Chem 205
Web problem set 4

*Question 1*:

Assuming that the osmotic pressure of a sample of sea water at $T_1$ $^0C$ is $P_1$ atm , calculate the work required under reversible conditions at this constant temperature to prepare V litre of pure water form this sea water . (Take the available volume of sea water as infinite and therefore unchanging in composition as one litre of pure water is extracted).
Express your answer in Joules.

In the process of extraction of pure water form the sea water ,work has been done against atmospheric pressure and osmotic pressure of sea water:

$$w = -PdV = -(\pi + P^0)dV$$

where $P^0$ is atmospheric pressure.

While the change in volume of sea water would be an amount of pure water extracted :

$dV = -V(pure \quad water)$ where the minus sign counts for an decrease in volume of sea water.

*Question 2:*

At temperature T the concentration of $Fe^{3+}$ inside a cell is $[Fe^{3+}]_{in}$ and outside $[Fe^{3+}]_{out}$ .The cell membrane is permeable to $Fe^{3+}$. What potential difference in volts would have to exist across the membrane for $Fe^{3+}$ to be in equilibrium at the stated conditions? Give your answer as the apsolute value of the potential difference in volts.

Under stated conditions potential difference across membrane would be :

$$\Delta\varepsilon = \varepsilon - \varepsilon^0 = -{RT}/{nF} \ln Q$$

where $Q = \frac{[Fe]_{lower \quad concentration}}{[Fe]_{higher \quad concentration}} = \frac{[Fe]_{out}}{[Fe]_{in}}$ and n=3.

*Question 3:*

At temperature T the concentration of $Ca^{2+}$ inside a cell is $[Ca^{2+}]_{in}$ and outside $[Ca^{2+}]_{out}$ . The cell membrane is permeable to $Ca^{2+}$ . The only ion present in addition to $Ca^{2+}$, $Cl^-$ is a protein ($Pr_{in}^{+/-}$) inside the cell. The protein holds a single positive or negative charge. The $Cl^-$ is at equilibrium across the membrane while the protein is inside the cell and cannot permeate the membrane. What is the concentration of $[Pr^{+/-}]_{in}$ ?

Inside and outside the cell solution of $CaCl_2$ disociates according to the reaction:

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

Inside the cell there is also a protein that contributes to ion concentration.If we assume that protein binds with negative $Cl^-$ ion

$$\Pr Cl \longrightarrow \Pr^+ + Cl^-$$

then concentration of $Cl^-$ ion inside the cell could be expressed as:

$$[Cl^-]_{in} = [Cl^-]_{CaCl2} + [Cl^-]_{\Pr Cl} = 2[Ca^{2+}]_{in} + x$$

| Inside cell | | | Outside cell | |
|---|---|---|---|---|
| $Ca^{2+}$ | $Cl^-$ | Pr | $Ca^{2+}$ | $Cl^-$ |
| $[Ca^{2+}]_{in}$ | $2*[Ca^{2+}]_{in}+x$ | x | $[Ca^{2+}]_{out}$ | $2*[Ca^{2+}\}_{out}$ |

$$(Ca^{2+} + 2Cl^-)_{in} \longrightarrow (Ca^{2+} + 2Cl^-)_{out}$$

At equilibrium reaction constant $K_{eq}$ can be expressed as:

$$K_{eq} = \frac{[Ca^{2+}]_{out}[Cl^-]^2_{out}}{[Ca^{2+}]_{in}[Cl]^2_{in}} = 1$$

*and Donnan equation becomes*:

$$[Ca^{2+}]_{out}[2*[Ca^{2+}]_{out}]^2 = [Ca^{2+}]_{in}[2*[Ca^{2+}]_{in} + x]^2$$

*from which protein concentration can be calculated*

$$\Rightarrow x = \sqrt{\frac{[Ca^{2+}]_{out}[2*[Ca^{2+}]_{out}]^2}{[Ca^{2+}\}_{in}}} - 2*[Ca^{2+}]_{in}$$

*<u>Question 4 :</u>*

Is the protein in Question 3 positively or negatively charged?

a. positively charged
b. negatively charged

Answer : If calculated concentration for protein in Question 3 is negative then it means that assumption that we used to calculate $Cl^-$ ion concentration , that protein bind with negative ion is wrong. So the answer in that case would be b.