Heterogeneous Anion Exchange Membranes for Electrochemical Applications

Ashleigh Herrera, Wayz R Khan, Chris J Cornelius

University of Nebraska Lincoln | NEBRASKA CENTER FOR ENERGY SCIENCES RESEARCH

Introduction

Anion exchange membranes (AEMs) have great potential for fuel cell applications. Unlike traditional proton-exchange membranes, which require acidic catalytic conditions like platinum, AEMs can operate with alternative catalysts and have better structural stability. Therefore, understanding morphological relationships of AEMs is crucial to both expanding current knowledge and opening possibilities for greater fuel cell applications.

Multiblock poly(arylene ether sulfone)-based copolymers (mPAES) containing quaternary ammonium groups were synthesized for this study. Water uptake, hydration, conductivity, and swelling ratio (also at varying temperatures) were measured to study the relationships between the different properties. Water uptake was measured from the mass of the wet and dry membrane. Hydration number was also measured. Conductivity was measured by four-probe electrochemical impedance spectroscopy (EIS). Swelling ratio involved measuring the thickness and length of the membrane in both wet and dry form.

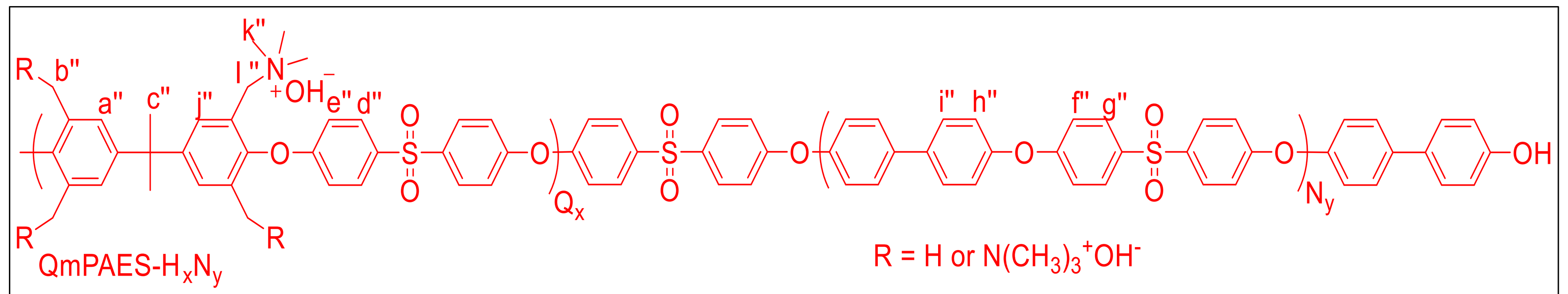
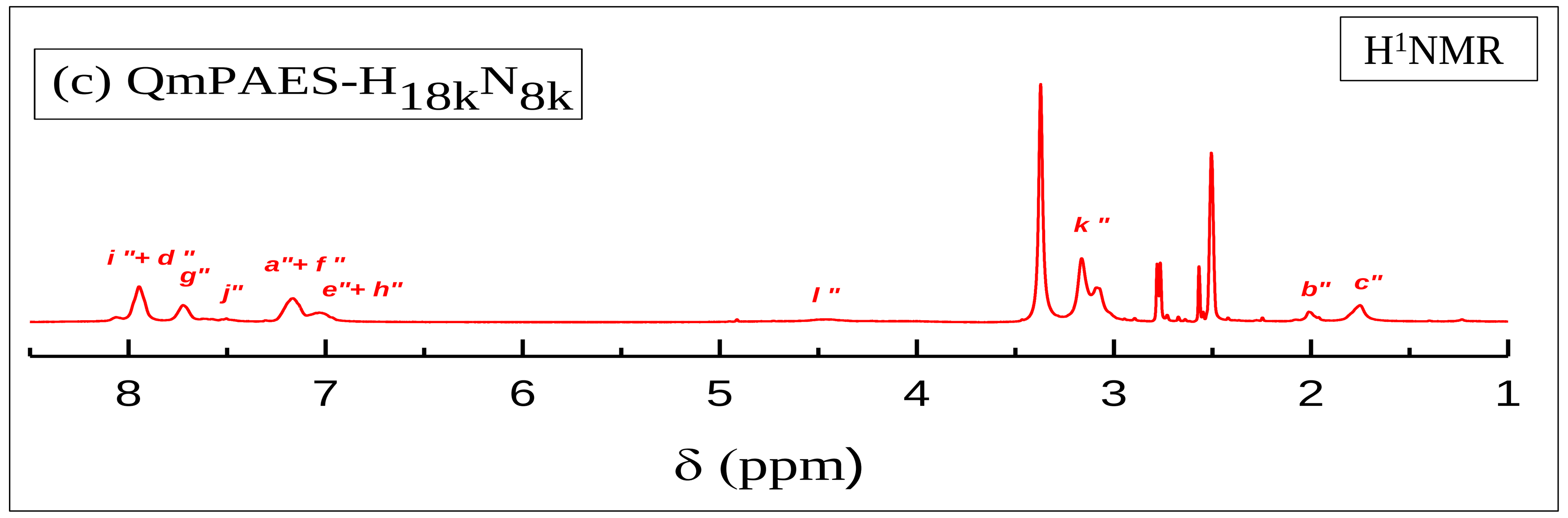
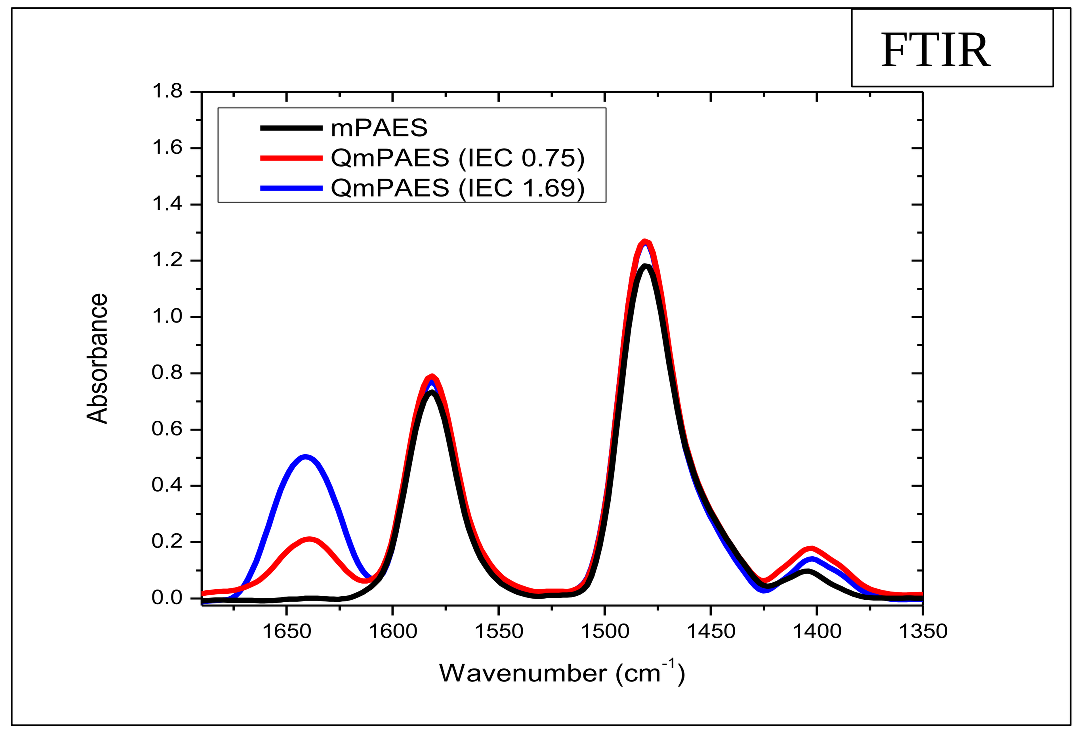


Figure 1. QmPAES structure



The peaks at ~1650 indicate the C-N group. The peaks at ~1575 indicate C=C. The peaks at ~1475 indicate C=C nonidentical to the ~1575 peak. Both are indicative of the phenyl ring bonding.



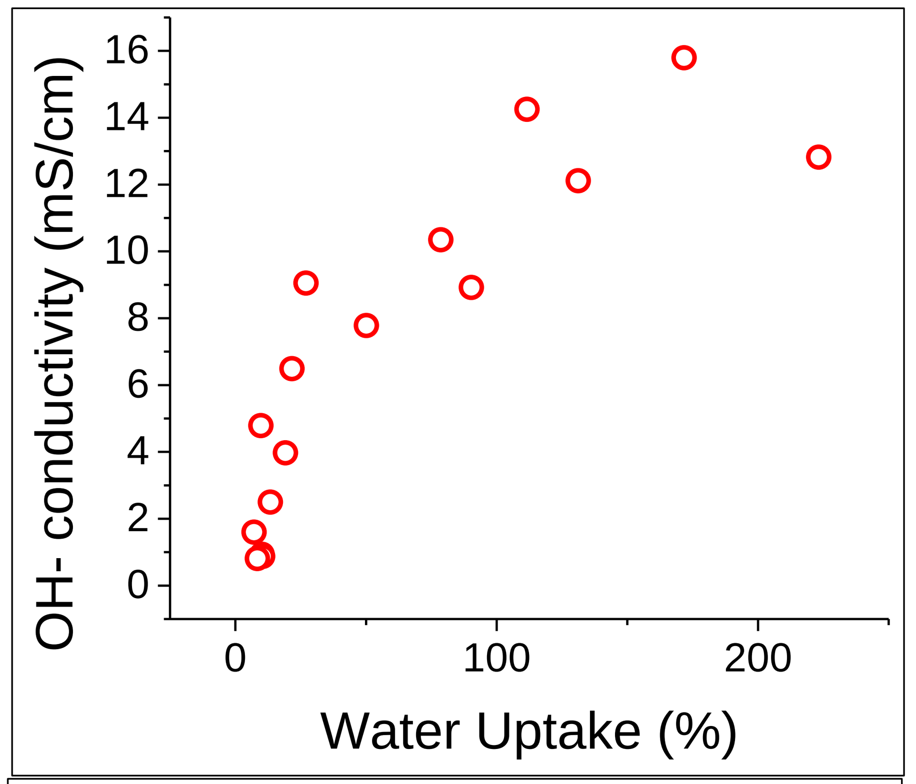


Figure 4. Water Uptake vs. Conductivity

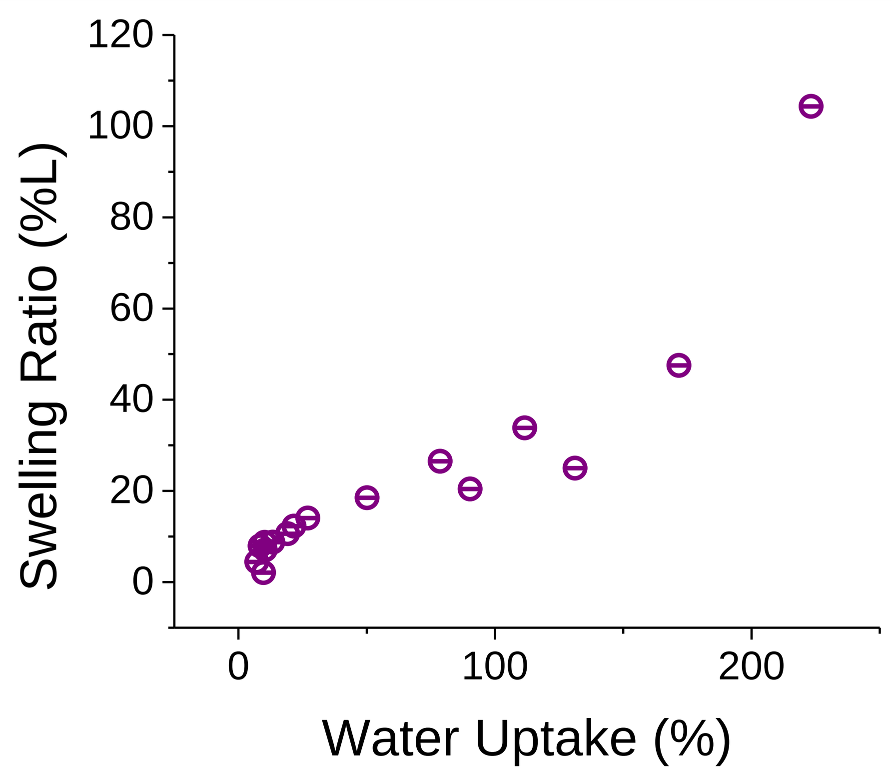


Figure 5. Water Uptake vs. Swelling Ratio

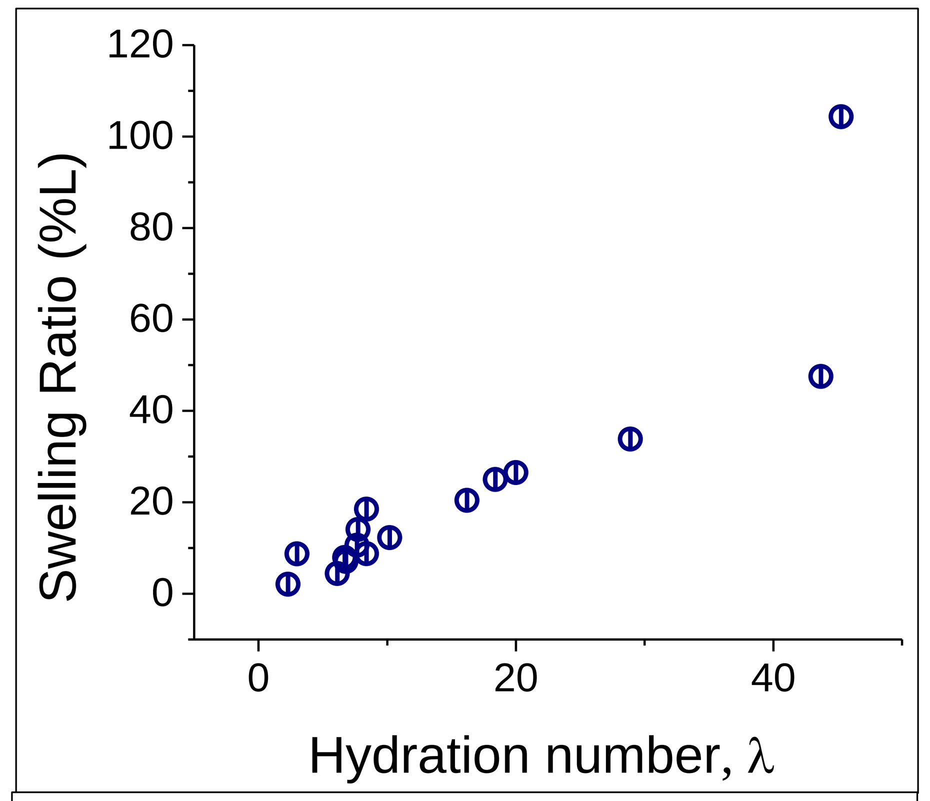


Figure 6. Hydration Number vs. Swelling Ratio

The membranes exhibited a nearly logarithmic trend with increasing water uptake and increasing conductivity.

Indicates- sharp then level growth in conductivity as membrane absorbs water.

The membranes exhibited a linear relationship between water uptake and swelling ratio.

Indicates-More water absorbed as membrane expands with water absorbance.

The membranes exhibited a nearly linear relationship between the hydration number and swelling ratio.

Indicates- The membranes would expand more with an increase in water attachment.

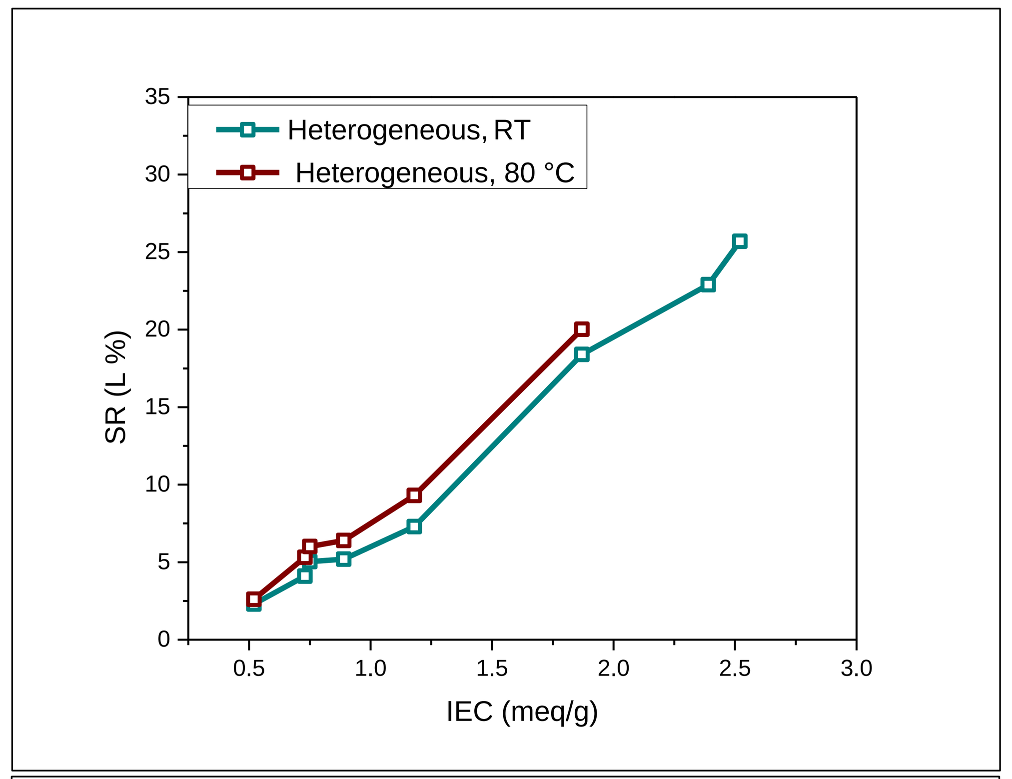


Figure 7. IEC vs. Swelling Ratio

The membranes exhibited increased swelling with increase in temperature. Ion Exchange Capacity was calculated from the amount of quaternary ammonium per gram of the material.

Indicates- higher temperatures demand an increase in expansion.

Conclusion

The quaternized membranes exhibited increasing relationships between the physicochemcial characteristics. Increasing water uptake correlated with increasing swelling and conductivity. This is indicative of the membranes having better conductivity the more water they absorb, but also a greater chance of expanding. This is an issue for fuel cell applications as high swelling can lead to breakage. However, these increases were sharp, occurring after a period of similarity and near stagnation of the water uptake and conductivity and swelling ratio. The increase in swelling ratio with temperature suggests a structural matter that results in expansion upon exposure to high heat. Overall, patterns of correlation do suggest the properties are related and therefore manipulatable. However, this opens questions for possibilities to only change certain properties.

Reference

1.Fan, Y. et al. The effect of block length upon structure, physical properties, and transport within a series of sulfonated poly(arylene ether sulfone)s. J. Memb. Sci. 430, 106–112 (2013).
2.Park, D., Kohl, P. A. & Beckham, H. W. Anion-Conductive Multiblock Aromatic Copolymer Membranes : Structure − Property Relationships. (2013).
3.Zhang, Z., Shen, K., Lin, L. & Pang, J. Anion exchange membranes based on tetra-quaternized poly (arylene ether ketone). 497, 318–327 (2016).