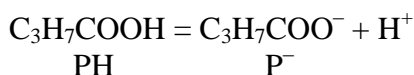


Problem 10-10 Conductivity, molar conductivity, dissociation constant

Calculate the conductivity of the $2 \cdot 10^{-5}$ molar solution of propionic acid, the dissociation constant of which has the value of $1.32 \cdot 10^{-5}$ (standard state infinite dilution, $c^{\text{st}} = 1 \text{ mol dm}^{-3}$, activity coefficients for all substances can be taken as equal to one). The conductivity of water used for the measurement was $6.6 \cdot 10^{-5} \text{ S m}^{-1}$ and the limiting molar conductivities of ions have the following values:

$$\lambda^{\infty}(\text{H}^+) = 0.03497 \text{ S m}^2 \text{ mol}^{-1}, \lambda^{\infty}(\text{C}_3\text{H}_7\text{COO}^-) = 0.00358 \text{ S m}^2 \text{ mol}^{-1} \quad [\kappa_{\text{solution}} = 4.88 \cdot 10^{-4} \text{ S m}^{-1}]$$

Solution:



$$c_0 = 2 \cdot 10^{-5} \text{ mol dm}^{-3}$$

$$\text{Balance: the conversion degree } \alpha = \frac{c_0 - c_{\text{PH}}}{c_0} \Rightarrow c_{\text{PH}} = c_0 (1 - \alpha)$$

$$c_{\text{P}^-} = c_{\text{H}^+} = c_0 \alpha$$

$$K = 1.32 \cdot 10^{-5} = \frac{a_{\text{P}^-} \cdot a_{\text{H}^+}}{a_{\text{PH}}} = \frac{\gamma_- \cdot c_{\text{P}^-} \cdot \gamma_+ \cdot c_{\text{H}^+}}{\gamma_{\text{PH}} \cdot c_{\text{PH}}} \cdot \frac{1}{c^{\text{st}}} = \frac{\gamma_{\pm}^2 \cdot c_0 \cdot \alpha^2}{1 - \alpha} \quad (\gamma_{\text{PH}} = 1, \gamma_{\pm} = 1, c^{\text{st}} = 1 \text{ mol dm}^{-3})$$

$$\alpha^2 + \frac{1.32 \cdot 10^{-5}}{2 \cdot 10^{-5}} \alpha - \frac{1.32 \cdot 10^{-5}}{2 \cdot 10^{-5}} = 0$$

$$\alpha^2 + 0.66 \alpha - 0.66 = 0$$

$$\alpha = -0.33 \pm (0.1089 + 0.66)^{1/2} = 0.54687$$

$$\alpha = \frac{\lambda}{\lambda^{\infty}}$$

$$\lambda^{\infty}(\text{H}^+) = 0.03497 \text{ S m}^2 \text{ mol}^{-1}, \lambda^{\infty}(\text{C}_3\text{H}_7\text{COO}^-) = 0.00358 \text{ S m}^2 \text{ mol}^{-1}$$

$$\lambda^{\infty} = \lambda^{\infty}(\text{H}^+) + \lambda^{\infty}(\text{C}_3\text{H}_7\text{COO}^-) = 0.03497 + 0.00358 = 0.03855 \text{ S m}^2 \text{ mol}^{-1}$$

$$\lambda = \alpha \cdot \lambda^{\infty} = 0.54687 \cdot 0.03855 = 0.021082$$

$$\lambda = \frac{\kappa}{c_0} = \frac{\kappa_{\text{solution}} - \kappa_{\text{water}}}{c_0} ; c_0 = 2 \cdot 10^{-5} \text{ mol dm}^{-3} = 2 \cdot 10^{-2} \text{ mol m}^{-3} (c_0 \text{ in mol m}^{-3}!!)$$

$$\left[\frac{\text{S m}^{-1}}{\text{mol m}^{-3}} = \text{S m}^2 \text{ mol}^{-1} \right]$$

$$\kappa_{\text{solution}} = \kappa_{\text{water}} + \lambda \cdot c_0 = 6.6 \cdot 10^{-5} + 0.021082 \cdot 2 \cdot 10^{-2} =$$

$$\kappa_{\text{solution}} = 4.8764 \cdot 10^{-4} \text{ S m}^{-1}$$