The Zinc and Iodine Book

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Building Fundamental Knowledge with Thematic Laboratory Activities for the Chemistry Educator

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This book is dedicated to Jean Lythcott

Thanks Jean for listening to my enthusiastic ramblings, for teaching in a way I never experienced, and for encouraging me to take a stand about what I know.

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from those of iodine and zinc? Explain using your reaction as an example.

- What are the identities of the three substances that were isolated?
- Is there a way to put energy into zinc iodide in order to regain the elements, zinc and iodine? If there is a way, how does it happen?
- What are the identities of the substances found after electrolysis and heating?

INTRODUCTION

Thematic-based Laboratory Curricula

In 1861 Michael Faraday wrote, *The History of the Candle*, which was a collection of chemical demonstrations all centered around the simple candle. Faraday was one of chemistry's great popularizers and a talented teacher. He used the theme of a candle because it was something his audience understood, it was inexpensive and safe, and it was a common reference point to connect and map more esoteric ideas about the physical world. In high school, I was fortunate enough to actually perform one of Faraday's candle activities. I had to sit quietly and watch, for over an hour, a small burning candle and make at least 100 descriptive observations. At the time it was probably one of the most unique experiences in my life, and while I didn't know it then, it strangely influenced my choice of becoming a chemist and my future profession as a chemical educator.

In the spirit of Faraday, I want to bring back the notion of thematic curriculum design in the academic chemistry laboratory. Simply put, I believe there should be another way to how laboratory manuals are designed. Thematic design provides an alternative to the practices of using commercial lab manuals that recycle activities that are decades old as well as the cut and paste model of choosing activities through the internet or in journals. Thematic design, instead, chooses an object, a concept, a procedure, or a teaching strategy that provides a reference point to understand new knowledge.

Like Faraday, the type of theme that I believe is worthwhile to explore is centered on the object, that is, the chemical substances. Below is a table that depicts the differences between traditional lab manuals and thematic ones in terms of variable knowledge. The key difference is that thematic curriculum has fewer variables that the learner has to contend with. Learning new concepts, new techniques, and being introduced to new substances can easily overwhelm many students. And once the preverbal lab report is handed in and students are just getting emotionally and mentally comfortable with the content, they are introduced with a whole new set of variables with the next lab activity. The only constant variable experienced by students is the instructional strategy used to teach them the concepts, techniques, and the properties of the substances they use. If the nature of the substances is held constant, students can decrease the cognitive complexity of learning. More students will enjoy learning about chemistry because they can apply more of what they know to the new lab activities they encounter.

Table 0.1: Showing the differences between traditional and thematic laboratory curricula.

	New variables being consistently introduced in a traditional lab curriculum	*New variables being consistently introduced in a thematic lab curriculum*
Conceptual Knowledge	yes	yes
Procedural Knowledge (Techniques)	yes	yes
Instructional Strategies	no	no
Chemical Substances	yes	no

Working Like A Scientist

Another benefit of developing a theme around a few chemical substances is the notion of working like a scientist. When feasibly possible, introductory students taking science courses should experience science as scientists do. Working like a scientist means seeing the world in a different way. In many cases it means closely examining the physical world over a prolonged period of time. This intense focus often creates expertise. As experts, scientists possess a depth of knowledge within a specialized field. They become experts in part by training their attention on only a few substances and their reactions. Examining zinc, iodine and their compounds in many different experimental situations allows students to approach expertise and work like scientists.

Cognitive Learning Theory and Thematic Curricula

According to cognitive scientists the brain can store new information in two major ways: in an isolated manner or connected to existing knowledge. If information is stored in isolation it will be harder to retrieve or remember. This is why it is often difficult for students to memorize a list of vocabulary words and then use them in conversation. Unrelated words are not taught in a context where there are explicit relationships between these new words and existing vocabulary. If on the other hand, a student learns new words, processes, or formulas that build upon previous learned material, then the brain can more readily integrate this new knowledge into cognition. Knowledge that is interconnected or networked creates a rich environment where information can be retrieved quickly and be remembered for a prolonged period of time. Thematic units for the classroom or lab can help students make cognitive connections that can be extremely useful to solve problems that depend on the retrieval of complex information. In terms of chemistry, studying a small group or family of chemical compounds can aid students working in the lab to build a knowledge base that can behave as

Figure 0.1: Zinc metal (Zn)

Figure 0.2: Solid Iodine (I_2)

an anchoring point to new chemical concepts, laws and theories.

The Uniqueness of Zinc and Iodine

So why choose zinc and iodine? The heart of this thematic laboratory manual is the reaction between zinc and iodine to produce zinc iodide, and then the decomposition of zinc iodide back into zinc and iodine. This is a unique chemical phenomena especially suited for academic laboratories if one considers that this pair of reactions is aesthetically pleasing, reliable, can be performed quantitatively, is safe, inexpensive, and can be conducted within a short amount of time. The ability of reactants to undergo a synthesis of a compound followed by a decomposition back into elements provides the basis for understanding the well known chemical phrase, "Same but not the Same." Conveying the essence of chemical change, this short axiom refers to the generation of chemical products that are similar to, but different from, the reactants that formed them. Same in the sense that a compound contains the same atoms as those of the reactants, and different in that these atoms are bonded in new configurations producing different chemical and physical properties. In the case of zinc and iodine, we have a grey solid reacting with a dark blue-black solid to form white zinc iodide. On a quantitative level, the synthesis of zinc iodide from its elements provides evidence for the Law of the Conservation of Mass, the Law of Constant Composition, and supports the Atomic Theory of Matter.

Another reason for choosing zinc and iodine is that other reactions between elements to form simple compounds have limitations and drawbacks. Reactions such as the well known syntheses of copper sulfide and magnesium oxide from their respective ele-

Table 0.2: Comparing the Zinc and Iodine Reaction to Traditional Syntheses

Synthesis	*Time*	*Safety*	*Availability of Materials*	*Cost*
Magnesium Oxide Synthesis	1. One trial per 1.5 hrs. 2. Involves heating and cooling. (Value = 2)	1. Burning of Mg produces bright light, but is shielded by crucible lid. 2. Crucibles can break during heating. (Value = 2)	All readily available and uses common equipment. (Value = 3)	1. Crucibles are costly ($2-4 ea.). 2. Only one reactant is purchased and it is inexpensive. (Value = 2)
Copper Sulfide Synthesis	1. One trial per 1.5 hrs. 2. Involves heating and cooling. (Value = 2)	1. During heating, H_2S is liberated. Choking on these fumes can occur if reaction is not well ventilated. 2. Crucibles can break during heating. (Value = 1)	All readily available and uses common equipment. (Value = 3)	1. Crucibles are costly ($2-4 ea.). 2. All substances are inexpensive. (Value = 2)
Zinc Iodide Synthesis	1. One trial per 0.75 hr. 2. Involves heating and cooling. (Value = 3)	1. Iodine can stain the hands and objects in the lab. (Iodine stains can be removed with a solution of sodium thiosulfate.) 2. Iodine is kept in solution during the reaction; it is not released as a gas which in large amounts can be toxic. (Value = 2)	All readily available and uses common equipment. (Value = 3)	1. All substances and materials are inexpensive. (Value = 3)

Concept Formation	*Motivation*	*Waste Disposal*	*Ability to Reform Elements to show Conservation of Matter*	*Totals out of 24*
1. Incomplete combustion can produce an erroneous empirical formula. 2. Students often have misconceptions involving colorless gases. 3. Crucibles can crack and break invalidating data. (Value = 1)	1. Reaction is not observable since it is covered by the crucible lid. 2. The change from the initial color of the reactant (gray) to the color of the product (white) is only slightly interesting to observe. (Value = 1)	1. The solid product must not be disposed through the sewer system. 2. The product must be collected separately as non-toxic waste. (Value = 2)	Elements cannot be easily reformed. (Value = 0)	13
1. More than one empirical formula can be formed (i.e. Cu_9S_5). 2. Crucibles can crack and break invalidating data. (Value = 2)	1. Reaction is not observable since it is covered by the crucible lid. 2. The change from the initial color of the reactants (copper and yellow) to the color of the product (black) is interesting to observe. (Value = 2)	1. The solid product must not be disposed through the sewer system. 2. The product must be collected separately as non-toxic waste. (Value = 2)	Elements cannot be easily reformed. (Value = 0)	14
1. Only ZnI_2 is formed, but is susceptible to hydration if not sealed. 2. Use of large boiling tubes prevents spills. (Value = 3)	1. The reaction is observable. 2. The exothermic warming of the test tube during the reaction is physically experienced. 3. The change from the initial color of the reactants (gray and dark purple) to the color of the product (white) is interesting to observe. (Value = 3)	1. The product dissolves in water and can be diluted and disposed through the sewer system. 2. Excess zinc metal can be recycled. (Value = 3)	Zinc and iodine can be easily reformed with a 9-Volt electrolysis apparatus and the decomposition of zinc iodide by heat. (Value = 3)	23

ments all have certain disadvantages when compared to the zinc iodide synthesis. In order to be concise, I organized a table to address the differences between these reactions. I used a three point system to compare different criterion such as time, safety, availability of materials, cost, concept formation, motivation, waste disposal, and the ability to reform the elements. As one can see, the zinc iodide synthesis has a greater utility in a few important areas.

The Versatility of a Chemical Theme

Zinc and iodine are versatile chemicals because they have an assortment of chemical properties which may enable students to construct an understanding of a breadth of conceptual information. Understanding different chemical theories, principles, laws, etc. is important, since it is the goal of science educators to have students know a large variety of scientific concepts in introductory classes and to have this knowledge integrated into a meaningful whole. Below is a list of some activities which utilize zinc and iodine as elements or in compound form. Many of these have the potential to be included with the activities in this resource and have been written up in the *Journal of Chemical Education*.

- Separating a zinc and iron mixture
- Separating an iodine and sulfur mixture
- Making brass
- Quantifying iodine in a commercial tincture of iodine
- Quantifying zinc in zinc ointment
- Calculating the atomic mass of zinc
- Determining the half life of I-131
- Calculating the specific heat of zinc
- Calculating the heat of displacement of zinc
- Enthalpy and entropy change in the triiodide equilibrium

- Heat of formation of zinc iodide
- Reaction of zinc and sulfur by electricity
- Iodide analysis of a superconductor
- Purification of zinc from a zinc/copper alloy
- An iodide selective electrode
- Making an electroscope using zinc
- Electroplating with zinc
- Migration of iodide ions
- Finding the dissociation constant of iodic acid
- LeChatlier's Principle using zinc and iodine solutions
- Stability constant of triiodide solutions
- Photosketching
- Rates of a chemical reaction: iodine and acetone
- A sulfide-iodide clock reaction
- Rate of dissolution of zinc in solutions of iodine
- An iodide catalyst
- Forming a coordination complex with zinc
- Zinc and enzymes
- Analysis of Vitamin C using iodine
- Calculating an iodine number in fats

With any list, there should be flexibility. For instance when dealing with acids and bases, it would be more prudent to use common acids and bases like HCl, NaOH, and acetic acid when developing activities. The choice of chemical substances have to make educational and practical sense. A chemical theme should begin with a few chemicals and grow in number over time. As students become familiar with zinc and iodine other zinc compounds can be introduced. For example, in the gas lab activity zinc carbonate is used in order for students to understand the ideal gas law. Like a seed that grows and spreads roots, a flexible theme will help students develop the kind of robust knowledge base that is required for success in introductory chemistry courses.

Zinc, iodine and zinc iodide in the specific forms, amounts and states of matter described in the activities can be used safely by teachers and students. These chemicals do not pose any unnecessary safety demands nor health risks beyond those normally found in academic laboratories. While iodine is labeled as a mild corrosive, it does not damage the skin quickly (it is used as a topical disinfectant). The bright yellow colored stains which iodine produces, allow rapid identification. Moreover, these stains are removable with rubbing alcohol or a dilute solution of sodium thiosulfate. Iodine gas, if inhaled in large quantities, is also toxic and thus, for this reason, is only used in one activity under a fume hood. Zinc, in the form of metal granules, is completely safe to use. Zinc powder, while not planned to be utilized in any of the manual's activities, is slightly toxic when inhaled. Finally, the disposal of all three of these substances is easily and safely accomplished by recycling and/or by performing three steps: ionization of the substance, dilution to standardized levels, and discharging of the substance in public sewage systems. And while this is a standard method of disposal, one should consult local authorities for current regulations.

Iodine Chemistry

Since iodine is the most reactive substance used in this lab resource I would like to allay some health concerns. Reviewing the literature indicates that there is no evidence to support that iodine causes allergic reactions. For instance, it is reported that,

> "Individuals may be led to believe that they are allergic to iodine, particularly after experiencing a reaction to iodated X-ray contrast media. To date, research has not confirmed that the condition 'iodine allergy' exists or that there is any cross-reactivity between the three sources of iodine, namely dietary iodine, iodated contrast media and povi-

done iodine. Research indicates that these patients should avoid the contrast media alone, and not dietary sources of iodine as well. There are also, however, no reports in the literature that prove that adverse reactions to elemental iodine (in whatever form) do not occur. Either iodine allergy is very rare or does not exist, or the methodology used in studies examining iodine allergy was flawed."

(taken from http://www.allergysa.org/jounals/march2004/

adverse%20reactions.pdf#search=%22frequency%20iodine%20allergy%22, accessed on August 1, 2012)

Given that academic laboratories deal with mercury spills in the lab, it doesn't seem that using iodine presents an unwarranted risk to students. While allergies to iodine are essentially non-existent, there are two safety concerns when handling iodine that I would like to address:

- Don't heat iodine or iodine compounds unless explicitly told to do so. When heated, solid iodine changes to a purple gas which is toxic to inhale in large doses. If you do observe purple gaseous iodine, do not let the gas escape into the air. Discontinue heating and move the source of iodine to a fume hood.
- Iodine, in any state, will stain hands and clothes orange. These stains should be removed since in time they could irritate the skin and damage fabrics. Iodine can be removed with a dilute solution of sodium thiosulfate which should be made available in the lab. If you notice an iodine stain away from the lab, rubbing alcohol can be used in place of sodium thiosulfate.

General Safety Guidelines

Safety is paramount to any endeavor. It is especially important in science because students are dealing with chemical reactions and performing techniques for the first time in your life. This makes the laboratory a new and exotic place and therefore, it can be a potentially hazardous place. The experiments that you will be performing do not involve any explosive or carcinogenic substances, and rest assured that all of the experiments are generally accepted to be very safe to perform. Students as well as instructors, the inexperienced as well as the experienced, should follow the below guidelines when performing these activities in order to prevent accidents and to enjoy their experience in the lab.

- Wear your goggles. Wear goggles. Wear goggles. The time you get lazy and take off your goggles is the time you can lose your sight. Contact lenses are not permitted. If you regularly wear contact lenses, you must bring a pair of glasses (with a current prescription) in order to enter the laboratory; these glasses cannot be worn in lieu of safety goggles. You must wear safety goggles over your prescription glasses.
- Next, use common sense. If it doesn't feel right, stop and ask the instructor.
- When working with a noxious substance, work with it under the hood.
- Know your chemicals by reading about them before working with them in the laboratory.
- Never ingest any laboratory chemicals even if it is known to be safe, like sodium chloride; airborne contamination can and does occur.
- Food and drinks can also become contaminated by airborne chemicals. Therefore, eat before lab (you will never like lab if your hunger makes you impatient and irritable). Never bring food into lab, even if it is wrapped up in your back pack. Gases have little respect for boundaries, such as canvas, paper and plastic.
- Dress in old clothes. Everyone spills stuff and holes can easily develop within a week or two after fibers have been damaged by acids or bases. Open-toed sandals or shoes cannot be worn in the lab and jewelry should be left at home. Long hair should be tied back since it could catch fire, interfere with your vision, or accidentally get into chemicals and equipment.
- Enjoy lab but don't play any jokes on people.
- No one is permitted in the laboratory outside of regularly scheduled hours without an instructor being present.

- Avoid breathing dust or vapor where possible.
- Know where all exits are in the laboratory. In case of fire never use the elevators. Know where all fire extinguishers, fire blankets, eye wash and shower stations are just in case you have to use them.
- Glass beakers look the same cool as they do hot. Use tongs if you have any doubts of their temperature.
- Always add acid to water, never water to acid. (The less dense water can splash when it is poured on the more dense acid and carry with it some acid onto your clothes or skin.)
- If a solution in a test tube is initially heated very intensely, the contents of the test tube could splatter. Do not position the test tube in a manner which allows the solution to be expelled in the direction of another student. Consider using a boiling chip to control boiling.
- Never rub your eyes with your hands while working in the lab. Always wash your hands after working in the lab.
- If you experience any irritation in your eyes, use the Eye Wash and rinse your eyes for 15 minutes. Notify medical personnel.
- If a spill occurs, notify anyone working around the spill as well as your instructor or the appropriate administrator.
- If you feel ill, move to a well ventilated area either near a window or outside the lab. Notify medical personnel.

General Disposal Guidelines

The disposal of toxic chemical waste is an important problem facing our society today. It affects everyone and everyone can help. We can dispose of our waste after each experiment in labeled bottles, most of which will be found under the hoods. This waste can then be treated by a licensed waste disposer at a minimum of expense. There are some guidelines that you should be aware of:

- When in doubt about pouring solutions down the drain, consult local authorities.
- Keep one type of waste separate from another; for example, discard organic and aqueous wastes into separate containers. Never add an acid or base into organic waste.
- Most organic wastes should not be poured down the drain, with the exception of ethanol.
- Halogen and non-halogen organic wastes should not be mixed.

Introducing the Chemical Activities

The remainder of this book describes 12 chemistry activities, many having multiple parts. They involve traditional content knowledge taught in first year college chemistry courses. While constructed with college students in mind, they can be altered for use on the high school level.

These activities have been in use at Hunter College of the City University of New York for over a decade. They have been revised, honed, re-worked, and revised again to make sure that students can collect quality data. Without well described procedures, students will get poor data, which will produce meaningless results when analyzed, and which will ultimately prevent learning from taking place. The domino effect is a key concern in laboratory education, therefore, a lot of effort went into producing detailed procedures.

With the exception of the topic of kinetics, background conceptual knowledge associated with each activity was not described. There are many good commercially available textbooks that contain this type of