BIOELECTRIC POTENTIALS-1

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BIOELECTRICITY

- Electrical conduction is executed via
  - electrons in metals
  - ions in aqueous solutions (and in living organisms)
- Ion including solutions are called ***electrolyte solutions.***
- There are two types of electrolytes:
  - Anions (- charged ions)
  - Cations (+ charged ions)
  - the primary ions of electrolytes (in physiology) are Na^{+}, K^{+}, Ca^{2+}, Mg^{2+}, Cl^{-}, HPO_4^{2-}, HCO_3^{-} etc.

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- The chemical composition of cells is different from the chemical content of the extracellular fluid.
- The underlying reason is that;
  - *Cell membranes* which encircle, and isolate the cell from the interstitial fluid.
  - *Active transport processes* in the cell membranes enable different matter concentrations in opposite sites of the membrane

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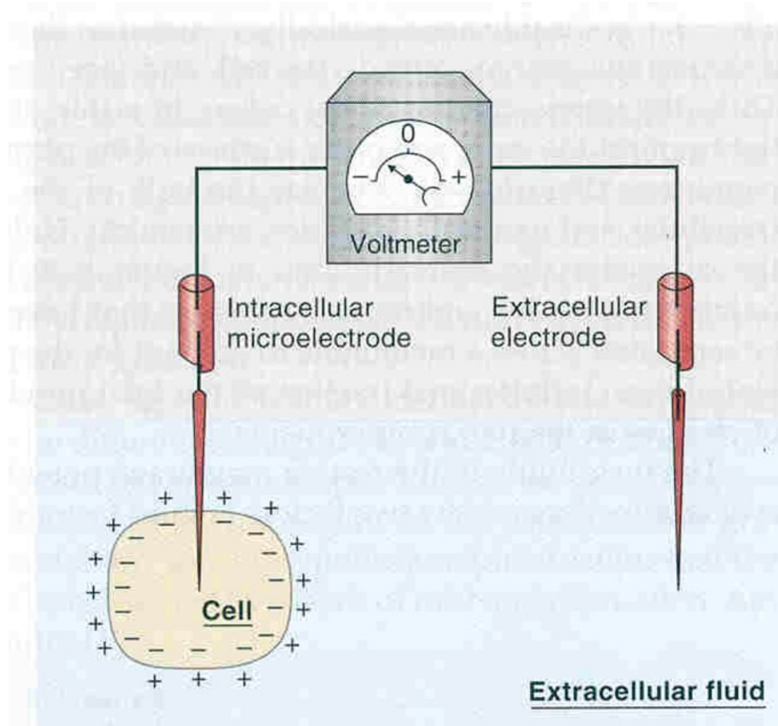
- The unequal distribution of oppositely charged ions inside and outside of the cell membrane creates a ***potential difference***.
  - Nerve and muscle cells; -65/-80/-100 mV
  - epithelial cells; -20/-40 mV
  - erythrocyte; -4 mV



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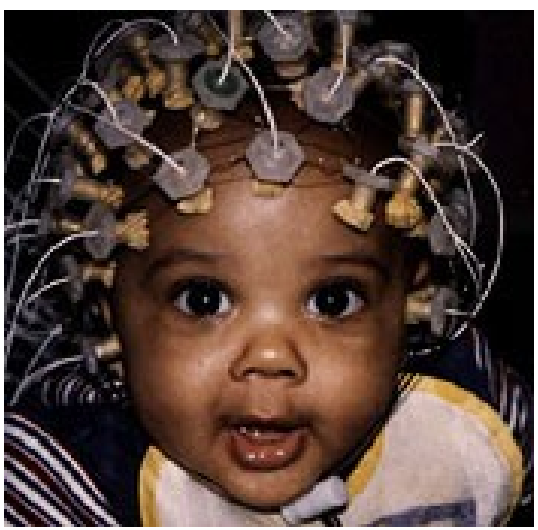
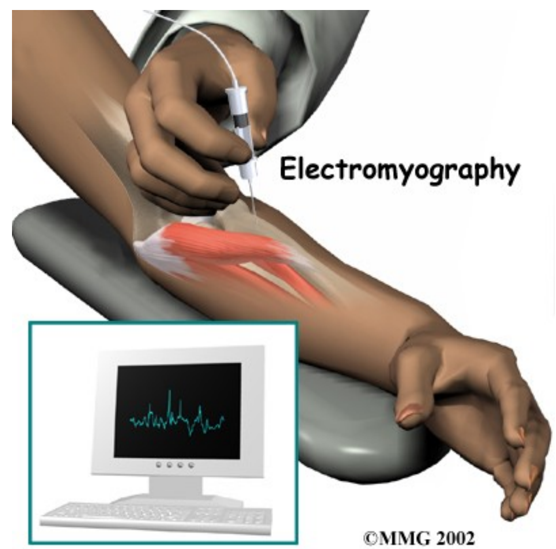
- All living cells have negative intracellular potential.
- The excitable cells are able to communicate electrically with other cells by modulating this potential difference;
  - Neurons
  - Muscle cells





Osmolarity

- **Osmotic concentration** also known as **osmolarity** is the measure of solute concentration, defined as the number of osmoles (Osm) of solute per liter (L) of solution.
- The osmolarity of a solution is usually expressed as **Osm/L** (pronounced "osmolar").
- The sum of solute moles in a solution gives the osmotic concentration.

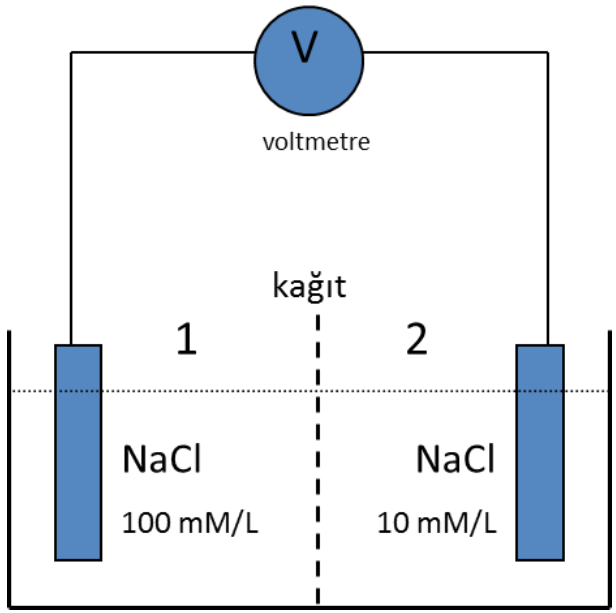
$$CaCl_2 \longrightarrow Ca^{+} + 2Cl^{-}$$

Osmotic concentration of 1 mole $CaCl_2$= 3 Osm/L

Electrical events in electrolyte solutions seperated by

- » **permeable,**
- » **semi-permeable and**
- » **selectively permeable barriers**

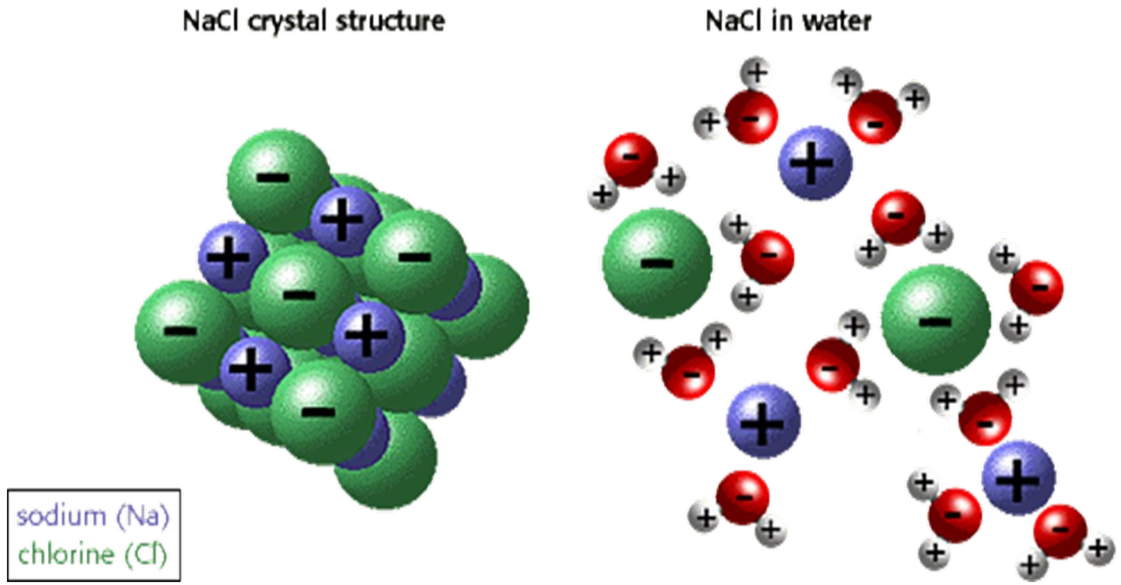
Electrical events in electrolyte solutions seperated by ***permeable barriers***

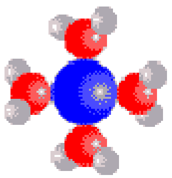


- A piece of paper is placed between two solutions, which have different concentrations, to avoid rapid mixture of solutions.
- Paper is permeable for both water and Na^{+} and Cl^{-} ions.
- Na^{+} and Cl^{-} ions will diffuse from chamber-1 to chamber-2.

Diffusion rates of ions

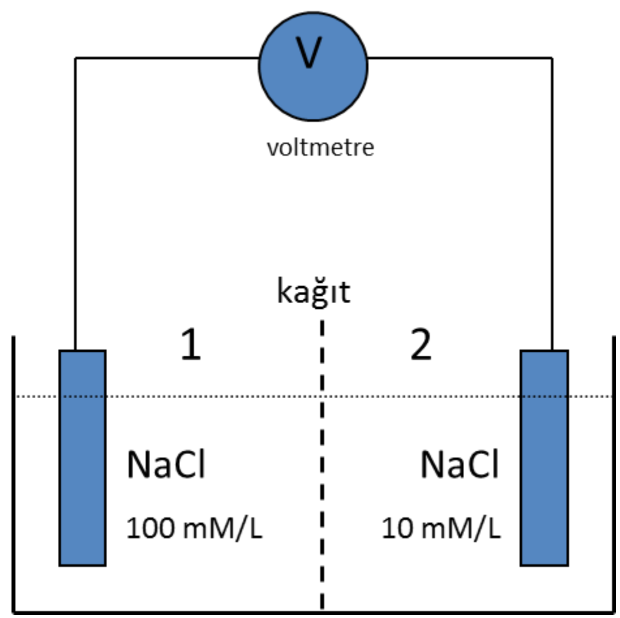
- Cl ions are more mobile than Na ions although they have larger atoms.
- Because of the ion-dipole interaction, Na ions hydrated by dipole water molecules and as a result they will gain larger size than Cl ions. Thats why they have lower mobility.





Diffusion Potential

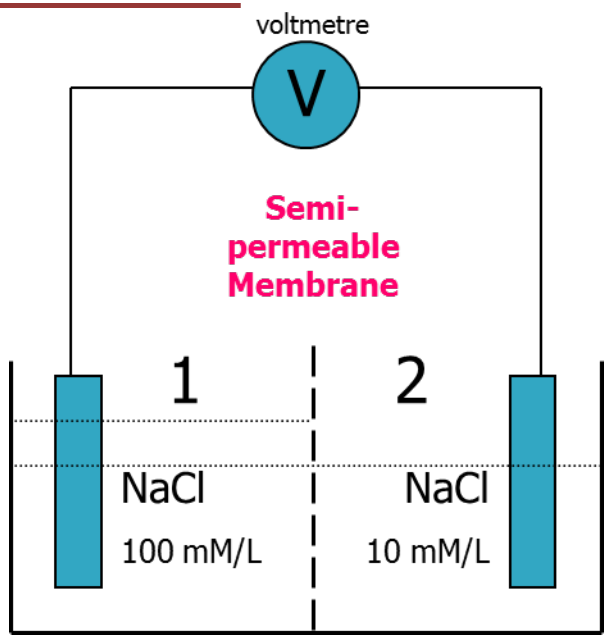
- Cl^- ions pass permeable barrier and arrive chamber-2 faster than Na^+ ions.
- A potential difference occurs between two chambers.
- Increasing negativity in chamber-2 slows down the passage of negative Cl ions and finally stops.
- Meanwhile, Na^+ ions will reach chamber-2.
- The potential difference between the two sides will be lost when the concentrations of both ions are equalized in both chambers.
- The *temporary potential difference* induced by different diffusion rates of ions is called **diffusion potential**.



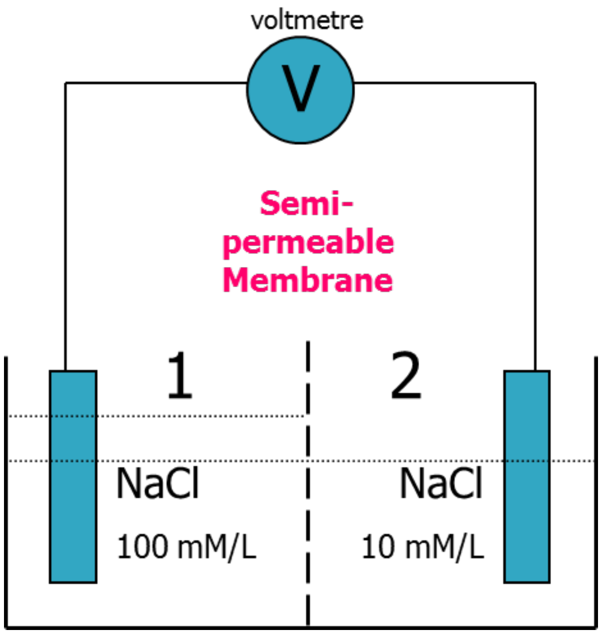
Diffusion rates of ions

- K^+ ions are more active than Na^+ ions, although they are larger.
  - The smaller the diameter of ion-A, the closer the negative ion-B to the positively charged nucleus of ion-A.
  - Because of the strong electrical attraction between them, a large number of ion –B clamp tightly to the ion_A.
  - Because the Na^+ ion has smaller diameter than K^+ ion, dipole water molecules clamp tightly to Na^+ ion and eventually make them larger ions compared to K^+. This is why the K^+ ions more mobile than Na^+

Electrical events in electrolyte solutions seperated by *<u>semi-permeable barriers</u>*

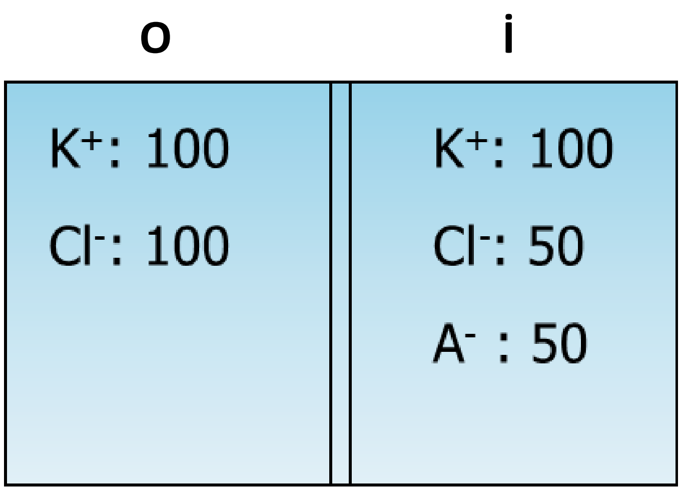


- A semi-permeable membrane, which is permeable to water but impermeable to ions, is placed between two solutions that have different concentrations.
- There wouldn't be any ion transmission between compartments.
- However, due to the difference in osmotic concentration , water passes from compartment-1 to compartment-2.

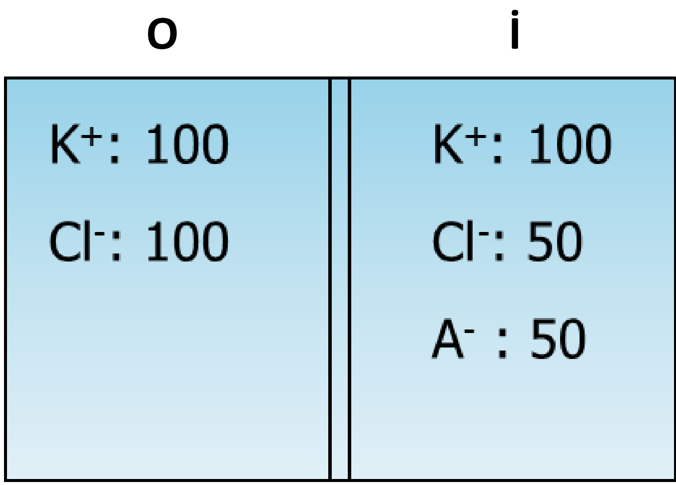


- Because of the water transmission to the compartment-1, hydrostatic pressure will increase in this compartment.
- Water transmission will stop when the hydrastatic pressure becomes equal to the osmotik pressure.
- Potential difference does not occur between compartments.

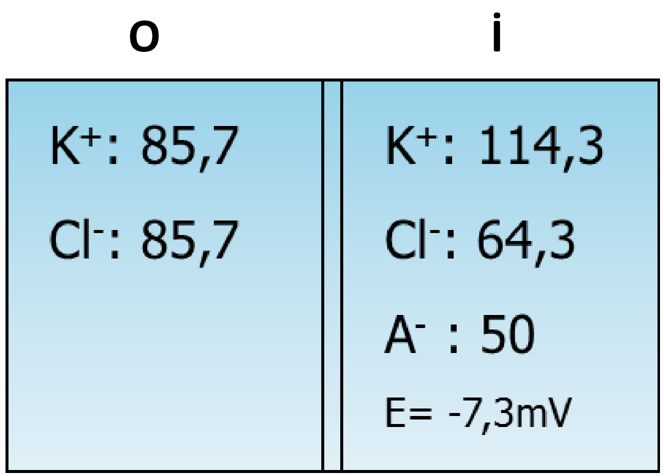
Electrical events in electrolyte solutions seperated by ***selectively-permeable barriers***



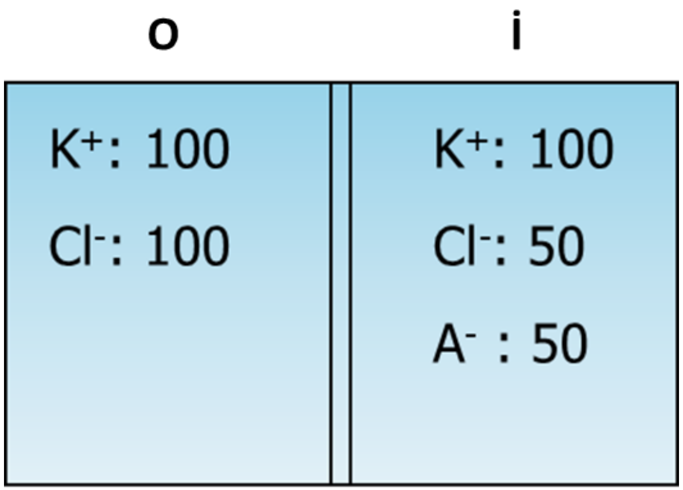
- Consider that there is a selectively permeable membrane between compartments 'o' and 'i'.
- The membrane is permeable to water and K^+, Cl^- ions, but impermeable to A^- (large organic anion).
- Concentrations are given in mM/l units.
- Both compartments are electrically neutral and their osmotic concentrations are equal at the beginning.



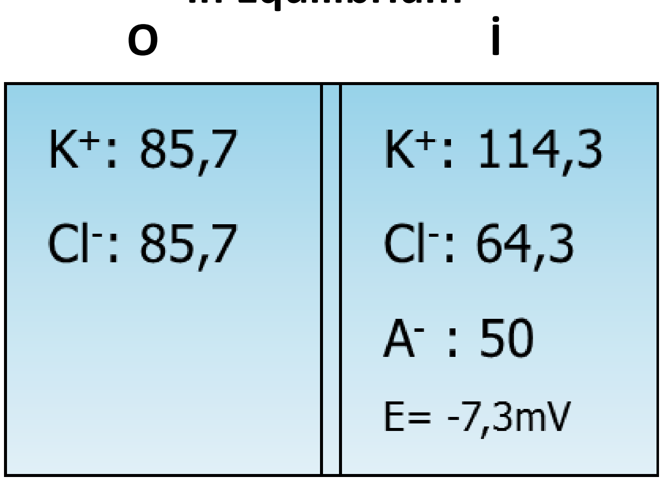
- Cl^- ions pass from ‘o’ to ‘i’ side under the influence of a concentration gradient.
- And a potential difference occurs.
- Although, K^- ions have initially equal concentrations in both compartments, under the influence of this potential difference, they pass from ‘o’ to ‘i’ side as Cl^- ions.
- The increasing K^+ gradient resists the passage of K^+ ions from ‘o’ to ‘i’.
- To avoid impairment of neutrality in ‘o’ side Cl^- passage stops.



- In equilibrium, electrical neutrality is maintained in both sides. However, there is an osmotic concentration difference between two sides.
- Because of this, a small amount of water passes from ‘o’ to ‘i’ side.
- If ‘i’ is an enclosed volume, then the osmotic pressure will increase in here.
- Adding an impermeable ion to the ‘o’ side will enable osmotic concentration which prevents pressure increase in ‘i’.
- Na^+ ions in the extracellular fluid perform this task in resting potential.

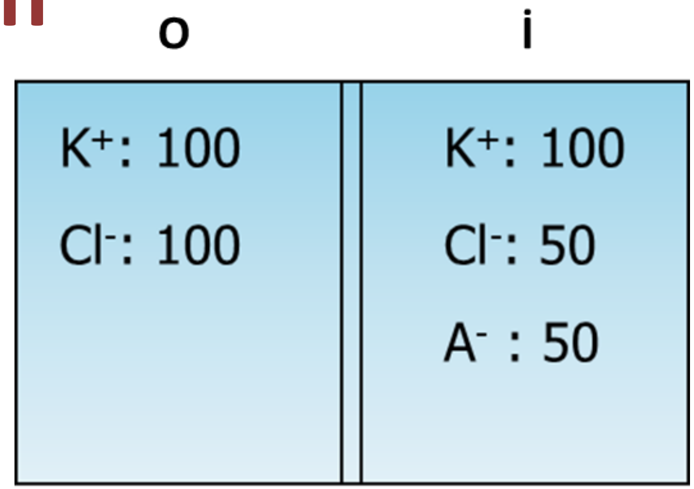


In Equilibrium



- Another important feature of the distribution of ions in equilibrium is that, the compartment ‘i’ has gained a negative potential compared to ‘o’ side.
- The potential difference between these two compartments prevents passage of K+ ions to the ‘o’ side and Cl- ions to the ‘i’ side.

Gibbs-Donnan Equilibrium



$K_o/K_i = Cl_i/Cl_o$

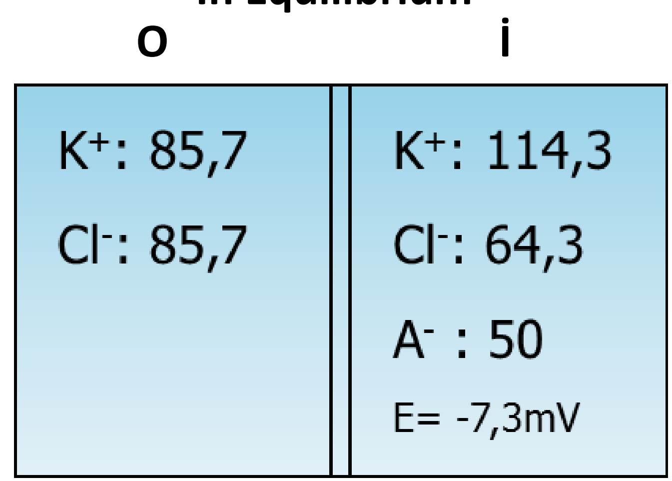
or

$K_o \times Cl_o = K_i \times Cl_i$

$85{,}7 \times 85{,}7 = 114{,}3 \times 64{,}3$

Gibbs-Donnan Equilibrium

In Equilibrium



Nernst Equation

$$E_k = \frac{RT}{zF} \ln\left(\frac{K_d}{K_i}\right)$$

By the help of Nernst Equation, it is possible to calculate the equlibrium potential based on the ion concentrations inside and outside of the cell