Curriculum Units by Fellows of the National Initiative
2007 Volume V: Renewable Energy

# Environmentalists and Chemists Unite: A Chemistry Class for our Changing World

Curriculum Unit 07.05.03, published September 2007
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## Introduction

When taken out of context, the standard high school chemistry curriculum can be seen as an obscure chain of unrelated factoids. Approaching chemistry in this manner presents several challenges for both the student and the teacher alike. By the time that students reach chemistry in their junior year in high school, this class is yet another item competing for their attention. The teacher must balance adhering to the mandated curriculum, staying true to the intent of the material and, most importantly, motivating the students to invest the energy required to learn. In a course that is designed primarily for students that intend to continue their studies at the college level, connecting a concept to their future studies in college or describing the impact of a poor grade on their GPA is often adequate motivation. However, in a vocational high school chemistry class where many students have no desire to attend college, the latter argument is insufficient. Although many students attending a vocational high school are not motivated by grades, a vocationally focused chemistry teacher can motivate students by relating content to the students' chosen vocations and topics important to youth culture.

This curriculum unit will address several standards-based curriculum components by situating them within the context of a topic that has been receiving significant attention in the popular media, the need for alternative energy sources. Although the theme of the unit is centered on alternative energy sources, it is intended to address content required in the chemistry curriculum, including atomic inventory, classification of matter, balancing equations, naming covalent compounds, moles, stoichiometry and heat capacity. Chemistry at our high school is taught over 16 weeks of 90-minute block periods, and the activities in this unit are expected to be carried out over the course of the first 8 weeks of the course. The 90-minute block period affords me the luxury of being able to integrate hands-on and minds-on activities into each of my class periods. It is recommended that teachers of eleventh graders switch teaching methods about every twenty minutes to maintain student engagement. Therefore, the activities in this unit are more like mini-lessons and need not be restricted to 90-minute block periods, but could be easily adapted to fit the more traditional 45-minute class schedule. In addition, the lessons presented in this unit are not intended to serve as the sole reinforcement for the chemistry content covered, but to serve as a unifying theme throughout a course that is commonly characterized by content that appears unrelated and irrelevant to students.

Although this unit was constructed with my high school chemistry class in mind, the rudimentary nature of some of the content and the intentional focus on the integration of several science content areas makes it easily adaptable to other high school courses such as Earth science, biology, or environmental science. For example, within our district, students are also asked to balance simple equations in tenth grade biology class. However, when they reach my eleventh grade chemistry class, they behave as if my class is their first exposure to these concepts. Therefore, an overlap of concepts should work well to reinforce content across grade levels.

## Part I: Atomic Inventory and Classification of Matter

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**Objectives and Strategies**

The first part of the unit, which addresses atomic inventory and classification of matter, will be presented at beginning of the course where students are being reacquainted with the elements and the periodic table. Although students have discussed elements in previous courses, upon entering chemistry class, most do not make a connection to the Earth systems and living systems that they have explored in previous science courses. Students will investigate the primary elements in the Earth's crust, atmosphere, oceans and in living things. Through this investigation, they will gain familiarity with the periodic table and review the factors that make the elements different (protons, neutrons and electrons). In addition, we will compare and contrast elements, compounds and mixtures as they relate to Earth and biological systems. The purpose of this section is to build a bridge between the students' prior knowledge and to begin to give the students a relationship with the Earth and build the foundation for understanding climate change.

Many students fail to realize that all matter, from the soil they are standing on, to the air that they are breathing, is composed of elements. In addition, the complex systems of the Earth and life are highly dependent upon a handful of very important elements. Most students do not know that their own bodies are primarily carbon, nitrogen, oxygen, phosphorus, sulfur and hydrogen. They are baffled to find that the same carbon that is present in their bodies is "the same" carbon that they would find in a piece of coal or in a tree. This leads to the question of what makes elements the same and what makes them different. This question will serve as the basis for the introduction to atomic inventory where students will learn that the primary similarities and differences between elements can be traced to the number of protons, neutrons and electrons. When asked to look at the periodic table through this lens, the intimidating chart on the wall becomes a living tool for understanding the world in which we live.

The poetic nature of science will be reinforced through the use of Primo Levi's fictional piece, *The Periodic Table* [1]. Primo Levi was a Jewish Italian chemist who suffered through the Holocaust and used his writing as an outlet for his internal turmoil that ultimately resulted in his suicide. Although most of Levi's writings are centered on his experiences in Auschwitz, *The Periodic Table* is slightly more autobiographical in nature as he uses the nature of several elements in the periodic table as metaphors for various portions of his life story.

My students will focus on the "Carbon" chapter in Levi's book. In this chapter, Levi traces an atom of carbon through the carbon cycle. It begins with carbon as a component of limestone and chronicles its journey into the air in the form of carbon dioxide, its entry into the living world through the process of photosynthesis, continuing through the body in the form of glucose, and ultimately its return to the Earth as a result of the inevitable demise of the host.

*The Periodic Table* will be a difficult read for most students and will need to be supported through pre-reading and guided reading activities. Although the battle will be arduous, it is well worth the effort. Reading this piece not only makes a tie to biology-based chemistry but also to literature. It allows the reader to take a glimpse into the emotional and spiritual nature of the relationship between a chemist and his life's work through metaphors that transcend the communicative capabilities of a traditional lecture on the periodic table.

In addition to using the Earth to demonstrate the nature of the elements, the Earth can also be used to explain how matter is classified. Matter is classified into two categories: mixtures and pure substances; where pure substances are elements and compounds and mixtures are physical combinations of the latter. Through the discussions of *The Periodic Table*, students should already be familiar with several elements and have been exposed to compounds including calcium carbonate, carbon dioxide, and glucose. This discussion can be extended to mixtures on the Earth. Air makes a great example of a homogeneous mixture of nitrogen, oxygen, argon and carbon dioxide because it includes elements and compounds so students will be less likely to develop a misconception that homogeneous mixtures are limited to only elements or compounds. Another great example of mixtures in Earth systems is a heterogeneous mixture such as granite.

In support of the mixture portion of the unit, students will learn how to use paper chromatography to separate the ink in markers into the component dyes, and then apply this technique to separating the pigments present in a leaf. Leaves appear green because the pigment chlorophyll reflects green light. Other pigments that are often present and masked by the green are carotenoids (orange), xanthophylls (yellow), and anthocyanins (red, purple). These colorful compounds differ in both size and polarity, and in the presence of the right solvent will make their way up the strip of chromatography paper at different rates and separate into distinct colorful bands [2]. This is quite a popular separation and many students may have performed it in middle school. However, students of all ages love pretty colors and the discussion can be extended into more sophisticated topics such as, conjugated double bonds, the structures and chemical properties of the pigments, the electromagnetic spectrum and polarity.

**Instructional Plan**

This section of the unit should take approximately two weeks to teach. It is important that at this stage students get the time to explore the elements and their properties so that they begin to build a personal relationship with chemistry. In addition to the group discussions around all the topics in the unit, students will read Primo Levi's *Periodic Table* chapter on carbon and complete an accompanying worksheet to scaffold the reading. After reading the story, students will research an element that we have discussed and write a story about the "life" of that element using the Levi text as a model. The pre-reading, during reading, and after reading activities can be found in Sample Activity 1 at the end of this unit.

After discussing classification of matter, students will first separate the dyes of water-soluble markers into their components [3]. They will then apply the same concept to complete a separation of pigment mixtures in a leaf through paper chromatography [4,5,6].

# Part II: Nomenclature and Reactions

### Objectives and Strategies

The next section of the unit introduces students to chemical reactions by looking at how humans impact the composition of the atmosphere. Students will learn how gasoline and diesel engines work, and we will look at the primary and side reactions that occur as a result of fuel combustion. Through examining the reactions, we will not only discuss the structure of reactions (product, reactant, etc), but we will also balance equations and learn the nomenclature rules for covalent compounds (e.g. CO, $CO_2$, $NO_x$). This section should be of interest to high school juniors that have recently begun driving but have very little understanding of how their car works or the impact of their driving on the environment. In addition, given the vocational nature of my school, students may have an interest in the workings of an engine. During this section of the unit, we will identify the source of the many of the "troubling" compounds resulting from combustion that we will discuss in an upcoming section of the unit on global warming.

In order for the students to truly understand how driving a car impacts the environment, they must first understand why they are using gasoline, what it does for the car, and the side effects of using gasoline to operate a car. Gasoline is very complex mixture produced by the fractional distillation of crude oil. It contains over 500 hydrocarbons and a range of solvents [7]. The hydrocarbons found in gasoline are selected based on their physical and chemical properties which are determined by their chain length and structures. As the carbon chain gets larger, the hydrocarbon becomes more viscous and its boiling point increases [8]. Therefore, short chain hydrocarbons are the most volatile and easily ignited because of weaker dispersion forces. In automotive gasoline, the perfect mixture of hydrocarbons must be obtained which balances flammability, volatility, and safety/transportability.

When hydrocarbons are burned, the potential energy stored in the bonds is ultimately released and converted to kinetic energy to move the car. A chemical reaction is simply a rearrangement of atoms where bonds are broken, atoms change partners, and bonds are reestablished. In order for energy to be released from a reaction, the energy required to break the bonds of the reactants must be less than the energy that is released as a result of the formation of new bonds in the products [9]. As an example, the complete combustion of octane is shown below.

$2\ C_8H_{18} + 25\ O_2 \longrightarrow 18\ H_2O + 16\ CO_2$ + Energy

Most cars operate on a four-stroke cycle that consists of the fuel intake, compression of the fuel, combustion of the fuel and finally the exhaust [10]. In a car engine, this cycle is repeated hundreds of times per minute. The fuel is mixed with air shortly before reaching the cylinder, the piston compresses the fuel/air mixture, and the spark plug ignites the fuel. That explosion drives the piston back down and the exhaust is released to the tail pipe. The primary difference between a diesel and gasoline engine is that, instead of using a spark plug, diesel engines rely on the heat produced from the compression of air in the cylinder to ignite the fuel that is subsequently injected. Depending on where this concept is introduced in the curriculum, a tie can be made to the gas laws and Gay Lussac's discovery of the direct relationship between pressure and temperature.

The diesel engine not only operates differently from the gasoline engine but also uses different fuel. Similar to gasoline, diesel fuel is a mixture of hydrocarbons, but diesel carbon chains are much longer ($C_{10}$ to $C_{20}$). The higher boiling point caused by long chains is not as important because diesel fuel does not need to be converted to a vapor before it is used. The length of the carbon chains in diesel is limited by the viscosity and the tendency for the fuel to become too thick to flow into the combustion chamber at lower temperatures [11,12].

Because both gasoline and diesel fuel are composed of hydrocarbons, the combustion products are similar. The standard products of complete combustion are carbon dioxide and water; however, this is not the only reaction that occurs. In reality, not all of the carbon is converted to carbon dioxide. If there is insufficient time or oxygen for the reaction to occur, carbon monoxide will be produced by the following reaction [13]:

$2\ C_8H_{18} + 17\ O_2 \longrightarrow 18\ H_2O + 16\ CO$

In addition to carbon monoxide, cars can also be a source of noxious gases. The high temperatures created in the internal combustion engine cause the nitrogen and oxygen in the air to react to form a range of potentially toxic nitrogen oxide compounds.

$N_2 + O_2 \longrightarrow NO_x$

All petroleum products also contain a small amount of sulfur. The amount is relatively insignificant in regular gasoline but is present to a greater extent in diesel fuel. When burned, the sulfur reacts with oxygen to form polluting sulfur oxides, the precursor to acid rain.

$S + O_2 \longrightarrow SO_2$

$2\ SO_2 + O_2 \longrightarrow 2\ SO_3$

$H_2O + SO_3 \longrightarrow H_2SO_4$

This section of the unit not only presents a grand opportunity for writing/balancing equations but also for introducing nomenclature rules for covalently bonded compounds. The students will be able to recognize the impact of their driving on air quality and the importance of low sulfur diesel fuels that are appearing at most gas stations. In addition, understanding the combustion reaction sets the foundation for the discussion on global warming in the next part of this unit, and enables them to determine the carbon footprint of other carbon-based fuels such as ethanol or biodiesel.

**Instructional Plan**

This section of the unit should take about two weeks to complete. Students will have numerous opportunities throughout the semester to balance reactions and name covalent compounds and the discussions around gasoline and engines serve as the hook. Student activities will consist primarily of applying the naming rules to the products of the combustion reaction and the side reactions and balancing a range of equations.

## Part III: Global Warming and Stoichiometry

### Objectives and Strategies

In this section of the unit on global warming and stoichiometry, we will introduce the concept of moles within the context of the stage in the carbon cycle where $CO_2$ is removed from the atmosphere through the process of photosynthesis. The significance of an increase in atmospheric $CO_2$ will be discussed as it relates to global warming. Students will compare the quantities (moles and atoms) of $CO_2$ consumed through photosynthesis vs. the quantities released as a result driving their cars through the use of stoichiometry. The purpose of this section is to demonstrate each student's personal contribution to atmospheric carbon as a result of driving.

Although most scientists have reached a consensus, many students have heard mixed messages with respect to the validity of the claim that global warming is a reality. The best way to squelch these doubts is to allow the students to experience the role that data play in differentiating a scientific argument from a philosophical argument. The World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) united to form the Intergovernmental Panel on Climate Change (IPCC) to take a look at the current scientific data on the anthropogenic (human-related) impact on climate change. This global collaboration of scientists utilizes data available from peer reviewed scientific literature as the basis for their argument and has issued several conclusive reports with respect to the reality of global warming [14]. The rigor of peer review is an extremely important concept for students to understand, and these discussions should improve their ability to construct quality lab reports and prepare them to be critical consumers beyond their science class.

According to the data presented by the IPCC, global temperature is increasing at a rate that correlates with the increase in the concentration of atmospheric global warming gases [15]. However, as all scientists know, correlation does not necessarily indicate causation. In order to determine if the increase in these gases has caused the increase in atmospheric temperature, it is important to understand how energy is transferred to the Earth and how that energy impacts the chemistry of the global warming gases.

Energy from the sun can follow three different paths. It can be transmitted, absorbed, or reflected. Approximately 50% of the energy that reaches our atmosphere never reaches the surface of the Earth. It is either reflected or absorbed by the atmosphere. The radiant energy that reaches the surface is either absorbed by the Earth or radiated to the atmosphere. Of the energy that is radiated to the atmosphere, approximately 84% is absorbed by "special" gases in the atmosphere and reradiated back to the Earth. This is a natural process that keeps the Earth at a comfortable and relatively constant temperature. The problem arises when the concentration of these special gases increases such that more than 84% of the energy is reradiated back to the Earth. This causes an unbalance in the natural cycle of absorption and radiation and subsequently leads to an increase in temperature [16].

Not every gas has this special ability to absorb and radiate energy to the extent that the greenhouse gases can. The geometry of certain molecules allows them to transmit visible light, but absorb electromagnetic energy in the infrared portion of the spectrum. Ultraviolet radiation has sufficient energy to break bonds, while infrared supplies only enough energy sufficient for vibration. The tendency to vibrate is determined by the bond angles, positions of lone pairs, strength of the bonds and masses of the component atoms. If given sufficient energy to vibrate, the bonds will vibrate for a short while until they return to their unexcited state and reradiate the energy back to the Earth [16].

The most abundant greenhouse gas is water, but carbon dioxide, has received most of the attention with respect to global warming. The primary reason carbon dioxide is at the center of the discussion is because humans have not added a significant amount of water to the atmosphere. However, this does not mean that water is not a major player in the climate change caused by greenhouse gases. Increasing the temperature will increase the amount of water vapor in the air that will in turn compound the effects of increasing the concentration of the other greenhouse gases [18].

Some of the primary greenhouse gases ($CO_2$, $N_2O$, $SO_2$) have already been discussed in this unit in relation to their production as a result of driving an automobile. However, the contribution of internal combustion to the concentration of $N_2O$ and $SO_2$ is minimal in comparison to other sources. It has been estimated that approximately 70% of anthropogenic nitrogen is a result of the agricultural industry [19], while the primary source of $SO_2$ is burning coal. In addition to the aforementioned compounds, methane, ozone and chlorofluorocarbons (CFCs) play a similar role in increasing the temperature of the Earth.

Carbon dioxide is generated by several natural processes, but the focus of this unit is how we can affect the anthropogenic contribution to the concentration of carbon dioxide. Carbon dioxide is captured by several natural sinks through the carbon cycle and normally the amount of $CO_2$ that is captured in the forests, soil, oceans and fossils is equivalent to the amount that is released through respiration and decomposition of rocks and living matter. When students begin to understand the chemistry behind global warming and the role that humans play in restoring the balance in the carbon cycle, they are empowered to take ownership over their personal contributions. In addition, I will emphasize the human impact through the use of images. There is very strong evidence that the temperature increases are melting glaciers, increasing the number of forest fires, increasing risk of disease, and increasing the risk of coastal communities to high intensity tropical cyclones (hurricanes, typhoons, etc) [20,21]. Al Gore's film, *An Inconvenient Truth*, presents some truly disturbing images that will undoubtedly engage students in this issue. For example, in one scene a polar bear struggles to regain its footing on a small piece of ice floating in the middle of the ocean. The use of these images will undoubtedly maintain student interest in global warming and provide the motivation to understand the accompanying chemistry.

A complementary method of engaging students in this issue is through the use of video games. Video games are a large part of youth culture and we often complain about the violence and negative influence that they can pass on to our children. In an effort to capture the influential nature of video games, there is currently a movement to develop dynamic, engaging, socially conscious and scientifically accurate video games. Microsoft is currently working on a global warming game for its Xbox 360 gaming system [17, 22].

As a hands-on experience, students will complete a lab to determine how much $CO_2$ a plant can consume through the process of photosynthesis [23]. Using a $CO_2$ probe, the students will measure the $CO_2$ consumption rate of a plant. They will then use stoichiometry to determine how much $CO_2$ they would emit as a result of driving their car and compare that to the amount of $CO_2$ that can be consumed by a plant (See Sample Activity 2).

**Instructional Plan**

This section of the unit should take about two weeks**.** It unit will begin with a viewing of the film *An Inconvenient Truth.* Next, students will measure how the concentration of $CO_2$ in a closed system decreases as a result of photosynthesis by a green plant. With these data as a basis, students will use stoichiometry to determine how many trees are needed to consume the $CO_2$ generated in driving a gasoline-fueled car for one year.

## Part IV: The Energy Potential of Biodiesel

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**Objectives and Strategies**

The final section of the unit will address a popular alternative fuel, biodiesel. Students will continue their interaction with stoichiometry to theoretically determine the amount of $CO_2$ generated from using biodiesel and comparing this to their results from part III, the combustion of regular gasoline. In addition, they will produce a lab scale amount of biodiesel and use this fuel to compare the energy ($Q = mc_pDT$) quality of biodiesel to the energy quality of regular diesel.

Biological sources of energy such as ethanol and biodiesel have been center stage in recent discussion on alternative energy sources [24]. However, ethanol is losing a bit of its promise within the scientific community as scientists begin to look more closely at its overall energy balance. Researchers at the University of Minnesota have found that ethanol (made from corn) returns 25% more energy than was invested in its production, while biodiesel (made from soybeans) returns 93% more energy. In addition, ethanol combustion produced 12% less greenhouse gases than fossil fuels, while biodiesel produced 41% fewer emissions [25]. Therefore, my class will look more closely at how biodiesel is made and its energy quality as compared to regular diesel.

The primary raw material for biodiesel is soybeans, but quite often the synthesis of biodiesel begins with an intermediate product, vegetable oil. To produce soybean oil, glycerol is esterified with fatty acid chains. Soybean oil from different sources will have different concentrations of fatty acids in the triglycerides, but a characteristic composition is: 8% palmitic acid ($C_{15}H_{31}CO_2CH_3$), 3% stearic acid ($C_{17}H_{35}CO_2CH_3$), 25% oleic acid ($C_{17}H_{33}CO_2CH_3$), 55% linoleic acid ($CH_3(CH_2)_4CH{=}CHCH_2CH{=}CH(CH_2)_7CO_2CH_3$), and 8% linolenic acid ($CH_3(CH_2CH{=}CH)_3(CH_2)_7CO_2CH_3$). In order to form biodiesel, the glycerol portion of the triglyceride is broken apart from the fatty acids by sodium hydroxide (NaOH) and is replaced by methanol to create three separate methyl esters. This tranesterifcation reaction also creates a waste product, glycerine [24,26]. In our class, students will perform the transesterification reaction in the laboratory and then compare the energy output from burning biodiesel to the energy generated from standard diesel [28,29,30,31].

Students can continue to use stoichiometry to compare the amount of carbon dioxide generated in a biodiesel car to that generated from a gasoline car as we did in an earlier exercise. The combustion reactions for biodiesel and standard diesel are shown below and the solution would follow a procedure similar to the one presented in Sample Activity 2 at the end of this unit.

$C_{19}H_{36}O_2 + 27\ O_2 \longrightarrow 19\ CO_2 + 18\ H_2O$ (Biodiesel) [32](Beaton)

$2\ C_{16}H_{34} + 49\ O_2 \longrightarrow 32\ CO_2 + 34\ H_2O$ (Standard Diesel)

Although based on these exercises, biodiesel may appear to be an attractive alternative, it is not practical for use as the sole energy source for the planet. The process of photosynthesis is very inefficient with respect to energy generation and in order to meet the world's energy demands, 31% of the total land area of the Earth would have to be covered in energy farms [33]. In addition, energy farms on this scale would negatively impact the ecosystem and be destructive to the way of life of rural communities [34]. Exploring this issue will reinforce to students how good science can not be performed in a vacuum and how a seemingly beneficial discovery can have negative consequences. Students in my class will review an article in a popular magazine where this issue is addressed. In addition, we will analyze a film that is scheduled to be released in the fall of 2007 *Fields of Fuel* that depicts biodiesel as the "silver bullet" that will address America's energy problems.

**Instructional Plan**

This section if the unit will last approximately one week. During this week, we will compare the composition of biodiesel to regular diesel and to gasoline. (See Sample Activity 3) We will then prepare a small amount of biodiesel to test its energy content by using it to heat water. Preparing the biodiesel will take two class periods and it can be tested during another class period. During the final activities of the unit, the students will critically analyze two popular media pieces related to biodiesel. The first piece is an article in a magazine that focuses on the negative impact of soybean farms in South America (See Sample Activity 4), while the second is a movie that encourages widespread adoption of biodiesel.

Given the vocational nature of my high school, this unit can be extended to include further investigation. We have an automotive technology shop that might be interested in collaborating to develop a vehicle that runs on biodiesel. This would require a major scale-up of our lab experiment, but could generate much excitement within our classroom and beyond. In addition, there is a biodiesel company that is relatively close to our school that may be worthy of a field trip. This unit can be taken in several directions and is highly dependant upon the interest level of the students.

## Sample Activity 1

(Part I Atomic Inventory and Classification of Matter)

Students will read the chapter on Carbon in Primo Levi's *Periodic Table* using the following as a guide.

Pre-reading

## Sample Activity 2

(Part III: Global Warming and Stoichiometry)

Environmentalists and Chemists Unite !!!

Aisha is a very socially conscious young lady. She is the president of her school's environmental club and is very active in her community. She knows that you are taking a chemistry class and needs your help.

Aisha just got her driver's license but wants to make sure that her driving is carbon neutral. In order to do this, she plans to plant trees that can consume the same amount of carbon dioxide that her car produces. She has heard a statistic that a maple tree consumes 2.52 lbs of carbon dioxide per year [35]. . .and this is where her expertise ends.

You are anxious to take on the challenge, but you need a bit more data, so you email your chemistry teacher. You receive the following response.

Dear Jamal,

It is wonderful to hear that you are not only helping a friend, but have also decided to take on such a worthwhile chemistry problem. Well, I would love to tell you that there is a straightforward answer to your question, but gasoline is a very complex mixture and its combustion increases the complexity even more. However, we can give your friend a general idea by assuming that her gasoline is 87% octane $C_8H_{18}$ and 13% heptane $C_7H_{16}$ by volume and the combustion goes to completion. You will also need to make some assumptions with respect to how many miles she will drive each year and the fuel efficiency of her car. I have also attached a data table that you may find useful.

Density heptane 684 g/L

Density octane 692 g/L

3.785 L = 1 gallon

2.2 lbs = 1 kg

With these data in hand, you are ready to start solving your problem. Aisha realizes that these would be useful to communicate more broadly, so she asks you to communicate your work, assumptions, and findings in the form of a brochure that she can display in her environmental awareness office. The front of the brochure should be catchy, attractive, and communicate your message related to global warming and major findings, while the back of your brochure should lay out the details of your assumptions and work.

**Sample Solution for Sample Activity 2: Environmentalists and Chemists Unite**

Assumptions:

Driver travels 12,000 miles per year

Car gets 24 miles per gallon of gasoline

12,000 miles /year x (1 gallon/ 24 miles) = 500 gallons/ years

Volume of Octane = 87% x 500 gallons/yr = 435 gallons octane/yr = 114.9 L octane/yr

Volume of Heptane = 13% x 500 gallons/yr = 65 gallons heptane/yr = 17.17 L heptane/yr

Mass of Octane = 114.9 L x 692 g/L = 79,530 g

Mass of Heptane = 17.17 L x 684 g/L = 11,746 g

MW Octane = 114 g/mol

MW Heptane = 100 g/mol

Moles of Octane = 79,530 g / 114 g/mol = 697.6 mol

Moles of Heptane = 11, 746 g/ 100 g/mol = 117.5 mol

Combustion of Heptane: $C_7H_{16}$ +11 $O_2$ ® 8 $H_2O$ + 7 $CO_2$

Combustion of Octane: 2 $C_8H_{18}$ +25 $O_2$ ®18 $H_2O$ + 16 $CO_2$

Moles $CO_2$ produced as a result of combustion of 117.5 moles $C_7H_{16}$ = 822 moles $CO_2$

Moles $CO_2$ produced as a result of combustion of 697.6 moles $C_8H_{18}$ = 5581 moles $CO_2$

Total moles $CO_2$ produced = 822 mol + 5581 mol = 6403 mol $CO_2$

MW $CO_2$ = 44 g/mol

Mass $CO_2$ = 281,700 g = 281.7 kg = 619.8 lb $CO_2$/yr

619.8 lb $CO_2$ produced/yr ¸ 2.5 lb $CO_2$ per tree consumed/yr = 248 Trees

## Sample Activity 3

(Part IV: The Energy Potential of Biodiesel)

Preparing Biodiesel

Add 200 mL of clean vegetable oil to a 500 mL Erlenmeyer flask.
Slowly add 2 mL 9 M NaOH to 30 mL of methanol ($CH_3OH$).
Stir for 2 minutes to make sodium methoxide ($Na^+ CH_3O^-$).
Add the $Na^+ CH_3O^-$ to the vegetable oil.
Stir for 10 minutes.
Transfer this mixture to a separatory funnel and allow the layers to separate. The biodiesel should be on top and the glycerol should be on the bottom.
Drain off the bottom layer into a beaker and set aside.
Add 20 mL of distilled water to the separatory funnel. Mix, and then allow the mixture to separate.
Drain the bottom layer again into a beaker and set aside.
Add an additional 20 mL of distilled water to the separatory funnel. Mix, and allow the mixture to separate overnight.
Finally, drain your biodiesel into an Erlenmeyer flask and cover.

Testing Biodiesel

- Prepare a soda can calorimeter by punching holes in the sides of the can and sliding a glass stirring rod through the holes.
- Suspend the soda can on a ring attached to a ring stand by resting the stirring rod on the sides of the ring.
- Add 10 mL of biodiesel diesel oil to an alcohol burner.
- Place the alcohol burner under your can and lower the can so that it is about 2 cm above the wick of the burner.
- Add 100 g of water to the can.
- Measure the initial temperature of the water.
- Light the burner and periodically stir the water.
- Record the temperature of the water every minute for 20 minutes.
- On your data table, circle the maximum temperature that the water reaches.
- Repeat this procedure, using standard diesel oil and fresh water in your beaker.

Analysis:

- How did the energy generated from burning biodiesel compare to the energy generated by burning standard diesel? Use: $Q = mc_p DT$. How does that impact how much of each fuel you might have to use in your car to get the same result?
- Compare the $CO_2$ generated from burning 100 g biodiesel ($C_{19}H_{36}O_2$) to burning an energy equivalent amount of standard diesel ($C_{16}H_{34}$).

## Sample Activity 4

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(Part IV: The Energy Potential of Biodiesel)

Critical Reading of Biofuel's Big Bean. Utne Magazine July 2007 p. 68

- How has eastern Paraguay changed since the amount of soybean farms increased?
- What were some of the human affects that the author mentioned as a result of the increase in soybean farms in eastern Paraguay?
- What happened to the animals?
- Who owns most of the land in Paraguay?
- Why is the demand for soy increasing?
- In what other countries are soy farms growing and what are some of the effects in those countries?
- Why does the author believe that some biotechnology companies are attracted to these countries?
- What impact does replacing rainforests with soybean plants have on the balance of carbon dioxide?
- How has the Ramirez family been impacted by the soybean farms?
- How has the growth of the soy industry impacted Paraguay's campesino leaders?
- Why do you think that this trend will continue or end?
- Do you think that the benefits of biodiesel outweigh the problems that the farmers in South America are enduring?

How might the problems currently in South America possibly affect you and your community?

## Implementing District Standards

(2.1.1) All matter is composed of minute particles called atoms. Most of the mass of an atom is concentrated in the nucleus. In the nucleus, there are neutrons with no electrical charge and positively charged protons. Negatively charged electrons surround the nucleus and overall, the atom is electrically neutral. (2.1.2) Elements and compounds are pure substances. Elements cannot be decomposed into simpler materials by chemical reactions. Elements can react to form compounds. Elements and/or compounds may also be physically combined to form mixtures. (2.1.3) Isotopes of a given element differ in the number of neutrons in the nucleus. Their chemical properties remain essentially the same.

(2.1.4) The periodic table arranges the elements in order of atomic number (the number of protons). The elements are grouped according to similar chemical and physical properties. As a result, an element's chemical and physical properties can be predicted knowing only its position on the periodic table.

(5.1.1) Minerals are the building blocks of rocks. Common rock-forming minerals found in Delaware (calcite, quartz, mica, feldspar, and hornblende) can be identified by their chemical and physical properties.

(5.2.5) The atmosphere can be described as being in a state of dynamic equilibrium that is maintained in part by plate tectonic processes that recycle atmospheric gases trapped in the ground back into the atmosphere.

(1.1.4) Understand that: Investigating most real-world problems requires building upon previous scientific findings and cooperation among individuals with knowledge and expertise from a variety of scientific fields. The results of scientific studies are considered valid when subjected to critical review where contradictions are resolved and the explanation is confirmed.

(1.2.2) The social, economic, and political forces of a society have a significant influence on what science and technology programs are pursued, funded, and implemented.

(2.3.1) The total mass of the system remains the same regardless of how atoms and molecules in a closed system interact with one another, or how they combine or break apart.

(2.4.1) Chemical reactions result in new substances with properties that are different from those of the component parts (reactants).

(2.5.1) Materials' properties determine their use. New materials can improve the quality of life. However, their development and production often raise social, economic, and environmental issues that require analyses of the risks and benefits.

6.2.2. Plant cells convert light energy into chemical energy through the process of photosynthesis. This chemical energy may be used for energy or to form plant structures. Photosynthesis adds oxygen to the atmosphere and removes carbon dioxide.

6.2.4 Photosynthesis and cellular respiration are complementary processes resulting in the flow of energy and the cycling of matter in ecosystems.

2.4.4 Energy is transformed in chemical reactions. Energy diagrams can illustrate this transformation. Exothermic reactions release energy. Endothermic reactions absorb energy.

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