Mineral Acid Concentration Process with Electrodialysis Leading to High Concentrations

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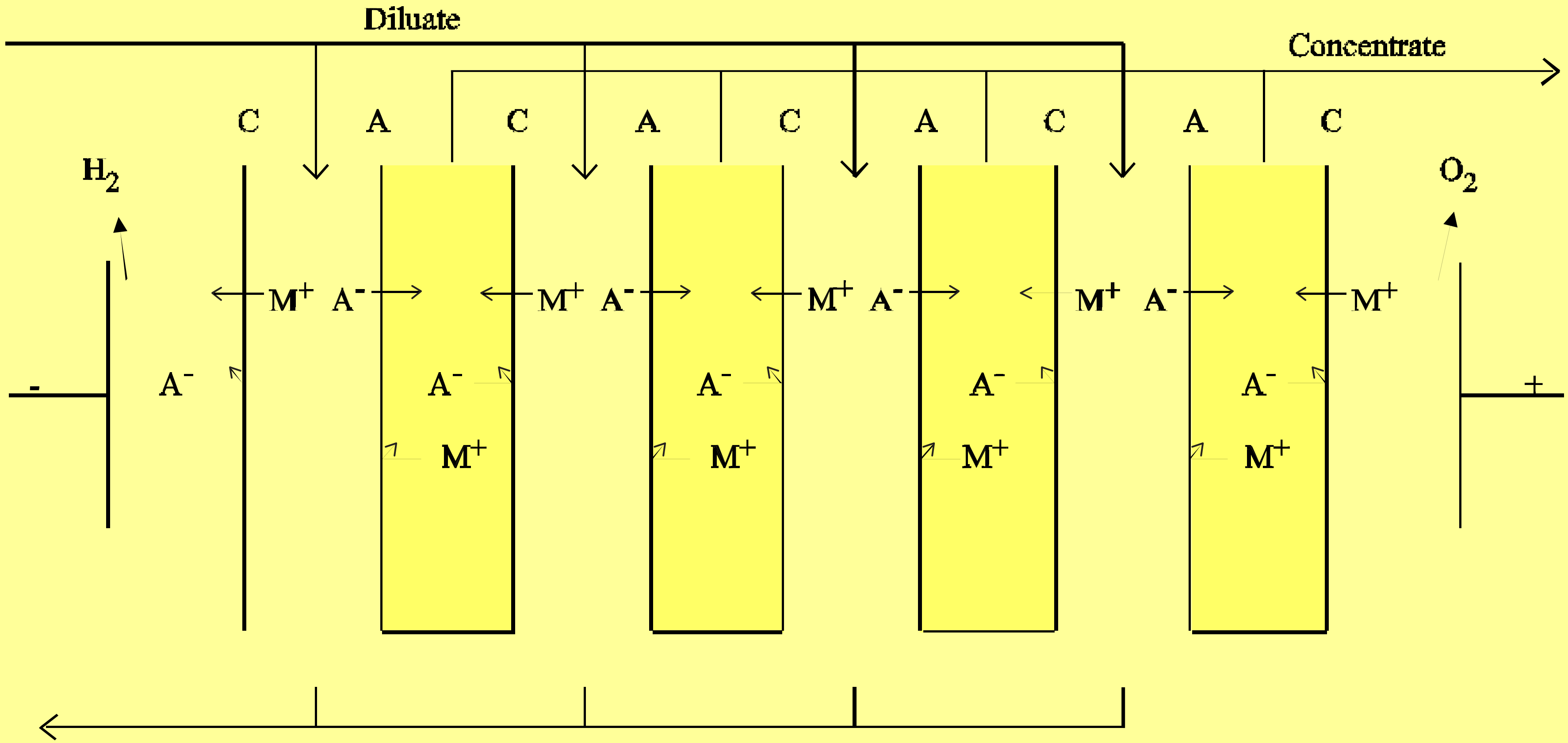
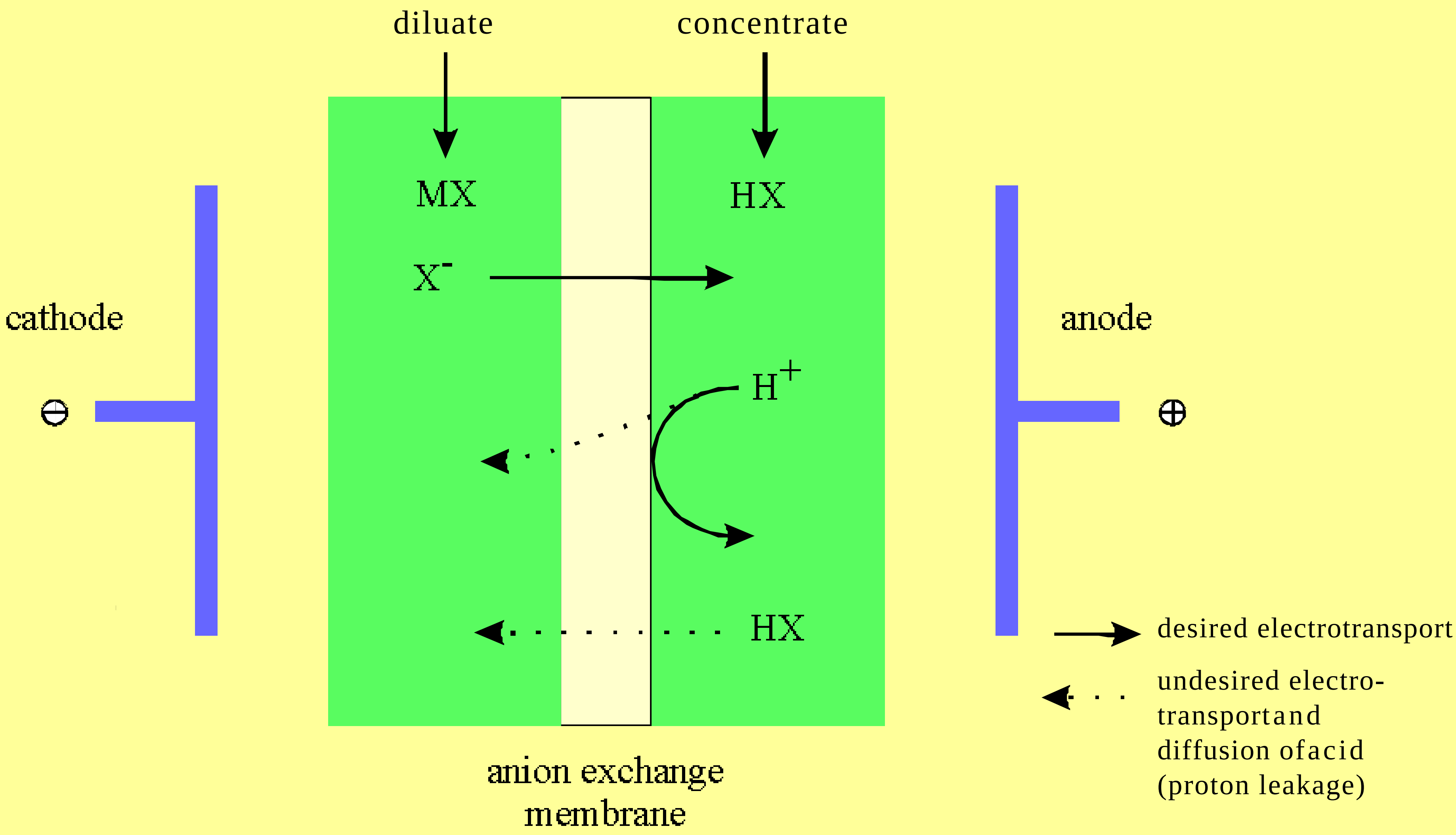
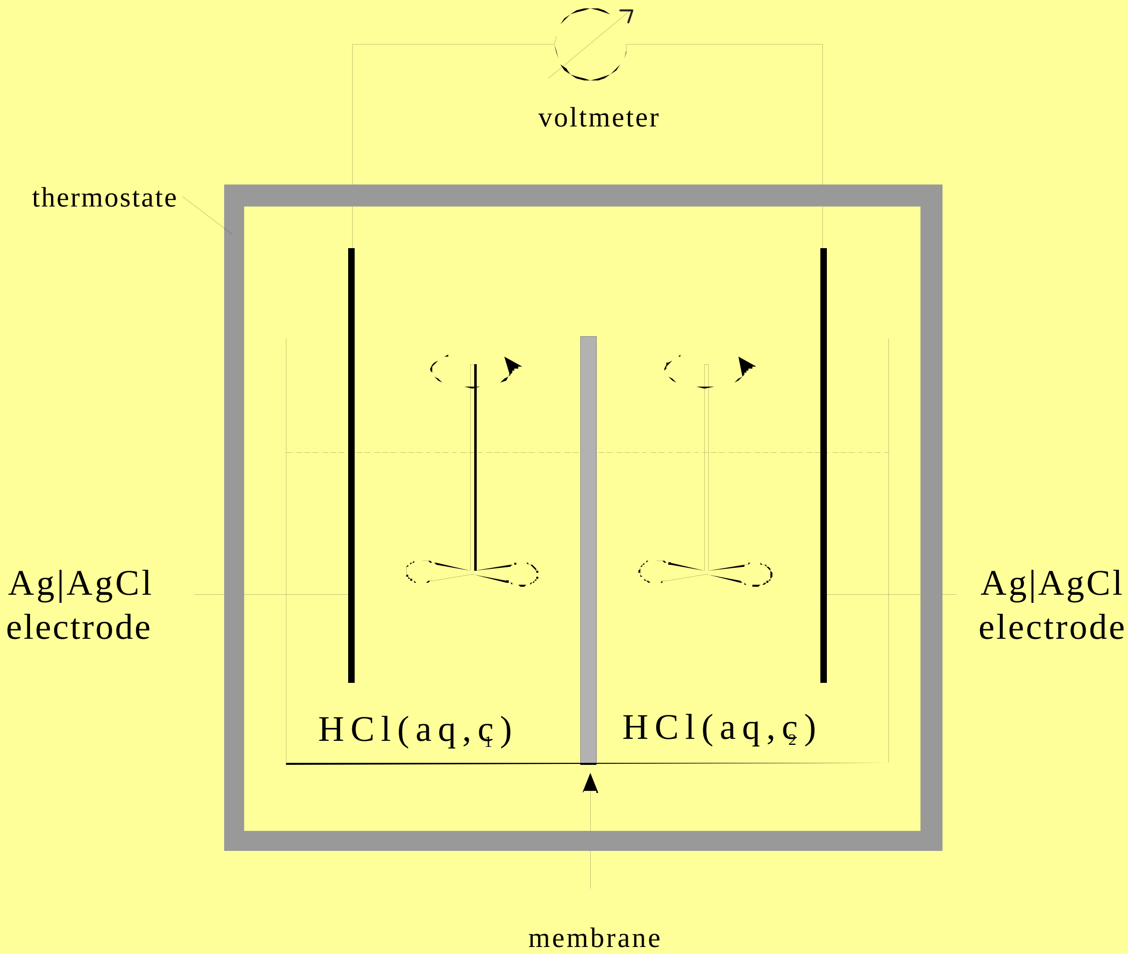
Principle of electrodialysis with closed concentrate chambers



Anion exchange membrane separating mineral acid and ion currents across membrane



Potentiometric measurement of transference numbers

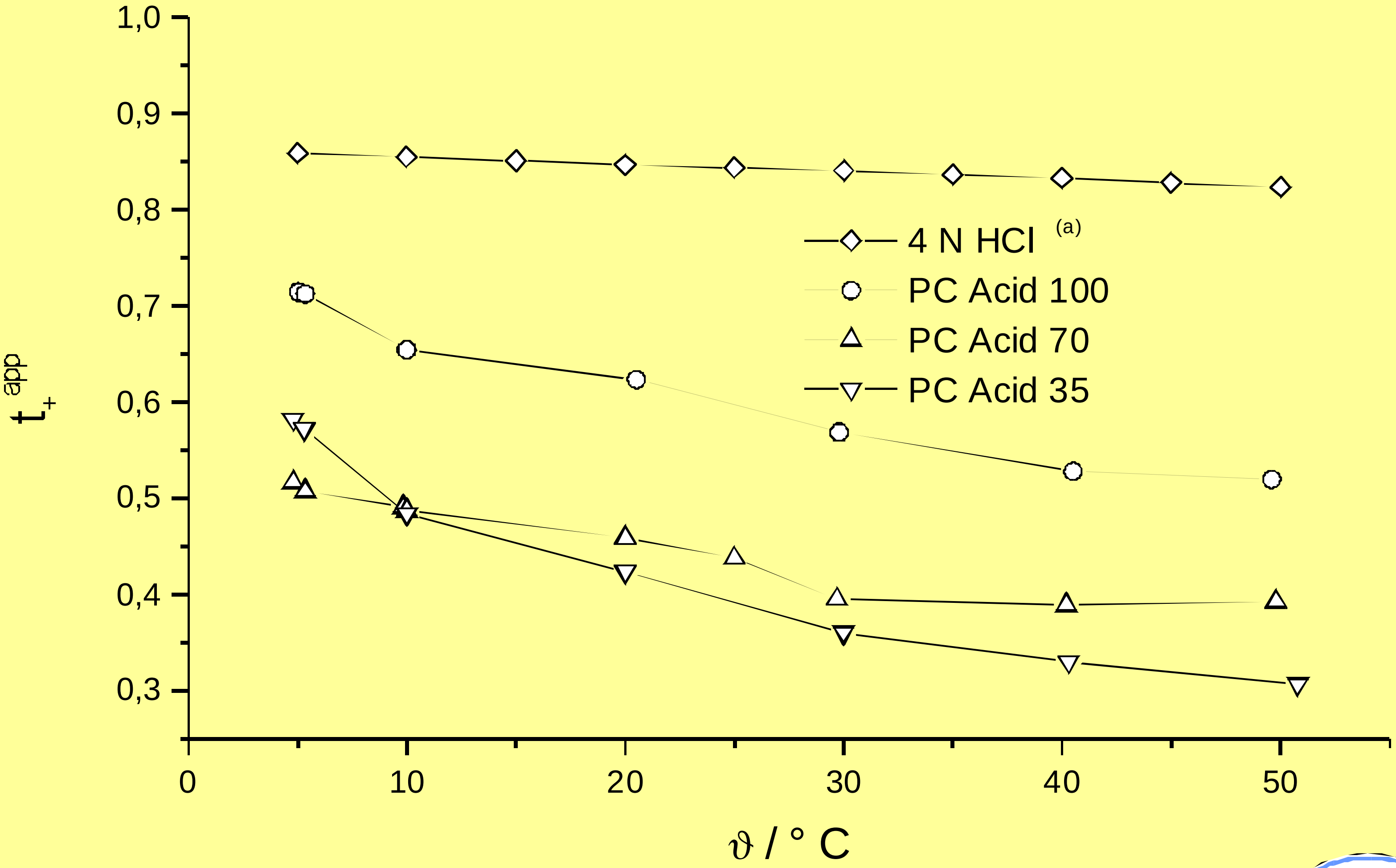


$$t_{+}^{app} = \frac{\Delta E}{\Delta E_{theo}}$$

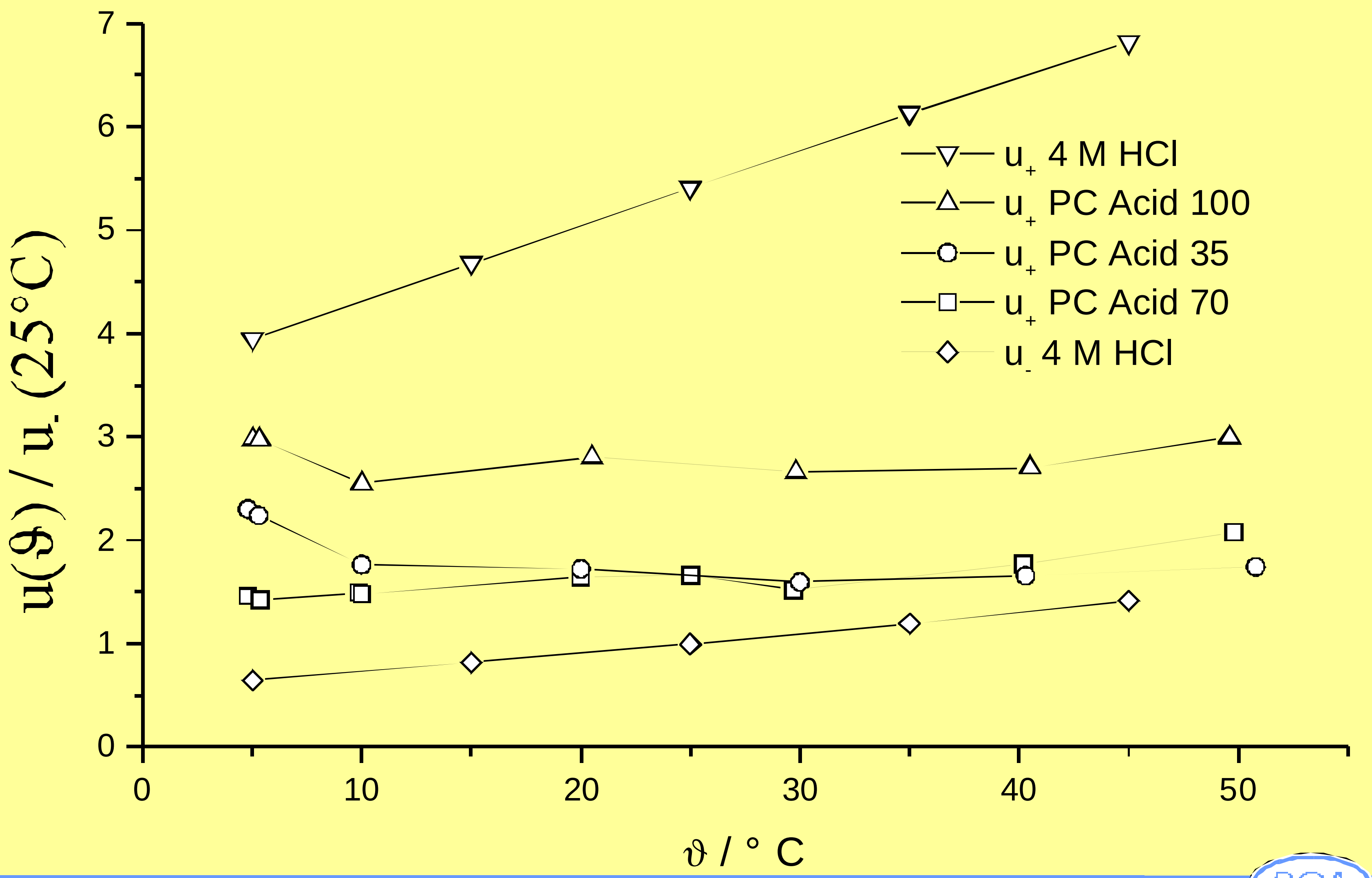
Ag|AgCl(s)|HCl(aq,c_1)|membrane|HCl(aq,c_2)|AgCl(s)|Ag

Transference numbers of H^+ in anion exchange membranes

determined potentiometrically between 1m and 4m HCl



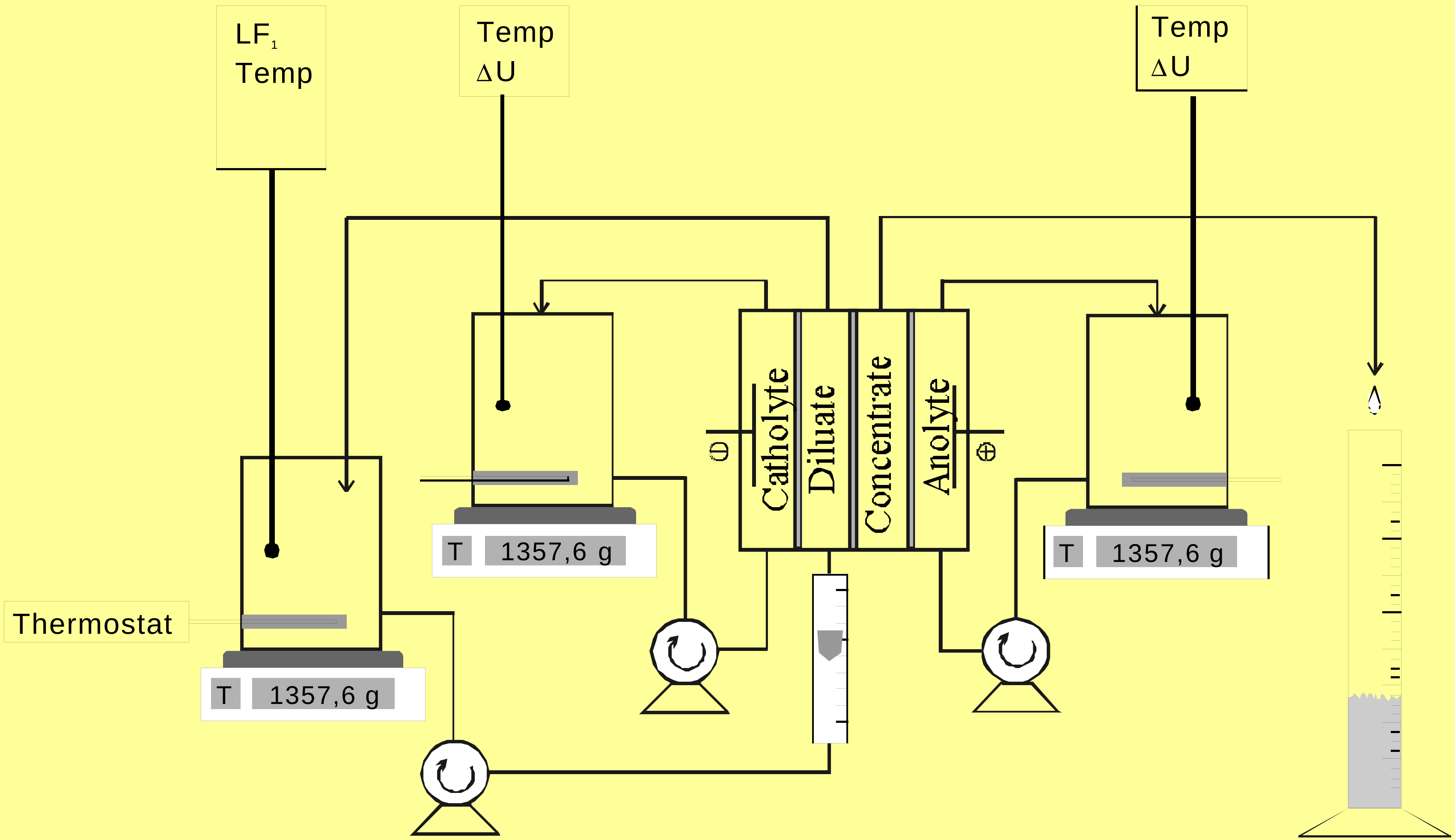
Ionic mobilities relative to the mobility of chloride in free solution at 25 °C



Results from potentiometric measurements:

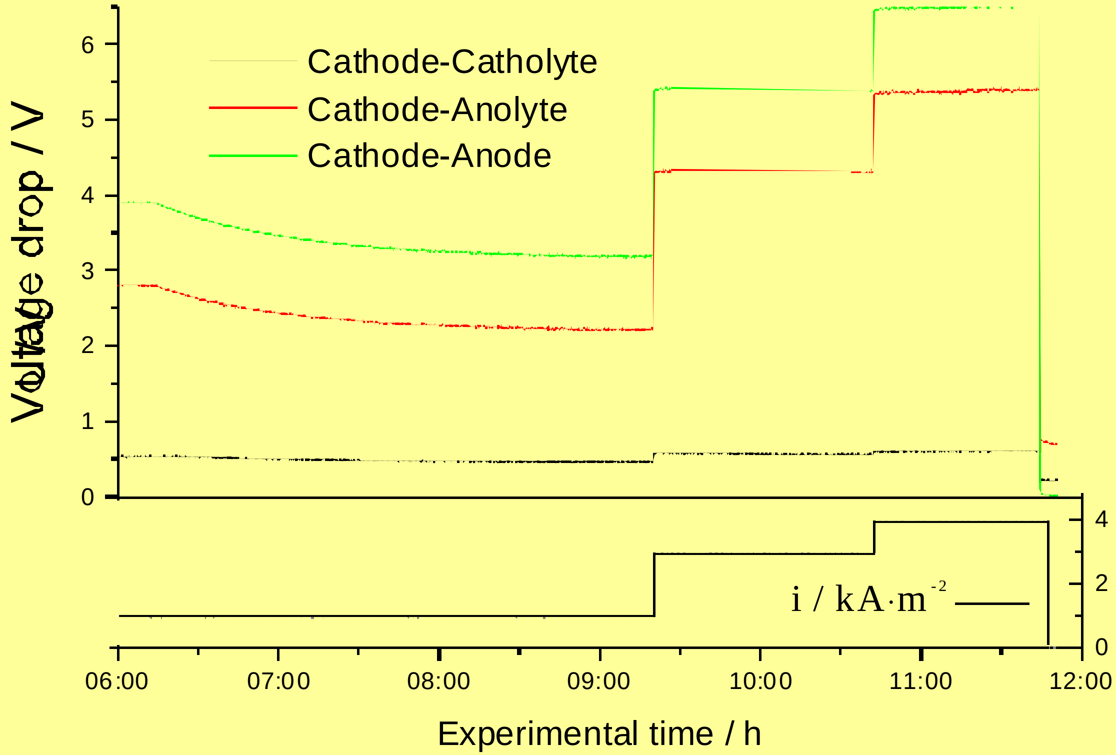
- Grotthus mechanism plays an important role for coion transport of protons
- The "better" the acidblocker, the higher is the effect
- The higher the temperature, the lower are the coion transference numbers

Experimental setup for electrodialysis



Concentration of HCl: Dependence of current density

Stack:	BEL 500 (10 x 10 cm^2);
	4 cell pairs (5 x PC SK; 4 x PC Acid 35);
Diluate:	68 g / l HCl
Anolyte and Catholyte:	about 1 N H_2SO_4 each
Concentrate:	initially pure water.



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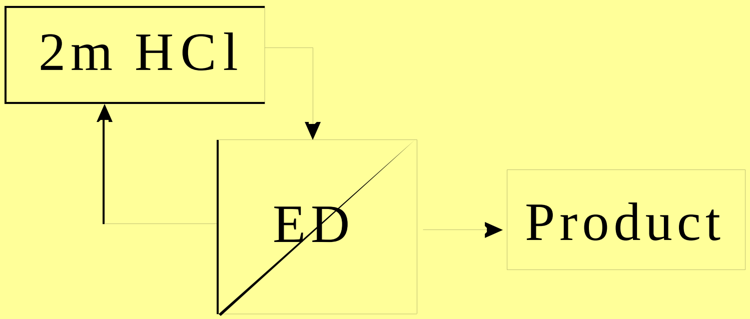
Results

HCl

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

Diluate 2 - 3 molar



i / $kA \cdot m^{-2}$	15 °C η	c_{max} / $mol \cdot kg^{-1}$	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 / $kA \cdot m^{-2}$	25 °C η	c_{max} / $mol \cdot kg^{-1}$	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 / $kA \cdot m^{-2}$	60 °C η	c_{max} / $mol \cdot kg^{-1}$	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

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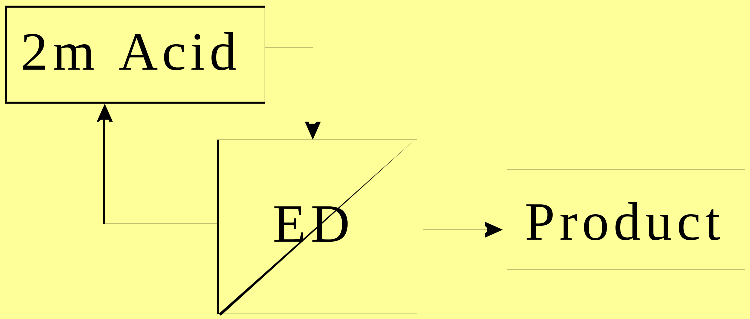
Results

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

HBr , HNO_3

Diluate 2 - 3 molar



HBr

i / $kA \cdot m^{-2}$	25 °C η	c_{max} / $mol \cdot kg^{-1}$
1	53,0	3,60
3	49,5	4,50

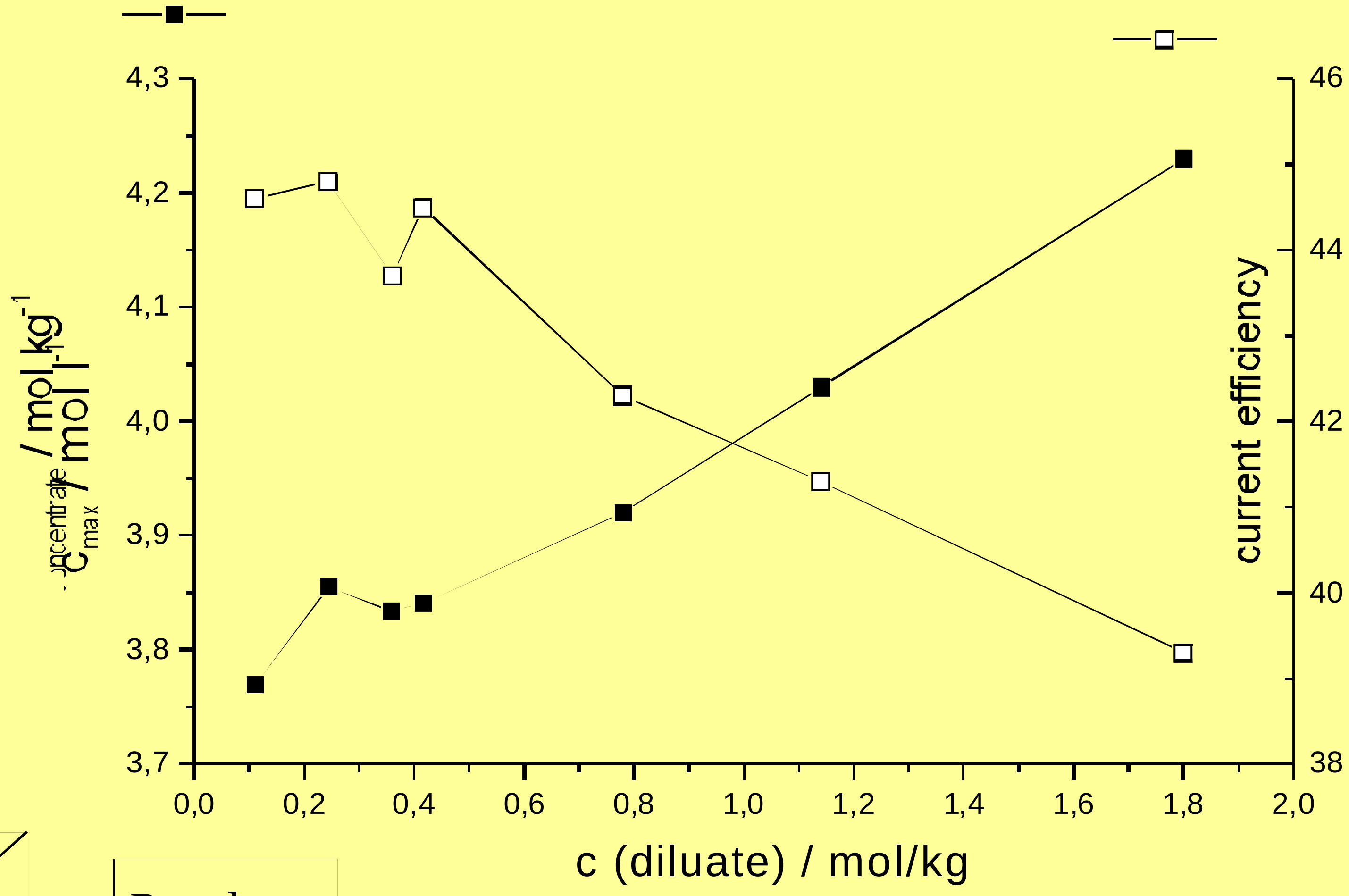
HNO_3

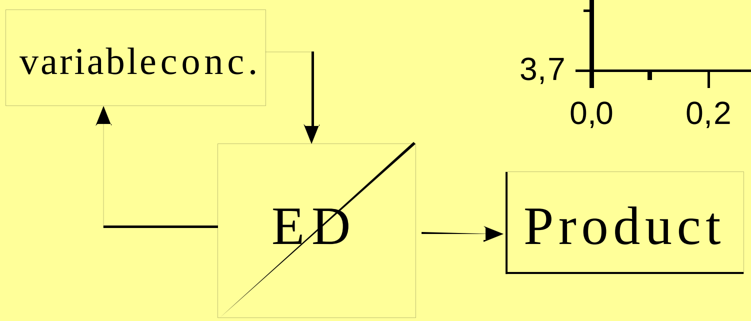
i / $kA \cdot m^{-2}$	25 °C η	c_{max} / $mol \cdot kg^{-1}$
1	35,7	5,39
3	40,5	6,45
4	40,9	6,50

Maximum product concentration in dependence of diluate concentration

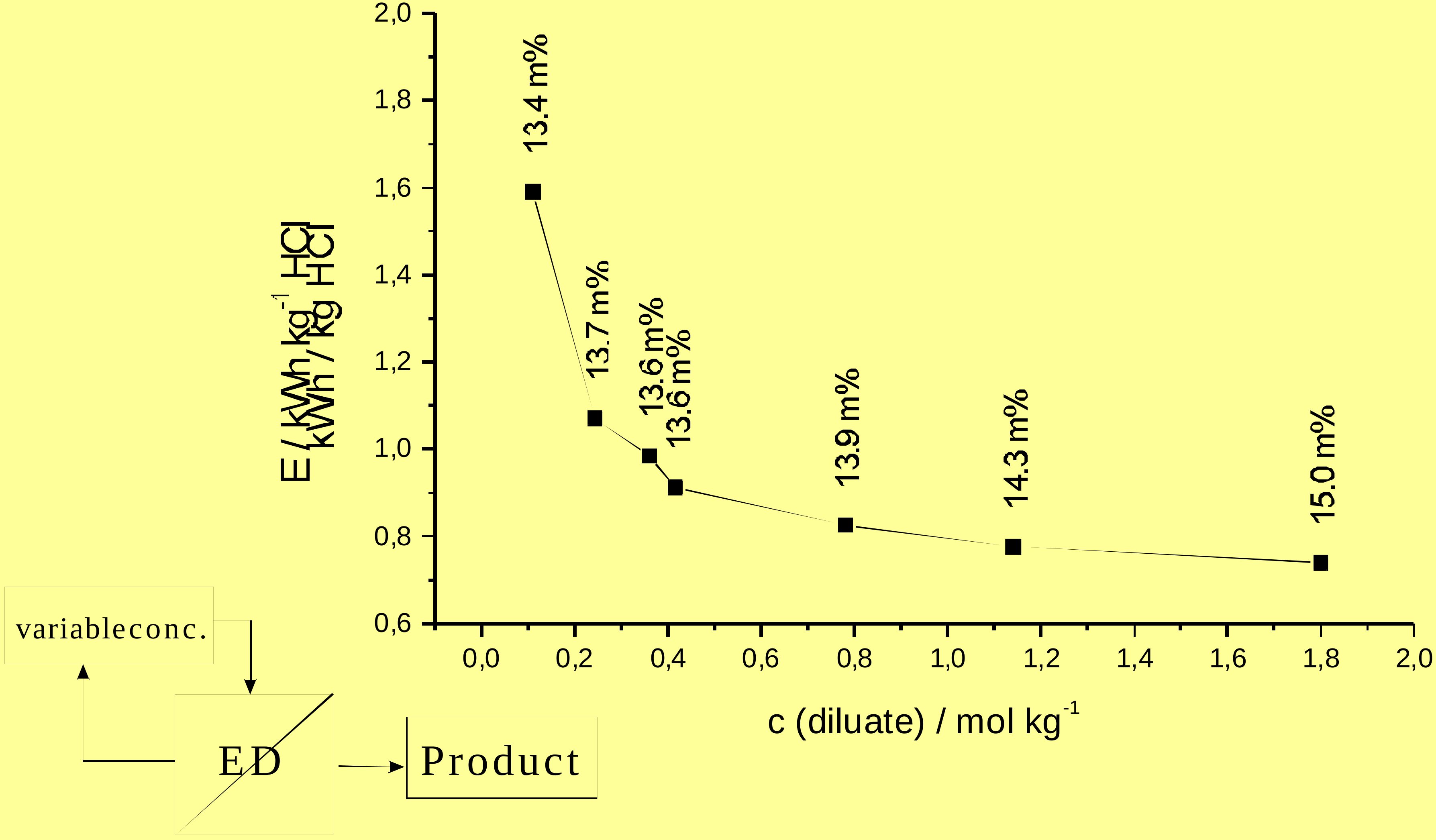
i = 1 kA m^{-2}

25 °C

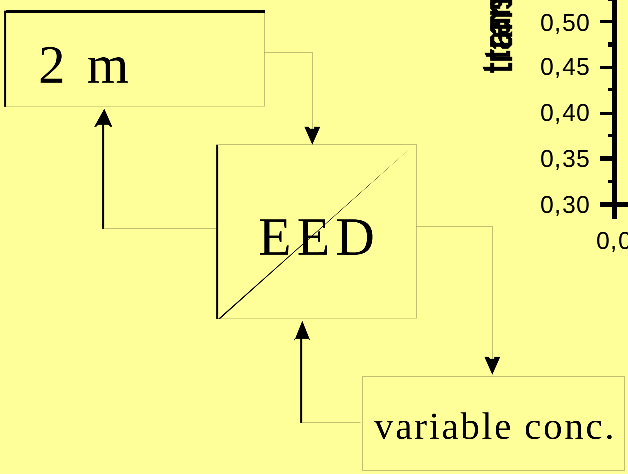


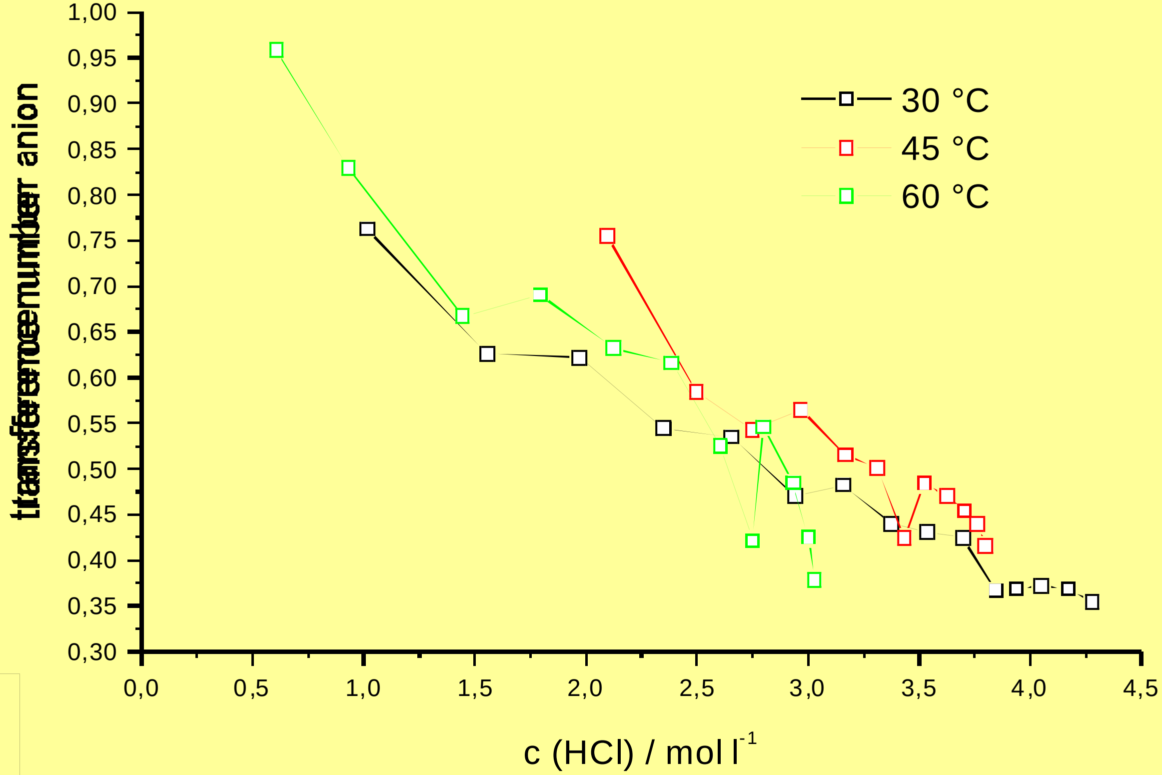


Energy consumption for concentrating HCl with electrodialysis

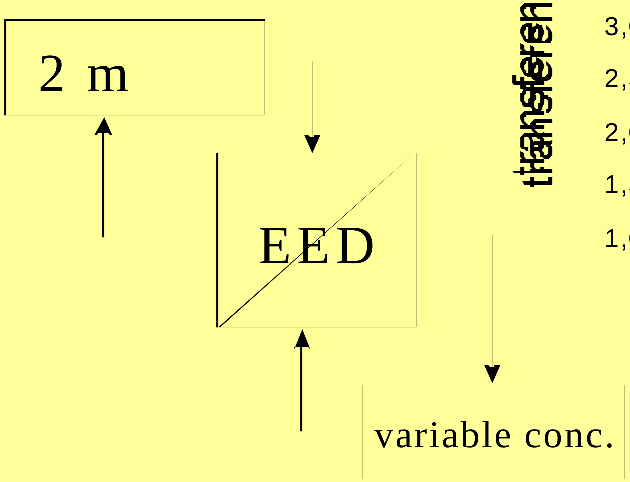


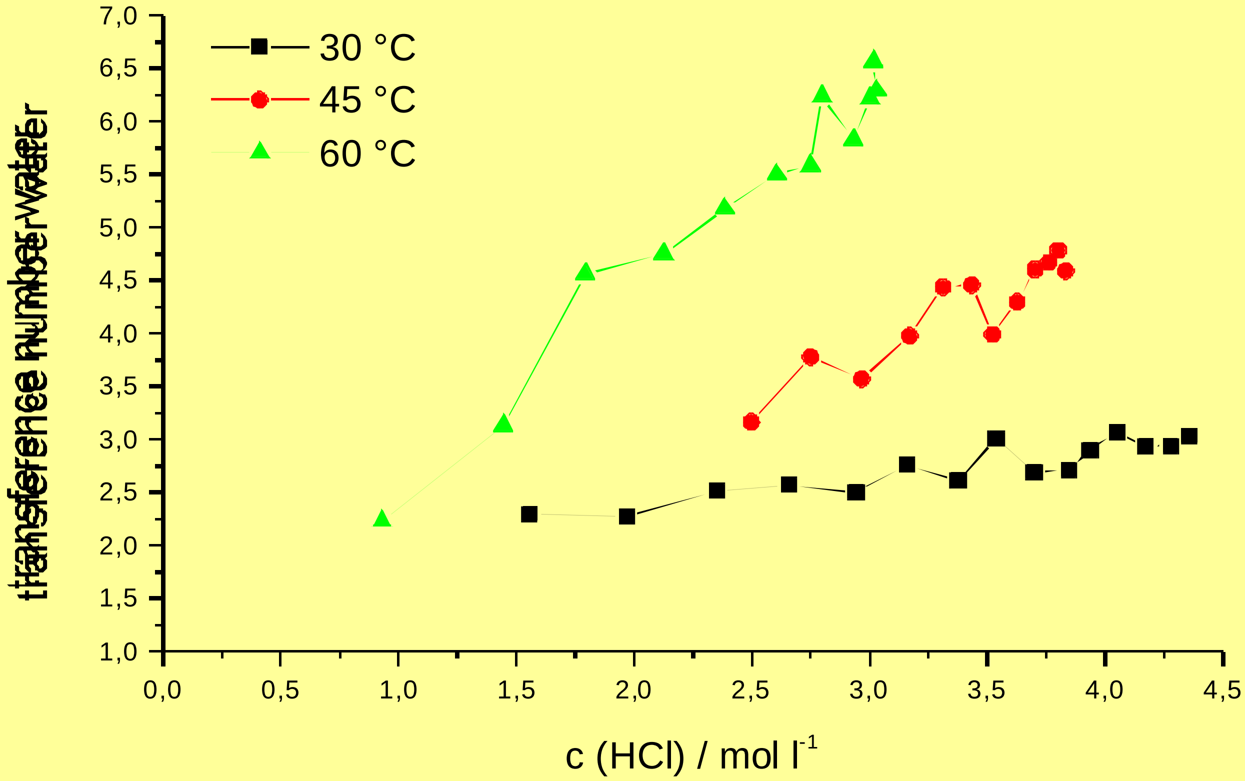
Current efficiency of HCl production by electro-electrodialytic salt splitting of NaCl





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 temperatrue → lower concentrations
- Higher current densities → higher concentrations

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