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A Chemistry Perspective: Gasoline or Biodiesel?

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Introduction

Technological advancements are continually developing new ways to make life more convenient and efficient for people. Cars, computers, and cell phones were once luxury items that have now become necessities. However, all these conveniences consume energy to run. As a result, the world's energy consumption has been continually increasing, with a majority of energy coming from fossil fuels. In the United States, 81% of its energy comes from non-renewable fossil fuels. [1] Due to the increase in energy dependence, people fear that the world is running out of fossil fuels but in there is plenty of fossil fuel left for us to use. [2] Due to technological advancements, we can now tap into previously untouchable sources of fossil fuels. [3] The real concern is the pollution created from the burning of fossil fuels and its effects on the environment. [4]

In this curriculum unit, I intend to educate students about the effects of fossil fuels on the environment from a chemical perspective. Over the course of four weeks, my students will explore parts of the California State Standards for chemistry under the sections titled "conservation of matter and stoichiometry" and "chemical thermodynamics." [5] The theme of energy will tie together the standards for reactions, stoichiometry, and heat energy. The goal is that students will make connections between difficult chemistry concepts using a topic that is relevant to their lives. In addition, students will analyze scientific articles about energy in order to develop their own opinions on the issue of energy consumption and conservation. As a culminating task, students will compare and contrast two sources of energy and choose one to promote as the main energy source for their community.

Rationale

My students attend Yerba Buena High School (YBHS) in San Jose, California. YBHS is one of 12 large high schools in the East Side Union High School District. Our school population ranges from 1600 to 1700 students where 69.5% of the students are low income and 66.8% are English-Learners. The majority of our population is comprised of Hispanic/Latino (57%) and Asian (32%) students. [6] In 2012, YBHS scored 683 on the Academic

Performance Index (API) and did not meet the target of 689. [7] Currently the school is in its fourth year of Program Improvement which is called the Restructuring Stage, which requires the development of an alternative governance to create a plan of major restructuring within the school. [8] YBHS also struggles with a graduation rate of only 65% which is significantly lower than our district's graduation rate of 76%. Many of the students who will participate in this unit will be the first in their family to pursue a college degree. [9]

The audiences for this curriculum unit are 10 th /11 th /12 th grade general chemistry students and AP chemistry students. Students opting to take general chemistry typically intend on furthering their education in college because chemistry is a required course for college readiness. Most students who take AP Chemistry are interested in pursuing a science major and take AP chemistry as a way of preparing for their general chemistry course in college. The unit will mainly focus on general chemistry students as the audience but can be modified for the AP chemistry curriculum. It is my intention to teach this unit to the general chemistry students at the beginning of the 4 th quarter during the stoichiometry unit and give students the opportunity to revisit thermochemistry. AP chemistry students will take on this unit in the middle of the 6 th quarter.

Yerba Buena High School students go to 6 classes every day, each class meeting for 58 minutes. AP science classes are designed as a block class and so students who take AP chemistry meet for 2 back-to-back periods. The entire district follows this format in order to allow AP science classes adequate time for labs. The unit is designed so that the activities can be incorporated as subsections in three consecutive units of reactions, stoichiometry, and thermochemistry, with a final wrap up activity that ties the units together. Alternatively, the activities could also be a unit on their own as a review of the three standards that shows how they are interrelated.

Background

What is energy?

In 2003, Rice University professor and Nobel Prize winner Richard Smalley made a list called "Top Ten Problems Facing Humanity Over the Next 50 Years." [10] In his list, he put energy as the number one problem. If energy is arguably the biggest concern for today's society, then it is important to understand the meaning of energy. It can be a mysterious word to some because it is an abstract entity that is elusive and not concrete. In the scientific context, energy is defined as the ability to produce change or do work. Energy can produce light, heat, motion, sound, growth, and can power technology. [11] Just as our body can take in food and convert food into energy that makes our body function, the world requires ways of capturing, storing, and converting energy to function. Developing new technology to efficiently make high value energy such as electricity and fuel using natural resources is a fast developing field in energy research.

What are the sources of energy?

There are two general categories for sources of energy: non-renewable and renewable energy. Non-renewable energy sources, as the name suggests, cannot be replenished once the energy source is used up. The ultimate source of non-renewable energy is fossil fuels. Fossil fuels come from plant and animal matter that have been decayed and processed naturally over millions of years. They are stored under the surface of the earth and must be extracted out of the ground. These energy sources include coal, petroleum, and natural gases. [12]

On the other hand, renewable energy sources are considered better options than non-renewable energy sources because they can be replenished and we will never run out of them. [13] Some sources of renewable energy are wind, solar, hydropower, and biofuels. Wind power can be harnessed through wind turbines and used to make electricity. Solar energy is power that comes from the sun's rays that can be captured by photovoltaic cells. The solar energy can be converted into heat or electricity. Water can also supply energy through dams to capture the energy of flowing water to generate electricity. Finally, plant and animals can be turned into biofuels by simply burning them or turning them into liquid fuels such as biodiesel. [14]

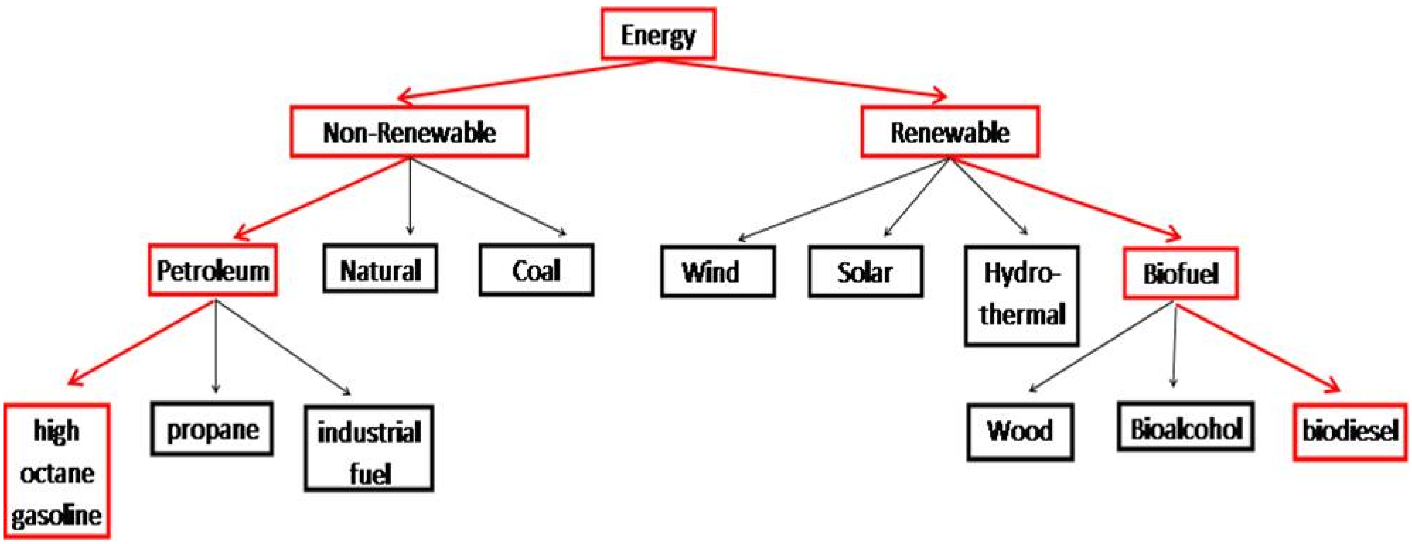

Figure 1: The flow chart shows a general overview of the different types of energy sources. The red portions of the flow chart outline the specific types of energy that will be the focus of this unit.

It is evident that there are many avenues we could take to capture energy for our use. It is impossible to go into detail about all the different energy sources as they are too numerous. For this unit, the focus will be on two sources of energy used specifically for transportation. Figure 1 is an outline of the different types of energy. It is not a comprehensive list by any means. This unit specifically compares two sources of energy. High octane gasoline made from petroleum will be the focus of non-renewable energy and biodiesel fuel made from plant seeds as the renewable energy.

High Octane Gasoline

Currently, 28% of the total energy production in the United States is dedicated to transportation. It is the second biggest area of energy consumption behind electrical power at 40% consumption. [15] Most cars use unleaded high octane gasoline as fuel. High octane gas is a mixture of at least 500 various hydrocarbons ranging from 5 to 12 carbon atoms. This mixture is created from crude oil which has been processed through many refinement steps. [16] When ignited, the gasoline releases a lot of energy which is used to move the car. The high octane gasoline goes through a combustion reaction which breaks down the gasoline, as it reacts with oxygen, into carbon dioxide and water. To put things into perspective, there were over 244 million cars registered in the US in 2008, compared to 79,000 registered cars in 1905 when the first affordable car was introduced. [17]

Crude oil, also known as petroleum, is a type of fossil fuel. There are different grades of crude oil and each grade is used for different purposes. Some of the perhaps surprising uses of crude oil are clothing, vitamin capsules, tires, and even toothpaste. Raw crude oil is of little use but can be refined to make numerous useful products ranging from asphalt for construction to plastics. There are three major refining processes to change crude oil into the desired product. These three steps are: Separation, Conversion, and Purification. [18]

In the separation stage, raw crude oil is distilled and separated by taking advantage of differing boiling points of the components of raw crude oil. Some examples of components with low boiling points are butane and propane and examples of high boiling point components are industrial fuels and asphalt base. The crude oil is placed in a distillation column so that compounds with lower boiling points will become vapors and rise to the top of the distillation column while those with high boiling points will remain at the bottom. [19] In this way, the crude oil mixture can be separated into its different components.

Some components can be used after the separation stage but others will need to go through a conversion process to convert low value oil into high valued ones, especially gasoline. This is done by taking the low-value long chain hydrocarbon oils and breaking the chains to make smaller molecules that are of higher value. Some examples of these higher value oils are kerosene used as jet fuel, gasoline, and diesel. [20]

In the final step, the converted components must be purified. The main purpose of this step is to remove sulfur. This is done by hydrotreating in which the components react with hydrogen under heat and high pressure in the presence of a catalyst. The sulfur in the converted components is extracted, resulting in hydrogen sulfide (H_2S) and the now desulfurized product. The product is now ready for use and the hydrogen sulfide is further refined into elemental sulfur and water. [21]

Biodiesel

One of the many possible renewable energy sources that are currently being explored is biofuels. Biodiesel is a specific type of biofuel can be made by recycling used frying oil such as corn oil from the kitchens or it can be harnessed from plant seeds. Some of the most common sources of biodiesel come from rapeseed oil, sunflower oil, and soybean oil. [22] The oils are transformed into biodiesel through a chemical process so that they can become fuels to power vehicles.

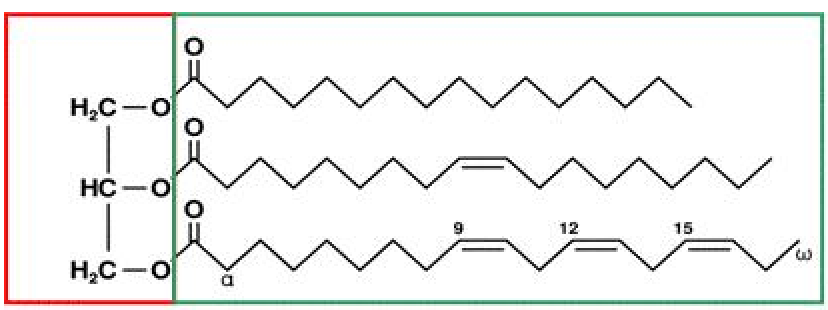

Figure 2: Triglyceride structure. The red box indicates the glycerin portion and the green box indicates the fatty acid chains. [23]

The structure of vegetable oil used to make biodiesel is called a triglyceride. It contains a glycerin molecule that is attached to three fatty acid chains as shown in figure 2. Vegetable oil cannot be used directly in a diesel engine because it is too viscous and so it must be chemically altered into biodiesel. This is done through a process called transesterification where the glycerin from the vegetable oil is replaced by methanol, thereby producing three fatty acid chains. These separated fatty acid chains can now be used as biodiesel. [24]

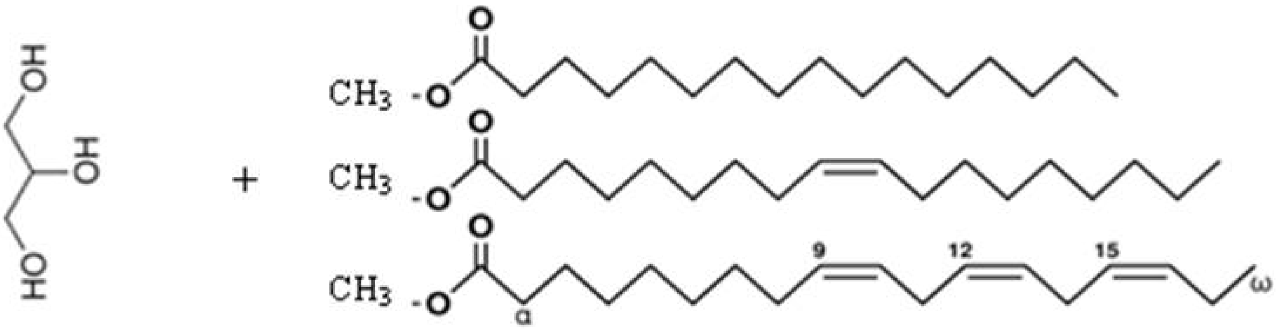

Figure 3: Production of biodiesel. The left side shows the structure of glycerin. The right structure shows three separate fatty acid chains that are now called biodiesel.

The process of making biodiesel is relatively simple. One of the benefits of biodiesel is that it can be made in large quantities in the industry or in small quantities at home. The first step to making biodiesel is to combine methanol with sodium hydroxide to make sodium methoxide ($NaOCH_3$). The sodium methoxide is the added to the vegetable oil to remove the glycerin and release the fatty acid chains as esters. Glycerin is denser than the fatty acid esters and will settle at the bottom of the mixture and the biodiesel can then be isolated. [25] The biodiesel is then purified using water to wash out any excess glycerin and then can be used as a fuel source.

Energy Reactions

Chemical reactions occur when molecules change their chemical compositions. There are five general reaction types: single displacement, double displacement, decomposition, synthesis, and combustion reactions. Energy from the both high octane gas and biodiesel are released through a process called combustion. A combustion reaction occurs when an organic molecule made of carbon, hydrogen, and oxygen atoms react with the oxygen molecules in the air. A spark is needed to overcome the activation energy needed to start the reaction. Once it starts, the reaction releases energy and forms carbon dioxide and water molecules as the products. [26] The general chemical equation is written below.

$CxHyOz + (x + y/4 – z/2)\ O_2 \longrightarrow x\ CO_2 + (y/2)H_2O$(equation 1)

When expressing reactions as a chemical equation, it should also be expressed in a way that follows the law of conservation of matter which states that matter cannot be created or destroyed. In chemical equations, this is shown by balancing the chemical equation. Both the left side (reactants) and the right side (products) of the arrow must have the same number of atoms. The equations below demonstrate the combustion of octane and a biodiesel fuel (the middle molecule on the right side of Figure 3 is used).

$\mathbf{2}\ C_8H_{18} + \mathbf{25}\ O_2 \longrightarrow \mathbf{16}\ CO_2 + \mathbf{18}\ H_2O$ (equation 2)

$C_{19}H_{36}O_2 + \mathbf{27}\ O_2 \longrightarrow \mathbf{19}\ CO_2 + \mathbf{18}\ H_2O$ (equation 3)

Balancing equations can be difficult because there is no mathematical equation that will provide the correct answer every time. However, it is possible to follow steps to get to the correct balanced equation. The first step is to write out the chemical equation with correct chemical formulas for the reactants on the left and products on the right. Then identify the atoms in the most complex substance and balance those atoms. The atoms that occur as free elements should be balanced last. Finally, if any coefficient in the balanced equation is a fraction, then the entire equation must be multiplied by the denominator of the fraction to make sure whole number coefficients are used. [27]

Stoichiometry of Energy Reactions

Once an energy reaction is written out as a balanced chemical equation, it is then possible to analyze the relationship between what is put in and what comes out of the reaction. In particular, the interest in energy reactions is the output of carbon dioxide molecules, the greenhouse gas of interest for this unit. The coefficients for the balanced equations show the mole relationships between the molecules involved in the reaction. From the examples above, we can see that two molecules of octane will produce 16 moles of carbon dioxide. The number of moles of carbon dioxide produced is 8 times greater than the number of moles of octane that is burned. In comparison, biodiesel fuel is a larger molecule and produces 19 moles of carbon dioxide for one mole of biodiesel.

Not only can we do these calculations by looking at molecule to molecule relationships between products and reactants, it is more practical to discuss this reaction in terms of the mass. Octane has a molar mass of 114.23 g/mol and carbon dioxide's molar mass is 44.01 g/mol. As an example, if 500. grams of octane fuel were burned, it is possible to calculate the mass of carbon dioxide that will be produced using their stoichiometric relationship. 500. grams of octane will release 1540 grams of CO_2 into the atmosphere. The molar mass of biodiesel is 296.50 g/mol so it is more than twice as heavy as octane. Using the same example, 500. grams of biodiesel fuel will release 1410grams of carbon dioxide.

This can be counter intuitive because equation 1 shows that 16 molecules or moles of carbon dioxide is produced compared to equation 2 which shows 19 molecules or moles for biodiesel. This is a good opportunity to point out the difference between mole to mole relationship which describes quantity with grams to grams relationship which describes mass. Because biodiesel is a larger molecule, 500. grams of biodiesel actually contain fewer moles than 500. grams of octane. As a result, the combustion of biodiesel produces less carbon dioxide than the same mass of octane gasoline.

Heat stored in chemical bonds

The reason why fossil fuels are such a precious source of fuel is that a lot of energy can be produced from a relatively small amount of it. The energy of the fuel source is stored within the bonds of the molecules. The energy released from fuel sources can be numerically calculated by looking at bond energies. Energy must be put in to break bonds but energy is released when bonds are broken. If there is a net release of energy, this reaction is exothermic and the numeric value is given a negative sign to indicate the release of energy. [28] If there is a net absorption of energy, this reaction is endothermic and the numeric value is given a positive sign.

Taking a look at the octane molecule from previous examples, students can calculate the energy needed to break the bonds and compare it with the energy released when the bonds of the products are formed. The reaction from equation 2 is written below in a way that shows the number of bonds broken on the reactant side and the number of bonds formed in the product side.

2 (18 C-H + 7 C-C) +25 (O=O) —> 16 (2 C=O) + 18 (2 H-O)(equation 4)

Bond type	Energy (kJ/mol)
C – H	413
C – C	347
C = C	614
O = O	495
C = O (in CO_2)	799
C = O (in ester)	745
C – O	358
O – H	467

Table 1: The average bond energies for bonds that are broken or formed during the combustion reaction of fuels. [29]

The energy of bonds broken in octane is calculated to be 32100 kJ while the bonds formed release -42400 kJ of energy. This means that -10300 kJ of energy is released for 2 moles of octane. This means that 1 mole of octane will release -5150 kJ and that excess energy is what we can use to power our cars. The same calculation can be done for equation 3, the combustion of biodiesel. A mole of biodiesel will release -11300 kJ of energy. In terms of quantity, biodiesel releases more energy per mole than octane.

As mentioned in the above paragraphs, it is also important to compare the energy content for equivalent mass as well, since octane and biodiesel do not have the same molar mass. This shows a clearer picture of the energy comparison because in real life, it is more practical to measure out masses of fuel than moles of fuel. Using the example of 500. grams of each fuel types, octane would release -22500 kJ and biodiesel would produce -19100 kJ of energy. In this case, octane releases more energy by mass.

So what is the point?

The Energy Crisis

Taking a look at energy consumption in units of British Thermal Unit (BTU) in the United States, energy use in 1949 was 31.982 Quadrillion BTU. Today, the country uses 97.301 Quadrillion BTU of energy. [30] This drastic increase in the amount of energy consumed in the United States has led to the push of moving away from non-renewable sources of energy toward renewable or sustainable energy sources.

Despite the data that show the significant increase in energy consumption, it has been argued that there is no need to fear running out of energy sources. As seen in previous energy crises, these crises are met with advancement of technology to meet the needs of the consumers. [31] Today's concern of energy is not the shortage of resources but the shortage of the rate of extraction of oil. [32]

If there is indeed an ample supply of fossil fuels to sustain the population, then the next step is to look at the consequences of using the current amount of energy and figure out if the environment can cope with the current energy usage. The issue at the forefront of energy use is the increase of greenhouse gases that is causing global climate change. In particular, the combustion of gasoline and biodiesel both release carbon dioxide into the air which is one of the biggest contributors to the climate change. However, there are two key differences between the two energy sources.

As mentioned before, biodiesel is a renewable energy source while high octane gasoline is non-renewable. Furthermore, biodiesel is made using plants that are part of the current carbon cycle and, therefore, does not introduce new carbon dioxide into the atmosphere. Plants get energy from the sun and use that energy to perform photosynthesis. Photosynthesis is the process by which plants take sunlight, carbon dioxide, and water from the atmosphere to produce oxygen gas that is released into the air and sugar that is stored up in the plant (equation 5)

Sunlight + CO_2 + H_2O —> O_2 + (CH_2O)(equation 5)

(CH_2O) + O_2 —> H_2O + CO_2(equation 6)

(CH_2O) is an abbreviated notation for a carbohydrate. Animals depend on the photosynthesis of plants as a source of oxygen and sugar (for food). As animals respire, they give back to the plants by providing them with carbon dioxide needed for photosynthesis (see equation 6). [33] The burning of biodiesel fuel does not contribute more carbon dioxide to the atmosphere but converts the carbon that is already part of the carbon cycle from plant matter into atmospheric carbon dioxide. In other words, biodiesels do not use sequestered carbon and so it is actually considered a carbon neutral compound.

Burning fossil fuels also releases CO_2 into the air. However, the problem with carbon dioxide emissions arise because fossil fuels are sequestered carbon molecules. These carbon molecules have been buried deep under the earth and are not part of the atmospheric carbon cycle. The combustion of these fuels introduces new carbon dioxide into the atmosphere. The increased carbon dioxide prevents unwanted heat from escaping out of the atmosphere. The extra heat that is contained within the earth's atmosphere impacts the environment. [34] This effect is called global climate change.

Gasoline or Biodiesel: Which is better?

Although it is true that high octane gasoline is a big contributor to global climate change, it is still the preferred fuel for transportation. The perfect fuel that provides a large amount of clean energy that can efficiently be harnessed at low cost is yet to be discovered. Many other factors, such as economics of fuel and energy policies, must be analyzed to understand the reasons why people choose carbon contributing gasoline over cleaner fuels.

One of the biggest driving forces for gasoline is there is an ample supply of petroleum that can be converted into gasoline. New technologies that allow us to extract petroleum from sources that we once thought were impossible have opened up opportunities for petroleum production. For example, shale oil is sedimentary rock that can release petroleum-like liquids when heated. [35] Until recently, it was thought to be impossible to extract liquid petroleum from solid rock. However, this new discovery has opened up a new source of petroleum for us to use instead of just conventional crude oil.

In addition to the abundance of petroleum fuels, the cost of high octane gasoline is relatively cheap. [36] From an economic standpoint, it makes more sense to use high octane gasoline as fuel because it is relatively cheap ($3.99/gallon) compared to commercial biodiesel ($4.11/gallon). [37] It is difficult to encourage people to pay more for biodiesel out of their environmental concerns when gasoline is cheaper and more readily available at the gas pumps.

Another struggle for biodiesel is that its production is not efficient. In 2011, 9% of the US energy came from renewable energy and of the 9%, only 13% of it was used in transportation. [38] The challenge is that because biodiesel comes from plants, there must be enough plant material to make the fuel. In order for biodiesel to make a significant impact, energy could be produced by deliberately growing energy crops. However, this requires substantial amount of land and water. In addition, photosynthesis is an inefficient process that converts only 1% of the sun's energy into biomass. [39] In light of these challenges, biodiesel may be an impractical energy source.

The answer to the question of which is better depends on each person's own personal convictions and their needs. It is a difficult question to answer but also provides opportunity to weigh out the pros and cons of each side for students to make their own decisions. Of course these are not the only options for energy sources as mentioned in figure 1. Although there is a big push to find the one source of energy that will provide all the energy needs of the world, perhaps finding ways to use multiple energy sources in moderation is an option that should be explored as well.

Strategies

Students learn in different ways. Some are visual learners while others understand ideas and concepts better by doing activities. The challenge with teaching a large group of students in a classroom is that it is very difficult to differentiate instruction to meet the needs of each individual student's learning styles. This unit will incorporate multiple teaching strategies so that throughout the unit students will learn by participating in a variety of activities.

Chemistry is a challenging class because the concepts can be hard to grasp. Students cannot see atoms let alone count out a mole of atoms. It is difficult for them to understand how bonds are formed and the idea of energy transfer. However, it is also a class that allows students to see evidence of these concepts through reactions. One strategy that that is incorporated in this unit is demonstrations. Since fuel sources are dangerous, demonstrations are great ways to show students chemistry concepts in a safe manner.

Along with demonstrations, laboratory activities are also helpful for students to actually perform chemical reactions that they learn about in the course. Students often struggle with laboratory skills especially in a chemistry lab and safety is a major concern because students may sometimes work with toxic chemicals and open flames. However, it is a valuable tool because laboratory activities give kinesthetic learners an opportunity to learn by doing and helps them practice safety skills. A common core standard for 9-10 th grade science is that students will be able to "follow precisely a complex multiple step procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text." [40] This standard fits well in this unit and students will not only go through the steps of a laboratory but also try to understand the purpose of each step and how it fits into the content they are learning.

Science classes also play an important role in developing students as critical thinkers. As we explore questions about energy that do not have clear answers, students will also do research and analyze articles to form their own opinions on the topic of energy. Another common core standard for science literacy is that students will be able to analyze text and identify central ideas. [41] The goal is for students to also think creatively outside of the box to even develop their own ideas for creating efficient, renewable, clean energy.

Finally, students will express their opinion and defend their opinion using the articles they read and their own research. Public speaking is an essential skill that students should develop but they are not given many opportunities to do so in the classroom. In this unit, they will give a presentation that will explain their point of view to the class and also offer solutions to our energy crisis.

Activities

Activity 1: Combustion of methane and isopropyl alcohol demonstrations

$CH_4 + 2\ O_2 \longrightarrow CO_2 + 2\ H_2O$ (equation 7)

Students will be able to visually see 2 combustion reactions. The first reaction is the combustion of methane gas (equation 7). This demonstration traps methane gas in a soap bubble and then ignites the bubble. The students will see a flame in mid air as the methane combusts and provides a clear visual for a combustion reaction.

In order to do this demonstration, easy access to a gas line is necessary. Most school gas lines use methane but teachers should double check before trying out this experiment. This demonstration requires three set ups. First, rubber tubing that is about 3 meters in length must be obtained. One end is connected to the gas line and the other end is attached to a plastic funnel. The second set up is a shallow bucket of soap and water mixture. To test out the soapy water, place the funnel's opening into the soapy water and a film should appear on the funnel's opening. The final set up is a long stick, such as a meter-long ruler, with a candle attached at the end.

Begin the demonstration by placing the opening of the funnel into the soapy water. Check to see that a soapy film covers the funnel opening. When the gas is turned on, the methane gas travels through the tubing into the funnel and makes a bubble filled with methane gas. Only a small amount of gas is needed or else the bubble will pop so practice is essential to get comfortable with this step. The bubble is carefully released from the funnel with the flick of the wrist. Because methane is less dense than air, the bubble will float to the ceiling. While the bubble is in the air, the lit candle is placed into the bubble, which will burst the bubble and ignites the methane gas. The students will see the combustion reaction occur in mid air (see Appendix B)

$2\ C_3H_7OH + 9\ O_2 \longrightarrow 6\ CO_2 + 8\ H_2O$(equation 8)

The second demonstration involves the combustion of isopropyl alcohol in a 5-gallon plastic bottle (equation 8). This demonstration is appropriate after students have had practice balancing equations and are somewhat comfortable with stoichiometric calculations. Since the balancing of this equation is more complicated than the combustion of methane gas, it can be used as an opportunity for students to do some calculations. Before the actual demonstration, ask the students to balance the equation themselves and predict how much water should result from the combustion of a certain amount of isopropyl alcohol.

To execute this demonstration, 15 mL (approximately 11.80 grams) of isopropyl alcohol is poured into the 5-

gallon plastic bottle. The bottle is then capped and rotated so that the alcohol coats the sides of the bottle. This is to make sure the alcohol vaporizes inside the bottle and is ready for combustion. If liquid is still left in the bottle, open the cap, discard the liquid, and recapped immediately. Weigh out the discarded liquid to calculate how much isopropyl alcohol remains in the bottle. The calculated mass will be used to determine the mass of water that should be produced from the reaction. The cap of the bottle is then opened and a lit candle attached to a meter stick is placed at the opening. When the alcohol is ignited, the students can see the combustion reaction in the bottle and water, a product of combustion reaction, will be left in the bottle afterwards. This demonstration will help students practice balancing equations and solve for the stoichiometric relationship between the mass of isopropyl alcohol burned and the mass of the water remaining. In addition, students can also calculate percent yield and discuss sources of error (See Appendix C).

Activity 2: Making biodiesel

The laboratory activity for this unit will be to make biodiesel from vegetable oil. Students will begin with vegetable oil and break the bonds of the triglyceride by using sodium methoxide. Once the biodiesel is made, students can compare it to the vegetable oil through a viscosity test to see the difference between the original vegetable oil and their final biodiesel product.

The actual procedure for making biodiesel from vegetable oil is simple but it is time consuming. Students should work in pairs for this lab if enough equipment is available. The lab will take two days to complete. On the first day, students will take vegetable oil and will make crude biodiesel through transesterification. To do this, students will measure out 14.0 mL of methanol and place the reagent in a jar with a lid. Next, they will measure out 0.50 grams of sodium hydroxide and add the sodium hydroxide into the jar with methanol. With the cap on, students will shake the jar to dissolve all the sodium hydroxide. This is an exothermic reaction so students should observe that the jar gets hot. Pressure will also build up so students should open the jar cap periodically to release the pressure. The resulting product from this reaction is sodium methoxide.

Next, students will obtain 60 mL of warm vegetable oil (around 50 $^{\circ}$C). The warm vegetable oil is then slowly added to the sodium methoxide. After securing the lid once more, students will carefully but vigorously shake the mixture for at least 10 minutes. The jar should then be labeled and set aside for the next day for the glycerin and the biodiesel to separate out.

The following day, students should observe two layers in their jar. Glycerin will appear cloudy at the bottom of the jar and the biodiesel in the top layer should look light yellow and clear. The product formed is crude biodiesel that can be washed for further purification. This is done by pouring only the top biodiesel layer into a separatory funnel, adding distilled water to the crude biodiesel and shaking the mixture. The polarity of the water molecules will pull all the impurities out, leaving purer biodiesel. The washing of the crude biodiesel is best done as a demonstration as it can get messy and time consuming. Also, if a separatory funnel is not available, the washing step can be skipped.

A comparison of the viscosity of the product and original vegetable oil will help students determine if they have successfully created biodiesel. If drops of the biodiesel and vegetable oil are allowed to run down a slanted surface, the biodiesel should move along faster because it is less viscous than the vegetable oil. In the post lab, students will calculate percent yield using the volume of vegetable oil used and the volume of biodiesel that they made. Volume is used for percent yield instead of mass because gasoline stations use dollars/volume for their pricing. Then students will calculate how much vegetable oil is required to fill a 10-

gallon tank car with biodiesel. See Appendix D for the biodiesel lab sheet.

Activity 3: Reading science articles and Report

A part of this unit is for students to calculate the energy released from high octane gasoline and biodiesel. Once students have calculated energy outputs they may wonder why there is a push for biodiesel when the energy output is less than high octane gasoline. At this time, students will be introduced to the idea of global climate change and the impact that high octane gasoline, made from fossil fuels, has on the environment. They will read articles taken from scientific sources that express different points of view. Some articles will argue that the world is running out of fossil fuels while others will claim that fossil fuel energy is plentiful. Some articles will support biodiesel production while others point out its downfalls.

After reading several articles and doing their own research on the internet, students will be asked to form their own opinion on what they think would be the best fuel for their community and support their opinions with facts from their own research. The students will write a persuasive essay based on the rubric in Appendix E.

Activity 4: Presentation

When the students are finished writing their essay and are able to confidently support their views, they will work with a partner to create a presentation on the best energy source for their community. The twist to this presentation is that each pair will be assigned a particular group with an interest in energy and the presentation will have to be from the viewpoint of that particular group. Some examples of these groups are oil companies, schools, college students, and environmentalists. The goal of the presentation is for students to recognize the complexity of this topic in that each interest group has their own perspective and there is no clear solution to this very important issue.

Appendix A

Implementing District Standards

Grades 9-12: California State Standards for Chemistry:

3.a. *Students know* how to describe chemical reactions by writing balanced equations.

3.e. *Students know* how to calculate the masses of reactants and products in a chemical reaction from the mass of one of the reactants or products and the relevant atomic masses.

3.f* *Students know* how to calculate percent yield in a chemical reaction.

7.b. *Students know* chemical processes can either release (exothermic) or absorb (endothermic) thermal energy.

Common Core State Standards Initiative: Science and Technical Subjects

Grade 9-10: Common Core Standards

CCSS.ELA-Literacy.RST.9-10.3 Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.

CCSS.ELA-Literacy.RST.9-10.9 Compare and contrast findings presented in a text to those from other sources (including their own experiments), noting when the findings support or contradict previous explanations or accounts.

Grade 11-12: Common Core Standards

CCSS.ELA-Literacy.RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.

Appendix B

Methane Bubble Demonstration

(modified from Flinn Scientific "Chem Fax: Methane Bubbles")

Materials:

1 meter stick with candle attached at one end

1 match or lighter

3-4 meters of rubber tubing

1 funnel

120 mL liquid dishwashing soap

800 mL water

1 small bucket or container

methane gas line

Safety:

1. Wear heat resistant apron and goggles.

2. The methane bubble formed should not be more than 4-5 inches in diameter. Larger bubbles can be dangerous.

3. Do not light the bubbles near light bulbs or smoke detectors.

4. Have a fire extinguisher ready in case of an accident.

Preparing for the demonstration:

1. Take the rubber tubing and connect one end to the gas line and the other end to the funnel.

2. Add 120 mL of dishwashing soap to the small bucket and add 800 mL of water.

Procedures for the demonstration

1. Place the funnel into the soapy water so that a soap film appears on the opening of the funnel.

2. Open the methane gas line to fill the funnel with methane gas. A bubble will appear at the end of the funnel.

3. Shake the bubble off of the funnel with a gentle flick of the wrist.

4. The bubble will begin to rise to the ceiling. As the bubble is suspended in the air, touch the lit candle to the bubble and observe the large flame.

Tips:

1. Always practice demos before demonstrating it in the classroom.

2. This demonstration is difficult to do alone. Procedure steps 1-3 can be done by a volunteer student but the lit candle should be handled by the teacher.

Appendix C

Isopropyl Alcohol Combustion Demonstration

(modified from Flinn Scientific "Chem Fax: Woosh Bottle")

Materials:

5-gallon plastic water jug with cap

15 mL isopropyl alcohol

1 meter stick with candle attached at one end

25-mL graduated cylinder

1 match or lighter

Safety:

1. Wear heat resistant apron and goggles.

2. Always recap the alcohol bottle and move it away from the demonstration area.

3. Never perform this demonstration in a glass bottle. It may shatter and cause serious injuries.

4. Have a fire extinguisher ready in case of an accident.

Procedures for the demonstration

1. Measure out 15 mL of isopropyl alcohol and record the mass.

2. Add the isopropyl alcohol into the 5-gallon plastic jug. Recap the alcohol bottle and move it away from the demonstration area.

3. Place the cap onto the 5-gallon jug and slowly swirl the jug to allow the alcohol to spray over the entire interior surface. This allows the alcohol to vaporize inside the jug.

4. Open the cap and remove any excess liquids. Record the mass of the liquid.

5. Place the jug on a sturdy surface. Light the candle attached to the meter stick and carefully place the lit candle to the opening of the jug.

6. Students will observe a flame inside the bottle and hear a "whoosh" sound.

7. After the reaction, water will collect inside the bottle. Remove the water and record its mass.

Tips:

1. Always practice demos before demonstrating it in the classroom.

2. This demonstration works well in a dimly lit room.

3. Do not use the plastic jug immediately after the demonstration. The carbon dioxide must be allowed to escape out of the jug and the jug will be hot.

4. Students can write out the equation for the combustion of isopropyl alcohol and calculate the mass of water that should have been made. Using this information and the actual mass of the water from step 7, students can calculate percent yield and discuss sources of error.

Appendix D

Making Biodiesel Laboratory

(Modified from Loyola University of Chicago: Biodiesel Labs)

Materials (per pair)

1 Mason jar with lid

250-mL graduated cylinder

25-mL graduated cylinder

1 balance or scale

1 weigh boat

1 spatula

100 mL vegetable oil

20 mL methanol

1.0 grams NaOH pellets

Safety:

1. Methanol is highly flammable and sodium hydroxide is highly caustic.

2. Wear safety goggles, aprons, and gloves.

Procedure:

Day 1: Making Sodium methoxide

1. Using a 25-mL graduated cylinder, measure out the methanol in the fume hood and pour it into the Mason jar. Seal the lid.

2. Using a balance, weigh out the NaOH pellets. This step must be done quickly as NaOH pellets absorb water from the atmosphere and this will change the mass.

3. Place the NaOH into the Mason jar, seal the lid, and shake until all the pellets have dissolved.

4. Periodically open the Mason jar under the fume hood to release the pressure. Note any observations.

Day 1: Making crude biodiesel

1. Using a 250-mL graduated cylinder, measure out the vegetable oil.

2. Pour the vegetable oil into the Mason jar and secure the lid.

3. Carefully but vigorously shake the mixture for about 10 minutes.

4. Label your group's jar and place it in the designated area over night.

Day 2: Isolating biodiesel

1. Obtain your group's Mason jar and record any changes.

2. The biodiesel is at the top and the glycerin (waste product) will be at the bottom.

3. Remove as much of the biodiesel as possible and record its volume.

4. Find the designated area of the laboratory with a slanted glass stand with "start" and "end" markings.

5. Place two drops of vegetable oil at the "start" position and time how long it takes for the oil to move to the "end" position.

6. Repeat Step 5 with the newly made biodiesel. Record the times.

Day 2: Clean Up

1. Clean all glassware and bench space with soap and water.

2. Place the Mason jar in the designated area under the fume hood.

Student Questions:

1. What did you observe as you mixed the vegetable oil and the sodium methoxide? Why do you think this happened?

2. In the final product, why was the glycerin at the bottom and biodiesel at the top of the jar?

3. Using 100. mL of vegetable oil, how much biodiesel was made?

4. Calculate the percent yield using volumes of vegetable oil and biodiesel.

5. If you wanted to fill a 10.0-gallon tank with biodiesel, how much vegetable oil would be needed?

Appendix E

Energy Essay Rubric

(Created using Rubistar)

Category	4	3	2	1
Position Statement	The position statement provides a clear, strong statement of the author's position on the topic.	The position statement provides a clear statement of the author's position on the topic.	A position statement is present, but does not make the author's position clear.	There is no position statement.
Support for Position	Includes 4 or more pieces of evidence that support the position statement and 1 counter-argument.	Includes 3 or more pieces of evidence that support the position statement.	Includes 2 pieces of evidence that support the position statement.	Includes 1 or fewer pieces of evidence.
Evidence and Examples	All of the evidence and examples are specific, relevant and the explanations support the author's position.	Most of the evidence and examples are specific, relevant and the explanations support the author's position.	At least one of the pieces of evidence and examples is relevant and has an explanation that supports the author's position.	Evidence and examples are NOT relevant AND/OR are not explained.

Accuracy	All supportive facts and statistics are reported accurately.	Almost all supportive facts and statistics are reported accurately.	Most supportive facts and statistics are reported accurately.	Most supportive facts and statistics were inaccurately reported.
Grammar and Spelling	Author makes no errors in grammar or spelling that distracts the reader from the content.	Author makes 1-2 errors in grammar or spelling that distract the reader from the content.	Author makes 3-4 errors in grammar or spelling that distract the reader from the content.	Author makes more than 4 errors in grammar or spelling that distracts the reader from the content.
Sources	All sources used for quotes, statistics and facts are credible and cited correctly.	All sources used for quotes, statistics and facts are credible and most are cited correctly.	Most sources used for quotes, statistics and facts are credible and cited correctly.	Many sources are suspect (not credible) AND/OR are not cited correctly.

Appendix F

Energy Presentation Rubric

(Created using Rubistar)

Category	4	3	2	1
Enthusiasm	Facial expressions and body language generate a strong interest and enthusiasm	Facial expressions and body language sometimes generate a strong interest and enthusiasm	Facial expressions and body language are used to try to generate enthusiasm, but seem faked.	Very little use of facial expressions or body language. Did not generate much interest.
Preparedness	Student is completely prepared and has obviously rehearsed.	Student seems pretty prepared but might have needed a couple more rehearsals.	The student is somewhat prepared, but rehearsal was lacking.	Student does not seem at all prepared to present.
Posture	Stands up straight, looks relaxed and confident. Establishes eye contact during the presentation.	Stands up straight and establishes eye contact during the presentation.	Sometimes stands up straight and establishes eye contact.	Slouches and/or does not look at people during the presentation.
Content	Shows a full understanding of the topic.	Shows a good understanding of the topic.	Shows a good understanding of parts of the topic.	Does not seem to understand the topic very well.
Time Limit	Presentation is 5-6 minutes long.	Presentation is 4 minutes long.	Presentation is 3 minutes long.	Presentation is less than 3 minutes OR more than 6 minutes.

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