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From Plants to Horsepower — an Introduction into the World of Oil

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by Arcadia Sloan

My Students, School Requirements and Textbook

"I hate chemistry!" "Why do we have to learn this?" "I will never use this again as long as I live!" For many science teachers, these statements are all too common. My high school requires that all sophomores, regardless of educational background or experience, take chemistry. Most of them have only had Algebra I and are currently enrolled in geometry. In addition, many of my students show great deficiencies in math and reading. Of course, that means that one of my greatest challenges is to turn what tends to be very abstract concepts into concrete concepts and ideas. We have chosen to use *Chemistry in the Community,* (ChemComm), as our textbook for our basic-level chemistry classses. ChemComm was written by the American Chemical Society as a project sponsored by the National Science Foundation. ChemComm is very heavily lab-based where the students must investigate, generate their own data, analyze those data, and then apply their knowledge in order to solve a problem presented in the text. The students are able to apply concepts from a more traditional chemistry in a less intimidating manner. The book would also be quite useful in an on-level or Pre-AP Chemistry class; however, it is also useful for low-level classes, because the class can be much more conceptually based and the higher level math can be more easily avoided. We are also a Middle Years Program (MYP) school, which means this unit is structured to meet the requirements of MYP, including a required essay. The Middle Years Program is part of the International Baccalaureate Program (IB). The IB program fosters cultural awareness and the focus is to develop students who are critical and reflective thinkers. The program also strives to help students make real-world connections to what it is they are learning. Assessments are used to discover the depth of knowlegde and the methods are very holistic. Most of the school's general education students do not complete the program; however, our curricula are geared towards making sure all students are educated in this manner throughout the school. Students, who are successful with the MYP requirements, are able to go through the IB program and graduate with an International Diploma.

Rationale

Our school is located in Tulsa, Oklahoma, which is home to a refinery owned by HollyFrontier Corporation. This refinery can handle 125,000 barrels per day and mostly processes sweet crude, but is also capable of handling sour crude. [1] Sour crude contains more than 0.5% sulfur, whereas sweet crude contains less than 0.5% sulfur. The downsides of sour crude will be discussed later. Many students could possibly start their future careers in the oil industry for several good reasons. For example, William Monday, the deputy warden at the William S. Key Correctional Center in Fort Supply, OK reports that prison guards have a starting salary of about $11.82 per hour. Entry-level oilfield jobs start at about $20 per hour. It is interesting to note that in Oklahoma, Dairy Queen gives employees an extra $200 after being on the payroll for 3 months and many businesses and govenment agencies cannot find enough workers. If one is able-bodied enough to do the work, income can be doubled or tripled by working in the oil patch. [2] Even if the Keystone XL Pipeline project into Oklahoma were stopped, the oil hub located in Cushing would continue to grow. Railroads and trucks carrying tar sands from Canada are filling in and railroads are carrying more crude oil that ever before. [3] In 2011, the oil and gas industry provided 300,000 jobs in Oklahoma and paid nearly $1 billion in gross production taxes. [4] In addition, approximately one-quarter of all jobs here are tied, either directly or indirectly, to the energy industry. [5] The oil industry in Oklahoma is generally painted in a very positive light and in my opinion, many in Oklahoma are hesitant to "bite the hand that feeds them." My students can easily see the benefits of the oil industry in our state. I would like my students to be able to understand the processes that form petroleum and refine it, so that they have an understanding of why petroleum can be used as liquid fuel energy. If they understand that, then they will also understand why refining petroleum and burning it contributes to an increase of carbon dioxide in the atmosphere and causes other environmental problems.They will also be able to make predictions about which types of fuels are most efficient.

The Making of Black Gold

Most students know that the ultimate source of energy for our planet comes from the sun. After that, it all seems to be a big mystery. How do plants use the sun and then how do green plants get turned into a thick, black ooze? In order to begin, one must have a basic understanding of the concepts of atoms and what makes up an atom. Atoms are made of positively charged particles, called protons, neutral particles, the neutrons, and extremely small, negatively charged particles, the electrons. The protons and neutrons are found in the center of the atom, the nucleus, and the electrons are found orbiting the nucleus at various energy levels. One can imagine the nucleus being the Earth and the electrons being the various satellites put into differing orbits so that they do not collide with one another. Just as the gravitational pull of the Earth prevents the satellites from flying into space, the attraction of the negatively charged electrons to the positively charged protons keeps the electrons orbiting the nucleus. An electron is able to receive energy in order to jump from its original state, the ground state, to the next higher energy level. When that energy is given off, the electron falls back to its original level, the ground state. Electrons cannot exist between orbits, either they have enough energy to be in a higher orbital, or they do not. The packet of energy accepted by an electron when electromagnetic radiation is absorbed in order to move to the next energy level is called a photon. This may also be thought of as the amount of energy lost by the electron when it returns to its ground state. The energy of one photon depends on the wavelength of the electromagnetic radiation and can be calculated using the equation E=hN. The amount of energy (E) is equal to Planck's Constant (h) multiplied by the frequency (N). It may also be expressed as E=hc/Λ. In this instance, the amount of energy (E) is equal to Planck's Constant multiplied by the speed of light (c) and divided by the wavelength (Λ). The value of Planck's Constant is 6.6 x 10^{-27} erg seconds and the value of the speed of light is 3x10^{17} nm sec^{-1} . [6]

In going through the material in the preceeding paragraph, students will learn about some of the very basics of atomic structure. These basics include the number of protons, neutrons, and electrons and their charges. Students will practice atomic number and atomic mass. Valence electrons will be discussed as well as how valence electrons interact to form both covalent and polar covalent bonds. Balancing very simple synthesis and decomposition equations will also be practiced, i.e. 2 H_2 + O_2 —> 2 H_2O. It is important at this point to only use equations that involve combining either two or three different elements (types of atoms) into one compound. The reverse is also true, to focus on decomposition of one compound into two or three different elements. Stay away from single and double replacement reactions at this point. The ability of valence electrons to absorb energy, jump to the next energy level and fall back again will also be emphasized. That carbon is so special because it has four valence electrons and can, therefore, make single-, double-, and triple-covalent bonds will be heavily emphasized. Since my curriculum is a spiraling one, the focus at this point will be on studying oxygen, hydrogen, carbon, sulfur, phosphorus and nitrogen. Take care to NOT get bogged down in the detail of all the trends on the periodic table and with the various groups and periods. This curriculum spirals and we can return to the other elements later. The big goal is to get and keep them excited about chemistry, not kill them with the boredom of memorizing the periodic chart.

What electromagnetic radiation is needed to excite one electron enough to jump to the next energy level and how does this have anything to do with photosynthesis? The radiation comes to plants in the form of light energy from the sun. Specifically, we are concerned with radiation in the visible spectrum, which is electromagnetic radiation between 400 nanometers (nm) and 700 nm. Think of ROY G BIV, which is an acronym for the colors of visible light when passed through a prism - red, orange, yellow, green, blue, indigo and violet. The shorter the wavelength, the higher the frequency, and therefore, the more energy it contains. The longer the wavelength, the lower the frequency, the less energy it contains. As an example, let's take red light, which is most beneficial for plants, at 680 nm and use the formula E=hc/Λ to obtain the amount of energy in a photon of red light. [7]

E=hc/Λ E= 6.6 x 10^{-27} erg seconds x (3 x 10^{17} nm sec^{-1}) / 680 nm = 2.9 x 10^{-12} ergs

One joule is equivalent to 10^{7} ergs and one calorie is equivalent to 4.184 joules.

So that (2.9 x 10^{-12} ergs/1) x (1 joule/10^{7} ergs) = 2.9 x 10^{-19} joules

and (2.9 x 10^{-19} joules/1) x (1 calorie/4.4184 joules) = 6.9 x 10^{-20} calories.

In order to make use of the values in an easier fashion later in the unit, it is best to go ahead and convert the values used in the above example into kilojoules (kJ) per mole instead of leaving it in joules per photon or calories per photon. Using Avogadro's number of 6.02 x 10^{23} and setting the units in photons per mole, we get

(6.9 x 10-20 calories/1 phonton) x (6.02 x 1023 photons/1 mole) = 41,500 calories/mole = 41.5 kcal/mole and

(41,500 calories/mole x 4.184 joules/1 calorie) = 174,000 joules/mole = 174 kJ/mole.

Table 2.1, "Energy content of monochromatic, visible, light", in the book, *Energy, Plants and Man*, gives values for various colors of light listed in kJ/mole, kcalories/mole and electron volts. This petroleum unit uses kJ/mole. The following values are given: red (700 nm) has 171 kJ/mole, red (680 nm) has 174 kJ/mole, yellow (600 nm) has 199kJ/mole, blue (500 nm) has 239 kJ/mole, and violet (400 nm) has 299 kJ/mole. It is noted that chlorophyll can aborb red light with a maximum wavelength of 680 nm.

We have several prisms on hand for the students to see that visible light is actually made up of a rainbow. Flinn Scientific's "Energy in Photons" activity, for example, can also be used to demonstate the equations above and the students can practice their math skills. At this point, it isn't necessary to fully understand the term "mole" as long as they can understand that it is just a word to indicate an amount. I usually set out a dozen pennies, a dozen marbles, a dozen paperclips, a dozen pencils, a dozen beakers, etc. to show that a "dozen" can have different masses, but it's still just a dozen somethings. Students are familiar with the term "calorie" and are generally OK with the idea that a joule is just another unit. This is also a good time to do a measurements lab so that the students get reaquainted with m, cm, mm, etc. I choose not to set up a calorimeter at this point and instead will do that in a water unit.

This unit makes the assumption that students have had biology and, because of the Priority Acadmic Student Skills (PASS) objectives in the state of Oklahoma, have at least a basic understanding of photosynthesis from a biological point of view. For this reason, we will only review the most relevant points of photosynthesis. It can be said that photosynthesis is the most important chemical process on Earth. Plants depend directly on photosynthesis for their energy and animals depend on it indirectly because they eat the plants. Going back through the history of the Earth, green plants and their ability to produce oxygen changed the chemically reducing atmosphere to one that is oxygen rich. Photosynthesis acts as the carbon dioxide sink in the carbon cycle, anually consuming about one hundred billion tonnes of carbon. [8] Most plants have a system of roots, a trunk and leaves arranged in such a way as to be able to collect as much sunlight as possible. The total amount of power produced by green plants carrying out photosynthesis is equal to 100 terawatts (TW) or 100 x 10^{12} watts. To put that in perspective, the worldwide consumption of energy per second is 15 TW and the total solar radiation striking the Earth is 174,000 TW. [9] Even though photosysthesis is not terribly efficient, more power is produced by green plants than what the 6 billion people on the planet are consuming.

Photosynthesis is a process by which energy gets stored in the bonds of glucose. In order for that to happen, there has to be an input of energy from somewhere or the reaction would not take place. In order to examine the process of photosynthsis, it is helpful to know where it takes place and how it starts. Chlorophyll (Chl) and Bacteriochlorophyll (BChl) are the two most important pigments in photosysthesis. These two molecules only absorb part of the visible spectrum, but they accept the radiation, transport excitation energy and transport electrons. Other accessory pigments absorb other parts of the visible spectrum. [10] In plants, chlorophyll is contained in membrane-bound proteins within organelles called chloroplasts. The chloroplasts contain stacks of flattened sacks called grana and each flattened sack is made up of the thylakoid membrane, which is the actual location of the pigments. The inside of the thylakoid is called the lumen and the outside is called the stroma. Light catching reactions take place within the thylakoid membranes. The light provides enough energy to begin the process of photosynthesis. Photosynthesis is the process by which plants take carbon dioxide and water and turn it into glucose and molecular oxygen.

This unit will keep to a very basic two-step process in order to demonstrate that electromagnetic radiation from the sun is what gets stored in glucose as chemical energy. Those two steps include the oxidation of water and the reduction of carbon dioxide. The acronym, OIL RIG (oxidation is lost, reduction is gained), helps to remind the students that for reduction to take place, electrons must be available. Those electrons are made available by oxidation of water to form molecular oxygen, hydrogen ions and free electrons. The equation is $2\ H_2O$ + light energy —> $O_2 + 4\ H^+ + 4\ e^-$. Oxygen is then released into the atmosphere and the other two products are, in turn, used to reduce carbon dioxide. Carbon dioxide combines with hydrogen ions and electrons to produce glucose and water. The equation can be shown as:

$6\ CO_2 + 24\ H^+ + 24\ e^-$ —> $C_6H_{12}O_6 + 6\ H_2O$.

Only the basics of re-dox reactions will be worked with and manipulated here. This is a good time to perform a water electroysis lab. The students can easily collect the hydrogen and oxygen and test for flamability. This is also the perfect time to practice balancing slighty more difficult reactions, i.e. photosynthesis, respiration, combustion, etc. Students can practice with other reactions as long as they stay with the types of atoms and compounds that fit into this unit. Also, basic stoichiometry now becomes an integral part of this unit, again, focusing only on reactions pertinent to this unit. Molar mass computations and conversions, and percent composition problems, also fit quite nicely here. It cannot be stressed enough, that this is a spiraling curriculum and the types of reactions and compounds found in the problem sets will not stray outside of the scope of this unit.

Closer examination of the oxidation of water allows students to tie the synthesis of glucose to particular wavelengths of visible light. In order to do this, the bond energies, the amount of heat to break one mole of molecules into their individual atoms, of the molecules involved in reactions of photosynthesis need to be examined. Most chemistry textbooks have a table of bond energies. An online table of bond energies can be found at http://butane.chem.uiuc.edu/cyerkes/Chem104ACSpring2009/Genchemref/bondenergies.html. For photosynthesis the following bond energies are necessary: H-H has 432kJ/mole, C-H has 413 kJ/mole, C-C has 347 kJ/mole, C-O has 358 kJ/mole, O-H has 467 kJ/mole, C=O in CO_2 has 799 kJ/mole, and O=O has 495 kJ/mole.

In order to calculate the amount of energy needed to oxidize water to form molecular hydrogen and oxygen ($2\ H_2O$ —> $2\ H_2 + O_2$), the difference between breaking the bonds of the reactant on one side of the equation and forming the bonds of the products on the other side of the equation must be considered. The amount of energy needed to break the bonds of two moles of water can be calculated by multiplying four times the bond energy of O-H, 467 kJ/mol, to get 1868 kJ. The energy needed to form two moles of hydrogen is found by multiplying two times the bond energy of H-H, 432 kJ/mole, to get 864 kJ. The energy needed to form one mole of oxygen is one times the bond energy of O=O, 495kJ/mole, for 495 kJ. The total value on the product side is then 864 kJ plus 495 kJ which is 1359 kJ. The difference between the reactant side, 1868 kJ, and the product side, 1359 kJ, is 509 kJ. It can be concluded that 509 kJ must be absorbed in order to get the reaction going. From our observations earlier, this amount of energy could easily be provided by four photons of 680 nm red light.

A comparison of the 509 kJ that must be absorbed to get the reactions going to the amount of energy found in one photon at 680 nm, 174 kJ, shows that 4 photons would provide more energy than what is needed. It is known that the use of two photosystems in plants allows two photons to transport the same electron. Photosystem II is the only reaction center that is able to use four photochemical charge separation events to oxidze water (2 H_2O + 4 photons —> O_2 + 4 H^+ + 4 e^-). [11] As stated earlier, this is not an efficient process. In fact, photosystem II is only about 84% efficient. [12]

Now that the basic means of using light energy to split (oxidize) water has been reviewed, it would be helpful to return to the reduction of carbon dioxide ($6CO_2$+$24H^+$ + 24 e^- —> $C_6H_{12}O_6$ + 6 H_2O). This is the final process of converting light energy into chemical energy. Photosynthesis is a strongly endergonic reaction and in fact, "The change in Gibbs energy, ΔG, is +2720 kJ per mole of glucose (or +454 kJ/mol CO_2) at 298 K". [13] Glucose is only one of the many organic compounds produced by plants, but it is also the basic building block of starch and cellulose.

In this section, activities revisit the idea of using valence electrons to form covalent bonds. Students will also model alkanes and alkenes and their isomers. The goal is not to have students memorize and name multiple alkanes and alkenes. The goal is simply to give the students a basic idea of how simple hydrocarbons, such as methane, ethylene and some alcohols, are named. Other activities or problem solving sets will have students perform calculations of bond energies using a table of bond energies. Now would also be a good time to review the basic concepts of the carbon cycle. Student groups could actually make posters of the carbon cycle with each separate chemistry section able to hang the best poster in the classoom.

Most students are familiar with the fact that petroleum is a fossil fuel; however, they do not really comprehend what that means. Why are they called fossil fuels? If carbon is in a cycle, which they learned in biology, how can decayed organic material be fossilized when it supposedly decayed and returned to the cycle? Only about 98-99% of organic matter completely decays. The rest gets detoured in the carbon cycle and is the source material for the formation of fossil fuels. [14] Some students, with a more conservative upbringing, may not believe that coal and oil came from once living organisms. Compounds that occur in living organims or that clearly come from biological origins called biomarkers are found in both coal and petroleum. [15] One of those compounds, pristane, is found in waxes of living plants and is a minor compound present in many petroleum samples. [16] Over many centuries, decaying marine organisms and terrestrial plants are mixed with mud and buried under layers of sediment. The increasing temperature and pressure metamorphose the biomass into a waxy substance, kerogen, and then into liquid and gaseous hydrocarbons. This process is called catagenesis and the reactions are temperature sensitive. The temperature range for converting kerogen into oil is considered to be between 130 °C and 150 °C. Keeping the various conditions around the globe in mind, the depths for these temperatures are usually between 4,000 and 5,000 meters. The oils and gases then migrate up through the rock layers until they become trapped in porous rocks. Drilling can then release the oil and gases from these resevoirs. [17]

There are two classification systems for petroleum, one is based on age-depth relationships and the other is based on composition relationships. The age-depth system is based on a geological perspective. Young-shallow oil has been buried a geologically short time at relatively lower temperatures and has experienced little catagenesis. The alkanes in this oil are large, tend to be viscous, have a high boiling range and a low API gravity; API is an abbreviation for American Petroleum Institute and API gravity is measured in degrees. At the top of the depth window for catagenesis, some anaerobic conversions could still be occuring, i.e. sulfate to hydrogen sufide. Organic compounds can incorporate the hydrogen sulfide, which results in high-sulfur oil. These oils take lots of effort to be converted into clean fuel products. They are hard to pump, yield low outputs in the initial distillation, and must be treated to reduce the amounts of sulfur and aromatics. The are undesirable as feedstocks for refineries. [18] When comparing petroleum products, those with lower API gravities are denser than those with higher API gravities. [19] Petroleum products with an API gravity less than 10° are denser than water whereas petroleum products with a value greater than 10° are less dense than water.

Young-deep oil has undergone categenesis at higher temperatures and with greater cracking so that the molecules are smaller. This oil has a lower boiling range and lower viscosity than the young-shallow oil. There is also less sulfur in this oil because C-S bonds are weaker than C-C bonds. Aromatic molecules are larger due to hydrogen redistribution and are then less soluble in a liquid phase so they preciptate out from the oil as a separate phase. [20]

For the most part, time and temperature for many geological processes are interchangeable. Longer times at lower temperatures can have the same effect as shorter times at higher temperatures. Old-shallow oils and young-deep oils have many of the same characteristics; however, because gases such as hydrogen sulfide become less soluble as the temperature increases, old-shallow oil is more likely to be more sour than a similar young-deep oil. [21]

Old-deep oils have been buried the longest time and have had the highest temperatures. These oils have cracked almost as much as possible without turning into gas. That means they contain small molecules, have low viscosity and the distillates have low boiling points. They are sweet instead of sour and are highly desired as refinery feedstocks. [22]

The high-quality standard of oil, regardless of where it is from, is called Pennsylvania crude because the first of the old-deep oils were found in Pennsylvania. Much of the world's high-quality oil has been used up and only 2% of the world's oil can be classified as Pennsylvania crude. Refiners are having to deal with increasingly sour oil and must work harder to produce clean liquid fuel products. [23]

The second classification system, the one related to composition, may be more useful for fuel process engineering because it places a greater focus on what the oil will be used for instead of the origins of the oil. [24] This classification system is based on the amounts of alkanes (paraffins), cycloalkanes (naphthenes) and aromatics and aromatic hydrocarbons in the oil.

"One such classification systems recognizes six types:

(1) Paraffinic crudes generally contain <1% sulfur; have API gravities above 35°, and have total paraffins and naphthenes >50%, with paraffins >40%.

(2) Paraffinic-naphthenic crudes usually also contain <1% sulfur, and also have total paraffins and naphthene >50%, but neither paraffins nor naphthenes can be >40%.

(3) Aromatic-intermediate crudes generally contain >1% sulfur but <25% naphthenes, with aromatic content >50% and paraffins <10%.

(4) Aromoatic-naphthenic crudes usually contain <1% sulfur but >25% naphthenes, with aromatic content >50% and paraffins <10%.

(5) Aromatic-asphaltic oils have >1% sulfur but <25% naphtenes, >50% aromatics, and < 10% paraffins.

(6) Asphaltic crudes fall outside the definition of type 5. Types 4, 5, and 6 are usually heavy crudes that may have formed by degradation of lighter oils. The Athabasca tar sands fall into type 5." [25]

Figure 11.4 on page 186 of Harold F. Schoberts, *Chemistry of Fossil Fuels and Biofuels,* relates the classification of oils in the age-depth system with their dominant end products after simple processing. Old-deep oils with a high paraffin content tend to become naphthenes. Old-deep oils with a lower concentration of paraffins, become gasoline. Young-deep and old-shallow oils with approximately a 50% - 50% combination of paraffins and aromatics become naphtha and kerosene. Young-shallow oils with a much higher concentration of aromatics become diesel and fuel oil and young-shallow oils with a very high concentration of aromatics become asphalt. [26] An OSHA website, https://www.osha.gov/dts/osta/otm/otm_iv/otm_iv_2.html, also has good information on the content of oil that would be appropriate for high school students.

Depending on where a school is located, various maps can be downloaded and used for showing the locations of oil deposits, tight oil deposits, shale oil and tar sands. Another good student project is to have them work in groups to simply report the differences between the different types of oil deposits. Students should be able to identify where many of these deposits are found. Using maps that show oil depth could also lead students to predict what type of oil is found in a particular area. Discussion questions can revolve around geology and the history of the Earth.

Refining

Once oil is out of the ground, it can be made into many products through the process of refining. This is a multi-step process and the goal is to produce products that are marketable, economical and, from an environmental point of view, acceptable. The first products in the refining process produce liquid fuels, which are mostly used for transportation, although they may also be used for other processes, such as producing steam for a power plants. The secondary products are used in the chemical industries and to make polymers. Not only are the oils being transported to refineries becoming increasingly more sour, as stated earlier, their API gravities have dropped from 30-40° in the late nineteenth century to 15-30° by the end of the last century. [27]

Our textbook, Chemistry in the Community, has very good diagrams for refining and distillation. Refining of petroleum will be dealt with by taking a field trip to the local refinery and the students will perform a distillation experiment. There are several good websites available that do an amazing job of breaking down the various processes of refining. Students should review some of these websites on their own and then come together as teams to explain specific processes to the rest of the class. These websites would be used as springboards for their research. Teachers can also use these websites to make a list of questions that students have to answer. A list of these websites can be found in Teacher Resources.

After student presentations on the various processes involved in refining, a condensation lab will be performed. Our school is located just a few miles from a refinery so we will take a field-trip to round out this portion of the unit. Using the information found in this section, the field-trip is not a neccessity in order to understand the overall processes, but it's fun.

Oil as an Energy Source

Combustion of hydrocarbons is a burning process. The hydrocarbons are combined with oxygen and the resulting reaction produces water and carbon dioxide. The energy released during combustion can be estimated from the bond energies and the more hydrogen atoms per carbon atom in a hydrocarbon, the more energy will be released during combustion. Petroleum has a high content of saturated hydrocarbons; however, it can also contain a significant amount of other molecules. Crude oil contains 45.2kJ/mole, but gasoline contains 48.1 kJ/mole. Gasoline has fewer of these other molecules. [28]

This is an important section, as we have come full circle with petroleum. Students can now use various sources of fuel in combustion reactions (pencil and paper) in order to make judgements about which types of fuels refined from petroleum are the most efficient. One again, mole-mole ratios and mole-mass conversions can be reinforced. When using bond energies to calculate which liquid fuel produces more energy upon combustion, it it important to remember that 1598 kJ is released in the formation of every mole of carbon dioxide produced in the combustion reaction.

From this point, the unit could delve into the detrimental effects of increasing carbon dioxide levels in the atmosphere. We will be doing a unit on gases after this unit. That unit incorporates levels of atmospheric carbon dioxide, hydrogen sulfide and other environmentally detrimental gases. It also includes ideas for cleansing the air, reducing pollution and comparing sources of energy.

Final Project

As stated earlier, we are an MYP school and my students have certain projects they have to turn in at various points in the year. This unit lends itself quite well to a 700-1200 word essay. The students receive a rubric for the essay. The rubic is quite specific, but they are evaluated on things such as how well they explain how science is applied to solving a specific problem; they must discuss and evaluate the use of science in addressing the problem; they must communicate effectively and document their sources properly. The full essay activity follows in the activity section.

Activities

Activity 1 - Balancing Equations

The concepts in this activity include balancing equations, the law of conservation of matter, coefficients, subscripts and chemical formulas. More formulas and equations can be used than what are used here. This activity is in keeping with the spirit of the unit and formulas and equations should be limited to covalant compounds.

Materials include data tables 1 and 2 and bingo chips or colored candies.

Procedure:

1. Copy Table 1 or make your own list of chemical formulas.

2. For each chemical formula in the table, have students list each element that is in the compound. Students write both the element symbol and name. They may use the periodic table, if necessary.

3. Students write the number of atoms of each element present. The first example has been completed.

4. Copy Data Table 2 for the students or provide your own list of chemical equations.

5. For each reaction in the table, students follow steps 6-9 as outlined below.

6. Give students different colored chips or candies to represent each different atom.

7. Students build one molecule of each reactant on the left side of their desks and one molecule of each product on the right side of their desks. They may use pieces of paper labeled with a + and = to aid in the formation of the equations.

8. Students count all the atoms of each elecment on the reactants side and all the atoms on the products side.

9. If the number of each like atom is equal, the equation is balanced. If the numbers are not equal, students add additional molecules to the appropriate side(s) until the total numbers of like atoms are equal on the reactants side and the products side.

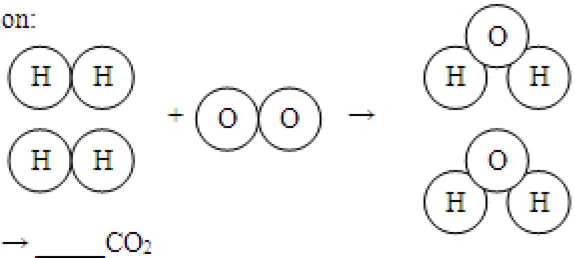
Table 1:

Name and Use	Formula	Atoms in Formula
1. Nitrous oxide	N_2O	N = nitrogen 2 O = oxygen 1
2. Sucrose	$C_{12}H_{22}O_{11}$	
3. TNT	$C_7H_5(NO_2)_3$	
4. Butane	C_4H_{10}	
5. Glucose	$C_6H_{12}O_6$	
6. Carbon dioxide	CO_2	
7. Methane	CH_4	

Data Table 2

1. __2__ H_2 + __1__ O_2 → __2__ H_2O

Molecular representation:



2. _____ C + _____ O_2 → _____ CO_2

Molecular representation:

3. _____ CO_2 + _____ H_2O → _____ $C_6H_{12}O_6$

Molecular representation:

4. _____ CH_4 + _____ O_2 → _____ CO_2 + _____ H_2O

Molecular representation:

5. _____ $C_{12}H_{22}O_{11}$ + _____ O_2 → _____ CO_2 + _____ H_2O

Molecular representation:

6. _____ C_3H_8 + _____ O_2 → _____ CO_2 + _____ H_2O

Molecular representation:

7. _____ CH_4 + _____ O_2 → _____ CO + _____ H_2O

Molecular representation:

Activity 2 – Types of Oil Formations

This is a group activity and will take two full 45-min class periods and part of a class period on the day of the assignment. Depending on how many groups are in the class, assign the following types of oil deposits: shale oil, tar sands, young-deep oil, old-deep oil, young-shallow oil, and old-shallow oil. Within groups, students should decide among themselves who will be responsible for which part of their presentation. One student should find where in the world a particular type of oil deposit is found. This should be shown on maps for the class. One student reports on how that type of oil deposit is recovered and the third student reports on how that type of deposit refined. If it is a large class and there are four students per group, the fourth student can report on how detrimental recovery of that type of oil is to the environment. Otherwise, the environmental aspect can be divided between the students who report on recovery and refining. One full class period should be set aside for research and another class period for the presentations.

Activity 3 – Refining

Using the five "How Stuff Works" websites found in Teacher Resources, students make group posters. The class should be divided into five groups and each group is assigned one of the websites. Students will be given large pieces of butcher paper in order to make their posters. This will take two class periods – one for research and drawing and one for presentations. My suggestion is that students are given the websites the day before the computer lab day so that they can become familiar with the processes at home.

Activity 4 – Final Essay

This will be the first essay of the year for chemistry and I always use one 45-minute class period to take them to the computer lab. They are given a preliminary assignment of finding at least five sources that would be considered unsuitable for use in a research paper. The next class period is then used to discuss why those sources would be bad choices for use in their essays.

Students must choose a problem related to this petroleum unit. They can either come up with an idea on their own or the teacher can compose a list of problems and allow the students to only choose from that list. Problems could include air pollution caused by the burning of a particular fossil fuel, environmental effects of drilling for oil, problems in transporting tar sands over long distances, or the amount of waste water produced when drilling for oil. The possibilities are endless. The essay must be between 700-1200 words, double-spaced and in Times New Roman font, size 12. The students are given two weeks to complete the assignment and must submit a hard-copy as well as an electronic copy via email. Students are not allowed to use wikipedia as a source, must have at least five sources and only 3 of those sources may be on-line sources. One block period or two regular class periods can be used to allow the students to begin their research in a computer lab, if your school is lucky enough have that luxury. The students must address how science can be used to solve the problem and whether or not science has been or is effective in solving that particular problem.

Teacher Resources

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https://www.osha.gov/dts/osta/otm/otm_iv/otm_iv_2.html - This website is from the Occupational Safety and Health Administration in the United States Departments of Labor and is an excellent source for all the stages of the refining process, including desalting, atmospheric distillation, vacuum distillation, solvent extraction and dewaxing, thermal cracking, catalytic cracking, hydrocracking, catalytic reforming, catalytic hydrotreating, isomerization, polymerization, and the list goes on. This is extremely detailed, but very well thought out in its organization and explanation. It is more information than students need to know; however, the information can be manipulated easily for assigned student reading. It is written so that high-schoolers can understand it and "Table IV:2-3. Overview of Petroleum Refining Processes" gives information about what the end products at each stage are used for.

http://www.world-petroleum.org/index.php?/Technology/petroleum-refining-courtesy-of-aip.html - This website is not nearly as detailed as the one from OSHA. Its big advantage for chemistry teachers is that it gives some of the chemical processes in chemical equation form; therefore, students can use those equations to practice balancing equations, mole-mass convertions, mole-mole ratio, etc.

http://science.howstuffworks.com/environmental/energy/oil-refining2.htm (From Crude Oil) http://science.howstuffworks.com/environmental/energy/oil-refining3.htm (The Refining Process)

http://science.howstuffworks.com/environmental/energy/oil-refining4.htm (Fractional Distillation)

http://science.howstuffworks.com/environmental/energy/oil-refining5.htm (Chemical Processing)

http://science.howstuffworks.com/environmental/energy/oil-refining6.htm (Treating and Blending the Fractions)

The five preceeding websites can be used independently but they are also linked together. These are clearly written and very succinct. Some have videos, links to videos and links to other pages, such as "What's the difference between gasoline, kerosene, diesel, etc.?"

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Appendix – Implementation of Academic Standards

High School Chemistry Priority Academic Student Skills (PASS) for Oklahoma

Process Standard 5.1 – Interpret an atomic model which explains a given set of observations.

Process Standard 5.2 - Select predictions based on models (e.g., electron configuration, bonding, compound formation), and when appropriate, apply mathematical reasoning to make accurate predictions.

Standard 1.1 – Matter is made of atoms. Atoms are composed of subatomic particles.

Standard 1.2 – Atoms interact with one another by transferring or sharing outer electrons that are farthest from the nucleus. These outer electrons govern the chemical properties of the element.

Standard 1.4.a – Valence electrons govern the chemical properties and reactivity of the element.

Standard 2.1 Chemical substances react in definite molar weight proportions and mass is conserved. Balanced chemical equations are used to determine molar ratios.

Standard 3.2 – Chemical reactions in a system either release energy to the surroundings or absorb energy from the surroundings, as a result of breaking or forming bonds between atoms.

Common Core Standards – Science

CCSS.ELA-Literacy.RST.9-10.1 Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.

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.9-10.7 Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

Notes

1. Tulsa Refinery – HollyFrontier, 2013

2. Joe Wertz, â€žWhy Oklahoma's Oil Boom Has Forced Dairy Queen to Offer Sign-On Bonuses", 2012

3. Joe Wertz, â€žCushing Oil Hub Will Grow With or Without Keystone XL, Pipeline Exec. Says", 2013

4. Mark Schlachtenhaufen, â€žStudy: Oil, gas provide 300,000 Oklahoma jobs", 2011

5. NPR, â€žEnergy Industry, State Impact Oklahoma", 2013

6. David Walker, *Energy, Plants and Man*, 29

7. David Walker, *Energy, Plants and Man*, 45

8. Harold H. Schobert, *Chemistry of Fossil Fuels and Biofuels*, 19

9. Sven Larsson, *Chemical Physics*, 375

10. Sven Larsson, *Chemical Physics*, 375

11. Iain McConnell, Gonghu Li and Gary W. Brudvig, "Energy Conversion in Natural and Artificial Photosynthesis," in *Chemistry and*

Biology Review, 436

12. Iain McConnell, Gonghu Li and Gary W. Brudvig, "Energy Conversion in Natural and Artificial Photosynthesis," in *Chemistry and Biology Review*, 436

13. Harold H. Schobert, *Chemistry of Fossil Fuels and Biofuels*, 19

14. Harold H. Schobert, *Chemistry of Fossil Fuels and Biofuels*, 103

15. Harold H. Schobert, *Chemistry of Fossil Fuels and Biofuels*, 103

16. Harold H. Schobert, *Chemistry of Fossil Fuels and Biofuels*, 104

17. James Speight, "Origin and Occurence," in *The Chemistry and Technology of Petroleum*, 4

18. Harold H. Schobert, *Chemistry of Fossil Fuels and Biofuels*, 182

19. "Degrees API", 2013

20. Harold H. Schobert, *Chemistry of Fossil Fuels and Biofuels*, 183

21. Harold H. Schobert, *Chemistry of Fossil Fuels and Biofuels*, 183

22. Harold H. Schobert, *Chemistry of Fossil Fuels and Biofuels*, 183

23. Harold H. Schobert, *Chemistry of Fossil Fuels and Biofuels*, 183

24. Harold H. Schobert, *Chemistry of Fossil Fuels and Biofuels*, 183

25. Harold H. Schobert, *Chemistry of Fossil Fuels and Biofuels*, 184

26. Harold H. Schobert, *Chemistry of Fossil Fuels and Biofuels*, 186

27. Harold H. Schobert, *Chemistry of Fossil Fuels and Biofuels*, 192

28. "Energy from Fossil Fuels", 2013