

DYEING OF AN ACRYLIC FABRIC WITH A FLUORESCENT CATIONIC DYE

Aims:

1. To dye an acrylic fabric with a fluorescent cationic dye.
2. To illustrate the effects of retarding agents on dyeing.
3. To determine which fibres in a multi-fibre fabric are dyed or stained by the cationic dye under different dyeing conditions.
4. To illustrate the nature of fluorescence by visual assessments and color measurement.

Theory:

Acrylic fibres obtained by using at least 85% acrylonitrile as a monomer are available in cationic dyeable or anionic dyeable forms. Cationic dyeable fibres contain negatively charged dye sites and therefore can be dyed with cationic (i.e. basic) dyes, whereas the anionic dyeable fibers contain positively charged dye sites and can be dyed with anionic dyes. Of these two forms, the cationic dyeable fibres are more common in commercial use. Cationic dyes have good solubility in water, high color value and are amongst the brightest dyes available. Most disperse dyes produce only pale shades on acrylic fibres however during the 1950's there was a range of disperse dyes available that gave good colour yields on Courtele and Orlon. Acid dyeable acrylic fibres have a tendency to yellow, and do not produce shades of comparable brightness to cationic dyes.

The glass transition temperature T_g is a very important property that affects the dyeing temperature T of acrylic fibres. Below the glass transition temperature T_g all of the amorphous areas of the fibres are compact and effectively immobile. Under these conditions the polymer molecules exhibit only small scale atomic movement. As a result, the dye molecules can not penetrate the fibre structure by diffusion, but remain on the surface resulting in ring dyeing. Actual dyeing does not take place below the glass transition temperature of the fibre. The rate at which dyeing occurs is related to the temperature difference $T - T_g$. Since the T_g of most acrylic fibres is between 70-75°C, most dyeing is started at or just below this temperature and then the dyebath is heated gradually (over 30-60 minutes) to 100°C. Actual dyeing times are a function of the auxiliaries used, the type of fibre, and the dye.

The exhaustion of a fluorescent basic dye will be studied at a constant temperature of 95°C, both in the presence of and in the absence of specific dyebath auxiliaries. The tendency of the cationic dye to strike rapidly and thus to dye unlevel is increased by this process.

The mechanism of dyeing of acrylic fibres with cationic dyes involves electrostatic attraction between the anionic sites on the fibre and the coloured cations of the ionized dye. This electrostatic attraction is reinforced by the attraction between the organic part of the dye cation and the acrylic polymer, dyeing can take place by an ion-exchange process in which the dye cation enters the fibre and displaces smaller inorganic cations such as the sodium ions which are often already present in the acrylic fibre. This mechanism is the electrical opposite of the mechanism of acid dyeing of wool and nylons.

The dye cations absorbed initially on the fibre surface resist diffusion into the interior of the fibre. Any significant diffusion is possible only by the freeing of the dye molecules from their local interactions with the polymer. This is effected by elevating the temperature of the dyebath. This temperature increase makes $(T - T_g)$ larger, so that the motions of the obstructing polymer chains also become greater or easier. These two distinct effects of temperature combine to assist the penetration of the dye into the fibre. If the dye initially exhausts unevenly, it is then very difficult to level the dye, so it is extremely important to control the initial rate of strike. This initial rate of strike is controlled by use of retarding agents.

There are two types of retarding agents

- (a) those that form a complex with the dye and thus tend to retain it in the dyebath, and
- (b) those that compete with the dye for the ionic dye sites in the ion-exchange dyeing process.

A cationic retarder based on a quaternary ammonium compound competes with the cationic dye for the anionic dye sites in the fibre. This competition reduces the initial strike rate of the dye, to promote level dyeing, but may also reduce the final dyebath exhaustion. In order to show the importance of correct dyeing conditions, a dyeing without any dyebath auxiliaries except the dye is included. The method incorporates a fixed dyeing temperature in order to promote unlevelness. A long liquor to goods ratio is used to permit complete immersion of the samples in the dyebaths in the Ahiba dyeing machine. Under normal commercial conditions dyeing takes place at liquor ratios from about 30:1 to 8:1.

Fluorescence and Colour Measurement

Dyed fabrics are generally viewed in "white light", which was shown by Newton to be a depends on how much power the light source emits at each different wavelength. The colour of an object viewed under that light source depends on the percentage of the light that is reflected by the object at each wavelength.

Fluorescent dyes give unusually bright and intense colours. Fluorescent dyes absorb light energy from a light source at short wavelengths and then re-emit some of this energy as light at a longer wavelength. The re-emitted longer wavelength light is added to the light reflected normally by the sample at the same longer wavelength, thus causing the remarkable brightness of the colour. The addition of the fluorescence emission to the normal light reflectance may give measured apparent reflectance values in excess of 100%.

Equipment and Chemicals

- Acrylic knitted fabric
- Multi-fiber Fabric
- 0.5% Yoracryl Brilliant Red 4G (C.I. Basic Red 14)
- 10% Solution of Quaternary Ammonium Retarder
- 10% Solution Sodium sulphate to promote levelness
- 1% Solution of E.D.T.A. {Ethylene diamine tetraacetic acid disodium salt} sequestering agent
- 10% Teric N10 nonionic surfactant
- 10% Acetic acid for pH control

Procedure

1. Obtain two samples of acrylic fabric each sample should weigh 10.0g.
2. Attach a 5" strip of multi-fiber fabric to each sample.
3. Mount each sample on holder for the Ahiba machine.
4. Prepare the following dyebaths:

Dyebath A: Liquor ratio 60:1

1% Yoracryl Brilliant Red 4G

Dyebath B: Liquor ratio 60:1

1% Yoracryl Brilliant Red 4G

3% Quaternary Ammonium Retarder

10% Sodium Sulphate

0.5% Acetic acid

0.5% Triton X-100

0.25% EDTA

Adjust pH to pH 4.0 – 4.5 before dyeing, by adding acetic acid.

5. All dyeings are to be carried out at 95°C in the Ahiba dyeing machine. Prepare the two dyebaths and place them in the Ahiba machine for 15 minutes to allow them to come to temperature before adding the fabric.
6. Add the fabric to the dyebaths and commence dyeing. The dyeings can be stopped when the dyebath containing only the dye, (dyebath A), has exhausted, or after 45 minutes, whichever comes first.
7. At the completion of the dyeing, rinse the samples in water and then dry.

Colour Measurement:

1. Measure the reflectance of each of the dyeings using the DATACOLOR SYSTEM.
2. Obtain C.I.E. colour specifications for the samples and compare the reflectance curve against that of C.I. Disperse Red 60 (Resolin Red FB).
3. Depending on the time available, reflectance measurements will be made using the Diano

Observations:

During the dyeings, observe and note any differences in dyeing behavior between dyeing A and dyeing B, and any differences in the appearances of the two dyed samples. Note also any differences in the appearances of the two multi-fiber fabric strips.

Discuss the differences in your lab report, and attempt to explain them. Include copies of the colour measurement results in your report. Describe the appearance of your dyed samples, and explain the phenomenon of fluorescence in your own words.

References

1. M.J. Schuler, Dyeing With Basic Dyes, Textile Chemist and Colorist, ,12,No.3,64-66 (1980):
2. E. R. Trotman, Dyeing and Chemical Technology of Textile Fibers, C. Griffin & Co., London (1984).