PHYSIOLOGY

النادي الطبي

Lec: 11+12 (Thursday 21/3)

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The scientists name

Equilibrium potential (Nerst potential)

- The concept of is simply an extension of the concept of diffusion potential. If there is a concentration difference for an ion across a membrane and the membrane is permeable to that ion, a potential difference (the diffusion potential) is created. Eventually, net diffusion of the ion slows and then stops because of that potential difference
- **Equilibrium potential** is the diffusion potential that <u>exactly balances</u> (*opposes*) the tendency for diffusion caused by a concentration difference. At electrochemical equilibrium, the chemical and electrical driving forces that act on an ion are equal and opposite; therefore, no net diffusion of the ions occur.
- **Nerst Potential** The potential across the cell membrane that exactly opposes net diffusion of a particular ion through the membrane= the membrane potential at which there is no net (overall) flow of that particular ion from one side of the membrane to the other
- At electrochemical equilibrium (Equilibrium Potential) , the chemical and electrical driving forces acting on an ion are equal and opposite, and no further net diffusion occurs
- Nernst Equation is used to calculate the equilibrium potential for an ion at a given concentration difference across a membrane, assuming that the membrane is permeable to that ion

* Our resting membrane potential (RMP) or nueron is the closest to the eqiullibrium potential of the K^+ ion?

A - True ✓

B - False X

because The RMP is -90 mV and the E.P. for the K^+ ions is also -90 mV

A massage to take home

The Resting membrane potential is closer to the K^+ ions

Nernst equation and calculations of the equilibrium potential (Nerst potential)

- Electromotive force (mv)

$= (RT/ZF) \log (C_o / C_i)$

. **EMF (mV)** = ±61 x log $\left(\frac{\text{Ion conc. Inside}}{\text{Ion conc. outside}} \right)$

always assume it's negative

- C is concentration of the ion $[X^+]$
- ***C_o = [X+] outside cell***
- ***C_i = [X+] inside cell***

(The massage on M. teams)

R: is the gas constant
K° (absolute) is 0 c° which is 273K
Z: valency is the charge of free ions, for example it's +1 for K and Na, while it is +2 for Ca
F: is the faradays constant is fixed at 96,485.3399 Coulomb (C) per mole of electrons, which means that one mole of electrons is equivalent to 96,485.3399 coulombs of electric charge. Assuming the valency is one with Na and K and the temperature is 37C° or 300K the constants will be 61 when the valency ions is one

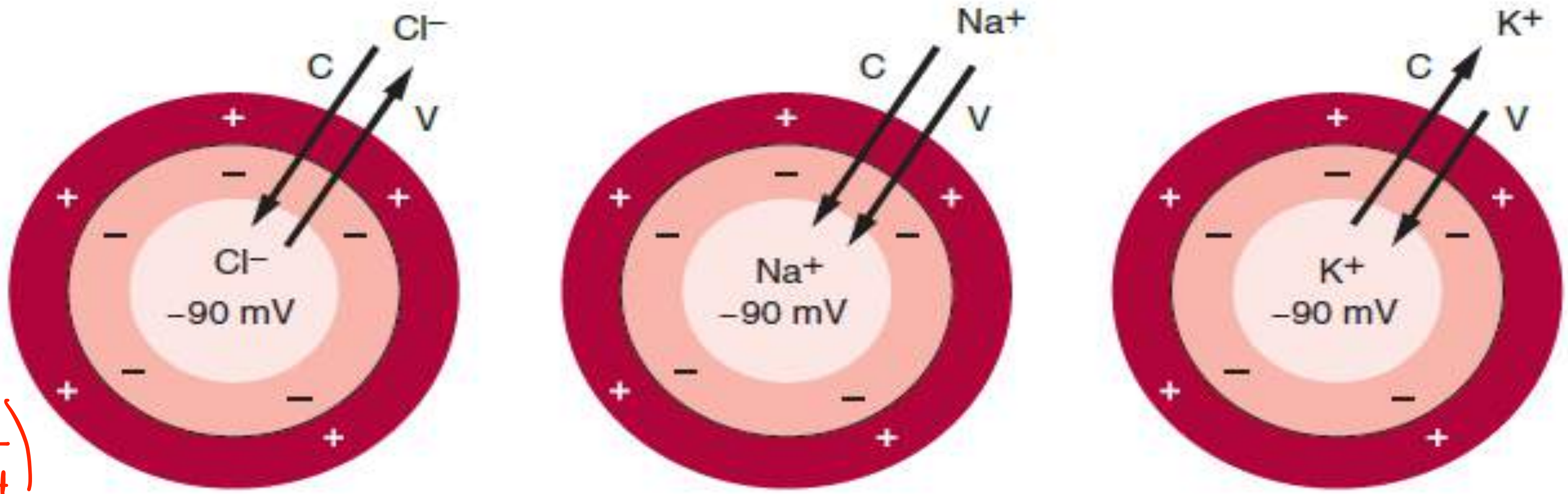
* The nerst equation measures the equilibrium potential of a particular ion like K^+, Ca^{2+}, Na^+, Cl^- and measures or estimates the membrane potential, where there is no removement of a particular, or when the membrane potential equals to the equilibrium potential of this particular. (so if you calculate the E.P. of the K^+ ion it will be close to the RMP but not the same)

The driving force on ions crossing through the membrane, voltage gradients (V), and concentration gradients (C) for the three most common ions in the solutions in the intracellular and extracellular fluids

* A note to take home

في الإمتحان احنا مطالبين
بمعادلة نيرنست ، رح يعطونا كل
المعطيات عدا ال (-61) و نطبق
و نحسب ،

$$= -61 \times \log\left(\frac{C_{in}}{C_{out}}\right)$$



$$E_{Cl} = \frac{60\text{ mV}}{-1}\log\frac{132}{4}$$

$$E_{Cl} = -90\text{ mV}$$

$$E_{Na} = \frac{60\text{ mV}}{+1}\log\frac{145}{12}$$

$$E_{Na} = +65\text{ mV}$$

$$E_K = \frac{60\text{ mV}}{+1}\log\frac{4}{155}$$

$$E_K = -95\text{ mV}$$

- with further experimentation, they started to change the K^+ ion and take curves, so at one point they found out that the nerst P. is not right (The nerst equation can't exactly calculate the R.M.P.)

Then some scientists came and completed nersts work and updated a formula, and they considered 2 things, the concentration of the 3 most important ions (K^+, Na^+, Cl^-) and the permeability (the diffusion potential relies on the C.G and the permeability).

The Potassium Nernst Potential

…also called the equilibrium potential

$$E_K = -61 \times \log \frac{K_i}{K_o}$$

Example: If K_o = 4 mM and K_i = 140 mM

E_K = -61 log(140/4)

E_K = -61 log(35)

E_K = -94 mV

So, if the membrane were permeable only to K+, the membrane potential (Vm) would be -94 mV

The Sodium Nernst Potential

$$E_{Na} = -61 \times \log \frac{Na_i}{Na_o}$$

Example: If Na_o = 142 mM and Na_i = 14 mM

E_{Na} = -61 log(14/142)

E_{Na} = -61 log(0.1)

E_{Na} = +61 mV

So, if the membrane were permeable only to Na^+, the membrane potential (Vm) would be +61 mV

(from M. Teams)

SAMPLE PROBLEM. *If the intracellular [Ca^{2+}] is 10^{-7} mol/L and the extracellular [Ca^{2+}] is 2×10^{-3} mol/L, at what potential difference across the cell membrane will Ca^{2+} be at electrochemical equilibrium?* Assume that 2.3RT/F = 60 mV at body temperature (37°C).

SOLUTION. Another way of posing the question is to ask what the membrane potential will be, given this concentration gradient across the membrane, if Ca^{2+} is the only permeant ion. Remember, Ca^{2+} is divalent, so z = +2. Thus

$$
\begin{aligned}
E_{Ca^{2+}} &= \frac{-60\text{ mV}}{z}\log_{10}\frac{C_i}{C_o} \\
&= \frac{-60\text{ mV}}{+2}\log_{10}\frac{10^{-7}\text{ mol/L}}{2\times 10^{-3}\text{ mol/L}} \\
&= -30\text{ mV}\log_{10} 5\times 10^{-5} \\
&= -30\text{ mV}\ (-4.3) \\
&= \underline{+129\text{ mV}}
\end{aligned}
$$

The Goldman-Hodgkin-Katz Equation

(also called the Goldman Equation)

Calculates V_m when more than one ion is involved.

sodium inside (+)

Potassium inside (+)

chlorine outside cuz its negativly charged (−)

$$\text{EMF (millivolts)} = -61 \times \log \frac{C_{Na_i^+} P_{Na^+} + C_{K_i^+} P_{K^+} + C_{Cl_o^-} P_{Cl^-}}{C_{Na_o^+} P_{Na^+} + C_{K_o^+} P_{K^+} + C_{Cl_i^-} P_{Cl^-}}$$

Na, K & Cl are the most important ions involved in development of membrane potentials in nerve and muscle fibers & neuronal cells

* The massage to take home

The best equation to exactly estimate the (R.M.P), bcuz it considers permeability

the diffusion potential depends on:
(1) permeability of the membrane (P) to each ion
(2) concentrations (C) of the respective ions on the inside (i) and outside (o) of the membrane

* Q: what if you have a membrane which is only permable to K^+ ions, what will happen?

$$Emf = -61 \times \log\left(\frac{\cancel{C_{Nai} P_{Na}} + C_{Ki} P_K + \cancel{C_{Cl_o^-} P_{Cl^-}}}{\cancel{C_{Na_o} P_{Na}} + C_{Ko} P_K + \cancel{C_{Cl_i^-} P_{Cl^-}}}\right)$$

$\Rightarrow$ $Emf = -61 \times \log\left(\frac{C_{Ki} P_K}{C_{Ko} P_K}\right)$ whish is The same as nerst

So, nerst equation is a special case of GHK equation

Cuz it is one ion and the membrane is permeable to That ion

The Goldman-Hodgkin-Katz Equation

(also called the Goldman Equation)

Calculates V_m when more than one ion is involved.

$$\text{EMF (millivolts)} = -61 \times \log \frac{C_{Na_i^+} P_{Na^+} + C_{K_i^+} P_{K^+} + C_{Cl_o^-} P_{Cl^-}}{C_{Na_o^+} P_{Na^+} + C_{K_o^+} P_{K^+} + C_{Cl_i^-} P_{Cl^-}}$$

the **quantitative importance** of each of the ions in determining the voltage is **proportional to the membrane permeability for that particular ion**.

The Goldman-Hodgkin-Katz Equation

Take home message…

The resting membrane potential is closest to the equilibrium potential for the ion with the highest permeability!

Question

[Nai]=15 mM [Ki]=150 mM [Cli]=10 mM
[Nao]=145 mM [Ko]=4 mM [Clo]=24 mM

determine the resting membrane potential in a typical neuron. Assume that pK = 1, pNa = 0.05, and pCl = 0.5.

$$\text{EMF (millivolts)} = -61 \times \log \frac{C_{Na_i^+} P_{Na^+} + C_{K_i^+} P_{K^+} + C_{Cl_o^-} P_{Cl^-}}{C_{Na_o^+} P_{Na^+} + C_{K_o^+} P_{K^+} + C_{Cl_i^-} P_{Cl^-}}$$

$$= -61 \text{ X } \log \frac{15\text{X}0.05 + 150\text{X}1 + 24\text{X}0.5}{145\text{X}0.05 + 4\text{X}1 + 10\text{X}0.5}$$

=-61 X log 10
=-61 mV

Question

[Nai]=15 mM [Ki]=150 mM [Cli]=10 mM
[Nao]=145 mM [Ko]=4 mM [Clo]=24 mM

Assume that in a neuron, the plasma membrane permeability values for potassium (K^+), sodium (Na^+), and Cl^- are the following: p_K = 1, p_{Na} = 12, and p_{Cl} = 0.5.
determine the membrane potential in this neuron.

$$\text{EMF (millivolts)} = -61 \times \log \frac{C_{Na_i^+} P_{Na^+} + C_{K_i^+} P_{K^+} + C_{Cl_o^-} P_{Cl^-}}{C_{Na_o^+} P_{Na^+} + C_{K_o^+} P_{K^+} + C_{Cl_i^-} P_{Cl^-}}$$

$$= -61 \text{ X } \log \frac{15\text{X}12 + 150\text{X}1 + 24\text{X}0.5}{145\text{X}12 + 4\text{X}1 + 10\text{X}0.5}$$

=-61 X log 0.195

=-61 X -0.71
=+ 43 mV