CHEMISTRY

Section II

7 Questions

Time—1 hour and 45 minutes

YOU MAY USE YOUR CALCULATOR FOR THIS SECTION.

Directions: Questions 1–3 are long free-response questions that require about 23 minutes each to answer and are worth 10 points each. Questions 4–7 are short free-response questions that require about 9 minutes each to answer and are worth 4 points each.

Write your response in the space provided following each question. Examples and equations may be included in your responses where appropriate. For calculations, clearly show the method used and the steps involved in arriving at your answers. You must show your work to receive credit for your answer. Pay attention to significant figures.

$$HC_2H_3O_2(aq) + H_2O(l) \rightleftarrows H_3O^+(aq) + C_2H_3O_2^-(aq)$$

1. The dissociation of ethanoic acid, $HC_2H_3O_2(aq)$, is represented above. A student is given the task of determining the value of K_a for $HC_2H_3O_2(aq)$ using two different experimental procedures.

   (a) The student is first asked to prepare 100.0 mL of 0.115 M $HC_2H_3O_2(aq)$ using a 2.000 M standard solution.

   (i) Calculate the volume, in mL, of 2.000 M $HC_2H_3O_2(aq)$ the student needs to prepare 100.0 mL of 0.115 M $HC_2H_3O_2(aq)$.

   (ii) Describe the procedure the student should use to prepare 100.0 mL of 0.115 M $HC_2H_3O_2(aq)$ using appropriate equipment selected from the list below. Assume that the student uses appropriate safety equipment.

   - 100 mL beaker
   - 100 mL graduated cylinder
   - 100 mL volumetric flask
   - Eye dropper
   - 500 mL wash bottle filled with distilled water
   - 2.000 M $HC_2H_3O_2(aq)$ in a 50 mL buret

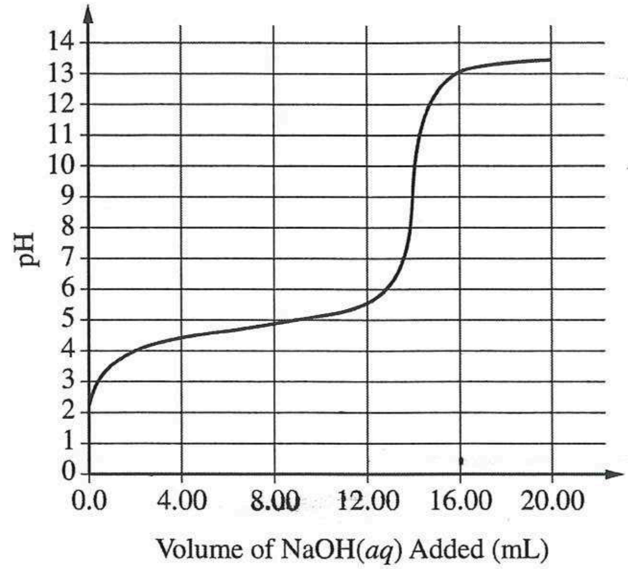
   (b) Using a pH probe, the student determines that the pH of 0.115 M $HC_2H_3O_2(aq)$ is 2.92.

   (i) Using the pH value, calculate the value of K_a for $HC_2H_3O_2(aq)$.

   (ii) Calculate the percent dissociation of ethanoic acid in 0.115 M $HC_2H_3O_2(aq)$.

In a separate experimental procedure, the student titrates 10.0 mL of the 2.000 M $HC_2H_3O_2(aq)$ with an $NaOH(aq)$ solution of unknown concentration. The student monitors the pH during the titration. The following titration curve was created using the experimental data presented in the table.

Volume of NaOH(aq) Added (mL)	pH
0.00	2.23
2.00	3.99
4.00	4.37
6.00	4.65
8.00	4.90
10.00	5.17
12.00	5.55
14.00	9.35
16.00	13.04
18.00	13.31
20.00	13.46



(c) Write the balanced net ionic equation for the reaction that occurs when $HC_2H_3O_2(aq)$ and $NaOH(aq)$ are combined.

(d) Calculate the molar concentration of the $NaOH(aq)$ solution.

(e) Explain how the student can estimate the value of K_a for $HC_2H_3O_2(aq)$ using the titration curve.

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4. A student is doing experiments with $CO_2(g)$. Originally, a sample of the gas is in a rigid container at 299 K and 0.70 atm. The student increases the temperature of the $CO_2(g)$ in the container to 425 K.

   (a) Describe the effect of raising the temperature on the motion of the $CO_2(g)$ molecules.

   (b) Calculate the pressure of the $CO_2(g)$ in the container at 425 K.

   (c) In terms of kinetic molecular theory, briefly explain why the pressure of the $CO_2(g)$ in the container changes as it is heated to 425 K.

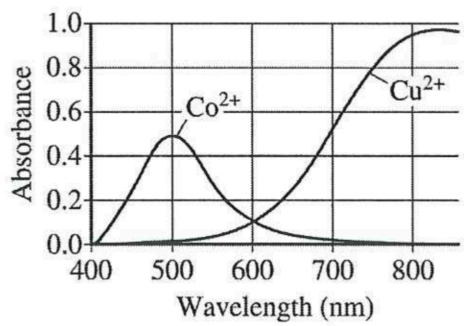
   (d) The student measures the actual pressure of the $CO_2(g)$ in the container at 425 K and observes that it is less than the pressure predicted by the ideal gas law. Explain this observation.

7. A student has 100. mL of 0.400 M $CuSO_4(aq)$ and is asked to make 100. mL of 0.150 M $CuSO_4(aq)$ for a spectrophotometry experiment. The following laboratory equipment is available for preparing the solution: centigram balance, weighing paper, funnel, 10 mL beaker, 150 mL beaker, 50 mL graduated cylinder, 100 mL volumetric flask, 50 mL buret, and distilled water.

   (a) Calculate the volume of 0.400 M $CuSO_4(aq)$ required for the preparation.

   (b) Briefly describe the essential steps to most accurately prepare the 0.150 M $CuSO_4(aq)$ from the 0.400 M $CuSO_4(aq)$ using the equipment listed above.

   The student plans to conduct a spectrophotometric analysis to determine the concentration of $Cu^{2+}(aq)$ in a solution. The solution has a small amount of $Co(NO_3)_2(aq)$ present as a contaminant. The student is given the diagram below, which shows the absorbance curves for aqueous solutions of $Co^{2+}(aq)$ and $Cu^{2+}(aq)$.



   (c) The spectrophotometer available to the student has a wavelength range of 400 nm to 700 nm. What wavelength should the student use to minimize the interference from the presence of the $Co^{2+}(aq)$ ions?

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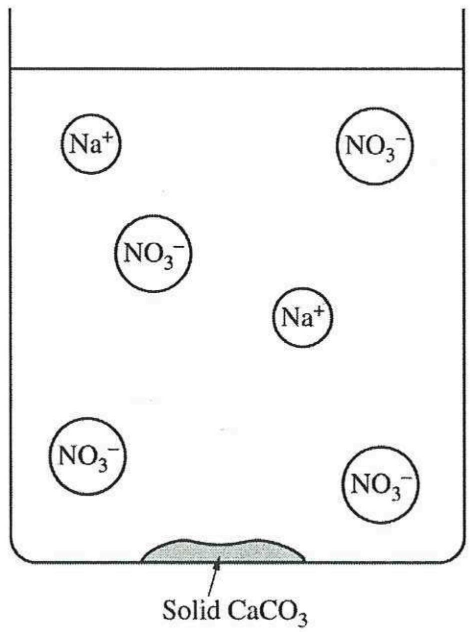
3. A student is given 50.0 mL of a solution of Na_2CO_3 of unknown concentration. To determine the concentration of the solution, the student mixes the solution with excess 1.0 *M* $Ca(NO_3)_2(aq)$, causing a precipitate to form. The balanced equation for the reaction is shown below.

$$Na_2CO_3(aq) + Ca(NO_3)_2(aq) \rightarrow 2\ NaNO_3(aq) + CaCO_3(s)$$

(a) Write the net ionic equation for the reaction that occurs when the solutions of Na_2CO_3 and $Ca(NO_3)_2$ are mixed.

(b) The diagram below is incomplete. Draw in the species needed to accurately represent the major ionic species remaining in the solution after the reaction has been completed.



The student filters and dries the precipitate of $CaCO_3$ (molar mass 100.1 g/mol) and records the data in the table below.

Volume of Na_2CO_3 solution	50.0 mL
Volume of 1.0 *M* $Ca(NO_3)_2$ added	100.0 mL
Mass of $CaCO_3$ precipitate collected	0.93 g

(c) Determine the number of moles of Na_2CO_3 in the original 50.0 mL of solution.

(d) The student realizes that the precipitate was not completely dried and claims that as a result, the calculated Na_2CO_3 molarity is too low. Do you agree with the student's claim? Justify your answer.

(e) After the precipitate forms and is filtered, the liquid that passed through the filter is tested to see if it can conduct electricity. What would be observed? Justify your answer.

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The student decides to determine the molarity of the same Na_2CO_3 solution using a second method. When Na_2CO_3 is dissolved in water, $CO_3^{2-}(aq)$ hydrolyzes to form $HCO_3^-(aq)$, as shown by the following equation.

$$CO_3^{2-}(aq) + H_2O(l) \rightleftarrows HCO_3^-(aq) + OH^-(aq) \qquad K_b = \frac{[HCO_3^-][OH^-]}{[CO_3^{2-}]} = 2.1 \times 10^{-4}$$

(f) The student decides to first determine $[OH^-]$ in the solution, then use that result to calculate the initial concentration of $CO_3^{2-}(aq)$.

(i) Identify a laboratory method (not titration) that the student could use to collect data to determine $[OH^-]$ in the solution.

(ii) Explain how the student could use the measured value in part (f)(i) to calculate the <u>initial</u> concentration of $CO_3^{2-}(aq)$. (Do not do any numerical calculations.)

(g) In the original Na_2CO_3 solution at equilibrium, is the concentration of $HCO_3^-(aq)$ greater than, less than, or equal to the concentration of $CO_3^{2-}(aq)$? Justify your answer.

(h) The student needs to make a CO_3^{2-}/HCO_3^- buffer. Is the Na_2CO_3 solution suitable for making a buffer with a pH of 6? Explain why or why not.