The preparation of biodiesel from rape seed oil – or other suitable vegetable oils

Method

Note

This method produces biodiesel relatively quickly, though the product is not pure enough to burn in an engine. It is more efficient to use a separating funnel after stage 1 and leave the mixture to separate. The washing separations are also better if each mixture is left for several hours to separate in a separating funnel (keeping the top layer each time). It is also better to have about five washings, but the whole process would then take a few days.

Stage 1

1. Weigh about 200 g of rape seed oil into a conical flask.
2. Carefully:
   a) add 30 g of methanol;
   b) then slowly add 2 g of a 50% (50 g per 100 cm^3 of solution) potassium hydroxide solution. Take care; potassium hydroxide is very corrosive.

   Additions of chemicals can be made directly into the conical flask on a top pan balance, zeroing the balance after each addition.
3. Mix well and leave overnight, stirring with a magnetic stirrer if possible.

Stage 2

1. Using portions of the mixture, centrifuge in tubes for 1 minute, then decant (or use a syringe) to remove the top layers into a conical flask. Discard the lower layers.
2. To wash the separated top layer, add 20 cm^3 of deionised water, with gentle mixing. Do not shake the mixture vigorously or an emulsion will form which is difficult to separate.
3. Repeat steps 1 and 2 once more.
4. The liquid you have is biodiesel. Weigh your product and keep it for further investigation.

Questions

1. What is the concentration in mol dm^{-3} of a 50% solution of potassium hydroxide?
2. What is left in the bottom layer in Stage 1?
3. What is the purpose of the washing steps?
4. In the commercial production of biodiesel, 1200 kg of rape seed oil produces 1100 kg of crude biodiesel. How does your yield compare with this?

Alkenes worksheet

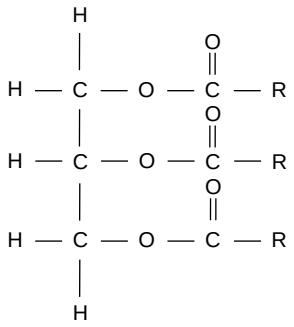
Rape seed oil contains approximately 20% of polyunsaturated oils, 10% of saturated oils and 70% monounsaturated oils.

Taking the structure of rape seed oil to be that below, answer the following questions:

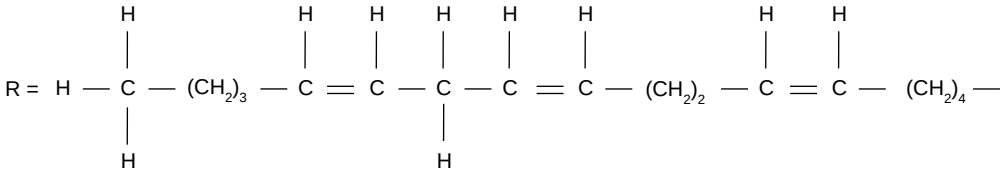
1. What is the functional group for alkenes?
2. How many moles of hydrogen would be required to saturate one mole of rape seed oil?
3. Explain why rape seed oil is classed as a polyunsaturated oil?
4. Geometrical isomerism is shown by rape seed oil. Using but-2-ene as an example, explain what is meant by geometrical isomerism.
5. What would be observed if bromine in hexane is added to rape seed oil? What type of reaction is occuring?
6. Give the mechanism for the reaction of bromine in hexane with ethene.

Extension

7. Devise an experiment to compare the unsaturation in samples of various vegetable oils.



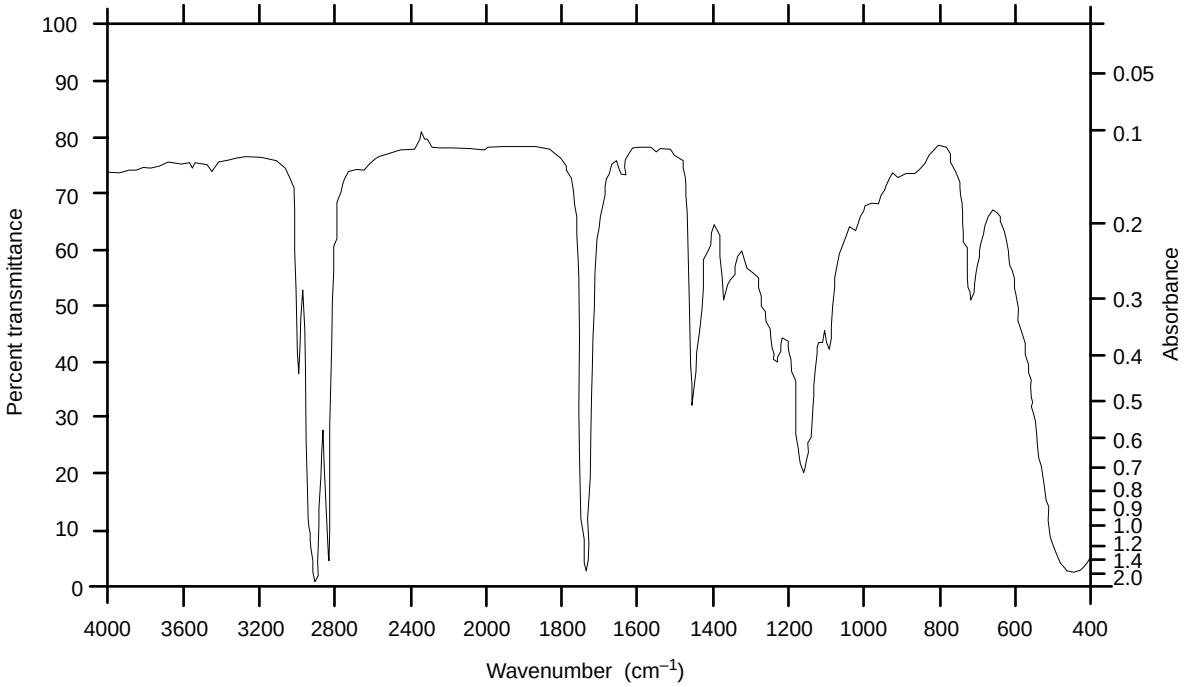
Glycerol ester



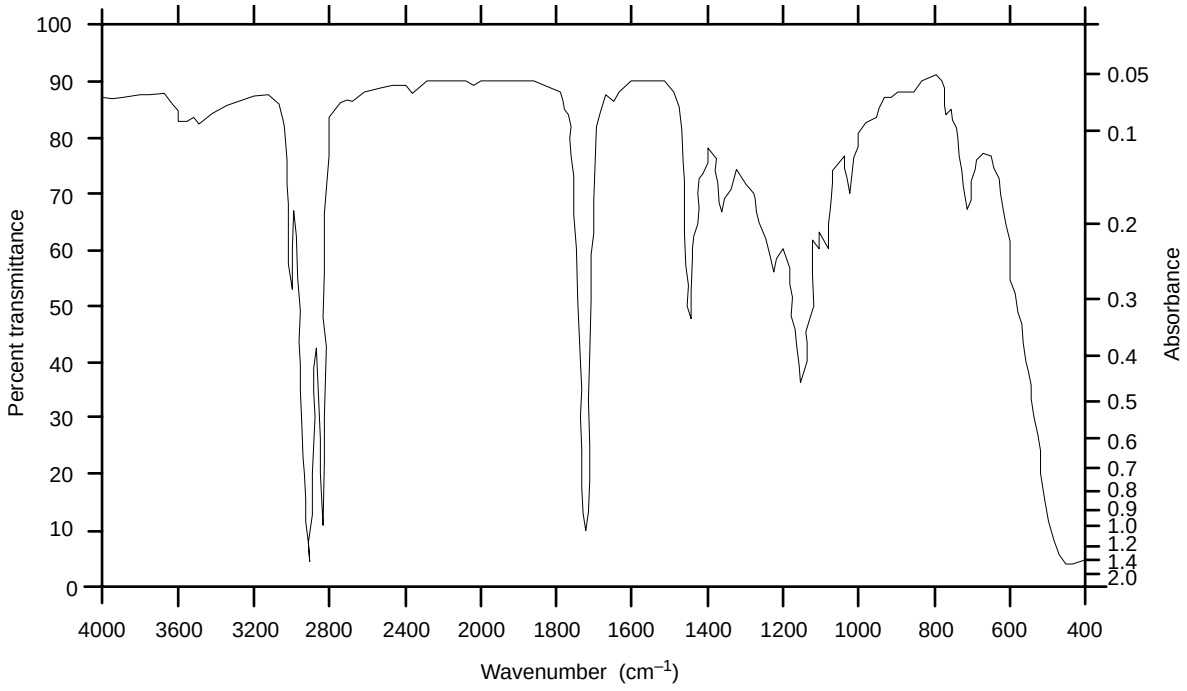
Infrared spectroscopy worksheets

Infrared spectroscopy is a qualitative technique which helps to determine the types of bonds present in a variety of compounds. The infrared radiation is absorbed by molecules as specific covalent bonds or parts of the molecule bend or stretch. The wavenumber at which absorption takes place indicates the type of bond present in the sample.

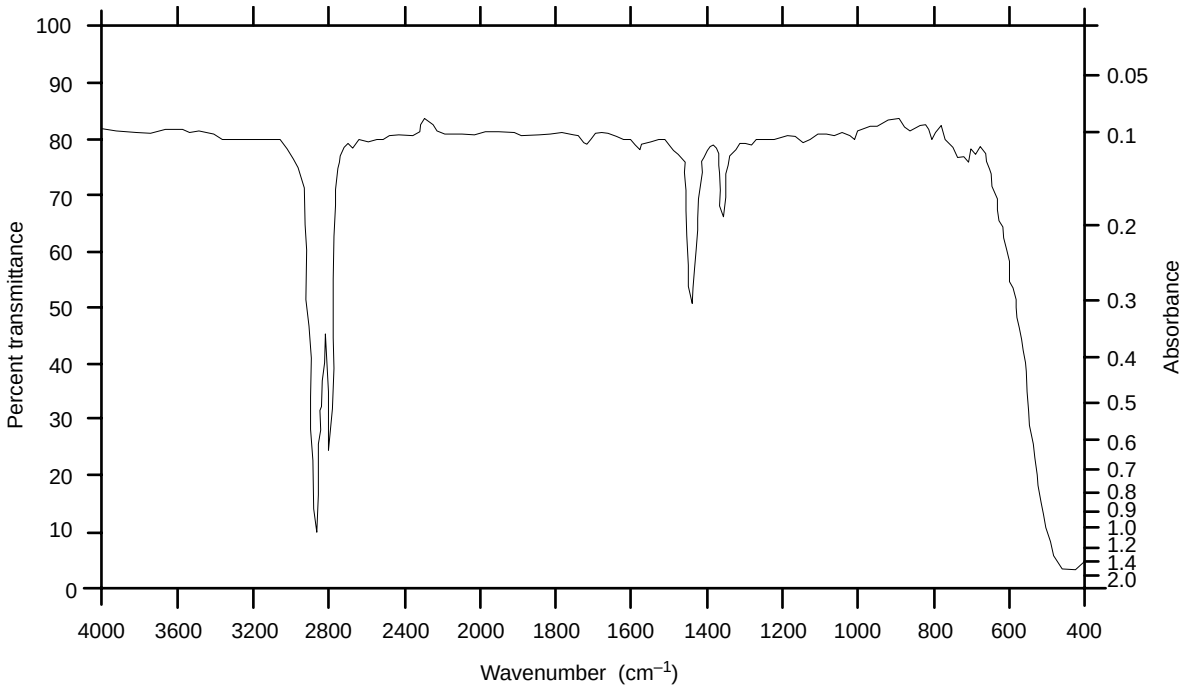
Use a data book and the infrared spectra of rape seed oil, biodiesel and fossil diesel provided to answer the questions that follow the spectra.



Infrared spectrum of rape seed oil



Infrared spectrum of biodiesel



Infrared spectrum of diesel

Questions

1. In the infrared spectra for rape seed oil and biodiesel what does the peak at 1740 cm^{-1} indicate?
2. Why does fossil diesel not show a peak in this region of the spectrum?
3. Why do all the spectra show peaks at 2820–2860 cm^{-1}?

Mass spectrometry worksheet

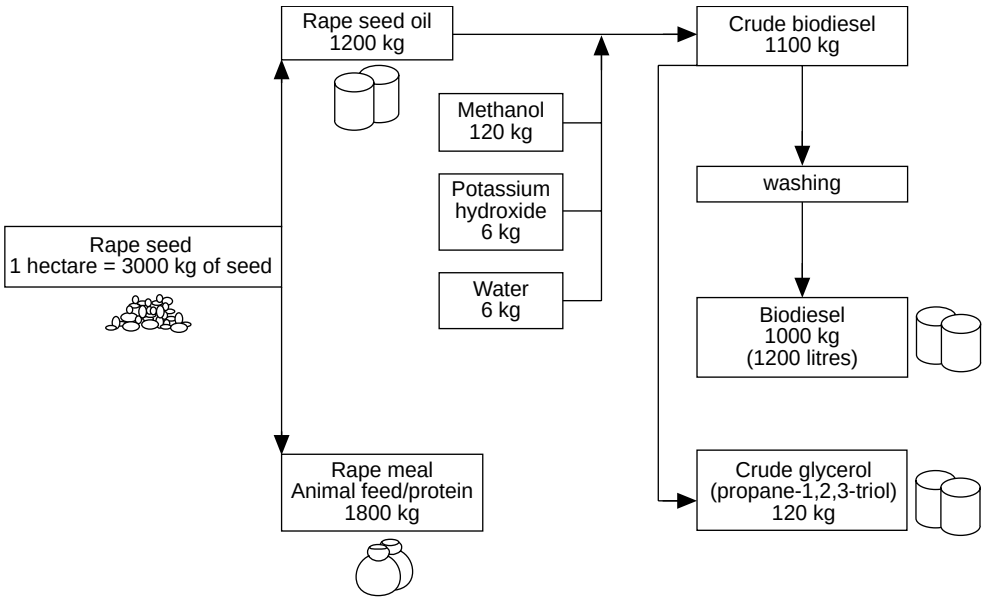
Mass spectrometry is an analytical technique which can be used to help identify a variety of compounds. The molecules of vapourised material are bombarded by electrons, causing the formation of positive molecular ions, which may then fragment forming other cations. These ions are accelerated and then deflected before being detected in turn.

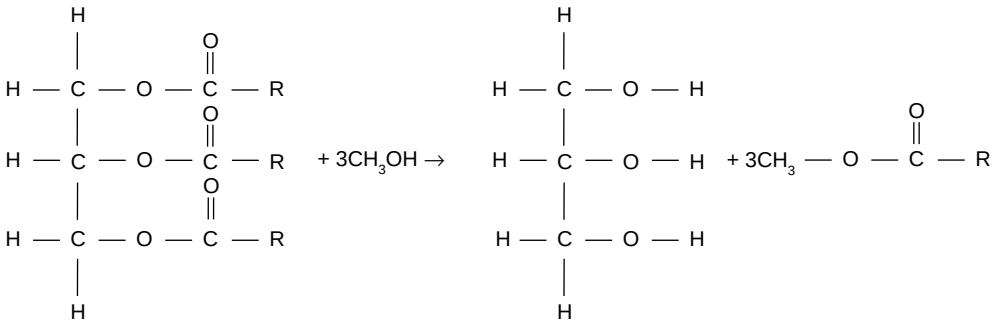
1. Molecular ions are radical cations. What is meant by (a) a radical and (b) a cation?
2. How are the cations (a) accelerated and (b) deflected?
3. In a mass spectrum of methanol where would you expect to find the molecular ion peak? Suggest two fragment ions that might be produced when this molecular ion fragments.
4. In many organic mass spectra a small peak is observed at a mass one unit greater than the molecular ion peak. Why is this?

Calculations worksheet

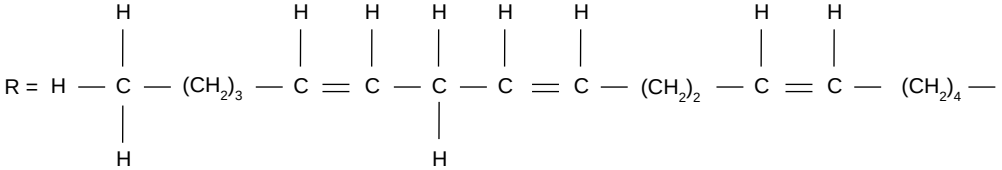
Use the equation provided in *Introducing biodiesel* and the flow chart below showing the stages in biodiesel production to answer the following questions.

1. Draw the structural formulae of rape seed oil and biodiesel.
2. Calculate the relative molecular masses of rape seed oil, methanol, biodiesel and glycerol (propane-1,2,3-triol).
3. 1200 kg of rapeseed oil is extracted from 3000 kg of rape seed. How many moles of oil are present?
4. Methanol is added in excess. How many moles of biodiesel should be produced?
5. In fact, 1200 kg of rape seed oil produces 1000 kg of biodiesel. What is the percentage yield of biodiesel?





Glycerol ester | Methanol | Glycerol | Methyl ester (biodiesel)

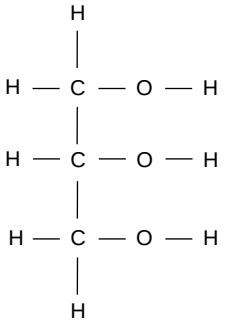


The production of biodiesel worksheet

Rape seed oil is the ester of a fatty acid. The ester functional group has a slight δ+ charge on the carbon of the C=O, as the oxygen is more electronegative than the carbon. Methanol acts as a nucleophile, attacking the electron deficient carbon, in a transesterification reaction (one ester being changed into a different ester).

1. Draw the functional group for esters.
2. Draw the structures of the following esters:
   (a) methyl ethanoate
   (b) propyl methanoate
   (c) ethyl methanoate.

   (If model kits are available you might like to make models of these esters)
3. What is the definition of electronegativity?
4. What is a nucleophile?
5. As well as esters what other types of organic chemicals are attacked by nucleophiles?
6. What is the systematic name for glycerol?



Glycerol

7. What reagent(s) and conditions would you use to produce methyl ethanoate? Write an equation for the reaction.

Extension

8. Many oils are obtained from plants and can be used to produce soaps, such as 'Palmolive'. This is known as saponification. Write an equation for the saponification of rape seed oil.

Thermochemistry worksheet

Using the equation below on the transesterification of rape seed oil answer the following questions.

1. a) When bonds are broken, is the process exo- or endothermic?

   b) Which bonds are broken for the reaction above to take place?

   c) Which bonds are formed in the process?

   d) What does this suggest about the value of the enthalpy change, ΔH, for the reaction?

2. By considering the reactants and products, what can you say about the probable values of ΔS for the reaction?

3. a) Write down the free energy equation in terms of ΔG, ΔH, ΔS and T.

   b) What is the likely value of ΔG for the reaction?

4. a) What does the value of ΔG suggest about the value of the equilibrium constant for the reaction?

   b) What does this tell you about the reaction?