Center for Research and Technology-Hellas
Chemical Process Engineering Research Institute
Laboratory of Inorganic Materials

CERAMIC MEMBRANES IN ENERGY AND ENVIRONMENT RELATED APPLICATIONS

Research at the Center of Research and Technology-Hellas

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CONTENTS

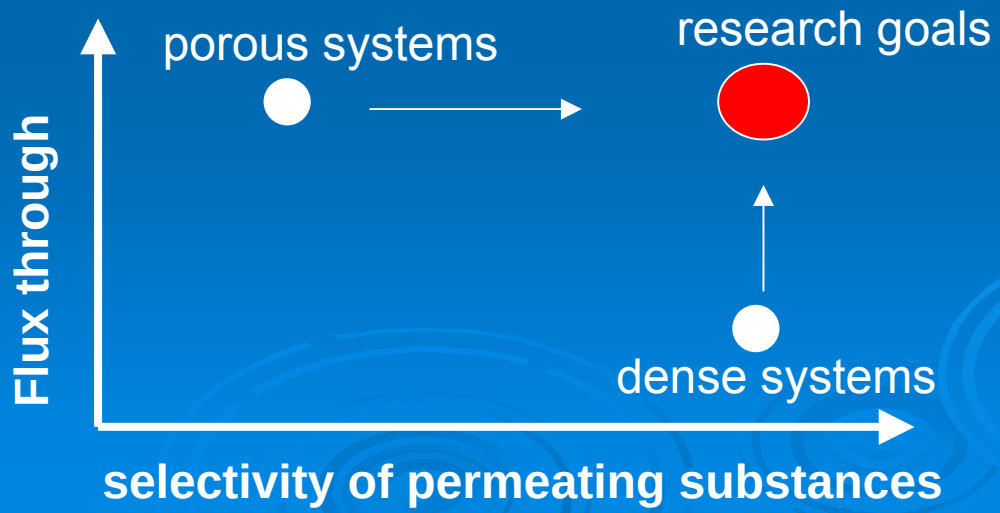
What is a membrane

A ceramic membrane is a thin semi-permeable film made of inorganic oxidic materials

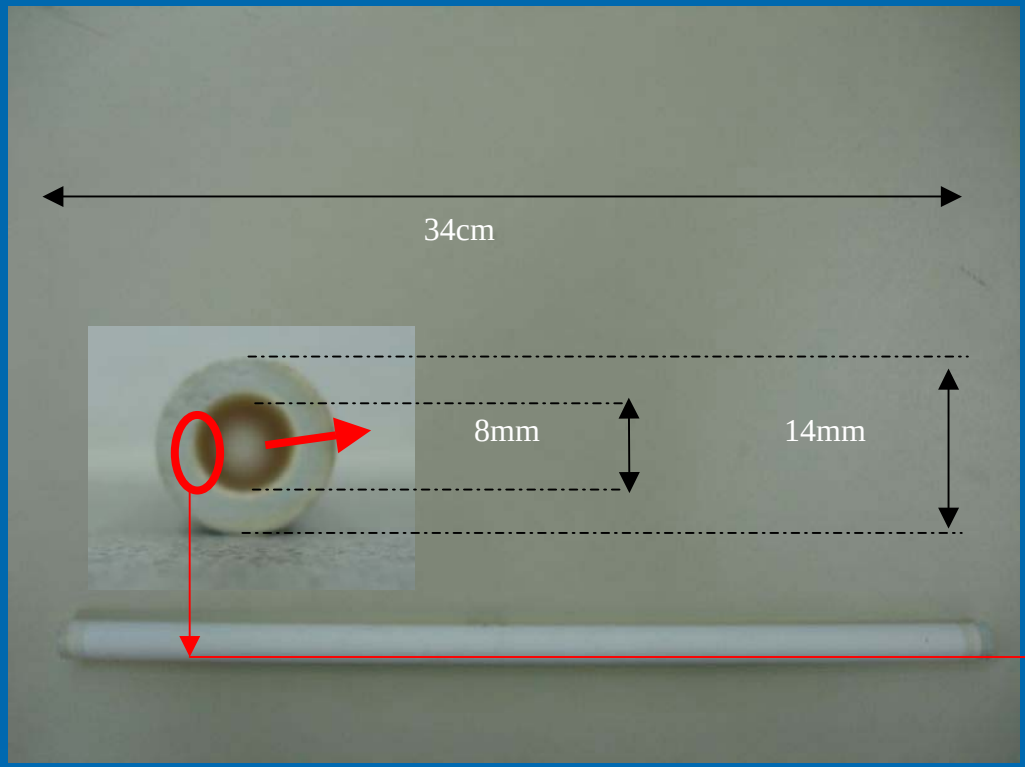
It can be porous so that selective transport takes place though the pores and through various mechanisms

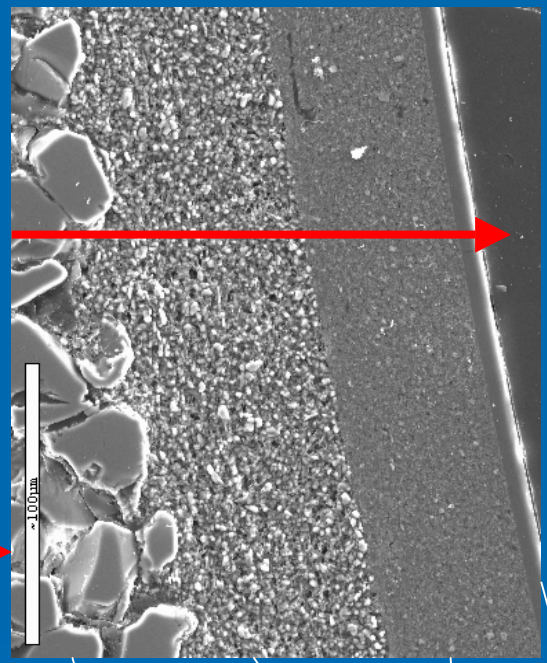
It can be non porous so that selective transport takes place through crystalline lattice diffusion

It can be self-supported when is thick and strong enough, or supported on substrates when is thin and mechanically weak



What is a membrane





nanoporous layer

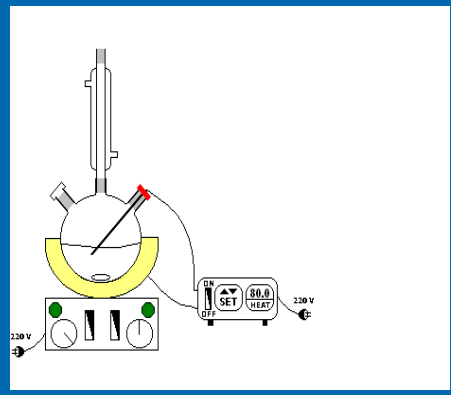
macroporous substrate

mesoporous “bridge” layers

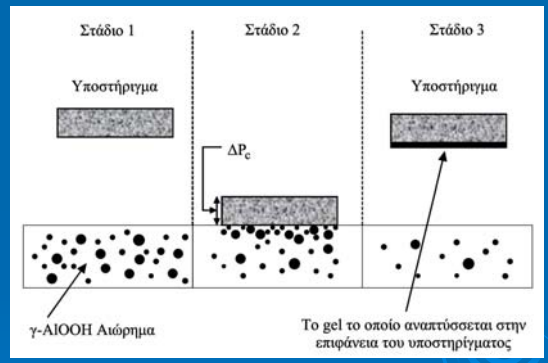
What is a membrane

Ceramic membranes at CERTH are prepared:

Step 1: Synthesis of stabilized nanoparticle dispersions by metal-alkoxide hydrolysis



Step 2: Membrane layer formation by dip-coating on porous substrates



Step 3: Eventual further pore surface modification or size reduction by wet impregnation or vapor deposition techniques

Porous membranes, Separation of gas mixtures

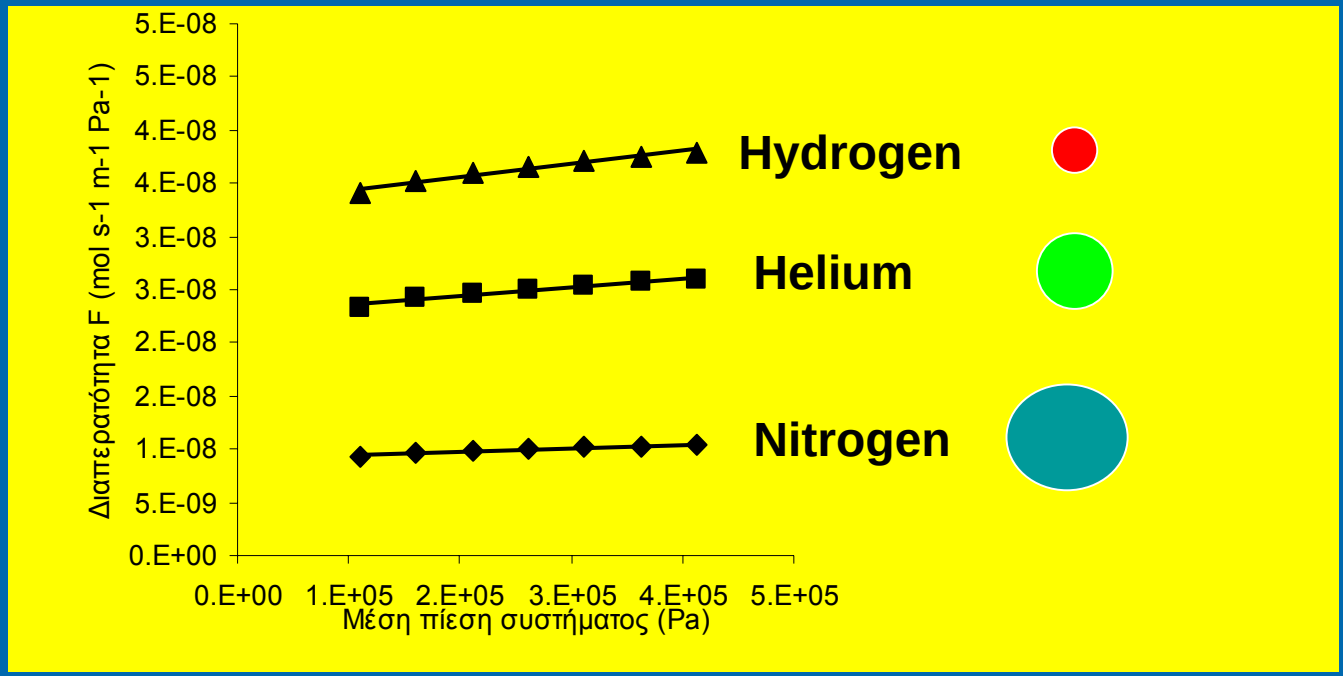
Scientific principle I: Knudsen law

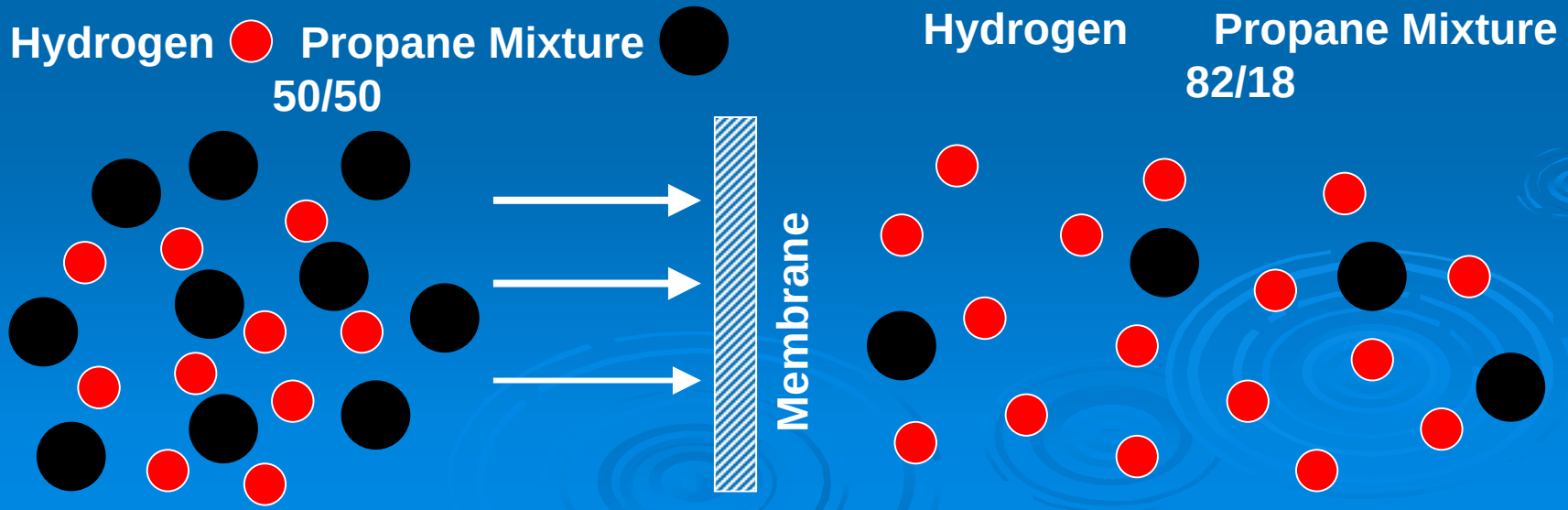
$$F_K = AD_K \frac{dC}{dx} = \frac{A2\varepsilon\mu_k r_m v_m}{3RT}\frac{\Delta P}{L} \qquad v_m = \sqrt{\frac{8RT}{\pi M}}$$

In simple words: At nanopore level small molecules move faster than large ones

This principle can form the basis for the development of separation techniques where mixtures of light (e.g. hydrogen) and heavy (e.g. hydrocarbons) components can be enriched in the light components

Porous membranes, Separation of gas mixtures





Porous membranes, Separation of gas mixtures

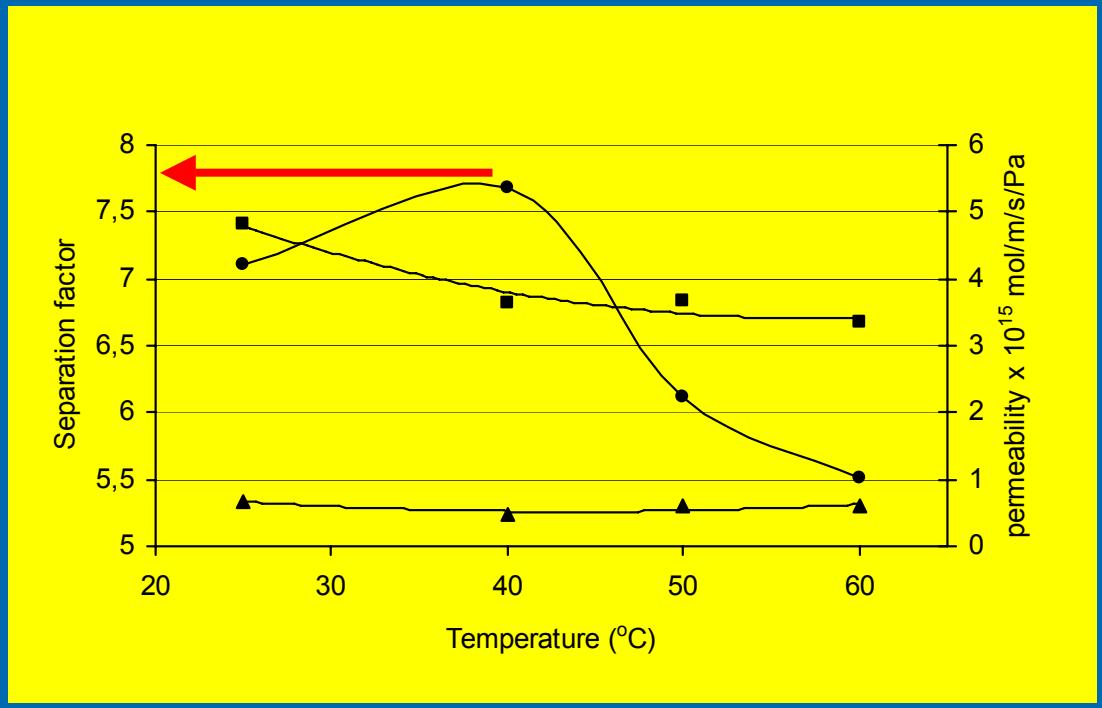
Scientific principle II: **Kelvin law**

$$\frac{\rho RT}{M}\ln\frac{P_t}{P_0} = -\frac{2\sigma\ \cos\vartheta}{r}$$

Vapor pressure of liquid concave in a pore is lower than that of the same liquid on a flat surface, it therefore condenses much earlier

This principle can form the basis for the development of separation techniques on mixtures containing a condensable and non-condensable and non-soluble component

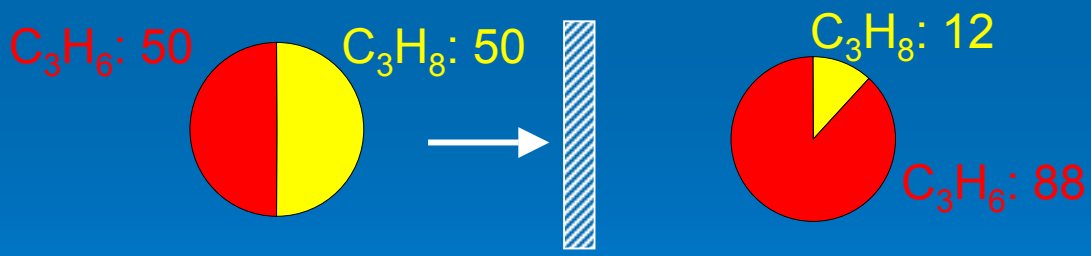
Porous membranes, Separation of gas mixtures

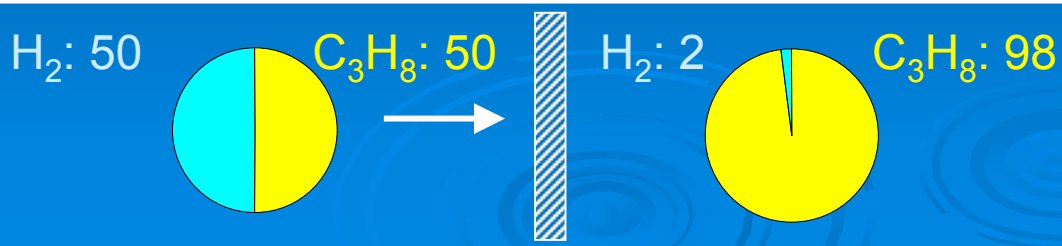


Propane C_3H_8

Propylene C_3H_6

Similar molecules very difficult to separate



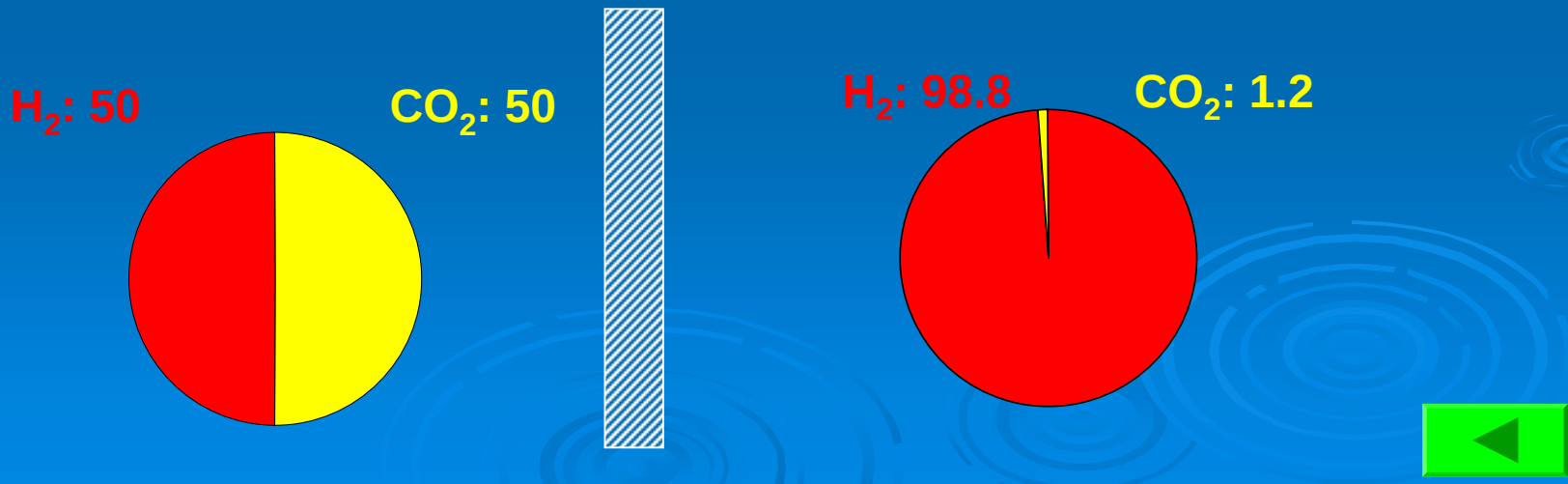


Porous membranes, Separation of gas mixtures

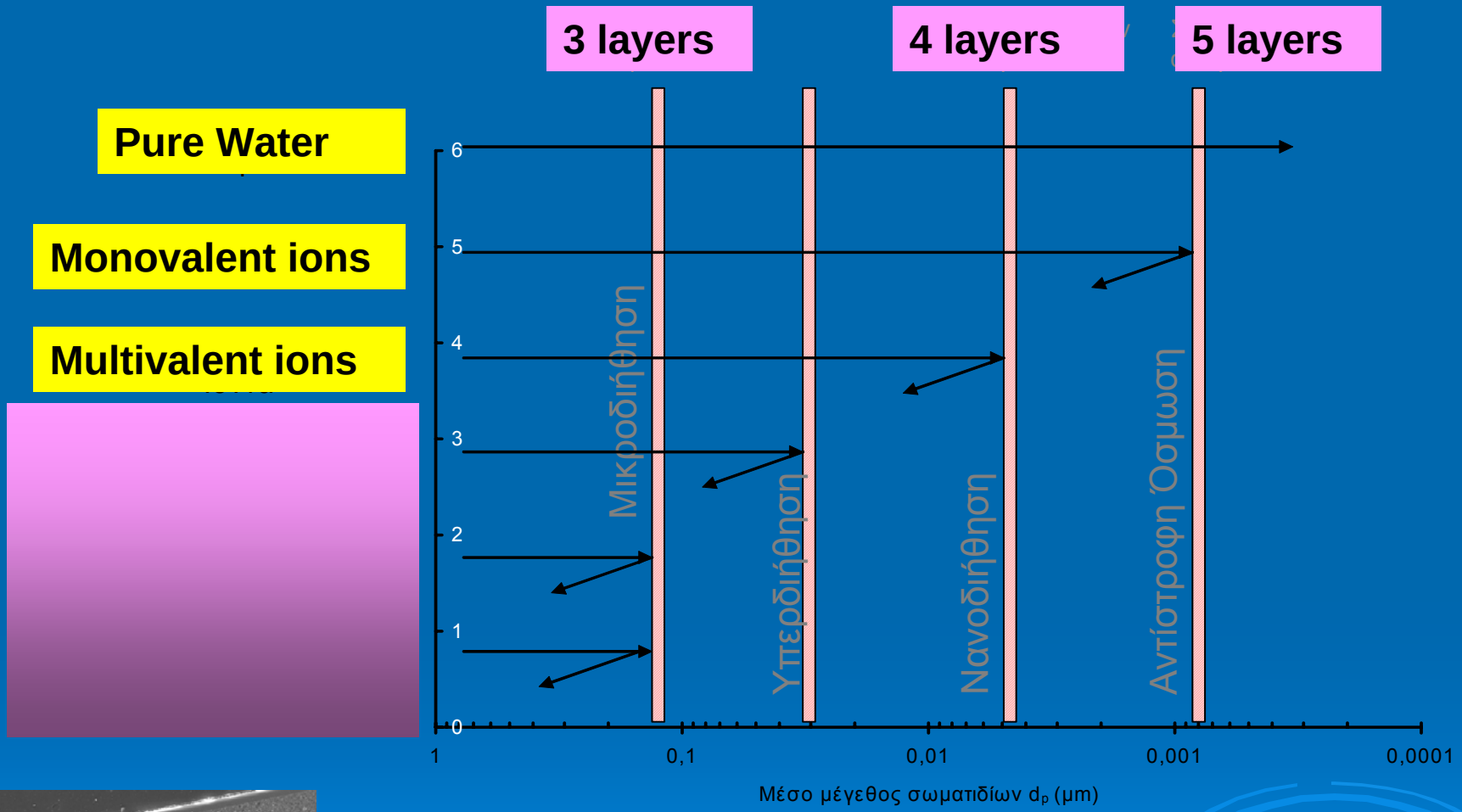
Scientific principle III : Activated microporous diffusion

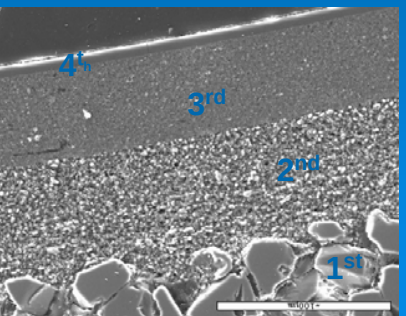
The pore is reduced down to the molecular dimensions and separation occurs by sieving

Vapor deposition techniques

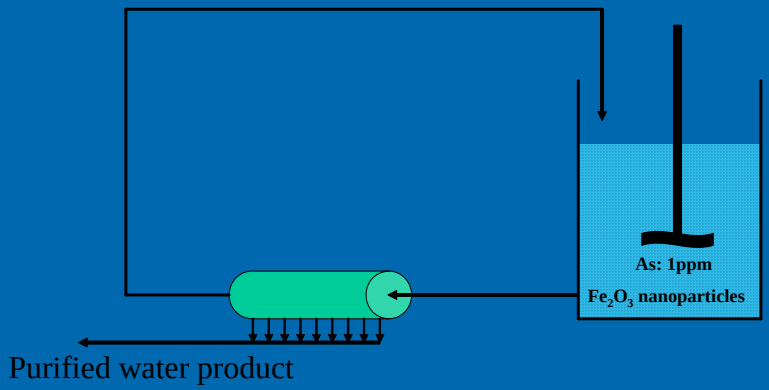


Porous membranes, Water treatment

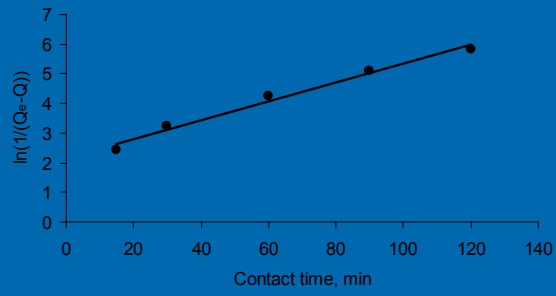


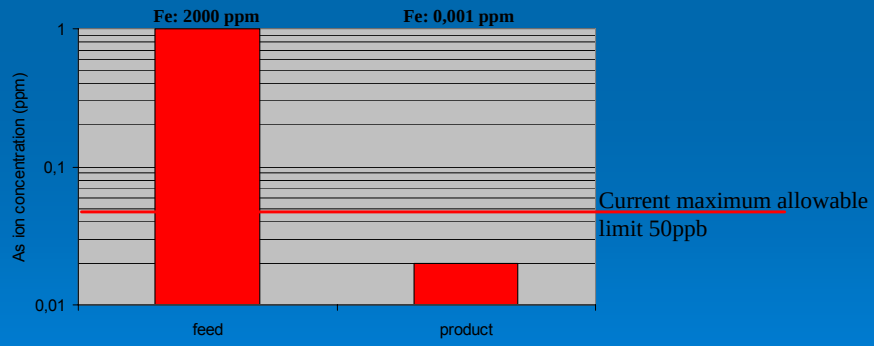


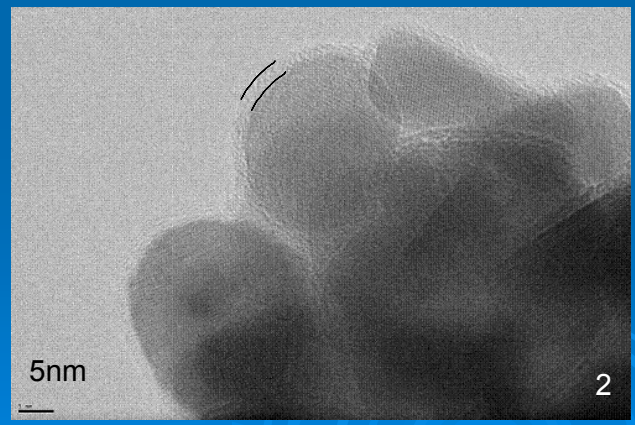
Removal of toxic metals (As, Cr) from water



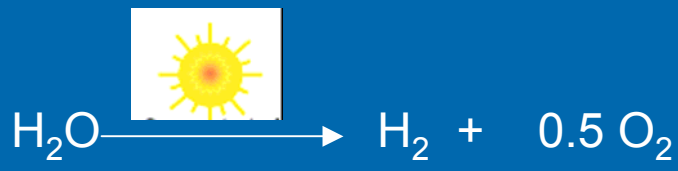
$$\ln\left(\frac{1}{Q_e - Q}\right) = K_{ad}t - \ln Q_c$$





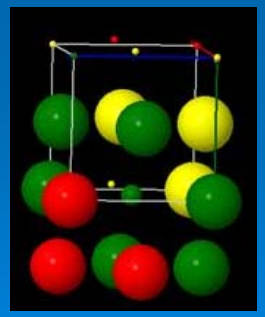


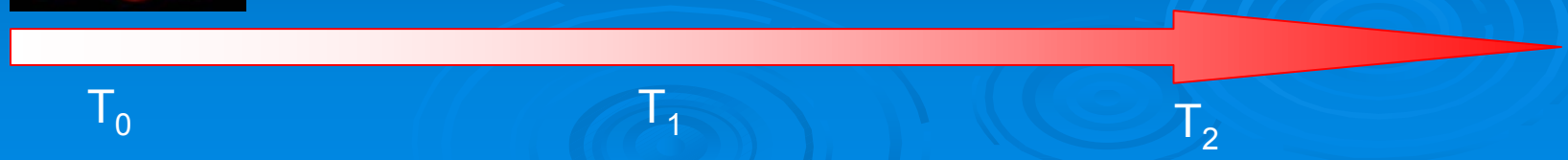
One of the most promising and long-term sustainable routes for the production of energy is:



The process currently under intensive research is the so-called RedOx process

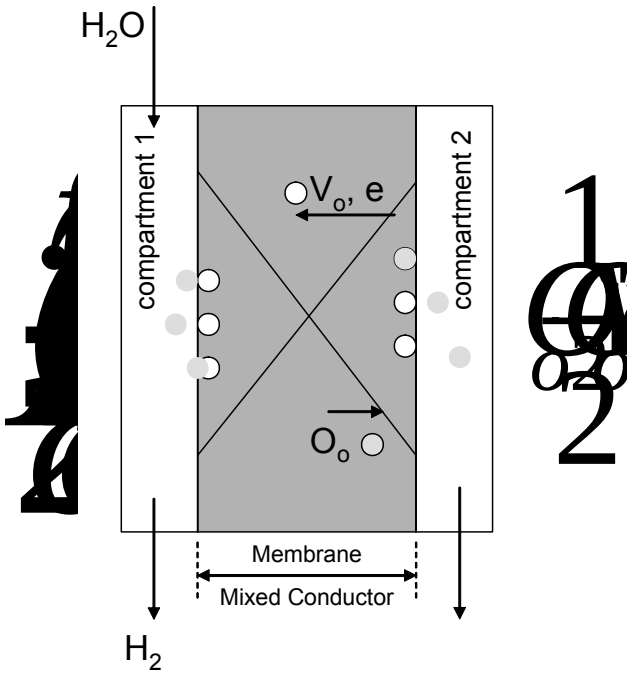
hydrogen production

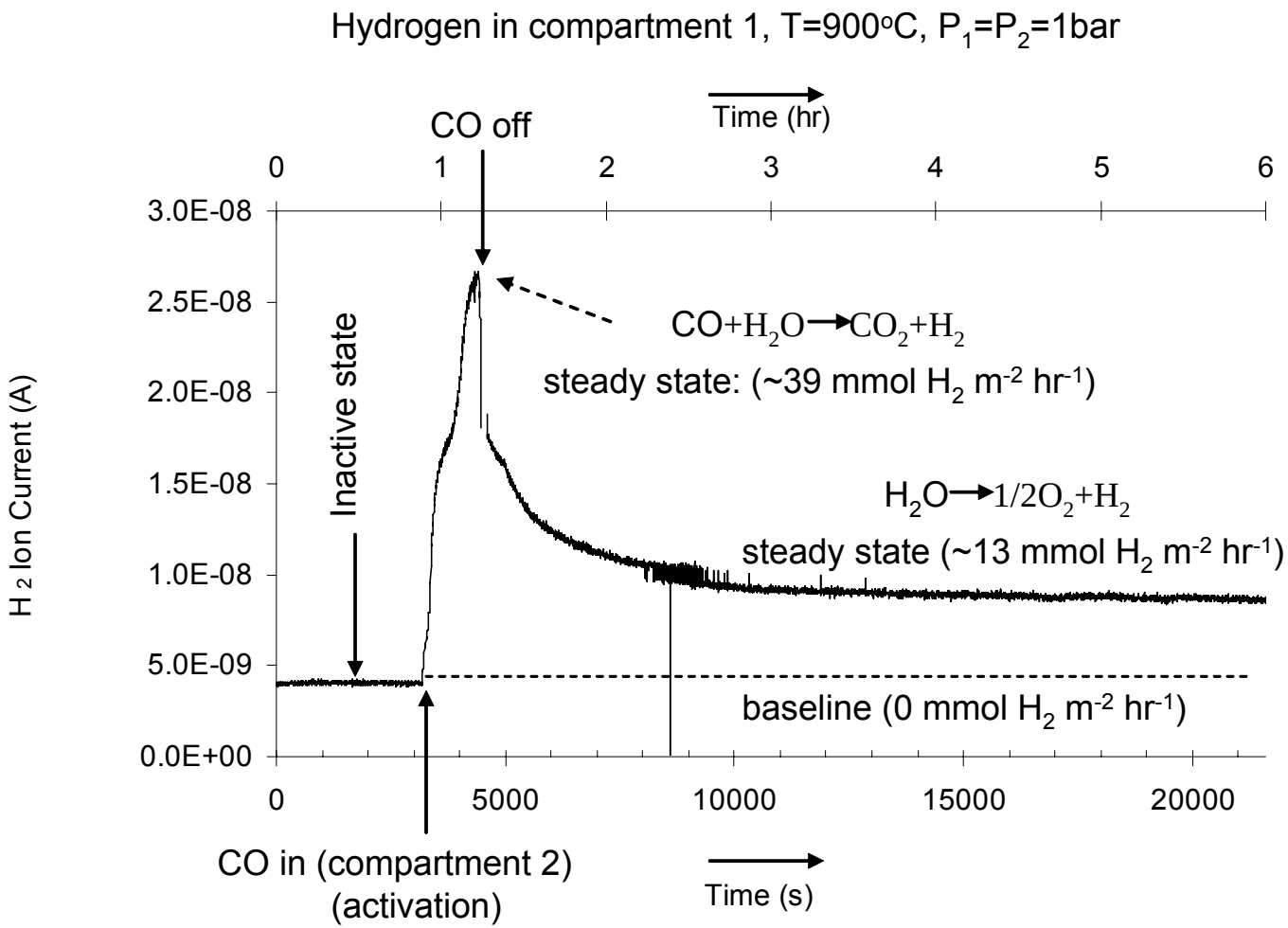




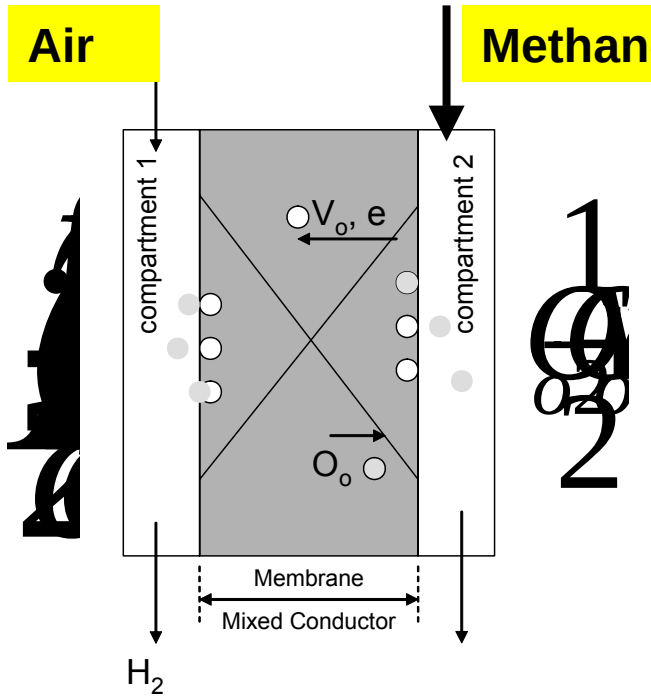
Dense Membranes, Hydrogen from renewable sources

Our research-proposal is based on a dense oxygen conducting membrane reactor




Hydrogen in compartment 1, T=900°C, P1=P2=1bar
Time (hr)
CO off
0
1
2
3
4
5
6
3.0E-08
2.5E-08
2.0E-08
1.5E-08
1.0E-08
5.0E-09
0.0E+00
H 2 Ion Current (A)
Inactive state
CO+H2O→CO2+H2
steady state: (~39 mmol H2 m-2 hr-1)
H2O→1/2O2+H2
steady state (~13 mmol H2 m-2 hr-1)
baseline (0 mmol H2 m-2 hr-1)
0
5000
10000
15000
20000
CO in (compartment 2)
(activation)
Time (s)

Dense Membranes, Environmental friendly combustion of natural gas

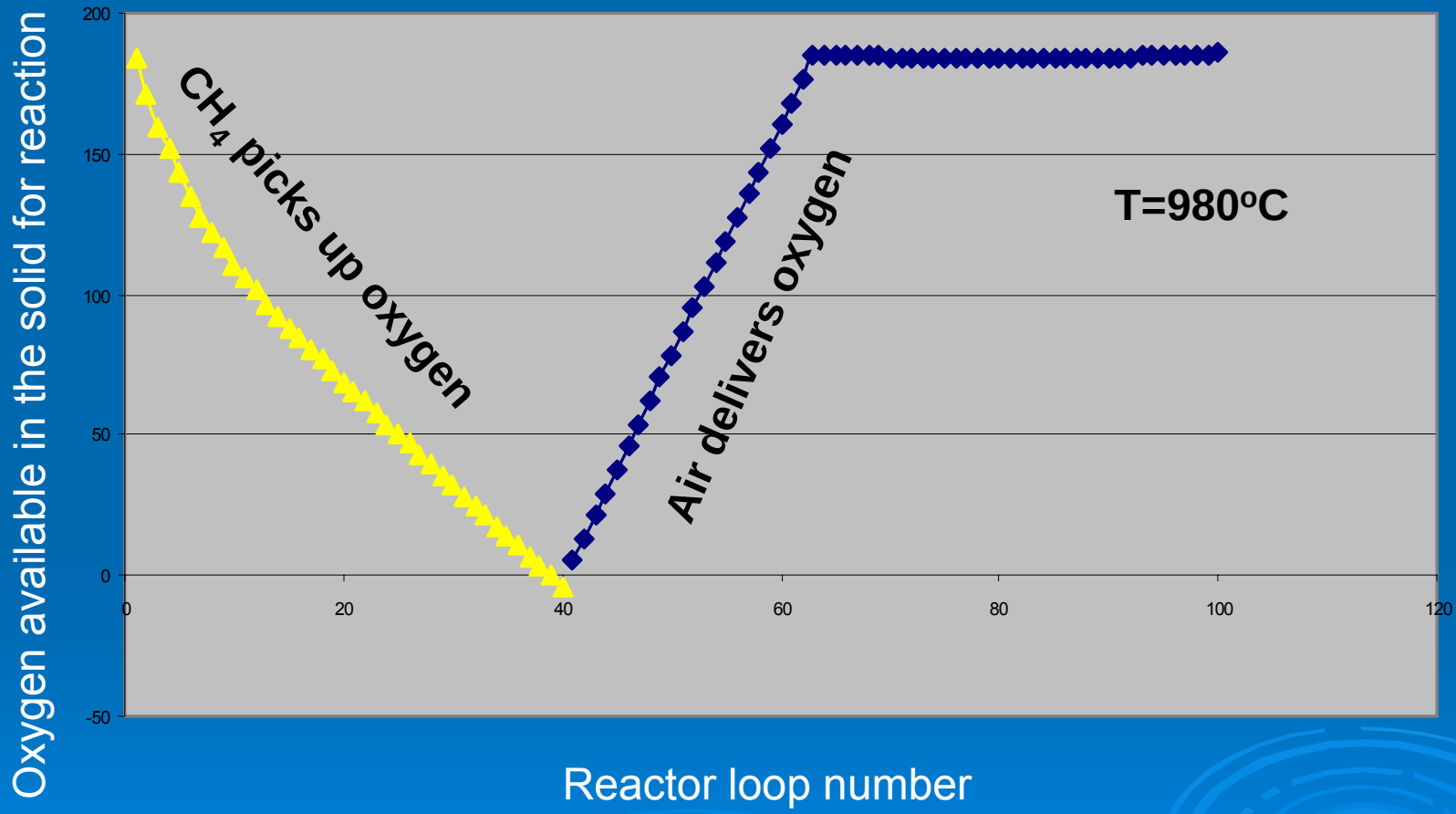


$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O + \text{Energy}$$

pure CO_2 → STORAGE

Dense Membranes, Environmental friendly combustion of natural gas

Material: $La_{0.7}Sr_{0.3}Cu_{0.05}Fe_{0.95}O_3$



CONCLUSIVE REMARKS

Porous ceramic membranes (specially modified to the nanoporous region) can give high separation factors and give rise to the development of efficient process, in particular for the separation of hydrogen

Porous ceramic membranes can provide technological solutions to many water treatment case-problems. The technology is quite mature to leave the laboratories

Dense oxygen conducting membranes can give rise to the development of green high temperature processes towards either hydrogen production from renewable sources or CO_2-capture oriented combustion of natural gas

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