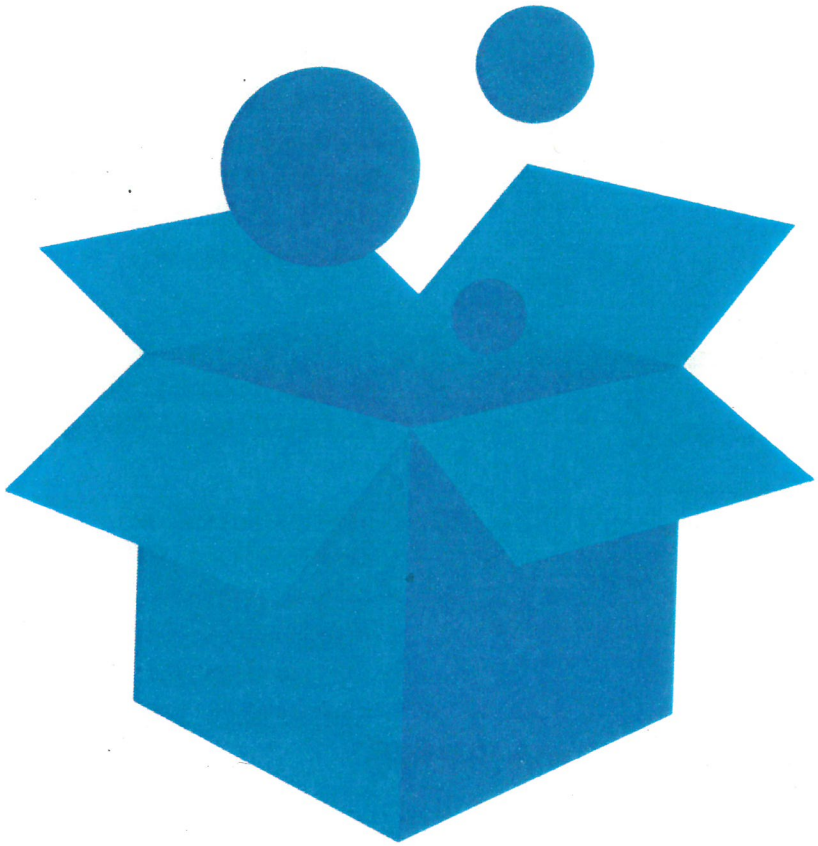
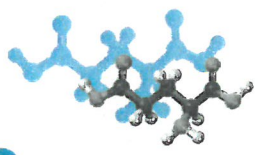
ChemBox 2017



Experiments are all supported by our website www.chembam.com

@chembameditor #chembox2017

- Carbon for water treatment
- Sensing with fluorescence
- Nanotech for waterproofing
- Cages for nuclear waste
- Biopolymers for cancer
- Fuel cells for energy



ChemBam

ChemBox 2017 kit:

Generic kit

Magnetic stirrer plates (6)
Magnetic stirrer bars (12)
Plastic 50 mL measuring cylinders (6)
Plastic 250 mL beakers (12)
Plastic funnels (12)
Weighing boats
Filter paper
Digital balances (4)
Permanent pens (12) – to label beakers
Plastic pipettes (100)
Spatulas (12)
100 mL glass conical flasks (12)
Safety glasses (24)

Carbon for water treatment

Laminated safety card
Crushed BBQ charcoal (100 g)
Methylene blue (2 g)
Activated carbon (200 g)

Sensing with fluorescence

Laminated safety card
Vitamin B2 capsules (48)
Washing powder (10 g)
Turmeric (45 g)
Tonic water (4 cans)
pH indicator paper (0-14)
1M HCl (aq) (50 mL)
1M NaOH (aq) (50 mL)
Ethanol (250 mL)
Plastic vials for solutions (50)
UV LED Flashlight
Sample bags (100)

This experiment requires FRESH SPINACH LEAVES

Nanotech for waterproofing

Dried lotus leaves (6)
Aluminium foil (sheet)

Cages for nuclear waste

Laminated safety card
Zeolite A powder (100 g)
Copper sulfate (s) (50 g)
Universal indicator solution (10 mL)
Citric acid (10 g)

Biopolymers for cancer

Laminated safety card
High G Alginate, Manugel GHB (15 g)
High M Alginate, ProtaSea AFH (15 g)
Red food colouring (5 g)
Green food colouring (5 g)
$FeCl_3$ (s) (5 g)
$CaCl_2$ (s) (5 g)

Fuel cells for future energy

Laminated safety card
Blu tack
Insulating tape
LEDs (24)
9 V batteries (12)
Crocodile clips and wires (30)
2 pence pieces (12)
Galvanised screws (pack)
Pencils (30)
Potassium hydroxide (100 g)
pH indicator paper (0-14)

This experiment requires FRESH POTATOES and voltmeters. Pencils need sharpening at both ends with a knife to make electrodes.

ChemBam

Sensing with fluorescence

ChemBam

SAFETY SHEET

Sensing genetic disorders with fluorescence

Substance	Hazard	Comment
Ethanol		H225 Highly flammable liquid and vapour H319 Causes serious eye irritation P210 Keep away from heat/sparks/open flames P280 Wear eye protection
1 M HCl (aq)		H290 May be corrosive to metals No precautionary statements
1 M NaOH (aq)		H290 May be corrosive to metals H314 Causes severe skin burns and eye damage P280 Wear eye protection
UV Lamp		Do not shine directly into eyes Do not expose skin to the light for excessive periods of time

Typical control measures to reduce risk

- Keep volumes of ethanol used low
- Keep careful control of stocks and UV source to prevent theft
- Set up UV lamp in a specific area, clamped on a retort stand if a torch, pointing away from user to prevent looking directly at the UV rays.

Assessing the risks

- What are the details of the activity to be undertaken? What are the hazards?
- What is the chance of something going wrong? *Eg, Is there the possibility of theft or foolish behaviour?*
- How serious would it be if something did go wrong?
- How can the risk(s) be controlled for this activity?

Emergency action

- **In the eye** — If solutions get in the eye, rinse for several minutes. Remove contact lenses if present and easy to do so and continue rinsing. If eye irritation persists see a doctor.
- **On skin** — If HCl(aq) or NaOH(aq) solution is spilt on skin, remove contaminated clothing and rinse with water.
- **Swallowed** — Do no more than wash the mouth with water. Do **not** induce vomiting. See a doctor.
- **Spilt on the floor, bench, etc** — Wipe any spilled ethanol solutions up with absorbent cloths.
- **Ethanol catches fire** — Report immediately to a fire marshal. Trained personnel: use water spray, alcohol-resistant foam, dry chemical or carbon dioxide.

ChemBam

Sensing genetic disorders with fluorescence

AIM

To make a selection of fluorescent solutions, and a molecular fluorescence pH sensor

YOU WILL NEED

- UV Lamp
- Beakers, conical flasks and glass stirring rods
- Filter paper and funnels
- Spatulas
- Ethanol
- 1M HCl (aq)
- 1M NaOH (aq)
- Spinach leaves
- Non-bio washing powder
- Turmeric (ground)
- Tonic water
- Vitamin B2 (riboflavin) tablets (capsules)
- Distilled water
- Universal indicator pH paper

PROCEDURE

Part 1:

Firstly, make up 5 fluorescent solutions, from materials that can be found in everyday items within the home.

In order to make up an **ethanolic chlorophyll solution**, crush up ~ 5 g of spinach leaves in 25 mL ethanol. (The easiest way to do this is to put the leaves in a sample/sandwich bag with the ethanol, and mash the leaves for several minutes with your hands.) Filter this solution, discarding the solid, and collect the green filtrate into a conical flask, labelled 'ethanolic chlorophyll'.

To make up an **ethanolic curcumin solution**, dissolve a spatula full (~0.3 g) of turmeric in 25 mL ethanol, and stir the solution well. Filter this solution and collect the yellow filtrate in a labelled conical flask.

To make up an **aqueous stilbene solution**, dissolve 2 g of non-bio washing power in 50 mL distilled water, stirring carefully so as not to create lots of bubbles. Filter this solution and collect the colourless filtrate into a labelled conical flask.

For the **aqueous quinine solution**, simply pour 25 mL tonic water into a labelled conical flask.

Finally, in order to make up an **aqueous riboflavin solution**, empty the contents of 1 vitamin B2 capsule into a beaker containing 50 mL distilled water, and stir the mixture thoroughly (note - much of the content will not dissolve well). Filter the mixture and collect the yellow filtrate into a labelled conical flask.

Pipette a few mLs of each solution into test tubes/small vials and look at them under UV light. Look at a sample of water and ethanol also, as a control. Record the colour of the solutions in daylight and also when they fluorescence under UV light.

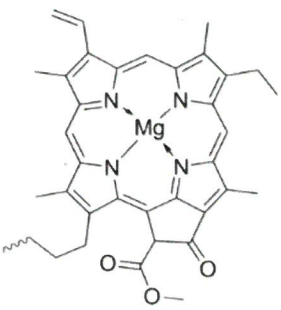
ChemBam

Part 2:

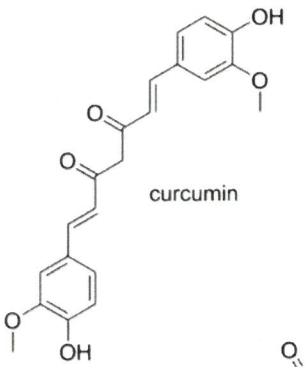
Now you can make a solution that can be used as a fluorescence sensor; to do this we need to use a molecule that responds to an input, and change the way in which it fluoresces - Take 2 test tubes and add 5 mL of distilled water and 1mL of the **aqueous riboflavin solution** to each, and mix them with a glass stirring rod. Test the pH of the solutions with universal indicator paper. With one of the test tubes, add a few drops of 1 M HCl and stir, until the pH of the solution reaches 1. Now look at the two solutions under a UV lamp, and compare the fluorescence. You can reverse the change by adding 1 M NaOH dropwise, bringing the pH back to 7. You can also see what happens to the fluorescence when the pH reaches 14.

QUESTIONS

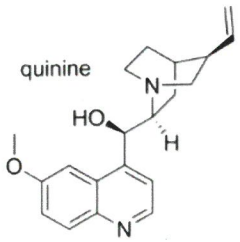
1. Looking at the structures of the molecules that are fluorescent, what do you notice that they all have in common?

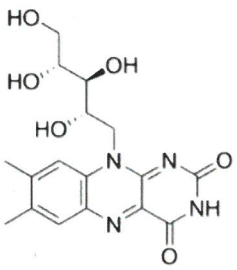


chlorophyll

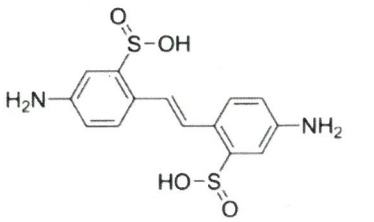


curcumin





riboflavin



4,4'-diamino-2,2'-stilbenedisulfonic acid

2. What are the fluorescent molecules doing when you shine UV light on them? What type (wavelengths) of light are they absorbing? What type of light are they emitting?
3. Why do you think fluorescent stilbene molecules are added as optical brighteners to washing powders? Paper also contains similar optical brighteners, have a look at some white paper in the dark under the UV lamp.
4. Is fluorescence a fast process? Does the fluorescence stop when you switch off the UV lamp?
5. Look at the two riboflavin solutions, what effect does the pH have on the fluorescence? Is the effect reversible? Looking at the molecular structure of riboflavin, can you suggest what is happening at low and high pH? (hint - you are affecting the N atoms in the ring system) Why does this affect the fluorescence?

ChemBam

Sensing genetic disorders with fluorescence – guide for teachers

AIMS

- For students to appreciate that many everyday items and fluorescent; teeth, highlighter pens, white clothing, bank notes, driving licenses, cheques, stamps, etc.

- For students to understand that 'fluorescent' materials absorb light, and re-emit light at a different wavelength (i.e. absorb UV light and emit visible light of a given colour)

- For students to understand that a sensor is a device that responds to an input, to give a measureable output. The fluorescence experiment uses riboflavin as a pH sensor; the brightness of the emission depends upon the pH of the solution. (This is because the emission depends upon which species is in solution, and there are several possible species across the pH range 1-14, due to the pKas of the various ring N-H bonds in the riboflavin molecule.)

- For students to understand that in the research lab, fluorescence sensors are being developed that respond to which DNA base is present in a sequence of DNA, so that we can detect SNPs, which can indicate disease.

QUESTIONS – answer guide for teachers

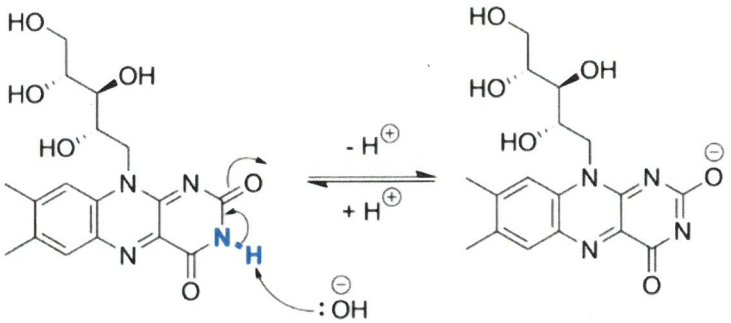
1. The structures of organic fluorescent molecules all tend to have conjugated pi-electrons in them. Students should be able to recognise that all the molecules contain several double-bonds. This could be extended to point out that they all have alternating double-single-double-single bonds, like benzene, and this leads to the electrons being delocalised over a large part on the molecule. When a molecule is 'excited' by absorbing UV-Visible light, these electrons excite to a higher energy level, before relaxing back down and emitting light.

2. When a molecule is 'excited' by absorbing UV-Visible light, the electrons in the molecule excite to a higher energy level, before relaxing back down and emitting light, of a lower energy (a blue-shifted colour, a longer wavelength)

3. Optical brighteners are added to washing powders so that when we stand in the sun, which produces quite a lot of UV light, out white clothes fluoresce slightly, and they look 'bright white'.... They may not be overly clean, they just look clean!

4. Fluorescence is fast, the re-emission of light usually happens within 1 ns of the molecule absorbing light; hence when you switch off the UV light source, you can't see any fluorescence. (Note, 'glow in the dark' paints and ceiling stars are phosphorescent, which is a much slower process, and these emit light a long time after absorbing the excitation light)
5. At pH1/0 the solution is very dim yellow under UV, it is brightest at pH7, and then the fluorescence switches off completely at pH14. At pH 14 the N-H on the ring is deprotonated by the OH- base present, and forms a different molecule:

ChemBam



(pKa ~10)

ChemBam

Sensing genetic disorders with fluorecence (preparation details for teachers and technicians)

SAFETY

Ethanol	H225 Highly flammable liquid and vapour H319 Causes serious eye irritation P210 Keep away from heat/sparks/open flames P280 Wear eye protection
HCl conc.	H290 May be corrosive to metals H314 Causes severe skin burns and eye damage H335 May cause respiratory irritation P261 Avoid breathing vapours P280 Wear protective gloves/eye protection P305+P351+P338 IF IN EYES: Rinse with water, remove contact lenses if present, and continue rinsing cautiously P310 Immediately call a POISON CENTRE or doctor
NaOH	H314 Causes severe skin burns and eye damage P280 Wear protective gloves/clothing/eye protection P305+P351+P338 IF IN EYES: Rinse with water, remove contact lenses if present, and continue rinsing cautiously P310 Immediately call a POISON CENTRE or doctor
UV Lamp	Do not shine directly into eyes Do not expose skin to the light for excessive periods of time Use with guidelines provided with the specific lamp/torch used

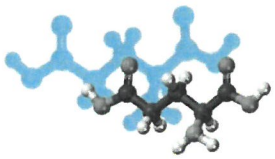
TO BUY

Spinach: Fresh spinach leaves can be purchased from a supermarket – they tend to last around a week in the fridge. If you decide to make up the chlorophyll solution before the experiment note that the ethanolic chlorophyll solution degrades rapidly – within 24 hours, and the green solution turns brown. A solution can be made up and kept for up to 48 hrs if wrapped in foil and kept in the fridge.

Washing powder: For the images used on the website we non-biological own brand washing powder purchased from a supermarket. Most washing powders contain 'optical brighteners', especially those which are specifically for white clothing.

Turmeric: Turmeric powder can be purchased from the supermarket for this experiment, or curcumin can be sourced from a chemical supplier. Supermarket turmeric was used for the photographs on the website.

Tonic water: Any tonic water contains quinine; cheap home-brand tonic water was used in the photographs on the website.



Vitamin B tablets: The tablets used for the demonstrations on the website were sourced online from Swanson (Riboflavin Vitamin B2 100 mg, 100 Capsules). Capsules are easy to open and pour the solid out of, and these work well. Be careful not to get mixed vitamin tablets, as other vitamins (such as B12) are also fluorescent, and will complicate this experiment.

UV Torch/Lamp: We purchased an inexpensive (<£10) UV LED Flashlight from Moobom for the photographs online. The fluorescence is much better to see in a dark room, although a setup can easily be made with a dark box and a viewing panel, or a TLC reader. Black bulbs could also be used; this just needs testing with the tonic water, to make sure that you can see the blue fluorescence.

TO PREPARE IN ADVANCE

1 M HCl (aq) solution

Dilute concentrated HCl down to form 500 mL of 1 M solution. 10 mL of 1 M acid will be enough per group for this activity. Always add the acid to water, **NOT** water to the concentrated acid. For example, add 40 mL 37% HCl to 300 mL of deionised water, and top this up to 500 mL with deionised water to make a 1 M solution. Do this dilution in a fumehood.

1M NaOH (aq) solution

Dissolve 20 g of NaOH in 500 mL of deionised water. Always add the base to water.

UV Lamp

Set up a UV viewing station, either in a dark room, or within a dark box with a viewing hole. If a torch is used, clamp the torch with a retort stand pointing away from viewers eyes.

STUDENTS WILL NEED

- Glass beakers (*4 100 mL)
- Glass stirring rods
- Conical flasks (*5 50 mL)
- Measuring cylinder, to measure 25 mL ethanol, 50 mL deionised water, 5 mL deionised water and 1 mL riboflavin solution
- Filter papers and funnel (*4 per group)
- 5 g spinach leaves
- Turmeric (1 pot for the whole class, ~0.2 g per group)
- Washing powder (500 g will last ages)
- Tonic water (each group only needs a few mL to see under the UV lamp)
- Vitamin B2 capsules (1 per group)
- Spatulas (Weighing boats / paper) (although weighing is not really necessary)
- Ethanol (50 mL per group)
- 1 M HCl (aq) (~10 mL per group)
- 1 M NaOH (aq) (~10 mL per group)
- Universal indicator paper (to determine pH 0/7/14)
- Distilled water (110 mL per group)
- A UV viewing station

Cages for nuclear waste

ChemBam

SAFETY SHEET

Cages for nuclear waste

Substance	Hazard	Comment
Copper(II) sulfate solution (0.8 M)		H302 Harmful if swallowed H319 Causes serious eye irritation H410 Very toxic to aquatic life with long lasting effects P273 Avoid release into the environment
Citric acid solution (5 mM)		H319 Causes serious eye irritation P280 Wear eye protection P305+P351+P338 IF IN EYES: Rinse with water, remove contact lenses if present, and continue rinsing cautiously
Zeolite A powder (4 Å molecular sieves)		H315 Causes skin irritation H319 Causes serious eye irritation H335 May cause respiratory irritation P261 Avoid breathing dust P305+P351+P338 IF IN EYES: Rinse with water, remove contact lenses if present, and continue rinsing cautiously
Universal indicator solution		H226: Flammable liquid and vapour H319: Causes serious eye irritation P210: Keep away from heat P301+P351+P338: IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.

Typical control measures to reduce risk

- Wear goggles to protect eyes from solutions
- Highlight to students to avoid breathing in the zeolite powder dust
- Remind students to wash hands after handling solutions

Assessing the risks

- What are the details of the activity to be undertaken? What are the hazards?
- What is the chance of something going wrong? *Eg, Is there the possibility of theft or foolish behaviour?*
- How serious would it be if something did go wrong?
- How can the risk(s) be controlled for this activity?

Emergency action

- **In the eye** — If solutions get in the eye, rinse for several minutes. Remove contact lenses if present and easy to do so and continue rinsing. If eye irritation persists see a doctor.
- **On skin** — If copper(II) sulfate/citric acid/universal indicator solution is spilt on skin, remove contaminated clothing and rinse with water.
- **Swallowed** — Do no more than wash the mouth with water. Do **not** induce vomiting. See a doctor.
- **Spilt on the floor, bench, etc** — Wipe any spilled solutions up with absorbent cloths.

ChemBam

Cages for nuclear waste

AIM

To observe ions exchanging from solution into the zeolite cavities of molecular sieves

YOU WILL NEED

- glass conical flasks
- 2% w/v copper(II) sulfate solution
- 0.1% w/v citric acid (aq) solution
- universal indicator solution
- Zeolite A powder (4 Å molecular sieve powder)
- measuring cylinder (for 50 mL)
- stirring rod
- plastic Pasteur pipette
- test tubes / vials
- spatula
- filter

PROCEDURE

Part 1: Ion exchange of Cu^{2+} ions

Measure out 50 mL of copper sulfate solution into two glass conical flasks, labelled A and B. Keep flask A as a control solution. Add 1 g of zeolite powder to solution B, and swirl the solution, continually for 5 min. Leave the solution to settle and move on to part 2.

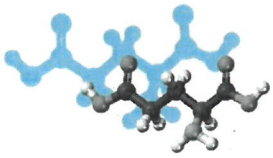
Part 2: Ion exchange of H^+ ions

Measure out 100 mL of citric acid solution into a beaker, and add 0.5 mL of universal indicator into the solution. Stir the solution, and note the colour and pH of this solution. Divide the solution into two glass conical flasks, labelled C and D. Keep flask C as a control solution, and add 1 g of zeolite powder to the solution, and swirl for 1 min. Note the colour change that you observe. Leave the solution to settle for 5 min.

Observations:

Without disturbing the settled solutions (B and D) note what you observe in each case. Carefully remove 2 mL of solution A and solution B (without disturbing the solid at the bottom) into separate test tubes / vials, and compare the colours. Finally, scoop out some of the solid from the bottom of solution B, onto some filter paper, and observe its colour.

ChemBam



QUESTIONS

1. Look at solutions A and B. When copper(II) ions are present in water, they have a blue colour. Compare the colour of the solutions taken from A and B – what do you notice?
2. Looking at the zeolite that has settled in solution B, what colour is this? What does this tell you about where the copper ions have gone from the solution?
3. What has replaced the Cu^{2+} ions from the zeolite, in this ion exchange experiment?
4. Looking now at solutions C and D – what is the pH of solution C? What is the pH of solution D? pH is a measure of H^+ concentration, as the pH gets lower, the concentration of H^+ increases. Which solution contains more H^+?
5. Can you explain what has happened to the solution in terms of ion exchange with the zeolite?
6. We have zeolites in the water filters in our dishwashers to 'soften water'. As the hard water runs through the filter, Ca^{2+} and Mg^{2+} ions exchange with Na^+ ions in the filter. Why do you think we have to add dishwasher salt (NaCl) to the filter every so often?
7. How do you think zeolites could be used to clean up nuclear waste in contaminated water? Once the zeolites have swapped all their Na+ ions with radioactive ions, what do you think is the main problem that we need to overcome?

ChemBam

Cage for nuclear waste (teacher guide to exercises and experiments)

AIM

- For students to observe the ion exchange properties of zeolite
- For students to appreciate that radioactive ions can also be exchanged into the zeolite pores, in order to trap nuclear waste

EXPERIMENT QUESTIONS– answer guide for teachers

1. Solution A, the control solution will be more blue in colour than solution B, as copper(II) ions have exchanged with sodium(I) ions from the zeolite in B, so there is less copper(I) in the solution. (Copper(II) ions in solution form $[Cu(H_2O)_6]^{2+}$ hexa-aqua complexes, which are blue.)
2. The zeolite powder (which is white initially) will take on a blue colour, as copper is trapped in the pores. This demonstrates that Cu^{2+} ions from the solution have exchange with colourless Na^+ ions in the zeolite pores, making the solid blue in colour.
3. Na^+ ions. Every Cu^{2+} ion exchanges with 2 Na^+ ions, to balance charge and keep the whole zeolite structure neutral. Also, water from the solution can enter the pores.
4. Solution C will look red, and is approximately pH 3. Once zeolite is added and the solution is swirled, the pH will increase, because H^+ ions from the citric acid solution will exchange with Na^+ ions in the zeolite, reducing the concentration of H^+ ions in solution, and therefore increasing the pH.
5. The pH will increase, because H^+ ions from the citric acid solution will exchange with Na^+ ions in the zeolite, reducing the concentration of H^+ ions in solution, and therefore increasing the pH.
6. Eventually the zeolite becomes saturated, as all the pores are filled with Ca^{2+} and Mg^{2+} ions, and therefore the filter stops removing these ions from the water. In order to regenerate the filter, it needs to be flushed with salt to exchange all the Mg^{2+} and Ca^{2+} ions back with Na^+ ions.
7. Contaminated water containing radioactive cations, such as Cs^+ ions can be passed through zeolite-type structures, to exchange with Na^+ ions, and trap the radioactive ions within the solid structure. The problem is that the ions are mobile and can easily be exchanged out again, and can be leached back out of the structure. Therefore the ions need to be permanently entrapped within the cage structure, after they have been exchanged in.

ChemBam

Cages for nuclear waste (preparation details for teachers and technicians)

SAFETY

$CuSO_4 \bullet 5H_20$	H302 Harmful if swallowed H315 Causes skin irritation H319 Causes serious eye irritation H410 Very toxic to aquatic life with long lasting effects P273 Avoid release to the environment P305+P351+P338 IF IN EYES: Rinse with water, remove contact lenses if present, and continue rinsing cautiously
Citric acid	H319 Causes serious eye irritation P280 Wear eye protection P305+P351+P338 IF IN EYES: Rinse with water, remove contact lenses if present, and continue rinsing cautiously
Universal Indicator Solution	H226: Flammable liquid and vapour H319: Causes serious eye irritation P210: Keep away from heat P301+P351+P338: IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
4 Å molecular sieve powder	H315 Causes skin irritation H319 Causes serious eye irritation H335 May cause respiratory irritation P261 Avoid breathing dust P305+P351+P338 IF IN EYES: Rinse with water, remove contact lenses if present, and continue rinsing cautiously

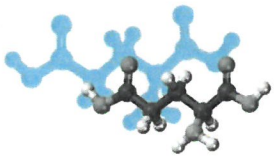
TO BUY

4 Å molecular sieve powder – this can be bought on Fisher scientific from Alfa Aesar (CAS 70955-01-0). Beads can be used, but the process is a lot slower and decolouration of the copper solutions takes a lot longer to observe.

$CuSO_4 \bullet 5H_20$ – can be purchased from a chemical supplier

Citric acid – can be purchased from a chemical supplier or a food supplier

ChemBam



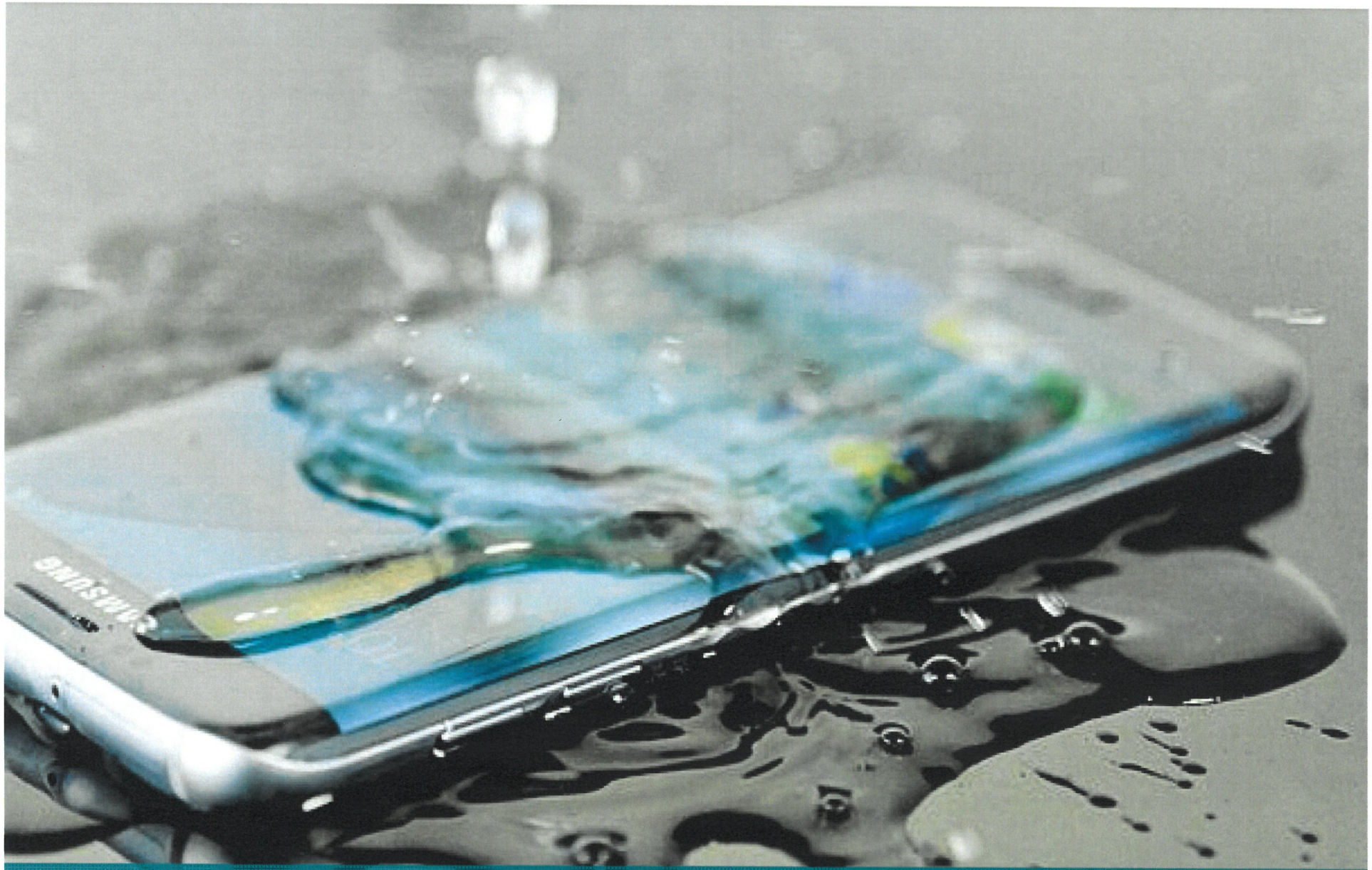
TO PREPARE IN ADVANCE

2% w/v Copper(II) sulfate (aq) solution
Each group of students requires 100 mL of solution. To make up 1 L of solution (for 10 groups) weigh out 20 g of $CuSO_4 \bullet 5H_20$ powder, and dissolve in 1 L of deionised water. (This solution is 0.08 M)

0.1% w/v citric acid (aq) solution
Each group of students requires 100 mL of solution. To make up 1 L of solution (for 10 groups) weigh out 1 g of citric acid powder, and dissolve in 1 L of deionised water. (This solution is 5 mM)

STUDENTS WILL NEED

- Glass conical flasks (*4 100 mL)
- 2% w/v copper(II) sulfate (aq) solution (100 mL)
- 0.1% w/v citric acid (aq) solution (100 mL)
- Universal indicator solution (0.5 mL per group)
- Zeolite A powder (2 g per group)
- Measuring cylinder (to measure 50 mL volume)
- Stirring rod
- Plastic Pasteur pipette
- Test tubes / vials (2 per group)
- Spatula
- Filter paper
- Weighing boats



Nanotech for waterproofing

ChemBam

Nanotech for waterproofing

AIM

To observe the effect of a natural functional nanomaterial with water, and compare it with flat surfaces of paper and foil

YOU WILL NEED

- A plastic Pasteur pipette
- 1-2 mL tap water
- a sheet of paper
- a small square of aluminium foil
- a square of a dried lotus leaf

PROCEDURE

Firstly take a sheet of paper, and drop a droplet of water onto the paper. Look at the droplets side-on, and draw the shape that you see. Tilt the paper and see if the droplet likes to 'stick' to the paper. Repeat this with foil. Finally, take a dried lotus leaf and try this.

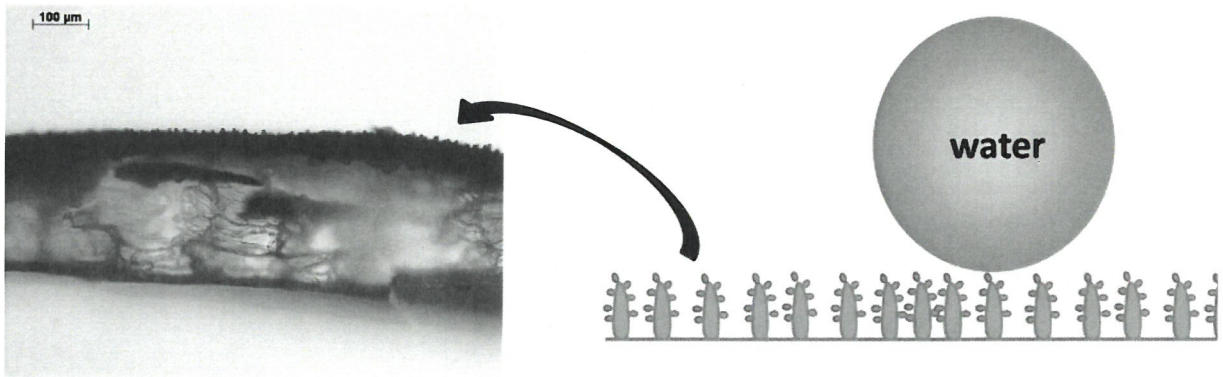
QUESTIONS

1. Which material repels the water the most? Which material attracts the water the most?

2. If you wanted to make a water-repellant surface, which surface would you try to replicate?

3. Do both sides of the lotus leaf behave the same?

MICROSCOPE IMAGE OF A LOTUS LEAF, SIDE ON:



ChemBam

Nanotech for waterproofing (teacher guide to exercises and experiments)

AIM

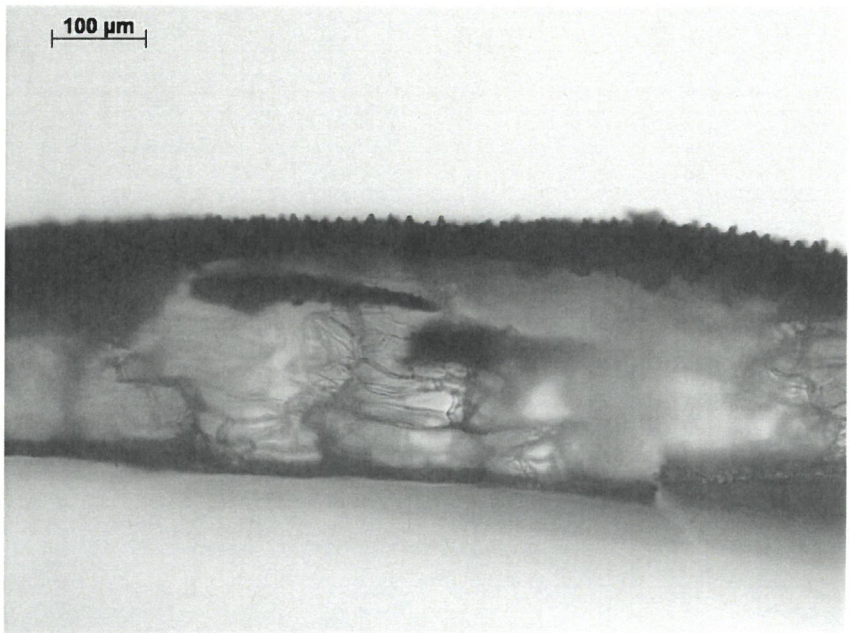
- For students to observe the ultra-water repellent surface of a dried lotus leaf, and understand that it is caused by the nano-structure of the leaf
- For students to appreciate that Chemists try to copy this nanotechnology to produce water-protective coatings for electronic devices and clothing

EXPERIMENT QUESTIONS– answer guide for teachers

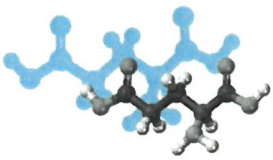
1. The lotus leaf is ultra-hydrophobic, and water rolls straight off, without even wetting the surface. Paper is quite hydrophobic, and water droplets stay quite rounded on the paper. Aluminium foil attracts the water the most, and the water droplet spreads out to have as much contact as it can with the surface.

2. Scientists make nano-structured surfaces to repel water; the water-repellence is a combination of the hydrophobicity of the chemicals at the surface, as well as their **topology**.

3. The under surface of the lotus leaf does not have the nano-structure to it, and does not repel water in the same fashion:



ChemBam



Nanotech for waterproofing (preparation details for teachers and technicians)

TO BUY

Aluminium foil: Any foil can be used, purchased simply from a supermarket

Dried Lotus leaves: These are inexpensive to buy from Chinese supermarkets, and are best bought whole. They can also be found from suppliers on the web, for example, from sous chef: http://www.souschef.co.uk/lotus-leaves.html?origin=product-search&kwd=&source=pla&gclid=CjwKEAjw7J3KBRCxv93Q3KSukXQSJADzFzVS2ik54jx5y2gsCfYGkoJQPjZqAyOyUEeigSHuzyGFeBoC5gzw_wcB It is possible to buy ~25 leaves for £5, and each leaf can be cut into ~30 pieces.

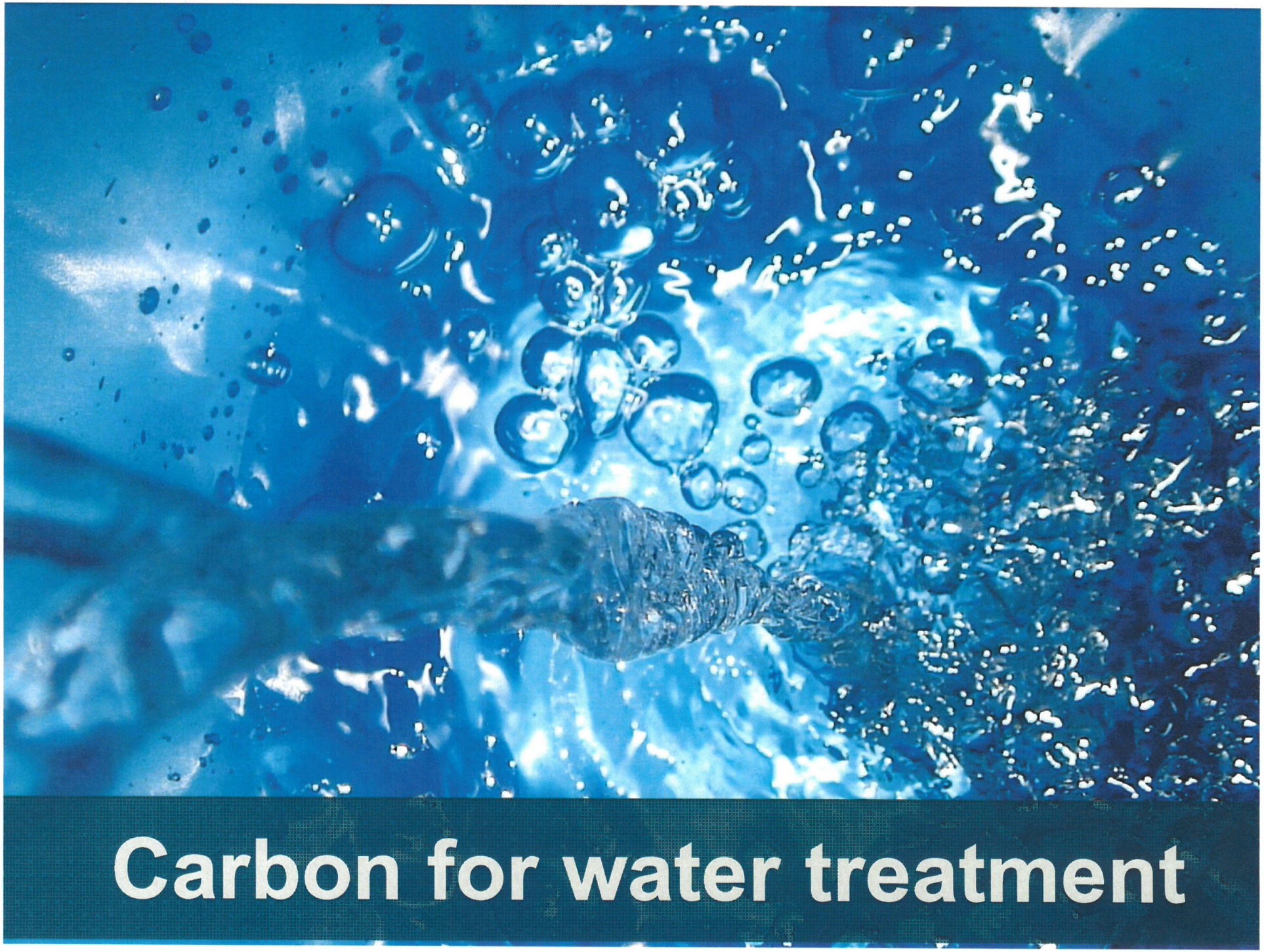
TO PREPARE IN ADVANCE

It is nice for the class to see the lotus leaves whole, but it is worth cutting most of them up into pieces ~ 6 x 6 cm, for the students to use, one for each pair.

Cut foil sheets into squares of ~ 6 x 6 cm, one for each pair of students.

STUDENTS WILL NEED

- Plastic Pasteur pipette
- Paper
- Lotus leaf
- Aluminium foil
- Tap water (~ 1-2 mL each) (perhaps provide a beaker for each pair)



Carbon for water treatment

ChemBam

SAFETY SHEET

Carbon for water treatment

Substance	Hazard	Comment
Methylene Blue		R22 Harmful if swallowed
E124 (Ponceau 4R)	-	Not a hazardous substance or mixture according to Regulation (EC) No. 1272/2008.
E102 (Tartrazine)		R42/43 May cause sensitization by inhalation and skin contact S22 Do not breathe dust. S36/37 Wear suitable protective clothing and gloves. S45 In case of accident or if you feel unwell, seek medical advice immediately
E133 (Brilliant Blue FCF)		R52/53 Harmful to aquatic organisms, may cause long-term adverse effects in the aquatic environment.
E110 (Sunset Yellow)		R36/37/38 Irritating to eyes, respiratory system and skin.

Typical control measures to reduce risk

- Work only with dilute dye solutions (0.001 g per 100 mL)
- Keep careful control of stocks to prevent theft
- Work preferentially with lower hazard dyes
- Use granules of carbon instead of powder

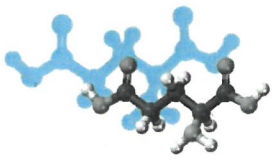
Assessing the risks

- What are the details of the activity to be undertaken? What are the hazards?
- What is the chance of something going wrong? *Eg, Is there the possibility of theft or foolish behaviour?*
- How serious would it be if something did go wrong?
- How can the risk(s) be controlled for this activity? *Eg, Can it be done safely? Does the procedure need to be altered? Should goggles or safety spectacles be worn?*

Emergency action

- **In the eye** — If dye solution contaminates the eye, flood with gently running tap water for 10 minutes. See a doctor.
- **Swallowed** — Do no more than wash the mouth with water. Do **not** induce vomiting. See a doctor.
- **Spilt on the floor, bench, etc** — Scoop spilled carbon into a container. Wipe any spilled dye solutions with absorbent cloths.

ChemBam



Carbon for water treatment

AIM

To see whether activated carbon or charcoal are better at removing molecules from water

YOU WILL NEED

- Glass beakers and stirring rods
- Measuring cylinder
- Filter papers and funnel
- Aqueous solutions of various dyes or food colourings (0.001 g per 100 mL)
- Activated carbon
- Crushed charcoal

PROCEDURE

Weigh 1 g of activated carbon into a beaker (make sure you label the beaker). Measure 100 ml of a dye solution into the cylinder and add to the beaker. Stir for 5 minutes and observe any colour loss. You may need to filter the mixture to remove any carbon powder. But beware; some dyes are adsorbed onto filter paper. Repeat this using 1 g of crushed charcoal and compare the two solutions.

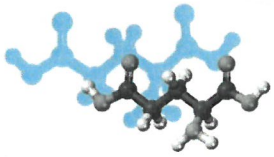
Try the same experiment with 0.5 g, 1.5 g and 2 g of activated carbon. Make sure you keep a 'control sample' of the original dye solution so you can compare the colour with your experiments.

Try the same experiment with some different dye solutions.

QUESTIONS

1. Is there a visible difference in the decolouration of the dye solutions between charcoal and activated carbon?
2. How much activated carbon do you need to add to completely remove the colour from the solution?
3. Calculate how many grams of dye can be adsorbed per gram of carbon.
4. Why does activated carbon adsorb dyes? Look up the chemical structure of some of your dyes. What features of the molecules might mean they can be easily adsorbed onto activated carbon?
5. How do different dyes compare? Discuss with your teacher why this might be.

ChemBam



Carbon for water treatment (teacher guide to exercises and experiments)

AIM

- For students to appreciate that providing clean water for people to drink is one of the biggest global challenges facing our world
- For students to appreciate that one way to remove pollutant from our water is to use activated carbon – this is used in many pond filters
- For students to appreciate that activated carbon is carbon with lots of small pores, and a very high surface area. If adsorbs pollutants, and if the carbon is not very porous it won't adsorb pollutants
- For students to appreciate that although activated carbon works well, it can be too expensive for large-scale water treatment in developing countries, and therefore researchers are trying to develop new types of cheap, available porous carbon materials

EXPERIMENT QUESTIONS– answer guide for teachers

1. Activated carbon will remove the colour from the solution much faster than the BBQ charcoal

2. This will vary, but is approximately 2 g.

3. In our experiment, using methylene blue solution, we found that 2 g of activated carbon was needed to remove almost all the blue colour.

   We know that the methylene blue solution contains 0.001 g per 100 mL and so 2 g of activated carbon adsorbed 0.001 g of methylene blue.

   This corresponds to 0.0005 g of methylene blue per gram of carbon.

   The relative formula mass of methylene blue is 320 $gmol^{-1}$.

   This means that 0.0000016 moles (or 1.6×10^{-6} mol) of methylene blue is adsorbed.

   This might not seem very much, but consider how many molecules of methylene blue this represents. We can use Avogadro's number (6.02×10^{23} mol^{-1}) to work this out.

   $1.6\times10^{-6} \times 6.02\times10^{23} = 9.6\times10^{17}$ molecules

4. Activated carbon adsorbs dyes as they are small, neutral molecules that can fit into the pores of the activated carbon. Compounds that are less water soluble are more likely to be adsorbed, and compounds that have less charge are more likely to have affinity for the carbon, rather than the water (polarity).

5. Different dyes will have different sizes/charges, and and will adsorb differently to the activated carbon. Shop bought food dyes and coloured drinks will contain a lot of colourless compounds in the water, which will adsorb but not decolour the solutions.

ChemBam

Carbon for water treatment (preparation details for teachers and technicians)

SAFETY

Methylene Blue	R22 Harmful if swallowed
E124 (Ponceau 4R)	Not a hazardous substance or mixture according to Regulation (EC) No. 1272/2008
E102 (Tartrazine)	R42/43 May cause sensitization by inhalation and skin contact S22 Do not breathe dust S36/37 Wear suitable protective clothing and gloves S45 In case of accident or if you feel unwell, seek medical advice immediately
E133 (Brilliant Blue FCF)	R52/53 Harmful to aquatic organisms, may cause long-term adverse effects in the aquatic environment
E110 (Sunset Yellow)	R36/37/38 Irritating to eyes, respiratory system and skin

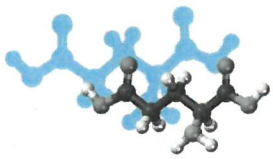
TO BUY

Activated carbon: For the images used on the website, we used activated carbon granules purchased from a scientific supplier (Alfa Aesar, -4+8 mesh activated carbon). However it is also possible to buy activated carbon at low cost from pond suppliers, although it is worth checking how well this works before trialling in the classroom. We have tried Finest-Filters granulated activated carbon (www.finest-filters.co.uk, info@finest-filters.co.uk), and this works well.

Charcoal: For the images used on the website we just used barbeque charcoal purchased from a supermarket, and crushed it by shaking the smaller pieces of charcoal from the bottom of the back, and crushing them in a plastic sample bag with a rolling pin.

Dyes: Pure dye and colouring powders can be purchased from scientific suppliers but food colouring powders can also be found at low cost from various websites. However these tend to contain other non-coloured additives that adsorb to the activated carbon, and therefore the stock solutions and amounts of activated carbon suggested in the student experiment may needed to be adjusted, as these are suggested for the methylene blue dye.

ChemBam

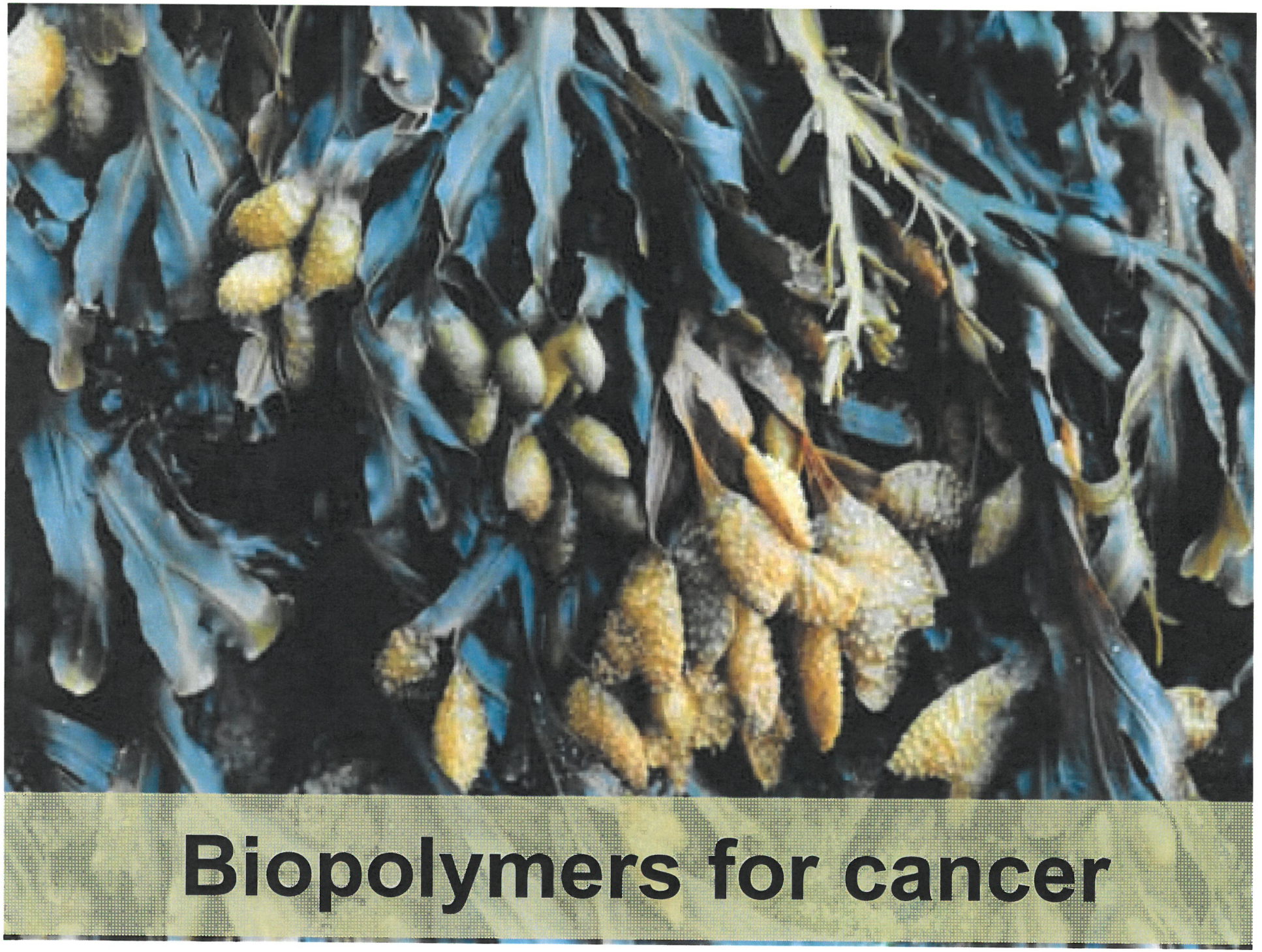


TO PREPARE IN ADVANCE

Methylene Blue solution (0.001 g per 100 mL)
Dissolve 0.1 g of methylene blue in water and make up to 100 mL stock solution in a volumetric flask. Dilute to correct concentration by measuring 10 mL of the stock solution and making up to 1 L with water. Each dye experiment with require 600 mL of solution.

STUDENTS WILL NEED

- Glass beakers (*6 150 mL) (plastic containers may stain with the dyes)
- Glass stirring rods
- Measuring cylinder, to measure 100 mL dye solutions
- Filter papers and funnel
- Aqueous solutions of various dyes or food colourings (0.001 g per 100 mL)
- Activated carbon granules 10-20 g per group (depending on how many dyes they test)
- Crushed charcoal 1-5 g per group (depending on if they choose to test all masses of charcoal)
- Weighing boats / paper
- Spatulas (for weighing)


Biopolymers for cancer

ChemBam

SAFETY SHEET

Biopolymers to prevent cancer

Substance	Hazard	Comment
0.1% w/v aq. $CaCl_2$ solution	-	Not a hazardous solution
0.1% w/v aq. $FeCl_3$ solution		H290: May be corrosive to metals H302: Harmful if swallowed H315: Causes skin irritation H318: Causes serious eye damage P280: Wear eye protection P302 + P352: IF ON SKIN: Wash with plenty of soap and water P305 + P351 + P338: IF IN EYES: Rinse cautiously with water for several minutes
2% w/v High G alginate solution (containing Manugel GHB and food colouring)	-	Not a hazardous solution
2% w/v High M alginate solution (containing Protsea AFH and food colouring)	-	Not a hazardous solution

Typical control measures to reduce risk

- Work only with dilute solutions or Ca(II) and Fe(III) salts

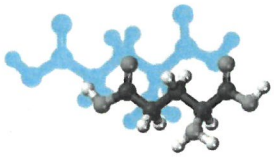
Assessing the risks

- What are the details of the activity to be undertaken? What are the hazards?
- What is the chance of something going wrong? *Eg, Is there the possibility of theft or foolish behaviour?*
- How serious would it be if something did go wrong?
- How can the risk(s) be controlled for this activity? *Eg, Can it be done safely? Does the procedure need to be altered? Should goggles or safety spectacles be worn?*

Emergency action

- **In the eye** — If salt or alginate solutions contaminates the eye, flood with gently running tap water for 10 minutes. See a doctor.
- **Swallowed** — Do no more than wash the mouth with water. Do **not** induce vomiting. See a doctor.
- **Spilt on the floor, bench, etc** — Scoop spilled carbon into a container. Wipe any spilled dye solutions with absorbent cloths.

ChemBam



Biopolymers to prevent cancer

AIM

To observe the binding of 2 different alginates with solutions containing Ca(II) and Fe(III) ions, to determine which is the most suited for an anti-cancer drug.

YOU WILL NEED

- 6 small beakers
- Plastic pipettes
- 2% w/v solution of 'High G' alginate (dyed with food colouring)
- 2% w/v solution of 'High M' alginate (dyed with food colouring)
- 0.1 % w/v $CaCl_2$ (aq) solution
- 0.1 % w/v $FeCl_3$ (aq) solution

PROCEDURE

Comparing the binding of calcium ions: Pour 25 mL of $CaCl_2$ solution into two beakers, and label them G and M. Using a plastic pipette, suck up 1-2 mL of the viscous 'High G alginate' solution, and pipette it dropwise into the $CaCl_2$ solution, in the beaker marked G. Repeat this with the 'High M alginate', in beaker M, and observe the difference - swirl the beakers for a few seconds. You can tip the gels into your hand, over a sink, to see the differences.

Comparing the binding of iron ions: Pour 25 mL of $FeCl_3$ solution into two beakers, and label them G and M. Do not get this solution on your hands as it is acidic and corrosive. Using a plastic pipette, suck up 1-2 mL of the viscous 'High G alginate' solution, and pipette it dropwise into the $FeCl_3$ solution, in the beaker marked G. Repeat this with the 'High M alginate', in beaker M. Gently swirl the solutions for a few seconds -what happens in each case?

Control experiment: Pour 25 mL of deionised water into two beakers, and label them G and M. Using a plastic pipette, suck up 1-2 mL of the viscous 'High G alginate' solution, and pipette it dropwise into the beaker marked G. Repeat this with the 'High M alginate', in beaker M. Gently swirl the solutions for a few seconds - what do these two solutions look like?

QUESTIONS

1. What do the two alginates look like when they interact with calcium ions? Can you pick up the gel balls?
2. Which alginate binds more strongly with calcium ions?
3. What do the two alginates look like when they interact with iron ions?
4. Look at the control solutions, where you have just mixed the alginates with water - what happens? What does this confirm?
5. Which of the two alginates do you think will act best as a drug to bind iron, in a calcium-rich environment?

ChemBam

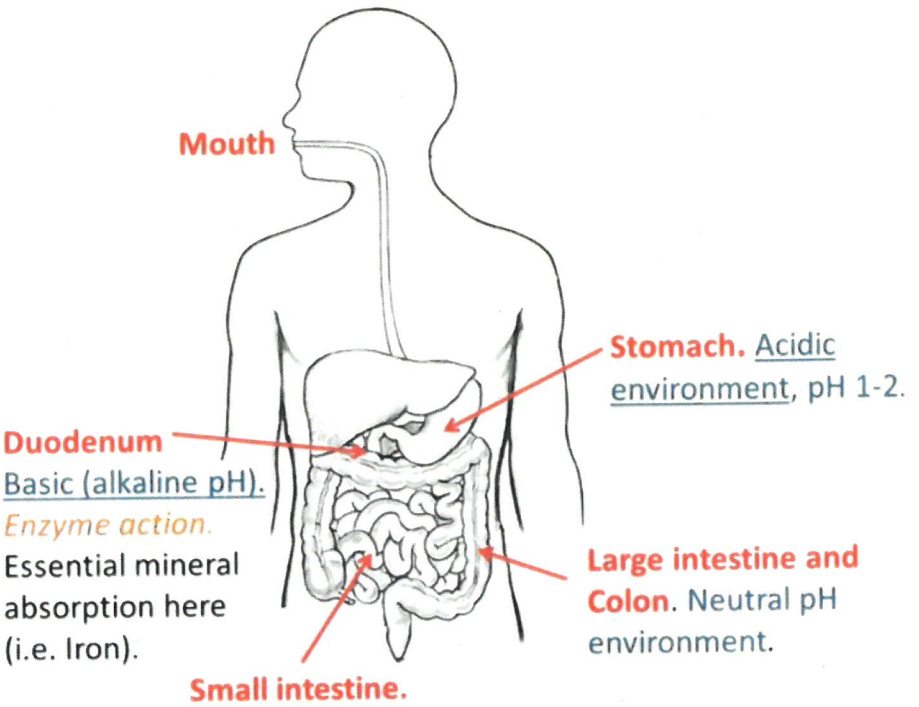
Biopolymers to prevent cancer - Exercise

Criteria required for drug design for colorectal cancer prevention:

QUESTIONS

1. What fundamental characteristic are we looking for in order to create a drug to prevent colorectal cancer?

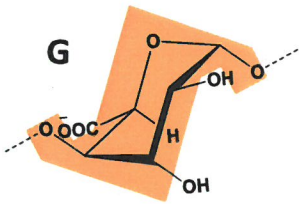
2. Thinking about the digestive system, and the different chemical environments that a drug will experience before it gets to the large intestine, what sort of things are important for the chemistry of the drug?

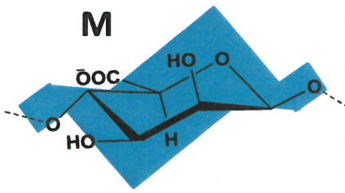


3. What other factors do you think are important when searching for a new drug, to be able to get the drug into clinical testing quite quickly?

G

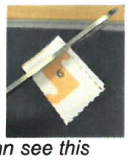
G





*These are the monomers β-D-mannuronate (**M**) and α-L-guluronate (**G**), that are linked by ether bonds in the alginate polymer. To see the difference in the structure of the polymer from 'GGGGGGG' linkages versus 'MMMMM' linkages:*

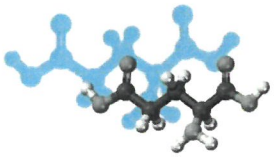
1) *cut along the black dashed lines to give three strips of paper*
2) *Fold along the red dashed line, and keep folding in a concertina*
3) *Cut the end of the strip so that it folds up to the end of the paper*
4) *Cut around the coloured shape along the green lines ONLY.*
5) *Open out the chain to see the polymer structure*



The 'GGGGGG' chains can form 'egg-boxes' when they are linked together with calcium – see if you can see this structure with 2 'GGGGG' chains. You can use 5p coins to represent the calcium ions.

M

ChemBam



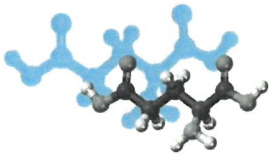
Biopolymers to prevent cancer (teacher guide to exercises and experiments)

AIM

- For students to appreciate what factors need to be thought about when designing a drug, in this instance to *prevent* cancer
- For students to understand that scientists believe there may be a link between high levels of free ion in the gut, and colorectal cancer. Be aware that this is talking about excess of iron, and iron is vital for healthy diets.
- For students to understand that scientists are therefore looking to create a drug that binds free iron that has not been absorbed by the body, in the large intestine
- For students to understand that a biopolymer is a long chain molecule (a polymer) made naturally, by plants or animals. Alginates are biopolymers found it seaweed, giving it structure.
- For students to understand that alginate polymers are made up of 'M' and 'G' monomers, which have different shapes, and thus sections of 'GGGGGGG' can form 'egg-box' shapes, and cross-link two polymers together, whilst binding calcium. In order to find a drug that can bind iron well in the body (the body also contains a lot of calcium), researchers are investigating 'high M' alginates.
- For students to compare the binding of calcium and iron ions by two different alginates.

EXERCISE 1 – answer guide for teachers
Criteria required for drug design for colorectal cancer prevention

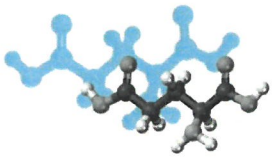
1. Following the research that suggests high excess iron in the large intestine in the lower gut could give rise to colorectal cancer, we are looking for a drug that can bind iron, to convert toxic free Fe ions into safe, bound Fe ions.
2. The drug needs to be stable whilst passing through the acidic stomach (at pH 1-2), through the alkaline duodenum, and also stable to enzyme activity.
3. Other factors to consider; the drug must be non-toxic and selective towards iron binding – if the drug fills all its binding sites with calcium it will not necessarily bind the iron in the large intestine. In order to get a drug to clinical trials quickly the drug needs to be cheap and a natural (non-synthetic) molecule – if a drug is made using chemicals such as alginates that are already approved for human consumption, human clinical trials can be performed much more quickly.



EXPERIMENT QUESTIONS– answer guide for teachers

1. The 'High G' alginate should bind calcium ions well, forming gels on the outer surface of any alginate pipetted into the solution, forming balls that can be picked up with fingers. (not the calcium does not bind in the centre of the balls, so they can be 'popped', and have liquid inside. The 'High M' will form a very soft gel, rather than balls, and you will not be able to pick up the balls in the same way. If ProtaSea is used it will remain a liquid.
2. High G
3. Both alginates should form some form of gel with the iron solution
4. The control solutions will just be liquids once stirred, with no gelation occurring. This confirms that the ions in the solutions are causing the gel formation.
5. High 'M' will be better for binding iron in the body. Although both bind iron well, the high 'G' also binds calcium very well, so it may already have saturated its binding sites with the calcium in the body, before it gets to the large intestine, so may not be so good at binding iron.

ChemBam



Biopolymers to prevent cancer (preparation details for teachers and technicians)

SAFETY

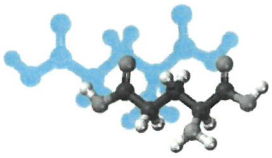
Manugel GHB alginate (55% G)	Not a hazardous substance according to Regulation (EC) No. 1272/2008
ProtaSea AFH alginate (30 % G)	Not a hazardous substance according to Regulation (EC) No. 1272/2008
Manucol LD alginate (40% G)	Not a hazardous substance according to Regulation (EC) No. 1272/2008
$CaCl_2$	H319 Can cause eye irritation P305+P351+P338 IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
$FeCl_3$	H290 May be corrosive to metals H302 Harmful if swallowed H315 Causes skin irritation H318 Causes serious eye damage P280 Wear protective gloves/eye protection P305+P351+P338 IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.

TO BUY

'High M' and 'High G' alginates: Sodium alginate is easy to buy on the internet, e.g. from 'Sous Chef'. This will usually be high G alginate, and can be used to demonstrate the binding of generic alginates with calcium and iron. If you do this, try it out beforehand. In order to compare 'high G' and 'high M' alginates, you can try to contact FMC Biopolymer directly to order Manugel GHB for 'High G' and Manucol LD for 'High M'. (The ProtaSea is no longer stocked by FMC). Supplies can also be sent out from Dr Zoe Schnepp (Z.Schnepp@bham.ac.uk) or Dr Nicola Rogers Simpson (N.J.Rogers.1@bham.ac.uk) at ChemBam, for trial experiments.

Dying the alginates: In order to see what happens to the alginates, and also to distinguish which is which easily (!) it helps to stain each alginate solution with food colouring – any food colouring can be used.

ChemBam



TO PREPARE IN ADVANCE

2% w/v Alginate solutions

Stir 200 mL of deionised water rapidly, and very gradually add 4 g of alginate powder to the vortex with stirring, in ~ 10 aliquots. Keep stirring to get a smooth viscous liquid, and add food dye to give it colour. Label each alginate 'High G' and 'High M', and dye them different colours.

200 mL of each is plenty for a whole class, although it might be easier to split each into 2 x 100 mL bottles for the class.

0.1% w/v $CaCl_2$ (aq) solution

Dissolve 1 g calcium chloride in 1 L deionised water, and stir until dissolved. (The class needs 50 mL per experiment group).

0.1% w/v $FeCl_3$ (aq) solution

Dissolve 1 g iron(III) chloride in 1 L deionised water, and stir until dissolved.

Dissolve 1 g iron(III) chloride in 1 L deionised water, and stir until dissolved. (The class needs 50 mL per experiment group).

STUDENTS WILL NEED

- 6 small plastic/glass beakers
- 2 plastic pipettes
- 2% w/v solution of 'High G' alginate (one per class can be passed around)
- 2% w/v solution of 'High M' alginate (one per class can be passed around)
- 0.1% w/v $CaCl_2$ solution (50 mL per group)
- 0.1 % w/v $FeCl_3$ solution (50 mL per group)
- Deionised water

Fuel cells for energy

ChemBam

SAFETY SHEET

Fuel cells for future energy

Substance	Hazard	Comment
0.38 M KOH (aq)		WARNING Causes skin and serious eye irritation Wear eye protection

Typical control measures to reduce risk

- Keep volumes and concentration of KOH(aq) used low (below 0.4 M)
- Keep careful control of stocks to prevent theft
- WEAR EYE PROTECTION

Assessing the risks

- What are the details of the activity to be undertaken? What are the hazards?
- What is the chance of something going wrong? *Eg, Is there the possibility of theft or foolish behaviour?*
- How serious would it be if something did go wrong?
- How can the risk(s) be controlled for this activity?

Emergency action

- **In the eye** — If solutions get in the eye, rinse for several minutes. Remove contact lenses if present and easy to do so and continue rinsing. If eye irritation persists see a doctor.
- **On skin** — If KOH(aq) solution is spilt on skin, remove contaminated clothing and rinse with water.
- **Swallowed** — Do no more than wash the mouth with water. Do **not** induce vomiting. See a doctor.
- **Spilt on the floor, bench, etc** — Wipe any spilled ethanol solutions up with absorbent cloths.
- **Ethanol catches fire** — Report immediately to a fire marshal. Trained personnel: use water spray, alcohol-resistant foam, dry chemical or carbon dioxide.

ChemBam

Fuel Cells for Future Energy

AIM

To make a battery and a fuel cell

YOU WILL NEED

- 6 small potatoes
- 6 x 2 pence (or 1 pence) pieces
- 6 x galvanised screws/nails
- 7 insulated wires with crocodile clips
- a voltmeter
- an LED
- 2 graphite electrodes (2 pencils work well, sharpened with a knife of both ends to extend the graphite, or 6 x 0.7 mm leads for propelling pencils, taped together per electrode)
- selotape
- Blu tack
- beaker
- 0.4 M KOH (aq)
- 1 x 9 V battery
- plastic knife
- universal indicator paper

PROCEDURE

Part 1 The Potato Battery

Push a penny about half way, into a potato. Push a nail into the potato, about 3 cm away from the penny, so that only 1 cm of the nail remains above the potato surface. Connect a crocodile wire to the penny, and to one side of the voltmeter, and another, to the nail and the other side of the voltmeter, and record the voltage. Now disconnect the voltmeter, and attach the crocodile clips to the LED – does it light? *You need to connect the LED the right way around; connect the nail to the negative side of the LED, i.e. the shorter wire, and the copper coin to the positive, longer, wire of the LED.* Make up 5 more potato batteries, and connect them together, starting with 2, 3, 4, 5, and all 6, measuring the voltages each time. This activity may need to be done as a class, connecting up with other students' potato batteries. Take a slice of potato and measure its pH.

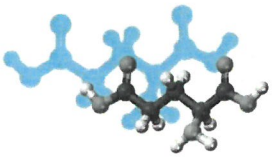
Part 2 The Alkaline Hydrogen Fuel Cell

Take the two pencil electrodes, and tape them together, using a piece of Blu tack in between the pencils, to space them, about a pencil width apart. Put 100 mL of 0.4 M KOH(aq) solution into a beaker, and place the electrodes into the beaker.

Electrolyse water to make you hydrogen/oxygen fuel stock: Firstly you need to make your feedstock of hydrogen and oxygen fuel. The simplest way to do this is to hydrolyse the water, using a 9 V battery. Connect a crocodile wire to the top of each pencil, with the clip connected directly to the graphite 'lead' of the pencil, and connect each wire to the anode and cathode of the 9 V battery. Observe the electrodes within the water, and leave them connected for 2-3 min. You should see bubbles forming on the graphite electrodes.

Electrolysis:

(+ve electrode) = Anode: $2\ OH^-(aq) \rightarrow \frac{1}{2}\ O_2(g) + H_2O(l) + 2\ e^-$
(-ve electrode) = Cathode: $2\ H_2O + 2\ e^- \rightarrow H_2 + 2\ OH^-(aq)$



Make your fuel cell: Disconnect the battery, and connect the electrodes up to the voltmeter, and observe the voltage over 5-10 min. Do this carefully, trying not to disturb the bubbles on the electrode surfaces, as this is your fuel! If you have time, charge up your fuel cell with the battery again, and see if you can light the LED. *You need to connect the LED the right way around; connect the negative electrode (where you connected the negative end of the battery and the hydrogen was produced) to the negative side of the LED, i.e. the shorter wire.* You will probably need to connect a few cells together.

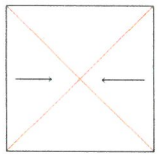
The alkaline fuel cell:

(-ve electrode) = Anode: $H_2 + 2\ OH^- \rightarrow 2\ H_2O + 2\ e^-$
(+ve electrode) = Cathode: $½\ O_2 + H_2O + 2\ e^- \rightarrow 2\ OH^-$

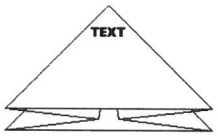
QUESTIONS

1. The potato battery is made up of two electrodes, and an electrolyte. What is acting as the electrodes, and what is acting as the electrolyte?
2. What is the pH of the potato?
3. This battery is an example of an electrochemical cell. Chemical energy is converted into electricity, due to a spontaneous redox reaction. The potato contains organic acids, and at the copper electrode (penny), protons from the acid form hydrogen. At the zinc electrode (galvanised screw), Zn oxidises to form Zn^{2+}. Give the half equations and overall equation for this cell.
4. What parts of the cell are being 'used up' in the chemical reaction, i.e. what is behaving as the fuel within the battery? What will happen when these eventually run out? Are they easy to keep renewing in the system?
5. What happens to the voltage as you connect up more potatoes? Can you light the LED?
6. For the fuel cell, you first need to electrolyse water to produce hydrogen and oxygen gas. What type of energy is being converted here?
7. You should observe the two electrodes bubbling, and one will bubble more than the other. Which bubbles more, the electrode attached to the positive or negative end of the 9 V battery? Write an equation for the reaction that is occurring – why do you produce twice as much gas at one of the electrodes?
8. Why do you think it helps to add a pinch of salt to the water?
9. When you disconnect the battery, and observe a voltage, what happens to this voltage over time? Why is this? What is the fuel in this cell?
10. What by-product is made when the hydrogen and oxygen react in a redox reaction? Why is this a 'greener' process than combustion?
11. What are the advantages and disadvantages of hydrogen fuel cells?

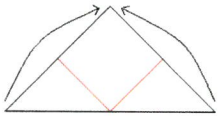
1. Start with printed side of paper face down on the table. The column of text on the printed side should be horizontal. Fold the paper from one corner to the diagonal corner and unfold again. Repeat with the other diagonal.



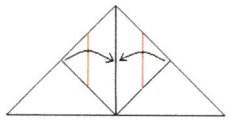
2. Fold across the diagonal creases, tucking the sides into the centre. You should only be able to see **some** text the correct way up at the top of the triangle you make, in a small yellow traingle.



3. Fold the two bottom corners up towards the central point of the triangle. The only text visible should be OH- and part of the half cell eqtn.



4. Fold both corners into the centre of the central diamond shape



CATHODE

CATHODE

ChemBam

$O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$

Alkaline

OH- OH- OH- OH- OH-

Applications

Transport (Cars, Buses)

Portable devices (laptops, mobile phones)

Power generation (small to large scale)

$O_2 + 4e^- \rightarrow 2O^{2-}$

Solid Oxide

O^{2-} O^{2-} O^{2-} O^{2-} O^{2-}

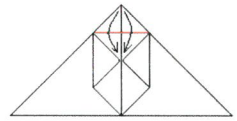
$2H_2 + 2O^{2-} \leftarrow 2H_2O + 4e^-$

$2H_2 + 4OH^- \leftarrow 4H_2O + 4e^-$

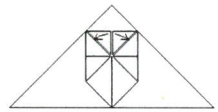
ANODE

ANODE

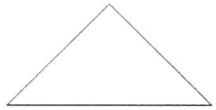
5. Fold the top two triangles down towards the points you made in step 4



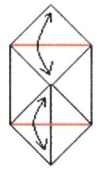
6. Tuck the newly made triangles into the pockets on either side. Take care not to accidentally only tuck them under the flap instead of inside it.



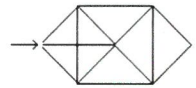
7. Turn over and repeat steps 3-6 on the other side.



8. Fold two points over to meet in the middle then unfold them and fold them the other way and back a few times to make sure it is well creas

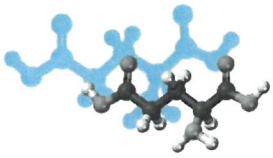


9. Blow hard into the hole at one end which should inflate the cube



10. Finished Cube!!

ChemBam



Fuel cells for future energy (teacher guide to exercises and experiments)

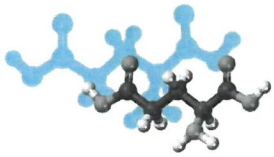
AIM

- For students to appreciate that electrochemistry is at play in batteries and fuel cells to produce a voltage from chemical energy
- For students to make an electrochemical cell using a potato and zinc, and couple several cells together to light an LED
- For students to electrolyse water to form H_2 and O_2, and then produce a voltage from the alkaline fuel cell

QUESTIONS– answer guide for teachers

1. The zinc in the galvanised nail is acting as the anode, and the copper coin is acting as the cathode. The potato, which is full of water and salts, provides the electrolyte.
2. The pH of the potato will be 5-6. Potatoes contain organic acids.
3. Anode: $Zn(s) \rightarrow Zn^{2+}(aq) + 2\ e^-$ (oxidation)
   Cathode: $2e^- + 2H^+(aq) \rightarrow H_2(g)$ (reduction)
   $Zn(s) + 2H^+(aq) \rightarrow Zn^{2+}(aq) + H_2(g)$
4. The Zn(s) and the $H^+(aq)$, i.e. the acid within the potato, will be consumed during the redox process; these are acting as the 'fuel' for the cell. As these react and run out, the voltage will gradually reduce to zero, as the system reaches equilibrium. These are not easy components to 'feed in' to the cell, continuously – this is more like a disposable battery.
5. As you connect up more potato cells in series, the voltage will increase, until eventually you can light the LED. It usually takes 4-6 potato cells to light an LED, albeit dimly!
6. Electrolysis is the reverse process to forming an electrochemical potential; electrical energy supplied by an external source drives a reaction that is NOT spontaneous, and is converted into chemical energy.
7. $H_2O \rightarrow H_2 + ½\ O_2$. You will produce H_2 gas, at the cathode (attached to the negative pole of the 9 V battery), at twice the rate that you produce O_2, due to the stoichiometry of the reaction.
8. The voltage gradually reduces to zero as the gas fuel reacts and runs out. The H_2 and O_2 are the 'fuel' for this cell.
9. The only by-product from this reaction is water; no CO_2 is formed in the fuel cell process.
10. Advantages; the reaction is clean, and doesn't produce greenhouse or polluting gasses. Water is a plentiful resource, which can be used to form the hydrogen in the first place. Fuel cells are not disposable, like many batteries. Fuel cells do not rely on non-renewable fossil fuels. Disadvantages: Hydrogen is explosive and difficult to store safely, and in a small volume. If hydrogen is produced by the electrolysis of water, energy is needed to do this; if this is done using energy produced by burning fossil fuels, it still contributes to greenhouse gas and other pollutant emissions.

ChemBam



Fuel cells for future energy (preparation details for teachers and technicians)

SAFETY

KOH	H290 May be corrosive to metals
	H302 Harmful if swallowed
	H314 Causes sever skin burns and eye damage
	P280 Wear protective gloves/clothing/eye protection

TO BUY

Potatoes: small potatoes are fine, but any size will work

Pennies: this acts as a copper electrode, either 1p or 2 p coins work fine

Galvanised screws: these provide the zinc needed for the redox; nearly all screws and nails sold are galvanised iron; they look blue/silver, as opposed to dark raw iron

Graphite electrodes: graphite electrodes can be purchased, although pencils that are sharpened at both ends with a knife to expose the graphite work well.

LEDs

Voltmeter: (mV-V range)

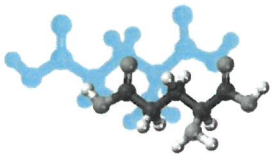
Insulated wires with crocodile clips

TO PREPARE IN ADVANCE

0.38 M KOH(aq) solution
Each student needs ~ 50 mL solution. To make up 1 L of 0.4 M KOH(aq), dissolve 21 g of KOH (s) in 1 L of deionised water, being careful to add base to water.

Carbon electrodes
If pencils are being used as electrodes, sharpen both ends of each pencil with a knife to expose ~3 mm of 'lead' at each end.

ChemBam



STUDENTS WILL NEED

- 6 small potatoes
- 6 x 2 pence (or 1 pence) pieces
- 6 x galvanised screws/nails
- 7 insulated wires with crocodile clips
- a voltmeter
- an LED
- 2 graphite electrodes (2 pencils work well, sharpened with a knife of both ends to extend the graphite, or 6 x 0.7 mm leads for propelling pencils, taped together per electrode)
- selotape
- blu tack
- 1 x beaker
- 0.4 M KOH (aq)
- 1 x 9 V battery
- plastic knife
- universal indicator paper