AIR POLLUTION TESTING, INC.

Source Emissions Testing Report for Coors Brewing Company: Golden, Colorado Facility

FID / FTIR Ethanol Measurements Can and Bottle Line Ducts

Report prepared for:
Coors Brewing Company
Mail Stop CE200
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Report reviewed by:
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Project Number : CB50113

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P
T

Table of Contents

APT

Tables

Charts

Appendices

1. Introduction

Air Pollution Testing, Inc. (APT) and Peak Analytical were contracted by Coors Brewing Company to conduct a series of source emissions tests on the effluent duct work from the can filler rooms (#1 Can through #10 Can) and the bottle filler rooms (#1 Bottle through #4 Quart). The purpose of the testing was to quantify the concentrations and mass emission rates of volatile organic compounds (VOCs) and ethanol from the 2 locations. Total VOC emissions were measured using a flame ionization detector (FID). Ethanol and total VOC emissions were measured using a Fourier Transform - Infrared (FTIR) analyzer.

The emissions data are being used to compare the results obtained from the two analytical methods in the measurement of the organic content of a gas stream. Additionally, the presence or absence of hydrocarbon species other than ethanol in the filler rooms exhaust is investigated.

Approximately 2 hours of concurrent FID/FTIR data were collected on 4-3-95 at the bottle filler rooms exhaust. Approximately 2 hours of concurrent FID/FTIR data were collected on 4-4-95 at the can filler rooms exhaust. FID-only data were collected for an additional hour (approximately) at each location.

Contact personnel involved with the emissions testing program are provided in Table 1.1 below.

Coors Brewing Company Can and Bottle Filler Rooms Emissions Testing Program Contact Personnel		
Name , Title	*Address*	*Phone / FAX*
Mr. Fred Varani, Environmental Project Director	Coors Brewing Company Mail Stop CE200 Golden, Colorado 80401	303-277-2057 / 303-277-5639
Mr. Paul Ottenstein, Project Manager	Air Pollution Testing 7711 West 6th Avenue, Unit I Lakewood, Colorado 80215	303-232-5213 / 303-232-5313
Mr. Clinton Lamoreaux, Field Engineer	Air Pollution Testing 7711 West 6th Avenue, Unit I Lakewood, Colorado 80215	303-232-5213 / 303-232-5313
Mr. Greg Nelson, FTIR Specialist	Peak Analytical 413 Somerset Drive Golden, Colorado 80401	303-279-4979 / 303-279-4979

Table 1.1 - Contact Personnel

2. Methods

In addition to the use of the FTIR instrumentation, APT tested in accordance with the following U.S. Environmental Protection Agency (EPA) source emissions test methods.

EPA Method 1 - Sample and Velocity Traverses for Stationary Sources
EPA Method 2 - Determination of Stack Gas Velocity and Volumetric Flow Rate (Type S Pitot Tube)
EPA Method 25A - Measurement of Total Gaseous Organic Concentration Using a Flame Ionization Analyzer

All of the above methods may be referenced in _40 CFR Part 60, Appendix A_.

3. Summary of Procedures

3.1. General Overview

In previous emissions testing programs, Coors Brewing Company has contracted emissions testing personnel to determine the VOC emissions from the filler rooms effluent ducts in accordance with EPA Method 25A. The assumption was made that the VOC emissions consisted principally of ethanol, and an empirical scaling factor was determined to correct the propane-calibrated FID data to true ethanol values (see Section 3.3.2. of this report for additional details on scaling factors). In these previous emissions testing programs, empirical values were determined by emissions testing personnel using tedlar bag standards of ethanol-in-air. Syringes of liquid ethanol weighed to the nearest 0.1 milligram were injected into bags filled with air metered by an NIST traceable bubble flow calibrator. Instrumental limitations on the measurement of the ethanol mass required that the bag concentrations be higher than the VOC values typically measured in the filler room ducts. The scaling factor determined at relatively high ethanol concentrations was assumed to be constant down to the observed field concentrations.

The current testing program utilized FTIR instrumentation to speciate the VOC emissions in the ducts. Concurrent with the FTIR measurements, EPA Method 25A instrumentation was used in order to compare the two measurement methods. The Method 25A FID was calibrated with propane-in-nitrogen calibration standards (prepared and certified to 1% accuracy in accordance with EPA Protocol 1) as in previous Coors Brewing Company emissions tests. Additionally, the FID and the FTIR were calibrated with ethanol-in-nitrogen calibration standards (manufacturer certified to 1% accuracy and stored in Accu-Life cylinders to ensure stable, accurate concentration values). The FTIR ethanol calibration was used to quantify the ethanol-specific signal;

the FID ethanol calibration was used to again determine an empirical scaling factor for ethanol response. The high and low concentration ethanol standards were selected to bracket the anticipated VOC emissions concentrations. This allowed determination of an empirical factor for the conversion of the propane-calibrated FID data to true ethanol values without extrapolation of the scaling factor data down to observed emissions concentrations (as had been the case in previous emissions testing programs). For further discussion of the various scaling factor determination methods and the relative results, see Section 6.1 - Uncertainty Discussion / FID Data of this report.

3.2. Gas Flow

Gas flow was determined in accordance with EPA Methods 1 and 2.

Each sampling period consisted of conducting a temperature and differential pressure traverse of the duct using a K-type thermocouple and an S-type pitot tube. Following sampling, the data were reduced to calculate the duct gas velocity and volumetric flow rate in units of feet per second (ft/sec), actual cubic feet per minute (acfm), and dry standard cubic feet per minute (dscfm). A molecular weight of 29.0 grams per mole was assumed for velocity calculations (per *40 CFR 60, Appendix A, Method 2, Section 3.6*).

All of the gas flow calculations presented in Section 5 - Results in this report assume negligible moisture content, and ambient concentrations of oxygen and carbon dioxide (and a molecular weight of 29.0 grams per mole). Previous sampling at the can and bottle line effluent ducts indicates an average moisture content of approximately 1.0% (wet volume percent). This value is the average of 18 measurements conducted over a 3 month period (10-92 through 12-92) at 6 different locations throughout the can and bottle line effluent ducts in accordance with EPA *Method 4 - Determination of Moisture Content in Stack Gases* as detailed in *40 CFR Part 60, Appendix A*. The impact of the omission of the moisture content on the emissions results calculations is discussed in Section 3.3.1.1 - FID Measurement of Total VOC Emissions / Measurement Procedures, FID in this report.

A velocity sampling traverse was conducted approximately once each hour during the VOC sampling.

3.3. FID Measurement of Total VOC Emissions

The field FID measurement procedures and the theory of operation of the FID are detailed in the following 2 sections.

3.3.1. Measurement Procedures, FID

Total VOC emissions were determined in accordance with EPA Method 25A.

Each sampling period consisted of extracting a gas sample from the approximate area center of the duct at a constant flow rate of approximately 2.5 liters per minute. Previous testing at the subject ducts indicates that no measurable VOC gradient exists in the ducts, and a single-point sample is representative. The sample was pulled through an approximately 20' length of unheated teflon sample line and into the sampling port of a JUM Model 3-100 FID. The total organic concentration was displayed on the analyzer front panel in units of parts per million, wet volume basis as propane (ppmvw as C_3H_8), logged to a computerized data acquisition system (CDAS), and recorded on a strip chart. Before and after each sampling period, the analyzer was challenged with propane-in-nitrogen calibration gases to calibrate the instrument, verify linearity of response, and quantify any zero or span drift for the previous sampling period. To ensure accurate data collection, the calibration gases were introduced to the analyzer at the sample probe tip at ambient pressure. Additionally, the analyzer was challenged with ethanol-in-nitrogen calibration gases to empirically determine the propane-calibrated analyzer response factor for ethanol. To ensure accurate data collection, the ethanol calibration gases were introduced to the FID at the sample probe tip at ambient pressure. Diagram 4.1 depicts the overall schematic of the FID sampling and analysis system.

Following sampling, the data were combined with concurrently collected gas flow data to calculate the VOC concentrations and emission rates in units of ppmvw as ethanol and pounds per hour (lb/hr) as ethanol.

3.3.1.1. Additional Notes, Omission of Moisture Content in Emissions Calculations

As indicated previously, the moisture content of the duct gas was assumed to be negligible in the emissions calculations presented in Section 5 - Results in this report. Previous measurements indicate that the true moisture content is approximately 1.0% (wet volume percent). The impact of the moisture content omission on the emissions calculations is almost negligible as detailed in the equations on the following page.

$$\textit{ethanol emissions (lb/hr)} = \frac{[\textit{ethanol conc. (ppmv, wet)}]}{(1 - B_{WS})} \cdot F_{DSCFM} \cdot k_1$$

$$= \frac{[\textit{ethanol conc. (ppmv, wet)}]}{(1 - B_{WS})} \cdot (1 - B_{WS}) \cdot v_s \cdot k_2$$

$$= [\textit{ethanol conc. (ppmv, wet)}] \cdot \sqrt{\frac{1}{M_A}} \cdot k_3$$

where : F_{DSCFM} = *gas flow (dry standard cubic feet per minute)*
B_{WS} = *gas moisture content (wet volume percent* / 100)
v_s = *gas velocity (feet per second)*
M_A = *gas molecular weight (grams per mole)*
k_1, k_2, k_3 = *terms with no functional moisture dependence*

As shown in the above equations, the only functional dependence of the ethanol lb/hr emissions on the moisture content of the duct gas comes from the contribution of the moisture content to the molecular weight. The increase in the ethanol concentration when the wet measurements are corrected (concentrated) to dry values is countered by the decrease in gas flow from the moisture term. The impact of the remaining moisture dependence is equal to the ratio of the square root of the assumed molecular weight (29.0 grams per mole) and the square root of the actual wet molecular weight (approximately 28.7 grams per mole). This results in an understatement of the ethanol lb/hr emissions in the current report by about 0.5%. This estimate on the error is actually somewhat high since the wet molecular weight of 28.7 grams per mole is calculated using only the oxygen, carbon dioxide, nitrogen, and water contributions. The actual wet molecular weight should also include a contribution from argon (atomic weight = 39.948 grams per mole). If the dry molecular weight value of 29.0 grams per mole (which accounts for argon) from *40 CFR 60, Appendix A, Method 2, Section 3.6* is corrected for the approximately 1% moisture in the duct gas, the actual wet molecular weight is calculated as 28.9 grams per mole. This results in an understatement of the ethanol lb/hr emissions in the current report by about 0.2%. In any case, the 0.5% or 0.2% understatement in the ethanol lb/hr emissions is not consequential given the precision and accuracy of the test methods. See Section 6.1 - Uncertainty Discussion / FID Data of this report for a further discussion on the uncertainty of the measurements.

3.3.1.2. Additional Notes, Sample Line Loss

As indicated in the previous text, sample gas was transported from the duct to the FID through an approximately 20' length of unheated teflon sample line. No likelihood of condensation of either duct gas moisture or ethanol existed. Firstly, the room-temperature sample line was at approximately the same temperature as the duct gas, so little or no cooling occurred during sample transport. Secondly, as illustrated in the vapor pressure curves at the back of Appendix 4 - Calibration Data and Certificates at the back of this report, ethanol condensation in the sample line would be expected to occur at concentrations of approximately 19,000 ppm, and moisture condensation in the sample line would be expected to occur at concentrations of approximately 2%. The 19,000 ppm ethanol was not observed (or approached). While vapor pressure curves are not presented for all possible volatile organic species, a similar vapor pressure argument could be developed for any truly "volatile organic compound". The 2% moisture content was not expected based on previous moisture sampling.

Additionally, the strip chart data gave no indication of sample line loss. Loss would have been evidenced by a slow return to zero when the sample probe was removed from the duct and the analyzer challenged with zero air. This is typically observed when condensation (or adsorption) of organics occurs in a sample line. As the condensed organics slowly evaporate (desorb) in the absence of the condensing (adsorbing) species in the gas stream, the analyzer slowly returns to zero. This was not observed. Further, any possible ethanol stripping mechanism (condensation included) would be expected to affect the calibration gases as well as the duct gas since the calibration gases were introduced to the analyzer through the entire length of sample line. This would tend to negate the effects of any hypothetical stripping mechanism on the final data.

3.3.2. Theory of Operation, FID

An FID is commonly used to measure the VOC content of a gas stream. It exploits the fact that when hydrocarbon species are burned in a flame, a fraction of the organic carbon atoms will be ionized into carbon cations (positively charged carbon atoms) and electrons. The FID consists of a hydrogen flame in an electrostatic field. Sample gas is passed through the flame and hydrocarbons are oxidized to carbon dioxide and water. The fraction of carbon atoms ionizing to carbon cations are attracted to a grounded plate. At the grounded plate, the carbon cations attract an electron to achieve electrical neutrality. In picking up the electron, a current is produced which is amplified and sent to a recording device (a strip chart and CDAS in the subject testing program). Theoretically, this signal is proportional to the total number of organic carbon atoms per unit volume in the sample gas. For many hydrocarbon species, the FID behaves in this fashion, acting as a carbon counting device. Ideally, the FID response to a 100 ppm C_3H_8 (propane) calibration gas will be 3 times the response to a 100 ppm CH_4 (methane) calibration gas because the propane has 3 times the number of organic carbon atoms per unit volume.

It has been demonstrated, however, that the FID response per organic carbon atom is somewhat dependent on the hydrocarbon species in the gas stream. In other words, the FID response to a 100 ppm propane calibration gas is not exactly 50 percent greater than the FID response to a 100 ppm ethanol (C_2H_5OH) calibration gas, even though the propane gas has 50% more organic carbon atoms per unit volume. Because of this fact, it is necessary to obtain an empirical scaling factor for each organic species in the gas stream to obtain the most accurate results possible from an FID. This is not always practical, and the total FID response, without scaling factors, is often used as a measurement of the total organic concentration of a gas stream. In this case, the results are reported in units of the calibration gas (generally propane) or as carbon. In the subject testing program, ethanol was believed to be the only organic species in the gas stream of measurable concentration. Consequently, the FID data were corrected using an empirical scaling factor developed for ethanol.

The scaling factor is determined by calibrating the FID with the reference gas, and introducing a known concentration of the species for which the scaling factor is required. In the subject testing program, the FID was calibrated on a range of 0 to 100 ppm propane. Zero air, 84.2 ppm, 48.5 ppm, and 28.8 ppm propane-in-nitrogen calibration gases were used for analyzer calibrations in accordance with EPA Method 25A. The analyzer was then challenged with 143.2 ppm and 15.11 ppm ethanol-in-nitrogen calibration gases. From this data, a correction factor to convert ethanol readings on a propane-calibrated FID to true ethanol concentrations was determined. While a single ethanol calibration gas would yield a correction factor, 2 gases were used to demonstrate the validity of the correction factor throughout the range of anticipated ethanol concentrations.

3.3. FTIR Measurement of Ethanol and Total VOC Emissions

The field FTIR pre-test preparation and evaluation procedures, measurement procedures, and the theory of operation of the FTIR are detailed in the following 3 sections

3.3.1. Pre-Test Preparation and Evaluations

Coors Brewing Company initially provided data regarding concentrations of ethanol in ducts which vent can and bottle container filling rooms. Temperature, pressure, percent moisture and CO_2 content were all used in order to evaluate data acquisition operating parameters for the FTIR analyzer.

The instrument used for all testing was a Mattson Instruments Polaris FTIR manufactured in 1989. Its optical resolution can be set as high as 0.5 cm^{-1}. A 1x data point zero filling can be turned on or off. Observation of the "Trading Rules" in FTIR spectrometry is an important aspect of optimizing any analysis and was carefully considered for the measurement of ethanol at Coors Brewery. They will be briefly reviewed with references to "Fourier Transform Infrared Spectrometry" by Peter Griffiths and James de Haseth.

The four main parameters; measurement time, resolution, throughput, and scan speed have significant and quantifiable relationships with signal to noise ratio (S/N). "For measurements made with a rapid scanning interferometer operating with a certain mirror velocity at a given resolution, S/N therefore increases with the square root of the number of scans being signal averaged."

The effects of changing resolution (which is a function of distance that the moving mirror in the interferometer travels during one scan) is more complicated. If all instrument parameters are held constant (including measurement time and iris setting) the S/N is halved on doubling the retardation distance (centimeters). Since S/N is proportional to the square root of the measurement time (seconds), the measurement time required to achieve a certain baseline noise level must be multiplied by 4x for every time the resolution (cm^{-1}) is doubled. If the aperture is stopped down to achieve "Full Width at Half Height" instrument resolution, the throughput is reduced by an additional one half when the resolution is doubled, causing the overall measurement time necessary to recover the original S/N to be a factor of 16.

The apodization function also affects both the resolution and the noise of the spectrum. "In general, to obtain the optimum S/N for spectra of small molecules with fine resolvable fine structure, boxcar truncation is preferable if side lobes from neighboring intense lines do not present an interference..." However, the greatest noise suppression for broad bands will be obtained with the triangle apodization.

The main instrument parameter that affects the specific detectivity of the detector, D* (in this case deuterated triglycine sulfate) is mirror velocity. This is optimized by choosing the best scan speed for the particular detector by running 100 percent lines and calculating RMS noise. The mirror velocity used for this application was a forward velocity of 3.16 mm/second, reverse velocity of 3.35 cm/second. This leads to a data acquisition rate of 10kHz if every other zero crossing of a 632.8 nanometer He-Ne laser is used to trigger data acquisition.

Given the above fundamental considerations, all instrument parameters were optimized to perform ethanol measurements on a continuous online basis. Reasons for choosing the 1061.170 cm^{-1} band follow. The natural line width of this band is very broad (approx. 75 cm-1 FWHH) which allowed the use of relatively low resolution of 16 cm^{-1}

which greatly enhanced the S/N. The low resolution made possible high numbers of coadded scans which improved the S/N.

The location of the 1061.170 cm^{-1} band is in a clear window region about as far away from the strong H_2O and CO_2 absorptions as practically possible in the mid infrared. The band is also located on a highly sensitive area of the single beam (emissivity) profile. All of these factors combine to give what was believed to be an acceptable sampling response time and good signal to noise in a area of high environmental vibration. Again, the rationale for using lower resolution is from Griffiths and de Haseth " A good guide is that the resolution should be no better than one-half the full width at half-height of the narrowest band in the spectrum. If measurements are taken at higher resolution, the resultant spectra will have a poorer S/N and/or take a longer time to measure than if the above criterion were applied, without any significant gain in information content."

During the set up and performance tests on site, spectral subtractions of duct gas minus water vapor (near the same concentration) were performed in order to reveal any interfering species. The plots of the raw data, comparisons with pure water vapor, and subtractions are included as Diagrams 4.5 to 4.13. These checks were important in order to specifically isolate ethanol as the analyte prior to quantitation and were done at higher (2 cm^{-1}) resolution. The spectral subtractions shown were done using previously acquired water vapor spectra under "nearly" the same conditions as the ethanol duct spectra. However, derivative band shapes arise from differences in: partial pressures within the cell, instrument resolution, cell pathlength, and slight wavelength uncertainty within the instrument. A nine page, scale-expanded, stacked plot of 2 cm^{-1} resolution Can Line ethanol versus water vapor has been included (Diagrams 4.5a through 4.5i)

The only non ethanol compound that appears during these comparisons is marked "Beer Peak" in Diagram 4.5 and is shown in Diagram 4.6 as a flavor component. This peak was revealed in a spectrum of "Beer headspace" taken of a freshly opened bottle of Coors Original Beer. Other polar compounds (excluding water and CO_2) present in brewing environments were not found. Aldehydes such as acetaldehyde were possible interferants but were not detected; no absorption was detected in the most intense band usually due to the carbonyl stretching vibration from 1770 - 1680 cm^{-1}.

Given that vapor phase molecules display little intermolecular interaction and that no interfering species were found, a multivariate quantitative analysis program such as Partial Least Squares (PLS) was not used and was believed to add complexity to the system. All raw data was stored to disk.

A complete listing of data acquisition and processing parameters follows: 200 scans coadded for background and sample, double sided acquisition of data points about the Zero Path Difference (ZPD), 50% iris setting, 2048 data points used in the Fast Fourier Transform (FFT), 256 data points used in the phase array, 1024 data points used in the FFT of the phase array, 16 cm^{-1} resolution, 1x zero fill, triangle apodization. The phase correction algorithm manipulates a complex data array containing real and imaginary points from an asymmetrical interferogram. These (256 points) selected symmetrically about the ZPD point are Fourier transformed with the complete interferogram data set. The specified apodization and zero filling are performed on both the phase data and the background and sample interferograms prior to Fourier transformation. This small phase spectrum is then used to compute the phase angle as a function of wavenumber. The resulting array of phase angles is then used to rotate the main set of Fourier transformed, complex data onto the real axis.

3.3.2. Measurement Procedures, FTIR

Calibration gases consisting of 15.11 ppm and 143.2 ppm ethanol in nitrogen were obtained prior to the analysis, and were run at Peak Analytical. This provided the opportunity to chose the analytical frequency and make path length adjustments necessary to optimize sensitivity and linearity. Using the band at 1061.170 cm^{-1}, the path length of the measurement cell was set to 4.0 meters.

A method was developed in which the FTIR spectrometer scanned (coadded interferograms) for a period of time necessary to achieve good signal/noise, then transmitted the data in absorbance format to a data acquisition computer. This computer saved the file (mid infrared region from 4000 - 400 cm^{-1}) to the hard disk giving it a unique name and time stamp. It then loaded the file and performed a net absorbance calculation, which is a peak height measurement using a consistent analytical baseline defined by two points. This calculation yielded a response in absorbance units which given to theory by the Beer-Lambert Law is linear to concentration. (A=abc where A is absorbance, a is the absorption coefficient, b is the pathlength, c is the concentration). This information was output to an online printer for a permanent hard copy and as a diagnostic to insure system operation. This computer served as a controller by continuously looping the above operation for a time specified by the operator. In this way, discrete (ppm ethanol) data points were taken approx. every 1 minute 40 seconds as compared with the FID detector which output on a continuous basis.

Scanning conditions were set as follows: resolution at 16 cm^{-1}, 200 scan background for 1 hr of sampling time, 200 scans per sample, wavelength region 4000 - 500 cm^{-1}, room temperature DTGS detector, water cooled glowbar source. The instruments were under nitrogen purge during all of the analysis. The instrument used was a Mattson Instruments Polaris FTIR spectrometer with FIRST data acquisition software and macros. These conditions were chosen in order to optimize time resolution and signal/noise without sacrificing spectral resolution (since the natural line width for ethanol is quite broad).

A sensitive pressure transducer was connected to the measurement cell and a direct readout was monitored during all sample and calibration analysis. A vacuum pump pulled a steady pressure of 11.7 psia through the 1.32 liter cell during sampling of both ducts. This pressure was matched using flow control of calibration gases which was critical to achieving absolute accuracy since the partial pressure of a gas has significant effect on its absorbance. A 20 foot length of quarter inch o.d. tubing was used to transport both sample and calibration gases to the cell. The pump was allowed to pull gas through the cell during the measurement runs.

The analysis of ethanol in the bottle line duct was done first, and calibrations were done before, during and after the sample measurements were done. Calibration data in the form of ethanol net absorbance peak heights at the C-C-O asymmetric stretching frequency of 1061.170 cm^{-1} were entered into a linear regression program to give a y=mx+b plot of absorbance vs concentration. The equation for the bottle line was ppm=1.60(A)+4.18. This sampling area had more vibration than the can line. The vibration was due to the fact that instrumentation was set on a grate and the combination of fork lifts driving underneath the grate, beverage cases transferring from a conveyor below to the one on our floor, and personnel walking nearby. The ppm data shown in the tables and graphs are for periods when the vibration was low.

The analysis of ethanol in the can line duct was done on the following day, using the same program and conditions. The equation for the can line duct was ppm=1.63(A)+1.01. This sampling area had no vibration but had higher ambient levels of ethanol in the area the equipment was located. A nitrogen purge of the equipment was done on a continuous basis.

Q.C. checks carried out were: 100% lines before and after the analysis, zero and span calibrations before and after the analysis, interferogram voltage and single beam spectrum checks for optical alignment. The same tubing was used for calibration as was for sampling. All samples and cal gases were pulled through the measurement system by the vacuum pump. A check valve was located at the inlet of the vacuum pump. This allowed for leak checking the system by evacuating the cell and all plumbing, shutting off the pump and bottle regulator valve while monitoring the vacuum gauge for leaks. Less than 0.1 PSIA/minute increase was considered adequate. Frequency checks were not carried out due to the employment of the He-Ne laser as the sample clock. The wavelength accuracy is better than 0.01 cm^{-1} over the entire 4000 - 500 cm^{-1} range.

3.3.3. Theory of Operation, FTIR

Infrared spectrophotometry is probably the most widely used tool in the world today for the identification of organic compounds. It has the largest reference database available for comparing unknowns. During the last fifteen years, commercial FTIR spectrometers using specialized optics for low concentration gas analysis have been moving from routine laboratory use to demanding online process measurement.

The FTIR contains four optical components: a white light source, interferometer, sampling optics, and a detector. The source of infrared radiation is usually some solid material heated to incandescence by an electric current. The radiation from the heated solid approaches the energy distribution of a theoretical black body. The heart of the instrument is the interferometer which is used to modulate the energy of the source. It is made of two mirrors and a beamsplitter. The beamsplitter is essentially a half-silvered mirror which reflects about 50 percent of an incident light beam and transmits the remaining 50 percent. One part of this split light beam travels to a moving mirror in one arm of the interferometer, and the other travels to a fixed mirror in the other arm. Both beams are reflected back to the beamsplitter where they recombine. Half of the recombined light is transmitted to the detector and half is reflected back to the source. When the two light beams recombine at the beamsplitter, an interference pattern is generated. This pattern varies with the displacement of the moving mirror and is detected by the detector as variations in the infrared energy level. The sampling optics are located between the interferometer and detector and can be replaced with specific accessories designed for gas, liquid or solid samples. For these measurements, a gas cell was used.

The resulting signal from the detector is an interferogram, where one scan of the moving mirror provides time domain (dimensionally in centimeters) data which is sampled and digitized by an A/D converter. Signal averaging by coadding many scans improves the signal to noise ratio. The cosine Fourier transform (Cooley-Tukey algorithm) is applied to this data and the result is an optical frequency domain (dimensionally waves per centimeter or cm^{-1}) spectrum. This operation is done using background conditions (i.e an inert gas such as nitrogen) and again with the sample, and these files are sent to a data acquisition computer. Finally, these files are ratioed sample/background to obtain a spectrum of the absorbing species.

The FTIR technique relies on the interaction of electromagnetic radiation with molecular vibrations and rotations. The absorption frequency depends on the molecular vibrational frequency. The absorption intensity depends on how effectively the infrared photon energy can be transferred to the molecule, which depends on the change in the dipole moment that occurs as a result of molecular vibration. Most of this energy is dissipated by vibrations of a single group of atoms within the molecule. These characteristic group absorptions give rise to the unparalleled specificity of FTIR spectrophotometry.

The spectrometer used in these measurements used a 90 degree Michelson cube corner interferometer, a silicon carbide source, a deuterated triglycine detector and an adjustable folded path "White Cell" gas cell. This cell is designed to measure low concentrations of gases by using mirrors that reflect the IR beam multiple times across the gas. This increases the pathlength without increasing the cell volume, improving measurement response time.

Since FTIR is a molecular vibrational spectroscopic technique, all species present in the sample gas stream will be detected at concentrations above the detection limits of the analyzer. Water vapor and carbon dioxide will be detected because their concentrations are relatively high, but they do not pose problems as interferents in this work. Work in the lab with standards and the EPA vapor phase library was done in order to choose the proper band so as to be truly ethanol selective in case other hydrocarbons were present in the gas stream. A high resolution spectrum of ethanol sampled from the can line duct has been included and peaks labeled in order to better understand this information. This is shown in Diagram 4.14. No other species were detected and/or identified during this analysis. Diagram 4.2 depicts the overall schematic of the FTIR sampling and analysis system.

4. Diagrams

Diagrams 4.1 through 4.14 provide schematics of the sampling and analytical instrumentation, a variety of FTIR spectra, and diagrams of the sampling locations.

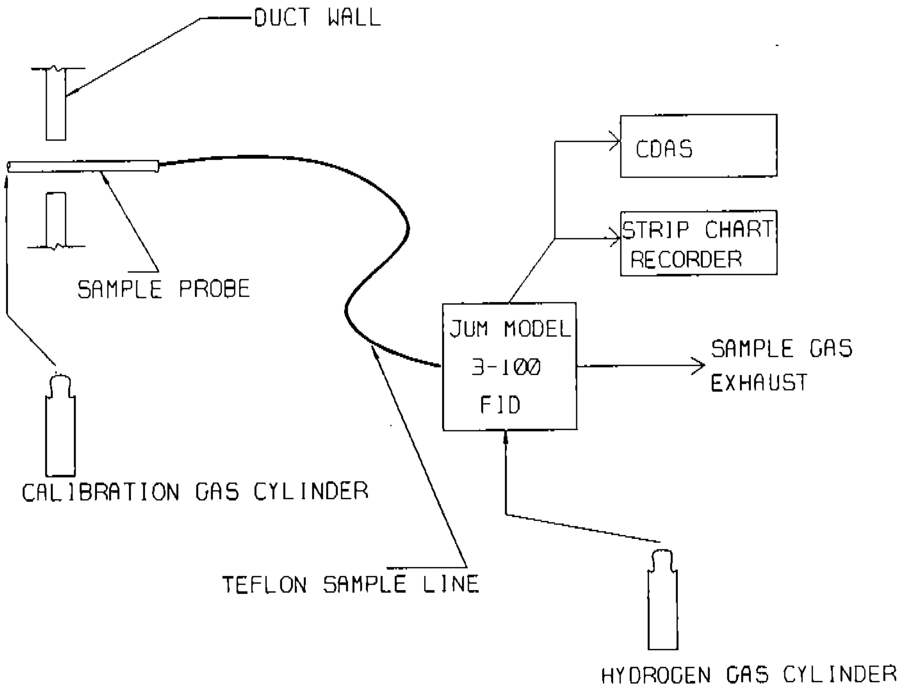


Diagram 4.1 - FID Sampling and Analytical Schematic

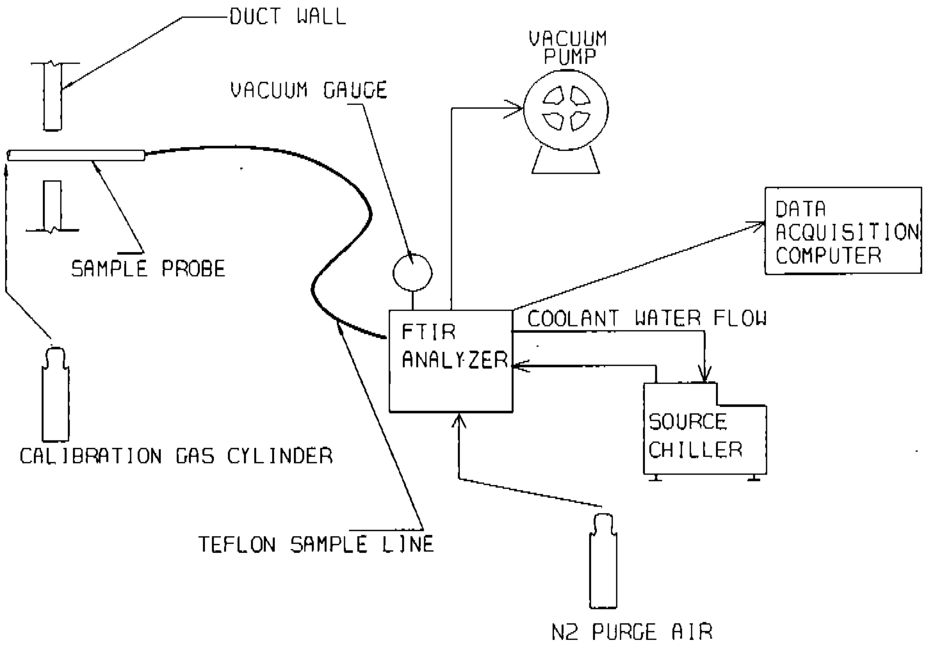


Diagram 4.2 - FTIR Sampling and Analytical Schematic

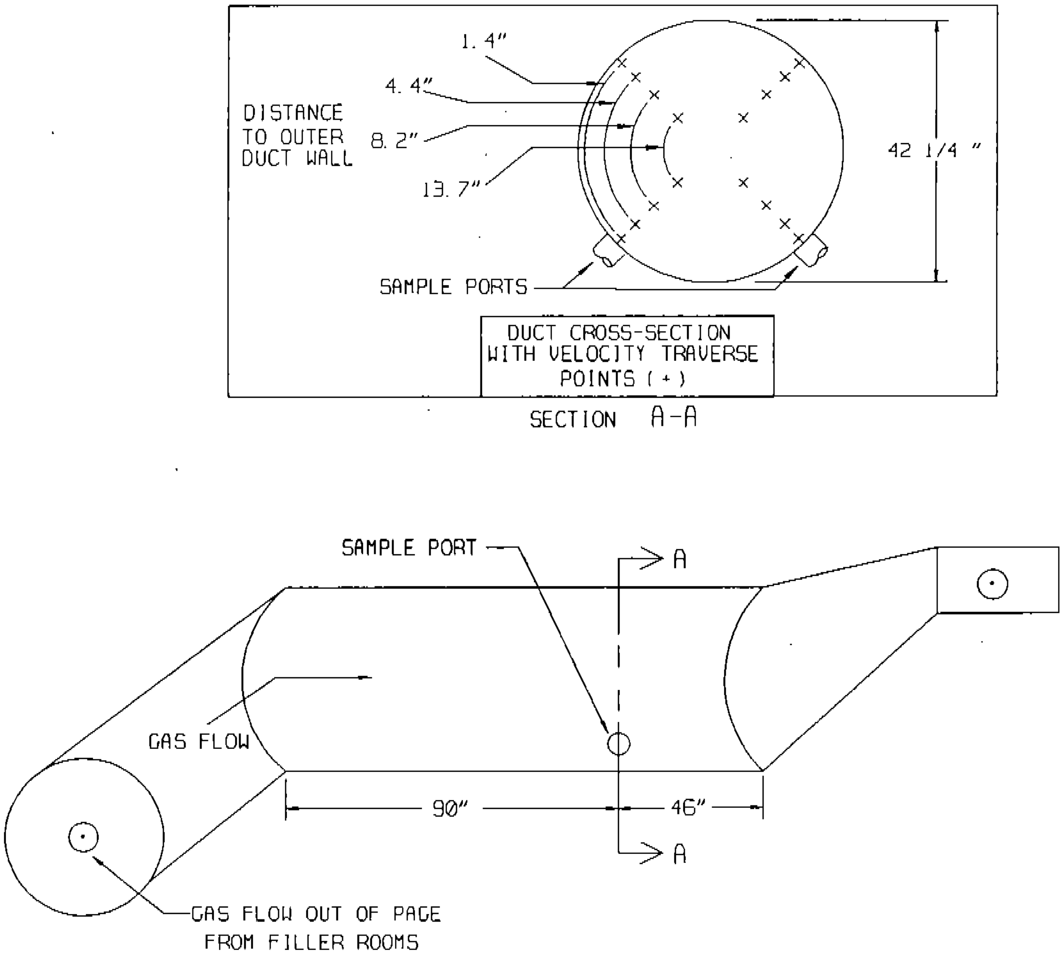


Diagram 4.3 - Bottle Filler Exhaust Duct

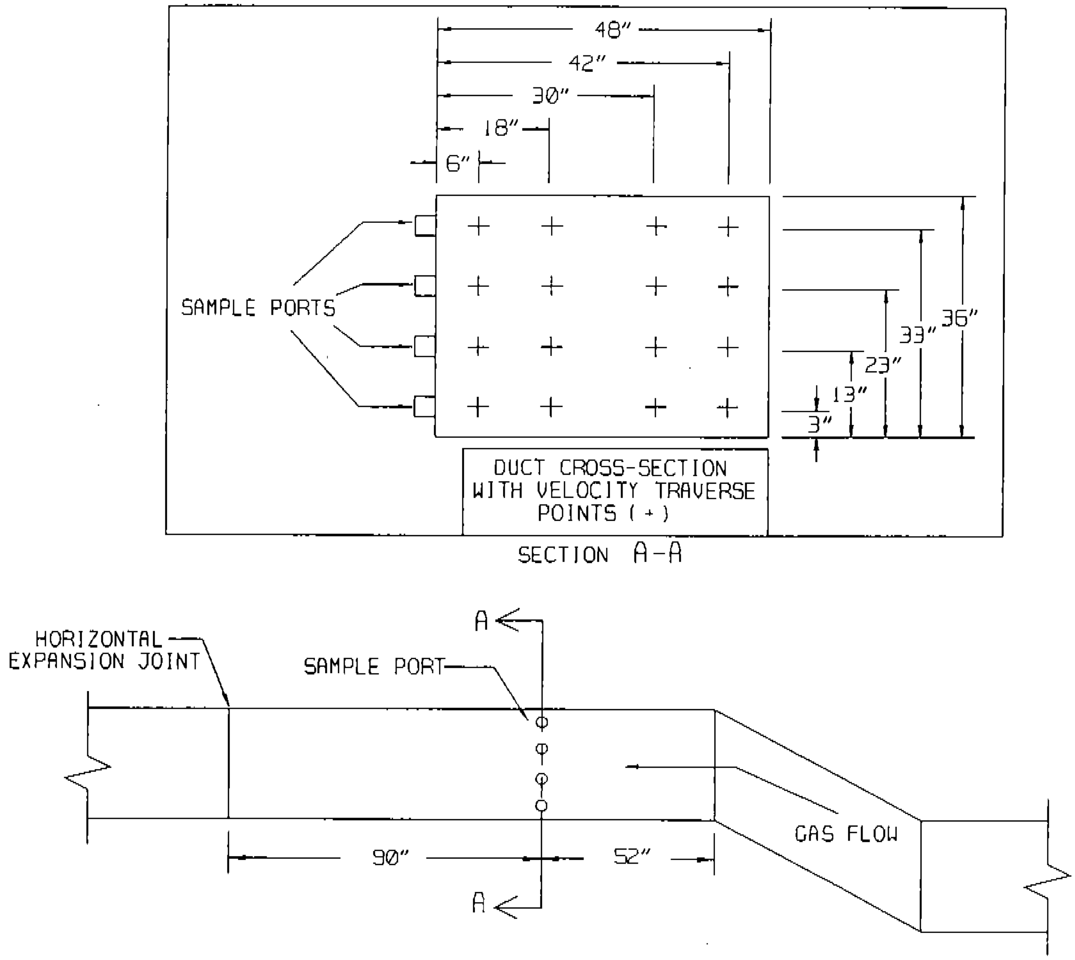


Diagram 4.4 - Can Filler Exhaust Duct

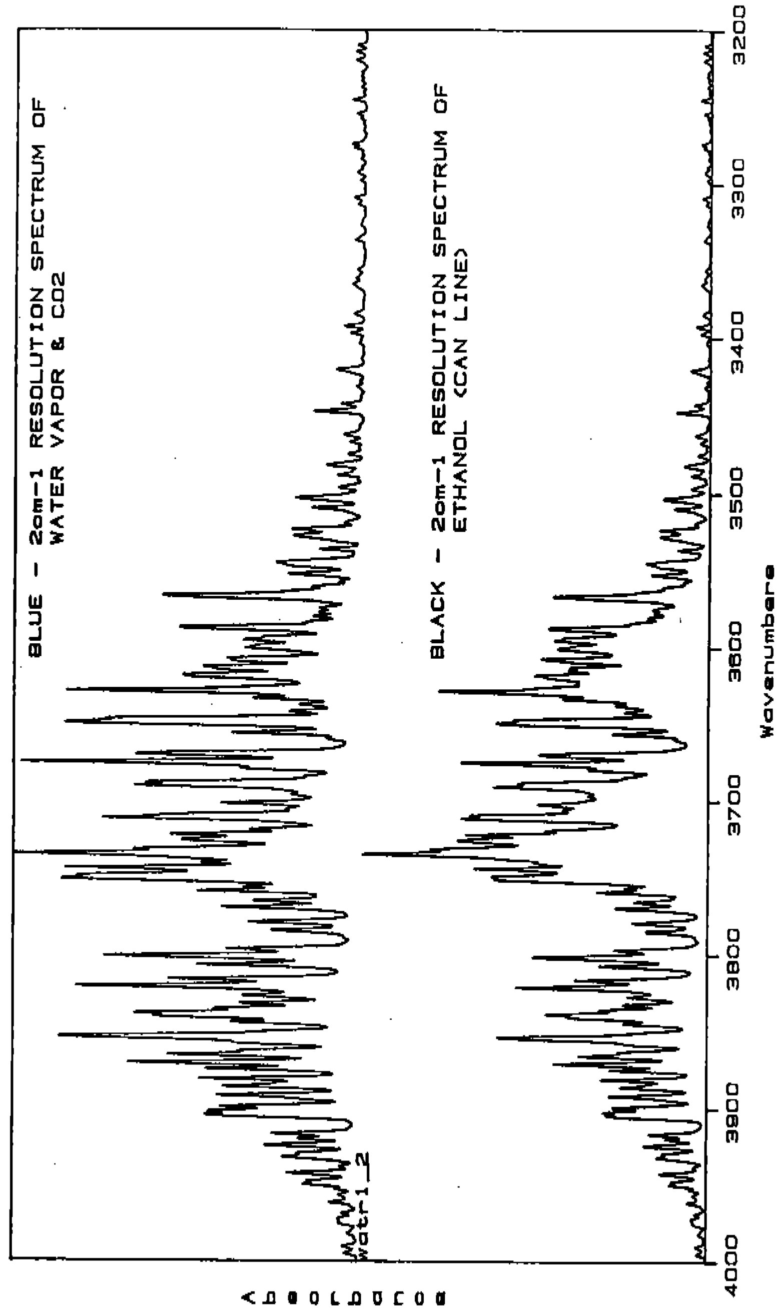


Diagram 4.5a - 2cm^{-1} Resolution FTIR Spectrum of Water Vapor and Carbon Dioxide versus Can Line Exhaust (4000 through 3200 wavenumbers)

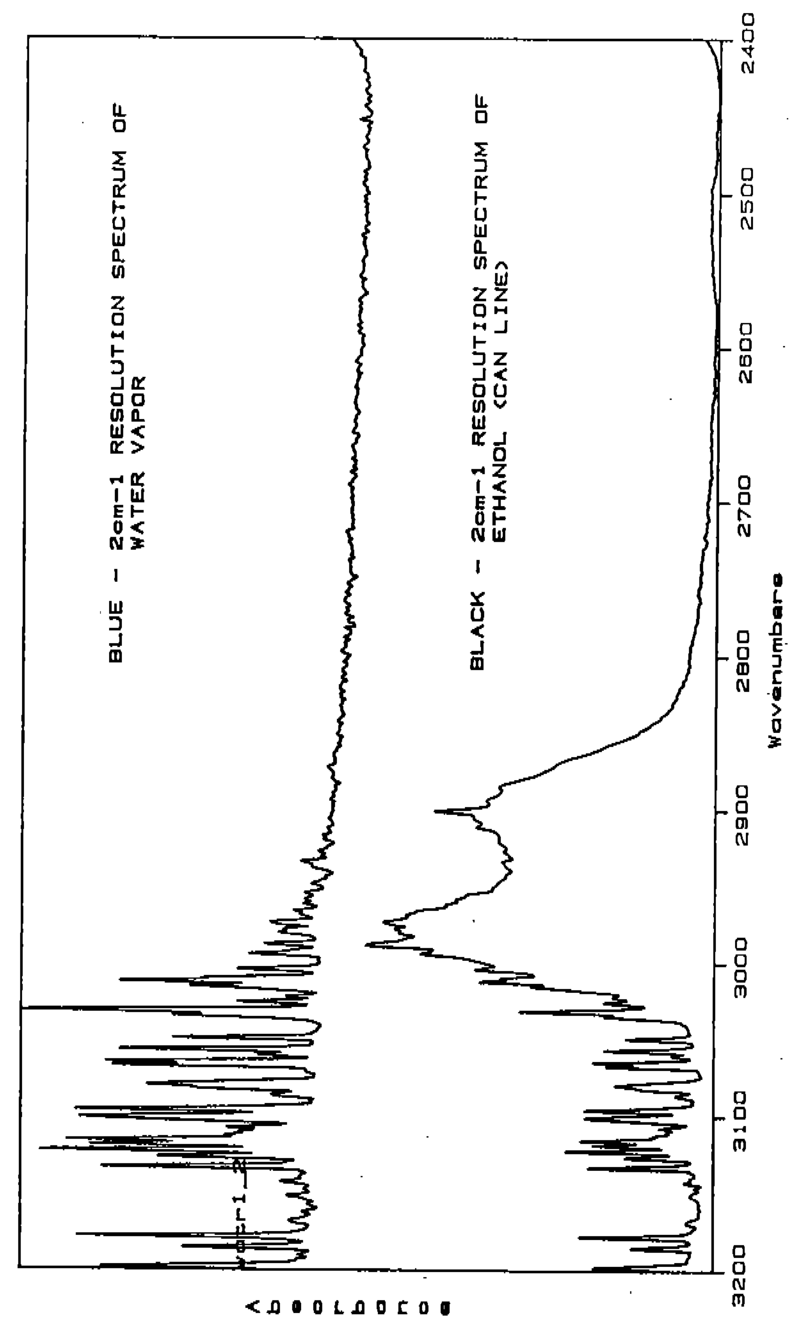


Diagram 4.5b - 2cm^{-1} Resolution FTIR Spectrum of Water Vapor and Carbon Dioxide versus Can Line Exhaust (3200 through 2400 wavenumbers)

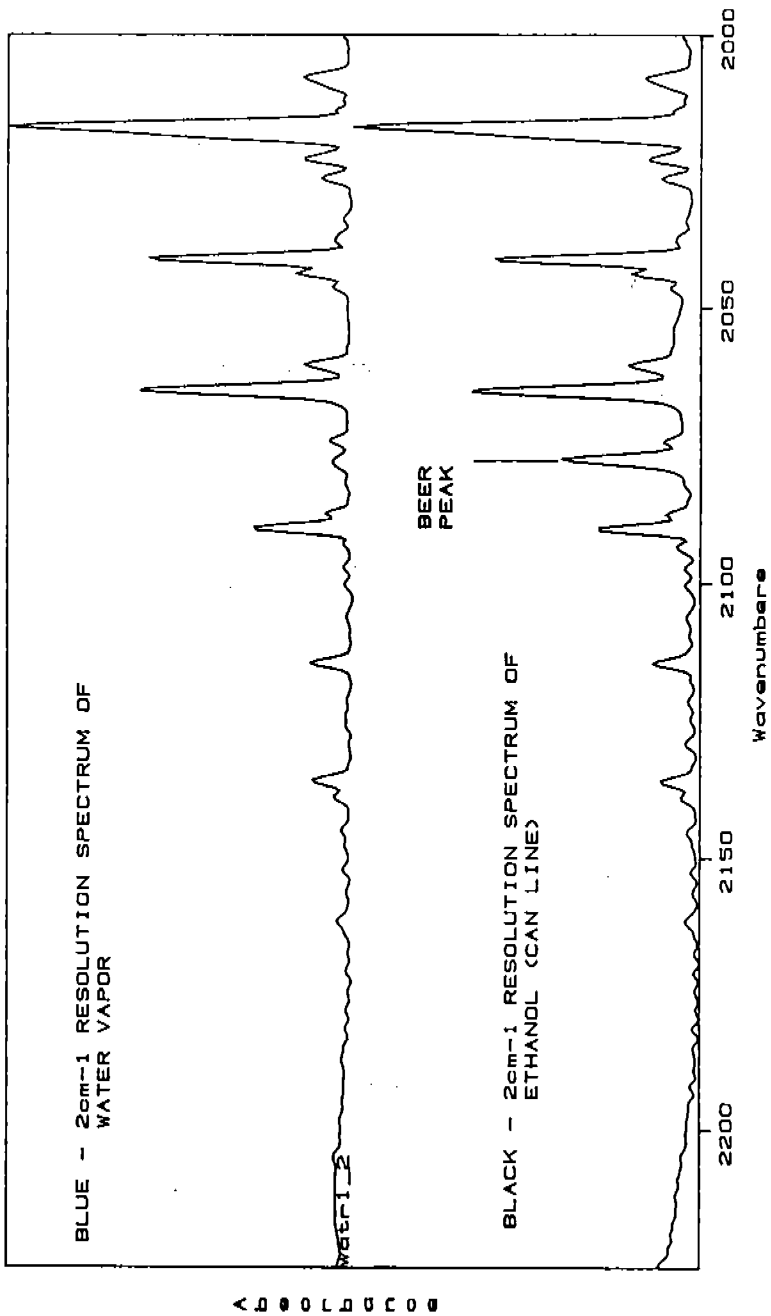


Diagram 4.5c - 2cm^{-1} Resolution FTIR Spectrum of Water Vapor and Carbon Dioxide versus Can Line Exhaust (2400 through 2000 wavenumbers)

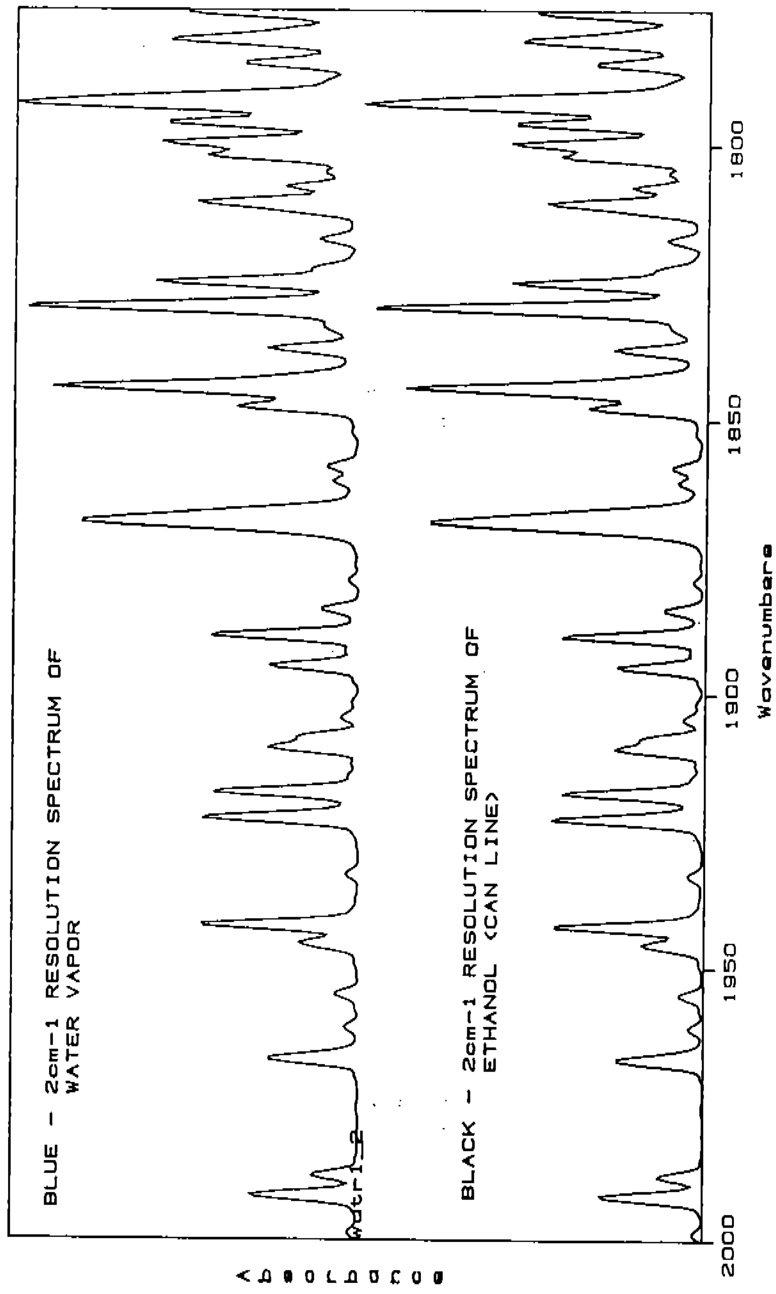


Diagram 4.5d - 2cm^{-1} Resolution FTIR Spectrum of Water Vapor and Carbon Dioxide versus Can Line Exhaust (2000 through 1775 wavenumbers)

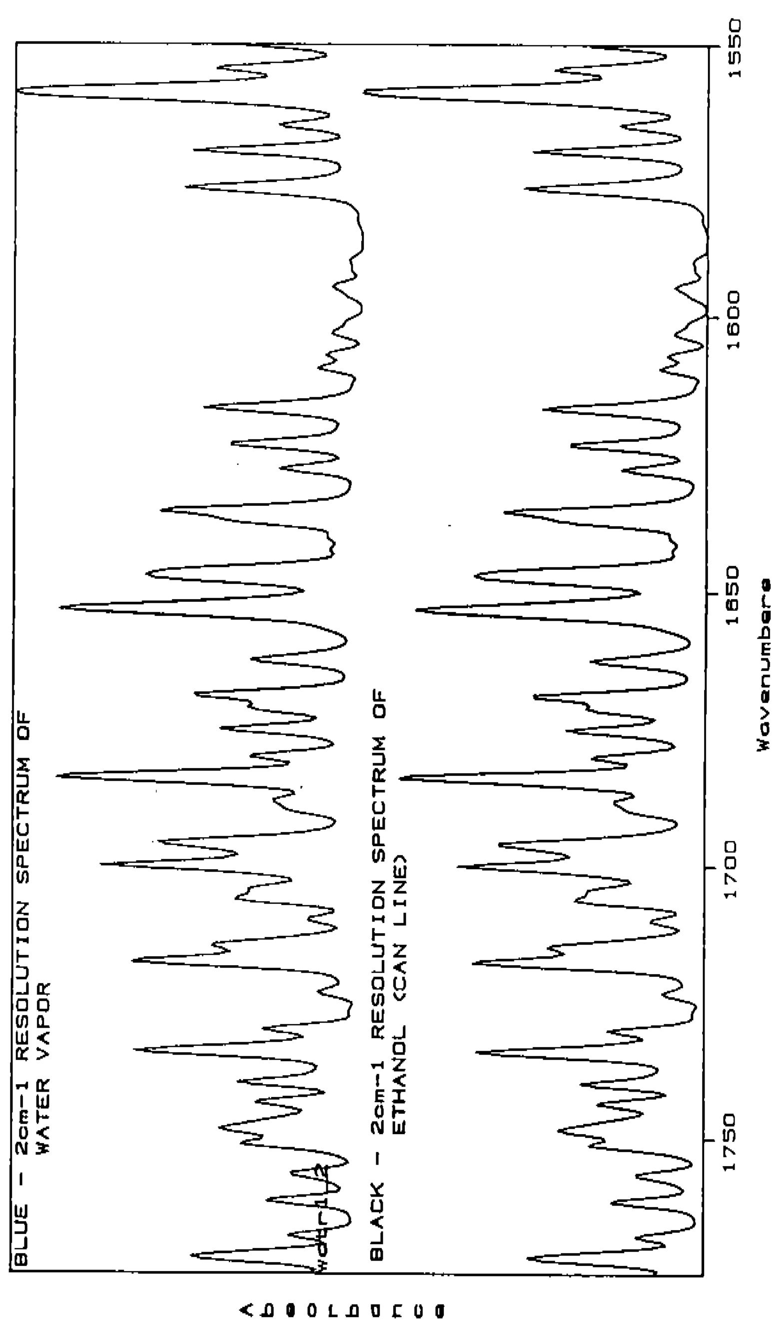


Diagram 4.5e - 2cm^{-1} Resolution FTIR Spectrum of Water Vapor and Carbon Dioxide versus Can Line Exhaust (1775 through 1550 wavenumbers)

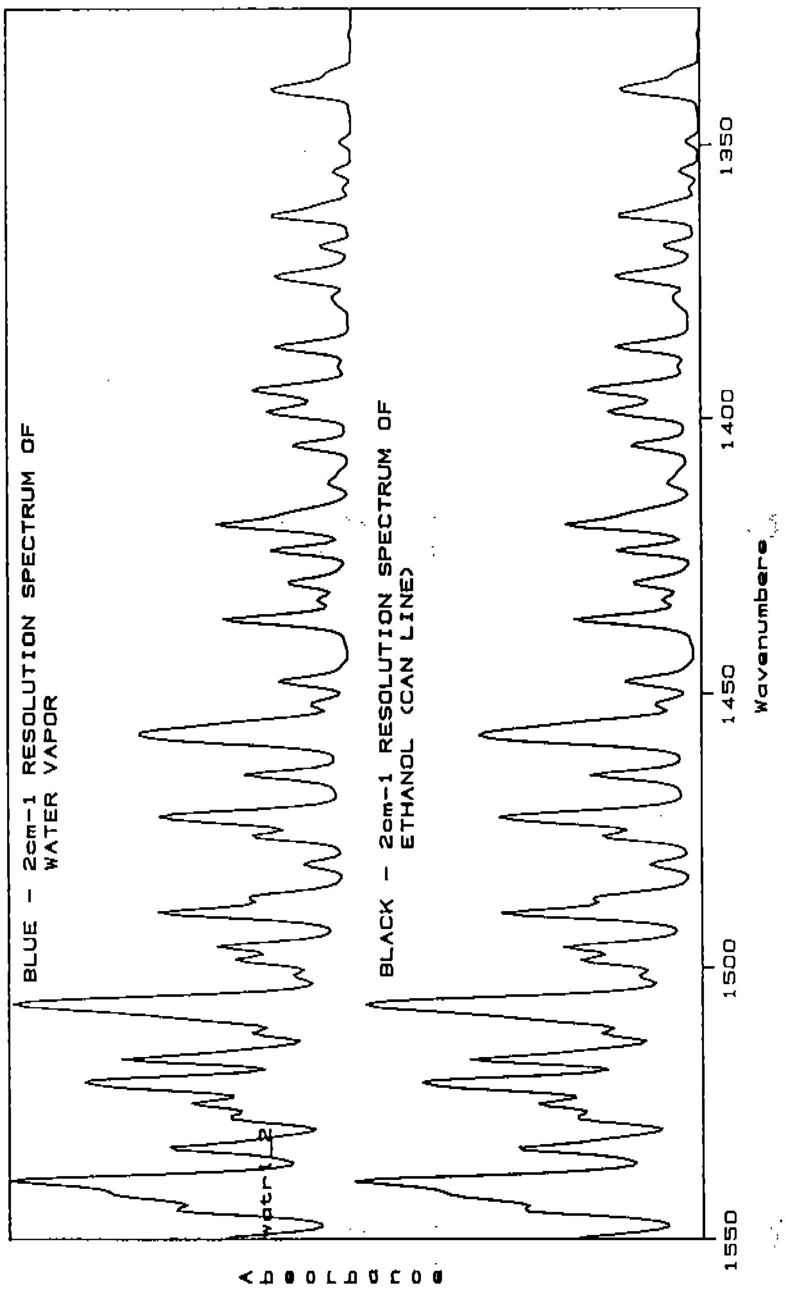


Diagram 4.5f - 2cm^{-1} Resolution FTIR Spectrum of Water Vapor and Carbon Dioxide versus Can Line Exhaust (1550 through 1325 wavenumbers)

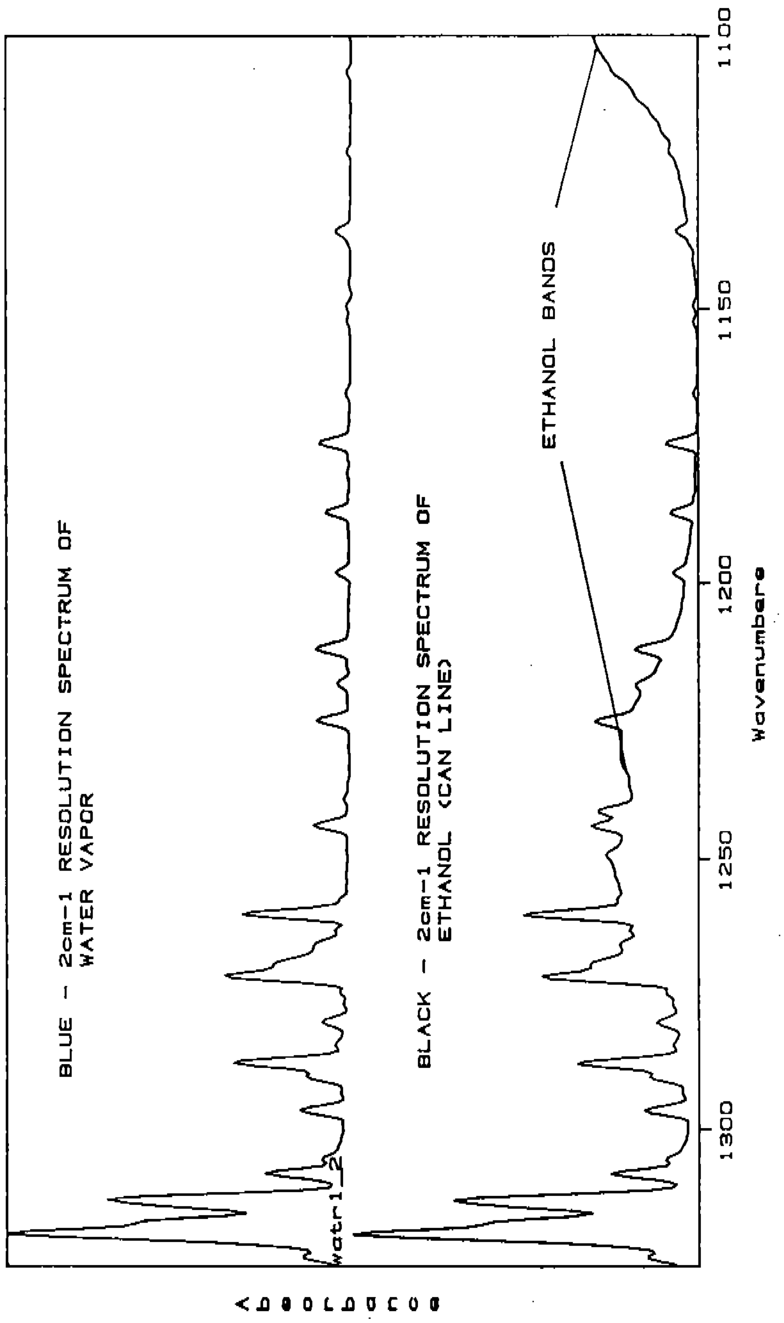


Diagram 4.5g - 2cm^{-1} Resolution FTIR Spectrum of Water Vapor and Carbon Dioxide versus Can Line Exhaust (1325 through 1100 wavenumbers)

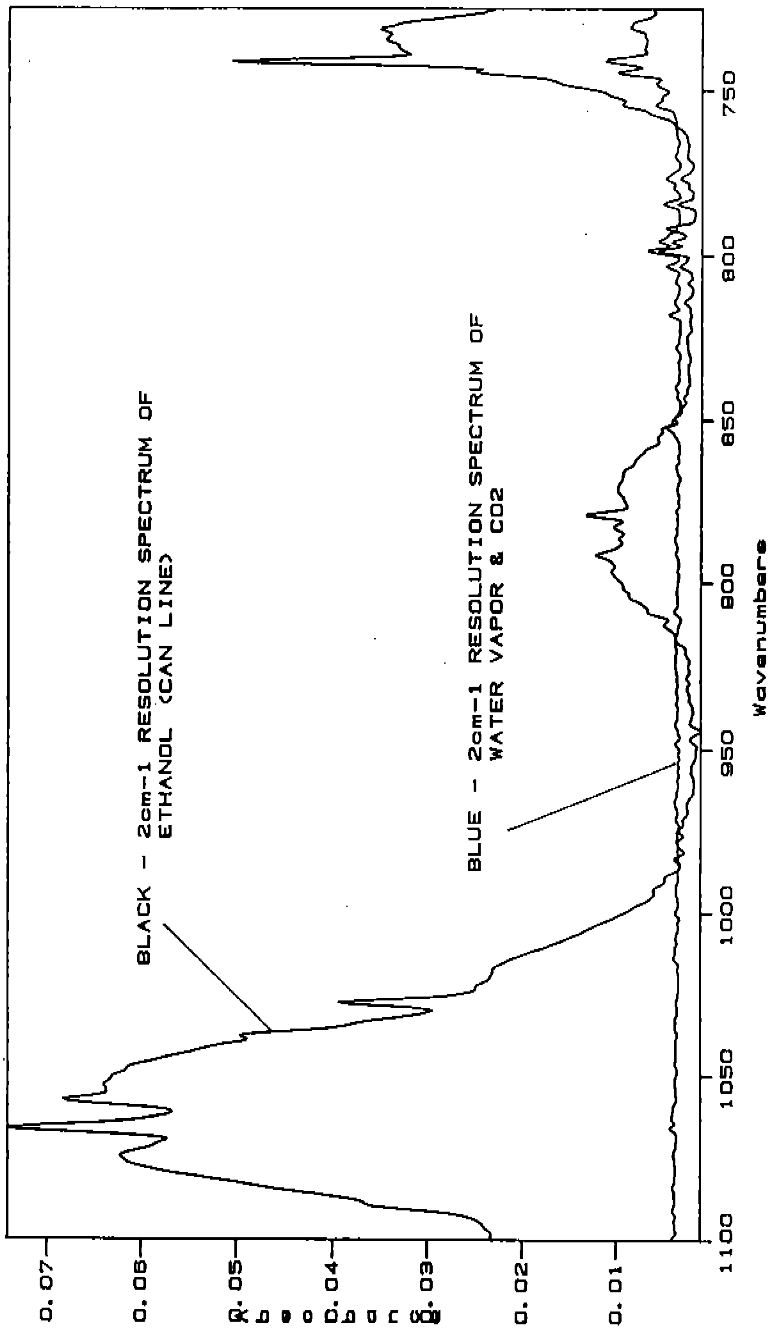


Diagram 4.5h - 2cm^{-1} Resolution FTIR Spectrum of Water Vapor and Carbon Dioxide versus Can Line Exhaust (1100 through 725 wavenumbers)

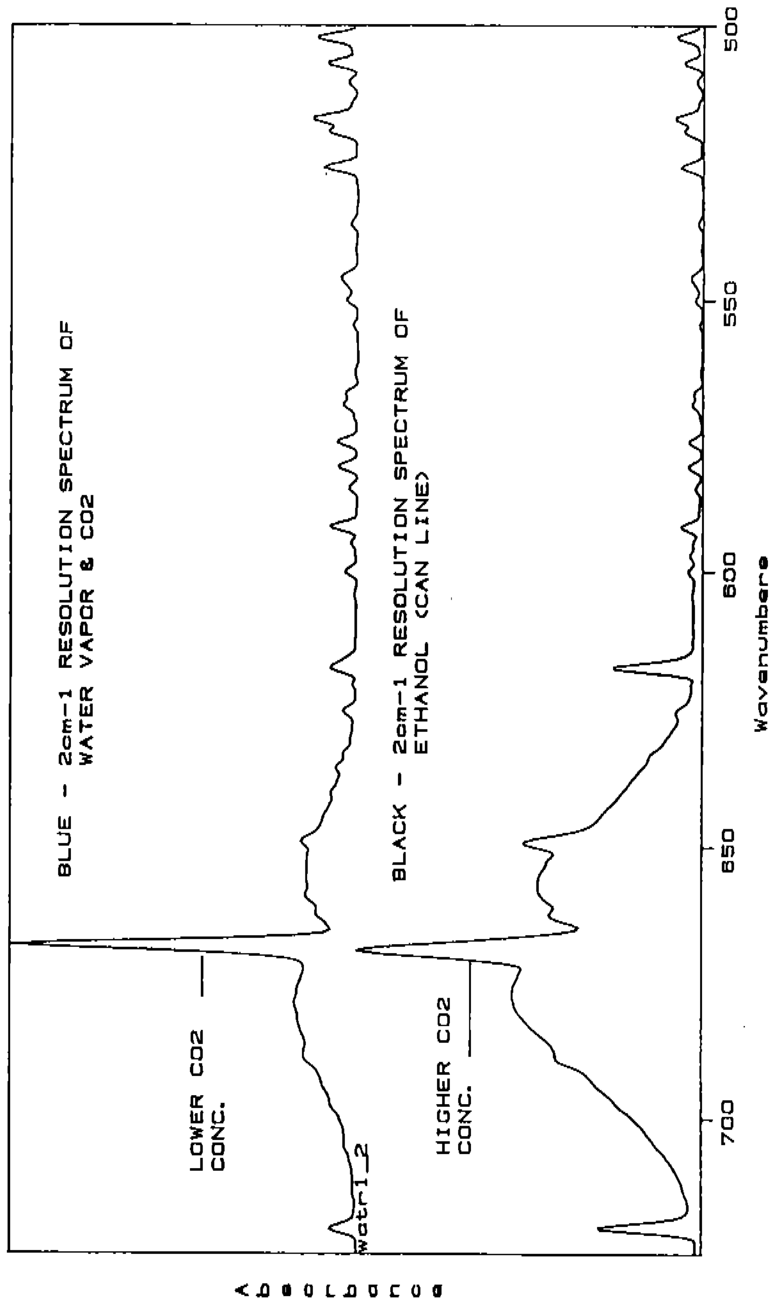


Diagram 4.5i - 2cm^{-1} Resolution FTIR Spectrum of Water Vapor and Carbon Dioxide versus Can Line Exhaust (725 through 500 wavenumbers)

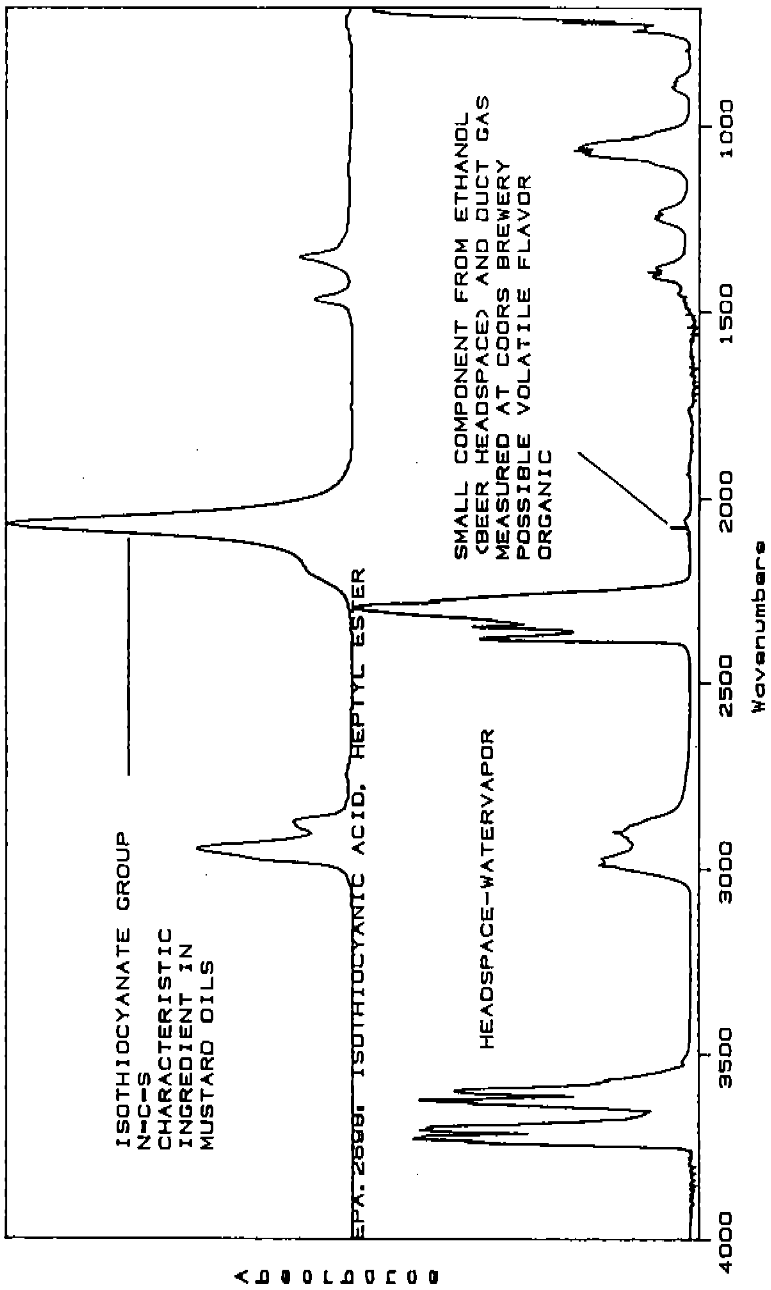


Diagram 4.6 - FTIR Spectrum of Small Component from Beer Headspace and Duct Gas, Possible Volatile Flavor Organic

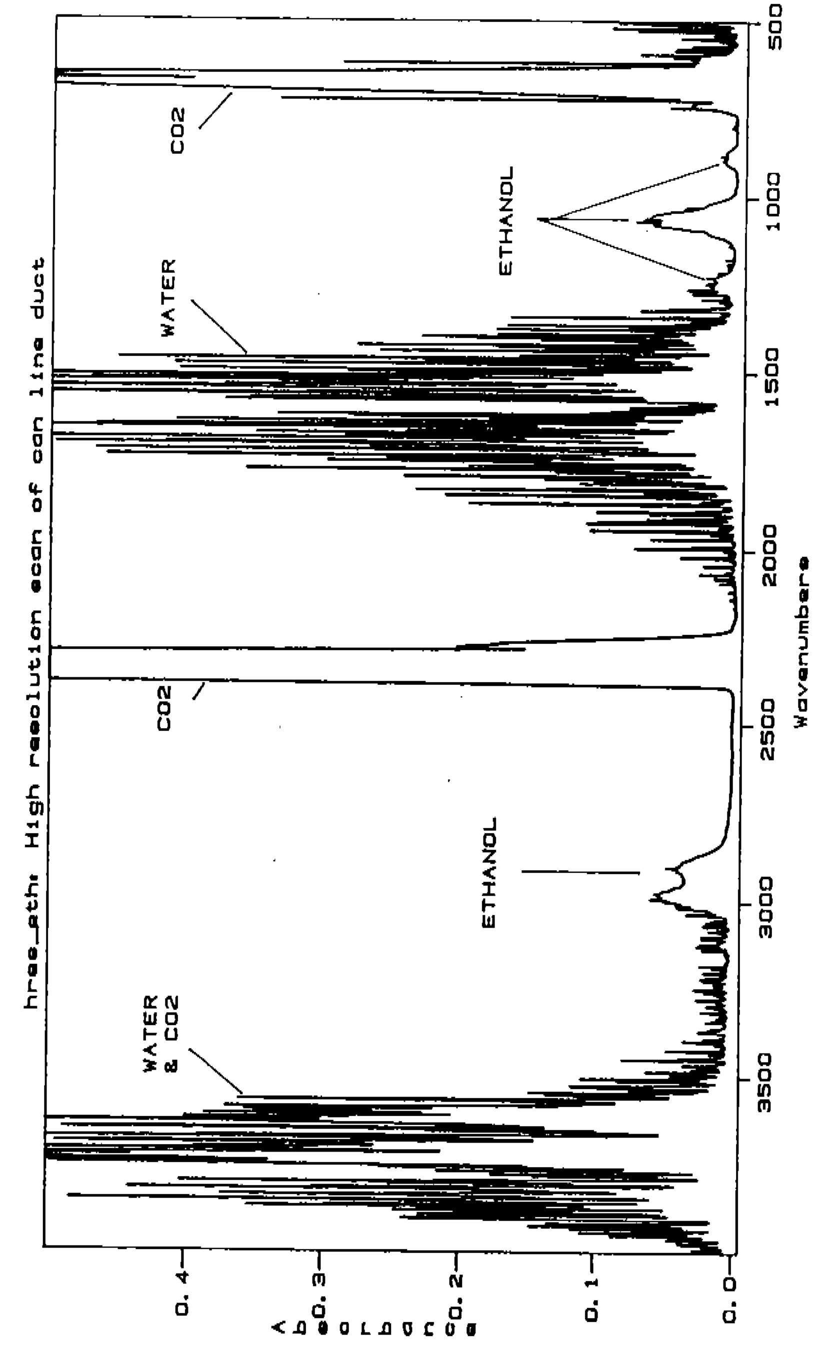


Diagram 4.7 - High Resolution FTIR Spectrum of Can Line Duct Gas

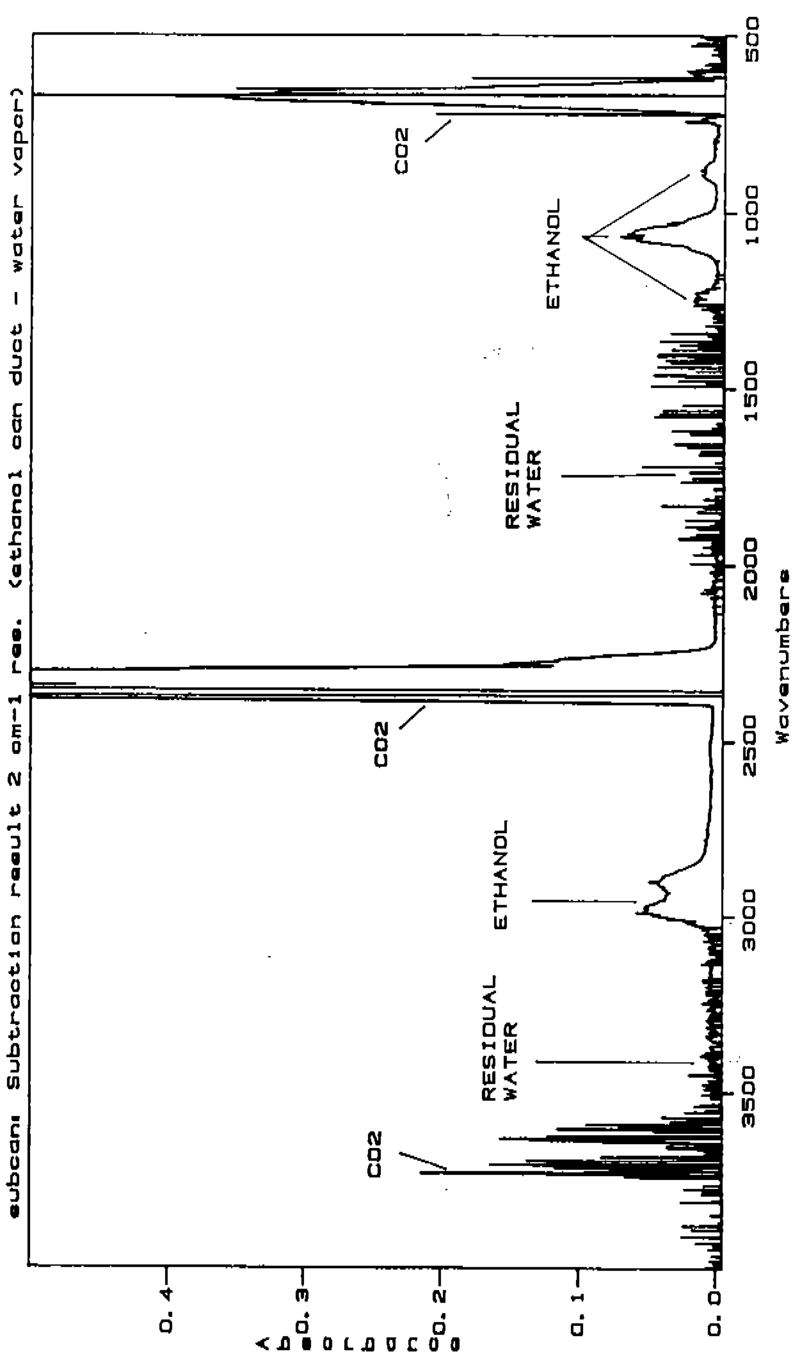


Diagram 4.8 - FTIR Subtraction Spectrum of Can Line Duct Gas - Water Vapor

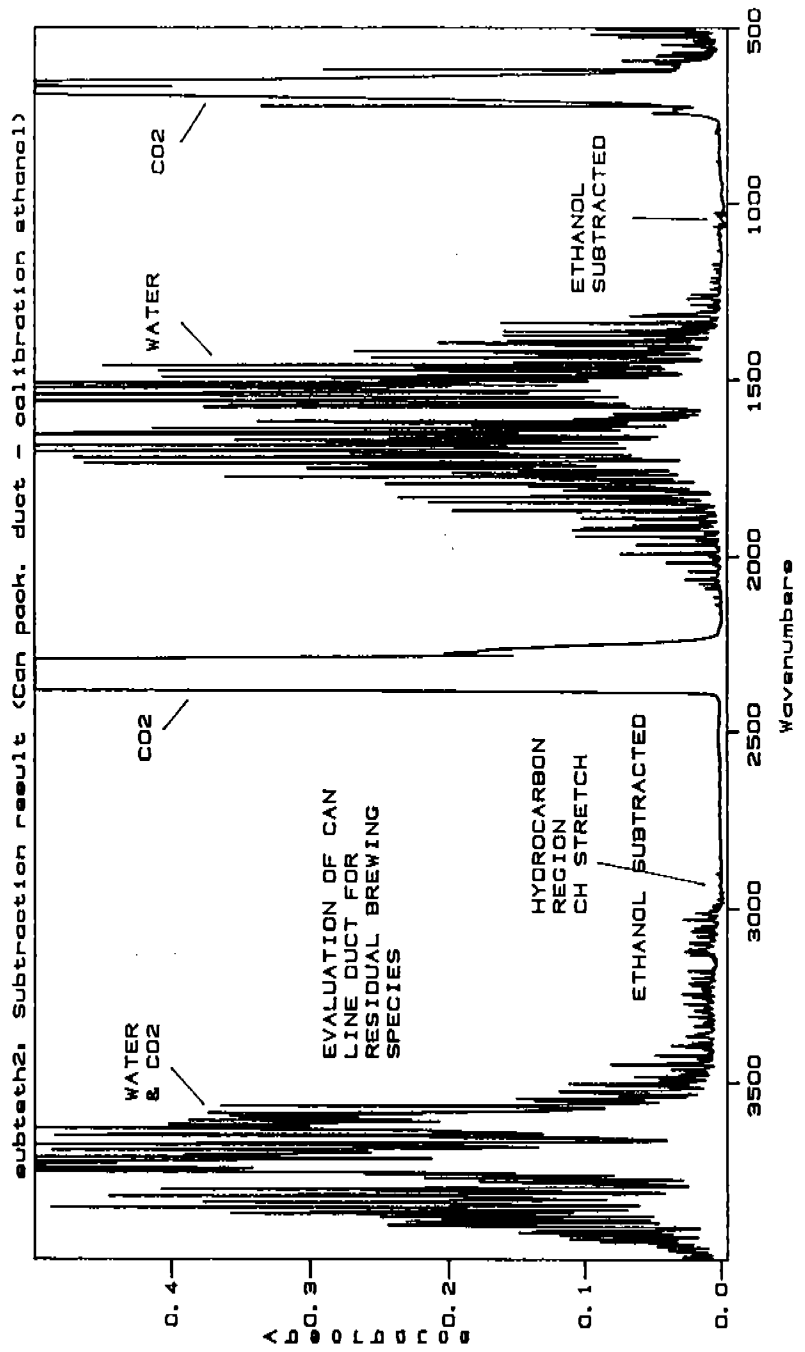


Diagram 4.9 - FTIR Subtraction Spectrum of Can Line Duct Gas - Ethanol Calibration Gas

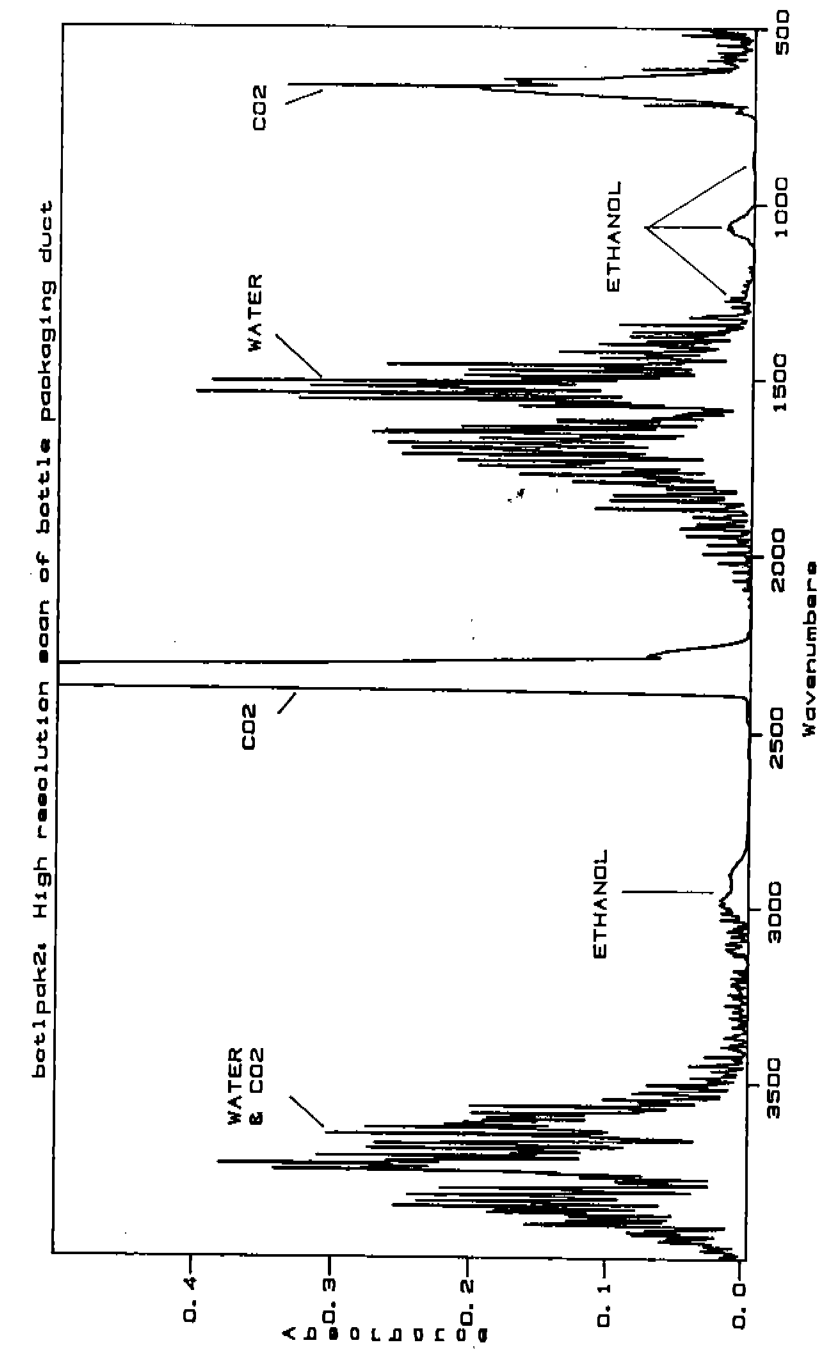


Diagram 4.10 - High Resolution FTIR Spectrum of Bottle Line Duct Gas

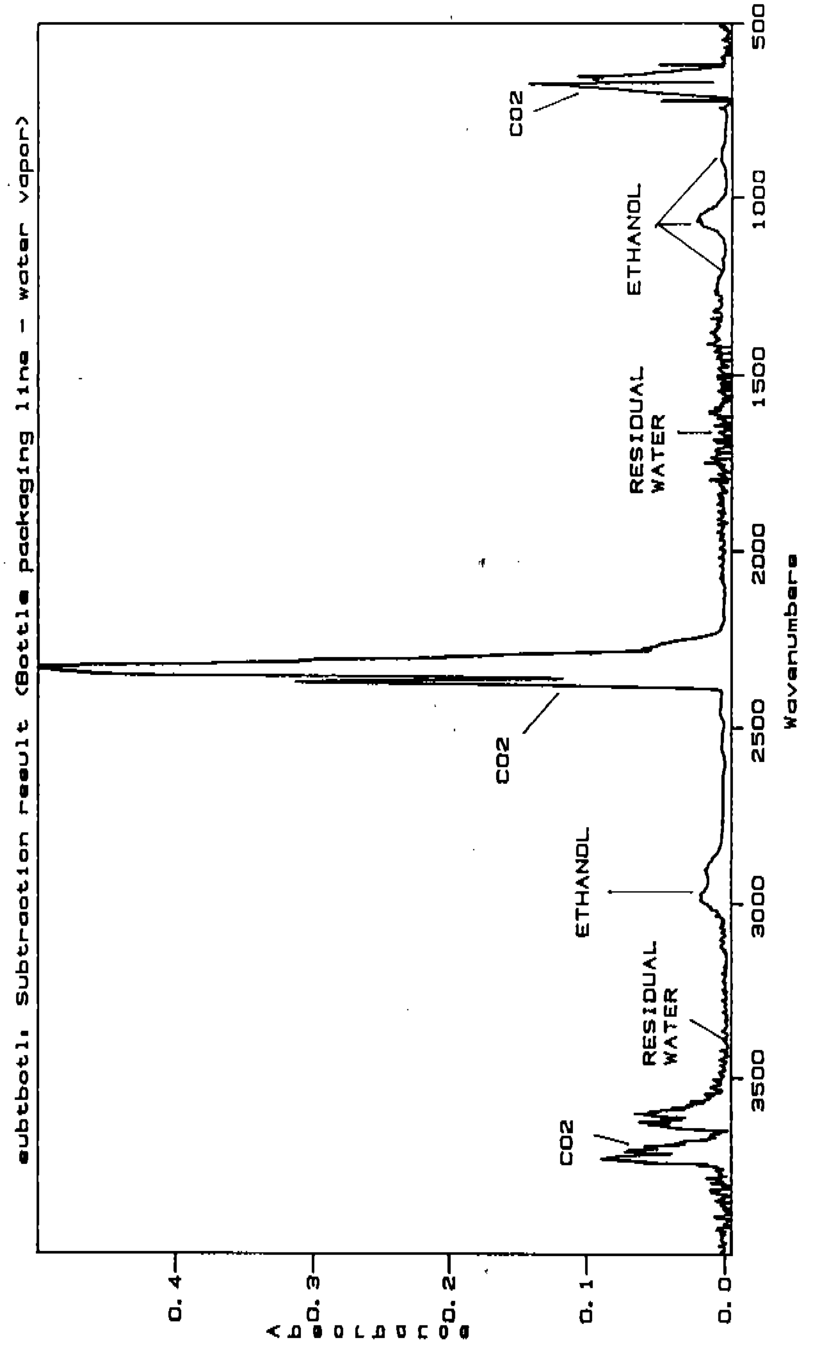


Diagram 4.11 - FTIR Subtraction Spectrum of Bottle Line Duct Gas - Water Vapor

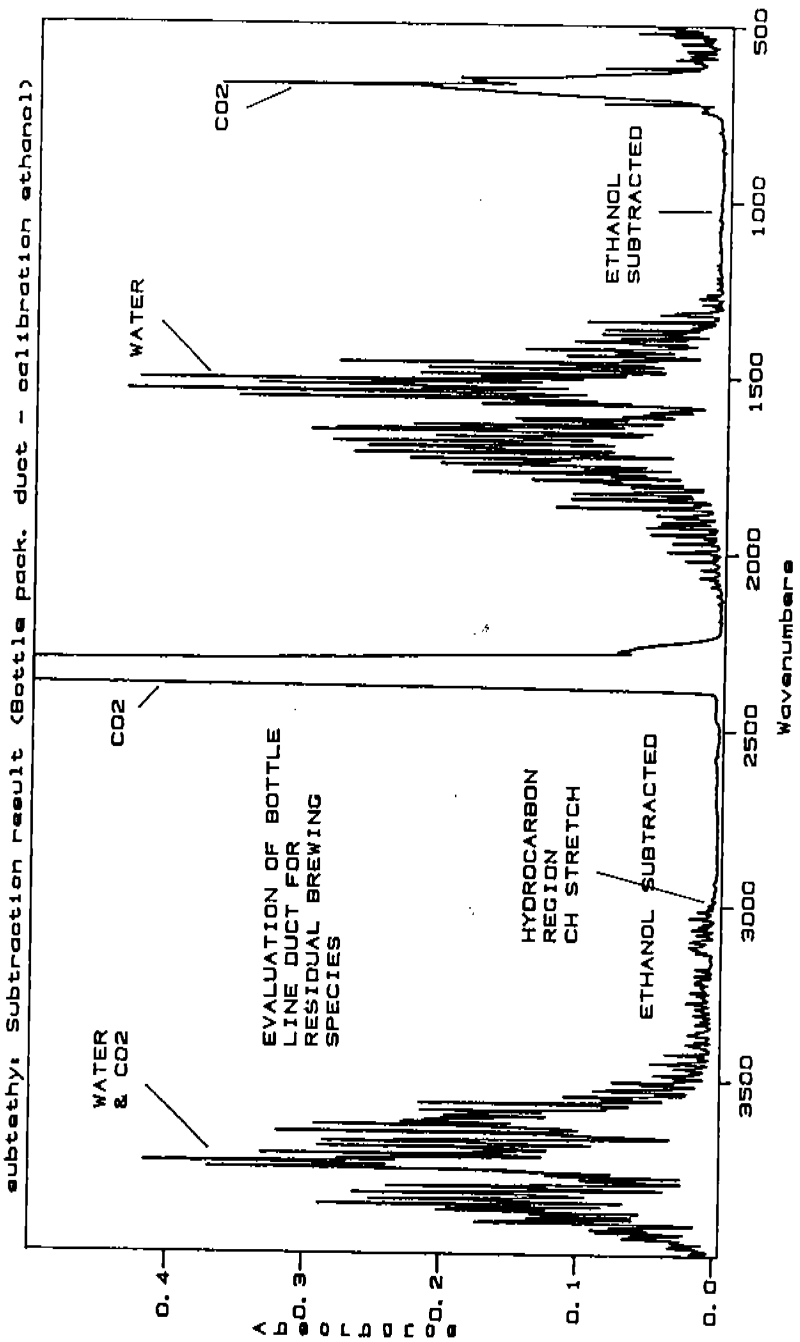


Diagram 4.12 - FTIR Subtraction Spectrum of Bottle Line Duct Gas - Ethanol Calibration Gas

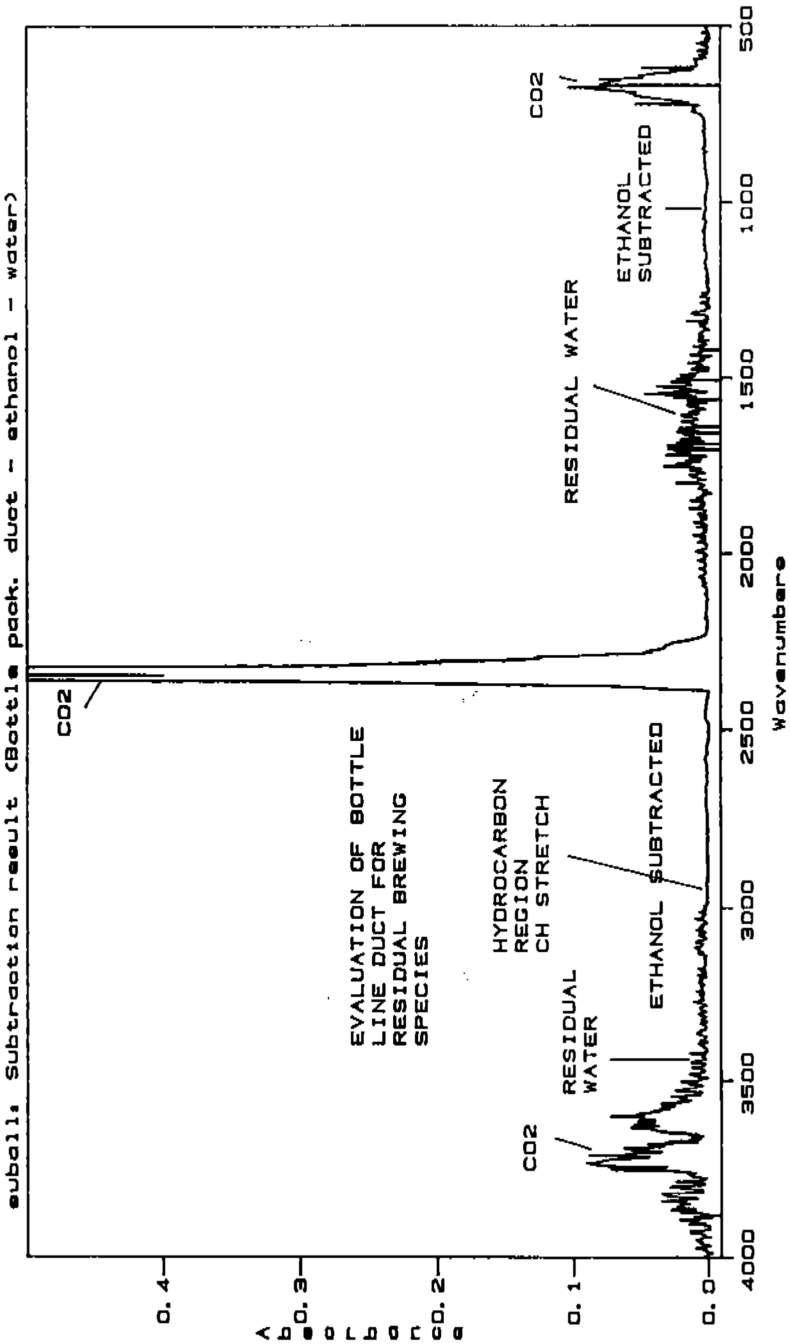


Diagram 4.13 - FTIR Subtraction Spectrum of Bottle Line Duct Gas - Ethanol Calibration Gas - Water Vapor

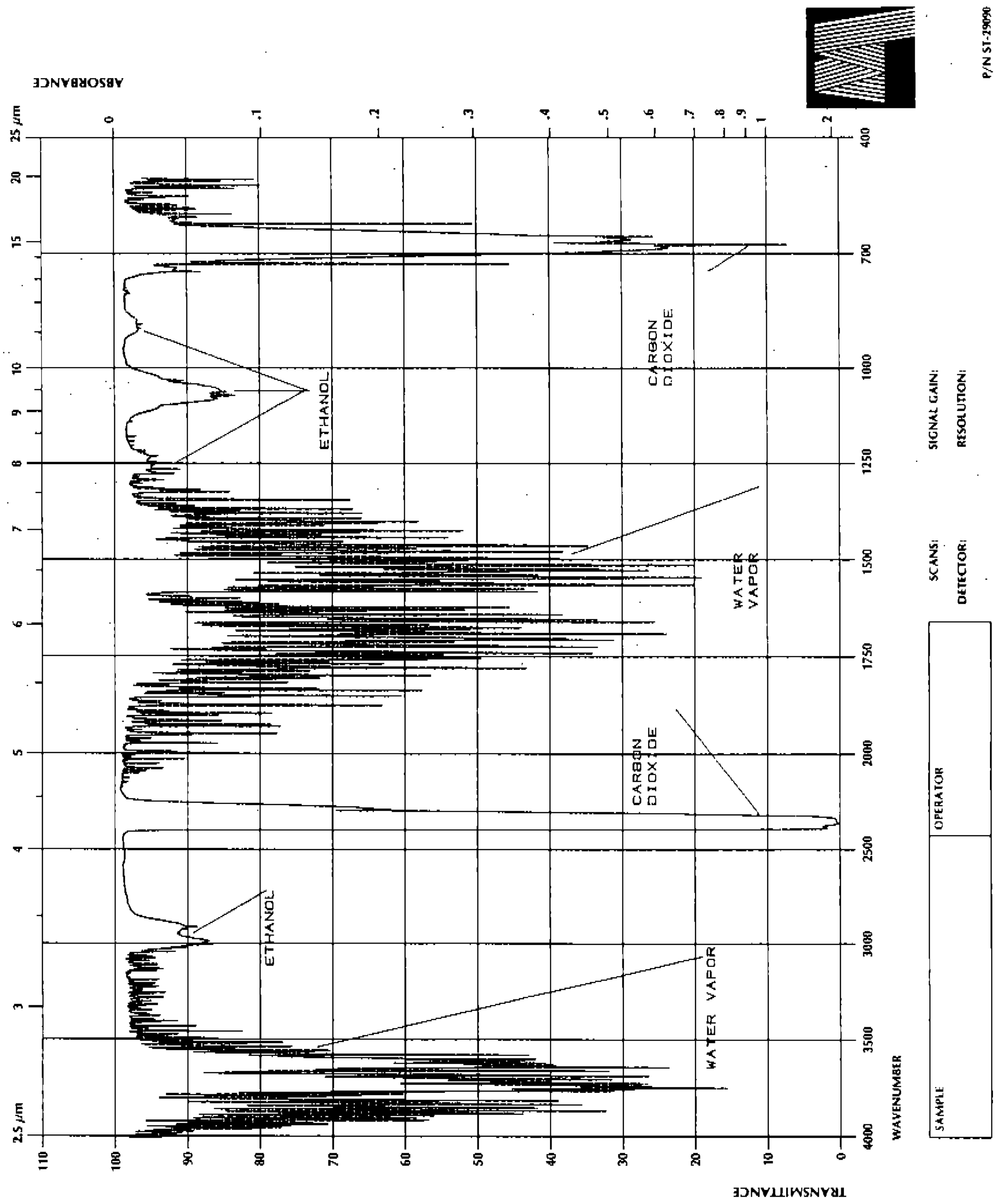


Diagram 4.14 - High Resolution FTIR Spectrum of Can Filler Exhaust

Results

The results of the testing are presented in Tables 5.1 and 5.2, and in Charts 5.1 through 5.6. Any testing parameters not found in the tables and charts may be found in *Appendix I - Testing Parameters / Sample Calculations* at the back of this report.

The following abbreviations are used in the tables and charts.

Temp. (°F) - temperature, degrees Fahrenheit

dscfm - dry standard (1 atmosphere pressure, 68 °F) cubic feet per minute

FID - flame ionization detector

FTIR - Fourier transform, infrared

ppmv - parts per million, volume basis

lb/hr - pounds per hour

FID Relative Error - the difference between the FID and FTIR data relative to the FTIR data

Coors Brewing Company Bottle Filler Exhaust Ethanol Emissions				
	Run #1 (1)	*Run #2 (2)*	*Run #3*	***Average***
Date	4-3-95	4-3-95	4-3-95	
Start Time	17:45	19:34	21:53	
Stop Time	18:45	20:53	22:53	
Gas Temp. (°F)	69	69	67	**68**
Gas Flow (dscfm)	20099	20272	18543	**19638**
FID Ethanol Concentration (ppmv)	88.1	95.3	118.7	**100.7**
FID Ethanol Emissions (lb/hr)	12.7	13.8	15.8	**14.1**
FTIR Ethanol Concentration (ppmv)	92.6	108.6	125.8	**109.0**
FTIR Ethanol Emissions (lb/hr)	13.3	15.8	16.7	**15.3**
FID Relative Error (%)	-4.8	-12.2	-5.6	**-7.6**

Table 5.1 - Bottle Filler Exhaust Emissions Results

(1) - Run #1 is essentially an FID-only sampling period. FTIR data were collected for only 11 minutes of this period (from 17:45-17:56).

(2) - During Run #2, a total of 60 minutes of FTIR data were collected discontinuously (from 19:35-20:05 and again from 20:23-20:53).

Coors Brewing Company Can Filler Exhaust Ethanol Emissions				
	Run #1	*Run #2* [1]	*Run #3*	***Average***
Date	4-4-95	4-4-95	4-4-95	
Start Time	16:30	18:02	19:06	
Stop Time	17:30	19:02	20:03	
Gas Temp. (°F)	72	72	77	**74**
Gas Flow (dscfm)	29452	28820	27763	**28678**
FID Ethanol Concentration (ppmv)	71.5	58.1	71.2	**66.9**
FID Ethanol Emissions (lb/hr)	15.1	12.0	14.2	**13.8**
FTIR Ethanol Concentration (ppmv)	68.4	N/A	77.7	**73.0**
FTIR Ethanol Emissions (lb/hr)	14.4	N/A	15.5	**15.0**
FID Relative Error (%)	4.5	N/A	-8.3	**-1.9**

Table 5.2 - Can Filler Exhaust Emissions Results

[1] - Run #2 is an FID-only sampling period. No FTIR data were collected during this period.

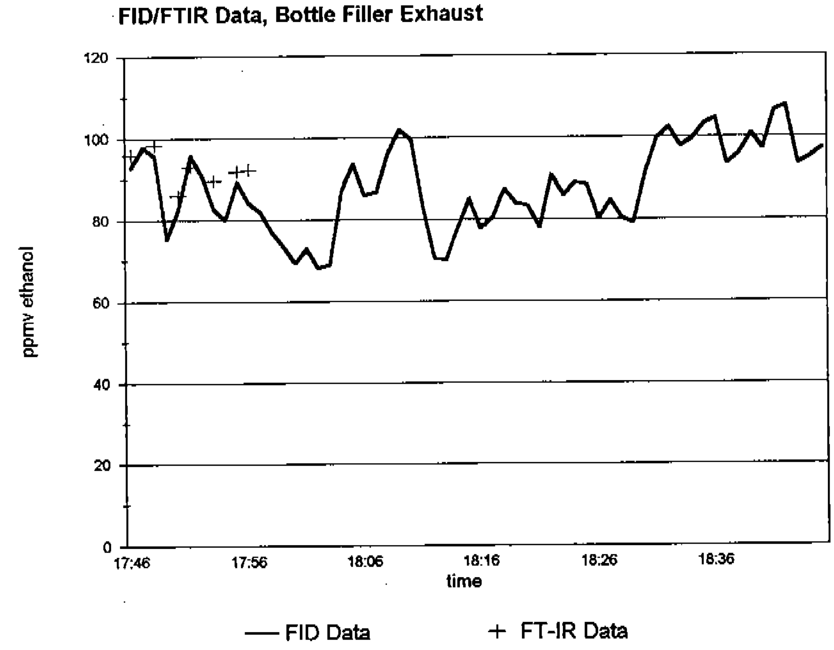


Chart 5.1 - FID/FTIR Emissions Data, Bottle Filler Exhaust 4-3-95

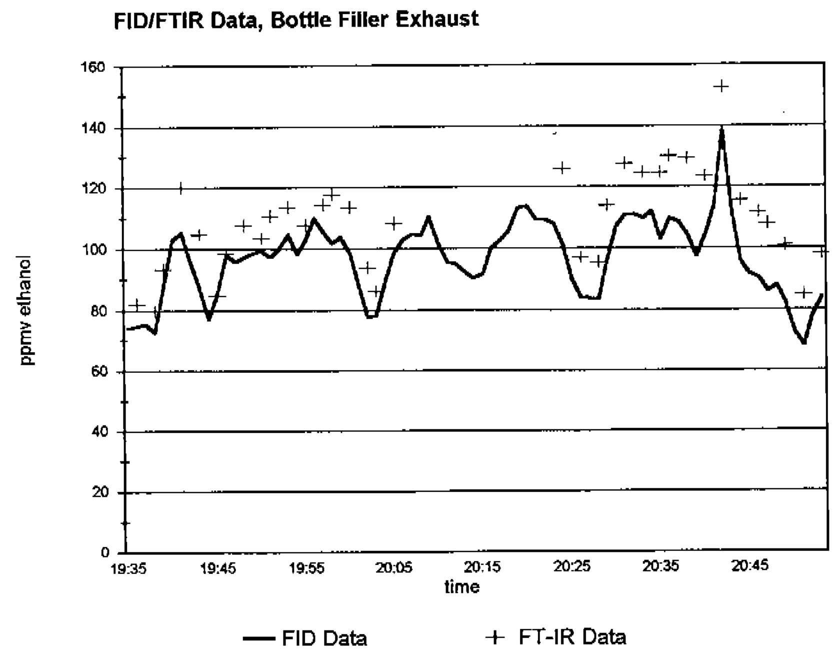


Chart 5.2 - FID/FTIR Emissions Data, Bottle Filler Exhaust 4-3-95

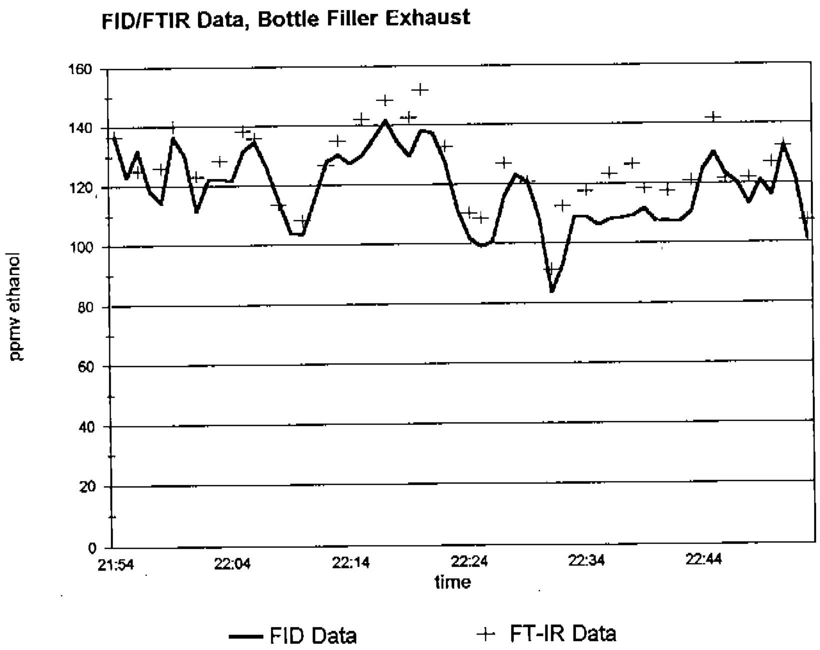


Chart 5.3 - FID/FTIR Emissions Data, Bottle Filler Exhaust 4-3-95

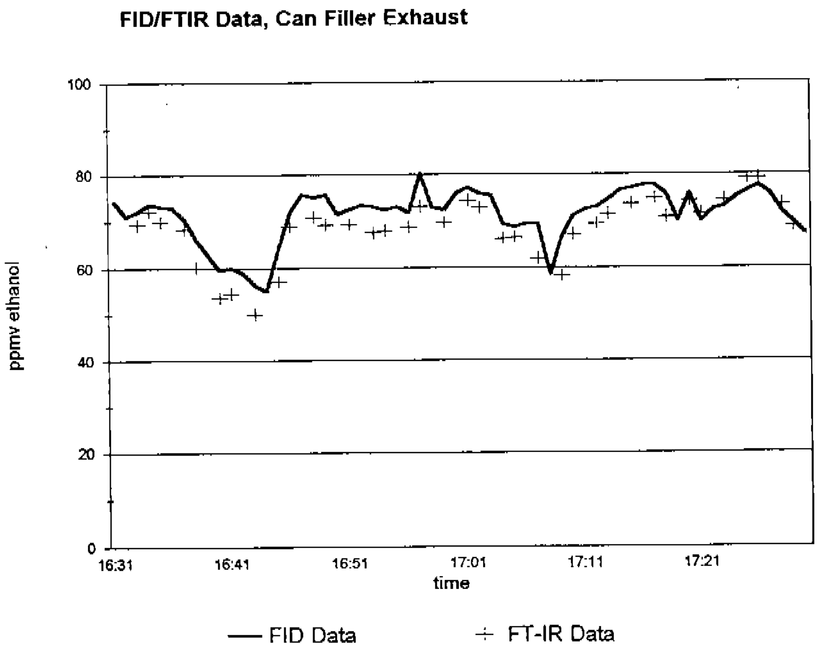


Chart 5.4 - FID/FTIR Emissions Data, Can Filler Exhaust 4-4-95

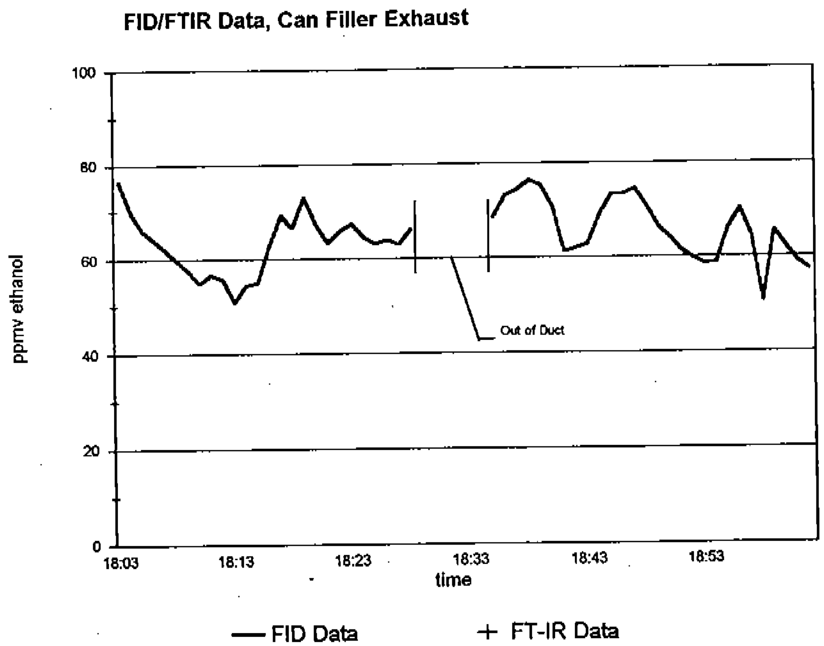


Chart 5.5 - FID/FTIR Emissions Data, Can Filler Exhaust 4-4-95

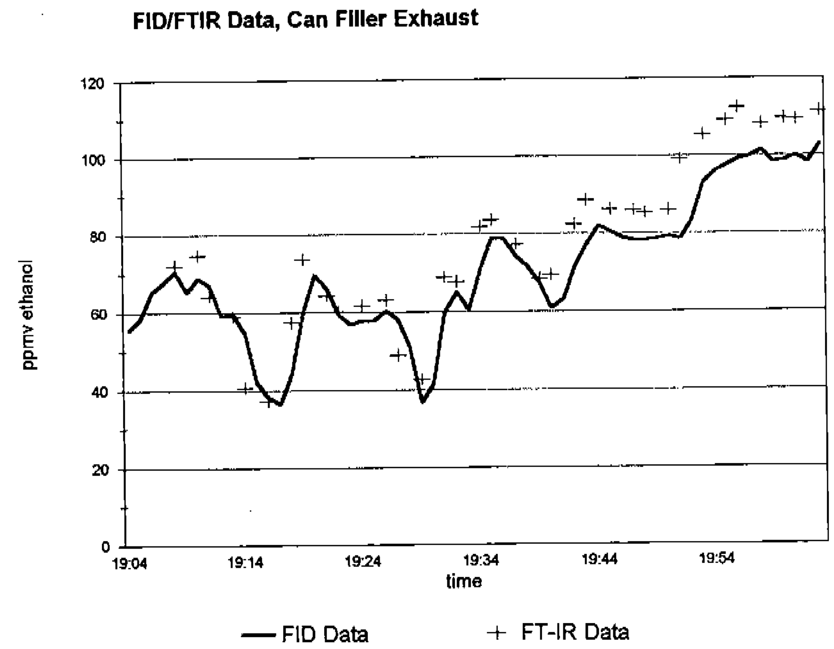


Chart 5.6 - FID/FTIR Emissions Data, Can Filler Exhaust 4-4-95

6. Uncertainty Discussion

6.1. FID Data

As previously indicated in this report, earlier emissions testing work was done on the same ducts considered in the current testing program. The propane-calibrated FID data were converted to ethanol values using an empirical scaling factor of 2.40 (volume concentration basis). This factor was the average yielded from the preparation and analysis of 5 bag standards. The current testing program determined 2 scaling factors, 2.23 with the 15.11 ppm ethanol calibration gas, and 2.02 with the 143.2 ppm ethanol calibration gas.

For the calculations presented in this report, a scaling factor of 2.12 (the average of 2.02 and 2.23) was used. The variation in scaling factors indicates that uncertainty exists in the conversion of the FID data to ethanol values. No trend in the scaling factor versus ethanol gas value is apparent, and it does not appear that the different scaling factors can be used to derive a scaling factor as a function of ethanol concentration. It seems more likely that the range of values represents a random error in the determination of the scaling factor. The source of the random error (i.e., uncertainties in the ethanol calibration standards, or variable FID response to ethanol, or ...) is not known. If the response truly demonstrates a "bell-curve" (or Gaussian) distribution, it would be necessary to conduct many scaling factor determination tests to arrive at the best average value.

In the current test program, an uncertainty is assigned to the data using the limited statistical data available. This report uses only the current scaling factor data. Other available data consist of (at least) the 5 measurements conducted previously by APT personnel using bag injections, and 2 values reported by the JUM manufacturer for a similar instrument (the Model VE-7). If all of these data are used, the average +/- the standard deviation yields 2.31 +/- 0.14 (or roughly 6%). The use of 2.31 as the scaling factor in the current report (versus 2.12) would increase the FID ethanol values in this report by about 9%. This would provide somewhat better agreement between the FID and FTIR data than is demonstrated in the current test program.

In summary, the value of the scaling factor to convert the FID data to FTIR data is not known with great precision. It almost certainly lies between 2.01 and 2.49 (the highest value measured in the Tedlar bag standard work). The subject data, combined with other measurements (conducted by another emissions testing company), indicate that the true value is probably close to 2.30. It may not be a constant from FID to FID. In the current testing program, the greatest deviation between the FID and FTIR data was 12.2%. In light of the various data available for the scaling factor determination, an estimate on the uncertainty of the scaling factor of 12% is reasonable, providing complete overlap (agreement) between the FID and FTIR data.

6.2. FTIR Data

The data obtained at each duct location were affected by different factors that were not anticipated during preparation in the laboratory. These were noted earlier as being excessive vibration at the bottle line duct location and relatively high ambient ethanol at the can line duct location. However, calibrations run during both tests indicate a high linear correlation of 0.998 for the bottle line data and 0.999 for the can line data. Had the cell pathlength been set shorter or much lower ethanol concentrations been encountered, the vibration would have been more of an issue. If the instrument purge was poor, the high ambient ethanol levels would have added to the uncertainty. In both cases, the analyte bands were at least several orders of magnitude higher than the noise level.

Other factors affecting the analysis were as follows. Other interfering species that might contribute to the measured response due to band overlap. The analyte band that was chosen for the analysis was believed to provide the most specificity in the presence of other hydrocarbons. If other compounds were present, they were below the detection limits for this measurement system and did not add to the response. Also critical to accuracy and precision was the ability to control and monitor the pressure in the measurement cell. As indicated earlier, a sensitive pressure transducer was connected to the measurement cell and a direct readout was monitored during all sample and calibration analysis.

7. Conclusions

The results of the subject testing program allow several conclusions.

- The previous emissions testing results conducted at the Coors Brewing Company filler room exhaust ducts using FID measurements and a scaling factor of 2.40 may have overstated the ethanol emissions by a maximum of about 13% (2.40÷2.12=1.13). As indicated previously, the 2.12 used in the current report is probably lower than the true scaling factor value, and the overstatement in the previous emissions testing results is consequently probably less than 13%. In other words, if the true scaling factor is 2.30, the overstatement in previous emissions reports using a scaling factor of 2.40 is about 4% (2.40÷2.30=1.04).

- FTIR and FID both provide similar results when used to measure ethanol in a gas stream. The data agree well in the current testing program, with a maximum deviation of 12.2% and an average deviation of 5.3% (not time weighted). If a Relative Accuracy Test Audit (RATA) was conducted on the FID using the FTIR as the reference method, it would almost certainly meet the 20% Relative Accuracy specification of Performance Specifications 2, 3, 5, and 7 (NO_X, SO_2, O_2, CO_2, TRS, and H_2S continuous emission monitoring systems) as detailed in _40 CFR, Part 60, Appendix B_. The same is clearly true using the FID as the reference method for certification of the FTIR.

- Total VOC content in the filler room exhaust ducts consists exclusively (within analytical detection limits) of ethanol. No other hydrocarbon species were detected by the FTIR instrumentation. While detection limits for all possible organic species cannot practically be determined, 5 ppm of most hydrocarbon species would almost certainly have been detected. Further indication of ethanol as the only significant VOC species is given by the close agreement between the FTIR ethanol data and the FID total VOC data expressed as ethanol. While it may be theoretically possible that 1 or 2 ppm of many VOCs existed in the gas stream but escaped FTIR detection, these hypothetical trace VOCs would have been detected by the FID. This would have resulted in the FID data (total VOCs expressed as ethanol) being higher than the FTIR ethanol data. This was not observed.

Appendix 1

Testing Parameters / Sample Calculations

Coors Brewing Company
Bottle Filler Exhaust
Ethanol Emissions
4-3-95

run #	*1	**2	3	Average
date	4-3-95	4-3-95	4-3-95	
start time	17:45	19:34	21:53	
stop time	17:56	20:53	22:53	
sample time (minutes)	11	60	60	
Field Reference Method Data				
(delta P)^1/2	0.678	0.684	0.624	0.662
pitot tube constant (unitless)	0.84	0.84	0.84	0.84
stack temp. (oF)	69	69	67	68
baro. press. (mbar)	831	832	833	832
stack press. (" water)	0.43	0.44	0.38	0.42
O2 (vol. %)	20.9	20.9	20.9	20.9
CO2 (vol. %)	0.0	0.0	0.0	0.0
stack diameter (")	42.3	42.3	42.3	42.3
ethanol, FID (ppmv)	88.1	95.3	118.7	100.7
ethanol, FT-IR (ppmv)	92.57	108.59	125.79	108.98
Calculations				
molecular weight dry	29.0	29.0	29.0	29.0
molecular weight wet	29.0	29.0	29.0	29.0
gas velocity (ft/sec)	42.0	42.3	38.5	40.9
gas flow (acfm)	24513	24693	22479	23895
gas flow (dscfm)	20099	20272	18543	19638
gas flow (ksdcfh)	1206	1216	1113	1178
gas flow (lb/hr)	90766	91545	83739	88683
ethanol, FID (lb/hr)	12.7	13.8	15.8	14.1
ethanol, FID (tons/year)	55.6	60.6	69.1	61.8
ethanol, FT-IR (lb/hr)	13.3	15.8	16.7	15.3
ethanol, FT-IR (tons/year)	58.4	69.1	73.2	66.9
FID/FT-IR Relative Difference	-4.8%	-12.2%	-5.6%	-7.6%

* - FT-IR sampling time cut short
** - discontinuous concurrent sampling time 19:35 - 20:05, 20:23 - 20:53

Coors Brewing Company
Bottle Filler Exhaust
Ethanol Emissions, Moisture Corrected
4-3-95

run #	*1	**2	3	Average
date	4-3-95	4-3-95	4-3-95	
start time	17:45	19:34	21:53	
stop time	17:56	20:53	22:53	
sample time (minutes)	11	60	60	
Field Reference Method Data				
(delta P)^1/2	0.678	0.684	0.624	0.662
pitot tube constant (unitless)	0.84	0.84	0.84	0.84
stack temp. (oF)	69	69	67	68
baro. press. (mbar)	831	832	833	832
stack press. (" water)	0.43	0.44	0.38	0.42
O2 (vol. %, dry)	20.9	20.9	20.9	20.9
CO2 (vol. %, dry)	0.0	0.0	0.0	0.0
H2O (vol. %, wet)	1.0	1.0	1.0	1.0
stack diameter (")	42.3	42.3	42.3	42.3
ethanol, FID (ppmv)	88.1	95.3	118.7	100.7
ethanol, FT-IR (ppmv)	92.57	108.59	125.79	108.98
Calculations				
molecular weight dry	28.8	28.8	28.8	28.8
molecular weight wet	28.7	28.7	28.7	28.7
gas velocity (ft/sec)	42.2	42.5	38.7	41.1
gas flow (acfm)	24629	24810	22585	24008
gas flow (dscfm)	19992	20164	18445	19534
gas flow (ksdcfh)	1200	1210	1107	1172
gas flow (lb/hr)	90339	91114	83345	88266
ethanol, FID (lb/hr)	12.8	13.9	15.8	14.2
ethanol, FID (tons/year)	55.8	60.9	69.4	62.1
ethanol, FT-IR (lb/hr)	13.4	15.9	16.8	15.3
ethanol, FT-IR (tons/year)	58.7	69.4	73.6	67.2
FID/FT-IR Relative Difference	-4.8%	-12.2%	-5.6%	-7.6%

* - FT-IR sampling time cut short
** - discontinuous concurrent sampling time 19:35 - 20:05, 20:23 - 20:53

Coors Brewing Company
Can Filler Exhaust
Ethanol Emissions
4-4-95

run #	1	*2	3	Average
date	4-4-95	4-4-95	4-4-95	
start time	16:30	18:02	19:06	
stop time	17:30	19:02	20:03	
sample time (minutes)	60	60	57	
Field Reference Method Data				
(delta P)^1/2	0.811	0.795	0.770	0.792
pitot tube constant (unitless)	0.84	0.84	0.84	0.84
stack temp. (oF)	72	72	77	74
baro. press. (mbar)	828	825	825	826
stack press. (" water)	-0.43	-0.39	-0.30	-0.37
O2 (vol. %)	20.9	20.9	20.9	20.9
CO2 (vol. %)	0.0	0.0	0.0	0.0
stack diameter (")	46.9	46.9	46.9	46.9
ethanol, FID (ppmv)	71.5	58.1	71.2	66.9
ethanol, FT-IR, (ppmv)	68.43	N/A	77.65	73.04
Calculations				
molecular weight dry	29.0	29.0	29.0	29.0
molecular weight wet	29.0	29.0	29.0	29.0
gas velocity (ft/sec)	50.5	49.6	48.2	49.4
gas flow (acfm)	36347	35693	34697	35579
gas flow (dscfm)	29452	28820	27763	28678
gas flow (ksdcfh)	1767	1729	1666	1721
gas flow (lb/hr)	133001	130149	125373	129508
ethanol, FID (lb/hr)	15.1	12.0	14.2	13.8
ethanol, FID (tons/year)	66.1	52.6	62.1	60.2
ethanol, FT-IR (lb/hr)	14.4	N/A	15.5	14.9
ethanol, FT-IR (tons/year)	63.3	N/A	67.7	65.5
FID/FT-IR Relative Difference	4.5%	N/A	-8.3%	-1.9%

* - no FT-IR data

Coors Brewing Company
Can Filler Exhaust
Ethanol Emissions, Moisture Corrected
4-4-95

run #	1	*2	3	Average
date	4-4-95	4-4-95	4-4-95	
start time	16:30	18:02	19:06	
stop time	17:30	19:02	20:03	
sample time (minutes)	60	60	57	
Field Reference Method Data				
(delta P)^1/2	0.811	0.795	0.770	0.792
pitot tube constant (unitless)	0.84	0.84	0.84	0.84
stack temp. (oF)	72	72	77	74
baro. press. (mbar)	828	825	825	826
stack press. (" water)	-0.43	-0.39	-0.30	-0.37
O2 (vol. %, dry)	20.9	20.9	20.9	20.9
CO2 (vol. %, dry)	0.0	0.0	0.0	0.0
H2O (vol. %, wet)	1.0	1.0	1.0	1.0
stack diameter (")	46.9	46.9	46.9	46.9
ethanol, FID (ppmv)	71.5	58.1	71.2	66.9
ethanol, FT-IR, (ppmv)	68.43	N/A	77.65	73.04
Calculations				
molecular weight dry	28.8	28.8	28.8	28.8
molecular weight wet	28.7	28.7	28.7	28.7
gas velocity (ft/sec)	50.7	49.8	48.4	49.7
gas flow (acfm)	36519	35862	34861	35747
gas flow (dscfm)	29295	28667	27615	28526
gas flow (ksdcfh)	1758	1720	1657	1712
gas flow (lb/hr)	132375	129537	124783	128898
ethanol, FID (lb/hr)	15.2	12.1	14.2	13.8
ethanol, FID (tons/year)	66.4	52.8	62.3	60.5
ethanol, FT-IR (lb/hr)	14.5	N/A	15.5	15.0
ethanol, FT-IR (tons/year)	63.6	N/A	68.0	65.8
FID/FT-IR Relative Difference	4.5%	N/A	-8.3%	-1.9%

* - no FT-IR data

Coors Brewing Company
Bottle Filler Exhaust
4-3-95
Method 25A : Measurement of Total Gaseous Organic Concentration Using a Flame Ionization Analyzer

Strip Chart Data

Run #1

		Zero (%FS	Span (%FS)	Actual Span (ppm)
Start	17:45	-0.1	48.6	48.5
Stop	18:45	-0.1	49.3	

	point #	%FS VOC	ppm VOC	point #	%FS VOC	ppm VOC
	1	44.3	43.9	31	37.0	36.7
	2	46.6	46.2	32	38.4	38.1
	3	45.7	45.2	33	41.6	41.3
	4	35.9	35.6	34	40.0	39.6
	5	39.4	39.1	35	39.7	39.4
	6	45.6	45.2	36	37.2	36.8
	7	43.3	42.9	37	43.3	42.9
	8	39.4	39.1	38	41.0	40.6
	9	38.1	37.8	39	42.4	42.0
	10	42.6	42.2	40	42.2	41.8
	11	40.2	39.8	41	38.2	37.9
	12	39.0	38.7	42	40.4	40.0
	13	36.7	36.4	43	38.3	37.9
	14	34.9	34.6	44	37.7	37.4
	15	33.1	32.8	45	43.6	43.2
	16	34.7	34.4	46	47.5	47.1
	17	32.5	32.2	47	48.8	48.4
	18	32.9	32.6	48	46.6	46.2
	19	41.6	41.2	49	47.4	47.0
	20	44.7	44.2	50	49.2	48.7
	21	41.0	40.6	51	49.8	49.3
	22	41.4	41.0	52	44.6	44.2
	23	45.8	45.4	53	45.8	45.4
	24	48.6	48.1	54	48.0	47.6
	25	47.5	47.0	55	46.3	45.9
	26	39.5	39.1	56	50.7	50.2
	27	33.5	33.3	57	51.3	50.8
	28	33.3	33.0	58	44.6	44.2
	29	37.0	36.7	59	45.4	44.9
	30	40.5	40.2	60	46.4	46.0
Averages:		40.0	39.6		43.8	43.4

Drift Cal. Avg. VOC (ppm as C3H8) | 41.5 |

Bottle Filler Exhaust
4-3-95
Method 25A : Measurement of Total Gaseous Organic Concentration Using a Flame Ionization Analyzer

Strip Chart Data

Run #2

		Zero (%FS	Span (%FS)	Actual Span (ppm)
Start	19:34	-0.1	48.6	48.5
Stop	20:53	-0.0	48.8	

point #	%FS VOC	ppm VOC	point #	%FS VOC	ppm VOC	point #	%FS VOC	ppm VOC
1	35.1	35.0	31	46.7	46.5	61	48.7	48.6
2	35.4	35.3	32	48.7	48.5	62	51.9	51.8
3	35.7	35.6	33	49.5	49.4	63	51.5	51.3
4	34.4	34.2	34	49.4	49.2	64	49.5	49.3
5	41.7	41.6	35	52.3	52.1	65	46.1	45.9
6	48.7	48.6	36	48.3	48.1	66	49.5	49.3
7	49.8	49.6	37	45.3	45.1	67	53.8	53.6
8	45.2	45.1	38	44.9	44.7	68	65.8	65.6
9	41.3	41.1	39	43.7	43.6	69	53.1	52.9
10	36.5	36.4	40	42.7	42.6	70	45.2	45.1
11	40.5	40.3	41	43.3	43.2	71	43.4	43.3
12	46.5	46.3	42	47.3	47.2	72	42.7	42.5
13	45.4	45.2	43	48.6	48.4	73	40.7	40.6
14	46.1	45.9	44	50.0	49.9	74	41.7	41.5
15	46.6	46.4	45	53.5	53.3	75	39.2	39.0
16	47.0	46.8	46	53.8	53.7	76	34.3	34.2
17	46.0	45.8	47	51.9	51.7	77	32.3	32.2
18	47.4	47.3	48	51.8	51.6	78	37.1	36.9
19	49.6	49.4	49	51.1	50.9	79	39.8	39.7
20	46.5	46.4	50	47.8	47.6			
21	48.8	48.6	51	42.5	42.4			
22	52.1	51.9	52	39.8	39.7			
23	50.0	49.8	53	39.6	39.4			
24	48.2	48.0	54	39.4	39.3			
25	49.2	49.0	55	45.7	45.5			
26	46.6	46.5	56	50.8	50.6			
27	41.5	41.4	57	52.5	52.3			
28	36.7	36.6	58	52.6	52.4			
29	37.0	36.9	59	52.0	51.8			
30	42.4	42.2	60	53.0	52.8			
Averages:	43.9	43.8		48.0	47.8		45.6	45.4

Drift Cal. Avg. VOC (ppm as C3H8) | 45.7 |

Coors Brewing Company
Bottle Filler Exhaust
4-3-95
Method 25A : Measurement of Total Gaseous Organic Concentration Using a Flame Ionization Analyzer

Strip Chart Data

Run #3

		Zero (%FS	Span (%FS)	Actual Span (ppm)
Start	21:53	-0.0	48.8	48.5
Stop	22:53	-0.0	48.7	

point #	%FS VOC	ppm VOC	point #	%FS VOC	ppm VOC
1	64.9	64.5	31	48.3	48.1
2	58.3	58.1	32	47.0	46.8
3	62.6	62.3	33	47.8	47.6
4	56.1	55.9	34	55.1	54.8
5	54.2	53.9	35	58.5	58.2
6	64.8	64.5	36	57.3	57.0
7	61.7	61.4	37	51.5	51.2
8	52.7	52.5	38	39.6	39.5
9	58.0	57.7	39	44.3	44.1
10	58.0	57.7	40	51.7	51.4
11	57.7	57.4	41	51.6	51.4
12	62.5	62.2	42	50.3	50.1
13	63.9	63.6	43	51.3	51.0
14	59.7	59.4	44	51.5	51.2
15	54.5	54.2	45	51.7	51.5
16	49.2	49.0	46	53.0	52.7
17	49.0	48.8	47	51.0	50.8
18	54.9	54.6	48	51.0	50.7
19	60.6	60.4	49	50.7	50.5
20	61.7	61.4	50	52.4	52.2
21	60.3	60.0	51	59.2	58.9
22	61.7	61.4	52	61.9	61.6
23	64.4	64.1	53	58.5	58.3
24	67.1	66.8	54	57.1	56.8
25	63.8	63.5	55	53.6	53.4
26	61.5	61.1	56	57.4	57.2
27	65.6	65.2	57	55.1	54.8
28	65.1	64.8	58	62.9	62.6
29	60.6	60.3	59	58.1	57.8
30	52.8	52.6	60	47.9	47.7
averages:	59.6	59.3		52.9	52.7

Drift Cal. Avg. VOC (ppm as C3H8) 56.0

Coors Brewing Company
Can Filler Exhaust
4-4-95
Method 25A : Measurement of Total Gaseous Organic Concentration Using a Flame Ionization Analyzer

Strip Chart Data

Run #1

		Zero (%FS	Span (%FS)	Actual Span (ppm)
Start	16:30	-0.1	48.6	48.5
Stop	17:30	-0.2	48.3	

point #	%FS VOC	ppm VOC	point #	%FS VOC	ppm VOC
1	35.1	35.1	31	36.3	36.4
2	33.5	33.6	32	35.7	35.8
3	34.0	34.1	33	35.6	35.7
4	34.7	34.8	34	32.7	32.8
5	34.5	34.6	35	32.3	32.4
6	34.4	34.5	36	32.8	32.9
7	33.3	33.3	37	32.7	32.8
8	31.2	31.3	38	27.6	27.7
9	29.7	29.8	39	31.4	31.5
10	28.0	28.1	40	33.6	33.6
11	28.3	28.4	41	34.1	34.2
12	27.8	27.9	42	34.4	34.5
13	26.6	26.7	43	35.1	35.2
14	25.9	26.0	44	36.1	36.1
15	30.2	30.3	45	36.3	36.4
16	33.9	34.0	46	36.6	36.7
17	35.7	35.7	47	36.6	36.7
18	35.5	35.5	48	35.7	35.8
19	35.7	35.8	49	33.1	33.2
20	33.7	33.8	50	35.8	35.9
21	34.2	34.3	51	33.0	33.1
22	34.7	34.8	52	34.1	34.2
23	34.5	34.5	53	34.5	34.6
24	34.1	34.2	54	35.5	35.5
25	34.4	34.5	55	36.0	36.1
26	33.9	33.9	56	36.5	36.6
27	37.8	37.8	57	35.8	35.8
28	34.4	34.5	58	33.9	34.0
29	34.1	34.2	59	32.9	33.0
30	35.8	35.9	60	31.6	31.7
Averages:	33.0	33.1		34.3	34.4

Drift Cal. Avg. VOC (ppm as C3H8) | 33.7 |

Coors Brewing Company
Can Filler Exhaust
4-4-95
Method 25A : Measurement of Total Gaseous Organic Concentration Using a Flame Ionization Analyzer

Strip Chart Data

Run #2

		Zero (%FS	Span (%FS)	Actual Span (ppm)
Start	18:02	-0.2	48.3	48.5
Stop	19:02	-0.2	47.9	

point #	%FS VOC	ppm VOC	point #	%FS VOC	ppm VOC
1	35.7	36.0	31	N/A	N/A
2	32.6	32.9	32	N/A	N/A
3	30.9	31.2	33	31.9	32.3
4	30.0	30.3	34	34.2	34.5
5	28.9	29.2	35	34.7	35.0
6	27.9	28.2	36	35.6	36.0
7	26.8	27.1	37	35.1	35.5
8	25.5	25.8	38	33.0	33.3
9	26.4	26.7	39	28.6	28.9
10	25.9	26.2	40	29.0	29.3
11	23.7	24.0	41	29.3	29.6
12	25.3	25.6	42	32.2	32.5
13	25.6	25.9	43	34.2	34.5
14	29.3	29.6	44	34.2	34.6
15	32.3	32.6	45	34.8	35.1
16	31.1	31.4	46	33.0	33.3
17	34.0	34.4	47	31.0	31.3
18	31.4	31.7	48	29.9	30.2
19	29.6	29.9	49	28.7	29.0
20	30.7	31.0	50	27.9	28.2
21	31.4	31.8	51	27.3	27.6
22	30.1	30.4	52	27.4	27.7
23	29.5	29.8	53	30.8	31.2
24	29.9	30.2	54	32.7	33.0
25	29.4	29.7	55	30.2	30.5
26	30.9	31.2	56	23.5	23.8
27	N/A	N/A	57	30.6	31.0
28	N/A	N/A	58	29.0	29.3
29	N/A	N/A	59	27.6	27.9
30	N/A	N/A	60	26.7	27.0
Averages:	25.5	25.8		28.8	29.1

Drift Cal. Avg. VOC (ppm as C3H8) | 27.4 |

Coors Brewing Company
Can Filler Exhaust
4-4-95
Method 25A : Measurement of Total Gaseous Organic Concentration Using a Flame Ionization Analyzer

Strip Chart Data

Run #3

		Zero (%FS	Span (%FS)	Actual Span (ppm)
Start	19:03	-0.2	48.3	48.5
Stop	20:03	-0.2	47.9	

point #	%FS VOC	ppm VOC	point #	%FS VOC	ppm VOC
1	26.0	26.2	31	33.2	33.5
2	27.4	27.7	32	36.9	37.2
3	30.5	30.8	33	36.9	37.2
4	31.6	31.9	34	34.7	35.0
5	33.0	33.3	35	33.4	33.7
6	30.5	30.8	36	31.4	31.7
7	32.1	32.5	37	28.4	28.7
8	31.3	31.6	38	29.4	29.7
9	27.5	27.8	39	33.5	33.8
10	27.8	28.1	40	36.1	36.4
11	25.6	25.9	41	38.4	38.7
12	19.7	19.9	42	37.7	38.0
13	17.9	18.1	43	36.9	37.2
14	17.0	17.3	44	36.6	37.0
15	20.6	20.9	45	36.6	37.0
16	28.1	28.4	46	36.8	37.2
17	32.5	32.8	47	37.1	37.5
18	30.9	31.2	48	36.7	37.1
19	27.7	28.0	49	39.1	39.4
20	26.5	26.8	50	43.7	44.0
21	27.0	27.3	51	44.9	45.3
22	27.0	27.3	52	45.7	46.1
23	28.2	28.5	53	46.4	46.8
24	27.1	27.4	54	46.8	47.2
25	23.9	24.2	55	47.6	48.0
26	17.2	17.4	56	46.1	46.5
27	19.4	19.7	57	46.2	46.6
28	27.8	28.1	58	46.9	47.3
29	30.4	30.7	59	46.0	46.4
30	28.3	28.6	60	48.2	48.6
Averages:	26.7	27.0		39.3	39.6

Drift Cal. Avg. VOC (ppm as C3H8) 33.3

Coors Brewing Company
Bottle Filler Exhaust
4-3-95
FID and FT-IR Ethanol Emissions Data

Field Data

Run #1 | FID Scaling Factor 2.12

Start 17:45
Stop 18:45

time	FID Data ppm VOC	FID Data ppm EtOH	FT-IR Data ppm EtOH	time	FID Data ppm VOC	FID Data ppm EtOH	FT-IR Data ppm EtOH
17:46	43.9	93.0	96.07	18:16	36.7	77.8	
17:47	46.2	97.9		18:17	38.1	80.7	
17:48	45.2	95.9	98.41	18:18	41.3	87.5	
17:49	35.6	75.5		18:19	39.6	84.0	
17:50	39.1	82.8	86.07	18:20	39.4	83.4	
17:51	45.2	95.9	93.29	18:21	36.8	78.1	
17:52	42.9	91.0		18:22	42.9	91.0	
17:53	39.1	82.9	89.75	18:23	40.6	86.1	
17:54	37.8	80.1		18:24	42.0	89.1	
17:55	42.2	89.4	91.96	18:25	41.8	88.7	
17:56	39.8	84.4	92.41	18:26	37.9	80.2	
17:57	38.7	82.0		18:27	40.0	84.9	
17:58	36.4	77.2		18:28	37.9	80.4	
17:59	34.6	73.4		18:29	37.4	79.2	
18:00	32.8	69.5		18:30	43.2	91.7	
18:01	34.4	73.0		18:31	47.1	99.8	
18:02	32.2	68.2		18:32	48.4	102.5	
18:03	32.6	69.1		18:33	46.2	97.9	
18:04	41.2	87.4		18:34	47.0	99.6	
18:05	44.2	93.8		18:35	48.7	103.3	
18:06	40.6	86.1		18:36	49.3	104.6	
18:07	41.0	87.0		18:37	44.2	93.8	
18:08	45.4	96.2		18:38	45.4	96.2	
18:09	48.1	102.0		18:39	47.6	100.9	
18:10	47.0	99.7		18:40	45.9	97.3	
18:11	39.1	82.9		18:41	50.2	106.5	
18:12	33.3	70.5		18:42	50.8	107.8	
18:13	33.0	70.0		18:43	44.2	93.7	
18:14	36.7	77.8		18:44	44.9	95.3	
18:15	40.2	85.2		18:45	46.0	97.5	
averages:	39.6	84.0	92.57		43.4	92.0	

	FID	FT-IR
concurrent sampling period averages:	88.1	92.57

oors Brewing Company
ottle Filler Exhaust
4-3-95
FID and FT-IR Ethanol Emissions Data

ield Data

Run #2

FID Scaling Factor
2.12

tart 19:34
top 20:53

time	FID Data ppm VOC	FID Data ppm EtOH	FT-IR Data ppm EtOH	time	FID Data ppm VOC	FID Data ppm EtOH	FT-IR Data ppm EtOH	time	FID Data ppm VOC	FID Data ppm EtOH	FT-IR Data ppm EtOH
19:35	35.0	74.1		20:05	46.5	98.7	107.99	20:35	48.6	103.0	124.54
19:36	35.3	74.8	82.09	20:06	48.5	102.8		20:36	51.8	109.7	130.04
19:37	35.6	75.5		20:07	49.4	104.6		20:37	51.3	108.8	
19:38	34.2	72.6	79.67	20:08	49.2	104.3		20:38	49.3	104.5	129.30
19:39	41.6	88.1	93.18	20:09	52.1	110.5		20:39	45.9	97.4	
19:40	48.6	102.9		20:10	48.1	102.0		20:40	49.3	104.5	123.37
19:41	49.6	105.2	119.82	20:11	45.1	95.6		20:41	53.6	113.7	
19:42	45.1	95.5		20:12	44.7	94.8		20:42	65.6	139.0	152.34
19:43	41.1	87.2	104.73	20:13	43.6	92.4		20:43	52.9	112.2	
19:44	36.4	77.1		20:14	42.6	90.3		20:44	45.1	95.6	115.61
19:45	40.3	85.5	84.75	20:15	43.2	91.6		20:45	43.3	91.8	
19:46	46.3	98.2	98.51	20:16	47.2	100.0		20:46	42.5	90.2	111.46
19:47	45.2	95.8		20:17	48.4	102.6		20:47	40.6	86.1	107.86
19:48	45.9	97.3	107.64	20:18	49.9	105.7		20:48	41.5	88.0	
19:49	46.4	98.4		20:19	53.3	112.9		20:49	39.0	82.7	100.83
19:50	46.8	99.3	103.35	20:20	53.7	113.7		20:50	34.2	72.5	
19:51	45.8	97.2	110.57	20:21	51.7	109.5		20:51	32.2	68.2	84.86
19:52	47.3	100.2		20:22	51.6	109.4		20:52	36.9	78.3	
19:53	49.4	104.7	113.42	20:23	50.9	108.0		20:53	39.7	84.2	98.17
19:54	46.4	98.3		20:24	47.6	101.0	125.90				
19:55	48.6	103.1	107.66	20:25	42.4	89.8					
19:56	51.9	110.0		20:26	39.7	84.1	96.83				
19:57	49.8	105.5	114.22	20:27	39.4	83.6					
19:58	48.0	101.7	117.51	20:28	39.3	83.3	95.35				
19:59	49.0	103.9		20:29	45.5	96.6	113.74				
20:00	46.5	98.5	113.40	20:30	50.6	107.2					
20:01	41.4	87.7		20:31	52.3	110.8	127.58				
20:02	36.6	77.5	93.71	20:32	52.4	111.1					
20:03	36.9	78.2	86.06	20:33	51.8	109.8	124.55				
20:04	42.2	89.5		20:34	52.8	112.0					
averages:	43.8	92.8	101.78		47.8	101.3	113.13		45.4	96.3	116.22

	FID	FT-IR
concurrent sampling period averages:	95.3	108.59

Coors Brewing Company
Bottle Filler Exhaust
4-3-95
FID and FT-IR Ethanol Emissions Data

Field Data

Run #3

FID Scaling Factor
2.12

Start 21:53
Stop 22:53

time	FID Data ppm VOC	FID Data ppm EtOH	FT-IR Data ppm EtOH	time	FID Data ppm VOC	FID Data ppm EtOH	FT-IR Data ppm EtOH
21:54	64.5	136.8	136.66	22:24	48.1	102.0	110.33
21:55	58.1	123.1		22:25	46.8	99.2	108.68
21:56	62.3	132.1	125.37	22:26	47.6	100.8	
21:57	55.9	118.5		22:27	54.8	116.2	127.11
21:58	53.9	114.3	126.00	22:28	58.2	123.4	
21:59	64.5	136.6	139.97	22:29	57.0	120.9	120.84
22:00	61.4	130.2		22:30	51.2	108.6	
22:01	52.5	111.3	123.26	22:31	39.5	83.7	91.61
22:02	57.7	122.3		22:32	44.1	93.4	112.30
22:03	57.7	122.4	128.41	22:33	51.4	109.0	
22:04	57.4	121.7		22:34	51.4	109.0	117.58
22:05	62.2	131.8	138.47	22:35	50.1	106.1	
22:06	63.6	134.8	135.85	22:36	51.0	108.2	123.38
22:07	59.4	126.0		22:37	51.2	108.6	
22:08	54.2	114.9	113.58	22:38	51.5	109.2	126.49
22:09	49.0	103.8		22:39	52.7	111.8	118.39
22:10	48.8	103.5	108.20	22:40	50.8	107.6	
22:11	54.6	115.7		22:41	50.7	107.5	117.50
22:12	60.4	127.9	126.98	22:42	50.5	107.0	
22:13	61.4	130.2	134.79	22:43	52.2	110.6	120.95
22:14	60.0	127.3		22:44	58.9	124.8	
22:15	61.4	130.1	142.04	22:45	61.6	130.6	141.57
22:16	64.1	135.9		22:46	58.3	123.5	121.69
22:17	66.8	141.5	148.49	22:47	56.8	120.4	
22:18	63.5	134.6		22:48	53.4	113.2	122.04
22:19	61.1	129.6	142.44	22:49	57.2	121.2	
22:20	65.2	138.3	151.80	22:50	54.8	116.2	127.27
22:21	64.8	137.3		22:51	62.6	132.7	132.49
22:22	60.3	127.9	132.66	22:52	57.8	122.5	
22:23	52.6	111.5		22:53	47.7	101.1	107.58
averages:	59.3	125.7	132.65		52.7	111.6	119.32

	FID	FT-IR
concurrent sampling period averages:	118.7	125.79

Coors Brewing Company
Can Filler Exhaust
4-4-95
FID and FT-IR Ethanol Emissions Data

Field Data

Run #1

FID Scaling Factor
2.12

Start 16:30
Stop 17:30

time	FID Data ppm VOC	FID Data ppm EtOH	FT-IR Data ppm EtOH	time	FID Data ppm VOC	FID Data ppm EtOH	FT-IR Data ppm EtOH
16:31	35.1	74.5		17:01	36.4	77.2	74.44
16:32	33.6	71.3		17:02	35.8	75.9	72.87
16:33	34.1	72.3	69.51	17:03	35.7	75.6	
16:34	34.8	73.7	72.24	17:04	32.8	69.4	66.22
16:35	34.6	73.3	70.02	17:05	32.4	68.7	66.58
16:36	34.5	73.1		17:06	32.9	69.7	
16:37	33.3	70.7	68.50	17:07	32.8	69.5	62.04
16:38	31.3	66.3	60.21	17:08	27.7	58.7	
16:39	29.8	63.1		17:09	31.5	66.8	58.38
16:40	28.1	59.6	53.78	17:10	33.6	71.3	67.20
16:41	28.4	60.2	54.48	17:11	34.2	72.5	
16:42	27.9	59.1		17:12	34.5	73.1	69.53
16:43	26.7	56.6	50.18	17:13	35.2	74.7	71.55
16:44	26.0	55.1		17:14	36.1	76.6	
16:45	30.3	64.3	57.21	17:15	36.4	77.1	73.77
16:46	34.0	72.0	69.04	17:16	36.7	77.7	
16:47	35.7	75.8		17:17	36.7	77.8	74.87
16:48	35.5	75.3	71.00	17:18	35.8	75.8	71.06
16:49	35.8	75.8	69.27	17:19	33.2	70.3	
16:50	33.8	71.7		17:20	35.9	76.0	74.46
16:51	34.3	72.7	69.28	17:21	33.1	70.2	71.63
16:52	34.8	73.7		17:22	34.2	72.5	
16:53	34.5	73.2	67.60	17:23	34.6	73.3	74.36
16:54	34.2	72.5	68.13	17:24	35.5	75.3	
16:55	34.5	73.2		17:25	36.1	76.5	79.14
16:56	33.9	72.0	68.78	17:26	36.6	77.6	79.14
16:57	37.8	80.2	73.14	17:27	35.8	76.0	
16:58	34.5	73.0		17:28	34.0	72.0	73.61
16:59	34.2	72.5	69.71	17:29	33.0	69.9	68.89
17:00	35.9	76.1		17:30	31.7	67.2	
averages:	33.1	70.1	65.67		34.4	72.8	71.04

	FID	FT-IR
concurrent sampling period averages:	71.5	68.43

Coors Brewing Company
Can Filler Exhaust
4-4-95
FID and FT-IR Ethanol Emissions Data

Field Data

Run #2

FID Scaling Factor
2.12

Start 18:02
Stop 19:02

	FID Data		FT-IR Data		FID Data		FT-IR Data
time	ppm VOC	ppm EtOH	ppm EtOH	time	ppm VOC	ppm EtOH	ppm EtOH
18:03	36.0	76.4		18:33	N/A	N/A	
18:04	32.9	69.8		18:34	N/A	N/A	
18:05	31.2	66.1		18:35	32.3	68.4	
18:06	30.3	64.2		18:36	34.5	73.2	
18:07	29.2	62.0		18:37	35.0	74.3	
18:08	28.2	59.7		18:38	36.0	76.3	
18:09	27.1	57.5		18:39	35.5	75.2	
18:10	25.8	54.8		18:40	33.3	70.7	
18:11	26.7	56.7		18:41	28.9	61.2	
18:12	26.2	55.6		18:42	29.3	62.0	
18:13	24.0	50.8		18:43	29.6	62.8	
18:14	25.6	54.3		18:44	32.5	68.9	
18:15	25.9	54.9		18:45	34.5	73.2	
18:16	29.6	62.7		18:46	34.6	73.2	
18:17	32.6	69.1		18:47	35.1	74.4	
18:18	31.4	66.6		18:48	33.3	70.6	
18:19	34.4	72.8		18:49	31.3	66.4	
18:20	31.7	67.2		18:50	30.2	64.1	
18:21	29.9	63.3		18:51	29.0	61.5	
18:22	31.0	65.7		18:52	28.2	59.8	
18:23	31.8	67.3		18:53	27.6	58.6	
18:24	30.4	64.5		18:54	27.7	58.8	
18:25	29.8	63.1		18:55	31.2	66.1	
18:26	30.2	64.0		18:56	33.0	70.1	
18:27	29.7	62.9		18:57	30.5	64.6	
18:28	31.2	66.2		18:58	23.8	50.5	
18:29	N/A	N/A		18:59	31.0	65.6	
18:30	N/A	N/A		19:00	29.3	62.1	
18:31	N/A	N/A		19:01	27.9	59.1	
18:32	N/A	N/A		19:02	27.0	57.3	
averages:	25.8	54.6	N/A		29.1	61.6	N/A

	FID
concurrent sampling period averages:	58.1

Coors Brewing Company
Can Filler Exhaust
4-4-95
FID and FT-IR Ethanol Emissions Data

Field Data

Run #3

FID Scaling Factor
2.12

Start 19:03
Stop 20:03

	FID Data		FT-IR Data		FID Data		FT-IR Data
time	ppm VOC	ppm EtOH	ppm EtOH	time	ppm VOC	ppm EtOH	ppm EtOH
19:04	26.2	55.6		19:34	33.5	71.0	81.87
19:05	27.7	58.7		19:35	37.2	78.9	83.59
19:06	30.8	65.3		19:36	37.2	78.9	
19:07	31.9	67.7		19:37	35.0	74.3	77.21
19:08	33.3	70.7	72.16	19:38	33.7	71.5	
19:09	30.8	65.3		19:39	31.7	67.3	68.44
19:10	32.5	68.8	74.59	19:40	28.7	60.9	69.39
19:11	31.6	67.1	64.06	19:41	29.7	63.0	
19:12	27.8	59.0		19:42	33.8	71.6	82.50
19:13	28.1	59.5	58.92	19:43	36.4	77.2	88.62
19:14	25.9	54.8	40.83	19:44	38.7	82.1	
19:15	19.9	42.3		19:45	38.0	80.6	86.43
19:16	18.1	38.4	37.20	19:46	37.2	78.9	
19:17	17.3	36.6		19:47	37.0	78.3	86.04
19:18	20.9	44.2	57.39	19:48	37.0	78.4	85.41
19:19	28.4	60.2	73.58	19:49	37.2	78.8	
19:20	32.8	69.5		19:50	37.5	79.4	86.03
19:21	31.2	66.2	64.18	19:51	37.1	78.6	99.21
19:22	28.0	59.4	60.23	19:52	39.4	83.6	
19:23	26.8	56.9		19:53	44.0	93.4	105.59
19:24	27.3	57.8	61.66	19:54	45.3	96.0	
19:25	27.3	57.9		19:55	46.1	97.7	109.36
19:26	28.5	60.4	62.95	19:56	46.8	99.1	112.64
19:27	27.4	58.1	48.97	19:57	47.2	100.1	
19:28	24.2	51.3		19:58	48.0	101.7	108.46
19:29	17.4	36.9	42.88	19:59	46.5	98.6	
19:30	19.7	41.7		20:00	46.6	98.8	109.90
19:31	28.1	59.7	68.76	20:01	47.3	100.2	109.54
19:32	30.7	65.1	67.64	20:02	46.4	98.3	
19:33	28.6	60.6		20:03	48.6	103.0	111.43
averages:	27.0	57.2	59.75		39.6	84.0	92.72

	FID	FT-IR
concurrent sampling period averages:	71.2	77.65

EPA Methods 1 - 2 : Determination of Stack Gas Velocity and Volumetric Flow Rate

Sample Calculations

$$\text{gas velocity (ft/sec)} = (85.49)\cdot(0.84)\cdot\sqrt{\Delta P}_{AVG}\cdot\sqrt{\frac{T_S+460}{\left[P_B+\frac{P_S}{(13.6)}\right]\cdot M_S}}$$

$$= (85.49)\cdot(0.84)\cdot(0.678)\cdot\sqrt{\frac{(69)+460}{\left[(24.55)+\frac{(0.43)}{(13.6)}\right]\cdot(29.0)}}$$

$$= 42.0$$

$$\text{gas flow (acfm)} = (60)\cdot\frac{\pi\cdot\left(\frac{D_S}{12}\right)^2}{4}\cdot V_S$$

$$= (60)\cdot\frac{\pi\cdot\left[\frac{(42.3)}{12}\right]^2}{4}\cdot(42.0)$$

$$= 24513$$

$$\text{gas flow (dscfm)} = (60)\cdot(1-B_{WS})\cdot V_S\cdot\frac{\pi\cdot\left(\frac{D_S}{12}\right)^2}{4}\cdot\frac{T_{STD}\cdot\left[P_B+\frac{P_S}{(13.6)}\right]}{(T_S+460)\cdot P_{STD}}$$

$$= (60)\cdot[1-(0.00)]\cdot(42.0)\cdot\frac{\pi\cdot\left[\frac{(42.3)}{12}\right]^2}{4}\cdot\frac{(528)\cdot\left[(24.55)+\frac{(0.43)}{(13.6)}\right]}{[(69)+460]\cdot(29.92)}$$

$$= 20099$$

$$\text{gas flow (lb/hr)} = (0.1557)\cdot F_{DSCFM}\cdot\frac{M_A}{(1-B_{WS})}$$

$$= (0.1557)\cdot(20099)\cdot\frac{(29.0)}{[1-(0.00)]}$$

$$= 90766$$

EPA Methods 1 - 2 : Determination of Stack Gas Velocity and Volumetric Flow Rate

Sample Calculations (continued)

Variables

B_{WS} - moisture content of the gas (wet volume percent/100)

F_{ACFM} - gas flow (actual cubic feet per minute)

F_{DSCFM} - gas flow (dry standard cubic feet per minute, where standard = 29.92 inches Hg and 68°F)

$F_{LB/HR}$ - gas flow (pounds per hour)

M_D - molecular weight of the dry gas (grams per mole)

M_A - molecular weight of the wet gas (grams per mole)

$\sqrt{\Delta P_{AVG}}$ - average square root of the stack gas pitot differential pressure (inches water)

P_B - barometric pressure (inches mercury)

P_S - stack pressure relative to barometric presure (inches water)

P_{STD} - standard pressure (29.92 inches mercury)

T_S - average stack temperature (°F)

T_{STD} - standard temperature (528 °R)

V_S - stack gas velocity (feet per second)

EPA Method 25A - Determination of Total Gaseous Organic Concentration Using a Flame Ionization Analyzer (Modified for Ethanol Emissions)

Sample Calculations

$$\text{VOC conc, drift cal (ppmvw as } C_3H_8) = \frac{(\%FS_{STACK}-\%FS_0)\cdot[\text{Span Gas Conc (ppmvd)}]}{(\%FS_{SPAN}-\%FS_0)}$$

$$= \frac{[(41.9)-(-0.1)]\cdot(48.5)}{[(49.0)-(-0.1)]}$$

$$= 41.5$$

$$\text{VOC conc. (ppmvw as ethanol)} = [\text{VOC conc. (ppmvw as } C_3H_8)]\cdot(F_{EMP})$$

$$= (41.5)\cdot(2.12)$$

$$= 88.1$$

$$\text{VOC emissions (lb/hr as ethanol)} = [\text{VOC conc. (ppmvw as ethanol)}]\cdot\frac{(F_{DSCFM})}{(1-B_{WS})}\cdot(7.167\cdot10^{-6})$$

$$= (88.1)\cdot\frac{(20099)}{[1-(0.00)]}\cdot(7.167\cdot10^{-6})$$

$$= 12.7$$

$$\text{VOC emissions (tons/year as ethanol)} = [\text{VOC emissions (lb/hr as ethanol)}]\cdot\frac{[(8760(\text{hours/year})]}{[2000(\text{pounds/ton})]}$$

$$= (12.7)\cdot\frac{(8760)}{(2000)}$$

$$= 55.6$$

Variables and Abbreviations

B_{WS} - moisture content of the gas (wet volume percent/100)

cal - calibrated

conc - concentration

F_{DSCFM} - gas flow (dry standard cubic feet per minute, where standard = 29.92 inches Hg and 68°F)

F_{EMP} - empirical scaling factor for propane→ethanol conversion, ppmv basis (unitless)

$\%FS_{SPAN}$ - average analyzer reading for span gas at probe tip (percent of full scale)

$\%FS_{STACK}$ - average analyzer reading for stack gas (percent of full scale)

$\%FS_0$ - average analyzer reading for zero gas at probe tip (percent of full scale)

lb/hr - pounds per hour

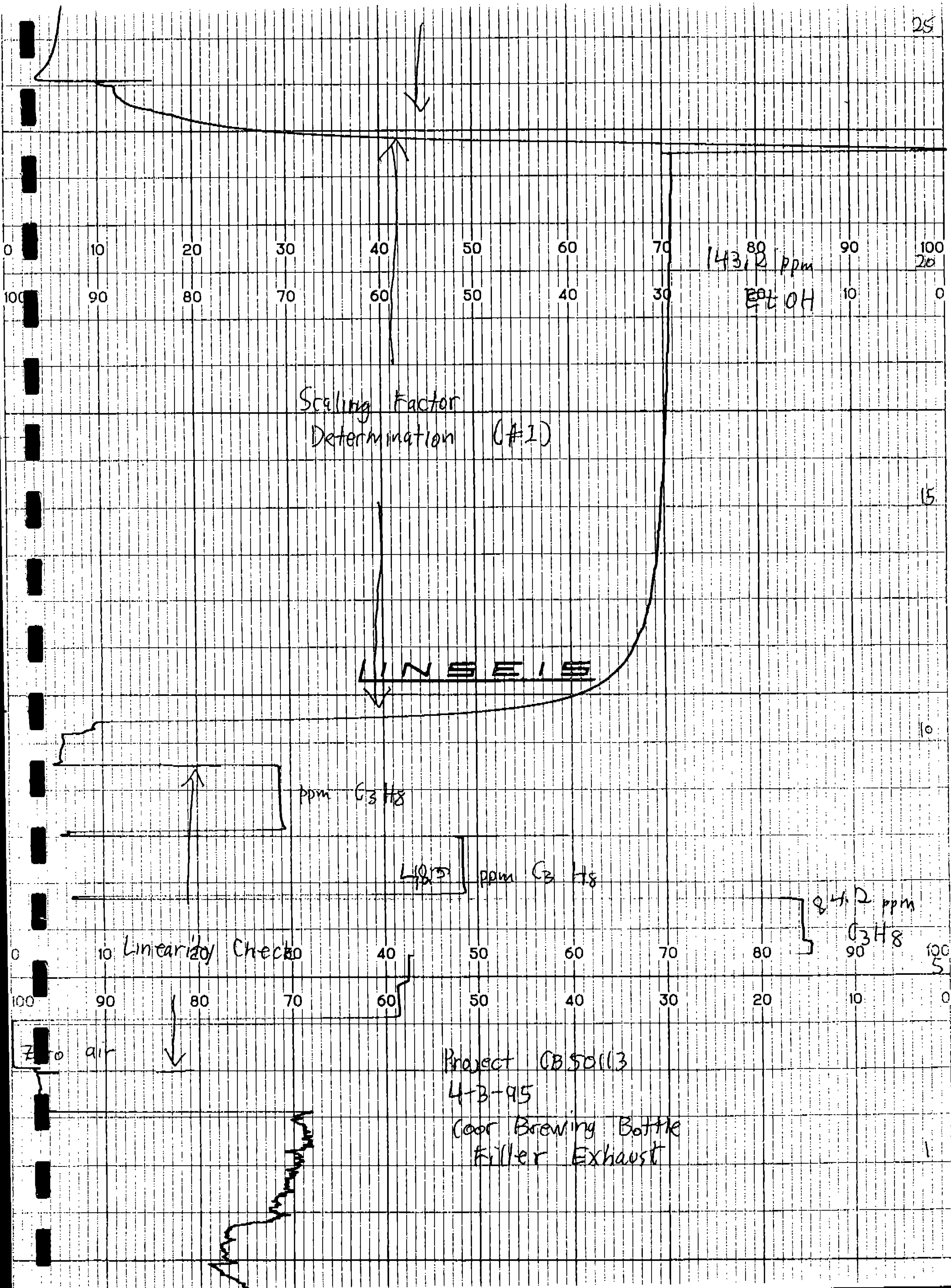
ppmvw - parts per million, wet volume basis

Appendix 2

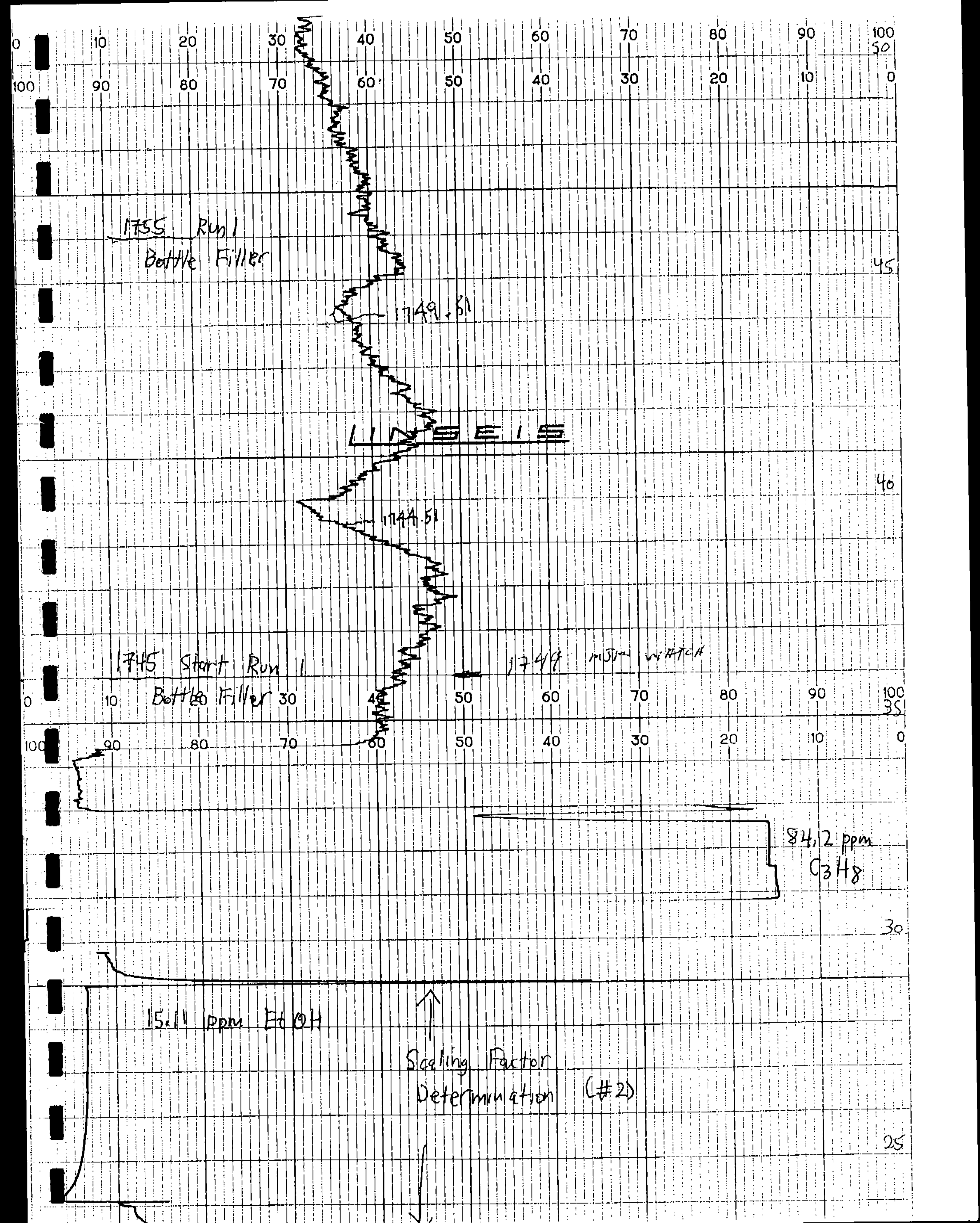
Field Data

Method 25A Strip Chart Data
Total VOCs

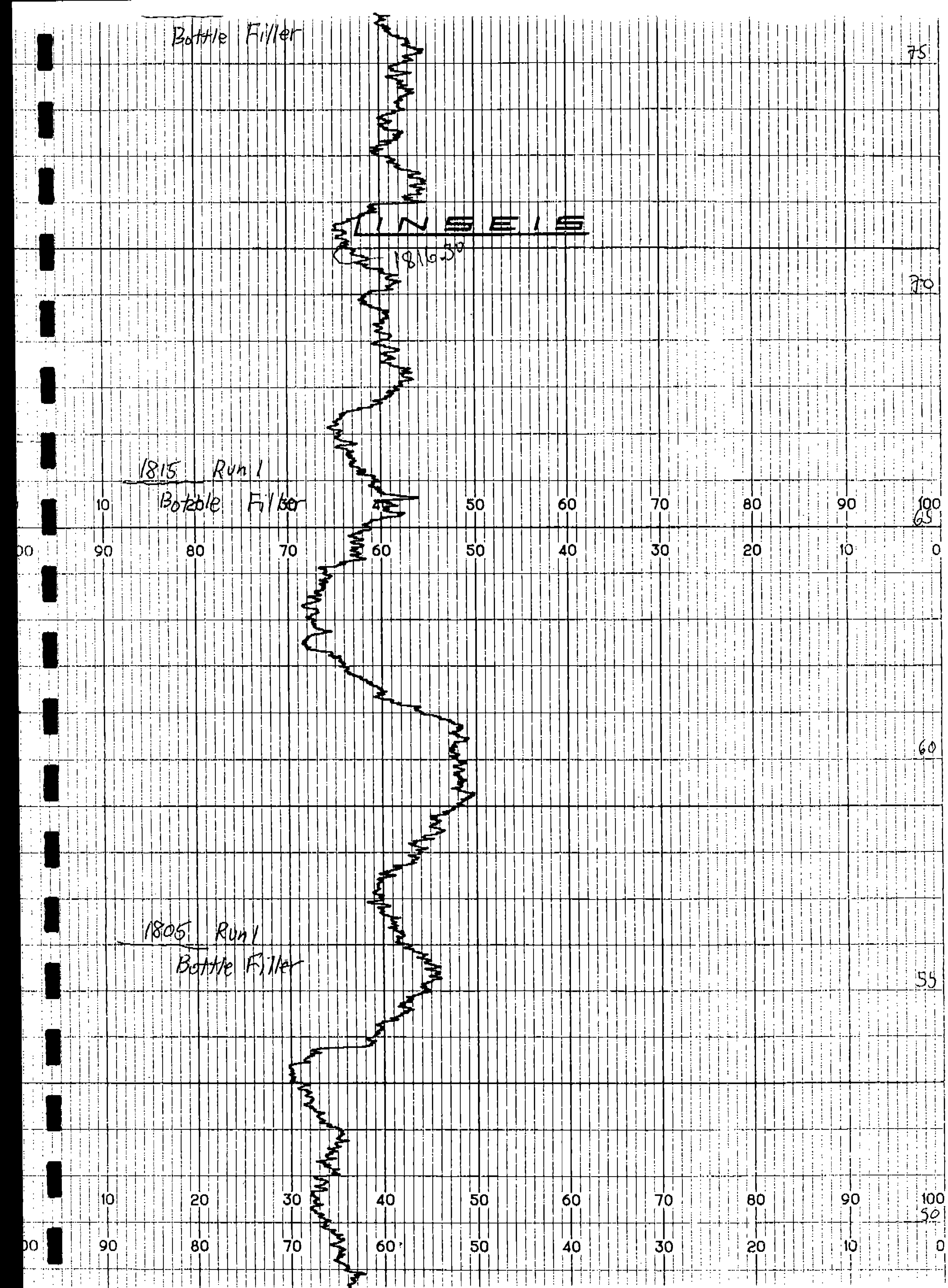
4-3-95 : Bottle Filler Exhaust

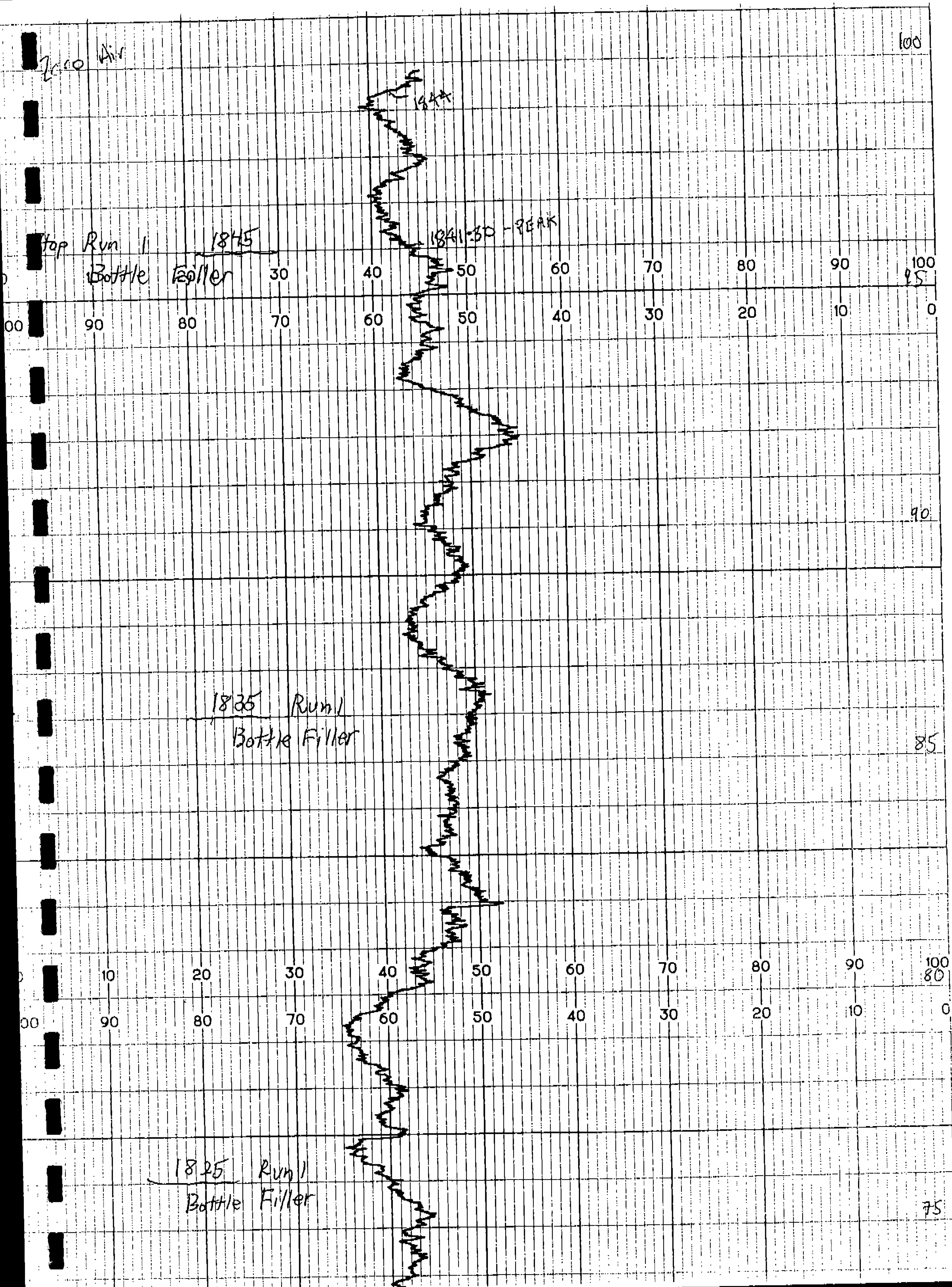


143.2 ppm EtOH
Scaling Factor Determination (#1)
LINSEIS
ppm C3H8
ppm C3H8
84.2 ppm C3H8
Linearity Check
Zero air
Project CB50113
4-3-95
Coor Brewing Bottle Filler Exhaust

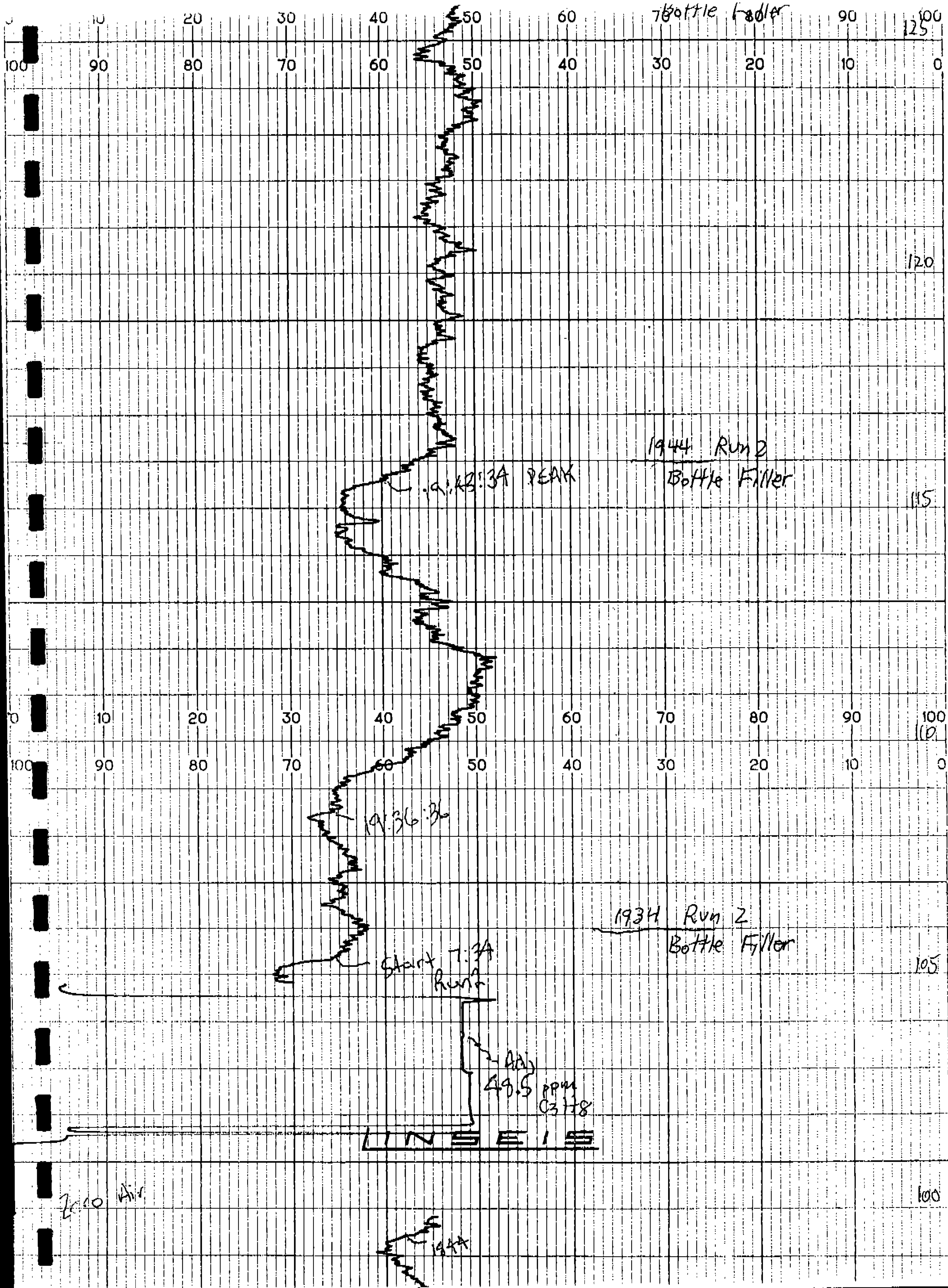


1755 Run 1
Bottle Filler
1749.61
1744.61
1745 Start Run 1
Bottle Filler
84.2 ppm
C3H8
15.11 ppm EtOH
Scaling Factor
Determination (#2)

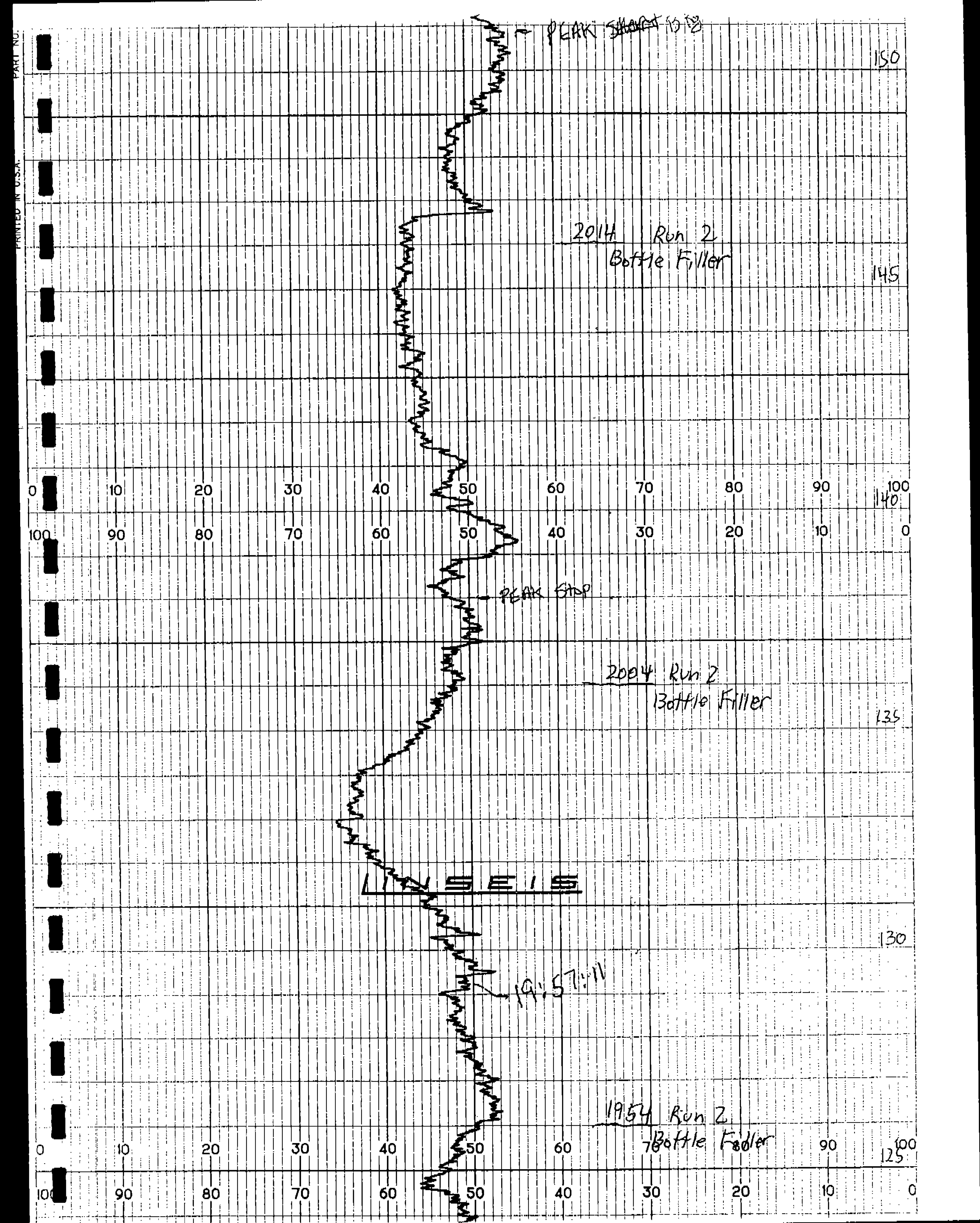

Bottle Filler
75
181630
70
1815 Run 1
Bottle Filler
65
60
1805 Run 1
Bottle Filler
55
50

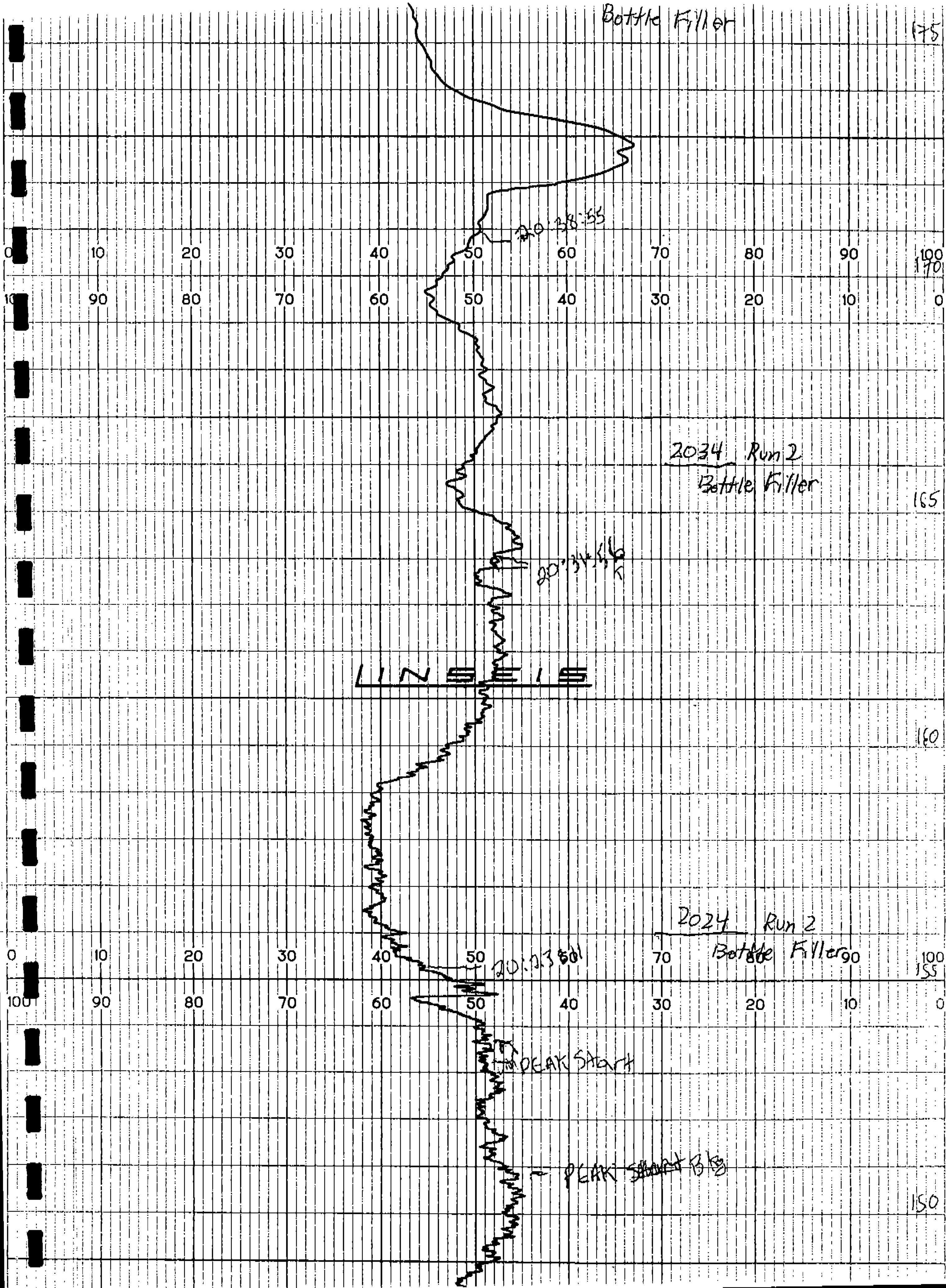


Zero Air
100
1844
Stop Run 1 1845
Bottle Filler
1841:30 - PEAK
30 40 50 60 70 80 90 100
95
90 80 70 60 50 40 30 20 10 0
90
1835 Run 1
Bottle Filler
85
10 20 30 40 50 60 70 80 90 100
80
90 80 70 60 50 40 30 20 10 0
1825 Run 1
Bottle Filler
75

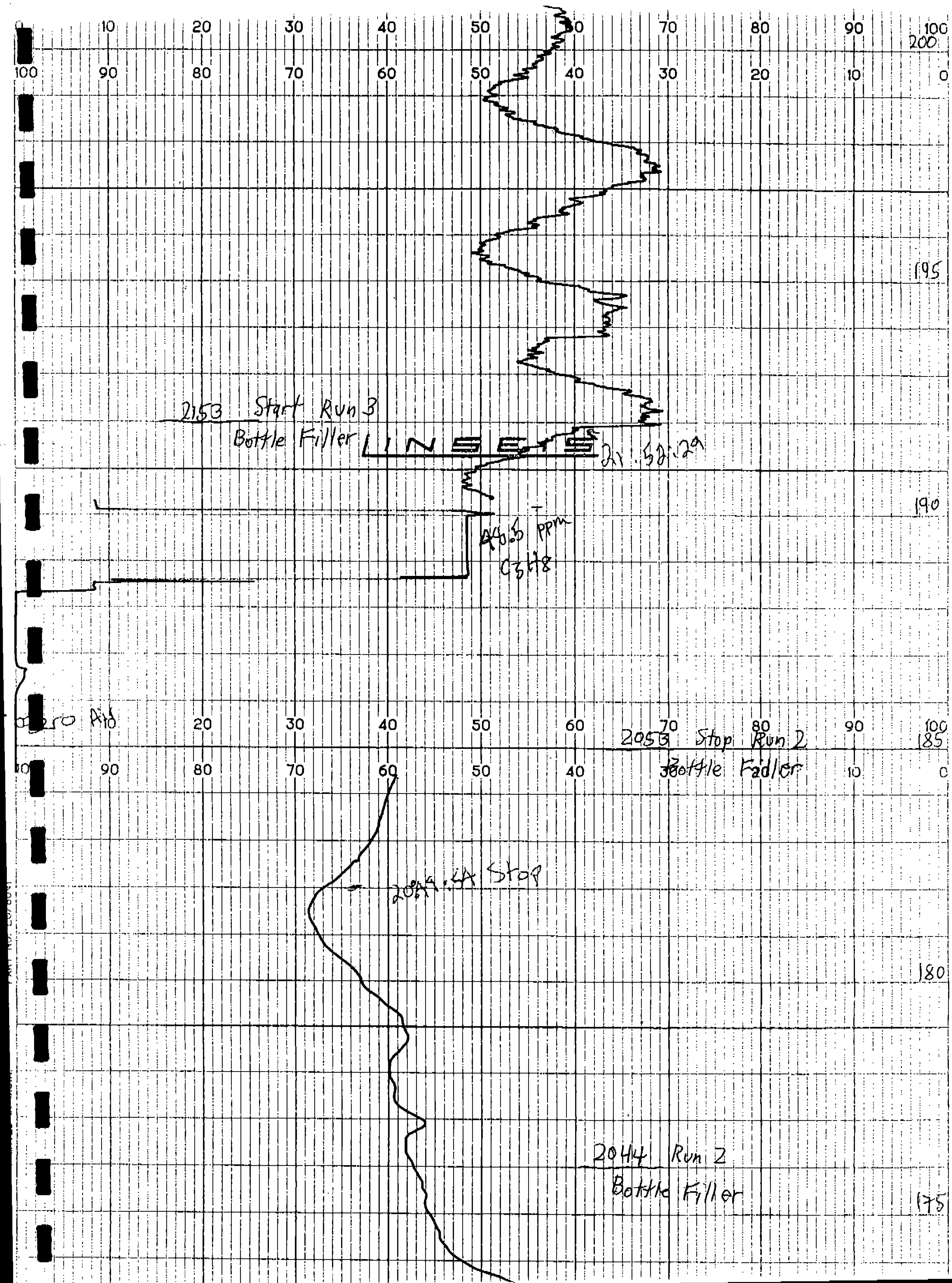


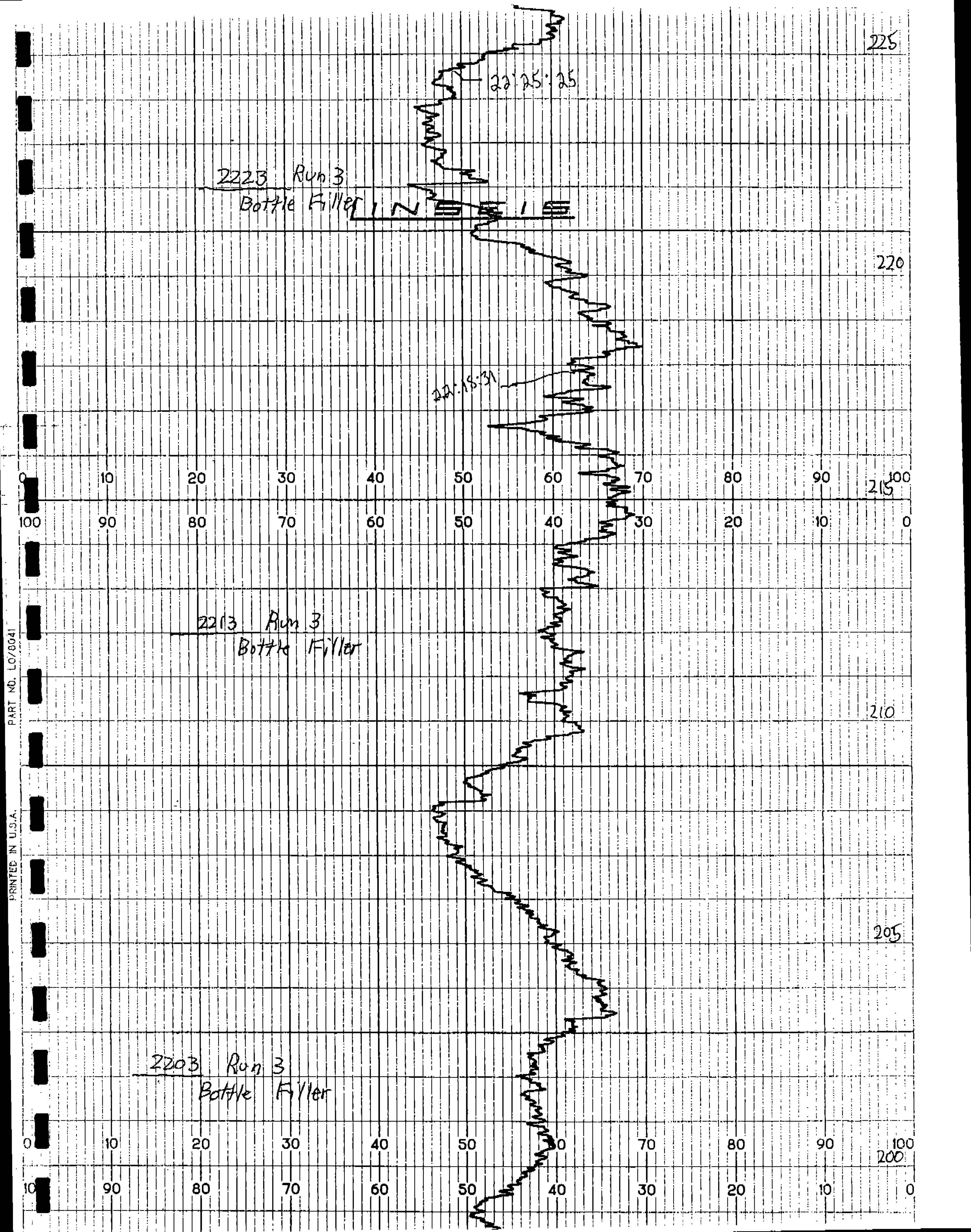
0 10 20 30 40 50 60 70 80 90 100
100 90 80 70 60 50 40 30 20 10 0
Bottle Filler
125
120
1944 Run 2
Bottle Filler
19:43:34 PEAK
115
110
19:36:36
1934 Run 2
Bottle Filler
Start 7:34
Run 2
105
49.5 ppm
LINSEIS
100
Zero Air
1944


PART NO.
PRINTED IN U.S.A.
PEAK
150
2014 Run 2
Bottle Filler
145
0 10 20 30 40 50 60 70 80 90 100
140
100 90 80 70 60 50 40 30 20 10 0
PEAK STOP
2004 Run 2
Bottle Filler
135
LINSEIS
130
19:57:11
1954 Run 2
Bottle Filler
0 10 20 30 40 50 60 70 80 90 100
125
100 90 80 70 60 50 40 30 20 10 0

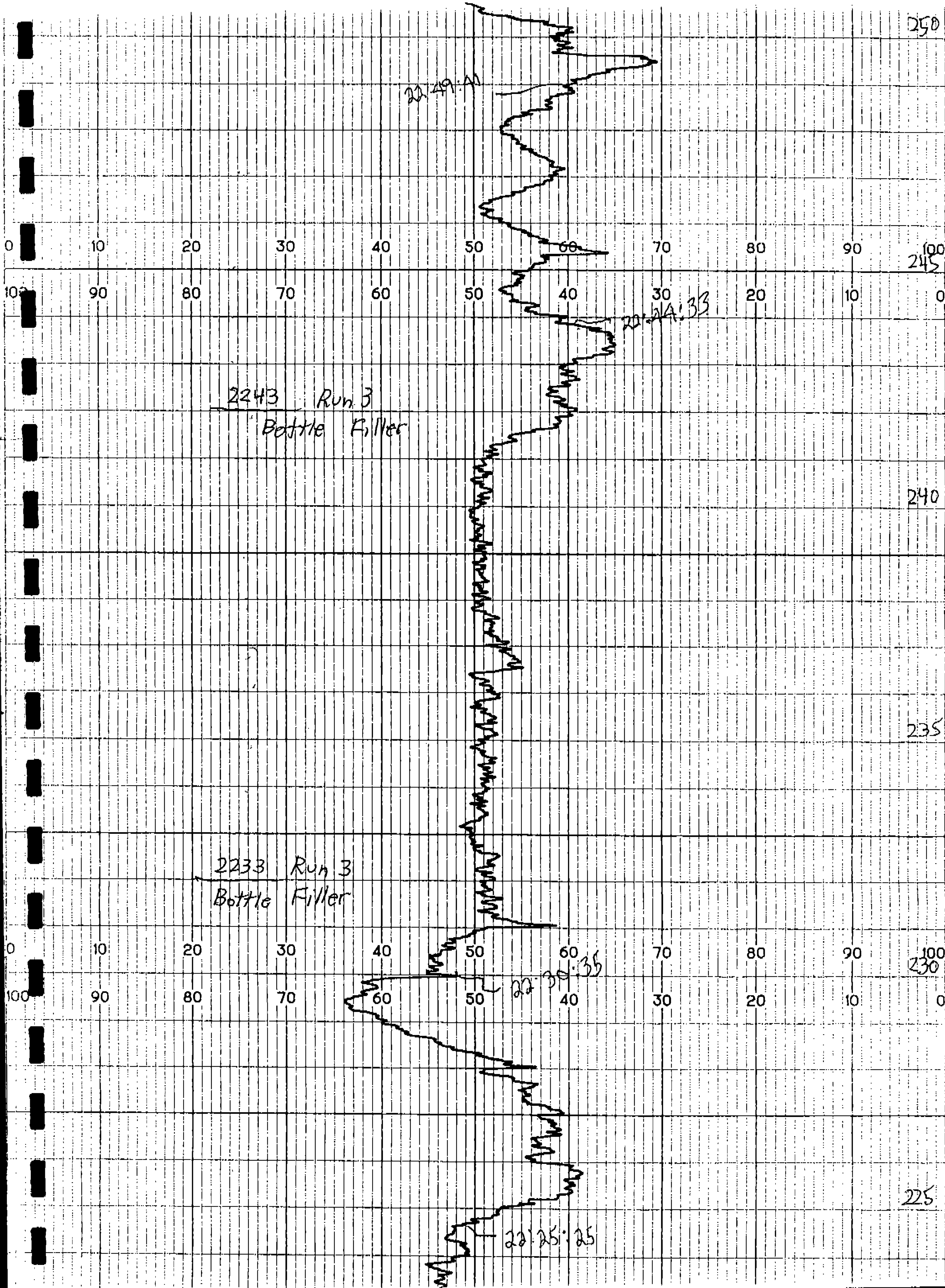


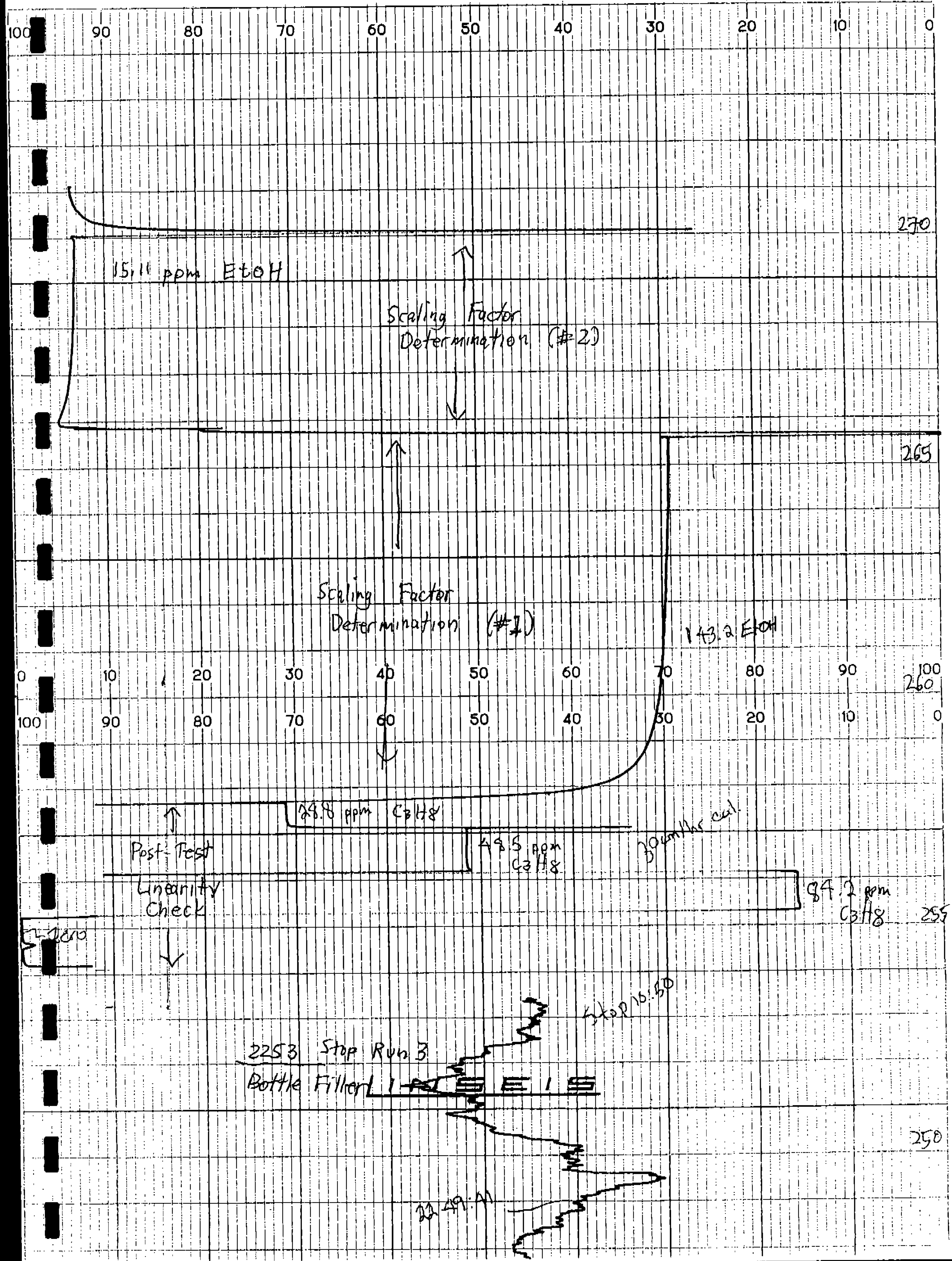
Bottle Filler
175
0 10 20 30 40 50 60 70 80 90 100
100 90 80 70 60 50 40 30 20 10 0
170
2034 Run 2
Bottle Filler
165
LINSEIS
160
2024 Run 2
Bottle Filler
155
PEAK Start
PEAK
150


0 10 20 30 40 50 60 70 80 90 100
100 90 80 70 60 50 40 30 20 10 0
200
195
2153 Start Run 3
Bottle Filler
190
ppm
C3H8
Zero Aid
2053 Stop Run 2
Bottle Filler
185
Stop
180
2044 Run 2
Bottle Filler
175



225
22:25:25
2223 Run 3
Bottle Filler
220
22:15:31
0 10 20 30 40 50 60 70 80 90 100
215
100 90 80 70 60 50 40 30 20 10 0
2213 Run 3
Bottle Filler
210
205
2203 Run 3
Bottle Filler
0 10 20 30 40 50 60 70 80 90 100
200
100 90 80 70 60 50 40 30 20 10 0
PART NO. LO/8041
PRINTED IN U.S.A.


250
22:49:41
0 10 20 30 40 50 60 70 80 90 100
245
100 90 80 70 60 50 40 30 20 10 0
22:44:33
2243 Run 3
Bottle Filler
240
235
2233 Run 3
Bottle Filler
0 10 20 30 40 50 60 70 80 90 100
230
22:30:35
100 90 80 70 60 50 40 30 20 10 0
225
22:25:25



15.1 ppm EtOH
Scaling Factor Determination (#2)
Scaling Factor Determination (#1)
143.2 EtOH
24.8 ppm C3H8
48.5 ppm C3H8
84.2 ppm C3H8
Post-Test Linearity Check
30 min/hr cal
2253 Stop Run 3
Bottle Filler
270
265
260
255
250

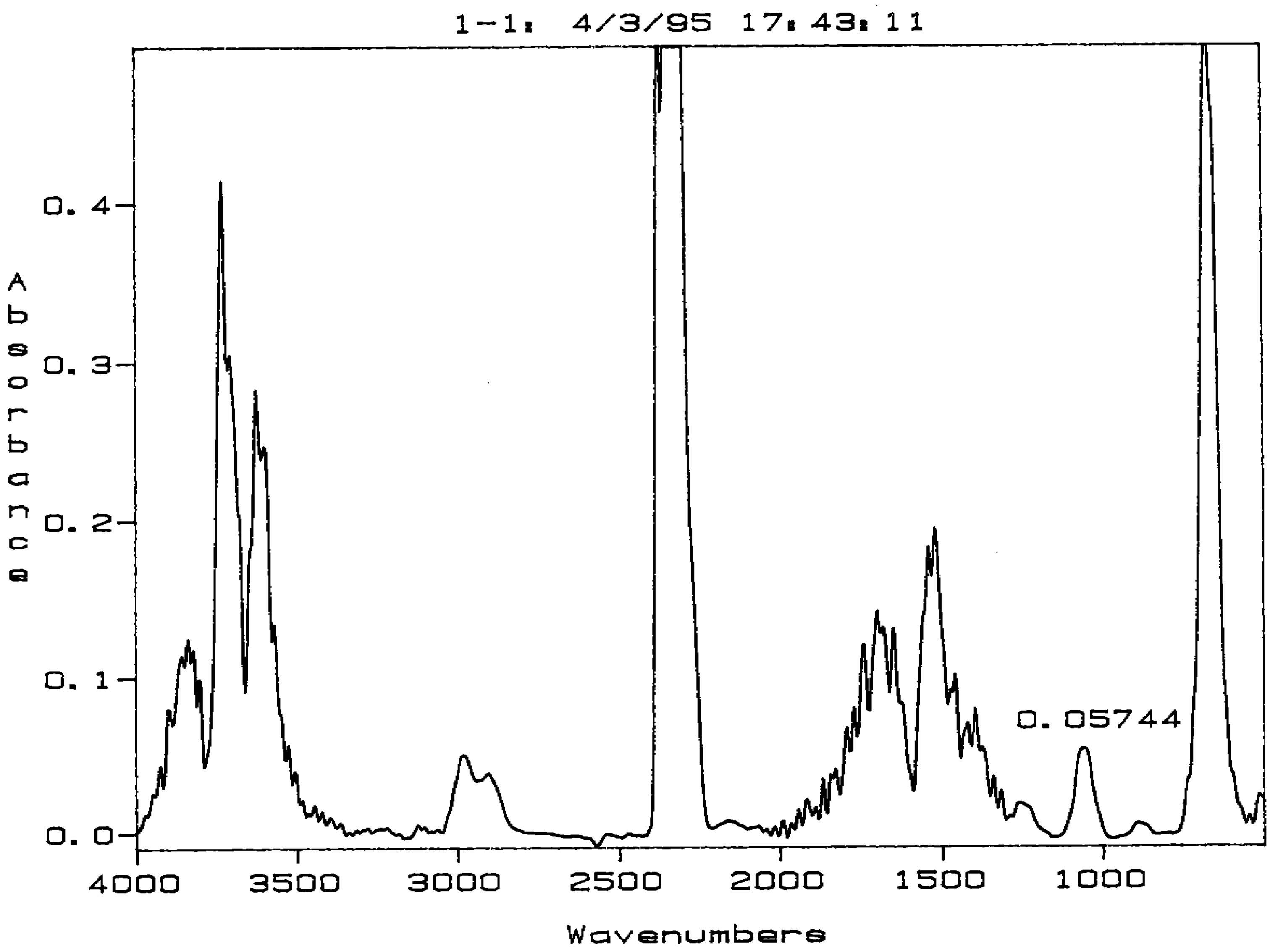
FTIR Spectra
Ethanol and Total VOCs

4-3-95 : Bottle Filler Exhaust

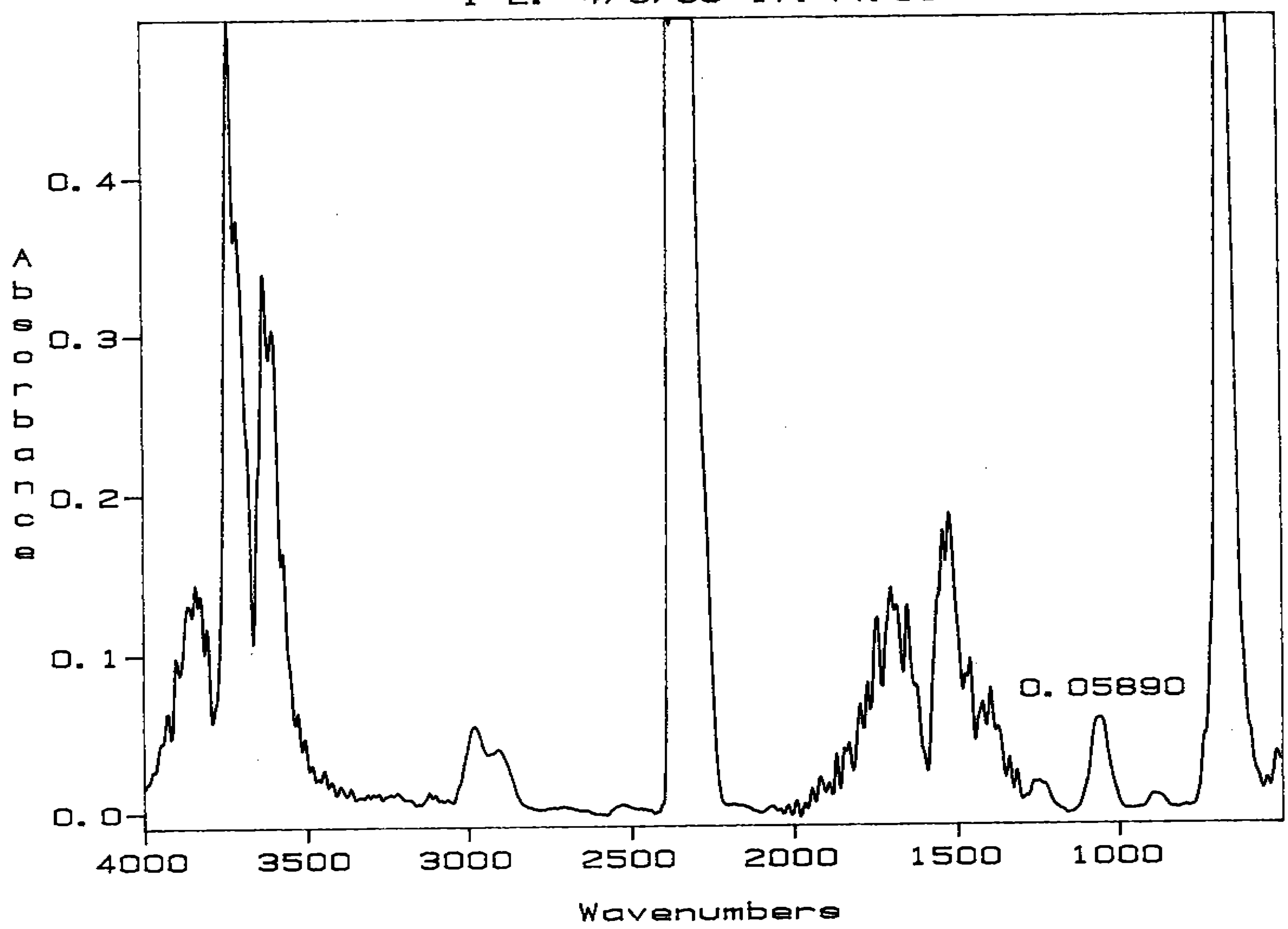
Cals for Coors Bottle line

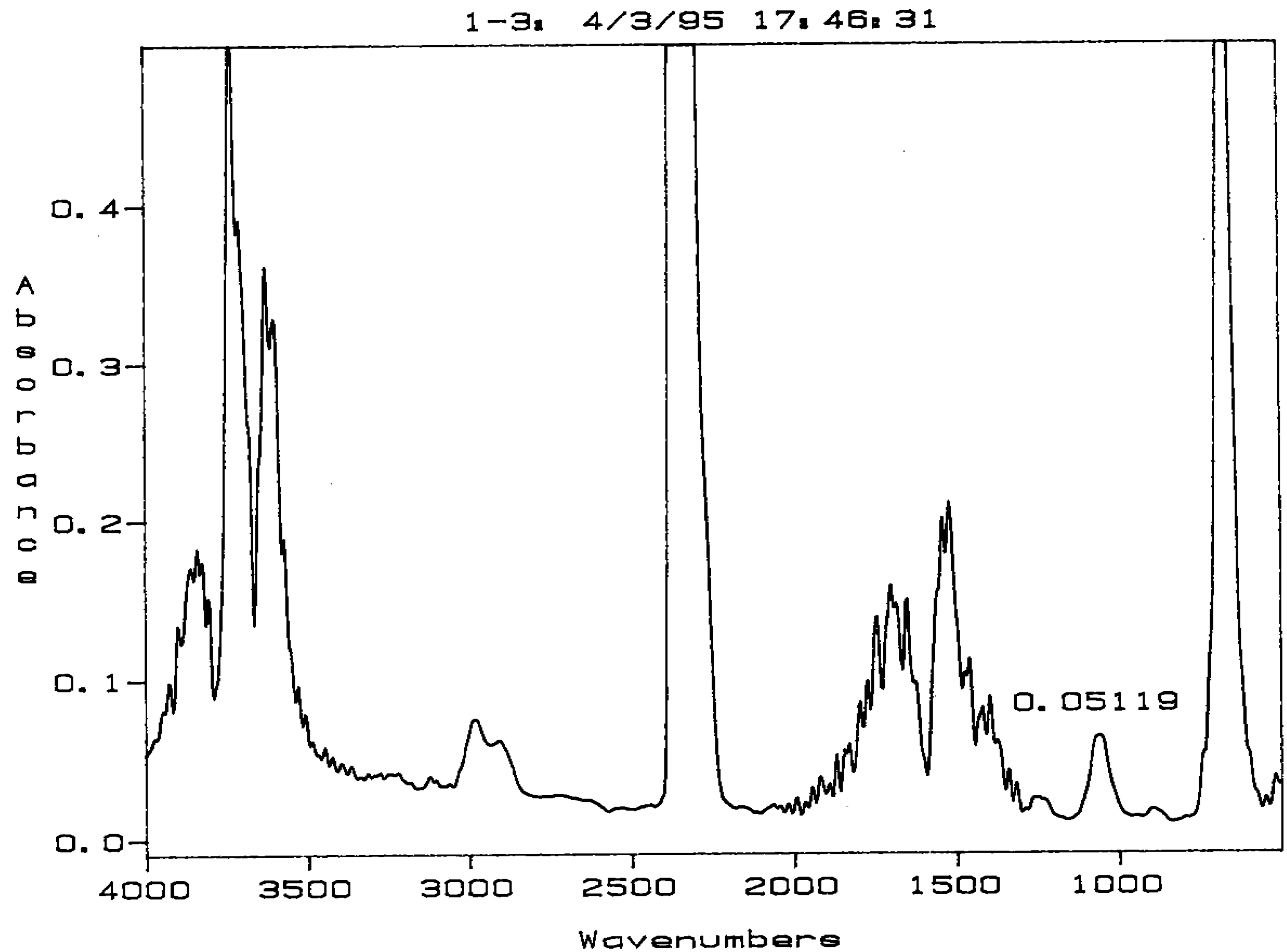
e[redacted]n	mA
15.11	6.56
15.11	6.78
15[redacted]11	6.67
15[redacted]11	6.12
15.11	7.84
14[redacted]2	83.89
14[redacted]2	88.73
143.2	83.35
143.2	88.28
14[redacted]2	85.13
14[redacted].2	89.19
143.2	86.49
14[redacted]2	88.17
14[redacted]2	88.84

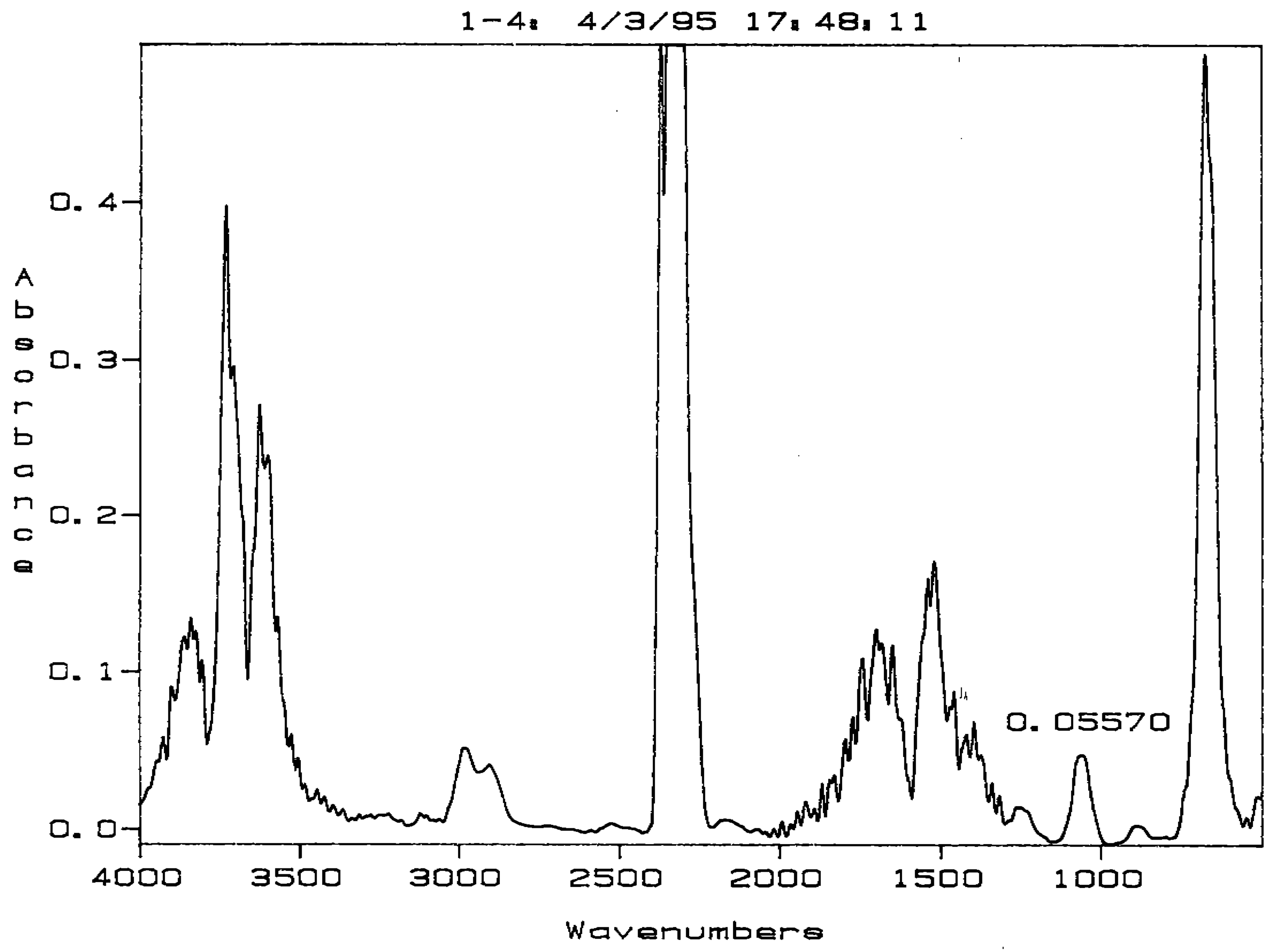
Where mA = miliabsorbance units


1-1: 4/3/95 17:43:11
Absorbance
0.4
0.3
0.2
0.1
0.0
0.05744
4000
3500
3000
2500
2000
1500
1000
Wavenumbers

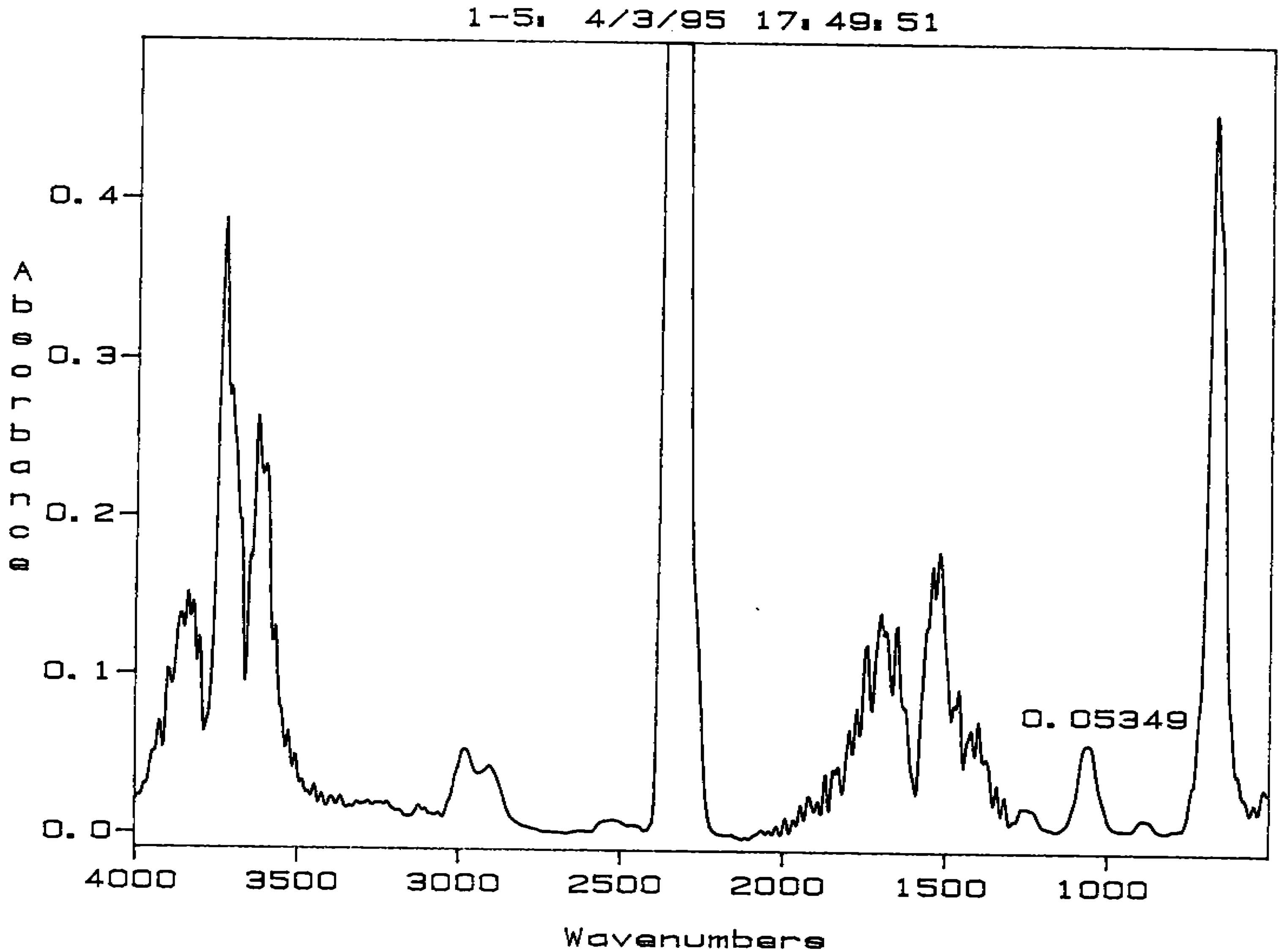
1-2: 4/3/95 17:44:51




1-3: 4/3/95 17:46:31
Absorbance
0.4
0.3
0.2
0.1
0.0
0.05119
4000
3500
3000
2500
2000
1500
1000
Wavenumbers



1-4: 4/3/95 17:48:11
Absorbance
0.4
0.3
0.2
0.1
0.0
0.05570
4000
3500
3000
2500
2000
1500
1000
Wavenumbers



1-5: 4/3/95 17:49:51
0.4
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Absorbance
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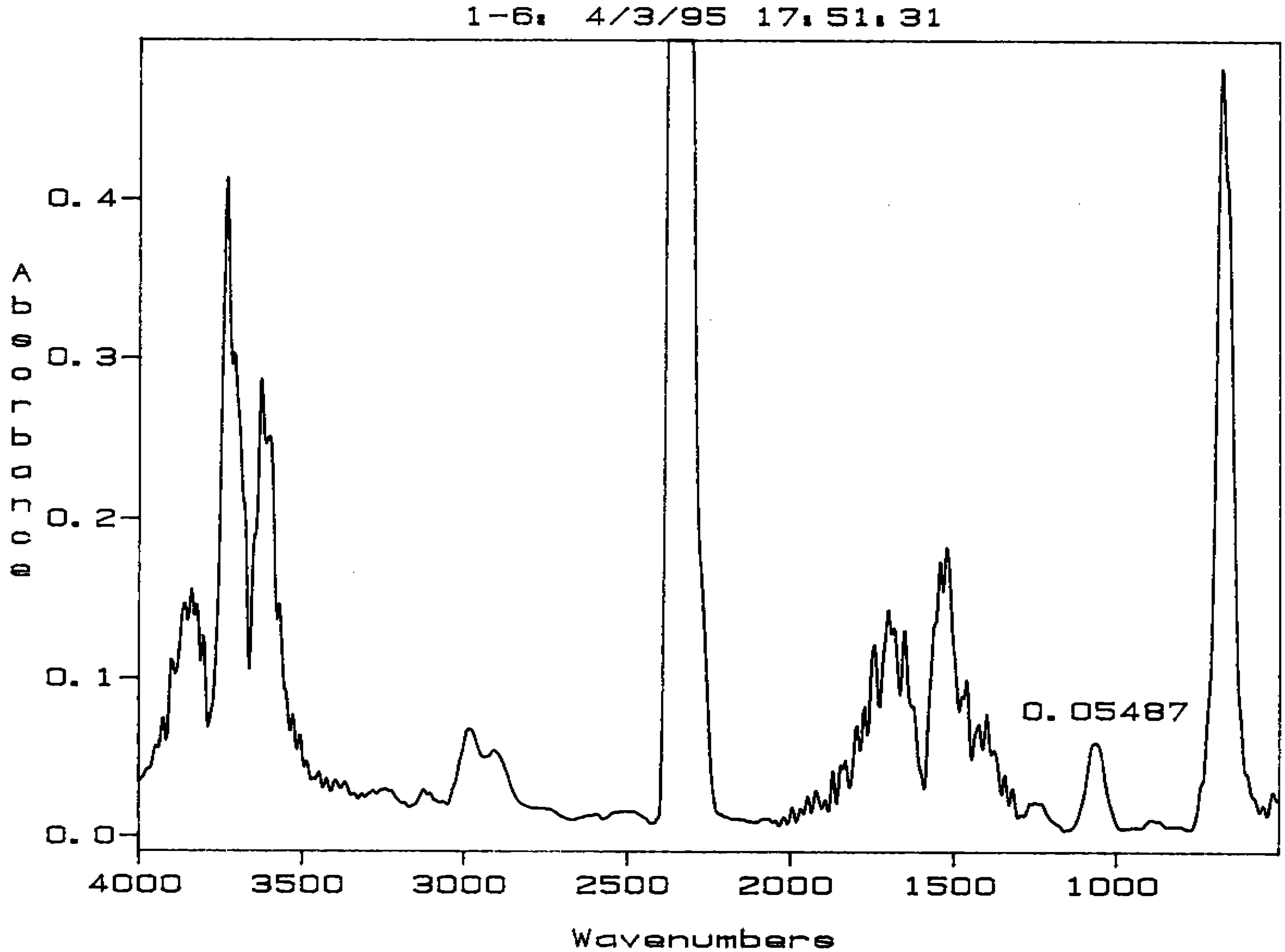
1500
1000
Wavenumbers


1-6: 4/3/95 17:51:31
Absorbance
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0.1
0.0
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3500
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2500
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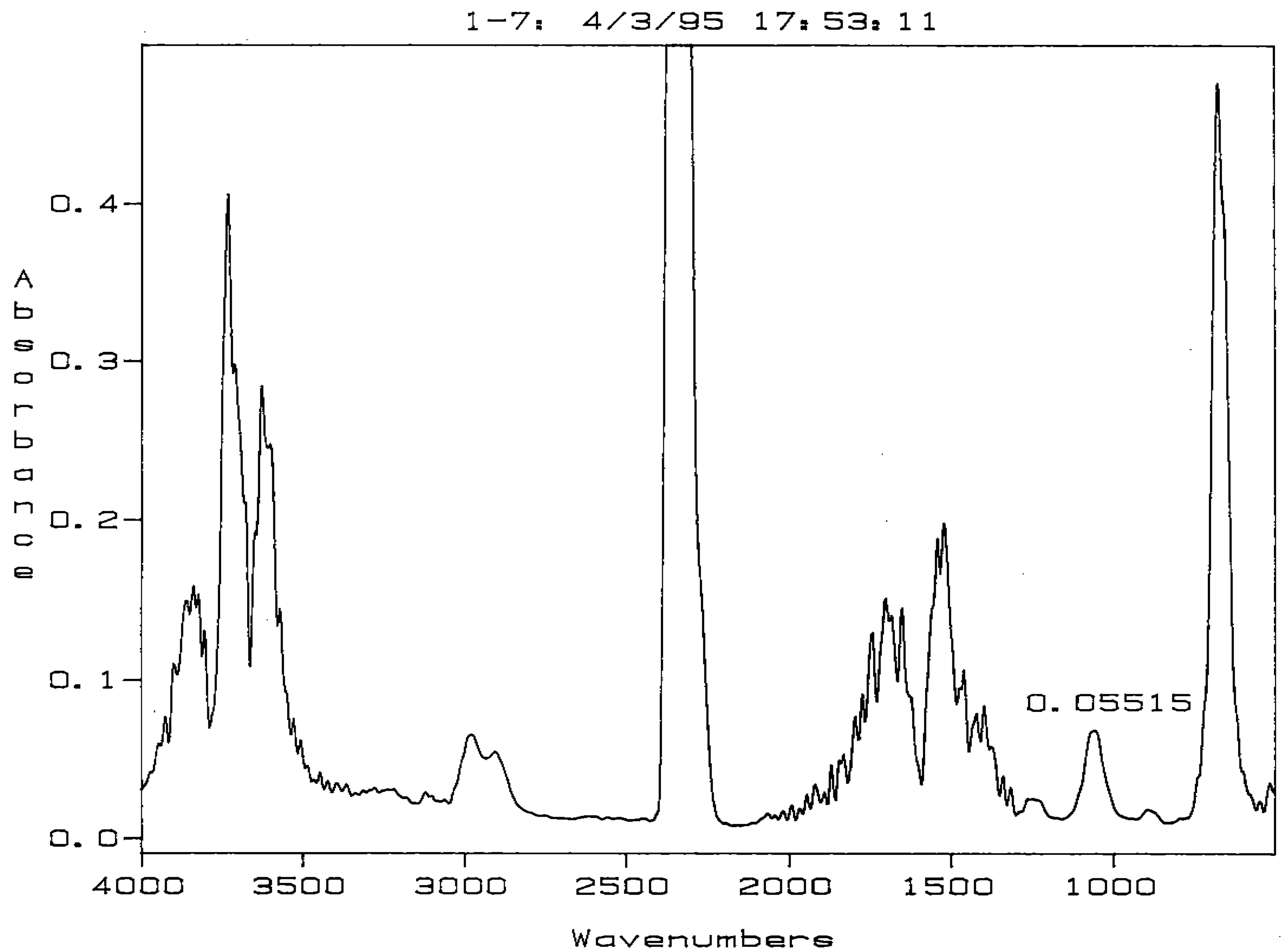
1500
1000
Wavenumbers


1-7: 4/3/95 17:53:11
Absorbance
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0.2
0.1
0.0
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4000
3500
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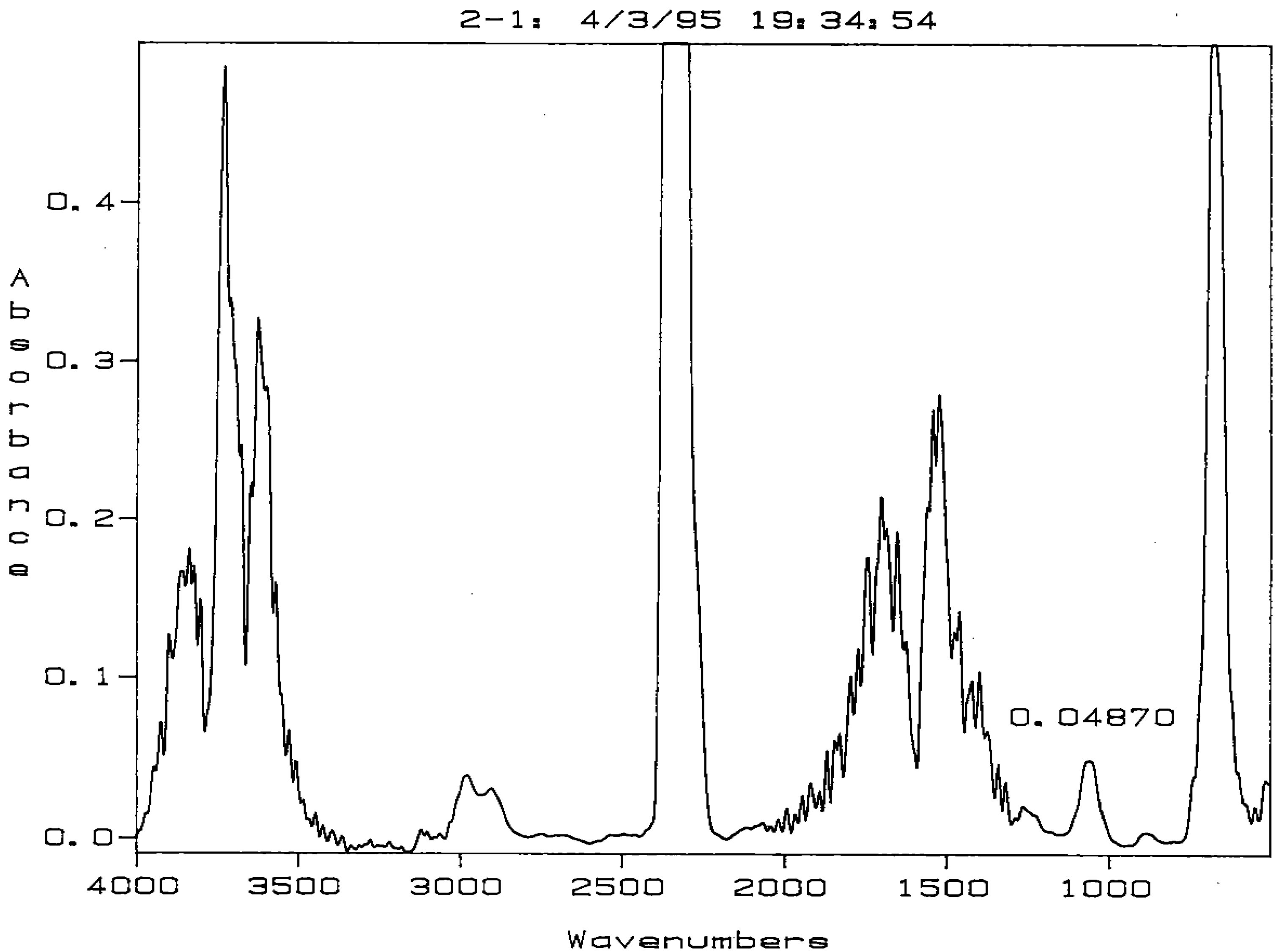
2500
2000
1500
1000
Wavenumbers



2-1: 4/3/95 19:34:54
0.4
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0.1
0.0
Absorbance
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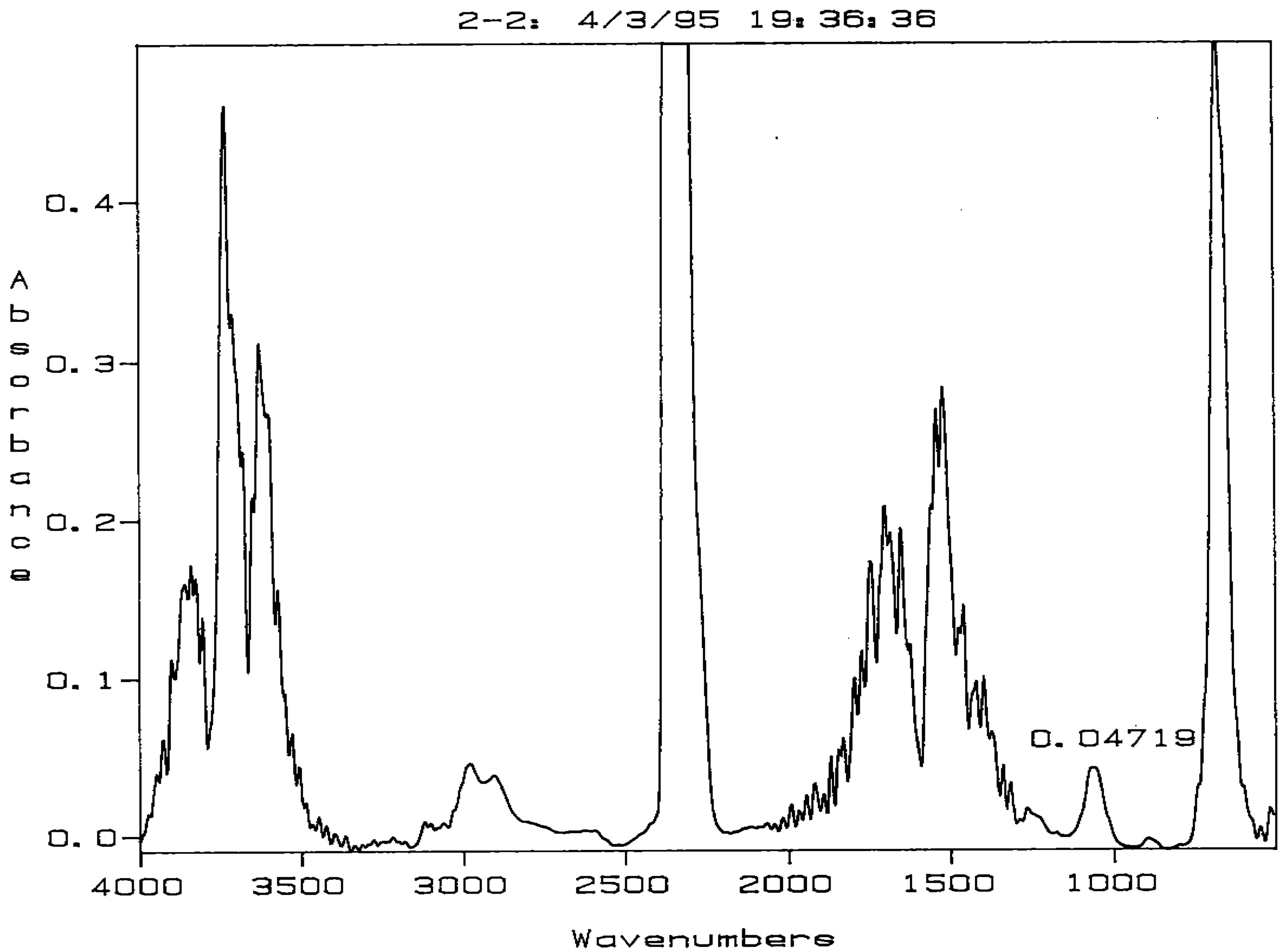
3500
3000
2500
2000
1500
1000
Wavenumbers



2-2: 4/3/95 19:36:36
Absorbance
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0.2
0.3
0.4
0.04719
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3500
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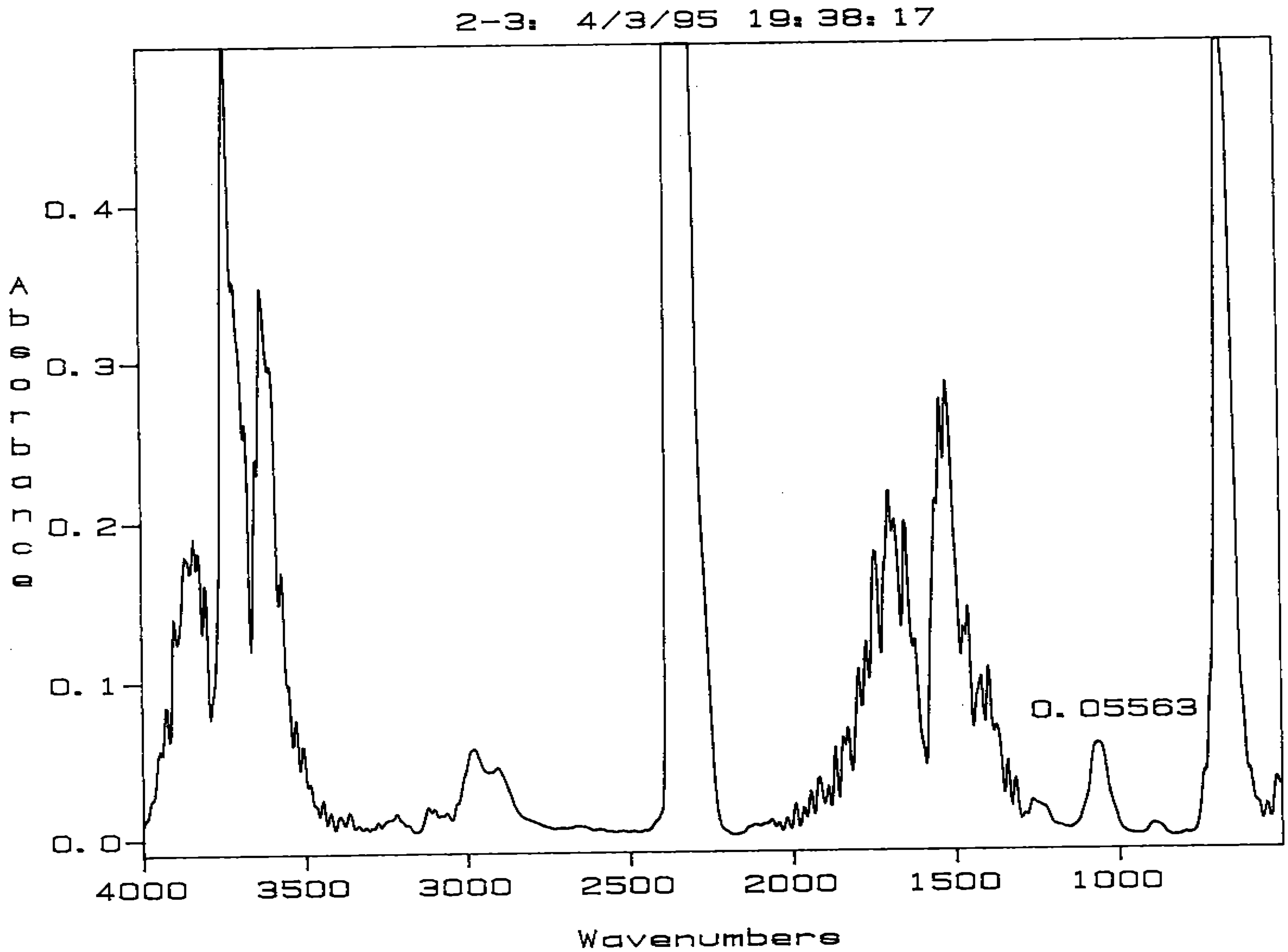
2500
2000
1500
1000
Wavenumbers


2-3: 4/3/95 19:38:17
Absorbance
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0.1
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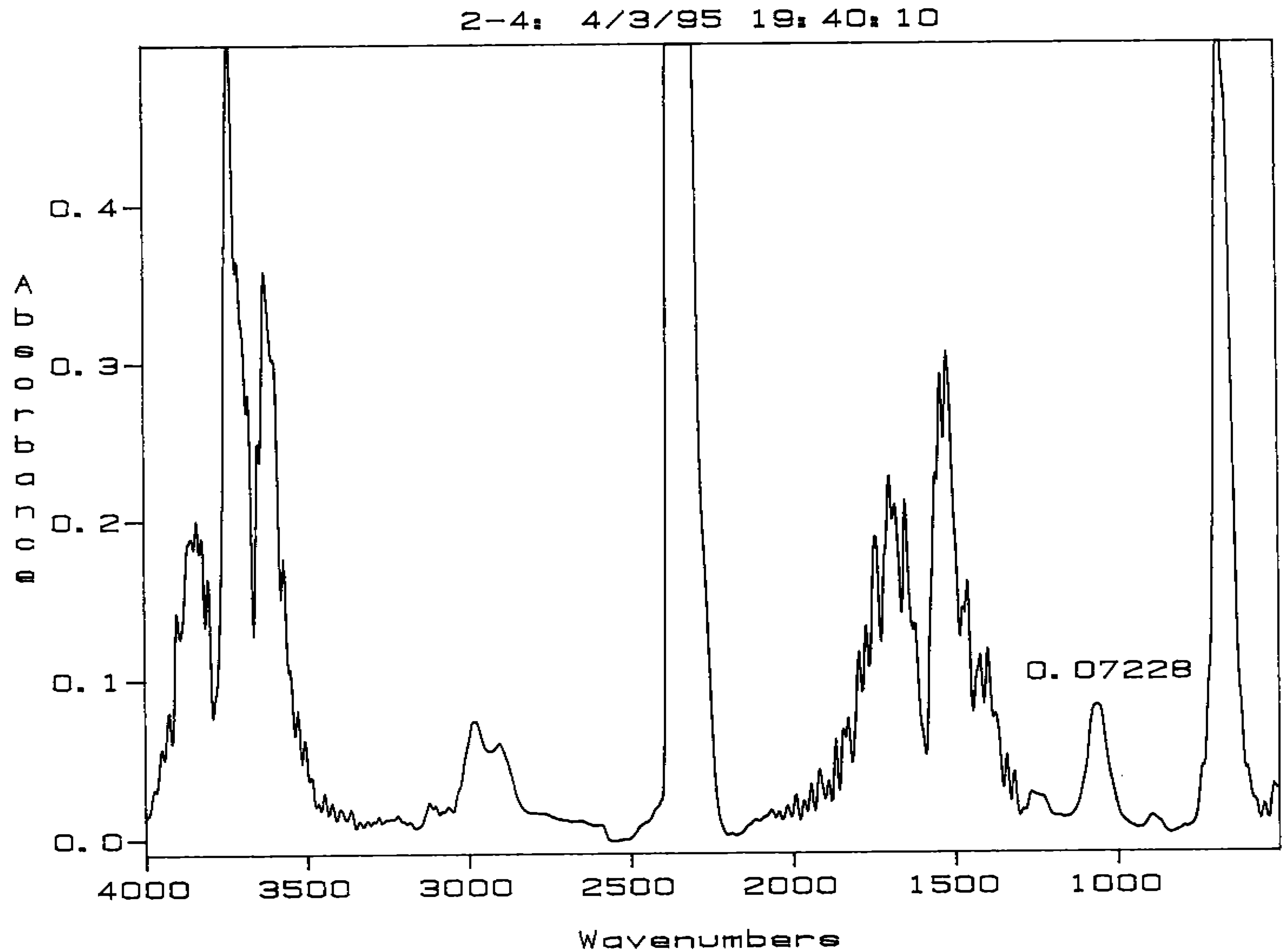
1500
1000
Wavenumbers


2-4: 4/3/95 19:40:10
Absorbance
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0.2
0.1
0.0
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3500
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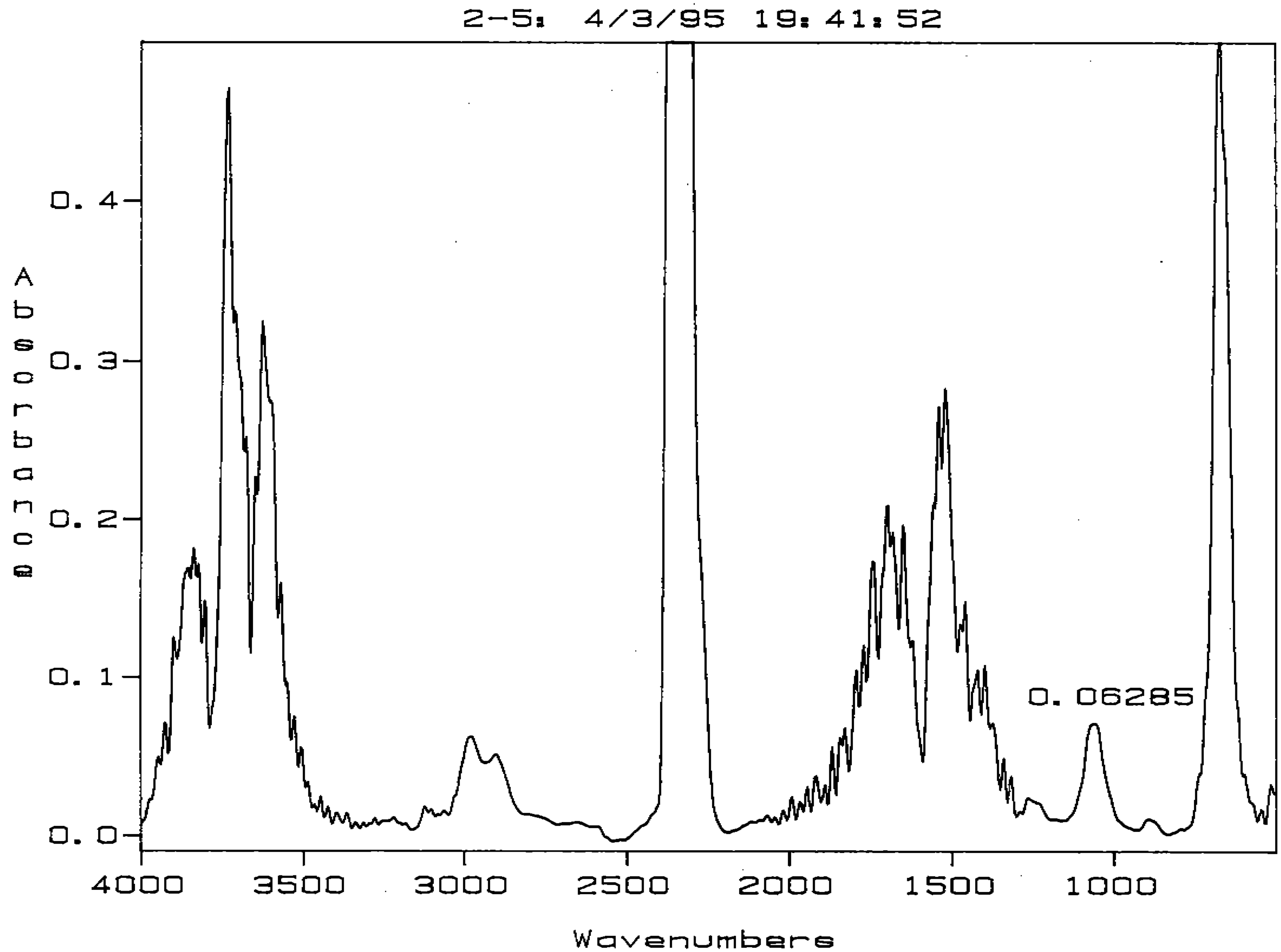
2500
2000
1500
1000
Wavenumbers


2-5: 4/3/95 19: 41: 52
Absorbance
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0. 2
0. 1
0. 0
0. 06285
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3500
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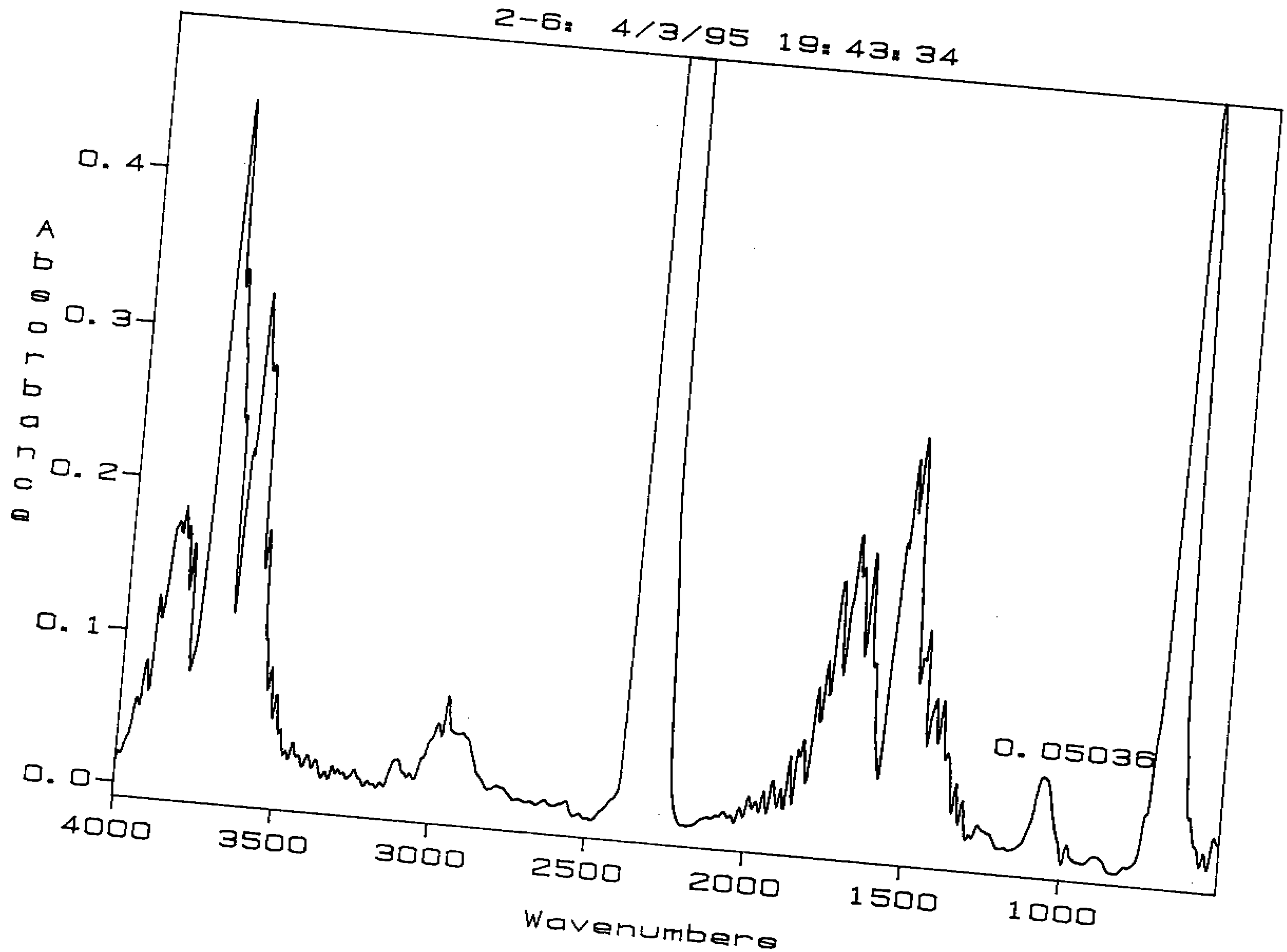
2500
2000
1500
1000
Wavenumbers


2-6: 4/3/95 19:43:34
Absorbance
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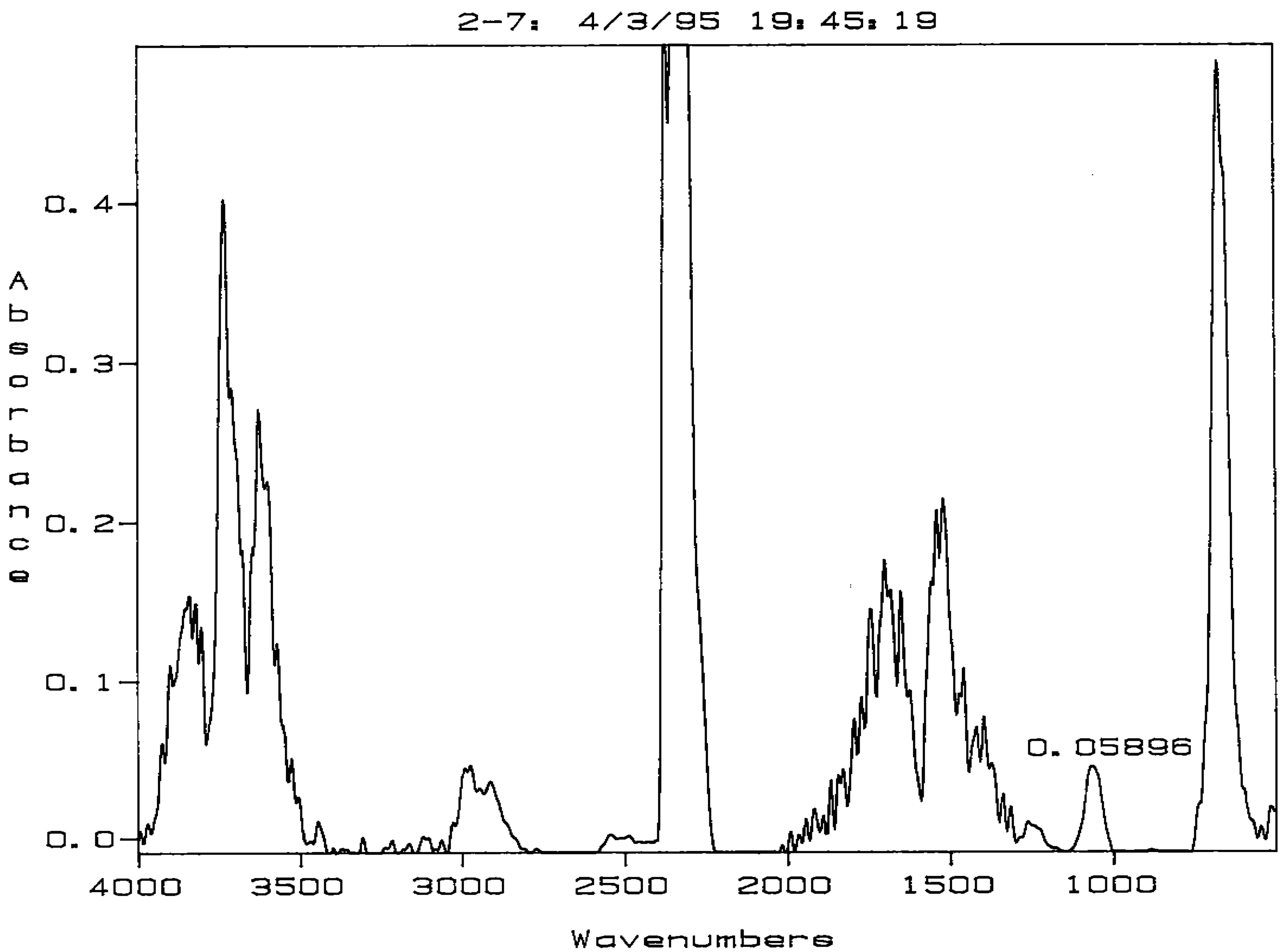
0.2
0.1
0.0
4000
3500
3000
2500
2000
1500
1000
Wavenumbers
0.05036


2-7: 4/3/95 19:45:19
Absorbance
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0.2
0.1
0.0
0.05896
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3500
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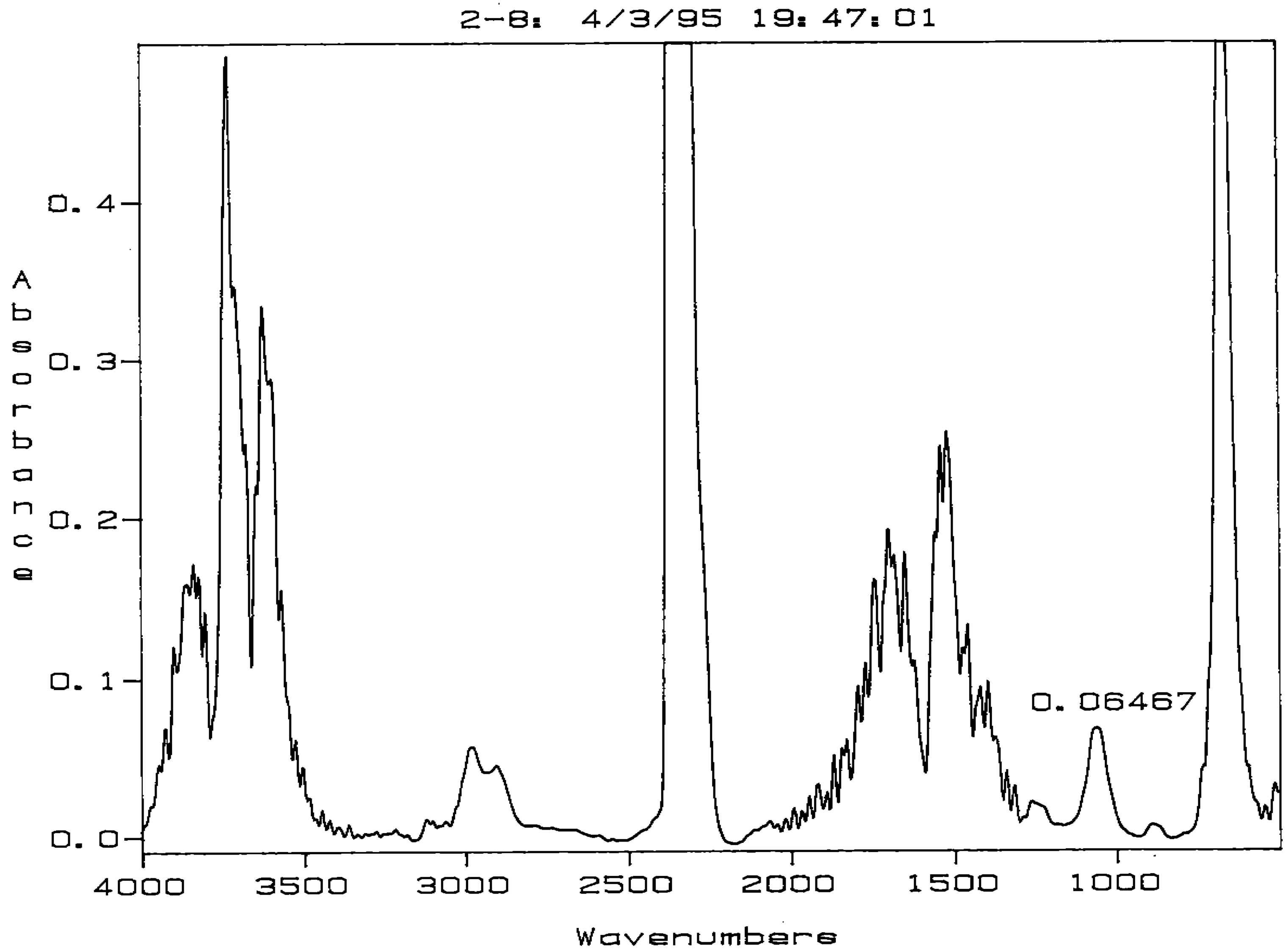
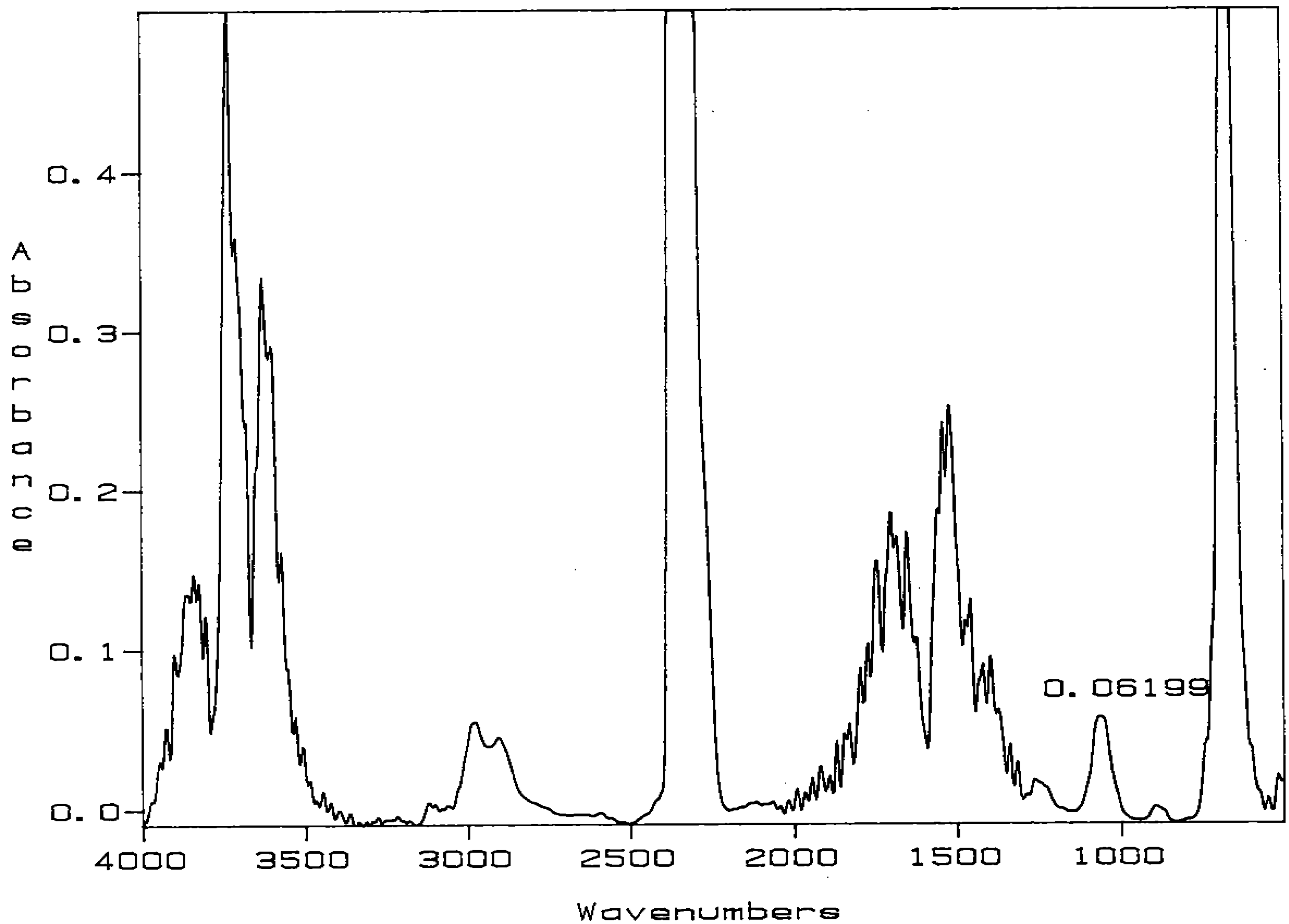
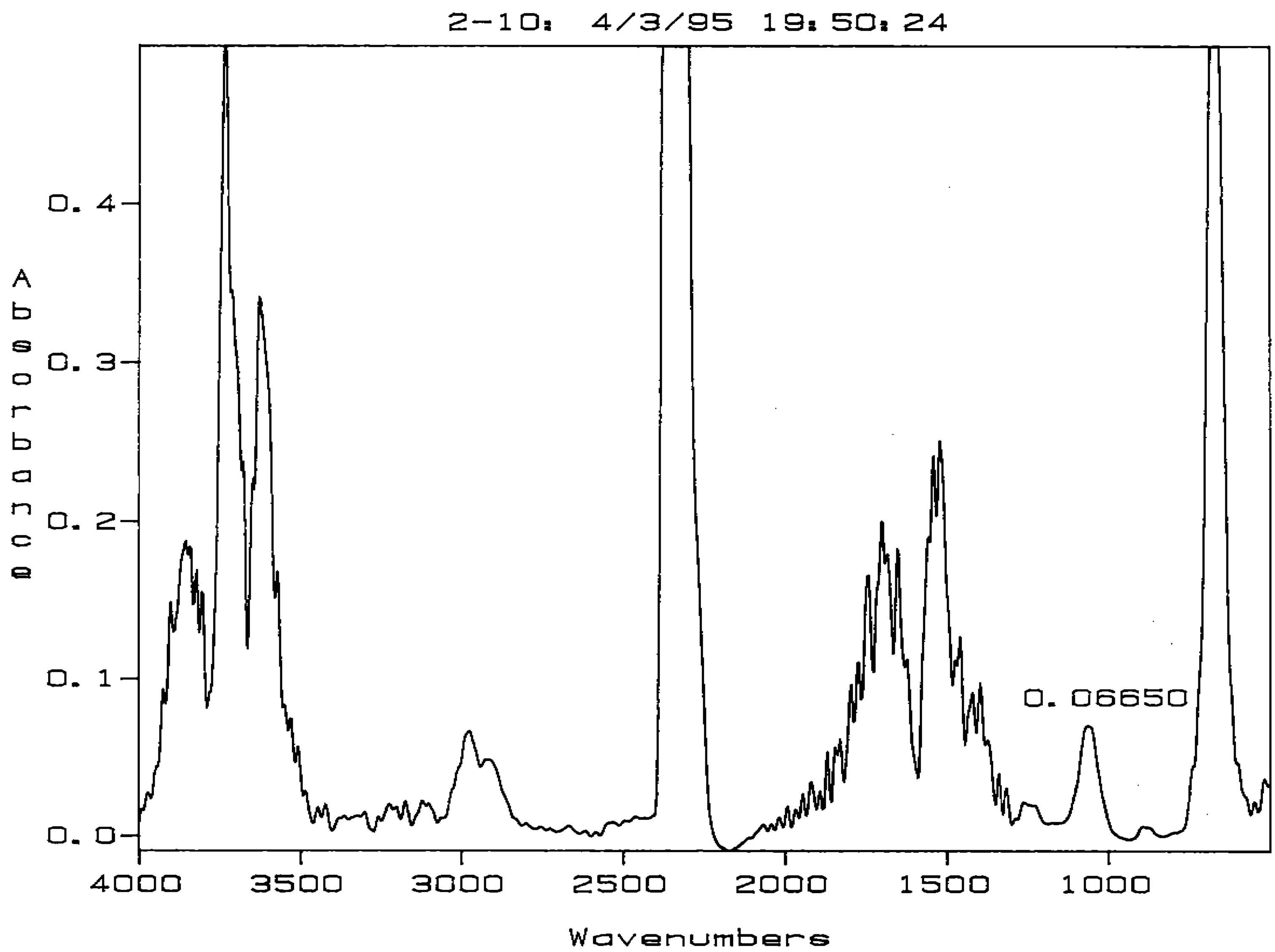
2500
2000
1500
1000
Wavenumbers


2-8: 4/3/95 19: 47: 01
0.4
0.3
0.2
0.1
0.0
Absorbance
0.06467
4000
3500
3000
2500
2000
1500
1000
Wavenumbers

2-9: 4/3/95 19: 48: 43




2-10: 4/3/95 19:50:24
Absorbance
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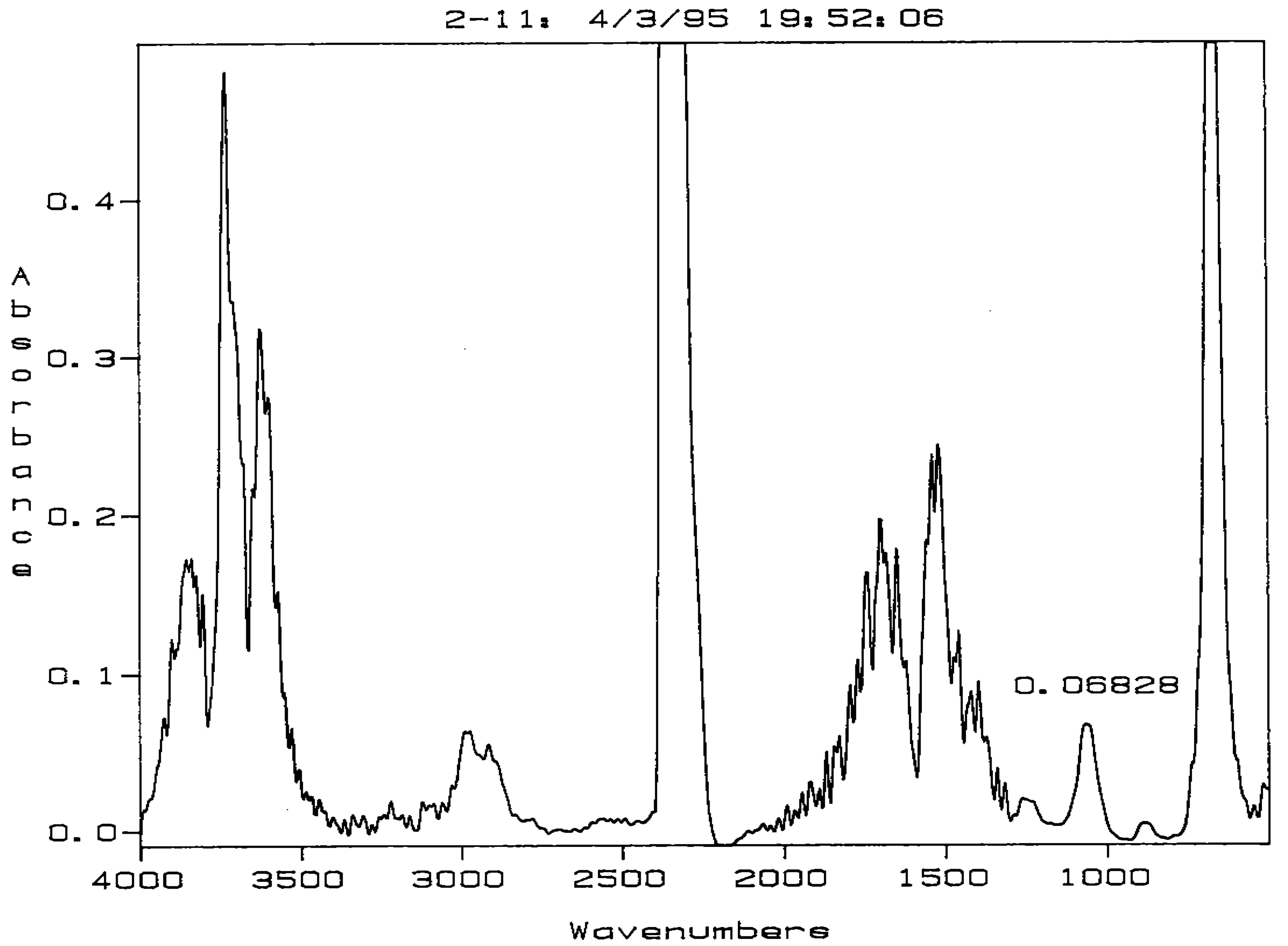
0.2
0.1
0.0
0.06650
4000
3500
3000
2500
2000
1500
1000
Wavenumbers


2-11: 4/3/95 19:52:06
Absorbance
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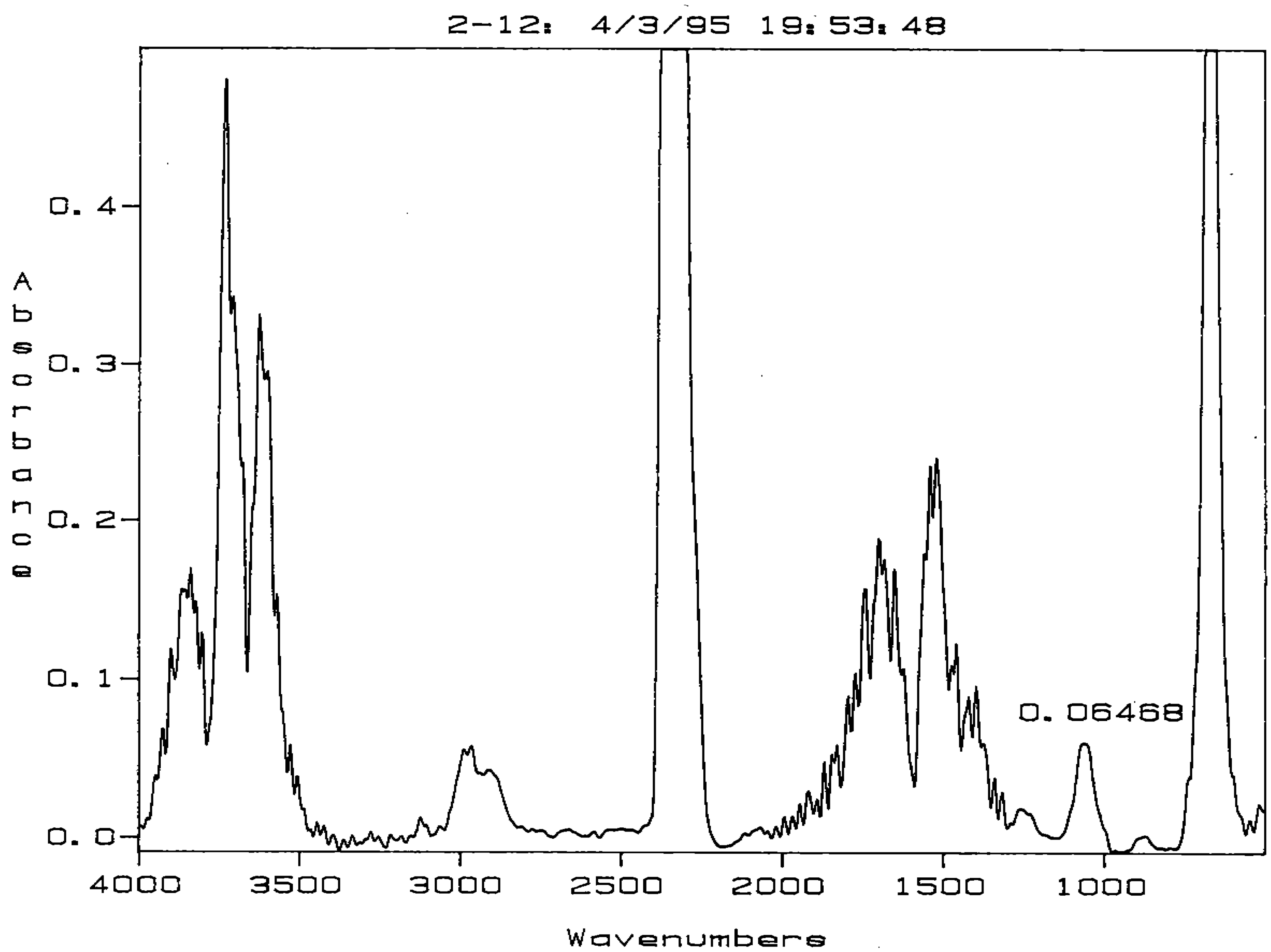
0.2
0.1
0.0
4000
3500
3000
2500
2000
1500
1000
Wavenumbers
0.06828


2-12: 4/3/95 19:53:48
Absorbance
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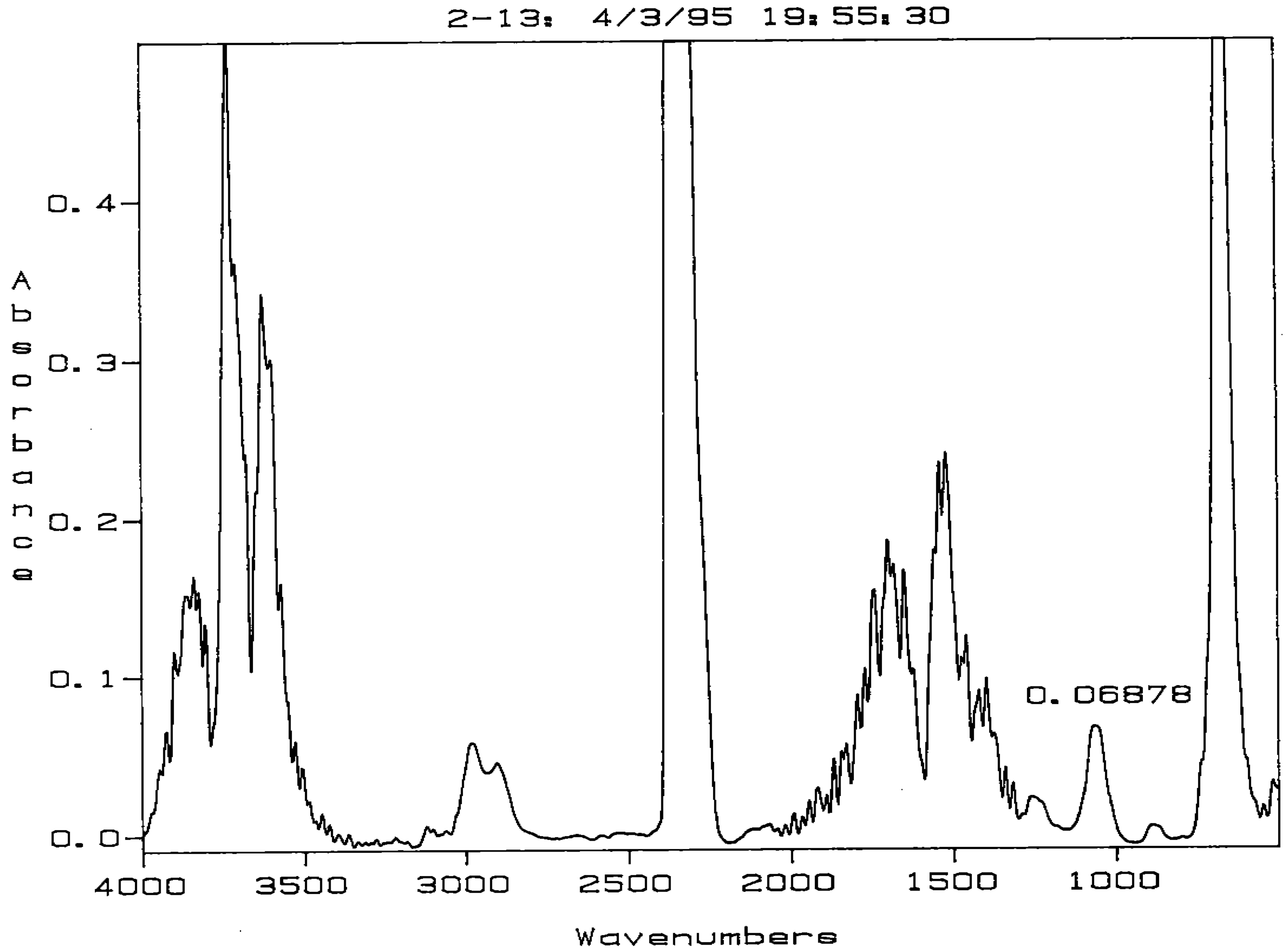
0.2
0.3
0.4
0.06468
4000
3500
3000
2500
2000
1500
1000
Wavenumbers



2-13: 4/3/95 19:55:30
Absorbance
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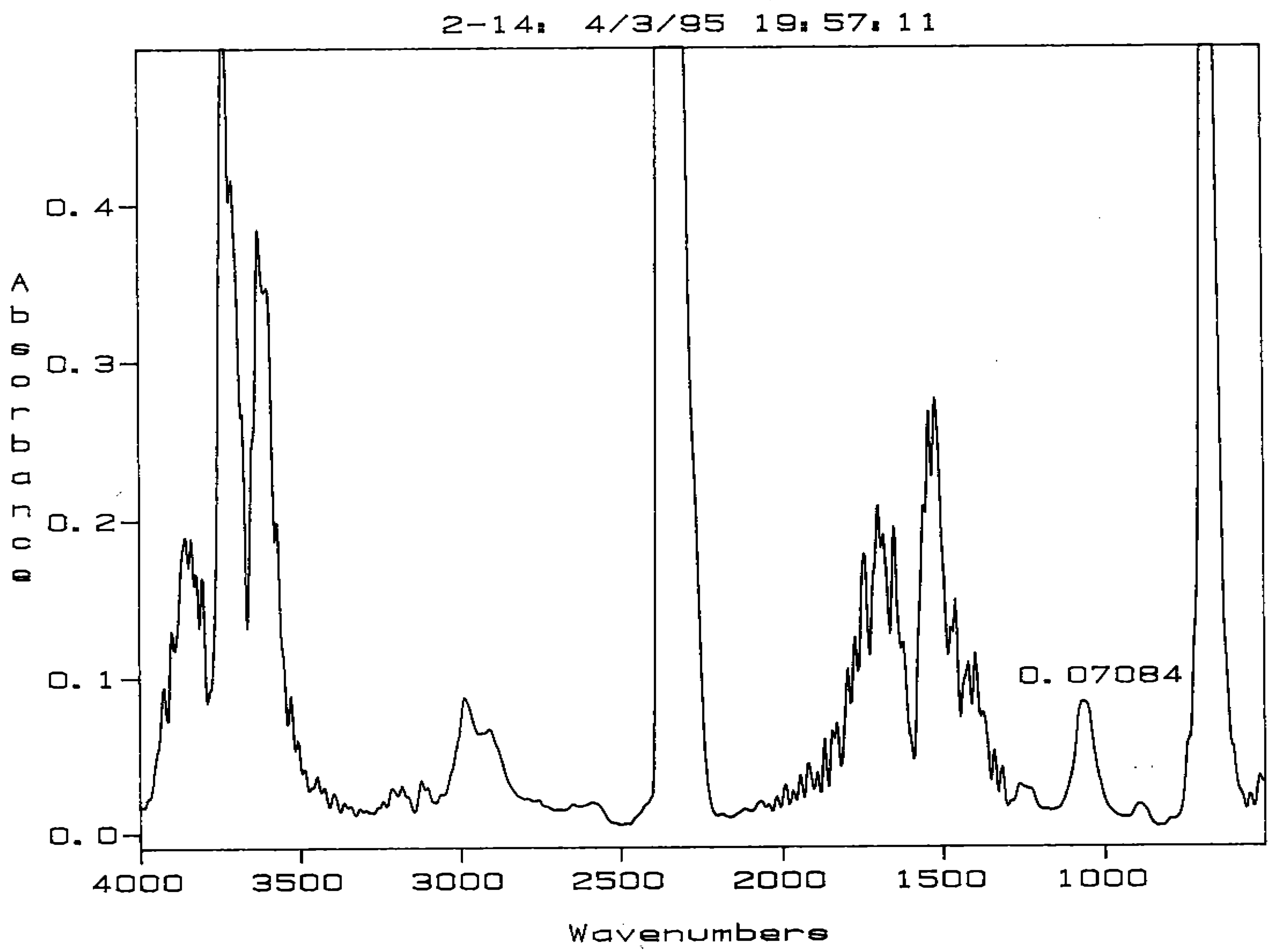
0.1
0.2
0.3
0.4
0.06878
4000
3500
3000
2500
2000
1500
1000
Wavenumbers


2-14: 4/3/95 19:57:11
0.07084
Absorbance
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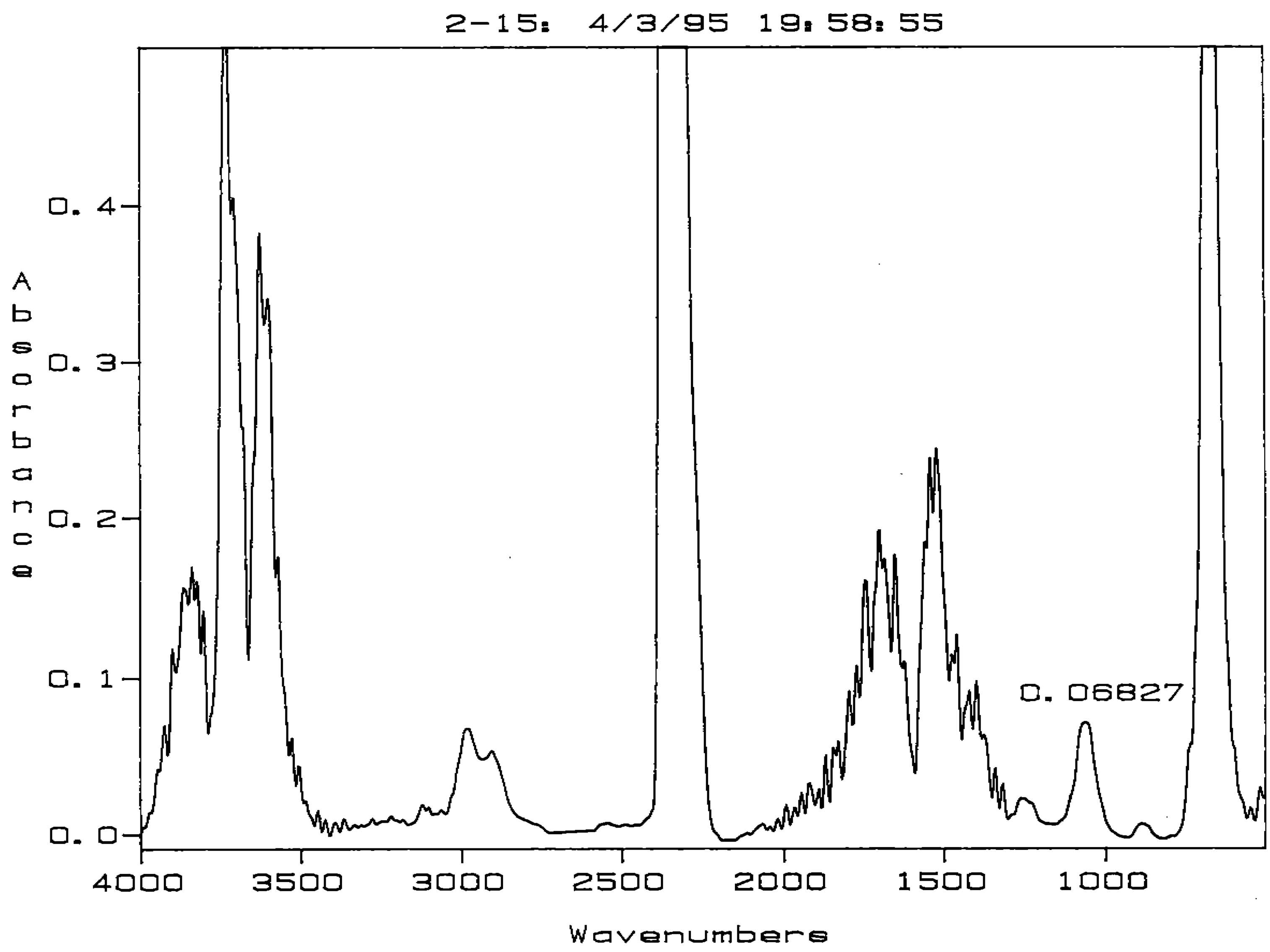
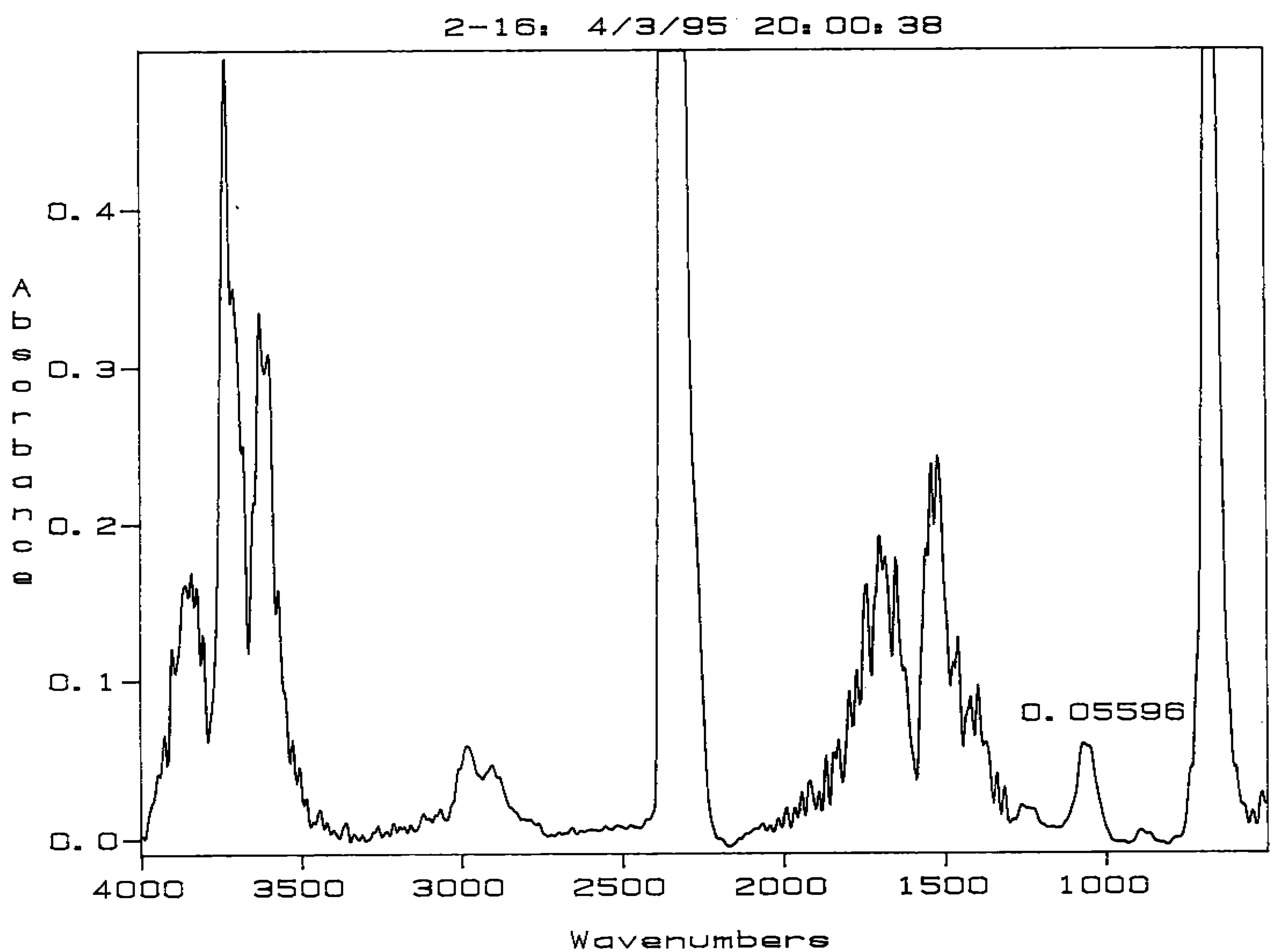
0.3
0.2
0.1
0.0
4000
3500
3000
2500
2000
1500
1000
Wavenumbers


2-15: 4/3/95 19:58:55
0.4
0.3
0.2
0.1
0.0
Absorbance
0.06827
4000
3500
3000
2500
2000
1500
1000
Wavenumbers



2-16: 4/3/95 20:00:38
Absorbance
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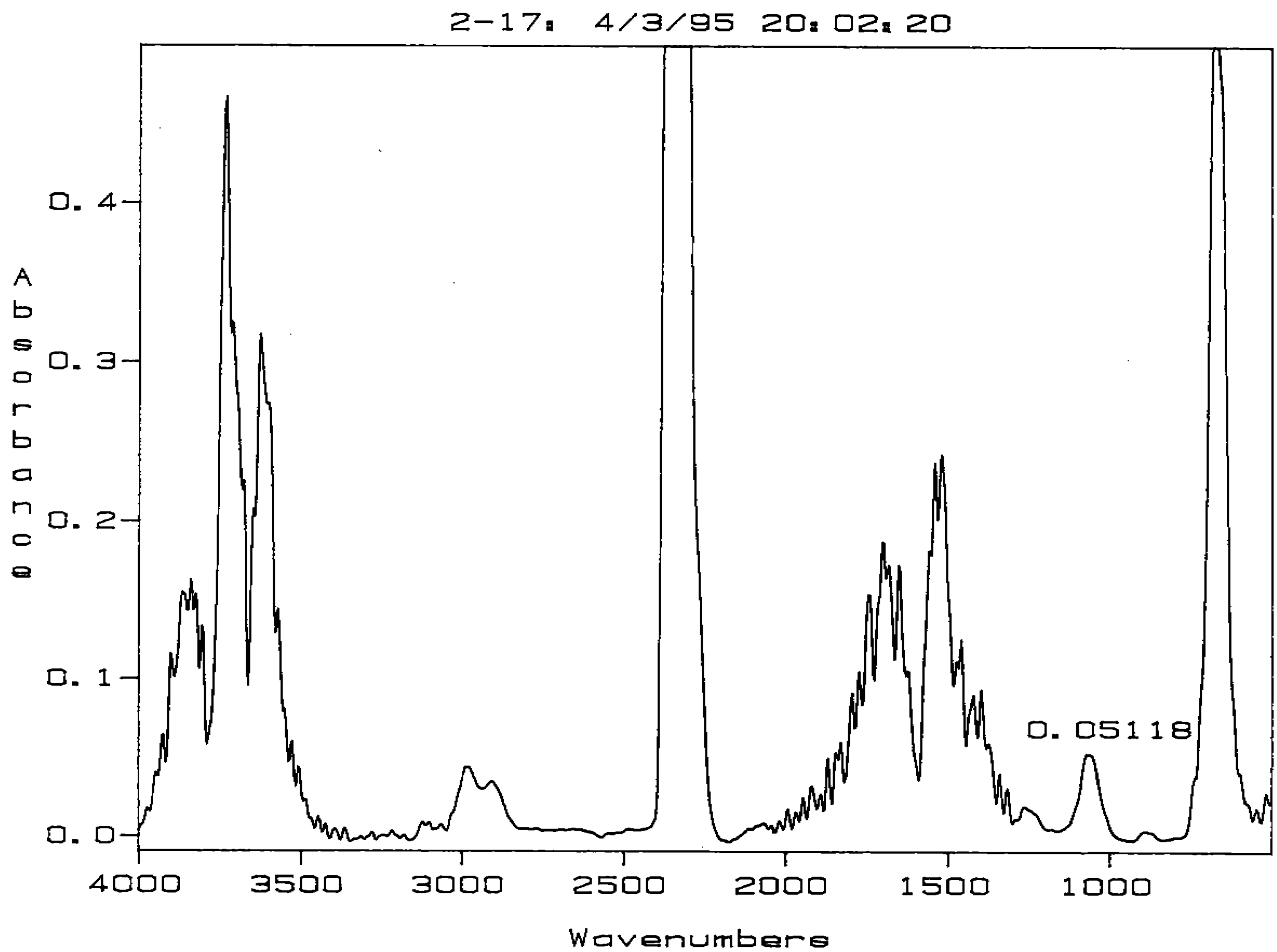
0.3
0.2
0.1
0.0
4000
3500
3000
2500
2000
1500
1000
Wavenumbers
0.05596


2-17: 4/3/95 20:02:20
Absorbance
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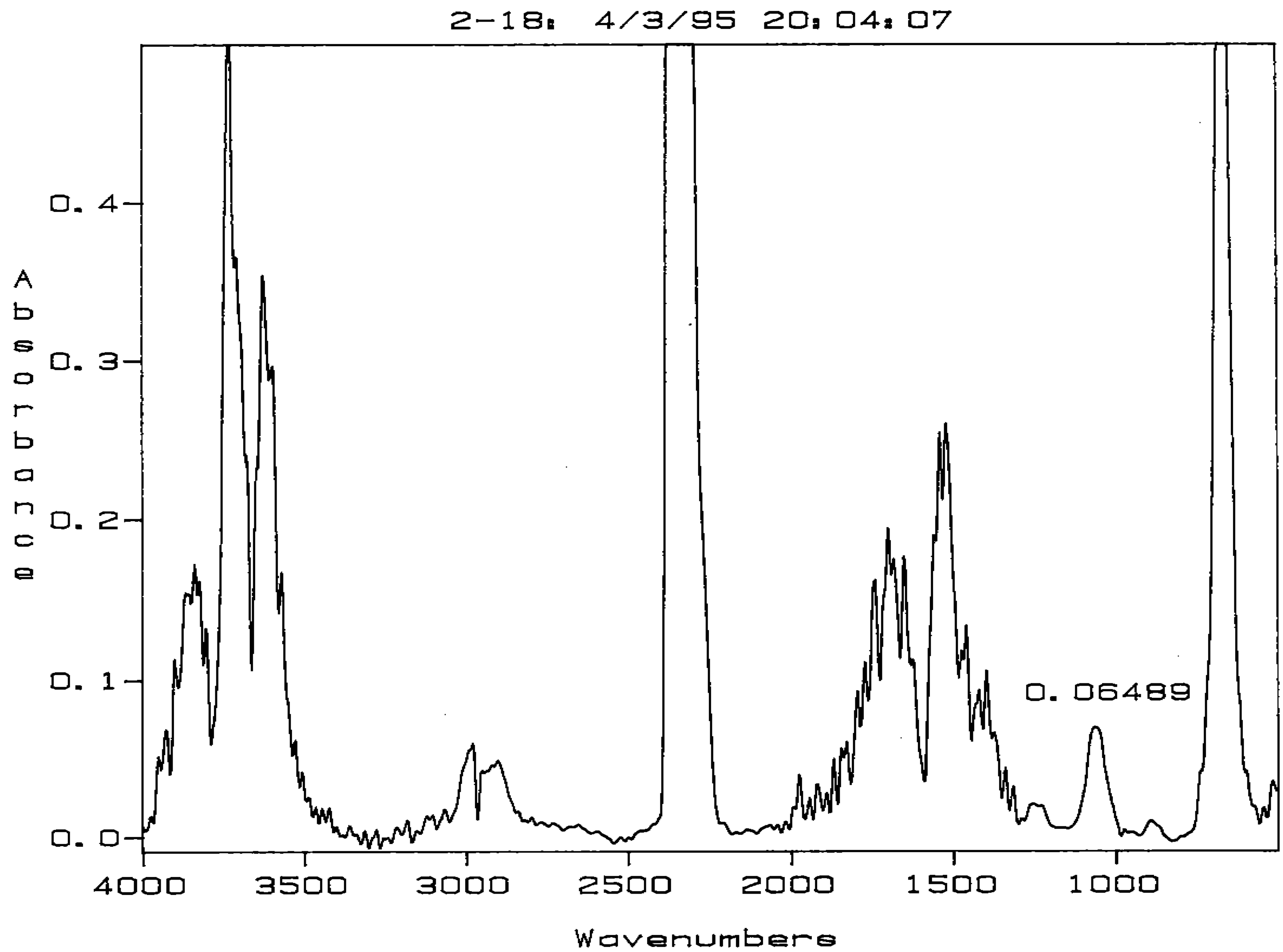
0.2
0.1
0.0
0.05118
4000
3500
3000
2500
2000
1500
1000
Wavenumbers


2-18: 4/3/95 20:04:07
Absorbance
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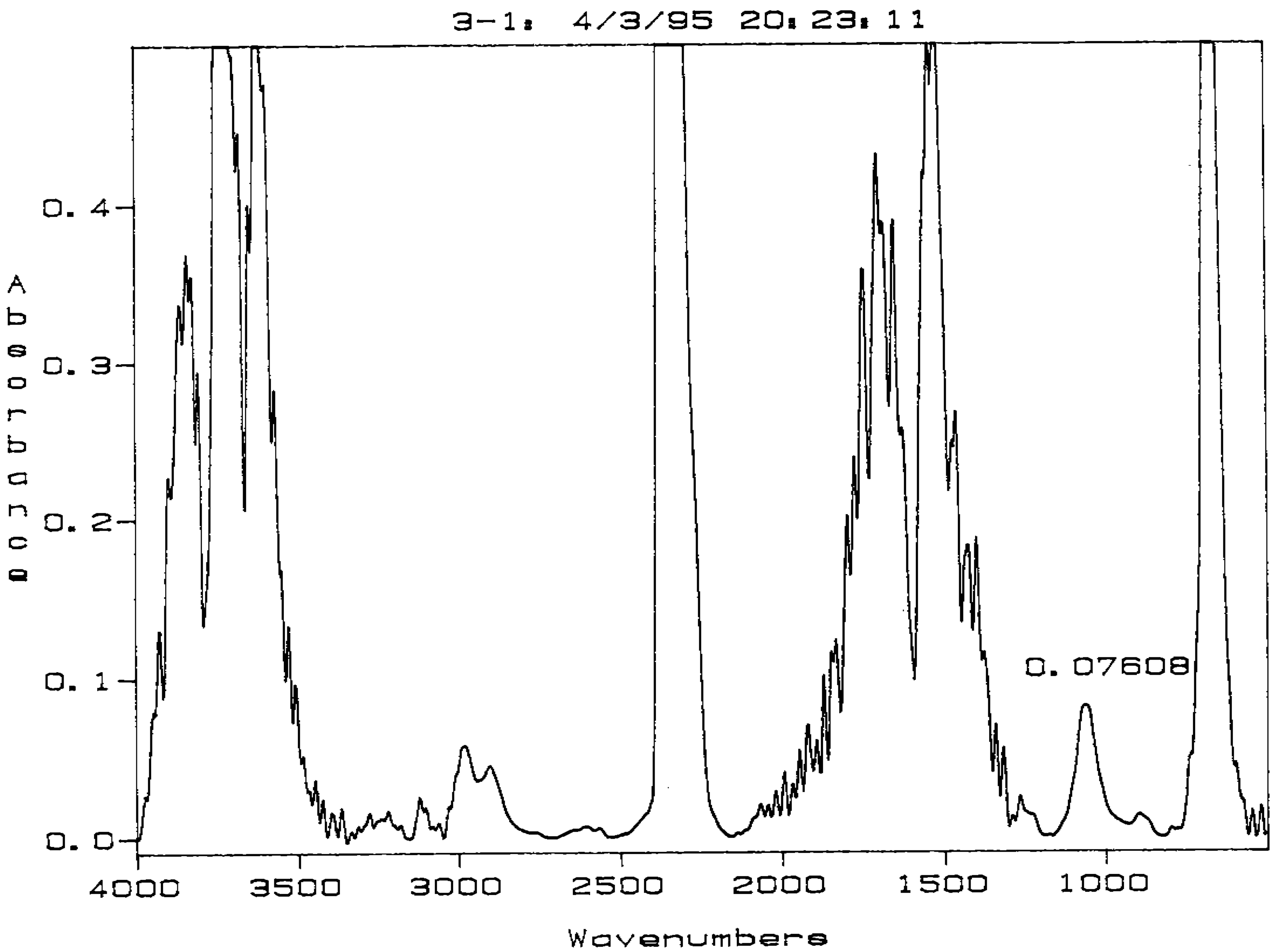
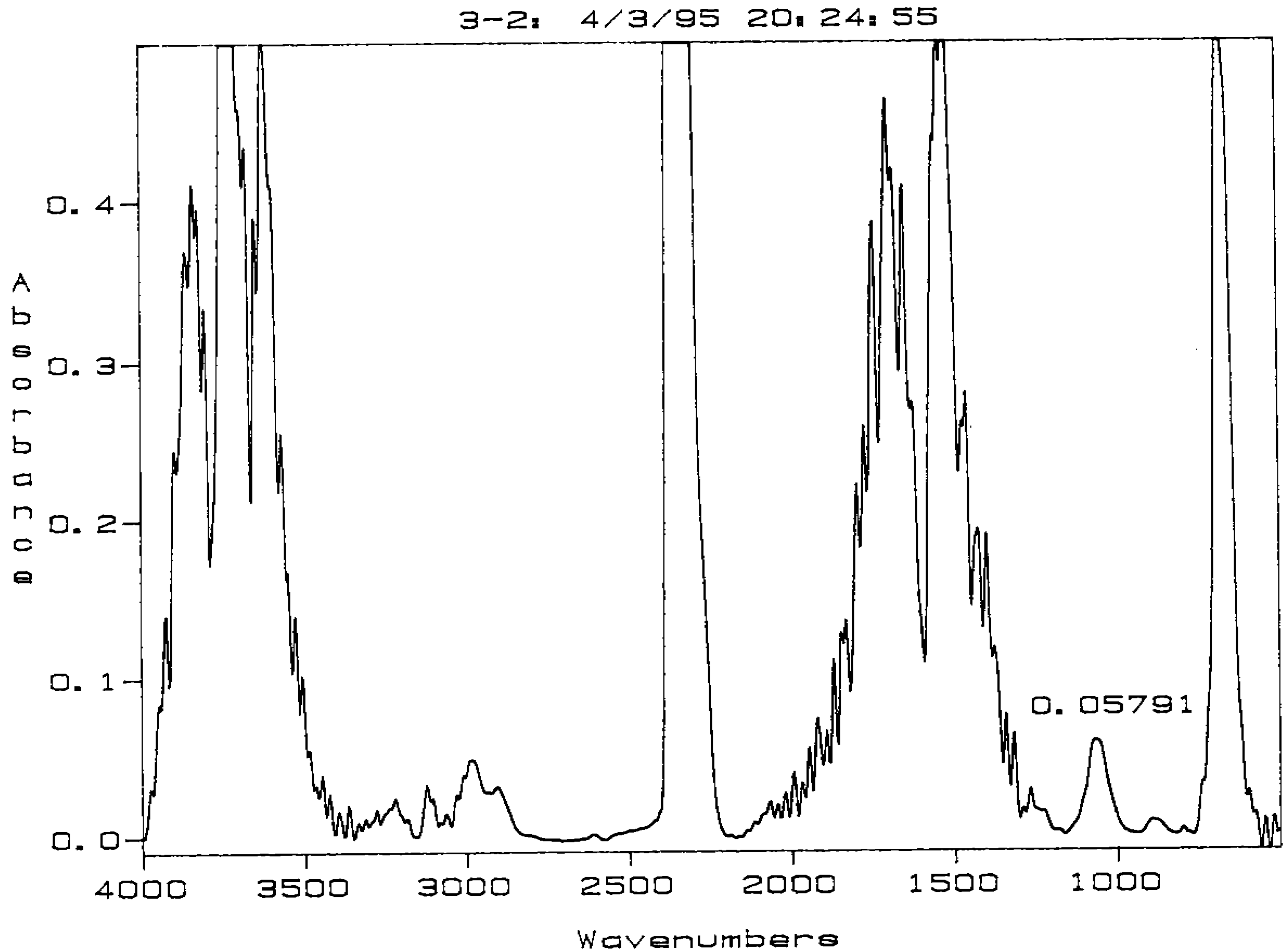
0.2
0.1
0.0
0.06489
4000
3500
3000
2500
2000
1500
1000
Wavenumbers


3-1: 4/3/95 20:23:11
0.07608
0.4
0.3
0.2
0.1
0.0
Absorbance
4000
3500
3000
2500
2000
1500
1000
Wavenumbers



3-2: 4/3/95 20: 24: 55
Absorbance
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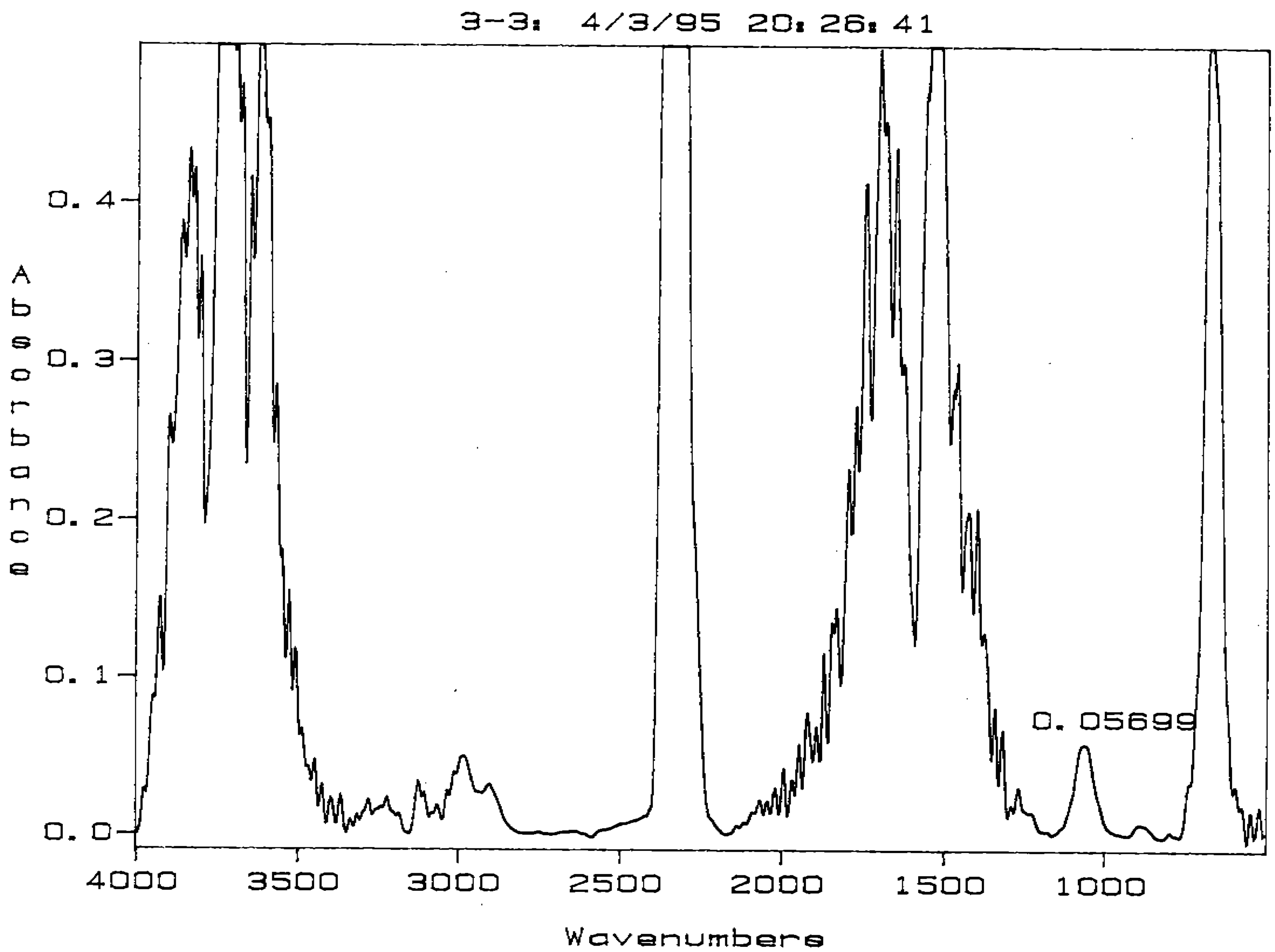
0.2
0.1
0.0
0.05791
4000
3500
3000
2500
2000
1500
1000
Wavenumbers


3-3: 4/3/95 20:26:41
Absorbance
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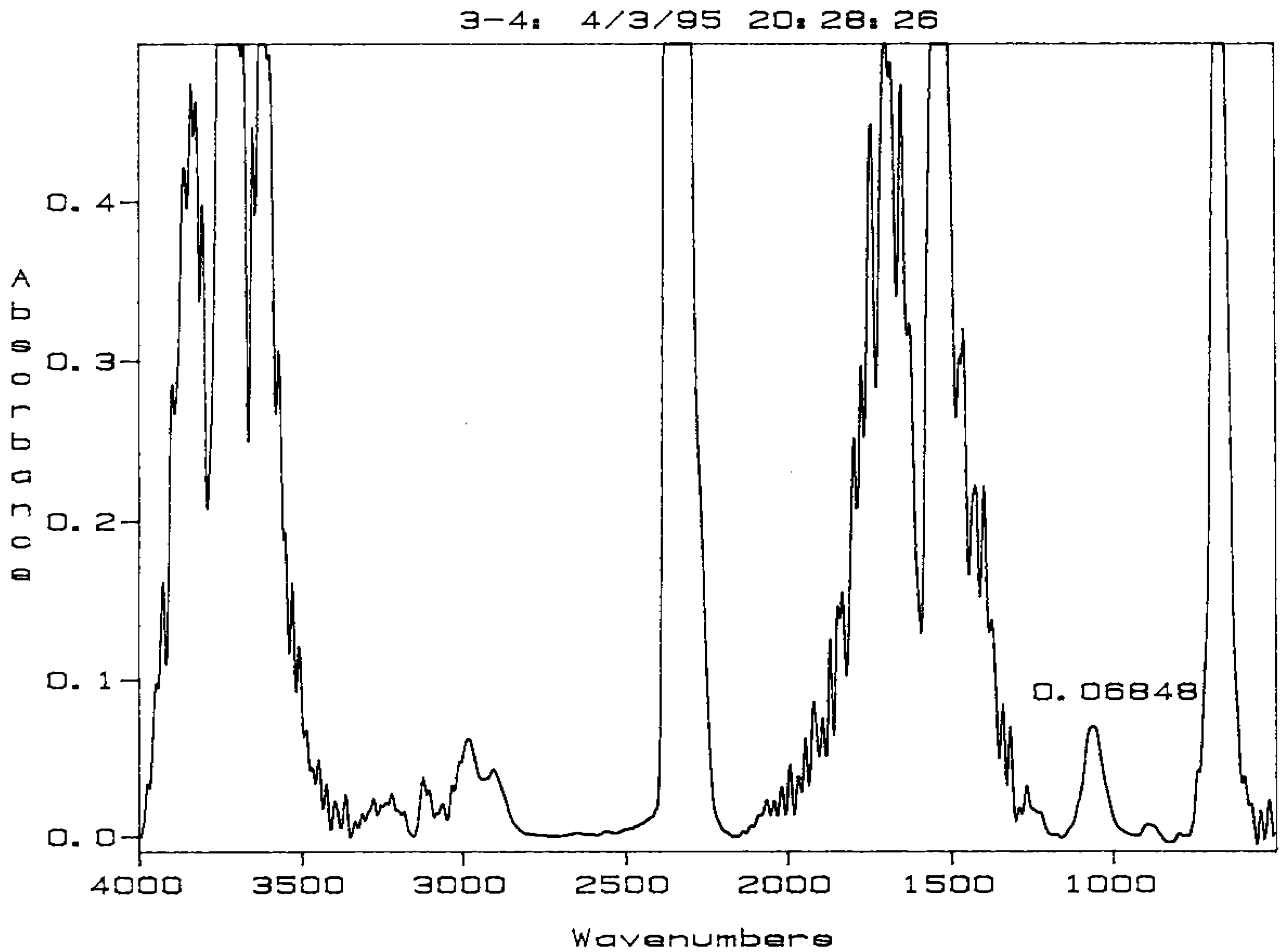
0.2
0.1
0.0
0.05699
4000
3500
3000
2500
2000
1500
1000
Wavenumbers


3-4: 4/3/95 20:28:26
Absorbance
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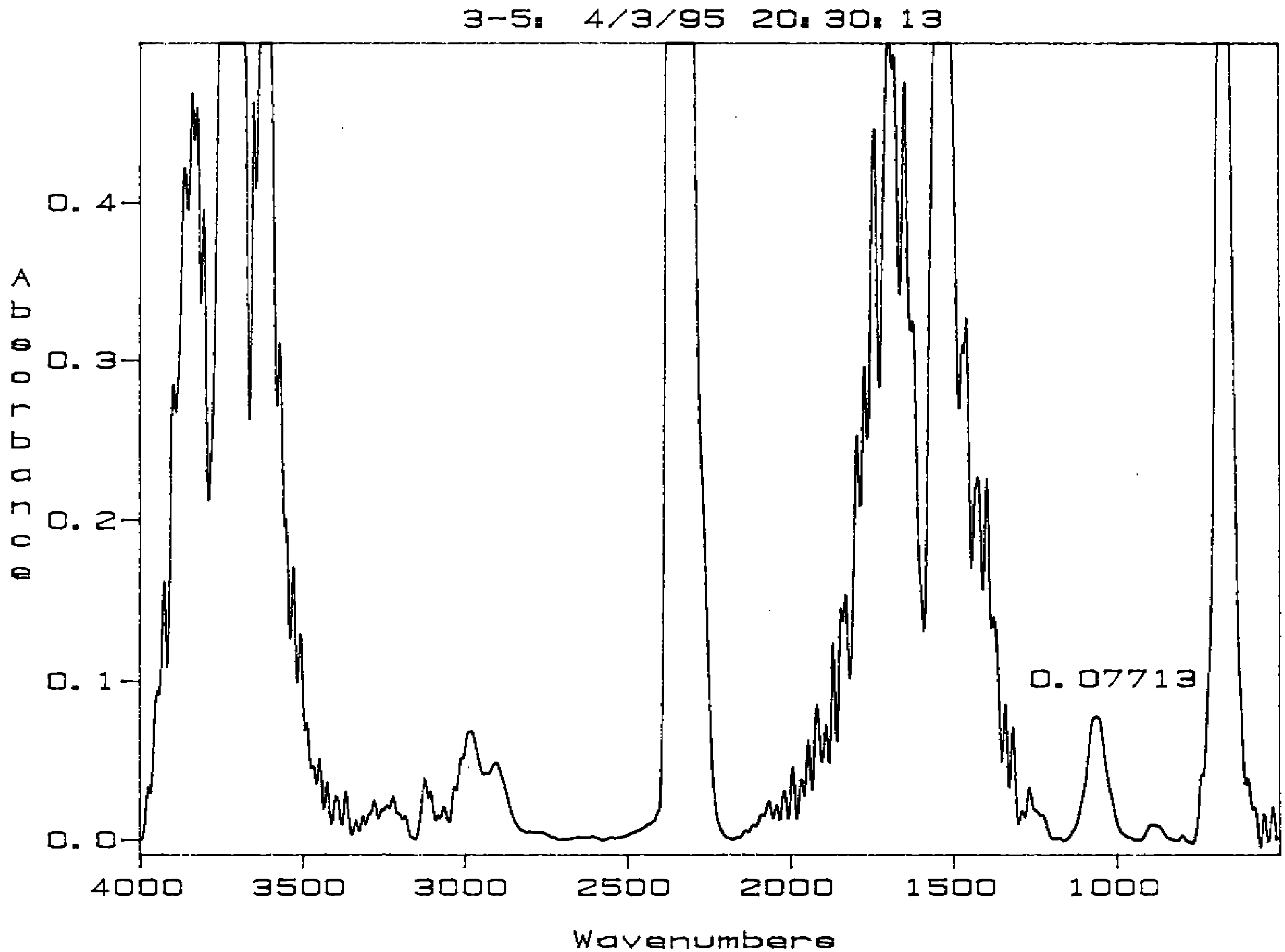
0.2
0.1
0.0
0.06848
4000
3500
3000
2500
2000
1500
1000
Wavenumbers


3-5: 4/3/95 20:30:13
0.07713
Absorbance
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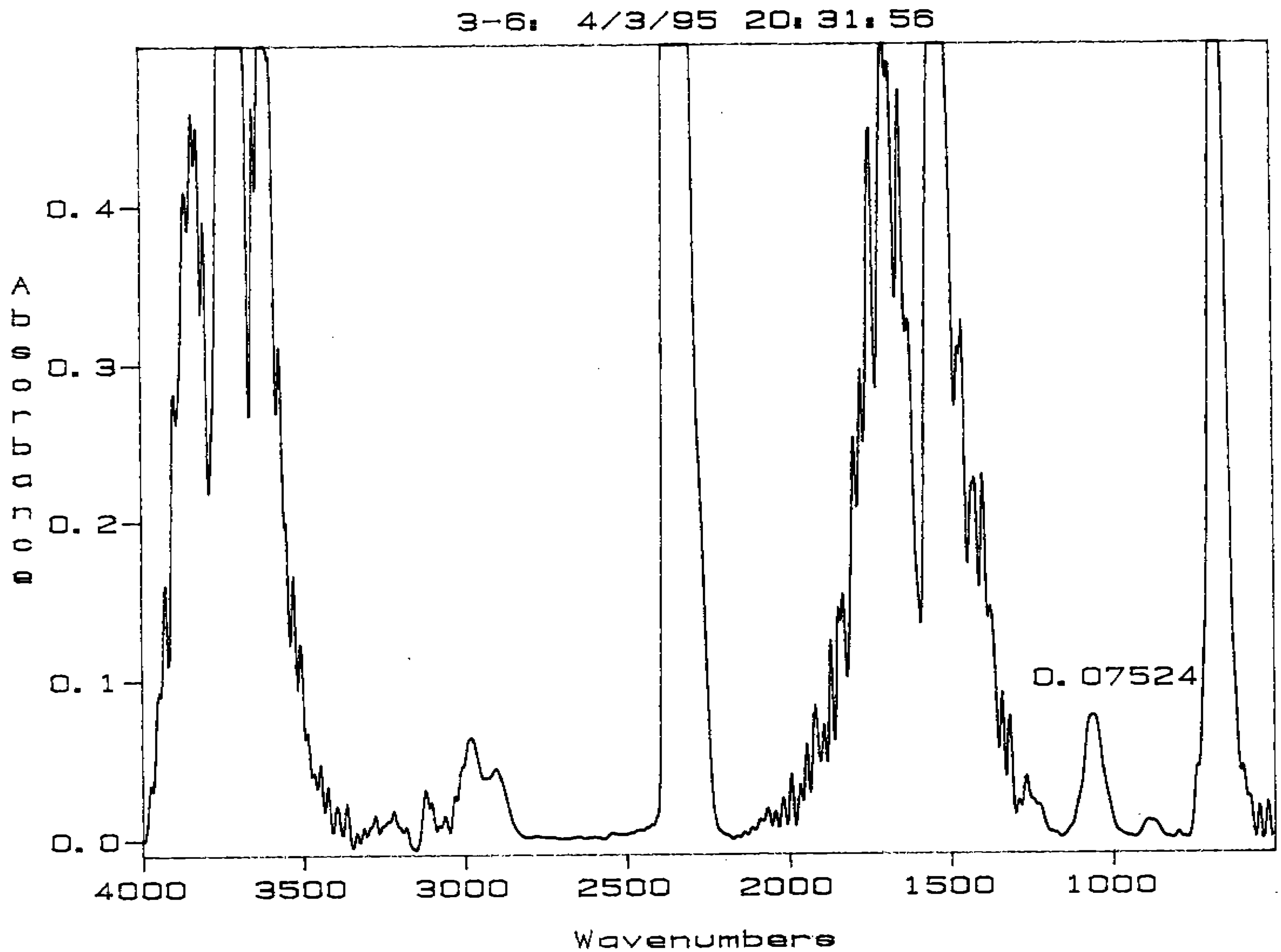
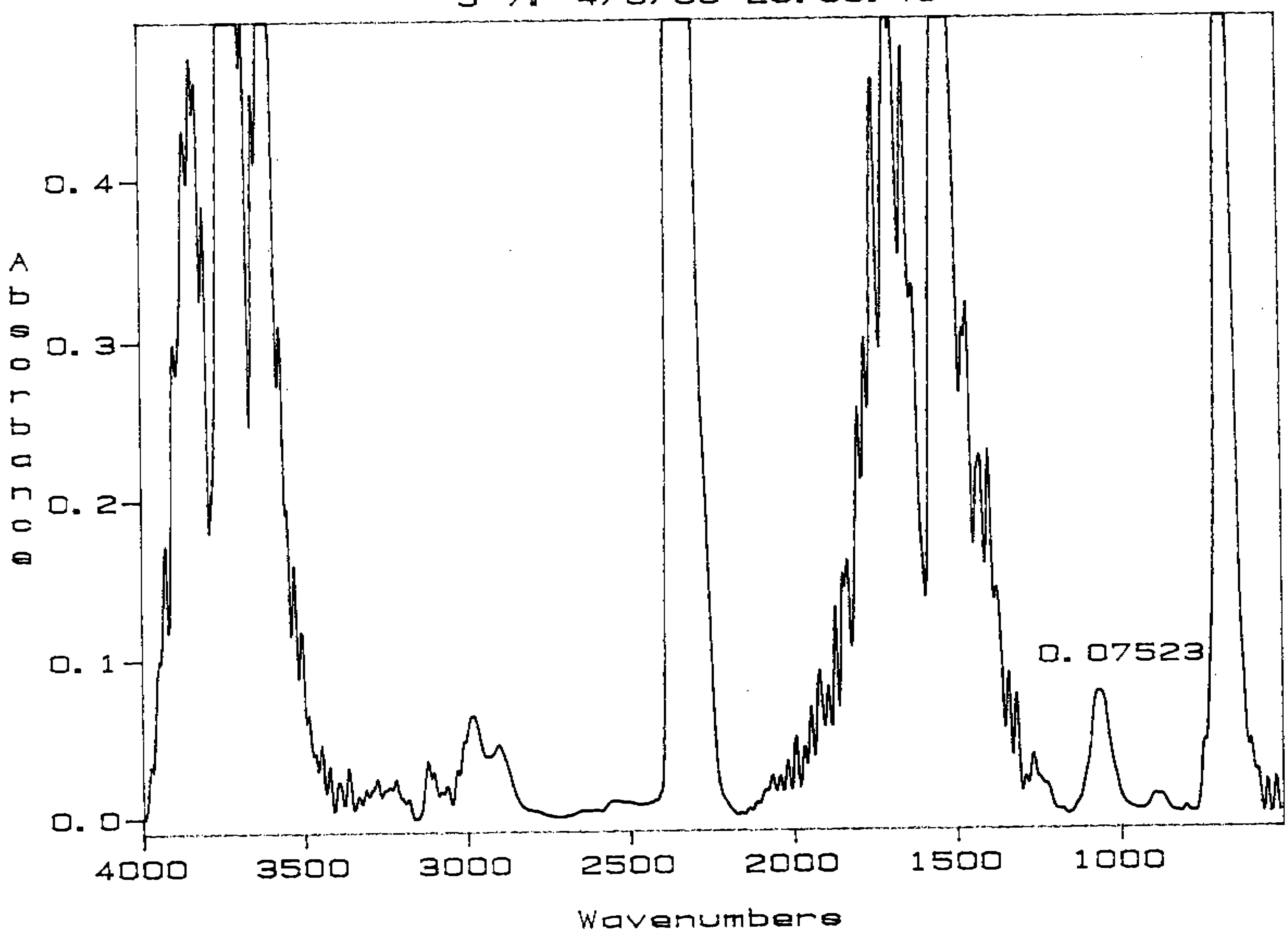
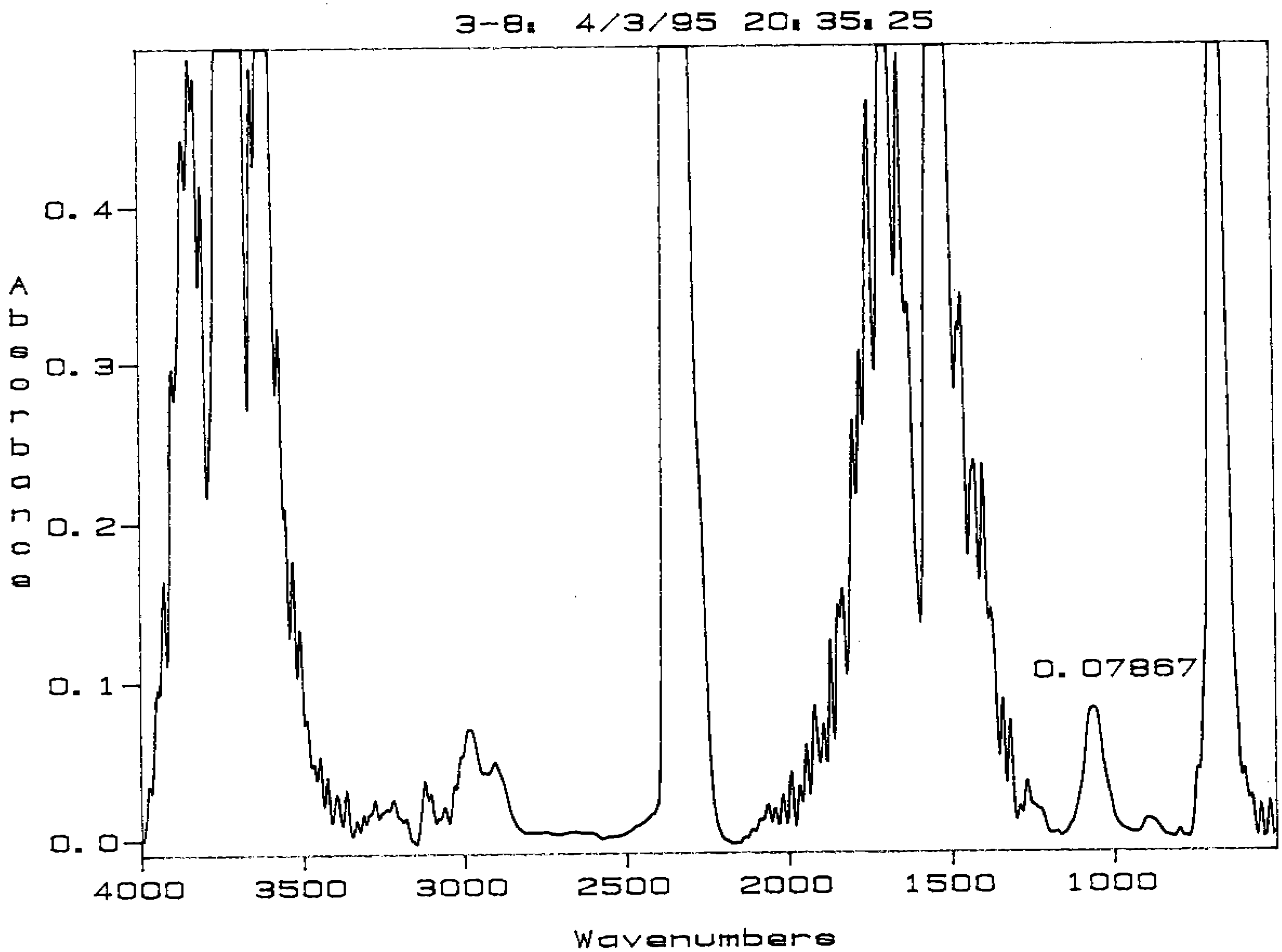
0.3
0.2
0.1
0.0
4000
3500
3000
2500
2000
1500
1000
Wavenumbers



3-6: 4/3/95 20:31:56
Absorbance
0.4
0.3
0.2
0.1
0.0
0.07524
4000
3500
3000
2500
2000
1500
1000
Wavenumbers

3-7: 4/3/95 20:33:40




3-8: 4/3/95 20:35:25
Absorbance
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0.2
0.3
0.4
0.07867
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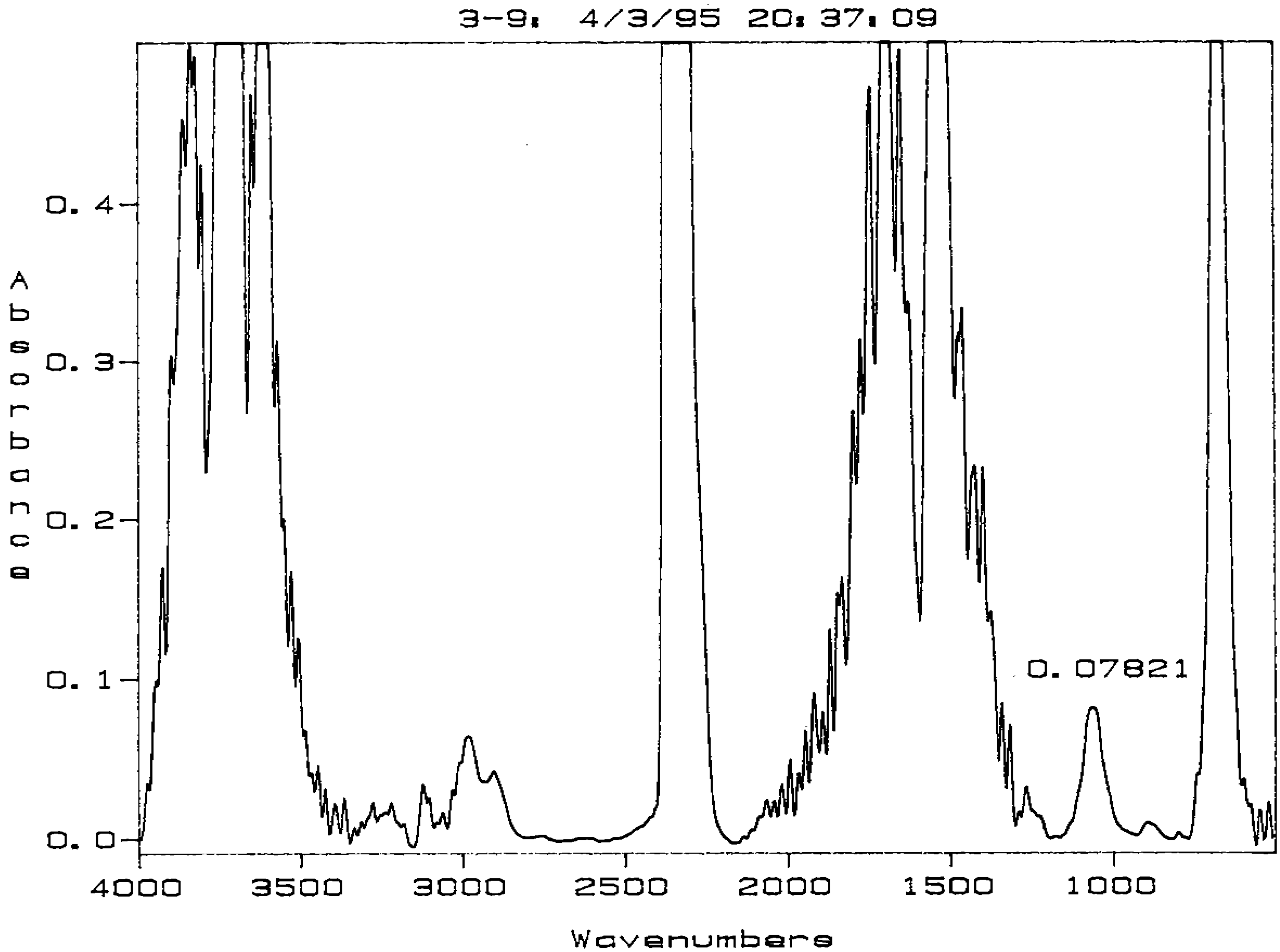
3500
3000
2500
2000
1500
1000
Wavenumbers


3-9: 4/3/95 20:37:09
Absorbance
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0.1
0.0
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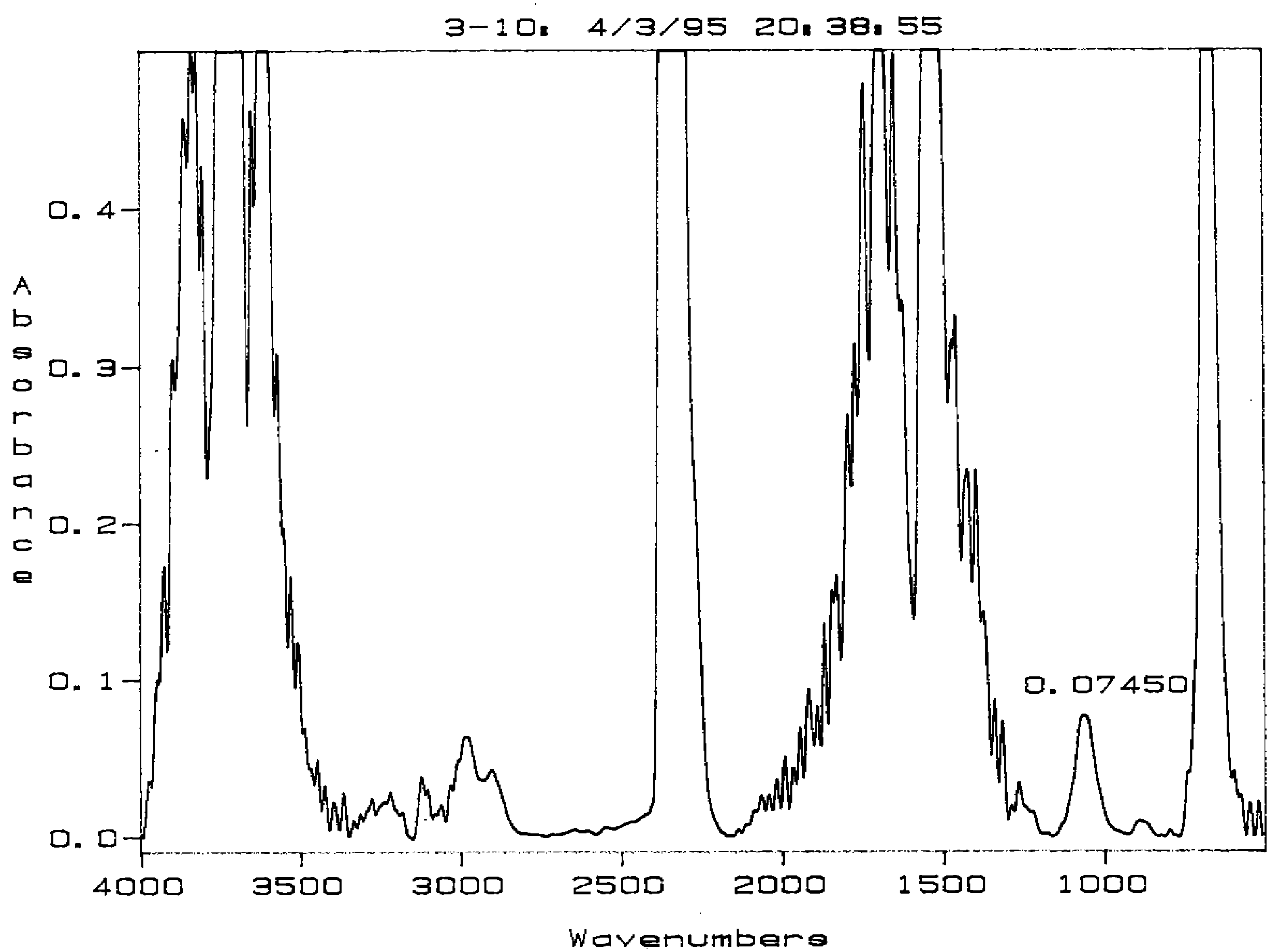
3500
3000
2500
2000
1500
1000
Wavenumbers
0.07821


3-10: 4/3/95 20:38:55
Absorbance
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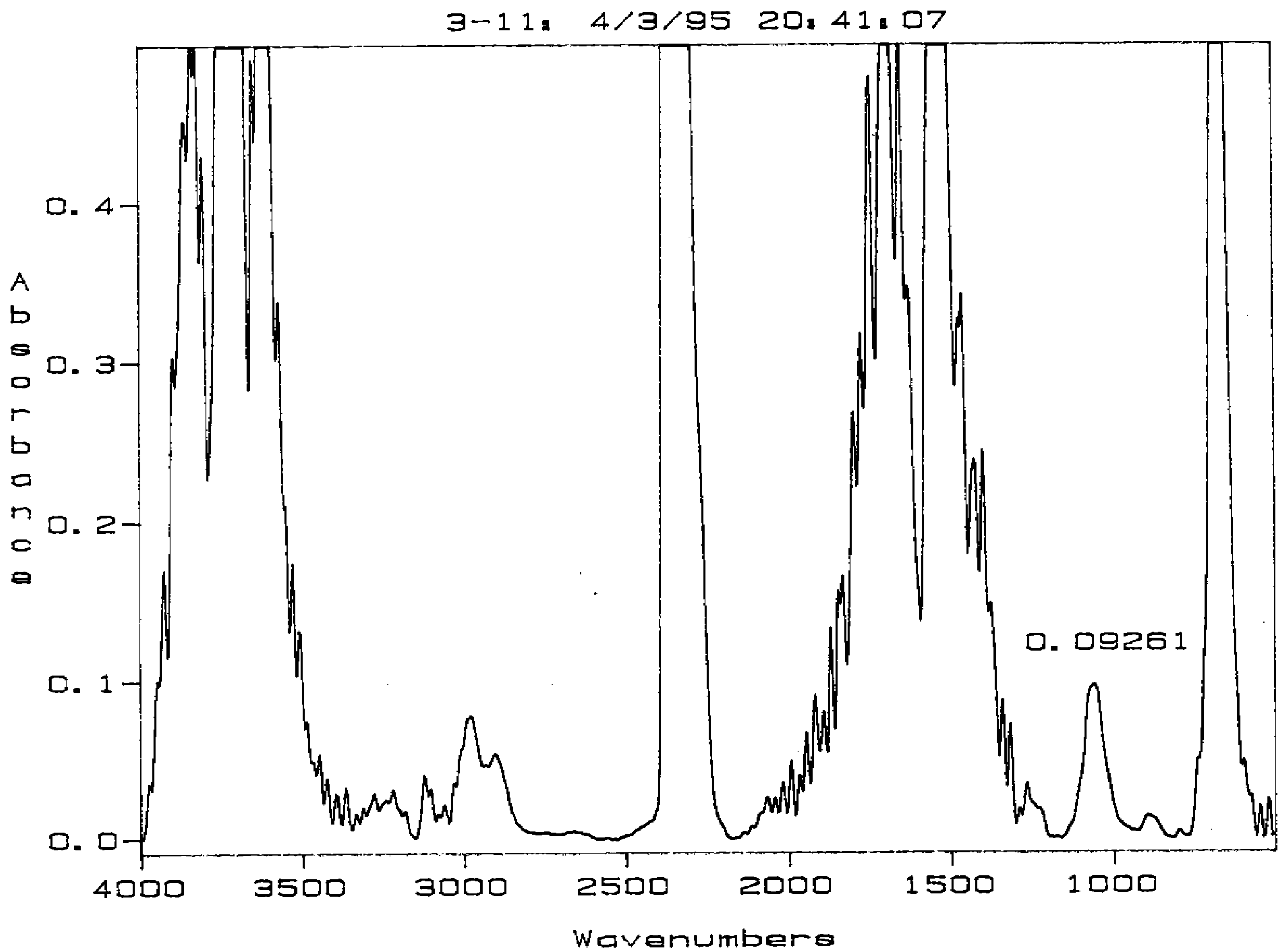
0.2
0.1
0.0
0.07450
4000
3500
3000
2500
2000
1500
1000
Wavenumbers


3-11: 4/3/95 20:41:07
0.09261
Absorbance
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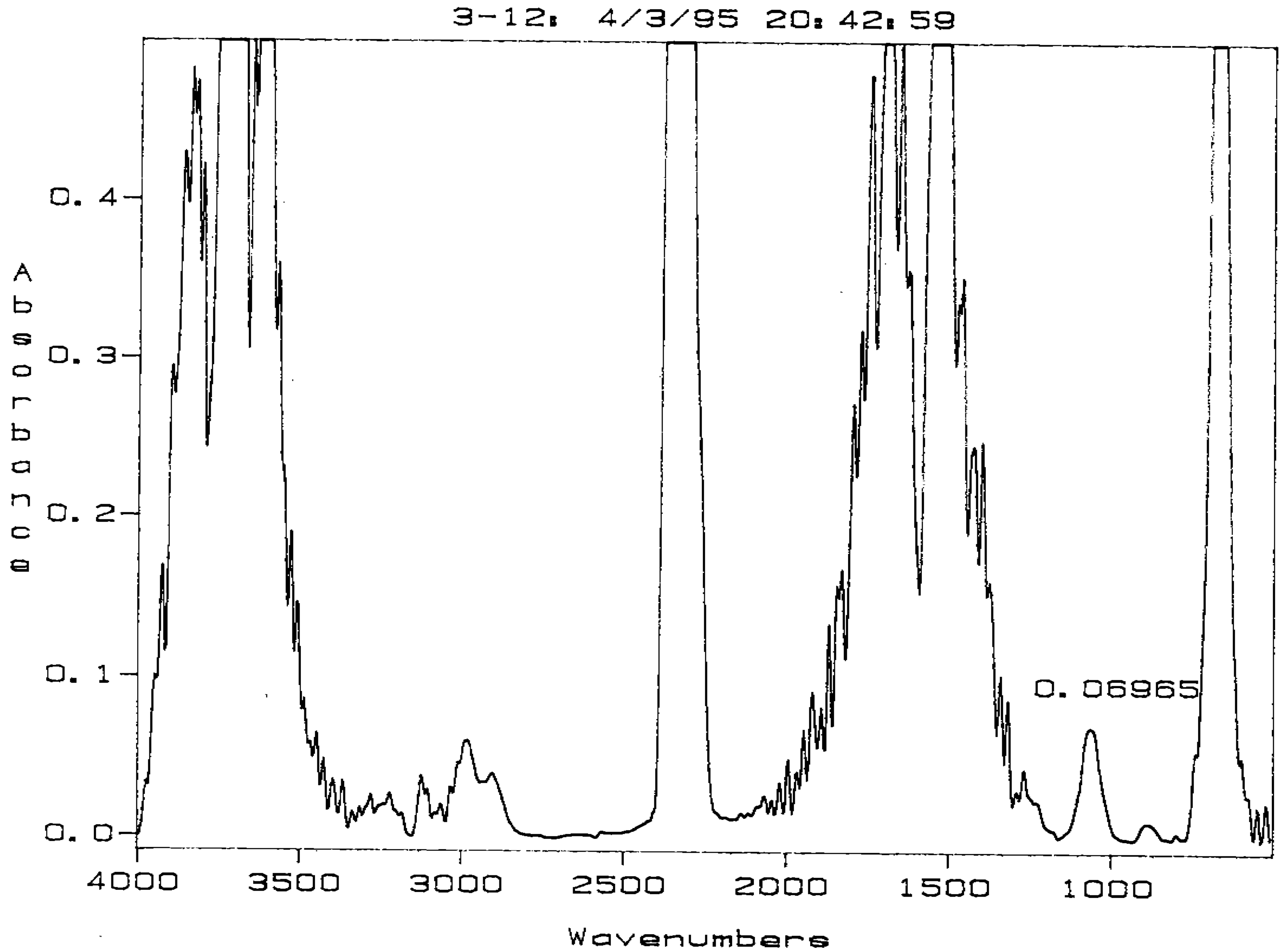
0.1
0.2
0.3
0.4
4000
3500
3000
2500
2000
1500
1000
Wavenumbers



3-12: 4/3/95 20:42:59
Absorbance
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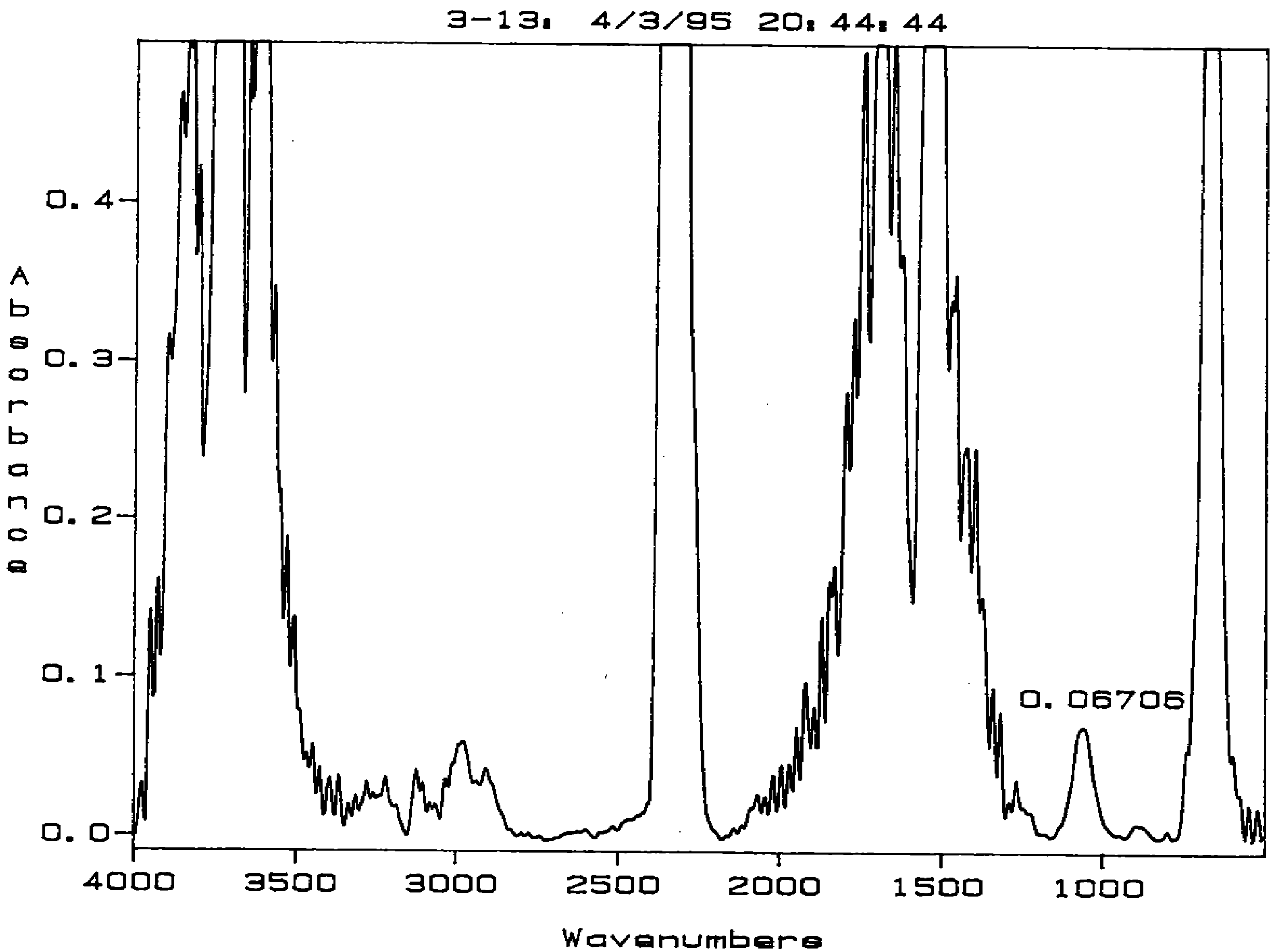
0.2
0.1
0.0
4000
3500
3000
2500
2000
1500
1000
Wavenumbers
0.06965


3-13: 4/3/95 20: 44: 44
Absorbance
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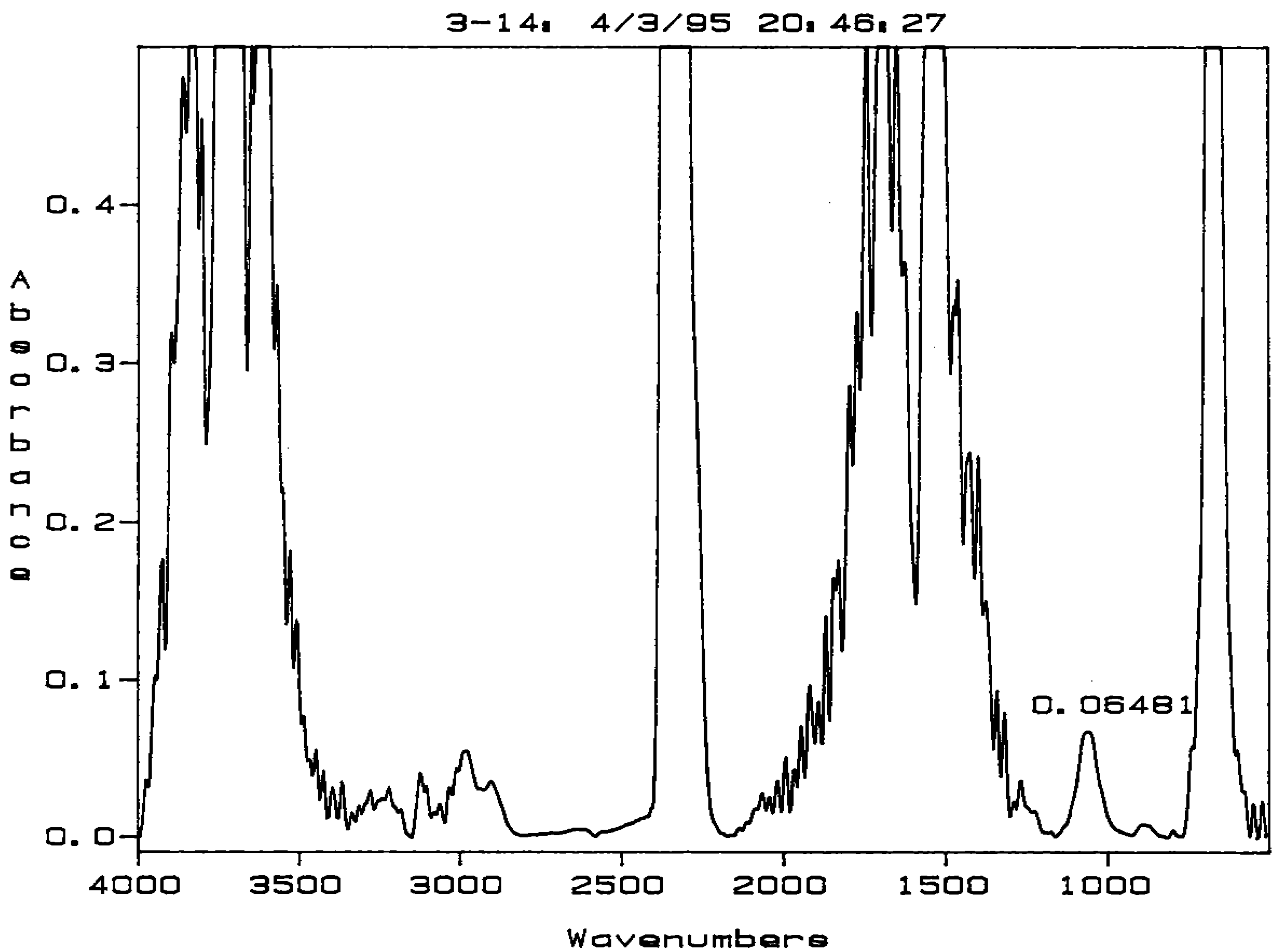
0.2
0.1
0.0
4000
3500
3000
2500
2000
1500
1000
Wavenumbers
0.06706



3-14: 4/3/95 20:46:27
Absorbance
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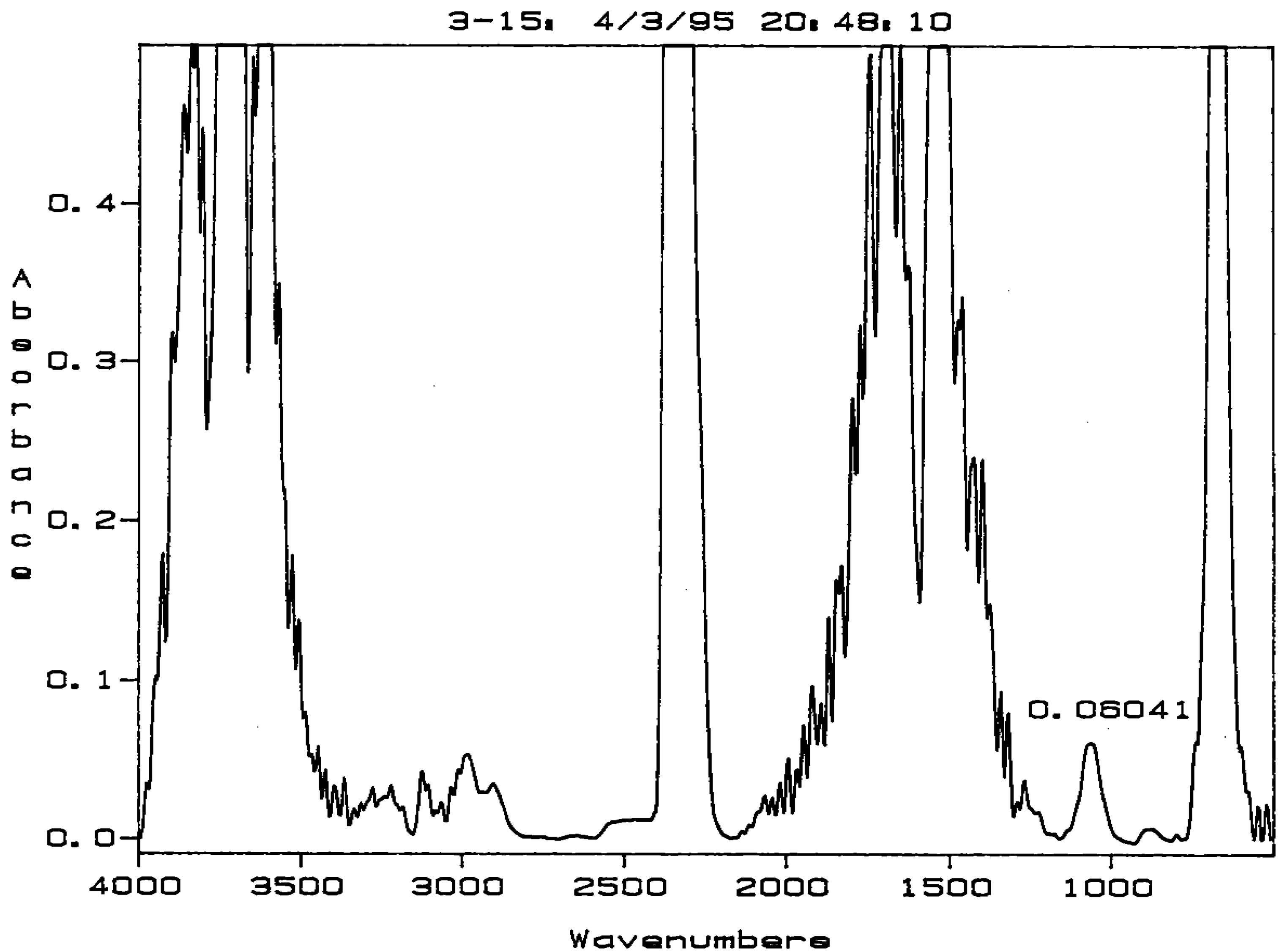
0.2
0.1
0.0
0.06481
4000
3500
3000
2500
2000
1500
1000
Wavenumbers



3-15: 4/3/95 20:48:10
Absorbance
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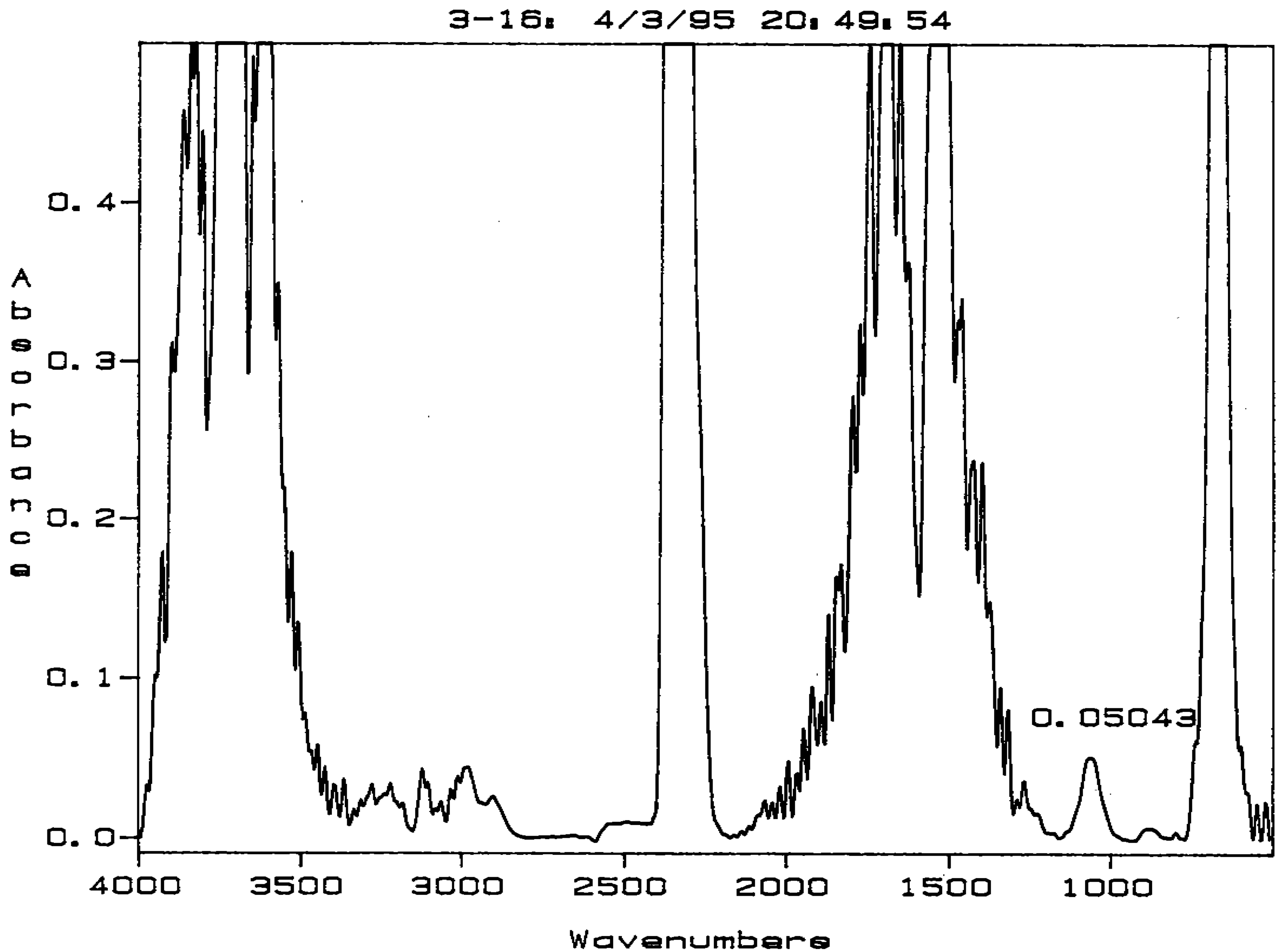
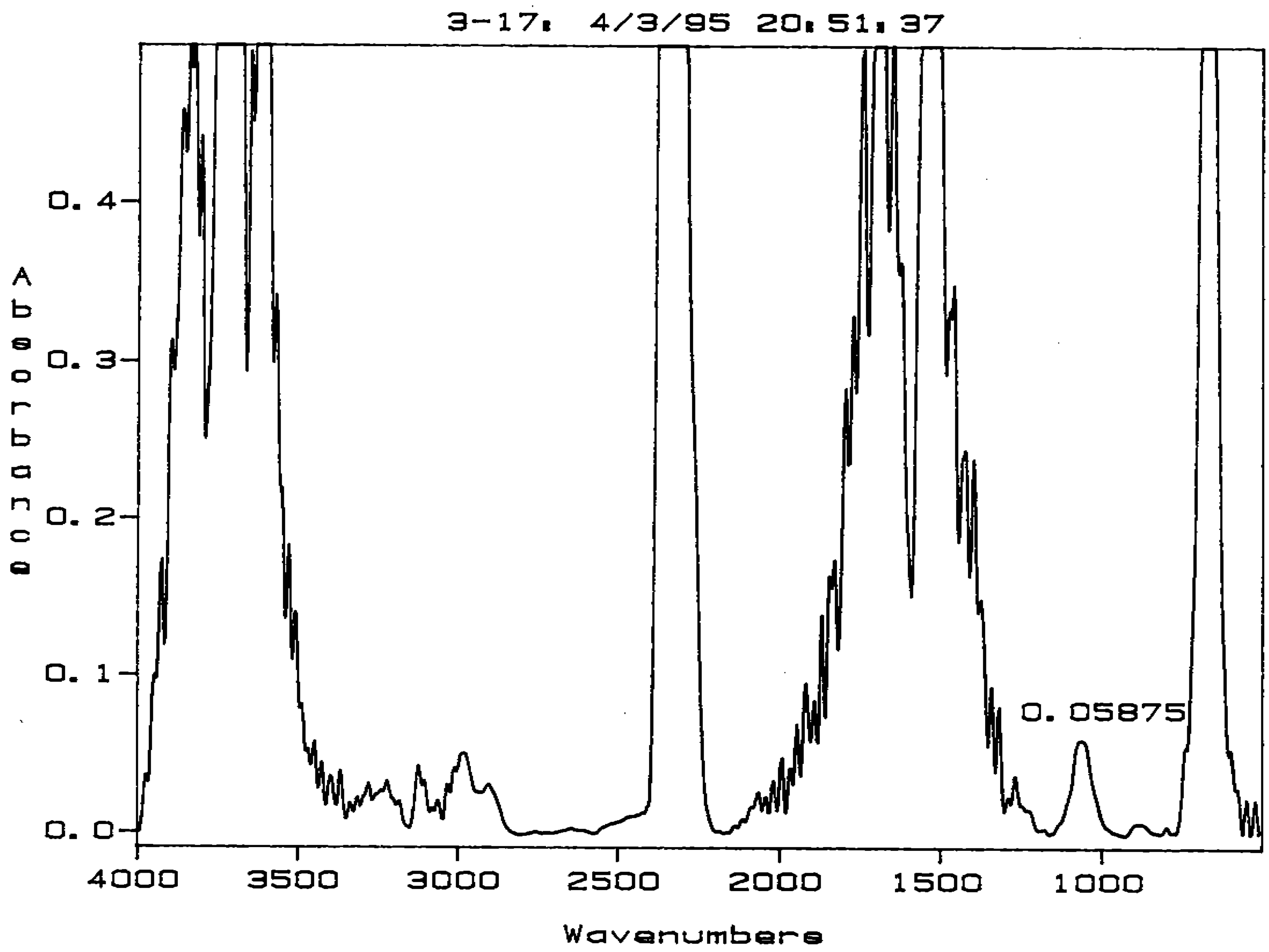
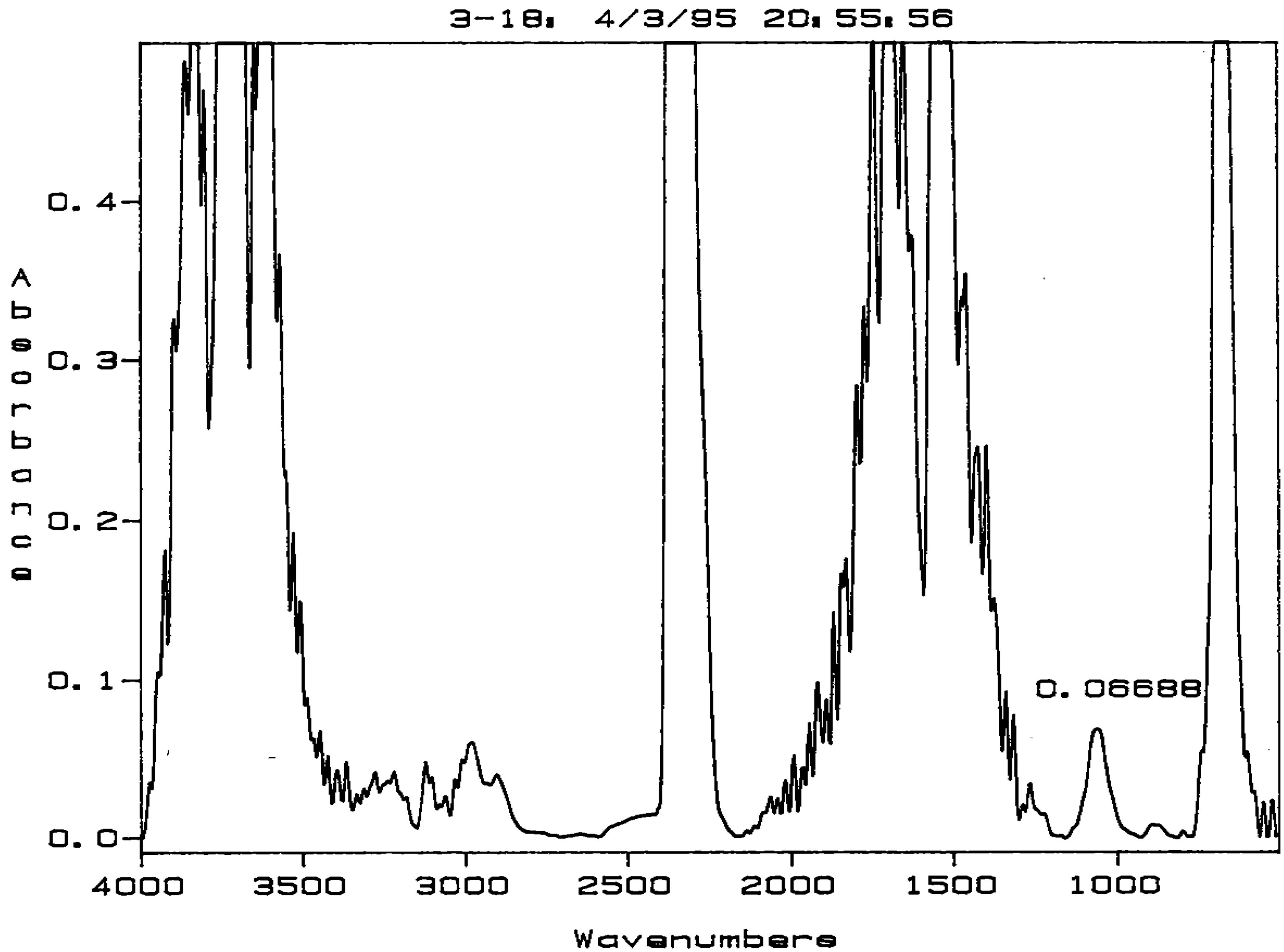
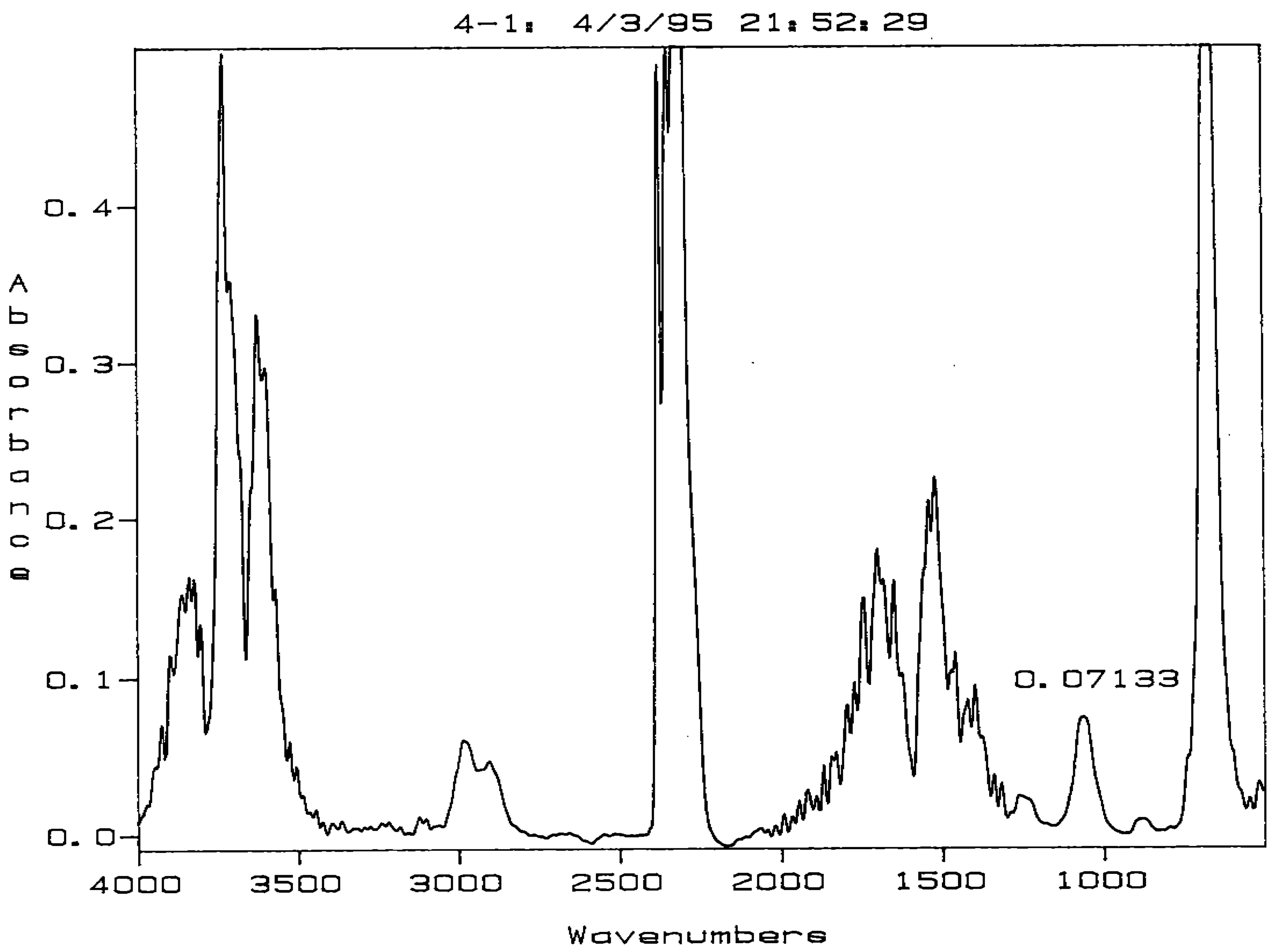
0.3
0.2
0.1
0.0
0.06041
4000
3500
3000
2500
2000
1500
1000
Wavenumbers



3-16: 4/3/95 20:49:54
0.4
0.3
0.2
0.1
0.0
Absorbance
0.05043
4000
3500
3000
2500
2000
1500
1000
Wavenumbers


3-17: 4/3/95 20:51:37
Absorbance
0.4
0.3
0.2
0.1
0.0
0.05875
4000
3500
3000
2500
2000
1500
1000
Wavenumbers


3-18: 4/3/95 20:55:56
Absorbance
0.4
0.3
0.2
0.1
0.0
0.06688
4000
3500
3000
2500
2000
1500
1000
Wavenumbers


4-1: 4/3/95 21:52:29
Absorbance
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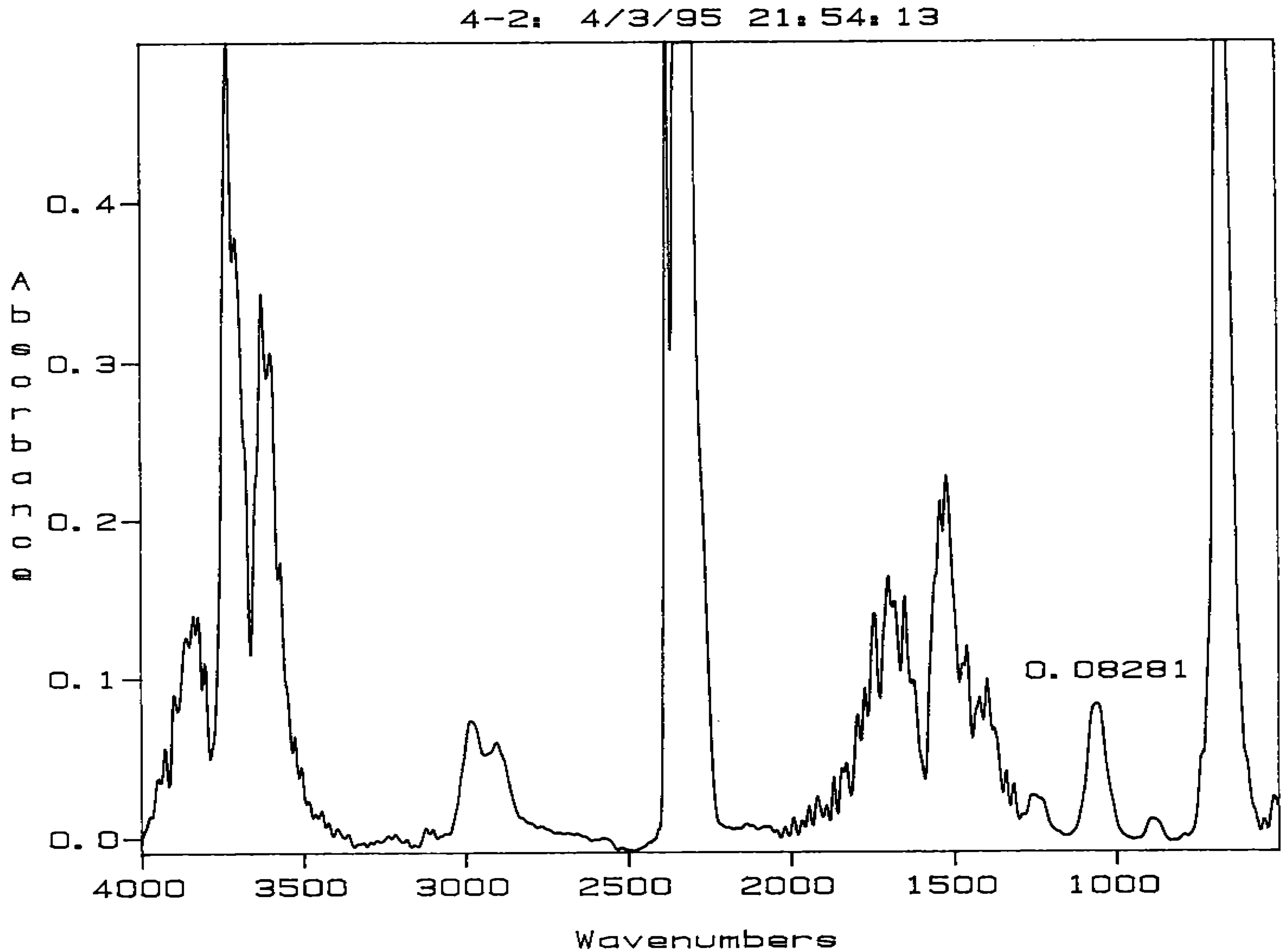
0.3
0.2
0.1
0.0
4000
3500
3000
2500
2000
1500
1000
Wavenumbers
0.07133


4-2: 4/3/95 21:54:13
Absorbance
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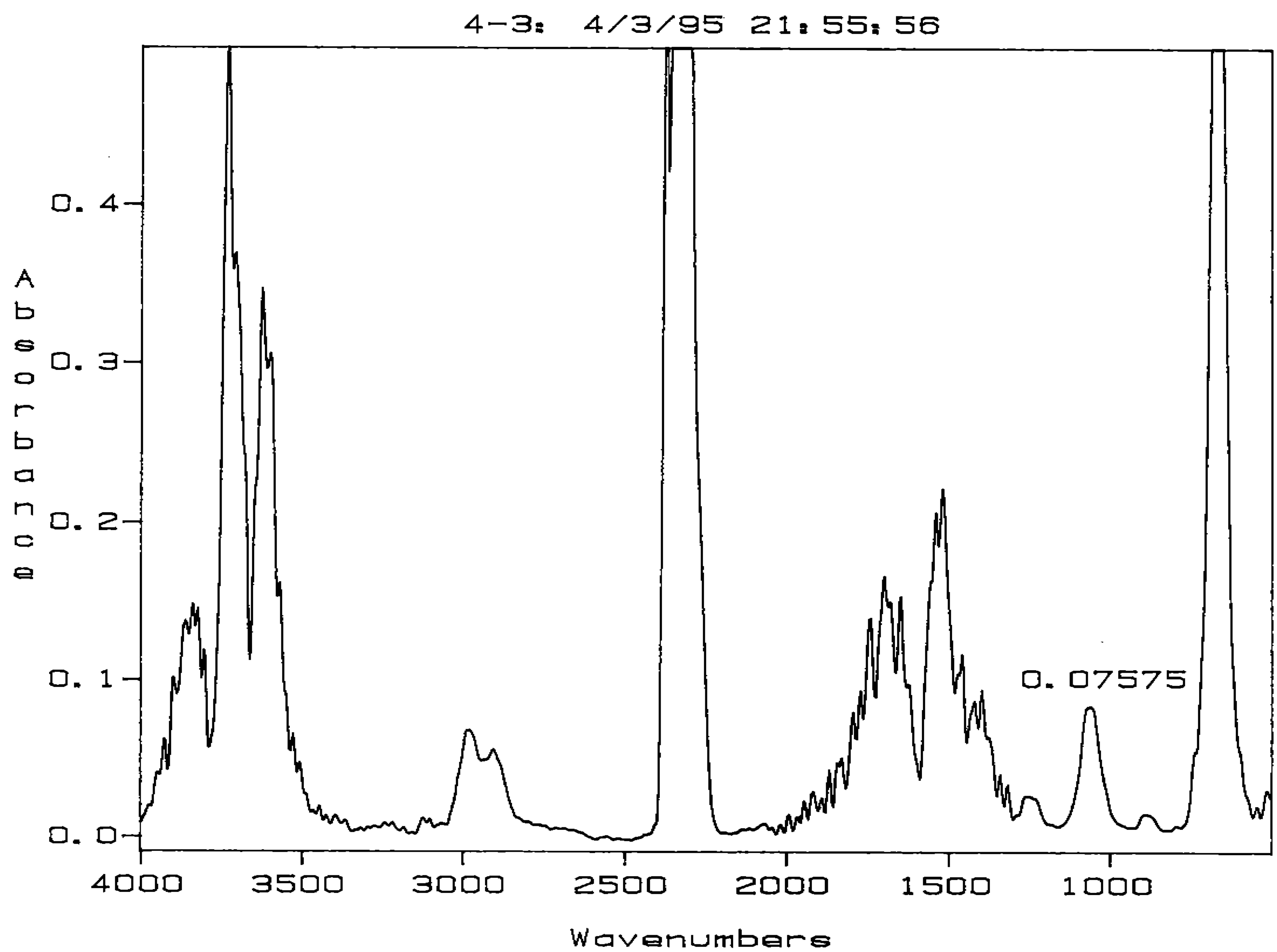
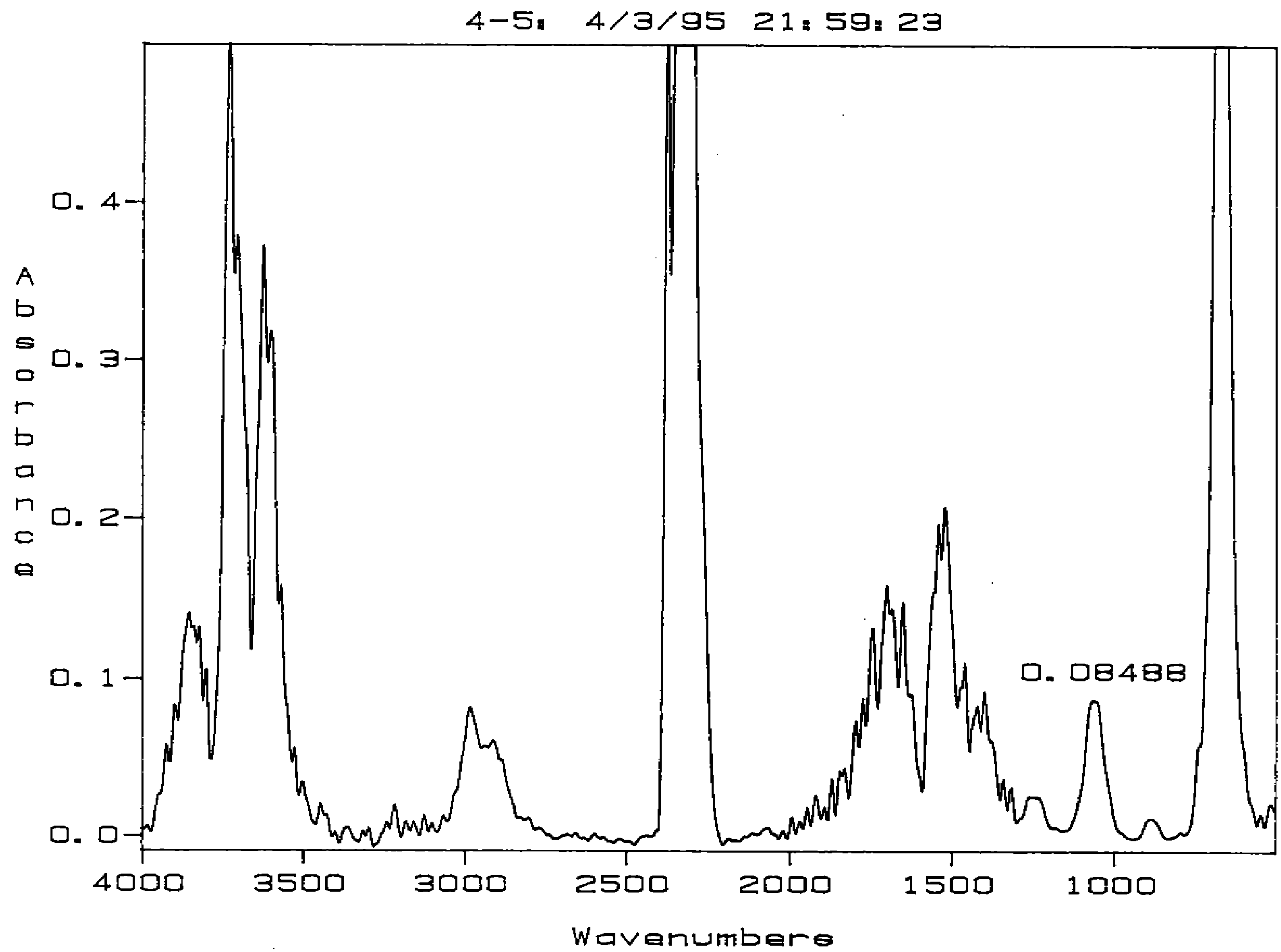
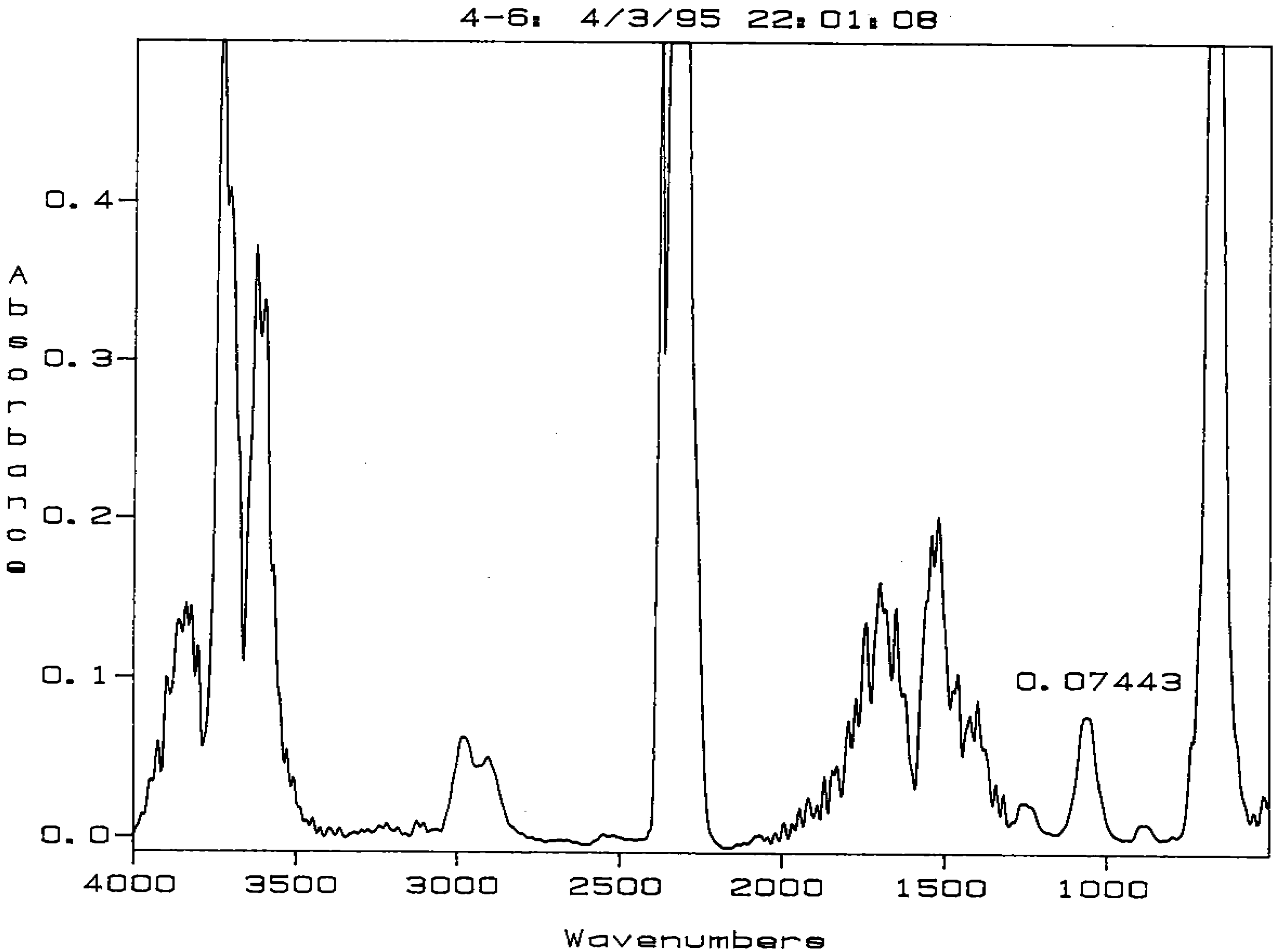
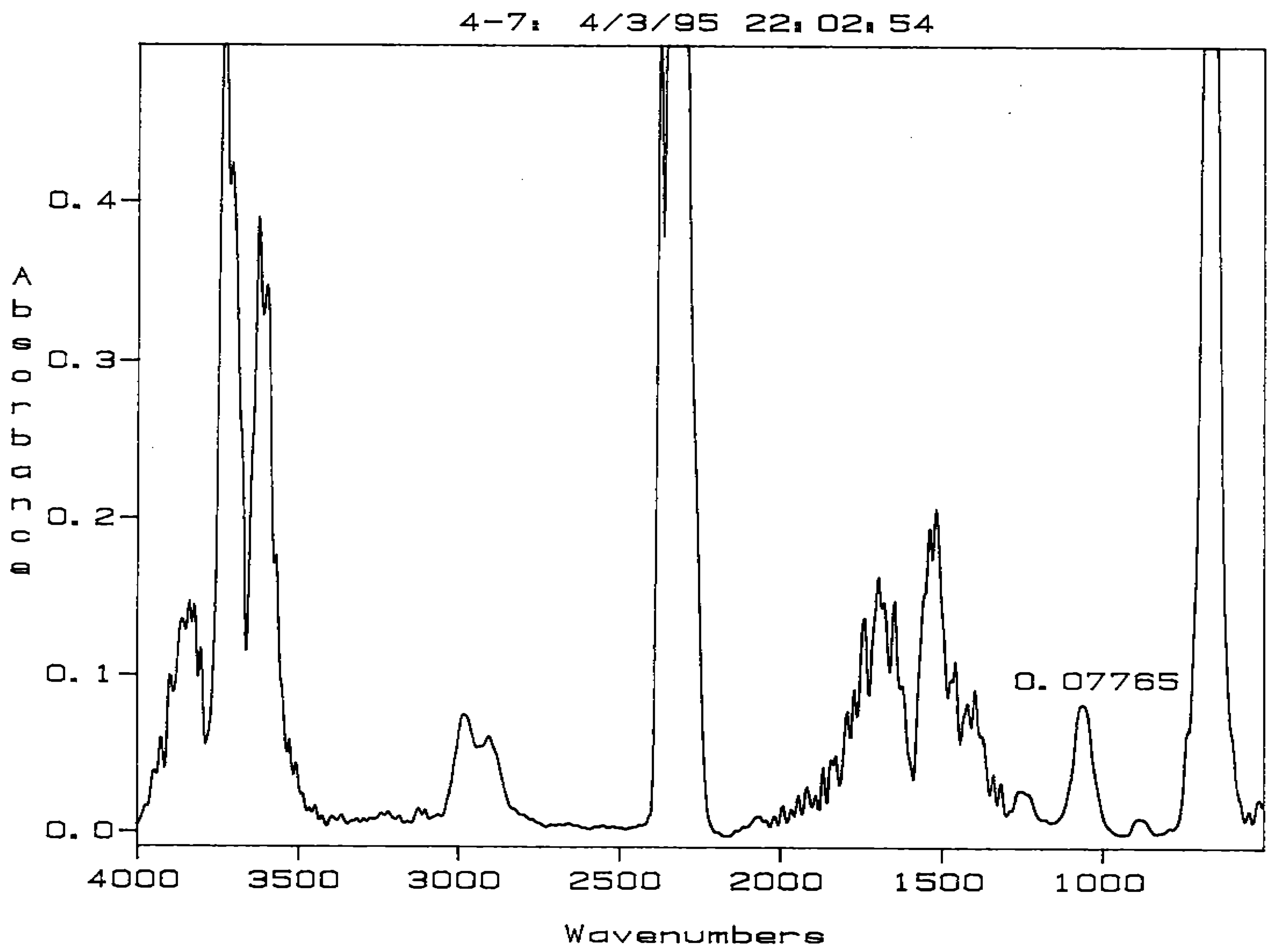
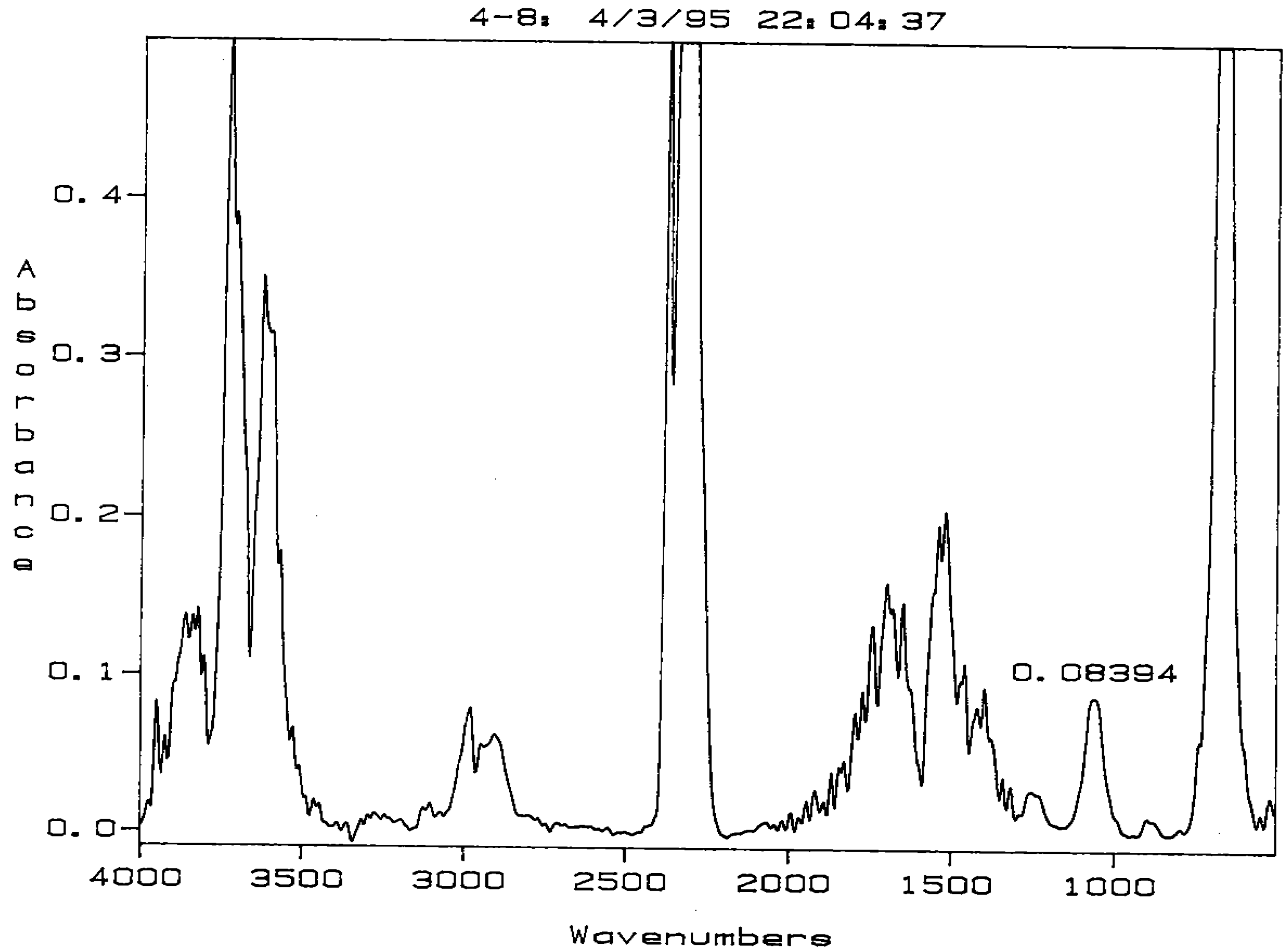
0.2
0.1
0.0
0.08281
4000
3500
3000
2500
2000
1500
1000
Wavenumbers

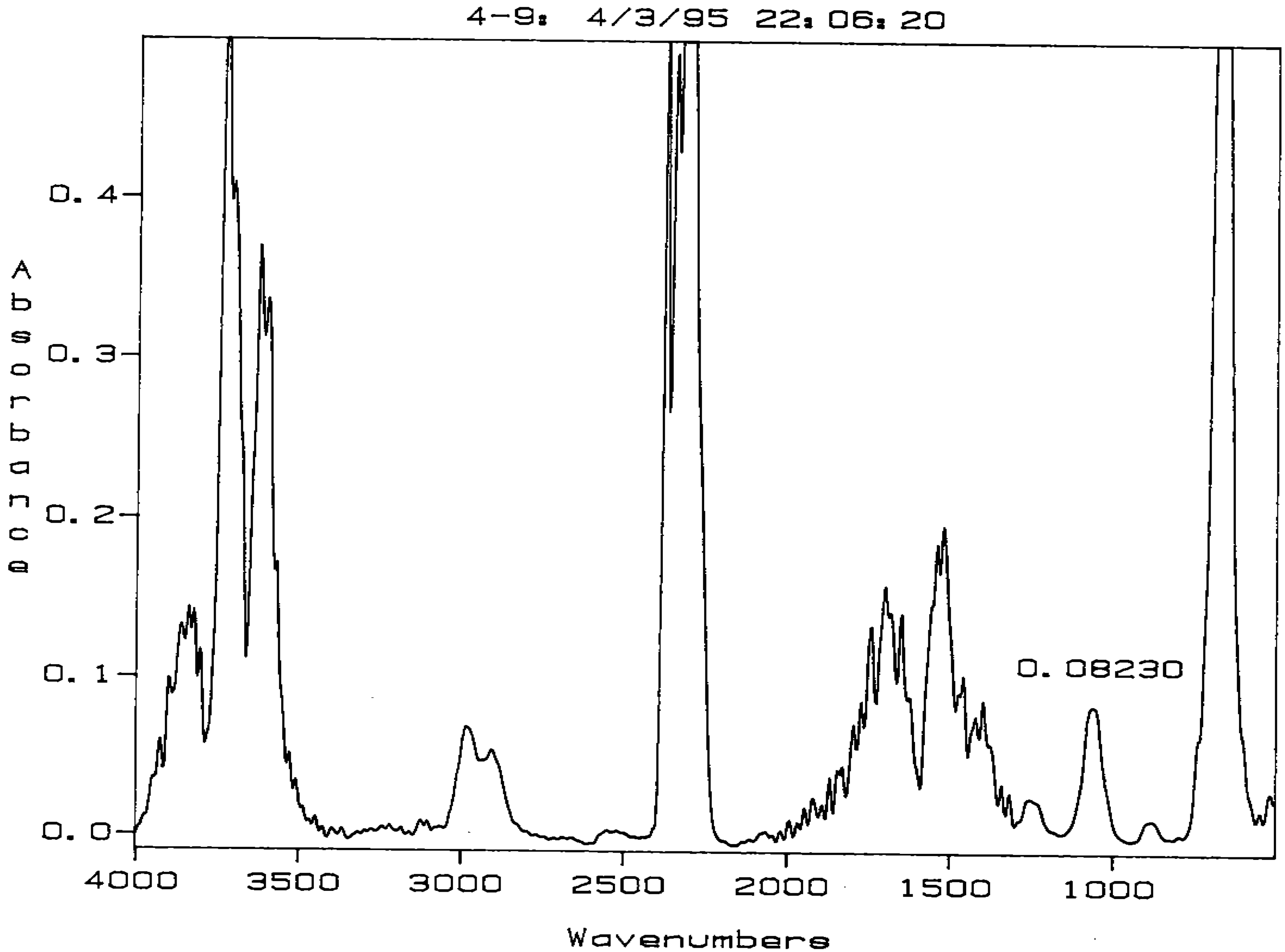

4-3: 4/3/95 21:55:56
Absorbance
0.4
0.3
0.2
0.1
0.0
0.07575
4000
3500
3000
2500
2000
1500
1000
Wavenumbers


4-5: 4/3/95 21:59:23
0.4
0.3
0.2
0.1
0.0
Absorbance
0.08488
4000
3500
3000
2500
2000
1500
1000
Wavenumbers

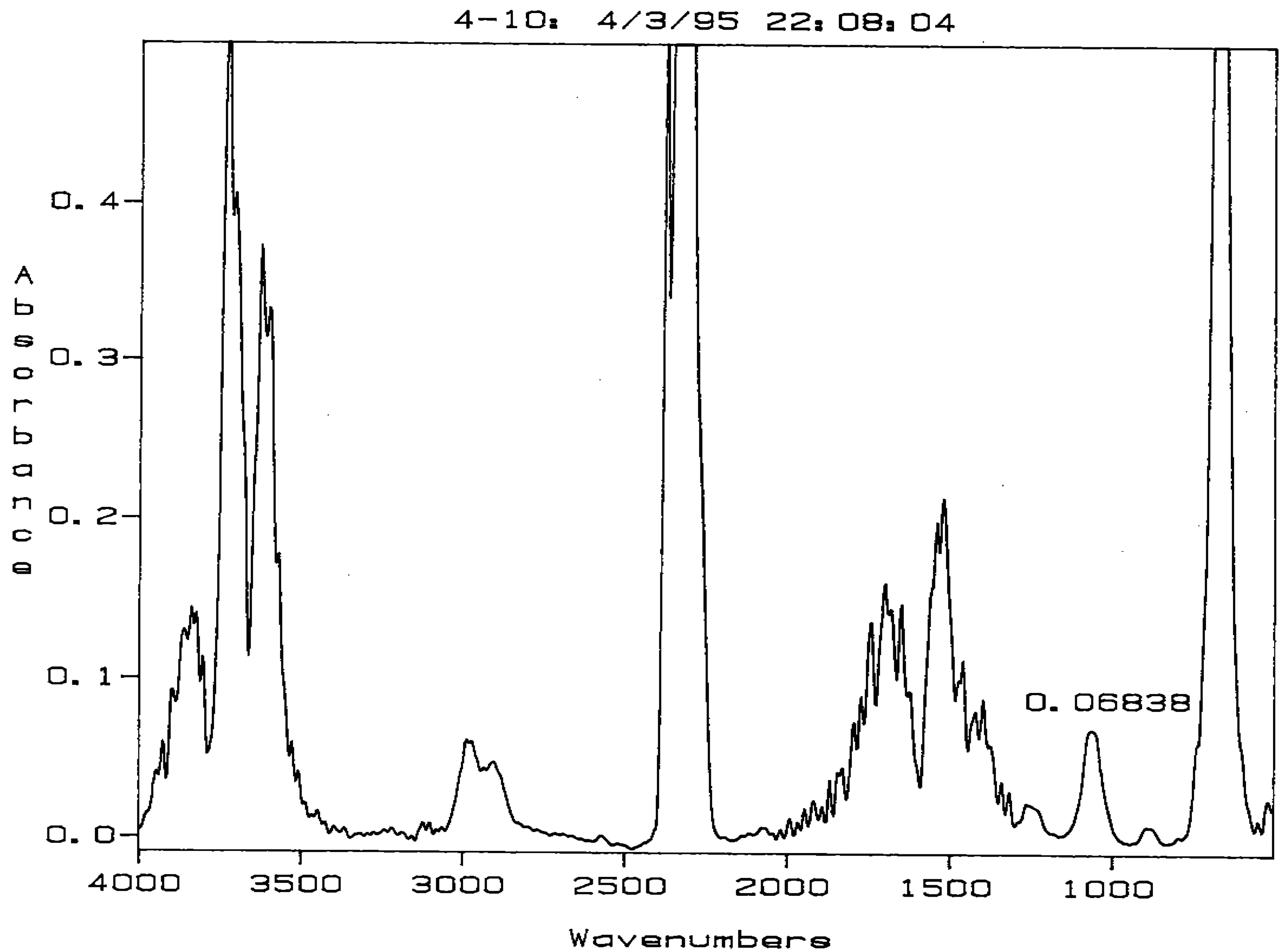

4-6: 4/3/95 22:01:08
0.4
0.3
0.2
0.1
0.0
Absorbance
0.07443
4000
3500
3000
2500
2000
1500
1000
Wavenumbers

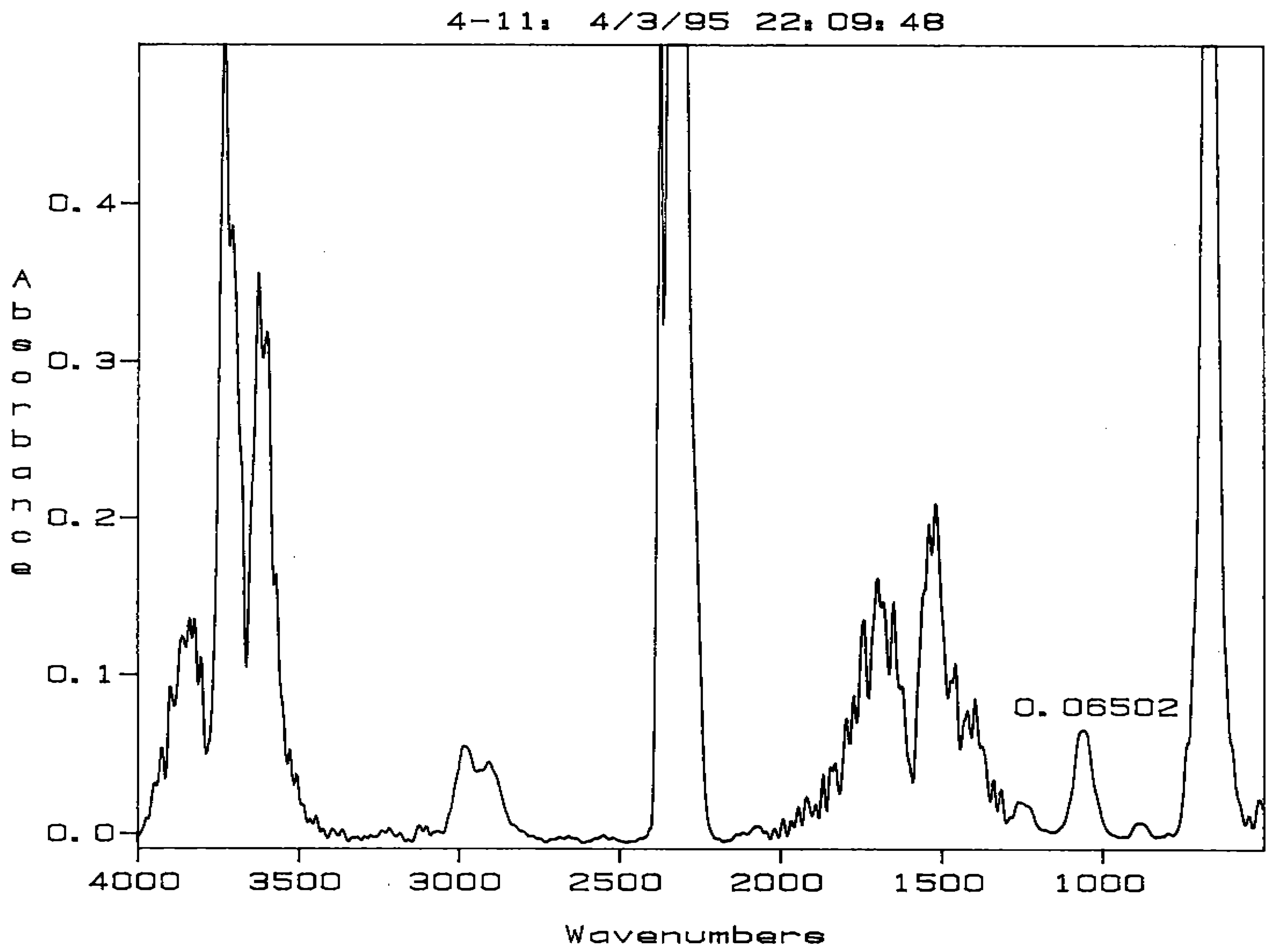

4-7: 4/3/95 22:02:54
Absorbance
0.4
0.3
0.2
0.1
0.0
0.07765
4000
3500
3000
2500
2000
1500
1000
Wavenumbers

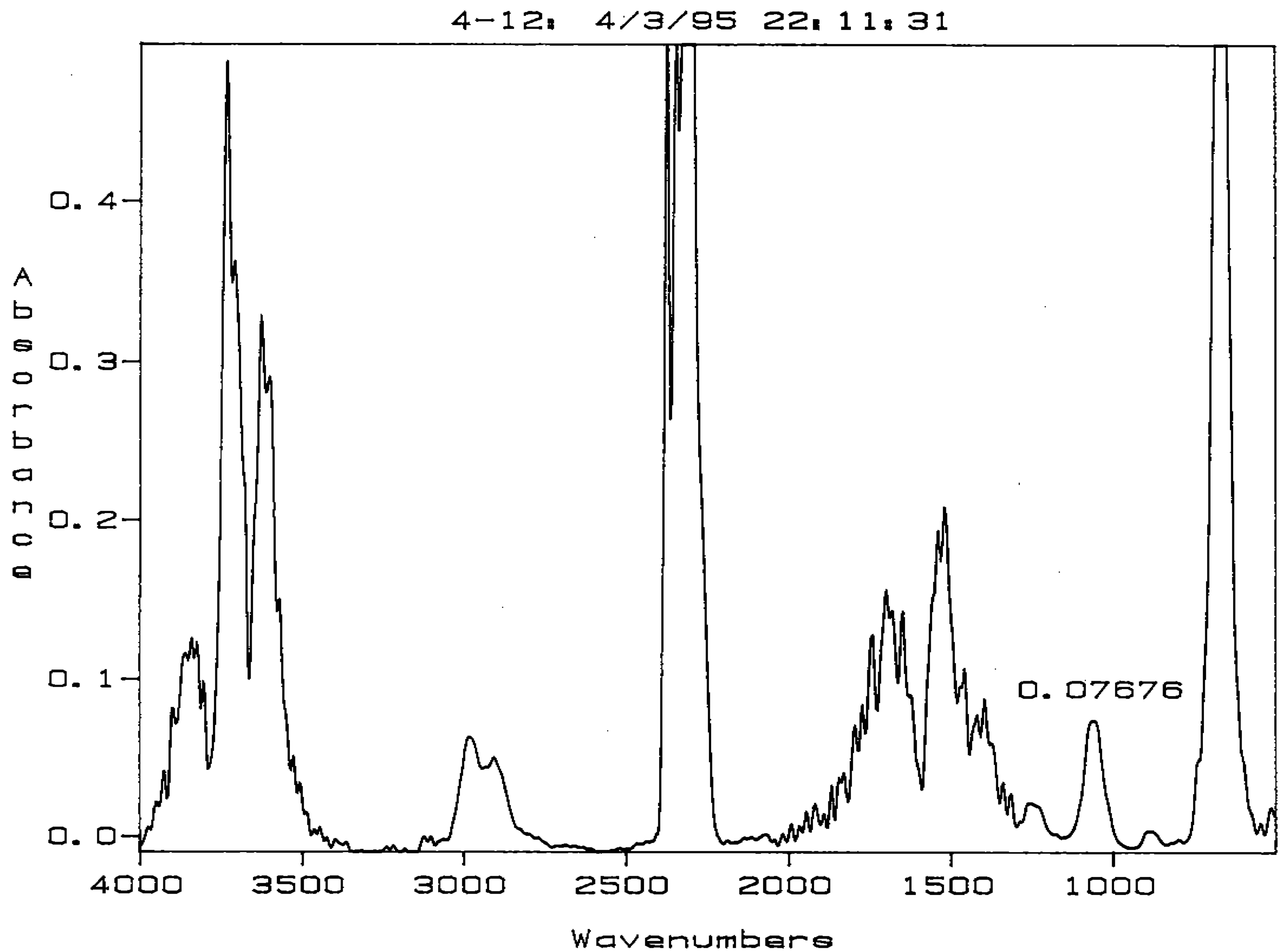

4-8: 4/3/95 22:04:37
0.4
0.3
0.2
0.1
0.0
Absorbance
0.08394
4000
3500
3000
2500
2000
1500
1000
Wavenumbers



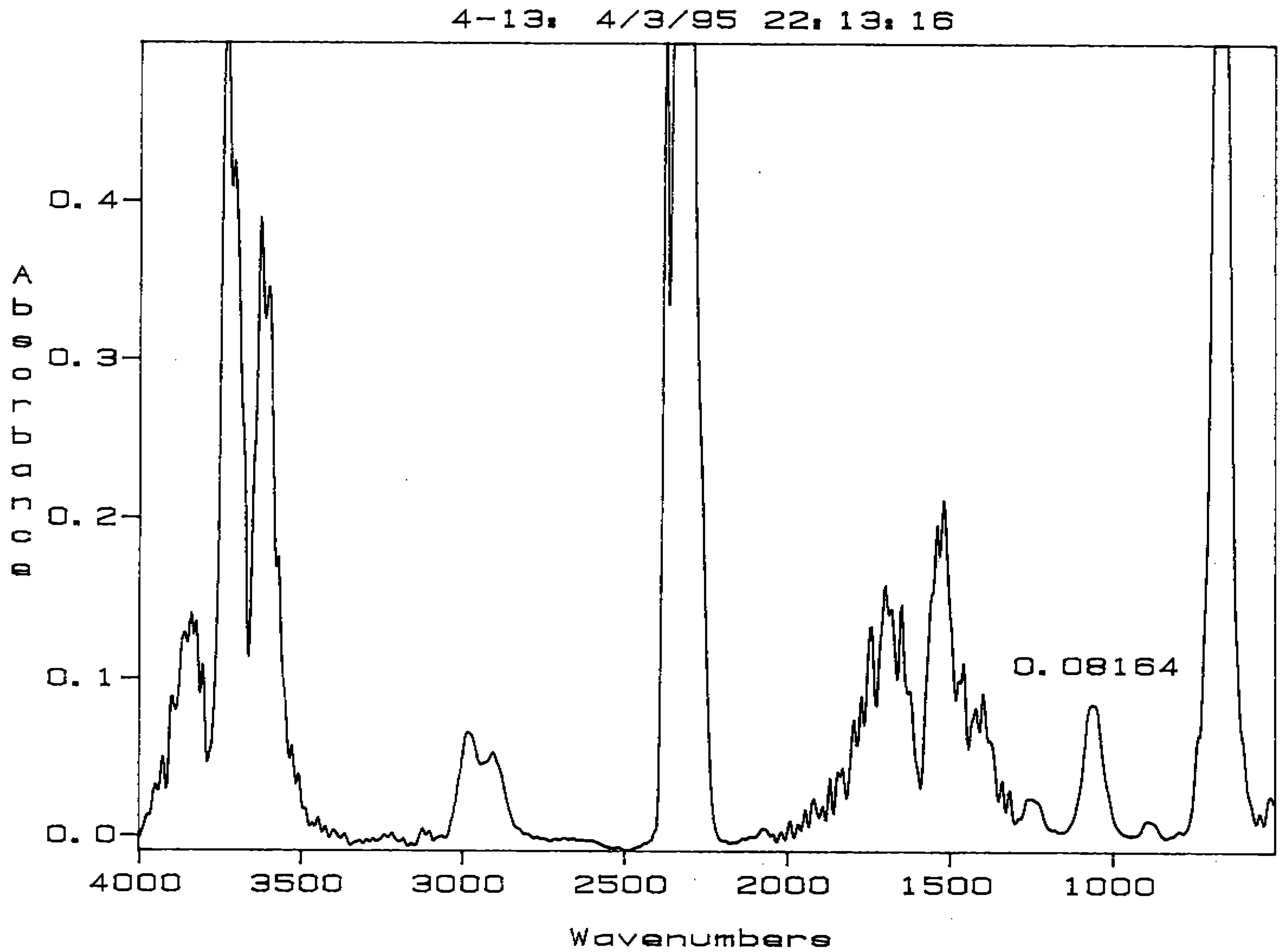
4-9: 4/3/95 22:06:20
Absorbance
0.4
0.3
0.2
0.1
0.0
0.08230
4000
3500
3000
2500
2000
1500
1000
Wavenumbers

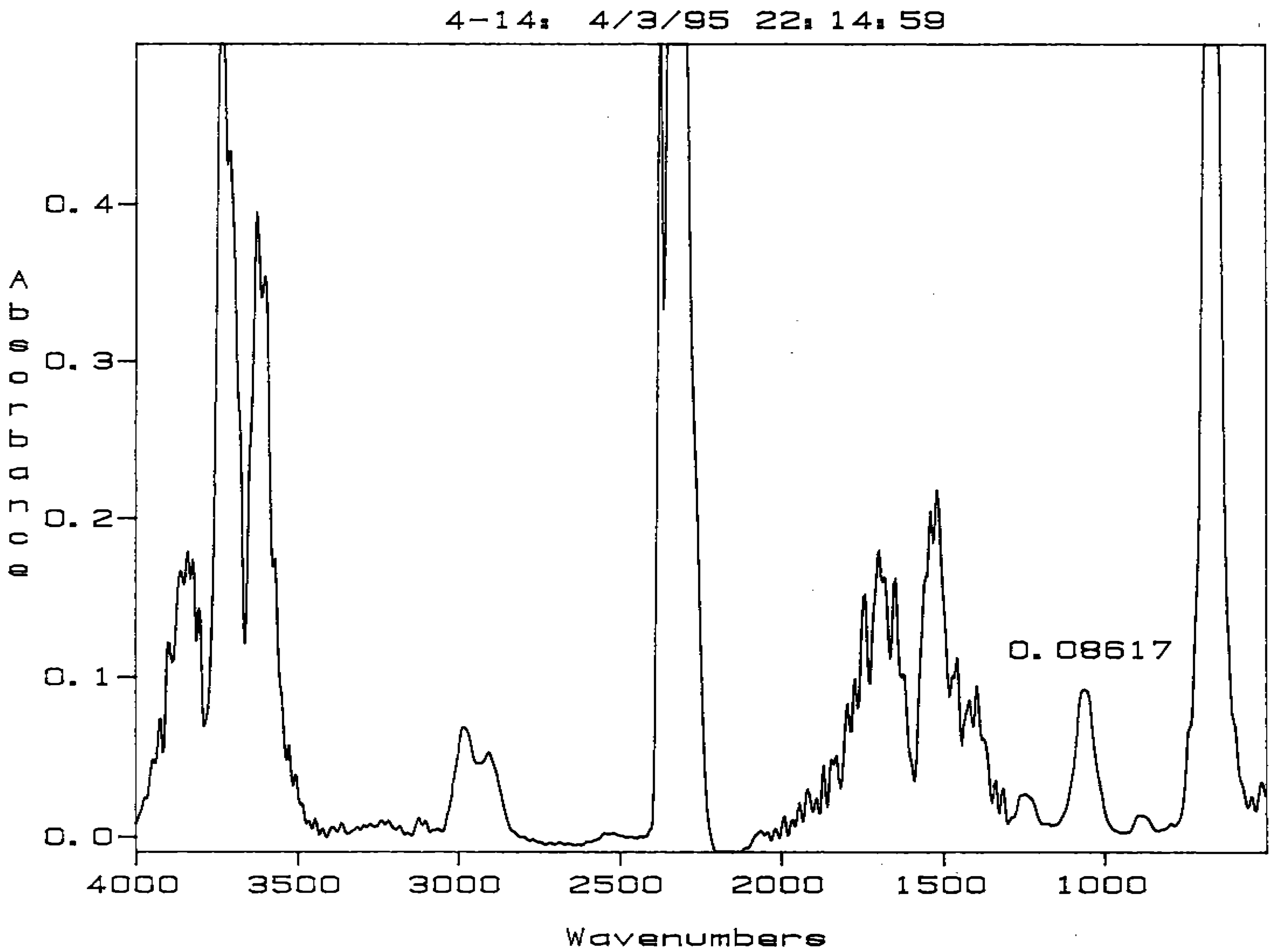

4-10: 4/3/95 22:08:04
Absorbance
0.4
0.3
0.2
0.1
0.0
0.06838
4000
3500
3000
2500
2000
1500
1000
Wavenumbers

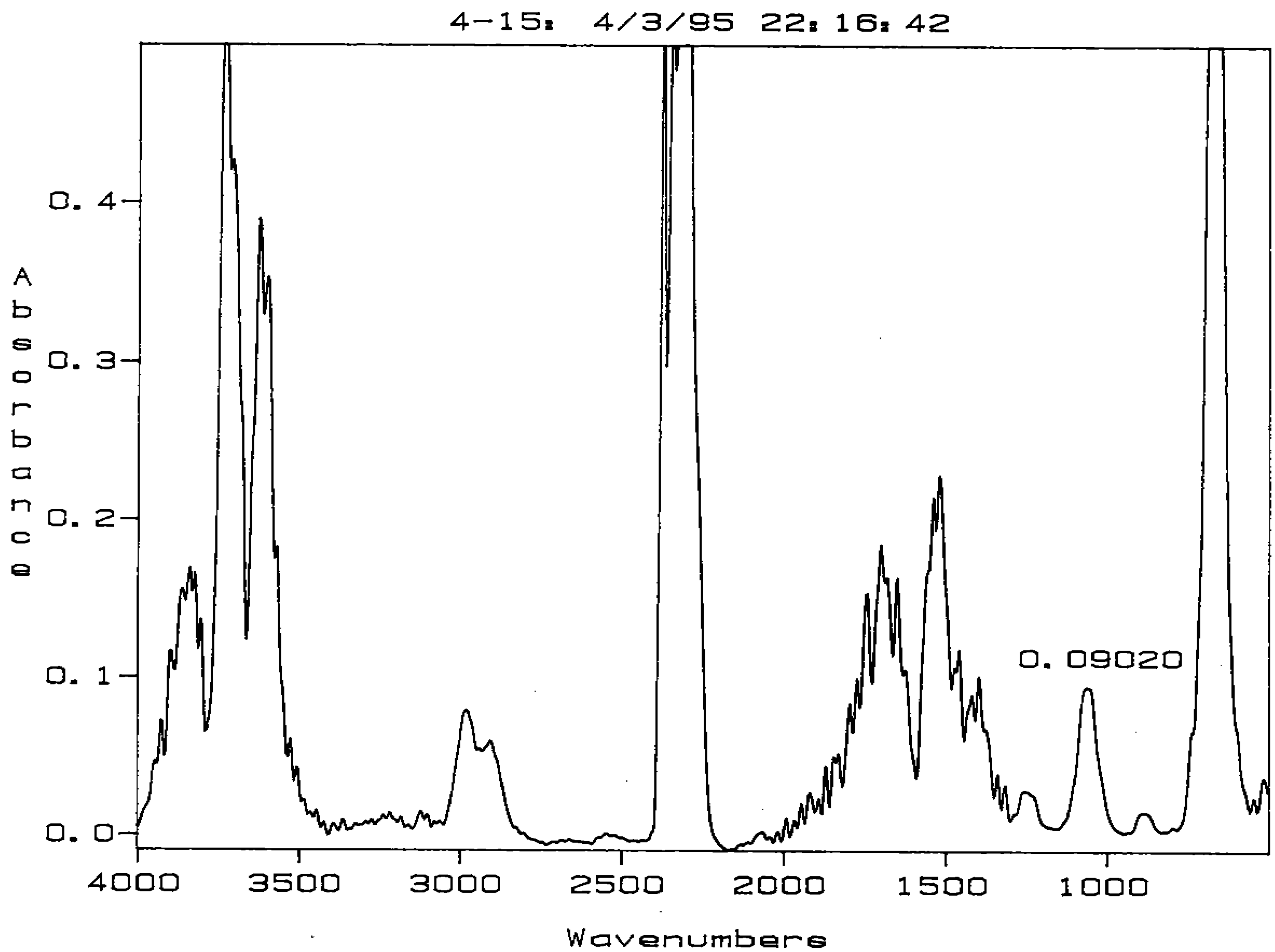

4-11: 4/3/95 22:09:48
0.4
0.3
0.2
0.1
0.0
Absorbance
0.06502
4000
3500
3000
2500
2000
1500
1000
Wavenumbers

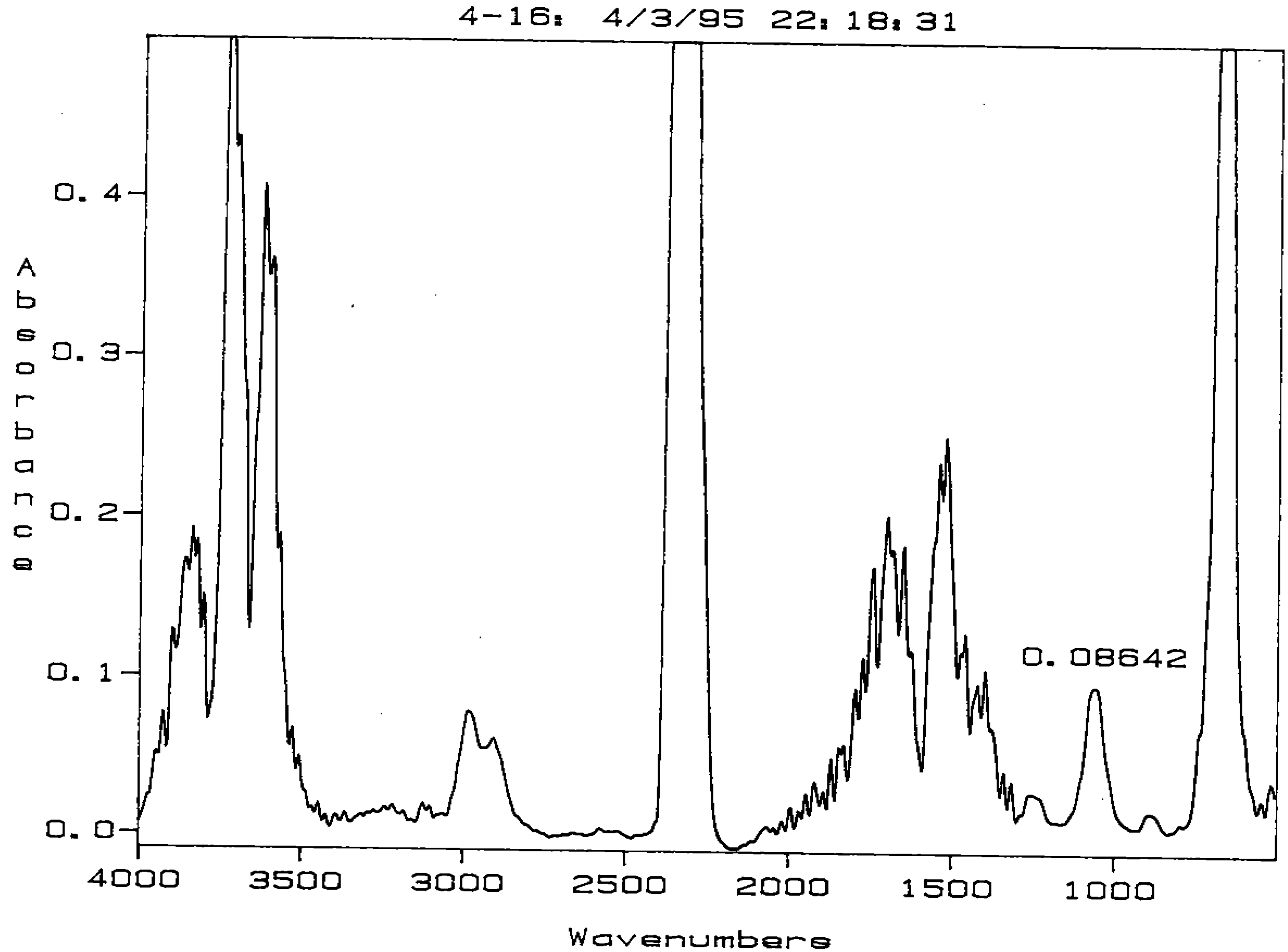


4-12: 4/3/95 22:11:31
Absorbance
0.4
0.3
0.2
0.1
0.0
0.07676
4000
3500
3000
2500
2000
1500
1000
Wavenumbers

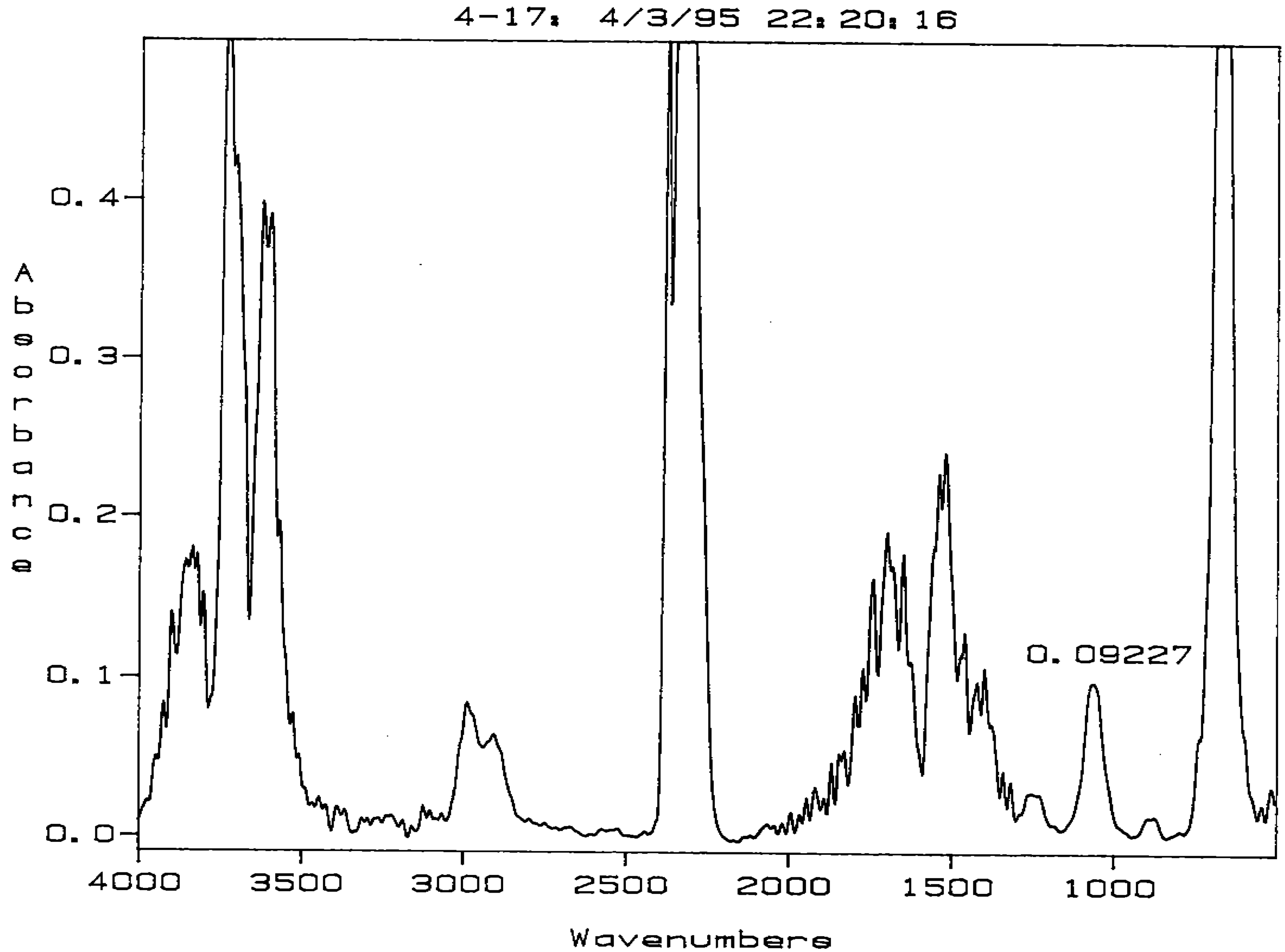

4-13: 4/3/95 22:13:16
Absorbance
0.4
0.3
0.2
0.1
0.0
0.08164
4000
3500
3000
2500
2000
1500
1000
Wavenumbers

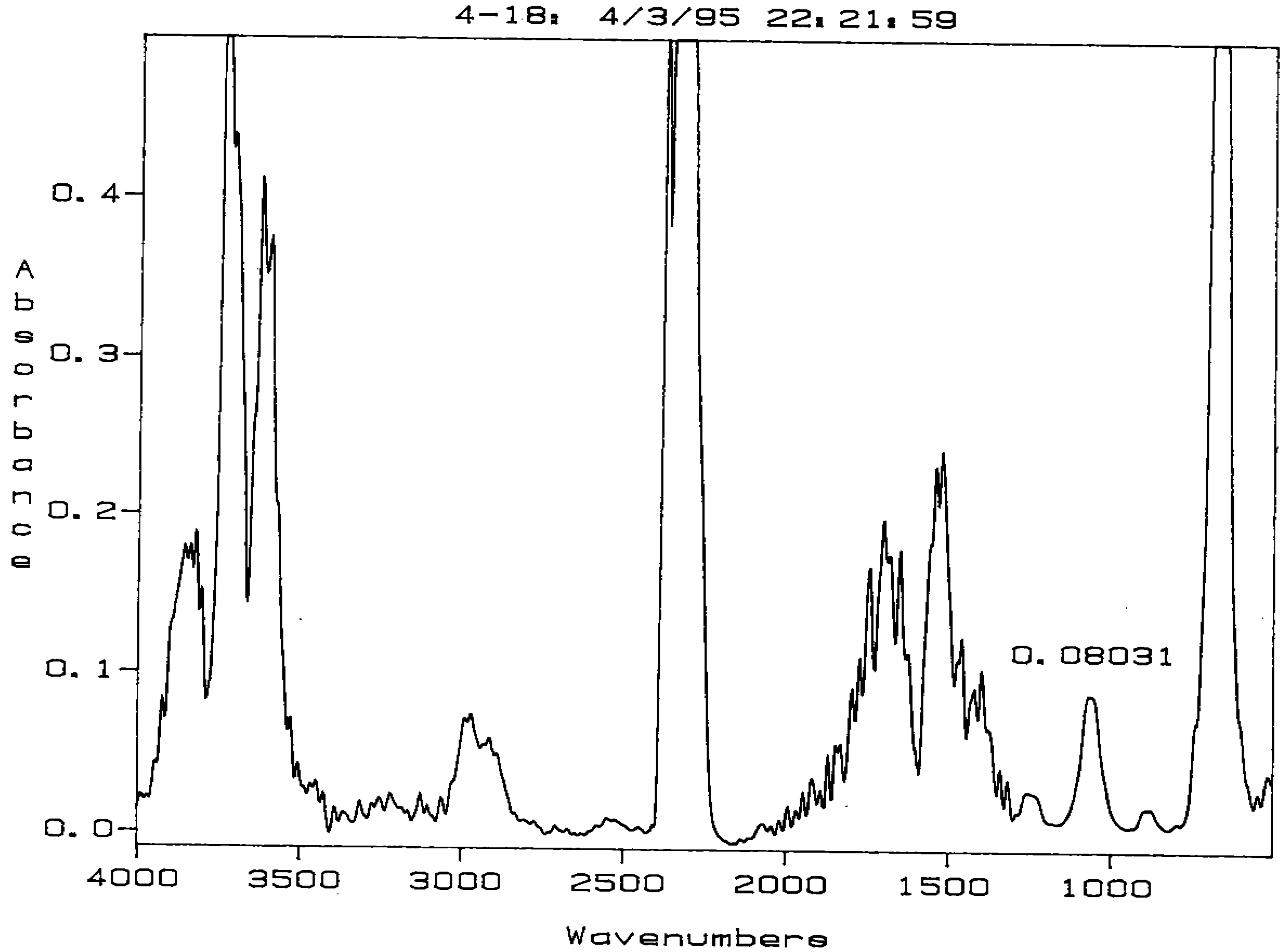

4-14: 4/3/95 22:14:59
Absorbance
0.4
0.3
0.2
0.1
0.0
0.08617
4000
3500
3000
2500
2000
1500
1000
Wavenumbers


4-15: 4/3/95 22: 16: 42
Absorbance
0. 4
0. 3
0. 2
0. 1
0. 0
0. 09020
4000
3500
3000
2500
2000
1500
1000
Wavenumbers

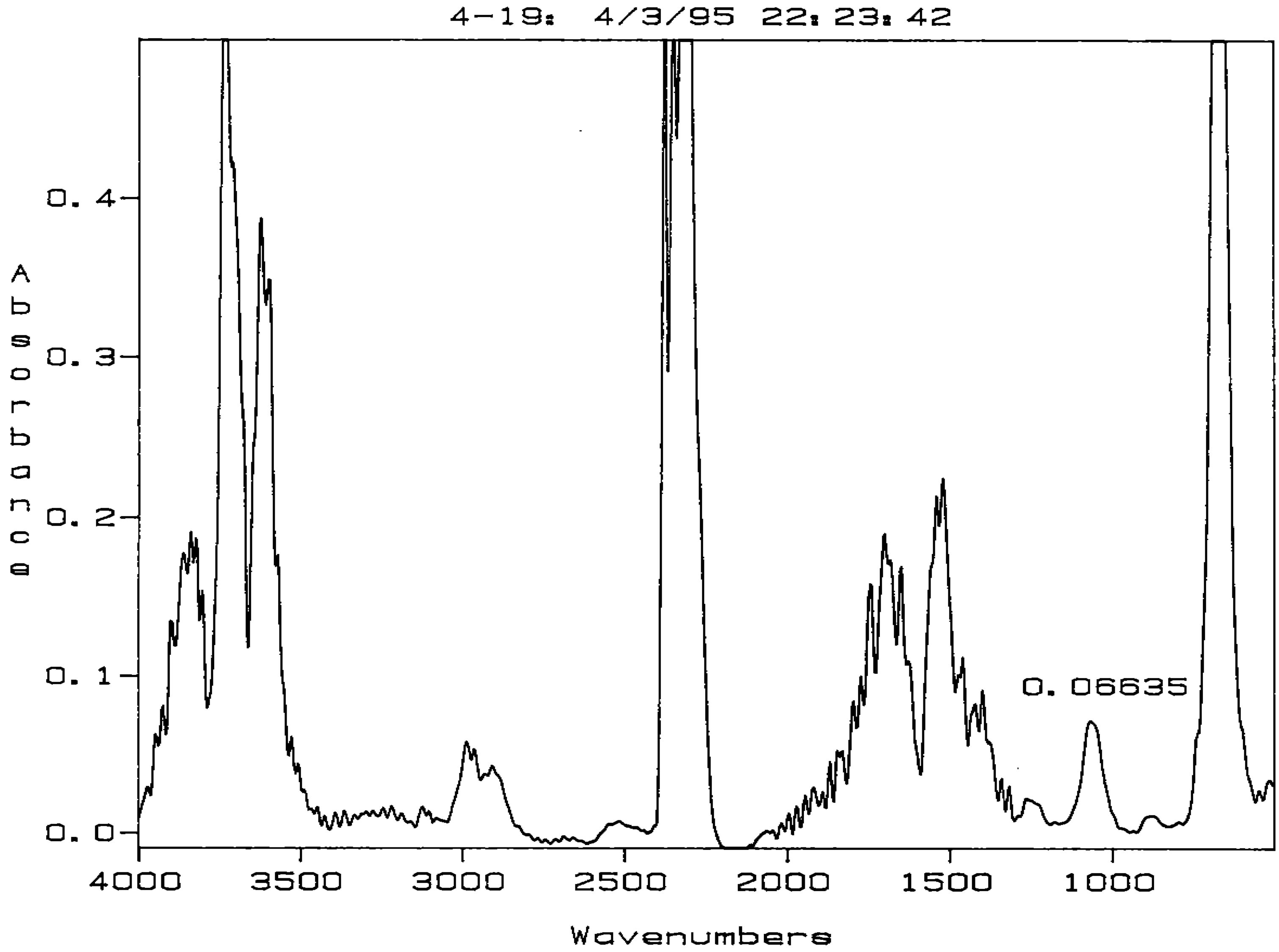


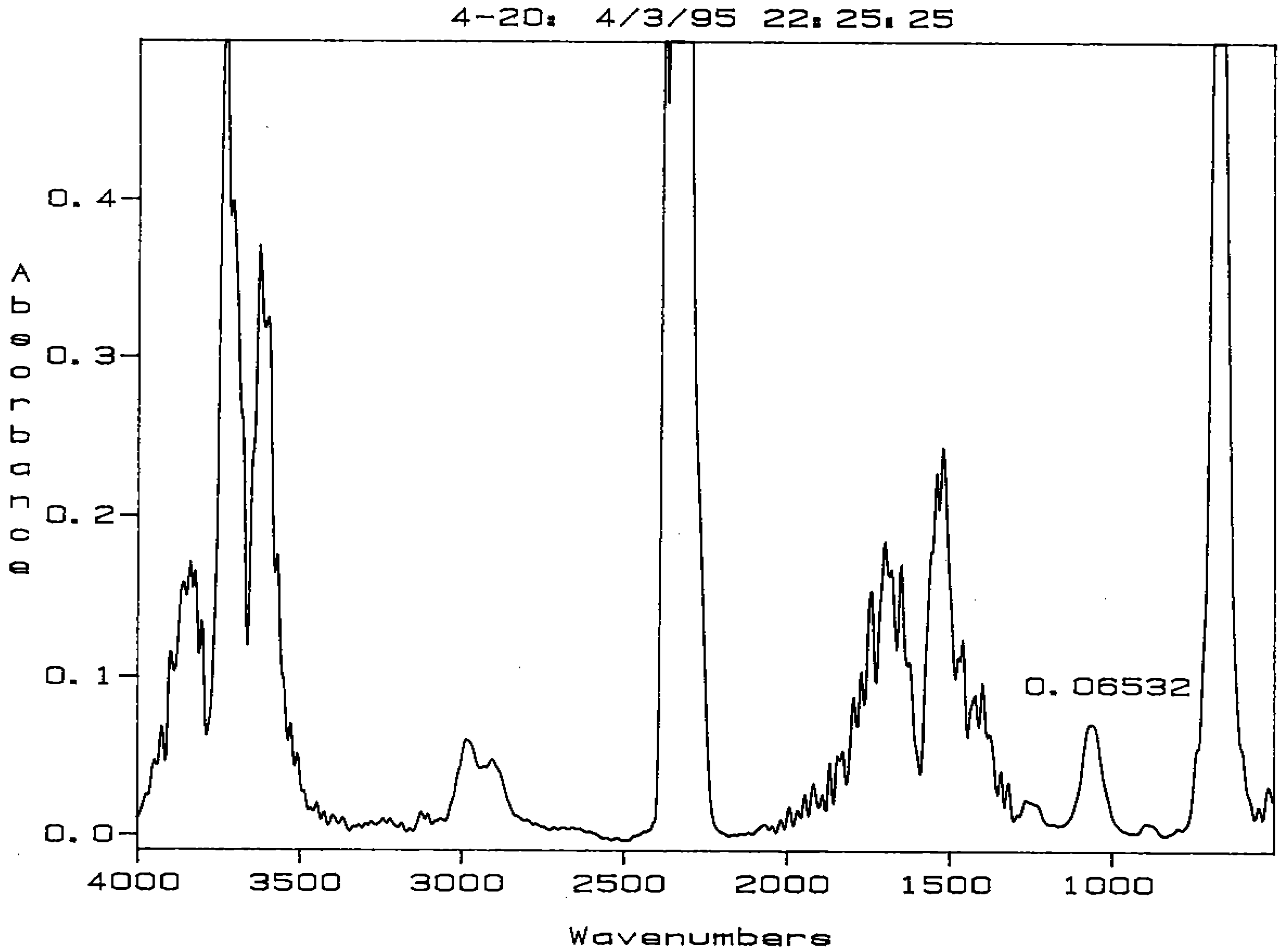
4-16: 4/3/95 22: 18: 31
Absorbance
0. 0
0. 1
0. 2
0. 3
0. 4
0. 08642
4000
3500
3000
2500
2000
1500
1000
Wavenumbers

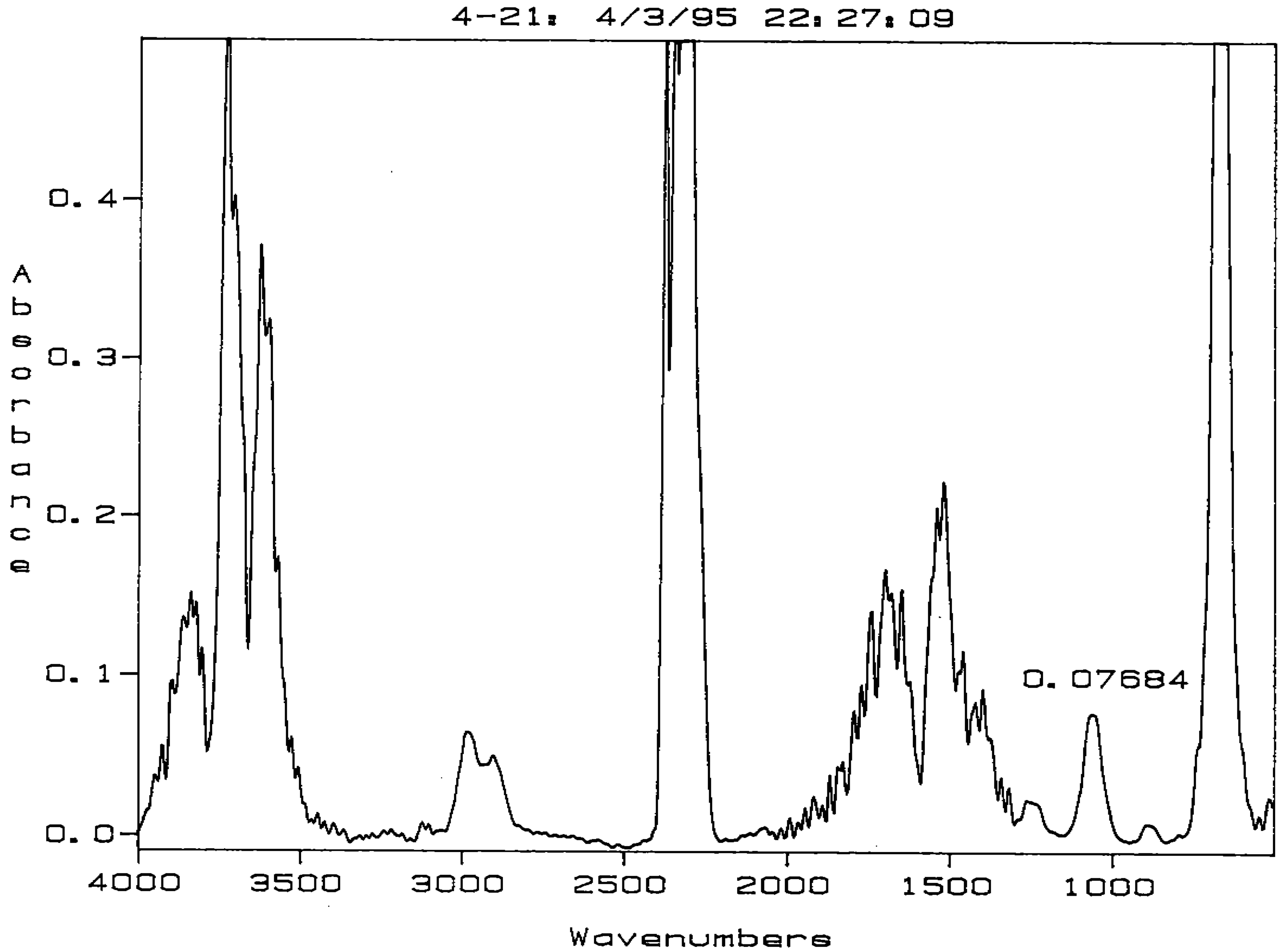

4-17: 4/3/95 22:20:16
Absorbance
0.0
0.1
0.2
0.3
0.4
0.09227
4000
3500
3000
2500
2000
1500
1000
Wavenumbers

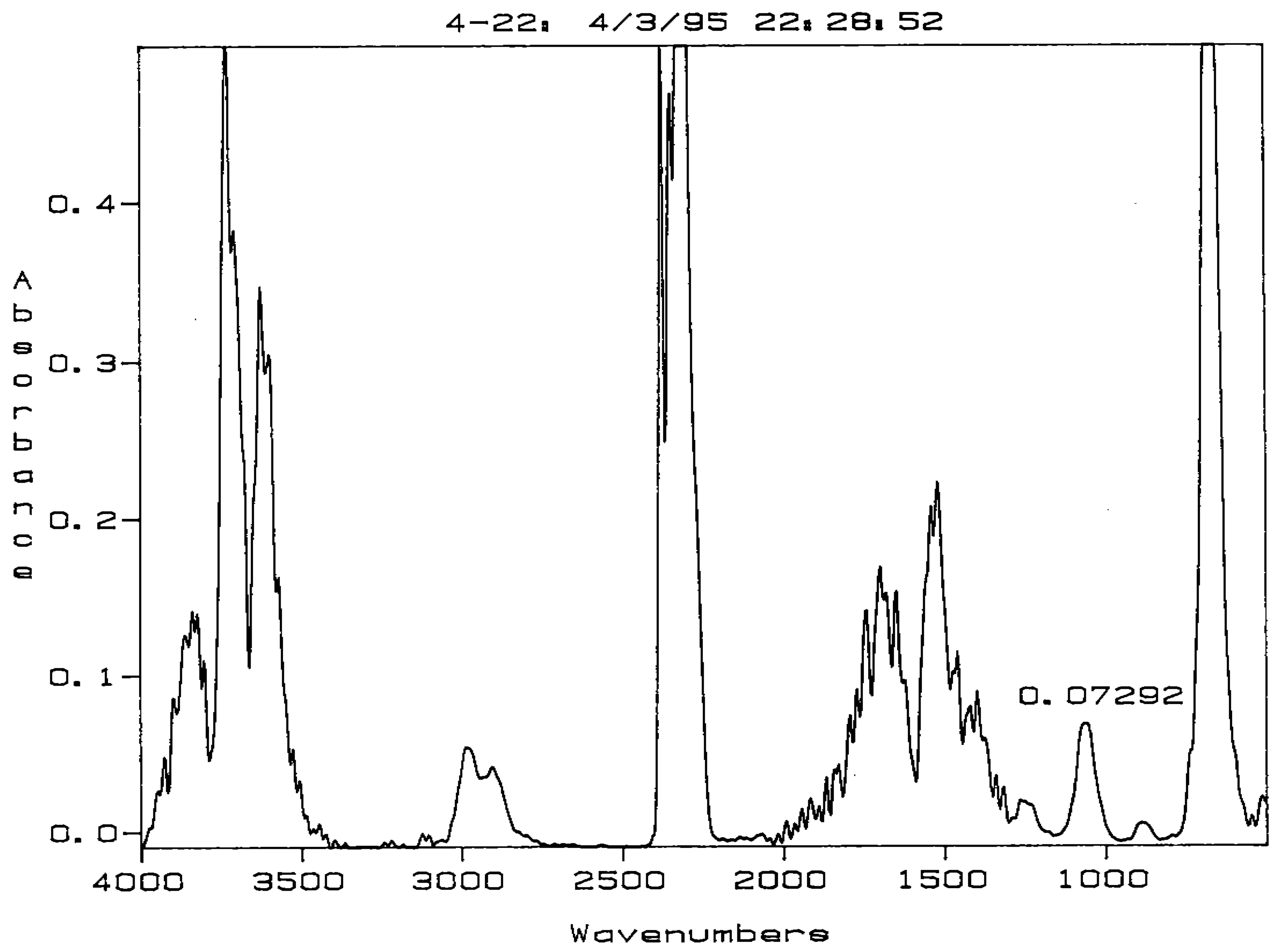


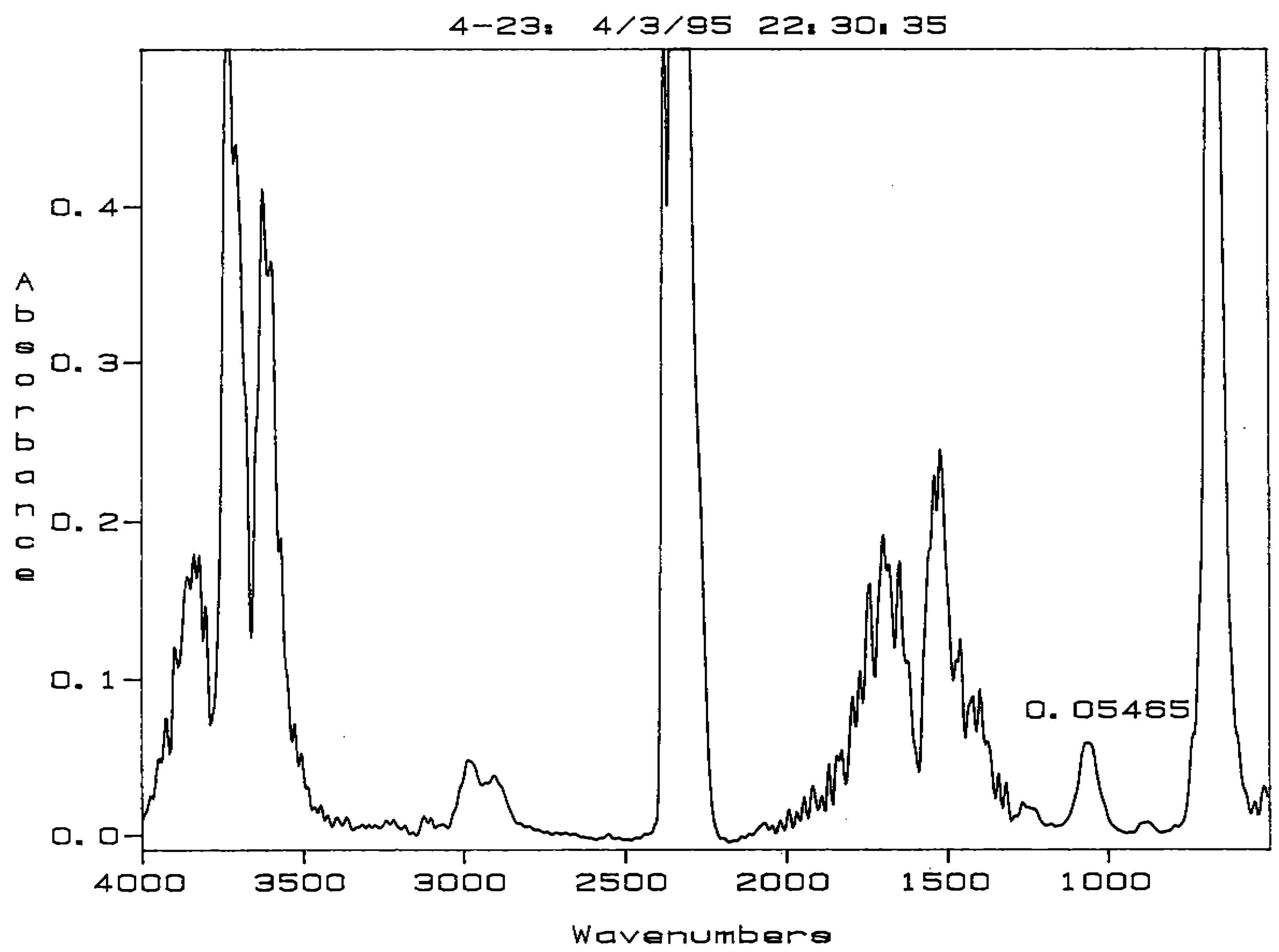
4-18: 4/3/95 22:21:59
Absorbance
0.4
0.3
0.2
0.1
0.0
0.08031
4000
3500
3000
2500
2000
1500
1000
Wavenumbers

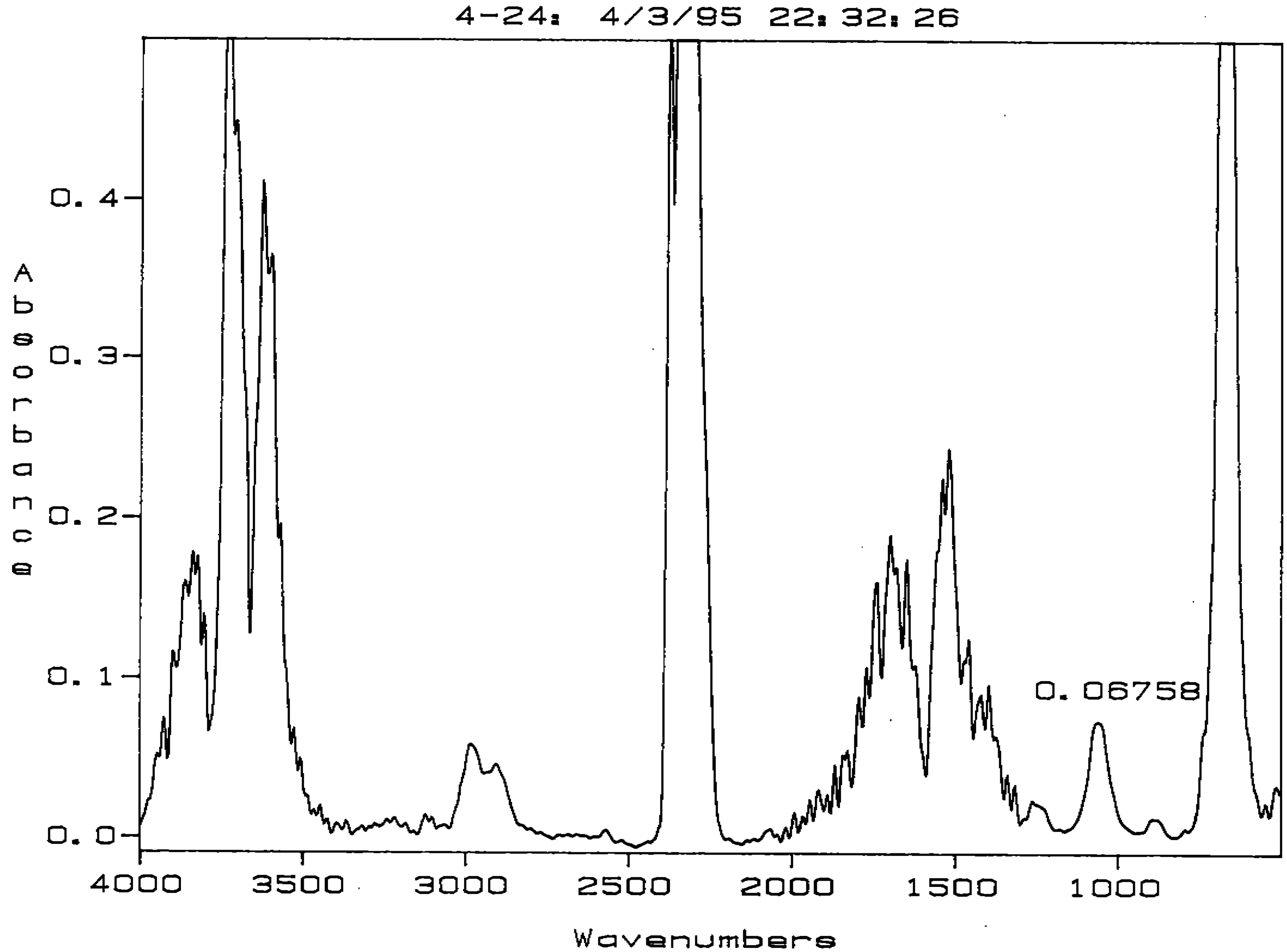

4-19: 4/3/95 22:23:42
Absorbance
0.4
0.3
0.2
0.1
0.0
0.06635
4000
3500
3000
2500
2000
1500
1000
Wavenumbers

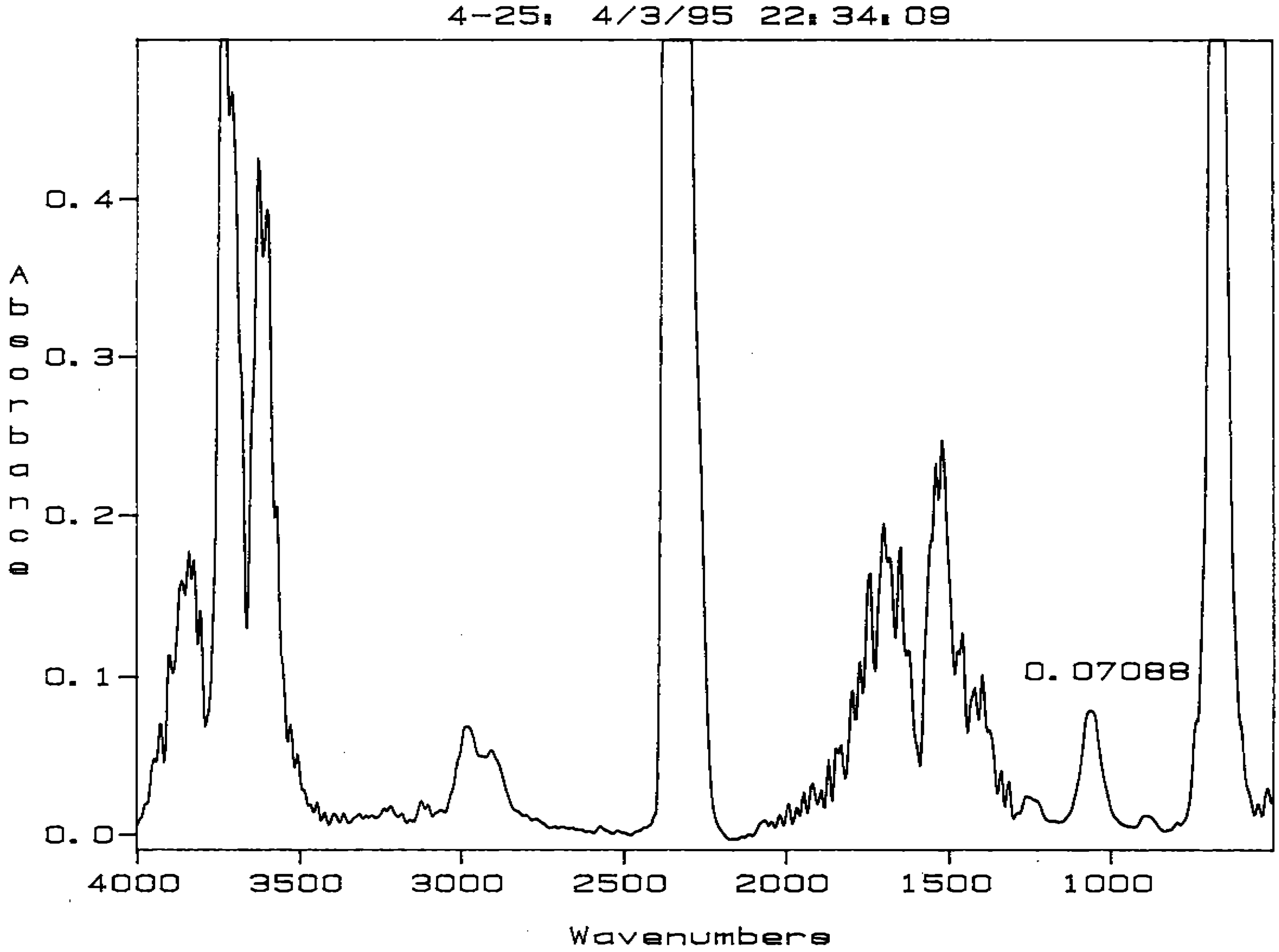

4-20: 4/3/95 22:25:25
Absorbance
0.4
0.3
0.2
0.1
0.0
0.06532
4000
3500
3000
2500
2000
1500
1000
Wavenumbers

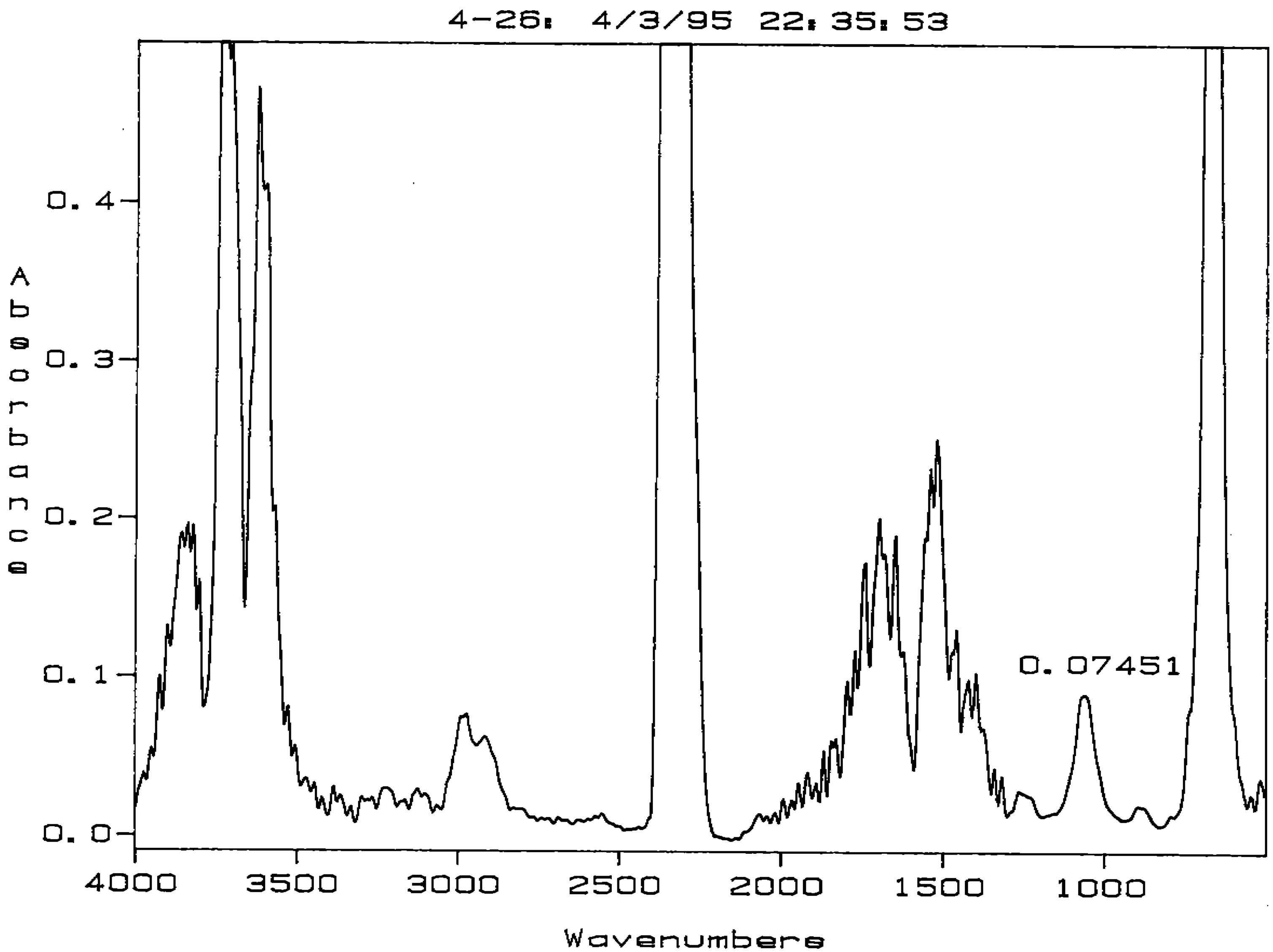

4-21: 4/3/95 22:27:09
Absorbance
0.4
0.3
0.2
0.1
0.0
0.07684
4000
3500
3000
2500
2000
1500
1000
Wavenumbers

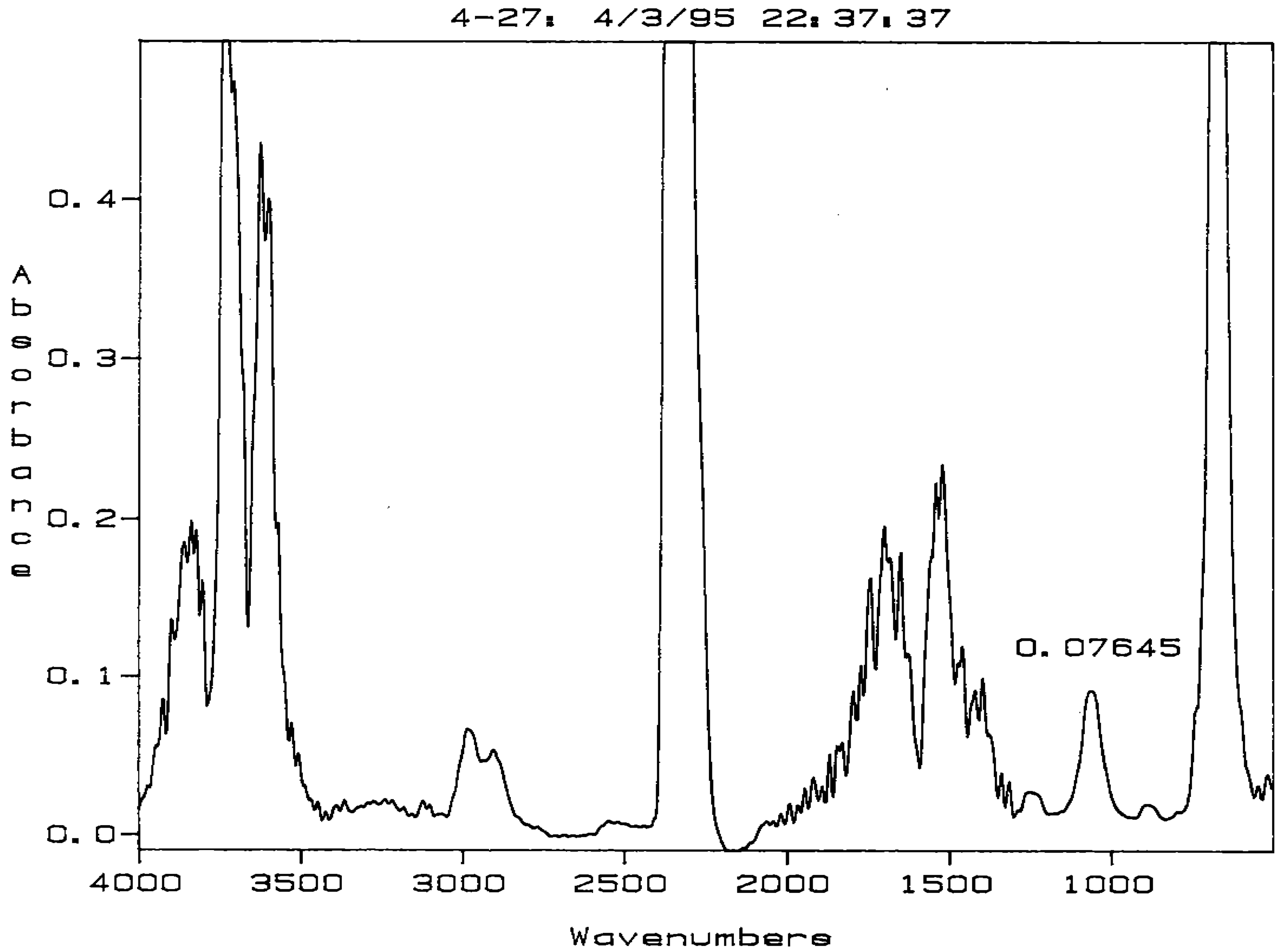

4-22: 4/3/95 22:28:52
0.4
0.3
0.2
0.1
0.0
Absorbance
0.07292
4000
3500
3000
2500
2000
1500
1000
Wavenumbers

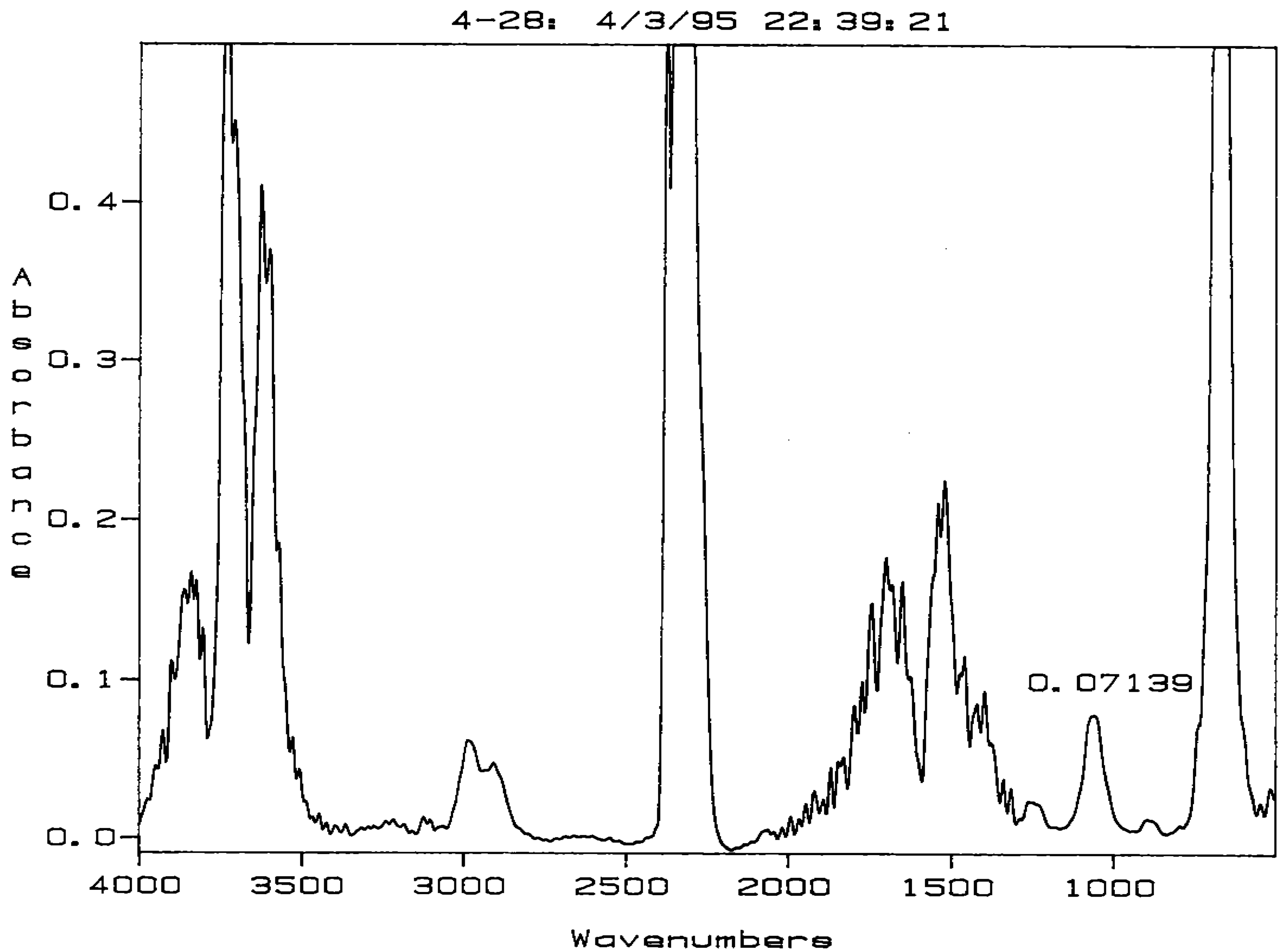

4-23: 4/3/95 22:30:35
Absorbance
0.0
0.1
0.2
0.3
0.4
0.05465
4000
3500
3000
2500
2000
1500
1000
Wavenumbers

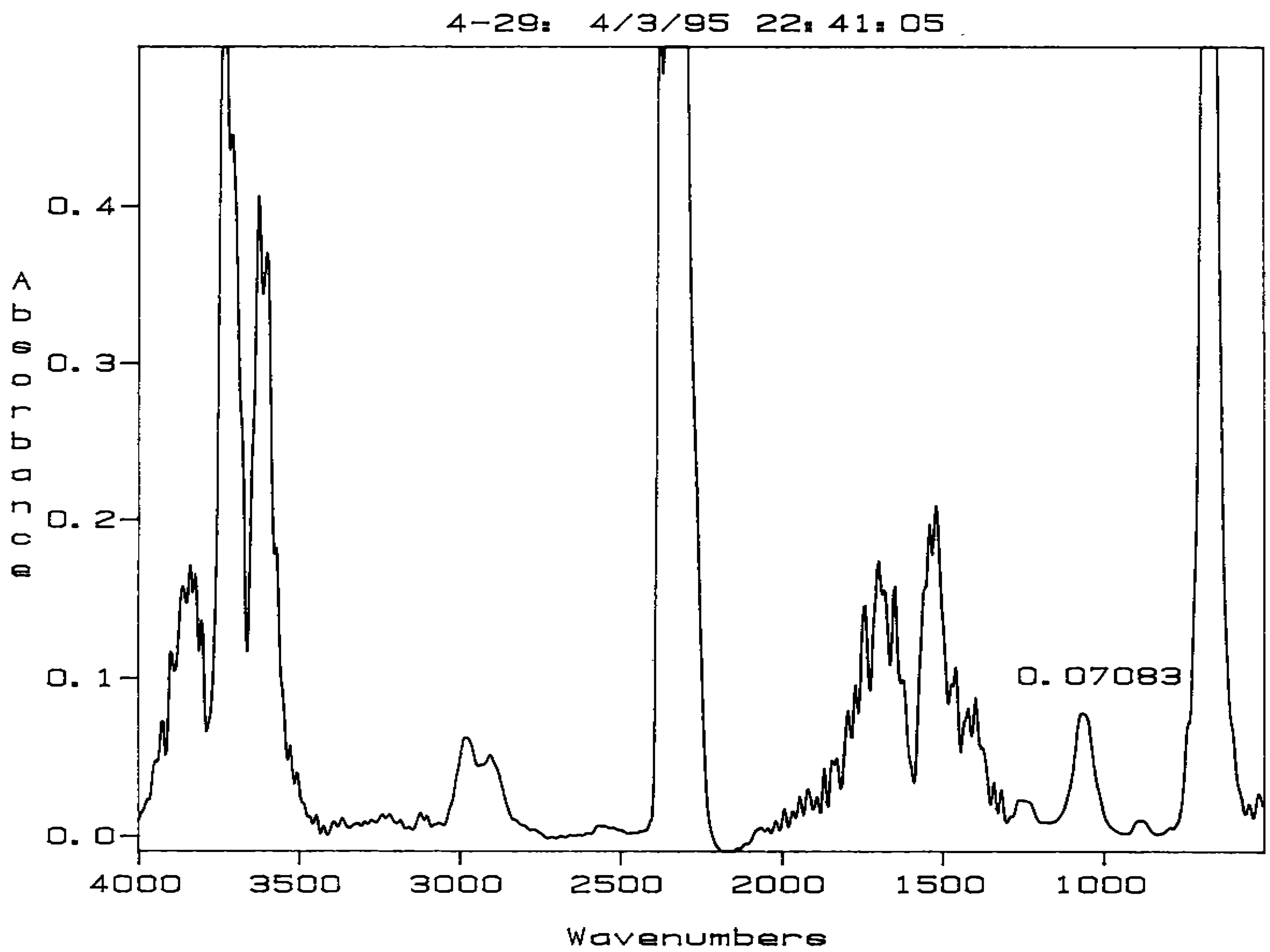

4-24: 4/3/95 22:32:26
Absorbance
0.4
0.3
0.2
0.1
0.0
4000
3500
3000
2500
2000
1500
1000
Wavenumbers
0.06758

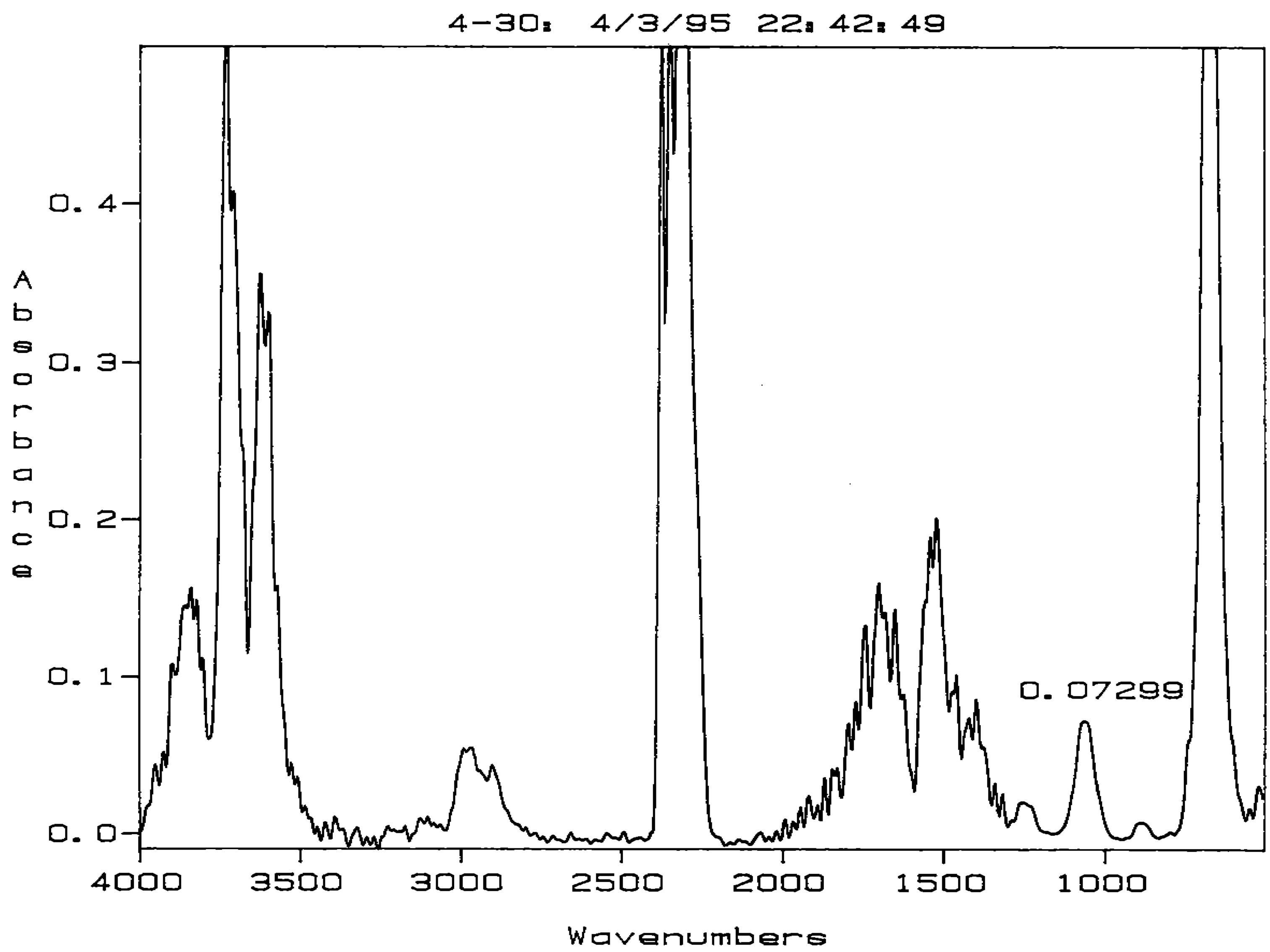

4-25: 4/3/95 22:34:09
Absorbance
0.4
0.3
0.2
0.1
0.0
0.07088
4000
3500
3000
2500
2000
1500
1000
Wavenumbers


4-26: 4/3/95 22:35:53
Absorbance
0.4
0.3
0.2
0.1
0.0
0.07451
4000
3500
3000
2500
2000
1500
1000
Wavenumbers

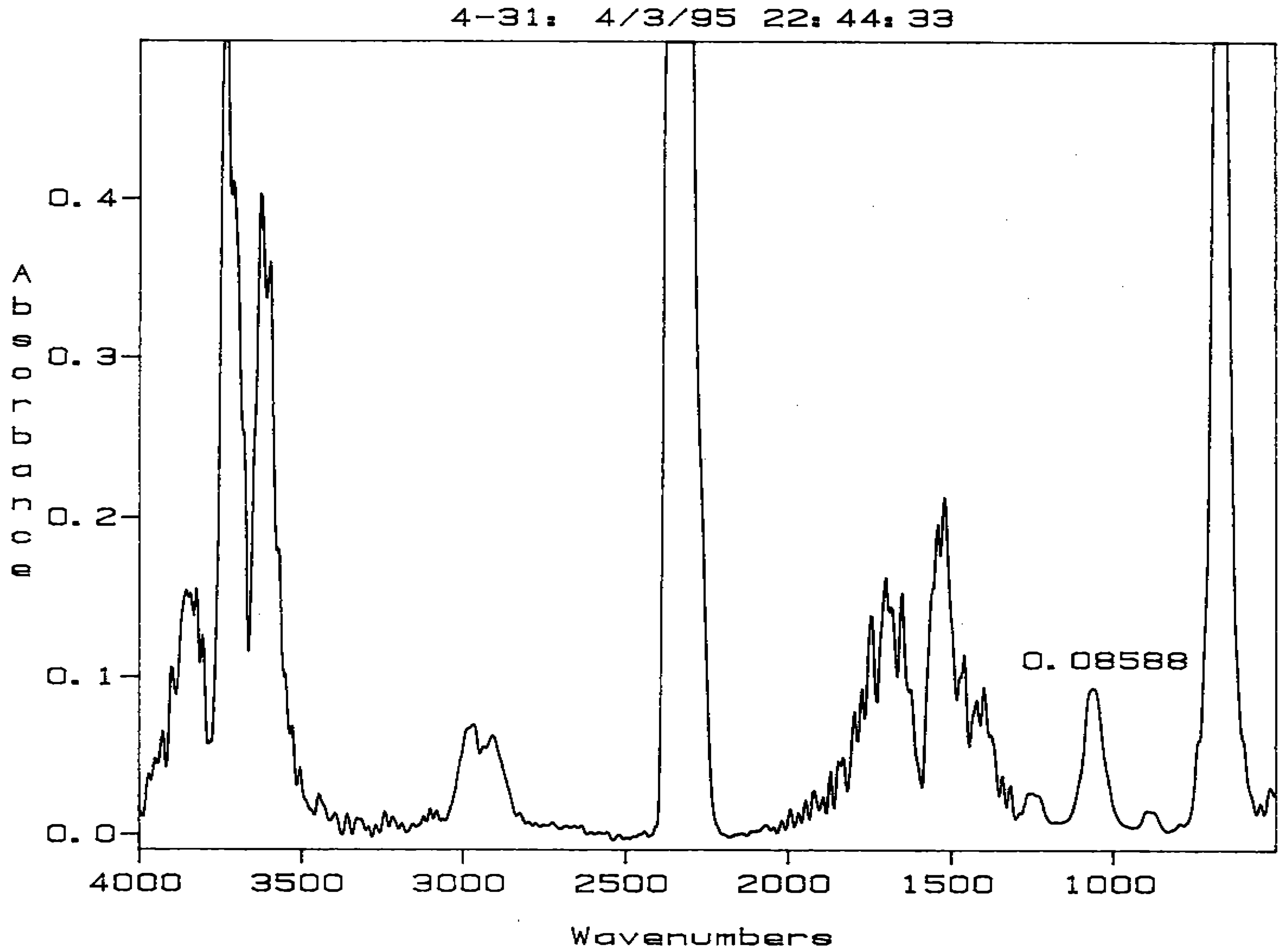

4-27: 4/3/95 22:37:37
Absorbance
0.4
0.3
0.2
0.1
0.0
0.07645
4000
3500
3000
2500
2000
1500
1000
Wavenumbers

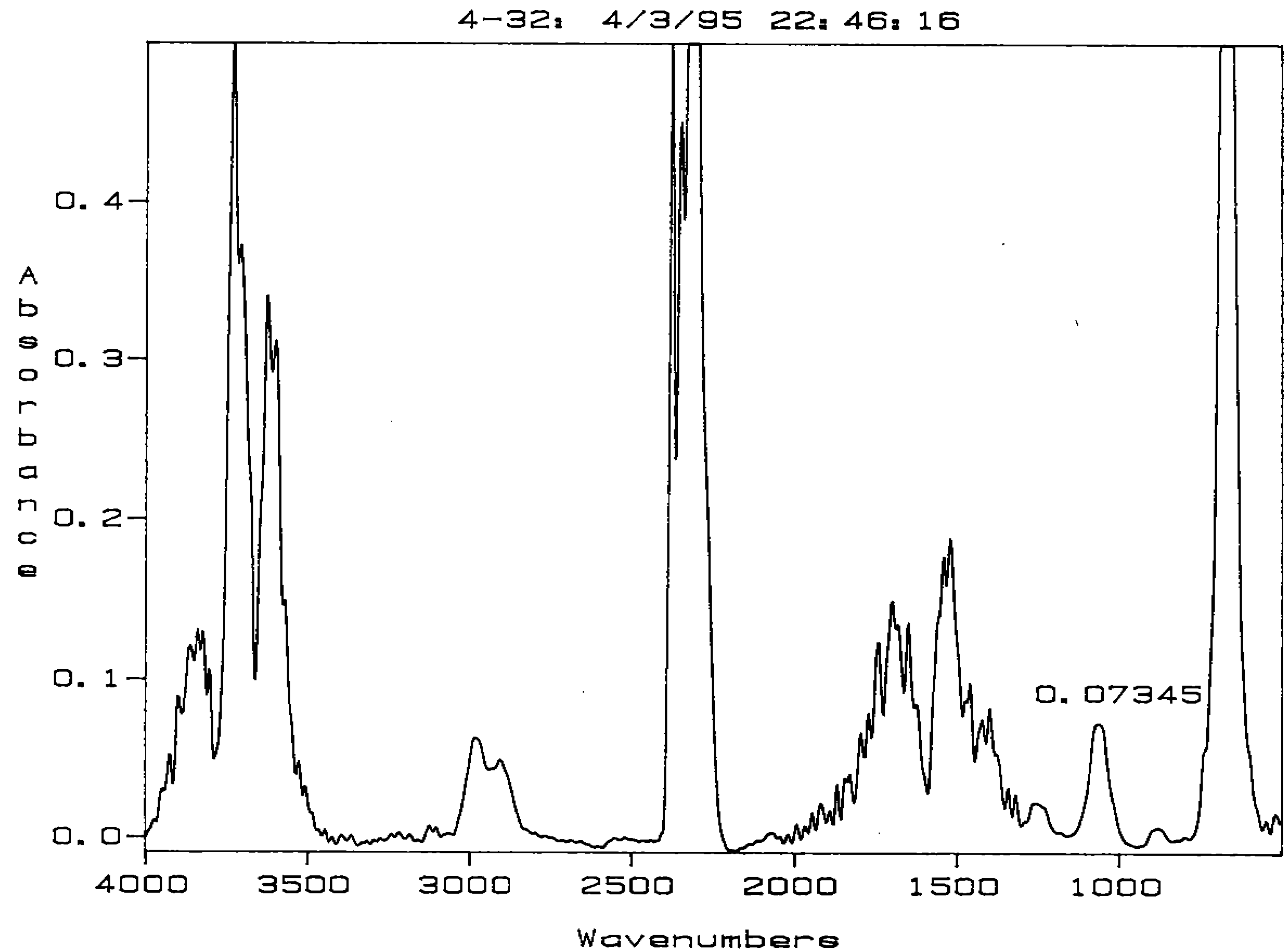

4-28: 4/3/95 22:39:21
0.4
0.3
0.2
0.1
0.0
Absorbance
0.07139
4000
3500
3000
2500
2000
1500
1000
Wavenumbers

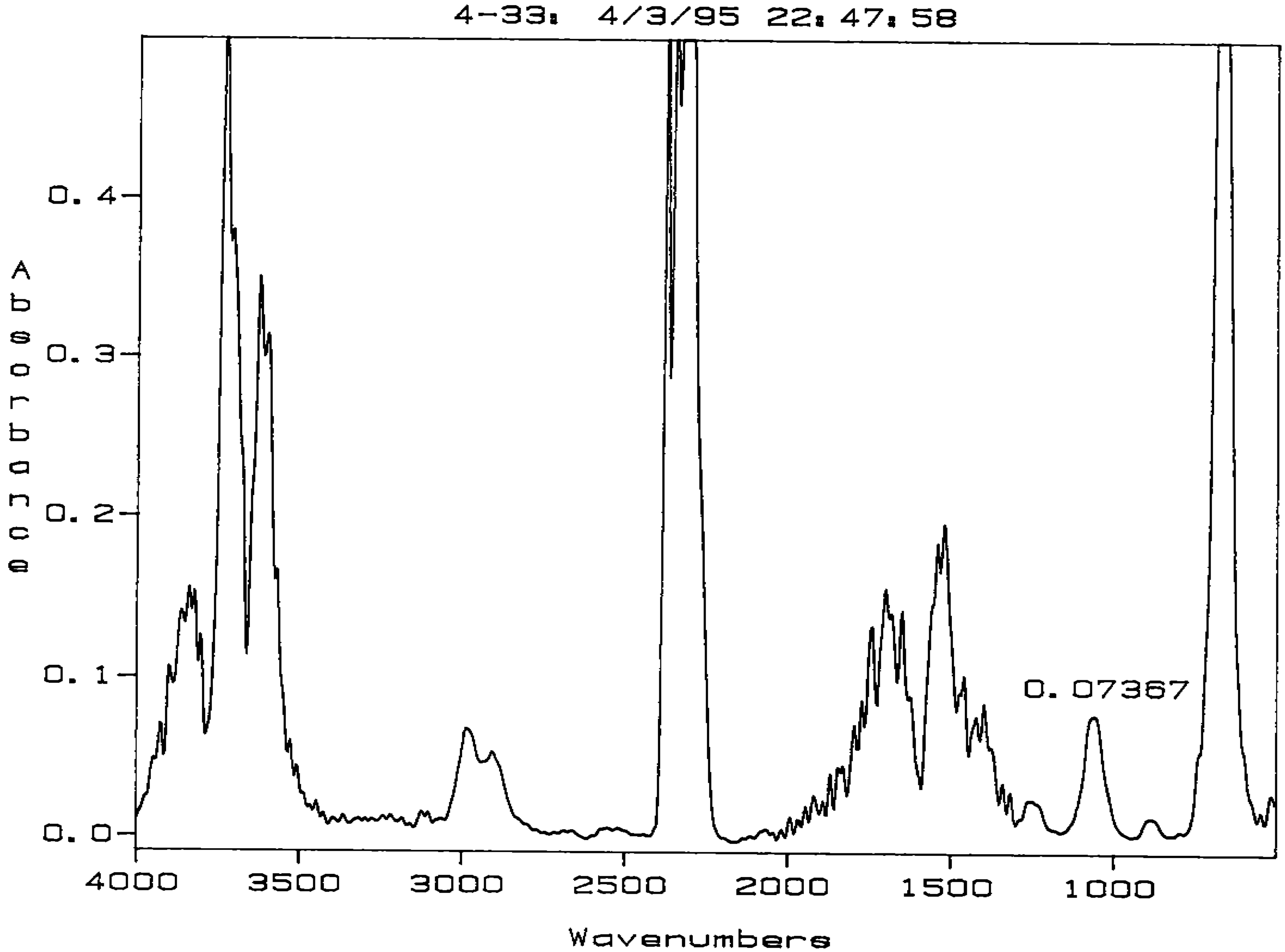

4-29: 4/3/95 22:41:05
0.4
0.3
0.2
0.1
0.0
Absorbance
0.07083
4000
3500
3000
2500
2000
1500
1000
Wavenumbers



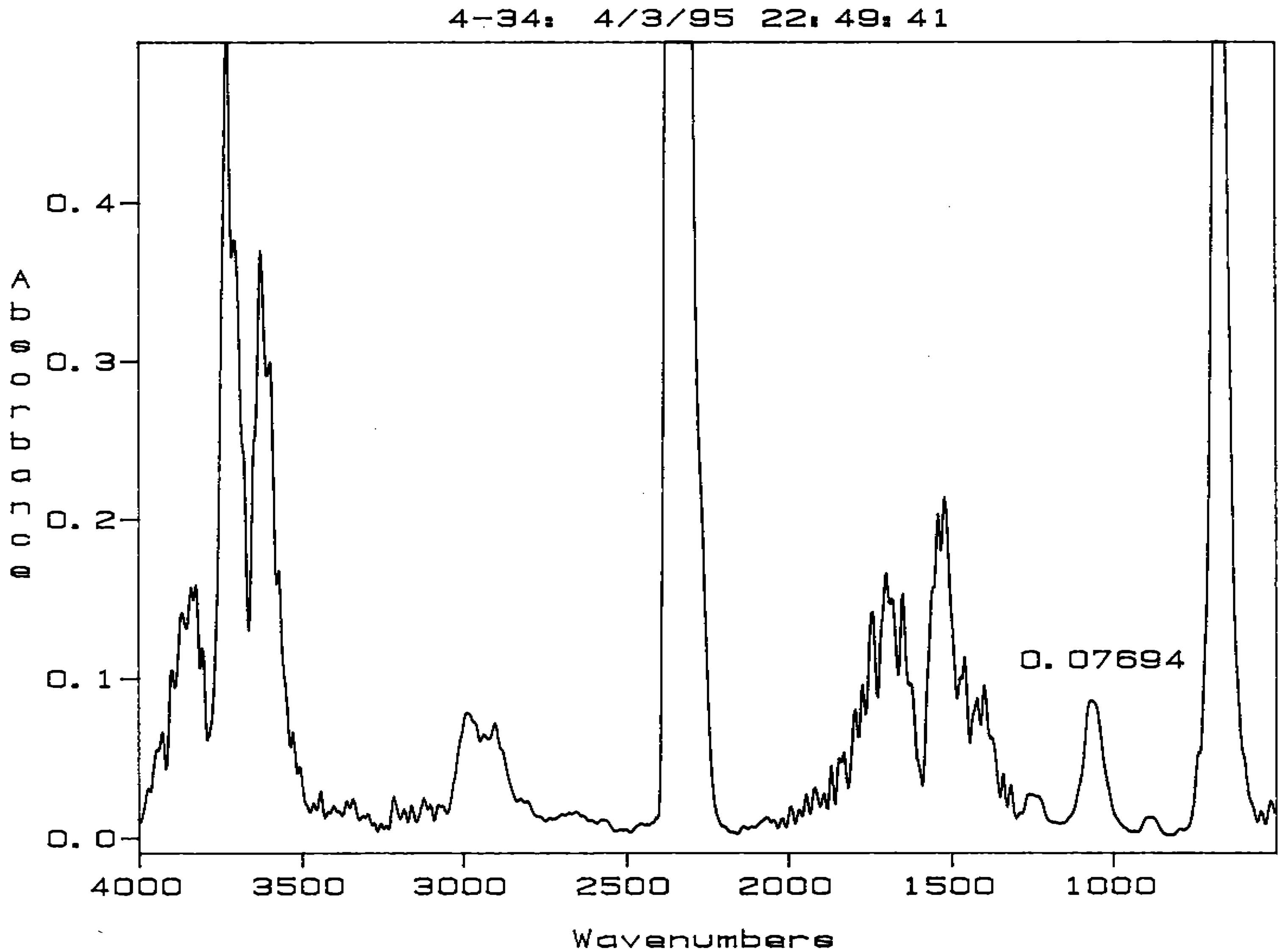
4-30: 4/3/95 22:42:49
Absorbance
0.4
0.3
0.2
0.1
0.0
0.07299
4000
3500
3000
2500
2000
1500
1000
Wavenumbers

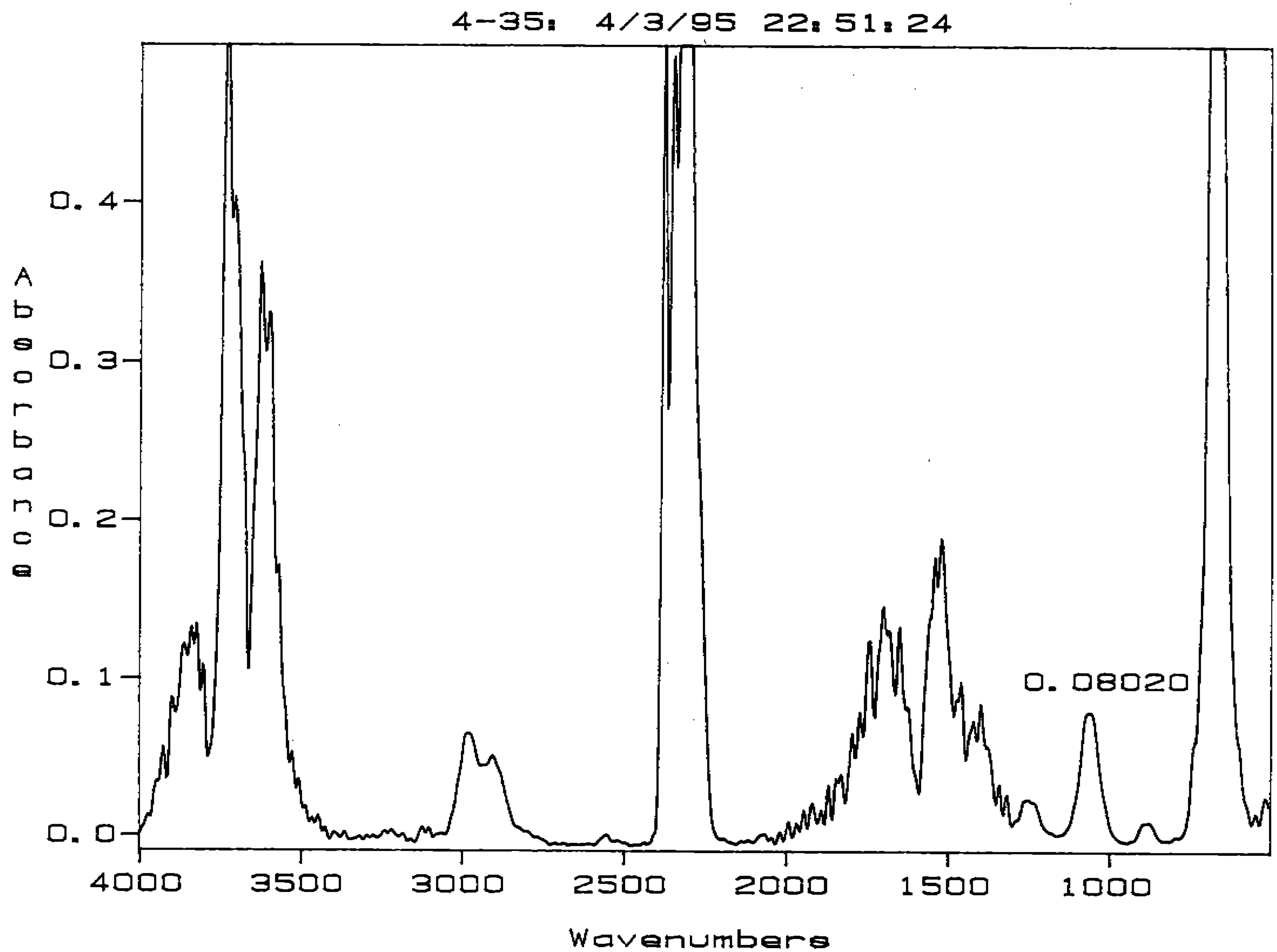

4-31: 4/3/95 22:44:33
Absorbance
0.4
0.3
0.2
0.1
0.0
4000
3500
3000
2500
2000
1500
1000
Wavenumbers
0.08588

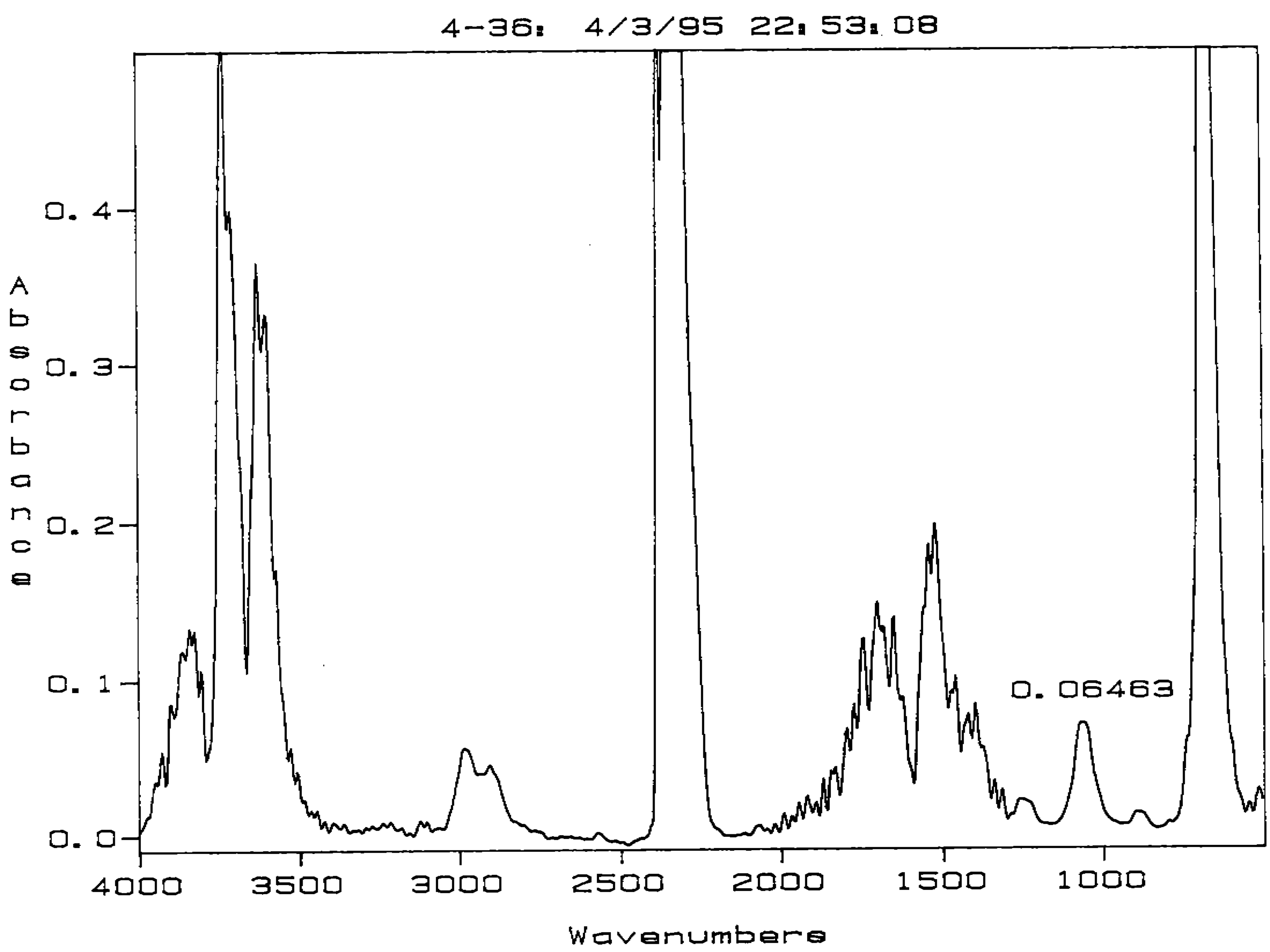

4-32: 4/3/95 22: 46: 16
Absorbance
0. 0
0. 1
0. 2
0. 3
0. 4
0. 07345
4000
3500
3000
2500
2000
1500
1000
Wavenumbers



4-33: 4/3/95 22:47:58
Absorbance
0.4
0.3
0.2
0.1
0.0
0.07367
4000
3500
3000
2500
2000
1500
1000
Wavenumbers

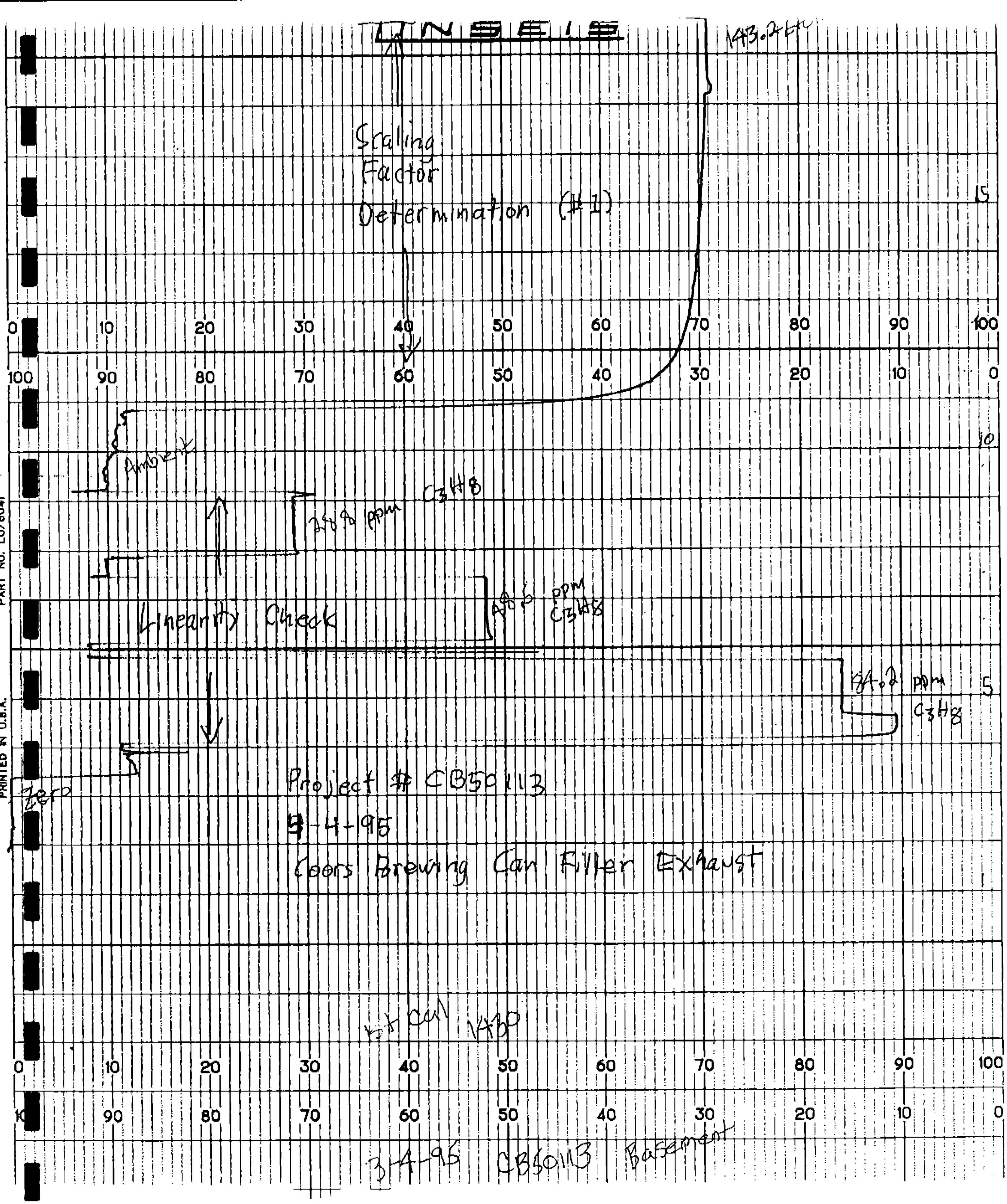

4-34: 4/3/95 22: 49: 41
Absorbance
0. 4
0. 3
0. 2
0. 1
0. 0
0. 07694
4000
3500
3000
2500
2000
1500
1000
Wavenumbers

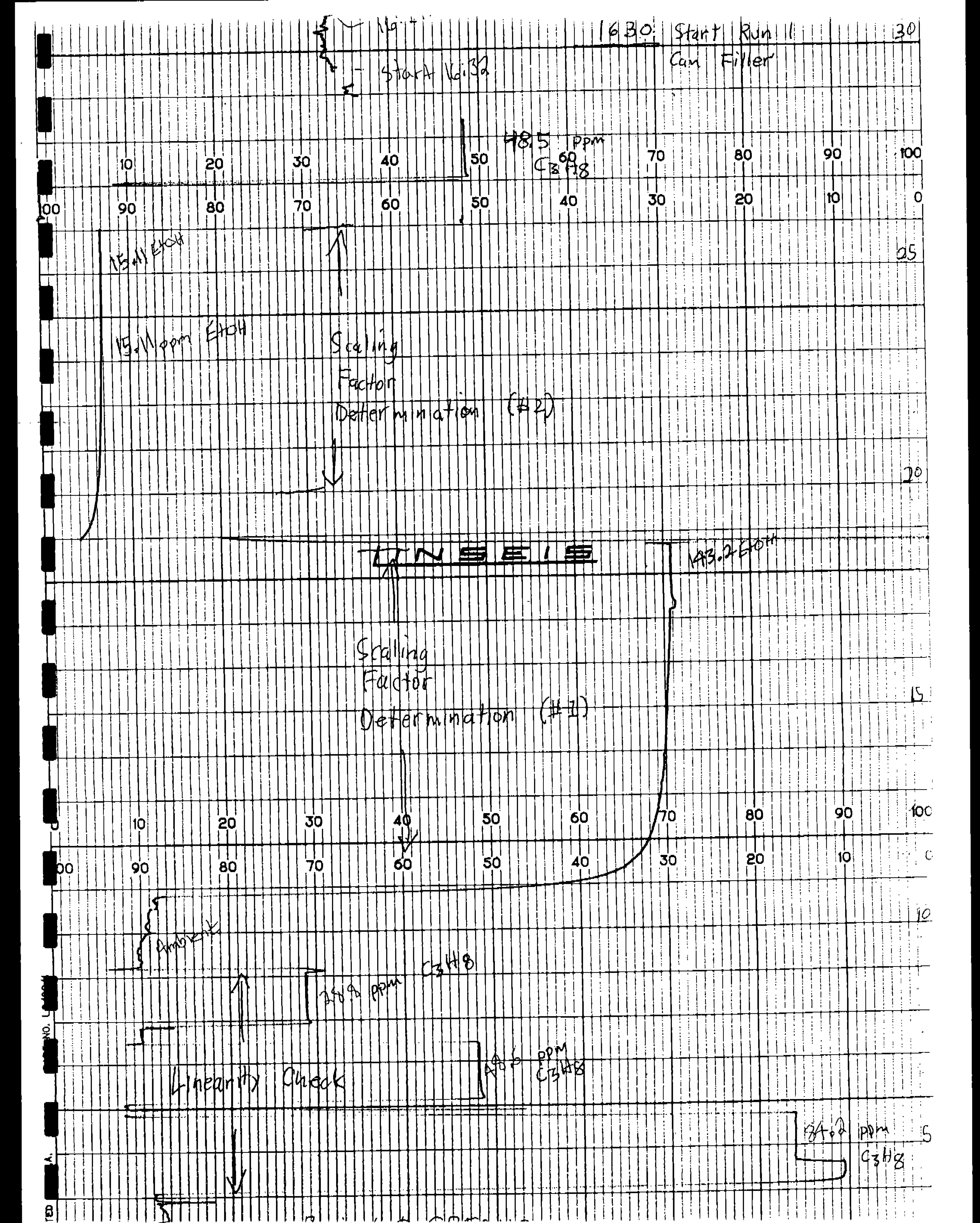

4-35: 4/3/95 22:51:24
0.4
0.3
0.2
0.1
0.0
Absorbance
0.08020
4000
3500
3000
2500
2000
1500
1000
Wavenumbers


4-36: 4/3/95 22:53:08
Absorbance
0.0
0.1
0.2
0.3
0.4
0.06463
4000
3500
3000
2500
2000
1500
1000
Wavenumbers

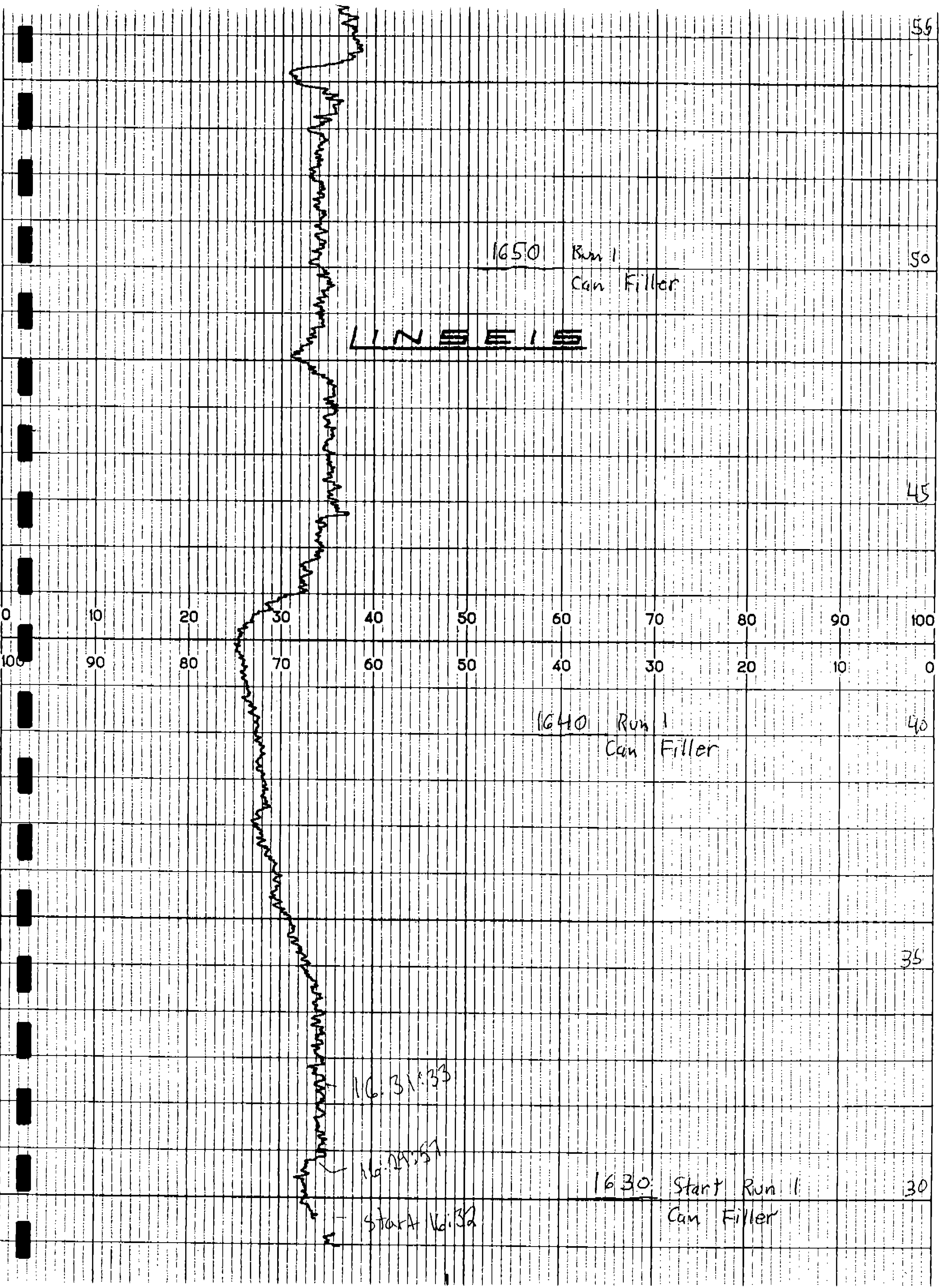
Method 25A Strip Chart Data
Total VOCs

4-4-95 : Can Filler Exhaust

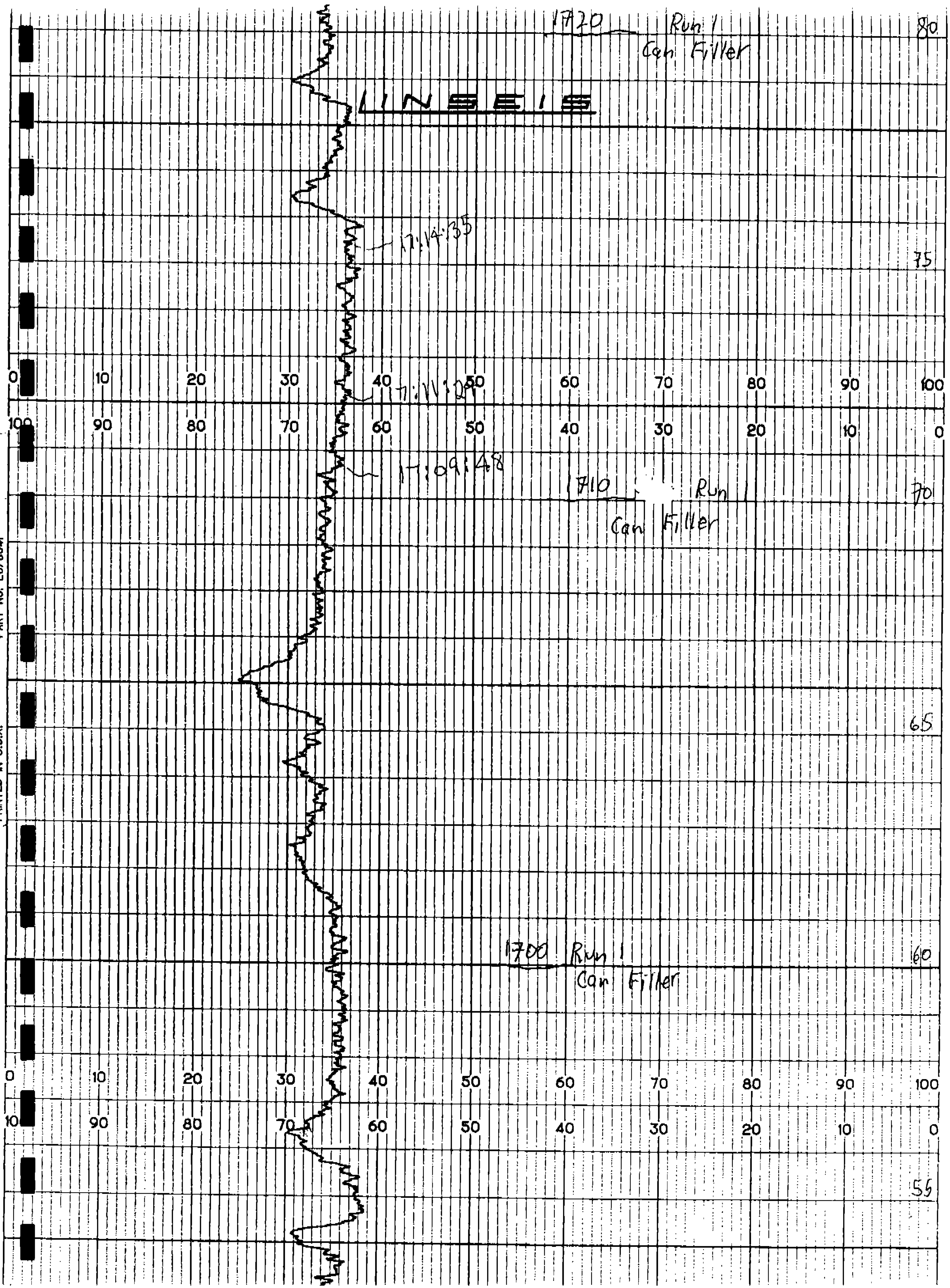

LINSEIS
Scaling Factor Determination (#1)
Ambient
288 ppm C3H8
406 ppm C3H8
Linearity Check
94.2 ppm C3H8
Zero
Project # CB50113
3-4-95
Coors Brewing Can Filler Exhaust
3-4-95 CB50113 Basement
PRINTED IN U.S.A.
PART NO. L076041

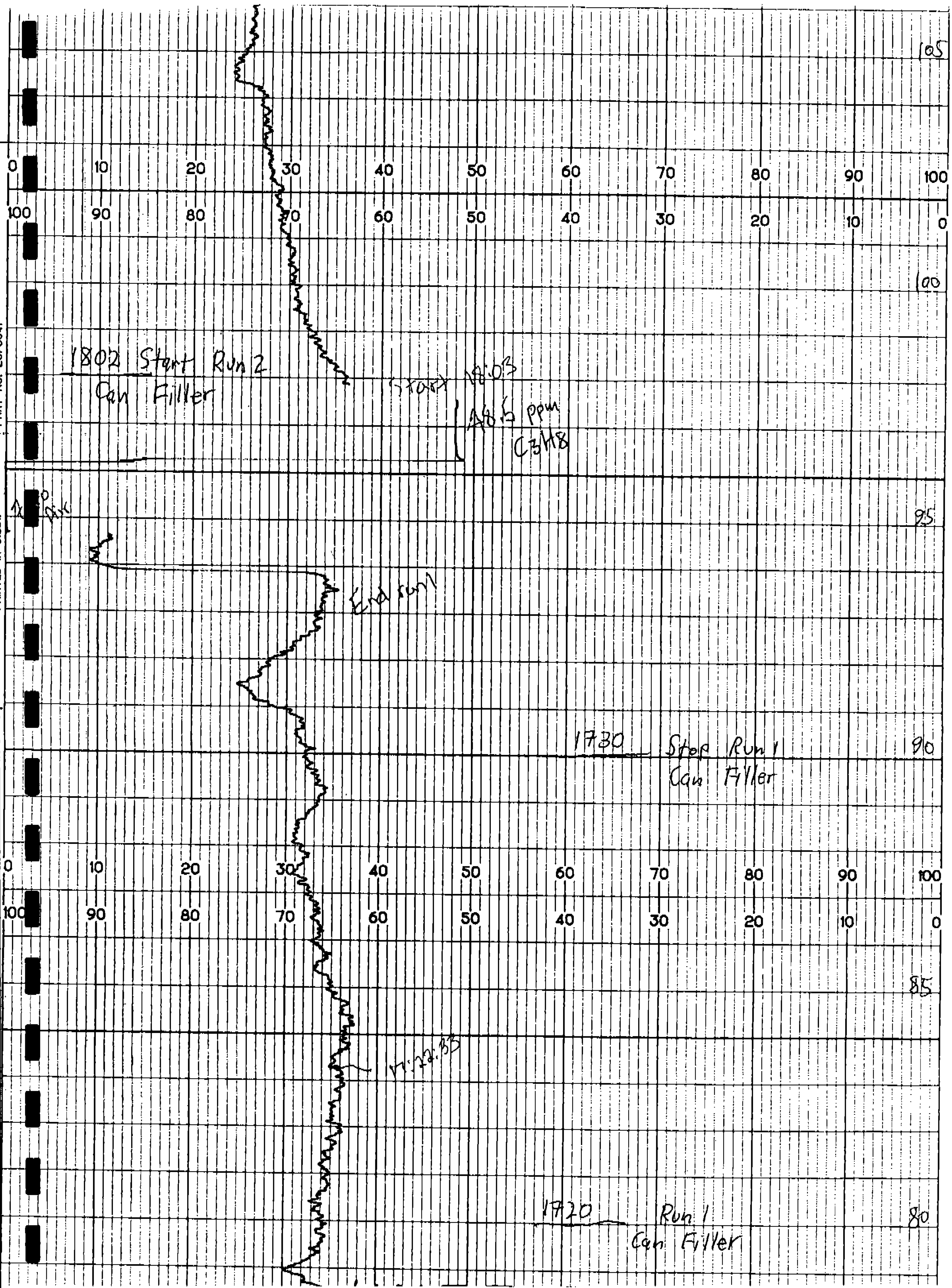


1630 Start Run 1
Can Filler
Start 16:32
48.5 ppm
C3H8
15.11 ppm EtOH
Scaling
Factor
Determination (#2)
LINSEIS
143.2 EtOH
Scaling
Factor
Determination (#1)
Ambient
ppm C3H8
Linearity Check
ppm
C3H8
34.2 ppm
C3H8

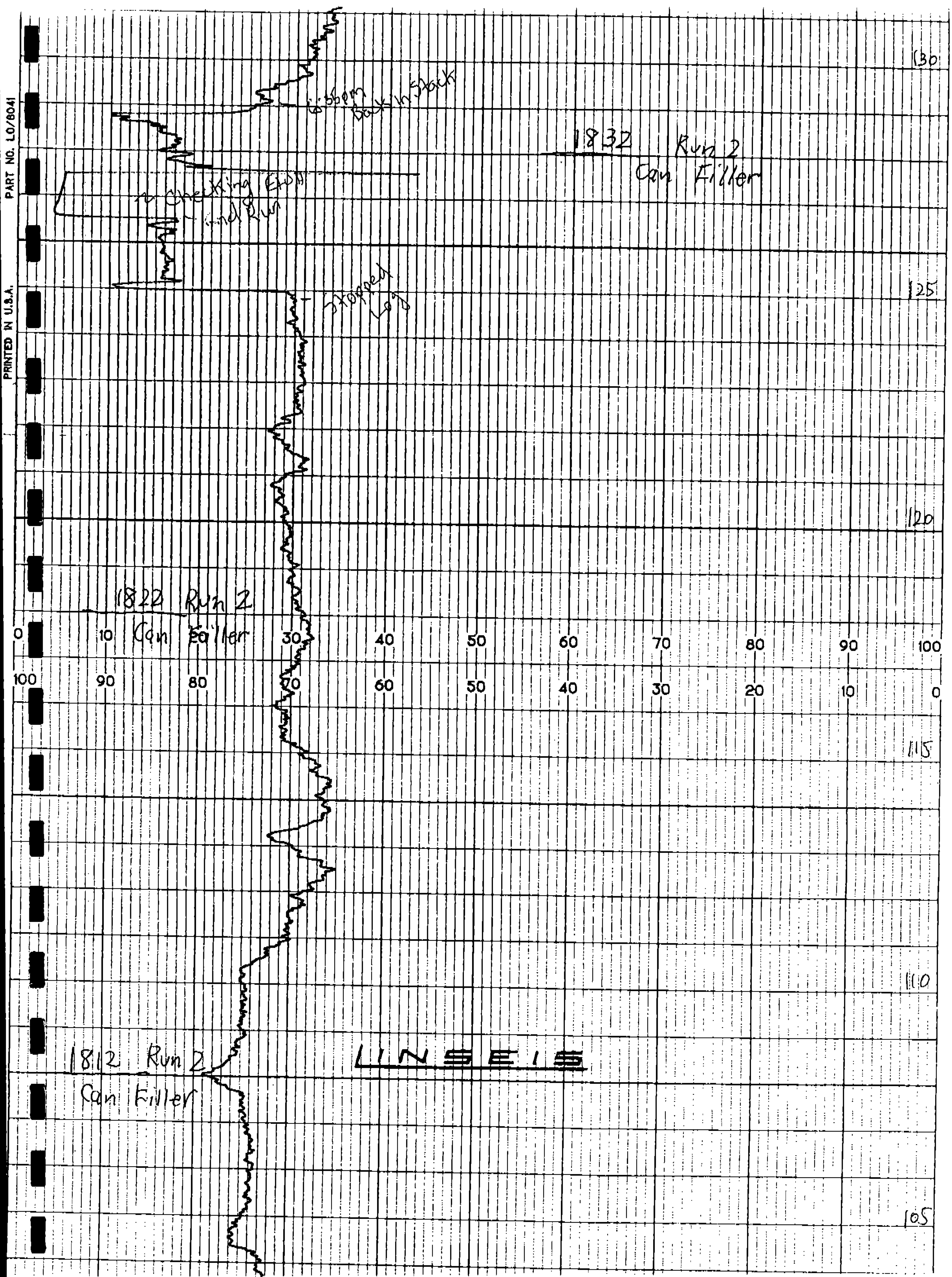


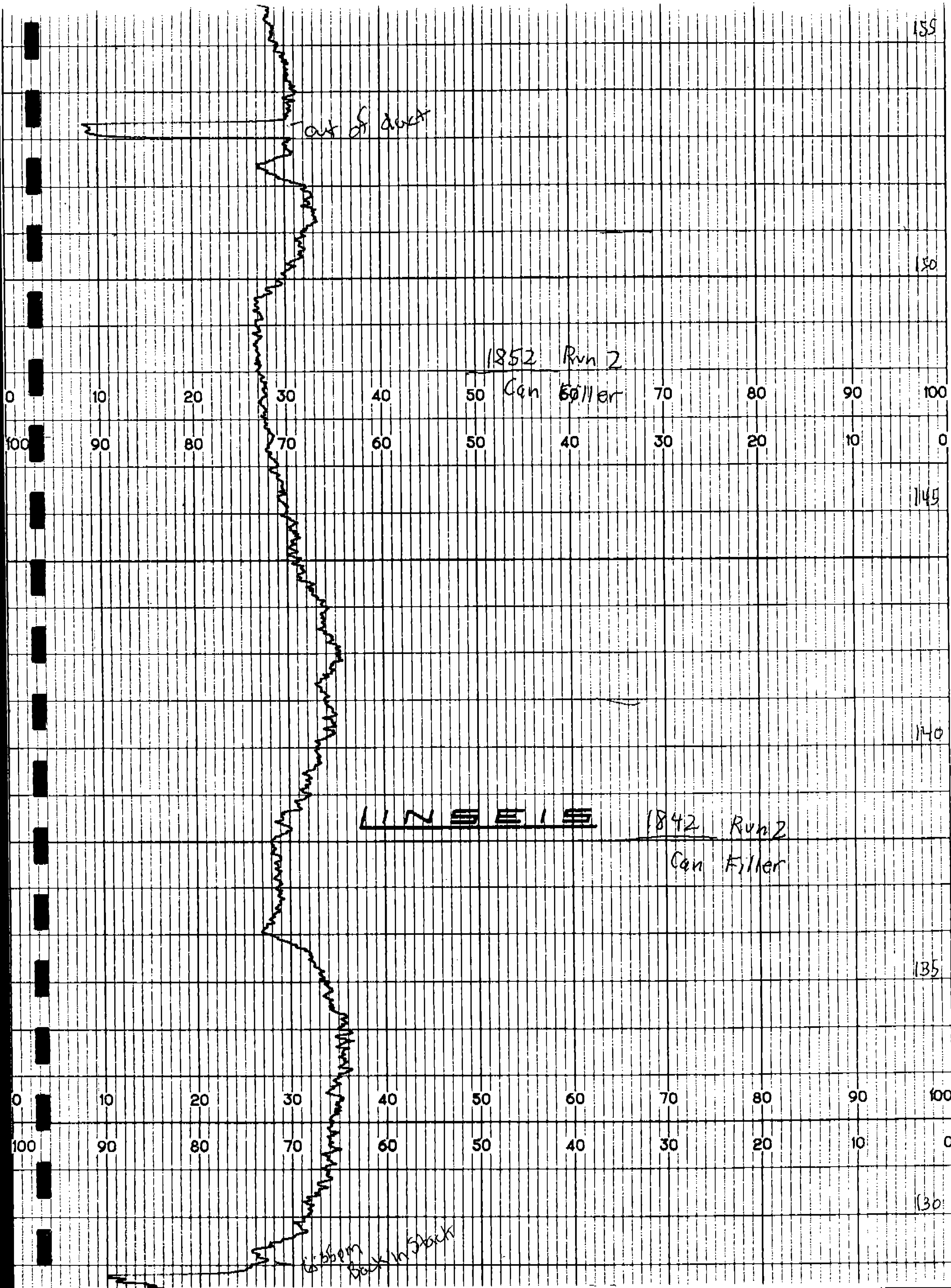
56
1650 Run 1
Can Filler
50
LINSEIS
45
0 10 20 30 40 50 60 70 80 90 100
100 90 80 70 60 50 40 30 20 10 0
1640 Run 1
Can Filler
40
35
16:31:33
1630 Start Run 1
Can Filler
30
Start 16:32


LINSEIS
1720 Run 1
Can Filler
80
17:14:35
75
0 10 20 30 40 50 60 70 80 90 100
17:11:29
100 90 80 70 60 50 40 30 20 10 0
17:09:48
1710 Run 1
Can Filler
70
65
1700 Run 1
Can Filler
60
0 10 20 30 40 50 60 70 80 90 100
10 90 80 70 60 50 40 30 20 10 0
55
PRINTED IN U.S.A.
PART NO. L07604

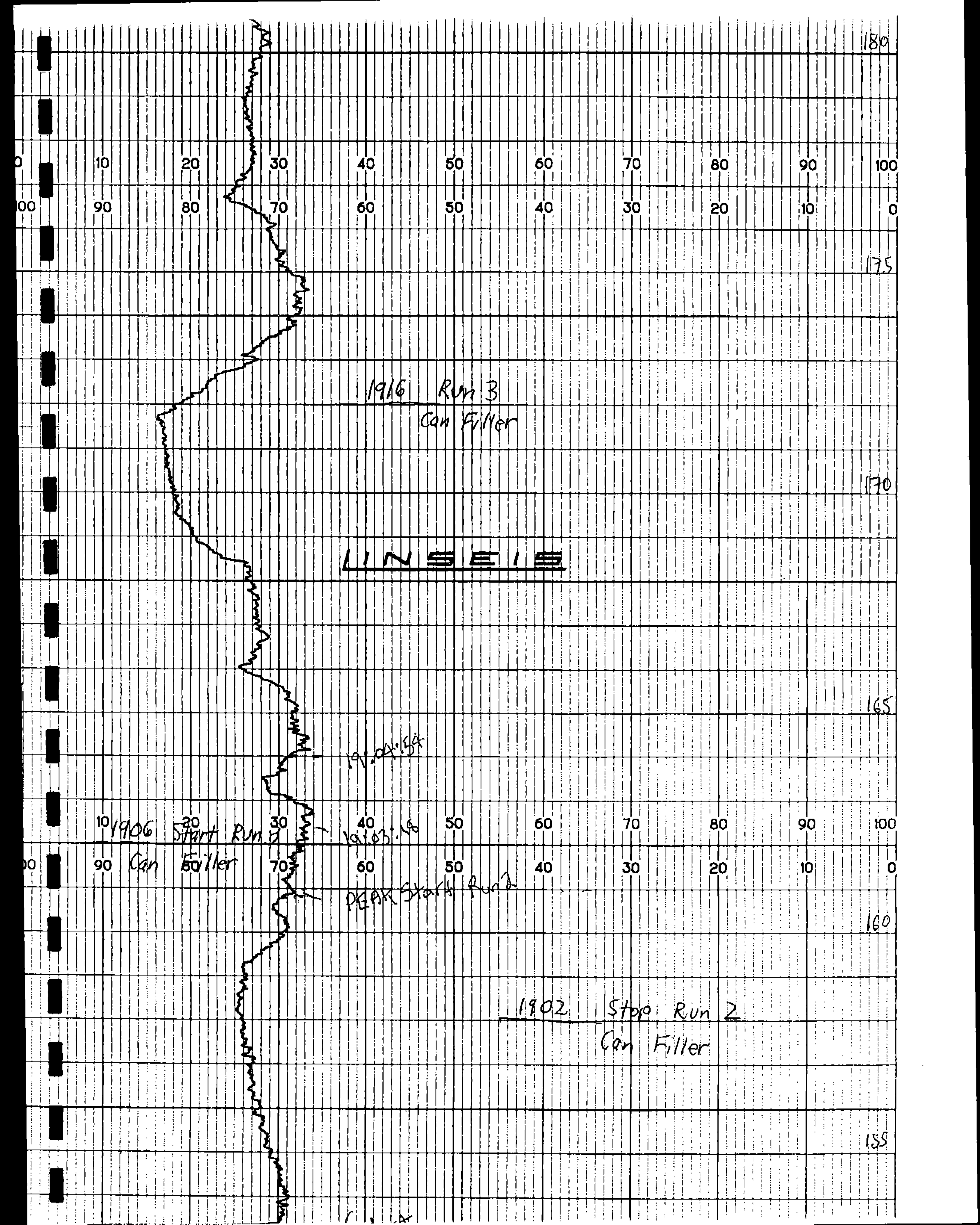


105
0 10 20 30 40 50 60 70 80 90 100
100 90 80 70 60 50 40 30 20 10 0
100
1802 Start Run 2
Can Filler
Start 18:03
48.6 ppm
C3H8
95
End run
1730 Stop Run 1
Can Filler
90
0 10 20 30 40 50 60 70 80 90 100
100 90 80 70 60 50 40 30 20 10 0
85
17:22:33
1720 Run 1
Can Filler
80

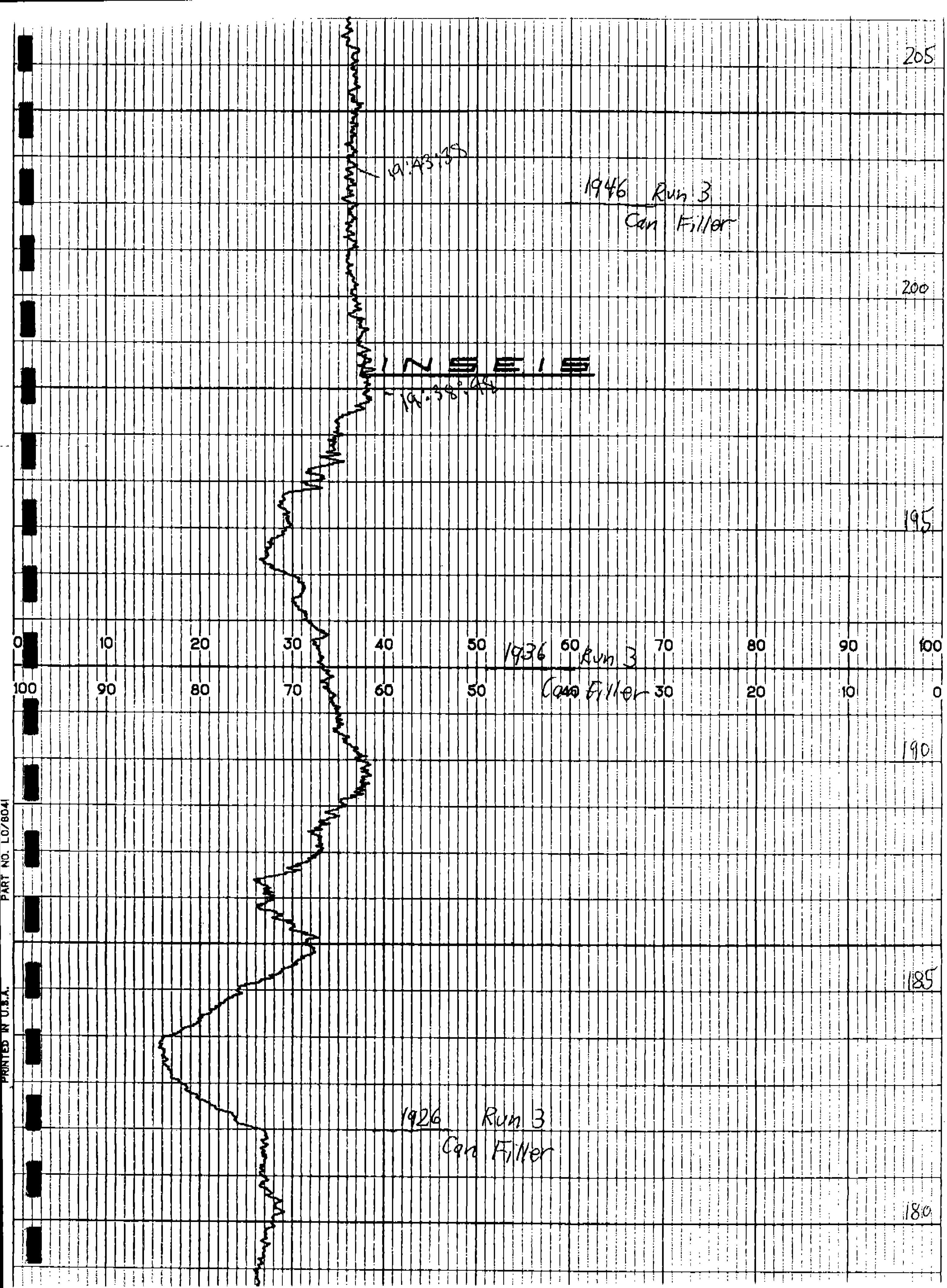

PART NO. LO/6041
PRINTED IN U.S.A.
130
6:35pm Back in Stack
1832 Run 2
Can Filler
Checking Exxon 2nd Run
Stopped Log
125
120
1822 Run 2
Can Filler
0 10 20 30 40 50 60 70 80 90 100
100 90 80 70 60 50 40 30 20 10 0
115
110
1812 Run 2
Can Filler
LINSEIS
105

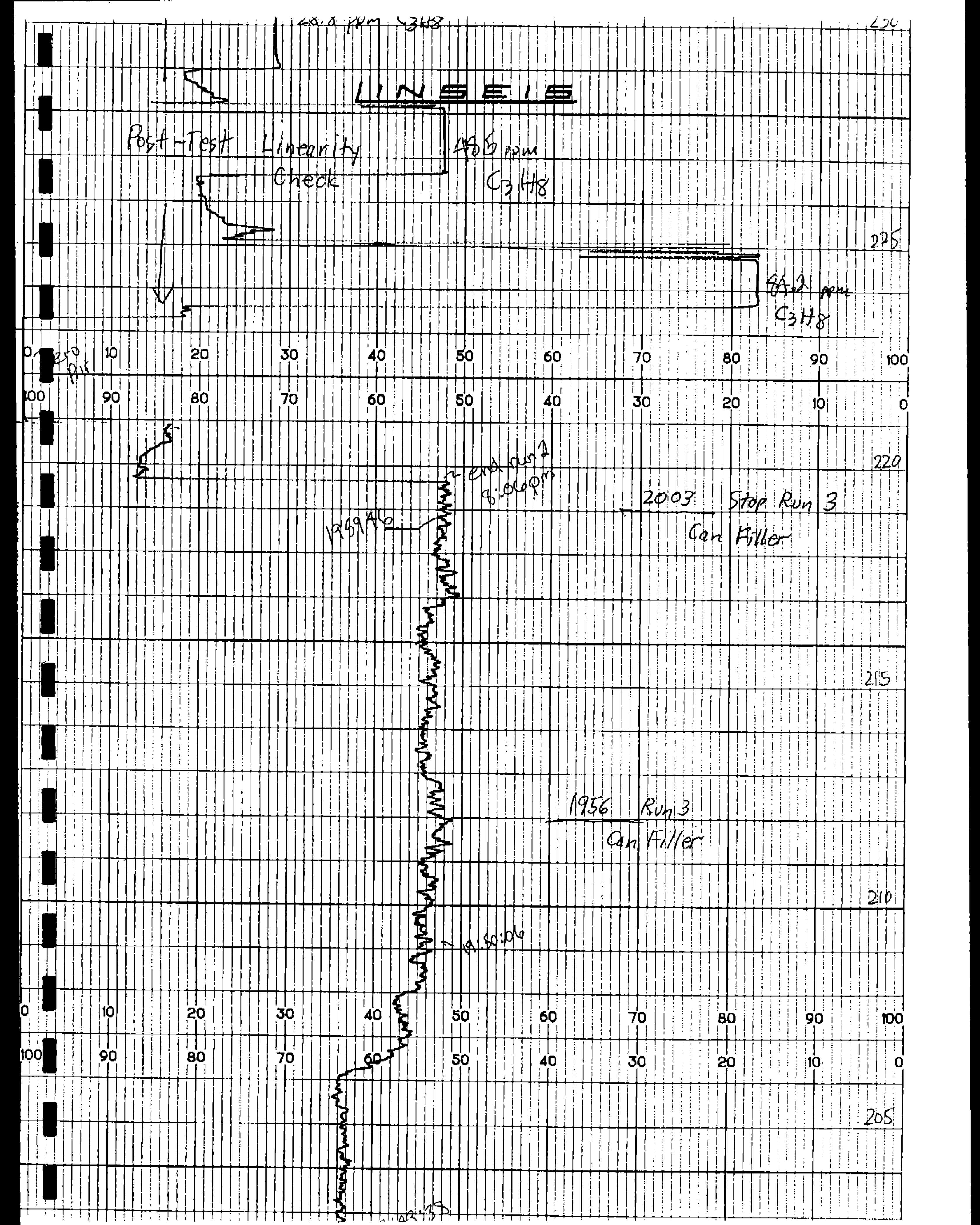


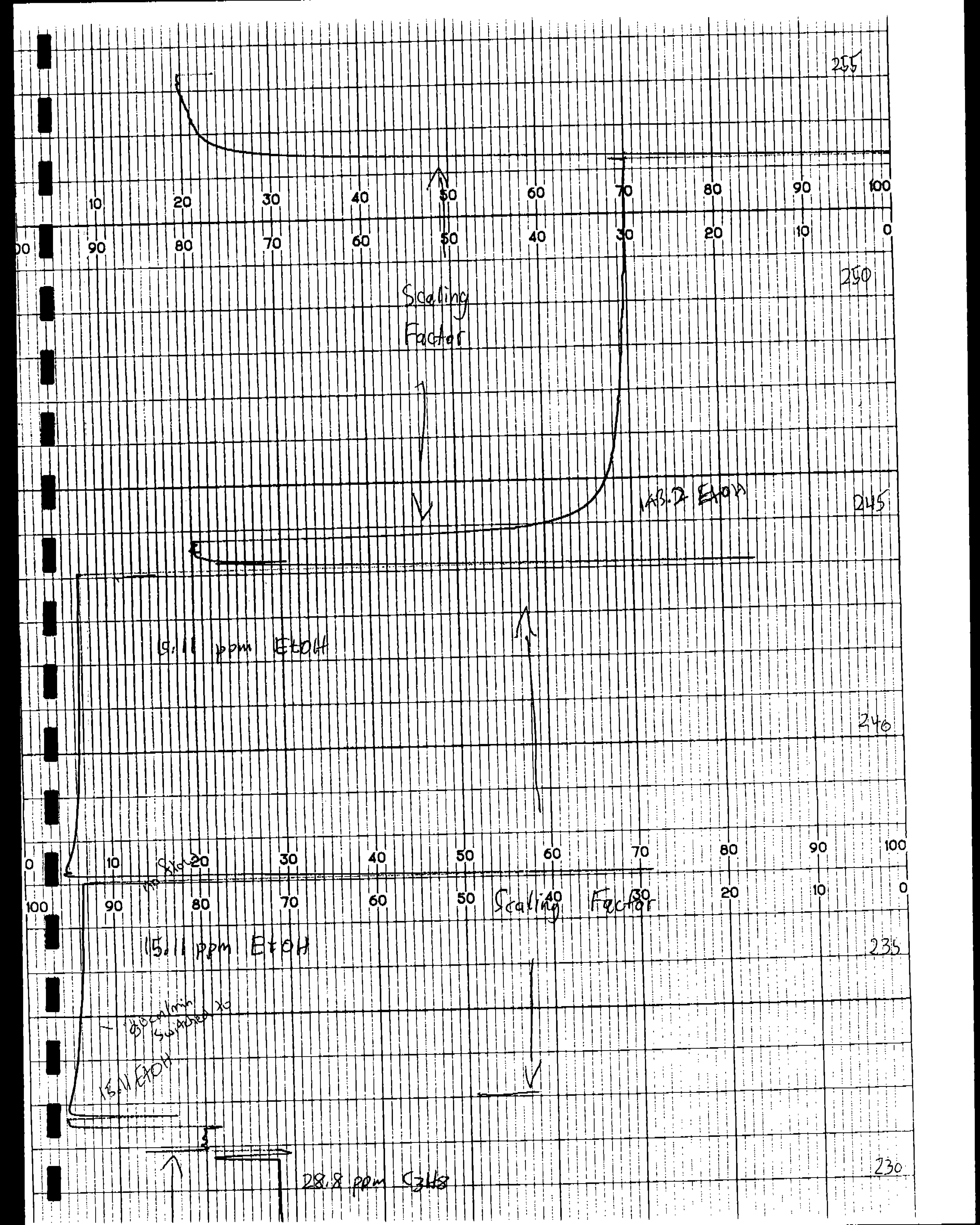
155
out of duct
150
1852 Run 2
Can Filler
0 10 20 30 40 50 60 70 80 90 100
100 90 80 70 60 50 40 30 20 10 0
145
140
LINSEIS
1842 Run 2
Can Filler
135
0 10 20 30 40 50 60 70 80 90 100
100 90 80 70 60 50 40 30 20 10 0
130



180
0 10 20 30 40 50 60 70 80 90 100
100 90 80 70 60 50 40 30 20 10 0
175
1916 Run 3
Can Filler
170
LINSEIS
165
19:04:54
1906 Start Run 3
Can Filler
19:03:46
PEAK Starts Run 2
160
1902 Stop Run 2
Can Filler
155


205
19:43:38
1946 Run 3
Can Filler
200
INSEIS
19:38:44
195
0 10 20 30 40 50 60 70 80 90 100
100 90 80 70 60 50 40 30 20 10 0
1936 Run 3
Can Filler
190
185
1926 Run 3
Can Filler
180
PART NO. L0/8041
PRINTED IN U.S.A.


LINSEIS
Post-Test Linearity Check
486 ppm C3H8
225
44.2 ppm C3H8
zero air
220
end run 2
8:06pm
1959 46
2003 Stop Run 3
Can Filler
215
1956 Run 3
Can Filler
210
19:30:06
205
0 10 20 30 40 50 60 70 80 90 100
100 90 80 70 60 50 40 30 20 10 0


255
Scaling Factor
250
143.2 EtOH
245
19.11 ppm EtOH
240
Scaling Factor
15.11 ppm EtOH
235
~ 800 cc/min switched to 15.11 EtOH
230
28.8 ppm C3H8

FTIR Spectra
Ethanol and Total VOCs

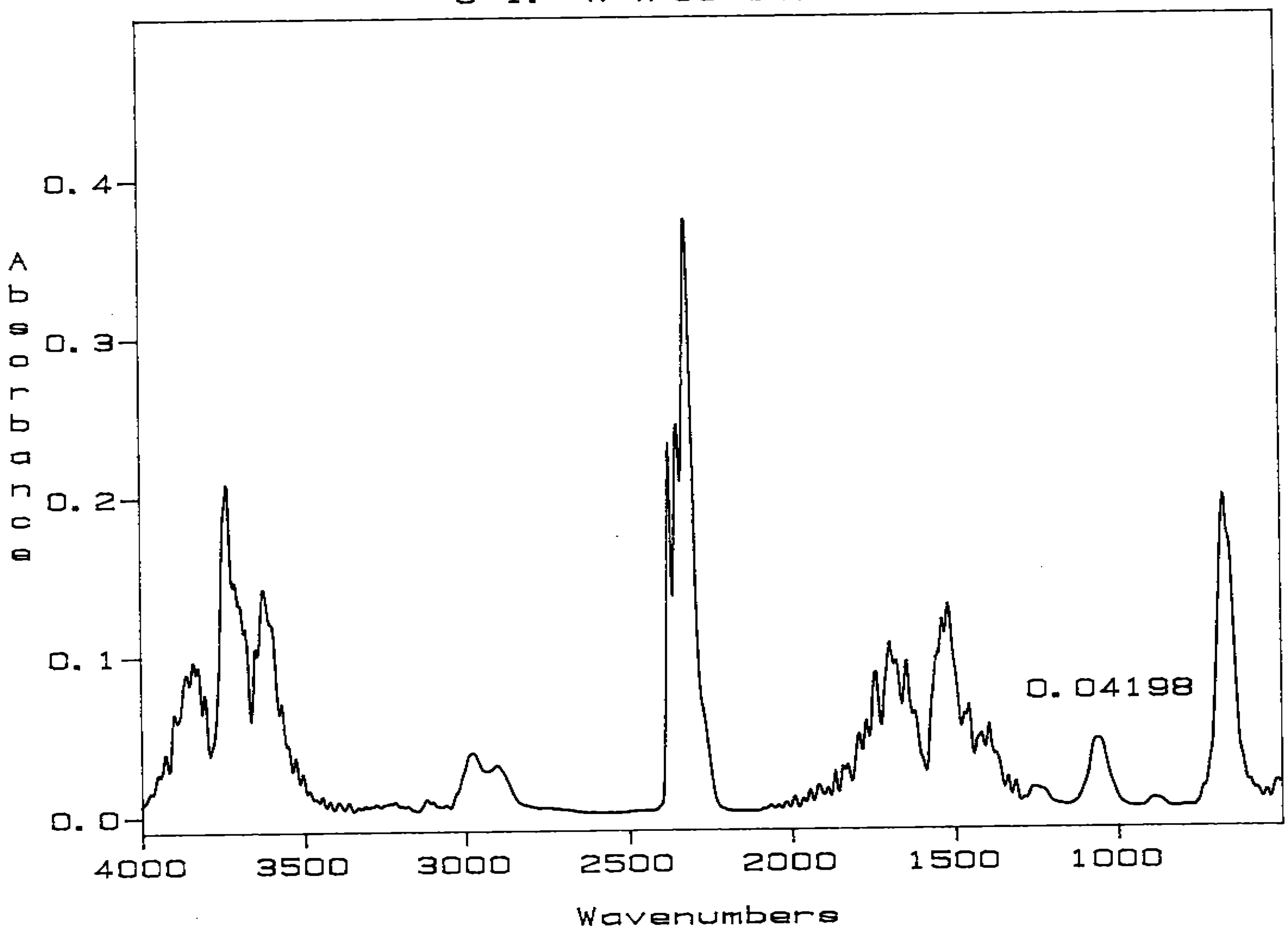
4-4-95 : Can Filler Exhaust

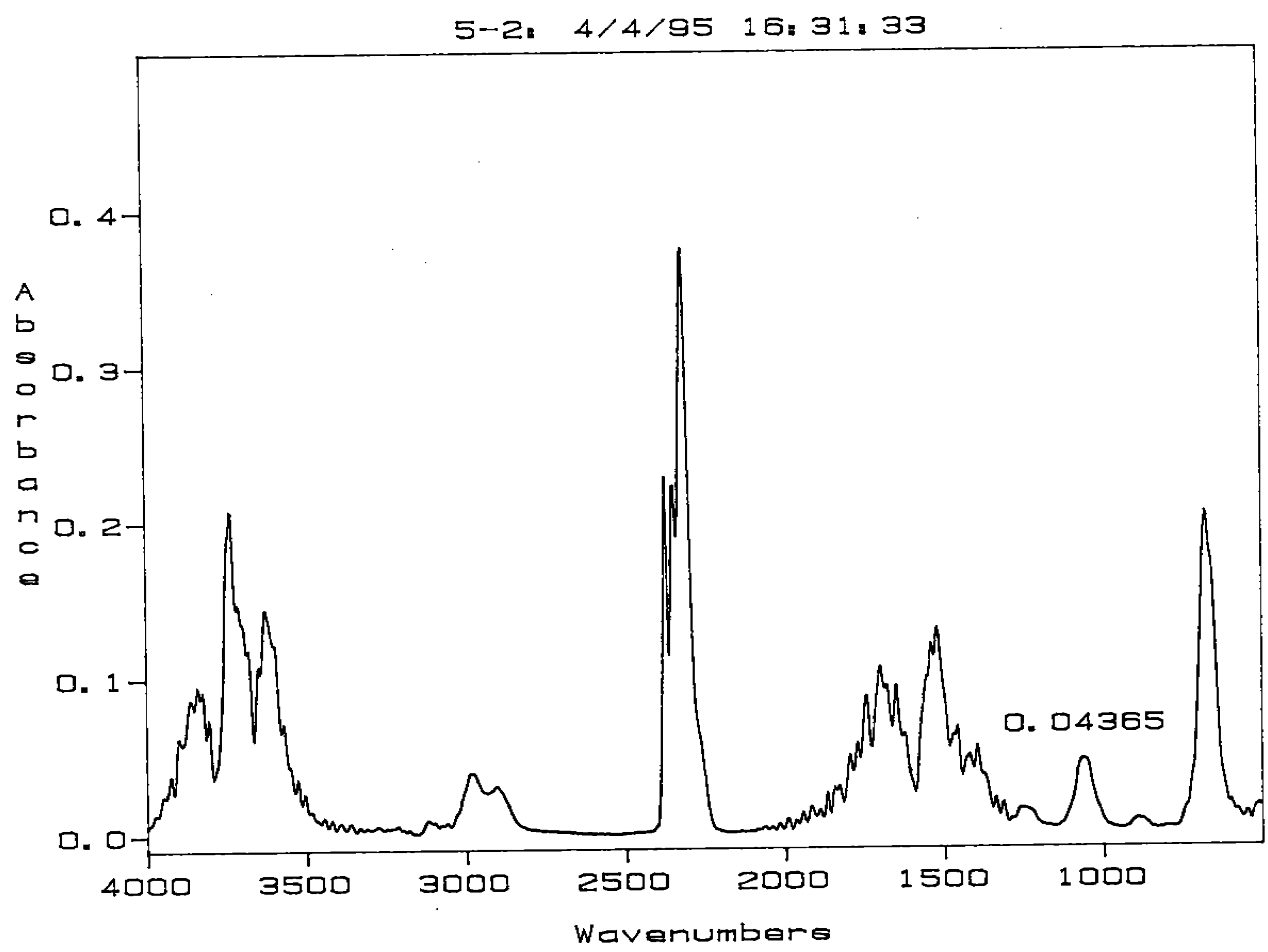
Cals for Coors Can line

ppm	mA
15.11	8.30
15.[illegible]1	8.51
15[illegible]1	9.11
14[illegible].2	86.02
143.2	85.62
14[illegible]2	86.39
14.[illegible]2	88.07
143.2	88.57
14[illegible]2	88.17

where mA = mili absorbance Units

5-1: 4/4/95 16:29:57




5-2: 4/4/95 16:31:33
Absorbance
0.0
0.1
0.2
0.3
0.4
0.04365
4000
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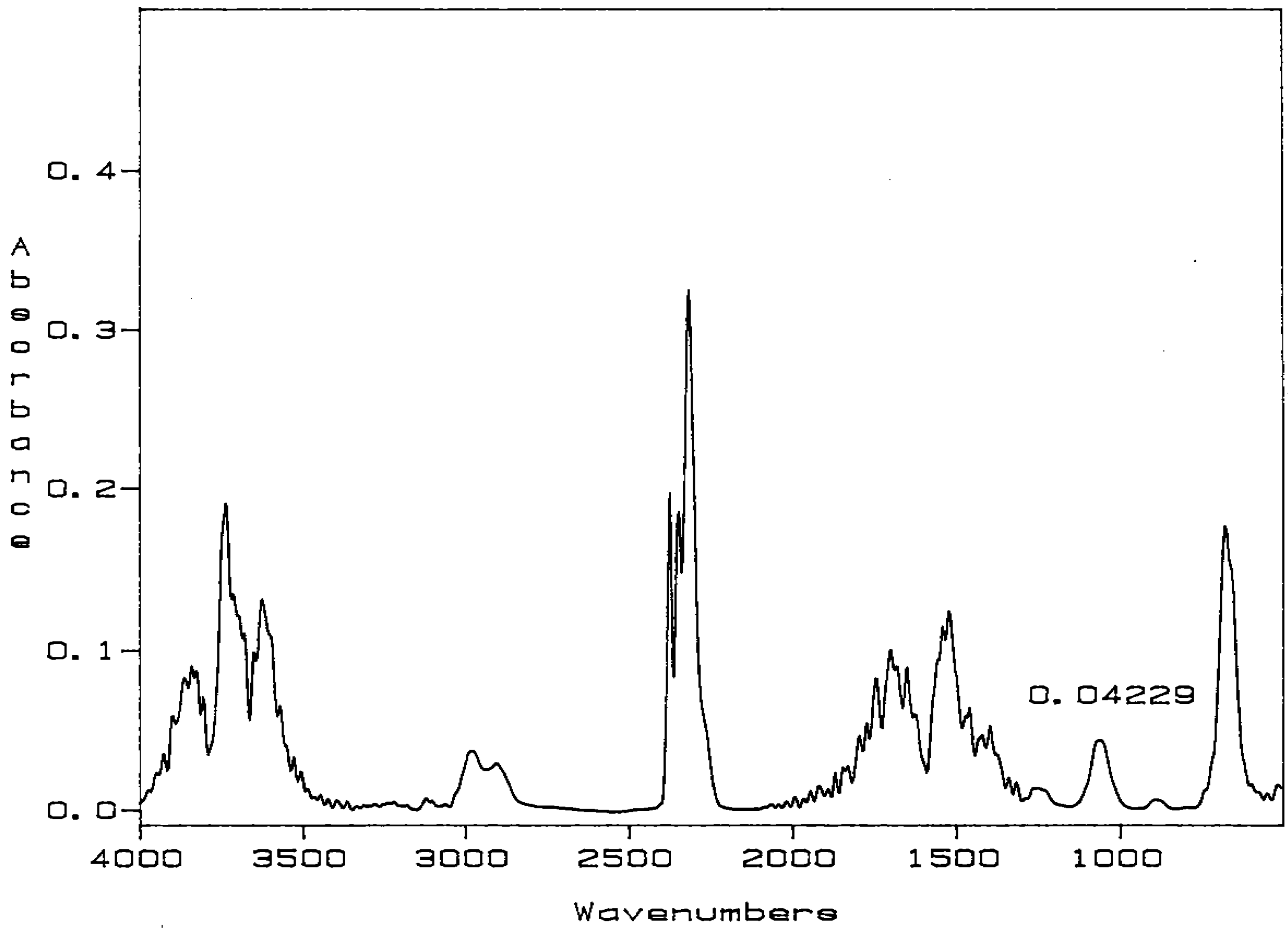
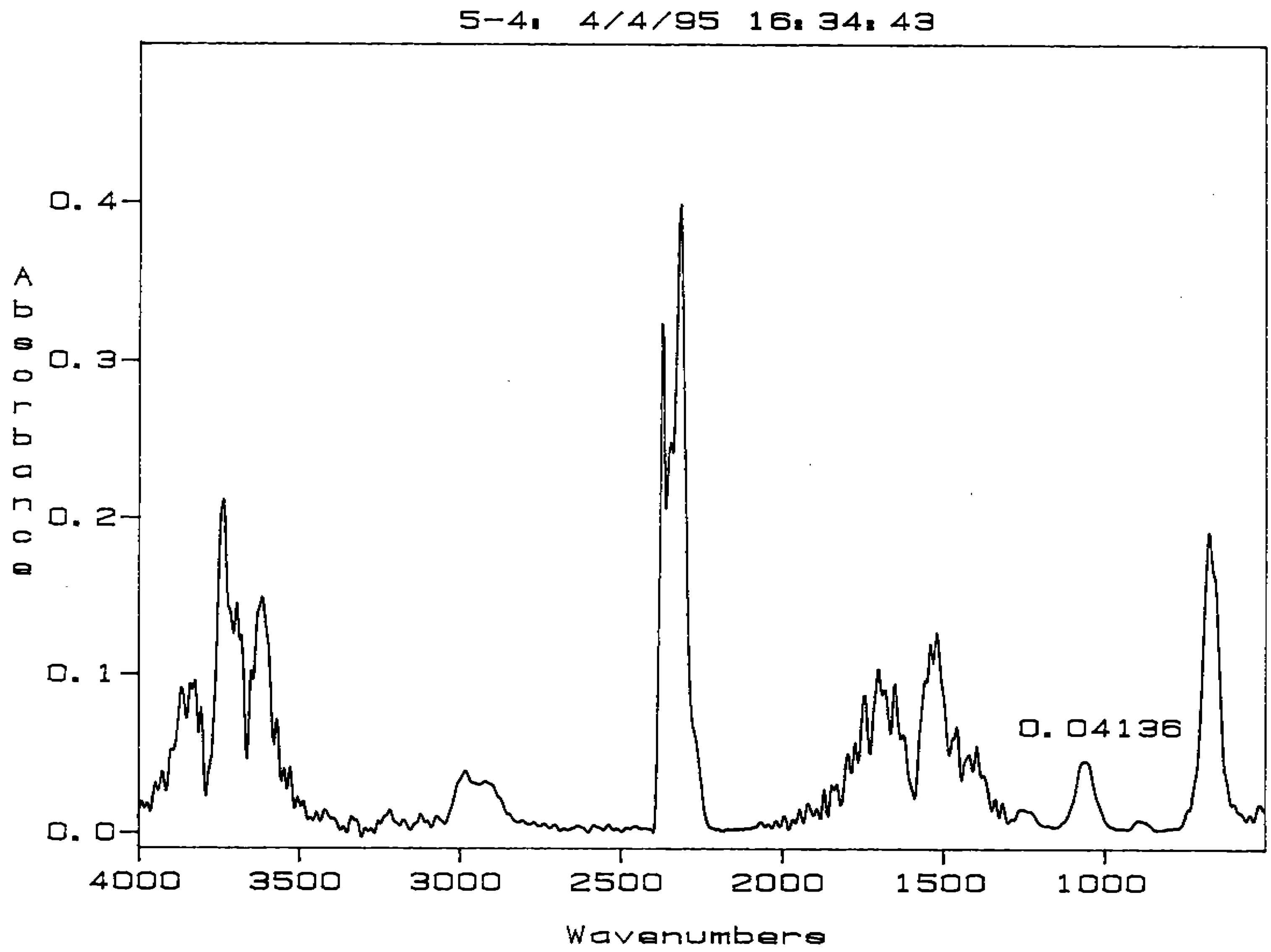
1000
Wavenumbers

5-3: 4/4/95 16:33:08




5-4: 4/4/95 16:34:43
Absorbance
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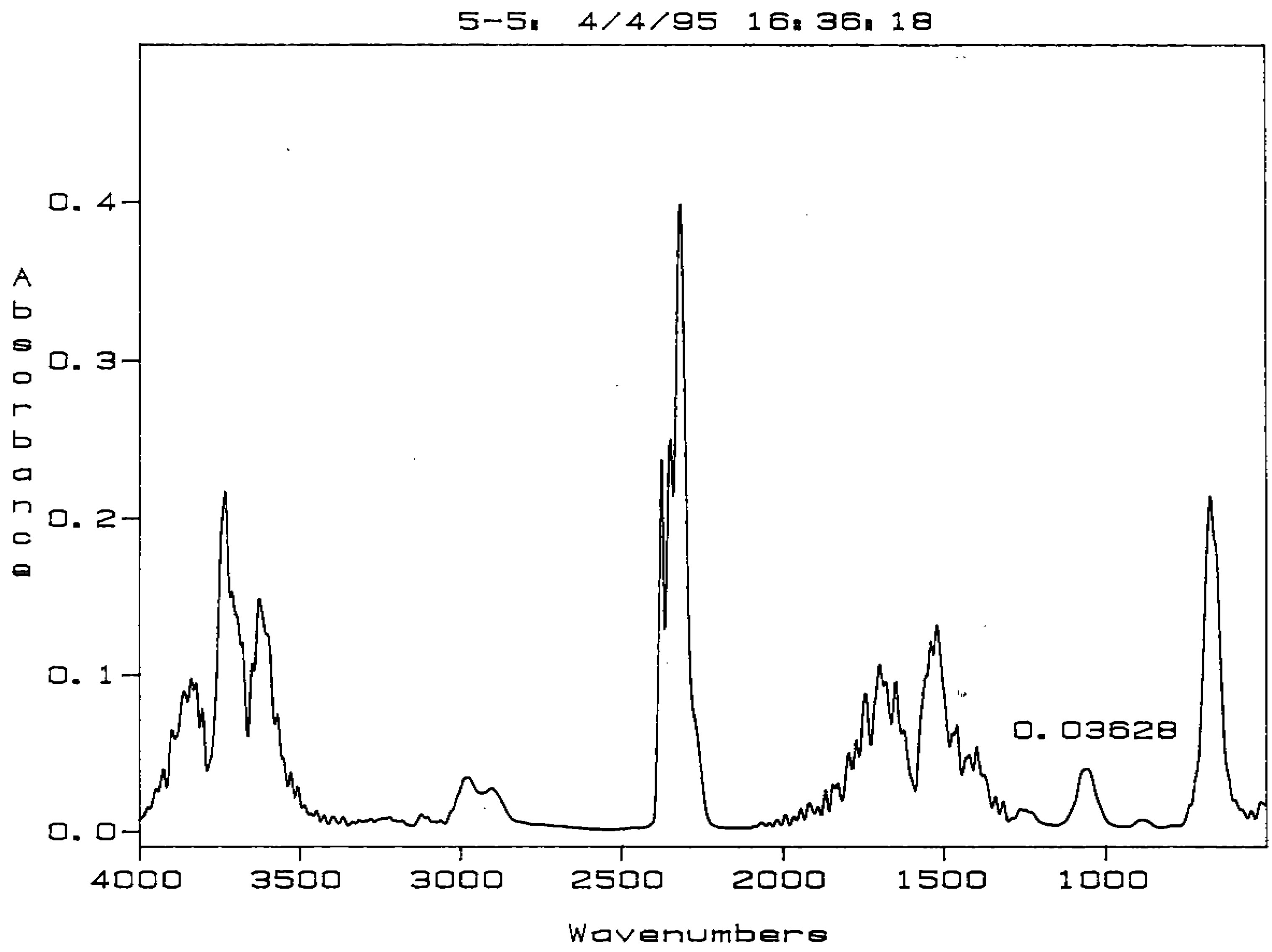
1000
Wavenumbers


5-5: 4/4/95 16:36:18
Absorbance
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0.1
0.0
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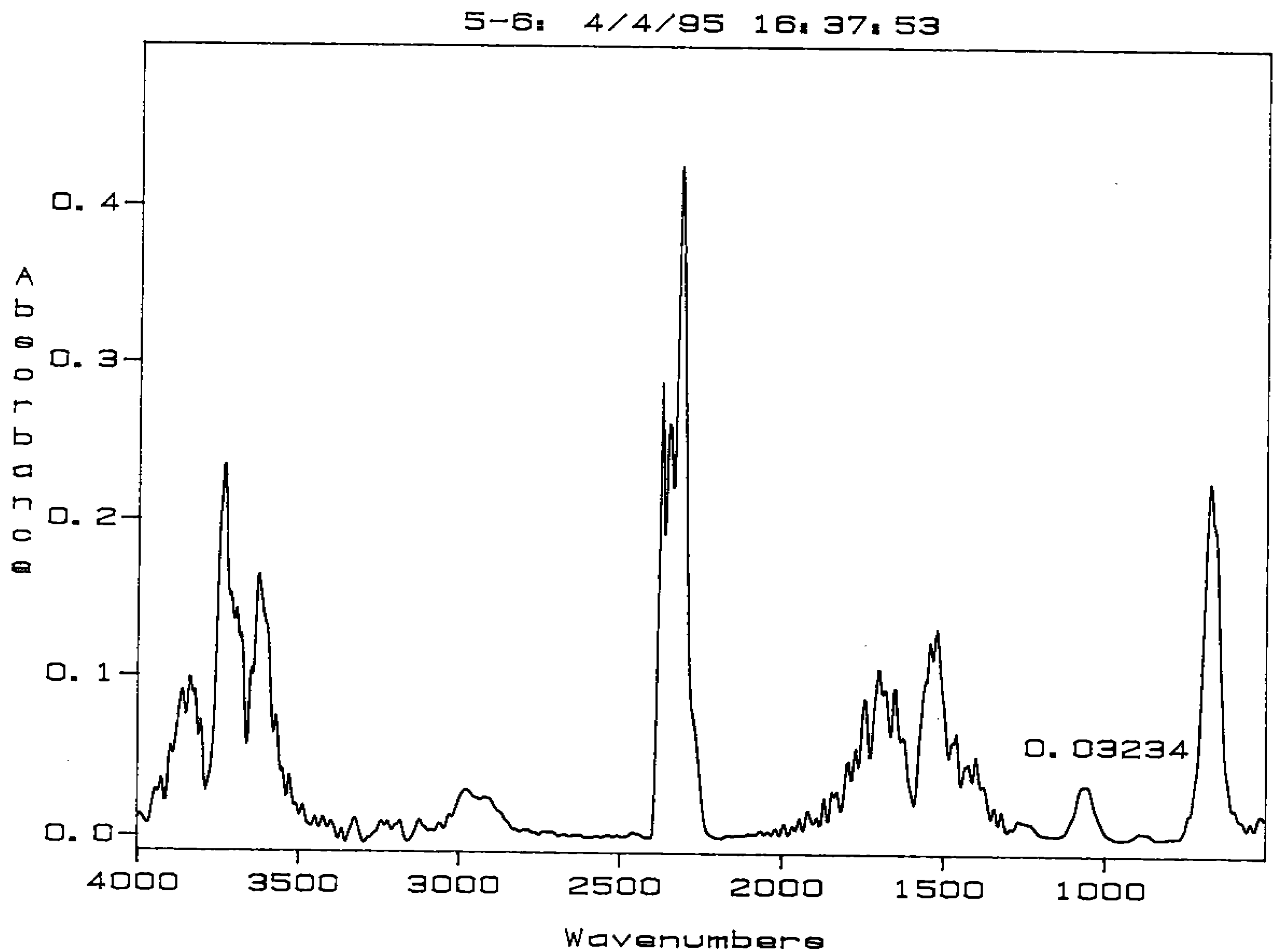
1500
1000
Wavenumbers


5-6: 4/4/95 16:37:53
Absorbance
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0.2
0.1
0.0
4000
3500
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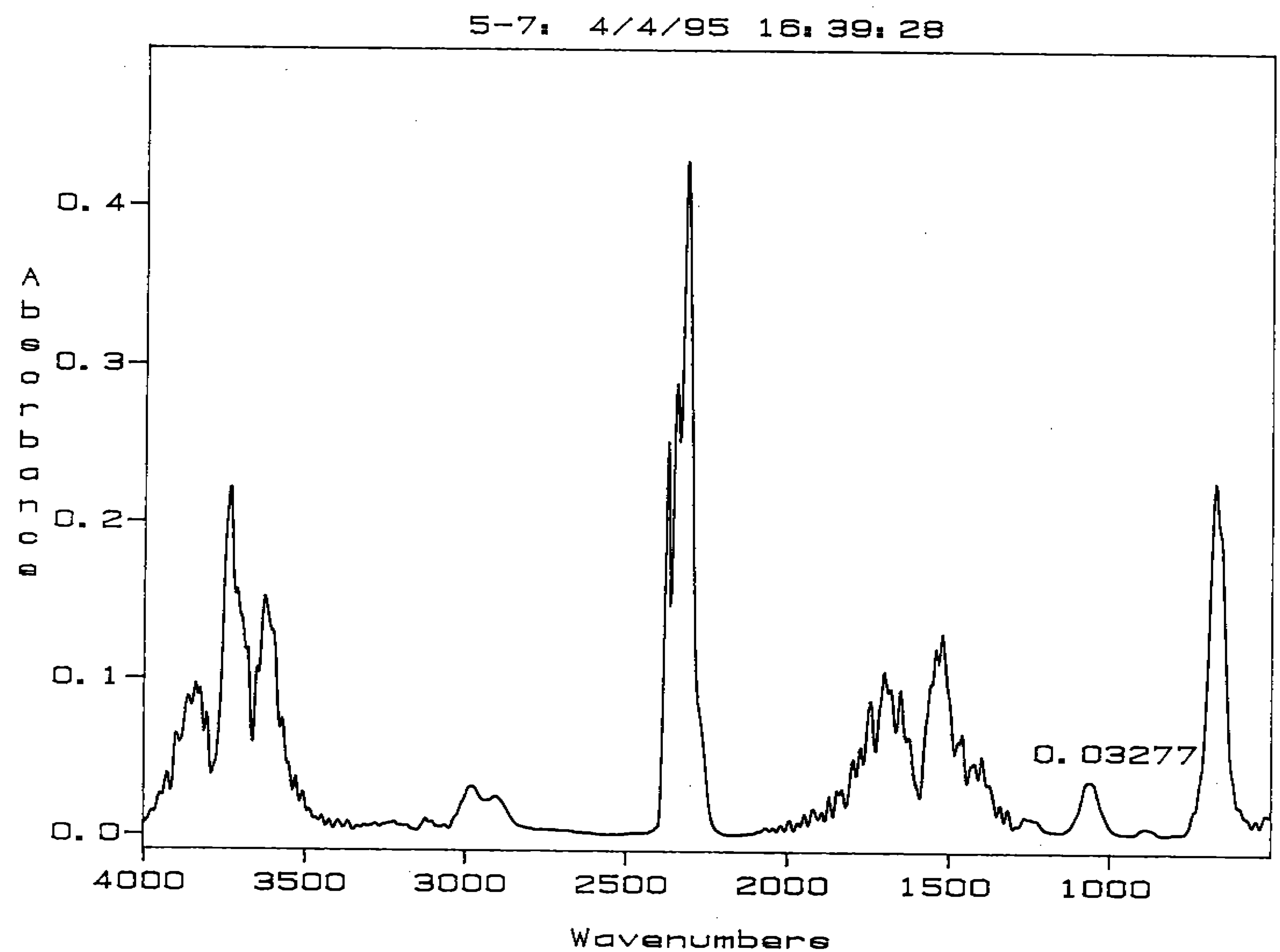
2500
2000
1500
1000
Wavenumbers
0.03234


5-7: 4/4/95 16:39:28
Absorbance
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0.1
0.0
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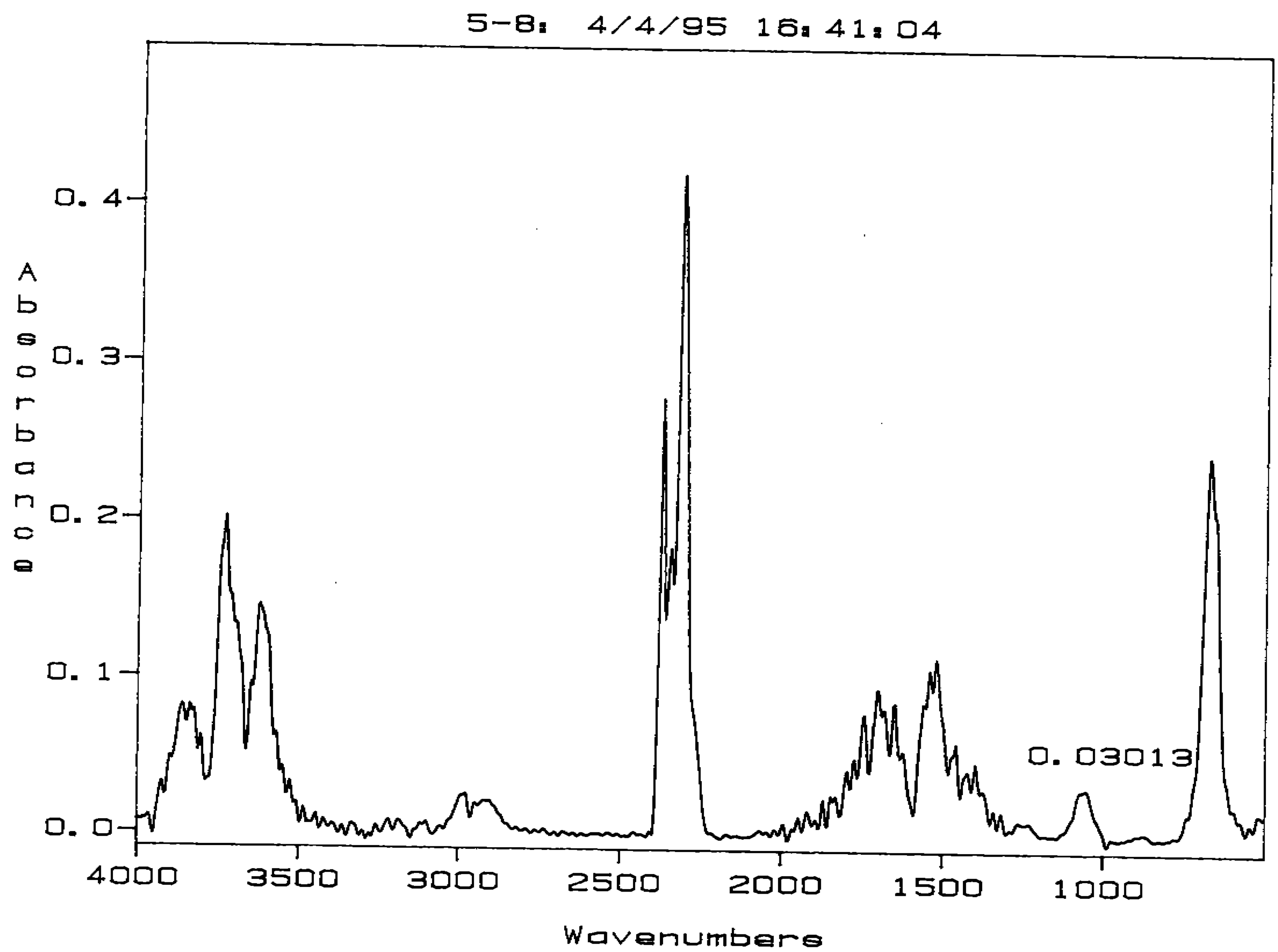
2500
2000
1500
1000
Wavenumbers


5-8: 4/4/95 16:41:04
Absorbance
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0.2
0.1
0.0
4000
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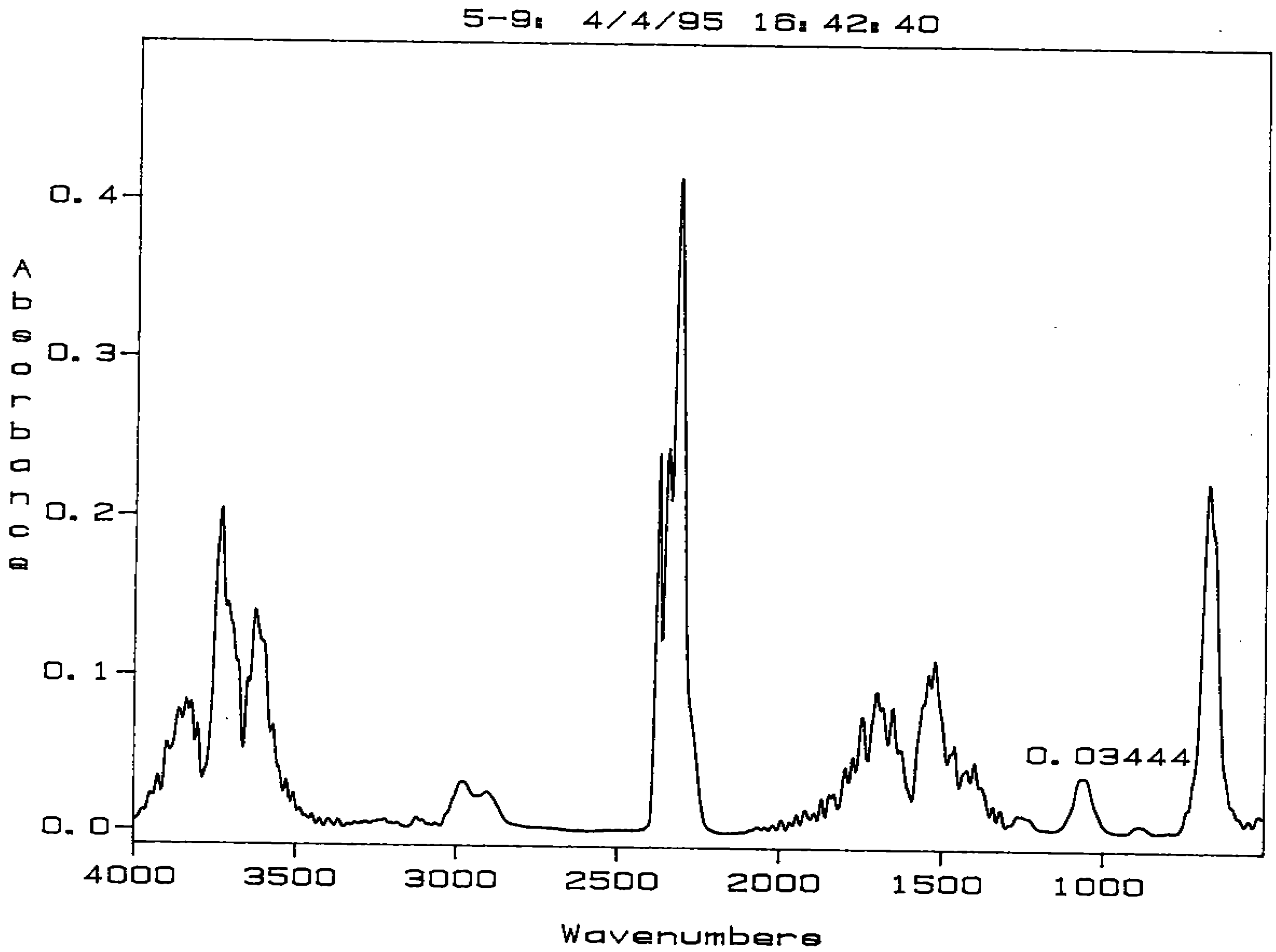
3000
2500
2000
1500
1000
Wavenumbers
0.03013


5-9: 4/4/95 16:42:40
Absorbance
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0.2
0.1
0.0
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3500
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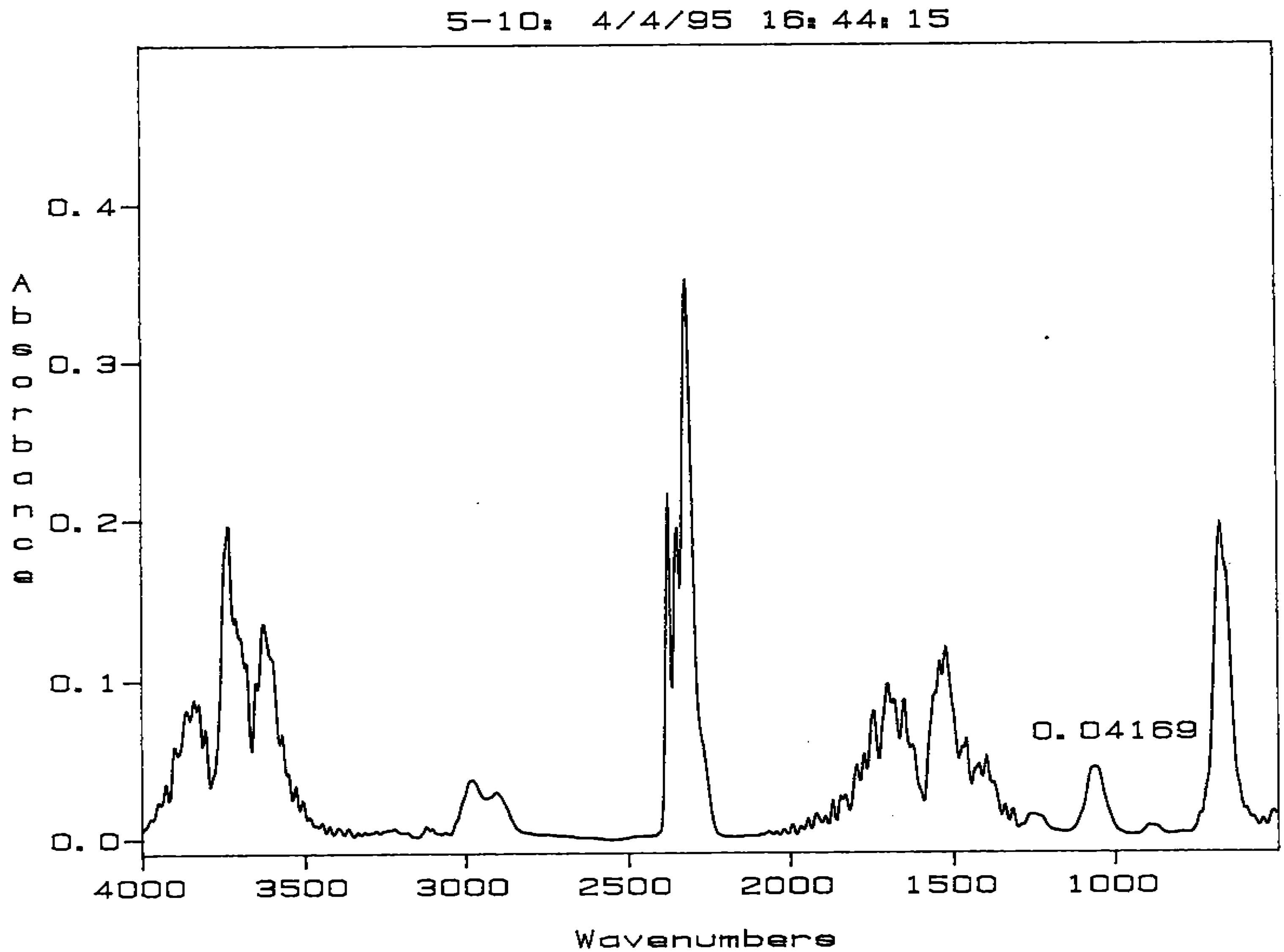
2500
2000
1500
1000
Wavenumbers



5-10: 4/4/95 16:44:15
Absorbance
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0.2
0.3
0.4
4000
3500
3000
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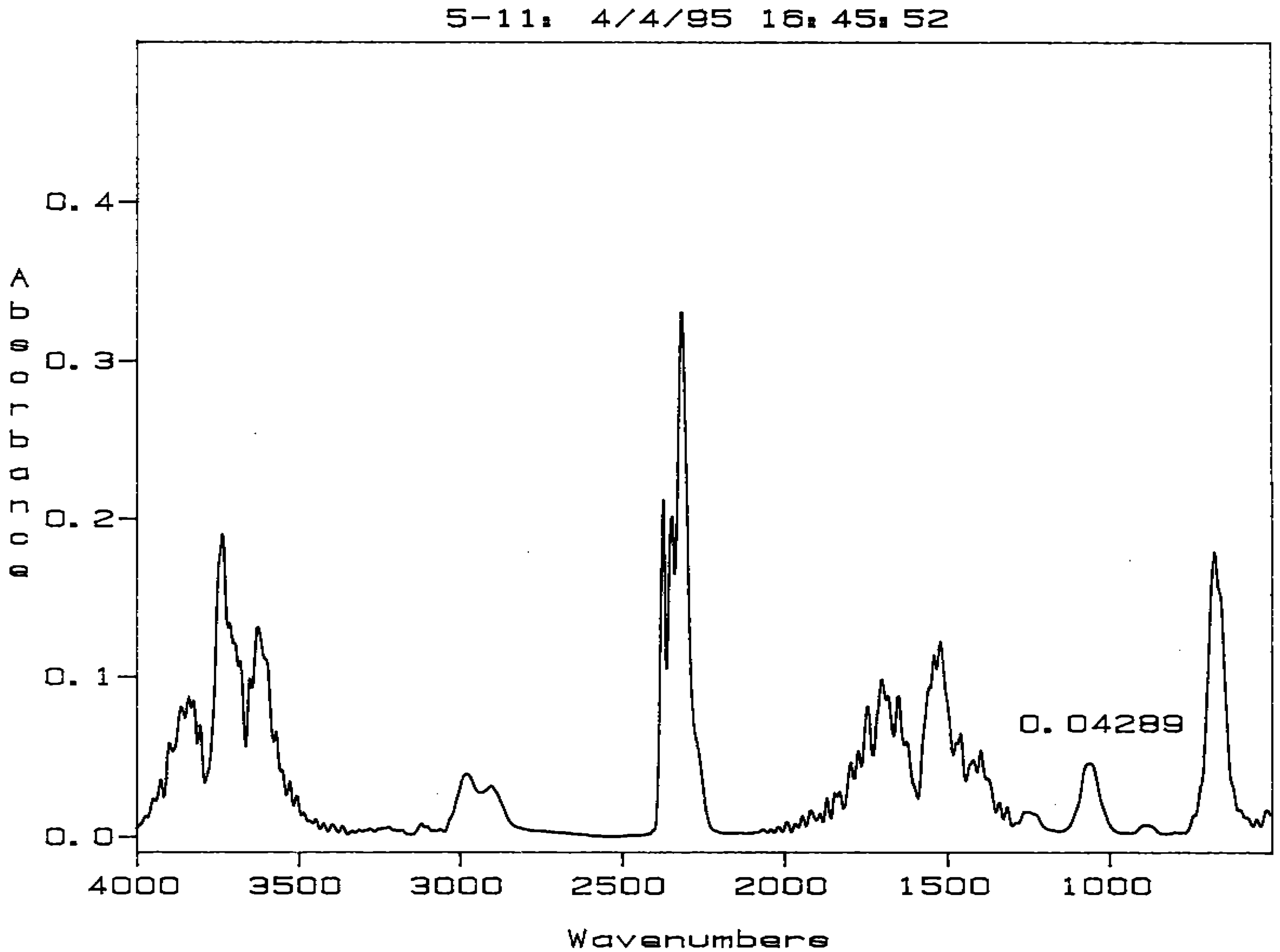
1000
Wavenumbers
0.04169


5-11: 4/4/95 16:45:52
Absorbance
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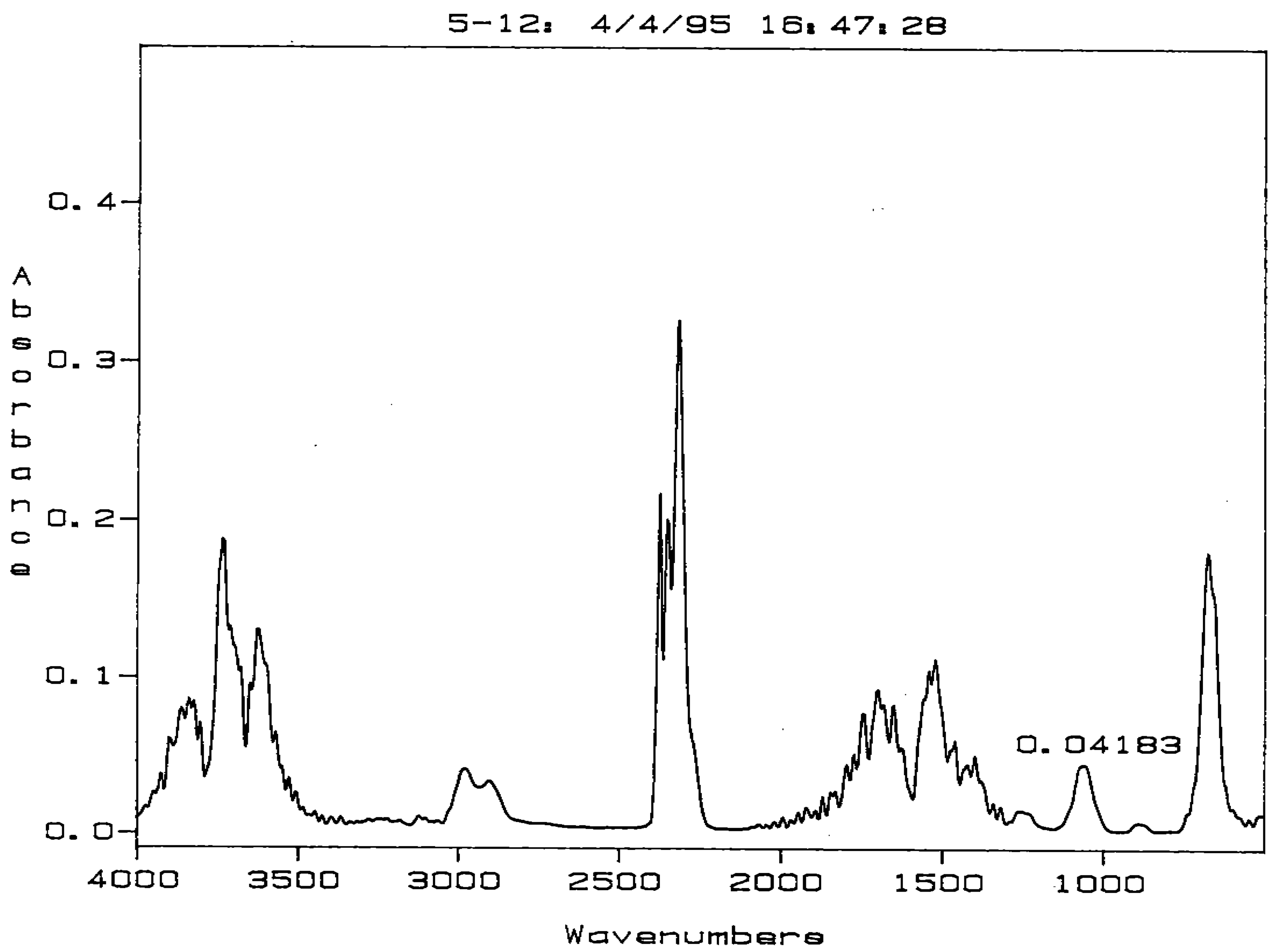
0.2
0.3
0.4
0.04289
4000
3500
3000
2500
2000
1500
1000
Wavenumbers


5-12: 4/4/95 16:47:28
Absorbance
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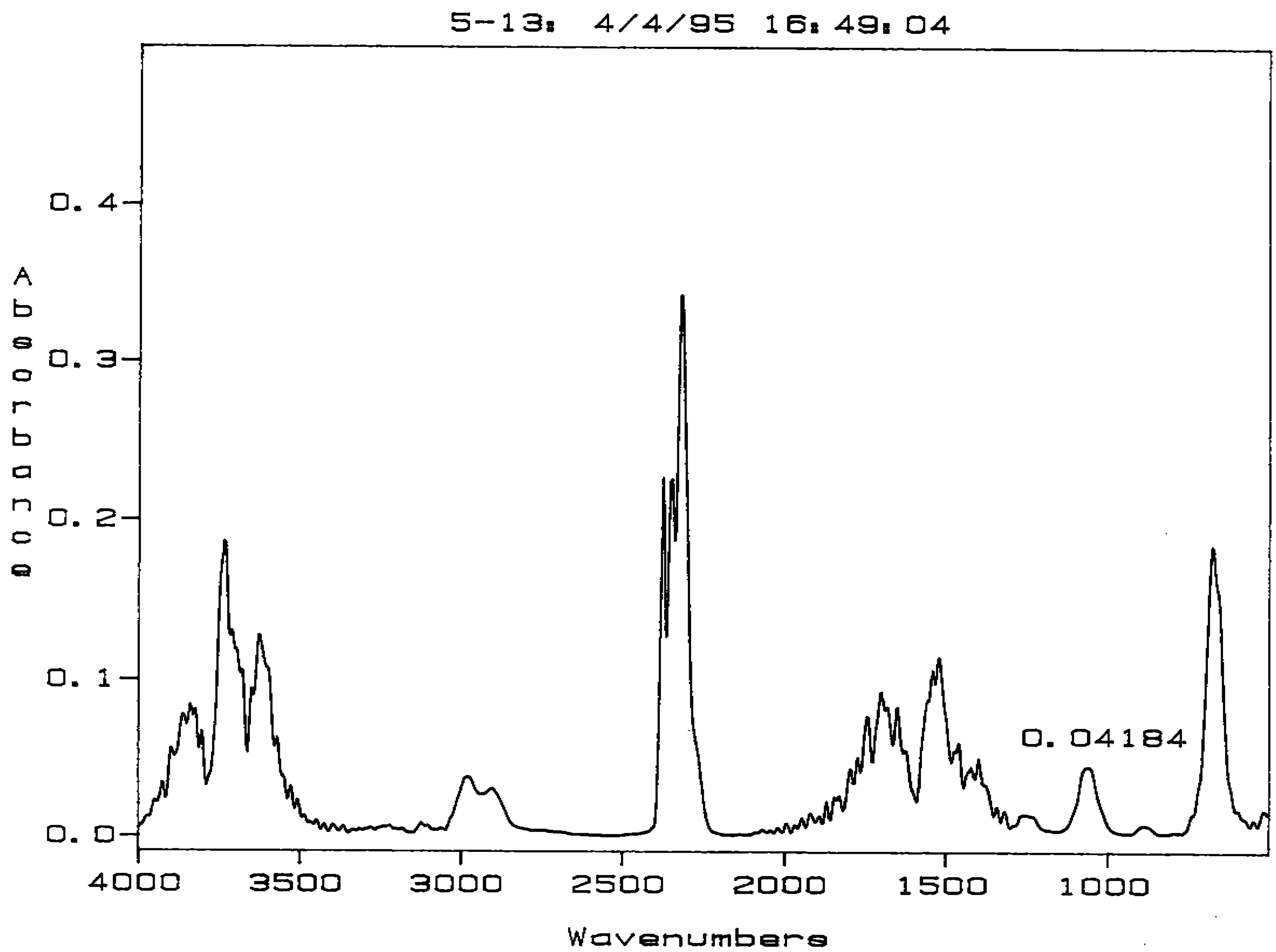
0.2
0.1
0.0
0.04183
4000
3500
3000
2500
2000
1500
1000
Wavenumbers


5-13: 4/4/95 16:49:04
Absorbance
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0.2
0.3
0.4
0.04184
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3500
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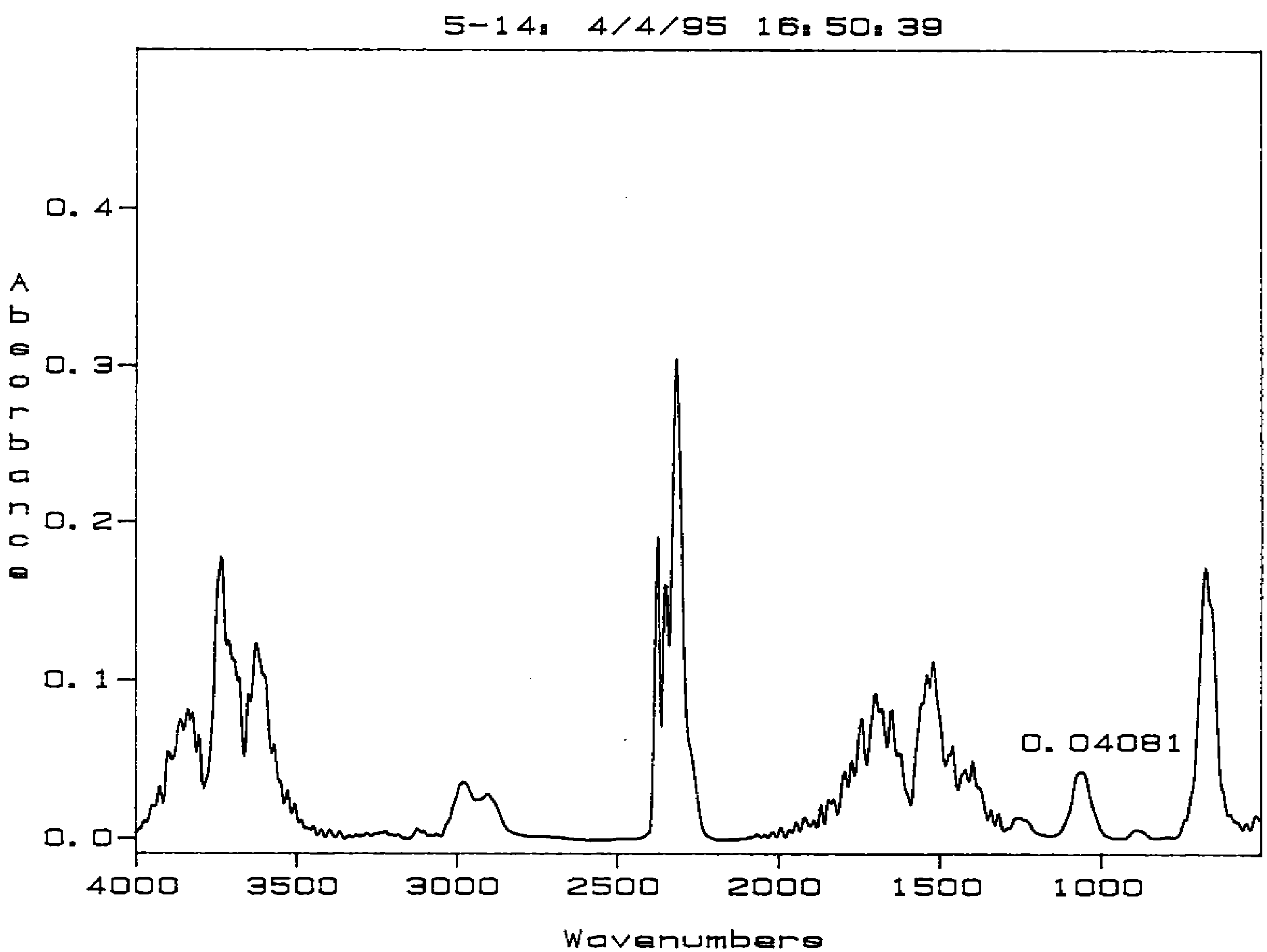
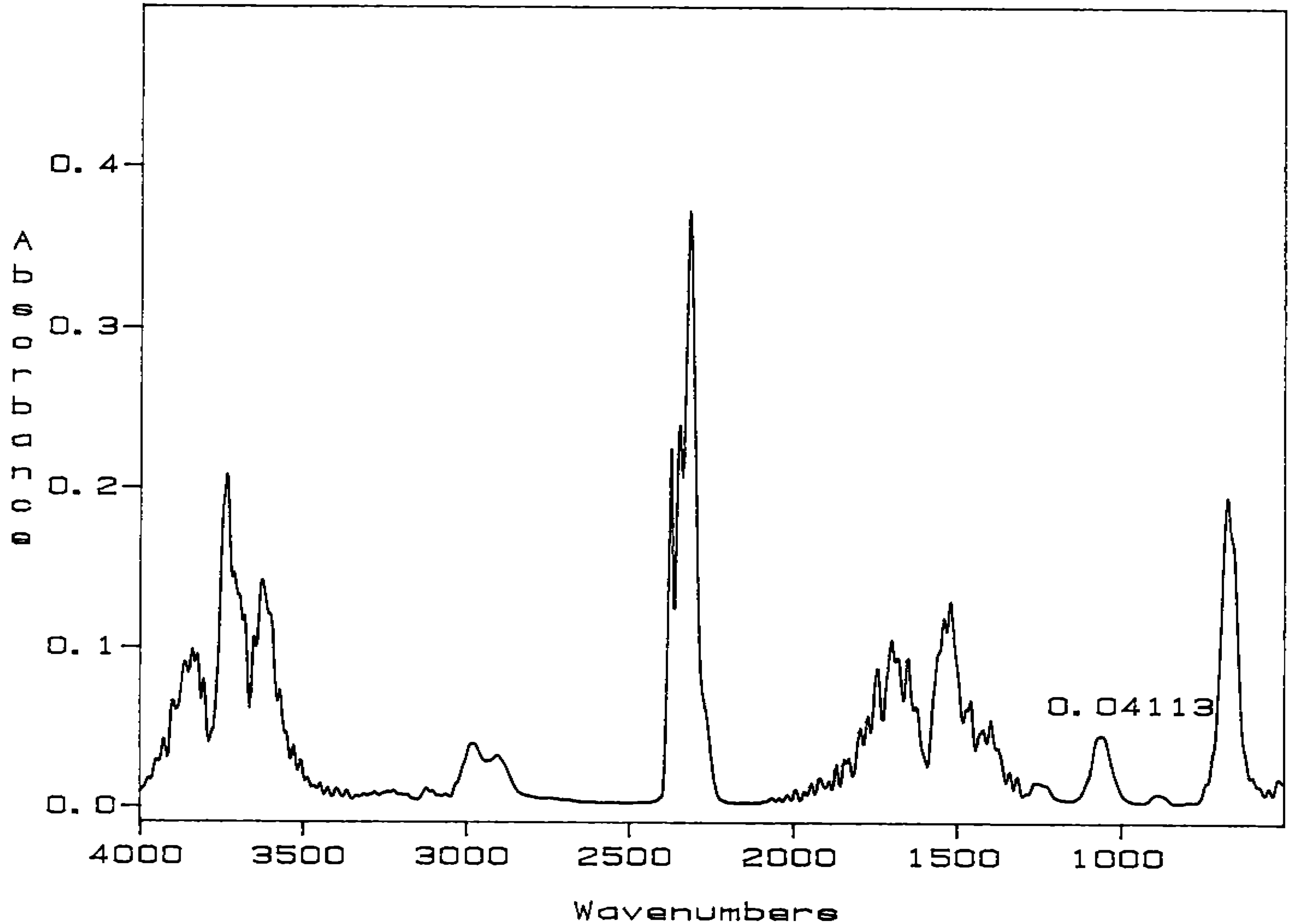
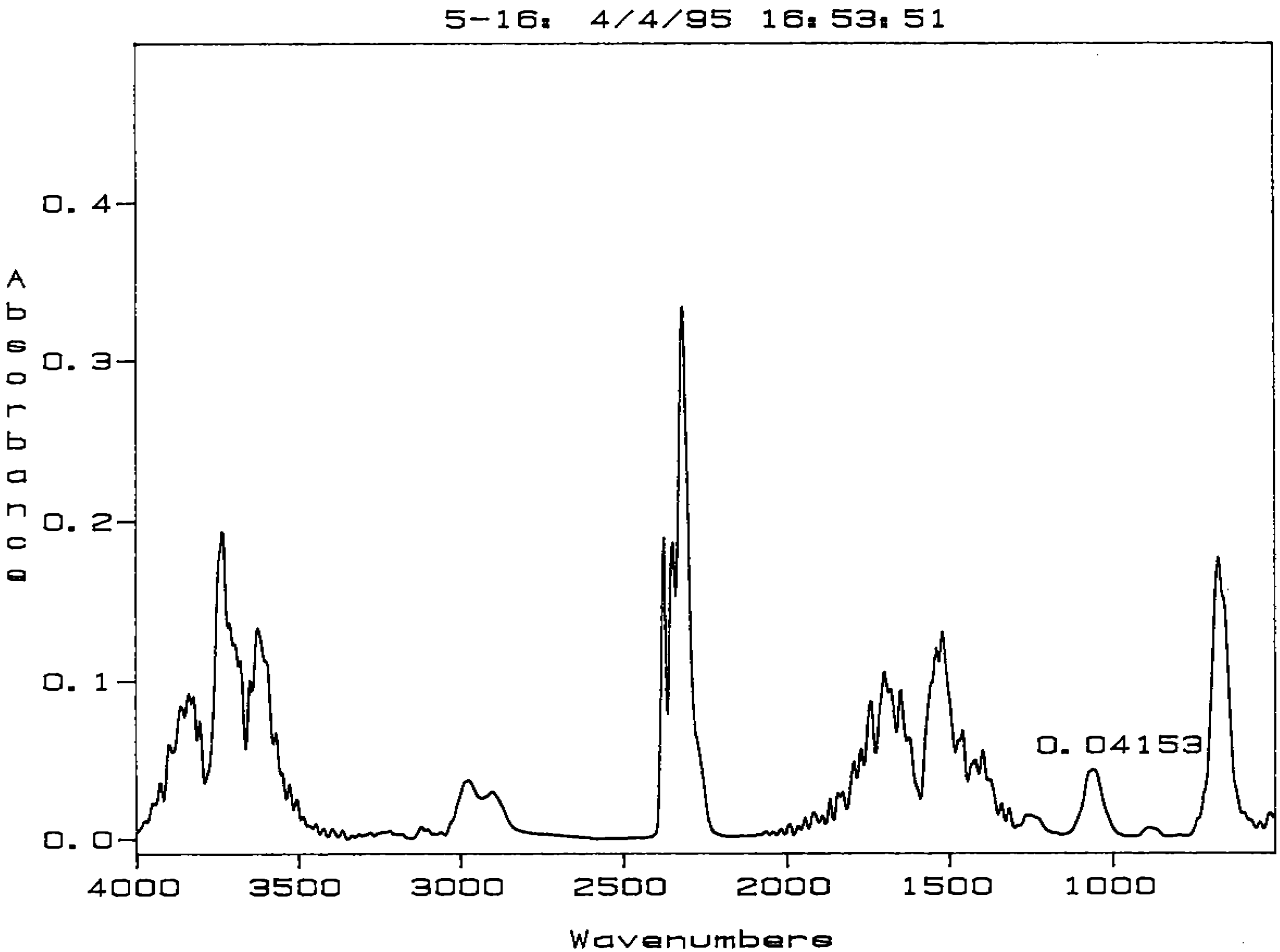
2500
2000
1500
1000
Wavenumbers


5-14: 4/4/95 16:50:39
Absorbance
0.4
0.3
0.2
0.1
0.0
0.04081
4000
3500
3000
2500
2000
1500
1000
Wavenumbers

5-15: 4/4/95 16:52:15




5-16: 4/4/95 16:53:51
0.04153
0.4
0.3
0.2
0.1
0.0
Absorbance
4000
3500
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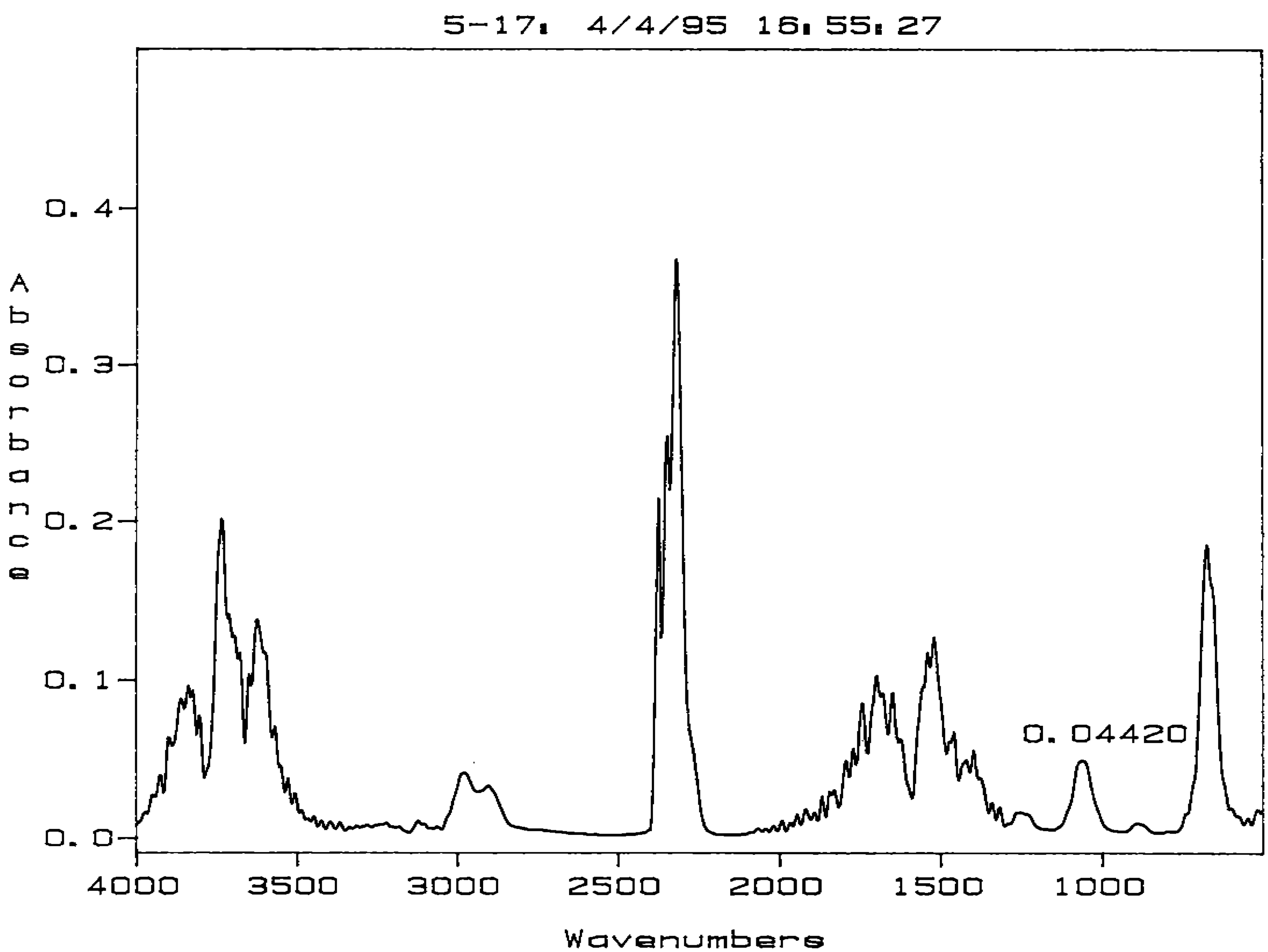
2500
2000
1500
1000
Wavenumbers


5-17: 4/4/95 16:55:27
Absorbance
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0.2
0.3
0.4
0.04420
4000
3500
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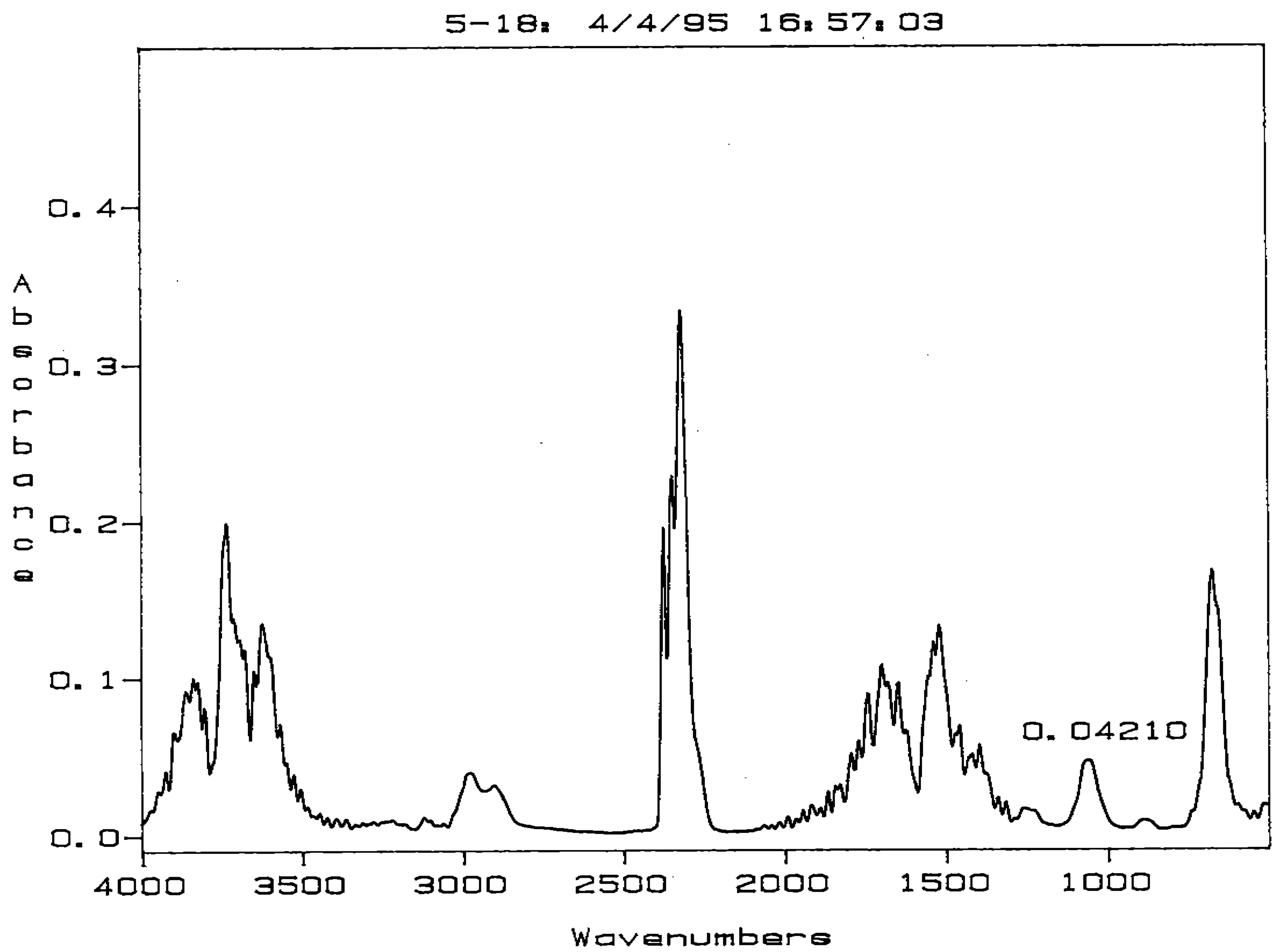
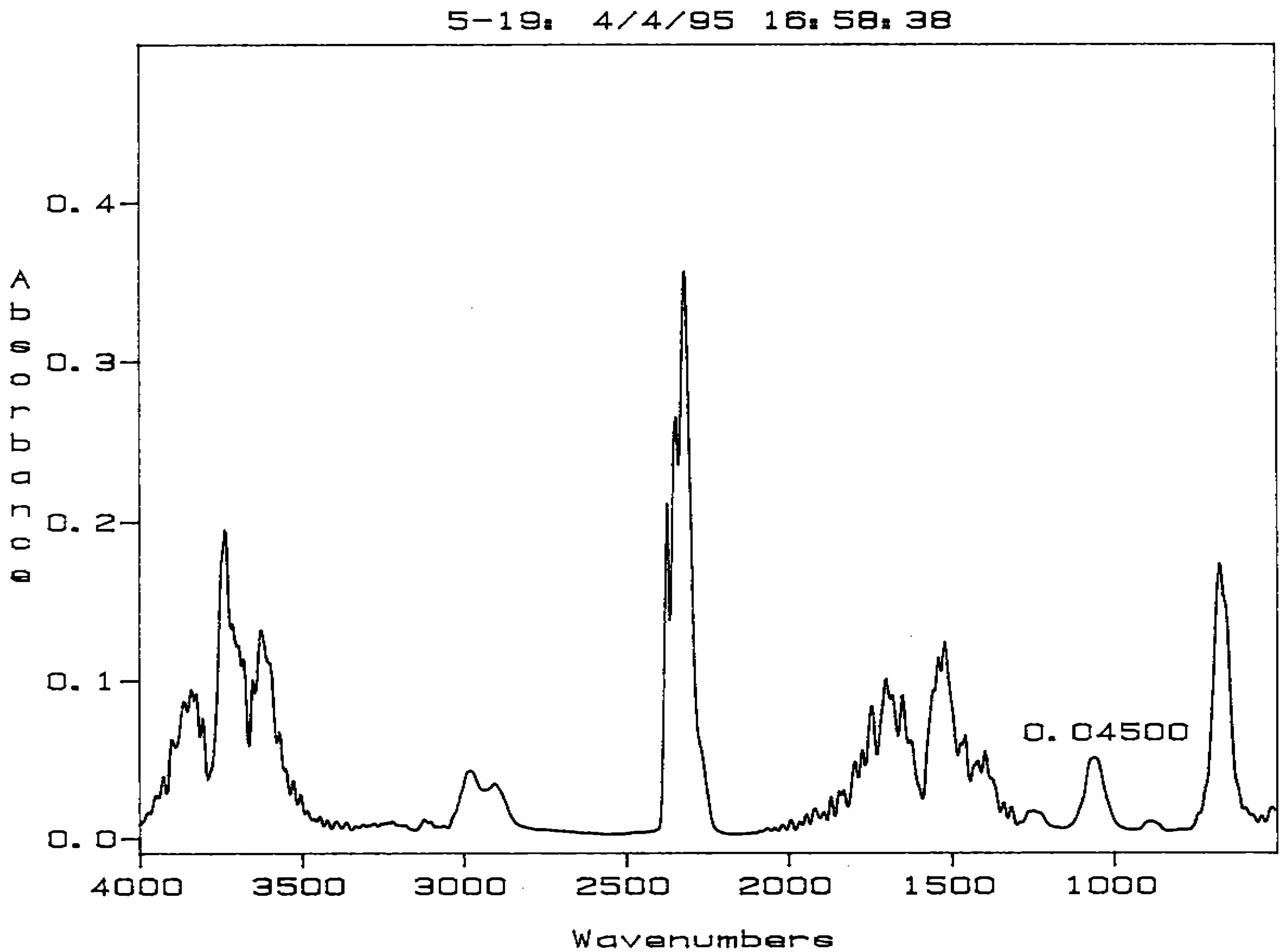
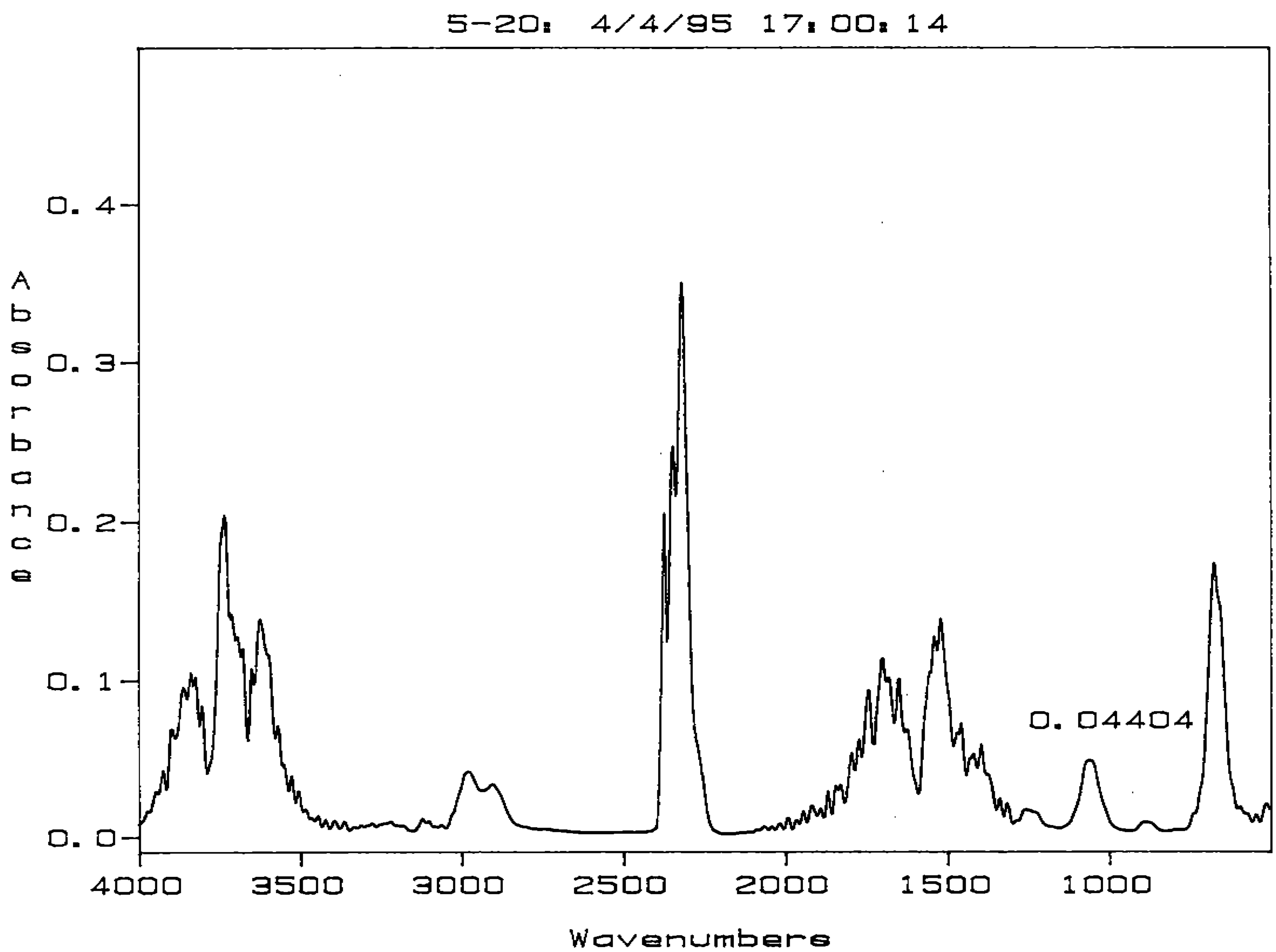
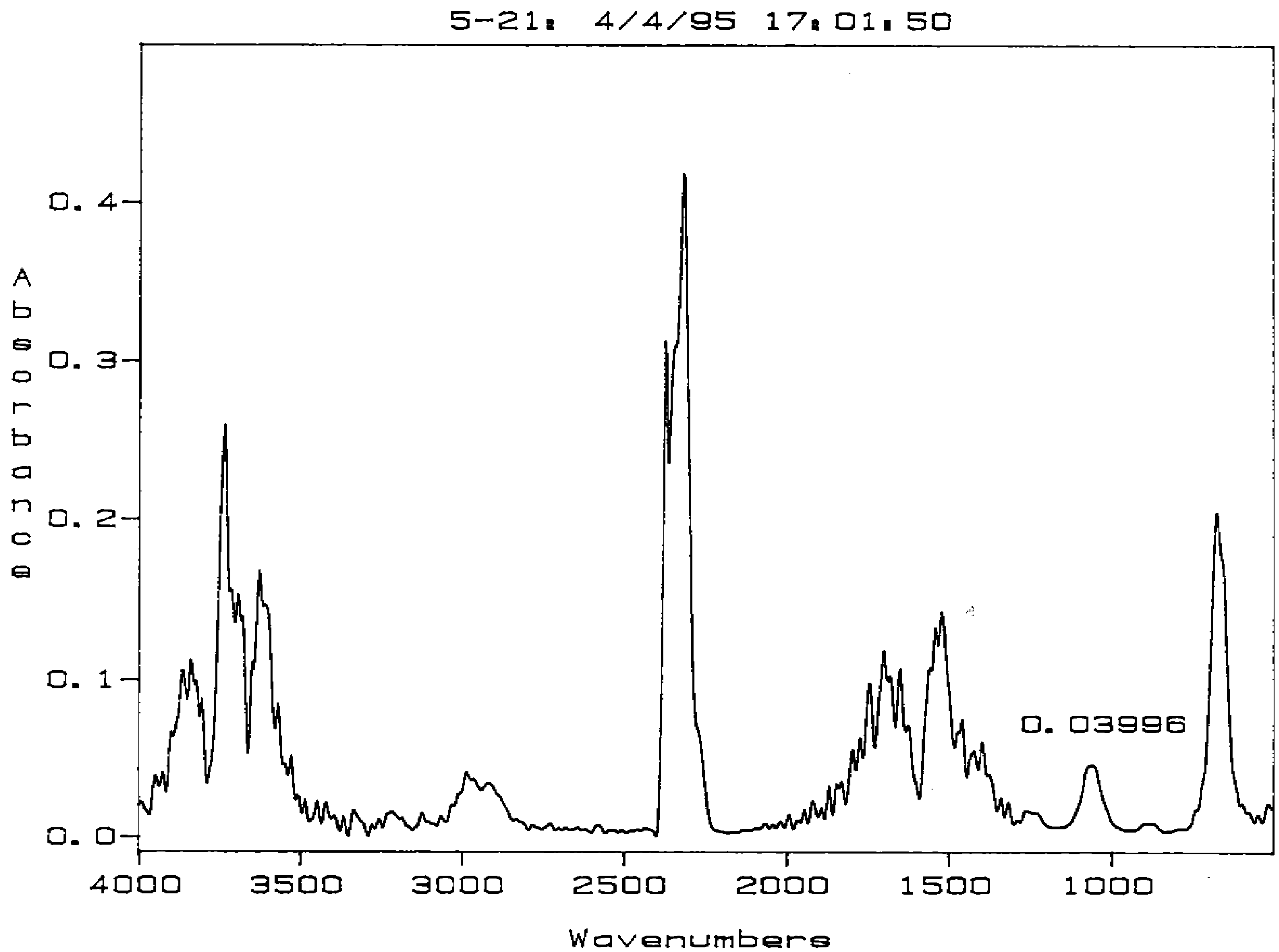
2500
2000
1500
1000
Wavenumbers


5-18: 4/4/95 16:57:03
Absorbance
0.0
0.1
0.2
0.3
0.4
0.04210
4000
3500
3000
2500
2000
1500
1000
Wavenumbers


5-19: 4/4/95 16:58:38
Absorbance
0.4
0.3
0.2
0.1
0.0
0.04500
4000
3500
3000
2500
2000
1500
1000
Wavenumbers


5-20: 4/4/95 17:00:14
0.4
0.3
0.2
0.1
0.0
Absorbance
4000
3500
3000
2500
2000
1500
1000
Wavenumbers
0.04404


5-21: 4/4/95 17:01:50
Absorbance
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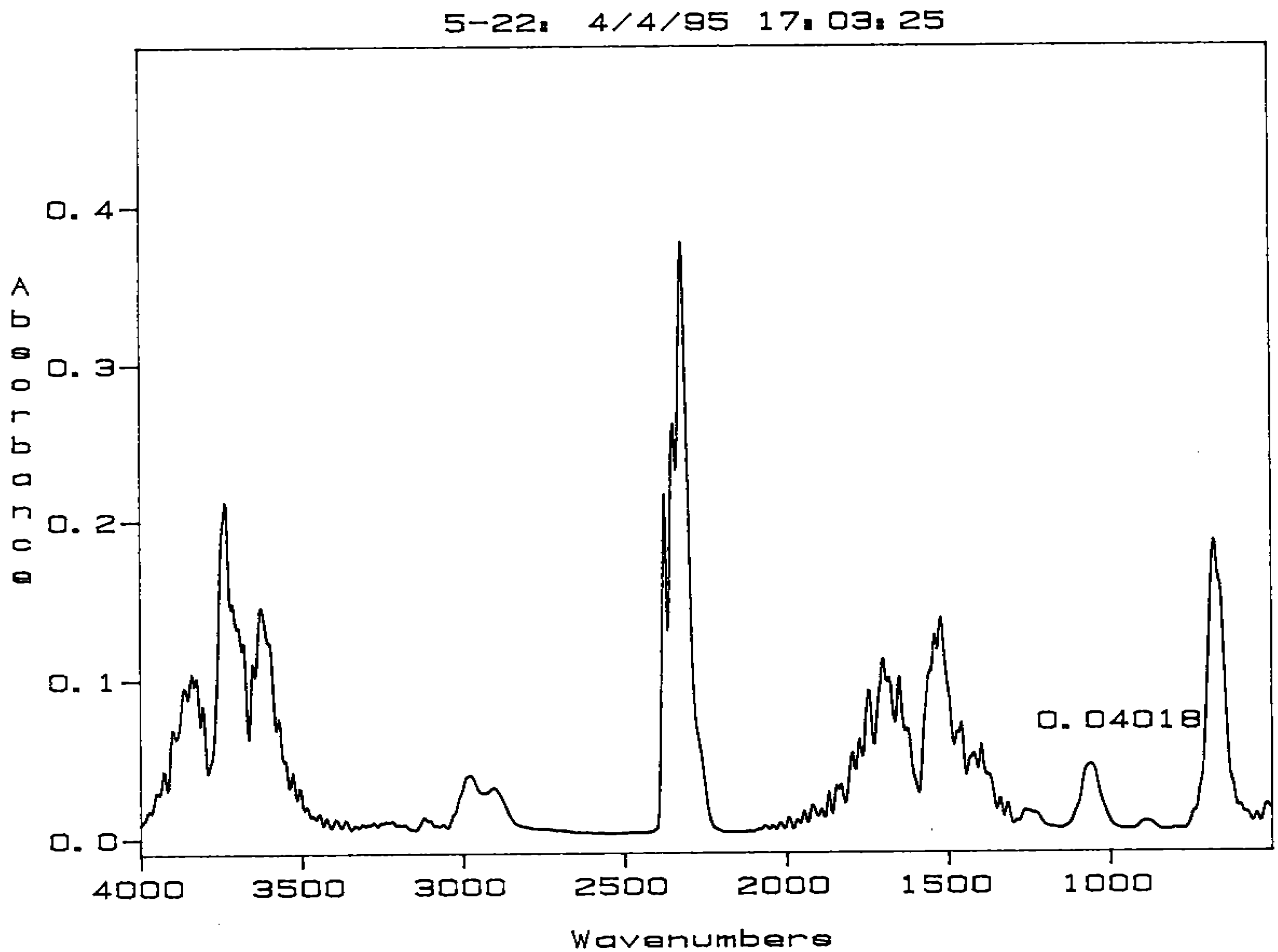
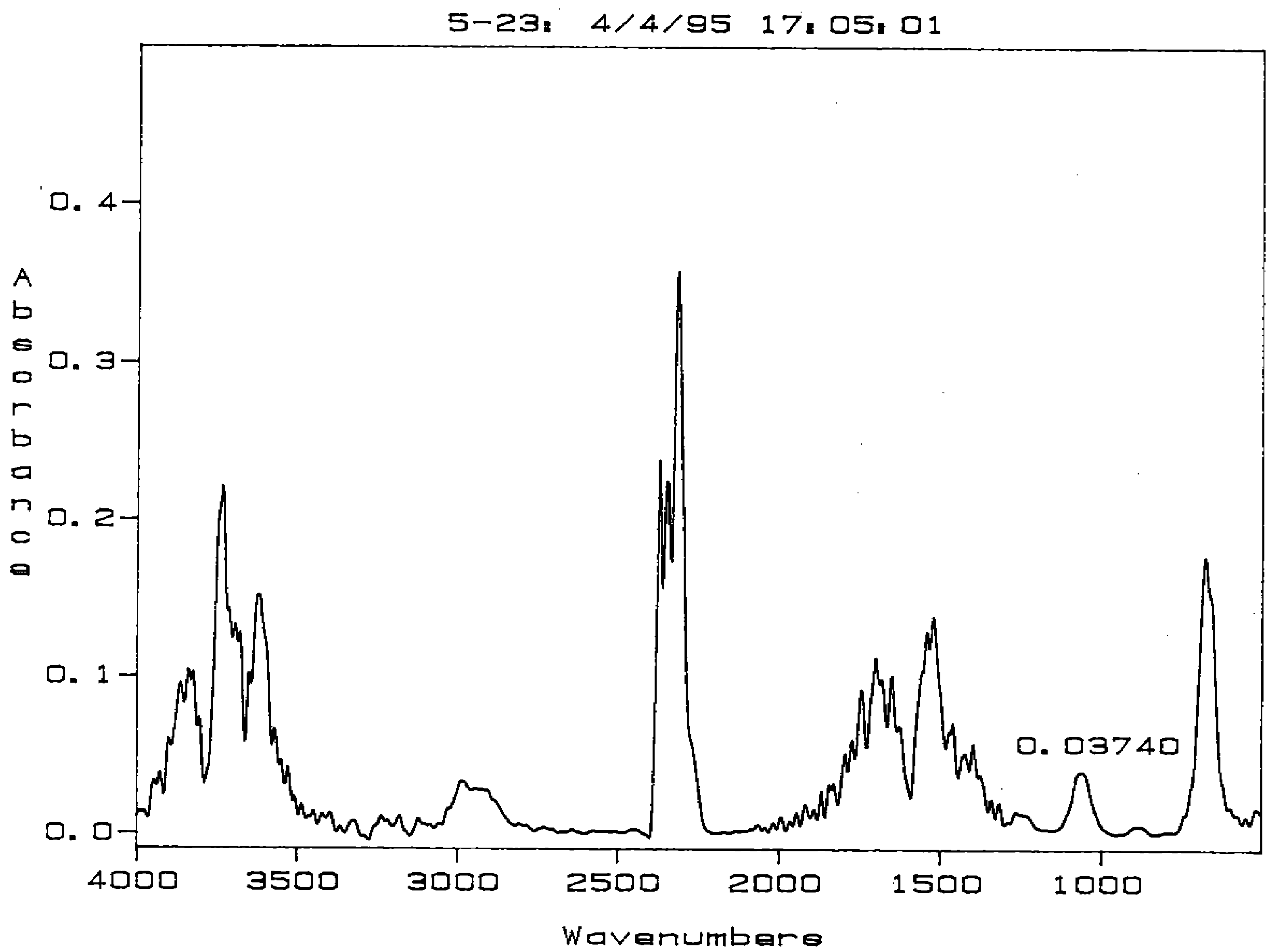
0.3
0.2
0.1
0.0
0.03996
4000
3500
3000
2500
2000
1500
1000
Wavenumbers



5-22: 4/4/95 17:03:25
Absorbance
0.4
0.3
0.2
0.1
0.0
0.04018
4000
3500
3000
2500
2000
1500
1000
Wavenumbers


5-23: 4/4/95 17:05:01
Absorbance
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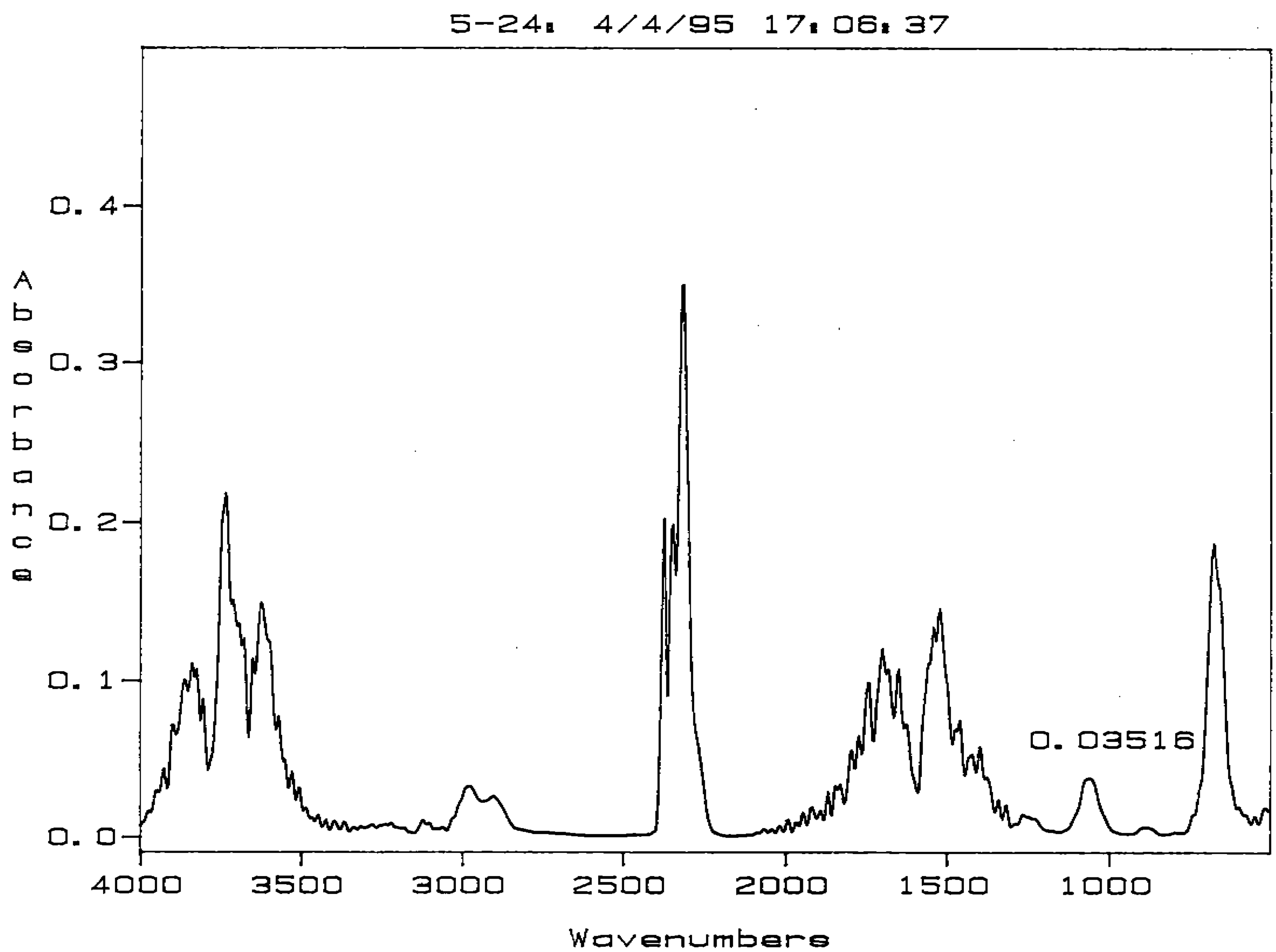
0.3
0.2
0.1
0.0
0.03740
4000
3500
3000
2500
2000
1500
1000
Wavenumbers


5-24: 4/4/95 17:06:37
Absorbance
0.0
0.1
0.2
0.3
0.4
4000
3500
3000
2500
2000
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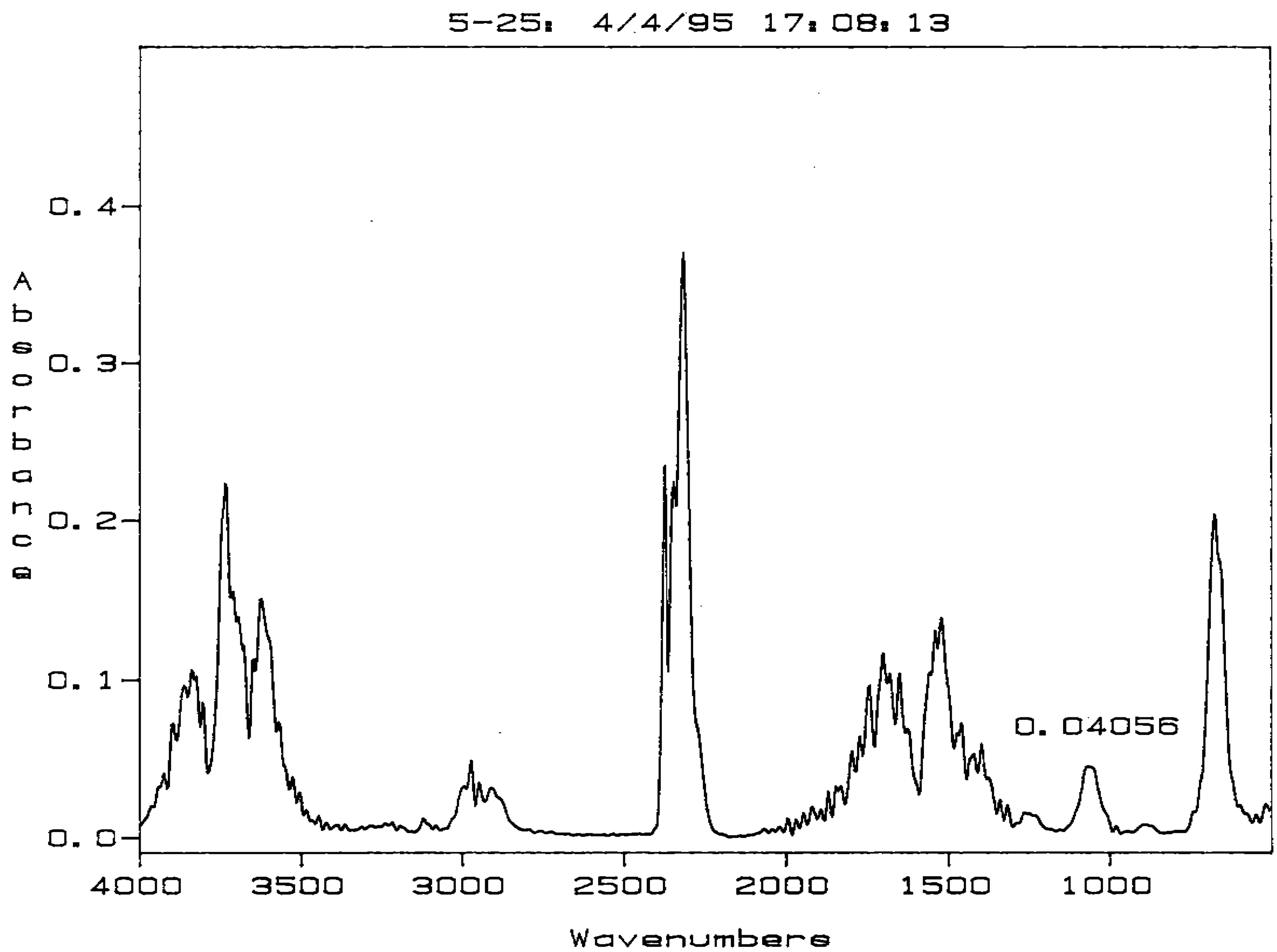
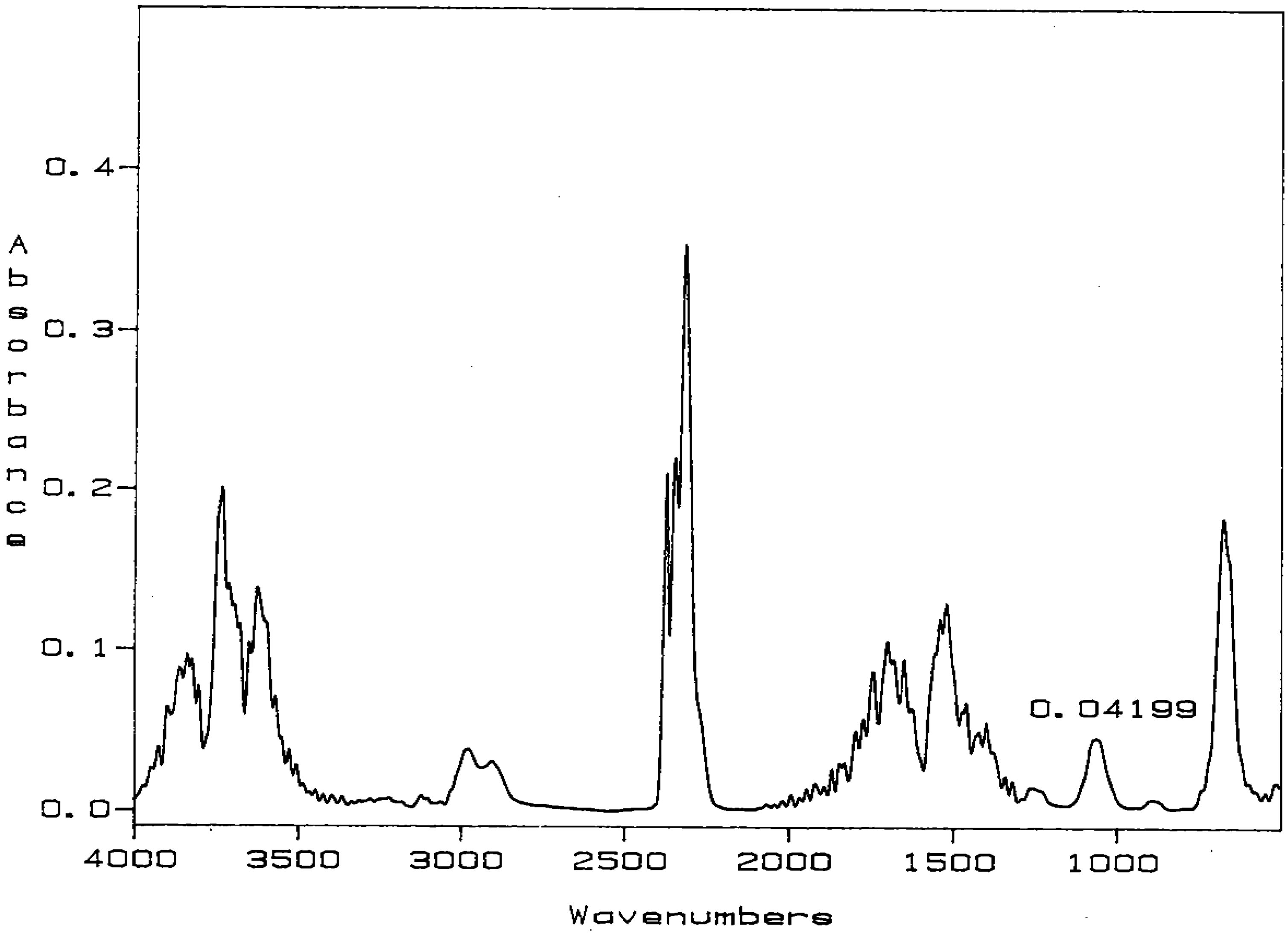
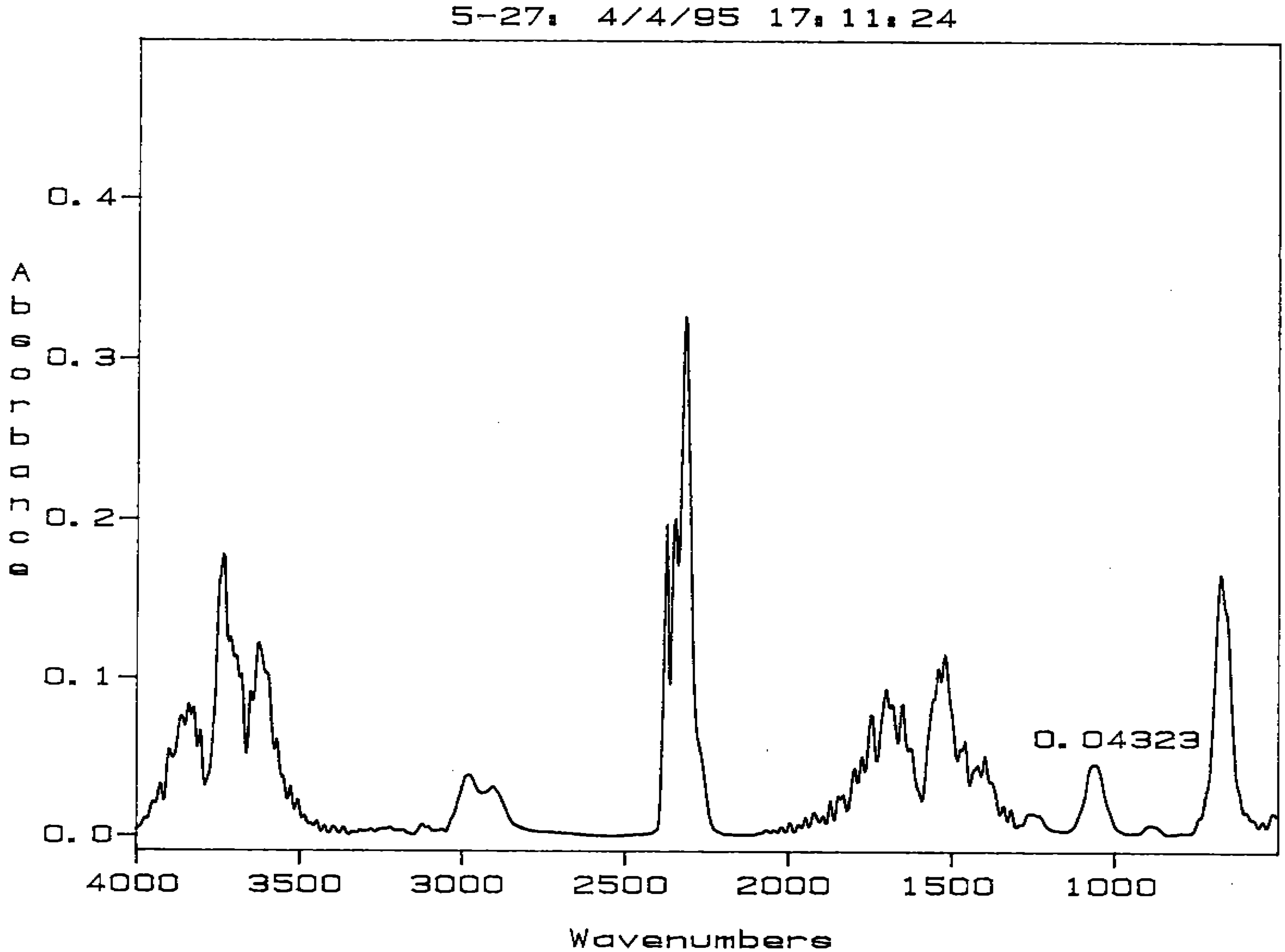
1000
Wavenumbers
0.03516


5-25: 4/4/95 17:08:13
Absorbance
0.4
0.3
0.2
0.1
0.0
0.04056
4000
3500
3000
2500
2000
1500
1000
Wavenumbers

5-26: 4/4/95 17:09:48




5-27: 4/4/95 17:11:24
Absorbance
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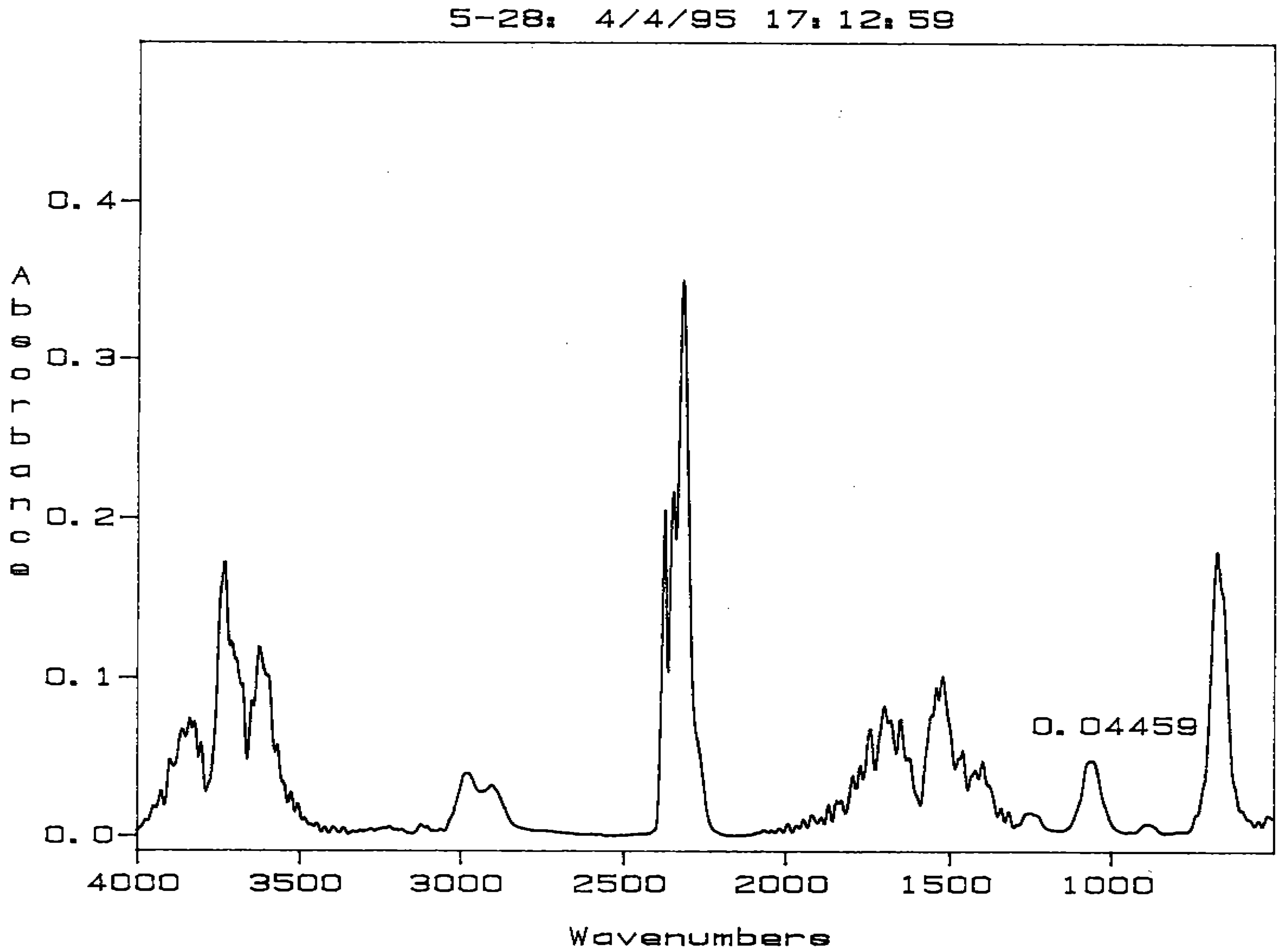
0.1
0.2
0.3
0.4
0.04323
4000
3500
3000
2500
2000
1500
1000
Wavenumbers


5-28: 4/4/95 17:12:59
Absorbance
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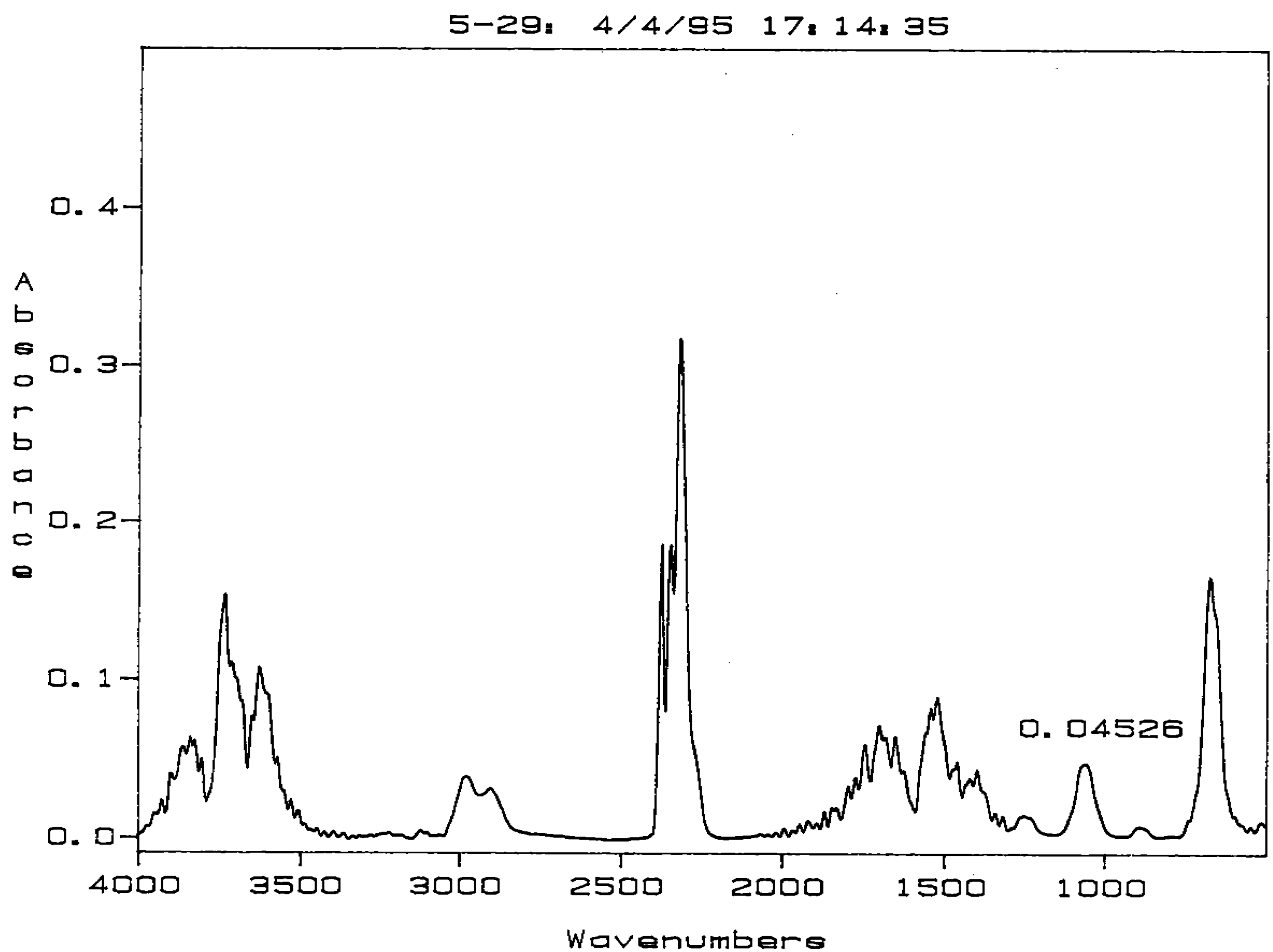
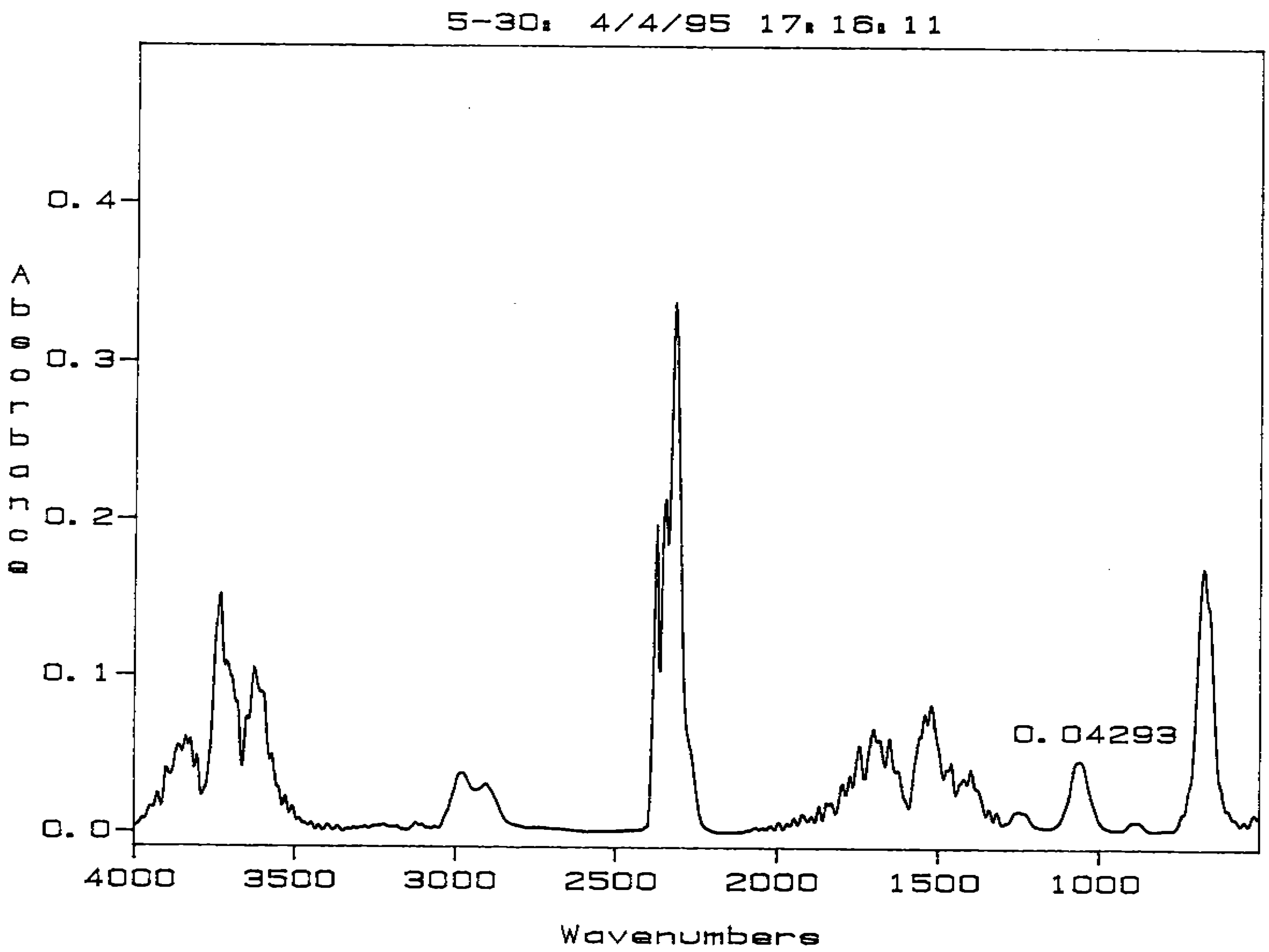
0.3
0.2
0.1
0.0
4000
3500
3000
2500
2000
1500
1000
Wavenumbers
0.04459


5-29: 4/4/95 17:14:35
0.4
0.3
0.2
0.1
0.0
Absorbance
0.04526
4000
3500
3000
2500
2000
1500
1000
Wavenumbers


5-30: 4/4/95 17:16:11
Absorbance
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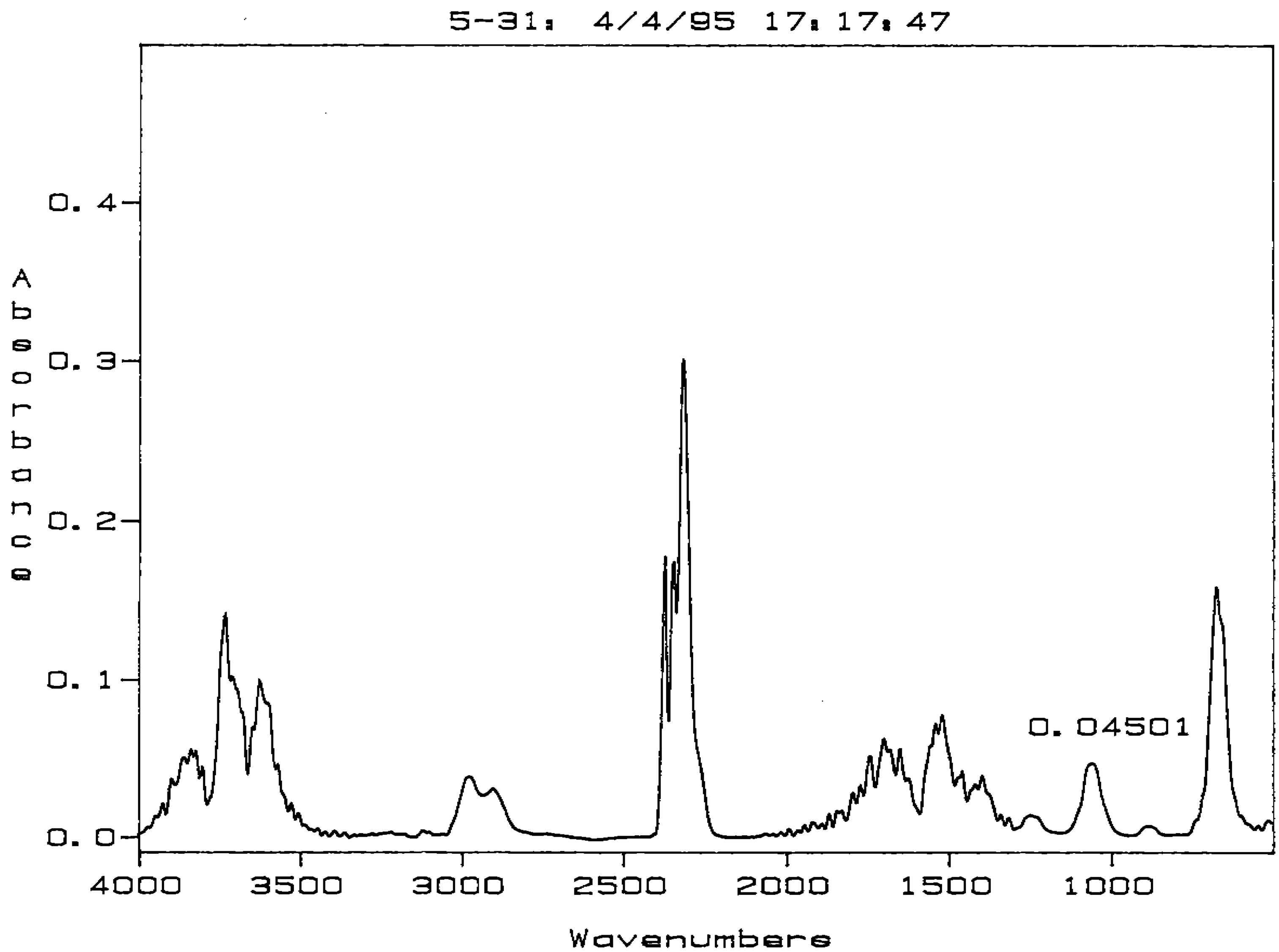
0.2
0.3
0.4
0.04293
4000
3500
3000
2500
2000
1500
1000
Wavenumbers


5-31: 4/4/95 17:17:47
Absorbance
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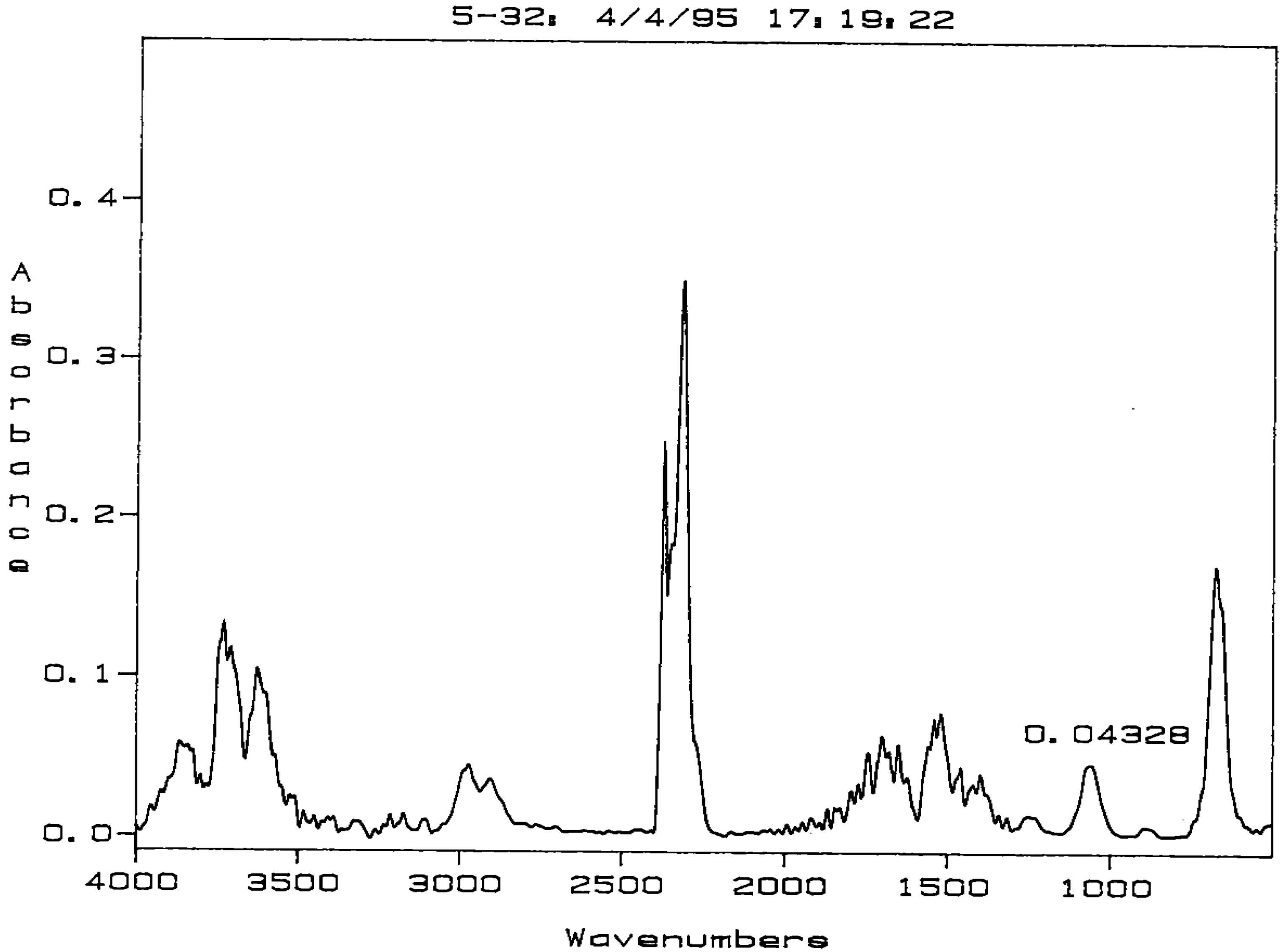
0.2
0.3
0.4
0.04501
4000
3500
3000
2500
2000
1500
1000
Wavenumbers


5-32: 4/4/95 17:19:22
Absorbance
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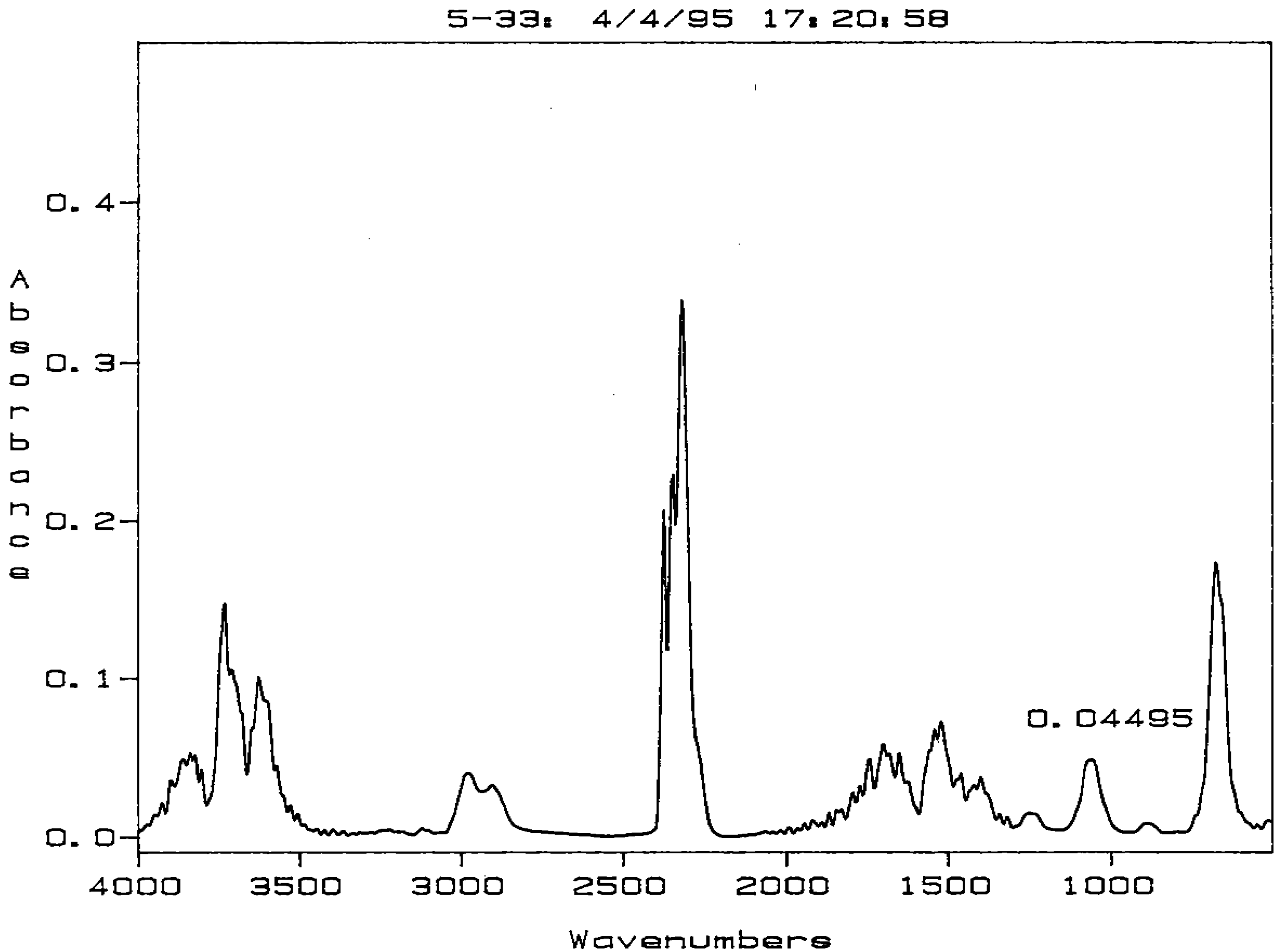
0.2
0.1
0.0
0.04328
4000
3500
3000
2500
2000
1500
1000
Wavenumbers


5-33: 4/4/95 17:20:58
Absorbance
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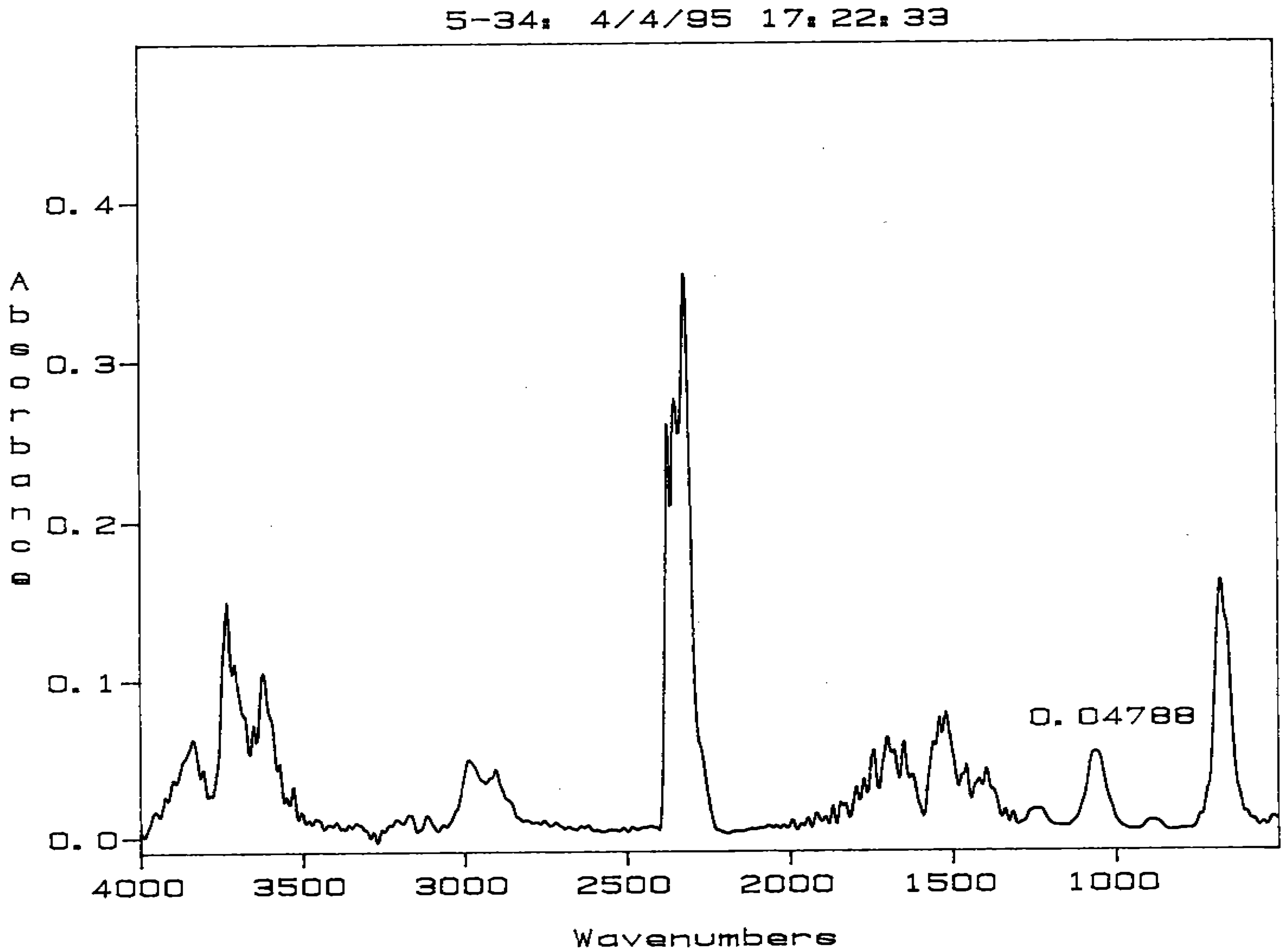
0.2
0.1
0.0
0.04495
4000
3500
3000
2500
2000
1500
1000
Wavenumbers


5-34: 4/4/95 17:22:33
Absorbance
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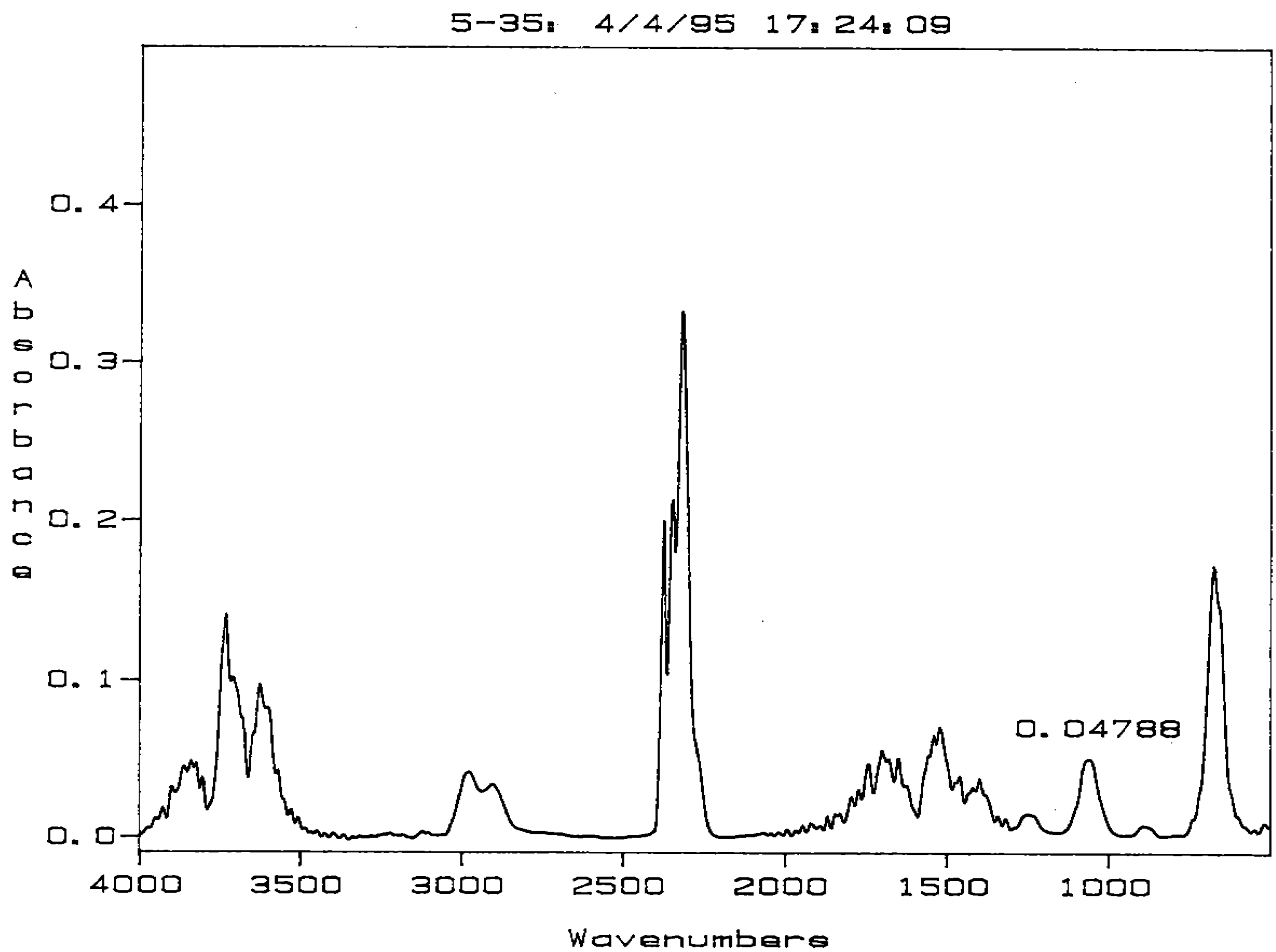
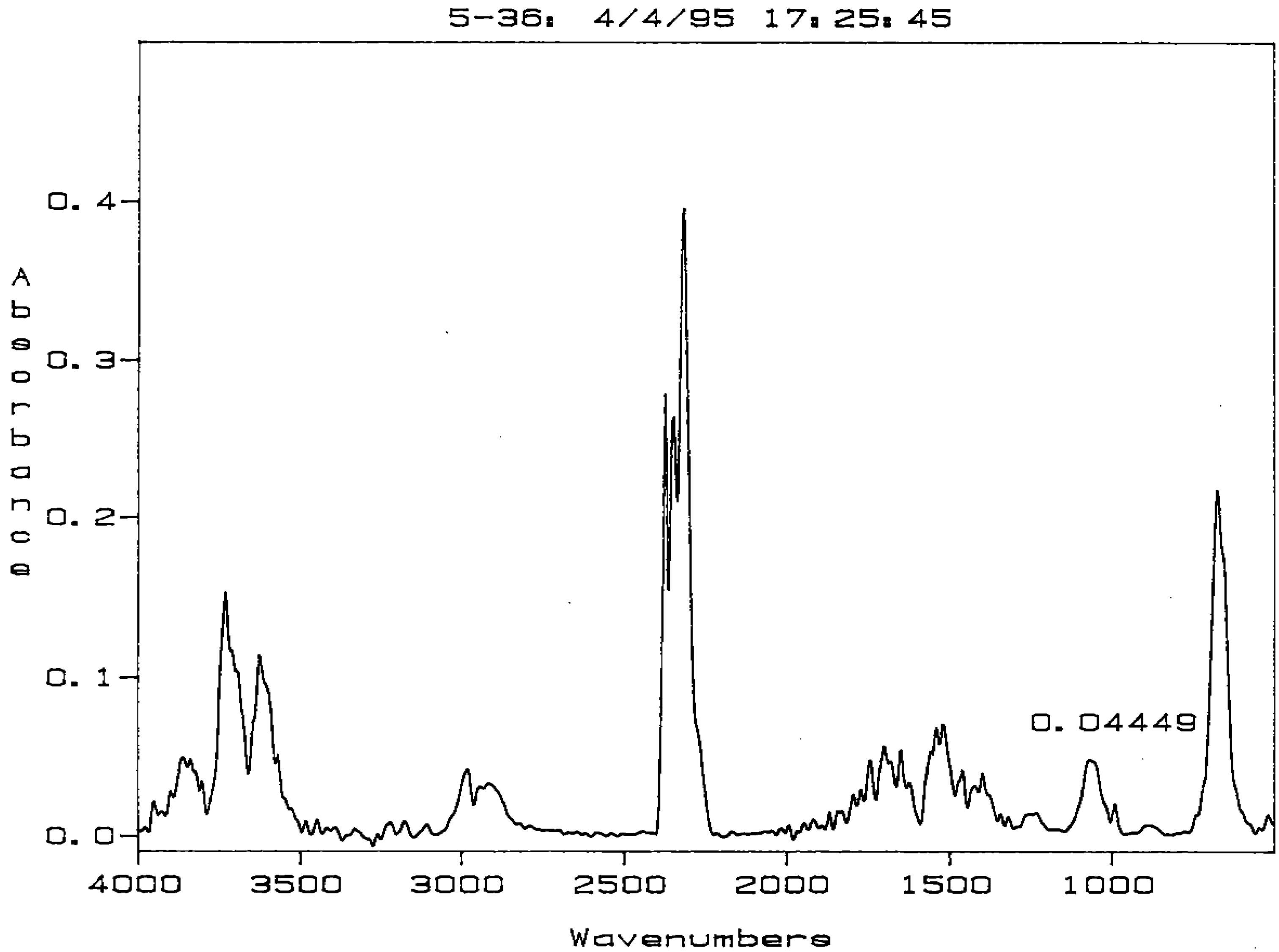
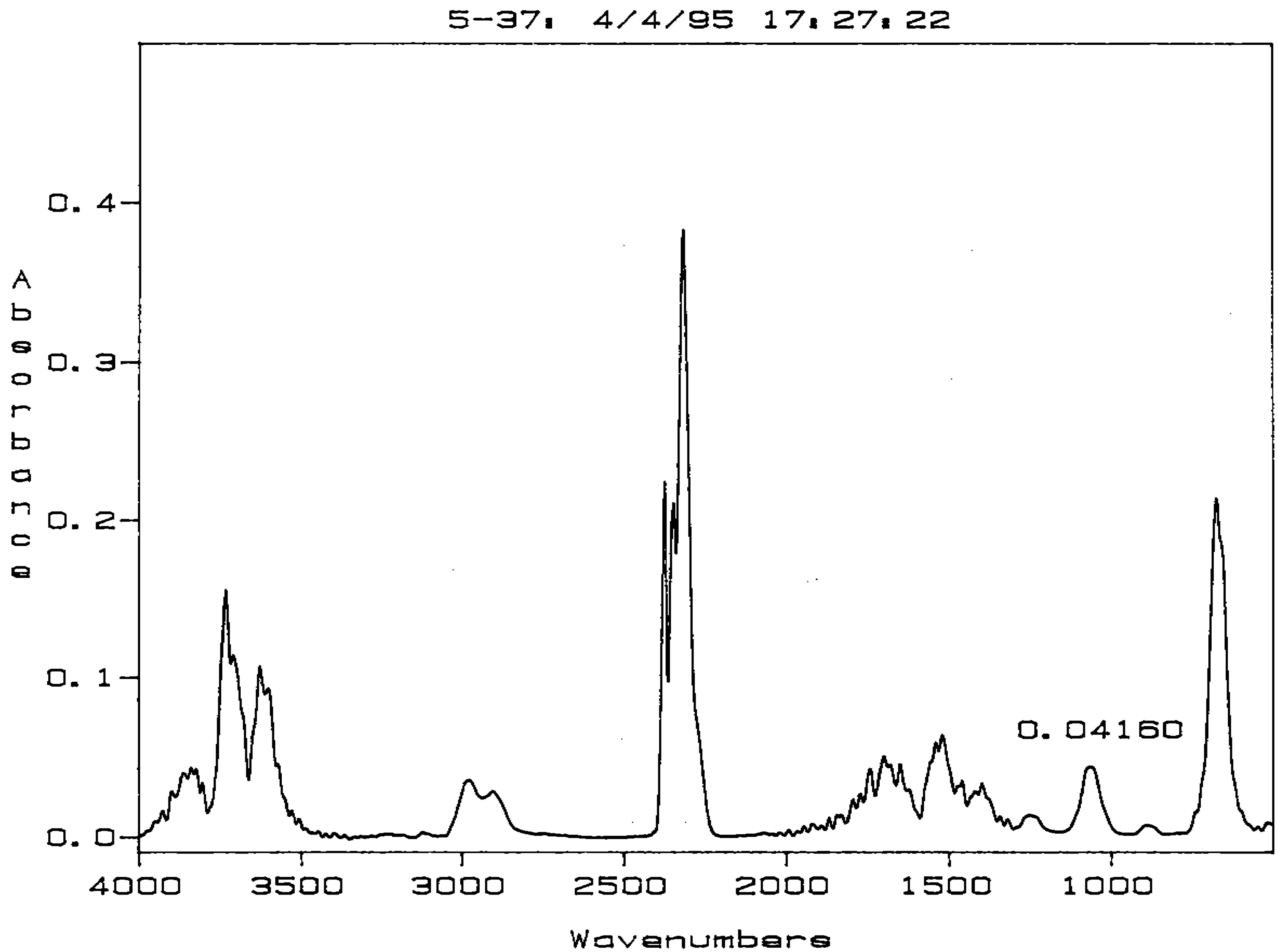
0.2
0.1
0.0
0.04788
4000
3500
3000
2500
2000
1500
1000
Wavenumbers


5-35: 4/4/95 17:24:09
0.4
0.3
0.2
0.1
0.0
Absorbance
0.04788
4000
3500
3000
2500
2000
1500
1000
Wavenumbers


5-36: 4/4/95 17:25:45
0.4
0.3
0.2
0.1
0.0
Absorbance
0.04449
4000
3500
3000
2500
2000
1500
1000
Wavenumbers


5-37: 4/4/95 17:27:22
Absorbance
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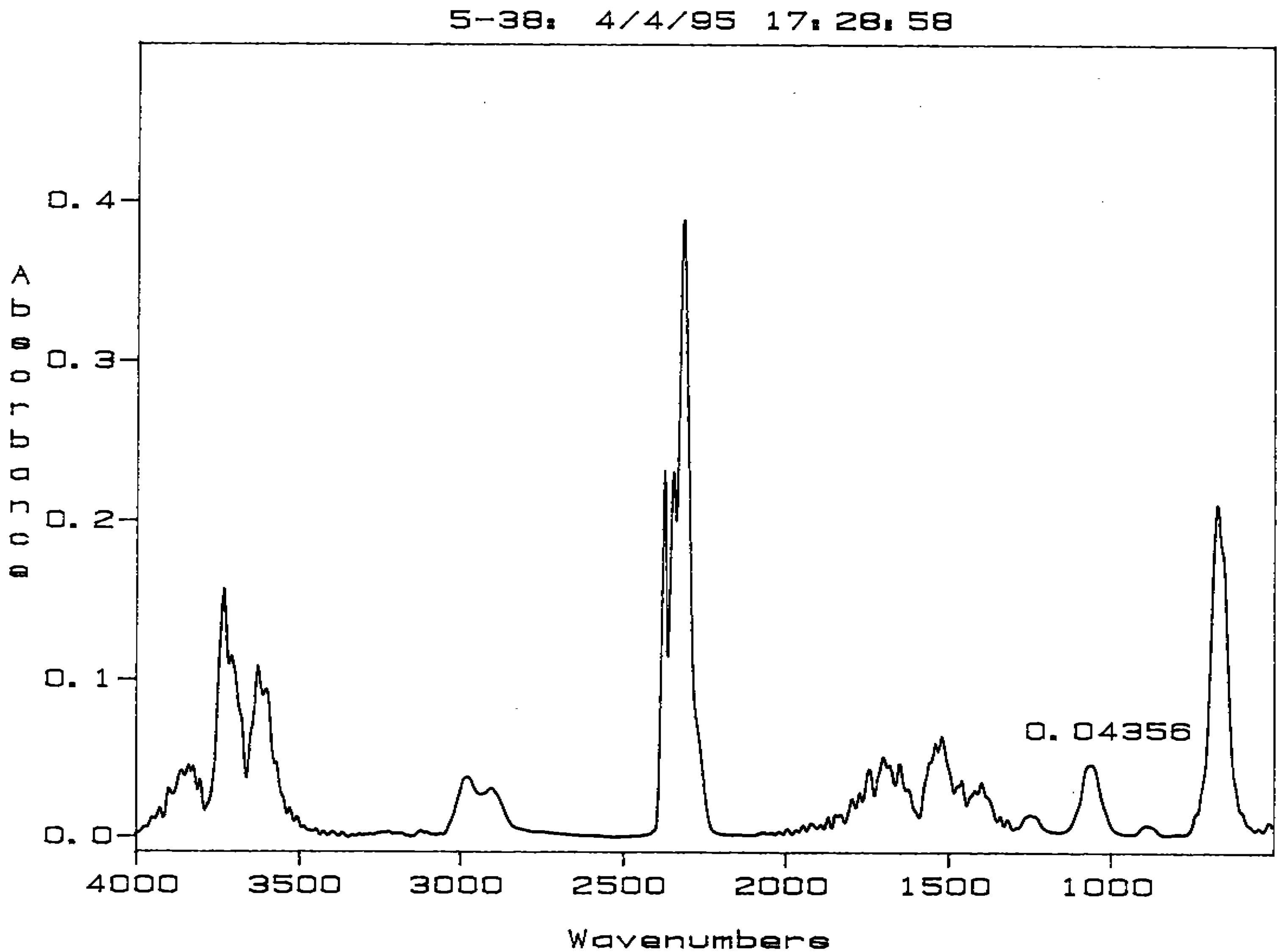
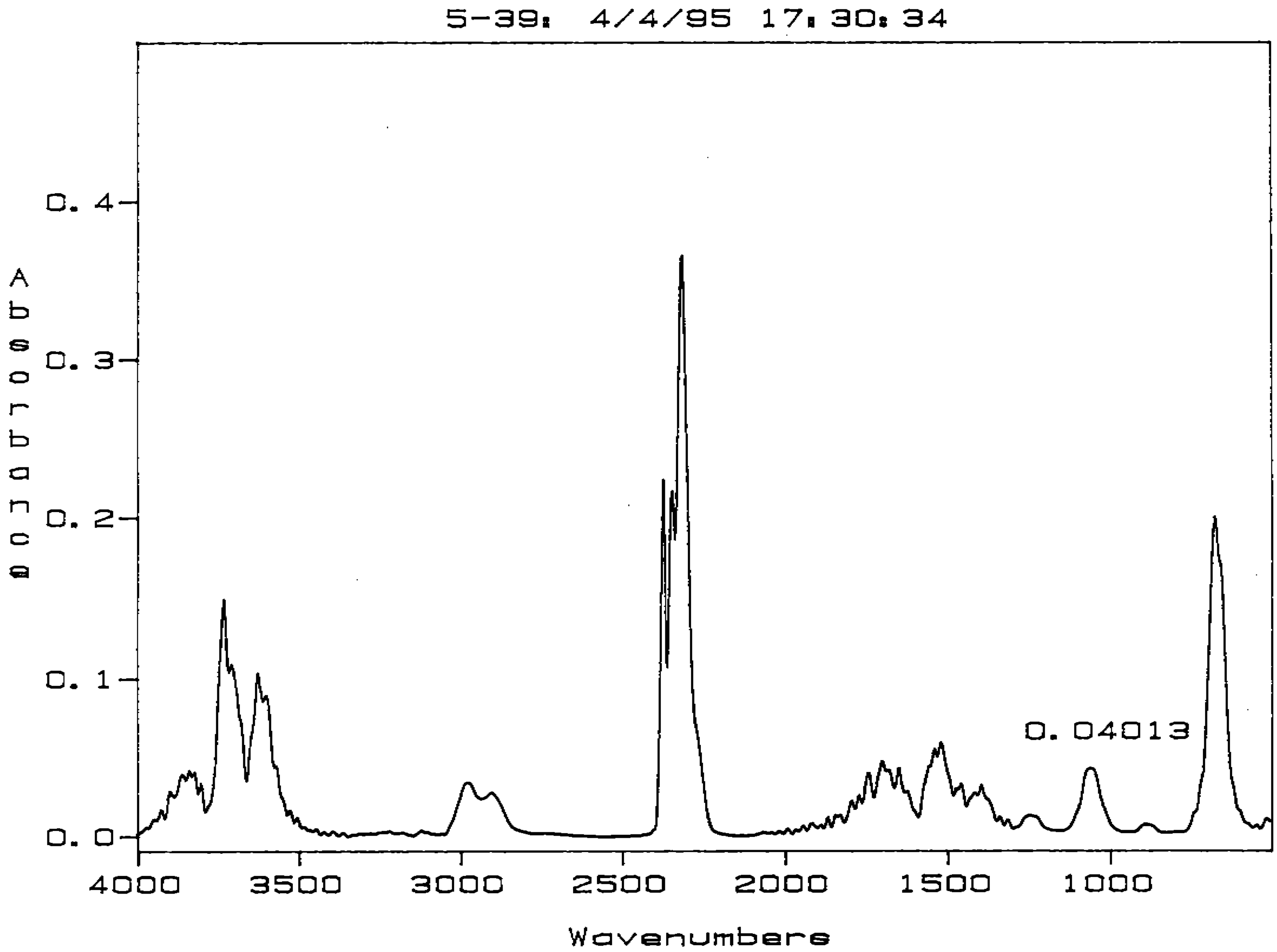
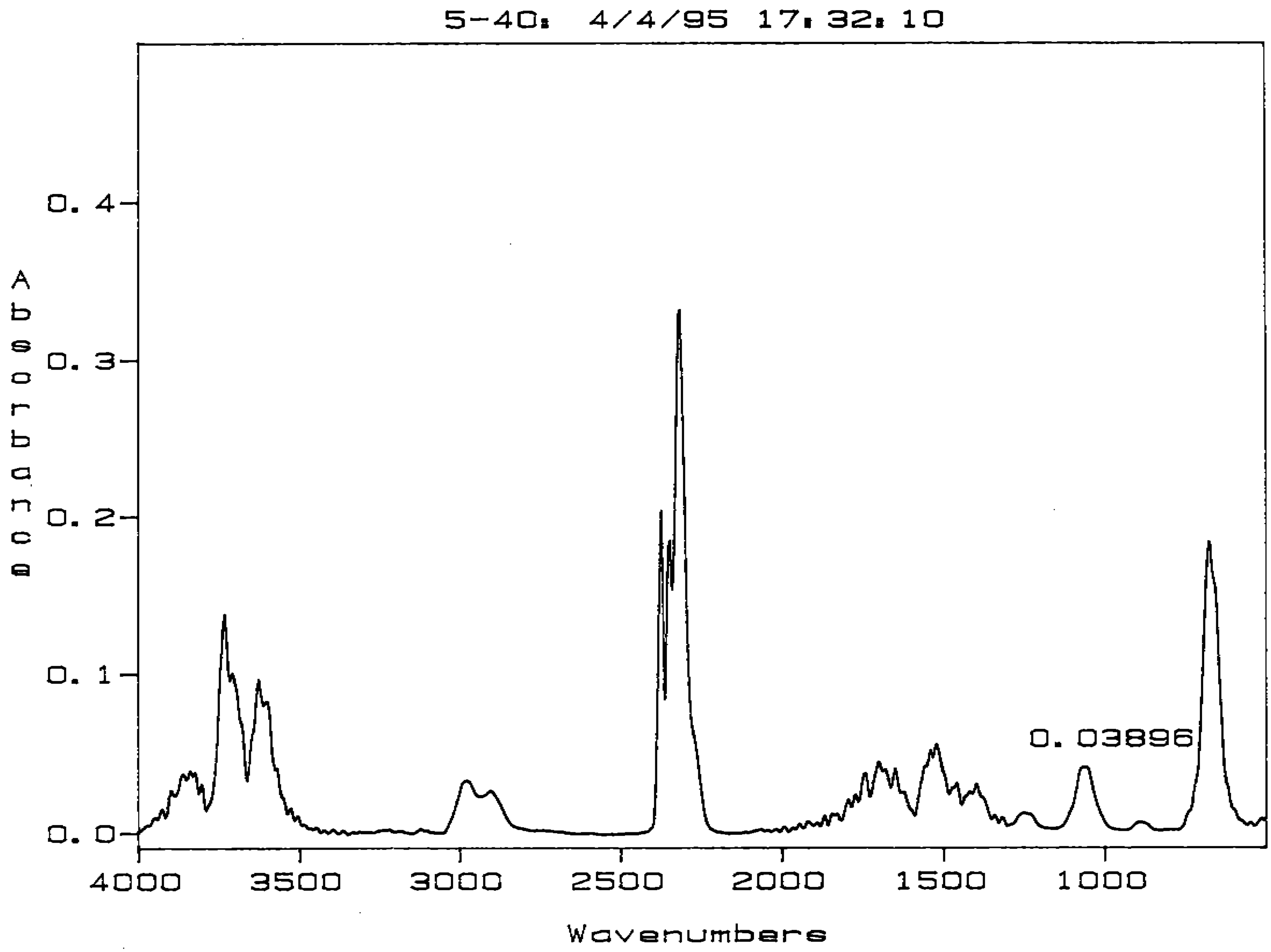
0.2
0.1
0.0
0.04160
4000
3500
3000
2500
2000
1500
1000
Wavenumbers


5-38: 4/4/95 17:28:58
0.4
0.3
0.2
0.1
0.0
Absorbance
0.04356
4000
3500
3000
2500
2000
1500
1000
Wavenumbers


5-39: 4/4/95 17:30:34
0.4
0.3
0.2
0.1
0.0
Absorbance
0.04013
4000
3500
3000
2500
2000
1500
1000
Wavenumbers



5-40: 4/4/95 17:32:10
Absorbance
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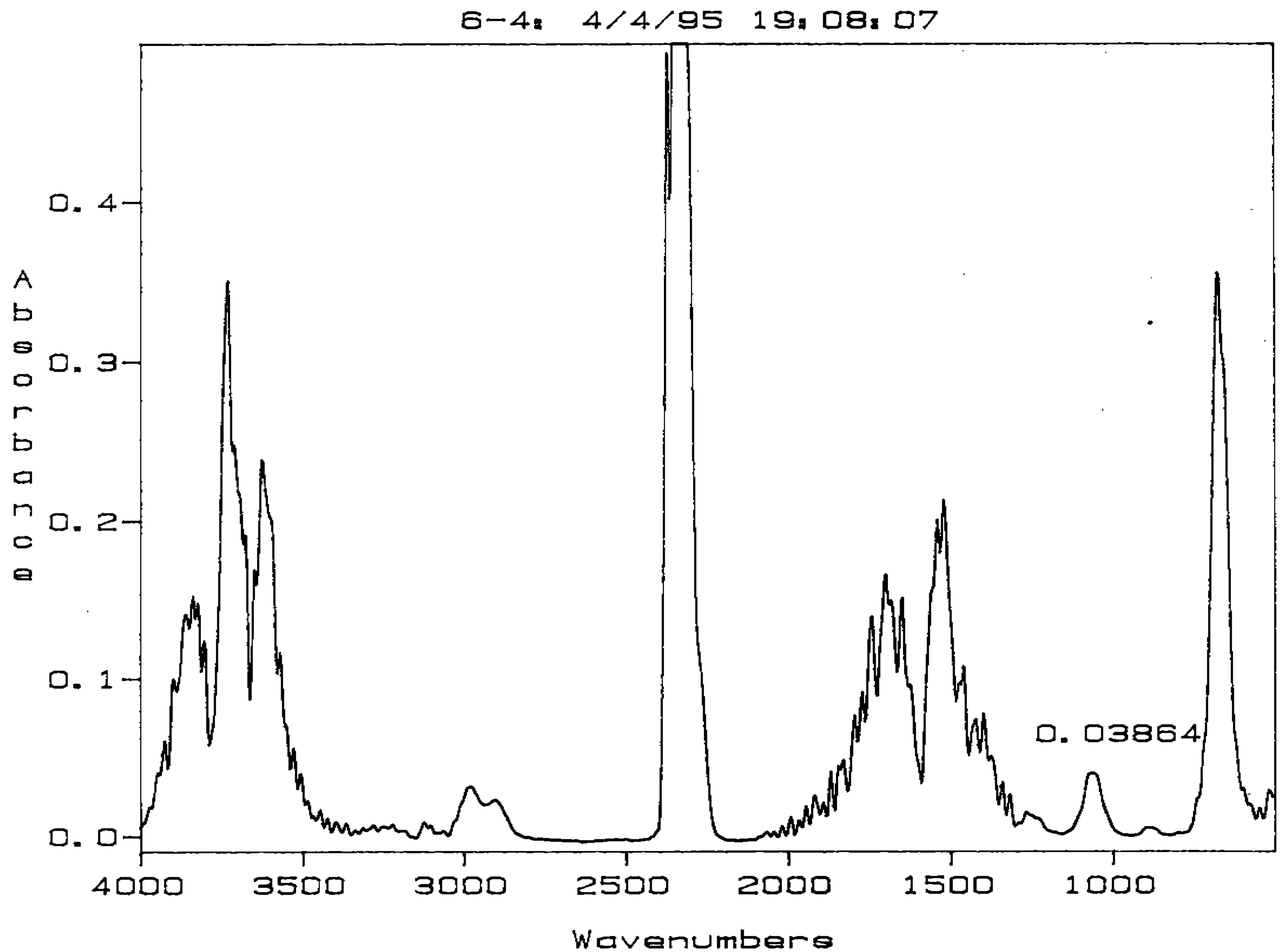
0.3
0.2
0.1
0.0
0.03896
4000
3500
3000
2500
2000
1500
1000
Wavenumbers



6-4: 4/4/95 19:08:07
Absorbance
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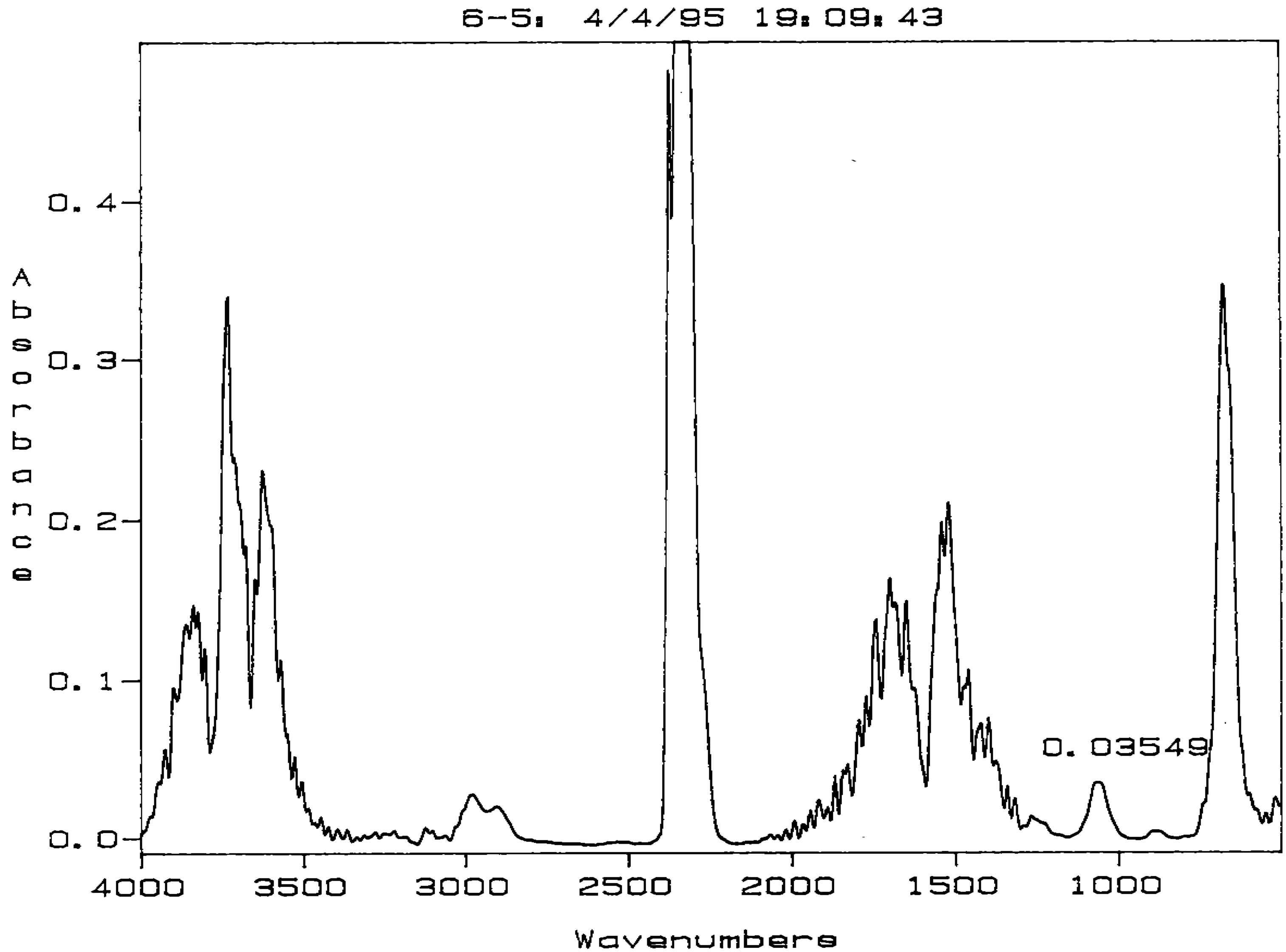
0.2
0.1
0.0
0.03864
4000
3500
3000
2500
2000
1500
1000
Wavenumbers



6-5: 4/4/95 19: 09: 43
Absorbance
0. 0
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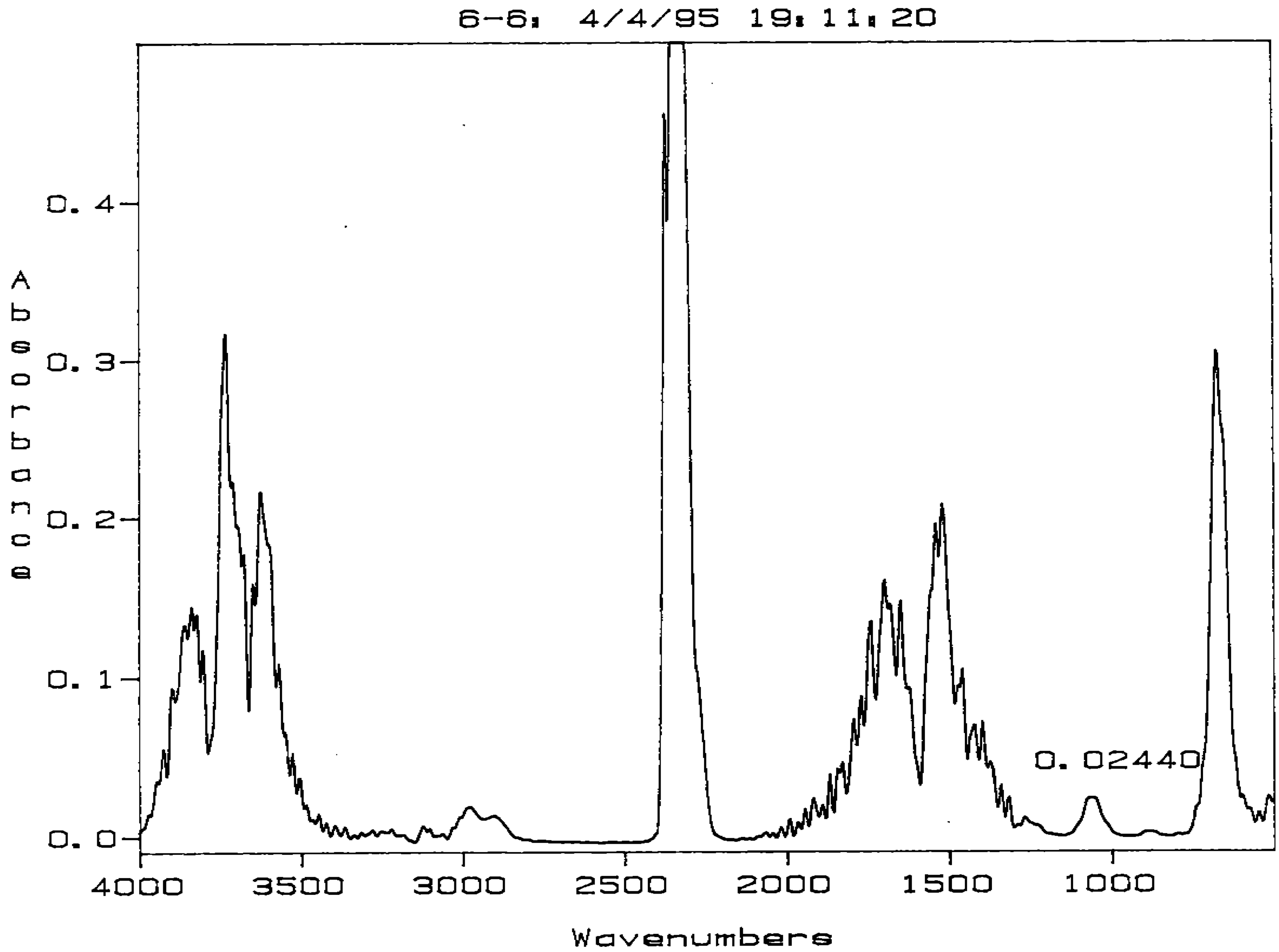
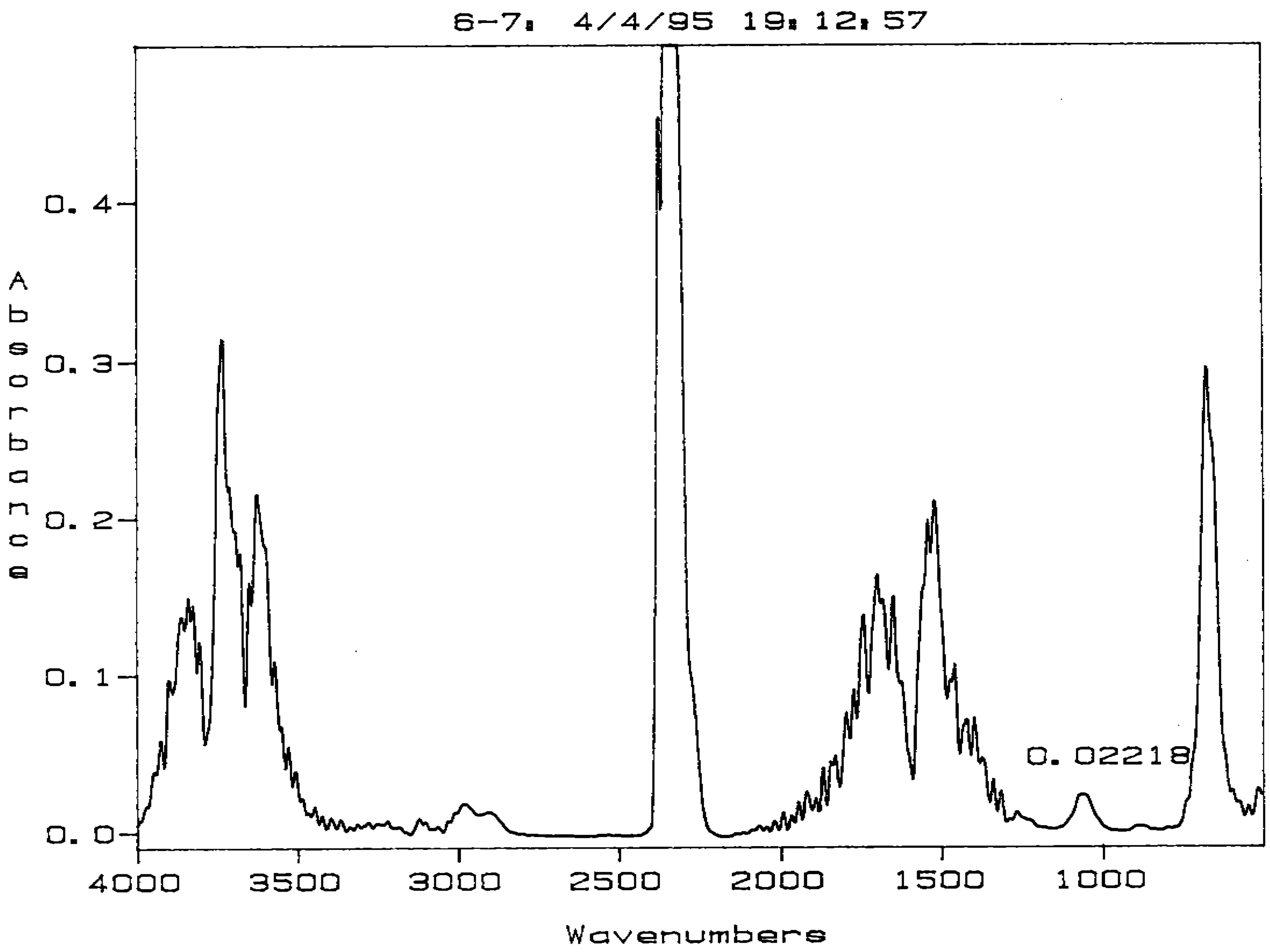
0. 2
0. 3
0. 4
0. 03549
4000
3500
3000
2500
2000
1500
1000
Wavenumbers


6-6: 4/4/95 19:11:20
0.4
0.3
0.2
0.1
0.0
Absorbance
0.02440
4000
3500
3000
2500
2000
1500
1000
Wavenumbers


6-7: 4/4/95 19:12:57
Absorbance
0.4
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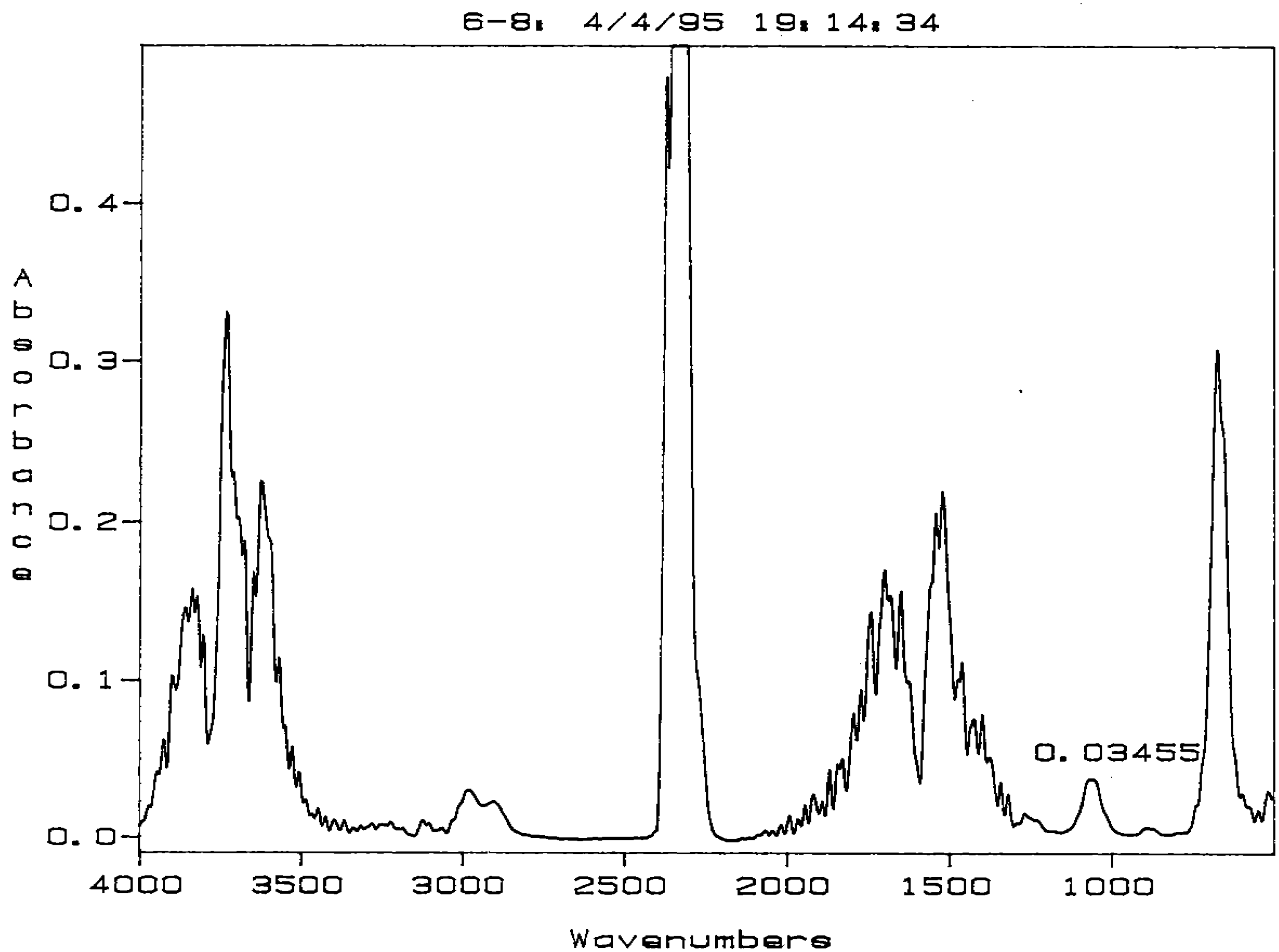
0.2
0.1
0.0
0.02218
4000
3500
3000
2500
2000
1500
1000
Wavenumbers


6-8: 4/4/95 19:14:34
Absorbance
0.4
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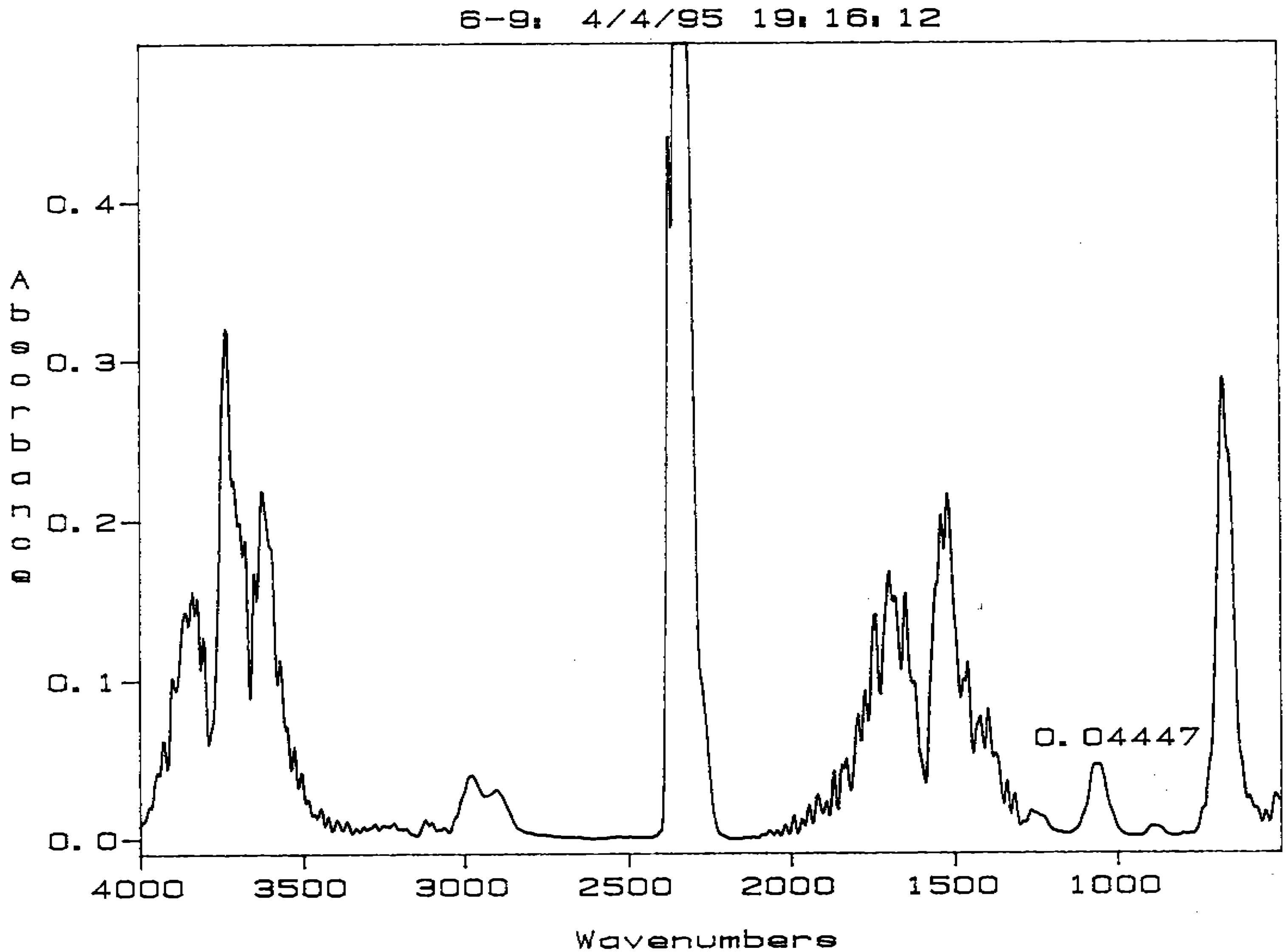
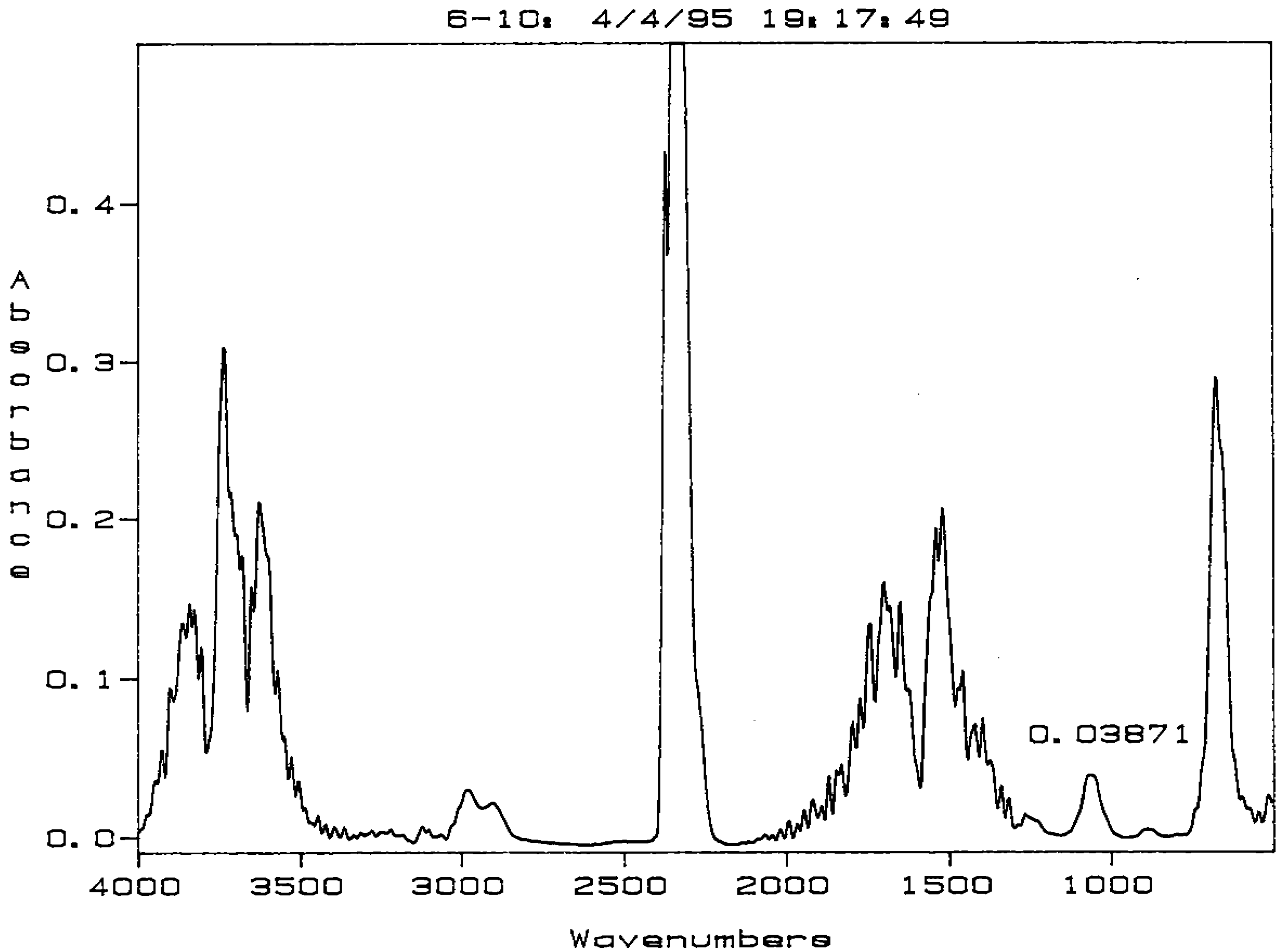
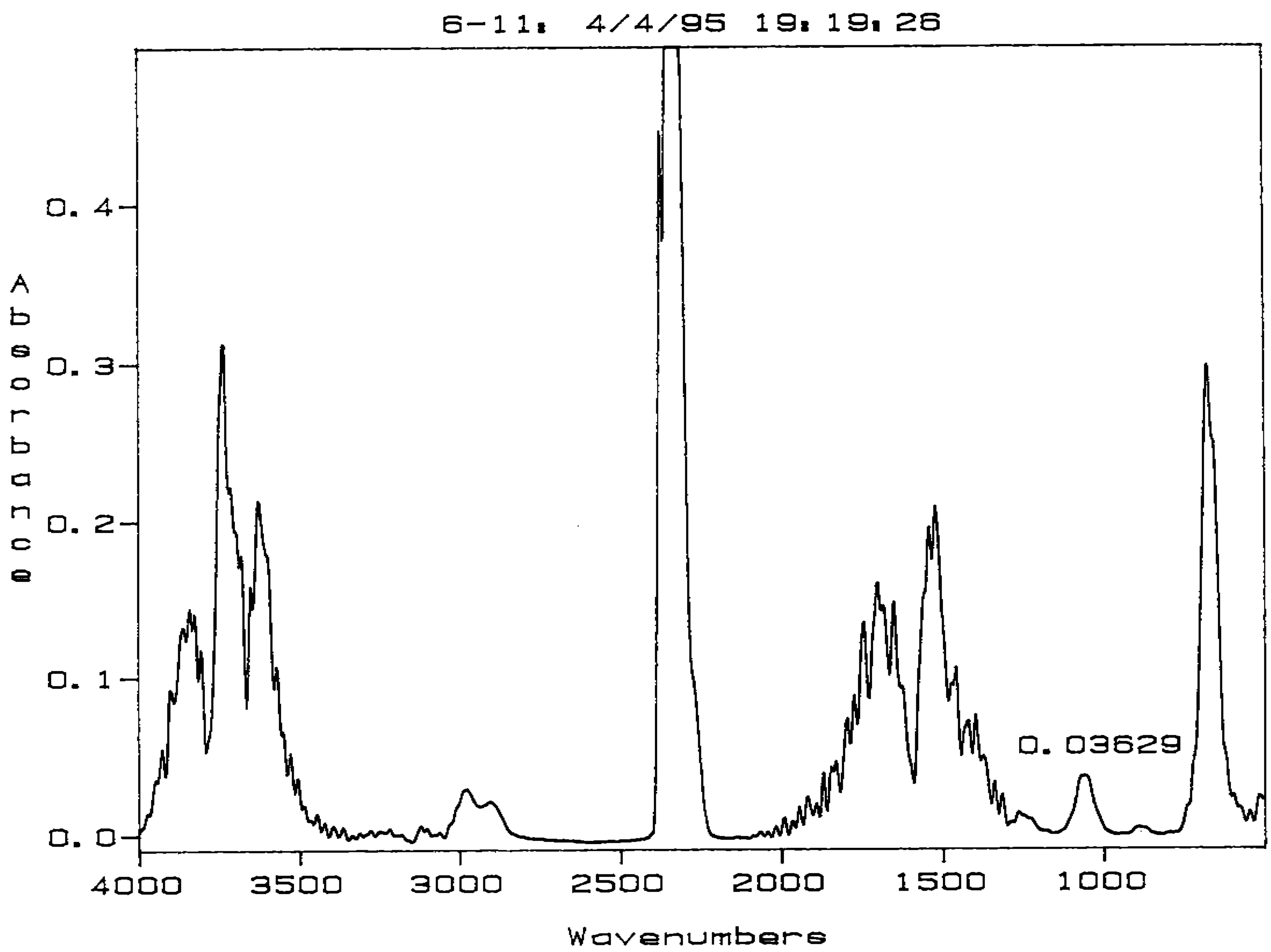
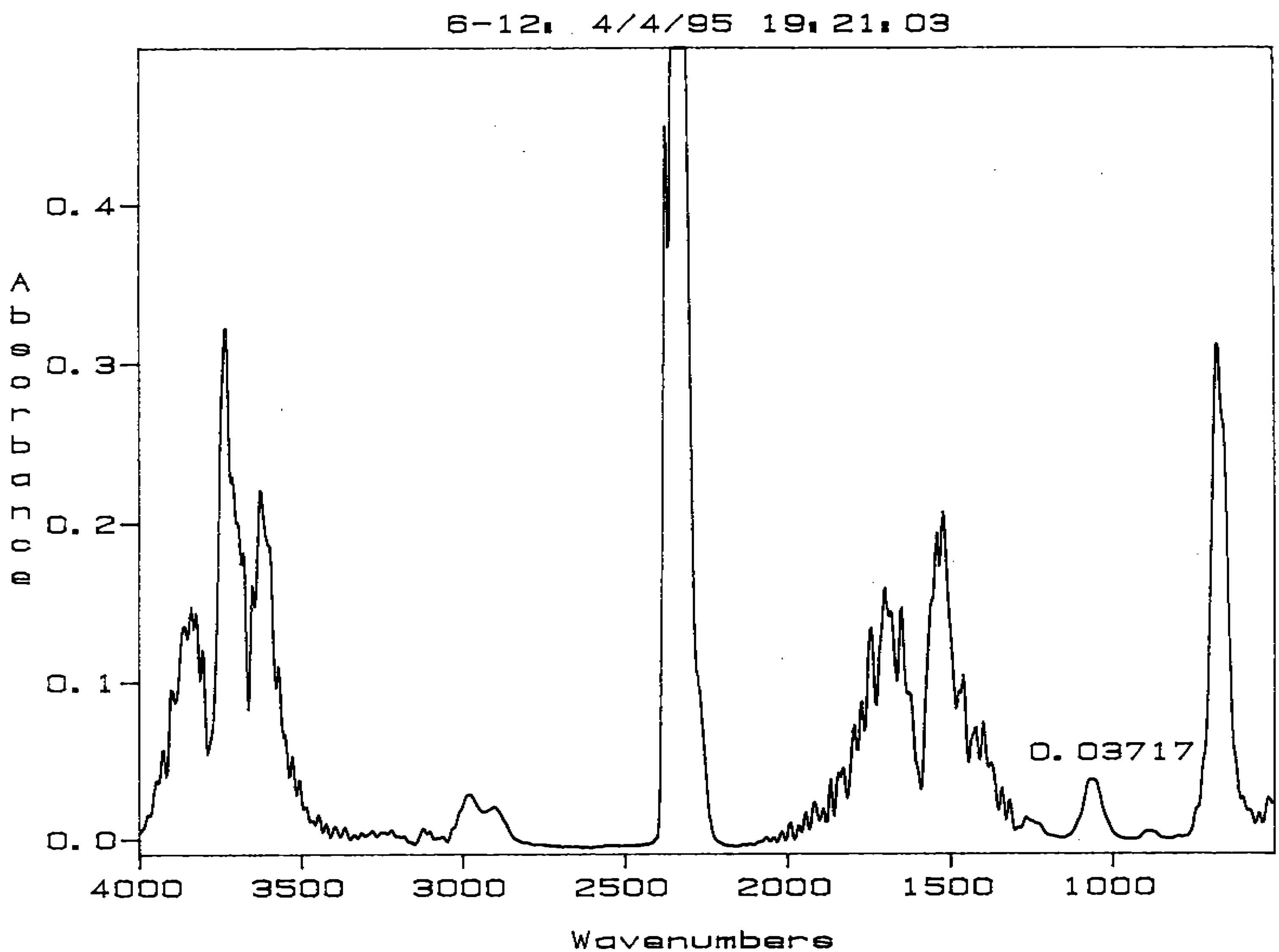
0.2
0.1
0.0
0.03455
4000
3500
3000
2500
2000
1500
1000
Wavenumbers

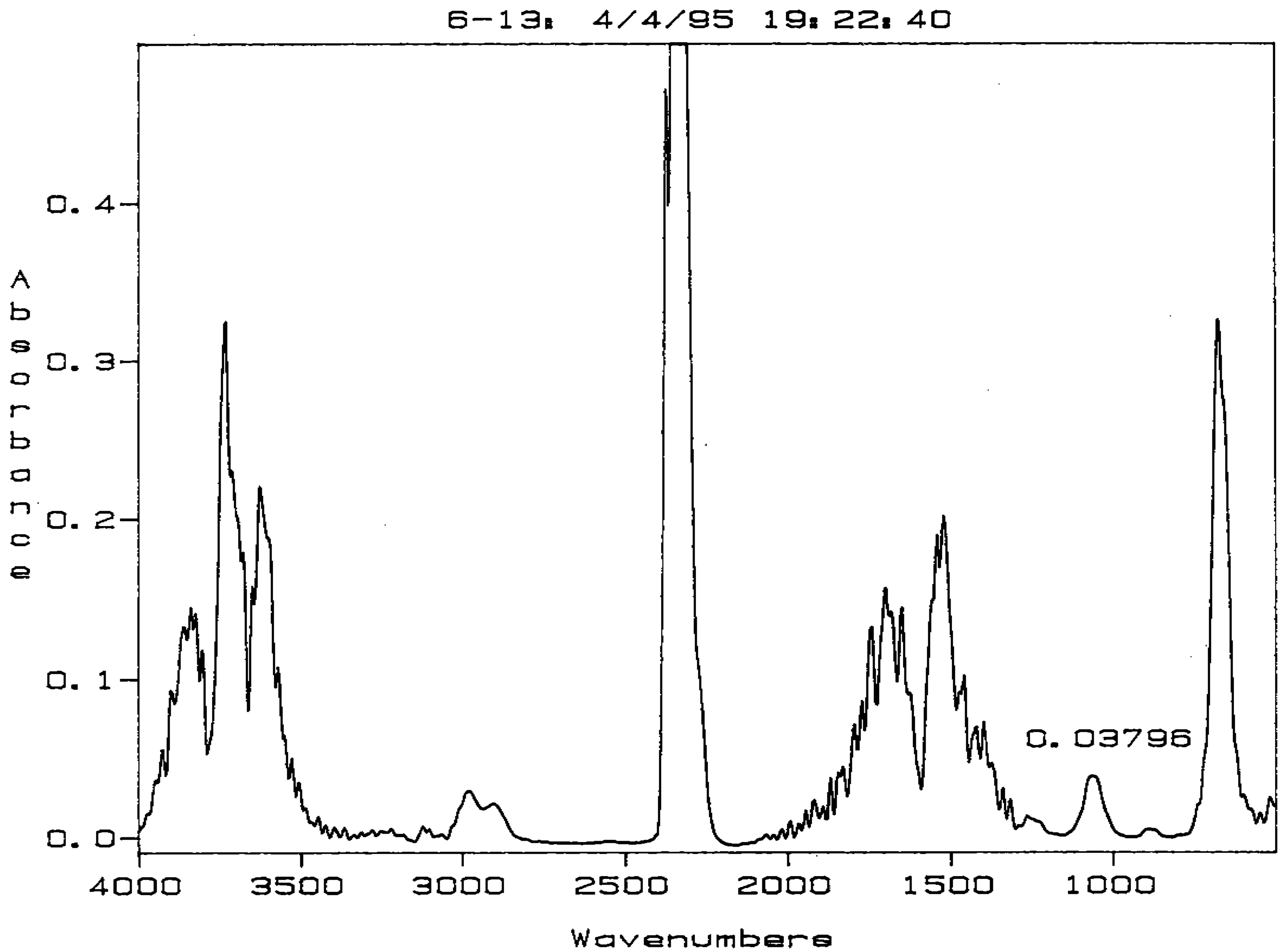

6-9: 4/4/95 19:16:12
0.4
0.3
0.2
0.1
0.0
Absorbance
0.04447
4000
3500
3000
2500
2000
1500
1000
Wavenumbers

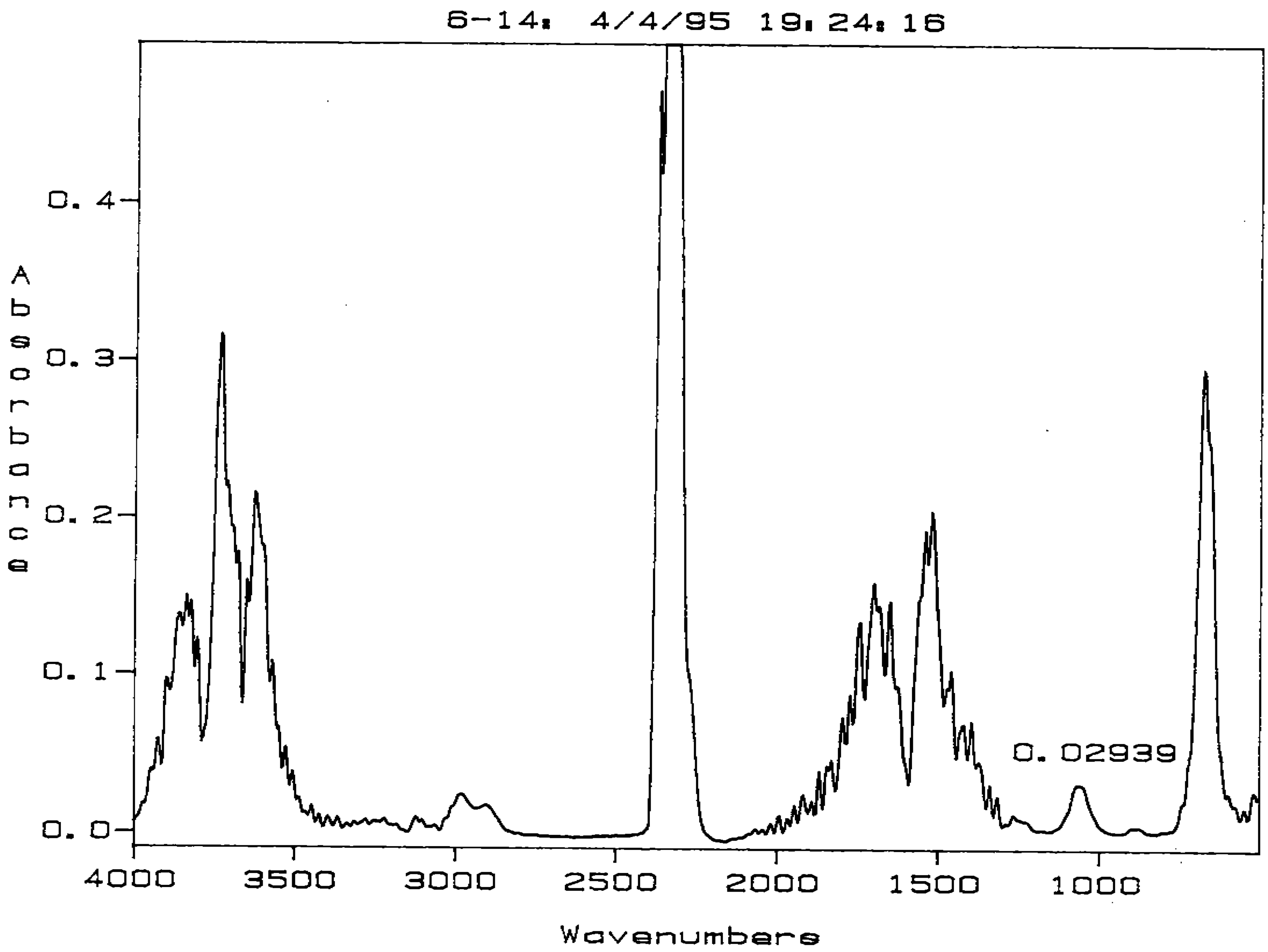

6-10: 4/4/95 19:17:49
Absorbance
0.4
0.3
0.2
0.1
0.0
0.03871
4000
3500
3000
2500
2000
1500
1000
Wavenumbers


6-11: 4/4/95 19:19:26
Absorbance
0.4
0.3
0.2
0.1
0.0
4000
3500
3000
2500
2000
1500
1000
Wavenumbers
0.03629

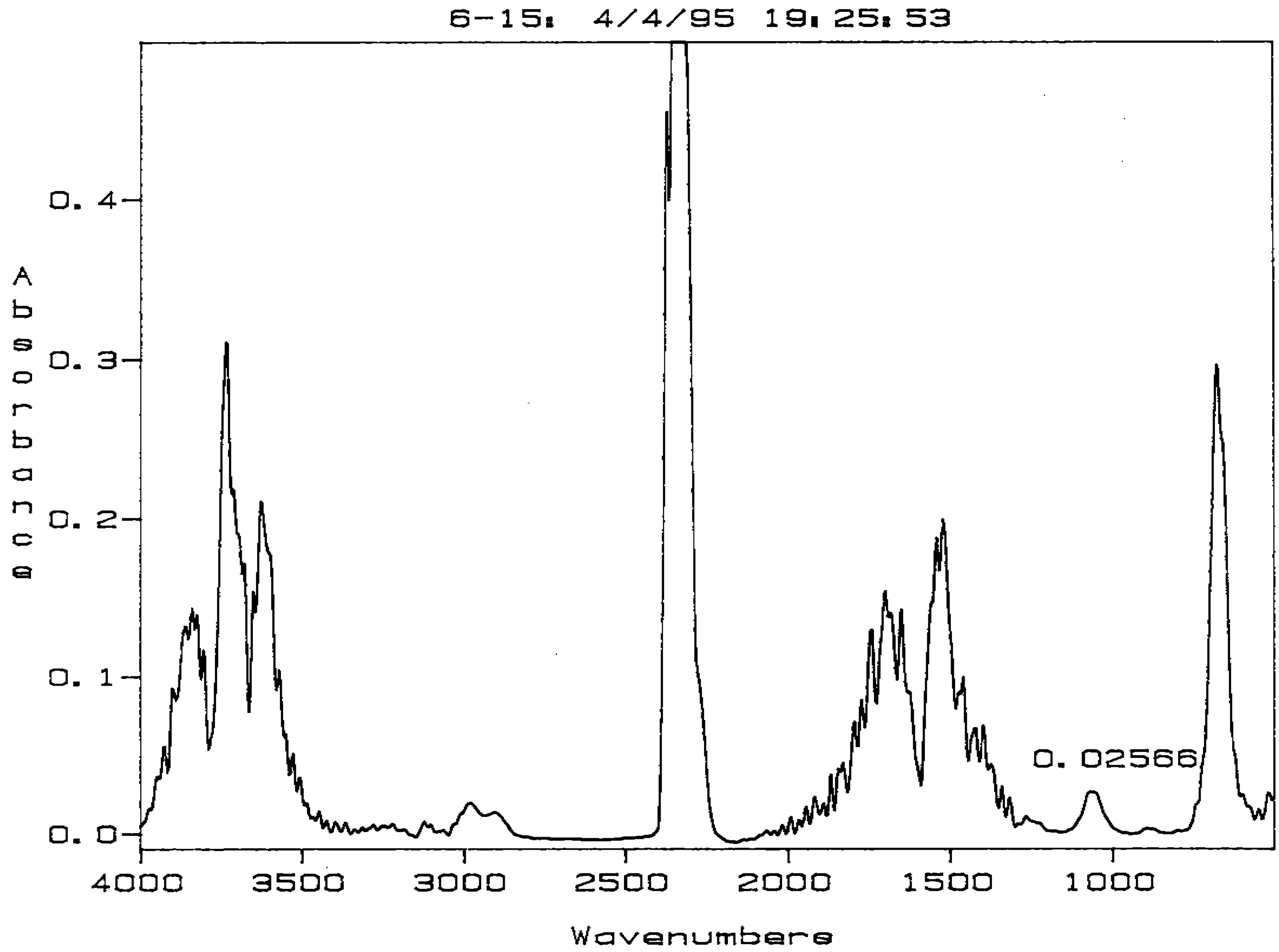


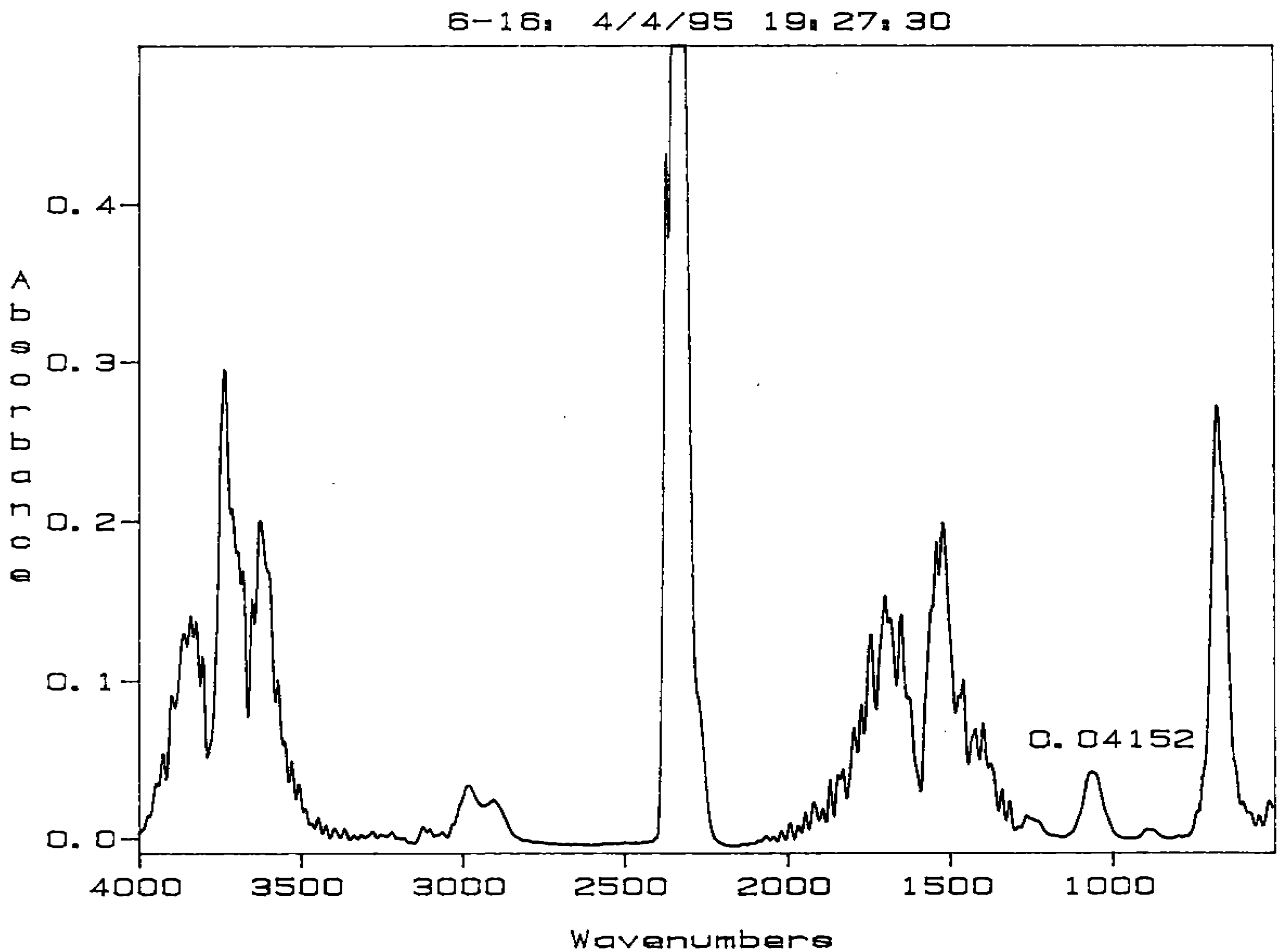
6-12: 4/4/95 19:21:03
Absorbance
0.0
0.1
0.2
0.3
0.4
0.03717
4000
3500
3000
2500
2000
1500
1000
Wavenumbers

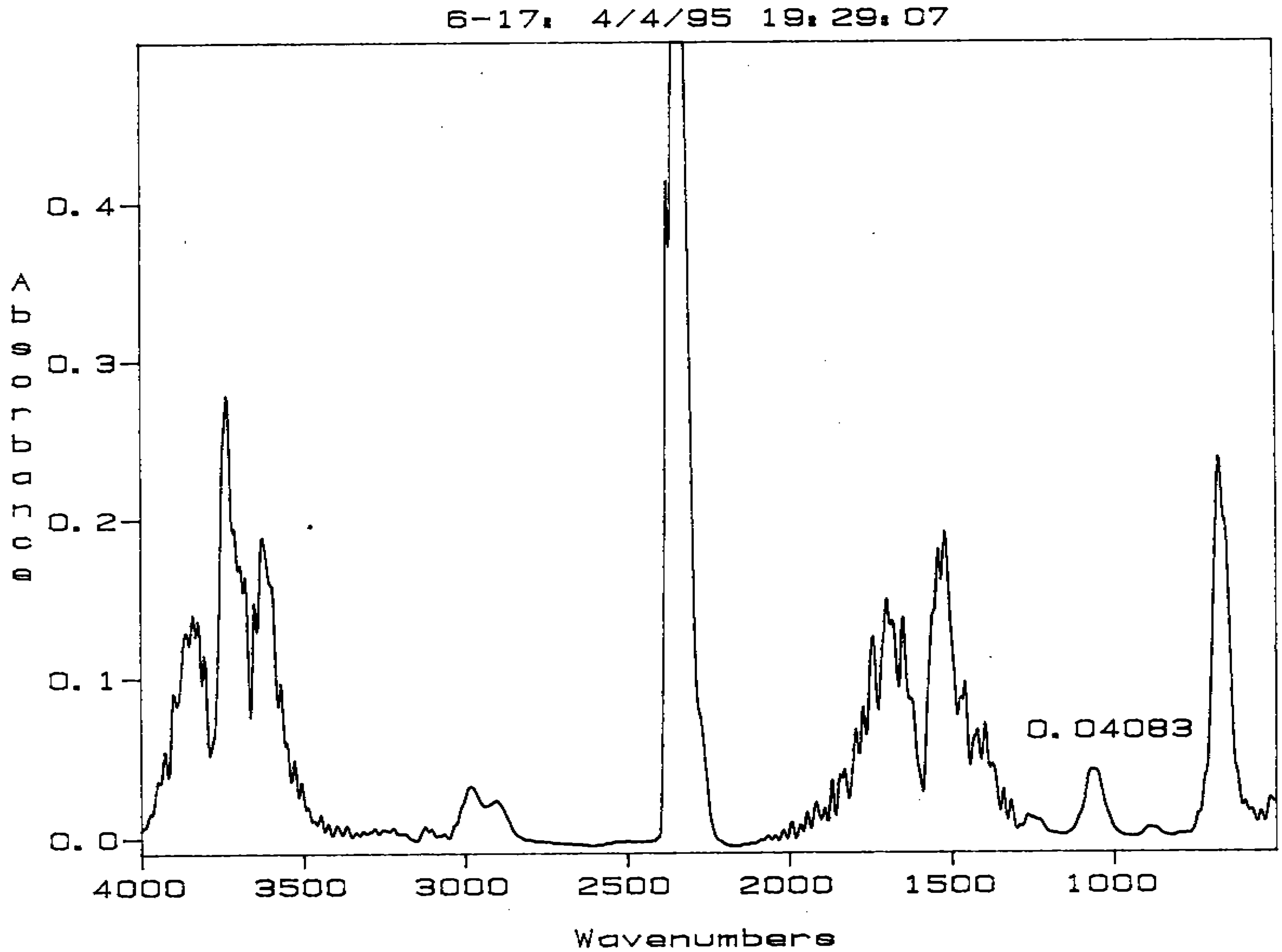

6-13: 4/4/95 19:22:40
0.4
0.3
0.2
0.1
0.0
Absorbance
0.03796
4000
3500
3000
2500
2000
1500
1000
Wavenumbers

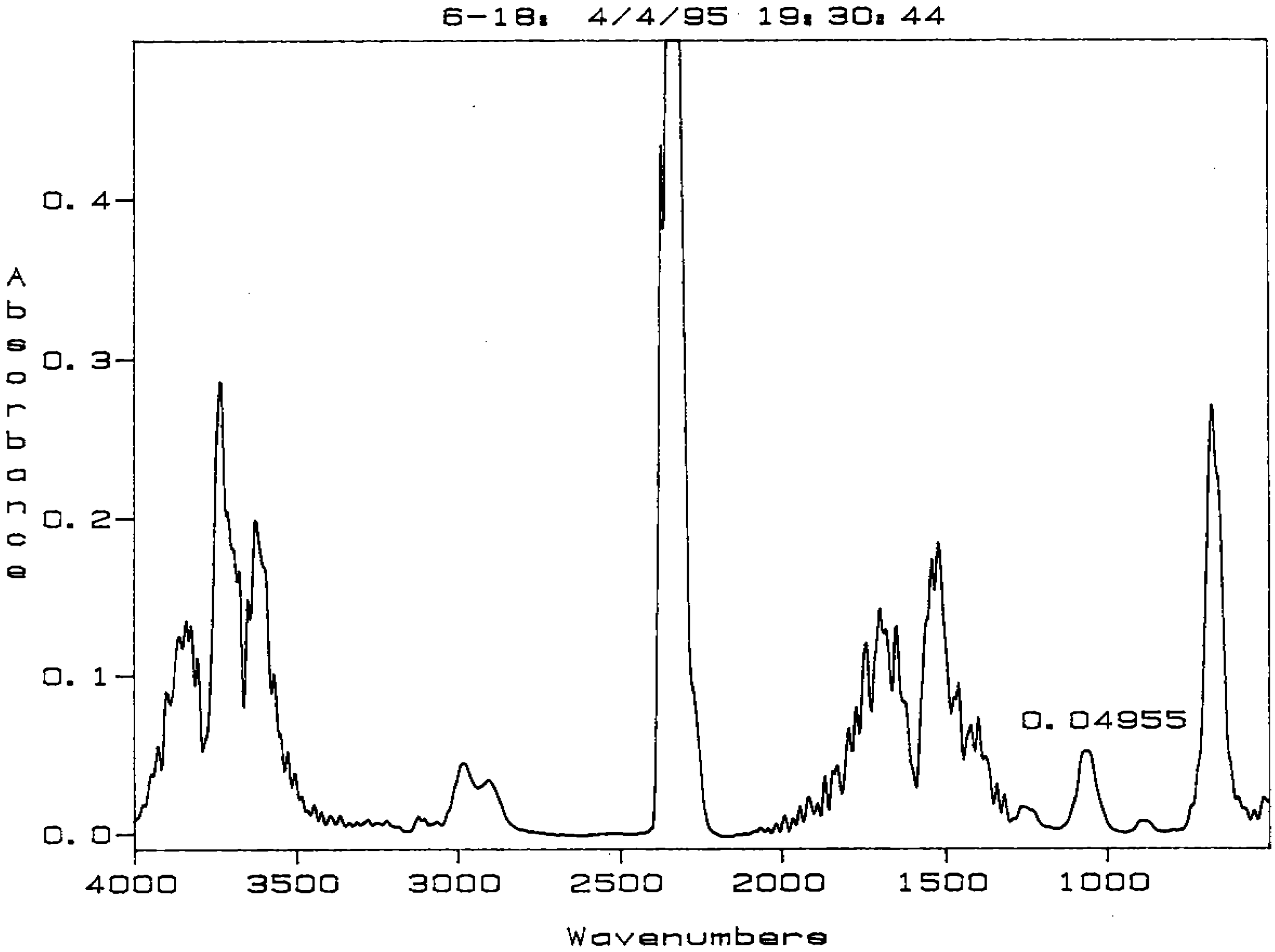


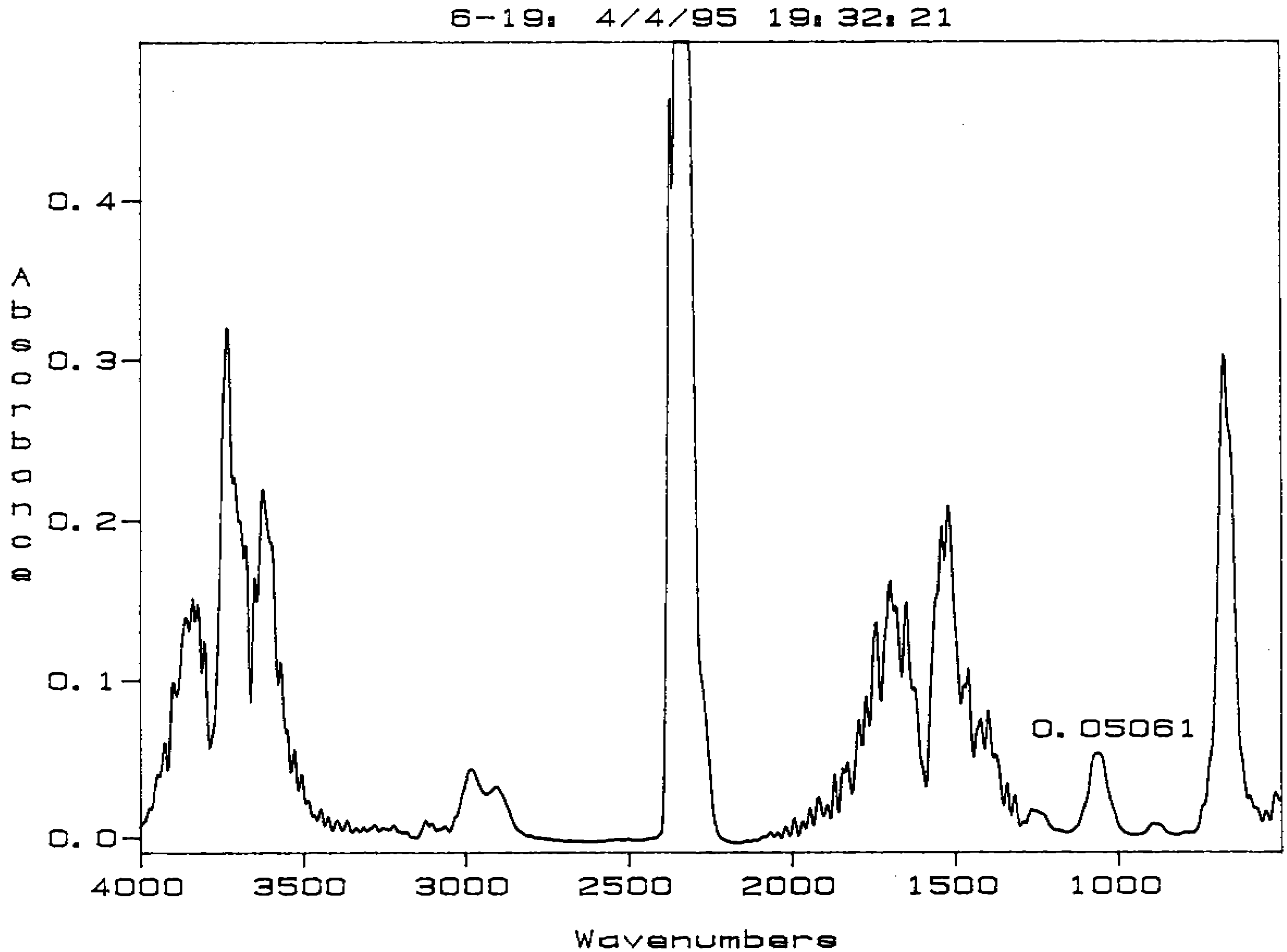
6-14: 4/4/95 19:24:16
0.4
0.3
0.2
0.1
0.0
Absorbance
0.02939
4000
3500
3000
2500
2000
1500
1000
Wavenumbers

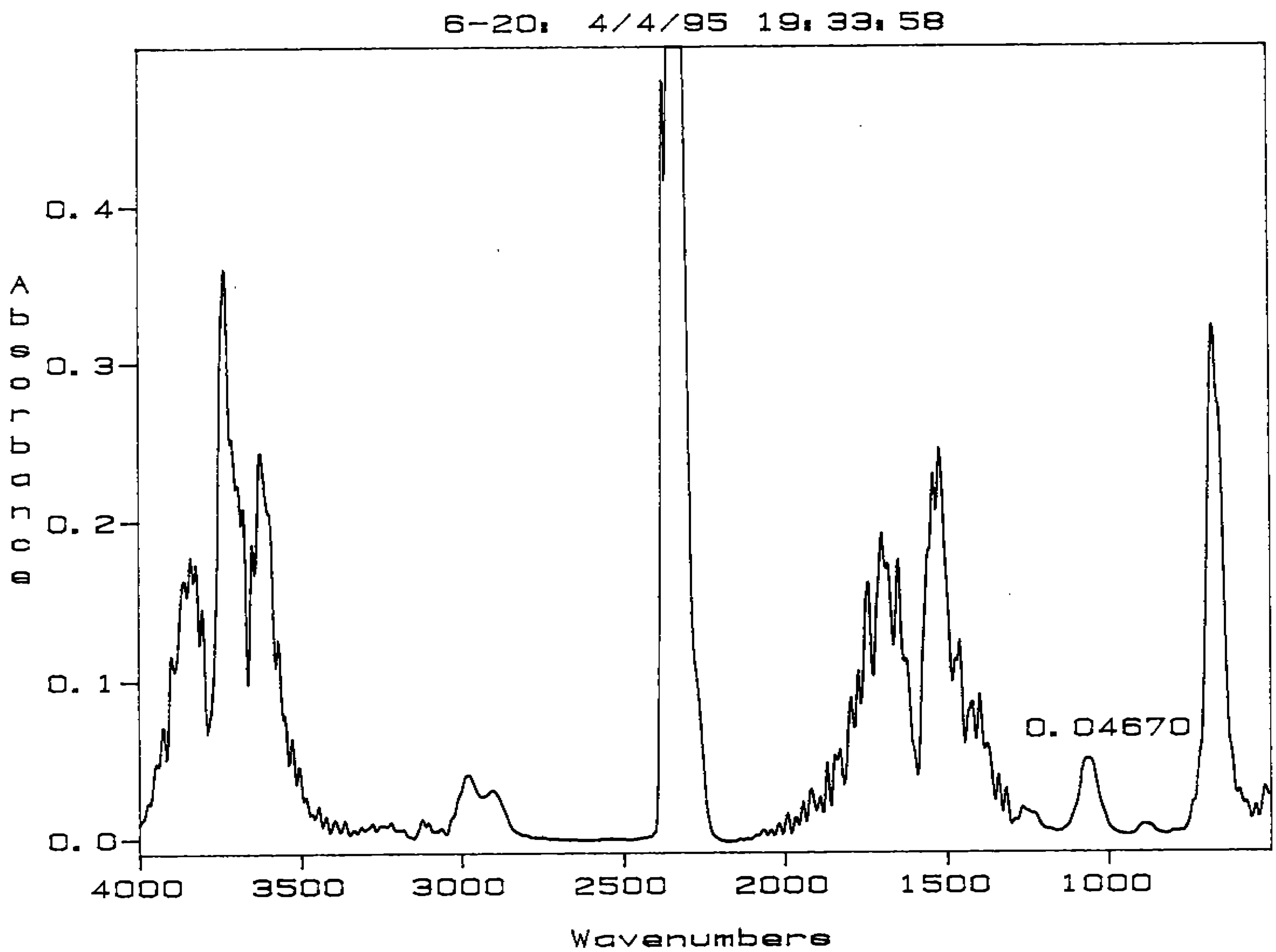

6-15: 4/4/95 19:25:53
Absorbance
0.0
0.1
0.2
0.3
0.4
0.02566
4000
3500
3000
2500
2000
1500
1000
Wavenumbers

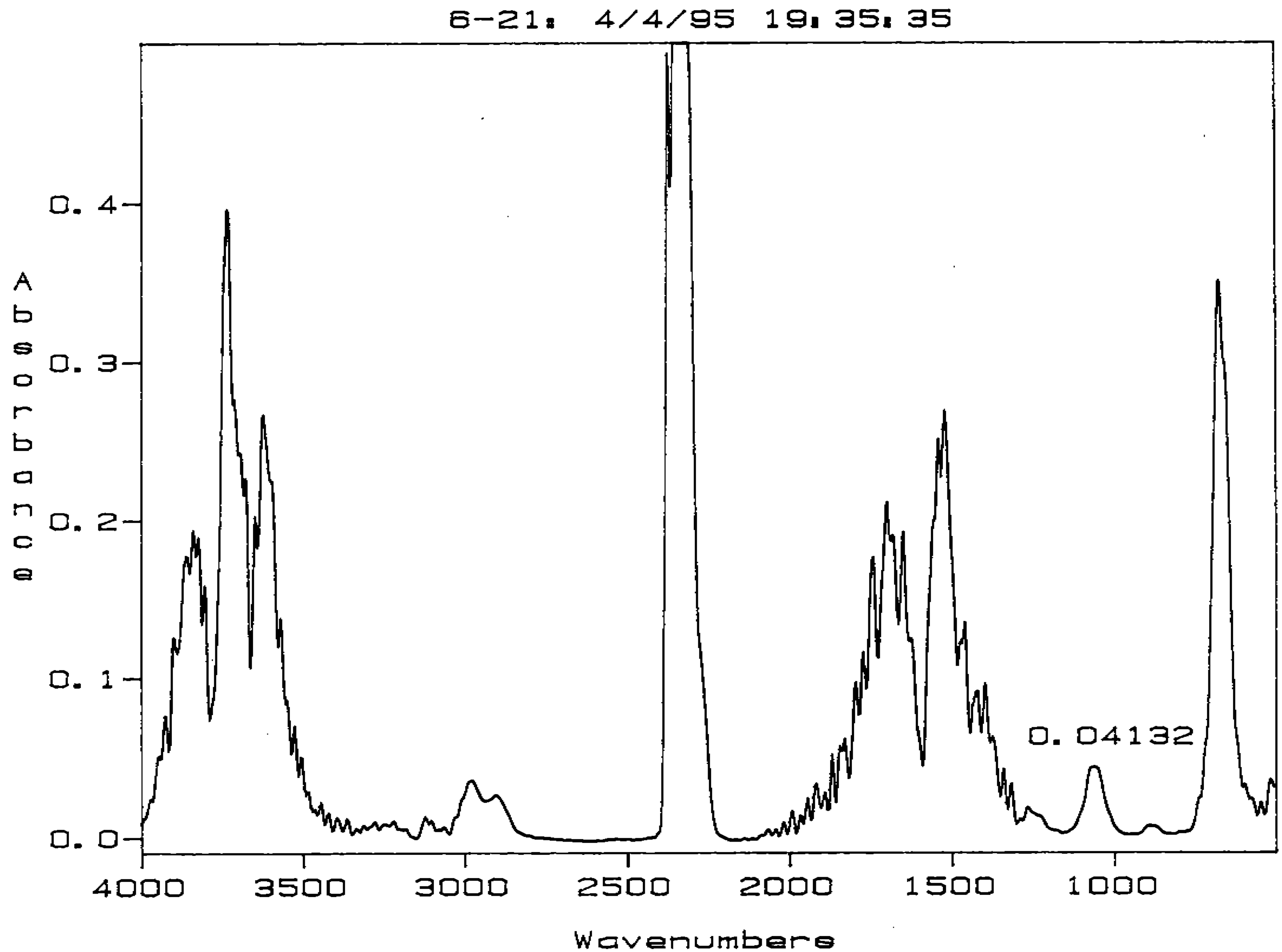

6-16: 4/4/95 19:27:30
Absorbance
0.4
0.3
0.2
0.1
0.0
0.04152
4000
3500
3000
2500
2000
1500
1000
Wavenumbers

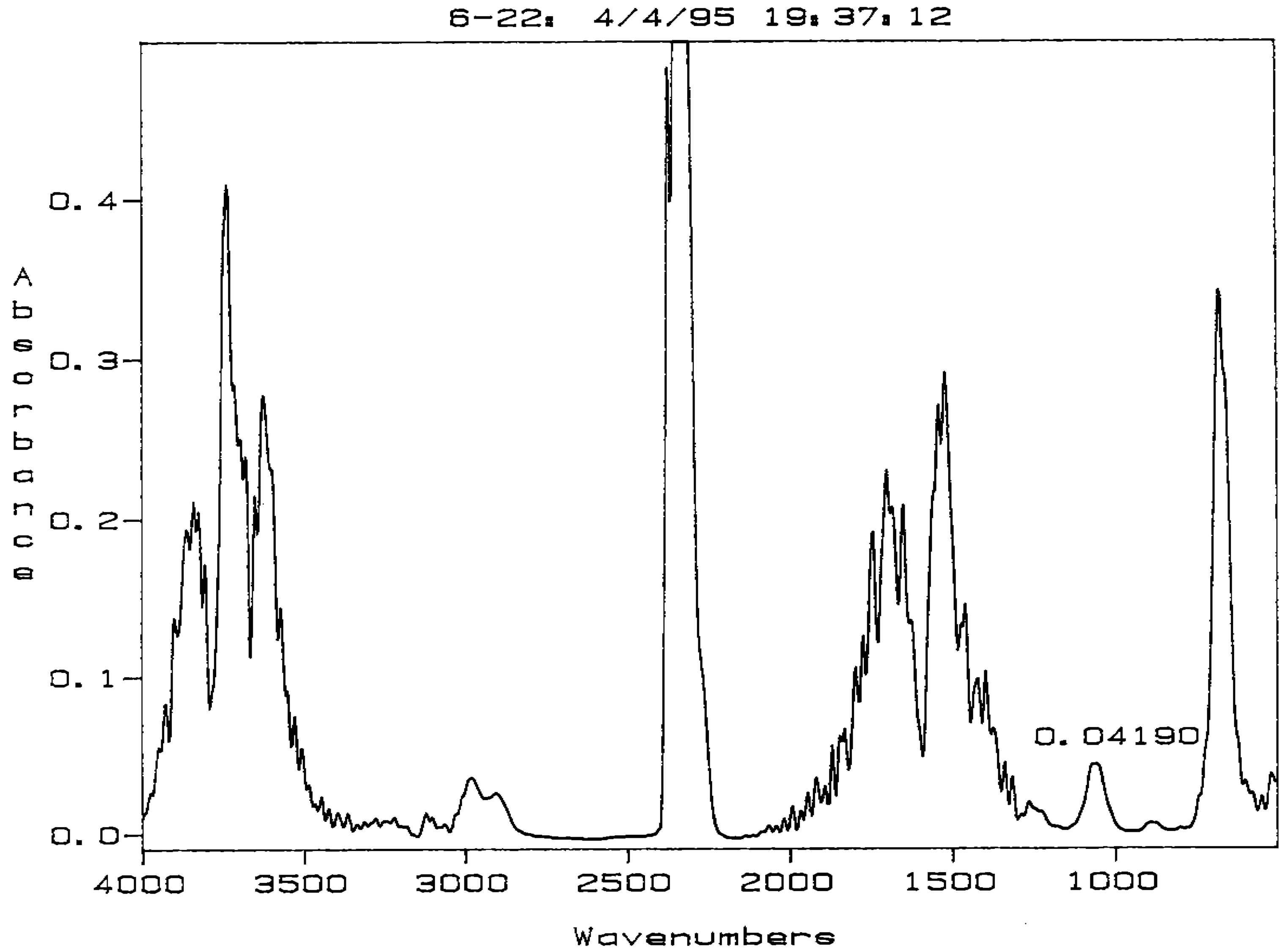

6-17: 4/4/95 19:29:07
Absorbance
0.4
0.3
0.2
0.1
0.0
0.04083
4000
3500
3000
2500
2000
1500
1000
Wavenumbers


6-18: 4/4/95 19:30:44
Absorbance
0.0
0.1
0.2
0.3
0.4
4000
3500
3000
2500
2000
1500
1000
Wavenumbers
0.04955

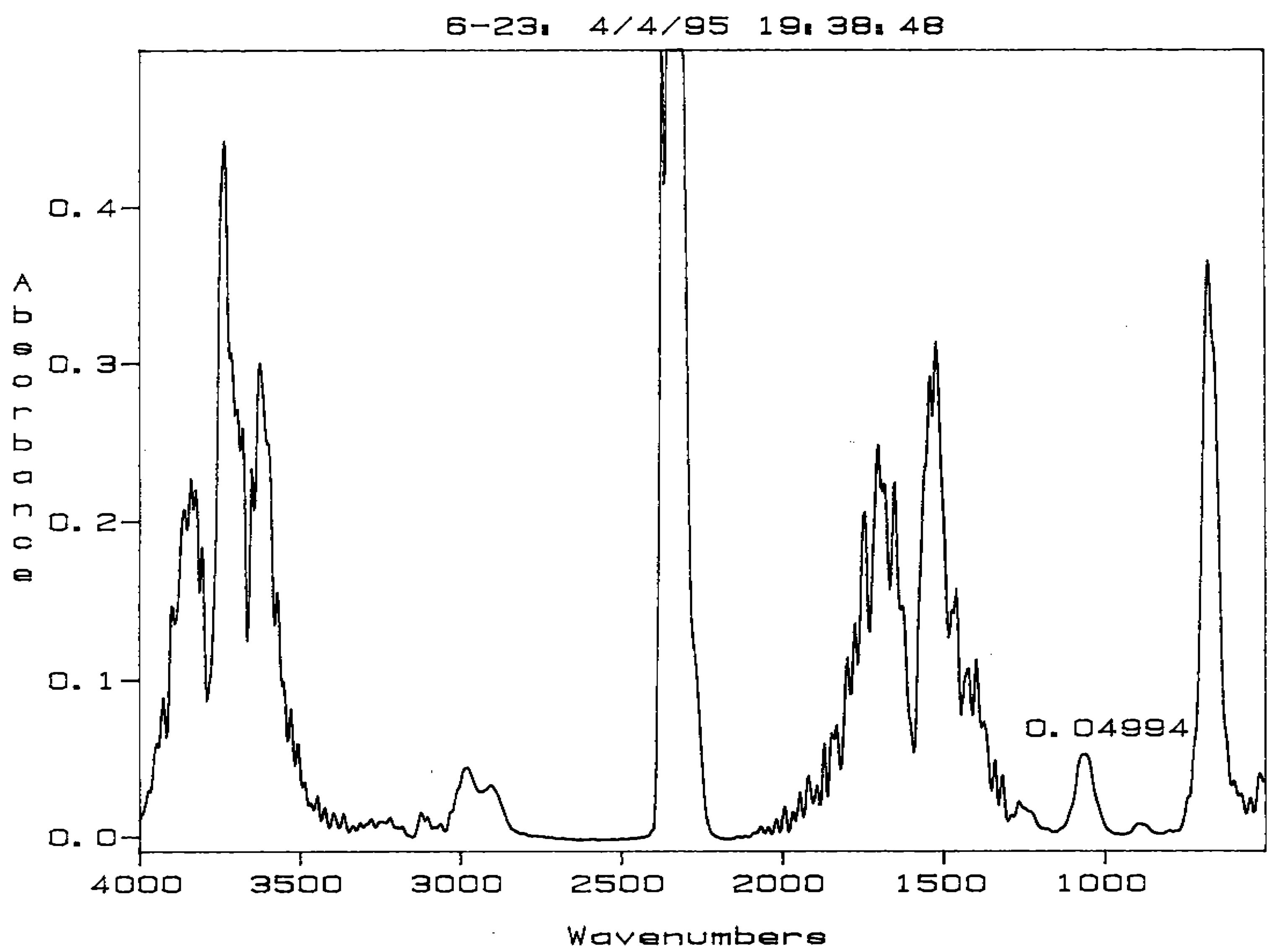

6-19: 4/4/95 19:32:21
0.4
0.3
0.2
0.1
0.0
Absorbance
0.05061
4000
3500
3000
2500
2000
1500
1000
Wavenumbers

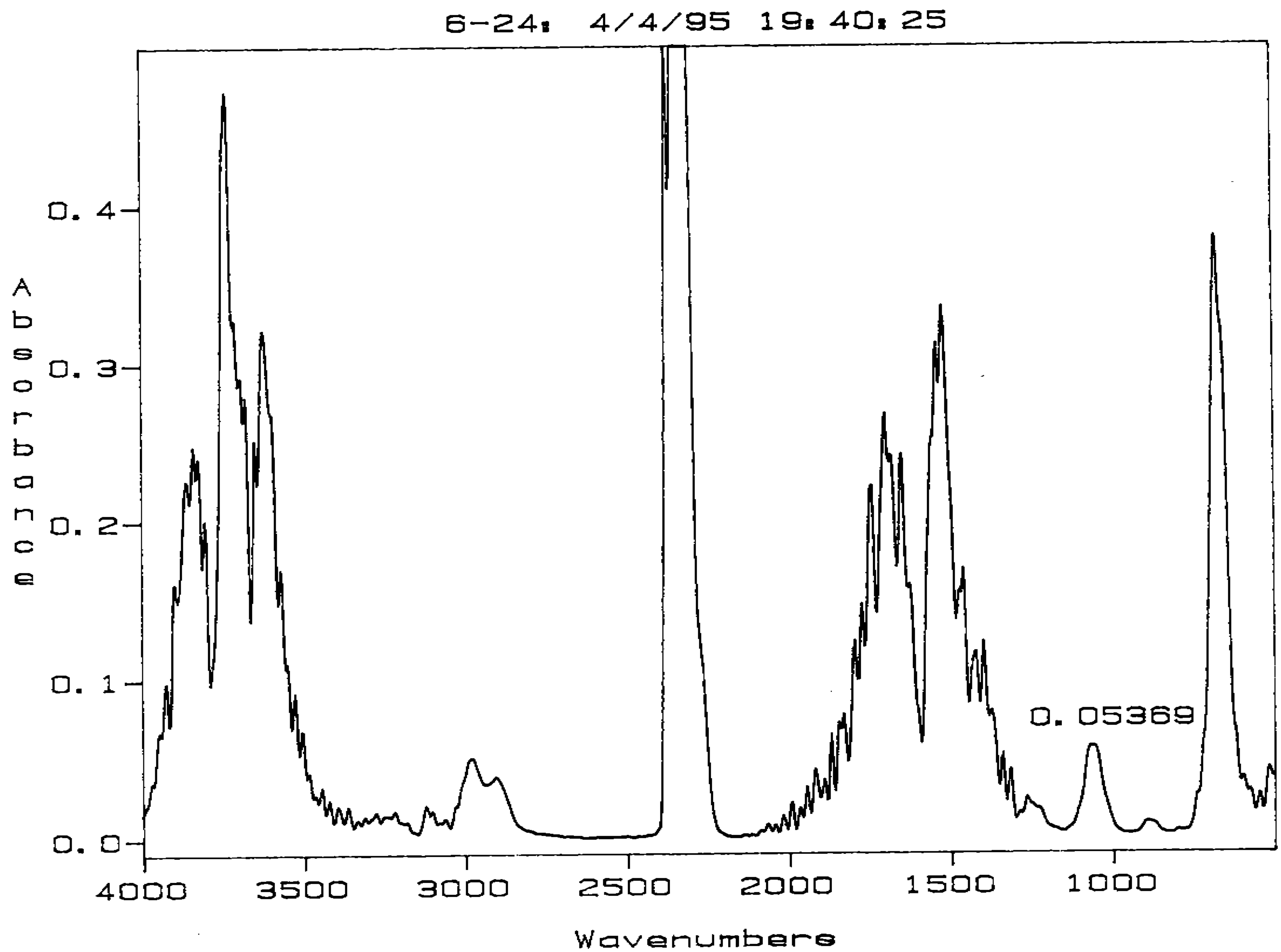

6-20: 4/4/95 19:33:58
0.4
0.3
0.2
0.1
0.0
Absorbance
0.04670
4000
3500
3000
2500
2000
1500
1000
Wavenumbers

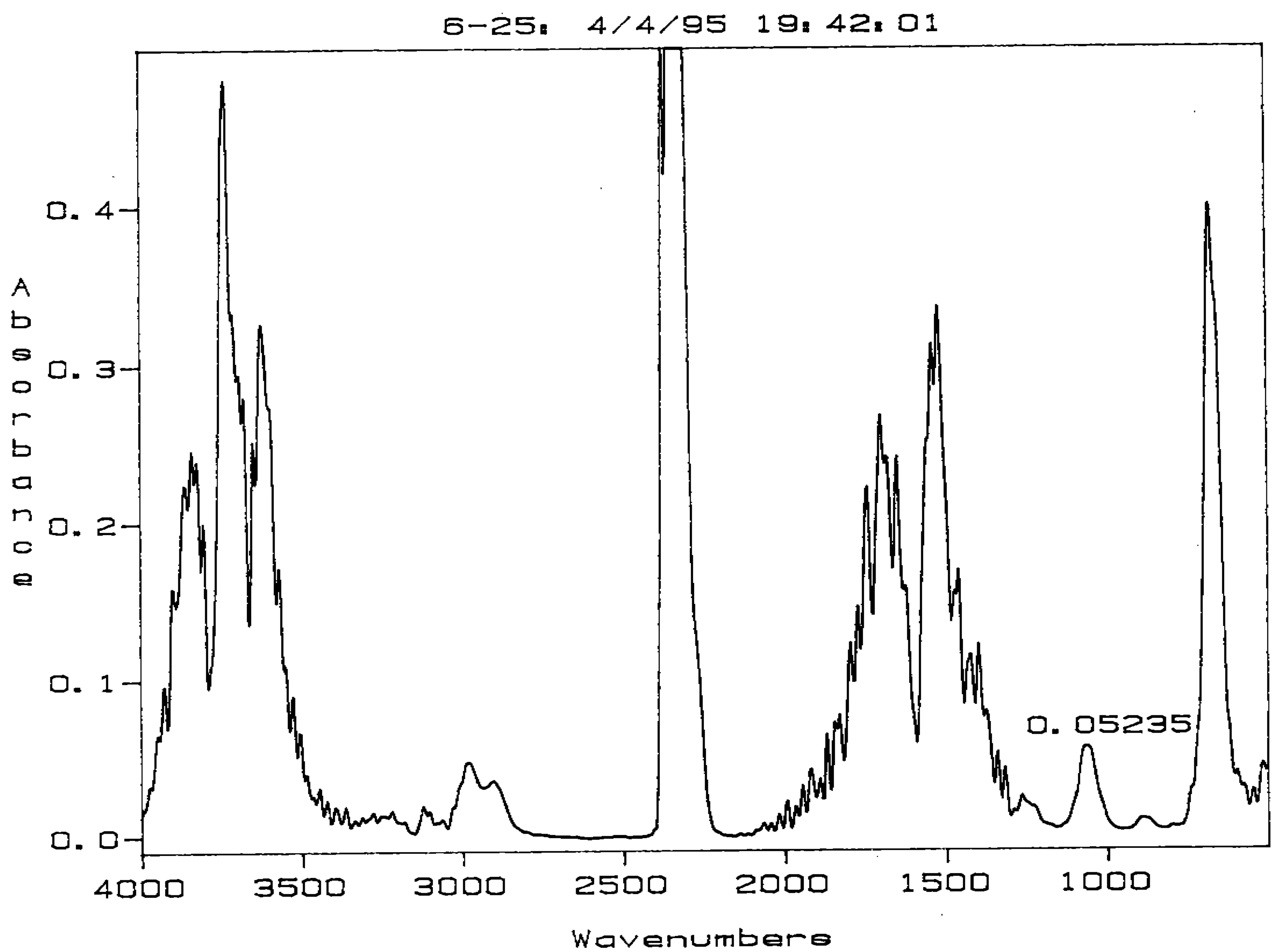

6-21: 4/4/95 19:35:35
0.4
0.3
0.2
0.1
0.0
Absorbance
0.04132
4000
3500
3000
2500
2000
1500
1000
Wavenumbers



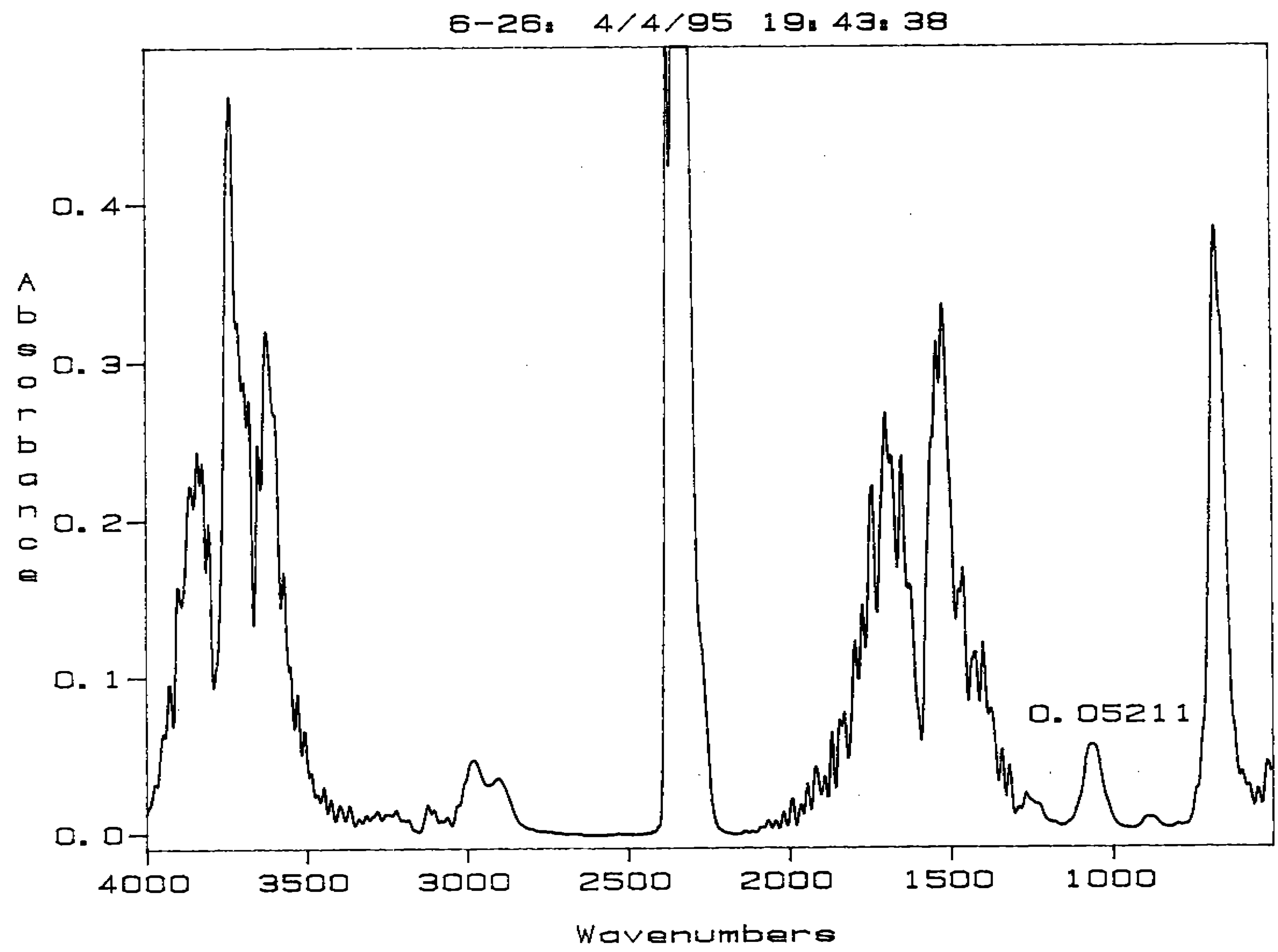
6-22: 4/4/95 19:37:12
Absorbance
0.4
0.3
0.2
0.1
0.0
0.04190
4000
3500
3000
2500
2000
1500
1000
Wavenumbers

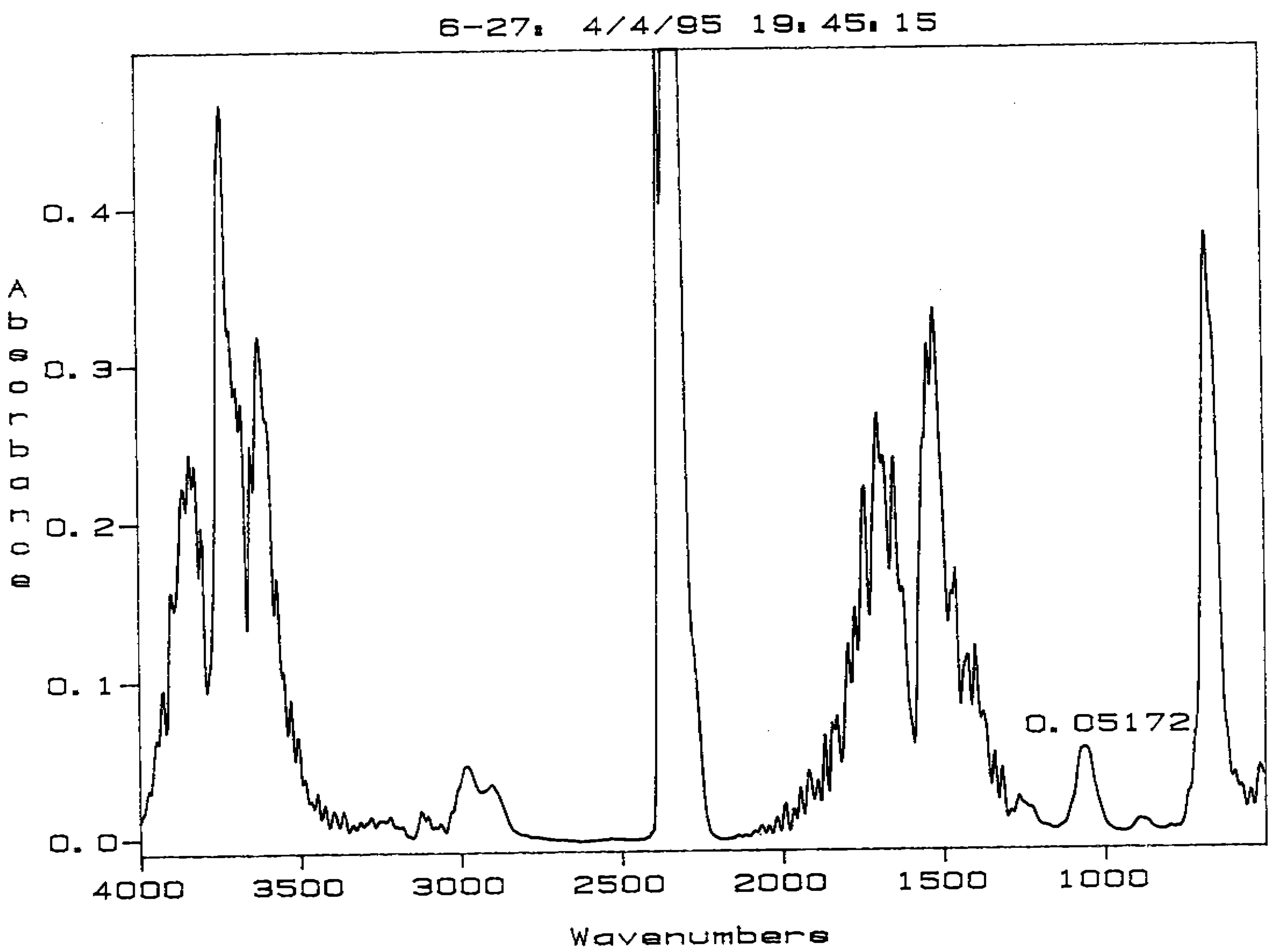

6-23: 4/4/95 19:38:48
Absorbance
0.0
0.1
0.2
0.3
0.4
0.04994
4000
3500
3000
2500
2000
1500
1000
Wavenumbers

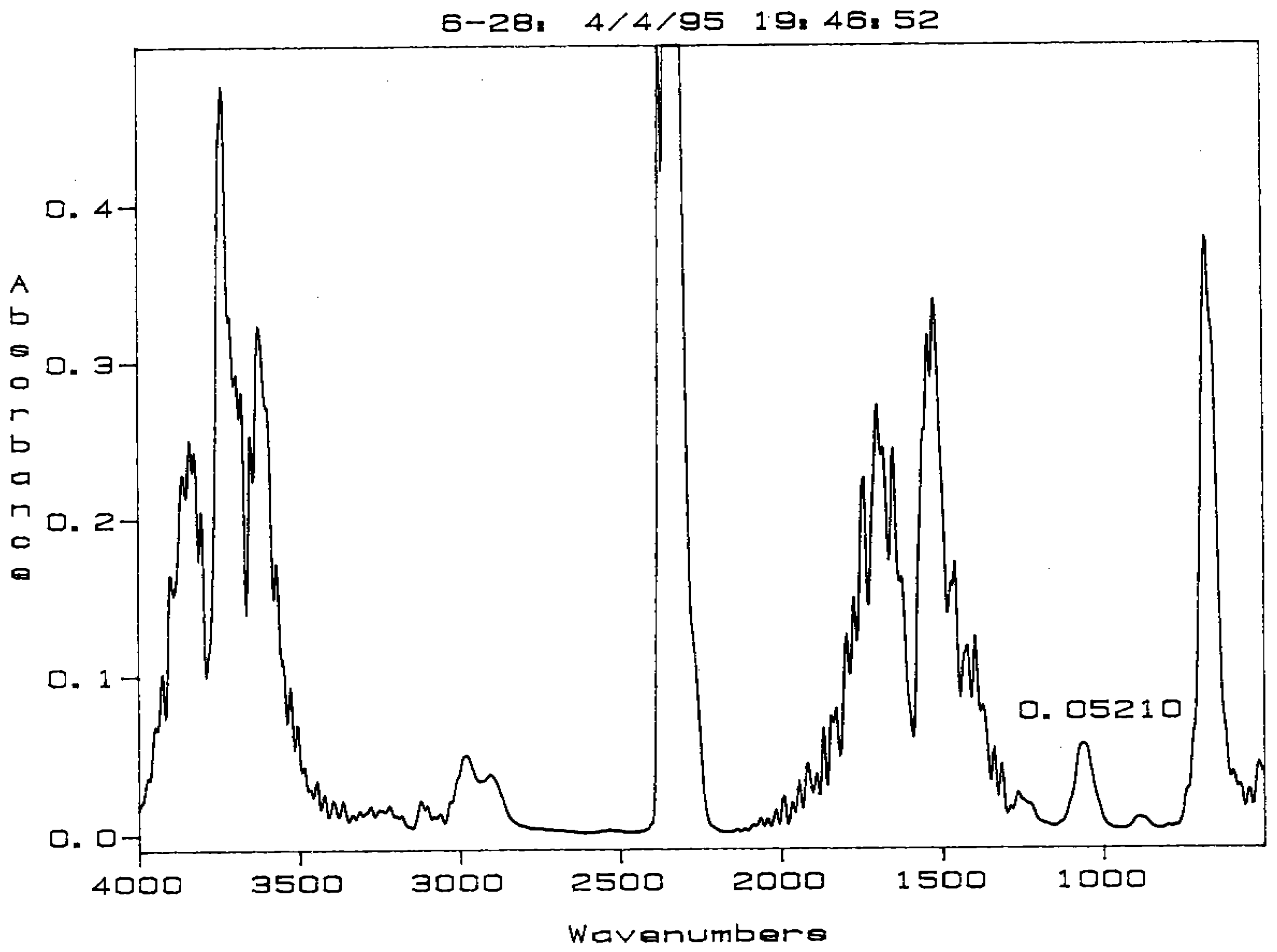

6-24: 4/4/95 19:40:25
Absorbance
0.0
0.1
0.2
0.3
0.4
4000
3500
3000
2500
2000
1500
1000
Wavenumbers
0.05369

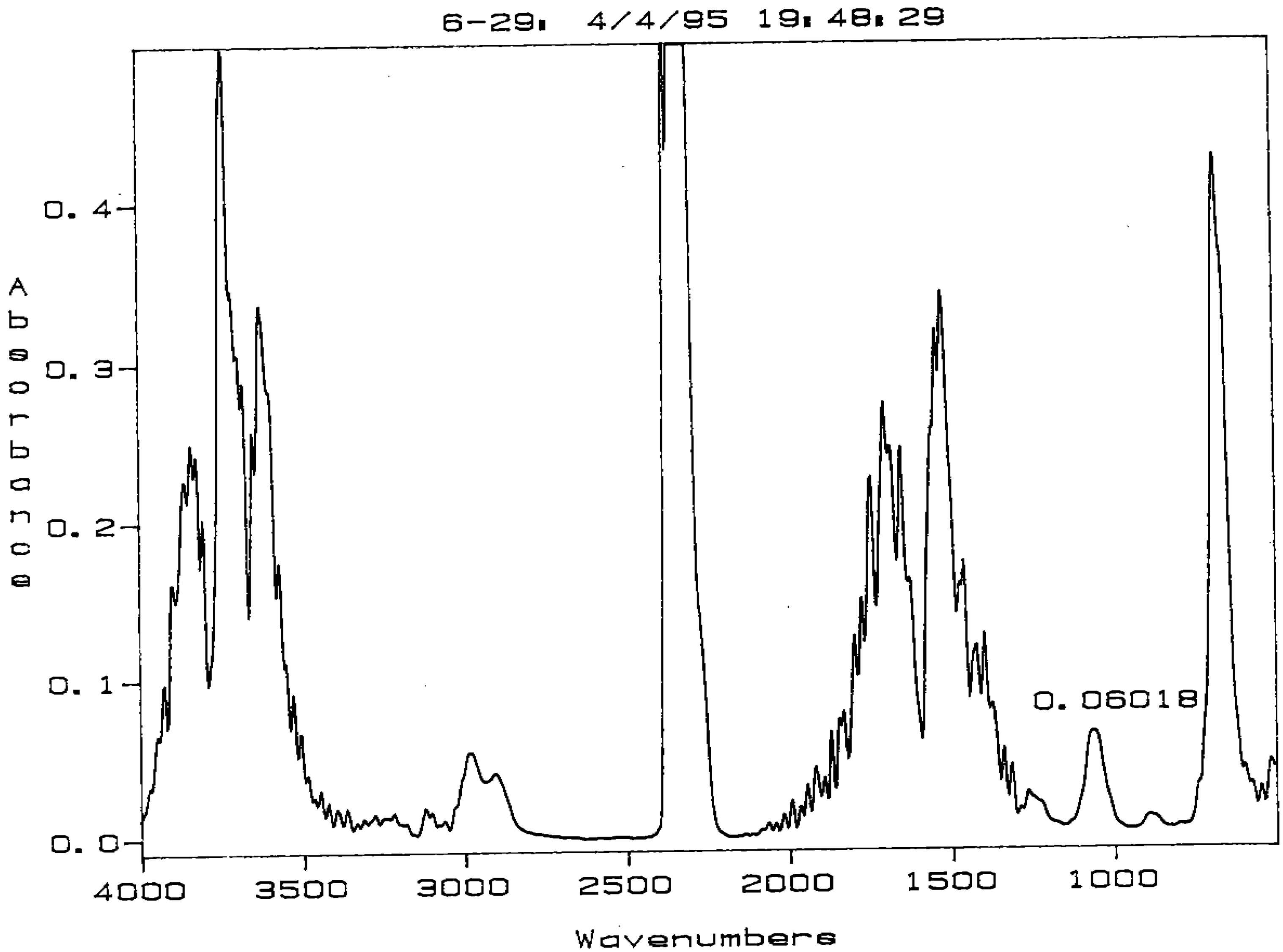


6-25: 4/4/95 19:42:01
Absorbance
0.4
0.3
0.2
0.1
0.0
0.05235
4000
3500
3000
2500
2000
1500
1000
Wavenumbers

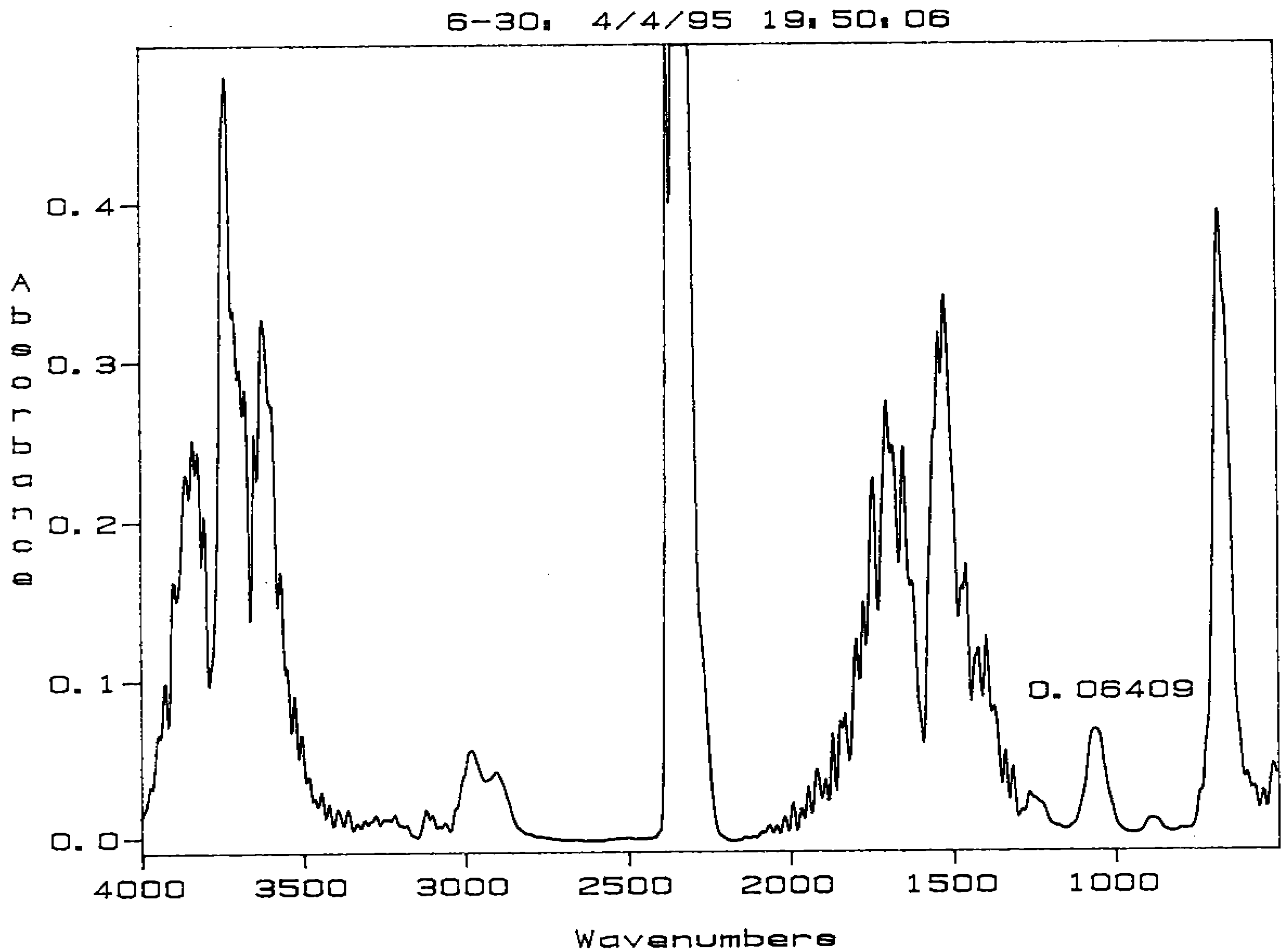

6-26: 4/4/95 19: 43: 38
Absorbance
0.4
0.3
0.2
0.1
0.0
0.05211
4000
3500
3000
2500
2000
1500
1000
Wavenumbers

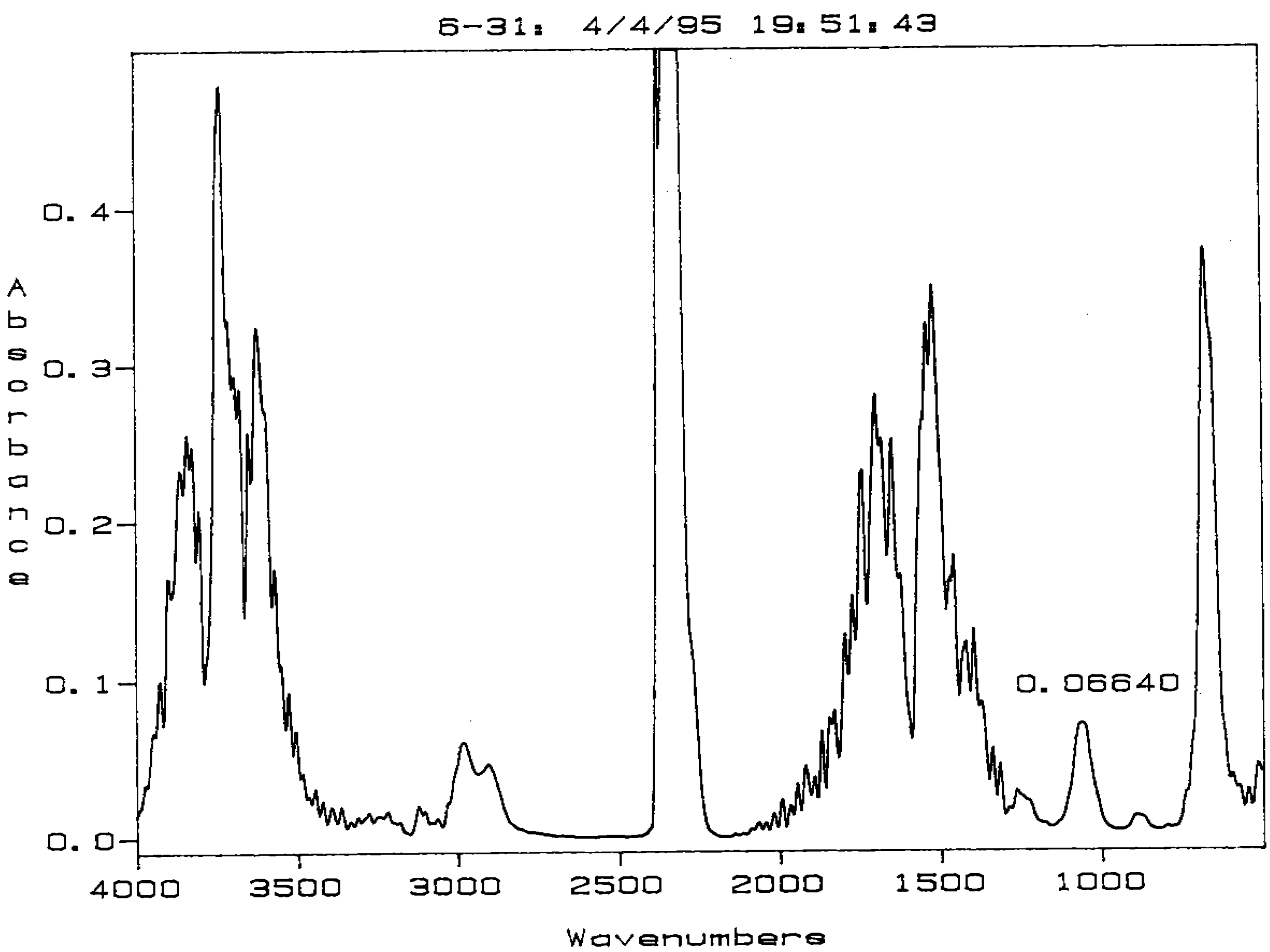

6-27: 4/4/95 19:45:15
Absorbance
0.4
0.3
0.2
0.1
0.0
0.05172
4000
3500
3000
2500
2000
1500
1000
Wavenumbers


6-28: 4/4/95 19:46:52
Absorbance
0.0
0.1
0.2
0.3
0.4
0.05210
4000
3500
3000
2500
2000
1500
1000
Wavenumbers

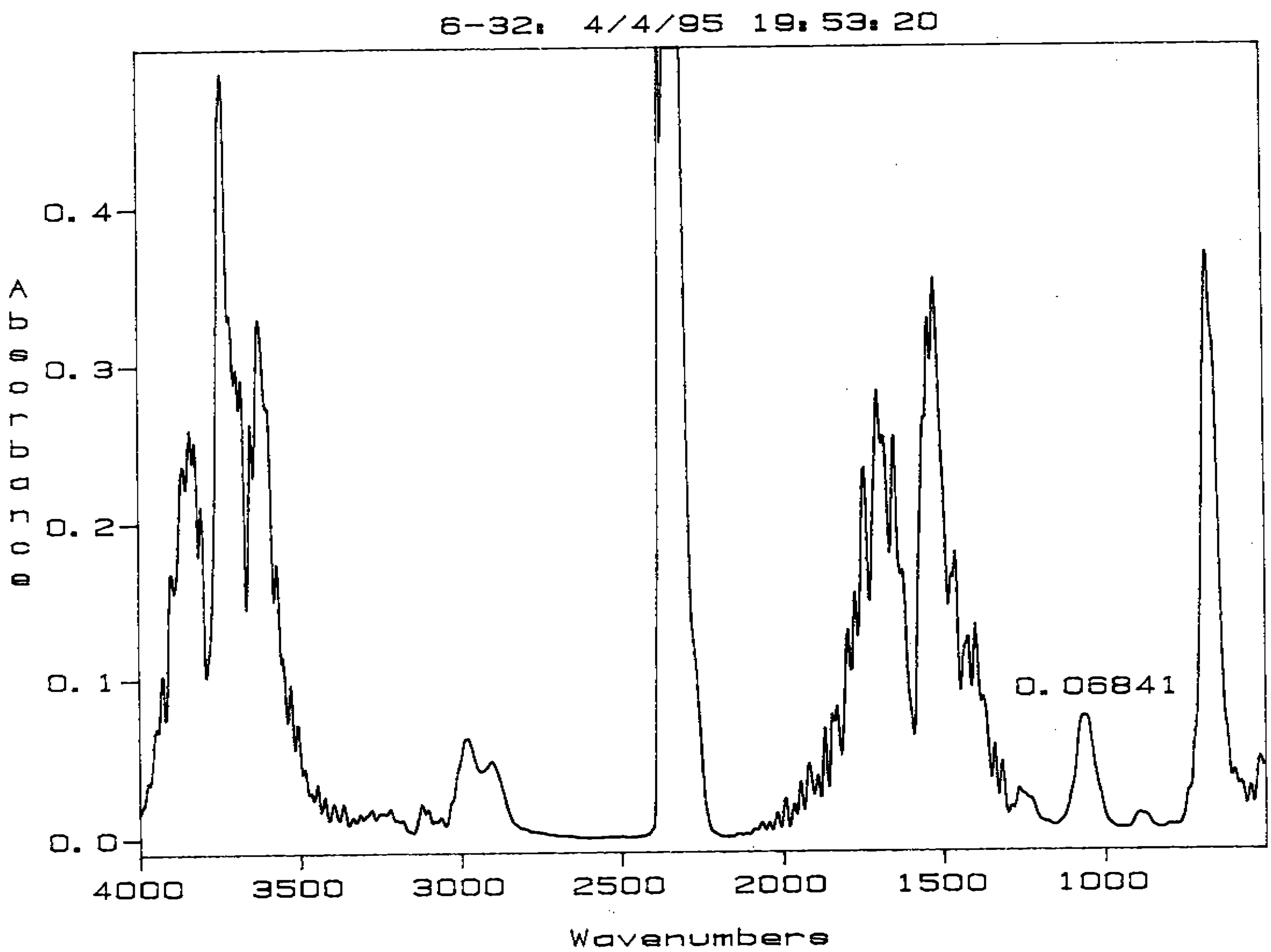


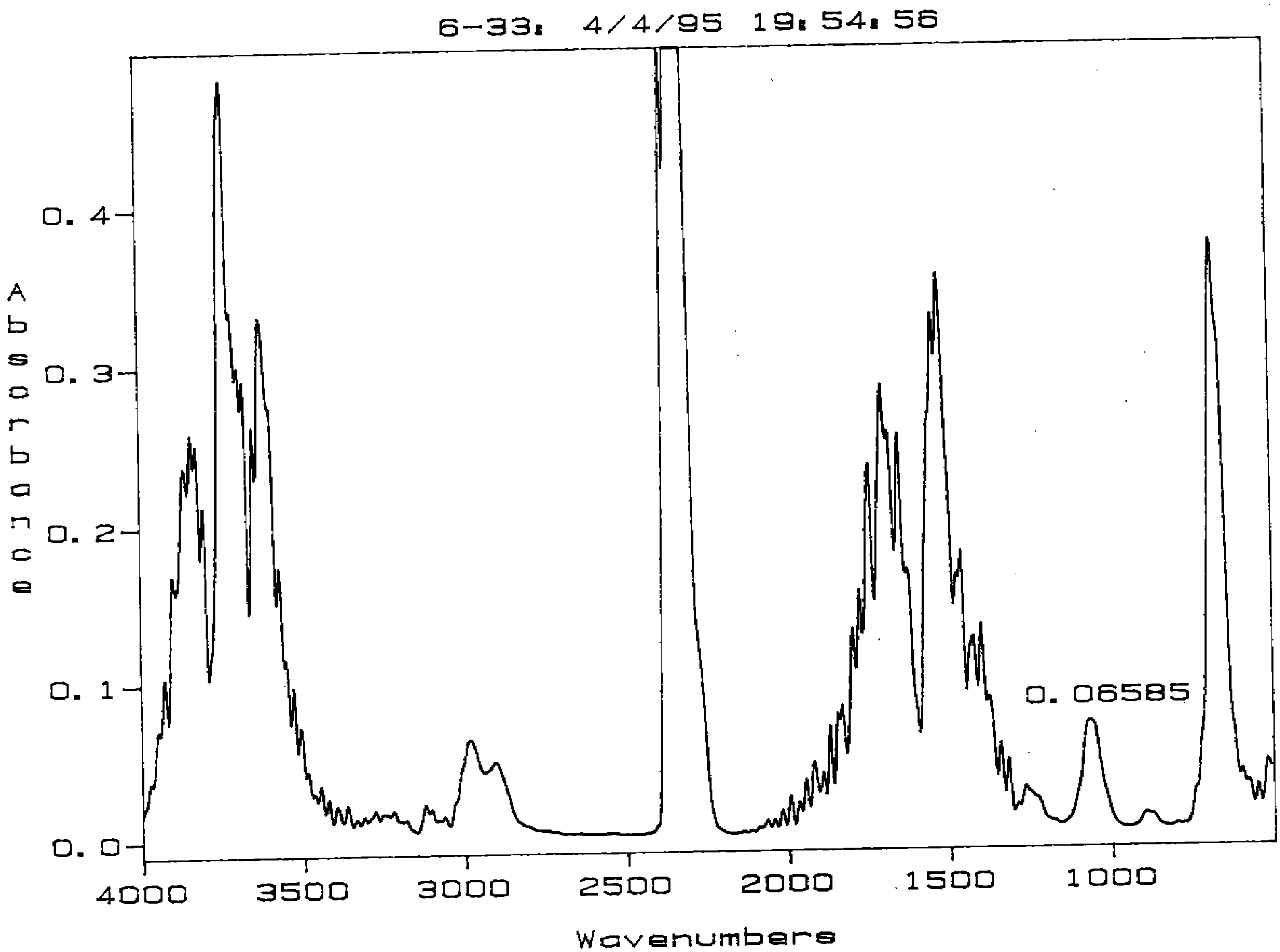
6-29: 4/4/95 19:48:29
Absorbance
0.0
0.1
0.2
0.3
0.4
4000
3500
3000
2500
2000
1500
1000
Wavenumbers
0.06018

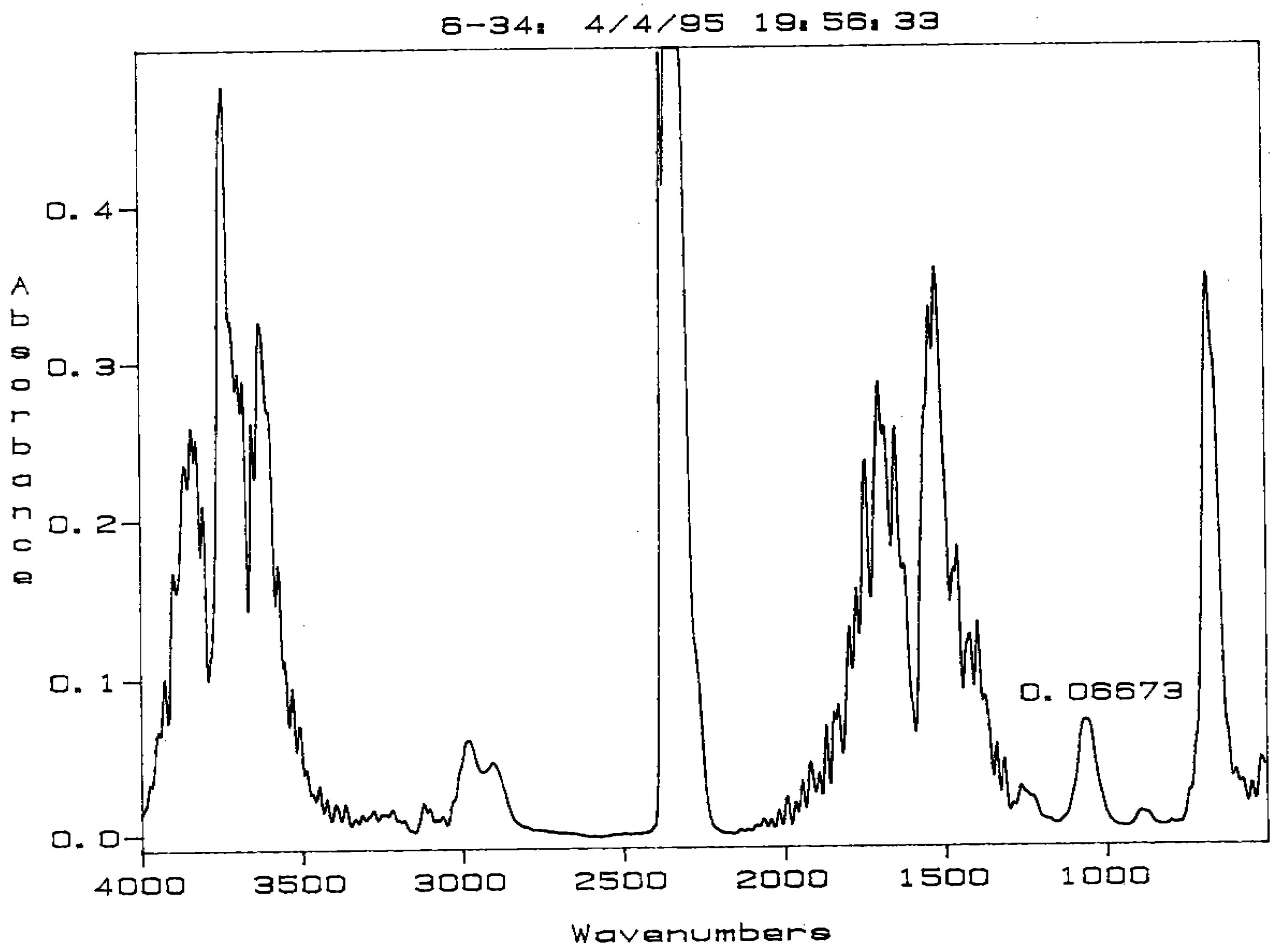

6-30: 4/4/95 19:50:06
0.4
0.3
0.2
0.1
0.0
Absorbance
0.06409
4000
3500
3000
2500
2000
1500
1000
Wavenumbers

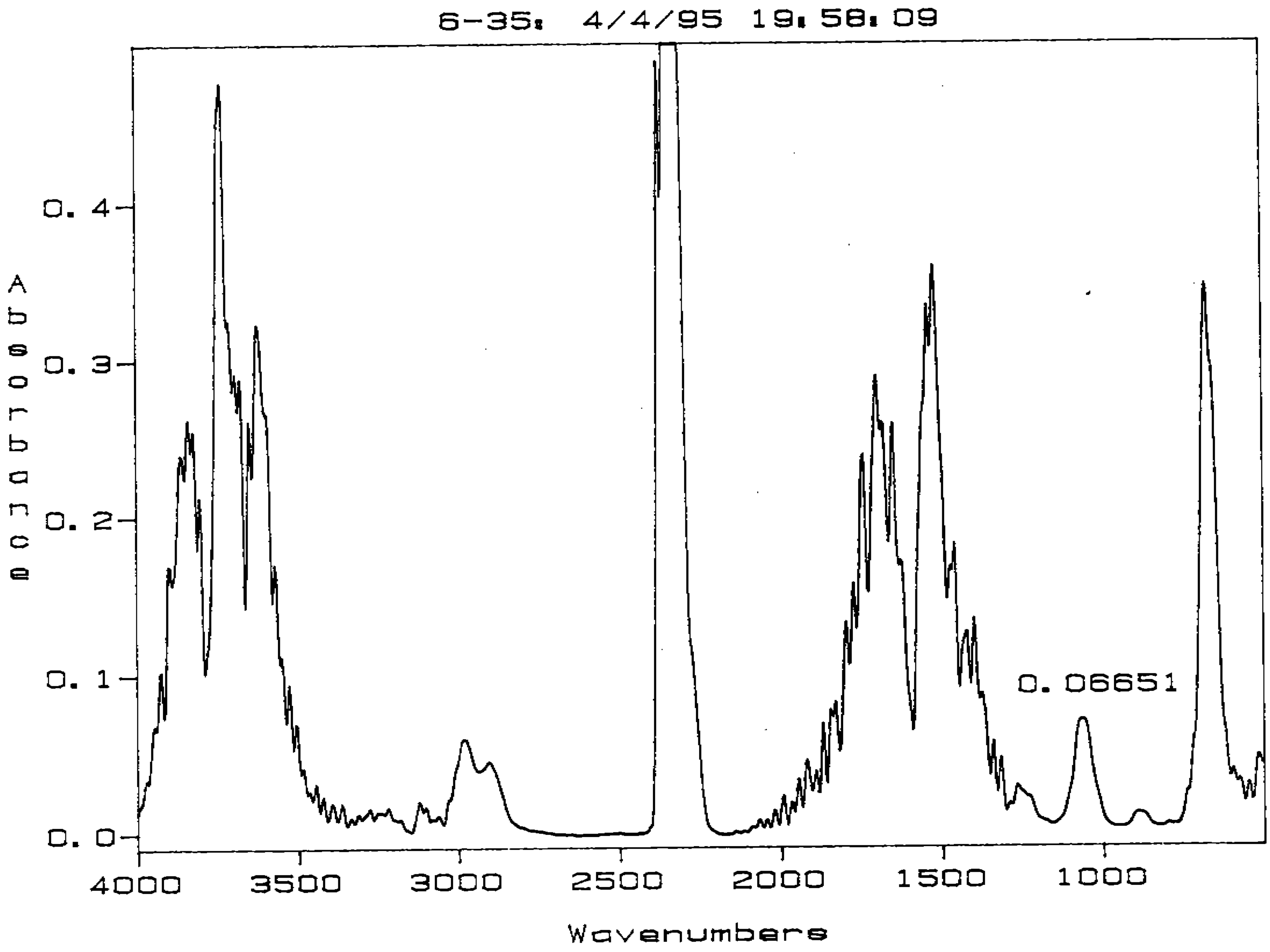


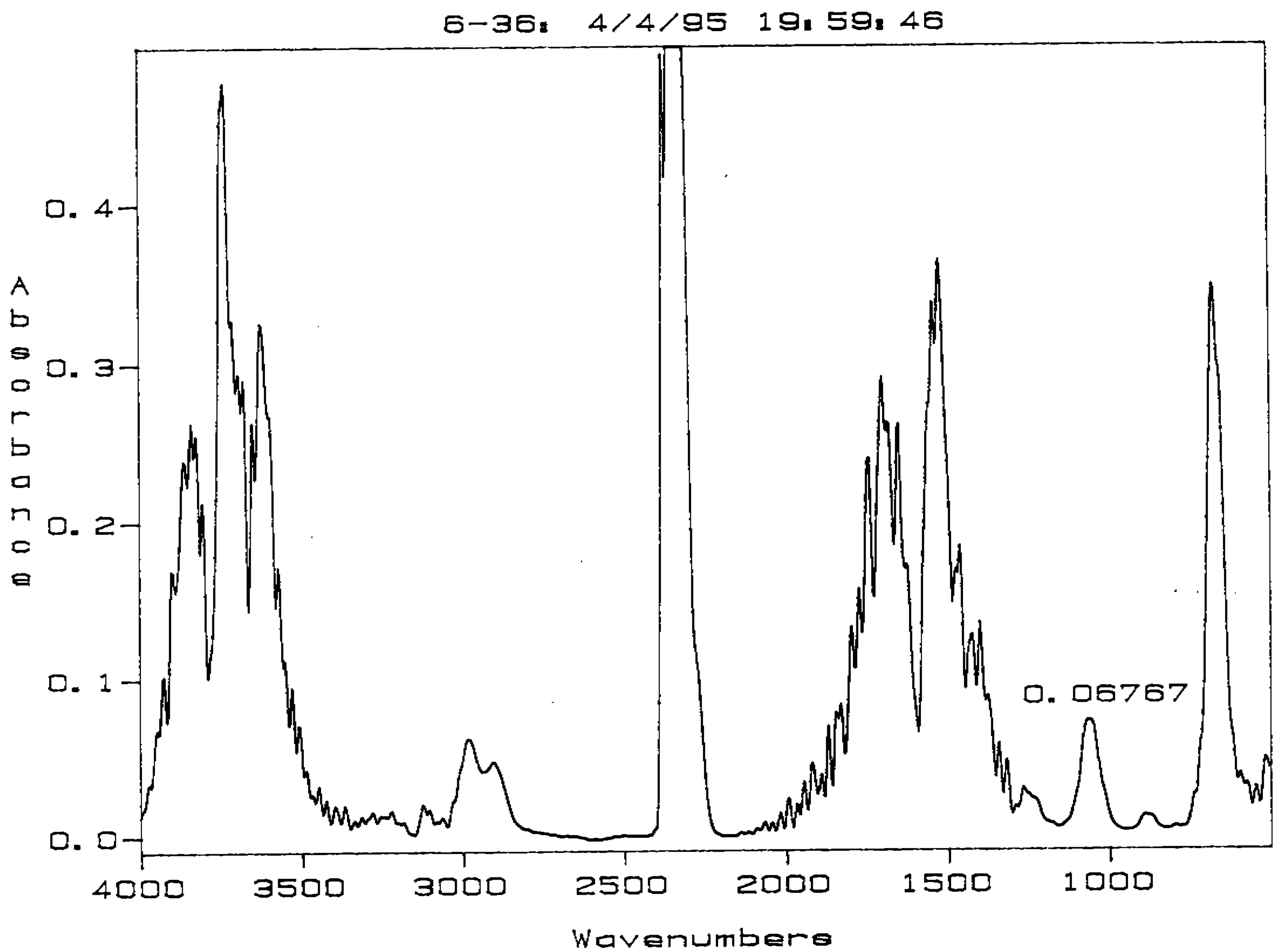
6-31: 4/4/95 19:51:43
Absorbance
0.4
0.3
0.2
0.1
0.0
4000
3500
3000
2500
2000
1500
1000
Wavenumbers
0.06640


6-32: 4/4/95 19:53:20
Absorbance
0.4
0.3
0.2
0.1
0.0
0.06841
4000
3500
3000
2500
2000
1500
1000
Wavenumbers


6-33: 4/4/95 19:54:56
Absorbance
0.4
0.3
0.2
0.1
0.0
0.06585
4000
3500
3000
2500
2000
1500
1000
Wavenumbers


6-34: 4/4/95 19:56:33
0.4
0.3
0.2
0.1
0.0
Absorbance
0.06673
4000
3500
3000
2500
2000
1500
1000
Wavenumbers


6-35: 4/4/95 19:58:09
Absorbance
0.4
0.3
0.2
0.1
0.0
0.06651
4000
3500
3000
2500
2000
1500
1000
Wavenumbers



6-36: 4/4/95 19:59:46
Absorbance
0.4
0.3
0.2
0.1
0.0
0.06767
4000
3500
3000
2500
2000
1500
1000
Wavenumbers

Appendix 3

Propane → Ethanol Conversion Data

Propane to Ethanol, Empirical Conversion Factor Determination - Tedlar Bag Standards

__Sample Calculations__

$$\text{ethanol conc. drift cal (ppmv as } C_3H_8) = \frac{(\%FS_{ETHANOL} - \%FS_0)\cdot[Span\ Gas\ Conc\ (ppmv)]}{(\%FS_{SPAN} - \%FS_0)}$$

$$= \frac{[(20.0)-(0.1)]\cdot(701)}{[(69.4)-(0.1)]}$$

$$= 201.3$$

$$\text{ethanol conc. (ppmv as ethanol)} = \left\{\frac{[ethanol\ mass\ (grams)]}{[flow\ rate\ (lpm)]\cdot[time\ (min)]}\right\}\cdot\frac{[T_B+460]}{P_B}\cdot(1.002x10^6)$$

$$= \left\{\frac{(0.0204)}{(1.85)\cdot(15.0)}\right\}\cdot\frac{[(70)+460]}{(842)}\cdot(1.002x10^6)$$

$$= 463.7$$

$$\text{scaling factor } (C_3H_8 \text{ to ethanol}) = \frac{[ethanol\ conc.\ (ppmv\ as\ ethanol)]}{[ethanol\ conc.\ (ppmv\ as\ C_3H_8)]}$$

$$= \frac{(463.7)}{(201.3)}$$

$$= 2.30$$

__Variables and Abbreviations__

cal - calibrated

conc - concentration

$\%FS_{SPAN}$ - average analyzer reading for propane span gas at probe tip (percent of full scale)

$\%FS_{ETHANOL}$ - average analyzer reading for ethanol gas (percent of full scale)

$\%FS_0$ - average analyzer reading for zero gas at probe tip (percent of full scale)

lpm - liters per minute

P_B - barometric pressure (millibars)

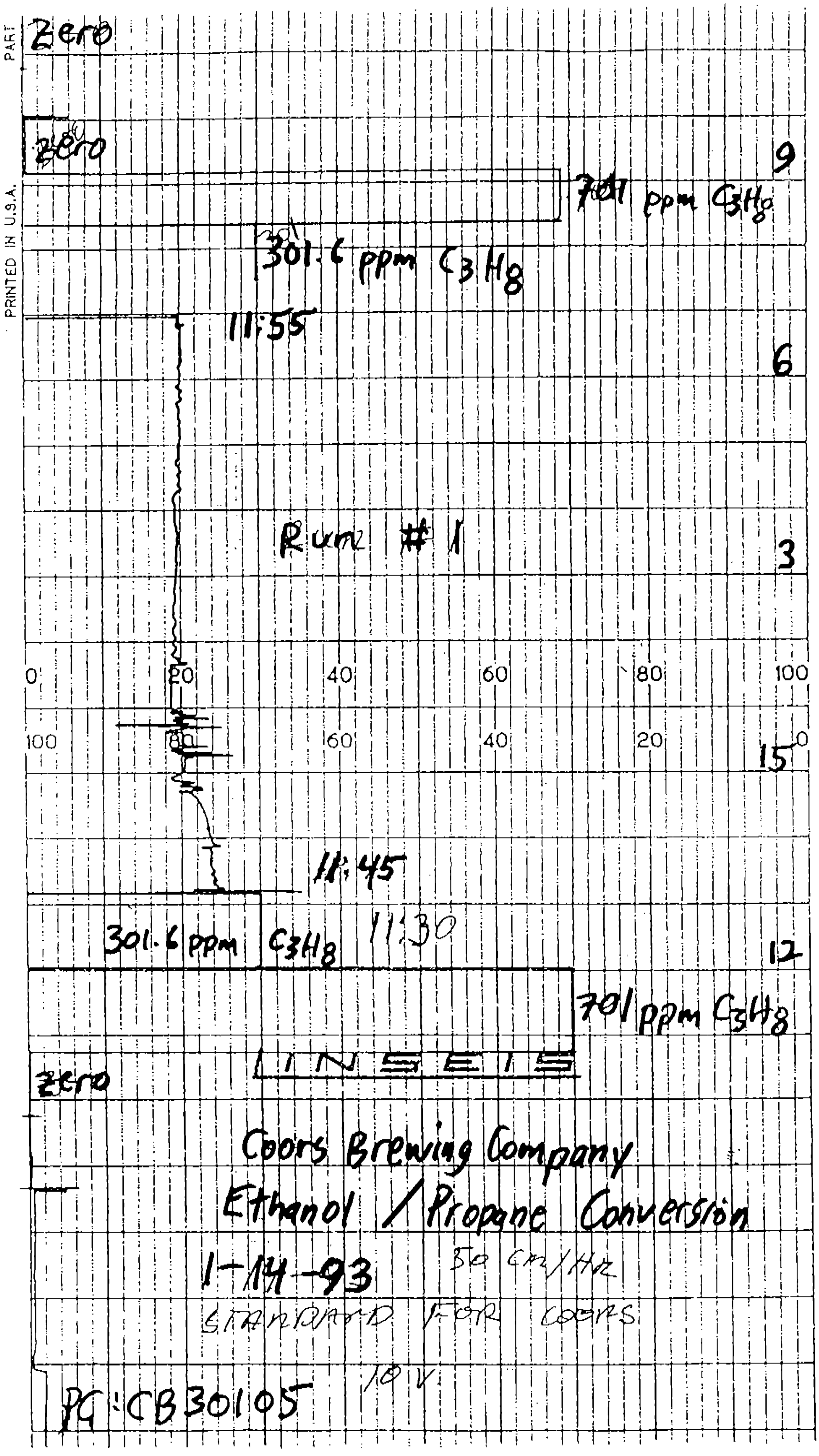
ppmv - parts per million, volume basis

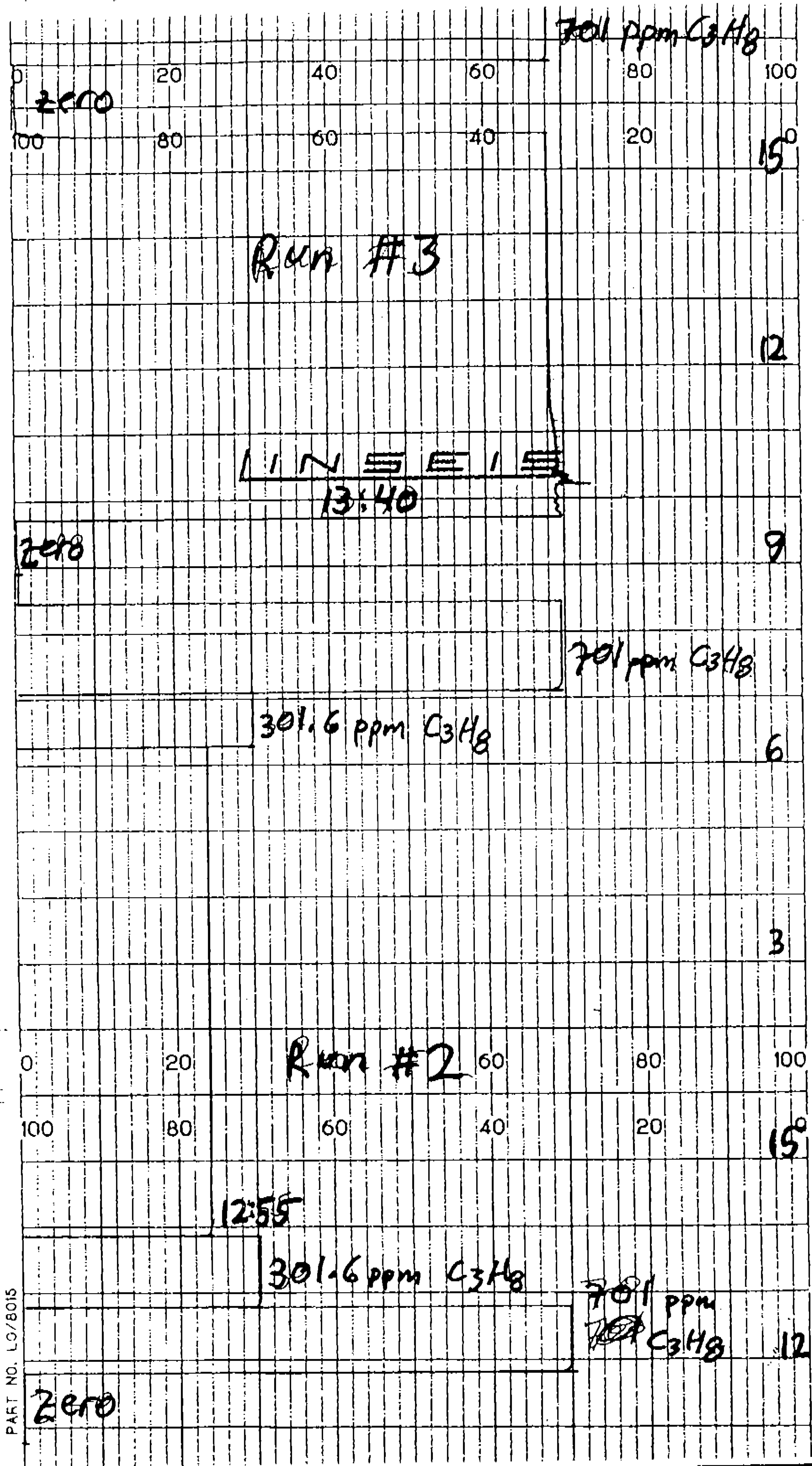
T_B - tedlar bag temperature (°F)

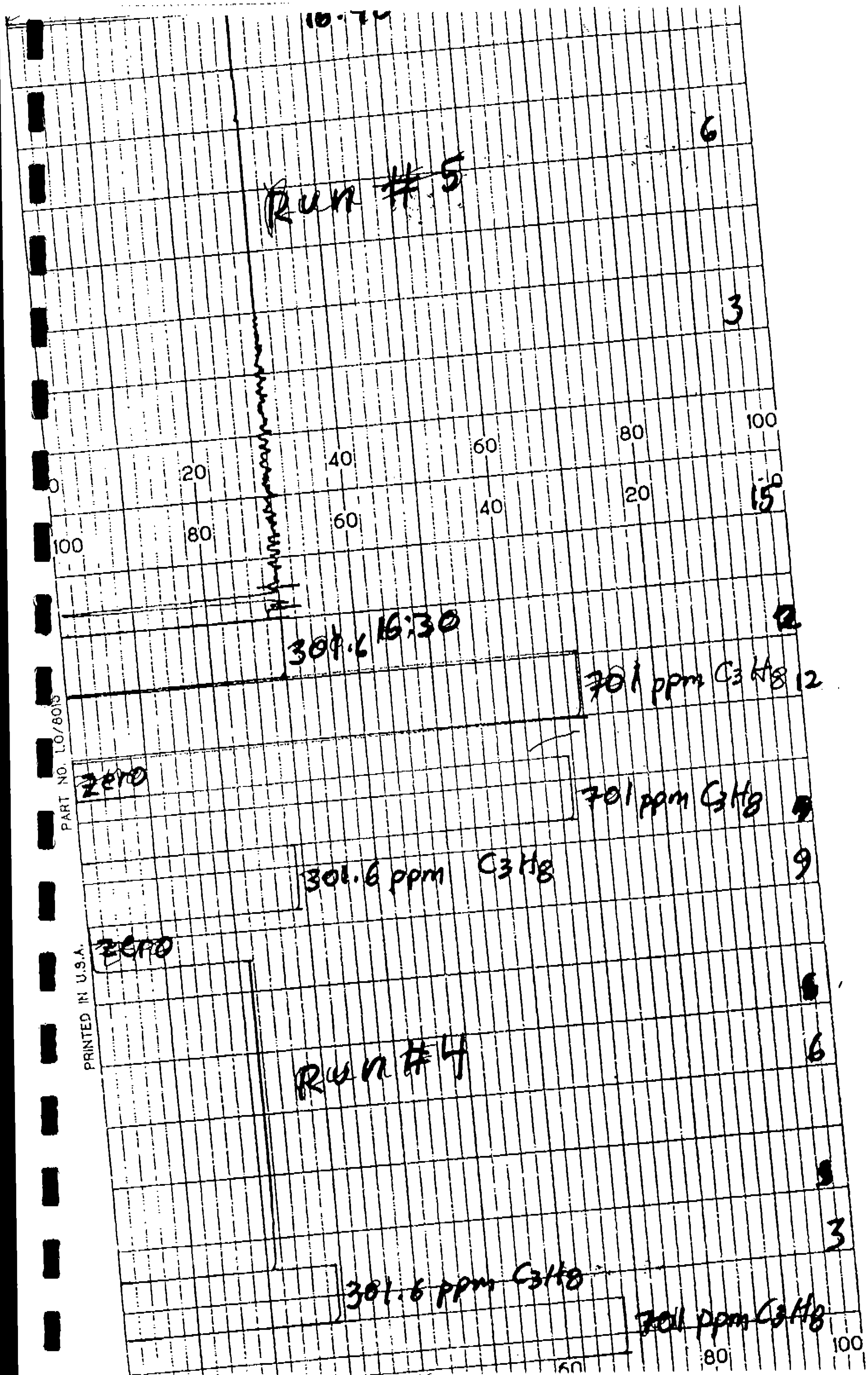
Coors Brewing Company
Propane to Ethanol Conversion Data
Tedlar Bag Standards
-14-93

Laboratory Data	Run #1	Run #2	Run #3	Run #4	Run #5	Average
baro. press. (mbar)	842	842	842	842	842	842
temp. (oF)	70	70	70	70	70	70
flow (lpm)	1.85	1.89	1.90	2.37	2.32	2.07
time (min.)	15.0	16.0	15.0	18.0	17.0	16.2
ethanol mass (grams)	0.0204	0.0281	0.0773	0.0350	0.0461	0.0414
FID Data						
ethanol (% of scale)	20.0	24.0	68.0	21.3	30.0	32.7
span gas (% of scale)	69.4	69.8	69.3	67.8	69.5	69.1
zero air (% of scale)	0.1	0.1	0.1	0.0	0.0	0.1
span gas value (ppmv)	701	701	701	701	701	701

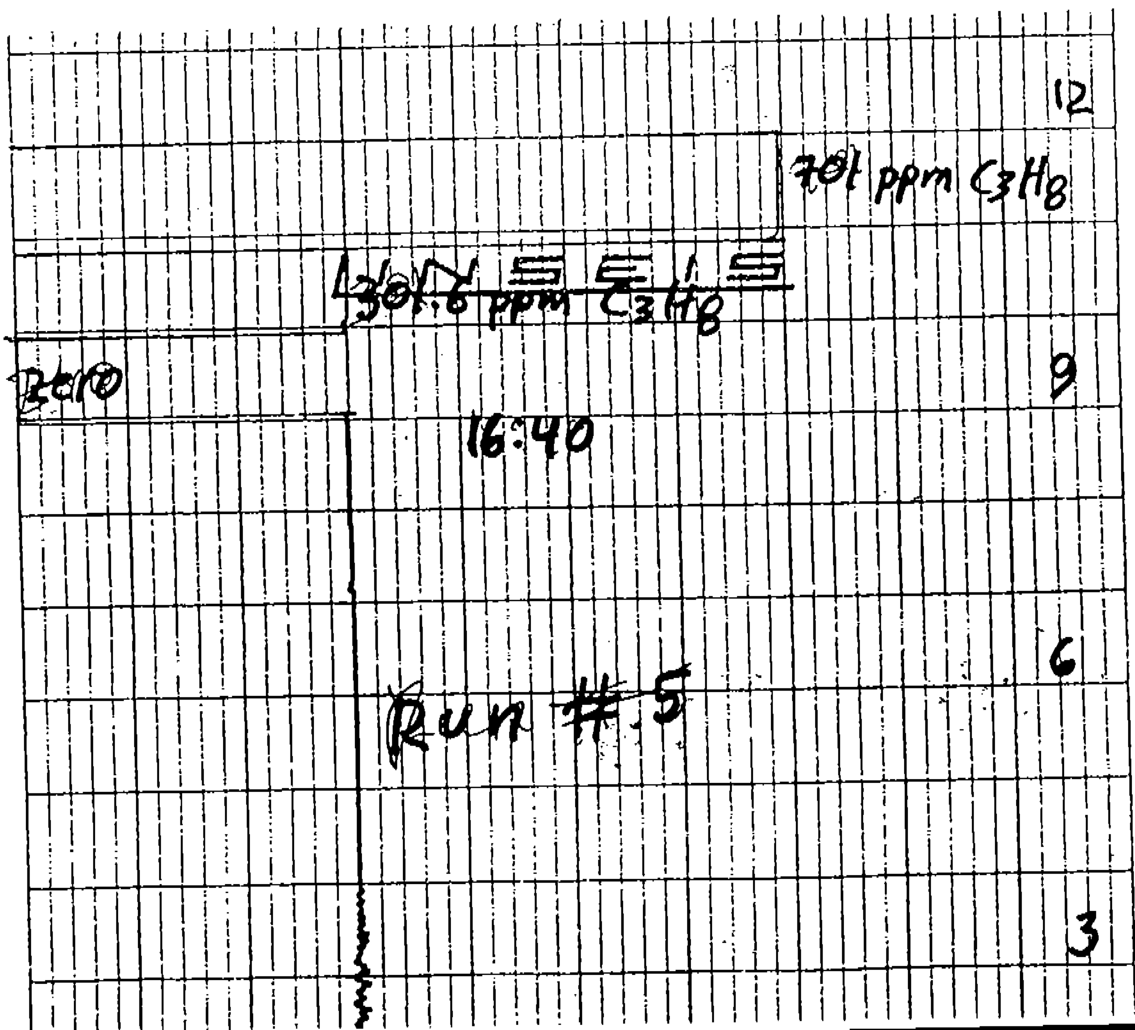
Calculations	Run #1	Run #2	Run #3	Run #4	Run #5	Average
ethanol conc. (ppmv as C3H8)	201.3	240.5	688.3	220.4	302.6	330.6
ethanol conc. (ppmv as propane)	463.7	586.1	1710.7	517.5	737.2	803.0
empirical scaling factor	2.30	2.44	2.49	2.35	2.44	2.40


PART
PRINTED IN U.S.A.
Zero
zero
9
701 ppm C_3H_8
301.6 ppm C_3H_8
11:55
6
Run #1
3
0 20 40 60 80 100
100 80 60 40 20 0
15
11:45
301.6 ppm C_3H_8
11:30
12
701 ppm C_3H_8
INSEIS
zero
Coors Brewing Company
Ethanol / Propane Conversion
1-14-93
30 CM/HR
STANDARD FOR COORS
10 V
PG: CB30105


701 ppm C3H8
0 20 40 60 80 100
zero
100 80 60 40 20 0
15
Run #3
12
LINSEIS
13:40
zero
9
701 ppm C3H8
301.6 ppm C3H8
6
3
Run #2
0 20 60 80 100
100 80 60 40 20 0
15
12:55
301.6 ppm C3H8
701 ppm C3H8
12
Zero
PART NO. LO/8015



Run #5
6
3
100
80
60
40
20
0
20
40
60
80
100
15
16:30
301.6
701 ppm C3H8
12
zero
701 ppm C3H8
301.6 ppm C3H8
9
zero
PART NO. LO/8015
PRINTED IN U.S.A.
Run #4
6
3
301.6 ppm C3H8
701 ppm C3H8
60
80
100


12
701 ppm C3H8
301.6 ppm C3H8
9
16:40
6
Run #5
3

AIR POLLUTION TESTING, INC.

Client Coors Brewing Co	
Golden, CO	
Date 1-14-93	

Sketch Location 1	Sketch Location 2

Pump # PCXR7		Pre-test flow (liter/min)	Post-test flow (liter/min)	Mid-test flow (liter/min)	Notes: Run #1
Method # Ethanol → Propane		1.88	1.85		Syringe Mass
Ta 70	Pb 842	1.82	1.86		2.0275 tare
Start time 11:25	Stop time 11:40	1.86	1.85		2.0071 final
Average Flows (liter/min)	1.85	1.85	1.85		0.0204 diff

Pump # PCXR7		Pre-test flow (liter/min)	Post-test flow (liter/min)	Mid-test flow (liter/min)	Notes: Run #2
Method # Ethanol → Propane		1.89	1.90		Syringe Mass
Ta 70	Pb 842	1.89	1.88		2.0249 tare
Start time 12:34	Stop time 12:50	1.91	1.86		1.9968 final
Average Flows (liter/min)	1.89	1.90	1.88		0.0281 diff

AIR POLLUTION TESTING, INC.

Client	Coors Brewing Co Golden, Co
Date	1-14-93

Sketch Location 1	Sketch Location 2

Pump # PCXR7		Pre-test flow (liter/min)	Post-test flow (liter/min)	Mid-test flow (liter/min)	Notes: Run #3
Method # Ethanol ⇒ Propane		1.88	1.89		Syringe Mass
Ta 70	Pb 842	1.88	1.90		2.0783 tare
Start time 13:20	Stop time 13:35	1.96	1.89		2.0010 final
Average Flows (liter/min)	1.90	1.91	1.89		0.0773 diff

Pump # PCXR7		Pre-test flow (liter/min)	Post-test flow (liter/min)	Mid-test flow (liter/min)	Notes: Run #4
Method # Ethanol ⇒ Propane		2.41	2.35		Syringe Mass
Ta 70	Pb 842	2.40	2.36		2.0415 tare
Start time 14:25	Stop time 14:43	2.36	2.35		2.0065 final
Average Flows (liter/min)	2.37	2.39	2.35		0.0350 diff

AIR POLLUTION TESTING, INC.

Client	Coors Brewing Co
	Golden, Co
Date	1-14-93

Sketch Location 1

Sketch Location 2

Pump # PCXR7		Pre-test flow (liter/min)	Post-test flow (liter/min)	Mid-test flow (liter/min)	Notes: Run #5
Method # Ethanol → Propane		2.34	2.33		Syringe Mass
Ta 70	Pb 842	2.31	2.30		2.0334 tare
Start time 16:08	Stop time 16:25	2.29	2.33		1.9873 final
Average Flows (liter/min)	2.32	2.31	2.32		0.0461 diff

Pump #		Pre-test flow (liter/min)	Post-test flow (liter/min)	Mid-test flow (liter/min)	Notes:
Method #					
Ta	Pb				
Start time	Stop time				
Average Flows (liter/min)					

Propane to Ethanol, Empirical Conversion Factor Determination - JUM VE-7 Data

Sample Calculations

$$\text{scaling factor } (C_3H_8 \text{ to ethanol}) = \frac{\left[\dfrac{(3 \textit{ carbons per } C_3H_8)}{(2 \textit{ carbons per ethanol})}\right]}{(\textit{carbon scaling factor})}$$

$$= \frac{\left(\dfrac{3}{2}\right)}{(0.65)}$$

$$= 2.31$$

Hydrocarbon Response Factors

6/90

Component	Resp.-Factor JUM-1	Resp.-Factor JUM-2
Methane	1.02	1.04
Propane	1.00	1.00
Acetylene	0.92	0.94
n-Butane	0.98	0.98
n-Hexane	0.85	0.86
n-Heptane	0.91	0.95
iso-Octane	0.99	0.98
cyclo-Hexane	0.93	0.94
Methanol	0.69	0.68
Ethanol	0.65	0.67
iso-Propanol	0.82	0.81
Benzene	1.05	1.05
Toluene	1.02	1.03
4-Ethyltoluene	0.88	0.89
p-Xylene	0.91	0.90
Acetone	0.72	0.73
Diethylether	0.75	0.77
Acetic Acid	0.58	0.55
Acetic Acid Ethylester	0.70	0.72
Acetic Acid Isobutylester	0.88	0.89
Dichlormethane	1.09	1.06
Chloroform	0.82	0.78
1, 1, 1,-Trichlorethane	1.06	1.02
Trichlorethane	1.03	1.01
Tetrachlorethene	1.22	1.20
Chlorbenzene	1.01	1.04
Number of Compounds	26	26
Average	0.903	0.903
Standard Tolerance	0.154	0.152

Data Compiled By :Tuv
Analyzer Type :Model VE-7
Fuel Type :100% H_2
Calibration Gas :Propane

Note: The respons factors are calculated as mg (carbon) per m^3.

Propane to Ethanol, Empirical Conversion Factor Determination - Certified Calibration Gases

Sample Calculations

$$\text{ethanol conc. drift cal (ppmv as } C_3H_8) = \frac{(\%FS_{ETHANOL} - \%FS_0)[Span\ Gas\ Conc\ (ppmv)]}{(\%FS_{SPAN} - \%FS_0)}$$

$$= \frac{[(71.18)-(-0.08)](84.2)}{[(84.37)-(-0.08)]}$$

$$= 71.05$$

$$\text{scaling factor (} C_3H_8 \text{ to ethanol)} = \frac{[ethanol\ conc.\ (ppmv\ as\ ethanol)]}{[ethanol\ conc.\ (ppmv\ as\ C_3H_8)]}$$

$$= \frac{(143.2)}{(71.05)}$$

$$= 2.02$$

Variables and Abbreviations

cal - calibrated

conc - concentration

$\%FS_{SPAN}$ - average analyzer reading for propane span gas at probe tip (percent of full scale)

$\%FS_{ETHANOL}$ - average analyzer reading for ethanol gas (percent of full scale)

$\%FS_0$ - average analyzer reading for zero gas at probe tip (percent of full scale)

ppmv - parts per million, volume basis

Coors Brewing Company
Bottle and Can Filler Exhaust
Propane to Ethanol Conversion Data
4-3-95

Field Data		Run #1	Run #2	Average
ethanol				
	concentration (ppmv)	143.2	15.11	79.16
	% of scale	71.18	6.74	38.96
propane				
	concentration (ppmv)	84.2	28.8	56.5
	% of scale	84.37	28.89	56.63
	% of scale (zero gas)	-0.08	-0.08	-0.08

Calculations

	Run #1	Run #2	Average
ethanol concentration as C3H8 (ppmv)	71.05	6.78	38.91
empirical scaling factor	2.02	2.23	2.12

Appendix 4

Calibration Data and Certificates

Scott Specialty Gases

500 WEAVER PARK ROAD, LONGMONT, CO 80501 (303) 442-4700, (303) 651-3094 FAX: (303) 772-7673

CERTIFICATE OF ANALYSIS: EPA Protocol Gas

Customer	Assay Laboratory	Purchase Order	951069
AIR POLLUTION TESTING	Scott Specialty Gases, Inc.	Scott Project #	0818339
7711 WEST 6TH AVENUE, SUITE 1	500 Weaver Park Road	CGA Fitting	350
LAKEWOOD, CO 80215	Longmont, CO 80501	QC Number	13169503
		File Number	18339-03

ANALYTICAL INFORMATION

This certification was performed according to EPA Traceability Protocol for Assay and Certification of Gaseous Calibration Standards; Procedure G1; September, 1993.

Cylinder Number	AAL-985	Certification Date	03/15/95	Expiration Date	03/15/98
Cylinder Pressure	2000 psig	Previous Certification Dates	None		

ANALYZED CYLINDER

Components	Certified Concentration	Analytical Uncertainty*
(Propane)	84.2 ppm	±1% Directly NIST Traceable
(Nitrogen)	Balance	

*Analytical uncertainty is inclusive of usual known error sources which at least includes precision of the measurement processes.

REFERENCE STANDARD

Type	Expiration Date	Cylinder Number	Concentration
NTRM 1668	06/07/96	ALM-032004	95.5 ppm C3H8 / Air

INSTRUMENTATION

Instrument/Model/Serial #	Last Date Calibrated	Analytical Principle
Hewlett Packard 5890A 3115A34623	03/15/95	Flame Ionization

ANALYZER READINGS (Z=Zero Gas R=Reference Gas T=Test Gas r=Correlation Coefficient)

Components	First Triad Analysis	Second Triad Analysis	Calibration Curve
(Propane)	Date 03/15/95 Response Units: V Z1 = 0.000 R1 = 96.270 T1 = 84.370 R2 = 96.130 Z2 = 0.000 T2 = 84.060 Z3 = 0.000 T3 = 84.120 R3 = 96.070 Avg. Conc. of Cyl. = 84.18 ppm		Concentration = A+Bx+Cx2+Dx3+Ex4 r = 0.999999 Constants: A = 486.94 B = 1161.98 C = 0 D = 0 E = 0

Special Notes Do not use when cylinder pressure is below 150 psig.

Mary Grehl

Analyst Mary Grehl

Scott Specialty Gases

500 WEAVER PARK ROAD, LONGMONT, CO 80501 (303) 442-4700, (303) 651-3094 FAX: (303) 772-7673

CERTIFICATE OF ANALYSIS: EPA Protocol Gas

Customer
AIR POLLUTION TESTING
7711 WEST 6TH AVENUE, SUITE 1
LAKEWOOD, CO 80215

Assay Laboratory
Scott Specialty Gases, Inc.
500 Weaver Park Road
Longmont, CO 80501

Purchase Order	951069
Scott Project #	0818339
CGA Fitting	350
QC Number	13159518
File Number	18339-02

ANALYTICAL INFORMATION

This certification was performed according to EPA Traceability Protocol for Assay and Certification of Gaseous Calibration Standards; Procedure G1; September, 1993.

Cylinder Number AAL-20970 Certification Date 03/15/95 Expiration Date 03/15/98
Cylinder Pressure 2000 psig Previous Certification Dates None

ANALYZED CYLINDER

Components	Certified Concentration	Analytical Uncertainty*
(Propane)	48.5 ppm	±1% Directly NIST Traceable
(Nitrogen)	Balance	

*Analytical uncertainty is inclusive of usual known error sources which at least includes precision of the measurement processes.

REFERENCE STANDARD

Type	Expiration Date	Cylinder Number	Concentration
NTRM 1668	06/07/96	ALM-032004	95.5 ppm C_3H_8 / Air

INSTRUMENTATION

Instrument/Model/Serial #	Last Date Calibrated	Analytical Principle
Hewlett Packard 5890A 3115A34623	03/15/95	Flame Ionization

ANALYZER READINGS (Z=Zero Gas R=Reference Gas T=Test Gas r=Correlation Coefficient)

Components	First Triad Analysis	Second Triad Analysis	Calibration Curve
(Propane)	Date 03/15/95 Response Units: V Z1 = 0.000 R1 = 96.270 T1 = 48.580 R2 = 96.130 Z2 = 0.000 T2 = 48.530 Z3 = 0.000 T3 = 48.400 R3 = 96.070 Avg. Conc. of Cyl. = 48.50 ppm		Concentration = A+Bx+Cx2+Dx3+Ex4 r = 0.999999 Constants: A = 486.94 B = 1161.98 C = 0 D = 0 E = 0

Special Notes Do not use when cylinder pressure is below 150 psig.

Mary Grehl
Analyst Mary Grehl

Scott Specialty Gases

500 WEAVER PARK ROAD, LONGMONT, CO 80501 (303) 442-4700, (303) 651-3094 FAX: (303) 772-7673

CERTIFICATE OF ANALYSIS: EPA Protocol Gas

Customer
AIR POLLUTION TESTING
7711 WEST 6TH AVENUE, SUITE 1
LAKEWOOD, CO 80215

Assay Laboratory
Scott Specialty Gases, Inc.
500 Weaver Park Road
Longmont, CO 80501

Purchase Order 951069
Scott Project # 0818339
CGA Fitting 350
QC Number 13159517
File Number 18339-01

ANALYTICAL INFORMATION

This certification was performed according to EPA Traceability Protocol for Assay and Certification of Gaseous Calibration Standards; Procedure G1; September, 1993.

Cylinder Number ALM-054568
Cylinder Pressure 2000 psig
Certification Date 03/15/95
Previous Certification Dates None
Expiration Date 03/15/98

ANALYZED CYLINDER

Components	Certified Concentration	Analytical Uncertainty*
(Propane)	28.8 ppm	±1% Directly NIST Traceable
(Nitrogen)	Balance	

*Analytical uncertainty is inclusive of usual known error sources which at least includes precision of the measurement processes.

REFERENCE STANDARD

Type	Expiration Date	Cylinder Number	Concentration
NTRM 1668	06/07/96	ALM-032004	95.5 ppm C3H8 / Air

INSTRUMENTATION

Instrument/Model/Serial #	Last Date Calibrated	Analytical Principle
Hewlett Packard 5890A 3115A34623	03/15/95	Flame Ionization

ANALYZER READINGS (Z=Zero Gas R=Reference Gas T=Test Gas r=Correlation Coefficient)

Components: (Propane)

First Triad Analysis

Date 03/15/95 Response Units: V

Z1 = 0.000	R1 = 96.270	T1 = 28.760
R2 = 96.130	Z2 = 0.000	T2 = 28.860
Z3 = 0.000	T3 = 28.900	R3 = 96.070

Avg. Conc. of Cyl. = 28.84 ppm

Second Triad Analysis

Calibration Curve

Concentration = A+Bx+Cx2+Dx3+Ex4
r = 0.999999
Constants: A = 486.94
B = 1161.98 C = 0
D = 0 E = 0

Special Notes Do not use when cylinder pressure is below 150 psig.

Analyst Mary Grehl

Scott Specialty Gases, Inc.

Shipped From: 1290 COMBERMERE STREET
TROY MI 48083
Phone: 810-589-2950 Fax: 810-589-2134

CERTIFICATE OF ANALYSIS

AIR POLLUTION TESTING INC
7711 W 6TH AVE
SUITE 1
LAKEWOOD CO 80215

PROJECT #: 05-78775-001
PO#: CB50113
ITEM #: 05021872 1AL
DATE: 3/20/95

CYLINDER #: ALM024006 ANALYTICAL ACCURACY: +/- 1%
FILL PRESSURE: 2000 PSI
BLEND TYPE : GRAVIMETRIC MASTER GAS

COMPONENT	REQUESTED GAS CONC MOLES		ANALYSIS (MOLES)	
ETHANOL	140.	PPM	143.2	PPM
NITROGEN		BALANCE		BALANCE

GRAVIMETRIC MASTER GAS

CERTIFIED TO HAVE BEEN BLENDED AGAINST NBS CERTFIED WEIGHTS AND VERIFIED CORRECT BY INDEPENDENT ANALYSIS

ANALYST: [signature]

Scott Specialty Gases, Inc.

Shipped From: 1290 COMBERMERE STREET
TROY MI 48083
Phone: 810-589-2950 Fax: 810-589-2134

CERTIFICATE OF ANALYSIS

AIR POLLUTION TESTING INC

7711 W 6TH AVE
SUITE 1
LAKEWOOD CO 80215

PROJECT #: 05-78775-002
PO#: CB50113
ITEM #: 05021871 1AL
DATE: 3/16/95

CYLINDER #: ALM030961
FILL PRESSURE: 2000 PSI
BLEND TYPE : GRAVIMETRIC MASTER GAS

ANALYTICAL ACCURACY: +/- 1%

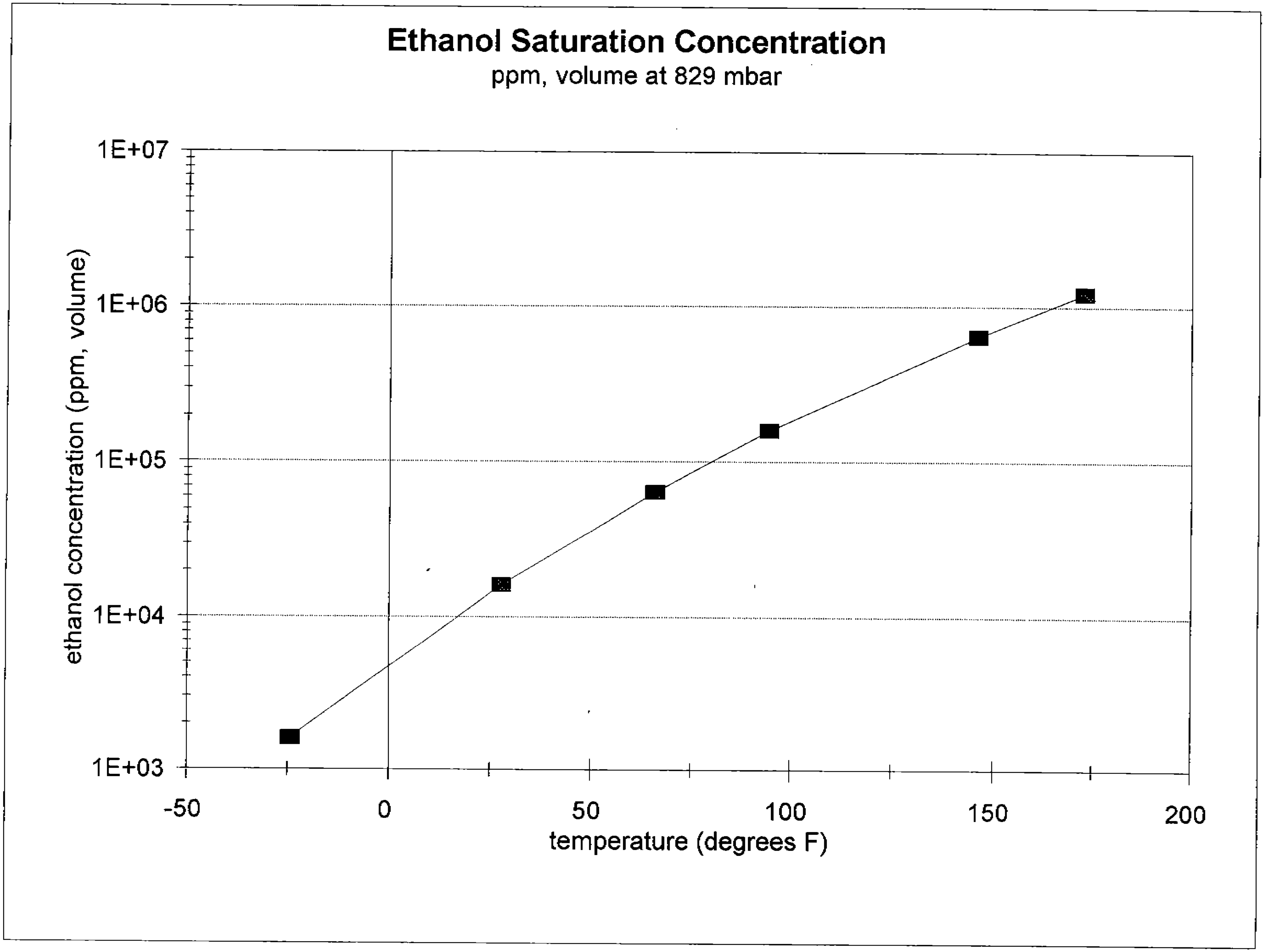
COMPONENT	REQUESTED GAS CONC MOLES	ANALYSIS (MOLES)
ETHANOL	14. PPM	15.11 PPM
NITROGEN	BALANCE	BALANCE

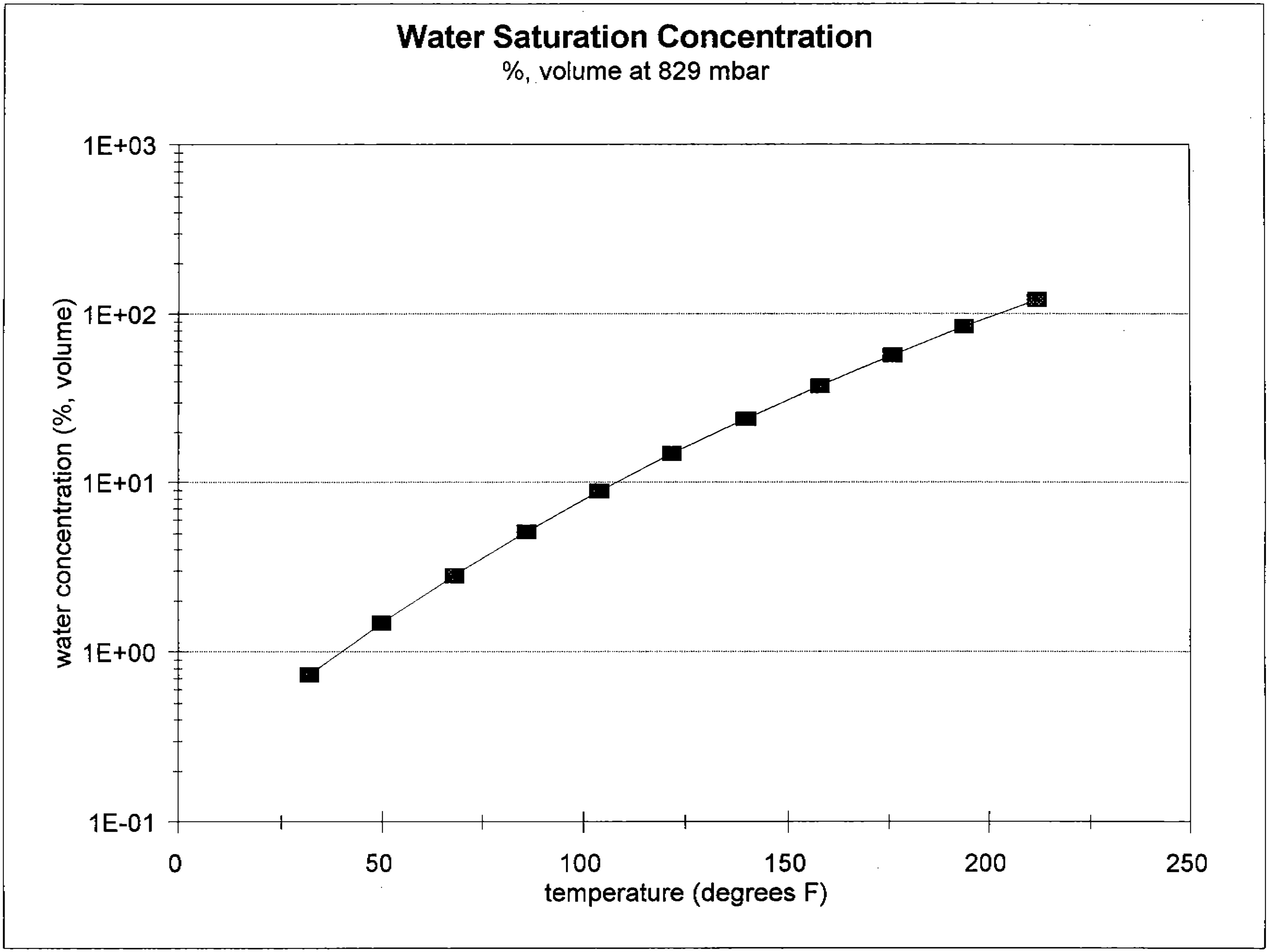
CERTIFIED

GRAVIMETRIC MASTER GAS

CERTIFIED TO HAVE BEEN BLENDED AGAINST NBS CERTFIED WEIGHTS AND VERIFIED CORRECT BY INDEPENDENT ANALYSIS

ANALYST: [signature]


Ethanol Saturation Concentration
ppm, volume at 829 mbar
1E+07
1E+06
1E+05
1E+04
1E+03
ethanol concentration (ppm, volume)
-50
0
50
100
150
200
temperature (degrees F)


Water Saturation Concentration
%, volume at 829 mbar
water concentration (%, volume)
1E+03
1E+02
1E+01
1E+00
1E-01
0
50
100
150
200
250
temperature (degrees F)