A new way of looking at the Rapid Chloride Permeability Test.

(Using Physics rather than Chemistry)

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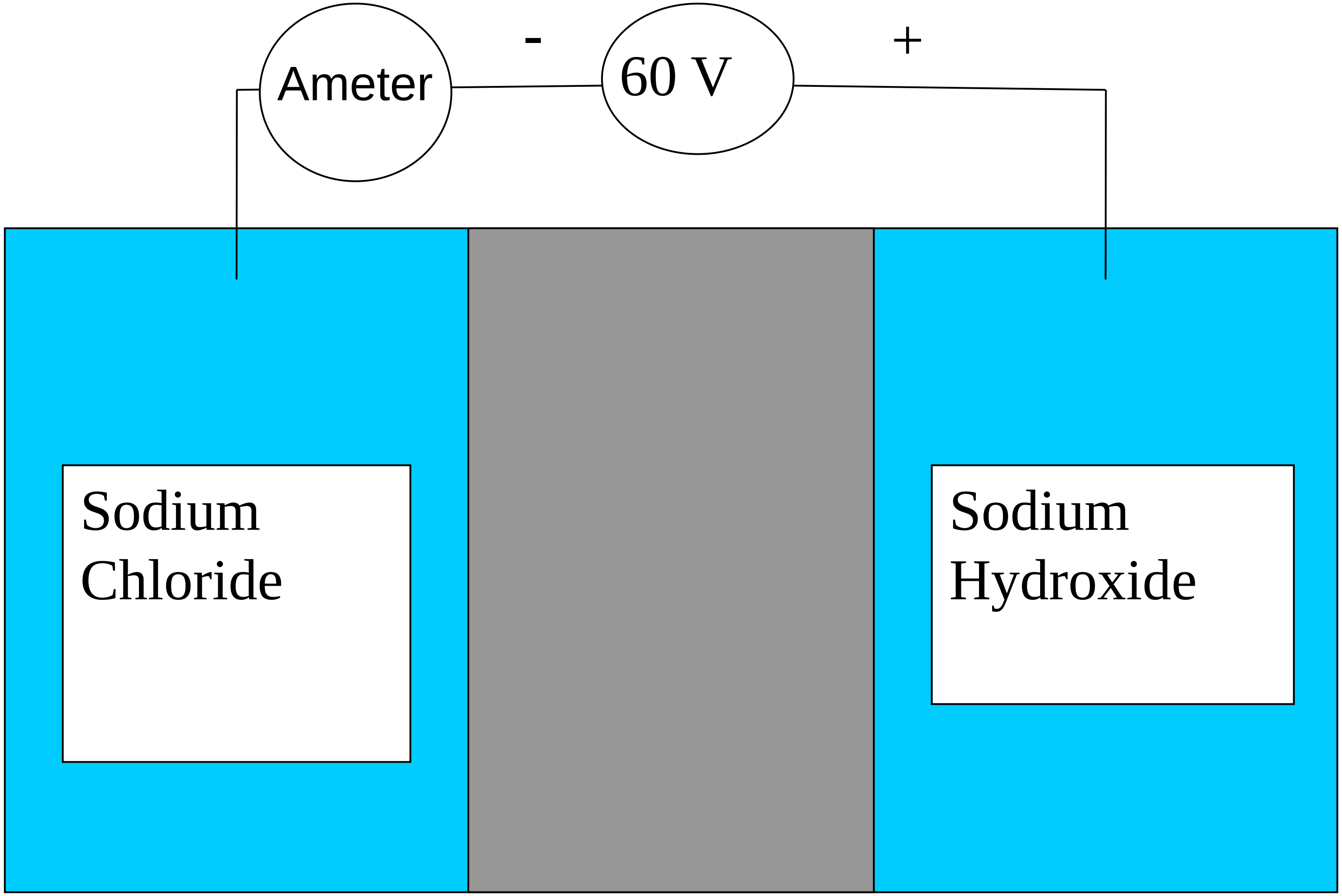
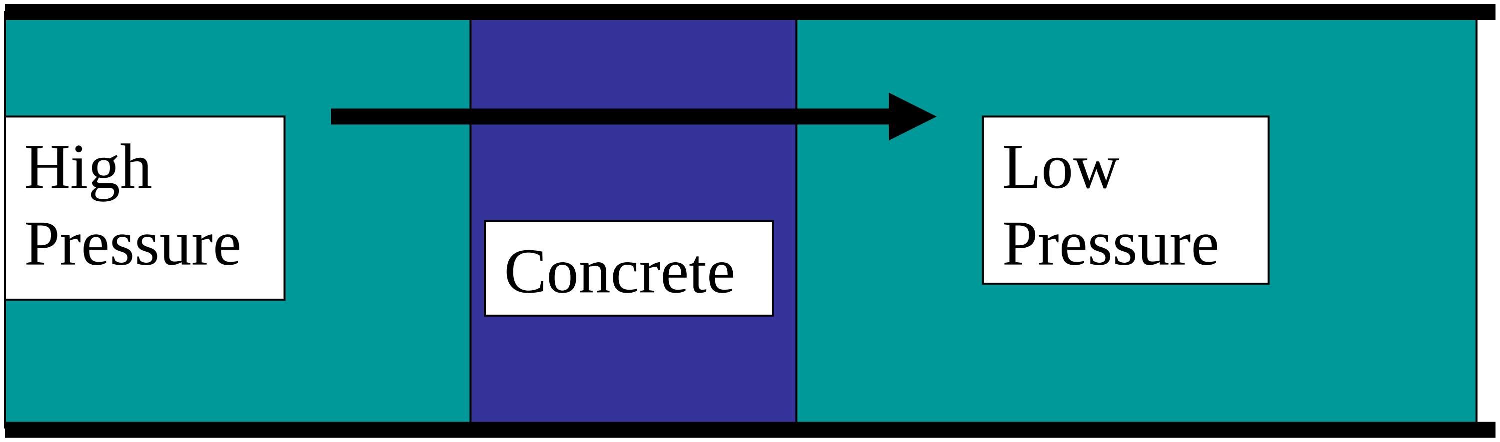
ASTM C1202 – Names for the Test

- Standard Test Method for Electrical Indication of Concrete’s Ability to Resist Chloride Ion Penetration (in the ASTM).
- The Rapid Chloride Permeability Test (after Whiting – who invented the test)
- The Coulomb Test (it measures Coulombs)

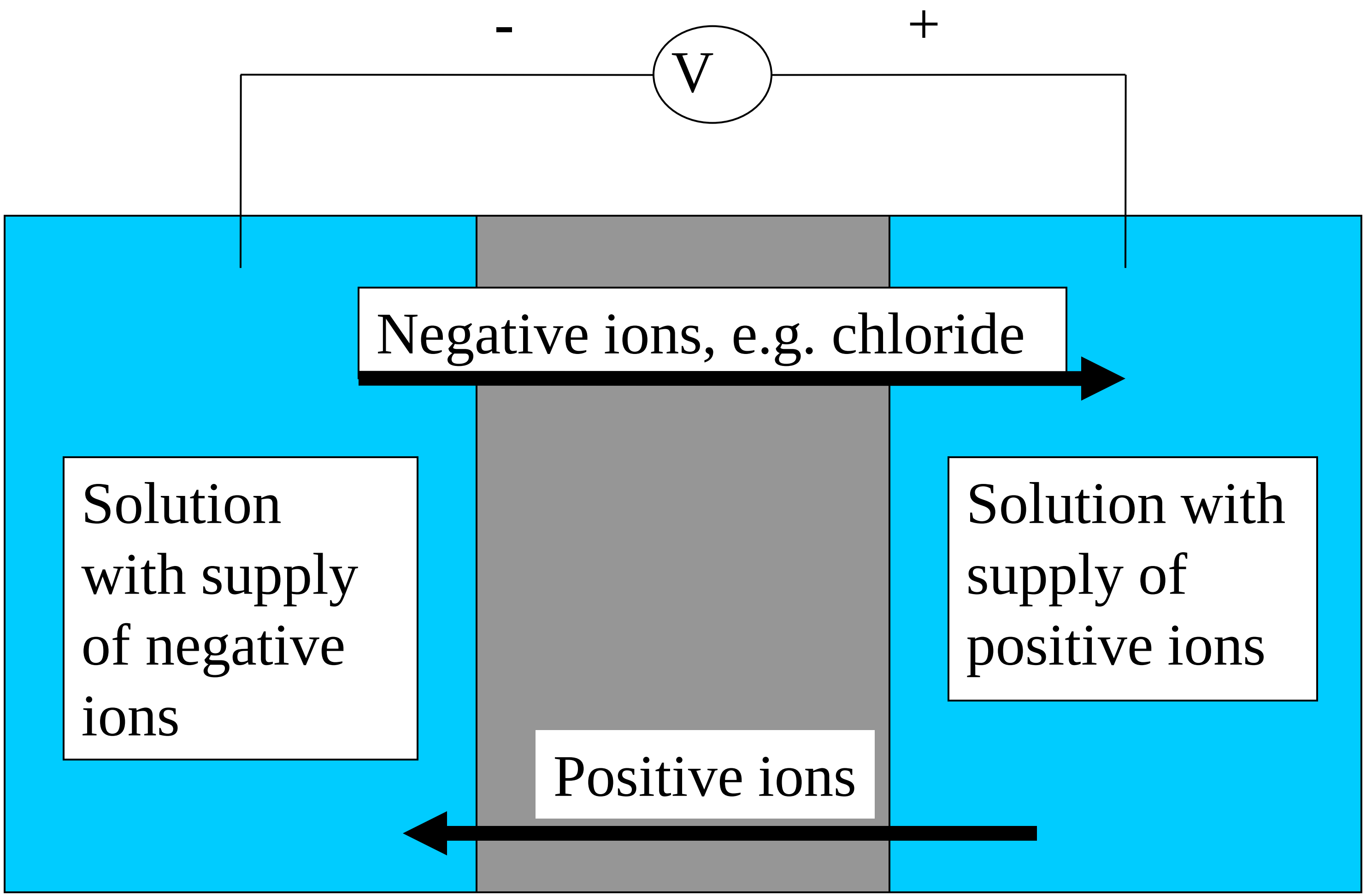
The test: Measure the current for 6 hours and calculate the total charge in Coulombs (i.e. the average current multiplied by the time)



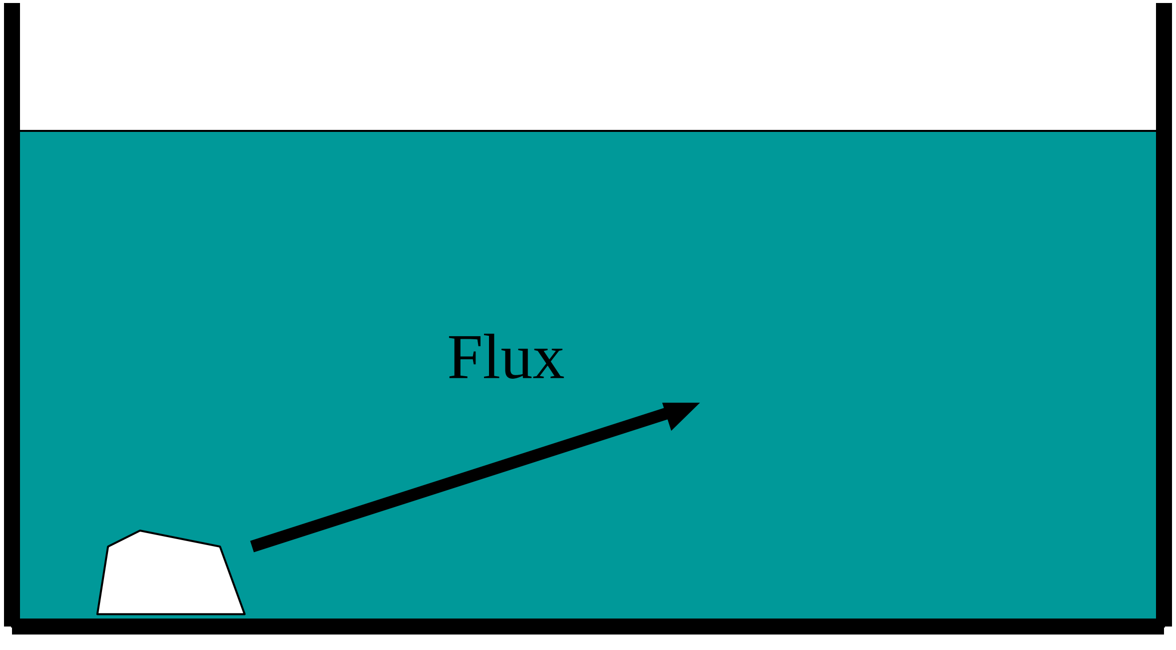
How to measure permeability ....not this test



Electromigration

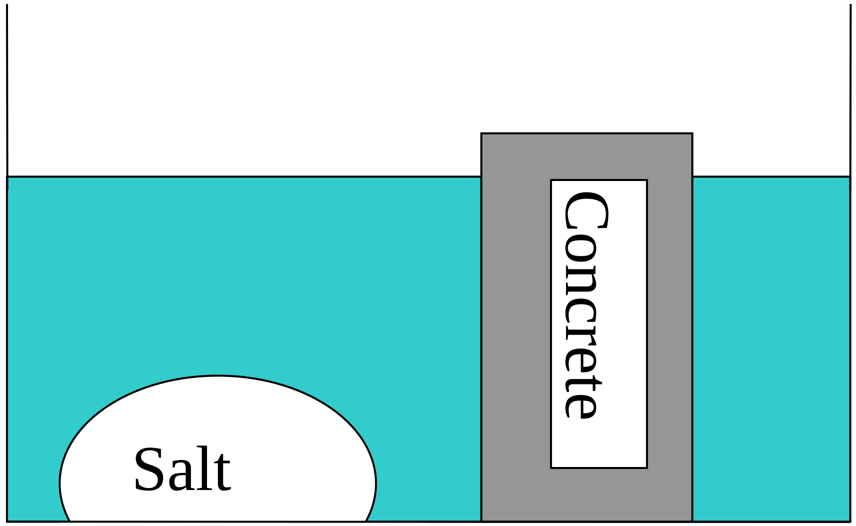


Salt dissolving into a solution



Diffusion

When the salt dissolves into the water it will assume an equal concentration at all points throughout the liquid and will enter the concrete



The Equations

Diffusion:

$$J = \varepsilon D \frac{dC}{dx} \qquad mol/m^2/s$$

The flux depends on the concentration gradient dC/dx

Electromigration:

$$J = \frac{\varepsilon DzECF}{RT} \qquad mol/m^2/s$$

The flux depends on the electrostatic field E (Volts/m)

Solving the hard way –

assuming E is constant

$$I = FADc_o a[\frac{2}{\beta\sqrt{\pi}} e^{(\frac{\alpha}{2} - \frac{\alpha^2}{\beta^2} - \frac{\beta^2}{16})} + \frac{1}{2}\mathrm{erfc}(\frac{\alpha}{\beta} - \frac{\beta}{4})]$$

where

$$a = \frac{zFE}{RT}$$

$$\alpha = ax$$

$$\beta = 2a\sqrt{Dt}$$

The Progress of a Chloride Ion

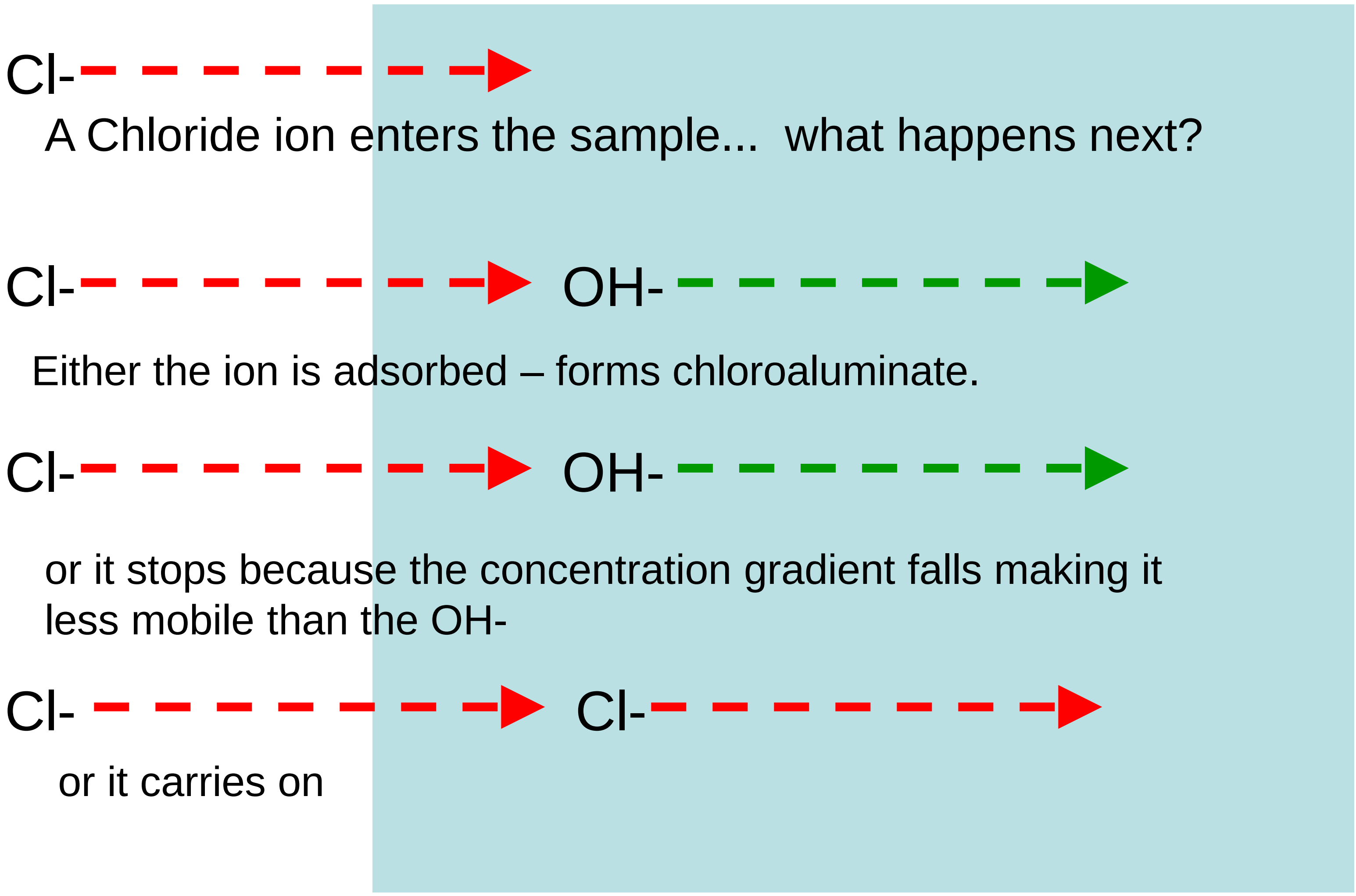
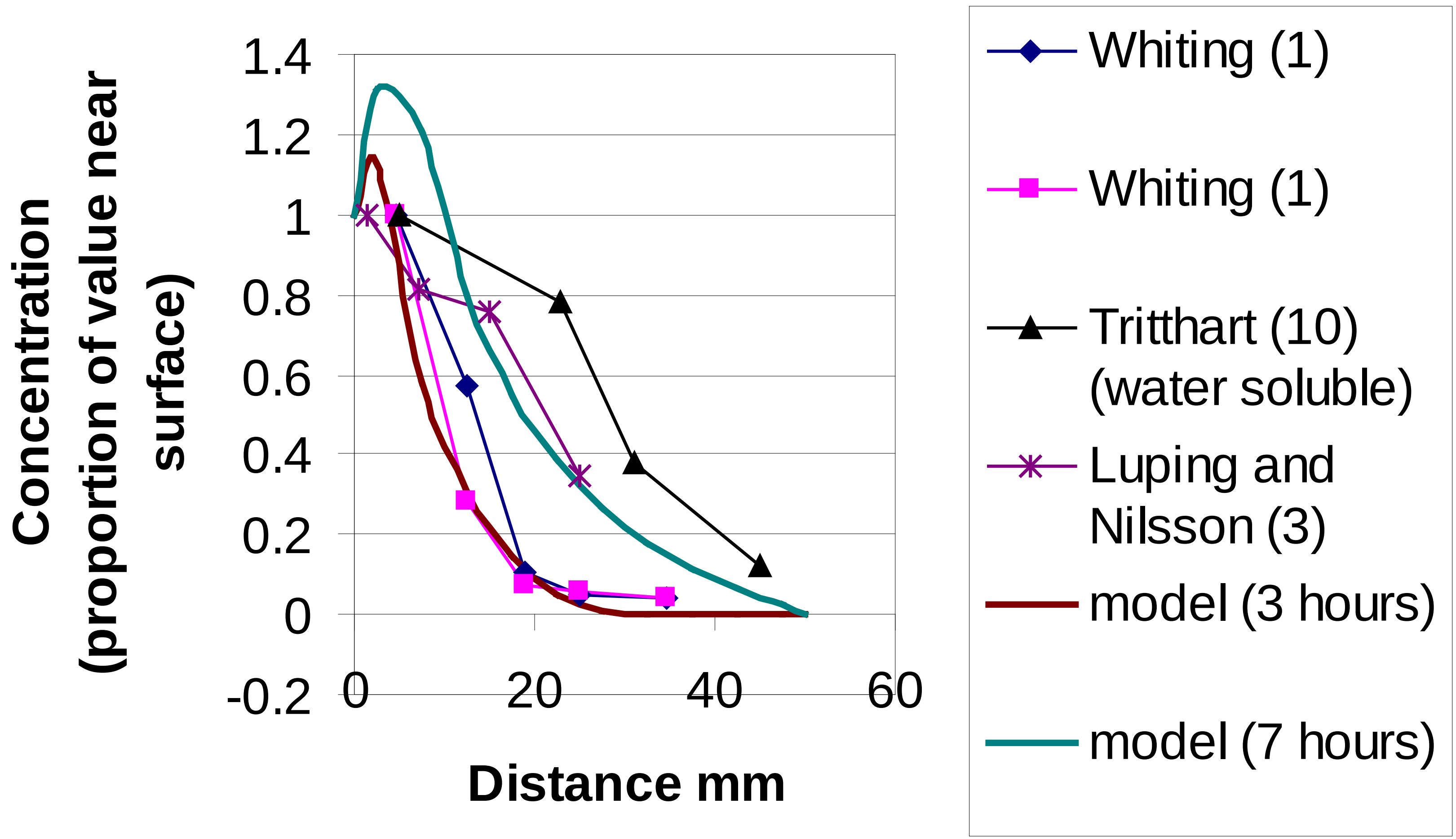
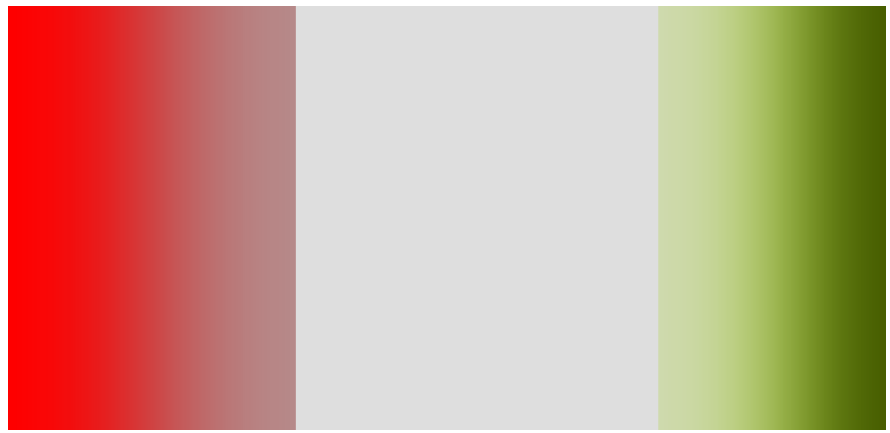


Figure 3. Comparison of model with reference data for chloride profiles.



Section through sample during test

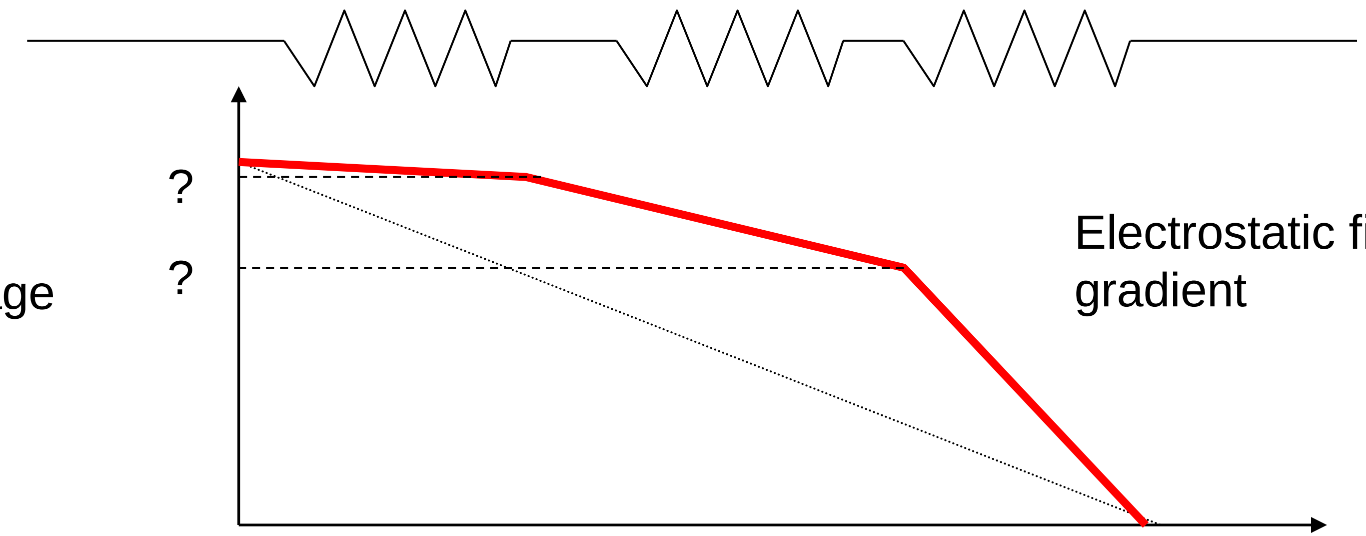


Chloride zone

Low resistance (high D)

Sodium zone

High resistance (low D)

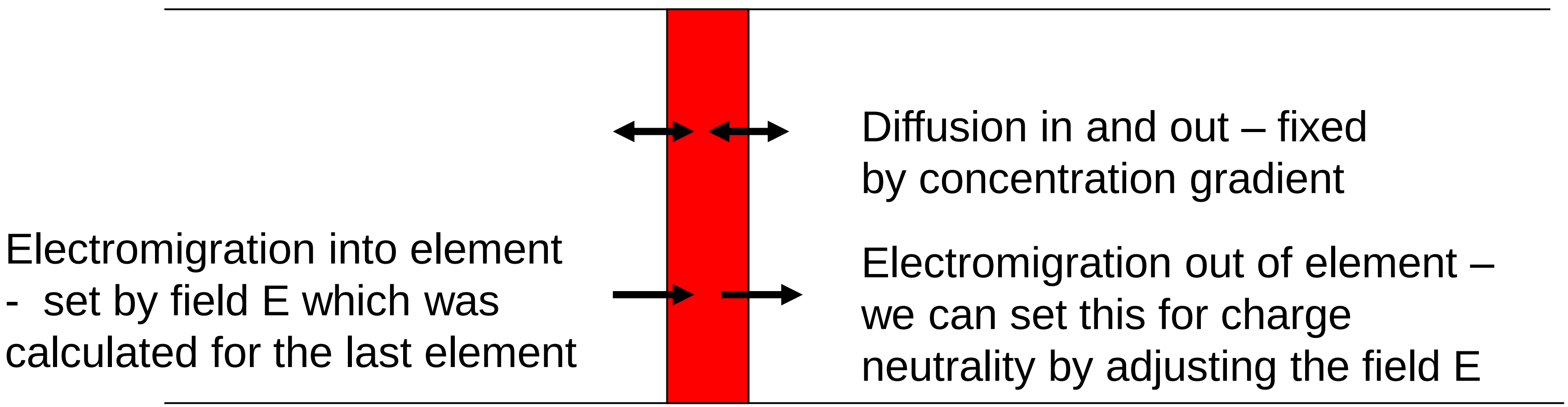


Voltage

Electrostatic field E is gradient

Modelling a thin slice of the sample for a short time step

Apply Kirchoff's law : current in = current out



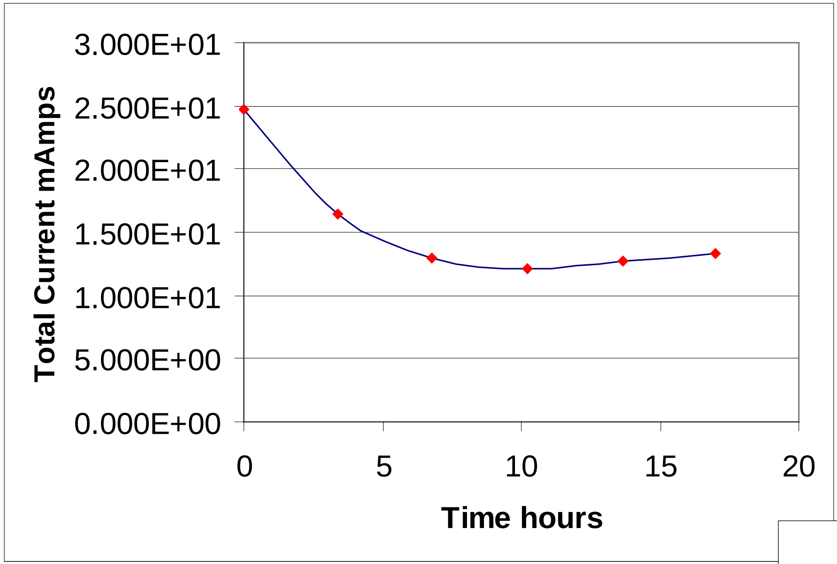
Final adjustments are needed to get the correct total voltage across the sample.

Input and output from computer model

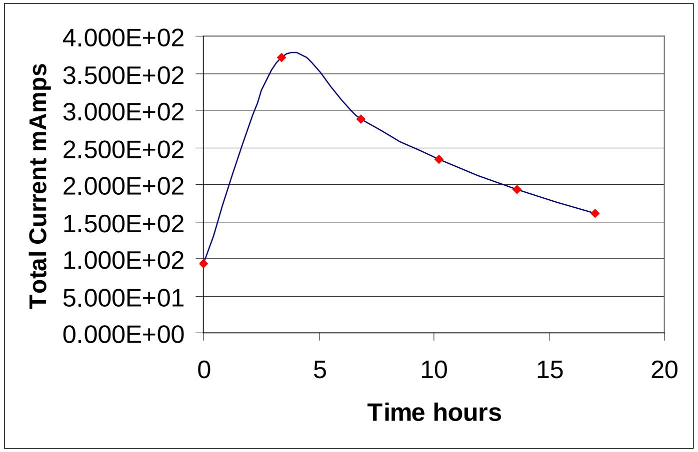
	Valence	Intrinsic Diffusion	Concentration mol/m3 (in liquid)			Capacity Factor			
	z	D m2/s	negative	in sample	positive		Time		Time step
hydroxyl	-1	1.65E-11	0	9.00E+01	300	0.2	17.02		105.10
chloride	-1	2.00E-10	500	0.00E+00	0	2			
sodium	1	2.00E-11	500	4.50E+01	300	0.2			Temperature
potassium	1	9.00E-11	0	4.50E+01	0	0.2			306.9
anion	1	0	0	0.00E+00	0	0.1			

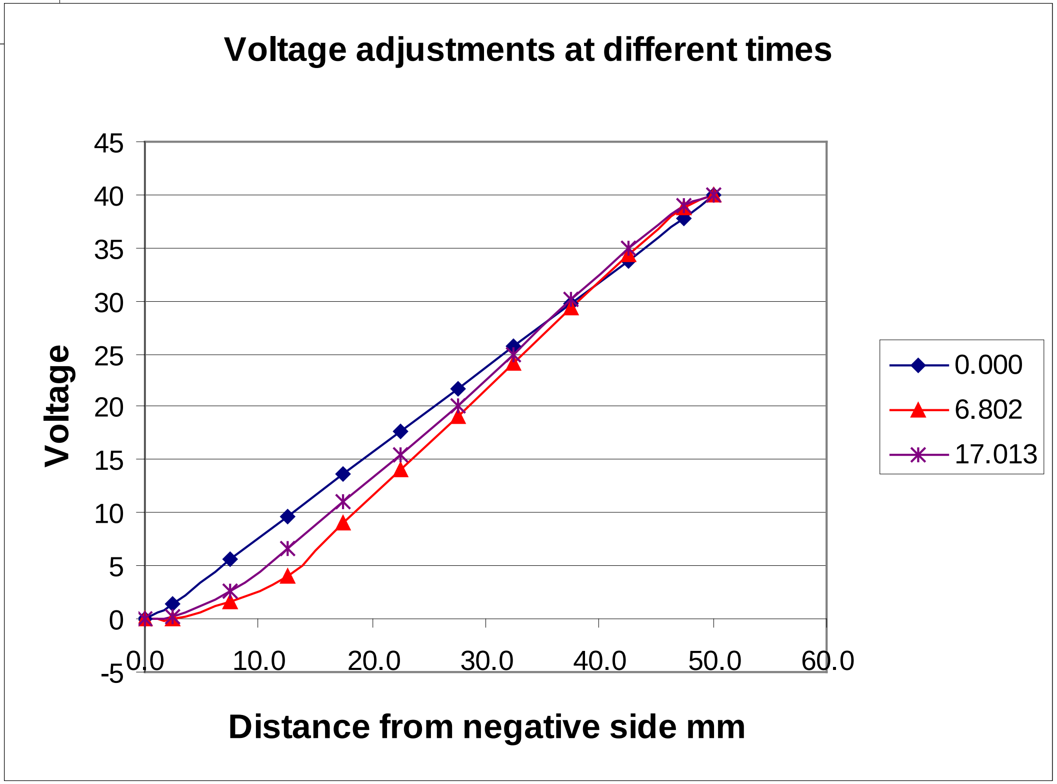
Initial current A	0.025
Final Current A	0.013
Total Charge Coulomb	884
Curvature	0.76
Average current	0.014

Model output for current and voltage

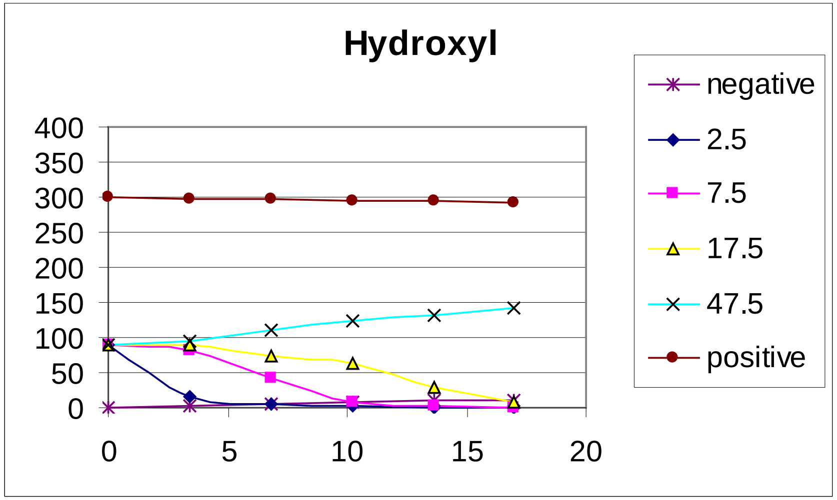


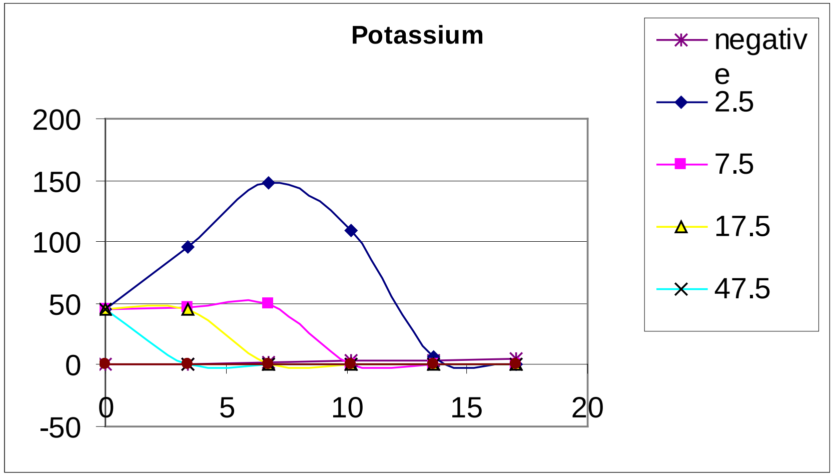
Current vs time with no voltage correction (average)

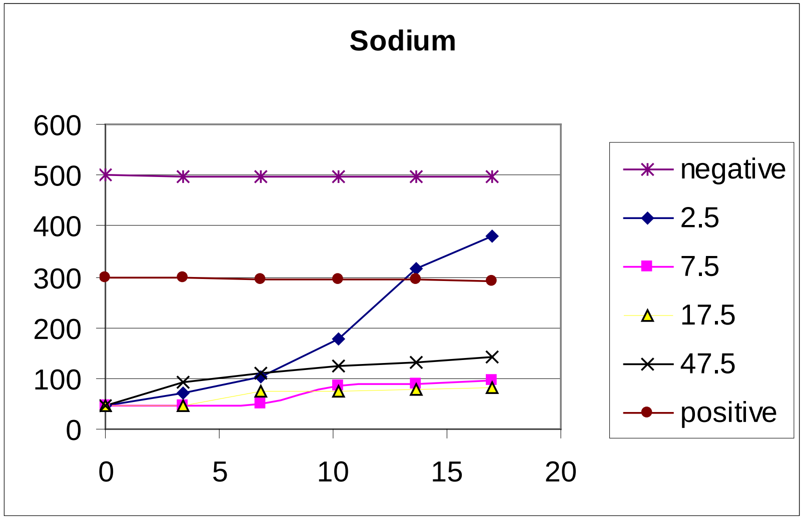


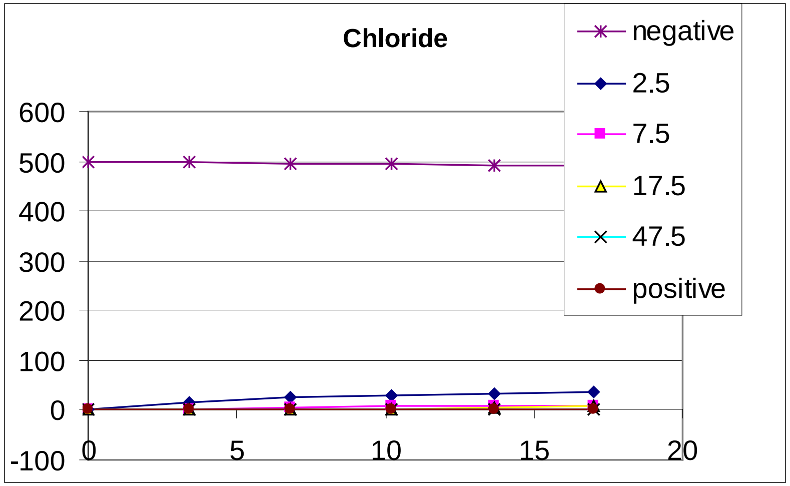


Concentrations in cells at distances from negative side in mol/m3 vs time in hours

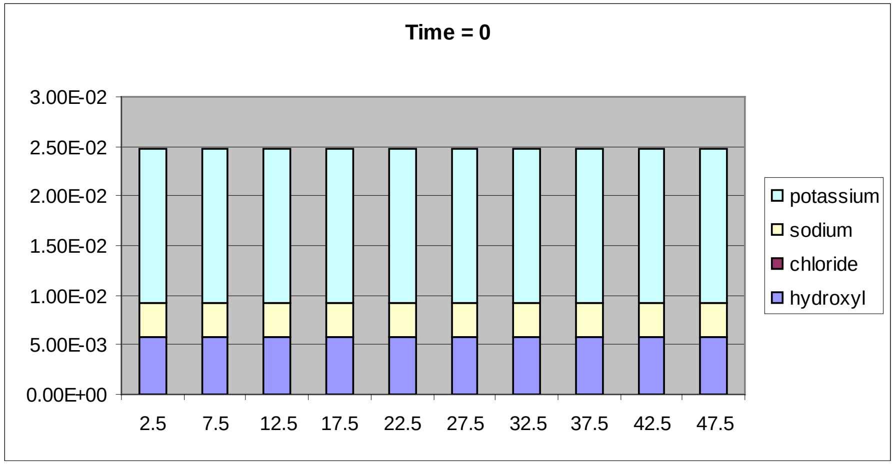


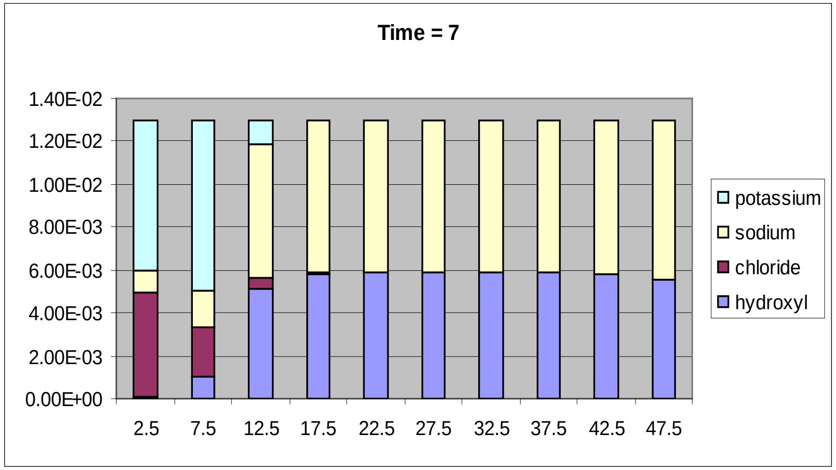


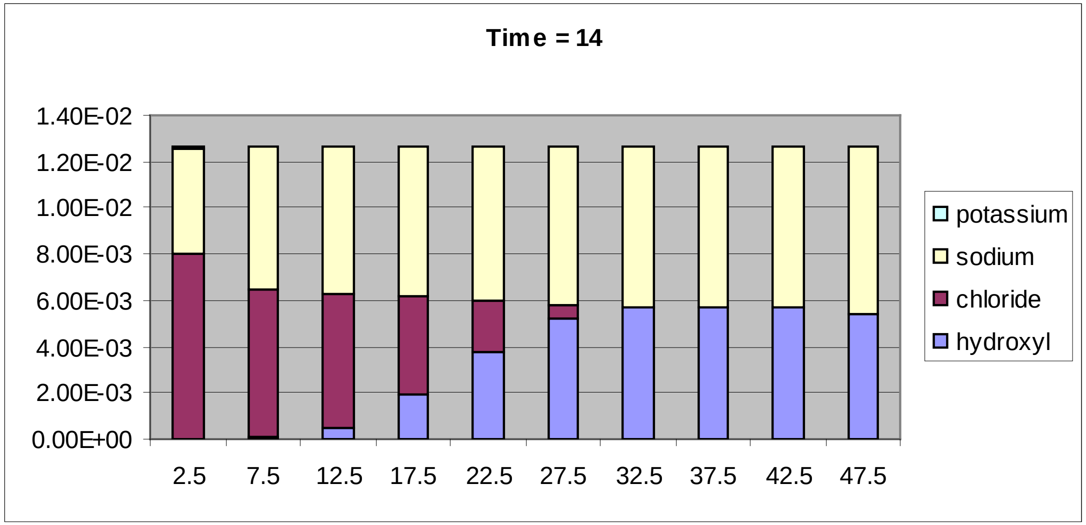




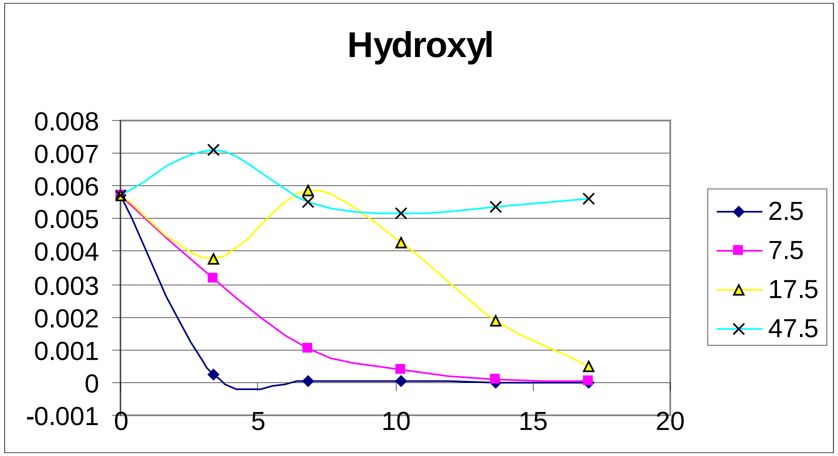
Current in amps at different times in hours vs position in mm from the negative side

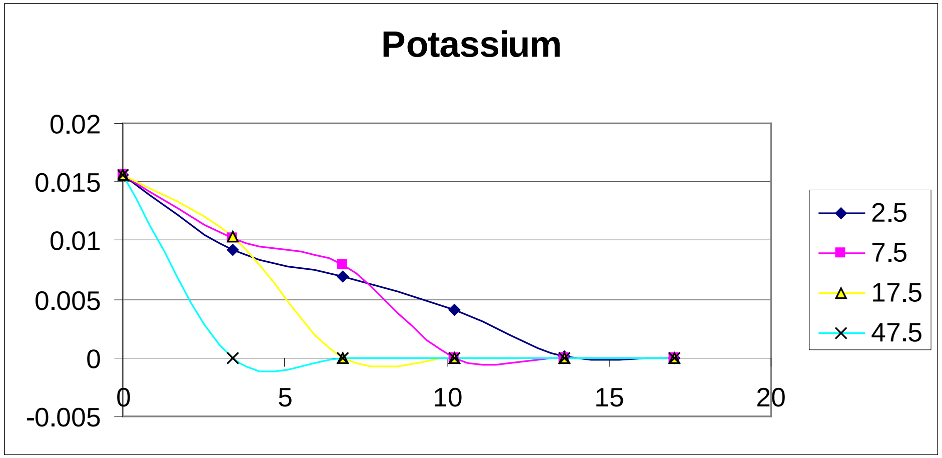


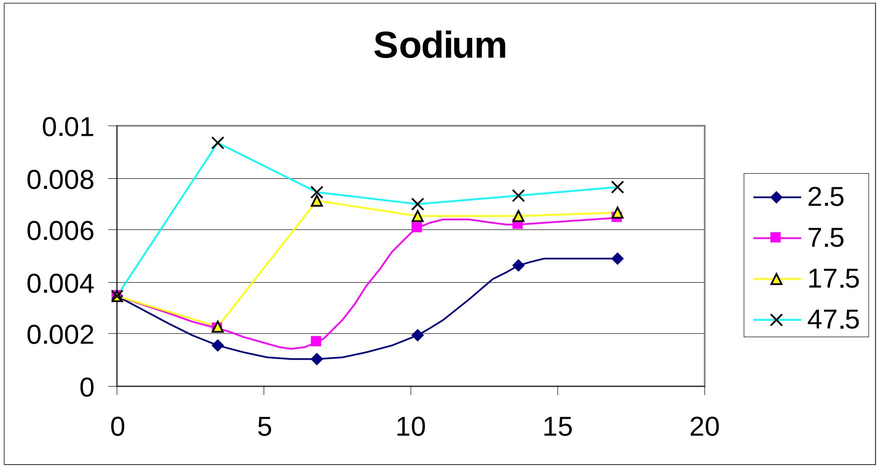




Current from elements in cells at distances from negative side in amps vs time in hours







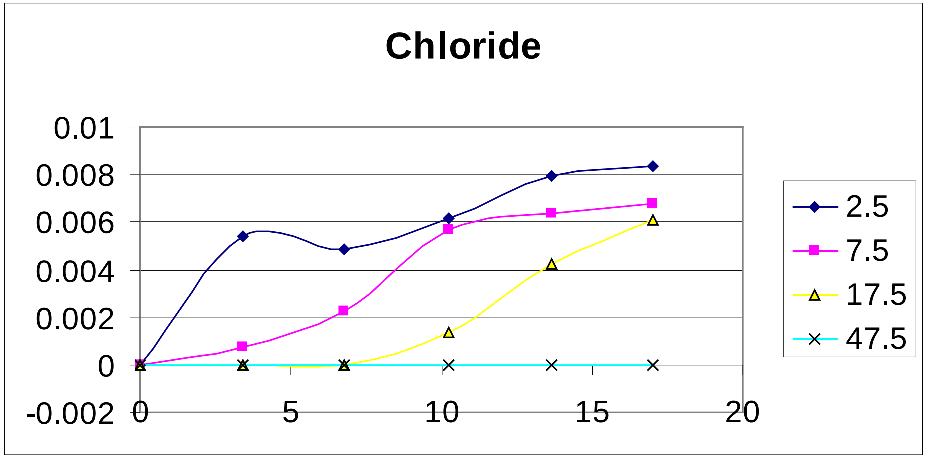


Figure 7 Predicted effect of chloride diffusion coefficient on current.

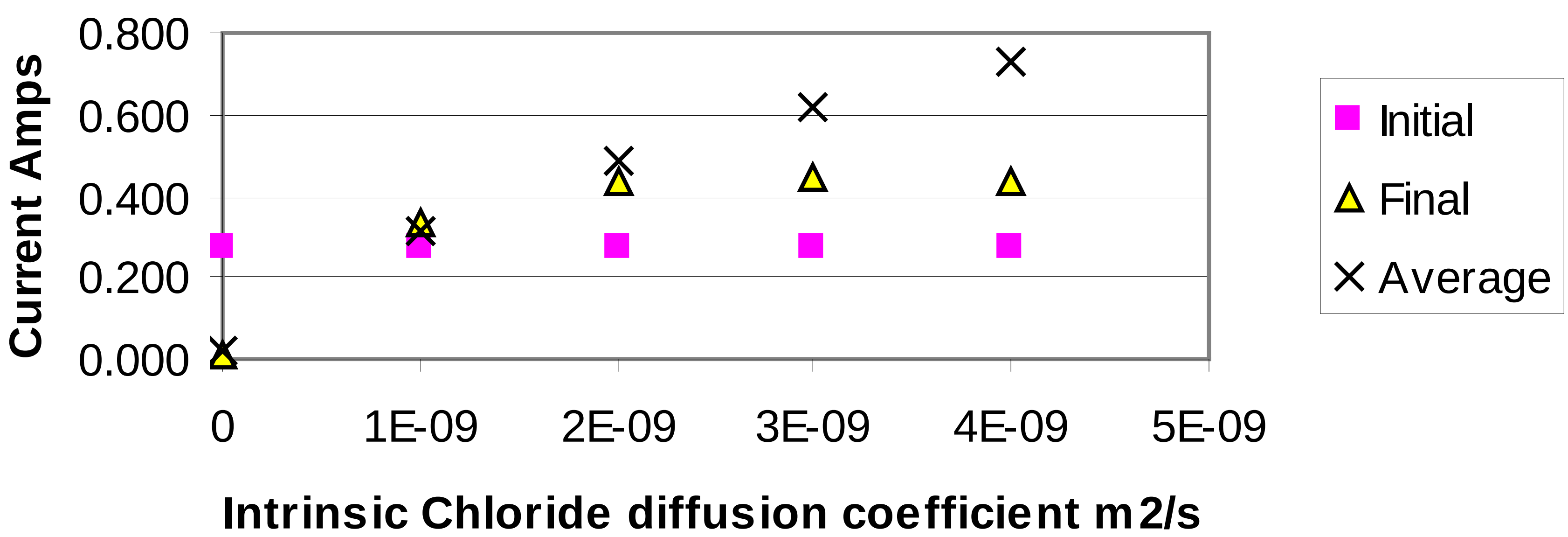
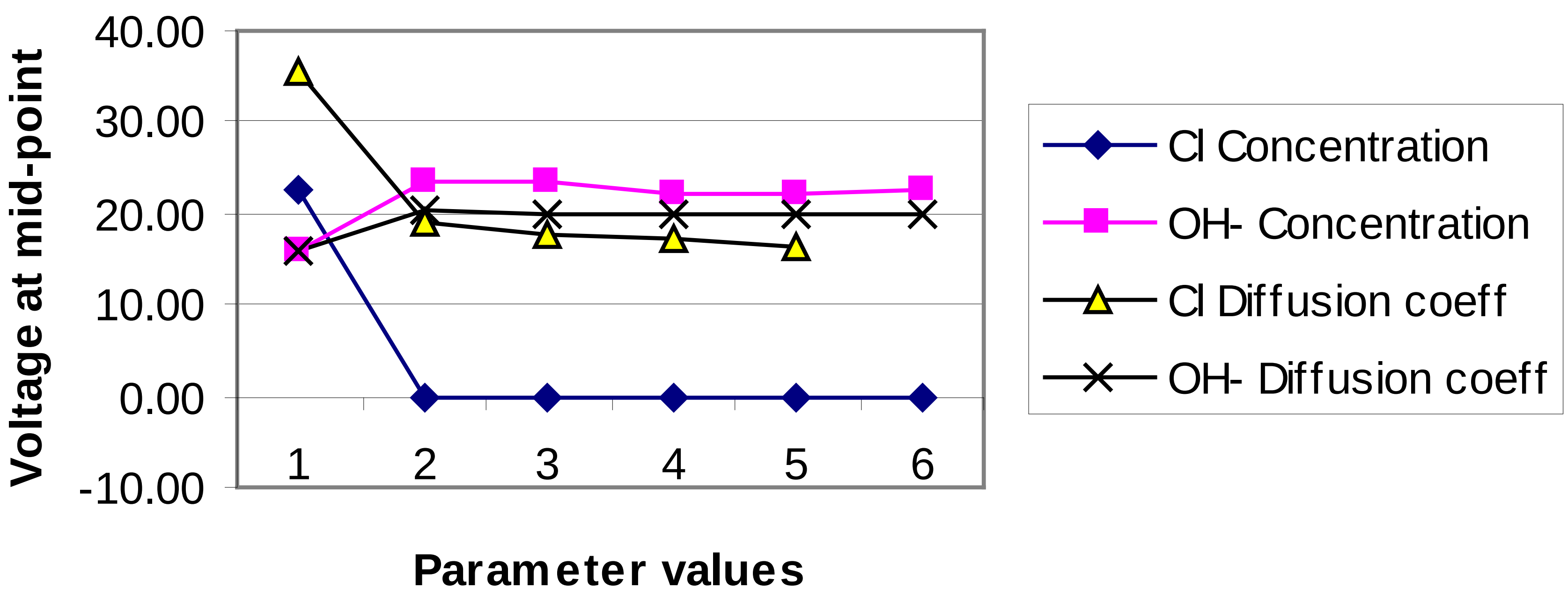


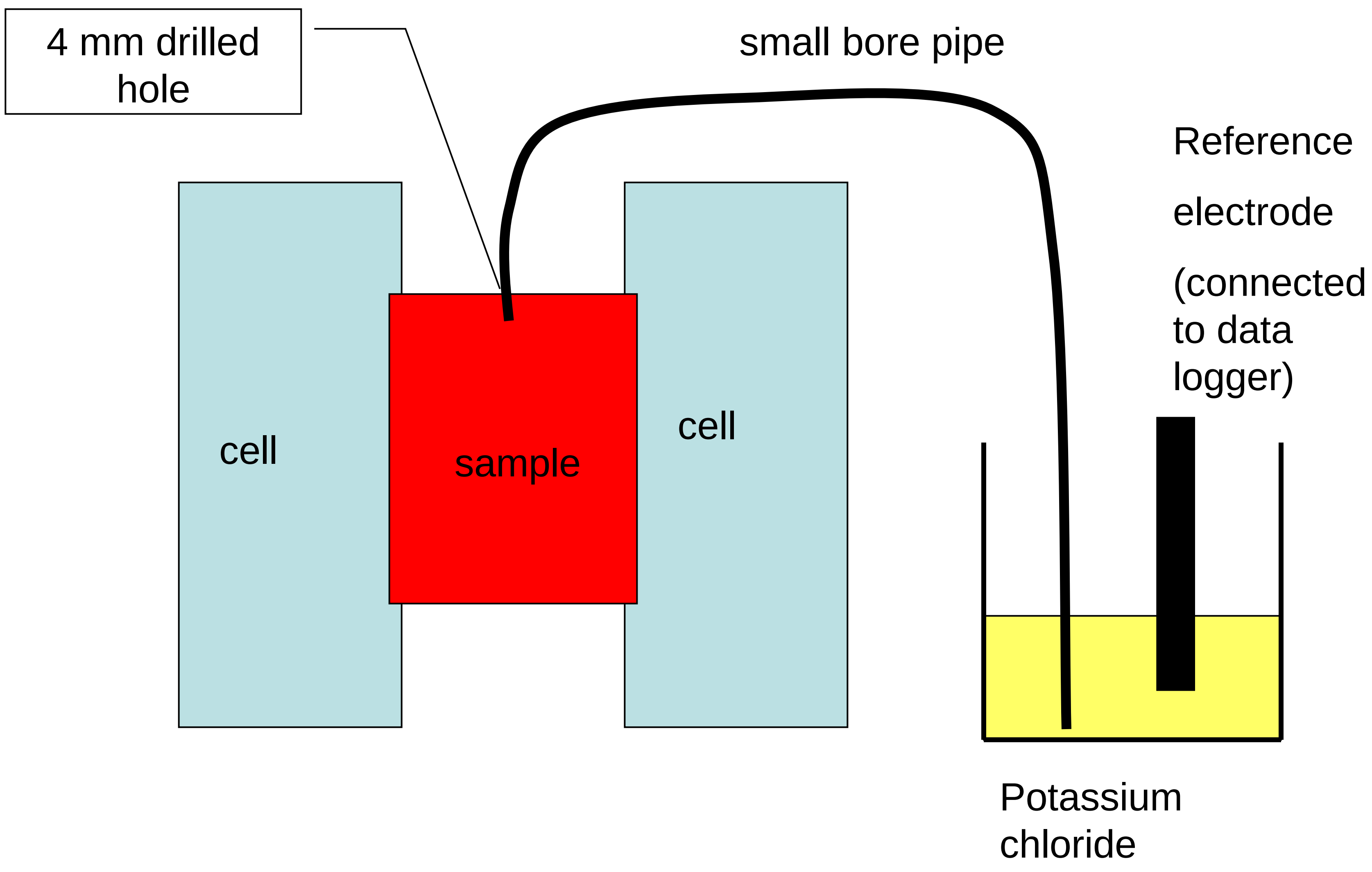
Figure 9. Predicted effect on mid-point voltage of varying different parameters.



How to get more from the test

- Measure the mid-point voltage
- Measure the initial and final current as well as the average
- Run for as long as possible
- Keep the reservoirs small so they get depleted.

Salt bridge measurements



Can you help?

I am looking for a research partner who has the resources to carry out the tests needed to develop this modelling method

Thank you

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