1 Ethanolamine ($HOC_2H_4NH_2$, $K_b=2.5 \times 10^{-5}$) is a weak base with the conjugate acid, $HOC_2H_4NH_3^+$. A 20.0-mL sample of a 0.40 *M* solution of ethanolamine is titrated with a 0.25 *M* solution of HCl.

$K_a = \frac{K_w}{K_b} = 4.0\times10^{-10}$ $\quad pK_a = 9.40$

A) W hat is the pH of the ethanolamine solution before the addition of any HCl.

	$HOC_2H_4NH_2$	+ H_2O ⇌	$HOC_2H_4NH_2$	+ OH^-
i	0.4M	-	∅	∅
c	$-x$	-	$+x$	$+x$
e	$0.4M - x \approx 0.4M$	-	x	x

$K_b = 2.5\times10^{-5} = \frac{x^2}{0.4}$ → pOH = 2.50

$x = 3.16\times10^{-3}M = [OH^-]$ → pH = 11.50

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

At midpt. pH = pKa = 9.40

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

	$HOCH_2CH_2NH_2$ +	HCl →	$HOCH_2CH_2NH_3^+$ +	Cl^-
start	20mL 0.4M	20mL 0.25M		
	8 mmol	5 mmol		
Δ	−5	−5	+5	
completion	3 mmol	∅ mmol	5 mmol	

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

D) W hat is the pH at the ***equivalence point***?

	$HOCH_2CH_2NH_2$ +	HCl →	$HOCH_2CH_2NH_3^+$ +	Cl^-
	20mL 0.4M	0.25M		
	8 mmol	8 mmol	∅	start
8 mmol HCl | 1L | 0.25 mol		32.0mL		
	∅ mmol	∅ mmol	$\frac{8\text{ mmol}}{52\text{ mL}} = 0.154M$	completion

= 32.0 mL HCl needed

	$HOCH_2CH_2NH_3^+$ +	H_2O ⇌	H_3O^+ +	$HOCH_2CH_2NH_2$
i	0.154 M		∅	∅
c	$-x$		$+x$	$+x$
e	$0.154 - x \approx 0.154$		x	x

$K_a = 4\times10^{-10} = \frac{x^2}{0.154}$

$x = 7.85\times10^{-6}M$

pH = 5.11

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

	$HOCH_2CH_2NH_2$ +	HCl →	$HOCH_2CH_2NH_3^+$ +	Cl^-
start	8 mmol	40×0.25 10 mmol	∅	
Δ	−8	−8	+8	
completion	∅	2 mmol	8 mmol	

$[H^+] = \frac{2\text{ mmol}}{60\text{ mL}} = 3.33\times10^{-2}$ $\quad pH = 1.48$

2. Ethylendiamine ($NH_2CH_2CH_2NH_2$) 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?

$NH_2CH_2CH_2NH_2 + 2HCl \xrightarrow{100\%} NH_3CH_2CH_2NH_3^{2+} + 2Cl^-$

25.0 mL 17.53 mL

M = ? 0.108 M

$$17.53\text{ mL HCl} \left| \frac{0.108\text{ mol HCl}}{1000\text{ mL}} \right| \frac{1\text{ mol Base}}{2\text{ mol HCl}} = 9.47\times10^{-4}\text{ mol}$$

$$\frac{9.47\times10^{-4}\text{ mol}}{0.025\text{ L}} = 0.0379\text{ M}$$

$[H_2NCH_2CH_2NH_2] = 0.0379\text{ M}$

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

mol of $H_3NCH_2CH_2NH_3^{2+} = 9.47\times10^{-4}$ mol

Total volume = 25.0 + 17.53 = 42.53 mL

$$[H_3NCH_2CH_2NH_3^{2+}] = \frac{9.47\times10^{-4}\text{ mol}}{0.04253\text{ L}} = 0.02226\text{ M}$$

$K_{b_2} = 2.7\times10^{-8}$ $K_{a_1} = \frac{10^{-14}}{K_{b_2}} = 3.7\times10^{-7}$

$H_3NCH_2CH_2NH_3^{2+} + H_2O \rightleftharpoons H_3NCH_2CH_2NH_3^{+} + H_3O^+$

i	0.0223 M	∅	∅
c	−x	+x	+x
e	0.0223 M − x	x	x

$$K_{a_1} = 3.7\times10^{-7} = \frac{x^2}{0.0223} \Rightarrow x = 9.1\times10^{-5}$$

pH = 4.04