Biodiesel Experiment

Use this link to see images of the experiment:
http://www.dynamicscience.com.au/tester/solutions1/chemistry/organic/biodsl1prac.htm

Biofuels are solids, liquids and gases made from dead biological materials that can be burnt for energy. The burning of these fuels does release CO_2 into the atmosphere. However as they release CO_2 that they have previously absorbed from the atmosphere, they are considered to be carbon neutral. Biofuels can be produced from plants or biological waste. Biological waste can be burnt or acted on by bacteria, crops can be specifically grown to produce biofuels such as ethanol. The most common fuel crops produce either ethanol, as in the case of corn and sugar, or biodiesel, which is used primarily for transport. During this practical we will produce biodiesel from vegetable oil.

Materials:

- 150mL of oil **(oil is a slip hazard! Alert your teacher or lab tech if any is spilt on the ground!)**
- hotplate
- 100mL beaker
- 1.05g potassium hydroxide (KOH) **(caution potassium hydroxide is extremely caustic)**
- 250mL conical flask
- thermometer
- 30mL methanol **(caution methanol is flammable and toxic)**
- stirring rod
- 2 funnels
- retort stand
- 1 separating funnels

SAFETY: Lab coats, safety glasses and gloves must be worn at all times during this experiment! Extraction fans must also be used.

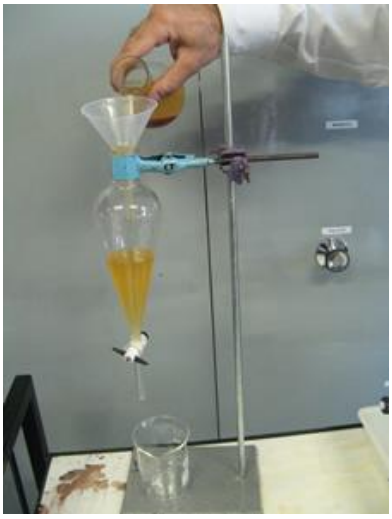
Method:

1. Add 30 mL of methanol to a 100 ml beaker

2. Weigh 1.05g of KOH and place it in the beaker with methanol. Stir until the KOH is completely dissolved (this will take a few minutes).

3. Place 150mL of vegetable oil in a 250mL flask and heat on the hotplate to about 55^{o}C. Turn off your hot plate.

4. Away from your hot plate, use a funnel to help you pour the oil into a 500ml schott bottle



5. Carefully pour the methanol and potassium hydroxide solution into the 250 mL conical flask with the oil and swirl the mixture. (Alert your teacher or lab tech immediately if you spill any methanol/potassium hydroxide solution!)

6. After vigorously swirling the mixture for at least 5 minutes the reaction is complete and the methanol layer disappears.

7. Pour the contents of the flask into separating funnel and let stand for at least 30 minutes.

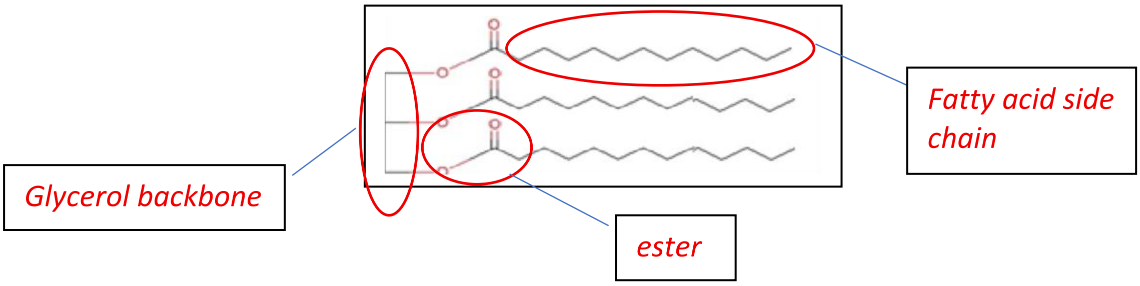
8. The mixture separates into layers. The glycerol from the vegetable oil sinks to the bottom while the biodiesel floats on top.

   Pour out the glycerol.

   Collect the biodiesel (you will be using this for a second experiment next week)

Questions

1. Plants and animals store fatty acids as triglycerides. A particular triglyceride is formed to store a fatty acid with the molecular formula $\mathbf{C_{12}H_{25}COOH}$.
   a. In the space provided, draw the **skeletal** formula of the triglyceride formed with this fatty acid. Clearly label the:
      - glycerol backbone
      - fatty acid side chain
      - functional groups present in the triglyceride.



   b. What is the general class of chemical reaction that forms the triglyceride?

_________________*Condensation* ____________________________

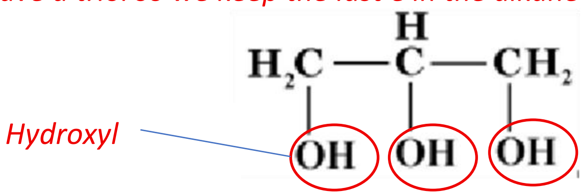
   c. In order to justify the answer to question b. above, name another product formed in conjunction with the triglyceride.

______________________H_2O_______________________________________

   d. Apart from the fatty acid there is another reactant involved in the formation of the triglyceride.

      i. Give the systematic IUPAC name of this reactant molecule and draw its structural formula in the box below.

Propane-1,2,3-triol
Usually we drop the e in the backbone name but the e is not dropped with diol or triol. We drop the e only when we have one hydroxyl group in the alcohol.
Here we have a triol so we keep the last e in the alkane name.



      ii. Label and name the functional groups present in this molecule.

____________________*Hydroxyl*________________________

2. What type of chemical reaction is shown below. Justify your response

Triglyceride + methanol → 3 methyl esters + glycerol

___________________________*Transesterification*_____________________________

The reaction involves the exchange of the glycerol part of the ester with methanol.

In each ester linkage of the triglyceride, the –OR group (from glycerol) is replaced by –OCH_3 (from methanol).

This produces three methyl esters (biodiesel) and glycerol.

The overall process is a substitution at the ester functional group, where the alcohol component is swapped.

3. With reference to intermolecular bonding, explain why the biodiesel, composed of methyl esters, has a lower melting temperature than the vegetable oil, composed of triglycerides?

Vegetable oils are composed of triglycerides that are composed of large molecules with three long fatty acid chains.

The molecules have strong van der Waals (dispersion) forces between the long non-polar chains, which require more energy to overcome.

Biodiesel (methyl esters) has smaller molecules — each fatty acid is now capped with a single methyl group instead of the glycerol backbone.

This reduces the surface area for van der Waals interactions, so less energy is needed to separate the molecules.

Therefore, biodiesel has a lower melting temperature than the original vegetable oil.

4. Why is it important for the melting temperature of biodiesel to be as low as possible?

Biodiesel must remain liquid at low temperatures to flow easily through fuel lines, filters, and injectors.

If the melting point is too high, biodiesel can solidify or gel in cold conditions, which clog engines or prevent proper combustion.

5. Petrodiesel is a mixture of hydrocarbons with long carbon chains between 10 and 15 carbon atoms long. The mixture of hydrocarbons is derived from the petrochemical industry. Biodiesel is intended to replace petrodiesel as a fuel in diesel engines.

   i. Write the balanced chemical equation for photosynthesis.

   ___________ *$6CO_2$ (g) + $6H_2O$ (l) → $C_6H_{12}O_6$ (aq) + $6O_2$ (g)*________________

   ii. Explain, using your answer to question i. above, why biodiesel is considered environmentally friendly when compared to petrodiesel.

   Biodiesel is produced from plants, which remove carbon dioxide from the atmosphere during photosynthesis.

   Atmospheric CO_2 is used to form organic molecules such as glucose.

   When biodiesel is burned, CO_2 is released, but most of this CO_2 was recently absorbed by plants so its net impact on the levels of CO_2 in the atmosphere are minimal.

   Petrodiesel, on the other hand, releases fossil carbon that has been stored underground for millions of years, increasing atmospheric CO_2 levels.

   iii. In very cold climates petrodiesel is a preferred fuel over biodiesel. Explain why with reference to intermolecular forces.

   Petrodiesel molecules are non-polar hydrocarbons with relatively weaker intermolecular forces of attraction, namely van der Waals forces or dispersion forces.

   These molecules remain liquid at lower temperatures.

   Biodiesel contains polar ester groups, which increase intermolecular attractions via dipole-dipole and dispersion forces and hence raise the melting point.

   As a result, biodiesel can gel or solidify in cold conditions, whereas petrodiesel remains in the liquid state and continues to flow.

   iv. Define the term "Renewable" giving one example.

   A resource that can be naturally replenished within a short time relative to human use so that it never runs out.

   Vegetable oils – plants can be replanted and harvested to extract the oil

   Solar energy and wind energy can be replenished daily.

v. Define the term "Sustainable" giving one example.

A resource that can be used without having a detrimental impact on the next generation.

vi. Is biodiesel renewable and/or sustainable? Justify your answer using one example.

Biodiesel produced from used cooking oil is renewable and sustainable.

Biodiesel produced from crops planted in fertile soil in place of food crops is not sustainable.

6. A vegetable oil was added to an aqueous solution of KOH and methanol. The mixture was shaken for at least 5 minutes and then transferred to a separating funnel and allowed to settle. After several minutes two layers were visible as shown in fig 1.

Figure 1 – the mixture containing biodiesel after settling.

   a. What is the top layer composed of?

   methyl esters (biodiesel)

   b. What is the bottom layer composed of?

   Glycerol and KOH(aq)

   c. With reference to intermolecular bonding and the physical properties of both layers, explain how these two layers form and the properties that each layer has.

Biodiesel molecules are largely non-polar, with intermolecular forces dominated by van der Waals (dispersion) forces.

Glycerol and the aqueous KOH layer are polar, forming strong hydrogen bonding and ion–dipole interactions with water.

Because polar and non-polar substances are immiscible, the two liquids separate into layers.

The glycerol–water layer is denser, so it settles at the bottom, while the less dense biodiesel layer floats on top.

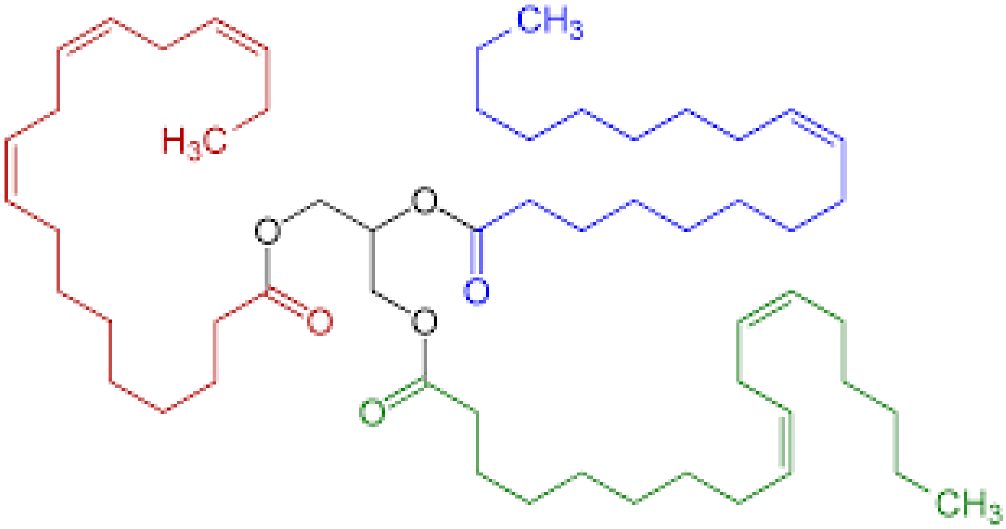


Figure 2 – shows a lipid molecule.

7. Consider the lipid molecule shown in fig. 2.
   a. Using item 21 of the VCAA Chemistry Data Book identify the colour coded fatty acids.

      Green ________*Linoleic*__________

      Blue ________ *Oleic* _______________

      Red ________ *Linolenic* _______________

   b. In what state is this molecule found at room temperature? Justify your answer with reference to intermolecular forces.

This lipid is liquid at room temperature.

The fatty acid chains are unsaturated, containing double bonds.

These double bonds (cis double bond, not necessary to know for this course) introduce kinks, preventing the molecules from packing closely.

As a result, the van der Waals forces (dispersion forces) between molecules are weaker.

Weak intermolecular forces contribute to a lower melting point, because there is enough energy at 25°C to overcome these forces and create a liquid state.

c. The fatty acids derived from the lipid molecule shown in fig. 2 were used to make “Biodiesel A” . Stearic acid was used to make a completely different biodiesel, “Biodiesel B”.

Compare the two fuels by completing the table below.

Property	Fuel A	Fuel B	Justification with reference to molecular structure
Viscosity	Highest Lowest	Highest Lowest	Biodiesel A has unsaturated chains with kinks, molecules cannot pack closely, hence weaker van der Waals forces so it flows more easily. Biodiesel B has saturated straight chains, stronger van der Waals forces higher viscosity as a greater surface area of the molecules can interact with each other.
Melting point	Highest Lowest	Highest Lowest	Biodiesel A has unsaturated chains with kinks, molecules cannot pack closely, hence weaker van der Waals forces so it melts at lower temperature. Biodiesel B has saturated straight chains, stronger van der Waals forces higher hence higher force of attraction more energy needed to overcome.
State at 25°C	(s), (l)	(s), (l)	Weak intermolecular forces in Fuel A hence it is a liquid at room temp. Close packing in Fuel B, hence not enough energy to disrupt the higher foces of attraction (dispersion forces)