

# Magic Dye Teachers' Notes

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## Magic Dye Mixture

This can be ordered from Kemtex Educational Supplies ([www.kemtex.co.uk](http://www.kemtex.co.uk)). The mixture is no longer listed as a product on the Kemtext website (due to low demand), however they will make up mixtures to order on request at a price of £5.75 per 100 g plus VAT.

There are also ways of making your own mixture out of three separate dyes, individually purchased. The RSC Classic Chemistry Demonstrations handbook contains one recipe ("48. Dyeing – three colours from the same dye-bath"), and others may be available on the web.

The Magic Dye from Kemtex is simply a mixture of an acid red dye, direct blue dye and disperse yellow dye. These are all available to order online in varying quantities from Kemtex. This method also allows you to customise the experiment by choosing which colours of dye you want to include. You can add as many or few as you like, in different colours. E.g.

- Direct Royal Blue, £6.50 for 100 g
- Disperse Mid Yellow, £6.75 for 100 g
- Acid Red, £7.50 for 100 g

Many more colours and quantities are available, so be creative! Just make sure you mix dyes which have different binding methods, so that all the dyes don't colour the same material type.

## White Material

Scraps and cut-offs of material can be bought cheaply from any material store. Only a small square is needed for this experiment.

## Background Chemistry

The Magic Dye is a mixture of three different dye molecules, a yellow disperse dye, a direct blue dye and an acid red dye.

The acid red dye has a chemical structure containing acidic groups such as  $-\text{CO}_2\text{H}$  and  $-\text{SO}_3\text{H}$  which bond with  $-\text{NH}$  groups in amide linkages. Materials like silk, wool and nylon contain these.

The direct blue dye has a chemical structure containing hydrogen bonding groups. These groups can hydrogen bond to  $-\text{OH}$  groups found on cotton and rayon.

The disperse yellow dye is not soluble in water. It exists in the bath as a fine solution is absorbed as a solid solution by hydrophobic materials such as cellulose acetate and polyester.

When the materials are put into the mixture the dyes only attach to the materials they can bond well with. The blue and yellow dyes both bond well to polyester cotton so therefore the material looks green when it comes out of the mixture.

The colours look brighter when the material has been boiled in the mixture for a few minutes because the extra heat energy helps to overcome the activation barrier to bond formation so more dye molecules can attach to the material.

This table shows the colours selected materials will be coloured using a mixture of the dyes mentioned above:

Material	Colour
silk	red
Polyester cotton	Green (blue+yellow)
cotton	blue
acetate	yellow
nylon	yellow

## During the experimental

The dyes still attach to the material if boiling water from a kettle is used to dissolve the magic dye and the material is left in it for a few minutes. However the colours come out brighter if the water can continue to boil on a hotplate, using a tripod and Bunsen burner or in a water bath if you have access to this equipment

This could be run as a class activity where each pair has their own beaker, solution and scraps of material or as a demo at the front of the class. You could also perhaps sew different scraps together into one piece, which will come out multi-coloured.

This can help to explain why when clothing dyes run in the washing machine, the labels and trim/seams can come out a different colour to the rest of the garment.

## Safety

Boiling water and hotplate

## Links to the curriculum

- bonding
- materials
- colour and dyes
- light absorption

## Relevance to solar energy

Scientists researching **dye-sensitised solar cells** often investigate various materials that can be used as semiconductors, e.g. titanium dioxide, zinc oxide or tin oxide. Unfortunately, many of these are white in appearance do not absorb visible light, which is the region of the spectrum with the most solar energy we want to capture.

Instead, coloured dyes are attached to the surface of the semiconductor. Their job is to absorb visible light. This allows an electron to get excited to a higher energy level and from here the electron gets injected into the semiconductor to create a current in the cell, giving us power.

However it is important to make sure that the dyes attach well to the semi-conductor to do its job and this depends on good bonding between the two. Therefore, we have to consider what types of bonding groups are on the dye so that it matches the groups on the semiconductor material. The most common bonding is acid groups like  $-\text{CO}_2\text{H}$  as they bond well to  $\text{TiO}_2$ .

An important part of the efficiency and the stability of a dye-sensitised solar cell is how well the dye is bonded to the semiconductor and how easily it can transfer excited electrons to it.