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Modification of a pH Titration Laboratory Experiment

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The inquiry-based approach is intended to increase students' comprehension of what they are doing in laboratory and why they are doing it.

The author has modified a traditional pH titration laboratory experiment to an inquiry-based approach she learned in a PACT (Partnership for the Advancement of Chemical Technology) NSF-funded short course on analytical problem solving during the summer of 1996. In this modification, students are given an initial handout and asked to complete a short, attention-getting exercise. They must continue to work on logical, short exercises given to them one-at-a-time, in handout format, in order to complete the entire laboratory experiment. The inquiry-based approach is intended to increase students' comprehension of what they are doing in laboratory and why they are doing it.

Our second-semester General Chemistry course at Harper College includes a traditional laboratory experiment involving generation of an acid–base titration curve using a pH meter.

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This experiment has been modified to an inquiry-based approach the author learned in a PACT (Partnership for the Advancement of Chemical Technology) NSF-funded short course in Analytical Problem Solving during the summer of 1996. When students perform this experiment, it is expected that they have learned the material in the acid–base equilibrium chapter of their textbook. They should understand how to do theoretical calculations of the pH of strong and weak acid and base solutions. They should also understand how to use the Henderson–Hasselbalch equation to calculate the pH of buffer systems.

Before we modified the experiment, our students titrated a strong acid with a strong base using a pH meter and examined the features of the titration curve. They then titrated a weak acid with a strong base and compared this titration curve to the first. Students also identified an unknown acid by determining its formula mass and equilibrium dissociation constant by inspection of their titration curves. All of these things were done in the traditional way, including prelaboratory discussion of the principles involved, prelaboratory reading and written assignments, a standard step-by-step procedure, and a postlaboratory discussion and assignment. We used Chemical Education Resources, Inc. module EQUL 339 *(Titrations Using a pH Meter)* as our student handout.

The rationale for modifying the experiment was two-fold: first, to increase students' awareness of what is happening on a molecular level in the reaction systems and second, to discover for themselves (rather than being told) how to determine the formula mass and acid dissociation constant of the unknown acid from their titration curves. The inquiry-based approach for this experiment has fourteen pages of student handouts. Students are given the first page as they enter the laboratory. They must complete the task(s) on each page of the handout before they can receive the next page. At Harper College, each laboratory section consists of 24 students. Each laboratory has six benches; four students can work comfortably at each. Two pH meters are placed at each bench and the students are asked to work with a partner for this particular experiment. They are asked to work together and present to the instructor a consensus of answers for each handout page.

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Experimental procedures

Page one of the modified experiment provides a simple task that gets the students started quickly. They are asked to compare the colors of phenolphthalein indicator in acid and base solutions.

Page two provides an indicator chart to which the students can compare their experimental results from page one. This gives a quick reinforcement of their technique and encourages them to continue with the two calculations that are also on this page. They are asked to calculate the expected pH of the two solutions they tested on page one and to verify that the indicator colors they observed make sense. This is a good review of pH calculations.

Page three of the experiment asks the students to start mixing the acid and base solutions. They mix the acid and base solutions from page one in a 2:1 ratio and are asked to observe the color of the resulting mixture. (This mixture correlates to the half-equivalence point of the titration curve.) The students are asked to think about the color they see and reason why the mixture retains the acid color (colorless) of phenolphthalein. They do this by writing a chemical equation for the neutralization reaction which occurs when the acid and base are mixed. Then they calculate the number of moles of each reactant used and decide which would be the limiting reactant. This is a good review of stoichiometry and provides a hands-on application of these fundamental principles. Finally, students are asked to think about what exactly is in their mixture on a molecular level. Hopefully, they conclude that what they have is a buffer system.

Page four of the experiment asks the students to calculate the expected pH of their buffer system and see if their result makes sense in terms of the indicator color of the actual mixture. This is a calculation that the students should have already learned in class, but doing it now (in the laboratory) provides a situation for its practical application.

Page five continues the mixing process and correlates to a point on the titration curve just before the pH starts to increase dramatically. Students are asked to add more of their “pink” sodium hydroxide to their mixture and see if the indicator color changes. Again, they are asked to think about how many moles of NaOH they have added, the reaction stoichiometry, and what exactly is in their mixture on a molecular level. And

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again, they are asked to decide if the color of the indicator agrees with their conceptual conclusions.

Page six of the experiment takes the mixture to a point on the titration curve just beyond the equivalence point, and page seven completes the mixing of the original acid and base solutions. At this stage in the experiment, students should have acquired a much better idea of how the contents of their reaction mixture change as base is added to acid than they could ever get from simply reading about it in a textbook or reviewing it in a prelaboratory discussion.

Page eight asks the students to think about a hypothetical mixture containing equal amounts of acid and base. Because volumes are measured with graduated cylinders and confusion may result from poor technique, the students are not asked to actually prepare this solution.

Finally, on page nine, the students are asked to perform a titration with a pH meter. They are encouraged to think about *why* they're doing the titration this way, instead of manually.

Pages 10 and 11 challenge the students to use their titration curves to obtain the information they need to calculate the formula mass and acid dissociation constant of their unknown. The first part of the experiment (pp 1–8) should provide the necessary insight they need to succeed.

Pages 12–14 contain interesting additional challenges for the student. On page 12, students are asked to inspect their titration curve and pick another suitable indicator (not phenolphthalein) for the titration they just performed. After deciding on another appropriate indicator, they are asked to perform a manual titration to see if it actually works. Pages 13 and 14 ask the students to consider how the titration would change if the acid titrated were diprotic instead of monoprotic.

Our first impression of the modification of our pH titration experiment to the inquiry-based approach is that it has increased our students' comprehension of what they are doing in laboratory, and why they are doing it. Students are asked to think about each stage of the titration and actually prove that they understand it before being allowed to proceed to the next step. The students' enthusiasm for this approach is obvious as they are performing the experiment.

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A set of student handouts (fourteen pages) is available (22jw1897.pdf, 28 Kbytes). A set with teacher's notes is available from the author upon written request.

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