AP® Chemistry
2003 Sample Student Responses

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1A,

CHEMISTRY
Section II
(Total time—90 minutes)

Part A
Time—40 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 the booklet with the pink cover. Do NOT write your answers on the green insert.

Answer Question 1 below. The Section II score weighting for this question is 20 percent.

$$C_6H_5NH_2(aq) + H_2O(l) \rightleftarrows C_6H_5NH_3^+(aq) + OH^-(aq)$$

1. Aniline, a weak base, reacts with water according to the reaction represented above.

   (a) Write the equilibrium constant expression, K_b, for the reaction represented above.

   (b) A sample of aniline is dissolved in water to produce 25.0 mL of a 0.10 M solution. The pH of the solution is 8.82. Calculate the equilibrium constant, K_b, for this reaction.

   (c) The solution prepared in part (b) is titrated with 0.10 M HCl. Calculate the pH of the solution when 5.0 mL of the acid has been added.

   (d) Calculate the pH at the equivalence point of the titration in part (c).

   (e) The pK_a values for several indicators are given below. Which of the indicators listed is most suitable for this titration? Justify your answer.

Indicator	pK_a
Erythrosine	3
Litmus	7
Thymolphthalein	10

a) $K_b = \frac{[OH^-][C_6H_5NH_3^+]}{[C_6H_5NH_2]}$

b) .0250L × .10 M = .0025 mol aniline

pH = 8.82

pOH = 14 − 8.82

= 5.18

$[OH^-] = 6.607 \times 10^{-6}$ M

$K_b = \frac{[6.607 \times 10^{-6}][6.607 \times 10^{-6}]}{[.10]}$

$K_b = 4.37 \times 10^{-10}$

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c) $C_6H_5NH_2 + H^+ \longrightarrow C_6H_5NH_3^+$

$H^+ = .10M \times .005L = 5\times10^{-4}$

	$C_6H_5NH_2$	H^+	$C_6H_5NH_3^+$
i	.0025 mol	5×10^{-4} mol	0
c	-5×10^{-4} mol	-5×10^{-4} mol	$+5\times10^{-4}$ mol
e	.002 mol	0	5×10^{-4} mol

$K_a = 1.0\times10^{-14} / 4.37\times10^{-10} = 2.29\times10^{-5}$

$pH = pK_a + \log\left(\frac{A^-}{HA}\right)$

$pH = 4.64 + \log\left(\frac{.002}{5\times10^{-4}}\right)$

$pH = 5.24$

d) $C_6H_5NH_2 + H^+ \longrightarrow C_6H_5NH_3^+$

	$C_6H_5NH_2$	H^+	$C_6H_5NH_3^+$
	.0025 mol	.0025 mol	0
	-.0025	-.0025	+.0025
	0	0	.0025 mol

$\frac{.0025\text{ mol}}{25\text{ mL} + 25\text{ mL}} = .05M$

$C_6H_5NH_3^+ \longrightarrow C_6H_5NH_2 + H^+$

	$C_6H_5NH_3^+$	$C_6H_5NH_2$	H^+
i	.05M	0	0
c	-x	+x	+x
e	.05-x	x	x

$K_a = \frac{[C_6H_5NH_2][H^+]}{[C_6H_5NH_3^+]}$

$2.29\times10^{-5} = \frac{[x][x]}{[.05-x]}$

$1.145\times10^{-6} = x^2$

$.00107 = x = [H^+]$

$pH = 2.97$

e) Erythrosine is most suitable because it's pK_a is closest to the pH of the equivalence point of the titration.

1B,

CHEMISTRY
Section II
(Total time—90 minutes)

Part A
Time—40 minutes
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a) $K_b = \dfrac{[OH^-][C_6H_5NH_3^+]}{[C_6H_5NH_2]}$

GO ON TO THE NEXT PAGE.

ADDITIONAL PAGE FOR ANSWERING QUESTION 1.

b) $K_b = \frac{[OH^-][C_6H_5NH_3^+]}{[C_6H_5NH_2]}$ $[OH^-] = [C_6H_5NH_3^+]$

$K_b = \frac{[6.60\times10^{-6}]^2}{[\ 1\ ]}$

pH = 8.82

pOH = 5.18

$[OH^-] = 6.60\times10^{-6}$

$K_b = 4.35\times10^{-10}$

c)

$C_6H_5NH_2 + H^+ \rightleftharpoons C_6H_5NH_3$

.0025 mol.	5×10^{-4} mol.	0
-5×10^{-4}	-5×10^{-4} mol.	$+5\times10^{-4}$
.002	0	5×10^{-4}

$\frac{.002}{.03}$ $\frac{5\times10^{-4}}{.03}$

[.0667] [.0166]

$C_6H_5NH_2$ $C_6H_5NH_3$

henderson - hassbock eq. $\frac{1\times10^{-14}}{4.35\times10^{-10}} = K_a$.

$K_a = 2.29\times10^{-5}$.

$pH = pK_a + \log\left(\frac{b}{a}\right)$

$= -\log(2.29\times10^{-5}) + \log\left(\frac{.0667}{.0166}\right)$

pH = 5.24

d) @ equil p.

mols acid = mols base.

$(mL)(.1) = (.025)(.1)$

25 ml acid.

henderson- hassbock

pH = pka + 0 @ equil.

pH = 4.64

[base] = [acid]

$\frac{[base]}{[acid]} = 1$

log(1) = 0

e) The erythrosine indicator is the best because it is closest to the pH of 4.64, the pH of the solution's equil. point.

1C1

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   (c) The solution prepared in part (b) is titrated with 0.10 M HCl. Calculate the pH of the solution when 5.0 mL of the acid has been added. ✓

   (d) Calculate the pH at the equivalence point of the titration in part (c). ✓

   (e) The pK_a values for several indicators are given below. Which of the indicators listed is most suitable for this titration? Justify your answer. ✓

Indicator	pK_a
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Litmus	7
Thymolphthalein	10

(a) $K_b = \dfrac{[C_6H_5NH_3^+][OH^-]}{[C_6H_5NH_2]}$

→

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1C2

b) $.1 M/L \times .025 L = .0025$ moles aniline

$pH = 8.82 \rightarrow [H_3O^+] = 10^{-8.82} = 1.51 \times 10^{-9}$ moles/L H_3O^+

$pOH = 5.16 \rightarrow [OH^-] = 10^{-5.18} = 6.61 \times 10^{-6}$ moles/L OH^-

$6.61 \times 10^{-6} M \times .025 L = 1.65 \times 10^{-7}$ moles

$C_6H_5NH_2 + H_2O \rightleftharpoons C_6H_5NH_3^+ + OH^-$

.0025 moles		0	0
$-x$		$+x$	$+x$
.0025 moles		1.65×10^{-7} moles	1.65×10^{-7} moles

$x = 1.65 \times 10^{-7}$ moles

$K_b = \frac{(1.65 \times 10^{-7})^2}{.0025} = 1.09 \times 10^{-11}$

c) $.10 \text{ moles/L} \times .005 L = .0005$ moles HCl

$C_6H_5NH_2 + H_3O^+ \rightleftharpoons C_6H_5NH_3^+ + H_2O$

.0025 moles	.0005 moles	0	0
$-.0005$ moles	$-.0005$ moles	$+.0005$	$+.0005$
.0020 moles	.0005	.0005	

$C_6H_5NH_2 + H_2O \rightleftharpoons C_6H_5NH_3^+ + OH^-$

.0020	.0005	0
$-x$	$+x$	$+x$

$1.09 \times 10^{-11} = \frac{(.0005)(x)}{(.0020)}$

$[OH^-] = x = \frac{(1.09 \times 10^{-11})(.0020)}{.0005} = 4.37 \times 10^{-11}$

$pOH = -\log(4.37 \times 10^{-11}) = 10.36$

$14 - 10.36 = pH = 3.64$

d)

$pOH = pK_b = -\log(1.09 \times 10^{-11}) = 10.96$

$pH = 14 - 10.96 = 3.04$

e) Erythrosine would be the most appropriate indicator since the pH's are all coming out in the lower end of the pH scale near 3.

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