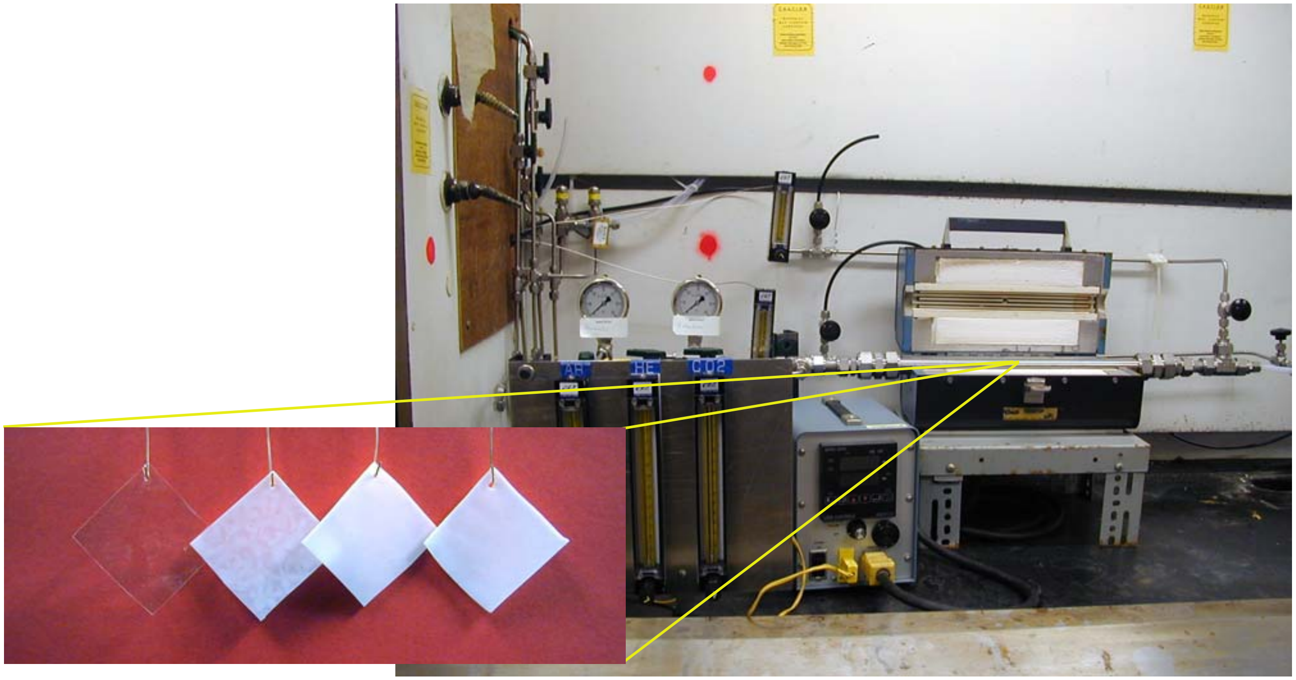
DOE/NETL-IR-2007-024

# Supported Ionic Liquid Membranes for Carbon Dioxide Separation

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***October 17, 2006***

***American Filtration & Separations Society***

# Goals

## Carbon Sequestration Programmatic Goal:

Capture and secure 90% of $CO_2$ emissions from new power plants with no more than 10% increase in the cost of energy services by 2012.

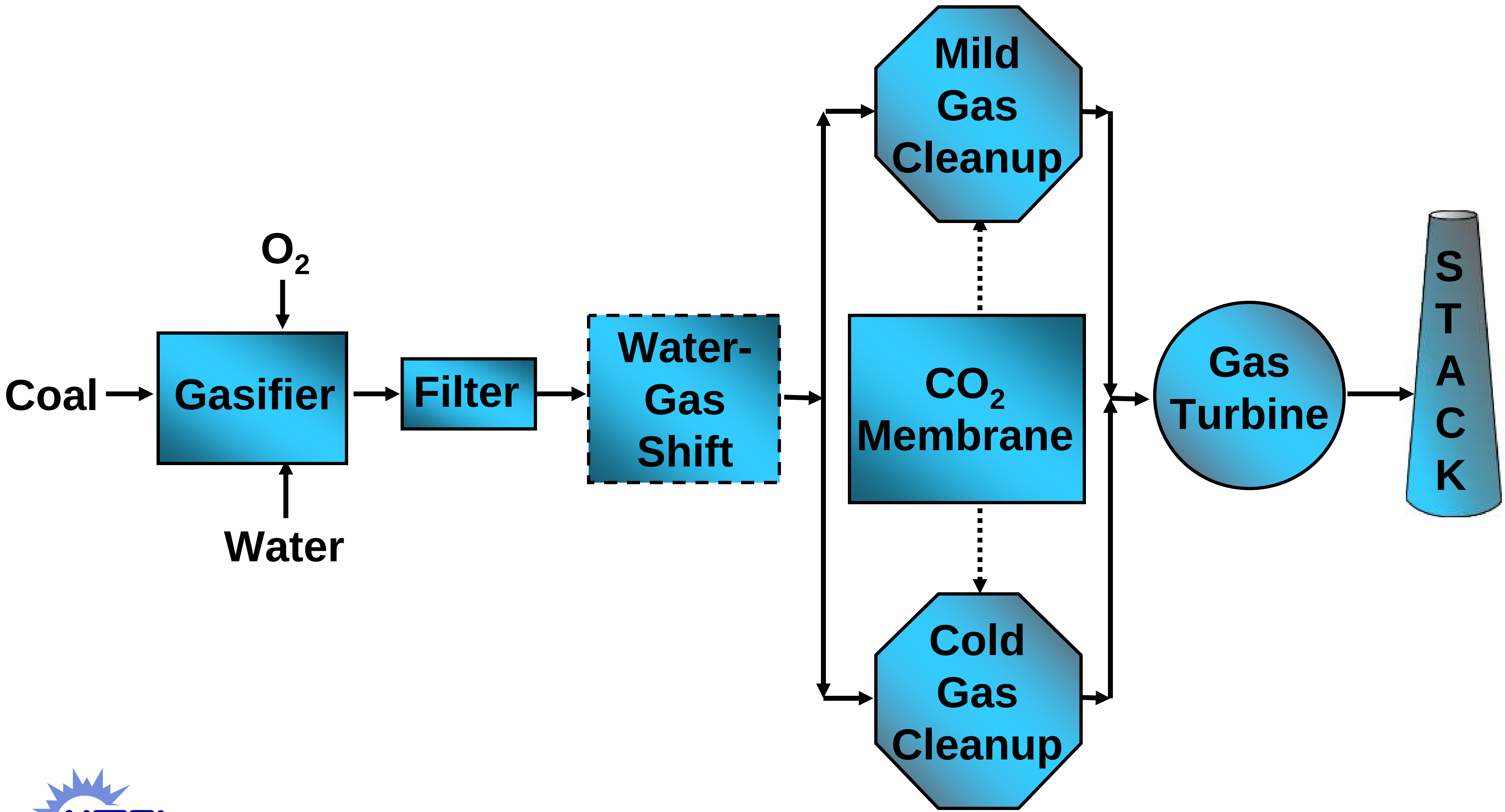
## Membrane Project Goal:

Support the sequestration programmatic goal by developing membranes which can lower the costs associated with precombustion capture of $CO_2$ from IGCC systems.

## SILM Study Goal:

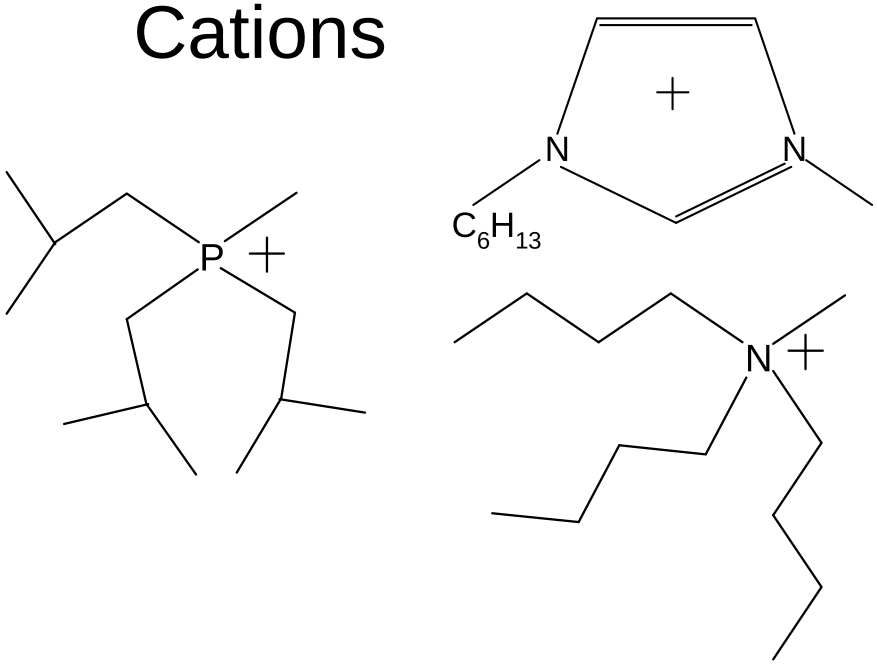
Develop $CO_2$ selective supported ionic liquid membranes with sufficient permeability and selectivity to allow capture of $CO_2$ at an acceptably low cost.

# Precombustion $CO_2$ Capture in IGCC

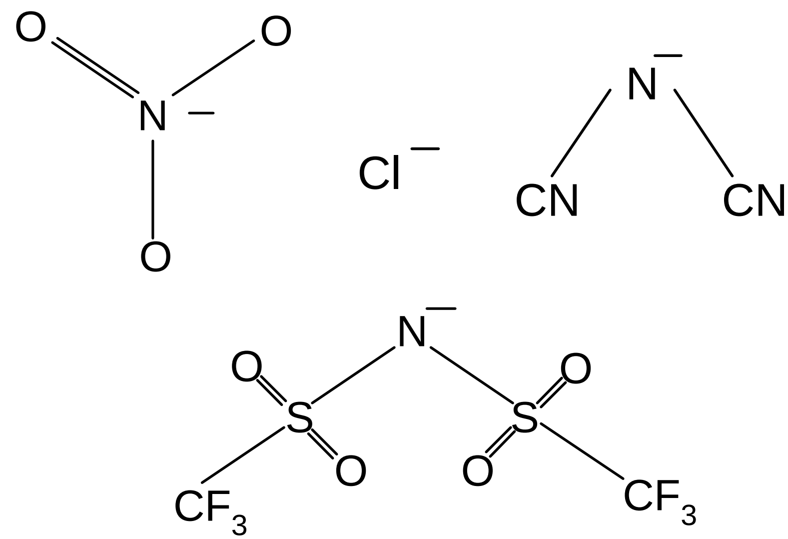


# Potential of Ionic Liquids

## Cations




## Anions




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

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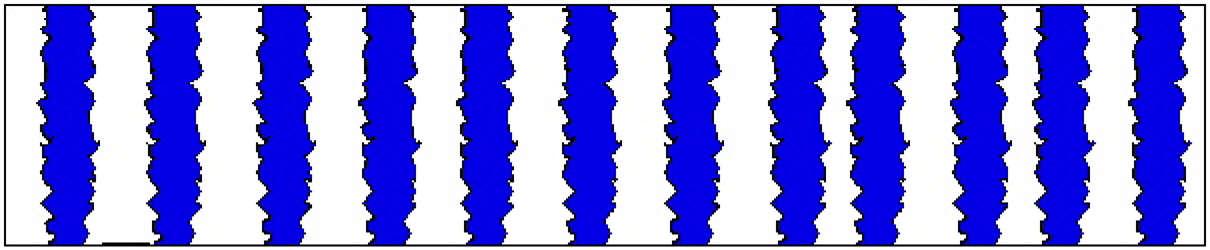
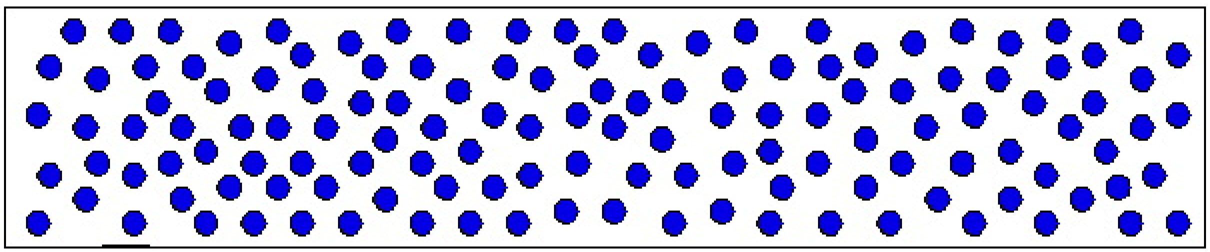
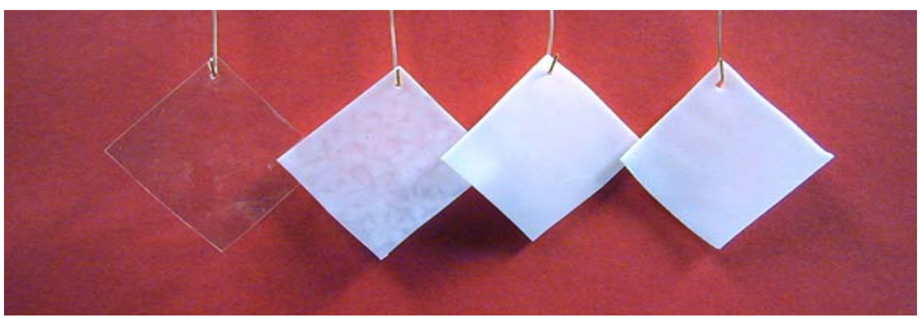
# Several Fabrication Options



Porous Substrate



Dense Substrate



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# Selection of Support Material Significant

PES Support-Supor®

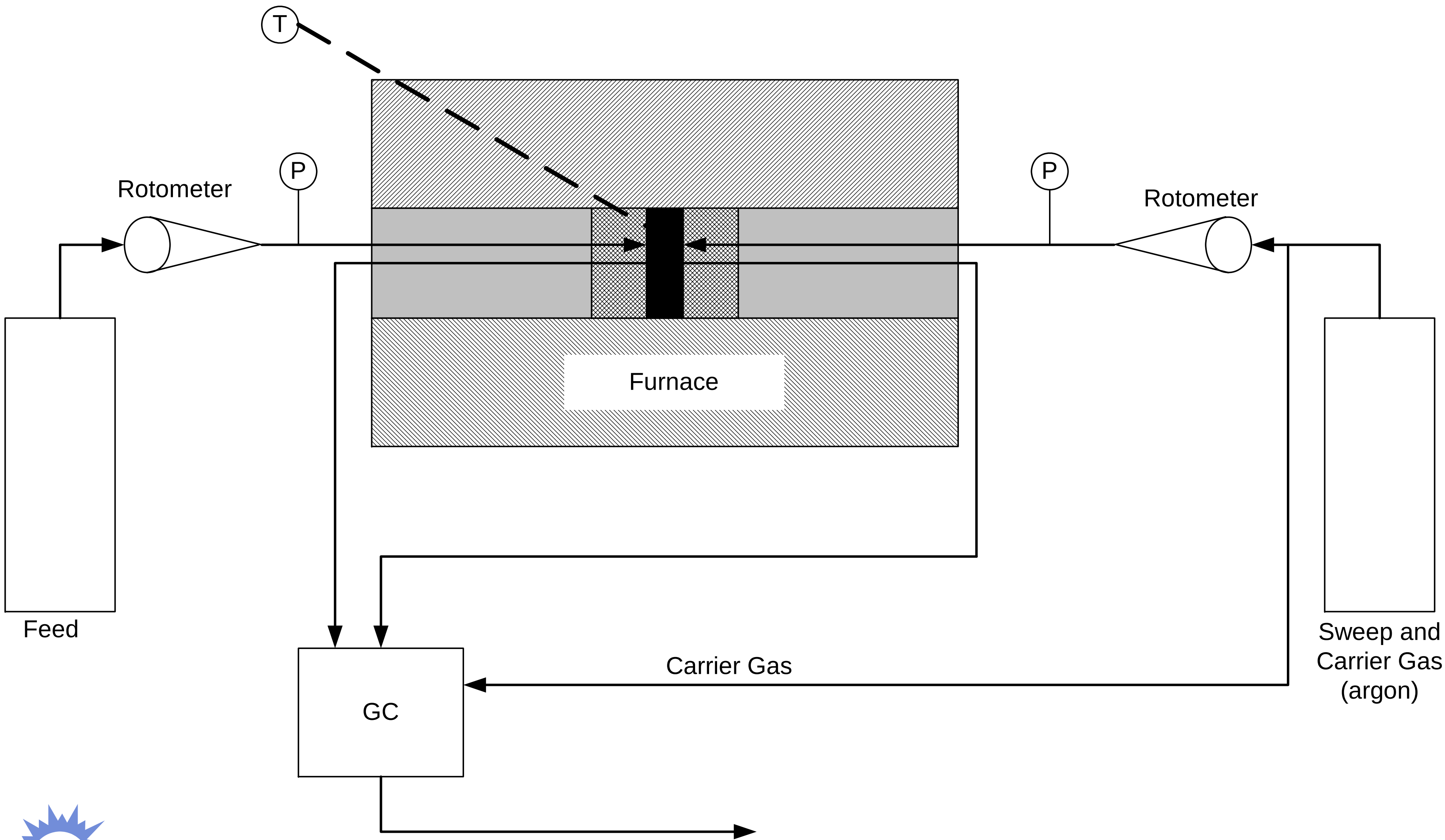
- Suggested by Noble et al. as a useful support*
- $T_g$ ~ 210°C
- Visible change when heated to 100°C in the presence of [hmim][$Tf_2N$]
- Membrane failure occurs at less than 50°C

PSF Support-HT Tuffryn®

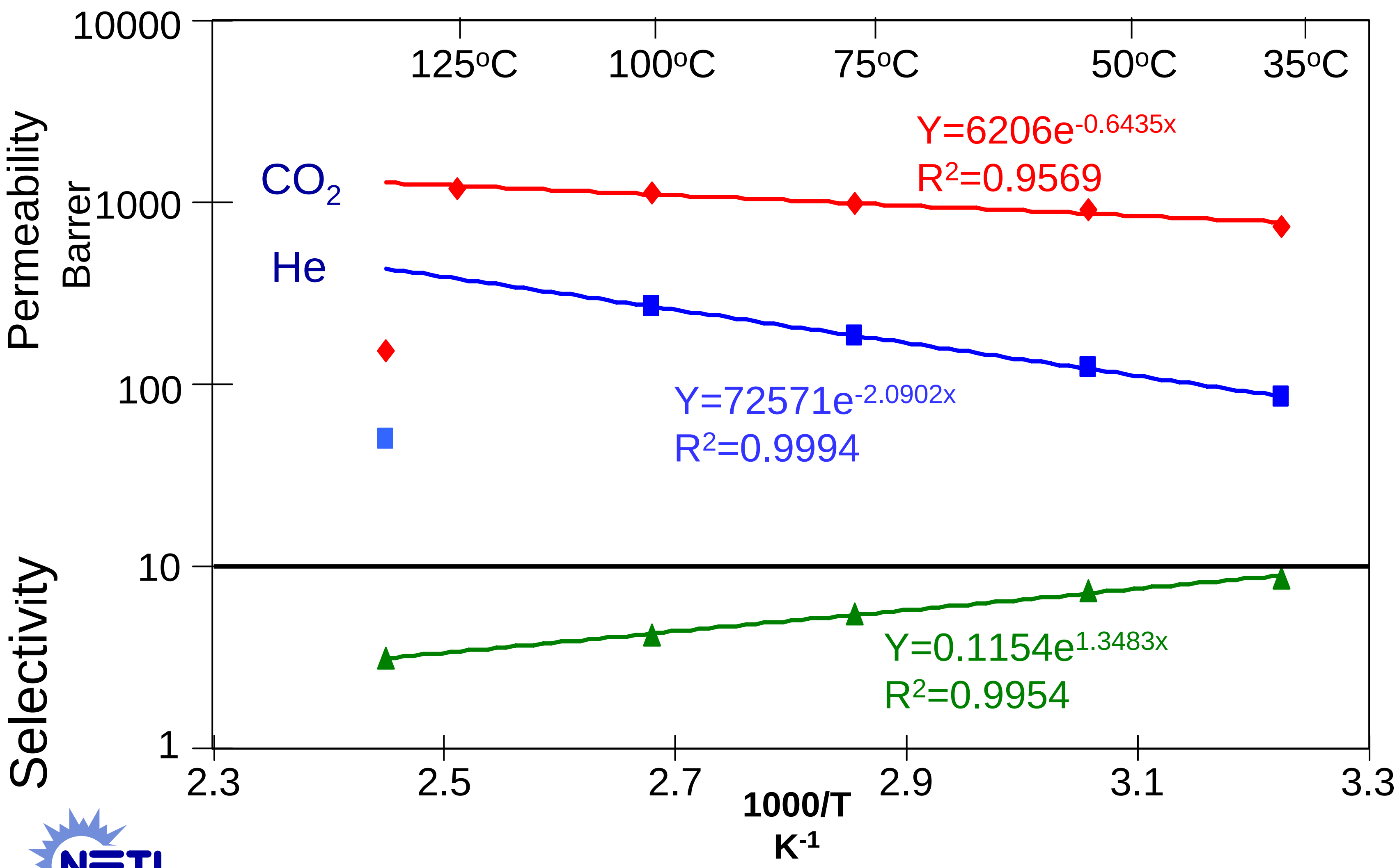
- Unmodified $T_g$ ~ 150°C
- Membrane stable to 125°C

*Scovazzo et al. in: R. Rogers, K. Seddon (EDS.) Industrial Applications of Ionic Liquids, American Chemical Society Books, 2002, Chapter 6.

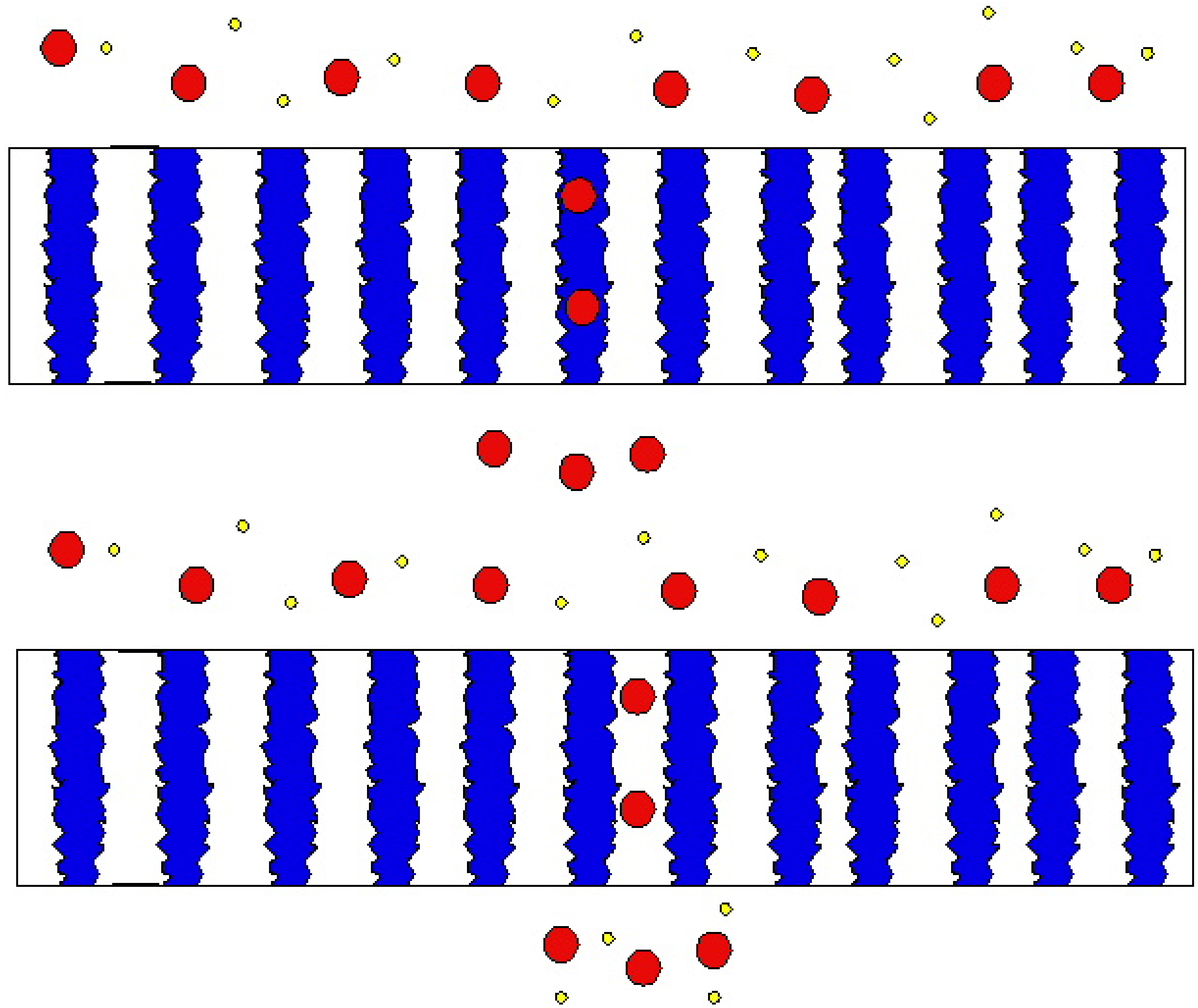
# Constant Pressure Flux Measurements



# Support Failure Limits Performance



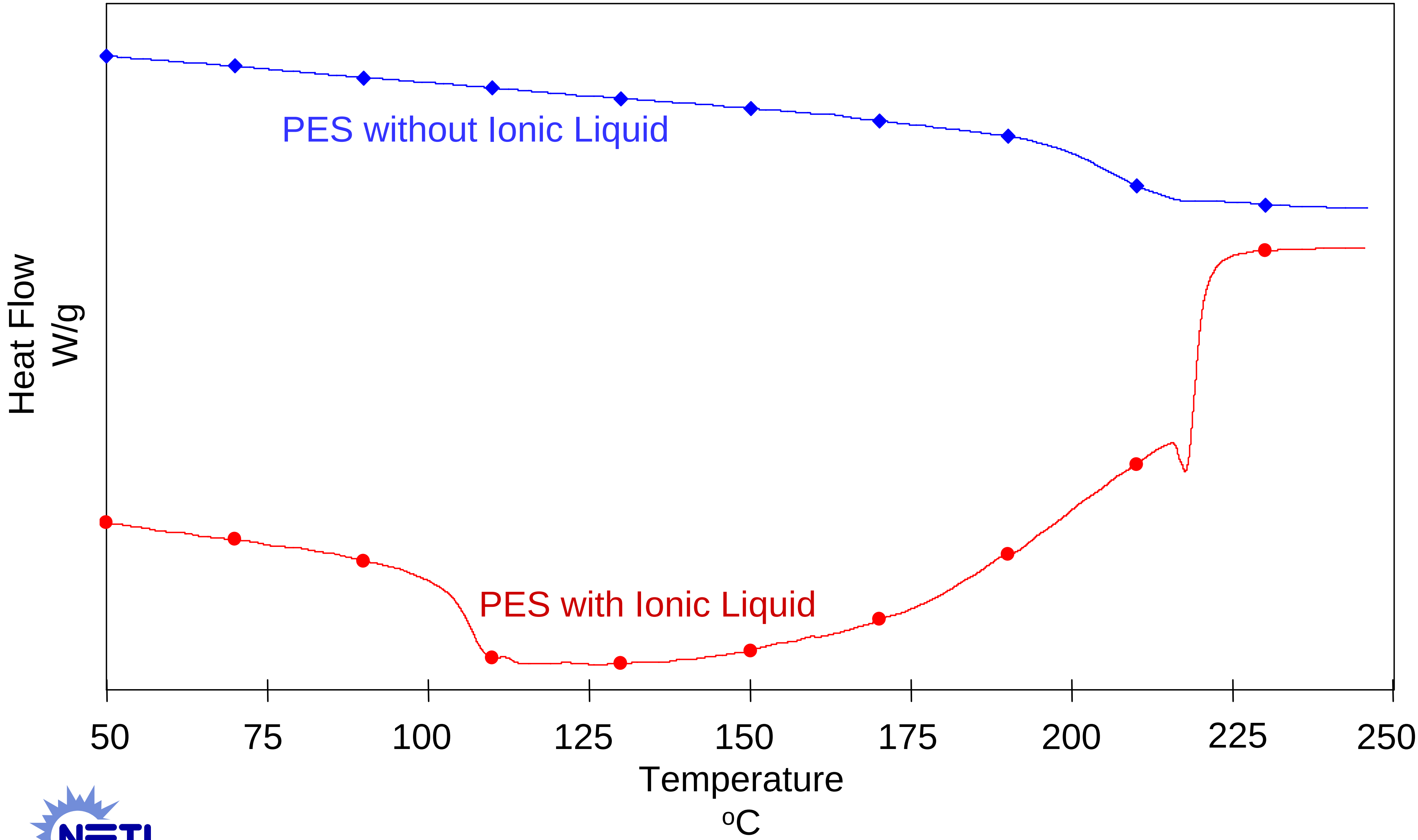
# Other Mechanisms Inconsistent



Original Mechanism

Pore Degradation

# DSC Confirms Large $T_g$ Reduction for PES

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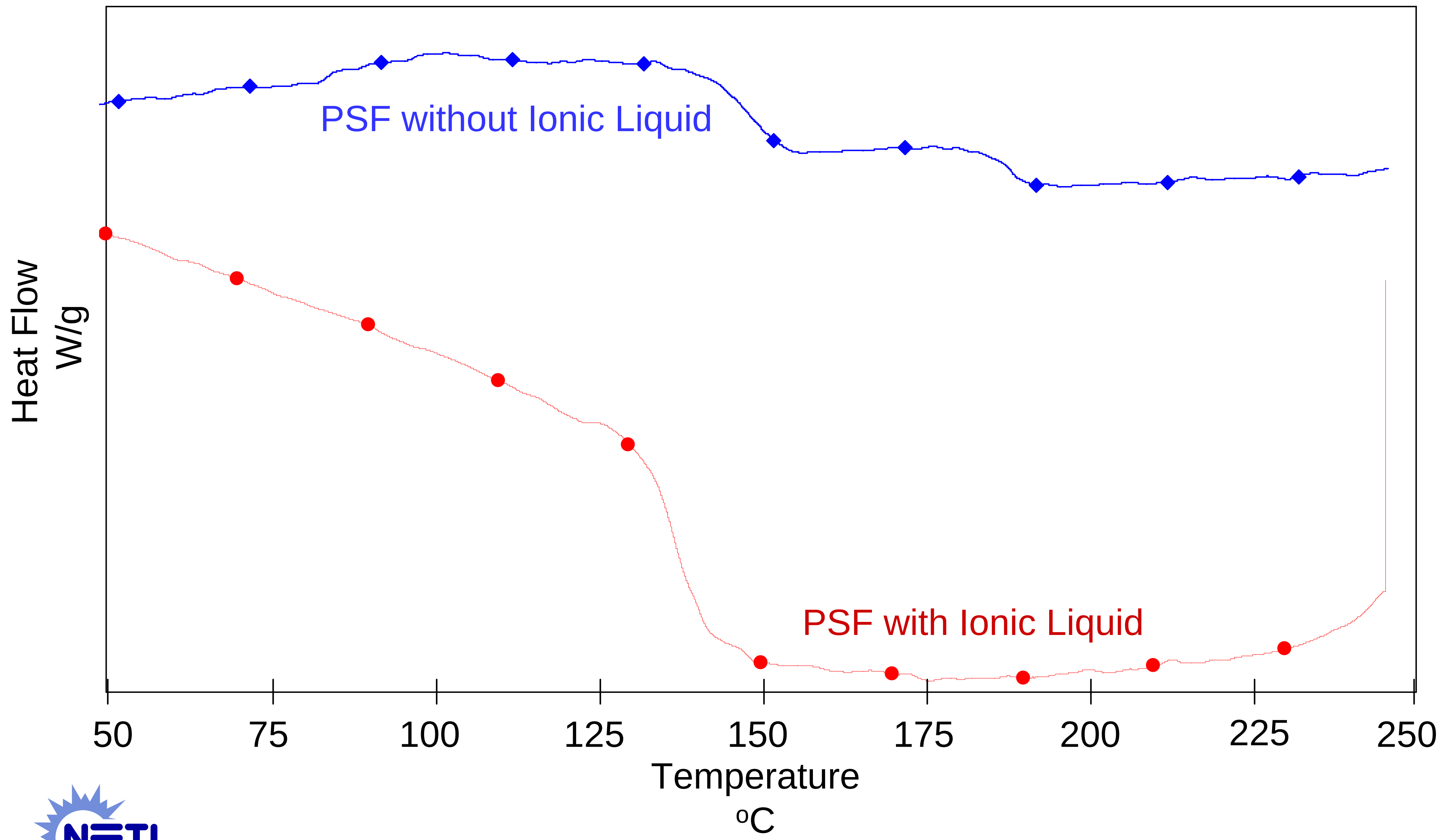
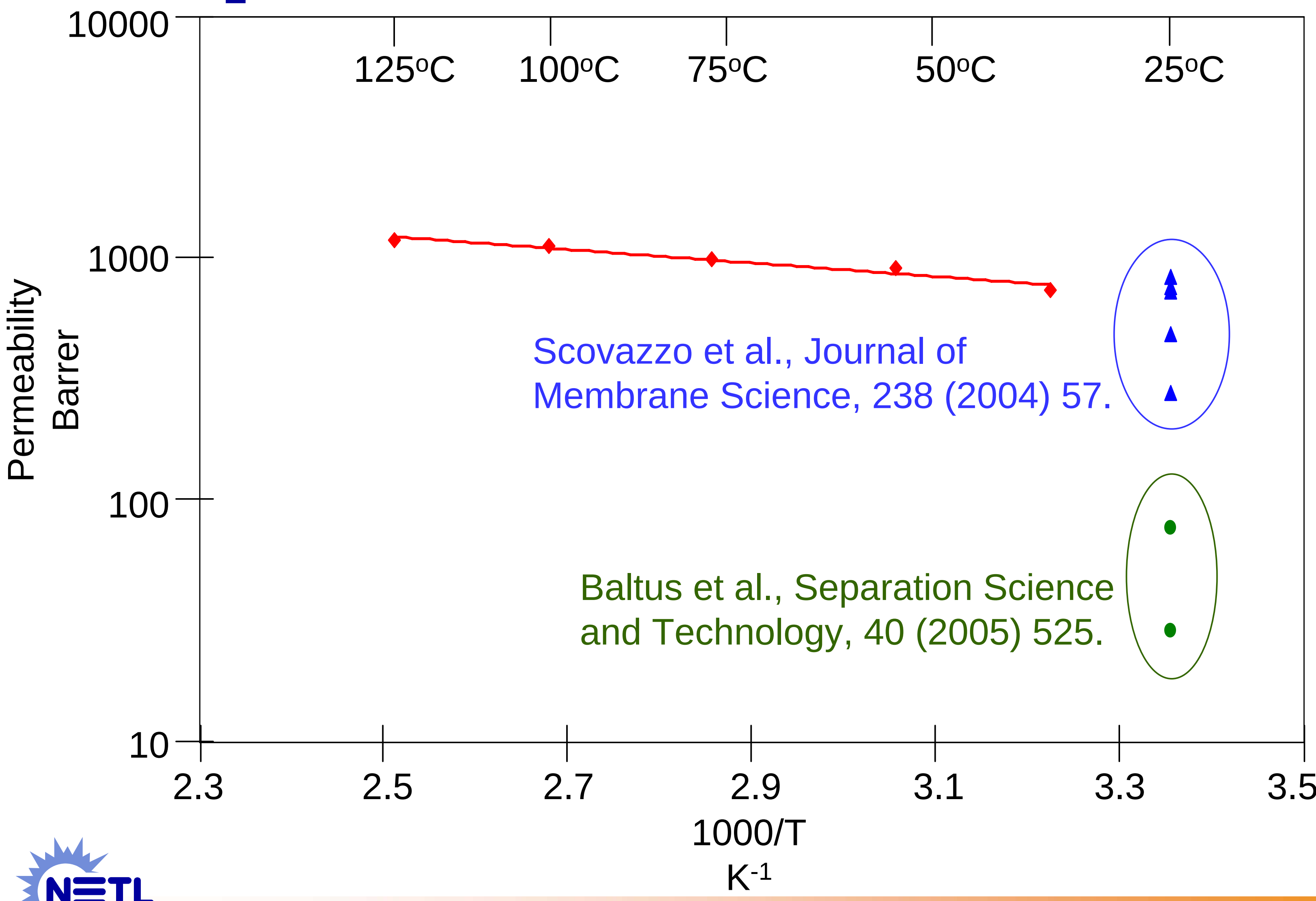
# PSF Less Affected



# $CO_2$ Permeabilities Similar to Literature

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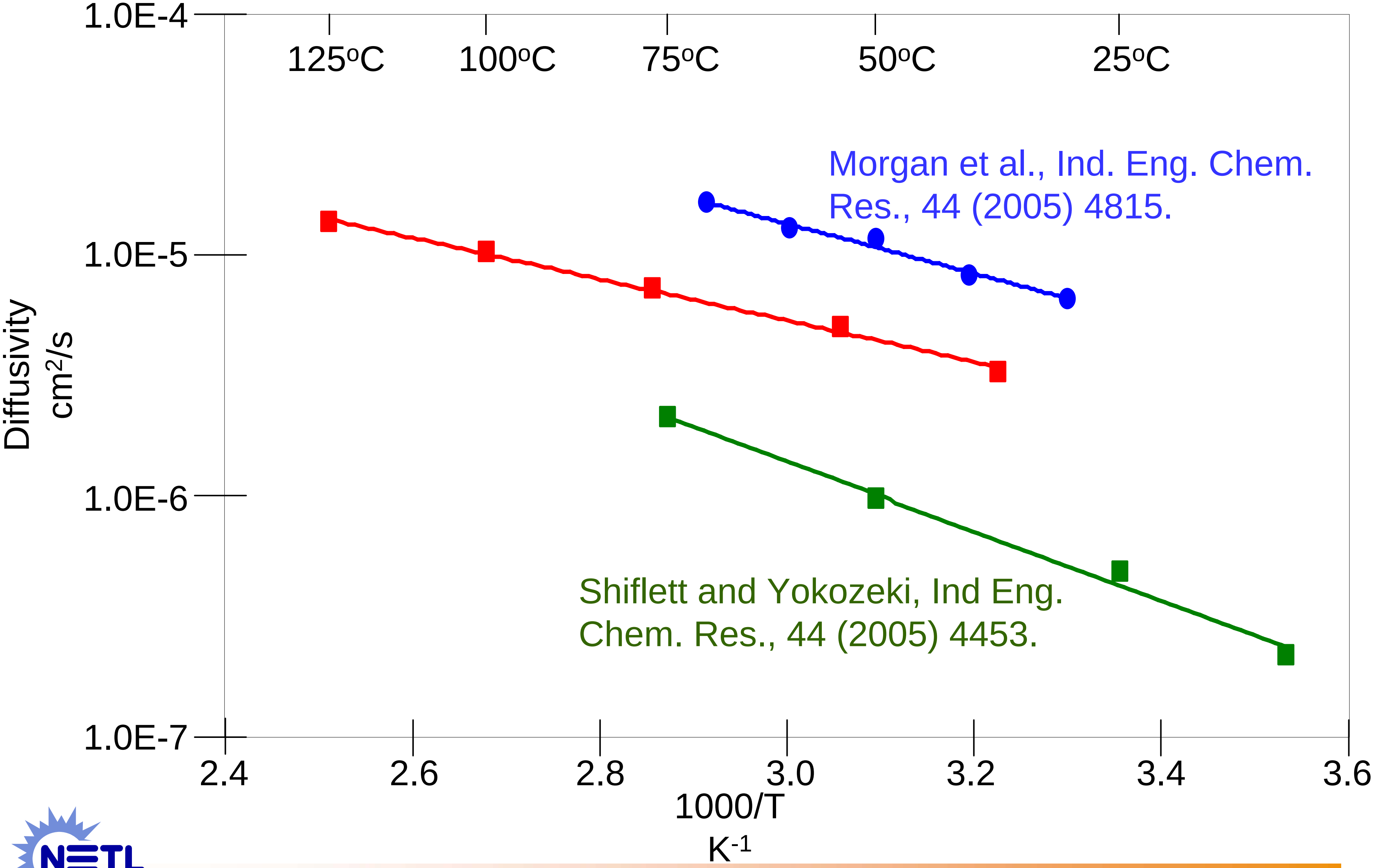
# $CO_2$ Diffusivities Comparable to Literature

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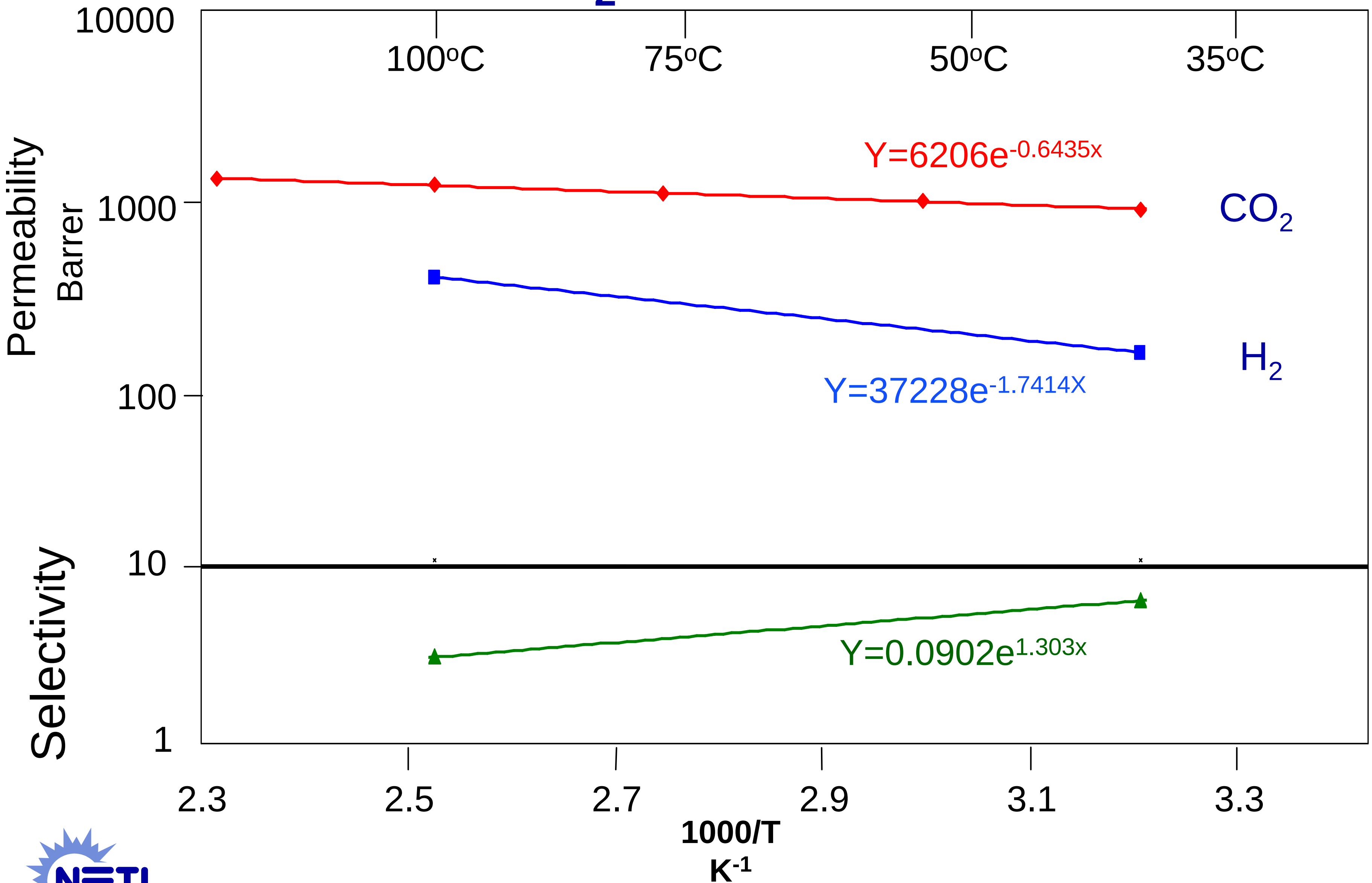
# He and $H_2$ Results Similar

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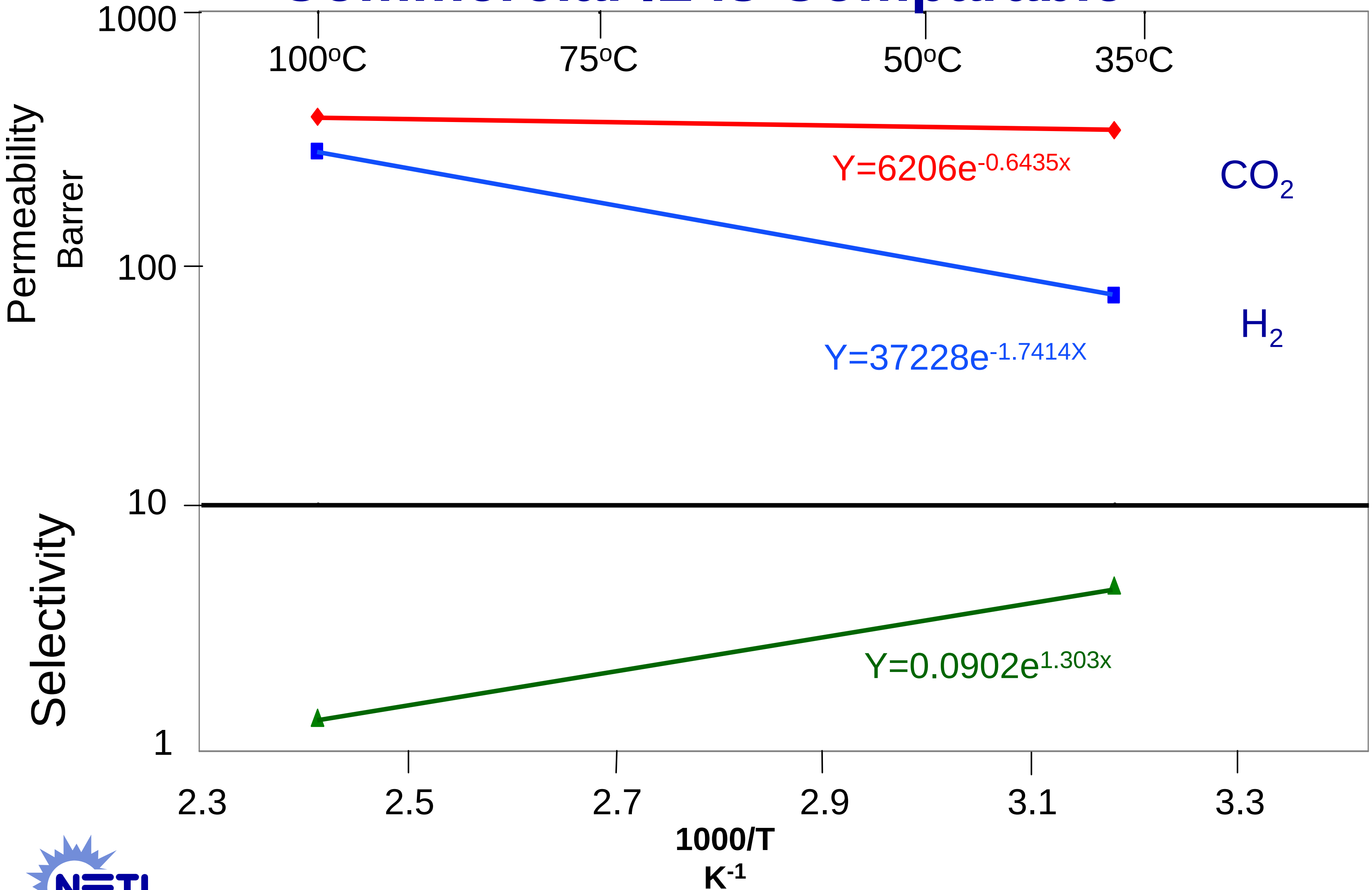
# Commercial IL is Comparable

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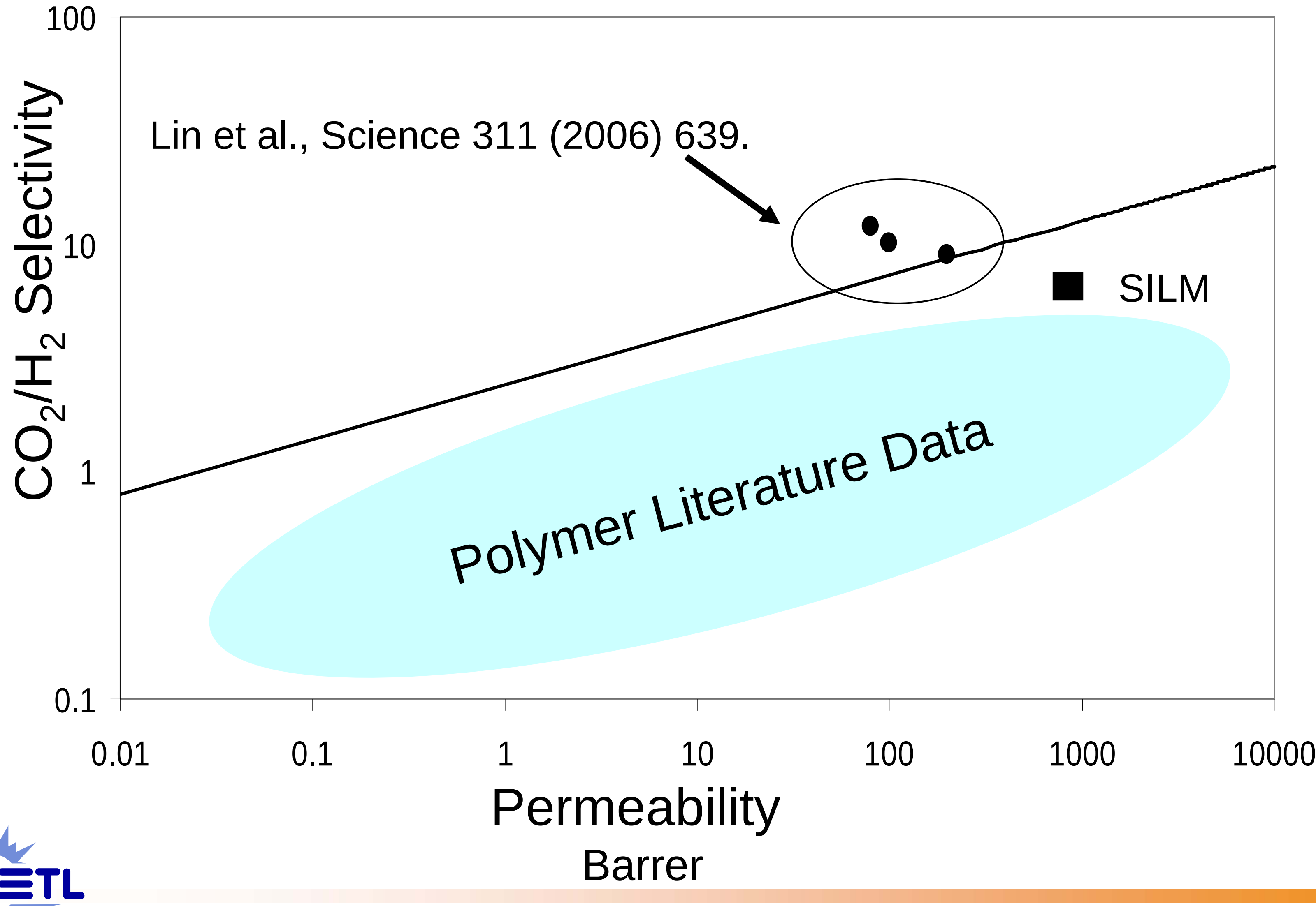
# Effect of $H_2O$ in Feed and Non-Ideality

| | Pure Gas | | Dry Gas Mixture | | Wet Gas Mixture | |
|---|---|---|---|---|---|---|
| Temperature (°C) | 37 | 100 | 37 | 100 | 37 | 100 |
| $CO_2$ Permeability (Barrer) | 817 | 1170 | 840 | 1040 | 742 | 1060 |
| $H_2$ Permeability (Barrer) | 136 | 359 | 121 | 350 | 109 | 367 |
| Selectivity ($CO_2/H_2$) | 6.4 | 3.3 | 7.0 | 3.0 | 6.8 | 2.9 |

# SILMs versus Polymers



# Summary

- Support selection in SILM is nontrivial.
- Support performance is predictable by DSC analysis.
- Current performance limited by support failure and IL blowout.
- Ideal and non-ideal selectivities similar.
- Performance not significantly impacted by a small amount of water in the feed.
- Unoptimized SILMs are competitive with the best polymer membranes.
- Industrially produced ILs of lower purity remain competitive.

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# 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.