A COMPARISON OF CERTAIN METHODS
OF DETERMINING THE FIBER COMPOSITION
OF BLENDS OF WOOL WITH
ACRYLIC FIBERS AND NYLON

by

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A COMPARISON OF CERTAIN METHODS OF DETERMINING THE FIBER COMPOSITION OF BLENDS OF WOOL WITH ACRYLIC FIBERS AND NYLON

INTRODUCTION

In recent years, the production and use of the synthetic fibers has greatly increased, and the use of blends of two or more staple fibers has become more acceptable among the consumers of household and clothing fabrics. In 1951, (37,509-512) textile manufacturers began to give greater consideration to blends of various synthetic fibers with wool. Orlon, nylon and Acrilan have become particularly important among the man-made fibers in blends with wool because of modified chemical and physical properties of the blends as compared to wool alone for various kinds of woven and knitted fabrics.

With increased production of these blended fabrics, the methods for identifying the fiber mixtures and for quantitative determination of the composition of the blends have become more important. The analysis of these products may be used for various purposes, such as informative labeling and customs examination, as well as the improvement of manufacturing processes.

The purpose of this study was to compare different methods for the quantitative analysis of blends of wool and Acrilan, wool and Orlon and wool and nylon combined with approximately equal amounts of the two fibers in known mixtures. The comparisons were based on the percentage of the fiber recovered, the time involved in the experiments, the cost of reagents used and the ease of execution.
As a result of class work on quantitative analysis of blended fabrics, it was believed that some of the standard methods of analysis recently developed were not entirely satisfactory. Upon searching the literature, other procedures were found, but few sources gave the percentage of the components recovered, and few comparisons were found of two or three methods.

The methods used in this study depended upon the use of selective solvents to dissolve one fiber from the blend. The simplest and most rapid methods which might be expected to yield relatively accurate results and might be handled efficiently were selected for comparison.

Four methods were used to analyze each of the three blends. A total of seven methods of analysis were employed, some procedures having been used for more than one kind of blend. The ammonium thiocyanate, zinc chloride, sodium hydroxide, and sodium hypochlorite methods were used on wool-Acrilan and wool-Orlon blends. The formic acid, hydrochloric acid, potassium hydroxide, and sodium hypochlorite methods were compared for wool-nylon blends.
REVIEW OF LITERATURE

Physical Methods of Analysis

Fiber mixtures may be analyzed by chemical or physical methods. The microscopical procedure described by Darbon (8,97-101) for counting fibers of different kinds in a sample required particular technique. Charlett, (7,68-69,71) also reported that this method required skill in the preparation and mounting of the fiber specimens.

The quantitative separation by flotation was reported to be more practical than the microscopical methods. Linley, (24,69-72) favored the flotation method because of its wide applicability to most of the blends. The flotation method is based on flotation of the two-fiber mixture in a suitable mixture of solvents whose density is intermediate between the density of the two fibers. It was believed by Mhatre (28,70-75) that this method involved a higher error than the solubility method and also required more difficult technique and staining or final microscopical checking for accuracy. This method cannot be used for blends of three or more fibers because of the limitation of the density of the solution used each time.

Weidenhammer, (36,41-45) also reported unreliable results by the flotation method, although this method had the advantage of requiring only a small amount of sample. Preston and Saha (31,381-388) found that the floatability of most fibers was not stable, due to
several factors, such as the natural properties of each fiber, kind of dyes, process of dyeing and the other fiber processings, as well as the difficulty in using the procedure itself. The Bureau of Home Economics also stated that the work was more intensive and required a high degree of skill and experience. (5,13-16)

Another physical method is the sedimentation method, which is based on the difference in specific gravity of various fibers. Frieser (16,1009-1010) had published his work in 1956 and discovered that the sedimentation method could not be applied to a mixture of fibers with specific gravities differing by less than 0.08.

Chemical Methods of Analysis

At the present time, the preferable methods of quantitative analysis of fiber mixtures are chemical or solubility methods (21,T75-T102). The principle of these methods is to select the solvent best suited for a mixture of certain fibers and which gives the most accurate results in simple, rapid ways.

Druce (10,T202-T208) divided the solubility methods into two major groups. The first group included the non-protein fibers, which dissolved completely in acid solution. This group included natural or man-made cellulosic fibers and synthetic fibers. The remaining protein fibers were collected and determined. In the second group, the protein fibers dissolved in alkaline solution, the weight loss of the sample after dissolution being considered as the weight of the protein fibers in the mixture. These two groups of solvents
may be applied to most fiber mixtures by selecting a suitable solvent.

Methods for Removal of Wool from Blends

Among the procedures found for removing wool from blends with other fibers were the sodium hydroxide, potassium hydroxide, and sodium hypochlorite methods.

The sodium hydroxide method was reported by the Bureau of Home Economics (5,13-16) to be a reliable and rapid one which was easy to perform as compared with the flotation method. Carboni (6,14,7-151) obtained successful results in separating natural protein fibers from the mixture by this method, and Antykov (2,11-19) used it in separating silk or wool from cotton. The National Bureau of Standards of the United States Department of Commerce (34,23;4-24;7) also used the sodium hydroxide method to determine wool in blends with cotton.

Wolf (37,273-276) found that there were slight losses of nylon, Orlon and Dacron in wool blends when determined in 5 percent sodium hydroxide. In the determination of viscose rayon in combination with cotton, wool and silk, McKay (26,25-28) found a loss of about 1 percent of the constituents in the mixture, which depended on the solution of viscose in 2 N sodium hydroxide at minus 3 degrees centigrade.

In his study of the separation of nylon from mixtures, Carboni (6,14,7-151) suggested that sodium hydroxide should be used in analyzing the natural protein fibers in blends. Moncrieff (29,423) suggested the dissolving of wool in boiling 5 percent sodium hydroxide. The sodium hydroxide method has been widely used in the
determination of wool blends because of simplicity and the small amount of reagent required.

When they compared the use of sodium hydroxide with sulfuric acid in separating wool from cotton and viscose rayon, Horowitz and Mandel (20,613-615) discovered that the weight of wool obtained by the acid method was higher than by the alkali method, which probably was due to the trace of sulfuric acid retained in the wool residue. Mease and Jessup (27,75) and Ryberg (32,296) also reported that sulfates were present in the samples of wool analyzed by the sulfuric acid method. Howlett and Morley and Urquhart (21, T75-T102) found that wool fibers recovered from mixtures of wool and cellulosic fibers by treatment with 75 percent sulfuric acid gained in weight for the same reason. Kehren (23,1226-1234) has mentioned that the sulfuric acid was less accurate and more dangerous.

Kehren (23,1226-1234) pointed out that the 0.3 N potassium hydroxide had been preferred by the West German Testing Station to determine wool in mixtures with cellulosic fibers such as viscose rayon and cuprammonium rayon. The potassium hydroxide method used in separating nylon from wool was reported by Bennett (4,58-59,71). He found it to be a practical method because the wool dissolved completely in boiling 5 percent potassium hydroxide, and this method was also reported by Gerber and Lathrop (18,437-440).

Druce (10,202-T208) had used sodium hypochlorite to separate protein fibers such as wool, chlorinated wool, raw and degummed silk, cashmere, mohair, Ardil B and Ardil F, Fibrolan EX, Lanital and
soybean fibers from cellulosic and synthetic fibers. He found that the 1 N sodium hypochlorite could be applied to any fiber mixture and that the procedure could be carried on at room temperature in a short period of time. For any protein fibers besides Vicara and tussah silk, fifteen minutes were needed. Tussah silk required fifteen additional minutes. Vicara required pretreatment with 4 percent sodium hydroxide and also necessitated thirty minutes for each treatment.

Wolf (37, 273-276) suggested sodium hypochlorite containing 10 to 15 percent available chlorine as the most suitable and quickest method for determining any blend containing wool and Orlon, nylon or Dacron when compared to the sodium hydroxide methods (5 percent and 40 percent sodium hydroxide). The slight losses of three synthetic fibers were less than 0.3 percent.

Fisher and Roberts suggested using sodium hypochlorite containing 3.3 percent available chlorine (13, 509 - 512) to remove wool from acetate, cotton, viscose, dynel, nylon, rayon, Orlon and Dacron in mixtures. The treatment was carried out at room temperature for 15 minutes. If a concentration of sodium hypochlorite much greater than 3.3 percent of available chlorine were used for removing wool from samples containing viscose rayon or cotton, some of the cellulosic materials would be dissolved. In the absence of rayon and cotton, sodium hypochlorite containing 10 percent of available chlorine could be used to remove wool.

In the case of wool, the cystine will be destroyed when reacted with hot alkali solution, such as sodium hydroxide or potassium
hydroxide and in cold solution of sodium hypochlorite, forming amino acids containing stable sulfur (1,334-360) which is due to the breakdown of the peptide chains giving amino acids.

Methods for Removal of Acrylic Fibers from Blends

Procedures found for removing acrylic fibers from blends with wool included the ammonium thiocyanate, zinc chloride, and nitric acid methods.

Fisher and Roberts (13,509-512) recently introduced a new method to separate Orlon from mixtures by means of 70 percent ammonium thiocyanate. The method could be used to determine the Orlon contents in mixtures with wool, Orlon being dissolved in the solution, while wool could be recovered and determined. The weight of Orlon will equal the loss in weight of the sample after the treatment.

The method employing 70 percent ammonium thiocyanate to separate Orlon from blends as reported by Fisher and Roberts (13,509-512) may be applied to Acrilan, because Orlon and Acrilan are very similar in their chemical structures. Most methods for the determination of Orlon may be used to analyze Acrilan too.

The zinc chloride method has been reported by Praeger (30,281-282). His work has stated the absolute solubility of Orlon in 57.1 percent or 66.7 percent zinc chloride at 40 to 45 degrees centigrade.

Vogler (38,209-222) proposed 65 percent nitric acid for dissolving nylon, Acrilan and X 51 from fiber mixtures.

It was understood that Orlon was attacked at the hydrogen bond
between the hydrogen atom of one chain and the nitril nitrogen of an adjacent chain when treated with suitable solvents. In order to make the polymers soluble, the solvent will break the hydrogen bonds (29,310-312).

Methods for Removal of Nylon from Blends

Extensive work has been reported on the analysis of nylon from fiber mixtures by means of such reagents as formic acid, hydrochloric acid, sulfuric acid, and metacresol. The formic acid method was favored in many references. Carboni (6,147-151) preferred to use formic acid in separating nylon from other fibers in a blend. Earland and Raven (12,T943-T944) found formic acid to be an excellent solvent for the determination of nylon from silk blends. Bennett (4,58-59,71) investigated the 90 percent formic acid method and found it to be a practical method for determining nylon in wool blends. This method was recommended by the laboratory of E. I. duPont de Nemours and Co. Inc. (11,344-345) and also in an article in Rayon and Synthetic Textiles (9,106-107). The concentration of 85 percent formic acid was studied by Vogler (35,209-222) and was suggested to determine nylon from fiber blends.

Moncrieff (29,h23) suggested metacresol besides 80 percent sulfuric acid and concentrated formic acid as a reagent to dissolve nylon in different fiber mixtures.

The comparison of three methods which were reported by Frieser in 1957 (17,200-202) for the separation of nylon from wool, cotton
and rayon staple fibers showed the formic acid method to be a good one compared with the potassium hydroxide and the sulfuric acid methods. He stated that, among these three methods, the potassium hydroxide and the formic acid methods were preferable to the modified sulfuric acid method because of the danger in the use of sulfuric acid. He also reported that all three methods gave accurate results. The potassium hydroxide method caused the loss in weight of polyamide of about 1.4 percent, and formic acid dissolved approximately 0.5 percent of the wool.

The method employing hydrochloric acid was reported by Freedman and Nechamkin in 1940 (15,540). This method introduced the determination of nylon in mixtures with cotton, linen, viscose, cuprammonium rayon, silk, wool and camel hair by the solution of nylon in cold concentrated hydrochloric acid. Glynn (19,T228) had dissolved Ardil from Ardil-wool mixtures in boiling 1 N hydrochloric acid, and only 84 percent of the wool was recovered. This low result must be due to the increase in temperature of the solution that caused more degradation of wool in the mixture and the long treatment which was required for Ardil.

The hydrochloric acid method was improved and recently accepted as the standard method by the American Society for Testing Materials in 1955 (3,102-103) for analysis of nylon from fiber mixtures with the specific gravity of hydrochloric acid recommended as 1.139.

The amide linkages of nylon will be destroyed easily by concentrated mineral acid (25,93-97), and the hydrogen bonds will break
down to result in the solution of nylon.

The reaction of nylon with concentrated hydrochloric acid was given by Moncrieff (29, 2h3) showing that the resultant products were mainly adipic acid and hexamethylene diammonium hydrochloride which was mainly used in the reprocessing of nylon from nylon waste. It should be presumed that the main products will be the original components of synthetic fibers.
MATERIALS AND METHODS

Preparation of Samples

The fibers used in this study were wool and the fibers given in Table I.

The synthetic fibers were obtained from the manufacturers free from sizing and finishing materials, and their lack of impurities was confirmed by preliminary tests. Consequently, only wool required the removal of non-fibrous materials.

The Removal of Non-fibrous Materials from Wool

The standard method of the American Society for Testing Materials (3,99) was selected. Sixty milliliters of carbon tetrachloride were used as the extracting solvent for each sample. The extraction was carried out in a Soxhlet extractor with approximately 1 to 2 grams of wool in it. The carbon tetrachloride siphoned over at least six times for a 2-hour period. The fiber was then removed and dried under the hood. The dried wool was immersed in hot distilled water twice and squeezed between each immersion. After this, the fiber was dried in air.

Weighing of Specimens

On the basis of preliminary moisture determinations for each fiber, sufficient fiber was weighed to give an oven-dry weight approaching the weights given in Table II.
### TABLE I

Types of Fiber

<table>
<thead>
<tr>
<th>Fiber</th>
<th>Type</th>
<th>Denier</th>
<th>Staple Length (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acrilan</td>
<td>SD regular 16</td>
<td>3.0</td>
<td>2</td>
</tr>
<tr>
<td>Orlon</td>
<td>---</td>
<td>3.0</td>
<td>2</td>
</tr>
<tr>
<td>Nylon</td>
<td>101</td>
<td>15.0</td>
<td>3</td>
</tr>
</tbody>
</table>
### TABLE II

The Weight of Fibers Required for Different Methods of Analysis

<table>
<thead>
<tr>
<th>Method</th>
<th>Wool (gram)</th>
<th>Acrylic Fibers, or Nylon (gram)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonium thiocyanate</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Formic acid</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Hydrochloric acid</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Potassium hydroxide</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Sodium hypochlorite</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Sodium hydroxide</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Zinc chloride</td>
<td>0.1</td>
<td>0.1</td>
</tr>
</tbody>
</table>
Methods Selected

The methods used in this study were based on the dissolution of one fiber in the blend by the selected solvent, leaving the other fiber unattacked. The residue was filtered, washed and dried to constant weight. The weight of the fiber dissolved was determined from the difference between the oven-dry weight of the sample before and after the treatment.

The following seven methods were selected for the analysis of the three combinations of fibers, and means were based on six replications.

<table>
<thead>
<tr>
<th>Wool-Acrilan</th>
<th>Wool-Orlon</th>
<th>Wool-Nylon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonium thiocyanate</td>
<td>Ammonium thiocyanate</td>
<td>Formic acid</td>
</tr>
<tr>
<td>Sodium hydroxide</td>
<td>Sodium hydroxide</td>
<td>Hydrochloric acid</td>
</tr>
<tr>
<td>Sodium hypochlorite</td>
<td>Sodium hypochlorite</td>
<td>Potassium hydroxide</td>
</tr>
<tr>
<td>Zinc chloride</td>
<td>Zinc chloride</td>
<td>Sodium hypochlorite</td>
</tr>
</tbody>
</table>

Before working with the blends, preliminary analyses were run in triplicate on the single fibers used in each method of analysis. The procedures used were evaluated on the basis of percentage recovery of fiber, of time required, ease of execution and cost of reagents.

Procedures for Analysis of Wool-Acrilan and Wool-Orlon Blends

1. **Ammonium Thiocyanate Method (13,509-512)**

Orlon was dissolved in boiling 70 percent ammonium thiocyanate. This method may be adapted for combinations of Orlon and Acrilan with
other kinds of fibers.

The accurately weighed sample of approximately 1 gram was placed in a 250-milliliter beaker. One hundred milliliters of hot 70 percent ammonium thiocyanate were added to the sample, then boiled gently for 10 minutes with frequent stirring. The residue was filtered by decantation, then filtered through the goose crucible and washed twice with two portions of 20 milliliters of hot 70 percent ammonium thiocyanate and five times with hot distilled water or until the water became neutral to litmus paper. Then suction was used to drain off the excess water. The residue was dried in air and put in the glass weighing bottle before transferring it to the vacuum oven to dry to constant weight at 105 to 110 degrees centigrade for 16 hours.

The 60 percent ammonium thiocyanate was used as a solvent for wool -Acrilan blends with the same procedure.

2. Sodium Hydroxide Method

This method was adopted from the American Society for Testing Materials (3,10h) for the determination of Acrilan or Orlon in the wool blends. The wool in the mixture was removed completely in boiling 5 percent sodium hydroxide, which left the Acrilan or Orlon as the residue.

The specimen weighing approximately 1 gram was immersed in 100 milliliters of boiling 5 percent sodium hydroxide solution and boiled for 10 minutes. The solution was stirred frequently during this period and then filtered through a weighed fritted glass filtering
crucible, using suction to remove the excess liquid. The fiber residue was washed twice with 100 milliliters of 5 percent sodium hydroxide solution. It was then washed three times with 150 milliliters of distilled water, twice with 100 milliliters of 5 percent acetic acid solution and then three times with 150 milliliters of distilled water. The residue was drained with the aid of suction. The residue was air dried, then put into the glass weighing bottle and dried to constant weight in the vacuum oven at 105 to 110 degrees centigrade for 16 hours.

3. Sodium Hypochlorite Method

Protein fibers were removed from samples of wool-Acrilan, wool-Orlon and Wool-nylon blends in sodium hypochlorite containing 6.5 percent available chlorine solution at room temperature. The sample was put in a 250-milliliter beaker, and 100 milliliters of sodium hypochlorite containing 6.5 percent of available chlorine were added. The solution and specimen were stirred vigorously and continuously for 15 minutes. The residue was then filtered through a weighed fritted glass filtering crucible with the aid of suction. The beaker was washed with 140 milliliters of the same concentration of sodium hypochlorite with slight suction. The crucible was drained, and the residue was washed with cold water until neutral to litmus paper. The specimen was washed with 100 milliliters of 5 percent acetic acid and with cold water until neutral. The residue was dried in the air first and put in the glass weighing bottle, then dried to constant weight in
a vacuum oven at 105 to 110 degrees centigrade for 16 hours.

4. Zinc Chloride Method

This method may be used either for mixtures of wool and Orlon or wool and Acrilan. The concentration of 57.1 percent of zinc chloride (ZnCl₂) was used to dissolve Orlon and Acrilan present in the blends. The mixed specimen weighing approximately 0.2 gram was placed in a 50-milliliter beaker, then 20 milliliters of 57.1 percent zinc chloride solution were added. The mixture was stirred constantly at 40 to 45 degrees centigrade on a water bath for 20 minutes. The solution was filtered with aid of suction through a weighed fritted glass filtering crucible. The specimen was washed with 5 milliliters of 57.1 percent zinc chloride without suction, then washed twice with 20 milliliters of dilute hydrochloric acid (1:4).

The residue was washed with 80 milliliters of cold water and finally washed with 200 milliliters of hot water and dried in the air. The residue and crucible were placed in the glass weighing bottle and dried to constant weight in a vacuum oven at 105 to 110 degrees centigrade for 16 hours.

Procedures for the Analysis of Wool-Nylon Blends

1. Formic Acid Method

Formic acid at high concentration will dissolve nylon in a few minutes. This method was applicable to the mixtures of nylon with wool, which will not dissolve in this solution. The method was
adapted from an article in Rayon and Synthetic Textiles (9,106-107).

A sample weighing approximately 1 gram was prepared. The fibers were cut to one inch in length. The sample was placed in a 100-milliliter Erlenmeyer flask with a ground glass stopper, 50 milliliters of 90 percent formic acid were added and then the glass stopper was inserted. The flask was put in a shaker and shaken gently for 2 hours. The solution was decanted into a glass beaker, taking care that no fiber was lost. The 100-mesh stainless steel sieve was used to collect the fiber. After another 50 milliliters of 90 percent formic acid were added, the glass stopper was replaced, and the mixture was shaken for another hour. By the end of this period, the solution was ready to be filtered. The solution was filtered through a weighed fritted glass filtering crucible. The flask was cleaned with 20 milliliters of 90 percent formic acid and the washing poured through the crucible. The wool residue was washed with 25 milliliters of 90 percent formic acid. If the washing solution clouded when dropped in cold water, the residue was not free from nylon. The 90 percent formic acid was used to wash the residue until it was freed from nylon.

The residue was finally washed with distilled water until the washing water was neutral to litmus paper, dried in the air, then put in the glass weighing bottle and transferred to dry in the vacuum oven at 105 to 110 degrees centigrade for 16 hours to obtain the constant weight of wool residue.
2. **Hydrochloric Acid Method**

Nylon will dissolve completely in concentrated hydrochloric acid. This method was adapted from the American Society for Testing Materials (3,102-103).

A specimen of approximately 1 gram containing nylon-wool was required. The wool fibers were cut approximately two inches in length. The specimen was immersed in 100 milliliters of hydrochloric acid with specific gravity of 1.139 in a 250-milliliter Erlenmeyer flask, shaken vigorously and allowed to stand for 15 minutes at room temperature. It was then shaken again and allowed to stand for another 15 minutes. The solution was then shaken for the last time and filtered through a weighed fritted glass filtering crucible. The residue was washed with a portion of the 20 milliliters of hydrochloric acid (specific gravity 1.139) which was used to clean the flask, then washed with 40 milliliters of hydrochloric acid (2:3) and with about 500 milliliters of distilled water until the filtrate was neutral to litmus paper.

After the suction was disconnected, 80 milliliters of ammonium hydroxide (8:92) were added to the crucible, and the fiber was allowed to soak for 10 minutes before applying suction to drain off the excess water. The residue was then washed with about 250 milliliters of distilled water and allowed to soak in the water for 15 minutes. The fiber residue was drained, dried in air and transferred to the vacuum oven in the glass weighing bottle where it was
dried to constant weight for 16 hours at 105° to 110 degrees centigrade.

3. Potassium Hydroxide Method

This method was adapted from Gerber and Lathrop (17,437-440). The boiling 5 percent potassium hydroxide was used to dissolve wool from the mixture with nylon.

A sample of approximately 1 gram containing wool-nylon was prepared. The sample was immersed in 50 milliliters of 5 percent boiled potassium hydroxide in a 125-milliliter beaker and boiled for 10 minutes with frequent stirring. The solution was filtered through a weighed fritted glass filtering crucible by the aid of suction. It was washed with 200 milliliters of hot distilled water, washed with 30 milliliters of 5 percent acetic acid and finally washed with another 200 milliliters of distilled water to be sure that the residue was neutral before removed to dry. The washing water was removed by suction, and the nylon residue was dried by air and transferred to dry in the vacuum oven in the glass weighing bottle at 105° to 110 degrees centigrade for 16 hours.

4. Sodium Hypochlorite Method

The procedure was the same as that for wool-Acrilan and wool-Orlon blends, but the sodium hypochlorite solution used for the wool-nylon specimens contained 3.3 percent of available chlorine.
Calculations

The oven-dry residue was weighed, and the percentage of the recovered weight of the residue was calculated in the following way:

\[ a = \text{oven-dry weight of fiber before treatment} \]
\[ b = \text{oven-dry weight of fiber after treatment} \]
\[ c = \text{percentage of fiber recovered from original} \]
\[ c = \frac{b \times 100}{a} \]

The standard deviation for the analysis of each blend by each method was determined using the formula of:

\[ s = \sqrt{\frac{\sum(x^2) - \frac{S(x)^2}{N}}{N-1}} \]  \hspace{2cm} (22.11)

The significance of the difference between two means was compared by the t-test:

\[ s^2 = \frac{\sum x^2}{2(N-1)} \]
\[ \bar{x}_1 - \bar{x}_2 = 2s^2/n \]
\[ t = \frac{\bar{x}_1 - \bar{x}_2}{\frac{s_{x_1-x_2}}{\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}} \]  \hspace{2cm} (33.87)

The significance of the difference between two standard deviations at the 1 percent level was calculated by the \( z \) test:

\[ z = 2.3026 \log \frac{s_1}{s_2} \]  \hspace{2cm} (14.246-247)

The percentage correction factor for the fiber recovered from each method of analysis was determined by the following formula:

\[ \text{C. F.} = \frac{100}{\text{percentage of fiber recovered}} \]
EXPERIMENTAL RESULTS

Percentage Fiber Composition and Percentage Recovery of Fibers

The data obtained in this study will be discussed on the basis of the percentages of fibers recovered from the blends and from samples of one fiber, the correction factors for individual fibers by each method, the time required for and ease of analysis, and the cost of reagents.

The mean percentages of the fiber composition of blends of wool with acrylic fiber or nylon before analysis and on the basis of analysis are given in Table III. The mean percentages of fibers found on the basis of analysis were slightly lower than in the original samples except for slight increases in the case of wool in blends with Acrilan as determined by the zinc chloride method which could be due to various factors such as the presence of undissolved Acrilan in wool residue. The gain in weight of nylon in wool-nylon blends by the sodium hypochlorite method was also reported by Druce (10,T202-T208) in 1956 using 1 N sodium hypochlorite to determine nylon from blends of wool and nylon. No explanation was given in his report. The gain might be due to the reaction of the nylon with the sodium hypochlorite solution.

The percentage recovery of fibers in the various blends and by different methods of analysis calculated on the basis of the weight of the fibers in the original blends is shown in Table IV.
### TABLE III

Mean Fiber Composition of Blends of Wool with Acrylic Fibers and Nylon before Analysis and on the Basis of Analysis by Different Methods

<table>
<thead>
<tr>
<th>Blends of Fibers</th>
<th>Method</th>
<th>Mean Percentage Fiber Composition of Blends Before Analysis</th>
<th>Mean Percentage Fiber Composition of Blends on the Basis of Analysis</th>
<th>Acrylan</th>
<th>Orlon or</th>
<th>Acrylan</th>
<th>Orlon or</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wool-Acrylan</td>
<td>Ammonium thiocyanate</td>
<td>60%</td>
<td>49.94</td>
<td>50.06</td>
<td>49.84</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Zinc chloride</td>
<td>57.1%</td>
<td>49.50</td>
<td>50.50</td>
<td>50.37</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Sodium hydroxide</td>
<td>5%</td>
<td>48.28</td>
<td>51.72</td>
<td>-</td>
<td>-</td>
<td>51.08</td>
</tr>
<tr>
<td></td>
<td>Sodium hypochlorite</td>
<td>6.5%</td>
<td>51.29</td>
<td>48.71</td>
<td>-</td>
<td>-</td>
<td>48.47</td>
</tr>
<tr>
<td></td>
<td>available chlorine</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wool-Orlon</td>
<td>Ammonium thiocyanate</td>
<td>70%</td>
<td>49.11</td>
<td>50.89</td>
<td>48.81</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Zinc chloride</td>
<td>57.1%</td>
<td>49.22</td>
<td>50.78</td>
<td>47.43</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Sodium hydroxide</td>
<td>5%</td>
<td>48.67</td>
<td>51.33</td>
<td>-</td>
<td>-</td>
<td>50.91</td>
</tr>
<tr>
<td></td>
<td>Sodium hypochlorite</td>
<td>6.5%</td>
<td>51.29</td>
<td>49.81</td>
<td>-</td>
<td>-</td>
<td>49.54</td>
</tr>
<tr>
<td></td>
<td>available chlorine</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wool-Nylon</td>
<td>Formic acid</td>
<td>90%</td>
<td>49.15</td>
<td>50.55</td>
<td>49.03</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Hydrochloric acid</td>
<td>specific gravity</td>
<td>1.139</td>
<td>47.92</td>
<td>52.08</td>
<td>47.26</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Potassium hydroxide</td>
<td>5%</td>
<td>49.62</td>
<td>50.38</td>
<td>-</td>
<td>-</td>
<td>50.27</td>
</tr>
<tr>
<td></td>
<td>Sodium hypochlorite</td>
<td>3.3%</td>
<td>49.73</td>
<td>50.27</td>
<td>-</td>
<td>-</td>
<td>50.95</td>
</tr>
<tr>
<td></td>
<td>available chlorine</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# TABLE IV

Mean Percentage Recovery of Fibers in Blends of Wool with Acrylic Fibers and Nylon by Different Methods of Analysis

<table>
<thead>
<tr>
<th>Blends of Fibers</th>
<th>Methods</th>
<th>Fiber Recovered</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>t</th>
<th>( \bar{t} )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Wool</td>
<td>Acrylic, Orlon or nylon</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td>Standard Deviation</td>
<td>Mean</td>
<td>Standard Deviation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wool-Acrilan</td>
<td>Ammonium thiocyanate</td>
<td>60%</td>
<td>99.00</td>
<td>0.375</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>0.0218</td>
<td>0.1395</td>
</tr>
<tr>
<td></td>
<td>Zinc chloride</td>
<td>57.1%</td>
<td>101.38</td>
<td>0.582</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>0.0128</td>
<td>0.2404</td>
</tr>
<tr>
<td></td>
<td>Sodium hydroxide</td>
<td>5%</td>
<td>---</td>
<td>98.76</td>
<td>0.196</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>Sodium hypochlorite</td>
<td>6.5%</td>
<td>---</td>
<td>99.52</td>
<td>0.154</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>available chlorine</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wool-Orlon</td>
<td>Ammonium thiocyanate</td>
<td>70%</td>
<td>99.40</td>
<td>0.315</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>0.0493</td>
<td>1.3815**</td>
</tr>
<tr>
<td></td>
<td>Zinc chloride</td>
<td>57.1%</td>
<td>96.35</td>
<td>1.254</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>0.0053</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>Sodium hydroxide</td>
<td>5%</td>
<td>---</td>
<td>99.13</td>
<td>0.139</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>Sodium hypochlorite</td>
<td>6.5%</td>
<td>---</td>
<td>99.46</td>
<td>0.139</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
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<tr>
<td></td>
<td>available chlorine</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wool-Nylon</td>
<td>Formic acid</td>
<td>90%</td>
<td>99.76</td>
<td>0.105</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>0.0127</td>
<td>1.542**</td>
</tr>
<tr>
<td></td>
<td>Hydrochloric acid</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>specific gravity</td>
<td>1.139</td>
<td>98.96</td>
<td>0.333</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>Potassium hydroxide</td>
<td>5%</td>
<td>---</td>
<td>99.56</td>
<td>0.124</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>Sodium Hypochlorite</td>
<td>3.3%</td>
<td>---</td>
<td>101.39</td>
<td>0.172</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>available chlorine</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

** Significant at the 1 percent level
The mean percentage of fibers recovered varied from 96.35 percent recovery of wool from wool-Orlon mixtures by the zinc chloride method to 101.39 percent recovery of nylon from wool-nylon blends by the sodium hypochlorite method. When the mean percentages of a given fiber recovered from the same kind of blend by two different methods of analysis were compared by the $t$ test, no significant differences were found. When the $\chi^2$ test was used to compare the corresponding differences in standard deviation, the standard deviation of the percentage of wool recovered from wool-Orlon blends by the zinc chloride method was greater than by the ammonium thiocyanate method, and the standard deviation of the percentage of wool in wool-nylon blends as determined by the hydrochloric acid method was greater than by the formic acid method.

The percentage recovery from specimens of one fiber by various methods of analysis is presented in Table V. In half of the cases, the percentage of one fiber recovered was slightly greater than the percentage of the same fiber recovered from blends by the same method of analysis, and in half of the cases the reverse was true. The differences varied from 0.03 percent to 1.14 percent. In both the analyses which were run on the wool and nylon blend and on the nylon alone using sodium hypochlorite containing 3.3 percent available chlorine, slightly more than 100 percent of fiber was recovered.

When 57.1 percent zinc chloride was used on wool alone or on wool and Orlon blends, slightly less than 100 percent of the fiber was recovered, but slightly more than 100 percent of wool was
TABLE V

Percentage Recovery from Specimens of One Fiber by Different Methods of Analysis

<table>
<thead>
<tr>
<th>Methods</th>
<th>Wool</th>
<th>Acrylan</th>
<th>Orlon</th>
<th>Nylon</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Standard</td>
<td>Mean</td>
<td>Standard</td>
</tr>
<tr>
<td>Ammonium thiocyanate 60 %</td>
<td>98.59</td>
<td>0.096</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Zinc chloride 57.1%</td>
<td>99.54</td>
<td>0.270</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Sodium hydroxide 5 %</td>
<td>---</td>
<td>---</td>
<td>98.73</td>
<td>0.351</td>
</tr>
<tr>
<td>Sodium hypochlorite 6.5%</td>
<td>---</td>
<td>---</td>
<td>99.63</td>
<td>0.160</td>
</tr>
<tr>
<td>Sodium hypochlorite available chlorine</td>
<td>---</td>
<td>---</td>
<td>99.89</td>
<td>0.061</td>
</tr>
<tr>
<td>Ammonium thiocyanate 70 %</td>
<td>98.26</td>
<td>2.456</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Formic acid 90 %</td>
<td>99.61</td>
<td>0.151</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Hydrochloric acid specific gravity 1.139</td>
<td>99.20</td>
<td>0.016</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Potassium hydroxide 5 %</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>98.83</td>
</tr>
<tr>
<td>Sodium hypochlorite 3.3%</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>100.30</td>
</tr>
</tbody>
</table>
recovered from wool–Acrilan blends.

In the present study, the losses in weight of nylon in potassium hydroxide and of wool in formic acid were less than the amounts reported by Frieser (1.4 percent and 0.5 percent respectively) \(^{(17,200-202)}\), and the percentage recovery of Orlon by means of 5 percent sodium hydroxide was slightly higher than the 98.60 and 98.61 percent reported by Wolf \(^{(37,273-276)}\).

The percentage correction factors of fibers recovered were slightly over 1 percent except in the case of wool recovered from wool–Acrilan blends by the zinc chloride method and of both nylon and wool–nylon blends analyzed by the sodium hypochlorite method, which are slightly less than 1 percent \(^{(Table \, VI)}\). The differences on correction factors based on treatments of one fiber as compared with blends were small.

**Time Required and Ease of Analysis**

The analysis of time required is given in Table VII. In using the ammonium thiocyanate and zinc chloride methods for determining wool from wool–Acrilan and wool–Orlon blends, it was difficult to control the temperature for the treatments, and considerable time was required for the preparation of the solutions, especially the ammonium thiocyanate solution. However, the two methods required about the same amount of time for the complete experiments.

In comparing the Acrilan recovered from wool–Acrilan blends by the sodium hypochlorite and the sodium hydroxide methods, the sodium
<table>
<thead>
<tr>
<th></th>
<th>Wool</th>
<th>Acrilan</th>
<th>Orlon</th>
<th>Nylon</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Alone</td>
<td>In Blend</td>
<td>Alone</td>
<td>In Blend</td>
</tr>
<tr>
<td>Ammonium thiocyanate</td>
<td>60%</td>
<td>1.014</td>
<td>1.006</td>
<td>---</td>
</tr>
<tr>
<td>Zinc chloride</td>
<td>57.1%</td>
<td>1.005</td>
<td>0.986*</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.005</td>
<td>1.038**</td>
<td>---</td>
</tr>
<tr>
<td>Sodium hydroxide</td>
<td>5%</td>
<td>---</td>
<td>1.013</td>
<td>1.012</td>
</tr>
<tr>
<td>Sodium hypochlorite</td>
<td>6.5%</td>
<td>---</td>
<td>1.004</td>
<td>1.005</td>
</tr>
<tr>
<td>Sodium hypochlorite available chlorine</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ammonium thiocyanate</td>
<td>70%</td>
<td>1.018</td>
<td>1.010</td>
<td>---</td>
</tr>
<tr>
<td>Formic acid</td>
<td>90%</td>
<td>1.004</td>
<td>1.002</td>
<td>---</td>
</tr>
<tr>
<td>Hydrochloric acid specific gravity</td>
<td>1.139</td>
<td>1.008</td>
<td>1.010</td>
<td>---</td>
</tr>
<tr>
<td>Potassium hydroxide</td>
<td>5%</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Sodium hypochlorite available chlorine</td>
<td>3.3%</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
</tbody>
</table>

* From wool-Acrilan blend
** From wool-Orlon blend
# TABLE VII

Time Required and Cost of Reagents per Specimen by Different Methods of Analysis

<table>
<thead>
<tr>
<th>Method</th>
<th>Time required (minutes)</th>
<th>Total cost per specimen (cents)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonium thiocyanate 60%</td>
<td>10</td>
<td>58</td>
</tr>
<tr>
<td>Zinc chloride 57.1%</td>
<td>20</td>
<td>3</td>
</tr>
<tr>
<td>Sodium hydroxide 5%</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>Sodium hypochlorite 6.5%</td>
<td>15</td>
<td>17</td>
</tr>
<tr>
<td>Ammonium thiocyanate 70%</td>
<td>10</td>
<td>69</td>
</tr>
<tr>
<td>Formic acid 90%</td>
<td>180</td>
<td>62</td>
</tr>
<tr>
<td>Hydrochloric acid 1.139</td>
<td>30</td>
<td>17</td>
</tr>
<tr>
<td>Potassium hydroxide 5%</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>Sodium hypochlorite 6.5%</td>
<td>15</td>
<td>9</td>
</tr>
</tbody>
</table>
hypoohlorite method seemed to have many advantages. Both procedures were simple and required only ordinary equipment. The amount of time required for treating the fiber in the solution was 15 minutes for the sodium hypochlorite method and 10 minutes for the sodium hydroxide method. The total amount of time spent was approximately the same because of the length of time required to bring the sodium hydroxide solution to the boiling point. The sodium hypochlorite appeared to be the preferable method from the standpoint of time consumed and ease of execution.

For the wool-nylon analyses, the formic acid method and the hydrochloric acid method were used to determine nylon from the blends. The two methods were similar in equipment and procedures used. The formic acid method had the disadvantage of requiring a long time for the treatment. The preparation of hydrochloric acid solution of a certain specific gravity required some expenditure of time. On the basis of the amount of time required, the hydrochloric acid method had an advantage over the formic acid method.

For the determination of wool from wool-nylon blends, the potassium hydroxide and the sodium hypochlorite methods were simple, and the time required was almost the same, including the time in preparation of the solvents.

Cost of Analysis

In the determination of wool-Acrilan and wool-Orlon blends, the cost of reagents for the ammonium thiocyanate, the sodium hypochlorite,
the sodium hydroxide and the zinc chloride methods were 58, 17, 6 and 3 cents respectively. The zinc chloride method was the cheapest partly because of the small amount of reagent required for small samples. The ammonium thiocyanate method was the most expensive because of the large amount of reagent and high concentration required for the specimen. For wool-Orlon analysis by means of the 70 percent ammonium thiocyanate solution the total cost was 69 cents.

For the wool-nylon analyses, the cost of reagents for the formic acid, hydrochloric acid, sodium hypochlorite and potassium hydroxide methods are 62, 17, 9 and 1 cents respectively. The low cost of the sodium hydroxide resulted from the low concentration of reagent required and the moderate cost of the reagent, while the high cost of the formic acid was related to the high concentration plus the large amount of reagent used and the high cost of the reagent itself (Appendix).
SUMMARY AND CONCLUSIONS

The comparisons of methods of fiber analysis for wool-Acrilan, wool-Orlon, and wool-nylon blends based on the percentage of fiber recovered, cost of reagents, time required and ease of execution have been presented.

Seven methods of analysis were selected. Four methods were compared for each blend. Ammonium thiocyanate, zinc chloride, sodium hydroxide and sodium hypochlorite were used for wool-Acrilan and wool-Orlon blends. Formic acid, hydrochloric acid, potassium hydroxide and sodium hypochlorite were compared for wool-nylon blends. Specimens containing approximately 50 percent of wool and 50 percent of Acrilan, Orlon or nylon were used in the study.

The percentage fiber compositions as determined by analysis were slightly lower than the percentages before analysis except for slight increases of the percentages of wool in wool-Acrilan blends as determined by the zinc chloride method and nylon in wool-nylon blends by the sodium hypochlorite method.

No significant differences were found in the mean percentage recovery of a given fiber from a certain blend by two methods of analysis. The standard deviations were significantly lower for the percentage recovery of wool from wool-Acrilan blends by the ammonium thiocyanate method than by the zinc chloride method, and from wool-nylon blends by the formic acid method as compared to the hydrochloric acid method.
Reagents used for the zinc chloride method cost the least, while the ammonium thiocyanate was the most expensive method among the four methods used in the analysis of wool-Acrilan and wool-Orlon blends. The potassium hydroxide method was the least expensive and the formic acid method was the most expensive method for the analysis of wool-nylon blends. The sodium hypochlorite required the least time for determining the three blends and was also easy to carry on.

From the standpoint of high recovery, low standard deviation, the time required for treatment, the moderate cost of reagents and ease of execution, the sodium hypochlorite with 6.5 percent available chlorine appeared to be the most desirable of the four methods of analyzing blends of wool with Acrilan or Orlon.

On the basis of high percentage recovery of wool and low standard deviation, the formic acid method appeared to be satisfactory for the analysis of wool-nylon blends. However, this method required a relatively long period of treatment, especially careful techniques of analysis, comparatively expensive reagents and more equipment than certain other procedures. The potassium hydroxide method was also characterized by relatively high percentage recovery and low standard deviation combined with the advantages of a short period of treatment, ease of execution, low cost of reagents and less special equipment than for the formic acid method. Consequently, the potassium hydroxide method would be more economical for use in a small laboratory with a limited amount of funds.
BIBLIOGRAPHY


<table>
<thead>
<tr>
<th>Method</th>
<th>Reagents</th>
<th>Milliliters of Reagent</th>
<th>Cost of Reagent per pound</th>
<th>Cost of Reagent per specimen</th>
<th>Total Cost per specimen</th>
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</thead>
<tbody>
<tr>
<td>Ammonium thiocyanate 60%</td>
<td>Ammonium thiocyanate 60%</td>
<td>1.40</td>
<td>2.93</td>
<td>58</td>
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<tr>
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<td>Hydrochloric acid 1:4</td>
<td>40</td>
<td>0.46</td>
<td>0.97</td>
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</tr>
<tr>
<td>Sodium hydroxide 5%</td>
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<td>1.04</td>
<td>2.34</td>
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<td>Acetic acid 5%</td>
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<td>3.3</td>
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<tr>
<td>Sodium hypochlorite 6.5%</td>
<td>Sodium hypochlorite 6.5%</td>
<td>1.40</td>
<td>4.00 (gal.) 15.0</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>available chlorine</td>
<td>Acetic acid 5%</td>
<td>100</td>
<td>1.43</td>
<td>1.65</td>
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<tr>
<td>Ammonium thiocyanate 70%</td>
<td>Ammonium thiocyanate 70%</td>
<td>1.40</td>
<td>2.93</td>
<td>.69</td>
<td>69</td>
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<tr>
<td>Formic acid 90%</td>
<td>Formic acid 90%</td>
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<td>1.61</td>
<td>.62</td>
<td>62</td>
</tr>
<tr>
<td>Hydrochloric acid 1.13%</td>
<td>Hydrochloric acid 1.13%</td>
<td>1.13</td>
<td>0.46</td>
<td>10</td>
<td>13</td>
</tr>
<tr>
<td>specific gravity</td>
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<td>130</td>
<td>0.46</td>
<td>1.92</td>
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<tr>
<td></td>
<td>Hydrochloric acid 2:3</td>
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<td>0.46</td>
<td></td>
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<tr>
<td></td>
<td>Ammonium hydroxide 8:92</td>
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<td>Potassium hydroxide 5%</td>
<td>Potassium hydroxide 5%</td>
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<td>Sodium hypochlorite 3.3%</td>
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<td>4.00 (gal.) 7.6</td>
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<td>Acetic acid 5%</td>
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<td>1.43</td>
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