BENG 186B: Principles of Bioinstrumentation Design

Lecture 9

Biopotential Electrodes

References

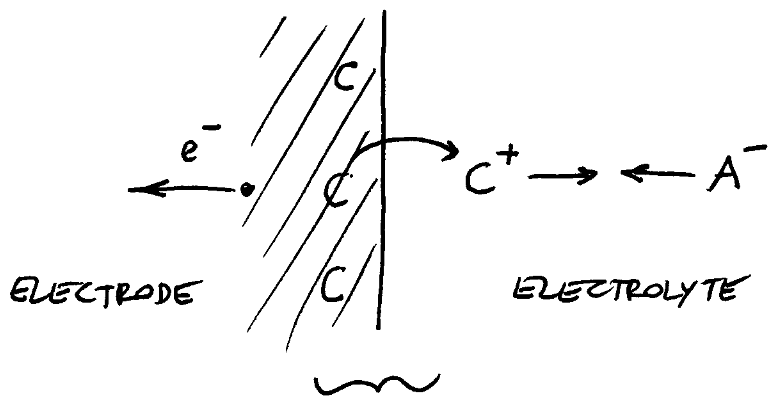
Webster, Ch. 5 (Sec. 5.1-5.5).
http://en.wikipedia.org/wiki/Standard_electrode_potential
http://en.wikipedia.org/wiki/Silver_chloride_electrode

BIOPOTENTIAL ELECTRODES

Webster, Chap. 5

Electrode: electrical conductor in electrical contact with biological tissue or chemical solution (electrolyte)

— Electrode - electrolyte interface: (Chap. 5.1)



C^+: CATION (pos. ion)

A^-: ANION (neg. ion)

metal atom C exits the lattice, leaving behind an electron in the electrode, and becoming a cation joining an anion in the electrolyte. This process is reversible!

→ Reduction – oxidation (REDOX) chemical reaction:

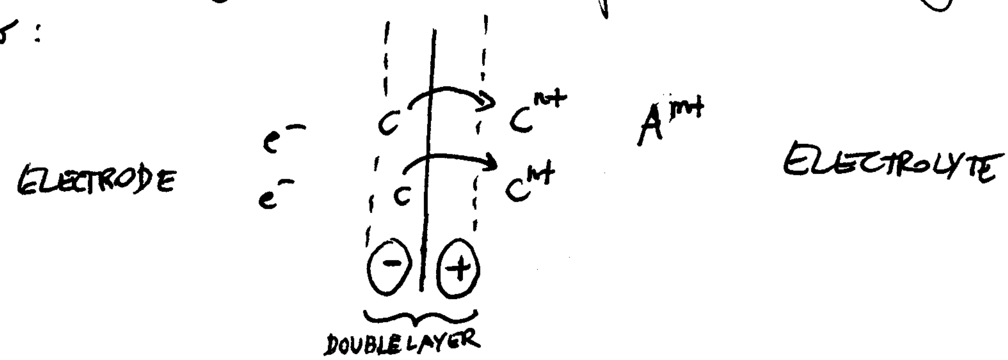
$$\begin{cases} C \underset{\text{red.}}{\overset{\text{ox.}}{\rightleftarrows}} C^{n+} + n\,e^- & (n\text{: valence of } C) \\ A^{m-} \underset{\text{red.}}{\overset{\text{ox.}}{\rightleftarrows}} A + m\,e^- & (m\text{: valence of } A) \end{cases}$$

Examples: C^{n+}: Cu^{++}, Ag^+, ... (metals)

A^{m-}: Cl^-, ...

— Polarization : (Chap. 5.2)

The exchange of charge (electrons and cations) at the electrode – electrolyte interface gives rise to a SPACE CHARGE at the interface, which gives rise to an EQUILIBRIUM POTENTIAL across the interface. This potential changes with current flowing across the interface, and could pose a barrier for current to flow:



Polarization potential (or total potential) of the electrode:

$$V_p = V_{electrode} - V_{electrolyte}$$
$$= E^0 + V_r + V_c + V_a$$

- E^0 : HALF-CELL POTENTIAL : function of electrode material (relative to $H_2 \rightleftharpoons 2H^+ + 2e^-$ reference $\overset{def.}{=} 0\,V$)
- V_r : OHMIC OVERPOTENTIAL : resistance of electrolyte (nonlinear in current)
- V_c : CONCENTRATION OVERPOTENTIAL $= \frac{RT}{nF} \ln(a_{C^{n+}})$
  n : valence of C^{n+}
  $a_{C^{n+}}$: "activity" of C^{n+}, increases with $[C^{n+}]$ but not the same!
- V_a : ACTIVITY OVERPOTENTIAL : due to activation energy barrier

- Polarizable electrode: ACTIVATION OVERPOTENTIAL V_a = LARGE
  - → no charge can flow (or flows only with much effort)
  - → good high-impedance voltage measurements only
- Non-polarizable electrode: V_a = SMALL and does not depend on the direction of current
  - → can easily take current in both directions
  - → good for both voltage and current measurements

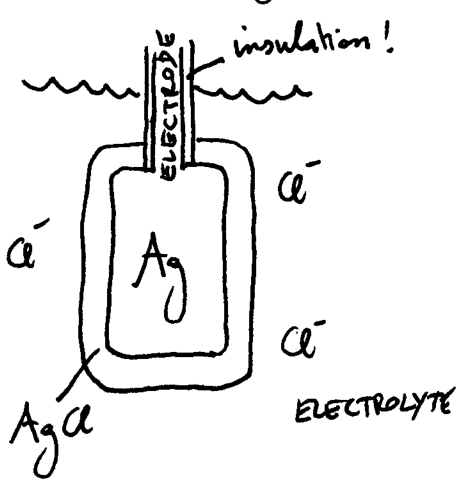
    PREFERRED for bioinstrumentation

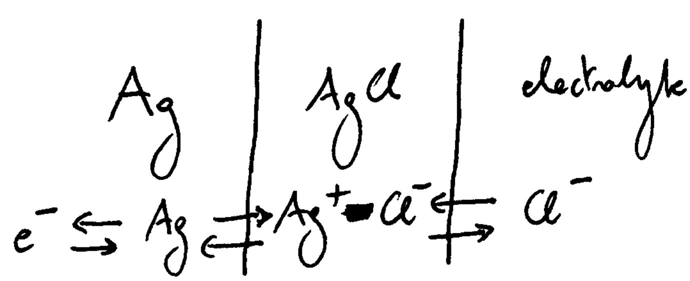
  Example: Ag/AgCl electrode

— Ag/AgCl electrode: (Chap. 5.3)

(SILVER / SILVER CHLORIDE)

Deposition of (non-soluble) AgCl on Ag makes a very good non-polarizable electrode for any biological tissue or biological electrolyte with Cl^- (almost all!)





$$Ag \rightleftharpoons Ag^+ + e^-$$

$$Ag^+ + Cl^- \rightleftharpoons AgCl \downarrow$$

deposits (non-soluble)

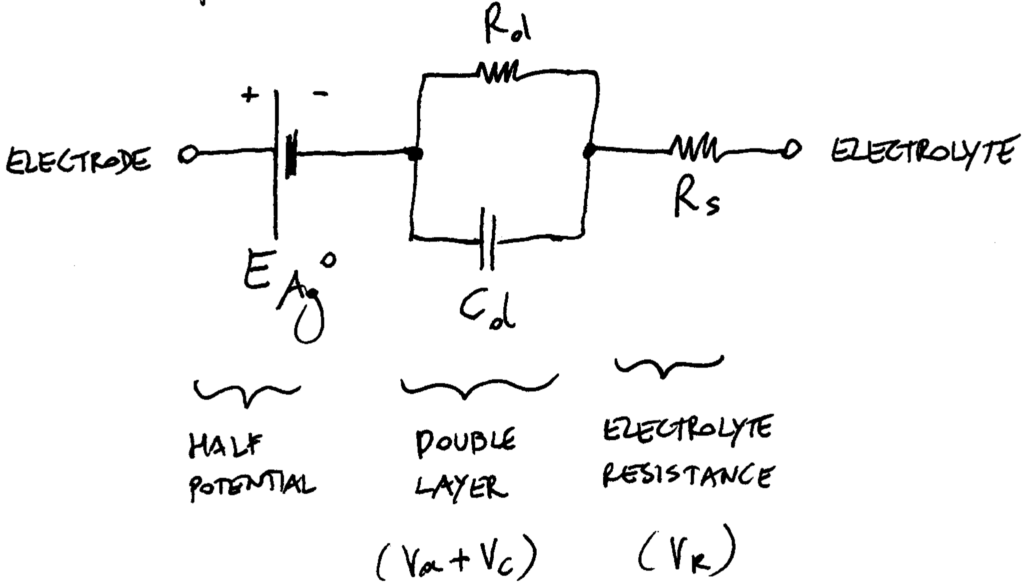
BUFFER!

$$a_{Ag^+} \cdot a_{Cl^-} = K_s \approx 10^{-10}$$

$$\Downarrow$$

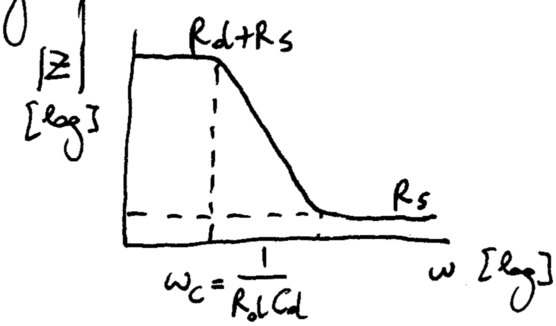
$$E \approx E^\circ_{Ag} + \frac{RT}{F} \ln \frac{K_s}{a_{Cl^-}}$$

- Electrode circuit model for Ag/AgCl or other non-polarizable electrodes:



$\Rightarrow$ DC: E_{Ag}^0 half-potential and $R_d + R_s$ resistance

AC: $Z(j\omega)$:



<u>NOTE</u>: For differential biopotential measurement between two IDENTICAL electrodes, the half potentials cancel (GOOD!) and the net impedance is twice the electrode impedance $Z(j\omega)$.

- Electrode-skin interface is also important!

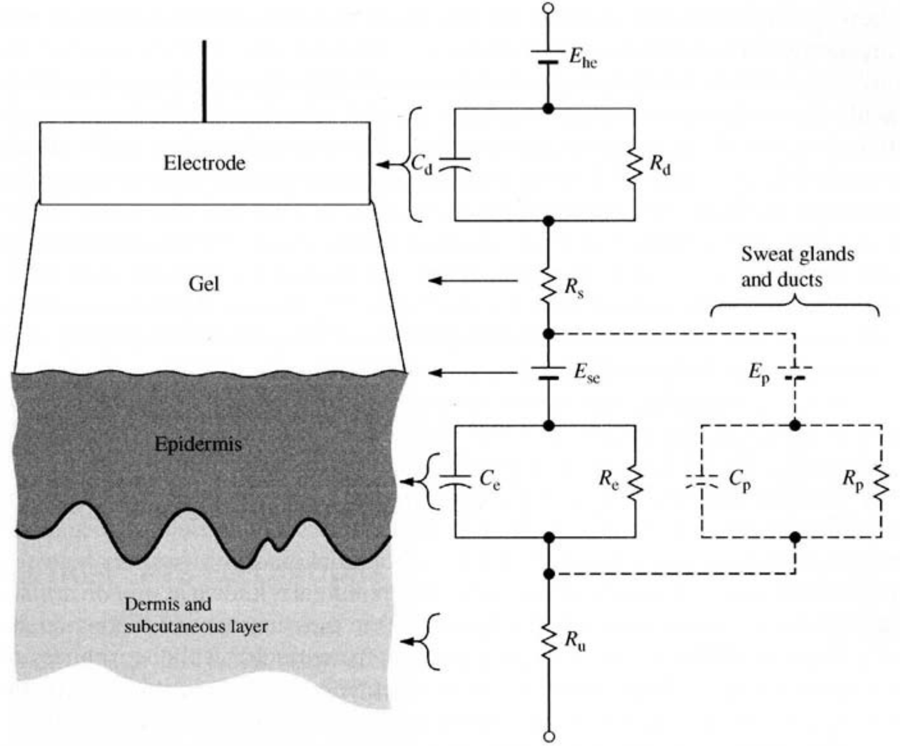


Figure 5.8 A body-surface electrode is placed against skin, showing the total electrical equivalent circuit obtained in this situation. Each circuit element on the right is at approximately the same level at which the physical process that it represents would be in the left-hand diagram.