

Ion beam analysis of materials for water purification: Partitioning of inorganic ions in FT30 reverse osmosis membranes

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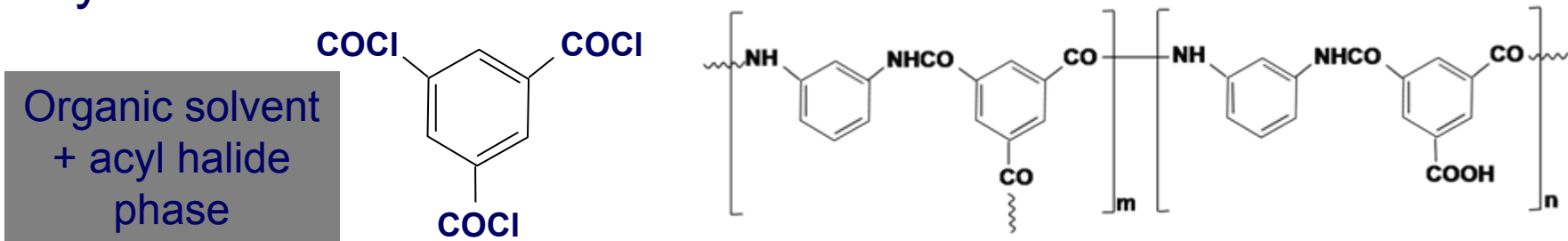
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Motivation: limited microscopic understanding of transport in interfacially polymerized membranes

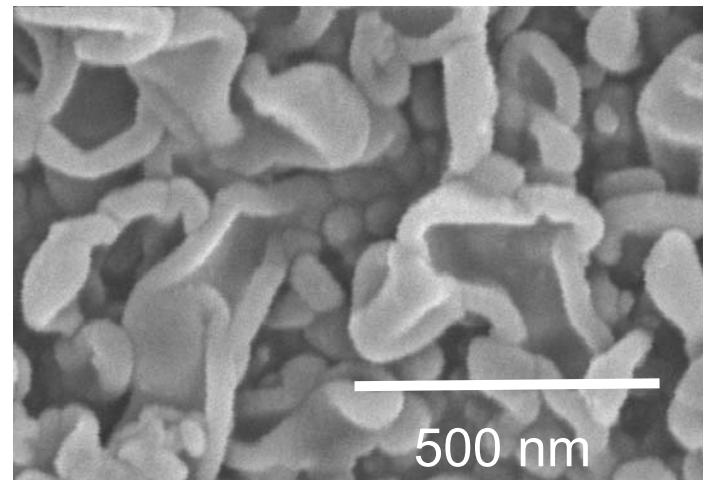
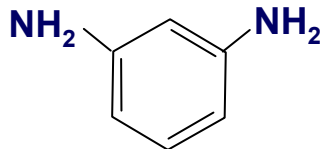
- Technology of polyamide membranes for purifying water has seen only minor incremental changes in >30 years.



Polyamide
~100 nm

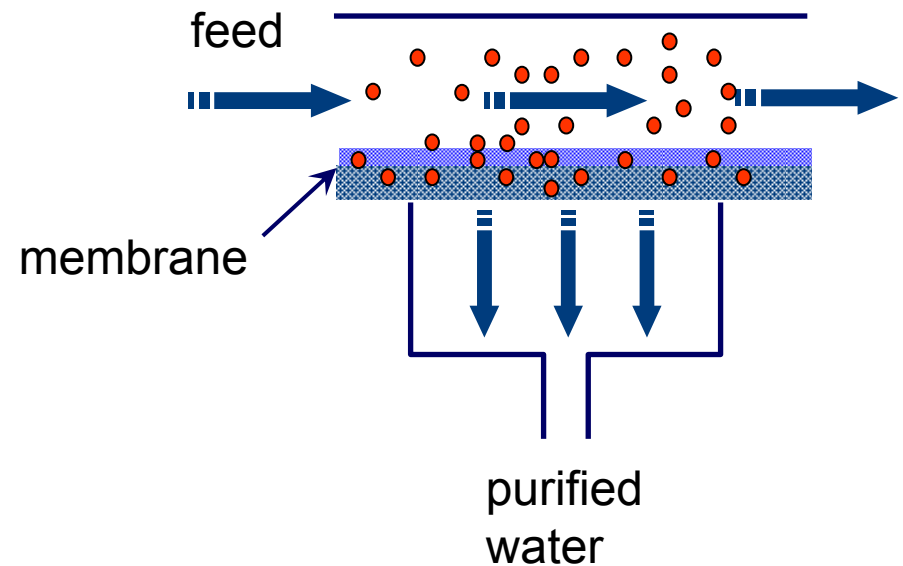


Water +
amine phase

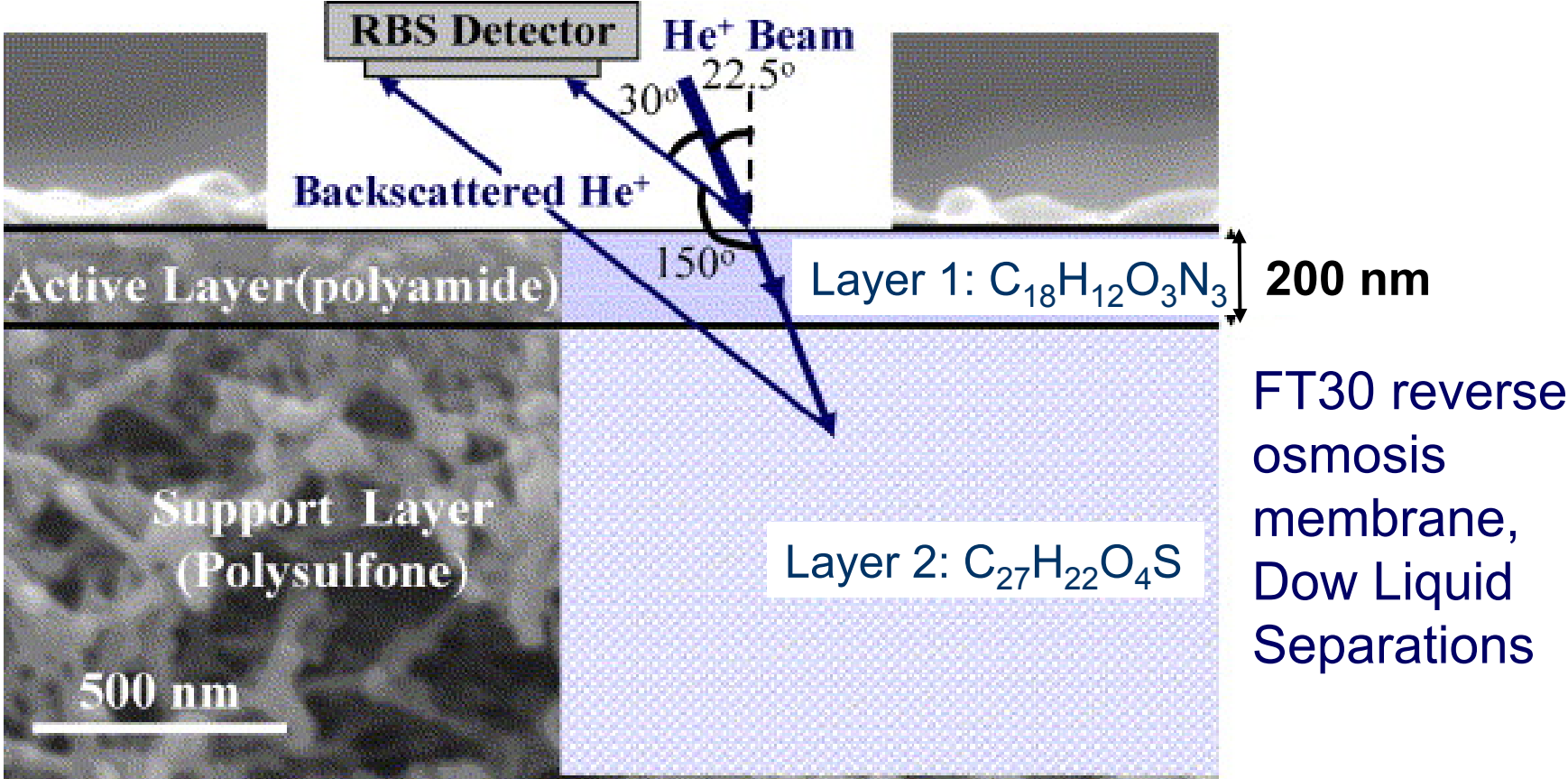


Permeability is the product of solubility (i.e., partition coefficient K) and diffusion constant D .

- Goal is high rejection of salts and contaminants
 - Need high permeability to water (solvent) but low permeability to contaminants (solute)
- Steady-state transport measurements cannot distinguish between small partition coefficient K and small diffusivity



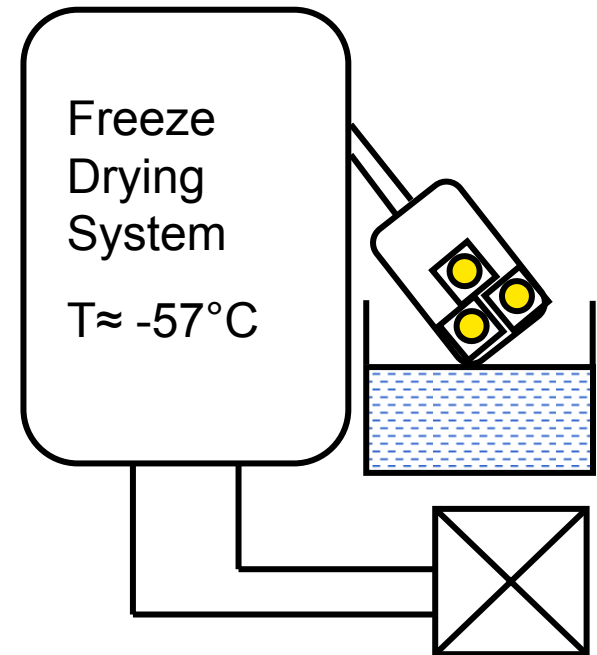
Use ion beam analysis (RBS) to measure K of salt ions



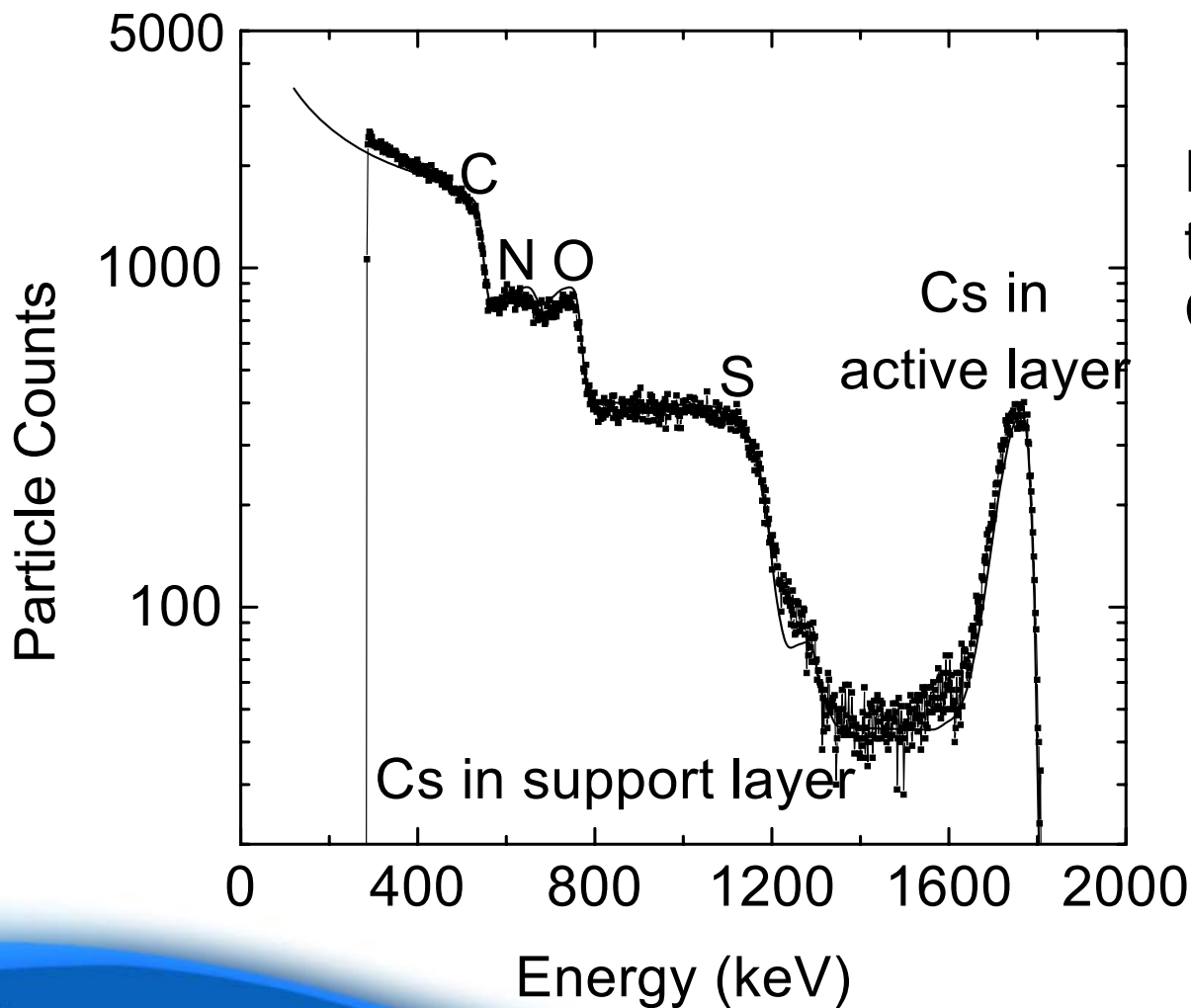
Conventional wisdom is $K \ll 1$; we find $K \approx 5$.

Sample preparation is critical

- Use high Z ions to increase sensitivity
 - Cs⁺ in CsCl
 - Br⁻ in KBr
 - WO₄²⁻ in Na₂WO₄
- Freeze-dry to remove water without disturbing the ion distribution
- Polysulfone is highly susceptible to ion beam damage
 - Scan RBS beam to minimize ion dose



RBS can determine both the K of the active layer and the porosity of the support layer



FT30 membrane treated in 0.05 M CsCl solution.



Ion Concentrations in Active Layers and Support Layers

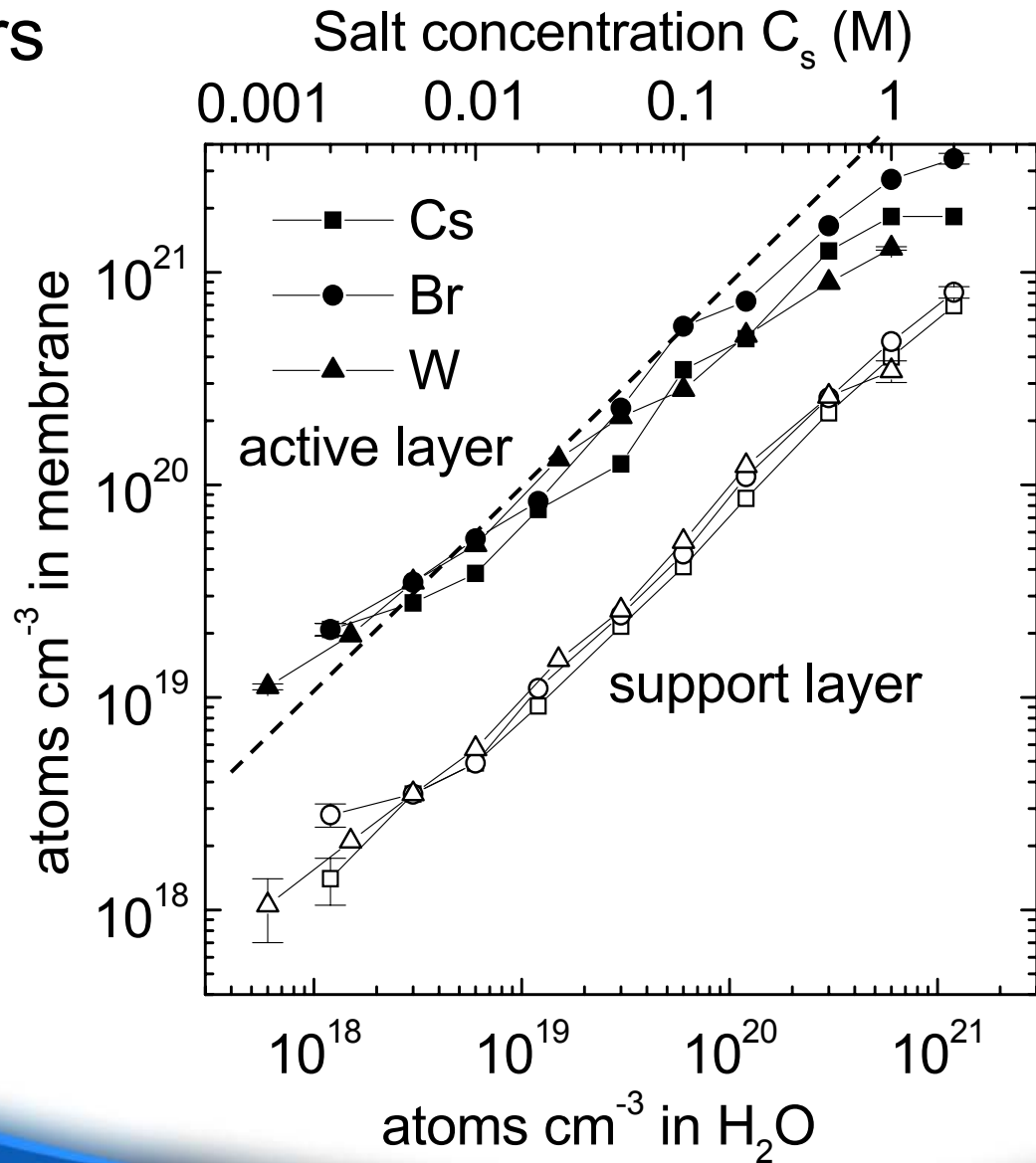
Cs^+ in CsCl

Br^- in KBr

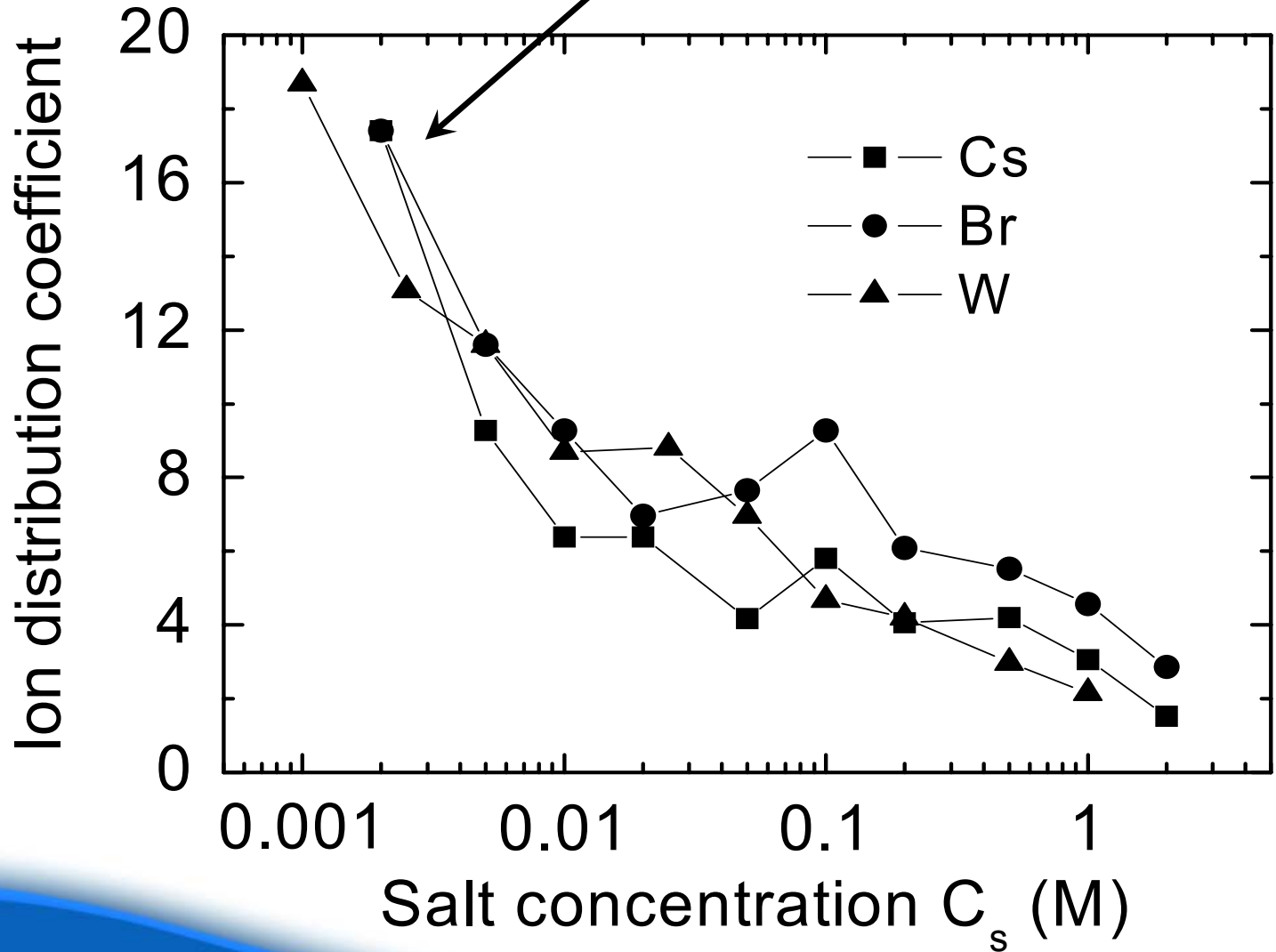
WO_4^{2-} in Na_2WO_4

Cs^+ , Br^- $r = 3 \text{ \AA}$

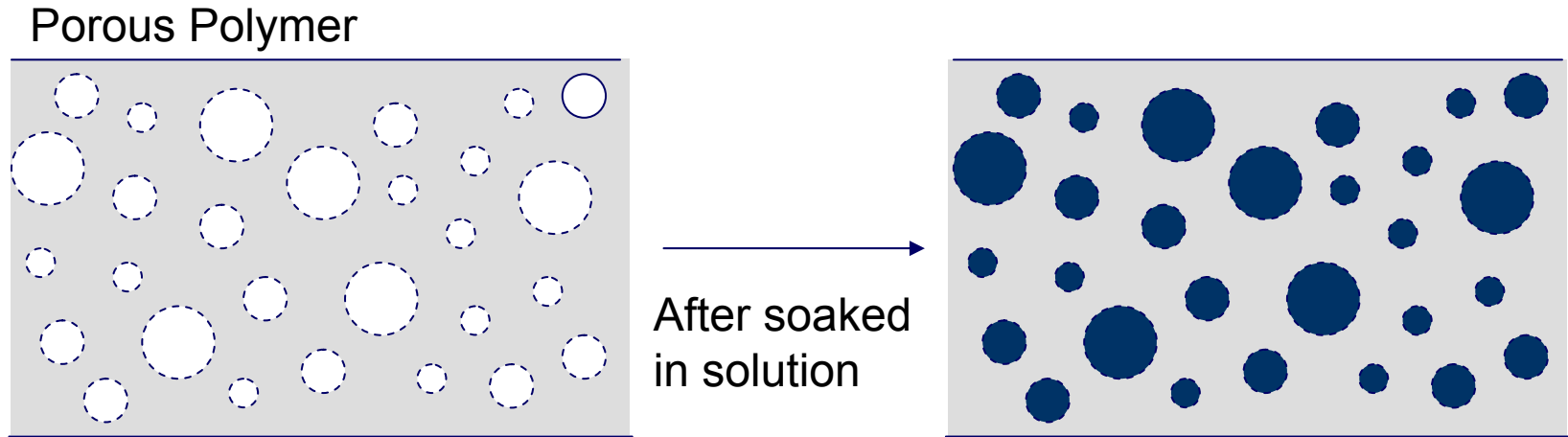
WO_4^{2-} $r = 4 \text{ \AA}$



Upturn caused by binding to charged functional groups



RBS can depth profile the porosity of the support layer



Atomic density of key element in solution: N_i . For example, 0.05 M equals to $3 \times 10^{19} \text{ cm}^{-3}$

Atomic density in polymer: $N_p \approx 9 \times 10^{22} \text{ cm}^{-3}$

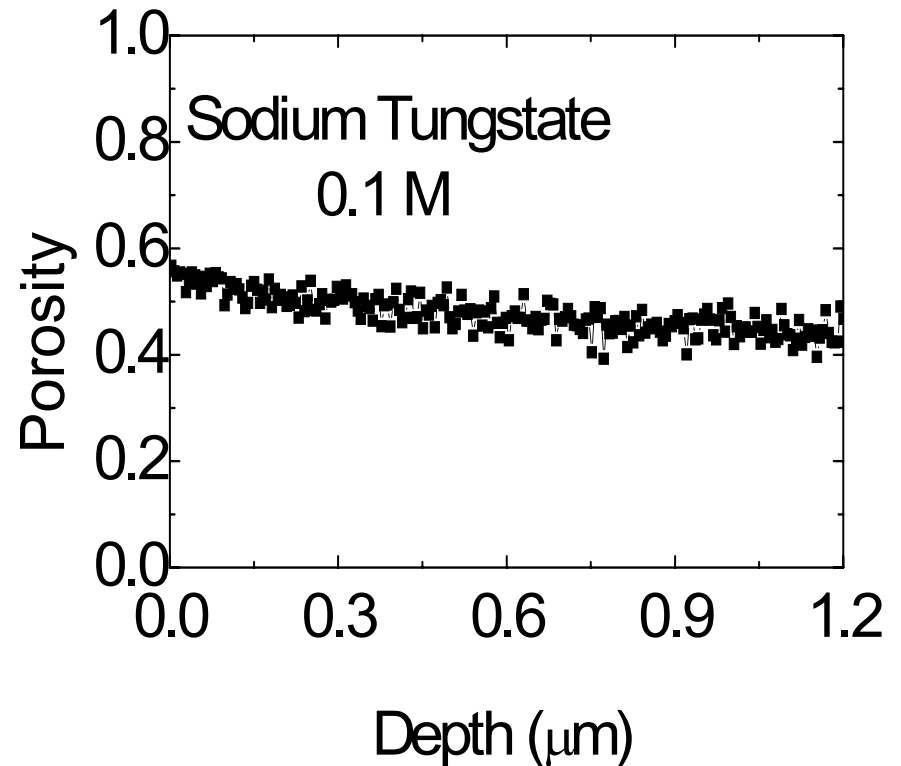
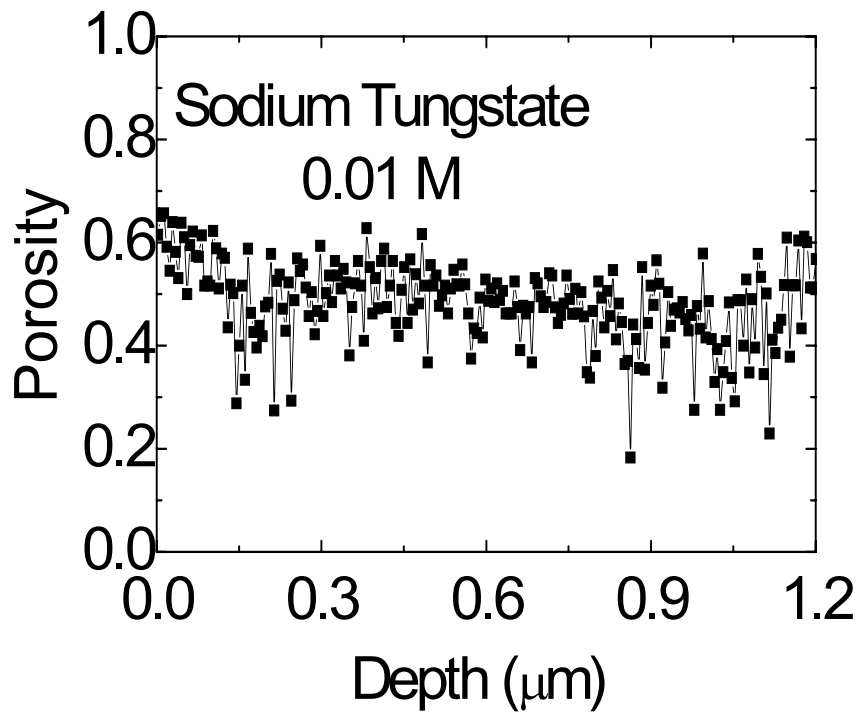
Volume of pores V_o and volume of polymer V_p

Atomic percentage of the key element in polymer $x = V_o N_i / V_p N_p$

$$\text{Porosity } \phi = V_o / (V_p + V_o) = \frac{x \frac{N_p}{N_i}}{1 + x \frac{N_p}{N_i}}$$



Profile of porosity in the support layer



Summary

- Ion beam analysis has much to offer the field of “materials for water purification”
- Freeze-drying is a critical step in sample preparation but are there still issues of ion redistribution?
- Partition coefficient of salt ions in the active layer is surprisingly high, $K \approx 6$, much larger expected based on conventional wisdom.
- Greater depth resolution would be helpful since interfacially polymerized membranes are thin (<200 nm) and highly inhomogeneous.

