Special section: Microscale Science / Sección especial: Ciencia en microescala
Microscale experiments with fabrics and a permanent marker

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Abstract

MULTIFIBER 6 (MF6) - a 5 x 5 cm piece of test fabric woven of 6 different fibres – is very suitable for student microscale experiments even for beginners: After marking these six substances with a black pen and wetting them, a reddish substance separates. During heating of the marked MF6 in water the coloured substance is dissolved and four of the six substances are permanently dyed, while cotton and polyester are not. The dyeing effect can be confirmed by heating fresh MF6, white sheep´s wool and white cotton thread in this coloured solution. Drying of wet MF6 at room temperature and in a deep-freeze is followed gravimetrically. For this experiment any other small piece of fabric may replace MF6. By "ironing" MF6 at too high a temperature the stabilities of the six substances can be easily tested. These experiments can be performed at home as the materials and chemicals are safe, available, cheap and easy to transport.

Key words: *wool, cotton, synthetic fibres, dye, dry, heat stability, sublimation*

INTRODUCTION

Chemistry deals with substances, their properties and the formation of new substances. Materials made by plants such as cellulose (cotton, linen) or by animals, such as proteins (wool, silk), and synthetic substances (polyamide, polyester, polyacrylic) are used as fibres which are spun, woven and dyed to make the fabrics of our clothes. Fabrics, their dyes, washing, drying and ironing are interesting subjects for young people. So student experiments with fabrics offer an access to chemistry by activities not only in the school but also at home (El-MARSAFY, 1989; EL-MARSAFY, 1995; EL-MARSAFY, SCHWARZ, 1996; WLOKA, 2002; El-MARSAFY, SCHWARZ, 2002; SCHWARZ, 2006 b, c). The materials for home experimentation like injection bottles, infusion bottles, dropper bottles, a two-pan scale, a stove heated by a candle, are easy to get (see below), cheap, versatile and safe. That means they can be packed, transported and used to do practical home works.

MULTIFIBER 6 (MF6) is a test fabric. It consists of six different substances (spun cellulose diacetate, bleached cotton, spun polyamide, spun polyester, spun polyacrylic and worsted wool) woven on a square of 5 x 5 cm (figure 1). Pieces of white cotton or linen, other fabrics or even white sheep´s wool or a cotton plug are also suitable for the experiments. MF6 was first introduced to microscale chemistry experimentation (MCE) by Livneh (LIVNEH, 2001).

To mark the six fabrics of MF6, black permanent markers were used. One of them, called TDK® CD-R PEN which is very common for labelling CDs gave two unexpected results: Its colour is a mixture including a water soluble component. This substance reacts with some of the substances in MF6 and other fibres.

The following experiments offer basic knowledge (for instance fibres, dyes, fuel, states of matter, physical changes, chemical reactions) and techniques (mixing and separating of substances, using scales, making weights, safe heating).

MATERIALS

MULTIFIBER 6 (Testfabrics, Inc. 415 Delaware Av. P.O. Box 26 West Pittston, PA 18643 USA, testfabrics@aol.com), white, washed sheep´s wool, cotton thread, TDK® CD-R PEN[1)], tray (made by cutting a 1 litre TetraPak container), 5 mL injection bottle, Type 1, 50 mL infusion bottle (ask at any hospital for empty Liquemin, Heparin and Imeron bottles[2)] or order at info@zscheile-klinger.de [3)]), plastic pipettes, stove with a candle in an aluminum beaker, circular steel lid of a can, insulated copper wire for weights, scissors, alarm clock, test tube holder (wooden clothes clamp) water, methylated spirit, toilet paper, matches.

[1)] - [3)] *For sources of supply*: [1)] "TDK® CD-R PEN" at www.google.com, [2)] SCHWARZ, 2002, [3)] SCHWARZ, 2003.

Experiments

1. Labelling the six different substances on MF6 and wetting them.
2. Heating in water MF6 labelled by a TDK® CD-R PEN.
3. Gravimetric drying MF6.
4. Ironing MF6 at too high a temperature.

1. Labelling the 6 different substances on WF6 and wetting them

Experiment 1. Mark the 6 fabrics of MF 6 (cellulose diacetate, cotton, polyamide, polyester, polyacrylic, wool) using the black CD-R PEN.
2. Drop water on each fabric just below the numbers.
3. Compare the time needed by each fabric to absorb the drops of water.
4. Add drops until each multifibre fabric is completely wetted.

Observations

1. In fabric 1 (cellulose diacetate), 2 (cotton) and 5 (polyacrylic) the water drops disappear immediately after adding them.

   Polyester (4) and polyamide (3) follow later. Water drops remain on the surface of the wool (figure 2). Complete wetting of wool takes the longest time.
2. The water entering the fabrics separates a red substance from the black marker in cellulose diacetate and polyacrylic.

The water solubility of the red component is confirmed by the following experiment.

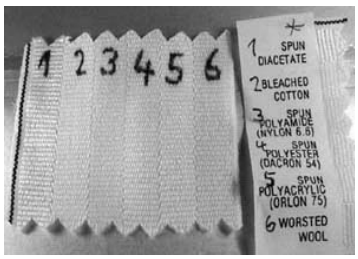

Figure 1
Testfabrics MF6 marked 1 - 6 marked 1-6 with a black TDK® CD-R Pen

Figure 2
Wetting the marked MF6 and separation of a red substance from the black colour

Testfabrics MF6 marked 1 - 6 marked Wetting the marked MF6 and separation 1-6 with a black TDK® CD-R Pen of a red substance from the black colour

Explanation

1. Cotton is made of cellulose fibres like filter paper. Both leave space between them. These absorb the water penetrating from the drops on the surface of each fabric by capillary forces. Wool fibres are the hair of sheep. Like human hair they are covered by a thin layer of fat which repels water. This repellent effect can be observed in daily life when a pullover is wetted for washing.

2. The black colour of the CD-R Pen is a mixture including a red substance with limited solubility in water. After its dissolution the red substance is transported by the water moving between the fibres during the wetting process. This separation of the red substance from the black mixture can be done on a filter circle paper in a well known procedure called *paper chromatography* (Schwarz 2006 d). The fibres of the MF6 and of the cellulose of the filter paper are the *stationary phases*, the water is the *mobile phase*.

2. Heating in water MF6 labelled by a TDK® CD-R PEN

Experiment

1. Place the MF6 from the previous experiment into an infusion bottle and add 20 mL water.
2. Take the stove to be heated by a candle. Cover it with a circular steel lid from a can.
3. Place the infusion bottle with the MF6 in water on the stove and heat it for 1 hour (figure 3).
4. After cooling cut off the side of MF6 with the black numbers, heat its remaining part in fresh water for another 1 hour (figure 4).

Observations

1. After the first heating the fabrics 1, 3, 5 and the water have reddish colours. The wool shows a brown colour, the cotton and the polyester remain white (figure 4).
2. The colour cannot be removed from cellulose diacetate, polyamide, polyacrylic and wool by heating the MF6 in fresh water.

Figure 3
MF6 of the previous experiment at the beginning of heating

Figure 4
MF6 of the previous experiment after heating, cutting off the numbers and heating again in fresh water

Explanations

(They must be limited as the red component in the black marker is an unknown substance).

1. The red substance is permanently bonded to other substances. Coloured substances with such properties are called dyes.
2. In the dyeing process the red substance forms new compounds by chemical reactions of the dye with cellulose diacetate, polyamide, polyacrylic and wool. This dyeing process takes also place if fresh MF6, white sheep wool are heated in the reddish solution left after experiment 2 (SCHWARZ, 2006 d).

3. Gravimetric drying of MF6

Fabrics can be dried not only in fresh air or in a dryer but also at temperatures far below 0°C.

The process by which a substance goes directly from the solid state to the gaseous state without passing through the liquid state is called sublimation (ZUMDAHL, 1989). Freeze drying by sublimation under vacuum is used to make instant coffee, for instance.

Experiment

1. Place a wet MF6 on the left pan of the scale and a dry one on the right pan[1].
2. To balance the scale add a piece of insulated copper wire on the right pan.
3. Start the alarm clock, wait until the scale is clearly unbalanced (Figure 5).
4. Remove pieces of wire to re-balance the scale again.
5. Fix the pieces of wire removed for re-balancing the scale on a chequered paper. Write down the times needed for evaporation.

[1] For this experiment MF6 may be replaced by piece of cotton, linen or other fabric.

Observations

1. After 5 minutes a slight loss of weight can be seen (figure 5).
2. After 115 more minutes the rest of the wire can be removed: The drying process is finished, the two MF6 have the same weight.
3. The following changes in weight can be measured after 13 / 29 / 50 / 65 / 80 / 120 minutes:
4. 3.9 cm / 9.4 (3.9+5.5) cm / 17.2 (9.4 + 7.8) cm / 21.8 (17.2 + 4.6) cm / 26.8 (21.8 + 5.0) cm / 32.4 (26.8 + 5.6) cm.

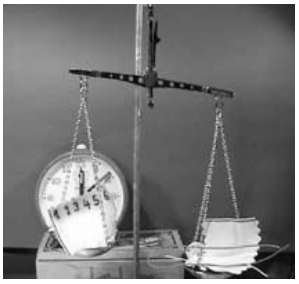

Figure 5

Drying effect of wet MF 6 to be measured after 5 minutes For weights and weighing see SCHWARZ 2002

Explanation

The wet MF6 had absorbed an amount of water equivalent to 32 cm wire = 2 g = 2 mL of water which evaporated at room temperature during 2 hours.

Plot a graph showing the loss of water [cm of wire] versus time.

Repeating the same experiment with a deep-freeze.

Observations

1. After 6 hours in the deep-freeze the fabric has clearly lost weight.
2. After one week the frozen water in the fabric has been reduced from 2 g (mL) to 0.4 g.
3. After two weeks MF6 is completely dried.

Explanation

At any temperature above the absolute zero point of minus 273°C the smallest particles of a substance are in permanent motion. The water particles on the surface can be released in the solid state as their bonding to other water particles is limited.

4. "Ironing" MF6 at too high a temperature

On a steam iron you can choose the temperatures suitable fabrics made of different substances. e Natural fibres can be ironed at higher temperatures than synthetic ones in the order "silk", "wool", "cotton" and "linen".

Experiment

You will compare the substances in a 1 cm stripe of MF6 while they are heated on circular steel lid of a can.

1. Make a micro spirit burner from a high 5-mL Liquemin injection bottle using a drilled piece of toilet paper as a wick.
2. Cut 1 cm stripe of MF6, mark it 1 - 6.
3. Place it on a circular steel lid of a can like seen in Figure 6. (1 = cellulose diacetate, 2 = cotton,... 6 = wool).
4. Heat the stripe on the lid symmetrically as to get the results like seen in figure 6, down).

Observation

(Figure 6 down)

1. After a few minutes cellulose diacetate (1), polyamide (3), polyester (4) and polyacrylic are melting,
2. In wool (6) small changes can be seen, cotton (2) did not change its texture or its colour.

Figure 6

A stripe of MF6 on a steel lid before (up) and after heating (down) F

Explanation

The decomposition of the synthetic fibres in fabrics 1, 3 - 5 is due to their chemical structure. This should not be taught at the secondary school level. From this experiment everybody should learn about the danger related to melting fabrics in case of fire.

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