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.

$pH = -\log[H^+]$ $[H^+] = 10^{-10.93} = 1.17 \times 10^{-11}$ $[OH^-] = \dfrac{K_w}{[H^+]} = \dfrac{1.00 \times 10^{-14}}{1.17 \times 10^{-11}} =$ **8.5×10^{-4} *M*** **OR** $pOH = 14 - pH = 14 - 10.93 = 3.07$ $pOH = -\log[OH^-]$ $[OH^-] = 10^{-3.07} =$ **8.5×10^{-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 $C_2H_5NH_2 = 0.500\ L \times \dfrac{0.500\ mol}{1.00\ L} =$ **0.250 mol** moles of $H_3O^+ = 0.500\ L \times \dfrac{0.200\ mol}{1.00\ L} =$ **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

$[C_2H_5NH_3^+] = \dfrac{0.100\ mol\ C_2H_5NH_3^+}{1.00\ L} =$ **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.

ADDITIONAL PAGE FOR ANSWERING QUESTION 1

1 (a) $n = \frac{m}{M} = \frac{14.85}{(2\times12.01)+(7\times1.01)+(14.01)} = 0.32927$ mol

$[C_2H_5NH_2] = \frac{n}{V} = \frac{0.32927}{0.500} = 0.659$ M

(b) $K_{eq} = \frac{[OH^-][C_2H_5NH_3^+]}{[C_2H_5NH_2]}$

(c) Ethylamine ($C_2H_5NH_2$) is weak base. Therefore it does not fully dissociate in water and the equilibrium lies at the left side because $K_{eq} \ll 1$. Thus, $C_2H_5NH_2(aq)$ is present in the solution at a higher concentration than $C_2H_5NH_3^+(aq)$ at equilibrium.

(d) (i) pH = 10.93

$pOH = 14 - pH = 14 - 10.93 = 3.07$

$[OH^-] = 10^{-3.07} = 8.51\times10^{-4}$ M

(ii) $C_2H_5NH_2(aq) + H^+(aq) \rightarrow C_2H_5NH_3^+(aq)$

(iii) $n_{C_2H_5NH_2} = VM = (0.500)(0.500) = 0.250$ mol

$n_{HCl} = VM = (0.500)(0.200) = 0.100$ mol

$C_2H_5NH_2(aq)$	+ $H^+(aq)$	→ $C_2H_5NH_3^+(aq)$
0.250 mol	0.100 mol	0
− 0.100 mol	− 0.100 mol	+ 0.100
0.150 mol	0	0.100 mol

$[C_2H_5NH_3^+] = \frac{n}{V_T} = \frac{0.100}{1.00} = 0.100$ M

→

GO ON TO THE NEXT PAGE.

ADDITIONAL PAGE FOR ANSWERING QUESTION 1

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

0.150 M — 0.100 M 8.51×10^{-4} M

$$K_b = \frac{[C_2H_5NH_3^+][OH^-]}{[C_2H_5NH_2]}$$

$$K_b = \frac{(0.100)(8.51 \times 10^{-4})}{(0.150)} = 5.67 \times 10^{-4}$$

GO ON TO THE NEXT PAGE.

CHEMISTRY
Section II
(Total time—95 minutes)

Part A
Time—55 minutes
YOU MAY USE YOUR CALCULATOR FOR PART A.

CLEARLY SHOW THE METHOD USED AND THE STEPS INVOLVED IN ARRIVING AT YOUR ANSWERS. It is to your advantage to do this, since you may obtain partial credit if you do and you will receive little or no credit if you do not. Attention should be paid to significant figures.

Be sure to write all your answers to the questions on the lined pages following each question in this booklet. Do NOT write your answers on the lavender insert.

Answer Questions 1, 2, and 3. The Section II score weighting for each question is 20 percent.

1. 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.

   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.

   (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.

   (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.

   (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.

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

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

a) MM of $C_2H_5NH_2$ = $12 \times 2 + 1.008 \times 7 + 14.01 = 45.086$ g

number of moles: $14.85\text{ g } C_2H_5NH_2 \times \frac{1\text{ mole } C_2H_5NH_2}{45.086\text{ g } C_2H_5NH_2} = 3.04\text{ mole} \approx 3\text{ mole}$

Molarity = $\frac{n}{V} = \frac{3\text{ mole}}{0.5\text{ L}} = 6M$

ADDITIONAL PAGE FOR ANSWERING QUESTION 1

b) equilibrium constant: $K_{eq} = \frac{[C_2H_5NH_3^+][OH^-]}{[C_2H_5NH_2]}$

c) $[C_2H_5NH_2] < [C_2H_5NH_3^+]$ because $C_2H_5NH_3^+$ is weak acid and does not give up H^+ much like strong acids.

d) i) $pH + pOH = 14$

$10.93 + pOH = 14$

$pOH = 3.07$

$-\log[OH^-] = 3.07$

$[OH^-] = 10^{-3.07} = 8.511 \times 10^{-4}$

ii) $C_2H_5NH_{2(aq)} + HCl_{(aq)} \rightleftarrows C_2H_5NH_{3(aq)}^+ + Cl^-_{(aq)}$

iii) moles of $C_2H_5NH_2 = M \times L = 0.5M \times 0.5L = 0.25$ moles

moles of $HCl = 0.5L \times 0.2M = 0.1$ moles

Since $C_2H_5NH_2$ and HCl have same rate of mole consumption, HCl is limiting agent.

$C_2H_5NH_3^+$ has 0.1 mole through reaction.

$\text{Molarity} = \frac{n}{V} = \frac{0.1 \text{ mole}}{0.5L + 0.5L} = 0.1M$

iv) $K_b = \frac{K_w}{K_a}$

$K_a = \frac{[C_2H_5NH^+][Cl^-]}{[C_2H_5NH_2][HCl]} = \frac{(0.1)^2}{0.5 \times 0.2} = 0.1 = 10^{-1}$

$K_b = \frac{1 \times 10^{-14}}{1 \times 10^{-1}} = 10^{-13}$

GO ON TO THE NEXT PAGE.

ADDITIONAL PAGE FOR ANSWERING QUESTION 1

a) $\frac{14.85}{45.03} = 0.32$ moles.

$\frac{0.32}{1.500} \times \frac{800}{1} = 0.16$ m/L.

b) $K_c = \frac{[C_2H_5NH_3^+][OH^-]}{[C_2H_5NH_2][H_2O]}$

c) $C_2H_5NH_2$ has higher concentration because it is a weak alkali

d) (i). PH = 10.93

$= 14 - 10.93$

$= 3.07$

$OH = -3.07$

$OH^- = 1.83 \times 10^{-5}$

GO ON TO THE NEXT PAGE.

ADDITIONAL PAGE FOR ANSWERING QUESTION 1

(ii) $C_2H_5NH_2 + H^+ \longrightarrow C_2H_5NH_3^+$

(iii)

$C_2H_5NH_2$

$0.500 \times \frac{500}{1000} = 0.25$ m/L

HCl

$0.200 \times \frac{500}{1000} = 0.15$ m/L

$C_2H_5NH_2 = 0.40$

(iv)

$K_b = \frac{[C_2H_5NH_2][OH^-]}{[C_2H_5NH_3]}$

$[OH^-] = K_b \frac{[C_2H_5NH_2]}{[C_2H_5NH_3]}$

>

GO ON TO THE NEXT PAGE.

AP® CHEMISTRY
2009 SCORING COMMENTARY (Form B)

Question 1

Sample: 1A
Score: 10

This response earned all 10 points: 2 for part (a), 1 for part (b), 1 for part (c), 1 for part (d)(i), 1 for part (d)(ii), 2 for part (d)(iii), and 2 for part (d)(iv).

Sample: 1B
Score: 5

This response earned 5 of the possible 10 points. In part (a) only 1 of the 2 points was earned because of a math error (the answer is incorrect by a factor of 10). In part (b) 1 point was earned for the correct equilibrium expression. In part (c) the point was not earned because the justification is incorrect. In part (d)(i) 1 point was earned for the correct concentration of hydroxide ion (correct significant figures and units were not required on this question). The point was not earned for the equation in part (d)(ii) because the equation is not in net ionic form. In part (d)(iii) both points were earned—the first for the correct initial number of moles of $C_2H_5NH_2$ and H^+ and the second for the correct final concentration of $C_2H_5NH_3^+$. In part (d)(iv) neither point was earned for the substitution of incorrect concentrations into the wrong expression.

Sample: 1C
Score: 3

This response earned 3 of the possible 10 points. In part (a) 1 point was earned for the calculation of the correct number of moles. In part (b) the point was not earned because "H_2O" is included in the equilibrium expression. In part (c) 1 point was earned for stating that ethylamine would be present in a higher concentration "because it is a weak alkali." In part (d)(i) the point was not earned because a math error resulted in an incorrect value. In part (d)(ii) 1 point was earned for the correct net-ionic equation. In part (d)(iii) neither point was earned because both the initial concentration of H^+ and the final concentration of $C_2H_5NH_3^+$ are incorrect. In part (d)(iv) neither point was earned because there is no substitution of concentrations into a proper expression.