Climate Change:
Some Chemistry Experiments
National Science Learning Centre, University of York

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Health and Safety

Teachers must make their own risk assessments of these experiments before using them. Suggestions are provided separately.

Acidity of CO₂

Carbon Dioxide with Universal Indicator

250mL measuring cylinder, ~30mL 1M ammonia solution, universal indicator solution, dry ice pellets or carbon dioxide gas generator

**In advance** the measuring cylinder is filled with water and Universal indicator is added to a reasonable colour density. Add a few mL of ammonia solution until indicator just turns purple.

**When ready** put in a few pellets of dry ice (or the tube from a carbon dioxide generator).

**Why?** The colour will change from purple through green to orange as the carbon dioxide dissolves in the water first neutralising the ammonia and then forming an excess of carbonic acid – a weak acid.

\[
\text{H}_2\text{O} + \text{CO}_2 \leftrightarrow \text{H}_2\text{CO}_3 \leftrightarrow \text{H}^+ + \text{HCO}_3^-
\]

Carbon Dioxide Bottle – The chemical Version of the Collapsing Can Experiment

Several 1 or 2 litre ‘thin walled’ plastics drinks bottles, filled with CO₂ (or supply dry ice pellets)
50mL of 2M NaOH in a shott bottle.

**In advance** If the drinks bottle is filled with CO₂ by displacement or by letting dry ice sublime in it for some time is sealed with tape it will last a few hours

**When ready** unscrew and pour about 40 -50mL of 2m NaOH into the bottle. Replace lid and shake.

**Why?** The bottle collapses as the CO₂ is neutralised by the alkali. The outside pressure becomes greater than the internal pressure so the walls of the bottle give and collapse.

\[
\text{CO}_2 + \text{NaOH} \rightarrow \text{NaHCO}_3
\]

Combustion Experiments
**Non burning £5 note** (an interesting ‘starter’ too!)

In advance prepare a 50% ethanol/water solution. Also required £5 notes and tongs. **When ready** soak the currency in the alcohol water mixture. Hold in a tongs and light the note with a spill AAWY from the stock solution of ethanol/water solution!

**Why?** The heat energy generated by the combustion is lower than that needed to burn wet paper.

**Expensive control experiment** Try the same thing with pure ethanol (methylated spirits) - here the energy is sufficient to ignite dry bank notes!

---

**Complete Combustion of Methanol - Water Canister Experiment**

18 litre water canister, methanol, spills, safety screen

**In Advance** check that there are no cracks in the water canister. Wrap cling film around the canister or place in front of safety screen. **When ready** pour around 40ML of methanol into the canister and shake to vaporise as much of the methanol as possible. Pour out all surplus methanol. Check positioning of canister away from combustible materials and put a lit spill at arms length near to the opening. When flame is out you can pour out water formed during the combustion. If necessary pour in some limewater solution and shake. Pour into a beaker to see cloudiness indicating CO\(_2\) [or use a CO\(_2\) meter!]

**Why?** Methanol vapour burns rapidly in air producing only carbon dioxide and water.

\[
\text{CH}_3\text{OH} + \frac{3}{2} \text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}
\]

---

**Incomplete Combustion – Ethyne Foam (Acetylene Foam)**

Calcium carbide, 250/400mL beaker, distilled water bottle, washing up liquid, spills matches, heat proof mat

**In Advance-nil**

**When ready** half fill the beaker with water, add a good squirt of washing up liquid, and add a few pieces (4/5) of calcium carbide. When sufficient foam ignite at arms length.

**Why?** Ethyne, C\(_2\)H\(_2\) burns incompletely in air so some blackness seen in flame. Occasionally smuts are seen floating in air. Note pure ethyne/acetylene needs an oxygen source to burn completely (oxy-acetylene cutters).

Argue that incomplete combustion is less efficient and uses up more fuel.

---

**Incomplete Combustion – Expanded Polystyrene**

Expanded polystyrene, tongs, heat proof mat, spills matches.

**In Advance-nil**

**When ready** hold a piece of the polystyrene (a hydrocarbon) in a tongs over the heat proof mat and ignite. Lots of black smuts of carbon will be seen floating.

**Why?** Polystyrene burns with incomplete combustion.
**Experiments in Which Carbon Dioxide is Produced**

Several industrial processes produce CO₂ as a byproduct even if energy considerations are not taken into account. These include:

- Aluminium extraction by electrolysis
- Iron Production via Blast Furnace
- Manufacture of cement from limestone (thermal decomposition of calcium carbonate)

**Iron Extraction - on A Match Head!**

Cigarette lighters, box of matches (not safety matches) small amount of iron (III) oxide, small amount of sodium carbonate, plastic petri dish and a bar magnet.

**In Advance**-nil

**When ready** Show that neither iron oxide nor sodium carbonate is magnetic. Take an unlit match dampen the head by dipping in water. Roll in some powdered iron(III) oxide and then into the sodium carbonate. Use the lighter to burn the match head. Crunch the match head onto a clean dry plastic petri dish. With the magnet underneath the Petri dish move it under the ashes. Sufficient iron is produced to be moved by the magnet.

**Why?** The iron oxide is reduced by the carbon/carbon monoxide formed when the match head is burnt. The carbon/carbon monoxide gets oxidised to carbon dioxide.

**Miscellaneous Experiments**

**Oxygen Foam**

100 Vol hydrogen peroxide, KI solid (loose!), spatula, 250mL measuring cylinder, black bag, food colouring and washing up liquid, bowel.

**In Advance**-split open a black bin bag to protect the bench and to allow overflow to be more easily wrapped up.

**When Ready.** Put 100 mL of 100Vol hydrogen peroxide into a 250mL measuring cylinder. Add a good squirt of good washing up liquid (e.g. Fairy). Add a few drops of food colouring (not essential). Throw in about 4 spatula loads of KI crystals in one go. Stand back.

**Why?** A reaction takes place in which iodide ions are oxidised to IO⁻ which then reacts with hydrogen peroxide forming oxygen. [Any iodine formed by a side reaction gets trapped in the foam].

\[
\begin{align*}
\text{H}_2\text{O}_2 + \text{I}^- & \rightarrow \text{IO}^- + \text{H}_2\text{O} \\
\text{H}_2\text{O}_2 + \text{IO}^- & \rightarrow \text{I}^- + \text{H}_2\text{O} + \text{O}_2
\end{align*}
\]

**Sublimation of Dry Ice – 3 experiments**

Dry ice, 250mL beaker, small heat proof mat, water bottle, disposable glove or deflated balloon, OHP
OHP method

In Advance. Nil
When ready put a few lumps of dry ice into a Petri dish on an OHP. Students will be able to see that the solid will shrink in size but does not leave a pool of liquid.
Care not to leave it on too long or you may crack the lens! Also be aware that water ice may form below Petri dish.
Why? Solid CO2 at RTP sublimes.

Balloon method.

In Advance. Nil
When ready put a few small lumps into a balloon or into a rubber disposable glove. Knot the end. As the dry ice expands the balloon inflates. Passing it around the students can sense there is no liquid in the balloon but a gas is inflating it.
Why? Solid CO2 at RTP sublimes

Beaker Method

In Advance. Nil
When ready put a good handful of dry ice into a beaker. Wet a small heat proof mat and stand the filled beaker on it. Wait a few minutes. The beaker will freeze to the mat.
Why? When the carbon dioxide sublimes (no liquid seen) the energy to change state must come from somewhere –some comes from the liquid water thus freezing it. Water freezes at 0°C whilst CO2 sublimes at -78°C.
Alternative Fuels Experiments

Mini Hydrogen Rockets
2 adapted small coke bottles, piezoelectric ‘igniters’, zinc granules, 1M sulphuric acid, dried yeast, ‘dilute’ hydrogen peroxide (try 5 Vol%), 3x petri dishes, 250mL beaker of water. Disposable pipette teats.

In Advance Cut a small hole in the lid of a ‘coke bottle and insert a small diameter straw –the diameter should be small enough to fit into the head of a disposable plastic teat pipette. Repeat for a second bottle.

The Hydrogen Generator
Into one bottle put a few pieces of old granulated zinc and ¾ fill with 1.0M sulphuric acid. (the acid may need to be more dilute if hydrogen comes off at too fast a rate).

The Oxygen Generator
Put a few spatula loads of dried yeast into the second bottle and add ‘dilute’ hydrogen peroxide. (Again the hydrogen peroxide may need to be more dilute if the oxygen comes off at too fast a rate).

Ignition System
Solder a small piece (10cm) of twin bell cord to a piezoelectric gas cooker igniter so that when the lighter is squeezed a small spark will jump from one strand to another. Cut a coke bottle cap so that it will fit over the wire to catch any water drips when in use and prevent them from entering the piezoelectric lighter.

When ready. Fill the disposable pipette heads with water by squeezing out the air when under water (use a large beaker).
Insert the

Hydrogen Balloons (with or without helium balloons)
Party Balloons, thin string or cotton, metre ruler, sellotape or elastic band, source of ignition.

In Advance Fill a couple of large balloons with hydrogen gas from a hydrogen cylinder and possibly purchase some helium balloons (‘non metallic’) from any ‘party shop’. Tether with 5ft of thin string or cotton. Ensure flash detectors are switched to manual. Ensure no flammable material at balloon height within a 3m radius i.e. no curtains or loose posters.
When ready light a spill attached to the end of a metre rule and hold the flame against the underside of the balloon. The heat puts a hole in the balloon and lets the gas escape. If it is hydrogen a sheet of flame is seen and a loud pop is heard. It is more spectacular if the room is darkened.
Why? Hydrogen gas reacts explosively with the oxygen in the air making water. Helium of course is inert and balloons of it will only pop as if filled with air. Hydrogen is an alternative fuel that does not contribute to global warming (if produced by electrolysis using solar energy)
APPENDIX

The following pages contain lengthier experiments related to greenhouse gases or fuels.
The Laboratory Synthesis of Biodiesel from Vegetable Oil

Introduction

The use of reclaimed vegetable oil, from for example fast food restaurants, to fuel road vehicles has received a lot of attention in recent years. In this experiment you will be making biodiesel from virgin vegetable oil to avoid the extra complications of filtering out the ‘crunchies’. Also used veggie oil and requires a titration to determine the mass of sodium hydroxide needed to react due to the acidic break down products created in use. Historically it is interesting to note that he first engines developed by Rudolf Diesel were intended to run on vegetable oil and were later adapted to run on the lower viscosity and cheaper petroleum diesel.

Safety

Whilst in the Lab
- Lab coats must be worn and done up
- Safety glasses are to be worn
- No eating or drinking
- Mobile phones should be turned off
- No earpieces are to be worn.
- The safety sheet accompanying this experiment should be read and signed to say that you have read it.
- If you have any questions about what you are expected to do then ask a demonstrator or the academic present.

Structures of Molecules Involved

\[\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{COOCH}_2\]

\[\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{COOCH}\]

\[\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{COOCH}_2\]

A triglyceride molecule with three long chained fatty acids (all myristic acid)

\[\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{COOCH}_3\]

The methyl ester of myristic acid (the biodiesel)

\[\text{CH}_2\text{OHCH(OH)CH}_2\text{OH}\]

Glycerol (propan-1,2,3-triol)
Method

1. Measure out 14 cm$^3$ of methanol and put into the 100 cm$^3$ conical flask.
2. Weigh out 0.50g of sodium hydroxide pellets. Crush these pellets with a pestle and mortar and transfer all of this into the methanol.
3. Place the conical flask containing the methanol and NaOH onto a magnetic stirrer (remember to put the follower into the flask!) and stir for 5-10 minutes until the NaOH dissolves.
4. Measure out 60 cm$^3$ of vegetable oil and add this to the reaction flask. Heat this on a hot plate to a temperature between 40 and 50 °C for 20 to 30 mins with continuous stirring such that the mixture does not separate into two layers.
5. While still warm pour the mixture into a separating funnel and allow to cool and separate (partition) into two layers. Do not let it stand for too long or heat above 50 °C otherwise the lower layer may solidify. Let out the lower layer into a weighed beaker (which contains unreacted methanol. glycerol, a trace of water and salts).

The Glycerol Layer

1. Warm the glycerol layer on a hot plate in the fume cupboard to remove the methanol (TOXIC). Weigh the container.
2. Add a spatula load of anhydrous calcium sulphate (a drying agent) and stir with a dry rod. Leave stand for 20 mins.
3. Compare the viscosity of your sample of glycerol with that of a sample provided.
4. Weigh a clean and dry 10 cm$^3$, measuring cylinder. Pipette into this at least 3cm of glycerol (preferably more) and weigh again. The density can now be calculated. Compare this with the density of glycerol which is 1.26 g cm$^{-3}$.
5. IF AVAILABLE run an infrared spectrum of this sample (any salts will not show up).

The Biofuel Layer

1. The top layer in the separating funnel should be the biofuel. Vacuum filter this layer (using a Buchner filtration apparatus) into a clean, dry side arm flask. When complete compare the viscosity of the biodiesil with that of the original vegetable oil and of the glycerol you have made.
2. Measure the volume of the biodiesil produced. Calculate the percent (by volume) conversion of the vegetable oil to biodiesil. Compare your answer to the 70% conversion (by volume) that is expected.
3. Pour your samples of glycerol and biodiesil into the appropriate bottles.
4. Wash up and dry your glassware and clean down your work place.
Chemical Safety Data: for Biodiesel Experiment V1.0

Sodium Hydroxide

Principal hazards
Contact with the eyes can cause serious long-term damage
The solid and its solutions are corrosive
Significant heat is released when sodium hydroxide dissolves in water

Safe handling
Always wear safety glasses.
Do not allow solid or solution to come into contact with your skin.
When preparing solutions swirl the liquid constantly to prevent "hot spots" developing.

Emergency
Eye contact: Immediately flush the eye with plenty of water. Continue for at least ten minutes and call for immediate medical help.
Skin contact: Wash off with plenty of water. Remove any contaminated clothing. If the skin reddens or appears damaged, call for medical aid.
If swallowed: If the patient is conscious, wash out the mouth well with water. Do not try to induce vomiting. Call for immediate medical help.

Methanol

Principal Hazards Methanol is toxic. If ingested or inhaled it can cause a wide range of harmful effects, from sickness, heart and liver damage to reproductive harm, blindness or death.
Methanol is very flammable. The pure liquid catches fire easily and aqueous solutions containing a significant amount of methanol can also catch fire. The flame above burning methanol is virtually invisible, so it is not always easy to tell whether a methanol flame is still alight.

Safe handling Always wear safety glasses.
Remove any source of ignition from the working area.
You should not breathe in the vapour, so use a fume cupboard if available. If this is not possible, ensure that the area in which you work is very well ventilated.

Emergency
Eye contact: Immediately flush the eye with plenty of water. Continue for several minutes and call for medical help.
Skin contact: A person whose clothes are soaked in methanol will be at serious risk from fire, so immediately remove any contaminated clothing and store well away from a source of ignition (preferably outside). Wash exposed skin with soap and water. If the skin reddens or appears damaged, or if methanol may have been swallowed, call for medical aid.
If swallowed: Call for immediate medical help; if the quantity swallowed is significant urgent medical action is vital.
Safety Sheet for Biodiesel Experiment V1.0

Name of student: ____________________________________________

I have read and understood the safety information for this experiment.

Signed: ____________________________ Date: ________________
Prelab Questions

To get the most out of the lab experience you need to work through these questions in advance of the practical visit.

1. What is a lipid?

2. What structural features allow fats and oils to be classified as lipids?

3. Define the following:
   a. saturated fatty acid
   b. unsaturated fatty acid
   c. polyunsaturated fatty acid

4. What is the structure of glycerol?

5. What intermolecular forces does glycerol have and why do these lead to a high viscosity and high boiling point?

6. What is the arrangement of atoms in a n ester link?

7. Why do fatty acid esters and glycerol separate into different layers?

8. Why would the unreacted methanol and sodium hydroxide be more soluble in the glycerol layer rather than in the biodiesil?

Postlab Question

1. Why has the biodiesil better physical properties than the starting vegetable oil for use in an engine?
Further Reading

The Veggie Van Organisation www.veggievan.org

References

**Technicianing List**

Per pair of students

- Hotplate /stirrer with follower
- Measuring cylinders 10 cm³, 25 cm³, 100 cm³
- Conical flask 100 cm³
- Beaker 100 cm³
- Separating funnel 125 cm³
- Buchner Funnel, side arm conical and seal for suction filtration
- Qualitative filter paper e.g. Whatman number 1
- Pestle and mortar
- Stirring rod

**Access to**

- A top pan balance
- A sample of glycerol (for comparison purposes)
- A Water pump for Buchner apparatus
- Containers/bottles to deposit glycerol and biodiesel

**Chemicals per pair**

- Methanol (GPR) 14 mL
- Sodium hydroxide pellets 0.5g
- Vegetable oil 60mL

**Cleaning**

- Detergent and paper towel
What is a Fuel Cell?
A fuel cell is a device that converts chemical energy (within a fuel) into electrical energy.

The cell can be used with a very wide range of fuels. These include:

- Methanol CH$_3$OH, is readily available
- Methanal or methanoic acid.
- Ethanol CH$_2$CH$_2$OH or any ethanol containing drink!
- Almost any alcohol, or alcohol containing fluid, such as car windscreen wash
- Sodium tetrahydroborate (III), NaBH$_4$.

**Naming Convention.** The cathode is the terminal into which electrons flow. Some find the fact that the cathode is positive confusing, but it is the case for all primary cells, batteries as well as fuel cells. This makes it the negative terminal for electrolytic cells and diodes, but the positive for sources of electrical power.

At a simplistic level the reaction in the cell can be thought of as the reaction:

\[
\text{HYDROGEN + OXYGEN } \rightarrow \text{ WATER + ENERGY}
\]

With the energy is produced as electrical energy rather than heat energy as it would be if a fuel was burnt conventionally.

The electric current comes from the reactions that occur at each electrode - the anode and cathode. Electrons are released at one electrode and move through an external circuit as an electric current through to the other electrode.

At the anode the fuel is oxidized - electrons are removed. These electrons pass round the external circuit to the cathode. Here the oxygen reacts, using these
electrons. The fuel electrode, the source of electrons, is thus the electrically negative electrode. The air or oxygen electrode is the electrically positive electrode it attracts the negative electrons.

The reaction at the anode, is different for each fuel but the reaction at the cathode is the same in all cases.

**Reaction at the cathode**

Electrons from the external circuit are absorbed at the cathode, reacting with oxygen from the air and water in the electrolyte. The electrode equation is:

\[ 4e^- + O_2 + 2H_2O \rightarrow 4OH^- \]

Note that hydroxide (OH-) ions are formed which keeps the electrolyte solution alkaline.

**Reactions at the anode with a hydrogen containing fuel**

Note that in all these anode reactions OH\(^-\) ions are involved. This is why the electrolyte is the alkaline. A solution of potassium or sodium hydroxide is used into which the fuel is mixed.

The simplest anode reaction that could occurs is

\[ H_2 + 2OH^- \rightarrow 2H_2O + 2e^- \]

The electrons released form the electric current.

**Anode reaction when using NaBH\(_4\), sodium tetrahydroborate (III) as fuel**

There are two routes when using NaBH\(_4\) fuel. In the first the NaBH\(_4\) is directly oxidized, according to the equation:

\[ NaBH_4 + 8OH^- \rightarrow NaBO_2 + 6H_2O + 8e^- \]

This reaction is promoted by the platinum catalyst on the electrode. However, this catalyst also promotes a reaction that produces hydrogen:

\[ NaBH_4 + 2H_2O \rightarrow NaBO_2 + 4H_2 \]

These four hydrogen molecules then react to produce eight electrons, as shown in the earlier equation: The overall result is **ONE molecule** of NaBH\(_4\) gives **EIGHT electrons** i.e. the sodium tetrahydroborate (III) is a good fuel.

**NOTE** When using this fuel the hydrogen production rate can be faster than the rate of use (especially at low currents) or if too much fuel is used.
Anode reactions when using methanol fuel.

This is a three-stage reaction, with each reaction releasing 2 electrons.

In the first the methanol, CH$_3$OH, reacts to form methanal (formaldehyde), HCHO.

\[
\text{CH}_3\text{OH} + 2\text{OH}^- \rightarrow \text{HCHO} + 2\text{H}_2\text{O} + 2\text{e}^- 
\]

The next stage is the reaction of the methanal to methanoic (formic) acid, HCOOH.

\[
\text{HCHO} + 2\text{OH}^- \rightarrow \text{HCOOH} + \text{H}_2\text{O} + 2\text{e}^- 
\]

The methanoic acid is finally oxidized to carbon dioxide, releasing a further two electrons.

\[
\text{HCOOH} + 2\text{OH}^- \rightarrow \text{CO}_2 + 2\text{H}_2\text{O} + 2\text{e}^- 
\]

It should be possible to detect the carbon dioxide produced using a CO$_2$ meter if it is released into the atmosphere.

This fuel gives **SIX** electrons for each molecule of fuel, which is very good, though not quite as good as NaBH$_4$.

Since CO$_2$ is acidic it will react with the alkaline electrolyte making potassium carbonate. This gradually uses up the electrolyte.

\[
\text{CO}_2 + 2\text{KOH} \rightarrow \text{K}_2\text{CO}_3 + \text{H}_2\text{O} 
\]

Anode reaction with ethanol fuel

Ethanol, or an ethanolic solution can be used as a fuel but only one stage of oxidation happens. This releases only two electrons per molecule of fuel.

\[
\text{C}_2\text{H}_5\text{OH} + 2\text{OH}^- \rightarrow \text{CH}_3\text{CHO} + 2\text{H}_2\text{O} + 2\text{e}^- 
\]

The product ethanal, CH$_3$CHO smells a little of apples!
SAFETY SHEET

Broken Glass
If you break any glassware do not attempt to clear it up. Please draw the attention of your demonstrator or nearest technician to it for clearing it up. Report any cuts obtained.

Potassium Hydroxide Solution (1.0mole/dm$^3$)
Always wear safety glasses. Contact with the eyes can cause serious long-term damage. Do not allow solid or solution to come into contact with your skin. The solid and its solutions are corrosive.

Methanol (Methyl alcohol)
Always wear safety glasses. Work in effective ventilation. Toxic by inhalation, ingestion or skin absorption. May be a reproductive hazard. Ingestion may be fatal. Risk of very serious, irreversible damage if swallowed. Exposure may cause eye, kidney, heart and liver damage. Chronic or substantial acute exposure may cause serious eye damage, including blindness. Irritant. Narcotic. UK exposure limits: long-term 200 ppm, short term 250 ppm.

Methanoic Acid (Formic Acid)
Always wear safety glasses. Contact with the eyes can cause serious long-term damage. Do not allow the acid, or solutions of it, to come into contact with your skin. Ensure that you work in an area that is well ventilated.

Ethanol
Wear safety glasses. Work in effective ventilation. Causes skin and eye irritation. Ingestion can cause nausea, vomiting and inebriation; chronic use can cause serious liver damage. [Note that "absolute" alcohol, which is close to 100% ethanol, may nevertheless contain traces of 2-propanol, together with methanol or benzene. The latter two are very toxic].

Sodium Tetrahydroborate (III), NaBH$_4$
Wear safety glasses and gloves. Ensure adequate ventilation. Toxic by ingestion. Risk of serious internal burns if ingested. Harmful if inhaled and in contact with skin. May cause burns or severe irritation in contact with skin or eyes. Keep solid dry. Stable, but reacts readily with water (reaction may be violent). Incompatible with water and oxidizing agents.

Antifreeze(Ethylene Glycol. Ethan-1,2-diol)
Wear safety glasses. Ensure adequate ventilation. Harmful if swallowed. May be harmful if inhaled or in contact with the skin. Skin and respiratory irritant. Severe eye irritant. Typical OEL 10 – 25 ppm. Reproductive hazard.

I have read and understood the Risk Assessments

Signed ________________________________
An Investigation of a Fuel Cell –
Or Can You Get Electricity Out Of Vodka / White Rum/ Gin ?

Safety Glasses and Lab coats to be worn at all times

Work in Pairs

You will need:
- Fuel Cell
- Measuring cylinder, 100mL
- Measuring cylinder, 10mL
- Beaker 25 mL
- 4x Leads and crocodile clips
- Motor
- Multimeter (with its own leads)
- Spatula
- Potassium hydroxide solution 1.0M (250mL bottle)
- A White spirit such as gin or vodka
- Methanol
- Ethanol
- Sodium tetrahydroborate (III) NaBH₄ Solid or Alkaline solution
- Windscreen washer solution (contains ethan-1,2-diol)
- Household methylated spirits

Access to
- A top pan balance
- Heating mantle (if temperature as a factor is being investigated)

The mini fuel cell consists of two components; red cathode, and a beaker-like anode, as shown below.
To Investigate the Fuel Cell Current Produced By Different Fuels

Safety Glasses and Lab coats to be worn at all times

Method

1. Remove the red cathode from the beaker anode.
2. Add potassium hydroxide solution* (1.0 mol dm⁻³) to the anode beaker until the level reaches the fill line. This will take about 65 cm³.
3. Add fuel being investigated:
   - For a liquid fuel measure out 5 cm³ using a measuring cylinder.
   - In the case of the solid sodium tetrahydroborate (III), NaBH₄ this must only be about 20 mg (0.02g), a very small pile on the end of a spatula or about 0.02 cm³ or 2 mm³.
   - *NB If a solution of sodium tetrahydroborate (III), NaBH₄ is provided this will be have the correct mass of the solid already dissolved in KOH so you do not need the 65 cm³ of KOH as in the other cases.
4. Gently swirl the anode beaker for a second or two to dissolve the fuel in the electrolyte. (In the case of NaBH₄ this will take a little longer, say 10 seconds. Small bubbles will be seen on the black electrode when this is complete.)
5. Attach the leads to the red cathode and connect the multimeter to the leads.
6. Insert the red cathode into the anode beaker. Swirl gently to clear any gas bubbles.
7. Measure the current with the ammeter once it has settled down.
8. Disconnect the meter and see if sufficient current is produced to run the motor or the bulb or the music cell.
9. When finished with this fuel swirl the electrolyte/fuel solution down the sink and wash way. Rinse the cell with distilled water.
10. Measure out a fresh portion of potassium hydroxide and add the next fuel to be investigated.
11. On completion the electrodes should preferably be gently dried using paper tissue.

NOTE. In use the electrolyte/fuel mixture will take some of the black colouring out of the anode - this is inevitable, and gradually declines during the first few uses of the cell.
Investigation of the Effect of Electrolyte Concentration on Current Produced.

Premise. The rate of chemical reactions is increased by an increase in concentration of reactants. Is this the case for the concentration of electrolyte?

Safety Glasses and Lab coats to be worn at all times

Method

You will need to decide one which fuel you are going to keep constant.

1. Remove the red cathode from the beaker anode.
2. Measure out 65cm$^3$ of the potassium hydroxide solution* (1.0 mol dm$^{-3}$) to the anode beaker until the level reaches the fill line. This will be about 65 cm$^3$.
3. Add the fuel being investigated:
   - For a liquid fuel measure out 5 cm$^3$ using a measuring cylinder.
   - *NB If a solution of sodium tetrahydroborate (III), NaBH$_4$ is provided this will be have the correct mass of the solid already dissolved in KOH so you do not need the 65 cm$^3$ of KOH as in the other cases
4. Gently swirl the anode beaker for a second or two to dissolve the fuel in the electrolyte. (In the case of NaBH$_4$ this will take a little longer, say 10 seconds. Small bubbles will be seen on the black electrode when this is complete.)
5. Attach the leads to the red cathode and connect the multimeter to the leads
6. Insert the red cathode into the anode beaker. Swirl gently to clear any gas bubbles.
7. Measure the current with the ammeter once it has settled down.
8. For amusement disconnect the meter and see if sufficient current is produced to run the motor or the bulb or the music cell. This stage is not necessary.
9. When finished with this fuel swill the electrolyte/fuel solution down the sink and wash way. Rinse the cell with distilled water.
10. Measure out a fresh portion of potassium hydroxide and water according to the table below. Add the same volume of fuel as before and measure the current.
11. Repeat for different concentrations of potassium hydroxide.
12. On completion the electrodes should preferably be gently dried using paper tissue

NOTE. In use the electrolyte/fuel mixture will take some of the black colouring out of the anode - this is inevitable, and gradually declines during the first few uses of the cell.
Name; __________________________________________

Investigation of the Effect of Electrolyte Concentration on Current Produced.

<table>
<thead>
<tr>
<th>Run</th>
<th>Volume of 1.0 mol/dm³ KOH</th>
<th>Volume of Water Added /cm³</th>
<th>Concentration of KOH / mol/dm³</th>
<th>Current /A Run 1</th>
<th>Current /A Run 2</th>
<th>Average Current /A</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>80</td>
<td>0</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>2</td>
<td>70</td>
<td>10</td>
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<td>3</td>
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<td>20</td>
<td>0.75</td>
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<td></td>
</tr>
<tr>
<td>4</td>
<td>50</td>
<td>30</td>
<td>0.63</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>5</td>
<td>40</td>
<td>40</td>
<td>0.50</td>
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<td></td>
</tr>
<tr>
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<td>30</td>
<td>50</td>
<td>0.38</td>
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</table>

Notes:
To Investigate the Current Produced in a Fuel Cell at Different Temperatures

Safety glasses and lab coats to be worn at all times

Method

1. Remove the red cathode from the beaker anode.
2. Add potassium hydroxide solution* (1.0 mol dm$^{-3}$) to the anode beaker until the level reaches the fill line. This will take about 65 cm$^3$.

3. Measure out 5 cm$^3$ using a measuring cylinder of the fuel being investigated.
4. Gently swirl the anode beaker for a second or two to dissolve the fuel in the electrolyte. Small bubbles will be seen on the black electrode when this is complete.

5. Take the temperature of the fuel alkali mixture.
6. Attach the leads to the red cathode and connect the multimeter to the leads.
7. Insert the red cathode into the anode beaker. Swirl gently to clear any gas bubbles.

8. Measure the current with the ammeter once it has settled down.
9. Disconnect the meter and see if sufficient current is produced to run the motor or the bulb or the music cell. This step is not essential.

10. When finished with this fuel swill the electrolyte/fuel solution down the sink and wash way. Rinse the cell with distilled water.
11. Warm up a fresh portion of potassium hydroxide WITHOUT THE FUEL to a temperature about 5°C higher than wanted.

12. Now then add the fuel and put the mixture into the cell and take the temperature.
13. Measure the current.
14. Repeat at a different temperature.

NOTEs. On completion the electrodes should preferably be gently dried using paper tissue in use the electrolyte/fuel mixture will take some of the black colouring out of the anode - this is inevitable, and gradually declines during the first few uses of the cell.
To Investigate the Current Produced in a Fuel Cell at Different Temperatures

Name: _________________________________

<table>
<thead>
<tr>
<th>Expt.</th>
<th>Target Temperature Of Electrolyte °C</th>
<th>Actual Temperature Of Electrolyte °C</th>
<th>Run 1 Current /A</th>
<th>Run 2 Current /A</th>
<th>Average Current /A</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Room Temperature</td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>2</td>
<td>30</td>
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<tr>
<td>5</td>
<td>60</td>
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</tbody>
</table>

NOTES
Technicianing notes

This pack of notes contains students' instructions for several investigations. The equipment list is for all of them

It is assumed that students will work in pairs

Students will need:

The appropriate experiment scripts

Equipment

Safety Glasses and Lab coats
Disposable gloves
Fuel Cell
Measuring cylinder,100mL
Measuring cylinder,10mL
Beaker 25 mL
4x Leads and crocodile clips
Multimeter (with its own leads)
Spatula
Thermometer

Chemicals

Potassium hydroxide solution 1.0M (250mL bottle)
A White spirit such as gin in 100mL bottle labelled ‘For lab use only’
Methanol in 100mL bottle labelled.
Ethanol in 100mL bottle labelled.
Windscreen washer solution (contains ethan-1,2-diol)
Household methylated spirits

Sodium tetrahydroborate (III) NaBH₄ Solid in a labelled sample tube.
OR sodium tetrahydroborate (III) equivalent of 0.02g per 65mL of 1.0M KOH. labelled as sodium tetrahydroborate (III) in KOH.
All chemicals to have appropriate hazard labels.

Optional
Music cell
Low current mounted bulb
Motor

Access to
A top pan balance (not needed if an alkaline solution of sodium tetrahydroborate (III) used.
Heating mantle (if temperature as a factor is being investigated)
Lab roll/paper towels
Distilled water
It might be simpler to prepare bulk KOH solution and fuel mixture, and keep this in a bottle. It should not deteriorate, and saves trouble, especially the dispensing of very small amounts of NaBH₄.

On completion the electrodes should preferably be gently dried using paper tissue.

**NOTE.** In use the electrolyte/fuel mixture will take some of the black colouring out of the anode - this is inevitable, and gradually declines during the first few uses of the cell.

### Additional Worksheets

*Alcohols as Fuels*

*Grätzel Cells will be distributed separately*

### *Alcohols as Alternative Fuels*

Grätzel Cells