AP® CHEMISTRY
2011 SCORING GUIDELINES (Form B)

Question 5
(9 points)

A student is instructed to prepare 100.0 mL of 1.250 *M* NaOH from a stock solution of 5.000 *M* NaOH. The student follows the proper safety guidelines.

(a) Calculate the volume of 5.000 *M* NaOH needed to accurately prepare 100.0 mL of 1.250 *M* NaOH solution.

$M_1V_1 = M_2V_2$ $V_1 = \frac{M_2V_2}{M_1} = \frac{(1.250\ M)(100.0\ \text{mL})}{5.000\ M} = 25.00\ \text{mL}$	1 point is earned for the correct volume.

(b) Describe the steps in a procedure to prepare 100.0 mL of 1.250 *M* NaOH solution using 5.000 *M* NaOH and equipment selected from the list below.

Balance	25 mL Erlenmeyer flask	100 mL graduated cylinder	100 mL volumetric flask
50 mL buret	100 mL Florence flask	25 mL pipet	100 mL beaker
Eyedropper	Drying oven	Wash bottle of distilled H_2O	Crucible

Pipet 25.00 mL of 5.000 *M* NaOH solution into the 100 mL volumetric flask. Fill the volumetric flask to the calibration line with distilled water; using an eyedropper for the last few drops is advised. Cap the volumetric flask and invert several times to ensure homogeneity.	1 point is earned for descriptions of any <u>two</u> of the three steps. An additional point is earned if all <u>three</u> steps are described.

(c) The student is given 50.0 mL of a 1.00 *M* solution of a weak, monoprotic acid, HA. The solution is titrated with the 1.250 *M* NaOH to the endpoint. (Assume that the endpoint is at the equivalence point.)

(i) Explain why the solution is basic at the equivalence point of the titration. Include a chemical equation as part of your explanation.

When a weak acid is titrated with a strong base, the reaction forms water and the A^- ion. $HA + OH^- \rightleftarrows A^- + H_2O$ The A^- ion formed in the titration reacts with the solvent water to release OH^- ions, making the solution basic at the equivalence point. $A^- + H_2O \rightleftarrows HA + OH^-$	1 point is earned for either the correct equation or a clear statement that the conjugate base, A^-, is a (weak) base. 1 point is earned for indicating that the solution is basic because of the formation of OH^-.

Question 5 (continued)

(ii) Identify the indicator in the table below that would be best for the titration. Justify your choice.

Indicator	pK_a
Methyl red	5
Bromothymol blue	7
Phenolphthalein	9

Because the pH is basic at the equivalence point, it is best to use an indicator that changes color in basic solution. Therefore, phenolphthalein would be the best indicator for the titration.	1 point is earned for an answer consistent with the answer to part (c)(i) with justification.

(d) The student is given another 50.0 mL sample of 1.00 *M* HA, which the student adds to the solution that had been titrated to the endpoint in part (c). The result is a solution with a pH of 5.0.

(i) What is the value of the acid-dissociation constant, K_a, for the weak acid? Explain your reasoning.

The resulting solution is at the half-equivalence-point, where $[HA] = [A^-]$, thus pH = pK_a = 5.0 $\Rightarrow$ $K_a = 1 \times 10^{-5}$.	1 point is earned for showing that the system is at the half-equivalence point. 1 point is earned for the correct value of K_a.

(ii) Explain why the addition of a few drops of 1.250 *M* NaOH to the resulting solution does not appreciably change its pH.

The resulting solution is a buffer; therefore adding a few drops of acid or base does not appreciably change the pH.	1 point is earned for indicating that the solution is a buffer.

Answer Question 5 and Question 6. The Section II score weighting for these questions is 15 percent each.

Your responses to these questions will be scored on the basis of the accuracy and relevance of the information cited. Explanations should be clear and well organized. Examples and equations may be included in your responses where appropriate. Specific answers are preferable to broad, diffuse responses.

5. A student is instructed to prepare 100.0 mL of 1.250 *M* NaOH from a stock solution of 5.000 *M* NaOH. The student follows the proper safety guidelines.

   (a) Calculate the volume of 5.000 *M* NaOH needed to accurately prepare 100.0 mL of 1.250 *M* NaOH solution.

   (b) Describe the steps in a procedure to prepare 100.0 mL of 1.250 *M* NaOH solution using 5.000 *M* NaOH and equipment selected from the list below.

Balance	25 mL Erlenmeyer flask	100 mL graduated cylinder	100 mL volumetric flask
50 mL buret	100 mL Florence flask	25 mL pipet	100 mL beaker
Eyedropper	Drying oven	Wash bottle of distilled H_2O	Crucible

   (c) The student is given 50.0 mL of a 1.00 *M* solution of a weak, monoprotic acid, HA. The solution is titrated with the 1.250 *M* NaOH to the endpoint. (Assume that the endpoint is at the equivalence point.)

      (i) Explain why the solution is basic at the equivalence point of the titration. Include a chemical equation as part of your explanation.

      (ii) Identify the indicator in the table below that would be best for the titration. Justify your choice.

Indicator	pK_a
Methyl red	5
Bromothymol blue	7
Phenolphthalein	9

   (d) The student is given another 50.0 mL sample of 1.00 *M* HA, which the student adds to the solution that had been titrated to the endpoint in part (c). The result is a solution with a pH of 5.0.

      (i) What is the value of the acid-dissociation constant, K_a, for the weak acid? Explain your reasoning.

      (ii) Explain why the addition of a few drops of 1.250 *M* NaOH to the resulting solution does not appreciably change its pH.

5a) ~~5.000M × 0.100L = 0.5000 mol~~ 1.250M × 0.100L = 0.125mol

0.125mol ÷ 5.000 mol/L = 0.025L = ~~25mL~~ 25.00mL

5b) Using a ~~pipet~~ 25mL pipet, rinsed with 5.000M NaOH, pipet 25 mL of 5.000 NaOH into ~~the~~ a ~~dry~~ 100mL volumetric flask. Next, top up the volumetric flask with ~~the~~ distilled water ~~until~~ to the 100mL mark. Cap the volumetric flask tightly and ~~shake~~ mix well.

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ADDITIONAL PAGE FOR ANSWERING QUESTION 5

5c) i) $HA + OH^- \longrightarrow H_2O + A^-$

Since A^- is the conjugate base of a weak acid, A^- will react with water

$A^- + H_2O \rightleftharpoons HA + OH^-$.

Since there is OH^- present, the solution is basic at equivalence point.

5c) ii) Phenolphthalein. Phenolphthalein is pink in basic solution. Since the solution is basic at equivalence point, a persistent light pink color in the solution will indicate the endpoint.

5d) i) Since there are equal amounts of HA and A^- in the solution, $\frac{[A^-]}{[HA]} = 1$

$pH = pK_a + \log \frac{[A^-]}{[HA]}$

Since there are equal amounts of HA and A^- in the solution, $\frac{[A^-]}{[HA]} = 1$ and $\log 1 = 0$

Hence $pH = pK_a$ and the value of Ka is $10^{-5.0}$

5d) ii) The solution is a buffer.

OH^- will react with HA to get A^-. Since there is more A^- in the solution, the equilibrium $A^- + H_2O \rightleftharpoons OH^- + HA$ will shift to the right to form HA again. Hence the solution does not appreciably change its pH.

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5B

ADDITIONAL PAGE FOR ANSWERING QUESTION 5

a) $5.000 \times V = 1.250 \times 0.1$

$\therefore V = 0.025L = 25mL$

b) ~~Use 25mL pipet to get 5.000M NaOH and gather that at 100mL volumetric flask. Use eye dropper to fill 100mL volumetric flask. by water.~~

distilled H_2O in wash bottle a little

c) 1) in equivalence point. A⁻(weak base) is remain so solution is basic.

ii) ~~Methyl red~~. Phenolphthalein.

d) i) 1.00M HA 100mL.

1.250M NaOH ◯ = half of HA,

$pH = pKa + \log \frac{[A^-]}{[HA]} = pKa + \log \frac{[OH^-]}{[HA]-[OH^-]} = pKa + \log 1 = pKa = 5.0$

$\therefore Ka = 1.0 \times 10^{-5}$

ii) solution is buffer solution when NaOH is added it react with HA and it formate weak base A^- so. pH ~~is~~ change a little.

b) Get 5.000M NaOH to use 25mL pipet
Gather that at 100mL volumetric flask.
To use. Wash bottle fill H_2O in 100mL volumetric flask but not full fill
last. using eyedropper to fill H_2O in volumetric flask full,

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Answer Question 5 and Question 6. The Section II score weighting for these questions is 15 percent each.

Your responses to these questions will be scored on the basis of the accuracy and relevance of the information cited. Explanations should be clear and well organized. Examples and equations may be included in your responses where appropriate. Specific answers are preferable to broad, diffuse responses.

5. A student is instructed to prepare 100.0 mL of 1.250 *M* NaOH from a stock solution of 5.000 *M* NaOH. The student follows the proper safety guidelines.

   (a) Calculate the volume of 5.000 *M* NaOH needed to accurately prepare 100.0 mL of 1.250 *M* NaOH solution.

   (b) Describe the steps in a procedure to prepare 100.0 mL of 1.250 *M* NaOH solution using 5.000 *M* NaOH and equipment selected from the list below.

Balance	25 mL Erlenmeyer flask	100 mL graduated cylinder	100 mL volumetric flask
50 mL buret	100 mL Florence flask	25 mL pipet	100 mL beaker
Eyedropper	Drying oven	Wash bottle of distilled H_2O	Crucible

   (c) The student is given 50.0 mL of a 1.00 *M* solution of a weak, monoprotic acid, HA. The solution is titrated with the 1.250 *M* NaOH to the endpoint. (Assume that the endpoint is at the equivalence point.)

      (i) Explain why the solution is basic at the equivalence point of the titration. Include a chemical equation as part of your explanation.

      (ii) Identify the indicator in the table below that would be best for the titration. Justify your choice.

Indicator	pK_a
Methyl red	5
Bromothymol blue	7
Phenolphthalein	9

   (d) The student is given another 50.0 mL sample of 1.00 *M* HA, which the student adds to the solution that had been titrated to the endpoint in part (c). The result is a solution with a pH of 5.0.

      (i) What is the value of the acid-dissociation constant, K_a, for the weak acid? Explain your reasoning.

      (ii) Explain why the addition of a few drops of 1.250 *M* NaOH to the resulting solution does not appreciably change its pH.

c) $\frac{1.250\ mol}{1000\ mL} = \frac{0.1250\ mol}{100\ mL}$ $\quad \frac{5.000\ mol}{1000\ mL} = \frac{0.1250}{x\ mL}$ $\quad x = 25\ mL$

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ADDITIONAL PAGE FOR ANSWERING QUESTION 5

b) 1- measure 25 mL of 5.000 M NaOH solution using a 25 mL pipet and put it in a 100 mL volumetric flask.

2- Fill the volumetric flask to the half with distilled water using the wash bottle of distilled H_2O and swirl the mixture in the volumetric flask.

3- Fill the rest of the volumetric flask until the 100 mL line with distilled water and swirl again.

c) i) because even when there are equals moles of NaOH and weak acid, the weak acid is not completely dissolve but NaOH is so there are more OH^- ions than the one that react with H^+.

$$NaOH + HA = H_2O + OH^- + A^+$$

ii) methyl red because it changes when the pH is basic.

d) i) $K_a = \frac{[H^+][A^-]}{[HA]}$ $\quad K_a = \frac{1\times10^{-5} \cdot 1\times10^{-5}}{1.00}$

$$K_a = 1\times10^{-10}$$

ii) because a buffer solution was formed between $HA \rightleftharpoons H^+ A^-$ that goes back and forth and make the pH more stable.

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AP® CHEMISTRY
2011 SCORING COMMENTARY (Form B)

Question 5

Sample: 5A
Score: 9

This response earned all 9 available points. Part (a) earned 1 point for calculating the correct volume of the concentrated aqueous NaOH solution needed, 25.00 mL. Part (b) earned 2 points for showing that a 25 mL pipet and a 100 mL volumetric flask were needed, that the volumetric flask should be filled to the 100 mL mark, and that the final solution should be mixed well. Part (c)(i) earned 2 points: 1 point for showing the generation of the A^- ion during the titration, and 1 point for showing the hydrolysis of A^- to generate OH^- ions. Part (c)(ii) earned 1 point for showing that the phenolphthalein is preferred because it changes color in the pH region near the equivalence point. Part (d)(i) earned 2 points: 1 point for showing that under the described conditions [HA] = [A^-] so that the pH = pK_a and the correct value of the K_a is calculated. Part (d)(ii) earned 1 point for the description of the buffer solution formed under these conditions.

Sample: 5B
Score: 6

Part (b) earned 1 of the 2 possible points for showing that a 25 mL pipet and a 100 mL volumetric flask were needed and that the volume of the final solution was 100 mL, but the response does not refer to the need to mix the final solution well so it did not earn the second point. Part (c)(i) earned 1 of 2 points for correctly pointing to the generation of the A^- ion in the titration. The second point was not earned because the response does not indicate why that ion would lead to a basic solution (the hydrolysis reaction). Part (c)(ii) did not earn the point because the student neglects to justify the choice of phenolphthalein as the indicator.

Sample: 5C
Score: 4

No points were earned in part (c)(i) for an inadequate explanation and an incorrect equation. Part (c)(ii) did not earn the point for the choice of the wrong indicator. No points were earned in part (d)(i) as the approach and final answer are incorrect.