Question 5

5. Three pure, solid compounds labeled X, Y, and Z are placed on a lab bench with the objective of identifying each one. It is known that the compounds (listed in random order) are KCl, Na_2CO_3, and $MgSO_4$. A student performs several tests on the compounds; the results are summarized in the table below.

Compound	pH of an Aqueous Solution of the Compound	Result of Adding 1.0 M NaOH to a Solution of the Compound	Result of Adding 1.0 M HCl Dropwise to the Solid Compound
X	> 7	No observed reaction	Evolution of a gas
Y	7	No observed reaction	No observed reaction
Z	7	Formation of a white precipitate	No observed reaction

(a) Identify each compound based on the observations recorded in the table.

Compound X _____ Na_2CO_3 _____

Compound Y _____ KCl _____

Compound Z _____ $MgSO_4$ _____

One point is earned for one correct identification, and a second point is earned for a second correct identification. (No points are earned if all three identifications are the same compound; no second point is earned if two identifications are the same compound.)

(b) Write the chemical formula for the precipitate produced when 1.0 M NaOH is added to a solution of compound Z.

$Mg(OH)_2$	One point is earned for the correct formula.

(c) Explain why an aqueous solution of compound X has a pH value greater than 7. Write an equation as part of your explanation.

CO_3^{2-} reacts with water to form OH^-. $CO_3^{2-}(aq) + H_2O(l) \rightarrow OH^-(aq) + HCO_3^-(aq)$	One point is earned for identifying CO_3^{2-} as a base. One point is earned for a correct equation.

Question 5 (continued)

(d) One of the testing solutions used was 1.0 *M* NaOH. Describe the steps for preparing 100. mL of 1.0 *M* NaOH from a stock solution of 3.0 *M* NaOH using a 50 mL buret, a 100 mL volumetric flask, distilled water, and a small dropper.

1,000 mL of 1.0 *M* NaOH contains 1.0 mol NaOH; therefore, 100. mL of 1.0 *M* NaOH contains 0.10 mol NaOH (i.e., 0.10 mol NaOH is needed for the solution) volume of 3.0 *M* NaOH needed $= 0.10 \text{ mol NaOH} \times \frac{1{,}000 \text{ mL}}{3.0 \text{ mol NaOH}}$ $= 33 \text{ mL}$ Step 1: Use the buret to deliver 33 mL of the 3.0 *M* NaOH stock solution into the clean 100 mL volumetric flask. Step 2: Add distilled water to the flask until the liquid level is just below the calibration line in the neck of the flask; swirl gently to mix. Step 3: Use the small dropper to add the last amount of distilled water, drop by drop, until the bottom of the meniscus in the flask neck is level with the calibration line. Insert the stopper, and invert the flask to mix.	One point is earned for using the buret to dispense 33 mL of NaOH(*aq*). One point is earned for adding distilled water to the calibration mark.

(e) Describe a simple laboratory test that you could use to distinguish between $Na_2CO_3(s)$ and $CaCO_3(s)$. In your description, specify how the results of the test would enable you to determine which compound was $Na_2CO_3(s)$ and which compound was $CaCO_3(s)$.

A water solubility test would work. Put a small amount of one substance in a beaker of distilled water. If the substance dissolves readily when stirred, then it is Na_2CO_3; if it does not dissolve, it is $CaCO_3$. **OR** A flame test would work. Dip a moistened wire into a sample of one of the substances and place the wire in the flame of a bunsen burner. If a bright orange-yellow color is observed, then the sample is Na_2CO_3; if a brick red color is observed, it is $CaCO_3$. Note: The student does NOT have to perform a confirmatory test on the other substance if one has already been identified with a test.	One point is earned for any reasonable test. One point is earned for interpreting the results that will identify one compound.

ADDITIONAL PAGE FOR ANSWERING QUESTION 5.

a) Compound X $NaCO_3$
Compound Y KCl
Compound Z $MgSO_4$

b) $Mg^{2+} + 2OH^- \rightarrow Mg(OH)_2$

c) $CO_3^{2-} + H_2O \rightleftharpoons HCO_3^- + OH$
The compound X has a pH > 7 because carbonate is a weak conjugate base of HCO_3^-. Some CO_3^{2-} pulls off a hydrogen from water to form hydroxide which makes the pH > 7

d) .1 x 1 = .1 Moles NaOH $\frac{.1}{3M} = .033$ L 3M NaOH
First pour 66 ml of distilled water into the volumetric flask. Then rinse the buret with distilled water and then the 3 M stock solution of NaOH. Fill the buret to 50 ml with 3 M NaOH and then drain into the volumetric flask until 33 ml of NaOH have been added.

e) Pour equal amounts of $NaCO_3$ and $CaCO_3$ into 1 L of water. Since Na_2CO_3 is soluble in water and $CaCO_3$ is not, the $CaCO_3$ will turn the water milky white.

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ADDITIONAL PAGE FOR ANSWERING QUESTION 5.

5 a. Compound X: Na_2CO_3

Y: KCl

Z: $MgSO_4$

b. $Mg(OH)_2$

c. $CO_3^{2-} + H_2O \rightarrow HCO_3^- + OH^-$

Because OH^- is present when Na_2HCO_3 is mixed with water, the pH is greater than 7.

d. $M_1V_1 = M_2V_2$

$1 \times 0.1 = 3.0 \cdot V$

$V = \frac{0.1}{3}$

$V = 0.0\overline{3}$

Using a 50mL buret, add 33.33 mL of the 3.0M stock solution of NaOH into the 100mL flask. Then fill the flask to 100. mL with distilled water.

e. Dissolve the compounds in distilled water and add NaOH to each. The flask with a precipitate contains $CaCO_3$, because $Ca(OH)_2$ is insoluble. NaOH, on the other hand, is soluble.

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Your responses to the rest of the questions in this part of the examination will be graded 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.

Answer BOTH Question 5 below AND Question 6 printed on pages 22-23. Both of these questions will be graded. The Section II score weighting for these questions is 30 percent (15 percent each).

5. Three pure, solid compounds labeled *X*, *Y*, and *Z* are placed on a lab bench with the objective of identifying each one. It is known that the compounds (listed in random order) are KCl, Na_2CO_3, and $MgSO_4$. A student performs several tests on the compounds; the results are summarized in the table below.

Compound	pH of an Aqueous Solution of the Compound	Result of Adding 1.0 *M* NaOH to a Solution of the Compound	Result of Adding 1.0 *M* HCl Dropwise to the Solid Compound
X	> 7	No observed reaction	Evolution of a gas
Y	7	No observed reaction	No observed reaction
Z	7	Formation of a white precipitate	No observed reaction

(a) Identify each compound based on the observations recorded in the table.

Compound *X* Na_2CO_3

Ke1 Compound *Y* KCl

Compound *Z* $MgSO_4$

(b) Write the chemical formula for the precipitate produced when 1.0 *M* NaOH is added to a solution of compound *Z*.

(c) Explain why an aqueous solution of compound *X* has a pH value greater than 7. Write an equation as part of your explanation.

(d) One of the testing solutions used was 1.0 *M* NaOH. Describe the steps for preparing 100. mL of 1.0 *M* NaOH from a stock solution of 3.0 *M* NaOH using a 50 mL buret, a 100 mL volumetric flask, distilled water, and a small dropper.

(e) Describe a simple laboratory test that you could use to distinguish between $Na_2CO_3(s)$ and $CaCO_3(s)$. In your description, specify how the results of the test would enable you to determine which compound was $Na_2CO_3(s)$ and which compound was $CaCO_3(s)$.

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ADDITIONAL PAGE FOR ANSWERING QUESTION 5.

b.) $MgSO_4 + NaOH \longrightarrow Na_2SO_{4(aq)} + MgOH_{(s)}$

c.) Compound X = $NaCO_3$

$NaCO_3 + H_2O \rightarrow NaHCO_3 + OH^-$

Compound X ($NaCO_3$) has a pH higher than 7 because when added to water, it reacts to form $NaHCO_3$ and OH^-. $NaHCO_3$ is a base, and the presence of OH^- caused the pH to increase, since $pOH = -\log[OH^-]$ The products cause a shift in pH since both have basic properties.

d.) $(3.0M\ NaOH)(V) = (1.0M\ NaOH)(.1L)$

$V = .030L$

$= 30\ mL$

Use a 50 mL buret to add 30 mL of 3.0 NaOH to a 100 mL volumetric flask. (To fill the buret, use a small dropper.) Then add enough distilled water to bring the volume to the 100 mL mark.

e.) To differentiate $Na_2CO_{3(s)}$ & $CaCO_{3(s)}$, I could place eq val amounts of the solids into separate distilled water flasks. The $NaCO_{3(s)}$ is soluble, so it would dissolve in the water. The $CaCO_3$ is unsoluble, so it would not dissolve, and would remain a solid in the water.

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AP® CHEMISTRY
2006 SCORING COMMENTARY

Question 5

Overview

The intent of this laboratory question was to assess students' ability to use laboratory data to solve problems and to work in a wet laboratory situation. In parts (a), (b), and (c), students were to use given data to explain laboratory observations; in part (d) they were asked to demonstrate their understanding of the use of common laboratory glassware. Part (e) revisited part (a). In part (a) students were given lab data and asked to identify compounds; in part (e) students had to design a laboratory procedure to distinguish between two compounds.

Sample: 5A
Score: 8

This response earned 8 out of 9 possible points: 2 points for part (a) (the formula for sodium carbonate is written incorrectly, but it is only a transcription error, not a conceptual one), 1 point for part (b), 2 points for part (c), 1 out of 2 possible points for part (d), and 2 points for part (e). Only 1 point was earned for part (d) because the response does not include filling the volumetric flask to the 100 mL mark.

Sample: 5B
Score: 7

Only 1 out of 2 points was earned in part (c) because the explanation fails to identify carbonate ion specifically as the base causing the high pH. The equation given is acceptable for the other point, as it shows production of OH^- and a conjugate acid form of CO_3^{2-} (HCO_3^- was a preferred response, but H_2CO_3 and CO_2 were acceptable). Only 1 point was earned for part (d) because the response does not include filling the volumetric flask to the 100 mL mark.

Sample: 5C
Score: 6

The point was not earned in part (b) because the formula given for the precipitate is incorrect. Only 1 point was earned in part (c) because carbonate ion is not identified as the base. Only 1 point was earned in part (d) because an incorrect amount of NaOH is used.