From Fries to Fuel

Biodiesel Synthesis Using Cooking Oil

Aaron Nichols

CHE 498 A

Marian College Undergraduate Research Symposium

April 14, 2009

From Fries to Fuel

- A look at:
  - The background of biodiesel
  - The chemical process
  - The experimental data and variables
- The construction of a biodiesel apparatus for an at-home production.
- Green Chemistry Applications

From Fries to Fuel

- This research project began after engaging in a organic chemistry lab designed by Dr. Carl Lecher.
- This topic intrigued me because of its unconventional and creative way to make fuel from a waste product.

Need for Alternative Fuels

- There is a growing need to move away from petroleum based fuels to the alternatives fuel and fuel sources
- Industrial Diesel fuel is produced from petroleum oil
- 1.5 billion barrels (*63 billion gallons) were produced in the U.S. last year.
- It reached its highest national average ever on August 8, 2009 when it reached $4.80 a gallon.

*http://tonto.eia.doe.gov/dnav/pet/pet_pnp_refp_dc_nus_mbbl_a.htm

Need for Alternative Fuels

- There is an increasing drive to move from petroleum based feed stock to a renewable and biological feed stock.
  - Ethanol in place of petroleum based gasoline.
  - Oils in place of petroleum diesel.

Using Soybean oil

Pros

- Renewable

Cons

- Raises price of food
- Not as efficient as other sources in regard to gallons/acre
  - Soybean – 50 gal/acre/year
  - Palm Oil – 650-1000 gal/acre/year

Using Algae

- Algae, used in photo-bioreactors, can be modified to produced oil, carbohydrates, biomass, etc.
- Ideal theory, still in infant stages.
- Highest efficiency – 5,000 to 20,000 gal/acre/year

Using Cooking Oil

- Utilizes a waste product (used cooking oil)
- Could be relatively free to acquire

- Problem: Collection may be unsuitable for massive production

K-Fuel in Kokomo, IN

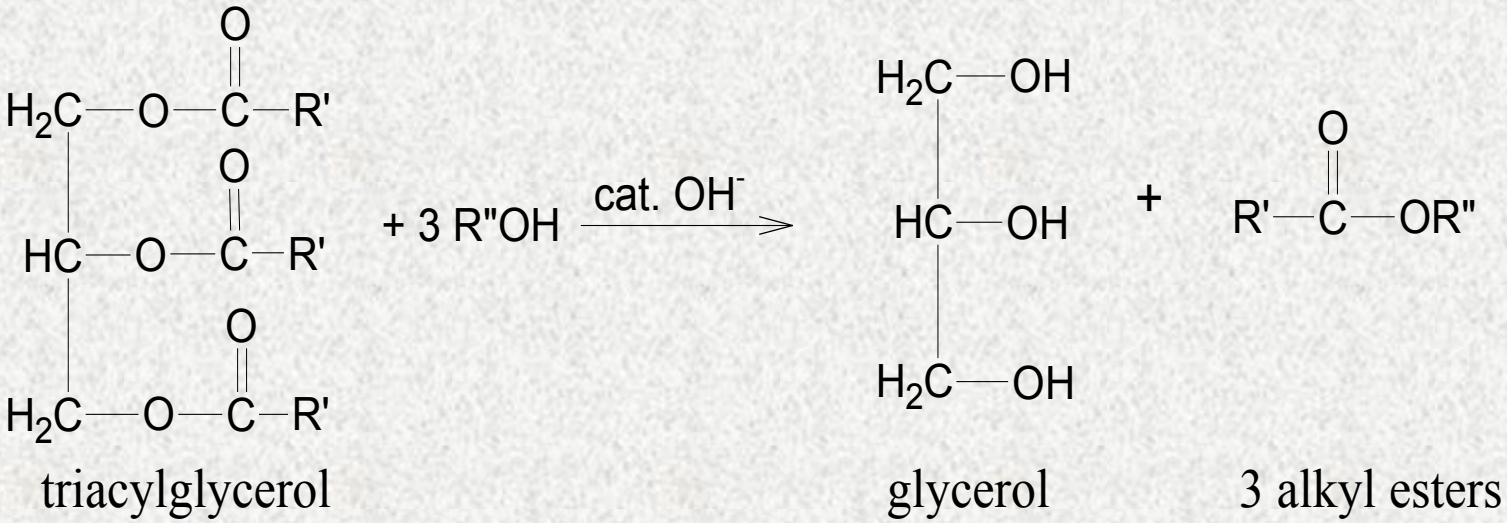
The City of Kokomo instituted K-fuel, a program to turn used cooking oil from city restaurants into biodiesel for city vehicles. The biodiesel produced cost just under $1.00 a gallon.

For this experiment…

- The organic chemistry experiment involved the creation of biodiesel from cooking oil as the primary source of triacylglycerol.
- Hydroxide (NaOH/KOH) and an alcohol (MeOH/EtOH) served as the reagents.

The Chemistry

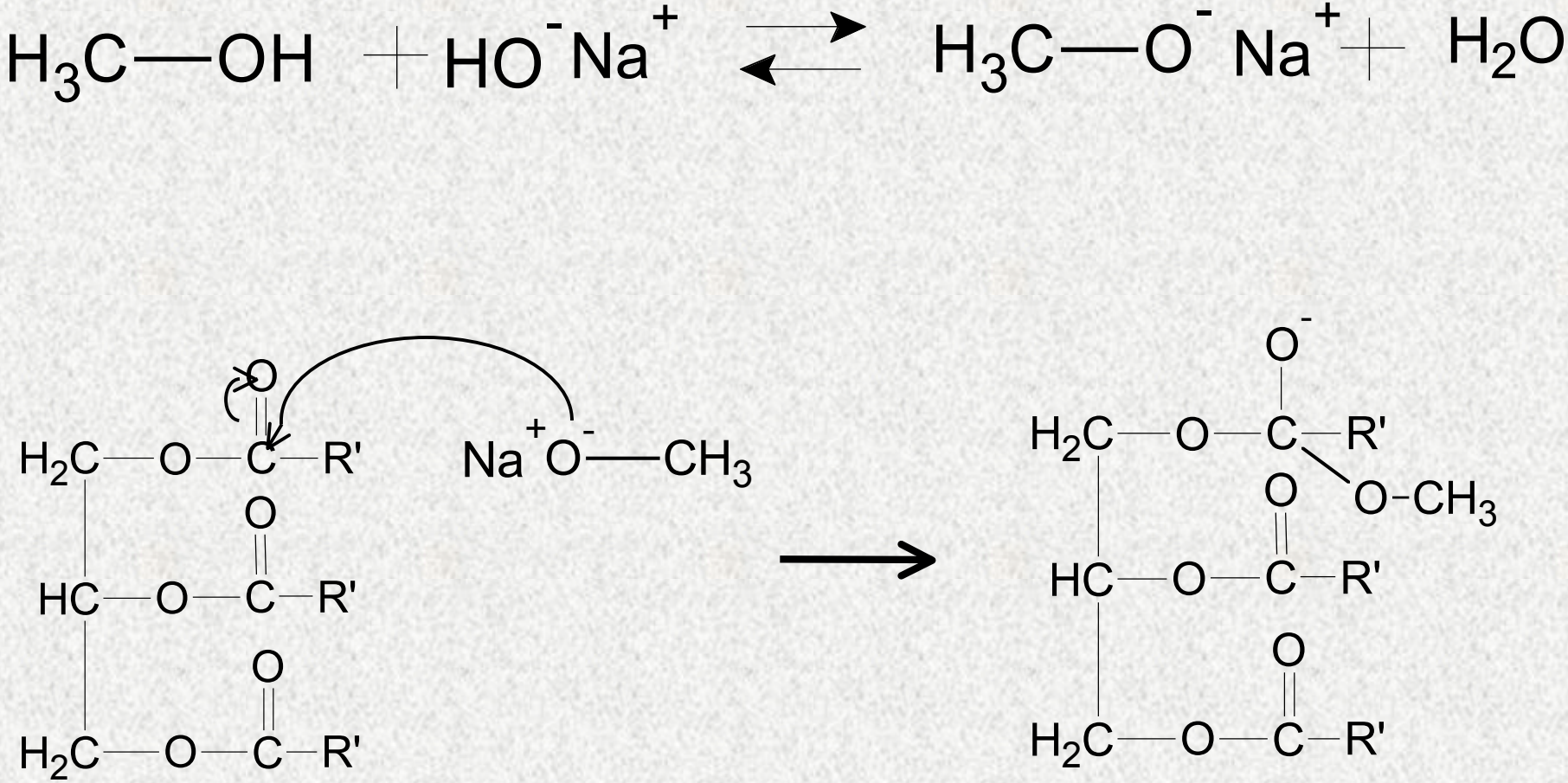
- Biodiesel is created from triacylglycerol molecules.
- This process is called transesterification.
  - Trans- from one ester to another



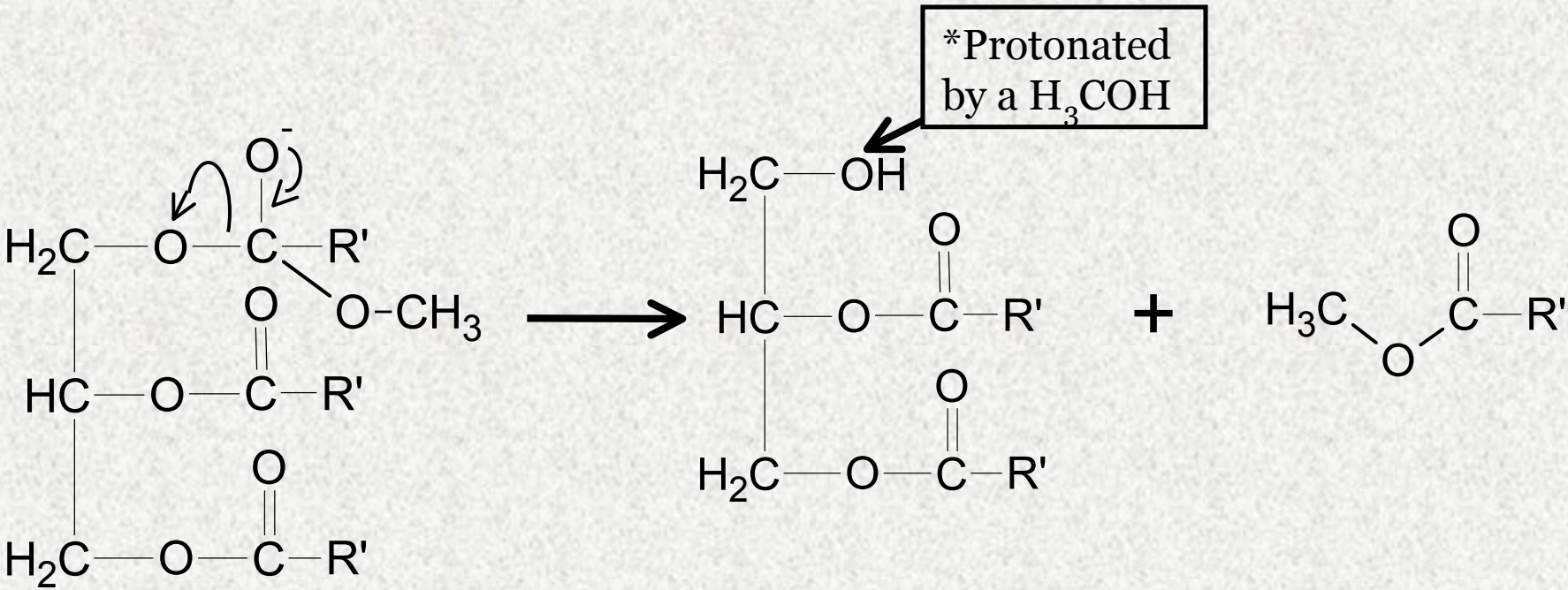
triacylglycerol glycerol 3 alkyl esters

Reaction Scheme from: *EXP 17 - Biodiesel - Spring 2007.doc* – Dr. Carl Lecher, Marian College, Indianapolis, IN

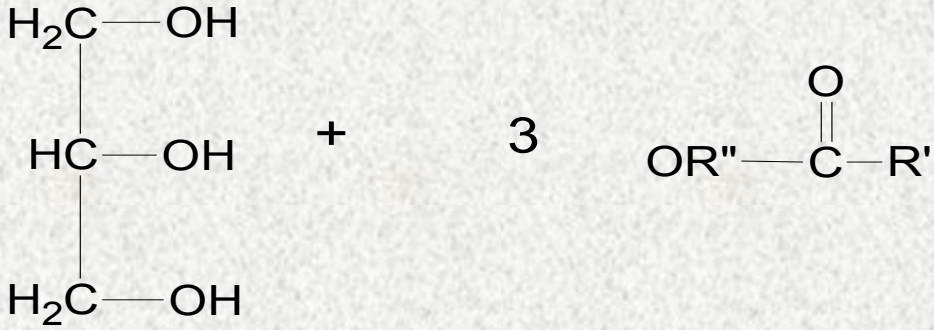
Transesterification



Transesterification



The process is done two more times for a total:



Sodium Hydroxide vs. Potassium Hydroxide

NaOH

- .40g used in experiment
- Average Mass Yield – 75%
- Cost
  - $13.04 per 8 lbs (lyedepot.com)
    - $.14 per mol
    - $.003 per g

KOH

- .56 used in experiment
- Average Mass Yield – 80%
- Cost
  - $23.39 per 8 lbs (lyedepot.com)
    - $.36 per mol
    - $.006 per g

Methanol vs. Ethanol

Methanol

- 10.0 mL used in experiment
- Average Mass Yield – 79 %

- Cost (Kokomo, IN)
  - $36.95 for 5 gallons ($7.39/gal)
  - $296.00 for 55 gallons ($5.38/gal)

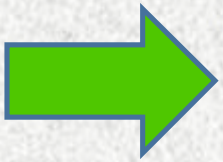
Ethanol

- *20.0 mL used in experiment*
- Average Mass Yield – 78%

- Cost
  - Difficult to calculate
    - Suppliers
      - Laboratory vs. Other
    - Shipping
    - Amount

Let's Get Bigger

- Micro Scale
  - 48.91 mL of oil
  - 10.0 mL of methanol
  - .40 g of sodium hydroxide



- Pilot Scale
  - 30 gallons of oil
  - 6 gallons of methanol
  - 92 g of sodium hydroxide

$$$ The Numbers $$$

Diesel at Pump

- 4/6/09 - $2.22 per gallon (*National Average)
  - Down $1.72 from last year ($3.94)
  - Down $2.53 from last August ($4.75)

Biodiesel

- $.26 (92 g NaOH)
- $32.28 (6 gal MeOH)
- ~$.05 (electricity)

$32.59 a batch

22.5 gallons @ $32.59 = $1.44 per gallon

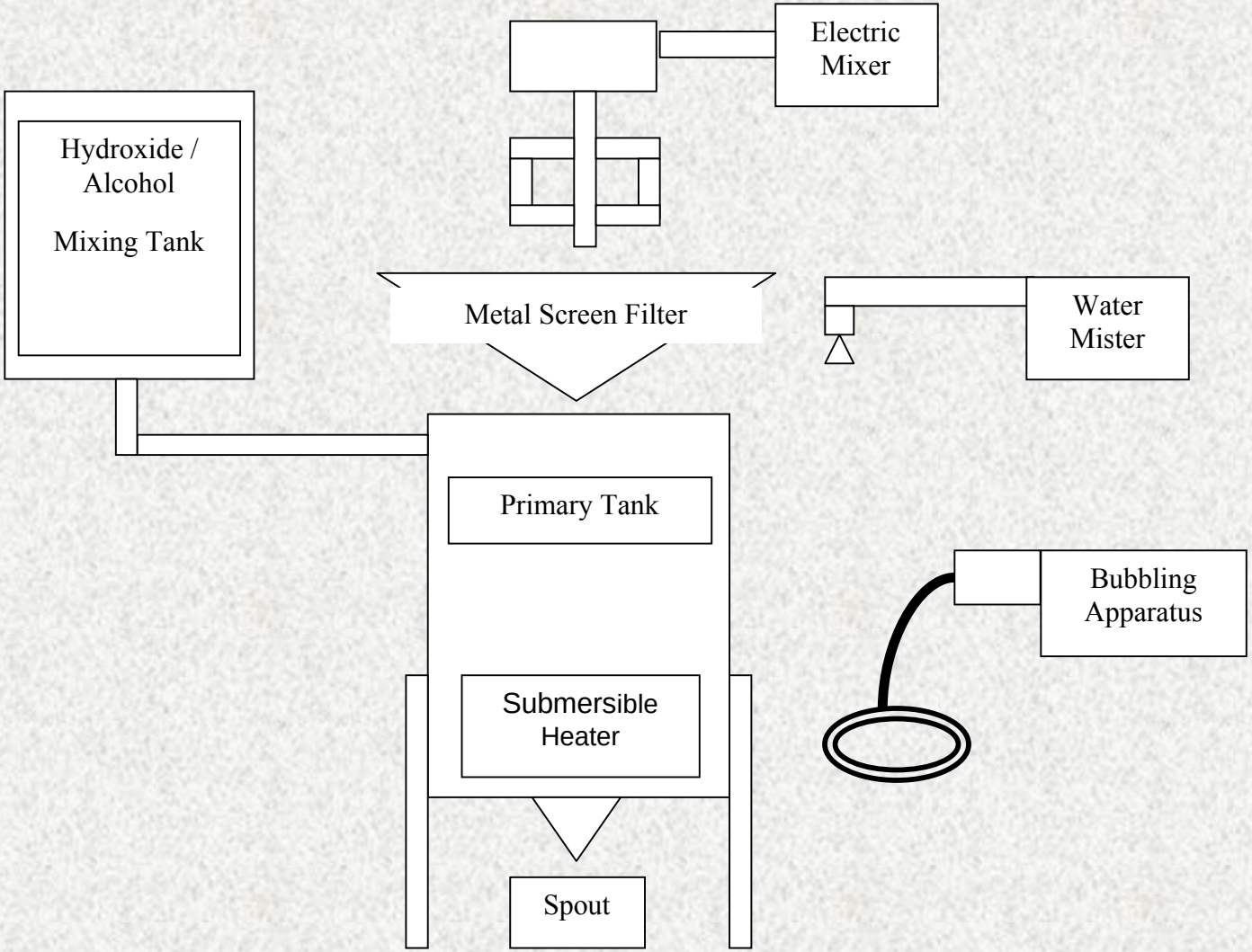
*http://tonto.eia.doe.gov/oog/info/gdu/gasdiesel.asp

$$$ The Numbers $$$

- Save $.78 a gallon (Save 35% on fuel)
- Save $3.31 a gallon from August (Save 69%)
- Yearly savings
    - 30 gallons a week –Save $1200
    - 60 gallons a week – Save $2400

- Affecting Prices
    - Methanol costs
    - Ethanol costs
    - Efficiency
        - 83% yield – $1.30

My Apparatus



WARNING

REDNECKS

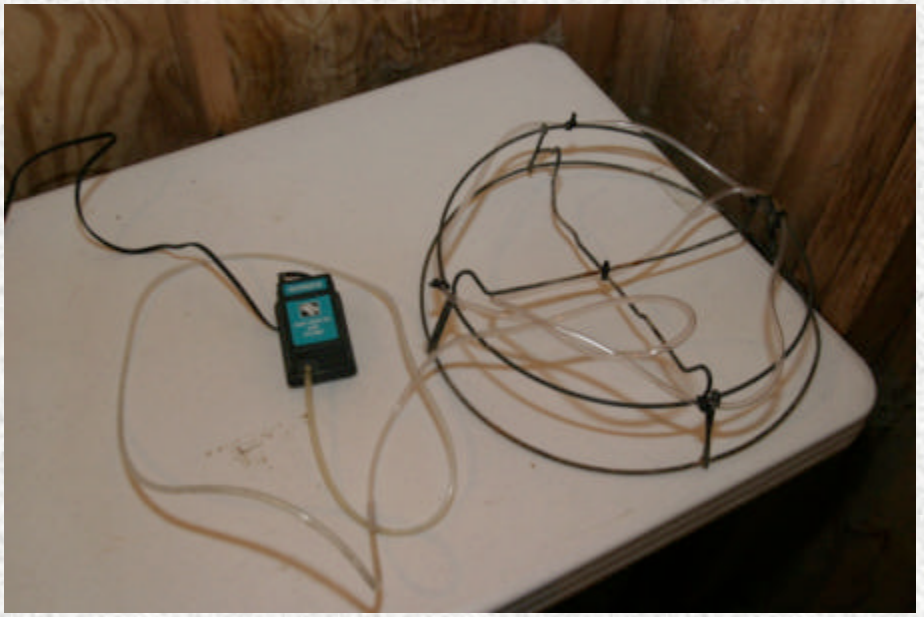
AT WORK

My Apparatus

My Apparatus

My Apparatus

My Apparatus



My Apparatus

- Cost of apparatus
  - Valves and Piping - $55.00
  - Tanks – Free
  - Wood, hoses/air-pump, motor – previously owned or scrapped
- Next Step
  - Acquire oil, sodium hydroxide, and methanol.
  - First attempt next week.
- Research:
  - Gelling
  - Additives

Green Applications

- Less harmful reagents
  - Hydroxide (catalyst)
  - Alcohol
- Using renewable feed stocks
  - Used cooking oil vs. Petroleum
  - Free feedstock
- Less hazardous byproducts
  - Glycerol

Green Applications

- Less hazardous process
  - Industrial refineries vs. At-home / Open table

Acknowledgements

- Master Carl Lecher, Ph. D. in Chemistry
- Dr. Roderick Macrae, Ph. D in Chemistry
- My father, Bob Nichols
- Fellow CHE 498 A students – June, Sinead, and Matt
- CHE 306 Organic Chemistry Students
- Marian College/Mathematics and Science Department
- God for the gift of creation


Questions?