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Part 2 Post-16 – Making biodiesel

Teacher's notes

The preparation of biodiesel from rapeseed oil – or other suitable vegetable oil.

Curriculum links

Biodiesel, a mixture of methyl esters of fatty acids, can be made very easily from a cooking oil made from rape seed, though other cooking oils may be tried. Enough fuel can be produced in a double lesson to burn, though it would not be pure enough to burn in an engine. This experiment could be used as a starting point for further student investigations at post-16 level.

Timing

60 min.

Level

Post-16 chemistry students.

Description

A cooking oil is mixed with methanol and a catalyst (potassium hydroxide). The resulting reaction (transesterification) produces biodiesel and glycerol which separate into two layers. The biodiesel, in the top layer, is removed and then washed with water to remove potassium hydroxide.

Apparatus (per group)

- Access to a balance
- Access to a centrifuge (and magnetic stirrer if available)
- One 250 cm^3 conical flask
- Two 100 cm^3 beakers
- One 10 cm^3 measuring cylinder
- 20 cm^3 measuring cylinder
- Teat pipettes
- Centrifuge tubes
- Sample tube and label.

Chemicals (per group)

- Deionised water
- 200 g Rape seed oil or other vegetable oil – *eg* cooking oil
- 30 g Methanol
- 2 g 50% Potassium hydroxide solution.
- Wear eye protection

- ▼ Methanol is flammable and poisonous
- ▼ Potassium hydroxide is corrosive.

It is the responsibility of the teacher to carry out a risk assessment.

Answers to questions on making biodiesel

1. 50% KOH has a concentration of 8.9 mol dm^{-3}.
2. Glycerol (propane-1,2,3-triol) is in the lower layer.
3. The washings remove potassium hydroxide.
4. Appropriate calculation – *ie* commercially 1,200 kg rape seed oil gives 1,100 kg of crude biodiesel. Therefore in this experiment you might expect to produce 200 x 1,100 g of crude biodiesel (= 183 g).

   1,200

   Comparison of students' yield with 183 g.

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Post-16 worksheets

Teacher's notes

The question sheet which follows deals with some chemical principles which are related to the structure, manufacture and uses of biodiesel. The questions may be particularly useful for revision, in that they revise a number of topics via a different route which has an environmental theme. The booklet *Introducing biodiesel* is referred to in the worksheets marked with an asterisk and provides background reading for all of them.

Curriculum links

*Alkenes** (students will need a databook giving infrared correlations.)

Infrared spectroscopy provides work on infrared spectra

Mass spectrometry

*Calculations** provides work on (biodiesel) yields

The production of biodiesel provides work on esters

Thermochemistry.*

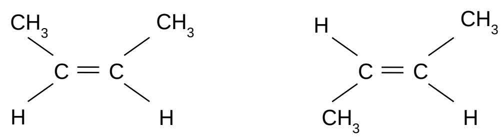
Answers to questions on post-16 worksheets

Alkenes

1. The functional group for alkenes is C=C.
2. Nine moles of H_2.
3. Polyunsaturates contain many C=C.
4. There is restricted rotation about C=C.

   Groups on the same side of the C=C are *cis.*

   Groups on different sides of the C=C are *trans.*

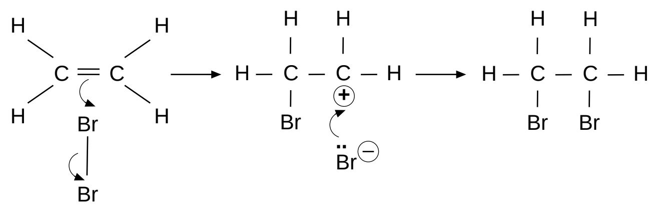


cis *trans*

5. Bromine is immediately decolourised.

   Electrophilic addition is occuring.

6.



7. Main points:

- same volumes of each vegetable oil;
- titrate against bromine in hexane;
- end-point is when the drop of bromine is not decolourised; and
- compare volumes of bromine needed – the most unsaturated oil requires the most bromine.

Infrared spectroscopy

1. The carbonyl of the ester group.
2. Fossil diesel is a hydrocarbon, so no absorbance is seen for the ester group.
3. This is the C–H stretch. All the molecules have a long hydrocarbon chain so this peak is present in all the spectra.

Mass Spectrometry

1. (a) An odd electron species/contains an unpaired electron.
   (b) Positive ion.
2. (a) The positive ions are accelerated by negatively charged plates.
   (b) The positive ions are deflected in a circular path by a magnetic field.
3. The molecular ion peak is at mass (or, strictly, mass/charge) 32.

   Fragment ions include CH_3^+ and OH^+.
4. These are caused by the presence of ^{13}C or ^{2}H.

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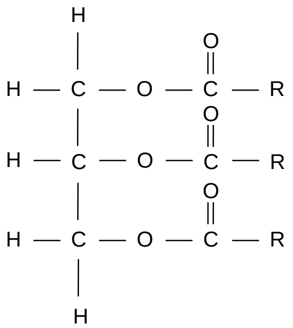
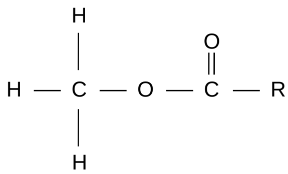
Calculations

1.

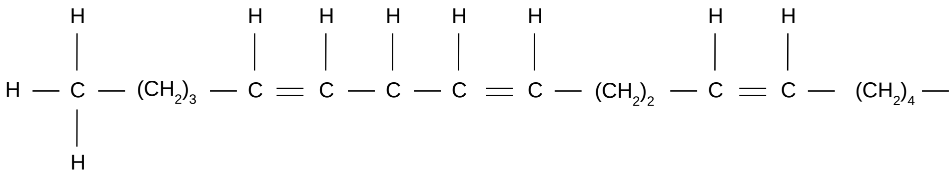


Rape seed oil



Biodiesel

where R is



Structures of rape seed oil and biodiesel

2. M_r values :

Rapeseed oil ($C_{57}H_{89}O_6$) = 869

Methanol (CH_3OH) = 32

Biodiesel ($C_{19}H_{31}O_2$) = 291

Glycerol ($C_3H_8O_3$) = 92

3. No. of moles of rapeseed oil $= \frac{1\ 200\ 000}{869} = 1380.9$

4. No. of moles of biodiesel = 3 x no. of moles of rapeseed oil

= 4142.7

5. % yield $= \frac{\text{mass of biodiesel} \times 100}{\text{theoretical mass}}$

$= \frac{1\ 000\ 000}{4142.7 \times 291} \times 100 = 83\%$

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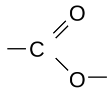
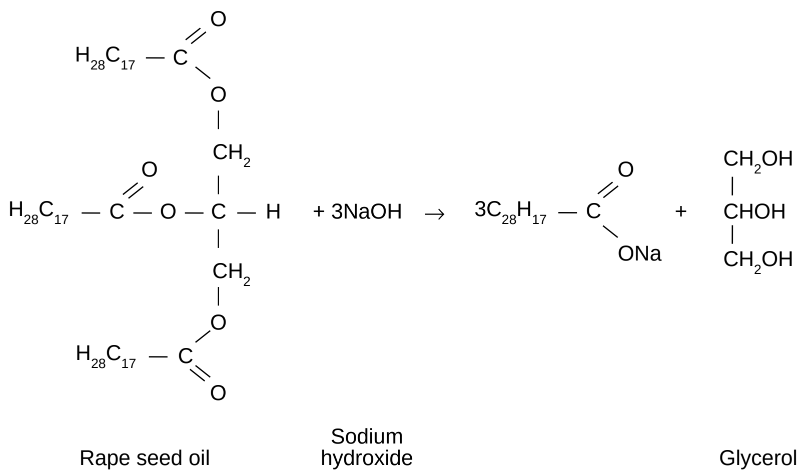
The production of biodiesel

1. 

2. a) CH_3COOCH_3
   b) $HCOOCH_2CH_2CH_3$
   c) $HCOOCH_2CH_3$
3. Electronegativity is the ability of an atom to attract electrons to itself within a covalent bond.
4. An electron pair donor which forms bonds with electron-deficient carbon atoms.
5. Halogenoalkanes, aldehydes, ketones and acid chlorides *etc*.
6. Propane-1,2,3-triol.
7. Reagents: ethanoic acid or ethanoyl chloride or ethanoic anhydride and methanol.

   Conditions: concentrated sulphuric acid and reflux for ethanoic acid. Direct reaction for the others.

   Appropriate equation.
8.



Equation for the saponification of rape seed oil