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CAUTION!
THE ACIDS AND BASES USED IN THIS EXPERIMENT ARE CORROSIVES AND IRRITANTS.

COVER ALL ACID/BASE SOLUTIONS WITH A WATCH GLASS OR PARAFILM.

Add a drop or two of phenolphthalein indicator to 20 mL of 0.1M acetic acid ($HC_2H_3O_2$). What color is the resulting solution? Cover it and save it for later.

In another beaker, add a drop or two of phenolphthalein indicator to 30 mL of 0.1M sodium hydroxide. What color is the resulting solution? Cover it and save it for later.

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As you can see in the indicator chart below, phenolphthalein's "acid" color is colorless, and its "base" color is pink.

(SHOW AN INDICATOR COLOR CHART IN THIS SPACE, PREFERABLY ONE FROM THE STUDENTS' TEXTBOOK)

Now, perform a calculation in the space below and show what the pH of a 0.1M acetic acid solution is expected to be. Does your answer agree with what you saw happen when you added the phenolphthalein indicator to the 0.1M acetic acid solution?

Perform another calculation in the space below and show what the pH of a 0.1M sodium hydroxide solution is expected to be. Does your answer agree with what you saw happen when you added the phenolphthalein indicator to the 0.1M sodium hydroxide solution?

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Add 10 mL of your pink 0.1M sodium hydroxide solution to your 20 mL of colorless 0.1M acetic acid solution and stir to mix. We'll call this reaction mixture #1. Save the extra sodium hydroxide for later. What color is reaction mixture #1?

Write a balanced chemical equation for the reaction of acetic acid solution with sodium hydroxide solution.

Now think about which chemical species should be present in your reaction mixture #1. (Consider the amounts of reactants you've mixed together and the color of the indicator.)

How many moles of acetic acid did you start with in reaction mixture #1? (Show your calculation.)

How many moles of sodium hydroxide did you add? (Show your calculation.)

Which is the limiting reactant? Explain.

List below which of the four reactants and products in your balanced chemical equation you think are now present in reaction mixture #1.

What general name is given to the type of solution that reaction mixture #1 is?

How many moles of sodium acetate and acetic acid exist in reaction mixture #1?

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Next, perform a calculation in the space below and show what the pH of reaction mixture #1 is expected to be. Does your answer agree with the color of the phenolphthalein indicator in your reaction mixture #1?

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Next take your reaction mixture #1, add another 9 mL of your pink 0.1M sodium hydroxide solution to it, and stir. This makes a total of 19 mL NaOH solution that we've added to the 20 mL of acetic acid solution. We'll call this reaction mixture #2. Save the extra sodium hydroxide for later. What color is your reaction mixture #2?

Think about which chemical species should be present in your reaction mixture #2. (Consider the amounts of reactants you've mixed together and the color of the indicator.)

What's the total number of moles of sodium hydroxide in 19 mL of 0.1M NaOH solution? (Show your calculation.)

List below which of the four reactants and products in your balanced chemical equation you think should be present in reaction mixture #2.

Does the color of reaction mixture #2 make sense with regard to what you've listed above? Explain.

Is reaction mixture #2 a buffer solution? Explain.

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Now take reaction mixture #2, add 2 more mL of your pink 0.1M sodium hydroxide solution to it, and stir. This makes a total of 21 mL NaOH solution that we've added to the 20 mL of acetic acid solution. We'll call this reaction mixture #3. Save the extra sodium hydroxide for later. What color is your reaction mixture #3?

Think about which chemical species should be present in your reaction mixture #3. (Consider the amounts of reactants you've mixed together and the color of the indicator.)

What's the total number of moles of sodium hydroxide in 21 mL of 0.1M NaOH solution? (Show your calculation.)

List below which of the four reactants and products in your balanced chemical equation you think should be present in reaction mixture #3.

Does the color of reaction mixture #3 make sense with regard to what you've listed above? Explain.

Is reaction mixture #3 a buffer solution? Explain.

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Now take reaction mixture #3, add the rest of your pink 0.1M sodium hydroxide solution to it, and stir. We'll call this reaction mixture #4. What color is your reaction mixture #4?

Think about which chemical species should be present in your reaction mixture #4. (Consider the amounts of reactants you've mixed together and the color of the indicator.)

What's the total number of moles of sodium hydroxide in 30 mL of 0.1M NaOH solution? (Show your calculation.)

List below which of the four reactants and products in your balanced chemical equation you think should be present in reaction mixture #4.

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Think about which chemical species would have been present in a reaction mixture made by adding 20 mL of 0.1M sodium hydroxide to 20 mL of 0.1M acetic acid. List below which of the four reactants and products in your balanced chemical equation you think would be present in such a reaction mixture.

What do you think the pH of this reaction mixture would have been? (Explain.)

What do you think the color of phenolphthalein indicator would be in this reaction mixture?

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The reason you've been able to calculate the number of moles of acid and base present in the reaction mixtures you've prepared so far is because the formula mass of acetic acid and sodium hydroxide are both known and can be used to calculate their solutions' concentration.

What would happen if either the acid or the base were unknown? In that case, you could perform a pH meter titration and the shape of the titration curve would give you the information you need to determine the formula mass of the unknown. This is an important tool that's utilized often in analytical chemistry.

Let's use the pH meter as we perform a titration of an unknown monoprotic weak acid with standardized sodium hydroxide solution. Place between 0.3 and 0.4 grams of the unknown acid (accurately massed) into a 250-mL beaker. Dissolve the acid in enough water to allow the pH meter's glass electrode tip to be completely immersed in the resulting solution (at least 50 mL). Add two or three drops of phenolphthalein indicator.

Titrate the acid with standardized NaOH solution using an automatic stirrer to keep the solution mixed as you titrate. (Ensure that the stir bar doesn't hit the tip of the glass electrode as it rotates.) Plot pH vs. volume of NaOH added as you perform the titration, noting at what volume of NaOH the indicator color changes.

NOTE: At first, you can add the NaOH in fairly large increments (3 or 4 mL). Make sure, however, that you steadily decrease the volume increments of NaOH added as you approach the endpoint of the titration. *You should be adding only a drop of titrant at a time during this stage of the titration, or else you won't be able to draw a complete titration curve.* After the endpoint has been passed, continue titrating with larger increments of NaOH solution so that you can draw the rest of the curve.

NOTE: Unlike a manual titration in which a visual indicator is used, you shouldn't add any more water to your beaker once the titration has begun and you've made your first pH measurement. Why?

Label the axes on your graph, the equivalence point, and the endpoint. Show your titration curve to the laboratory instructor.

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Use the equivalence volume from your titration curve to calculate the formula mass of the unknown acid. Explain and show your calculations below.

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Use the half-equivalence volume from your titration curve to calculate the K_a of the unknown acid. Explain and show your calculations below.

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Look at the shape of your titration curve around the equivalence point. Select another indicator (not phenolphthalein) from the chart on Page 2 of this experiment that would be appropriate for this particular titration. Which indicator did you choose?

Now test whether this indicator works by performing another, manual titration (without the pH meter).

Calculate the formula mass of the unknown acid using the manual titration volume of NaOH used to reach an endpoint and compare it with the formula mass calculated from the pH meter titration. Repeat the manual titration at least once to ensure precision.

Show your calculations below. Include the percent difference between the formula masses obtained from the two methods (manual vs. pH meter titration).

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Oxalic acid is a weak, diprotic acid. Write a balanced equation for the complete neutralization of oxalic acid with sodium hydroxide.

Find the values for the K_a's of oxalic acid from your textbook or a handbook and record them in the space below.

What do you think the titration curve for oxalic acid would look like? Draw a rough sketch below.

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Using your sketch and the K_a's from the previous page (Page 13), select two indicators from the chart on Page 2 of this lab experiment that would signal the neutralization of each hydrogen in oxalic acid separately. In the space below, write the names of the indicators you chose, their pH range, and why you chose them.

Place about 0.1 gram of oxalic acid, accurately massed, in an Erlenmeyer flask and dissolve it in about 50-75 mL of water. Add two or three drops of the first indicator you've selected and titrate manually with standardized NaOH solution until a color change occurs.

Now add three or four drops of the second indicator you've selected and continue titrating until another color change occurs and the oxalic acid is completely neutralized.

Calculate the formula mass of oxalic acid from your titration data and compare it to the formula mass calculated from its chemical formula. Show your calculations below. Include the percent difference between the two formula masses.