

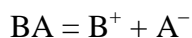
Problem 8-07 Solution of the salt of the weak base and weak acid

Aqueous solution of the salt of weak acid (AH) and weak base (BOH) at the temperature of 25 °C and concentration of 0.0025 mol dm⁻³ has pH = 9.65. Calculate the dissociation constant of the weak acid in question, if you know that the dissociation constant conjugated to the weak base BOH has the value of $K_{B^+} = 1.32 \cdot 10^{-9}$ (all for standard state of infinite dilution, $c^{\text{st}} = 1 \text{ mol dm}^{-3}$, and unit activity coefficients).

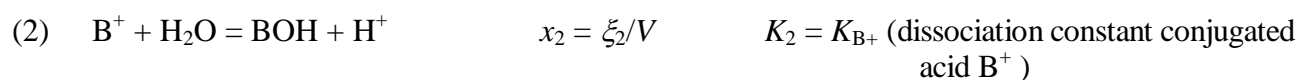
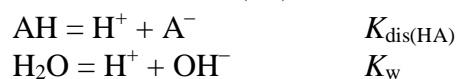
$$[K_{\text{dis (HA)}} = 3.26 \cdot 10^{-11}]$$

Solution:

The salt of weak base and weak acid BA is completely dissociated to ions



which undergo by further reactions with water:



Balance:

Initial concentration of the salt BA: $c_0 = 0.0025 \text{ mol dm}^{-3}$

$$c_{\text{A}^-} = c_0 - x_1$$

$$c_{\text{B}^+} = c_0 - x_2$$

$$c_{\text{HA}} = x_1$$

$$c_{\text{BOH}} = x_2$$

$$c_{\text{H}^+} = x_2 + x_3 \quad \text{pH} = 9.65 \Rightarrow c_{\text{H}^+} = 10^{-9.65} = 2.26872 \cdot 10^{-10} \text{ mol dm}^{-3}$$

$$c_{\text{OH}^-} = x_1 + x_3 \quad K_v = 1 \cdot 10^{-14} = c_{\text{H}^+} \cdot c_{\text{OH}^-} \quad (c^{\text{st}} = 1 \text{ mol dm}^{-3})$$

$$c_{\text{OH}^-} = \frac{K_w}{c_{\text{H}^+}} = \frac{10^{-14}}{2.23872 \cdot 10^{-10}} = 4.467 \cdot 10^{-5} \text{ mol dm}^{-3}$$

$$K_1 = \frac{K_w}{K_{\text{dis (HA)}}} = \frac{c_{\text{AH}} \cdot c_{\text{OH}^-}}{c^{\text{st}} \cdot c_{\text{A}^-}} = \frac{x_1 \cdot (x_1 + x_3)}{c^{\text{st}} \cdot (c_0 - x_1)}, \quad (c^{\text{st}} = 1 \text{ mol dm}^{-3})$$

$$\frac{1 \cdot 10^{-14}}{K_{\text{dis (HA)}}} = \frac{x_1 \cdot 4.467 \cdot 10^{-5}}{2.5 \cdot 10^{-3} - x_1}$$

$$K_2 = K_{\text{ac (BOH)}} = \frac{c_{\text{BOH}} \cdot c_{\text{H}^+}}{c_{\text{B}^+}} = \frac{x_2 \cdot (x_2 + x_3)}{c_0 - x_2}$$

$$1.32 \cdot 10^{-9} = \frac{x_2 \cdot 2.23872 \cdot 10^{-5}}{2.5 \cdot 10^{-3} - x_2}$$

$$1.32 \cdot 10^{-9} \cdot 2.5 \cdot 10^{-3} - 1.32 \cdot 10^{-9} \cdot x_2 = x_2 \cdot 2.23872 \cdot 10^{-10}$$

$$x_2 = \frac{1.32 \cdot 10^{-9} \cdot 2.5 \cdot 10^{-3}}{1.32 \cdot 10^{-9} + 2.23872 \cdot 10^{-10}} = 2.1375 \cdot 10^{-3}$$

$$c_{\text{OH}^-} - c_{\text{H}^+} = x_1 + x_3 - x_2 - x_3 = x_1 - x_2$$

$$x_1 = c_{\text{OH}^-} - c_{\text{H}^+} + x_2 = 4.467 \cdot 10^{-5} - 2.23872 \cdot 10^{-10} + 2.1375 \cdot 10^{-3} = 2.18217 \cdot 10^{-3}$$

$$K_{\text{dis (HA)}} = \frac{K_{\text{w}}}{x_1 \cdot c_{\text{OH}^-}} \cdot (c_0 - x_1) = \frac{1 \cdot 10^{-14}}{2.18217 \cdot 10^{-3} \cdot 4.467 \cdot 10^{-5}} \cdot (0.0025 - 2.18217 \cdot 10^{-3})$$

$$K_{\text{dis (HA)}} = 3.26 \cdot 10^{-11}$$