

# Transport modelling of RO

Symbolically:

$$J = \frac{(\text{permeability})(\text{driving force})}{\text{thickness}} = (\text{permeance})(\text{driving force}) = \frac{\text{driving force}}{\text{resistance}}$$

- ▶ permeability =  
 $f$ (membrane properties, diffusivity, other physical properties)
- ▶ permeance: easier to calculate:
  - ▶ given the driving force (easy to measure)
  - ▶ given the flux (easy to measure)
- ▶ units are always case specific and must be self-consistent  
[check!]

# Simplified RO modelling

- ▶ We don't consider "cake build-up": we assume that solid particles are mostly removed in an upstream separation step
- ▶ So  $\Delta P$  overcomes osmotic pressure and membrane resistance

## 1. Solvent flux

$$J_v = J_{\text{solv}} = \frac{(\Delta P - \Delta \pi)}{R_{m,v} + \cancel{R_{cp,v}}} \overset{0}{=} \frac{P_{\text{solv}}}{\ell_M} (\Delta P - \Delta \pi)$$

$R_{m,v} = f(\ell_M = \text{membrane's thickness, diffusivity of solvent in membrane})$

## 2. Solute (salt) flux

$$J_{\text{salt}} = \frac{(\text{permeability})(\text{driving force})}{\text{resistance}} = \frac{P_{\text{salt}}}{\ell_M} (C_w - C_p)$$

- ▶ Our assumption:  $C_{\text{wall}} \approx C_{\text{bulk}} = \text{bulk solute conc}^n = C_p$ 
  - ▶ how would you enforce this reasonable assumption?
- ▶ Crudely assume:  $C_{\text{bulk}} \approx C_{\text{feed}}$  [for back-of-envelope calculations]
- ▶  $P_{\text{solv}}$  = permeability of the solvent [notation:  $P_{\text{solv}} \equiv P_w$ ]
- ▶  $C_p$  = concentration of solute in the permeate
- ▶  $P_{\text{salt}}$  = permeability of the salt through membrane

## Example to try

Brackish water of 1.8wt% NaCl at 25°C and 1000 psia is fed to a spiral wound membrane.

Conditions on the permeate side are 0.05 wt% NaCl, at same temperature, but 50 psia.

The permeance of water has been established as  $1.1 \times 10^{-4} \text{ kg.s}^{-1}.\text{m}^{-2}.\text{atm}^{-1}$  [how would you get this number?] and  $16 \times 10^{-8} \text{ m.s}^{-1}$  for salt is determined experimentally.

1. Calculate the flux of water in LMH.
2. What is the flux of salt through the membrane?
3. How do these fluxes compare?
4. Calculate the rejection coefficient,  $R$ , for salt.

## Another example: calculating permeances

At 25 °C in a lab membrane with area  $A = 2 \times 10^{-3} \text{ m}^2$  we feed a solution of 10 kg NaCl per  $\text{m}^3$  solution so well mixed and so rapidly that essentially it has the same strength leaving.

The permeate is measured as 0.39 kg NaCl per  $\text{m}^3$  solution at a rate of  $1.92 \times 10^{-8} \text{ m}^3 \cdot \text{s}^{-1}$  when applying a constant pressure difference of 54.42 atm.

Calculate the permeance constants for solvent and salt (these were previously given, this example shows how to calculate them experimentally), as well as the rejection coefficient.

## Some questions to consider

1. What happens, in terms of osmosis, on a really hot day to fluid flow in a tree?
2. Is  $P_{\text{solv}}$  going to change if we use a different solute?
3. If we double the pressure drop, will we double the solvent flux?
4. Why did we not take osmotic pressure in account for microfiltration and ultrafiltration?
5. In RO: what will be the expected effect of increasing operating temperature?

## Some old and new terminology

Recall from ultrafiltration:

- ▶  $R = 1 - \frac{C_P}{C_{\text{feed}}} \approx 1 - \frac{C_P}{C_{\text{bulk}}}$
- ▶ This rejection coefficient,  $R$ , also applies to reverse osmosis.
- ▶ A new term = cut = conversion = recovery =  $\theta = \frac{Q_P}{Q_F}$  is between 40 and 50% typically