Quiz 9

Useful information:

\[ K_w = 1 \times 10^{-14} \]
\[ K_{a,HNO_2} = 5.6 \times 10^{-4} \]

1. (10 pts) What is the pH of a 4.7 \times 10^{-9} M solution of KNO_2?

- THE SIMPLE SOLUTION IS NOT CORRECT, BUT OR FOR THE PURPOSES OF THIS QUIZ,

\[ \text{KNO}_2(s) \rightarrow K^+ + NO_2^- \quad \text{NO}_2^- \text{ is conjugate base of HNO}_2 \]

**INITIAL**:

- \[ 4.7 \times 10^{-9} \]
- \[ 0 \quad 0 \]

**EQUIL.**:

- \[ 4.7 \times 10^{-9} - x \]
- \[ x \quad x \]

\[ \frac{K_b}{K_a} = \frac{x^2}{4.7 \times 10^{-9} - x} = \frac{K_w}{5.6 \times 10^{-4}} = 1.786 \times 10^{-11} \]

\[ x^2 = 1.786 \times 10^{-11} (4.7 \times 10^{-9} - x) \]

Assume \( x \) is small \( \Rightarrow \)

\[ x_0 = 2.897 \times 10^{-10} \]

HMM, only 10 \( x \) smaller than 4.7 \( \times \) 10^{-9}

So iterate:

\[ x_1 = 2.806 \times 10^{-10} \]
\[ x_2 = 2.809 \times 10^{-10} \]

Or use quadratic equation:

\[ x = 2.809 \times 10^{-10} \]

\[ [\text{OH}^-] = x \quad \text{so} \quad p[\text{OH}^-] = -\log(x) = 9.55 \]

\[ pH = 14 - 9.55 = 4.45 \]

HMM, we added a base and ended up with \( pH < 7 \), something is wrong. See next solution...
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\[ K_w = 1 \times 10^{-14} \]
\[ K_{a,\text{HNO}_2} = 5.6 \times 10^{-4} \]

1. (10 pts) What is the pH of a \(4.7 \times 10^{-9}\) M solution of KNO₂?

The correct solution.

Since we only added \(4.7 \times 10^{-9}\) M base, we need to worry about how much OH⁻ was already present in the pure water.

\[ 2\text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{OH}^- \]

This is the primary equilibrium!

\[ [\text{H}_3\text{O}^+][\text{OH}^-] = 1 \times 10^{-14} = K_w \]

In pure water \([\text{H}_3\text{O}^+] = [\text{OH}^-] = x\)

\[ x^2 = 1 \times 10^{-14} \Rightarrow x = 1 \times 10^{-7} \]

So, the initial concentration of [OH⁻] is \(1 \times 10^{-7}\) M.

Now, repeat the other solution with these initial values.

\[ \text{NO}_2^- + \text{H}_2\text{O} \rightleftharpoons \text{HNO}_2 + \text{OH}^- \]

I: \(4.7 \times 10^{-9} - x\)

Equil: \(4.7 \times 10^{-9} - x\)

\[ K_b = \frac{K_w}{K_{a,\text{HNO}_2}} = \frac{1.786 \times 10^{-11}}{4.7 \times 10^{-9}} = \frac{x(1 \times 10^{-7} + x)}{4.7 \times 10^{-9} - x} \]

Assume \(x\) is small ⇒ \(x = 8.393 \times 10^{-13}\)

or use quadratic eq. ⇒ \(x = 8.391 \times 10^{-13}\)

\[ [\text{OH}^-] = 1 \times 10^{-7} + x = 1 \times 10^{-7} \]

So, \(p\text{OH} = 7\) and \(\text{pH} = 7\)