Fabrics and Fashion

At a glance

	Content summary	National Curriculum links	Activities
Lesson 1	Carrying out a range of tests on known and unknown fabrics; understanding the chemical structure of fabrics	Chemical bonding; properties of materials; aspects of working scientifically	**Activity A:** Testing fabrics
Lesson 2	Making a sample of indigo dye; investigating the chemistry and history of jeans	Recognising the importance of peer review of results and communication of results to audiences; evaluating social and environmental implications	**Activity B:** Making indigo dye **Activity C:** Investigating jeans

Background and National Curriculum links

The activities are intended for two Year 10-11 lessons on fashion, focusing on how fashion and chemistry intersect.

Lesson 1

In the first lesson, students test chemical and physical properties of a selection of natural and synthetic fabrics. They develop understanding of chemical structure and bonding within different fabrics. They consider how effective the tests were at identifying unknown fabrics.

National Curriculum

- chemical bonding;
- bulk properties of materials related to bonding and intermolecular forces;
- explaining everyday and technological applications of science;
- interpreting observations and other data, including identifying patterns and trends, making inferences and drawing conclusions;
- applying a knowledge of a range of techniques.

Lesson 2

In lesson 2, students make indigo dye and investigate the history of denim and jeans, including considering 'sustainable' fashion. They prepare presentations and are peer-assessed.

National Curriculum

- evaluating associated personal, social, economic and environmental implications;
- recognising the importance of peer review of results and of communication of results to a range of audiences;

Teacher subject knowledge

Understanding the chemical structures of natural (plant and animal) and synthetic fibres is helpful.

Cross-curricular links: the history of fabrics and clothing

Anthropologists estimate that humans began to clothe themselves between 100,000 and 500,000 years ago. Early clothing was made from leaves, fur, animal skins, bones and shells. In 2016, scientists established that a cloth found in Huaca, northern Peru dates from 6700BCE, making it one of the world's oldest woven textiles and the oldest dyed with indigo. For centuries, clothing depended on natural materials such as cotton, wool, felt, leather, flax and silk. In the 1880s, the first artificial fibre, rayon, was made from cellulose found in wood. Nylon, the first completely synthetic fibre, was produced in 1934 by Wallace Carothers of DuPont. Since then, many new textiles have been manufactured, with a wide range of properties. Textile science studies the chemical, engineering and manufacturing knowledge associated with textiles and their development. Fashion and textile manufacturing contributed about £9 billion to the UK economy in 2017.

Fabrics also link to historical contexts. Linen was favoured fabric in ancient Egypt for its cool qualities in extreme heat. Cotton grows in warm climates in countries that include the US, China, India, Brazil, Pakistan and Turkey. In nineteenth century USA in particular, cotton and slave trades were intertwined. Cotton fibres were shipped from the USA around the world for weaving into fabrics. Wool from sheep, goats (cashmere, mohair), rabbits (angora), alpaca and llama (the wool of both animals is called 'alpaca') is grown in many countries worldwide. Trade in local wool has contributed to the UK economy over many centuries. Silk, from the silkmoth *Bombyx mori* (silk) was first traded in China from 4000BCE onwards. The 'Silk Roads' describes trading routes extending from China.

The UK fashion industry contributes around £26 billion annually to the economy and offers a range of employment opportunities. London Fashion Week, which runs annually in mid-September, showcases around 80 designers from 24 countries, as well as new talent. Sustainable fashion is an important development of which students may be aware.

Student background knowledge

Students are likely to know that fabrics such as cotton, wool, acrylic and polyester differ from each other, but not why. Knowledge and understanding of covalent bonding and polymers as long chain molecules made of repeating units known as monomers is helpful.

Resources and timing

Two 50 – 60 minute lessons are required.

Technical requirements

Lesson 1

Activity A: Testing fabrics

Students will test:

- a set of labelled fabric 'standards' and
- a set of 'unknown' fabric samples.

The fabric 'standards' should include plant, animal and synthetic fibres, i.e. cotton, linen, jute, hemp, rayon, wool, mohair, alpaca, nylon, polyester, acrylic.

Students can bring in unknown fabrics from clothing that they no longer wear.
Cut all samples into 10 x 10cm squares.

For testing fabrics

A results table is provided.

General results for the chemical and burning tests for cotton, wool, nylon and polyester are provided.

A strong recommendation is to test the actual fabric standard samples before the lesson. Fabrics may only react with harsher solvents than those suggested. Teachers can demonstrate the solvent tests using concentrated sulfuric acid, formic acid or sodium hydroxide solution at 40^0C.

Several tests require shredded fibres to increase the surface area. Shredding samples may take time, so it is helpful to do this before the lesson.

Tests on students' own fabric samples can be treated as genuine research.

Students can work in pairs or small groups. In groups, students can take responsibility for one or more tests each for all fabric samples. Results can then be shared across the group.

Students do not have to test all fabrics. These can be shared around the class. Some tests are easier to perform than others. This may help in planning work for students with different ability levels.

Fabrics made from mixed fibres such as polyester cotton may give inconclusive results.

Each group or pair of student requires:

- 1 set of labelled fabric standard samples
- 1 set of unknown fabric samples

- A copy of the blank table
- Access to a balance accurate to 0.01 g
  - 250 cm^3 beaker
  - Scissors
  - Paper towels
  - Timer
  - Test tubes, two for each fabric sample
  - 2 dropping pipettes
  - Glass rod
  - Access to propanone (acetone) (HARMFUL); 0.5 $moldm^{-3}$ sodium hydroxide solution (CORROSIVE)
  - Bunsen burner, heatproof mat, tongs
  - Eye protection

Questions to discuss

Identify the unknown fabric samples.

Why is it important to test all the samples in the same way?

- We need to carry out fair tests on the fabrics, especially if we are trying to identify unknowns.
- What do the results tell us about the chemical structures of the fibres?
- They must have different chemical structures because of the variation in test results.
- Plant-based fibres (cotton, linen) are formed from a carbohydrate, cellulose. This is a polymer made of glucose molecules. Glucose is the monomer.
- Animal-based fibres are formed from a protein, keratin (hair). This is a polymer made of amino acids. The sequence of amino acids is determined by the genes of the animal.
- Synthetic fibres are polymers made from petroleum-based substances. Polyester is a polymer made from alternately repeating monomers of an organic acid and organic alcohol. Nylon has a complicated structure, again involving two alternating monomers.
- Fibres are held together by a combination of intramolecular and intermolecular bonds. Solvents disrupt the bonds. The reactions may break the fibres apart from each other and /or break up the fibres into monomer units.

If fabrics gave inconclusive results, what other tests could be done to identify them?

- Compare test results with more standard samples;
- Testing with different solvents;

- Examining individual fibres under a microscope;
- Testing to see if the fabric holds a dye;
- Various advanced methods such as static secondary ion mass spectroscopy (SSIMS), X-ray photoelectron spectroscopy (XPS) and scanning electron microscopy (SEM).

When is fabric tested in real life?

- In forensic analysis – crime scene samples are tested to confirm who was present and to find out what happened.
- When developing new fabrics – fabrics for extreme environments, non-clothing purposes, modifying existing fabrics; examples – sports clothing, fabrics for underwater / polar / mountaineering expeditions.

Extensions

Discuss images associated with certain fabrics and how clothing influences our perceptions of people we see and meet.

Investigate the origins and history of fabrics they tested. Visit a fashion and textile museum. Find out how fabrics, dyes and fashions have changed over time.

How are fabrics recycled?

Discuss what 'sustainable fashion' means. Collect clothes for a charity shop, emphasising re-using clothing. Arrange a clothes swap, at which people bring clothing that they are prepared to exchange.

Find out about the textile industry. Visit a local site. This might be a textile weaving factory or a fashion house where clothes are designed and made. Find out what is / was made there. What factors have influenced changes in the factory / mill / fashion house over time?

Resources

Information about the UK Fashion and Textile Industry can be found at:

UKFT: The biggest network for UK fashion and textile businesses

The website United Kingdom – Fashion & Textile Museums (fashionandtextilemuseums.com) has information about fashion and textile museums in the UK and worldwide.

This article about a new process for textile recycling was published in *The Guardian* newspaper: https://www.theguardian.com/fashion/2019/mar/17/holy-grail-how-textile-recycling-can-help-slash-emissions-pollution-and-landfill.

The website Green Dreamer offers an introduction to sustainable fashion: What is Sustainable Fashion? (An Introduction and 3 Steps for Getting Started) — GREEN DREAMER

Lesson 2

Activity B: Making indigo dye

For the microscale indigo dye experiment, each student pair / group will need :

- 10 cm^3 beaker
- Small filter funnel and filter paper
- 1 $moldm^{-3}$ sodium hydroxide solution (CORROSIVE)
- Deionised water
- Propanone (FLAMMABLE, EYE IRRITANT)
- 2-Nitrobenzaldehyde (HARMFUL IF SWALLOWED, IRRITANT)
- Eye protection
- Two dropping pipettes

Optional step: dyeing a piece of cotton fabric

- Small squares of white cotton about 5 cm x 5 cm
- Alkaline sodium dithionite (bisulfite) solution (see CLEAPSS advice for preparation)

This solution will be clear and colourless.

Instructions for preparing experiments on a microscale are available at: http://www.rsc.org/resource/download/res00000532/cmp00000575.pdf.

Notes about indigo:

Questions and further work

1. What colour is indigo?

   Deep blue

2. What gas in the air reacts with the dye to produce the blue indigo colour?

   Oxygen

3. How could you change the depth of colour made by the dye?

   Change the concentration of the dye solution

4. Find out about the history of indigo – where does it come from?
   - Indigo was originally produced from the plant *Indigofera tinctoria*. The natural dye has been used for over 6000 years. Large areas of land were used to grow plants that yielded indigo dye. One estimate is that in the 19th century around 1.7 million acres of land in India annually produced about 9000 tonnes of dye.
   - The German chemist Adolf von Baeyer tried several times to produce a successful method for making synthetic indigo. He started in 1865 and finally made indigo in 1879. Nearly twenty years later, German chemical companies BASF and Hoescht sold the first synthetic indigo.

- Today, around 50,000 tonnes of synthetic indigo are made annually. Each pair of jeans requires about 10 g of indigo.

5. Is synthetic indigo more sustainable and 'greener' to use than natural indigo? Why / why not?
   - There are arguments both ways. Synthetic indigo does not require plants and can be made efficiently. However, the chemicals are expensive, water is required and waste is created from the process. Natural indigo from plants has to be extracted and land is needed for growing the plants, which cannot be used for other purposes.

Activity C: Investigating Jeans

Students prepare presentations on topics linked to denim jeans. Introductory resources are provided. Topics:

- The history of denim fabric
- The history of denim jeans
- How cotton is made
- How denim is dyed to create different colours
- Making 'sustainable' and 'ethical' jeans
- How indigo is made using 'green' processes

Invite students to use peer assessment to mark the presentations, thinking about, for example:

  - The clarity of information;
  - What they learned from listening to the presentation;
  - The quality of the slides / resources used when giving the presentation.

Extensions

Jeans for Genes (https://www.jeansforgenesday.org/) is an annual fund-raising event for charities supporting children with genetic disorders. Organise an event that supports Jeans for Genes.

Investigate the history of dyes, from indigo to Perkin's mauveine and azo dyes. Run a dyeing workshop. Ask students to bring a white cotton t-shirt to dye. Investigate 'tie-dyeing' using string. Try batik dyeing using wax.

Organise an ethical fashion show featuring clothing made from sustainable fabrics, are second-hand and / or can be recycled. Discuss what 'ethical' and 'sustainable' fashion means.

Resources

History of jeans: http://www.historyofjeans.com/#targetText=History%20of%20Jeans%20and%20Denim,jean%20or%20jeane%2C%20was%20manufactured.

How cotton for jeans is made: http://www.madehow.com/Volume-1/Blue-Jeans.html, http://www.historyofjeans.com/jeans-making/how-jeans-are-made/.

Ethical issues in making jeans: https://www.fluencecorp.com/blue-jeans-water-footprint/.

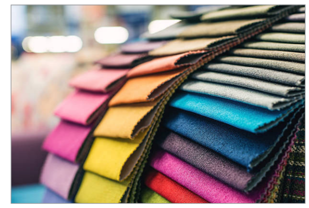
Greener processes for making indigo: https://www.chemistryworld.com/news/indigo-genes-dyeing-to-make-jeans-cleaner-and-greener/3008499.article.
NOTE: this article includes some technical details of the process.

Ethical jeans: https://goodonyou.eco/the-ultimate-2019-guide-to-ethical-denim/.

Textile recycling: A number of websites promote organisations that offer ways of recycling jeans. Students can investigate these and consider which (if any) may be appropriate for their situation.

Activities

Lesson 1 Activity A: Testing fabrics



[images of fabric swatches - Bing images]

- In this investigation you will test fabrics used in clothing.
- Test all the fabric samples in the same way.
- You will be given 'standard' fabric samples.
  Record the results of tests on these in the table.
- Next, test unknown fabric samples. Compare results with the standard fabrics. Work out what the unknown fabrics are.
- Wear eye protection while you are doing the tests.

Test	What you need	What to do	What to look for
Observations	Fabric	Describe the fabric texture, its 'handle' (how it feels) and fluidity	Rough, smooth, fluffy Warm or cool to touch Stiff or flexible
Strength	Fabric Scissors Ruler	Make a 2 cm cut in the sample. With fingers placed at the edges, pull the fabric until it tears	Grade strength from 1 – tears easily to 5 – will not tear
Droplet	Fabric, paper towel, water, dropping pipette, timer	Lay fabric on a paper towel. Place 5 drops of water on the centre of the fabric. Time how long it takes for the water to soak completely into the fabric	Using the timings, rate the permeability of the fabric from 1 – very fast to 5 – doesn't soak in
Soak	Dry fabric Balance Beaker Water Glass rod	Find the mass of the dry fabric. Put water in the beaker. Push the fabric under the water for 30 seconds. Take the fabric out. Hold until it stops dripping. Find the mass of the wet fabric	Calculation: Soak mass = wet mass / dry mass
Sodium hydroxide	Shredded fibres Test tube and rack Sodium hydroxide solution Dropper, Glass rod	Put shredded fabric fibres in the test tube. Add sodium hydroxide solution to about 2cm depth. Leave for at least 10 minutes	Check if the fibres dissolve completely, partially or not at all
Propanone	Shredded fibres Test tube and rack Propanone Dropper Glass rod	Put shredded fabric fibres in the test tube. Add propanone solution to about 2cm depth. Leave for at least 10 minutes	Check if the fibres dissolve completely, partially or not at all
Burning	Fabric fibres Tongs Bunsen burner Heatproof mat	Set the Bunsen flame to gentle blue. Hold a small sample of fabric fibres to the side of the flame, but not in the flame	Watch what happens. See if the fabric burns, the colour of any flame. Describe the smell. What colour is the ash? Is it hard, crumbly, like small beads or wispy?

Questions

1. Why is it important to test all the samples in the same way?
2. What do the results tell us about the chemical structures of the fibres?
3. What other tests could be done to identify fabrics you were not sure about?
4. When is fabric tested in real life?

Fashion Lesson 1 Activity A: Testing fabrics

Fabric	TEST						
	Observations	Strength	Soak	Drip	Sodium hydroxide	Propanone	Burning
Sample 1							
Sample 2							
Sample 3							
Sample 4							
Unknown 1 This fabric is ….							
Unknown 2 This fabric is ….							
Unknown 3 This fabric is ….							

Fashion Lesson 1 Activity A: Testing fabrics. Expected results for solvent and burning tests

Note that these are general results rather than specific. Test the actual fabrics prior to the lesson.
The solvent tests may require harsher solvents and / warming for a result to be observed.

Fabric	Notes	Sodium hydroxide	Propanone	Burning
Cotton	Cotton is a plant-based fibre made from cellulose. Cellulose is a thermoset polymer.	Soluble – but may be resistant at room temperature. If no change occurs warm to 40°C.	Resistant	Cotton burns with a yellow flame, smells like burning paper and gives a black, powdery ash.
Wool	Wool is an animal-based fibre made from the protein keratin. Keratin is a thermoset polymer.	Soluble – but may be resistant at room temperature. If no change occurs warm to 40°C.	Resistant	Wool shrinks then catches light, but does not stay alight when removed from the flame. Little smoke is produced. Burning wool smells like burnt hair. The ash is gritty and resembles easily crushable bread.
Nylon	Nylon is a condensation polymer made from two monomers. The precise structures of nylons vary. Nylon is a thermoplastic.	Resistant	Soluble	Nylon melts then burns, giving off white smoke, smells like rubbish and gives a hard, shiny grey/brown ash.
Polyester	Polyester is a condensation polymer made from two monomers, both of which have an 'ester' group, formula –COO– . The precise structures of polyesters vary. Polyester is a thermoplastic.	Resistant	Soluble	Polyester melts then burns, giving off black smoke, smells sweet like geraniums, gives a black shiny ash.
Acrylic	Acrylic is an addition polymer that must contain at least 85% by weight of acrylonitrile. In practice most acrylics also include small amounts of other vinyl monomers.	Soluble – but may be resistant at room temperature. If no change occurs warm to 40°C.	Resistant	Acrylic melts then burns, giving off black smoke, smells like a piece of hot iron metal and gives ash that resembles the burnt head of a match.

Lesson 2 Activity B: Making indigo dye

You are going to make some indigo. Indigo is used to dye denim.

Equipment

- $10\ cm^3$ beaker
- Small filter funnel and filter paper
- $1\ moldm^{-3}$ sodium hydroxide solution (CORROSIVE)
- Deionised water
- Propanone (FLAMMABLE, EYE IRRITANT)
- 2-Nitrobenzaldehyde (HARMFUL IF SWALLOWED, IRRITANT)
- Eye protection
- Two dropping pipettes

Jeans Pants Clothing - Free photo on Pixabay

Instructions

1. Fill a dropping pipette with propanone. Squirt the propanone gently into a $10\ cm^3$ beaker.
2. Add the contents of one plastic dropping pipette of 2-nitrobenzaldehyde.
3. Add 1 – 2 cm^3 deionised water. Swirl the beaker gently to mix. A yellow solution should form.
4. Add $1\ moldm^{-3}$ sodium hydroxide solution dropwise until there is no further change. A dark-blue/purple precipitate of indigo should form.
5. Filter the liquid and precipitate. The precipitate is indigo dye.

To dye fabric using the indigo.

Equipment

- Sodium dithionite solution
- Cotton fabric
- Glass rod
- Paper towel

Instructions

1. Dissolve the solid indigo in sodium dithionite.
2. Dip a piece of cotton fabric in the solution. Stir with a glass rod then leave for a few minutes.
3. Remove the fabric from the solution and leave it to dry on the paper towel. The indigo should turn blue when exposed to air.

Questions

1. What colour is indigo?
2. What gas in the air reacts with the dye to produce the indigo colour?
3. How could you change the depth of colour made by the dye?
4. Find out about the history of indigo – where does it come from?
5. Is synthetic indigo more sustainable and 'greener' to use than natural indigo? Why / why not?

Lesson 2 Activity C: Investigating Jeans

Prepare a presentation on one of these topics:

- The history of denim fabric
- The history of denim jeans
- How cotton is made
- How denim is dyed to create different colours
- Making ‘sustainable’ and ‘ethical’ jeans
- How indigo is made using ‘green’ processes

You will be peer-assessed on these criteria:

- The clarity of the information that you gave;
- What others learned from listening to your presentation;
- The quality of the slides / resources that you used.