TEXTILE DYES: REACTIVE DYES

Reactive dyes are available in a wide range of colours, even in very bright tones. They form bonds between their reactive groups and textile fibres, which gives excellent colour fastness. They are especially suitable for cellulose fibres, but can also be used to dye protein fibres and polyamide.

Four dye batches with different types of cellulose fabrics, photo: Maija Fagerlund

BASIC PROCESS STEPS IN PIGMENT DYEING AND PRINTING

1. EXHAUSTION, where the dye is transferred from the dyebath to the fibre (dyeing) or another method of applying the dye into fibre (screen or digital printing, hand-painting)

2. FIXATION, where the reaction takes place to fix the dye to the fibre

3. POST-DYE WASHING, where any excess dye is removed

- Different reactive dyes have different degrees of reactivity, and this has an influence in the temperature of the exhaustion phase. In general, the higher the reactivity (= the speed at which the dye exhausts onto the fibre), the lower its **application temperature**. See the suitable temperatures for different Remazol reactive dyes in Contemporary Colour Methods, p. 119-122

- Once the dye has exhausted onto the fibre with the addition of an **electrolyte such as Glauber´s salt**, the reaction is promoted by the addition of an **alkali such as calcinated soda**.

- While the alkaline phase promotes the reaction of the dye with the fibre, it has the side effect of encouraging reaction of the dye with water (=hydrolysis). This is undesirable because:
    - hydrolysed dye would be wasted and end up in waste water
    - its presence on the fibre would reduce colour fastness

- There is always a degree of hydrolysis with reactive dyeing, and the dyer must minimize this by dyeing at as low a liquor-to-goods ratio as the machinery will allow. The **liquor-to-goods** ratio is the ratio between the volume of the dyebath and the weight of goods. For example, a dyeing of 5 kg of goods in 100 L of water has a liquor-to-goods ratio expressed as 20:1

- The final phase of the dyeing process is to remove any hydrolysed dye from the fibre by rinsing (first in cold water, then in hot, and finally in cold again)

ENVIRONMENTAL ASPECTS

Waste water from dye houses using reactive dyes contain unfixed dye, alkali and considerable amounts of salt. Some of the reactive dyes also contain metals. Hydrolysis should be minimised in the dyeing process to avoid waste dye. Various end-of-pipe treatments such as decolorisation can be performed to help to clean the waste water, however it is also important to minimise the use of chemicals. However, especially considerable amounts of salt is always released in reactive dyeing process.

On the other hand, modern reactive dyes are known for their bright colours and very good colour fastness - textiles dyed with reactive dyes will last long without fading, and durability is also an important factor when considering environmental aspects of different textile processes.

Thomas Bechtold, Tung Pham: Textile Chemistry, 2019, Walter de Gruyter GmbH, Berlin/Boston
Maija Pellonpää-Forss (2018) Contemporary Colour Methods
Woodhead Publishing Series in Textiles: Number 126: Textiles and Fashion - Materials, Design and Technology, Edited by Rose Sinclair, 19.5.1.2 Reactive dyes

DYEING PROCESS OF REACTIVE DYES FOR CELLULOSE FIBERS

In the page 129 of the book Contemporary Colour Methods by Maija Pellonpää-Forss, it is explained how to calculate the amount of dyestuff and auxiliaries (glauber´s salt and calcined soda) needed in reactive dyeing process:

- **The volume of dyeing liquor** is calculated as the ratio of dry weight of material to be dyed to the amount of liquor needed. The ratio is often 1:20. Dyeing with a smaller liquor ratio results easily in an uneven outcome, whereas when using a larger liquor ratio, the desired depth of shade is not reached and the consumption of auxiliaries increases.
- **The amount of dye** is calculated as the percentage of dry weight of material to be dyed.
- **The amounts of auxiliaries** are calculated as grams per litre of dyeing liquor, unless otherwise announced in the instructions.

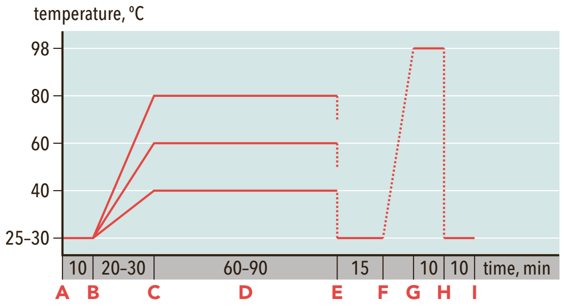
The amounts of auxiliaries according to dyeing temperature and the depth of shade in liquor ratio 1:15–1:20

Dyeing depth of shade, %			0.1–0.5	0.5–1.5	1.5–3	> 3
All colours*	Electrolyte	Cooking- or Glauber's salt	20–30	30–50	50–70	80**
Dyes with dyeing temperature of 40–60 °C	Alkali	Calcined soda, g/l***	3–5	5–10	10–15	15–20
	or	Calcined soda, g/l and NaOH, 32 %, ml/l****	5 1	5 1–1.5	5 1.5–2	5 2–3
Dyes with dyeing temperature of 60–80 °C	Alkali	Calcined soda, g/l	2–3	3	3–5	5–10
	or	Calcined soda, g/l and NaOH, 32 %, ml/l	5 –	5 0.5	5 0.5–1	5 1–1.5

Maija Pellonpää-Forss (2018) Contemporary Colour Methods, p.129

In the page 131, the stages of dyeing process of reactive dyes for cellulose fibres are explained:

Dyeing process diagram



Stages of the dyeing process

A: Measure 25–30 °C water, salt, dissolved dye and wetted material and place into the dyeing pot. Thus, the dyeing liquor is measured straight from the tap at 25–30 °C. Add Glauber's salt and stir to aid the dissolving. Undissolved auxiliaries bind dye in a different manner when coming into contact with the textile surface, which produces an uneven dyeing result. Allow for the material to absorb the dye and auxiliaries for 10 minutes. Agitate the material diligently, especially during the first half of the dyeing time.

B: After 10 minutes of dyeing, remove the material with a ladle and add half of the alkali that is dissolved in a small amount of liquor taken from the pot. Use either calcined soda (= soda ash), or the combination of calcined soda and lye (= NaOH) as the alkali. Salt makes dye molecules migrate towards the fibres' surface, close to their bonding sites, whereas alkali causes the dye-fibre bond.

B–C: Raise the temperature according to the dyeing process diagram to what is optimal for the colour in question (see list of colours on p. 119–124). Different colours are most active in different temperatures. For some colours, the dye-fibre affinity is strongest at 40 °C, while for others at 60 or 80 °C. If the dyeing temperature differs from the optimal, the dye fixation rate is not complete. Some colours are applicable at more than one temperature. For dyeing colour blends, the temperature is selected according to what is suitable for both components. If the optimal temperature is not known, all Remazol dyes can be dyed at 60 °C.

C–E: The dyeing time at the highest temperature varies between 60–90 minutes, which depends on the depth of shade. For pale shades, 60 minutes is a sufficient dyeing time, whereas deep shades are dyed 90 minutes, in order to reach the highest possible colour yield.

D: Add the remaining alkali in the middle of the dyeing time. The alkali is again dissolved to liquid taken from the dyeing liquor, and not poured onto the material directly. During this stage, most of the dye molecules have already reached their binding sites on the fibres, and adding alkali accelerates the fixing process. Also, the colour shade begins to level by diffusion, more specifically, dye detaches from areas where the dye concentration is higher than average and migrates to areas with a concentration lower than average.

E–F: Cold rinsing removes the auxiliaries that are no longer needed, and simultaneously some of the unbonded dye also. Cold water in rinses saves energy.

F–G: Heat the water for the finishing wash.

G–H: Immerse the material into 98 °C water and wash in boiling water for approx. 10 min. The boil-wash removes the remaining unbonded dye. Add detergent accordingly, especially if there are significant colour differences on the textile surface, or if colour turquoise is in question. The detergent binds unbonded dye molecules to itself, thus preventing them from returning to fibres. For reaching a good outcome, it is important to rinse off thoroughly the alkali and salt before the hot wash. If auxiliaries still remain in the material during the boil-wash, the affinity between unbonded dye and fibres is activated, which complicates the washing. This kind of poorly bonded dye detaches the material during washes upon wear, thus weakening the wash fastness.

H–I: Final rinse: rinse off the unbonded dye residue and the possible detergent, as in regular laundry.

Maija Pellonpää-Forss (2018) Contemporary Colour Methods, p.131

NOTE

- Wear gloves during the whole process
- Wear a mask and use fume cabinet when handling the chemicals before they are solvent into water
- Dissolve dye and calsinated soda always in fume cabinet, and preferably also Glauber´s salt

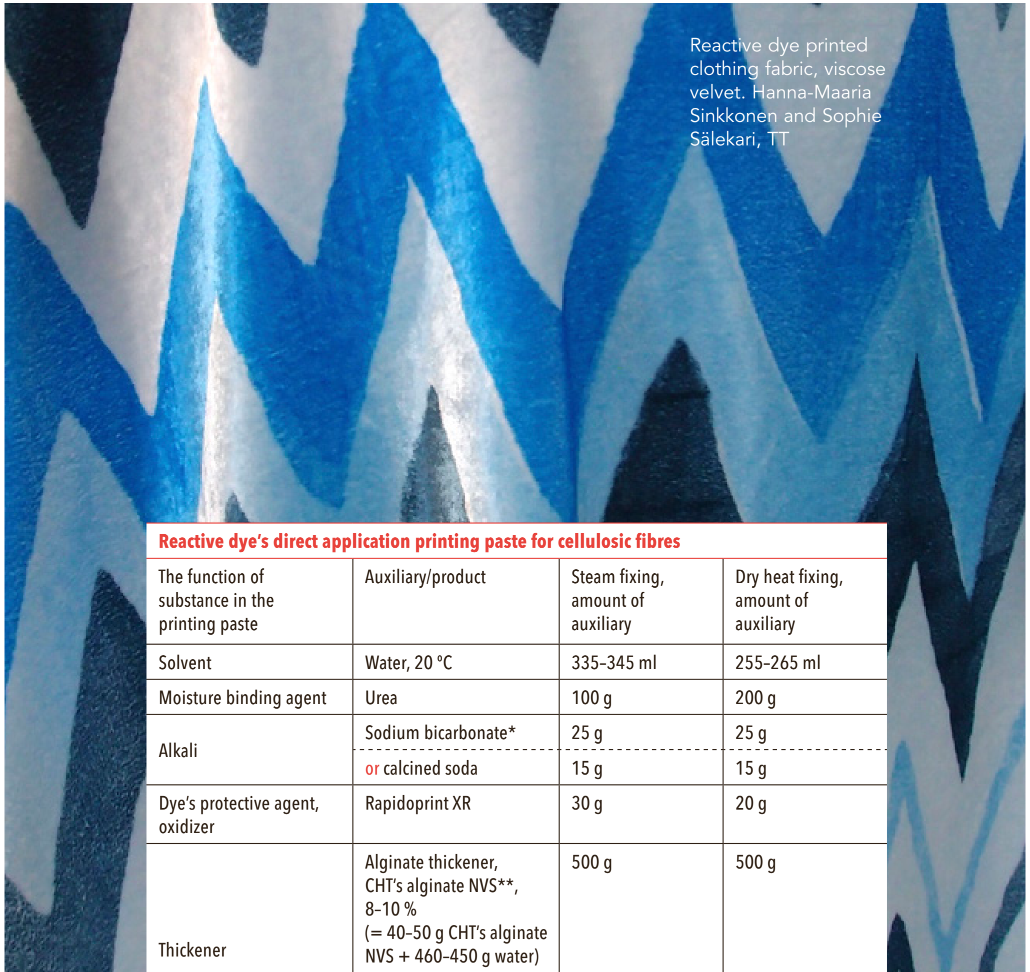
As with printing, the exhaust dying process we use on the course mimics the industrial process, but in a small scale. Have a look in here the industrial facilites of one of the very few dye houses in Finland, Lappajärven värjäämö: https://www.youtube.com/watch?v=bM4NYu7cngo

PRINTING (AND HAND-PAINTING) PROCESSES OF REACTIVE DYES FOR CELLULOSE FIBERS

- Reactive dyes are the second most frequently used colourants in textile printing after pigment dyes
- Reactive dye printing requires an alkali as a fixing agent to establish the molecular bonds between the dyes and the fibres
- Screen printing with reactive dyes also requires thickener
- Electrolyte such as Glauber´s salt is not needed, as colour is applied directly onto the desired areas
- In digital printing, the reactive dye is printed on a fabric pre-treated with the alkali
- Fixation process, which attaches reactive dyes to the fabrics, is generally made by steaming (or, industrially, in curing oven - note the difference in recipes)
- This is followed by washing to remove the excess dye and (in screen printing) thickening agent

Woodhead Publishing Series in Textiles: Number 126: Textiles and Fashion - Materials, Design and Technology, Edited by Rose Sinclair, 20.2.2 Reactive dye printing, Maija Pellonpää-Forss: Contemporary Colour Methods

In page 149 of Contemporary Colour Methods, the recipes and process of screen printing with reactive dyes on cellulose are explained:



Reactive dye printed clothing fabric, viscose velvet. Hanna-Maaria Sinkkonen and Sophie Sälekari, TT

Reactive dye's direct application printing paste for cellulosic fibres

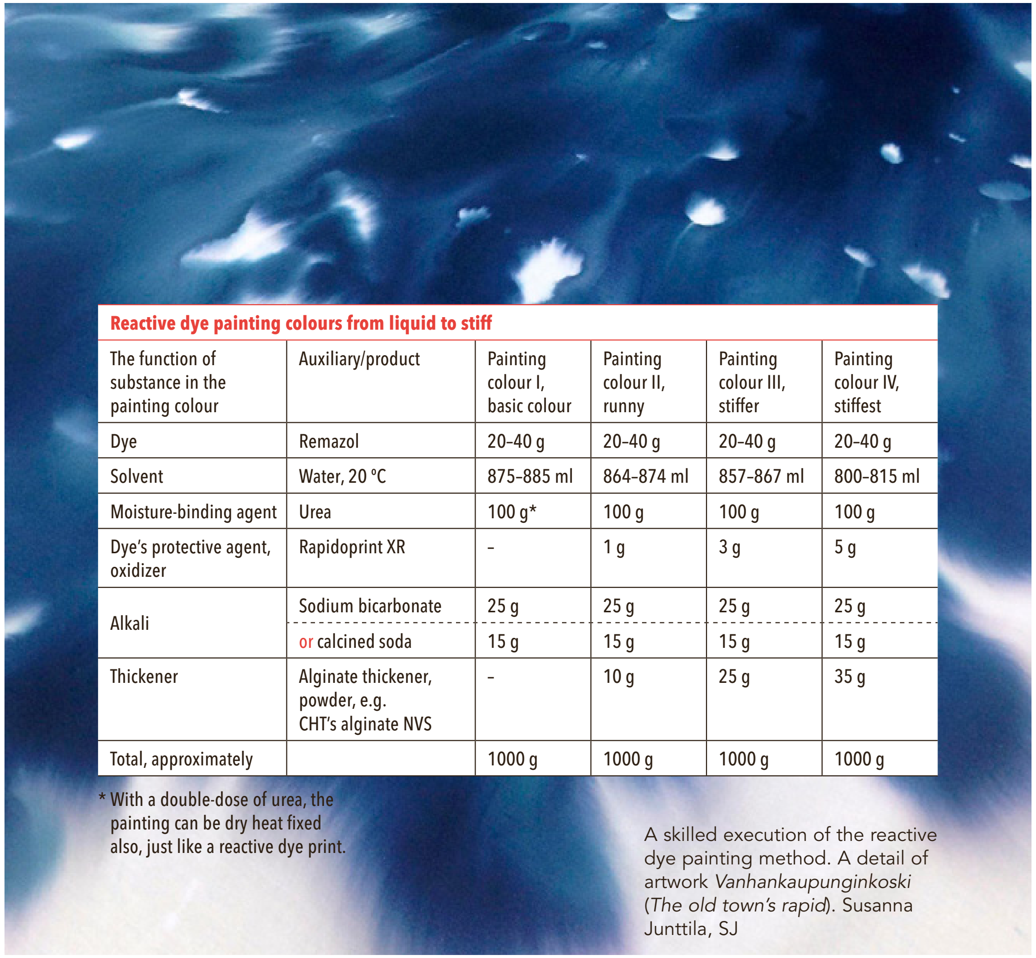
The function of substance in the printing paste	Auxiliary/product	Steam fixing, amount of auxiliary	Dry heat fixing, amount of auxiliary
Solvent	Water, 20 °C	335–345 ml	255–265 ml
Moisture binding agent	Urea	100 g	200 g
Alkali	Sodium bicarbonate*	25 g	25 g
	or calcined soda	15 g	15 g
Dye's protective agent, oxidizer	Rapidoprint XR	30 g	20 g
Thickener	Alginate thickener, CHT's alginate NVS**, 8–10 % (= 40–50 g CHT's alginate NVS + 460–450 g water)	500 g	500 g
	or Lyoprint RD-HT, 7 % (= 35 g Lyoprint + 465 g water)	500 g	500 g
Total, approximately		1000 g	1000 g

Stages of reactive dye printing

- Prepare the printing paste and print colour.
- Attach the base fabric to a rubber- or plastic-covered table for printing.
- Print the fabric.
- Detach the printed fabric from the table and dry.
- Fix the dye with steam, or with dry heat (providing that the printing paste contains a sufficient amount of urea).
- Rinse with cold and then with lukewarm water to remove the thickener and auxiliaries.
- Remove unbonded dye in a boil-wash with or without detergent. A boil-wash is repeated if necessary.
- Apply the final rinse to remove unbonded dye and detergent.
- Dry the material.

Maija Pellonpää-Forss (2018) Contemporary Colour Methods, p.149

In the page 145, the recipes and process of painting with reactive dyes on cellulose are explained:



Reactive dye painting colours from liquid to stiff

The function of substance in the painting colour	Auxiliary/product	Painting colour I, basic colour	Painting colour II, runny	Painting colour III, stiffer	Painting colour IV, stiffest
Dye	Remazol	20–40 g	20–40 g	20–40 g	20–40 g
Solvent	Water, 20 °C	875–885 ml	864–874 ml	857–867 ml	800–815 ml
Moisture-binding agent	Urea	100 g*	100 g	100 g	100 g
Dye's protective agent, oxidizer	Rapidoprint XR	–	1 g	3 g	5 g
Alkali	Sodium bicarbonate	25 g	25 g	25 g	25 g
	or calcined soda	15 g	15 g	15 g	15 g
Thickener	Alginate thickener, powder, e.g. CHT's alginate NVS	–	10 g	25 g	35 g
Total, approximately		1000 g	1000 g	1000 g	1000 g

* With a double-dose of urea, the painting can be dry heat fixed also, just like a reactive dye print.

A skilled execution of the reactive dye painting method. A detail of artwork *Vanhankaupunginkoski* (*The old town's rapid*). Susanna Junttila, SJ

Preparing the painting colour

- Dissolve alkali, urea and oxidizer in approximately half the amount of warm water. Add the remaining water, which is cold. Add alginate powder gradually with an electric mixer. After the consistency is settled, the solution/paste is ready to use.
- Add dye; granulates as such, powders dissolved in a small amount of hot water.
- Consider preparing generously the amount of clear painting liquor (without dye), as it is used for diluting the dyes to create paler shades. Keeping the liquor's pH value constant is important when diluting painting colours.

Painting

- The amount of alginate regulates, e.g. the dye's ability to absorb into the material.
- The fabric can be attached to a frame that is off the table top, to avoid dye from running onto the table. Alternatively, a backing cloth can be placed underneath the fabric to absorb the excess dye that passes through the painted fabric.
- When painting wet-on-wet, the first layer of dye cannot absorb new dye like when painting wet-on-dry. For the same reason, shades painted on wet fabric remain lighter.

Drying, fixing the dye and finishing washes

- Dry the painting and fix the dye by steaming. It can be also dry heat fixed, but the painting colour must then contain a double-dose of urea.
- Apply the finishing washes as in other reactive dye methods for cellulosic fibres.

Maija Pellonpää-Forss (2018) Contemporary Colour Methods, p.145

NOTE

- Printing/painting paste will only stay good for couple of weeks – make only the amount you need
- Wear gloves during the whole process
- Wear a mask and fume cabinet when handling the chemicals before they are solvent into water