Electronic Supplementary Material (ESI) for Chemistry Education Research and Practice.
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Appendix A: Example of ADI Investigation

Investigation 2
How much acetic acid is in vinegar?

Introduction: Vinegar and olive oil are the primary ingredients in many salad dressings. Acetic acid, present in vinegar, gives vinegarette dressings their characteristic bite. Vinegar is an aqueous solution containing acetic acid as the solute. Your team has been hired by a producer of Italian dressings to perform a quality control analysis of the vinegar supply they currently use. The company has received complaints that one of their dressings does not have the usual zing expected from an Italian dressing. The company has concluded that the problem might be with the vinegar because the added seasonings and olive oil are okay. Your team is asked to determine the concentration (molarity and mass percent) of acetic acid in the vinegar sample. Your team was selected because of your reputation for performing exemplary titrations.

Goals: As you complete this investigation you will:
1. Standardize a NaOH(*aq*) solution.
2. Titrate a vinegar sample with the standardized NaOH(*aq*) solution.
3. Measure the density of a vinegar sample.
4. Calculate the molarity and mass percent of acetic acid in the vinegar sample.

Guiding Question: How much acetic acid is in vinegar?

Materials

Vinegar	Beakers
NaOH(*aq*) solution	Erlenmeyer flasks, 125 mL
KHP - Potassium hydrogen phthalate	Buret stand with buret
Phenolphthalein indicator	Funnel
10 mL pipettes	Analytical balances

Safety Precautions:
Wear goggles at all times. You are working with strong acids and bases that can cause damage to skin and eyes.
Dispose of any excess liquids in appropriate containers.

Getting Started: Titration is a common laboratory technique for determining concentration of solutions and molecular masses of compounds. In this investigation, a base will be added to an acid to reach the *equivalence point*. This is the point where just enough base has been added to react with all of the acid present. An indicator can be used to detect changes in pH during a titration and can also help identify the equivalence point. The equivalence point can be detected if a few drops of phenolphthalein solution are added to the titration vessel. Phenolphthalein is an acid/base indicator that is colorless in an acid environment and red in a base environment. If a base is slowly added to the acid, with phenolphthalein present, the solution will start out colorless. As long as acid is present the solution will be colorless. When the solution is faint pink in color, enough base has been added to react with all the acid. This visual color change is called the *end point* of the titration. If too much base is added, then the solution will be red.

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KHP is a primary standard, which means it is a substance of a known high degree of purity that undergoes one invariable reaction with the other reactant of interest. Your first task is to *standardize* the NaOH solution using solid KHP ($KC_8H_5O_4$, 204.22 g/mol). This means you need to determine its molarity to at least three significant figures. You will need at least three titrations that agree within 1%.

You have two other tasks to accomplish in the lab. You must determine the density of the vinegar solution and the molarity of the acetic acid in vinegar. The mass percent of acetic acid can be calculated from your data.

To accomplish your tasks, you will need to make very accurate volume and mass measurements. Burets and pipets are useful in accurately measuring volumes. The buret and pipet are described in Appendix G. Before you begin, make sure you understand their proper use.

Titration Tips:

- Watch the titration video on Blackboard.
- Rinse buret with solution to be titrated.
- Use a consistent amount of indicator (2 – 3 drops).
- Remove air bubbles from buret tip.
- Rinse down inside of the flask as you near endpoint.

Interactive Poster Session: Once your group has completed your work, prepare a whiteboard that you can use to share and justify your ideas. See the handout provided for details on this process

Report: Once you have completed your research, you will need to prepare an ***investigation report*** that consists of three sections. This report may require more than 2 pages with data tables. This report must be typed and any diagrams, figures, or tables should be embedded into the document.

Section 1: What concept and/or technique were you investigating? Relate this concept to the guiding question. Describe titration and its use in conjunction with molar stoichiometry to determine concentration.

Section 2: How did you go about your work and why did you conduct your investigation in this way?

Section 3: The argument in this investigation is not so much for your result but for the validity and reliability of your data. This report should include a comprehensive data table similar to the one you used in the pre-lab exercise where you found the molarity of your base. Do not report on the base standardization process, other than to report the NaOH molarity with standard deviation. You need to provide justification for discarding any of the vinegar titration trials. You should show **one** complete calculation of the molarity and mass % of the vinegar. Your final answer for the vinegar molarity should include a standard deviation.

Remember: An argument is not just an answer to the question. It is claim or conclusion supported by evidence with a rationale for why the evidence supports the claim or conclusion.