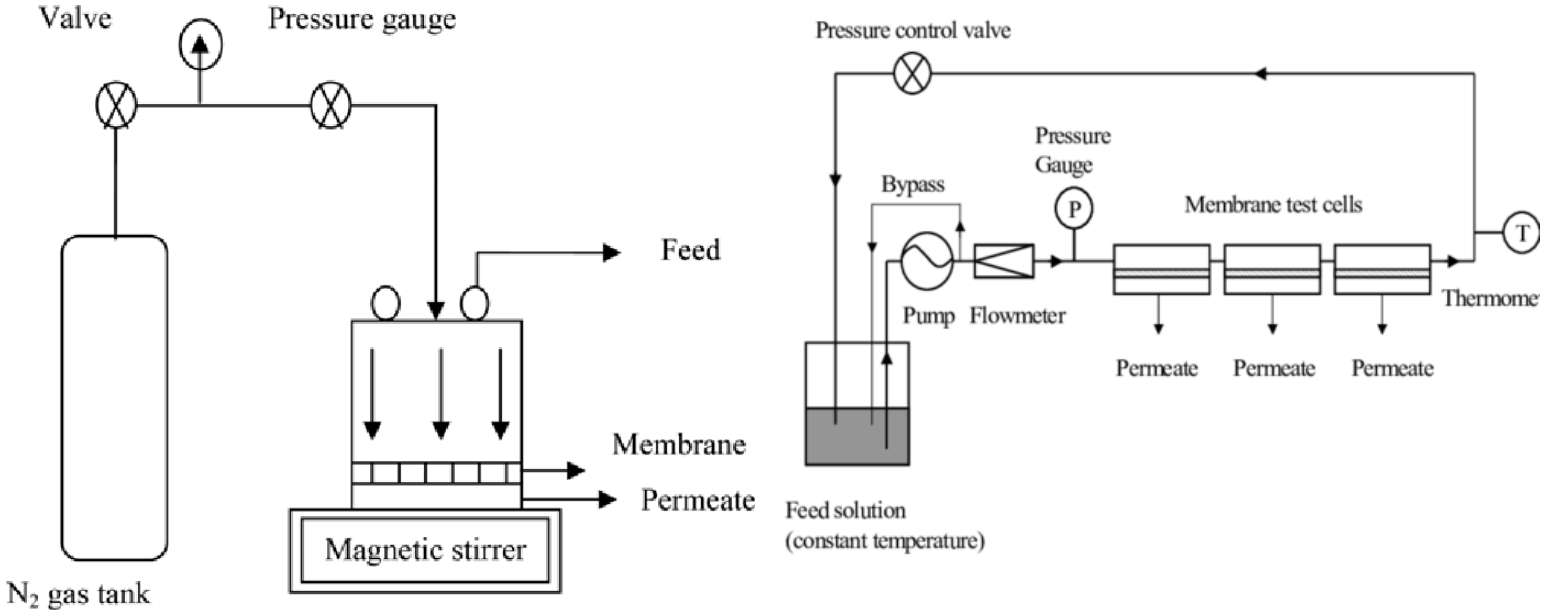


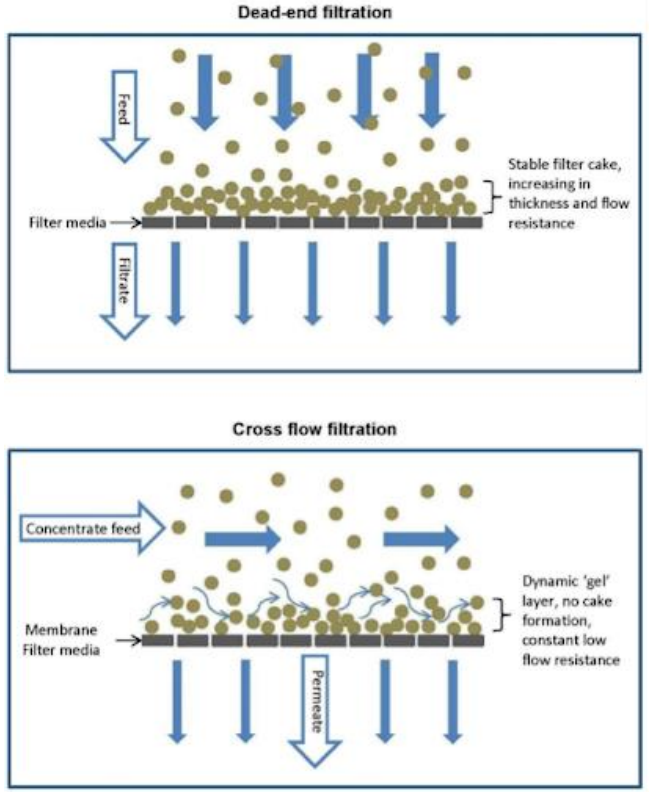
Prepare the membrane for application
Module the membrane

- Module the membrane sheet to spiral module



Nanofiltration evaluation
Dead-end VS cross-flow

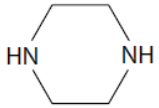
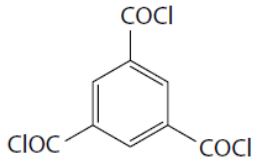
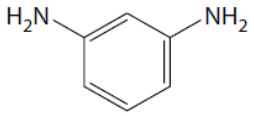
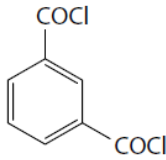
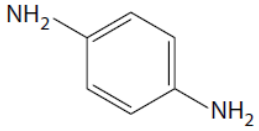
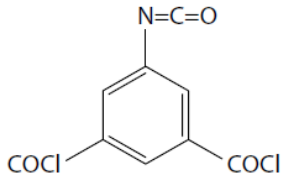




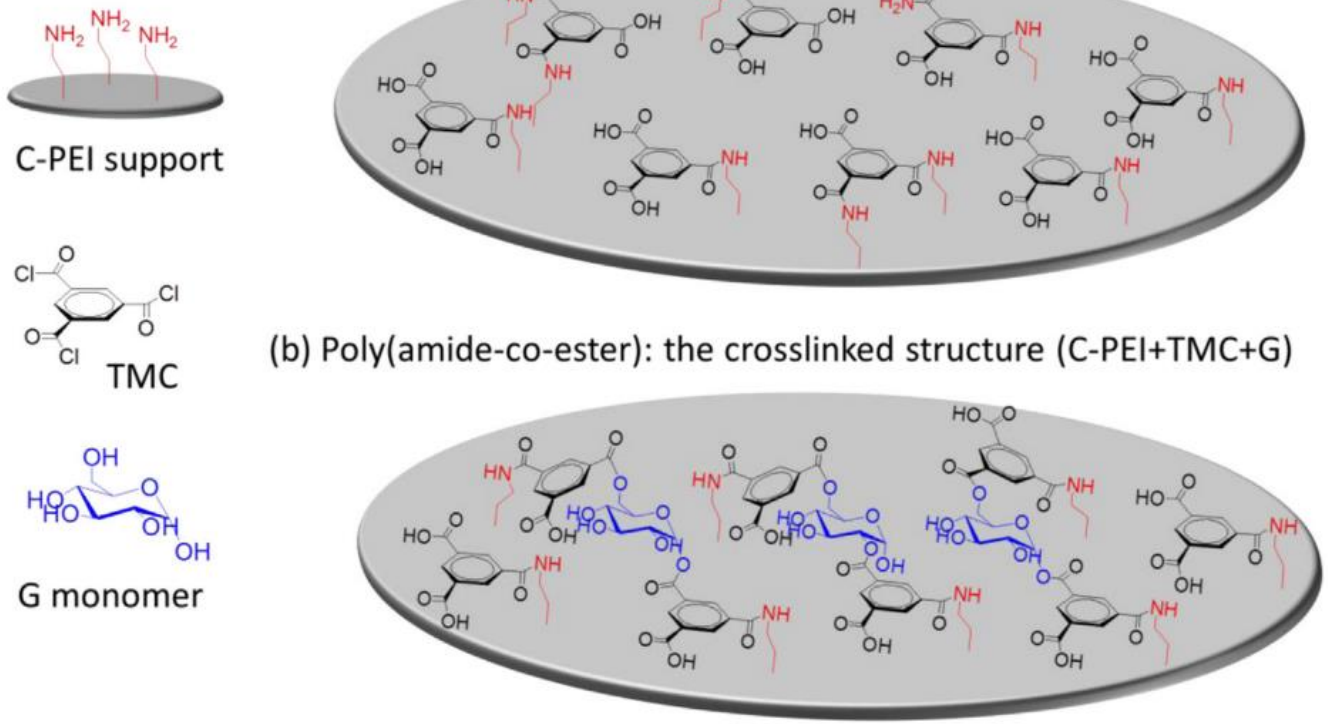
Polyamide TFC membrane
The used monomers

- The aqueous phase contains a diamine monomer
- The organic phase contains a acid chloride

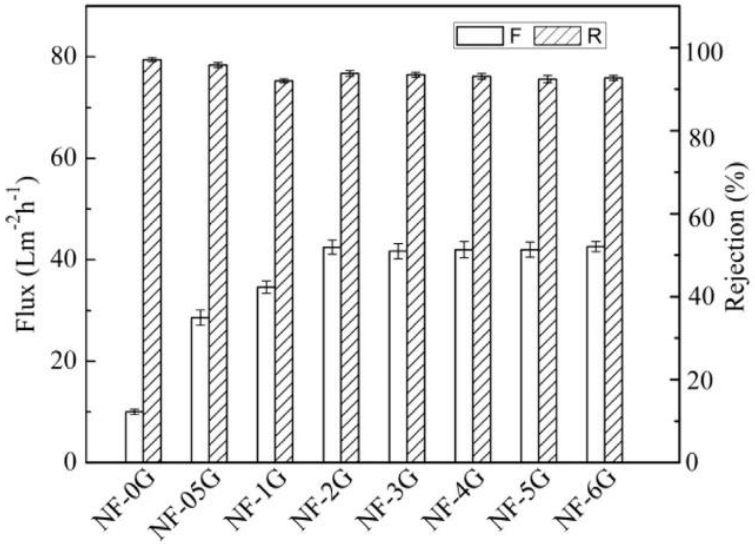
Organic Structure of Commonly Used Monomers for PA Thin Layer Synthesis Together with Their Respective MW

Amine Monomer (Abbreviation)	Chemical Structure	Molecular Weight (g mol^{-1})	Acyl Chloride Monomer (Abbreviation)	Chemical Structure	Molecular Weight (g mol^{-1})
Piperazine (PIP)		86.14	Trimesoyl chloride (TMC)		265.48
m-Phenylenediamine (MPD)		108.10	Isophthaloyl chloride (IPC)		203.02
p-phenylenediamine (PPD)		108.10	5-isocyanato-isophthaloyl chloride (ICIC)		243.04

poly(amide-co-ester) nanofiltration membrane Hydrophilic membrane

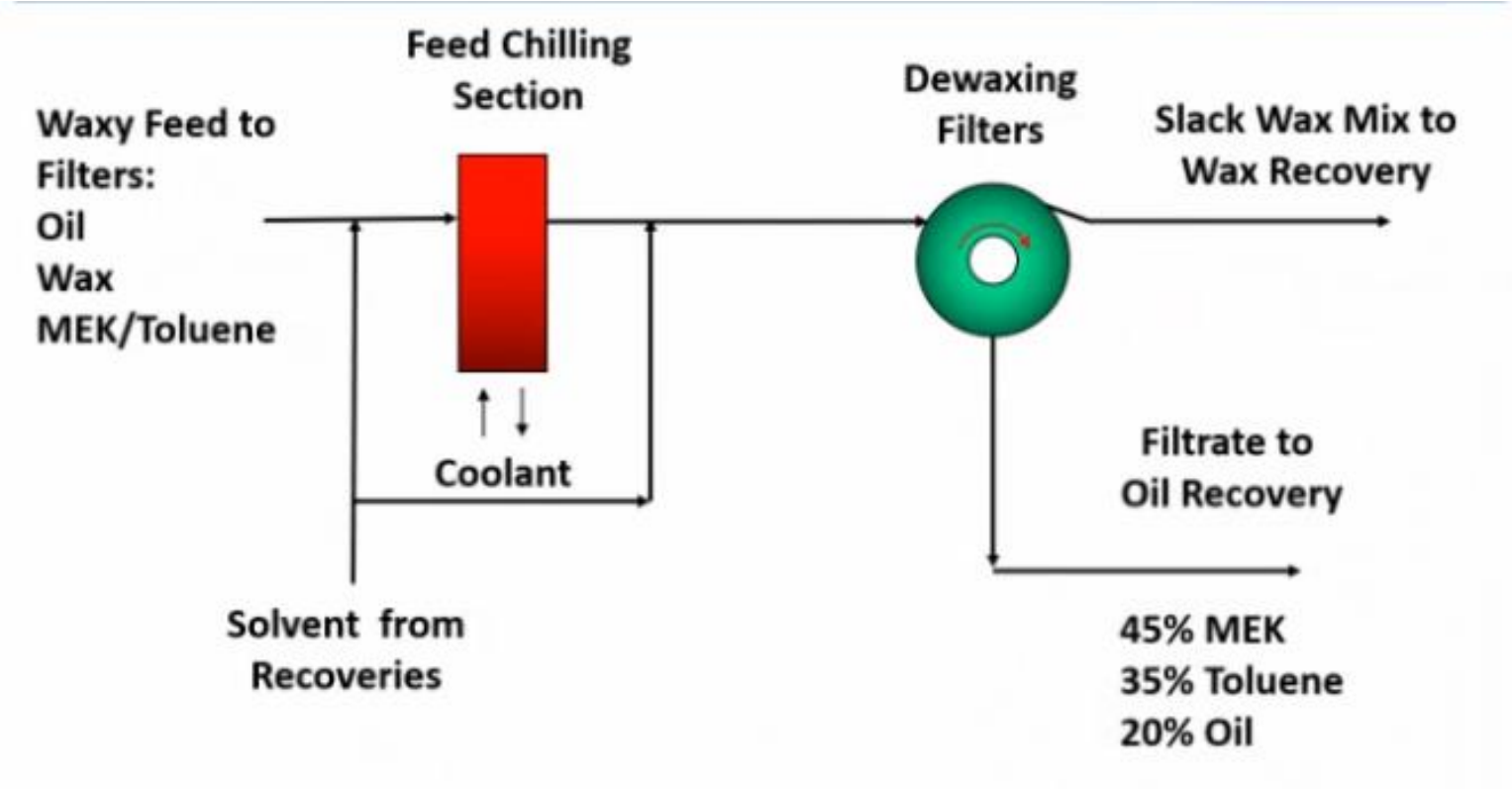


Membrane	Contact angles (deg)
NF-0G	40.7 ± 2.8
NF-1G	30.6 ± 1.6
NF-2G	29.1 ± 0.9
NF-4G	26.5 ± 0.5



Bian et al. Journal of Membrane Science 504 (2016) pp185–195

Nanofiltration for organic system
Lube oil extraction



lab scale 1993

Large scale 1999

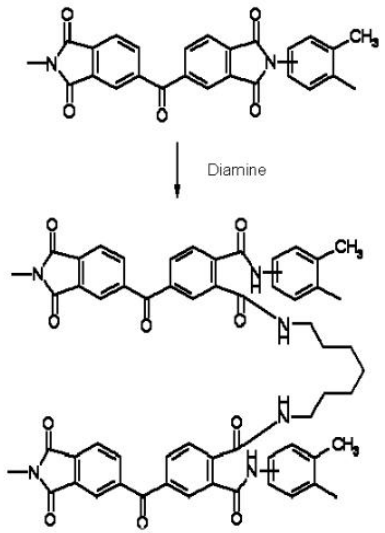
Capacity 11,000 m^3/day solvent

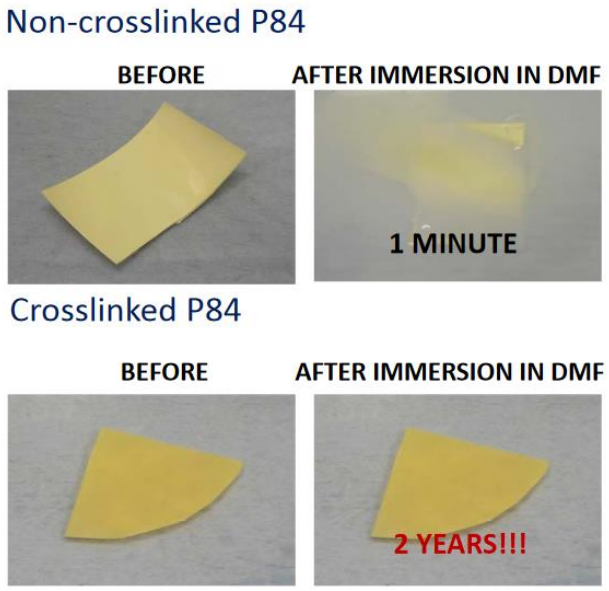
Project cost $6 million in 2000

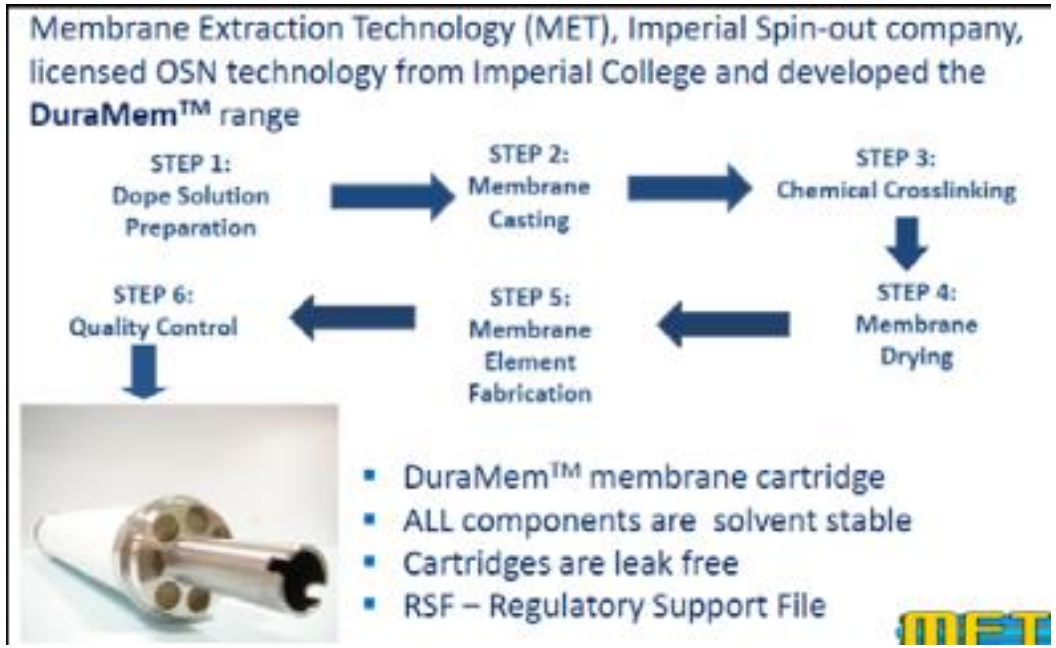
Net benefits $6 million per year

From aqueous to organic solvent applications
Organic solvent nanofiltration (OSN) membranes

- Membrane solvent resistant
- Crosslinking the membrane

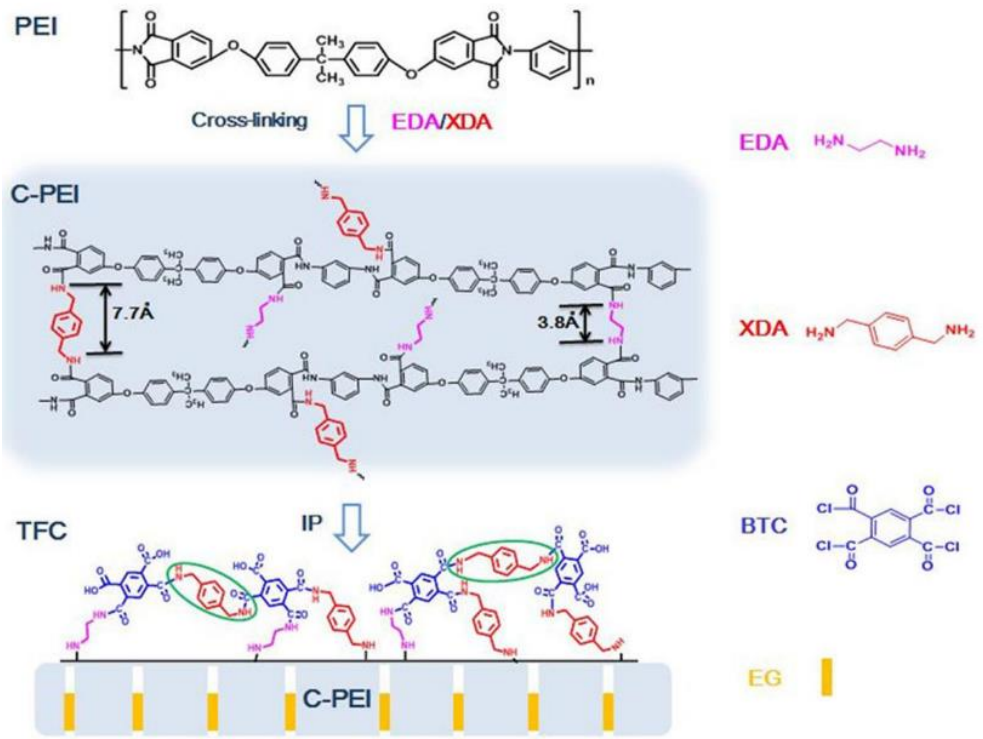




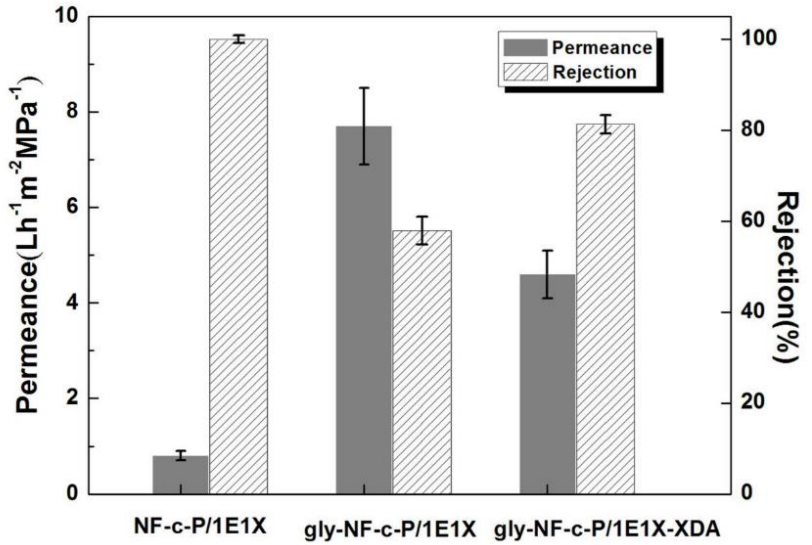


Toh etal.,J.Membr.Sci.301(2007) pp1-10

Polyamide OSN membrane
one step IP with different crosslinkers



Ethylene glycol filling inside the intermediate pores.

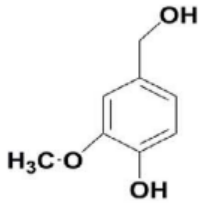


The permeance and rejection of modified NF membranes of gly-NF-c-P/1E1X and gly-NF-c-P/1E1X-XDA versus NF-c-P/1E1X for **RB DMF solution**.

Xiao et al. Separation and Purification Technology 206 (2018) pp 247-255

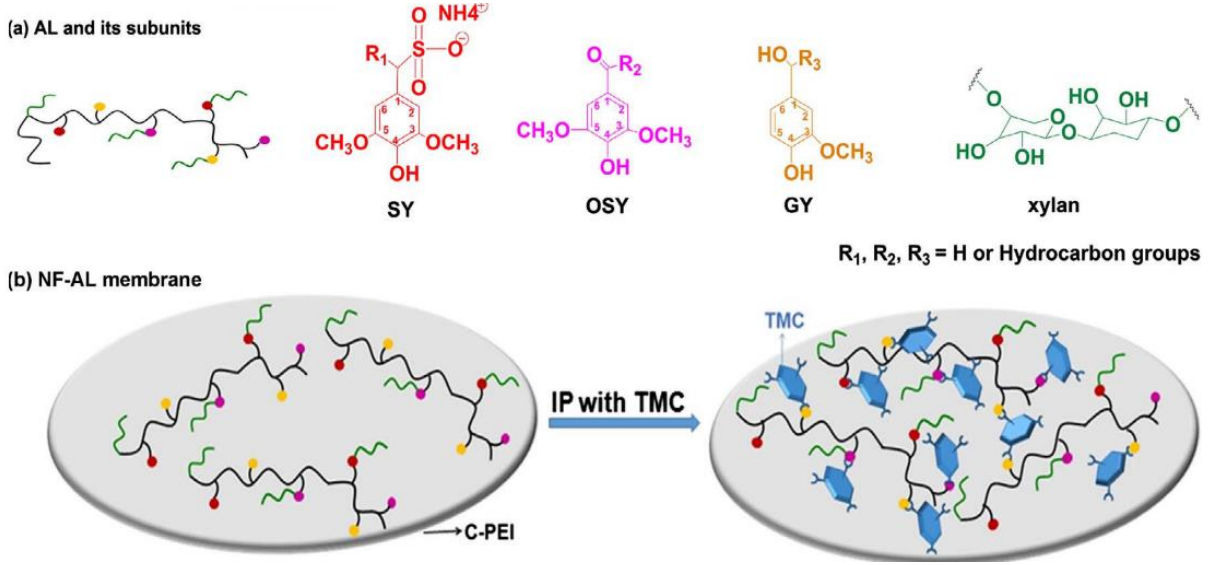
Polyarylester OSN nanofiltration membrane
High DMSO permeance

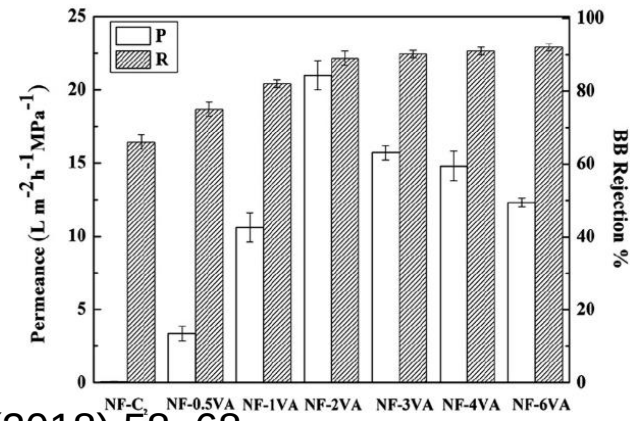
vanillic alcohol was adopted
high DMSO permeance
21 Lm−2 h−1 MPa−1

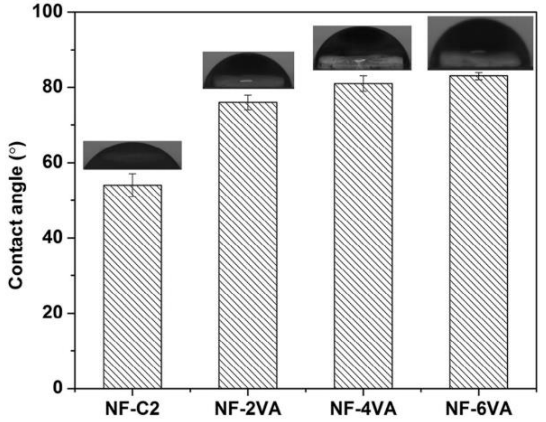


vanillic alcohol

The performance of NF membranes with different VA concentrations (0, 0.5%, 1%, 2%, 3%, 4%, 6% (w/v)) for a 0.01 g L−1 BB DMSO solution.



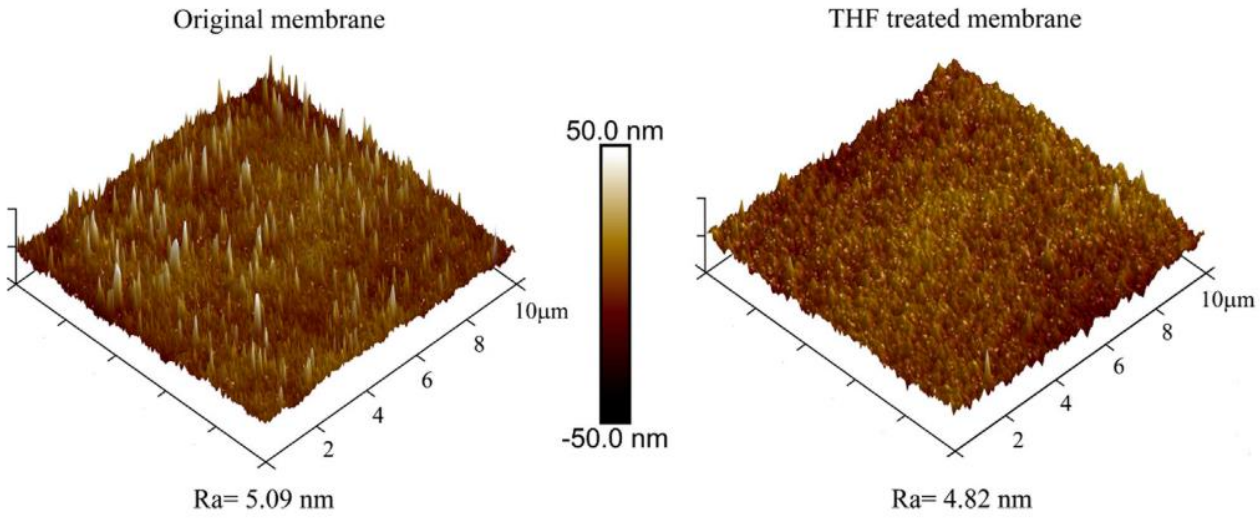


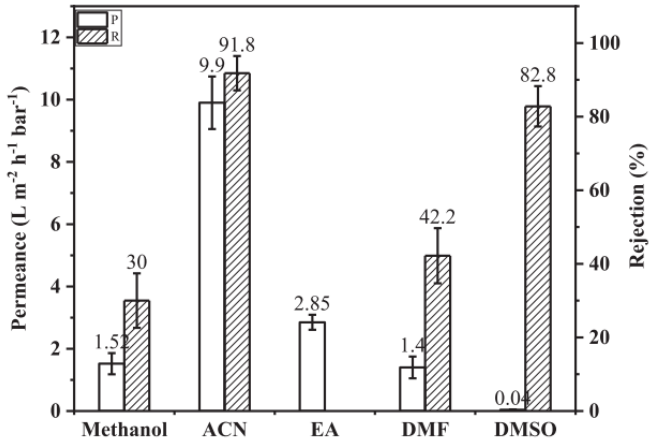


Zhou et al. Separation and Purification Technology 193 (2018) 58–68

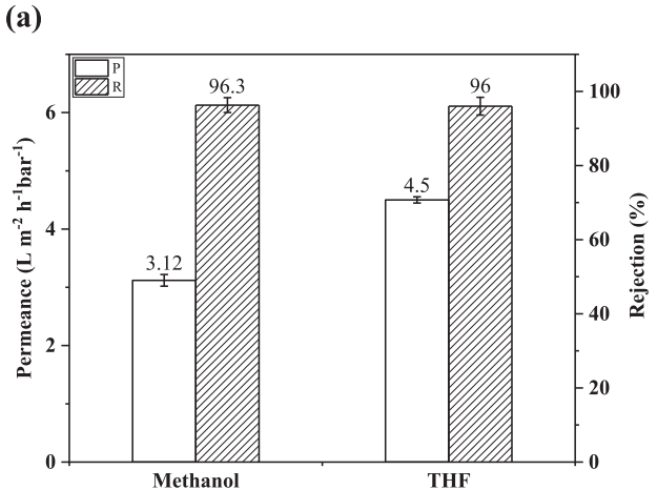
TFC membrane post treatment
Solvent activation

Polyetheramide membrane
24 h-THF immersion





Original membrane

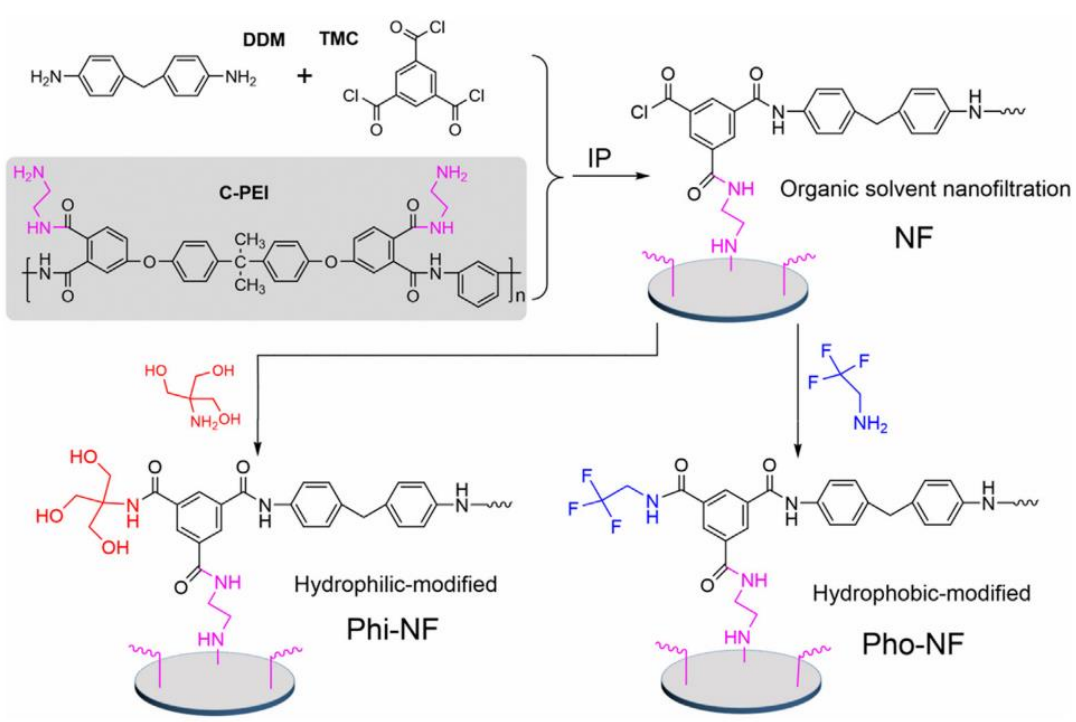


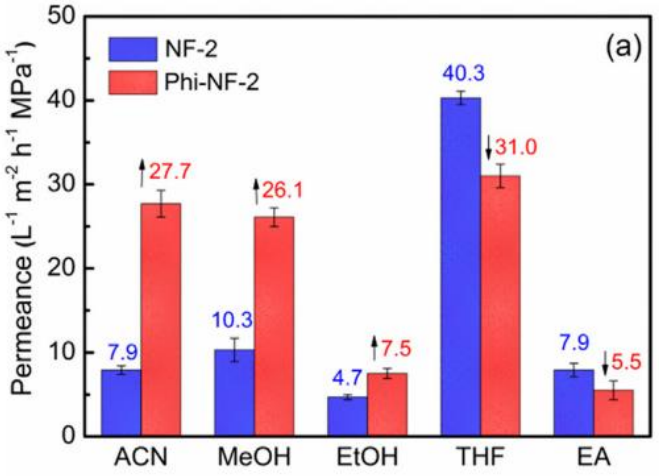
Treated membrane

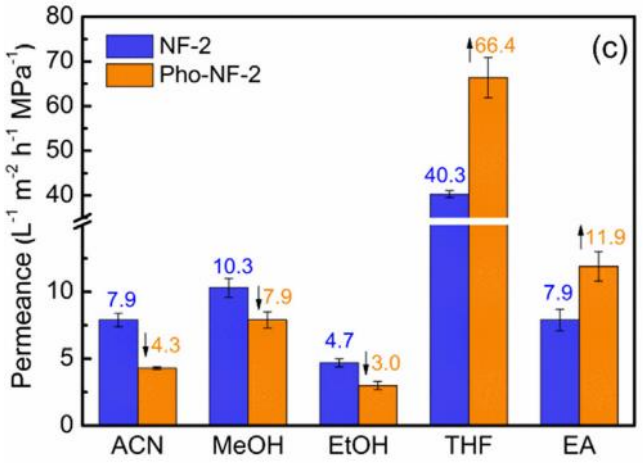
Almijbilee et al. Separation and Purification Technology 234 (2020) 116033

Surface hydrophobicity effect
Modulate hydrophobicity polyamide OSN membrane surface

Hydrophobic- High THF permeance



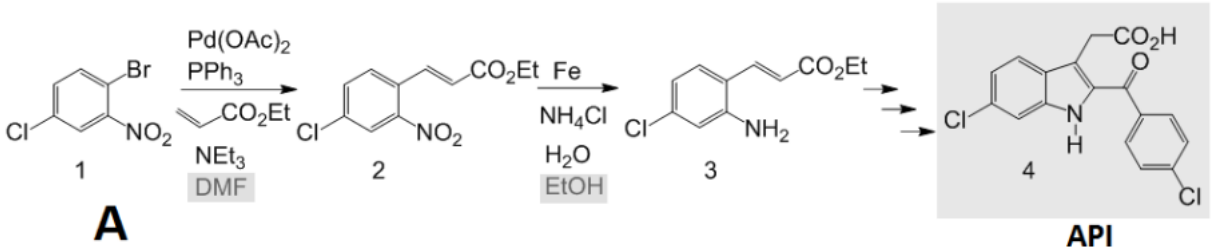




OSN applications to Sequential Reactions pharmaceutical applications

Synthesis route for a COX-2 inhibitor candidate drug published by Pfizer

Multi-step synthesis that require solvent exchange – DMF to Ethanol

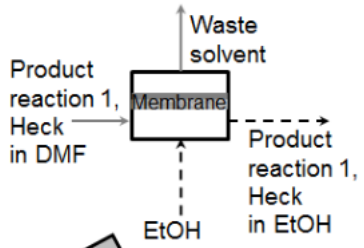


A

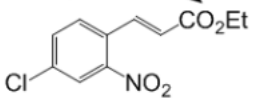
Published procedure for solvent exchange

1. Extraction with toluene
2. Wash with 1 N HCl
3. Wash with water
4. Wash with water
5. Concentration to oil via evaporation
6. Crystallisation in hexane
7. Dissolution in ethanol

Membrane cascade solvent exchange



B



Ethanol solution of cinnamate

OSN applications in food industries

- Concentrated the **fruit juices** without losing the color and taste
- Milk industries **protein valorization** between (200–1000 Da)
- Recovery of **lactic acids (LA) and amino acids**
- Vegetable oil processing, the molecular weight of triglycerides and phospholipids are roughly in the range of 900 and 800 Da
- Flavonoids, protein, and other natural products extraction

Concluding

- Extraction by membranes save massive amounts of energy over alternatives such as evaporation
- Nanofiltration in organic solvents is still in its infancy relative to RO, but will also lead to massive energy savings
- Understanding membrane formation and function can lead to fundamental insights which catalyze process improvements
- Most important membrane improvements are likely to be improving stability and chemical resistance, and selectivity

Acknowlegdements....

- Al-qasim green university-college of food science
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- Dr. Ali Raad
- Chemical Process Intensification (*CPI*) team

.....and to you for listening