**Quiz Free Response Practice #2** (2011 #1, 10 points)

| Beaker 1 | Beaker 2 | Beaker 3 |
|----------|----------|----------|
| 0.100 $M$ HCl | 0.100 $M$ NH$_3$ | 0.100 $M$ NH$_4$Cl |
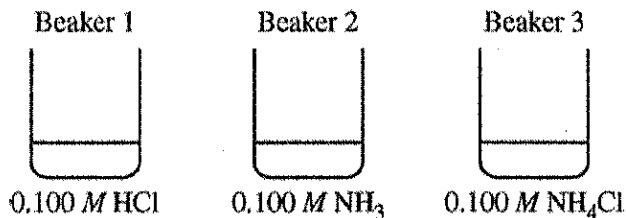
2. Each of three beakers contains 25.0 mL of a 0.100 M solution of HCl, NH$_3$, or NH$_4$Cl, as shown above. Each solution is at 25°C.

   a. Determine the pH of the solution in beaker 1. Justify your answer. (1 point)

   b. In beaker 2, the reaction $NH_3(aq) + H_2O(l) \leftrightarrow NH_4^+(aq) + OH^-(aq)$ occurs. The value of $K_b$ for $NH_3(aq)$ is 1.8 × 10$^{-5}$ at 25°C.

      i. Write the $K_b$ expression for the reaction of $NH_3(aq)$ with $H_2O(l)$. (1 point)

      ii. Calculate the [OH$^-$] in the solution in beaker 2. (2 points)

   c. In beaker 3, the reaction $NH_4^+(aq) + H_2O(l) \leftrightarrow NH_3(aq) + H_3O^+(aq)$ occurs.

      i. Calculate the value of $K_a$ for $NH_4^+(aq)$ at 25°C. (1 point)

      ii. The contents of beaker 2 are poured into beaker 3 and the resulting solution is stirred. Assume that volumes are additive. Calculate the pH of the resulting solution. (2 points)

   d. The contents of beaker 1 are poured into the solution made in part (c)(ii). The resulting solution is stirred. Assume that volumes are additive. Is the resulting solution an effective buffer? Justify your answer. (1 point)

a.) $pH = -\log [H_3O^+] = -\log [HCl] = -\log (0.100) = \boxed{1.000}$

b.) (i) $K_b = \dfrac{[NH_4^+][OH^-]}{[NH_3]}$

(ii) $K_b = \dfrac{x^2}{0.100 - x} \approx \dfrac{x^2}{0.100} = 1.8E-5 \Rightarrow x = \sqrt{(0.100)(1.8E-5)}$

$= \boxed{1.3 \times 10^{-3} M} = [OH^-]$

$K_b \ll 1 \Rightarrow x \text{ negligible}$

c.) (i) $K_a = \dfrac{K_w}{K_b} = \dfrac{1.0E-14}{1.8E-5} = \boxed{5.6 \times 10^{-10}}$

(ii) Since $[NH_3] = [NH_4^+] \Rightarrow$ ideal buffer! $\Rightarrow pH = pK_a$

$= -\log (5.6E-10)$

$= \boxed{9.25}$

d.) This Sol'n is NOT an effective buffer: the $NH_3$ in Sol'n from C.) (ii) will react with the $H_3O^+$ from Sol'n 1, leaving only $NH_4^+$. B/c there is no species left in Sol'n to neutralize an added acid, it is no longer an effective buffer.