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 goldenrod booklet. Do NOT write your answers on the lavender insert.

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

$$C_6H_5COOH(s) \rightleftarrows C_6H_5COO^-(aq) + H^+(aq) \qquad K_a = 6.46 \times 10^{-5}$$

1. Benzoic acid, C_6H_5COOH, dissociates in water as shown in the equation above. A 25.0 mL sample of an aqueous solution of pure benzoic acid is titrated using standardized 0.150 *M* NaOH.

   (a) After addition of 15.0 mL of the 0.150 *M* NaOH, the pH of the resulting solution is 4.37. Calculate each of the following.

   (i) $[H^+]$ in the solution

   (ii) $[OH^-]$ in the solution

   (iii) The number of moles of NaOH added

   (iv) The number of moles of $C_6H_5COO^-(aq)$ in the solution

   (v) The number of moles of C_6H_5COOH in the solution

   (b) State whether the solution at the equivalence point of the titration is acidic, basic, or neutral. Explain your reasoning.

   In a different titration, a 0.7529 g sample of a mixture of solid C_6H_5COOH and solid NaCl is dissolved in water and titrated with 0.150 *M* NaOH. The equivalence point is reached when 24.78 mL of the base solution is added.

   (c) Calculate each of the following.

   (i) The mass, in grams, of benzoic acid in the solid sample

   (ii) The mass percentage of benzoic acid in the solid sample

CHEMISTRY

Section II

(Total time—95 minutes)

Part A

Time—55 minutes

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

$$HF(aq) + H_2O(l) \rightleftarrows H_3O^+(aq) + F^-(aq) \qquad K_a = 7.2 \times 10^{-4}$$

1. Hydrofluoric acid, $HF(aq)$, dissociates in water as represented by the equation above.

   (a) Write the equilibrium-constant expression for the dissociation of $HF(aq)$ in water.

   (b) Calculate the molar concentration of H_3O^+ in a 0.40 M $HF(aq)$ solution.

   $HF(aq)$ reacts with $NaOH(aq)$ according to the reaction represented below.

   $$HF(aq) + OH^-(aq) \rightarrow H_2O(l) + F^-(aq)$$

   A volume of 15 mL of 0.40 M $NaOH(aq)$ is added to 25 mL of 0.40 M $HF(aq)$ solution. Assume that volumes are additive.

   (c) Calculate the number of moles of $HF(aq)$ remaining in the solution.

   (d) Calculate the molar concentration of $F^-(aq)$ in the solution.

   (e) Calculate the pH of the solution.

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1. Answer the following questions that relate to the chemistry of halogen oxoacids.

   (a) Use the information in the table below to answer part (a)(i).

Acid	K_a at 298 K
HOCl	2.9×10^{-8}
HOBr	2.4×10^{-9}

   (i) Which of the two acids is stronger, HOCl or HOBr ? Justify your answer in terms of K_a.

   (ii) Draw a complete Lewis electron-dot diagram for the acid that you identified in part (a)(i).

   (iii) Hypoiodous acid has the formula HOI. Predict whether HOI is a stronger acid or a weaker acid than the acid that you identified in part (a)(i). Justify your prediction in terms of chemical bonding.

   (b) Write the equation for the reaction that occurs between hypochlorous acid and water.

   (c) A 1.2 M NaOCl solution is prepared by dissolving solid NaOCl in distilled water at 298 K. The hydrolysis reaction $OCl^-(aq) + H_2O(l) \rightleftarrows HOCl(aq) + OH^-(aq)$ occurs.

   (i) Write the equilibrium-constant expression for the hydrolysis reaction that occurs between $OCl^-(aq)$ and $H_2O(l)$.

   (ii) Calculate the value of the equilibrium constant at 298 K for the hydrolysis reaction.

   (iii) Calculate the value of $[OH^-]$ in the 1.2 M NaOCl solution at 298 K.

GO ON TO THE NEXT PAGE.

(d) A buffer solution is prepared by dissolving some solid NaOCl in a solution of HOCl at 298 K. The pH of the buffer solution is determined to be 6.48.

(i) Calculate the value of $[H_3O^+]$ in the buffer solution.

(ii) Indicate which of $HOCl(aq)$ or $OCl^-(aq)$ is present at the higher concentration in the buffer solution. Support your answer with a calculation.

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2. A student was assigned the task of determining the molar mass of an unknown gas. The student measured the mass of a sealed 843 mL rigid flask that contained dry air. The student then flushed the flask with the unknown gas, resealed it, and measured the mass again. Both the air and the unknown gas were at 23.0°C and 750. torr. The data for the experiment are shown in the table below.

Volume of sealed flask	843 mL
Mass of sealed flask and dry air	157.70 g
Mass of sealed flask and unknown gas	158.08 g

(a) Calculate the mass, in grams, of the dry air that was in the sealed flask. (The density of dry air is 1.18 g L^{-1} at 23.0°C and 750. torr.)

(b) Calculate the mass, in grams, of the sealed flask itself (i.e., if it had no air in it).

(c) Calculate the mass, in grams, of the unknown gas that was added to the sealed flask.

(d) Using the information above, calculate the value of the molar mass of the unknown gas.

After the experiment was completed, the instructor informed the student that the unknown gas was carbon dioxide (44.0 g mol^{-1}).

(e) Calculate the percent error in the value of the molar mass calculated in part (d).

(f) For each of the following two possible occurrences, indicate whether it by itself could have been responsible for the error in the student's experimental result. You need not include any calculations with your answer. For each of the possible occurrences, justify your answer.

Occurrence 1: The flask was incompletely flushed with $CO_2(g)$, resulting in some dry air remaining in the flask.

Occurrence 2: The temperature of the air was 23.0°C, but the temperature of the $CO_2(g)$ was lower than the reported 23.0°C.

(g) Describe the steps of a laboratory method that the student could use to verify that the volume of the rigid flask is 843 mL at 23.0°C. You need not include any calculations with your answer.

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Section II
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Part A
Time—55 minutes
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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 $C_2H_5NH_2$.

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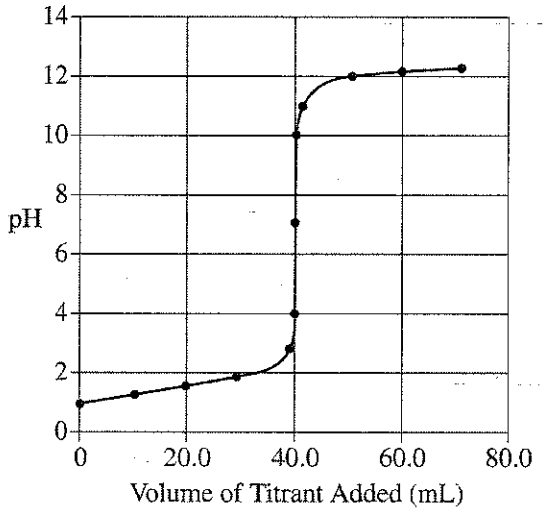
Answer Question 5 and Question 6. The Section II score weighting for these questions is 15 percent each.

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 solution of 0.100 *M* HCl and a solution of 0.100 *M* NaOH are prepared. A 40.0 mL sample of one of the solutions is added to a beaker and then titrated with the other solution. A pH electrode is used to obtain the data that are plotted in the titration curve shown above.

   (a) Identify the solution that was initially added to the beaker. Explain your reasoning.

   (b) On the titration curve above, circle the point that corresponds to the equivalence point.

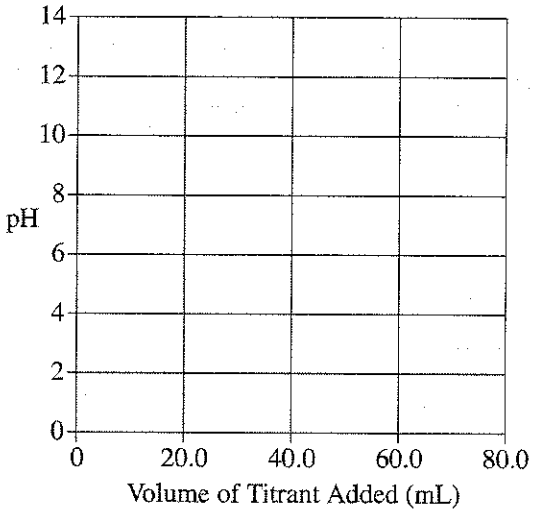
   (c) At the equivalence point, how many moles of titrant have been added?

   (d) The same titration is to be performed again, this time using an indicator. Use the information in the table below to select the best indicator for the titration. Explain your choice.

Indicator	pH Range of Color Change
Methyl violet	0 – 1.6
Methyl red	4 – 6
Alizarin yellow	10 – 12

   (e) What is the difference between the equivalence point of a titration and the end point of a titration?

   (f) On the grid provided on the next page, sketch the titration curve that would result if the solutions in the beaker and buret were reversed (i.e., if 40.0 mL of the solution used in the buret in the previous titration were titrated with the solution that was in the beaker).



CHEMISTRY

Section II

(Total time—95 minutes)

Part A

Time—55 minutes

YOU MAY USE YOUR CALCULATOR FOR PART A.

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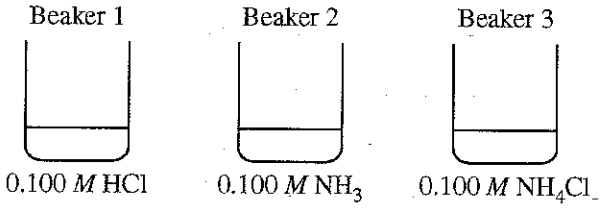

1. Each of three beakers contains 25.0 mL of a 0.100 *M* solution of HCl, NH_3, or NH_4Cl, as shown above. Each solution is at 25°C.

   (a) Determine the pH of the solution in beaker 1. Justify your answer.

   (b) In beaker 2, the reaction $NH_3(aq) + H_2O(l) \rightleftarrows NH_4^+(aq) + OH^-(aq)$ occurs. The value of K_b for $NH_3(aq)$ is 1.8×10^{-5} at 25°C.

   (i) Write the K_b expression for the reaction of $NH_3(aq)$ with $H_2O(l)$.

   (ii) Calculate the $[OH^-]$ in the solution in beaker 2.

   (c) In beaker 3, the reaction $NH_4^+(aq) + H_2O(l) \rightleftarrows NH_3(aq) + H_3O^+(aq)$ occurs.

   (i) Calculate the value of K_a for $NH_4^+(aq)$ at 25°C.

   (ii) The contents of beaker 2 are poured into beaker 3 and the resulting solution is stirred. Assume that volumes are additive. Calculate the pH of the resulting solution.

   (d) The contents of beaker 1 are poured into the solution made in part (c)(ii). The resulting solution is stirred. Assume that volumes are additive.

   (i) Is the resulting solution an effective buffer? Justify your answer.

   (ii) Calculate the final $[NH_4^+]$ in the resulting solution at 25°C.

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.

CHEMISTRY

Section II

(Total time—95 minutes)

Part A

Time—55 minutes

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

1. A 1.22 g sample of a pure monoprotic acid, HA, was dissolved in distilled water. The HA solution was then titrated with 0.250 *M* NaOH. The pH was measured throughout the titration, and the equivalence point was reached when 40.0 mL of the NaOH solution had been added. The data from the titration are recorded in the table below.

Volume of 0.250 *M* NaOH Added (mL)	pH of Titrated Solution
0.00	?
10.0	3.72
20.0	4.20
30.0	?
40.0	8.62
50.0	12.40

(a) Explain how the data in the table above provide evidence that HA is a weak acid rather than a strong acid.

(b) Write the balanced net-ionic equation for the reaction that occurs when the solution of NaOH is added to the solution of HA.

(c) Calculate the number of moles of HA that were titrated.

(d) Calculate the molar mass of HA.

The equation for the dissociation reaction of HA in water is shown below.

$$HA(aq) + H_2O(l) \rightleftarrows H_3O^+(aq) + A^-(aq) \qquad K_a = 6.3 \times 10^{-5}$$

(e) Assume that the initial concentration of the HA solution (before any NaOH solution was added) is 0.200 *M*. Determine the pH of the initial HA solution.

(f) Calculate the value of $[H_3O^+]$ in the solution after 30.0 mL of NaOH solution is added and the total volume of the solution is 80.0 mL.