Name: _____

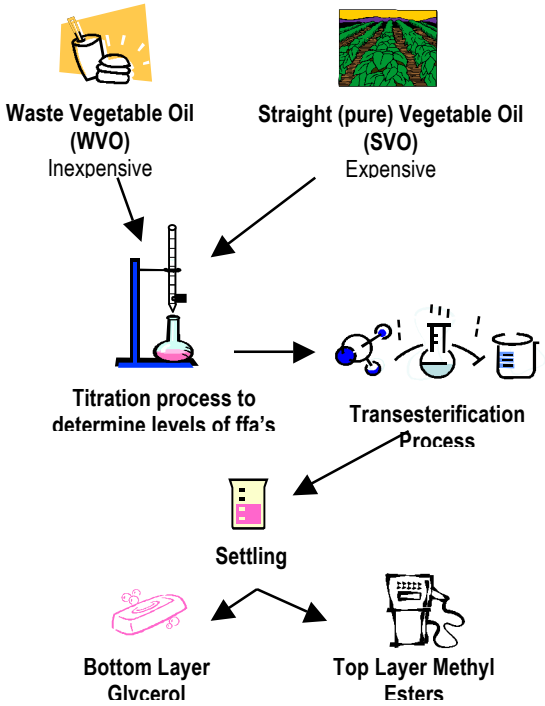
The Biodiesel Lab

Determining Molarity Through the Use of Titration

MdBioLab has purchased a new generator that can run on biodiesel fuel. Biodiesel is a renewable form of energy that is manufactured from the natural oils found in vegetables. It is used in diesel engines and provides a cleaner burning alternative to petroleum-based diesels.

Biodiesel is created from vegetable oil through a chemical process called **transesterification**. This process uses sodium hydroxide, a very strong base, to convert the vegetable oil into a combustible liquid. The transesterification process separates the oil into two products, methyl esters (biodiesel fuel) and glycerol (a valuable by-product used to make soap and other skin care products).

Unfortunately, the transesterification reaction is sensitive to the presence of free fatty acids, which occur more prevalently in waste vegetable oil that has degraded over time. Luckily, the same chemical that is used to catalyze the reaction which produces biodiesel, sodium hydroxide, can also be used to eliminate or "neutralize" these acids.



The levels of free fatty acids can be determined through a process called acid/base **titration**. A titration is a way of determining the concentration of a substance by adding a known concentration of a reagent to it until we see an effect. In our case, we will add a known concentration of sodium hydroxide to the free fatty acids contained in vegetable oil until we see a color change (this color change is due to a change in pH which we can observe by adding a pH indicator). When the mixture's color has been changed (from yellow to bright pink), then it has reached its **equivalence point** and the free fatty acids have been neutralized.

$$2NaOH + [\text{free fatty acid}] \rightarrow Na_2[\text{neutralized free fatty acid}] + 2H_2O$$

We need your help to determine the molarity of free fatty acids in the waste vegetable oil. To do so you will need to find the equivalence point for the waste vegetable oil.

What is molarity?

MATERIALS

0.01 M Sodium hydroxide (NaOH)	Micropipettes & tips	Burette
Waste vegetable oil (WVO)	Indicator solution (turmeric)	Isopropyl alcohol
Collection containers	Graduated cylinder	Clamp stand

PART I – Perform a rough titration of waste vegetable oil

For comparison and practice, you will first perform a titration of the waste vegetable oil:

- ☐ 1. Label one of the two collection containers **RT** (rough titration).
- ☐ 2. Pour 10 mL of isopropyl alcohol into a graduated cylinder. Add the isopropyl alcohol to the container.
- ☐ 3. Add 1000 μL of the straight vegetable oil sample from the tube labeled SVO to the container labeled RT containing the isopropyl alcohol. Gently swirl the contents of the container for 10 seconds.
- ☐ 4. Add 100 μL of the indicator solution (turmeric) to the oil/isopropyl alcohol mixture in the RT container and gently swirl the contents for 10 seconds. **Note the mixture's initial color.**
- ☐ 5. Record the 'initial reading' of sodium hydroxide (NaOH) in the burette. Be sure to be precise in your measurement and record the data in table 1.
- ☐ 6. Carefully position the burette directly over the SVO beaker. Add one drop of the NaOH solution from the burette into the container by turning the handlebars. **DO THIS SLOWLY and CAREFULLY. Only add ONE DROP at a time.**
- ☐ 7. Swirl the beaker paying attention to any prolonged color change.
- ☐ 8. Repeat steps 6 and 7 until the mixture turns bright pink and remains that color for at least 15 seconds.
- ☐ 9. Once your mixture is bright pink, record the 'final reading' of NaOH in the burette in Table 1.

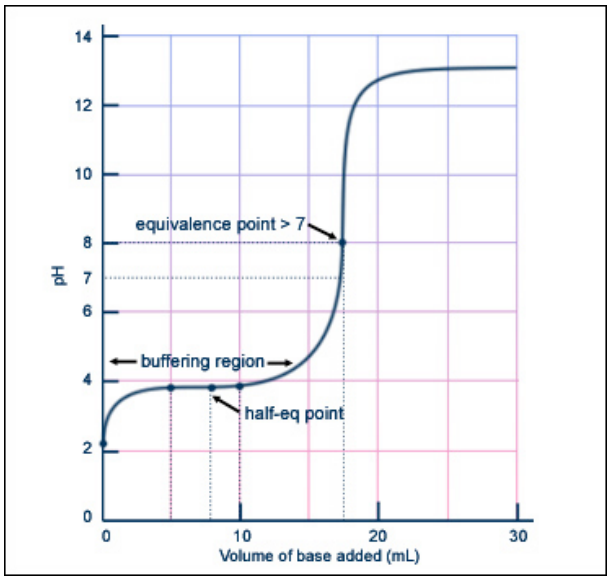


Figure 1: Example Titration Curve

Table 1 – Amount of 0.01M NaOH added to the waste vegetable oil (WVO)		
Final reading of 0.01 M NaOH solution in burette	_____	**mL**
Initial reading of 0.01 M NaOH solution in burette	_____	**mL**
Total amount of 0.01 M NaOH added to the beaker	_____	**mL**

QUICK CHECK:

When does the equivalence point occur?

Why does the equivalence point for this titration occur at a pH > 7?

PART II – Determine the concentration of free fatty acids in waste vegetable oil (WVO)

- ☐ 10. Label the second collection container **FT** (final titration, waste vegetable oil).
- ☐ 11. Pour 10 mL of isopropyl alcohol into a graduated cylinder. Add the isopropyl alcohol to the container labeled FT.
- ☐ 12. Add 1000 μL **(V_{acid})** of the waste vegetable oil sample from the tube labeled WVO to the container labeled FT containing the isopropyl alcohol. Gently swirl the contents of the container for 10 seconds.
- ☐ 13. Add 100 μL of the indicator solution (turmeric) to the oil/isopropyl alcohol mixture in the FT container and gently swirl the contents of the container for 10 seconds.
- ☐ 14. Record the 'initial reading' of sodium hydroxide (NaOH) in the burette. Be sure to be precise in your measurement and record the data in table 2.
- ☐ 15. Carefully position the burette directly over the FT container. Carefully add one drop of the NaOH solution from the burette into the beaker by turning the handlebars. Use the amount of NaOH that was used in part 1 as an approximation for the equivalence point.
- ☐ 16. Swirl the beaker paying attention to any prolonged color change.
- ☐ 17. Repeat steps 15 and 16 until the mixture turns bright pink and remains that color for at least 15 seconds.
- ☐ 18. Once your mixture is bright pink, record the 'final reading' of NaOH in the burette in Table 2:

Table 2 – Amount of 0.01 M NaOH added to Waste Vegetable Oil (WVO)	
Final reading of 0.01 M NaOH solution in burette	_____ **mL**
Initial reading of 0.01 M NaOH solution in burette	_____ **mL**
Total amount of 0.01 M **(M_{base})** NaOH added to the beaker	_____ **mL (V_{base})**

PART III – Determine the ratio of acid to base

$$2NaOH + [\text{free fatty acid}] \rightarrow Na_2[\text{neutralized free fatty acid}] + 2H_2O$$

Based upon the above reaction, what is the mol ratio of acid to base (i.e. how many mols of free fatty acid can be "neutralized" by only 1 mol of NaOH) ?

_____ (**C**)

PART IV – Determine the molarity of free fatty acids

Because the equivalence point occurs when the amount of acid is equal to the amount of base, we can derive the following equation, which can be used to determine the molarity of free fatty acids in the WVO:

$$M_{acid} = (M_{base} \times V_{base} \times C) / V_{acid}$$

Calculate M_{acid} (the molarity of free fatty acids in the waste vegetable oil) by plugging in the numbers from PART II and PART III (do not forget to record and cancel your units):