Chemistry 103
Paper Making and Properties of Paper

This lab will be divided into two parts:
- Experiments to characterize the properties of paper.
- Hand papermaking in which each student will make several sheets of flax, cotton, and abaca papers suitable for letterpress printing. Katherine McCanless Ruffin will guide students in this part of the lab.

Properties of Paper. Paper is a key art material serving as a support and ground for pencil, pastels, ink, watercolor, and acrylic paintings. Chemically, paper is a composed of the natural polymer cellulose, a linear carbohydrate consisting of repeating units of the sugar glucose. The individual sugars are linked by single covalent bonds; in addition, the long cellulose chains composing paper fibers interact with one another via hydrogen bonds. These bonds between paper fibers convey high mechanical strength, consistent with the place of cellulose polymers as the major structural component in plants. In this lab, students will examine the following characteristics of paper: (1) The effect of water on paper, (2) the absorption character of different types of paper, (3) density of paper, (4) the presence of starch in paper, and (5) the pH of various papers. These experiments are adaptations of ones developed by David Dempsey of Smith College.

The papers to be examined include the following:
- Machine-made papers: newsprint, copy paper, and water color paper
- Handmade papers: A commercial Japanese kozo paper often used for brush paintings and samples of the three papers to be made in the lab: flax, cotton, and abaca.

A. The Effect Water On Paper. Water, as students will learn in the papermaking portion of this lab, an essential component in paper production. Because of its chemical structure (many hydroxyl groups available for hydrogen-bonding), paper usually has water molecules associated with it; the water is absorbed from moisture in the air. Here you will determine the amount of water absorbed by various papers as a percentage of the paper s weight. Prepare a table, similar to that shown below, containing a column for each paper to be examined the masses of the paper will be recorded in the rows. Follow the procedure (Steps 1-3) on the next page for each paper tested.

Table 1. Water absorbency of paper as measured by increase in mass.

Mass, grams	Paper 1	Paper 2
Dry Paper		
Wet Paper + water		
Water absorbed[1]		
Percentage change[2]		

[1](wet paper - dry paper)
[2]Percentage change = 100% x water absorbed/weight of dry paper

1. Obtain a 4-5-cm square of each type of paper to be tested and record the surface characteristics and feel of each.

2. Tare the empty weighing pan and then determine the dry weight (mass) of paper by adding the paper to the pan. Enter the value for the mass into the table.

3. Wet the paper sample in the following manner and then reweigh the wetted paper sample using the same dry weighing pan for each sample: Lay the paper sample on the surface of a pan of water and record your observations as the paper absorbs moisture from the water bath. When the paper is completely wet, carefully remove it from the water and allow excess water to drain for 30 seconds prior to re-weighing. Record the mass of the wet paper. Calculate the increase in mass as a percentage of the original dry paper.

B. Interaction of ink on paper. Early in the semester, you used chromatography paper to separate the different components (colors) in ink using the technique of paper chromatography. Here you will use a single ink to evaluate the capillary response of a variety of papers.

1. Cut a narrow strip (0.3-0.5 cm x 4-5 cm) of the paper to be tested and a marking pen.

2. Make a single dot, 1-2 mm wide, about near the bottom of the strip.

3. Add a small amount of methyl alcohol to the bottom of a disposable glass vial. Insert the paper strip into the vial so that the bottom is in the alcohol; the spot should not be in the alcohol. Allow the ink to be drawn up the paper.

4. Remove the paper from the beaker and record your observations about the relative interactions of alcoholic solvent and ink with the various types of paper.

C. Machine direction in commercial papers. Machine-made papers have a definite grain direction due to the speed of the moving screen on which the paper is formed. The fibers orient themselves parallel to that motion. This alignment affects the strength of the paper and its behavior on wetting. Students should test all the machine-made papers and at least one of the handmade papers for comparison.

1. Cut two strips (0.5 inch x 2 inch) from the test paper: Cut one strip parallel to the long dimension of the sample sheet and the other perpendicular to it. Mark each carefully for identification.

2. Place each strip, one at a time, on the surface of a water bath. Observe the predominant direction of the curl of each piece in the first few seconds it sits on the surface of the water. Carefully record your results.

3. Try tearing the sample paper in both directions. Is there a noticeable difference in the smoothness of the tear? Correlate the results of these tests (curling in water and tearing) with the alignment of fibers in the paper.

D. Starch in paper. Starch has been used as a sizing agent to reduce the absorbency of paper for several thousand years. The Chinese were first to use it to prevent feathering of inks applied to paper. Starch also serves as an adhesive to laminate layers of paper to produce thick boards, such as mat boards. Iodine forms a deep purple complex with starch molecules and, hence, can be used to test for this sizing agent. If a drop of an iodine solution (I_2 in 0.1 M KI) is applied to paper sized with starch, a purple color immediately appears. Test each of the paper samples for starch and report your results.

E. Acidity of paper: Determining the pH of the paper. We will use an acid-base indicator to obtain a rough estimate of the pH of several test papers. The indicator is impregnated in the felt tip of a pen; the indicator is transferred to the test paper by drawing a line on the paper. The color of the dried indicator-ink will then show the approximate pH of the paper. Each manufacturer of such pH-pens uses a different acid-base indicator so that the directions must be consulted to interpret the colors observed. In general, an indicator is selected that displays one color (purple, for example) above pH 7 and a different one (yellow) below pH 6.0. At values between 6 and 7, a mix of the two colors is observed. In testing coated papers (e.g., those with sizing applied to the surface), it first necessary to tear the sheet open so that the paper itself is exposed for testing. Papers showing a pH above 7 are regarded alkaline; whereas, those with pH values less than 6 are acidic and prone to acid degradation.

Discussion of Results.

In discussing the results of your testing, you should find the following table of paper densities useful. Correlate, in particular, the percentage of water of absorbed and the interaction of the papers with ink (chromatography) with the densities.

Table 2. Density of Papers Tested

Paper	Density in gm/cm^3.
Water color paper	0.57
Copy paper	0.87
Newsprint	0.63
Kozo	0.54
Flax	0.66
Cotton	0.63
Abaca	0.45