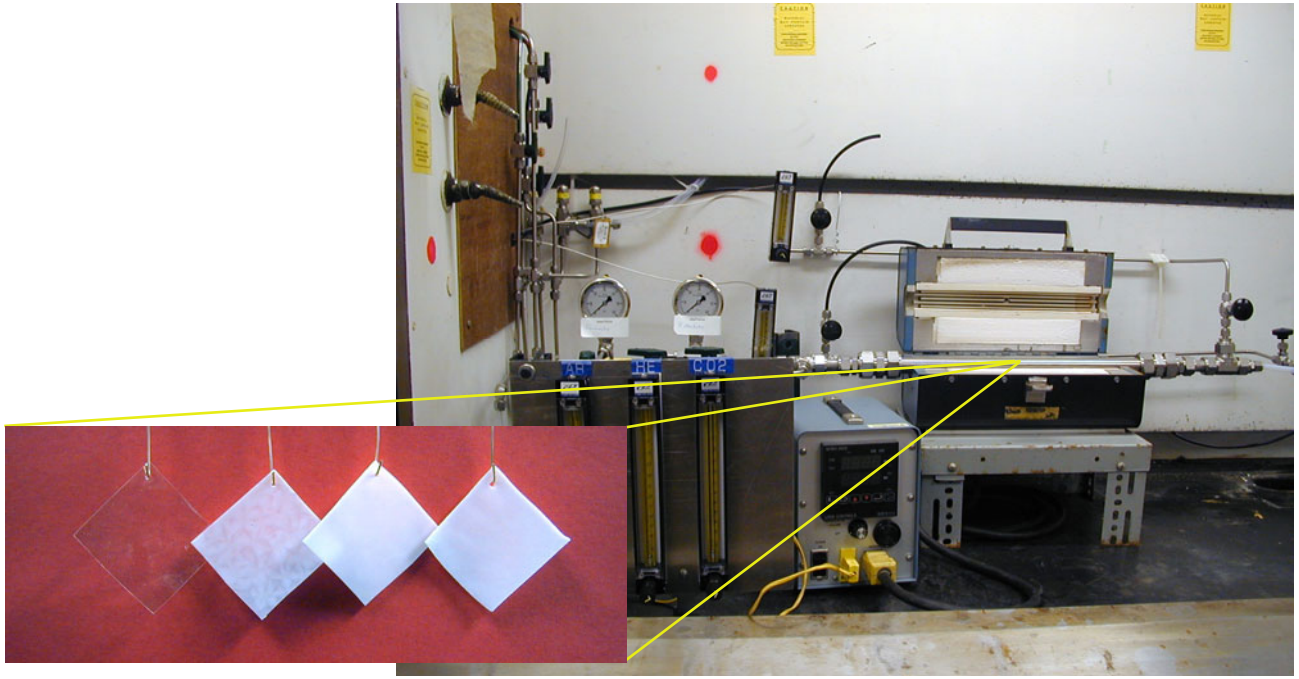
Carbon Dioxide Separation with Supported Ionic Liquid Membranes

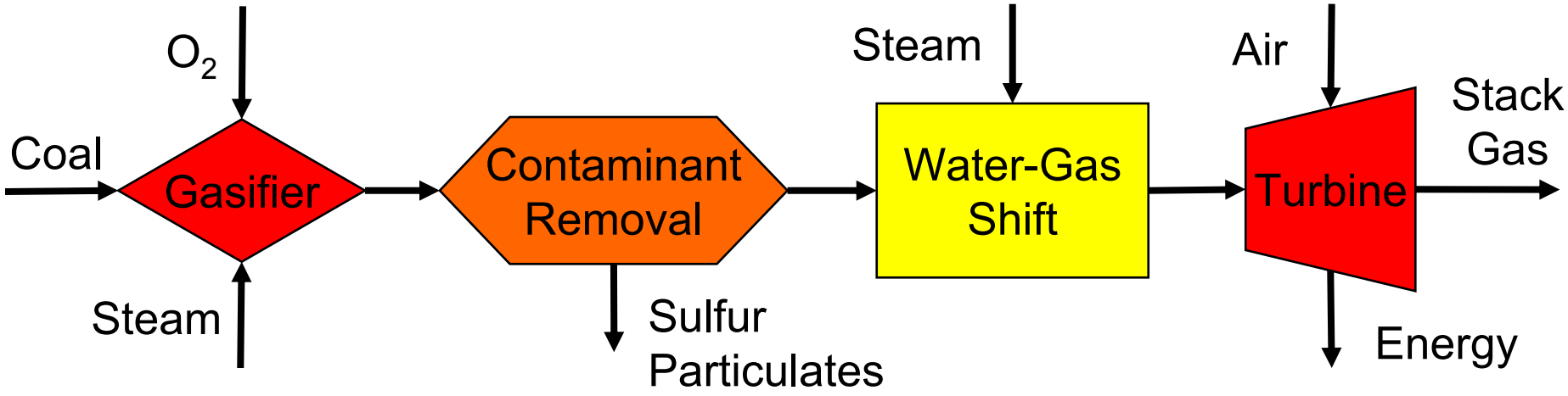


David Luebke, Jeffery Ilconich,
Christina Myers, Henry Pennline

May 9, 2007

Sixth Annual Conference on Carbon Capture & Sequestration

Integrated Gasification Combined Cycle (IGCC)



- **Significant component of future power generation**
- **Possible efficiency enhancement**
- **Potential to produce H_2 or electricity**

Water-Gas Shift

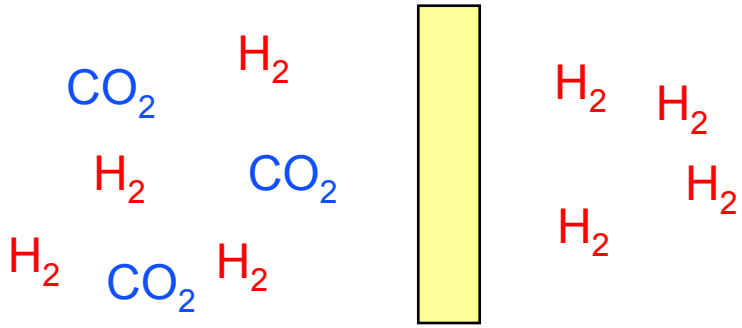
$$CO + H_2O \rightleftharpoons H_2 + CO_2$$

Additional Steam
Cooling

H_2 Removal
CO_2 Removal

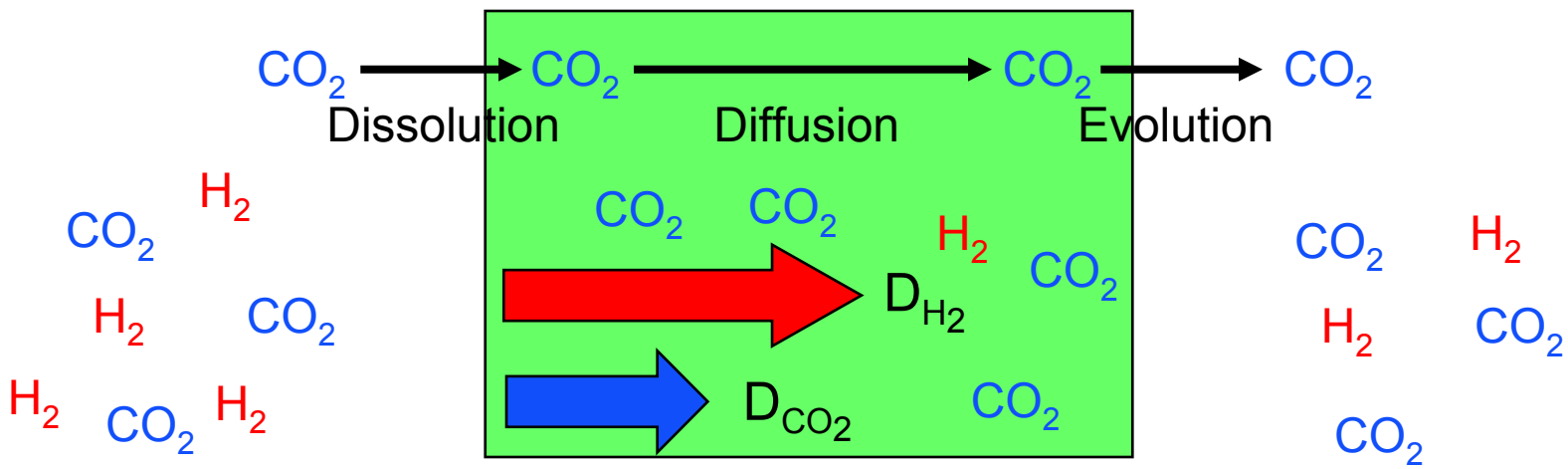
- **Conventional**
  - Catalyst Needed
  - Cooling to 260°C
  - Additional Steam
- **Improvement through Separation**
  - Separation above 500°C: No Catalyst
  - Cooling Only to Separation Temperature
  - Only Stoichiometric Steam Required

CO_2 Selective Membranes: Solution Diffusion



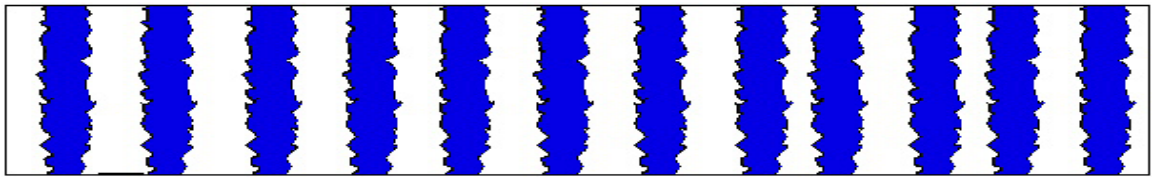
Knudsen Diffusion/
Molecular Sieving

Solution Diffusion



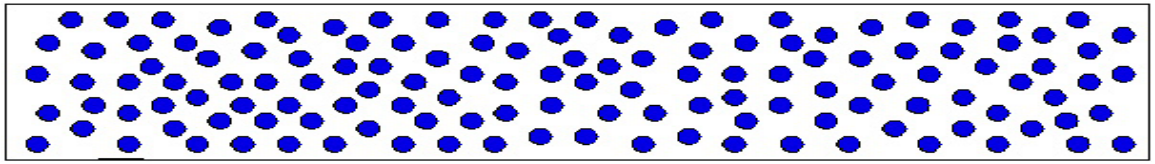
Permeability = Solubility X Diffusivity

Supported Liquid Membranes



Porous Substrate

Scovazzo, J. Membr. Sci. 238 (2004) 57.



Dense Substrate

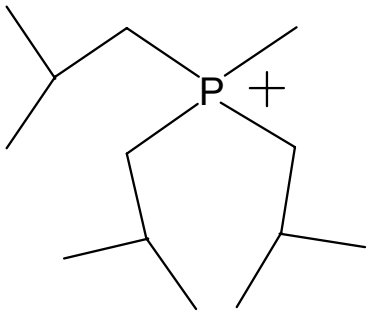
Zou and Ho, J. Membr. Sci. 286 (2006) 310.

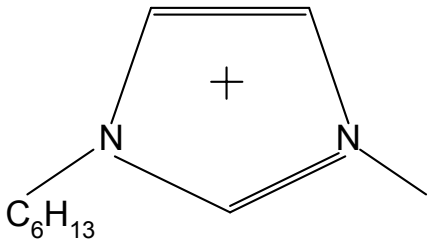
Polymerized Liquid

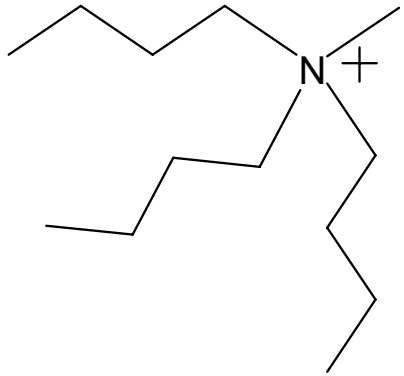
Tang, Macromolecules 38 (2005) 2037.

Potential of Ionic Liquids

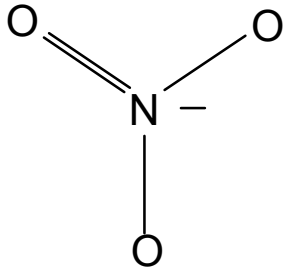
Cations

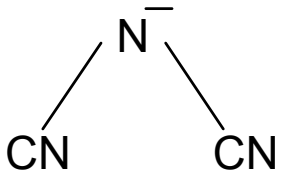


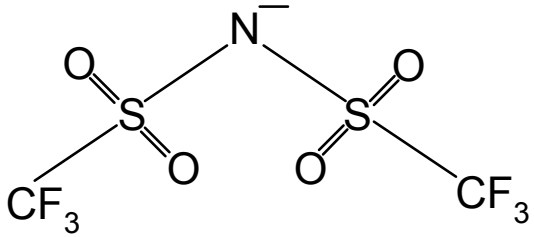




Anions







- **Negligible Vapor Pressure**
- **Thermally Stable above 200°C**
- **High CO_2 Solubility Relative to H_2, N_2, and CH_4**

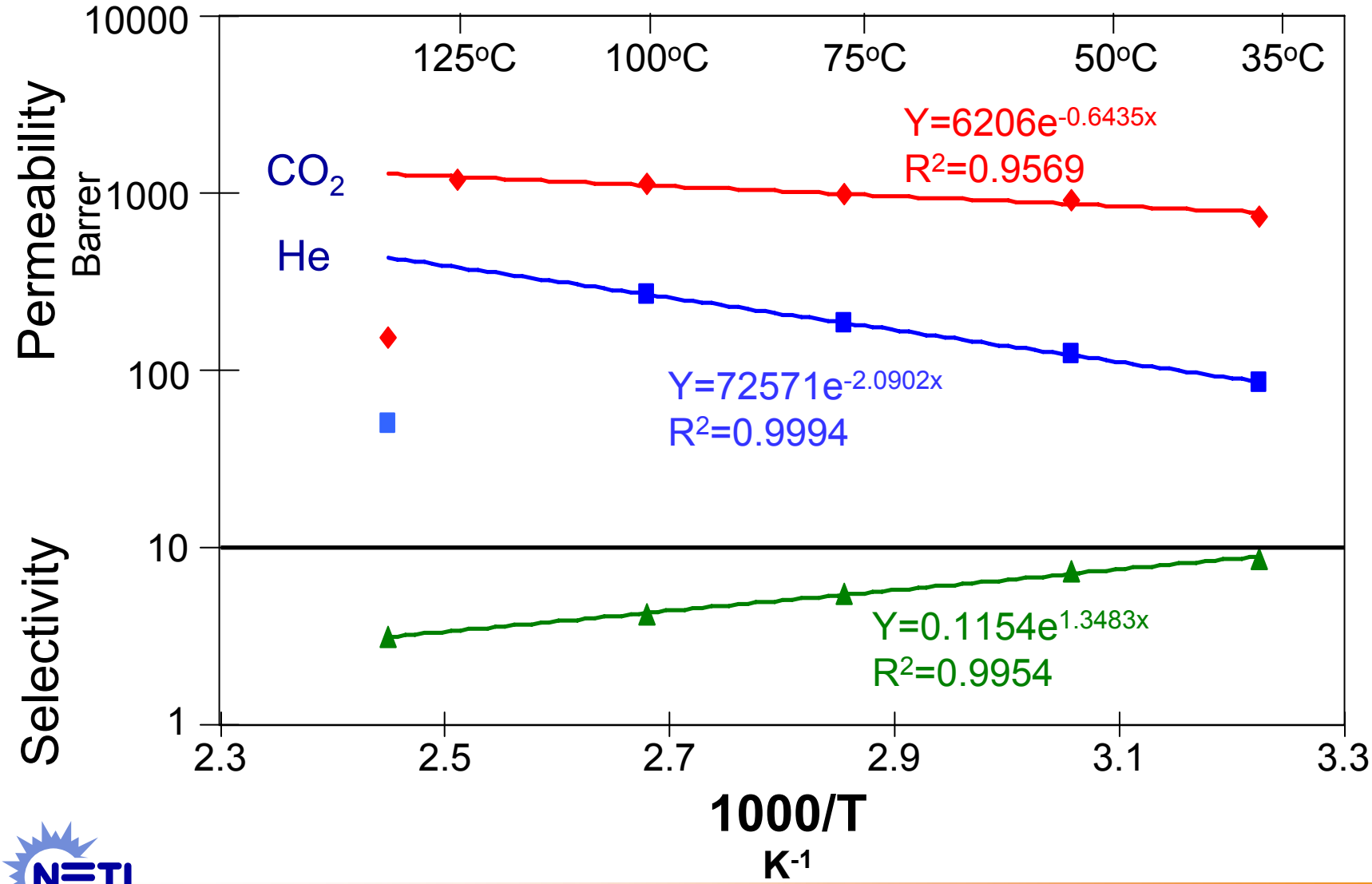
Step 1: Proof of Concept

Membrane Testing

- Ionic liquids in porous polymer supports
- Ionic liquid saturated with water before testing
- Constant pressure flow system
- Pressure slightly greater than 1 atm
- Argon sweep
- Mixed gas permeabilities and selectivities

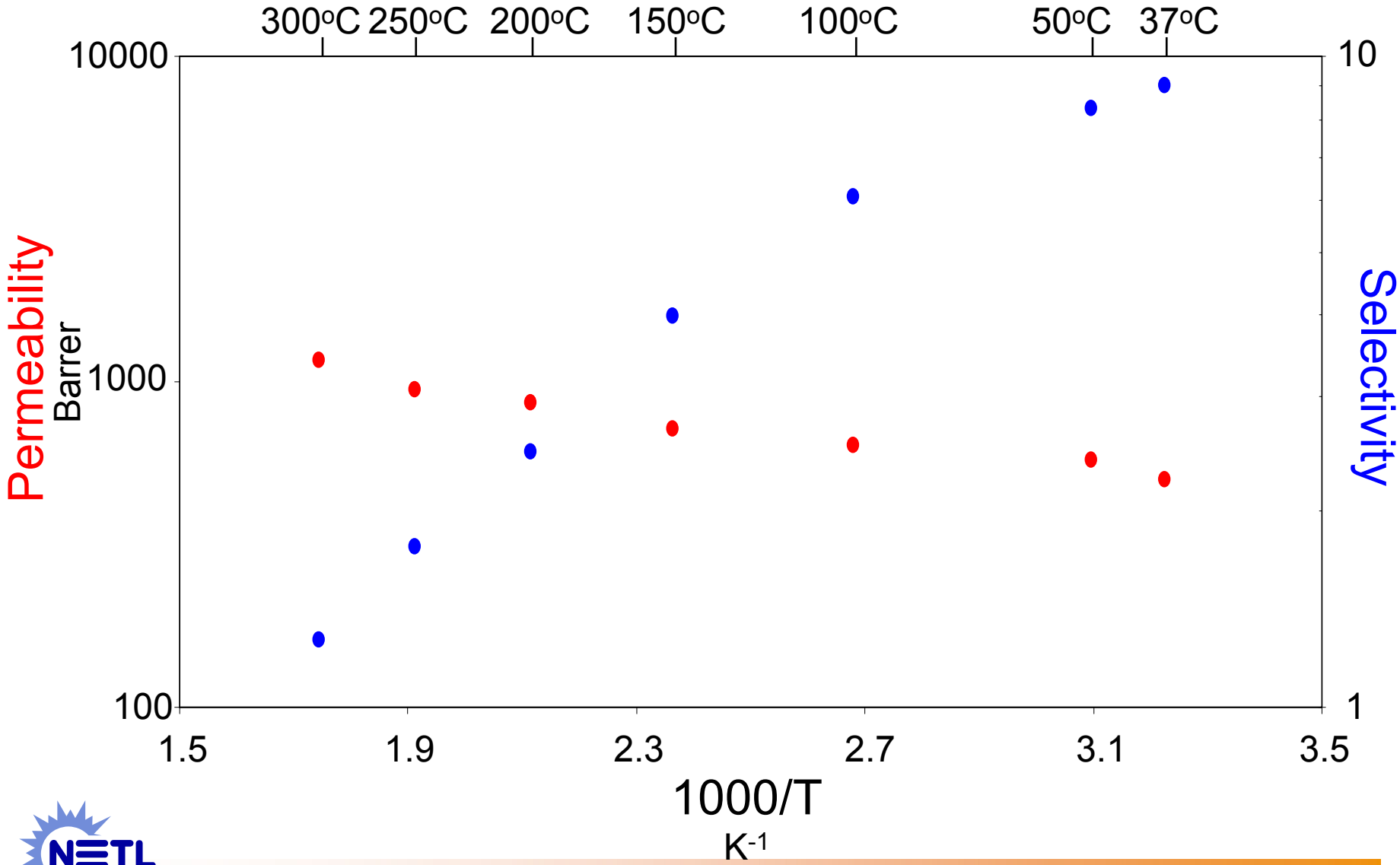
Step 1: Proof of Concept

Support Failure Limits Performance



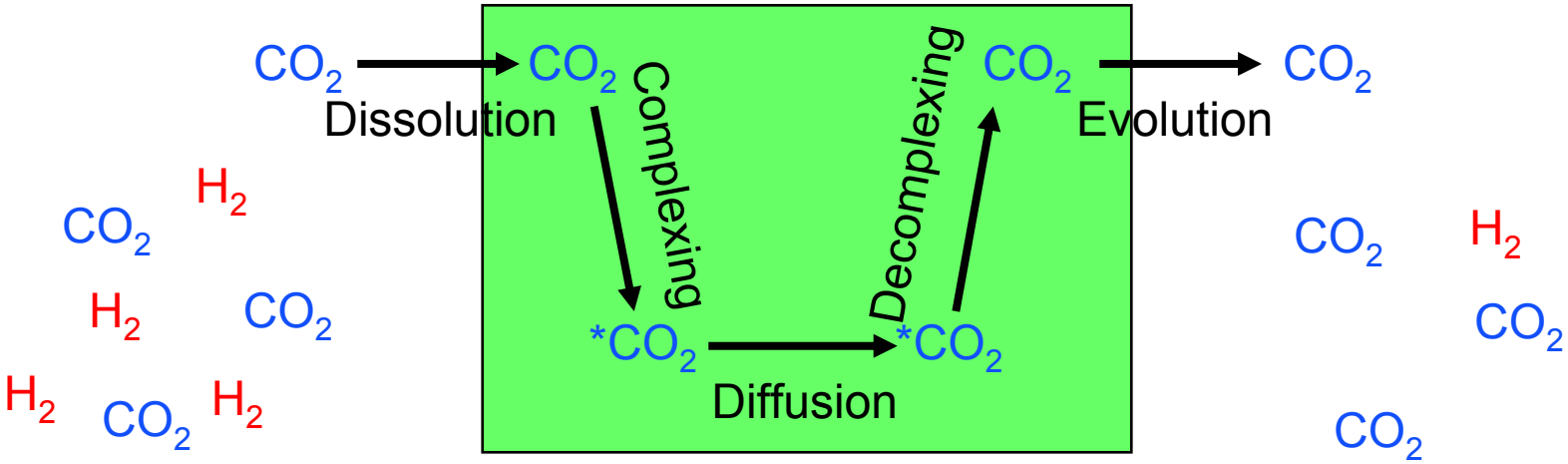
Step 2: Support Improvement

Cross-linking Stabilizes Support



Step 3: Ionic Liquid Improvement

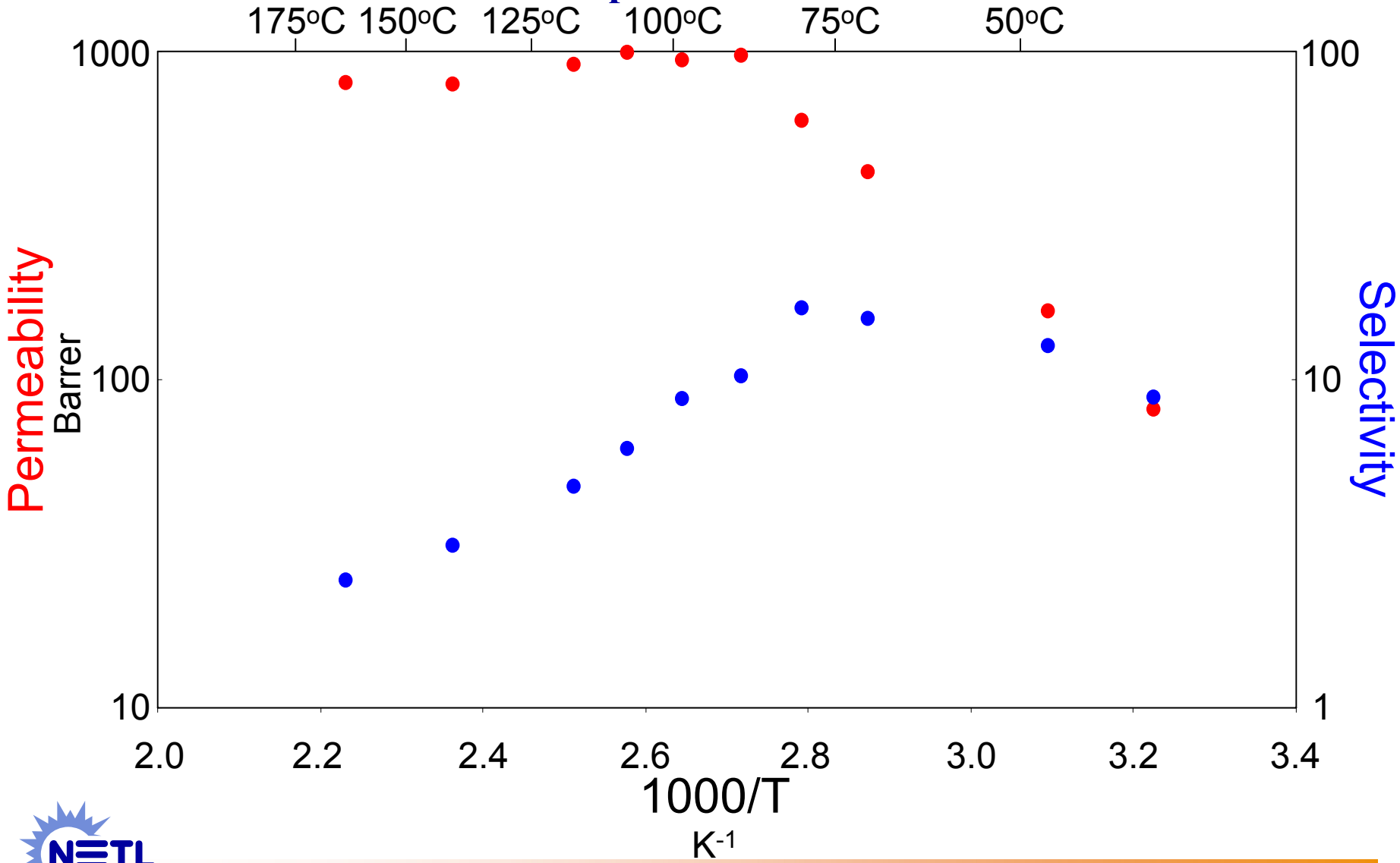
Facilitated Transport?



- **Probable Increase in Solubility**
- **Potential to Optimize for Higher Temperature**
- **New Rate Limiting Step at Low Temperature**

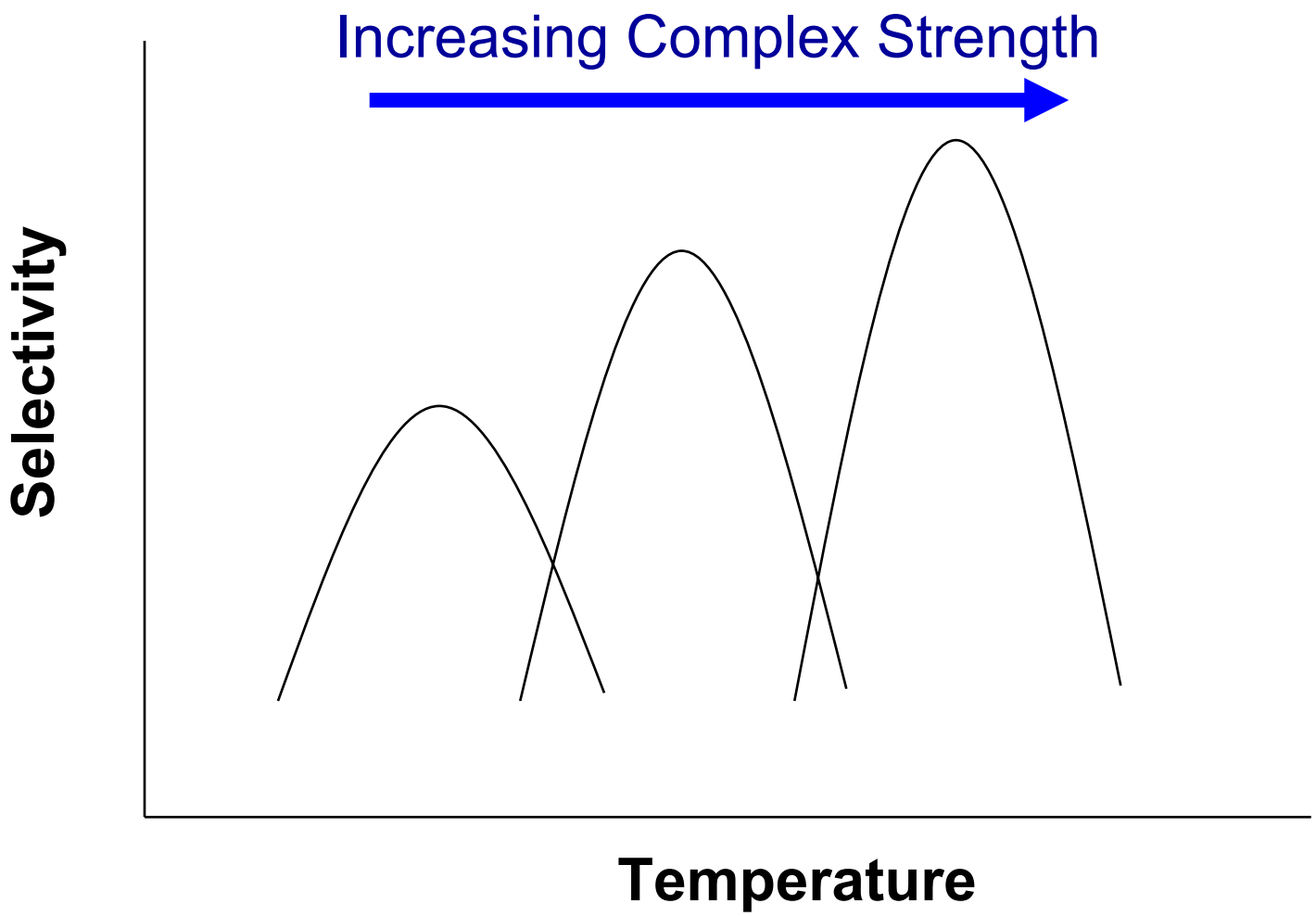
Step 3: Ionic Liquid Improvement

Facilitated Transport Increases Performance

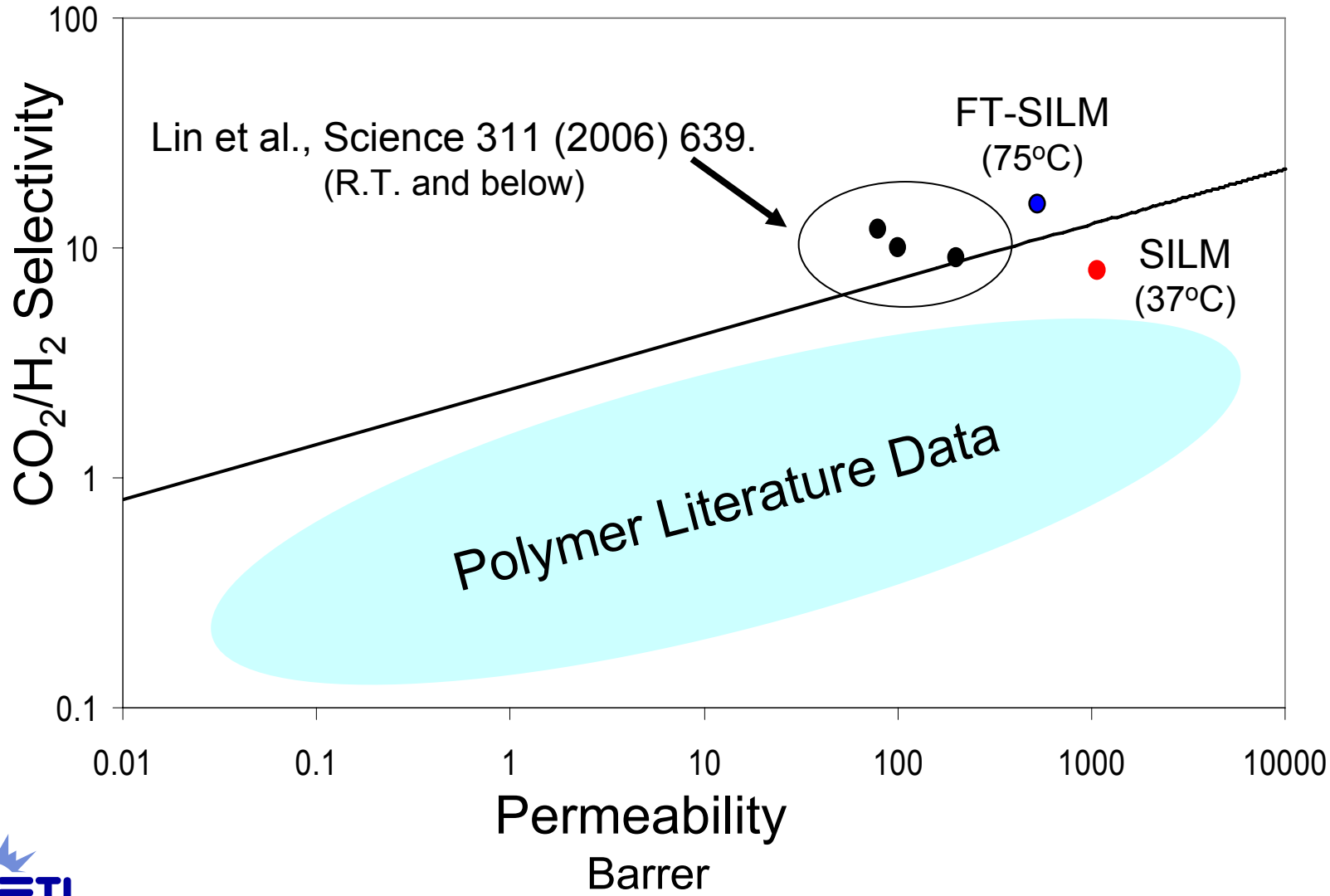


Step 3: Ionic Liquid Improvement

Stronger Complexes for Better Performance



SILMs versus Polymers



Summary

- High temperature CO_2 selective membranes may facilitate water-gas shift and enhance IGCC efficiency
- Ionic liquid membranes with cross-linked supports may be employed at water-gas shift conditions
- Ionic liquid based facilitated transport membranes have the potential for superior performance at elevated temperatures.

Acknowledgements

The authors gratefully acknowledge the Brennecke and Maginn research groups at the University of Notre Dame. Their efforts in the synthesis and characterization of the ionic liquids along with their invaluable expertise in these areas have been very beneficial in the development of this exciting new technology. We look forward to continued fruitful collaboration.