Zeta-potential (ζ)

Measurements employing Phase Analysis Light Scattering (PALS) and Streaming Potential

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BELBaR training course

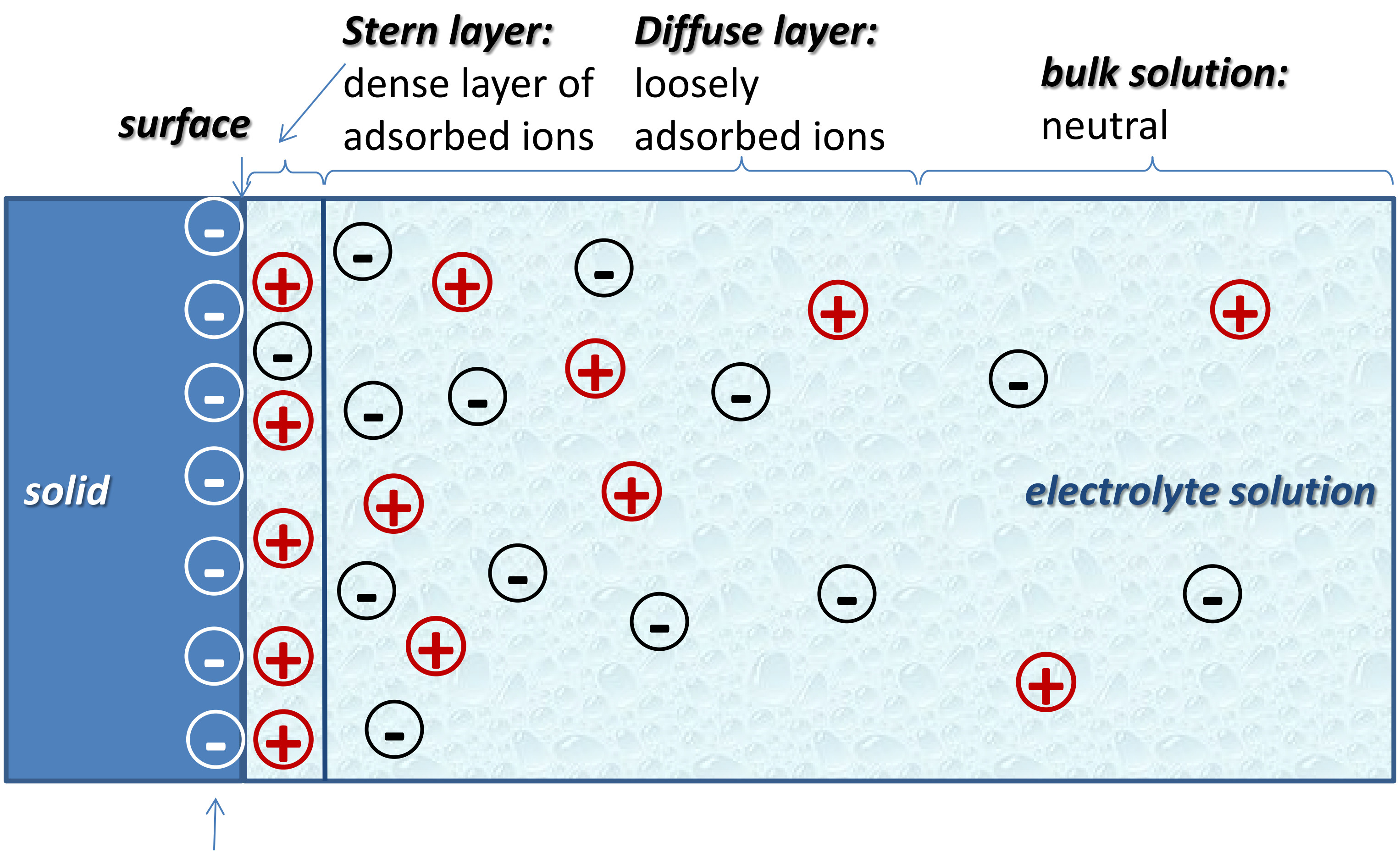
“Swelling clays: From compacted bentonite to clay colloids in the context of nuclear waste disposal”

Karlsruhe, Germany,
October 14-16th, 2015

Outline

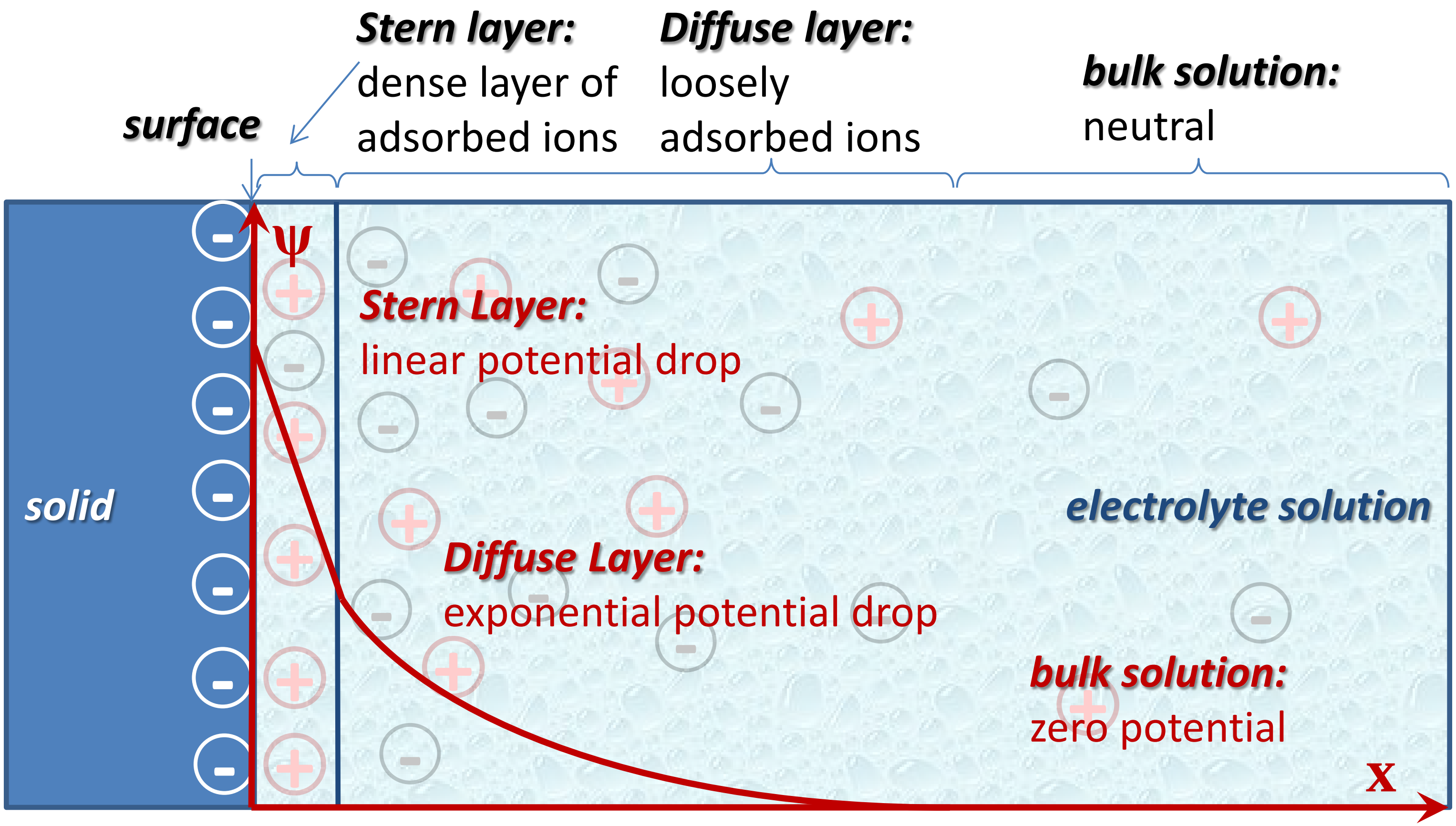
- What is the zeta-potential?
- Methods at KIT-INE:
  - Streaming potential measurements with the SurPASS electrokinetik analyzer
  - Phase analysis light scattering (PALS) using a Brookhaven Instruments PALS zeta-potential analyzer

Zeta-potential (ζ)

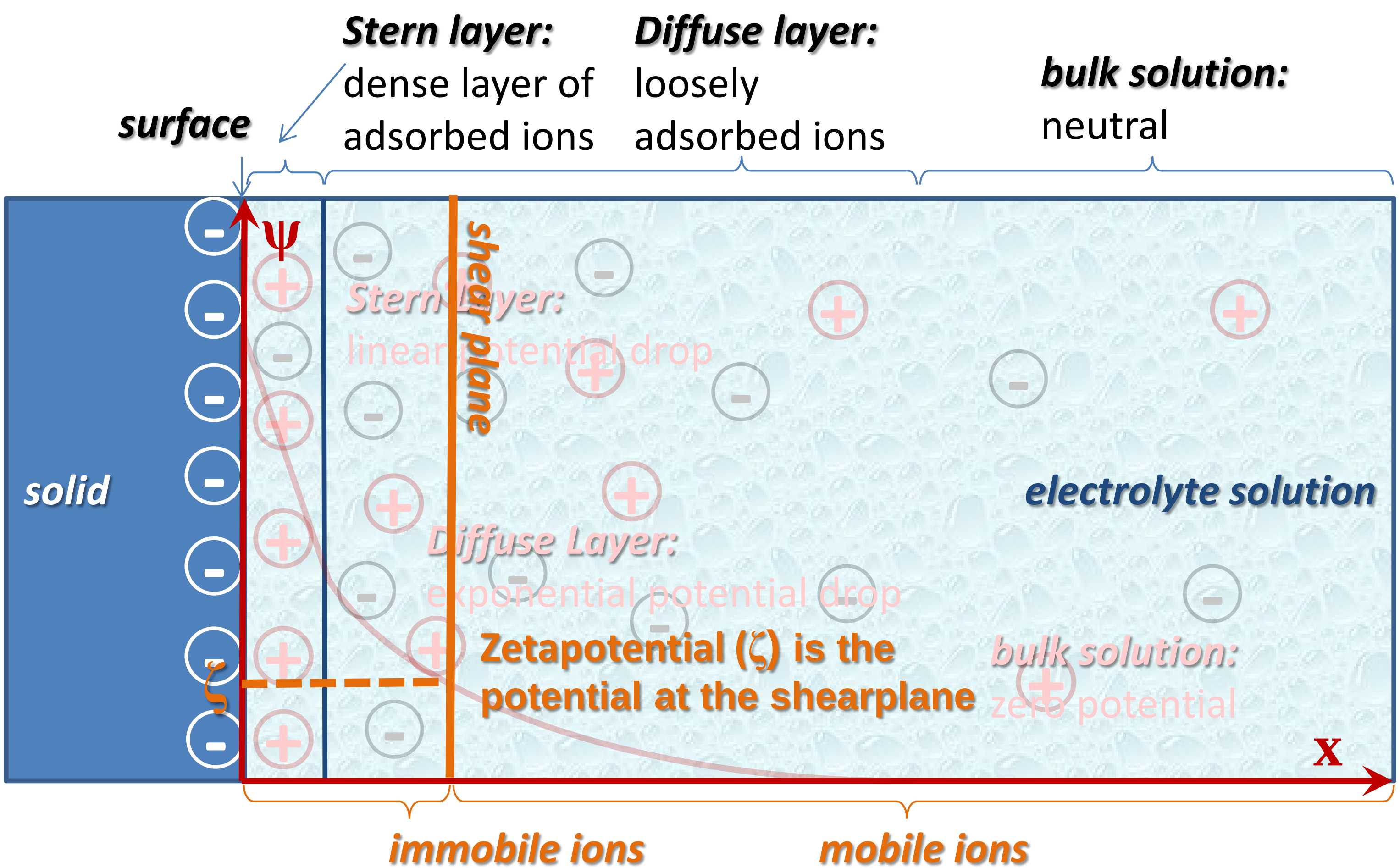


surface charge: (often „-“)
arises from
functional groups,
de-/protonation reactions
permanent layer charge…

Zeta-potential (ζ)



Zeta-potential (ζ)



Zetapotential is an electrokinetik property that appears due to a relative movement between solid and liquid.

Streaming potential

electrolyte solution is pumped through a sample cell containing the solid of interest

↓

pressure difference arises (Δp)

↓

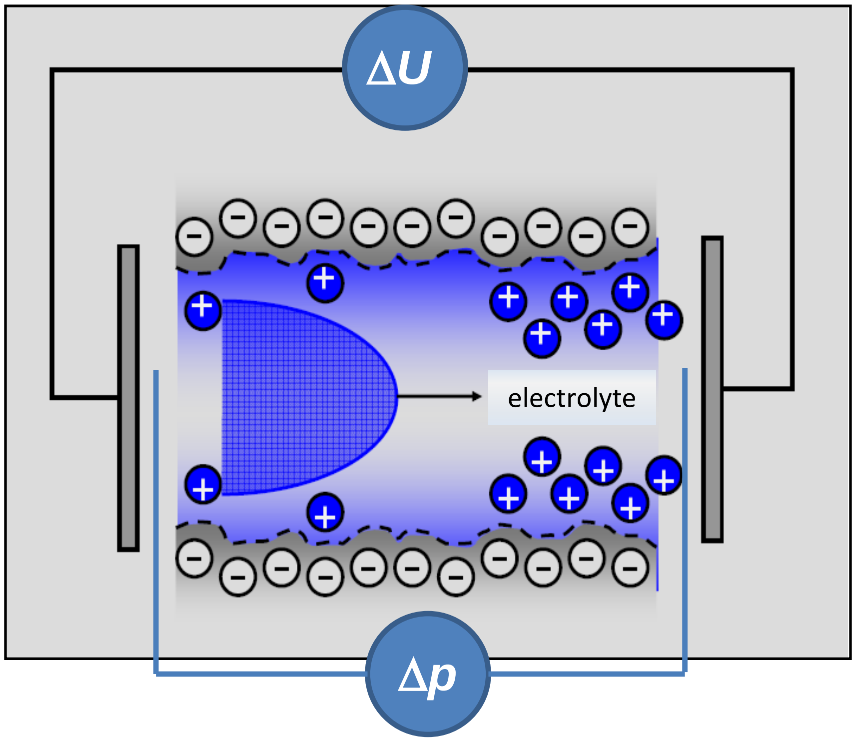
relative movement of charges in the electrical double layer generates a potential difference

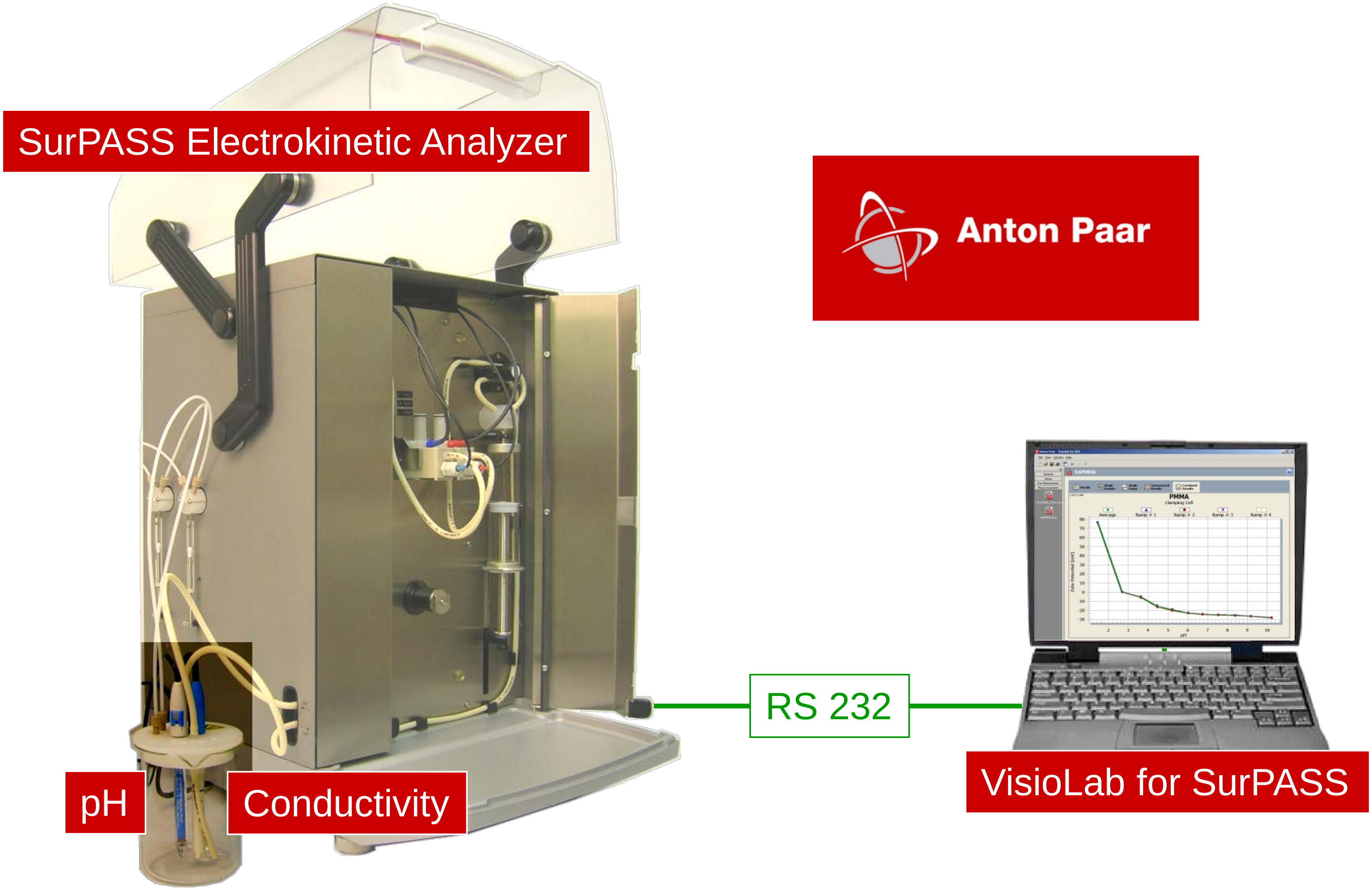
↓

this is called streaming potential $\Delta U = \Delta U(\Delta p)$

↓

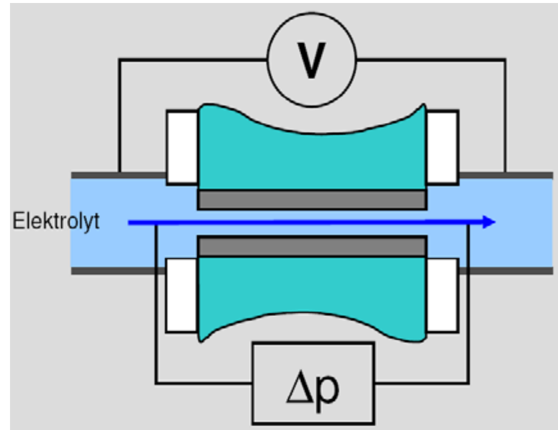
measurements are performed in a linear regime where $dU/dp = const.$ (called coupling coefficient)



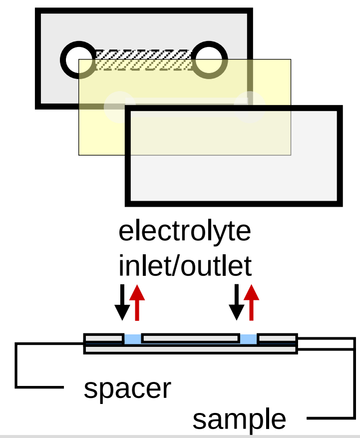

SurPASS Electrokinetic Analyzer
Anton Paar
RS 232
pH
Conductivity
VisioLab for SurPASS

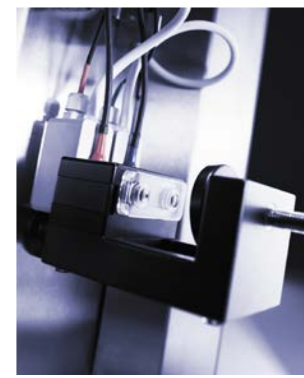
Several cells for various types of samples

- Adjustable-Gap-Cell:
  - rectangular, flat samples (20 mm x 10 mm)

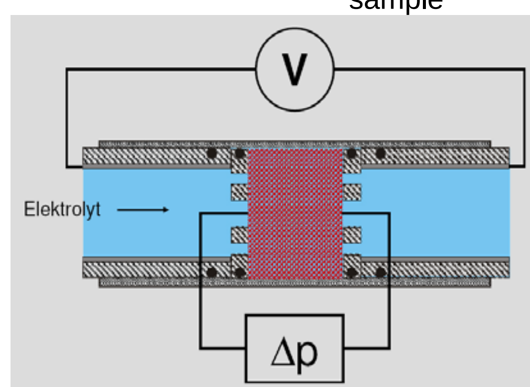


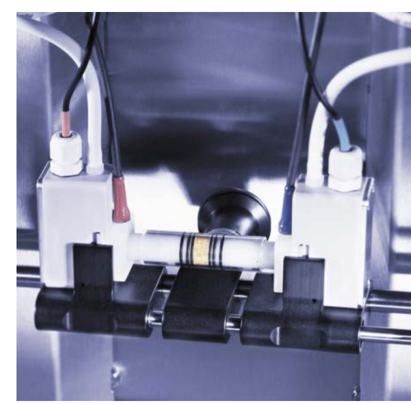
- Clamping-Cell:
  - planar samples (> 40 mm), measured against reference



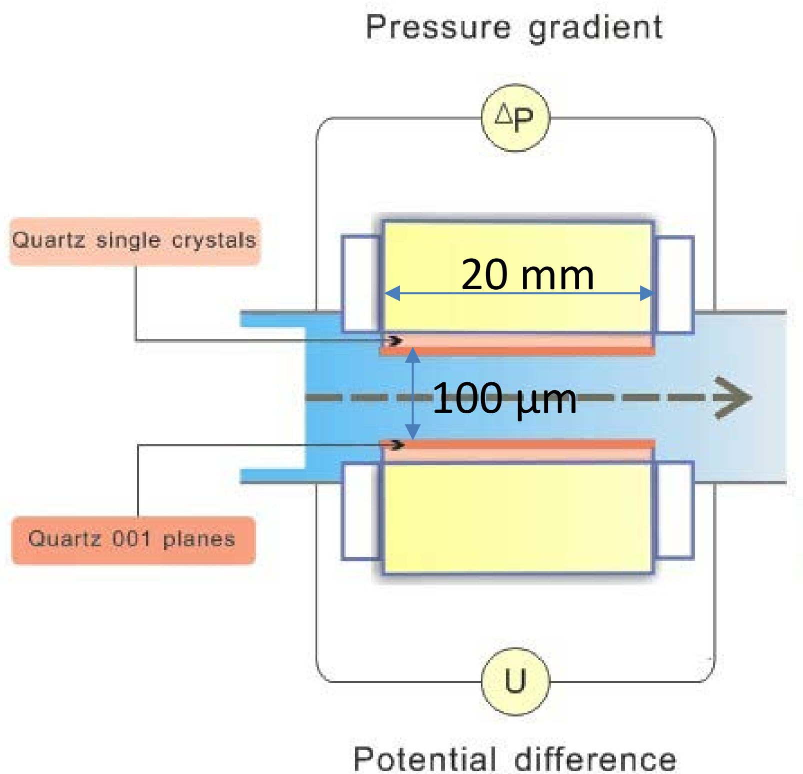


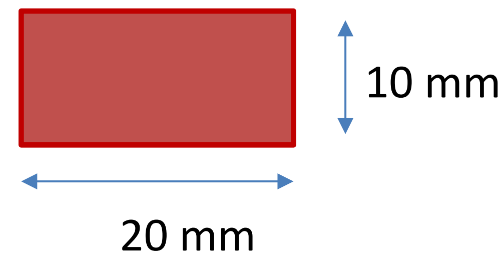
- Powder-Cell:
  - particles larger than 50 µm (not too large, i.e. < 1 mm)





Adjustable-Gap-Cell

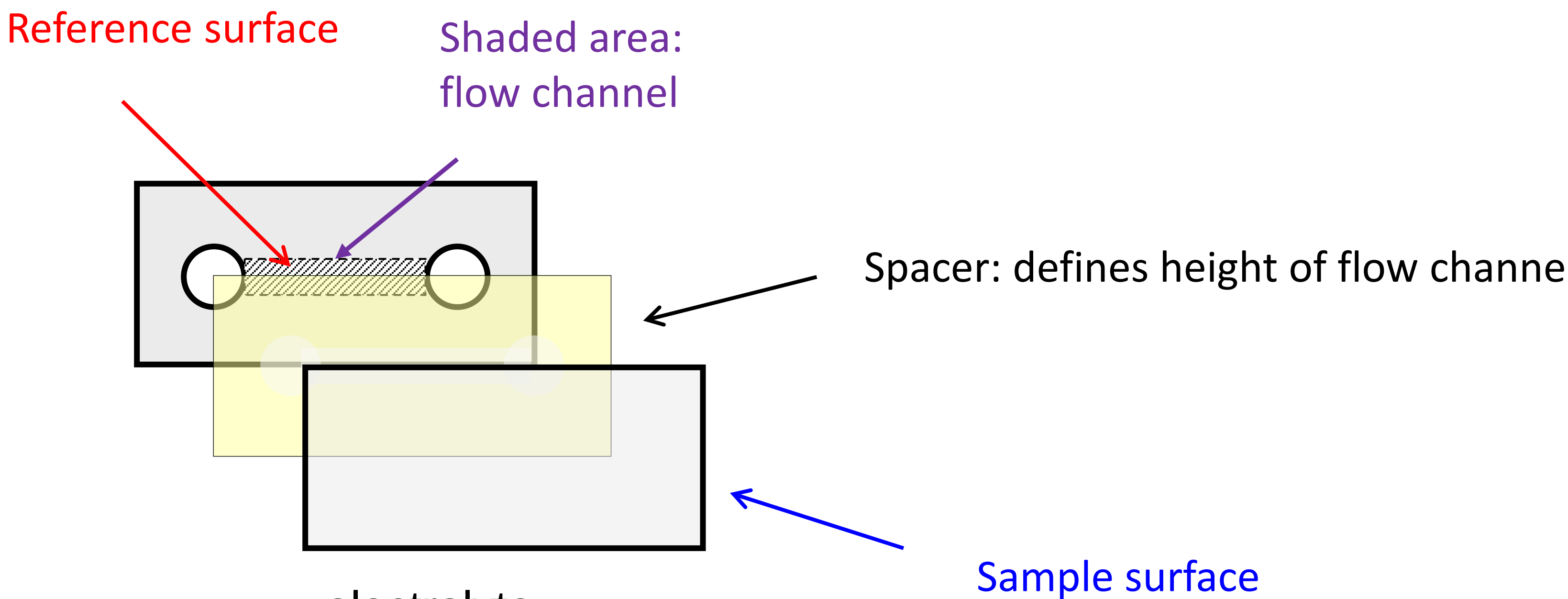


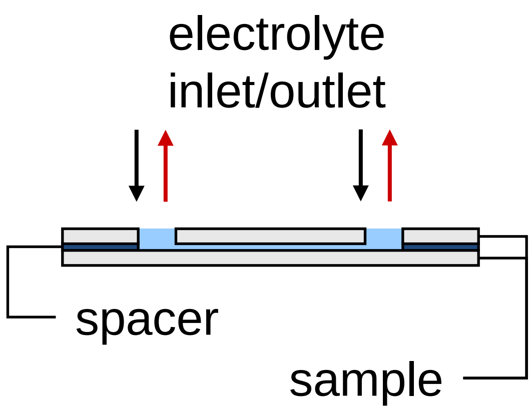


- Single crystal samples
- Any flat and smooth solid surface (suitable to be cut to a size of 20 mm x 10 mm x ~0.5 - 5 mm)

Clamping-cell

- Flat membranes
- Foils
- Polymer sheets
- Any rigid sample, thickness and shape don’t matter, with a flat surface (> ~ 40 mm x 10 mm)

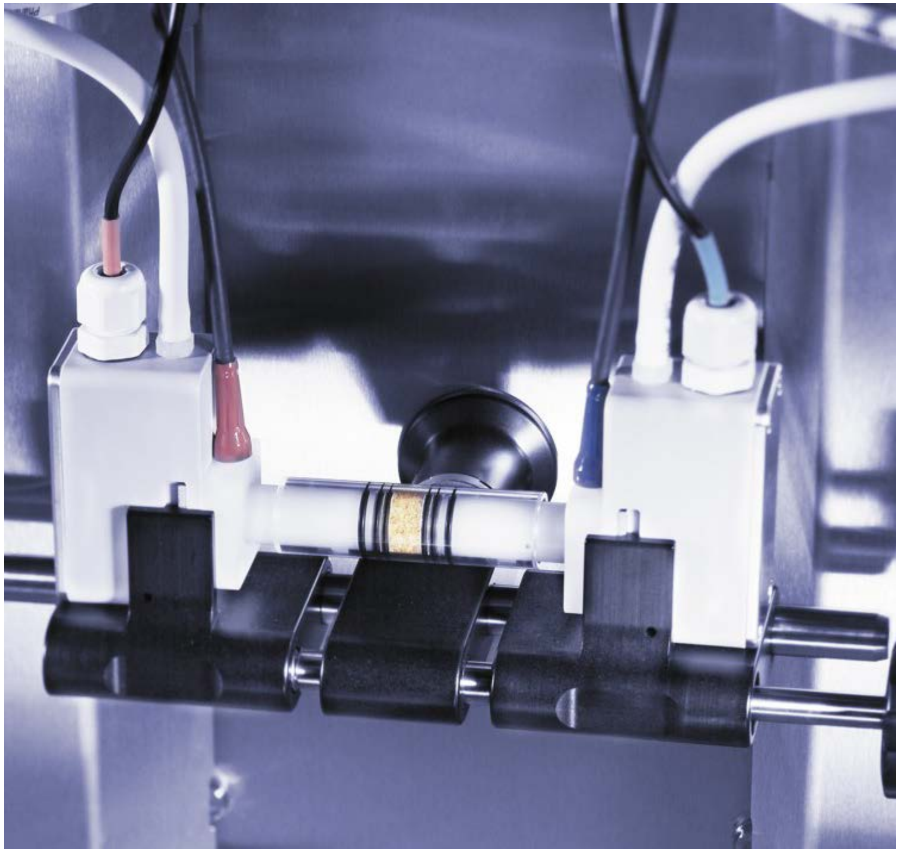




Reference sample must be measured!!

***Zeta-potential of the sample surface*:**

$$\zeta_{measured} \approx (\zeta_{reference} + \zeta_{sample})/2$$



Powder-cell

- Natural and technical fibres
- Hair
- Textile fibres and fabrics
- Powder samples with > 25 µm (rather 50 µm) size
- Particles and granular samples

Zeta-potential

length of sample

dynamic viscosity

$$\zeta = \frac{dU}{dp} \cdot \frac{\eta}{\varepsilon\varepsilon_0} \cdot \frac{L}{AR}$$

permittivity

permittivity of free space

cross section of flow channel

electrical resistance

Helmholtz-Smoluchowski equation:

Streaming potential
in a defined geometry

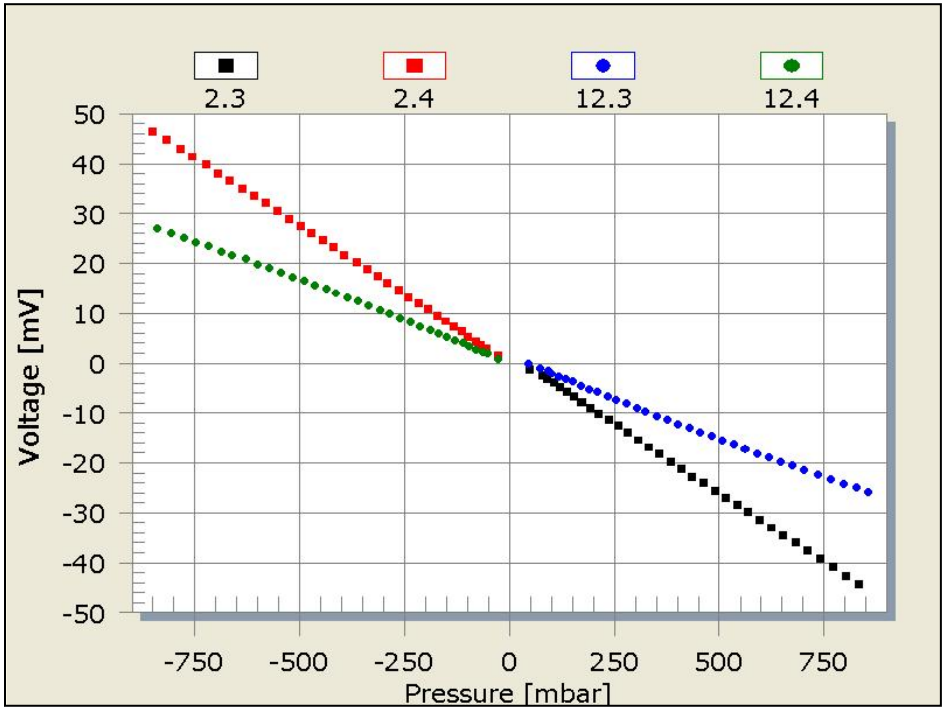
Adjustable Gap Cell
Clamping Cell

Fairbrother Mastin (IS > 1mM)
Streaming potential
for powder samples

Powder Cell

inverse Debye length

$$\kappa = \sqrt{\frac{2000 N_A e^2 I}{\epsilon\epsilon_0 k_B T}}$$

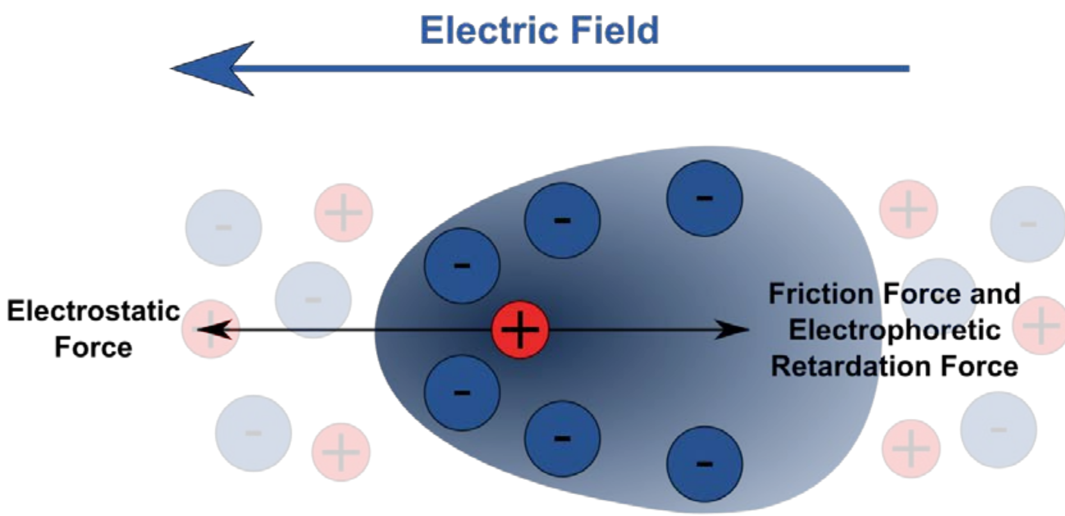


- Electrolyte flow from left $\rightarrow$ right
- Measurement of streaming potential at various differential pressure
- Reversal of flow direction
- Linear regression for evaluation of “pressure ramp” slope

$$\zeta = \frac{dU}{dp} \times \frac{\eta}{\varepsilon \times \varepsilon_0} \times \kappa$$

Phase Analysis Light Scattering (PALS)

In PALS the solution is stationary and the charged particles move in an electric field



electrophoretic mobility, u

Smoluchowski equation:

$$u = \frac{\epsilon \epsilon_0 \zeta}{\eta}$$

$[u]$ = $m^2/(Vs)$ = $m/s/(V/m)$

valid for:

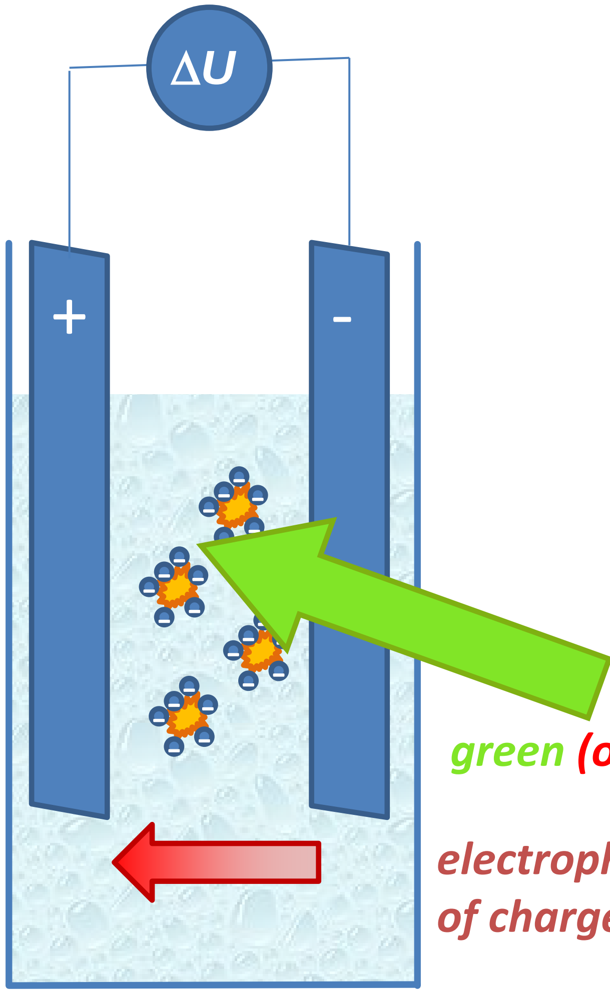
$\kappa a \gg 1$

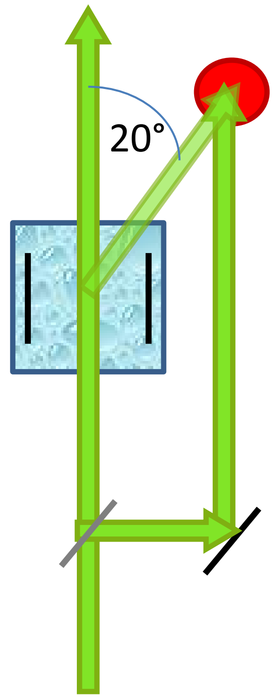
a: particle diameter (m)

$$\kappa = \sqrt{\frac{2000 N_A e^2 I}{\epsilon \epsilon_0 k_B T}}$$

Hückel approx. for $\kappa\alpha \approx 1$

Phase Analysis Light Scattering (PALS)





The electrophoretic mobility, u, is derived from phase shift measurements between laser light scattered by the moving particles at 20° and a direct laser beam.

Phase Analysis Light Scattering (PALS)

- We perform PALS on a Brookhaven Instruments PALS zeta-potential analyzer
- PALS measurments are best performed on particles that form a stable suspension
- Particle sizes are optimally < 1 µm (up to 5 or 10 µm may be possible)
- Measurements are best performed at a count rate of 1500.000 counts/s
  - The laser power is adjusted automatically
  - If this countrate is not achievable within the adjustable range of the laser power, the suspension concentration must be adjusted (> 1 ppm, < 1000 ppm) depends also on size and morphology

Possibilities to measure Zeta-potential at INE

- SurPASS electrokinetik analyzer
  - Adjustable-Gap-Cell: flat solid samples 20 mm x 10 mm
  - Clamping Cell: flat solid samples > 40 mm x 10 mm
  - Powder Cell: Coarse particle > 50 µm diameter

- Phase analysis light scattering (PALS)
  - Stable suspensions, particles ≤ 1 µm

- In general ionic strength should be ≤ 0.1 mol/L

Karlsruhe Institute of Technology

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…thanks for your attention!