Equilibrium potentials for ions

Imagine a simple model in which two solutions, A and B, with different concentrations of an ion (Na^+), are separated by a membrane. Assume that concentration of Na^+ ion is greater in compartment A than in B. If there is no electrical gradient between the solutions A and B, then Na^+ ions diffuse from A into the B, as it is a molecule with no charge (positive or negative). On the other hand, if solution A is electrically negative compared to solution B, things get to be more complicated. Concentration gradient for Na^+ still moves Na^+ from A into the B, but at the same time, electrical potential difference moves Na^+ in the opposite direction, from B into the A. Finally, the flux of Na^+ across the membrane is determined by both the Na^+ concentration gradient and the electrical potential across the membrane. The force that moves ions across the membrane is called **electrochemical potential**. When the electrical force driving ion into the cell (or compartment A) exactly balances the chemical force driving that same ion out of the cell (A) the potential across the membrane develops. This potential is called **equilibrium potential** for that ion. The equilibrium potential can be calculated from the **Nernst Equation**:

$$E_A - E_B = -60\text{mV}/z * \log(X_A/X_B)$$

<u>Example 1</u>.

Calculate the equilibrium potential for ion K^+, if the concentration of K^+ is 10 times greater in compartment A (0.1M) than in compartment B (0.01M). Which compartment (A or B) has to be positively charged?

<u>Example 2</u>.

Determine whether $HCO3^-$ is in equilibrium. Concentration of $HCO3^-$ is 10 times greater in compartment A (1M) which is positively charged, then in compartment B (0.1M) which is negatively charged. EA-EB = +100mV. If $HCO3^-$ is not in equilibrium, determine the direction of the flux for $HCO3^-$.

Important Points

1. If the real (measured) electrical gradient is equal to the calculated electrical potential for particular ion (using the Nernst Equation), that ion is in equilibrium and as many ions move in as move out.
2. It measured electrical gradient is greater than calculated Nernst potential, then electrical gradient for particular ion is greater than concentration gradient for the same ion, and the diffusion of ion across the membrane will be determined by the direction of electrical potential.
3. If the measured electrical gradient is lower than calculated Nernst potential, then concentration gradient for particular ion is greater than electrical gradient, and the diffusion of ion across the membrane will be determined by the direction of concentration potential (chemical force).
4. If the measured electrical gradient has an opposite charge (positive or negative) than calculated Nernst potential, then both electrical and concentration gradient direct the ion into the same direction, and ion can’t reach the equilibrium.