Chemistry the next generation
part of Chemistry for our future

15
ACTIVITY

green plastics

age group 14-18

1½ HRS

50 STUDENTS

20-25 STUDENTS PER GROUP

2* SUPERVISORS

1500**

background

This activity introduces students to green chemistry (**www.greener-industry.org**), the need to change to a more sustainable society and the issue of fossil fuels versus bio-plastics.

pre-planning required

weeks before
Ensure equipment is clean and is working, order chemicals and disposables.

days before
Ensure that all materials are available. Run through experiments with the actual buffers, chemicals and enzymes that are to be used on the day.

facilities required

- General chemistry laboratory – tables, power points, waste disposal and fume cupboards
- Computer, projector and screen for presentation

materials required

- disposable gloves
- safety glasses
- aprons
- The chemicals you'll need are listed overleaf

Suggested timings for the day

The activity takes one and a half hours. The experiments are designed to reach a good visual end point in 40-45 minutes. If time is limited the experiments need to be set up and allowed to run during the talk.

- Arrival
- Greeting and assign experiments (5 minutes)
- Introduction to experiments (5 minutes)
- Set-up (15–20 minutes)
- Talk and questions (45 minutes)
- Experimental results and wrap up (15 minutes)

*** ONE TEAM LEADER AND PRESENTER, THREE TO HELP RUN DEMONSTRATIONS (for two separate experiments to run in parallel).**

A SINGLE EXPERIMENT REQUIRES TWO PEOPLE TO HANDLE 20–25 STUDENTS.

**** £1500 TO SET UP TWO SEPARATE PARALLEL EXPERIMENTS.**
It costs half this amount to run one experiment or two in sequence. Main costs are the orbital shaker and dosing pipettes. Consumables – ie buffers, chemicals, enzymes, pH papers, pipette tips and glass vials are around £200 for 50–60 students (the major part of this cost is the vials – which can be washed and reused).

This activity is based on a workshop run by Dr Dave Lathbury and Dr Andrew Wells, Astra Zeneca, Loughborough.

SAFETY
A risk assessment must be done for this activity.

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Chemicals required

- Hydroxypropyl methyl cellulose mol wt 90,000 – available from Sigma-Aldrich **www.sigmaaldrich.com**
- 0.1 N Phthalate buffer (pH4) – available from Fisher Scientific **www.fisher.co.uk**
- pH 7, 0.1 N Phosphate buffer – available from Fisher Scientific **www.fisher.co.uk**
- Benzonitrile – available from Sigma-Aldrich **www.sigmaaldrich.com**
- Product, benzamide, and samples of polymers made from natural products (polylactides etc) – available from Sigma-Aldrich **www.sigmaaldrich.com**
- Cellulase 13L enzyme solution – available from Biocatalysts **www.biocatalysts.com**
- An alternative enzyme product is Novozymes Celluclast 1.5L – available from Sigma-Aldrich **www.sigmaaldrich.com**
- Nitrile Hydratse cells, product number 43.30 – available from Codexis **www.codexis.com**

Further information

Visit the Royal Society of Chemistry website at **www.chemsoc.org/networks/learnnet/green/index2.htm** and **www.rsc.org/education/teachers/learnnet/green-chem.htm** for more information on green chemistry.

green plastics

Green chemistry is both the chemistry of the future and the chemistry of today. It is based on a number of principles that ensure that both processes and end products are clean and safe. Green chemistry aims to conserve both energy and raw materials. In practice, this means that 'green' processes are often cheaper than conventional methods. Some current processes are already 'green', and use of green chemistry is growing because it is environmentally friendly, and it is being encouraged by legislation and international agreements that aim to reduce pollution. One of the basic ideas of green chemistry is to prevent production of hazardous and polluting materials rather than producing them and then cleaning up.

Green chemistry:

- is safe;
- conserves raw materials and energy; and
- is more cost-effective than conventional methods.

Approaches to making chemical processes 'greener' include:

- redesigning production methods to use different starting materials;
- using different reaction conditions, catalysts, solvents etc; and
- using production methods with fewer steps.

So what are green plastics and why are they important for our future? At the moment a lot of plastics are made from petroleum. However, alternatives need to be found as fossil fuel resources are finite and alternative energy sources and ways of making materials such as plastics are needed. Also the world's resources are not used very efficiently and produce a large amount of waste material. Green plastics are vital in providing a biodegradable solution and minimising waste.

There are very limited supplies of fossil fuels:

- Gas – 75 giga tons, 45 years
- Coal – 925 giga tons, 100 years
- Oil – 120 giga tons, 25 years

Plastics and polymers are all around us and are hugely important in our everyday lives. In 2000 the world production of plastics was 150 million metric tons. By 2010 this will have risen by 5.5% to 256 million metric tons. In 2000 the value of this business was $265 billion and the estimate for 2010 is $365 billion.

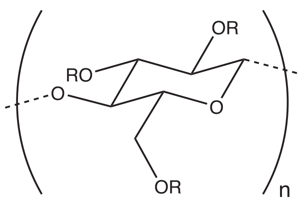
This cannot be maintained. The world population is approximately 6.7 billion and this is projected to stabilise at 10–15 billion with a five to six fold increase in demand for commodities such as chemicals and materials along with a four fold increase in energy demand. It is vital that sustainable 'green' processes and products continue to be developed.

The experiments

1. The hydrolysis of polypropylene

Shake 200 mg of polypropylene chips with 2 cm^3 of pH 7 buffer solution in a glass vial at room temperature. Note your observations.

2. The hydrolysis of a cellulose derivative



R = H or CH_3 or $CH_2CH(OH)CH_3$

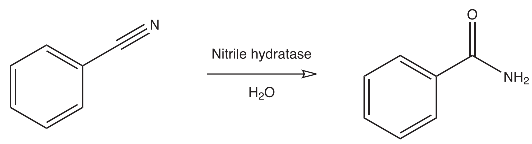
1. Take two 4 cm^3 vials containing 100 mg of hydroxypropylmethyl cellulose (molecular weight ~90,000)
2. Add 2 cm^3 of 0.1N phthalate buffer (pH4) to each vial Cap the vials and shake then vigorously to disperse the solid.
3. To one vial only add 100 µl of Biocatalysts cellulase 13L enzyme solution.
4. Cap the vial and shake both vials on the orbital shaker at 500 rpm at room temperature for one hour. Note the difference between the two vials. What has happened to the vial containing enzyme?
5. Measure the pH of the vial containing the enzyme and compare to the starting buffer.

3. The hydrolysis of biodegradable poly l-lactide

1. Shake 200 mg of poly l-lactide, 2 cm^3 of pH 5 buffer solution and 50 µl of esterase enzyme in a glass vial at room temperature. Note your observations.
2. Repeat the above experiment without the enzyme. Note your observations.

The materials are quite stable as solids in the absence of enzyme. The enzyme degrades the polymers to small water soluble compounds that can be used by micro-organisms and plants as food. In this way carbon goes back to nature!

4. The hydrolysis of benzonitrile – mimic of the Mitsubishi Acrylamide Process



1. Take two 4 cm^3 vials, one containing 3 mg of freeze dried cells.
2. Add 1 cm^3 of 0.1N phosphate buffer (pH7) to each vial.
3. Cap the vial and shake it to disperse the cells.
4. Add 100 µl of benzonitrile to each vial.
5. Cap the vials and shake both vials on the orbital shaker at 500 rpm at room temperature for one hour. Note what has happened to the reactions.
6. Measure the pH of the reactions and compare these to the starting buffer.

NOTE

This experiment must be done in a fume cupboard.