

Mineral Acid Concentration Process with Electrodialysis Leading to High Concentrations

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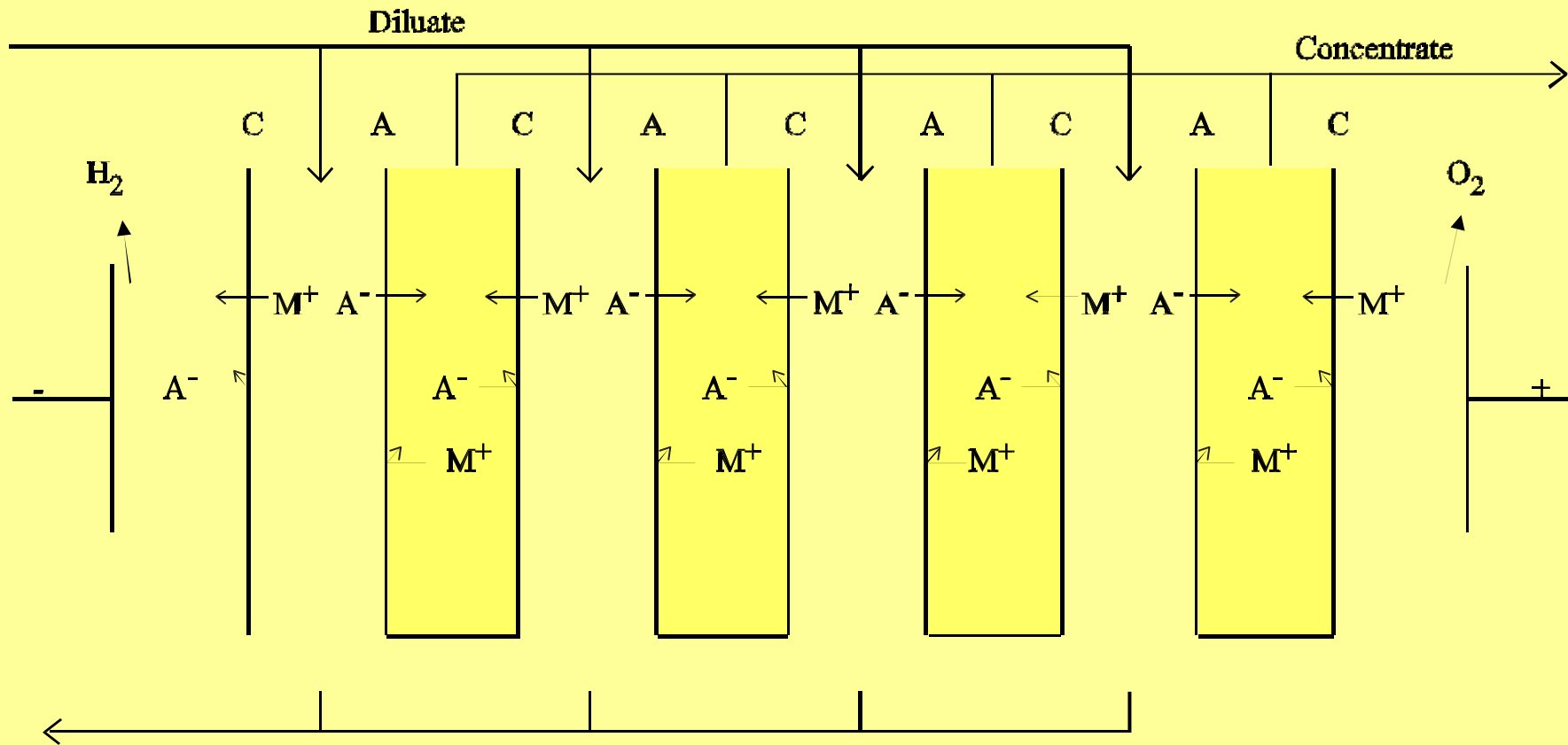
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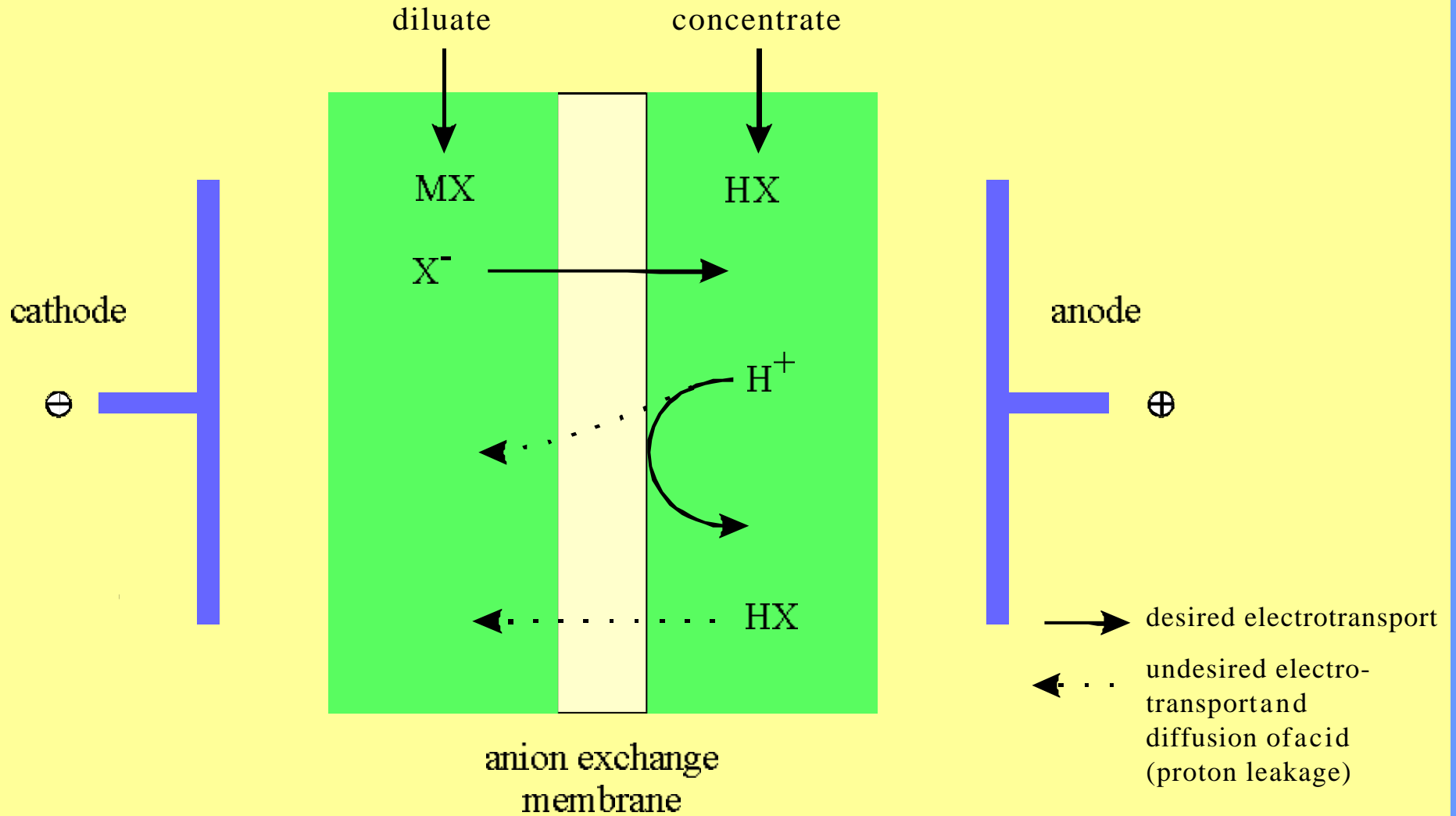
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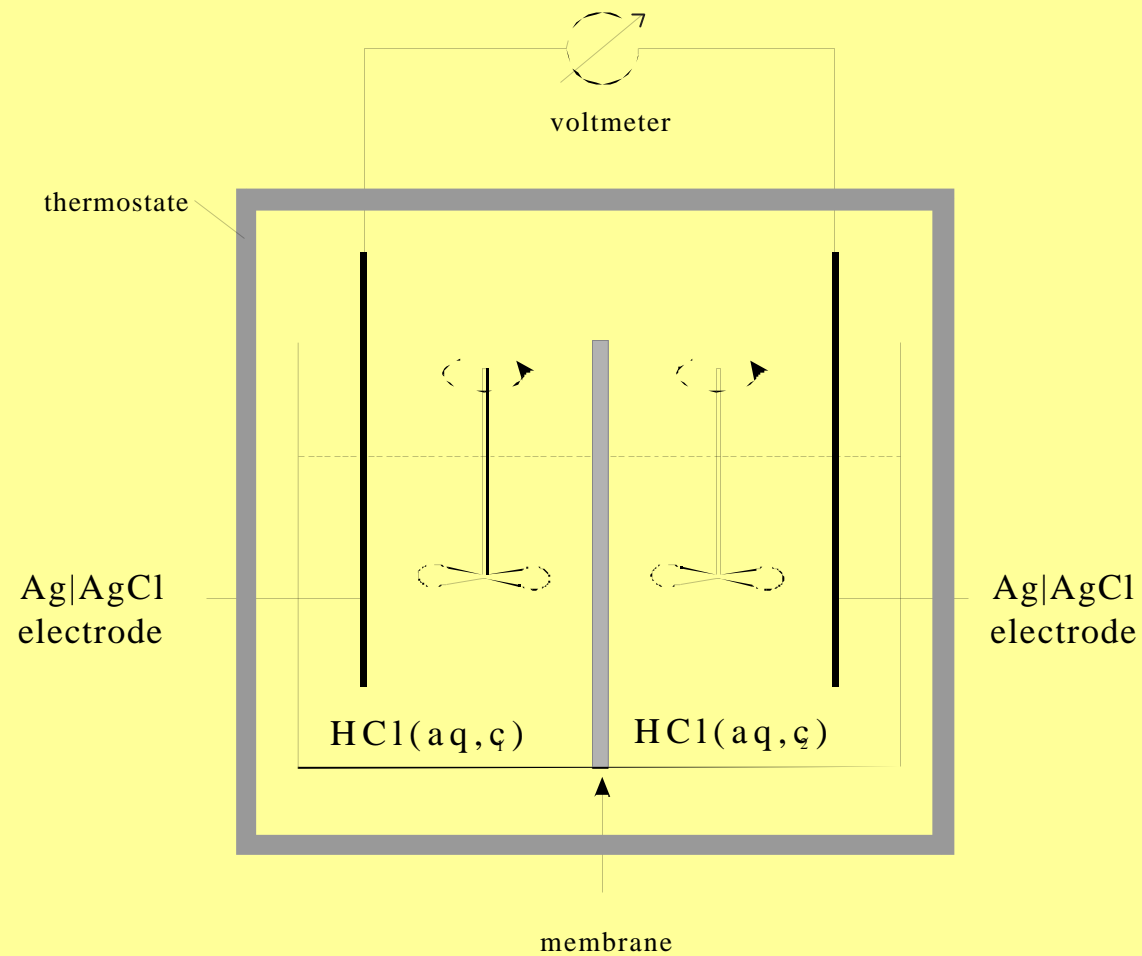
Principle of electrodialysis with closed concentrate chambers



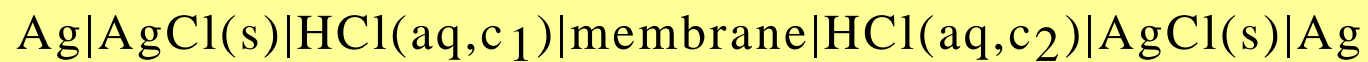
Anion exchange membrane separating mineral acid and ion currents across membrane



Potentiometric measurement of transference numbers

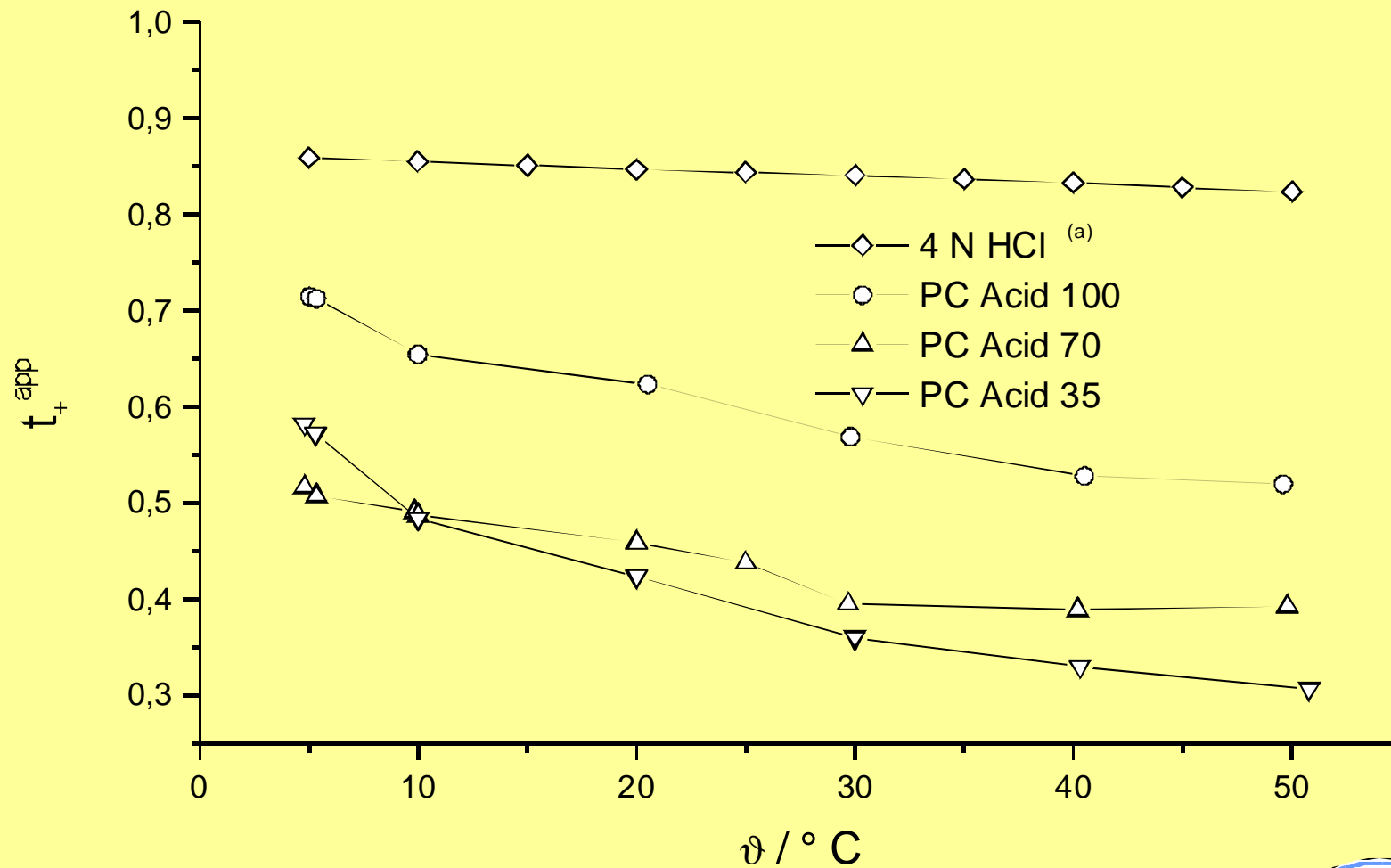


$$t_+^{app} = \frac{\Delta E}{\Delta E_{theo}}$$

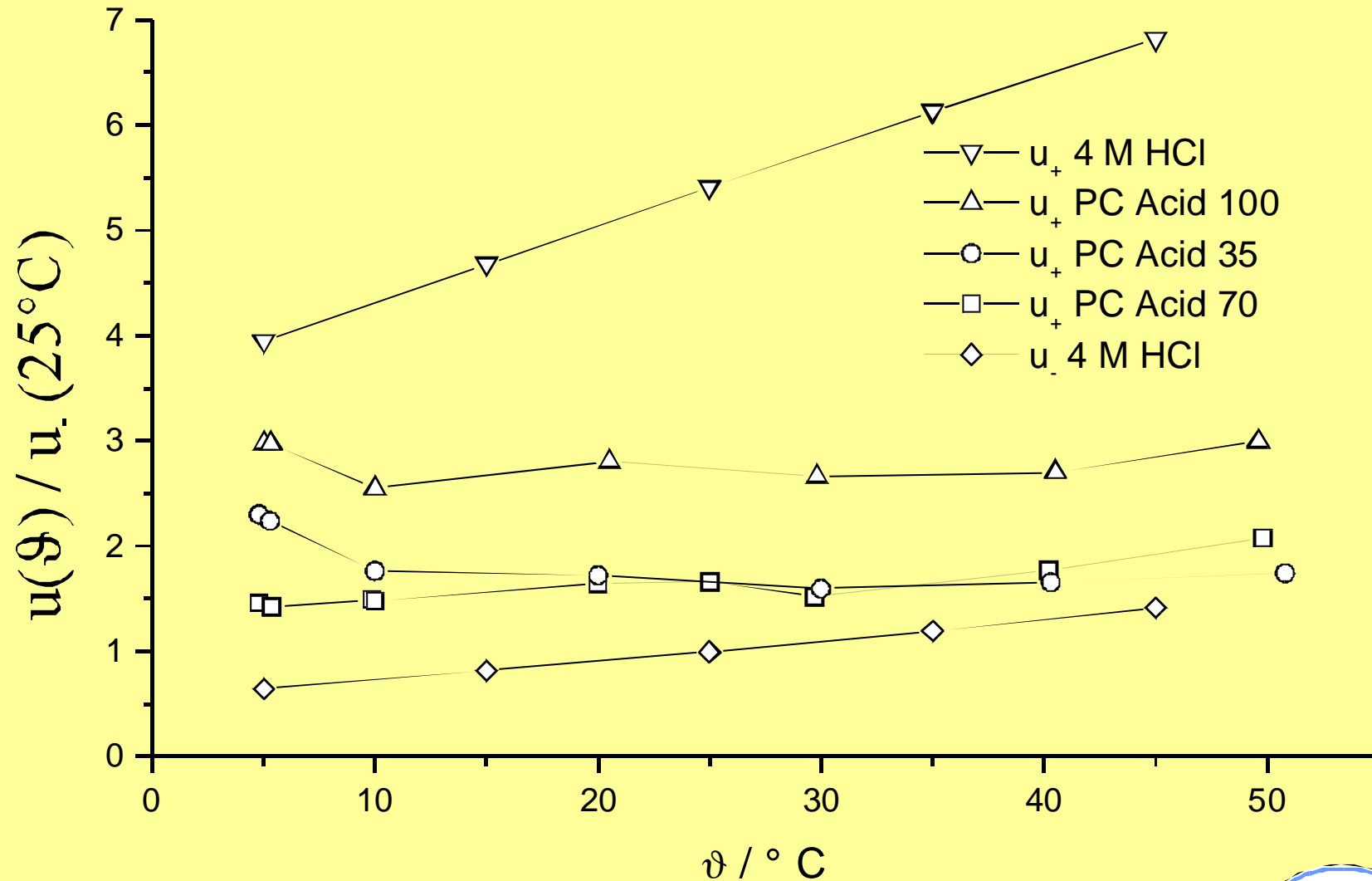


Transference numbers of H^+ in anion exchange membranes

determined potentiometrically between 1m and 4m HCl



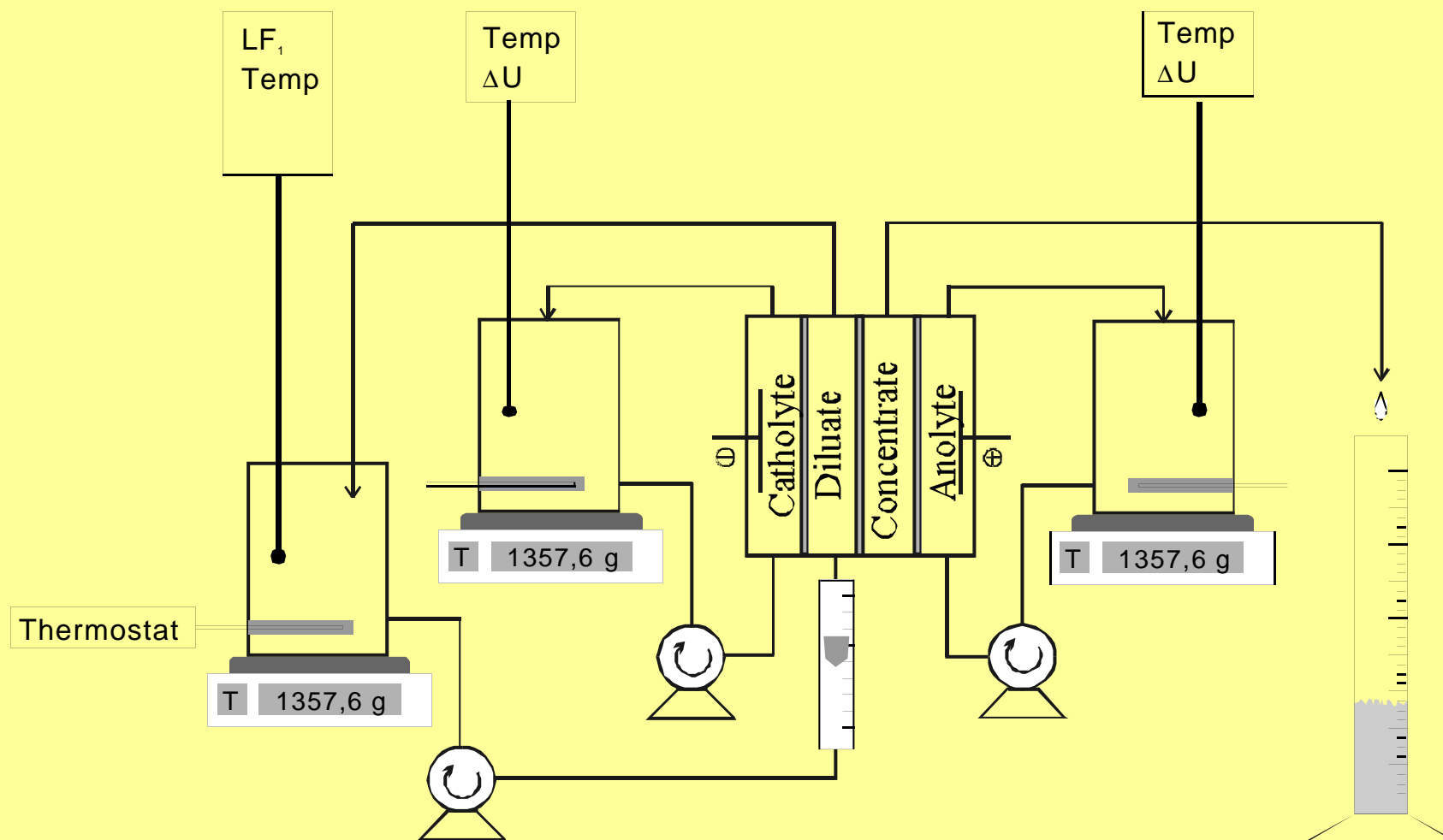
Ionic mobilities relative to the mobility of chloride in free solution at 25 °C



Results from potentiometric measurements:

- Grotthus mechanism plays an important role for coion transport of protons
- The "better" the acidblocker, the higher is the effect
- The higher the temperature, the lower are the coion transference numbers

Experimental setup for electro dialysis



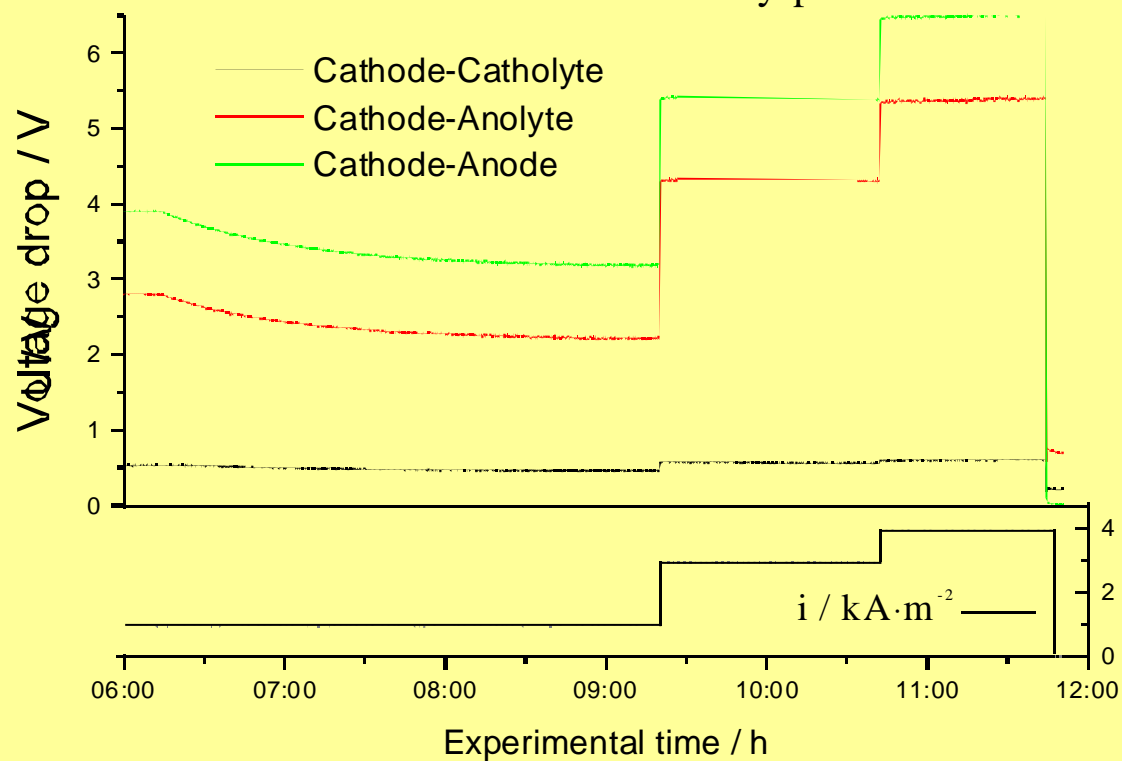
Concentration of HCl: Dependence of current density

Stack: BEL 500 (10 x 10 cm²);
4 cell pairs (5 x PC SK; 4 x PC Acid 35);

Diluate: 68 g / l HCl

Anolyte and Catholyte: about 1 N H₂SO₄ each

Concentrate: initially pure water.

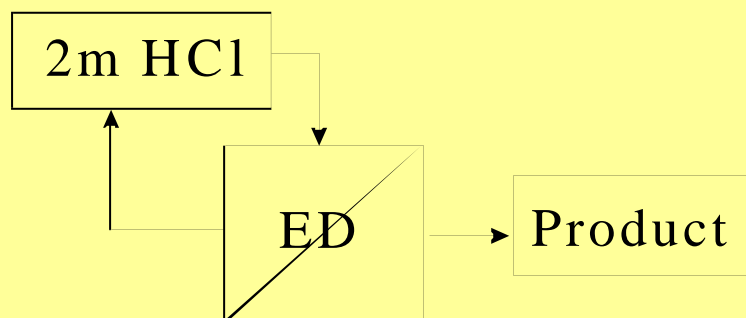


Results

HCl

Current efficiency,
maximum concentration
and energy consumption
for the electrodialysis
of acids

Diluate 2 - 3 molar



i / kA·m ⁻²	15 °C		
	η	c _{max} / mol·kg ⁻¹	E / kWh kg ⁻¹ HCl
1	34,2	5,56	1,5
3	34,8	7,12	3,7
4	37,0	7,30	4,2 (20°C)

i / kA·m ⁻²	25 °C		
	η	c _{max} / mol·kg ⁻¹	E / kWh kg ⁻¹ HCl
1	39,6	5,18	1,0
3	38,85	6,86	2,7
4	40,8	7,10	3,3

i / kA·m ⁻²	60 °C		
	η	c _{max} / mol·kg ⁻¹	E / kWh kg ⁻¹ HCl
1	38,5	4,90	0,7
3	41,7	6,38	1,6
4	42,0	6,75	2,0

Results

Current efficiency,
maximum concentration
and energy consumption
for the electrodialysis
of acids

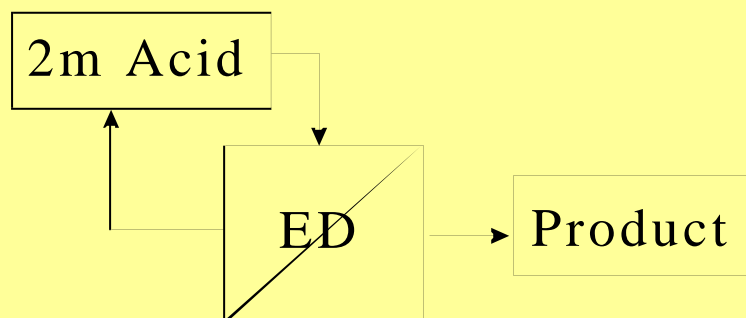
HBr, HNO₃
Diluate 2 - 3 molar

HBr

i / kA·m ⁻²	25 °C	
	η	c _{max} / mol·kg ⁻¹
1	53,0	3,60
3	49,5	4,50

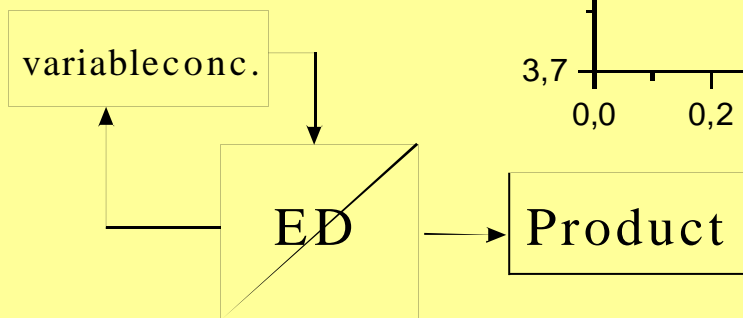
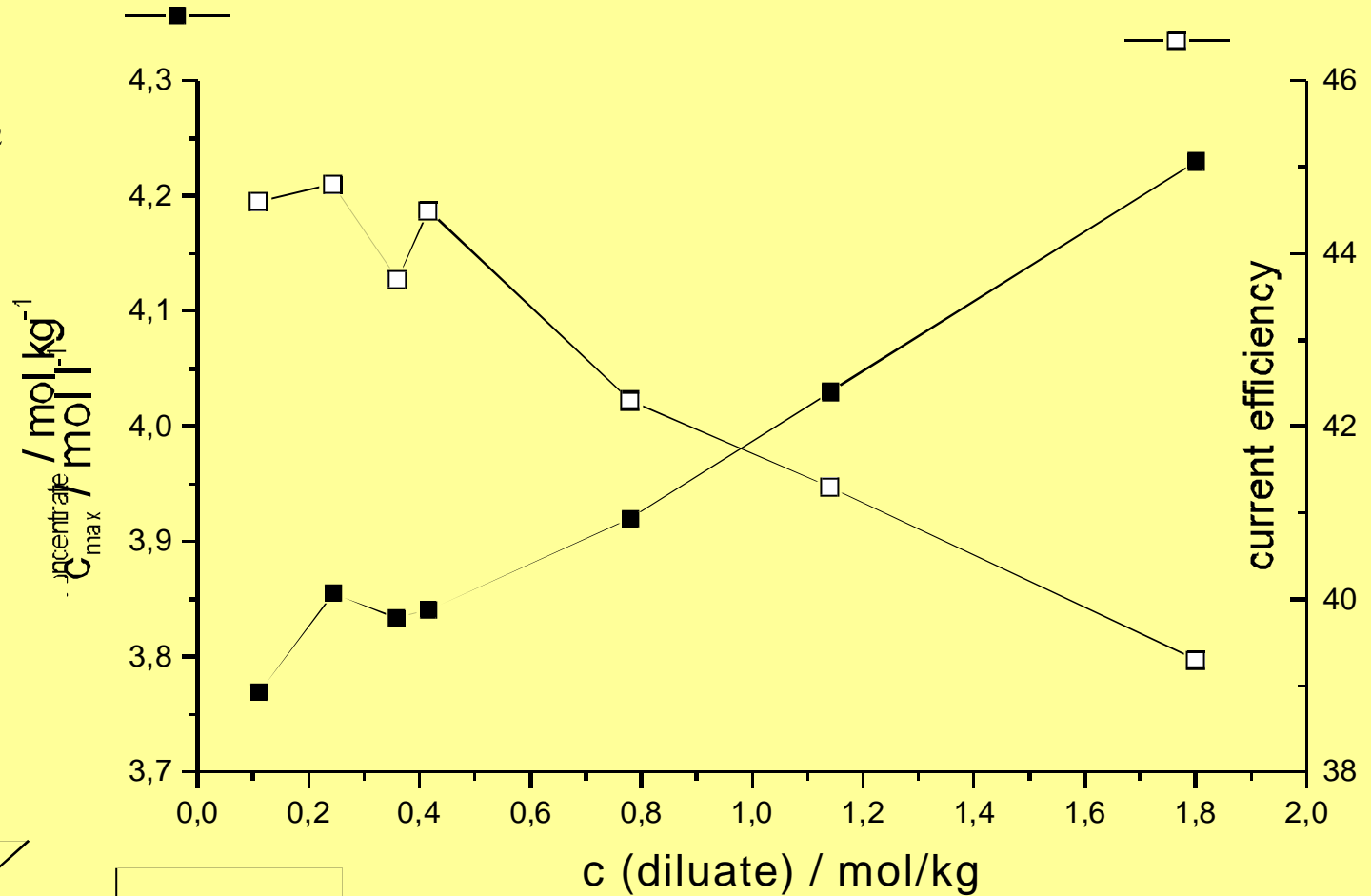
HNO₃

i / kA·m ⁻²	25 °C	
	η	c _{max} / mol·kg ⁻¹
1	35,7	5,39
3	40,5	6,45
4	40,9	6,50

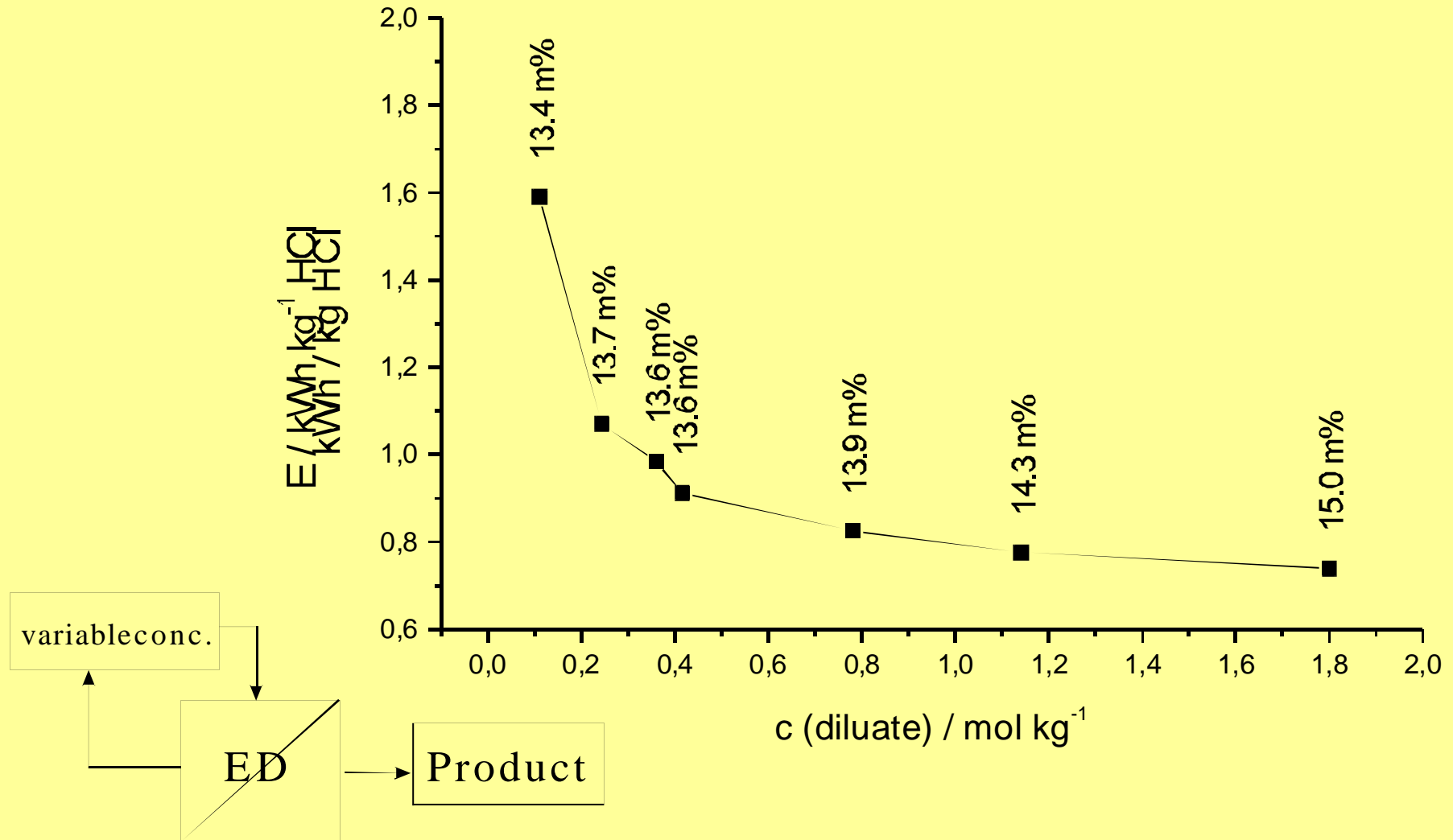


Maximum product concentration in dependence of diluate concentration

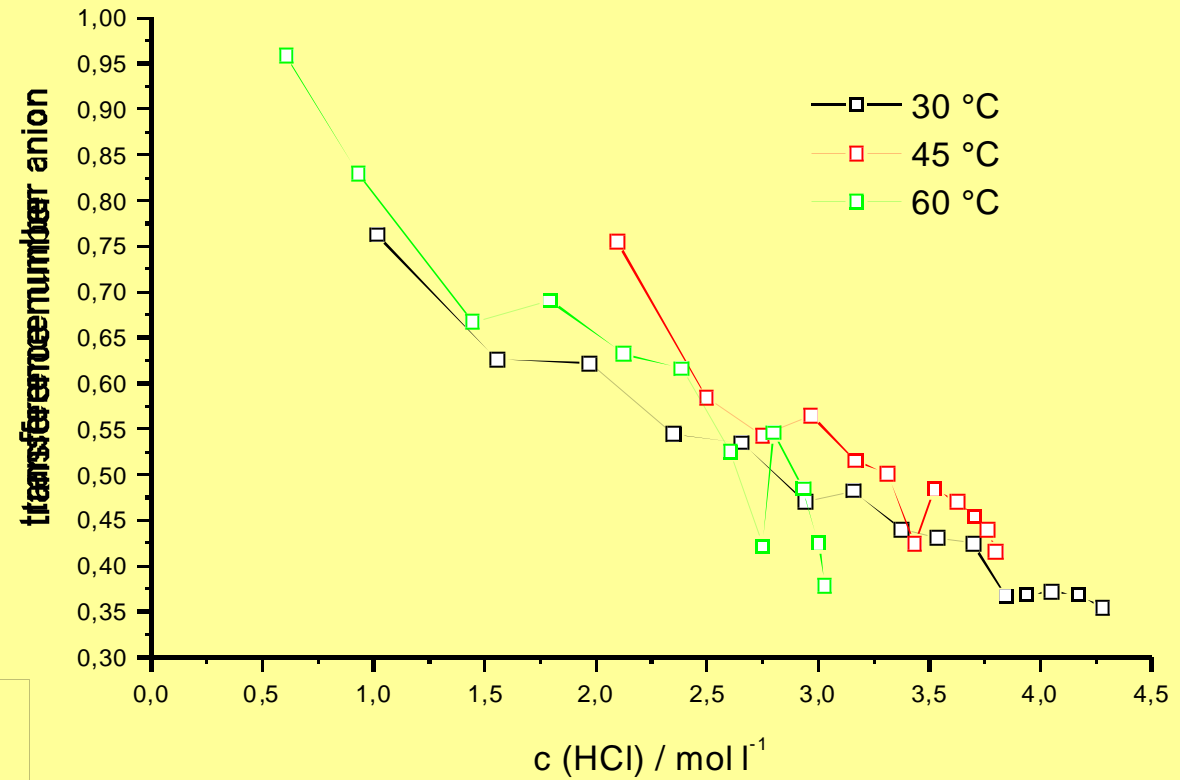
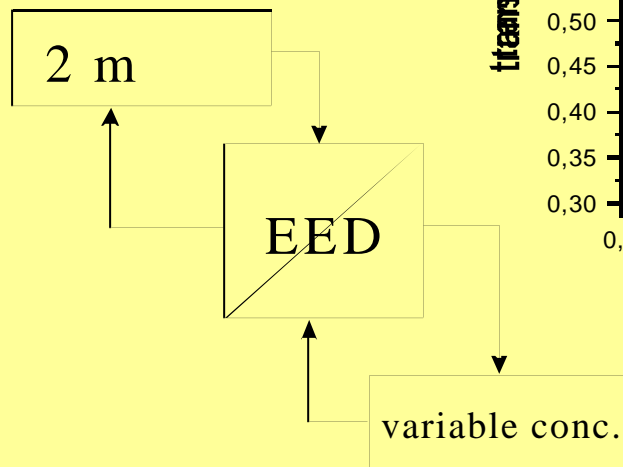
$i = 1 \text{ kA m}^{-2}$
 $25 \text{ }^\circ\text{C}$



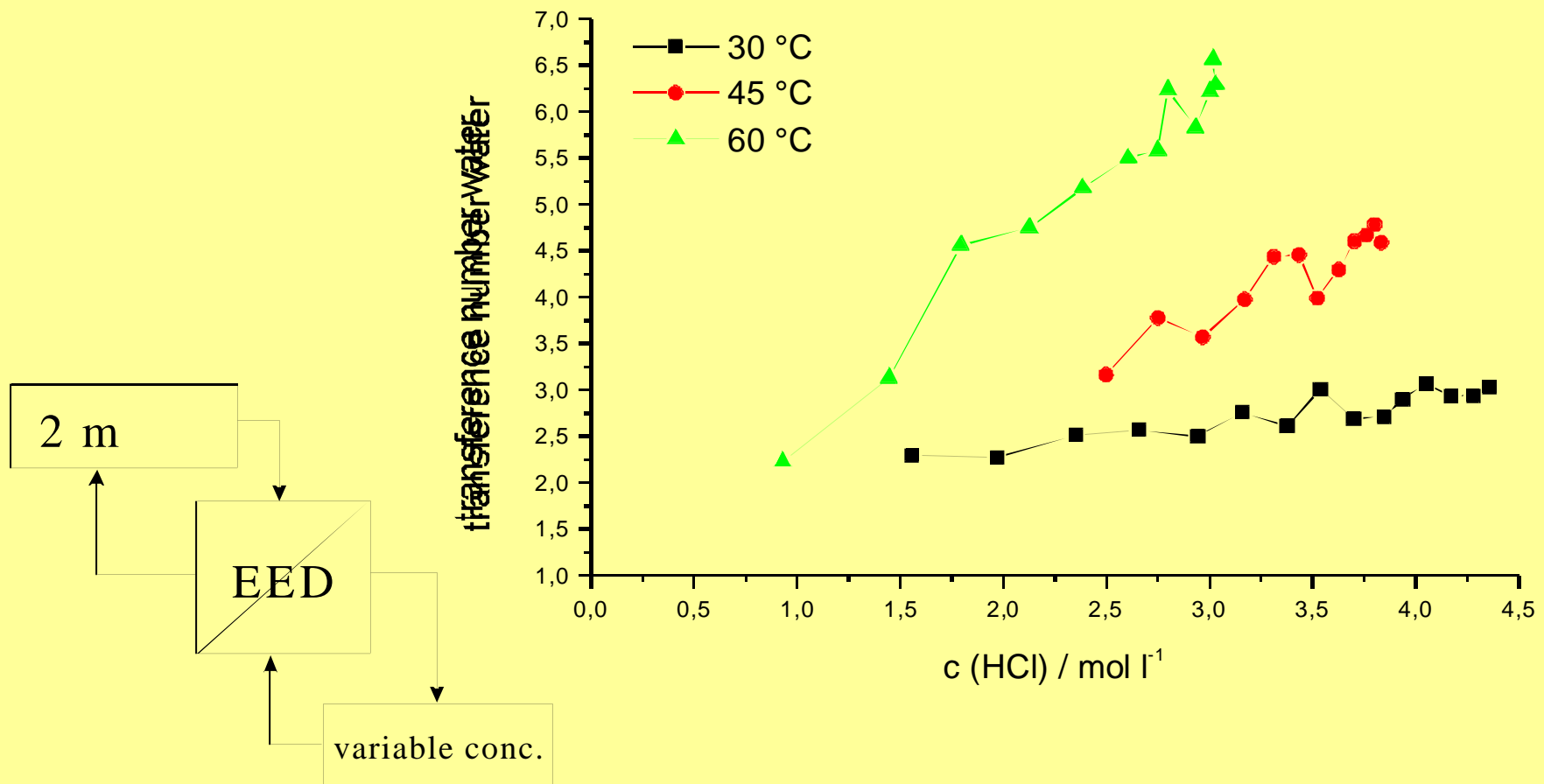
Energy consumption for concentrating HCl with electro dialysis



Current efficiency of HCl production by electro-electrodialytic salt splitting of NaCl



Corresponding water transport for HCl production at different temperatures



Conclusion:

- Electrodialysis of mineral acids → acidblocker membranes
- Current efficiency in acid ED lower than in conventional ED
- H^+ - transport over negative - entropic states
- "Normal" electro-osmotic water fluxes observed
- Higher temperature → higher current efficiencies
- Higher temperature → lower concentrations
- Higher current densities → higher concentrations