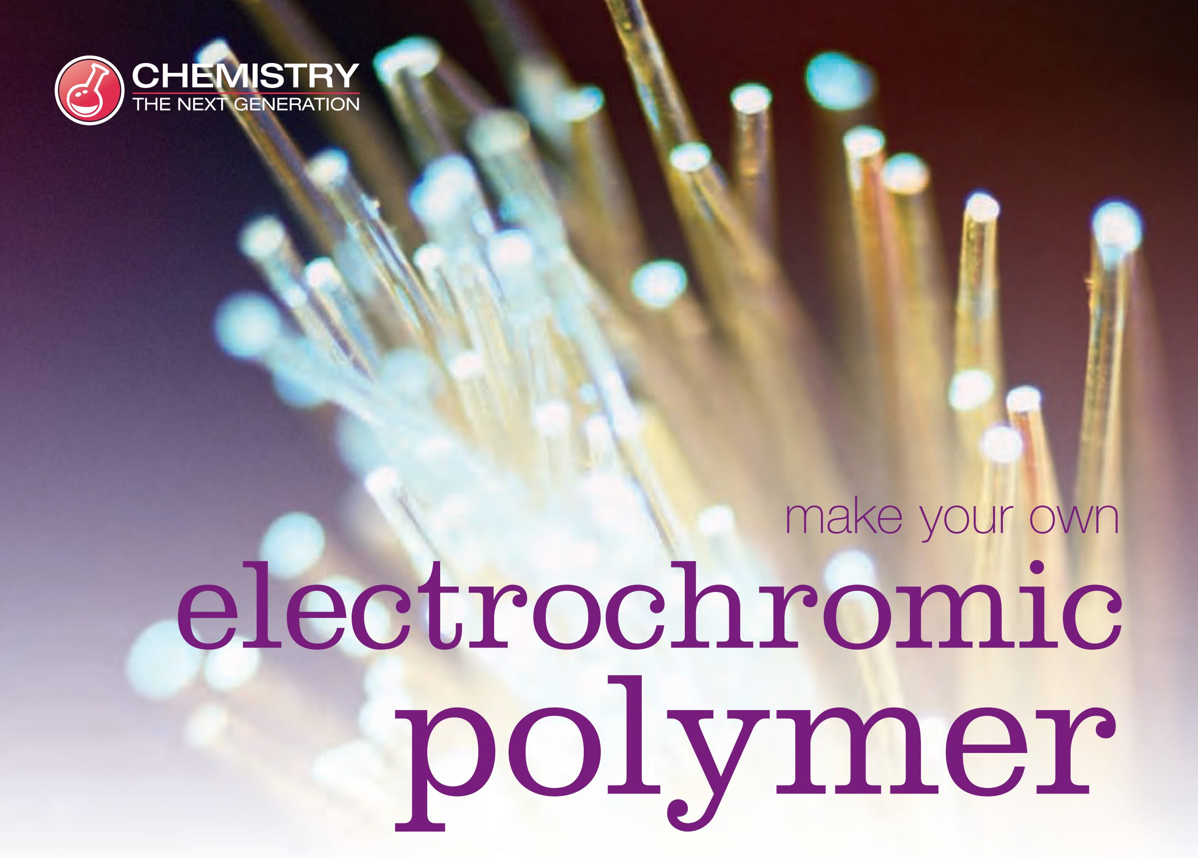

CHEMISTRY THE NEXT GENERATION

4 ACTIVITY

make your own

# electrochromic polymer

16-18 age group | 45 MINS | 40 STUDENTS | 2 STUDENTS PER GROUP | 4 SUPERVISORS | 50

## background

In recent years chemists have worked hard to make polymers that conduct electricity as well as metals. The best polymers produced can conduct electricity almost as well as copper – one of the best conducting metals. The properties of electroactive polymers can be altered by applying an electrical potential. Electrochromic polymers like polyaniline are very important because their colour can be controlled electrically. Light emitting polymers are also important and are used in devices known as organic light emitting diodes (OLEDs) which are beginning to be used in modern displays.

## pre-planning required

### weeks before

- Collect the materials needed to run 20 versions of the experiment – there should be 20 battery supply boxes allowing the application of a variable voltage from -1.5 V to +1.5 V
- Order or distil aniline
- Check battery packs

### days before

- On the day or the day before, prepare the deposition and testing solutions

## facilities required

Appropriate tables only. This experiment is designed to be run in a sink and fume cupboard free location and so is very versatile for events away from scientific departments.

### Suggested timings for the day

This is a **45 minute session** with an introduction to polymers, particularly electroactive examples, and a run through of the procedure. There will then be time at the end to work through the questions.

The beakers should be labelled as deposition solution and testing solution and filled before beginning the experiment.

After the experiment do not pour the aniline solution down the sink. Use a waste bottle.

This activity is based on a workshop run by Dr Jonny Woodward, University of Leicester.

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## materials required

### Solutions

- deposition solution – 1 $dm^3$ of 2M HCl (aq) with 200 $cm^3$ of aniline added
- testing solution – one $dm^3$ of a solution containing 0.5M HCl (aq) and 0.5M KCl (aq)

### Student kits

Each student pair (or group) requires the following apparatus:

- indium-tin oxide (ITO) conducting glass slide
- a battery pack
- a red and a black cable with banana plugs
- two crocodile clips to fit banana plugs
- one copper electrode
- two 100 $cm^3$ beakers – one to contain 50 $cm^3$ of deposition solution and the other 50 $cm^3$ of testing solution
- tissues
- gloves

### SAFETY

A risk assessment must be done for this activity. A spill cleanup kit should also be available.

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## SAFETY

This experiment uses a dilute acidic solution of aniline which is toxic and a possible carcinogen. Laboratory coats, safety glasses and gloves should be worn at all times during this experiment. If you spill any of the solution on your skin, rinse immediately under the tap with cold water and then wash with soap.

## NOTE

The biggest problem associated with this experiment is that if the Indium-Tin Oxide (ITO) coated slide is placed at negative potential of -1.5 V the oxide layer is rapidly reduced, destroying the conductivity of the glass. Thus any ITO surface that makes contact with the testing solution that is not covered with polymer risks being damaged. The ITO slides are best wrapped in the centre with a piece of insulation tape so that the section that enters both the deposition and testing solutions is always completely submerged and covered with polymer.

Even with the polymer protection if the slide is held at negative potential, the ITO will still be reduced. Thus it is essential to only apply the negative potential just long enough to cause the colour change and then immediately turn the potential to zero. This will allow the slides to be reused, although almost certainly the students will damage some of them.

The best way to clean the slides is to wipe them with a tissue immediately after removing them from the testing solution.

### Answers

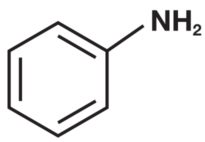
1. Oxidation is Loss of electrons
Reduction is Gain of electrons

The mnemonic for remembering this is **OILRIG**.

2. If the polymer appears green, it must be absorbing all other colours of visible light. This means that it must be absorbing light at both the red and blue ends of the spectrum, allowing only the green light to pass through. There is an excellent opportunity to discuss some basics of absorption spectroscopy here, along with ideas of colour chemistry and also the electromagnetic spectrum.

The molecule contains the functional groups amine and aryl group/benzene ring.

Aniline

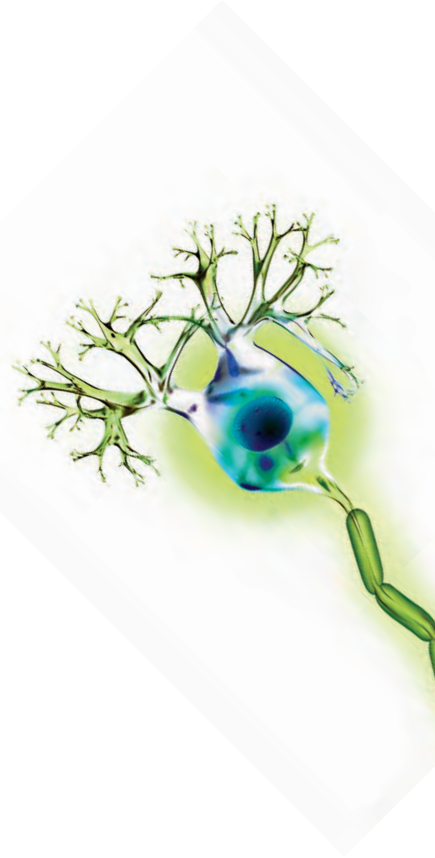



4. Depending on their age, students should have come across:

a. Addition polymerisation – polymers like polythene and PVC
b. Condensation polymerisation – polymers like nylon.

Once again, this question is an excellent chance to open up the discussion and expand upon/revise some of these ideas.

# make your own electrochromic polymer



## introduction

Conducting polymers that are able to change colour in response to electronic signals are likely to spread into many applications. For example, windows that change from transparent to opaque at the touch of a button, and greeting cards that display flashing messages. Chemists have opened the door to new applications for colour-changing polymers.

In recent years chemists have worked hard to make polymers that conduct electricity as well as metals. The best polymers can now conduct electricity almost as well as copper – one of the most conductive metals. Electroactive polymers are materials whose properties can be altered by applying an electrical potential. Electrochromic polymers like polyaniline are very important because their colour can be controlled electrically. Light emitting polymers are also important and are used in devices known as organic light emitting diodes (OLEDs) which are beginning to be used in modern displays.

### The experiment

In this experiment you will have the opportunity to prepare a polymer film using electrochemical deposition. The polymer you will be preparing is polyaniline which has some very special properties.

- The polymer can exist in a series of different oxidation states, each of which is a different colour. You will be able to use electrochemistry to allow you to switch the polymer between these different oxidation states.
- One particular oxidation state of the polymer is electrically conducting. Polymers and plastics are generally electrical insulators. The possibility of making polymers that can conduct electricity opens up a whole range of potential technological applications.

Conducting and electroactive polymers have a range of applications which include those listed below.

### Conducting polymers

- electrostatic materials
- conducting adhesives
- printed circuit boards
- artificial nerves
- aircraft structures

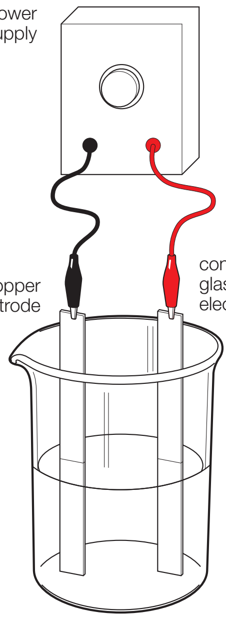
### Electroactive polymers

- molecular electronics
- electrical displays
- chemical, biochemical and thermal sensors
- drug release systems
- optical computers

### Making the polymer and testing it

There are two parts to this experiment. First, the polymer is deposited from a monomer solution onto a conducting glass electrode. In the second part, the polymer coated slide is placed into an ionic solution and a varying potential is applied so that you can observe the various oxidation states.

You will have one kit for each pair or group.




### Polymer deposition

1. Attach a crocodile clip to the black cable and clip it to the copper electrode. Place the electrode into the deposition solution and plug the other end of the cable into the black terminal on the power supply unit.

2. Attach a crocodile clip to the red cable and carefully clip the other end to the conducting glass slide. Place the slide

continued overleaf

> **NOTE**
> Only the green emeraldine salt form is a conducting polymer.

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carefully into the deposition solution and make sure that the copper electrode and glass slide do not touch each other.

3 Make sure that the dial on the power supply is set to one.

4 Connect the red cable to the red terminal on the power supply.

You should now see that a green layer of polyaniline is deposited onto the glass slide. When the green layer is clearly visible, carefully remove the glass slide from the solution.

## Testing the electrochromic properties of the polymer

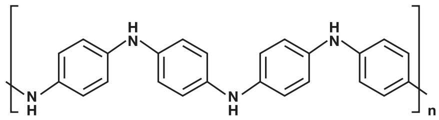
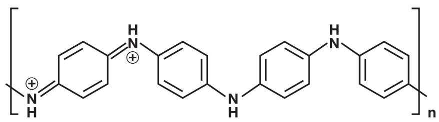
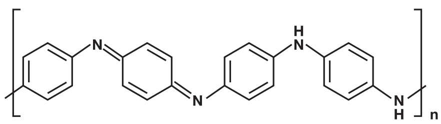
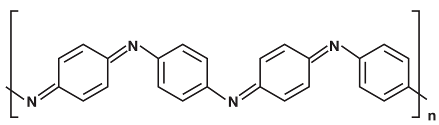
1 Transfer both the electrodes into the testing solution. The glass slide should turn dark blue. This is because the new solution is not acidic unlike the deposition solution and the polymer is sensitive to pH as well as potential.

2 Turn the dial on the power supply to maximum. What happens?

3 Next turn the dial on the power supply to minimum. Watch carefully the series of colour changes that take place.

4 Experiment with the power supply control and see if you can get the slide to remain permanently in four differently coloured states.

The chart below shows the different coloured forms of the polymer.

| | | |
|---|---|---|
|  | Leucoemeraldine | Colourless<br>Fully reducing<br>Insulating |
|  | Emeraldine salt | Green<br>Partially oxidised<br>Conducting |
|  | Emeraldine base | Blue<br>Partially oxidised<br>Insulating |
|  | Pernigraniline | Purple<br>Fully oxidised<br>Insulating |

## questions

1 Define oxidation and reduction in terms of electron transfer.

2 The emeraldine salt form of the polymer is green. Which region(s) of the visible spectrum must it be absorbing in? How about the other forms of the polymer?

3 Polymers are made from repeating units. In the table above, how many repeating aniline units are shown for each form of the polymer?

4 Polymers are made from small molecules known as monomers. The monomer molecule used is aniline. Draw the structure of aniline and identify the two organic functional groups present in the molecule.

5 What other method of making polymers have you come across? Give three examples of the kind of polymers that can be made using these techniques.

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