

# **Smart Textiles: The Chemistry of Thermochromic Textile**

# What are Thermochromic Materials?

- Substances that undergo a reversible change of colour when their temperature is altered.
- Classified as "Smart Materials" due to their responsive properties.



## Particle Arrangement & Phase Change

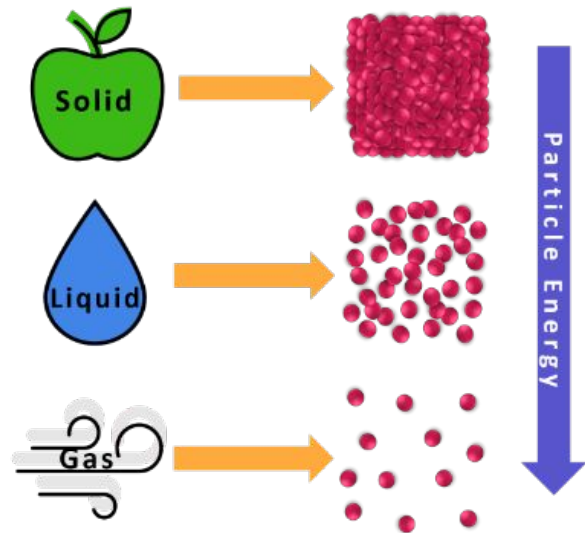
Junior Science

- **Solid State:** Developer and Dye are held together.
- **Liquid State:** Melting allows separation, resulting in color loss.

*The thermal energy will be absorbed or released during the change of physical states of substances (EDB, 2025, p. 56).*



### Arrangement of Particles in Matter Phases



Matter transitions into different forms when thermal energy moves in or out of a system.

**Thermochromic Textile is one of the real life examples in the fashion industry.**

## 2. Chemistry Knowledge

# Thermal Energy & Conduction

Junior Science

Thermochromic textile is a good example of thermal energy exchange via heat transfer and conduction.



### Heat Transfer

Thermal energy flows from skin (high temp) to fabric (low temp) via physical contact.



### Conduction

The microcapsule absorbs energy required for the latent heat of fusion.

*"Infer the direction of transfer of thermal energy" (EDB, 2025, p. 57).*

*"Identify the evidence for conduction" (EDB, 2025, p. 57).*



### 3. Chemistry Knowledge

## Chemical Equilibrium & Reversibility

Senior Chemistry

Dye and developer exist in a **dynamic balance**. The chemical reaction within thermochromic textiles is entirely reversible.



*Reversible and irreversible reactions by using suitable examples (EDB, 2018, p. 44).*

The color change is a dynamic balance between the colored complex and the separated components.



#### 4. Chemistry Knowledge

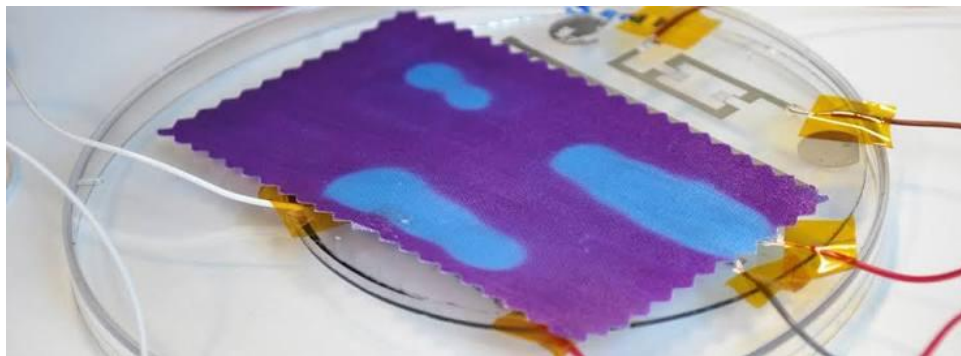
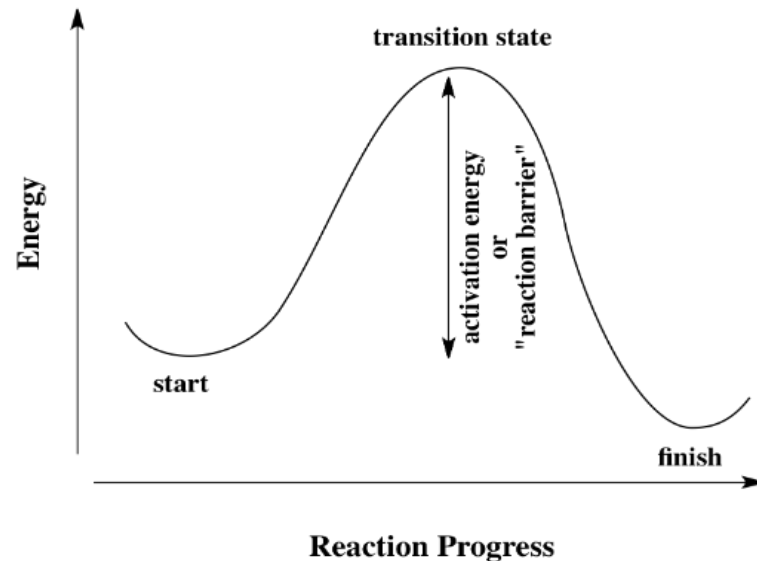
## Activation Energy Barrier

Senior Chemistry

Engineers customize "switching" temperatures by adjusting the thermal energy hurdle required for phase change.

- **Higher  $E_a$ :** Fabric remains stable at high temps.
- **Lower  $E_a$ :** Changes at skin contact.

*"Explain the meaning of the term activation energy" (EDB, 2018, p. 54).*



Thermochromic textiles provide a clear, practical example of activation energy in action.

## 5. Real World Application

# Interconnections between science, technology, society and the environment

(EDB, 2018, p. 14).



### Medical

Fever-detecting infant clothing or bandages.

*"Appreciate relationship between chemistry and other disciplines"*



### Safety

Industrial gear alerting high-heat hazards.

*"Be aware of STSE connections"*



### Consumer

Adaptive fashion.

*"Maintain sense of wonder and curiosity about chemistry" (EDB, 2018, p. 3).*



## Thermochromic Yarns' Application in Fever Detection for Young Children (Xia et al., 2024).



## 5. Real World Application

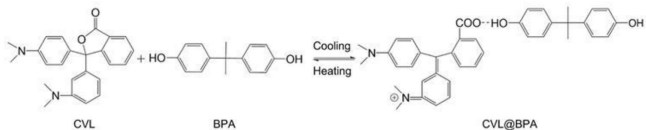
# Two Primary Types of Thermochromic Textiles

## 1. Liquid Crystals

Change color continuously via light interference as their molecular spacing shifts with temperature. (Highly sensitive, used in medical thermometers)

## 2. Leuco Dyes

Shift between a distinct colored and colorless state through structural chemical changes. More durable, widely used in textiles and consumer printing (Pu & Fang, 2022).



leuco dye   weak acid



## 5. Real World Application

# Intermolecular Forces in Textile Adhesion

Senior Chemistry

A thermochromic dye is useless if it washes right out of the shirt. To protect the highly sensitive dye from air, water, and detergents, it is microencapsulated into polymer shells then attach to the fiber. The microscopic world of intermolecular forces explain how the microencapsulated are securely attach to the textile.



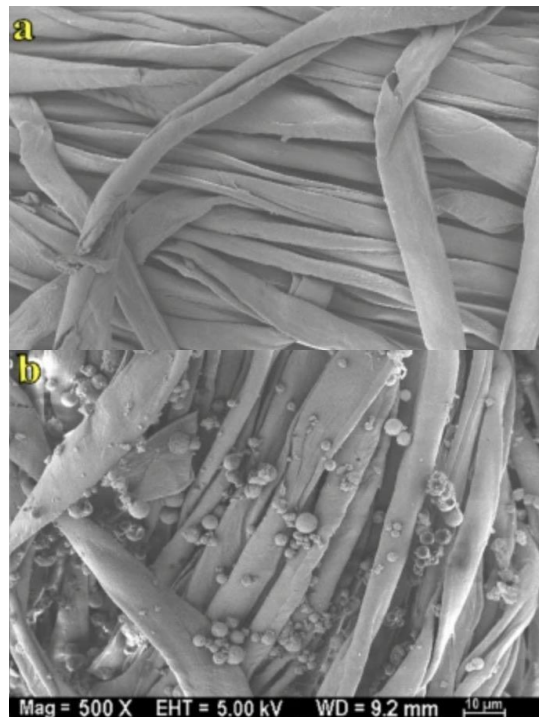
## Cotton (Cellulose)

Cotton is a natural polymer made of cellulose, which contains numerous **-OH (hydroxyl)** groups. This chemical structure allows the microcapsules containing the dye to adhere securely to the fabric fibers primarily through extensive **hydrogen bonding**.



## Polyester (Synthetic)

Polyester is a synthetic polymer containing **ester linkages**. Unlike cotton, it lacks extensive -OH groups, meaning the dye microcapsules must primarily rely on **dipole-dipole** interactions and **van der Waals forces** to adhere to the material.



**Top:** SEM micrographs of untreated cotton fiber

**Bottom:** Thermochromic dyestuff adsorbed onto the fibre surface.

Image from Toprak-Cavdur et al. (2026).

# Thermochromic textile in the runway



# Thermochromic textile in the runway



Kunihiro Morinaga

## 6. Applying the Thermochromic pigment

# Silkscreen Techniques

Screen printing involves transferring ink onto a substrate, such as fabric or paper, by forcing it through a stenciled mesh screen.

To achieve a multi-colored design, each individual color must be applied using its own specific screen and printing pass.

## Types of Print:

- 01 Screen print** (all types of fabric, white based)
- 02 Heat press** (100% cotton)
- 03 Digital print** (100% polyester)
- 04 Fabric Dye** e.g. tie-dye (100% cotton)



# Steps for Screen Print

## 01 Design & Creation

Prepare artwork and apply light-sensitive emulsion to a mesh screen. Expose screen to light; wash out the design area to create a stencil.

## 02 Setup

Secure the screen onto the printing frame. Position and flatten the fabric underneath.

## 03 Printing

Use a squeegee to press ink through the stencil onto the fabric.

## 04 Curing & Finishing

Carefully lift the screen to reveal the design. Apply heat (heat press/dryer) to permanently bond the ink. Clean the screen immediately for reuse.



## Silkscreen Techniques Examples



Alexander McQueen 2010ss



Dolce & Gabbana 2013ss



Dries Van Noten 2025ss

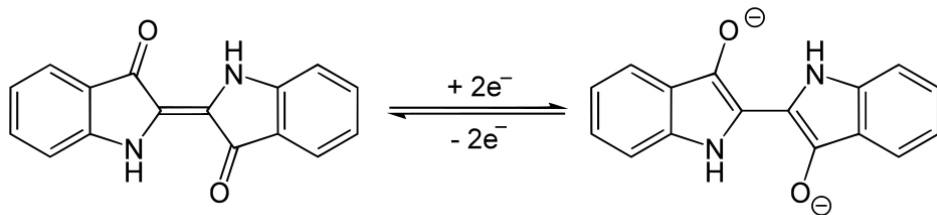
# Indigo Dye

## Redox Reactions

Indigo dye (used for blue jeans and traditional textiles) is a perfect real-world example of redox chemistry.

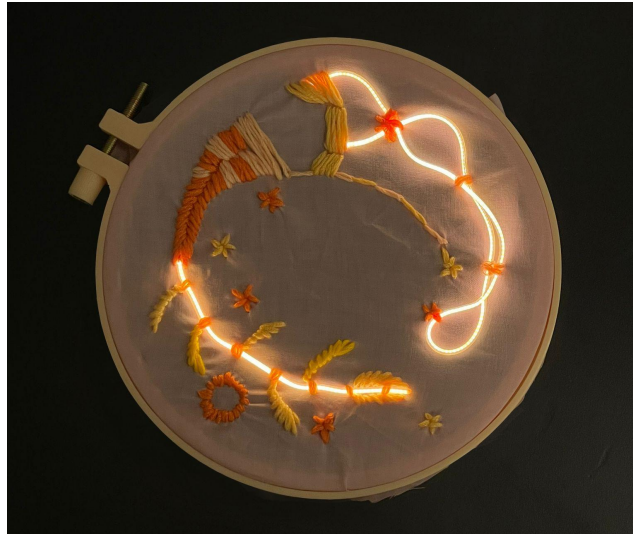
Indigo is naturally insoluble in water, meaning it can't bond to fabric. It must first be reduced (using a reducing agent like sodium dithionite) into a water-soluble form called "leucoindigo," which is yellowish-green.

The fabric is soaked in this reduced solution. When pulled out and exposed to the air, oxygen oxidizes the leucoindigo back into its insoluble blue form, physically trapping it inside the cotton fibers.



# Mix of techniques

- Print + Embellishment
- Print + Led



# Print in different way

## Print + embellishments



Miu Miu 2025ss



Lace + print

## Print on feathers



Loewe 2025ss

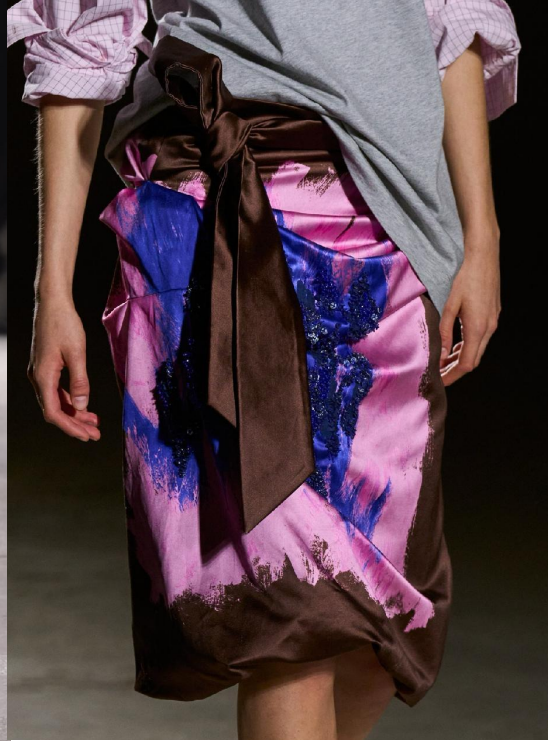
# *Print on different surface*



Jil Sander 2025ss



Bottega Veneta 2025ss



Dries Van Noten 2025ss

## Color-changing Screen Print Dress





**Thermochromic pigment:  
Fades when a hair dryer heats  
up the fabric**



**Photochromic pigment:  
Changes color under UV light**