**Nernst Equation**

**Nernst Equation** is an equation used to calculate the electrical potential of a chemical reaction. In its equilibrium state, the Nernst equation should be zero. It also shows the direct relation between energy or potential of a cell and its participating ions. The equation is proposed by a German chemist, Walther H. Nernst (1864-1941).

Nernst equation can be expressed as follows:

$$E_{cell} = E^{\theta}_{cell} - \frac{RT}{zF} ln \frac{[red]}{[oxi]}$$

where

$E_{cell}$ is the half-cell potential difference

$E^{\theta}_{cell}$ is the standard half-cell potential

R is the universal gas constant; R = 8.314471 J $K^{-1}$ $mol^{-1}$

T is the thermodynamics temperature, in *Kelvin*; 0 K = -273.15$^{o}$C

z is the number of moles of electrons transferred between cells (defined by the valency of ions)

F is the Faraday's constant; F = 96,485.3415 C $mol^{-1}$

[red] is the concentration of ion that gained electrons (reduction)

[oxi] is the concentration of ion that lost electrons (oxidation)

Membrane potential

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Nernst equation is also can be used to calculate the potential of an ion across the membrane. For potential difference of a membrane, we can manipulate the Nernst Equation as follows:

$$E_m = \frac{RT}{zF} ln \frac{[A^-]_o}{[A^-]_i}$$

or

$$E_m = 2.303 \frac{RT}{zF} log_{10} \frac{[A^-]_o}{[A^-]_i}$$

where

$E_m$ is the potential difference of an ion between membranes

R is the universal gas constant; R = 8.314471 J $mol^{-1}$

T is the thermodynamics temperature, in *Kelvin*; 0 K = -273.15$^o$C

z is the number of moles of electrons transferred between membranes (defined by the valency of ion)

F is the Faraday's constant; F = 96,485.3415 C $mol^{-1}$

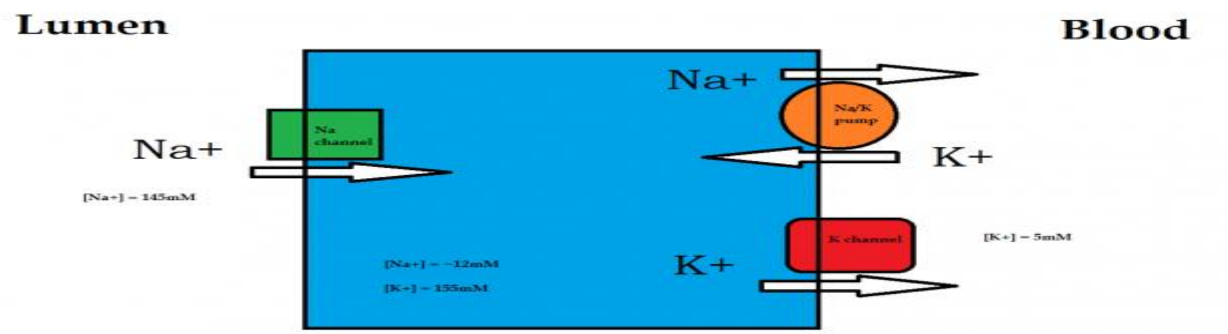
$[A^-]_o$ is the concentration of ion outside the membrane (in this case is anion, negative charge ion)

$[A^-]_i$ is the concentration of ion inside the membrane (in this case is anion, negative charge ion)

## Application

Using study of frog skin

In biochemistry, Nernst equation can be used to calculate the potential difference of ion between membranes. Hans H. Ussing, a Danish scientist, used a frog skin to measure the potential difference of sodium and potassium ions across the membranes with his famous invention, the Ussing chamber.



Using model of transepithelial ions absorption [2].

For example at the standard condition and temperature of 25°C (298K), the above sodium ion membrane potential can be calculated as:

$$E_m = 2.303\frac{RT}{zF}log_{10}\frac{[Na^+]_o}{[Na^+]_i}$$

$$E_m = 2.303\frac{(8.314)(298)}{(1)(96{,}485)}log_{10}\frac{[145]}{[12]}$$

$$E_m = 2.303x0.0256\ldots log_{10}(12.08\ldots)$$

$$E_m = 0.06398\ldots V$$

$$E_m = 63.98\ mV$$

## Goldman equation

**Goldman equation** is an equation used to calculate the electrical equilibium potential across the cell's membrane in the presence of more than one ions taking into account the selectivity of membrane's permeability. It is derived from the Nernst equation. In presence of more than one ion, the Nernst equation can be modified into Hodgkin-Katz-Goldman equation or is commonly known as Goldman equation. Goldman equation is proposed by David E. Goldman of Columbia University together with Alan L. Hodgkin and Bernard Katz. It is used to determine the equilibrium potential across a cell's membrane using all of the ions taht can cross the membrane. The Hodgkin-Katz-Goldman equation is essentially a combined Nernst equation, taking into account the permeability's of the many ions present in real cells.

The Goldman equation can be expressed as follows:

$$E_m = \frac{RT}{zF} ln(\frac{P_A.[A]_o + P_B.[B]_o}{P_A.[A]_i + P_B.[B]_i})$$

or

$$E_m = 2.303 \frac{RT}{zF} log_{10}(\frac{P_A.[A]_o + P_B.[B]_o}{P_A.[A]_i + P_B.[B]_i})$$

where

$E_m$ is the potential difference of an ion between membranes

R is the universal gas constant; R = 8.314471 J mol-1

T is the thermodynamics temperature, in Kelvin; 0 K = -273.15oC

z is the number of moles of electrons transferred between membranes (defined by the valency of ion)

F is the Faraday's constant; F = 96,485.3415 C mol-1

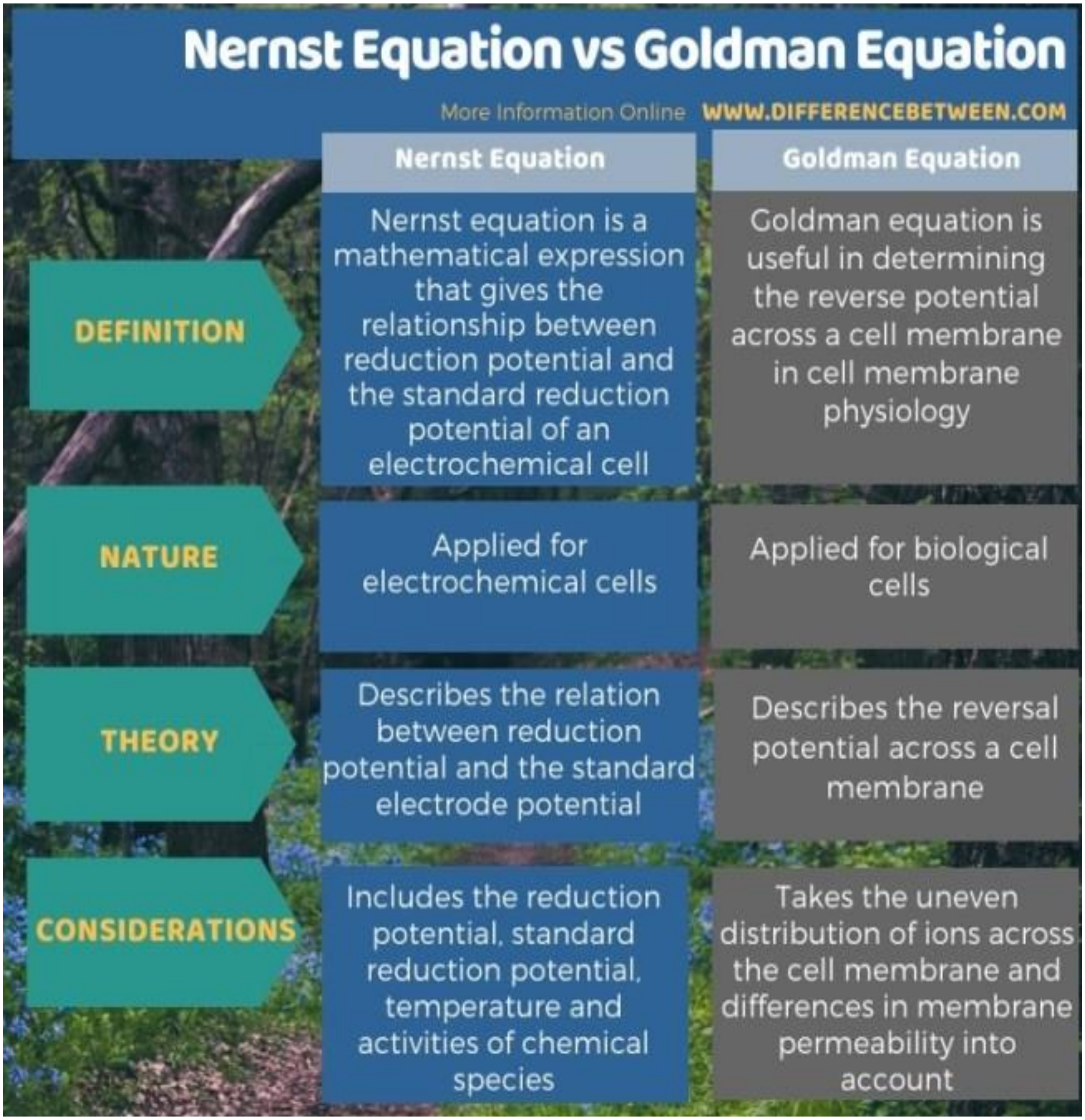
$P_{A \text{ or } B}$ is the permeability of the membrane to a particular ion (A or B)

$[A \text{ or } B]_o$ is the concentration of ion outside the membrane

$[A \text{ or } B]_i$ is the concentration of ion inside the membrane

**Nernst Equation and Goldman Equation**

Nernst equation and the Goldman equation are mathematical expressions that can be used as measurements of the potential of electrochemical cells. The key difference between Nernst equation and Goldman equation is that the Nernst equation describes the relation between reduction potential and the standard electrode potential, whereas the Goldman equation is a derivative of the Nernst equation and describes the reversal potential across a cell membrane.



# Nernst Equation vs Goldman Equation

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| | Nernst Equation | Goldman Equation |
|---|---|---|
| DEFINITION | Nernst equation is a mathematical expression that gives the relationship between reduction potential and the standard reduction potential of an electrochemical cell | Goldman equation is useful in determining the reverse potential across a cell membrane in cell membrane physiology |
| NATURE | Applied for electrochemical cells | Applied for biological cells |
| THEORY | Describes the relation between reduction potential and the standard electrode potential | Describes the reversal potential across a cell membrane |
| CONSIDERATIONS | Includes the reduction potential, standard reduction potential, temperature and activities of chemical species | Takes the uneven distribution of ions across the cell membrane and differences in membrane permeability into account |

Nernst equation and the Goldman equation are mathematical expressions that can be used as measurements of the potential of electrochemical cells. The key difference between Nernst equation and Goldman equation is that the Nernst equation describes the relation between reduction potential and the standard electrode potential, but the Goldman equation is a derivative of the Nernst equation and describes the reversal potential across a cell membrane.