1. An unknown salt is NaCN, NaCH₃COO, NaF, NaCl or NaOCl. When 0.100 mole of the salt is dissolved in 1.0 L of water, the pH of the solution is 8.07. Using the pKₐ values (right) determine the identity of the salt.

\[
K_b = [HA][OH^-]/[A^-] = x^2/(0.100 - x)
\]
\[
pH = 8.07 \quad \therefore \quad pOH = 5.93 \quad \text{and} \quad [OH^-] = 1.2 \times 10^{-6} \text{ M}
\]
\[
\therefore K_b = (1.2 \times 10^{-6})^2/0.100 = 1.4 \times 10^{-11} \text{ M}
\]
\[
pK_b = 10.84 \quad \therefore \quad pK_a = 3.16 \quad \text{and the salt is NaF} \quad \text{(NB rounding error)}
\]

2. Captain Picard, of the Starship Enterprise, has been told by his superiors that only a chemist can be trusted with the combination to the safe containing the dilithium crystals (NB: at room temperature, dilithium is a gas – see p. 410 of Silberberg) used in powering the ship. The combination is the pH of solution A described below, followed by the pH of solution C (for example if the pH of solution A is 3.47 and that of solution C is 8.15, then the combination to the safe is 3-47-8-15).

The chemist must fine the combination using only the information below.

- Solution A is 50.0 mL of 0.100 M solution of the weak monoprotic acid HX.
- Solution B is a 0.050 M solution of the salt NaX. It has a pH of 10.02.
- Solution C is made by adding 15.0 mL of 0.250 M KOH to solution A.

What is the combination of the safe?

**Solution B - weak base**

\[
K_b = [HX][OH^-]/[X^-] = x^2/(0.050 - x)
\]
\[
pH = 10.02 \quad \therefore \quad pOH = 3.98 \quad \text{and} \quad [OH^-] = 1.05 \times 10^{-4} \text{ M}
\]
\[
\therefore K_b = (1.05 \times 10^{-4})^2/0.050 = 2.2 \times 10^{-7} \text{ M}
\]
\[
pK_b = 7.34 \quad \therefore \quad pK_a = 4.54 \times 10^{-8} \text{ M} \quad \text{and pK_a} = 7.34
\]

**Solution A - weak acid**

\[
K_a = [H^+][X^-]/[HX] = x^2/(0.100 - x) = 4.54 \times 10^{-8} \text{ M}
\]
\[
\therefore \quad x = 6.74 \times 10^{-5} \text{ M} \quad \text{and pH} = 4.17
\]

**Solution C - buffer**

amount of OH added = 0.015 x 0.250 = 3.75 x 10⁻³ moles
amount of HX in solution A = 0.050 x 0.100 = 5.00 x 10⁻³ moles
after addition total volume = 65 mL and
[HX] = (5.00x10⁻³)-(3.75x10⁻³))/0.065 = 0.0192 M
[X⁻] = 3.75 x 10⁻³ /0.065 = 0.0577 M
pH = pK_a + log[base]/[acid] = 7.34 + log (0.0577/0.0192) = 7.82

Combination is 4-17-7-82
3.

A constitutional formula of histidine, an amino acid of importance maintaining the catalytic activity of proteolytic (protein cleaving) enzymes is:

The $pK_1$, $pK_2$ and $pK_3$ values for histidine are 1.81, 6.05 and 9.15. These values correspond to the $\alpha$-COOH group, the imidazole ring (right) and the $\alpha$-NH$_3^+$ group respectively.

In a buffer solution, where $pH = pK_a$, the concentration of the acid and its conjugate base are equal. The following table gives the constitutional formulas of the acid species associated with those $pK_a$ values. Complete the table by giving the constitutional formulas of the conjugate bases associated with these $pK_a$ values.

<table>
<thead>
<tr>
<th>pH = $pK_a$</th>
<th>constitutional formulas of the acid species</th>
<th>constitutional formulas of its conjugate base</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.81</td>
<td><img src="https://example.com/histidine1.png" alt="Constitutional formula of histidine" /></td>
<td><img src="https://example.com/histidine2.png" alt="Constitutional formula of histidine's conjugate base" /></td>
</tr>
<tr>
<td>6.05</td>
<td><img src="https://example.com/histidine3.png" alt="Constitutional formula of histidine" /></td>
<td><img src="https://example.com/histidine4.png" alt="Constitutional formula of histidine's conjugate base" /></td>
</tr>
<tr>
<td>9.15</td>
<td><img src="https://example.com/histidine5.png" alt="Constitutional formula of histidine" /></td>
<td><img src="https://example.com/histidine6.png" alt="Constitutional formula of histidine's conjugate base" /></td>
</tr>
</tbody>
</table>