PROBLEM BASED LEARNING, POLYMER MEMBRANES, AND IONIC LIQUIDS

UNIVERSITY OF NOTRE DAME

Dr. Joan Brennecke, Dr. Aruni Desilva, Dr. William Phillip,

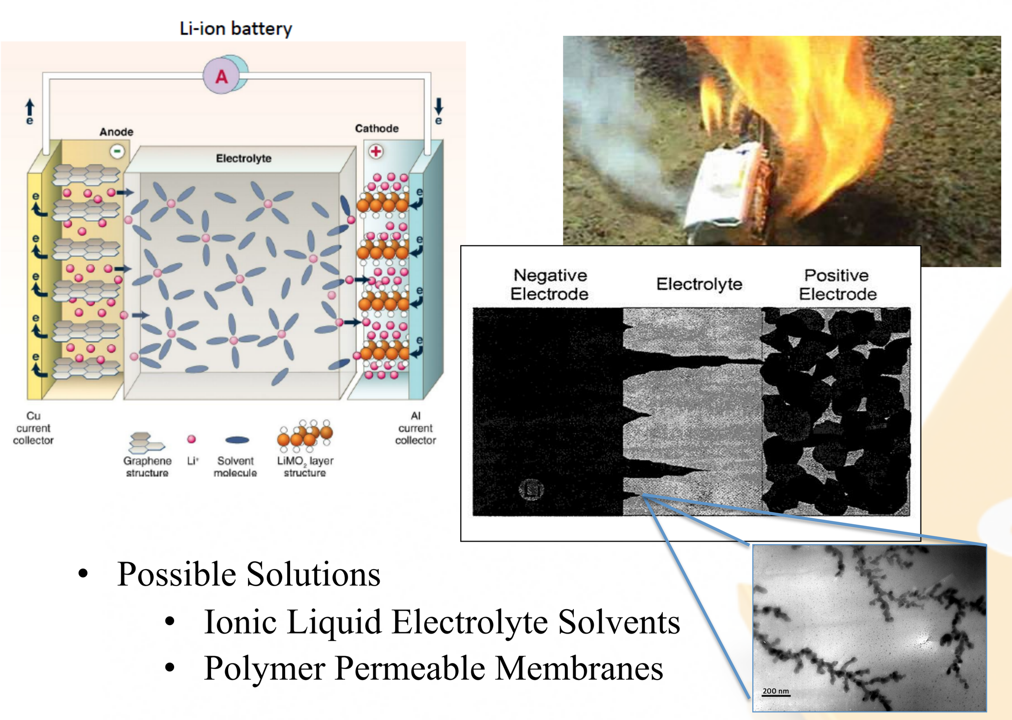
Jacob Weidman, Dan Fagnant, & Thomas C. Adams

Chemical and Biomolecular Engineering, University of Notre Dame

SOUTH BEND NewTech HIGH SCHOOL

Introduction

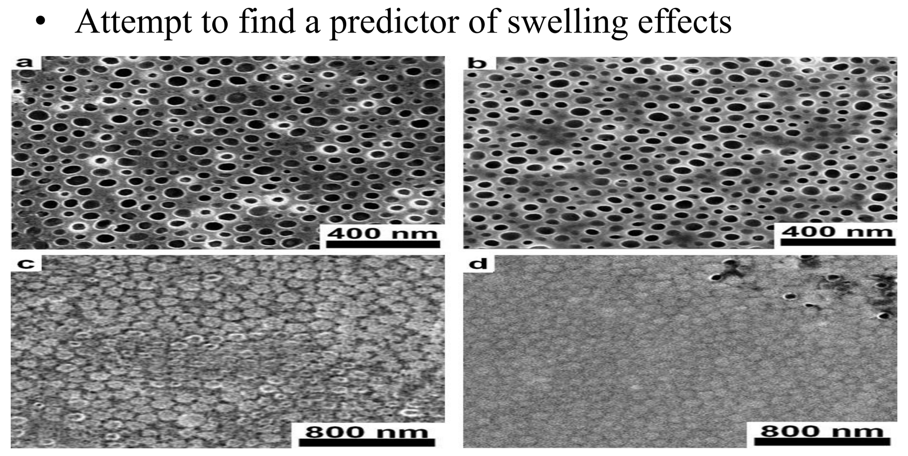
- Renewable energy has many challenges
  - Solar – Only during daylight hours
  - Wind – Only when the wind blows
  - Electric Cars – Batteries can be dangerous
- Storage is a necessity - Batteries need to be safer
- Lithium Ion Batteries
  - Dendrite growth can cause shorts / fires
  - Organic solvents are flammable



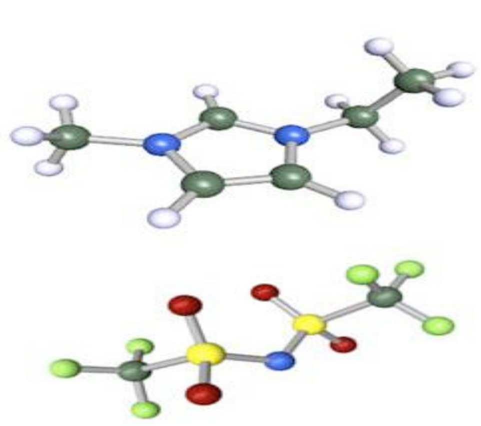
- Possible Solutions
  - Ionic Liquid Electrolyte Solvents
  - Polymer Permeable Membranes

Problem

- Wetting membranes with ionic liquids cause swelling
- Need to predict permeable membrane diameter
  - Must be big enough for lithium ions to pass
  - Must be small enough to block dendrite growth
- Attempt to find a predictor of swelling effects

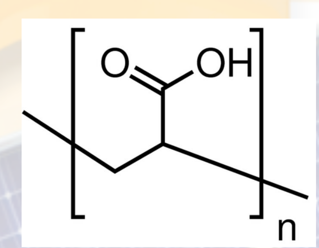


- Kamlet-Taft parameters (α, β, and π) predict hydrogen bonding and polarities of the ionic liquids, which may affect the swelling of polymer membrane

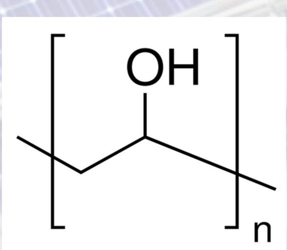


Materials and Methods

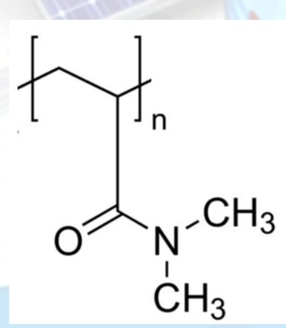
- To calculate Kamlet-Taft Values
  - Dilute dye in ionic liquids
    - Reichardt's Dye (30)
    - 4-nitroaniline
    - N, N-diethyl-4-nitroaniline
  - 250 µM / L
  - Run UV-Vis scan to find maximum absorbance
  - Calculate E_N^T – normalized polarity based on max
  - Calculate Kamlet-Taft Values of α, β, and π*
    - α – Hydrogen Bond Donor – Acidity
    - β – Hydrogen Bond Acceptor – Basicity
    - π – Dipolarity / Polarizibility Ratio
- Soak samples of Emim[Tf_2N] and Hmim[Tf_2N] in:
  - Poly (Acrylic Acid) – PAA



  - Poly (Vinyl Alchol) – PVA



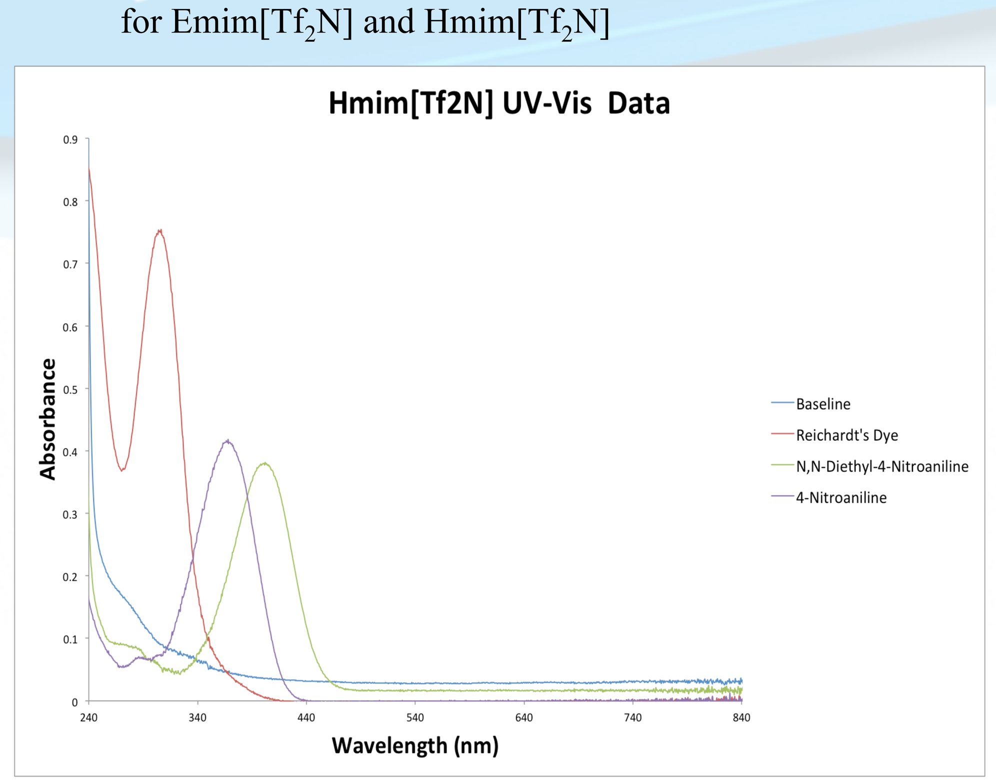
  - Poly (Dimethylacrylamide) – PDMA

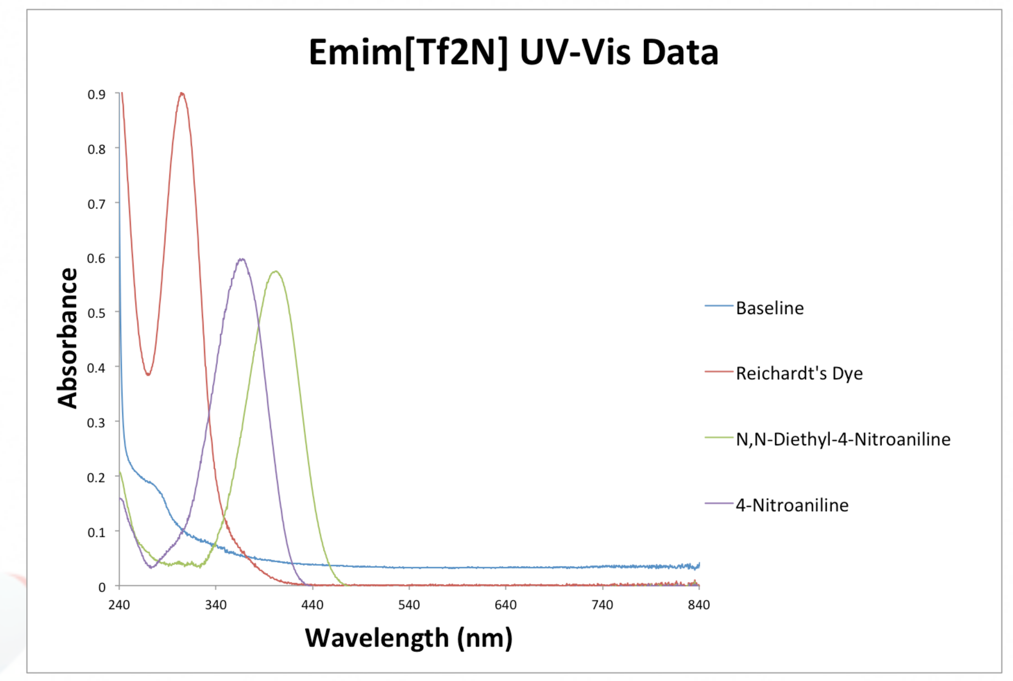


- Determine effects of ionic liquids on polymer membranes

Results

- UV-Vis Scan confirmed published Kamlet-Taft values for Emim[Tf_2N] and Hmim[Tf_2N]





- Subtle differences in Kamlet-Taft values (published):

Ionic Liquid	Abbreviation	Alph	Beta	Pi*
1-Hexyl-3-methylimidazolium bis(trifluoromethanesu	[C6C1im][NTf2]	0.65	0.26	0.97
1-Hexyl-3-methylimidazolium chloride	[C6C1im]Cl	0.48	0.94	1.02
1-Hexyl-3-methylimidazolium bromide	[C6C1im]Br	0.45	0.74	1.09
1-Butyl-3-methylimidazolium bis(trifluoromethanesul	[C4C1im][NTf2]	0.72	0.24	0.9
1-Ethyl-3-methylimidazolium bis(trifluoromethanesul	[C2C1im][NTf2]	0.71	0.23	0.98
1-Octyl-3-methylimidazolium bis(trifluoromethanesul	[C8C1im][NTf2]	0.6	0.29	0.96

- Differences in membrane diameters as well:

Poly(acrylic acid)	PAA MW (	Diameter (nm) in emim	Diameter (nm) in hmim
	130	3789	4542
Poly(vinyl alcohol)	PVA MW		
	40	3316	3850
Poly(dimethylacrylamide	PDMA MW		
	76	4565	5177

- Hmim[Tf_2N] has a higher β value
- Hmim[Tf_2N] has a slighty larger diameter
- However both Emim[Tf_2N] and Hmim[Tf_2N] have very similar π* values
- Perhaps one could look at swelling effects of Hmim[Cl] or Hmim[Br] due to the variation of Kamlet-Taft values

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- If β correlates to an increase in diameter than Hmim[Cl] should have the largest diameter
- However, if π* correlates to an increase in diameter than Hmim[Br] should have the largest diameter

Conclusions

Hydrogen Bonding or Dipolarity / Polarizibility may actually determine the swelling effects of ionic liquids. However, more data is needed. One could try wetting the polymer membranes with Hmim[Br] or Hmim[Cl] to determine if either β or π* have an greater correlation. Lastly, this research can be used to model real-world challenges, and strategies to solve them. In an effort to prepare students for college and / or career, Tom Adams will present these results to his high school students. Students will follow this curriculum unit outline.

Day	Lesson
1	• Entry Event 1 – ND Energy Presentation – Dr. Brennecke • Knows / Need to Knows • Reflection – Engineering Design – Literacy Task
2	• Entry Event 2 –Lithium Battery Youtube Videos • Standards – NGSS – Engineering and Design • Reflection – Engineering Design – Literacy Task
3	• Brainstorm / Project Outline • Entry Event 3 – Youtube – Electrolyte Dough • Scaffolding 1 – Al / Cu Electrolyte Battery Design • Reflection – Engineering Design– Literacy Task
4	• Make Electrolyte Dough / Aluminum Can Batteries • Scaffolding 2 – Salts – Can Salt Exist as a Liquid? • Reflection – Engineering Design – Literacy Task
5	• Entry Event 4 – Ionic Liquids • Scaffolding 3 – Lithium Battery Design • Scaffolding 4 – Dendrite Growth – Fire • Scaffolding 5 – Polymer Membranes • Reflection – Engineering Design– Literacy Task
6	• Entry Event 5 – Predicting Swelling Effects • Scaffolding 6 – Kamlet-Taft Values • Scaffolding 7 – Hydrogen Bonding • Reflection – Engineering Design– Literacy Task
7	• Modeling with Notre Dame RET Data • Write Quadratic Regressions in Excel • Find Max Absorbance Based on Equations • Reveal Kamlet-Taft Values • Reflection – Engineering Design– Literacy Task
8	• Entry Event 6 – Membrane / IL Solvent Data • Make Observations and Determine Correlations • Reflection – Engineering Design– Literacy Task
9	• Create Abstract for Poster Session – Literacy Task • Create Poster • Reflection – Engineering Design– Literacy Task
10	• Finish Culminating Products • Practice Presentation – Peer Reviewed
11	• Poster Session

Possible collaboration with ND Remote Labs

Literature Cited

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