The Chemistry of Water Pollution and Ozone Depletion

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Introduction

Though chemistry studies all matter and its interactions, all chemists deal primarily with compounds. The materials we interact with everyday are mostly made of atoms bound together. Very rarely does an element remain unbound in nature. From the type of drugs designed to treat diseases, the dyes in the clothing we wear, to the very air we breathe we experience chemistry every day. It is through the different types of arrangements of atoms that the substances we are familiar with take shape. The arrangement of atoms within structure determines the type of reactions that occur and the properties of the resulting substances. Thus, chemical bonding is a pivotal concept in chemistry.

Bonding is consistently one of the most challenging topics for my students. I know that my students struggle with the abstract nature of the topic because the closest I can generally bring them to bonding is through modeling kits. The inherent problem to the traditional methods used here is that the students do not usually tie the content to prior knowledge of every day materials. Traditionally students struggle with the task of evaluating and predicting products of new substances. I believe this occurs for two reasons. First, the substances most Chemistry teachers rely on to teach these topics are unidentifiable chemicals and do not create a lingering connection for students. Secondly, the chemicals used are not explored sufficiently to help students “see” the properties. During this seminar I decided to have my students approach bonding differently. I believe that my students will connect better with the material if they explore the properties of substances that are relevant and important in their everyday lives. Therefore, I choose to focus on the chemistry of water pollution and ozone depletion.

This unit is designed to help students explore the chemistry of everyday pollutants and research how it impacts our planet. First, the students will evaluate the bonding and intermolecular forces in common water pollutants to gain greater insight into how these chemicals enter the water system and interact with our environment. As groups they will create presentations that illustrate the importance of the chemical structure of one pollutant and have the opportunity to explore the social and environmental impact of that substance. Lastly, they will evaluate the multistep breakdown of ozone in the presence of chlorofluorocarbons and UV light. All my activities allow the students to work in groups to analyze the chemistry of pollution.

Classroom Environment

I teach in Charlotte- Mecklenburg County in Charlotte, NC. This unit was developed for students in the Honors Chemistry program at Mallard Creek High School. Mallard Creek is a very large urban high school with 2150 students. Our student body is 31%White, 54% African-American and 15% other (Asian, Hispanic, Indian and multi-racial). There are several graduation plans offered at Mallard Creek and we have a very diverse student body. My high school is on a block and modified block schedule. Last year my school had 80.9% proficiency and only 58.5% of our students met expected growth. Though our graduation rate was at an impressive 95.6%, our teachers have begun professional development to raise the rigor of the classes in our high school. Our school focus has shifted from proficiency to growth.

I teach 3 Chemistry Honors classes and 3 Chemistry Standard classes throughout the year on a block schedule for 90 minute periods. I see my students every day in one semester. My standard students are primarily 11th and 12th graders while my honors students are primarily 10th and 11th graders. My Honors classes have between 31-34 students while my Standard classes have 24-29 students. Since my school is relatively new we do not have extensive lab materials.

I have been teaching at Mallard Creek for 4 years now and have become personally involved in the Literacy Team at my school. Most of planning focuses on the content of chemistry and the ability of my students to master reading sciences. As outlined in *A Time to Act*, there is a national crisis involving the literacy of secondary students in the content area.[1] Therefore, this unit is designed to teach content and science writing skills. I will use requirements of the Common Core Standards and strategies that focus on struggling readers and writers to facilitate learning. My unit will have components that I will use in my Standard Chemistry class; however, the entire unit will be written for my Honors Chemistry class.

This lesson is created for a group of students that have been placed in accelerated courses to allow them to have access to more Advanced Placement science courses in their junior and senior year of their high school path. They are all at or above grade levels in their math classes and have a strong work ethic. The students come from varied backgrounds and socioeconomic groups, but all consistently show growth in science as measured on their 8th grade End of Grade Test. This lesson will have components to it that require advanced Chemistry and are designed to be a supplement in an honors course.

Strategies

The demand for STEM degrees has risen drastically since the 1950's; however, the time spent in the classroom on science has dwindled. Since the onset of No Child Left Behind

(NCLB) the focus of education has shifted dramatically towards reading and writing. Jon Miller of Michigan State University said, “Having a basic knowledge of scientific principles is no longer a luxury but, in today’s complex world, a necessity”.[1] Based on this finding and the advice of many others the American Association for the Advancement of Science (AAAS) established Project 2061.[2] This project was designed to promote science literacy and create a science literate population. There is a need in our society to not only create a science literate population, but to spark the desire to engage with science again.[3]

In my classroom I’ve heard enough negative commentary about science to fill a book. From, “I’m not good at science” to “It’s always been hard for me” my student lament about their lack of success in all science classes. Therefore, I want to bring back the scientist in my students through inquiry. Inquiry is our natural method of figuring out the world around us. For over 30 years research has supported that inquiry-based teaching is the “central strategy for teaching science”.[4] The NSTA defines scientific inquiry as “the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Scientific inquiry also refers to the activities through which students develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world.”[5]

The research suggests that there are several methods for implementing teaching through inquiry. I have decided that the 5 E’s: Engage, Explore, Explain, Elaborate, and Evaluate will suite my style of teaching and my students best. This method creates an environment that allows students to find an “in” to the lesson.

The Engagement stage in the process will allow students to relax and begin the natural inquiry process.[6] To pull my students in I will use real substances to explore bonding so that the concepts I teach can be linked to actual experiences. This portion of the unit will create the sense of awe, of personal experience, and allow students to talk about the science they experience rather than learn about.

Simultaneously, I want my students to explore concepts they have already mastered. To thoroughly explore bonding my students will solve problems using prior knowledge. As they transition from the excitement of real world based introductions, they will be challenged to answer questions about the conclusions they independently draw using electron configuration and stability arguments. The Lewis Structures my students create bring in knowledge about the periodic table, electron configuration and electronegativity of each atom. Most of this work will take place in groups so that each student is supported and challenged. My role in this transition will be to facilitate group discussion and provide resources so that the students can draw correct conclusions without my input.

My students will continue to draw conclusions, analyze problems, and investigate patterns as we progress through the unit. They elaborate and explain their conclusions as we begin applying bonding to real life chemistry and finally, my students demonstrate their knowledge when they analyze the properties of water and several other compounds. In each of the stages of inquiry I will continue to provide my students with feedback, support, and the resources necessary to allow them to further their understanding of bonding and the interaction of particles. By asking students to support claims with evidence strengthens my students ability to process large amounts of intricate information.

Content Objectives

In this unit I have several content objectives I want my students to master, as well as several processing and literacy goals. First they will learn the content as outlined in the Essential Standards. Essential Standard 1.2 outlines that my students will "Understand the bonding that occurs in simple compounds in terms of bond type, strength, and properties".[7] This includes "qualitatively comparing the relative strengths of ionic, covalent, and metallic bonds, inferring the type of bond and chemical formula formed between two atoms, comparing intra- and inter- particle forces, and comparing the properties of ionic, covalent, metallic, and network compounds."[8] They will also be able to tie bonding to electron configuration, the octet rule, and potential energy diagrams in bonding.

Rationale and Background Pertinent to the Unit

This unit fits at the end of my Bonding Content Unit. It is a four day exploration into ozone and water and how the two substances interact with other chemicals in the environment. This unit is designed to help students see the chemistry in our environment. They will have the opportunity to explore the chemistry, the social impact and ways to help clean up our environment in two separate activities. Each activity is designed to incorporate inquiry, peer collaboration, and help students bring bonding and reactions together.

To work through this activity there are several topics the students need to have mastered. Specifically, the students need to have a firm understanding of how the atom is organized and what contributes to the stability of a system so they can predict and analyze different substances. First, my students must know that the quantum mechanical model of the atom stipulates that the atom consists of two main regions: the nucleus and orbitals. Reactions can occur at both regions of the atom; however, they involve different mechanics. Nuclear stability is dependent on the neutron to proton ratio while chemical stability relies on electron configuration. Most of the substances we experience in our everyday lives are compounds formed in chemical reactions. During chemical reactions atoms are simply rearranged. I've integrated reactions into this unit because they complement bonding so well.

My students will rely heavily on the interpretation of the Periodic Table and the wealth of information in its underlying structure. They all have Periodic Tables that have been annotated with vital information. For example, they have learned that the Periodic Table is arranged by atomic number and representative atoms in the same group have the same number of valence electrons. They would have been made already aware that reactivity is directly related to an atoms radius, nuclear charge and electron configuration. In prior lessons we would have already begun discussing possible configurations for ions and molecules by exploring ways to fulfill the octet of each atom. My students know that the Octet Rule states that atoms will lose, gain or share electrons in order to obtain a full energy level, which normally requires 8 valence electrons in the outer shell, except for hydrogen. In this unit we will incorporate the electron configuration of constituent atoms into almost every activity to help anchor each activity. This is done to ensure that my students have a method for determining if a compound, its constituent atoms, a radical, or an atom are stable or unstable. It also allows students to use prior knowledge to explain how atoms and ions may interact with other substances. For example, my students will examine the atomic orbitals of the central atom in each species in the decomposition of ozone to determine whether it is stable or unstable. They will use their knowledge of electron configuration to explain why a substance reacts to form the products in each step.

Before I begin this enrichment unit I will have completed teaching the fundamental concepts in bonding. The bonding unit is aligned with the new Essential Standards and teaches my students several important concepts about the three major bond types: ionic, metallic, and covalent. They are responsible for being able to determine bond type, draw Lewis Dot Structures, identify salts and molecules, identify bond and molecular polarity, determine the VSEPR geometry of molecules, and predict physical properties based on the most predominant intermolecular force. For example, students need to know that molecules are generally softer than salts, that they have a wide range of melting and boiling points do not conduct heat or electricity and are not always soluble. They also need to be able to interpret experimental data to identify unknown substances based on properties.

In my initial instruction my students learned how to identify the bond type by focusing on the first element present in the chemical formula. This was relatively easy to introduce because I had already taught my students that salts, or ionic substances, contain cations, which are generally metals, and anions, which are generally non-metals. Likewise, they already know that molecules contain all non-metals. This background knowledge allowed my students to easily connect the formulas of different substances to the physical properties that are inherent to the general bond type in the compound. The dual connection of tangible substances along with their chemical formulas allows students to create links to new material and apply their knowledge of prior content.

This link allows me to show them a quantitative method for bond type determination through electronegativity values. They will need to understand that elements with high electronegativity values attract electrons more strongly in a bond. If those atoms come into contact with another nonmetal the resulting bond will generally be covalent. The actual difference in electronegativity of a covalent bond ranges from 0.0 to 1.7. Within that range there are polar bonds and non-polar bonds. A polar bond results from the uneven distribution of electrons between two atoms of similar but not equal electronegativities. In laymen terms, the electrons are shared unequally. The nonpolar bond results from the even distribution of electrons between two atoms with relatively equal electronegativities. Lastly, ionic bonds are created when two atoms with largely different electronegativities react and the electrons are completely transferred to the atom with the highest electronegativity. Any bond with a difference in electronegativity values above 1.7 are considered ionic. This concept is notably significant to the unit as it lays the foundation for the structure and properties of each substance.

Unit Content

By the time we reach this enrichment unit they will be able to compare different substances and infer relative relationships based on bonding. The first activity in my unit allows my students to explore the arrangement of the atoms based on the transfer, sharing, or mobilization of valence electrons in a more in depth perspective. Here we will examine the Lewis Structures of each bond type extensively by examining everyday pollutants.

Both activities in this unit involve drawing Lewis Structures and predicting the interaction of a substance with other substances. Therefore, it is essential that my students understand that Lewis Structures are representations of how valence electrons from each atom within a compound are transferred or shared to create a new substance. If the compound is ionic they are asked to show the resulting negative and positive ion with the appropriate number of electrons and charges in brackets. If one of the ions is a polyatomic ion they should follow the rules to create Lewis Structures of molecules adjusting the number of total valence electrons for the ion. If the substance is a neutral molecule they will draw the molecule according to the following steps:

1. The least electronegative element is in the center of the molecule. Exceptions – Carbon is always in the middle and Hydrogen is never in the middle.
2. The remaining elements should be placed around the central atom. If the central atom is a period 2 element it cannot have more than 4 surrounding atoms.
3. The number of valence electrons for each element should be counted and summed. This represents the total number of electrons present in the final structure.
4. A bond, represented by a dash, should be drawn from the central atom to all surrounding atoms.

5. All bonding electrons should be added and subtracted from the total number of valence electrons.
6. The remaining electrons should be given to surrounding atoms with the highest electronegativity first until an octet is reached.
7. Once all electrons have been distributed the formal charge of each atom should be assessed to see if multiple bonds are required.

Formal charge is a numerical assignment that represents electron densities in a substance. In other words, assigning formal charges allows a student to see where the electrons belong. The rules for formal charges are:

1. Formal charges are assigned for each atom in a molecule.
2. Formal charge = # of valence electrons – (lone electrons + # of bonds)
3. The sum of all formal charges must equal the net charge on the structure.
4. The best structure is one where the least number of atoms have a formal charge.
5. Multiple bonds are drawn to create molecules with formal charges of zero on all atoms.
6. In the event that you cannot get all formal charges to zero, the negative formal charge should always lie with the atom with the highest electronegativity.

My students will also be expected to analyze a formula or a structure and predict how it will interact with other structures. In the first activity my students will explore the interaction of several substances and water. They will examine the structure of many common substances and make a predetermination of solubility, intermolecular force, and properties based on the Lewis structures and geometries of each substance. My students will use their knowledge of molecular geometries to determine is a molecule is polar or non-polar and they will identify the predominant intermolecular force as hydrogen bonding, ion-ion attraction, ion-molecule attraction, dipole-dipole attraction, or London dispersion forces. For example, my students know that salts contain ionic bonds. These bonds are created by the electrostatic attraction of cations and anions and are held together by ion-ion attraction. The positive charge of the cation and the negative charge of the anion are attracted much like magnets. They also know that water is a polar molecule because of its asymmetrical distribution of electrons around the central atom. Using this information they should be able to determine that all salts do not react with water, but dissolve in it because of the ion-molecule attraction between the ions and the positive and negative pole on water.

Even with our constant contact with water many people do not understand how or why certain compounds are damaging to our water systems. For this reason, I will have my students examine the chemical composition of several pollutants to explain why their presence harms ecosystems. My goal is make sure they have firsthand knowledge of how we impact the state of the hydrological system of our planet by looking at how pollutants enter, move through and remain in the water on our planet. In the first activity my students will evaluate the structure of fertilizer salts, Styrofoam, plastic polymers, arsenic salts and combustion by products such as NO_x and SO_2 gases.

All the substances I choose in this activity are common enough to be relevant to my students and simple enough to interpret with their knowledge of bonding. The first two substances my students will evaluate in this activity are the nitrate and phosphate ions found in fertilizers. These ions are the leading contributor to eutrophication, one of the largest global pollution issues. Over the last 50 years global population growth has contributed to the increase in food production and land use, therefore causing an increase in sewage discharge and agricultural runoff.[9] The nitrates and phosphates from fertilizers used to stimulate the increased land use have entered riverbeds, lakes and streams. These chemicals act as nutrients to algae and stimulate algal blooms, a sudden population explosion of algae. Their chemical structure and physical properties has allowed them to easily migrate into estuaries and coastal waterways where the accumulation has devastated fish populations. During intense algal blooms the population of bacterial populations also increases as they move in to decompose the organic matter.[10] These microbes can cause significant and sudden drops in the level of dissolved oxygen. This dramatic drop in dissolved oxygen causes extreme aquatic and plant life death.[11]

Both the Styrofoam and plastics are significant because of the heavy use of plastics in our everyday life. According to the EPA, 13 million tons of plastic was generated in 2009 and only 7% was recovered for recycling.[12] The amount of plastic waste that ends up in our oceans cannot be calculated, but its impact is certainly gaining a great deal of attention. For this reason, I will focus on the accumulation of microplastics in our oceans and their physical and chemical implications on human and marine ecosystems. Most plastics in the ocean are considered non-biodegradable because they cannot be broken down by bacterial action or oxidation into simpler molecules such as methane, carbon dioxide and water.[13] In landfills plastics can be considered biodegradable if temperatures are consistently above 58˚C, where some plastics begin to slowly break down into smaller molecules; however, in the ocean the temperature is far below that.[14] In the ocean plastics tend to break into small fragments because of wave motion and UV light degradation. These fragments are integrated into ecosystems at varying depths. The environmental impact occurs as smaller fish consume the plastic pellets and are then consumed by larger fish. The process continues as larger fish consume contaminated fish and the concentration of the contaminants increases in a process called bioaccumulation.

Arsenic salts are naturally occurring in the soils and sands of our planet. The most notable case of arsenic poisoning remains in Bangladesh; however, many countries worldwide have contaminated wells. Arsenic poisoning causes lungs and kidney problems and skin lesions and discoloration. Because this is not a man made problem, but a problem that arises from our need to find alternative sources for fresh water it easily falls into the category of pollutants I am addressing.

Lastly, I want my students to explore gases that react with water to form acidic lakes and acid rain. Both NO_x and SO_2 are byproducts of combustion. Sulfur dioxide is produced when the sulfur compounds in coal combusts in the following reaction:

$$S(s) + O_2(g) \rightarrow SO_2(g)$$ [15]

Sulfur dioxide dissolves in water to form sulfurous acid in the following reaction:

$$SO_2(g) + H_2O(l) \rightarrow H_2SO_3(aq)$$ [16]

NO_X compounds are a family of nitrogen oxides that form when oxygen in a combustion reaction reacts with the nitrogen in our air rather than the hydrocarbon. The reaction is:

$$\text{Energy} + N_2(g) \rightarrow 2NO(g)$$ [17]

Nitric oxide is a very reactive chemical and it further reacts with the oxygen in the air to form nitrogen dioxide.

$$2NO(g) + O_2(g) \rightarrow 2\ NO_2(g)$$ [18]

Nitrogen dioxide reacts further to produce nitric acid in the following reaction:

$$NO_2(g) + \bullet OH(g) \rightarrow HNO_3(l)$$ [19]

This liquid is completely soluble in water. All acid rain causes biological, social and structural damage to our planet.

It is essential that I lay the foundation for several concepts not normally taught in high school Honors Chemistry in order to accomplish the goals of the first activity of my unit. First, I will introduce polymers and radicals through a series of lectures and videos. My students will not need to understand the different mechanisms used to form polymers; rather, they will simply need to understand that polymers are chains that contain smaller base units, or monomers, that are covalently bonded together. Likewise, I will be introducing the basic definition of radicals. My students will learn that radicals are substances with an unpaired electron. As stated before, structures gain stability by following the octet rule. Radicals are highly unstable substances that can initialize chain reactions. Though this is not a standard topic it emphasizes several key standards in the new Essential Standard course of study.

In addition to the topics above I will discuss the multistep decomposition of ozone into oxygen. The decomposition occurs naturally because oxygen is more stable than ozone; however, in the presence of UV radiation and chloroflurocarbons the process occurs much quicker. Ozone depletion fits very well with the theme of pollutants and their effects on nature due to chemical structure. At first glance these molecules appear to be very similar. It is only when you find the formal charge and geometry of the two molecules that the differences become apparent. When drawing the two structures the students will see that diatomic oxygen is connected with a double bond and has a linear geometry that results in a nonpolar molecule. On the other hand, ozone forms a structure that contains one double bond and one single bond. In fact, the best representation of the ozone molecule includes two different resonance structures. In addition, the central atom in both resonance structures contains a lone pair of electrons that create a bent molecule. The resulting structure is polar and has vastly different properties than oxygen. The ozone molecule is more reactive suggesting that the bonds in the molecule are broken easier than in oxygen. It is also well known that the two molecules absorb UV radiation at different intervals. In fact, if we did not have ozone in that atmosphere we would experience radiation exposure from particles with wavelengths between 242 – 320 nm.[20]

Our ozone layer has been a topic in environmental news for over 50 year. In the early 1970's scientist began to wonder what happened to aerosol chemicals once they reached the upper atmosphere. Two scientists, Frank Rowland and Mario Molina, were particularly interested in the reactivity of chlorofluorocarbons, a particularly stable compound used in refrigeration processes. They found that high energy radiation, especially UV-C, corresponding to 220 nm or less, can break carbon chlorine bonds.[21] Once hailed as a chemical milestone, chlorofluorocarbons were identified as the catalyst destroying our upper atmosphere.

To strengthen their knowledge of reactivity based on structure I will use the interactions between photons produced from the suns radiation with ozone. In this portion of the unit I break my students into groups and assign each group one step in the reaction. The students will be asked to draw and create models of each of the reactants to use as evidence for why the products are generated. The students will write a paragraph explaining the stability of each species within the reaction. After each group has successfully finished each reaction they will form new groups in which one member has evaluated different steps in the decomposition process. The students will provide their group members with a synopsis of their mechanism.

The following series represents the five reactions that each group will evaluate.

$$CCl_2F_2 + \text{photon} \rightarrow \bullet CClF_2 + \bullet Cl$$ [22]

In this reaction highly reactive chlorine radicals are formed. My students know that atoms want to have 8 valence electrons to be stable. Therefore, it is an easy jump to explain that radicals, like chlorine, are highly unstable and will react in order to fulfill their octet. Since the majority of our stratosphere is composed of ozone, O_3, it is logical to presume that a possible reactant of the chlorine radical is O_3. The first step of this reaction occurs when "chlorine pulls an oxygen atom away from ozone." [23]

$$2 \bullet Cl + 2\, O_3 \rightarrow 2 \bullet ClO + 2\, O_2$$ [24]

In this section I have the ability to show corresponding structures, formal charges, and polarity of all the involved molecules. Not only will my students get to learn about the chemistry of stratosphere, but they will see why certain substances are so reactive. The next reaction series, where the resulting $\bullet ClO$ molecule continues to react in order to finally form O_2, only illustrates the destructive nature of chloroflurocarbons.

$$\bullet ClO + \bullet ClO \rightarrow ClOOCl$$ [25]

$$ClOOCl + \text{UV photon} \rightarrow \bullet ClOO + \bullet Cl$$ [26]

$$\bullet ClOO + \text{UV photon} \rightarrow \bullet Cl + O_2$$ [27]

$$2\, O_3 \rightarrow 3\, O_2$$ [28]

In the final net reaction, the outcome always involves the destruction of ozone to form oxygen. Using ozone and oxygen as my basis for teaching polar and nonpolar molecules allows me to emphasize the importance of chemical reactions, reaction pathways, and bonding. My students will generate a step by step examination of how ozone reacts with chlorine radicals in the presence of UV radiation. They will have examined a complete reaction, multiple structures and the formation of a more stable product. This activity ties together all my goals. My students will evaluate several structures of common pollutants in the first activity and will use their knowledge of stability and bonding to explain why a series of reactions occur to decompose a molecule from one form into another.

Classroom Activities

Activity 1 – Predicting Properties in Everyday Pollutants

Students are given a molecular modeling kit and paired into groups of 3. The groups in this activity should be created to ensure students with gaps are met. This allows students to work together and refine their knowledge by explaining concepts to other students. It also facilitates my movement in the classroom. Groups can use the resources given to them and work through content issues together.

Each individual will receive a copy of the handout "Predicting Properties in Everyday Pollutants".(Appendix A) The students have 75 minutes to correctly complete the handout as a group. They are allowed to use their notes from lectures, their textbooks and each other as a resource in this activity. In this activity I direct students to the posters created in the beginning of the unit for bond type determination, definitions, and helpful hints on how to create Lewis Structures. This activity is predominantly student centered and I remain as a guide to help students identify how to find the answers. Students are instructed that they must obtain my signature on each line before they move to the next substance. This ensures that students are correctly completing each portion of the assignment before progressing to the next. When I check each group I look to make sure that each student has completed all parts of the assignment and I provide feedback on the accuracy of each answer.

To begin this activity I will arrange the students' desks so that students are grouped separately from the other groups. This ensures that the groups are forced to work through the activity together. The students begin by determining compound and bond type. Students that struggle with this portion of the activity should use the definitions of salts and molecules to figure out how to decode the chemical formulas they are given. After students identify the compound and bond type they will draw and then build a model of the Lewis Structure of each compound. In cases where the structures cannot be drawn given their knowledge of nomenclature they have been provided the structure. They should still create a model of the structure. In the last part of this activity my students are asked to identify the molecular geometries, the predominant intermolecular force and the resulting physical and chemical properties with water such as solubility. This has a tendency of being very difficult for my students. To help them easily identify the correct answer I direct my students towards their reference pages and their notes on how molecules and ions interact with water. I generally have students create a model of water so that we can literally hold the molecule they have created up to the water molecule and see if there is a site where the models may interact.

To wrap up this activity the class discusses the similarities and differences in compounds they examined. Limit this discussion to 10 minutes. I try to get my students to see the big picture that allows them to group substances as molecules that will react with water, molecules that do not react and will not dissolve, and salts that do not react with water but readily dissolve. Ask the students leading questions such as, "What compounds seem to be more likely to react with water?" "What compounds are more likely to dissolve in water?" As we go through our discussion I tell the students to include notes on the side of their work to help them understand why certain compounds fall into these categories.

Activity 2 – Presentations on Everyday Pollutants in Our Water

Students are given a 90 minute period to work on a presentation on one of the nine substances they evaluated in the first activity. The presentation must be created using Prezi, a medium that allows students to navigate through information in 2.5D space. Begin this activity with a quick 5 to 10 minute tutorial on how to create a Prezi presentation. I will allow the students to create their own groups of three. I assigned the substance to each group to make sure there was an even distribution of topics. In order to fit this into one class period the students are given three resources they can incorporate into their presentation. They will be required to use these three resources and they will also be required to find one more source. The students will present their presentations to the class in three days.

The students should work to incorporate several components into their presentations. They should focus first on how the chemical they are examining enters the water supply. In this initial focus they should be able to evaluate if the entry is manmade or natural, is it a byproduct or the intended chemical created, and where it occurs. Here the students should be answering questions such as, "Is this chemical avoidable? Is this chemical vital to our way of life? Does human activity increase or decrease the need for this chemical? Does human activity create the problem and why?” Have the students create an opinion that their presentation can focus on.

The next focus should illustrate the chemical composition of the substance. The chemical and structural formula should be included. The students should focus on the physical and chemical properties of the substance. In this section of the presentation students can include, where available, the chemical reactions used to create the substance. This section should answer questions such as, “What are the pros and cons of this substance? How do the properties of this substance address a certain need in society?” In this portion the students should focus on facts and not opinion.

The third focus ties the chemical to the real world by examining the environmental impact of this chemical. In particular, the students should focus on the interaction of this chemical and water. This portion of the presentation can illustrate the interaction of the chemical on people and different ecosystems. Students should address questions such as, “What part of our lives are impacted by this chemical? What are the health risks to different ecosystems from this chemical? What are the health risks to people? Is the effect permanent or reversible?”

To end the presentations the students should focus on any changes that can be made to correct or limit the production of this chemical. The students will have the ability to emphasize any alternative products, manufacturing processes, or human behavior that may alter the production of their substance. Encourage students to explore known alternatives when available. Students should address questions such as, “Is there a safer alternative? Is chemistry necessary to change the pollutant or does human behavior need to be altered?”

When students present their Prezi to the class each student will have a handout that lists the nine substances with large blanks next to them. As each groups present the students are asked to write down key facts for each chemical. They will be asked to summarize in one paragraph the information presented by the groups. The presentations should last one 90 minute period.

Activity 3 – Ozone Destruction and Reaction Pathways

In this activity students are put into groups of 3 by achievement on the last two activities. Students who did very well with the first activity were grouped with students who did not do well. Because this activity connects bonding to other concepts and requires high level thinking skills it is essential to place struggling students with other students to help instigate that thought process. In this activity students are given one of five different reactions in the multistep breakdown of stratospheric ozone. Each group is responsible for drawing the Lewis Structures of all constituent substances and explaining why the products are formed using stability arguments.

To begin this activity, I will show the tutorial on www.wwnorton.com/chemistry and view *Chemistry of the Upper Atmosphere* and *Collision Theory*. All the tutorials on this website are free and accessible to all. The first tutorial illustrates how UV light influences reactivity in the upper atmosphere and introduces the students to free radicals. The second tutorial shows the reaction pathway for ozone destruction in the presence of chlorofluorocarbons. Have a 5-10 minute discussion about the reactions they will be examining and why the catalyst and UV light are vital to this reaction.

In the activity students are asked to draw the Lewis structure of each compound in their reaction and use electron configuration to explain why the products are more stable than the reactants. Be sure to assist students by emphasizing the rules for drawing the best Lewis Structure. Ask them what contributes to the stability of a substance? Have them draw the valence electrons orbital notation to show the pairing of electrons in the structures. Ask them how the octet rule is fulfilled in each of the substances. This should take about 30 minutes.

After each group has completed their reaction the groups are rearranged to form new groups of five students. Each member of the group will have the structures and explanations for one of the five reactions. They are responsible for explaining their answer to the other students. Give groups another 30 minutes to complete this activity.

End Notes

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Teacher resources
Resources on bonding:
http://www.wwnorton.com/college/chemistry/gilbert2/chemtours/chemtour.asp
This website has tutorials on bonding. View the following tutorials: Bonding, Lewis Dot Structures, Periodic Table, Resonance, Expanded Valence Shells, Partial Charges and Bond Dipoles, Hydrogen Bonding and Water, and Intermolecular forces.
http://www.chem.ucla.edu/harding/tutorials/formalcharge.pdf This is a pdf file on how to calculate formal charges.
http://chemed.chem.purdue.edu/genchem/topicreview/bp/ch8/lewis.html This is website that walks you through drawing Lewis Structures.
http://www.chem1.com/acad/webtext/chembond/ This is a great online text book that illustrates and explains bonding.
Resources on water
http://www.edinformatics.com/math_science/water_ice.htm This website has different links to water and ice information and interactive water molecules in a java applet.
http://www.idswater.com/water/us/home.aspx This website is a great resource for learning about water chemistry.

Resources on pollutants
http://www.epa.gov/osw/conserve/materials/plastics.htm This website has facts on plastic consumption.

Resources on ozone
http://www.beyonddiscovery.org/content/view.article.asp?a=73 This website has it all on ozone and chloroflurocarbons.

Appendix A

1. Predicting Properties in Everyday Pollutants

Compound	Compound Type (Salt or Molecule) and Bond Type	Class and Geometry of Molecules	Lewis Structure (showing charges where necessary)	Predominant Intermolecular Force	Physical and Chemical Properties
NH_4NO_3 Ammonium nitrate Fertilizer					Soluble in H_2O: _______ React with H_2O:_______
$C_{16}H_{14}O_3$ Polycarbonate Plastic					Soluble in H_2O: _______ React with H_2O:_______
HNO_3 produced from combustion in cars					Soluble in H_2O: _______ React with H_2O:_______
SO_2 Sulfur dioxide combustion byproduct from burning coal					Soluble in H_2O: _______ React with H_2O:_______

Compound	Compound Type (Salt or Molecule) and Bond Type	Class and Geometry of Molecules	Lewis Structure (showing charges where necessary)	Predominant Intermolecular Force	Physical Properties
$C_{12}H_{25}C_6H_4SO_3Na$ Detergent					Soluble in H_2O: ______ React with H_2O:______
$(C_8H_8)_n$ PolystyreneStyrofoam					Soluble in H_2O: ______ React with H_2O:______
$(NH_4)_3PO_4$ Ammonium phosphate fertilizer					Soluble in H_2O: ______ React with H_2O:______
NaH_2AsO_4 Arsenic salts in soils					Soluble in H_2O: ______ React with H_2O:______

2. Presentation on Everyday Pollutants

Each group will create a presentation that teaches the class about the interaction of your pollutant and water. Your presentation should not last more than 10 minutes. It should include the following topics.

Topic One: How does the chemical enter our water system?

1. Is this chemical a man made product?
2. Is this chemical vital to our way of life?
3. Does human activity increase or decrease the need for this chemical?
4. Does human activity create the problem and why?

Topic Two: What is the chemical composition of the pollutant?

1. What is the chemical and structural formula of the pollutant?
2. What are the chemical and physical properties of the pollutant?
3. Show any and all chemical reactions used to create the chemical (where applicable).
4. What are the pros and cons of the substance?
5. How do the properties of this substance address a certain need in society?

Topic Three: What is the impact of this pollutant on the environment?

1. What part of our lives is impacted by this chemical?
2. What are the health risks to different ecosystems from this chemical?
3. What are the health risks to people?
4. Is the effect permanent or reversible?

Topic Four: What can we do to change this problem?

1. Emphasize any alternative products, manufacturing processes, or human behavior that may alter the production of their substance.
2. Is there a safer alternative?
3. Is chemistry necessary to change the pollutant or does human behavior need to be altered?

Resources for students:

Fertilizers:

1. Go to http://www.nbclearn.com/portal/site/learn/chemistry-now/chemistry-of-household-cleaners to find articles and videos on ammonia and fertilizers.
2. Go to http://chemistrydaily.com/chemistry/Eutrophication to find information on prevention.
3. Go to http://www.epa.gov/owow/NPS/Ag_Runoff_Fact_Sheet.pdf to read about agricultural runoff.
4. Go to http://scifun.chem.wisc.edu/chemweek/PDF/Agricultural_Fertilizers.pdf to read about fertilizer properties.

Polycarbonates:

1. Go to http://www.wwnorton.com/college/chemistry/gilbert2/chemtours/chemtour.asp and watch the tutorial on: Polymers.
2. Go to http://www.cnbc.com/id/15840232?video=1620084176&play=1 and watch "Trash Inc: The Secret Life of Garbage"
3. Go to http://www.americanchemistry.com/hops/intro_to_plastics/students.html to find information about the history of plastics
4. Go to http://www.chem1.com/acad/webtext/states/polymers.html to find awesome details about the environment and plastics.
5. Go to http://www.enviroliteracy.org/article.php/1188.html to find even more awesome details about the environment and plastics.
6. Go to http://portal.acs.org/portal/PublicWebSite/education/resources/highschool/chemmatters/archive/CNBP_024548 and read "Plastics Go Green".

HNO_3 and SO_2:

1. Go to http://www.umac.org/ocp/HowisAcidRainFormed/info.html to get information on the formation of acid rain.
2. Go to http://www.lakescientist.com/learn-about-lakes/water-quality/acid-rain.html to find information on how acid rain affects lakes.
3. Go to http://www.wwnorton.com/college/chemistry/gilbert2/chemtours/chemtour.asp and watch the tutorials on: Acid Rain and Acid-Base Ionization.

Styrofoam:

1. Go to http://www.wwnorton.com/college/chemistry/gilbert2/chemtours/chemtour.asp and watch the tutorial on: Polymers.
2. Go to http://www.cnbc.com/id/15840232?video=1620084176&play=1 and watch "Trash Inc: The Secret Life of Garbage"
3. Go to http://www.quadlock.com/green_building/eps_and_the_environment.pdf to find facts about polystyrene and its uses.
4. Go to http://www.nbclearn.com/portal/site/learn/chemistry-now/chemistry-of-plastics to find tons of information about plastics. There are videos and articles here.

Detergent:

1. Go to http://www.nbclearn.com/portal/site/learn/chemistry-now/chemistry-of-detergents to watch a video that explains how detergents work in water.
2. Go to http://www.pollutionissues.co.uk/household-cleaners-detergents.html to read about types of detergents that enter the water supply.
3. Go to http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1256306/pdf/amjphnation00157-

0108.pdf to read about detergents in the water supply and how to eliminate the problem.

Arsenic:

1. Go to http://portal.acs.org/portal/PublicWebSite/education/resources/highschool/chemmatters/archive/WPCP_008628 to read about arsenic poisoning and how to avoid it.
2. Go to http://www.physics.harvard.edu/~wilson/arsenic/arsenic_project_introduction.html to find information about arsenic poisoning and tons of links to more information.
3. Go to http://www.water2drink.com/how_it_works/arsenic.asp to find great information about arsenic as a chemical and what areas in the US have issues with arsenic poisoning.
4. Go to http://www.unicef.org/search/search.php?querystring=Bangladesh+water to find tons of articles and statistics on arsenic poisoning in Bangladesh.

3. Ozone Depletion by Chlorofluorocarbons

In your group analyze one of the following reactions. In the box below your reaction draw the Lewis Structure for each substance in the reaction. Determine if the products are more stable than the reactants and explain why.

CCl_2F_2 + photon $\rightarrow$ •$CClF_2$ + •Cl (1)

2 •Cl + 2 O_3 $\rightarrow$ 2 •ClO + 2 O_2 (2)

•ClO + •ClO $\rightarrow$ ClOOCl (3)

$$ClOOCl + \text{UV photon} \rightarrow \bullet ClOO + \bullet Cl \quad (4)$$

$$\bullet ClOO + \text{UV photon} \rightarrow \bullet Cl + O_2 \quad (5)$$

$$2\ O_3 \rightarrow 3\ O_2 \quad (6)$$