Key: Yellow highlight = required component

Gas Chromatography & Biofuel

Subject Area(s) Chemistry, Measurement, Problem Solving, Science & Technology

Associated Unit **Intermolecular Forces**

Lesson Title **Gas Chromatography and Biofuel**

Header

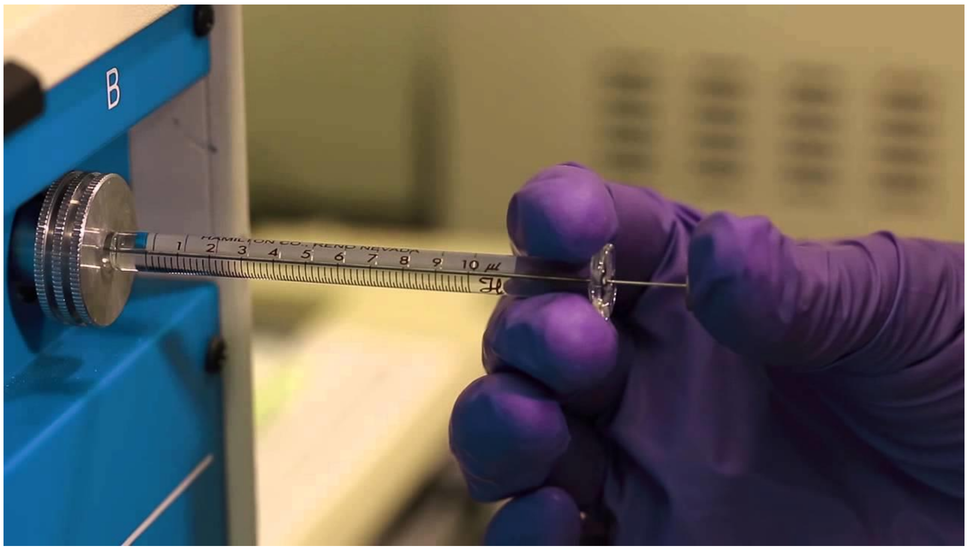


Image 1
Image file: ___?
ADA Description: *Gloved scientist injecting gas into a gas chromotagraph via a micro syringe.*
Source/Rights: Copyright © ___?NC State,
May 13, 2015, https://i.ytimg.com/vi/6Z61ezJFfyA/maxresdefault.jpg

Grade Level Chemistry, 11-12th grade

Time Required **Several days (can be spread out through the school year)**

Summary

- Teacher demo learning about Gas Chromatography (GC)
- Students design will product biofuels and then do a series of tests to characterize the fuel they created, one of which will incorporate the gas chromatographer. The students will be asked to engineer a fuel that meets specific criterion and purpose.

Engineering Connection
Chemical Engineering

Engineering Category =

Choose the category that best describes this lesson's amount/depth of engineering content:

- Relating science and/or math concept(s) to engineering
- **Engineering analysis or partial design**
- **Engineering design process**

Keywords

biodiesel, chemical engineering, physical properties, fuel analysis,

Educational Standards **(List 2-4)**

State STEM Standard (required)

Source, year, standard number(s)/letter(s), grade band and text (its unique ID# is optional)

	Statement Notation SC.912.P.8.6 **Description** Physical Science Matter Distinguish between bonding forces holding compounds together and other attractive forces, including hydrogen bonding and van der Waals forces. **Education Level** Grades 9 - 12 **Subject** Science **PURL** http://asn.jesandco.org/resources/S1130987 *From <https://www.teachengineering.org/standards/browse>*
	Statement Notation SC.912.P.8.7 **Description** Physical Science Matter Interpret formula representations of molecules and compounds in terms of composition and structure. **Education Level** Grades 9 - 12 **Subject** Science **PURL** http://asn.jesandco.org/resources/S1130988 *From <https://www.teachengineering.org/standards/browse>*
	Statement Notation SC.912.P.8.9

	Description Physical Science Matter Apply the mole concept and the law of conservation of mass to calculate quantities of chemicals participating in reactions. **Education Level** Grades 9 - 12 **Subject** Science **PURL** http://asn.jesandco.org/resources/S113098A *From <https://www.teachengineering.org/standards/browse>*
	Statement Notation SC.912.P.8.12 **Description** Physical Science Matter Describe the properties of the carbon atom that make the diversity of carbon compounds possible. **Education Level** Grades 9 - 12 **Subject** Science **PURL** http://asn.jesandco.org/resources/S113098D *From <https://www.teachengineering.org/standards/browse>*
	Statement Notation SC.912.P.8.13 **Description** Physical Science Matter Identify selected functional groups and relate how they contribute to properties of carbon compounds. **Education Level** Grades 9 - 12 **Subject** Science **PURL** http://asn.jesandco.org/resources/S113098E

	From <https://www.teachengineering.org/standards/browse>
	Statement Notation SC.912.P.8.11 **Description** Physical Science Matter Relate acidity and basicity to hydronium and hydroxyl ion concentration and pH. **Education Level** Grades 9 - 12 **Subject** Science **PURL** http://asn.jesandco.org/resources/S113098C *From <https://www.teachengineering.org/standards/browse>*
	Statement Notation SC.912.P.10.1 **Description** Physical Science Energy Differentiate among the various forms of energy and recognize that they can be transformed from one form to others. **Education Level** Grades 9 - 12 **Subject** Science **PURL** http://asn.jesandco.org/resources/S113098F *From <https://www.teachengineering.org/standards/browse>*
	Statement Notation SC.912.P.10.2 **Description** Physical Science Energy Explore the Law of Conservation of Energy by differentiating among open, closed, and isolated systems and explain that the total energy in an isolated system is a conserved quantity. **Education Level** Grades 9 - 12

	Subject Science **PURL** http://asn.jesandco.org/resources/S1130990 *From <https://www.teachengineering.org/standards/browse>*
	Statement Notation SC.912.P.10.4 **Description** Physical Science Energy Describe heat as the energy transferred by convection, conduction, and radiation, and explain the connection of heat to change in temperature or states of matter. **Education Level** Grades 9 - 12 **Subject** Science **PURL** http://asn.jesandco.org/resources/S1130992 *From <https://www.teachengineering.org/standards/browse>*
	Statement Notation SC.912.N.1.1 **Description** Nature of Science The Practice of Science Define a problem based on a specific body of knowledge, for example: biology, chemistry, physics, and earth/space science, and do the following: 1. pose questions about the natural world, 2. conduct systematic observations, 3. examine books and other sources of information to see what is already known, 4. review what is known in light of empirical evidence, 5. plan investigations, 6. use tools to gather, analyze, and interpret data (this includes the use of measurement in metric and other systems, and also the generation and interpretation of graphical representations of data, including data tables and graphs), 7. pose answers, explanations, or descriptions of events, 8. generate explanations that explicate or describe natural phenomena (inferences), 9. use appropriate evidence and reasoning to justify these explanations to others, 10. communicate results of scientific investigations, and 11. evaluate the merits of the explanations produced by others.

	Education Level Grades 9 - 12 **Subject** Science **PURL** http://asn.jesandco.org/resources/S1130955 *From <https://www.teachengineering.org/standards/browse>*
	Statement Notation SC.912.N.4.1 **Description** Nature of Science Science and Society Explain how scientific knowledge and reasoning provide an empirically-based perspective to inform society's decision making. **Education Level** Grades 9 - 12 **Subject** Science **PURL** http://asn.jesandco.org/resources/S1130966 *From <https://www.teachengineering.org/standards/browse>*
	Statement Notation SC.912.N.4.2 **Description** Nature of Science Science and Society Weigh the merits of alternative strategies for solving a specific societal problem by comparing a number of different costs and benefits, such as human, economic, and environmental. **Education Level** Grades 9 - 12 **Subject** Science **PURL** http://asn.jesandco.org/resources/S1130967 *From <https://www.teachengineering.org/standards/browse>*

ITEEA Standard (required)

	Description Technology and Society Students will develop an understanding of the cultural, social, economic, and political effects of technology. **Education Level** Grades K - 12 **Subject** Technology **PURL** http://asn.jesandco.org/resources/S11416BA *From <https://www.teachengineering.org/standards/browse>*
	Description Technology and Society Students will develop an understanding of the effects of technology on the environment. **Education Level** Grades K - 12 **Subject** Technology **PURL** http://asn.jesandco.org/resources/S11416BB *From <https://www.teachengineering.org/standards/browse>*
	Description Design Students will develop an understanding of engineering design. **Education Level** Grades K - 12 **Subject** Technology **PURL** http://asn.jesandco.org/resources/S11416BF *From <https://www.teachengineering.org/standards/browse>*
	Description Design Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving. **Education Level**

	Grades K - 12 **Subject** Technology **PURL** http://asn.jesandco.org/resources/S11416C0 *From <https://www.teachengineering.org/standards/browse>*
	Description Abilities for a Technological World Students will develop abilities to assess the impact of products and systems. **Education Level** Grades K - 12 **Subject** Technology **PURL** http://asn.jesandco.org/resources/S11416C3 *From <https://www.teachengineering.org/standards/browse>*
	Description The Designed World Students will develop an understanding of and be able to select and use energy and power technologies. **Education Level** Grades K - 12 **Subject** Technology **PURL** http://asn.jesandco.org/resources/S11416C6 *From <https://www.teachengineering.org/standards/browse>*
	Description The Designed World Students will develop an understanding of and be able to select and use transportation technologies. **Education Level** Grades K - 12 **Subject** Technology **PURL** http://asn.jesandco.org/resources/S11416C8

	From <https://www.teachengineering.org/standards/browse>

NGSS Standard (strongly recommended)

	Statement Notation HS-PS1-3 **Description** Matter and Its Interactions Students who demonstrate understanding can: Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles. **Education Level** Grades 9 - 12 **Subject** Science **Comment** Assessment Boundary: Assessment does not include Raoult's law calculations of vapor pressure. **Comment** Clarification Statement: Emphasis is on understanding the strengths of forces between particles, and not on naming specific intermolecular forces (such as dipole-dipole). Examples of particles could include ions, atoms, molecules, and networked materials (such as graphite). Examples of bulk properties of substances could include the melting point and boiling point, vapor pressure, and surface tension. **PURL** http://asn.jesandco.org/resources/S2454538 *From <https://www.teachengineering.org/standards/browse>*
	Statement Notation HS-PS1-4 **Description** Matter and Its Interactions Students who demonstrate understanding can: Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy. **Education Level** Grades 9 - 12 **Subject** Science **Comment** Assessment Boundary: Assessment does not include calculating the total bond energy changes during a chemical reaction from the bond energies of reactants and products. **Comment** Clarification Statement: Emphasis is on the idea that a chemical reaction is a system that affects the energy change. Examples of models could include molecular-level drawings and diagrams of

reactions, graphs showing the relative energies of reactants and products, and representations showing energy is conserved.

PURL
http://asn.jesandco.org/resources/S2454542

From <https://www.teachengineering.org/standards/browse>

Statement Notation
HS-PS3-1

Description
Energy

Students who demonstrate understanding can:

Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.

Education Level
Grades 9 - 12

Subject
Science

Comment
Assessment Boundary: Assessment is limited to basic algebraic expressions or computations; to systems of two or three components; and to thermal energy, kinetic energy, and/or the energies in gravitational, magnetic, or electric fields.

Comment
Clarification Statement: Emphasis is on explaining the meaning of mathematical expressions used in the model.

PURL
http://asn.jesandco.org/resources/S2454551

From <https://www.teachengineering.org/standards/browse>

CCSS Standard (strongly recommended)

Statement Notation
CCSS.Math.Practice.MP1

Alt. Statement Notation
MP.1

Description
Standards for Mathematical Practice

Make sense of problems and persevere in solving them.

Education Level
Grades K - 12

Subject
Math

Comment

	Mathematically proficient students start by explaining to themselves the meaning of a problem and looking for entry points to its solution. They analyze givens, constraints, relationships, and goals. They make conjectures about the form and meaning of the solution and plan a solution pathway rather than simply jumping into a solution attempt. They consider analogous problems, and try special cases and simpler forms of the original problem in order to gain insight into its solution. They monitor and evaluate their progress and change course if necessary. Older students might, depending on the context of the problem, transform algebraic expressions or change the viewing window on their graphing calculator to get the information they need. Mathematically proficient students can explain correspondences between equations, verbal descriptions, tables, and graphs or draw diagrams of important features and relationships, graph data, and search for regularity or trends. Younger students might rely on using concrete objects or pictures to help conceptualize and solve a problem. Mathematically proficient students check their answers to problems using a different method, and they continually ask themselves, "Does this make sense?" They can understand the approaches of others to solving complex problems and identify correspondences between different approaches. **PURL** http://asn.jesandco.org/resources/S2366906 *From <https://www.teachengineering.org/standards/browse>*
	Statement Notation CCSS.Math.Practice.MP3 **Alt. Statement Notation** MP.3 **Description** Standards for Mathematical Practice Construct viable arguments and critique the reasoning of others. **Education Level** Grades K - 12 **Subject** Math **Comment** Mathematically proficient students understand and use stated assumptions, definitions, and previously established results in constructing arguments. They make conjectures and build a logical progression of statements to explore the truth of their conjectures. They are able to analyze situations by breaking them into cases, and can recognize and use counterexamples. They justify their conclusions, communicate them to others, and respond to the arguments of others. They reason inductively about data, making plausible arguments that take into account the context from which the data arose. Mathematically proficient students are also able to compare the effectiveness of two plausible arguments, distinguish correct logic or reasoning from that which is flawed, and—if there is a flaw in an argument—explain what it is. Elementary students can construct arguments using concrete referents such as objects, drawings, diagrams, and actions. Such arguments can make sense and be correct, even though they are not generalized or made formal until later grades. Later, students learn to determine domains to which an argument applies. Students at all grades can listen or read the arguments of others, decide whether they make sense, and ask useful questions to clarify or improve the arguments. **PURL** http://asn.jesandco.org/resources/S2366908

	From <https://www.teachengineering.org/standards/browse>

Pre-Requisite Knowledge
Students will need to have a good understanding of intermolecular forces. This unit will apply those concepts.

Learning Objectives
After this lesson, students should be able to:

- Use a Gas Chromatograph and explain how it works
- Synthesis biofuel with a degree of control over its physical properties
    - Characterize and analyze the biofuel they created via the following methods:
        - Gas chromatography
        - Freezing/Melting point
        - Percent Yield
        - Titration
        - Calorimetry

Introduction / Motivation (5E – Engage)

- How do you separate a mixture of gases?
- Discussion on current fuel sources for transportation and the idea of biorecycling
- Burn a sample of biofuel

Lesson Background & Concepts for Teachers (5E – Explain)

- Gas Chromatography Demos & exploration
- Review of intermolecular forces

Vocabulary / Definitions

Word	Definition
Gas chromatography	A method of analyzing gases which separates them through a medium based on intermolecular forces
Intermolecular forces	Force that holds atoms or molecules together physically
Calorimetry	Process of measuring the heat of a reaction, physical change or combustion
Titration	Method of assessing the pH of a substance
Melting /Freezing Point	Determing at what temperature a substance will go from solid to liquid or vice versa
Hydrocarbon chains	Molecules based in carbon with hydrogens attached

Associated Activities (5E – Explore)

1. Gas Chromatograph Demo
2. Gas Chromatograph Lab
3. Synthesis & Analysis of biofuels

Lesson Closure

Report on what fuel may have been created and the evidence they have to support this claim, and what could potentially be done with that fuel and any byproducts.

Assessment (5E – Evaluate)

Pre-Lesson Assessment
Descriptive Title: Warm Up Questions (student self assessment)

Post-Introduction Assessment
Descriptive Title: Report on fuel they created as well as a writing about what they have learned

Lesson Summary Assessment
Descriptive Title: Report on what fuel may have been created and the evidence they have to support this claim, and what could potentially be done with that fuel and any byproducts.

Lesson Extension Activities (5E – Extension)

Analyze the fuels created by your peers. What might have caused this differences? Engineer a biofuel for a specific purpose.

References

*Misna, Deb, and Jack Randall. *Gas Chromatography Investigations with the Mini GC*. 2nd ed. Beaverton: Vernier Software & Technology, 2012. Print.

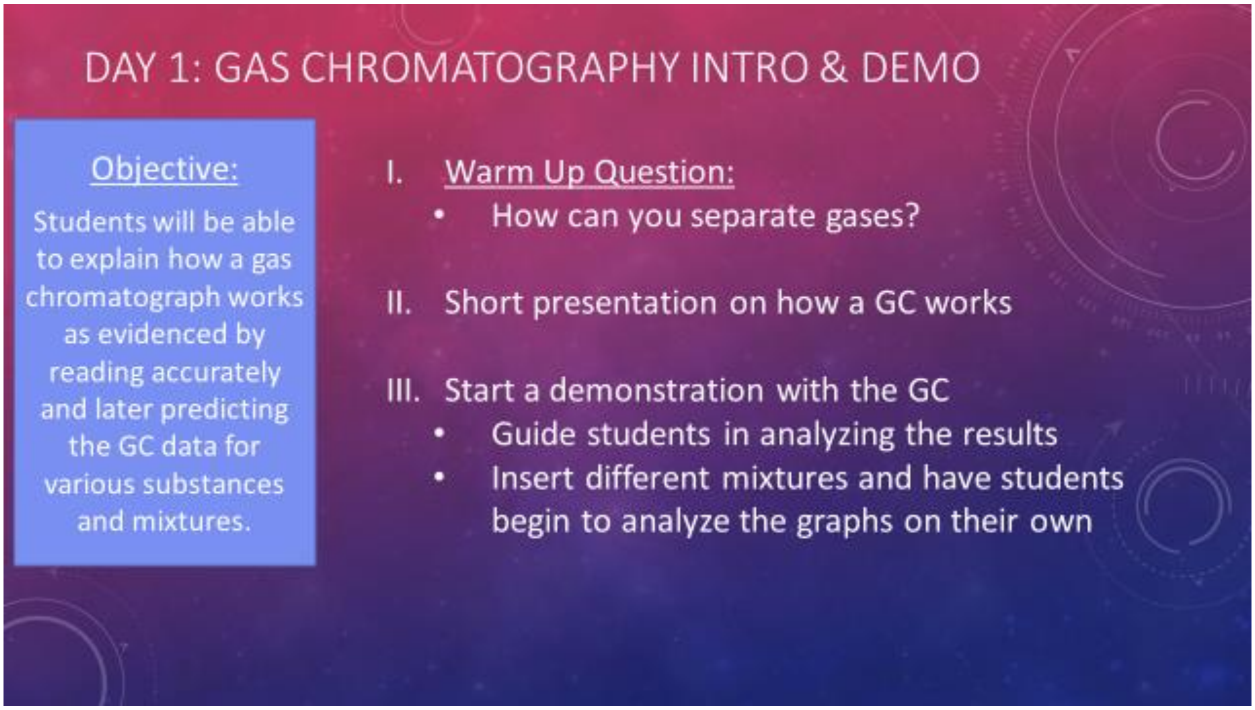
Attachments

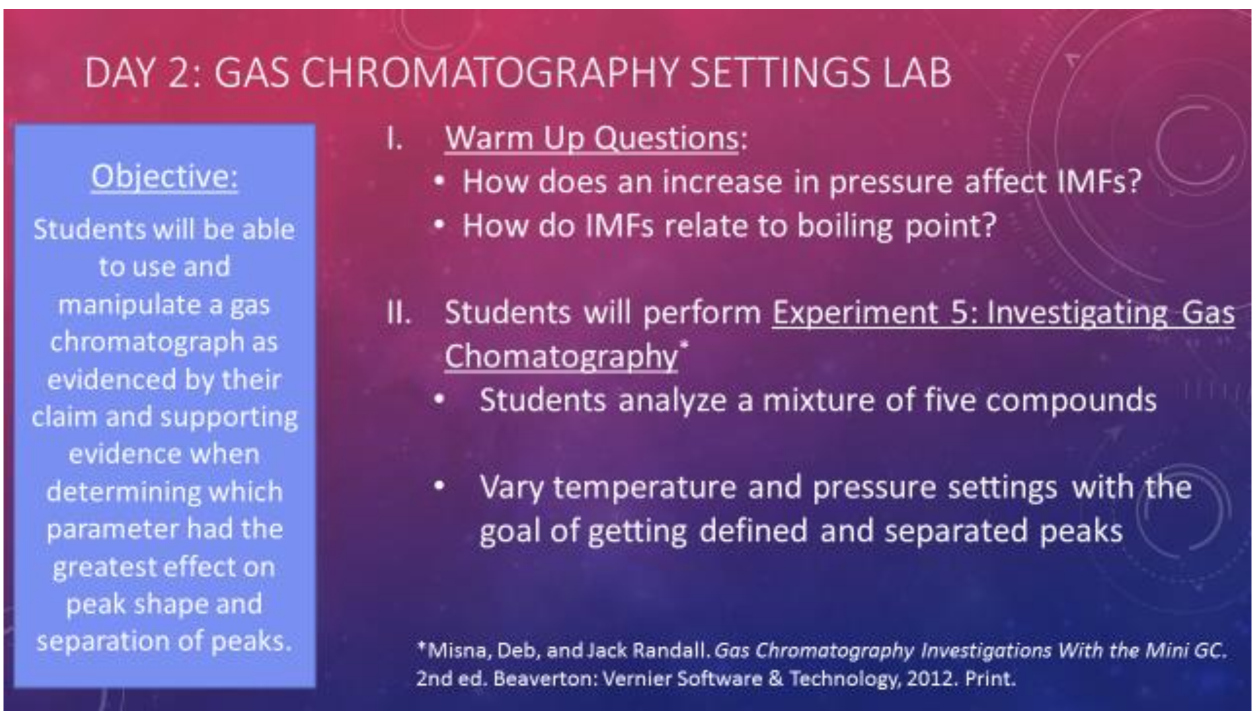
- A suggested daily lesson plan with objectives and bellwork
- BioFuel Synthesis directions

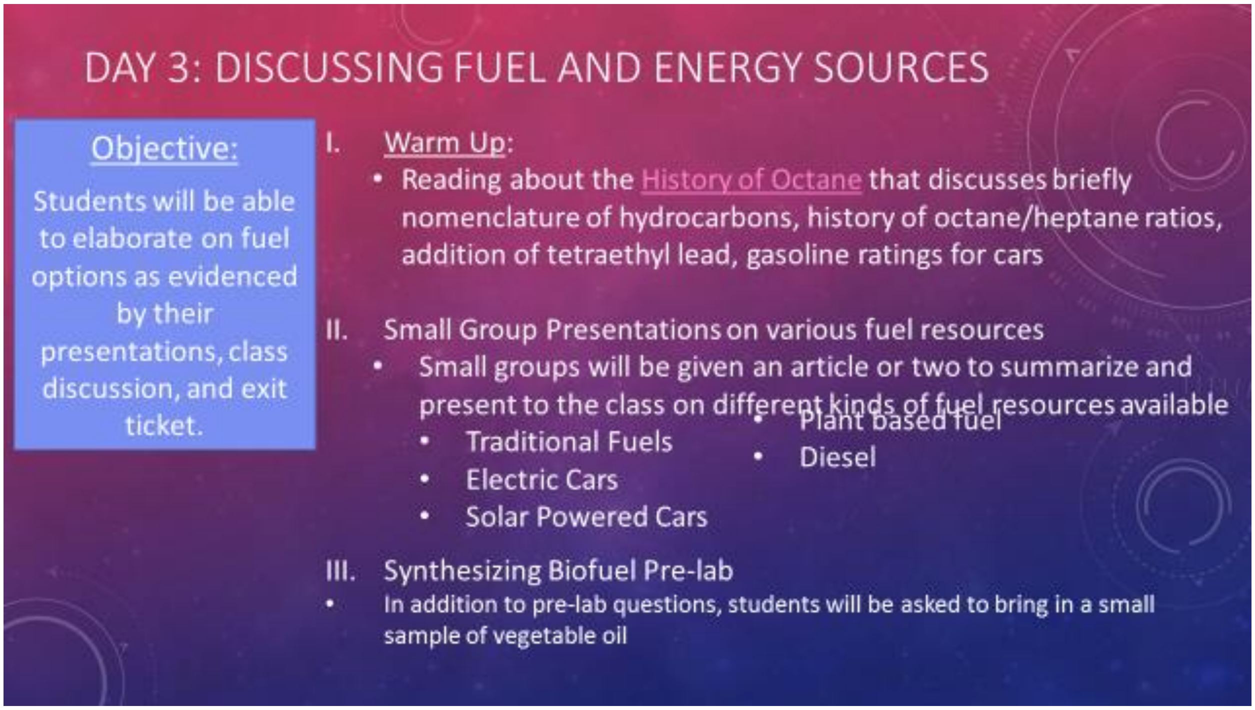
Supporting Program

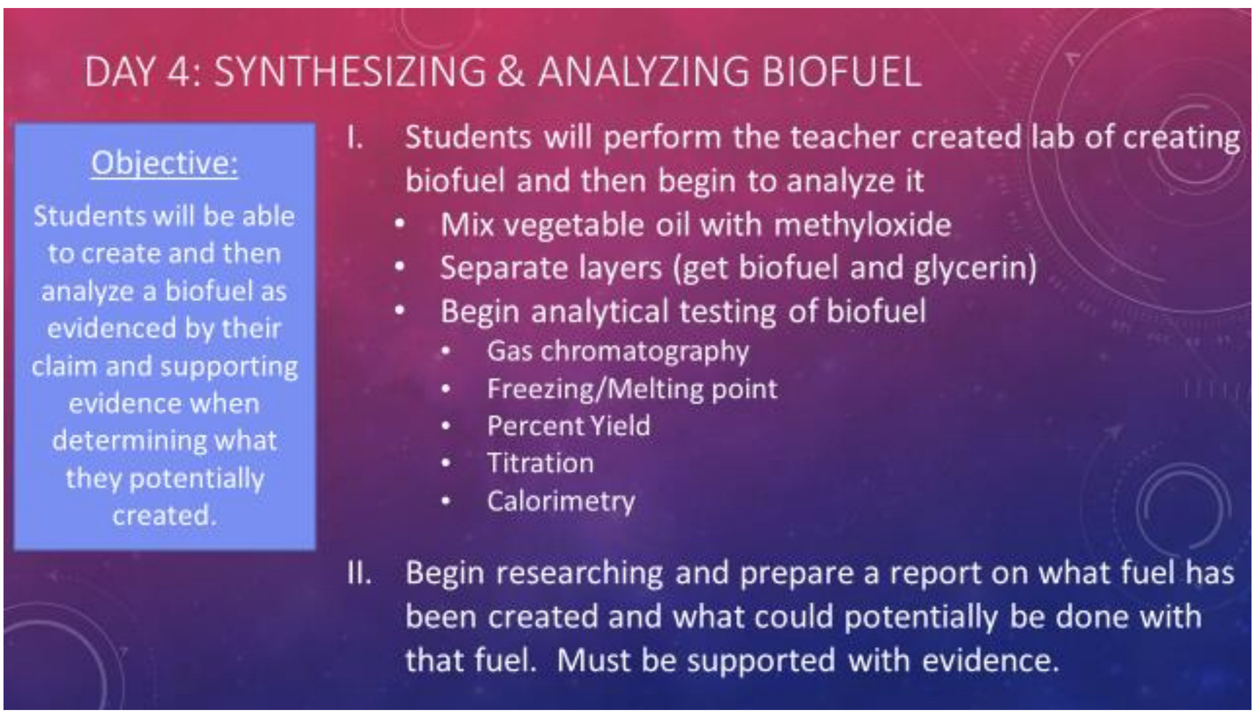
For more information about the program visit: http://fmri-ret.eng.usf.edu/. The Research Experience for Teachers (RET) at the Functional Materials Research Institute at USF is funded by the National Science Foundation under award number 1301054.

Suggested Daily Summary & Objectives






DAY 3: DISCUSSING FUEL AND ENERGY SOURCES
Objective:
Students will be able to elaborate on fuel options as evidenced by their presentations, class discussion, and exit ticket.
I. Warm Up:
• Reading about the History of Octane that discusses briefly nomenclature of hydrocarbons, history of octane/heptane ratios, addition of tetraethyl lead, gasoline ratings for cars
II. Small Group Presentations on various fuel resources
• Small groups will be given an article or two to summarize and present to the class on different kinds of fuel resources available
• Traditional Fuels
• Electric Cars
• Solar Powered Cars
• Plant based fuel
• Diesel
III. Synthesizing Biofuel Pre-lab
• In addition to pre-lab questions, students will be asked to bring in a small sample of vegetable oil


DAY 4: SYNTHESIZING & ANALYZING BIOFUEL
Objective:
Students will be able to create and then analyze a biofuel as evidenced by their claim and supporting evidence when determining what they potentially created.
I. Students will perform the teacher created lab of creating biofuel and then begin to analyze it
• Mix vegetable oil with methyloxide
• Separate layers (get biofuel and glycerin)
• Begin analytical testing of biofuel
• Gas chromatography
• Freezing/Melting point
• Percent Yield
• Titration
• Calorimetry
II. Begin researching and prepare a report on what fuel has been created and what could potentially be done with that fuel. Must be supported with evidence.

DAY 5: PEER REVIEW OF BIOFUEL REPORTS

Objective:

Students will be able to critically analyze the pros and cons of biofuel resources as evidenced by their questioning, discussion, and final conclusions regarding the success of the biofuels created in the classroom.

I. Students will begin by trading reports in small groups and analyzing which biofuels created might be of the greatest benefit for different purposes.

II. Students will change groups and report out their findings from their initial groups.

III. Students will write a one or two paragraph summary of what they learned:
   - I. Can highlight any trends/observations from the class
   - II. Can expand their thoughts on the use of biofuels
   - III. Must cite evidence to support their claims

Synthesis of Biofuel

Materials Needed for Biofuel Synthesis:

a. Various vegetable oils
b. Sodium hydroxide pellets
c. Methanol
d. Beaker
e. Glass stir rod
f. Magnetic stir bar
g. Magnetic stir plate
h. Temperature probe
i. Iron Ring
j. Ring Stand
k. Separation funnel
l. Small glass vials to hold the biofuel and glycerin byproducts

Procedure for Biofuel Synthesis

a. Create solution of methanol and sodium hydroxide (sodium methoxide) by stirring with a stir bar for 5-10 minutes.
    i. 15 mL methanol to 0.30g NaOH
b. Measure out 60 mL of the oil and also take the mass.
c. Then add the vegetable oil to the reaction flask and heat to 45-50°C for 25-30 minutes while continuing to use the stir bar so the created layers do not separate yet.
d. While still warm, pour the mixture into the separatory funnel and allow the mixture to cool and separate into two layers.
    i. Do not let stand for too long in case the lower layer solidifies.
e. Drain the lower layer into a glass vial. Label it glycerin.
    i. This could be another question…have students solve based on density values which layer is glycerin and which is biodiesel. If so…have students take mass and volume measurements of each layer produced.
f. The top layer should be the biofuel. Pour biofuel into graduated cylinder to measure volume and mass. Then transfer sample to another glass vial and label it biofuel.