Wood Ash Titration: A Greener Titration Experiment

A case study prepared by Beyond Benign as part of the Green Chemistry in Higher Education program: A workshop for EPA Region 2 Colleges and Universities

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Summary:
Titration experiments are commonly performed in general chemistry courses to demonstrate technique and to understand acid/base chemistry. Typical titration experiments involve the titration of an acid with a standardized solution of a base. Acids can be benign, such as acetic acid, or more toxic, such as oxalic acid. The experiment outlined in this case study is designed to replace experiments utilizing oxalic acid, an acid with high human health hazards. The wood ash titration also allows students to consider using renewable feedstocks for chemical reactions and processes.

Reduction in waste and purchasing costs:
For every semester this reaction is implemented with 100 students, there is an overall ***cost savings of $120.11*** in purchasing and waste disposal costs and a ***reduction in waste from 7 gallons to 0-3.4 gallons***. The greener version of the Clock Reaction also ***eliminates the use of 375 grams of oxalic acid and the use of phenolphthalein indicator***, both of which have human health hazards.

Background:
This case study is a result of an EPA Region 2 Source Reduction grant[1] titled *Green Chemistry in Higher Education: A Workshop for Region 2 Colleges and Universities*. The Green Chemistry in Higher Education workshop was carried out at Siena College on July 18-21, 2013. 29 faculty members participated from 20 different institutions in New York and New Jersey. The workshop consisted of three main focus areas: green chemistry case studies for lecture and course work, green chemistry laboratory exercises, and toxicology and environmental impact.

During the workshop participants were able to test a variety of greener laboratory exercises for introductory and organic chemistry courses. One of the labs was a titration experiment using wood ash developed by Professor Irv Levy at Gordon College, one of the instructors at the Green Chemistry in Higher Education workshop at Siena College. Four faculty members from the workshop indicated that they will be implementing this laboratory exercise to replace a traditional experiment during the academic year of 2013-2014 or 2014-2015: Andy Eklund, Alfred University (NY), Jia Luo, Monmouth University (NJ), Abby O'Connor, The College of New Jersey (NJ) and Matthew Fountain, SUNY Fredonia (NY). The reduction in chemicals used and cost savings for this new experiment are outlined in the following pages. Andy Eklund from Alfred University has implemented this laboratory exercise in his general chemistry laboratory course to replace a traditional experiment using oxalic acid.

[1] **Disclaimer: Although the information in this document has been funded wholly or in part by the United States Environmental Protection Agency under assistance agreement X9-96296312 to Beyond Benign, it has not gone through the Agency's publications review process and, therefore, may not necessarily reflect the views of the Agency and no official endorsement should be inferred.**

Additional Resources for Green Chemistry in General Chemistry and Beyond:

Greener Educational Materials (GEMs) Database (University of Oregon)

- Website: http://greenchem.uoregon.edu/gems.html
- Description: Searchable database with Green Chemistry educational materials uploaded by faculty members and educators world-wide
- Most curriculum is available for download (free-of-charge) or with primary literature information
- Google map of Green Chemistry educators

American Chemical Society's Green Chemistry Institute

- Website: www.acs.org/greenchemistry
- Description: Green Chemistry Resources for educators and students
- Experiments and Curriculum available for download
- List of ACS books on Green Chemistry

Green Chemistry Commitment

- Website: www.greenchemistrycommitment.org
- Description: A program of Beyond Benign to adopt Green Chemistry Learning Objectives in higher education.
- Case studies are available, university highlights, and curriculum resources

Beyond Benign

- Website: www.beyondbenign.org
- Description: Green Chemistry Curriculum available on-line (free-of-charge)
- Regional Outreach and Community Educational Events

GCEdNet - Green Chemistry Education Network

- Website: http://cmetim.ning.com/
- Description: A place where Green Chemistry educators share resources
- Blogs, discussions and chat rooms

University of Scranton Greening Across The Chemistry Curriculum

- Website: http://www.scranton.edu/faculty/cannm/green-chemistry/english/drefusmodules.shtml
- Description: Green Chemistry modules available for download
- Power point presentations, hand-outs available

Carnegie Mellon University Institute for Green Science

- Website: http://igs.chem.cmu.edu/
- Description: Green Chemistry modules available for download
- Power point presentations, hand-outs available

Traditional Experiment:

In this traditional experiment,[2] a solution of oxalic acid is prepared and titrated with sodium hydroxide solution to an end-point in order to calculate the concentration of sodium hydroxide. The indicator is used in this experiment is typically phenolphthalein, a suspected carcinogen that also has reproductive hazards.

Titration Experiment
Traditional Experiment

Chemicals avoided per class of 100 students:
350 grams oxalic acid
Phenolphthalein indicator solution

Chemicals used and hazards:
The chemicals that are typically used in this experiment are listed below, along with a list of the hazards. The amounts are estimated based on common procedures used at Alfred University and others.[2]

Table 1. Chemicals used, human health and aquatic toxicity data:

Chemical:	**Amount used (per student group):**	**Flammability:***	**Human health toxicity:**[3]	**Aquatic toxicity:**[3]
Oxalic acid	0.5 g - 2.5g (dissolved in 75 - 100 mL of water) x 3 (7.5 g oxalic acid and 300 mL water max)	n/a	*High Toxicity* LD50 (oral, rat) 1,080 mg/kg; LD50 (dermal, rabbit) 20,000 mg/kg; Causes serious damage to eyes	*Low Toxicity* LC50 (fish, 48 hr) 160 mg/l; EC50 (daphnia, 48 hr) 162.2 mg/l
Sodium hydroxide (1M)	55 - 75 mL x 3 (225 mL 1 M NaOH) (9 g NaOH in 225 mL) (0.06 gal)	n/a	*Causes severe skin burns and eye damage*	*Moderate Toxicity* LC50 (fish, 96 hr) 45.4-125 mg/l; EC50 (daphnia, 48 hr) 40.4 mg/l
Phenolphthalein indicator solution (0.5% wt. in ethanol: water (1:1))	0.1 mL	*Flammable solvent (ethanol)*	*Suspected carcinogen - IARC Group 2B, Reproductive hazard*	*Low Toxicity*

[2] "pH Titration of Oxalic Acid", University of Pittsburgh at Bradford, Science in Motion, Chemistry Lab 017.

[3] Human health and aquatic toxicity data was gathered from Globally Harmonized Safety Data Sheets, which can be obtained from Sigma-Aldrich [http://www.sigmaaldrich.com/united-states.html].

* NFPA codes can be found here: http://en.wikipedia.org/wiki/NFPA_704#Red

Traditional Experiment, Continued:

The purchasing and waste disposal costs associated with this procedure are estimated in the following table. Purchasing costs were estimated based on prices available from Sigma-Aldrich:[5]

Total amounts of chemicals used and disposed of per class of 100 students:

- ***375 g oxalic acid (4 gallons liquid waste)***
- ***3 gallons NaOH liquid waste***
- ***Phenolphthalein indicator solution***
- ***7 gallons of total liquid waste***

Titration Experiment

Traditional Experiment

Volume of waste and purchasing and waste disposal costs per class of 100 students:

7 gallons of liquid waste

$160.35 in purchasing and disposal costs

Table 2. Purchasing and waste disposal costs:

Chemical:	**Amount per 100 students:**	**Waste disposal cost**[6]	**Purchasing cost:**[5]	**Purchasing cost per 100 students:**	**Waste disposal cost per 100 students:**	**Total cost (per 100 students)**
Oxalic acid	375 g oxalic acid, 15 L of water (3.96 gallons of liquid waste)	$11.27/gal	$86.60, 1 kg	$32.48	$44.63	$77.10
Sodium hydroxide (1M)	11.25 L (450 g, 2.97 gal)	$11.27/gal	$54.30, 500 g	$48.87	$33.47	$82.34
Phenolphthalein indicator solution (0.5% wt. in ethanol: water (1:1))	5 mL (0.0013 gal)	$11.27/gal	$17.90, 100 mL	$0.90	$0.01	$0.91
TOTAL	**7 gal waste**			**$82.25**	**$78.11**	**$160.35**

Total purchasing and waste disposal costs per class of 100 students:

- ***$82.25 in purchasing costs***
- ***$78.11 in waste disposal costs***
- ***$160.35 total cost***

[5] Sigma-Aldrich [http://www.sigmaaldrich.com/united-states.html, Accessed July 18, 2014].
[6] Waste disposal costs are based on the EPA Cost Calculator Tool [http://www.epa.gov/p2/pubs/resources/measurement.html#calc, accessed December 2014].

Wood Ash Titration
A Greener Approach

Volume of waste and purchasing and waste disposal costs per class of 100 students:
0-3.4 gallons of liquid waste*
$40.24 in purchasing and disposal costs

A Greener Approach:

The greener approach for a titration lab involves extracting base from wood ash and titrating the base with a known standard of potassium hydrogen phthalate (KHP) to determine the concentration of base in the sample of wood ash. A greener indicator, thymolphthalein, is also used in place of phenolphthalein. The experiment can be used to discuss renewable feedstocks, and the procedure can be linked to other experiments, such as the preparation of biodiesel or soap. The wood ash used in this experiment can be disposed of in the trash, or can be composted.

The Wood Ash Titration experiment was developed by Professor Irv Levy at Gordon College, one of the instructors at the Green Chemistry in Higher Education workshop at Siena College. Dr. Andy Eklund from Alfred University has successfully implemented this greener alternative that replaces a traditional titration experiment using oxalic acid.

Table 3. Chemicals used, human health and aquatic toxicity data:

Chemical:	**Amount used (per student group):**	**Flammability:**	**Human health toxicity:**[3]	**Aquatic toxicity:**[3]
Wood ash	50 g	n/a	n/a	n/a
Water	250 mL (0.066 gal)	n/a	n/a	n/a
Potassium hydrogen phthalate in water (10 mL)	0.08g in 10 mL water (0.003 gal)	n/a	*Low Toxicity* LD50 (oral, rat) >3,200 mg/kg	*Low Toxicity*
Thymolphthalein indicator (1 g in 100 mL ethanol/water (1:1))	0.1 mL (0.001 g)	*Flammable solvent (ethanol)*	*Low Toxicity*	*Low Toxicity*

* The volume of waste can be reduced to close to zero if the liquid waste can be disposed of properly down the drain.

Wood Ash Titration

A Greener Approach

Volume of waste and purchasing and waste disposal costs per class of 100 students:

0-3.4 gallons of liquid waste*

$40.24 in purchasing and disposal costs

A Greener Approach, Continued:

The purchasing and waste disposal costs associated with this procedure are estimated in the following table. Purchasing costs were estimated based on prices available from Sigma-Aldrich:[5]

Total amounts of chemicals used and disposed of per class of 100 students:

- ***2.5 kg of wood ash***
- ***0-3.4 gallons of waste****
- ***Thymolphthalein indicator solution***

Table 4. Purchasing and waste disposal costs:

Chemical:	**Amount per 100 students:**	**Waste disposal cost**[6]	**Purchasing cost:**[5]	**Purchasing cost per 100 students:**	**Waste disposal cost per 100 students:**	**Total cost (per 100 students)**
Wood ash	2,500 g	n/a	n/a	$0.00	$0.00	$0.00
Water	12.5L (3.3 gal)	$11.27/gal	n/a	$0.00	$37.19	$37.19
Potassium hydrogen phthalate in water (10 mL)	4 g in 500 mL (0.13 gal)	$11.27/gal	$36.00, 100 g	$1.44	$1.47	$2.91
Thymolphthalein indicator (1 g in 100 mL ethanol/water (1:1))	5 mL (0.05g) (0.0013 gal)	$11.27/gal	$25.00, 10 g	$0.13	$0.01	$0.14
TOTAL	**3.4 gal waste**			**$1.57**	**$38.67**	**$40.24**

Total purchasing and waste disposal costs per class of 100 students:

- ***$1.57 in purchasing costs***
- ***$38.67 in waste disposal costs****
- ***$40.24 total cost***

* The volume of waste can be reduced to close to zero if the liquid waste can be disposed of properly down the drain.

Wood Ash Titration
Summary

***Waste avoided*:**
Eliminates use of oxalic acid and phenolphthalein indicator
Reduction in 3.6 – 7 gallons of waste
Cost comparison:
Reduction in $120.11 in purchasing and disposal costs

***Traditional Experiment Summary*:**

Total amounts of chemicals used and disposed of per class of 100 students:

- ***375 g oxalic acid (4 gallons liquid waste)***
- ***3 gallons NaOH liquid waste***
- ***Phenolphthalein indicator solution***
- ***7 gallons of total liquid waste***

Total purchasing and waste disposal costs per class of 100 students:

- ***$82.25 in purchasing costs***
- ***$78.11 in waste disposal costs***
- ***$160.35 total cost***

***A Greener Approach Summary*:**

Total amounts of chemicals used and disposed of per class of 100 students:

- ***2.5 kg of wood ash***
- ***Thymolphthalein indicator solution***
- ***0-3.4 gallons of waste****

Total purchasing and waste disposal costs per class of 100 students:

- ***$1.57 in purchasing costs***
- ***$38.67 in waste disposal costs****
- ***$40.24 total cost***

Conclusions:

For every semester that this reaction is implemented per group of 100 students, there is a cost savings of $120.11 in purchasing and waste disposal costs, and the waste reduction is dropped by 3.5 gallons of waste. The waste could also possibly drop to zero depending on waste disposal policies and procedures due to the use of benign chemicals. The greener titration experiment also avoids the use of 375 grams of oxalic acid, a chemical with high human health hazards, and avoids the use of phenolphthalein, an indicator that is a suspected carcinogen that also has reproductive hazards.

APPENDIX A: Laboratory Exercise

Wood Ash Titration: Renewable Resources for the Preparation of Biodiesel

Written by Professor Irv Levy, Gordon College

SUMMARY:
The 12 Principles of Green Chemistry guide us to use catalysts to improve the energy and atom efficiency of reactions. The principles also guide us to use renewable feedstocks. In this experiment, we can see how waste from one process can be used productively in another. Specifically, biodiesel can be made from waste vegetable oil, a renewable feedstock that was traditionally discarded by the food preparation industry. To prepare biodiesel from the vegetable oil, base is needed as a catalyst. In this lab we will focus on the catalyst and its source from another "waste material" – wood ash.

Wood ash has been used as a valuable source of base throughout history. In this experiment we will extract the basic substances from a sample of wood ash and then determine their base potential compared to sodium hydroxide, the base often used in the production of biodiesel.

Chemistry Concepts:
Acid-Base Titration; Catalysis

Green Chemistry Concepts:
Renewable Feedstocks; Catalysis

Ash Water Titration: Renewable Resources for the Preparation of Biodiesel
HAND-OUT PAGE

Obtain two conical coffee filters, place one into the other giving a double-layered filter and obtain the mass of the empty filters. Scoop about ½ cup wood ash (about 50 g) into the filters. Obtain the mass of ash in the filters by subtracting the new mass from the original. To a 50 mL Erlenmeyer flask is added 70-80 mg potassium hydrogen phthalate (KHP) acid. Record the exact mass of the KHP. Add about 10 mL deionized water to the KHP in the flask and swirl to dissolve the solid. Add 2-3 drops thymolphthalein indicator to the acid solution in the flask.

Pour about 150 mL deionized water into opened ashes resting in a 250 mL beaker. Let water steep for about 2-3 minutes. Remove ash, squeezing the water into the beaker. Into a 150 mL beaker, filter ash water through another double-layered coffee filter. Transfer the filtered ash water into a 250 mL volumetric flask. Repeat this extraction a second time using 100 mL deionized water, filtering, then adding it to the 250 mL volumetric flask. Add deionized water as needed to bring the volumetric flask to its mark.

Fill a 50 mL buret with filtered ash water, taking care to remove the air bubble from the tip. Titrate the KHP solution with filtered ash water to a light blue end point. Calculate the molarity of the ash water base by using the endpoint assumption. We will determine the NaOH equivalance of the base obtained in the final calculations.

Data:

1. Mass ash = __________ g
2. Mass KHP = __________ g
3. Initial buret volume = __________ mL
4. Final buret volume = __________ mL
5. Volume base = __________ mL = __________ L
6. Moles KHP = Mass KHP / FW KHP = __________ moles
7. Titration results yield molarity of base in ash water
   At titration endpoint:
   Moles base = Moles acid, giving:
   Moles base = Moles KHP, giving:
   Volume base (L) x Molarity base = Moles KHP, giving:
   (note: L, not mL)
   Molarity base = Moles KHP / Volume base (L) = __________ molar
8. NaOH equivalence
   Moles base = Molarity base x Volume ash water (L) = __________ moles
   Recall that the volume of ash water is 250 mL, 0.25L
   Mass base equivalent = Moles base x FW (NaOH) = __________ g NaOH equiv.
9. Ash to Base equivalence
   Mass base equivalent / Mass ash = __________ g NaOH equivalent per g ash

Ash Water Titration: Renewable Resources for the Preparation of Biodiesel
Instructor Notes

Purpose:
To reexamine the use of NaOH as a catalyst in the production of biodiesel, by using an alternative material (wood ash waste), to develop the technique of acid/base titration and to introduce the principles of green chemistry to students.

TIME REQUIRED: ~60 MINUTES

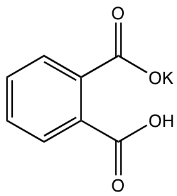
GREEN CHEMISTRY PRINCIPLES:
- Prevent waste: Waste wood ash is still useful for the extraction of base; left over wood ash can be recycled/composted, and base isolated can be used in further preparation of biodiesel
- Use renewable feedstocks: used wood ash as a base that can be used with another renewable feedstock (vegetable oil) to produce biodiesel
- Use safer solvents and reaction condition: no organic solvents are used
- Increases energy efficiency: experiment was run at ambient temperature and pressure

OBJECTIVES:
- To learn how to perform extractions
- To learn how to perform acid/base titrations
- To introduce students to the principles of green chemistry

MATERIALS
- wood ash
- potassium hydrogen phthalate (KHP)
- deionized water
- thymolphthalein indicator
- (2) 250mL beakers
- 250mL volumetric flask
- 50mL Erlenmeyer flask
- fluted filter paper (15cm diameter)
- 50mL burette
- balance
- funnel

ADVANCE PREPARATION
Finding wood ash: You can get wood ash from your fireplace, a pizza parlor that uses a wood oven, a fireplace store or a store that sell wood stoves. It is necessary to strain the wood ash with a colander to remove bits of charcoal, foreign matter, etc. It is recommended that the ash be strained twice. It is advisable to do this outdoors since a great deal of dust is usually produced. Use protective equipment to avoid exposure to dust (mask). The grey/white ash is what is needed – black charred wood should be kept to a minimum. If you choose to use wood ash from a fire pit make sure that it is dry and has never been rained on or wet.

Thymolphthalein indicator preparation: Dissolve 1g solid thymolphthalein in 50mL of 100% ethanol, then dilute with 50mL deionized water



KHP is $HOCOC_6H_4COOK$; FW = 204.23 g/mole

NaOH; FW = 40.00 g/mole

RESOURCES:
Traditional soapmaking requires "dripping the lye" from wood ash. This same technique has been applied to the production of biodiesel. For more information you might consult:

http://journeytoforever.org/biodiesel_mike.html

SAFETY INFORMATION
- No unusual safety concerns with this lab besides standard laboratory safety procedures.

TEACHING STRATEGIES
- Dimensional Analysis /Factor Labeling

DISPOSAL
- No special hazards are associated with these materials check with local codes for disposal.

Taking it Further
- Compare the end points of wood ash from different places
- Do the experiment in triplicate and compare the results
- Compare the end points of ash from different types of trees
- Compare the end point of the first extraction to the second or third
- Compare temperature of the extraction water (cold or warm, vs. room temperature) on the outcome
- Optimize the extraction to maximize the base
- Evaporate the base down to use as a catalyst in the preparation of biodiesel
- How wood ash has been used in history

Ash Water Titration: Renewable Resources for the Preparation of Biodiesel
Student Worksheet

The 12 Principles of Green Chemistry guide us to use catalysts to improve the energy and atom efficiency of reactions. The principles also guide us to use renewable feedstocks. In this experiment, we can see how waste from one process can be used productively in another. Specifically, biodiesel can be made from waste vegetable oil, a renewable feedstock that was traditionally discarded by the food preparation industry. To prepare biodiesel from the vegetable oil, base is needed as a catalyst. In this lab we will focus on the catalyst and its source from another "waste material" – wood ash.

Wood ash has been used as a valuable source of base throughout history. In this experiment we will extract the basic substances from a sample of wood ash and then determine their base potential compared to sodium hydroxide, the base often used in the production of biodiesel.

- **Prevent waste:** Waste wood ash is still useful for the extraction of base; left over wood ash can be recycled/composted, and base isolated can be used in further preparation of biodiesel
- **Use renewable feedstocks:** used wood ash as a base that can be used with another renewable feedstock (vegetable oil) to produce biodiesel
- **Use safer solvents and reaction condition:** no organic solvents were used
- **Increases energy efficiency:** experiment was run at ambient temperature and pressure

- To learn how to perform extractions
- To learn dimensional analysis
- To learn how to perform titrations
- To understand the principles of green chemistry

- wood ash
- potassium hydrogen phthalate (KHP)
- deionized water
- thymolphthalein indicator
- (2) 250mL beakers
- 250mL volumetric flask
- 50mL Erlenmeyer flask
- fluted filter paper
- 50mL buret
- balances
- funnel

Useful Formulas
MOLES KHP = MASS KHP ÷ FW KHP

Volume base (L) x Molarity base = Moles of base

At the titration endpoint:

Moles base = Moles acid
Moles base = Moles KHP

Procedure:

Preparation of ash water (base):

1. Put a small beaker on the balance, then place an opened fluted filter paper into the empty beaker, and zero the balance.
2. Scoop about 50g of wood ash into the filter. Accurately record the mass of the wood ash.
3. Transfer the wood ash from the filter paper to a 400mL beaker. Do this gently to avoid making a lot of dust. Don't worry if a little of the ash sticks to the filter paper.
4. Add 150mL deionized water to the ashes in the beaker. Do this slowly to avoid making a lot of dust. Stir the resulting slurry with a glass stirring rod for about 1 minute.
5. Suspend funnel over 300mL Erlenmeyer flask, placing the filter paper used in the earlier step inside the funnel.
6. Stir the ash water beaker well and pour as much as possible into the funnel without overflowing the filter paper. Don't worry if a little bit of ash gets into the filtered water. Wait until some of the liquid drains through the funnel then stir the slurry again and pour more into the funnel. Repeat until all of the slurry has been poured into the filter.
7. At this point it is likely that some of the ash is still in the beaker. If so, scrape as much as possible into the filter.
8. Obtain an additional 100mL deionized water and use it in several small portions to rinse the residue from the beaker into the filter.
9. After the dripping stops and no liquid is visible in the ashes in the filter, remove the filter paper and discard the used ashes as directed by your instructor.
10. Obtain a new fluted filter paper and filter the ash water from the Erlenmeyer flask into a 250mL volumetric flask. Add deionized water as needed to bring the 250mL volumetric flask to its mark. (Remember to measure the volume by looking at the bottom of the meniscus.) The ash water is now ready for titration.

Titration of ash water

1. Label two 50mL Erlenmeyer flasks A and B.
2. Zero weighing paper, and obtain approximately 70 to 80mg (0.070 to 0.080g) of potassium hydrogen phthalate (KHP) acid.
3. Record the exact mass of the KHP.
4. Transfer to Erlenmeyer A.
5. Repeat steps 2 and 3 and transfer to Erlenmeyer B.
6. Add about 10mL deionized water to the KHP in each flask and swirl to dissolve the solid.
7. Add 2 drops of thymolphthalein indicator to the acid solution in each flask, set aside.
8. Fill a 50mL buret with filtered ash water, taking care to remove the air bubble from the tip.
9. Place a white sheet of paper under the 50mL flask containing the acid so you can clearly see the color change.
10. Titrate the KHP solution with filter ash water quickly with flask A to estimate the endpoint of the reaction
11. Repeat the titration slowly with flask B to get an exact reading, to a light blue end point.
12. Calculate the molarity of the ash water base, using the fact that at the titration endpoint the moles of acid equals moles of base.

STUDENT DATA:

Mass of empty filters ________ g

Mass of ash and filter ________ g

Mass ash ________ g

Mass KHP (A) ________ g

Mass KHP (B) ________ g

Initial buret volume (A) _________ mL

Final buret volume (A) _________ mL

Volume base (A) __________mL ___________L

Initial buret volume (B) __________ mL

Final buret volume (B) __________ mL

Volume base (B) ___________mL ___________L

ANALYZE THE RESULTS

What is the volume (B) of the base required to reach endpoint ________L

How many moles of KHP were used? ________moles

Given that moles of KHP = moles of base at end point and moles of base = molarity of base x Volume (L) of base:

What is the molarity of the base? ________M

NaOH base equivalence

Moles base (wood ash) x FW (NaOH) = ___________ g NaOH equivalent

Wood ash to Base equivalence

Mass NaOH base equivalent ÷ Mass wood ash = ___________ grams NaOH equivalent to grams wood ash

DRAW CONCLUSIONS:

To make 1L of biodiesel from fresh vegetable oil, about 4g of NaOH is needed.

1. How much NaOH would be needed to make 100 gallons of biodiesel?

2. What mass of ash would be needed to obtain sufficient base to make 100 gallons of biodiesel?

3. Why is using wood ash a greener option than using NaOH?

4. Wood ash found at an old campsite would not work well for this method. Why not?

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Download this and other case studies at the following link:
http://www.greenchemistrycommitment.org/resources/case-studies/