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Enhancing General Chemistry Labs to Construct Engaging, Colorful Experiments

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Overarching Goal: Provide students with captivating laboratory experiments to solidify lecture material and connect their studies to real-world issues.

Abstract:

General Chemistry I (CHEM 121) sets the foundation for the chemistry education of Valparaiso students; therefore, it is critical that the CHEM 121 lecture and laboratory courses provide rich learning experiences that are meaningful, focused, and engaging. In this project, two new or significantly revised laboratory experiments were incorporated into the curriculum during the Spring 2018 semester: 1) The Limiting Reagent in Action: Determining the Formula of a Precipitate and 2) The Analysis of Microplastic Pollution in Local Soil. The common goals of both labs were to increase student understanding of challenging general chemistry concepts by enhancing student engagement. For Experiment 1, this was accomplished by adding additional qualitative testing to study the reactions; in the case of Experiment 2, this was accomplished by directly connecting course material to study real-world pollution problems facing NW Indiana. Results of this work and its impact on student learning in CHEM 121 are described.

Limiting Reagent in Action:

Experimental methods:

- Applying the method of continuous variation to determine the identity of an unknown phosphate, a set of eight precipitation reactions was performed by mixing varying concentrations of cobalt and phosphate ion reactants according to Table 1
- Quantitative Precipitate (ppt.) Analysis: Each precipitate was separated from the mixture by centrifugation and dried. Experimental ppt. masses were plotted as a function of reactant mole fraction to identify the limiting reactant
- Qualitative Supernatant Analysis: Each supernatant was tested qualitatively via observation of supernatant color and reactivity with $Fe(NO_3)_3$ to determine the excess reactant

$Co^{2+}_{(aq)} + H_2PO_4^{1-}{}_{(aq)} \rightarrow Co(H_2PO_4)_{2(s)}$ eq. 1

$Co^{2+}_{(aq)} + HPO_4^{2-}{}_{(aq)} \rightarrow CoHPO_{4(s)}$ eq. 2

$3\ Co^{2+}_{(aq)} + 2PO_4^{3-}{}_{(aq)} \rightarrow Co_3(PO_4)_{2(s)}$ eq. 3

Test tube	Volume of 0.3 M $CoCl_2$ (mL)	Volume of 0.3 M Phosphate (mL)
0	0.0	7.0
1	1.0	6.0
2	2.0	5.0
3	3.0	4.0
4	4.0	3.0
5	5.0	2.0
6	6.0	1.0
7	7.0	0.0

Table 1. Reactant amounts

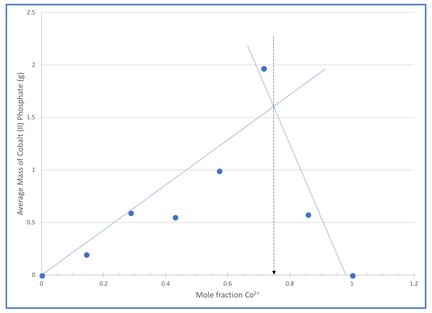


Figure 1. Average Mass of Cobalt (II) Phosphate vs. Mole Fraction of Co^{2+}

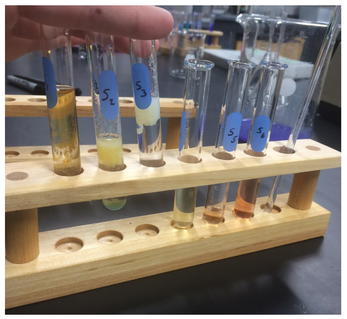


Figure 2. Qualitative test results

Results

- My work: Developed 3 total methods of analysis (2 qualitative, 1 quantitative) that reliably allowed determination of unknown phosphate
- Student results: All students were able to correctly identify unknown based on each of the three methods
- Post-lab question observations: Students expressed a range of opinions on whether qualitative or quantitative analysis provides more compelling evidence when identifying their unknown

Analysis of Microplastic Pollution in Local Soil:

Experimental methods:

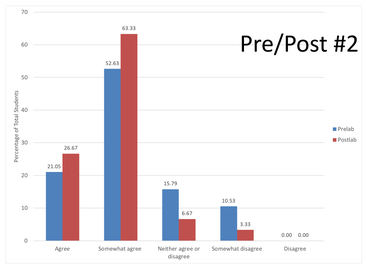
- Soil samples were collected both upstream (A) and downstream (B) from a local wastewater treatment plant and dried
- Microplastics/microfibers were separated from bulk soil according to their a) size using sieves and b) density by suspending them in a $ZnCl_2$ solution (1.3 g/mL)
- Low density materials were filtered using vacuum filtration and analyzed with a microscope
- Microplastics were further purified by removing natural materials using the Fenton reaction:

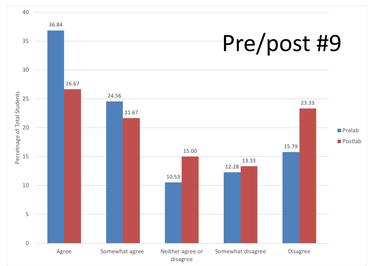
$Fe^{2+} + H_2O_2 \rightarrow Fe^{3+} + HO\cdot + OH^-$

$Fe^{3+} + H_2O_2 \rightarrow Fe^{2+} + HOO\cdot + H^+$

- Final analysis of samples was performed using microscopy after the Fenton reaction solution was vacuum filtered

Figure 3. Vacuum filtration apparatus





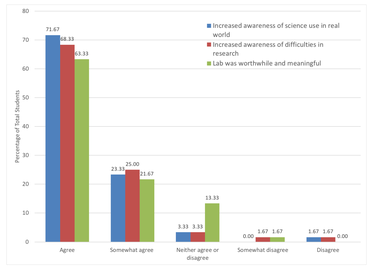


Figure 4. Results of selected survey questions. Question 2 (left) and 9 (middle) were pre/post questions pertaining to scientific process; the right panel shows student opinion on microplastics research.
(2) "I have a good understanding of how scientific research is performed in the real world."
(9) "Research is about collecting data which backs your argument."

Results

- My work: Successfully adapted 3-week CHEM 111 experiment to be performed in CHEM 121 during 2 weeks
- Student results: Students gained experience performing research and were specifically able to identify microfibers and microplastics in soil samples
- Post-lab surveys: Students showed a modest positive shift regarding how they think research is performed and how it should be conducted and interpreted
- Post-lab surveys: Students indicated increased awareness about microplastic pollution and why it should be studied/monitored

Discussion:

Limiting Reagent:

- Students gained a more complete understanding of limiting reactant stoichiometry
- Multiple analysis modes provided students with several complementary approaches to solve a chemical problem
- Experiment was more visually appealing by employing a transition metal that formed colorful compounds
- Future Work: More fully investigate student conceptions about what constitutes compelling evidence

Microplastic Pollution:

- Students gained experience applying their classroom learning to perform experiments that address real-world issues
- Students had a somewhat better perspective on how the research process works and what it means
- Future Work: Increase student engagement by having students supply their own soil samples and hypothesize and present their results