AP® CHEMISTRY
2009 SCORING GUIDELINES (Form B)

Question 1 (10 points)

A pure 14.85 g sample of the weak base ethylamine, $C_2H_5NH_2$, is dissolved in enough distilled water to make 500. mL of solution.

(a) Calculate the molar concentration of the $C_2H_5NH_2$ in the solution.

$n_{C_2H_5NH_2} = 14.85\text{ g } C_2H_5NH_2 \times \frac{1\text{ mol } C_2H_5NH_2}{45.09\text{ g } C_2H_5NH_2}$ $= 0.3293\text{ mol } C_2H_5NH_2$ $M_{C_2H_5NH_2} = \frac{0.3293\text{ mol } C_2H_5NH_2}{0.500\text{ L}} = \mathbf{0.659\ \textit{M}}$	One point is earned for the correct number of moles. One point is earned for the correct concentration.

The aqueous ethylamine reacts with water according to the equation below.

$$C_2H_5NH_2(aq) + H_2O(l) \rightleftarrows C_2H_5NH_3^+(aq) + OH^-(aq)$$

(b) Write the equilibrium-constant expression for the reaction between $C_2H_5NH_2(aq)$ and water.

$K_b = \frac{[C_2H_5NH_3^+][OH^-]}{[C_2H_5NH_2]}$	One point is earned for the correct expression.

(c) Of $C_2H_5NH_2(aq)$ and $C_2H_5NH_3^+(aq)$, which is present in the solution at the higher concentration at equilibrium? Justify your answer.

$C_2H_5NH_2$ is present in the solution at the higher concentration at equilibrium. Ethylamine is a weak base, and thus it has a small K_b value. Therefore only partial dissociation of $C_2H_5NH_2$ occurs in water, and $[C_2H_5NH_3^+]$ is thus less than $[C_2H_5NH_2]$.	One point is earned for the correct answer with justification.

Question 1 (continued)

(d) A different solution is made by mixing 500. mL of 0.500 *M* $C_2H_5NH_2$ with 500. mL of 0.200 *M* HCl. Assume that volumes are additive. The pH of the resulting solution is found to be 10.93.

(i) Calculate the concentration of $OH^-(aq)$ in the solution.

$pH = -\log[H^+]$ $[H^+] = 10^{-10.93} = 1.17 \times 10^{-11}$ $[OH^-] = \frac{K_w}{[H^+]} = \frac{1.00 \times 10^{-14}}{1.17 \times 10^{-11}} = \mathbf{8.5 \times 10^{-4}\ M}$ **OR** $pOH = 14 - pH = 14 - 10.93 = 3.07$ $pOH = -\log[OH^-]$ $[OH^-] = 10^{-3.07} = \mathbf{8.5 \times 10^{-4}\ M}$	One point is earned for the correct concentration.

(ii) Write the net-ionic equation that represents the reaction that occurs when the $C_2H_5NH_2$ solution is mixed with the HCl solution.

$C_2H_5NH_2 + H_3O^+ \rightarrow C_2H_5NH_3^+ + H_2O$	One point is earned for the correct equation.

(iii) Calculate the molar concentration of the $C_2H_5NH_3^+(aq)$ that is formed in the reaction.

moles of $C_2H_5NH_2 = 0.500\ L \times \frac{0.500\ mol}{1.00\ L} = \mathbf{0.250\ mol}$ moles of $H_3O^+ = 0.500\ L \times \frac{0.200\ mol}{1.00\ L} = \mathbf{0.100\ mol}$	One point is earned for the correct number of moles of $C_2H_5NH_2$ and H_3O^+.

	$[C_2H_5NH_2]$	$[H_3O^+]$	$[C_2H_5NH_3^+]$
initial value	0.250	0.100	~ 0
change	−0.100	−0.100	+0.100
final value	0.150	~ 0	0.100

$[C_2H_5NH_3^+] = \frac{0.100\ mol\ C_2H_5NH_3^+}{1.00\ L} = \mathbf{0.100\ M}$	One point is earned for the correct concentration.

Question 1 (continued)

(iv) Calculate the value of K_b for $C_2H_5NH_2$.

$[C_2H_5NH_2] = \frac{0.150 \text{ mol } C_2H_5NH_2}{1.00 \text{ L}} = \mathbf{0.150\ \textit{M}}$	One point is earned for the correct calculation of the molarity of $C_2H_5NH_2$ after neutralization.
$K_b = \frac{[C_2H_5NH_3^+][OH^-]}{[C_2H_5NH_2]} = \frac{(0.100)(8.5 \times 10^{-4})}{0.150} = \mathbf{5.67 \times 10^{-4}}$	One point is earned for the correct value.