1. These questions are related to an aqueous 0.020 M hydrogen fluoride (HF) solution at 25 °C. The $K_a$ for HF is $6.8 \times 10^{-4}$.

(a) Write down the three acid-base reactions that are occurring in this solution and identify the conjugate acid-base pairs in the reactions.

$$
\begin{align*}
\text{HF} + \text{H}_2\text{O} &\rightleftharpoons \text{F}^- + \text{H}_3\text{O}^+ \\
\text{F}^- + \text{H}_2\text{O} &\rightleftharpoons \text{HF} + \text{OH}^- \\
\text{H}_2\text{O} + \text{H}_2\text{O} &\rightleftharpoons \text{H}_3\text{O}^+ + \text{OH}^-
\end{align*}
$$

(b) Write the equilibrium constant expressions for all of the reactions in part (a) and give the equilibrium constant for each.

$$
\begin{align*}
K_a &= \frac{[\text{F}^-][\text{H}_3\text{O}^+]}{[\text{HF}]} = 6.8 \times 10^{-4} \\
K_b &= \frac{[\text{HF}][\text{OH}^-]}{[\text{F}^-]} = 1.5 \times 10^{-11} \\
K_w &= [\text{H}_3\text{O}^+][\text{OH}^-] = 1.0 \times 10^{-14}
\end{align*}
$$

(c) In addition to molecular water, there are four other species in this solution. Identify them and rank them from the one present in the highest concentration to the one in the lowest concentration.

$$
\text{HF} > \text{F}^- \approx \text{H}_3\text{O}^+ > \text{OH}^-
$$

(d) Do you expect the pH of this solution to be greater than 7 or less than 7?

(e) Do you expect the pOH of this solution to be greater than 7 or less than 7?
(f) What is the pH of the solution?

Let \( x = \frac{mol}{L} \) of HF that is dissociated at equilibrium.

\[
K_a = \frac{[F^-][H_3O^+]}{[HF]} = 6.8 \times 10^{-4} = \frac{x^2}{0.020 - x}
\]

\[x = \sqrt{(6.8 \times 10^{-4})(0.020 - x)}\]

assuming \( x \ll 0.020 \) M

\[x_1 = 3.67 \times 10^{-3}\]
\[x_2 = 3.33 \times 10^{-3}\]
\[x_3 = 3.37 \times 10^{-3}\]
\[x_4 = 3.36 \times 10^{-3}\]
\[x_5 = 3.36 \times 10^{-3}\]

\[pH = -\log(3.36 \times 10^{-3}) = 2.47\]

2. These questions are related to an aqueous 0.010 M sodium nitrite (NaNO_2) solution at 25 °C. The \( K_a \) for HNO_2 is 7.1 \times 10^{-4}.

(a) Write down the three acid-base reactions that are occurring in this solution and identify the conjugate acid-base pairs in the reactions.

\[\text{NO}_2^- + \text{H}_2\text{O} \rightleftharpoons \text{HNO}_2 + \text{OH}^-\]
\[\text{HNO}_2 + \text{H}_2\text{O} \rightleftharpoons \text{NO}_2^- + \text{H}_3\text{O}^+\]
\[\text{H}_2\text{O} + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{OH}^-\]

(b) Write the equilibrium constant expressions for all of the reactions in part (a) and give the equilibrium constant for each.

\[K_b = \frac{[\text{HNO}_2][\text{OH}^-]}{[\text{NO}_2^-]} = 1.4 \times 10^{-11}\]
\[K_a = \frac{[\text{NO}_2^-][\text{H}_3\text{O}^+]}{[\text{HNO}_2]} = 7.1 \times 10^{-4}\]
\[K_w = [\text{H}_3\text{O}^+][\text{OH}^-] = 1.0 \times 10^{-14}\]
(c) In addition to molecular water, there are five other species in this solution. Identify them and rank them from the one present in the highest concentration to the one in the lowest concentration.

\[ \text{Na}^+ > \text{NO}_2^- > \text{HNO}_2 \approx \text{OH}^- > \text{H}_3\text{O}^+ \]

(d) What is the pH of this solution?

Let \( x = \frac{\text{mol}}{L} \) of \( \text{NO}_2^- \) that is reacted at equilibrium (also is \( [\text{OH}^-] \)).

\[ K_a = \frac{[\text{NO}_2^-][\text{OH}^-]}{[\text{NO}_2^-]} = 1.4 \times 10^{-11} = \frac{x^2}{0.010 - x} \]

\[ x = \sqrt{(1.4 \times 10^{-11})(0.010 - x)} \]

\[ x = 3.7 \times 10^{-7} \text{ M} \]

\[ pOH = -\log(3.7 \times 10^{-7}) = 6.43 \]

\[ pH = 14.00 - 6.43 = 7.57 \]