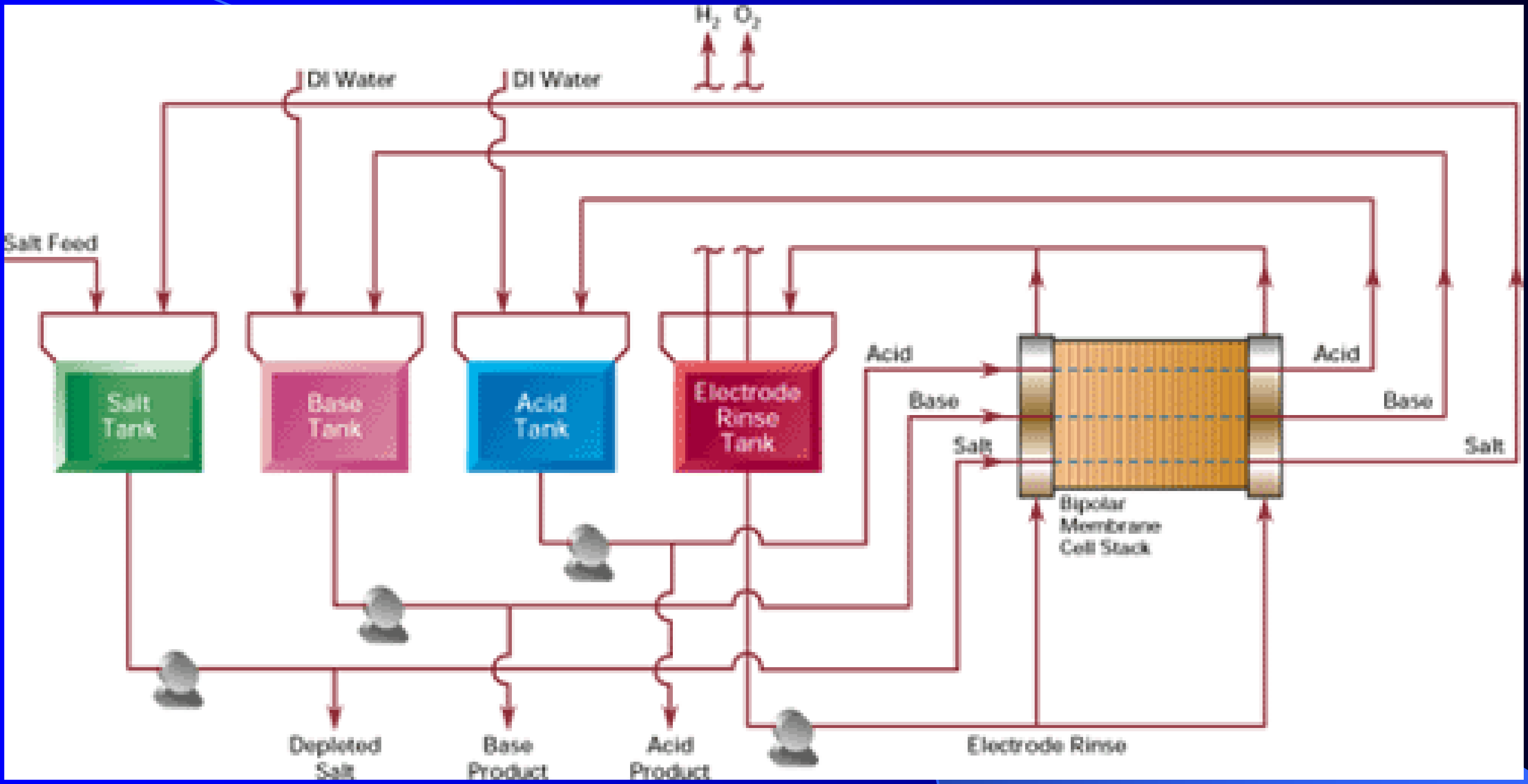
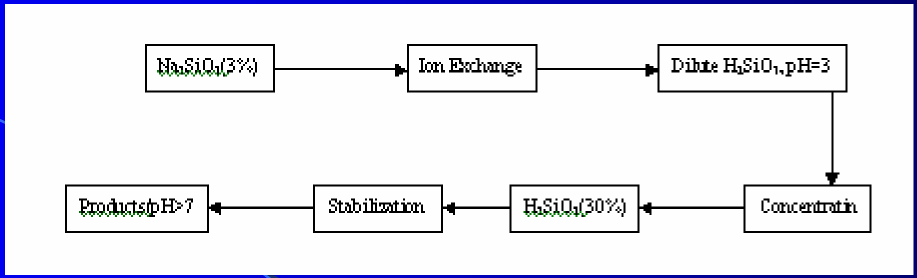
Cleaning production

---- Production of inorganic acid and base



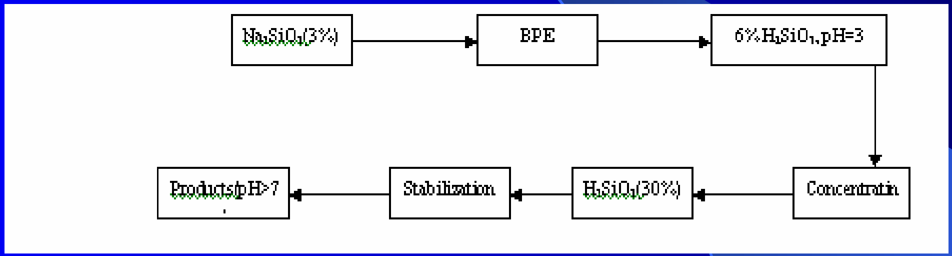
Cleaning production

---- Production of silicic acid (H_2SiO_3)



Conventional process---

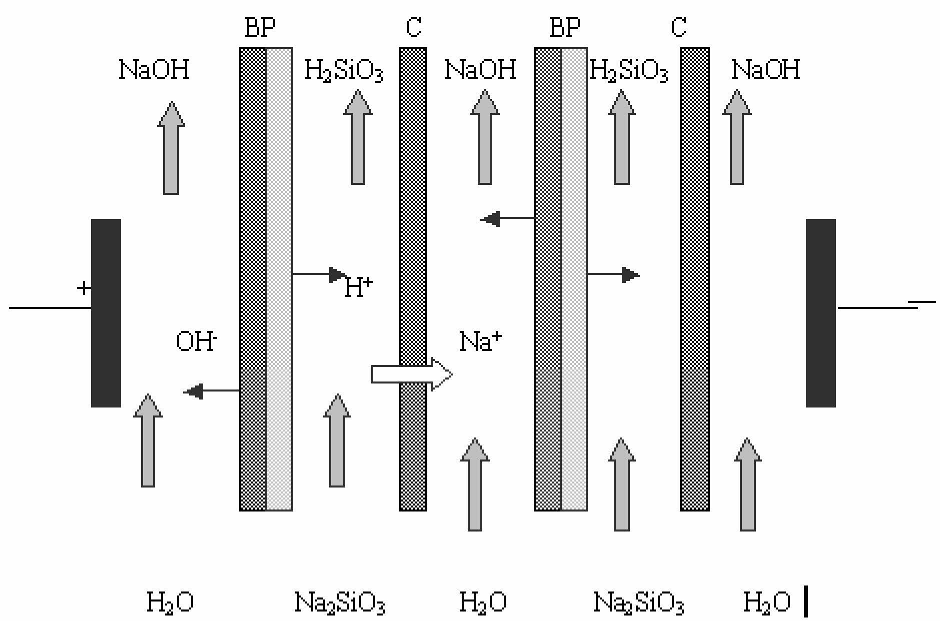
Ion exchange method:Energy consumption >1 kwh/kg products



Bipolar membrane electrodialysis(BPE) :Energy consumption >0.6 kwh/kg products; Operation conditions :

V=2.5-4V(I=10-12 mA/cm^2), **h** =55-75%, Sio_2=6-10%, pH=3.

Cell arrangements of **silicic acid production**

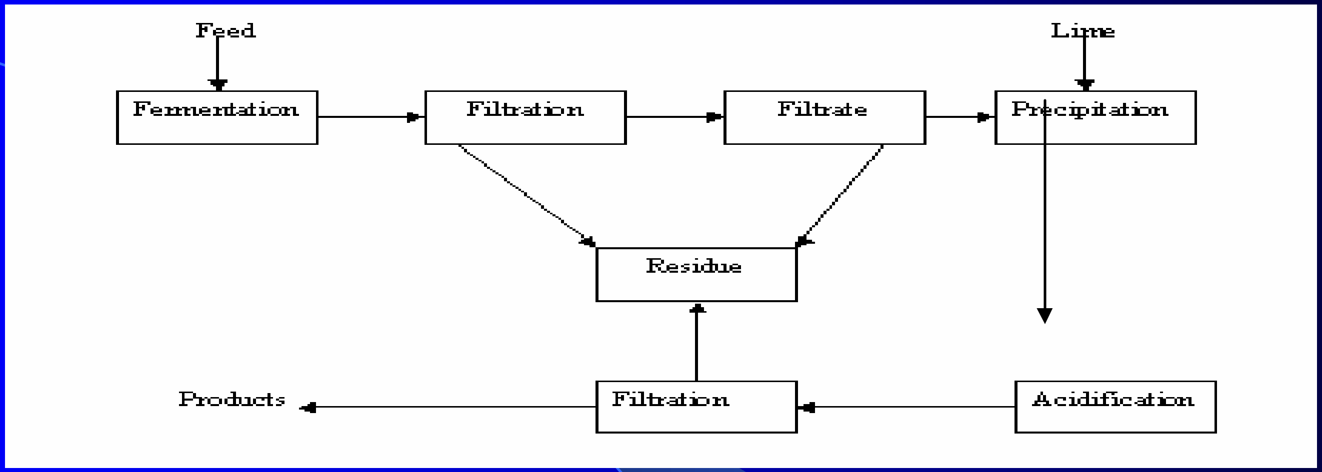


Note: BME is suitable for technology of Na_2SiO_3 production where raw materials is SiO_2 and Na_2CO_3 or SiO_2 and NaOH.

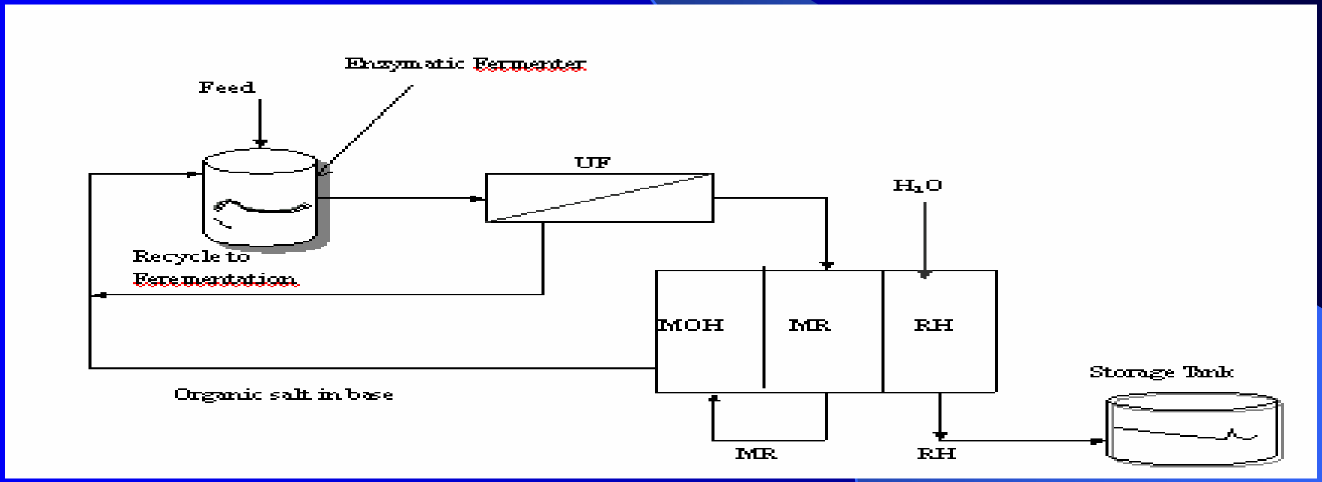
Cleaning production

-- Production of organic acid

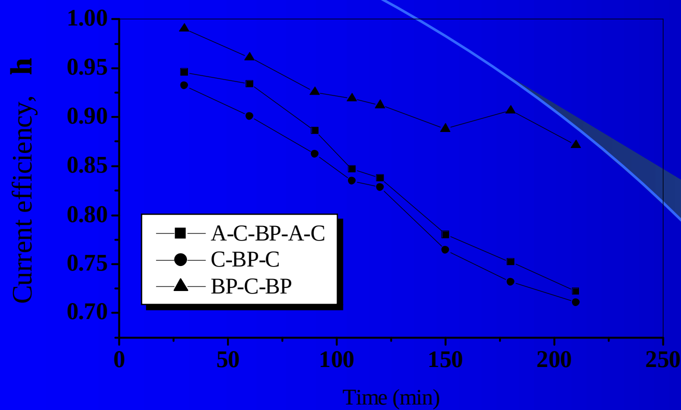
Conventional process



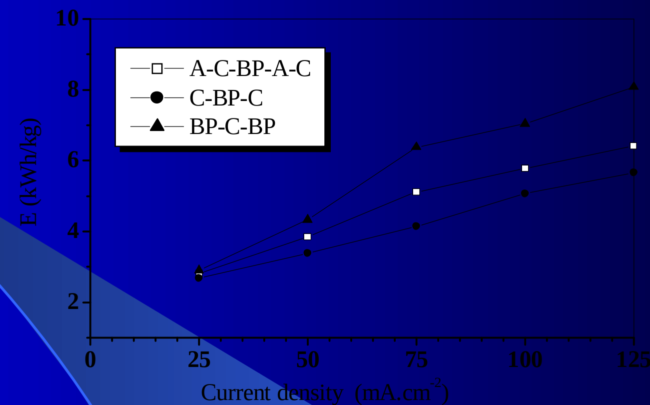
Bipolar process



Pilot test--Cell configurations of citric acid production



Current efficiencies for citric acid production versus time at i=100 mA.cm^{-2}.

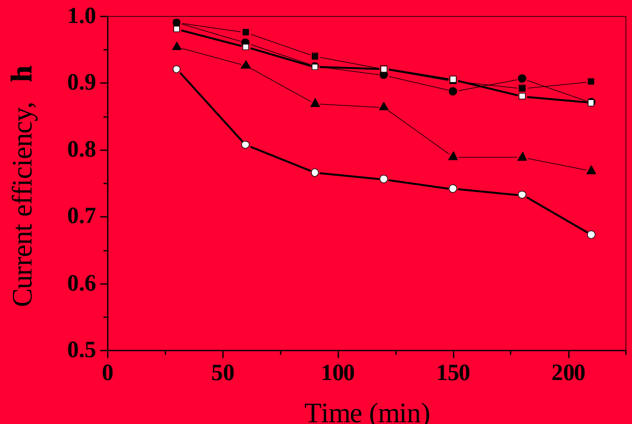


Energy consumption for the production of citric acid production versus current density.

Refs:Xu T W et al, Chem. Eng. process, 2001, in press

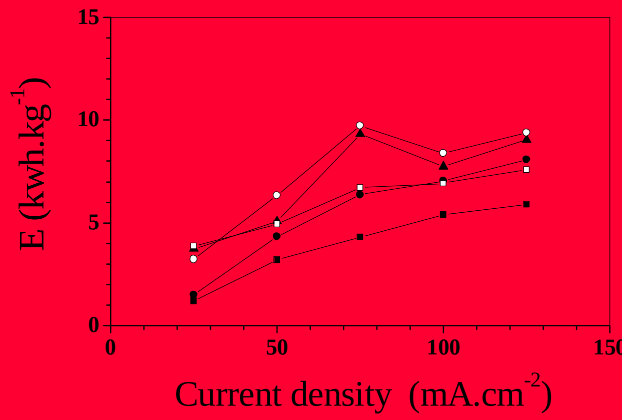
Xu T W et al, J Membr. Sci., 2001, revised

Pilot test--Results of citric acid



Current efficiencies for citric acid production versus time at i=100 $mA.cm^{-2}$.

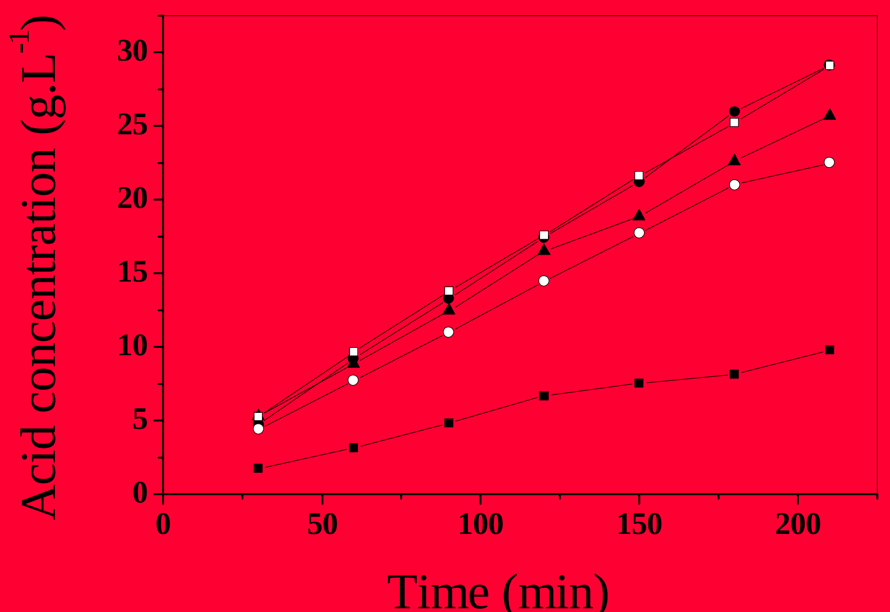
$0.1M\ Na_3Cit,\ 0.5M\ Na_2SO_4$; $0.5M\ Na_3Cit,\ 0.5M\ Na_2SO_4$; $1M\ Na_3Cit,\ 0.25M\ Na_2SO_4$; $1M\ Na_3Cit,\ 0.5M\ Na_2SO_4$; $1M\ Na_3Cit,\ 1M\ Na_2SO_4$.



Energy consumption for the production of citric acid production versus current density.

$0.1M\ Na_3Cit,\ 0.5M\ Na_2SO_4$; $0.5M\ Na_3Cit,\ 0.5M\ Na_2SO_4$
$1M\ Na_3Cit,\ 0.25M\ Na_2SO_4$; $1M\ Na_3Cit,\ 0.5M\ Na_2SO_4$
$1M\ Na_3Cit,\ 1M\ Na_2SO_4$

Pilot test--Results of citric acid

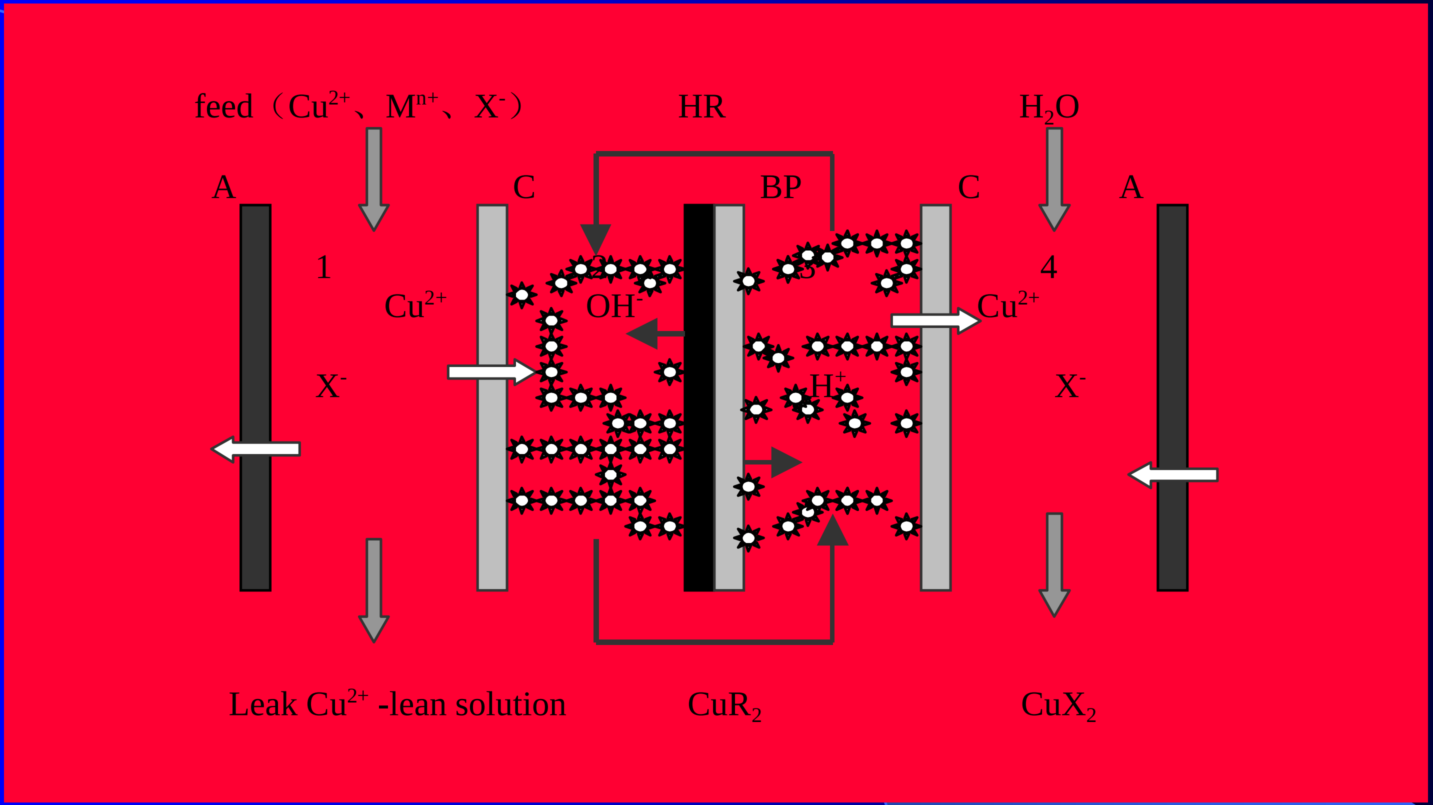


Time dependence of citric acid concentration in the acid compartment ($i=100\ mA.cm^{-2}$).

- ■ 0.1M Na_3Cit, 0.5M Na_2SO_4;
- ● 0.5M Na_3Cit, 0.5M Na_2SO_4;
- ▲ 1M Na_3Cit, 0.25M Na_2SO_4;
- □ 1M Na_3Cit, 0.5M Na_2SO_4;
- ○ 1M Na_3Cit, 1M Na_2SO_4.

Cleaning separation

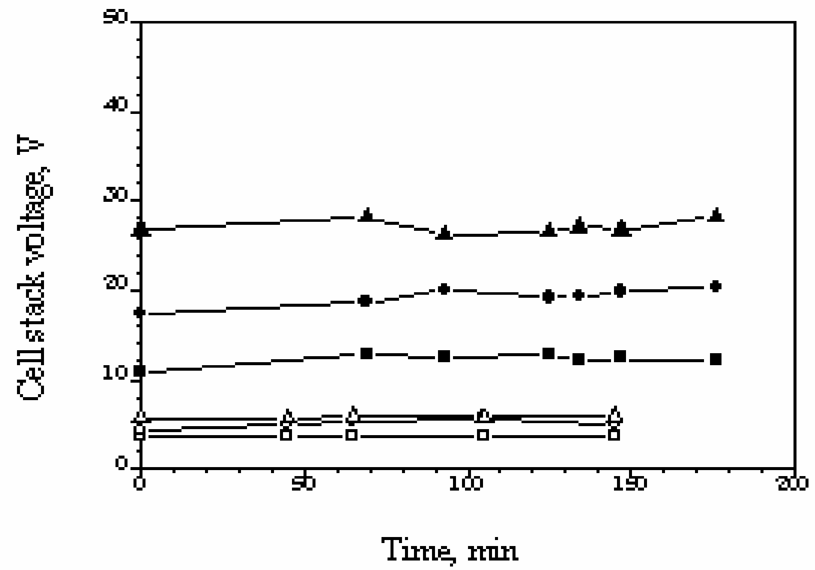
--schematic of **Electro-extraction and –back extraction**



HR-extractant and ✸represents ion exchange resin

Cleaning separation--

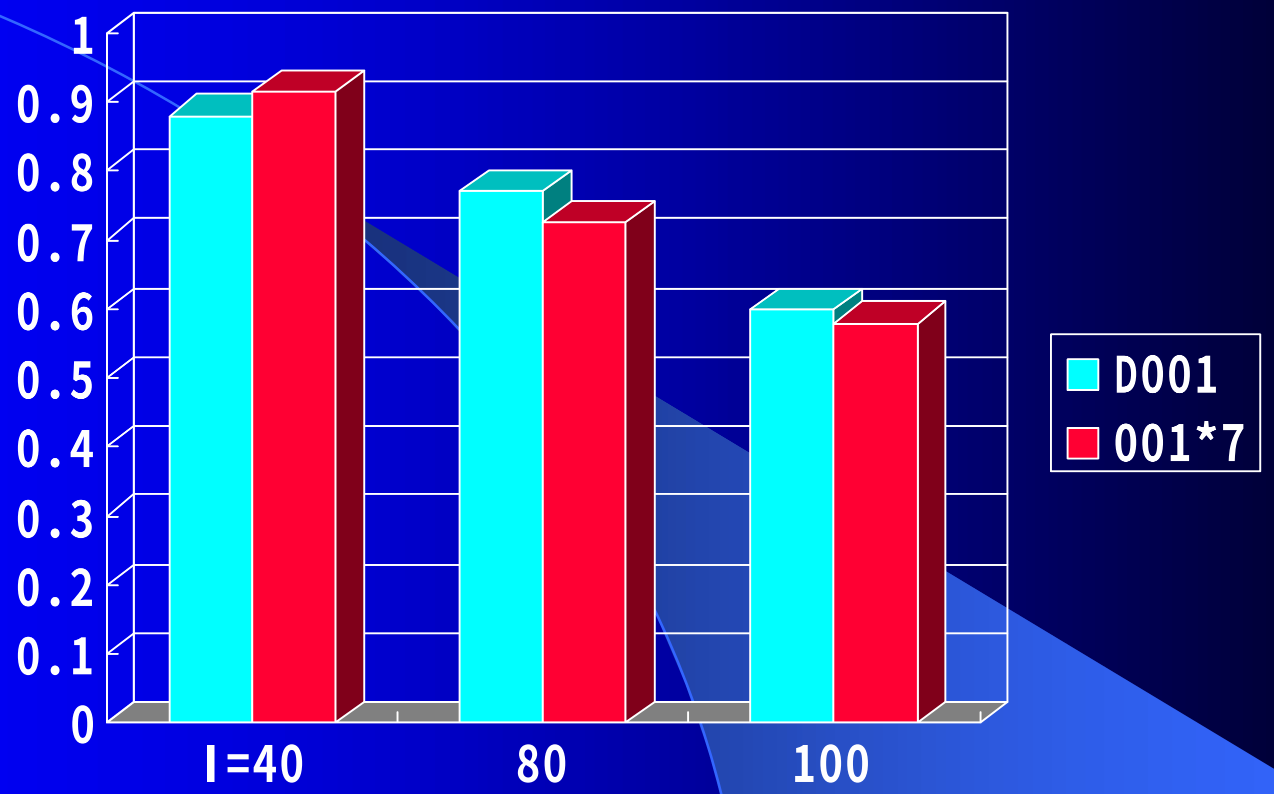
Cell voltages changes of Electro-extraction and –back extraction



Cell voltage changes at various current densities 50(square), 80 (circle) and 100 (triangle) mA cm^{-2},respectively for electroextraction. Solid simbols for D001 porous resin and open simbols for 001*7 resin.

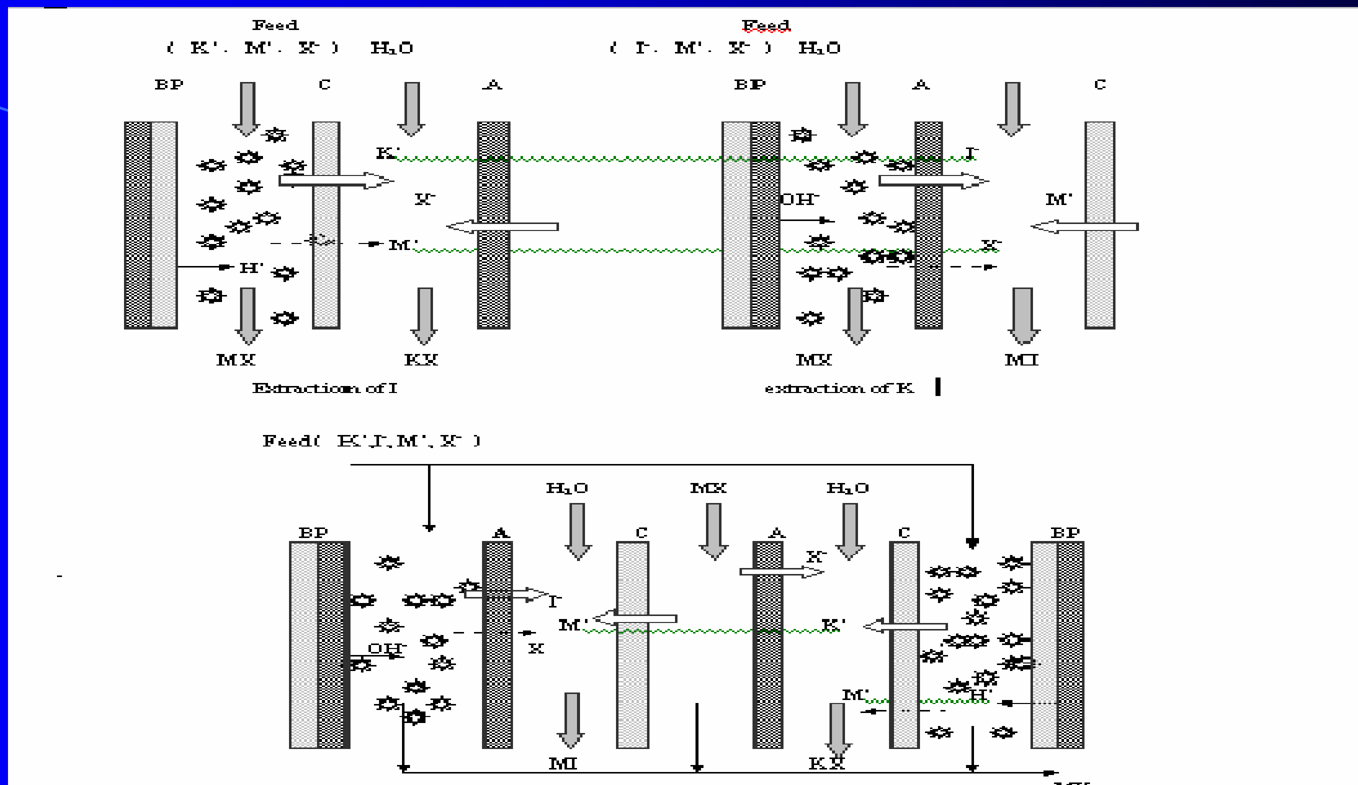
Cleaning separation--

Current efficiency of Electro-extraction and –back extraction



Cleaning separation

----Separation of ions with equal valence and same sign

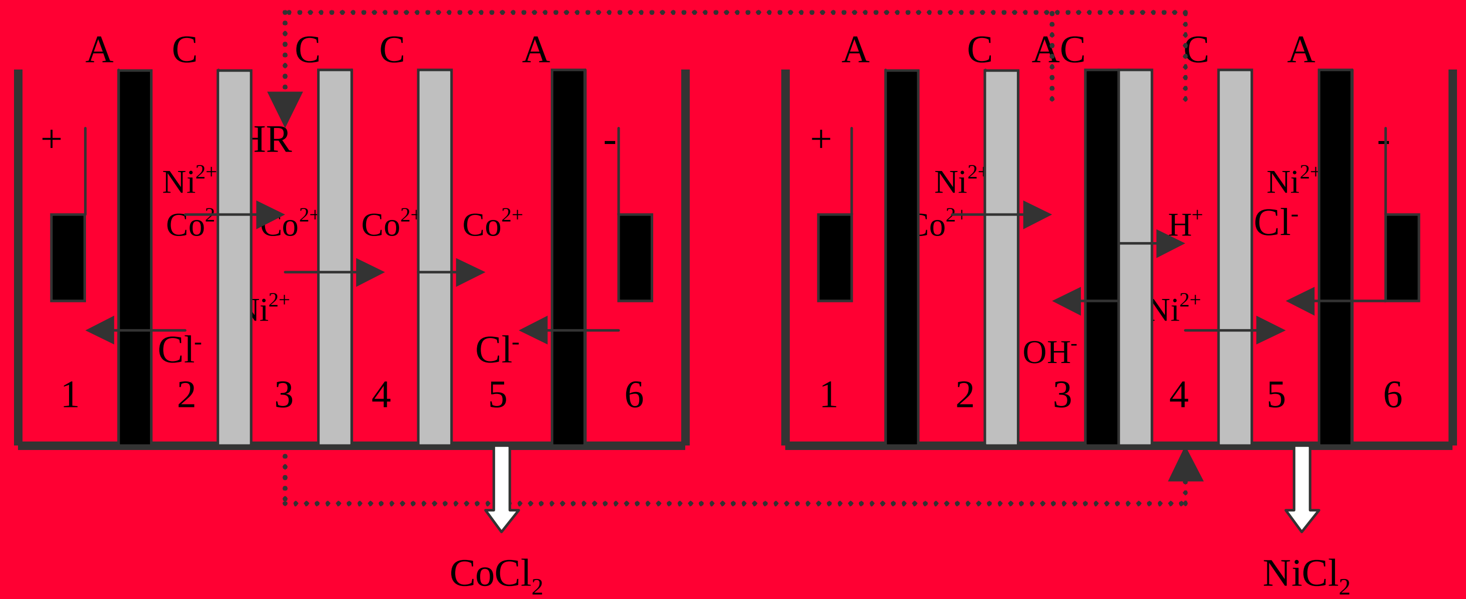


Separation of K^+ and I^- from M^+ and X^-

Ref: Xu T W et al. Desalination, 2001, in press.

Cleaning separation

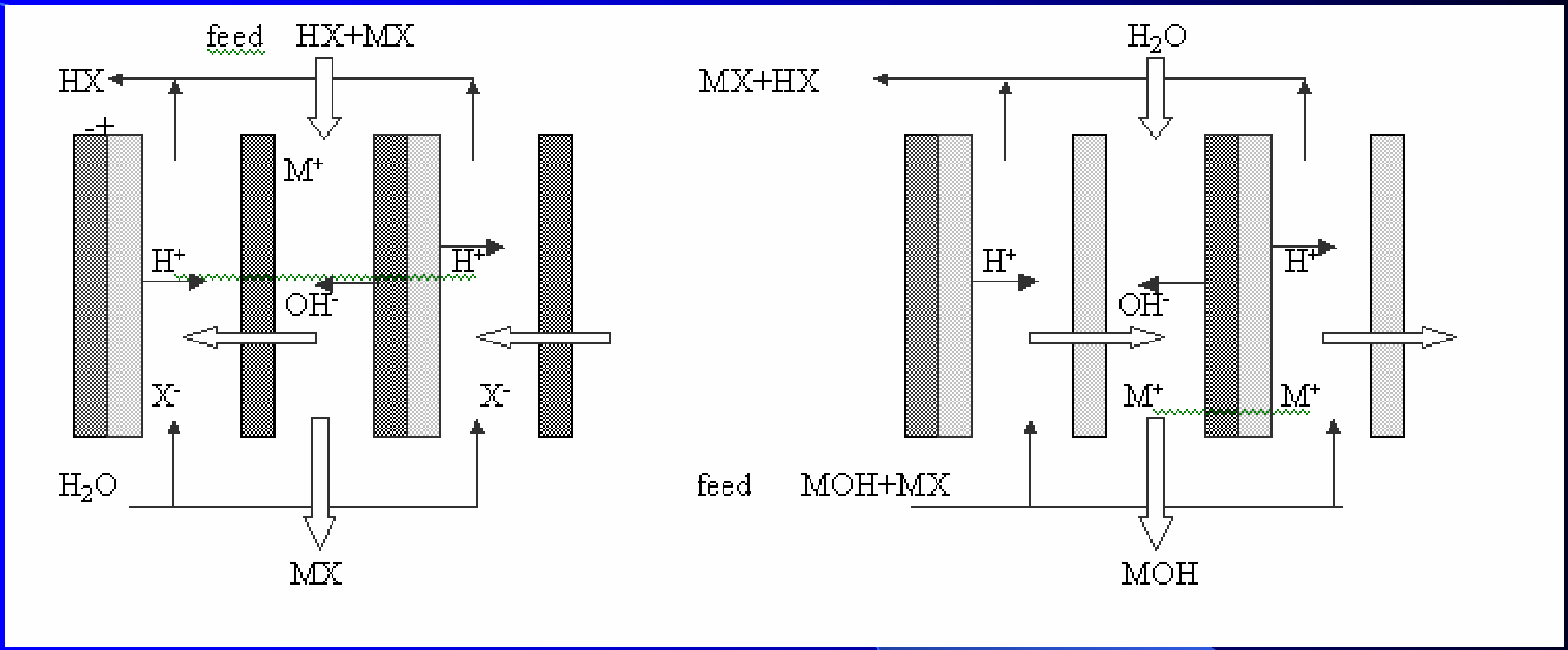
----Separation of ions with equal valence and same sign



Separation of Ni^{2+}、Co^{2+} by BP process

(A-Anion membrane,C-cation membrane,AC-bipolar membrane, HR coordinate agent)

Cleaning recovery ----Recovery of acid and bases from the spent liquors



Cell unit for acid recovery Cell unit for base recovery

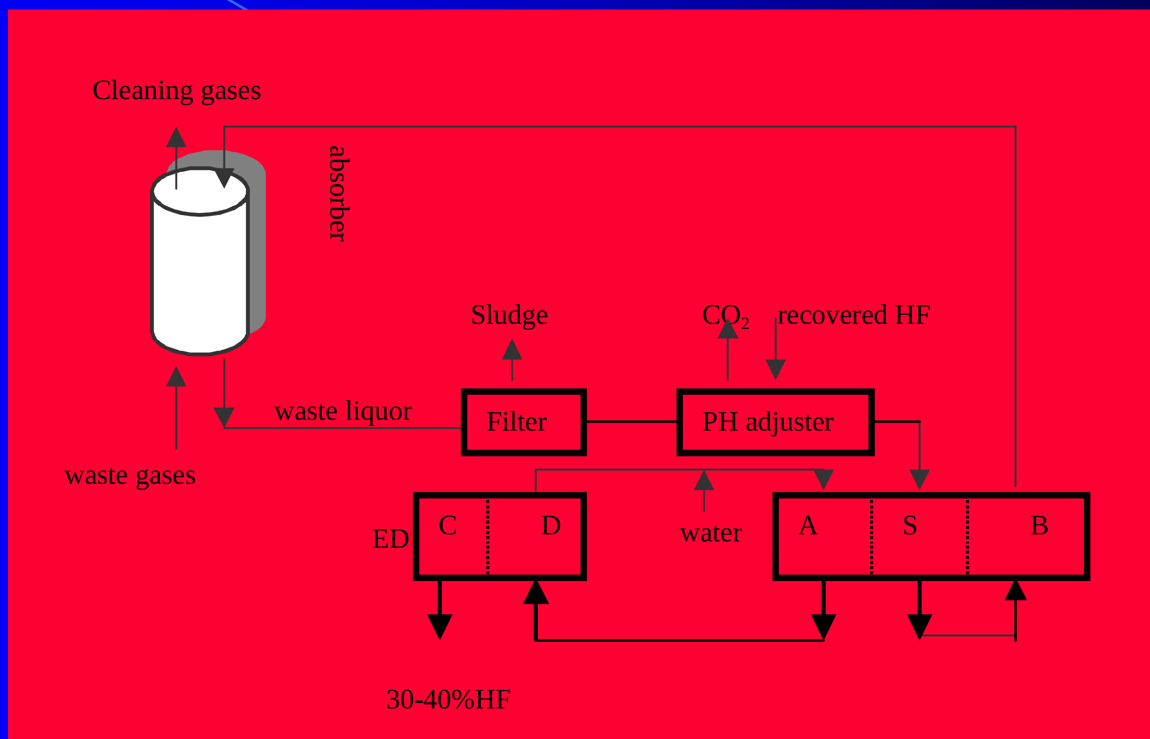
Potential areas using this technology

- Purification of spent sulfuric acid from lead acid batteries;
- Isolation of pure caustic soda from an $NaOH/NaNO_3$ mixture in the Ni/Cd battery manufacture;
- Recovery of excess HCL and NaOH from ion exchange regeneration streams;
- Recovery of spent sulfuric acid from aluminum anodizing baths;
- Recovery of purified nitric acid from uranium processing operations;
- Separation and purification of HNO_3 and NH_4NO_3 system;
- Recovery of mineral acids from mining/metal recovery operations;
- Purification of organic acids resulting from fermentation processes

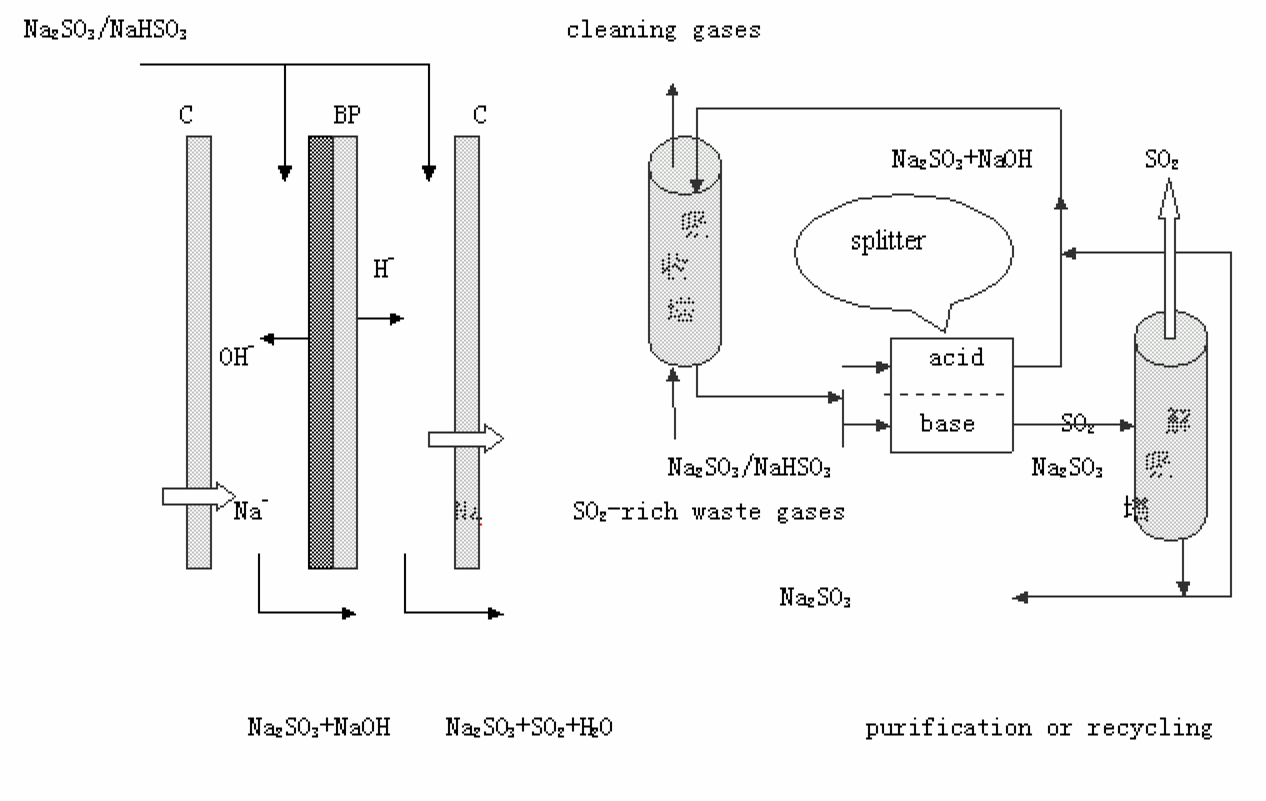
Cleaning recovery ----Control of fluorine leakage from Uranium fluoride production

HF(gases, radioactive elements) +KOHÛKF+H_2O

2KF+$Ca(OH)_2$ÛCaF_2(solid, radioactive elements)+2KOH



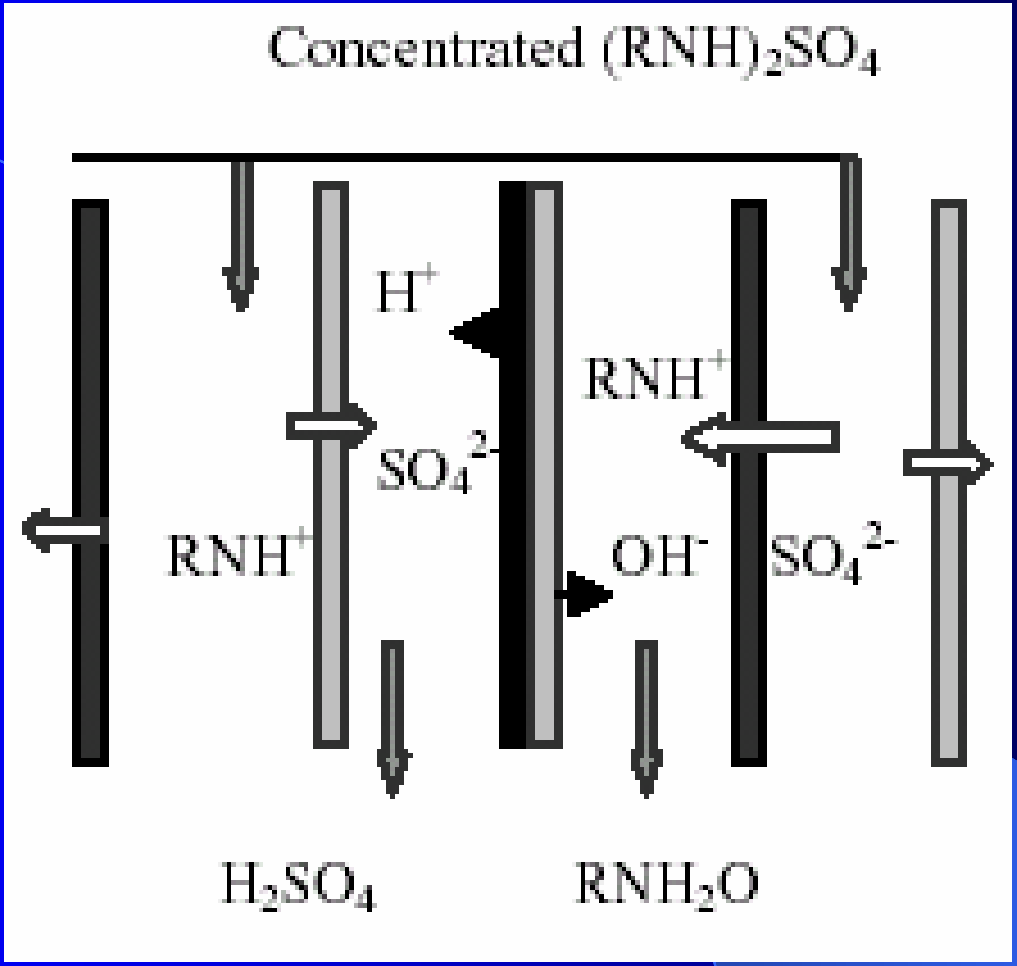
Cleaning recovery--recovery of acidified gases (CO_x、NO_x and SO_x)



Two-compartment conversion unit for $NaHSO_3$

Soxal™ de-sulfur process

NEW WET DESULFURIZATION PROCESS



Cleaning resources:

---Bipolar membrane-based accumulator (cell)

Ag/Ag_2O;ectrode：

Cathode reaction： $Ag_2O+H_2O+2e^- \rightarrow 2Ag+2OH^-$; theoretical potential： 0.344V;

Anode reaction： $2Ag+2Cl^- \rightarrow 2AgCl+2e^-$; theoretical potential： -0.222V;

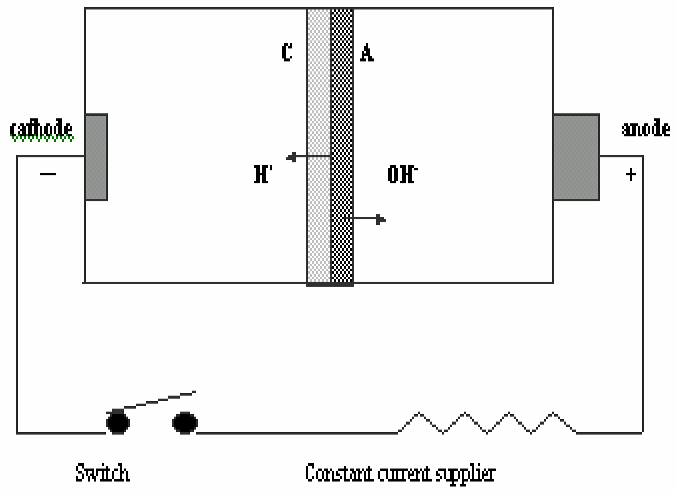
Neutral reaction： $2H^++2OH^- \rightarrow 2H_2O$; theoretical potential： 0.828V;

Total： 0.95V

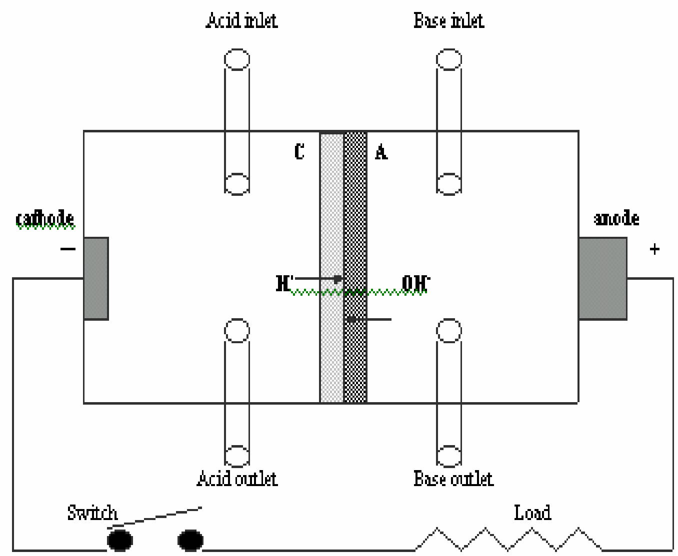
Conventional energy-supply electrodes

Cathode	Anode
AgCl	$Ag/Fe/H_2/Po/Zn/Zn(Hg)$
AgO	$Ag/[Co(NH_3)_6]^{2+}/Fe/[Fe(CN)_6]^{4-}/Ni$
Ag_2	$Ag//Fe/[Fe(CN)_6]^{4-}/Pb/Zn$
Co^{3+}	$Ag/[Fe(CN)_6]^{4-}/H_2/Pb/Zn$
Fe^{3+}	$Ag/[Co(NH_3)_6]^{2+}/[Fe(CN)_6]^{4-}/ H_2/Pb$
O_2	$Cr^{2+}/Ti^{3+}/ H_2/Pb/Zn(Hg)$
Cl_2	$Cr^{2+}/Ag/Ti^{3+}/ H_2/Zn(Hg)$

Charge and discharge of a bipolar membrane battery



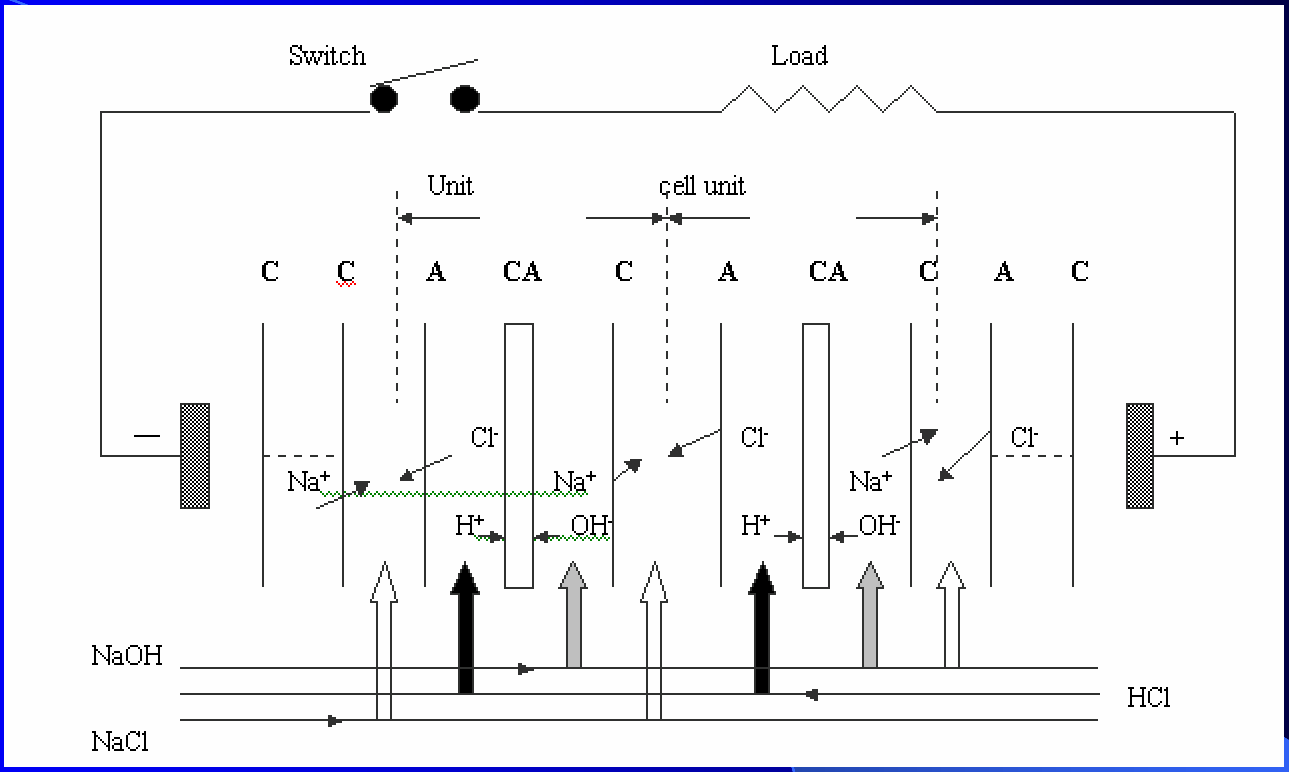
Charge process of a bipolar membrane cell



Discharge process of a bipolar membrane cell

Refs: J. Walther, N.Y. et al, US patent 4311771, 1982/01/19.
E. K. Zholkovskij,et al J Membr. Sci., 141(1998)231-243.

A typical BP stack



Bipolar battery (100 unit, 40-80V, 60KW/m^2)

Future focus

- Bipolar membrane with high performance
- Design and establishment of new BPED
- BPED in non-aqueous systems, such as EtOH→EtNa
- Electro-acidification --production of soy protein isolates
- Mechanism of transport and reaction in BPED
- Catalytic water splitting technology
- Ion separation based on a bipolar membrane including BP-nanofiltration
- Daily use products based on bipolar membrane process