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VCE Chemistry $\frac{3}{4}$
AOS 1 (Fuels & Energy) [1.0]
Experimental SAC Solutions

50 Marks.

Section A: SAC Questions (50 Marks)



Context

- As the world has been progressively moving towards a 'green' society, the use of renewable fuels has become an area of great focus. One such fuel is biodiesel - which can be produced in a school laboratory. The information that follows includes an overview of a practical investigation performed by a group of Year 12 chemistry students.



Equipment:

- Bottle of coconut oil.
- Vial containing concentrated NaOH(aq).
- Vial containing methanol.
- 2 Beakers.
- Measuring cylinder.
- Glass tray.
- Kettle.
- Water.

Space for Personal Notes



Methodology

1. In a kettle, heat 500 *mL* of water until hot but not boiling.
2. Fill up the glass tray with the hot water.
3. Measure 100 *mL* of coconut oil using the measuring cylinder.
4. Under a fume cupboard, pour the canola oil into a clean beaker.
5. Pour 50 *g* of methanol into the same beaker.
6. Place 10 drops of concentrated NaOH(aq) into the same beaker, and place this beaker into the tray containing the hot water.
7. Let the beaker sit for 30 minutes.
8. Return after 30 minutes and observe 2 separate layers within the beaker.
9. Pour out the top layer from the beaker into a separate clean beaker, after which each beaker contains one distinct layer.
10. Dispose of any waste, clean the equipment used and store it away safely.

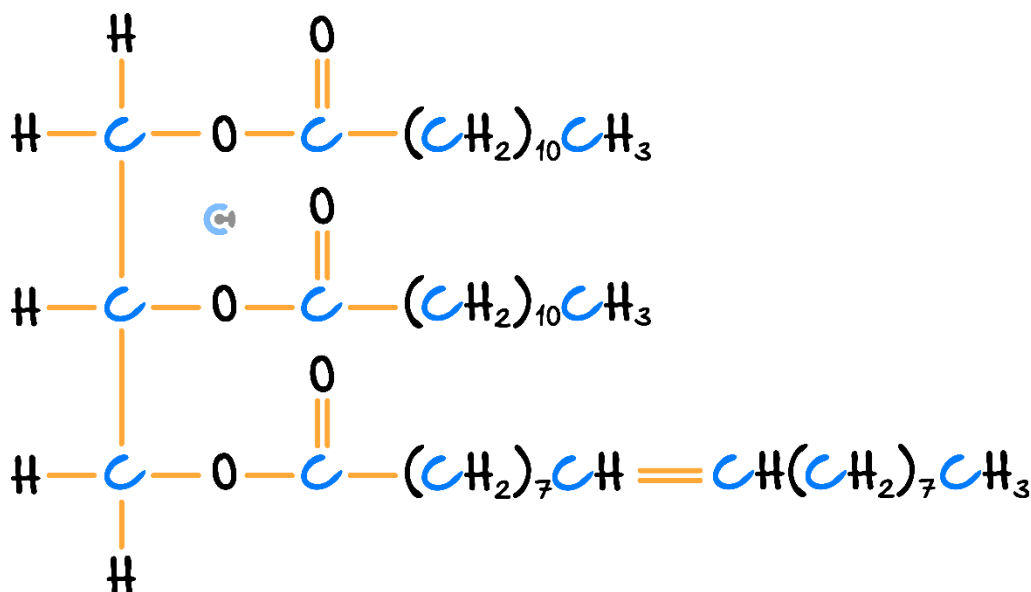


Results: The following picture was taken by the students in relation to Step 8 of their method.



Question 1 (9 marks)

Coconut oil is known to contain a mixture of chemicals, but a major component is the species shown below:



For all questions relating to coconut oil from the experiment, you may assume it is referring to the structure shown above unless otherwise specified.

- a. State the class of organic molecules under which the above structure can be classified. (1 mark)

Triglycerides

b.

- i. List the fatty acid(s) comprising the above molecule. (1 mark)

Lauric acid, Oleic acid

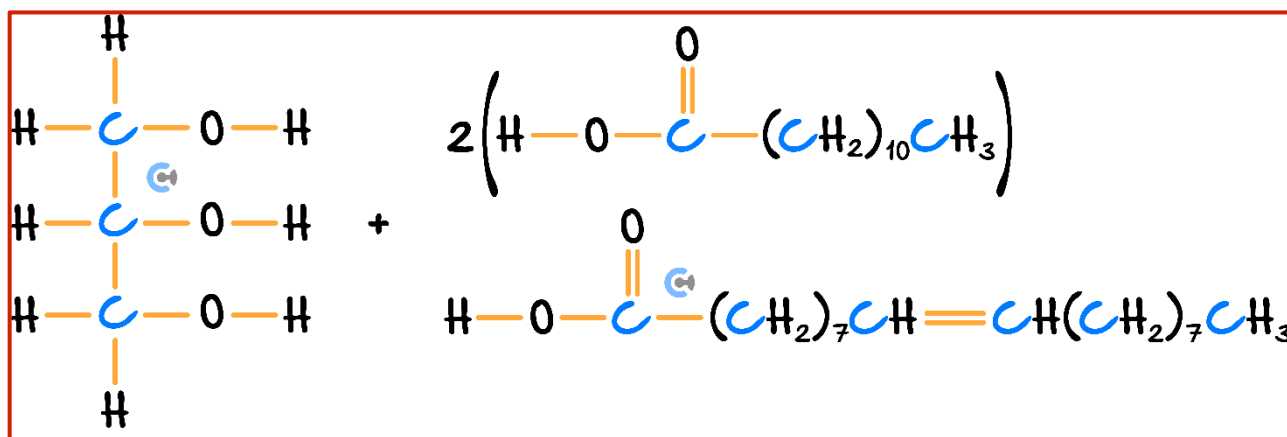
- ii. Coconut oil is often classified as an unsaturated fat. Explain what this means, and use your answer to **part b. i.**, to justify your answer. (2 marks)

The fatty acid chain(s) contain a carbon-carbon double bond (1).
This is evident in Oleic acid (2).

- c. Circle and label one of the oxygen-containing functional groups on the structure above. (1 mark)

Solution Pending

- d.
- i. If one of the students were to ingest the above molecule as part of coconut oil, draw the structural formula of the **products** formed. That is, draw the structures of the products of the oil's hydrolysis. You may use semi-structural formulae for the hydrocarbon chains. (3 marks)



- ii. If the above structure were to be synthesised in the laboratory by reacting the relevant fatty acids and glycerol, state the **other** product that would be evolved. (1 mark)

Water (reverse of reaction in part d. i.)

Question 2 (12 marks)

- a. Write a suitable aim for this experiment. (1 mark)

To react coconut oil with methanol in the presence of concentrated NaOH to produce biodiesel.

- b. State the type of reaction taking place in this experiment. (1 mark)

Transesterification

c.

- i. State the role of NaOH(aq) in this experiment. (1 mark)

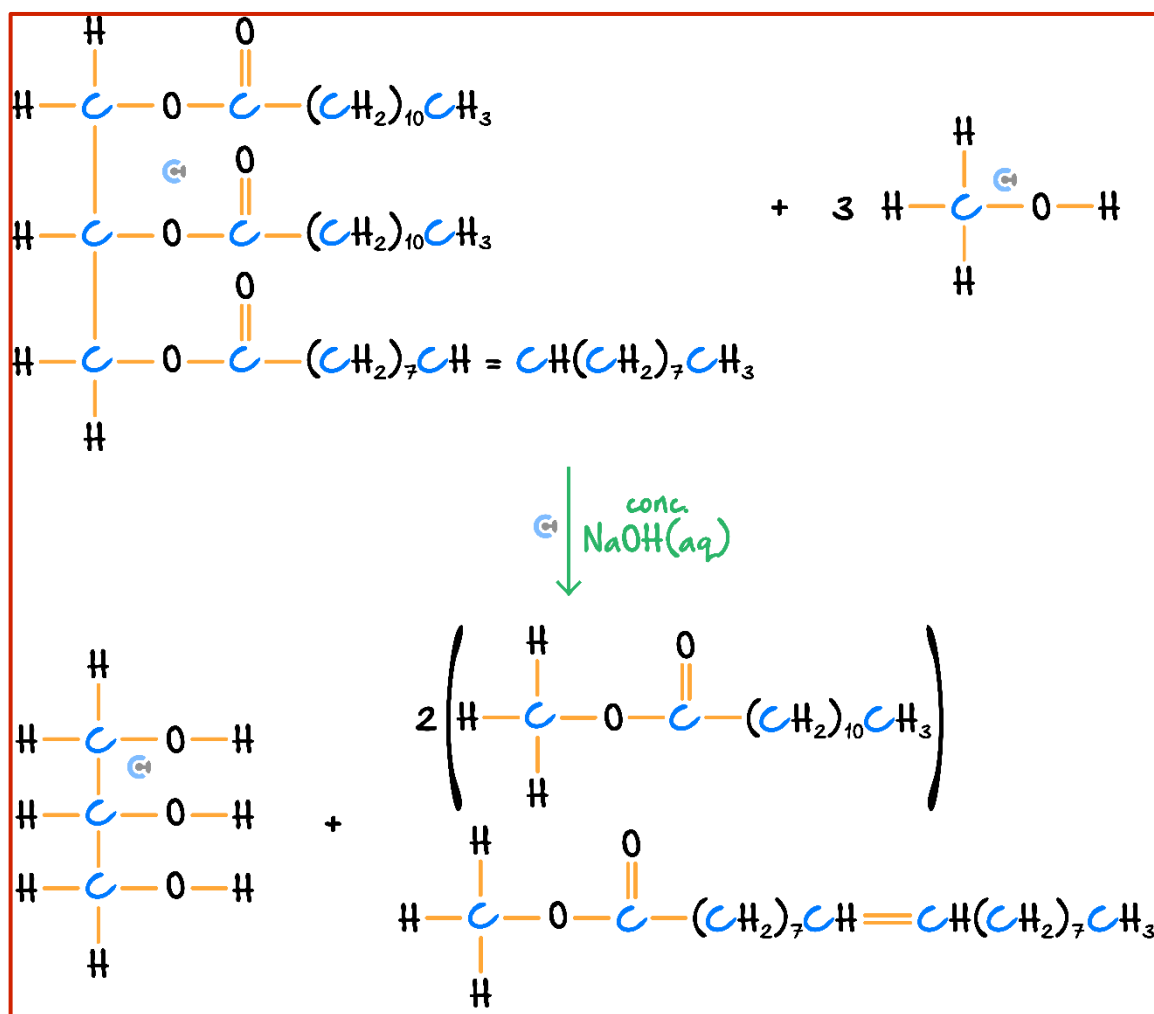
It is a catalyst.

- ii. Suggest why the NaOH(aq) has to be concentrated. What might have occurred had it been diluted before Step 6? (2 marks)

Because it helps speed up the rate of the reaction/it would interfere with the reaction if it was diluted (1).

It would have caused the reaction to be too slow/may have interfered with it/lowered the yield of biodiesel produced (2).

- d. Draw the full reaction taking place in this experiment using structural formulae. You may use semi-structures for hydrocarbon chains. Ensure to include any relevant coefficients to balance the equation. (5 marks)



- e. With reference to the structure you have drawn in **part d.**, explain why biodiesel molecules are often classified as 'fatty acid methyl esters'. (2 marks)

Because ester functional group, fatty acid chain (1),
and methyl from the methanol are used to make it (2).

Question 3 (7 marks)

- a. Suggest why the beaker had to be placed in a hot water bath in Step 6 of the method. (1 mark)

To increase the rate of reaction/allow the reaction to take place effectively.

- b. State why the experiment had to be conducted under a fume cupboard. (1 mark)

To prevent the inhalation of toxic fumes.

- c. Propose any other relevant safety precautions which should have been taken by the students. Justify your answer. (3 marks)

Should have worn gloves to prevent any chemicals such as NaOH splashing onto skin (1).

Should have worn safety glasses to prevent any fumes from entering eyes + splash hazard, such as NaOH (2).

They also should have prepared a risk assessment and looked over a Material Safety Data Sheet (MSDS) beforehand to make themselves of any other hazards (3).

Other answers may be accepted.

- d. In terms of fuel performance, truck drivers still favour the use of petrol and regular diesel over biodiesel. Explain why this is the case, with reference to its structure. (2 marks)

Because biodiesel has a lower energy content (1), and is not as effective as a fuel. It releases less energy upon combustion as it is partially oxidised due to the ester functional group, and has less C – H bonds (2).

Question 4 (11 marks)

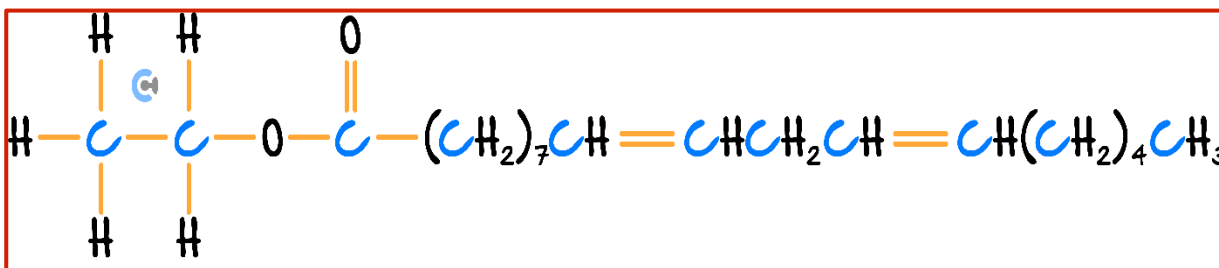
- a. Explain why biodiesel is considered to be a renewable fuel. (2 marks)

Because it can be replenished naturally (via transesterification of plant oils/animal fats.) within a relatively short period of time (less than a week.). 1 mark for definition and 1 for specifically explaining each aspect in relation to biodiesel.

- b. Biodiesel is sometimes made using ethanol rather than methanol. Explain why this change might be considered more sustainable. Ensure to include any relevant equations and 'Green chemistry principles' from the Data Book. (4 marks)

Because it can produced as bioethanol (1).
This is made from the fermentation of waste matter in the presence of yeast (2).
This upholds the Green chemistry principle of 'Use of renewable feedstocks' (3),
and the reaction is: $\text{C}_6\text{H}_{12}\text{O}_6 (\text{aq}) \xrightarrow{\text{yeast}} 2\text{C}_2\text{H}_5\text{OH} (\text{aq}) + 2\text{CO}_2 (\text{g})$ (4).

- c. Draw the structure of a biodiesel molecule made using ethanol and linoleic acid as the fatty acid. You may use a semi-structural formula for the fatty acid chain. (3 marks)



- d. Write the balanced equation for the complete combustion of the biodiesel molecule you have drawn in **part c.** at SLC. (2 marks)

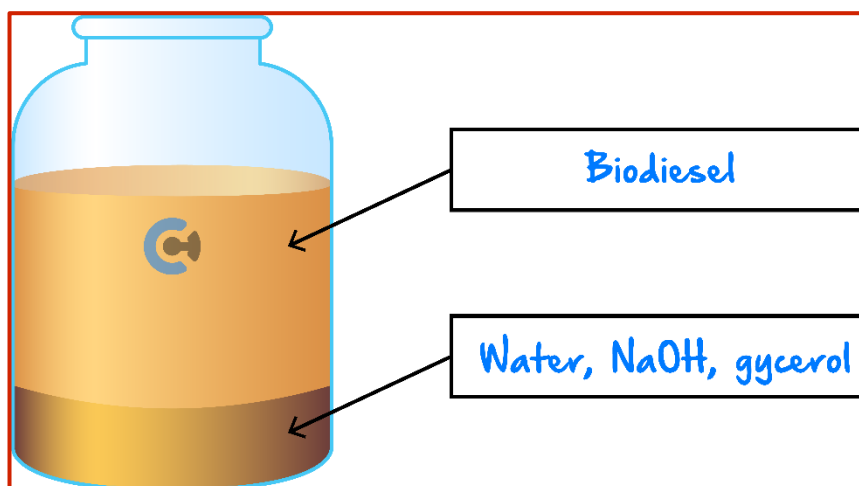


Question 5 (11 marks)

- a. Explain why two layers were observed in Step 8, as shown in the 'Results' section. (2 marks)

Because there is a non-polar/oil layer and a polar/aqueous layer (1). They are separated according to their respective densities – the non-polar layer floats on top whilst the polar layer sinks to the bottom (2).

- b. List each of the chemicals expected to be found in the respective layers below by filling in the boxes, assuming all the reactants have been consumed. (3 marks)



- c. Comment on the purity of the biodiesel obtained as a result of Step 9. Explain any sources of error and propose a suitable technique that could be applied to improve this step. (5 marks)

It will be largely impure (1).

Despite the two visible layers, they are not perfectly separate, so some of the top layer would contain water and other polar components, and the bottom layer would contain some of the biodiesel (2).

Just using one's judgement to pour out the two layers invokes random error (3) and hinders not only the purity of the biodiesel (accuracy), but also the experiment's repeatability and precision (4).

Using a centrifuge or distillation or solvent extraction or chromatography could be an effective method of better separating the components (5).

- d. State which section your response to **part c.** would likely feature within a scientific report/poster. (1 mark)

Discussion

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