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A PROTOCOL FOR THE ANALYSIS OF NAIL POLISH

By

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ABSTRACT

A PROTOCOL FOR THE ANALYSIS OF NAIL POLISH

By

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Nail polish has been largely ignored in the forensic science literature, and this research opens the door to further investigation into the uses of a proposed scheme of analysis.

In this research, a three-part protocol for the analysis of nail polish is proposed. Fourier transform infrared spectroscopy is used for the comparison of chemical compositions. Microspectrophotometry is used to compare their specific color. Lastly, traditional light microscopy is used to further distinguish them. By combining these three techniques, almost all nail polishes studied were distinguishable from each other.

Five blind samples were analyzed and compared to the nail polishes that were analyzed in this project. The conclusions drawn about the blind samples were all correct, demonstrating the usefulness of this protocol.

To my two best friends: my Maker and my husband.

ACKNOWLEDGMENTS

I have been inspired and encouraged by several people through the course of this project. First of all, I'd like to thank Cheryl Lozen of the Michigan State Police Crime Lab who took me under her wing as an intern and fueled my love of trace evidence. A very special thanks to Dr. Jay Siegel, my professor, my coach and my friend. Thank you for teaching me to question everything and always seek the truth in everything.

I wouldn't be who I am today without the encouragement of my parents who always taught me to never settle for less than my best. A simple thank you is so inadequate! Thanks to my new husband, Doug, for walking with me through every step of the way and being my cheerleader every time I needed it. I love you! Lastly, I give thanks to the Lord, who is the source of my strength and everything I have. *Trust in the Lord with all your heart and lean not on your own understanding; in all your ways acknowledge Him and He will make your paths straight. (Proverbs 3:6)*

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INTRODUCTION

In the age of DNA analysis, the focus of research seems to have been drawn to forensic biology. Although most trace evidence cannot be used to identify a specific source of the questioned material, the accumulation of supporting circumstantial evidence can be very persuasive in the courtroom.

Nail polish has been largely overlooked in research, and possibly at the crime scene as well. Although nail polish manufacturers are constantly trying to make their product more durable and chip-resistant, it still becomes damaged even in normal day-to-day activities such as washing dishes and typing on a keyboard. If a woman wearing nail polish is attacked and she fights back by hitting and scratching her attacker, it is possible that her nail polish would flake off and embed in or stick to her attacker's clothing. Consider also the possibility that a victim tied up on the floor of the backseat or in the trunk of her kidnapper's car may leave nail polish evidence as she desperately tries to untie her hands behind her. The traces of nail polish that break off may be the only pieces of evidence that link her to the defendant's car. Nail polish can also be found as evidence in the form of a smear on a hard surface such as a wall or door, placed there by a flailing arm of a woman attempting to escape.

Classification

In order to establish a protocol of analysis for a forensic material, it is helpful to classify it as a particular type of substance. According to the following definitions from the *Forensic Science Handbook* (Saferstein, 2002), nail polish

could potentially be placed into three closely-related categories: paints, coatings and lacquers. A paint is defined as "a suspension of a pigment in an oil vehicle" or more broadly as "any surface coating designed for protection of a surface or for decoration, or both.". Nail polish would satisfy this definition, as it is a decorative type of surface coating. Secondly, a coating is defined as, a "surface covering intended to provide protection, corrosion resistance or an aesthetically attractive appearance or to perform some specialized purpose.". The use of nail polish to improve the appearance of one's nails could classify this material as a coating. Thirdly, lacquers are defined as "fast-drying coatings, clear or pigmented, that dry by evaporation of the solvent rather than by oxidation or polymerization.". Solvent evaporation is the predominant means by which nail polish dries. In conclusion, nail polish could fall into either of these three categories, but generally falls under the heading of a type of paint.

Review of Literature

The only journal article found to report research on nail polishes actually focused more on automotive paint than nail polish. In this research, Garold L. Gresham et al. analyzed thirty-nine automobile paints and only five nail polishes, each of which was a different brand, using secondary ion mass spectrometry (SIMS) to compare the chemical compositions. Their results indicated that the five brands were distinguishable, but nothing further was concluded regarding nail polishes. Gresham discusses how they determined the effects of SIMS on the chemical properties by alternating reflectance FTIR and SIMS to check for

any change in the FTIR spectra after the sample was analyzed by SIMS. It was concluded that there was some modification of the surface of the nail polish by SIMS analysis, but it was not significant. (Gresham, 2000) Their use of FTIR to evaluate the affect of SIMS indicates that the researchers had confidence in the analysis of nail polish by FTIR, which was not questioned or tested further in this research.

Perhaps there have been few journal articles published on nail polish because some may consider it to be similar enough to paint, which has been researched thoroughly. One should not assume that nail polish has the same properties as paint or other coatings due to differences in the purpose of the material, and therefore, differences in the composition and properties. This research was necessary to show that different brands and colors of nail polish could be distinguished by a protocol which is similar to the well-accepted method of analysis used for paint.

Purpose of this Research

The purpose of this research project is to develop an efficient, reliable and accurate scheme of analysis to compare and potentially identify nail polishes found as trace evidence at crime scenes or on persons. Three methods are used in combination for the proposed scheme. Fourier transform infrared spectroscopy (FTIR) is used to compare the chemical composition. Second, microspectrophotometry is used to compare the exact color of the material. Lastly, microscopy, the most basic technique of trace evidence analysis, is

applied to compare microscopic characteristics of the nail polishes.

Project Overview

Several different studies are conducted on various samples of nail polish. Initially, an aging study is conducted to determine how long it takes for solvents to evaporate from nail polish painted on a glass slide. This determines if the solvent components play a role in the identifying characteristics of or the discrimination between nail polishes for the studies to follow. Second, the analysis of twenty different colors of one brand of nail polish (Covergirl Nailslicks) tests the ability to distinguish between differently colored nail polishes with otherwise very similar chemical composition. Third, several nail polishes that are visibly similar in color, but from different brands, are analyzed. This tests the ability to distinguish between closely related colors by microspectrophotometry as well as to determine whether microscopy or FTIR can be used to distinguish between different brands. Fourth, a lot study is conducted involving the analysis of several samples of Covergirl Nailslicks Ice Blue Pink nail polish from different production lots as differentiated by the numbers printed on the bottom of the bottles. The purpose of this study is to determine if one can distinguish between different lots of the same nail polish. Fifth, a reproducibility study is conducted to determine the amount of variation from sample to sample by analyzing the same brand and color of nail polish twenty times. Finally, the entire scheme of analysis is tested with five blind samples in an attempt to identify each nail polish brand and color.

Introduction to the Techniques

There are a few other techniques that could potentially be used for the analysis of nail polish, based on its similarity to paint. These include pyrolysis gas chromatography- mass spectroscopy (pGC-MS), scanning electron microscopy-energy dispersive x-ray analysis (SEM-EDX) , reflectance FTIR, (Saferstein, 2002) and perhaps with more research, microchemical or solubility tests that are currently used for paints and coatings.

The three techniques used in this research are all based upon different scientific principles, which reduces the likelihood of inaccurate results. Importantly, none of the techniques in this research consume the evidence sample. Microscopy and microspectrophotometry do not change the nail polish in any way. For FTIR, the nail polish sample is ground to a powder, mixed with potassium bromide (KBr) and made into a solid pellet. This changes only the physical form of the nail polish, not the color or chemical composition. FTIR should be performed last, but if it is necessary to recover the nail polish from the KBr pellet for further analysis, the potassium bromide could be dissolved away by water, leaving the nail polish in the form of a fine powder.

Visible light can be seen in a range of colors such as red, orange, yellow, green, blue and violet as well as everything in between. The different colors result from differences in the wavelengths (or the reciprocal of the frequency) of the light. Visible light is a spectrum, ranging from 400 nanometers (nm) wavelength for violet colors to 800 nm for red colors. Microspectrophotometry

can be a very useful tool for comparing colored materials by identifying exactly what wavelength(s) of light shines through the material. While the human eye can be used to distinguish between some colors, microspectrophotometry is able to distinguish between many more closely-related colors than the naked eye. Two slightly different colors of pink nail polish may appear to be the same color, but microspectrophotometry in most cases should be able to tell the difference between them. Microspectrophotometry is used for fibers, plastics, paint, ink, colored glass, and other applications.

Below 400 nm is the ultraviolet range of light, and above 800 nm is the infrared range of light. When infrared light is focused on a sample, the molecules absorb radiation at certain frequencies, producing increased vibration of chemical bonds between atoms. This vibration is detected by the infrared spectrophotometer and produces a spectrum which shows the intensity of the absorption of infrared light at each wavelength in the range analyzed. Each type of chemical substance produces a different FTIR spectrum, making it a useful tool for distinguishing between closely-related chemicals. FTIR is used for analyzing forensic samples such as controlled substances, fibers, plastic, paint, paper, ink, toxicology samples, explosives, adhesives, tapes, and several other applications. (Saferstein, 2002) One limitation of FTIR is that substances less than 5% weight in concentration will most likely not be detected. This is especially a problem if the minor and major components of the substrate are similar, because the major components' peaks will mask those of the minor components.

Microscopy is used in this research because it is the most basic of analysis techniques. It can, however, be a very discriminating tool in the examination of trace evidence. Traditional light microscopy does not require the use of complicated or expensive equipment, and does not consume or change the evidence sample, which can be limited in forensic samples.

MATERIALS & METHODS

Samples

The following is a list of the nail polishes that were used in this research.

Covergirl Nailslicks colors:

Cabernet	Cherry Brandy
Cherry Truffle	Classic Red
Cranberry Cream	Fabulous Fuchsia
Grape Ice	Ice Blue Pink (Lot #s 1353, 2170, 2191, 2206, and 2232)
Mauvelicious	Mauve Sunrise
Peek-A-Boo Pink	Pink Aura
Pink Snow	Pink Wink
Plum Frost	Satin Mauve
Silver Plum	Tickled Pink
Twilight Mauve	Well Red

L'Oreal Shockproof Mulberry Creme

L'Oreal Shockproof Sheer Moonberry Perle

Maybelline Express Finish Daring Berry

Maybelline Express Finish Native Berry

Revlon Love Her Madly

Revlon Wine With Everything

Revlon Super Top Speed Winey

Sally Hansen Hard as Nails Oasis Dawn Cream

Sally Hansen Maximum Growth Beautiful Berry

Fourier Transform Infrared Spectroscopy

The Nicolet-Protégé 460 Fourier transform infrared spectrophotometer (FTIR), employing an MCT-A detector, was used to compare the chemical compositions of various groups of nail polishes. For each of the five studies that follow, a standard protocol was used for the preparation of the nail polish for analysis. The following procedure was used for analyses on FTIR in all studies in this project (unless otherwise indicated).

After shaking the nail polish bottle for at least 10 seconds, nail polish was painted onto a clean glass slide and allowed to dry for at least twenty-four hours before further preparation. A small amount (approximately 1 mm by 2 mm) of the dried nail polish was used to make a potassium bromide (KBr) micropellet. The first time the FTIR instrument was used each day, the bench was aligned. The sample was analyzed using fifty scans, then the KBr micropellet was removed and the background was run using fifty scans. When the instrument was finished analyzing the sample and background, the baseline was automatically adjusted by the OMNIC 5.1 software. The Y-axis scale was normalized so that the tallest peak was equal to 1.0 Absorbance units, for easier comparison. The wavelengths of all significant peaks were labeled on the spectrum. Peak heights were also labeled using the automatic peak height function to mark the tallest

portion of each peak. All equipment used in the preparation of the KBr pellet were cleaned with acetone and Kimwipes™, then allowed to dry.

Aging study

The purpose of the aging study was to determine how the chemical composition of the nail polish changes as it dries, how fast the solvents evaporate, and if the composition continues to change after the solvents have evaporated. The results of this study are used to determine how long a sample would have to dry to avoid any unnecessary error due to solvent evaporation during the studies to follow.

The aging study was conducted by making samples from one bottle of nail polish (Covergirl Nailslicks Twilight Mauve) on a clean glass slide. After specific time increments had passed, a small amount of the nail polish was removed and made into a potassium bromide pellet for analysis by Fourier transform infrared spectroscopy. This method was conducted on samples at the following intervals:

5 minutes

10 minutes

15 minutes

60 minutes

90 minutes

2 hours

3 hours

4 hours

24 hours

1 week

2 weeks

The spectra were compared to identify the peaks which change over time and those which do not. Those peaks which changed were tracked over time to determine if there was a pattern of change as the nail polish dried and when the changing ceased.

Reproducibility study

The purpose of the reproducibility study was to determine how much variation occurs in chemical composition from analysis to analysis, as detected by FTIR, using one nail polish. Covergirl Nailslicks Twilight Mauve was used to make several samples on glass slides. Twenty samples were taken (after waiting at least 24 hours) and these were analyzed and compared for any differences between the spectra. To obtain values for the variation between these identical samples, the spectra were stored in a software library and each sample was searched against it. The software program automatically compared the shape, relative height and position along the horizontal axis for each peak in the spectra that was being searched and the spectra that were stored in the library. The software was able to calculate a rating (a "percent match") of how closely any two spectra relate to each other. There are several types of

searches that could be done, each of which places more weight on differentiation between specific features of the spectra. For example, a squared difference search would be best if one is especially concerned mainly with the predominant peaks, while an absolute derivative search places more weight on small differences between the positions of the peaks along the X-axis. The search that was used for this research, a correlation search, was recommended by the software as producing the best results for most applications. The formula used by the program is a lengthy and highly complicated one, precluding its presentation in the current writing.

The search results list the other nail polishes in the library in order of the degree to which they match the sample that was searched, with a match rating called the "percent match". This percent match is a rating of how close one nail polish is related chemically to another nail polish. The differences between the samples would be used as a standard for sample-to-sample variation. For the other studies, a spectrum with variation that was not within this normal sample-to-sample variation would be considered to be a different nail polish.

Brand study

The purpose of the brand study was to determine if there were differences in chemical composition of nail polishes that are different brands and types. Ten nail polishes that were visually very similar in color were chosen for analysis. These samples represented five brands, or seven subcategories (for example, two were Sally Hansen brand nail polishes; one of them was 'Sally

Hansen Maximum Growth Nourishing Nail Color', and the other was 'Hard As Nails', two different subcategories of Sally Hansen).

These ten nail polishes were analyzed by FTIR, as outlined previously. The spectra were added to a software library for comparison to other nail polishes. The percent matches of each spectra were compared to each other to determine if different brands or types of similar color nail polish could be distinguished from each other.

Covergirl study

The purpose of the Covergirl study was to determine if there are differences in chemical composition between differently colored nail polishes of one brand. Twenty colors of Covergirl Nailslicks nail polish were used to make samples on clean glass slides, which were allowed to dry twenty-four hours, then analyzed according to the method outlined previously. The ingredients on the labels were recorded and compared. Those which had the same ingredients listed on the label in the same order were compared closely to determine if the dyes, pigments or other minor variations could be detected using FTIR.

Lot study

The lot study was performed to determine if the chemical composition of nail polish from different production lots or batches of the same brand and color could be distinguished from each other by FTIR. Five bottles of Covergirl Nailslicks Ice Blue Pink nail polish, all from different lots were purchased and

analyzed by FTIR according to the method outlined previously. The spectra were compared to determine if there is a detectable difference in chemical composition between batches of the same nail polish.

Microspectrophotometry

To compare the precise color of the nail polishes in this research project, microspectrophotometry was performed on the five groups of nail polish, just as in the FTIR analysis. Each time the SEE 1100 microspectrophotometer was turned on, it was calibrated using filters traceable to National Institute of Science & Technology (NIST) standards. Calibration procedures used during this research project are in Appendix A.

Method of Analysis

Slides that were prepared for analysis by FTIR were used for microspectrophotometry. Each slide was placed on the stage of the microspectrophotometer and the sample was brought into focus. The aperture was moved just off the sample and a reference scan was run. Five sample scans were run on each sample, in different areas of the nail polish smear. Another reference scan was run before each sample scan that was outside of the previous field of view. Once all five sample scans were run, the positions of the peaks were marked by the software. If any obvious peaks were not identified by the software, the peak position was marked manually, using the cursor.

The above procedure was conducted on the ten nail polishes of a similar

color, the twenty samples of Covergirl Nailslicks nail polish, and the five lots of Covergirl Nailslicks Ice Blue Pink. Within the brand study, one pair and one triplet were especially close in color (visually). The similar pair is L'Oreal Shockproof Sheer Moonberry Perle and Revlon Love Her Madly. The triplet included Revlon Super Top Speed Winey, Revlon Wine With Everything, and Maybelline Express Finish Native Berry. The spectra were compared against each other to determine if microspectrophotometry could distinguish between different colors, even colors that appear very similar.

The aging study was conducted on Covergirl Nailslicks Twilight Mauve to determine whether or not the color of this nail polish changed as it dried or "aged". The nail polish was painted on a clean glass slide and was analyzed as before at the following intervals:

5 minutes

10 minutes

15 minutes

30 minutes

45 minutes

60 minutes

90 minutes

2 hours

3 hours

4 hours

For the reproducibility study, twenty sample scans were taken of Covergirl

Nailslicks Twilight Mauve, instead of the usual 5. These scans were printed out on two plots for easier viewing. The plots were also printed out "stacked" which separated the spectra, with their peaks marked. The peak positions in the spectra would be compared to identify any variation that occurs among samples.

Microscopic Examination

As with most trace evidence, microscopic analysis can play a major role in the comparison of similar materials. The goal of this research was primarily to obtain a reproducible, reliable method of analyzing nail polish. However, microscopic analysis relies heavily on interpretation and is therefore subject to human error. In this research, traditional light microscopy was applied, as opposed to polarized light microscopy.

Sample preparation for microscopic analysis was minimal; each nail polish was painted on a clean glass slide and allowed to dry. Under 400X magnification, the sample was brought into focus and was examined in several areas of the sample to assure a representative sampling of the material. Several characteristics were compared, including the grain and color of the substrate, the presence and size of any particles, and the color and distribution of those particles. All nail polishes analyzed were compared microscopically against each other to assess how discriminating microscopy can be for the identification of nail polishes.

Blind test

A blind test was conducted to evaluate the protocol used in this research for accuracy in comparing and identifying nail polishes. Five nail polish samples were prepared by Dr. Jay A. Siegel, PhD., Professor of Forensic Science at Michigan State University. The nail polishes available to choose from for the blind samples included all nail polishes analyzed in this research plus four other nail polishes, including two brands that had not been analyzed. The author was unaware of which nail polishes were used to make these samples. The five samples were analyzed by FTIR, microspectrophotometry and light microscopy using the protocol presented herein to compare their characteristics to those analyzed and to identify the brand and color of each of the blind samples.

RESULTS & DISCUSSION

FTIR

Fourier transform infrared spectroscopy, a powerful and discriminating technique, was used to compare the chemical compositions of nail polishes of different brands and within one brand. A software library was built, containing the spectra from these nail polishes. Each nail polish was searched against this library, producing a list of similar nail polishes in order of their percent match to the nail polish in question.

Aging Study

There was no continuous trend of change in chemical composition observed as the samples aged, as detected by FTIR. The spectrum for the sample that had dried five minutes (see Figure 1) was the most unique sample (had the lowest percent match across all samples) in the aging study. The spectrum for the sample that had dried ten minutes (see Figure 2) did not differ significantly from the other samples (see Figure 3), suggesting that the majority of solvent evaporation and any other chemical changes occur in less than ten minutes.

Reproducibility study

The FTIR spectra of the twenty samples of Covergirl Nailslicks Twilight Mauve (see Figure 4) were all very similar, as was expected. A library was

built, containing only the reproducibility samples, and each of the twenty samples was searched against this library. The average lowest percent match (the twentieth ranked match) from these searches was 96.01%. The lowest percent match that falls within two standard deviations from the mean was 96.64%. Statistically, 95% of the data should fall within two standard deviations, to limit any skewing of the data by outliers. These two percentages were used as standards for ranges of acceptable error within one nail polish. Nail polishes that fell outside of this range in other studies could be excluded as a common source.

Since FTIR was used to compare the chemical compositions, the information gained from the spectra was compared to the list of chemical ingredients listed on each bottle. Based on the comparison of the ingredients, it should be expected that the nail polishes with similar formulas would have similar FTIR spectra, and the nail polishes with very different ingredients would have different FTIR spectra.

There are a few ingredients that were found in every nail polish analyzed. These are butyl acetate, ethyl acetate and isopropyl alcohol. All nail polishes listed the following on the "may contain" ingredient lists: bismuth oxychloride, iron oxides, mica and titanium dioxide (one nail polish does contain, the others may contain). The rest of the ingredients are not constant throughout all nail polishes studied, which supports the hypothesis that the chemical compositions may be used to distinguish one nail polish from another.

5 minutes Covergirl Nailslicks Twilight Mauve

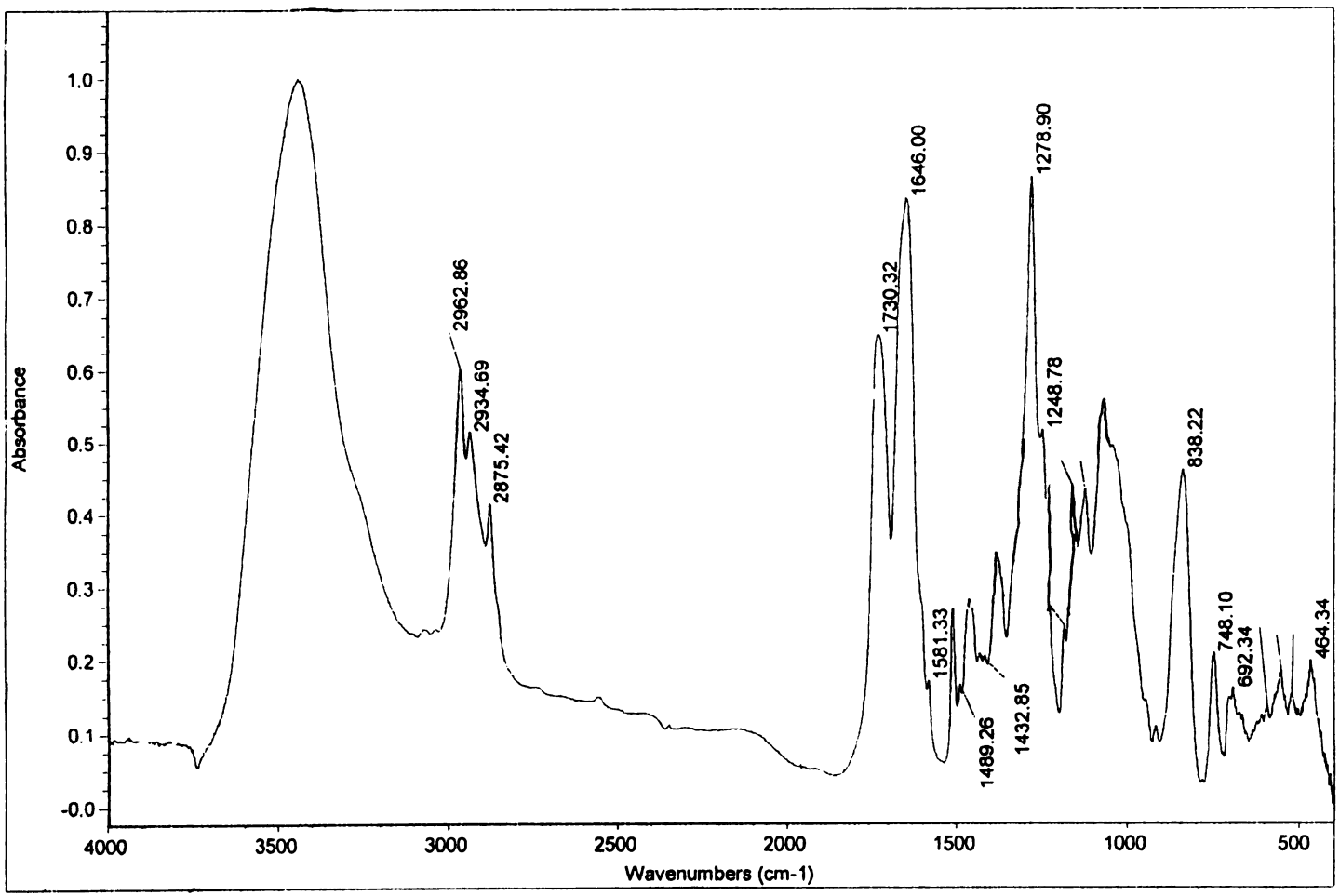

Figure 1. FTIR Spectrum of 5 Minute Aged Sample

10 minutes Covergirl Nailslicks Twilight Mauve

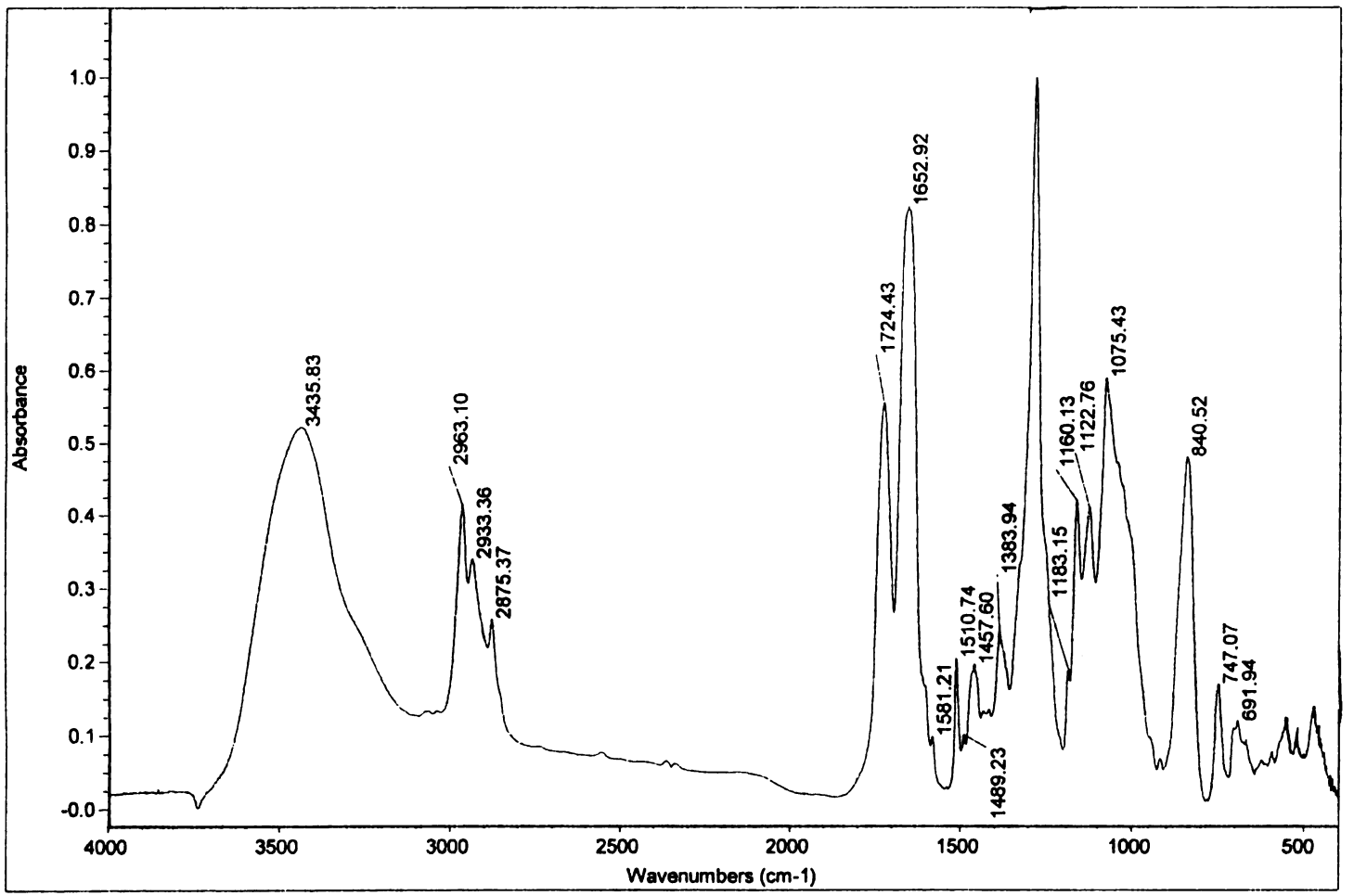

Figure 2. FTIR Spectrum of 10 Minute Aged Sample

4 hours Covergirl Nailslicks Twilight Mauve

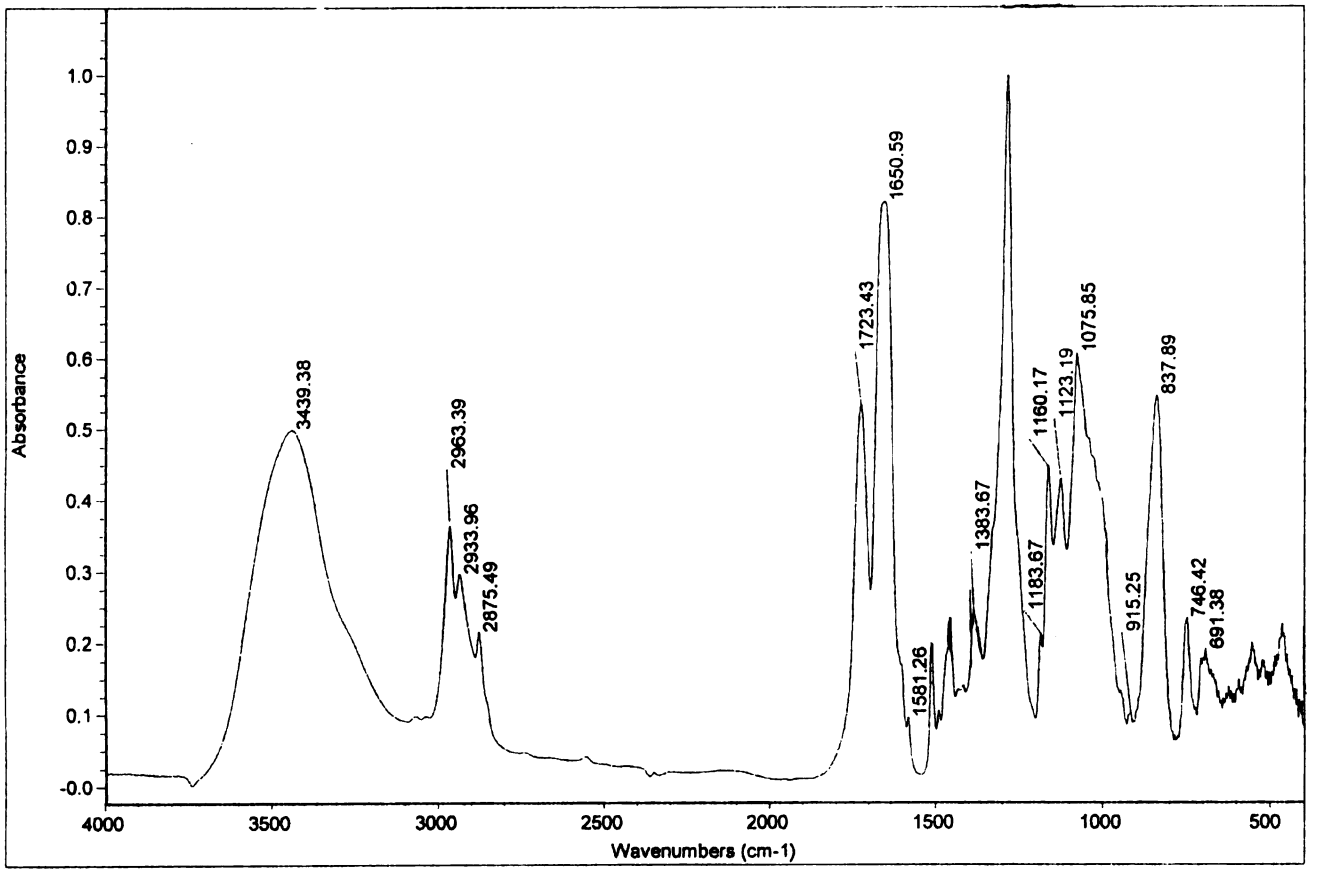

Figure 3. FTIR Spectrum of 4 Hour Aged Sample

#1 Covergirl Nailslicks Twilight Mauve

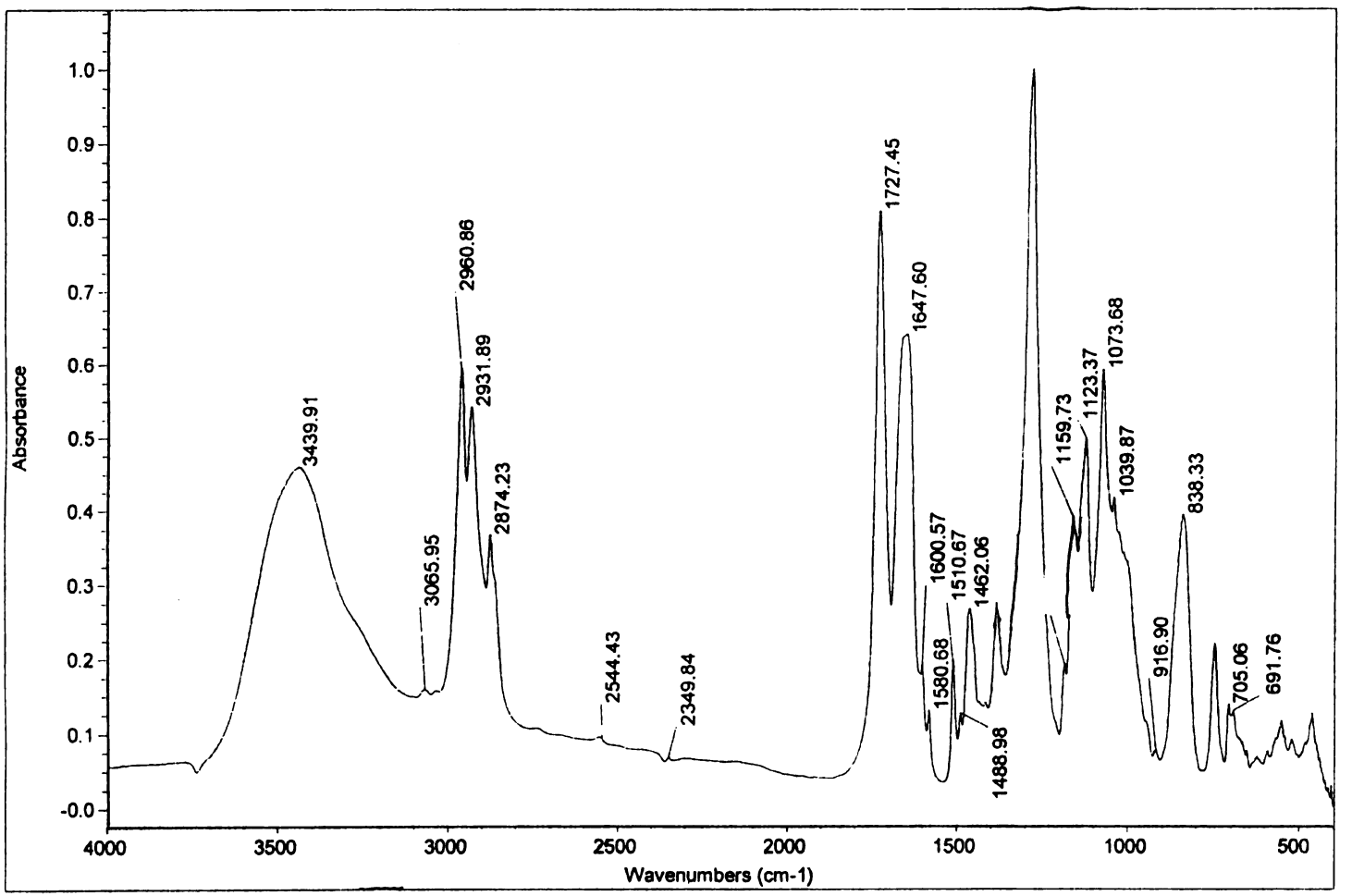

Figure 4. FTIR Spectrum of Reproducibility Sample #1

Brand Study

Table 1 shows a chart of the number of differences in ingredients, which is based only on the presence or absence of each ingredient, not on the relative amount of each ingredient. The relative amount of each ingredient could possibly be compared based on the order of the ingredients on the bottle, assuming that they are in order of proportion, but this really doesn't tell anything about the actual amount of that chemical. For example, consider two theoretical nail polishes that have the same ingredients, in the same order on the labels, and both are in order with the main ingredients starting first. One of those nail polishes is mostly composed of the first two ingredients, and the rest are minimal in quantity, while the ingredients in the other nail polish gradually decrease in amount down the list of ingredients. Theoretically, the FTIR spectra should be distinguishable because their chemical makeup would be different due to varied amounts of each ingredient even though their ingredient lists were identical. Therefore, the order of ingredients on the label should not be used to estimate or compare the amount of each ingredient.

What can be compared is the presence or absence of the ingredients. Of course, not all of the differences in the FTIR spectra will be accounted for by comparing the presence or absence of ingredients, as pointed out above. This is merely a tool for comparison, to see if dissimilar chemical ingredients can be a cause for differences in the FTIR spectra.

Nail polishes in the brand study revealed that three pairs of nail polishes had identical ingredients listed on the labels. These were the two Revlon colors

(Wine With Everything and Love Her Madly), the two L'Oreal Shockproof colors (Sheer Moonberry Perle and Mulberry Cream), and the two Maybelline Express Finish colors (Native Berry and Daring Berry).

Table 1. Similarity of ingredients in the Brand Study.

Identical	**Covergirl Cranberry Cream**	**L'Oreal Sheer Moonberry Perle**	**L'Oreal Mulberry Creme**	**Maybelline Native Berry**	**Maybelline Daring Berry**	**Revlon Wine With Everything**	**Revlon Love Her Madly**	**Revlon Super Top Speed Winey**	**Sally Hansen Maximum Growth Beautiful Berry**	**Sally Hansen Hard As Nails Oasis Dawn Cream**
		L'Oreal Mulberry Creme	L'Oreal Sheer Moonberry Perle	Maybelline Daring Berry	Maybelline Native Berry	Revlon Love Her Madly	Revlon Wine With Everything			
Decreasing similarity of ingredients	Sally Hansen Hard As Nails Oasis Dawn Cream	Revlon Super Top Speed Winey	Revlon Super Top Speed Winey	Sally Hansen Maximum Growth Beautiful Berry	Sally Hansen Maximum Growth Beautiful Berry	Revlon Super Top Speed Winey	Revlon Super Top Speed Winey	Revlon (both)	Covergirl Cranberry Cream	Maybelline (both)
	L'Oreal (both)	Revlon (both)	Revlon (both)	Covergirl Cranberry Cream	Covergirl Cranberry Cream	L'Oreal (both)	L'Oreal (both)	L'Oreal (both)	L'Oreal (both)	L'Oreal (both)
	Revlon (both)	Covergirl Cranberry Cream	Covergirl Cranberry Cream	L'Oreal (both)	L'Oreal (both)	Covergirl Cranberry Cream	Covergirl Cranberry Cream	Covergirl Cranberry Cream	Revlon (both)	Covergirl Cranberry Cream
	Maybelline (both)	Maybelline (both)	Maybelline (both)	Revlon (both)	Revlon (both)	Maybelline (both)	Maybelline (both)	Maybelline (both)	Revlon Super Top Speed Winey	Revlon (both)
	Revlon Super Top Speed Winey	Sally Hansen Hard As Nails Oasis Dawn Cream	Sally Hansen Hard As Nails Oasis Dawn Cream	Revlon Super Top Speed Winey	Revlon Super Top Speed Winey	Sally Hansen Maximum Growth Beautiful Berry	Sally Hansen Maximum Growth Beautiful Berry	Sally Hansen Maximum Growth Beautiful Berry	Maybelline (both)	Revlon Super Top Speed Winey
	Sally Hansen Maximum Growth Beautiful Berry	Sally Hansen Maximum Growth Beautiful Berry	Sally Hansen Maximum Growth Beautiful Berry	Sally Hansen Hard As Nails Oasis Dawn Cream	Sally Hansen Hard As Nails Oasis Dawn Cream	Sally Hansen Hard As Nails Oasis Dawn Cream	Sally Hansen Hard As Nails Oasis Dawn Cream	Sally Hansen Hard As Nails Oasis Dawn Cream	Sally Hansen Maximum Growth Beautiful Berry	Sally Hansen Hard As Nails Oasis Dawn Cream

Considering these three pairs and the twenty Covergirl nail polishes, it seems as though nail polish formulas within each brand, and within the subtype of each brand, are relatively constant, according to the results of FTIR. This is not the case with Sally Hansen, based on the significant differences between the spectra of these two nail polishes. On the other hand, Sally Hansen Hard As Nails Oasis Dawn Creme and Sally Hansen Maximum Growth Beautiful Berry are in different subcategories so it could be expected that they would have some differences, especially considering that they have different "purposes" (the first is for hard, chip-resistant nails, and the second nail polish's purpose is to promote nail growth and health).

For the different brands studied (Covergirl, Maybelline, Revlon, Sally Hansen and L'Oreal), the FTIR spectra of the nail polishes within each brand had a higher percent match than with any nail polish of another brand (Table 2). The exception was Sally Hansen, where the chemical composition of these two nail polishes were drastically different from each other, which may be explained by their dissimilar ingredients. The results of this study show that FTIR is a useful technique in distinguishing between different brands of nail polish (see Figures 5 and 6).

On average, three nail polishes in the brand study had a 96.64% match or higher, and three nail polishes had a 96.01% match or higher. In other words, out of twenty Covergirl nail polishes and nine other nail polishes in the brand study, twenty-six could be eliminated as a common source, leaving only three possibly consistent nail polishes on average.

Table 2. FTIR Percent Match Results of the Brand Study.

Within% match standard	**Covergirl Cranberry Cream**	**L'Oreal Mulberry Creme**	**L'Oreal Sheer Moonberry Perle**	**Maybelline Daring Berry**	**Maybelline Native Berry**	**Revlon Love Her Madly**	**Revlon Wine With Everything**	**Revlon Super Top Speed Winey**	**Sally Hansen Hard As Nails Oasis Dawn Cream**	**Sally Hansen Maximum Growth Beautiful Berry**
	Covergirl Cranberry Cream	L'Oreal Mulberry Creme	L'Oreal Sheer Moonberry Perle	Maybelline Daring Berry	Maybelline Native Berry	Revlon Love Her Madly	Revlon Wine With Everything	Revlon Super Top Speed Winey	Sally Hansen Oasis Dawn Cream	Sally Hansen Beautiful Berry
				Maybelline Native Berry	Maybelline Daring Berry	Revlon Wine With Everything	Revlon Love Her Madly			
Decreasing percent match	Sally Hansen Oasis Dawn Cream	L'Oreal Sheer Moonberry Perle	L'Oreal Mulberry Cream	Sally Hansen Beautiful Berry	L'Oreal Sheer Moonberry Perle	Revlon Super Top Speed Winey	Revlon Super Top Speed Winey	Revlon Wine With Everything	Covergirl Cranberry Cream	Maybelline Daring Berry
	L'Oreal Sheer Moonberry Perle	Covergirl Cranberry Cream	Sally Hansen Oasis Dawn Cream	Covergirl Cranberry Cream	Covergirl Cranberry Cream	L'Oreal Sheer Moonberry Perle	L'Oreal Sheer Moonberry Perle	Revlon Love Her Madly	L'Oreal Sheer Moonberry Perle	Maybelline Native Berry
	Maybelline Native Berry	Sally Hansen Oasis Dawn Cream	Covergirl Cranberry Cream	L'Oreal Sheer Moonberry Perle	Sally Hansen Oasis Dawn Cream	Maybelline Native Berry	Maybelline Native Berry	Maybelline Native Berry	Maybelline Native Berry	L'Oreal Sheer Moonberry Perle
	Maybelline Daring Berry	Maybelline Native Berry	Maybelline Native Berry	Sally Hansen Oasis Dawn Cream	Sally Hansen Beautiful Berry	L'Oreal Mulberry Cream	L'Oreal Mulberry Cream	L'Oreal Sheer Moonberry Perle	L'Oreal Mulberry Cream	L'Oreal Mulberry Cream
	L'Oreal Mulberry Cream	Maybelline Daring Berry	Maybelline Daring Berry	L'Oreal Mulberry Cream	L'Oreal Mulberry Cream	Maybelline Daring Berry	Maybelline Daring Berry	Maybelline Daring Berry	Maybelline Daring Berry	Covergirl Cranberry Cream
	Revlon Wine With Everything	Revlon Wine With Everything	Revlon Wine With Everything	Revlon Wine With Everything	Revlon Wine With Everything	Covergirl Cranberry Cream	Covergirl Cranberry Cream	Covergirl Cranberry Cream	Revlon Wine With Everything	Sally Hansen Oasis Dawn Cream
	Revlon Super Top Speed Winey	Revlon Love Her Madly	Revlon Super Top Speed Winey	Revlon Super Top Speed Winey	Revlon Super Top Speed Winey	Sally Hansen Oasis Dawn Cream	Sally Hansen Oasis Dawn Cream	L'Oreal Mulberry Cream	Revlong Super Top Speed Winey	Revlon Wine With Everything
	Sally Hansen Beautiful Berry	Sally Hansen Beautiful Berry	Revlon Love Her Madly	Revlon Love Her Madly	Revlon Love Her Madly	Sally Hansen Beautiful Berry	Sally Hansen Beautiful Berry	Sally Hansen Oasis Dawn Cream	Sally Hansen Beautiful Berry	Revlon Super Top Speed Winey
	Revlon Love Her Madly	Revlon Super Top Speed Winey	Sally Hansen Beautiful Berry					Sally Hansen Beautiful Berry	Revlon Love Her Madly	Revlon Love Her Madly

L'Oreal (Shock Proof) Sheer Moonberry Perle

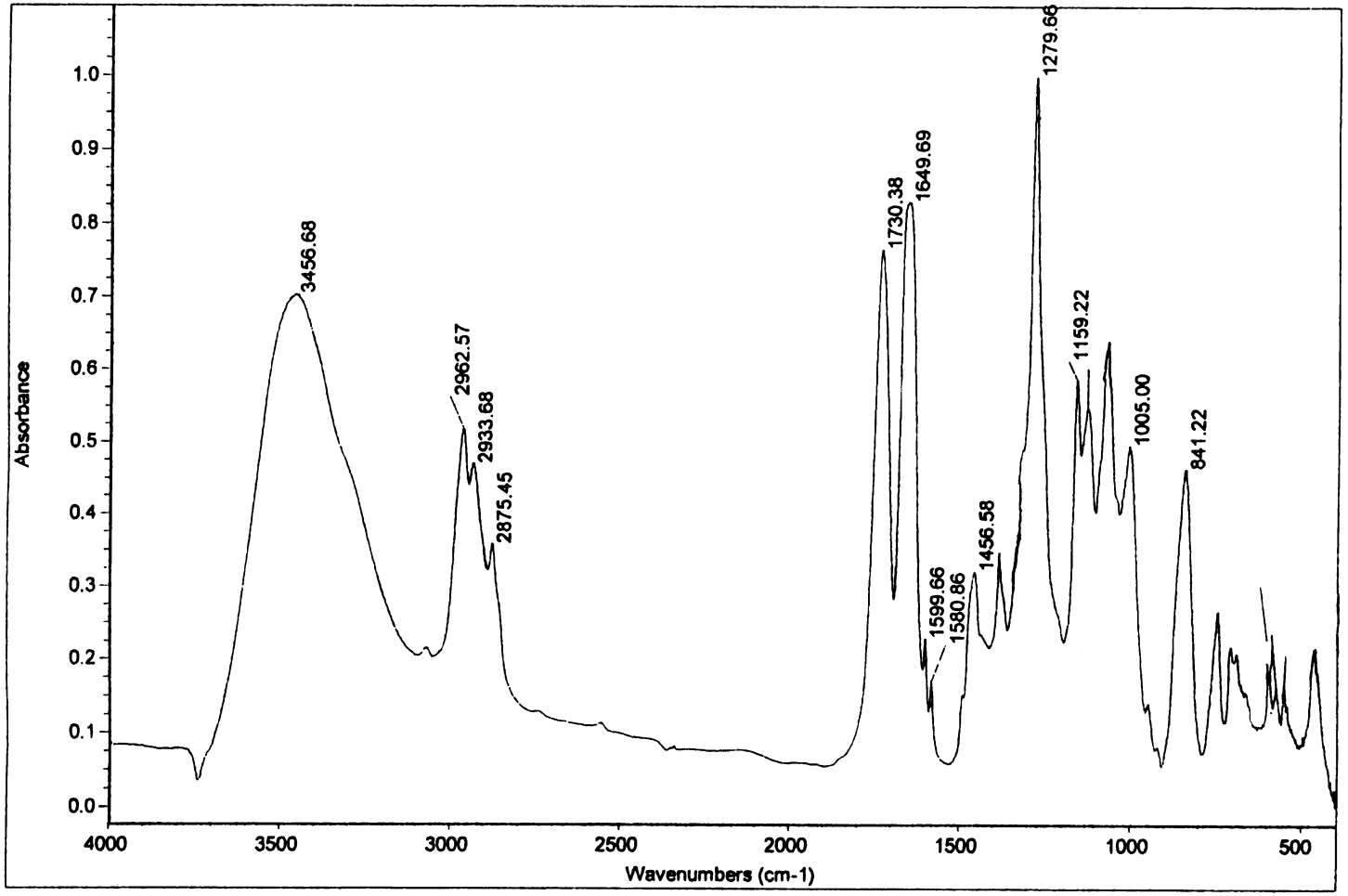

Figure 5. FTIR Spectrum of L'Oreal Sheer Moonberry Perle

Maybelline (Express Finish) Daring Berry

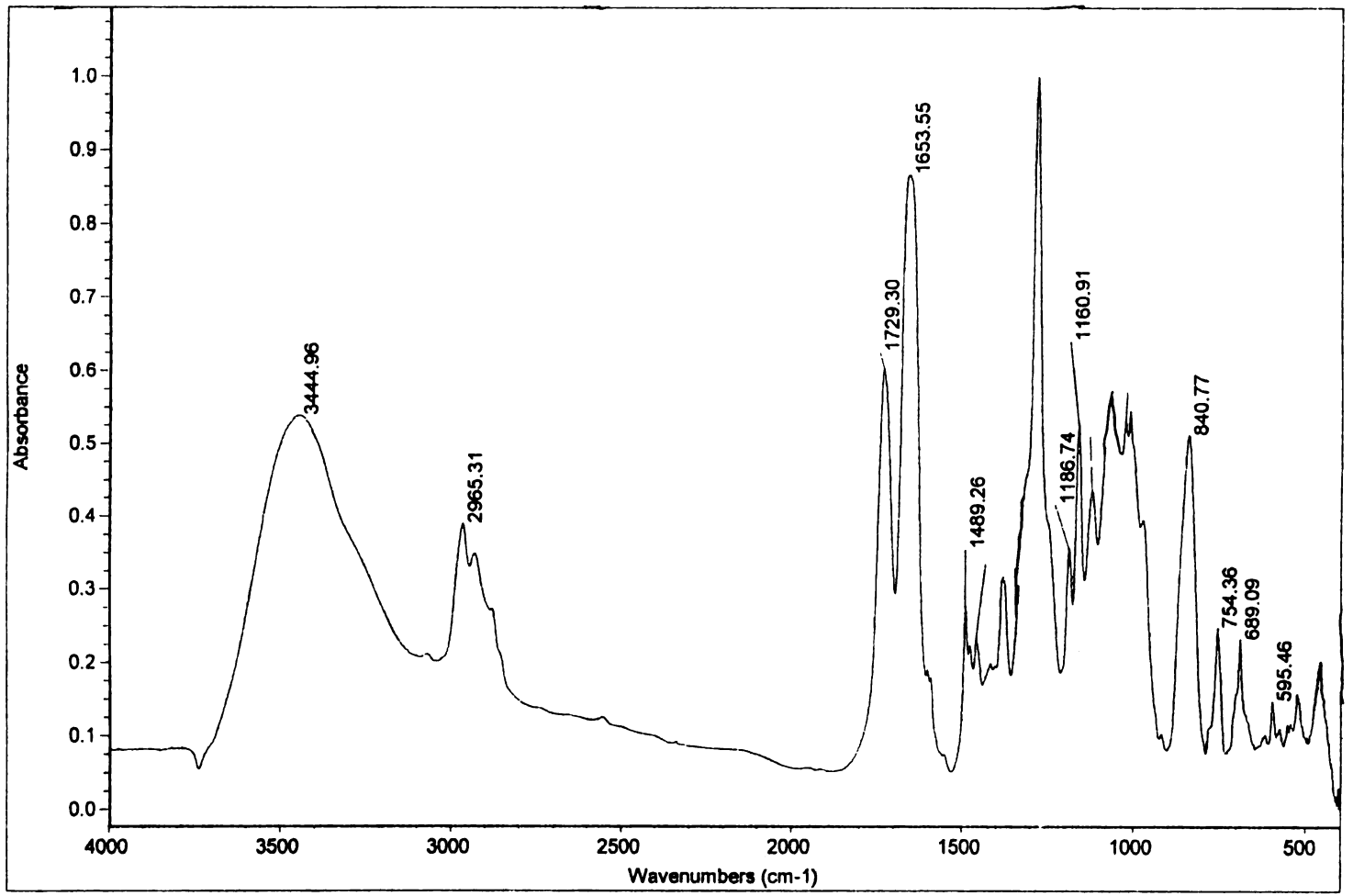

Figure 6. FTIR Spectrum of Maybelline Daring Berry

Covergirl Study

By comparing the ingredients in the twenty Covergirl Nailslicks colors, they could be put into three classes of composition (Table 3).

Table 3. Ingredients of the Covergirl Nail Polishes in this Study.

Category 1	**Category 2**	**Category 3**
Pink Wink	Cherry Truffle	Mauve Sunrise
Cabernet	Tickled Pink	
Classic Red	Well Red	
Satin Mauve		
Cherry Brandy		
Twilight Mauve		
Pink Aura		
Peek-A-Boo Pink		
Ice Blue Pink		
Mauvelicious		
Plum Frost		
Fabulous Fuchsia		
Grape Ice		
Pink Snow		
Cranberry Cream		
Silver Plum		
Base ingredients	Base ingredients +: Red 30 Lake	Base ingredients +: Red 30 Lake Aluminum Powder

Category 1 nail polishes contain what will be referred to as the "base ingredients" which are common to all of the Covergirl nail polishes studied. Category 2 has three colors which contain the base ingredients plus Red 30 Lake. Mauve Sunrise is the only nail polish in Category 3 and differs from category 1 in that it contains both Red 30 Lake and Aluminum Powder.

Comparing the percent matches of the FTIR spectra, it appears that the

nail polishes in each category are no more similar to each other than they are to other Covergirl nail polishes. Additionally, Mauve Sunrise is no more similar to those in category 2 than to those in category 1. Mauve Sunrise had the most unique spectrum of the Covergirl nail polishes. Therefore, four conclusions may be drawn: a) Red 30 Lake is not in significant enough quantities to produce a measurable difference in the spectra, b) the proportion of the common ingredients differs enough to produce enough error to make small differences in composition, c) the ingredients on the "may contain" list account for the differences in composition that cover over the small differences from Red 30 Lake, or d) any combination of the previous theories. Most likely, there is more than one factor contributing to the unexpected results.

The Covergirl nail polishes had higher percent matches with each other than with nail polishes of other brands (see Figures 7 and 8), with only a few exceptions. Mauve Sunrise had as low of a percent match as the different brands did, pointing to its unique composition. When both Plum Frost and Pink Snow were searched against the library, they had similar results in that for both of them, Fabulous Fuchsia, and Silver Plum had low percent matches, along with Mauve Sunrise. All three were below Sally Hansen Oasis Dawn Creme. It is possible that Oasis Dawn Creme just had a higher match than most other Covergirl nail polishes. When Grape Ice was searched against the library, Fabulous Fuchsia had a percent match just lower than Sally Hansen Oasis Dawn Creme. Mauve Sunrise also had a low percent match.

Covergirl Nailslicks Classic Red

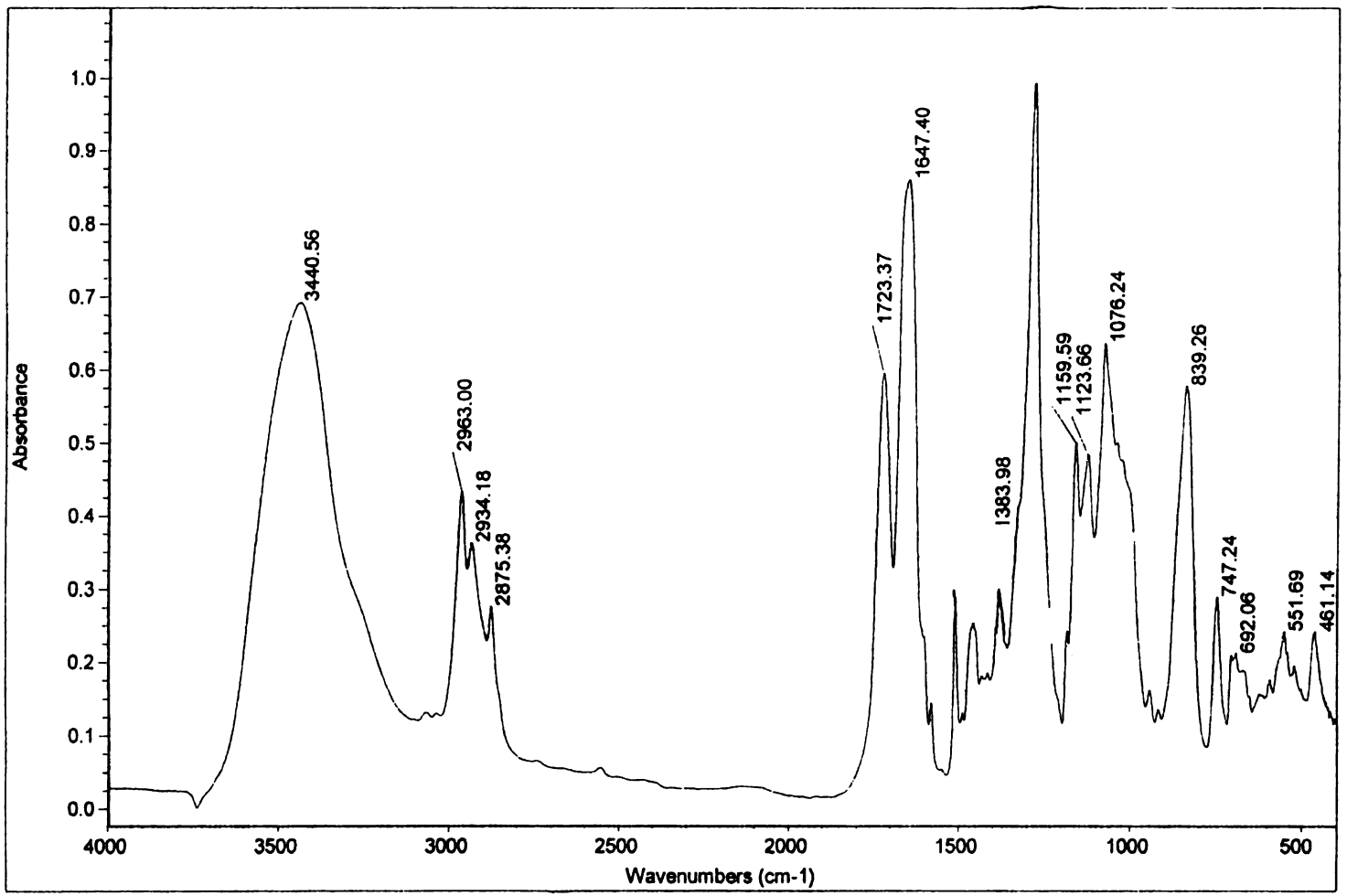

Figure 7. FTIR Spectrum of Covergirl Nailslicks Classic Red

Covergirl Nailslicks Pink Wink

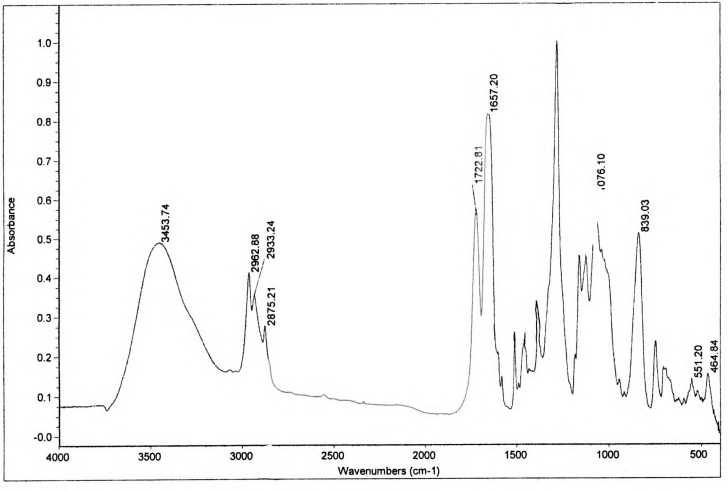

Figure 8. FTIR Spectrum of Covergirl Nailslicks Pink Wink

On average, fourteen Covergirl nail polishes had a percent match of 96.64% or higher. Fifteen nail polishes had a percent match of 96.01% or higher. Therefore, out of twenty Covergirl nail polishes and nine others from different brands, only fourteen or fifteen of them can be excluded as being from a common source. Infrared spectroscopy was not able to efficiently distinguish between many of the nail polishes within the Covergirl brand. This may not be the case for all brands, such as Sally Hansen. The two Sally Hansen nail polishes studied were easily distinguished from each other, and therefore might be an indication that other nail polishes within this brand can be distinguished from each other. Further research would be needed for confirmation of this hypothesis.

Lot Study

The five lots of Covergirl Nailslicks Ice Blue Pink were essentially indistinguishable by FTIR. Only lot numbers 1353 and 2191 could be distinguished from each other using the 96.64% match standard (see Figures 9 and 10). If the 96.01% standard was used, none of them could be distinguished from each other because all five of them have a percent match higher than 96.01%. FTIR was only able to distinguish between two of the five lots of Covergirl Nailslicks Ice Blue Pink that were analyzed.

Microspectrophotometry

The specific color of each nail polish was analyzed by

Lot #1353 Covergirl Nailslicks Ice Blue Pink

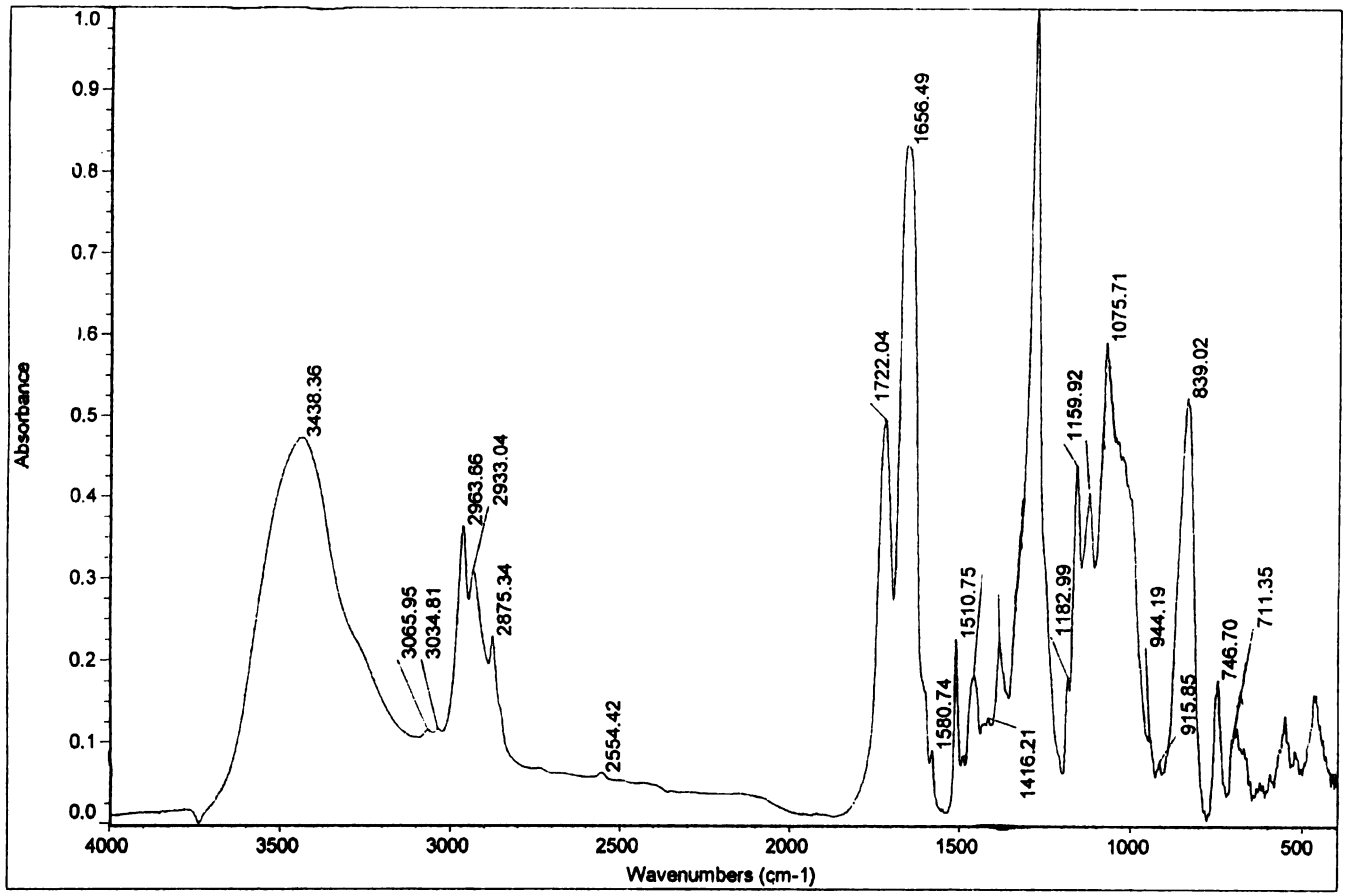

Figure 9. FTIR Spectrum of Covergirl Nailslicks Ice Blue Pink Lot # 1353

Lot # 2191 Covergirl Nailslicks Ice Blue Pink

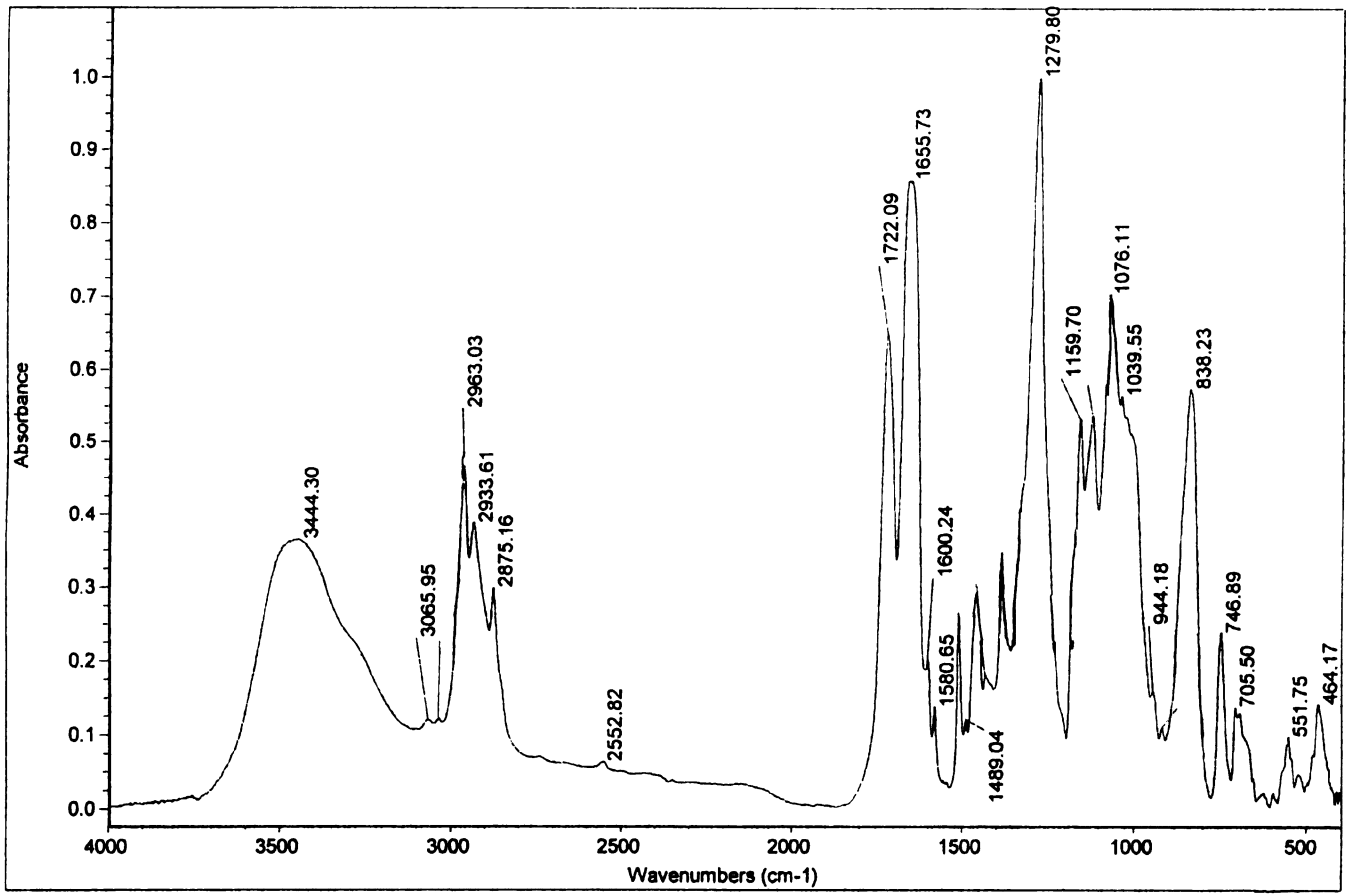

Figure 10. FTIR Spectrum of Covergirl Nailslicks Ice Blue Pink Lot # 2191

microspectrophotometry. The spectrum produced can be compared by the wavelength of light absorbed, the shape of the peaks and the relative intensity of multiple peaks in the spectrum.

Aging Study

The wavelengths of the peaks in the spectra for Covergirl Nailslicks Twilight Mauve as it aged showed that the color of the nail polish did not change as it dried (see Figures 11, 12 and 13). The wavelengths of the peaks were consistently within the range of normal variation for one nail polish. This result was expected, since the hardening of the nail polish is suspected to occur as the solvents evaporate and possibly as the resins polymerize, neither of which would be suspected to affect the color.

Reproducibility Study

The wavenumbers of the two peaks in the microspectrophotometry spectrum for Covergirl Nailslicks Twilight Mauve were compared to the twenty spectra obtained in the reproducibility study. The spectra were all consistent with each other (see Figure 14), with some variation in the specific wavelengths of the peaks. The range of wavenumbers for the peaks was: 504.9 to 509.1, a difference of 4.2 units, and 540.6 to 548.5, a difference of 7.9 units (see Table 4). On the second peak, note that there were two outliers: 546 and 548.5. All the rest of the samples had wavelengths between 540.6 and 544.4 (a difference of 3.8 units). This study showed that the run-to-run variation for one sample

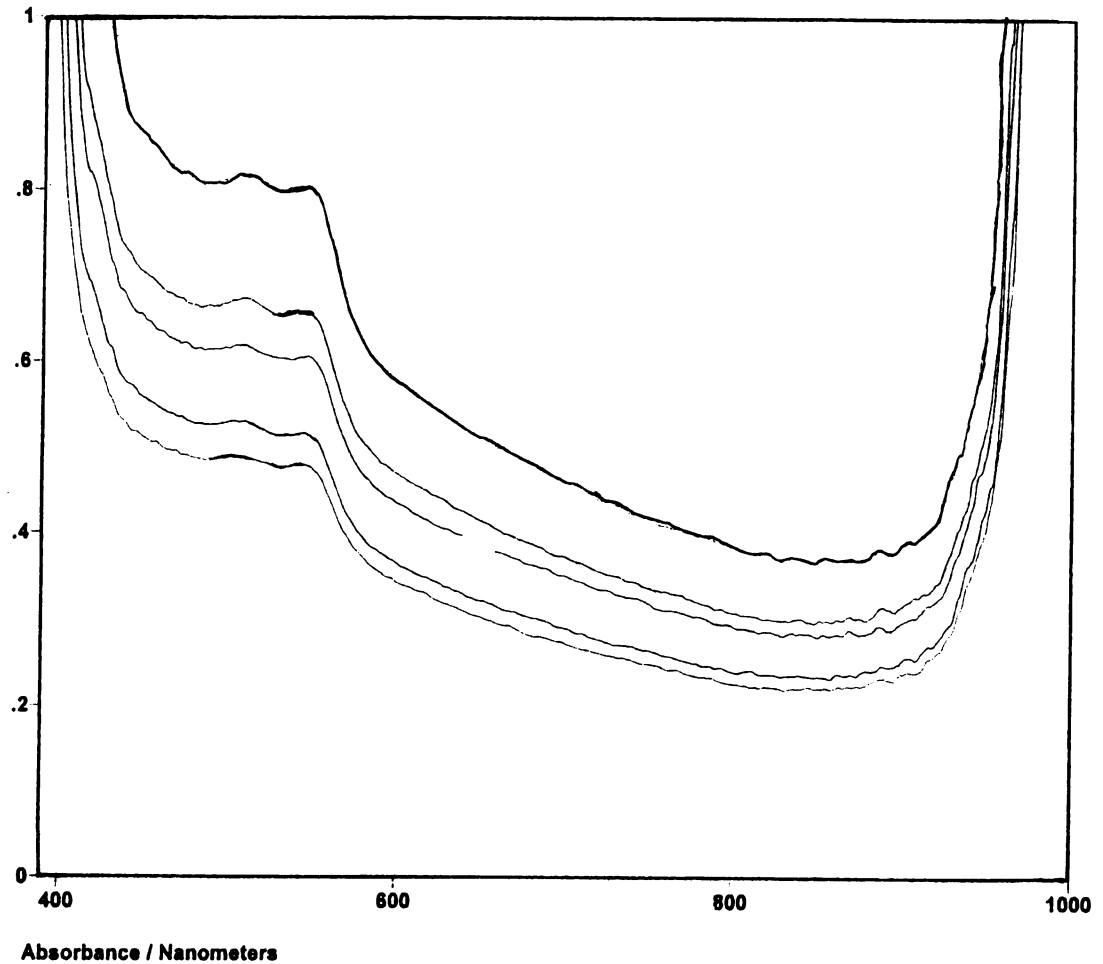

Figure 11. UV-Visible Spectra of 5 Minute Aged Sample

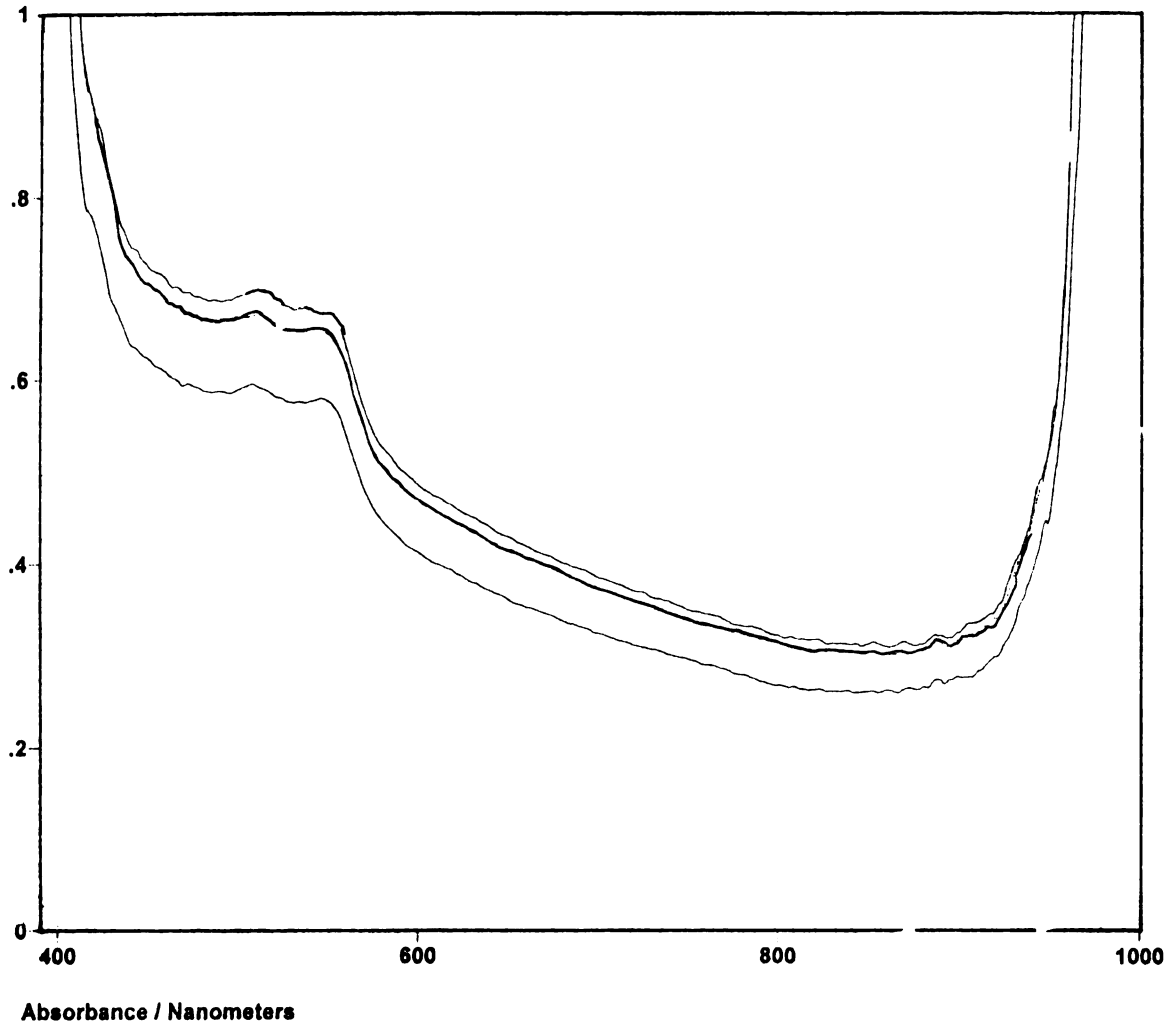

Figure 12. UV-Visible Spectra of 10 Minute Aged Sample

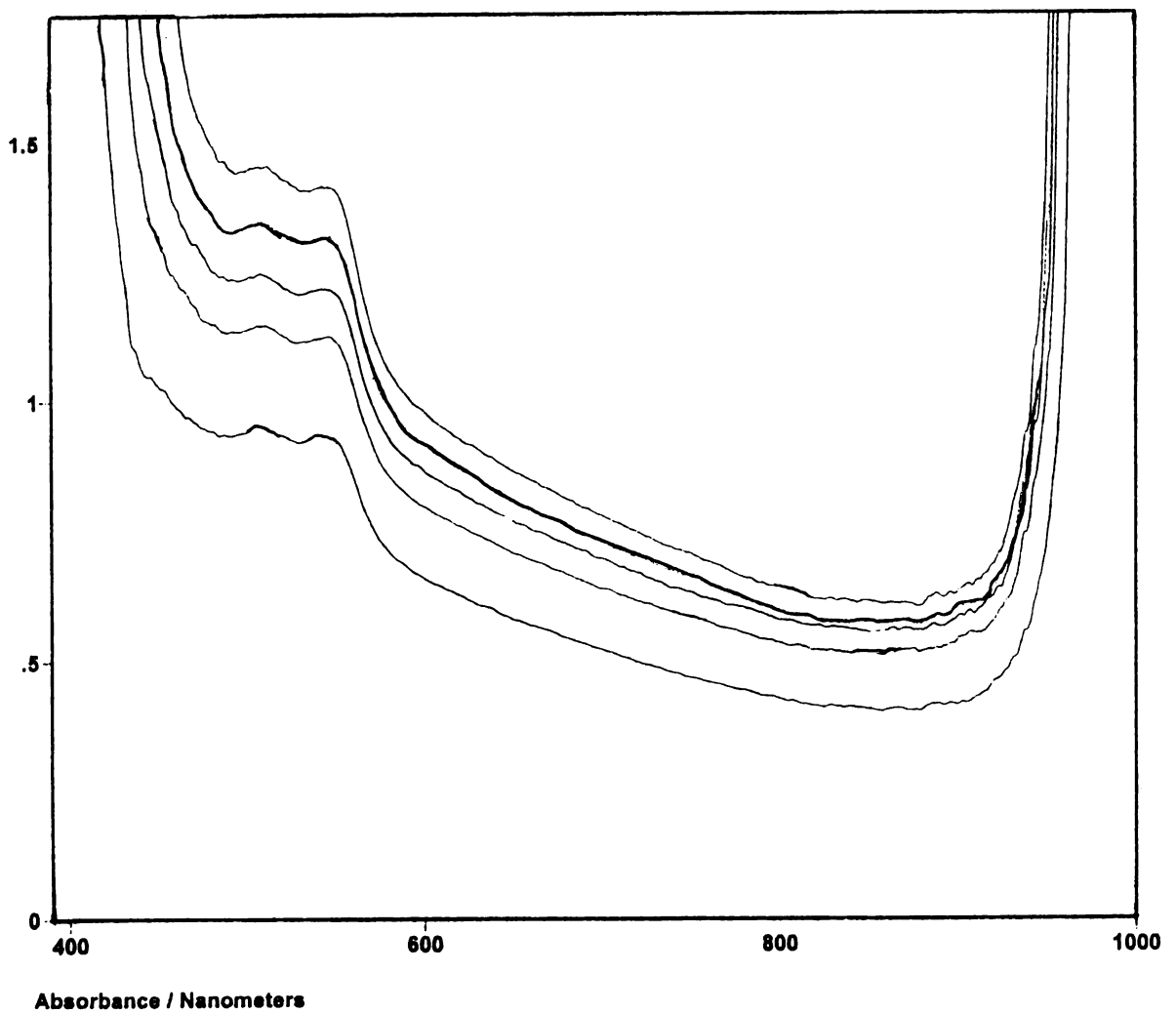

Figure 13. UV-Visible Spectra of 4 Hour Aged Sample

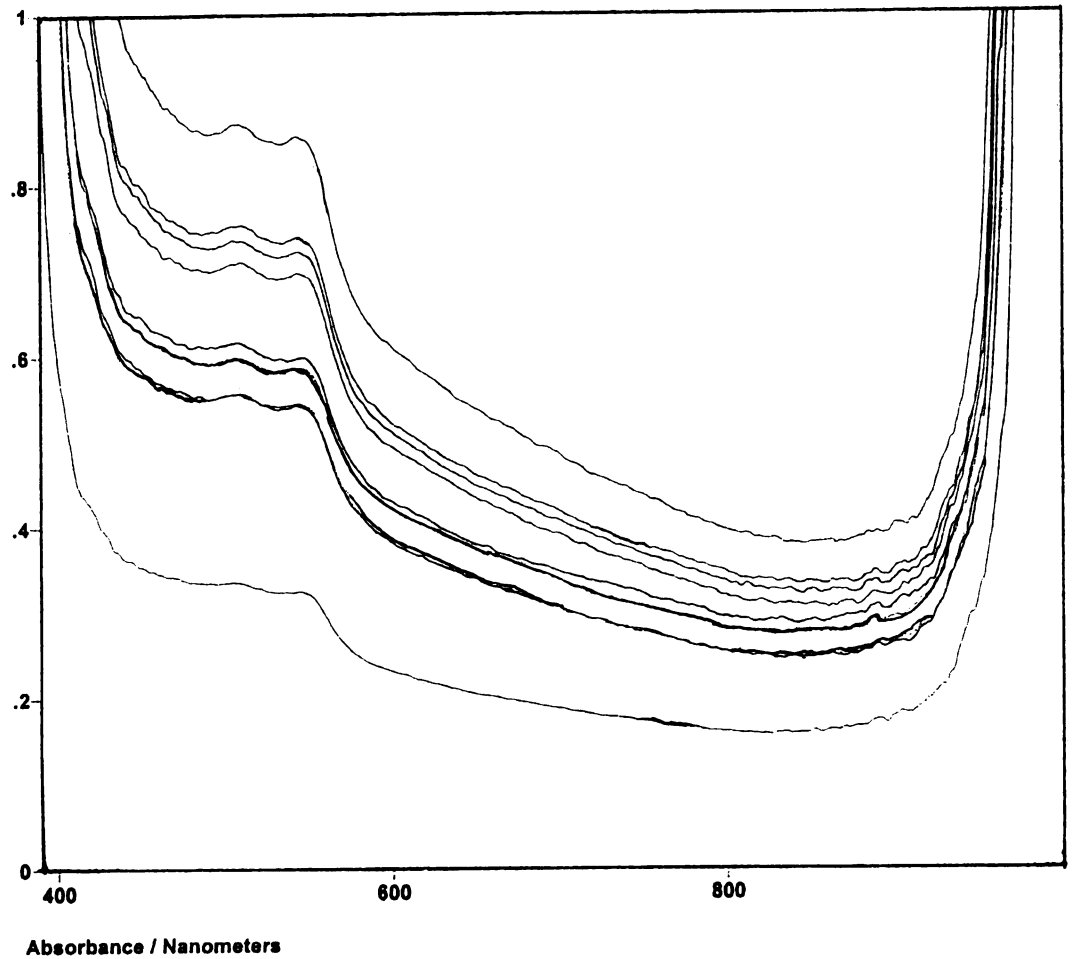

Figure 14. UV-Visible Spectra of Reproducibility Samples #1-10

was within four to eight units of absorbance. Some of this variation could have come from the manual marking of peaks. This variance was used in following studies as a standard for acceptable error within one nail polish. If the wavelengths of two samples differed by more than this standard, they could be considered to be different colors.

Brand study

Covergirl Nailslicks Cranberry Cream, Maybelline Express Finish Daring Berry (see Figure 15), and Maybelline Express Finish Native Berry could not be distinguished from each other by microspectrophotometry. All three nail polishes had two peaks around 529 and 569 nanometers absorbance. The other seven colors in this study, however, could be distinguished from each other, even those which appeared visually very similar in color [L'Oreal Shockproof Sheer Moonberry Perle (see Figure 16) with Revlon Love Her Madly, and Revlon Super Top Speed Winey with Revlon Wine With Everything and Maybelline Express Finish Native Berry]. Sally Hansen Hard As Nails Oasis Dawn Cream did not produce a useful spectrum, most likely because either the coloring agents were not dense enough to have detectable absorption or that the beige color did not reflect an outstanding amount of any particular range of visible light. Results are summarized in Table 5.

Table 4. Microspectrophotometry peak wavelengths for the Reproducibility study.

Sample #	Peak 1 (nm)	Peak 2 (nm)
1	506.6	548.5
2	508.2	542.7
3	507.7	542.5
4	507.4	541.1
5	507	540.9
6	508.1	542.6
7	506.3	542.7
8	505.0	541.6
9	504.9	540.8
10	507.0	541.2
11	507.3	540.6
12	507.1	543.1
13	509.1	546.0
14	507.5	542.4
15	507.0	544.4
16	505.6	542.6
17	507.0	542.3
18	508.1	543.2
19	508.2	543.0
20	506.1	543.0

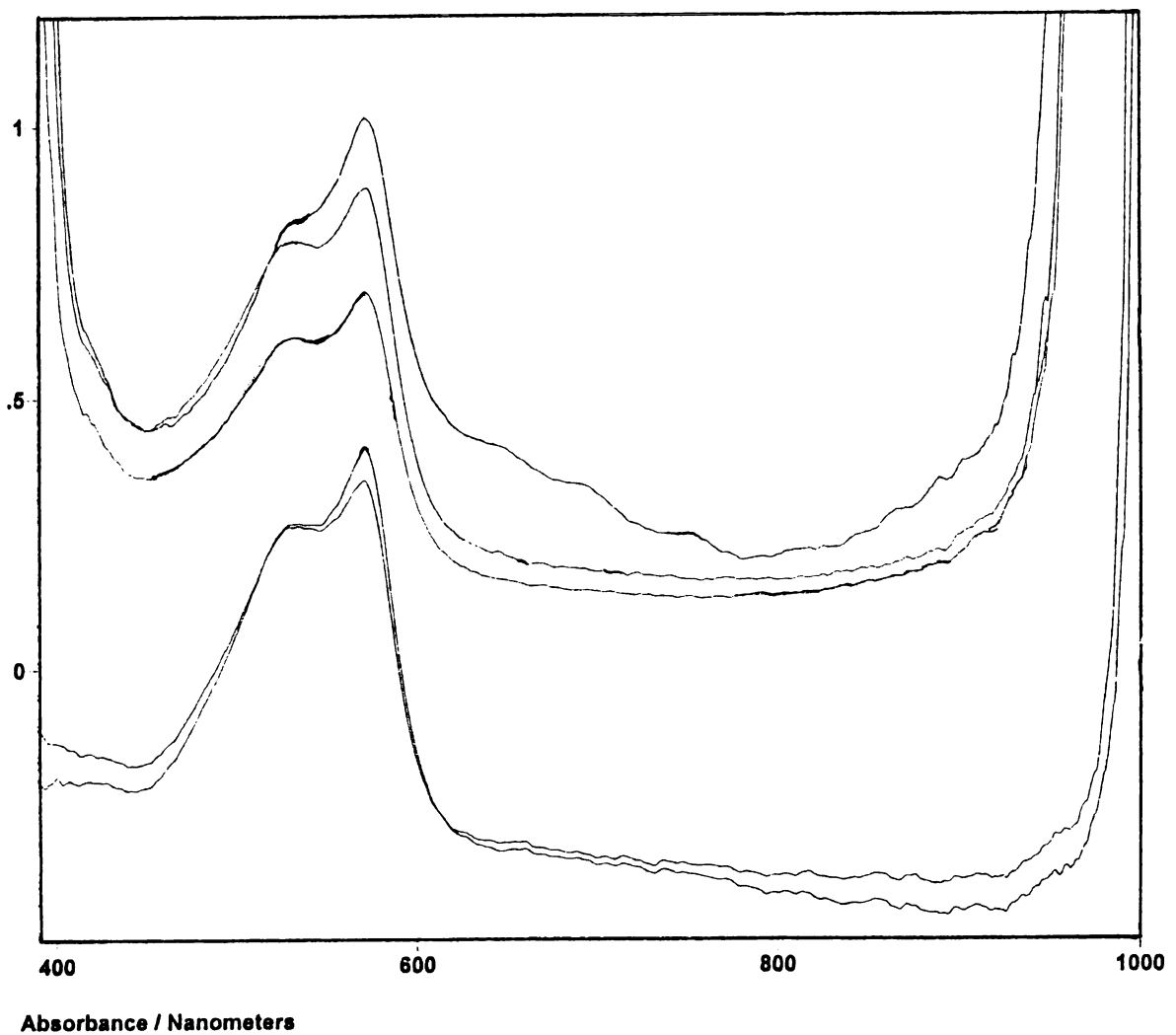

Figure 15. UV-Visible Spectra of Maybelline Daring Berry

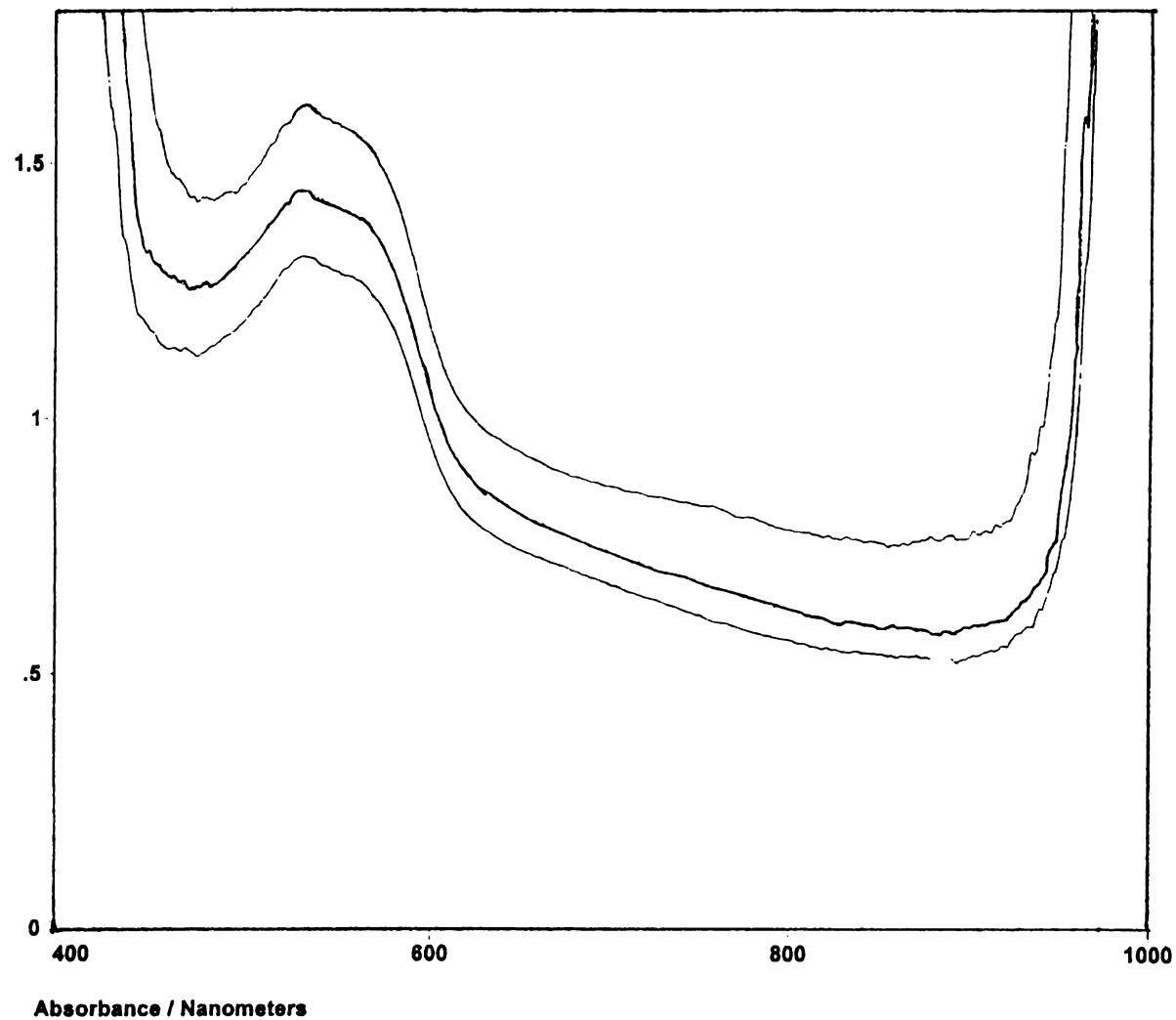

Figure 16. UV-Visible Spectra of L'Oreal Sheer Moonberry Perle

Table 5. Microspectrophotometry Results for the Brand Study.

Could Not Be Distinguished From Each Other	Could Be Distinguished From Others In The Study	Did Not Produce a Useful Spectrum
Covergirl Cranberry Cream,	L'Oreal Mulberry Cream	Sally Hansen Hard As Nails Oasis Dawn Cream
Maybelline Daring Berry, and	L'Oreal Sheer Moonberry Perle	
Maybelline Native Berry.	Revlon Love Her Madly	
	Revlon Wine With Everything	
	Revlon Super Top Speed Winey	
	Sally Hansen Maximum Growth Beautiful Berry	

Covergirl Study

Silver Plum, Satin Mauve and Ice Blue Pink were not able to be distinguished from each other by microspectrophotometry. All three had peaks with wavelengths around 511 and 546 nm.

Plum Frost and Cherry Brandy had similar spectra. Both of them had a broad peak around 524. They were distinguished from each other only by the unique spectra of the red particles found in Cherry Brandy, but absent from Plum Frost.

Twilight Mauve, Pink Snow, and Pink Aura were indistinguishable by the wavelengths, shape and relative heights of their peaks. All three samples had peaks with wavelengths around 508 and 543 nm.

Mauve Sunrise, Peek-A-Boo Pink and Tickled Pink did not produce useful spectra, perhaps because of their pale colors. All other samples were distinguishable from each other by microspectrophotometry (see Figures 17 and 18).

Table 6. Microspectrophotometry Results for the Covergirl Study.

Could Not Be Distinguished From Each Other	Could Be Distinguished From Others In The Study	Did Not Produce a Useful Spectrum
Ice Blue Pink,	Cabernet	Mauve Sunrise
Satin Mauve, and	Cherry Brandy	Peek-A-Boo Pink
Silver Plum.	Cherry Truffle	Tickled Pink
	Classic Red	
Pink Aura,	Cranberry Cream	
Pink Snow, and	Fabulous Fuchsia	
Twilight Mauve.	Grape Ice	
	Mauvelicious	
	Pink Wink	
	Plum Frost	
	Well Red	

One reason that some colors were not able to be distinguished from each other by microspectrophotometry could be because they are different intensities of the same shade. It is possible, especially within one brand, that the same combination and relative amounts of dyes are used, but are "diluted" during production to make several shades of the same color. In this case, microspectrophotometry would only detect differences in the intensity of the

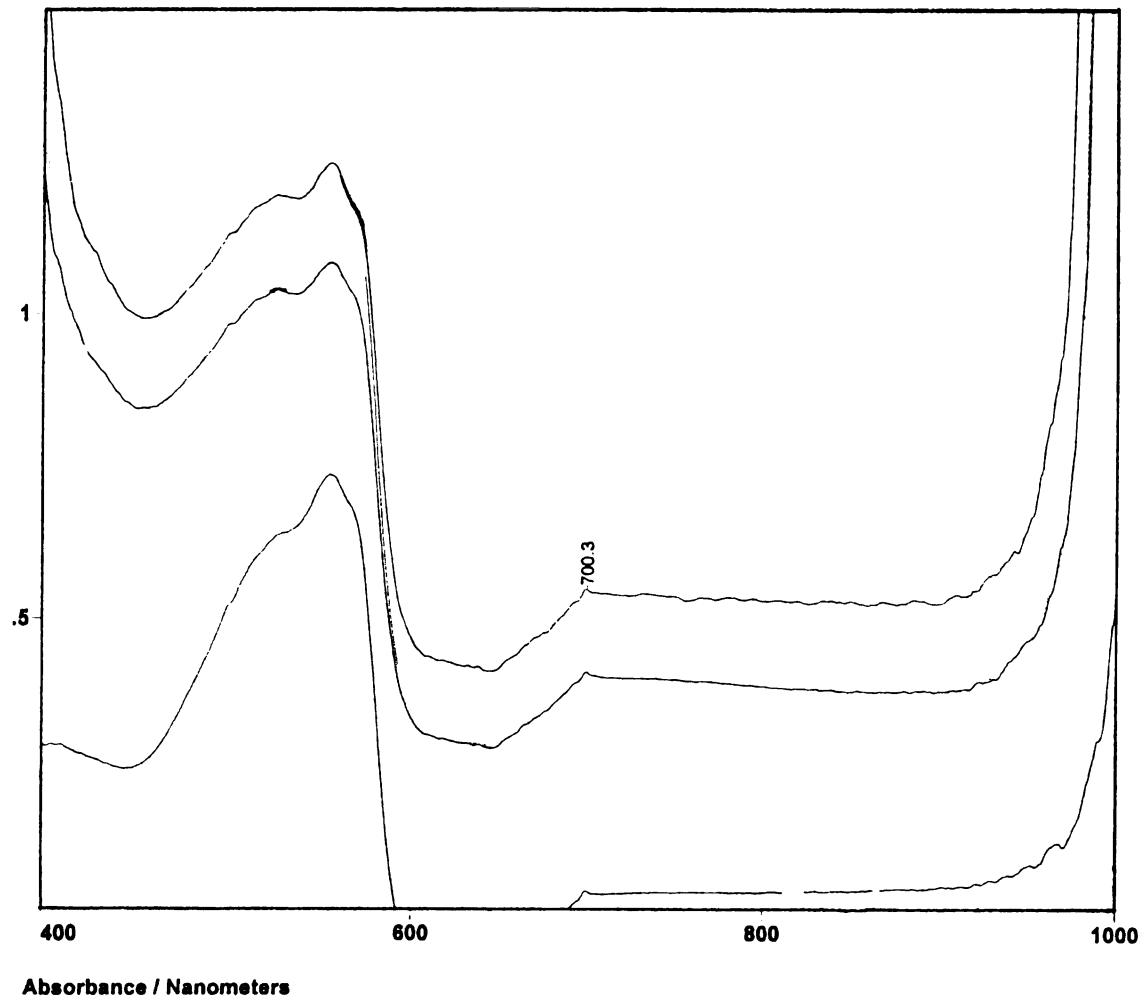

Figure 17. UV-Visible Spectra of Covergirl Nailslicks Classic Red

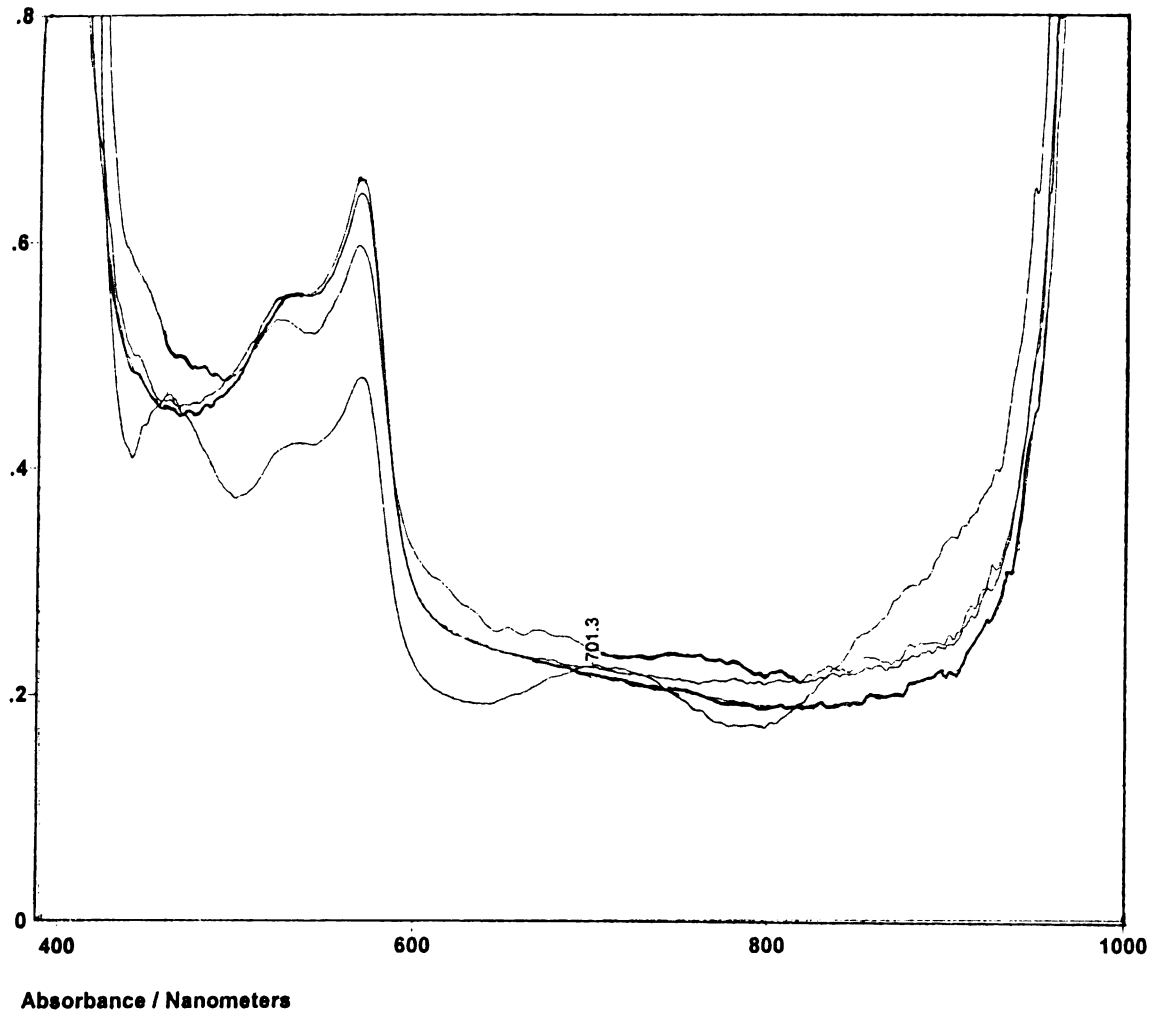

Figure 18. UV-Visible Spectra of Covergirl Nailslicks Pink Wink

color (which is not used for comparison), not in the wavelengths of the peaks.

Lot Study

The five lots of Covergirl Nailslicks Ice Blue Pink that were analyzed showed that they were consistent in color with each other (see Figures 19 and 20). The ranges of wavelengths of the two peaks were within normal ranges of error for one nail polish, as determined by the reproducibility study. One factor that has not yet been necessary to discuss is the peak height ratio comparison. Most of the other nail polishes analyzed thus far by microspectrophotometry have been easily distinguished by wavelengths alone. Looking at the overlaid spectra of the five lots, it appears that the peaks in lot number 2191 are of a different ratio than the peaks in the other lots. More specifically, the height of the second peak in lot number 2191 was a larger proportion of the total of the two peaks. This indicates that this lot of nail polish contains a slightly different proportion of dyes or other coloring agents. The other four lots are indistinguishable by the wavelengths, shape and heights of the peaks.

Microscopic Examination

Comparative microscopy was conducted differently than the other techniques. The nail polishes were not divided into separate studies; they were all compared against each other to determine how useful microscopy is for distinguishing between nail polishes, regardless of their brand or color. Some of the characteristics used in comparison included the grain, the size and colors of

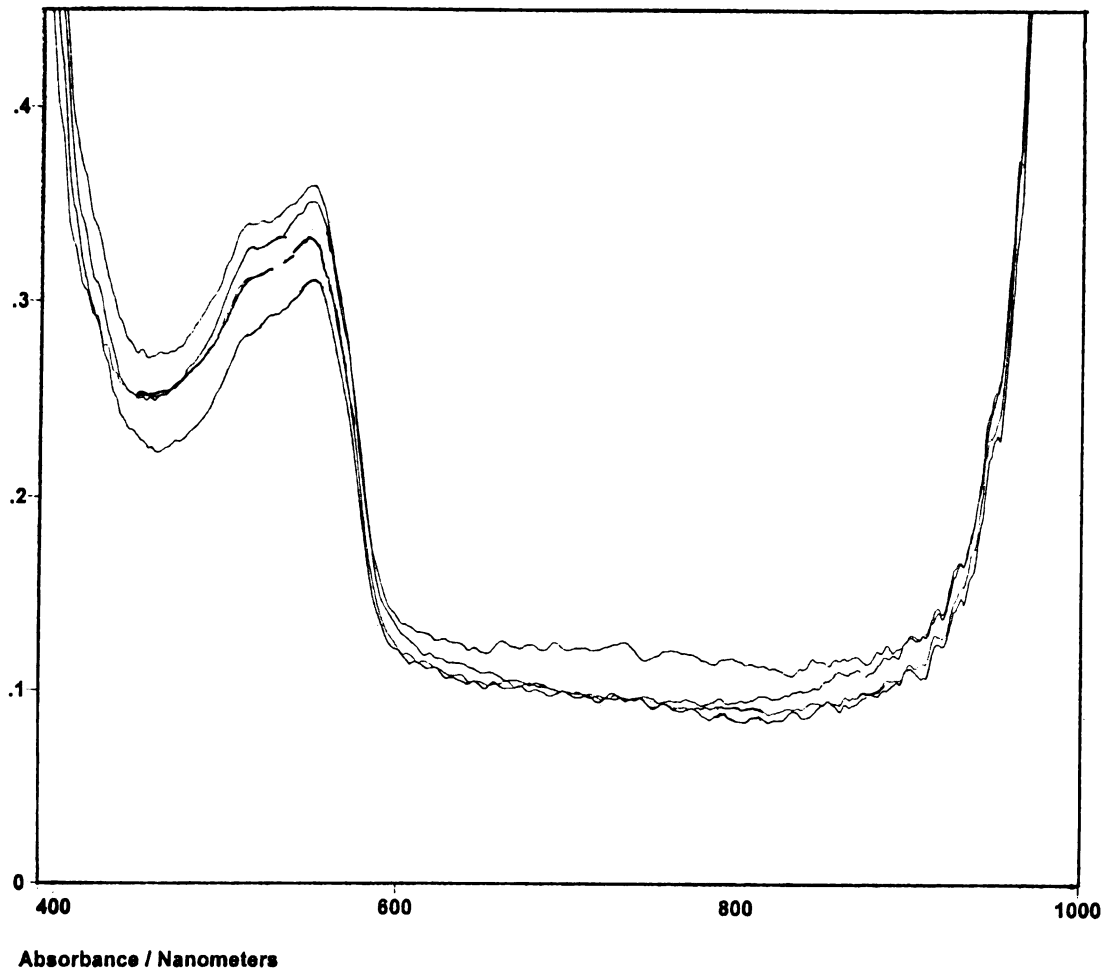

Figure 19. UV-Visible Spectra of Covergirl Nailslicks Ice Blue Pink Lot # 1353

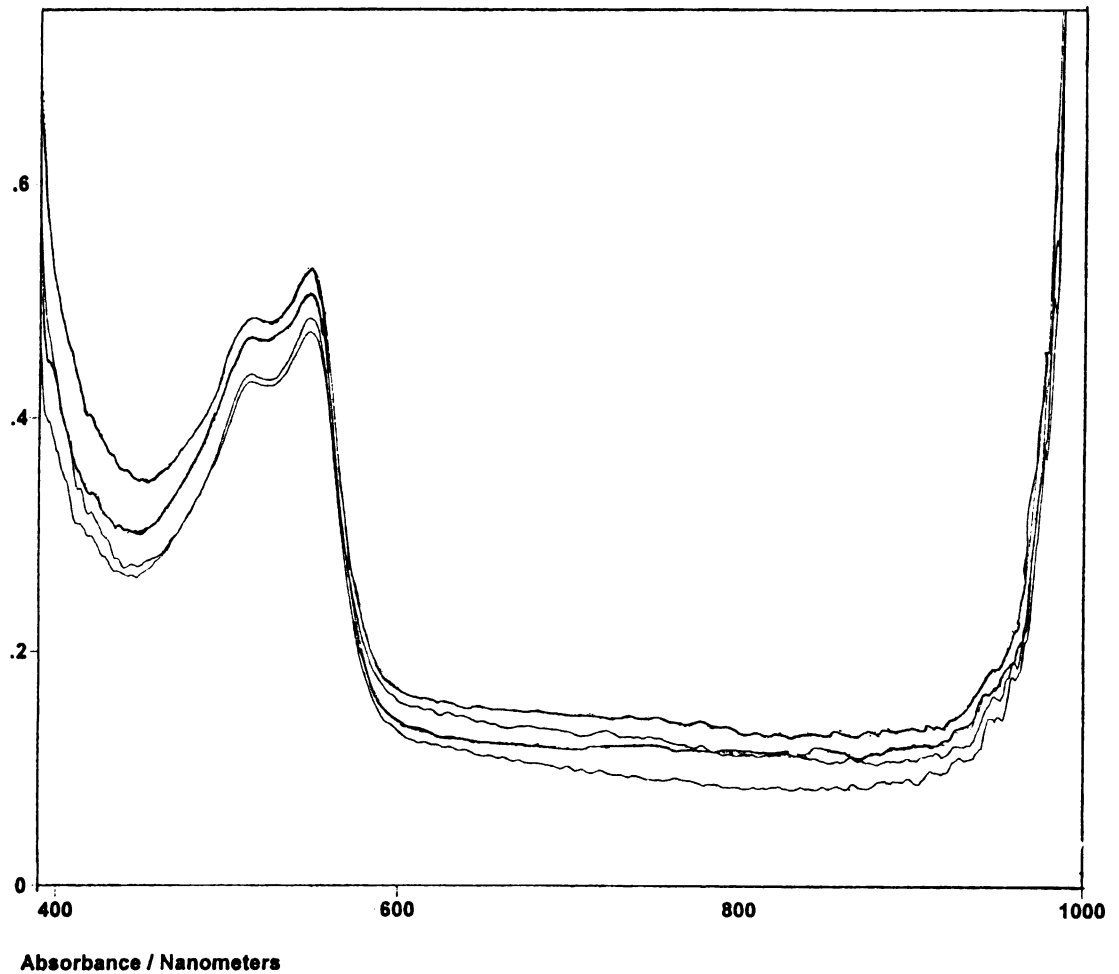

Figure 20. UV-Visible Spectra of Covergirl Nailslicks Ice Blue Pink Lot # 2191

particles, and the relative amounts of particles.

Microscopy was able to distinguish between each of the nail polishes in this research with the exception of the five lots of Covergirl Nailslicks Ice Blue Pink. These lots could not be distinguished from each other, but they could be distinguished from the other nail polishes.

There are three groups of nail polishes that could not be distinguished by microspectrophotometry, but microscopy was able to discriminate between them. The results of the microscopy are shown below in Tables 7 through 9, and in Appendix D. Each of the nail polishes within the three groups of nail polishes were examined at 400X magnification, and compared to each other. The following is a description of what was viewed under the microscope for each of those nail polishes. In the tables below, the italicized portions are the predominant particles noted for that sample.

Group A consists of three Covergirl Nailslicks colors: Silver Plum, Satin Mauve and Ice Blue Pink.

Table 7. Microscopy Results for Group A

Covergirl Nailslicks Silver Plum	
Grain	Coarse granules
Small Particles	Pink
Medium and small particles	Violet, pink, green, blue, pale yellow, peach
Large and very large particles	*Clear, pale yellow*
Covergirl Nailslicks Satin Mauve	
Grain	*Fine particles, densely distributed*
Small Particles	Red, clear shiny particles
Medium particles	NONE
Large and very large particles	NONE
Covergirl Nailslicks Ice Blue Pink	
Grain	Fine and coarse particles
Small Particles	*Violet, blue*, green, peach, pink, red
Medium particles	*Violet, blue*, green, peach, pink
Large particles	NONE

Each of the three nail polishes in Group A could be distinguished from each other microscopically. Silver Plum was the only one of the three that had large and very large sized clear and pale yellow particles. Satin Mauve was the only one in the group that had small clear, shiny particles. Ice Blue Pink was the only one that had predominantly violet and blue small and medium particles, and did not have large particles or small clear, shiny particles.

Group B consists of three Covergirl Nailslicks nail polishes: Pink Aura, Pink Snow and Twilight Mauve.

Table 8. Microscopy Results for Group B.

Covergirl Nailslicks Pink Aura	
Grain	Fine
Small Particles	None
Medium particles	*Pink, clear*, periwinkle, pinkish-peach
Large particles	*Pink, clear*, periwinkle, pinkish-peach
Covergirl Nailslicks Pink Snow	
Grain	Fine
Small Particles	*Clear*, purple, blue, green, yellow, orange, some pink (all pale in color)
Medium particles	*Clear*, purple, blue, green, yellow, orange, some pink (all pale in color)
Large and very large particles	*Clear*
Covergirl Nailslicks Twilight Mauve	
Grain	Fine
Small Particles	None
Medium particles	*Blue*, pink, some green, some orange
Large particles	None

All three nail polishes in Group B could be distinguished from each other. Pink Snow is distinguished by its large and very large particles that are transparent. Pink Aura and Twilight Mauve are distinguished from each other by their predominant particles and the presence of large particles in Pink Aura which are not present in Twilight Mauve.

Group C consists of Covergirl Nailslicks Cranberry Cream, Covergirl Nailslicks Pink Wink, Maybelline Express Finish Native Berry, and Maybelline Express Finish Daring Berry.

Table 9. Microscopy Results for Group C.

Covergirl Nailslicks Cranberry Cream	
Grain	*Fine pinkish-red*
Small Particles	White shiny particles (approximately 30 per field of view at 400X), some elongated (approximately 9 out of 30)
Medium particles	None
Large particles	None
Maybelline Express Finish Native Berry	
Grain	*Medium*
Small Particles	White shiny particles (approximately 75 per field of view at 400X) mostly elongated , some small round (10 out of 75)
Medium particles	Violet, blue, peach, green
Large particles	None
Maybelline Express Finish Daring Berry	
Grain	Fine, medium
Small particles	*Dark red-orange*, some blue
Medium particles	*Dark red-orange*
Large particles	*Dark red-orange*
Covergirl Nailslicks Pink Wink	
Grain	Medium and coarse, not very dense
Small particles	*Peach*, pink, few: blue, green, red
Medium particles	*Peach*, pink, yellow, blue
Large particles	Peach, blue, pale yellow/clear, a few very large multicolored clumps

All four nail polishes in Group C could be distinguished from each other. The first two listed in Group C can be distinguished from each other by the presence of medium sized particles in Maybelline Express Finish Native Berry, while no medium particles were noted in the Covergirl Nailslicks Cranberry Cream. Although the main portions of both nail polishes are similar in appearance under the microscope, there was a difference in the amount of small white, shiny particles per field of view. These particles were seen in greater proportion in the Maybelline nail polish in comparison to the Covergirl sample. Also, there were more small elongated shiny particles than small round shiny particles in the Maybelline while the opposite is true for Covergirl Nailslicks Cranberry Cream.

Covergirl Nailslicks Pink Wink can be distinguished by its unique predominant peach colored particles that are not a major component of the others. Maybelline Express Finish Daring Berry can easily be distinguished from the other four in this group because of its predominant dark red-orange particles that are not noted in the rest of Group C.

In summary, each of the nail polishes that could not be distinguished by microspectrophotometry could be distinguished by traditional light microscopy.

Blind Tests

FTIR

After analyzing the five blind samples by Fourier transform infrared spectroscopy, each was searched against the library of nail polishes from this

research project. Blind sample numbers 1 (see Figure 21), 2, 4 and 5 were all consistent with Covergirl nail polish and inconsistent with Sally Hansen, Maybelline, Revlon and L'Oreal brands. The top two matches for blind sample #3 (see Figure 22) were both Maybelline nail polishes, with a percent match rating near 99%. The next highest match was only a 90% match, and was outside of the normal range of variation that occurs within one brand (with the exception of Sally Hansen brand) and therefore neither Covergirl, L'Oreal, Revlon nor Sally Hansen could be considered to be the brand of blind sample #3.

Microspectrophotometry

Blind sample number 1 (see Figure 23) had three peaks with wavelengths around 489, 510 and 545 nm. The closest matches of the nail polishes that had been analyzed were Covergirl Nailslicks Pink Aura, Pink Snow and Twilight Mauve. All other nail polishes analyzed were excluded.

Blind sample number 2 had a spectrum that was unique to all the nail polishes analyzed. The spectrum had several peaks close together between 521 and 574 nanometers absorbance. All nail polishes analyzed were excluded. Blind sample number 3 (see Figure 24) had three peaks with wavelengths around 488 nm, 525 nm and 569 nm. The closest matches out of the nail polishes that had been analyzed were Covergirl Nailslicks Cranberry Cream, Maybelline Express Finish Native Berry and Daring Berry. All other nail polishes analyzed were excluded.

Blind Sample # 1

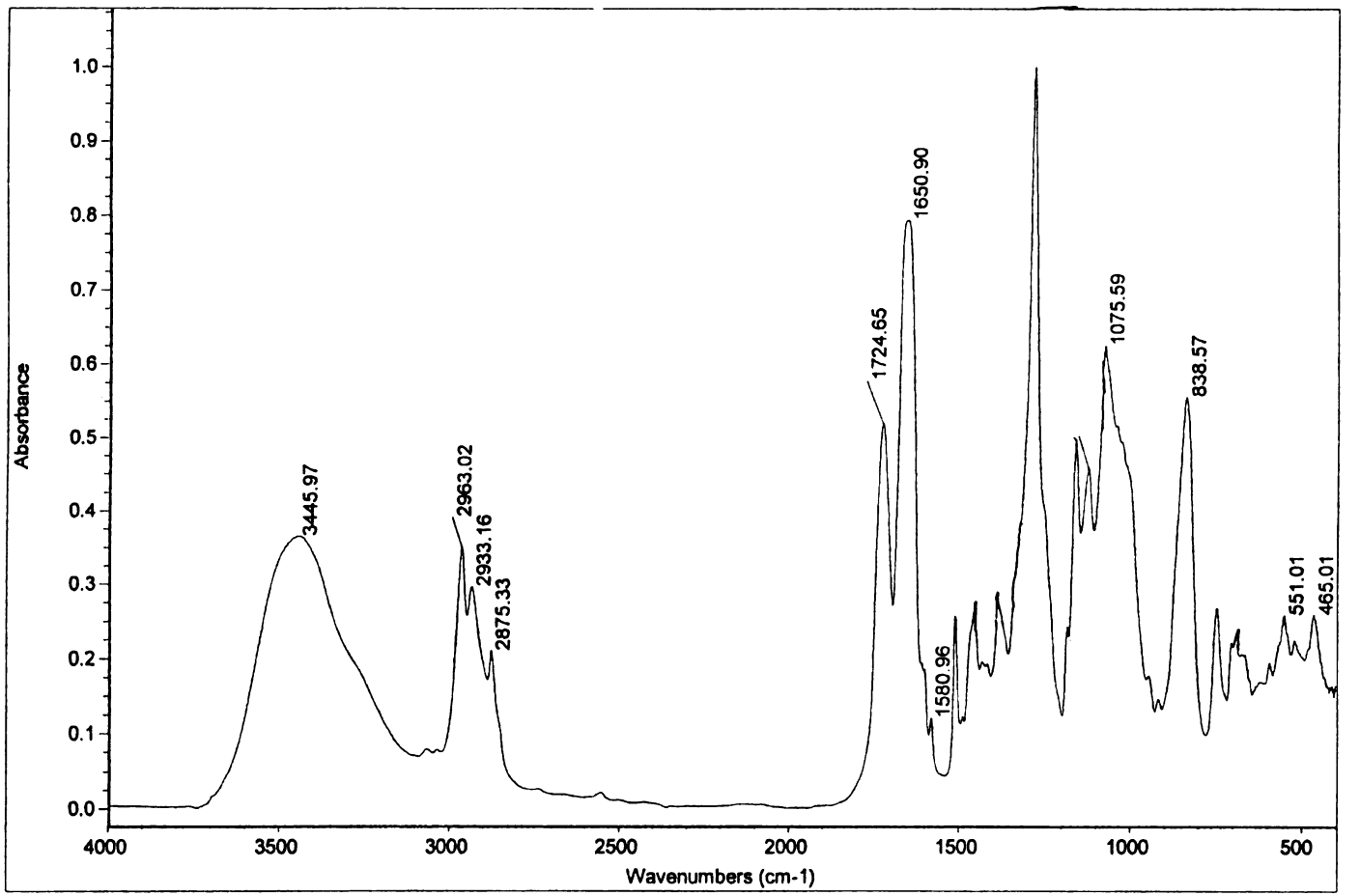

Figure 21. FTIR Spectrum of Blind Sample #1

Blind Sample # 3

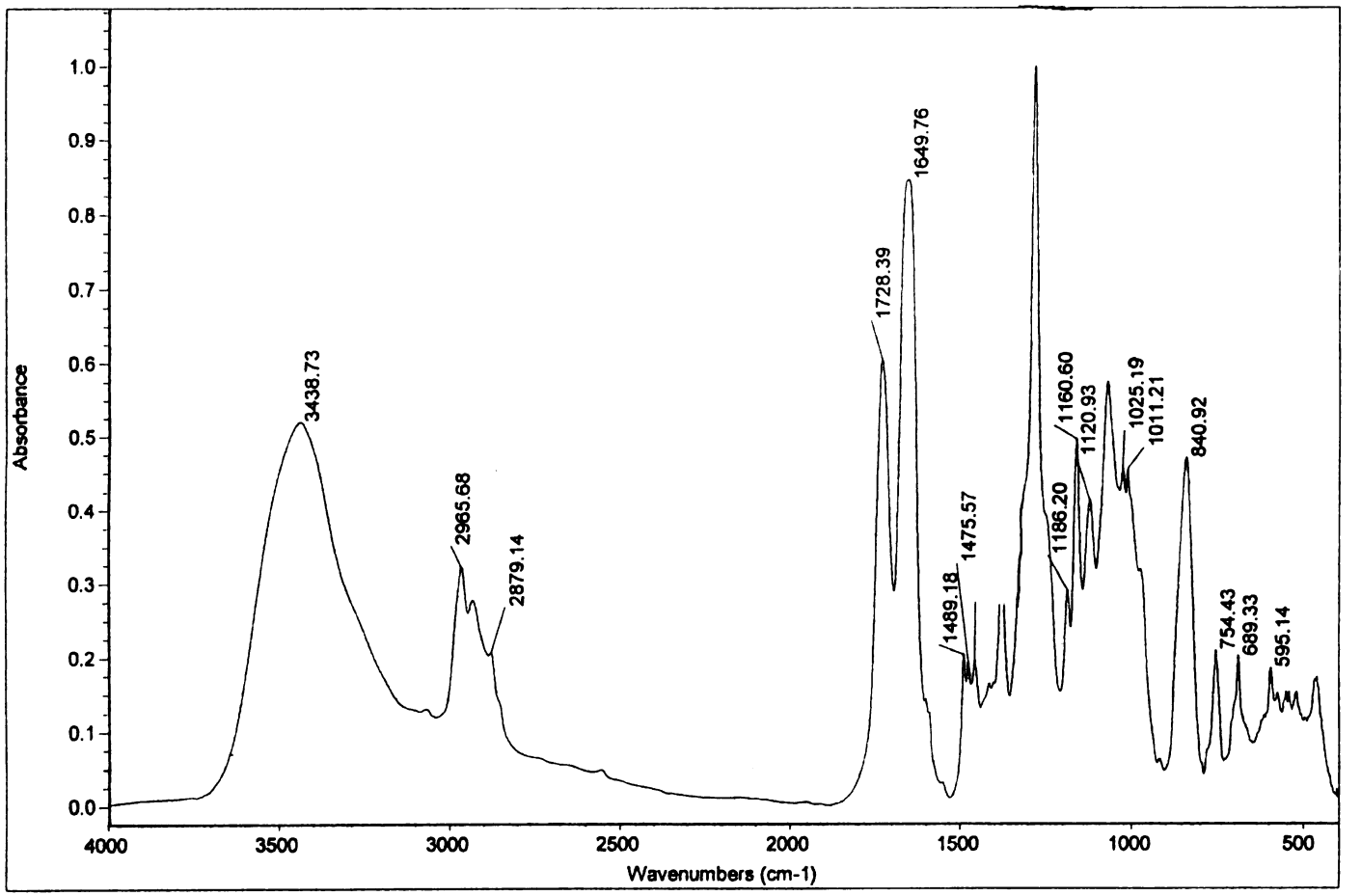

Figure 22. FTIR Spectrum of Blind Sample #3

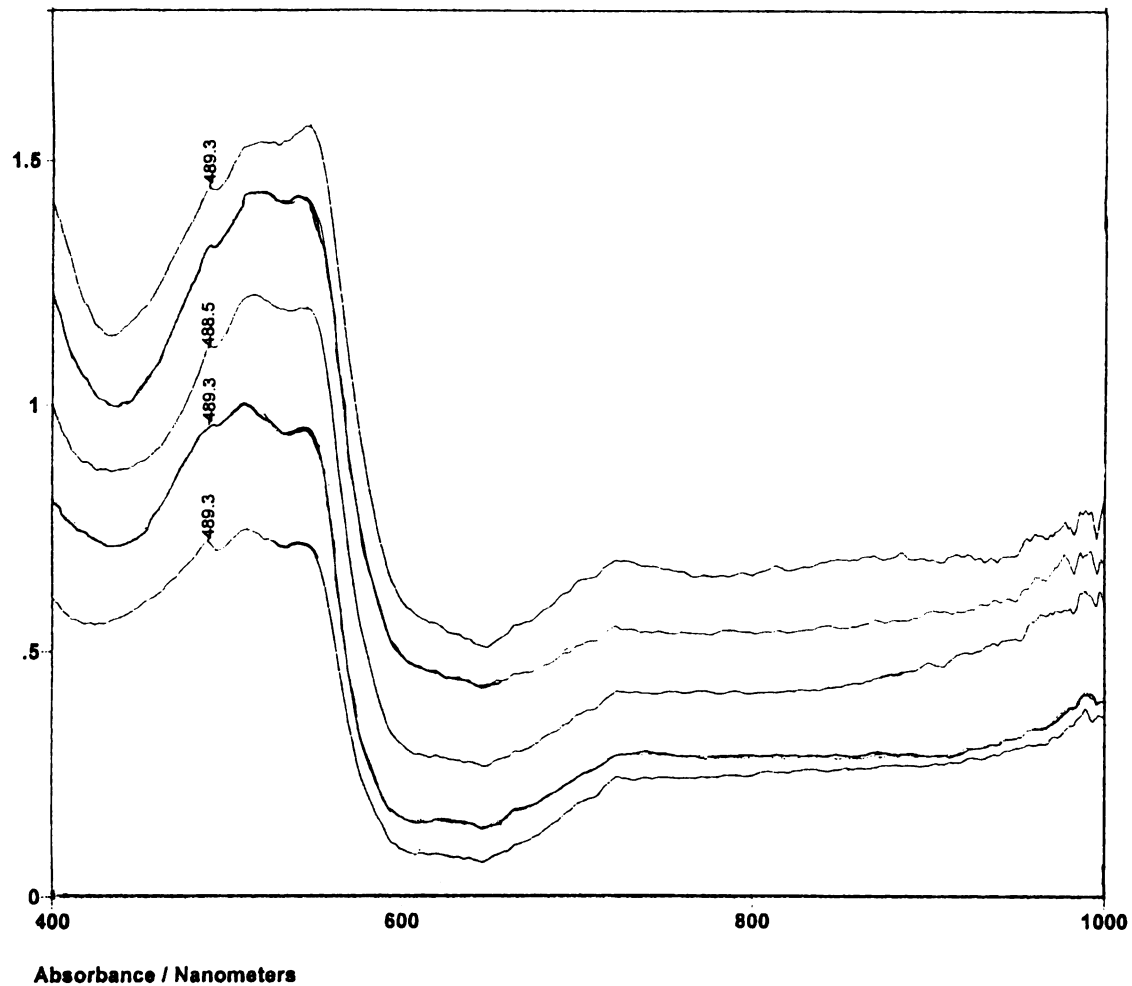

Figure 23. UV-Visible Spectra of Blind Sample #1

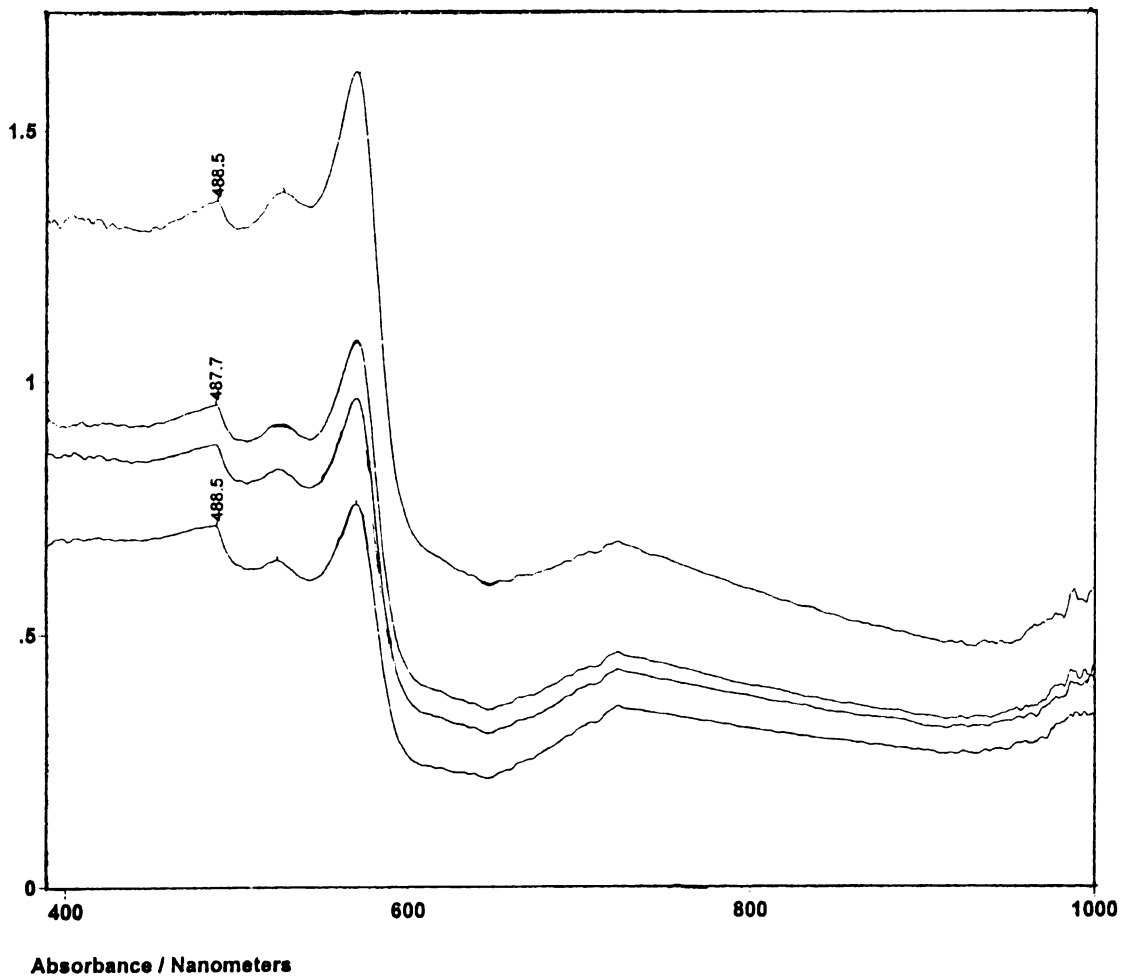

Figure 24. UV-Visible Spectra of Blind Sample #3

Blind sample numbers 4 and 5 were indistinguishable from each other by microspectrophotometry. The both had three peaks with wavelengths around 489, 510 and 548 nm. The closest matches to these two blind samples are Covergirl Nailslicks Ice Blue Pink, Satin Mauve and Silver Plum. All other nail polishes analyzed were excluded.

Microscopic Examination

Microscopic analysis showed that blind sample number 1 was consistent with Covergirl Nailslicks Pink Aura, and inconsistent with all other nail polishes examined.

Table 10. Microscopy Results for Blind Sample Number 1.

Blind Sample #1	
Grain	Fine
Small particles	NONE
Medium particles	*Pink, blue-violet*, pinkish-peach, few green
Large particles	*Pink, blue-violet*, pinkish-peach

Blind sample #2 was not consistent with any of the nail polishes that were examined.

Table 11. Microscopy Results for Blind Sample Number 2.

Blind Sample #2	
Grain	*Medium*
Small particles	Blue, some pink
Medium particles	Some blue
Large particles	NONE

Blind sample #3 was consistent with Maybelline Express Finish Native Berry and was inconsistent with all other nail polishes analyzed.

Table 12. Microscopy Results for Blind Sample Number 3.

Blind Sample #3	
Grain	*Medium*
Small particles	White, shiny particles (round and elongated, about 50-60 per field)
Medium particles	Blue, violet, green, peach
Large particles	NONE

Blind sample numbers 4 and 5 are indistinguishable from each other and from Covergirl Nailslicks Ice Blue Pink. All other nail polishes analyzed were inconsistent with blind samples 4 and 5.

Table 13. Microscopy Results for Blind Sample Numbers 4 and 5.

Blind Sample #4	
Grain	Coarse, sparsely distributed
Small particles	*Blue, violet*, pink, orange, some green and red
Medium particles	*Blue, violet*, pink, orange, some green
Large particles	NONE
Blind Sample #5	
Grain	Coarse, sparsely distributed
Small particles	*Blue, violet*, pink, orange, some green and red
Medium particles	*Blue, violet*, pink, orange, some green
Large particles	NONE

Summary

Table 14 summarizes the conclusions from each of the three techniques applied to the blind samples. Underneath the name of the technique, the nail polishes that were consistent with each blind sample are listed. The results of FTIR that are in parentheses had percent matches that fell between 96.01% and 96.64%.

Although FTIR results for blind sample #4 indicated that Ice Blue Pink lot numbers 2170, 2206, and 2232 were all consistent with #4, lot number 2170 had the highest match out of the lots. Even though one could not conclude that Ice Blue Pink lot number 2170 was the only possibility, the fact that it had the highest match of the lots supports the accuracy of the technique since this lot number was the one used to make the sample.

Table 14. Summary of Results for Blind Samples.

	FTIR	Microspectro-photometry	Microscopy	Actual Nail Polish
1	All Covergirl except Silver Plum, Fabulous Fuchsia and Mauve Sunrise	Pink Aura, Pink Snow, Twilight Mauve	Pink Aura (excluded Pink Snow and Twilight Mauve)	Covergirl Pink Aura
2	Consistent with Covergirl brand, Plum Frost, Tickled Pink, Grape Ice, Cabernet, Pink Snow, (Twilight Mauve, Peek-A-Boo Pink or Mauvelicious)	Excluded all nail polishes analyzed	None	Covergirl Rich Garnet (not analyzed)
3	Consistent with Maybelline brand, Maybelline Express Finish Native Berry or Daring Berry	Covergirl Nailslicks Cranberry Cream, Maybelline Express Finish Native Berry or Daring Berry	Maybelline Express Finish Native Berry	Maybelline Express Finish Native Berry
4	Consistent with Covergirl brand, Classic Red, Satin Mauve, Cranberry Cream, Well Red, Cherry Brandy, Pink Aura, Tickled Pink, (Mauvelicious, Pink Wink, Cherry Truffle, Ice Blue Pink lot #s 2170, 2206, 2232, Peek-A-Boo Pink)	Ice Blue Pink lot #s 2170, 2206, 2232, 1353, 2191,Satin Mauve, Silver Plum	Ice Blue Pink lot #s 2170, 2206, 2232, 1353, 2191	Covergirl Ice Blue Pink, lot #2170
5	Consistent with Covergirl brand, Classic Red, Well Red, Satin Mauve, Pink Aura, Cranberry Cream, Cherry Brandy, Ice Blue Pink lot #s 2232, 2206, 1353, 2170, 2191, Cherry Truffle, Mauvelicious, (Pink Wink, Twilight Mauve, Fabulous Fuchsia, Silver Plum, Tickled Pink)	Ice Blue Pink lot #s 2232, 2206, 1353, 2170, 2191, Satin Mauve, Silver Plum	Ice Blue Pink lot #s 2232, 2206, 1353, 2170, 2191	Covergirl Ice Blue Pink, lot #2232

For blind sample #5, FTIR did not eliminate any of the lots of Covergirl Ice Blue Pink. The highest match out of the lots of Ice Blue Pink was number 2232, which in fact was the lot number used to make the sample. This piece of information, along with blind #4 supports the discriminating power of FTIR.

CONCLUSIONS

Reproducibility studies on infrared spectroscopy indicated that there was a small amount of error from sample to sample of one bottle of nail polish. This error was used as a standard for the other studies to judge whether or not the matches could be excluded or included as potentially common sources. Microspectrophotometry had very little error from run to run and was demonstrated to be a reliable and reproducible technique.

The only technique that was able to distinguish between brands was Fourier transform infrared spectroscopy. Although microspectrophotometry and microscopy could distinguish between individual nail polishes of different brands, they could not be used to make a conclusion as to what brand the nail polish might be. FTIR was useful in the blind tests, where this technique was used not only to identify what brand each sample could be, but also to eliminate a few of the possible matches of nail polishes within that brand (in some cases). Each brand studied had unique chemical compositions that could be distinguished from each other.

FTIR, microspectrophotometry and microscopy were all useful in discriminating between nail polishes within the Covergirl brand. FTIR was the least useful technique for this study, as this method's strength was in determining what brand a questioned sample could be, not necessarily in narrowing down the possibility of the matches. Microspectrophotometry was demonstrated to be useful for distinguishing between different nail polishes of

the same brand. There were four small groups of nail polish that could not be distinguished from each other by microspectrophotometry, but the rest of them had unique spectra. Microscopy was the most useful method because each nail polish was unique, microscopically, and was able to be distinguished from all others examined.

The only way that lots of Covergirl Nailslicks Ice Blue Pink were distinguished from each other in this research was by using FTIR and searching a library of nail polish spectra to compare the closest matches to a given nail polish. In some cases, some of the lots could be excluded from matching a given sample because they had lower percent match ratings than the standard (96.64 % or 96.01%), as was seen in the blind tests. Microspectrophotometry and microscopy were not useful in discriminating between these five lots. The results of the lot study are not surprising, since each lot should have the same ingredients.

It was demonstrated that differences in the ingredients listed on the bottles of Covergirl nail polish in this research did not necessarily coincide with differences in the FTIR spectra. Therefore, the similarity or difference between nail polish ingredients cannot be used to include or exclude potential matches.

The aging study demonstrated that the majority of the solvent evaporation and possibly polymerization that occurs as nail polish dries is over in less than ten minutes. Since the samples in the other studies were allowed to dry for at least twenty-four hours, change in chemical composition due to drying was not a source of error. Microspectrophotometry showed that the color of nail

polish did not change as it dried over a four hour period.

The conclusions drawn about the five blind samples that were analyzed were all correct. This shows the ability to apply infrared spectroscopy, microspectrophotometry and microscopy to nail polish and obtain accurate results objectively.

SUGGESTED PROTOCOL

Before beginning a scheme of analysis for forensic evidence, there are several factors which a scientist must keep in mind, including the quantity of sample available, what tests must be performed, which if any use up the sample, and what order the tests should be conducted in. Considering these and other factors, a protocol is suggested for the comparison of forensic nail polish samples.

If a forensic scientist was to receive a questioned chip of nail polish and a known sample of nail polish, s/he must first assess the quantity of sample available. If there is limited quantity, then reflectance FTIR should be conducted, as opposed to transmittance FTIR using a micropellet. This is because the physical form of the nail polish is destroyed by making a pellet, although the chemical composition is unchanged. Reflectance FTIR does not change the chemical or physical properties of the substance being analyzed. (Humecki, 1995)

If the questioned and known samples are large enough and in good condition, the forensic scientist must determine whether or not a physical match can be made between the two samples. This could be conducted with the aid of a stereomicroscope. In most cases, the evidentiary samples are small, and physical matches are not possible.

The first step in the comparison of the questioned and known samples is to study each under a microscope and take note of the identifying characteristics

that can be seen. These may include the size and distribution of the grain, and the size, shape, color and distribution of any particles visualized. One should look at several areas of the sample to look for irregularities within that sample.

The second step would be to analyze the specific color of each sample using a microspectrophotometer. Again, it is important to analyze a representative sample of the substance. Therefore, at least five areas should be analyzed.

Thirdly, the chemical composition could be compared, using either a micropellet for Fourier Transform Infrared spectroscopy, transmission microscopy FTIR, or reflectance FTIR. If a sample is limited in quantity, then either reflectance or transmission microscopy FTIR should be used, in order to conserve the evidence.

Lastly, the results of all examinations should be taken into account when drawing a conclusion as to whether or not the questioned sample could or could not have come from the same source as the known sample.

FUTURE RESEARCH

Although nail polish has been analyzed in forensic science laboratories in the past, research has now been performed which demonstrated the abilities of three techniques to distinguish between nail polishes of different brands, colors, and in some cases, different lots. This research shows the significance of a "match" between two nail polishes that has only been assumed previously. Before research, forensic scientists could only assume that FTIR would be able to detect differences in the chemical compositions of nail polishes. This is a dangerous assumption because of the possibility that all nail polishes could have the same major components that would overpower any differences in minor components, making all nail polishes appear consistent with each other. Now that more research has been conducted, the full potential of technology can be realized for the analysis of nail polish.

There are several potential research projects that could stem from the present work. The first is a study of transfer and persistence of nail polish as trace evidence. The present research has shown the significance of the results of analysis, however, a transfer-persistence study would show the significance of the presence of nail polish evidence at the crime scene.

As a continuation of the present research, more brands of nail polish could be studied to compare for differences between the formulas. These brands could be added to a library for comparison to questioned samples.

Another area of potential research is a study of the affect of layering

different nail polishes on top of one another. Layering presents a problem because as the second coat is painted on, the solvents may begin to dissolve the first coat before the solvents evaporate, resulting in a blending of layers. It is doubtful that these layers could be separated as easily as they are in automobile paint analysis, but perhaps another method could be devised for analysis of layers as applied to nail polish. It may not be possible to analyze the layers together because differences in thickness of the layers may skew results due to differences in proportion of the ingredients. (p. 171, Practical Guide to Infrared Microspectroscopy)

Nail polish can be found as evidence in the form of chips or as smears on hard surfaces. Research may need to be performed to figure out efficient ways of collection and analysis of nail polish in the form of a smear.

More research needs to be conducted on clear and light-toned nail polishes. Since these do not have much, if any, color, microspectrophotometry cannot be used to compare these nail polishes. On the other hand, beige or brownish colored nail polishes most likely have a balance of several colors, and do not have distinct peaks in the UV-visible spectra. These three groups of polishes should be further researched to develop another method of comparison, since microspectrophotometry would not be useful.

Other techniques could be researched as an application to nail polish analysis. These techniques could include scanning electron microscopy- energy dispersive X-ray analysis (SEM-EDX), or pyrolysis gas chromatography-mass spectroscopy.

Lastly, microchemical tests that are currently used for paints could be researched as an application to nail polish for an additional method of discriminating between brands.

APPENDICES

APPENDIX A

Microspectrophotometry Calibration Procedure

Due to the sensitive nature of the instrument and the need for a high degree of accuracy in results, the SEE Microspectrophotometer was calibrated each time it was turned on, following the recommendations of the manufacturer. The following is the step-by-step procedure that was followed for the calibration. All filters used in this procedure were supplied by the manufacturer and were calibrated in accordance with the standards from the National Institute of Science and Technology (NIST)

The toggle switch on the back of the back of the Microspectrophotometry instrument was turned on and the light intensity was turned up to 10. After the instrument had warmed up for 20 minutes, the calibration was begun. Several filters from SEE were used in the calibration of the instrument. The SEE Image software and the Grams/32 software were opened. On the SEE Image program, the "Grab" command was clicked to show what was under the microscope on the 20x objective. The reference filter was placed upon the stage and the ink spot was brought into focus, then the aperture was moved off the ink spot. The Kohler illumination was checked by turning the field stop all the way to the right . The condenser focusing knobs were adjusted to make the decagon shape around the aperture have a blue hue. The centering screws were adjusted to center the aperture in the field of view. The field stop was turned 2 places to the left.

On the Grams/32 program, "Autogain" was clicked. To adjust the maximum Y counts, the parameters button was clicked and the sampling frequency was adjusted to attempt to bring the maximum y counts of

autogain near 3500. This was often unsuccessful.

After the autogain was satisfactory, a dark scan was performed by closing the transmission shutter and clicking "Dark Scan". The data file was named "{c:\see\calibration\dmmddyy-1.dr0" where "mmddyy" represents the date. A reference scan was performed by opening the transmission shutter and selecting "Reference scan". The data file was named "c:\see\calibration\rmmddyy-1.rf0".

The Holmium Oxide filter was placed on top of the field stop. Sample scan was selected and the % transmission was selected as the measurement. The data file was named "c:\see\calibration\hommddyy-1.spc". The NIST data values were overlaid, compared to be sure that the values obtained from the sample scan are within acceptable parameters from NIST. This spectrum was printed out and stored in the log book. Next, the Holmium Oxide filter was replaced with the Didymium filter on the field stop. This sample scan was performed, saved as the file "c:\see\calibration\didmmddyy-1.spc and the values were again compared to the NIST values. Next, the Didymium filter was replaced with Neutral density filter OD=0.1. This sample scan was run and measured as absorbance. The data file was saved as "c:\see\calilbration\01ndmmddyy-1.spc". This filter was then replaced with a Neutral Density filter OD=0.5. This sample scan was run and saved as "c:\see\calibration\05ndmmddyy-1.spc". Lastly, this filter was replaced with a Neutral Density filter OD=1.0. This file was saved as "c:\see\calibration\1ndmmddyy-1.spc". All three

neutral density filter spectra were compared to the NIST values and printed out.

APPENDIX B

Fourier Transform Infrared Spectra

15 minutes Covergirl Nailslicks Twilight Mauve

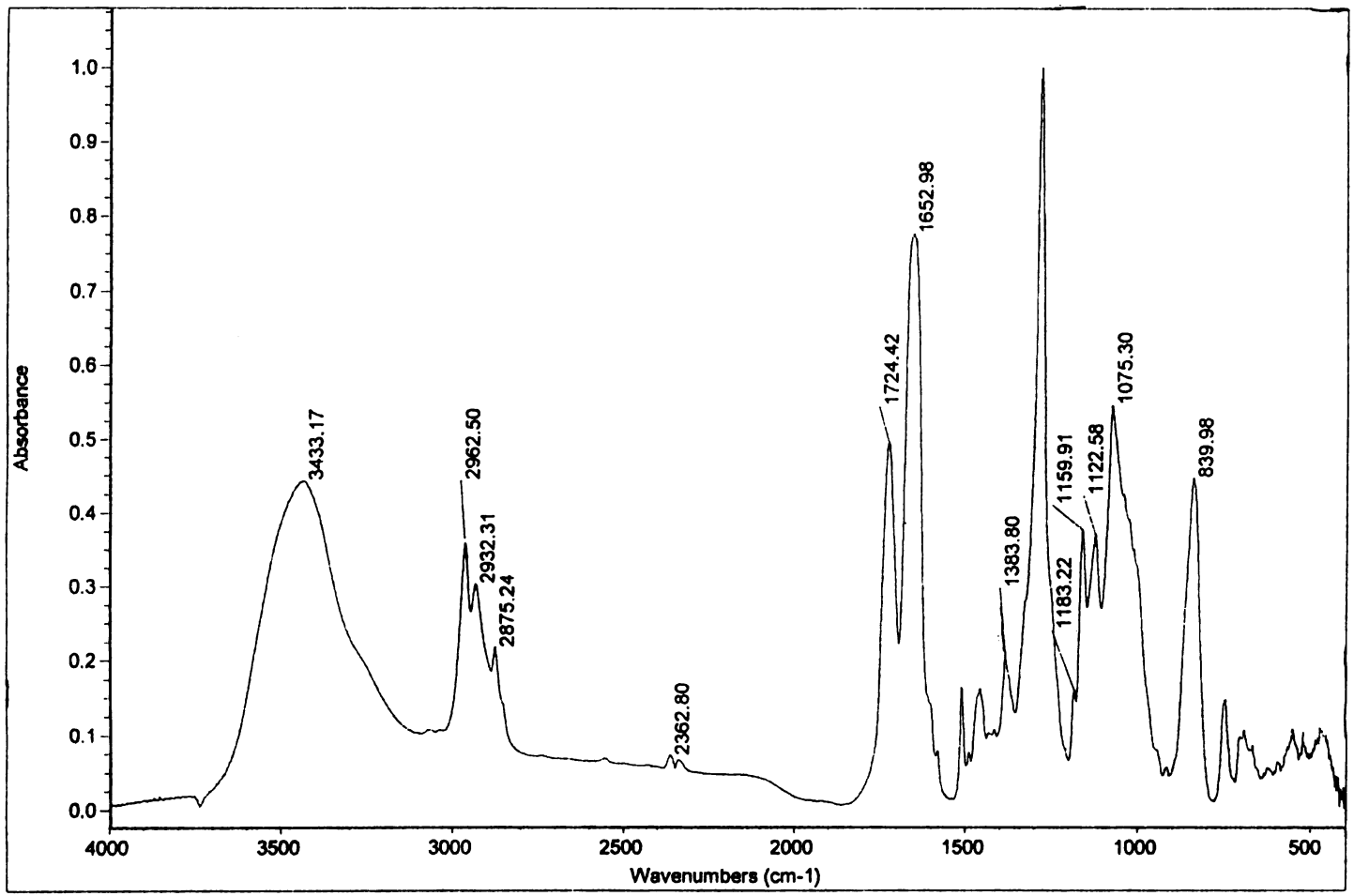

Figure 25. FTIR Spectrum of 15 Minute Aged Sample

30 minutes Covergirl Nailslicks Twilight Mauve

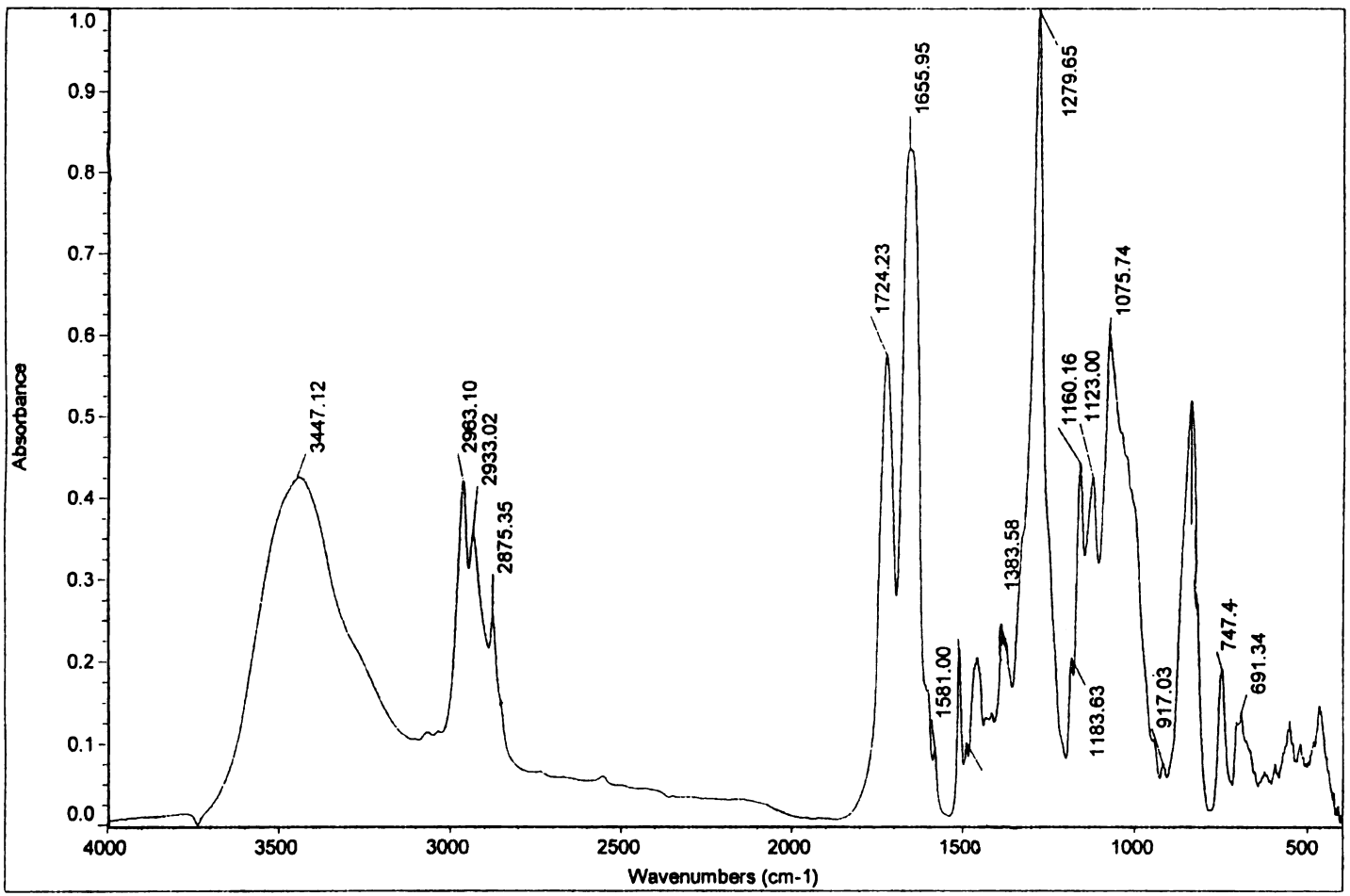

Figure 26. FTIR Spectrum of 30 Minute Aged Sample

45 minutes Covergirl Nailslicks Twilight Mauve

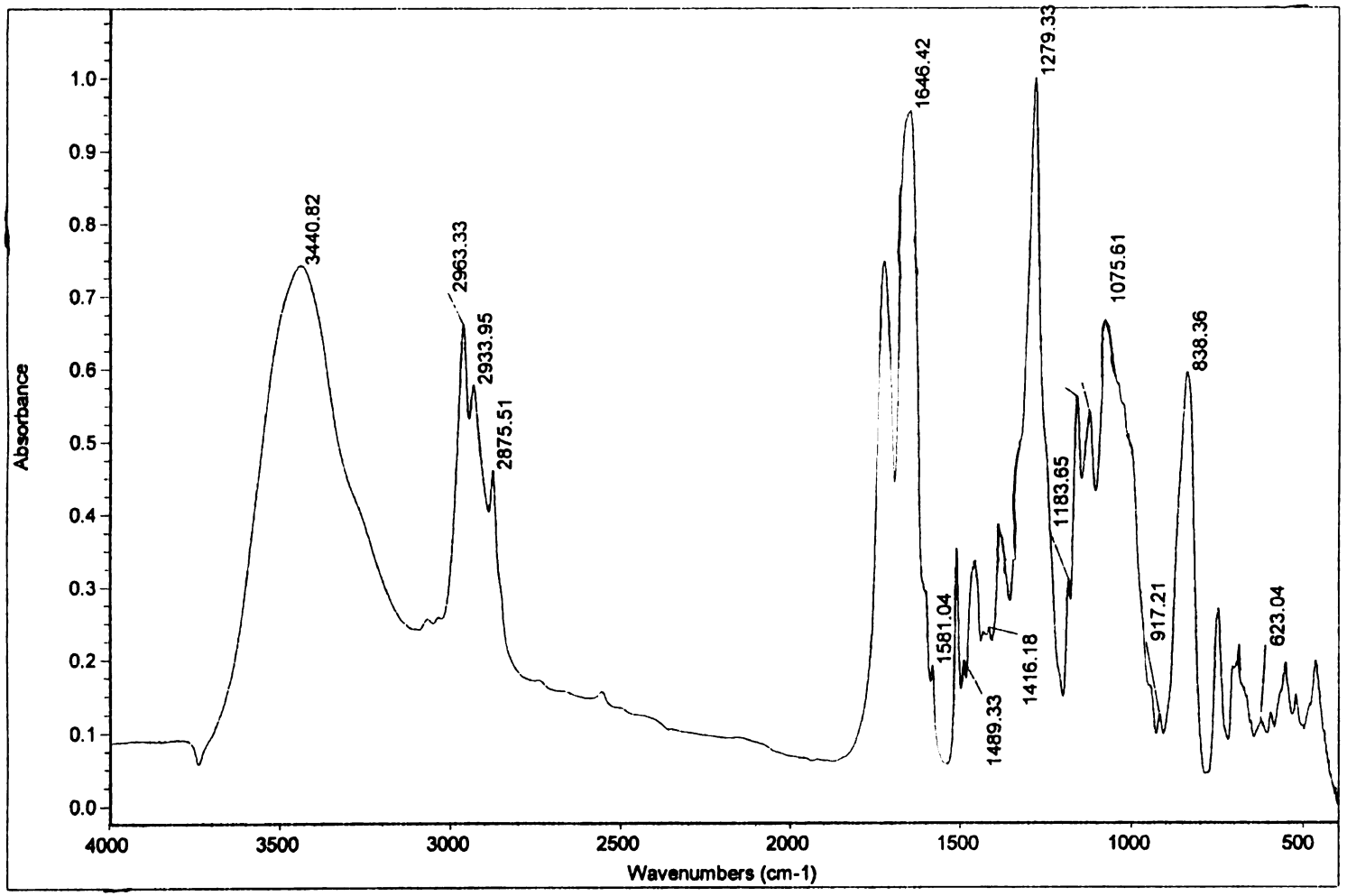

Figure 27. FTIR Spectrum of 45 Minute Aged Sample

60 minutes Covergirl Nailslicks Twilight Mauve

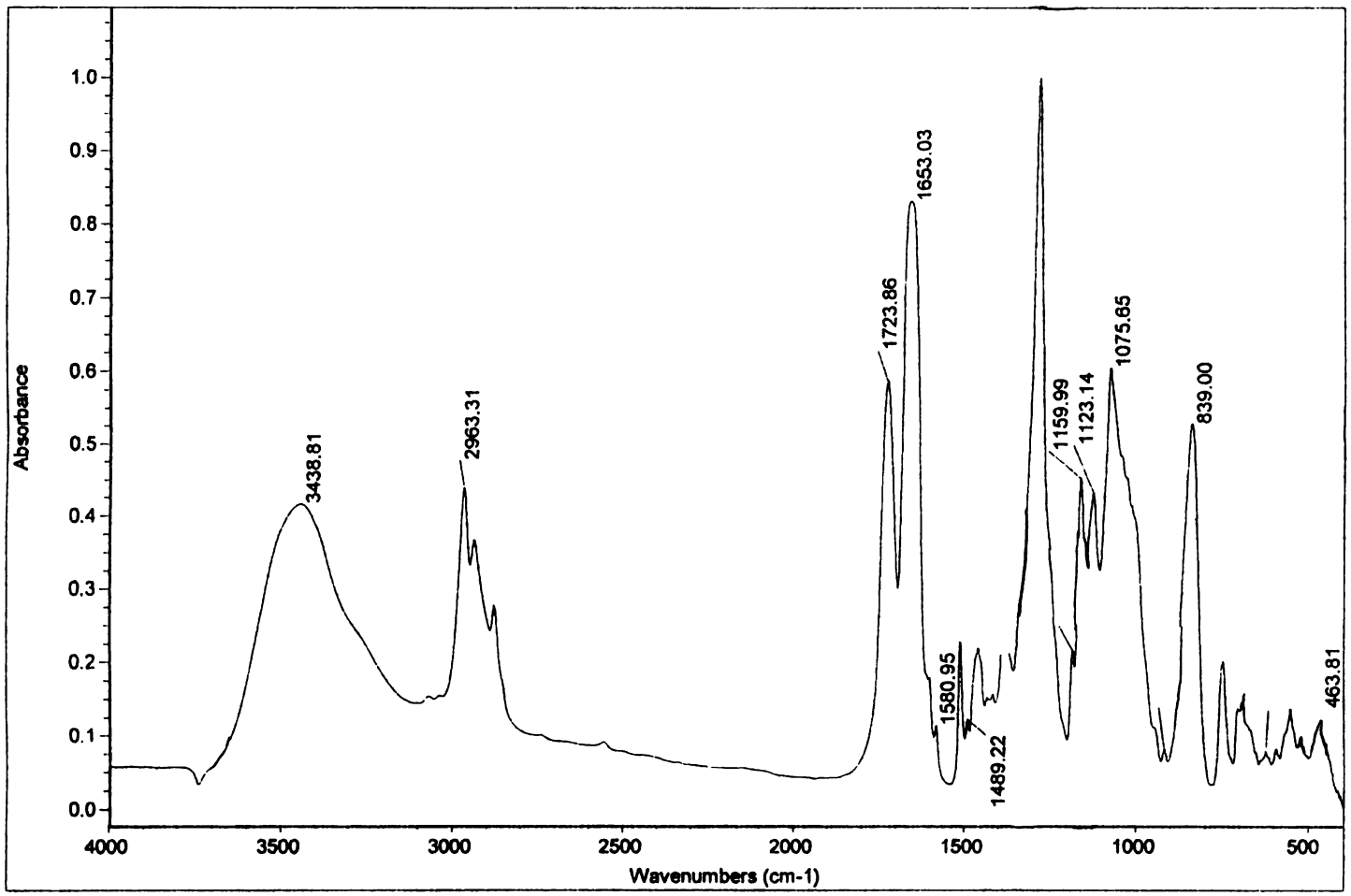

Figure 28. FTIR Spectrum of 60 Minute Aged Sample

90 minutes Covergirl Nailslicks Twilight Mauve

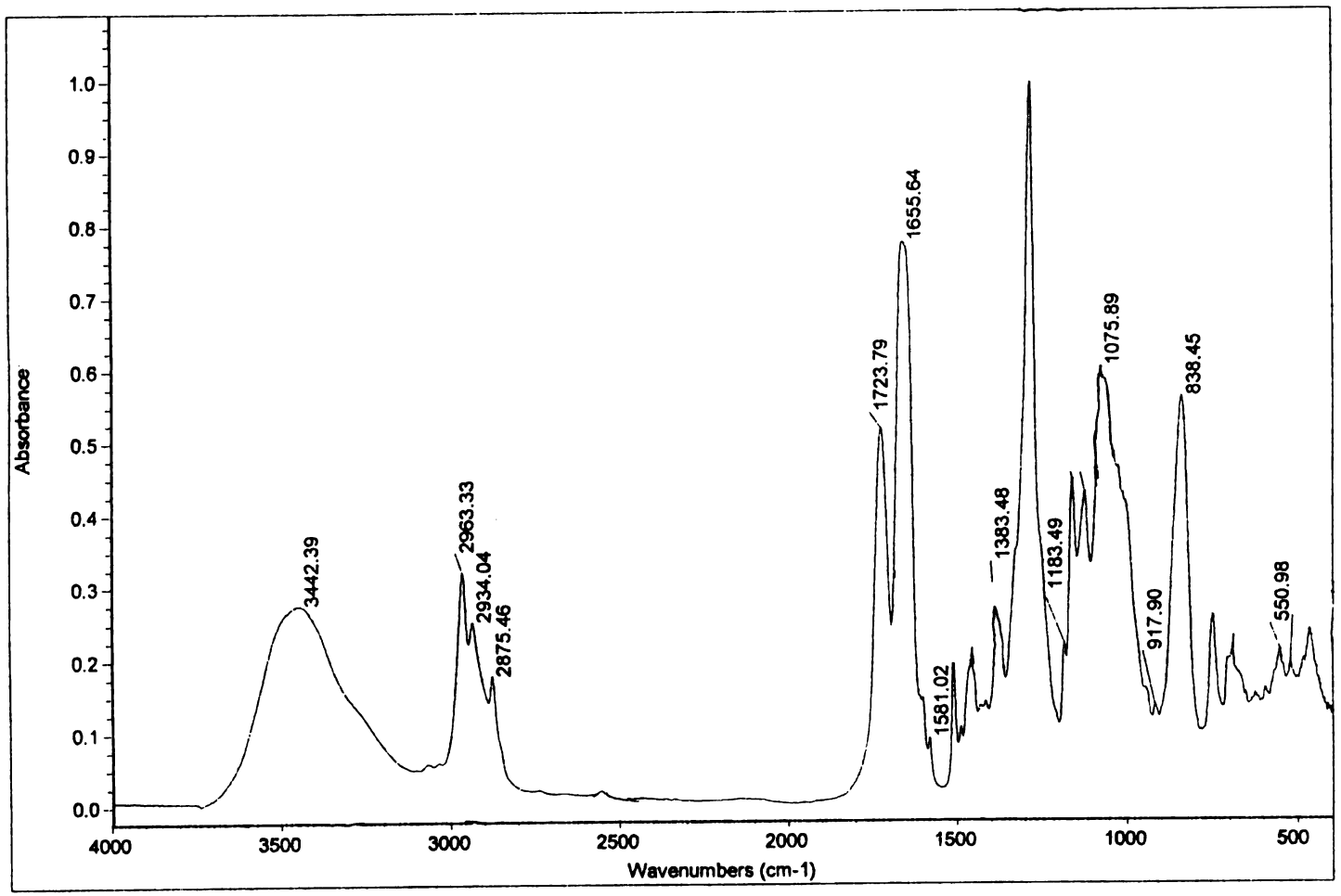

Figure 29. FTIR Spectrum of 90 Minute Aged Sample

2 hours Covergirl Nailslicks Twilight Mauve

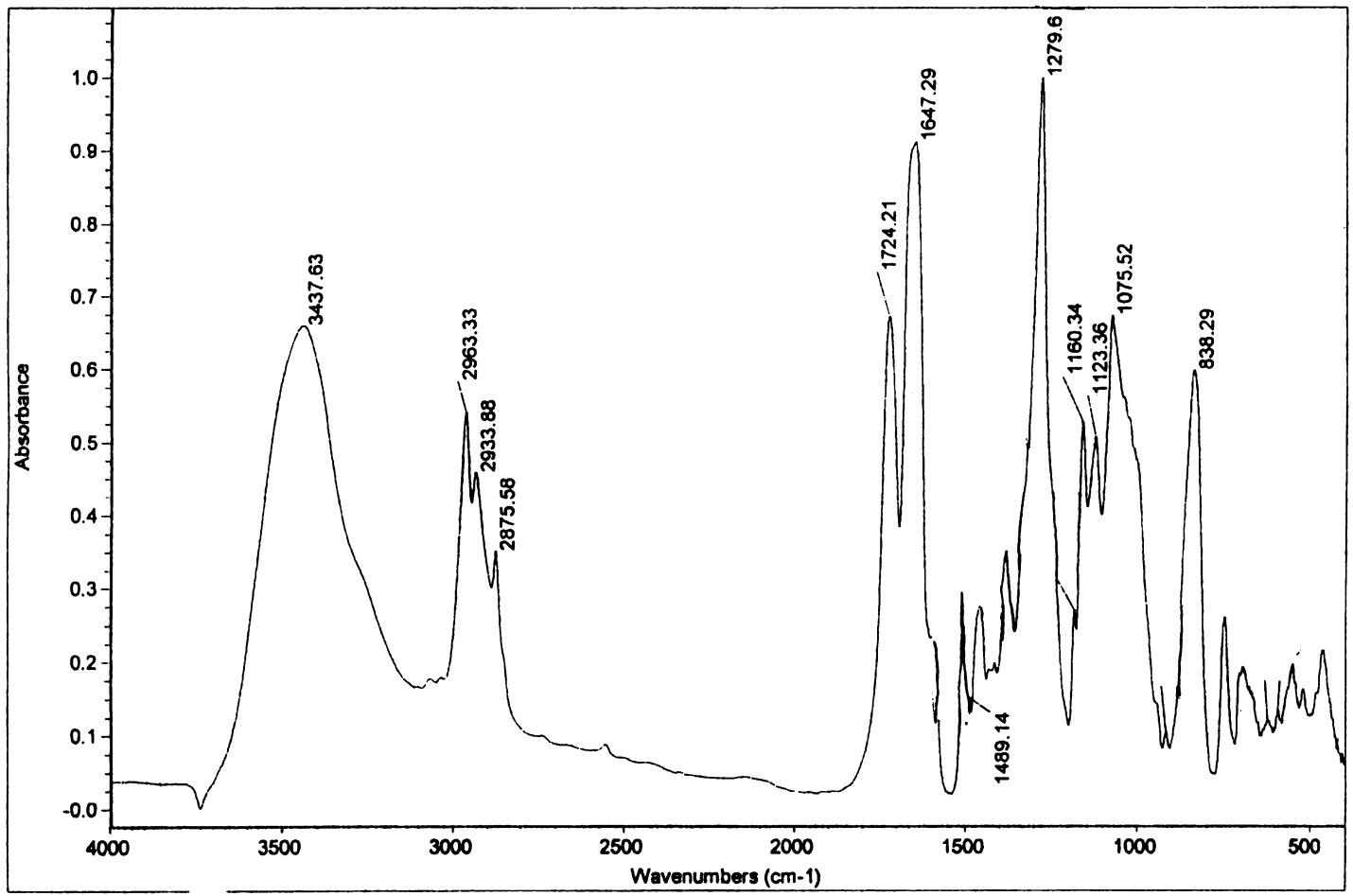

Figure 30. FTIR Spectrum of 2 Hour Aged Sample

3 hours Covergirl Nailslicks Twilight Mauve

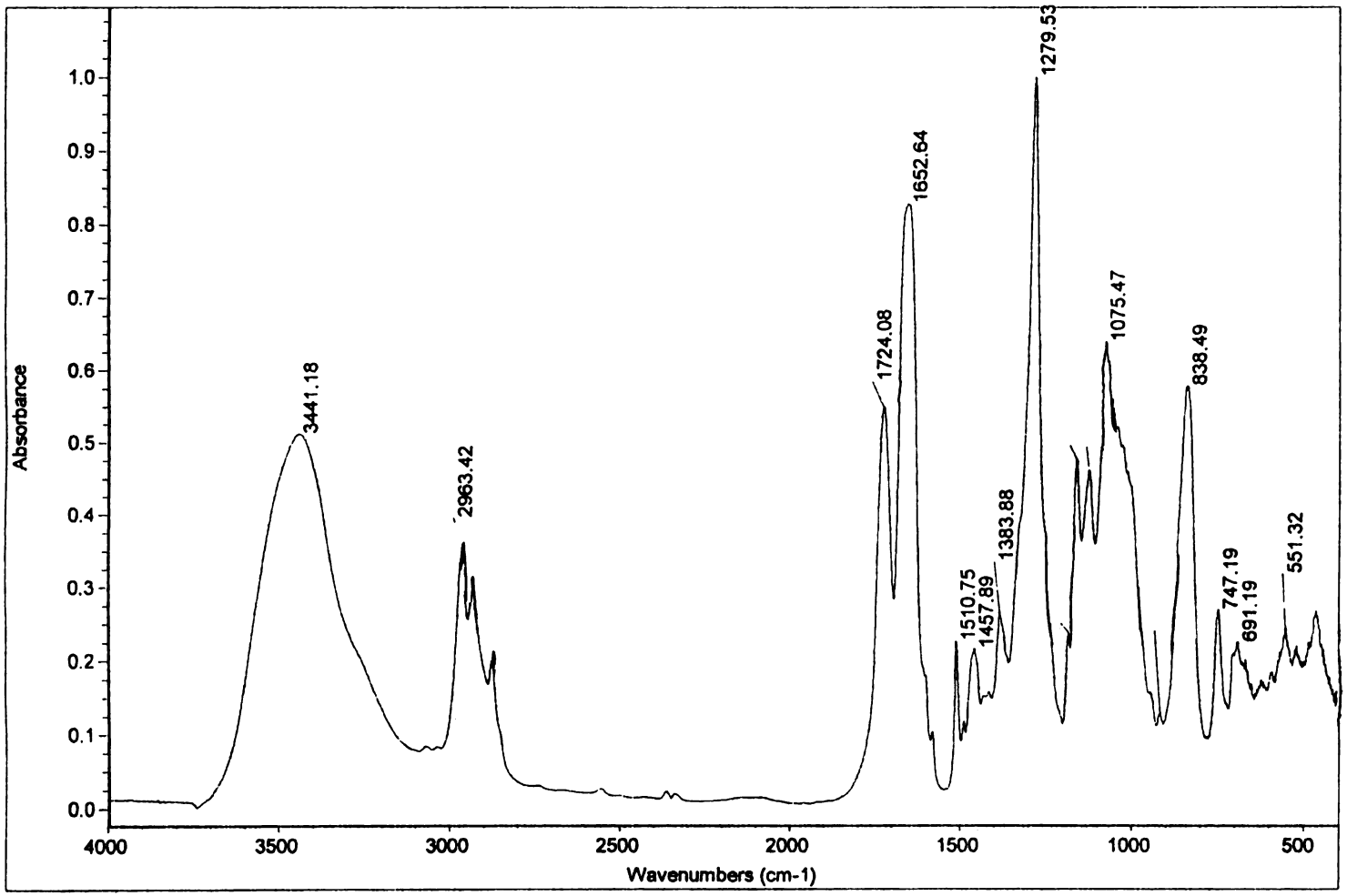

Figure 31. FTIR Spectrum of 3 Hour Aged Sample

1 day Covergirl Nailslicks Twilight Mauve

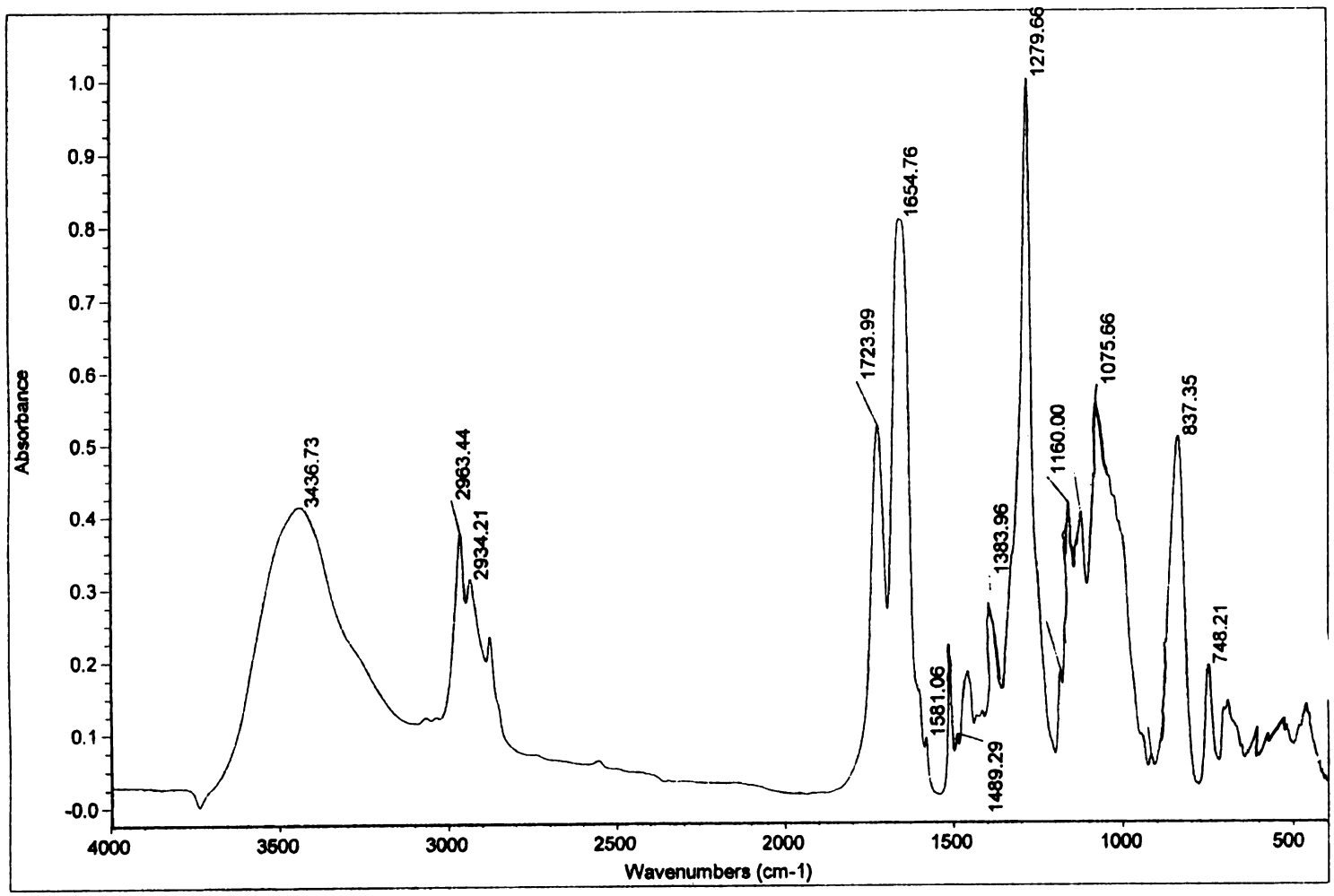

Figure 32. FTIR Spectrum of 1 Day Aged Sample

2 weeks Covergirl Nailslicks Twilight Mauve

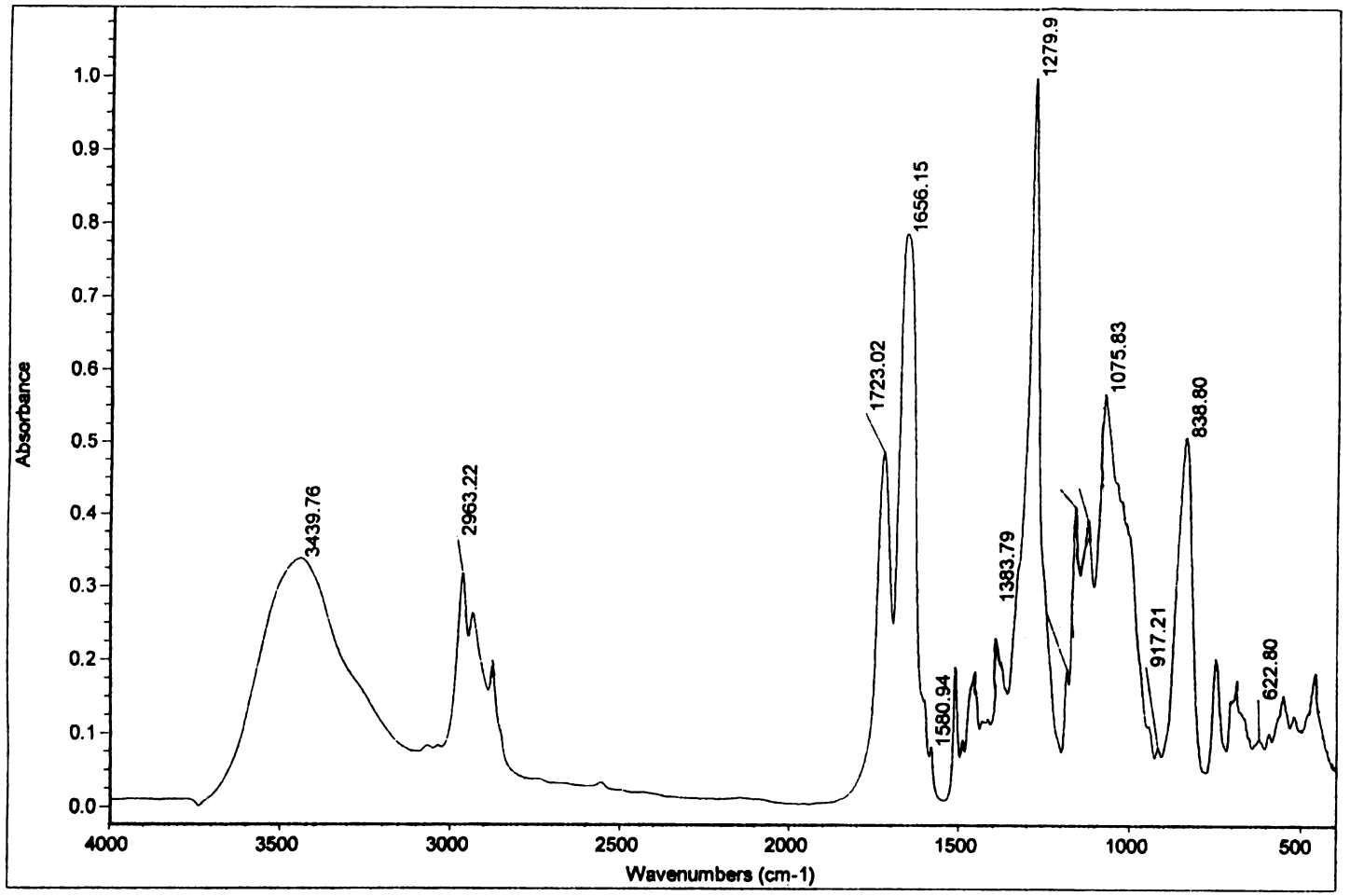

Figure 33. FTIR Spectrum of 2 Week Aged Sample

#10 Covergirl Nailslicks Twilight Mauve

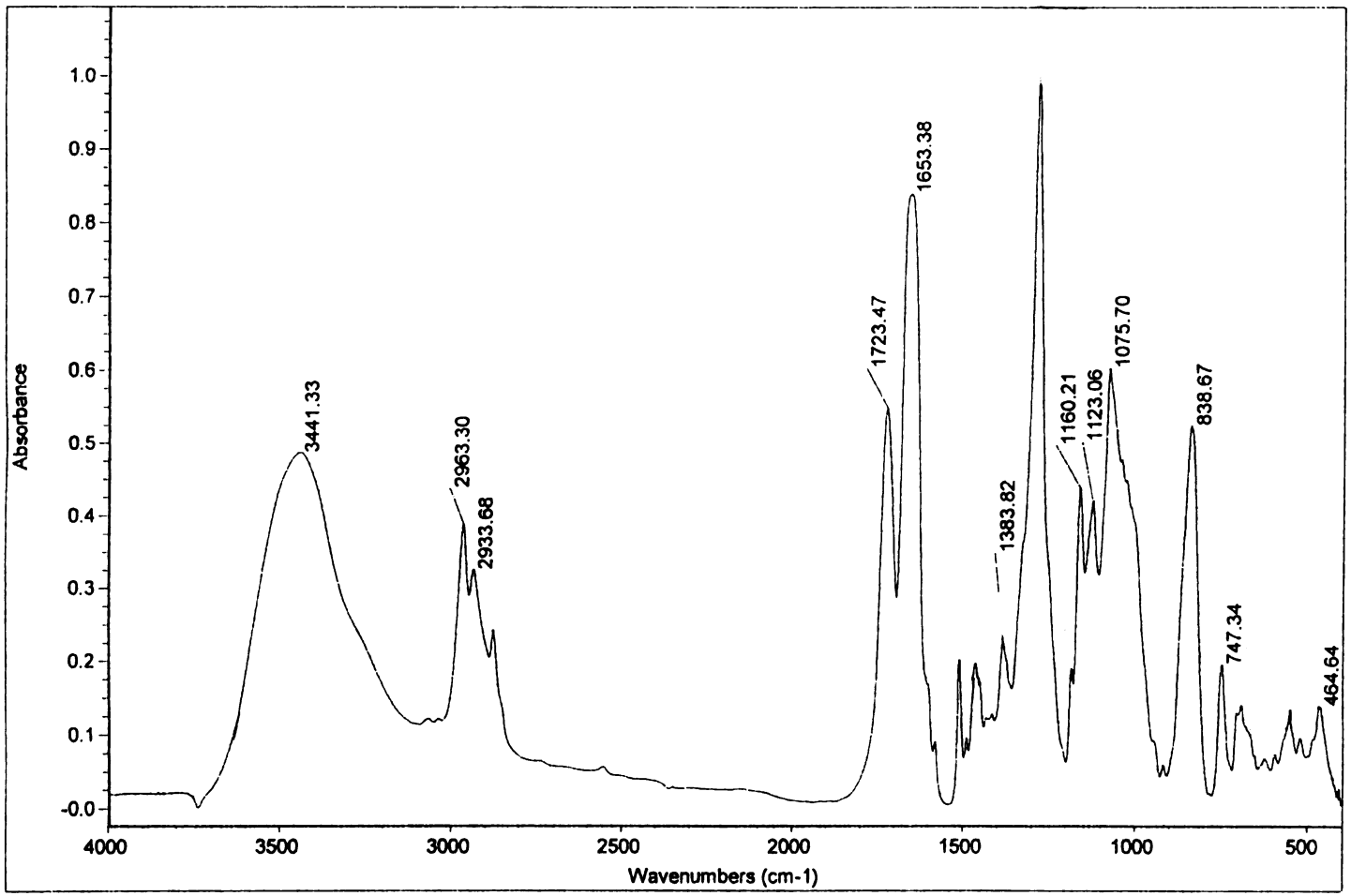

Figure 34. FTIR Spectrum of Reproducibility Sample #10

#20 Covergirl Nailslicks Twilght Mauve

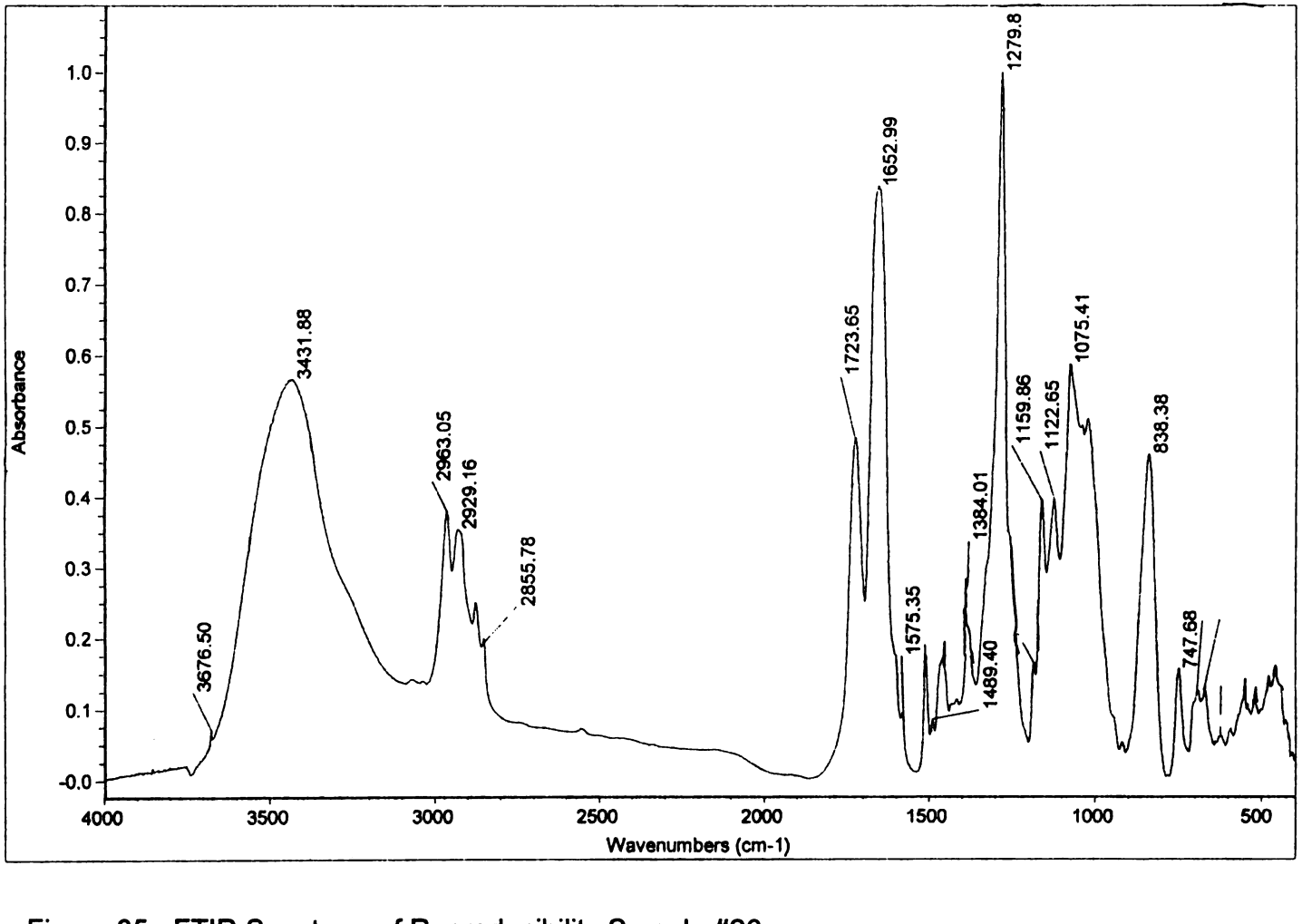

Figure 35. FTIR Spectrum of Reproducibility Sample #20

Covergirl Nailslicks Cranberry Cream

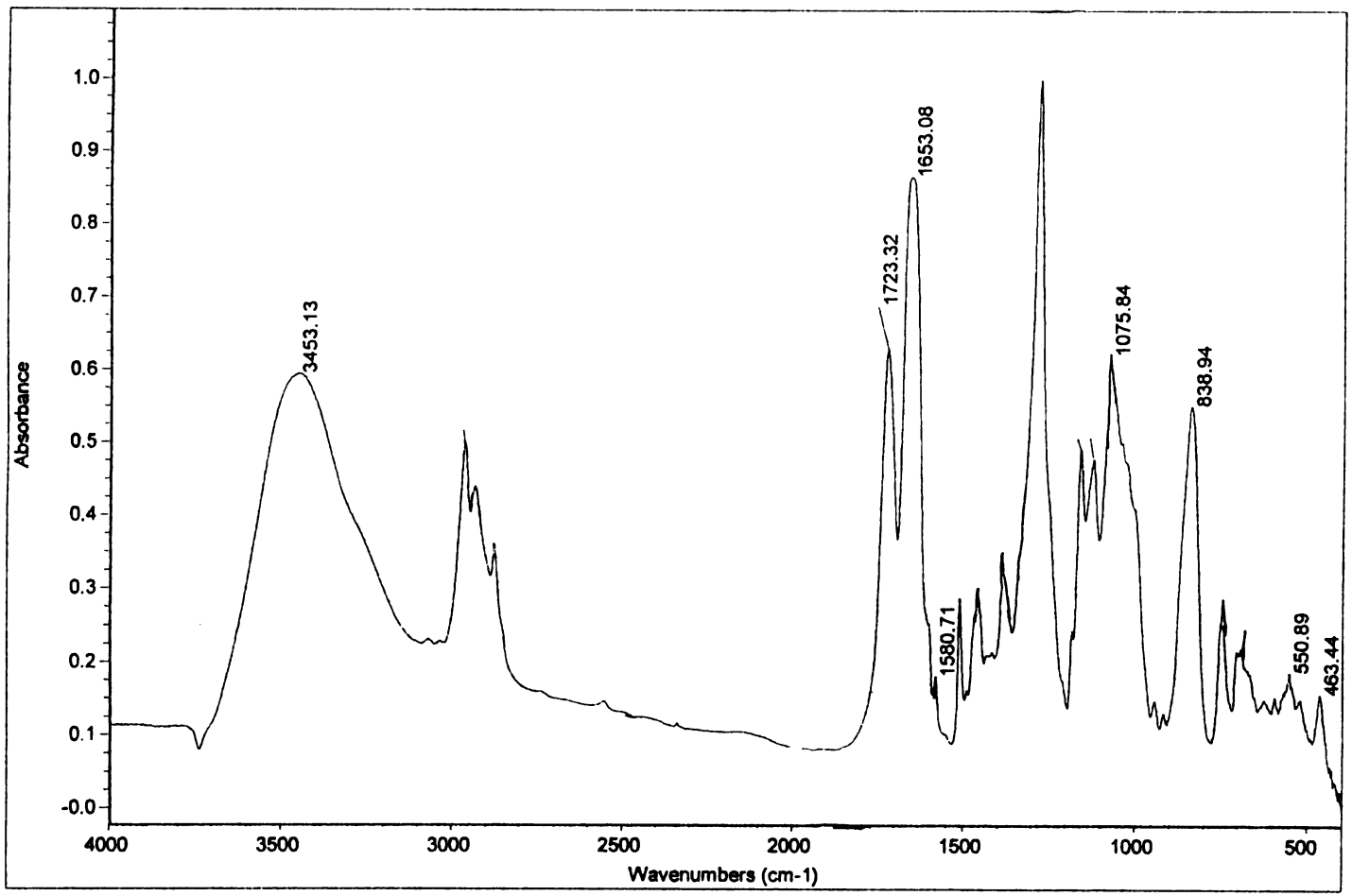

Figure 36. FTIR Spectrum of Covergirl Nailslicks Cranberry Cream

L'Oreal (Shock Proof) Mulberry Creme

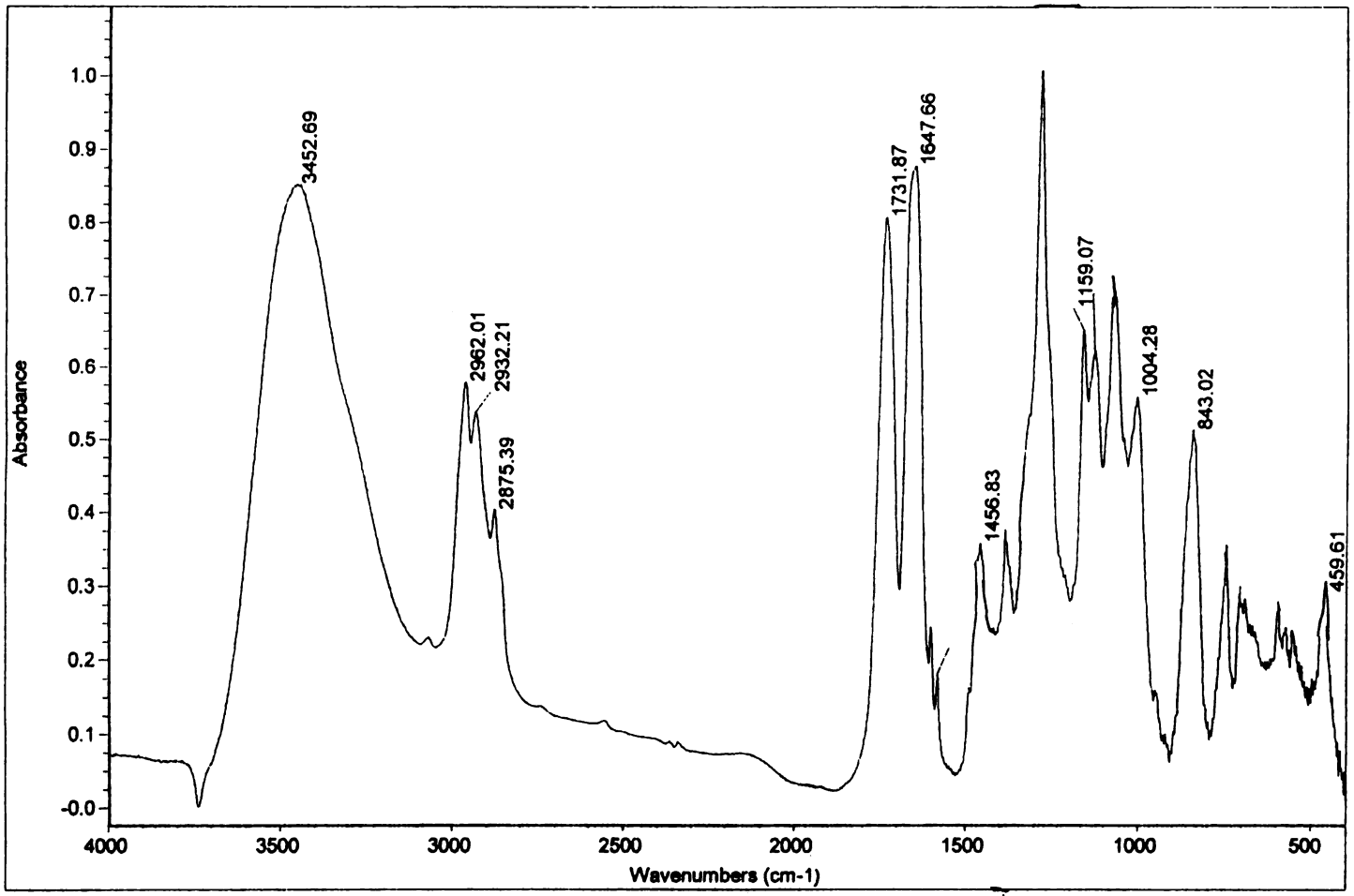

Figure 37. FTIR Spectrum of L'Oreal Mulberry Creme

Maybelline (Express Finish) Native Berry

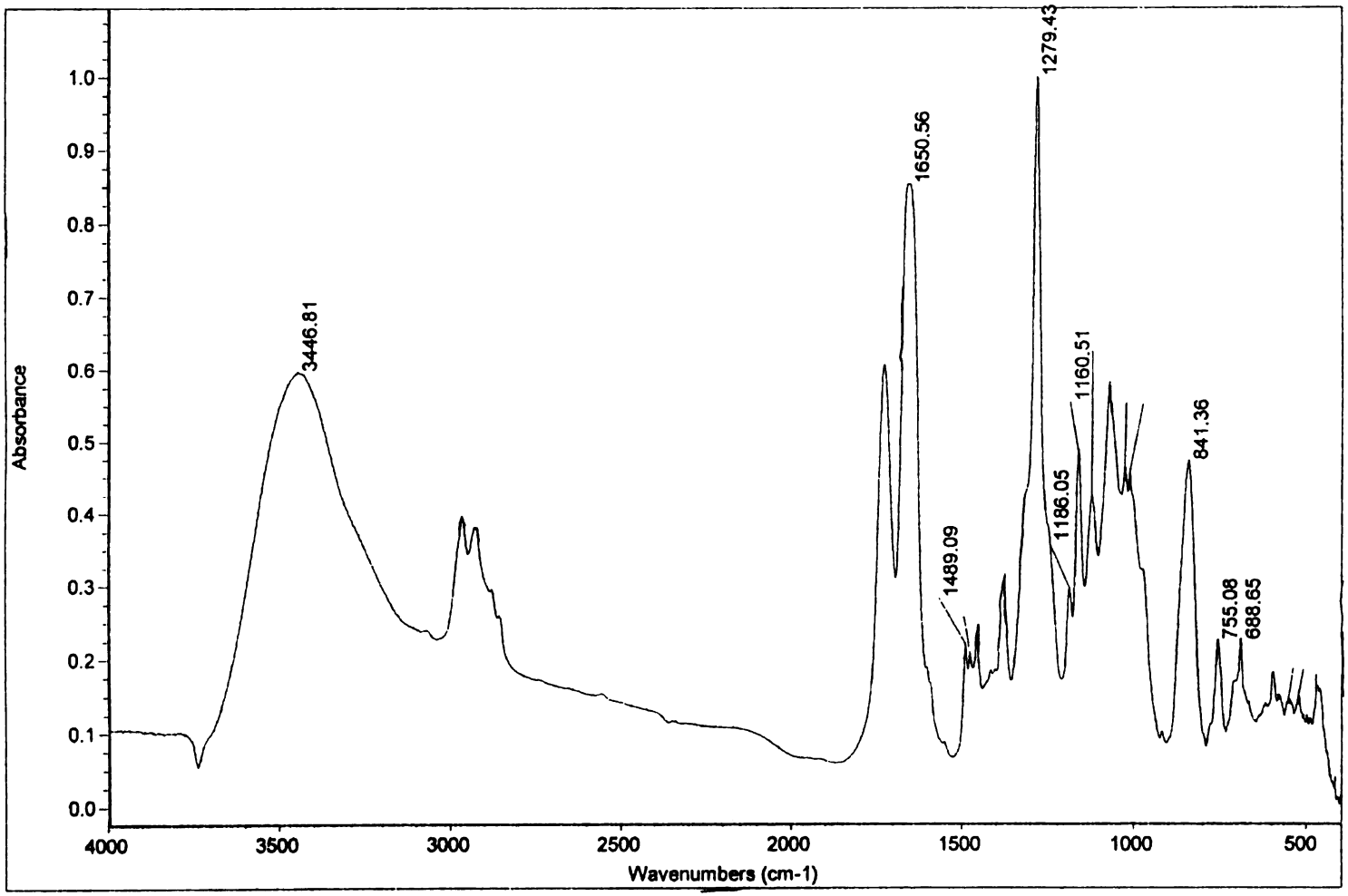

Figure 38. FTIR Spectrum of Maybelline Native Berry

Revlon Love Her Madly

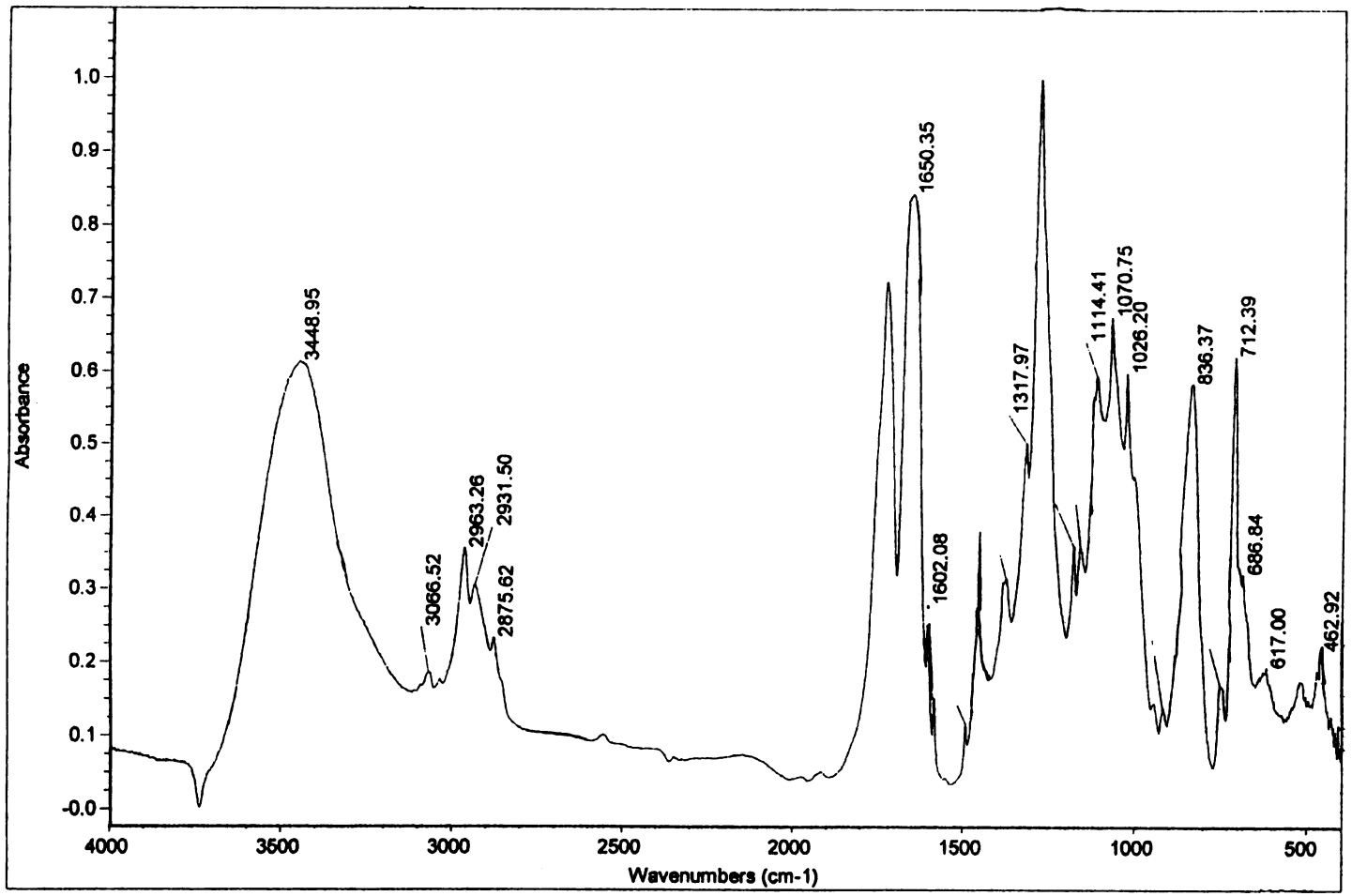

Figure 39. FTIR Spectrum of Revlon Love Her Madly

Revlon Wine With Everything

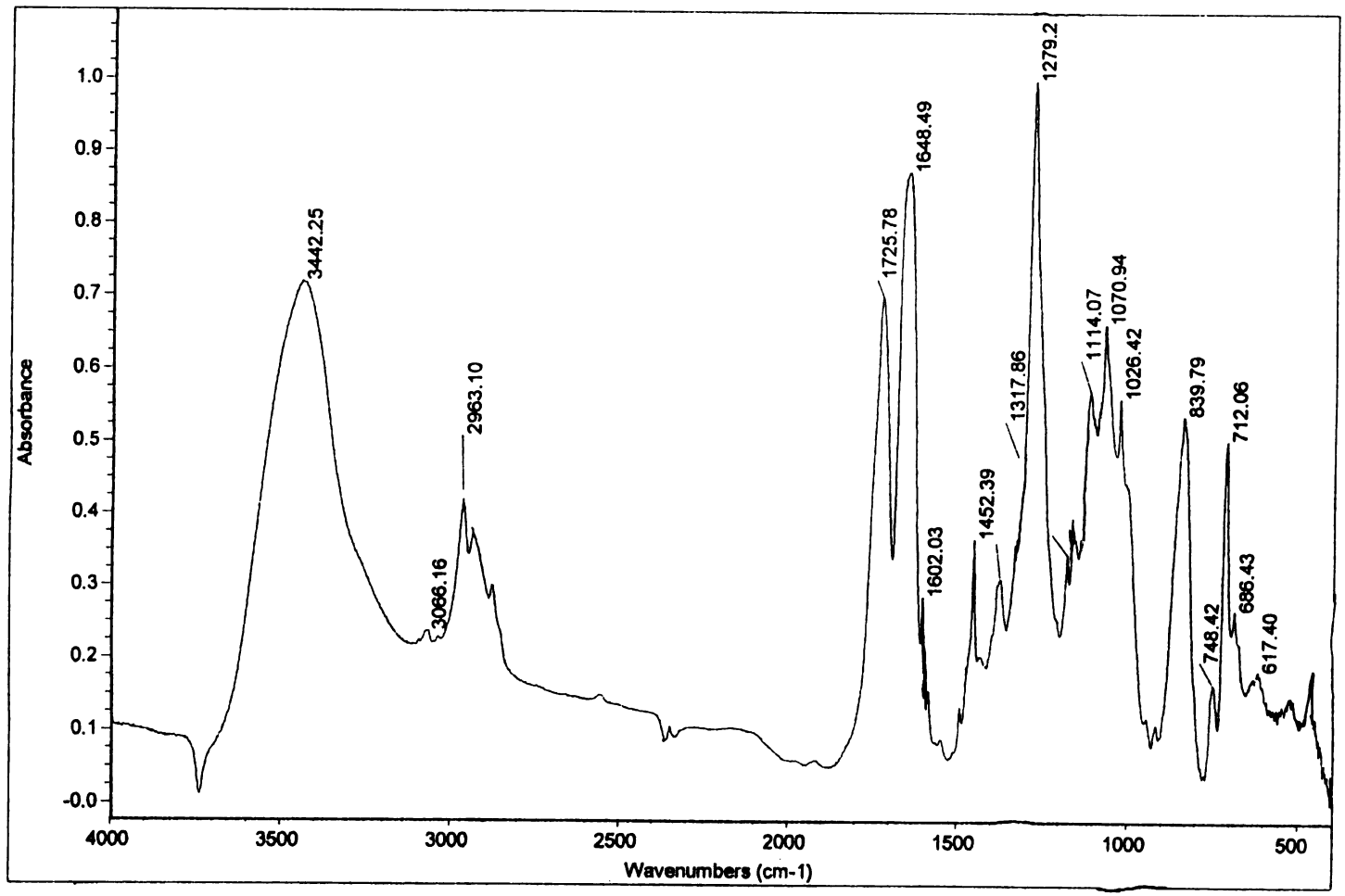

Figure 40. FTIR Spectrum of Revlon Wine With Everything

Revlon (Super Top Speed) Winey

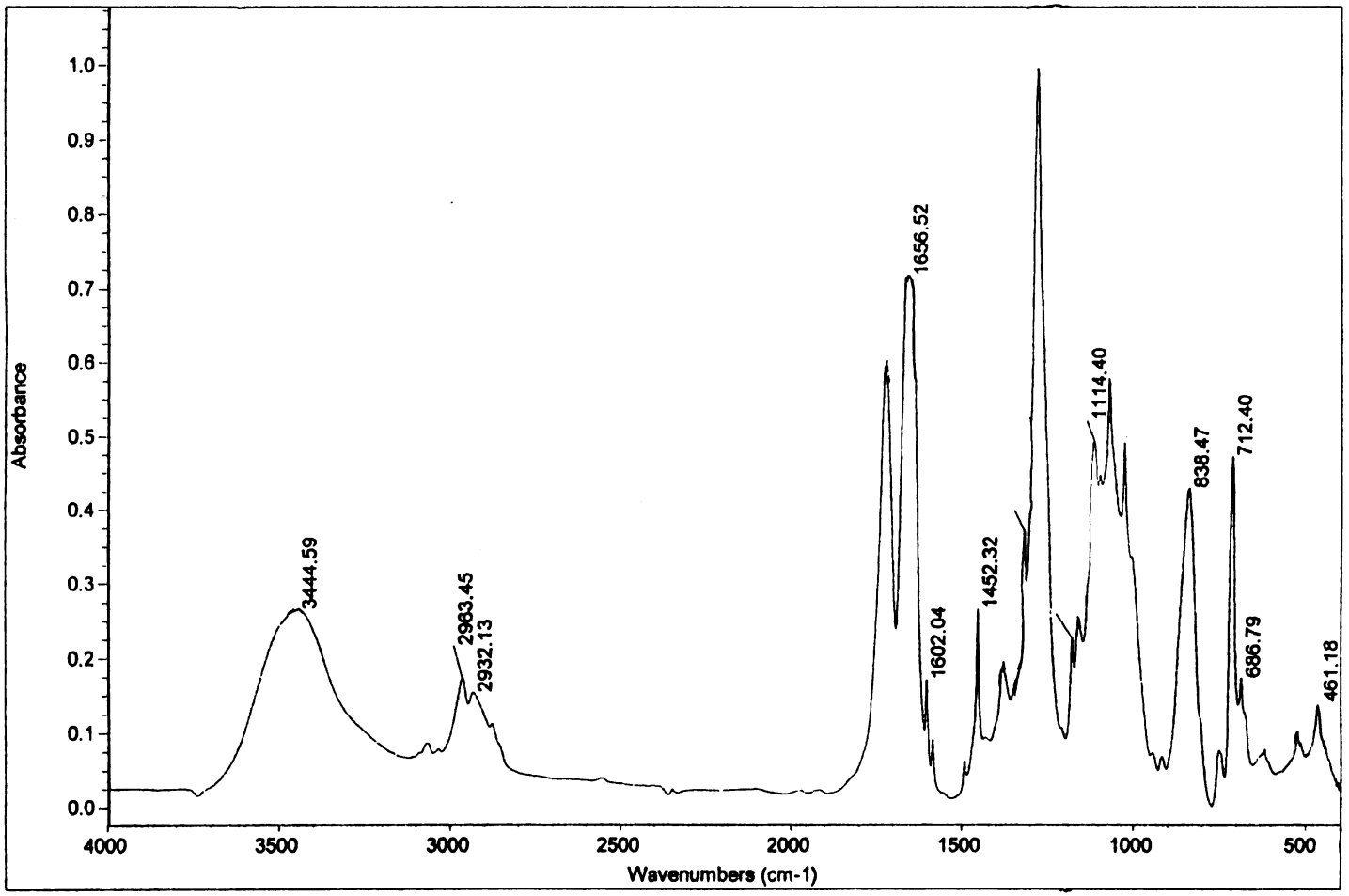

Figure 41. FTIR Spectrum of Revlon Super Top Speed Winey

Sally Hansen (Hard As Nails) Oasis Dawn Cream

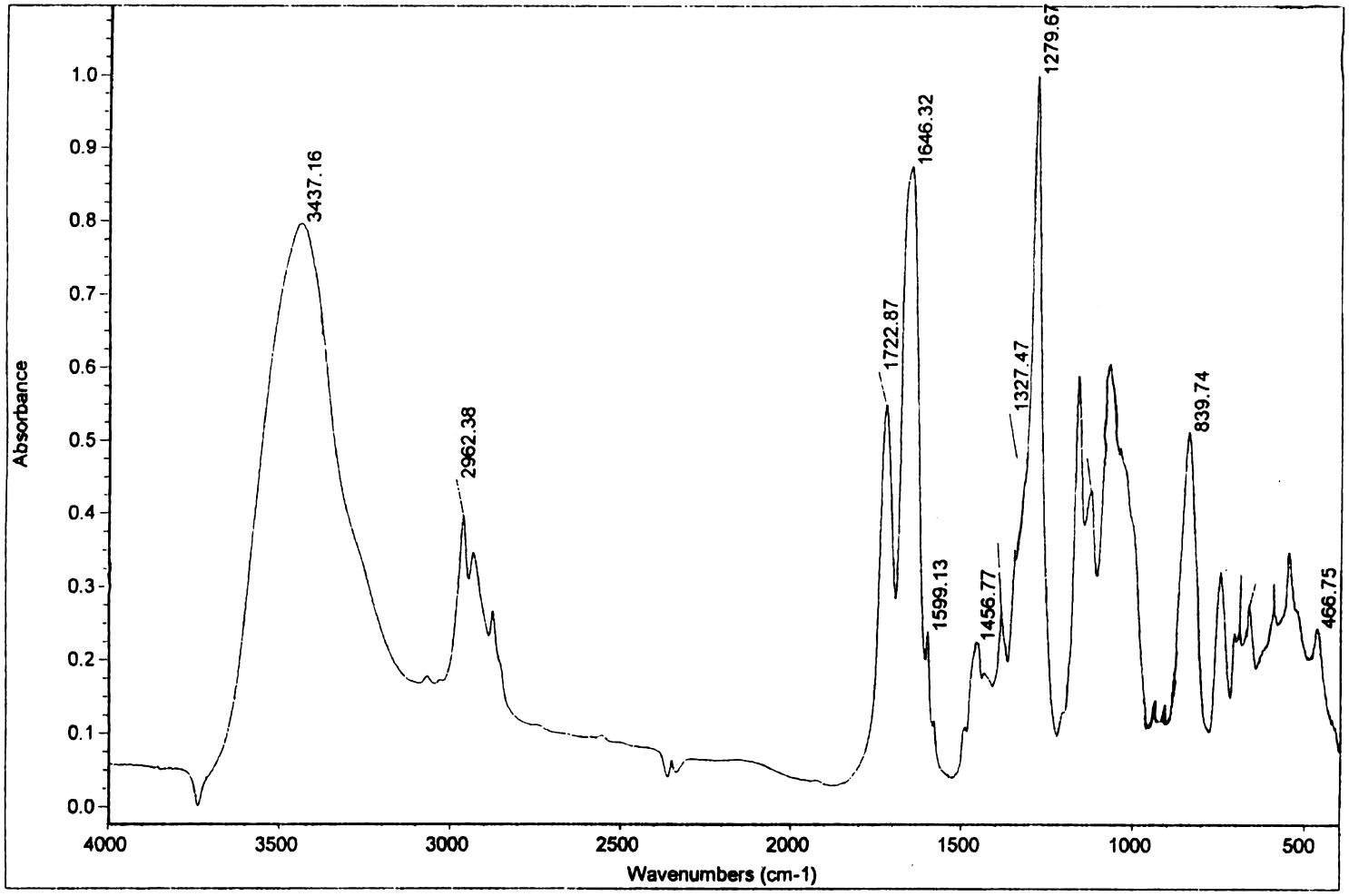

Figure 42. FTIR Spectrum of Sally Hansen Hard As Nails Oasis Dawn Cream

Sally Hansen (Maximum Growth) Beautiful Berry

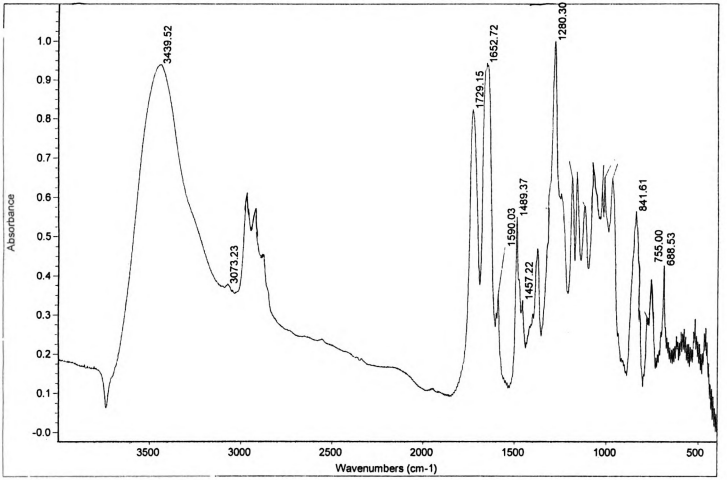

Figure 43. FTIR Spectrum of Sally Hansen Maximum Growth Beautiful Berry

Covergirl Nailslicks Cabernet

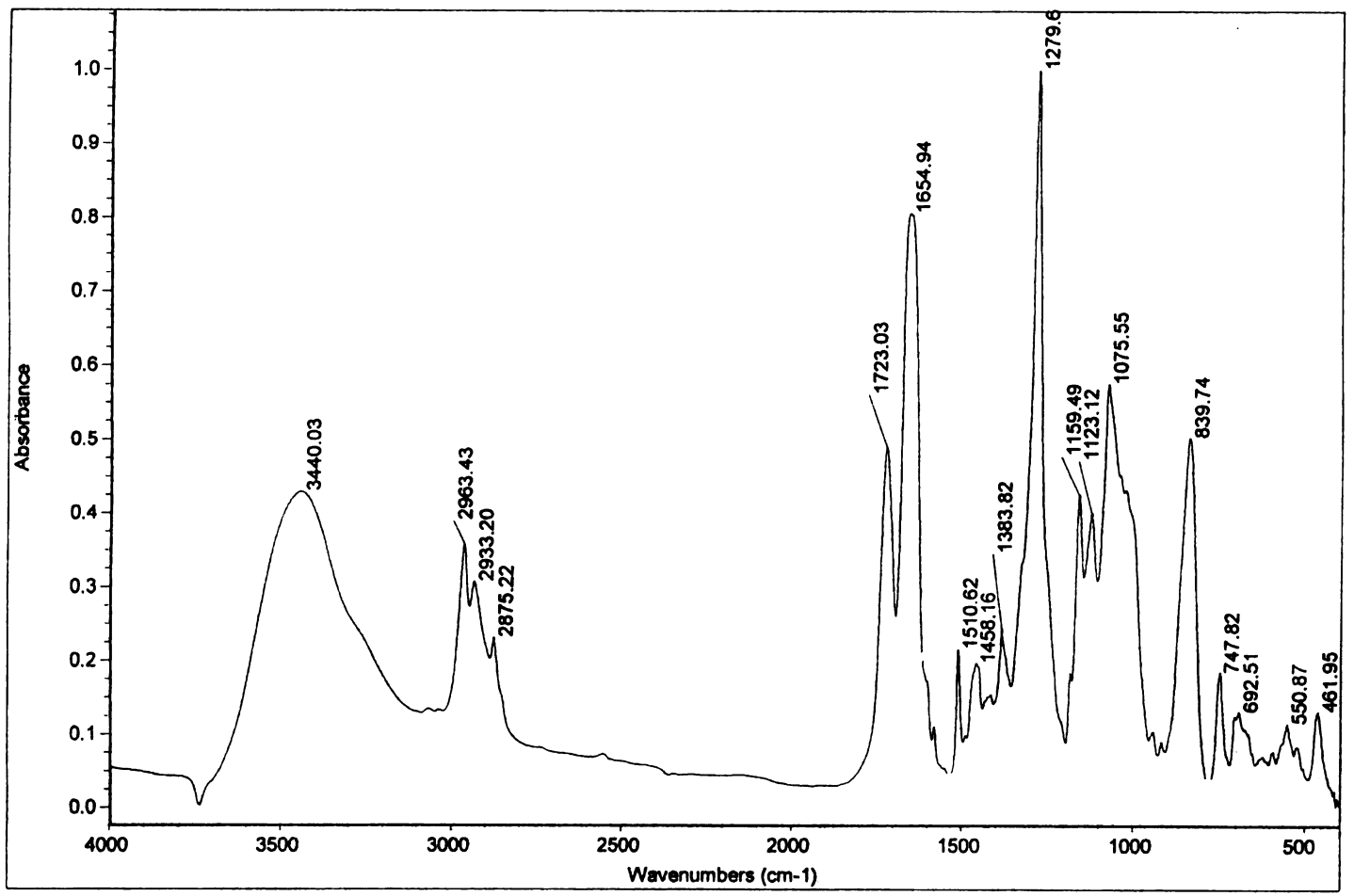

Figure 44. FTIR Spectrum of Covergirl Nailslicks Cabernet

Covergirl Nailslicks Cherry Brandy

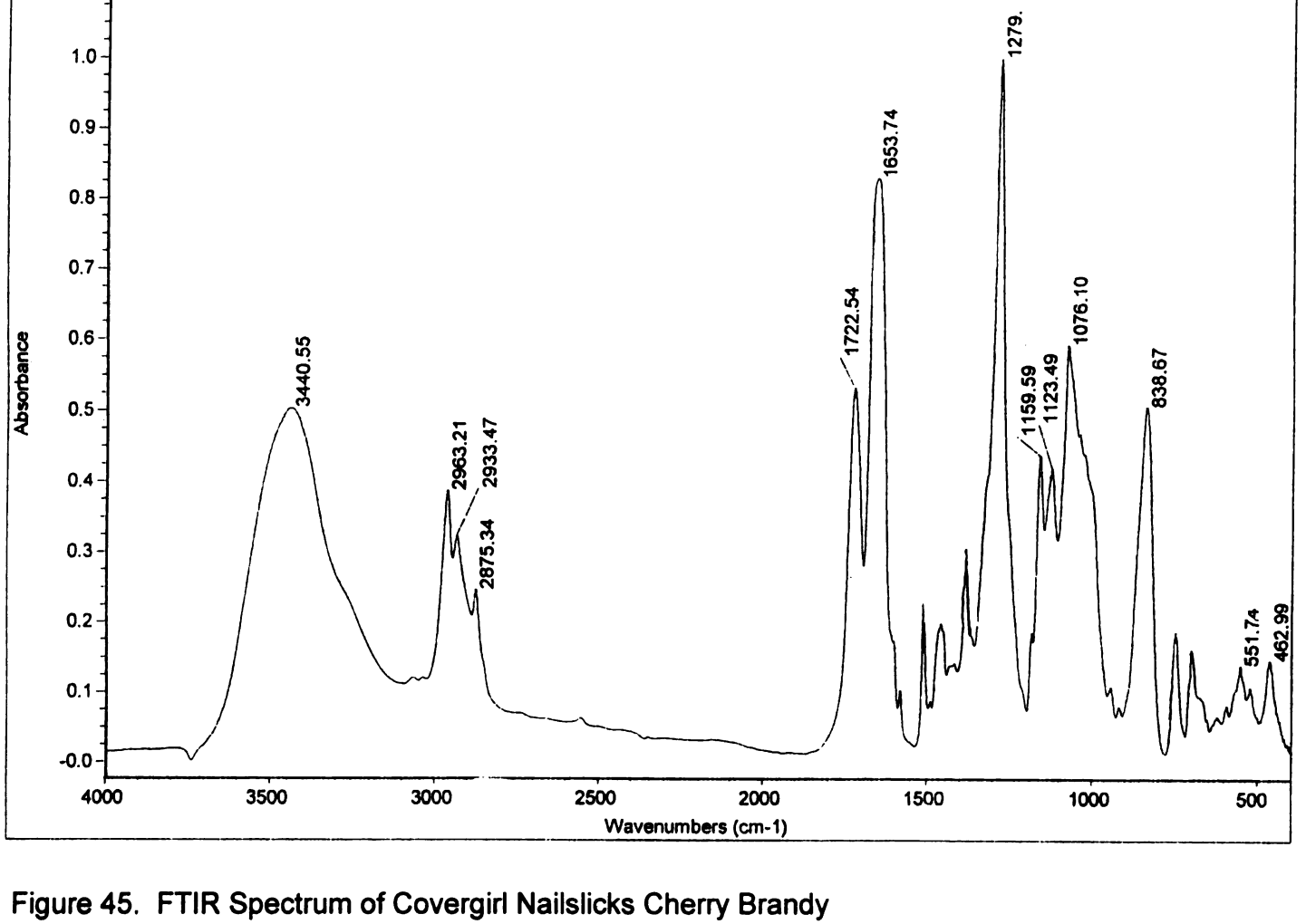

Figure 45. FTIR Spectrum of Covergirl Nailslicks Cherry Brandy

Covergirl Nailslicks Cherry Truffle

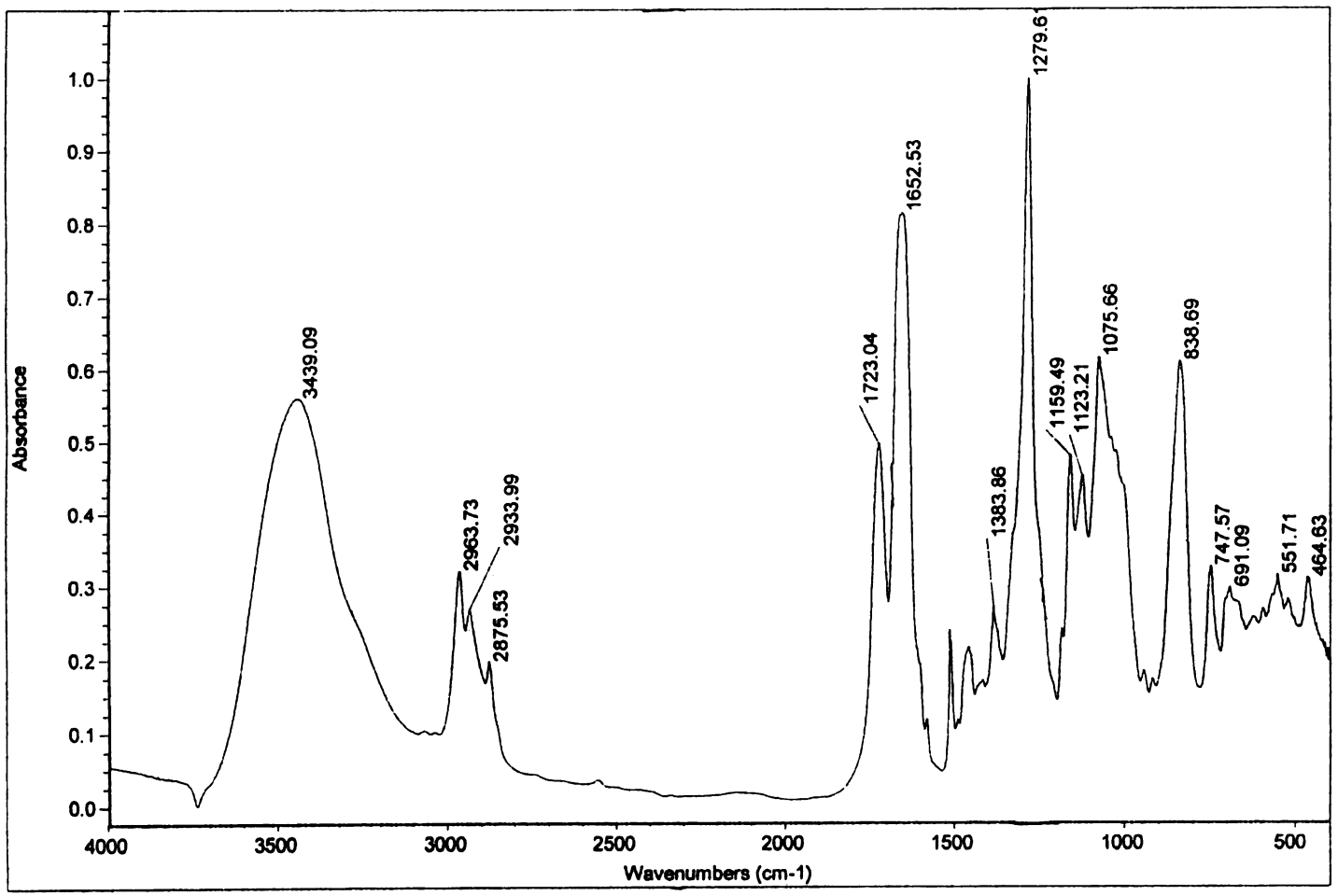

Figure 46. FTIR Spectrum of Covergirl Nailslicks Cherry Truffle

Covergirl Nailslicks Fabulous Fuchsia

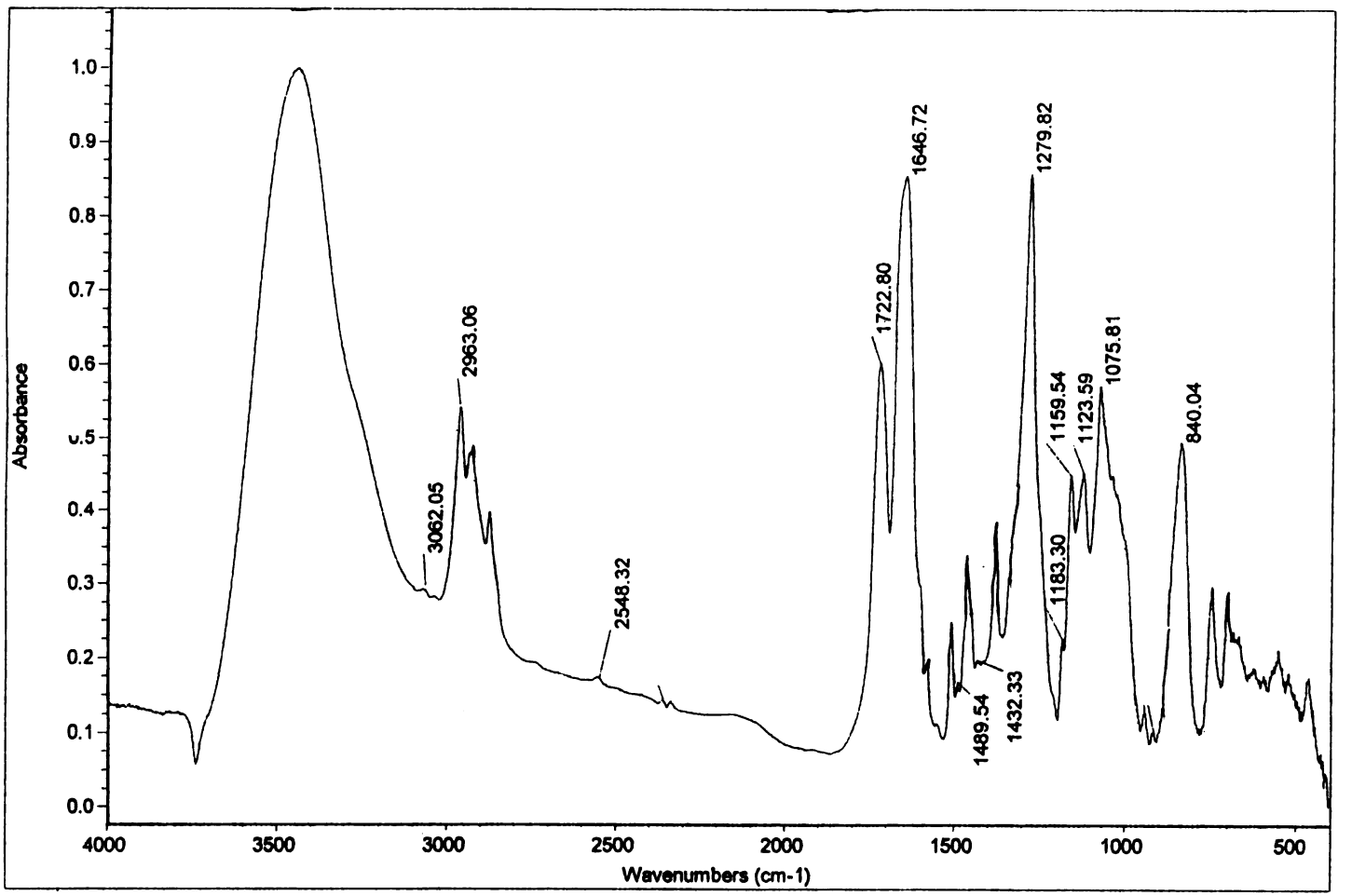

Figure 47. FTIR Spectrum of Covergirl Nailslicks Fabulous Fuchsia

Covergirl Nailslicks Grape Ice

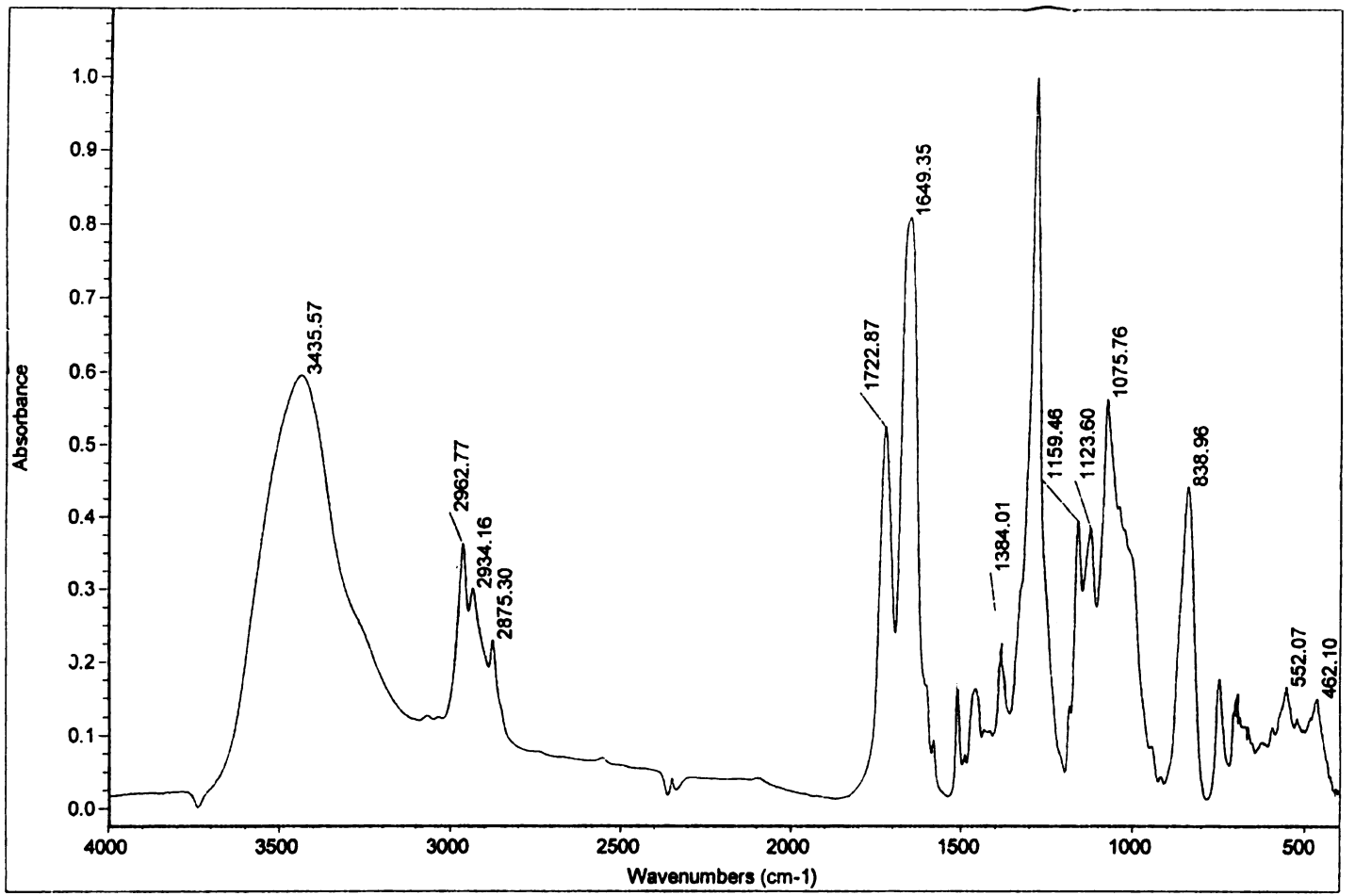

Figure 48. FTIR Spectrum of Covergirl Nailslicks Grape Ice

Covergirl Nailslicks Ice Blue Pink

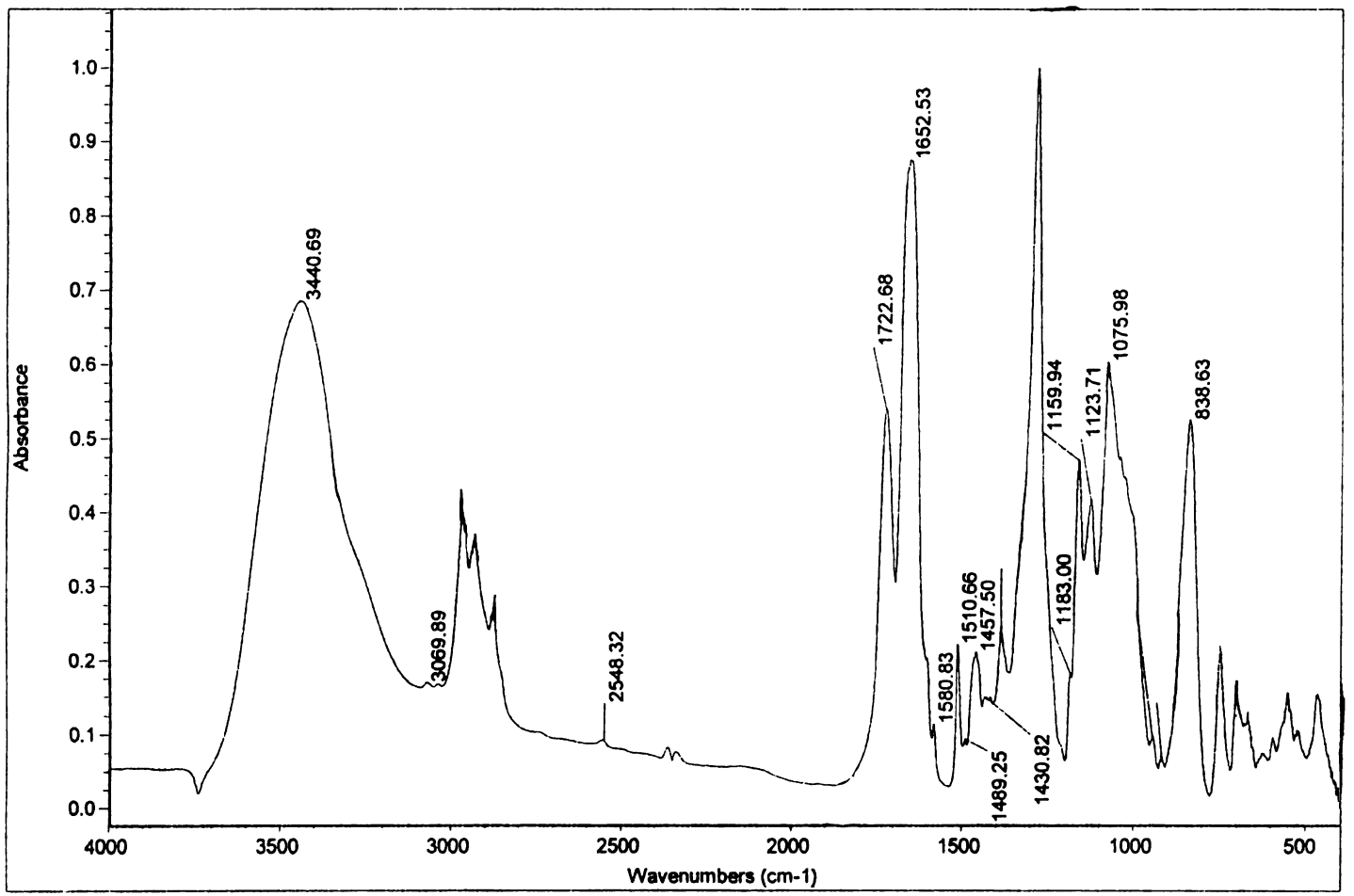

Figure 49. FTIR Spectrum of Covergirl Nailslicks Ice Blue Pink

Covergirl Nailslicks Mauve Sunrise

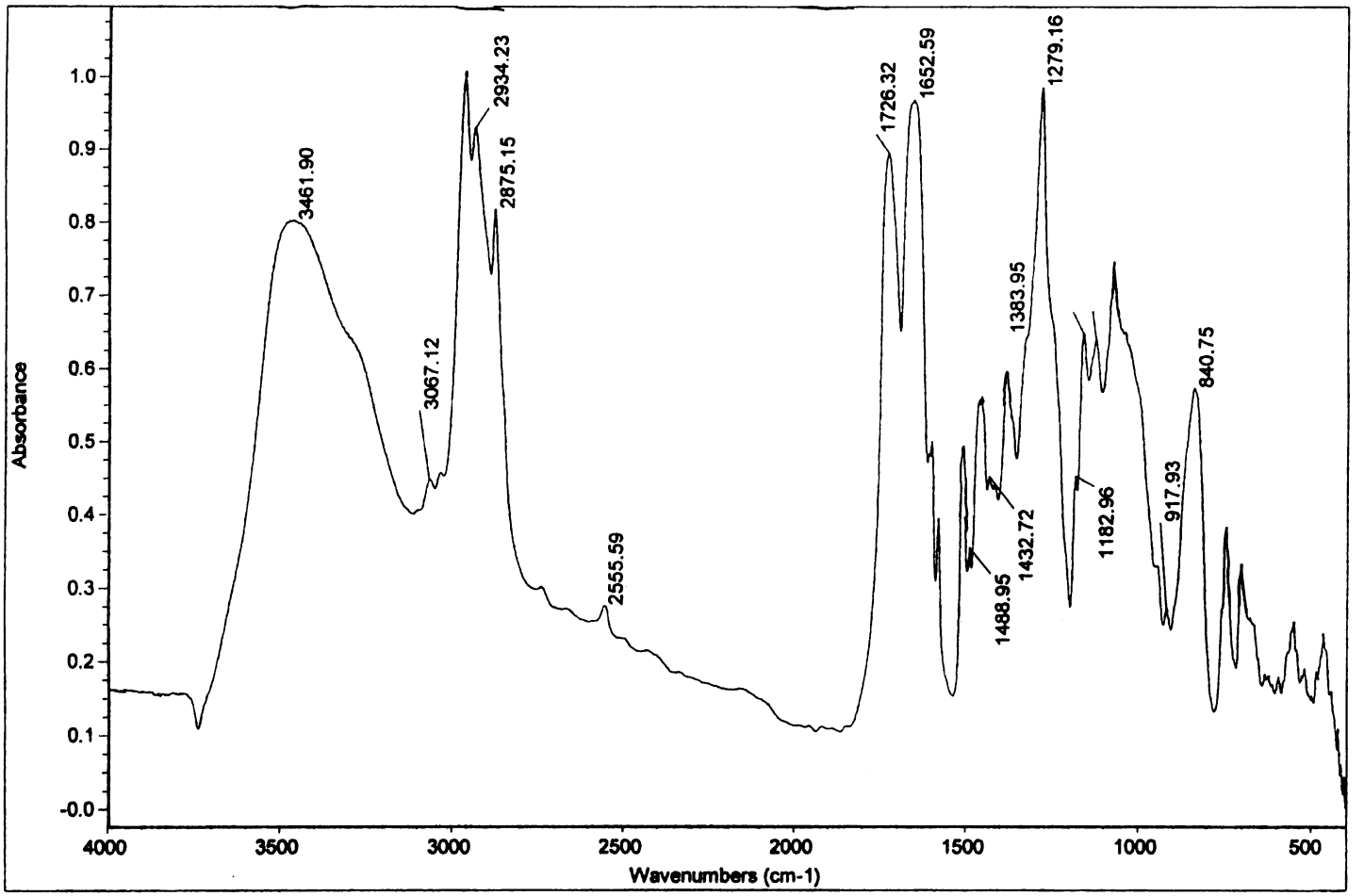

Figure 50. FTIR Spectrum of Covergirl Nailslicks Mauve Sunrise

Covergirl Nailslicks Mauvelicious

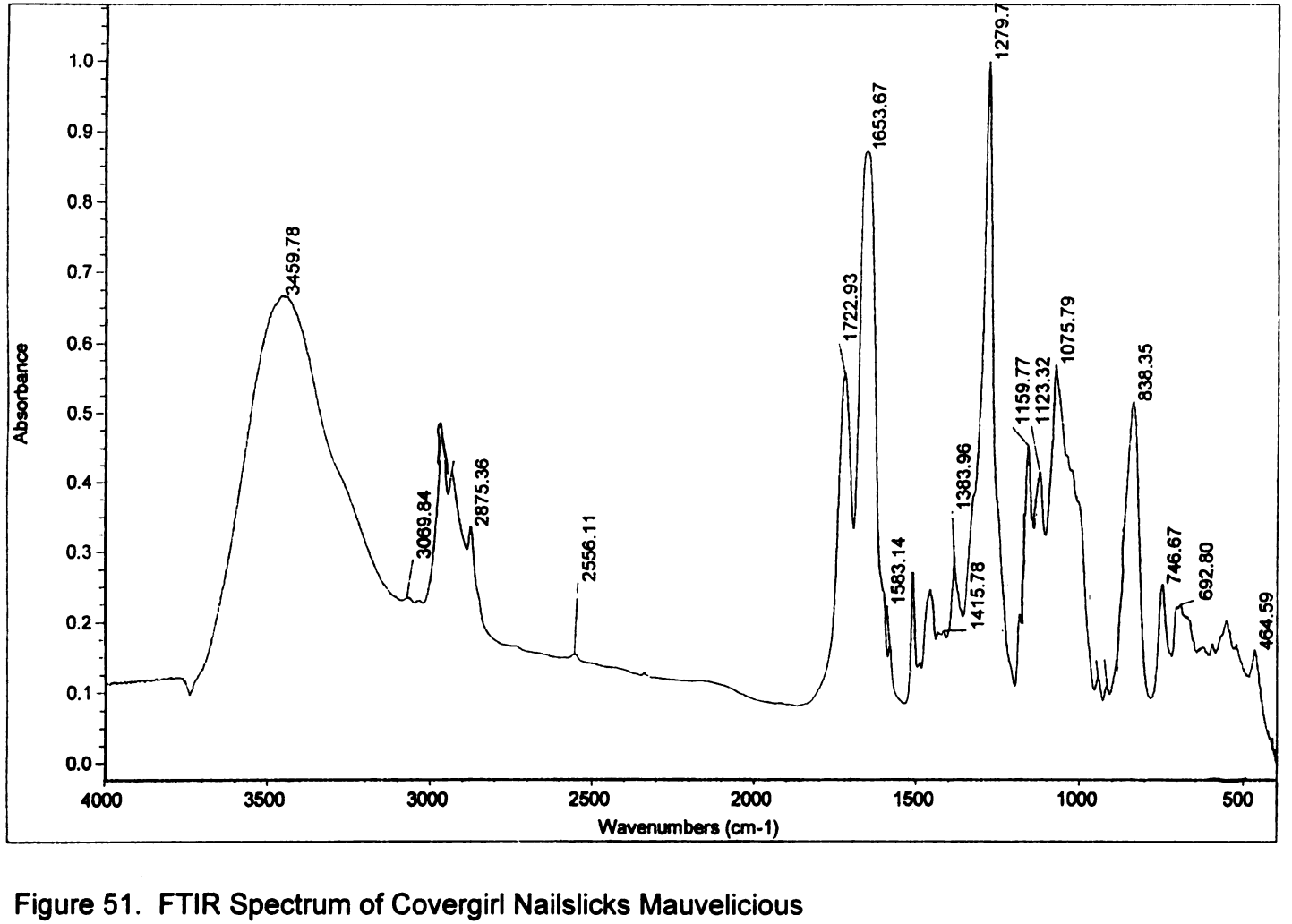

Figure 51. FTIR Spectrum of Covergirl Nailslicks Mauvelicious

Covergirl Nailslicks Peek-A-Boo Pink

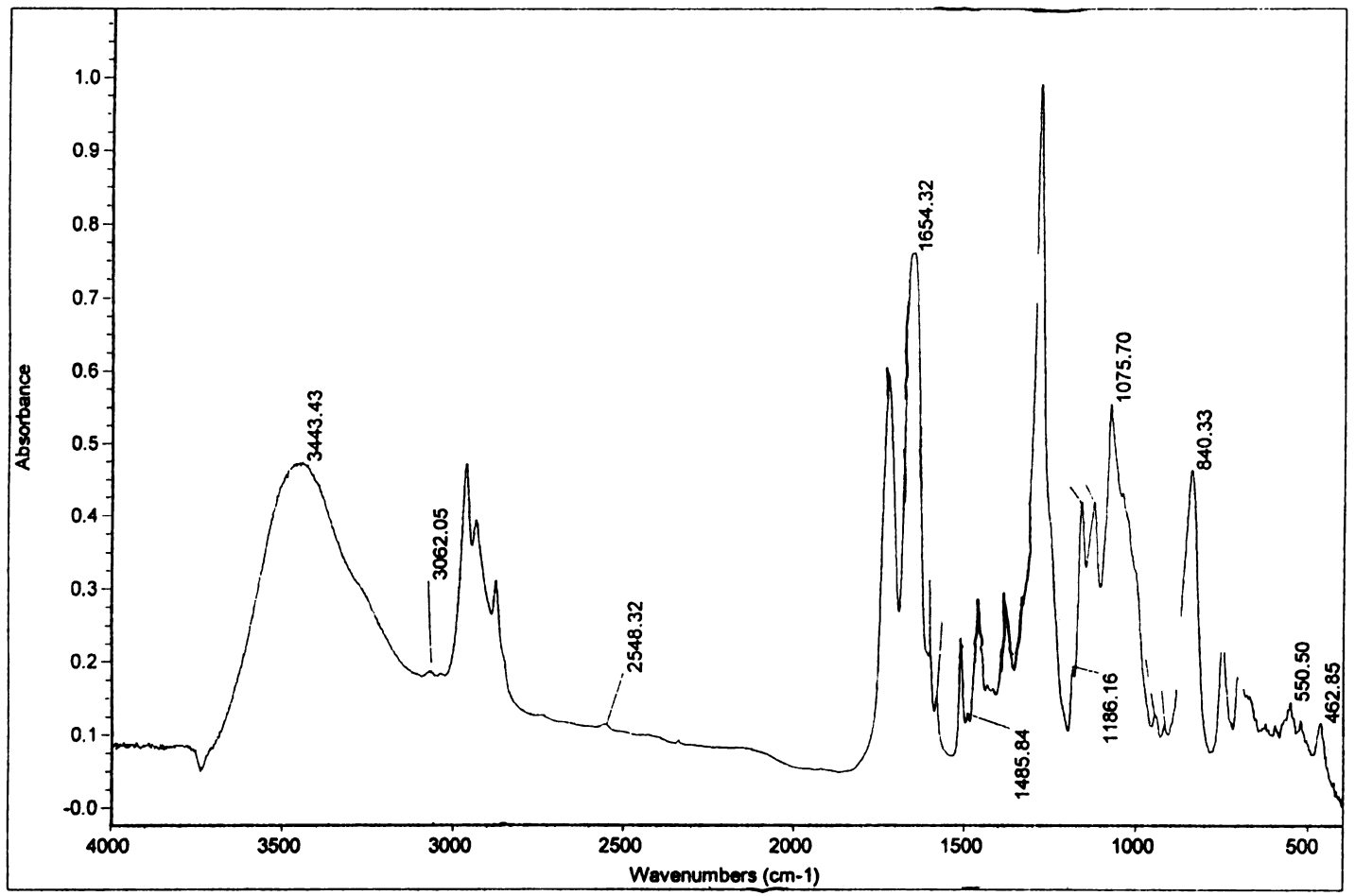

Figure 52. FTIR Spectrum of Covergirl Nailslicks Peek-A-Boo Pink

Covergirl Nailslicks Pink Aura

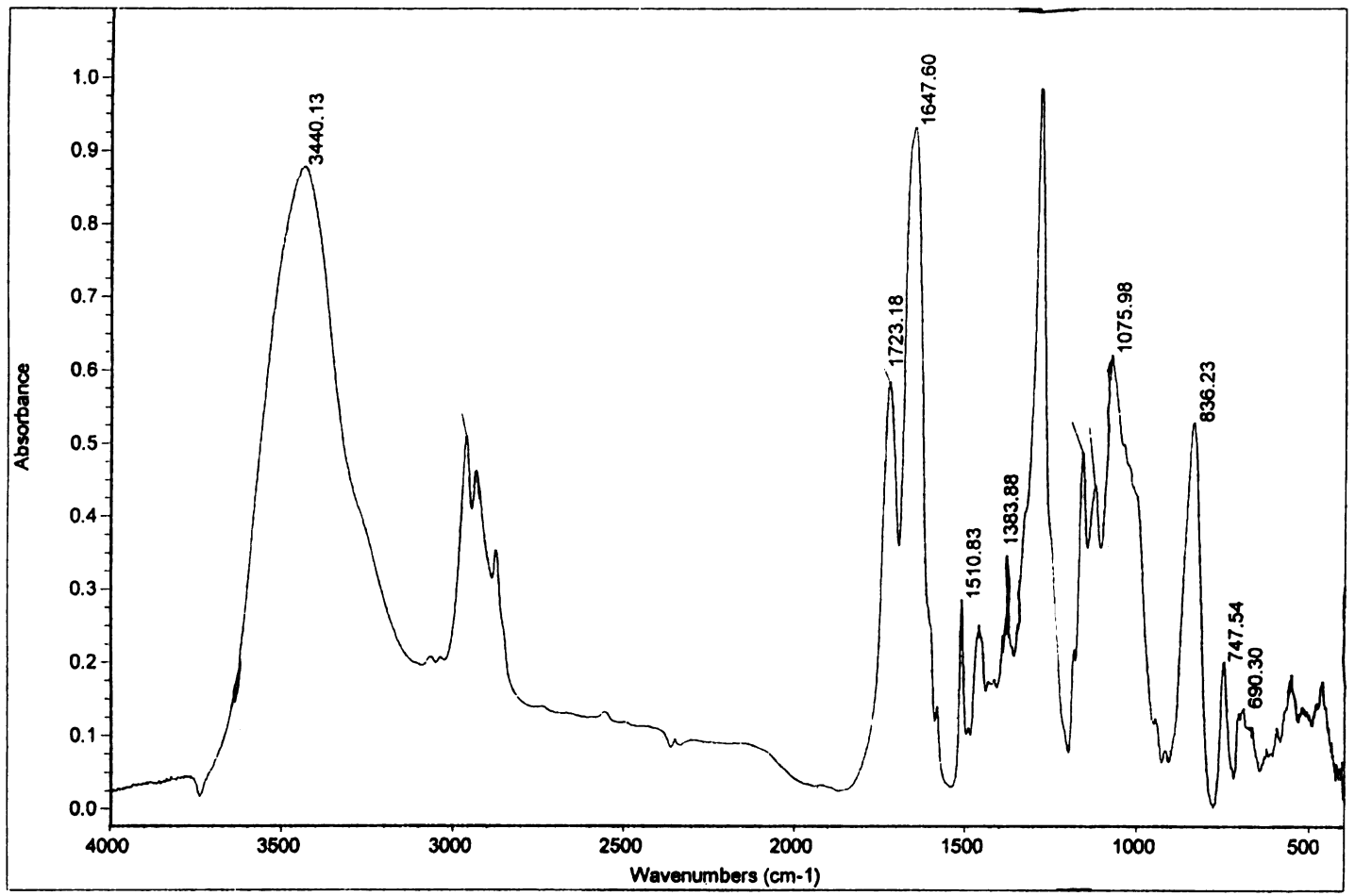

Figure 53. FTIR Spectrum of Covergirl Nailslicks Pink Aura

Covergirl Nailslicks Pink Snow

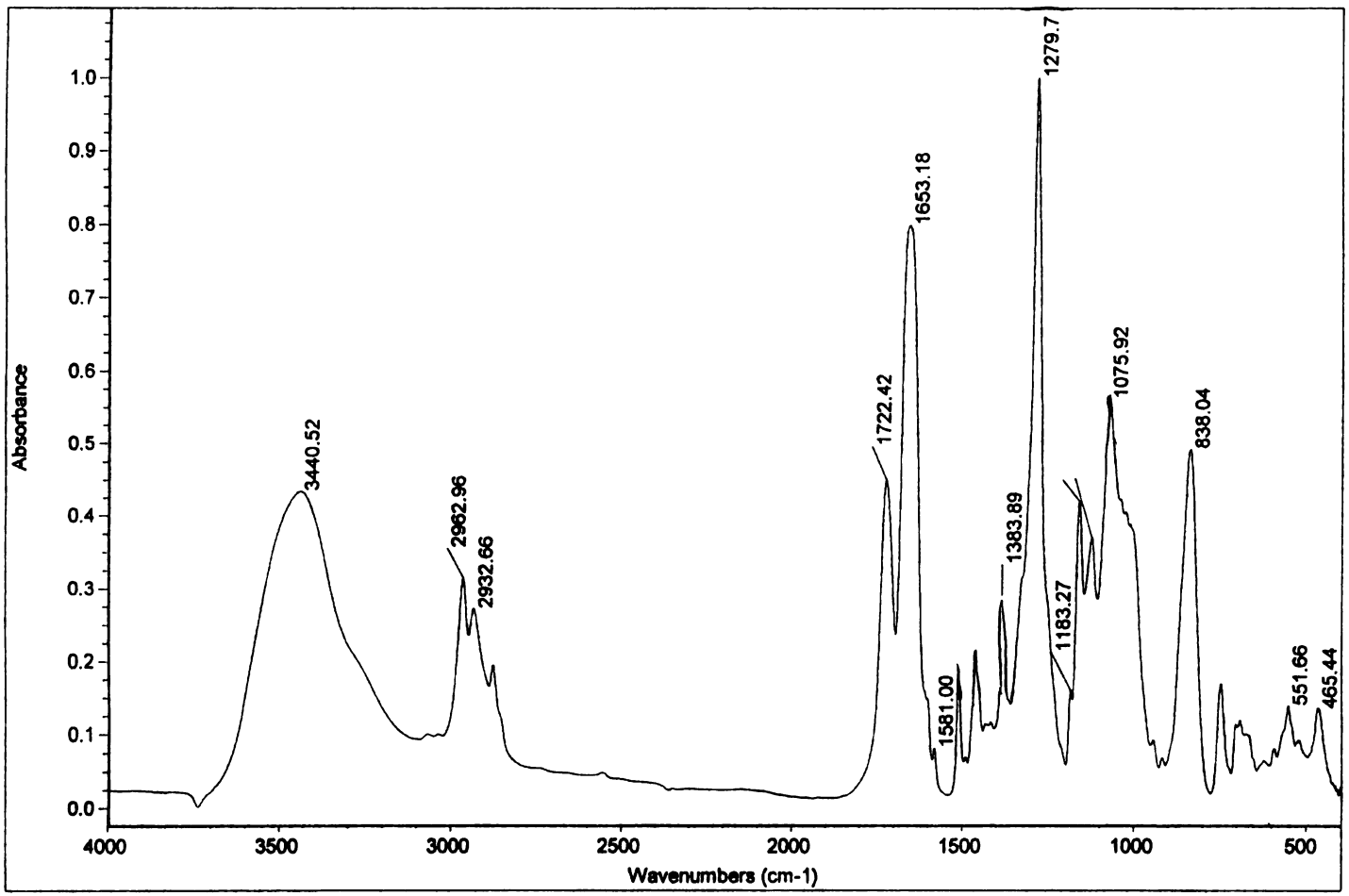

Figure 54. FTIR Spectrum of Covergirl Nailslicks Pink Snow

Covergirl Nailslicks Plum Frost

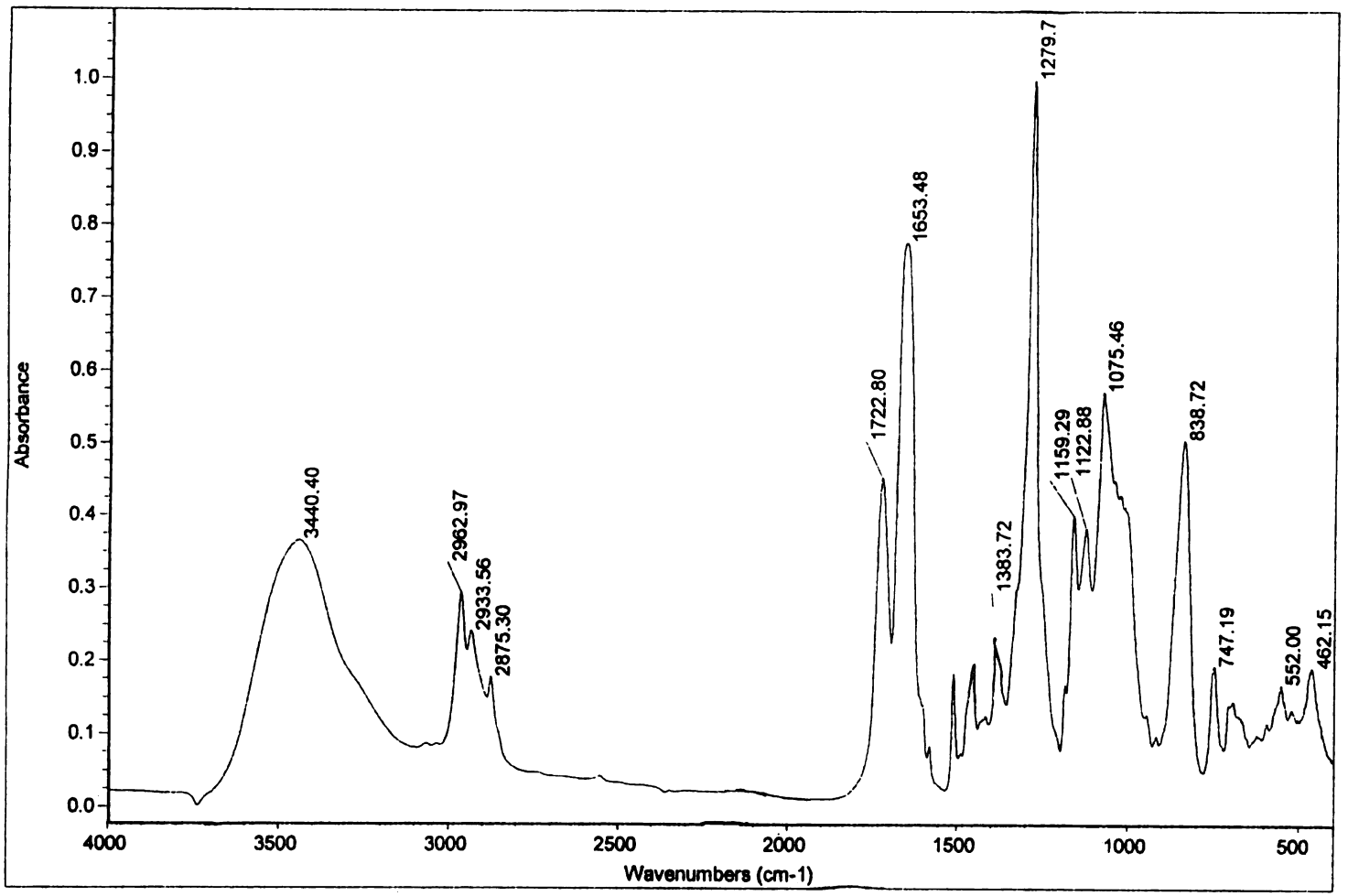

Figure 55. FTIR Spectrum of Covergirl Nailslicks Plum Frost

Covergirl Nailslicks Satin Mauve

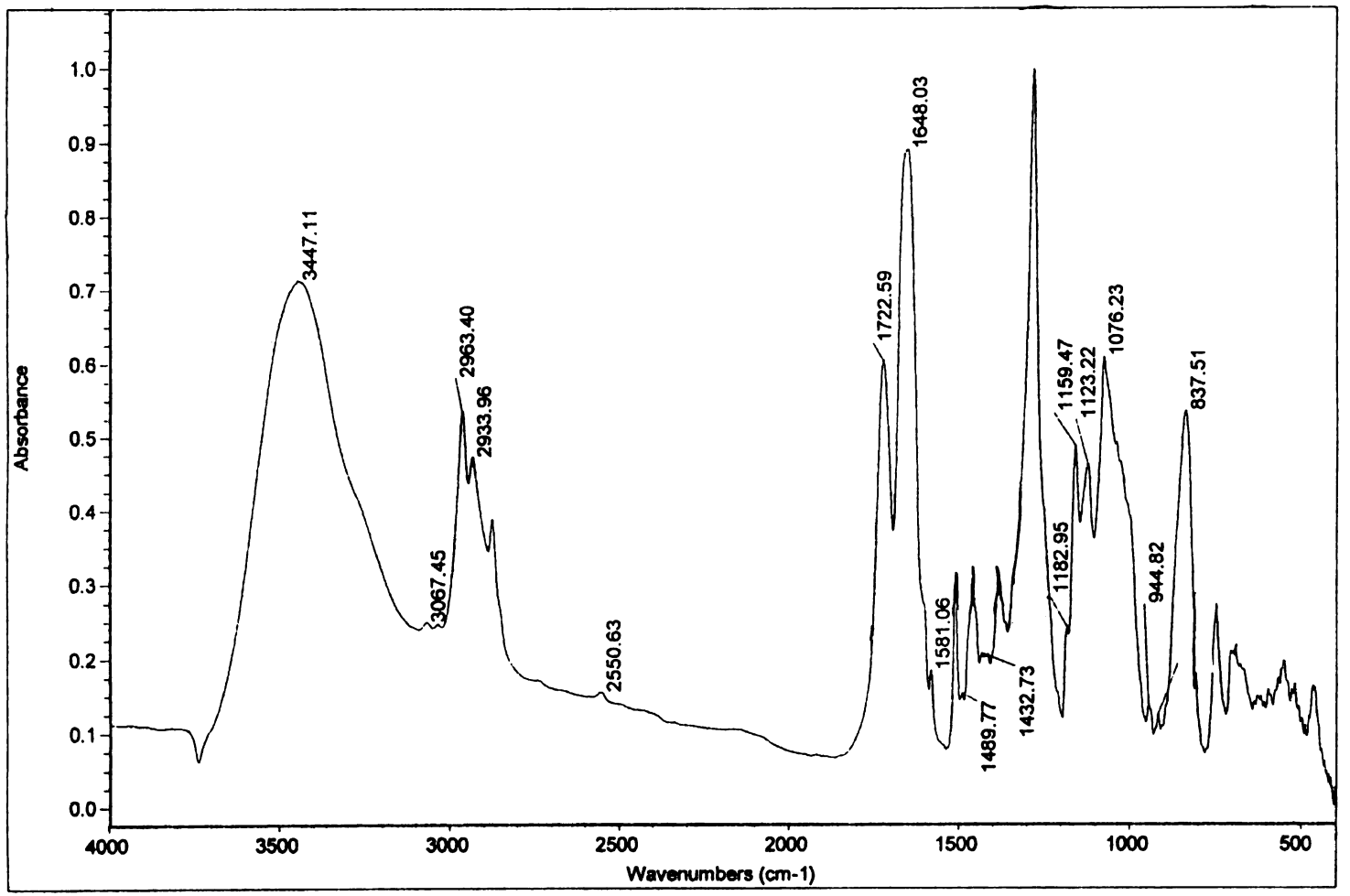

Figure 56. FTIR Spectrum of Covergirl Nailslicks Satin Mauve

Covergirl Nailslicks Silver Plum

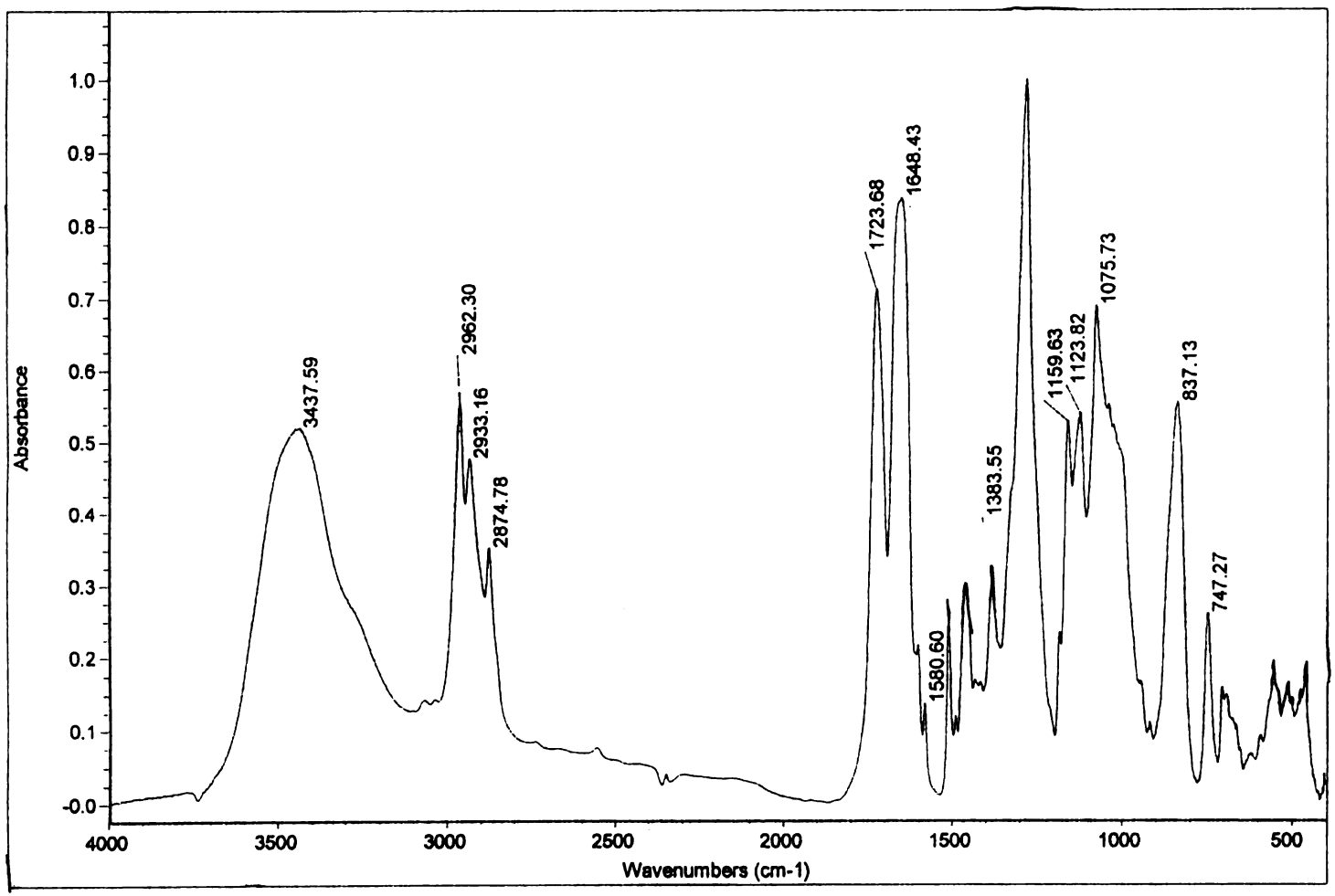

Figure 57. FTIR Spectrum of Covergirl Nailslicks Silver Plum

Covergirl Nailslicks Tickled Pink

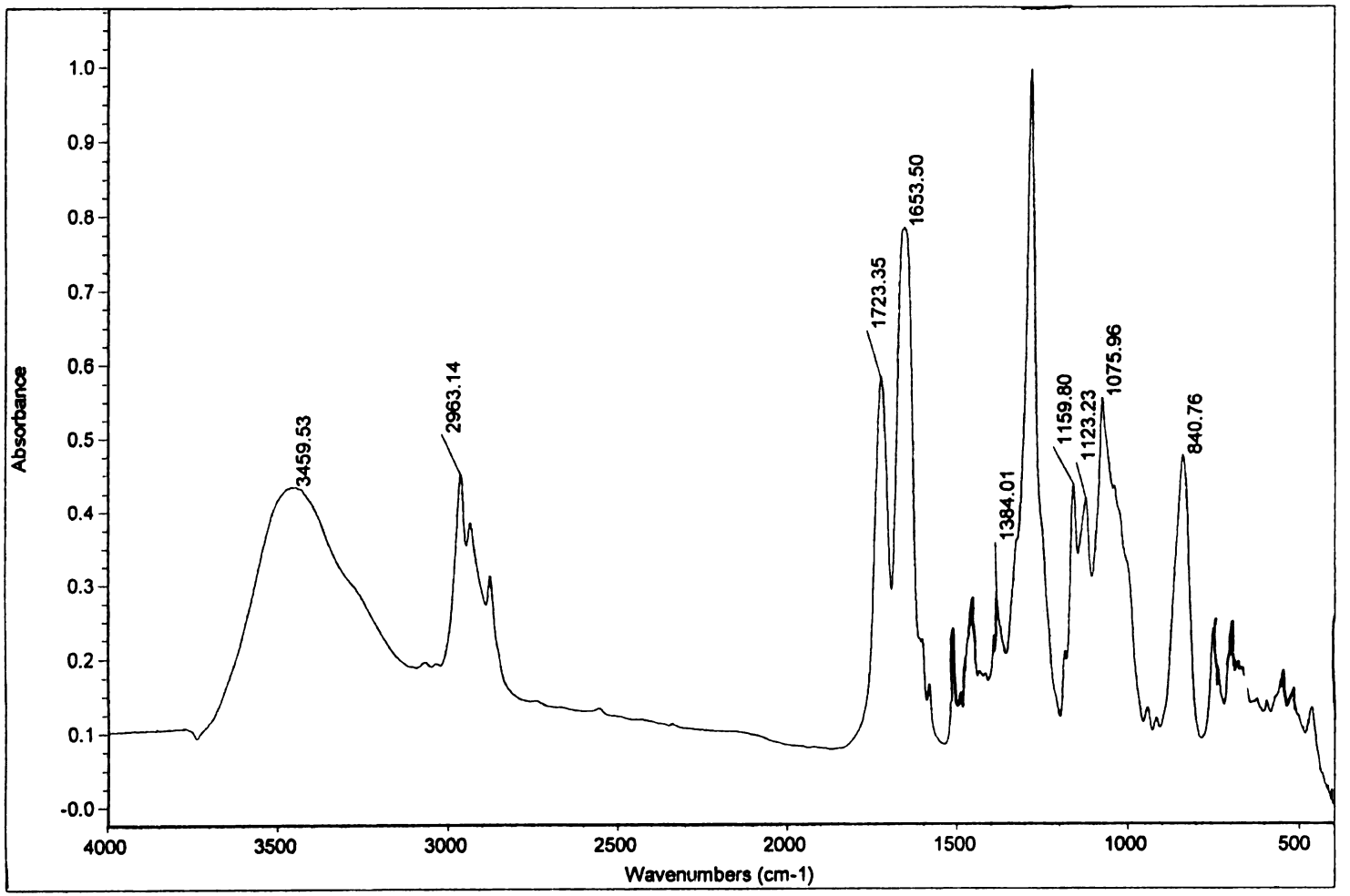

Figure 58. FTIR Spectrum of Covergirl Nailslicks Tickled Pink

Covergirl Nailslicks Twilight Mauve

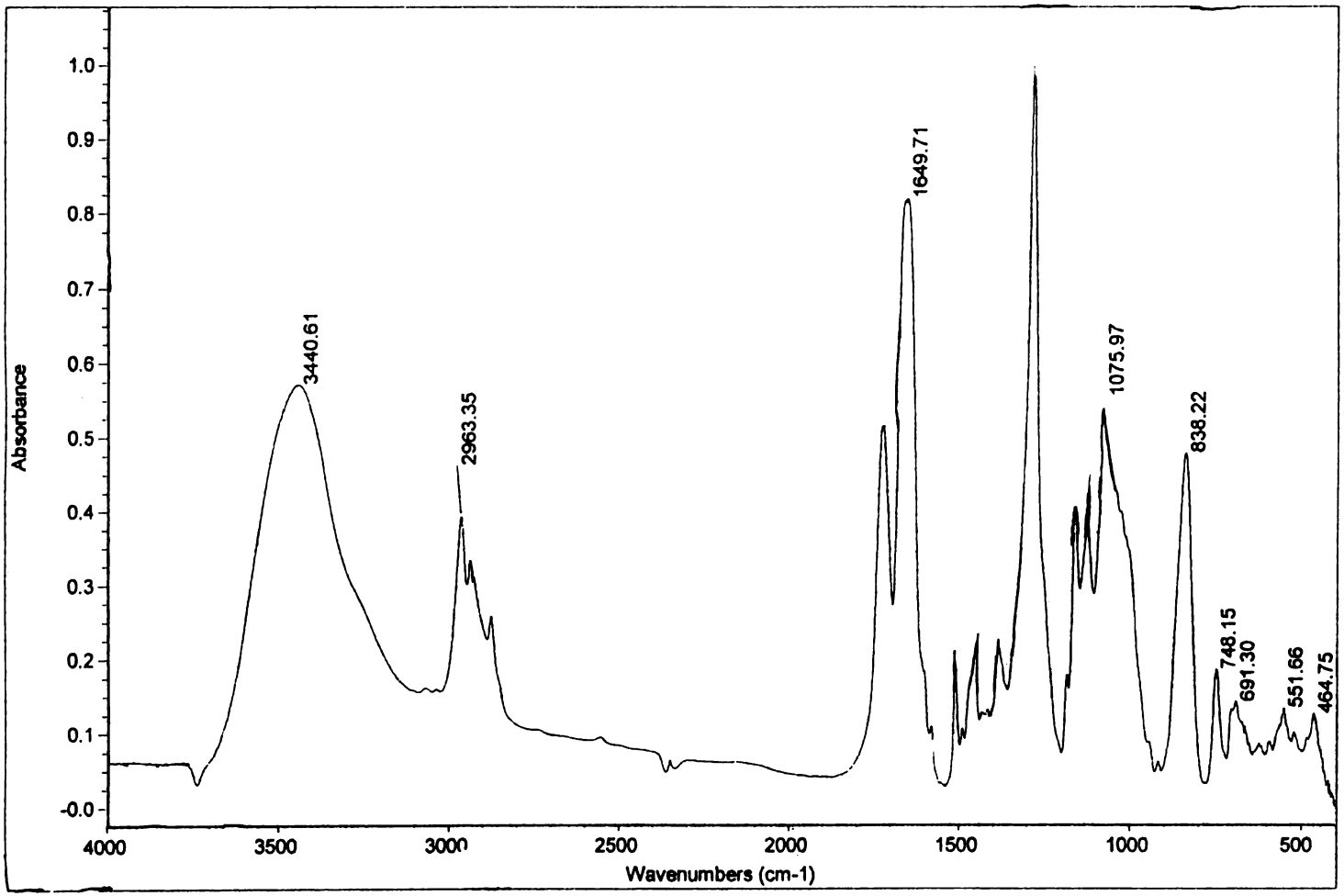

Figure 59. FTIR Spectrum of Covergirl Nailslicks Twilight Mauve

Covergirl Nailslicks Well Red

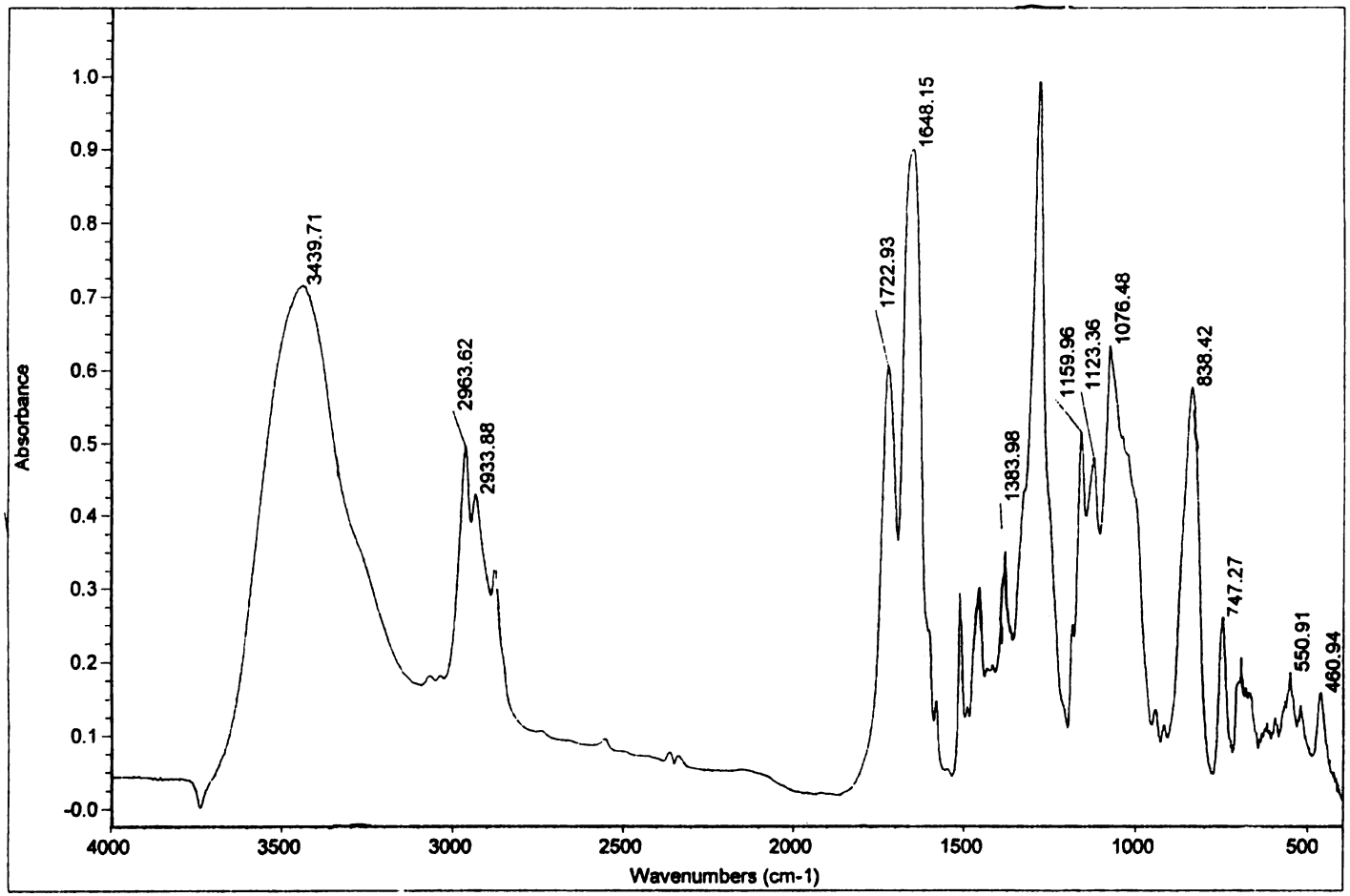

Figure 60. FTIR Spectrum of Covergirl Nailslicks Well Red

Lot #2170 Covergirl Nailslicks Ice Blue Pink

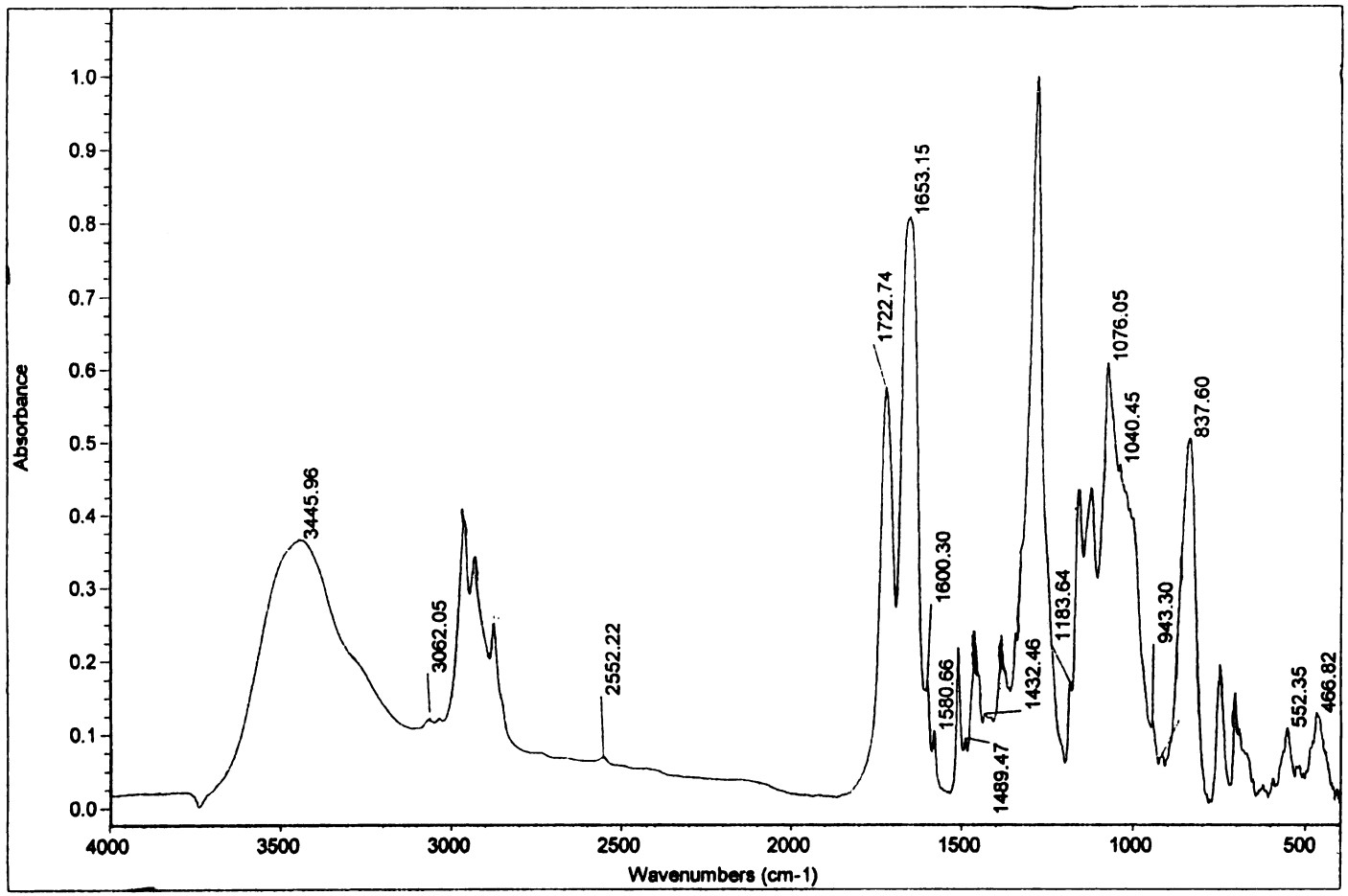

Figure 61. FTIR Spectrum of Covergirl Nailslicks Ice Blue Pink Lot # 2170

Lot # 2206 Covergirl Nailslicks Ice Blue Pink

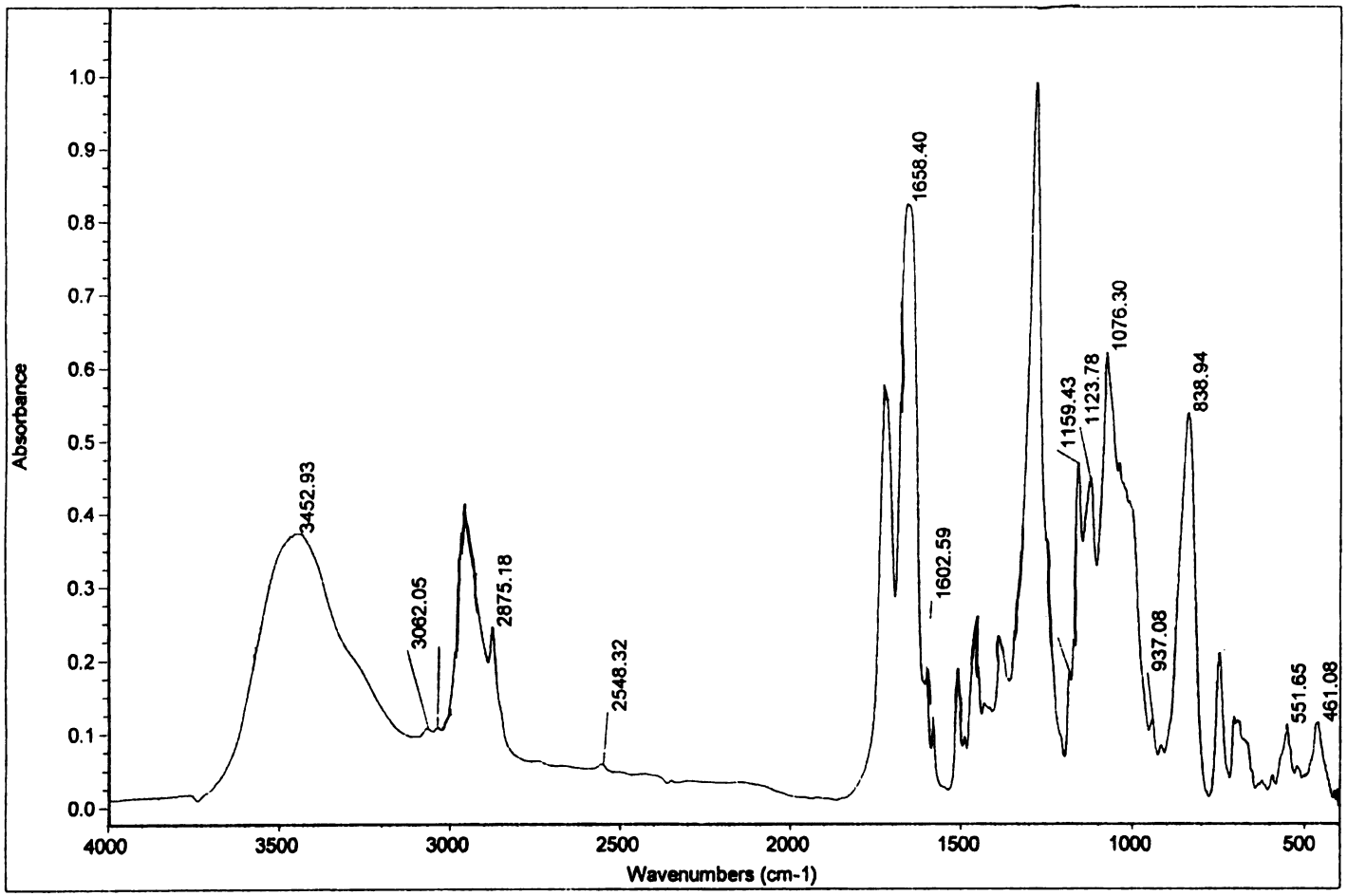

Figure 62. FTIR Spectrum of Covergirl Nailslicks Ice Blue Pink Lot # 2206

Lot# 2232 Covergirl Nailslicks Ice Blue Pink

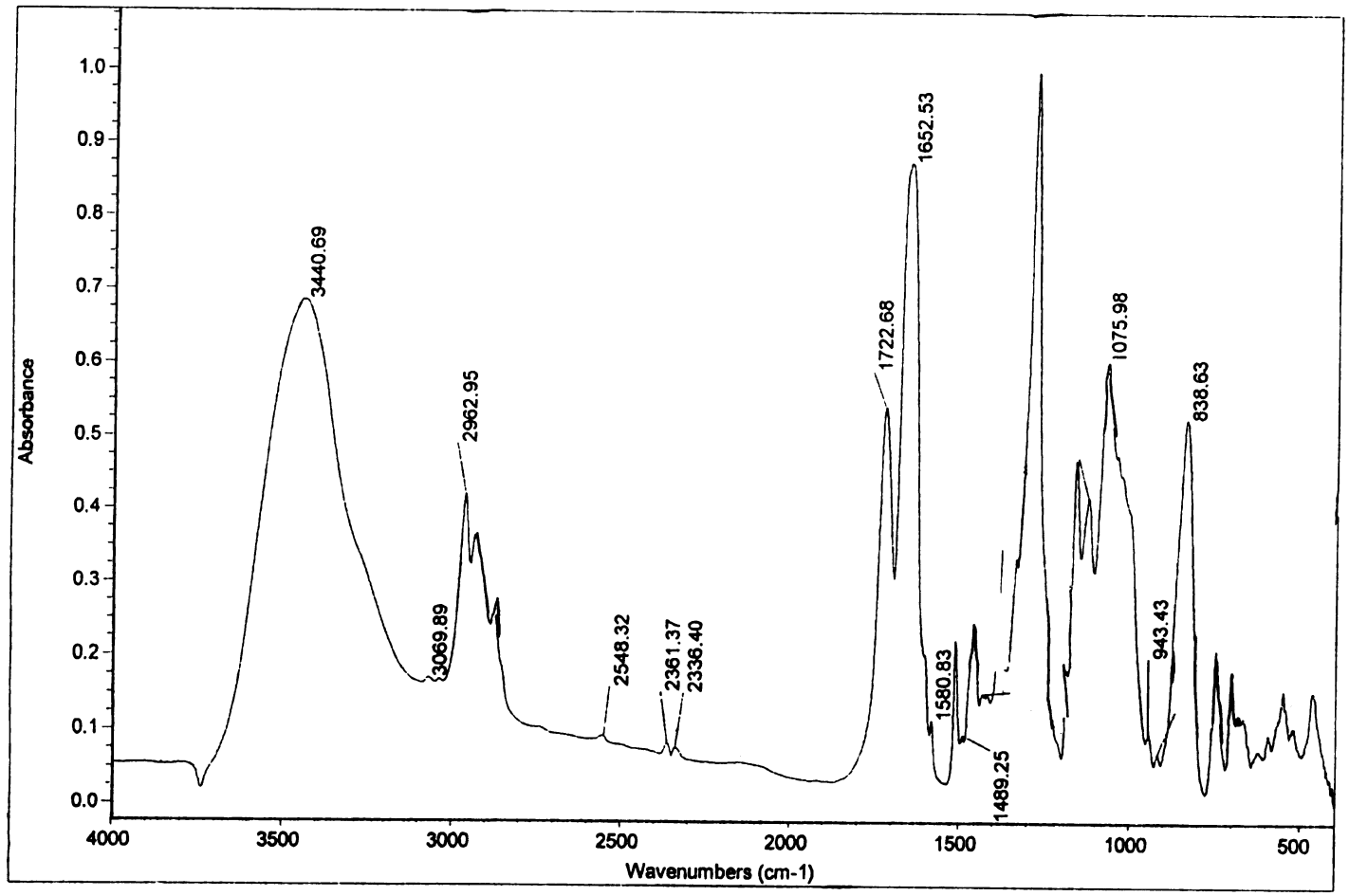

Figure 63. FTIR Spectrum of Covergirl Nailslicks Ice Blue Pink Lot # 2232

Blind Sample # 2

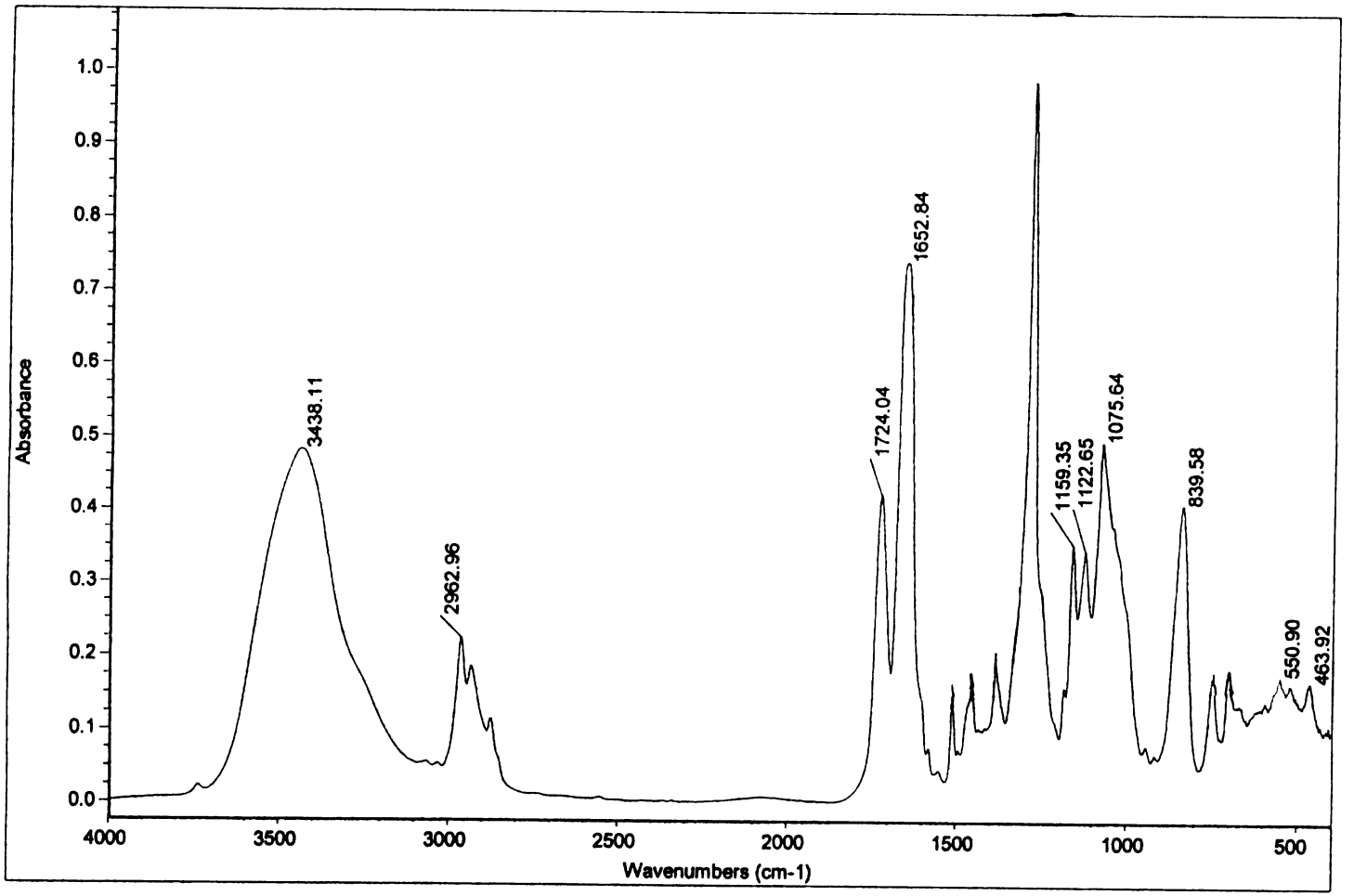

Figure 64. FTIR Spectrum of Blind Sample #2

Blind Sample #4

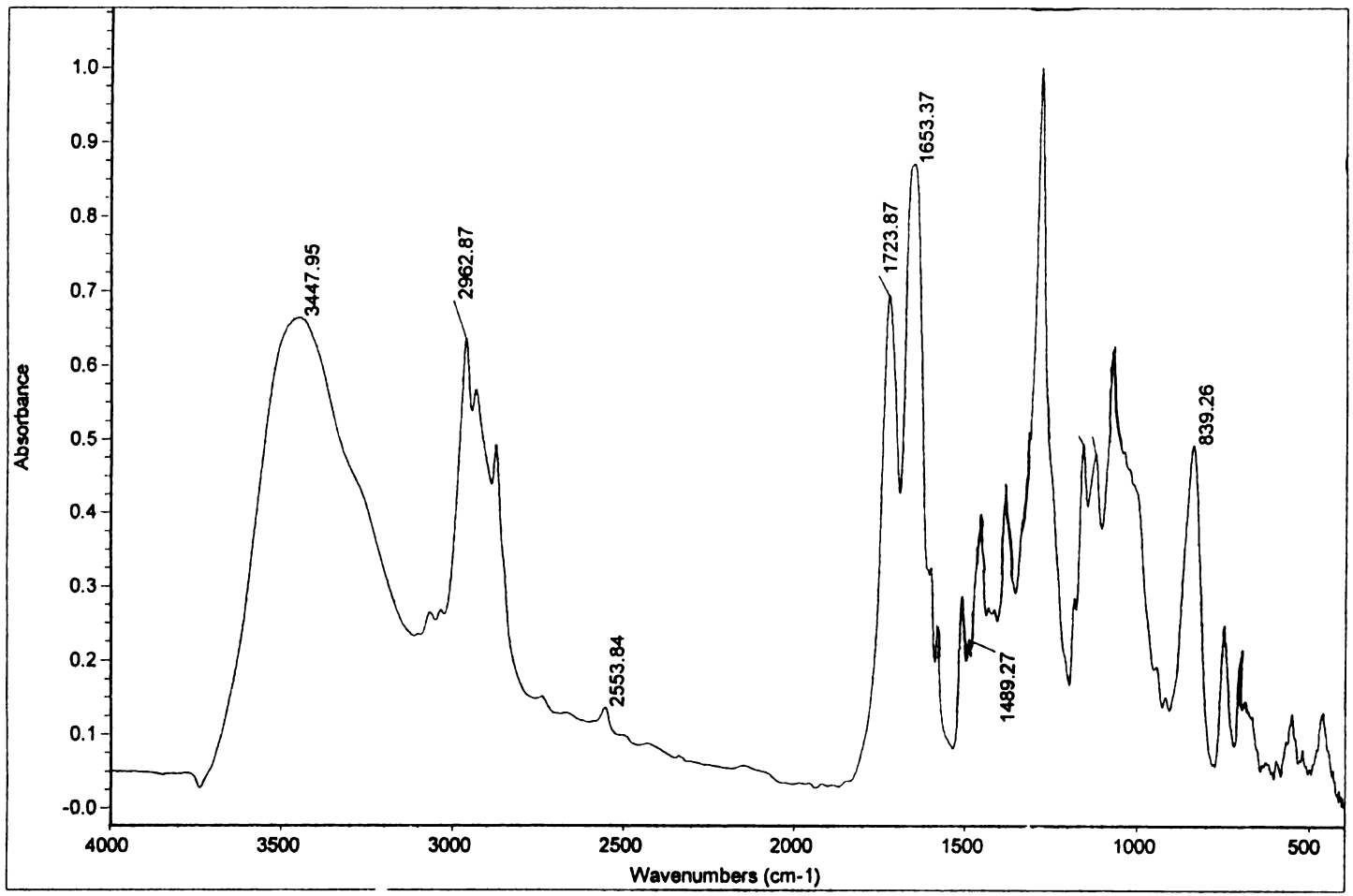

Figure 65. FTIR Spectrum of Blind Sample #4

Blind Sample # 5

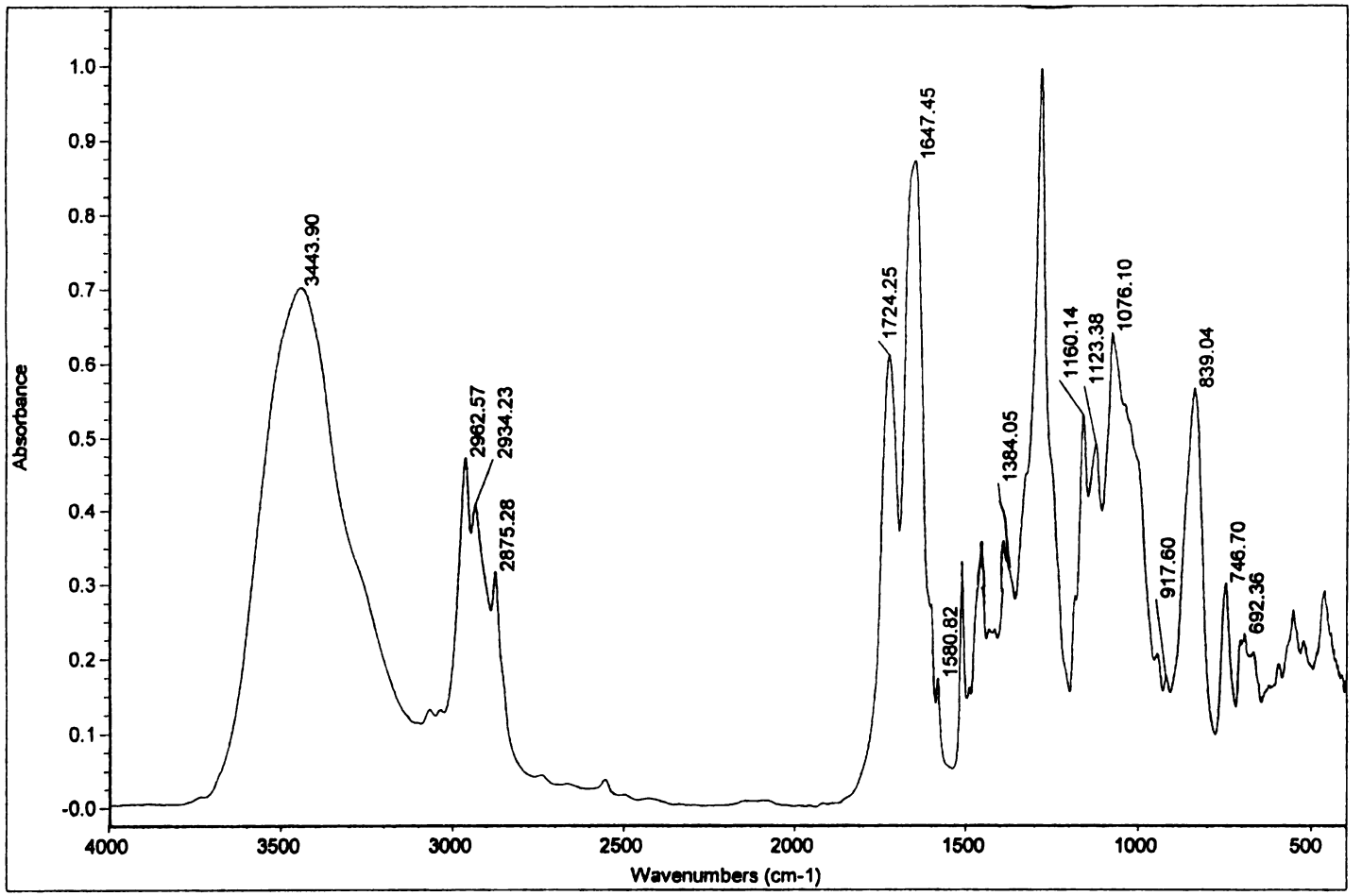

Figure 66. FTIR Spectrum of Blind Sample #5

Blank KBr Sample

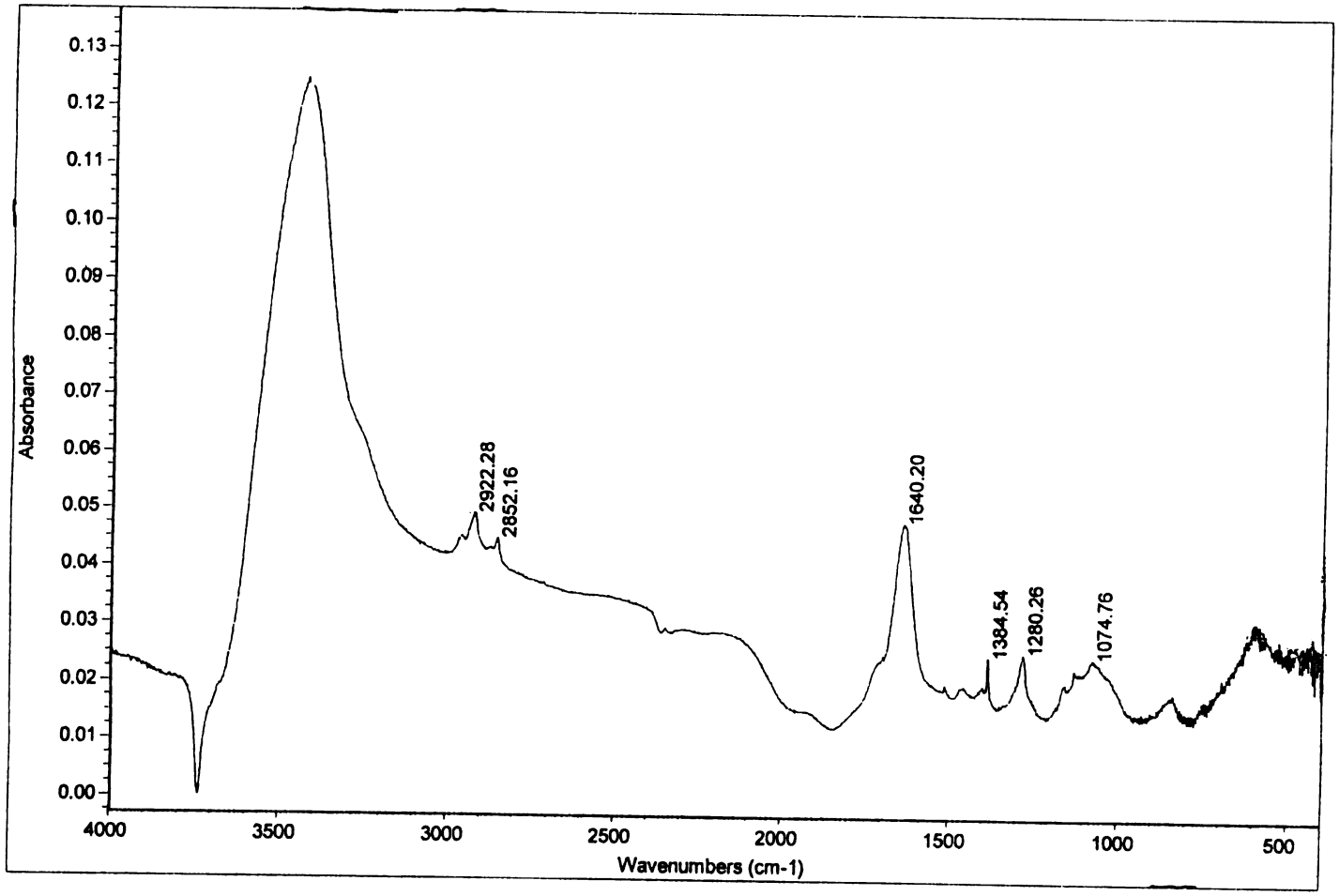

Figure 67. FTIR Spectrum of Blank Potassium Bromide Sample

APPENDIX C

Microspectrophotometry UV-Visible Spectra

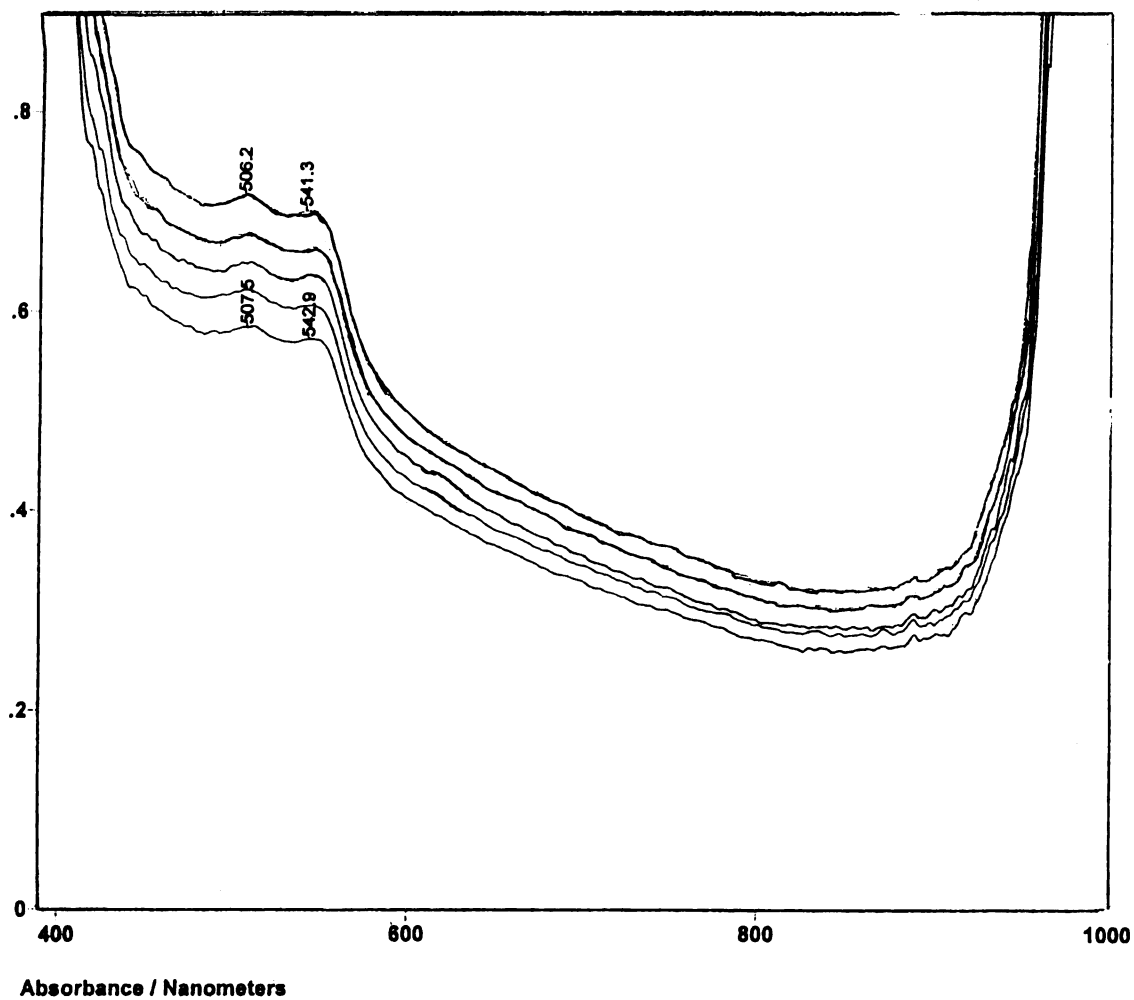

Figure 68. UV-Visible Spectra of 15 Minute Aged Sample

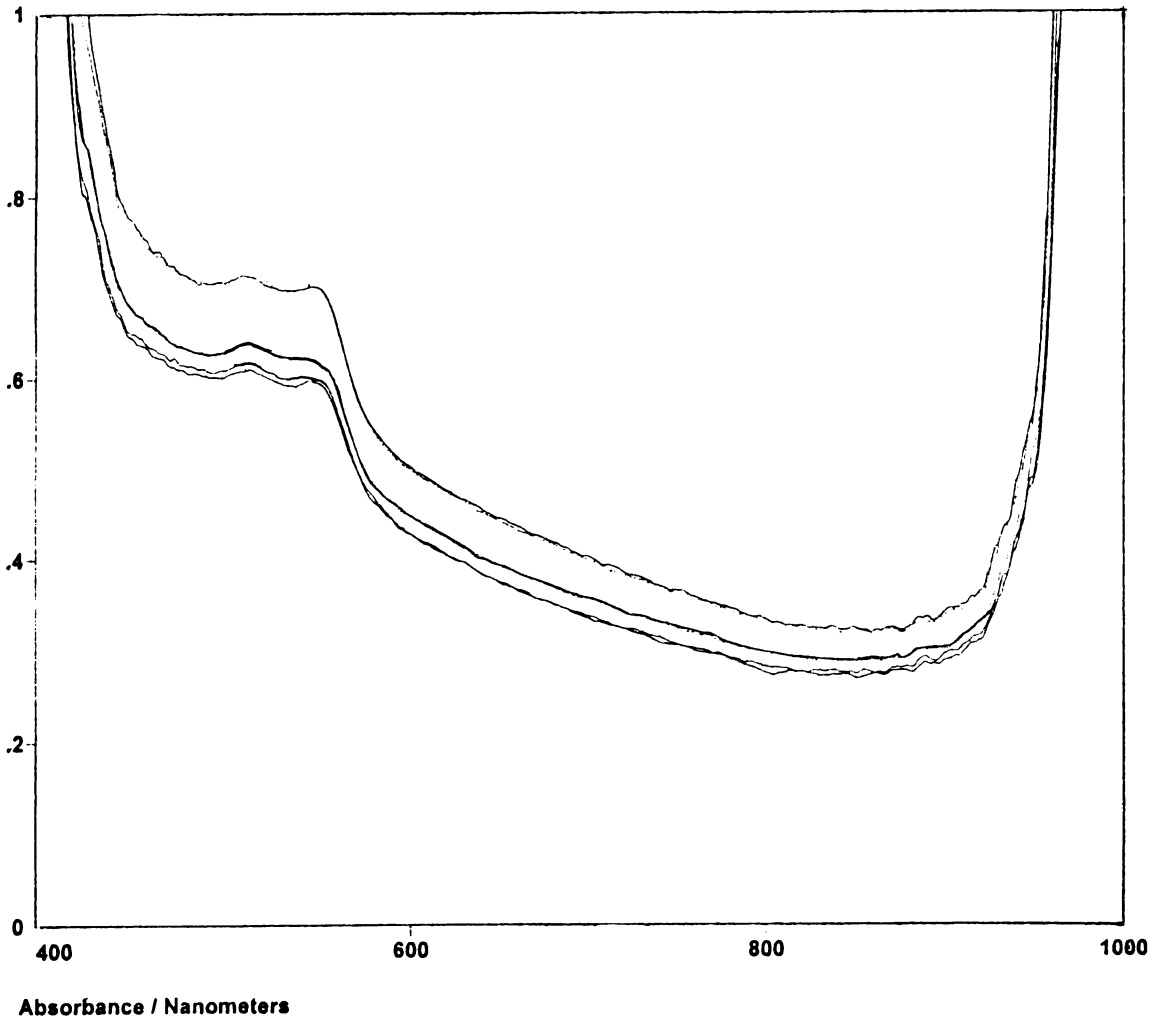

Figure 69. UV-Visible Spectra of 45 Minute Aged Sample

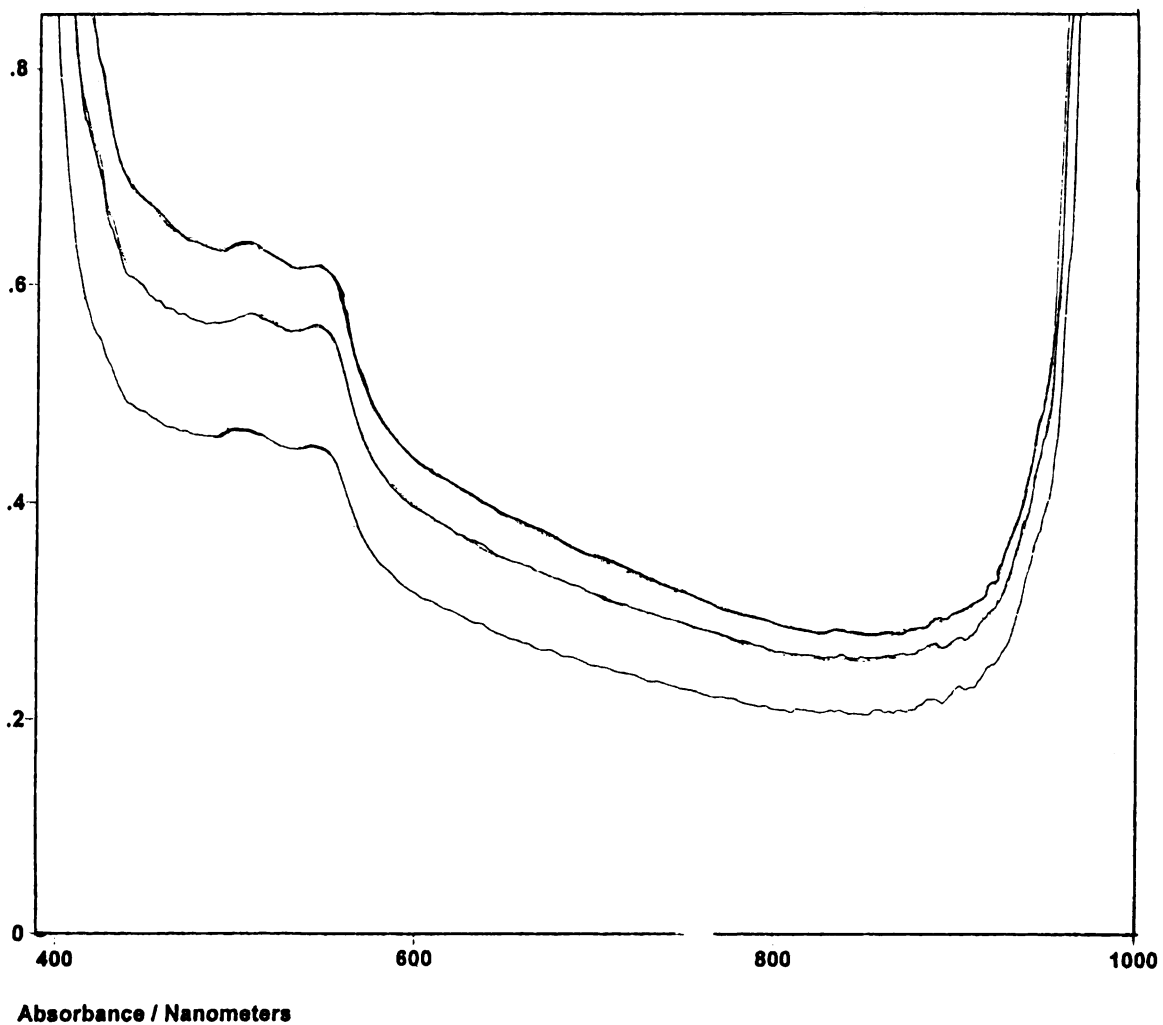

Figure 70. UV-Visible Spectra of 60 Minute Aged Sample

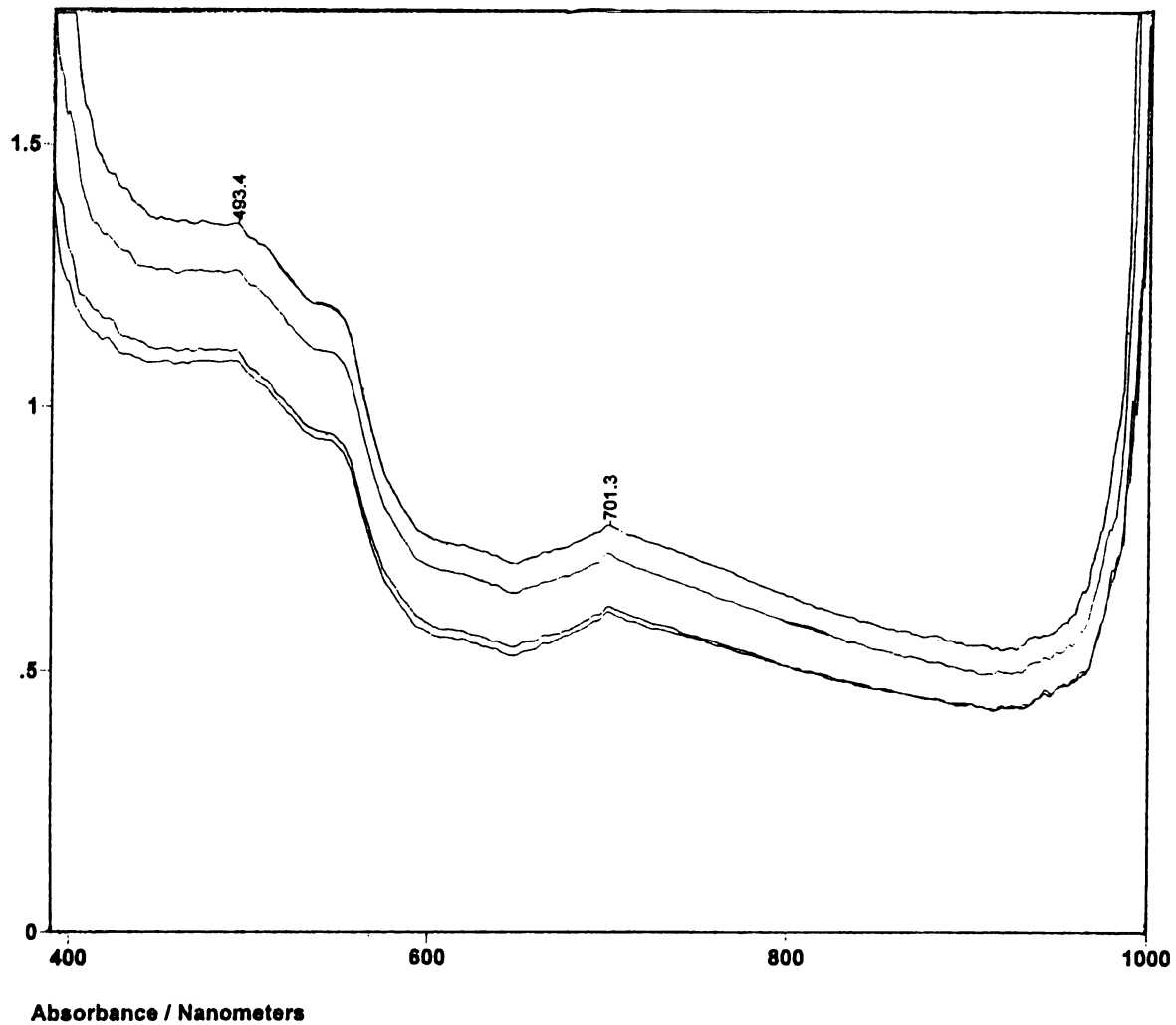

Figure 71. UV-Visible Spectra of 90 Minute Aged Sample

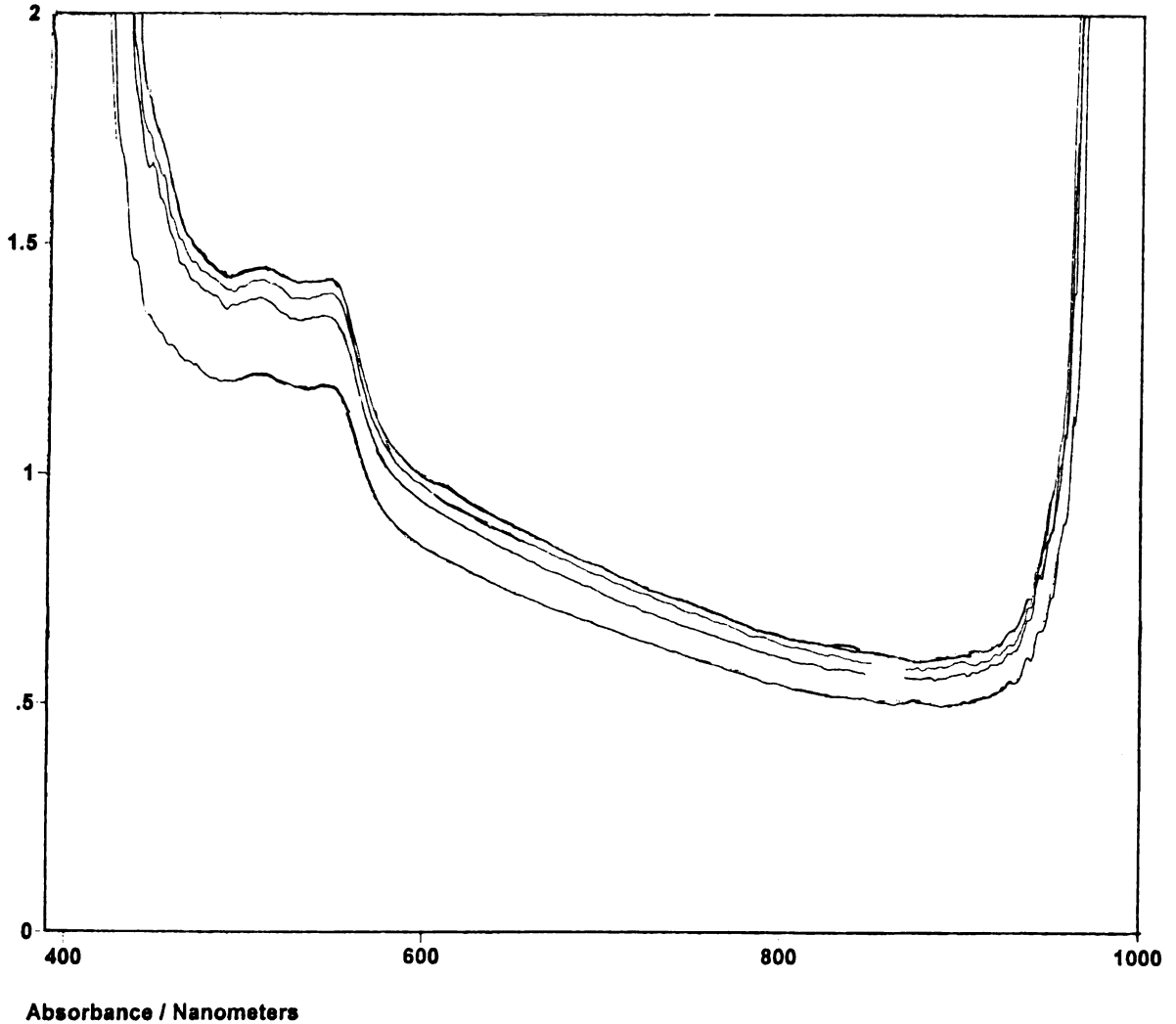

Figure 72. UV-Visible Spectra of 2 Hour Aged Sample

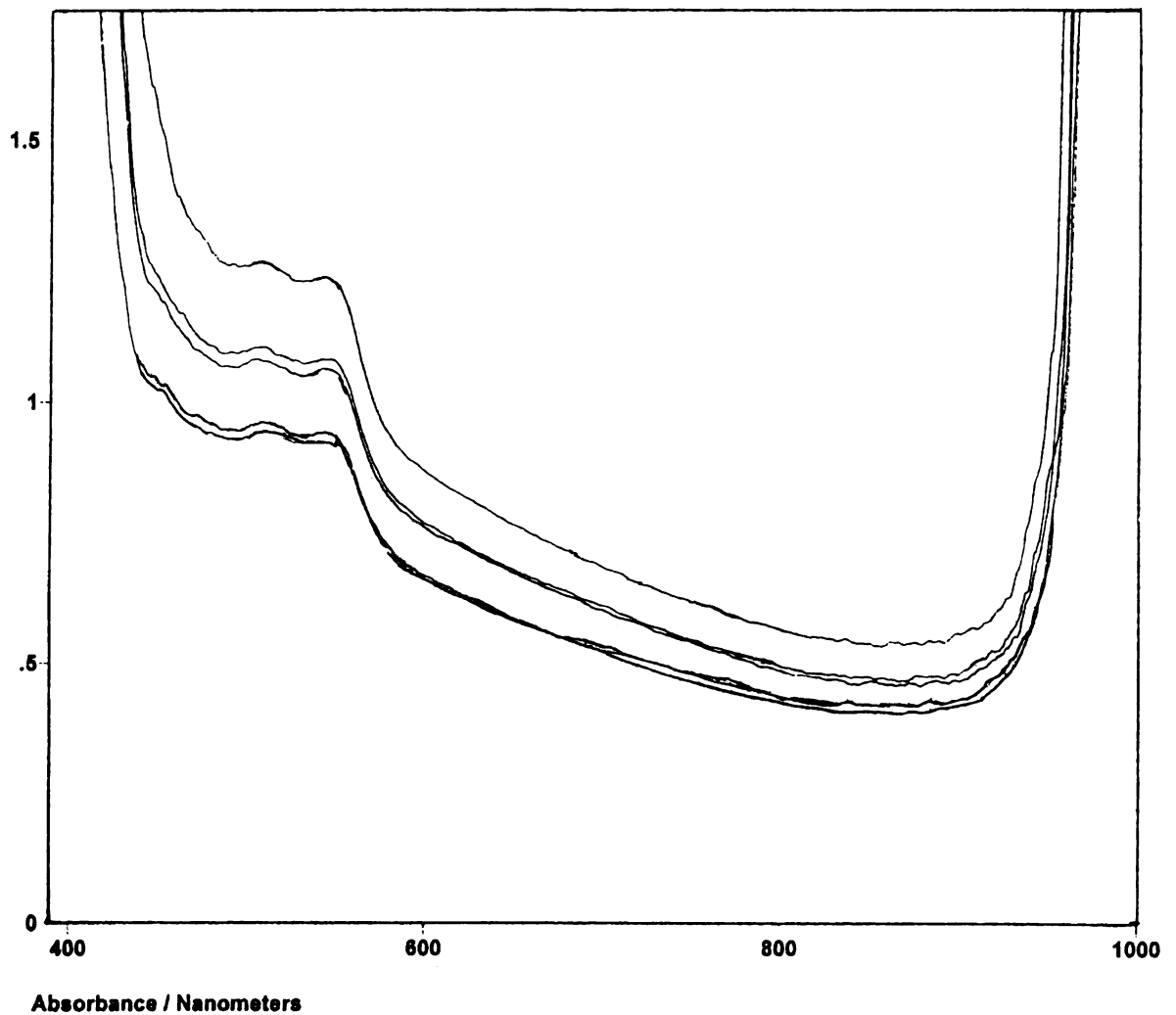

Figure 73. UV-Visible Spectra of 3 Hour Aged Sample

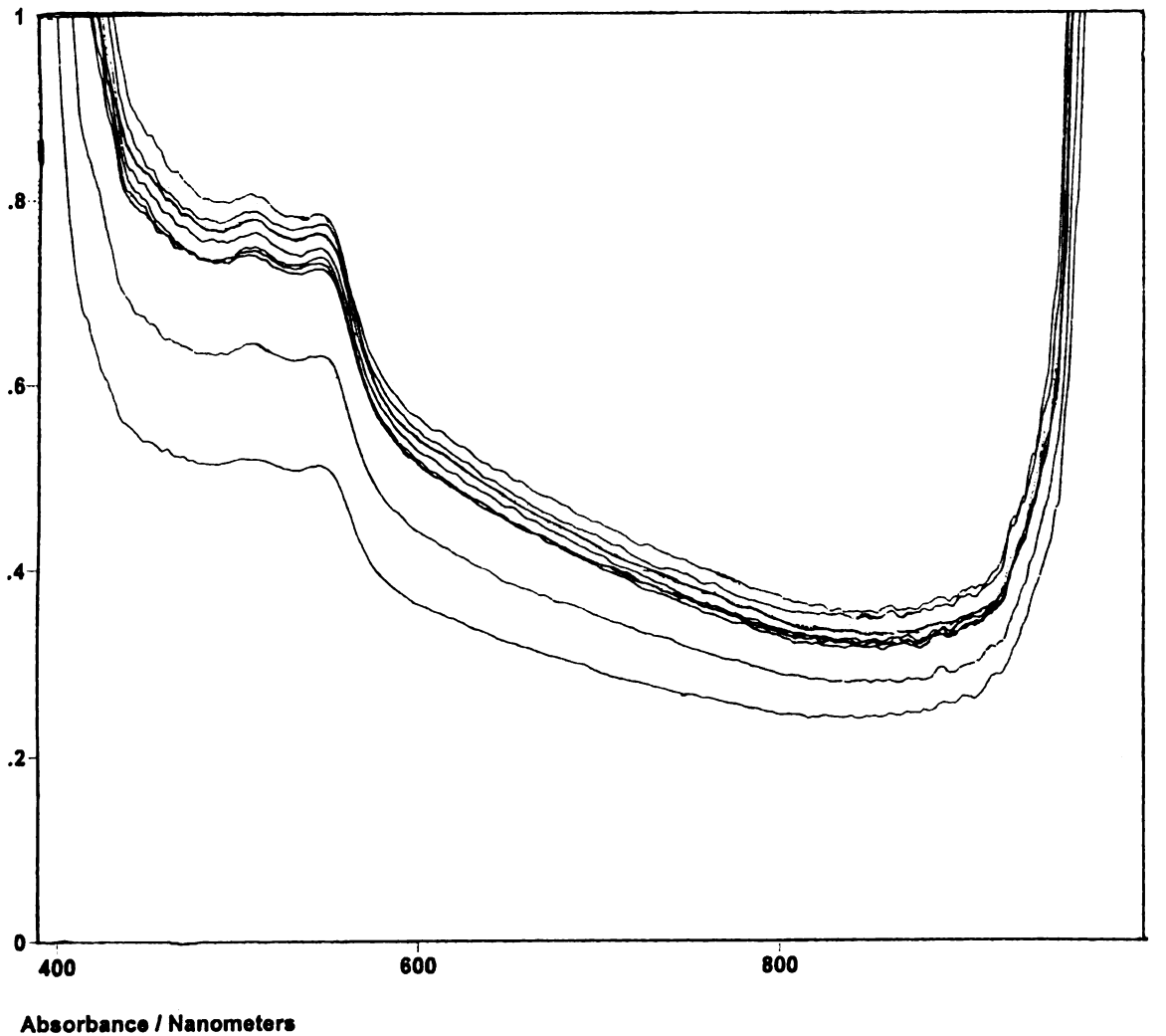

Figure 74. UV-Visible Spectra of Reproducibility Samples #11-20

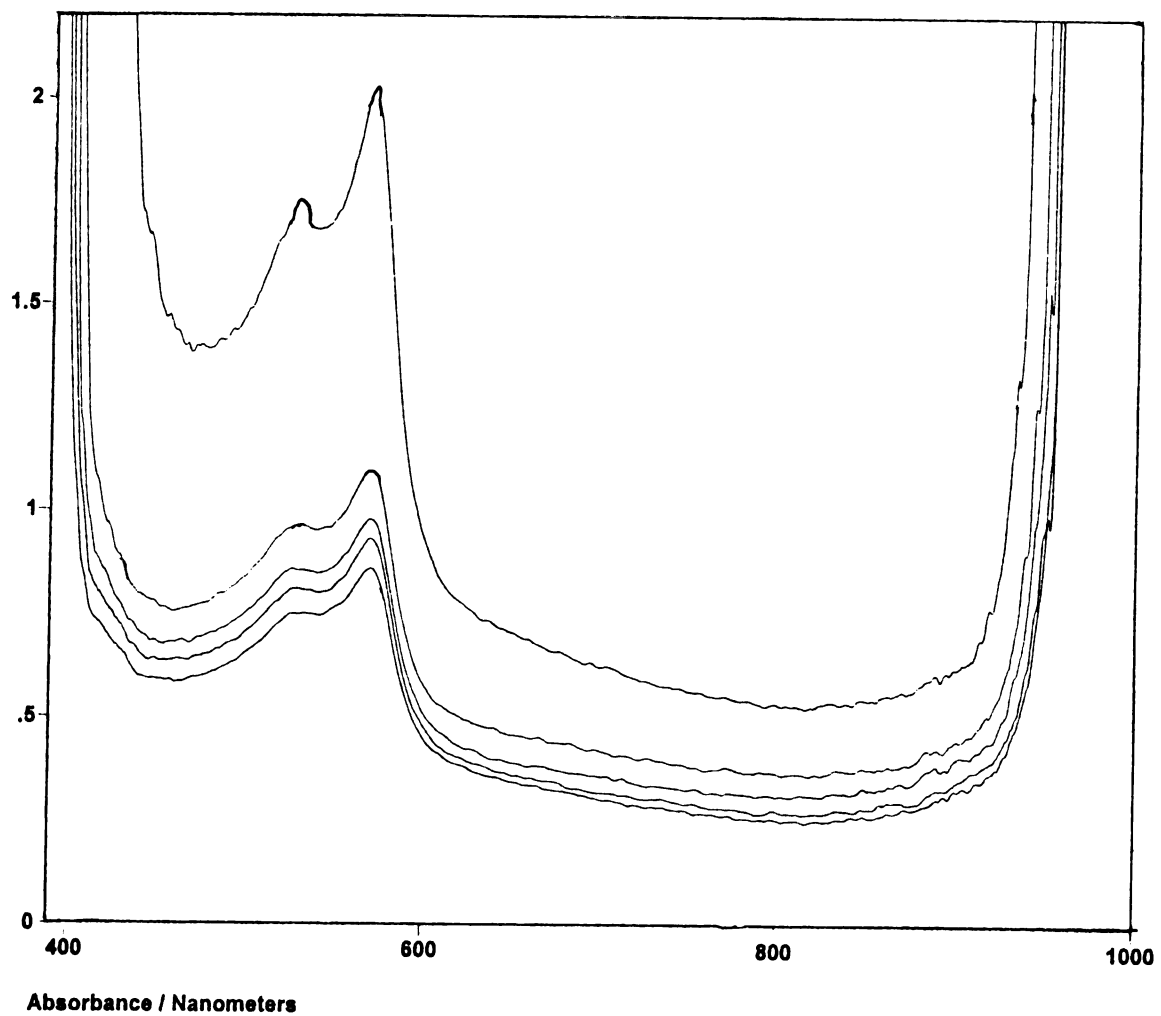

Figure 75. UV-Visible Spectra of Covergirl Nailslicks Cranberry Cream

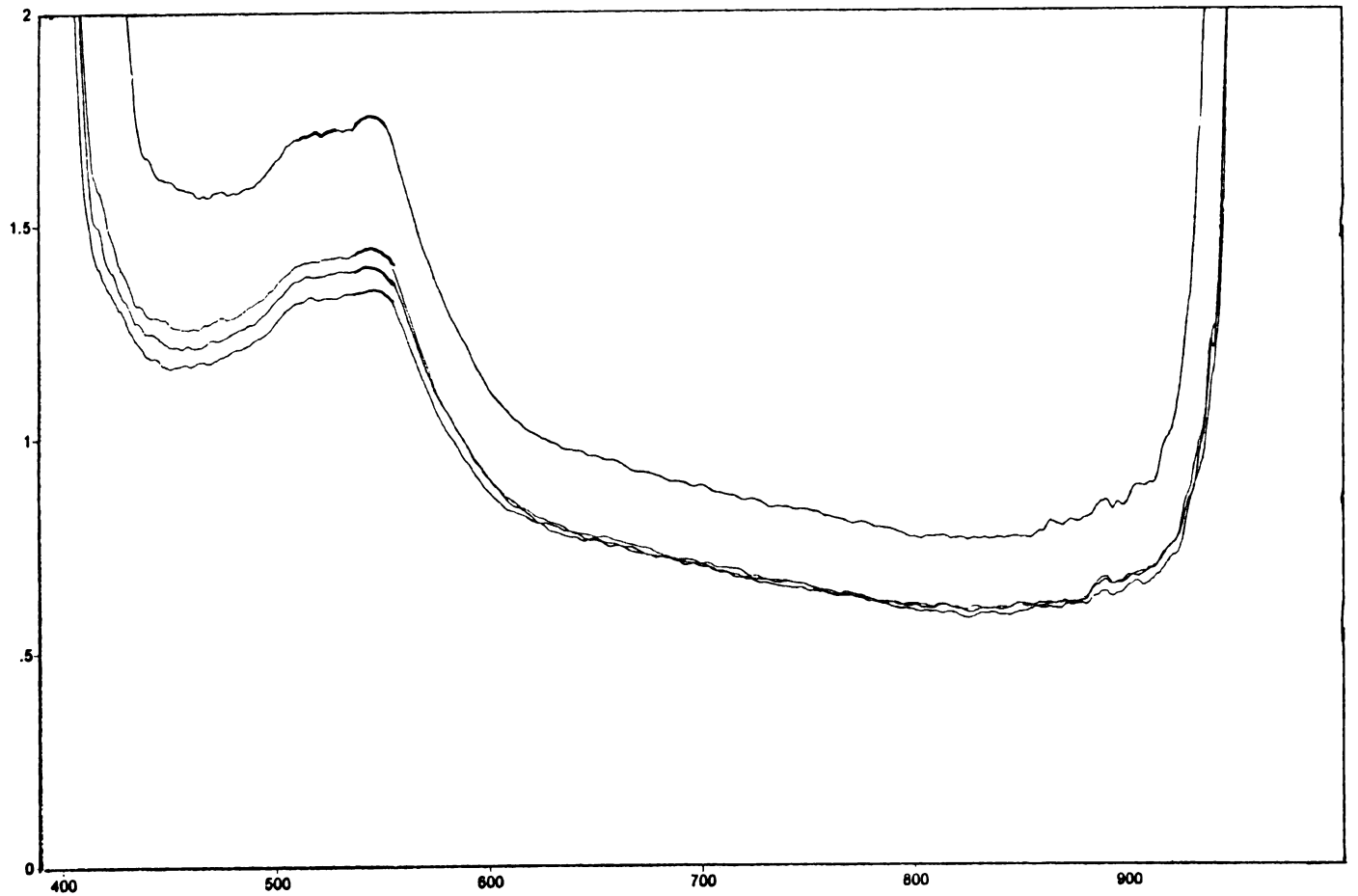

Figure 76. UV-Visible Spectra of L'Oreal Mulberry Creme

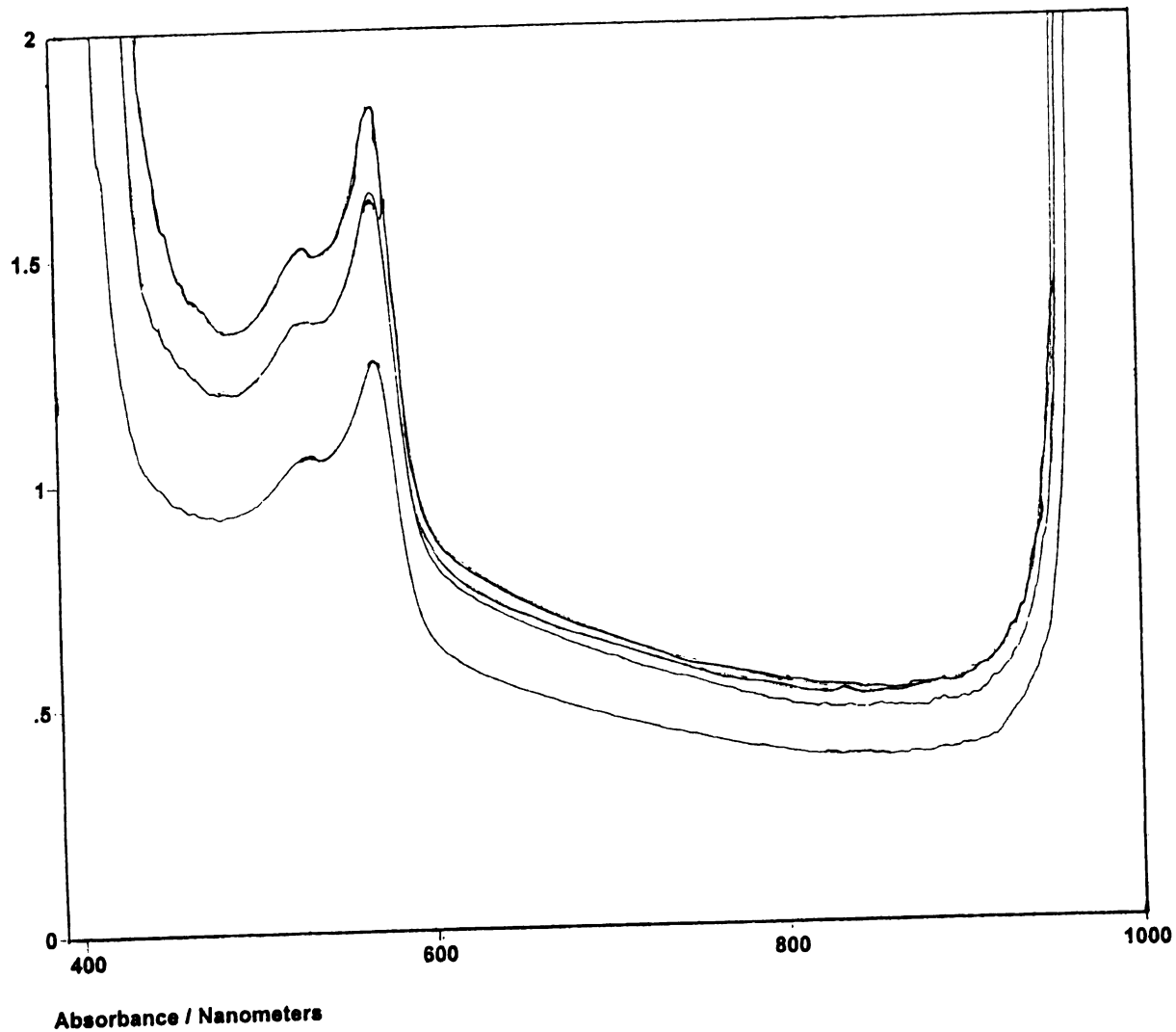

Figure 77. UV-Visible Spectra of Maybelline Native Berry

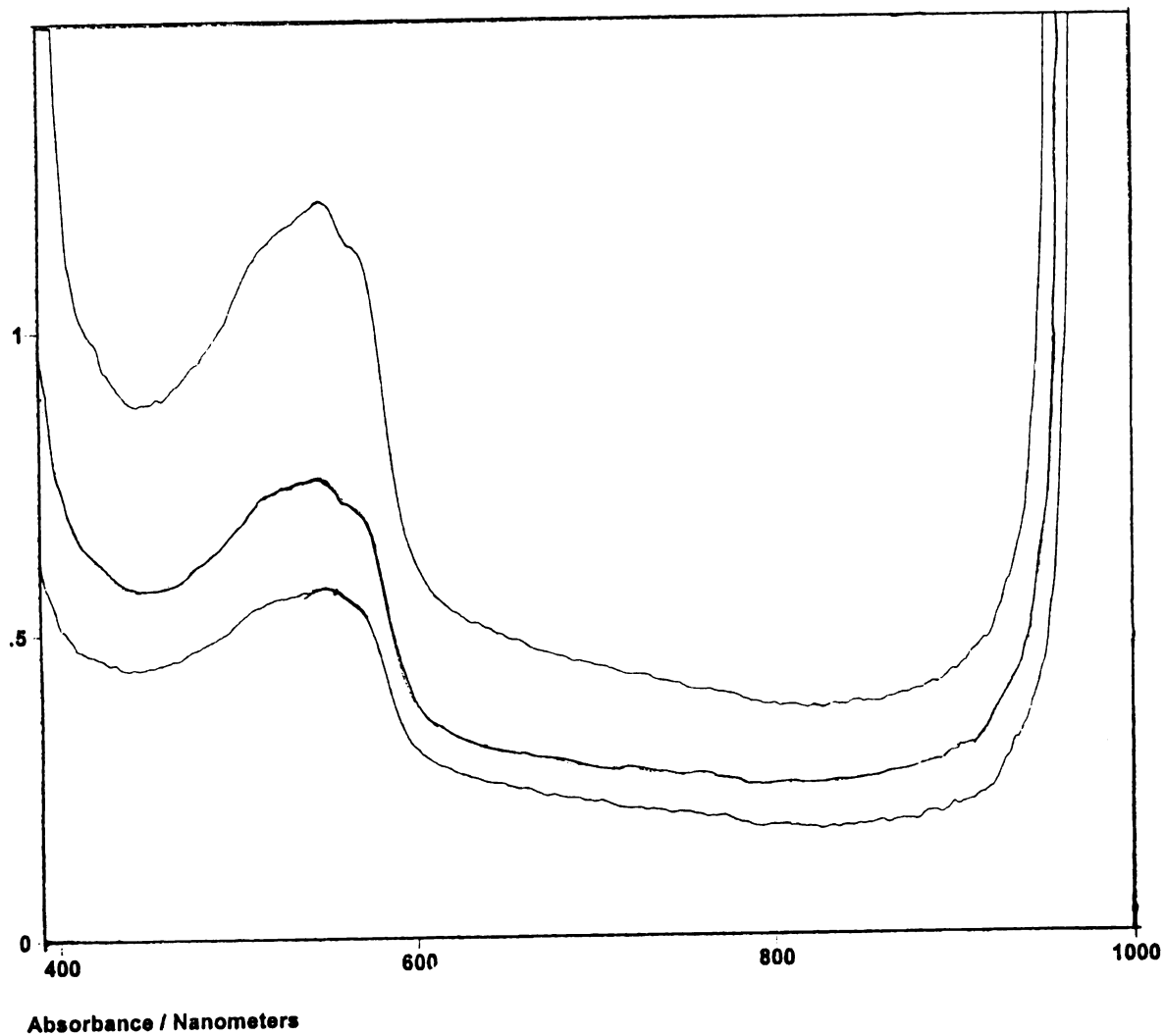

Figure 78. UV-Visible Spectra of Revlon Love Her Madly

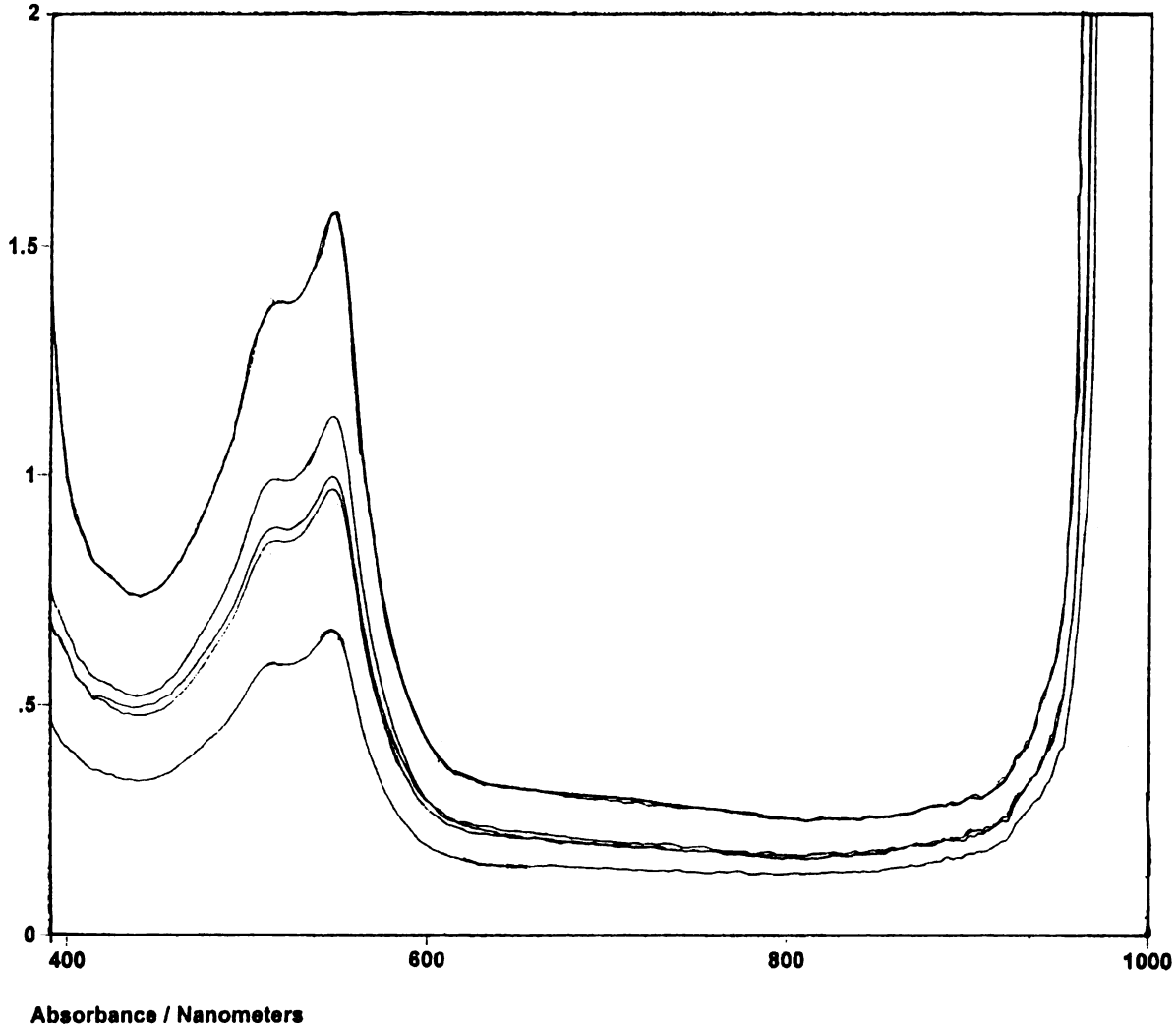

Figure 79. UV-Visible Spectra of Revlon Wine With Everything

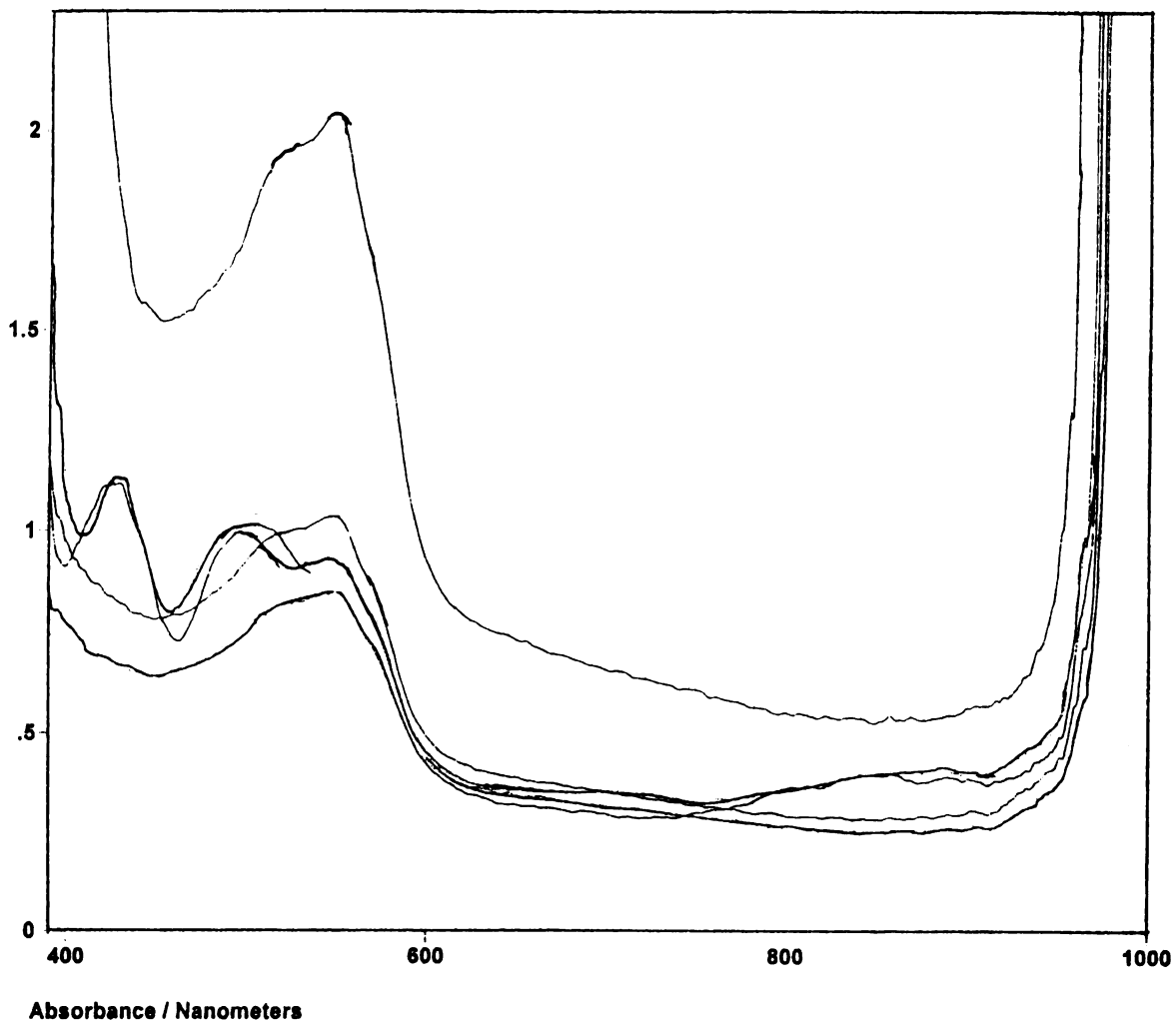

Figure 80. UV-Visible Spectra of Revlon Super Top Speed Winey

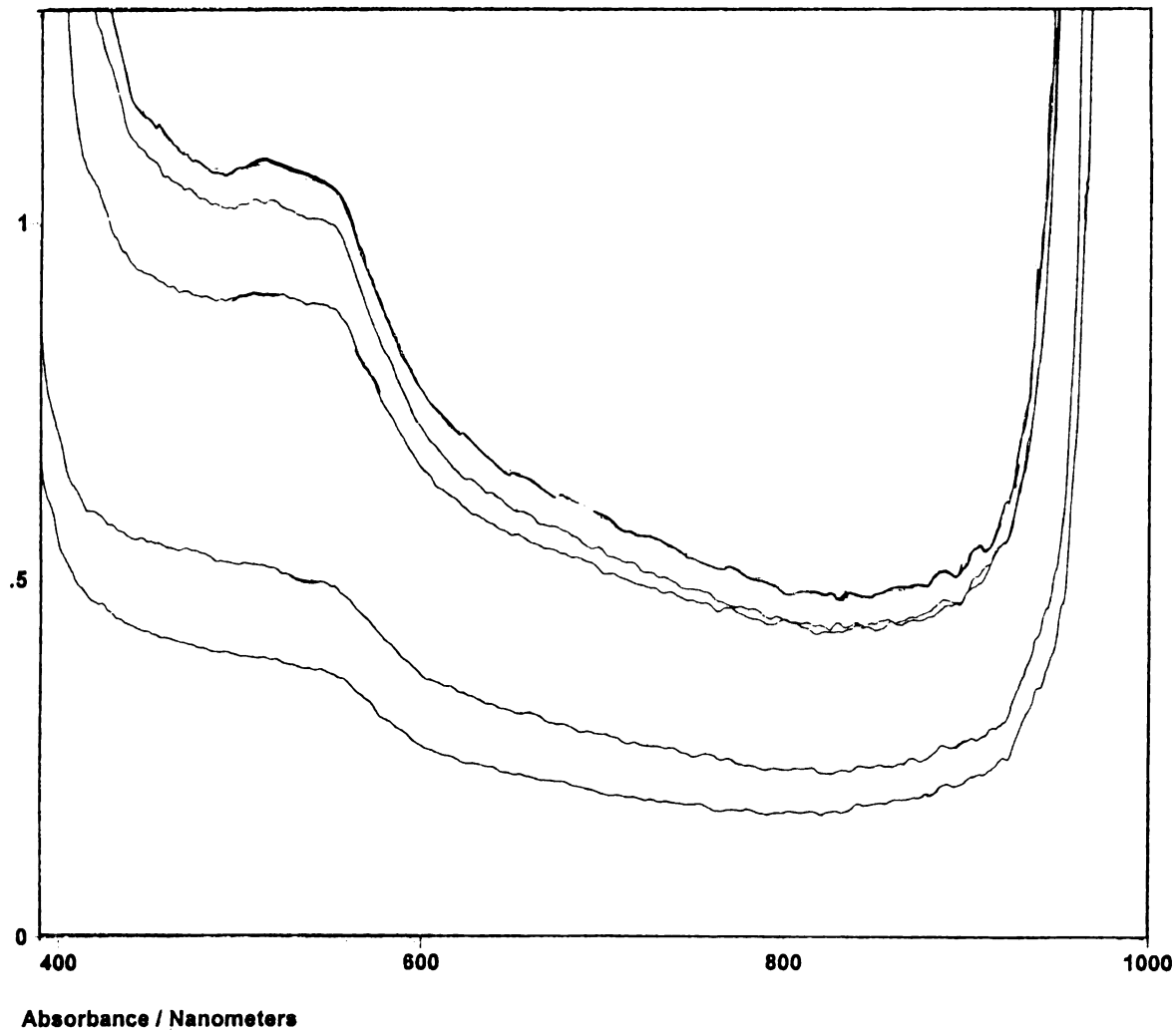

Figure 81. UV-Visible Spectra of Sally Hansen Hard As Nails Oasis Dawn Cream

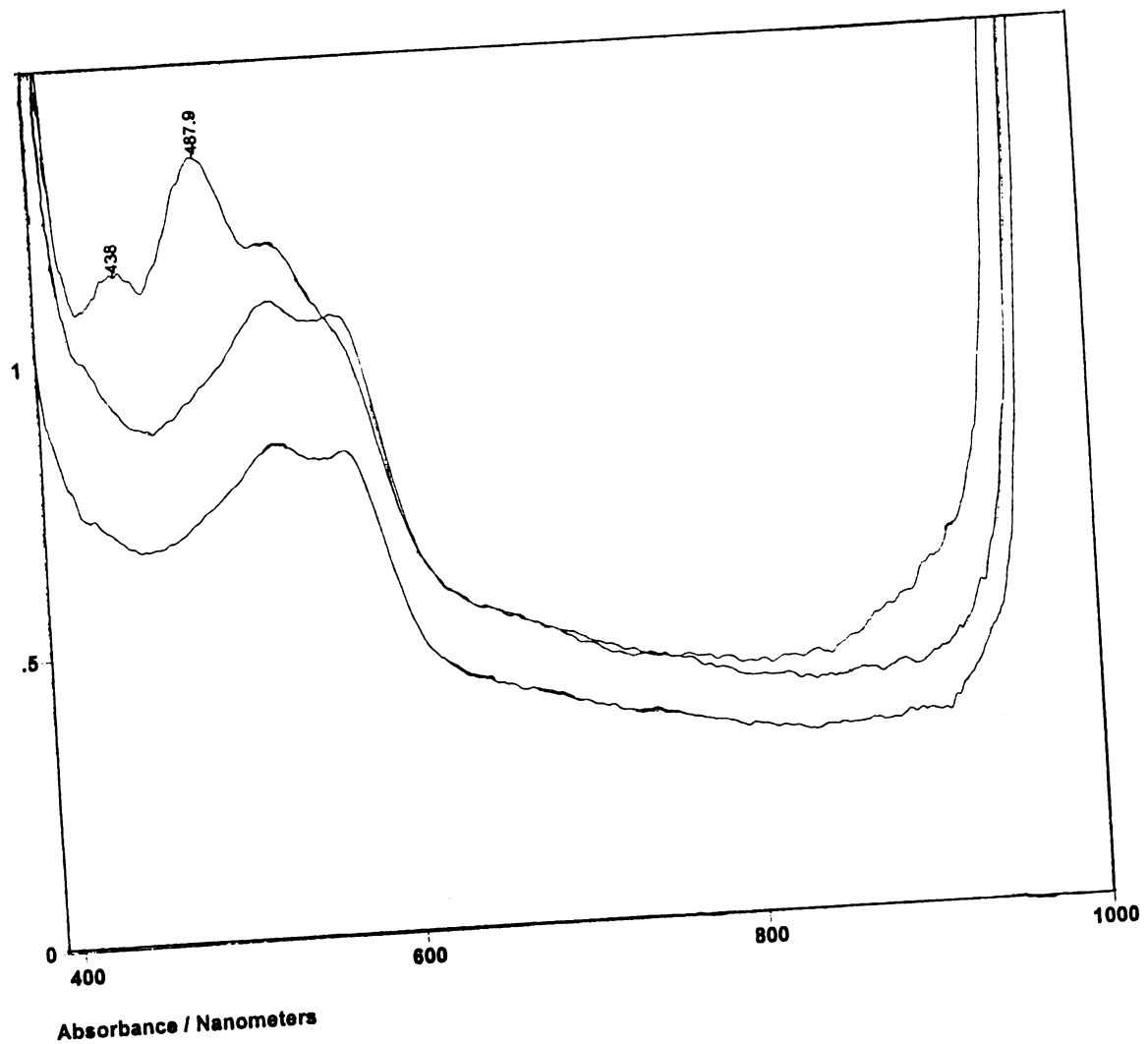

Figure 82. UV-Visible Spectra of Sally Hansen Maximum Growth Beautiful Berry

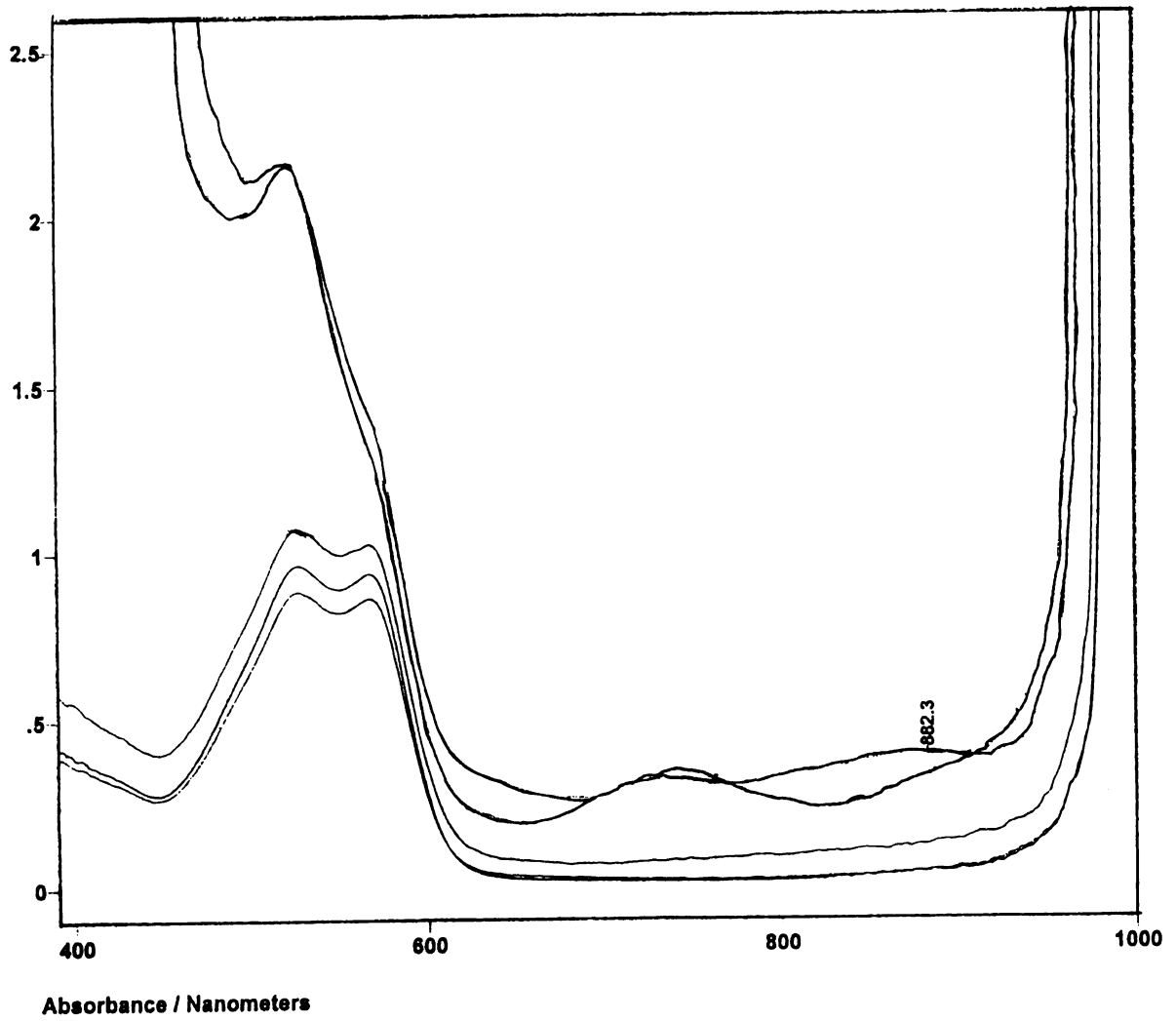

Figure 83. UV-Visible Spectra of Covergirl Nailslicks Cabernet

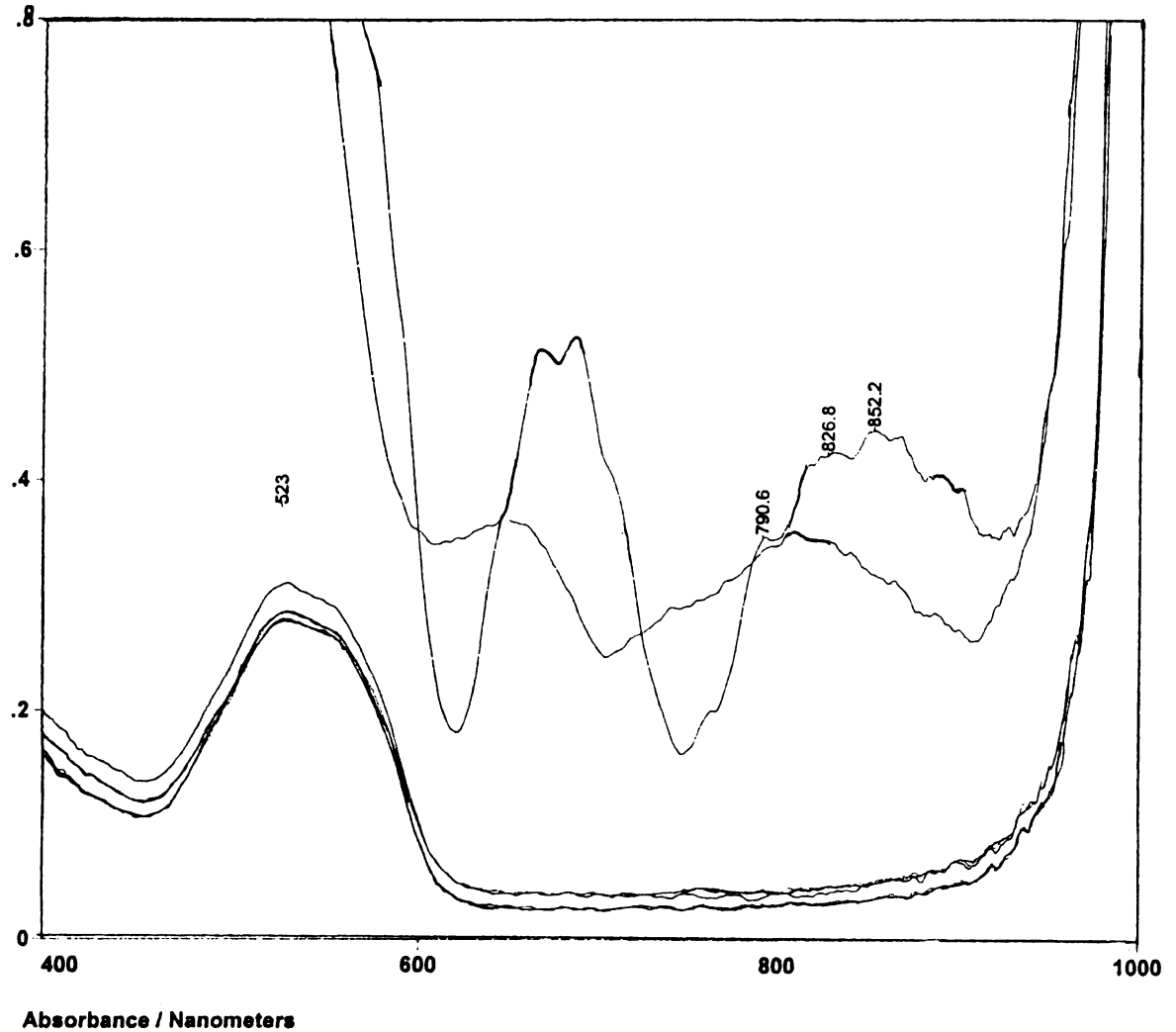

Figure 84. UV-Visible Spectra of Covergirl Nailslicks Cherry Brandy

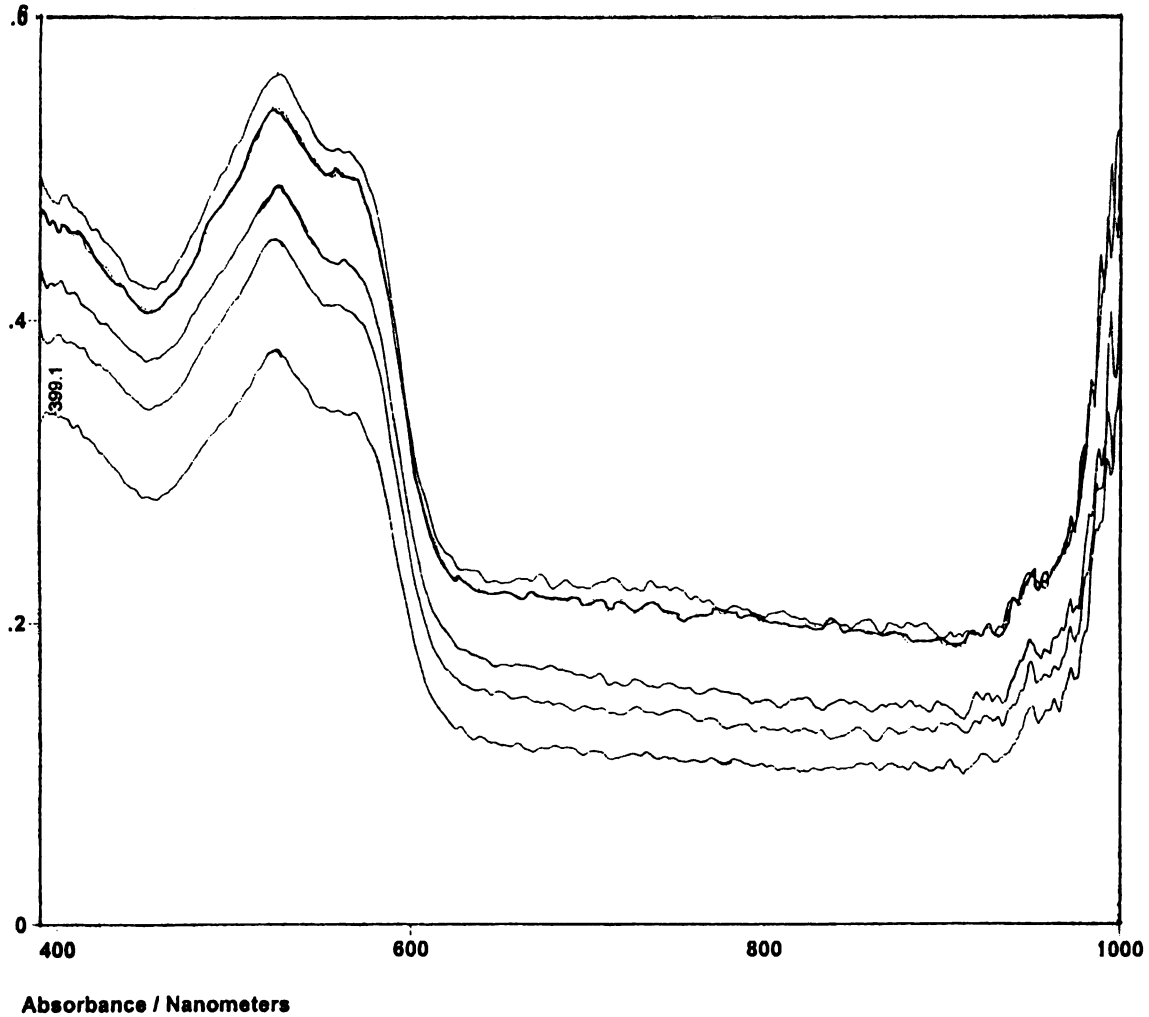

Figure 85. UV-Visible Spectra of Covergirl Nailslicks Cherry Truffle

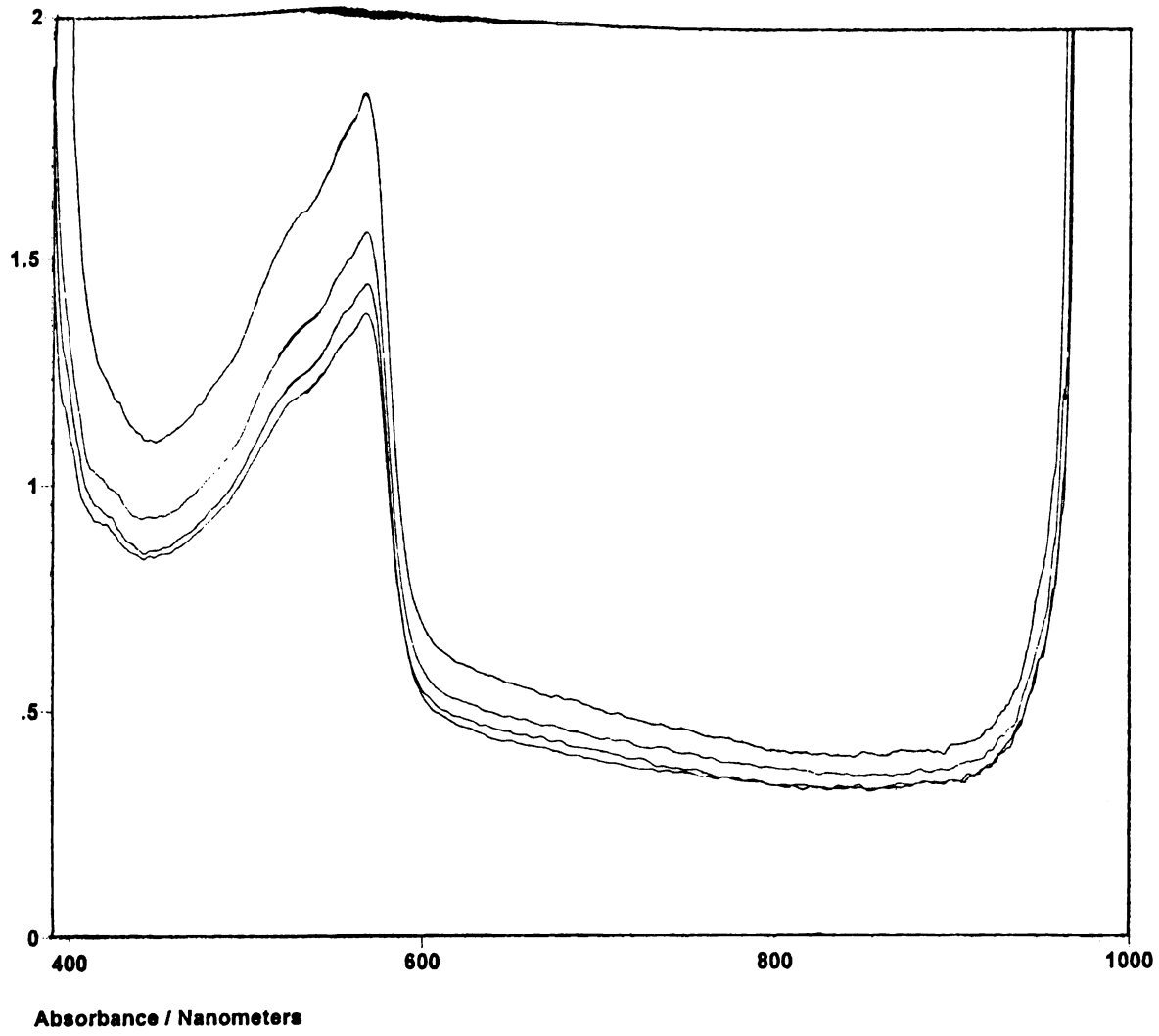

Figure 86. UV-Visible Spectra of Covergirl Nailslicks Fabulous Fuchsia

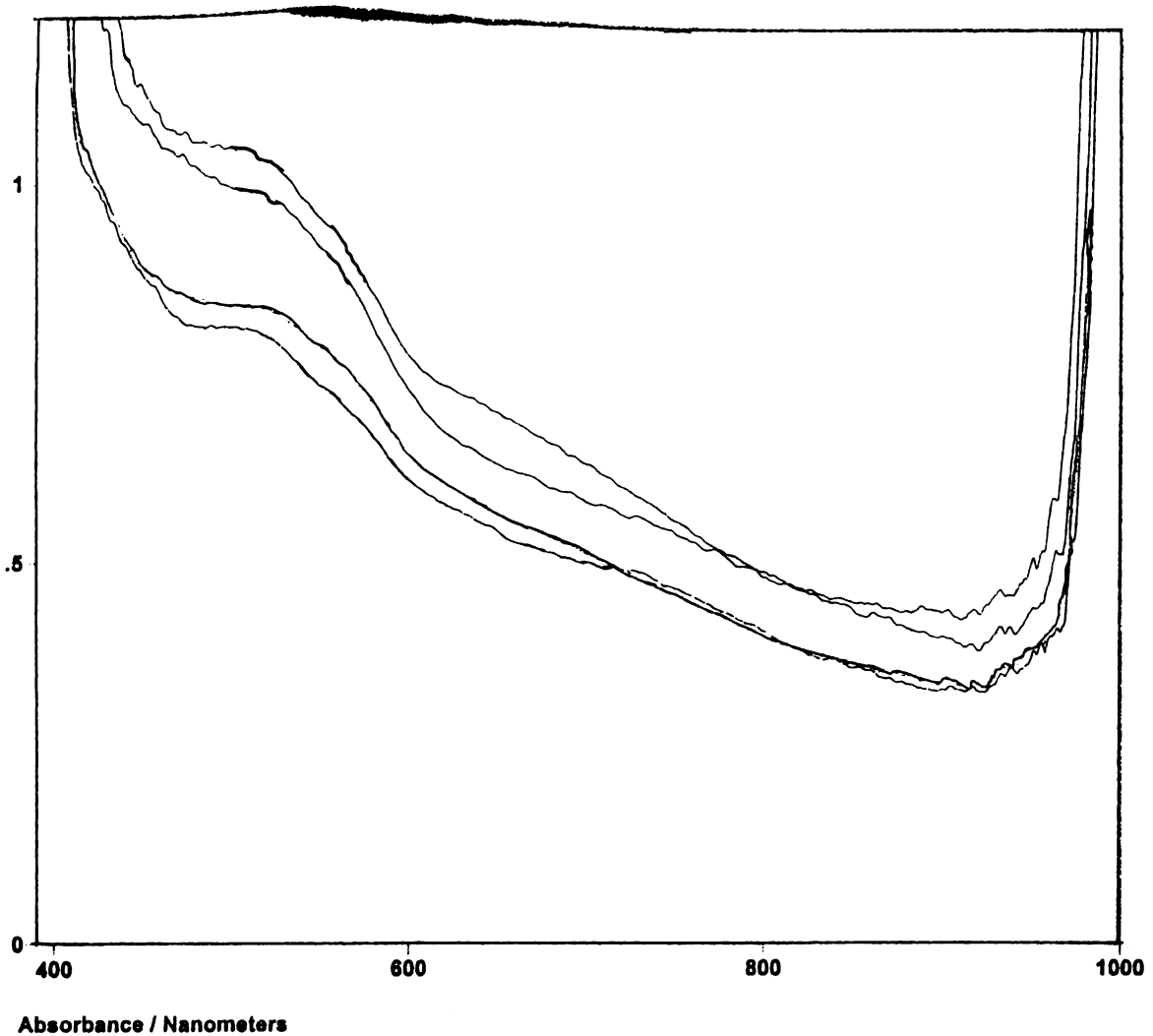

Figure 87. UV-Visible Spectra of Covergirl Nailslicks Grape Ice

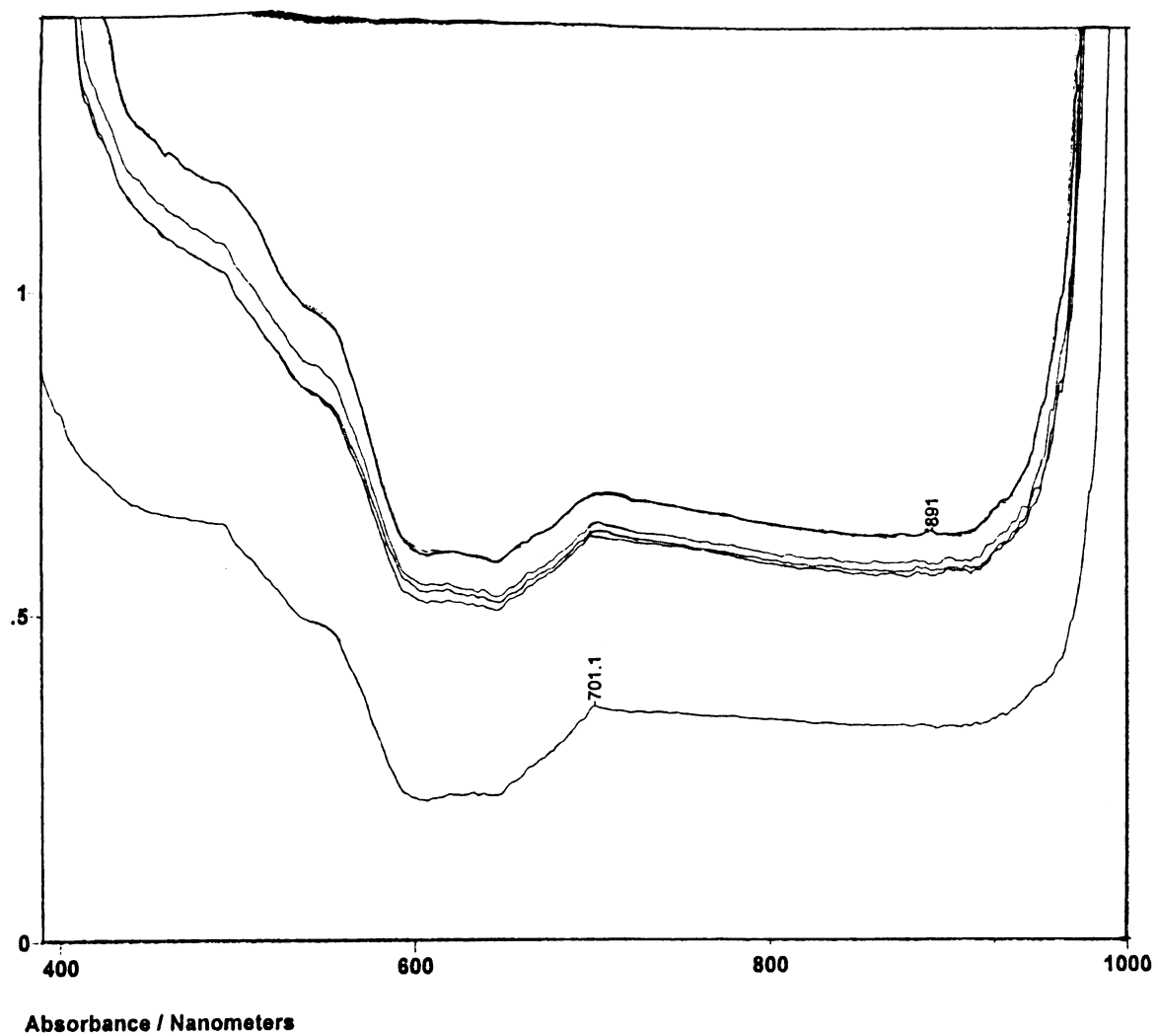

Figure 88. UV-Visible Spectra of Covergirl Nailslicks Ice Blue Pink

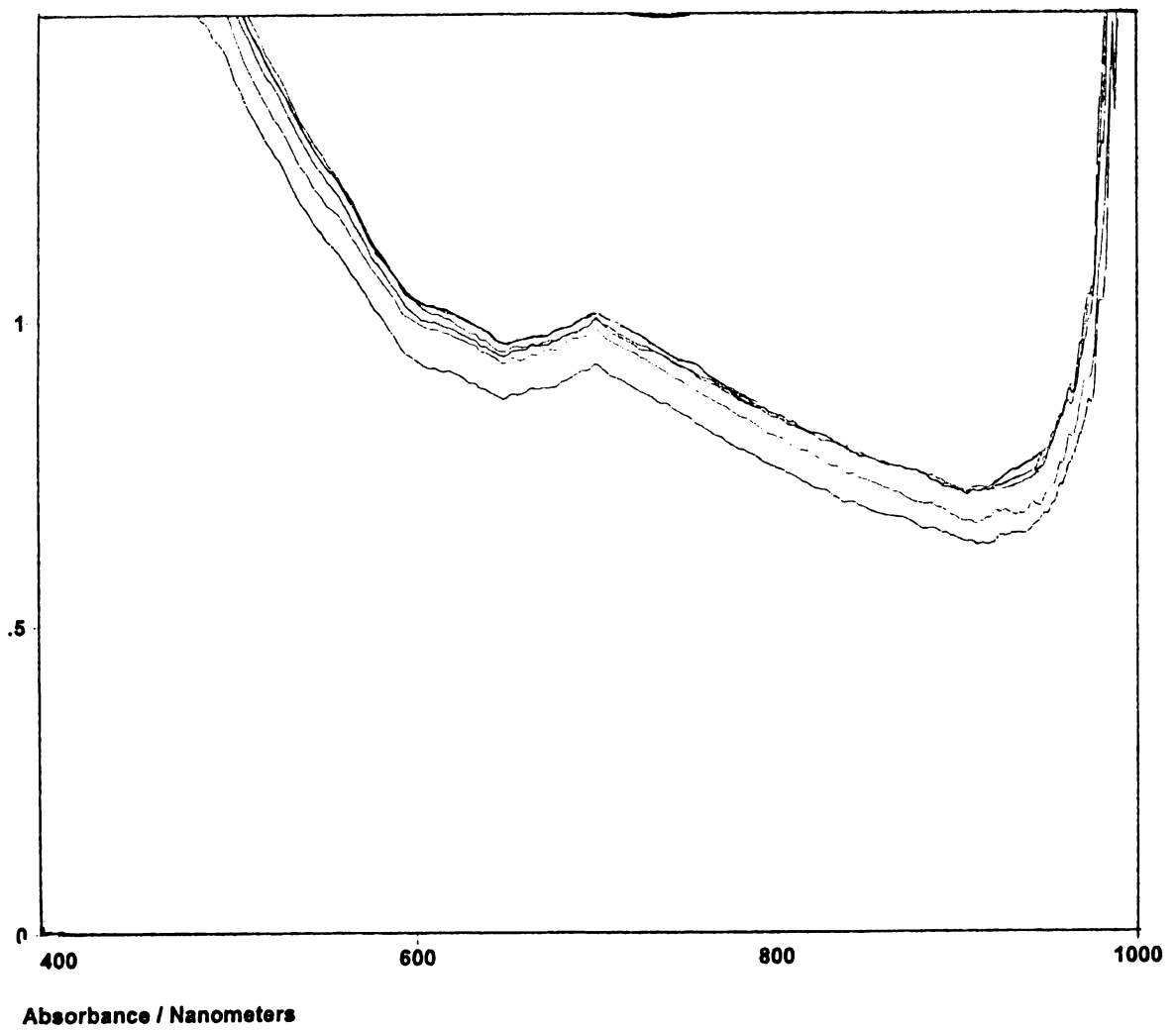

Figure 89. UV-Visible Spectra of Covergirl Nailslicks Mauve Sunrise

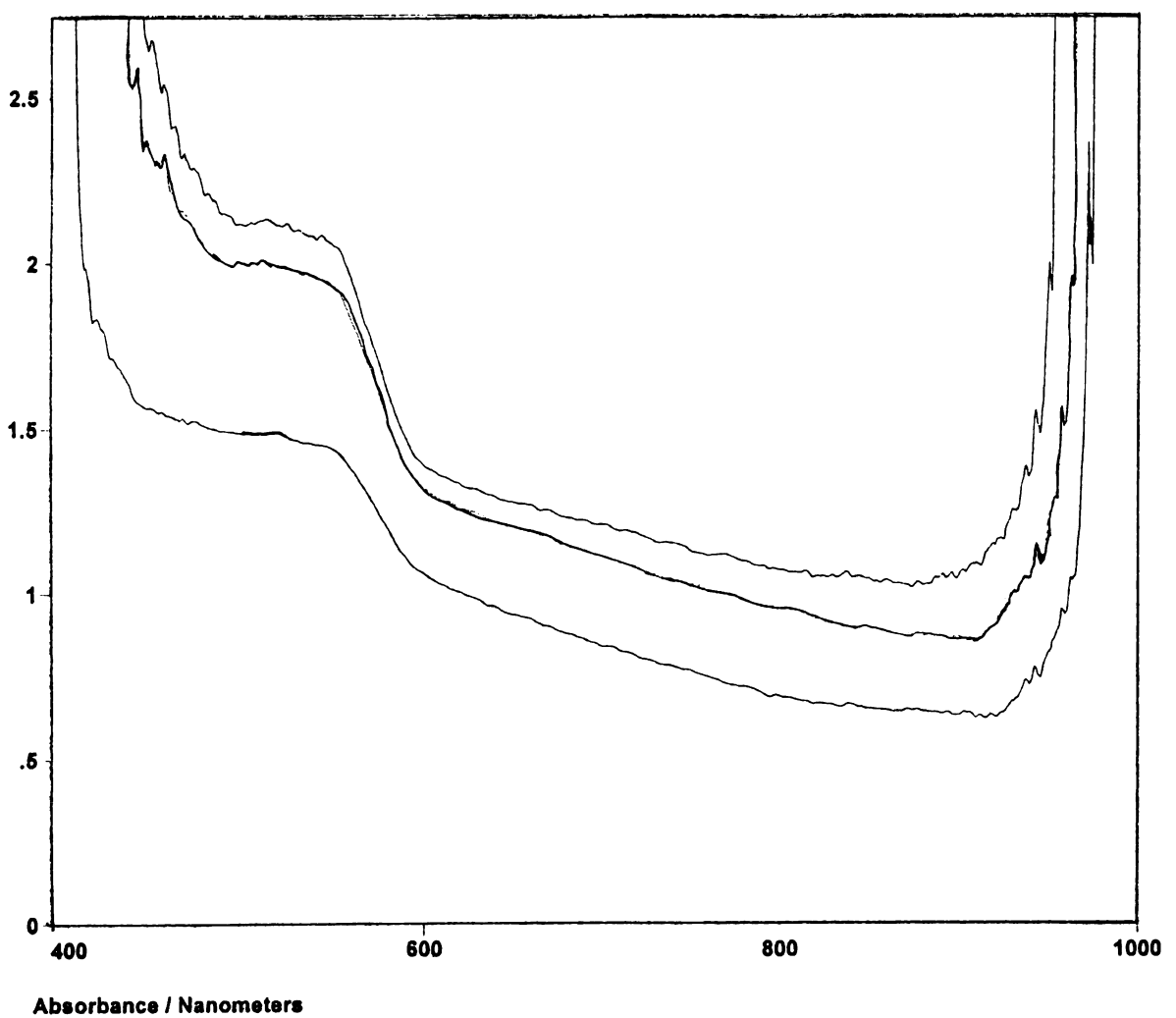

Figure 90. UV-Visible Spectra of Covergirl Nailslicks Mauvelicious

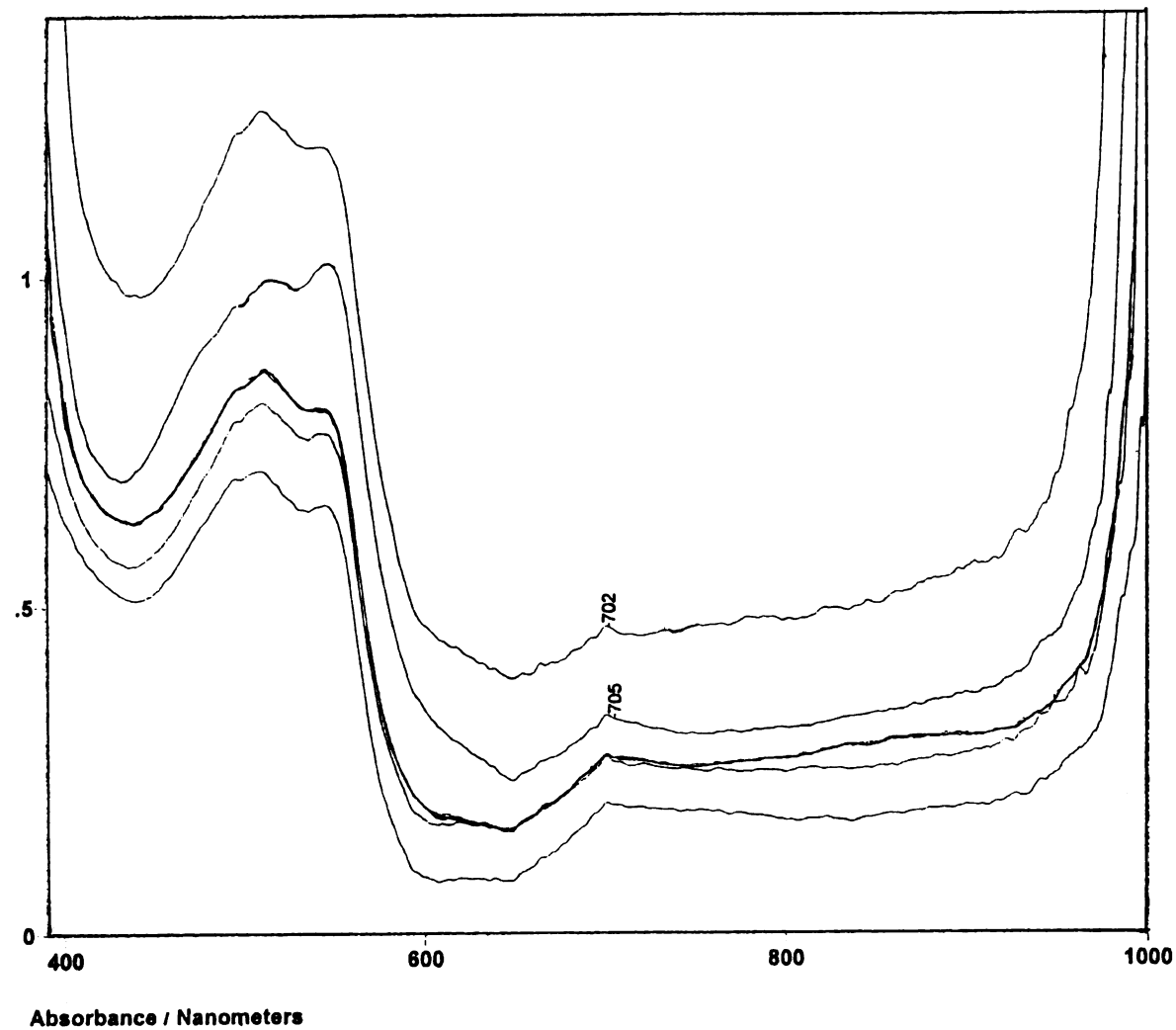

Figure 91. UV-Visible Spectra of Covergirl Nailslicks Pink Aura

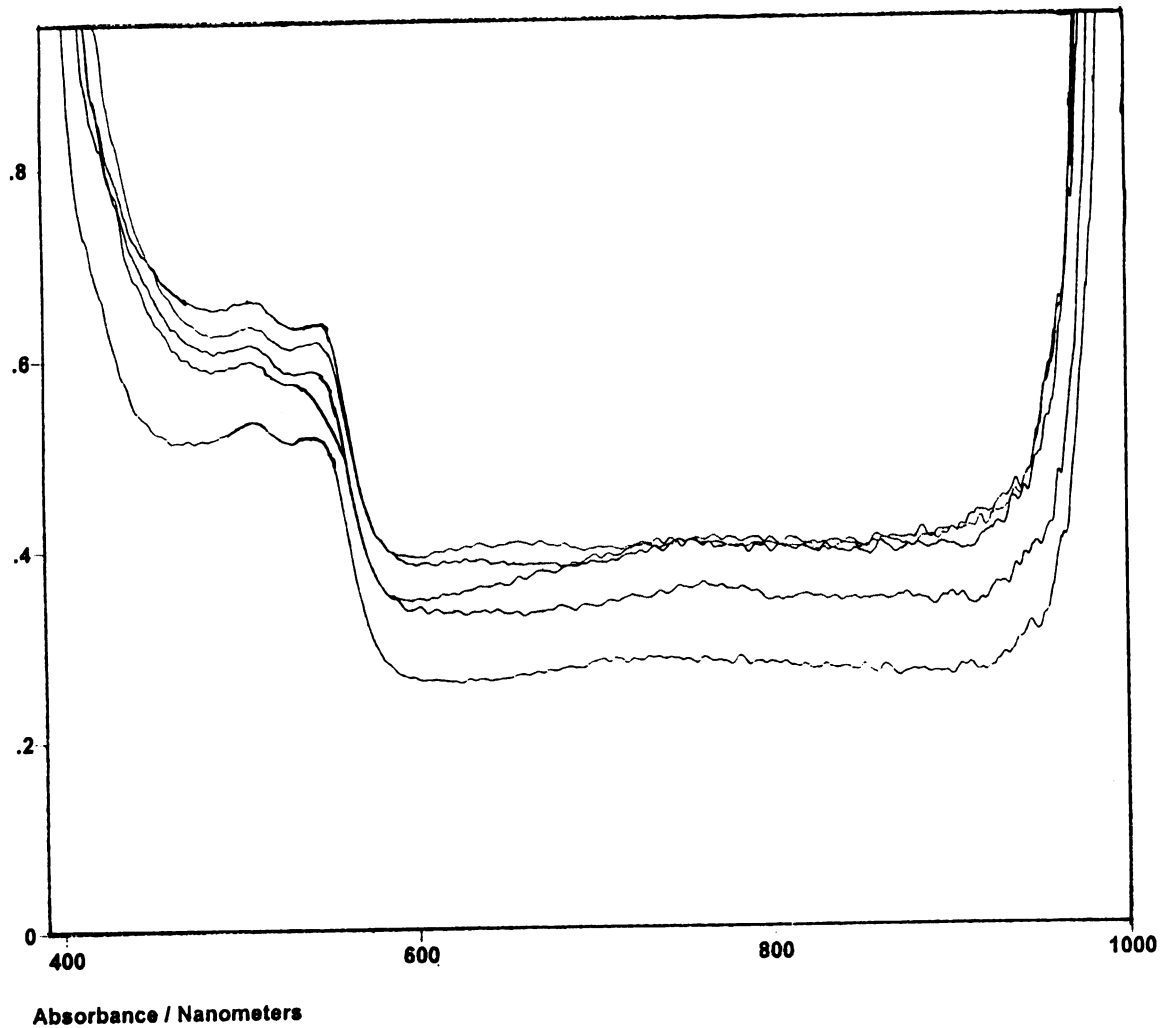

Figure 92. UV-Visible Spectra of Covergirl Nailslicks Pink Snow

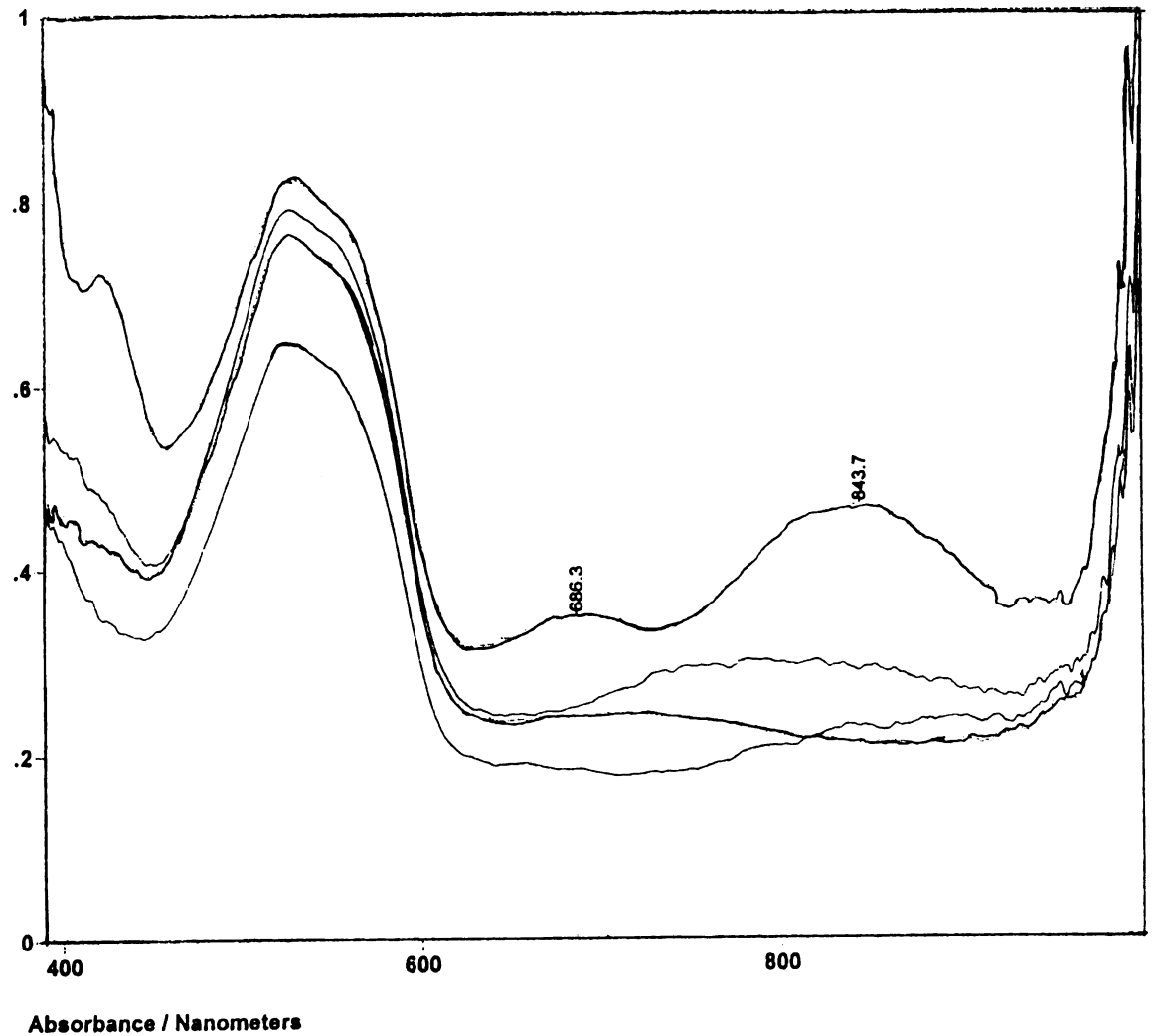

Figure 93. UV-Visible Spectra of Covergirl Nailslicks Plum Frost

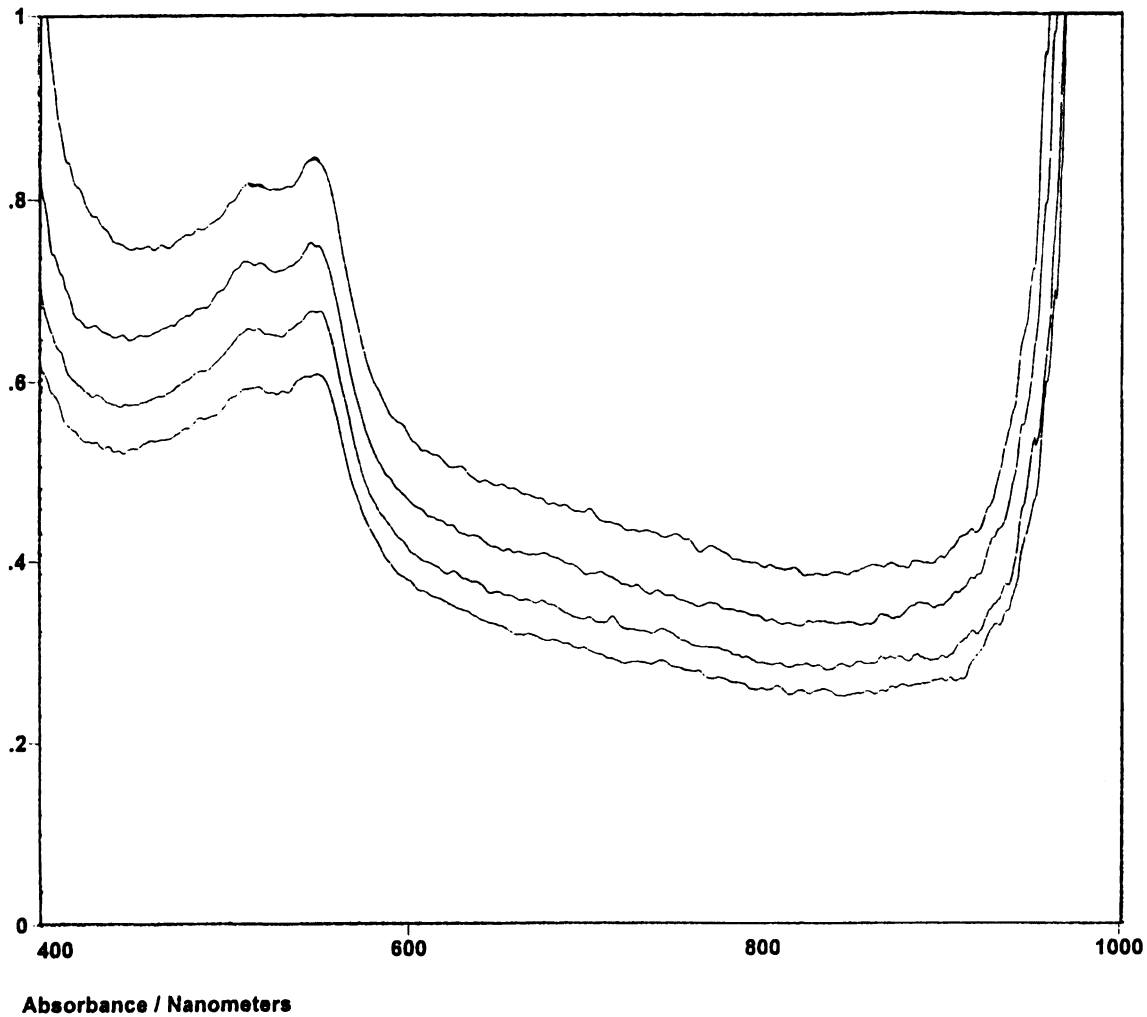

Figure 94. UV-Visible Spectra of Covergirl Nailslicks Satin Mauve

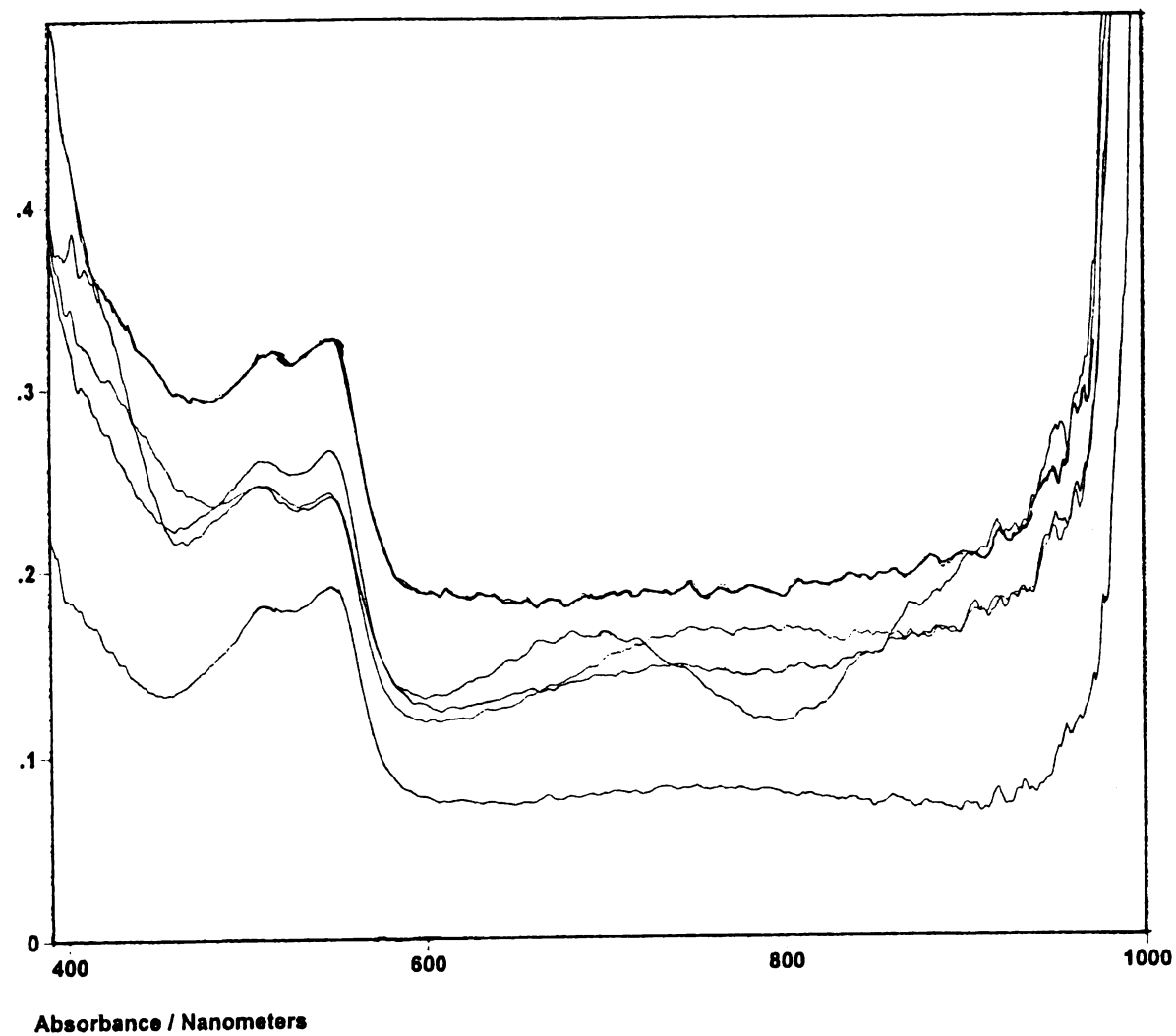

Figure 95. UV-Visible Spectra of Covergirl Nailslicks Silver Plum

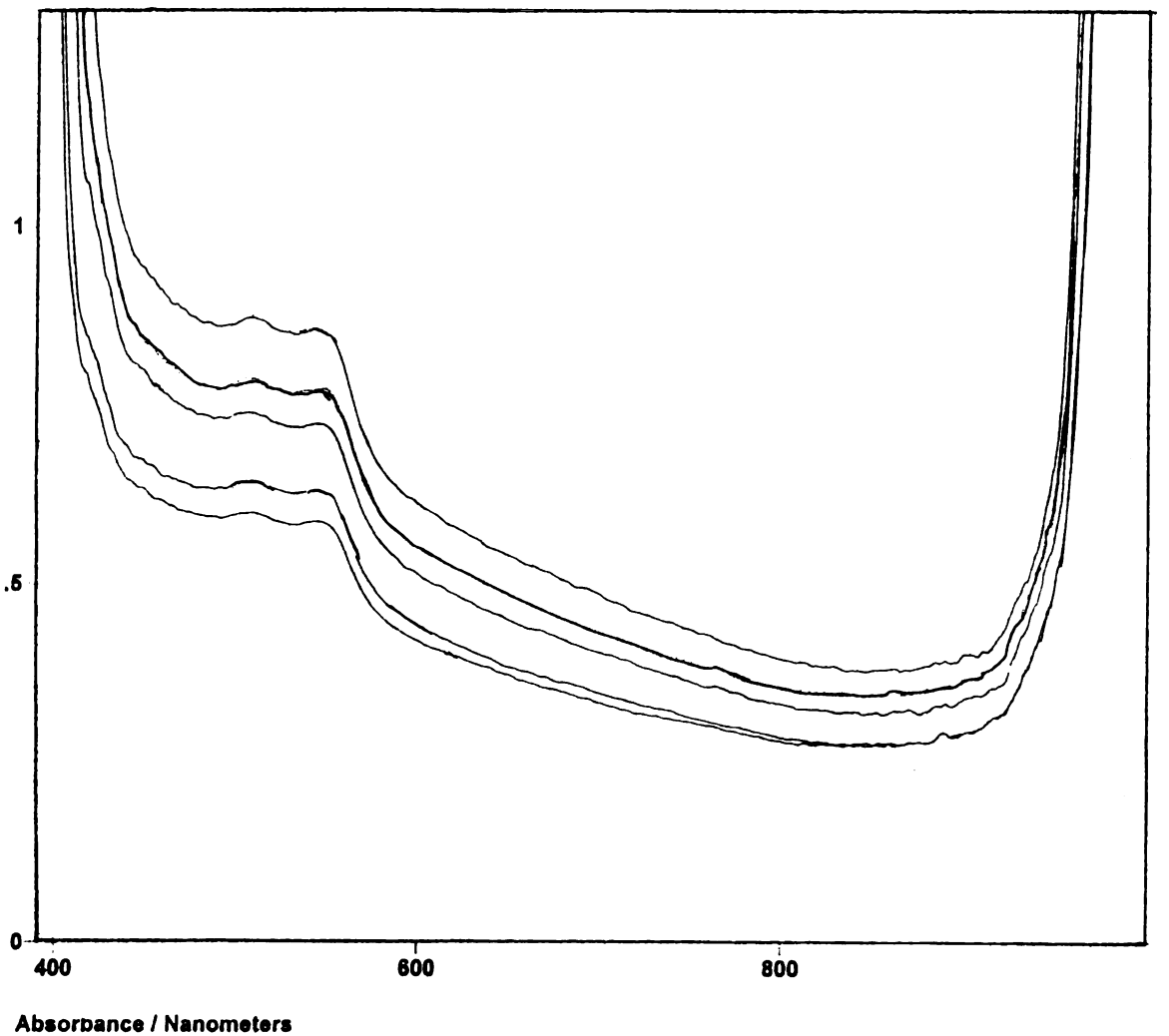

Figure 96. UV-Visible Spectra of Covergirl Nailslicks Twilight Mauve

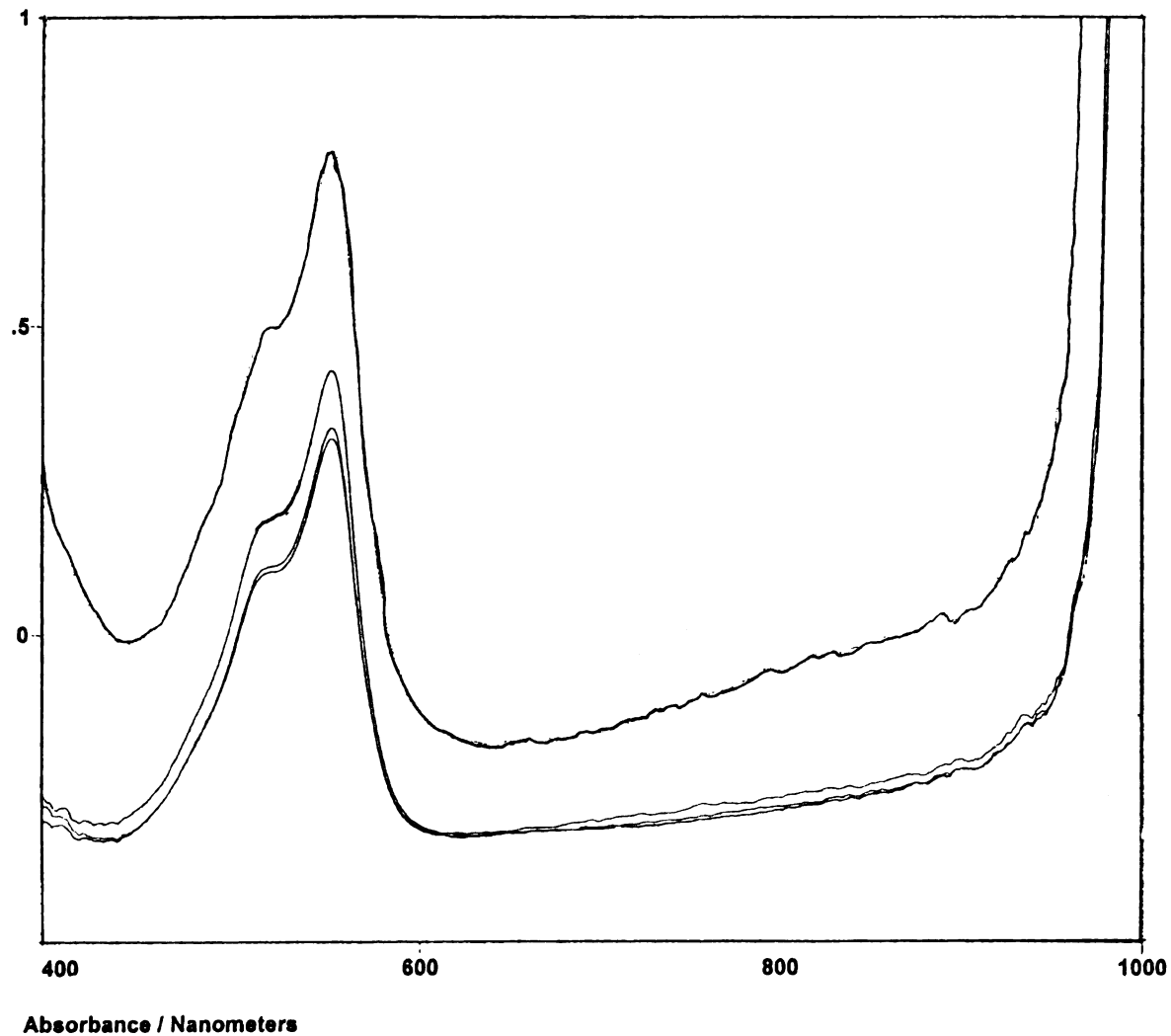

Figure 97. UV-Visible Spectra of Covergirl Nailslicks Well Red

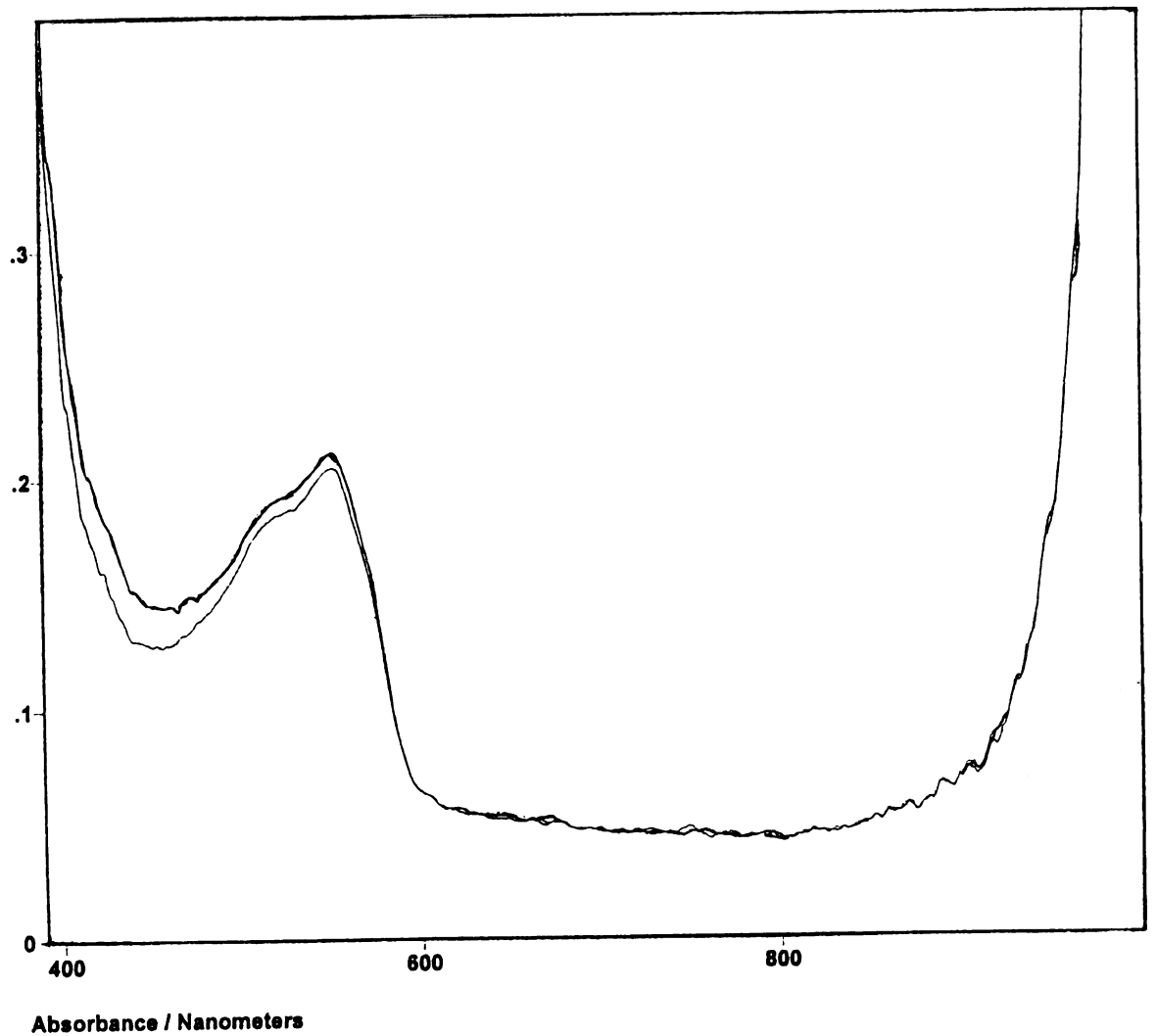

Figure 98. UV-Visible Spectra of Covergirl Nailslicks Ice Blue Pink Lot # 2170

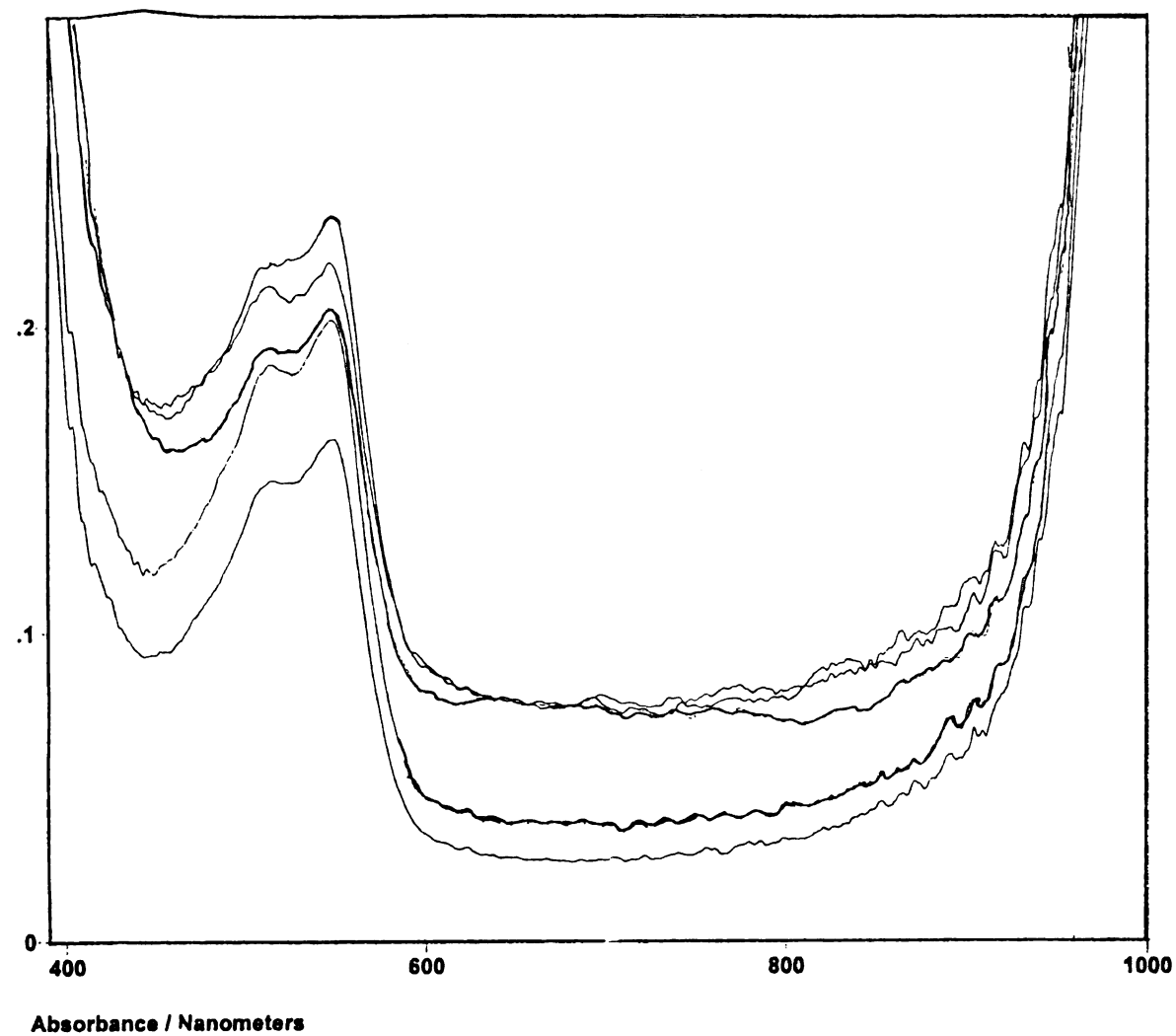

Figure 99. UV-Visible Spectra of Covergirl Nailslicks Ice Blue Pink Lot # 2206

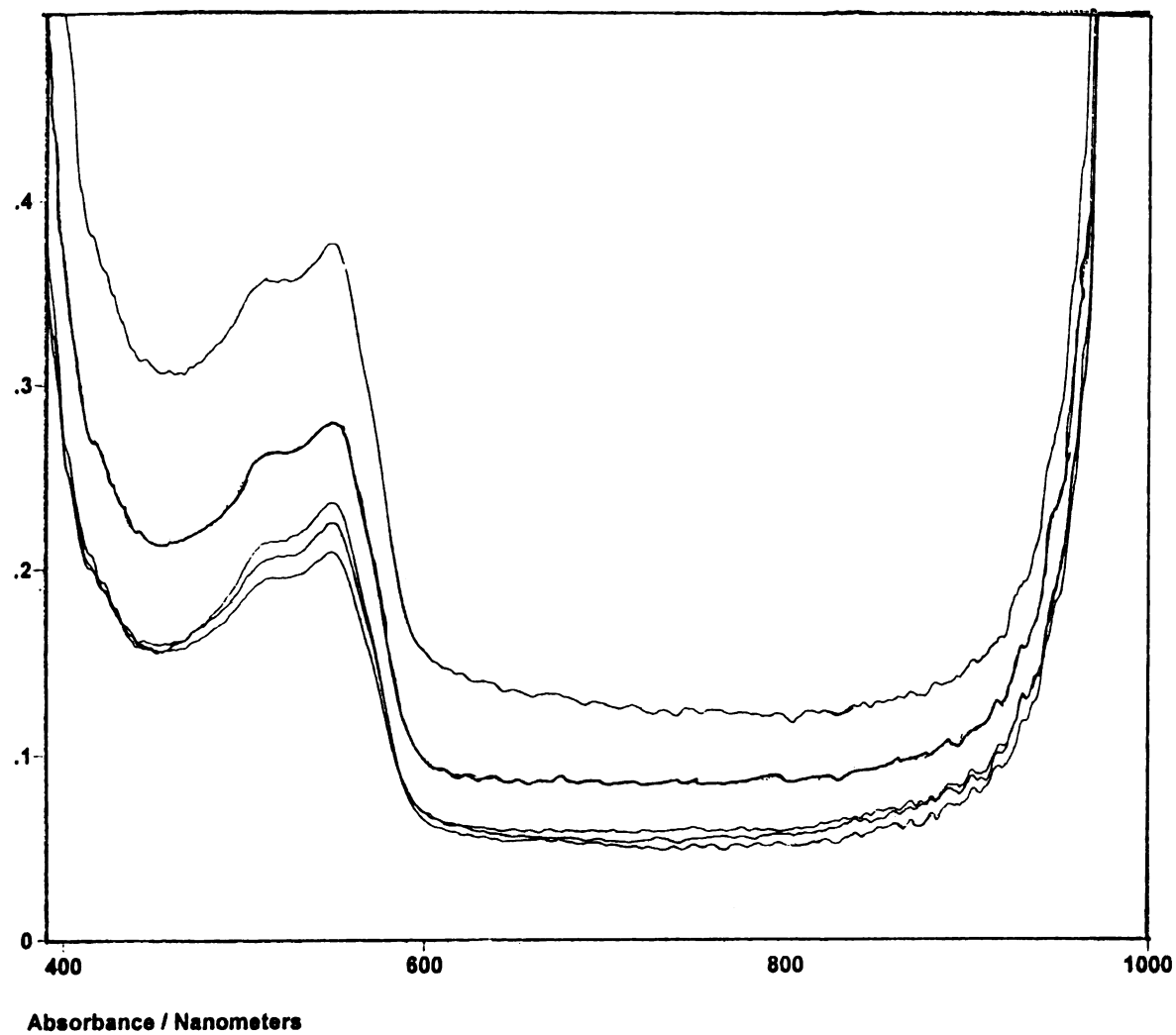

Figure 100. UV-Visible Spectra of Covergirl Nailslicks Ice Blue Pink Lot # 2232

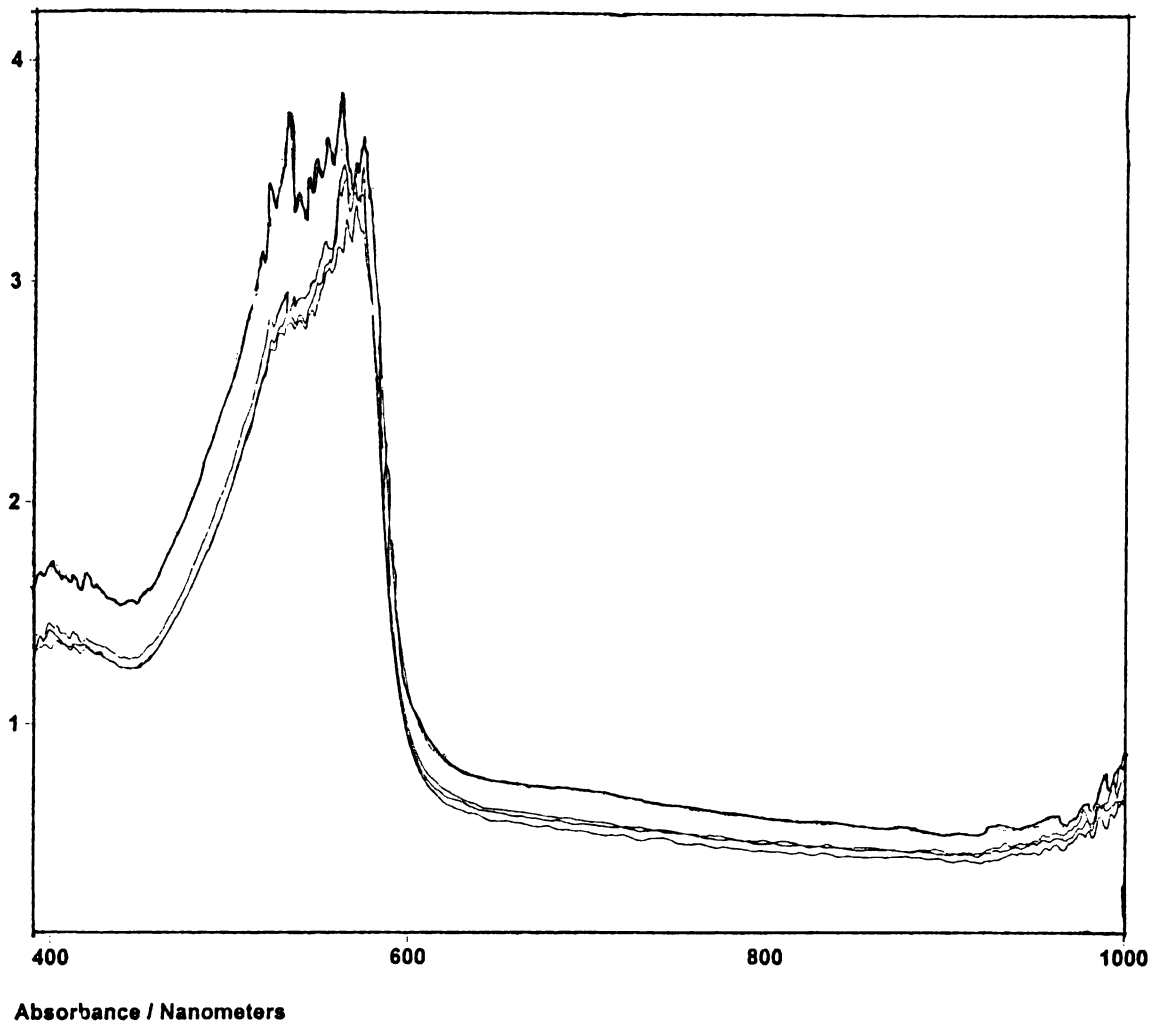

Figure 101. UV-Visible Spectra of Blind Sample #2

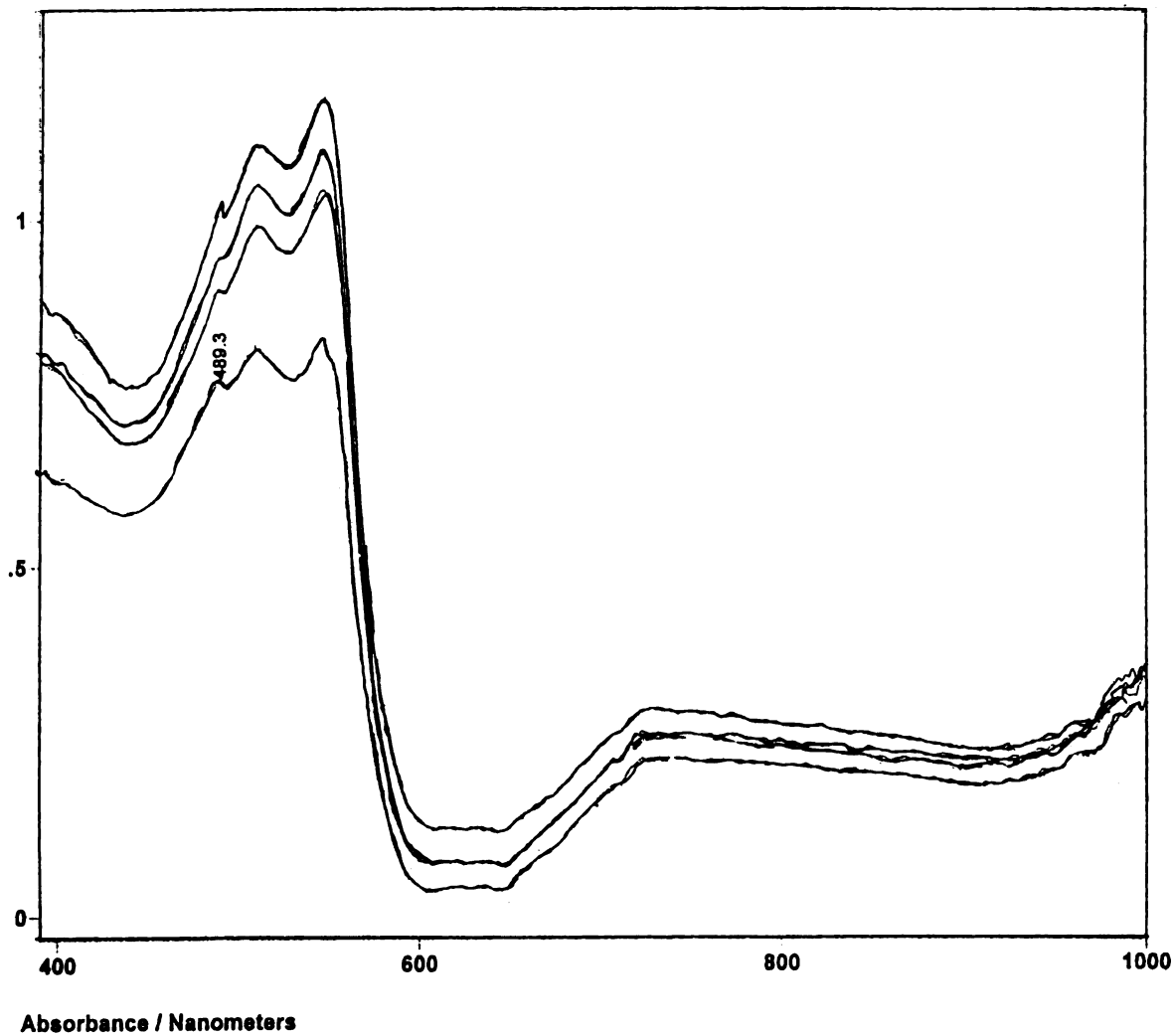

Figure 102. UV-Visible Spectra of Blind Sample #4

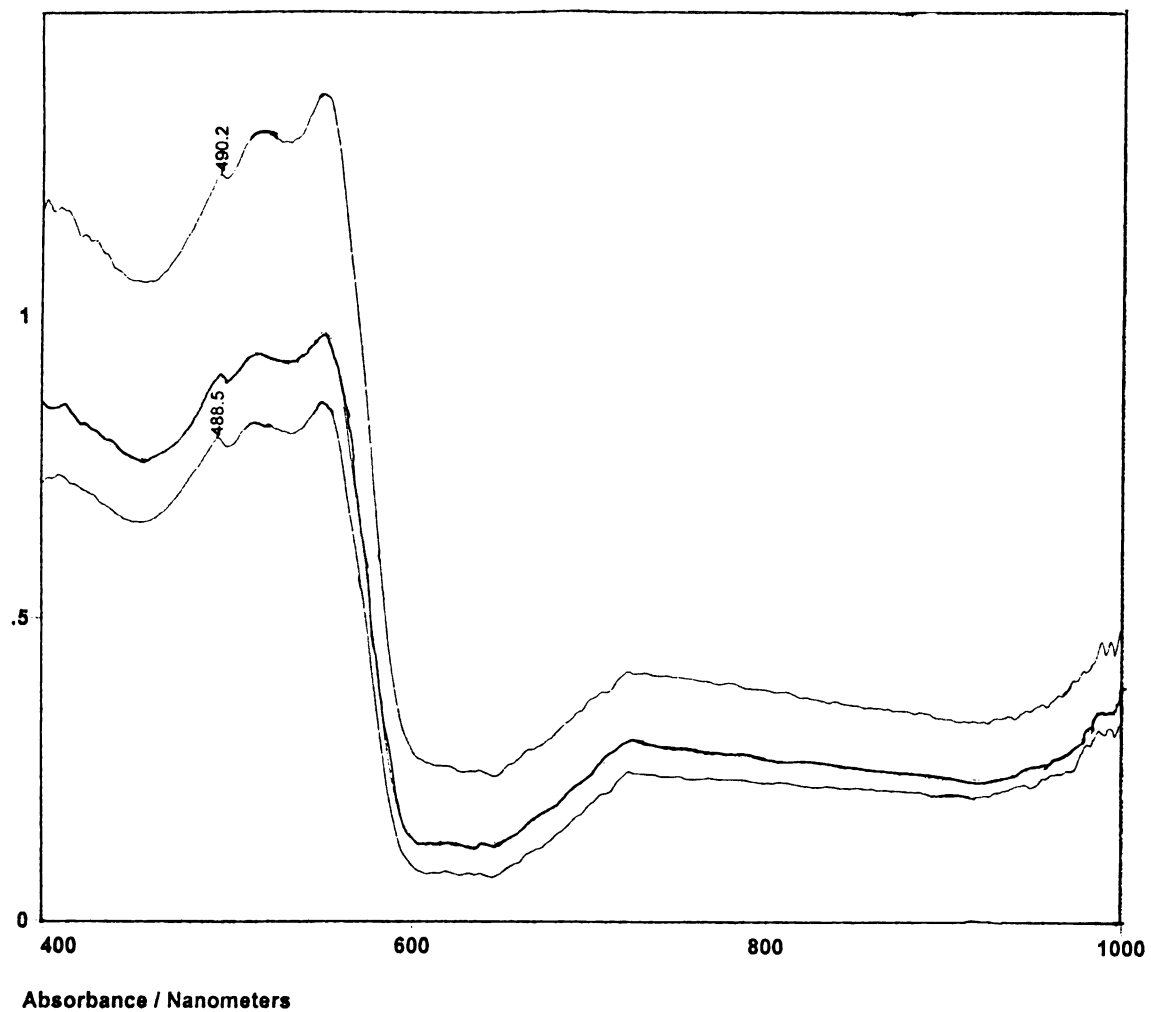

Figure 103. UV-Visible Spectra of Blind Sample #5

APPENDIX D

Microscopy Results for the Brand and Covergirl Studies

Table 15. Microscopy Results for the Brand Study.

Revlon Super Top Speed Winey	
Grain	Fine, medium
Small particles	*Pink*
Medium particles	*Pink*
Large particles	*Pink*
Revlon Wine With Everything	
Grain	Coarse
Small particles	Some black, Pink
Medium particles	NONE
Large particles	NONE
Revlon Love Her Madly	
Grain	Coarse, sparse
Small particles	Few black, Pink
Medium particles	Few Pink
Large particles	NONE
L'Oreal Sheer Moonberry Perle	
Grain	Medium, coarse
Small particles	*Blue*, some pink
Medium particles	*Blue*, some pink
Large particles	Some blue
L'Oreal Mulberry Cream	
Grain	*Coarse*
Small particles	Some red
Medium particles	NONE
Large particles	NONE
Sally Hanson Maximum Growth Beautiful Berry	

Grain	Coarse
Small particles	Violet, yellow-orange, orange
Medium particles	*Orange*
Large particles	Some orange, some very large pale yellow/clear
Sally Hanson Hard As Nails Oasis Dawn Creme	
Grain	Coarse, dense
Small particles	Pinkish-red, white/shiny (50-70 per field), some black
Medium particles	Pale yellow/clear
Large particles	NONE

Table 16. Microscopy Results for the Covergirl Study.

Covergirl Nailslicks Mauve Sunrise	
Grain	Coarse, dense
Small particles	*Orange*, blue, green, pink, violet
Medium particles	Orange, blue, green, pink, violet
Large particles	NONE
Covergirl Nailslicks Peek-A-Boo Pink	
Grain	*Fine*
Small particles	Orange, pink
Medium particles	Very few: blue, orange, red
Large particles	NONE
Covergirl Nailslicks Tickled Pink	
Grain	*Medium, dense*
Small particles	Pink, blue, violet, white/shiny round
Medium particles	Very few: pale pink/clear, blue, orange
Large particles	NONE
Covergirl Nailslicks Mauvelicious	
Grain	*Fine*
Small particles	Pink, red, white/shiny round (80 per field)
Medium particles	NONE
Large particles	NONE

Table 16. Microscopy Results for the Covergirl Study. (Continued)

Covergirl Nailslicks Classic Red	
Grain	Coarse, sparse
Small particles	Pink, blue, red
Medium particles	*Pink*, some: blue-violet, peach, white/shiny
Large particles	NONE
Covergirl Nailslicks Well Red	
Grain	Fine, medium, sparse
Small particles	*Pink*, blue-violet, red, white/shiny
Medium particles	Few pinkish-orange
Large particles	NONE
Covergirl Nailslicks Cabernet	
Grain	Fine
Small particles	*Dark red*, clear, white/shiny
Medium particles	Dark red, clear
Large and very large particles	Dark red
Covergirl Nailslicks Cherry Truffle	
Grain	*Coarse, dense*
Small particles	Red, orange, pink
Medium particles	Clear, pink
Large particles	Very few red

Table 16. Microscopy Results for the Covergirl Study. (Continued)

Covergirl Nailslicks Plum Frost	
Very Grain	Fine and coarse
Small particles	NONE
Medium particles	*Peach/orange*, blue-green, a few pink
Large particles	*Peach/orange*, blue-green, a few pink
Covergirl Nailslicks Fabulous Fuchsia	
Very Grain	*Fine*
Small particles	*Peach, pink, few: blue, green, red*
Medium particles	*Peach,* pink, yellow, blue
Large particles	NONE
Covergirl Nailslicks Cherry Brandy	
Grain	Coarse
Small and very small particles	*Dark red-orange*
Medium particles	*Dark red-orange*, Blue-violet, clear, some pink
Large particles, some very large	*Dark red-orange*
Covergirl Nailslicks Grape Ice	
Grain	Coarse, dense
Small particles	*Pink, peach, blue, yellow-green, violet*
Medium particles	*Pink, peach, blue, yellow-green, violet*
Large particles	Pink, green, orange, blue

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