**Biodiesel**

Student Guide





**Researching Chemistry**

**Higher**

Photo: Wikipedia, GDFL

Higher Physics Topical Investigation Skin Cancer—Prevention and Cure

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**Investigation Brief**

Suntan creams stop harmful UV radiation reaching the skin. Manufacturers’ products are rated with a Sun Protection Factor (SPF). Suntan creams can have SPF values from 6 to over 50.

UV radiation monitors normally measure irradiance in output intensity per unit area. Thus, a typical low intensity UV lamp may emit approximately 10 mWcm-2.

The aim of this investigation is to determine the effect of various suntan creams on the transmission of UV radiation. In particular, the relationship between SPF and absorption should be found.

**Investigation Notes**

UV lamps can be harmful. Make sure that you read the safety leaflet which is supplied with the UV lamp. Some cheap UV monitors do not measure the irradiance of UV radiation. Rather, they give an indication of UV index. It is possible to undertake this investigation with such a monitor, but results will be less reliable and accurate. UV radiation does not pass through many transparent materials (including glass). However, UV transparent acrylics are readily available.

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**Overview of the assignment and activities.**

What is involved in the unit Researching Chemistry?

Studying chemistry involves learning chemistry facts and concepts. It also involves developing particular skills. These include research skills, which may involve you in doing investigative experiments or researching information, perhaps from the internet. The aim of this unit is to help you develop these chemistry skills. You will learn some chemistry facts, probably in some depth, however it is the development of skills which is the focus of the unit.

What chemistry content will I be learning?

The context for your work is renewable sources of energy, in particular, **biodiesel**

Our ever-increasing use of technology demands a huge supply of energy and we have devised many ways to supply this energy.

A lot of research is being undertaken to develop sustainable sources of energy, that is, sources that will not run out. These are **renewables**.

Hydroelectric, solar, wind and tidal power are examples of renewable energy sources. But there is a need for fuels that will enable cars and lorries to run as well. In this unit, you will carry out research and an investigation into biodiesel.

What activities will I be doing?

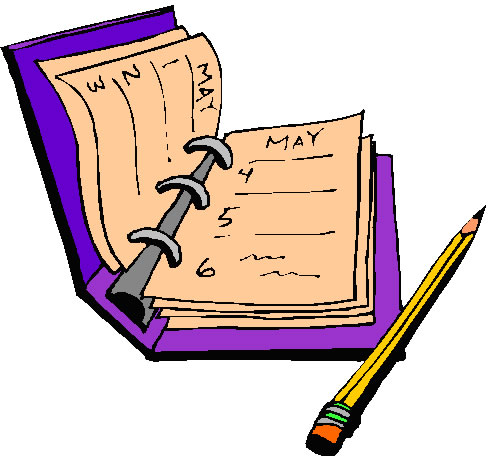
There are three types of activities in the unit.

**Undertaking literature based research** is a hugely important skill. In this unit, this is best carried out as web-based research. It is easy to simply look up a single fact on the internet, but undertaking a more structured project is more complex. Sifting through what is often a large amount of data is demanding. Keeping track of what you are trying to find out is one of the most difficult parts of this type of research, and summarising what you have found, without merely cutting and pasting someone else’s work is also challenging. There are several research briefs which can be used in preparation for your investigation.

**Investigative practical work** can be fun and challenging. Planning and designing experiments is often the hardest part of this work. Actually carrying out the experiment may be straightforward. The experiments you are likely to carry out in your investigation are not the kind where you can simply look up the results beforehand. There may be no right or wrong answers. What you find is what you find and your way of doing the experiment may not be similar to others in your class.

**Scientific communication** is hugely important. It does not matter how interesting or ground breaking your work is; if you cannot communicate your results then you have not completed your work. Information from your web research and data from your practical work will contribute to an assignment that you will complete under supervised conditions. This assignment is assessed externally by the SQA. You can pass this unit without completing the assignment, but you cannot get an overall course award in Higher Chemistry without doing so.

**Organising your work and carrying out the activities**

Some of the work you carry out in this unit will be in preparation for your research into biodiesel. When you carry out the research activities themselves, it is likely that you will be responsible for organising your work.

How will I organise

my work?

You are required to produce a report on the results of a piece of web-based research, and you may produce a report of your practical investigation. You are strongly advised not to produce these “as you go along”. Rather, it is very good practice to maintain a diary, or record of work. This should record all your experimental results, ideas, problems you met, references and all the other day to day observations and data that you want recorded. The record of work is your record and as such it should be in a format that suits you. However, experience shows that students who organise their work for ease of reference are likely to be able to extract the information more easily and the resulting reports are likely to be easier to produce.

Will I do the same work as everyone else in my class?

This material includes a number of web-based research and practical investigation briefs. It is likely that students within the same class will be allocated different activities, depending on resources available and other classroom management issues.

It is probable that you will undertake some of the work as part of a group. Sometimes, within your team, you will be undertaking the same task and other times you will each focus on a different part of the task. In either case, it is important that discussion takes place. Agree the part that each member of the team will play and ensure that there is time to share the results of the work.

What about teamwork?

The web allows you to access a huge amount of information.

Using the internet for background research

Make sure that you remain focussed as you carry out your research. It is very easy to get side-tracked. Keep reminding yourself what you are trying to find out as you surf.

Interesting, but not relevant, sites can be visited later. Sites that seem to be promising can be bookmarked so that they can be returned to later.

Tables, graphs and pictures can be copied into a folder. It is likely that some will be used and some will not.

It is worthwhile spending a few moments considering what keywords may best be entered into your search engine.

The web contains many sites containing reliable information – but inevitably some data is unreliable. How can we know what is reliable? As a general rule, information that is not attributed to a source is likely to be unreliable. Professional and government sites are useful. Online encyclopaedias and chat forums are likely to be less reliable. Often it is quite easy to access the same data from a number of sites. This doesn’t guarantee the reliability of the information, but it does help.

For more advice on effective web-based research see the Education Scotland resource on <http://www.educationscotland.gov.uk/resources/nq/r/nqresource_tcm4629006.asp?strReferringChannel=nationalqualifications&strReferringPageID=tcm:4-672951-64.>

**Assessment issues**

As you work on this unit, you will carry out activities which develop your skills in undertaking research in physics.

What do I have to do to pass this unit?

Two of the activities contribute to the unit assessment. To be awarded the unit, you need to demonstrate that your work is of at least the required standard in each of the two types of activity.

The two types of activities are:

* Undertaking web based research
* Carrying out investigative practical work - you need to take an active part in planning and carrying out an investigation.

Do I need evidence?

For the web based research, you should ensure that you retain evidence that your work is of the required standard. Each year SQA will ask to see the evidence from a number of candidates. This process is easiest to manage if your evidence is stored in an e-portfolio. You can store text based work, together with pictures, web pages, and any other material which you wish to present as evidence. If you do not use an e-portfolio, you should ensure that your evidence can be easily accessed.

Make sure you:

1) Record at least two sources of information relevant to your focus question. Sufficient detail should be given to allow someone else to find your sources easily. For a website, the URL shown here is perfectly adequate <https://education.gov.scot/>

2) Write a brief summary of the information of relevance contained in each of the sources you have identified.

What about assessment in the Higher Chemistry exam?

The Higher unit - Researching Chemistry is available as a free standing unit. It is also a required unit for a course award in Higher Chemistry. There will not be any questions in the Higher Chemistry course assessment which specifically relate to the topic of this unit. However, there will be questions in the course assessment which relate to the skills that you have developed in the unit. The following are the skills which may be assessed in the course assessment:

* Selecting information from texts, tables, charts, graphs and diagrams,
* Presenting information in a variety of forms,
* Processing information,
* Planning and designing an experiment,
* Evaluating experimental procedures,
* Drawing conclusions and making predictions based on evidence provided.

**Communication Stage**

This will be conducted under a high degree of supervision. This means that:

* You will be in the direct sight of the assessor/teacher
* You must not discuss your work with each other.

During the communication stage you will have access to the following resources:

The material collected during the research stage. This may include, for example, statistical, graphical, numerical or experimental data; data/information from the internet; published articles or extracts; notes taken from a visit or talk; notes taken from a written or audio-visual source.

Once you have agreed the format of your scientific communication with your teacher, you should produce a report on your investigation containing the following key features:

|  |  |  |
| --- | --- | --- |
| Criteria | Mark | Expected response |
| Aim | 1 | The aim must be clearly stated and appropriate to the investigation undertaken. |
| Apply knowledge and understanding of chemistry | 4 | Provide correct explanations of the topic researched using chemistry terms/ideas which are at a depth appropriate to Higher Chemistry.  The response might include: a statement of the principles involved, formulae, chemical equations, calculations, chemical properties related to bonding present. |
| Risk assessment | 1 | State the majority of appropriate safety measures taken during the experimental  work. |
| Select information | 2 | The data/information selected by the candidate for presentation/processing/analysis is both relevant and sufficient. |
| Process and present | 4 | Processing can include, for example; performing calculations; manipulating data, summarising referenced text.  It must be clear where the raw or extracted data/information came from.  Presenting processed data/information can include for example appropriate formats from; summary, graph, table, chart or diagram (one must be a graph, table, chart or diagram) In each case, sufficient detail should be included to convey the data/information.  The source of the original data must be clearly referenced. |
| Analyse data/information | 2 | Analysis will include interpreting data/information included in the report (which may or may not have been processed by the student) to identify relationships. This may include further calculations. |
| Conclusion | 1 | State a valid conclusion that relates to the aim(s) and is supported by evidence from the student’s research. |
| Evaluation | 3 | Students must make judgements based on criteria. The criteria, upon which judgements of the investigation are made, may include the following:   * Robustness of findings * Validity of sources * Reliability of data/information * Evaluation of experimental procedure. |
| Presentation | 2 | An appropriate title and structure must be given. The references to at least two sources used in the report are given in sufficient detail to allow them to be retrieved by a third party.  If one of the sources is an experiment/practical activity, then the title and the aim should be recorded. |

In the late 19th century, the combination of developing engine technology and the increasing availability of suitable fuel, led to the arrival of vehicles powered by the internal combustion engine.

Why is this topical?

Over the decades, the numbers of these vehicles has increased phenomenally. A combination of innovative manufacturing methods bringing prices down, such as Henry Ford’s production line, and the growing wealth of individuals, especially in the industrialised nations, has made these vehicles ubiquitous throughout most of the world. To the point where there are now well over a billion vehicles worldwide.

Increased vehicle ownership and usage leads to increased fuel usage. Worldwide consumption of petrol and diesel for vehicles is over 1,000 Gt (Gigatonnes) each.

This situation has many effects:

A recent study suggests that as many as 470,000 deaths are caused annually by air pollution. Vehicles, though not the only cause, are a major cause of this pollution.

Worldwide vehicles are responsible for over 15% of global CO2 emissions – and this figure does not include figures for vehicle manufacture or oil production.

Road traffic accidents kill 1.24 million people annually worldwide.

Interest in making diesel from vegetable oils has been around intermittently since the invention of the diesel engine itself. It was not, however, until the 1990s, largely due to attempts at reducing CO2 emissions, that biodiesel production became large scale.

It is not common, in the UK at least, for vehicles to run entirely on biodiesel – apart from some individuals and a few large organisations. In the European Union as a whole, though, diesel fuel usually has 7% biodiesel added to it.

**Media Items**

1. How biodiesel is made – Methes energy - <https://www.youtube.com/watch?v=xLa83KIaEyw>

2. A page from Strathclyde university summarising biodiesel production. <http://www.esru.strath.ac.uk/EandE/Web_sites/02-03/biofuels/what_biodiesel.htm>

3. An Oxfam report highlighting some problems with biofuel production - <http://www.oxfam.org/en/grow/policy/hunger-grains>

4. A comparison from Oregon of pollution from biodiesel and conventional diesel. [http://www.deq.state.or.us/aq/diesel/reducepollution.htm](http://www.deq.state.or.us/aq/diesel/reducepollution.htm%20)

5. Item from Penn State in the USA with a review of biodiesel including facts about engine performance.

<http://pubs.cas.psu.edu/FreePubs/pdfs/uc204.pdf>

*A – “Is it cheaper to make your own biofuel from vegetable oil than to buy diesel from a local filling station?”*

**Research Brief**

Modern society is energy hungry. Our use of technology demands a huge supply of energy and we have devised many ways to supply this energy. Fossil fuels, including coal, oil and gas, provide a significant proportion of our energy requirements in this country. However, these energy sources are not sustainable. There is a limited supply of fossil fuels and we will eventually run out of them. Although the supplies of nuclear fuel can potentially last much longer, they too will eventually run out.

A lot of research is being undertaken to develop sustainable sources of energy, that is, sources that will not run out. These are **renewables**. Hydroelectric, solar, wind and tidal power are examples of renewable energy sources.

Most of these renewable, however, while fine for electricity generation or supplying houses and factories, are not suitable for small, mobile uses, in particular they are not suitable for cars and lorries.

In this initial research activity you will find out some background information about biofuels.

In carrying out your research you should answer the following questions.

**A - background**

* How much petrol / diesel is used in the UK – on average, per hour/day/week?
* What proportion of fuel is currently produced from non-sustainable sources?
* Some diesel fuels on sale in the UK are a blend of traditional mineral diesel obtained from crude oil and biodiesel. How much biodiesel is included in these blends?
* What proportion of our fuel requirements could be provided by biofuels?

**B - Focus questions**

A1 Different people have different reasons for being interested in producing biodiesel. What reasons are given for manufacturing biodiesel?

A2 What is the reaction used to produce biodiesel from edible oils? The answer should name the types of reactant molecules and should include a word equation for the reaction.

A3 What safety hazards are associated with the production of biodiesel?

A4 What different oils are used for the production of biodiesel and why are they chosen?

A5 What are the effects on a vehicle’s performance when using biodiesel compared to petroleum diesel?

A7 What arguments are given against biodiesel production?

A8 Biodiesel is described as being “carbon neutral”. What does this mean, and is this claim true?

Answer the questions by carrying out research. It is probable that this is best undertaken using web-based research. You are advised to have completed an activity in which you consider the issues of undertaking web-based research. This may have been done during your work on other units in Higher Chemistry.

You may work individually or as part of a team.

Produce a report of your findings. This may be hand written, printed or electronic and saved in an e-portfolio.

If you work as part of a team that produces one report, you should include a short statement at the end of the report that indicates which part of the work you were responsible for.

**Investigation Brief**

The petrol and diesel used in cars are mixtures of hydrocarbons. In the engine, these fuels are burned and the rapid expansion in the cylinder due to the combustion produces movement of the pistons. This in turn is translated into movement of the vehicle.

Petrol and diesel are fossil fuels and this their burning produces a net increase in atmospheric carbon dioxide leading to climate change. So alternative fuels with a smaller ‘carbon footprint’ are being investigated. One of these is biodiesel, a series of esters made from alcohols and the fatty acids in oils.

The aim of this investigation is find out if biodiesel made from fresh vegetable oils might be a suitable replacement for the traditional fossil fuel.

Discuss how you will carry out the investigation.

Whilst planning your experimental work you should think about:

* which vegetable oil will you use in this experiment
* finding out the price of conventional diesel in local filling stations
* the apparatus and chemicals will you need
* the cost of the reagents used in your experiment
* what hazards there are when making biodiesel and what will you do to minimise risk.

Write your plan in your record of work.

**Making biodiesel**

Biodiesel is a mixture of [methyl esters](javascript:doStructure('methylester.htm')) of [fatty acids](javascript:doStructure('fattyacid.htm')) (long chain [carboxylic acids](http://www.rsc.org/Education/Teachers/Resources/green/glossary/home.htm#carboxylicacid)). It has similar properties to the diesel fuel made from crude oil that is used to fuel many vehicles. It can be made easily from vegetable cooking oil that contains compounds of fatty acids. The synthesis is a simple chemical reaction that produces biodiesel and [propane-1,2,3-triol (glycerol)](javascript:doStructure('propane123.htm')). Cooking oil is mixed with [methanol](javascript:doStructure('methanol.htm')) and potassium hydroxide is added as a catalyst. The products separate into two layers, with the biodiesel on the top. The biodiesel is separated and washed, and is then ready for further experimentation.

**Drying your oil**

### What you will need

A sample of the oil

**Either**

access to an oven at 120°C

**or**

* A bottle of anhydrous magnesium sulphate
* balance, weighing boat and spatula
* A clamp stand, boss head and clamp
* A filter funnel and filter paper

### What you do:

a) Place the beaker of filtered waste oil in the oven at 120°C and leave it overnight. This will remove the residual water.

**or**

b) Shake the sample with 3g anhydrous magnesium sulphate/100 cm3 of oil to remove any residual water.

Leave overnight and then filter.

**Making the potassium methoxide**

Potassium methoxide is made in advance.

**This process is hazardous and may be done for you - Wear goggles and gloves**

### What you will need

* A balance able to read to 2 d.p.
* A weighing boat
* A spatula
* A bottle of potassium hydroxide (check the assay level is on the label) (Care: Corrosive)
* A bottle of methanol (Care: Flammable, Toxic)
* 2 x 250 cm3 beakers
* A measuring cylinder
* A magnetic stirrer, seeker and a stirring rod
* A bottle to store the potassium methoxide in
* Labels and hazardous pictograms for the bottle

### What you do:

1. Weigh out 4.5-4.6g potassium hydroxide (strongly corrosive)
2. Measure 100 cm3 methanol (highly flammable and toxic) and pour into a 250cm3 beaker
3. Pour the potassium hydroxide into the methanol and stir until dissolved.
4. This takes approximately 2 hours so you will need to use a magnetic stirrer
5. Some unreacted hydroxide may remain in the bottom of the beaker.
6. Bottle and label with toxic and corrosive pictograms.

**Preparing your biodiesel**

### What you need:

* A separating funnel
* A clamp stand, boss head and clamp or ring
* A beaker of oil
* A bottle of potassium methoxide solution
* A 100 cm3 measuring cylinder
* A 10 cm3 measuring cylinder
* A large beaker
* A bottle of salt solution

### What you do:

1. Measure 50 cm3 treated oil –either fresh or waste (filtered and dried) and place in the separating funnel
2. Add 10cm3 of the prepared potassium methoxide solution
3. Stopper and shake vigorously for 2 minutes. Occasionally remove the stopper and then replace. This is to relieve pressure in the separating funnel
4. Leave to separate overnight or place tubes in a centrifuge for 5 minutes
5. The glyceride should separate out to the bottom. The supernatant may be dark in colour.
6. Carefully remove the top layer of biodiesel using a teat pipette. Remove the bottom layer of glycerine from the separating funnel and return your biodiesel to it.
7. Add 10 cm3 of salt solution and invert it carefully 10 times. **DO NOT SHAKE** the mixture as an emulsion can form
8. Transfer the bottom salt water layer to a beaker
9. Weigh the amount of biodiesel you have collected and compare it to the amount of vegetable oil you started with.

**Reporting your results**

Whichever format you have chosen your report should contain;

* a clear statement of the aim of your investigation.
* a brief explanation of how biodiesel is made including a chemical equation for the key reaction.
* your experimental observations and results including the volume of biodiesel formed.
* your calculation, based on your experimental results and the price of the ingredients, of the cost of materials required to make one litre of biodiesel.
* a comparison between the cost of your biodiesel and the price of diesel at a local filling station.
* a description of any ways that your method could be improved to increase the yield of biodiesel or to reduce the production of waste.
* a mention of any other costs associated with the manufacture of biodiesel which were not included in your calculation.

B *– “Is it cheaper to make your own biofuel from used cooking oil than to buy diesel from a local filling station?”*

**Research Brief**

Modern society is energy hungry. Our use of technology demands a huge supply of energy and we have devised many ways to supply this energy. Fossil fuels, including coal, oil and gas, provide a significant proportion of our energy requirements in this country. However, these energy sources are not sustainable. There is a limited supply of fossil fuels and we will eventually run out of them. Although the supplies of nuclear fuel can potentially last much longer, they too will eventually run out.

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In carrying out your research you should answer the following questions.

**A - background**

* How much petrol / diesel is used in the UK – on average, per hour/day/week?
* What proportion of fuel is currently produced from non-sustainable sources?
* Some diesel fuels on sale in the UK are a blend of traditional mineral diesel obtained from crude oil and biodiesel. How much biodiesel is included in these blends?
* What proportion of our fuel requirements could be provided by biofuels?
* What are the safety hazards associated with the production of biodiesel?

**B - Focus questions**

B1 What is the reaction that is used to produce biodiesel from edible oils? Your answer should name the types of reactant molecules and should include a word equation for the reaction.

B2 What changes take place in vegetable oils when used for deep fat frying?

B3 Making biodiesel is one possible use for used cooking oils. What other uses are there for used cooking oils..

B4 What are the safety hazards associated with the production of biodiesel?

B5 What hazards do used cooking oils pose to health or the environment?

B6 Can you buy biodiesel made from used cooking oils in Scotland? Your answer should include the price per litre of any oils you find for sale.

Answer the questions by carrying out research. It is probable that this is best undertaken using web-based research. You are advised to have completed an activity in which you consider the issues of undertaking web-based research. This may have been done during your work on other units in Higher Chemistry.

You may work individually or as part of a team.

Produce a report of your findings. This may be hand written, printed or electronic and saved in an e-portfolio.

If you work as part of a team that produces one report, you should include a short statement at the end of the report that indicates which part of the work you were responsible for.

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Petrol and diesel are fossil fuels and this their burning produces a net increase in atmospheric carbon dioxide leading to climate change. So alternative fuels with a smaller ‘carbon footprint’ are being investigated. One of these is biodiesel, a series of esters made from alcohols and the fatty acids in oils.

In many of our towns and cities, a lot of vegetable oil is used for deep frying the foods that are widely on sale. As the oils can only be used a certain number of times for this process, there is a lot of used vegetable oil that needs to be disposed of.

The aim of this investigation is find out if biodiesel made from waste vegetable oils might be a suitable replacement for the traditional fossil fuel.

Discuss how you will carry out the investigation.

Whilst planning your experimental work you should think about:

* which vegetable oil will you use in this experiment
* finding out the price of conventional diesel in local filling stations
* the apparatus and chemicals will you need
* the cost of the reagents used in your experiment
* what hazards there are when making biodiesel and what will you do to minimise risk.

Write your plan in your record of work.

**A method for making biodiesel from waste oil**

The process is very similar to the preparation of biodiesel from fresh vegetable oil. There are two differences.

1. Waste oil contains particles of food waste so it needs to be filtered
2. In waste oil a certain proportion of the triglycerides have been hydrolysed to leave free fatty acids (FFAs). A titration is needed to determine the level of FFAs so you can ensure that the correct amount of catalyst is added.

**Filtering your oil**

### What you do:

1. Filter the oil through a double layer of muslin to remove any debris from food preparation. The oil will still be cloudy after this treatment.
2. Now filter the cloudy oil through either a standard size coffee filter paper or through student grade filter paper. The oil will be a much clearer dark brown after this filtration.

(If you are filtering a large amount then the process takes time).

**Drying your oil**

### What you will need

* A sample of the filtered oil

Either

* access to an oven at 120°C

or

* A bottle of anhydrous magnesium sulphate
* balance, weighing boat and spatula
* A clamp stand, boss head and clamp
* A filter funnel and filter paper

### What you do:

1. Place the beaker of filtered waste oil in the oven at 120°C and leave it overnight. This will remove the residual water.

or

1. Shake the sample with 3g anhydrous magnesium sulphate/100 cm3 of oil to remove any residual water.

Leave overnight and then filter.

**Determining the amount of free fatty acids (FFA) present in the filtered oil**

Some of the oil will have been broken down into free fatty acids during the cooking process. This will require a larger addition of the base at the trans-esterification step than is required for new oil. It is necessary to determine how much of the waste oil has been broken down into free fatty acids to be able to calculate how much extra potassium hydroxide is required to neutralise the FFA.

### What you will need

* Filtered and dried oil.
* Propan-2-ol
* 10cm3 measuring cylinder
* 0.1% potassium hydroxide solution
* Test tubes and test tube rack.
* 1 cm3 disposable Pasteur pipette
* Thymol blue indicator

### What you do:

1) Blank (your control)

1. Add 5 drops of thymol blue indicator to 10 cm3 propan-2-ol: the solution should be pale yellow
2. Using a disposable 1cm3 graduated pipette, add a 0.1% potassium hydroxide solution drop wise with shaking until the colour change from yellow to blue is observed.
3. Repeat three times and take the average.

*Thymol blue is chosen as there is a definite change in colour in the pH range of the solution.*

2) Sample

1. Dissolve 1 cm3 of oil in 10 cm3 propan-2-ol.
2. Add 5 drops of thymol blue indicator
3. Using a disposable 1cm3 graduated pipette, add a 0.1% potassium hydroxide solution drop wise with shaking until the colour change from yellow to blue is observed.
4. Repeat three times and take the average.

*To get the measurement, you can either use the markings on the pipette to get the volume to the nearest ¼ cm3 or count the drops. You will need to check first but most 1 cm3 pasteur pipettes will give around 23 – 25 drops per cm3 so, knowing that and the number of drops, you can easily calculate the volume. The second method is more accurate but this level of accuracy is not essential.*

Subtract the average of the blank (control) from the average of the oil samples. The answer is the number of grammes of potassium hydroxide needed to neutralise the free fatty acids.

The actual amount of potassium hydroxide you need to add depends on the purity of your reagent.

|  |  |
| --- | --- |
| KOH Assay (%) | Mass to Add to 1 Litre (g) |
| 85 | 5.8 |
| 90 | 5.5 |
| 92 | 5.3 |
| 100 | 4.9 |

To each litre of oil, you need to add:

* 200 cm3 of methanol
* Mass of ethanol from the table above **plus** the extra mass determined from your titration

If you are using 50 cm3 of oil, as described in the method, you will have to work out the composition of your potassium methoxide in advance

**Making the potassium methoxide**

Potassium methoxide is made in advance.

**This process is hazardous and may be done for you - Wear goggles and gloves**

### What you will need

* A balance able to read to 2 d.p.
* A weighing boat
* A spatula
* A bottle of potassium hydroxide (check the assay level is on the label) (Care: Corrosive)
* A bottle of methanol (Care: Flammable, Toxic)
* 2 x 250 cm3 beakers
* A measuring cylinder
* A magnetic stirrer, seeker and a stirring rod
* A bottle to store the potassium methoxide in
* Labels and hazardous pictograms for the bottle

### What you do:

1. Weigh out the amount of potassium hydroxide (strongly corrosive) determined from your calculations above.
2. Measure the calculated volume of methanol (highly flammable and toxic) and pour into a 250cm3 beaker
3. Pour the potassium hydroxide into the methanol and stir until dissolved.
4. This takes approximately 2 hours so you will need to use a magnetic stirrer
5. Some unreacted hydroxide may remain in the bottom of the beaker.
6. Bottle and label with toxic and corrosive pictograms.

**Preparing your biodiesel**

### What you need:

A separating funnel

A clamp stand, boss head and clamp or ring

A beaker of oil

A bottle of potassium methoxide solution

A 100 cm3 measuring cylinder

A 10 cm3 measuring cylinder

A large beaker

A bottle of salt solution

### What you do:

1. Measure 50cm3 treated oil –either fresh or waste (filtered and dried) and place in the separating funnel
2. Add 10cm3 of the prepared potassium methoxide solution
3. Stopper and shake vigorously for 2 minutes. Occasionally remove the stopper and then replace. This is to relieve pressure in the separating funnel
4. Leave to separate overnight or place tubes in a centrifuge for 5 minutes
5. The glyceride should separate out to the bottom. The supernatant may be dark in colour.
6. Carefully remove the top layer of biodiesel using a teat pipette. Remove the bottom layer of glycerine from the separating funnel and return your biodiesel to it.
7. Add 10 cm3 of salt solution and invert it carefully 10 times. **DO NOT SHAKE** the mixture as an emulsion can form
8. Transfer the bottom salt water layer to a beaker
9. Weigh the amount of biodiesel you have collected and compare it to the amount of vegetable oil you started with.

**Reporting your results**

Whichever format you have chosen your report should contain;

* a clear statement of the aim of your investigation.
* a brief explanation of how biodiesel is made including a chemical equation for the key reaction.
* your experimental observations and results including the volume of biodiesel formed.
* your calculation, based on your experimental results and the price of the ingredients, of the cost of materials required to make one litre of biodiesel.
* a comparison between the cost of your biodiesel and the price of diesel at a local filling station.
* a description of any ways that your method could be improved to increase the yield of biodiesel or to reduce the production of waste.
* a mention of any other costs associated with the manufacture of biodiesel which were not included in your calculation.

C *– “How good is biodiesel as a fuel?”*

**Research Brief**

Modern society is energy hungry. Our use of technology demands a huge supply of energy and we have devised many ways to supply this energy. Fossil fuels, including coal, oil and gas, provide a significant proportion of our energy requirements in this country. However, these energy sources are not sustainable. There is a limited supply of fossil fuels and we will eventually run out of them. Although the supplies of nuclear fuel can potentially last much longer, they too will eventually run out.

A lot of research is being undertaken to develop sustainable sources of energy, that is, sources that will not run out. These are **renewables**. Hydroelectric, solar, wind and tidal power are examples of renewable energy sources.

Most of these renewable, however, while fine for electricity generation or supplying houses and factories, are not suitable for small, mobile uses, in particular they are not suitable for cars and lorries.

In this initial research activity you will find out some background information about biofuels.

In carrying out your research you should answer some of the following questions.

* How much petrol / diesel is used in the UK – on average, per hour/day/week?
* What proportion of fuel is currently produced from non-sustainable sources?
* Some diesel fuels on sale in the UK are a blend of traditional mineral diesel obtained from crude oil and biodiesel. How much biodiesel is included in these blends?
* What proportion of our fuel requirements could be provided by biofuels?
* How much does it cost to produce fuel from each of the different sources? Remember to take into account capital costs as well as running costs.
* What type of chemical reaction is used to produce biodiesel? Your answer should name the types of reactant molecules and should include a word equation for the reaction.
* What are the environmental issues related to biofuels?
* What are the safety hazards associated with the production of biodiesel?
* How does the energy produced by biodiesel from fresh oil compare to that of petroleum diesel?
* How does the energy produced by biodiesel from waste oil compare to that of petroleum diesel?
* How does the energy obtained from burning biodiesel compare with the theoretical yield calculated from bond energies?
* What are the products produced when oil and biodiesel burn?
* How much carbon dioxide is produced when burning biodiesel compared to vegetable oil or petroleum diesel?

Answer the questions by carrying out research. It is probable that this is best undertaken using web-based research. You are advised to have completed an activity in which you consider the issues of undertaking web-based research. This may have been done during your work on other units in Higher Chemistry.

You may work individually or as part of a team.

Produce a report of your findings. This may be hand written, printed or electronic and saved in an e-portfolio.

If you work as part of a team that produces one report, you should include a short statement at the end of the report that indicates which part of the work you were responsible for.

**Investigation Brief**

The petrol and diesel used in cars are mixtures of hydrocarbons. In the engine, these fuels are burned and the rapid expansion in the cylinder due to the combustion produces movement of the pistons. This in turn is translated into movement of the vehicle.

The petrol and diesel used in cars are mixtures of hydrocarbons. In the engine, these fuels are burned and the rapid expansion in the cylinder due to the combustion produces movement of the pistons. This in turn is translated into movement of the vehicle.

Petrol and diesel are fossil fuels and this their burning produces a net increase in atmospheric carbon dioxide leading to climate change. So alternative fuels with a smaller ‘carbon footprint’ are being investigated. One of these is biodiesel, a series of esters made from alcohols and the fatty acids in oils.

In order for biodiesel to be suitable as a replacement for conventional diesel, it needs to have certain characteristics. Amongst other things, it needs to burn easily enough and to give off a sufficient amount of energy. It needs to be able to flow round the engine and it needs to burn reasonably cleanly.

The aim of this investigation is find out if biodiesel made from vegetable oils (fresh or waste) might be a suitable replacement for the traditional fossil fuel.

Discuss how you will carry out the investigation.

Whilst planning your experimental work you should think about:

* which source of vegetable oil will you use for making your biodiesel
* What are the requirements of a good fuel such as conventional diesel.
* How you can assess your biodiesel to see if it is a good fuel.
* the apparatus and chemicals will you need
* what hazards there are when making biodiesel and what will you do to minimise risk.

Write your plan in your record of work.

**Investigation Brief**

### pH and Viscosity

### What you will need

### A sample of biodiesel, from fresh or waste oil.

### A sample of the oil you used

### Two test tubes (the same size) and a test tube rack

### A piece of pH paper and a colour chart

### What you do:

1. Pour some biodiesel into one of the test tubes.
2. Pour some oil into the empty test tube so the depth is the same as the biodiesel you have.
3. Tear two small pieces from the end of the pH paper you have. Make sure they are small enough not to get caught in the test tubes.
4. At the same time, add a piece to each test tube and shake them gently to make sure the paper gets wet and starts to sink into the liquids.
5. Watch how fast they sink and if they change colour.
6. Try to match the colour of each piece of pH paper to a number on the chart you have.

### Enthalpy of combustion

### What you will need

### Some of your biodiesel and the oil you made it from

### An evaporating basin

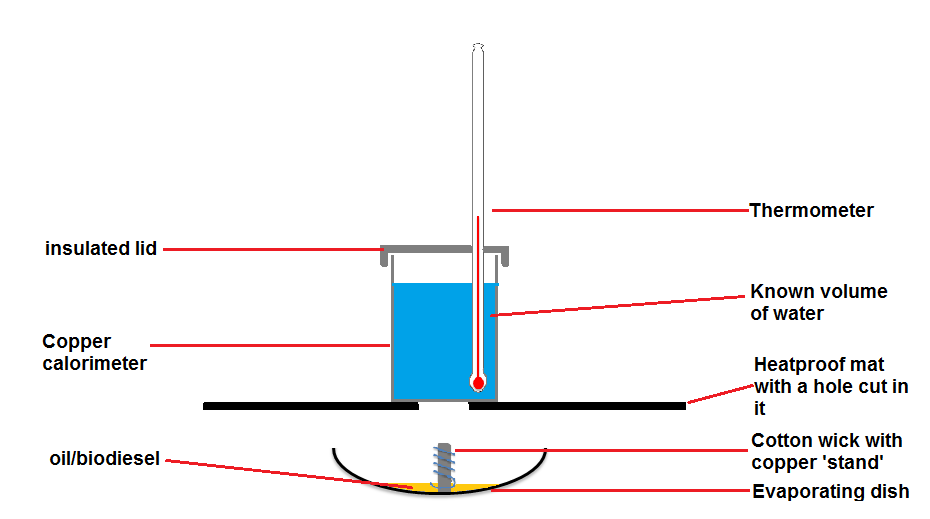
### A piece of cotton to make a wick from

### A piece of copper wire (to hold the wick together)

### A 100 cm3 measuring cylinder

### Access to a balance able to read to 2 decimal places

### This apparatus set up



### The apparatus is sensitive to draughts. It is a good idea to construct a sort of box out of heatproof mats or corriflute or anything else suitable.

This should be carried out in a well ventilated room. If it is being repeated a lot then use a fume cupboard. Keep the fan off until the measurements are complete then switch it on to clear the fumes.

### What you do:

1. Make up wicks by rolling the cotton fabric, then wrap a length of copper wire around it to hold it together, making a foot so that it can stand in an evaporating basin (See photos below)
2. Accurately measure out 100 cm3 of cold water into the copper beaker
3. Place lid on and put it into the box unit making sure the thermometer bulb is submerged in the water in the copper can in the box unit. It should look like this when it is set up for the experiment:
4. Take the initial temperature reading of the water.
5. Weigh your basin and wick. Record its mass
6. Add 3 cm3 of your sample i.e. biodiesel/vegetable oil into the evaporating basin. Dip the end of the wick in the liquid and sit it in the basin.
7. Record the total mass of the basin, oil and wick.
8. Set the evaporating basin under the hole in the box and light the wick.
9. Watch the temperature increase. When it is 10 - 20°C above the starting temperature extinguish the flame by placing a heat mat over the basin.
10. Keep watching the temperature rise and record the final temperature when it stops
11. Weigh the evaporating basin again, record the reading and calculate the difference in mass.
12. Remove the copper beaker, clean the soot off, and refill with water for next sample.
13. Repeat with another sample. Repeat measurements can also be taken and averages calculated.
14. Now repeat the experiment using kerosene (this is very similar to diesel fuel).

Calculate the energy content of the oil and biodiesel burned and hence the energy content/g

Energy Content = cmΔT c = 4.18kJkg-1oC-1

Energy Content/g = cmΔT

Mass Loss

**Reporting your results**

# There are many different ways of presenting your findings. With your teacher you should agree the format that you will use.

Whichever format you have chosen your report should contain;

* a clear statement of the aim of your investigation.
* a brief explanation of how biodiesel is made including a chemical equation for the key reaction.
* your experimental observations and results.
* your calculations, based on your experimental results, of the amount of energy produced by burning biodiesel compared to oil or kerosene..
* a comparison between the effectiveness of your biodiesel and diesel at a local filling station.
* a description of any ways that your method could be improved to improve the effectiveness of your fuel.

*D – “Does biodiesel burn more cleanly than conventional diesel”?*

**Research Brief**

Modern society is energy hungry. Our use of technology demands a huge supply of energy and we have devised many ways to supply this energy. Fossil fuels, including coal, oil and gas, provide a significant proportion of our energy requirements in this country. However, these energy sources are not sustainable. There is a limited supply of fossil fuels and we will eventually run out of them. Although the supplies of nuclear fuel can potentially last much longer, they too will eventually run out.

A lot of research is being undertaken to develop sustainable sources of energy, that is, sources that will not run out. These are **renewables**. Hydroelectric, solar, wind and tidal power are examples of renewable energy sources.

Most of these renewable, however, while fine for electricity generation or supplying houses and factories, are not suitable for small, mobile uses, in particular they are not suitable for cars and lorries.

In this initial research activity you will find out some background information about biofuels.

In carrying out your research you should answer some of the following questions.

**A - background**

* How much petrol / diesel is used in the UK – on average, per hour/day/week?
* What proportion of fuel is currently produced from non-sustainable sources?
* Some diesel fuels on sale in the UK are a blend of traditional mineral diesel obtained from crude oil and biodiesel. How much biodiesel is included in these blends?
* What proportion of our fuel requirements could be provided by biofuels?
* What are the safety hazards associated with the production of biodiesel?

**B - Focus questions**

D1 What are diesel particulates and what hazards do they pose?

D2 What monitoring of particulate levels has been undertaken in Scotland?

D3 Biodiesel is described as being “carbon neutral”. What does this mean, and is this claim true?

D4 What can be done to conventional diesel fuel to reduce the production of acid rain?

D5 What studies have been done comparing biodiesel emissions with conventional diesel fuel?

D6 Burning biodiesel reduces the levels of polycyclic aromatic hydrocarbons (PAH). Why do people want to reduce the emissions of polycyclic aromatic hydrocarbons?

Answer the questions by carrying out research. It is probable that this is best undertaken using web-based research. You are advised to have completed an activity in which you consider the issues of undertaking web-based research. This may have been done during your work on other units in Higher Chemistry.

You may work individually or as part of a team.

Produce a report of your findings. This may be hand written, printed or electronic and saved in an e-portfolio.

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**Investigation Brief**

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Petrol and diesel are fossil fuels and this their burning produces a net increase in atmospheric carbon dioxide leading to climate change. So alternative fuels with a smaller ‘carbon footprint’ are being investigated. One of these is biodiesel, a series of esters made from alcohols and the fatty acids in oils.

As well as the problems associated with carbon dioxide emissions, petrol and diesel are in the spotlight because of other emissions: nitrogen and sulphur oxides can contribute to acid rain as well as irritating the lings, especially of people suffering from asthma; particulates produced by diesel engines can enter deep into the lungs and can lodge there, eventually leading to an increased chance of cancer. Indeed, it has recently been announced that from 2020, diesel vehicles that fail to meet stringent new standards will be charge double the fee to enter London.

The aim of this investigation is find out if biodiesel made from vegetable oils (fresh or waste) might be a suitable replacement for the traditional fossil fuel in terms of the pollutants it emits..

Discuss how you will carry out the investigation.

The experiment described below can be adapted to give a measure of the amount of particulates (soot) and the quantity of acidic gases produced when a fuel is burnt.

Whilst planning your experimental work you should think about:

* how, using the apparatus described below, you could measure the quantity of particulates (soot) formed when a fuel burns
* how you could use the apparatus described below to measure the quantity of gases released which could cause the formation of acid rain
* how you will ensure a fair comparison of the two fuels
* what hazards there are when carrying out your experiment and how you will minimise risk.

Write your plan in your record of work.

### Burning products

# Safety

### Wear eye protection.

### Take care if you have to insert glass tubing into the stoppers yourself. Make sure that your teacher shows you the correct technique.

### What you will need

### Glass tubing

### Mineral wool

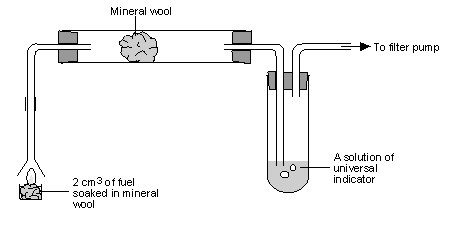
### samples of oil and biodiesel

### 0.1M sodium hydroxide

### crucible or sample cup

### vacuum pump

Set up the apparatus as shown below:



### What to do

1. Pour 125 cm3 of distilled water into the 250 cm3 flask and add 10 cm3 of universal indicator. Add one drop of 0.1 Msodium hydroxide solution and gently swirl the flask so that the colour of the solution is violet or at the most basic end of the universal indicator colour range.
2. Place 10 cm3 of this solution into the boiling tube.
3. Assemble the apparatus illustrated in Figure 1, attaching it to the filter pump with the vacuum tubing.
4. Place 2 cm3 of biodiesel onto a wad of mineral wool in the metal sample cup.
5. Turn on the water tap so the filter pump pulls air through the flask and ignite the biodiesel. Position the funnel directly over the burning fuel, so as to capture the fumes from the burning fuel.  Mark or note the position of the tap handle so you can run the pump at the same flow rate later in the experiment.
6. Allow the experiment to run until the universal indicator turns yellow and time how long this takes.
7. Record what happens in the funnel and in the glass tube containing the second piece of mineral wool.
8. Clean the apparatus, and repeat the experiment using 2 cm3 of kerosene (this is very similar to diesel fuel).

**Reporting your results**

There are many different ways of presenting your findings. With your teacher you should agree the format that you will use.

Whichever format you have chosen your report should contain;

* a clear statement of the aim of your investigation.
* a brief explanation of how biodiesel is made including a chemical equation for the key reaction.
* your experimental observations and results.
* any calculations, based on your experimental results, of the pollution produced by burning biodiesel.
* a description of any ways that your method could be improved to reduce the production of waste.

*E – “What is the degree of unsaturation in different oils and biodiesels?”*

**Research Brief**

Modern society is energy hungry. Our use of technology demands a huge supply of energy and we have devised many ways to supply this energy. Fossil fuels, including coal, oil and gas, provide a significant proportion of our energy requirements in this country. However, these energy sources are not sustainable. There is a limited supply of fossil fuels and we will eventually run out of them. Although the supplies of nuclear fuel can potentially last much longer, they too will eventually run out.

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In carrying out your research you should answer some of the following questions.

**A - background**

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* Some diesel fuels on sale in the UK are a blend of traditional mineral diesel obtained from crude oil and biodiesel. How much biodiesel is included in these blends?
* What proportion of our fuel requirements could be provided by biofuels?
* What are the safety hazards associated with the production of biodiesel?

**B - Focus questions**

D1 How does the iodine values vary between different oils?

D2 How does the iodine values vary between biodiesels made from different oils?

D3 How do different iodine values relate to different physical properties of oils or biodoesels?

D4 How do different iodine values relate to the amount of energy released from different oils or biodoesels?

Pupils should answer the questions by carrying out research. It is probable that some of this is best undertaken using web-based research. Pupils are advised to have completed an activity in which they consider the issues of undertaking web-based research. This may have been done during work on other units in Higher Chemistry.

Pupils may work individually or as part of a team.

Pupils should produce a report of their findings. This may be hand written, printed or electronic and saved in an e-portfolio.

If pupils work as part of a team that produces one report, each member of the team should include a short statement at the end of the report that indicates which part of the work he/she was responsible for.

**Investigation Brief**

To compare the chemical stability properties of different biodiesel fuels, it is desirable to have a measurement for the stability of the fuel against such oxidation.

Currently the most common method for doing this, and the one specified in many of the biodiesel fuel specifications is called the Iodine Number or Iodine Value. The Iodine Value is not determined by measuring the stability of the fuel, rather it is determined by measuring the number of double bonds in the mixture of fatty acid chains in the fuel by introducing iodine into 100 grams of the sample under test and measuring how many grams of that iodine are absorbed. Iodine absorption occurs at double bond positions - thus a higher IV number indicates a higher quantity of double bonds in the sample.

The Iodine Value can be important because many Biodiesel fuel standards specify an upper limit for fuel that meets the specification and this can affect the oils that may be used for biodiesel production.

The Iodine value (IV) does not necessarily make the best measurement for stability as it does not take into account the positions of the double bonds available for oxidation. In some cases this can lead to IV values that are misleading.

The aim of this investigation is find out how the iodine values of different oils and biofuels relates to other properties of the fuels

Pupils should discuss how they will carry out the investigation.

Whilst planning experimental work they should think about:

* how, using the apparatus described below, they could measure the quantity of particulates (soot) formed when a fuel burns
* how they could use the apparatus described below to measure the quantity of gases released which could cause the formation of acid rain
* how they will ensure a fair comparison of the two fuels
* what hazards there are when carrying out the experiment and how they will minimise risk.

Pupils should write their plan in their record of work.

The experiment described below shows how to determine the iodine value of an oil/fat or biofuel by reacting with Wiji’s solution (iodine monochloride) and then back titrating any remaining iodine with sodium thiosulphate.

**Determining the iodine value**

The iodine value is the number of grams of iodine that can be absorbed by 100g of fat or oil.

The fat or oil (or your biodiesel) is treated with excess Wijs solution, which contains iodine monochloride). This reacts at the double bonds, adding iodine.

Potassium iodide is then added which liberates any unreacted iodine. This iodine is then determined by titration with sodium thiosulphate.

The more double bonds (the greater the amount of unsaturation), the less iodine there is left over to titrate.

**Apparatus**

* Burettes
* Conical Flasks
* Reagents
* Wijs Solution
* Fat or Oil sample
* Cyclohexane
* 10% potassium iodide solution
* 0.25M sodium thiosulphate
* Freshly made starch indicator solution

Standard Sodium Thiosulphate Solution

Make 500ml of 0.25M Sodium Thiosulphate solution from ampoules or by dissolving an accurately weighed amount of the solid in distilled or deionised water and standardising the solution to determine the exact concentration.

**Procedure**

1. Accurately weigh 0.2-0.3g of the fat or oil sample into a clean conical flask.

2. Dissolve the fat or oil in 10cm3 cyclohexane.

3. Add 25 cm3 Wijs solution from a dispenser (Pipette/Measuring cylinder)

4. Prepare a blank solution as above but omit the fat or oil.

5. Mix the samples well and leave to stand in the dark for about 30 minutes.

6. After 30 minutes add 20 cm3 of 10% potassium iodide solution and 100cm3 distilled water to each of the flasks.

7. Titrate the solution to a pale yellow colour, then add 2-3cm3 starch solutions and continue titrating to the colourless endpoint ensuring that the flask is well shaken to remove all traces of colour.

8. The blank must be carried out at the same time as the sample as the Wijs solution deteriorate.

**Calculation**

The iodine value of the fat or oil is calculated given that the difference between the volume of thiosulphate used in the blank and in the test sample gives the amount equivalent to the iodine absorbed by the fat or oil, so that

1cm3 sodium thiosulphate ≡ a known mass of iodine

This can be calculated from the blank since we know that 2 moles of thiosulphate reacts with 1 mole of Iodine

We can thus calculate the mass of iodine which reacts with 1cm3 of sodium thiosulphate solution.

Example

For a sodium thiosulphate solution of molarity of 0.2500M sodium thiosulphate this would be

1/1000 x 0.2500 = 0.00025 moles thiosulphate

1 mole Iodine reacts with 2 moles thiosulphate

So number of moles iodine = 0.00025/2 = 0.000125 moles iodine

Therefore mass of iodine is given by - No of moles= mass /atomic mass

Mass of iodine = no of moles x atomic mass of iodine

= 0.000125 x 254= 0.03175g

Thus

Iodine value = (B-T) x (calculated mass of iodine per cm3 thiosulphate solution) x 100/W

*Where B = blank titre of standardised sodium thiosulphate solution*

*T= sample titre of standardised sodium thiosulphate solution*

*W= mass in grams of sample of fat or oil.*

*100 is used because the iodine number is expressed as a number per 100g of the fat or oil.*