

1. Ethanolamine ($\text{HOC}_2\text{H}_4\text{NH}_2$, $K_b = 2.5 \times 10^{-5}$) is a weak base with the conjugate acid, $\text{HOC}_2\text{H}_4\text{NH}_3^+$. A 20.0-mL sample of a 0.40 M solution of ethanolamine is titrated with a 0.25 M solution of HCl.

$$K_a = \frac{K_w}{K_b} = 4.0 \times 10^{-10} \quad pK_a = 9.40$$

- A) What is the pH of the ethanolamine solution before the addition of any HCl.



$$K_b = 2.5 \times 10^{-5} = \frac{x^2}{0.4}$$

$$x = 3.16 \times 10^{-3} \text{ M} = [\text{OH}^-]$$

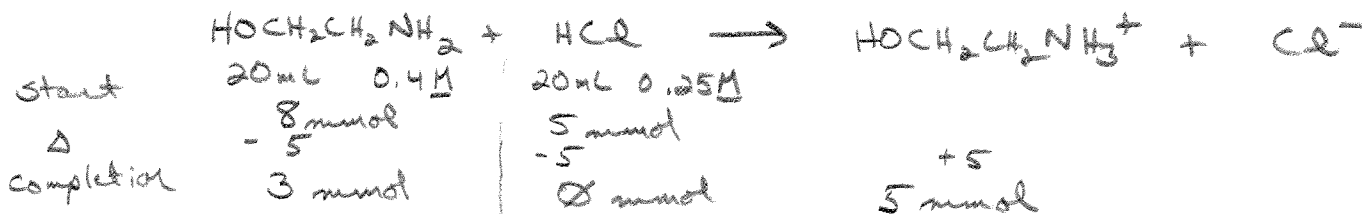
$$pOH = 2.50$$

$$pH = 11.50$$

- B) What is the pH at the **midpoint** of the titration?

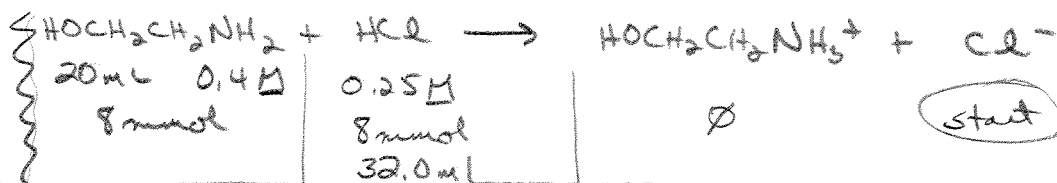
At midpt. $pH = pK_a = 9.40$

- C) What is the pH of the solution after the addition of 20.0 mL of HCl solution?



$$pH = pK_a + \log \frac{\text{base}}{\text{acid}} = 9.40 + \log \left(\frac{3}{5} \right) = 9.18 = pH$$

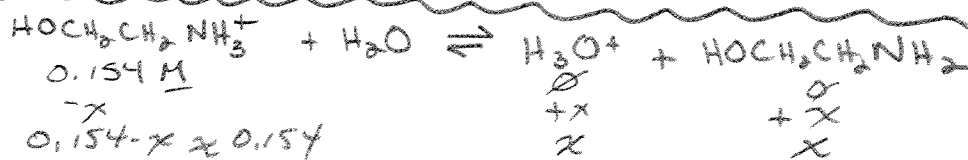
- D) What is the pH at the **equivalence point**?



8 mmol HCl / 1 L = 0.25 M

0 mmol HCl, 0 mmol HCl, $\frac{8 \text{ mmol}}{52 \text{ mL}} = 0.154 \text{ M}$ (completion)

= 32.0 mL HCl needed

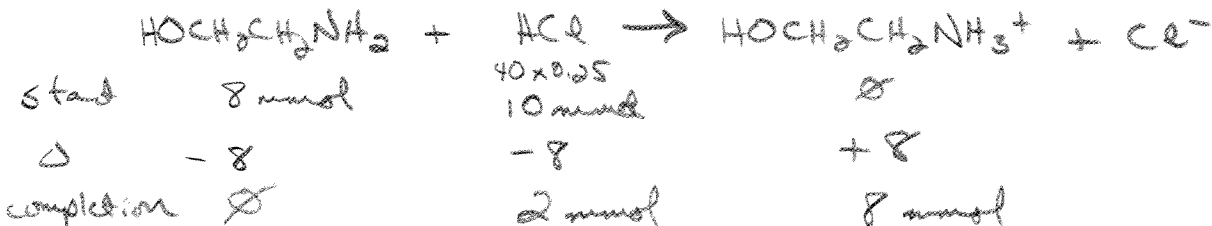


$$K_a = 4 \times 10^{-10} = \frac{x^2}{0.154}$$

$$x = 7.85 \times 10^{-6} \text{ M}$$

$$pH = 5.11$$

- E) What is the pH of the solution after the addition of 40.0 mL of HCl solution?

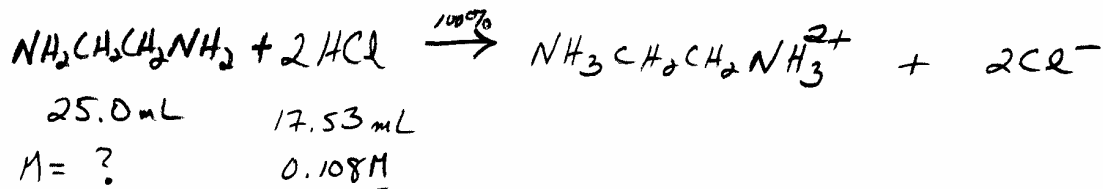


$$[\text{H}^+] = \frac{2 \text{ mmol}}{60 \text{ mL}} = 3.33 \times 10^{-2}$$

$$pH = 1.48$$

2. Ethylenediamine ($\text{NH}_2\text{CH}_2\text{CH}_2\text{NH}_2$) is a dibasic amine. A 25.0 mL sample of the base is titrated with a 0.108 M of HCl and 17.53 mL of the ~~base~~ acid is required to reach the equivalence point.

A. What is the concentration of ethylenediamine in the sample?



$$\frac{17.53 \text{ mL HCl} / 0.108 \text{ mol HCl} / 1000 \text{ mL}}{2 \text{ mol HCl}} = \frac{9.47 \times 10^{-4} \text{ mol}}{0.025 \text{ L}} = \boxed{0.0379 \text{ M}} \quad [\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2] =$$

B. What will be the pH of the solution at the equivalence point? The K_b values of ethylenediamine can be found in the appendix of your book.

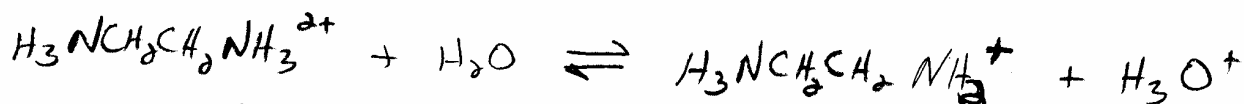
At equivalence

$$\text{mol of } \text{H}_3\text{NCH}_2\text{CH}_2\text{NH}_3^{2+} = 9.47 \times 10^{-4} \text{ mol}$$

$$\text{Total Volume} = 25.0 + 17.53 = 42.53 \text{ mL}$$

$$[\text{H}_3\text{NCH}_2\text{CH}_2\text{NH}_3^{2+}] = \frac{9.47 \times 10^{-4} \text{ mol}}{0.04253 \text{ L}} = 0.02226 \text{ M}$$

$$K_{b2} = 2.7 \times 10^{-8} \quad K_{a1} = \frac{10^{-14}}{K_{b2}} = 3.7 \times 10^{-7}$$



$$\begin{array}{l} \text{I} \\ \text{C} \\ \text{e} \end{array} \quad 0.0223 \text{ M}$$

$$-x$$

$$0.0223 \text{ M} - x$$

$$0$$

$$+x$$

$$x$$

$$0$$

$$+x$$

$$x$$

$$K_{a1} = 3.7 \times 10^{-7} = \frac{x^2}{0.0223} \Rightarrow x = 9.1 \times 10^{-5} \quad \boxed{\text{pH} = 4.04}$$