Supported ionic liquid membranes for selective separation of volatile organic vapour and pollutants from gas stream

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COST INFORMATION DAY in the Czech Republic

EXIL (European network for Exchange of knowledge about **Ionic Liquids**)

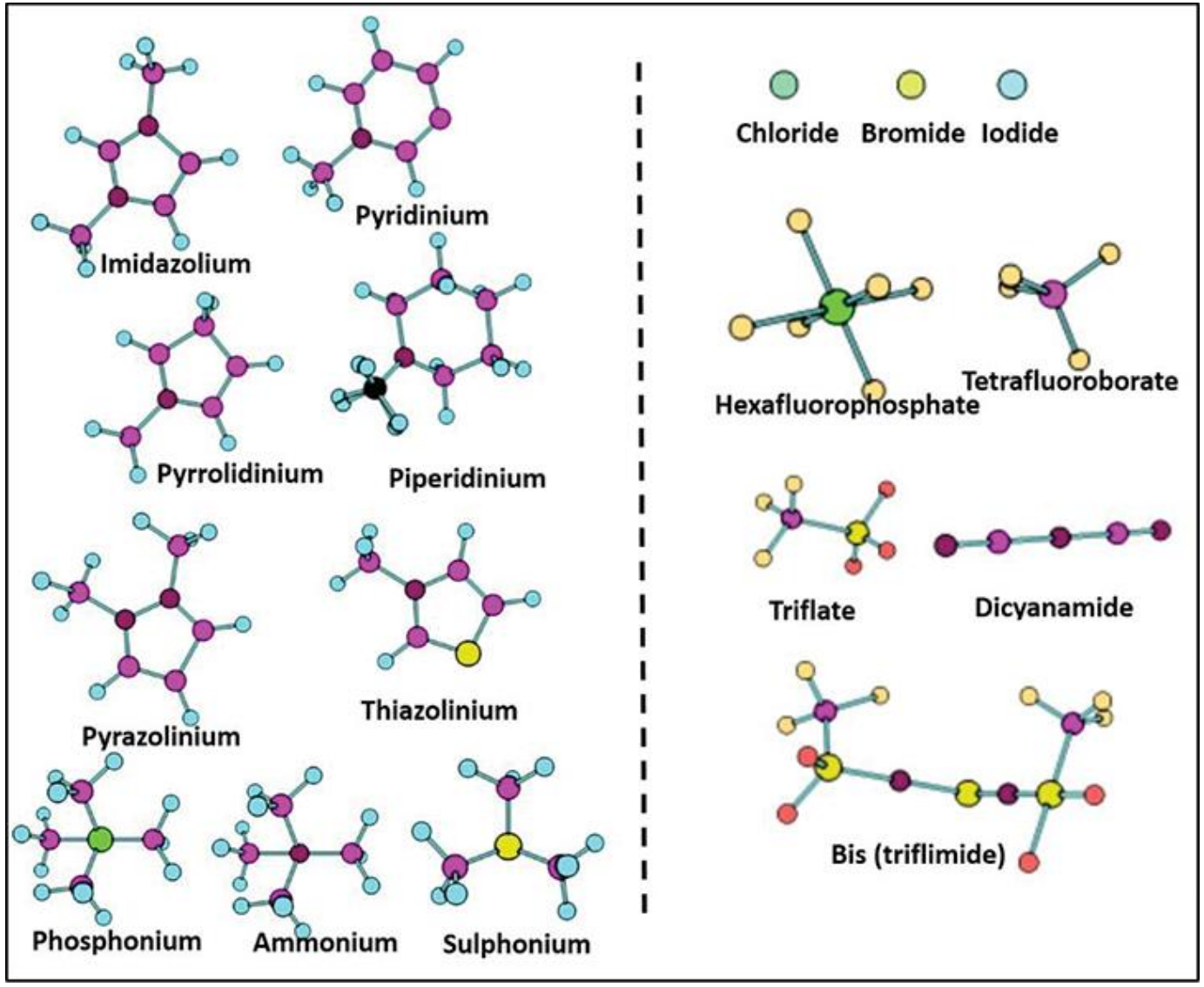
cost
EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

MINISTRY OF EDUCATION, YOUTH AND SPORTS

TECHNOLOGY CENTRE CAS

Google pictures

IONIC LIQUIDS



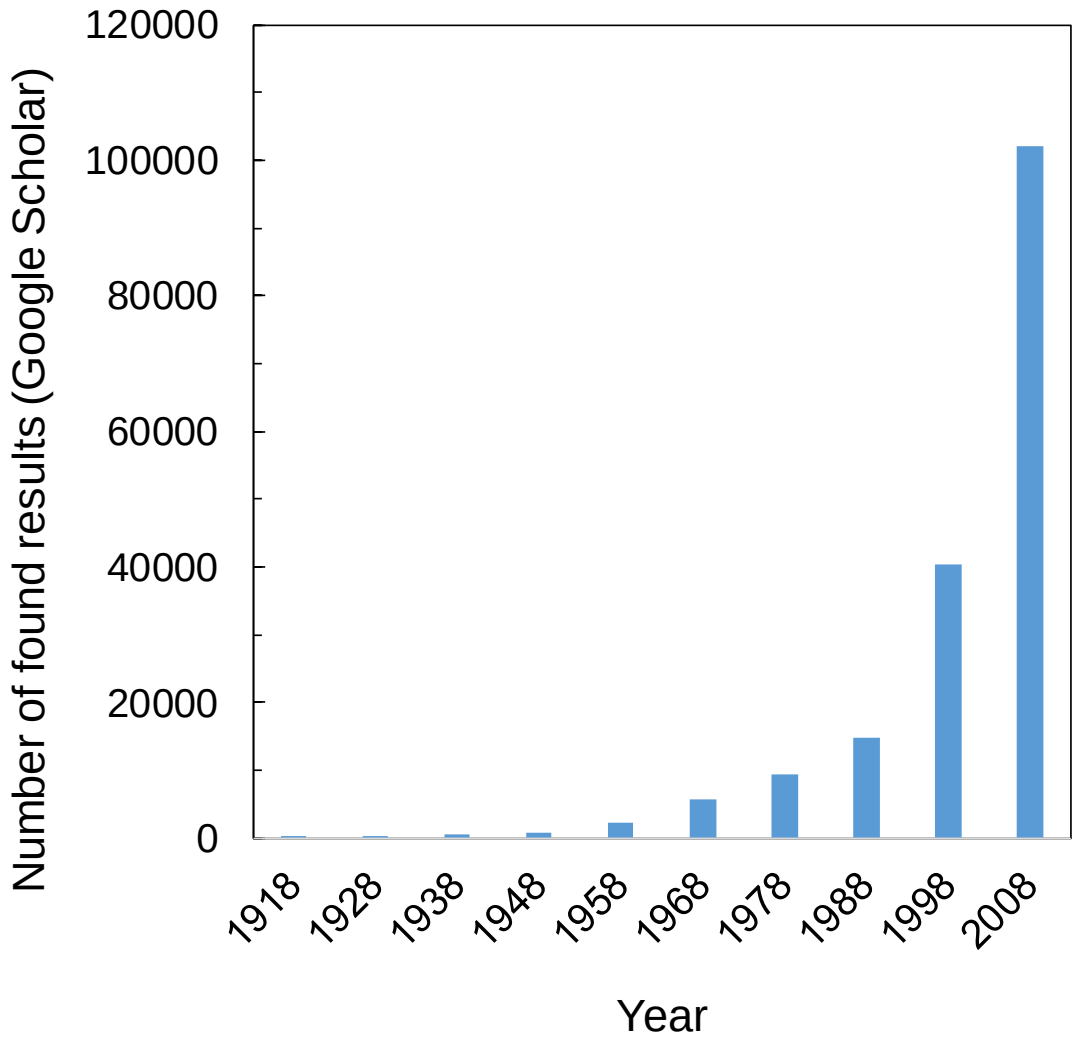
... they are magic
.... they conduct electricity
.... they do not evaporate
... they are said to be green solvent
...

- Unsymmetrical organic cation and organic/inorganic anion
- Salts (neutral) that are liquid at low temperature (below 30°C) … RTILs
- Works at mild conditions

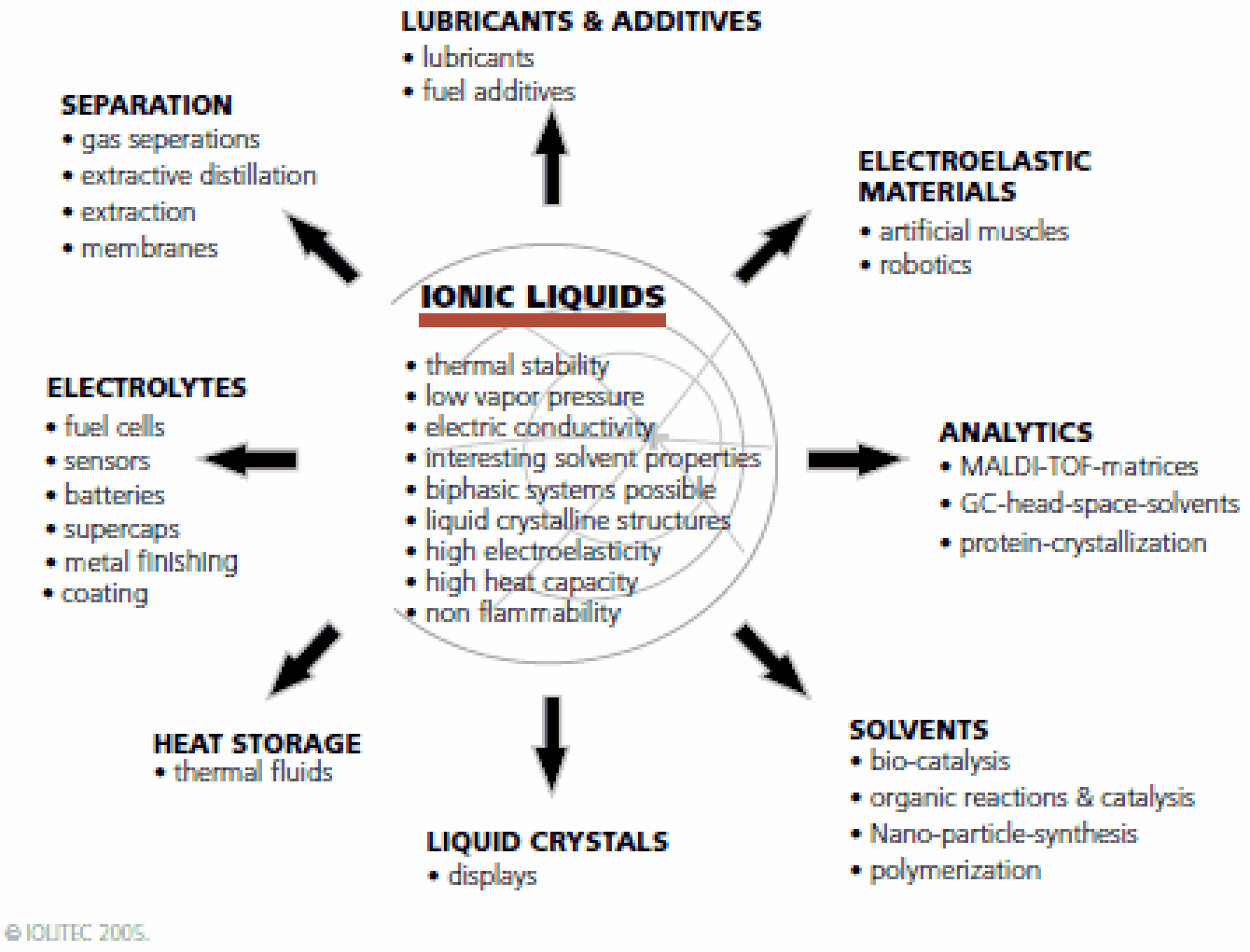
Google pictures

IONIC LIQUIDS

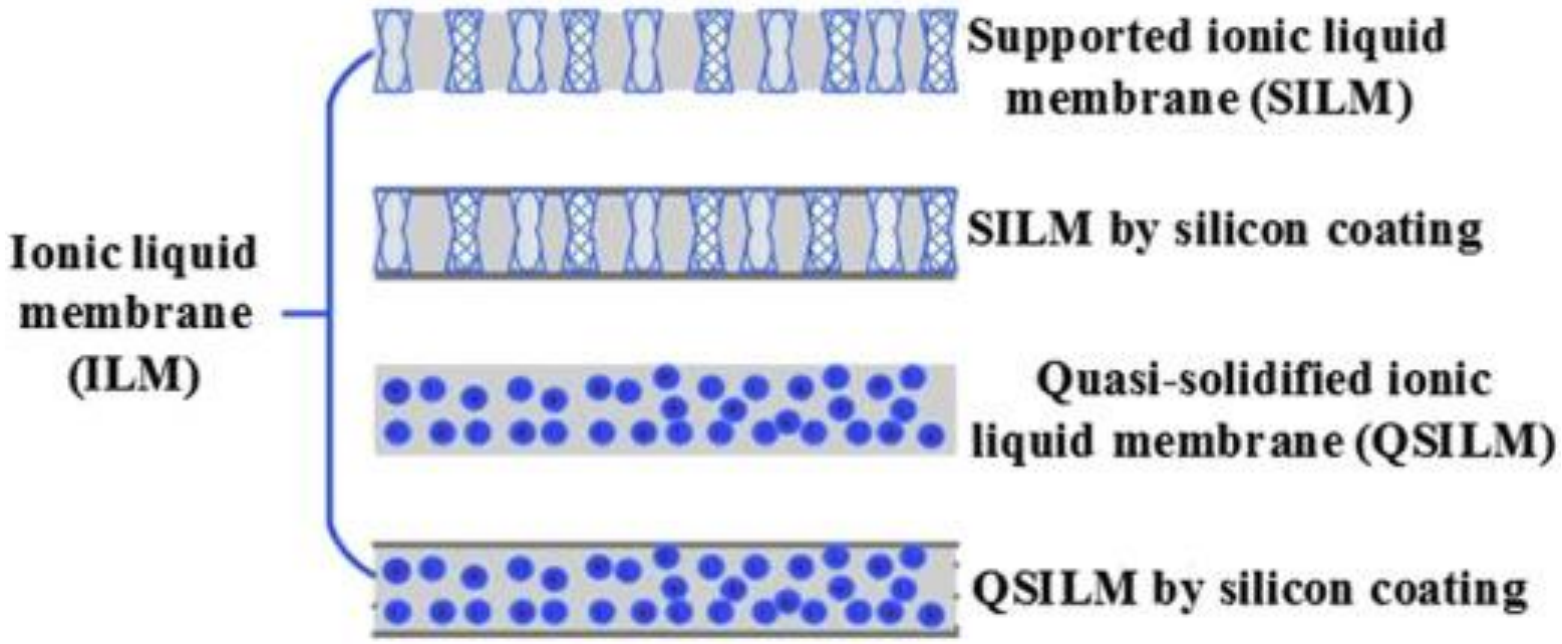
- Rapid growth of interest
- Tailored to address the needs of a specific application
- High thermal stability and chemical inertness
- Relatively low cost
- Easily separated and recycled
- Non-toxic to enzyme or fermentation

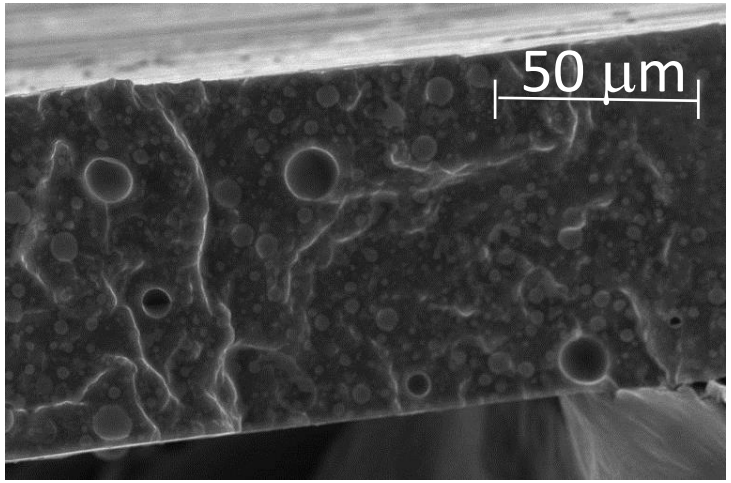


IONIC LIQUIDS



How to prepare membrane with IL?





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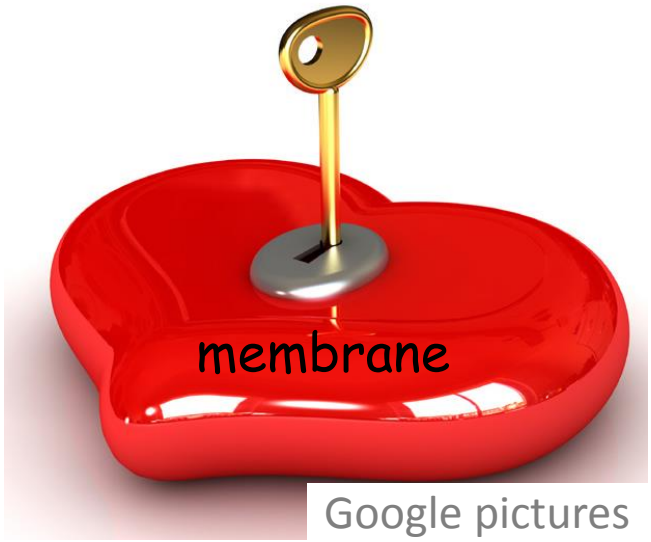
Membrane separation



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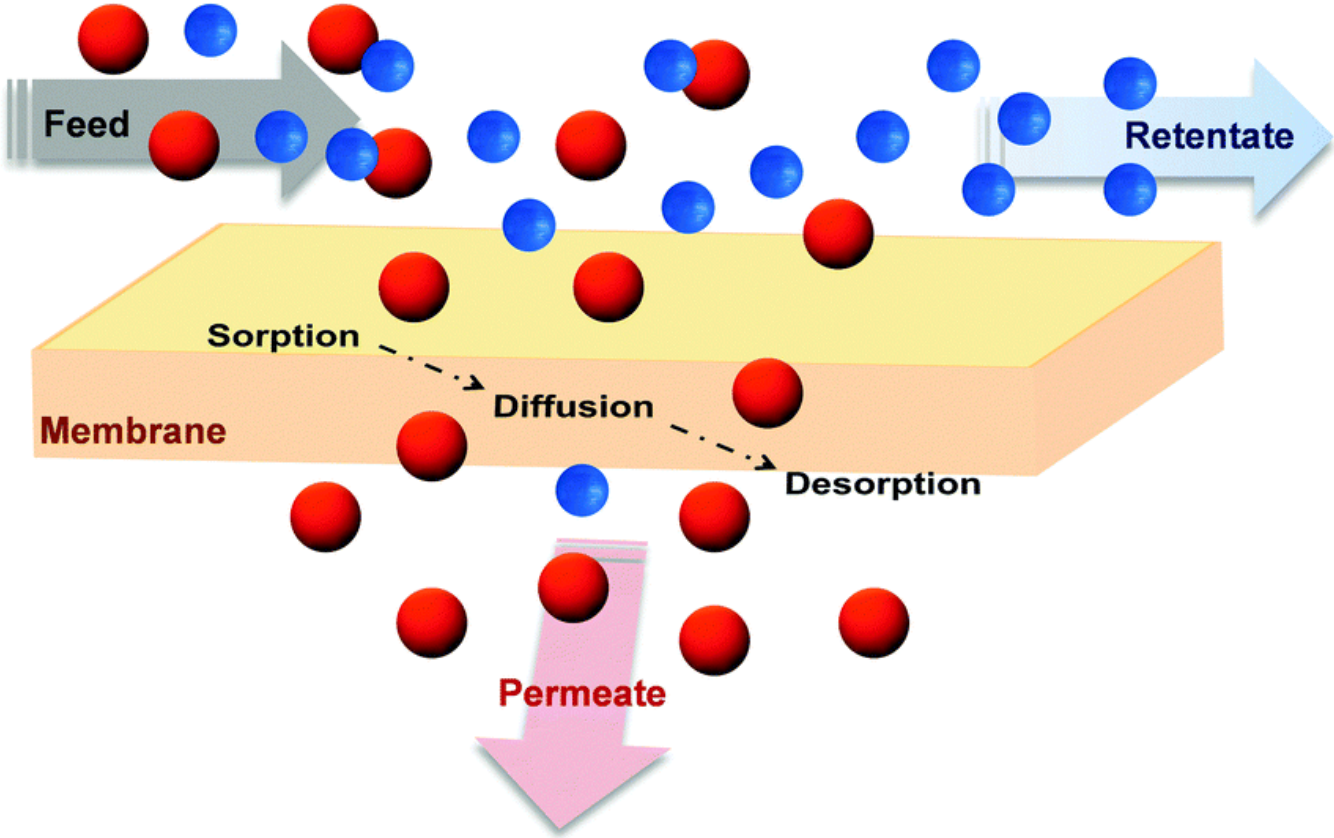
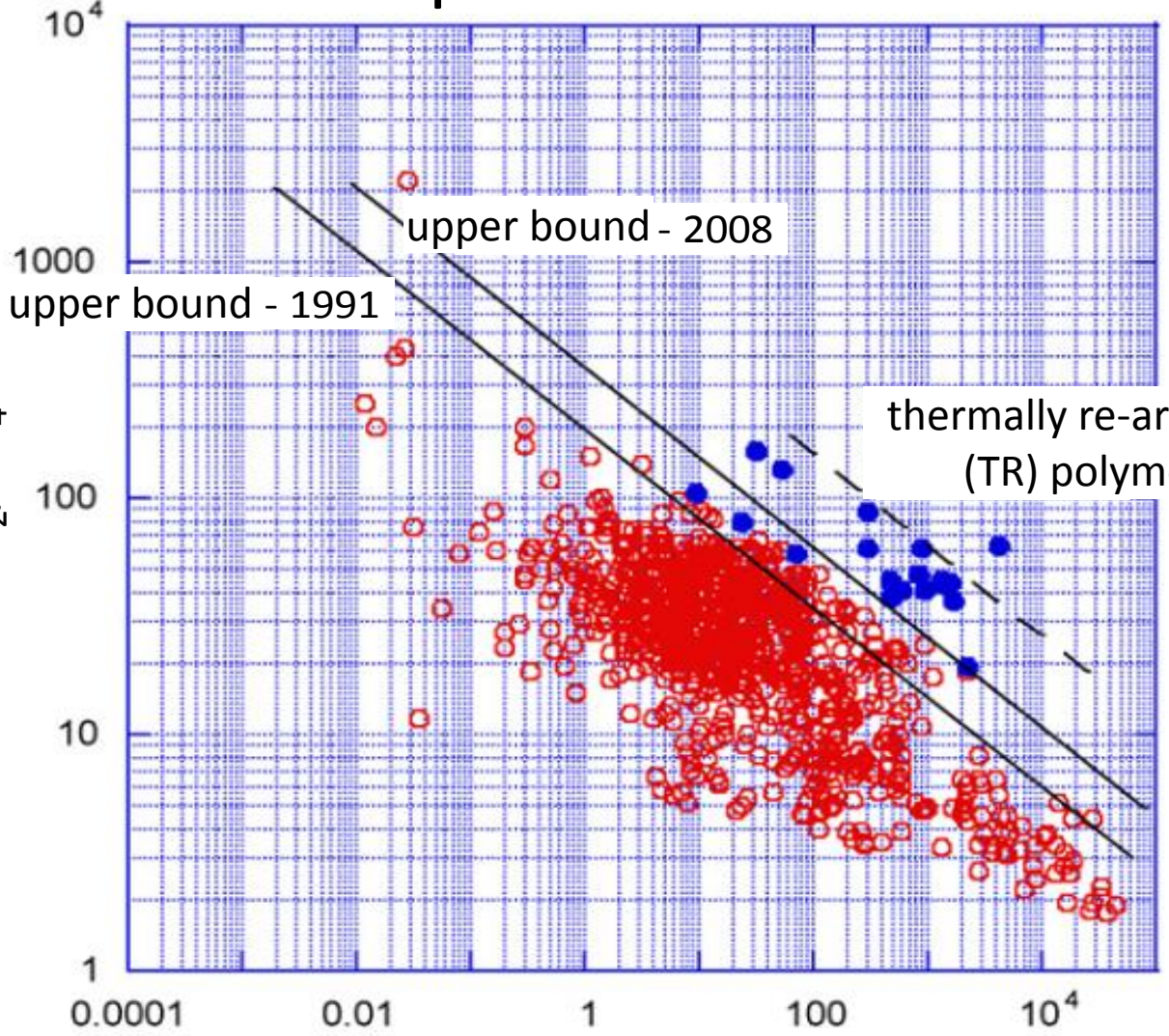


heart of membrane process

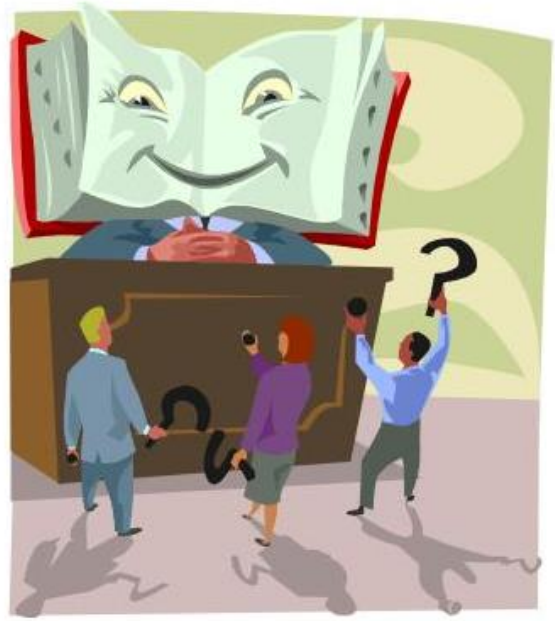
→ key parameter for the successful of membrane separation

$$S(c)_i \times D(c)_i = P_i$$

Robeson plot



Why must the cell membrane maintain SELECTIVE PERMEABILITY?



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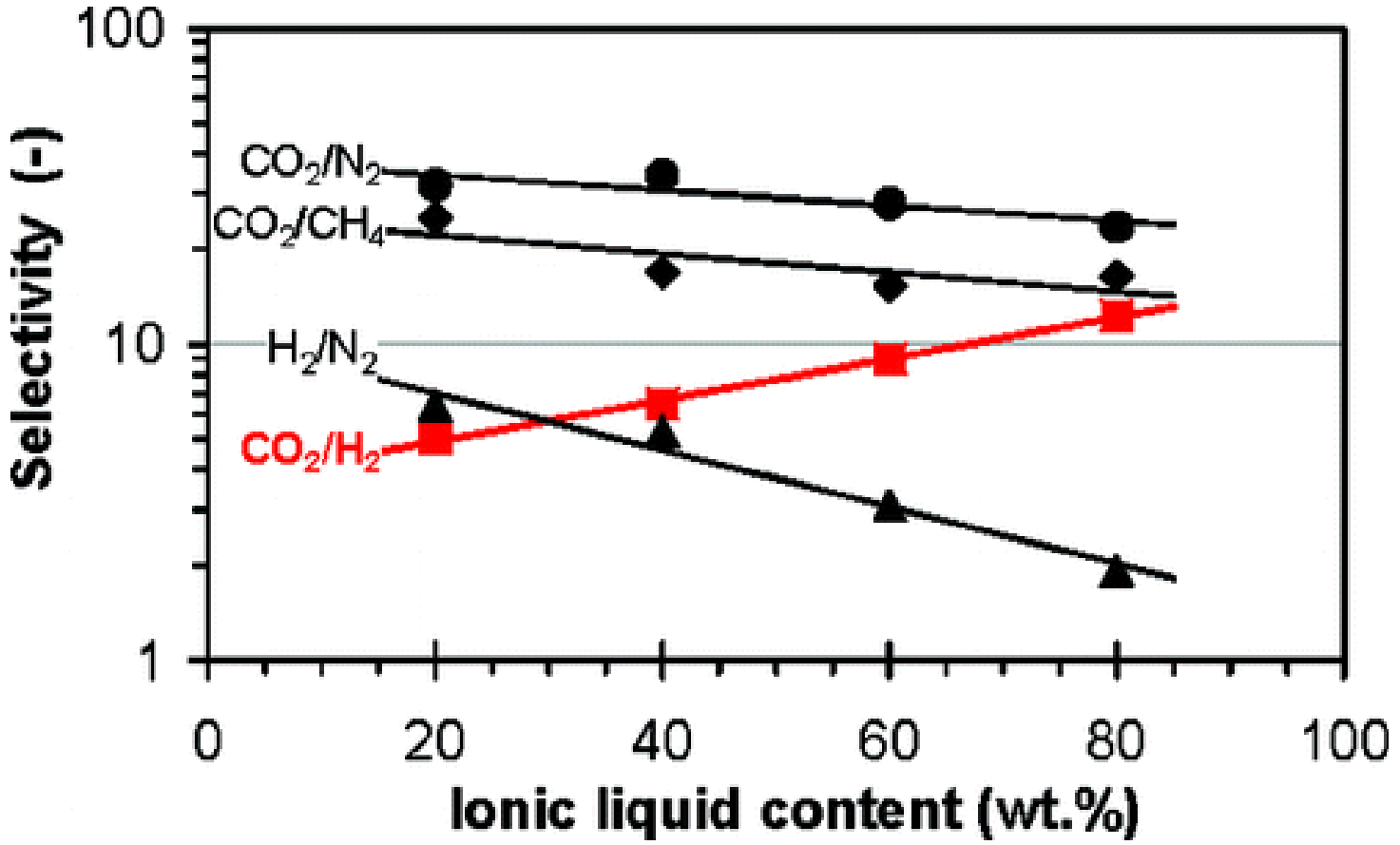
Improvement of separation properties thanks to IL



J. Jansen et al.: High ionic liquid content polymeric gel membranes: preparation and performance, ***Macromolecules* 2011**, *44* (1), pp 39–45

Biogas as a source of ecological energy

- Gaseous mixture contains mostly CH_4 and CO_2
- Other components like H_2S, NH_3 or siloxanes are present in trace concentrations
- Exact composition of biogas depends on its origin
  - sewage digester
  - farm biogas plant
  - landfill

  and can vary at different seasons

Biogas rises during anaerobic digestion of animal and vegetable waste.

Google pictures

Biogas upgrading processes

- Drying – water vapor removal
- Desulfurization
- Removal of other trace compounds (ammonia and siloxanes)
- Carbon dioxide removal
  - Absorption (water scrubbing, ammines)
  - Adsorption (porous solids – zeolites or active carbon)
  - Cryogenic separation
  - Membranes separation

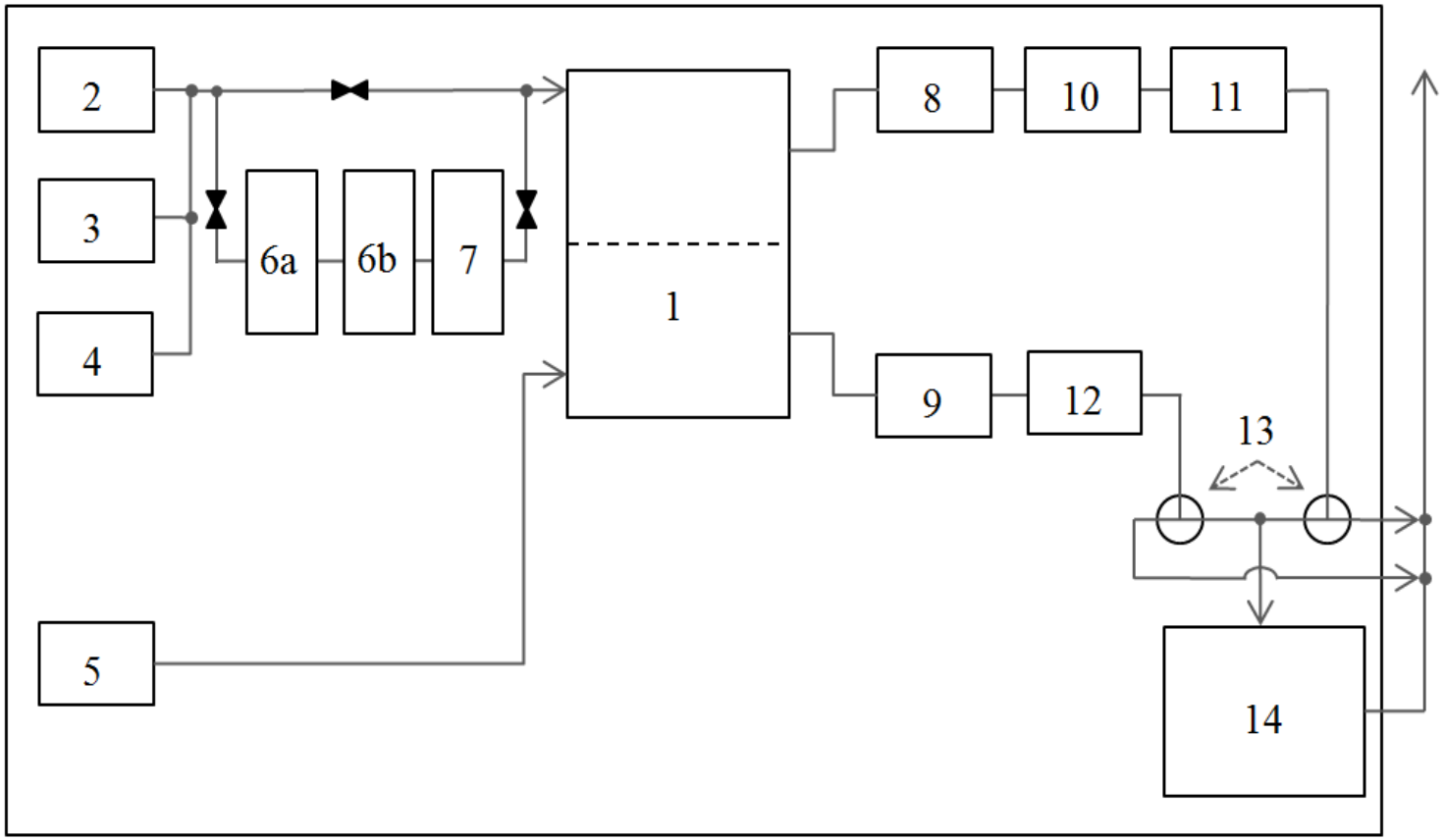
Membrane separation

- Energy savings
- Environmental friendliness
- Easy handling
- Continuous process
- Compact design and small footprint

- polyimides (PI)
- facilitated transport membranes
- mixed matrix membranes (MMMs)
- carbon molecular sieves (CMS)
- polyethyleneoxide (PEO)
- liquid membranes (LMs)

A. Brunetti, F. Scura, G. Barbieri, E. Drioli: Membrane technologies for CO_2 separation. Journal of Membrane Science 359 (2010) 115–125.

Gas permeation apparatus



1: permeation cell,

2: raw biogas flow controller,

3: CH_4 flow controller,

4: CO_2 flow controller,

5: N_2 flow controller,

6: humidifier (6a at T_{lab} and 6b is heated),

7: temperature and humidity sensor,

8,9: cold traps,

10: back pressure regulator,

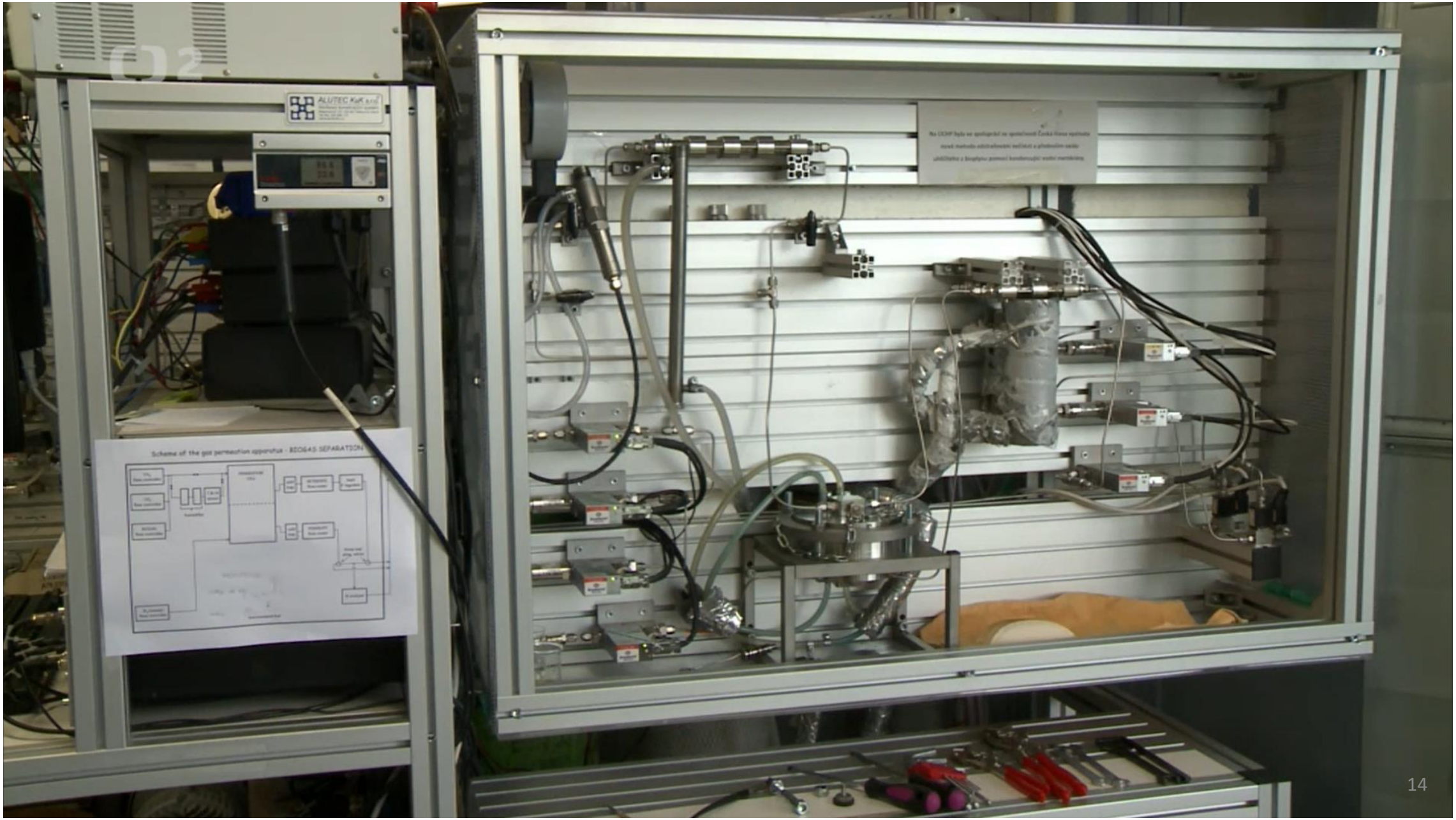
11: retentate flow meter,

12: permeate flow meter,

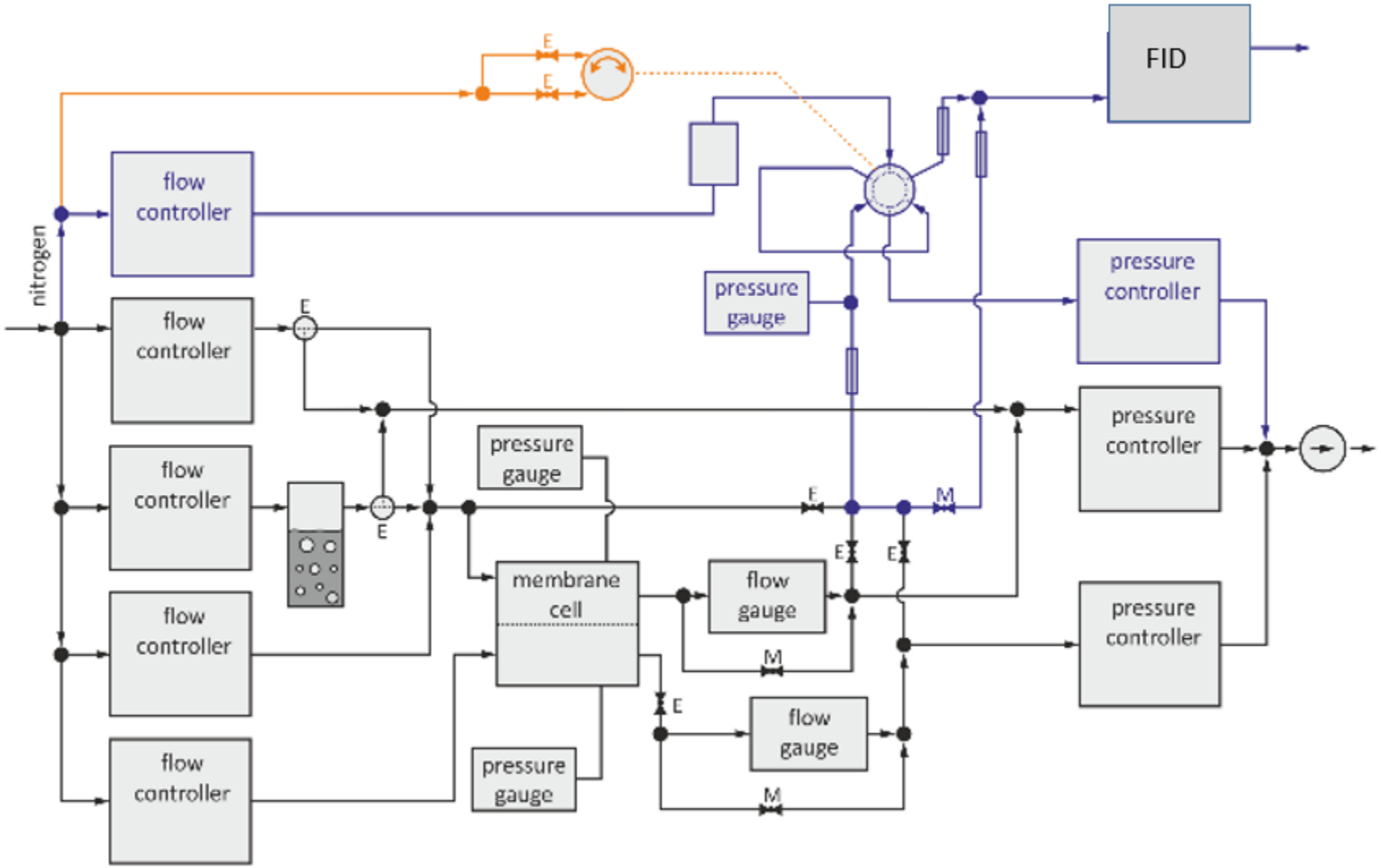
13: three-way electromagnetic valves,

14: IR analyzer.

Gas permeation apparatus



Organic vapour separation



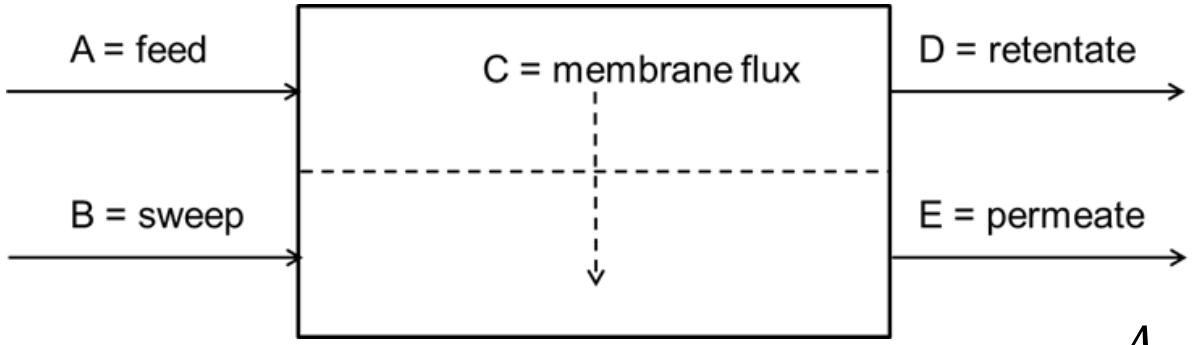
Modification:

- Cold trap for permeate stream

Innovation:

- Inline-FID analyses of all streams

Study of vapour permeation



$$A_{\mathrm{N_2}} - C_{\mathrm{N_2}} - D_{\mathrm{N_2}} = 0, \qquad \text{Eq. (1)}$$

$$A_{\mathrm{VOC}} - C_{\mathrm{VOC}} - D_{\mathrm{VOC}} = 0, \qquad \text{Eq. (2)}$$

$$B_{\mathrm{N_2}} + C_{\mathrm{N_2}} - E_{\mathrm{N_2}} = 0, \qquad \text{Eq. (3)}$$

$$B_{\mathrm{VOC}} + C_{\mathrm{VOC}} - E_{\mathrm{VOC}} = 0, \qquad \text{Eq. (4)}$$

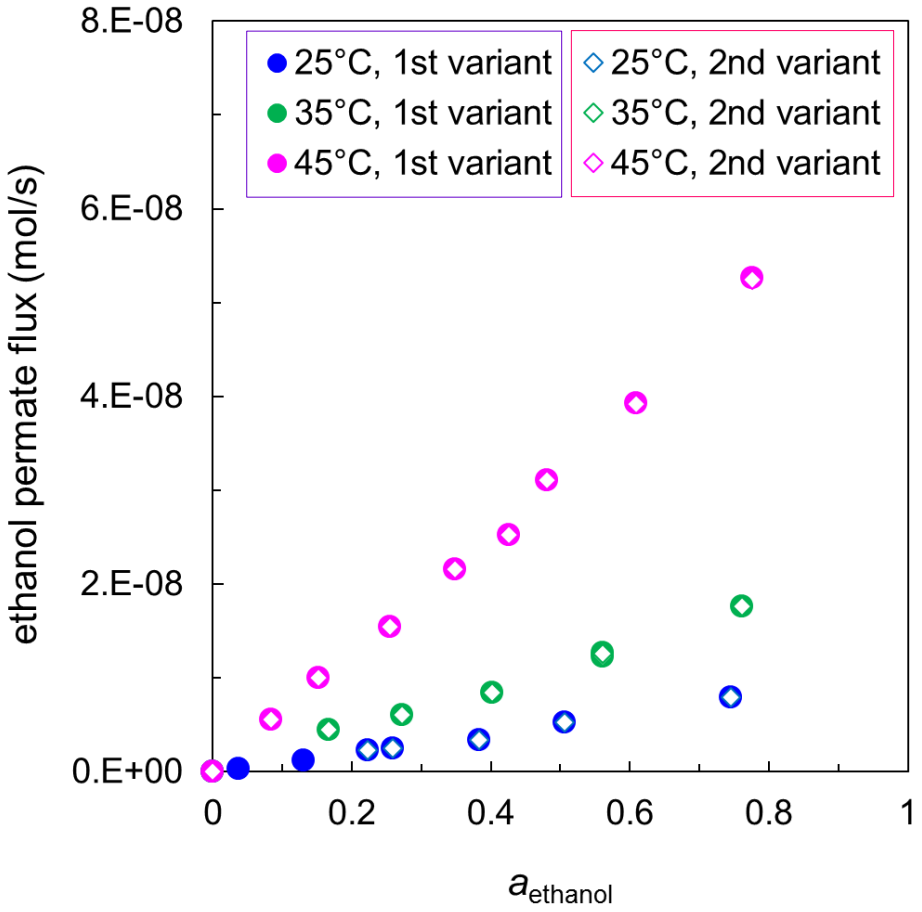
$$\left(1 - x_{\mathrm{E,VOC}}\right) \cdot E_{\mathrm{VOC}} - x_{\mathrm{E,VOC}} \cdot E_{\mathrm{N_2}} = 0, \qquad \text{Eq. (5)}$$

$$C_{\mathrm{N_2}} = 0, \qquad \text{Eq. (6)}$$

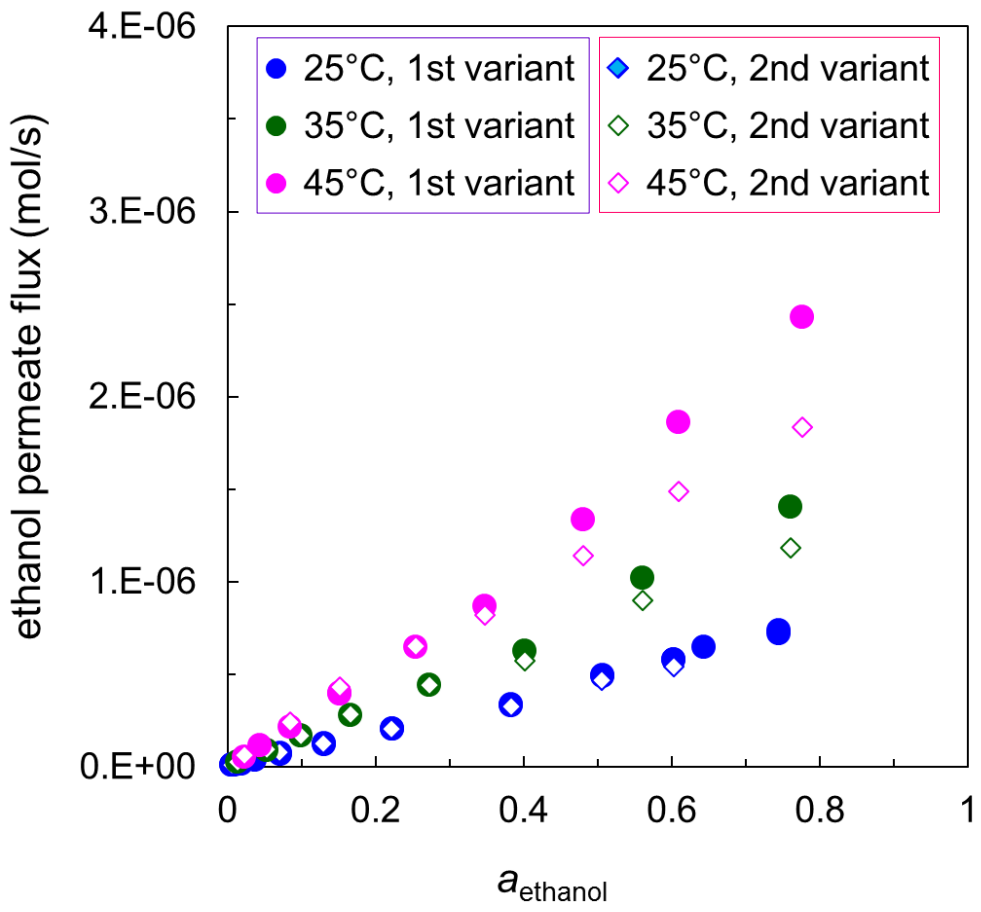
$$C_{\mathrm{N_2}} + C_{\mathrm{VOC}} = V/(\mathrm{R} \cdot T) \cdot (\mathrm{d}P/\mathrm{d}\tau), \qquad \text{Eq. (7)}$$

Study of vapour permeation

Ethanol vapour permeation in LDPE membrane



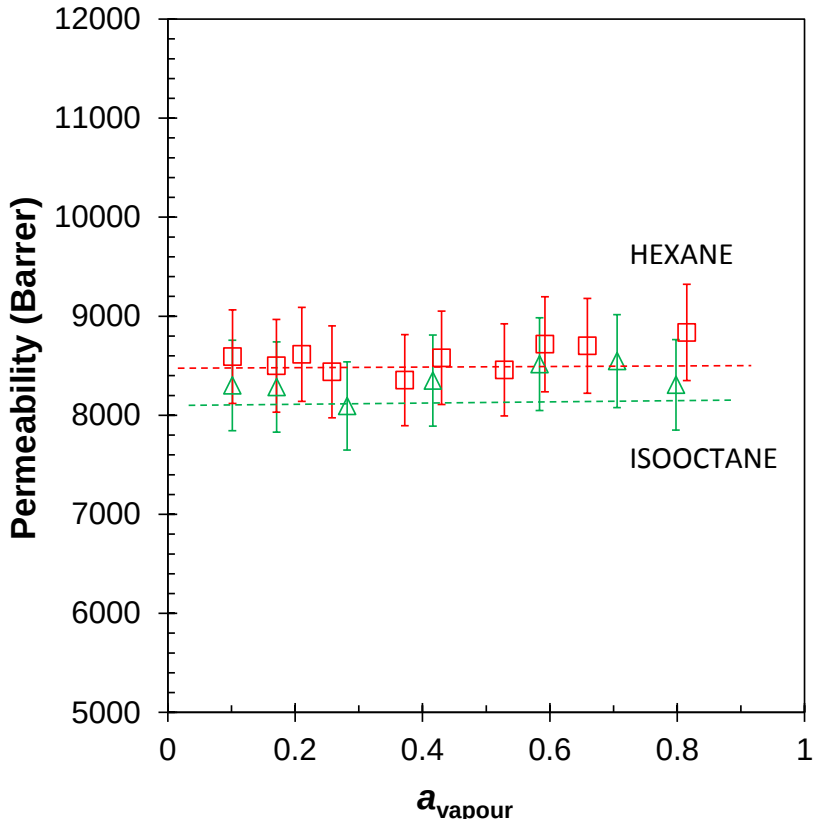
Ethanol vapour permeation in IL membrane

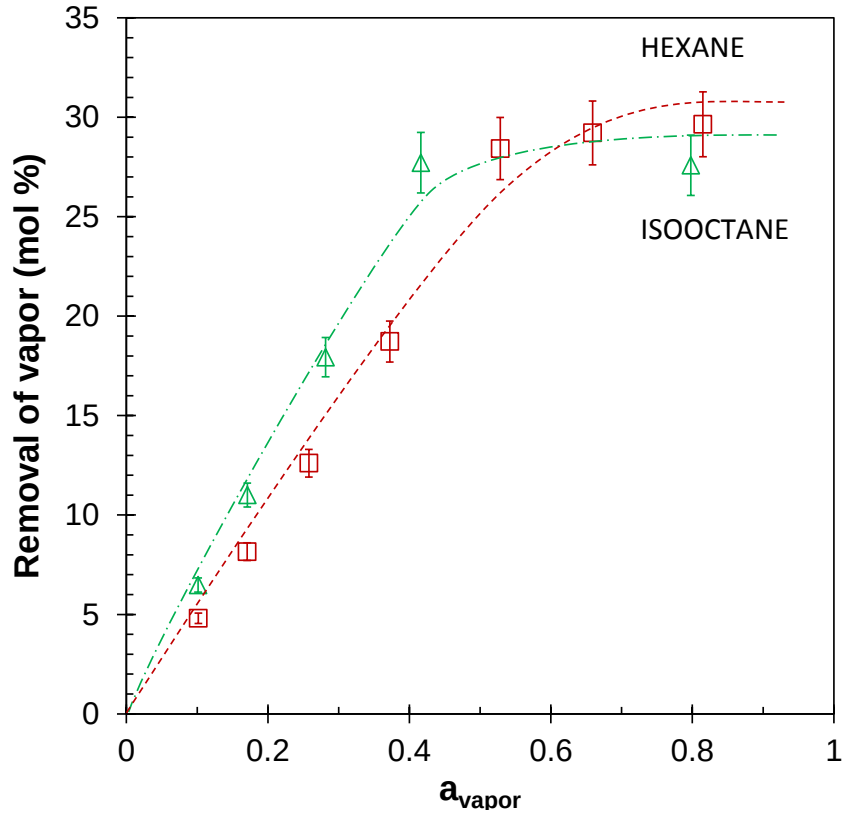


L. Morávková et al./Chemical Papers 68 (12) 1739–1746 (2014)

Study of vapour permeation

Hexane and isooctane permeation in IL membrane





- IL membrane: hexane removal up to 30mol. % × poly(vinylidene fluoride-co-hexafluoropropylene) membrane is impermeable

L. Morávková et al./Chemical Papers 68 (12) 1739–1746 (2014)

Summary of representative published results within the project

Study of sorption properties

- Randova A. et al.: A New Prediction Method for Organic Liquids Sorption into Polymers. J. Membrane Sci. 475, 545-551 (2015).
- Randova A. et al.: Sorption of Organic Liquids in Poly(ethylene chlorotrifluoroethylene) Halar®901: Experimental and Theoretical Analysis. Polym. Test 58, 199-207 (2017).

Study of vapour transport properties

- Moravkova L. et al.: Vapour Permeation and Sorption in Fluoropolymer Gel Membrane Based on Ionic Liquid 1-Ethyl-3-Methylimidazolium bis(trifluoromethylsulfonyl)Imide. Chem. Pap. 68(12), 1739-1746 (2014).
- Vopicka O. et al.: Ethanol Sorption and Permeation in Fluoropolymer Gel Membrane Containing 1-Ethyl-3-Methylimidazolium bis(Trifluoromethylsulphonyl)Imide Ionic Liquid. Chem.Eng.Process. 94(SI), 72-77 (2015).
- Petrusova Z. et al.: Comparison of Hexane Vapour Permeation in Two Different Polymeric Membranes via an Innovative In-Line FID Detection Method. Chem. Biochem. Eng. Q. 31(2), 145-160 (2017).

Study of gas permeation – review papers

- Karaszova M. et al.: Progress in Separation of Gases by Permeation and Liquids by Pervaporation Using Ionic Liquids: A Review. Sep. Purif. Technol. 132, 93–101 (2014).
- Karaszova M. et al.: Gas Permeation Processes in Biogas Upgrading: A Short Review. Chem. Pap. 69(10), 1277–1283 (2015).
- Izak P. et al.: Catalytic Ionic-Liquid Membranes: The Convergence of Ionic-Liquid Catalysis and Ionic-Liquid Membrane Separation Technologies. ChemPlusChem 83(1), 7-18 (2018).

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and fruitful contacts with new trends at the specialised institutes

WHAT CAN WE OFFER TO THE WORLD?

Handy workshop and ingenious apparatuses

... FOR YOUR KIND ATTENTION

FINANTIAL SUPPORT FROM CZECH MINISTRY OF EDUCATION, YOUTH AND SPORTS (**COST PROJECT LD 14094**) IS GREATLY APPRECIATED.