Answer on Question #71652 - Chemistry - Physical Chemistry

Question:
Calculate the pH of a 0.1M solution of sodium acetate. What is the percent hydrolysis?

Solution:
Firstly, let's consider the sodium acetate hydrolysis reaction equation:

$$Na^+ + Ac^- + H_2O \leftrightarrow HAc + Na^+ + OH^-;$$

Or in the short form:

$$Ac^- + H_2O \leftrightarrow HAc + OH^-.$$

The percent hydrolysis is the ratio:

$$h, \% = 100\% \cdot \frac{[HAc]}{[HAc] + [Ac^-]} = 100\% \cdot \frac{[HAc]}{0.1\ M}.$$

As one could see from the reaction equation, the hydrolysis of sodium acetate runs preferentially on anion, as anion is a weak acid and cation is a strong base. To get the equilibrium concentration of acetic acid, we can use the equilibrium constant of this reaction:

$$K = \frac{[HAc][OH^-]}{[Ac^-]}.$$

As one can see, this equation can be expressed as a protonation of acetate anion with the water ionization taken into account.
The constant of protonation of acetate anion logKa = 4.76 and it corresponds to the following equation:

$$Ac^- + H^+ \leftrightarrow HAc$$

$$K_p = \frac{[HAc]}{[Ac^-][H^+]} = 10^{4.76}.$$

The ionization of water is expressed by the constant:

$$K_w = [H^+][OH^-] = 10^{-14}.$$

Thus, now we can get the hydrolysis constant as a function of protonation and water ionization constants:

$$K = \frac{[HAc][H^+][OH^-]}{[Ac^-][H^+]} = K_p K_w = 10^{4.76} \cdot 10^{-14} = 10^{-9.24}$$

Finally, we can consider the equilibrium concentration of acetate $[Ac^-]$ as $[Ac^-] = 0.1 - [HAc]$ and presume that $[HAc] = [OH^-]$. So:

$$10^{-9.24} = \frac{[HAc]^2}{0.1 - [HAc]}$$

As $[HAc] \ll 0.1$:

$$10^{-9.24} = \frac{[HAc]^2}{0.1}$$

$$[HAc] = \sqrt{0.1 \cdot 10^{-9.24}} = 7.6 \cdot 10^{-6} M$$

The pH is:

$$[OH^-] = 7.6 \cdot 10^{-6}\ M; pH = 14 - pOH = 8.88.$$

The percent of hydrolysis is:

$$h, \% = 100\% \cdot \frac{[HAc]}{0.1\ M} = 100\% \cdot \frac{7.6 \cdot 10^{-6} M}{0.1\ M} = 0.0076\ \%\ .$$

Answer: pH = 8.88; 0.0076% hydrolysis occurred.

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