Experiment 4 – Colorful Chemistry

DYES AND PIGMENTS are colorful compounds used to change the appearance of objects. Nature produces them to make flowers attractive to insects and to people, to tell predators to back off, and to catch the sunlight for energy. Humans have learned to use such naturally colored substances from a very early time, as cave paintings and ceramic artifacts testify. It was not until the past century or so that we have discovered how to make our own dye molecules. The creation of new colors and their applications in the textile and printing industries was at least partially responsible for bringing synthetic organic chemistry to the foreground of scientific research!

THE DIFFERENCE BETWEEN DYES AND PIGMENTS is that dyes are water-soluble and pigments are not. Dyes can be classified according to their structures and also based on their mode of application to fibers. According to structural differences, the most common dyes can be classified as *azo, cationic, anthraquinone,* and *indigo* (**Figure 1**). Depending on their mode of application, dyes can be grouped into the following types: *direct, mordant, ingrain, vat, disperse, reactive,* and *solvent*.

Azo Benzene (Parent of azo dyes) | **Alkylmmonium triphenylmethane** (Parent of some cationic dyes) | **Anthraquinone** | **Indigo**

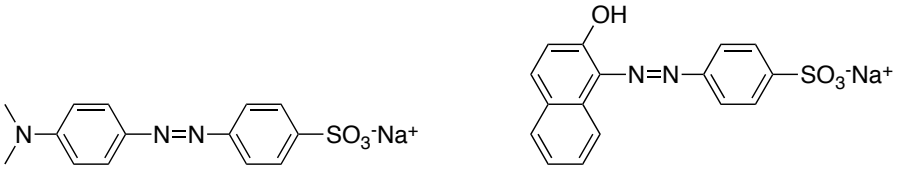
Figure 1. Structural families of dyes

LET'S BRIEFLY CONSIDER THE NATURE OF COLOR. As you have learned in your general chemistry classes, objects appear colored because they absorb certain wavelengths of the visible spectrum (400 – 750 nm) and reflect the complementary colors. Thus, a compound that absorbs blue light will appear orange and one that absorbs red will appear green. But what is it about the structures of these compounds that make them absorb certain wavelengths? A short explanation is the *extent and nature of the conjugation* present in the compound. A conjugated compound has a network of linked p-orbitals (forming pi-bonds), appearing structurally as alternating double and single bonds. This is apparent in all of the examples of dyes in **Figure 1** above. In general, the more extended a conjugated system (the larger the number of pi electrons involved), the longer the wavelength absorbed (towards red), and the shorter the wavelength emitted (towards violet). There are many other factors involved, as you will observe, including contribution of *ortho/para*-activators and *meta*-deactivators.

Azo Dyes encompass the largest family of dyes. They contain an azo group, -N=N-, linking two aromatic rings. Because of their extended conjugated pi-orbital systems, these aromatic compounds absorb in the visible region of the electromagnetic spectrum and are deeply colored, often vibrant orange. This implies that azo dyes *absorb* relatively short wavelengths of light.

TO BE USEFUL AS DYES, AZO COMPOUNDS MUST BE SOLUBLE IN WATER. This can be achieved by having polar and ionic groups attached to the aromatic rings. Sodium salts of sulfonic ($-SO_3Na$) and carboxylic ($-CO_2Na$) acids work well for this purpose. Methyl Orange and

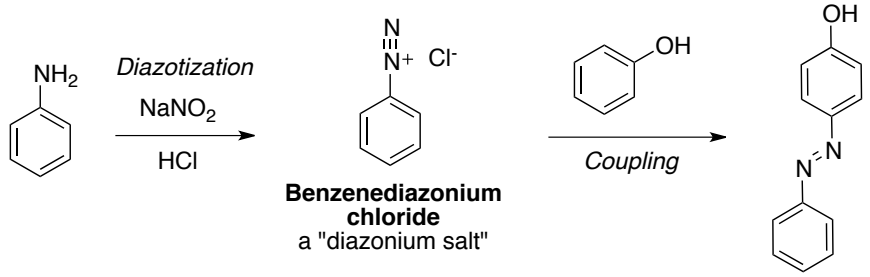
Naphthalene Orange II are such examples of cationic azo dyes (**Figure 2**). Simple changes in substituents and substitution patterns can make significant enough changes to be noticed by the naked eye. Azo dyes without ionic groups are insoluble in water. These insoluble compounds can be used as pigments or, in solution with a suitable solvent, as *solvent dyes*.



Methyl Orange **Naphthalene Orange G** or **Orange II**

Figure 2. Examples of azo dyes

THE SYNTHESIS OF AZO DYES can be accomplished in two steps (**Figure 3**). In the first step, an aromatic amine is transformed into a diazonium salt by the reaction of nitrous acid obtained *in situ* by mixing sodium nitrite and a mineral acid. Diazotization reactions are usually performed at low temperatures to avoid the decomposition of the diazonium salts. These compounds are unstable at higher temperatures due to their tendency to expel nitrogen gas. Some **diazonium salts are explosive when dry and must be kept in solution**. In the second step, the diazonium salt is coupled to an aromatic compound, usually an aniline or phenol, to yield an aromatic azo compound.



Benzenediazonium chloride
a "diazonium salt"

Figure 3. Synthesis of azo dyes.

THE COUPLING REACTION BETWEEN DIAZONIUM SALTS and aromatic compounds takes place by an electrophilic aromatic substitution (EArS) mechanism (**Figure 4**). The diazo-nitrogen farthest from the ring is attacked by the aromatic ring. The coupling typically takes place in the *para*-position relative to the electron-donating group. When used as a *direct dye*, a solution of the dye is made in water and the fabric is soaked in the solution. *Ingrain dyeing* is also useful for applying these water-insoluble dyes. The coupling reaction between the diazonium salt and the activated aromatic ring takes place directly on the fabric. For instance, if cotton is immersed in a solution with 2-naphthol at pH 10, removed from the liquid, and then treated with a solution of the diazonium salt of 4-nitroaniline, a deep red color called American Flag Red is obtained.

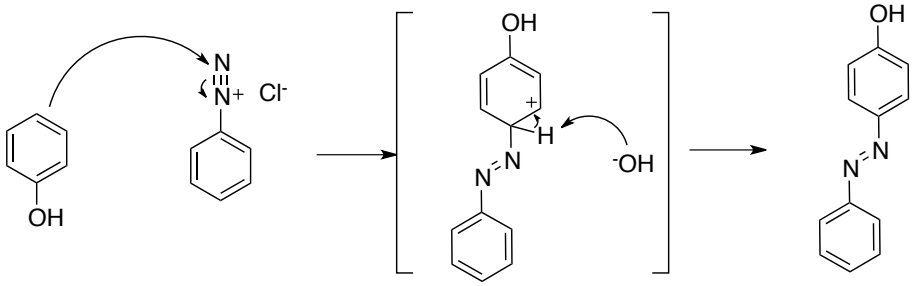
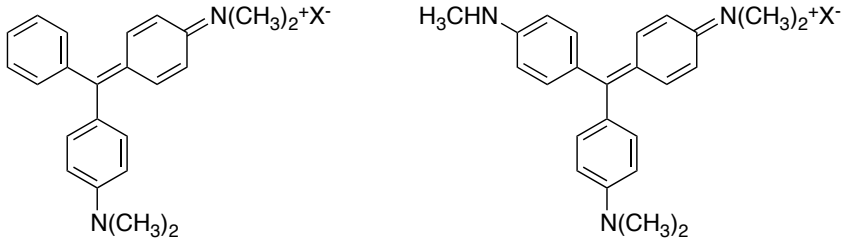


Figure 4. Mechanism for Diazo Coupling

Cationic Dyes

THERE ARE VARIOUS CHEMICAL CLASSES OF *CATIONIC DYES*, the most important being the derivatives of triphenylmethane, such as Methyl Violet and Malachite Green (**Figure 5**). In triphenylmethane dyes, three aromatic rings are directly attached to a central sp^2-hybridized carbon atom. At least two of the rings have a dialkylamino group (-NR_2) *para* to the central carbon. These molecules are highly conjugated and have the positive charge delocalized among all three aromatic groups. Notice that just one extra lone pair from the methyl amine group donating into the system drastically changes the color from green to violet!



Malachite Green **Methyl Violet**

Figure 5. Cationic Dyes.

Anthroquinone Dyes & Mordant Dyeing

THESE DYES OF NATURAL ORIGIN were used for centuries to dye cotton and leather with beautiful red hues. The most important dye of this class is alizarin, which is the main component of the dyestuff obtained from the roots of the madder plant *Rubia tinctorum*. These dyes are applied to fabrics in the presence of metal ions such as aluminum, iron, tin, and chromium. This method is called *mordant dyeing*, where the fabric is pre-treated (soaked) in a specific salt solution before dyeing. In these complexes, the metal ion is at the center and the dye and fiber molecules are bound as ligands (**Figure 6**). When alizarin is used to color cotton, a red hue is obtained if the metal is aluminum or tin, a deep violet shade with Fe^{2+}, and brown-black is Fe^{3+} is used instead. Other dyes capable of binding to metals can be used as mordant dyes as well.

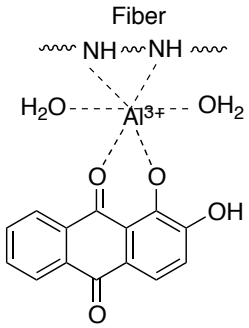


Figure 6. Mordant Dyeing with alizarin.

Indigo Dye

THE USE OF INDIGO, the dye of blue jeans, goes back at least 4000 years. The pigment was obtained from several indigenous plants from India and was introduced into the Middle East by Phoenician merchants. From there its use spread around the Mediterranean region and the rest of Europe. Indigo and its derivatives give blue-purple colors.

INDIGO IS SYNTHESIZED BY THE CONDENSATION of *o*-nitrobenzaldehyde and acetone under basic conditions (**Figure 7a**). The overall reaction is completed in a matter of minutes. *Vat dyes* such as indigo are insoluble in water but dissolve upon reduction with sodium dithionite

($Na_2S_2O_4$) under basic conditions. The reduced dye, called the *leuco* form, is soluble in water and is applied onto the fiber by immersion. Upon drying and exposure to atmospheric oxygen, the dye is re-oxidized and acquires its original color (**Figure 7b**). Notice that the carbonyl carbon of blue indigo is reduced (how many C-O bonds are in the reactant vs. product?). Dithionite is oxidized to sulfite in the process. While in the leuco-indigo solution, the fabric is yellow, but it quickly turns blue after it is removed.

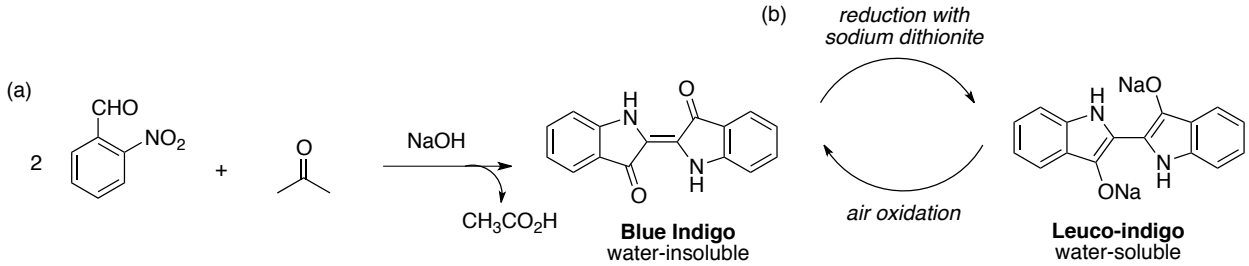


Figure 7. (a) Synthesis of Indigo and (b) reduction to leuco-indigo

Dyeing

TO UNDERSTAND THE PROCESS OF DYEING we must consider the chemical nature of fibers and fabrics. Different fibers subjected to the same dyeing process produce different color shades because each type of fiber reacts with the dye molecules in a unique way. Fibers with an abundance of polar groups, such as cotton and wool, are easier to dye than others with only a few polar residues, such as silk, polyesters, acetates, and acrylics. In general, synthetic fibers are less absorbent than natural ones and require special methods for color application. For example, polyesters are generally dyed using high pressure and temperature.

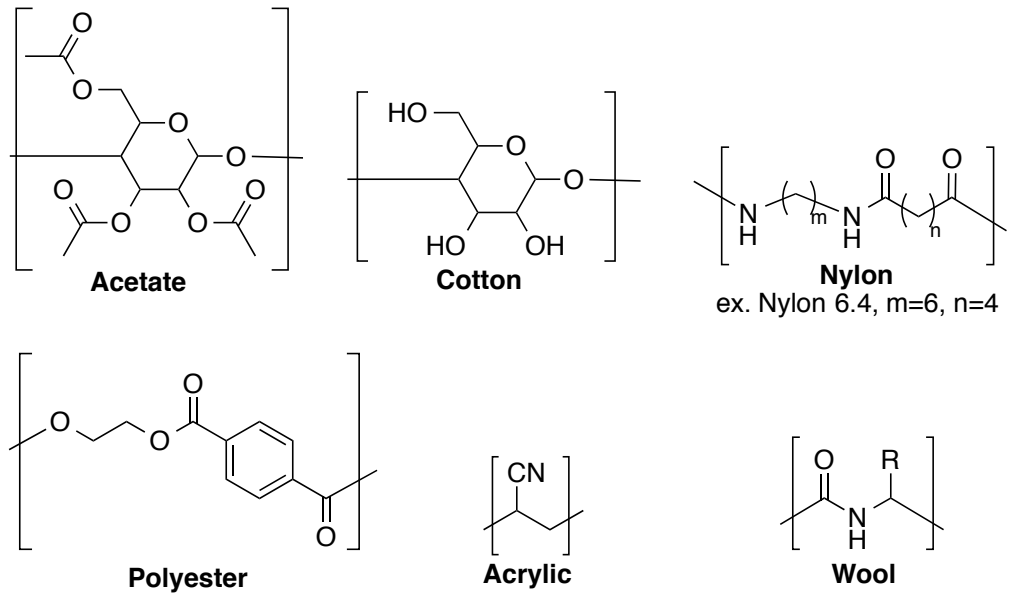


Figure 8. Structures of the repeating units of fibers

EXPERIMENT OVERVIEW

In this experiment, students will synthesize dyes and use them to dye fabric swatches containing multiple types of fabric (**Figure 8**). STUDENTS ARE WELCOME TO BRING SMALL PIECES OF FABRIC FROM HOME TO DYE IN ADDITION TO THE SWATCH. SHOELACES ARE AN EXAMPLE OF AN APPROPRIATE-SIZED MATERIAL. The overall objective is to observe the different colors or qualities of fabrics that can be obtained with one dye, as well as comparison of different dyes and dyeing methods. Students will not perform every part of the experiment themselves, so it is important that the class pools their results together to make full comparisons.

Thread a paperclip through the acetate (smoother) end of the fabric swatch *before* dyeing. The order is: acetate, cotton, nylon, polyester, acrylic, and wool. Each fabric strip should be labeled with your name, the dye, mordant, or other conditions if applicable on a securely fastened tag. Attach this tag to the paperclip immediately after dyeing and rinsing.

Rough notebook guidelines are given for each part. **Start a new notebook page for each reaction.** Please write neatly on these pages. Include the products and % yield where appropriate. All reagent tables should include the following: mmol, mg or mL, MW, bp/mp, and density. Safety notes should follow the table and the written procedure is directly after that. Refer to the Safety & Clean-up table that follows the procedure and write pertinent notes for each reaction.

There are several parts of the experiment that are split up between students. Your notebook should include only the steps that you are assigned. Use the summary table below to ensure your preparation is complete. The experiment is separated by "**Team Cat**" and "**Team Dog**." Look for the adorable icons to see which parts of the experiment to prepare for each week.

Table 1. Team Assignment and Notebook Preparation Overview

	 **Team Cat** Pair closer to the chalkboard	 **Team Dog** Pair farther from the chalkboard
Day 1	*__Part A__ *Magneson *__B.1__ (coupling) *__C.1__ (direct dyeing) *__C.2__ (mordant dyeing) *__C.3__ (Malachite green)	*__Part A__ *Solochrome Orange II *__B.2__ (coupling) *__C.1__ (direct dyeing) *__C.2__ (mordant dyeing) *__C.3__ (Eosin Y)
	Print Table 3 (page 11) and bring with you to lab both days.	
Day 2	*__Part D__	*__Part D__

Before leaving the lab both days, record your observations (**Table 3,** p. 11) for your dyes as well as for the other teams' dyes. Make your own observations with descriptions and depth of color! Do not copy someone else's descriptions.

Down time during reactions or dyeing? If you are prepared for the next steps of the experiment and looking for a way to kill time, take this opportunity to write a draft of the experimental methods section. It is to your benefit to do this in lab while you can ask your TA questions!

DAY 1 PROCEDURE

A. Synthesis of the Diazonium Salt of 4-Nitroaniline

All pairs perform this step. Start a new notebook page and include the proper components (see p. 5).

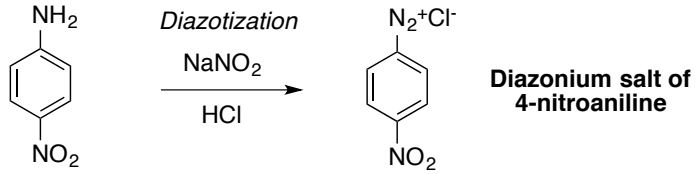


Figure 9. Diazotization of 4-Nitroaniline.

In a 13 x 100 mm labeled test tube ("Substrate"), mix 0.70 g of 4-nitroaniline, 0.38 g of sodium nitrite, and 1.5 mL of water to make a suspension (it will not dissolve). Cool this suspension in an ice-water bath. In a separate labeled test tube ("acid"), mix water (1.5 mL) and concentrated HCl (1.5 mL) placed in an ice-water bath (important to add water first, then acid). Allow these solutions to cool for 10 minutes. Keep both solutions in the ice bath while *slowly* transferring the acid solution *drop-wise* to the substrate. Stir with a glass rod in between drops and stir occasionally for 10 minutes after the addition. Stir gently to avoid breaking through the bottom of the test tube.

Add a few ice cubes to a separate test tube. Wet a small piece of cotton, place in a glass funnel, and add a two ice cubes on top for a cold filtration. Filter the reaction mixture (it will be thick) through the glass funnel with the *small, loosely packed* piece of cold, wet cotton and collect the filtrate in the test tube with ice. Rinse the substrate test tube and filter with 2 mL of cold water. It is OK if some solid particles pass through the filter. The product (diazo salt) is *explosive in solid/dry form*. Immediately wash anything you will not use in **Part B** and proceed to **B.1** (Team Cat) or **B.2** (Team Dog). **Change your gloves before moving on, even if they appear clean.**

B. Coupling Reactions with the Diazonium Salt of 4-Nitroaniline

B.1. Coupling with 1-Naphthol: Synthesis of Magneson II

Start a new notebook page and include the proper components (see p. 5).

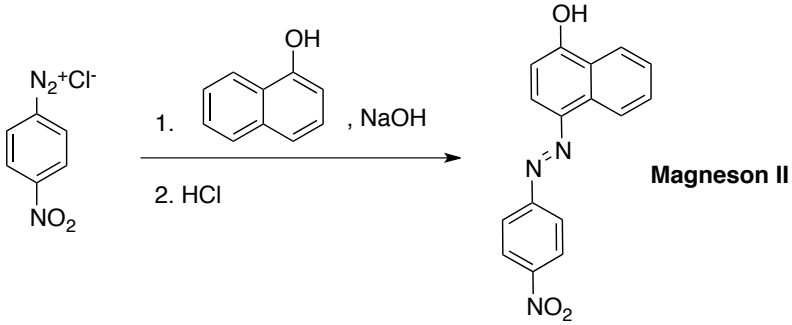


Figure 10. Synthesis of Magneson II.

Dissolve 0.74 g of 1-naphthol in 10 mL of a 2.5 M NaOH solution in a 25-mL Erlenmeyer flask and place it in an ice-water bath. Use a pipet to *slowly* add the diazonium salt solution from Step A with continuous stirring in the ice-water bath, careful not to break the test tube with the

stir rod. These solutions should be kept in the ice-bath to keep the temperature low and provide secondary containment in case of spills. Observe and record any color change.** Let it stand on ice for about 10 minutes with occasional stirring. *Slowly* add concentrated HCl *drop-wise* to obtain pH 3-4 (approximately 1.5 mL).** Slowly add 1 g of NaCl portion-wise and heat to a boil on a hotplate. Remove from the heat once it has reached a boil. Let the system cool to room temperature then place in an ice-water bath to promote crystal formation. After about 10 minutes, vacuum-filter the solid using a small Buchner funnel and pre-weighed filter paper. Wash the solid on the filter with 2 mL of COLD water (you should have pre-cooled a test tube of diH_2O in an ice bath) and let it dry for at least 10 minutes.** Weigh the product with the filter paper on a tared watch glass and proceed to **Steps C.1** and **C.2**.

B.2. Coupling with Salicylic Acid: Synthesis of Solochrome Orange M

Start a new notebook page and include the proper components (see p. 5).

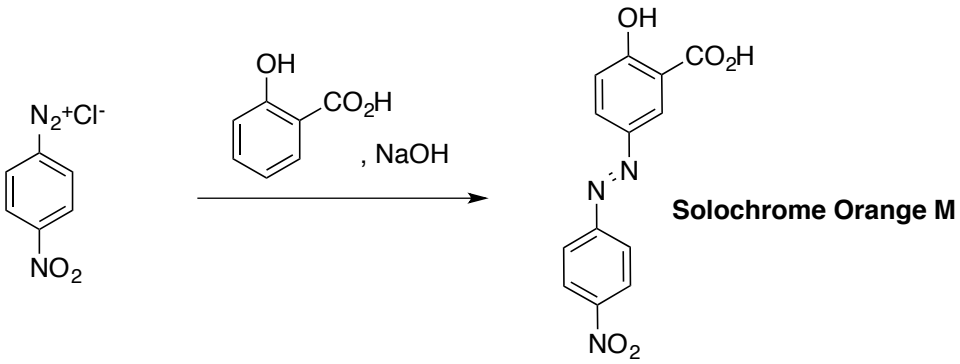


Figure 11. Synthesis of Solochrome Orange M.

Dissolve 0.68 g of salicylic acid in 10 mL of a 2.5 M NaOH solution in a 25-mL Erlenmeyer flask and place it in an ice-water bath. *Slowly* and with continuous stirring add the diazonium salt solution from Step A *drop-wise*.** These solutions should be kept in the ice-bath to keep the temperature low and provide secondary containment in case of spills. Observe and record any color change. Let it stand on ice for about 10 minutes with occasional stirring. Slowly add 1 g of NaCl portion-wise and heat to a boil on a hotplate. Remove from the heat once it has reached a boil. Let the system cool to room temperature then place in an ice-water bath to promote crystal formation. After about 10 minutes, vacuum-filter the solid using a small Buchner funnel and pre-weighed filter paper.** Wash the solid on the filter with 2 mL of COLD water (you should have pre-cooled a test tube of diH_2O in an ice bath) and let it air dry for at least 10 minutes. Weigh the product with the filter paper on a tared watch glass and proceed to **Steps C.1** and **C.2**

** **Change your gloves when you see this symbol AND when they appeared soiled.**

C. Direct & Mordant Dyeing

*Start a new notebook page for the dyeing procedures (**C.1** and **C.2** on same page). Be sure to include safety notes.*

Thread a paperclip through the acetate (smoother) end of each fabric swatch *before* dyeing. The order is: acetate, cotton, nylon, polyester, acrylic, and wool. Each fabric strip should be labeled with your name, the dye, mordant, or other conditions if applicable on a securely fastened tag. Attach this tag to the paperclip immediately after dyeing and rinsing.

C.1. Direct Dyeing with Diazo Dyes - one partner performs this step

To a 100-mL beaker add 20 mL of water and 50 mg of the solid dye. Scrape the solid directly off the filter paper and onto the weigh paper. If the product weight is close to 50 mg, you can dunk the filter paper directly into the water rather than scraping it off the paper. **Perform the remainder of this step in the fume hood.** For Magneson II (Team Cat), add 3 mL of 2.5 M sodium hydroxide.** For Solochrome Orange M (Team Dog), use 1.5 mL of 2.5 M NaOH.** Heat on a hotplate while stirring with a glass rod. Add a strip of fabric and boil for about 3 minutes. Remove from the heat using tweezers and generously rinse the swatch with a squirt bottle into a large beaker labeled "**dye waste**." Pat dry between paper towels and clean the tip of the squirt bottle.** Let the solution cool down to room temperature and dye another strip at this temperature. Record your observations in **Table 3**. Note any changes to the fabric as a result of the different temperature. You may use this bath to dye one of the mordant-treated swatches (**C.2**), otherwise, dispose of this dye solution in the liquid waste.

C.2 Mordant Dyeing – other partner performs this step

This step may be performed at your bench-top station. Obtain fabric swatches pre-treated with the following salts: copper (II) sulfate, aluminum potassium sulfate, and iron (II) sulfate. Use the dye made in **B.1** (Magneson, Cat Team) or **B.2** (Solochrome, Dog Team) and make a new solution, following the same procedure indicated for direct dyeing (**C.1**) but without heat. One at a time, soak fabric strips pre-treated with the mordants for 3 minutes. Rinse each swatch thoroughly into the dye waste beaker and pat dry between paper towels.** Compare these to the untreated fabric. One dye bath should be enough to dye three fabric swatches.

C.3. Direct Dyeing with Malachite Green and Eosin Y – Day 1 or 2

Start a new notebook page. Include the structure of the assigned dye and the written procedure on one page of your notebook.

Perform this step in the fume hood. Obtain 20 mL of the Malachite Green (Cat Team) or Eosin Y (Team Dog) solution. Add a strip of fabric and bring the system to a boil on a hot plate.** After about 3 minutes of boiling, use tweezers to remove from the heat and rinse the swatch into the waste beaker. Pat dry between paper towels and clean the tip of the squirt bottle.** Marvel at your work!

** **Change your gloves when you see this symbol AND when they appeared soiled.**

DAY 2 PROCEDURE

D. Vat Dyeing with Indigo

*Start a new notebook page. Copy the reaction scheme (**Figure 7**), make a table of reagents (amounts, properties, safety), and outline the procedure. Include pertinent clean up and safety notes in a table after the procedure.*

D.1. Synthesis of Indigo

Perform this reaction in the fume hood. In a 50-mL beaker add a stir bar, 100 mg of *o*-nitrobenzaldehyde, 1 mL of acetone, and 1 mL of water. Stir the suspension on a stir-plate and add 1 mL of a 2.5 M NaOH solution drop-wise.** Blue indigo should start to form immediately as a black-blue sludge. Bring the beaker back to your bench-top and let the reaction mixture stand undisturbed at room temperature for 10 minutes. Transfer to an ice-water bath for an additional 10 minutes. Collect the solid by vacuum filtration onto pre-weighed filter paper, performed at your bench-top. Wash the solid on the filter with 2 mL COLD water, allowing all the liquid to pass through before following with 2 mL of ethanol.** Let the solid air dry with the vacuum on for 10 minutes, weigh the product, and calculate the % yield. If the yield is greater than 100%, place the filter paper with solid back on the funnel and dry for an additional 10 minutes.

D.2. Dyeing with Indigo

To a 100-mL beaker equipped with a magnetic stir bar, add 25 mL of water and dunk the filter paper containing indigo directly into the beaker with the aid of tweezers. If possible, take out the filter paper after most of the indigo has dissolved, otherwise the paper can remain in the beaker. Add 5 mL of 2.5 M NaOH.** Boil on a hotplate with stirring with magnetic stir bar. Add 7 mL of a freshly made solution of sodium dithionite (10%). Boil and observe any color change. If the blue color persists add more sodium dithionite (1 mL at a time, up to 3 mL) until the solid dissolves and solution turns clear yellow.** Consult your TA if you've added more than 10 mL total of dithionite solution as it may be appropriate to move on.

Turn off the heat, add a strip of fabric, and let it sit in the hot bath for 3 minutes. Use tweezers to remove from heat. Rinse well into a labeled waste beaker, dry with paper towels, then let it air dry. It may take a few minutes for the indigo to dry and be oxidized so you should wait to record observations.

Adapted from Palleros, D. R. "Dyes and Pigments," *Experimental Organic Chemistry*, **2000**. Wiley: New York. p. 611 - 634.

** **Change your gloves when you see this symbol AND when they appeared soiled.**

Table 1. Clean-up & Safety
Read carefully and copy the pertinent notes into the specific pages of your notebook.
There should be a separate table for each part of the procedure.

Clean-up	Safety
Although it's pretty, you're working with some nasty stuff in this lab. Don't wear any of your favorite clothes! Wear goggles and gloves throughout the experiment and generally minimize your chemical exposure when possible. *Change gloves often (look for ** in the procedure) and* *DO NOT WEAR GLOVES OUTSIDE THE LAB.*	
Keep isolated solids on the filter paper and dispose in solid waste after you're sure you're done with them!	4-nitroaniline, 1-naphthol, and malachite green are highly toxic – minimize exposure
Liquid waste: mother liquors, dye baths, and other liquids	Sodium nitrite is a toxic oxidizer
	Ethanol and acetone are flammable
Solid waste: filter papers, pipets, and contaminated paper towels	Hydrochloric acid and sodium hydroxide are corrosive
Part B: Rinse pipets or anything used with diazonium salts with water or liquid from ice baths and dispose in solid waste; wash glassware immediately!	Parts A & B: Diazonium salts are explosive in solid state! Wash this glassware immediately.
	Irritants: naphthols, salicylic acid, o-nitrobenzaldehyde, $Na_2S_2O_4$, and ANS

Pre-lab Questions

Week 1

1. What structural characteristics give dyes their color? List two examples that fit this trend.

2. List the main functional group and associated intermolecular force (IMF) in the fibers of cotton, wool, nylon, polyester, acetate, and acrylic. Examples of IMF's include hydrogen-bonding (H-bonding) and dipole-dipole interactions. "Polar" and "non-polar" are technically not IMF's!

3. Consider the dye Orange II (**Figure 2**). Do you expect this dye to adhere better to cotton or to polyester? Base your response on the information in #2 above.

4. Convert 0.70 g of 4-nitroaniline into mmols. This is the theoretical number of mmols of diazonium salt produced in Part A. Calculate the theoretical yield of Magneson II or Solochrome Orange (the one you're making in Part B) in mmol and mg. Show your work, including mmol conversion of starting materials.

5. Briefly explain mordant dyeing. What is the role of the mordant and why do fabrics dyed by these methods keep their colors so well?

Week 2

6. Explain the general process of vat dyeing. Redraw the structure of blue indigo and circle the atom that is being reduced in the vat dyeing process (**Figure 7b**).

7. Calculate the mmoles of o-nitrobenzeldehyde and acetone used. Determine the limiting reagent and report the theoretical yield of blue indigo in mmol and mg. Show your work.

8. Consult the Experimental Methods section of the Technical Writing Guidelines and complete a draft of this section for **Parts A & B** as they were completed in Week 1 in 3 paragraphs:
(1) General Methods, (2) **Part A**, (3) **Part B.1** or **B.2**.

In-lab Questions

1. Print and bring Table 3 (p. 11) with you to lab and complete as you work. **Record your own observations. DO NOT COPY YOUR PARTNERS' DATA!** You do not need to type up this table for the report but do make sure your observations are neat and easy to read. It may be necessary to print the table a second time to make your observations more organized.

2. Report the yield (in mg and %) for the coupling step in the synthesis of Magneson II or Solochrome Orange M *in one complete sentence*. Show your work.

3. Report the yield (in mg and %) for the synthesis of indigo *in one complete sentence*. Show your work.

4. *For any one dye under normal conditions (without mordant)*, briefly comment on the abilities of different fabrics to absorb the dye. Include comments on the structural features of both the fiber and the dye.

5. Discuss any differences in fabric strips dyed with azo dyes at room temperature vs. those dyed at a boil.

6. Discuss the results of mordant dyeing. What were the differences using the same dye with different mordants? What were the differences using the dye with and without a mordant?

7. Comment on how the extent in conjugation (number of pi-electrons, electron withdrawing/donating groups) effected the color of the compounds.

Table 3. Observations of Fabric Dyeing – Print this page and bring to lab both days

Dye & conditions	**Acetate**	**Cotton**	**Nylon**	**Polyester**	**Acrylic**	**Wool**
Magneson II boiling						
Magneson II room temp.						
Magneson II w/ Al^{3+}						
Magneson II w/ Cu^{2+}						
Magneson II w/ Fe^{2+}						
Solochrome Orange boiling						
Solochrome Orange room temp.						
Solochrome Orange w/ Al^{3+}						
Solochrome Orange w/ Cu^{2+}						
Solochrome Orange w/ Fe^{2+}						
Malachite Green						
Eosin Y						
Indigo						

Exp 6 - Colorful Chemistry Name _____

Section Day _____ Time _____ TA Name _____

Team Name _____

CHEM 8M GRADING RUBRIC - Use as cover page for report

SECTION	INSTRUCTOR COMMENTS	POINTS ASSIGNED
IN-LAB QUIZZES		**/ 10**
LAB REPORT		
ABSTRACT One paragraph, four-six sentences: Purpose, procedure, main result(s), and conclusion(s).	NONE	/ 0
INTRODUCTION Original responses to pre-lab questions with TA initials		/ **40**
RESULTS The main results are stated, as outlined in the in-lab questions, using complete sentences.		/ **35**
EXPERIMENTAL DETAILS **(no characterization)** Per guidelines online. General Methods plus one paragraph per reaction for Parts A, B, & D.		**/ 30**
NOTEBOOK PAGES Proper format: reaction scheme, chemical info table, experimental procedure, waste and clean-up procedure.		/ **40**
NEATNESS AND ORGANIZATION Proper grammar and format per instructions in syllabus and writing guidelines		/ **10**
LAB TECHNIQUE & CLEAN UP Lab space left clean, proper technique, instructions followed, checked in with TA before leaving. DRAWER CLEAN.		**/ 10**
	LAB REPORT TOTAL	**/ 175**