CHEMISTRY
THE NEXT GENERATION

2
ACTIVITY

renewable energy – from

sunlight to electricity

age group 14-18

1½ HRS

25 STUDENTS

4 STUDENTS PER GROUP

1 SUPERVISOR

£200

background

Renewable energy is generally considered as being from an energy resource that is replaced rapidly by a natural process such as power generated from the sun or from the wind. Most renewable forms of energy, other than geothermal and wave power, ultimately come from the sun. Visible light can be converted directly to electricity by devices called solar cells. There are two different types of solar cells – photovoltaic cells and Grätzel cells.

In this activity students make their own Grätzel cells and use them to power a calculator.

pre-planning required

weeks before
Purchase four commercial solar cell kits from Man Solar (www.mansolar.com). Each kit costs £49.16. The kit contains: indium-tin-oxide (ITO) conducting plates, coated TiO2 plates, crocodile clips, iodide electrolyte, paper clips, pencil, hibiscus tea, petri dish, tweezers, voltmeter, calculator.

day before
Determine the conducting sides of the uncoated transparent plates using a multimeter and place a sellotape strip across the top.

facilities required

- sockets
- wash basin

materials required

- cotton buds
- food dye – Ribena, ordinary tea, cranberry juice and turmeric powder
- oven
- kettle
- baking tray
- hot plates
- lamps
- beakers
- white board
- gloves
- laboratory coats
- goggles
- measuring balance
- measuring cylinders

Suggested timings for the day – 1½ hours.

Answers

1. Renewable energy – solar, wind, geothermal, water and biomass. Non-renewable energy – oil, coal, nuclear energy and natural gas.

2. Generating electricity.

3. Devices that use sunlight energy to create electric energy.

4. Photovoltaic cells and Grätzel cells (dye sensitised cells).

5. a) Sunlight energy strikes electrons within the adsorbed dye molecules.
b) The electrons gain this energy and escape the dye molecules.
c) The electrons accumulate at the negative plate (dyed TiO_2 plate) and flow through the circuit creating an electric current.
d) The dye is regenerated with its lost electrons by the iodide electrolyte, via iodide ions, being oxidised to tri-iodide ions. The tri-iodide ions are then reduced (gain back electrons) at the graphite plate.
e) The cycle starts again.

Further information

Visit the websites **www.mansolar.com** and **www.howstuffworks.com/solar-cell.htm**

SAFETY

A risk assessment must be done for this activity.

This activity is based on a workshop run by Dr David Worrall, University of Loughborough and is part of the *Partnership for Public Engagement Project* funded by the Engineering and Physical Sciences Research Council (EPSRC).

renewable energy – from

sunlight to electricity

introduction

Renewable energy is generally considered as being from an energy resource that is replaced rapidly by a natural process such as power generated from the sun or from the wind. Most renewable forms of energy, other than geothermal and wave power, ultimately come from the sun.

On earth, sunlight is a very important form of energy. Every day, the sun releases large amounts of energy into space some is infrared and ultraviolet light, but most of it is visible light. Some of this energy is used to warm the Earth's surface, drive ocean currents, rivers, and winds, and is used by plants to make food. Life on earth depends totally on the sun.

Visible light can be converted directly to electricity by devices called solar cells. There are two different types of solar cells – photovoltaic cells and Grätzel cells.

Most photovoltaic cells are made by putting two separate thin silicon wafers with different electrical properties together, along with wires to enable electrons to travel between layers. When sunlight strikes the solar cell, electrons naturally travel from one layer to the other through the wire because of the different properties of the two wafers.

Single cells produce tiny amounts of electricity – just enough to light up a small light bulb or power a calculator. Larger arrays of solar cells can be used in Earth-orbiting satellites and water pumping applications.

Grätzel solar cells are dye sensitised solar cells that use a dye for directly converting the sunlight's energy into electrical energy. They are prepared from two conducting transparent glass plates. One plate is coated with graphite and the other is coated with TiO_2, onto which a dye is adsorbed.

The two plates are sandwiched together and a drop of iodide electrolyte is placed between the plates to give a working Grätzel solar cell.

An electric current is initiated when electrons within the dye molecules are excited by sunlight energy (*1*), *fig 1*. These excited electrons have enough energy to leave the dye molecules and accumulate at the TiO_2 plate (*2*). They then move along a wire between the two plates, creating an electric current (*3*). The dye molecules are then regenerated by the iodide ions through oxidation. The oxidised tri-iodide ions are then reduced back at the graphite plate (*4*).

Grätzel cells are currently being researched at leading universities and in industry and they may be commercialised in the near future.

GLOSSARY

absorb
To take up a substance through pores (like a sponge).

adsorb
To gather a gas, liquid or dissolved substance on a surface.

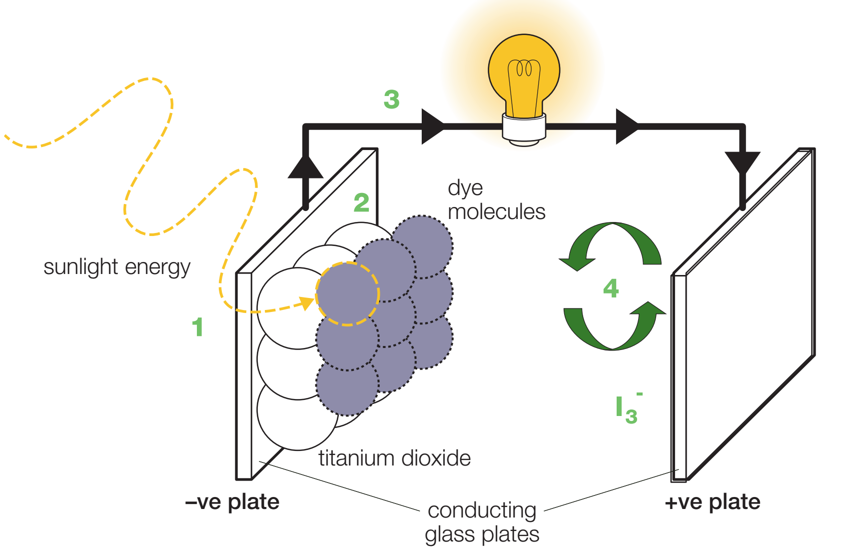


Figure 1. This illustrates how a Grätzel cell creates an electric current from sunlight energy.

the experiment

In this activity you will be making your own dyed sensitised solar cells and measuring the current produced. The student to produce the highest current from their cell will be given a prize. The best five working Grätzel cells will be used to power a small electronic calculator.

Five different dyes are used – *ie* Ribena (20 ml), hibiscus tea (1 g), ordinary tea (1 teabag), cranberry juice (40 ml) and turmeric (0.5 g) and the experimental procedure is the same for each dye.

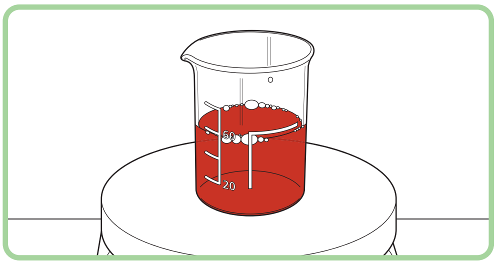
In groups of five you will prepare five Grätzel solar cells and each group will use a different dye. Each student will get to prepare their own Grätzel cell.

Preparing the dyed TiO_2 plates (negative plate)

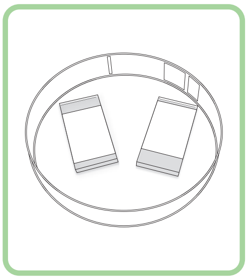
SAFETY

Care: do not touch the hot beaker or plates.

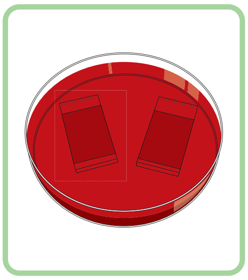
1. Carefully add the dye source to a beaker of boiling water (40 ml) and allow to boil.



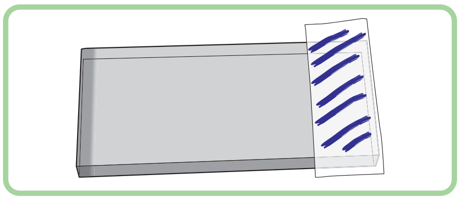
2. Place the TiO_2 plates into a petri dish. Make sure the TiO_2 coated sides are facing up. Ask a member of staff to pour the dye solution into the petri dish.



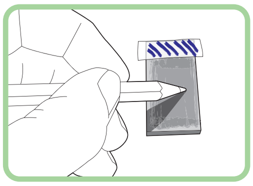
3. The TiO_2 plates should be completely covered with the dye solution. Leave to soak for 10 minutes. While you are waiting you can prepare **the graphite (positive) plates**



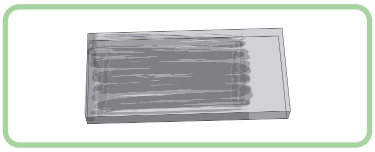
a) *Take the uncoated plates and coat them with graphite using a pencil. Coat the side with the sellotape strip. This side has been pre-treated with a transparent layer of a thin conducting film and will have a resistance of ~30 ohms. A multimeter can be used to determine the conducting side. The non conducting side will show infinite resistance.*



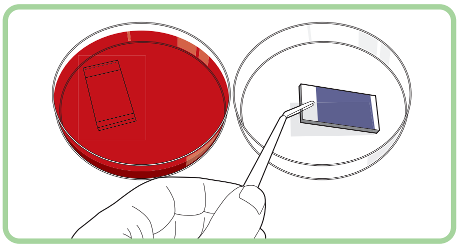
b) *The plate should be completely covered with graphite. Gently shake the plates to remove any loose graphite particles.*



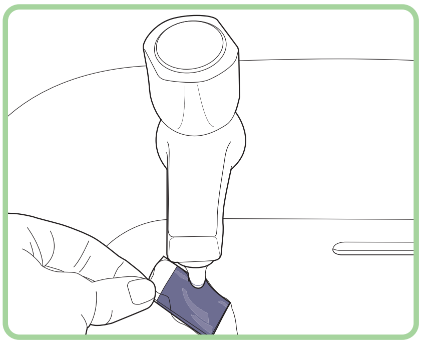
c) *Carefully remove the sellotape strip. This uncoated part is where you connect the crocodile clip.*



4. After 10 minutes of soaking, use tweezers to remove the dyed TiO_2 plates out of the dye solution and into a clean petri dish. Take care not to touch the dyed TiO_2 layers.



5. Carefully rinse the dyed TiO_2 plates under tap water to remove the excess dye solution.

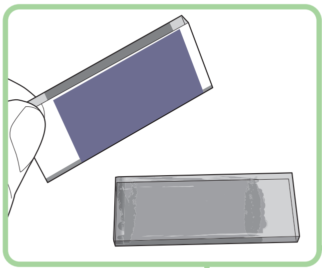


6. Carefully place the dyed TiO_2 plates into an oven to dry. Once the plates are dry ask a member of staff to transfer the plates to your desk.

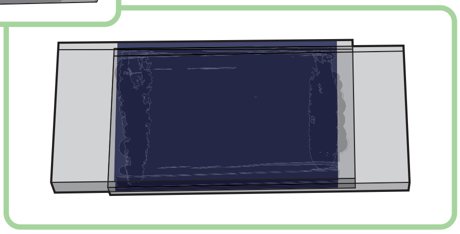
Do not touch the plates until they have cooled down.

Making the solar cells

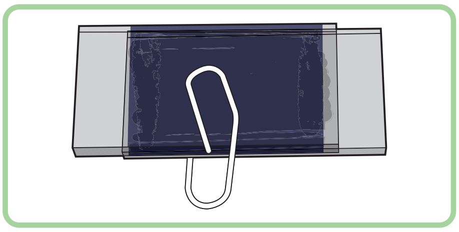
Now that you have graphite-coated plates and dyed TiO_2 plates you can make a Grätzel solar cell.



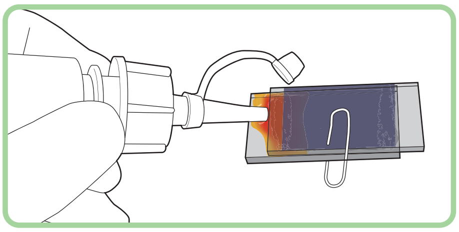
1. Take the dyed TiO_2 plates and place them facing down onto the coated graphite. They should be placed so that they are slightly offset to allow connections for the crocodile clips (below).



2. Carefully clamp the two plates together with a paper clip to stop them moving around. The paper clip will need to be transformed into a clamp.



3. Carefully add one drop of iodide electrolyte solution between the two plates of the solar cell on either side. You will see the electrolyte flow through the cell.



4. You can now connect your Grätzel cell to a multimeter to measure the current. Firstly, place the Grätzel cell under a lamp (a set-up to be used by all students) and measure the current produced. Tabulate the results, so that it can be determined who and which dye has produced the highest current.

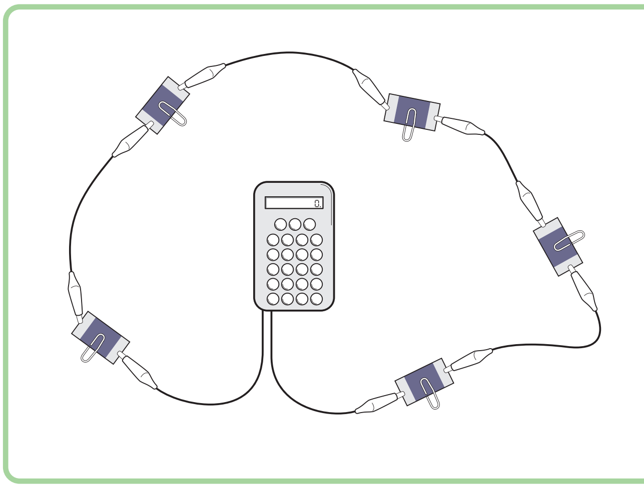
SAFETY

You must wear gloves to avoid skin contact with the iodide electrolyte.

Powering-up the calculator

1. Place all five Grätzel cells in a line, making sure that the dyed TiO_2 plates of each of the cells are facing up. Now connect the Grätzel cells in series using crocodile clips. It is important that the graphite plate (+ve) of one Grätzel cell is connected to the dyed TiO_2 plate (-ve) of another Grätzel cell. This is repeated until all Grätzel cells are connected in series. The positive and negative plate at the end of the line of Grätzel cells will be used to connect to a calculator.

2. Illuminate the Grätzel cells using a desk lamp and measure the total voltage that is produced using a multimeter. A voltage of 1.2 V will sufficiently power a calculator. Once you have a achieved a voltage of 1.2 V, you can replace the multimeter with the calculator.



3. If it is a sunny day you can take it outside.

questions

1. Name the renewable and non-renewable sources?
2. What are the uses of these sources?
3. What are solar cells?
4. Name two types of solar cells?
5. How does a Grätzel cell work?