Texas Christian University Green Chemistry Cleanup: Revamp, Reorganize and Recycle

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Project Summary

TCU Chemistry Club collaborated with O.D. Wyatt High School to redesign chemistry experiments through the lens of green chemistry. All experiments included a "Green Chemistry Principles" section clearly stating which principles are followed in each experiment. Following the redesign, the school's chemical store room was reorganized based on chemical compatibility and chemicals not needed were properly disposed. An inventory system was adopted to track remaining chemicals. This project will have long-term positive effects on the high school as the students will be exposed to green chemistry principles, the faculty will see the ease at which green chemistry experiments can be implemented.

Over 40 Student, Faculty and Staff Volunteers
Over 30 Meetings
Over 500 volunteer hours

Revamp

Purpose
Based off of the district guidelines of Fort Worth ISD, fourteen experiments were created to cover content over one year of material. The experiments were structured to follow the twelve principles of green chemistry, focusing on easy disposal methods of the ending products and include comprehensive safety protocol for all labs. The experiments themselves were created with the intent of utilizing interactive laboratory questions designed to prompt further learning.

List of Experiments

- The chemistry of Cat Litter
- Introduction to Green Chemistry Principles: Atom Economy
- The Copper Cycle
- The Periodic Table Windsock
- Air Bag Stoichiometry
- The pH Scale: Examining Common Household Products
- Enthalpy of Combustion
- Sublimation of Caffeine
- Electron Configurations and Naming Compounds
- The Periodic Table
- S'more Stoichiometry
- Solubility Reactions
- Gas Laws
- Half-Life of Candium: Radioactive Decay

Example:

TITLE: The pH Scale: Examining Common Household Products

Teacher Background Information: In this lab students will use common household products, and natural indicators to examine the pH scale.

Safety Information: Safety glasses/goggles should be worn at all times. Thoroughly wash hands after completion of experiment. Long hair should be tied back to avoid contamination.

Educational Goals: The goals of this experiment focus on teaching the pH scale and concepts of acids, bases and neutral compounds.

Student Objectives: Students will…
- Develop a pH scale based on their own procedure examining household products with 3 natural indicators and pH paper
- Determine the pH of a series of other household products, based on a scale developed in part 1 of the experiment

Materials Needed Per Group
- pH = 1, 3, 5 (HCl solutions)
- pH = 7 (water)
- pH = 9, 11, 13 (NaOH solutions)
- Sprite
- Lemon juice
- Antacid Tablets
- Coffee
- Vinegar
- Orange juice
- Shampoo
- Baking soda in water
- Drain Cleaner
- Milk
- Salt water
- Coca Cola
- Milk of magnesia
- Hand Soap
- Bleach
- Various indicators juices (blueberry juice, cabbage juice, beet juice)*
- Beakers
- Pipettes
- Spotting/well plates

Time Required: 45-60 minute class period

Key Terms:
Acid
Base
Neutral
pH scale

Teacher Prep: Prepare the pH scale of acid/bases prior to the lab, pH 1, 3 and 5 with 0.1, 0.001 and 1 x 10^{-5} M HC, respectively, pH = 7 with tap water, and pH 9, 11 and13 with 1 x 10^{-5}, 0.001 M and 0.1 M NaOH, respectively.

All other products are available at the general store. For baking soda, dissolve some in water prior to the experiment. Cabbage juice can be purchased or prepared. To prepare, boil red cabbage in water to pull the color into the water solution. Blueberry and beet juice can be purchased.

The pH Scale: Examining Common Household Products

Introduction
Acid base chemistry is a fundamental concept essential to all branches of chemistry. The terms *Acid* and base were coined by Swedish chemist, Svante Arrhenius in the 1800's. Acids were substances known to have a sour taste and reacted with substances called bases. Bases had a bitter taste and made skin slippery on contact. Scientists use a system called the pH scale to measure how acidic or basic a substance is compared to other materials. The pH scale ranges from 0 to 14, where pH less than 7 is acidic, pH at 7 is neutral and pH greater than 7 is basic. Pure water is neutral, but after mixing, some chemicals will test acidic or basic in the solution. While acid base chemistry can be explored using caustic chemicals like hydrochloric acid (acid) and sodium hydroxide (base), many common household substances like juices, vinegar, and baking soda can be used to study acid and base chemistry without the dangers and cleanup associated with stronger chemicals. For example, vinegar and lemon juice are acidic, while milk of magnesia and bleach are basic.

Safety Information: Safety glasses/goggles should be worn at all times. Thoroughly wash hands after completion of experiment. Long hair should be tied back to avoid contamination.

Green chemistry principles focused on in this lab
- Prevention (1): Develop the experiment using common household products and on small scale, inherently reducing to reduce waste production.
- Design for Degradation (10): The waste generated can be easily disposed in the municipal waste system.
- Safer Chemistry for Accident Prevention (12): Use common household products and natural indicators to examine the pH scale without using strong acids or bases in the laboratory.

Vocabulary
Acid: Tests at a pH lower than 7 on the pH scale. Acids react with bases to form salts, dissolve some metals and often are sour in taste.
Base: Tests at a pH higher than 7 on the pH scale. Bases react with acids to form salts, have a bitter taste and tend to be slippery upon touch (i.e. soap).
Neutral: Tests at a pH of 7 on the pH scale.
pH scale: A logarithmic scale used to quickly and easily compare the acidic and basic properties of materials.

Materials per student group
- pH = 1, 3, 5 (HCl solutions)
- pH = 7 (water)
- pH = 9, 11, 13 (NaOH solutions)
- Sprite
- Lemon juice
- Antacid Tablets
- Coffee
- Vinegar
- Orange juice
- Shampoo
- Baking soda in water
- Drain Cleaner
- Milk
- Salt water
- Coca Cola
- Milk of magnesia
- Hand Soap
- Bleach
- Various indicators juices (blueberry juice, cabbage juice, beet juice)*
- Beakers
- Pipettes
- Spotting plates/Wells

Procedure
Part 1: You will be creating your own pH scale using a series of acid (HCl), neutral (water) and basic (NaOH) solutions that have been prepared by your teacher along with three natural indicators: blueberry juice, cabbage juice and beet juice. Using your well plate, design your own procedure to figure out the color range of each natural indicator and fill in the tables below. 4-5 drops of the acid, neutral or basic solution with 2-3 drops of the natural indicator should be enough to determine the color change. You will use this to estimate the pH of unknown samples in part 2.

Part 2: Using your results from Part 1, determine the pH of the following household products: sprite, lemon juice, antacid tablets, coffee, vinegar, orange juice, shampoo, baking soda, drain cleaner, milk, salt water, coca cola, milk of magnesia, hand soap, and bleach.

Each experiment includes a teacher prep page, introduction for students, green chemistry principles, vocabulary, materials, procedure, data collection, pre-lab questions and post-lab questions.

Reorganize

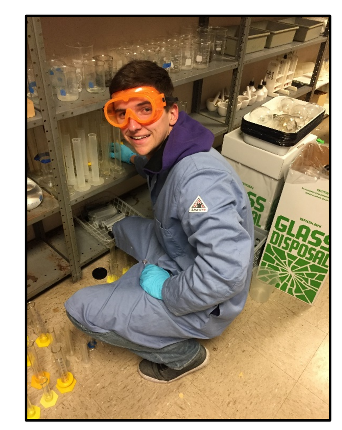
Purpose
This phase of the project included reorganizing the chemical supply room at O.D. Wyatt. Student and teacher volunteers were trained on proper lab safety and were tasked with cleaning the chemical supply room. The chemicals were evaluated to determine their need based on the new curriculum and then containers were examined for integrity of the bottles assuming continued use. Two years worth of chemicals were kept on hand and resorted into the room. All chemicals that were no longer needed or deemed not safe were set aside for disposal following state and federal guidelines. The Flynn Scientific method for reorganization of a laboratory room was followed. First, inorganic materials were separated from organic materials. Once separated by class, the chemicals were further broken down into compatibility groups such as Inorganic 1, Organic 4, etc. to avoid the risk of future accidents due to accidental mixing of incompatible chemicals. After separating the bottles into their respective compatibility groups, the solids and liquids in each family were separated and alphabetized. Acids, bases and flammables were placed in their respective cabinets. All shelves in the room were relabeled (ex. Column A, Shelf 3) to quickly identify inner locations of chemicals and supplies in the room.

Before the Cleanup




During the Cleanup



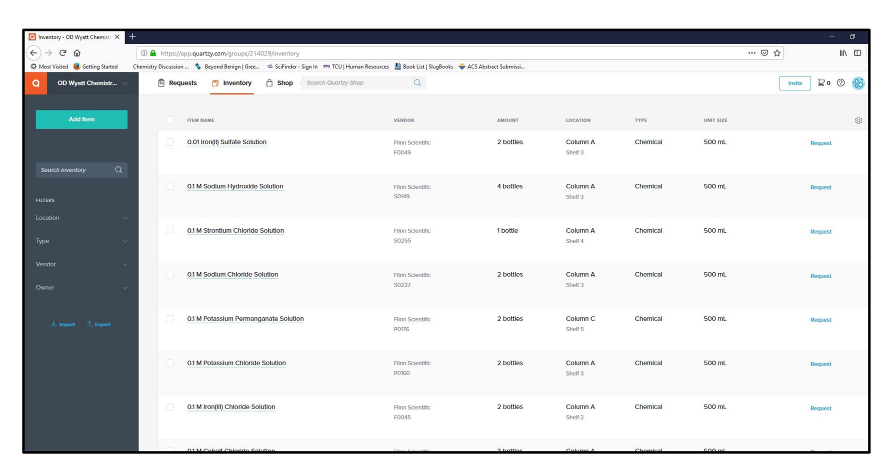



After the Cleanup



Adoption of an Inventory System

During the cleanup, a current and accurate inventory of the remaining chemicals was recorded. An online inventory system, Quartzy, was adopted to track the remaining chemicals. This program is advantageous as it is a free inventory tracking system, cloud based, and all data can easily be exported to Microsoft Excel at any time. In addition, the software can be set up to send a weekly and/or monthly backup of the inventory.

Recycle

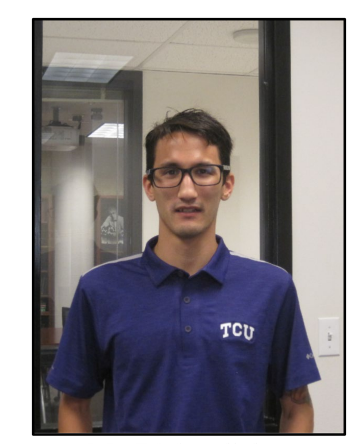
Purpose
The last phase of this community outreach project focused on waste minimization at O.D. Wyatt High School. Following the fundamentals of green chemistry, we were able to rewrite a curriculum of laboratory exercises within the learning requirements of Tarrant County School District. This allowed the students to substitute toxic, flammable, and corrosive chemicals within the old curriculum with safer environmentally friendly alternative chemicals. With lab exercises allowing for chemical substitution and/or total replacement of hazardous chemicals, while not comprising the scientific concepts, O.D. Wyatt was left with many unused chemical bottles no longer having a purpose in their chemical store room. This surplus of expired, unused, and caustic chemicals built over decades of teachers is not only a safety burden for a program no longer needing these chemicals to continue or conduct labs of past generations but also posed both an environmental regulation liability and a finical burden to the district in proper handling and disposal. Many high schools in the country are not properly funded for basic student needs, let alone chemical disposal from labs no longer performed in a high school setting.



Sorting of bottles based on compatibility for disposal

Collecting chemicals deemed hazardous waste

Neutralizing acids and bases for drain disposal



Mr. Rich Adickes Educating volunteers on proper disposal methods

Bottles awaiting pickup from Veolia, FWISD's contracted licensed waste handling company

Rich Adickes, Hazardous Materials Safety Manager, helped assist the students organize the chemicals no longer needed by O.D. Wyatt High School. Chemicals were broken down into 2 categories. The first category was comprised of chemicals that could be disposed of safely down the drain and in the municipal landfill, either by elementary neutralization or by solid waste determinations. The second category covered waste that was determined to be hazardous waste by federal and state regulations. This waste was set aside and packaged for a certified TSDF (Treatment Storage and Disposal Facility) or Hazardous waste Disposal Company to dispose of accordingly. These chemical were then stored by state of matter, waste code, packing compatibility and group by DOT (Department of Transportation) codes.

Chemical Name	Liquid or Solid	Quantity	Age	Flinn Disposal Code*	EPA Code	DOT CLASS	Packing Group	Possible UN	Shipping Name
1 Container 5 gallon bucket full (Small Bottles)									
Calcium Nitrate	Solid	Collective	Unknown	26b	D001	5.1 (6.1)	PG I or PG II	UN1479	Waste Oxiding Solids, Silver Nitrate; n.o.s
Sodium Nitrate	Solid	Collective	Unknown	26b	D001	5.1 (6.1)	PG I or PG II	UN1479	Waste Oxiding Solids, Silver Nitrate; n.o.s
Silver Nitrate	Solid	Collective	Unknown	11	D001 ; D011	5.1 (6.1)	PG I or PG II	UN1479	Waste Oxiding Solids, Silver Nitrate; n.o.s
Potassium Nitrate	Solid	Collective	Unknown	26b	D001	5.1 (6.1)	PG I or PG II	UN1479	Waste Oxiding Solids, Silver Nitrate; n.o.s
Ammonium Nitrate	Solid	Collective	Unknown	26b	D001	5.1 (6.1)	PG I or PG II	UN1479	Waste Oxiding Solids, Silver Nitrate; n.o.s
1 Container 5 gallon bucket									
Ethyl Alchohol	Liquid	Collective	Unknown	26n	D001	3	PG II	UN1993	Waste Flammable Liquid, n.o.s (Methanol, N-butyl alcohol)
Isopropyl Alcohol	Liquid	Collective	Unknown	18a	D001	3	PG II	UN1993	Waste Flammable Liquid, n.o.s (Methanol, N-butyl alcohol)
Xylene	Liquid	Collective	Unknown	18a	D001 ; U239	3	PG II	UN1993	Waste Flammable Liquid, n.o.s (Methanol, N-butyl alcohol)
Ethonal	Liquid	Collective	Unknown	26b	D001	3	PG II	UN1993	Waste Flammable Liquid, n.o.s (Methanol, N-butyl alcohol)
Kerosene oil	Liquid	Collective	Unknown	18b	D001	3	PG II	UN1993	Waste Flammable Liquid, n.o.s (Methanol, N-butyl alcohol)
n-butyl alcohol	Liquid	Collective	Unknown	18b	U031; D001	3	PG II	UN1993	Waste Flammable Liquid, n.o.s (Methanol, N-butyl alcohol)
1-propanol	Liquid	Collective	Unknown	18b	D001	3	PG II	UN1993	Waste Flammable Liquid, n.o.s (Methanol, N-butyl alcohol)
methyl alcohol	Liquid	Collective	Unknown	18a	U154; D001	3	PG II	UN1993	Waste Flammable Liquid, n.o.s (Methanol, N-butyl alcohol)
propanoic acid	Liquid	Collective	Unknown	24a	D001	3	PG II	UN1993	Waste Flammable Liquid, n.o.s (Methanol, N-butyl alcohol)
universal indicator	Liquid	Collective	Unknown	26b	D001	3	PG II	UN1993	Waste Flammable Liquid, n.o.s (Methanol, N-butyl alcohol)
Box 18									
Sodium Chromate 0.2 M Solution	Liquid	4 * 50 mL = 200 mL	Unknwon	12a	D001; D007	5.1 (6.1)	PG II	UN3099	Oxidixing liquid, Toxic, n.o.s
Sodim Dichromate 0.2 M Solution	Liquid	4 * 50 mL = 200 mL	Unknwon	12a	D001; D007	5.1 (6.1)	PG II	UN3099	Oxidixing liquid, Toxic, n.o.s
Sodim Dichromate 0.2 M Solution	Liquid	1 * 30 mL = 30 mL	Unknwon	12a	D001; D007	5.1 (6.1)	PG II	UN3099	Oxidixing liquid, Toxic, n.o.s
Box 19									
Hydroxylamine Hydrochloride	Solid	100 g	Unknwon		No EPA	8	PG II	UN2923	
Mercury Thermometer	Liquid	10 mL	Unknwon		D009	6.1	PG II		Send out as Universal Waste
Mercury	Liquid	10 mL	Unknwon		D009	6.1	PG II	Un2024	Waste Mercuy compound, liquid, n.o.s
Box 28									
Oil	Liquid	8 * 22 oz = 176 oz (~5,204 mL)	Unknown	24a	No EPA				Universal Oil
Carbol Fuschin Solution	Liquid	3 * 15 mL = 45 mL	Unknown		D001	3	PG II	UN1993	Waste Flammable Liquid, n.o.s
Hydroxyamine Hydrochloride	Solid	2 * 100 g = 200 g	Unknown		No EPA		PG II	UN1993	Waste Flammable Liquid, n.o.s
Sulfur	Solid	1 * 10 g = 10 g	Unknown		No EPA	6.1	PG II	UN1993	Waste Flammable Liquid, n.o.s
Formaldehyde	Liquid	1 * 35 mL = 35 mL	Unknown		D001	3	PG II	UN1993	Waste Flammable Liquid, n.o.s
Potassium Bromide	Liquid	23 * 50 mL = 1150 mL	Unknown		No EPA			UN1993	
Potassium Bromide	Solid	1 * 100 g = 100 g	Unknown		No EPA			UN1993	
Potassium Iodate	Solid	1 * 100 g = 100 g	Unknown		D001	3	PG II	UN1993	Waste Flammable Liquid, n.o.s
Potassium Iodate	Liquid	1 * 75 mL = 75 mL	Unknown		D001	3	PG II	UN1993	Waste Flammable Liquid, n.o.s
Guaiacol Solution 0.2% in Isopropyl Alcohol	Liquid	1 * 100 mL = 100 mL	Unknown	18a	D001	3	PG II	UN1993	Waste Flammable Liquid, n.o.s
Cobaltous Chloride	Solid	1 * 100 g = 100 g		27f	No EPA				

If given the chance, would you do this project all over again? YES!!!!!

Acknowledgements

TCU Department of Risk Management
Mr. Richard Adickes
TCU Chemistry Club